

Armmite F4

User Manual

MMBasic Ver 5.07.00

A consolidated manual for the Armmite F4

For more details on MMBasic go to

<http://geoffg.net/maximite.html>

and <http://mmbasic.com>

For updates to this manual look for the latest on

The Back Shed Forum or the Fruit of the Shed website.

<https://www.thebackshed.com/forum/ViewTopic.php?FID=16&TID=13523>

and <http://fruitoftheshed.com/MMBasic.ArmmiteF4-Manual.ashx>

About

The Armmite F4 was conceived and developed by Peter Mather (matherp on the Back Shed Forum). It is a port to STM32 of MMBasic developed by Geoff Graham and uses the MMBasic interpreter written by Geoff Graham (<http://geoffg.net>).

Support

Support questions should be raised on the Back Shed forum (<http://www.thebackshed.com/forum/Microcontrollers>) where there are many enthusiastic Maximite and Micromite and Armmite users who would be only too happy to help. The developers of both the Armmite F4 and MMBasic are also regulars on this forum.

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Maury Quijada wrote the image resize and image rotate code.

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This Manual

This manual relies heavy on content from the following manuals be Geoff Graham.

Micromite User Manual

Micromite Plus User Manual

Colour Maximite 2 User Manual

Also the following manuals by Peter Mather.

Micromite Extreme User Manual

Armmite H7 User Manual

Armmite L4 User Manual

Much information is also gleaned from posts (mainly by Peter Mather) in various threads relating to Armmite F4 on The Back Shed Forum. Many contributors may recognise their work within this document and are thanked for their contributions.

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Introduction

Armmite F4 (STM32F407VET6 development board) single board that has everything you need - USB serial port, RTC with battery, SDcard slot, TFT header. It runs faster than the MM+ and is much cheaper as a complete system. Lots of projects like Geoff's Super Clock, DDS signal generator, and boat computer are easy to port to the ArmmiteF4 with display and run superbly.

The [STM32F407VET6 STM32 Cortex-M4 Development Board](#) which has a pin compatible TFT screen available to plug directly in.

The matching display is 16-bit parallel and very fast
Buy the pair from [here and many other vendors](#)



Note there are lots of variants of STM32F407 development boards. You must buy the one pictured for the firmware to work.

The Armmite F4 firmware version will work on this PCB with no configuration necessary and no ancillary hardware needed. i.e. the main peripherals will work immediately on power up.

The firmware can be loaded to the board over the USB port with no programmer needed and the MMBasic console will be on the USB, no USB/UART needed.

The speed of the port is about 1.3x faster than a MM+ at 120MHz. Peripherals include 4 x UART, 2 x SPI, 8 x PWM/Servo, 2 x I2C, 13 x 12-bit ADC, 2 x 12-bit DAC, 16-bit parallel TFT I/F supporting the screen above and any SSD1963 display using an adapter board.

There are 47 user configurable pins (DOUT, DIN, etc.)

The firmware uses a different way of interfacing with the TFT screens using the STM32F407's FSMC interface. This treats the screen as a memory device and allows for very fast performance (clear screen on the ILI9341 currently takes 6 mSec). Touch is supported with full GUI functionality. The pins used by the FSMC interface are not available to MMBasic if the screen is not used.

The basic features of the Armmite F4 are:

- **Low cost affordable fun.** The firmware (including the BASIC interpreter) is completely free. The STM32F407VET6 development board is low cost and needs no assembly. The firmware can be loaded using free software so a programmer or special equipment is not required to get started. If the specified LCD is purchased it plugs in with not modification required.
- **Instant startup** into the BASIC interpreter. Program space is 132KB, enough for reasonable sized programs while general RAM used for variables, buffers etc is 114KB.
- **Full featured BASIC interpreter** with double precision floating point, 64-bit integers and string variables, long variable names, arrays of floats, integers or strings with multiple dimensions, extensive string handling and user defined subroutines and functions. Typically it will execute a program at xxx lines per second.
- **PS2 Keyboard support.** The keyboard can have US, UK, FR, GR, BE, IT or ES key mappings.
- **Stereo audio output** can play WAV and FLAC files, generate precise sine wave tones.
- **A full screen editor** is built into the firmware. It includes advanced features such as colour coded syntax, search and copy, cut and paste to and from a clipboard. With one key press the program can be saved and run. If an error occurs another key press will return to the editor with the cursor placed on the line that caused the error.
- **Full support for SD cards** including editing and running programs on the SD card as well as opening files for reading, writing or random access. Cards up to 32GB formatted in FAT16 are supported and the files can also be read and written on personal computers running Windows, Linux or the Mac operating system. .
- **Programs can be easily transferred** from another computer (Windows, Mac or Linux) using the SD card, XModem protocol or by streaming the program over the serial console input.
- **Battery backed clock** will keep the correct time, even with the power disconnected.
- **Power is 5 volts at 220mA typical from an USB port or charger.**

Micromite Family Summary

The Micromite Family consists of five major types, the standard Micromite, the Micromite Plus, the Micromite eXtreme, the Pi-cromite, the Armmite L4, the Armmite F4 and the Armmite H7. All use the same BASIC interpreter and have the same basic capabilities however they differ in the number of I/O pins, the amount of memory, the displays that they support and their intended use.

- Standard Micromite Comes in a 28-pin or 44-pin package and is designed for small embedded controller applications and supports small LCD display panels. The 28-pin version is particularly easy to use as it is easy to solder and can be plugged into a standard 28-pin IC socket.
- Micromite Plus This uses a 64-pin and 100-pin TQFP surface mount package and supports a wide range of touch sensitive LCD display panels from 1.44" to 8" in addition to the standard features of the Micromite. It is intended as a sophisticated controller with easy to create on-screen controls such as buttons, switches, etc.
- Micromite eXtreme This comes in 64, 100-pin and 144-pin TQFP surface mount packages. The eXtreme version has all the features of the other two Micromites but is faster and has a larger memory capacity plus the ability to drive a VGA monitor for a large screen display. It works as a powerful, self contained computer with its own BASIC interpreter and instant start-up.
- Pi-cromite Runs on all versions of the Raspberry Pi with a 40-pin I/O connector. No analogue input capability but 5x faster than a Micromite eXtreme when running on a Pi 3.
- Armmite L4 Runs on the STM32L43x series chips. Is targeted for low power usage.
- Armmite F4 Runs on Armmite F4 (STM32F407VET6 development board) single board that has everything you need.
- Armmite H7 Runs on the NUCLEO-H743ZI processor. This is the highest speed single-chip Micromite currently available.
- Colour Maximite 2 The Colour Maximite 2 is a small self contained computer inspired by the home computers of the early 80's such as the Tandy TRS-80, Commodore 64 and Apple II. It includes its own BASIC interpreter and powers up in under a second into the BASIC interpreter. Output is to a VGA screen rather than LCDPanels.

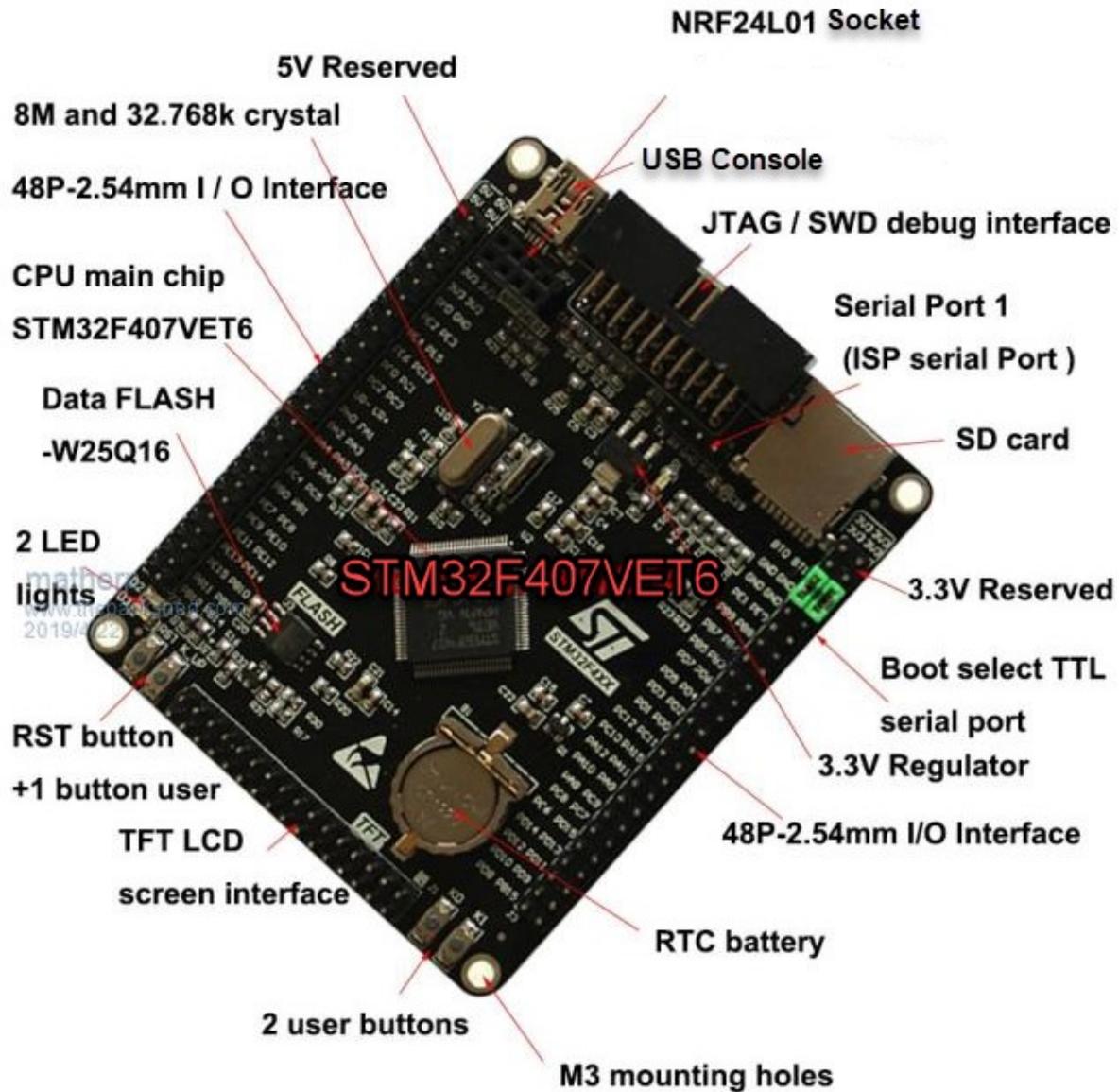
	Micromite		Micromite Plus		Micromite eXtreme	Armmite F4	Armmite H7
	28-pin DIP	44-pin SMD	64-pin SMD	100-pin SMD	100/144/64 -pin SMD	100 pin STM32F407VET6	NUCLEO-H743ZI2
Maximum CPU Speed	48 MHz	48 MHz	120 MHz	120 MHz	252MHz	168MHz	480MHz
Maximum BASIC Program Size	59 KB	59 KB	100 KB	100 KB	540 KB	132K	512KB
RAM Memory Size	52 KB	52 KB	108 KB	108 KB	460 KB	114K	512KB
Clock Speed (MHz)	5 to 48	5 to 48	5 to 120	5 to 120	200 to 252	168MHz	400
Total Number of I/O pins	19	33	45	77	75/115/46	47	102
Number of Analog Inputs	10	13	28	28	40/48/24	13	26
Number of Serial I/O ports	2	2	3 or 4	3 or 4	3 or 4	4	4
Number of SPI Channels	1	1	2	2	3/3/2	2	4

Number of I ² C Channels	1	1	1 + RTC	1 + RTC	2/2/1 + RTC	2	2
Number of 1-Wire I/O pins	19	33	45	77	75/115/46	47	96
PWM or Servo Channels	5	5	5	5	6	8	8
Serial Console	✓	✓	✓	✓	✓	✓	✓
USB Console			✓	✓	✓	✓	x
PS2 Keyboard and LCD Console			✓	✓	✓	✓	
USB Keyboard and LCD Console					✓		✓
SD Card Interface			✓	✓	✓	✓	✓
Supports ILI9341 LCD Displays	✓	✓	✓	✓	✓	✓	✓
Supports Ten LCD Panels from 1.44" to 8" (diameter)			✓	✓	✓+ ILI9481	SSD1963 ILI9341_P16 OTM8009A_16	✓+ ILI9481
Supports VGA Displays					✓		
Sound Output (WAV/tones)			✓	✓	✓	On-chip DACs	On-chip DACs
Supports PS2 Mouse Input					✓		
Floating Point Precision	Single	Single	Double S/W	Double S/W	Double H/W	Double S/W	Double H/W
Power Requirements	3.3V 30 mA	3.3V 30 mA	3.3V 80 mA	3.3V 80 mA	3.3V 160 mA	3.3V 200mA	3.3V 200mA

Armmite F4 Features

The Armmite F4 is a port of MMBasic to support a specific development board based on STM32F407VET6 Cortex-M4 32-bit RISC CPU processor which provides nearly all of the services for the user. This includes the flash memory (where the BASIC interpreter is installed),

This image provides an overview of its hardware features:



STM32F407VET6 Data Sheet and Schematic

This manual will describe the resulting features of the development board as a result of this specific MMBasic implementation. The STM32F407 Data Sheet and Schematic should be consulted to clarify any information on the wiring or underlying capabilities of the development board and its processor. They are available on these links.

https://github.com/mcauser/BLACK_F407VE/blob/master/docs/STM32F407VET6_datasheet.pdf

https://github.com/mcauser/BLACK_F407VE/blob/master/docs/STM32F407VET6_schematics.pdf

https://www.thebackshed.com/forum/uploads/panky/2021-02-24_164500_STM32F407VET6_schematic-english-2.pdf (with english translations, courtesy of @panky of TBS forum)

The features of the specific implementation, both hardware and software are summarized here. Many are further detailed within the manual.

STM32F407VET6 Cortex-M4 32-bit RISC CPU @ 168MHz

This is a 32-bit ARM processor with 512K of flash and 196K of RAM. It runs at 168MHz. It includes a dedicated display interface which is used to support 16bit parallel LCD Panels on the FSMC connector. The MMBasic firmware is loaded onto the flash memory of this chip and provides the MMBasic interpreter for the Armmite F4.

The Armmite F4 clock is 168Mhz.

132Kbyte program and 114Kbyte variable space

The Armmite F4 supports MMBasic programs up to 132Kbytes in size. Variable space is 114Kbyte.

```
ARMmite MMBasic Version 5.07.00b1
Copyright 2011-2020 Geoff Graham
Copyright 2016-2020 Peter Mather

> memory
Flash:
  0K ( 0%) Program (0 lines)
 132K (100%) Free

RAM:
  0K ( 0%) 0 Variables
  0K ( 0%) General
 114K (100%) Free
>
```

MM.DEVICE\$

On the Armmite F4 the read only variable MM.DEVICE\$ will return " Armmite F4".

Double Precision Floating Point

The Armmite F4 uses the hardware floating point capability of the STM32F407VET6 chip. All floating point uses double precision calculations.

Random Number Generation

The Armmite F4 uses the hardware random number generator in the STM32 series of chips to deliver true random numbers. This means that the RANDOMIZE command is no longer needed and is not supported.

Longstring handling

The Armmite F4 supports a comprehensive set of commands and functions for handling long strings stored in integer arrays

Input Output Pins and Protocols

Forty seven input/output pins with 13 capable of analog input. Built in support for an IR remote control, temperature and humidity sensors. Communications protocols include I2C, asynchronous serial, RS232, IEEE 485, SPI and 1-Wire. These can be used to communicate with many sensors (temperature, humidity, acceleration, etc) as well as for sending data to test equipment.

USB Console (the default)

By default MMBasic starts with the USB console enabled.

Four Serial Ports

The four serial ports share pins used for other functions, so may not be available if the other functions are required. COM1 can be dedicated as a serial console to replace the USB console if desired.

Eight PWM Channels

Minimum frequency is 1Hz, maximum is 24MHz. Duty cycle and frequency accuracy will depend on frequency. **The frequency can be any value upto 240,000,000.**

PWM 1A,1B,1C

PWM 2A,2B,2C

PWM 3A,3B

Two SPI Channels

The Armmite F4 supports two SPI channels. The second channel operates the same as the first, the only difference is that the commands use the notation SPI2 (for example SPI2 WRITE, etc).

Note that if the Armmite F4 is configured for a SPI based LCD panel or touch then SPI2 channel is not available for MMBasic. The SPI1 channel is available for use in MMBasic and is prewired on the development board for the onboard W25Q16 Flash chip and the NRF24L01 socket. See Appendix F for an example program to access the W25Q16 flash from MMBasic.

I2C

You can use I2C exactly the same as for the Micromite with the following limitations:

The implementation does not support 10-bit addressing (i.e. options 0 and 1 only).

The implementation does not support I2C slave mode.

A second I2C channel can be used using the command *I2C2*.

I2C ports are dedicated and cannot be used for general purpose I/O

1-Wire Communication

The 1-Wire protocol was developed by Dallas Semiconductor to communicate with chips using a single signalling line. Any pin can be used. See Appendix C for details.

Dual 12-bit DACs

The Armmite F4 has 2 12-bit DACs built into the chip. The analogue levels can be set using the DAC command. In addition they can be used by the PLAY FLAC command. The pins cannot be used for general purpose I/O. The DACs support an arbitrary function generator capability using the DAC START command.

Three 12-bit ADCs

Analogue to digital conversion can be carried out in 12-bit resolution, 10-bit resolution, and 8-bit resolution depending on the frequency of the conversion. In addition the ADC can read the voltage being output on the DACs, the battery backup voltage, the chip die temperature and the internal reference voltage. Using the ADC command conversion of three channels can be set to run in the background at up to 500,000 samples per second per channel and one of the channels can be set to provide edge-triggering of the conversion.

Battery Backed-up Built-in Real time clock (RTC)

The Armmite F4 includes a built-in RTC. A lithium CR1220 coin cell battery on the development board keeps the internal ARM STM32 real time clock running while the power is off and also keeps a bank of 4KB RAM alive at the same time. The real time clock is used to provide the correct time to MMBasic on startup and the battery backed RAM is used to store saved variables and options. The life of this battery life is about 3 to 4 years of normal use. All time and date functions work directly with the RTC and the timing can be trimmed with an OPTION command. The real time clock can be read at millisecond precision. The 32,768Hz crystal for the RTC is also used to discipline the main CPU oscillator ensuring accuracy of commands like TIMER. If you find that the time drifts while the power is off you can use the OPTION RTC CALIBRATE command to correct for any inaccuracies.

SPI LCD Panel and Touch Connector

The Armmite F4 software supports the ILI9341 and ILI9481 LCD panels with touch supported.

The development boards has no dedicated socket for them so individual wiring of the pins or an adaptor board is required. See [Appendix XX](#) for some details of adaptors.

16-bit interface to SSD1963, ILI9341 and OTM8009A Based LCD Displays

The Armmite F4 drives the SSD1963 and some other 16-bit parallel bus LCD displays. For extra speed the SSD1963 controllers run with a reduced colour range (65 thousand colours RGB565) compared to 16 million colours with the normal 8-bit interface. SPI touch is supported. The ILI9341 16 bit LCD that is purchased with the STM32F407VET6 development board, while only 320*240 pixels, plugs directly into the board via the 32 pin FSMC connector. All other LCD panels will require an adaptor board. [See Appendix XX for details.](#)

PS2 Keyboard Connection

A PS2 keyboard can be connected using the PS2 KB_CLK and KB_DATA lines on pins PD3 and PA15 respectively. The software supports the PS2 keyboard but there is no actual PS2 connector. See later in this document for more details.

Audio Output

The Armmite F4 has no audio socket connect to the board as supplied, however the audio appears on the DAC pins PA4 and PA5. See the later section [Audio Output](#) for information on connecting these to an amplifier.

MMBasic can generate audio in several formats ranging from simple sine wave tones through to playing FLAC and WAV audio files. (MP3 is not supported because of high processor resources required to decode)

The output is high impedance suitable for feeding into an amplifier. **It cannot directly drive a loudspeaker, headphones or any low impedance load and might be damaged if that was attempted.**

Extended WAV File Playback

The Armmite F4 can play WAV files (like the Micromite Plus) however, it is also capable of playing WAV files recorded with sampling rates of 24 KHz, 44.1KHz, and 48 KHz.

Temperature Sensor

The Dallas DS18B20 temperature sensor can be used to measure temperature. Support for the DS18B20 is built into MMBasic – see the section *Special Device Support* in this manual for the details. Any pin can be used.

External I/O connectors

The pins on the development board have been allocated to various MMBasic functions as outlined in the table in section [Pin and Connector Capabilities](#).

W25Q16 Flash

STM32F407VET6 development board has a 16Mbit (ie 2MByte of 8 bits) windbond flash chip built in. It is not directly accessed by the MMBasic firmware, but is available to use from with an MMBasic program.

It is connected to SPI1 and its chip select pin is PB0. (35) [Appendix E](#) has an example program for formatting and accessing it.

RST Key

Used to reset the Armmite F4 and start the bootup sequence as if the power had been cycled.

Key 0 Switch

User available key. Has special function to enable Serial Console if held while power is being applied. Connects ground to PE4 pin when pressed.

Key 1 Switch

User available key. Has special function to reset MMBasic if held while power is being applied. Connects ground to PE3 pin when pressed.

Key_UP Switch

Connects to the Wake-Up pin PA0 via a 10K resistor. Will wake the Armmite F4 from sleep mode.

LED D2 and D3

Two LEDs wired via 510 ohm resistors to 3.3v and are connect to IO pins PA6 and PA7 for immediate use to get started on flashing a LED.

Power LED

The power led D1 (green) is illuminated whenever power is applied.

VAR SAVE/RESTORE/CLEAR

The Armmite F4 allows the saving of up to 4K of data in battery backed up RTC RAM. This is achieved with the VAR SAVE command which will save the variables listed on its command line in to the battery backed up RAM. These variables can be restored with the VAR RESTORE command which will add all the saved variables to the variable table of the running program. Normally this command is placed near the start of a program so that the variables are ready for use by the program.

This facility is intended for saving calibration data, user selected options and other items. This is true RAM and is not subject to wear the same way as the flash used in the Micromites, so can be used as frequently as required. This area is cleared when ever a new program is loaded or VAR CLEAR is used.

Saving Options

Options are saved in 80 bytes battery backed up RTC RAM. The options are not overwritten when new firmware is loaded, so if you had an LCDPANEL configured and loaded new firmware, then it would still be configured. Use the command OPTION RESET to set the options to the default values if required.

WS2812 support

The Armmite F4 supports the WS2812 Led driver. This chip needs very specific timing to work properly and by incorporating support in the Armmite F4 firmware the user can program these chips with minimum effort. The command **WS2812** is used to set the colours of the LEDs. There is no limit to the size of the WS2812 string supported.

GPS support

The Armmite F4 support connection of a GPS to any of the 4 serial interfaces. The command **OPEN "COMn:baudrate" as GPS** is used to enable reception of NMEA GPS messages. THE **GPS()** function can then be used to interrogate the GPS data which is automatically parsed in the Armmite firmware. In addition **PRINT #GPS,string\$** can be used to automatically append a correct checksum to a GPS message.

OPTION VCC command

The Armmite F4 supports the OPTION VCC command. This allows the user to precisely set the supply voltage to the chip and is used in the calculation of voltages when using analogue inputs e.g. OPTION VCC 3.15. The parameter is not saved and should be initialised either on the command line or in a program. **The Armmite F4 has a reference value programmed in during production and this can be used to set the OPTION VCC value. E.g OPTION VCC XXXXXXXXXX**

CPU SLEEP commands

The Armmite F4 CPU sleep command as follows:

CPU SLEEP

The wakeup pin is PA0, however any other COUNT pin (PE1,PE3, PE4 and PA8) can also be used to wake the processor if enabled with SETPIN pinno, CIN or PIN or FIN.

CPU SLEEP time

The Armmite uses the RTC to generate an interrupt to wake the processor after a period of sleep. Any period can be specified including fractions of seconds and because the RTC is used the timing will be accurate. Using the embedded ARMMITE F4 date and time functions makes it easy to sleep until any particular time. e.g.

```
Midnight_tonight% = epoch(date$+" 00:00:00")+86400 'epoch at start of day today + secs in a day
```

```
CPU SLEEP Midnight_tonight% - epoch(now) ' sleep until midnight tonight
```

Watchdog Timer

One of the possible uses for the Armmite F4 is as an embedded controller. It can be programmed in MMBasic and when the program is debugged and ready for "prime time" the AUTORUN configuration setting can be turned on. The chip will then automatically run its program when power is applied and act as a custom integrated circuit performing some special task. The user need not know anything about what is running inside the chip.

However there is the possibility that a fault in the program could cause MMBasic to generate an error and return to the command prompt. This would be of little use in an embedded situation as the Armmite F4 would not have anything connected to the console. Another possibility is that the MMBasic program could get itself stuck in an endless loop for some reason. In both cases the visible effect would be the same... the program would stop running until the power was cycled.

To guard against this the watchdog timer can be used. This is a timer that counts down to zero and when it reaches zero the processor will be automatically restarted (the same as when power was first applied), this will occur even if MMBasic was sitting at the command prompt. Following the restart the automatic variable MM.WATCHDOG will be set to true to indicate that the restart was caused by a watchdog timeout.

The WATCHDOG command should be placed in strategic locations in the program to keep resetting the timer and therefore preventing it from counting down to zero. Then, if a fault occurs, the timer will not be reset, it will count down to zero and the program will be restarted (assuming the AUTORUN option is set).

PIN Security

Sometimes it is important to keep the data and program in an embedded controller confidential. In the Armmite F4 this can be done by using the OPTION PIN command. This command will set a pin number (which is stored in flash) and whenever the Armmite F4 returns to the command prompt (for whatever reason) the user at the console will be prompted to enter the PIN number. Without the correct PIN the user cannot get to the command prompt and their only option is to enter the correct PIN or reboot the Armmite. When it is rebooted the user will still need the correct PIN to access the command prompt.

Because an intruder cannot reach the command prompt they cannot list or copy a program, they cannot change the program or change any aspect of MMBasic or the Armmite. Once set the PIN can only be removed by providing the correct PIN as set in the first place. If the number is lost the only method of recovery is to reset MMBasic as described below (which will erase the program).

There are other time consuming ways of accessing the data (such as using the STM32Cube Programmer to examine the flash memory) so this should not be regarded as the ultimate security but it does act as a significant deterrent.

Single, Secure HEX File

If you write a program for the Armmite F4 and set the following options:

```
OPTION BREAK 0
OPTION AUTORUN ON
```

you will end up with a program that cannot be stopped or interrupted. To further bullet proof it you could use the watchdog timer and OPTION PIN.

You can then use STM32CubeProgrammer to read the complete flash memory of the Armmite F4 and export it as a hex file. This will contain the MMBasic firmware as well as your BASIC program and the above options.

This file can be sent to someone as custom firmware for the STM32F407VET6 development board. They can load the hex file and it will immediately start running your program. To them it will be indistinguishable from firmware written in C (other than the startup banner produced by MMBasic). They do not have to load MMBasic and they do not need know anything about programming for the Armmite F4.

The Serial Console

Using the OPTION BAUDRATE command the baud rate of the console can be changed to any speed up to 230400 bps. Changing the console baud rate to a higher speed makes the full screen editor much faster in redrawing the screen. If you have a reliable connection to the Micromite it is worth changing the speed to at least 115200.

Once changed the console baud rate will be permanently remembered unless another OPTION BAUDRATE command is used to change it. Using this command it is possible to accidentally set the baud rate to an invalid speed and in that case the only recovery is to reset MMBasic as described below.

When running as an embedded controller the serial console may no longer be required for programming. On the standard Micromite it can then be used as a third serial port and OPTION BAUDRATE used to set the required speed. If you do this it might be worth using the OPTION BREAK command to disable the break key to prevent an unintended CTRL-C in the console receive data from halting the running program.

Other useful options are OPTION CONSOLE NOECHO which will stop MMBasic from automatically echoing characters received on the console and OPTION CONSOLE INVERT which will invert the data on the transmit and receive lines so that it can be used with RS232 devices.

Resetting MMBasic

MMBasic can be reset to its original configuration using either one of two methods:

- The chip can be reprogrammed with the Armmite F4 firmware using STM32CubeProgrammer.
- Holding KEY 1 down while applying power, or pressing the RST button. You can connect ground to PE3 pin if you find it difficult to hold the small button down.

Either method will result in the program memory and saved variables being completely erased and all options (security PIN, console baud rate, etc) will be reset to their initial defaults.

Unsupported commands

If you are familiar with the Micromites then this list will save you looking for things that are not there.

- Changing CPU Speed. OPTION CPU SPEED is not available.
- The LIBRARY command is not supported.

Loading the MMBasic Firmware

Once you have the development board you need to load the MMBasic firmware. This only needs to be done once unless you need to load an updated version.

The latest [Armmite F4 software](#) is normally available on The Back Shed (TBS) forum. You will need to scroll through the thread and selected the latest version. Download it and extract the ArmmiteF407.bin or similar file to your computer.

You will place the development board in Boot Loader mode by setting jumpers for BT0 and BT1 pins, connect it to your computer via a USB cable and use the free STM32CubeProgrammer application to load the firmware.

Appendix G at the end of this document gives a very detailed description of loading the firmware as well as how to obtain the free STM32CubeProgrammer.

If you have not done so, you should go to Appendix G now.

When you complete the steps there you should have the MMBasic command prompt and are ready to go!

Options not cleared when firmware updated

If you reload the firmware after you have been using the Armmite, note that loading the new firmware will not clear the previous options as seen via OPTION LIST. These are now stored in battery backed-up ram so loading the firmware won't change them. If you don't want your original options, use OPTION RESET to set the default options.i.e.

```
OPTION LCDPANEL ILI9341_16, RLANDSCAPE
```

```
OPTION TOUCH PB12, PC5
```

Power and Console Connections

USB Console (the default)

In the Armmite F4 all programming is done through the console. At the console you can enter commands, edit programs, run programs and observe the output of your program – including error messages! This is by default pointed to the USB connector on STM32F407VET6 development board. There is nothing that you need to do on the Armmite F4 to use the USB console. Just plug the USB cable from the Armmite F4 into your host computer and MMBasic will automatically create a virtual serial port over USB so that you can communicate with it from a Windows, Linux or Macintosh computer using nothing more than the USB port.

The Armmite F4 has three options for the console input/outputs. These are the default USB console, a serial console on COM1 or optional PS2 keyboard and LCD display. The PS2 keyboard and LCD display if enabled as a console operate in parallel with the currently configured console, anything received from any of the inputs is placed in the input queue for the interpreter or your program to read and anything outputted by your program or the interpreter will be sent to all devices (if they are connected).

The communications protocol used is the CDC (Communication Device Class) protocol and there is native support for this in Windows 10, Linux (the cdc-acm driver) and Apple OS/X. Macintosh users can refer to the document "Using Serial Over USB on the Macintosh" on <http://geoffg.net/maximite.html>.

You can then use a terminal emulator such as Tera Term to connect to this communications port and it will work the same as if you were using a hardwired serial console. In Tera Term you do not have to specify a baud rate because the USB connection will run as fast as it can.

Be aware however that the USB connection will be reset if the Armmite F4 is reset and there are many things that can do this including the watchdog timer, the command CPU RESET and so on.

Tera Term on Windows 10 now seems to be able to automatically reconnect the console after a reset so you may not suffer the same frustration as past users.

If the loss of the USB console during development becomes an issue, the console can be switched to the serial console and be accessed via a USB to serial bridge connected to the serial console pins on the Armmite F4 board.

Another aspect to be aware of is that you should not use the CPU SLEEP command while a USB session is active. The results will be undefined but could possibly cause the Armmite F4 to crash and reboot.

On a Windows computer the Armmite F4 will appear as an additional serial port in Device Manager as illustrated on the right.

You also need a terminal emulator program on your desktop computer. This program acts like an old fashioned computer terminal where it will display text received from a remote computer and any key presses will be sent to the remote computer over the serial link.

The terminal emulator that you use should support VT100 emulation as that is what the editor built into the MMBasic expects. For Windows users it is recommended that you use Tera Term as this has a good VT100 emulator and is known to work with the XModem protocol which you can use to transfer programs to and from the Armmite F4 (Tera Term can be downloaded from: <http://tera-term.en.lo4d.com/>).



Other terminals are MMEdit and GFXTerm [more details to come.....](#)

Power Requirements

The USB connector is for power and the serial console over USB. The power requirement of the Armmite F4 is 5V at 160mA to 250mA (typical). This is within the capabilities of most USB chargers however some PCs (especially older laptops) may have trouble supplying this. If your Armmite F4 is suffering from intermittent issues such as reboots, errors reading the SD card, etc then it would be worth changing the power supply to one with a much higher capacity (for example, 2 amps or more).

The Armmite F4 software requests the host to provide 500mA on the 5V pin of the USB connector. Where the host supports this this should be enough to supply the Armmite F4 and most LCD panels. When one of the larger SSD1963 panels that require a 5V connection, an alternate method of supplying 5V power may need to be considered.

Switching to Serial Console (via Option Command)

By default the Console is directed to the USB connector. It can be redirected to the serial port on the board by either of these two methods.

If a working console on the USB is available connection and enter this command.

```
OPTION SERIAL CONSOLE ON
```

This routes the console to the serial connection on J6 of the board (near the SDCARD socket). The board needs to be restarted. You need a USB to serial module to connect from the PC. The terminal emulator and the serial port that it is used should be set to the Armmite F4 default of 115200 bauds 8 data bits and one stop bit.

Switching to Serial Console (via Key 0 at Restart)

If the USB console is not available for use or not working then use this method.

Hold Key 0 on the development while restarting the board by connecting power or pressing the RST button.

The system will start up with the OPTION SERIAL CONSOLE ON already selected. Connect to the J6 serial port as above.

Restoring USB Console (via Option Command)

To return to the USB console issue the following command from the serial console:

```
OPTION SERIAL CONSOLE OFF
```

will redirect to the USB console.

The USB cable will need to be removed and reinserted if it is in place, as the host computer will have marked it faulty as it previously would not have initiated properly as a serial port.

OPTION RESET

Issuing this command also return to the default state with the console directed to the USB connection. It will also reset all other options to their default values. This for the Armmite F4 means enabling the default ILI9341_P16 LCDPANEL and TOUCH.

The USB cable will need to be removed and reinserted if it is in place, as the host computer will have marked it faulty as it previously would not have initiated properly as a serial port.

Restoring USB Console (via Key 1 at Restart)

If the serial console is non available, or its speed is unknown a full reset of MMBasic will restore the USB Console.

Holding Key 1 on the development while restarting the board by connecting power or pressing the RST button will reset MMBasic. ***This will clear all program and variable memory and clear all options.***

It will also restore the USB console as the default.

The USB cable will need to be removed and reinserted if it is in place, as the host computer will have marked it faulty as it previously would not have initiated properly as a serial port.

COM1 available when not used as Serial console

The Armmite firmware controls the CDC connection as follows:

On power up, if no USB connection is plugged in (separate 5V supply) console output is discarded.
On power up, if a USB connection is plugged in console output will be buffered until a terminal emulator is connected.

Once running, if the USB connection is removed (separate 5V power) console output is discarded.
Once running, if the USB connection is re-inserted, console output will be restored from the point at which the USB was re-connected.

During development, USB resets can be a nuisance. You can use

OPTION SERIAL CONSOLE ON

to use an external USB/UART connected to the J6 header (just under and to the left of the SDcard slot in the picture above). The pinout on this is compatible with many of the CP2102 USB/UART PCBs which can be plugged directly onto the J6 header. In this mode the USB connection is completely disabled but you can still use the USB connection to power the board.

OPTION SERIAL CONSOLE OFF

is used to re-enable USB. After this the J6 header supports COM1 communications.

If the console is redirected to COM1 then when a USB cable is plugged in the USB Serial Bus device will fail to initialise correctly. This indicates the console is not on the USB connector.



Apple Macintosh

The Apple Macintosh (OS X) is somewhat easier as it has the device driver and terminal emulator built in. First start the application 'Terminal' and at the prompt list the connected serial devices by typing in:

```
ls /dev/tty.*
```

The USB to serial converter will be listed as something like `/dev/tty.usbmodem12345`. While still at the Terminal prompt you can run the terminal emulator at 115200 baud by using the command:

```
screen/dev/tty.usbmodem12345 115200
```

By default, the function keys will not be correctly defined for use in the Armmites built in program editor so you will have to use the control sequences as defined in the section *Full Screen Editor* of this manual. To avoid this you can reconfigure the terminal emulator to generate these codes when the appropriate function keys are pressed.

Instructions for Linux are here: <http://www.thebackshed.com/forum/ViewTopic.php?FID=16&TID=12171>

Shortcut Keys

When you are using a VT100 compatible terminal emulator on the console you can use the following function keys to insert a command at the command prompt:

F2	RUN
F3	LIST
F4	EDIT
F10	AUTOSAVE
F11	XMODEM RECEIVE
F12	XMODEM SEND

Pressing the key will insert the text at the command prompt, just as if it had been typed on the keyboard.

Using Serial Console via a USB – Serial Converter

It is unlikely your modern computer will have an actual serial port. The serial port is achieved using cheap and popular USB to Serial converters.

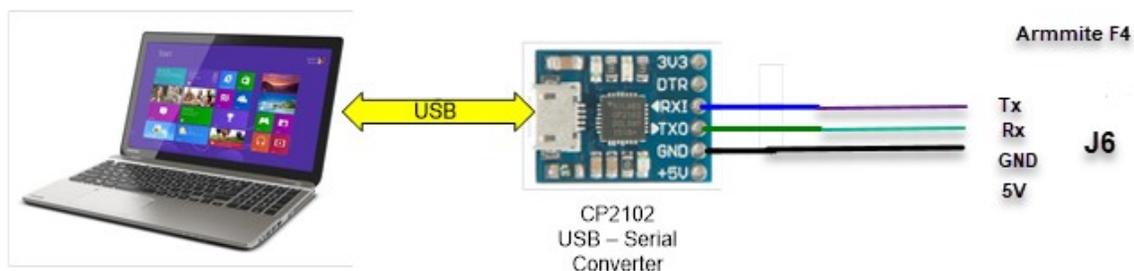
The serial console when enabled defaults to 115200 baud which uses TTL signal levels. This is similar to the RS232 interface on older personal computers but the TTL signal level is inverted and swings from zero to 3.3V.

There are many USB to serial converters on the market. These provide a TTL level serial interface on one side and a USB interface on the other. When connected to your computer the converter will appear as a virtual serial port. Recommended are converters based on the Silicon Labs CP2102 chip, they can be found on eBay for a few dollars (search for "CP2102") and work perfectly with the Micromite and Armmite F4. You should avoid converters based on the FTDI FT232RL chip as many Chinese manufacturers use non genuine chips which will not work with the current Windows drivers.

The serial interface side of the converter will generally have a ground pin and a 3.3V power output pin and this can be used to power the Micromite. The converter will also have two pins marked TX (or similar) for transmit and RX (or similar) for receive. The TX pin of the serial converter must go to the RX pin of the Micromite and the RX pin must go to the TX pin.

If you have a serial converter that operates at 5V you can still use it with the Armmite F4. All you need do is place a 1K resistor in series with the transmit signal from the converter. The resistor will limit the current to a safe level.

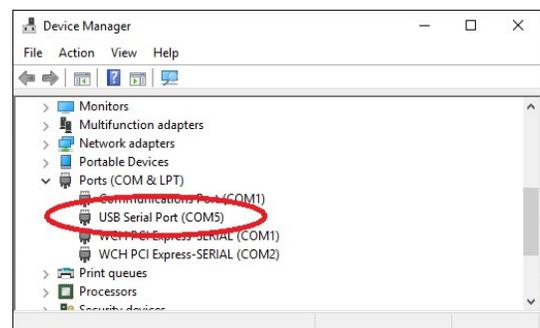
Below is a typical connection using the CP2102 converter. Note that the 3.3V output from the converter can be as high as 4.3V so its would be best to connect the 5v output to the 5v connector on the Armmite and let it convert to the correct voltage.



When you plug the USB side of the converter into your computer you may have to load a driver to make it work with the operating system. Once this is done you should note the port number created by your computer for the virtual serial connection. In Windows this can be done by starting Device Manager and checking the "Ports (COM & LPT)" entry for a new COM port as shown on the right.

Terminal Emulators

You also need a terminal emulator program on your desktop computer. This program acts like an old fashioned computer terminal where it will display text received from a remote



computer and any key presses will be sent to the remote computer over the serial link.

The terminal emulator that you use should support VT100 emulation as that is what the editor built into the Armmite expects. For Windows users it is recommended that you use Tera Term as this has a good VT100 emulator and is known to work with the XModem protocol which you can use to transfer programs to and from the Armmite F4 (Tera Term can be downloaded from: <http://tera-term.en.lo4d.com/>).

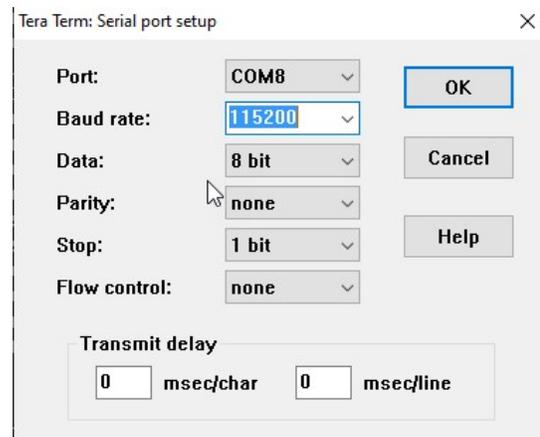
The terminal emulator and the serial port that it is using should be set to the ARmmite F4 standard of 115200 baud, 8 data bits and one stop bit. The screen shot on the right shows the setup for Tera Term. Note that the "Port:" setting will vary depending on which USB port your USB to TTL serial converter was plugged into.

If you are using Tera Term do not set a delay between characters and if you are using Putty set the backspace key to generate the backspace character.

Troubleshooting

If you cannot see the startup banner, try disconnecting the USB-serial converter and join its TX and RX pins. Then try typing something into the terminal emulator. You should see your characters echoed back, if not it indicates a fault with the converter or the terminal emulator.

If the USB-serial converter checks out the fault could be related to the console connection to the Micromite. Make sure that TX connects to RX and vice versa and that the baudrate is 115200. If you have an oscilloscope you should be able to see a burst of activity on the Armmite's TX line on power up. This is the Armmite sending its startup banner.



Pin and Connector Capabilities

Table showing Pin function and connector position

The capabilities and allocation of each pin are detailed in this table. MMBasic can address the pins via their pin number of connector name.

STM32F407VET6			MMBASIC	TFT-FSMC		OBS		
PIN	NAME	Connector	FUNCTIONS	NAME	PIN	TYPES	ADC	EXT.
1	PE02	J2-11	IR			DIN - DOUT		
2	PE03	J2-12	Count 2			DIN - DOUT		KEY1/INT2
3	PE04	J2-13	Count 3			DIN - DOUT		KEY0/INT3
4	PE05	J2-14	PWM-3A			DIN - DOUT		TIM9_CH1
5	PE06	J2-15	PWM-3B			DIN - DOUT		TIM9_CH2
6	VBAT							
7	PC13	J2-16				DIN - DOUT		
8	PC14		OSC32_IN					
9	PC15		OSC32_OUT					
10	GND			GND	1,30 32			
11	3.3V			3.3V	31			
12	OSC_IN		OSC8_IN					
13	OSC_OUT		OSC8_OUT					
14	RST	JTAG-15	NRST	RST	2			15 JTAG-RST
15	PC00	J2-17	15			DIN - DOUT - AIN	ADC_10 [A]	
16	PC01	J2-18	16			DIN - DOUT - AIN	ADC_11 [B]	
17	PC02	J2-19	17			DIN - DOUT - AIN	ADC_12 [C]	
18	PC03	J2-20	18			DIN - DOUT - AIN	ADC_13 [A]	
19	VDD							
20	VREF-	J2-21						
21	VREF+	J2-22						
22	VDDA							
23	PA00	J2-23	COM3-TX			DIN - DOUT - AIN	ADC_0 [A]	KEY_UP WK_UP
24	PA01	J2-24	COM3-RX			DIN - DOUT - AIN	ADC_1 [A]	
25	PA02	J2-25	COM4-TX			DIN - DOUT - AIN	ADC_2 [A]	
26	PA03	J2-26	COM4-RX			DIN - DOUT - AIN	ADC_3 [A]	
27	GND							
28	3.3V							
29	PA04	J2-27	DAC-1				DAC-1	
30	PA05	J2-28	DAC-2				DAC-2	
31	PA06	J2-29	PWM-1A			DIN - DOUT - AIN	ADC_6 [A]	LED D2
32	PA07	J2-30	PWM-1B			DIN - DOUT - AIN	ADC_7 [A]	LED D3
33	PC04	J2-31	33			DIN - DOUT - AIN	ADC_14 [B]	
34	PC05	J2-32	T_IRQ	PEN- IRQ	27	DIN - DOUT - AIN	ADC_15 [B]	
35	PB00	J2-33	PWM-1C			DIN - DOUT - AIN	ADC_8 [A]	F_CS
36	PB01	J2-34	LCD_BL	BL	28			TIM3_CH4
37	PB02	J3-6	BOOT1			DIN - DOUT		
38	PE07	J2-35	FSMC_D4	D4	14			

STM32F407VET6			MMBASIC	TFT-FSMC		OBS		
PIN	NAME	Connector	FUNCTIONS	NAME	PIN	TYPES	ADC	EXT.
39	PE08	J2-36	FSMC_D5	D5	13			
40	PE09	J2-37	FSMC_D6	D6	12			
41	PE10	J2-38	FSMC_D7	D7	11			
42	PE11	J2-39	FSMC_D8	D8	10			
43	PE12	J2-40	FSMC_D9	D9	9			
44	PE13	J2-41	FSMC_D10	D10	8			
45	PE14	J2-42	FSMC_D11	D11	7			
46	PE15	J2-43	FSMC_D12	D12	6			
47	PB10	J2-44	I2C2-SCL			DIN - DOUT		
48	PB11	J2-45	I2C2-SDA			DIN - DOUT		
49	VCAP1		VCAP					
50	3.3V		VDD					
51	PB12	J2-46	T_CS	T_CS	24	DIN - DOUT		
52	PB13	J2-47	SPI2-CLK	T_CLK	23	DIN - DOUT 3ma		
53	PB14	J2-48	SPI2-IN	T_MISO	26	DIN - DOUT		
54	PB15	J3-48	SPI2-OUT	T_MOSI	25	DIN - DOUT		
55	PD08	J3-47	FSMC_D13	D13	5			
56	PD09	J3-46	FSMC_D14	D14	4			
57	PD10	J3-45	FSMC_D15	D15	3			
58	PD11	J3-44	VBUS_FS			DIN - DOUT		
59	PD12	J3-43	PWM-2A			DIN - DOUT		TIM4_CH1
60	PD13	J3-42	FSMC_A18	DC	21			
61	PD14	J3-41	FSMC_D0	D0	18			
62	PD15	J3-40	FSMC_D1	D1	17			
63	PC06	J3-39	COM2-TX			DIN - DOUT		
64	PC07	J3-38	COM2-RX			DIN - DOUT		
65	PC08	J3-37	SDIO_D0					
66	PC09	J3-36	SDIO_D1					
67	PA08	J3-35	Count 4			DIN - DOUT		INT4
68	PA09	J3-34	COM1-TX			DIN - DOUT		J6-TXD
69	PA10	J3-33	COM1-RX			DIN - DOUT		J6-RXD
70	PA11	J3-32	USB-DM			USB D-		
71	PA12	J3-31	USB-DP			USB D+		
72	PA13	JTAG-7	SWDIO			DIN - DOUT		7 JTAG-TMS
73	VCAP2							
74	GND							
75	3.3V							
76	PA14	JTAG-9	SWCLK			DIN - DOUT		9 JTAG-TCK
77	PA15	J3-30	KBD_CLK			DIN - DOUT		5 JTAG-TDI
78	PC10	J3-29	SDIO_D2					
79	PC11	J3-28	SDIO_D3					
80	PC12	J3-27	SDIO_CK					
81	PD00	J3-26	FSMC_D2	D2	16			
82	PD01	J3-25	FSMC_D3	D3	15			
83	PD02	J3-24	SDIO_CMD					

STM32F407VET6			MMBASIC	TFT-FSMC		OBS		
PIN	NAME	Connector	FUNCTIONS	NAME	PIN	TYPES	ADC	EXT.
84	PD03	J3-23	KBD_DATA			DIN - DOUT		
85	PD04	J3-22	FSMC_NOE	RD	19			
86	PD05	J3-21	FSMC_NWE	WR	20			
87	PD06	J3-20	87			DIN - DOUT		
88	PD07	J3-19	FSMC_NE1	CS	22			
89	PB03	J3-18	SPI_CLK			DIN - DOUT		JP2-5 NRF-SCK
90	PB04	JTAG-3	SPI_IN			DIN - DOUT		JP2-7 NRF-MISO
91	PB05	J3-17	SPI-OUT			DIN - DOUT		JP2-6 NRF-MOSI
92	PB06	J3-16	I2C-SCL			DIN - DOUT		JP2-3 NRF_CE
93	PB07	J3-15	I2C-SDA			DIN - DOUT		JP2-4 NRF_CS
94	BOOT0	J3-5	BOOT0					
95	PB08	J3-14	PWM-2B			DIN - DOUT		JP2-8 NRF-IRQ
96	PB09	J3-13	PWM-2C			DIN - DOUT		TIM4_CH4
97	PE00	J3-12	97			DIN - DOUT		
98	PE01	J3-11	COUNT 1			DIN - DOUT		INT1
99	GND							
100	3.3V							

Explanation of keys used in above table

The following summary includes information based on the authors interpretation of the STM32F407VET6 data sheet and the schematic of the development board. These should be consulted for more detailed information.

An explanation of some of the codes used in the above table is also provided.

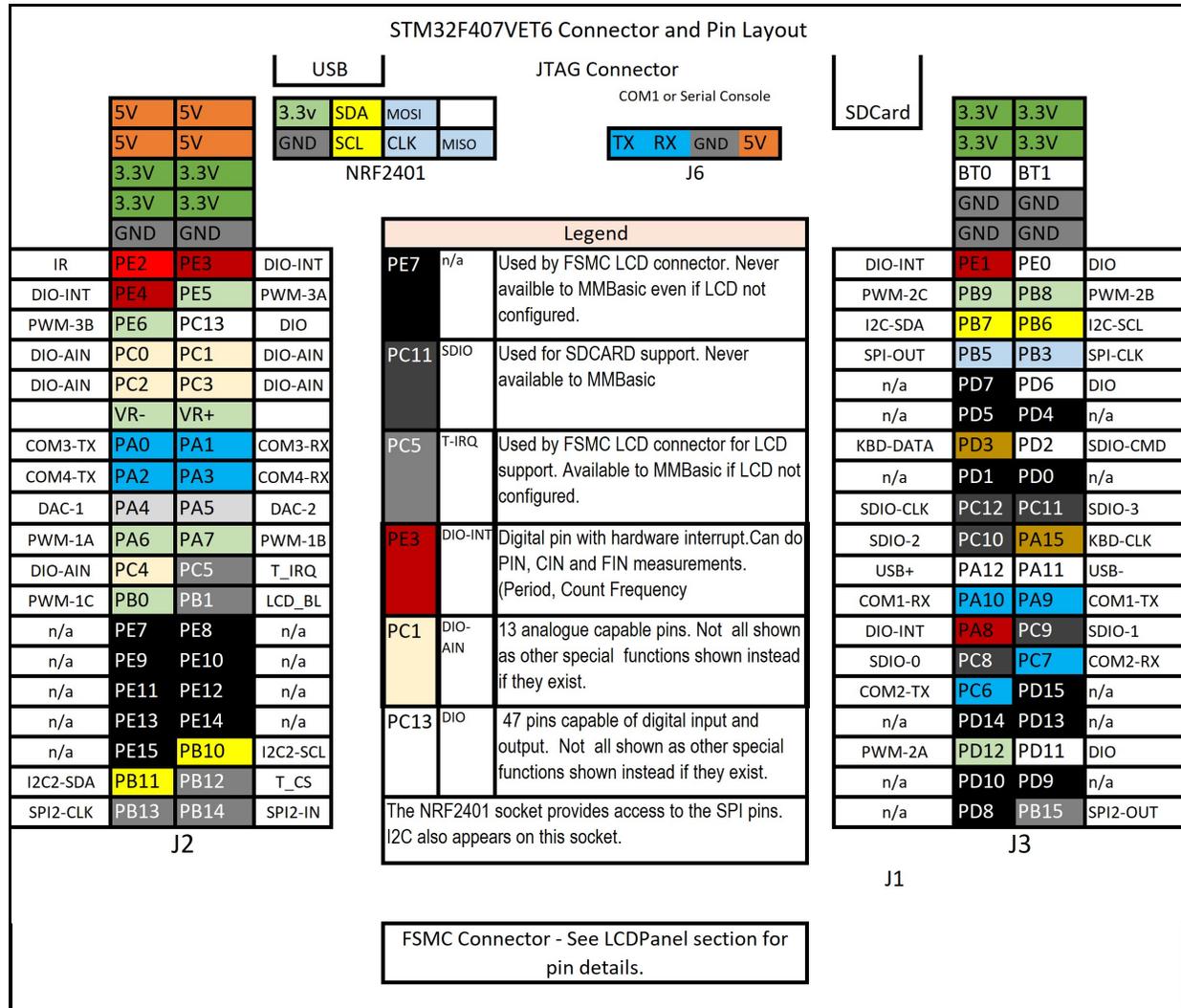
https://github.com/mcauser/BLACK_F407VE/blob/master/docs/STM32F407VET6_datasheet.pdf

https://github.com/mcauser/BLACK_F407VE/blob/master/docs/STM32F407VET6_schematics.pdf

Code or Item	Details
DIN -DOUT	These pins can be used as digital output and input. They are 5V tolerant and can sink or source a maximum of 25mA..
DIN-DOUT (3ma)	This pin, PB13 is supplied from VBAT and can only deliver 3mA. It cannot be used to drive a LED
DIN – DOUT -AIN	These pins are analogue capable. i.e. can be used to read voltage. They can be used as digital output and input. They are 5V tolerant and can sink or source a maximum of 25mA EXCEPT when in the AIN analogue mode, as they are then connected to the 3.3v ADC and must not exceed 3.3v The total current sunk or sourced for all pins combined cannot exceed 150mA in total.
PULL-UP	Weak pull-ups to 3.3v are typically 40K ohms for all pins except for PA10 and PA12 which are 11K.
PULL-DOWN	Weak pull-downs to GND are typically 40K ohms for all pins except for PA10 and PA12 which are 11K

	Pull-up and pull-down resistors are designed with a true resistance in series with a switchable PMOS/NMOS. This MOS/NMOS contribution to the series resistance is minimum (~10% order).
INTx COUNTx	These 4 pins PE1, PE3, PE4 and PE8 have hardware interrupts and can be used with the SETPIN CIN, PIN and FIN options for count, period and frequency measurements.
WK_UP	This is the wakeup pin. It can be used to wake the CPU after a CPU SLEEP command. Any of the 4 count pins will also wake the CPU if they are configured.
ADC_x [A] ADC_x [B] ADC_x [C]	These are analogue capable pins that can be connected to the ADC. The [A], [B] or [C] indicates which of the three input on the ADC they connect to. This is important when using the ADC command, as three input channels must have an appropriate A, B or C type pin. The ADC command in this manual details which pins can be used for each input.
I2C Pullups	Neither of the data line (SDA) or clock (SCL) for either of the I2C ports have pullup resistors (to 3.3V) installed. These may need to be installed if not already on the peripheral being used. DOES MMBASIC ENABLE THE PULLUP ?????
External Components	A number of pins have some external components attached to them on the development board. This needs to be considered if you want to use those pins. PA14 SWCLK on the JTAG-9 pin can be used but has a 10K pullup PA13 SWDIO on the JTAG-7 pin can be used but has a 10k pullup PB2 BOOT1 has 10K pulldown to ground.
47 Digital Pins	All digital pins can be used for digital I/O using the PIN() function and command and use the pin name as the reference. For example, pin PE4 can be set to an output using SETPIN PE4, DOUT and then the pin set high (ie, to 3.3V) using the command PIN(PE4)=1
KEY0	Key
KEY1	Key 1 on PE3 can be used to completely reset the Armmite F4 to its "factory default" condition. If that pin is connected to ground or KEY 1 held down on power up all options will be reset to their defaults and any program in flash memory erased. Note that external circuitry connected to this pin (eg, a capacitor) must not look like a short circuit at power up as this might trigger a reset.
K_UP	K_UP connects GND to the WK_UP pin when pressed.
NRF2401 Socket	SPI and I2C both appear at this socket. It is a convenient place to connect to them.

