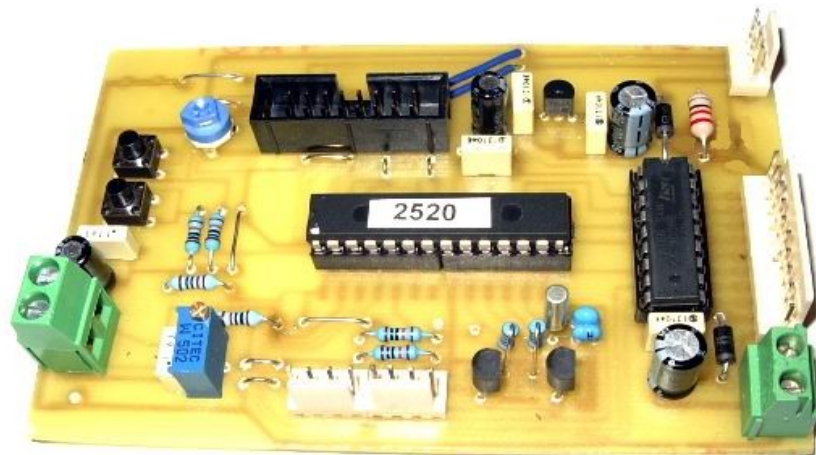


DIY Temperature Multi Controller

January 2006 - updated December 2007

The Temperature Multi Controller was developed for my marine reef tank, the main feature of it was to simply and cheaply, provide accurate temperature control for both heating and cooling in one unit.



the latest version – pcb07

- user definable temperature set points for three outputs
- user definable Alarm output for over and under temperature
- a temperature range of 21.0 to 33.0 deg
- a resolution and accuracy of 0.1deg C
- temperatures and information displayed on a 16 x 2 LCD matrix
- a simple two button control for the menu system and data entry
- now with more menu selectable features -
- two lighting channels, one with lights kill on over temperature alarm
- two timer/doser channels with optional switch inputs for auto level etc.
- two timers with wavemaker options
- minimum and maximum temperature recorders and loggers etc.
- Centigrade and Fahrenheit scales
- alarm telephone dialler outputs
- battery backup
- system tools

Typical operation would be:-

Heating on at 24.9 off at 25.0
Cooling Fan on at 25.5 off at 25.2
Chiller Unit on at 26.0 off at 25.2 (coolers always go off together)
Sound Alarm if temperature goes below 24.0 or above 28.0

The cost of all parts for the micro unit including a small 2x16 LCD GB £30
NB excludes mains PSU and relays etc.

Safety Warning and Disclaimer

The unit has been successfully controlling my tank for over four years so I am happy to offer the low voltage dc micro circuit and program to other fish keeping/electronics enthusiasts to use for their own interest and development.

No warranty for its function or reliability is given or implied .

No details of the mains power supply or relay/mains output board will be provided as any constructor should be well able to make up their own - if not then please read the following -

IMPORTANT.

IF YOU CANNOT DESIGN AND BUILD YOUR OWN MAINS BASED CIRCUITS IN ACCORDANCE WITH YOUR WITH YOUR LOCAL COUNTRY, ELECTRICAL LEGISLATION, SAFETY REGULATIONS AND EMC DIRECTIVES ETC. -

THEN PLEASE, STOP READING THIS PROJECT AND GO AND BUY AN APPROVED COMMERCIAL UNIT FROM YOUR LOCAL AQUATIC OUTLET !!

MAINS ELECTRICITY WILL KILL !! - DO NOT RISK YOU OR YOUR FAMILY !!!

Pictures of typical LCD messages

Time 10:04 ALARM
Temp 2LOW HEATNG



Time 10:05
Temp 24.1 HEATNG



Time 10 05
Temp 25.0



Time 10:05
Temp 26.3 COOL1



Time 10 06
Temp 27.4 COOL12



Time 10:06 ALARM
Temp 2HI COOL12



PCB Boards

The following pages show all the PCB boards and component silks, - these have been created at 600dpi.

When printed out to a standard 600dpi laser printer, good copy was given and when measured with a printers rule, were accurate to + or – 1/4mm. (the silks to within 1/2mm)

Please check your print outs are accurate with a good ruler - cheap plastic ones can be over 1mm out.

If you cannot get good copy please let me know and I will supply the original layouts as created by the Proteus program which you can download and use to print out the files or supply to a pcb maker.

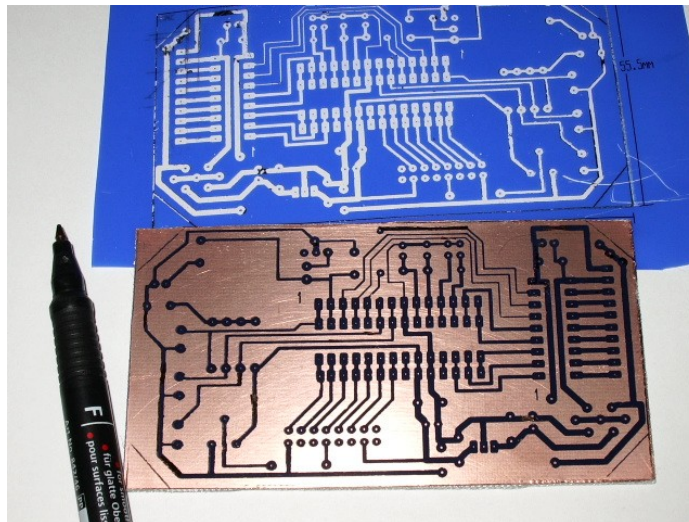
PCB Board production.

The PCB have been produced on a single sided board so making it easy to make your own.

