Pineapple Control 1 (for want of a better name!)

by Mixtel90

Rev. 3.1 PCB

This is intended to be the latest version of my aquarium automation controller, but it can be customized in far too many different ways for it to be dedicated to that task.

The PCB is 100mm x 100mm and is designed to fit the enclosure used for the CMM2. Reasons for this will become apparent later.

The "horsepower" of the system is a RP2040-Zero, a very cheap and small clone of the original Raspberry Pi Pico. In my case I have used MMBasic as the control language, but you could equally well use something like Circuit Python as there are only two dedicated pins - GP0 and GP1 are used for the I2C connection to a RTC module and a SSD1306 128x64 OLED display. Everything else is wired to pins in one form or another.

(Note: this photograph is of the prototype Version 3.0 board and it has the wrong connectors for DC2 and RGB. DC1 and AC1 (RLA) are omitted and some resistors are missing. V3.0 has now been superseded.)
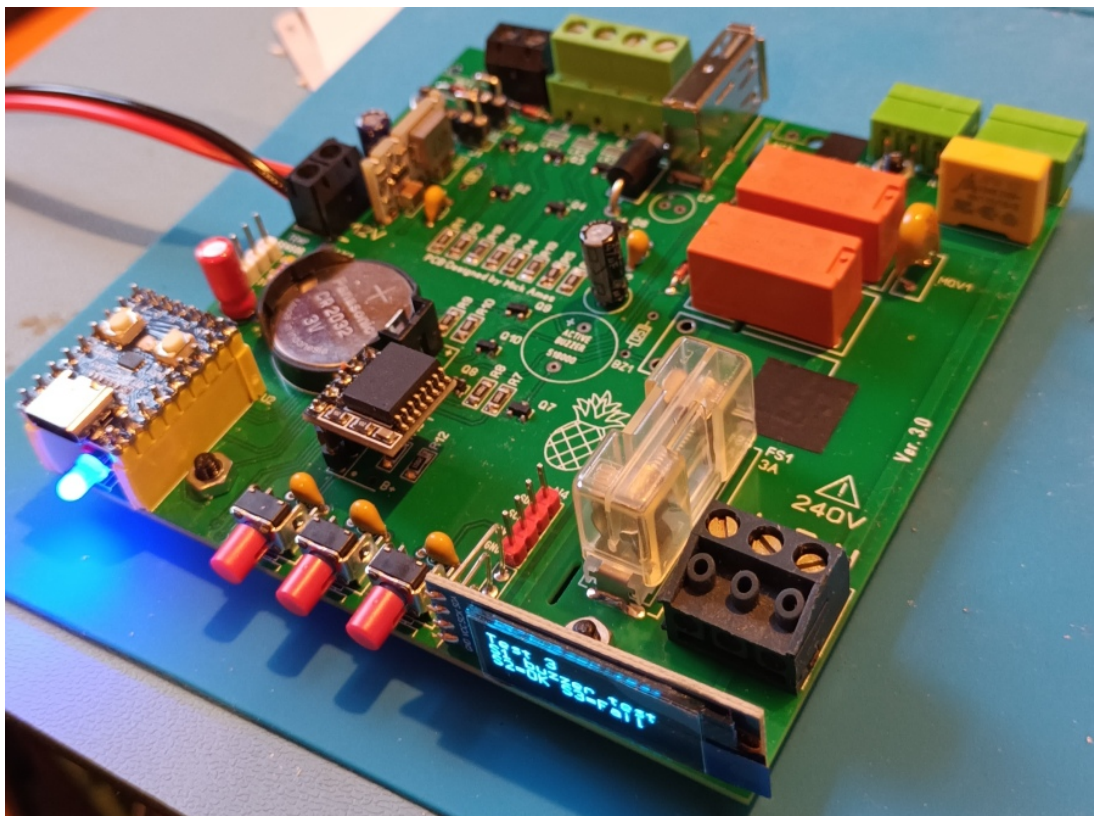
The board has connectors for the following outputs:

