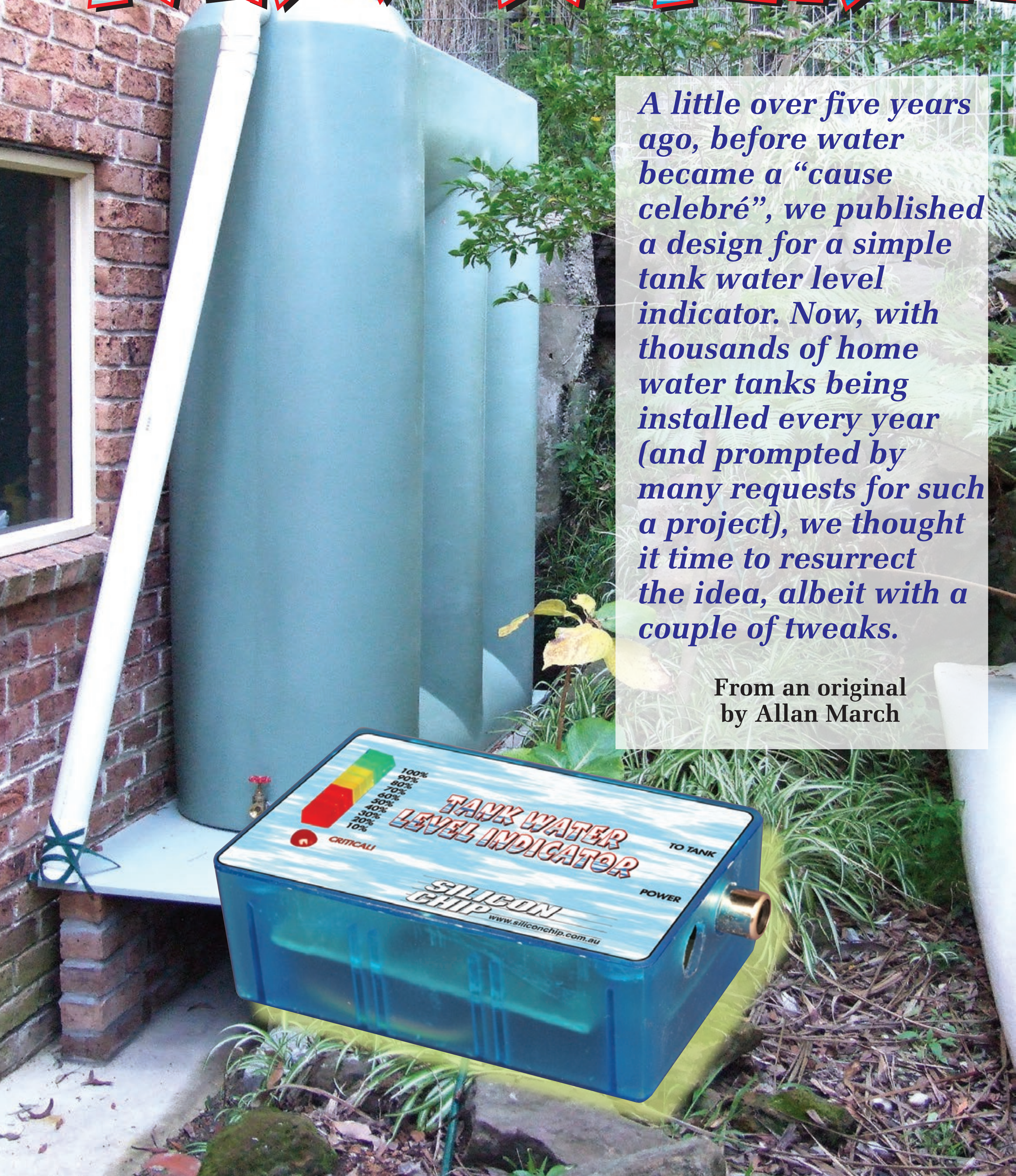
TANK WATER LE

A little over five years ago, before water became a "cause celebré", we published a design for a simple tank water level indicator. Now, with thousands of home water tanks being installed every year (and prompted by many requests for such a project), we thought it time to resurrect the idea, albeit with a couple of tweaks.

From an original by Allan March



EVEL INDICATOR

HOME WATER TANKS are undoubtedly a good idea. Why pay for water when you can catch it free? You can have the greenest garden in the street, along with the cleanest car, while you thumb your nose at the water restrictions now in place in most capitals and many regional centres.

But once installed, how can you determine how full (or how empty!) your tank really is?

There are several traditional methods for finding the level of water, among them: (1) tapping down the side of the tank until the sound suddenly changes; (2) on a hot day feeling down the tank for a change in temperature; (3) pouring boiling water down the side of the tank and looking for the line of condensation and (4) removing the tank cover and dipping in a measuring stick.

The first two methods are notoriously unreliable, while the last two also have their problems. Only the last is accurate. But who wants to clamber up on top of a tank each time you want to find out how much water is inside it?

That's where this simple circuit comes in. It uses a row of ten coloured LEDs arranged in a bargraph display to give a clear indication of how the water supply is holding up. The more LEDs that light, the higher the water in the tank.

The LEDs are arranged in the familiar "traffic light" colours of green, yellow and red to instantly indicate relative levels at a glance (green is good, yellow not so good and red is bad!) as well as the specific levels represented by the individual LEDs.

A further red LED lights when the tank level drops below a critical threshold. This can simply be to warn you of impending localised drought (hey, your tank's empty!) – or it (or indeed any of the ten-LED "string") could be used to trigger an audible alarm, turn on a pump etc, as we will discuss later.

There are no fancy microcontrollers or digital displays used in this project. Instead, it uses just a handful of common parts to keep the cost as low as possible.

It can be used in a traditional metal tank or one of the new slimline plastic jobs. As long as you can get very access inside the tank from the top to the bottom, this circuit will work.

Circuit description

Fig.1 shows the circuit, which only has a few differences to the April 2002 circuit. As in that design, it is based on an LM3914 linear LED dot/bar display driver (IC1) which in this case drives not five but ten LEDs (LEDs 1-10).

Pin 9 of the LM3914 is tied high so that the display is in bargraph mode and the height of the LED column indicates the level of the water in the tank. However, (and this is one of the minor tweaks we've made), this pin can be easily isolated, turning the display into a dot type, thus saving power. If you're running from a battery supply in the bush, often every milliamp is sacred!

Indeed, the PC board pattern has been arranged so that a miniature switch could be included to swap between bar and dot modes.

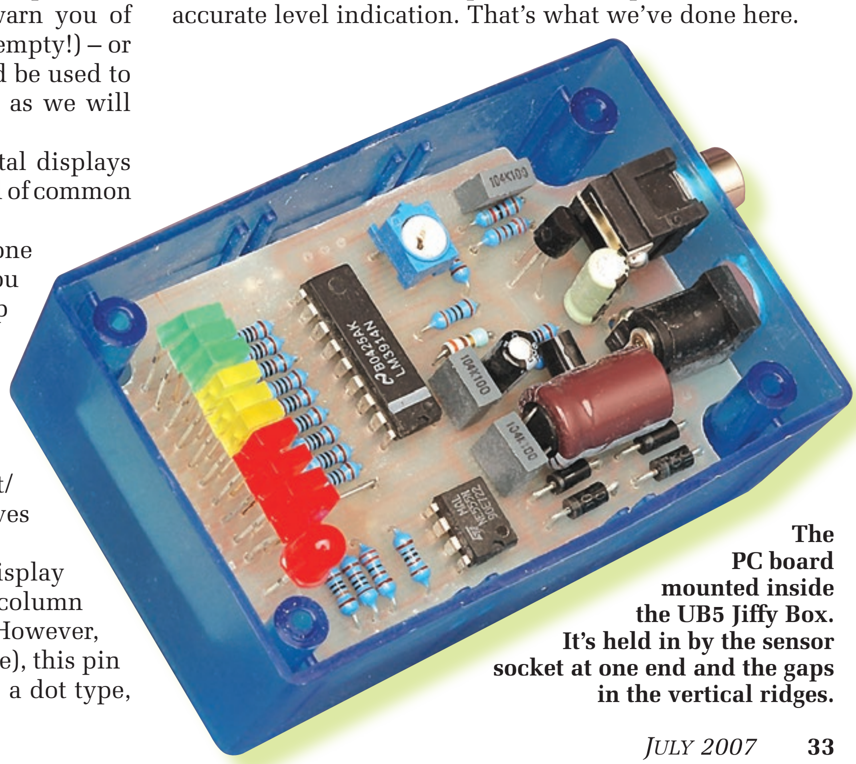
The full-scale range of the bargraph depends on the voltage on pin 6. This voltage can be varied using VR1 from about 1.61V to 2.36V. After taking into account the voltage across the 390Ω resistor on pin 4, this gives a full-scale range that can be varied (using VR1) between about 1.1V (VR1 set to 0Ω) and 2V (VR1 set to 470Ω).

By the way, if you're wondering where all the above voltages came from, just remember that IC1 has an internal voltage reference that maintains 1.25V between pins 7 & 8. This lets us calculate the current through VR1 and its series 1kΩ resistor and since this same current also flows through the series 1.5kΩ and 390Ω resistors, we can calculate the voltages on pins 6 and 4.

As well as setting the full-scale range of the bargraph, VR1 also adjusts the brightness of LEDs 1-10 over a small range. However, this is only a secondary effect – it's the full-scale range that's important here.

IC1's outputs directly drive LEDs 1-10 via 1kΩ current limiting resistors.

If you recall the original circuit, it had only five LEDs, all the same colour (green), to show water level . Changing the LED colours was no problem but a common request has been to use the full 10 outputs of the chip to obtain a more accurate level indication. That's what we've done here.



The PC board mounted inside the UB5 Jiffy Box. It's held in by the sensor socket at one end and the gaps in the vertical ridges.