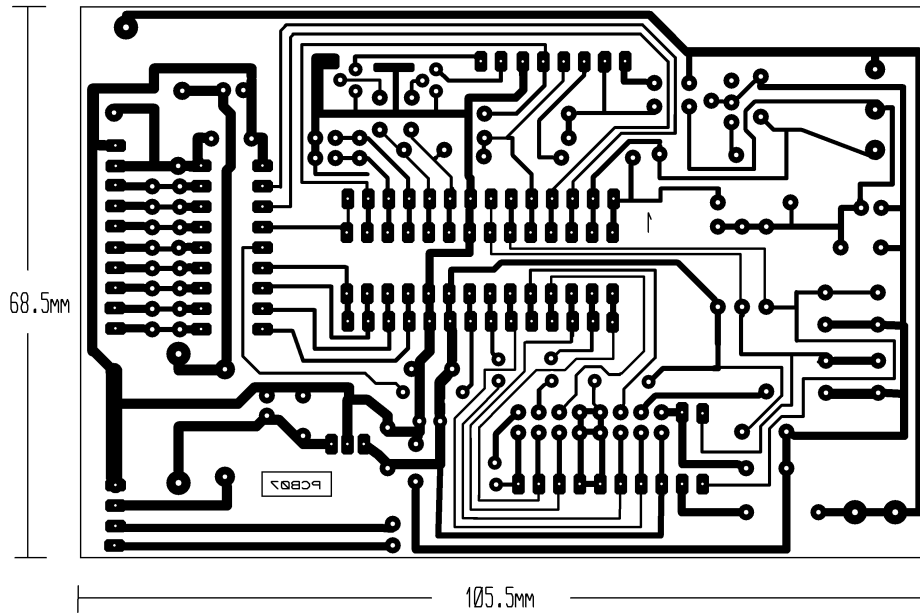
The PCB design is laser printed to the film which is then hand ironed onto the copper board, any slight imperfections touched up with an etch resist pen.

Even better than the costly blue film is using a page of printed glossy magazine - it does work !

See -<http://www.electro-tech-online.com/electronic-projects-design-ideas-reviews/30943-toner-transfer-pcb-possible-2.html?highlight=making+pcbs>

