WATER LEVEL INDICATOR

This simple circuit lights a string of LEDs to quickly indicate the level in a rainwater tank. It's easy to build and can be powered from an AC or DC plugpack supply.

By ALLAN MARCH

There are two traditional methods for finding the level of water in a tank: (1) tapping down the side of the tank until the sound suddenly changes; and (2) removing the tank cover and dipping in a measuring stick. The first method is notoriously unreliable, while the second method can be awkward and time-consuming.

After all, 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 five green 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. A sixth red LED lights when the tank level drops below a critical threshold.

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.

Circuit description

Fig.1 shows the circuit details. It's based on an LM3914 linear LED dot/bar display driver (IC1) which drives five green LEDs (LEDs 1-5). Pin 9 of the LM3914 is tied high so that the display is in bargraph mode and the height of the green LED column indicates the level of the water in the tank.

The full-scale range of the bargraph depends on the voltage on pin 6. This voltage can be varied using VR1 from

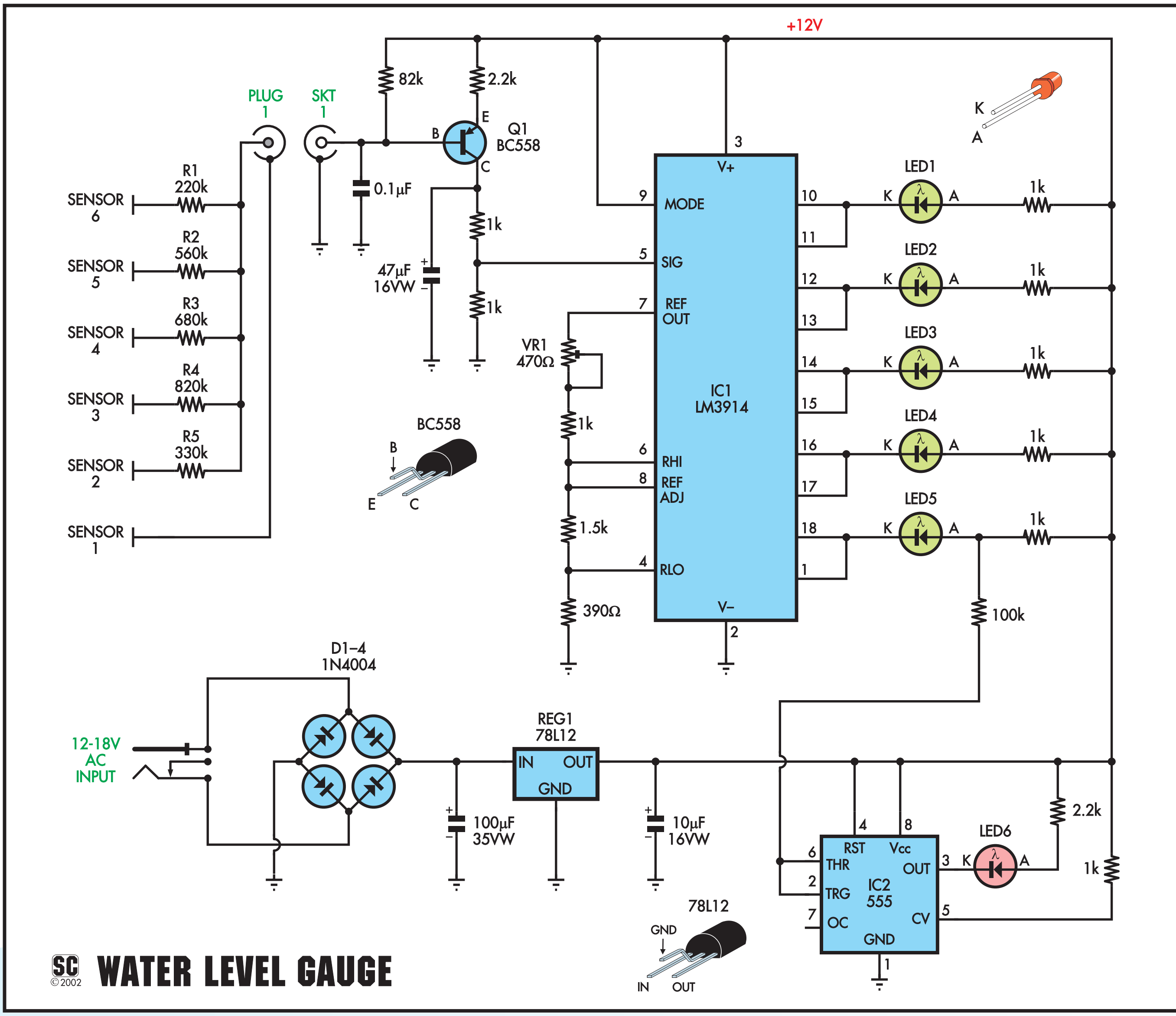


Fig.1: the circuit is based on an LM3914 dot/bar display driver (IC1) which drives LEDs 1-5. Its output depends on the number of sensors covered by water – the more covered, the higher the voltage on Q1's collector and the greater the voltage on pin 5 (SIG) of IC1. LED6 provides the critical level warning.

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 1-5 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 1-5 via 1kΩ current limiting resistors. Note, however, that an LM3914 has 10 comparator outputs but we only need five steps for this application. That's done by wiring the outputs of successive comparator pairs in parallel – ie, pins 1 & 18 are wired together, as are pins 17 & 16 and so on.