STM32407VET6 Connector and Pin Layout



STM32407VET6 Pins by Function

Function	Pins
COM1	TX - PA9 RX-PA10 OPTION SERIAL CONSOLE - to use as a serial console
COM2	TX - PC6 RX - PC7
COM3	TX - PA0 TX- PA1
COM4	TX - PA3 RX -PA2
I2C	SCL - PB6 (Can be also pickup from the NRF2401 socket) SDA - PB7 (Can be also pickup from the NRF2401 socket)
I2C2	SCL - PB10 SDA - PB11
SPI	CLK - PB3 (Can be also pickup from the NRF2401 socket) IN -PB4 (MISO) (not broken out to J2 or J3 - Pickup from the NRF2401 socket) OUT - PB5 (MOSI) (Can be also pickup from the NRF2401 socket)
SPI2	CLK - PB13 IN - PB14 (MISO) OUT - PB15 (MOSI)
DAC	1-PA4 2-PA5
PWM 1	1A -PA06 1B- PA07 1C- PB0
PWM 2	2A- PD12 2B- PB8 2C- PB9
PWM 3	3A- PE5 3B- PE6
KEYBOARD	CLOCK - PA15 DATA - PD3
Count Pins	PE1, PE3, PE4 and PA8 have hardware interrupts. They can be used with SETPIN CIN,FIN and PIN parameters for counting, frequency and period measurements
WAKE UP	PA0 is the wake up pin. K_UP will ground it when pressed. The count pins will also cause a wake up if configured.
Analogue Pins	The 13 pins PC0, PC1, PC2, PC3, PA0, PA1, PA2, PA3, PA6, PA7, PC4, PC5 and PB0 can be used as analogue pins. i.e. Capable of voltage measurement. Use SETPIN with AIN parameter.
ADC Pins	ch1 PC0, PC3, PA0, PA1, PA2, PA3, PA6, PA7, PB0 (Analogue A pins) ch2 PC2 (Analogue C pin) ch3 PC1, PC4, PC5 (Analogue B pins) The ADC has three input channels. The pins available to use for each channel are show above.

Quick Start Tutorial

The following assumes that you have programmed MMBasic into a suitable microcontroller and that you have the console connected to a suitable terminal emulator (see the previous chapter).

A Simple Program

Assuming that you have correctly connected a terminal emulator to the Micromite and have the command prompt (the greater than symbol as shown above, ie, >) you can enter a command line followed by the enter key and it will be immediately run.

For example, if you enter the command PRINT 1/7 you should see this:

```
> PRINT 1/7
0.142857
>
```

This is called immediate mode and is useful for testing commands and their effects.

To enter a program you can use the EDIT command which is fully described later in this manual. However to get a quick feel for how it works, try this sequence (your terminal emulator must be VT100 compatible):

- At the command prompt type, EDIT followed by the ENTER key.
- The editor should start up and you can enter this line: PRINT "Hello World"
- Press the F1 key in your terminal emulator (or CTRL-Q which will do the same thing). This tells the editor to save your program and exit to the command prompt.
- At the command prompt type RUN, followed by the ENTER key.
- You should see the message: Hello World

Congratulations. You have just written and run your first program on the Armmite F4. If you type EDIT again you will be back in the editor where you can change or add to your program.

Flashing a LED on the STM32F407VET6 board

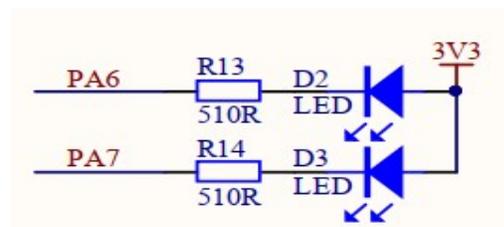
The board already has two diodes set up to use. D2 of pin PA6

D3 on pin PA7. Lets flash D2.

Use the EDIT command to enter the following program:

```
SETPIN PA6, DOUT
DO
  PIN(PA6) = 1
  PAUSE 300
  PIN(PA6) = 0
  PAUSE 300
LOOP
```

The STM32F407VET6 has these LEDs with appropriate resistors ready to go on the PA6 and PA7 pins.



When you have saved and run this program you should be greeted by the LED flashing on and off. It is not a great program but it does illustrate how your Armmite F4 can interface to the physical world via your programming.

The chapter [Using the I/O pins](#) later in this manual provides a full description of the I/O pins and how to control them.

Setting the AUTORUN Option

You now have the Armmite F4 doing something useful (if you can call flashing a LED useful). Assuming that this is all that you want the Micromite to do you can then instruct it to always run this program whenever power is applied.

To do this you first need to regain the command prompt and you can do this by entering CTRL-C at the console. This will interrupt the running program and return you to the command prompt.

Then enter the command:

```
OPTION AUTORUN ON
```

This instructs MMBasic to automatically run your program whenever power is applied. To test this you can remove the power and then re apply it. The Armmite should start up flashing the LED.

If this is all that you want, you can disconnect the console and it will sit there flashing the LED on and off forever. If ever you wanted to change something (for example the pause between on and off) you can attach your terminal emulator to the console, interrupt the program with a CTRL-C and edit it as needed.

This is the great benefit of the Armmites and Micromites, it is very easy to write and change a program.

Using MMBasic

Commands and Program Input

At the command prompt you can enter a command and it will be immediately run. Most of the time you will do this to tell the Armmite to do something like run a program or set an option. But this feature also allows you to test out commands at the command prompt.

To enter a program, the easiest method is to use the EDIT command. This will invoke the full screen program editor which is built into MMBasic and is described later in this manual. It includes advanced features such as search and copy, cut and paste to and from a clipboard.

You can also compose the program on your desktop computer using something like Notepad and then transfer it to the Armmite via the XModem protocol (see the XMODEM command) or by streaming it up the console serial link (see the AUTOSAVE command).

A third and very convenient method of writing and debugging a program is to use MMEdit. This is a program running on your Windows computer (also will run on Linux under Wine) which allows you to edit your program on your computer then transfer it to the Micromite with a single click of the mouse. MMEdit was written by Jim Hiley and can be downloaded for free from <https://www.c-com.com.au/MMEdit.htm>.

With all of these methods of entering and editing a program the result is saved in non volatile flash memory (this is transparent to the user). With the program held in flash memory it means that it will never be lost, even when the power is unexpectedly interrupted or the processor restarted.

One thing that you cannot do is use the old BASIC way of entering a program which was to prefix each line with a line number. Line numbers are optional in MMBasic so you can still use them if you wish but if you enter a line with a line number at the prompt MMBasic will simply execute it immediately.

Line Numbers, Program Structure and Editing

The structure of a program line is:

```
[line-number] [label:] command arguments [: command arguments] ...
```

A label or line number can be used to mark a line of code.

A label has the same specifications (length, character set, etc) as a variable name but it cannot be the same as a command name. When used to label a line the label must appear at the beginning of a line but after a line number (if used), and be terminated with a colon character (:).

Commands such as GOTO can use labels or line numbers to identify the destination (in that case the label does not need to be followed by the colon character). For example:

```
GOTO xxxx
- - -
xxxx: PRINT "We have jumped to here"
```

Multiple commands separated by a colon can be entered on the one line (as in INPUT A: PRINT B).

Running Programs

A program is set running by the RUN command. You can interrupt MMBasic and the running program at any time by typing CTRL-C on the console input and MMBasic will return to the command prompt.

You can list a program in memory with the LIST command. This will print out the program while pausing every 24 lines.

You can completely erase the program by using the NEW command.

Programs in the Armmite and Micromite is held in non volatile flash memory. This means that it will not be lost if the power is removed and, if you have the AUTORUN feature turned on, the Micromite/Armmite will

start by automatically running the program when power is restored (use the OPTION command to turn AUTORUN on).

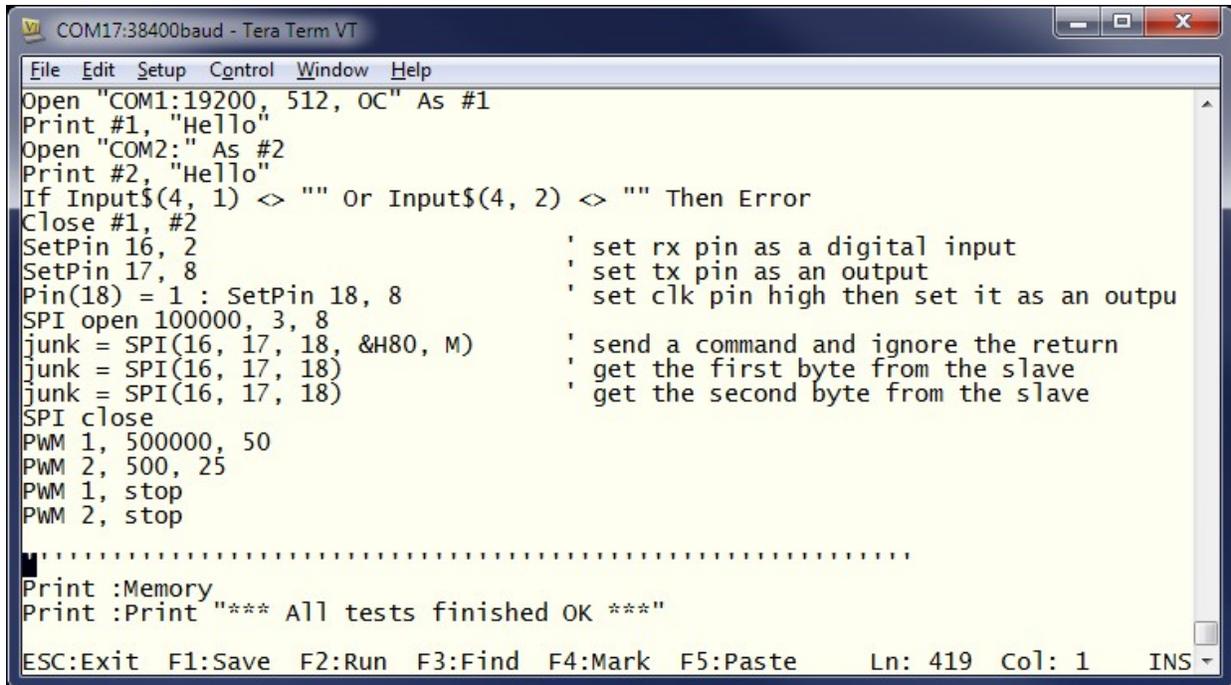
Setting Options

Many options can be set by using commands that start with the keyword OPTION. They are listed in the Options section of this manual. For example, you can set the baud rate of the console with the command:

```
OPTION BAUDRATE 115200
```

Full Screen Editor

An important productivity feature of the Micromites/Armmites is the full screen editor. This will work with any VT100 compatible terminal emulator (Tera Term is recommended).



```
COM17:38400baud - Tera Term VT
File Edit Setup Control Window Help
Open "COM1:19200, 512, 0C" As #1
Print #1, "Hello"
Open "COM2:" As #2
Print #2, "Hello"
If Input$(4, 1) <> "" Or Input$(4, 2) <> "" Then Error
Close #1, #2
SetPin 16, 2           ' set rx pin as a digital input
SetPin 17, 8           ' set tx pin as an output
Pin(18) = 1 : SetPin 18, 8 ' set clk pin high then set it as an output
SPI open 100000, 3, 8
junk = SPI(16, 17, 18, &H80, M) ' send a command and ignore the return
junk = SPI(16, 17, 18)         ' get the first byte from the slave
junk = SPI(16, 17, 18)         ' get the second byte from the slave
SPI close
PWM 1, 500000, 50
PWM 2, 500, 25
PWM 1, stop
PWM 2, stop
.....
Print :Memory
Print :Print "*** All tests finished OK ***"
ESC:Exit F1:Save F2:Run F3:Find F4:Mark F5:Paste Ln: 419 Col: 1 INS
```

The full screen program editor is invoked with the EDIT command. The cursor will be automatically positioned at the last place that you were editing at or, if your program had just been stopped by an error, the cursor will be positioned at the line that caused the error.

If you are used to an editor like Notepad, you will find that the operation of this editor is familiar. The arrow keys will move your cursor around in the text, home and end will take you to the beginning or end of the line. Page up and page down will do what their titles suggest. The delete key will delete the character at the cursor and backspace will delete the character before the cursor. The insert key will toggle between insert and overwrite modes. About the only unusual key combination is that two home key presses will take you to the start of the program and two end key presses will take you to the end.

At the bottom of the screen the status line will list the various function keys used by the editor and their action. In more details these are:

- | | |
|-----------|---|
| ESC | This will cause the editor to abandon all changes and return to the command prompt with the program memory unchanged. If you have changed the text you will be asked if you really what want to abandon your changes. |
| F1: SAVE | This will save the program to program memory and return to the command prompt. |
| F2: RUN | This will save the program to program memory and immediately run it. |
| F3: FIND | This will prompt for the text that you want to search for. When you press enter the cursor will be placed at the start of the first entry found. |
| SHIFT-F3 | Once you have used the search function you can repeatedly search for the same text by pressing SHIFT-F3. |
| F4: MARK | This is described in detail below. |
| F5: PASTE | This will insert (at the current cursor position) the text that had been previously cut or copied (see below). |

If you pressed the mark key (F4) the editor will change to the *mark mode*. In this mode you can use the arrow keys to mark a section of text which will be highlighted in reverse video. You can then delete, cut or copy the marked text. In this mode the status line will change to show the functions of the function keys in the mark mode. These keys are:

ESC	Will exit mark mode without changing anything.
F4: CUT	Will copy the marked text to the clipboard and remove it from the program.
F5: COPY	Will just copy the marked text to the clipboard.
DELETE	Will delete the marked text leaving the clipboard unchanged.

You can also use control keys instead of the functions keys listed above. These control keystrokes are:

LEFT	Ctrl-S	RIGHT	Ctrl-D	UP	Ctrl-E	DOWN	Ctrl-X
HOME	Ctrl-U	END	Ctrl-K	PageUp	Ctrl-P	PageDn	Ctrl-L
DEL	Ctrl-]	INSERT	Ctrl-N	F1	Ctrl-Q	F2	Ctrl-W
F3	Ctrl-R	ShiftF3	Ctrl-G	F4	Ctrl-T	F5	Ctrl-Y

If you are using Tera Term, Putty, MMEdit or GFXterm as the terminal emulator it is also possible to position the cursor by left clicking the PC's mouse in the terminal emulator's window.

The best way to learn the full screen editor is to simply fire it up and experiment.

The editor is a very productive method of writing a program. With the command EDIT you can write your program on the Armmite. Then, by pressing the F2 key, you can save and run the program. If your program stops with an error you can press the function key F4 which will run the command EDIT and place you back in the editor with the cursor positioned at the line that caused the error. This edit/run/edit cycle is very fast.

Using the OPTION BAUDRATE command the baud rate of the console can be changed to any speed up to 230400 bps. Changing the console baud rate to a higher speed makes the full screen editor much faster in redrawing the screen. If you have a reliable connection to the Armmite it is worth changing the speed to at least 115200. 115200 is the default speed on the Serial Console for the Armmite F4.

The editor expects that the terminal emulator is set to 24 lines per screen with each line 80 characters wide. Both of these assumptions can be changed with the OPTION DISPLAY command to suit non standard displays.

Note that a terminal emulator can lose its position in the text with multiple fast keystrokes (like the up and down arrows). If this happens you can press the HOME key twice which will force the editor to jump to the start of the program and redraw the display.

Colour Coded Editor Display

The editor has the ability to colour code the edited program with keywords, numbers and comments displayed in different colours. By default the output is not colour coded but this feature can be enabled with the command:

```
OPTION COLOURCODE ON
```

or disabled with:

```
OPTION COLOURCODE OFF
```

This setting is saved in flash memory and is automatically applied on startup.

Note:

- This feature requires a terminal emulator that can interpret the appropriate escape codes and respond correctly. It works correctly with Tera Term however, Putty needs its default background colour to be changed to white (Settings >> Colours >> Default Background >> Modify).
- Colour coding the editor's output requires many extra characters to be sent to the terminal emulator and this can slow down the screen update at lower baud rates. If colour coding is used it is recommended that the baud rate be set to a higher speed (115200) as discussed above.

Supported LCD Displays, Touch and PS2 Keyboard

16 Bit Parallel Interface LCD Panels

The Armmite F4 supports a number of LCD Panels with 16 bit parallel interface. These are preferred due to their increased speed, and some are not much difference in price to the SPI screens. The ILI9341_P16 that can be ordered with the STM32F407VET6 plugs directly into the FSMC connector without any need for additional wiring.

The supported panels are:

ILI9341 P16 Available with a matching connector, but also available with a 40pin connector which needs an adaptor.

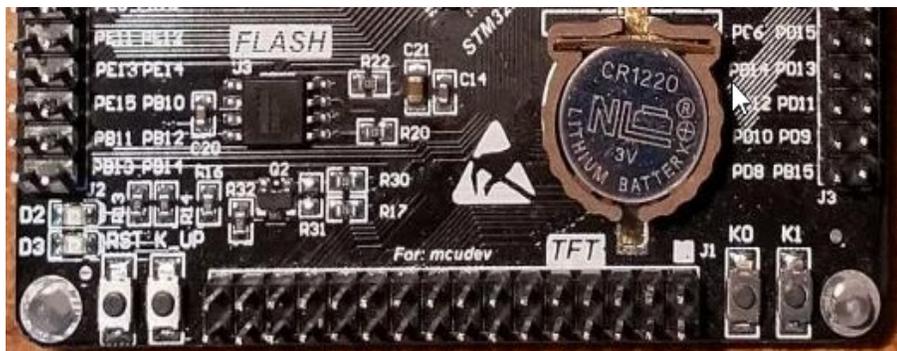
SSD1963 4" 5" 7" 8" 9" These are high quality, have been available long term and need an adaptor board.

OTM8009A 800*480 IPS display. Is cheaper than the SSD1963 an can be a good choice.

Pin out for FSMC connector.

The pinout below is for the FSMC LCDPANEL connection at the end of the board. This is viewed from the top of the board. The pin numbers and function as shown below. You will need this if you want to make an adaptor board.

PEN-IRQ is the same as T-IRQ. The LCD-BL pin is controlled by the BACKLIGHT command. The T-CLK, MOSI and MISO pins are SPI2 and can be used to connect to an SPI LCD Panel. Touch uses the same SPI2, PEN-IRQ and T-CS.



FSMC LCD Connector – Top View

31	29	27	25	23	21	19	17	15	13	11	9	7	5	3	1
3.3V	n/c	Pen-IRQ	MOSI	T-CLK	DC	RD	B1	B3	B5	B7	B9	B11	B13	B15	GND
GND	GND	LCD-BL	MISO	T-CS	CS	WR	B0	B2	B4	B6	B8	B10	B12	B14	RST
32	30	28	26	24	22	20	18	16	14	12	10	8	6	4	2

Pins not available to MMBasic or SPI LCD Panels.

The B0-B15 data pins, DC, CS, RD, WR, RST pins can only be used by the 16bit parallel LCD Panels. They cannot be used from MMBasic and can not be allocated for use by SPI LCD Panels.

SPI LCD panels need RST, D/C and CS pins, but you need to allocate them from the available DIN-DOUT pins, you cannot use any of these.

SSD1963 Power Considerations

For 4.3", 5", 7" versions make sure the backlight control jumper on the display is set to 1963_PWM. You can then leave the LED_A pin disconnected but it is benign if it is wired to 3.3V or the LCD_BL pin on the STM32F407 (PB1)

For 4.3" and 5" displays only the 3.3V supply is needed.

For 7" displays the 5V pin on the display should be connected. I found that my STM32F407 board was able to supply adequate power but this will depend on the USB port on the computer used. The USB enumeration code now asks for 500mA which is adequate for a 7" display (400mA) + the STM32F407 board itself.

For 9" displays using the Ritech adapter I needed to use an external 5V supply connected to the 5V pin.

SPI Based LCD Panels

The standard Armitte F4 includes support for colour LCD display panels using the ILI9341 controller and an SPI interface. These have a 240x320 pixel colour TFT display, come in a variety of sizes (2.2", 2.4" and 2.8") and are low cost (typically US\$8). The Armmite F4 also supports this display in addition to many more ranging in size from 1.44" to 8" . .

On eBay you can find suitable displays by searching for the controller name (ILI9341).

There are many similar displays on the market however some have subtle differences that could prevent them from working with the Armmite. MMBasic was tested with the displays illustrated below so, if you wish to guarantee success make sure your display matches the photographs and the specifications listed below.

The ILI9341 based displays use an SPI interface and have the following basic specifications:

- A 2.2, 2.4 or 2.8 inch display
- Resolution of 240 x 320 pixels and a colour depth of 262K/65K
- A ILI9341 controller with a SPI serial interface

The display illustrated also has a touch sensitive facility which is fully supported by MMBasic. There are versions of this display without the touch controller (the 16-pin IC on the bottom right of the PCB) but there is not much point in purchasing these as the price difference is small.

There is a version which uses a TFT panel that requires the colours to be inverted. This is supported by the Micromite by specifying the controller type as ILI9341_I.



Connecting SPI Based LCD Panels

The SPI based display controllers share the SPI2 interface with the touch controller (if present).

The following table lists the connections required between the LCD display board and the Armmite

ILI9341 Display	Description	Connector	Pin
T_IRQ	Touch Interrupt	FSMC	27
T_DO	Touch Data Out (MISO)	FSMC	26
T_DIN	Touch Data In (MOSI)	FSMC	25
T_CS	Touch Chip Select	FSMC	24
T_CLK	Touch SPI Clock	FSMC	23
SDO (MISO)	Display Data Out (MISO)	FSMC	26
LED	The FSMC LCD-BL can only drive at logic levels. If the LCD		

	panel does not have a driver transistor built in, unless you provide a driving circuit you cannot connected to the FSMC LCD-BL pin. If you can drive the backlight with logic level then the BACKLIGHT command and the LCD-BL pin can be used to control the LCD's backlight. Otherwise the LCD backlight should be connected to VCC via a suitable resistor to give a satisfactory backlight.		
SCK	Display SPI Clock	FSMC	23
SDI (MOSI)	Display Data In (MOSI)	FSMC	25
D/C	Display Data/Command Control	Configurable	
RESET	Display Reset (when pulled low)	Configurable	
CS	Display Chip Select	Configurable - Optional if Touch not used.	
GND	Ground		
VCC	5V supply (the controller draws less than 10 mA)		

Note: Be careful to ground yourself when handling the display as the ILI9341 controller is sensitive to static discharge and can be easily destroyed.

Where a Micromite connection is listed as "configurable" the specific pin should be specified with the OPTION LCDPANEL or OPTION TOUCH commands (see below).

The backlight power (the LED connection) should be supplied from the main 5V supply via a current limiting resistor. A typical value for this resistor is 18Ω which will result in a LED current of about 63 mA. The value of this resistor can be varied to reduce the power consumption or to provide a brighter display.

Important: Care must be taken with display panels that share the SPI port between a number of devices (display controller, touch, etc). In this case all the Chip Select signals must be configured in MMBasic or disabled by a permanent connection to 3.3V. If this is not done any unconnected Chip Select pins will float causing the wrong controller to respond to commands on the SPI bus.

Supported SPI Panels

- ILI9481 SPI based 480*320 SPI touch controller
- ILI9341 SPI based 2.2", 2.4" and 2.8" panels using the ILI9341 controller

Configuring MMBasic

To use the displays MMBasic must be configured using the OPTION LCDPANEL command which is normally entered at the command prompt. Every time the Armmite is restarted MMBasic will automatically initialise the display. This command can also be embedded in a program with certain conditions – see the section [Embedding Configuration Options in a Program](#) for more details.

The syntax is:

```
OPTION LCDPANEL controller, orientation, D/C pin, reset pin [,CS pin]
```

Where:

'controller' can be either ILI9341 or ILI9481

'orientation' can be LANDSCAPE, PORTRAIT, RLANDSCAPE or RPORTRAIT. These can be abbreviated to L, P, RL or RP. The R prefix indicates the reverse or "upside down" orientation.

'D/C pin' and 'reset pin' are the I/O pins to be used for these functions. Any free pin can be used.

'CS pin' can also be any free I/O pin and is optional if a touch controller is not used. This parameter can be left off the command and the CS pin on the LCD display wired permanently to ground. If the touch controller is used this pin must then be specified and connected to an I/O pin.

e.g

```
OPTION LCDPANEL ILI9341, LANDSCAPE, PE0, PD6, PC4
```

In some circumstances it may be necessary to interrupt power to the LCD panel while the Armmite is running (eg, to save battery power) and in that case the GUI RESET LCDPANEL command can be used to reinitialise the display the same as in power up.

If the LCD panel is no longer required, the command `OPTION LCDPANEL DISABLE` can be used which will return the I/O pins for general use.

To test the display, you can enter the command `GUI TEST LCDPANEL`. You should see an animated display of colour circles being rapidly drawn on top of each other. Press the space key on the console's keyboard to stop the test.

Important: The above test may not work if the display has a touch controller and the touch controller has not been configured (ie, the touch Chip Select pin is floating). In this case configure the touch controller (see below) and then retry `GUI TEST LCDPANEL`.

To verify the configuration, you can use the command `OPTION LIST` to list all options that have been set including the configuration of the LCD panel.

Touch Support

All the supported LCD panels are supplied with a resistive touch sensitive panel and associated controller chip. To use the touch feature in MMBasic the touch controller must first be connected to the Armmite F4 (see the above chapter for the details) and then configured (see below).

Configuring Touch

To use the touch facility MMBasic must be configured using the `OPTION TOUCH` command which is normally entered at the command prompt. This should be done after the LCD panel has been configured. Every time the Armmite is restarted MMBasic will automatically initialise the touch controller. This command can also be embedded in a program with certain conditions – see the section [Embedding Configuration Options in a Program](#)

The syntax is:

```
OPTION TOUCH PC5, PB12[, click]
```

The optional *click* pin will cause an audible click when a touch is detected if a piezo buzzer is connected between it and GND. Command `GUI BEEP period` will cause a beep of duration *period* msec.

If the touch facility is no longer required use the command `OPTION TOUCH DISABLE` to disable the touch feature and return the I/O pins for general use (the 'T_CS pin' should be held high to disable the controller).

Calibrating the Touch Screen

Before the touch facility can be used it must be calibrated using the `GUI CALIBRATE` command.

This command will present a target in the top left corner of the screen. Using a pointy but blunt object such as a toothpick press exactly on the centre of the target and hold it down for at least a second. MMBasic will record this location and then continue the calibration by sequentially displaying the target in the other three corners of the screen for touch and calibration.

The calibration routine may warn that the calibration was not accurate. This is just a warning and you can still use the touch feature if you wish but it would be better to repeat the calibration using more care.

Following calibration, you can test the touch facility using the `GUI TEST TOUCH` command. This command will blank the screen and wait for a touch. When the screen is touched a white dot will be placed on the display marking the position on the screen. If the calibration was carried out successfully the dot should be displayed exactly under the location of the stylus on the screen.

To exit the test routine, you can press the space bar on the console's keyboard.

Touch Functions

To detect if and where the screen is touched you can use the following functions in a BASIC program:

- `TOUCH(X)`
Returns the X coordinate of the currently touched location.
- `TOUCH(Y)`
Returns the Y coordinate of the currently touched location.

Both functions return -1 if the screen is not being touched. See the [Advanced Graphics](#) sections for more information on using touch.

Touch Interrupts

The following command will enable the touch interrupt. A separate subrouting can be called for each of the touch down and touch up events.

‘Set up the interrupt

```
GUI INTERRUPT IntTouchDown, IntTouchUp
```

‘These subroutines is called each time there is a touch on the LCDPanel

```
SUB IntTouchDown
```

```
    PRINT TOUCH(X), TOUCH(Y)
```

```
END SUB
```

```
SUB IntTouchUp
```

```
    PRINT "you took your finger off"
```

```
END SUB
```

Specifying the number zero (single digit) as the argument will cancel both of these interrupts. ie:

```
GUI INTERRUPT 0
```

See the [Advanced Graphics](#) sections for more information on using touch and it interaction with the graphic controls.

LCD Display as the Console Output

A PS2 keyboard can be used on its own as an alternative input method but it works particularly well when the LCD display panel is used as the console output. The LCD must be in the landscape or reverse landscape orientation and it must be first configured using OPTION LCDPANEL.

To enable the output to the LCD panel you should use the following command:

```
OPTION LCDPANEL CONSOLE [font [, fc [, bc [, blight]]]
```

'font' is the default font, 'fc' is the default foreground colour, 'bc' is the default background colour and 'blight' is the default backlight brightness (2 to 100). These settings are saved in flash and are used to configure MMBasic at power up. They are all optional and default to font 2, white, black and 100%.

Colour coding in the editor (see below) is also turned on by this command (OPTION COLOURCODE OFF will turn it off again). To disable using the LCD panel as the console the command is OPTION LCDPANEL NOCONSOLE.

Used with a PS2 keyboard this option turns the Armmite F4 into a self contained computer with its own keyboard and display. Rather like a modern version of the Maximite (see <http://geoffg.net/maximite.html>).

PS2 Keyboard

The connection diagram for the keyboard is shown on the below. The Armmite enables weak pullups on the clock and data lines so the 4.7 K resistors shown in the diagram are optional and for most keyboards there will be no ill effects if they are omitted. Refer to the pinout diagrams in section [Pin and Connector Capabilities](#) to see the pins used.

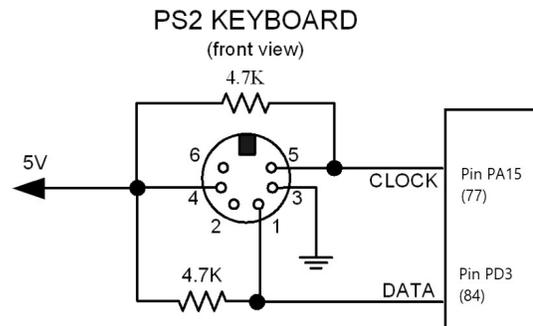
If you don't have a PS2 keyboard they may not be as hard to come by as you may think. See this thread on the backshed forum. Many wired keyboards still support PS2 even though they have a USB connector and operate as a USB keyboard. If you find one that works as PS2 and is currently available, please add to the thread.

<https://www.thebackshed.com/forum/ViewTopic.php?FID=16&TID=13440>

PS2 Connection for Armmite F4

The PS2 connector can be bypassed, just plug the USB connector on the keyboard into a female usb breakout board and run D+ to the F4 keyboard clock (PA15, pin 77) and D- to keyboard data (PD3, pin 84), set OPTION KEYBOARD US and test. Connect 5V and GND as well.

If it doesn't work it is worth swapping D+ and D- over and trying to add the 4.7K resistors as trouble shooting steps, but some USB keyboards just will no longer support PS2.



Before the keyboard can be used it must first be enabled by specifying the language of the keyboard:

OPTION KEYBOARD language

Where 'language' is a two character code such as US for the standard keyboard used in the USA, Australia and New Zealand. Other keyboard layouts that can be specified are United Kingdom (UK), French (FR), German (GR), Belgium (BE), Italian (IT) or Spanish (ES). Note that the non US layouts map some of the special keys present on these keyboards but the corresponding special character will not display as they are not part the standard Armmite F4 fonts (another character will be used instead).

This command configures the I/O pins dedicated to the keyboard and initialises it for use. As with the similar commands for TOUCH, etc this option will be saved in flash memory and automatically applied on power up. If you want to remove the keyboard you can do this with the OPTION KEYBOARD DISABLE command.

User Defined LCD Panels in MMBasic

It is possible to write drivers for LCD Panels in MMBasic. The link below details these drivers and has an example for an I2C SSD1306 128*32 display panel that work for the Armmite F4.

`OPTION LCDPANEL USER, 128, 32`

<https://www.thebackshed.com/forum/ViewTopic.php?TID=10159&PID=140808#140808>

Loadable Driver LCD Panels as CSUBs

With the introduction of CSUBs it should now be possible to write loadable drivers for the Armmite F4.

There are none written at present. The link below points to a table maintained on the Fruit of the Shed wiki page that is usually kept up to date with the drivers available for the Micromite and Armmites.

<http://fruitoftheshed.com/MMBasic.LCD%20Panel%20list.ashx>

Variables, Expressions and Operators

In MMBasic command names, function names, labels, variable names, file names, etc are not case sensitive, so that "Run" and "RUN" are equivalent and "dOO" and "Doo" refer to the same variable.

Variables

Variables can start with an alphabetic character or underscore and can contain any alphabetic or numeric character, the period (.) and the underscore (_). They may be up to 32 characters long.

A variable name or a label must not be the same as a function or one of the following keywords: THEN, ELSE, GOTO, GOSUB, TO, STEP, FOR, WHILE, UNTIL, LOAD, MOD, NOT, AND, OR, XOR, AS.

Eg, step = 5 is illegal as STEP is a keyword.

MMBasic supports three different types of variables:

1. Double Precision Floating Point.

These can store a number with a decimal point and fraction (eg, 45.386) however they will lose accuracy when more than 14 digits of precision are used. Floating point variables are specified by adding the suffix '!' to a variable's name (eg, i!, nbr!, etc). They are also the default when a variable is created without a suffix (eg, i, nbr, etc).

2. 64-bit Signed Integer.

These can store positive or negative numbers with up to 19 decimal digits without losing accuracy but they cannot store fractions (ie, the part following the decimal point). These are specified by adding the suffix '%' to a variable's name. For example, i%, nbr%, etc.

3. A String.

A string will store a sequence of characters (eg, "Tom"). Each character in the string is stored as an eight bit number and can therefore have a decimal value of 0 to 255. String variable names are terminated with a '\$' symbol (eg, name\$, s\$, etc). Strings can be up to 255 characters long.

Note that it is illegal to use the same variable name with different types. Eg, using nbr! and nbr% in the same program would cause an error. This is different from the original Colour Maximite which allowed this.

Most programs use floating point variables as these can deal with the numbers used in typical situations and are more intuitive when dealing with division and fractions. So, if you are not bothered with the details, always use floating point.

Constants

Numeric constants may begin with a numeric digit (0-9) for a decimal constant, &H for a hexadecimal constant, &O for an octal constant or &B for a binary constant. For example &B1000 is the same as the decimal constant 8. Constants that start with &H, &O or &B are always treated as 64-bit unsigned integer constants.

Decimal constants may be preceded with a minus (-) or plus (+) and may be terminated with 'E' followed by an exponent number to denote exponential notation. For example 1.6E+4 is the same as 16000.

When a constant number is used it will be assumed that it is an integer if a decimal point or exponent is not used. For example, 1234 will be interpreted as an integer while 1234.0 will be interpreted as a floating point number.

String constants are surrounded by double quote marks ("). Eg, "Hello World".

OPTION DEFAULT

A variable can be used without a suffix (ie, !, % or \$) and in that case MMBasic will use the default type of floating point. For example, the following will create a floating point variable:

```
Nbr = 1234
```

However the default can be changed with the OPTION DEFAULT command. For example, OPTION DEFAULT INTEGER will specify that all variables without a specific type will be integer. So, the following will create an integer variable:

```
OPTION DEFAULT INTEGER  
Nbr = 1234
```

The default can be set to FLOAT (which is the default when a program is run), INTEGER, STRING or NONE. In the latter all variables must be specifically typed otherwise an error will occur.

The OPTION DEFAULT command can be placed anywhere in the program and changed at any time but good practice dictates that if it is used it should be placed at the start of the program and left unchanged.

OPTION EXPLICIT

By default MMBasic will automatically create a variable when it is first referenced. So, `Nbr = 1234` will create the variable and set it to the number 1234 at the same time. This is convenient for short and quick programs but it can lead to subtle and difficult to find bugs in large programs. For example, in the third line of this fragment the variable `Nbr` has been misspelt as `Nbrs`. As a consequence the variable `Nbrs` would be created with a value of zero and the value of `Total` would be wrong.

```
Nbr = 1234
Incr = 2
Total = Nbrs + Incr
```

The OPTION EXPLICIT command tells MMBasic to not automatically create variables. Instead they must be explicitly defined using the DIM, LOCAL or STATIC commands (see below) before they are used. The use of this command is recommended to support good programming practice. If it is used it should be placed at the start of the program before any variables are used.

DIM and LOCAL

The DIM and LOCAL commands can be used to define a variable and set its type and are mandatory when the OPTION EXPLICIT command is used.

The DIM command will create a global variable that can be seen and used throughout the program including inside subroutines and functions. However, if you require the definition to be visible only within a subroutine or function, you should use the LOCAL command at the start of the subroutine or function. LOCAL has exactly the same syntax as DIM.

If LOCAL is used to specify a variable with the same name as a global variable then the global variable will be hidden to the subroutine or function and any references to the variable will only refer to the variable defined by the LOCAL command. Any variable created by LOCAL will vanish when the program leaves the subroutine.

At its simplest level DIM and LOCAL can be used to define one or more variables based on their type suffix or the OPTION DEFAULT in force at the time. For example:

```
DIM nbr%, s$
```

But it can also be used to define one or more variables with a specific type when the type suffix is not used:

```
DIM INTEGER nbr, nbr2, nbr3, etc
```

In this case `nbr`, `nbr2`, `nbr3`, etc are all created as integers. When you use the variable within a program you do not need to specify the type suffix. For example, `MyStr` in the following works perfectly as a string variable:

```
DIM STRING MyStr
MyStr = "Hello"
```

The DIM and LOCAL commands will also accept the Microsoft practice of specifying the variable's type after the variable with the keyword "AS". For example:

```
DIM nbr AS INTEGER, s AS STRING
```

In this case the type of each variable is set individually (not as a group as when the type is placed before the list of variables).

The variables can also be initialised while being defined. For example:

```
DIM INTEGER a = 5, b = 4, c = 3
DIM s$ = "World", i% = &H8FF8F
DIM msg AS STRING = "Hello" + " " + s$
```

The value used to initialise the variable can be an expression including user defined functions.

The DIM or LOCAL commands are also used to define an array and all the rules listed above apply when defining an array. For example, you can use:

```
DIM INTEGER nbr(10), nbr2, nbr3(5,8)
```

When initialising an array the values are listed as comma separated values with the whole list surrounded by brackets. For example:

```
DIM INTEGER nbr(5) = (11, 12, 13, 14, 15, 16)
```

or

```
DIM days(7) AS STRING = ("", "Sun", "Mon", "Tue", "Wed", "Thu", "Fri", "Sat")
```

STATIC

Inside a subroutine or function it is sometimes useful to create a variable which is only visible within the subroutine or function (like a LOCAL variable) but retains its value between calls to the subroutine or function. You can do this by using the STATIC command. STATIC can only be used inside a subroutine or function and uses the same syntax as LOCAL and DIM. The difference is that its value will be retained between calls to the subroutine or function (ie, it will not be initialised on the second and subsequent calls).

For example, if you had the following subroutine and repeatedly called it, the first call would print 5, the second 6, the third 7 and so on.

```
SUB Foo
  STATIC var = 5
  PRINT var
  var = var + 1
END SUB
```

Note that the initialisation of the static variable to 5 (as in the above example) will only take effect on the first call to the subroutine. On subsequent calls the initialisation will be ignored as the variable had already been created on the first call.

As with DIM and LOCAL the variables created with STATIC can be float, integers or strings and arrays of these with or without initialisation.

CONST

Often it is useful to define an identifier that represents a value without the risk of the value being accidentally changed - which can happen if variables were used for this purpose (this practice encourages another class of difficult to find bugs).

Using the CONST command you can create an identifier that acts like a variable but is set to a value that cannot be changed. For example:

```
CONST InputVoltagePin = 26
CONST MaxValue = 2.4
```

The identifiers can then be used in a program where they make more sense to the casual reader than simple numbers. For example:

```
IF PIN(InputVoltagePin) > MaxValue THEN SoundAlarm
```

A number of constants can be created on the one line:

```
CONST InputVoltagePin = 26, MaxValue = 2.4, MinValue = 1.5
```

The value used to initialise the constant is evaluated when the constant is created and can be an expression including user defined functions.

The type of the constant is derived from the value assigned to it; so for example, MaxValue above will be a floating point constant because 2.4 is a floating point number. The type of a constant can also be explicitly set by using a type suffix (ie, !, % or \$) but it must agree with its assigned value.

Expressions and Operators

MMBasic will evaluate a mathematical expression using the standard mathematical rules. For example, multiplication and division are performed first followed by addition and subtraction. These are called the rules of precedence and are detailed below.

This means that $2 + 3 * 6$ will resolve to 20, so will $5 * 4$ and also $10 + 4 * 3 - 2$.

If you want to force the interpreter to evaluate parts of the expression first you can surround that part of the expression with brackets. For example, $(10 + 4) * (3 - 2)$ will resolve to 14 not 20 as would have been the case if the brackets were not used. Using brackets does not appreciably slow down the program so you should use them liberally if there is a chance that MMBasic will misinterpret your intension.

The following operators, in order of precedence, are implemented in MMBasic. Operators that are on the same level (for example + and -) are processed with a left to right precedence as they occur on the program line.

Arithmetic operators:

^	Exponentiation (eg, b^n means b ⁿ)
* / \ MOD	Multiplication, division, integer division and modulus (remainder)
+ -	Addition and subtraction

Shift operators:

x << y x >> y	These operate in a special way. << means that the value returned will be the value of x shifted by y bits to the left while >> means the same only right shifted. They are integer functions and any bits shifted off are discarded. For a right shift any bits introduced are set to the value of the top bit (bit 63). For a left shift any bits introduced are set to zero.
------------------	--

Logical operators:

NOT INV	invert the logical value on the right (eg, NOT a=b is a<>b) or bitwise inversion of the value on the right (eg, a = INV b)
<> < > <= =< >= =>	Inequality, less than, greater than, less than or equal to, less than or equal to (alternative version), greater than or equal to, greater than or equal to (alternative version)
=	equality
AND OR XOR	Conjunction, disjunction, exclusive or

The operators AND, OR and XOR are integer bitwise operators. For example PRINT (3 AND 6) will output 2.

The other logical operations result in the integer 0 (zero) for false and 1 for true. For example the statement PRINT 4 >= 5 will print the number zero on the output and the expression A = 3 > 2 will store +1 in A.

The NOT operator will invert the logical value on its right (it is not a bitwise invert) while the INV operator will perform a bitwise invert. Both of these have the highest precedence so they will bind tightly to the next value. For normal use of NOT or INV the expression to be operated on should be placed in brackets. Eg:

```
IF NOT (A = 3 OR A = 8) THEN ...
```

String operators:

+	Join two strings
<> < > <= =< >= =>	Inequality, less than, greater than, less than or equal to, less than or equal to (alternative version), greater than or equal to, greater than or equal to (alternative version)
=	Equality

String comparisons respect case. For example "A" is greater than "a".

Mixing Floating Point and Integers

MMBasic automatically handles conversion of numbers between floating point and integers. If an operation mixes both floating point and integers (eg, PRINT A% + B!) the integer will be converted to a floating point number first, then the operation performed and a floating point number returned. If both sides of the operator are integers then an integer operation will be performed and an integer returned.

The one exception is the normal division ("/") which will always convert both sides of the expression to a floating point number and then return a floating point number. For integer division you should use the integer division operator "\".

Functions will return a float or integer depending on their characteristics. For example, PIN() will return an integer when the pin is configured as a digital input but a float when configured as an analog input.

If necessary you can convert a float to an integer with the INT() function. It is not necessary to specifically convert an integer to a float but if it was needed the integer value could be assigned to a floating point variable and it will be automatically converted in the assignment.

64-bit Unsigned Integers

MMBasic on the Armmite F4 supports 64-bit signed integers. This means that there are 63 bits for holding the number and one bit (the most significant bit) which is used to indicate the sign (positive or negative). However it is possible to use full 64-bit unsigned numbers as long as you do not do any arithmetic on the numbers.

64-bit unsigned numbers can be created using the &H, &O or &B prefixes to a number and these numbers can be stored in an integer variable. You then have a limited range of operations that you can perform on these. They are << (shift left), >> (shift right), AND (bitwise and), OR (bitwise or), XOR (bitwise exclusive or), INV (bitwise inversion), = (equal to) and <> (not equal to). Arithmetic operators such as +, -, etc may be confused by a 64-bit unsigned number and could return nonsense results.

Note that shift right is a signed operation. This means that if the top bit is a one (a negative signed number) and you shift right then it will shift in ones to maintain the sign.

To display 64-bit unsigned numbers you should use the HEX\$(), OCT\$() or BIN\$() functions.

For example, the following 64-bit unsigned operation will return the expected results:

```
X% = &HFFFF0000FFFF0044
Y% = &H800FFFFFFFFFFFFFFF
X% = X% AND Y%
PRINT HEX$(X%, 16)
```

Will display "800F0000FFFF0044"

Implementation Characteristics

Maximum program size (as plain text) is 132KB. Note that MMBasic tokenises the program when it is stored in flash so the final size in flash might vary from the plain text size.

Maximum length of a command line is 255 characters.

Maximum length of a variable name or a label is 32 characters.

Maximum number of dimensions to an array is 8.

Maximum number of arguments to commands that accept a variable number of arguments is 50.

Maximum number of nested FOR...NEXT loops is 10.

Maximum number of nested DO...LOOP commands is 10.

Maximum number of nested GOSUBs, subroutines and functions (combined) is 50.

Maximum number of nested multiline IF...ELSE...ENDIF commands is 10.

Maximum number of user defined subroutines and functions (combined): 100

Maximum number of interrupt pins that can be configured: 10

Numbers are stored and manipulated as single precision floating point numbers or 64-bit signed integers. The maximum floating point number allowable is 3.40282347e+38 and the minimum is 1.17549435e-38. The Armmite F4 uses double precision

The range of 64-bit integers (whole numbers) that can be manipulated is ± 9223372036854775807.

Maximum string length is 255 characters.

Maximum line number is 65000.

Maximum number of background pulses launched by the PULSE command is 5.

Compatibility

MMBasic implements a large subset of Microsoft's GW-BASIC. There are numerous differences due to physical and practical considerations but most standard BASIC commands and functions are essentially the same. An online manual for GW-BASIC is available at <http://www.antonis.de/qbebooks/gwbasmn/index.html> and this provides a more detailed description of the commands and functions.

MMBasic also implements a number of modern programming structures documented in the ANSI Standard for Full BASIC (X3.113-1987) or ISO/IEC 10279:1991. These include SUB/END SUB, the DO WHILE ... LOOP, the SELECT...CASE statements and structured IF .. THEN ... ELSE ... ENDIF statements.

Using the I/O pins

Digital Inputs

A digital input is the simplest type of input configuration. If the input voltage is higher than 2.5V the logic level will be true (numeric value of 1) and anything below 0.65V will be false (numeric value of 0). The inputs use a Schmitt trigger input so anything in between these levels will retain the previous logic level. Pins marked as 5V are 5V tolerant and can be directly connected to a circuit that generates up to 5.5V without the need for voltage dropping resistors.

In your BASIC program you would set the input as a digital input and use the PIN() function to get its level. For example:

```
SETPIN PA0, DIN
IF PIN(PA0) = 1 THEN PRINT "High"
```

The SETPIN command configures pin PA0 as a digital input and the PIN() function will return the value of that pin (the number 1 if the pin is high). The IF command will then execute the command after the THEN statement if the input was high. If the input pin was low the program would just continue with the next line in the program.

The SETPIN command also recognises a couple of options that will connect an internal resistor from the input to either the supply or ground. This is called a "pullup" or "pulldown" resistor and is handy when connecting to a switch as it saves having to install an external resistor to place a voltage across the contacts.

Analog Inputs

Pins marked as ANALOG can be configured to measure the voltage on the pin. The input range is from zero to 3.3V and the PIN() function will return the voltage. For example:

```
> SETPIN PA0, AIN
> PRINT PIN(PA0)
2.345
>
```

You will need a voltage divider if you want to measure voltages greater than 3.3V. For small voltages you may need an amplifier to bring the input voltage into a reasonable range for measurement.

The measurement uses the analog power pin (pin 28 on the 28-pin chip and 17 on the 44-pin chip) as the reference voltage and MMBasic scales the reading by assuming that the voltage on this pin is exactly 3.3V. Normally the Micromite is powered from a voltage regulator so this assumption is correct. However, when battery power is used, the supply voltage can vary which will cause inaccurate readings. In that case the program should scale the reading accordingly. For example:

```
A = (PIN(x) / 3.3) * PowerV
```

where "PowerV" is the voltage on the analog power pin.

The measurement of voltage is very sensitive to noise on the Analog Power and Ground pins. For accurate and repeatable voltage measurements care should be taken with the PCB design to isolate the analog circuit from the digital circuits and ensure that the Analog Power supply is as noise free as possible. Note that if the voltage on an analog input is greater than the voltage on the Analog Power pin it can cause damage or a "CPU Exception" (ie, crash) when an attempt is made to read that voltage.

Counting Inputs

The pins marked as COUNT can be configured as counting inputs to measure frequency, period or just count pulses on the input.

For example, the following will print the frequency of the signal on pin 15:

```
> SETPIN PE3, FIN
> PRINT PIN(PE3)
110374
>
```

In this case the frequency is 110.374 kHz.

By default the gate time is one second which is the length of time that MMBasic will use to count the number of cycles on the input and this means that the reading is updated once a second with a resolution of 1 Hz. By specifying a third argument to the SETPIN command it is possible to specify an alternative gate time between 10 ms and 100000 ms. Shorter times will result in the readings being updated more frequently but the value returned will have a lower resolution. The PIN() function will always return the frequency in Hz regardless of the gate time used.

For example, the following will set the gate time to 10ms with a corresponding loss of resolution:

```
> SETPIN PE3, FIN, 10
> PRINT PIN(PE3)
110300
>
```

For accurate measurement of signals less than 10 Hz it is generally better to measure the period of the signal. When set to this mode the Micromite will measure the number of milliseconds between sequential rising edges of the input signal. The value is updated on the low to high transition so if your signal has a period of (say) 100 seconds you should be prepared to wait that amount of time before the PIN() function will return an updated value.

The COUNTING pins can also count the number of pulses on their input. When a pin is configured as a counter (for example, SETPIN PE3, CIN) the counter will be reset to zero and Micromite will then count every transition from a low to high voltage. The counter can be reset to zero again by executing the SETPIN command a second time (even though the input was already configured as a counter).

The response to input pulses is very fast and the Armmite can count pulses as narrow as 10 nS. The frequency response depends on the load on the processor (ie, the number of counting inputs and if serial or I²C communications is used). It can be as high as 800 kHz with no other activity but is normally about 300 kHz.

Digital Outputs

All I/O pins can be configured as a standard digital output. This means that when an output pin is set to logic low it will pull its output to zero and when set high it will pull its output to 3.3V. In MMBasic this is done with the PIN command. For example PIN(PE3) = 0 will set pin PE3 to low while PIN(PE3) = 1 will set it high. When operating in this mode, a pin is capable of sourcing 10 mA which is sufficient to drive a LED or other logic circuits running at 3.3V.

The "OC" option on the SETPIN command makes the output pin open collector. This means that the output driver will pull the output low (to zero volts) when the output is set to a logic low but will go to a high impedance state when set to logic high. If you then connect a pull-up resistor to 5V (on pins that are 5V tolerant) the logic high level will be 5V (instead of 3.3V using the standard output mode). The maximum pull-up voltage in this mode is 5.5V.

Pulse Width Modulation

The PWM (Pulse Width Modulation) command allows the Micromite to generate square waves with a program controlled duty cycle. By varying the duty cycle you can generate a program controlled voltage output for use in controlling external devices that require an analog input (power supplies, motor controllers, etc). The PWM outputs are also useful for driving servos and for generating a sound output via a small transducer.

There are three PWM controllers; the first has three outputs and the second two to give a total of eight PWM outputs. The frequency of each controller can be independently set from 20 Hz to 500 kHz and the duty cycle for each output (ie, eight outputs) can also be independently set from between 0% and 100% with a 0.1% resolution when the frequency is below 25 kHz (above 25 kHz the resolution is 1% or better up to 250 kHz).