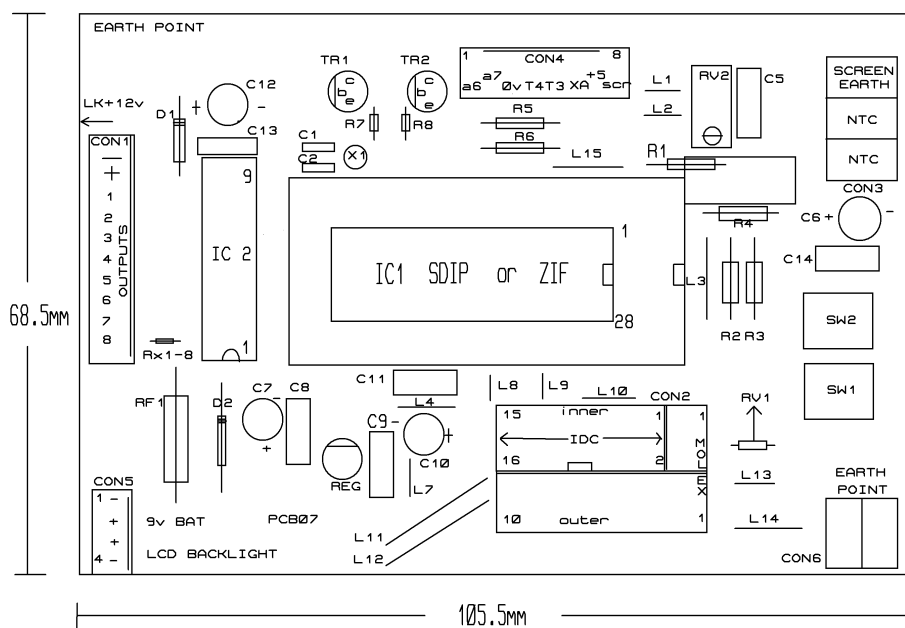


PCB07 TOP VIEW – LOOKING DOWN AT COPPER TRACKS THROUGH THE BOARD

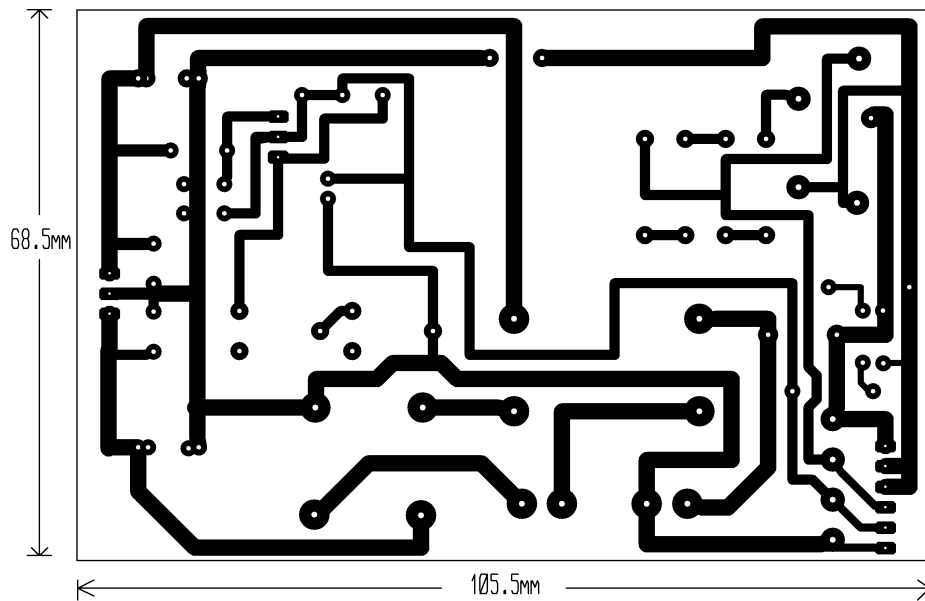


SCREEN VIEWS MAY NOT BE TO SCALE

PCB07 with Component Silk for 18F2520 chip

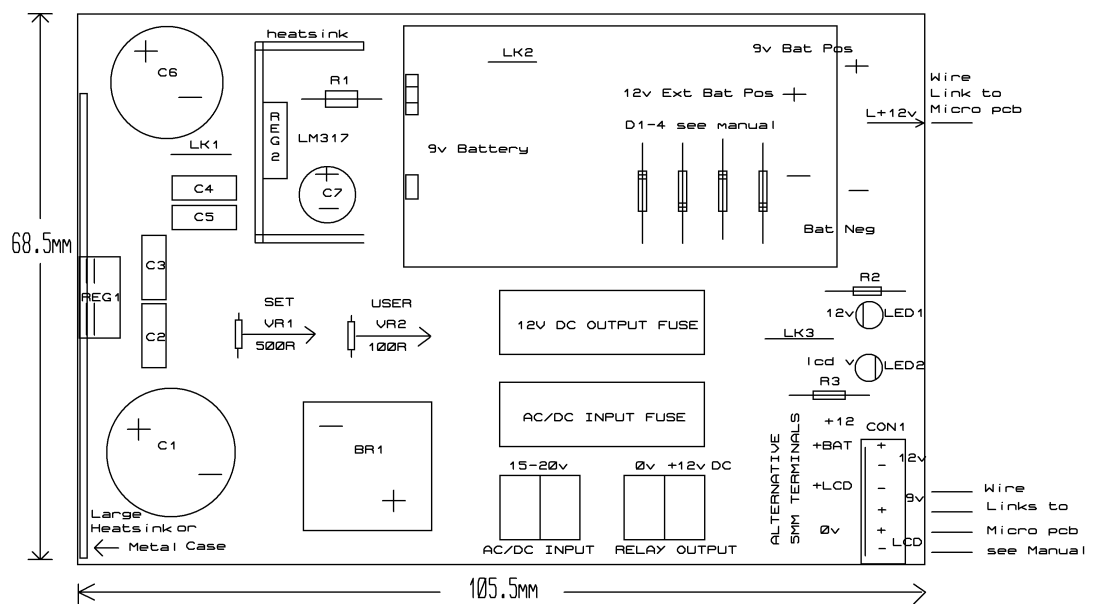


PCB dcpsu TOP VIEW – LOOKING DOWN AT COPPER TRACKS THROUGH THE BOARD

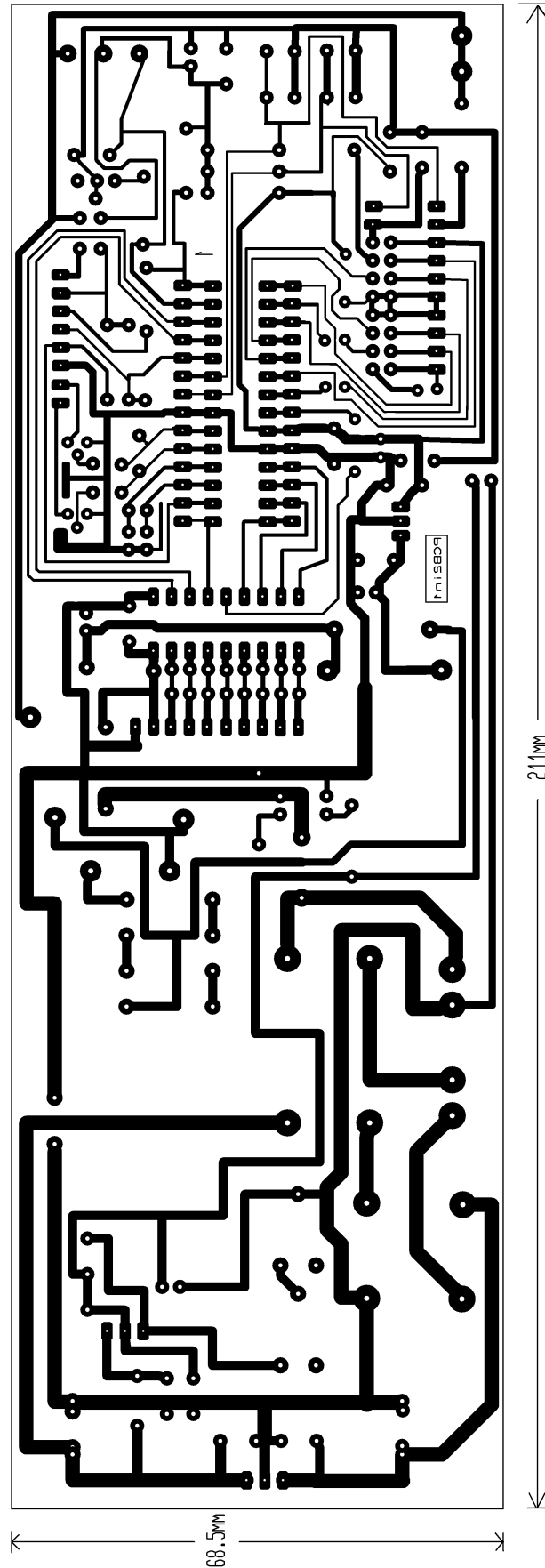


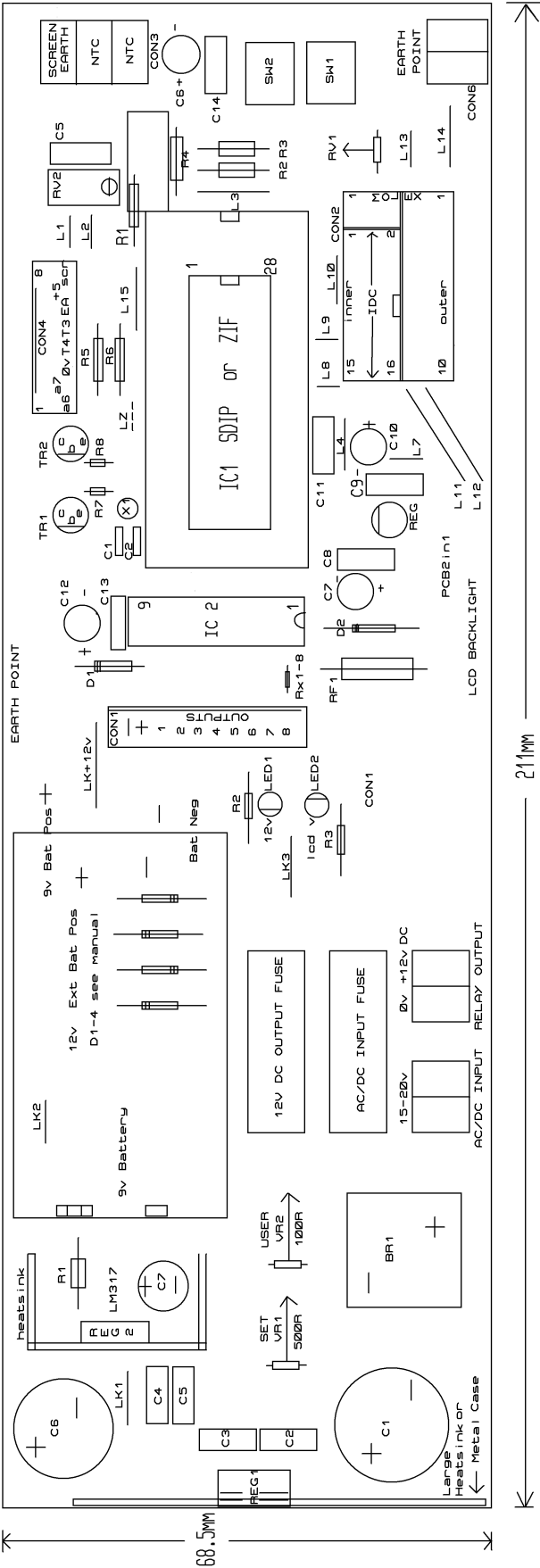
SCREEN VIEWS MAY NOT BE TO SCALE

PCB dcpsu Component Silk



PCB 2 in 1 Provides an “all in one “ board for all the DC circuitry.
Just follow the construction notes for the dcpsu and the micro board and add link LK+12v





Micro PCB Parts List

LCD HD44780 compatible	2 X 16	Parallel I/F	1
C1,2	27 pf	Ceramic Capacitor	2
C5,8,9,11,13,14	100 nf	Polyester MM Capacitor	6
C6,10	22 uf	Elect Cap 16v 2.5mm radial	2
C7,12	100 uf	Elect Cap 25v 2.5mm radial	2
R1,2,3,4,5,6	10 K	Resistor .6w or .4w	6
R7,8	4K7	Resistor .6w or .4w	2
RV1	10 K	Min Pre set Horizontal .3W	1
RV2	5 K	20+ turn Pre set Top Adjust	1
NTC	10 K	Thermistor RS 151-237 or equiv	1
D1,2	1 A	IN4004/5/6 types	2
REG1	+5v 100ma	T092 Regulator	1
RF1	22 uh	Small Choke or similar	1
X1	32.768 K Hz	Clock Crystal	1
IC1	18F2520 I/SP **	28 pin Microchip	1
IC2	ULN2803A	Relay Driver IC	1
IC1SKT	28 pin 0.3"	DIL Socket	1
IC2SKT	18 pin 0.3"	DIL Socket	1
TR1,2	BC337	Transistor NPN	2
SW1,2	Min Switch	Push to Make – Momentary	2
Links	Solid Core Cable	To make wire links – per meter	1
Cables	To Suit Connectors		
PCB s	As Required		
Box	To Suit	Metal Preferred for screening	1
<i>Optional Connectors</i>			
CON1	10 Way	.1" Pcb Header & Socket	1
CON2 for IDC	2 x 8 Way	IDC Pcb Header & Plug	1