Water level sensor

The input signal for IC1 is provided by an assembly consisting of six 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.

As shown in Fig.1, sensor 1 is connected to ground, while sensors 2-5 are connected in parallel to the base of PNP transistor Q1 via resistors R5-R1. 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 R5-R1 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

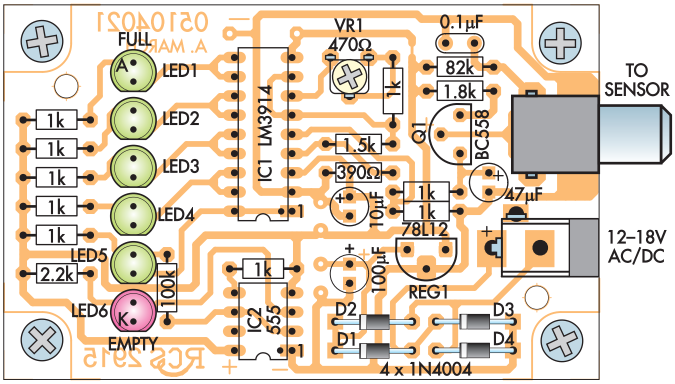


Fig.2: follow this diagram when installing the parts on the PC board. Note that some parts have to be omitted for 12V battery operation – see text.

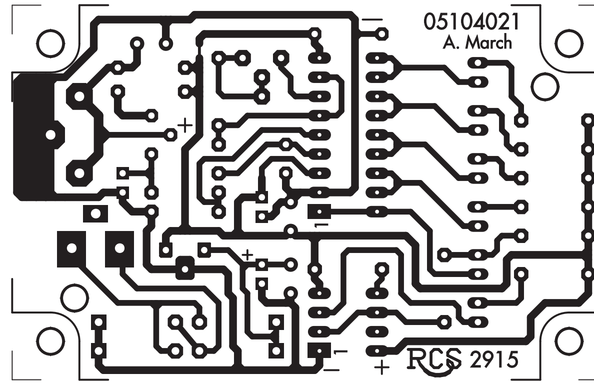


Fig.3: this is the full-size etching pattern for the PC board. Check your board carefully before installing any of the parts.

IC1 (ie, LEDs 1-5 are off). However, if the water covers sensor 2, the sensor end of resistor R5 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 of current 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 & 18 of IC1 to switch low and so the first green LED (LED5) in the bargraph lights.

As each successive sensor is covered by water, additional resistors are switched in parallel with R5 and Q1's base is pulled lower and lower. As a result, Q1 turns on "harder" with each step (ie, its 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 LED6 (red) to provide a warning when the water level falls below the lowest sensing point; ie, when all the green LEDs are 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, LED5 is on and its anode is at about 2V. This "low" voltage 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 LED6 is off.