When the Micromite is powered up or the PWM OFF command is used the PWM outputs will be set to high impedance (they are neither off nor on). So, if you want the PWM output to be low by default (zero power in most applications) you should use a resistor to pull the output to ground when it is set to high impedance. Similarly, if you want the default to be high (full power) you should connect the resistor to 3.3V.

Interrupts

Interrupts are a handy way of dealing with an event that can occur at an unpredictable time. An example is when the user presses a button. In your program you could insert code after each statement to check to see if the button has been pressed but an interrupt makes for a cleaner and more readable program.

When an interrupt occurs MMBasic will execute a special section of code and when finished return to the main program. The main program is completely unaware of the interrupt and will carry on as normal.

Any I/O pin that can be used as a digital input can be configured to generate an interrupt using the SETPIN command with up to ten interrupts active at any one time. Interrupts can be set up to occur on a rising or falling digital input signal (or both) and will cause an immediate branch to the specified user defined subroutine. The target can be the same or different for each interrupt. Return from an interrupt is via the END SUB or EXIT SUB commands. Note that no parameters can be passed to the subroutine however within the interrupt subroutine calls to other subroutines are allowed.

If two or more interrupts occur at the same time they will be processed in order of the interrupts as defined with SETPIN. During the processing of an interrupt all other interrupts are disabled until the interrupt subroutine returns. During an interrupt (and at all times) the value of the interrupt pin can be accessed using the PIN() function.

Interrupts can occur at any time but they are disabled during INPUT statements. Also interrupts are not recognised during some long hardware related operations (eg, the TEMPR() function) although they will be recognised if they are still present when the operation has finished.. When using interrupts the main program is completely unaffected by the interrupt activity unless a variable used by the main program is changed during the interrupt.

Because interrupts run in the background they can cause difficult to diagnose bugs. Keep in mind the following factors when using interrupts:

- For most programs MMBasic will respond to an interrupt in under 30µs however some commands (such as the TEMPR() function) can block interrupts for up to 200ms and it is possible for an interrupt (eg, a button press) to occur and vanish within this window and in that case it will never be recognised.
- When inside an interrupt all other interrupts are blocked so your interrupts should be short and exit as soon as possible. For example, never use PAUSE inside an interrupt. If you have some lengthy processing to do you should simply set a flag and immediately exit the interrupt, then your main program loop can detect the flag and do whatever is required.
- The subroutine that the interrupt calls (and any other subroutines called by it) should always be exclusive to the interrupt. If you must call a subroutine that is also used by an interrupt you must disable the interrupt first (you can reinstate it after you have finished with the subroutine).
- Remember to disable an interrupt when you have finished needing it – background interrupts can cause strange and non-intuitive bugs.

In addition to interrupts generated by the change in state of an I/O pin, an interrupt can also be generated by other sections of MMBasic including timers and communications ports. The list of all these interrupts (in high to low priority ranking) is:

1. CSUB Interrupt
2. ON KEY
3. I2C Slave Rx
4. I2C Slave Tx
5. COM1: Serial Port
6. COM2: Serial Port
7. COM3: Serial Port
8. COM4: Serial Port
9. GUI Int Down
10. GUI Int Up
11. WAV Finished
12. IR Receive
13. I/O Pin Interrupts in order of definition
14. Tick Interrupts (1 to 4 in that order)

As an example: If an ON KEY interrupt occurred at the same time as a COM1: interrupt the ON KEY interrupt subroutine would be executed first and then, when the interrupt subroutine finished, the COM1: interrupt subroutine would then be executed.

Timing

MMBasic has a number of features that make it easy to time events and control external circuitry that needs timing.

MMBasic maintains an internal clock. You can get the current date and time using the DATE\$ and TIME\$ functions and you can set them by assigning the new date and time to them. The calendar will start from zero each time Armmite is first powered up **except** if the RTC returns a realistic date (ie > 2018) in which case it will set its time from the battery backed-up RTC included in the Armite F4.

The PAUSE command will freeze the execution of the program for a specified number of milliseconds. So, to create a 12ms wide pulse you could use the following:

```
SETPIN 4, DOUT
PIN(4) = 1
PAUSE 12
PIN(4) = 0
```

You can also create a pulse using the PULSE command. This will generate very narrow pulses (eg, 20µs) or long pulses up to several days. Long pulses are run in the background and the program will continue uninterrupted.

Another useful feature is the TIMER function which acts like a stopwatch. You can set it to any value (usually zero) and it will count upwards every millisecond.

A timing function is also provided by the SETTICK command. This command will generate an interrupt at regular intervals (specified in milliseconds). Think of it as the regular "tick" of a watch. For example, the following code fragment will print the current time and the voltage on pin 2 every second. This process will run independently of the main program which could be doing something completely unrelated.

```
SETPIN PC0, AIN
SETTICK 1000, DOINT
DO
    ` main processing loop
LOOP

SUB DOINT          ` tick interrupt
    PRINT TIME$, PIN(PC0)
END SUB
```

The second line sets up the "tick" interrupt, the first parameter of SETTICK is the period of the interrupt (1000ms) and the second is the starting label of the interrupt code. Every second (ie, 1000 ms) the main processing loop will be interrupted and the program starting at the label DOINT will be executed.

Up to four "tick" interrupts can be setup. These interrupts have the lowest priority.

The accuracy of the Micromite's internal clock can vary by a little due to manufacturing tolerances and temperature. To compensate for this the OPTION CLOCKTRIM command can be used to trim the clock to a more accurate value.

Subroutines and Functions

A program defined subroutine or function is simply a block of programming code that is contained within a module and can be called from anywhere within your program. It is the same as if you have added your own command or function to the language.

Subroutines

A subroutine acts like a command and it can have arguments (sometimes called a parameter list). In the definition of the subroutine they look like this:

```
SUB MYSUB arg1, arg2$, arg3
  <statements>
  <statements>
END SUB
```

And when you call the subroutine you can assign values to the arguments. For example:

```
MYSUB 23, "Cat", 55
```

Inside the subroutine `arg1` will have the value 23, `arg2$` the value of "Cat", and so on. The arguments act like ordinary variables but they exist only within the subroutine and will vanish when the subroutine ends. You can have variables with the same name in the main program and they will be hidden by the arguments defined for the subroutine.

When calling a subroutine you can supply less than the required number of values and in that case the missing values will be assumed to be either zero or an empty string. You can also leave out a value in the middle of the list and the same will happen. For example:

```
MYSUB 23,, 55
```

Will result in `arg2$` being set to the empty string "" .

Rather than using the type suffix (eg, the \$ in `arg2$`) you can use the suffix `AS <type>` in the definition of the subroutine argument and then the argument will be known as the specified type, even when the suffix is not used. For example:

```
SUB MYSUB arg1, arg2 AS STRING, arg3
  IF arg2 = "Cat" THEN ...
END SUB
```

Local Variables

Inside a subroutine you can define a variable using `LOCAL` (which has the same syntax as `DIM`). This variable will only exist within the subroutine and will vanish when the subroutine exits. You can have a variable in your main program with the same name but it will be hidden and the local variable used while the subroutine is executed.

If you do not declare the variable as `LOCAL` within the subroutine and `OPTION EXPLICIT` is not in force it will be created as a global variable and be visible in your main program and subroutines, just like a normal variable declared outside a subroutine or function.

Functions

Functions are similar to subroutines with the main difference being that the function is used to return a value in an expression. The rules for the argument list in a function are similar to subroutines. The only difference is that brackets are required around the argument list when you are calling a function, even if there are no arguments (they are optional when calling a subroutine).

To return a value from the function you assign a value to the function's name within the function. If the function's name is terminated with a \$, a % or a ! the function will return that type, otherwise it will return whatever the `OPTION DEFAULT` is set to. You can also specify the type of the function by adding `AS <type>` to the end of the function definition.

For example:

```
FUNCTION Fahrenheit(C) AS FLOAT
  Fahrenheit = C * 1.8 + 32
END FUNCTION
```

Passing Arguments by Reference

If you use an ordinary variable (ie, not an expression) as the value when calling a subroutine or a function, the argument within the subroutine/function will point back to the variable used in the call and any changes to the argument will also be made to the supplied variable. This is called passing arguments by reference.

For example, you might define a subroutine to swap two values, as follows:

```
SUB Swap a, b
  LOCAL t
  t = a
  a = b
  b = t
END SUB
```

In your calling program you would use variables for both arguments:

```
Swap nbr1, nbr2
```

And the result will be that the values of `nbr1` and `nbr2` will be swapped.

Unless you need to return a value via the argument you should not use an argument as a general purpose variable inside a subroutine or function. This is because another user of your routine may unwittingly use a variable in their call and that variable will be "magically" changed by your routine. It is much safer to assign the argument to a local variable and manipulate that instead.

Passing Arrays

Single elements of an array can be passed to a subroutine or function and they will be treated the same as a normal variable. For example, this is a valid way of calling the Swap subroutine (discussed above):

```
Swap dat(i), dat(i + 1)
```

This type of construct is often used in sorting arrays.

You can also pass one or more complete arrays to a subroutine or function by specifying the array with empty brackets instead of the normal dimensions. For example, `a()`. In the subroutine or function definition the associated parameter must also be specified with empty brackets. The type (ie, float, integer or string) of the argument supplied and the parameter in the definition must be the same.

In the subroutine or function the array will inherit the dimensions of the array passed and these must be respected when indexing into the array. If required the dimensions of the array could be passed as additional arguments to the subroutine or function so it could correctly manipulate the array. The array is passed by reference which means that any changes made to the array within the subroutine or function will also apply to the supplied array.

For example, when the following is run the words "Hello World" will be printed out:

```
DIM MyStr$(5, 5)
MyStr$(4, 4) = "Hello" : MyStr$(4, 5) = "World"
Concat MyStr$()
PRINT MyStr$(0, 0)

SUB Concat arg$()
  arg$(0,0) = arg$(4, 4) + " " + arg$(4, 5)
END SUB
```

Early Exit

There can be only one `END SUB` or `END FUNCTION` for each definition of a subroutine or function. To exit early from a subroutine (ie, before the `END SUB` command has been reached) you can use the `EXIT SUB` command. This has the same effect as if the program reached the `END SUB` statement. Similarly you can use `EXIT FUNCTION` to exit early from a function.

Examples

There is often the need for a special command or function to be implemented in MMBasic but in many cases these can be constructed using an ordinary subroutine or function which will then act exactly the same as a built in command or function.

For example, sometimes there is a requirement for a TRIM function which will trim specified characters from the start and end of a string. The following provides an example of how to construct such a simple function in MMBasic.

The first argument to the function is the string to be trimmed and the second is a string containing the characters to trim from the first string. RTrim\$() will trim the specified characters from the end of the string, LTrim\$() from the beginning and Trim\$() from both ends.

```
' trim any characters in c$ from the start and end of s$
Function Trim$(s$, c$)
  Trim$ = RTrim$(LTrim$(s$, c$), c$)
End Function
```

```
' trim any characters in c$ from the end of s$
Function RTrim$(s$, c$)
  RTrim$ = s$
  Do While Instr(c$, Right$(RTrim$, 1))
    RTrim$ = Mid$(RTrim$, 1, Len(RTrim$) - 1)
  Loop
End Function
```

```
' trim any characters in c$ from the start of s$
Function LTrim$(s$, c$)
  LTrim$ = s$
  Do While Instr(c$, Left$(LTrim$, 1))
    LTrim$ = Mid$(LTrim$, 2)
  Loop
End Function
```

As an example of using these functions:

```
S$ = " ****23.56700 "
```

```
PRINT Trim$(s$, " ")
```

Will give "****23.56700"

```
PRINT Trim$(s$, " *0")
```

Will give "23.567"

```
PRINT LTrim$(s$, " *0")
```

Will give "23.56700"

Special Functions

There are a number of features of the Armmite F4 that enable the advanced user to add features to MMBasic and perform special operations at startup. Most programs will not need to use these features but they are handy for the advanced user who needs more control over the Armmite F4.

Embedded C Routines

It is possible to add program modules that are written in the C language to MMBasic. They are called CSubs and to the BASIC program they look the same as the MMBasic built in functions and subroutines. Generally these modules can run much faster than a BASIC program. The example below shows a CSub that reverses the order of a string. The CSub is loaded as part of your basic code.

```
Dim instring$="1234567890"  
Dim outstring$  
strrev instring$, outstring$  
Print outstring$  
End
```

```
CSub strrev  
00000000  
b085b480 6078af00 687b6039 60bb781b b2da68bb 701a683b 60fb2301 683ae00d  
441368fb 68fa68b9 32011a8a 440a6879 701a7812 330168fb 68bb60fb 68fb1c5a  
d8ec429a 461a68bb 0300f04f 46194610 46bd3714 7b04f85d bf004770  
End CSub
```

MM.STARTUP

There may be a need to execute some code on initial power up, regardless of the program in main memory. Perhaps to initialise some hardware, set some options or print a custom startup banner. This can be accomplished by creating a subroutine with the name MM.STARTUP and ensuring it is included in the program. When the Armmite F4 is first powered up or reset or CPU RESTART command issued it will search for this subroutine and, if found, it will be run once. It can be used to initialise a MMBasic USER defined LCDPanel at power up:

```
SUB MM.STARTUP  
  Print "I have been reset by CPU RESTART or pwer up"  
END SUB
```

Using MM.STARTUP is similar to using the OPTION AUTORUN feature, the difference being that the AUTORUN option will cause the whole program in memory to be run from the start where MM.STARTUP will just run the code within the subroutine. The AUTORUN option and MM.STARTUP can be used together and in that case the MM.STARTUP subroutine is run first, then the program in main memory.

Note that you should not use MM.STARTUP for general setup of MMBasic (like dimensioning arrays, opening communication channels, etc) before running a program. The reason is that when you use the RUN command MMBasic will clear the interpreter's state ready for a fresh start.

MM.PROMPT

If a subroutine with this name exists it will be automatically executed by MMBasic instead of displaying the command prompt. This can be used to display a custom prompt, set colours, define variables, etc all of which will be active at the command prompt.

This subroutine can be located anywhere in the main program.

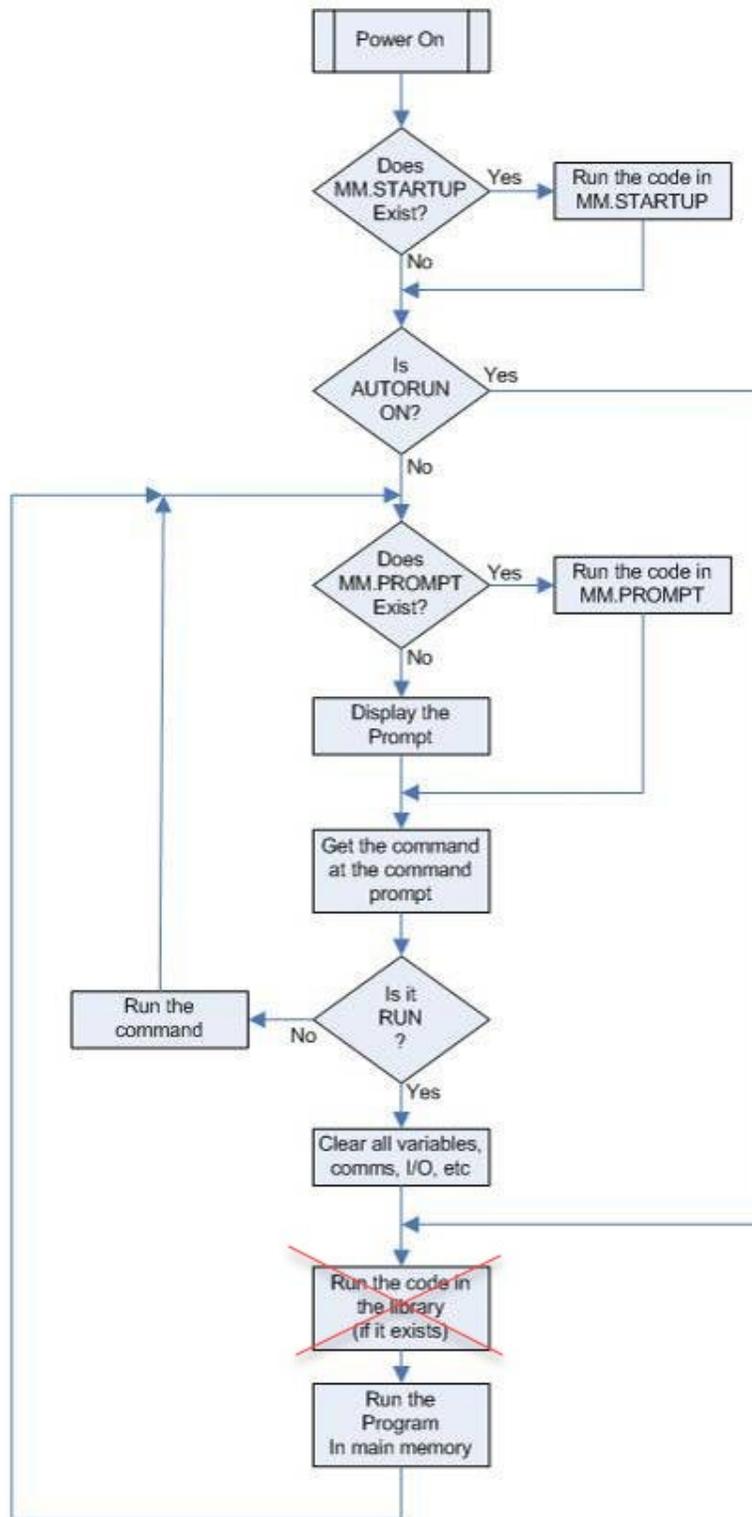
Note that MMBasic will clear all variables and I/O pin settings when a program is run so anything set in this subroutine will only be valid for commands typed at the command prompt (ie, in immediate mode). As an example the following will display a custom prompt:

```
SUB MM.PROMPT  
  PRINT TIME$ "> ";  
END SUB
```

Note that while constants can be defined they will not be visible because a constant defined inside a subroutine is local to a subroutine. However, DIM will create variables that are global that that should be used instead.

Flow Diagram

The operation of MMBasic at startup and the interaction between the special functions is best illustrated using a flow diagram. The following is a high level diagram (for example, it does not show the complications caused by the CONTINUE command) but it does place the functions of MM.STARTUP and MM.PROMPT into context. It is the same as the previous Micromites except there is no library. MM.STARTUP must be included in the program somewhere:



Embedding Configuration Options in a Program

Normally configurations options such as OPTION LCDPANEL are entered at the command prompt to configure the Micromite for an attached display panel, touch controller, etc. The drivers for these devices are enabled at startup so after using the option command the Micromite will immediately restart (ie, reboot). The user does not notice this (because it is quick) but this it is the reason why the commands should be entered at the command prompt and not in a program.

For most users entering the commands at the prompt is sufficient. However, for various reasons sophisticated users might need to embed these commands in a program and it is possible to do this if a few simple rules are followed. These are:

- The commands must be at the start of the programs (they may be preceded by comments).
- They should be in the same order as they would be entered at the command prompt. For example OPTION LCDPANEL should come before OPTION TOUCH.
- They should be thoroughly tested at the command prompt before being embedded in a program as errors may not be detected and can cause the Micromite to behave strangely.
- They must be followed by the command OPTION SAVE.

When MMBasic finds configuration commands in a program it will record the settings without restarting the processor. Then, when it encounters the OPTION SAVE command, all the settings will be saved to flash and the processor will be restarted to enable all the drivers at the same time. After the restart the program will be run again but this time the configuration commands and OPTION SAVE command will have no effect because the devices are already configured and the drivers enabled.

The calibration parameters for the touch controller can also be configured in this way. To do this you should use GUI CALIBRATE to calibrate the touch screen at the command prompt in the normal way. Then use OPTION LIST which will list the calibration parameters as something like:

```
GUI CALIBRATE 0, 252, 306, 932, 730
```

This string must be included before the OPTION SAVE so that the touch calibration settings will be saved along with the other options.

This restart only occurs once at the first time the configuration options are encountered. If another program with different embedded options is run MMBasic will detect the change, reconfigure the drivers and execute another reboot and re run the program.

Errors in the configuration commands (for example the same I/O pin allocated to two different functions) are often detected during the reboot. However, this is not guaranteed so the configuration commands should be thoroughly tested at the command prompt before being embedded in a program.

This is an example of the sequence to configure SPI ILI 9341 LCD Panel:

```
OPTION LCDPANEL ILI9341, LANDSCAPE, PE0, PD6, PC4
OPTION TOUCH PC5, PB12
GUI CALIBRATE 0, 252, 306, 932, 730
OPTION SAVE
```

Electrical Characteristics

Power Supply

Voltage range:	2.3 to 3.6V (3.3V nominal). Absolute maximum 4.0V.
Current draw:	31 mA to 6 mA depending on the clock speed.
Current in sleep:	40 μ A (plus current draw from the I/O pins).

Digital Inputs

Logic Low:	0 to 0.65V
Logic High:	2.5V to 3.3V on normal pins 2.5V to 5.5V on pins rated at 5V
Input Impedance:	>1 M Ω . All digital inputs are Schmitt Trigger buffered.
Frequency Response:	Up to 300 kHz (pulse width 20 nS or more) on the counting inputs (pins 15 to 18).

Analog Inputs

Voltage Range:	0 to 3.3V
Accuracy:	Analog measurements are referenced to the supply voltage on pin 28 and the ground on pin 27. If the supply voltage is precisely 3.3V the typical accuracy of readings will be \pm 1%.
Input Impedance:	>1 M Ω (for accurate readings the source impedance should be < 5K)

Digital Outputs

Typical current draw or sink ability on any I/O pin:	10 mA
Absolute maximum current draw or sink on any I/O pin:	25 mA
Absolute maximum current draw or sink for all I/O pins combined:	150 mA
Maximum open collector voltage:	5.5V

Timing Accuracy

All timing functions (the timer, tick interrupts, PWM frequency, baud rate, etc) are dependent on the internal clock. The Micromite uses a fast RC oscillator which has a specified tolerance of \pm 0.9% but typically is within \pm 0.1% at 24 $^{\circ}$ C.

PWM Output

Frequency range:	20 Hz to 500 kHz
Duty cycle:	0% to 100% with 0.1% resolution below 25 kHz

Serial Communications Ports

Console:	Default 115200 baud. Range is 100 bps to 230400 bps
COM ports	Default 9600 baud. Range is 10 bps to 230400 bps

Other Communications Ports

SPI	10 Hz to 10 MHz
I ² C	10kHz to 400 kHz.
1-Wire:	Fixed at 15 kHz.

Flash Endurance

Over 10,000 erase/write cycles.

Every program save incurs one erase/write cycle. In a normal program development, it is highly unlikely that more than a few hundred program saves would be required.

Saved variables (VAR SAVE command) and configuration options (the OPTION command) are stored in the RTC battery backed up RAM and DO NOT use or impact the life of the flash.

Basic Drawing Features

There are ten basic drawing commands that you can use within MMBasic to draw images on the LCDPANEL

Screen Coordinates

All screen coordinates and measurements on the screen are done in terms of pixels with the X coordinate being the horizontal position and Y the vertical position. The top left corner of the screen has the coordinates X=0 and Y=0 and the values increase as you move down and to the right of the screen.

Read Only Variables

In the Armmite F4 there are six read only variables which provide useful information about the display currently connected.

- MM.HRES
Returns the width of the display (the X axis) in pixels.
- MM.VRES
Returns the height of the display (the Y axis) in pixels.
- MM.FONTHEIGHT
Returns the height of the current font (in pixels). All characters in a font have the same height.
- MM.FONTWIDTH
Returns the width of a character in the current font (in pixels). All characters in a font have the same width.
- MM.HPOS
Returns the X coordinate of the text cursor (ie, the horizontal location (in pixels) of where the next character will be printed on the LCD panel)
- MM.VPOS
Returns the Y coordinate of the text cursor (ie, the vertical location (in pixels) of where the next character will be printed on the LCD panel)

Drawing Commands

The drawing commands have optional parameters. You can completely leave these off the end of a command or you can use two commas in sequence to indicate a missing parameter. For example, the fifth parameter of the LINE command is optional so you can use this format:

```
LINE 0, 0, 100, 100, , rgb(red)
```

Optional parameters are indicated below by italics, for example: *font*.

In the following commands C is the drawing colour and defaults to the current foreground colour. FILL is the fill colour which defaults to -1 which indicates that no fill is to be used.

The drawing commands are:

- CLS *C*
Clears the screen to the colour C. If C is not specified the current default background colour will be used.
- PIXEL *X, Y, C*
Illuminates a pixel. If C is not specified the current default foreground colour will be used.
- LINE *X1, Y1, X2, Y2, LW, C*
Draws a line starting at X1 and Y1 and ending at X2 and Y2.
LW is the line's width and is only valid for horizontal or vertical lines. It defaults to 1 if not specified or is changed to 1 if the line is a diagonal.
- BOX *X, Y1, W, H, LW, C, FILL*
Draws a box starting at X and Y1 which is W pixels wide and H pixels high.
LW is the width of the sides of the box and can be zero. It defaults to 1.
- RBOX *X, Y1, W, H, R, C, FILL*
Draws a box with rounded corners starting at X and Y1 which is W pixels wide and H pixels high.
R is the radius of the corners of the box. It defaults to 10.

- `TRIANGLE X1, Y1, X2, Y2, X3, Y3, C, FILL`
Draws a triangle with the corners at X1, Y1 and X2, Y2 and X3, Y3. C is the colour of the triangle and FILL is the fill colour. FILL can omitted or be -1 for no fill.
- `CIRCLE X, Y, R, LW, A, C, FILL`
Draws a circle with X and Y as the centre and a radius R. LW is the width of the line used for the circumference and can be zero (defaults to 1). A is the aspect ratio which is a floating point number and defaults to 1. For example, an aspect of 0.5 will draw an oval where the width is half the height.
- `ARC x, y, r1, r2, a1, a2, c`
Draws an arc with the centre at x and y, r1 and r2 are the inner and outer radius defining the thickness of the arc (if they are the same the arc will be one pixel thick), a1 and a2 are the start and end angles in degrees and c is the colour.
- `POLYGON n, xarray%(), yarray%(), C, FILL`
Draws a outline or filled polygon defined by the x, y coordinate pairs in xarray%() and yarray%(). 'n' is the number of points to use in drawing the polygon. If the last xy-coordinate pair is not the same as the first the firmware will automatically create an additional xy-coordinate pair to complete the polygon.
- `TEXT X, Y, STRING, ALIGNMENT, FONT, SCALE, C, BC`
Displays a string starting at X and Y. ALIGNMENT is 0, 1 or 2 characters (a string expression or variable is also allowed) where the first letter is the horizontal alignment around X and can be L, C or R for LEFT, CENTER or RIGHT aligned text and the second letter is the vertical alignment around Y and can be T, M or B for TOP, MIDDLE or BOTTOM aligned text. The default alignment is left/top. FONT and SCALE are optional and default to that set by the FONT command. C is the drawing colour and BC is the background colour. They are optional and default to that set by the COLOUR command.

Colours

Colour is specified as a true colour 24 bit number where the top eight bits represent the intensity of the red colour, the middle eight bits the green intensity and the bottom eight bits the blue. For example the colour red is `&HFF0000` and yellow is `&HFFFF00`. An easier way to generate a colour value is to use the `RGB()` function which has the form: `RGB(red, green, blue)`

A value of zero for a colour represents black and 255 represents full intensity.

The `RGB()` function also supports a shortcut where you can specify common colours by naming them. For example, `RGB(red)` or `RGB(cyan)`. The colours that can be named using the shortcut form are white, black, blue, green, cyan, red, magenta, yellow, brown and gray.

Because the Armmite F4 uses double precision floating point it can store the 24 bit number representing colour (ie, returned by the `RGB()` function) in either a floating point variable or an integer variable.

MMBasic will automatically translate all colours to the format required by the individual display controller which, in the case of the ILI9341, ST7735 and ILI9163 controllers, is 65K colours in the 565 format. In LCD panels using the SSD1963 controller colours are displayed using the full 24-bit colour range (16 million colours).

The default colour for commands that require a colour parameter can be set with the `COLOUR` command. This is handy if your program uses a consistent colour scheme, you can then set the defaults and use the short version of the drawing commands throughout your program (the USA spelling `COLOR` is also accepted).

The `COLOUR` command takes the format:

```
COLOUR foreground-colour, background-colour
```

Fonts

The Armmite F4 has seven built in fonts plus it can use embedded fonts to a maximum of 16 fonts.

There are seven built in fonts. These are:

Font Number	Size (width x height)	Character Set	Description
1	8 x 13	All 95 characters	A small font where a dense display is required.
2	12 x 20	All 95 characters	General use on 480 x 272 displays
3	16 x 24	All 95 characters	General use on 800 x 480 displays
4	16 x 24 BOLD	All 95 characters	A bold version of font #3
5	24 x 32	All 95 characters	Large font, very clear
6	32 x 50	0 to 9 plus some symbols	Numbers plus decimal point, positive, negative, equals, degree and colon symbols. Very clear.
7	6 x 8	All 95 ASCII characters	A small font useful when low resolutions are used.

In all fonts (including font #7) the back quote character (60 hex or 96 decimal) has been replaced with the degree symbol (°).

Embedded Fonts

The Armmite F4 supports embedded fonts. Note that because of the way the fonts are managed you cannot redefine fonts 1 or 6.

These fonts work exactly same as the built in font (ie, selected using the FONT command or specified in the TEXT command).

The format of an embedded font is:

```
DefineFont #Nbr
    hex [[ hex[...]]
    hex [[ hex[...]]
END DefineFont
```

It must start with the keyword "DefineFont" followed by the font number (which may be preceded by an optional # character). Any font number in the range of 2 to 5 and 8 to 16 can be specified and if it is the same as a built in font it will replace that font. The body of the font is a sequence of 8-digit hex words with each word separated by one or more spaces or a new line. The font definition is terminated by an "End DefineFont" keyword. These can be placed anywhere in a program and MMBasic will skip over it.

This format is the same as that used by the Micromite and additional fonts and information can be found in the Embedded Fonts folder in the Micromite firmware download. These fonts cover a wide range of character sets including a symbol font (Dingbats) which is handy for creating on screen icons, etc.

In addition to using embedded fonts a program can dynamically load one font from the SD card using the LOAD FONT command. A program can load many fonts using this method during the course of its execution but each new font will overwrite the previously loaded font.

The format of fonts loaded using LOAD FONT have a similar format as the embedded fonts described above except that no comments or blank lines are allowed, the font number must always be #8, the first word must be on a line on its own and the following lines (except the last) must have exactly eight words per line.

As an example, the following is a tiny (6x4 pixel) font that is useful in the 320x200 display mode:

```
DefineFont #8
60200604
44000000 00A04040 A0AEAE00 82406C6C EACC2048 00004460 84204424 E4A48044
00E404A0 00800400 040000E0 00480240 4CE0AAEA 48C24044 C062C2E0 E820E2AA
EA68E0E2 8048E2E0 EAE0EAEA 0404C0E2 80040400 0E208424 2484000E 4040E280
4A60E84A CACAA0EA 608868C0 E8C0AACA E8E8E0E8 60EA6880 E4A0EAAA 2A22E044
A0CAAA40 AEE08888 EEAEA0EA 40AA4AA0 4A80C8CA ECCA60AE C04268A0 AA4044E4
```

```

A4AA60AA A0EEAA40 AAA04AAA 48E24044 E088E8E0 E2004208 004AE022 F0000000
0C000084 AA8CE06A 608806C0 0660AA26 E42460AC 24AE0640 40A0CA88 22204044
A0CC8AA4 0EE044C4 AA0CA0EE 40AA04A0 06C8AA0C 880662AA C0C60680 0A60444E
AE0A60AA E0AE0A40 0AA0440A 6C0E24A6 608464E0 C4400444 006CC024 E0EEEE00
End DefineFont

```

You can convert and create font files to this format using the program FontTweak from: <https://www.com.com.au/MMedit.htm>

Rotated Text

As described in the *Micromite User Manual* the alignment of the text in the TEXT command can be specified by using one or two characters in a string expression for the third parameter of the command. In the Micromite Plus you can also specify a third character to indicate the rotation of the text. This character can be one of:

- N for normal orientation
- V for vertical text with each character under the previous running from top to bottom.
- I the text will be inverted (ie, upside down)
- U the text will be rotated counter clockwise by 90°
- D the text will be rotated clockwise by 90°

This extra feature applies in the TEXT and GUI CAPTION commands.

As an example, the following will display the text "LCD Display" vertically down the left hand margin of the display panel and centred vertically:

```
TEXT 0, 250, "LCD Display", "LMV", 5
```

Positioning is relative to the top left corner of the character when viewed normally so inverted 100,100 will have the top left pixel of the first character at 100,100 and the text will then be above y=101 and to the left of x=101. Similarly "R" in the alignment string is viewed from the perspective of the character in whatever orientation it is in (not the screen).

Transparent Text

If the display is capable of transparent text the TEXT command will allow the use of -1 for the background colour. This means that the text is drawn over the background with the background image showing through the gaps in the letters. Displays capable of transparent text are any that use the ILI9341 controller or an SSD1963 controller. Using the LOAD command you can load an image from the SD card.

BLIT Command

If the display is capable of transparent text (see the above subheading) programs can also use the BLIT command. This allows a portion of the image currently showing on the display to be copied to a memory buffer and later copied back to the display. This is useful when something needs to be drawn over the background and later removed without damaging the image in the background. Examples include a game where a character is moving about in front of a landscape or the moving needle of a photorealistic gauge.

The available commands are:

```

BLIT READ #b, x, y, w, h
BLIT WRITE #b, x, y, w, h
BLIT CLOSE #b

```

#b is the buffer number in the range of 1 to 64. x and y are the coordinates of the top left corner and w and h are the width and height of the image. READ will copy the display image to the buffer, WRITE will copy the buffer to the display and CLOSE will free up the buffer and reclaim the memory used.

These commands can be used to copy a portion of the display to another location (by copying to a buffer then writing somewhere else) but a simpler method is to use an alternative version of the BLIT command as follows:

```
BLIT x1, y1, x2, y2, w, h
```

This will copy a portion of the image at x1/y1 to the location x2/y2. w and h specify the width and height of the image to be copied. The source and destination areas can overlap and the BLIT command will perform the copy correctly.

This form of the BLIT command is particularly useful for creating graphs that can scroll horizontally or vertically as new data is added.

The Armmite F4 allows up to 64 buffers, but the limiting factor will be the amount of memory used by the open buffers. This is dependent on the size of the buffers required to hold the area you read in. e.g. A 32*32 section loaded in to a Blit buffer will use 32*32*3 bytes. i.e 3K. There is only 114K of memory for all variable etc used by the program, so you need to be aware of this when filling blit buffers.

Backlight Control

The brightness of the backlight on a SSD1963 LCD panel can be controlled with the BACKLIGHT command:

```
BACKLIGHT percent
```

Where 'percent' is the degree of brightness ranging from 0 (fully off) to 100 (full brightness). This can be changed as often as required and makes a huge difference to the power requirements of the display. For example, a brightness of 50% will halve the current consumption (compared to 100%) while only making a small difference to the perceived visual brightness. The SSD1963 backlight jumpers should be set to use it own PWM as detailed below.

The BACKLIGHT command also supports other LCD panels supported on the Armmite F4. The command controls a PWM signal on the BL connector, but with brightness ranging from 0 (full brightness) to 100 (fully off)

The SSD1963 based LCD panels have three pairs of solder pads on the PCB which are grouped under the heading "Backlight Control" as illustrated on the right. Normally the pair marked "LED-A" are shorted together with a zero ohm resistor and this allows control of the backlight's brightness with a PWM (pulse width modulated) signal on the LED-A pin of the display panel's main connector.



The Armmite F4 expects the SSD1963 controller to be set to use the SSD1963 for brightness control. The zero ohm resistor should be removed from the pair marked "LED-A" and used to short the nearby pair of solder pads marked "1963-PWM". The Armmite F4 can then control the brightness via the SSD1963 controller.

Load Image

As previously described in the [SD Card Support](#) section the LOAD IMAGE command can be used to load a bitmap image from the SD card and display it on the LCD display. This can be used to draw a logo or add an ornate background to the graphics drawn on the display. All types of the BMP format including black and white and true colour 24-bit images. The image can be positioned anywhere on the screen and be of any size (pixels that end up being positioned off the screen and will be ignored).

Example of Basic Graphics

As an example, the following program will draw a simple digital clock on the VGA monitor.

```
CLS
CONST DBlue = RGB(0, 0, 128)           ' A dark blue colour
COLOUR RGB(GREEN), RGB(BLACK)         ' Set the default colours
FONT 6                                 ' Set the default font

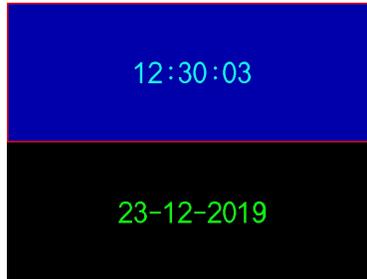
BOX 0, 0, MM.HRes-1, MM.VRes/2, 3, RGB(RED), DBlue

DO
  TEXT MM.HRes/2, MM.VRes/4, TIME$, "CM", 6, 1, RGB(CYAN), DBlue
  TEXT MM.HRes/2, MM.VRes*3/4, DATE$, "CM"
LOOP
```

The program starts by defining a constant with a value corresponding to a dark blue colour and then sets the defaults for the colours and the font. It then draws a box with red walls and a dark blue interior. Following this the program enters a continuous loop where it performs two functions:

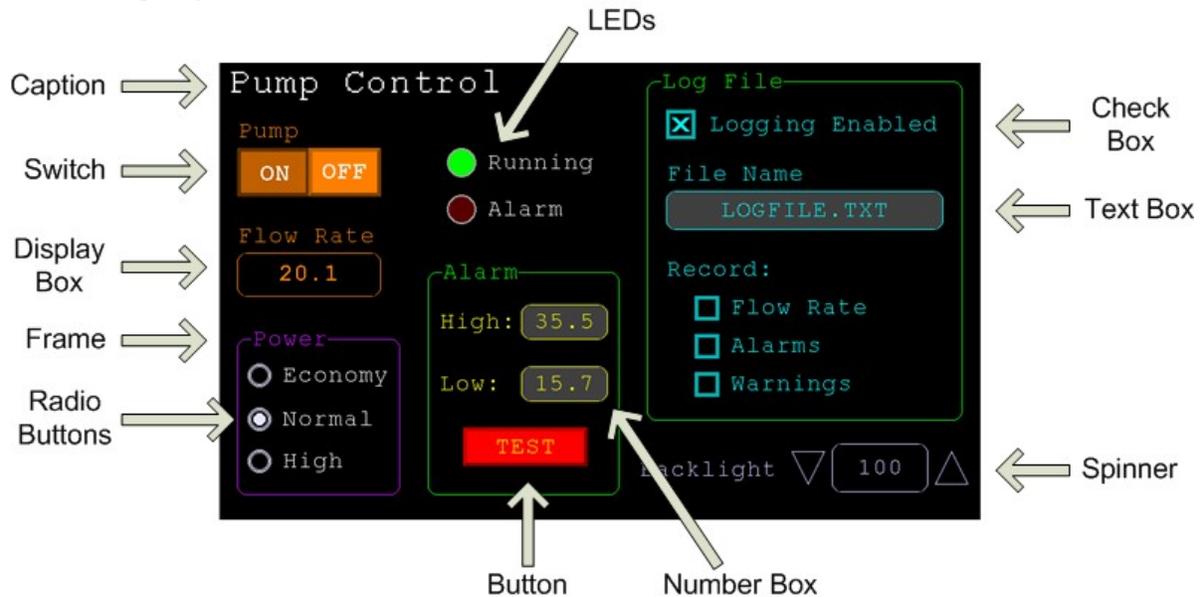
- Displays the current time inside the previously drawn box. The string is drawn centred both horizontally and vertically in the middle of the box. Note that the TEXT command overrides both the default font and colours to set its own parameters.
- Draws the date centred in the lower half of the screen. In this case the TEXT command uses the default font and colours previously set.

The screenshot shows the result.



Advanced Graphics

The Armmite F4 incorporates a suite of advanced graphic controls that respond to touch, these include on screen switches, buttons, indicator lights, keyboard, etc. MMBasic will draw the control and animate it (ie, a switch will appear to depress when touched). All that the BASIC program needs to do is invoke a single line command to specify the basic details of the control.



Each control has a reference number called '#ref' in the description of the control. By default this can be any number between 1 and 100 and the upper limit can be changed with the OPTION CONTROL command. The reference number is used to identify a control. For example, a check box can be created thus:

```
GUI CHECKBOX #10, "Test", 100, 100, 50, rgb(BLUE)
```

And the program can check its value by using its reference number in the CtrlVal() function:

```
IF CtrlVal(#10) THEN ...
```

The # character is optional but serves to remind the programmer that this is not an ordinary number.

In the following commands any arguments that are in italic font (eg, *Width*, *Height*) are optional and if not specified will take the value of the previous command that did specify them. This means for example, that a number of radio buttons with the same size and colour can be specified with only the first button having to list all the details. Note that with the colour specification this is different to the Basic Drawing Commands which default to the last COLOUR command.

All strings used in GUI controls and the MsgBox can display multiple lines by using the tilde character (~) to separate each line in the string. For example, a push button's caption can be "ALARM~TEST" and this would be displayed as two lines. For all controls the font used for the caption will be whatever is set with the FONT command and the colours will be whatever was set by the last COLOUR command.

If the display is capable of transparent text these commands will allow the use of -1 for the background colour. This means that the text is drawn over the background with the background image showing through the gaps in the letters. Displays capable of transparent text are any that use the ILI9341 controller or an SSD1963 controller. The latter must have the RD pin specified in the OPTION LCDPANEL command.

The advanced graphics controls are:

Frame

```
GUI FRAME #ref, caption$, StartX, StartY, Width, Height, Colour
```

This will draw a frame which is a box with round corners and a caption. A frame does not respond to touch but is useful when a group of controls need to be visually brought together. It can also be used to surround a group of radio buttons and MMBasic will arrange for the radio buttons surrounded by the frame to be exclusive – that is,

when one radio button is selected any other button that was selected and within the frame will be automatically deselected.

LED

GUI LED #ref, caption\$, CenterX, CenterY, Diameter, Colour

This will draw an indicator light (it looks like a panel mounted LED). When its value is set to one it will be illuminated and when it is set to zero it will be off (a dull version of its colour attribute). The LED can be made to flash by setting its value to the number of milliseconds that it should remain on before turning off.

The caption will be drawn to the right of the LED and will use the colours set by the COLOUR command. The LED control is not animated when touched but its reference number can be found using TOUCH(REF) and TOUCH(LASTREF) in the touch interrupts and any required animation can be done in MMBasic.

Check Box

GUI CHECKBOX #ref, caption\$, StartX, StartY, Size, Colour

This will draw a check box which is a small box with a caption. Both the height and width are specified with the 'Size' parameter. When touched an X will be drawn inside the box to indicate that this option has been selected and the control's value will be set to 1. When touched a second time the check mark will be removed and the control's value will be zero. The caption will be drawn to the right of the Check Box and will use the colours set by the COLOUR command.

Push Button

GUI BUTTON #ref, caption\$, StartX, StartY, Width, Height, FColour, BColour

This will draw a momentary button which is a square switch with the caption on its face. When touched the visual image of the button will appear to be depressed and the control's value will be 1. When the touch is removed the value will revert to zero. Caption can be a single string with two captions separated by a vertical bar (|) character (eg, "UP|DOWN"). When the button is up the first string will be used and when pressed the second will be used.

Switch

GUI SWITCH #ref, caption\$, StartX, StartY, Width, Height, FColour, BColour

This will draw a latching switch with the caption on its face. When touched the visual image of the button will appear to be depressed and the control's value will be 1. When touched a second time the switch will be released and the value will revert to zero. Caption can be a single string with two captions separated by a | character (eg, "ON|OFF"). When this is used the switch will appear to be a toggle switch with each half of the caption used to label each half of the toggle switch.

Radio Button

GUI RADIO #ref, caption\$, CenterX, CenterY, Radius, Colour

This will draw a radio button with a caption. When touched the centre of the button will be illuminated to indicate that this option has been selected and the control's value will be 1. When another radio button is selected the mark on this button will be removed and its value will be zero. Radio buttons are grouped together when surrounded by a frame and when one button in the group is selected all others in the group will be deselected. If a frame is not used all buttons on the screen will be grouped together.

The caption will be drawn to the right of the button and will use the colours set by the COLOUR command.

Display Box

GUI DISPLAYBOX #ref, StartX, StartY, Width, Height, FColour, BColour

This will draw a box with rounded corners. Any text can be displayed in the box by using the CtrlVal(r) = command. This is useful for displaying text, numbers and messages. This control is not animated when touched but its reference number can be found using TOUCH(REF) and TOUCH(LASTREF) in the touch interrupts and any required animation can be done in MMBasic.

Text Box

GUI TEXTBOX #ref, StartX, StartY, Width, Height, FColour, BColour

This will draw a box with rounded corners. When the box is touched a QWERTY keyboard will appear on the screen as shown on the right. Using this virtual keyboard any text can be entered into the box including upper/lower case letters, numbers and any other characters in the ASCII character set. The new text will replace any text previously in the box.

Ent is the enter key, Can is the cancel key and will close the text box and return it to its original state, the triangle is the shift key, the [] key will insert a space and the &12 key will select an alternate key selection with numbers and special characters (there are two sets of special characters and the shift key will switch between them).



The value of the control can be set to a string starting with two hash characters (##) and in that case the string (without the leading two hash characters) will be displayed in the box with reduced brightness. This can be used to give the user a hint as to what should be entered (called "ghost text"). Reading the value of the control displaying ghost text will return an empty string. When a key is pressed the ghost text will vanish and be replaced with the entered text.

MMBasic will try to position the virtual keyboard on the screen so as to not obscure the text box that caused it to appear. A pen down interrupt will be generated when the keyboard is deployed and a key up interrupt will be generated when the Enter or Cancel keys are touched and the keyboard is hidden. If necessary the virtual keyboard can be dismissed by the program (same as touching the cancel button) with the command: GUI TEXTBOX CANCEL. If the virtual keyboard is not displayed this will do nothing.

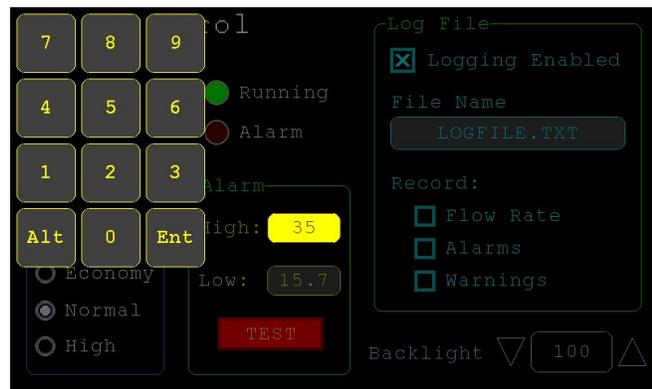
Number Box

GUI NUMBERBOX #ref, StartX, StartY, Width, Height, FColour, BColour

This will draw a box with rounded corners. When the box is touched a numeric keypad will appear on the screen as shown on the right. Using this virtual keypad any number can be entered into the box including a floating point number in exponential format. The new number will replace the number previously in the box.

The Alt key will select an alternative key selection and the other special keys are the same as with the text box.

Similar to the Text Box, the value of the control can be set to a literal string with two leading hash characters (eg. "##Hint") and in that case the string (without the leading two characters) will be displayed in the box with reduced brightness. Reading this will return zero and when a key is pressed the ghost text will vanish.



MMBasic will try to position the virtual keypad on the screen so as to not obscure the number box that caused it to appear. A pen down interrupt will be generated when the keypad is deployed and a key up interrupt will be generated when the Enter key is touched and the keypad is hidden. Also, when the Enter key is touched the entered text will be evaluated as a number and the NUMBERBOX control redrawn to display this number.

If necessary the virtual keypad can be dismissed by the program (same as touching the cancel button) with the command: GUI NUMBERBOX CANCEL. If it is not displayed this command will do nothing.

Formatted Number Box

GUI FORMATBOX #ref, Format, StartX, StartY, Width, Height, FColour, BColour

This will draw a box with rounded corners. When the box is touched a numeric keypad will appear similar to a Number Box. The difference is that the Formatted Number Box will require the user to enter numbers according to a specific format for dates, time, etc. Invalid keys on the keypad will be disabled and the user will be guided in their entry with guide text. This means that the programmer can be assured that the entry made by the user will always be in a fixed format.

The type of entry is controlled by the 'Format' argument as follows:

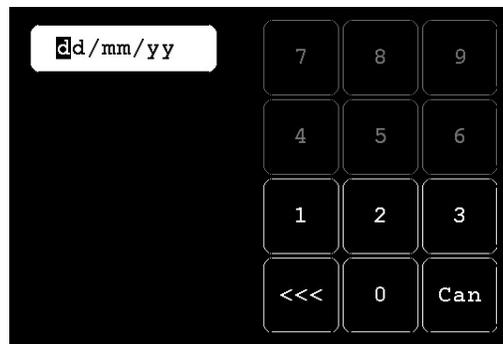
DATE1	Date in UK/Aust/NZ format (dd/mm/yy)
DATE2	Date in USA format (mm/dd/yy)
DATE3	Date in international format (yyyy/mm/dd)
TIME1	Time in 24 hour notation (hh:mm)
TIME2	Time in 24 hour notation with seconds (hh:mm:ss)
TIME3	Time in 12 hour notation (hh:mm AM/PM)
TIME4	Time in 12 hour notation with seconds (hh:mm:ss AM/PM)
DATETIME1	Both date (UK fmt) and time (12 hour) (dd/mm/yy hh:mm AM/PM)
DATETIME2	Both date (UK fmt) and time (24 hour) (dd/mm/yy hh:mm)
DATETIME3	Both date (USA fmt) and time (12 hour) (mm/dd/yy hh:mm AM/PM)
DATETIME4	Both date (USA fmt) and time (24 hour) (mm/dd/yy hh:mm)
LAT1	Latitude in degrees, minutes and seconds (d° mm' ss" N/S)
LAT2	Latitude with seconds to one decimal place (dd° mm' ss.s" N/S)
LONG1	Longitude in degrees, minutes and seconds (ddd° mm' ss" E/W)
LONG2	Longitude with seconds to one decimal place (ddd° mm' ss.s" E/W)
ANGLE1	Angle in degrees and minutes (ddd° mm')

For example:

```
GUI FORMATBOX #1, DATE1, 300, 150, 200, 50
```

would create a data entry box and when it is touched a keypad will appear as shown on the right. Note that:

- The display box is filled with a guide string to prompt the user as to the data required.
- Because the day of the month can only start with a digit from 0 to 3 all other keys are disabled. This also happens with other numbers that have a limited range.
- The value of the control retrieved via `CtrlVal(#1)` is a string. As an example, if the user entered the date for the 8th of May 2020 the returned string would be "08/05/20" (ie, the UK/Aust/NZ format as specified by DATE1).



The value of the control can be pulled apart using the string functions or, in some cases, the string can be used directly. For example, if using the above format box to get a date from the user the Micromite's internal clock could then be directly set as follows:

```
DATE$ = CtrlVal(#1)
```

The RTC SETTIME command will accept a single string argument in the format of *dd/mm/yy hh:mm* so similarly the RTC time could be set as follows if the formatted box used DATETIME2 for 'Format':

```
RTC SETTIME CtrlVal(#1)
```

You can use the USA style DATETIME4 to get the date/time. In that case you would use this to set the RTC:

```
RTC SETTIME MID$(CtrlVal(#1),4,3) + LEFT$(CtrlVal(#1),2) + RIGHT$((CtrlVal(#1),9)
```

MMBasic will try to position the virtual keypad on the screen so as to not obscure the format box that caused it to appear. A pen down interrupt will be generated when the keypad is deployed and a key up interrupt will be generated when all the required data has been entered and the keypad is hidden.

If necessary the virtual keypad can be dismissed by the program (same as touching the cancel button) with the command: GUI FORMATBOX CANCEL (if the keypad is not displayed this command will do nothing).

Spin Box

```
GUI SPINBOX #ref, StartX, StartY, Width, Height, FColour, BColour, Step,  
Minimum, Maximum
```

This will draw a box with up/down icons on either end. When these icons are touched the number in the box will be incremented or decremented by the 'StepValue', holding down the touch will repeat at a fast rate. 'Minimum' and 'Maximum' set a limit on the value that can be entered. 'StepValue', 'Minimum' and 'Maximum' are optional and if not specified 'StepValue' will be 1 and there will be no limit on the number entered. A pen down interrupt will be generated every time up/down is touched or when automatic repeat occurs.

Caption

```
GUI CAPTION #ref, text$, StartX, StartY, Alignment, FColour, BColour
```

This will draw a text string on the screen. It is similar to the basic drawing command TEXT, the difference being that MMBasic will automatically dim this control if a keyboard or number pad is displayed.

'Alignment' is zero to three characters (a string expression or variable is also allowed) where the first letter is the horizontal alignment around X and can be L, C or R for LEFT, CENTER, RIGHT and the second letter is the vertical alignment around Y and can be T, M or B for TOP, MIDDLE, BOTTOM. A third character can be used to indicate the rotation of the text. This can be 'N' for normal orientation, 'V' for vertical text with each character under the previous running from top to bottom, 'I' the text will be inverted (ie, upside down), 'U' the text will be rotated counter clockwise by 90° and 'D' the text will be rotated clockwise by 90°. The default alignment is left/top with no rotation.

If the colours are not specified this control will use the colours set by the COLOUR command.

Circular Gauge

```
GUI GAUGE #ref, StartX, StartY, Radius, FColour, BColour, min, max,  
nbrdec, units$, c1, ta, c2, tb, c3, tc, c4
```

This will define a graphical circular analogue gauge with a digital display in the centre showing the value and units. If specified the gauge will be coloured to provide a graphical indication of the signal level (eg, green for OK, yellow for warning, etc).

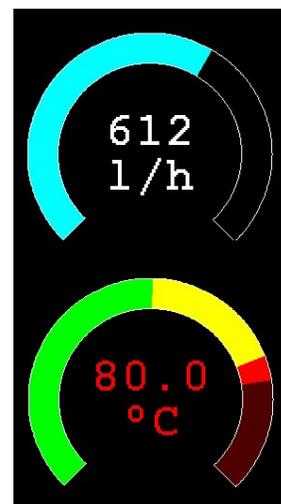
'StartX' and 'StartY' are the coordinates of the centre of the gauge while 'Radius' is the distance from the centre to the outer edge.