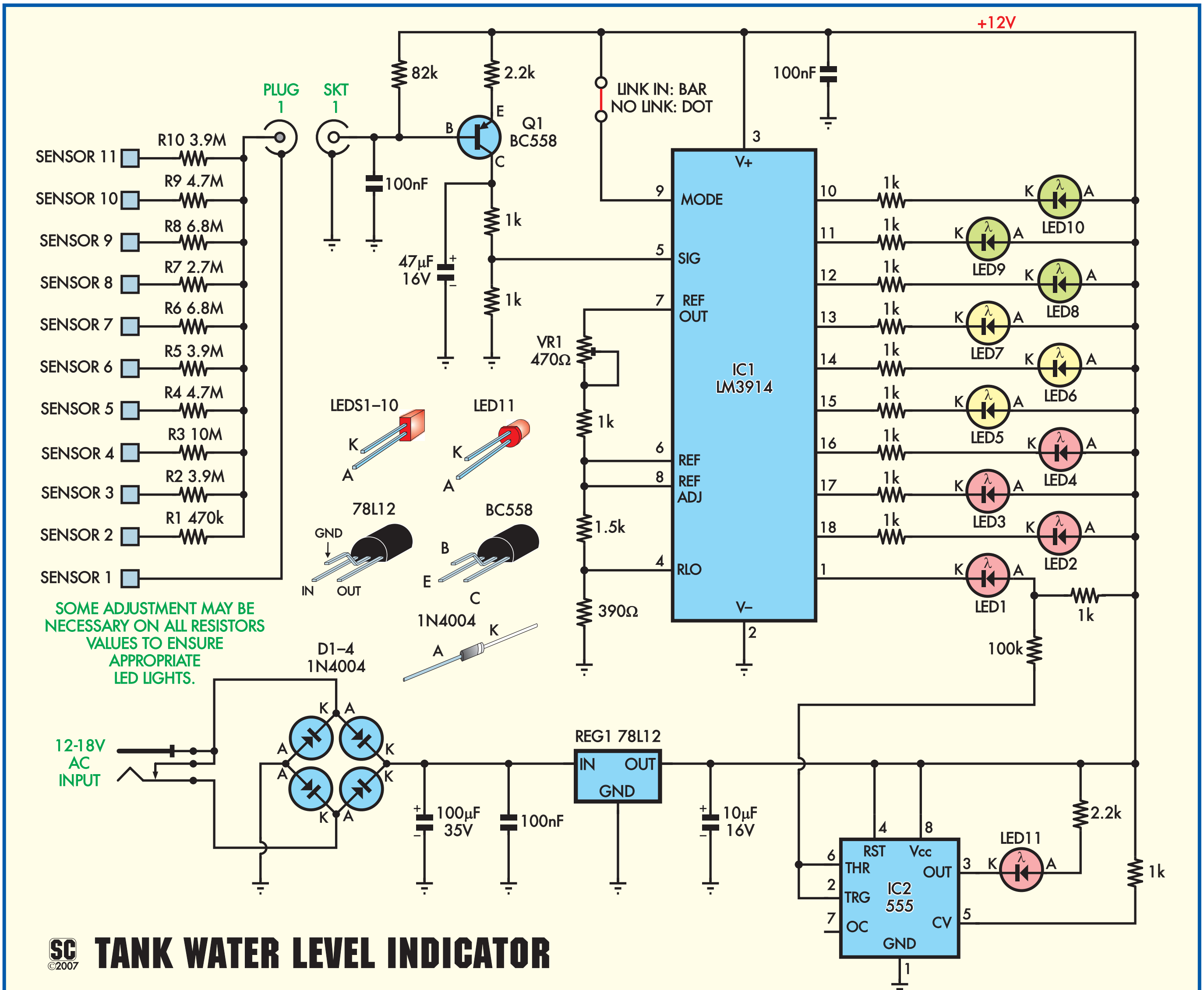


Fig.1: the circuit is essentially a bargraph display, calibrated so that appropriate LEDs light up as the sensors are covered by the rising tank water level. The 555 timer triggers another LED when the water level falls to critical.

If you *do* only need five levels, you could omit LEDs 2, 4, 6, 8 and 10 and tie pin 11 to pin 10, 13 to 12, 15 to 14, 17 to 16 and 1 to 18 – as per the original 2002 circuit. In this case we'd use two green, one yellow and two red LEDs in the bargraph.

Water level sensor

The input signal for IC1 is provided by an assembly consisting of 11 sensors located in the water tank and connected to the indicator unit via light-duty figure-8 cable. This sensor assembly relies on the fact that there is a fairly low (and constant) resistance between a pair of electrodes in a tank of water, regardless of the distance between them.

Every school child is taught that pure water is an insulator. This circuit demonstrates the fact that even rain water is not exactly pure!

As shown in Fig.1, sensor 1 is connected to ground, while sensors 2-10 are connected in parallel to the base of PNP transistor Q1 via resistors R1-R10. Q1 functions as an inverting buffer stage and its collector voltage varies according to how many sensor resistors are in-circuit (ie, how many sensors are covered by water).

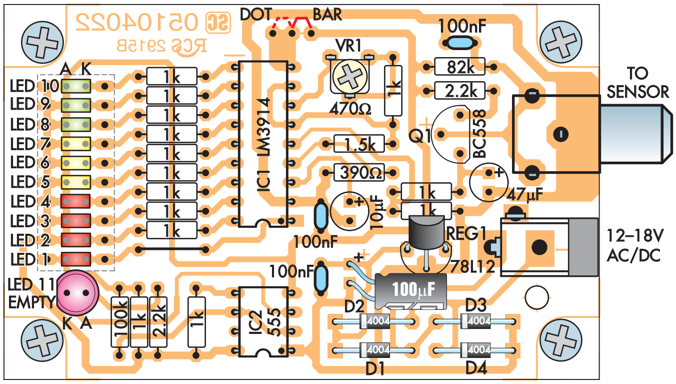
When the water level is below sensor 2, resistors R1-R10 are out of circuit and so Q1's base is pulled high by an 82kΩ resistor. As a result, Q1 is off and no signal is applied to IC1 (therefore, LEDs 1-10 are off).

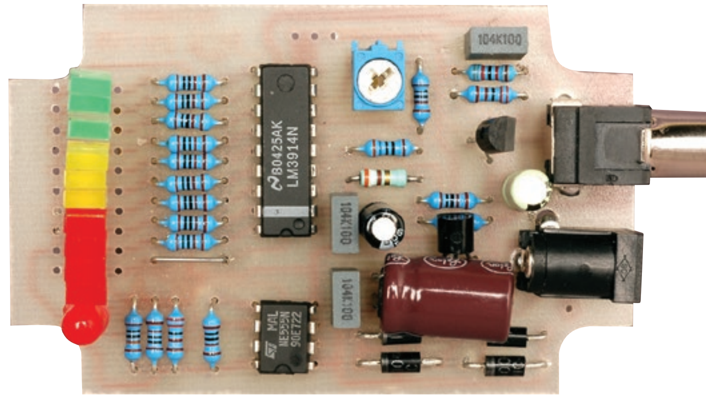
However, if the water covers sensor 2, the sensor end of resistor R1 is essentially connected to ground. This resistor and the 82kΩ resistor now form a voltage divider and so about 9.6V is applied to Q1's base.

As a result, Q1's emitter is now at about 10.2V which means that 0.8mA flows through the 2.2kΩ emitter resistor. Because this same current also flows through the two 1kΩ collector load resistors, we now get about 0.8V DC applied to pin 5 (SIG) of IC1. This causes pins 1 of IC1 to switch low and so the first red LED (LED1) in the bargraph lights.

As each successive sensor is covered by water, an additional resistor is switched in parallel with R1 and Q1's base is pulled lower and lower.

As a result, Q1 turns on "harder" with each step (ie, its





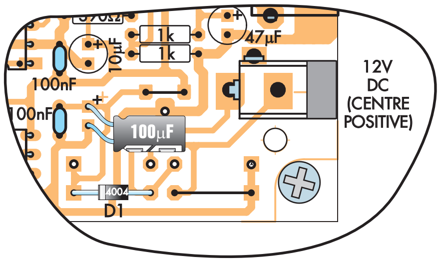


Fig.2: the PC board parts layout with matching photo alongside. Note the "laid over" regulator and filter capacitor. Fig.3, right, is the relevant section of the PC board revised for 12V DC operation.

collector current increases) and so the signal voltage on pin 5 of IC1 increases accordingly. IC1 thus progressively switches more outputs low to light additional LEDs.

Note that Q1 is necessary to provide a reasonably low-impedance drive into pin 5 (SIG) of IC1, while keeping the current through the water sensors below the level at which electrolysis becomes a problem.

Critical level indication

IC2 is a 555 timer IC and it drives LED11 (a 5mm round type to be obviously different) to provide a warning when the water level falls below the lowest sensing point; ie, when all the other LEDs have been extinguished.

However, in this role, IC2 isn't used as a timer. Instead, it's wired as a threshold detector and simply switches its output at pin 3 high or low in response to a signal on its threshold and trigger inputs (pins 6 & 2).

It works like this: normally, when there is water in the tank, LED1 is on and its cathode is low. This pulls pins 6 & 2 of IC2 low via a 100kΩ resistor, so that these two pins sit below the lower threshold voltage. As a result, the pin 3 output of IC2 is high and LED11 is off.

However, if the water level falls below sensor 2, LED1 turns off and its cathode "jumps" to near +12V. This exceeds the upper threshold voltage of IC2 and so pin 3 switches low and LED11 turns on to give the critical low-level warning.

As the control pin (pin 5) of IC2 is tied to the positive supply rail via a 1kΩ resistor, it will switch at thresholds of $0.46V_{CC}$ (5.5V) and $0.92V_{CC}$ (11V) instead of the usual 555 thresholds of $1/3V_{CC}$ and $2/3V_{CC}$. This is necessary to ensure that IC2 switches correctly to control LED11.

Power sources

Power for the unit is normally derived from a 12VAC plugpack supply. This drives a bridge rectifier D1-D4 whose output (nominally about 17V) is then filtered using a 100µF 35V electrolytic capacitor. This is applied to a 12V 3-terminal regulator (REG1). The 12V output from REG1 is then filtered using a 10µF electrolytic capacitor.

Another change to the 2002 design is the inclusion of 100nF capacitors in parallel with the electros to prevent oscillation. Provision was made for these on the original PC board but were not specified. For the cost of a couple of capacitors, we think it's cheap insurance.

The reason a regulated supply rail is used is to ensure that the water level indication doesn't change due to supply variations.

Having said that, the circuit is just as happy being powered from 12VDC, eg in a mobile home or caravan, or even a solar-backed battery supply in the bush.

A 12V supply with centre positive can be plugged into the power socket. In this case, regulator REG1 and diodes D2, D3 & D4 can be omitted. Both D4 and REG1 are then replaced by wire links – ie, install a link instead of D4 and install a link between the IN & OUT terminals of REG1. These changes are shown in Fig.3.