	Voltage	Current	Type	GPIO	Intended Use
DC1	5/12V	150mA	open drain	GP8	Carbon dioxide solenoid (future)
DC2	5/12V	150mA	open drain	GP9	White top light 12V PWM
RGB-1	5V	2A via diode	WS2812B		2x WS2812B strips with common 4V5 supply
			GPIO via	GP12	Top strip data
			470R	GP13	Backlight strip data
RGB-2	5V	150mA	open drain		RGB top light 5V PWM
		each output		GP11	R
				GP10	G
				GP14	B
DC3	5V	150mA	switched +5	GP4	Small USB air pump
AC1	<250VAC	2A resistive	NO relay	GP27	Spare (or mains air pump)
AC2	<250VAC	2A resistive	NO relay	GP15	Heater
AC3	<250VAC	2A resistive	NO relay	GP7	Filter pump

The DC and RGB outputs are open-drain except DC3. The DC1, DC2 and DC3 outputs have protection diodes.

RGB-1 and RGB-2 are alternative configurations of the same 4-pin connector, they are not both available at the same time. RGB-1 is the default configuration on a new PCB. Solder blob links must be changed to obtain RGB-2 It is quite possible to use 12V PWM for the RGB outputs rather than 5V, merely fit D2 anode into the more distant hole in the PCB (adjacent to Q6). Note the 360mW maximum dissipation for the BSS123 MOSFETs (1W for the AO3400). C7 must have a voltage rating of 15V or more.

The PCB has also been arranged such that GP12 and GP13 are available on H7 and could be used as COM1 TX and COM1 RX respectively (UART0) if not required to drive WS strips. I have no use for this facility, but it seemed like a good idea at the time. :)

The following devices are also connected on the PCB:

	Device	GPIO	Intended Use	
BZ1	Piezo sounder	GP2	Temperature alarm	
LED	Blue or Green	GP5	Power on	3-wire common
	Red	GP6	Fault indication	cathode 2-colour
S1	Active low button	GP29	"Down"	
S2	Active low button	GP28	"Up"	
S3	Active low button	GP3	"Select"	
	Remote temperature sensor	GP26	Tank temperature	DS18B20 but resistor can be disconnected if required.
	I2C0 SDA	GP0		Common to RTC
	I2C0 SCL	GP1		and OLED display
	(I2C SDC and I2C SCL in MMBasic)			

As previously mentioned, the PCB is intended to fit the same case as the CMM2. As the board does not occupy the full width there are spaces at the rear to fit the 12V input socket and a 2.5mm jack socket for the temperature sensor at one side and the mains supply cable at the other. The mains supply is connected to the PCB via a pluggable terminal block so it can easily be removed if changes to the PCB need to be made later.