'min' is the value associated with the minimum value of the gauge and 'max' is the maximum value. When CtrlVal() is used to assign a value (floating point or integer) to the gauge the analogue portion of the gauge will be drawn to a length proportional to the range between 'min' and 'max'. At the same time the digital value will be drawn in the centre of the gauge using the current font settings (set with the FONT command). 'nbrdec' specifies the number of decimal places to be used in this display. Under the digital value the 'units\$' will be displayed (this can be skipped or a zero length string used if not required).

Normally the analogue graph is drawn using the colour specified in 'Fcolour' however a multi colour gauge can be created using 'c1' to 'c4' for the colours and 'ta' to 'tc' for the thresholds used to determine when the colour will change.

Specifically, 'c1' is the colour to be used for values up to 'ta'. 'c2' is the colour to be used for values between 'ta' and 'tb', 'c3' is used for values between 'tb' and 'tc' and c4 is used for values above 'tc'. Colours and thresholds not required can be left off then list. For example, for a two colour gauge only 'c1', 'ta' and 'c2' need to be specified.

When colours and thresholds are specified the background of the gauge will be drawn with a dull version of the gauge colour at that level ("ghost colouring") so that the user can appreciate how close to the various thresholds the actual value is. Also the digital value displayed in the centre will also change to the colour specified by the current value.



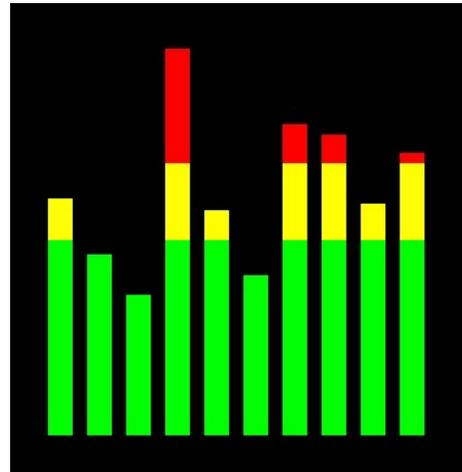
If only one colour is required for the whole analogue graph it can be specified by just using 'c1' and leaving all the following parameters off.

Bar Gauge

```
GUI BARGAUGE #ref, StartX, StartY, width, height, FColour, BColour, min,
max, c1, ta, c2, tb, c3, tc, c4
```

This will define either a horizontal or vertical bar gauge. The gauge can be coloured to provide a graphical indication of the signal level (eg, green for OK, yellow for warning, etc) and many bar graphs can be packed close together so that a number of values can be displayed simultaneously using a small amount of screen space (as shown in the image which consists of ten bar gauges).

If the width is less than the height the bar gauge will be drawn vertically with the analogue graph growing from the bottom towards the top. Otherwise, if the width is more than the height, it will be drawn horizontally with the analogue graph growing from the left towards the right. In both cases 'StartX' and 'StartY' reference the top left coordinate of the bar graph while 'width' is the horizontal width and 'height' the vertical height.



The bar graph does not have a digital display of its value but other than that the parameters are the same as for the circular gauge (described above).

'min' and 'max' specify the range of values for the bar and, if specified, 'c1' to 'c4' and 'ta' to 'tc' specify the colours and thresholds for the analogue bar image. Note that unlike the circular bar gauge a "ghost image" of the colours is not shown in the background.

As with the circular gauge, if only one colour is required for the whole gauge it can be specified by just using 'c1' and leaving all the following parameters off.

Area

```
GUI AREA #ref, StartX, StartY, Width, Height
```

This will define an invisible area of the screen that is sensitive to touch and will set TOUCH(REF) and TOUCH(LASTREF) accordingly when touched or released. It can be used as the basis for creating a custom control which is defined and managed by the BASIC program.

Interacting with Controls

Using the following commands and functions the characteristics of the on screen controls can be changed and their value retrieved.

- = CTRLVAL(#ref)
This is a function that will return the current value of a control. For controls like check boxes or switches it will be the number one (true) indicating that the control has been selected by the user or zero (false) if not. For controls that hold a number (eg, a SPINBOX) the value will be the number (normally a floating point number). For controls that hold a string (eg, TEXTBOX) the value will be a string. For example:

```
PRINT "The number in the spin box is: " CTRLVAL(#10)
```
- CTRLVAL(#ref) =
This command will set the value of a control. For off/on controls like check boxes it will override any touch input and can be used to depress/release switches, tick/untick check boxes, etc. A value of zero is off or unchecked and non zero will turn the control on. For a LED it will cause the LED to be illuminated or turned off. It can also be used to set the initial value of spin boxes, text boxes, etc. For example:

```
CTRLVAL(#10) = 12.4
```
- GUI FCOLOUR colour, #ref1 [, #ref2, #ref3, etc]
This will change the foreground colour of the specified controls to 'colour'. This is especially handy for a LED which can change colour.

- GUI BCOLOUR colour, #ref1 [, #ref2, #ref3, etc]
This will change the background colour of the specified controls to 'colour'.
- = TOUCH(REF)
This is a function that will return the reference number of the control currently being touched. If no control is currently being touched it will return zero.
- = TOUCH(LASTREF)
This is a function that will return the reference number of the control that was last touched.
- GUI DISABLE #ref1 [, #ref2, #ref3, etc]
This will disable the controls in the list. Disabled controls do not respond to touch and will be displayed dimmed. The keyword ALL can be used as the argument and that will disable all controls on the currently displayed page. For example:
GUI DISABLE ALL
- GUI ENABLE #ref1 [, #ref2, #ref3, etc]
This will undo the effects of GUI DISABLE and restore the controls in the list to normal operation. The keyword ALL can be used as the argument for all controls on the currently displayed page.
- GUI HIDE #ref1 [, #ref2, #ref3, etc]
This will hide the controls in the list. Hidden controls will not respond to touch and will be replaced on the screen with the current background colour. The keyword ALL can be used as the argument.
- GUI SHOW #ref1 [, #ref2, #ref3, etc]
This will undo the effects of GUI HIDE and restore the controls in the list to being visible and capable of normal operation. The keyword ALL can be used as the argument for all controls.
- GUI DELETE #ref1 [, #ref2, #ref3, etc]
This will delete the controls in the list. This includes removing the image of the control from the screen using the current background colour and freeing the memory used by the control. The keyword ALL can be used as the argument and that will cause all controls to be deleted.

MsgBox()

The MsgBox() function will display a message box on the screen and wait for user input. While the message box is displayed all controls will be disabled so that the message box has the complete focus.

The syntax is:

```
r = MsgBox(message$, button1$ [, button2$ [, button3$ [, button4$]])
```

All arguments are strings. 'message\$' is the message to display. This can contain one or more tilde characters (~) which indicate a line break. Up to 10 lines can be displayed inside the box. 'button1\$' is the caption for the first button, 'button2\$' is the caption for the second button, etc. At least one button must be specified and four is the maximum. Any buttons not included in the argument list will not be displayed.

The font used will be the default font set using the FONT command and the colours used will be the defaults set by the COLOUR command. The box will be automatically sized taking into account the dimensions of the default font, the number of lines to display and the number of buttons specified.

When the user touches a button the message box will erase itself, restore the display (eg, re enable all controls) and return the number of the button that was touched (the first button will return 1, the second 2, etc). Note that, unlike all other GUI controls the BASIC program will stop running while the message box is displayed, interrupts however will be honoured and acted upon.

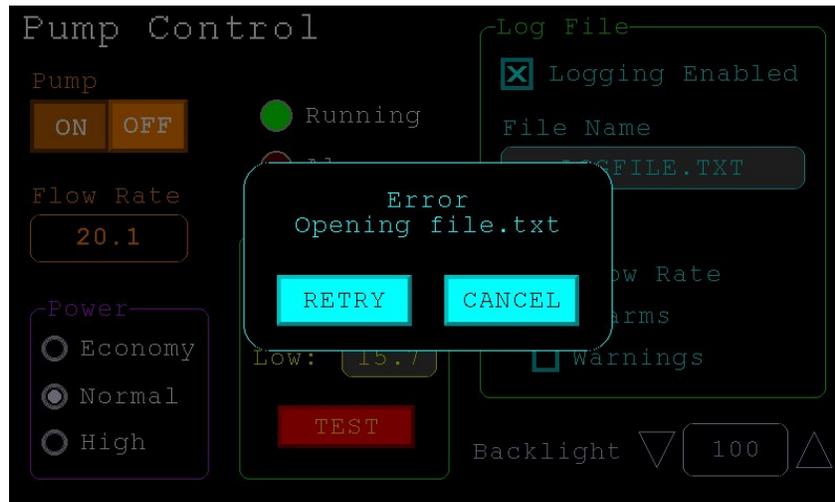
To illustrate the usage of a message box will the following program fragment will attempt to open a file and if an error occurs the program will display an error message using the MsgBox() function. The message has two lines and the box has two buttons for retry and cancel.

```

Do
  On Error Skip
  Open "file.txt" For Input As #1
  If MM.ErrNo <> 0 Then
    if MsgBox("Error~Opening file.txt","RETRY","CANCEL") = 2 Then Exit Sub
  EndIf
Loop While MM.ErrNo <> 0

```

This would be the result if the file "file.txt" did not exist:



Advanced Graphics Programming Techniques

When programming using the advanced GUI commands implemented on the Armite F4 there are a number of hints and techniques to consider that will make it easier to develop and maintain your program.

The User Should Be In Control

Traditional character based programs are normally in control of the interaction with the user. For example, the program may display a menu and prompt the user to select an action. If the user selects an invalid option the program would display an error message and display the menu options again.

However graphical based programs such as that created using the advanced GUI commands are different. Usually the program just starts running doing what it normally does (eg, control temperature, speed, etc) and it is the user's job to select and change parameters without being prompted. This is a different way of programming and is often hard for the traditional programmer to get used to this different technique.

As an example, consider a program that is to control a cutting device. The traditional program would prompt the user for the speed and cutting time. When both have been entered the program would prompt to start the cutting cycle. However, a graphical based program would display two number boxes where the user could enter the speed and time along with a run button. The number boxes could be filled with default values and the run button would be disabled if the user entered an invalid speed or time. When the run button is touched the cutting cycle would start.

A good example of this type of graphical interface is the dialogue box used on a Windows/IOS/Android computer to set the time and date. It displays a number of boxes where the user can enter the date/time along with an OK button that tells the program to accept the data entered. At no time is the user forced to make a selection from a menu. Also, the current time/date is already displayed in the entry boxes so the user can accept them as the default if they wanted to do so.

If you need some inspiration as to how your graphical program should look and feel check your nearest GUI based operating system to see how they operate.

Program Structure

Typically a program would start by defining the controls (which MMBasic will draw on the screen), then it would set the defaults and finally it would drop into a continuous loop where it would do whatever job it was design to do. For example, take the case of a simple controller for a motor where the user could select the speed and cause the motor to run by pressing an on screen button.

To implement this function the program would look something like this:

```
GUI CAPTION #1, "Speed (rpm)", 200, 50           ' label the number box
GUI NUMBERBOX #2, 200, 100, 150, 40           ' define and draw the number box
CtrlVal(#2) = 100                             ' default value for the speed
GUI BUTTON #3, "RUN", 200, 350, 0, RGB(red)    ' define and draw the RUN button

DO                                             ' this runs in a loop forever
  IF CtrlVal(#3)<10 OR CtrlVal(#3)>200 THEN    ' check the speed setting
    GUI DISABLE #3                           ' disable RUN if it is invalid
  ELSE                                         ' otherwise
    GUI ENABLE #3                             ' enable the RUN button
  ENDIF

  IF CtrlVal(#3) = 1 THEN                     ' if the button is pressed
    SetMotorSpeed CtrlVal(#2)                 ' make the motor run
  ELSE                                         ' otherwise the button is up
    SetMotorSpeed 0                           ' therefore set motor speed to zero
  ENDIF
LOOP
```

Note that the user is not prompted to do anything; the program just sits in a loop reacting to the changes that the user has made to the controls (ie, the user is in control).

Disable Invalid Controls

As in the above example, disabling a control will prevent a user from using it and MMBasic will redraw it in a dull colour to indicate that it is not available. This is the equivalent of an error message in a traditional text based program and is more user friendly than popping up a message box which must be dismissed before anything else can be done.

There are many times that a control could be invalid, for example when an input is not ready or simply when an option or action does not apply. Later, when the control becomes valid you can use the GUI ENABLE command to return it to use. Another example is when a GUI NUMBERBOX keypad is displayed MMBasic will automatically disable all other controls on the screen so that it is obvious to the user where their input is required.

Disabling a control still leaves it on the screen, so that the user knows that it is there but it will be dimmed and will not respond to touch. Not responding to touch also means that the user cannot change it and an interrupt will not be generated when it is touched. This is handy for you the programmer because you do not have to check if the control is valid before acting on it.

Use Constants for Control Reference Numbers

The advanced controls use a reference number to identify the control. To make it easy to read and maintain your program you should define these numbers as constants with easy to recognise names.

For example, in the following program fragment MAIN_SWITCH is defined as a constant and this constant is used wherever the reference number for that control is required:

```
CONST MAIN_SWITCH = 5
CONST ALARM_LED = 6
'...
GUI SWITCH MAIN_SWITCH, "ON|OFF", 330, 50, 140, 50, RGB(white), RGB(blue)
GUI LED ALARM_LED, 215, 220,30, RGB(red)
'...
IF CtrlVal(MAIN_SWITCH) = 0 THEN ... ' for example turn the pump off
IF ALARM THEN CtrlVal(ALARM_LED) = 1
```

It is much easier to remember what MAIN_SWITCH does than remembering what control the number 5 refers to. Also, when you have a lot of controls it is much easier to renumber the controls when all their numbers are defined at the one place at the start of the program.

By default the reference number must be a number between 1 and 100 however the upper limit can be changed with the OPTION CONTROL command. Increasing the number will consume more RAM and decreasing it will recover some RAM.

The Main Program Is Still Running

It is important to realise that your main BASIC program is still running while the user is interacting with the GUI controls. For example, it will continue running even while a user holds down an on screen switch and it will keep running while the virtual keyboard is displayed as a result of touching a TEXTBOX control.

For this reason your main program should not arbitrarily update touch sensitive screen controls, because they might change the on screen image while the user is using them (with undefined results). Normally when a BASIC program using GUI controls starts it will initialise controls such as a SPINBOX, NUMBERBOX and TEXTBOX to some initial value but from then on the main program should just read the value of these controls – it is the responsibility of the user to change these, not your program.

However, if you do want to change the value of such an on-screen control you need some mechanism to prevent both the program and the user making a change at the same time. One method is to set a flag within the key down interrupt to indicate that the control should not be updated during this time. This flag can then be cleared in the key up interrupt to allow the main program to resume updating the control.

Note that this discussion only applies to controls that respond to touch. Controls such as CAPTION can be changed at any time by the main program and often are.

Use Interrupts and SELECT CASE Statements

Everything that happens on a screen using the advanced controls will be signalled by an interrupt, either touch down or touch up. So, if you want to do something immediately when a control is changed, you should do it in an interrupt. Mostly you will be interested in when the touch (or pen) is down but in some cases you might also want to know when it is released.

Because the interrupt is triggered when the pen touches any control or part of the screen you need to discover what control was being touched. This is best performed using the TOUCH(REF) function and the SELECT CASE statement.

For example, in the following fragment the subroutine PenDown will be called when there is a touch and the function TOUCH(REF) will return the reference number of the control being touched. Using the SELECT CASE the alarm LED will be turned on or off depending on which button is touched. The action could be any number of things like raising an I/O pin to turn on a physical siren or printing a message on the console.

```
CONST ALARM_ON = 15
CONST ALARM_OFF = 16
CONST ALARM_LED = 33
GUI INTERRUPT PenDown
'...
GUI BUTTON ALARM_ON, "ALARM ON ", 330, 50, 140, 50, RGB(white), RGB(blue)
GUI BUTTON ALARM_OFF, "ALARM OFF ", 330, 150, 140, 50, RGB(white), RGB(blue)
GUI LED ALARM_LED, 215, 220, 30, RGB(red)
'...
DO : LOOP      ' the main program is doing something

' this sub is called when touch is detected
SUB PenDown
  SELECT CASE TOUCH(REF)
    CASE ALARM_ON
      CtrlVal(ALARM_LED) = 1
    CASE ALARM_OFF
      CtrlVal(ALARM_LED) = 0
  END SELECT
END SUB
```

The SELECT CASE can also test for other controls and perform whatever actions are required for them in their own section of the CASE statement.

The important point is that the maintenance of the controls (eg, responding to the buttons and turning the alarm LED off or on) is done automatically without the main program being involved – it can continue doing something useful like calculating some control response, etc.

Touch Up Interrupt

In most cases you can process all user input in the touch down interrupt. But there are exceptions and a typical example is when you need to change the characteristics of the control that is being touched. For example, if you wanted to change the foreground colour of a button from white to red when it is down. When it is returned to the up state the colour should revert to white.

Setting the colour on the touch down is easy. Just define a touch down interrupt and change the colour in the interrupt when that control is touched. However, to return the colour to white you need to detect when the touch has been removed from the control (ie, touch up). This can be done with a touch up interrupt.

To specify a touch up interrupt you add the name of the subroutine for this interrupt to the end of the GUI INTERRUPT command. For example:

```
GUI INTERRUPT IntTouchDown, IntTouchUp
```

Within the touch up subroutine you can use the same structure as in the touch down sub but you need to find the reference number of the last control that was touched. This is because the touch has already left the screen and no control is currently being touched. To get the number of the last control touched you need to use the function TOUCH(LASTREF)

The following example shows how you could meet the above requirement and implement both a touch down and a touch up interrupt:

```
SUB IntTouchDown
  SELECT CASE TOUCH(REF)
    CASE ButtonRef
      GUI FCOLOUR RGB(RED), ButtonRef
    END SELECT
END SUB

SUB IntTouchUp
  SELECT CASE TOUCH(LASTREF)
    CASE ButtonRef
      GUI FCOLOUR RGB(WHITE), ButtonRef
    END SELECT
END SUB
```

Keep Interrupts Very Short

Because a touch interrupt indicates a request by the user it is tempting to do some extensive programming within an interrupt. For example, if the touch indicates that the user wants to send a message to another controller it sounds logical to put all that code within the interrupt. But this is not a good idea because the Micromite Plus cannot do anything else while your program is processing the interrupt and sending a message could take many milliseconds.

Instead your program should update a global variable to indicate what is requested and leave the actual execution to the main program. For example, if the user did touch the "send a message" button your program could simply set a global variable to true. Then the main program can monitor this variable and if it changes perform the logic and communications required to satisfy the request.

Remember the commandment "Thou shalt not hang around in an interrupt".

Multiple Screens

Your program might need a number of screens with differing controls on each screen. This could be implemented by deleting the old controls and creating new ones when the screen is switched. But another way to do this is to use the GUI SETUP and PAGE commands. These allow you to organise the controls onto pages and with one simple command you can switch pages. All controls on the old page will be automatically hidden and controls on the new page will be automatically shown.

To allocate controls to a page you use the GUI SETUP nn command where nn refers to the page in the range of 1 to 32. When you have used this command any newly created controls will be assigned to that page. You can use GUI SETUP as many times that you want. For example, in the program fragment below the first two controls will be assigned to page 1, the second to page 2, etc.

```
GUI SETUP 1
GUI Caption #1, "Flow Rate", 20, 170,, RGB(brown),0
GUI Displaybox #2, 20, 200, 150, 45

GUI SETUP 2
GUI Caption #3, "High:", 232, 260, LT, RGB(yellow)
GUI Numberbox #4, 318, 6,90, 12, RGB(yellow), RGB(64,64,64)

GUI SETUP 3
GUI Checkbox #5, "Alarms", 500, 285, 25
GUI Checkbox #6, "Warnings", 500, 325, 25
```

By default only the controls setup as page 1 will be displayed and the others will be hidden.

To switch the screen to page 3 all you need do is use the command PAGE 3. This will cause controls #1 and #2 to be automatically hidden and controls #5 and #6 to be displayed. Similarly PAGE 2 will hide all except #3 and #4 which will be displayed.

You can specify multiple pages to display at the one time, for example, PAGE 1, 3 will display both pages 1 and 3 while hiding page 2. This can be useful if you have a set of controls that must be visible all the time. For example, PAGE 1, 2 and PAGE 1, 3 will leave the controls on page 1 visible while the others are switched on and off.

It is perfectly legal for a program to modify controls on other pages even though they are not displayed at the time. This includes changing the value and colours as well as disabling or hiding them. When the display is switched to their page the controls will be displayed with their new attributes.

It is possible to place the PAGE commands in the touch down interrupt so that pressing a certain control or part of the screen will switch to another page.

Note that when ALL is used for the list of controls in commands such as GUI ENABLE ALL this only refers to the controls on the pages that are currently selected for display. Controls on other pages will be unaffected.

All programs start with the equivalent of the commands GUI SETUP 1 and PAGE 1 in force. This means that if the GUI SETUP and PAGE commands are not used the program will run as you would expect with all controls displayed.

A typical usage of the PAGE command is shown below. Two buttons (which are always displayed) allow the user to select between the first page and the second page. The switch is done in the touch down interrupt.

```
GUI SETUP 1
GUI Button #10, "SELECT PAGE ONE", 50, 100, 150, 30, RGB(yellow), RGB(blue)
GUI Button #11, "SELECT PAGE TWO", 50, 140, 150, 30, RGB(yellow), RGB(blue)

GUI SETUP 2
GUI Caption #1, "Displaying First Page", 20, 20

GUI SETUP 3
GUI Caption #2, "Displaying Second Page", 20, 50

Page 1, 2
GUI INTERRUPT TouchDown
Do
    ' the main program loop
Loop

Sub TouchDown
    If Touch(REF) = 10 Then Page 1, 2
    If Touch(REF) = 11 Then Page 1, 3
End Sub
```

Multiple Interrupts

With many screen pages the interrupt subroutine could get long and complicated. To work around that it is possible to have multiple interrupt subroutines and switch dynamically between them as you wish (normally after switching pages). This is done by redefining the current interrupt routines using the GUI INTERRUPT command.

For example, this program fragment uses different interrupt routines for pages 4 and 5 and they are specified immediately after switching the pages.

```
PAGE 4
GUI INTERRUPT P4keydown, P4keyup
...
PAGE 5
GUI INTERRUPT P5keydown, P5keyup
...
```

Using Basic Drawing Commands

There are two types of objects that can be on the screen. These are the GUI controls and the basic drawing objects (PIXEL, LINE, TEXT, etc). Mixing the two on the screen is not a good idea because MMBasic does not track the position of the basic drawing objects and they can clash with the GUI controls.

As a result, unless you are prepared to do some extra programming, you should use either the GUI controls or the basic drawing objects – but you should not use both. So, for example, do not use TEXT but use GUI CAPTION instead. If you only use GUI controls MMBasic will manage the screen for you including erasing and redrawing it as required, for example when a virtual keyboard is displayed.

Note that the CLS command (used to clear the screen) will automatically set any GUI controls on the screen to hidden (ie, it does a GUI HIDE ALL before clearing the screen).

The main problem with mixing basic graphics and GUI controls occurs with the Text Box, Formatted Box and Number Box controls which display a virtual keyboard. This can erase any basic graphics and MMBasic will not know to restore them when the keyboard is removed. If you want to mix basic graphics with GUI controls you should:

- Intercept the touch down interrupt for the Text Box, Formatted Box and Number Box controls as that indicates that a virtual keyboard is about to be displayed and that will give you the opportunity to redraw your non GUI basic graphics in anticipation of this event (for example, draw them in a dimmed state to appear as if they are disabled).
- Intercept the touch up interrupt for the same controls as that indicates that the virtual keyboard has been removed and you could then redraw any non GUI graphics in their original state.

The following example demonstrates this technique. On a 5" or 7" display it initially draws a box filled with bright blue using the basic drawing commands. Then, when the number pad is about to pop up it will redraw the box in a dull colour. Finally, when the keypad is removed from the screen the pen up interrupt will redraw the box in its original colours.

```
GUI INTERRUPT TouchDownInterrupt, TouchUpInterrupt
BOX 400, 250, 300, 200, , RGB(WHITE), RGB(BLUE)
GUI NUMBERBOX 1, 318,100,90,40,RGB(YELLOW),RGB(64,64,64)
DO : LOOP

SUB TouchDownInterrupt
  IF TOUCH(REF) = 1 THEN BOX 400, 250, 300, 200, , RGB(128,128,128), RGB(0,0,128)
END SUB

SUB TouchUpInterrupt
  IF TOUCH(LASTREF) = 1 THEN BOX 400, 250, 300, 200, , RGB(WHITE), RGB(BLUE)
END SUB
```

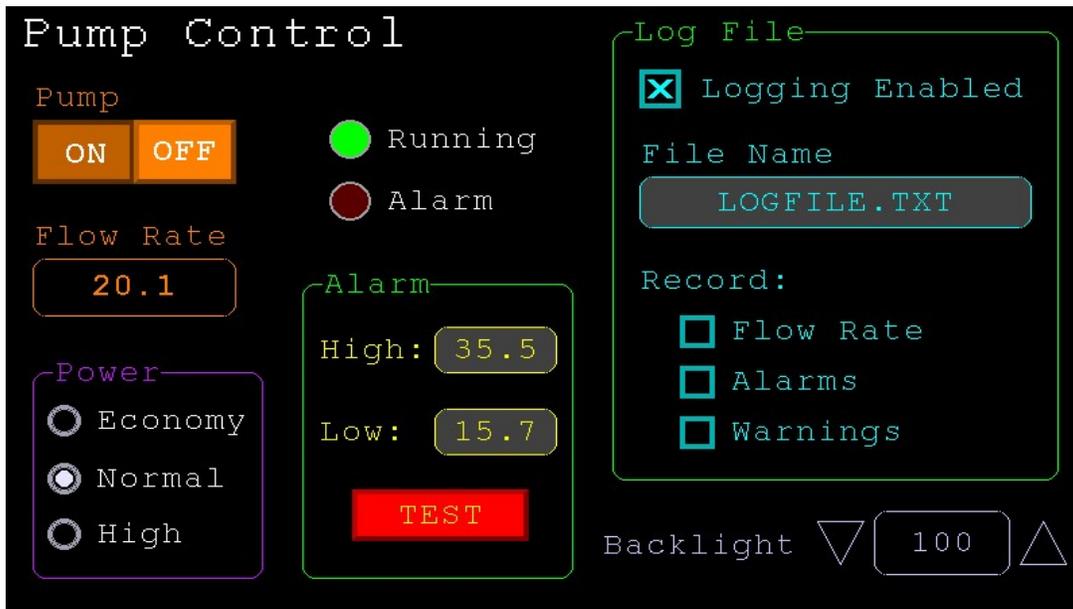
Overlapping Controls

Controls can be defined to overlap on the display, this mostly occurs with GUI AREA which, as an example, you might want to capture a touch that was intended for (say) a GUI BUTTON. This will allow you to create your own animation for the button rather than that provided by MMBasic. In this case the control that you wish to respond to the touch (ie, GUI AREA) should have a lower reference number (ie, #ref) than the control that it is covering (ie, the GUI BUTTON). This is because when the screen is touched MMBasic will check the current list of active controls starting with control number 1 and working upwards. When a match is made MMBasic will take the appropriate action and terminate the search. This results in the lower numbered control effectively masking out a higher numbered control covering the same screen area as the touched location.

The Pump Control Example GUI Program

As a test you can enter the following "Pump Control" demonstration program as shown in this YouTube video: <https://youtu.be/j12LidkzG2A>. It will draw a selection of advanced controls as shown below.

These controls are active so that you can test how they work.



Note that this demonstration expects a 800 x 480 pixel LCD panel in landscape orientation with touch (ie, a 5", 7" or 8" SSD1963 based panel or the OTM8009A 800*480).

```

.....
' Demonstration program for the Micromite+ and Armmite F4
' It does not do anything useful except demo the various controls
,
' Geoff Graham, October 2015
.....

```

Option Explicit

Dim ledsY

Colour RGB(white), RGB(black)

' reference numbers for the controls are defined as constants

Const c_head = 1, c_pmp = 2, sw_pmp = 3, c_flow = 4, tb_flow = 5

Const led_run = 6, led_alarm = 7

Const frm_alarm = 20, nbr_hi = 21, nbr_lo = 22, pb_test = 23

Const c_hi = 24, c_lo = 25

Const frm_pump = 30, r_econ = 31, r_norm = 32, r_hi = 33

Const frm_log = 40, cb_enabled = 41, c_fname = 42, tb_fname = 43

Const c_log = 44, cb_flow = 45, cb_pwr = 46, cb_warn = 47

Const cb_alarm = 48, c_bright = 49, sb_bright = 50

' now draw the "Pump Control" display

CLS

GUI Interrupt TouchDown, TouchUp

' display the heading

Font 2,2 : GUI Caption c_head, "Pump Control", 10, 0

Font 3 : GUI Caption c_pmp, "Pump", 20, 60, , RGB(brown)

' now, define and display the controls

' first display the switch

Font 4

GUI Switch sw_pmp, "ON|OFF", 20, 90, 150, 50, RGB(white),RGB(brown)

CtrlVal(sw_pmp) = 1

' the flow rate display box

Font 3 : GUI Caption c_flow, "Flow Rate", 20, 170,, RGB(brown),0

Font 4 : GUI Displaybox tb_flow, 20, 200, 150, 45

CtrlVal(tb_flow) = "20.1"

```

' the radio buttons and their frame
Font 3 : GUI Frame frm_pump, "Power", 20, 290, 170, 163, RGB(200,20,255)
GUI Radio r_econ, "Economy", 43, 328, 12, RGB(230, 230, 255)
GUI Radio r_norm, "Normal", 43, 374
GUI Radio r_hi, "High", 43, 418
CtrlVal(r_norm) = 1      ' start with the "normal" button selected

' the alarm frame with two number boxes and a push button switch
Font 3 : GUI Frame frm_alarm, "Alarm", 220, 220, 200, 233, RGB(green)
GUI Caption c_hi, "High:", 232, 260, "LT", RGB(yellow)
GUI Numberbox nbr_hi, 318, MM.VPos-6, 90, MM.FontHeight+12, RGB(yellow), RGB(64, 64, 64)
GUI Caption c_lo, "Low:", 232, 325, "LT", RGB(yellow), 0
GUI Numberbox nbr_lo, 318, MM.VPos-6, 90, MM.FontHeight+12, RGB(yellow), RGB(64, 64, 64)
GUI Button pb_test, "TEST", 257, 383, 130, 40, RGB(yellow), RGB(red)
CtrlVal(nbr_lo) = 15.7 : CtrlVal(nbr_hi) = 35.5

' draw the two LEDs
Const ledsX = 255, coff = 50      ' define their position
ledsY = 105 : GUI LED led_run, "Running", ledsX, ledsY, 15, RGB(green)
ledsY = ledsY+49 : GUI LED led_alarm, "Alarm", ledsX, ledsY, 15, RGB(red)
CtrlVal(led_run) = 1      ' the switch defaults to on so set the LED on

' the logging frame with check boxes and a text box
Colour RGB(cyan), 0
GUI Frame frm_log, "Log File", 450, 20, 330, 355, RGB(green)
GUI Checkbox cb_enabled, "Logging Enabled", 470, 50, 30, RGB(cyan)
GUI Caption c_fname, "File Name", 470, 105
GUI Textbox tb_fname, 470, 135, 290, 40, RGB(cyan), RGB(64, 64, 64)
GUI Caption c_log, "Record:", 470, 205, , RGB(cyan), 0
GUI Checkbox cb_flow, "Flow Rate", 500, 245, 25
GUI Checkbox cb_alarm, "Alarms", 500, 285, 25
GUI Checkbox cb_warn, "Warnings", 500, 325, 25
CtrlVal(cb_enabled) = 1
CtrlVal(tb_fname) = "LOGFILE.TXT"

' define and display the spinbox for controlling the backlight
GUI Caption c_bright, "Backlight", 442, 415, , RGB(200,200,255), 0
GUI Spinbox sb_bright, MM.HPos + 8, 400, 200, 50, , , 10, 10, 100
CtrlVal(sb_bright) = 100

' All the controls have been defined and displayed. At this point
' the program could do some real work but because this is just a
' demo there is nothing to do. So it just sits in a loop.
Do : Loop

' the interrupt routine for touch down
' using a select case command it has a different process for each control
Sub TouchDown
  Select Case Touch(REF)      ' find out the control touched
    Case cb_enabled          ' the enable check box
      If CtrlVal(cb_enabled) Then
        GUI ENABLE c_fname, tb_fname, c_log, cb_flow, cb_alarm, cb_warn
      Else
        GUI Disable c_fname, tb_fname, c_log, cb_flow, cb_alarm, cb_warn
      EndIf
    Case sb_bright           ' the brightness spin box
      BackLight CtrlVal(sb_bright)
    Case sw_pmp              ' the pump on/off switch
      CtrlVal(led_run) = CtrlVal(sw_pmp)
      CtrlVal(tb_flow) = Str$(CtrlVal(sw_pmp) * 20.1)
      CtrlVal(r_norm) = 1
    Case pb_test             ' the alarm test button
      CtrlVal(led_alarm) = 1
  End Select
End Sub

```

```

    GUI beep 250
    Case r_econ          ' the economy radio button
        CtrlVal(tb_flow) = Str$(CtrlVal(sw_pmp) * 18.3)
    Case r_norm         ' the normal radio button
        CtrlVal(tb_flow) = Str$(CtrlVal(sw_pmp) * 20.1)
    Case r_hi           ' the high radio button
        CtrlVal(tb_flow) = Str$(CtrlVal(sw_pmp) * 23.7)
    End Select
End Sub

' interrupt routine when the touch is removed
Sub TouchUp
    Select Case Touch(LASTREF) ' use the last reference
        Case pb_test         ' was it the test button
            CtrlVal(led_alarm) = 0 ' turn off the LED
    End Select
End Sub

```

Miscellaneous Features

Serial Interface

The Armmite F4 has built in support for up to four serial interfaces. COM1, COM2, COM3 and COM4 are available as standard. When the serial console is enable (OPTION SERIAL CONSOLE ON) COM1 is unavailable and becomes the console.

All serial ports on the Armmite F4 can operate at high speed (up to 1M baud) and support the INV, OC and S2 options. In addition COM1 supports the DE and 9BIT options (for RS485).

SPI Interface

The Armmite F4 has built in support for two SPI interfaces. The commands to control these interfaces use the identifier SPI for the first SPI port and SPI2 for the second port. All commands and functions that can be used on the first port (SPI) can be used on the second by using the identifier SPI2. These are:

- SPI2 OPEN
- SPI2 WRITE
- SPI2 READ
- = SPI2(args, ...)
- SPI2 CLOSE

SPI based displays, the touch controller and the SD Card interface (if implemented) will all use the second SPI interface (SPI2). If any of these features are enabled SPI2 will be unavailable to BASIC programs (which should use the first SPI channel instead).

Upgrading Your BASIC Program in the Field

Often it is desirable to send an upgraded version of your BASIC program to a user and let them load it under control of the program already running on the Micromite Plus. This can be easily accomplished with the command:

```
LOAD "filename.bas", R
```

Where *filename.bas* is the name of the upgraded BASIC file on the SD card. This will load the BASIC program into the Micromite's program memory and immediately restart the CPU and run the new program.

Your program could execute this command when the user touched a screen button –or- it could check once every minute for that file name and, if found, load and run it. Then, all you have to do is send the updated program (on an SD card) to your user to initiate an upgrade. Easy.

CSUBs

It is possible to write C code and have it compile as inline code. This can then be loaded into MMBasic as a CSUB which can be called just like it was another MMbasic command. Writing CSUBs is beyond the scope of this document other than to document the CSUB command which actually loads the actual CSUB once its developed.

This thread on TBS forum is a starting point for it you want further information. It refers to the Colour Maximite 2, it will be the same for the Armmite F4 except the Armmite F4 has its own header file, ARMF4CFunction.h which is distribute with the Armmite F4 firmware.

<https://www.thebackshed.com/forum/ViewTopic.php?PID=149266#149266>

SD Card Support

The SDcard is always enabled in the Armmite F4 firmware and no configuration is necessary.

The Armmite F4 has full support for SD cards. This includes opening files for reading, writing or random access and loading and saving programs.

The firmware will work with cards up to 64 GB formatted in FAT16 or FAT32 and the files created can also be read/written on personal computers running Windows, Linux or the Mac operating system.

The Armmite F4 has full support for programs, files and directories on the SD card. This includes opening files for reading, writing or random access and editing and running programs.

MMBasic will work with cards up to 128GB in capacity. Cards larger than 32GB should be formatted as exFAT and cards 32GB or less formatted as FAT32. Small capacity cards may not be reliable so the recommended size is 8GB formatted as FAT32.

In the following note that:

- The filename can be a string expression, variable or constant. If it is a constant the string must be quoted (eg, KILL "MYPROG.BAS").
 - Long file/directory names are supported in addition to the old 8.3 format.
 - The maximum file/path length is 63 characters.
 - Upper/lowercase characters and spaces are allowed although the file system is not case sensitive.
 - Directory paths are allowed in file/directory strings. (ie, OPEN "/dir1/dir2/file.txt" FOR ...).
 - Forward slashes or back slashes are valid in paths between directories. Eg /dir/file.txt or \dir\file.txt.
 - The current MMBasic time is used for file create and last access times.
 - Up to ten files can be simultaneously open.
 - Except for INPUT, LINE INPUT and PRINT the # in #fnbr is optional and may be omitted.
- OPEN fname\$ FOR mode AS #fnbr
Opens a file for reading or writing. 'fname\$' is the file name in 8.3 format. 'mode' can be INPUT, OUTPUT, APPEND or RANDOM. '#fnbr' is the file number (1 to 10).
 - PRINT #fnbr, expression [[,;]expression] ... etc
Outputs text to the file opened as #fnbr.
 - INPUT #fnbr, list of variables
Read a list of comma separated data into the variables specified from the file previously opened as #fnbr.
 - LINE INPUT #fnbr, variable\$
Read a complete line into the string variable specified from the file previously opened as #fnbr.
 - CLOSE #fnbr [,#fnbr] ...
Close the file(s) previously opened with the file number '#fnbr'.

Programs can be loaded from or saved to the SD card using two commands.

- LOAD fname\$ [, R]
Load a BASIC program from the SD Card. The optional suffix ",R" will cause the program to be run after it has been loaded.
- SAVE fname\$
Save the current program to the SD card.

Load and Save Image

Images can be loaded from or saved to the SD card using two commands.

- **LOAD IMAGE** *fname\$* [, *startx*, *starty*]
Load a BMP file and display it on the LCD screen at *startx*, *starty*. (these default to the top left corner of the display if not specified).

SAVE IMAGE *fname\$* [, *x*, *y*, *w*, *h*]

Save the current LCD screen image as a BMP file. This will save the image as a 24-bit true colour BMP file (the extension .BMP) will be added if an extension is not supplied. [*x*, *y*, *w*, *h*] define the area to be saved. If omitted the entire screen is saved.

Load and Save Data

Memory content can be loaded from or saved to the SD card using two commands.

- **SAVE DATA** *fname\$*, *address*, *size*
Save memory *size* bytes starting memory *address* to *filename\$* as binary data.
- **LOAD DATA** *fname\$*, *address*
Load binary data into the memory at *address*

File and Directory Management

Basic file and directory manipulation can be done from within a BASIC program.

- **FILES** [*wildcard*]
Search the current directory and list the files/directories found.
- **KILL** *fname\$*
Delete a file in the current directory.
- **NAME** *fnameold\$* AS *fnamenew\$*
Renames a file in the current directory.
- **MKDIR** *dname\$*
Make a sub directory in the current directory.
- **CHDIR** *dname\$*
Change into to the directory *\$dname*. *\$dname* can also be "." (dot dot) for up one directory or "\" for the root directory.
- **RMDIR** *dir\$*
Remove, or delete, the directory 'dir\$' on the SD card.
- **SEEK** *#fnbr*, *pos*
Will position the read/write pointer in a file that has been opened for RANDOM access to the 'pos' byte.

Also there are a number of functions that support the above commands.

- **INPUT\$(*nbr*, *#fnbr*)**
Will return a string composed of '*nbr*' characters read from a file previously opened for INPUT with the file number '*#fnbr*'. If less than '*nbr*' characters are available the function will return with what it has (including an empty string if no characters are available).
- **DIR\$(*fspec*, *type*)**
Will search an SD card for files and return the names of entries found.
- **EOF(*#fnbr*)**
Will return true if the file previously opened for INPUT with the file number '*#fnbr*' is positioned at the end of the file.

- LOC(#fnbr)
For a file opened as RANDOM this will return the current position of the read/write pointer in the file.
- LOF(#fnbr)
Will return the current length of the file in bytes.

XModem Transfer

In addition to the standard method of XModem transfer which copies to or from the program memory the Micromite Plus can also copy to and from a file on the SD card. The syntax is:

```
XMODEM SEND filename$
or
XMODEM RECEIVE filename$
```

Where 'filename\$' is the file to save or send. As is common throughout MMBasic 'filename\$' can be a string expression, variable or constant. If it is a constant the string must be quoted (eg, XMODEM SEND "PRBAS") In the case of receiving a file, any file on the SD card with the same name will be automatically overwritten.

Example of Sequential I/O

In the example below a file is created and two lines are written to the file (using the PRINT command). The file is then closed.

```
OPEN "fox.txt" FOR OUTPUT AS #1
PRINT #1, "The quick brown fox"
PRINT #1, "jumps over the lazy dog"
CLOSE #1
```

You can read the contents of the file using the LINE INPUT command. For example:

```
OPEN "fox.txt" FOR INPUT AS #1
LINE INPUT #1, a$
LINE INPUT #1, b$
CLOSE #1
```

LINE INPUT reads one line at a time so the variable a\$ will contain the text "The quick brown fox" and b\$ will contain "jumps over the lazy dog".

Another way of reading from a file is to use the INPUT\$() function. This will read a specified number of characters. For example:

```
OPEN "fox.txt" FOR INPUT AS #1
ta$ = INPUT$(12, #1)
tb$ = INPUT$(3, #1)
CLOSE #1
```

The first INPUT\$() will read 12 characters and the second three characters. So the variable ta\$ will contain "The quick br" and the variable tb\$ will contain "own".

Files normally contain just text and the print command will convert numbers to text. So in the following example the first line will contain the line "123" and the second "56789".

```
nbr1 = 123 : nbr2 = 56789
OPEN "numbers.txt" FOR OUTPUT AS #1
PRINT #1, nbr1
PRINT #1, nbr2
CLOSE #1
```

Again you can read the contents of the file using the LINE INPUT command but then you would need to convert the text to a number using VAL(). For example:

```

OPEN "numbers.txt" FOR INPUT AS #1
LINE INPUT #1, a$
LINE INPUT #1, b$
CLOSE #1
x = VAL(a$) : y = VAL(b$)

```

Following this the variable x would have the value 123 and y the value 56789.

Random File I/O

For random access the file should be opened with the keyword RANDOM. For example:

```

OPEN "filename" FOR RANDOM AS #1

```

To seek to a record within the file you would use the SEEK command which will position the read/write pointer to a specific byte. The first byte in a file is numbered one so, for example, the fifth record in a file that uses 64 byte records would start at byte 257. In that case you would use the following to point to it:

```

SEEK #1, 257

```

When reading from a random access file the INPUT\$() function should be used as this will read a fixed number of bytes (ie, a complete record) from the file. For example, to read a record of 64 bytes you would use:

```

dat$ = INPUT$(64, #1)

```

When writing to the file a fixed record size should be used and this can be easily accomplished by adding sufficient padding characters (normally spaces) to the data to be written. For example:

```

PRINT #1, dat$ + SPACE$(64 - LEN(dat$));

```

The SPACE\$() function is used to add enough spaces to ensure that the data written is an exact length (64bytes in this example). The semicolon at the end of the print command suppresses the addition of the carriage return and line feed characters which would make the record longer than intended.

Two other functions can help when using random file access. The LOC() function will return the current byte position of the read/write pointer and the LOF() function will return the total length of the file in bytes.

The following program demonstrates random file access. Using it you can append to the file (to add some data in the first place) then read/write records using random record numbers. The first record in the file is record number 1, the second is 2, etc.

```

RecLen = 64
OPEN "test.dat" FOR RANDOM AS #1
DO
  abort: PRINT
  PRINT "Number of records in the file =" LOF(#1)/RecLen
  INPUT "Command (r = read,w = write, a = append, q = quit): ", cmd$
  IF cmd$ = "q" THEN CLOSE #1 : END
  IF cmd$ = "a" THEN
    SEEK #1, LOF(#1) + 1
  ELSE
    INPUT "Record Number: ", nbr
    IF nbr < 1 or nbr > LOF(#1)/RecLen THEN PRINT "Invalid record" : GOTO abort
    SEEK #1, RecLen * (nbr - 1) + 1
  ENDIF
  IF cmd$ = "r" THEN
    PRINT "The record = " INPUT$(RecLen, #1)
  ELSE
    LINE INPUT "Enter the data to be written: ", dat$
    PRINT #1,dat$ + SPACE$(RecLen - LEN(dat$));
  ENDIF
LOOP

```

Random access can also be used on a normal text file. For example, this will print out a file backwards:

```
OPEN "file.txt" FOR RANDOM AS #1
FOR i = LOF(#1) TO 1 STEP -1
    SEEK #1, i
    PRINT INPUT$(1, #1);
NEXT i
CLOSE #1
```


Generating Sine Waves

The PLAY TONE command also uses the audio output and will generate sine waves with selectable frequencies for the left and right channels. This feature is intended for generating attention catching sounds but, because the frequency is very accurate, it can be used for many other applications. For example, signalling DTMF tones down a telephone line or testing the frequency response of loudspeakers.

The syntax of the command is:

```
PLAY TONE left, right, duration, interrupt
```

left and *right* are the frequencies in Hz to use for the left and right channels. The tone plays in the background (the program will continue running after this command) and 'dur' specifies the number of milliseconds that the tone will sound for.

duration is optional and if not specified the tone will continue until explicitly stopped or the program terminates. *interrupt* (if specified) will be triggered when the duration has finished.

The frequency can be from 1 Hz to 20 KHz and is very accurate (it is based on a crystal oscillator). The frequency can be changed at any time by issuing a new PLAY TONE command.

Utility Commands

There are a number of commands that can be used to manage the sound output:

PLAY PAUSE	Temporarily halt (pause) the currently playing file or tone.
PLAY RESUME	Resume playing a file or tone that was previously paused.
PLAY STOP	Terminate the playing of the file or tone. The sound output will also be automatically stopped when the program ends.
PLAY VOLUME L, R	Set the volume to between 0 and 100 with 100 being the maximum volume. The volume will reset to the maximum level when a program is run.

Special Device Support

To make it easier for a program to interact with the external world the MMBasic firmware of the Armmite F4 includes specific drivers for a number of common peripheral devices. See the the next section *Other Device Support* for a sample od other devices that can/have be supported by writing drivers in the MMBasic language itself.

These are:

- Infrared remote control receiver and transmitter
- The DS18B20 temperature sensor and DHT22 temperature/humidity sensor
- LCD display modules
- Numeric keypads
- Ultrasonic distance sensor

Infrared Remote Control Decoder

You can easily add a remote control to your project using the IR command. When enabled this function will run in the background and interrupt the running program whenever a key is pressed on the IR remote control.

It will work with any NEC or Sony compatible remote controls including ones that generate extended messages. Most cheap programmable remote controls will generate either protocol and using one of these you can add a sophisticated flair to your Micromite based project. The NEC protocol is also used by many other manufacturers including Apple, Pioneer, Sanyo, Akai and Toshiba so their branded remotes can be used.

To detect the IR signal you need an IR receiver connected to the IR pin (pin PE2 on the Armmite F4) as illustrated in the diagram. The IR receiver will sense the IR light, demodulate the signal and present it as a TTL voltage level signal to this pin. Setup of the I/O pin is automatically done by the IR command.

NEC remotes use a 38kHz modulation of the IR signal and suitable receivers tuned to this frequency include the Vishay TSOP4838, Jaycar ZD1952 and Altronics Z1611A.

Sony remotes use a 40 kHz modulation but receivers for this frequency can be hard to find. Generally, 38 kHz receivers will work but maximum sensitivity will be achieved with a 40 kHz receiver.

To setup the decoder you use the command:

```
IR dev, key, interrupt
```

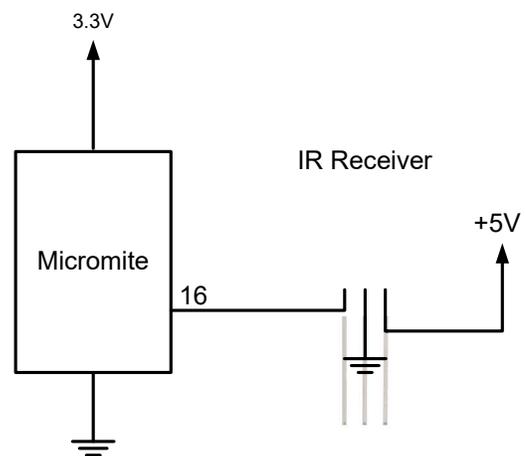
Where *dev* is a variable that will be updated with the device code and *key* is the variable to be updated with the key code. *Interrupt* is the interrupt subroutine to call when a new key press has been detected. The IR decoding is done in the background and the program will continue after this command without interruption.

This is an example of using the IR decoder:

```
IR DevCode, KeyCode, IR_Int          ' start the IR decoder
DO
  ' < body of the program >
LOOP

SUB IR_Int                          ' a key press has been detected
  PRINT "Received device = " DevCode " key = " KeyCode
END SUB
```

IR remote controls can address many different devices (VCR, TV, etc) so the program would normally examine the device code first to determine if the signal was intended for the program and, if it was, then take action based on the key pressed. There are many different devices and key codes so the best method of determining what codes your remote generates is to use the above program to discover the codes.



The IR function uses the same I/O pin as the wakeup signal for the CPU SLEEP command and it is possible to combine them so that an incoming IR signal will wake the Micromite which will then decode the IR signal. In this way you can have a Micromite running on battery power that will wake up on an IR signal, do something based on the signal, then go back to sleep.

The following is an example:

```

IR DevCode, KeyCode, IR_Int      ' start the IR decoder
DO
  CPU SLEEP                       ' now sleep until a signal
LOOP

SUB IR_Int                        ' a key press has been detected
  < do some work based on the key press >
END SUB                           ' return to sleep again

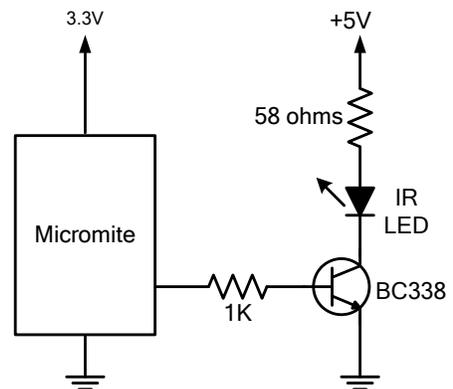
```

Infrared Remote Control Transmitter

Using the IRSEND command you can transmit a 12 bit Sony infrared remote control signal. This is intended for Micromite to Micromite communications but it will also work with Sony equipment that uses 12 bit codes. Note that all Sony products require that the message be sent three times with a 26 ms delay between each message.

In previous versions of the Micromite firmware this command was built into MMBasic but now it is distributed as a CSub module which works exactly the same. See the file *IRSend.pdf* which is included in the *Embedded C Modules* folder in the Micromite firmware zip file.

The circuit on the right illustrates what is required. The transistor is used to drive the infrared LED because the output of the Micromite is limited to about 10mA. This circuit provides about 50 mA to the LED.



To send a signal you use the command:

```
IRSEND pin, dev, key
```

Where pin is the I/O pin used, dev is the device code to send and key is the key code. Any I/O pin on the Micromite can be used and you do not have to set it up beforehand (IRSEND will automatically do that).

The modulation frequency used is 38 kHz and this matches the common IR receivers (described in the previous page) for maximum sensitivity when communicating between two Micromites.

Measuring Temperature

The TEMPR() function will get the temperature from a DS18B20 temperature sensor. This device can be purchased on eBay for about \$5 in a variety of packages including a waterproof probe version.

The DS18B20 can be powered separately by a 3V to 5V supply or it can operate on parasitic power from the Micromite as shown on the right. Multiple sensors can be used but a separate I/O pin and a 4.7K pullup resistor is required for each one.

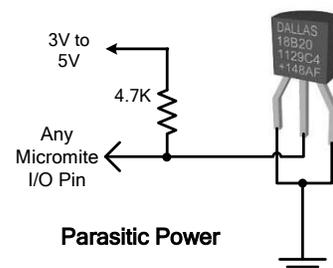
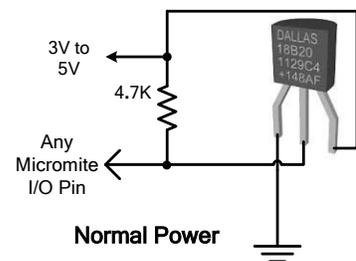
To get the current temperature you just use the TEMPR() function in an expression. For example:

```
PRINT "Temperature: " TEMPR(pin)
```

Where 'pin' is the I/O pin to which the sensor is connected. You do not have to configure the I/O pin, that is handled by MMBasic.

The returned value is in degrees C with a resolution of 0.25 °C and is accurate to ±0.5 °C. If there is an error during the measurement the returned value will be 1000.

The time required for the overall measurement is 200ms and the running program will halt for this period while the measurement is being made. This also means that interrupts will be disabled for this period. If you do not want



this you can separately trigger the conversion using the TEMPR START command then later use the TEMPR() function to retrieve the temperature reading. The TEMPR() function will always wait if the sensor is still making the measurement.

For example:

```

TEMPR START PE0
< do other tasks >
PRINT "Temperature: " TEMPR(PE0)

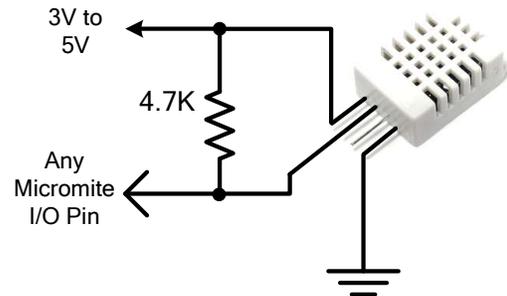
```

Measuring Humidity and Temperature

The HUMID command will read the humidity and temperature from a DHT22 humidity/temperature sensor. This device is also sold as the RHT03 or AM2302 but all are compatible and can be purchased on eBay for under \$5.