D1 should remain in circuit to protect against reverse battery connection. Or at the expense of another half volt or so (which shouldn't cause any problems), D1-D4 can be left in situ and then it won't matter which polarity the power connector uses. REG1 is still omitted in this case.

Also, with a known 12V supply (ie, one which doesn't rise markedly above 12V), the 100µF capacitor can be changed to a cheaper (and smaller) 16V type.

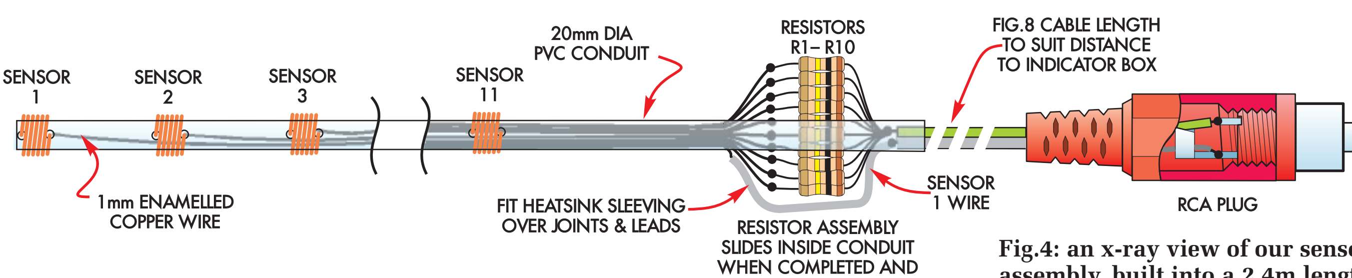


Fig.4: an x-ray view of our sensor assembly, built into a 2.4m length of 20mm PVC electrical conduit.

Construction

Construction is straightforward, with all the parts installed on a PC board coded 05104022 and measuring 80 x 50mm. This is installed in a standard "UB5" (83 x 54 x 31mm) plastic case, with the LEDs all protruding through the lid.

We happened to use one of the translucent blue types (because they look spiffy!) but they also come in black, grey and clear.

Before fitting any components to the PC board, you'll probably need to modify it by cutting the four inwards-rounded corners which accommodate the pillars in the case. The easiest way to do this is drill out the four corner holes with a much larger drill (say 8mm) then cutting from each of the edges of the board to the hole edges.

We also found that our PC board was slightly oversize (by perhaps 2mm) to fit into the plastic case but a couple of minutes with a file soon took care of that. Check to see that your board is a neat (friction) fit in the top of the case. Don't worry about the holes for the power and sensor plugs – we'll do those later.

Fig.2 shows the parts layout on the PC board. Begin the assembly by installing the resistors (and the single link at the bottom of the LED resistors connected to LED10), diodes and capacitors (with the exception of the 100µF electro), then install transistor Q1 and the ICs (but not the regulator). Make sure that the diodes and ICs are installed the right way around. The same applies to the electrolytic capacitors – be sure to install each one with its positive lead oriented as shown in Fig.2.

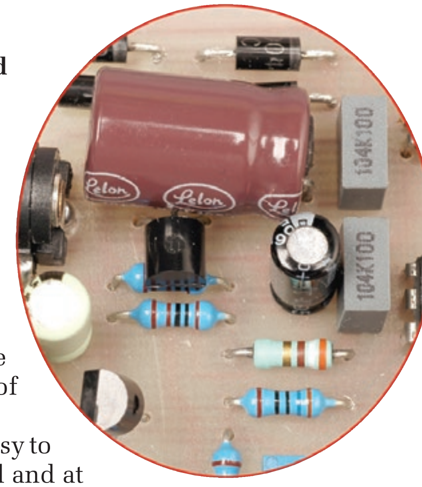
While the circuit calls for a 100µF 35V electro as the main smoothing capacitor, these are now fairly hard to get and you may be forced to use a physically larger 100µF, 50V instead.

The only way this is going to fit (and allow the LEDs to poke through the case lid) is to lay it on its side. This, in turn, means that the 3-terminal regulator (REG1) also needs to be installed almost flat with its legs under the capacitor (you can see what we mean from the photos).

Trimpot VR1 can now be installed, followed by the RCA socket and the 2.5mm power socket. The two sockets are both PC-mounting types and mount directly on the board.

The LEDs are fitted last and must be installed so that the top of each LED is 15mm above the PC board. This ensures that the LEDs all just protrude through the lid when the board is mounted in the case. Make sure that all LEDs are correctly oriented

Here's the sensor assembly, built on a 2.4m length of 20mm PVC electrical conduit. Each "sensor" (250mm of bared 1mm enamelled copper wire wound around the conduit) is spaced 200mm apart. A drop of glue on the end of each wire would hold the "coil" tight but be careful not to cover too much bare wire with glue! The wires emerge at the top of the conduit to their respective resistors. The copper wire sensors should last a long time in the relatively pure tank water.



Close-up of the PC board area showing the "lent-over" regulator and 100µF electrolytic capacitor.

– the anode lead is the longer of the two. Note that there are four holes provided for each the LEDs – you need to use the innermost pairs of holes.

It's not particularly easy to get ten LEDs all aligned and at the same height. We cheated a bit by sticky-taping the reds, greens and yellows together as sets, aligning those three sets and then soldering them in. The pads on the board are arguably a little close together to fit standard rectangular LEDs without splaying their legs a little but they can be made to look good!

Dot operation

As mentioned earlier, you can easily convert the LM3914 (IC1) from bar to dot operation if that's what you prefer. All you have to do is cut the thinned section of track between two pads immediately above and to the left of the trimpot.

If you want to get really clever, a miniature single pole, two position switch can be installed in place of the cut link (ie, between the two pads) so you can switch between bar and dot modes at will. This can be arranged so that it emerges through the case lid.

Checking it out

If a visual check confirms that you have all components in the right way and there are no solder bridges or dry joints, set the pot to mid way and plug in the power lead. If all is OK, the "tank empty" LED should light but all the others should remain unlit.

If the reverse happens, adjust the pot so that the "tank empty" LED lights and all others are off.

Now lick your finger and press hard on the two solder joints (ie under the PC board) of the sensor connect or, CON1 – the sensor connector. You should be rewarded with one or more lit LEDs in the string (with the "tank empty" LED going out). The harder you press, the more LEDs should come on. You are, of course, simulating the resistor sensor string with your wet finger. The harder you press, the lower the resistance – and the more LEDs will light.

Final assembly

The PC board is designed to snap into the purpose-designed locators in the vertical ridges on the side of the case. However, first you need to drill two holes in one end of the case, so that they line up with the RCA socket and the power socket when the board is installed (see Fig.6).

You should only introduce the PC board to these holes and the ridge gaps after the PC board is working properly and set up because once in, it's very difficult to get out again!

There is one 5mm hole to be drilled here (for the "tank empty" LED), along with a slot 25 x 5mm for the ten bargraph LEDs. The front-panel artwork (Fig.6) can be photocopied and glued to the case lid.

Sensor assembly

The sensor assembly is made by threading 10 lengths of 1mm enamelled copper wire through 20mm OD PVC electrical conduit – see Fig.4. This conduit should be long enough to reach the bottom of the tank, with sufficient left over to fasten the top end securely. The reason for using 1mm wire is primarily to make it easy to thread it through the conduit. Unfortunately, a single 100g roll isn't quite enough for all ten sensors: you'll need part of a second roll.

The top sensor (S10) is placed about 100-150mm below the overflow outlet at the top of the tank, while the other sensors are spaced evenly down the tube.

The distance apart is entirely up to you – depending on how accurate you want the readout and also, of course, the height of your tank.

Begin by using a 1.5mm drill to drill holes through the tube wall at the appropriate points, including a hole for the bottom sensor (S1) to hold it in place securely. The holes should be angled up slightly to convince the 1mm wire that this is the direction to head during the next step.

That done, you can thread the wires through by pushing them through the drilled holes and then up the tube. The end of each wire should also be smoothed before pushing it into the tube, to avoid scratching the enamel of the wires already in the tube. Leave about 250mm of wire on the outside of the tube at each point.

It's a good idea to trim each successive wire so that it protrudes say 20mm further out of the top of the tube than its predecessor. This will allow you to later identify the individual wires when attaching the resistors.

When all 11 wires have been installed, the next step is to solder the wire for S1 to the "earthy" side of the figure-8 lead, cover it with insulating sleeving and pull the covered joint down about 50mm into the 8mm tube. This done, the resistors can be soldered to their appropriate wires.

Push about 15mm of 2.5mm sleeving over each wire before attaching its resistor. This sleeving should then pulled up over the joint and the bottom end of each resistor after it is soldered. Once all the resistors have been soldered, the wires should be pulled down so that the joints are just inside the tube, as shown in the photo.

When this process is complete, there will be 10 resistors protruding from the top of the conduit. Their remaining leads are then twisted together, soldered to the other side of the figure-8 cable and covered with heatshrink tubing.

The other end of the figure-8 cable is fitted with an RCA plug, with the resistor lead going to the centre pin and the sensor 1 lead going to the earth side of the connector.

The next step is to scrape away the enamel from the 150mm wire lengths at each sensor point and wind them firmly around the outside of the tube. A 30mm length of 20mm copper water pipe can be pushed over sensor 1 to add weight and increase the surface area if desired.

On no account should solder be used on the submerged part because corrosion will result from galvanic action.

Finally, the end of the plastic conduit and the holes can

Parts List – Tank Water Level Indicator

1 PC board, code 05104022, 80 x 50mm
1 UB5 plastic case, 83 x 54 x 31mm
1 PC-mount RCA socket
1 RCA plug
1 PC-mount 2.5mm power socket
1 12V AC 500mA plugpack
2 100g spools 1.0mm enamelled copper wire
1 length (to suit) 20mm-OD PVC electrical conduit

Semiconductors
1 LM3914 linear dot/bar driver (IC1)
1 NE555 timer (IC2)
1 BC558 PNP transistor (Q1)
1 78L12 12V regulator (REG1)
4 1N4004 diodes (D1-D4)
4 rectangular red LEDs (LEDs1-4)
3 rectangular yellow LEDs (LEDs5-7)
3 rectangular green LEDs (LEDs8-10)
1 5mm red LED (LED11)

Capacitors
1 100µF 35V PC electrolytic
1 47µF 16V PC electrolytic
1 10µF 16V PC electrolytic
3 100nF MKT polyester

Resistors (0.25W, 1%)

1 10MΩ	2 6.8MΩ	2 4.7MΩ	3 3.9M
1 2.7MΩ	1 470kΩ	1 100kΩ	1 82kΩ
2 2.2kΩ	1 1.5kΩ	14 1kΩ	1 390Ω

1 470Ω trimpot

Miscellaneous
Light-duty figure-8 cable, 2.5mm PVC sleeving, heatshrink tubing.