CON2 for MOLEX	10 Way	.1" Pcb Header & Socket	2
CON3	3 Way	5mm Pcb Terminal	1
CON4	8 Way	.1" Pcb Header & Socket	1
CON5	4 Way	.1" Pcb Header & Socket	1
CON6	2 Way	5mm Pcb Terminal	1

see Parts buying on next page

** In some countries the 18F2520 is still not readily available.

Please see pages 23 & 24 for details of building with the earlier 16F876A chip

DC PSU Parts List

C1	2200 uf	Elect Cap 50v	1
C2,3,4,5	100 nf	Polyester MM Capacitor	4
C6	1000 uf	Elect Cap 25v	1
C7	100 uf	Elect Cap 25v	1
R1	240 R	.6w or .4w Resistor	1
R2	3K3	.6w or .4w Resistor	1
R3	1 K	.6w or .4w Resistor	1
LED1,2	3 mm	Standard LEDs colour to suit	2
VR1	500R	Horizontal Pre set	1
VR2	100R	Horizontal Pre set	1
REG1	7812	!2v Reg 1A/2A/3A to suit Relays	1
REG2	LM317T	Variable Reg 1.5A	1
HS1	Large Heat sink	For REG1 or use metal case	1
HS2	Small Heat sink	For LM317	1
BR1	6A 60 / 100v	Bridge Rectifier	1
FS1, 2	20mm	PCB Fuse holder	2
CON1,2	2 Way	5mm Pcb Terminal	2
BATTERY and HOLDER	9V	PP3 / 6LF22 + holder + clip	1
<i>Optional Components</i>	<i>If separate pcb</i>		
CON3	6 Way	.1" Pcb Header & Socket	1
	<i>If external 12v batt used</i>		
D1,2,3,4	1A 100v	1N4004/5/6	4

Parts Buying

In North America the 5K pre-set RV2 is not readily available - so use a 10K version and change R1 to 4K7 to compensate.

The circuit works best with the RS NTC or similar bead types - large discs or rods should be avoided.

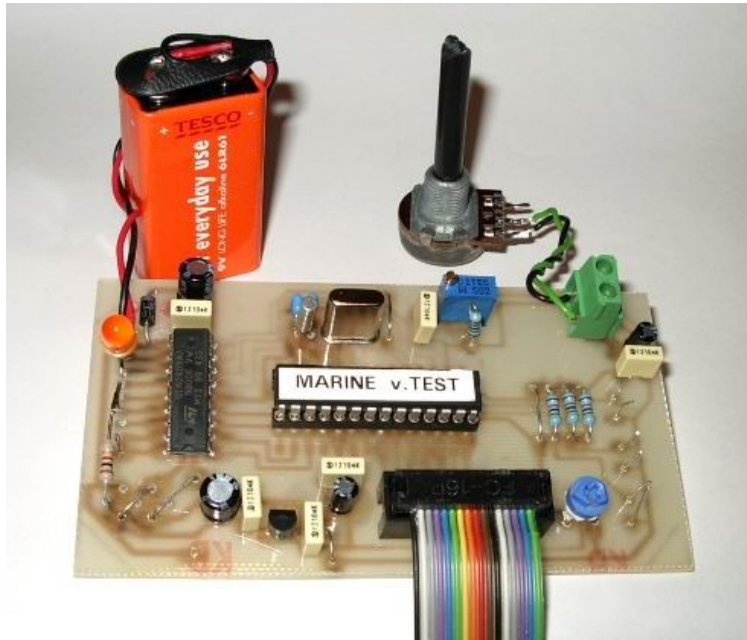
If the Microchip PIC 18F2520 chip is not readily available in your area, I'm told that if you, as a hobbyist, register with Microchip, you may get samples for free! - see also the previous page re the 16F876A version.