In previous versions of the Micromite firmware this command was built into MMBasic but now it is distributed as a CSub module which works the same. See the file *Humid.pdf* which is included in the *Embedded C Modules* folder in the Micromite firmware zip file.

The DHT22 can be powered from 3.3V or 5V (5V is recommended) and it should have a pullup resistor on the data line as shown. This is suitable for long cable runs (up to 20 meters) but for short runs the resistor can be omitted as the Micromite also provides an internal weak pullup.



To get the temperature or humidity you use the HUMID command with three arguments as follows:

```
HUMID pin, tVar, hVar
```

Where 'pin' is the I/O pin to which the sensor is connected. You can use any I/O pin but if the DHT22 is powered from 5V it must be 5V capable. The I/O pin will be automatically configured by MMBasic.

'tVar' is a floating point variable in which the temperature is returned and 'hVar' is a second variable for the humidity. Both of these variables must be declared first as floats (using DIM). The temperature is returned as degrees C with a resolution of one decimal place (eg, 23.4) and the humidity is returned as a percentage relative humidity (eg, 54.3).

For example:

```

DIM FLOAT temp, humidity
HUMID pin, temp, humidity
PRINT "The temperature is" temp " and the humidity is" humidity

```

Measuring Distance

Using a HC-SR04 ultrasonic sensor and the DISTANCE() function you can measure the distance to a target.

This device can be found on eBay for about \$4 and it will measure the distance to a target from 3cm to 3m. It works by sending an ultrasonic sound pulse and measuring the time it takes for the echo to be returned.

Compatible sensors are the SRF05, SRF06, Parallax PING and the DYP-ME007 (which is waterproof and therefore good for monitoring the level of a water tank).

On the Micromite you use the DISTANCE function as follows:

```
d = DISTANCE(trig, echo)
```

Where trig is the I/O pin connected to the "trig" input of the sensor and echo is the pin connected the "echo" output of the sensor. You can also use 3-pin devices and in that case only one pin number is specified.



The value returned is the distance in centimetres to the target. The I/O pins are automatically configured by this function but note that they should be 5V capable as the HC-SR04 is a 5V device.

LCD Display

The LCD command will display text on a standard LCD module with the minimum of programming effort.

This command will work with LCD modules that use the KS0066, HD44780 or SPLC780 controller chip and have 1, 2 or 4 lines. Typical displays include the LCD16X2 (futurlec.com), the Z7001 (altronics.com.au) and the QP5512 (jaycar.com.au). eBay is another good source where prices can range from \$10 to \$50.

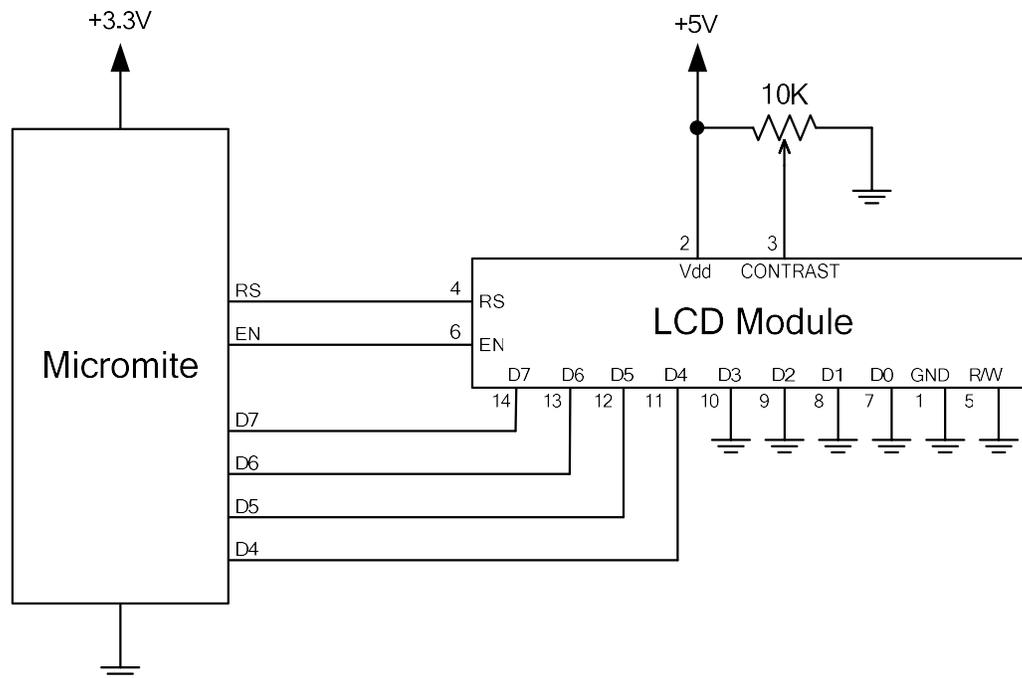


To setup the display you use the LCD INIT command:

```
LCD INIT d4, d5, d6, d7, rs, en
```

d4, d5, d6 and d7 are the numbers of the I/O pins that connect to inputs D4, D5, D6 and D7 on the LCD module (inputs D0 to D3 and R/W on the module should be connected to ground). 'rs' is the pin connected to the register select input on the module (sometimes called CMD or DAT). 'en' is the pin connected to the enable or chip select input on the module.

Any I/O pins on the Micromite can be used and you do not have to set them up beforehand (the LCD command automatically does that for you). The following shows a typical set up.



To display characters on the module you use the LCD command:

```
LCD line, pos, data$
```

Where line is the line on the display (1 to 4) and pos is the position on the line where the data is to be written (the first position on the line is 1). data\$ is a string containing the data to write to the LCD display. The characters in data\$ will overwrite whatever was on that part of the LCD.

The following shows a typical usage where d4 to d7 are connected to pins 2 to 4 on the Micromite, rs is connected to pin 23 and en to pin 24..

```
LCD INIT 2, 3, 4, 5, 23, 24
LCD 1, 2, "Temperature"
LCD 2, 6, STR$(TEMPR(15))      ' DS18B20 connected to pin 15
```

Note that this example also uses the TEMPR() function to get the temperature (described above).

Keypad Interface

A keypad is a low tech method of entering data into a Micromite based system. The Micromite supports either a 4x3 keypad or a 4x4 keypad and the monitoring and decoding of key presses is done in the background. When a key press is detected an interrupt will be issued where the program can deal with it.

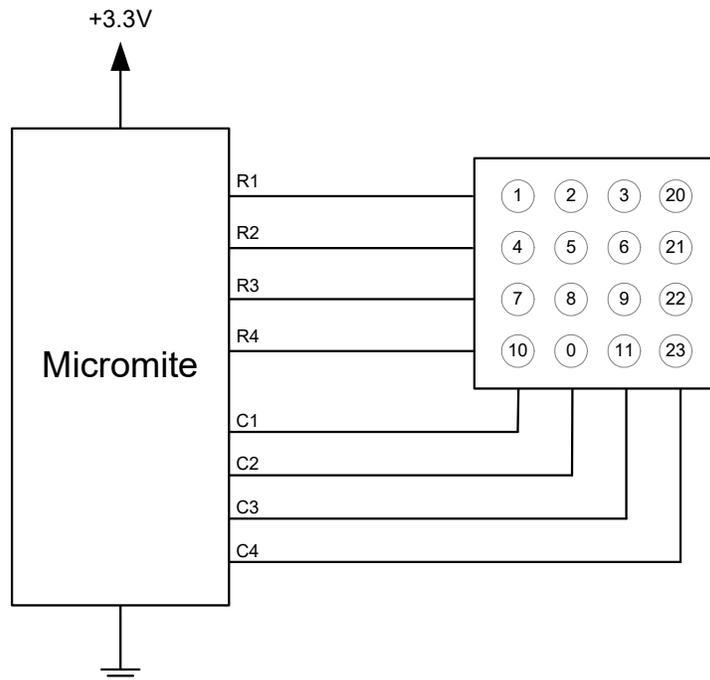
Examples of a 4x3 keypad and a 4x4 keypad are the Altronics S5381 and S5383 (go to www.altronics.com).

To enable the keypad feature you use the command:

```
KEYPAD var, int, r1, r2, r3, r4, c1, c2, c3, c4
```

Where var is a variable that will be updated with the key code and int is the name of the interrupt subroutine to call when a new key press has been detected. r1, r2, r3 and r4 are the pin numbers used for the four row connections to the keypad (see the diagram below) and c1, c2, c3 and c4 are the column connections. c4 is only used with 4x4 keypads and should be omitted if you are using a 4x3 keypad.

Any I/O pins on the Micromite can be used and you do not have to set them up beforehand, the KEYPAD command will automatically do that for you.



The detection and decoding of key presses is done in the background and the program will continue after this command without interruption. When a key press is detected the value of the variable var will be set to the number representing the key (this is the number inside the circles in the diagram above). Then the interrupt will be called.

For example:

```
Keypad KeyCode, KP_Int, 2, 3, 4, 5, 21, 22, 23 ' 4x3 keyboard
DO
  < body of the program >
LOOP

SUB KP_Int ' a key press has been detected
  PRINT "Key press = " KeyCode
END SUB
```

WS2812 Support

The Armmite F4 has built in support for the WS2812 multicolour LED chip. This chip needs a very specific timing to work properly and with the **WS2812 command it is easy to control these devices with minimal effort.**

This command will output the required signals needed to drive a chain of WS2812 LED chips connected to the pin specified and set the colours of each LED in the chain. The syntax of the command is:

```
WS2812 type, pin, colours%()
```

Note that the pin must be set to a digital output before this command is used.

The colours%() array should be sized to have exactly the same number of elements as the number of LEDs to be driven. Each element in the array should contain the colour in the normal RGB888 format (0 - &HFFFFFF). There is no limit to the size of the WS2812 string supported.

'type' is a single character specifying the type of chip being driven as follows:

O = original WS2812

B = WS2812B

S = SK6812

As an example:

```
DIM b%(4)=(RGB(red), Rgb(green), RGB(blue), RGB(Yellow), Rgb(cyan))
SETPIN 5, DOUT
WS2812 O, 5, b%()
```

will output the specified colours to an array of five WS2812 LEDs daisy chained off pin 5.

Other Devices and Support Resources

The Back Shed Forum

Fruit of the Shed Wiki

Some Examples

The following is a sample of some of the devices that can be controller by/connected to the Armmite F4. Basically anything that communicates via Serial, SPI, I2C, 1-Wire, outputs a voltage, current etc.

CAN Adaptor

INA219 Current Sensor

ESP8266 ESP01

ACS712 Current sensor.

BMP280 Pressure and Humidy sensor

HC05 Bluetooth adaptors

KY040 Rotary Encoder

PCA9685 I2C PWM Driver

Predefined Read Only Variables

These variables are set by MMBasic and cannot be changed by the running program.

MM.VER	The version number of the firmware as a floating point number in the form aa.bbccc where aa is the major version number, bb is the minor version number and cc is the revision number. For example version 5.03.00 will return 5.03 and version 5.03.01 will return 5.0301.
MM.DEVICES\$	A string representing the device or platform that MMBasic is running on. Currently this variable will contain one of the following: "Maximite" on the standard Maximite and compatibles. "Colour Maximite" on the Colour Maximite and UBW32. "Colour Maximite 2" on the Colour Maximite 2. "DuinoMite" when running on one of the DuinoMite family. "DOS" when running on Windows in a DOS box. "Generic PIC32" for the generic version of MMBasic on a PIC32. "Micromite" on the PIC32MX150/250 "Micromite MkII" on the PIC32MX170/270 "Micromite Plus" on the PIC32MX470 "Micromite Extreme" on the PIC32MZ series "Armmite F4" on Armmite F4
MM.ERRNO MM.ERRMSG\$	If a statement caused an error which was ignored these variables will be set accordingly. MM.ERRNO is a number where non zero means that there was an error and MM.ERRMSG\$ is a string representing the error message that would have normally been displayed on the console. They are reset to zero and an empty string by RUN, ON ERROR IGNORE or ON ERROR SKIP.
MM.ERRNO	Is set to the error number if a statement involving the SD card fails or zero if the operation succeeds. This is dependent on the setting of OPTION ERROR. The possible values for MM.ERRNO are: 0 = No error 1 = No SD card found 2 = SD card is write protected 3 = Not enough space 6 = Cannot find file 7 = Cannot find file or directory 8 = Cannot create directory 12 = Hardware error 13 = File system error 14 = Directory not empty 16 = Syntax or general programming error
MM.INFO\$(AUTORUN)	Returns "On" or "Off" depending on the status of OPTION AUTORUN
MM.INFO\$(CPUSPEED)	Returns the CPU speed as a string
MM.INFO\$(LCDPANEL) MM.INFO\$(PIN pinno)	Returns the name of the LCD panel configured or a blank string Returns the status of I/O pin "pinno". Valid returns are:

MM.INFO\$(SDCARD)	“Invalid”, “Reserved”, “In Use”, and “Unused”
MM.INFO\$(TOUCH)	Returns status of SDCARD. Valid results are: “Not Present” if no SD Card and “Ready” if SD Card is inserted.
MM.HRES MM.VRES	Returns the status of the Touch controller. Valid returns are: “Disabled”, “Not calibrated”, and “Ready”
MM.HRES MM.VRES	Integers representing the horizontal and vertical resolution of the LCD display panel (if configured) in pixels.
MM.FONTHEIGHT MM.FONTWIDTH	Integers representing the height and width of the current font (in pixels).
MM.HPOS MM.VPOS	The current horizontal and vertical position (in pixels) following the last graphics or print command.
MM.WATCHDOG	An integer which is true if MMBasic was restarted as the result of a Watchdog timeout (see the WATCHDOG command). False if MMBasic started up normally.
MM.I2C	Following an I ² C write or read command this integer variable will be set to indicate the result of the operation as follows: 0 = The command completed without error. 1 = Received a NACK response 2 = Command timed out
MM.ONEWIRE	Following a 1-Wire reset function this integer variable will be set to indicate the result of the operation as follows: 0 = Device not found. 1 = Device found

Operators and Precedence

The following operators are listed in order of precedence. Operators that are on the same level (for example + and -) are processed with a left to right precedence as they occur on the program line.

Numeric Operators (Float or Integer)

NOT INV	NOT will invert the <u>logical</u> value on the right. INV will perform a <u>bitwise inversion</u> of the value on the right. Both of these have the highest precedence so if the value being operated on is an expression it should be surrounded by brackets. For example, <pre>IF NOT (A = 3 OR A = 8) THEN ...</pre>
^	Exponentiation (eg, b^n means b^n)
* / \ MOD	Multiplication, division, integer division and modulus (remainder)
+ -	Addition and subtraction
x << y x >> y	These operate in a special way. << means that the value returned will be the value of x shifted by y bits to the left while >> means the same only right shifted. They are integer functions and any bits shifted off are discarded. For a right shift any bits introduced are set to the value of the top bit (bit 63). For a left shift any bits introduced are set to zero.
<> < > <= =< >= =>	Inequality, less than, greater than, less than or equal to, less than or equal to (alternative version), greater than or equal to, greater than or equal to (alternative version)
=	Equality (also used in assignment to a variable, eg implied LET).
AND OR XOR	Conjunction, disjunction, exclusive or. These are bitwise operators and can be used on 64-bit unsigned integers.

The operators AND, OR and XOR are integer bitwise operators. For example PRINT (3 AND 6) will output 2.

The other logical operations result in the integer 0 (zero) for false and 1 for true. For example the statement PRINT 4 >= 5 will print the number zero on the output and the expression A = 3 > 2 will store +1 in A.

String Operators

+	Join two strings
<> < > <= =< >= =>	Inequality, less than, greater than, less than or equal to, less than or equal to (alternative version), greater than or equal to, greater than or equal to (alternative version).
=	Equality

String comparisons respect the case of the characters (ie "A" is greater than "a").

Option Settings

This table lists the various option commands which can be used to configure MMBasic and change the way it operates. Options that are marked as permanent will be saved in non volatile memory and automatically restored when the Armmite F4 is restarted. Options that are not permanent will be reset on startup.

	Permanent?	
OPTION AUTORUN OFF ON	✓	Instruct MMBasic to automatically run the program stored in flash when it starts up or is restarted by the WATCHDOG command. This is turned off by the NEW command but other commands that might change program memory (EDIT, etc) do not change this setting. Entering the break key (default CTRL-C) at the console will interrupt the running program and return to the command prompt despite this option.
OPTION BASE 0 1		Set the lowest value for array subscripts to either 0 or 1. This must be used before any arrays are declared and is reset to the default of 0 on power up.
OPTION BAUDRATE nbr	✓	Set the baud rate for the console to 'nbr'. This change is made immediately and will be remembered even when the power is cycled. The baud rate should be limited to the speeds listed in Appendix A for COM1. Using this command it is possible to set the console to an unworkable baud rate and in this case MMBasic should be reset as described in the chapter "Resetting MMBasic". This will reset the baud rate to the default of 38400.
OPTION BREAK nn		Set the value of the break key to the ASCII value 'nn'. This key is used to interrupt a running program. The value of the break key is set to CTRL-C key at power up but it can be changed to any keyboard key using this command (for example, OPTION BREAK 4 will set the break key to the CTRL-D key). Setting this option to zero will disable the break function entirely.
OPTION CASE UPPER LOWER TITLE		Change the case used for listing command and function names when using the LIST command. The default is TITLE but the old standard of MMBasic can be restored using OPTION CASE UPPER. This option will be remembered even when the power is removed.
OPTION COLOURCODE ON or OPTION COLOURCODE OFF		Turn on or off colour coding for the editor's output. Keywords will be in cyan, numbers in red, etc. The default is off. Notes: <ul style="list-style-type: none"> • This setting is saved in flash memory and is applied on startup. • Colour coding requires a terminal emulator that can interpret the appropriate escape codes. It works correctly with Tera Term however Putty needs its default background colour to be changed to white. • If colour coding is used it is recommended that the baud rate for the serial console be set to a high speed. • The keyword COLORCODE (USA spelling) can also be used.

<p>OPTION CONSOLE ECHO or OPTION CONSOLE NOECHO or OPTION CONSOLE INVERT or OPTION CONSOLE NOINVERT or OPTION CONSOLE AUTO</p>	<p>✓</p>	<p>Used to set options for the console serial port.</p> <p>NOECHO will turn off the echoing of characters received at the console. ECHO will re enable the echo. The default is ECHO at bootup and the option is reset to ECHO whenever the program returns to the command prompt. This option is useful when the console is used as a general purpose serial port.</p> <p>INVERT will invert the data polarity on both the console transmit and receive lines. This allows the console to be used with RS232 signals without a converter (see the chapter "Low Cost RS-232 Interface" in Appendix A). It also allows the use of a PICAXE style programming cable.</p> <p>NOINVERT will restore the console to its normal operation and is the default.</p> <p>AUTO will automatically invert the data polarity on the console depending on the signal level at power up (a low input means that the console will be inverted). This will automatically switch between TTL serial and RS232 serial input. Note that there is a 200ms startup delay when AUTO is used.</p> <p>This option will be remembered even when the power is removed.</p>
<p>OPTION DEFAULT FLOAT INTEGER STRING NONE</p>		<p>Used to set the default type for a variable which is not explicitly defined.</p> <p>If OPTION DEFAULT NONE is used then all variables must have their type explicitly defined.</p> <p>When a program is run the default is set to FLOAT for compatibility with previous versions of MMBasic.</p>
<p>OPTION DISPLAY lines [,chars]</p>	<p>✓</p>	<p>Set the characteristics of the display terminal used for the console. Both the LIST and EDIT commands need to know this information to correctly format the text for display.</p> <p>'lines' is the number of lines on the display and 'chars' is the width of the display in characters. The default is 24 lines x 80 chars and when changed this option will be remembered even when the power is removed.</p> <p>Note that the documentation for the VT100 ASCII Video Terminal initially listed incorrect specifications for the composite video. If you are using this project with the Micromite check the website http://geoffg.net/terminal.html for the correct specifications.</p>
<p>OPTION EXPLICIT</p>		<p>Placing this command at the start of a program will require that every variable be explicitly declared using the DIM command before it can be used in the program.</p> <p>This option is disabled by default when a program is run. If it is used it must be specified before any variables are used.</p>
<p>OPTION LIST</p>		<p>This will list the settings of any options that have been changed from their default setting and are the type that is saved in flash. This command is useful when configuring options that reserve I/O pins (ie, OPTION LCDPANEL or OPTION TOUCH) and you need to know what pins are in use.</p>

OPTION PIN nbr	✓	<p>Set 'nbr' as the PIN (Personal Identification Number) for access to the console prompt. 'nbr' can be any non zero number of up to eight digits. Whenever a running program tries to exit to the command prompt for whatever reason MMBasic will request this number before the prompt is presented. This is a security feature as without access to the command prompt an intruder cannot list or change the program in memory or modify the operation of MMBasic in any way. To disable this feature enter zero for the PIN number (ie, OPTION PIN 0).</p> <p>A permanent lock can be applied by using 99999999 for the PIN number.</p> <p>If a permanent lock is applied or the PIN number is lost the only way to recover is to reset MMBasic as described in the chapter "Resetting MMBasic" (this will also erase the program memory).</p>
OPTION RESET		<p>Reset all saved options (including the PIN) to the default values.</p> <p>Restores these two options on the Armmite F4 OPTION LCDPANEL ILI9341_16, RLANDSCAPE OPTION TOUCH PB12, PC5</p>
OPTION RTC CALIBRATE ±n	✓	<p>Used to calibrate the battery backed Real Time Clock that keeps time in the Armmite F4.</p> <p>'n' is a number between -511 and + 512. A change of ±1 should equate to about 0.0824 seconds per day. Negative numbers will slow the clock down, positive will speed it up (different from the Micromite).</p> <p>This setting is remembered even after a firmware upgrade.</p>
OPTION SAVE		<p>Used to save configuration options that are embedded in a program. See the section "Special Functions " for more details.</p>
OPTION TAB 2 4 8	✓	<p>Set the spacing for the tab key. Default is 2.</p> <p>This option will be remembered even when the power is removed.</p>
OPTION SERIAL CONSOLE OFF or OPTION SERIAL CONSOLE ON	✓	<p>Disable or enable the serial console. When the console is disabled the serial port can be opened as COM4:.</p> <p>This command can only be run from the command line and will cause a restart so if the command was issued via the USB console the connection will be lost and will need to be re-established. The new value will be remembered, even when the power is cycled or a new program loaded.</p> <p>Note that the other OPTION CONSOLE commands supported by the standard Micromite (OPTION CONSOLE INVERT, etc) are also recognised.</p>
OPTION CONTROLS nn	✓	<p>Set the maximum number of controls that can be created by a program to 'nn'. This can be any number from 1 to 1000. The default is 100. A larger number will use more RAM (each control entry uses about 50 bytes of RAM).</p> <p>This command can only be run from the command line and the new value will be remembered, even when the power is cycled or a new program loaded.</p>

OPTION KEYBOARD nn	✓	<p>Enable an attached PS2 keyboard and set its language type.</p> <p>'nn' is a two character code defining the keyboard layout. The choices are US for the standard keyboard layout in the USA, Australia and New Zealand, UK (United Kingdom), FR (French), GR (German), BE (Belgium), IT (Italian) or ES (Spanish). OPTION KEYBOARD DISABLE will disable the keyboard and return the I/O pins to normal use.</p> <p>See the section "<i>PS2 Keyboard</i>" for details of connecting the keyboard.</p> <p>This command can only be run from the command line and the new value will be remembered, even when the power is cycled or a new program loaded.</p>
OPTION LCDPANEL controller, orientation, D/C pin, reset pin [,CS pin] or OPTION LCDPANEL DISABLE	✓	<p>Configures the Armmite F4 to work with an SPI LCD panel.</p> <p>'controller' can be:</p> <ul style="list-style-type: none"> • ILI9481 SPI based 480*320 SPI touch controller • ILI9341 SPI based 2.2", 2.4" and 2.8" panels using the ILI9341 controller <p>'orientation' can be LANDSCAPE, PORTRAIT, RLANDSCAPE or RPORTRAIT. These can be abbreviated to L, P, RL or RP. The R prefix indicates the reverse or "upside down" orientation.</p> <p>SPI based panels:</p> <p>'C/D pin' and 'reset pin' are the Armmite I/O pins to be used for these functions. Any free pin can be used. 'CS pin' can also be any I/O pin but is optional. If a touch controller is not used this parameter can be left off the command and the CS pin on the LCD display wired permanently to ground. If the touch controller is used this pin must then be specified and connected to an Armmite pin.</p>
OPTION LCDPANEL controller, orientation or OPTION LCDPANEL DISABLE	✓	<p>Configures the Armmite F4 to work with an attached parallel 16 bit bus LCD panel.</p> <p>'controller' can be:</p> <ul style="list-style-type: none"> • ILI9341_P16 3.2" ILI9341 16bit parallel controller • SSD1963_4_16 4.3" panels using the SSD1963 controller • SSD1963_5_16 5" panels using the SSD1963 controller • SSD1963_5A_16 alternative version of the 5" panel • SSD1963_7_16 7" panels using the SSD1963 controller • SSD1963_7A_16 alternative version of the 7" panel • SSD1963_8_16 8" panels using the SSD1963 controller • OTM8009A_16 3.97" IPS 800*480 display. <p>'orientation' can be LANDSCAPE, PORTRAIT, RLANDSCAPE or RPORTRAIT. These can be abbreviated to L, P, RL or RP. The R prefix indicates the reverse or "upside down" orientation.</p> <p>The pins used are fixed and not available to MMBasic if not used</p> <p>For SSD1963 based panels:</p> <p>This command only needs to be run once as the parameters are stored in non volatile memory. When the Armmite is restarted the display will be automatically initialise ready for use. If the LCD panel is no longer required, the command OPTION LCDPANEL DISABLE can be used to disable the LCD panel.</p>
OPTION LCDPANEL CONSOLE [font [, fc [,bc	✓	<p>Configures the LCD display panel for use as the console output.</p> <p>The LCD can be any of the parallel supported LCD panels in the</p>

blight]]] or OPTION LCDPANEL NOCONSOLE		landscape or reverse landscape orientation and it must be first configured using OPTION LCDPANEL xxxxxx (above). 'font' is the default font, 'fc' is the default foreground colour, 'bc' is the default background colour and 'blight' is the default backlight brightness (2 to 100). These parameters are optional and default to font 2, white, black and 100%. These settings are applied at power up. Colour coding in the editor is also turned on by this command (OPTION COLOURCODE OFF will turn it off again). This setting is saved in flash and will be automatically applied on startup. To disable it use the OPTION LCDPANEL NOCONSOLE command.
OPTION MILLISECONDS OFF		Default. The time\$ function returns the time as “HH:MM:SS”
OPTION MILLISECONDS ON		The time\$ function returns the time as “HH:MM:SS.MMM”
OPTION SERIAL CONSOLE OFF	✓	Restores the console to the USB connection. Command would need to be given via the serial console connection.
OPTION SERIAL CONSOLE ON	✓	Redirects the console to the serial port located at J6 on the board. The console is no longer available on the USB connection
OPTION SERIAL PULLUP DISABLE	✓	permanently stored option that disables pullups on all serial ports
OPTION SERIAL PULLUP ENABLE	✓	default: permanently stored option that enables pullups on all serial ports
OPTION TOUCH T_CS pin, T_IRQ pin OPTION TOUCH PC5, PB12 or OPTION TOUCH DISABLE	✓	Configures the Armmite F4 to suit the touch sensitive feature of an attached LCD panel. 'T_CS pin' and 'T_IRQ pin' are hardwired and must be PB12 for T-IRQ and PC5 for T_CS. This command only needs to be run once as the parameters are stored in non volatile memory. Every time the Armmite is restarted MMBasic will automatically initialise the touch controller. If the touch facility is no longer required, the command OPTION TOUCH DISABLE can be used to disable the touch feature and return the I/O pins for general use.
OPTION VCC voltage		Specifies the voltage (Vcc) supplied to the STM32 chip. When using the analog inputs to measure voltage the STM32 chip uses its supply voltage (Vcc) as its reference. This voltage can be accurately measured using a DMM and configured using this command to allow for a more accurate measurement. The parameter is not saved and should be initialised either on the command line or in a program. The default if not set is 3.3.

Commands

Square brackets indicate that the parameter or characters are optional.

` (single quotation mark)	Starts a comment and any text following it will be ignored. Comments can be placed anywhere on a line.
? (question mark)	Shortcut for the PRINT command.
<p>ADC</p> <p>ADC OPEN frequency, channel1-pin [,channel2-pin] [,channel3-pin] [, interrupt]</p> <p>ADC FREQUENCY frequency</p> <p>ADC TRIGGER channel, level</p> <p>ADC START channel1array!() [,channel2array!()] [,channel3array!()]</p> <p>ADC CLOSE</p>	<p>The ADC functionality can capture up to 3 channels of analog data in the background at up to 500KHz per channel (480KHz for 400MHz processors) with user selectable triggering</p> <p>Open the ADC channels. "frequency" is the sampling frequency in Hz. Above 320KHz the conversion is 8-bits per channel Above 160KHz to 320KHz the conversion is 10-bits per channel From 160KHz and below the conversion is 12-bits per channel</p> <p>This is automatically applied in the firmware. 'channel1-pin' can be one of PC0, PC3 ,PA0,PA1, PA2, PA6, PA7, PB0 'channel2-pin' must be PC2 'channel3-pin' can be one of PC1, PC4, PC5 'interrupt' is a normal MMBasic subroutine that will be called when the conversion completes.</p> <p>Allows the ADC frequency to be adjusted after the ADC START command. This command is only valid if the number of bits calculated in the table above does not change.</p> <p>Sets up triggering of the ADC. This should be specified before the ADC START command. The 'channel' can be a number between one and three depending on the number of pins specified in the ADC OPEN command. The 'level' can be between -VCC and VCC. A positive number indicates that the trigger will be on a positive going transition through the specified voltage. A negative number indicates a negative going transition through the specified voltage.</p> <p>Starts ADC conversion. The floating point arrays must be the same size and their size will determine the number of samples. Once the start command is issued the ADC(s) will start converting the input signals into the arrays at the frequency specified. If the OPEN command includes an interrupt, then the command will be non-blocking. If an interrupt is not specified, the command will be blocking and wait for the array is filled. The samples are returned as floating point values between 0 and VCC.</p> <p>Closes the ADC and returns the pins to normal use</p>
ARC x, y, r1, [r2], rad1, rad2, colour	<p>Draws an arc of a circle or a given colour and width between two radials (defined in degrees). Parameters for the ARC command are: 'x' is the X coordinate of the centre of arc.</p>

	<p>'y' is the Y coordinate of the centre of arc. 'r1' is the inner radius of the arc. 'r2' is the outer radius of the arc - can be omitted if 1 pixel wide. 'rad1' is the start radial of the arc in degrees. 'rad2' is the end radial of the arc in degrees. 'colour' is the colour of the arc.</p>
<p>AUTOSAVE or AUTOSAVE CRUNCH</p>	<p>Enter automatic program entry mode.</p> <p>This command will take lines of text from the console serial input and save them to memory. This mode is terminated by entering Control-Z which will then cause the received data to be saved into program memory overwriting the previous program.</p> <p>The CRUNCH option instructs MMBasic to remove all comments, blank lines and unnecessary spaces from the program before saving. This can be used on large programs to allow them to fit into limited memory. CRUNCH can be abbreviated to the single letter C.</p> <p>At any time, this command can be aborted by Control-C which will leave program memory untouched.</p> <p>This is one way of transferring a BASIC program into the Armmite. The program to be transferred can be pasted into a terminal emulator and this command will capture the text stream and store it into program memory. It can also be used for entering a small program directly at the console input.</p>
<p>BACKLIGHT percentage%</p>	<p>Sets to intensity of the backlight on LCD Display by either sending a command to the SSD1963 panels or changing the PWM signal to the BL pin on the other LCD Displays</p> <p>0 is off, 100 is full intensity. A value somewhere between can be used to minimise power drawn while still giving a readable display.</p>
<p>BEZIER xs, ys, xc1, yc1, xc2, yc2, xe, ye, colour</p>	<p>Draws a cubic Bezier curve by specifying the start and end points and two control points. Parameters for the BEZIER command are:</p> <p>xs: X coordinate of start point ys: Y coordinate of start point xc1: X coordinate of first control point yc1: Y coordinate of first control point xc2: X coordinate of second control point yc2: Y coordinate of second control point xe: X coordinate of end point ye: Y coordinate of end point colour: Colour of curve</p>
<p>BLIT READ [#]b, x, y, w, h [,pagenumber] or BLIT WRITE [#]b, x, y or BLIT CLOSE [#]b</p>	<p>Copy one section of the display screen to or from a memory buffer.</p> <p>BLIT READ will copy a portion of the display to the memory buffer '#b'. The source coordinate is 'x' and 'y' and the width of the display area to copy is 'w' and the height is 'h'. When this command is used the memory buffer is automatically created and sufficient memory allocated. The optional parameter page number specifies which page is to be read. The default is the current write page. This buffer can be freed and the memory recovered with the BLIT CLOSE command. Set the pagenumber to FRAMEBUFFER to read from the framebuffer – see the FRAMEBUFFER command</p> <p>BLIT WRITE will copy the memory buffer '#b' to the display. The destination coordinate is 'x' and 'y' using the width/height of the buffer.</p>

	<p>BLIT CLOSE will close the memory buffer '#b' to allow it to be used for another BLIT READ operation and recover the memory used.</p> <p>Notes:</p> <ul style="list-style-type: none"> • Sixty four buffers are available ranging from #1 to #64. • When specifying the buffer number the # symbol is optional. • All other arguments are in pixels.
BLIT x1, y1, x2, y2, w, h	<p>Copy one section of the display screen to another part of the display. The source coordinate is 'x1' and 'y1'. The destination coordinate is 'x2' and 'y2'. The width of the screen area to copy is 'w' and the height is 'h'. All arguments are in pixels and the source and destination can overlap.</p>
BOX x, y, w, h [,lw] [,c] [,fill]	<p>Draws a box on the LCD display with the top left hand corner at 'x' and 'y' with a width of 'w' pixels and a height of 'h' pixels.</p> <p>'lw' is the width of the sides of the box and can be zero. It defaults to 1.</p> <p>'c' is the colour and defaults to the default foreground colour if not specified.</p> <p>'fill' is the fill colour. It can be omitted or set to -1 in which case the box will not be filled.</p> <p>All parameters can be expressed as arrays and the software will plot the number of boxes as determined by the dimensions of the smallest array. 'x', 'y', 'w', and 'h' must all be arrays or all be single variables /constants otherwise an error will be generated. 'lw', 'c', and fill can be either arrays or single variables/constants.</p> <p>See the chapter "Basic Drawing Commands" for a definition of the colours and graphics coordinates.</p>
CAT string1\$, string2\$	<p>A synonym for the INC command to make use with strings more obvious e.g. CAT string1\$, string2\$ appends string2\$ to string1\$</p>
CHDIR dir\$	<p>Change the current working directory on the SD card to 'dir\$'</p> <p>The special entry ".." represents the parent of the current directory and "." represents the current directory. "/" is the root directory.</p>
CIRCLE x, y, r [,lw] [,a] [,c] [, fill]	<p>Draw a circle on the video output centred at 'x' and 'y' with a radius of 'r' on the LCD display. 'lw' is optional and is the line width (defaults to 1). 'c' is the optional colour and defaults to the current foreground colour if not specified.</p> <p>The optional 'a' is a floating point number which will define the aspect ratio. If the aspect is not specified the default is 1.0 which gives a standard circle</p> <p>'fill' is the fill colour. It can be omitted or set to -1 in which case the circle will not be filled.</p> <p>All parameters can be expressed as arrays and the software will plot the number of circles as determined by the dimensions of the smallest array. 'x', 'y' and 'r' must all be arrays or all be single variables /constants otherwise an error will be generated. 'lw', 'a', 'c', and fill can be either arrays or single variables/constants.</p> <p>See the chapter "Basic Drawing Commands" for a definition of the colours and graphics coordinates.</p>

CLEAR	Delete all variables and recover the memory used by them.
CLOSE [#]nbr [, [#]nbr] ...	<p>Close the file(s) previously opened with the file number '#fnbr'</p> <p>Close the serial communications port(s) previously opened with the file number 'nbr'. The # is optional. Also see the OPEN command.</p> <p>The text "GPS" can be substituted for [#]nbr to close a communications port used for a GPS receiver.</p>
CLS [colour]	Clears the LCDPANEL. Optionally 'colour' can be specified which will be used for the background when clearing the screen.
COLOUR fore [, back] or COLOR fore [, back]	<p>Sets the default colour for commands (TEXT etc) that display on the on the LCDPANEL and accept a background or foreground colour parameter..</p> <p>'fore' is the foreground colour, 'back' is the background colour. The background is optional and if not specified will default to black.</p>
CONST id = expression [, id = expression] ... etc	<p>Create a constant identifier which cannot be changed once created.</p> <p>'id' is the identifier which follows the same rules as for variables. The identifier can have a type suffix (!, %, or \$) but it is not required. If it is specified it must match the type of 'expression'. 'expression' is the value of the identifier and it can be a normal expression (including user defined functions) which will be evaluated when the constant is created.</p> <p>A constant defined outside a sub or function is global and can be seen throughout the program. A constant defined inside a sub or function is local to that routine and will hide a global constant with the same name.</p>
CONTINUE	<p>Resume running a program that has been stopped by an END statement, an error, or CTRL-C. The program will restart with the next statement following the previous stopping point.</p> <p>Note that it is not always possible to resume the program correctly – this particularly applies to complex programs with graphics, nested loops and/or nested subroutines and functions.</p>
CONTINUE DO or CONTINUE FOR	Skip to the end of a DO/LOOP or a FOR/NEXT loop. The loop condition will then be tested and if still valid the loop will continue with the next iteration.
CPU RESTART	<p>Will force a restart of the processor.</p> <p>This will clear all variables and reset everything (eg, timers, COM ports, I²C, etc) similar to a power up situation but without the power up banner.</p> <p>If OPTION AUTORUN has been set the program will restart.</p>
CPU SLEEP	The CPU sleeps until there is a signal on the wakeup pin. Pin PA0 is the wakeup pin, however any other COUNT pin can also be used to wake the processor if it is enabled with SETPIN pinno, CIN or PIN or FIN.
CPU SLEEP time	The Armmite uses the RTC to generate an interrupt to wake the processor after a period of sleep. Any period can be specified including fractions of seconds and because the RTC is used the timing will be accurate. Using the

	<p>embedded ARMMITE F4 date and time functions makes it easy to sleep until any particular time. e.g.</p> <p><i>Midnight_tonight% = epoch(date\$+ " 00:00:00")+86400 'epoch at start of day today + secs in a day</i></p> <p><i>CPU SLEEP Midnight_tonight% - epoch(now) 'sleep until midnight tonight</i></p>
<p>CSUB name [type [, type] ...] hex [[hex[...] hex [[hex[...] END CSUB</p>	<p>Defines the binary code for an embedded machine code program module written in C or ARM assembler. The module will appear in MMBasic as the command 'name' and can be used in the same manner as a built-in command. Multiple embedded routines can be used in a program with each defining a different module with a different 'name'.</p> <p>The first 'hex' word must be the offset (in 32-bit words) to the entry point of the embedded routine (usually the function main()). The following hex words are the compiled binary code for the module. These are automatically programmed into MMBasic when the program is saved. Each 'hex' must be exactly eight hex digits representing the bits in a 32-bit word and be separated by one or more spaces or new lines. The command must be terminated by a matching END CSUB. Any errors in the data format will be reported when the program is loaded into flash by the RUN command. During execution MMBasic will skip over any CSUB commands so they can be placed anywhere in the program.</p> <p>The type of each parameter can be specified in the definition. For example: CSub MySub integer, integer, string. This specifies that there will be three parameters, the first two being integers and the third a string.</p> <p>Note:</p> <ul style="list-style-type: none"> • Up to ten arguments can be specified ('arg1', 'arg2', etc). • If a variable or array is specified as an argument the C routine will receive a pointer to the memory allocated to the variable or array and the C routine can change this memory to return a value to the caller. In the case of arrays, they should be passed with empty brackets e.g. arg(). In the CSUB the argument will be supplied as a pointer to the first element of the array. • Constants and expressions will be passed to the embedded C routine as pointers to a temporary memory space holding the value.
<p>CTRLVAL(#ref) =</p>	<p>This command will set the value of an advanced control.</p> <p>'#ref' is the control's reference number.</p> <p>For off/on controls like check boxes it will override any touch input and can be used to depress/release switches, tick/untick check boxes, etc. A value of zero is off or unchecked and non zero will turn the control on. For a LED it will cause the LED to be illuminated or turned off. It can also be used to set the initial value of spin boxes, text boxes, etc.</p> <p>For example:</p> <p style="text-align: center;">CTRLVAL(#10) = 12.4</p>

<p>DAC n, voltage</p> <p>DAC START frequency, DAC1array%() [,DAC2array%()]</p> <p>DAC STOP</p>	<p>Sets the DAC channel (1 or 2) to the voltage requested. This command cannot be used if the DACs are in use for audio output.</p> <p>Sets up the DAC to create an arbitrary waveform. DAC1array%() and optional DAC2array%() should contain numbers in the range 0-4095 to suit the 12-bit DACs.</p> <p>Once started the output continues in the background and control returns to MMBasic.</p> <p>The software automatically and separately uses the number of items in each of the arrays to drive the DACs.</p> <p>The frequency is the rate at which the DACs change value. The maximum frequency is 700KHz.</p> <p>As an example if there are 180 items in the array c%() which are displayed at a frequency of 100,000 Hz this will give a waveform frequency of $100,000/180 = 555\text{Hz}$. If there are 90 items in the array d%() at the same frequency of 100,000 Hz this will at the same time produce a waveform frequency of $100,000/90 = 1111\text{Hz}$.</p> <p>Stops the DAC output and returns the DACs to normal use.</p>
<p>DATA constant[,constant]...</p>	<p>Stores numerical and string constants to be accessed by READ.</p> <p>In general string constants should be surrounded by double quotes ("). An exception is when the string consists of just alphanumeric characters that do not represent MMBasic keywords (such as THEN, WHILE, etc). In that case quotes are not needed.</p> <p>Numerical constants can also be expressions such as $5 * 60$.</p>
<p>DATE\$ = "DD-MM-YY" or DATE\$ = "DD/MM/YY"</p>	<p>Set the date of the internal clock/calendar.</p> <p>DD, MM and YY are numbers, for example: DATE\$ = "28-7-2024" The year can be abbreviated to two digits (ie, 24).</p> <p>The date is set to "01-01-2000" on first power up but the date will be remembered and kept updated as long as the battery is installed and can maintain a voltage of over 2.5V. The firmware looks for a date > 2018 before it allows the clock to run without reset on restart. Otherwise the firmware can't know that the clock has been properly initialised.</p>
<p>DEFINEFONT #n hex [[hex[...] hex [[hex[...] END DEFINEFONT</p>	<p>This will define an embedded font which can be used exactly same as the built in fonts (ie, selected using the FONT command or specified in the TEXT command).</p> <p>MMBasic must execute the font in order for it to be loaded. '#n' is the font's reference number (1 to 16). It can be the same as an existing font (except fonts 1, 6 and 7) and in that case it will replace that font.</p> <p>Each 'hex' must be exactly eight hex digits and be separated by spaces or new lines from the next. Multiple lines of 'hex' words can be used with the command terminated by a matching END DEFINEFONT.</p>
<p>DIM [type] decl [,decl]... where 'decl' is: var [length] [type] [init] 'var' is a variable name with</p>	<p>Declares one or more variables (ie, makes the variable name and its characteristics known to the interpreter).</p> <p>When OPTION EXPLICIT is used (as recommended) the DIM, LOCAL or STATIC commands are the only way that a variable can be created. If this option is not used then using the DIM command is optional and if not used</p>

optional dimensions
 'length' is used to set the maximum size of the string to 'n' as in LENGTH n
 'type' is one of FLOAT or INTEGER or STRING (the type can be prefixed by the keyword AS - as in AS FLOAT)
 'init' is the value to initialise the variable and consists of:
 = <expression>
 For a simple variable one expression is used, for an array a list of comma separated expressions surrounded by brackets is used.

Examples:

```
DIM nbr(50)
DIM INTEGER nbr(50)
DIM name AS STRING
DIM a, b$, nbr(100), strn$(20)
DIM a(5,5,5), b(1000)
DIM strn$(200) LENGTH 20
DIM STRING strn(200)
    LENGTH 20
DIM a = 1234, b = 345
DIM STRING strn = "text"
DIM x%(3) = (11, 22, 33, 44)
```

the variable will be created automatically when first referenced.
 The type of the variable (ie, string, float or integer) can be specified in one of three ways:

By using a type suffix (ie, !, % or \$ for float, integer or string). For example:

```
DIM nbr%, amount!, name$
```

By using one of the keywords FLOAT, INTEGER or STRING immediately after the command DIM and before the variable(s) are listed. The specified type then applies to all variables listed (ie, it does not have to be repeated). For example:

```
DIM STRING first_name, last_name, city
```

By using the Microsoft convention of using the keyword "AS" and the type keyword (ie, FLOAT, INTEGER or STRING) after each variable. If you use this method the type must be specified for each variable and can be changed from variable to variable. For example:

```
DIM amount AS FLOAT, name AS STRING
```

Floating point or integer variables will be set to zero when created and strings will be set to an empty string (ie, ""). You can initialise the value of the variable with something different by using an equals symbol (=) and an expression following the variable definition. For example:

```
DIM STRING city = "Perth", house = "Brick"
```

The initialising value can be an expression (including other variables) and will be evaluated when the DIM command is executed. See the chapter "Defining and Using Variables" for more examples of the syntax.

As well as declaring simple variables the DIM command will also declare arrayed variables (ie, an indexed variable with up to five dimensions). Note that this is different from the original Colour Maximize and Micromite versions of MMBasic which supported up to eight dimensions.

Following the variable's name the dimensions are specified by a list of numbers separated by commas and enclosed in brackets. For example:

```
DIM array(10, 20)
```

Each number specifies the number of elements in each dimension. Normally the numbering of each dimension starts at 0 but the OPTION BASE command can be used to change this to 1.

The above example specifies a two dimensional array with 11 elements (0 to 10) in the first dimension and 21 (0 to 20) in the second dimension. The total number of elements is 231 and because each floating point number on the Armmite F4 requires 8 bytes a total of 1848 bytes of memory will be allocated.

Strings will default to allocating 255 bytes (ie, characters) of memory for each element and this can quickly use up memory when defining arrays of strings. In that case the LENGTH keyword can be used to specify the amount of memory to be allocated to each element and therefore the maximum length of the string that can be stored. This allocation ('n') can be from 1 to 255 characters.

For example: DIM STRING s(5, 10) will declare a string array with 66 elements consuming 16,896 bytes of memory while:

```
DIM STRING s(5, 10) LENGTH 20
```

Will only consume 1,386 bytes of memory. Note that the amount of memory allocated for each element is n + 1 as the extra byte is used to track the actual length of the string stored in each element.

If a string longer than 'n' is assigned to an element of the array an error will be produced. Other than this, string arrays created with the LENGTH

	<p>keyword act exactly the same as other string arrays. This keyword can also be used with non array string variables but it will not save any memory.</p> <p>In the above example you can also use the Microsoft syntax of specifying the type <u>after</u> the length qualifier. For example:</p> <pre>DIM s(5, 10) LENGTH 20 AS STRING</pre> <p>Arrays can also be initialised when they are declared by adding an equals symbol (=) followed by a bracketed list of values at the end of the declaration. For example:</p> <pre>DIM INTEGER nbr(4) = (22, 44, 55, 66, 88)</pre> <p>or</p> <pre>DIM s\$(3) = ("foo", "boo", "doo", "zoo")</pre> <p>Note that the number of initialising values must match the number of elements in the array including the base value set by OPTION BASE. If a multi dimensioned array is initialised then the first dimension will be initialised first followed by the second, etc.</p> <p>Also note that the initialising values must be after the LENGTH qualifier (if used) and after the type declaration (if used).</p>
DO <statements> LOOP	This structure will loop forever; the EXIT DO command can be used to terminate the loop or control must be explicitly transferred outside of the loop by commands like GOTO or EXIT SUB (if in a subroutine).
DO WHILE expression <statements> LOOP	Loops while "expression" is true (this is equivalent to the older WHILE-WEND loop, also implemented in MMBasic). If, at the start, the expression is false the statements in the loop will not be executed, not even once.
DO <statements> LOOP UNTIL expression	Loops until the expression following UNTIL is true. Because the test is made at the end of the loop the statements inside the loop will be executed at least once, even if the expression is true.
EDIT	Invoke the full screen editor. See the section <i>Full Screen Editor</i> for details of how to use the editor.
ELSE	Introduces a default condition in a multiline IF statement. See the multiline IF statement for more details.
ELSEIF expression THEN or ELSE IF expression THEN	Introduces a secondary condition in a multiline IF statement. See the multiline IF statement for more details.
END	End the running program and return to the command prompt.
END FUNCTION	Marks the end of a user defined function. See the FUNCTION command. Each function must have one and only one matching END FUNCTION statement. Use EXIT FUNCTION if you need to return from a function from within its body.
ENDIF or END IF	Terminates a multiline IF statement. See the multiline IF statement for more details.
END SELECT	Marks the end of a SELECT CASE construction . see SELECT CASE

END SUB	Marks the end of a user defined subroutine. See the SUB command. Each sub must have one and only one matching END SUB statement. Use EXIT SUB if you need to return from a subroutine from within its body.
ENDIF	
ERASE variable [,variable]...	Deletes variables and frees up the memory allocated to them. This will work with arrayed variables and normal (non array) variables. Arrays can be specified using empty brackets (eg, dat ()) or just by specifying the variable's name (eg, dat). Use CLEAR to delete all variables at the same time (including arrays).
ERROR [error_msg\$]	Forces an error and terminates the program. This is normally used in debugging or to trap events that should not occur.
EXIT DO EXIT FOR EXIT FUNCTION EXIT SUB	EXIT DO provides an early exit from a DO...LOOP EXIT FOR provides an early exit from a FOR...NEXT loop. EXIT FUNCTION provides an early exit from a defined function. EXIT SUB provides an early exit from a defined subroutine. The old standard of EXIT on its own (exit a do loop) is also supported.
FTT	Now is part of the MATH command. See the MATH command
FILES [fspec\$]	Lists files in the current directory on the SD card. 'fspec\$' (if specified) can contain search wildcards. Question marks (?) will match any character and an asterisk (*) will match any number of characters. If omitted, all files will be listed. For example: <ul style="list-style-type: none"> *.* Find all entries *.TXT Find all entries with an extension of TXT E*.* Find all entries starting with E X?X.* Find all three letter file names starting and ending with X
FONT [#]font-number, scaling	This will set the default font for displaying text on the LCDPANEL. Fonts are specified as a number. For example, #2 (the # is optional) See the chapter "Basic Graphics" for details of the available fonts. 'scaling' can range from 1 to 15 and will multiply the size of the pixels making the displayed character correspondingly wider and higher. Eg, a scale of 2 will double the height and width.
FOR counter = start TO finish [STEP increment]	Initiates a FOR-NEXT loop with the 'counter' initially set to 'start' and incrementing in 'increment' steps (default is 1) until 'counter' is greater than 'finish'. The 'increment' can be an integer or floating point number. Note that using a floating point fractional number for 'increment' can accumulate rounding errors in 'counter' which could cause the loop to terminate early or late. 'increment' can be negative in which case 'finish' should be less than 'start' and the loop will count downwards.