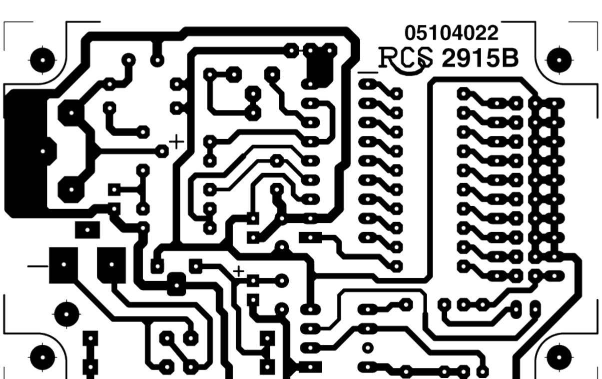


Fig.5: full size PC board artwork. This was adapted from the original (April 2002) PC board by Bob Barnes of RCS Radio.

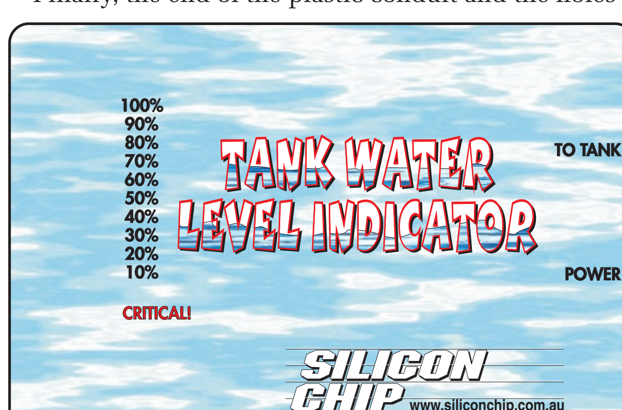
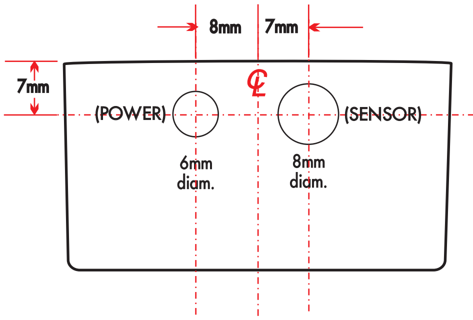
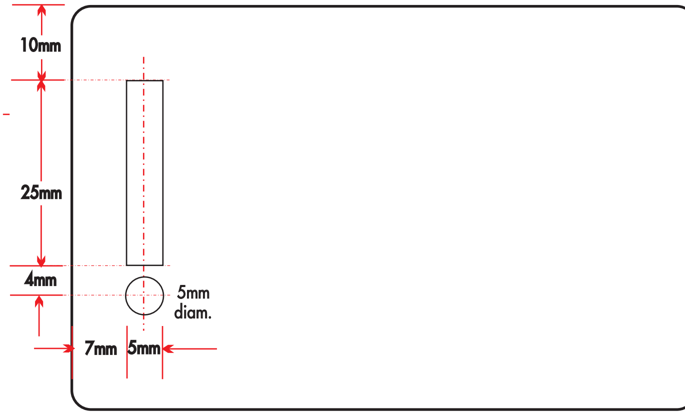


Fig.6: front panel artwork. A photocopy of this may be used as a drilling template for the front panel.

Fig.7: drilling detail for the box end (right) and box lid (far right). The slot can be made by drilling a row of 4.5mm holes down the centreline and enlarging with a small file.





be sealed with neutral-cure silicone sealant. However, don't get any silicone sealant on the coiled sensor wires, as this will reduce the contact area (and perhaps render them ineffective).

Switching on

Now for the big test. Apply power to the unit and check that the red "tank empty" LED comes on and that there is +12V on pin 3 of IC1. If all is well, the unit can now be tested by connecting the sensor assembly and progressively immersing it (starting with sensor 1) in a large container full of water (we used a swimming pool). When sensor 1 and sensor 2 are immersed, LED1 should extinguish and LED2 should come on.

Similarly, when sensors 1, 2 & 3 are immersed, LEDs 1-5 should be on and so on until all LEDs are lit.

Finally, trimpot VR1 must be set so that the appropriate LEDs light as the sensors are progressively immersed in water. In practice, you should find the two extremes of the pot range over which the circuit functions correctly, then set the pot midway between these two settings.

Using it on metal tanks

If the tank is of made of metal, you can dispense with Sensor 1 and connect the tank directly to the circuit ground. You must also ensure sensors 2-10 do not touch the walls of the tank. This can be done by slipping a length of 25mm-OD PVC conduit over the completed probe, securing it at the top so that the water inside can follow the level in the tank.

Controlling other devices

You could use this project to control something external – for example, a pump to refill the tank from a larger storage tank or reservoir, a siren or warning alarm, perhaps trigger a radio link to remotely warn, and so on. Provision has been made on the PC board for this: you will note that each of the LEDs, with the exception of the "critical level" LED has another pair of pads associated with it – these are intended to connect to external circuitry.

The reason the "critical level" LED has no extra pads is not simply lack of space – we would imagine that any action you wanted to take would have happened long before the water level reached that critical point.

However, if you really wanted to, this level could also be used as outlined here for the rest of the LEDs – it's just that you'd have to arrange connections yourself.

As the LM3914 outputs go low to turn on their LEDs, these could also switch on a PNP transistor (with suitable current limiting resistors), leaving the LEDs in place. That transistor could be used to switch, say, a relay to control whatever you wished.

You could also switch an optocoupler, such as a 4N28, in parallel with the LEDs, itself perhaps switching a relay. With due care to power wiring, a Triac optocoupler might be used instead.

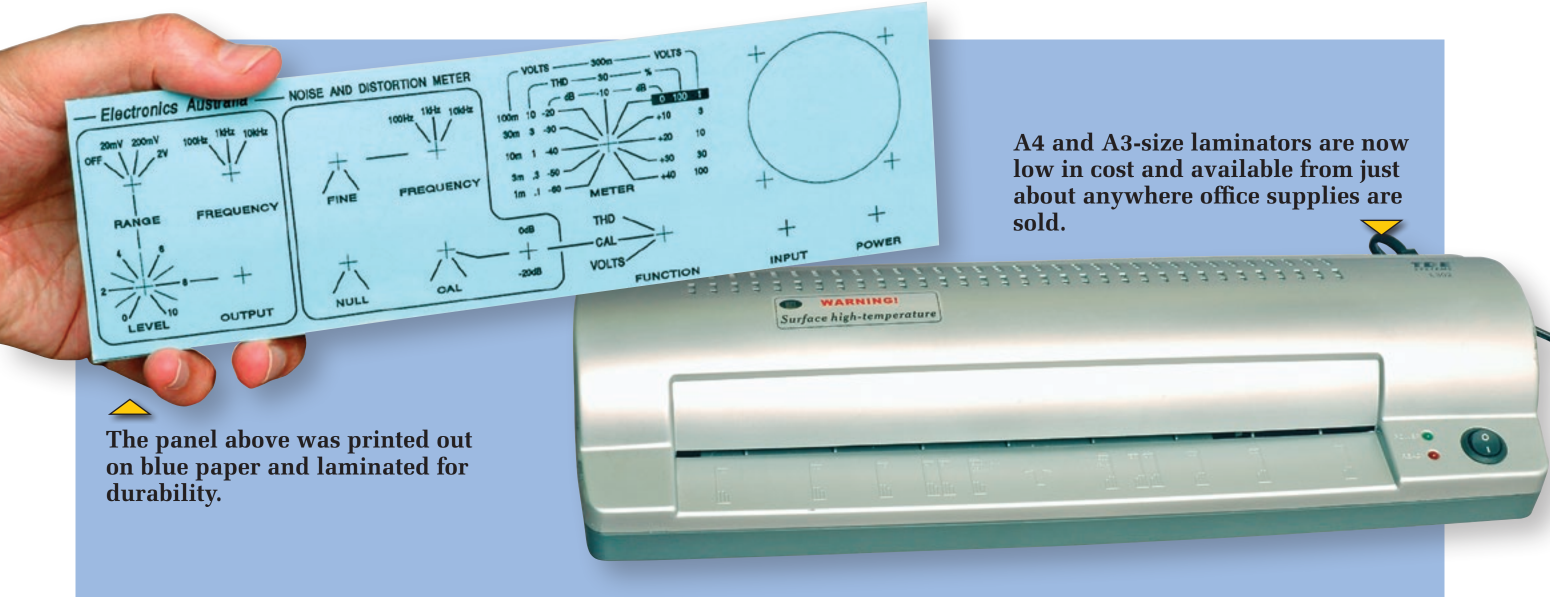
Solid-state relays are also an option, providing you can get one which operates when its input is taken low. Of course, a transistor could invert the LM3914 output for you.

Regardless of what you are controlling, you MUST take into account the following:

- Get your project working as described (ie, stick to low voltage!) before attempting to interface it to anything.
- Anything switching or controlling mains voltages must be more-than-adequately insulated, with cable clamps to prevent broken leads contacting anything else.
- Ensure that any relays, etc, you use are rated for both the voltage and the current of the device being controlled. Bear in mind that pump motors, for example, usually have a significantly higher starting current than running current.
- If in doubt, don't! **SC**

Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	10MΩ	brown black blue brown	brown black black green brown
❑	2	6.8MΩ	blue grey green brown	blue grey black yellow brown
❑	2	4.7MΩ	yellow violet green brown	yellow violet black yellow brown
❑	3	3.9MΩ	orange white green brown	orange white black yellow brown
❑	1	2.7MΩ	red violet green brown	red violet black yellow brown
❑	1	470kΩ	yellow violet yellow brown	yellow violet black orange brown
❑	1	100kΩ	brown black yellow brown	brown black black orange brown
❑	1	82kΩ	grey red orange brown	grey red black red brown
❑	2	2.2kΩ	red red red brown	red red black brown brown
❑	1	1.5kΩ	brown green red brown	brown green black brown brown
❑	14	1kΩ	brown black red brown	brown black black brown brown
❑	1	390Ω	orange white brown brown	orange white black black brown



A4 and A3-size laminators are now low in cost and available from just about anywhere office supplies are sold.