The LCD connector2 can be either a 2x8 way IDC cable header suitable for short IDC cable lengths when mounting the LCD inside the main box, or a 2 x 10way .1" headers for wiring to a multi core cable when mounting the LCD and switches remotely – say on the tank lid etc.

The use of screened cables is recommended throughout with the screen connected to Earth.

Construction and Testing

The Micro PCB – General Notes



An early Mk1 board in a simple test jig made up of a 9v battery, 22k pot and led with resistor.

If a LCD with a back light is used you **must** have a separate power supply for those LEDs .

They usually need about 4.2v dc, but see your lcd data sheet.

The dc psu board provides a suitable variable supply for most standard units.

The Temp Probe is made from the NTC and about 100mm of approx 10-16mm diameter, non toxic plastic tube, with the NTC placed near the bottom, and filled with aquarium silicone.

Try and ensure the area at the top, where the cable goes into the probe case, is very well sealed and always positioned above the water level.

Against perhaps obvious thinking do provide a thickish (2-5mm all round) sealing layer over the NTC, they are very quick to react to temp changes - a thicker layer helps improve the overall stability.

Make sure you place the probe in an area of good water movement but not in the direct path of a circulation pump, the heating or cooling flows.

LINK Z should NOT be fitted, this is only for use with future options.

Outputs - Relays & S S Relays

The original design was for use with mechanical/coil relays but solid state relays can equally be used, provided a suitable series resistor, RX 1-8 , is used.

Provision is made on the PCB for them to be used, but **you must cut the track under the resistor for each one you use** or erase the PCB tracks before etching.

There is no reason why you cannot 'mix and match' the outputs to whatever type you choose - just use the right resistor/cut track / or track for each device you choose.

The Micro PCB – Testing and Setup

Construction should be straight forwards, but before connecting everything the following tests are recommended. As small DC volt and MA meter is required, together with a 9v battery and a 22k pot.

Without either ic plugged in and the LCD disconnected -
Connect the 9v battery and measure the voltage out of the regulator as 5v.
Then measure the current from the battery – should be 1-3ma approx.

Next, one at a time, disconnecting the power each time, try the chips which should add another 3 ma, and finally the LCD, (no back lights) to give a running load well under 10ma - typically 5-7ma.

Adjust RV1, almost fully anticlockwise, to give best readable display with no background 'blocks' visible

All outputs can be tested from the menu Relay Tests routine.

After entering the menu Calibration routine, *slowly* adjust the 22k pot, and test the functions and outputs work in-line with the display message. (2.68v on pin2 gives approx 25deg)

The temperature display may not seem totally stable in this mode, but once connected to a proper probe all is stable.

Calibration

Is best done on an existing tank. From the menu select the quick calibration routine (auto resets after 3 minutes)
Set RV2 to its midway position.

Place a good reference thermometer in the tank with the Probe next to it – and leave for 4 minutes to fully stabilise.

Adjust RV2 trimmer to give the correct temp. One full turn clockwise on RV2 should increase the display by about 0.4deg C for the 10k NTC.

Finding a good reference thermometer can be difficult, several ordinary thermometers will probably all give different readings - choose the middle average one - or try the Tropic Marin glass 'High Precision Thermometer' - which I used to calibrate the original values.

Operational Notes

ADJ TEMP is the temp to keep at – heating comes on at just 0.1degc below that.

For cooling, I suggest you allow at least 0.3deg c, above the ADJ TEMP setting, before cooler1 comes on.

Both cooler 1 and 2 are switched off by the same value; again allow at least 0.2deg c above the ADJ TEMP. as once the coolers are switched off a fair bit of temp. reduction can still be given as all the 'cooling' is taken out of the unit.

Backup heating - the old comment about using two small heaters rather than one large, is a good point. What I have done for many years is to use one heater on my Micro Controller with a running temp of say 25.0 c.

A second heater, (with, if possible, a separate circulation pump,) set by its own internal thermostat to say 24c, and connected to a separate mains socket from the micro controller, so any failure to the micro circuit, and the heating will be maintained, short of a total power cut, at that slightly lower but safe temperature.

The Power Supply

The 12v input power for the micro PCB should be from a 12v DC regulated source e.g. 7812 reg.
You can use your own PSU or the simple unit below.



A simple 12v DC PSU with variable output for the LCD Backlight and Battery Backup

As can be seen from the above picture this is a very simple 12v regulator which should be fitted with a 7812 style regulator to match your load requirements.

Typically for all solid state outputs or 1-3 small standard relays a 1A device should be fine.
For 4 or more relays use a 2A or 3A version dependant on the coil load of your relays.

The 7812 regulator should be mounted onto a suitable large heat sink or to a metal case etc.

NB - the unit was designed for LCD back lights that run on a nominal / maximum of 4.2V
Please check yours is compatible before connecting to this unit or adjust to the required voltage.

Voltage Test and Set Up Procedure

Set VR1 to minimum, fully anticlockwise, and VR2 to maximum, fully clockwise.

Apply power and test the main regulator for 12v output.

Connect your meter to the BL output and 0v. This should give about 1.75v.

Slowly increase VR1 until 4.2v is shown.

This is the maximum voltage - adjusting VR2 will now reduce the voltage, acting as a dimmer.