	See also the NEXT command.
<pre> FUNCTION xxx (arg1 [,arg2, ...]) [AS <type>} <statements> <statements> xxx = <return value> END FUNCTION </pre>	<p>Defines a callable function. This is the same as adding a new function to MMBasic while it is running your program.</p> <p>'xxx' is the function name and it must meet the specifications for naming a variable. The type of the function can be specified by using a type suffix (ie, xxx\$) or by specifying the type using AS <type> at the end of the functions definition. For example:</p> <pre> FUNCTION xxx (arg1, arg2) AS STRING </pre> <p>'arg1', 'arg2', etc are the arguments or parameters to the function (the brackets are always required, even if there are no arguments). An array is specified by using empty brackets. ie, arg3(). The type of the argument can be specified by using a type suffix (ie, arg1\$) or by specifying the type using AS <type> (ie, arg1 AS STRING).</p> <p>The argument can also be another defined function or the same function if recursion is to be used (the recursion stack is limited to 50 nested calls).</p> <p>To set the return value of the function you assign the value to the function's name. For example:</p> <pre> FUNCTION SQUARE (a) SQUARE = a * a END FUNCTION </pre> <p>Every definition must have one END FUNCTION statement. When this is reached the function will return its value to the expression from which it was called. The command EXIT FUNCTION can be used for an early exit.</p> <p>You use the function by using its name and arguments in a program just as you would a normal MMBasic function.</p> <p>For example:</p> <pre> PRINT SQUARE (56.8) </pre> <p>When the function is called each argument in the caller is matched to the argument in the function definition. These arguments are available only inside the function.</p> <p>Functions can be called with a variable number of arguments. Any omitted arguments in the function's list will be set to zero or a null string.</p> <p>Arguments in the caller's list that are a variable (ie, not an expression or constant) will be passed by reference to the function. This means that any changes to the corresponding argument in the function will also be copied to the caller's variable. Arrays are passed by specifying the array name with empty brackets (eg, arg()) and are always passed by reference.</p> <p>You must not jump into or out of a function using commands like GOTO, GOSUB, etc. Doing so will have undefined side effects including the possibility of ruining your day.</p>
GOSUB	See <i>Obsolete Commands and Functions</i> section.
GOTO target	See <i>Obsolete Commands and Functions</i> section. Branches program execution to the target, which can be a line number or a label.
<pre> GUI BITMAP x, y, bits [, width] [, height] [, scale] [, c] [, bc] </pre>	<p>Displays the bits in a bitmap on an LCD panel starting at 'x' and 'y' on an attached LCD panel.</p> <p>'height' and 'width' are the dimensions of the bitmap as displayed on the LCD</p>

	<p>panel and default to 8x8.</p> <p>'scale' is optional and defaults to that set by the FONT command.</p> <p>'c' is the drawing colour and 'bc' is the background colour. They are optional and default to the current foreground and background colours.</p> <p>The bitmap ('bits') can be an integer or a string variable or constant and is drawn using the first byte as the first bits of the top line (bit 7 first, then bit 6, etc) followed by the next byte, etc. When the top line has been filled the next line of the displayed bitmap will start with the next bit in the integer or string.</p> <p>See the chapter "Basic Drawing Commands" for a definition of the colours and graphics coordinates.</p>
<p>GUI CALIBRATE</p> <p>Or</p> <p>GUI CALIBRATE c1,c2,c3,c4,c5</p>	<p>This command is used to calibrate the touch feature on an LCD panel. It will display a series of targets on the screen and wait for each one to be precisely touched.</p> <p>The second version allows the calibration parameters to be entered directly without having to go through the manual calibration process. The parameters 'c1', 'c2', etc can be found by running a normal calibration process then using OPTION LIST which will list the parameters for that LCD panel. This is useful when the command is embedded in a program.</p>
<p>GUI RESET LCDPANEL</p>	<p>Will reinitialise the configured LCD panel. Initialisation is automatically done when the Micromite starts up but in some circumstances it may be necessary to interrupt power to the LCD panel (eg, to save battery power) and this command can then be used to reinitialise the display.</p>
<p>GUI AREA #ref, startX, startY, width, height</p>	<p>This will define an invisible area of the screen that is sensitive to touch and will generate touch down and touch up interrupts. It can be used as the basis for creating custom controls which are defined and managed by the program.</p> <p>'#ref' is the control's reference number. 'startX' and 'startY' are the top left coordinates while 'width' and 'height' set the dimensions.</p>
<p>GUI BCOLOUR colour, #ref1 [, #ref2, #ref3, etc]</p>	<p>This will change the background colour of the specified controls to 'colour' which is an RGB value for the drawing colour.</p> <p>'#ref' is the control's reference number.</p>
<p>GUI BEEP msec</p>	<p>This will sound the pizeo buzzer if configured with the OPTION TOUCH command.</p> <p>'msec' is the number of milliseconds that the buzzer should be driven. A time of 3ms produces a click while 100ms produces a short beep.</p>

<p>GUI BARGAUGE #ref, StartX, StartY, width, height, FColour, BColour, min, max, c1, ta, c2, tb, c3, tc, c4</p>	<p>Define either a horizontal or vertical analogue bar gauge.</p> <p>'#ref' is the control's reference number.</p> <p>'StartX' and 'StartY' are the top left coordinates of the bar while 'width' is the horizontal width and 'height' the vertical height. If the width is less than the height the bar gauge will be drawn vertically with the graph growing from the bottom towards the top. Otherwise it will be drawn horizontally with the graph growing from the left towards the right.</p> <p>'Fcolour' is the colour used for the gauge while 'Bcolour' is the background colour. 'min' is the minimum value of the gauge and 'max' is the maximum value (both floating point).</p> <p>A multi colour gauge can be created using 'c1' to 'c4' for the colours and 'ta' to 'tc' for the thresholds used to determine when the colour will change.</p> <p>'width', 'height', 'FColour', 'BColour', 'min' and 'max' are optional and will default to the values used in the previous definition of a GUI BARGAUGE.</p> <p>'c1', 'ta', 'c2', 'tb', 'c3', 'tc' and 'c4' are optional and if not specified the gauge will use less colours. If all are omitted the gauge will be drawn using 'Fcolour'.</p> <p>The section <i>Advanced Graphics</i> has a more detailed description.</p>
<p>GUI BUTTON #ref, caption\$, startX, startY, width, height [, FColour] [,BColour]</p>	<p>This will draw a momentary button which is a square switch with the caption on its face.</p> <p>When touched the visual image of the button will appear to be depressed and the control's value will be 1. When the touch is removed the value will revert to zero.</p> <p>#ref' is the control's reference (a number from 1 to 100).</p> <p>'caption\$' is the string to display on the face of the button. It can be a single string with two captions separated by a character (eg, "UP DOWN"). When the button is up the first string will be used and when pressed the second will be used.</p> <p>'startX' and 'startY' are the top left coordinates while 'width' and 'height' set the dimensions. 'FColour' and 'BColour' are RGB values for the foreground and background colours.</p> <p>'width', 'height', FColour and 'BColour' are optional and default to that used in previous controls or set with the COLOUR command.</p>
<p>GUI CAPTION #ref, text\$, startX, startY [,align\$] [, FColour] [, BColour]</p>	<p>This will draw a text string on the screen.</p> <p>'#ref' is the control's reference number.</p> <p>'text\$' is the string to display. 'startX' and 'startY' are the top left coordinates.</p> <p>'align\$' is zero to three characters (a string expression or variable is also allowed) where the first letter is the horizontal alignment around X and can be L, C or R for LEFT, CENTER, RIGHT and the second letter is the vertical alignment around Y and can be T, M or B for TOP, MIDDLE, BOTTOM. A third character can be used in the string to indicate the rotation of the text. This can be 'N' for normal orientation, 'V' for vertical text with each character under the previous running from top to bottom, 'I' the text will be inverted (ie, upside down), 'U' the text will be rotated counter clockwise by 90° and 'D' the text will be rotated clockwise by 90°. The default alignment is left/top with no rotation.</p> <p>'FColour' and 'BColour' are RGB values for the foreground and background colours. On a display that supports transparent text BColour can be -1 which</p>

	<p>means that the background will show through the gaps in the characters.</p> <p>FColour and 'BColour' are optional and default to the colours set by the COLOUR command.</p>
<p>GUI CHECKBOX #ref, caption\$, startX, startY [, size] [, colour]</p>	<p>This will draw a check box which is a small box with a caption. When touched an X will be drawn inside the box to indicate that this option has been selected and the control's value will be set to 1. When touched a second time the check mark will be removed and the control's value will be zero.</p> <p>'#ref' is the control's reference number.</p> <p>The string 'caption\$' will be drawn to the right of the control using the colours set by the COLOUR command.</p> <p>'startX' and 'startY' are the top left coordinates while 'size' set the height and width (the box is square). 'colour' is an RGB value for the drawing colour. 'size' and 'colour' are optional and default to that used in previous controls.</p>
<p>GUI DELETE #ref1 [,#ref2, #ref3, etc] or GUI DELETE ALL</p>	<p>This will delete the controls in the list. This includes removing the image of the control from the screen using the current background colour and freeing the memory used by the control.</p> <p>'#ref' is the control's reference number. The keyword ALL can be used as the argument and that will disable all controls.</p>
<p>GUI DISABLE #ref1 [,#ref2, #ref3, etc] or GUI DISABLE ALL</p>	<p>This will disable the controls in the list. Disabled controls do not respond to touch and will be displayed dimmed.</p> <p>'#ref' is the control's reference number. The keyword ALL can be used as the argument and that will disable all controls.</p> <p>GUI ENABLE can be used to restore the controls.</p>
<p>GUI DISPLAYBOX #ref, startX, startY, width, height, FColour, BColour</p>	<p>This will draw a box with rounded corners that can be used to display a string</p> <p>'#ref' is the control's reference number.</p> <p>'startX' and 'startY' are the top left coordinates while 'width' and 'height' set the dimensions. 'FColour' and 'BColour' are RGB values for the foreground and background colours. 'width', 'height', 'FColour' and 'BColour' are optional and default to that used in previous controls.</p> <p>Any text can be displayed in the box by using the CtrlVal(r) = command. This is useful for displaying text, numbers and messages.</p> <p>This control does not respond to touch.</p>
<p>GUI ENABLE #ref1 [,#ref2, #ref3, etc] or GUI ENABLE ALL</p>	<p>This will undo the effects of GUI DISABLE and restore the control(s) to normal operation.</p> <p>'#ref' is the control's reference number. The keyword ALL can be used as the argument and that will disable all controls.</p>
<p>GUI FCOLOUR colour, #ref1 [, #ref2, #ref3, etc]</p>	<p>This will change the foreground colour of the specified controls to 'colour' which is an RGB value for the drawing colour.</p> <p>'#ref' is the control's reference number.</p>

<p>GUI FRAME #ref, caption\$, startX, startY, width, height, colour</p>	<p>This will draw a frame which is a box with round corners and a caption.</p> <p>#ref' is the control's reference number.</p> <p>'caption\$' is a string to display as the caption. 'startX' and 'startY' are the top left coordinates while 'width' and 'height' set the dimensions. 'colour' is an RGB value for the drawing colour. 'width', 'height' and 'colour' are optional and default to that used in previous controls.</p> <p>A frame is useful when a group of controls need to be visually brought together. It is also used to surround a group of radio buttons and MMBasic will arrange for the radio buttons surrounded by the frame to be exclusive. ie, when one radio button is selected any other button that was selected and within the frame will be automatically deselected.</p> <p>A frame does not respond to touch.</p>
<p>GUI FORMATBOX #ref, Format, startX, startY, width, height, FColour, BColour</p>	<p>This will draw a box with rounded corners that can be used to create a virtual keypad for entry of data using a specific format.</p> <p>#ref' is the control's reference number.</p> <p>'startX' and 'startY' are the top left coordinates while 'width' and 'height' set the dimensions. 'FColour' and 'BColour' are RGB values for the foreground and background colours. 'width', 'height', 'FColour' and 'BColour' are optional and default to that used in previous controls.</p> <p>The 'Format' argument specifies the format of the entry as follows:</p> <p>DATE1 Date in UK/Aust/NZ format (dd/mm/yy) DATE2 Date in USA format (mm/dd/yy) DATE3 Date in international format (yyyy/mm/dd) TIME1 Time in 24 hour notation (hh:mm) TIME2 Time in 24 hour notation with seconds (hh:mm:ss) TIME3 Time in 12 hour notation (hh:mm AM/PM) TIME4 Time in 12 hour notation with seconds (hh:mm:ss AM/PM) DATETIME1 Date (UK fmt) and time (12 hour) (dd/mm/yy hh:mm AM/PM) DATETIME2 Date (UK fmt) and time (24 hour) (dd/mm/yy hh:mm) DATETIME3 Date (USA fmt) and time (12 hour) (mm/dd/yy hh:mm AM/PM) DATETIME4 Date (USA fmt) and time (24 hour) (mm/dd/yy hh:mm) LAT1 Latitude in degrees, minutes and seconds (dd° mm' ss" N/S) LAT2 Latitude with seconds to one decimal place (dd° mm' ss.s" N/S) LONG1 Longitude in degrees, minutes and seconds (ddd° mm' ss" E/W) LONG2 Longitude seconds to one decimal place (ddd° mm' ss.s" E/W) ANGLE1 Angle in degrees and minutes (ddd° mm')</p> <p>For example, this command:</p> <pre>GUI FORMATBOX #1, LAT1, 50, 50, 300, 50</pre> <p>would create a format box which would accept the entry of latitude in the format of dd° mm' ss" N/S. The value of CtrlVal(#1) would be a string which includes the numbers and separating characters. For example an entry of 17 degrees, 32 minutes and 1 second south would result in the string 17° 32' 01" S</p> <p>MMBasic will try to position the virtual keypad on the screen so as to not obscure the format box that caused it to appear. A pen down interrupt will</p>

	<p>be generated just before the keypad is deployed and a key up interrupt will be generated when the entry is complete and the keypad is hidden.</p>
<p>GUI FORMATBOX CANCEL</p>	<p>This will dismiss a virtual keypad if it is displayed on the screen. It is the same as if the user touched the cancel key except that the touch up interrupt is not generated. If a keypad is not displayed this command will do nothing.</p>
<p>GUI GAUGE #ref, StartX, StartY, Radius, FColour, BColour, min, max, nbrdec, units\$, c1, ta, c2, tb, c3, tc, c4</p>	<p>Define a graphical circular analogue gauge with a digital display in the centre.</p> <p>'#ref' is the control's reference number.</p> <p>'StartX' and 'StartY' are the coordinates of the centre of the gauge, 'Radius' is the distance from the centre to the outer edge.</p> <p>'min' is the minimum value of the gauge and 'max' is the maximum value (both floating point).</p> <p>'nbrdec' specifies the number of decimal places to be used when drawing the digital value in the centre of the gauge. Under this 'units\$' will be displayed.</p> <p>'Fcolour' is the colour used for the gauge while 'Bcolour' is the background colour. A multi colour gauge can be created using 'c1' to 'c4' for the colours and 'ta' to 'tc' for the thresholds used to determine when the colour will change. When colours and thresholds are specified the background of the gauge will be drawn with a dull version of the colour at that level. Also the digital value will change to the colour specified by the current value.</p> <p>'Radius', 'FColour', 'BColour', 'min', 'max', 'nbrdec' and 'units\$' are optional and will default to the values used in the previous definition of a GUI GAUGE.</p> <p>'c1', 'ta', 'c2', 'tb', 'c3', 'tc' and 'c4' are optional and if not specified the gauge will use less colours. If all are omitted the gauge will be drawn using 'Fcolour'.</p> <p>The section <i>Advanced Graphics</i> has a more detailed description.</p>
<p>GUI HIDE #ref1 [,#ref2, #ref3, etc] or GUI HIDE ALL</p>	<p>This will hide the controls in the list. Hidden controls do not respond to touch and will not be visible.</p> <p>'#ref' is the control's reference number. The keyword ALL can be used as the argument and that will hide all controls.</p> <p>GUI SHOW can be used to restore the controls.</p>
<p>GUI INTERRUPT down [, up]</p>	<p>This command will setup an interrupt that will be triggered on a touch on the LCD panel and optionally if the touch is released.</p> <p>'down' is the subroutine to call when a touch down has been detected. 'up' is the subroutine to call when the touch has been lifted from the screen ('up' and 'down' can point to the same subroutine if required).</p> <p>Specifying the number zero (single digit) as the argument will cancel both of these interrupts. ie:</p> <pre>GUI INTERRUPT 0</pre>
<p>GUI LED #ref, caption\$, centerX, centerY, radius, colour</p>	<p>This will draw an indicator light which looks like a panel mounted LED. A LED does not respond to touch.</p> <p>'#ref' is the control's reference number.</p> <p>The string 'caption\$' will be drawn to the right of the control using the colours set by the COLOUR command.</p>

	<p>'centerX' and 'centerY' are the coordinates of the centre of the LED and 'radius' is the radius of the LED. 'colour' is an RGB value for the drawing colour. 'radius' and 'colour' are optional and default to that used in previous controls.</p> <p>When a LED's value is set to a value of one it will be illuminated and when it is set to zero it will be off (a dull version of its colour attribute). The LED can be made to flash on then off by setting the value of the LED to a number greater than one which is the time in milliseconds that it should remain on.</p> <p>The colour can be changed with the GUI FCOLOUR command.</p>
<p>GUI NUMBERBOX #ref, startX, startY, width, height, FColour, BColour</p>	<p>This will draw a box with rounded corners that can be used to create a virtual numeric keypad for data entry.</p> <p>#ref' is the control's reference number.</p> <p>'startX' and 'startY' are the top left coordinates while 'width' and 'height' set the dimensions. 'FColour' and 'BColour' are RGB values for the foreground and background colours. 'width', 'height', FColour' and 'BColour' are optional and default to that used in previous controls.</p> <p>When the box is touched a numeric keypad will appear on the screen. Using this virtual keypad any number can be entered into the box including a floating point number in exponential format. The new number will replace the number previously in the box.</p> <p>The value of the control can set to a literal string (not an expression) starting with two hash characters. For example: CtrlVal(nnn) = "##Enter Number" and in that case the string (without the leading two hash characters) will be displayed in the box with reduced brightness. This can be used to give the user a hint as to what should be entered (called "ghost text"). Reading the value of the control displaying ghost text will return zero. When the control is used normally the ghost text will vanish.</p> <p>MMBasic will try to position the virtual keypad on the screen so as to not obscure the number box that caused it to appear. A pen down interrupt will be generated just before the keypad is deployed and a key up interrupt will be generated when the Enter key is touched and the keypad is hidden. Also, when the Enter key is touched the entered number will be evaluated as a number and the NUMBERBOX control redrawn to display this number.</p>
<p>GUI NUMBERBOX CANCEL</p>	<p>This will dismiss a virtual keypad if it is displayed on the screen. It is the same as if the user touched the cancel key except that the touch up interrupt is not generated. If a keypad is not displayed this command will do nothing.</p>
<p>GUI RADIO #ref, caption\$, centerX, centerY, radius, colour</p>	<p>This will draw a radio button with a caption.</p> <p>#ref' is the control's reference number.</p> <p>The string 'caption\$' will be drawn to the right of the control using the colours set by the COLOUR command.</p> <p>'centerX' and 'centerY' are the coordinates of the centre of the button and 'radius' is the radius of the button. 'colour' is an RGB value for the drawing colour. 'radius' and 'colour' are optional and default to that used in previous controls.</p> <p>When touched the centre of the button will be illuminated to indicate that this option has been selected and the control's value will be 1. When another</p>

	<p>radio button is selected the mark on this button will be removed and its value will be zero. Radio buttons are grouped together when surrounded by a frame and when one button in the group is selected all others in the group will be deselected. If a frame is not used all buttons on the screen will be grouped together.</p>
<p>GUI REDRAW #ref1 [,#ref2, #ref3, etc] or GUI REDRAW ALL</p>	<p>This will redraw the controls on the screen. It is useful if the screen image has somehow been corrupted.</p> <p>#ref' is the control's reference number. The keyword ALL can be used as the argument and that will first clear the screen then redraw all controls. This is useful if the whole screen needs to be refreshed.</p>
<p>GUI SETUP #n</p>	<p>This will allocate any new controls created to the page '#n'.</p> <p>This command can be used as many times as needed while GUI controls are being defined. The default when a program starts running is GUI SETUP 1. See also the GUI PAGE command.</p>
<p>GUI SHOW #ref1 [,#ref2, #ref3, etc] or GUI SHOW ALL</p>	<p>This will undo the effects of GUI HIDE and restore the control(s) to being visible and capable of normal operation.</p> <p>#ref' is the control's reference number. The keyword ALL can be used as the argument and that will disable all controls.</p>
<p>GUI SPINBOX #ref, startX, startY, width, height, FColour, BColour, Step, Minimum, Maximum</p>	<p>This will draw a box with up/down icons on either end. When these icons are touched the number in the box will be incremented or decremented. Holding down the up/down icons will repeat the step at a fast rate.</p> <p>#ref' is the control's reference number.</p> <p>'startX' and 'startY' are the top left coordinates while 'width' and 'height' set the dimensions. 'FColour' and 'BColour' are RGB values for the foreground and background colours.</p> <p>'width', 'height', FColour and 'BColour' are optional and default to that used in previous controls.</p> <p>'Step' sets the amount to increment/decrement the number with each touch. 'Minimum' and 'Maximum' set limits on the number that can be entered. All three parameters can be floating point numbers and are optional. The default for 'Step' is 1 and 'Minimum' and 'Maximum' if omitted will default to no limit.</p>
<p>GUI SWITCH #ref, caption\$, startX, startY, width, height, FColour, BColour</p>	<p>This will draw a latching switch which is a square switch that latches when touched.</p> <p>#ref' is the control's reference number.</p> <p>'caption\$' is a string to display as the caption on the face of the switch. 'startX' and 'startY' are the top left coordinates while 'width' and 'height' set the dimensions. 'FColour' and 'BColour' are RGB values for the foreground and background colours. 'width', 'height', FColour and 'BColour' are optional and default to that used in previous controls.</p> <p>When touched the visual image of the button will appear to be depressed and the control's value will be 1. When touched a second time the switch will be released and the value will revert to zero. Caption can consist of two captions separated by a character (eg, "ON OFF"). When this is used the</p>

	<p>switch will appear to be a toggle switch with each half of the caption used to label each half of the toggle switch.</p>
<p>GUI TEXTBOX #ref, startX, startY, width, height, FColour, BColour</p>	<p>This will draw a box with rounded corners that can be used to create a virtual keyboard for data entry</p> <p>#ref' is the control's reference number.</p> <p>'startX' and 'startY' are the top left coordinates while 'width' and 'height' set the dimensions. 'FColour' and 'BColour' are RGB values for the foreground and background colours. 'width', 'height', FColour and 'BColour' are optional and default to that used in previous controls. On a display that supports transparent text BColour can be -1 which means that the background will show through the gaps in the characters.</p> <p>When the box is touched a QWERTY keyboard will appear on the screen. Using this virtual keyboard any text can be entered into the box including upper/lower case letters, numbers and any other characters in the ASCII character set. The new text will replace any text previously in the box.</p> <p>The value of the control can set to a string starting with two hash characters. For example:</p> <pre>CtrlVal(nnn) = "##Enter Filename"</pre> <p>and in that case the string (without the leading two hash characters) will be displayed in the box with reduced brightness. This can be used to give the user a hint as to what should be entered (called "ghost text"). Reading the value of the control displaying ghost text will return an empty string. When the control is used normally the ghost text will vanish.</p> <p>MMBasic will try to position the virtual keyboard on the screen so as to not obscure the text box that caused it to appear. A pen down interrupt will be generated just before the keyboard is deployed and a key up interrupt will be generated when the Enter key is touched and the keyboard is hidden.</p>
<p>GUI TEXTBOX CANCEL</p>	<p>This will dismiss a virtual keyboard if it is displayed on the screen. It is the same as if the user touched the cancel key except that the touch up interrupt is not generated. If a keyboard is not displayed this command will do nothing.</p>
<p>HUMID pin, tvar, hvar</p>	<p>Returns the temperature and humidity using the DHT22 sensor. Alternative versions of the DHT22 are the AM2303 or the RHT03 (all are compatible). 'pin' is the I/O pin connected to the sensor. Any I/O pin may be used.</p> <p>'tvar' is the variable that will hold the measured temperature and 'hvar' is the same for humidity. Both must be present and both must be floating point variables.</p> <p>For example: HUMID 2, TEMP!, HUMIDITY!</p> <p>Temperature is measured in °C and the humidity is percent relative humidity. Both will be measured with a resolution of 0.1. If an error occurs (sensor not connected or corrupt signal) both values will be 1000.0.</p> <p>Normally the signal pin of the DHT22 should be pulled up by a 1K to 10K resistor (4.7K recommended) to the supply voltage.</p>
<p>I2C</p>	<p>The I2C commands will send and receive data over an I²C channel.</p> <p>I2C (no suffix) refers to channel 1 while commands I2C2 and I2C3 refer to channels 2 and 3 using the same syntax.</p> <p>Also see <i>Appendix B</i>.</p>

I2C OPEN speed, timeout	<p>Enables the I²C module in master mode. 'speed' is the clock speed (in KHz) to use and must be one of 100 or 400.</p> <p>'timeout' is a value in milliseconds after which the master send and receive commands will be interrupted if they have not completed. The minimum value is 100. A value of zero will disable the timeout (though this is not recommended).</p>
I2C WRITE addr, option, sendlen, senddata [,senddata]	<p>Send data to the I²C slave device. 'addr' is the slave's I²C address.</p> <p>'option' can be 0 for normal operation or 1 to keep control of the bus after the command (a stop condition will not be sent at the completion of the command)</p> <p>'sendlen' is the number of bytes to send.</p> <p>'senddata' is the data to be sent - this can be specified in various ways (all values sent will be between 0 and 255):</p> <ul style="list-style-type: none"> • The data can be supplied as individual bytes on the command line. Example: I2C WRITE &H6F, 0, 3, &H23, &H43, &H25 • The data can be in a one dimensional array specified with empty brackets (ie, no dimensions). 'sendlen' bytes of the array will be sent starting with the first element. Example: I2C WRITE &H6F, 0, 3, ARRAY() <p>The data can be a string variable (not a constant). Example: I2C WRITE &H6F, 0, 3, STRING\$</p>
I2C READ addr, option, rcvlen, rcvbuf	<p>Get data from the I²C slave device. 'addr' is the slave's I²C address.</p> <p>'option' can be 0 for normal operation or 1 to keep control of the bus after the command (a stop condition will not be sent at the completion of the command)</p> <p>'rcvlen' is the number of bytes to receive.</p> <p>'rcvbuf' is the variable or array used to save the received data - this can be:</p> <ul style="list-style-type: none"> • A string variable. Bytes will be stored as sequential characters in the string. • A one dimensional array of numbers specified with empty brackets. Received bytes will be stored in sequential elements of the array starting with the first. Example: I2C READ &H6F, 0, 3, ARRAY() <p>A normal numeric variable (in this case rcvlen must be 1).</p>
I2C CLOSE	<p>Disables the master I²C module and returns the I/O pins to a "not configured" state. They can then be configured using SETPIN. This command will also send a stop if the bus is still held.</p>
I2C2	<p>As above but for 2nd I2C channel.</p>
IF expr THEN stmt [: stmt] or IF expr THEN stmt ELSE stmt	<p>Evaluates the expression 'expr' and performs the statement following the THEN keyword if it is true or skips to the next line if false. If there are more statements on the line (separated by colons (:)) they will also be executed if true or skipped if false.</p> <p>The ELSE keyword is optional and if present only one true statement is allowed following the THEN keyword. If 'expr' is resolved to be false the single statement following the ELSE keyword will be executed.</p>

	<p>The 'THEN statement' construct can be also replaced with: GOTO linenummer label'.</p> <p>This type of IF statement is all on one line.</p>
<pre>IF expression THEN <statements> [ELSEIF expression THEN <statements>] [ELSE <statements>] ENDIF</pre>	<p>Multiline IF statement with optional ELSE and ELSEIF cases and ending with ENDIF. Each component is on a separate line.</p> <p>Evaluates 'expression' and performs the statement(s) following THEN if the expression is true or optionally the statement(s) following the ELSE statement if false. The ELSEIF statement (if present) is executed if the previous condition is false and it starts a new IF chain with further ELSE and/or ELSEIF statements as required.</p> <p>One ENDIF is used to terminate the multiline IF.</p>
<pre>INC a[, b]</pre>	<p>Increments a by 1 by default. If b is supplied then a is adjusted by the value of b. If b is -ve then a is decremented by that amount. E.g. INC a, -1</p>
<pre>INPUT ["prompt\$";] var1 [,var2 [, var3 [, etc]]]</pre>	<p>Will take a list of values separated by commas (,) entered at the console and will assign them to a sequential list of variables.</p> <p>For example, if the command is: INPUT a, b, c</p> <p>And the following is typed on the keyboard: 23, 87, 66</p> <p>Then a = 23 and b = 87 and c = 66</p> <p>The list of variables can be a mix of float, integer or string variables. The values entered at the console must correspond to the type of variable.</p> <p>If a single value is entered a comma is not required (however that value cannot contain a comma).</p> <p>'prompt\$' is a string constant (not a variable or expression) and if specified it will be printed first. Normally the prompt is terminated with a semicolon (;) and in that case a question mark will be printed following the prompt. If the prompt is terminated with a comma (,) rather than the semicolon (;) the question mark will be suppressed.</p>
<pre>INPUT #nbr, list of variables</pre>	<p>Same as the normal INPUT command except that the input is read from a file previously opened for INPUT as '#fnbr' or a serial port previously opened for INPUT as 'nbr'. See the OPEN command.</p>
<pre>IR dev, key , int or IR CLOSE</pre>	<p>Decodes NEC or Sony infrared remote control signals.</p> <p>An IR Receiver Module is used to sense the IR light and demodulate the signal. It should be connected to the IR pin (see the pinout tables). This command will automatically set that pin to an input.</p> <p>The IR signal decode is done in the background and the program will continue after this command without interruption. 'dev' and 'key' should be numeric variables and their values will be updated whenever a new signal is received ('dev' is the device code transmitted by the remote and 'key' is the key pressed).</p> <p>'int' is a user defined subroutine that will be called when a new key press is received or when the existing key is held down for auto repeat. In the interrupt subroutine the program can examine the variables 'dev' and 'key' and take appropriate action.</p> <p>The IR CLOSE command will terminate the IR decoder and return the I/O pin to a not configured state.</p> <p>Note that for the NEC protocol the bits in 'dev' and 'key' are reversed. For example, in 'key' bit 0 should be bit 7, bit 1 should be bit 6, etc. This does</p>

	<p>not affect normal use but if you are looking for a specific numerical code provided by a manufacturer you should reverse the bits. This describes how to do it: http://www.thebackshed.com/forum/forum_posts.asp?TID=8367</p> <p>See the chapter "Special Hardware Devices" for more details.</p>
IR SEND pin, dev, key	<p>Generate a 12-bit Sony Remote Control protocol infrared signal.</p> <p>'pin' is the I/O pin to use. This can be any I/O pin which will be automatically configured as an output and should be connected to an infrared LED. Idle is low with high levels indicating when the LED should be turned on.</p> <p>'dev' is the device being controlled and is a number from 0 to 31, 'key' is the simulated key press and is a number from 0 to 127.</p> <p>The IR signal is modulated at about 38KHz and sending the signal takes about 25mS.</p>
IRETURN	
KILL file\$	<p>Deletes the file or empty directory specified by 'file\$'. If there is an extension it must be specified.</p>
LCD INIT d4, d5, d6, d7, rs, en or LCD line, pos, text\$ or LCD CLEAR or LCD CLOSE	<p>Display text on an LCD character display module. This command will work with most 1-line, 2-line or 4-line LCD modules that use the KS0066, HD44780 or SPLC780 controller (however this is not guaranteed).</p> <p>The LCD INIT command is used to initialise the LCD module for use. 'd4' to 'd7' are the I/O pins that connect to inputs D4 to D7 on the LCD module (inputs D0 to D3 should be connected to ground). 'rs' is the pin connected to the register select input on the module (sometimes called CMD). 'en' is the pin connected to the enable or chip select input on the module. The R/W input on the module should always be grounded. The above I/O pins are automatically set to outputs by this command.</p> <p>When the module has been initialised data can be written to it using the LCD command. 'line' is the line on the display (1 to 4) and 'pos' is the character location on the line (the first location is 1). 'text\$' is a string containing the text to write to the LCD display.</p> <p>'pos' can also be C8, C16, C20 or C40 in which case the line will be cleared and the text centred on a 8 or 16, 20 or 40 line display. For example:</p> <pre>LCD 1, C16, "Hello"</pre> <p>LCD CLEAR will erase all data displayed on the LCD and LCD CLOSE will terminate the LCD function and return all I/O pins to the not configured state.</p> <p>See the chapter "Special Hardware Devices" for more details.</p>
LCD CMD d1 [, d2 [, etc]] or LCD DATA d1 [, d2 [, etc]]	<p>These commands will send one or more bytes to an LCD display as either a command (LCD CMD) or as data (LCD DATA). Each byte is a number between 0 and 255 and must be separated by commas. The LCD must have been previously initialised using the LCD INIT command (see above).</p> <p>These commands can be used to drive a non standard LCD in "raw mode" or they can be used to enable specialised features such as scrolling, cursors and custom character sets. You will need to refer to the data sheet for your LCD to find the necessary command and data values.</p>
LET variable = expression	<p>Assigns the value of 'expression' to the variable. LET is automatically assumed if a statement does not start with a command. For example:</p> <pre>Var = 56</pre>

<p>LINE x1, y1, x2, y2 [, LW [, C]]</p>	<p>Draws a line starting at the coordinates 'x1' and 'y1' and ending at 'x2' and 'y2'.</p> <p>'LW' is the line's width and is only valid for horizontal or vertical lines. It defaults to 1 if not specified or if the line is a diagonal. 'C' is an integer representing the colour and defaults to the current foreground colour.</p> <p>All parameters can now be expressed as arrays and the software will plot the number of lines as determined by the dimensions of the smallest array. 'x1', 'y1', 'x2', and 'y2' must all be arrays or all be single variables /constants otherwise an error will be generated. 'lw' and 'c' can be either arrays or single variables/constants.</p>
<p>LINE INPUT [prompt\$, string-variable\$</p>	<p>Reads an entire line from the console input into 'string-variable\$'.</p> <p>'prompt\$' is a string constant (not a variable or expression) and if specified it will be printed first.</p> <p>Unlike INPUT, this command will read a whole line, not stopping for comma delimited data items.</p> <p>A question mark is not printed unless it is part of 'prompt\$'.</p>
<p>LINE INPUT #nbr, string-variable\$</p>	<p>Same as the LINE INPUT command except that the input is read from a file previously opened for INPUT as '#fnbr' or a serial communications port previously opened for INPUT as 'nbr'. See the OPEN command.</p>
<p>LIST [file\$] or LIST ALL [file\$]</p>	<p>List a program on the serial console.</p> <p>LIST on its own will list the program with a pause at every screen full.</p> <p>LIST ALL will list the program without pauses. This is useful if you wish to transfer the program in the Maximite to a terminal emulator on a PC that has the ability to capture its input stream to a file.</p> <p>In most cases the filename 'file\$' is required however if EDIT file\$ or RUN file\$ has been used previously the "current program name" will have been set and in that case LIST will default to using that filename.</p>
<p>LIST FILES [fspec\$] [, sort]</p>	<p>Lists files in the current directory on the SD card.</p> <p>'fspec\$' (if specified) can contain search wildcards. Question marks (?) will match any character and an asterisk (*) will match any number of characters. If omitted, all files will be listed.</p> <p>For example:</p> <ul style="list-style-type: none"> * Find all entries *.TXT Find all entries with an extension of TXT E*.* Find all entries starting with E X?X.* Find all three letter file names starting and ending with X <p>'sort' specifies the sort order as follows:</p> <ul style="list-style-type: none"> size by ascending size time by ascending time/date name by file name (default if not specified) type by file extension
<p>LIST COMMANDS LIST FUNCTIONS</p>	<p>Lists all valid commands</p> <p>List all valid functions and operators</p>
<p>LOAD FONT file\$</p>	<p>Load the font contained in 'file\$' on the SD card and install it as font #8.</p> <p>See the section <i>Basic Graphics</i> earlier in this manual.</p> <p>You can convert font files designed for the original Colour Maximite using</p>

	FontTweak from: https://www.c-com.com.au/MMedit.htm
LOAD file\$ [,R]	Loads a program called 'file\$' from the current drive into program memory. If the optional suffix ,R is added the program will be immediately run without prompting. If an extension is not specified ".BAS" will be added to the file name.
LOAD DATA fname\$, address	Loads the raw binary contents of file <i>fname\$</i> and stores it in memory starting at <i>address</i> . Together with SAVE DATA this allows you to very easily to save and restore the contents of an array to and from disk. The code tries to protect you from crashing the system to the extent possible but there are many ways you can misuse the LOAD DATA command if you try. You can use PEEK to find out where the data for an array is located in memory. See SAVE DATA as well.
LOAD IMAGE file\$ [, x, y]	Load a bitmapped image from the SD card and display it on the LCD panel. "file\$" is the name of the file and 'x' and 'y' are the screen coordinates for the top left hand corner of the image. If the coordinates are not specified the image will be drawn at the top left hand position on the screen. If an extension is not specified ".BMP" will be added to the file name. All types of the BMP format are supported including black and white and true colour 24-bit images.
LOCAL variable [, variables] See DIM for the full syntax.	Defines a list of variable names as local to the subroutine or function. This command uses exactly the same syntax as DIM and will create variables that will only be visible within the subroutine or function. They will be automatically discarded when the subroutine or function exits.
LONGSTRING	The LONGSTRING commands allow for the manipulation of strings longer than the normal MMBasic limit of 255 characters. Variables for holding long strings must be defined as single dimensioned integer arrays with the number of elements set to the number of characters required for the maximum string length divided by eight. The reason for dividing by eight is that each integer in an MMBasic array occupies eight bytes.
LONGSTRING APPEND array%(), string\$	Append a normal MMBasic string to a long string variable. array%() is a long string variable while string\$ is a normal MMBasic string expression.
LONGSTRING CLEAR array%()	Will clear the long string variable array%(). ie, it will be set to an empty string.
LONGSTRING COPY dest%(), src%()	Copy one long string to another. dest%() is the destination variable and src%() is the source variable. Whatever was in dest%() will be overwritten.
LONGSTRING CONCAT dest%(), src%()	Concatenate one long string to another. dest%() is the destination variable and src%() is the source variable. src%() will be added to the end of dest%() (the destination will not be overwritten).
LONGSTRING LCASE array%()	Will convert any uppercase characters in array%() to lowercase. array%() must be long string variable.

LONGSTRING LEFT dest%(), src%(), nbr	Will copy the left hand 'nbr' characters from src%() to dest%() overwriting whatever was in dest%(). ie, copy from the beginning of src%(). src%() and dest%() must be long string variables. 'nbr' must be an integer constant or expression.
LONGSTRING LOAD array%(), nbr, string\$	Will copy 'nbr' characters from string\$ to the long string variable array%() overwriting whatever was in array%().
LONGSTRING MID dest%(), src%(), start, nbr	Will copy 'nbr' characters from src%() to dest%() starting at character position 'start' overwriting whatever was in dest%(). ie, copy from the middle of src%(). 'nbr' is optional and if omitted the characters from 'start' to the end of the string will be copied src%() and dest%() must be long string variables. 'start' and 'nbr' must be an integer constants or expressions.
LONGSTRING PRINT [#n,] src%()	Prints the longstring stored in 'src%()' to the file or COM port opened as '#n'. If '#n' is not specified the output will be sent to the console.
LONGSTRING REPLACE array%() , string\$, start	Will substitute characters in the normal MMBasic string string\$ into an existing long string array%() starting at position 'start' in the long string.
LONGSTRING RESIZE array%(), newsize	Sets the stored size of a long string array%() to newsize
LONGSTRING SETBYTE array%(), pos, byte	Used to set the byte at position <i>pos</i> to the value <i>byte</i> . Pos respects the OPTION BASE setting.
LONGSTRING RIGHT dest%(), src%(), nbr	Will copy the right hand 'nbr' characters from src%() to dest%() overwriting whatever was in dest%(). ie, copy from the end of src%(). src%() and dest%() must be long string variables. 'nbr' must be an integer constant or expression.
LONGSTRING TRIM array%(), nbr	Will trim 'nbr' characters from the left of a long string. array%() must be a long string variables. 'nbr' must be an integer constant or expression.
LONGSTRING UCASE array%()	Will convert any lowercase characters in array%() to uppercase. array%() must be long string variable.
LOOP [UNTIL expression]	Terminates a program loop: see DO.
MATH	The math command performs many simple mathematical calculations that can be programmed in BASIC but there are speed advantages to coding looping structures in the firmware and there is the advantage that once debugged they are there for everyone without re-inventing the wheel. Note: 2 dimensional maths matrices are always specified DIM matrix(n_columns, n_rows) and of course the dimensions respect OPTION BASE. Quaternions are stored as a 5 element array w, x, y, z, magnitude.
Simple array arithmetic	
MATH SET nbr, array()	Sets all elements in array() to the value nbr. Note this is the fastest way of clearing an array by setting it to zero.
MATH SCALE in(), scale ,out()	This scales the matrix in() by the scalar scale and puts the answer in out(). Works for arrays of any dimensionality of both integer and float and can convert between. Setting b to 1 is optimised and is the fastest way of copying

<p>MATH INTERPOLATE array1(), array(2), ratio, array3()</p> <p>Matrix arithmetic</p> <p>MATH M_PRINT array()</p> <p>MATH M_TRANSPOSE in(), out()</p> <p>MATH M_MULT in1(), in2(), out()</p> <p>Vector arithmetic</p> <p>MATH V_PRINT array()</p> <p>MATH V_NORMALISE inV(), outV()</p> <p>MATH V_MULT matrix(), inV(), outV()</p> <p>MATH V_CROSS inV1(), inV2(), outV()</p> <p>Quaternion arithmetic</p> <p>MATH Q_INVERT inQ(), outQ()</p> <p>MATH Q_VECTOR inV(), outVQ() MATH Q_VECTOR x,y,z,outVQ()</p> <p>MATH Q_CREATE theta, x, y, z, outRQ()</p> <p>MATH Q_MULT inQ1(), inQ2(), outQ()</p> <p>MATH Q_ROTATE , RQ(), inVQ(), outVQ()</p>	<p>an entire array</p> <p>This implements the following equation on every array element $out = (in2 - in1) * ratio + in1$. Arrays can have any number of dimensions and must be distinct and have the same number of total elements</p> <p>Quick mechanism to print a 2D matrix one row per line.</p> <p>Transpose matrix in() and put the answer in matrix out(), both arrays must be 2D but need not be square. If not square then the arrays must be dimensioned in(m,n) out(n,m)</p> <p>Multiply the arrays in1() and in2() and put the answer in out(). All arrays must be 2D but need not be square. If not square then the arrays must be dimensioned in1(m,n) in2(p,m) ,out(p,n)</p> <p>Quick mechanism to print a small array on a single line</p> <p>Converts a vector inV() to unit scale and puts the answer in outV() $(sqr(x*x + y*y +)=1$ There is no limit on number of elements in the vector</p> <p>Multiplies matrix() and vector inV() returning vector outV(). The vectors and the 2D matrix can be any size but must have the same cardinality.</p> <p>Calculates the cross product of two three element vectors inV1() and inV2() and puts the answer in outV()</p> <p>Invert the quaternion in inQ() and put the answer in outQ()</p> <p>Converts a vector inV() to a normalised quaternion vector outVQ() with the original magnitude stored.</p> <p>Generates a normalised rotation quaternion outRQ() to rotate quaternion vectors around axis x,y,z by an angle of theta. Theta is specified in radians.</p> <p>Multiplies two quaternions inQ1() and inQ2() and puts the answer in outQ()</p> <p>Rotates the source quaternion vector inVQ() by the rotate quaternion RQ() and puts the answer in outVQ()</p>
<p>MEMORY</p>	<p>List the amount of memory currently in use. For example:</p> <pre>Flash: 39K (6%) Program (1450 lines) 527K (94%) Free</pre> <p>RAM:</p>

	<p>0K (0%) 0 Variables 1K (0%) General 5470K (100%) Free</p> <p>Notes:</p> <ul style="list-style-type: none"> • General memory is used by serial I/O buffers, etc. • Memory usage is rounded to the nearest 1K byte.
MID\$(str\$, start [, num]) = str2\$	The characters in 'str\$', beginning at position 'start', are replaced by the characters in 'str2\$'. The optional 'num' refers to the number of characters from 'str2' that are used in the replacement. If 'num' is omitted, all of 'str2' is used. Whether 'num' is omitted or included, the replacement of characters never goes beyond the original length of 'str\$'.
MKDIR dir\$	Make, or create, the directory 'dir\$' on the SD card.
NAME old\$ AS new\$	Rename a file or a directory from 'old\$' to 'new\$'. Both are strings. A directory path can be used in both 'old\$' and 'new\$'. If the paths differ the file specified in 'old\$' will be moved to the path specified in 'new\$' with the file name as specified.
NEW	Deletes the program in flash, clears all variables including saved variables and resets the interpreter (ie, closes files, serial ports, etc).
NEXT [counter-variable] [, counter-variable], etc	NEXT comes at the end of a FOR-NEXT loop; see FOR. The 'counter-variable' specifies exactly which loop is being operated on. If no 'counter-variable' is specified the NEXT will default to the innermost loop. It is also possible to specify multiple variables as in: NEXT x, y, z
ON ERROR ABORT or ON ERROR IGNORE or ON ERROR SKIP [nn] or ON ERROR CLEAR	This controls the action taken if an error occurs while running a program and applies to all errors discovered by MMBasic including syntax errors, wrong data, missing hardware, SD Card access, etc. ON ERROR ABORT will cause MMBasic to display an error message, abort the program and return to the command prompt. This is the normal behaviour and is the default when a program starts running. ON ERROR IGNORE will cause any error to be ignored. ON ERROR SKIP will ignore an error in a number of commands (specified by the number 'nn') executed following this command. 'nn' is optional, the default if not specified is one. After the number of commands has completed (with an error or not) the behaviour of MMBasic will revert to ON ERROR ABORT. If an error occurs and is ignored/skipped the read only variable MM.ERRNO will be set to non zero and MM.ERRMSG\$ will be set to the error message that would normally be generated. These are reset to zero and an empty string by ON ERROR CLEAR. They are also cleared when the program is run and when ON ERROR IGNORE and ON ERROR SKIP are used. ON ERROR IGNORE can make it very difficult to debug a program so it is strongly recommended that only ON ERROR SKIP be used.
ON KEY target	Setup an interrupt which will call 'target' user defined subroutine whenever there is one or more characters waiting in the serial console input buffer. Note that all characters waiting in the input buffer should be read in the interrupt subroutine otherwise another interrupt will be automatically generated as soon as the program returns from the interrupt. To disable this interrupt, use numeric zero for the target, ie: ON KEY 0

<p>ONEWIRE RESET pin or ONEWIRE WRITE pin, flag, length, data [, data...] or ONEWIRE READ pin, flag, length, data [, data...]</p>	<p>Commands for communicating with 1-Wire devices. ONEWIRE RESET will reset the 1-Wire bus ONEWIRE WRITE will send a number of bytes ONEWIRE READ will read a number of bytes 'pin' is the I/O pin (located in the rear connector) to use. It can be any pin capable of digital I/O. 'flag' is a combination of the following options: <ul style="list-style-type: none"> 1 - Send reset before command 2 - Send reset after command 4 - Only send/recv a bit instead of a byte of data 8 - Invoke a strong pullup after the command (the pin will be set high and open drain disabled) 'length' is the length of data to send or receive 'data' is the data to send or variable to receive. The number of data items must agree with the length parameter. See also <i>Appendix C</i>.</p>
<p>OPEN fname\$ FOR mode AS [#]fnbr</p>	<p>Opens a file for reading or writing. 'fname' is the filename with an optional extension separated by a dot (.). Long file names with upper and lower case characters are supported. A directory path can be specified with the backslash as directory separators. The parent of the current directory can be specified by using a directory name of .. (two dots) and the current directory with . (a single dot). For example OPEN ".\dir1\dir2\filename.txt" FOR INPUT AS #1 'mode' is INPUT, OUTPUT, APPEND or RANDOM. The maximum filename/directory length is 63 chars to reduce the buffer needed so don't use filenames > 63 chars INPUT will open the file for reading and throw an error if the file does not exist. OUTPUT will open the file for writing and will automatically overwrite any existing file with the same name. APPEND will also open the file for writing but it will not overwrite an existing file; instead any writes will be appended to the end of the file. If there is no existing file the APPEND mode will act the same as the OUTPUT mode (i.e. the file is created then opened for writing). RANDOM will open the file for both read and write and will allow random access using the SEEK command. When opened the read/write pointer is positioned at the end of the file. 'fnbr' is the file number (1 to 10). The # is optional. Up to 10 files can be open simultaneously. The INPUT, LINE INPUT, PRINT, WRITE and CLOSE commands as well as the EOF() and INPUT\$() functions all use 'fnbr' to identify the file being operated on. See also OPTION ERROR and MM.ERRNO for error handling.</p>
<p>OPEN comspec\$ AS [#]fnbr</p>	<p>Will open a serial communications port for reading and writing. Two ports are available (COM1: and COM2:) and both can be open simultaneously. If OPTION CONSOLE SCREEN is used then the console serial port is available as COM3:. Using 'fnbr' the port can be written to and read from using any command or function that uses a file number. 'comspec\$' is the communication specification and is a string (it can be a string variable) specifying the serial port to be opened and optional parameters. The default is 9600 baud, 8 data</p>

	<p>bits, no parity and one stop bit.</p> <p>It has the form "COMn: baud, buf, int, int-trigger, (DEN or DEP), 7BIT, (ODD or EVEN), INV, OC, S2"</p> <p>Where:</p> <ul style="list-style-type: none"> • 'n' is the serial port number for either COM1:, COM2 or COM3:.. • 'baud' is the baud rate. This can be any value between 1200 (the minimum) and 1000000 (1MHz). Default is 9600. • 'buf' is the receive buffer size in bytes (default size is 256). The transmit buffer is fixed at 256 bytes. • 'int' is a user defined subroutine which will be called when the serial port has received some data. The default is no interrupt. • 'int-trigger' sets the trigger condition for calling the interrupt subroutine. If it is a normal number the interrupt subroutine will be called when this number of characters has arrived in the receive queue. <p>All parameters except the serial port name (COMn:) are optional. If any one parameter is left out then all the following parameters must also be left out and the defaults will be used.</p> <p>Six options can be added to the end of 'comspec\$'</p> <ul style="list-style-type: none"> • 'INV' specifies that the transmit and receive polarity is inverted. • 'OC' will force the transmit pin (and DE on COM1:) to be open collector. The default is normal (0 to 3.3V) output. • 'S2' specifies that two stop bits will be sent following each character transmitted. • '7BIT' will specify that 7 bit transmit and receive is to be used. • 'ODD' will specify that an odd parity bit will be appended (8 bits will be transmitted if 7BIT is specified, otherwise 9) • 'EVEN' will specify that an even parity bit will be appended (8 bits will be transmitted if 7BIT is specified, otherwise 9) • 'DEP' will enable RS485 mode with a positive output on the COM1-DE pin • 'DEN' will enable RS485 mode with a negative output on the COM1-DE pin
<p>OPEN comspec\$ AS GPS [,timezone_offset] [,monitor]</p>	<p>Will open a serial communications port for reading from a GPS receiver. See the GPS function for details. The sentences interpreted are GPRMC, GNRMC, GPCGA and GNCGA.</p> <p>The timezone_offset parameter is used to convert UTC as received from the GPS to the local timezone. If omitted the timezone will default to UTC. The timezone_offset can be a any number between -12 and 14 allowing the time to be set correctly even for the Chatham Islands in New Zealand (UTC +12:45).</p> <p>If the monitor parameter is set to 1 then all GPS input is directed to the console. This can be stopped by closing the GPS channel.</p>
<p>OPTION</p>	<p>See the section <i>Options</i> earlier in this manual.</p>

PAGE #n [,#n2, #n3, etc]	<p>This will switch the display to show controls that have been assigned (via the GUI SETUP command) to the page numbers specified on the command line (#n, #n2, etc). Any controls that were displayed but are not on the current list of pages will be automatically hidden. Any controls on a page that was displayed on the old screen and is also specified in the new PAGE command will remain unaffected.</p> <p>The default when a program starts running is PAGE 1 and GUI SETUP 1. This means that if these commands are not used the program will run as normal showing all GUI controls that have been defined.</p> <p>See also the GUI SETUP command.</p>
PAUSE delay	<p>Halt execution of the running program for 'delay' ms. This can be a fraction. For example, 0.2 is equal to 200 µs. The maximum delay is 2147483647 ms (about 24 days).</p> <p>Note that interrupts will be recognised and processed during a pause.</p>
PIN(pin) = value	<p>For a 'pin' configured as digital output this will set the output to low ('value' is zero) or high ('value' non-zero). You can set an output high or low before it is configured as an output and that setting will be the default output when the SETPIN command takes effect.</p> <p>See the function PIN() for reading from a pin and the command SETPIN for configuring it.</p>
PIXEL x, y [,c]	<p>Set a pixel on an attached VGA monitor to a colour.</p> <p>'x' is the horizontal coordinate and 'y' is the vertical coordinate of the pixel. 'c' is a 24 bit number specifying the colour.</p> <p>'c' is optional and if omitted the current foreground colour will be used.</p> <p>All parameters can be expressed as arrays and the software will plot the number of pixels as determined by the dimensions of the smallest array. 'x' and 'y' must both be arrays or both be single variables /constants otherwise an error will be generated. 'c' can be either an arrays or a single variable or constant.</p> <p>See the chapter "Basic Drawing Commands" for a definition of the colours and graphics coordinates.</p>
PLAY TONE left [, right [, dur]] [[[, interrupt]]]	<p>Generates two separate sine waves on the sound output left and right channels. The tone plays in the background (the program will continue running after this command).</p> <p>'left' and 'right' are the frequencies in Hz to use for the left and right channels.</p> <p>'dur' specifies the number of milliseconds that the tone will sound for. MMBasic will round the time to the next nearest complete waveform of the first frequency specified so that the tone will always finish with the DC level in the middle and no discontinuity. If the duration is not specified the tone will continue until explicitly stopped or the program terminates.</p> <p>'interrupt' is optional and is an interrupt subroutine to call when the tone has completed.</p> <p>The frequency can be from 1Hz to 20KHz and is very accurate (it is based on a crystal oscillator). The frequency can be changed at any time by issuing a new PLAY TONE command.</p>
PLAY WAV file\$ [, interrupt] or	<p>Play an audio file on the audio (DAC) output.</p> <p>'file\$' is the file to play (the appropriate extension will be appended if</p>

PLAY FLAC file\$ [, interrupt]	<p>missing). The file is played in the background, 'interrupt' is optional and is the name of a subroutine that will be called when the file has finished playing.</p> <p>For WAV files MMBasic will automatically compensate for the frequency, number of bits and number of channels of the WAV file.</p> <p>For FLAC files the supported frequencies are:</p> <ul style="list-style-type: none"> 44100Hz 16-bit(CD quality) and 24-bit 48000Hz 16-bit and 24-bit 88200Hz 16-bit and 24-bit 96000Hz 24-bit <p>Maximums for FLAC and WAV file playback are 96KHz 24-bit. Both will auto-configure to the file provided. As an indication, 96KHz 24-bit FLAC uses just over 50% of the CPU's resources.</p> <p>If fname\$ is a directory then the firmware will list all the files of the relevant type in that directory and start playing them one-by-one. To play files in the current directory use an empty string (ie, ""). Each file listed will play in turn and the optional interrupt will fire when all files have been played. The filenames are stored with full path so you can use CHDIR while tracks are playing without causing problems.</p> <p>All files in the directory are listed if the command is executed at the command prompt but the listing is suppressed in a program</p>
PLAY PAUSE PLAY RESUME PLAY STOP	<p>PLAY PAUSE will temporarily halt the currently playing file or tone.</p> <p>PLAY RESUME will resume playing a sound that was paused.</p> <p>PLAY STOP will terminate the playing of the file or tone. When the program terminates for whatever reason the sound output will also be automatically stopped.</p>
PLAY VOLUME left, right	<p>Will adjust the volume of the audio output.</p> <p>'left' and 'right' are the levels to use for the left and right channels and can be between 0 and 100 with 100 being the maximum volume. There is a linear relationship between the specified level and the output.</p> <p>The volume defaults to maximum when a program is run.</p>