The AC connectors are 3-pin but the centre pin is not connected. I recommend putting a bit of heat shrink on this if possible. (although 500V tests were carried out without insulating this.) External equipment connected to these must be "double insulated" Class 2. You must not connect equipment that requires an Earth connection as there is no continuity to PE. This is perfectly normal for most aquarium equipment. There should be 30mA earth leakage protection on the incoming supply.
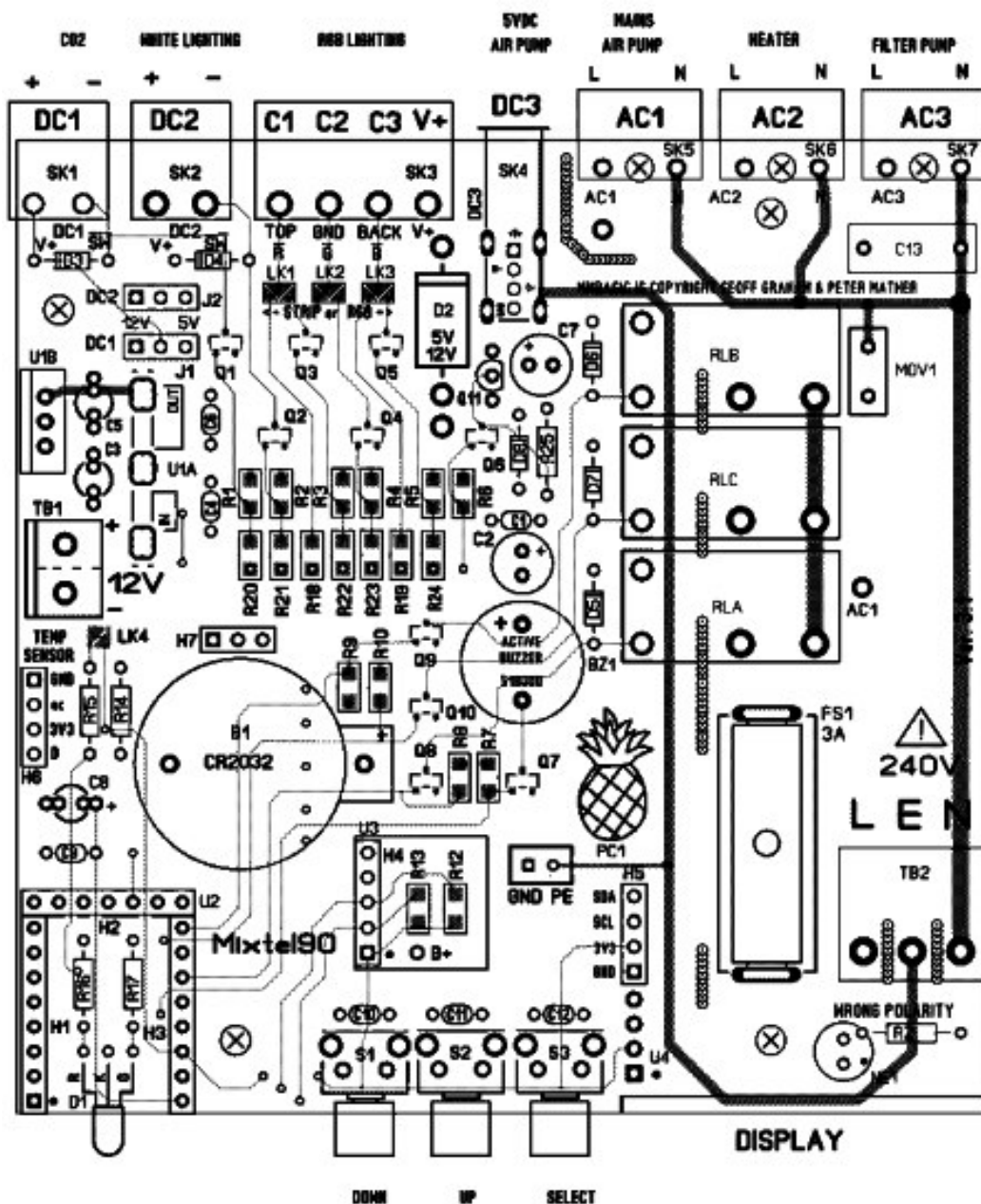
There is an on-board shrouded fuse and a small Varistor to help protect against spikes on the mains supply. I have tested the PCB prior to assembly using a 500V DC insulation tester and obtained readings greater than 200M (the top limit of the instrument) on all Live, Neutral and Earth tracks. An Earth track on both the top and bottom of the PCB separates the low voltage side. This also connects to the shell of the USB socket, so it is electrically bonded to mains Earth and forms an earthed barrier between the low voltage and mains connectors (it is not connected to DC negative so does not bypass the EMC reduction capacitor in switch mode supplies). The PCB is also slotted to increase insulation where considered necessary. The 500V tests were repeated on the prototype board, populated with the exception of the AC1 circuit, with the test software running and with both relays closed. It was not possible to test L-N this time due to the presence of MOV1. Once again resistance values were greater than 200M.

The AC3 mains output has a small capacitor across the load to give a little suppression as it switches. It may not be required, but I think an unsuppressed filter pump motor was causing occasional problems on the first version of my aquarium controller as it was switched, so a capacitor has been included here.

Feel free to change FS1 to suit your application. The PCB tracks are rated for 6A total, 2A per relay.

I would recommend only fitting mains AC outputs where needed and using the plastic rear panel of the enclosure to blank off unneeded positions. AC1 is not active by default, it requires a link wire to RLA, as well as installing RLA etc. for this. You can, of course, use the "mains" side for other purposes such as low voltage AC or DC switching. It is an isolated section in its own right.