The panel above was printed out on blue paper and laminated for durability.

Making Panels For Projects

While it's easy enough to source all of the bits 'n' pieces for the projects described in SILICON CHIP, labelling for the front/rear panels can be a real problem. Sure, a neat printing job with a permanent marker can be functional but it doesn't look very professional. Besides, what if you want to add graphics?

By PETER SMITH

THE QUICKEST AND EASIEST way to produce front-panel labels for our projects is to make use of the original artwork published in the magazine or posted on our website. Magazine artwork can be photocopied and then laminated. For even better results, try scanning in the artwork (or printing the EPS version from our website) onto good quality inkjet paper. Again, lamination can be used for lasting protection.

John Wark's guide

In fact, John Wark recently wrote in with a seven-step guide to producing top-quality results using lamination. His steps are as follows:

(1). Make two copies of the artwork, one in colour (or on coloured paper) if desired. Note that the use of standard 80gsm paper and the lamination material specified below will allow the completed panel to fit in the slot of typical instrument cases.

(2). Trim the copies to suit the size of the panel and glue the monochrome copy to the panel using water-soluble glue (a "Glu-Stik" works well).

(3). Drill the panel using the label as a template. Small pilot holes should be drilled initially to ensure accuracy. A tapered reamer can be used to enlarge holes in soft materials such as plastic and aluminium.

(4). Remove the paper template by washing under a tap. Be sure to remove all traces of the glue.

(5). Laminate the remaining copy using an 80 micron sleeve and trim to size.

(6). Apply a very thin coating of gel type contact cement to the surface of the panel. If the panel is removable and has rough and smooth sides, choose the rough side. Apply the label to the panel, taking care to get good alignment and smoothing out as necessary.

(7). Allow time for the contact cement to cure and then cut out any holes using a small-bladed craft knife.

John's method is long lasting, looks good and is cheap. However, other methods are available if you don't like the lamination approach.

Scotchmark Laser Labelling

Good results can also be obtained using the "Scotchmark" laser labelling system. Silver and white polyester sheets are available from Wiltronics Research at **www.wiltronics.com.au/catalogue/shop.php?cid=262**. They also have over-laminates that don't require a special applicator.

Yet another method is described in the April 2002 issue of SILICON CHIP, where we demonstrate how to use the 3-part "Quick-Mark" system from Computronics (see **www.computronics.com.au/quickmark**). Back issues are available from our subscriptions department – see the subscription page for details.

We're often asked what graphics package is suitable for creating custom labels. We use CorelDRAW, but virtually any graphics package that allows you to work in physical dimensions (mm) would be suitable. SC

PICAXE plays music!

One of the most popular uses of PICAXE chips is in sound orientated projects. Both the new PICAXE-14M and PICAXE-28X1 support the 08M 'play' and 'tune' commands, which allow the PICAXE chips to play mobile phone ring-tones directly via a piezo sounder.

by CLIVE SEAGER (www.rev-ed.co.uk)

But what if you want to play real songs or sounds? The most obvious answer is to record your sound as an MP3 file and play it from the PICAXE chip.

Unfortunately, though, MP3 files are very large and *no* microcontroller, PICAXE included, has sufficient memory to store many files.

Fortunately a company called FDTI (www.ftdichip.com), based in Glasgow, Scotland has produced a very neat 'VMUSIC2' module ideal for this type of application.

The VMUSIC2 module

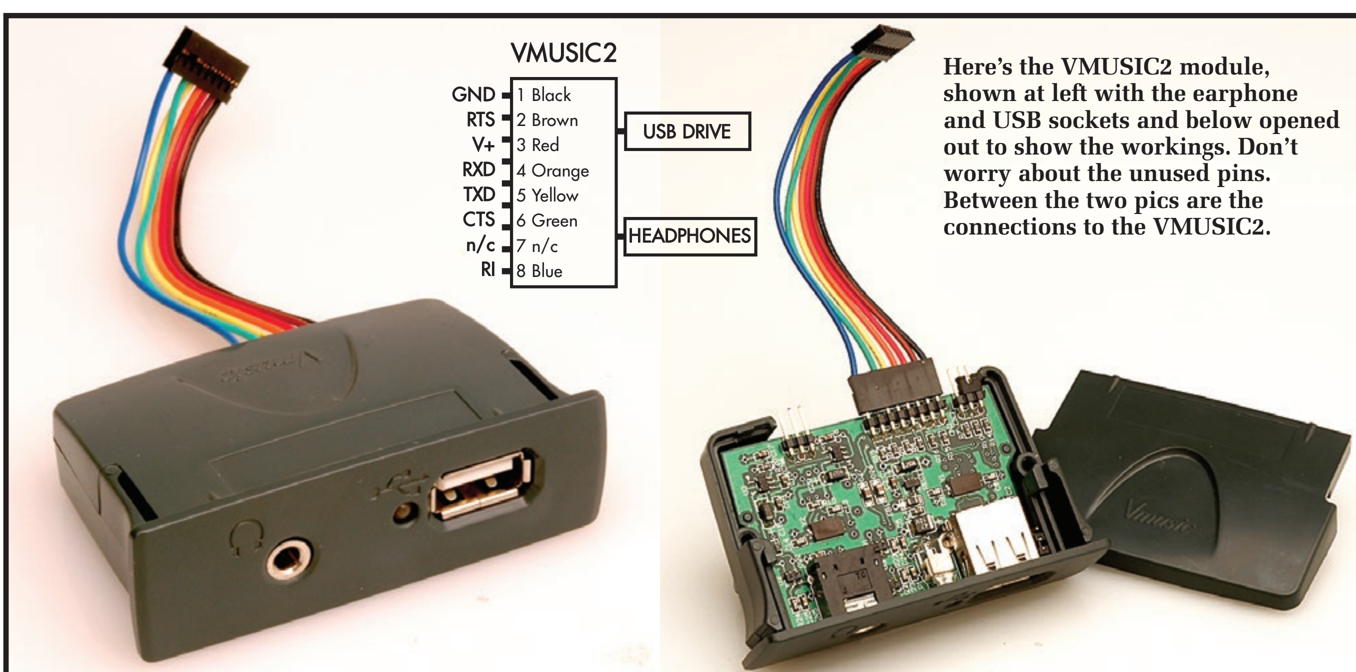
The FTDI VMUSIC2 module is shown below. It is supplied in a neat plastic enclosure but this is very easy to pop open if you want to look inside! The enclosure has a bi-colour LED, a headphone socket and USB thumb drive socket on the front, while on the rear there's an 8 wire connector to connect power and control signals.

Pop open the enclosure and you will find two main components on the PC board - a Vinculum VCN1L USB host controller IC and a VS1003 MP3 playback IC.

In simple terms, MP3 files are read from a USB thumb drive by the VCN1L USB controller and then decoded and played back via the VS1003 chip. The VS1003 sound output line will drive headphones directly; we also used the external speakers from our computer for testing purposes.

It can also drive most amplifiers if you want some real sound!

So to use the system, all we need to do is download a few MP3 (or WAV)



Here's the VMUSIC2 module, shown at left with the earphone and USB sockets and below opened out to show the workings. Don't worry about the unused pins. Between the two pics are the connections to the VMUSIC2.

files from a computer onto a USB 'thumb drive', move the thumb drive to the VMUSIC2 module and then use the PICAXE chip to send play/stop etc commands to the VMUSIC2 module.

VMUSIC2 Connections

The VMUSIC2 is supplied with a colour-coded 8-wire connector. Unfortunately this is on a 2mm (not 2.54mm) pitch and so will not easily connect to stripboard or breadboard layouts. So in the end we simply cut one end of the connector off and soldered the wires to our project board directly. Table 1 shows the function of the different wires.

Connection to the PICAXE chip is made via a serial (RS232) link, so the wires can connect directly to the PICAXE input/outputs pins.

Although the VMUSIC2 supports CTS/RTS serial handshaking, we have not used that feature here, so it is essential to tie the green wire (CTS) to 0V. Note also that the VMUSIC2 'transmit' (output) pin connects to a PICAXE 'receive' (input) pin and vice versa.

The VMUSIC2 requires a nominal 5V supply on the red and black wires (we ran it quite happily at 4.5V from 3xAA cells; you could also use 4xAA NiCad or NiMH rechargeables to provide 4.8V).

Connecting to a PICAXE-14M chip

The VMUSIC2 module supports serial connections at a 9600 baud rate. If you've been playing with PICAXEs, you'll know that the maximum baud rate of a PICAXE-14M is 4800 when running at the (default) 4MHz.

However if we double the internal clock speed of the 14M to 8MHz (via a 'setfreq m8' command) everything now runs twice as fast and so we get the desired 9600 baud rate!

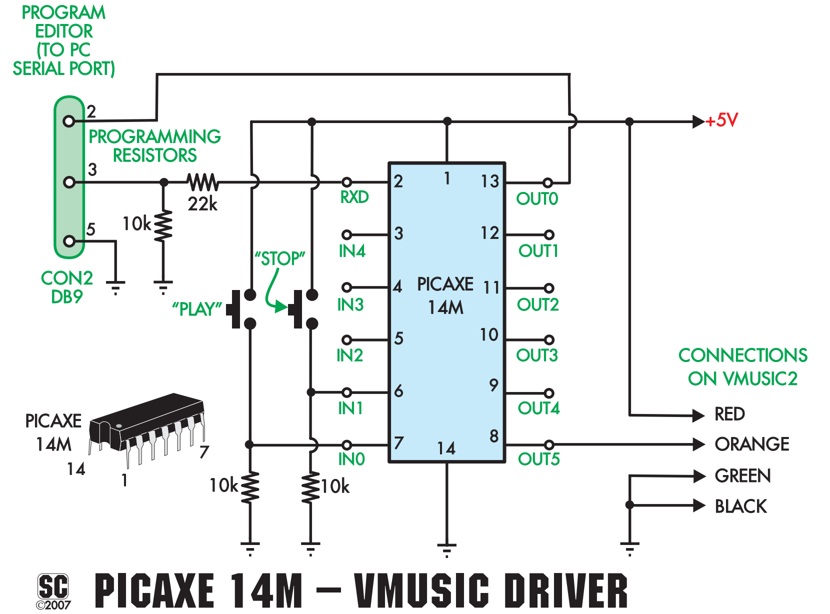


Fig.1: the simplest possible connection to the VMUSIC2: just one signal wire plus power (green in this case must be tied to 0V). Below is the protoboard layout of this circuit.