Once set, lightly seal VR1 with a blob of silicone to ensure it is not accidentally 'trimmed'

Battery Backup

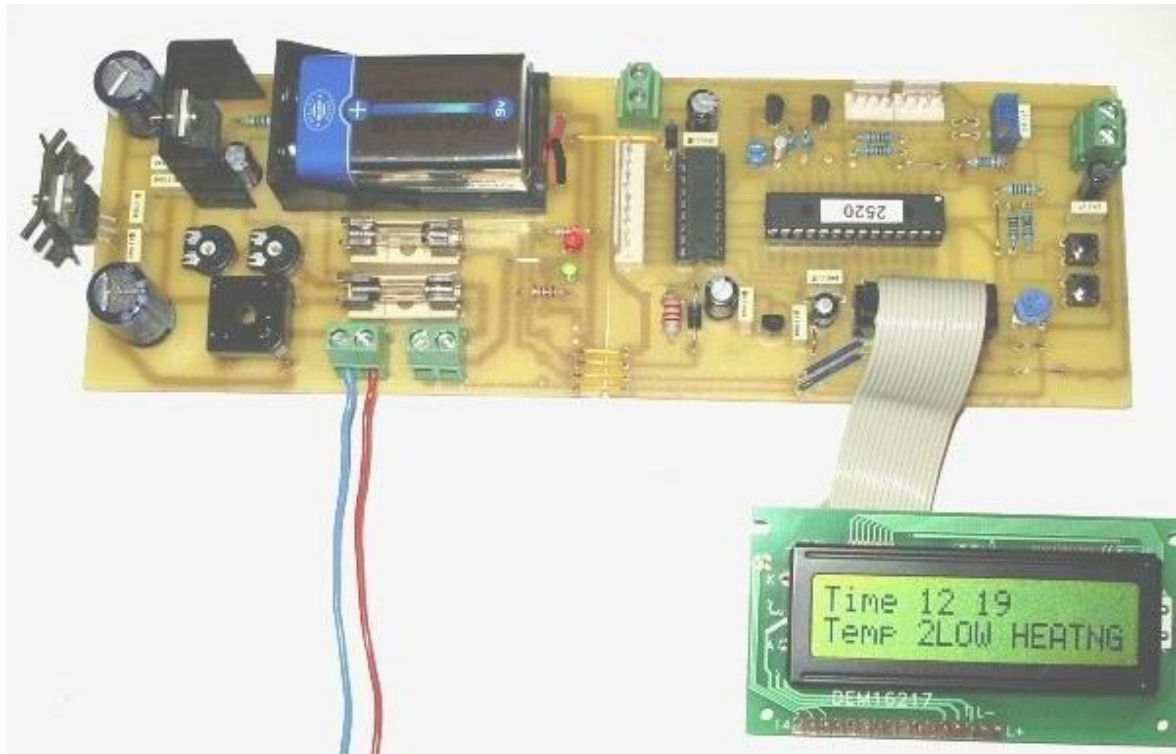
A simple battery backup can be added to protect the Real Time Clock.

Its connection method allows the LCD to remain powered on, so when a power cut is experienced you can still monitor the actual tank temperature.

With a cheap zinc PP3 battery, when the mains was switched off for 3-4 hour per night, it gave 27hrs of power.

If you are wanting to use a larger external 12v battery then fit Diodes 1-4 to drop it to 9V

Connecting the two boards



Heat sink shown on Reg1 +12v is for testing only - use a large one operationally !!

The two boards joined as one with the five yellow wire links.

Use the Molex connectors or soldered cables if you want to have them separate

The 2 in 1 Board

This PCB is simply as the above circuit boards but joined by tracks as one board for those who like an integrated package.

No additional notes have been produced for this board – simply follow the existing notes for the two individual boards, but it is recommended that the dcpsu part is built and tested before the micro.

Suppression

The micro unit can be 'reset' by electrical interference from your mains equipment so you should take whatever steps are required to prevent such occurrences.

All signal cables serving the micro unit should be made with screened cables, with the screen taken to the earth points; and /or fitted with ferrite rings close to the metal box.

A small choke is fitted to the micro unit just before the 5v reg, but additional mains filtering may be required to this unit and the devices being controlled.

I cannot give any advice on mains suppression.

With the data values being stored in EE memory, if the micro is reset by interference, then it may be difficult to notice a reset has happened.

For this reason a Resets counter has been added to the min/max recorder function, so you can easily monitor what's been happening.

Note that when first powered on it will show '1' reset for that start up - it can be cleared when clearing the min/max temps.

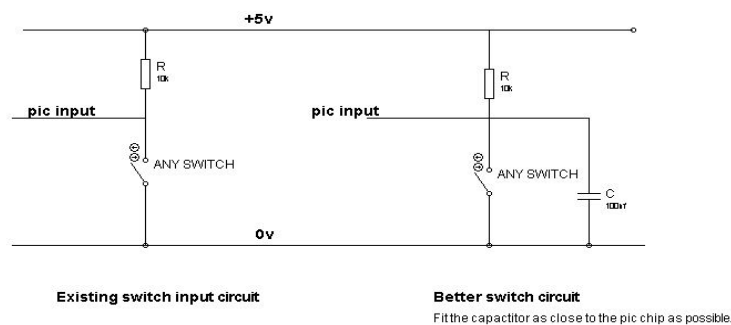
Dec 2007.

There has been just one reported problem of electrical interference causing a reset to the micro.

The problem, when switching on the MH lights, interference was believed to be being picked up from one of the switch inputs / cables.

Fitting a 100nf capacitor to the switch input affected, in this case the Alarm SW input to pin1 overcame the problem.

If any similar problems are encountered, then try fitting these 100nf capacitor to all the 5 switches, preferably as close to the pic chip as practicable. - see circuit below.



Pic Programmers

There is a host of PIC programmers and development boards, DIY or ready made, to choose from.

For about GB £10 you can build the little programmer below. (most parts probably in your spares box)



A simple, low cost way to program most 28 & 40 pin 16F and 18F pic micros.
Uses WinPic free ware and requires a parallel port.

Please email for full manual and PCB layouts etc.

However, you may want to program more chips and /or only have USB ports, then I can fully recommend the new, ready built, Microchip PicKit2 USB Programmer.