The plugs and sockets used for the mains outlets are non-compliant, at least in the UK, as the Live output is not fully shrouded so they should not be used for this purpose. However, I've been unable to find any compliant connectors in a similar (or even slightly larger) PCB-mounting style. I decided to compromise by making the Live pins moderately difficult, but not impossible, to touch if you are determined. The AC plugs are screwless and should also be wrapped in a layer or two of self-amalgamating tape to cover the entry point of the wires.

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Not all applications will require all the components. Feel free to leave out what you don't need!

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Please see the later Usage section regarding limitations of the USB connection.

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I repeat, this PCB has been designed to fit into a plastic enclosure, on plastic PCB mounting pillars. There is no accessible metalwork that is not connected to mains Earth or to the low voltage supply negative where applicable. If you wish to use it at mains voltages please bear this in mind.

Although originally designed as an aquarium controller, please note that the device is NOT to be regarded as waterproof or even splashproof and should not be located close to the aquarium if unprotected.

Bill of Materials

| Name	Value	Comment
B1	CR2032	3V cell with holder
BZ1	518000	5V active piezo sounder
C1	100n	Ceramic cap
C2	47uF	electrolytic capacitor
C3		capacitor
C4	100n	Ceramic cap
C5		capacitor
C6	100n	Ceramic cap
C7	10uF	electrolytic capacitor
C8	10uF	electrolytic capacitor
C9	100n	Ceramic cap
C10	100n	Ceramic cap
C11	100n	Ceramic cap
C12	100n	Ceramic cap
C13	100nF	310V class X 13x5
D1	LED	red/green common cathode
D2	1N5401	3A diode
D3	1N4148	diode
D4	1N4148	diode
D5	1N4148	diode
D6	1N4148	diode
D7	1N4148	diode
D8	1N4148	diode
FS1	3A	20mm fuse and holder
H1	8-way	0.1in female socket header
H2	7-way	0.1in female socket header
H3	8-way	0.1in female socket header
H4	5-way	0.1in male pin header
H5	4-way	0.1in male pin header
H6	4-way	0.1in male pin header
H7	3-way	0.1in male pin header
J1	3-way	0.1in male pin header with jumper
J2	3-way	0.1in male pin header with jumper
LK1	STRIP	PCB configuration link
LK2	STRIP	PCB configuration link
LK3	STRIP	PCB configuration link
LK4	closed	PCB configuration link
LK5	closed	PCB configuration link
NE1	6mm	glass neon
PC1		
Q1	AO3400	N-channel SOT23 MOSFET (alt. BSS123)
Q2	AO3400	N-channel SOT23 MOSFET (alt. BSS123)
Q3	AO3400	N-channel SOT23 MOSFET (alt. BSS123)
Q4	AO3400	N-channel SOT23 MOSFET (alt. BSS123)
Q5	AO3400	N-channel SOT23 MOSFET (alt. BSS123)
Q6	BSS123	N-channel SOT23 MOSFET

Q7	BSS123	N-channel SOT23 MOSFET
Q8	BSS123	N-channel SOT23 MOSFET
Q9	BSS123	N-channel SOT23 MOSFET
Q10	BSS123	N-channel SOT23 MOSFET
Q11	TP2104N3-G	P-channel TO92 MOSFET
Q11B	AO3401	P-channel SOT23 MOSFET
R1	10K	1206 SMD resistor
R2	10K	1206 SMD resistor
R3	10K	1206 SMD resistor
R4	10K	1206 SMD resistor
R5	10K	1206 SMD resistor
R6	10K	1206 SMD resistor
R7	10K	1206 SMD resistor
R8	10K	1206 SMD resistor
R9	10K	1206 SMD resistor
R10	10K	1206 SMD resistor
R12	10K	1206 SMD resistor
R13	10K	1206 SMD resistor
R14	2R2	resistor
R15	4K7	resistor
R16	1K	resistor
R17	1K	resistor
R18	470R	1206 SMD resistor
R19	470R	1206 SMD resistor
R20	220R	1206 SMD resistor
R21	220R	1206 SMD resistor
R22	220R	1206 SMD resistor
R23	220R	1206 SMD resistor
R24	220R	1206 SMD resistor
R25	4K7	resistor
RLA	RE030012	Schrack 12vDC 6A AC1 relay
RLB	RE030012	Schrack 12vDC 6A AC1 relay
RLC	RE030012	Schrack 12vDC 6A AC1 relay
RZ	220K	resistor
S1	B3F-315n	Horizontal 6x6 tactile switch c/w B32cap
S2	B3F-315n	Horizontal 6x6 tactile switch c/w B32cap
S3	B3F-315n	Horizontal 6x6 tactile switch c/w B32cap
SK1	15A 5.08mm	2-way horiz closed end pluggable header
SK2	15A 5.08mm	2-way horiz closed end pluggable header
SK3	15A 5.08mm	4-way horiz closed end pluggable header
SK4	USB-A vert	FCI 73725-0110BLF (RS 771-0048)
SK5	10A 3.81mm	3-way horiz closed end pluggable header Hartmann STLZ1550/03G
SK6	10A 3.81mm	3-way horiz closed end pluggable header Hartmann STLZ1550/03G
SK7	10A 3.81mm	3-way horiz closed end pluggable header Hartmann STLZ1550/03G
TB1		5mm pitch terminal block
TB2	AK130	Phoenix pluggable terminal block with PST1/3 5mm pin strip