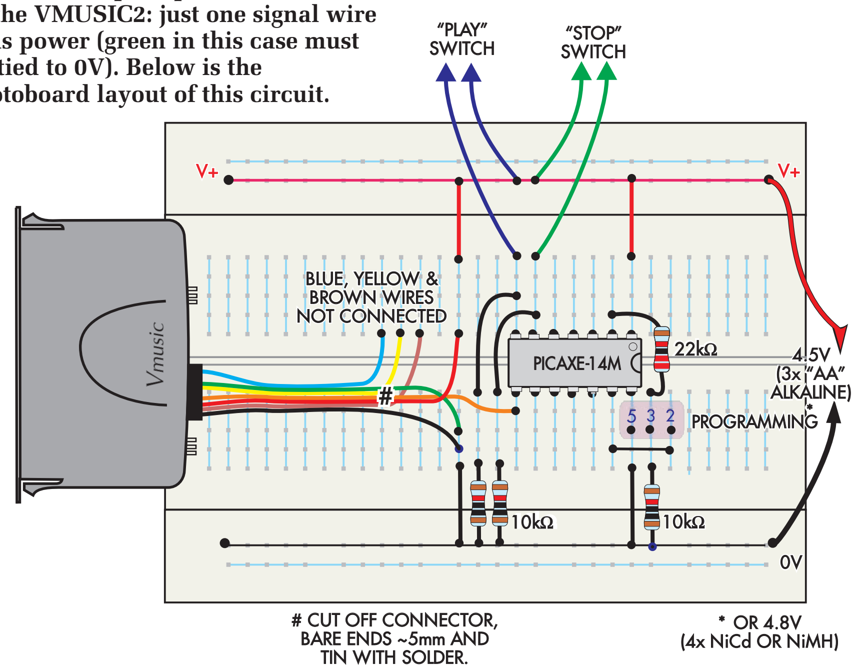


Table 1 – Connections

VMUSIC2	PICAXE
1 Black	GND – 0V
2 Brown	RTS – not connected
3 Red	V+ – V+
4 Orange	RXD – output pin
5 Yellow	TXD – input pin
6 Green	CTS – 0V
7 (not used)	
8 Blue	RI – not connected

Table 2 - VMUSIC2 commands

Play track "filename.mp3"	serout 5,t9600_8, ("vpf filename.mp3",CR)
Play all tracks	serout 5,t9600_8, ("w3a",CR)
Stop track	serout 5,t9600_8, ("vst",CR)
Skip to Next Track	serout 5,t9600_8, ("vsf",CR)
Skip to Start of current Track	serout 5,t9600_8, ("vsb",CR)
Skip to Previous Track	serout 5,t9600_8, ("vsb",CR,"vsb",CR)
Pause	serout 5,t9600_8, ("e")
Resume (after pause)	serout 5,t9600_8, (CR)
Set Volume	serout 5,t9600_8, ("vwr",$0B,vol_right,vol_left,CR)
;where $00 = maximum volume, $FE is the minimum	
Suspend disk	serout 5,t9600_8, ("sud",CR)
Wakeup disk	serout 5,t9600_8,("wkd",CR)
Get firmware version	serout 5,t9600_8,("fwv",CR)

Program 1 – VMUSIC2 to PICAXE 14M (1)

```
#picaxe 14m                              ; set picaxe type

init:
    setfreq m8                           ; double speed
    pause 1000                           ; allow 500ms to wake-up

main:
    serout 5,t9600_8,("vpf 1.mp3",CR)    ; send play 1.mp3
    pause 20000                          ; wait 10 seconds
    serout 5,t9600_8,("vst",CR)          ; send stop
    pause 20000                          ; wait 10 seconds
    serout 5,t9600_8,("vpf 2.mp3",CR)    ; send play 2.mp3
    pause 20000                          ; wait 10 seconds
    serout 5,t9600_8,("vst",CR)          ; send stop
    pause 20000                          ; wait 10 seconds
    goto main
```

The four PICAXE program listings above and right are all that you need to get the PICAXE to talk to the VMUSIC2 – or is it sing to it? Don't forget the 08M is being run at double speed so all your normal time-dependent variables must be doubled!

Program 2 – VMUSIC2 to PICAXE 14M (2)

```
#picaxe 14m                              ; set picaxe type

init:
    setfreq m8                           ; double speed
    pause 1000                           ; allow 500ms to wake-up

main:
    if pin0 = 1 then do_play             ; play switch pushed
    if pin1 = 1 then do_stop             ; stop switch pushed
    goto main

do_play:
    pause 10                             ; short debounce time
    if pin0 = 1 then do_play             ; wait until switch released
    serout 5,t9600_8,("vpf 1.mp3",CR)    ; send play 1.mp3
    goto main

do_stop:
    pause 10                             ; short debounce time
    if pin1 = 1 then do_stop             ; wait until switch released
    serout 5,t9600_8,("vst",CR)          ; send stop command
    goto main
```

Fig.1 shows the simplest connection method possible, just one wire (and power) to a PICAXE-14M chip. In this mode the PICAXE-14M issues commands directly to the VDRIVE2 module without feedback.

Program 1 shows a program to play ten seconds of each of the two music files '1.mp3' and '2.mp3'. Remember that the chip is running twice as fast as normal, so to get a 10 second delay you actually have to enter 20000 (milliseconds) for the pause command!

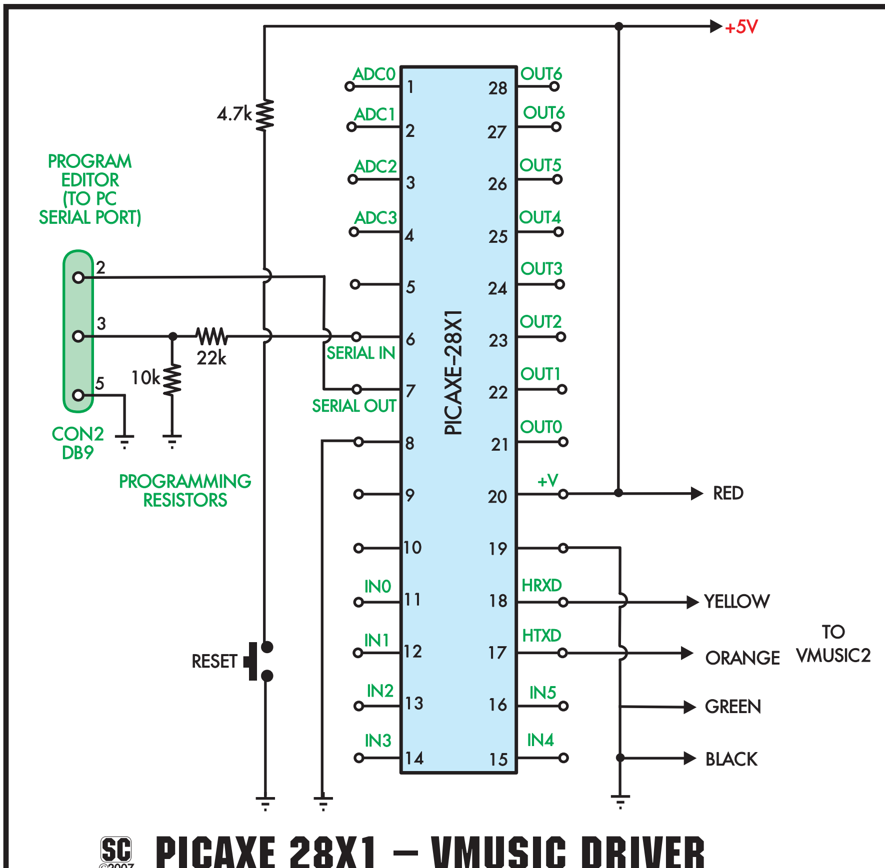


Fig.2: here the VMUSIC2 drives the new PICAXE-28XI chip. You not only get more control and functions but sixteen times the memory!

You could use the Revolution Education PICAXE-14 project board (AXE117) for testing but it would be quite simple to make up your own pc board/stripboard layout or, as we have shown here, use the breadboard approach taken with many of the PICAXE projects in SILICON CHIP.

'vpf filename' and 'vst' are the commands required by the VMUSIC2 to play and stop mp3 files. Table 2 shows all the most common VMUSIC2 commands.

Note that as each letter in the MP3 filename uses up memory in the PICAXE, it is far better to rename your files "1.mp3", "2.mp3" etc. rather than "Meatloaf - Bat out of hell.mp3"!

Of course you could now add switches to the PICAXE circuit, so that when a switch is pressed the song is played. Program 2 shows this type of idea, with two switches connected to PICAXE inputs 0 and 1.

Connecting to a PICAXE-28X1 chip

Although the VMUSIC2 will work fine with a PICAXE-14M chip, you will probably soon run out of memory on more complex programs. In this case it would be advisable to switch to the new PICAXE-28X1 chip, as it has 16x more memory! The PICAXE-28

Program 3 – VMUSIC2 to PICAXE 28X1

```
#picaxe 28x1      ; set picaxe type

symbol first_byte = b0
symbol point = b1
symbol temp = b2
symbol loopcounter = b3

setup:
        ; setup serial hardware
        ; at 9600 with background receive
        hsersetup b9600_4,%01

init:
        ; Send Es until the unit responds correctly
        hserout 0,("E",CR)
        gosub       get_response
        if first_byte <> "E" then init

main:
        ; check to see if a drive is actually inserted
        ; response will start D for yes and N for no
        hserout 0,(CR)
        gosub       get_response
        if first_byte <> "D" then main

        ; play track 1.mp3
        ; response will start D if ok, C if not
        hserout 0,("vpf 1.mp3",CR)
        gosub       get_response
        if first_byte <> "D" then main

        ' play ten seconds
        pause 10000

        ' pause for 5 seconds
        hserout 0,("e")             ; note no CR here
        pause 5000

        ' play another ten seconds
        hserout 0,(CR)
        gosub       get_response
        pause 10000

        'stop
        hserout 0,("vst",CR)
        gosub       get_response
        pause 5000

        goto main

        ; Sub procedure to receive background bytes
get_response:
        pause 1000                  ; wait a while
        point = 0                   ; reset local pointer

        get point,first_byte        ; Save the first reply byte
        do
          get point,temp            ; get returned byte
          sertxd (temp)             ; transmit it
          inc point                 ; increment pointer
        loop while temp <> CR       ; if not CR loop

        hserptr = 0                 ; reset the background receive pointer
        return
```

Program 4 – logging

```
logging:
        readadc 1, b20              ; readadc value into variable b20

        ; create a log file called 'log.txt'
        hserout 0,("opw log.txt",CR)
        gosub       get_response

        bintoascii b20,b5,b6,b7     ; convert loopcounter byte to 3 ascii digits
                                    ; and write 8 bytes loop_xyz
        hserout 0,("wrf ",$00,$00,$00,$09,CR,"value ",b5,b6,b7)
        gosub       get_response

        hserout 0,("clf log",CR)
        gosub       get_response

        pause 1000

        goto logging
```

protoboard (AXE022P) is ideal for testing but again it would be quite simple to make up your own PC board/ stripboard layout.