<http://www.microchipdirect.com/productsearch.aspx?Keywords=PG164120>

For anyone with a MikroE EasyPic4 development board, I have a special trial version to run on it using the pic18F4520 chip - Just email me for a copy and port set up details.

Software Functions

Operation of the Keys and Menus

When in the main display, Key A is used to enter the Main Menu and to advance to the next function.

When in the Main Menu, Key B is used to change the value of that function e.g. to advance the time. In this mode, Key B has 3 different advancement rates, press singly and two press and hold speeds.

All the values you change in Menu A are stored in non volatile memory in case of power failure. This is done every time the main menu is exited and on every hour.

The unit will run immediately on a preprogrammed set of default temperatures.

When in the main display, pressing Key B will invoke the statistics menus on the lower line. Functions can be selected as shown by the messages, or left alone it will automatically exit.

When you enter either of the menus, all other functions stop, apart from the real time clock, so you should not stay in this mode longer than necessary.

To avoid any problems with the menus being left open or a key sticking on, the system will reboot after 8 minutes, if a key was stuck on, then a message is displayed and the key routines bypassed.

Menu A functions



Press key A until the above screen appears then release to enter the main menu.

Note - if you continue to hold key A down other menus will appear every 3 seconds and then return to the main menu again. These are described later.

Adj CLOCK



Set to the current time.

Adj LT1on - LT1off



The required times, between 00:01 and 23:59, should be entered. Set to 00:00 if this function is not required

LT1 is linked to the Over Temp Alarms, and if these temps are exceeded the Light is turned off. See the Alarm section for more info.

Adj LT2on - LT2off

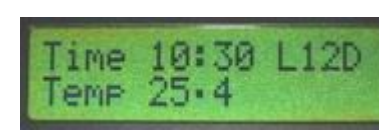
The required times, between 00:01 and 23:59, should be entered.
Set to 00:00 if this function is not required

Adj TM3on -TM3off

The required times, between 00:01 and 23:59, should be entered.
Set to 00:00 if this function is not required

Adj INTV3

The Interval or Off time of the timing cycle in hours and minutes
By setting the interval time to 00:00 and the dose time to 1 or more minutes it will run in a continuous mode thus acting like a standard lighting channel.

Adj DOSE3

The Dose or ON time on the timing cycle in minutes only. Hours are ignored.

TIMER3 ON

Sets the timer on or off without having to change the above settings.

TIMER3 SW

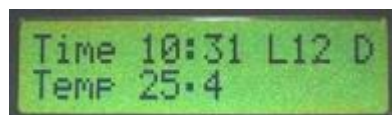
Is designed for an Auto Top Up; when TM3SW activated – the LCD will display 'S' - standby.
 When the float switch is activated (closed) the output is turned on and the display will show 'T' for Top Up
 The output remains on until either the switch goes off or the dose time is exceeded; whichever first.
 An interval then follows and will not allow further top ups until its cycle is finished.

Adj TM4on -TM4off

The required times, between 00:01 and 23:59, should be entered.
 Set to 00:00 if this function is not required

Adj INTV4

The Interval or Off time of the timing cycle in hours and minutes
 By setting the interval time to 00:00 and the dose time to 1 or more minutes it will run in a continuous mode thus acting like a standard lighting channel.

Adj DOSE4

The Dose or ON time on the timing cycle in minutes only. Hours are ignored.

TIMER4 ON

Sets the timer on or off without having to change the above settings.

TIMER4 SW

Is designed for a *push* switch to invoke a feeding period when the circulation pumps are turned off.
 Once set a 'S' for Standby will be displayed on the LCD.
 When the *push* switch is pressed and released the output turns on and displays 'C' for Circulation and remains on for the dose4 time, then returns to standby. Any interval time is ignored.
 To make this function work, you must use a relay with changeover contacts suitably wired.

Adj TEMP

Set to the temperature you want to maintain.

Adj CHL1

Set to the temperature Chiller1 comes on.

Adj CHL2

Set to the temperature Chiller2 comes on.

Adj CHLSOFF

Set to the temperature both Chiller 1 and 2 are turned off.

WAVEMAKER ON

Turn the Wavemaker function On or Off

Adj ALARMLO and ALARM HI

Set to the temperatures you want the user Alarm routines to activate.

ALARM ON

Select YES if you want the alarm to activate when the Alarm LO and HI points are reached

ALARM PULSE

Select NO if you want the standard continuous alarm signal

Select YES if you want the alarm to send out a series of pulses for alarm dialler units etc.

The Alarm System details:-

System Alarm

If the temperature is below 21.0c or above 33.0c, the respective 2 LO or 2 HI message is shown, together with the 'ALARM' message on the LCD, and the Alarm output will be turned on.

If the 2 HI message is given when LT1 output is on, this is automatically switched off for safety

The Menu A users Alarm on/off selection has no effect on this routine

External Alarm

Users own external alarm contacts can be connected and will activate instantly.

Users Alarm

The Menu A Alarm LO and HI set points allows the user to specify those temperatures, much closer to the normal operating temperatures so giving early indication of a problem.

Once you have specified those temperatures, you need to turn the ALARM ON to activate.

If the Alarm HI message is given, when L1 output is on, it is automatically switched off for safety

Alarm Pulse function

With the Alarm Pulse function ON, a series of 1 second pulses are sent out, to allow the users to connect a variety of alarm diallers or SMS text signalling units.

The micro is programmed to do 4, double 1 second pulses at 5 minutes intervals followed by 7 more every 30 minutes.

The pulsed output is separated into three alarm conditions and outputted on the following ports.

External alarm via output 8, Low Alarm via output 9 - TR1, High Alarm via output 10 - TR2, with the alarms being prioritised in the same order. e.g. a High Alarm will override the External Alarm signal.

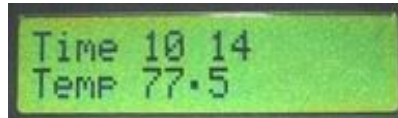
Important Point - when using this function it automatically suppresses the output for the wavemaker function.

Calibrate



This gives instant LCD feedback to allow the temperature sensor to be trimmed with RV2. After 3 minutes, the system automatically reverts to the normal 95second sensing cycle.