<p>POKE BYTE addr%, byte or POKE SHORT addr%, short% or POKE WORD addr%, word% or POKE INTEGER addr%, int% or POKE FLOAT addr%, float! or POKE VAR var, offset, byte or POKE VARTBL, offset, byte</p>	<p>Will set a byte or a word within the CPU's virtual memory space. POKE BYTE will set the byte (ie, 8 bits) at the memory location 'addr%' to 'byte'. 'addr%' should be an integer. POKE SHORT will set the short integer (ie, 16 bits) at the memory location 'addr%' to 'word%'. 'addr%' and short% should be integers. POKE WORD will set the word (ie, 32 bits) at the memory location 'addr%' to 'word%'. 'addr%' and 'word%' should be integers. POKE INTEGER will set the MMBasic integer (ie, 64 bits) at the memory location 'addr%' to int%. 'addr%' and int%' should be integers. POKE FLOAT will set the word (ie, 64 bits) at the memory location 'addr%' to 'float!'. 'addr%' should be an integer and 'float!' a floating point number. POKE VAR will set a byte in the memory address of 'var'. 'offset' is the ±offset from the address of the variable. An array is specified as var(). POKE VARTBL will set a byte in MMBasic's variable table. 'offset' is the ±offset from the start of the variable table. Note that a comma is required after the keyword VARTBL.</p>
<p>POLYGON n, xarray%(), yarray%() [, bordercolour] [, fillcolour] POLYGON n(), xarray%(), yarray%() [, bordercolour()] [, fillcolour()] POLYGON n(), xarray%(), yarray%() [, bordercolour] [, fillcolour]</p>	<p>Draws a filled or outline polygon with n xy-coordinate pairs in xarray%() and yarray%(). If 'fillcolour' is omitted then just the polygon outline is drawn. If 'bordercolour' is omitted then it will default to the current default foreground colour. If the last xy-coordinate pair is not the same as the first the firmware will automatically create an additional xy-coordinate pair to complete the polygon. The size of the arrays should be at least as big as the number of x,y coordinate pairs. 'n' can be an array and the colours can also optionally be arrays as follows: POLYGON n(), xarray%(), yarray%() [, bordercolour()] [, fillcolour()] POLYGON n(), xarray%(), yarray%() [, bordercolour] [, fillcolour] The size of the n array determines the number of polygons that will be drawn. The elements of array n() define the number of xy-coordinate pairs in each of the polygons. e.g DIM n(1)=(3,3) would define that 2 polygons are to be drawn with three vertices each. The xy-coordinate pairs for all the polygons are stored in xarray%() and yarray%(). The xarray%() and yarray%() parameters must have at least as many elements as the total of the values in the n array. Each polygon can be closed with the first and last elements the same. If the last element is not the same as the first the firmware will automatically create an additional xy-coordinate pair to complete the polygon. If fill colour is omitted then just the polygon outlines are drawn. The colour parameters can be a single value in which case all polygons are drawn in the same colour or they can be arrays with the same cardinality as n. In this case each polygon drawn can have a different colour of both border and/or fill. For example, this will draw 3 triangles in yellow, green and red: DIM c%(2)=(3,3,3) DIM x%(8)=(100,50,150,100,50,150,100,50,150) DIM y%(8)=(50,100,100,150,200,200,250,300,300) DIM fc%(2)=(rgb(yellow),rgb(green),rgb(red)) POLYGON c%(),x%(),y%(),fc%(),fc%()</p>
<p>PORT(start, nbr [,start, nbr]...) = value</p>	<p>Set a number of I/O pins simultaneously (ie, with one command). 'start' is an I/O pin number and the lowest bit in 'value' (bit 0) will be used to set that pin. Bit 1 will be used to set the pin 'start' plus 1, bit 2 will set pin</p>

	<p>'start'+2 and so on for 'nbr' number of bits. I/O pins used must be numbered consecutively and any I/O pin that is invalid or not configured as an output will cause an error. The start/nbr pair can be repeated if an additional group of output pins needed to be added.</p> <p>For example; PORT(15, 4, 23, 4) = &B10000011 Will set eight I/O pins. Pins 15 and 16 will be set high while 17, 18, 23, 24 and 25 will be set to a low and finally 26 will be set high.</p> <p>This command can be used to conveniently communicate with parallel devices like LCD displays. Any number of I/O pins (and therefore bits) can be used from 1 to the number of I/O pins on the chip.</p> <p>See the PORT function to simultaneously read from a number of pins.</p>
<p>PRINT expression [[,;]expression] ... etc</p>	<p>Outputs text to the console (either the VGA screen or the serial or both if they are available). Multiple expressions can be used and must be separated by either a:</p> <ul style="list-style-type: none"> • Comma (,) which will output the tab character • Semicolon (;) which will not output anything (it is just used to separate expressions). • Nothing or a space which will act the same as a semicolon. <p>A semicolon (;) at the end of the expression list will suppress the automatic output of a carriage return/ newline at the end of a print statement.</p> <p>When printed, a number is preceded with a space if positive or a minus (-) if negative but is not followed by a space. Integers (whole numbers) are printed without a decimal point while fractions are printed with the decimal point and the significant decimal digits. Large floating point numbers (greater than six digits) are printed in scientific number format.</p> <p>The function TAB() can be used to space to a certain column and the string functions can be used to justify or otherwise format strings.</p>
<p>PRINT #nbr, expression [[,;]expression] ... etc</p>	<p>Same as the normal PRINT command except that the output is directed to a file previously opened for OUTPUT or APPEND as '#nbr' or to a serial communications port previously opened as 'nbr'. See the OPEN command.</p>
<p>PRINT #GPS, string\$</p>	<p>Outputs a NMEA string to an opened GPS device. The string must start with a \$ character and end with a * character. The checksum is calculated automatically by the firmware and is appended to the string together with the carriage return and line feed characters.</p>
<p>PRINT @(x, y) expression Or PRINT @(x, y, m) expression</p>	<p>Same as the standard PRINT command except that the cursor is positioned at the coordinates x, y expressed in pixels.</p> <p>Example: PRINT @(150, 45) "Hello World"</p> <p>The @ function can be used anywhere in a print command.</p> <p>Example: PRINT @(150, 45) "Hello" @(150, 55) "World"</p> <p>The @(x,y) function can be used to position the cursor anywhere on or off the screen. For example, PRINT @(-10, 0) "Hello" will only show "llo" as the first two characters could not be shown because they were off the screen.</p> <p>The @(x,y) function will automatically suppress the automatic line wrap normally performed when the cursor goes beyond the right screen margin.</p> <p>If 'm' is specified the mode of the video operation will be as follows:</p> <ul style="list-style-type: none"> m = 0 Normal text (white letters, black background) m = 1 The background will not be drawn (ie, transparent) m = 2 The video will be inverted (black letters, white background) m = 5 Current pixels will be inverted (transparent background)

<p>PULSE pin, width</p>	<p>Will generate a pulse on 'pin' with duration of 'width' ms. 'width' can be a fraction. For example, 0.01 is equal to 10µs and this enables the generation of very narrow pulses.</p> <p>The generated pulse is of the opposite polarity to the state of the I/O pin when the command is executed. For example, if the output is set high the PULSE command will generate a negative going pulse. Notes:</p> <ul style="list-style-type: none"> • 'pin' must be configured as an output. • For a pulse of less than 3 ms the accuracy is $\pm 1 \mu\text{s}$. • For a pulse of 3 ms or more the accuracy is $\pm 0.5 \text{ ms}$. • A pulse of 3 ms or more will run in the background. Up to five different and concurrent pulses can be running in the background and each can have its time changed by issuing a new PULSE command or it can be terminated by issuing a PULSE command with zero for 'width'.
<p>PWM 1, freq, 1A PWM 1, freq, 1A, 1B PWM 1, freq, 1A, 1C</p> <p>PWM 2, freq, 2A PWM 2, freq, 2A, 2B PWM 2, freq, 2A, 2B, 2C</p> <p>PWM 3, freq, 3A PWM 3, freq, 3A, 3B</p> <p>PWM channel, STOP</p>	<p>Generate a pulse width modulated (PWM) output for driving analog circuits, sound output, etc.</p> <p>There are a total of eight outputs designated as PWM. (they are also used for the SERVO command). Controller 1 can have one, two or three outputs, controller 2 can have one, two or three outputs, while controller 3 can have one or two outputs. All three controllers are independent and can be turned on and off and have different frequencies.</p> <p>'1', '2' or '3' is the controller number and 'freq' is the output frequency . 1A, 1B and 1C are the duty cycle for each of the controller 1 outputs while 2A, 2B and 2C are the duty cycle for the controller 2 outputs. 3A and 3B are for controller 3. The specified I/O pins will be automatically configured as outputs while any others will be unaffected and can be used for other duties.</p> <p>The duty cycle for each output is independent of the others and is specified as a percentage. If it is close to zero the output will be a narrow positive pulse, if 50 a square wave will be generated and if close to 100 it will be a very wide positive pulse</p> <p>Minimum frequency is 1Hz, maximum is 24MHz. Duty cycle and frequency accuracy will depend on frequency. The frequency can be any value of 240,000,000. The output will run continuously in the background while the program is running and can be stopped using the STOP command. The frequency and duty cycle can be changed at any time (without stopping the output) by issuing a new PWM command.</p> <p>The PWM function will take control of any specified outputs and when stopped the pins will be returned to a high impedance "not configured" state.</p>
<p>RBOX x, y, w, h [, r] [,c] [,fill]</p>	<p>Draws a box with rounded corners on the VGA monitor starting at 'x' and 'y' which is 'w' pixels wide and 'h' pixels high.</p> <p>'r' is the radius of the corners of the box. It defaults to 10.</p> <p>'c' specifies the colour and defaults to the default foreground colour if not specified.</p> <p>'fill' is the fill colour. It can be omitted or set to -1 in which case the box will not be filled.</p> <p>All parameters can now be expressed as arrays and the software will plot the number of boxes as determined by the dimensions of the smallest array. 'x', 'y', 'w', and 'h' must all be arrays or all be single variables /constants otherwise an error will be generated. 'r', 'c', and 'fill' can be either arrays or single variables/constants.</p> <p>See the chapter "Basic Drawing Commands" for a definition of the colours and graphics coordinates.</p>

READ variable[, variable]...	Reads values from DATA statements and assigns these values to the named variables. Variable types in a READ statement must match the data types in DATA statements as they are read. See also DATA and RESTORE.
REM string	REM allows remarks to be included in a program. Note the Microsoft style use of the single quotation mark to denote remarks is also supported and is preferred.
RESTORE [line]	Resets the line and position counters for the READ statement. If 'line' is specified the counters will be reset to the beginning of the specified line. 'line' can be a line number or label. If 'line' is not specified the counters will be reset to the start of the program.
RMDIR dir\$	Remove, or delete, the directory 'dir\$' on the SD card.
RUN file\$ or RUN file\$, cmdline	Run the program 'file\$' held on the SD card. Note that 'file\$' must be a string constant (ie, "MYPROG.BAS") including the quotes required around a string constant. It cannot be a variable or expression. If 'cmdline' is specified it will be available to the running program as the string returned by MM.COMDLINES\$. 'cmdline' is not processed by MMBasic so it can contain numbers, commas, quoted strings, etc. It is the responsibility of the running program to decode this string of characters. 'file\$' can be omitted and in that case MMBasic will run the "current program name" which is the file last used by RUN, EDIT or AUTOSAVE.
SAVE DATA fname\$, address, size	Saves <i>size</i> bytes to file <i>fname\$</i> starting from <i>address</i> . Data is saved in raw binary format. Together with LOAD DATA this allows you to very easily to save and restore the contents of an array to and from disk. The code tries to protect you from crashing the system to the extent possible but there are many ways you can misuse the LOAD DATA command if you try. See LOAD DATA as well.
SAVE IMAGE file\$ [,x, y, w, h]	Save the current image on the LCD display as a 24-bit BMP file. 'file\$' is the name of the file. If an extension is not specified ".BMP" will be added to the file name. 'x', 'y', 'w' and 'h' are optional and are the coordinates (x and y are the top left coordinate) and dimensions (width and height) of the area to be saved. If not specified the whole screen will be saved.
SEEK [#]fnbr, pos	Will position the read/write pointer in a file that has been opened on the SD card for RANDOM access to the 'pos' byte. The first byte in a file is numbered one so SEEK #5,1 will position the read/write pointer to the start of the file.
SELECT CASE value CASE testexp [[, testexp] ...] <statements> <statements> CASE ELSE <statements> <statements>	Executes one of several groups of statements, depending on the value of an expression. 'value' is the expression to be tested. It can be a number or string variable or a complex expression. 'testexp' is the value that 'exp' is to be compared against. It can be: <ul style="list-style-type: none"> • A single expression (ie, 34, "string" or PIN(4)*5) to which it may equal • A range of values in the form of two single expressions separated by the keyword "TO" (ie, 5 TO 9 or "aa" TO "cc")

<p>END SELECT</p>	<ul style="list-style-type: none"> • A comparison starting with the keyword "IS" (which is optional). For example: IS > 5, IS <= 10. <p>When a number of test expressions (separated by commas) are used the CASE statement will be true if any one of these tests evaluates to true.</p> <p>If 'value' cannot be matched with a 'testexp' it will be automatically matched to the CASE ELSE. If CASE ELSE is not present the program will not execute any <statements> and continue with the code following the END SELECT.</p> <p>When a match is made the <statements> following the CASE statement will be executed until END SELECT or another CASE is encountered when the program will then continue with the code following the END SELECT.</p> <p>An unlimited number of CASE statements can be used but there must be only one CASE ELSE and that should be the last before the END SELECT.</p> <p>Example:</p> <pre> SELECT CASE nbr% CASE 4, 9, 22, 33 TO 88 statements CASE IS < 4, IS > 88, 5 TO 8 statements CASE ELSE statements END SELECT </pre> <p>Each SELECT CASE must have one and one only matching END SELECT statement. Any number of SELECT...CASE statements can be nested inside the CASE statements of other SELECT...CASE statements.</p>
<p>SERVO 1, freq, 1A SERVO, freq, 1A, 1B SERVO 1, freq, 1A, 1C</p> <p>SERVO 2, freq, 2A SERVO 2, freq, 2A, 2B SERVO 2, freq, 2A, 2B, 2C</p> <p>SERVO 3, freq, 3A SERVO 3, freq, 3A, 3B</p> <p>SERVO channel, STOP</p>	<p>Generate a constant stream of positive going pulses for driving a servo.</p> <p>The Armmite F4 has three servo controllers with the first and second being able to control up to three servos and the third two servos. All controllers are independent and can be turned on and off and have different frequencies. This command uses the I/O pins that are designated as PWM. (the two commands are very similar).</p> <p>'1', '2' or '3' is the controller number. 'freq' is the output frequency (between 20Hz and 1000 Hz) and is optional. If not specified it will default to 50 Hz</p> <p>1A, 1B and 1C are the pulse widths for each of the controller 1 outputs while 2A ,2B and 2C are the pulse widths for the controller 2 outputs. 3A and 3B are the output for controller 3. The specified I/O pins will be automatically configured as outputs while any others will be unaffected and can be used for other duties.</p> <p>The pulse width for each output is independent of the others and is specified in milliseconds, which can be a fractional number (ie, 1.536). For accurate positioning the output resolution is about 0.005 ms. The minimum value is 0.01ms while the maximum is 18.9ms. Most servos will accept a range of 0.8ms to 2.2ms. The output will run continuously in the background while the program is running and can be stopped using the STOP command. The pulse widths of the outputs can be changed at any time (without stopping the output) by issuing a new SERVO command.</p> <p>The SERVO function will take control of any specified outputs and when stopped the pins will be returned to a high impedance "not configured" state.</p>
<p>SETPIN pin, cfg [, option]</p>	<p>Will configure an external I/O pin.</p> <p>'pin' is the I/O pin to configure, 'cfg' is the mode that the pin is to be set to and 'option' is an optional parameter. 'cfg' is a keyword and can be any one of the following:</p>

	<p>OFF Not configured or inactive</p> <p>AIN Analog input (ie, measure the voltage on the input). 'option' can be used to specify the number of bits in the conversion. Valid values are 8, 10 and 12. The default (if not specified) is 12 bits. The more bits the longer the conversion will take. Valid for pins PA0, PA1, PA2, PA3, PC0, PC1, PC2, PC3, PA6, PA7, PC4, PC5, PB0</p> <p>DIN Digital input If 'option' is omitted the input will be high impedance If 'option' is the keyword "PULLUP" a simulated resistor will be used to pull up the input pin to 3.3V If the keyword "PULLDOWN" is used the pin will be pulled down to zero volts. The pull up/down is a constant current of about 50µA. Pull-up and pull-down resistors are designed with a true resistance in series with a switchable PMOS/NMOS. This MOS/NMOS contribution to the series resistance is minimum (~10% order) Valid for all available 47 pins</p> <p>FIN Frequency input 'option' can be used to specify the gate time (the length of time used to count the input cycles). It can be any number between 10 ms and 100000 ms. Note that the PIN() function will always return the frequency correctly scaled in Hz regardless of the gate time used. If 'option' is omitted the gate time will be 1 second. Valid for pins PE1, PE3, PE4, PA8</p> <p>PIN Period input 'option' can be used to specify the number of input cycles to average the period measurement over. It can be any number between 1 and 10000. Note that the PIN() function will always return the average period of one cycle correctly scaled in ms regardless of the number of cycles used for the average. If 'option' is omitted the period of just one cycle will be used. Valid for pins PE1, PE3, PE4, PA8</p> <p>CIN Counting input Valid for pins PE1, PE3, PE4, PA8</p> <p>DOUT Digital output 'option' can be "OC" in which case the output will be open collector (or more correctly open drain). The functions PIN() and PORT() can also be used to return the value on one or more output pins .</p> <p>Previous versions of MMBasic used numbers for 'cfg' and the mode OOUT. For backwards compatibility they will still be recognised.</p> <p>See the function PIN() for reading inputs and the statement PIN(= for setting an output. See the command below if an interrupt is configured.</p>
<p>SETPIN pin, cfg, target [, option]</p>	<p>Will configure 'pin' to generate an interrupt according to 'cfg'. Any I/O pin capable of digital input can be configured to generate an interrupt with a maximum of ten interrupts configured at any one time. 'cfg' is a keyword and can be any one of the following:</p> <p>OFF Not configured or inactive</p>

	<p>INTH Interrupt on low to high input INTL Interrupt on high to low input INTB Interrupt on both (ie, any change to the input)</p> <p>'target' is a user defined subroutine which will be called when the event happens. Return from the interrupt is via the END SUB or EXIT SUB commands. 'option' can be the keywords "PULLUP" or "PULLDOWN" as specified for a normal input pin (SETPIN pin DIN). If 'option' is omitted the input will be high impedance.</p> <p>This mode also configures the pin as a digital input so the value of the pin can always be retrieved using the function PIN().</p>
SETTICK period, target [, nbr]	<p>This will setup a periodic interrupt (or "tick"). Four tick timers are available ('nbr' = 1, 2, 3 or 4). 'nbr' is optional and defaults to timer number 1.</p> <p>The time between interrupts is 'period' milliseconds and 'target' is the interrupt subroutine which will be called when the timed event occurs. The period can range from 1 to 2147483647 ms (about 24 days).</p> <p>These interrupts can be disabled by setting 'period' to zero (ie, SETTICK 0, 0, 3 will disable tick timer number 3).</p>
SORT array() [,indexarray] [,flags] [,startposition] [,elementstosort]	<p>This command takes an array of any type (integer, float or string) and sorts it into ascending order in place.</p> <p>It has an optional parameter 'indexarray%()'. If used this must be an integer array of the same size as the array to be sorted. After the sort this array will contain the original index position of each element in the array being sorted before it was sorted. Any data in the array will be overwritten.</p> <p>flag values are: bit0: 0 (default if omitted) normal sort - 1 reverse sort bit1: 0 (default) case dependent - 1 sort is case independent</p> <p>startposition defines which element in the array to start the sort. Default is 0 (OPTION BASE 0) or 1 (OPTION BASE 1)</p> <p>elementstosort defines how many elements in the array should be sorted. Default is all elements after the startposition</p> <p>This allows connected arrays to be sorted. See the section <i>Sorting Data</i> in the tutorial Programming with the Colour Maximite 2 for an example.</p>
SPI OPEN speed, mode, bits or SPI READ nbr, array() or SPI WRITE nbr, data1, data2, data3, ... etc or SPI WRITE nbr, string\$ or SPI WRITE nbr, array() or SPI CLOSE	<p>Communications via an SPI channel. The command SPI refers to channel 1. The command SPI2 refers to channel 2 and has an identical syntax.</p> <p>'nbr' is the number of data items to send or receive</p> <p>'data1', 'data2', etc can be float or integer and in the case of WRITE can be a constant or expression.</p> <p>If 'string\$' is used 'nbr' characters will be sent.</p> <p>'array' must be a single dimension float or integer array and 'nbr' elements will be sent or received.</p> <p>See Appendix D for the details.</p>

SPI2	As for SPI but for the second channel.
<p>STATIC variable [, variables] See DIM for the full syntax.</p>	<p>Defines a list of variable names which are local to the subroutine or function. These variables will retain their value between calls to the subroutine or function (unlike variables created using the LOCAL command).</p> <p>This command uses exactly the same syntax as DIM. The only difference is that the length of the variable name created by STATIC and the length of the subroutine or function name added together cannot exceed 32 characters.</p> <p>Static variables can be initialised to a value. This initialisation will take effect only on the first call to the subroutine (not on subsequent calls).</p>
<p>SUB xxx (arg1 [,arg2, ...]) <statements> <statements> END SUB</p>	<p>Defines a callable subroutine. This is the same as adding a new command to MMBasic while it is running your program.</p> <p>'xxx' is the subroutine name and it must meet the specifications for naming a variable.</p> <p>'arg1', 'arg2', etc are the arguments or parameters to the subroutine. An array is specified by using empty brackets. ie, arg3(). The type of the argument can be specified by using a type suffix (ie, arg1\$) or by specifying the type using AS <type> (ie, arg1 AS STRING).</p> <p>Every definition must have one END SUB statement. When this is reached the program will return to the next statement after the call to the subroutine. The command EXIT SUB can be used for an early exit.</p> <p>You use the subroutine by using its name and arguments in a program just as you would a normal command. For example: MySub a1, a2</p> <p>When the subroutine is called each argument in the caller is matched to the argument in the subroutine definition. These arguments are available only inside the subroutine. Subroutines can be called with a variable number of arguments. Any omitted arguments in the subroutine's list will be set to zero or a null string.</p> <p>Arguments in the caller's list that are a variable (ie, not an expression or constant) will be passed by reference to the subroutine. This means that any changes to the corresponding argument in the subroutine will also be copied to the caller's variable and therefore may be accessed after the subroutine has ended. Arrays are passed by specifying the array name with empty brackets (eg, arg()) and are always passed by reference. Brackets around the argument list in both the caller and the definition are optional.</p>
<p>SYNC [period] [,units]</p>	<p>The SYNC command with parameters sets up a fast timer and stores the period. The SYNC command without parameters waits for the timer to reach the period specified and then resets the timer and returns. As this all happens in the firmware the timing period is extremely accurate.</p> <p>Valid units are: If parameter is omitted: the period is expressed in raw clock counts 1/84,000,000 seconds U or u: the period is expressed in microseconds M or m: the period is expressed in milliseconds S or s: the period is expressed in seconds</p> <p>In all cases the maximum period allowed is just over 51 seconds but, of course, for longer periods there are lots of other ways of doing this. The command is specifically targeted at short periods.</p> <p>This code below will toggle a pin at 100 uSec intervals.</p> <pre> SYNC 100,u DO </pre>

	<pre> SYNC pin(PC2)=1 SYNC pin(PC2)=0 LOOP </pre>
<pre> TEMPR START pin [, precision] </pre>	<p>This command can be used to start a conversion running on a DS18B20 temperature sensor connected to 'pin'.</p> <p>Normally the TEMPR() function alone is sufficient to make a temperature measurement so usage of this command is optional.</p> <p>This command will start the measurement on the temperature sensor. The program can then attend to other duties while the measurement is running and later use the TEMPR() function to get the reading. If the TEMPR() function is used before the conversion time has completed the function will wait for the remaining conversion time before returning the value.</p> <p>Any number of these conversions (on different pins) can be started and be running simultaneously.</p> <p>'precision' is the resolution of the measurement and is optional. It is a number between 0 and 3 meaning:</p> <ul style="list-style-type: none"> 0 = 0.5°C resolution, 100 ms conversion time. 1 = 0.25°C resolution, 200 ms conversion time (this is the default). 2 = 0.125°C resolution, 400 ms conversion time. 3 = 0.0625°C resolution, 800 ms conversion time.
<pre> TEXT x, y, string\$ [,alignment\$] [, font] [, scale] [, c] [, bc] </pre>	<p>Displays a string on the VGA monitor starting at 'x' and 'y'.</p> <p>'string\$' is the string to be displayed. Numeric data should be converted to a string and formatted using the Str\$() function.</p> <p>'alignment\$' is a string expression or string variable consisting of 0, 1 or 2 letters where the first letter is the horizontal alignment around 'x' and can be L, C or R for LEFT, CENTER, RIGHT and the second letter is the vertical alignment around 'y' and can be T, M or B for TOP, MIDDLE, BOTTOM. The default alignment is left/top.</p> <p>A third letter can be used in the alignment string to indicate the rotation of the text. This can be 'N' for normal orientation, 'V' for vertical text with each character under the previous running from top to bottom, 'I' the text will be inverted (ie, upside down), 'U' the text will be rotated counter clockwise by 90° and 'D' the text will be rotated clockwise by 90°</p> <p>'font' and 'scale' are optional and default to that set by the FONT command.</p> <p>'c' is the drawing colour and 'bc' is the background colour. They are optional and default to the current foreground and background colours.</p> <p>See the chapter "Basic Drawing Commands" for a definition of the colours and graphics coordinates.</p>
<pre> TIME\$ = "HH:MM:SS" or TIME\$ = "HH:MM" or TIME\$ = "HH" </pre>	<p>Sets the time of the internal clock. MM and SS are optional and will default to zero if not specified. For example TIME\$ = "14:30" will set the clock to 14:30 with zero seconds.</p> <p>The time is set to "00:00:00" on first power up however the time will be remembered and kept updated as long as the battery is installed and can maintain a voltage of over 2.5V. Battery life should be 3 to 4 years even if the computer is powered off.</p>
<pre> TIME\$ = ±sec </pre>	<p>Adds or subtracts 'sec' seconds from the current time being maintained by MMBasic. This makes it easier to fine tune the current time.</p>

<p>TIMER = msec</p>	<p>Resets the timer to a number of milliseconds. Normally this is just used to reset the timer to zero but you can set it to any positive integer.</p> <p>See the TIMER function for more details.</p>
<p>TRACE ON or TRACE OFF or TRACE LIST nn</p>	<p>TRACE ON/OFF will turn on/off the trace facility. This facility will print the number of each line (counting from the beginning of the program) in square brackets as the program is executed. This is useful in debugging programs.</p> <p>TRACE LIST will list the last 'nn' lines executed in the format described above. MMBasic is always logging the lines executed so this facility is always available (ie, it does not have to be turned on).</p>
<p>TRIANGLE X1, Y1, X2, Y2, X3, Y3 [, C [, FILL]]</p>	<p>Draws a triangle on the VGA monitor with the corners at X1, Y1 and X2, Y2 and X3, Y3. 'C' is the colour of the triangle and defaults to the current foreground colour. 'FILL' is the fill colour and defaults to no fill (it can also be set to -1 for no fill).</p> <p>All parameters can be expressed as arrays and the software will plot the number of triangles as determined by the dimensions of the smallest array. 'x1', 'y1', 'x2', 'y2', 'x3', and 'y3' must all be arrays or all be single variables /constants otherwise an error will be generated 'c' and 'fill' can be either arrays or single variables/constants.</p>
<p>VAR SAVE var [, var]... or VAR RESTORE or VAR CLEAR</p>	<p>VAR SAVE will save one or more variables into battery backed-up ram. They can be restored later (normally after a power interruption).</p> <p>'var' can be any number of numeric or string variables and/or arrays. Arrays are specified by using empty brackets. For example: var()</p> <p>VAR RESTORE will retrieve the previously saved variables and insert them (and their values) into the variable table.</p> <p>The VAR SAVE command can be used repeatedly. Variables that had been previously saved will be updated with their new value and any new variables (not previously saved) will be added to the saved list for later restoration.</p> <p>VAR CLEAR will erase all saved variables. Also, the saved variables will be automatically cleared by the NEW command or when a new program is loaded via AUTOSAVE, XMODEM, etc.</p> <p>This command is normally used to save calibration data, options, and other data which needs to be retained across a power interruption. Normally the VAR RESTORE command is placed at the start of the program so that previously saved variables are restored and immediately available to the program when it starts.</p> <p>Notes:</p> <ul style="list-style-type: none"> • The storage space available to this command is 4KB. The memory used is battery backed RAM which operates at high speed and can be written to an unlimited number of times without restriction (unlike the Micromite). • Using VAR RESTORE without a previous save will have no effect and will not generate an error. • If, when using RESTORE, a variable with the same name already exists its value will be overwritten. • Saved arrays must be declared (using DIM) before they can be restored. • Be aware that string arrays can rapidly use up all the memory allocated to this command. The LENGTH qualifier can be used when a string array is declared to reduce the size of the array (see the DIM command). This is not needed for ordinary string variables.

WATCHDOG timeout or WATCHDOG OFF	<p>Starts the watchdog timer which will automatically restart the processor when it has timed out. This can be used to recover from some event that disabled the running program (such as an endless loop or a programming or other error that halts a running program). This can be important in an unattended control situation.</p> <p>'timeout' is the time in milliseconds (ms) before a restart is forced. This command should be placed in strategic locations in the running BASIC program to constantly reset the watchdog timer and therefore prevent it from counting down to zero.</p> <p>If the timer count does reach zero (perhaps because the BASIC program has stopped running) the Maximite will be restarted and the automatic variable MM.WATCHDOG will be set to true (ie, 1) indicating that an error occurred. On a normal startup MM.WATCHDOG will be set to false (ie, 0).</p> <p>WATCHDOG OFF will disable the watchdog timer (this is the default on a reset or power up). The timer is also turned off when the break character (normally CTRL-C) is used on the console to interrupt a running program.</p>
WHILE	
WS2812	<p>This command outputs the required signals to drive one or more WS2812 LED chips connected to 'pin'. Note that the pin must be set to a digital output before this command is used.</p> <p>'type' is a single character specifying the type of chip being driven:</p> <ul style="list-style-type: none"> O = original WS2812 B = WS2812B S = SK6812 <p>The 'colours%()' array should be an integer array sized to have exactly the same number of elements as the number of LEDs to be driven. Each element in the array should contain the colour in the normal RGB888 format (ie, 0 to &HFFFFFF).</p> <p>dim b%(6)=(rgb(red), rgb(green), rgb(blue), rgb(Yellow), rgb(cyan), rgb(magenta), rgb(white))</p> <p>setpin 1,dout</p> <p>ws2812 1,b%()</p> <p>will output the specified colours to an array of 7 WS2812 LEDs</p>
XMODEM SEND or XMODEM RECEIVE or XMODEM CRUNCH XMODEM SEND file\$ or XMODEM RECEIVE file\$	<p>Transfers a BASIC program to or from a remote computer using the XModem protocol. The transfer is done over the serial console connection. XMODEM SEND will send the current program held in the Armmite's program memory to the remote device. XMODEM RECEIVE will accept a program sent by the remote device and save it into the Micromite's program memory overwriting the program currently held there. Note that the data is buffered in RAM which limits the maximum program size.</p> <p>The CRUNCH option works like RECEIVE but it instructs MMBasic to remove all comments, blank lines and unnecessary spaces from the program before saving. This can be used on large programs to allow them to fit into limited memory.</p> <p>SEND, RECEIVE and CRUNCH can be abbreviated to S, R and C.</p> <p>You can also specify 'file\$' which will transfer the data to/from a file on the SD card. If the file already exists it will be overwritten when receiving a file.</p> <p>The XModem protocol requires a cooperating software program running on the remote computer and connected to its serial port. It has been tested on</p>

	<p>Tera Term running on Windows and it is recommended that this be used. After running the XMODEM command in MMBasic select: File -> Transfer -> XMODEM -> Receive/Send from the Tera Term menu to start the transfer.</p> <p>The transfer can take up to 15 seconds to start and if the XMODEM command fails to establish communications it will return to the MMBasic prompt after 60 seconds and leave the program memory untouched.</p> <p>Download Tera Term from http://ttssh2.sourceforge.jp/</p>
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Functions

Note that the functions related to communications functions (I²C, 1-Wire, and SPI) are not listed here but are described in the appendices at the end of this document.

Square brackets indicate that the parameter or characters are optional.

ABS(number)	Returns the absolute value of the argument 'number' (ie, any negative sign is removed and the positive number is returned).
ACOS(number)	Returns the inverse cosine of the argument 'number' in radians.
AND	
AS	
ASC(string\$)	Returns the ASCII code for the first letter in the argument 'string\$'.
ASIN(number)	Returns the inverse sine value of the argument 'number' in radians.
ATAN2(y, x)	Returns the arc tangent of the two numbers x and y as an angle expressed in radians. It is similar to calculating the arc tangent of y / x, except that the signs of both arguments are used to determine the quadrant of the result.
ATN(number)	Returns the arctangent of the argument 'number' in radians.
BAUDRATE(comm [, timeout])	Returns the baudrate of any data received on the serial communications port 'comm'). This will sample the port over the period of 'timeout' seconds. 'timeout' will default to one second if not specified. Returns zero if no activity on the port within the timeout period.
BIN\$(number [, chars])	Returns a string giving the binary (base 2) value for the 'number'. 'chars' is optional and specifies the number of characters in the string with zero as the leading padding character(s).
BIN2STR\$(type, value [,BIG])	Returns a string containing the binary representation of 'value'. 'type' can be: INT64 signed 64-bit integer converted to an 8 byte string UINT64 unsigned 64-bit integer converted to an 8 byte string INT32 signed 32-bit integer converted to a 4 byte string UINT32 unsigned 32-bit integer converted to a 4 byte string INT16 signed 16-bit integer converted to a 2 byte string UINT16 unsigned 16-bit integer converted to a 2 byte string INT8 signed 8-bit integer converted to a 1 byte string UINT8 unsigned 8-bit integer converted to a 1 byte string SINGLE single precision floating point number converted to a 4 byte string DOUBLE double precision floating point number converted to a 8 byte string By default the string contains the number in little-endian format (ie, the least significant byte is the first one in the string). Setting the third parameter to 'BIG' will return the string in big-endian format (ie, the most significant byte is the first one in the string) In the case of the integer conversions, an

	<p>error will be generated if the 'value' cannot fit into the 'type' (eg, an attempt to store the value 400 in a INT8).</p> <p>This function makes it easy to prepare data for efficient binary file I/O or for preparing numbers for output to sensors and saving to flash memory.</p> <p>See also the function STR2BIN</p>
BOUND(array() [,dimension])	<p>This returns the upper limit of the array for the dimension requested.</p> <p>The dimension defaults to one if not specified. Specifying a dimension value of 0 will return the current value of OPTION BASE.</p> <p>Unused dimensions will return a value of zero.</p> <p>For example: DIM myarray(44,45) BOUND(myarray(),2) will return 45</p>
CHOICE(condition, ExpressionIfTrue, ExpressionIfFalse)	<p>This function allows you to do simple either or selections much more efficiently and faster than using IF THEN ELSE ENDIF clauses.</p> <p>The condition is anything that will resolve to nonzero (true) or zero (false) The expressions are anything that you could normally assign to a variable or use in a command.</p> <p>e.g. print choice(1, "hello","bye") will print "Hello" print choice(0, "hello","bye") will print "Bye" a=1:b=1:print choice(a=b, "hello","bye") will print "Hello"</p>
CHR\$(number)	<p>Returns a one-character string consisting of the character corresponding to the ASCII code indicated by argument 'number'.</p>
CINT(number)	<p>Round numbers with fractional portions up or down to the next whole number or integer.</p> <p>For example, 45.47 will round to 45 45.57 will round to 46 -34.45 will round to -34 -34.55 will round to -35</p> <p>See also INT() and FIX().</p>
COS(number)	<p>Returns the cosine of the argument 'number' in radians.</p>
CTRLVAL(#ref)	<p>Returns the current value of an advanced control.</p> <p>#ref' is the control's reference.</p> <p>For controls like check boxes or switches it will be the number one (true) indicating that the control has been selected by the user or zero (false) if not. For controls that hold a number (eg, a SPINBOX) the value will be the number (normally a floating point number). For controls that hold a string (eg, TEXTBOX) the value will be a string.</p>
CWD\$	<p>Returns the current working directory on the SD card as a string.</p> <p>The format is: A:/dir1/dir2.</p>
DATES\$	<p>Reads the RTC and returns the date as a string in the form "dd-mm-yyyy"</p>

DATETIMES\$(n)	Returns the date and time corresponding to the epoch number n (number of seconds that have elapsed since midnight GMT on January 1, 1970). The format of the returned string is “dd-mm-yyyy hh:mm:ss”. Use the text NOW to get the current datetime string, i.e. ? DATETIMES\$(NOW)
DAYS\$(date\$)	Returns the day of the week for a given date as a string “Monday”, “Tuesday” etc. The format for date\$ is “dd-mm-yyyy”. Use NOW to get the day for the current date, e.g. ? DAYS\$(NOW)
DEG(radians)	Converts 'radians' to degrees.
DIR\$(fspec, type) or DIR\$(fspec) or DIR\$()	<p>Will search an SD card for files and return the names of entries found. 'fspec' is a file specification using wildcards the same as used by the FILES command. Eg, "*. *" will return all entries, "*.TXT" will return text files. 'type' is the type of entry to return and can be one of:</p> <p>ALL Search for both files and directories DIR Search for directories only FILE Search for files only (the default if 'type' is not specified)</p> <p>The function will return the first entry found. To retrieve subsequent entries use the function with no arguments. ie, DIR\$(). The return of an empty string indicates that there are no more entries to retrieve.</p> <p>This example will print all the files in a directory:</p> <pre>f\$ = DIR\$("*. *", FILE) DO WHILE f\$ <> "" PRINT f\$ f\$ = DIR\$() LOOP</pre> <p>You must change to the required directory before invoking this command.</p>
DISTANCE(trigger, echo) or DISTANCE(trig-echo)	<p>Measure the distance to a target using the HC-SR04 ultrasonic distance sensor.</p> <p>Four pin sensors have separate trigger and echo connections. 'trigger' is the I/O pin connected to the "trig" input of the sensor and 'echo' is the pin connected to the "echo" output of the sensor.</p> <p>Three pin sensors have a combined trigger and echo connection and in that case you only need to specify one I/O pin to interface to the sensor.</p> <p>Note that any I/O pins used with the HC-SR04 should be 5V capable as the HC-SR04 is a 5V device. The I/O pins are automatically configured by this function and multiple sensors can be used on different I/O pins.</p> <p>The value returned is the distance in centimetres to the target or -1 if no target was detected or -2 if there was an error (ie, sensor not connected).</p>
ELSE	Part of IF – ELSE – ENDIF construction. See IF command
EOF([#]nbr)	<p>Will return true if the file previously opened on the SD card for INPUT with the file number ‘#nbr’ is positioned at the end of the file.</p> <p>For a serial communications port this function will return true if there are no characters waiting in the receive buffer. #0 can be used which refers to the console's input buffer.</p> <p>The # is optional. Also see the OPEN, INPUT and LINE INPUT commands and the INPUT\$ function.</p>

EPOCH(DATETIMES\$)	Returns the epoch number (number of seconds that have elapsed since midnight GMT on January 1, 1970) for the supplied DATETIMES\$ string. The format for DATETIMES\$ is "dd-mm-yyyy hh:mm:ss". Use NOW to get the epoch number for the current date and time, i.e. ? EPOCH(NOW)
EVAL(string\$)	Will evaluate 'string\$' as if it is a BASIC expression and return the result. 'string\$' can be a constant, a variable or a string expression. The expression can use any operators, functions, variables, subroutines, etc that are known at the time of execution. The returned value will be an integer, float or string depending on the result of the evaluation. For example: S\$ = "COS (RAD (30)) * 100" : PRINT EVAL (S\$) Will display: 86.6025
EXP(number)	Returns the exponential value of 'number', ie, e ^x where x is 'number'.
FIELD\$(string1, nbr, string2 [, string3])	Returns a particular field in a string with the fields separated by delimiters. 'nbr' is the field to return (the first is nbr 1). 'string1' is the string to search and 'string2' is a string holding the delimiters (more than one can be used). 'string3' is optional and if specified will include characters that are used to quote text in 'string1' (ie, quoted text will not be searched for a delimiter). For example: s1 = "foo, boo, zoo, doo" r\$ = FIELD\$(s1, 2, ",") will result in r\$ = "boo". While: s1 = "foo, 'boo, zoo', doo" r\$ = FIELD\$(s1, 2, ",", "'") will result in r\$ = "' boo, zoo'".
FIX(number)	Truncate a number to a whole number by eliminating the decimal point and all characters to the right of the decimal point. For example 9.89 will return 9 and -2.11 will return -2. The major difference between FIX and INT is that FIX provides a true integer function (ie, does not return the next lower number for negative numbers as INT() does). This behaviour is for Microsoft compatibility. See also CINT() .
FOR	Part of the <i>FOR x=a TO b STEP c : NEXT</i> construction See FOR in command section See NEXT in command section
GETSCANLINE	This will report on the line that is currently being drawn on the VGA monitor. Using this to time updates to the screen can avoid timing effects caused by updates while the screen is being updated.
GOSUB GOTO	See obsolete commands.Jumps to a sub routine or label.
GPS()	The GPS functions are used to return data from a serial communications channel opened as GPS. The function GPS(VALID) should be checked before any of these functions are used to ensure that the returned value is valid.

GPS(ALTITUDE)	returns current altitude if sentence GGA enabled
GPS(DATE)	returns the normal date string corrected for local time e.g. "12-01-2017"
GPS(DOP)	returns DOP (dilution of precision) value if sentence GGA enabled
GPS(FIX)	returns 0=no fix, 1=fix, etc. if sentence GGA enabled
GPS(GEOID)	Returns the geoid-ellipsoid separation. if sentence GGA enabled
GPS(LATITUDE)	returns the latitude in degrees as a floating point number, values are -ve for South of equator
GPS LONGITUDE)	returns the longitude in degrees as a floating point number, values are -ve for West of the meridian
GPS(SATELLITES)	returns number of satellites in view if sentence GGA enabled
GPS(SPEED)	returns the ground speed in knots as a floating point number
GPS(TIME)	returns the normal time string corrected for local time e.g. "12:09:33"
GPS(TRACK)	returns the track over the ground (degrees true) as a floating point number
GPS(VALID)	<p>returns: 0=invalid data, 1=valid data. ALWAYS CHECK THIS VALUE TO ENSURE DATA IS VALID BEFORE USING OTHER GPS() FUNCTION CALLS</p> <p>GPS will accept \$GNGGA and \$GNRMC as well as \$GPGGA and \$GPRMC strings.</p>
HEX\$(number [, chars])	Returns a string giving the hexadecimal (base 16) value for the 'number'. 'chars' is optional and specifies the number of characters in the string with zero as the leading padding character(s).
INKEY\$	<p>Checks the console input buffer and, if there is one or more characters waiting in the queue, will remove the first character and return it as a single character in a string. If this is a carriage return, it is likely that there will be a line feed character following as often the enter key will produce a CR/LF pair.</p> <p>If the input buffer is empty this function will immediately return with an empty string (ie, "").</p>
INPUT\$(nbr, [#]fnbr)	<p>Will return a string composed of 'nbr' characters read from a file on the SD card previously opened for INPUT with the file number '#fnbr'. This function will read all characters including carriage return and new line without translation.</p> <p>Will return a string composed of 'nbr' characters read from a serial communications port opened as 'fnbr'. This function will return as many characters as are waiting in the receive buffer up to 'nbr'. If there are no characters waiting it will immediately return with an empty string.</p>

	<p>#0 can be used which refers to the console's input buffer. The # is optional. Also see the OPEN command.</p>
INSTR([start-position,] string-searched\$, string-pattern\$)	<p>Returns the position at which 'string-pattern\$' occurs in 'string-searched\$', beginning at 'start-position'.</p> <p>Both the position returned and 'start-position' use 1 for the first character, 2 for the second, etc. The function returns zero if 'string-pattern\$' is not found.</p>
INT(number)	<p>Truncate an expression to the next whole number less than or equal to the argument. For example 9.89 will return 9 and -2.11 will return -3.</p> <p>This behaviour is for Microsoft compatibility, the FIX() function provides a true integer function.</p> <p>See also CINT() .</p>
INV	See Operators section
JSON\$(array%(), string\$)	<p>Returns a string representing a specific item out of the JSON input stored in the longstring array%()</p> <p>e.g.</p> <p>JSON\$(a%(), "name") JSON\$(a%(), "coord.lat") JSON\$(a%(), "weather[0].description") JSON\$(a%(), "list[4].weather[0].description")</p> <p>Examples taken from api.openweathermap.org</p> <p><i>Many JSON data sets are quite large and may be too big to parse with the memory available to the Armmite F4. Where the memory is exhausted the effect on the Armmite F4 may be unpredictable, however if there is an issue the firmware will attempt to force a software reset and print a relevant error.</i></p> <p>If the data set you are working with is too large and can't be made smaller another approach will be required.</p>
LCASE\$(string\$)	Returns 'string\$' converted to lowercase characters.
LCOMPARE(array1%(), array2%())	<p>Compare the contents of two long string variables array1%() and array2%(). The returned is an integer and will be -1 if array1%() is less than array2%(). It will be zero if they are equal in length and content and +1 if array1%() is greater than array2%(). The comparison uses the ASCII character set and is case sensitive.</p>
LEFT\$(string\$, nbr)	Returns a substring of 'string\$' with 'nbr' of characters from the left (beginning) of the string.
LEN(string\$)	Returns the number of characters in 'string\$'.
LGETBYTE(array%(), n)	Returns the numerical value of the 'n'th byte in the LONGSTRING held in 'array%()'. This function respects the setting of OPTION BASE in determining which byte to return.
LGETSTR\$(array%(), start,	Returns part of a long string stored in array%() as a normal MMBasic string.

length)	The parameters start and length define the part of the string to be returned.
LINSTR(array%(), search\$ [start])	Returns the position of a search string in a long string. The returned value is an integer and will be zero if the substring cannot be found. array%() is the string to be searched and must be a long string variable. Search\$ is the substring to look for and it must be a normal MMBasic string or expression (not a long string). The search is case sensitive. Normally the search will start at the first character in 'str' but the optional third parameter allows the start position of the search to be specified.
LLEN(array%())	Returns the length of a long string stored in array%()
LOC([#]fnbr)	For a file on the SD card opened as RANDOM this will return the current position of the read/write pointer in the file. Note that the first byte in a file is numbered 1. For a serial communications port opened as 'fnbr' this function will return the number of bytes received and waiting in the receive buffer to be read. #0 can be used which refers to the console's input buffer. The # is optional.
LOF([#]fnbr)	For a file on the SD card this will return the current length of the file in bytes. For a serial communications port opened as 'fnbr' this function will return the space (in characters) remaining in the transmit buffer. Note that when the buffer is full MMBasic will pause when adding a new character and wait for some space to become available. The # is optional.
LOG(number)	Returns the natural logarithm of the argument 'number'.
MATH	The math function performs many simple mathematical calculations that can be programmed in Basic but there are speed advantages to coding looping structures in C and there is the advantage that once debugged they are there for everyone without re-inventing the wheel.
Simple functions	
MATH(ATAN3 x,y)	Returns ATAN3 of x and y
MATH(COSH a)	Returns the hyperbolic cosine of a
MATH(LOG10 a)	Returns the base 10 logarithm of a
MATH(SINH a)	Returns the hyperbolic sine of a
MATH(TANH a)	Returns the hyperbolic tan of a
Simple Statistics	
MATH(CHI a())	Returns the Pearson's chi-squared value of the two dimensional array a())
MATH(CHI_p a())	Returns the associated probability in % of the Pearson's chi-squared value of the two dimensional array a())

MATH(MAX a())	Returns the maximum of all values in the a() array, a() can have any number of dimensions
MATH(MEAN a())	Returns the average of all values in the a() array, a() can have any number of dimensions
MATH(MEDIAN a())	returns the median of all values in the a() array, a() can have any number of dimensions
MATH(MIN a())	Returns the minimum of all values in the a() array, a() can have any number of dimensions
MATH(SD a())	Returns the standard deviation of all values in the a() array, a() can have any number of dimensions
MATH(SUM a())	Returns the sum of all values in the a() array, a() can have any number of dimensions
Vector Arithmetic MATH(MAGNITUDE v())	Returns the magnitude of the vector v(). The vector can have any number of elements
MATH(DOTPRODUCT v1(), v2())	Returns the dot product of two vectors v1() and v2(). The vectors can have any number of elements but must have the same cardinality
MAX(arg1 [, arg2 [, ...]]) or MIN(arg1 [, arg2 [, ...]])	Returns the maximum or minimum number in the argument list. Note that the comparison is a floating point comparison (integer arguments are converted to floats) and a float is returned.
MID\$(string\$, start) or MID\$(string\$, start, nbr)	Returns a substring of 'string\$' beginning at 'start' and continuing for 'nbr' characters. The first character in the string is number 1. If 'nbr' is omitted the returned string will extend to the end of 'string\$'
MOD	Operator implementing the mathematical MOD operator, which return the remainder after division of two number.e.g ? 10 MOD 4 Returns 2 See Operators section
MSGBOX (msg\$, b1\$ [,b2\$... b4\$])	This function will display a message box on the screen with one to four touch sensitive buttons. All other controls will be disabled until the user touches one of the buttons. The message box will then be erased, the previous controls will be restored and the function will return the number of the button touched (the first button is number one) 'msg\$' is the message to display. This can contain one or more tilde characters (~) which indicate a line break. Up to 10 lines can be displayed inside the box. 'b1\$' is the caption for the first button, 'b2\$' is the caption for the second button, etc. At least one button must be specified and four is the maximum. Any buttons not included in the argument list will not be displayed.
NOT	See Operators section

OCT\$(number [, chars])	Returns a string giving the octal (base 8) representation of 'number'. 'chars' is optional and specifies the number of characters in the string with zero as the leading padding character(s).
OR	See Operators section
PEEK(BYTE addr%) PEEK(SHORT addr%) PEEK(WORD addr%) PEEK(INTEGER addr%) PEEK(FLOAT addr%) PEEK(VARADDR var) PEEK(VAR var, ±offset) PEEK(VARTBL, ±offset) PEEK(PROGMEM, ±offset)	Will return a byte or a word within the CPU's virtual memory space. BYTE will return the byte (8-bits) located at 'addr%' SHORT will return the short integer (16-bits) located at 'addr%' WORD will return the word (32-bits) located at 'addr%' INTEGER will return the integer (64-bits) located at 'addr%' FLOAT will return the floating point number (64-bits) located at 'addr%' VARADDR will return the address (32-bits) of the variable 'var' in memory. An array is specified as var(). VAR, will return a byte in the memory allocated to 'var'. An array is specified as var(). VARTBL, will return a byte in the memory allocated to the variable table maintained by MMBasic. Note that there is a comma after VARTBL. PROGMEM, will return a byte in the memory allocated to the program. Note that there is a comma after the keyword PROGMEM. Note that 'addr%' should be an integer.
PI	Returns the value of pi.
PIN(pin)	Returns the value on the external I/O 'pin'. Zero means digital low, 1 means digital high and for analog inputs it will return the measured voltage as a floating point number. Frequency inputs will return the frequency in Hz. A period input will return the period in milliseconds while a count input will return the count since reset (counting is done on the positive rising edge). The count input can be reset to zero by resetting the pin to counting input (even if it is already so configured). This function will also return the state of a pin configured as an output. Also see the SETPIN and PIN() = commands.
PIN(function)	Returns the value of a special function. 'function' is a string (ie, it can be a string variable or string constant). For example PRINT PIN("BAT"). It can be one of: "BAT" The voltage of the backup battery. "TEMP" The temperature of the STM32 processor's core. "DAC1" The output voltage of DAC1 (on the audio output). "DAC2" The output voltage of DAC2 (on the audio output). "SREF" The stored calibrated value of the internal reference voltage measured with a supply of exactly 3.3V. This is programmed into the chip during production. "IREF" The measured value of the internal reference voltage. The actual value of VREF+ can be calculated as: $3.3 * \text{PIN}(\text{"SREF"}) / \text{PIN}(\text{"IREF"})$ and this can be used to set OPTION VCC.