U1A	5V reg	4A switching regulator
U1B	7805	alternative regulator

These are alternatives - see notes

U2	module	RP2040-Zero
U3	module	self-contained RTC
U4	module	SSD1306 OLED display

Enclosure	Multicomp Pro G738 or G748A Instrument Case 140x110x35 mm (Jaycar HB5970, Altronics H0472, Element14 1526699, Farnell 1526699)
Screw	M4x6	4-off Self tapping screw to fix PCB into case
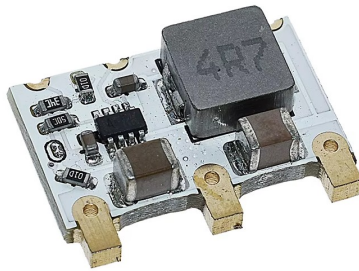
U3   U1A   SK5-7

Component Notes

With a new RTC module the CR2032 and holder aren't needed (and will do nothing even if you fit them). When the battery on the RTC has finally expired, desolder it. Put a piece of thin, insulated wire from the battery positive pad (next to the connector) round to the top of the RTC pcb, soldering it to the pin that normally has no connection (next to the - pin). By default, if you now plug the RTC in again, it will be powered by the CR2032. Alternatively you can run the wire down to the B+ pad on the pcb, and possibly break the solder blob link - just in case some future version of the RTC does actually use that pin.

D2 is used as a voltage dropper when using WS2812B light strip. It reduces the supply voltage slightly (which has negligible effect on the brightness) to make sure the Pico can drive the strips at about 3V high logic level. If you are using the outputs for RGB or digital switching you can link D2 out - it's not needed.

FS1 holder has lugs (they are what I happened to have). I just bent them down to go through slots in the PCB. They are difficult to touch with the cover on, but some silicone or even glue gun might help. I actually used a 2A TD fuse.

The 4K7 resistor for the temperature sensor can be taken out of service by breaking LK4. The board has been designed in this way so that other sensors, such as a MCP9701A active thermistor, can be used instead of a DS18B20.

When used as output devices the BSS123 MOSFETs, are not very powerful, but are ok for my needs. There are far better devices available but these were very cheap (for 100!) and one of the aims of this project was to give me some SOT-23 and 1206 SMD soldering practice! The AO3400 is vastly superior and is just as cheap (from AliExpress). The PCB is marked to use a TP2104N3-G as Q11 as I already had these. A much better alternative is the AO3401. Pads are provided for this on the rear of the PCB. Once again, this is very cheap and easy to obtain. These AO34nn series of MOSFETs have a much lower power dissipation and will run cooler, as well as having more current carrying capability.

The incoming mains pluggable terminal strip is available from several manufacturers, usually much cheaper. Note that they are sometimes sold without the 5mm pin header though. You could use a different type of terminal here.