Fahrenheit Scale



Displays in 0.5F steps.

Please note that when changing the set point temperatures in the menu, you will have to press key B approx 3 times to increase the Fahrenheit value by 0.5.

Relay Test



Switches each output on and off, in turn, at 1.5 second intervals, then restores the original outputs.

Other Key A Functions.

As well as the main menu the following quick access functions are available by pressing and holding Key A. When the desired function is shown release key A to enter.

Lights Extra



Allows you to manually turn on or off the two lighting channels.

Also, 30 minutes of extra time can be instantly added to the existing on time.

Note that only the relevant options are given dependant on the current lights status.

Wavemaker Status



Shows the current pump operation and how much time is left before the next event.

Program Wavemaker 1 and 2

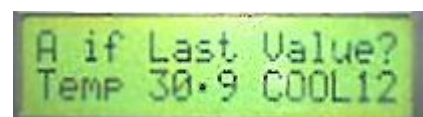
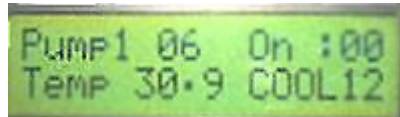


These timers allow you to program wave patterns by using from 1 to 32 on /off periods per pump

Whenever SW4 is pressed, a 5 minute off feed cycle is given.

Although designed as a Wavemaker, you can use them for any other function like dosers etc.

Important Point - you cannot use the Wavemaker if the Alarm Pulse function is in use.



You are asked to enter the ON time in 1 – 99 minutes, which must be followed with a valid OFF time.

Enter as many on/off pairs as required - when finished, just leave the next ON time at 00 and press key A. This signifies the last value to the program.

You are asked to confirm this and review the data if required.

If changing an existing pattern, it is recommended you first turn the Wavemaker Off from the Main Menu

All data entered is immediately stored in Eeprom so not data can be lost.

Menu B Functions

Press key B to enter -

The menu will then automatically run to the end without any need to press a key again.

Prompts are given to enter the sub functions.

Min Max Display



Displays the current days, 00:01 – 23:59 temperatures - cleared at 00:00

Reset Events

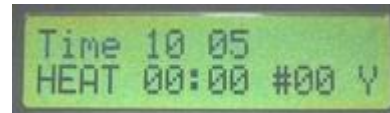


Displays the number of times the system has been Reset.

B to Clear Min Max

Clears Min and Max to the current temperature and also clears the Resets counter.

B for Statistics



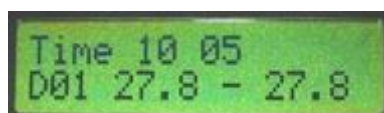
Shows the total number of times a function has switched on and the total time it has been on for.

Heater, Chiller1, Chiller2 and above the users Alarm Hi Temperature

The first line of each device display is for the current day 00:01 – 23:59

The second line, denoted by Y, is for the previous 24 hours.

B for Min/Max Log



Displays the previous 14 Days logs – automatically rolled over.

Building with the 16F876A chip

The project can be built on the PCB 07 with this chip, but the following program features are lost.

Extended temp scale to 33.0deg C	- to 29.9deg C only
Fahrenheit Scale – menu selectable	- Centigrade only
14 days of min/max temps stored	- only 4 days
External Input to trigger the alarm	- none
2 extra i/o ports	- none
Plenty of Memory to allow new features - no updates at all.	

Part List for the 16F876A

The following changes to the parts list on Page 10 should be made.

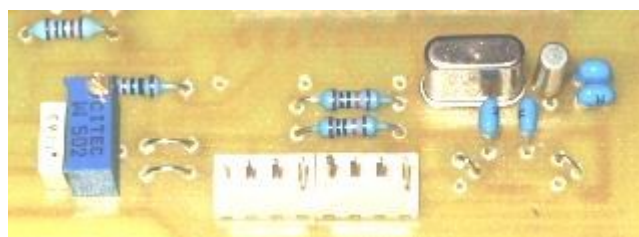
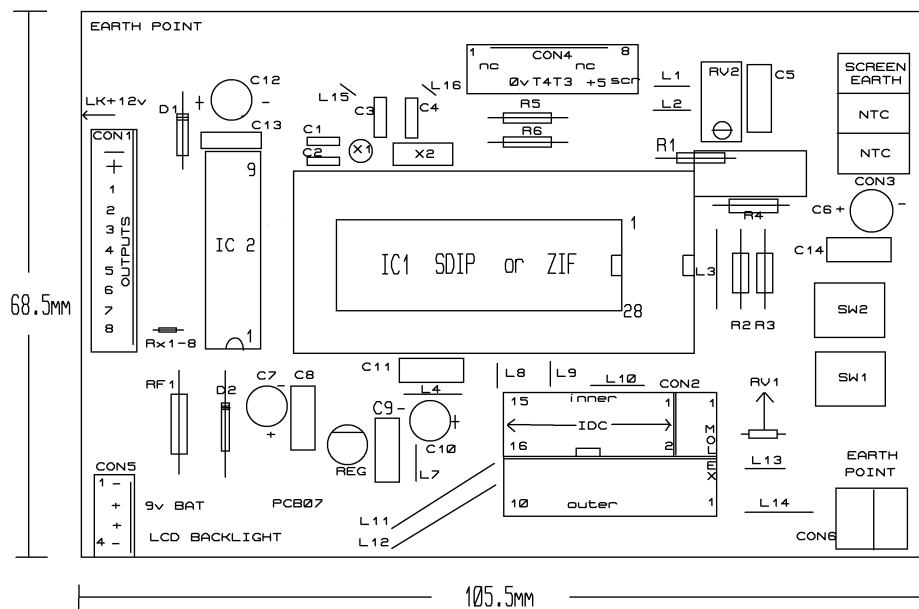
Delete - R7, R8, TR1 & TR2

Add in - X2 4Mhz Xtal, C1 & C2 33pf Ceramic Capacitors

Building the Circuit

Using the component silk below should be no problem, although care is needed to get the location of Links 15 and 16 correct - see photo below.

PCB07 with Component Silk for 16F876A chip



Links 15 and 16

Circuit diagram for PIC16F876A