One of the new features of the 28X1 is its 'internal' enhanced hardware serial module. This module is far more efficient than the serial connection via the standard input/ output pins, and also supports much higher baud rates (the 9600 required here is no problem at all!). It also allows serial receives in the background (while the PICAXE processes other tasks).

Fig.2 shows a slightly more complex connection, where the VMUSIC2 is connected to both the hardware serial in and hardware serial out pins. This now allows the VMUSIC2 to send replies and information back to the 28X1 chip – ie, we now know if a command has been received and understood.

Program 3 shows how to get replies from the VMUSIC2 module. This is achieved via the 'get response' sub procedure, which receives the serial replies from the PICAXE serial port hardware.

Each reply can be of different length, so the sub-procedure only returns when the terminating carriage return (CR) byte is received.

Data Logging

A secondary feature of the VMUSIC2 (and the primary feature of its cheaper, non-MP3, little brother, the VDRIVE2) is to read and write to files onto the USB thumb drive. This makes it ideal for data logging experiments.

Program 4 shows part of a program to use the fileopen (opw), file write (wrf) and file close (clf) commands. Further details for these commands can be found in the VMUSIC2/ VDRIVE2 datasheets.

Summary

The VMUSIC2 is a neat, economical, solution to playing MP3 and WAV songs and sounds. It is easily interfaced to a PICAXE chip making it ideal for linking into many musical projects.

The file reading / writing functions will also appeal to many data-logging type experiments.

For further details, schematics and technical datasheets for the VMUSIC2/VDRIVE2 module please visit **www.vinculum.com** SC

SERVICEMAN'S LOG

I just hate doing repair quotations

Giving quotes to repair equipment such as a TV sets is not that easy. As often as not, providing an accurate quote means spending a great deal of time tracking down the fault, by which time the job has really been done. And if the customer then rejects the quote, you don't get a cent for your time.

I just hate doing quotations because of all the implications involved. The requests come in many different forms, often starting with a phone call which goes as follows: "I live in Outer Woop Woop. Do you do free quotes?"

In other words, are you prepared to drive all the way out to my place, strip down the set and repair it before you can give me a cast-iron guaranteed quote and then put it all back to how it was and return home – all for free. Not even charities do that.

Then you have the guy who thinks he is being really helpful because he has jammed his 150cm rear-projection TV in the back of his smallish station wagon and brought it in, expecting a free quote based on a quick view through the rear window. Obviously, I'm expected to fit my Kryptonite eye adaptor, remotely scan all the circuits and, without diagrams or test instruments, locate the exact fault and suggest a cheap fix.

Other clients think that by just quoting the set's model number is enough for me to surely know the cost of the repair.

For all these misguided people I have to tell them that free guesses are free because they are worthless. In most instances, I have to repair the problem first to be sure, because often the original symptom hides other problems behind it.

The insurance companies are more reasonable in that they will pay for the quote but this is still going to be a close guesstimate, because the cost of doing the full repair often exceeds the quote.

HOW TO NOT HATE DOING QUOTATIONS...

Dead Panasonic TX-21FJ50A

For example, I had a Panasonic TX-21FJ50A employing a GP-3 chassis come in dead. Apparently, it had been hit by a lightning strike during a storm and was the subject of an insurance claim.

Removing the set's back revealed absolutely no sign of any visible damage – no fuses gone, no resistors blown or blackened and no exploded semiconductors. The only clue I had was that there were no voltage outputs from the switchmode power supply and the only measurable voltage was +330V to the chopper IC (IC801, STRW6754), which would not decay at switch-off.

OK, you say, quote for the IC and you'll be right. Well, no! I ordered the IC and the 8.2V zener (D820) that "hangs" off it and fitted them first before even starting the quote. This was just as well because although this restored all the power to the set and the picture was back, there was now no sound.

I checked all the menus and the inputs and then – using a wet finger

– established that the sound output ICs were in fact working OK. I could even get noise out of the loudspeakers all the way back to the digital sound microprocessor (IC2102), a large-scale 80-pin surface-mounted IC.

The original part number of MSP-3410GAB83 is now substituted by CIAB00002133 and is pretty expensive and labour intensive to replace. So what was I supposed to do now? Buy this IC and spend a couple of hours replacing it so that I could be sure there was nothing else wrong and that this was the only thing left to repair?

The fact is, if I had done that and the quote had been rejected, I would then be down the mine by a serious amount – especially as this set isn't that expensive to replace lock, stock and barrel. In the end, it was a gamble I wasn't prepared to take and the set was written off.

The fact is, it is sometimes very difficult to keep costs under control, especially when you have a lot of logistics. By logistics, I mean getting the technician, test equipment and parts, etc to the inside of the TV. If a set has to be collected and delivered and is large, heavy and requires more than one person plus a large van, you can see how these logistics can create equally large expenses.

In order to overcome some of these problems, I try to just transport the chassis or the particular faulty circuit board back to the workshop but even this sometimes doesn't work.

Sony rear-projection set

I was recently called out to a Sony KP-E61SN11 61-inch (155cm) rear projection TV using an RG-1 chassis. The set was dead at switch-on and the client reported that it then took a very long time to come on.

When I arrived, I discovered that the set was kept in his garage at a block of units near the sea. The problem with rear projection TVs is that the board sits along the bottom of the cabinet and in order to work on it, it has to be at waist level. In this case, this wasn't possible, so I removed the power supply and took it back to the workshop where it was repaired, checked and tested.

The set was now going a little better but was still cutting out, so next I brought in the horizontal deflection board. This too was repaired, after which the set stayed on a bit longer. I then discovered that the HV unit was arcing so I had to order a new one. This was duly fitted but I still wasn't out of the woods, as the vertical deflection IC, which is on the next board, was faulty, as were the convergence ICs. All this travelling made the repair very expensive.

Samsung convergence faults

Recently, I have repaired several Samsung rear-projection TVs, mostly for convergence faults. These faults are usually the convergence ICs, which are STK392-010 amplifiers. And when they go, they invariably take a number of fusible resistors with them.

Unfortunately, one can never be sure of the full extent of the damage with these types of faults and whether it is one or both of the ICs. However, previous jobs can give you a ballpark range for a cost estimate.

Once I had a Samsung SP-42W5HPX/XSA – supposedly using a J42 chassis – with only a blue convergence error. Like all projection TVs, access to the lower chassis is poor and you have to unplug a lot of the wiring harness until the deflection panel is accessible.

I replaced the blue ICZ04 with an STK392-040 and measured all the resistors and fuses around the ICs but found nothing untoward. I then reassembled everything and switched on.

The sound came through OK but I was mortified to find that I no longer had any picture whatsoever. There was

Items Covered This Month

- Panasonic TX-21FJ50A TV set (GP-3 chassis)
- Sony KP-E61SN11 rear projection TV set (RG-1 chassis)
- Samsung SP-42W5HPX/XSA rear projection TV set
- Sharp LC30HV2M LCD TV
- LG PDP 42V7 plasma TV
- LG MS-1942 microwave oven
- Panasonic PT-AX100 projector
- Panasonic TX-68FJ50A TV set (GP3 chassis)
- JVC GNP420E plasma TV
- Metz A2TF97 TV set (696 chassis)

no OSD either and the only sign of life I had was an arc of coloured spots on the top righthand side. However, the CRT filaments were obviously alight and I could hear the rush of EHT static. What's more, the deflection yoke was fully plugged in, as were all the other plugs as far as I was concerned. This set should now have been a goer, so why was it giving me grief?

I subsequently spent a great deal of time checking my work and retracing my tracks, all the time trying to restrain my rising panic. I mean, what could I tell my client? Was I going to have to come up with something along the lines of "oops, sorry, I've jiggered your set and as my car is full (and too small), I cannot take it back to the workshop to fix it. And no, you won't be able to watch telly all long weekend as I haven't got a loan set on board."

I could see all this going down like a lead balloon, especially if I also told them I had no idea what was causing the problem.

In the end, I decided the best course of action was to calm down, remove the whole chassis and start again. I examined the PC board for dry joints and resoldered a number of possible suspects. I also resoldered the heatsink earth connections and then reassembled the chassis very carefully and methodically.

I had a lot of problems reconnecting the focus lead to the focus assembly on the front. This was because I couldn't work out how the front escutcheon came off. It was probably being held on by a screw I couldn't see at top centre and I didn't want to use force in case I broke something that I would really regret. The service manual gave no clues.

Anyway, by keeping my cool, I eventually completed the re-installation and gingerly switched the set on.

I don't know what it was that I had done the second time around which I hadn't done the first time (or whether my prayers had simply worked) but I was extremely pleased to find that the picture had been completely restored and everything was now OK.

Thank heavens they're not all like that.

Who's the dirty rat?

One of the companies I sub-contract for is involved in selling, installing and servicing upmarket AV systems to clubs, hotels and even homes.

One such club had an AV system that also included PA (public address) and surveillance. This system had been going for over six months without problems but then the music system stopped working in one of the rooms. A service call was made and it didn't take long to find a break in a cable behind the rack of amplifiers. This was quickly repaired, after which the system worked normally again.

A few weeks later, another service call was booked when a camera stopped working. This fault was tracked down to another cable being cut in a different location not far from the first. Once again, the repair was straightforward and the system was soon back on air.