NE1 and RZ are optional. They are intended for use in countries that use reversible mains plugs and should always be fitted in these cases. As the neon is connected between N and E it will light if the plug is reversed. The polarity is important as only the live side of the supply is switched by the relays. With the polarity incorrect the unswitched side of the outputs is live at all times. When the PCB is fitted in the enclosure it may not be possible to see the neon as it is behind the display. It is recommended that a small hole is drilled in the front panel just above the display. As the inside of the enclosure will normally be dark it should be reasonably easy to tell if the neon is lit. It may be prudent to mount the neon a few mm up from the surface of the PCB (insulate the leads) so that it stands just higher than the display. The specified value for RZ is for 220/240V. You may need to change it to suit your local supply.

The board will accept a 7805 regulator, a switching 7805-package regulator or a 4A switching regulator found on AliExpress. The choice will depend on your application. Without any external loads on the 5V rail a 7805 gets slightly warm. It is positioned so that a small heatsink can be added if required.

Gate resistors are fitted for all outputs that might drive PWM loads, under which condition they restrict the current pulses from the RP2040 GPIO outputs. The remainder of the outputs do not have gate resistors as it is considered that there is no problem because they are switched infrequently.

Assembly & Test

As usual, start assembling with the lowest components (the MOSFETs and SMD resistors) first. If you don't you'll curse later. :) Then fit the normal resistors and LED before the sockets for the RP2040-Zero!

The display is a bit fiddly to fit. I used quite stiff silver-plated copper wire, leaving it too long then carefully bending each in turn. That leaves the wires at odd lengths - which is handy for getting them through the holes in the PCB. Solder them before trimming. The front of the display PCB, not the glass, should be flush with the edge of the PCB. My intention is to glue a small plastic block behind the display to secure it, but a blob of hot glue might be just as effective.

When fitting into the case the fixing point behind DC1 will require a 4mm spacer, This is a bit of an odd size, however a simple piece of tubular spacer and a nut and bolt will do fine here. It is well away from anything that could be at mains voltage. You can just about manage without this support.

To configure MMBasic for this board you will require the following options to be set:

OPTION SYSTEM I2C GP0, GP1
OPTION LCDPANEL SSD1306I2C32, LANDSCAPE
OPTION RTC AUTO ENABLE

A set of tests (written in MMBasic) is included as part of the construction pack so that correct operation of the board can be confirmed. These currently test the buttons, display and simple control of all outputs. There is a sequence of 7 interactive tests with a 3s delay after each:

First the system time is displayed for a few seconds. This is just to test that the display is working.

Test 1 - buttons
Test 2 - LEDs
Test 3 - Buzzer
Test 4 - AC outputs (toggle)
Test 5 - DC outputs (toggle)
Test 6 - WS or RGB outputs depending on your configuration choice (simple output test only.)
Test 7 - Temperature sensor (only tested as an active low digital input)

Usage

Because the RP2040-Zero used in this project has no isolation diode for the USB VBUS supply some precautions have to be taken to prevent a back-feed into the USB port of a connected PC. This won't necessarily cause damage in all cases, but there is always the possibility.

Please note that the USB-C connector is intended for updating the firmware and your program. There will be insufficient current available from the USB source to power anything attached to the system.

Disconnect the incoming 12V supply before connecting the USB plug and re-connect it after removing the USB connection. While programming do not do anything to switch on any significant loads as you may overload the USB supply.

If you are developing software on the PCB then it's a good idea to use single LEDs with series resistors for monitoring, with outputs set for 5V. Do not connect the 12V supply. If you require more 5V current than the USB source will supply (it's sometimes limited on laptops) then use a powered hub.

Note that there is a problem when using this for an aquarium. Failure of the 12V or 5V supplies means that the heater and filter both shut down. On larger tanks the best way to handle this is to use a second heater, set to just below the minimum of the main heater. This should have its own mains supply so that the controller can be unplugged. Normally it won't operate but it will take over if the main heater is lost. (It is quite common to use two or more heaters on large tanks for exactly this reason).

Front and rear plates

These plates should be 30mm x 135mm. If printed accurately at full size you will be able to use them as templates to mark out the plates to cut whatever holes you wish. Alternatively, Gerber files are included so that you can get a set of plates made with either 2 or 3 AC sockets.