	<p>“VDDA” Returns the value of the external analogue reference voltage (VREF+/VDDA pin) by using a known value of the internal reference. Use OPTION VCC pin(VDDA) to set analogue measurements to accurately compensate for the actual value of the external reference.</p>
PIXEL(x, y)	<p>Returns the colour of a pixel on the VGA monitor. 'x' is the horizontal coordinate and 'y' is the vertical coordinate of the pixel. See the chapter "Basic Drawing Commands" for a definition of the colours and graphics coordinates.</p>
PORT(start, nbr [,start, nbr]...)	<p>Returns the value of a number of I/O pins in one operation.</p> <p>'start' is an I/O pin number and its value will be returned as bit 0. 'start'+1 will be returned as bit 1, 'start'+2 will be returned as bit 2, and so on for 'nbr' number of bits. I/O pins used must be numbered consecutively and any I/O pin that is invalid or not configured as an input will cause an error. The start/nbr pair can be repeated up to 25 times if additional groups of input pins need to be added.</p> <p>This function will also return the state of a pin configured as an output. It can be used to conveniently communicate with parallel devices like memory chips. Any number of I/O pins (and therefore bits) can be used from 1 to the number of I/O pins on the chip.</p> <p>See the PORT command to simultaneously output to a number of pins.</p>
POS	<p>See Obsolete Commands and Functions section.</p> <p>For the console returns the position of the cursor on the current line.</p> <p>Use MM.INFO\$(</p>
PULSIN(pin, polarity) or PULSIN(pin, polarity, t1) or PULSIN(pin, polarity, t1, t2)	<p>Measures the width of an input pulse from 1µs to 1 second with 0.1µs resolution.</p> <p>'pin' is the I/O pin to use for the measurement, it must be previously configured as a digital input. 'polarity' is the type of pulse to measure, if zero the function will return the width of the next negative pulse, if non zero it will measure the next positive pulse.</p> <p>'t1' is the timeout applied while waiting for the pulse to arrive, 't2' is the timeout used while measuring the pulse. Both are in microseconds (µs) and are optional. If 't2' is omitted the value of 't1' will be used for both timeouts. If both 't1' and 't2' are omitted then the timeouts will be set at 100000 (ie, 100ms).</p> <p>This function returns the width of the pulse in microseconds (µs) or -1 if a timeout has occurred. The measurement is accurate to ±1 µs.</p> <p>Note that this function will cause the running program to pause while the measurement is made and interrupts will be ignored during this period.</p>
RAD(degrees)	<p>Converts 'degrees' to radians.</p>
RGB(red, green, blue [, trans]) or RGB(shortcut [, trans])	<p>Generates an RGB true colour value. 'red', 'blue' and 'green' represent the intensity of each colour. A value of zero represents black and 255 represents full intensity.</p> <p>'shortcut' allows common colours to be specified by naming them. The colours that can be named are white, black, blue, green, cyan, red, magenta, yellow, brown and gray. For example, RGB(red) or RGB(cyan).</p> <p>'trans' is the level of transparency for colour depths 4 and 12. It is optional</p>

	and defaults to 15 if not specified.
RIGHT\$(string\$, number-of-chars)	Returns a substring of 'string\$' with 'number-of-chars' from the right (end) of the string.
RND(number) or RND	Returns a pseudo-random number in the range of 0 to 0.999999. The 'number' value is ignored if supplied. The Armmite F4 uses the hardware random number generator in the STM32 series of chips to deliver true random numbers. This means that the RANDOMIZE command is no longer needed and is not supported.
SGN(number)	Returns the sign of the argument 'number', +1 for positive numbers, 0 for 0, and -1 for negative numbers.
SIN(number)	Returns the sine of the argument 'number' in radians.
SPACE\$(number)	Returns a string of blank spaces 'number' characters long.
SPI(data) or SPI2(data)	Send and receive data using an SPI channel. A single SPI transaction will send data while simultaneously receiving data from the slave. 'data' is the data to send and the function will return the data received during the transaction. 'data' can be an integer or a floating point variable or a constant.
SQR(number)	Returns the square root of number.
STEP	Part of the <i>FOR x=a TO b STEP c : NEXT</i> construction See FOR in command section See NEXT in command section
STR2BIN(type, string\$ [,BIG])	Returns a number equal to the binary representation in 'string\$'. 'type' can be: INT64 converts 8 byte string representing a signed 64-bit integer to an integer UINT64 converts 8 byte string representing an unsigned 64-bit integer to an integer INT32 converts 4 byte string representing a signed 32-bit integer to an integer UINT32 converts 4 byte string representing an unsigned 32-bit integer to an integer INT16 converts 2 byte string representing a signed 16-bit integer to an integer UINT16 converts 2 byte string representing an unsigned 16-bit integer to an integer INT8 converts 1 byte string representing a signed 8-bit integer to an integer UINT8 converts 1 byte string representing an unsigned 8-bit integer to an integer SINGLE converts 4 byte string representing single precision float to a float DOUBLE converts 8 byte string representing single precision float to a float By default the string must contain the number in little-endian format (ie, the least significant byte is the first one in the string). Setting the third parameter to 'BIG' will interpret the string in big-endian format (ie, the most significant byte is the first one in the string). This function makes it easy to read data from binary data files, interpret numbers from sensors or efficiently read binary data from flash memory

	<p>chips.</p> <p>An error will be generated if the string is the incorrect length for the conversion requested</p> <p>See also the function BIN2STR\$</p>
<p>STR\$(number)</p> <p>or</p> <p>STR\$(number, m)</p> <p>or</p> <p>STR\$(number, m, n)</p> <p>or</p> <p>STR\$(number, m, n, c\$)</p>	<p>Returns a formatted string in decimal (base 10) representation of 'number'.</p> <p>If 'm' is specified sufficient spaces will be added to the start of the number to ensure that the number of characters before the decimal point (including the negative or positive sign) will be at least 'm' characters. If 'm' is zero or the number has more than 'm' significant digits no padding spaces will be added.</p> <p>If 'm' is negative, positive numbers will be prefixed with the plus symbol and negative numbers with the negative symbol. If 'm' is positive then only the negative symbol will be used.</p> <p>'n' is the number of digits required to follow the decimal place. If it is zero the string will be returned without the decimal point. If it is negative the output will always use the exponential format with 'n' digits resolution. If 'n' is not specified the number of decimal places and output format will vary automatically according to the number.</p> <p>'c\$' is a string and if specified the first character of this string will be used as the padding character instead of a space (see the 'm' argument).</p> <p>Examples:</p> <pre> STR\$(123.456) will return "123.456" STR\$(-123.456) will return "-123.456" STR\$(123.456, 1) will return "123.456" STR\$(123.456, -1) will return "+123.456" STR\$(123.456, 6) will return " 123.456" STR\$(123.456, -6) will return " +123.456" STR\$(-123.456, 6) will return " -123.456" STR\$(-123.456, 6, 5) will return " -123.45600" STR\$(-123.456, 6, -5) will return " -1.23456e+02" STR\$(53, 6) will return " 53" STR\$(53, 6, 2) will return " 53.00" STR\$(53, 6, 2, "*") will return "*****53.00" </pre>
<p>STRING\$(nbr, ascii)</p> <p>or</p> <p>STRING\$(nbr, string\$)</p>	<p>Returns a string 'nbr' bytes long consisting of either the first character of string\$ or the character representing the ASCII value 'ascii' which is a decimal number in the range of 32 to 126.</p>
<p>TAB(number)</p>	<p>Outputs spaces until the column indicated by 'number' has been reached on the console output.</p>
<p>TAN(number)</p>	<p>Returns the tangent of the argument 'number' in radians.</p>
<p>TEMPR(pin)</p>	<p>Return the temperature measured by a DS18B20 temperature sensor connected to 'pin' (which does not have to be configured).</p> <p>The returned value is degrees C with a default resolution of 0.25°C. If there is an error during the measurement the returned value will be 1000.</p> <p>The time required for the overall measurement is 200ms and interrupts will be ignored during this period. Alternatively the TEMPR START command can be used to start the measurement and your program can do other things while the conversion is progressing. When this function is called the value will then be returned instantly assuming the conversion period has expired. If it has not, this function will wait out the remainder of the conversion time</p>

	<p>before returning the value.</p> <p>The DS18B20 can be powered separately by a 3V to 5V supply or it can operate on parasitic power. See the chapter "Special Hardware Devices" for more details.</p>
TIMES	<p>Returns the current time based on MMBasic's internal clock as a string in the form "HH:MM:SS" in 24 hour notation. For example, "14:30:00".</p> <p>If the OPTION MILLISECOND ON command has been used this function will return the time including milliseconds as a decimal fraction of the seconds. For example: "14:35:06.239".</p> <p>To set the current time use the command TIMES = .</p>
TIMER	<p>Returns the elapsed time in milliseconds (eg, 1/1000 of a second) since reset. This is a fractional floating point number with a resolution of 1µs.</p> <p>The timer is reset to zero on power up or a CPU restart and you can also reset it to any value by using TIMER as a command.</p>
TO	<p>Part of the <i>FOR x=a TO b STEP c : NEXT</i> construction</p> <p>See FOR in command section</p> <p>See NEXT in command section</p>
TOUCH(DOWN)	Will return true if the screen is currently being touched.
TOUCH(UP)	Will return true if the screen is currently NOT being touched.
TOUCH(LASTX)	Will return the X coordinate of the last location that was touched.
TOUCH(LASTY)	Will return the Y coordinate of the last location that was touched.
TOUCH(REF)	Will return the reference number of the control that is currently being touched or zero if no control is being touched.
TOUCH(LASTREF)	Will return the reference number of the last control that was touched.
UCASE\$(string\$)	Returns 'string\$' converted to uppercase characters.
UNTIL	
VAL(string\$)	<p>Returns the numerical value of the 'string\$'. If 'string\$' is an invalid number the function will return zero.</p> <p>This function will recognise the &H prefix for a hexadecimal number, &O for octal and &B for binary.</p>
WHILE	
XOR	See Operators section

Obsolete Commands and Functions

These commands and functions are mostly included to assist in converting programs written for Microsoft BASIC. For new programs the corresponding modern commands in MMBasic should be used.

These commands may be removed in the future to recover memory for other features.

GOSUB target	Initiates a subroutine call to the target, which can be a line number or a label. The subroutine must end with RETURN. New programs should use defined subroutines (ie, SUB...END SUB).
IF condition THEN linenbr	For Microsoft compatibility a GOTO is assumed if the THEN statement is followed by a number. A label is invalid in this construct. New programs should use: IF condition THEN GOTO linenbr label
IRETURN	Returns from an interrupt when the interrupt destination was a line number or a label. New programs should use a user defined subroutine as an interrupt destination. In that case END SUB or EXIT SUB will cause a return from the interrupt.
ON nbr GOTO GOSUB target[,target, target,...]	ON either branches (GOTO) or calls a subroutine (GOSUB) based on the rounded value of 'nbr'; if it is 1, the first target is called, if 2, the second target is called, etc. Target can be a line number or a label. New programs should use SELECT CASE.
POS	For the console, returns the current cursor position in the line in characters.
RETURN	RETURN concludes a subroutine called by GOSUB and returns to the statement after the GOSUB.

Appendix A

Serial Communications

Two serial ports are available for asynchronous serial communications labelled COM1: and COM2:. In addition, if the serial console is disabled then that port is available as COM3:.

After being opened the serial port will have an associated file number and you can use any commands that operate with a file number to read and write to/from it. A serial port is also closed using the CLOSE command.

The following is an example:

```
OPEN "COM1:4800" AS #5      ` open the first serial port with a speed of 4800 baud
PRINT #5, "Hello"          ` send the string "Hello" out of the serial port
dat$ = INPUT$(20, #5)      ` get up to 20 characters from the serial port
CLOSE #5                   ` close the serial port
```

The OPEN Command

A serial port is opened using the command:

```
OPEN comspec$ AS #fnbr
```

'fnbr' is the file number to be used. It must be in the range of 1 to 10. The # is optional.

'comspec\$' is the communication specification and is a string (it can be a string variable) specifying the serial port to be opened and optional parameters. The default is 9600 baud, 8 data bits, no parity and one stop bit.

It has the form "COMn: baud, buf, int, int-trigger, 7BIT, (ODD or EVEN), INV, OC, S2" where:

- 'n' is the serial port number for either COM1:, COM2 or COM3:..
- 'baud' is the baud rate. This can be any value between 1200 (the minimum) and 1000000 (1MHz). Default is 9600.
- 'buf' is the receive buffer size in bytes (default size is 256). The transmit buffer is fixed at 256 bytes.
- 'int' is a user defined subroutine which will be called when the serial port has received some data. The default is no interrupt.
- 'int-trigger' sets the trigger condition for calling the interrupt subroutine. It is an integer and the interrupt subroutine will be called when this number of characters has arrived in the receive queue.

All parameters except the serial port name (COMn:) are optional. If any one parameter is left out then all the following parameters must also be left out and the defaults will be used.

The following options can be added to the end of 'comspec\$'

- 'INV' specifies that the transmit and receive polarity is inverted. Default is non inverted.
- 'OC' will force the transmit pin to be open collector. The default is normal (0 to 3.3V) output.
- 'S2' specifies that two stop bits will be sent following each character transmitted. Default is one stop bit.
- '7BIT' will specify that 7 bit transmit and receive is to be used. Default is 8 bits.
- 'ODD' will specify that an odd parity bit will be appended (8 bits will be transmitted if 7BIT is specified, otherwise 9)
- 'EVEN' will specify that an even parity bit will be appended (8 bits will be transmitted if 7BIT is specified, otherwise 9)
- 'DEP' will enable RS485 mode with a positive output on the COM1-DE pin
- 'DEN' will enable RS485 mode with a negative output on the COM1-DE pin

Input/Output Pin Allocation

When a serial port is opened the pins used by the port will be automatically set to input or output as required and the SETPIN and PIN commands will be disabled for the pins. When the port is closed (using the CLOSE command) all pins used by the serial port will be set to a not-configured state and the SETPIN command can then be used to reconfigure them.

The connections for each COM port are shown in the I/O connector pinout diagrams in the beginning of this manual. Note that Tx means an output from the Maximate and Rx means an input to the Maximate.

The signal polarity is standard for devices running at TTL voltages (for RS232 voltages see below). Idle is voltage high, the start bit is voltage low, data uses a high voltage for logic 1 and the stop bit is voltage high. These signal levels allow you to directly connect to devices like GPS modules (which generally use TTL voltage levels).

When a serial port is opened MMBasic will enable an internal pullup resistor (to Vdd) on the Rx (receive data) pin. This has a value of about 100K and its purpose is to prevent the input from floating if it is left unconnected. Normally this is fine but it can cause a problem if you have an external resistor in series with the Rx pin, in that case this resistor and the pullup resistor will form a voltage divider limiting how high or low the voltage on the Rx pin can swing and that in turn might mean that the input signal is not recognised. The solution is to use the command SERIAL PULLUP DISABLE to disable it.

Examples

Opening a serial port using all the defaults:

```
OPEN "COM2:" AS #2
```

Opening a serial port specifying only the baud rate (4800 bits per second):

```
OPEN "COM2:4800" AS #1
```

Opening a serial port specifying the baud rate (9600 bits per second) and receive buffer size (1KB):

```
OPEN "COM1:9600, 1024" AS #8
```

The same as above but with two stop bits enabled:

```
OPEN "COM1:9600, 1024, S2" AS #8
```

An example specifying everything including an interrupt, an interrupt level, inverted and two stop bits:

```
OPEN "COM1:19200, 1024, ComIntLabel, 256, INV, S2" AS #5
```

Reading and Writing

Once a serial port has been opened you can use any command or function that uses a file number to read from and write to the port. Data received by the serial port will be automatically buffered in memory by MMBasic until it is read by the program and the INPUT\$() function is the most convenient way of doing that. When using the INPUT\$() function the number of characters specified will be the maximum number of characters returned but it could be less if there are less characters in the receive buffer. In fact the INPUT\$() function will immediately return an empty string if there are no characters available in the receive buffer.

The LOC() function is also handy; it will return the number of characters waiting in the receive buffer (ie, the maximum number characters that can be retrieved by the INPUT\$() function). Note that if the receive buffer overflows with incoming data the serial port will automatically discard the oldest data to make room for the new data.

The PRINT command is used for outputting to a serial port and any data to be sent will be held in a memory buffer while the serial port is sending it. This means that MMBasic will continue with executing the commands after the PRINT command while the data is being transmitted. The one exception is if the output buffer is full and in that case MMBasic will pause and wait until there is sufficient space before continuing. The LOF() function will return the amount of space left in the transmit buffer and you can use this to avoid stalling the program while waiting for space in the buffer to become available.

If you want to be sure that all the data has been sent (perhaps because you want to read the response from the remote device) you should wait until the LOF() function returns 256 (the transmit buffer size) indicating that there is nothing left to be sent.

Serial ports can be closed with the CLOSE command. This will wait for the transmit buffer to be emptied then free up the memory used by the buffers, cancel the interrupt (if set) and set all pins used by the port to the not configured state. A serial port is also automatically closed when commands such as RUN and NEW are issued.

Interrupts

The interrupt subroutine (if specified) will operate the same as a general interrupt on an external I/O pin.

When using interrupts you need to be aware that it will take some time for MMBasic to respond to the interrupt and more characters could have arrived in the meantime, especially at high baud rates. For example, if you have specified the interrupt level as 250 characters and a buffer of 256 characters then quite easily the buffer will have overflowed by the time the interrupt subroutine can read the data. In this case the buffer should be increased to 512 characters or more.

Low Cost RS-232 Interface

The RS-232 signalling system is used by modems, hardwired serial ports on a PC, test equipment, etc. It is the same as the serial TTL system used on the Armmite F4 with two exceptions:

- The voltage levels of RS-232 are +12V and -12V where TTL serial uses +3.3V and zero volts.
- The signalling is inverted (the idle voltage is -12V, the start bit is +12V, etc).

It is possible to purchase cheap RS-232 to TTL converters on the Internet but it would be handy if it was possible to directly interface to RS-232.

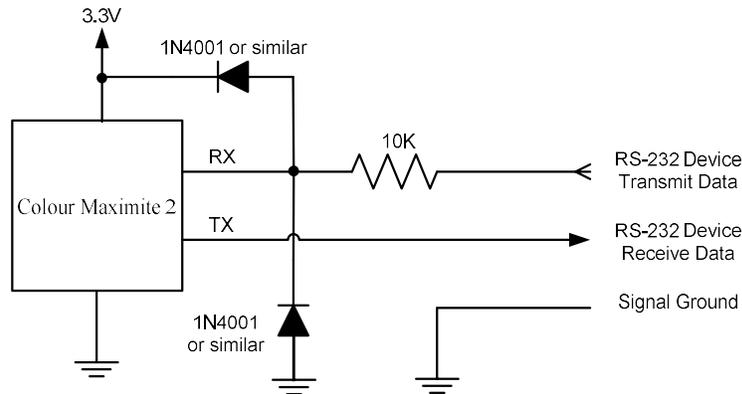
The first issue is that the signalling polarity is inverted with respect to TTL. On the Armmite F4 COM1: can be specified to invert the transmit and receive signal (the 'INV' option) so that is an easy fix.

For the receive data (that is the $\pm 12V$ signal from the remote RS-232 device) it is easy to limit the voltage using a series resistor of (say) $10K\Omega$ and two diodes that will clamp the input voltage to the 3.3V rail and ground. The input impedance of the I/O pin is very high so the resistor will not cause a voltage drop but it does mean that when the signal swings to the maximum $\pm 12V$ it will be safely clipped by the diodes.

For the transmit signal (from the Armmite F4 to the RS-232 device) you can connect this directly to the input of the remote device. The output will only swing the signal from zero to 3.3V but most RS-232 inputs have a threshold of about +1V so the signal will still be interpreted as a valid signal.

These measures break the rules for RS-232 signalling, but if you only want to use it over a short distance (a metre or two) it should work fine.

Use this circuit:



And open COM1: with the invert option. For example:

```
OPEN "COM1: 4800, INV" AS #1
```

Appendix B

I²C Communications

The Armmite F4 implements three I²C channels, two on the rear I/O connector and the third dedicated to the front panel Wii connector. All operate in master mode (slave mode is not available).

There are four commands that can be used:

I2C OPEN speed, timeout	Enables the I ² C module in master mode. The I2C command refers to channel 1 while commands I2C2 and I2C3 refer to channels 2 and 3 using the same syntax. ‘speed’ is the clock speed (in KHz) to use and must be one of 100 or 400. ‘timeout’ is a value in milliseconds after which the master send and receive commands will be interrupted if they have not completed. The minimum value is 100. A value of zero will disable the timeout (though this is not recommended).
I2C WRITE addr, option, sendlen, senddata [,senddata]	Send data to the I ² C slave device. The I2C command refers to channel 1 while commands I2C2 refer to channels 2 using the same syntax. ‘addr’ is the slave’s I ² C address. ‘option’ can be 0 for normal operation or 1 to keep control of the bus after the command (a stop condition will not be sent at the completion of the command) ‘sendlen’ is the number of bytes to send. ‘senddata’ is the data to be sent - this can be specified in various ways (all values sent will be between 0 and 255): <ul style="list-style-type: none">• The data can be supplied as individual bytes on the command line. Example: I2C WRITE &H6F, 0, 3, &H23, &H43, &H25• The data can be in a one dimensional array specified with empty brackets (ie, no dimensions). ‘sendlen’ bytes of the array will be sent starting with the first element. Example: I2C WRITE &H6F, 0, 3, ARRAY()• The data can be a string variable (not a constant). Example: I2C WRITE &H6F, 0, 3, STRING\$
I2C READ addr, option, rcvlen, rcvbuf	Get data from the I ² C slave device. The I2C command refers to channel 1 while commands I2C2 refer to channels 2 using the same syntax. ‘addr’ is the slave’s I ² C address. ‘option’ can be 0 for normal operation or 1 to keep control of the bus after the command (a stop condition will not be sent at the completion of the command) ‘rcvlen’ is the number of bytes to receive. ‘rcvbuf’ is the variable or array used to save the received data - this can be: <ul style="list-style-type: none">• A string variable. Bytes will be stored as sequential characters in the string.• A one dimensional array of numbers specified with empty brackets. Received bytes will be stored in sequential elements of the array starting with the first. Example: I2C READ &H6F, 0, 3, ARRAY()• A normal numeric variable (in this case rcvlen must be 1).
I2C CLOSE	Disables the master I ² C module and returns the I/O pins to a "not configured" state. They can then be configured using SETPIN. This command will also send a stop if the bus is still held. The I2C command refers to channel 1 while commands I2C2 refer to channels 2 using the same syntax.

Following an I²C write or read command the automatic variable MM.I2C will be set to indicate the result of the operation as follows:

- 0 = The command completed without error.
- 1 = Received a NACK response
- 2 = Command timed out

7-Bit Addressing

The standard addresses used in these commands are 7-bit addresses (without the read/write bit). MMBasic will add the read/write bit and manipulate it accordingly during transfers.

Some vendors provide 8-bit addresses which include the read/write bit. You can determine if this is the case because they will provide one address for writing to the slave device and another for reading from the slave. In these situations you should only use the top seven bits of the address. For example: If the read address is 9B (hex) and the write address is 9A (hex) then using only the top seven bits will give you an address of 4D (hex).

Another indicator that a vendor is using 8-bit addresses instead of 7-bit addresses is to check the address range. All 7-bit addresses should be in the range of 08 to 77 (hex). If your slave address is greater than this range then probably your vendor has specified an 8-bit address.

I/O Pins

Refer to the [Pin and Connector Capabilities table](#) at the beginning of this manual for the pin numbers used for the I²C channels 1 and 2. Their signals are marked as data line (SDA) and clock (SCL). When the I2C CLOSE command is used the I/O pins are reset to a "not configured" state. They can then be configured as per normal using SETPIN.

Neither the data line (SDA) and clock (SCL) for either I²C ports have any pullup resistors installed on the development board. When running the I²C bus at above 100 kHz the cabling between the devices becomes important. Ideally the cables should be as short as possible (to reduce capacitance) and also the data and clock lines should not run next to each other but have a ground wire between them (to reduce crosstalk).

If the data line is not stable when the clock is high, or the clock line is jittery, the I²C peripherals can get "confused" and end up locking the bus (normally by holding the clock line low). If you do not need the higher speeds then operating at 100 kHz is the safest choice. When enabled the I2C pins have a 40K internal pullup. Another 10K external pullup may be required if the speed of 400kHz is used or the runs are long.

Example

As an example, the following program will read and display the current time (hours and minutes) maintained by a PCF8563 real time clock chip connected to I²C channel 2:

```
DIM AS INTEGER RData(2)      ' this will hold received data
I2C2 OPEN 100, 1000         ' open the I2C channel
I2C2 WRITE &H51, 0, 1, 3    ' set the first register to 3
I2C2 READ &H51, 0, 2, RData() ' read two registers
I2C2 CLOSE                  ' close the I2C channel
PRINT "Time is " RData(1) ":" RData(0)
```

Appendix C

1-Wire Communications

The 1-Wire protocol was developed by Dallas Semiconductor to communicate with chips using a single signalling line. This implementation was written for MMBasic by Gerard Sexton.

There are three commands that you can use:

ONEWIRE RESET pin	Reset the 1-Wire bus
ONEWIRE WRITE pin, flag, length, data [, data...]	Send a number of bytes
ONEWIRE READ pin, flag, length, data [, data...]	Get a number of bytes

Where:

pin - The I/O pin (located in the rear connector) to use. It can be any pin capable of digital I/O.

flag - A combination of the following options:

- 1 - Send reset before command
- 2 - Send reset after command
- 4 - Only send/recv a bit instead of a byte of data
- 8 - Invoke a strong pullup after the command (the pin will be set high and open drain disabled)

length - Length of data to send or receive

data - Data to send or variable to receive.

The number of data items must agree with the length parameter.

And the automatic variable

MM.ONEWIRE	Returns true if a device was found
------------	------------------------------------

After the command is executed, the I/O pin will be set to the not configured state unless flag option 8 is used.

When a reset is requested the automatic variable MM.ONEWIRE will return true if a device was found. This will occur with the ONEWIRE RESET command and the ONEWIRE READ and ONEWIRE WRITE commands if a reset was requested (flag = 1 or 2).

The 1-Wire protocol is often used in communicating with the DS18B20 temperature measuring sensor and to help in that regard MMBasic includes the TEMPR() function which provides a convenient method of directly reading the temperature of a DS18B20 without using these functions.

Appendix D

SPI Communications

The Serial Peripheral Interface (SPI) communications protocol is used to send and receive data between integrated circuits. The command SPI refers to channel 1 and SPI2 refers to channel 2. SPI2 is not listed below however it is available on the Armmite F4 and has an identical syntax.

I/O Pins

The SPI OPEN command will automatically configure the relevant I/O pins . (listed at the start of this manual). MISO stands for Master In Slave Out and because the Armmite F4 is always the master that pin will be configured as an input. Similarly MOSI stands for Master Out Slave In and that pin will be configured as an output.

When the SPI CLOSE command is used these pins will be returned to a "not configured" state. They can then be configured as per normal using SETPIN.

SPI Open

To use the SPI function the SPI channel must be first opened. The syntax for opening the SPI channel is:

```
SPI OPEN speed, mode, bits
```

Where:

- 'speed' is the speed of the clock. This can be 25000000, 12500000, 6250000, 3125000, 1562500, 781250, 390625 or 195315 (ie, 25MHz, 12.5MHz, 6.25MHz, 3.125MHz, 1562.5KHz, 781.25KHz, 390.625KHz or 195.3125KHz). For any other values the firmware will select the next valid speed that is equal or slower than the speed requested.
- 'mode' is a single numeric digit representing the transmission mode – see Transmission Format below.
- 'bits' is the number of bits to send/receive. This can be 8 or 16 for the Armmite F4
- It is the responsibility of the program to separately manipulate the CS (chip select) pin if required.

Transmission Format

The most significant bit is sent and received first. The format of the transmission can be specified by the 'mode' as shown below. Mode 0 is the most common format.

Mode	Description	CPOL	CPHA
0	Clock is active high, data is captured on the rising edge and output on the falling edge	0	0
1	Clock is active high, data is captured on the falling edge and output on the rising edge	0	1
2	Clock is active low, data is captured on the falling edge and output on the rising edge	1	0
3	Clock is active low, data is captured on the rising edge and output on the falling edge	1	1

For a more complete explanation see: http://en.wikipedia.org/wiki/Serial_Peripheral_Interface_Bus

Standard Send/Receive

When the SPI channel is open data can be sent and received using the SPI function. The syntax is:

```
received_data = SPI(data_to_send)
```

Note that a single SPI transaction will send data while simultaneously receiving data from the slave. 'data_to_send' is the data to send and the function will return the data received during the transaction. 'data_to_send' can be an integer or a floating point variable or a constant.

If you do not want to send any data (ie, you wish to receive only) any number (eg, zero) can be used for the data to send. Similarly if you do not want to use the data received it can be assigned to a variable and ignored.

Bulk Send/Receive

Data can also be sent in bulk:

```
SPI WRITE nbr, data1, data2, data3, ... etc
```

or
SPI WRITE nbr, string\$

or
SPI WRITE nbr, array()

In the first method 'nbr' is the number of data items to send and the data is the expressions in the argument list (ie, 'data1', data2' etc). The data can be an integer or a floating point variable or a constant.

In the second or third method listed above the data to be sent is contained in the 'string\$' or the contents of 'array()' (which must be a single dimension array of integer or floating point numbers). The string length, or the size of the array must be the same or greater than nbr. Any data returned from the slave is discarded.

Data can also be received in bulk:

```
SPI READ nbr, array()
```

Where 'nbr' is the number of data items to be received and array() is a single dimension integer array where the received data items will be saved. This command sends zeros while reading the data from the slave.

SPI Close

If required the SPI channel can be closed as follows (the I/O pins will be set to inactive):

```
SPI CLOSE
```

Examples

The following example shows how to use the SPI port for general I/O. It will send a command 80 (hex) and receive two bytes from the slave SPI device using the standard send/receive function:

```
PIN(10) = 1 : SETPIN 10, DOUT      ' pin 10 will be used as the enable signal
SPI OPEN 5000000, 3, 8             ' speed is 5MHz and the data size is 8 bits
PIN(10) = 0                        ' assert the enable line (active low)
junk = SPI(&H80)                   ' send the command and ignore the return
byte1 = SPI(0)                     ' get the first byte from the slave
byte2 = SPI(0)                     ' get the second byte from the slave
PIN(10) = 1                        ' deselect the slave
SPI CLOSE                          ' and close the channel
```

The following is similar to the example given above but this time the transfer is made using the bulk send/receive commands:

```
OPTION BASE 1                      ' our array will start with the index 1
DIM data%(2)                       ' define the array for receiving the data
PIN(10) = 1 : SETPIN 10, DOUT      ' pin 10 will be used as the enable signal
SPI OPEN 5000000, 3, 8             ' speed is 5MHz, 8 bits data
PIN(10) = 0                        ' assert the enable line (active low)
SPI WRITE 1, &H80                  ' send the command
SPI READ 2, data%()                ' get two bytes from the slave
PIN(10) = 1                        ' deselect the slave
SPI CLOSE                          ' and close the channel
```

Appendix E W25Q Windbond

'armite F4 Flash test

```
OPTION BASE 1
DIM AS INTEGER F_CS = 35
DIM AS INTEGER x
DIM AS INTEGER myArray(256)

SETPIN F_CS, DOUT
SPI OPEN 10000000,0,8
x = WB.ID%()
PRINT "Device ID = ";HEX$(x)
x = WB.JEDECID%()
PRINT "JEDEC ID = ";HEX$(x)
PRINT "Pagecount = ";WB.PAGECOUNT%()
x = WB.SERIAL%()
PRINT "Serial No = ";HEX$(x)

PRINT
x = WB.Write_Disable()
PRINT "Status registers:"
FOR n = 1 TO 3
  x = WB.READSTATUS(n)
  PRINT STR$(n);" ";BIN$(x,8)
NEXT n
PRINT

x = WB.READPAGE(1, myArray())
FOR n = 1 TO 100
  PRINT myArray(n);" ";
  IF n MOD 10 = 0 THEN PRINT
NEXT n
z$ = WB.READSTRING$(2)
IF LEN(z$)<>255 THEN PRINT z$

TIMER = 0
x = WB.Write_Enable()
x = WB.ERASE()
PAUSE 1000
PRINT BIN$(WB.READSTATUS(1),8)
DO
  PAUSE 100
  x = WB.READSTATUS(1)AND 1
LOOP UNTIL x = 0
PRINT "Erased in ";TIMER; "mS"
PRINT BIN$(WB.READSTATUS(1),8)
x = WB.Write_Enable()
x = WB.WRITESTRING(2,"Freddy is here!!")
DO
  PAUSE 100
  x = WB.READSTATUS(1)AND 1
LOOP UNTIL x = 0

x = WB.Write_Enable()
x = WB.WRITESTRING(2,"Barney is here!!", 20)
DO
  PAUSE 100
  x = WB.READSTATUS(1)AND 1
LOOP UNTIL x = 0

z$ = WB.READSTRING$(2)
PRINT z$
PRINT WB.READSTRING$(2,20)
```

```

x = WB.READPAGE(2, myArray())
FOR n = 1 TO 100
  PRINT myArray(n);" ";
  IF n MOD 10 = 0 THEN PRINT
NEXT n

FOR n = 1 TO 100
  myArray(n) = n
NEXT n
x = WB.Write_Enable()
x = WB.WRITEPAGE(1, myArray())
PAUSE 1000
FOR n = 1 TO 100
  myArray(n) = 0
NEXT n

x = WB.READPAGE(1, myArray())
FOR n = 1 TO 100
  PRINT myArray(n);" ";
  IF n MOD 10 = 0 THEN PRINT
NEXT n

'x = WB.Write_Enable()
'x = WB.READSTATUS(2)
'x = WB.Write_Enable()
'x = x and &B11111101
'y = WB.WRITESTATUS(2, x)
'pause 1000
'print
'for n = 1 to 3
'x = WB.READSTATUS(n)
'print str$(n);" ";bin$(x,8)
'next n
'
SPI CLOSE
FUNCTION WB.Write_Enable()
'SPI OPEN 1000000,0,8
PIN(F_CS)=0
SPI WRITE 1, &H06
PIN(F_CS)=1
'SPI CLOSE
END FUNCTION

FUNCTION WB.Write_Volatile_Enable()
'SPI OPEN 1000000,0,8
PIN(F_CS)=0
SPI WRITE 1, &H50
PIN(F_CS)=1
'SPI CLOSE
END FUNCTION

FUNCTION WB.Write_Disable()
'SPI OPEN 1000000,0,8
PIN(F_CS)=0
SPI WRITE 1, &H04
PIN(F_CS)=1
'SPI CLOSE
END FUNCTION

FUNCTION WB.READSTATUS(reg)
LOCAL adr
SELECT CASE reg
  CASE 1 : adr = &H05
  CASE 2 : adr = &H35
  CASE 3 : adr = &H15

```

```

END SELECT

'SPI OPEN 1000000,0,8
PIN(F_CS)=0
SPI WRITE 1, adr
WB.READSTATUS=SPI(0)
PIN(F_CS)=1
'SPI CLOSE
END FUNCTION

FUNCTION WB.WRITESTATUS(reg, myData)
LOCAL adr
SELECT CASE reg
CASE 1 : adr = &H01
CASE 2 : adr = &H31
CASE 3 : adr = &H11
END SELECT
'SPI OPEN 1000000,0,8
PIN(F_CS)=0
SPI WRITE 2, adr, myData
PIN(F_CS)=1
'SPI CLOSE
END FUNCTION

FUNCTION WB.ID%()
'W25Q64FV &HEF16
'W25Q16JV &HEF14
LOCAL AS INTEGER mybyte(5)
'SPI OPEN 1000000,0,8
PIN(F_CS)=0
SPI WRITE 1, &H90
SPI READ 5, mybyte()
PIN(F_CS)=1
'SPI CLOSE
WB.ID%=mybyte(4)*256+mybyte(5)
END FUNCTION

FUNCTION WB.JEDECID%()
'W25Q64FV &HEF4017
'W25Q16JV &HEF4015
LOCAL AS INTEGER mybyte(3)
'SPI OPEN 1000000,0,8
PIN(F_CS)=0
SPI WRITE 1, &H9F
SPI READ 3, mybyte()
PIN(F_CS)=1
'SPI CLOSE
WB.JEDECID%=mybyte(1)*256*256+mybyte(2)*256+mybyte(3)
END FUNCTION

FUNCTION WB.PAGECOUNT%()
'W25Q64FV &HEF4017
'W25Q16JV &HEF4015
LOCAL AS INTEGER mybyte(3)
'SPI OPEN 1000000,0,8
PIN(F_CS)=0
SPI WRITE 1, &H9F
SPI READ 3, mybyte()
PIN(F_CS)=1
'SPI CLOSE
WB.PAGECOUNT%=1 << (mybyte(3)-8)
END FUNCTION

FUNCTION WB.SERIAL%()
LOCAL AS INTEGER mybyte(8)

```

```

LOCAL AS FLOAT n
' SPI OPEN 1000000,0,8
PIN(F_CS)=0
SPI WRITE 5, &H4B,0,0,0,0
SPI READ 8, mybyte()
PIN(F_CS)=1
' SPI CLOSE

WB.SERIAL%=mybyte(1)
FOR n = 2 TO 8
    WB.SERIAL%=WB.SERIAL%*256+mybyte(n)
NEXT n
END FUNCTION

FUNCTION WB.READPAGE(adr, my%())
LOCAL adr1, adr2,adr3
adr = adr<<8
adr1 = (adr>>16) AND &HFF
adr2 = (adr>>8) AND &HFF
adr3 = adr AND &HFF
' SPI OPEN 1000000,0,8
PIN(F_CS)=0
SPI WRITE 4, &H03, adr1, adr2, adr3
SPI READ 256, my%()
PIN(F_CS)=1
' SPI CLOSE
END FUNCTION

FUNCTION WB.WRITEPAGE(adr, my%())
LOCAL adr1, adr2,adr3
adr = adr<<8
adr1 = (adr>>16) AND &HFF
adr2 = (adr>>8) AND &HFF
adr3 = adr AND &HFF
' SPI OPEN 1000000,0,8
PIN(F_CS)=0
SPI WRITE 4, &H02, adr1, adr2, adr3
SPI WRITE 256, my%()
PIN(F_CS)=1
' SPI CLOSE
END FUNCTION

FUNCTION WB.READSTRING$(adr, offset = 0)
LOCAL adr1, adr2,adr3,strLen,my%(256),n
adr = (adr<<8) + offset
adr1 = (adr>>16) AND &HFF
adr2 = (adr>>8) AND &HFF
adr3 = adr AND &HFF
' SPI OPEN 1000000,0,8
PIN(F_CS)=0
SPI WRITE 4, &H03, adr1, adr2, adr3
strLen = SPI(0)
SPI READ strLen, my%()
PIN(F_CS)=1
IF strLen > 0 THEN
    FOR n = 1 TO strLen
        WB.READSTRING$ = WB.READSTRING$ + CHR$(my%(n))
    NEXT n
ENDIF
' SPI CLOSE
END FUNCTION

FUNCTION WB.WRITESTRING(adr, myStr$, offset = 0)
LOCAL adr1, adr2,adr3,strLen ',my%(256),n
adr = (adr<<8) + offset
adr1 = (adr>>16) AND &HFF

```

```

adr2 = (adr>>8) AND &HFF
adr3 = adr AND &HFF
strLen = LEN(myStr$)
' my%(1) = strLen
' for n = 1 to strLen
'   my%(n+1) = asc(mid$(myStr$,n,1))
' next n
' SPI OPEN 1000000,0,8
PIN(F_CS)=0
SPI WRITE 4, &H02, adr1, adr2, adr3
SPI WRITE 1, strLen
SPI WRITE strLen, myStr$
'spi write strLen+1, my%()
PIN(F_CS)=1
' SPI CLOSE
END FUNCTION

```

```

FUNCTION WB.ERASE()
PIN(F_CS)=0
SPI WRITE 1, &HC7
PIN(F_CS)=1
' SPI CLOSE
END FUNCTION

```

Appendix F

Special Keyboard Keys

MMBasic generates a single unique character for the function keys and other special keys on the keyboard. These are shown in this table as hexadecimal and decimal numbers:

Keyboard Key	Key Code (Hex)	Key Code (Decimal)
Up Arrow	80	128
Down Arrow	81	129
Left Arrow	82	130
Right Arrow	83	131
Insert	84	132
Home	86	134
End	87	135
Page Up	88	136
Page Down	89	137
Alt	8B	139
F1	91	145
F2	92	146
F3	93	147
F4	94	148
F5	95	149
F6	96	150
F7	97	151
F8	98	152
F9	99	153
F10	9A	154
F11	9B	155
F12	9C	156

If the shift key is simultaneously pressed then 40 (hex) is added to the code (this is the equivalent of setting bit 6). For example Shift-F10 will generate DA (hex).

The shift modifier only works with the function keys F1 to F12; it is ignored for the other keys.

MMBasic will translate most VT100 escape codes generated by terminal emulators such as Tera Term and Putty to these codes (excluding the shift and control modifiers). This means that a terminal emulator operating over a USB or a serial port opened as console will generate the same key codes as a directly attached keyboard.

Appendix G

Loading the Firmware

The STM32 processor includes its own programmer/bootloader so the Armmite F4 firmware can be easily loaded via USB using a personal computer or laptop (special hardware is not needed). Just follow these steps.

Go to <https://www.st.com/en/development-tools/stm32cubeprog.html> and download the STM32CubeProgrammer software. This is free software but STM do require you to have an STM account or provide your name and email address. They will email you a link to download the software. Then install this software on your computer (Windows, Linux and macOS are supported).

With the STM32F407VET6 development board unplugged set the BT0 and BT1 jumpers as in the picture to enable the bootloader mode.

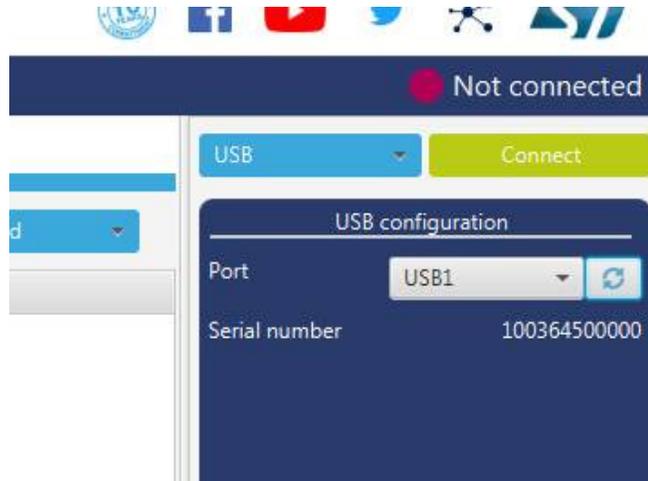


Note:
BT1 has a pulldown resistor as part of the board, so its jumper is not actually required.
All that is required is the BT0 jumper.

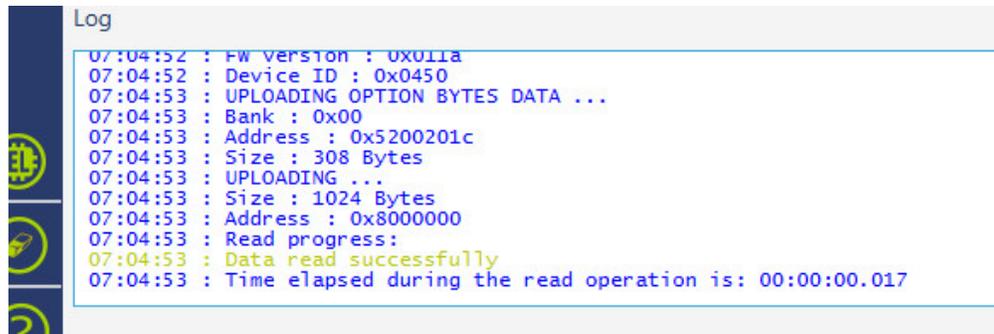
Using a USB Type-A to Type-B cable connect the USB port on the Armmite F4 to a USB port on your desktop computer. This will power up the STM32F407VET6 development board and you should also hear a sound from your computer as it connects and you should see the STM32Bootloader appear as a new device.



Run the STM32CubeProgrammer software on your computer. On the top right of the program window select USB as the communications method. If the program does not recognise the USB connection click on the small blue circle to the right of the Port drop down list to refresh the entry. Your screen should look like the illustration on the right (the USB port number may vary).



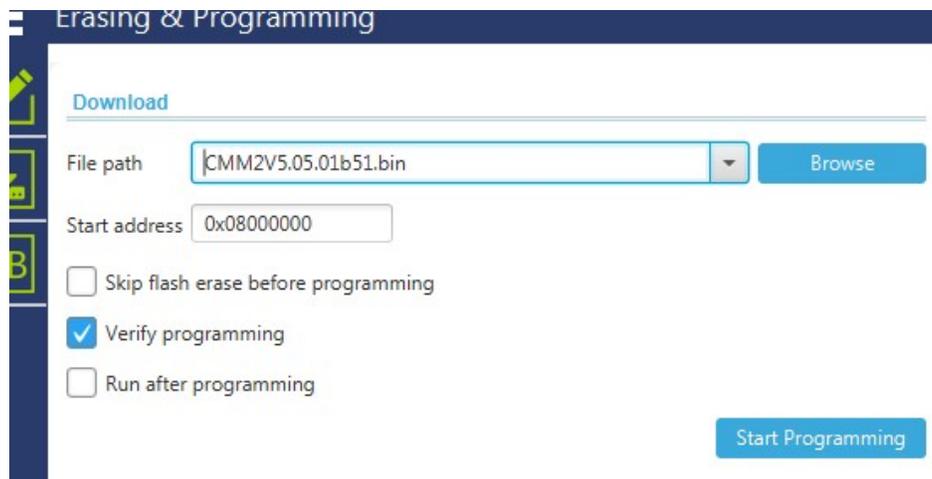
Click on the "Connect" button. You should then see a series of messages as shown in the screenshot below finishing with the message "Data read successfully". Any messages in red will indicate an error.



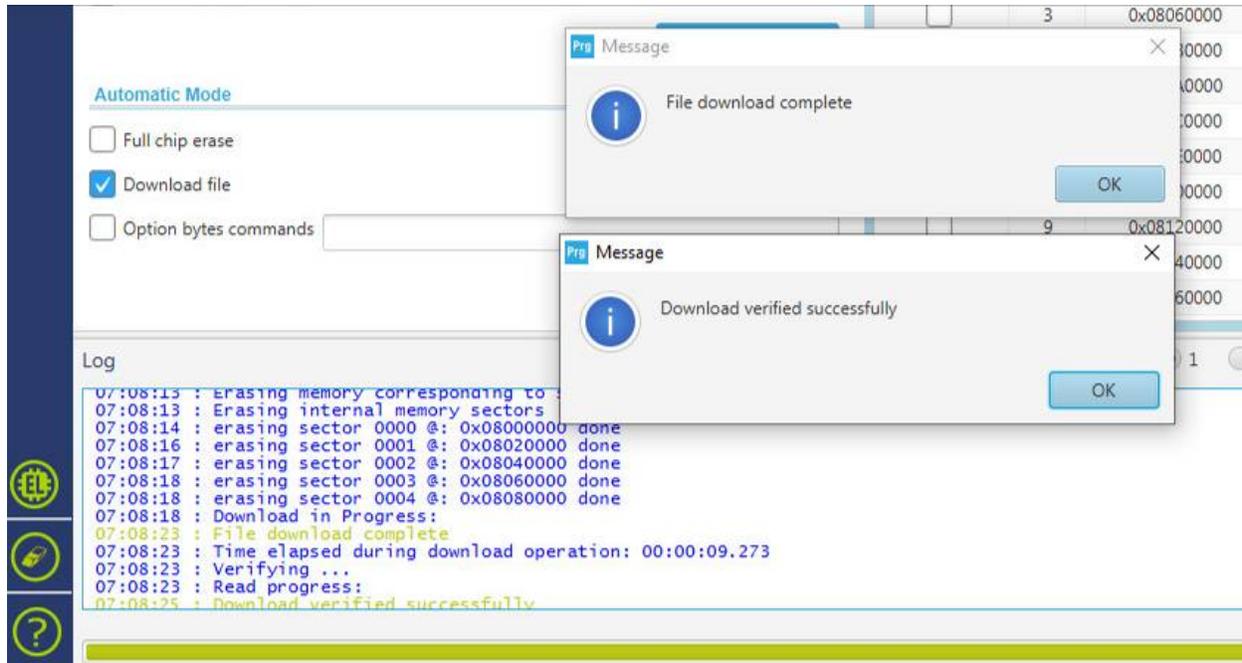
Click on the download button () on the left side of the STM32CubeProgrammer window and the software will switch to the "Erasing and Programming" mode as shown below.

Use the "Browse button" to select the firmware file (it will have an extension of .bin). Tick the "Verify programming" checkbox.

Finally, click on the "Start Programming" button.



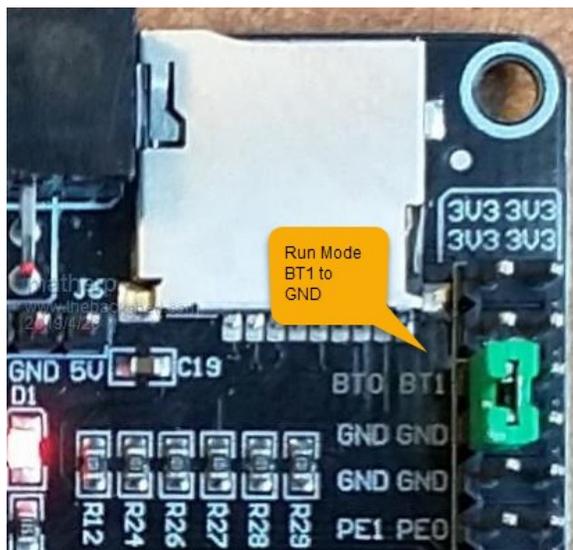
The STM32CubeProgrammer software will then program the firmware into the flash memory on the STM32 CPU on STM32F407VET6 development board (the STM32CubeProgrammer software calls this "downloading"). After a short time a dialog box will pop up saying that "File download completed". Do not do anything at this point as the software will then start reading back the firmware programmed into the flash. When this has completed successfully another dialog box will pop up saying "Download verified successfully" as shown below. The whole operation will take under a minute and any messages in red will indicate an error.



Then:

- Dismiss all the dialog boxes and close the STM32CubeProgrammer software.
- Disconnect the USB cable from the STM32F407VET6 development board.
- Set the Boot 0 and Boot 1 jumpers as below to enable the USB as the console by setting jumpers as below.

BT0 to GND, BT1 removed.



- Reconnect the USB cable to the STM32F407VET6 development board.

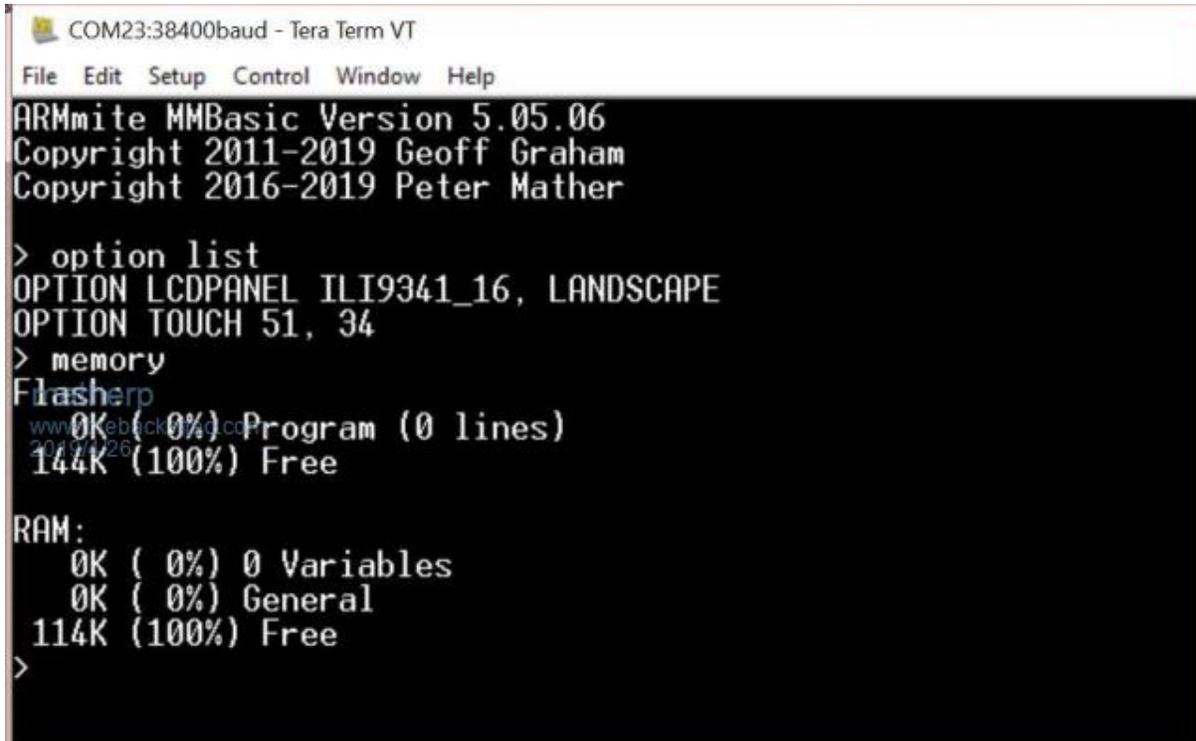
This should power up the STM32F407VET6 which will then connect to your desktop computer via USB.

In Windows the connection will appear in Device Manager as "USB Serial Port" as illustrated on the right (the COM number will probably be different):



If this doesn't happen immediately try pressing the RST button on the board and unplugging and re-plugging the USB connection. Some computers seem to take time to recognise a different device on the same physical USB port.

Connect a terminal emulator to the port and you should see the Armmite copyright banner.

A screenshot of a terminal emulator window titled 'COM23:38400baud - Tera Term VT'. The window shows the following text:

```
File Edit Setup Control Window Help
ARMMite MMBasic Version 5.05.06
Copyright 2011-2019 Geoff Graham
Copyright 2016-2019 Peter Mather

> option list
OPTION LCDPANEL ILI9341_16, LANDSCAPE
OPTION TOUCH 51, 34
> memory
Flasherp
www.keba.ch
2019/11/26
0K (0%) Program (0 lines)
144K (100%) Free

RAM:
0K (0%) 0 Variables
0K (0%) General
114K (100%) Free
>
```

If not, press return to wake up the USB connection and if this still doesn't work try disconnecting the terminal emulator and re-connecting, pressing RST, unplugging and re-plugging.

The Armmite firmware controls the CDC connection as follows:

On power up, if no USB connection is plugged in (separate 5V supply) console output will be black-holed.

On power up, if a USB connection is plugged in console output will be buffered until a terminal emulator is connected.

Once running, if the USB connection is removed (separate 5V power) console output is black-holed

Once running, if the USB connection is re-inserted, console output will be restored from the point at which the USB was re-connected.

Alternative Method – Using COM 1

An alternative method of loading the firmware is via COM1 using a USB to serial adaptor. You may want to try this as a trouble shooting step if you fail to program using the USB port on the board. Connect the USB to J6 the COM1 port on the STM32F407VET6. The USB to serial adaptor is covered near the start of this manual.

In Windows the connection will appear in Device Manager as "USB Serial Port" as illustrated on the right (the COM number will probably be different):



Install the STM32CubeProgrammer software on your computer as described above.

Run the software and select UART in the top right corner (as illustrated on the right). Then select the correct COM port number as reported in Device Manager. Finally make sure that the baudrate is set to 115200 baud and the parity set to even:

From then on the process is the same as that described above when using a direct USB connection via the keyboard port:

- Click on "Connect".
- Select "Erase & Programming" mode.
- Browse for the firmware file.
- Tick the "Verify programming" checkbox.
- Click on "Program".

The whole operation will take about 5 minutes.



When the programming/verify has completed set the Boot 0 and Boot 1 jumpers to enable the console. BT0 to GND, BT1 removed.

Note: MMBasic will start up with USB Console enabled as the default. See section at the start of this manual to switch to serial console at startup.

Linux and the Raspberry Pi

Loading the firmware from a Linux computer and/or the Raspberry Pi has some special considerations and these are explained here: <http://www.thebackshed.com/forum/ViewTopic.php?FID=16&TID=12171>