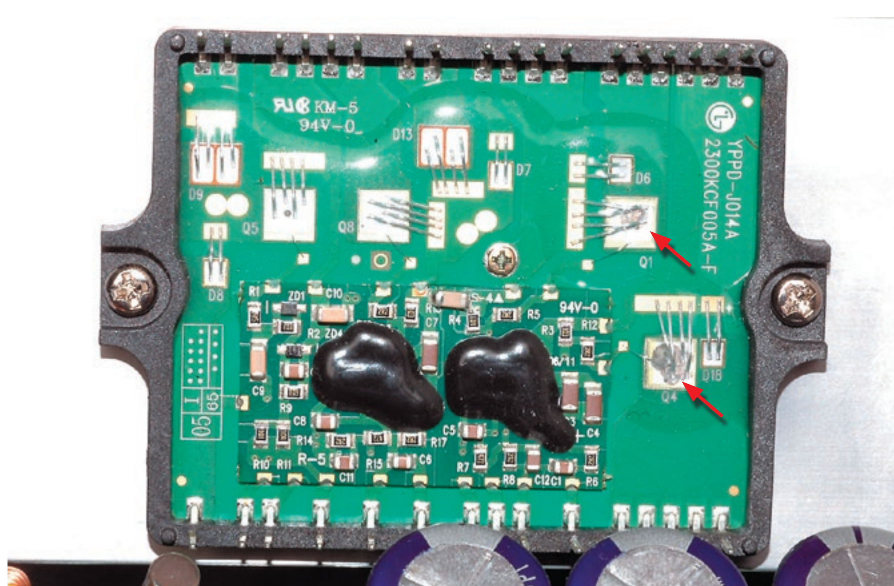
Unfortunately, that was not the end of the story. Over the next six months, numerous more calls were made to repair broken cables in different rooms and systems. Though none looked like they had been cut with side cutters, it was beginning to look like faulty cables, or, more disturbing, someone maliciously cutting them.

The mystery continued until a chance comment by one of the girls working in the club that she wouldn't be seen dead in the equipment room, as she had seen the size of the rat that lived in there! Finding and disposing of the rodent halted any further service calls!

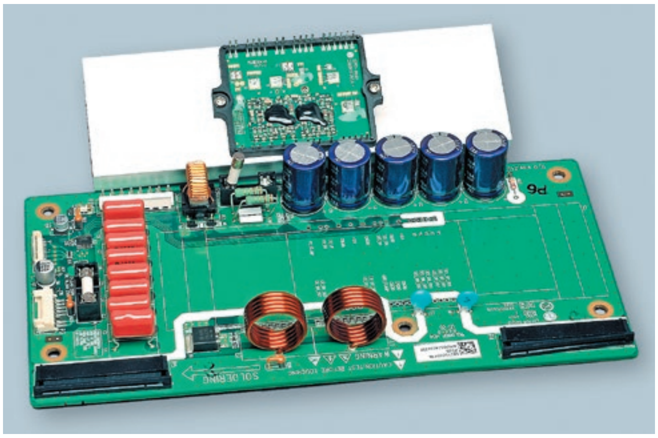
In fact, this story reminded me of another many years ago about a black and white TV with no sound in a takeaway restaurant. When the back was removed, the fault was easy to spot – the loudspeaker cone had been totally eaten away by rodents!

LG plasma TVs

In previous Serviceman's Log articles I have mentioned replacing the Z Sustain, Y Sustain and Control Boards in LG manufactured plasma



A close-up view of the IC underneath the heatsink on the Z SUS board in LG plasma sets. Note the discoloration beneath transistors Q1 & Q4 (arrowed)



It takes a lot of effort to desolder the IC – just one of the reasons why the Z SUS board is not a repairable item.

TVs together as a kit (Part No: 6871VSNB03E). The reason for this is that they are all matched, modified and upgraded. Most times, the no picture problem is due to fuse FS1 (+VS) T4.0AH going open circuit because of the IC underneath the heatsink on the Z SUS board.

The accompanying photograph of the IC clearly shows the discoloration of Q1 and Q4 underneath the clear epoxy resin. The board is not considered repairable to component level. It takes a lot of effort just to desolder the IC and no, it is not available as a spare part.

Sharp LCD TV

We had a Sharp LC30HV2M LCD TV come in under warranty with the complaint that it "made a popping noise and smelled". Well, you would complain about that!

When we got it on the bench, the set was actually dead. Obviously, the reported symptoms were its last dying throes. I soon found that FET Q1 (2SK2917) was short circuit and a quick look around showed a fair bit of destruction. Most manufacturers insist you just change the board, so we ordered a new "Display Power Unit".

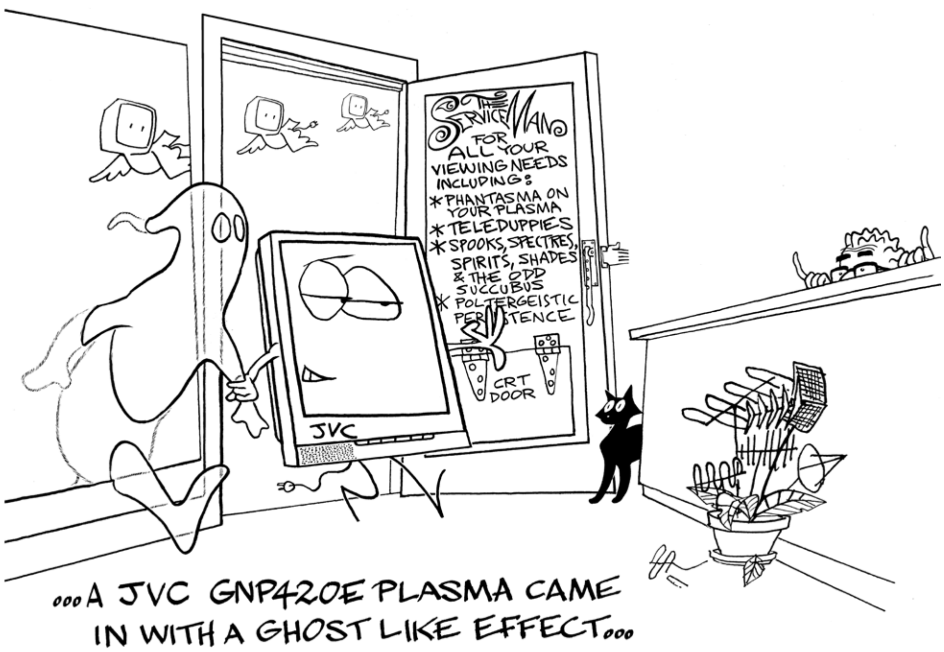
We were therefore quite surprised when we received a box of 22 parts instead – mostly surface mounted components (parts kit BQC-30HV2/4-1 – see Service Bulletin CTV199R). Not only that, they also suggested we resolder both ends of nine other surface-mounted resistors.

We were somewhat annoyed with this as there was a fair bit of work involved and we don't get much for warranty repairs. Anyway, we attended to these dry joints first and were surprised at how bad they were for surface-mounted components. When you heated one end, the part actually began to move!

When we replaced the parts, we found only about half of them to be faulty but – get this – it still didn't fix the power supply! Further detailed investigation revealed that R31, the 10kΩ bias resistor to Q9 (2SK2717), was high at 18kΩ. Replacing it finally fixed the problem.

LG microwave oven

We recently experienced an unusual problem with an LG microwave oven with no display. When we removed the control module, we checked the small mains transformer to find it open circuit. Easy, we thought – just order a new one and replace it, which is what we did to find it made no difference!



Next, we checked both the new and old transformers to find both now had continuity which meant we had obviously misdiagnosed. In fact, it wasn't until we checked a few other parts like resistors and found that they too measured open circuit that we worked out what was happening.

These boards are now sprayed with totally invisible shellac which acts as a very good insulator. This means that in order to check components, you either need to resolder the connections or use a meter with extremely sharp probes to penetrate through to the PC board tracks.

So it fooled us. In this case, it was the display itself that was faulty.

The ghostly JVC plasma

We recently had a JVC GMP420E plasma set come in with a ghost-like effect. It is hard to describe but this symptom is somewhat like CRT persistence, where a bright object remains in the background of the picture after the scene has changed. In addition, the picture was snowy, even on AV mode.

Technical support advised us that this was due to a fault in the scan and control modules, so this set was beyond economic repair.

Panasonic projector

We had a Panasonic PT-AX100 projector come in under warranty, the owner complaining that it was unexpectedly shutting down a minute or so after it started.

We found that after the lamp had been on for about 80 seconds, the power was shutting off. At the same time, the power monitor LED would go orange and start to flash. The self-check screen indicated a failure of the iris unit ("OK" LED turns red).

What happens is that after a few hundred hours of operation, the heat inside the unit causes the mechanism to begin to intermittently seize. And once the iris stops, the projector protection circuit cuts in.

A new modified iris unit is now supplied by Panasonic – Part No: TXZEN01VKD3.

Panasonic TV set

I recently made a house call on a Panasonic TX-68FJ50A (GP3 chassis), the owner complaining that there was no picture. Well, that was quite true – there was a black raster, the OSD (on-screen display) menu functions were all working and the sound was OK too. If tuned to a blank channel, the screen would mute to blue.

Turning up the G2 screen control revealed the faint imprint of a picture. I then checked the voltage on the beam limiter pin on the flyback transformer and this revealed a negative voltage instead of a positive one.

Following the path past R558, I soon came across R557 which is connected to the +140V rail. This resistor was open circuit but I was faced with a problem as to what its real value should be. The circuit showed it to be 88.8kΩ but the 5-band resistor on the board was green, white, black, red and brown, which reads 59kΩ.

Initially, I fitted an 82kΩ resistor which restored the picture. I then decided to replace it with 27kΩ and 33kΩ resistors in series (= 60kΩ). That made no discernable difference to the picture quality, so why do the designers fit a 1% non-preferred value when it isn't critical?

Metz TV set

A Metz A2TF97 TV (696 chassis) was stuck on PR1 (DVD AV) and no control functions were working, either via the front panel or the remote control, It was as if a button was stuck permanently on.

The cause was an I^2C bus line that was shorting to ground. Pinpointing the exact location of the fault meant disconnecting each device on this bus until the short was cleared. This turned out to be the first tuner and a new one restored all the functions. **SC**