However, if the water level falls below sensor 2, LED5 turns off and the anode of LED5 "jumps" to +12V. This voltage exceeds the upper threshold voltage of IC2 and so pin 3 switches low and LED6 turns on to give the critical low-level warning.

Note that the control pin (pin 5) of IC2 is tied to the positive supply rail via a 1kΩ resistor. This causes IC2 to switch at thresholds of 0.46Vcc (5.5V) and 0.92Vcc (11V) instead of the usual $^1/_3$Vcc and $^2/_3$Vcc and is necessary to ensure that IC2 switches correctly to control LED6.

Power for the unit is derived from a 12-18VAC plugpack supply. This drives a bridge rectifier D1-D4 and its output is then filtered using a 100µF electrolytic capacitor and applied to a 12V 3-terminal regulator (REG1). The output from REG1 is then filtered using a 10µF electrolytic capacitor and used to power the circuitry.

Note that a regulated supply rail is necessary to ensure that the water

Table 1: Resistor Colour Codes

❏	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	1	820kΩ	grey red yellow brown	grey red black orange brown
❏	1	680kΩ	blue grey yellow brown	blue grey black orange brown
❏	1	560kΩ	green blue yellow brown	green blue black orange brown
❏	1	330kΩ	orange orange yellow brown	orange orange black orange brow
❏	1	220kΩ	red red yellow brown	red red black orange brown
❏	1	100kΩ	brown black yellow brown	brown black black orange brow
❏	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
❏	9	1kΩ	brown black red brown	brown black black brown brown
❏	1	390Ω	orange white brown brown	orange white black black brown

level indication doesn't change due to supply variations.

Construction

Construction is straightforward, with all the parts installed on a PC board coded 05104021 and measuring 80 x 50mm. This is installed in a standard plastic case, with the LEDs all protruding through the lid.

Fig.2 shows the parts layout on the PC board. Begin the assembly by installing the resistors, diodes and capacitors, then install the ICs, transistor Q1 and the 3-terminal regulator (REG1). 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 on Fig.2.

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 33mm above the PC board. This ensures that the LEDs all just protrude through the lid when the board is mounted in the case on 10mm spacers. Make sure that all LEDs are correctly oriented – the anode lead is the longer of the two.

Dot operation

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 immediately to the left of the 0.1µF capacitor and install a wire link between the two vacant holes at the top of the board near IC1. Alternatively, the link can be omitted (ie, pin 9 can be either pulled low or left open circuit).

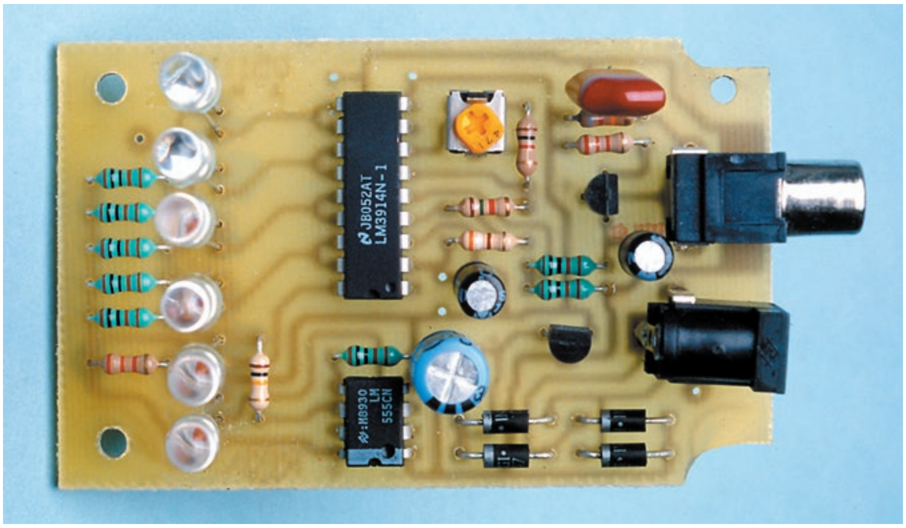
Battery operation

If the unit is intended for 12V battery operation in a mobile home or caravan, regulator REG1 and diodes D2, D3 & D4 are 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.

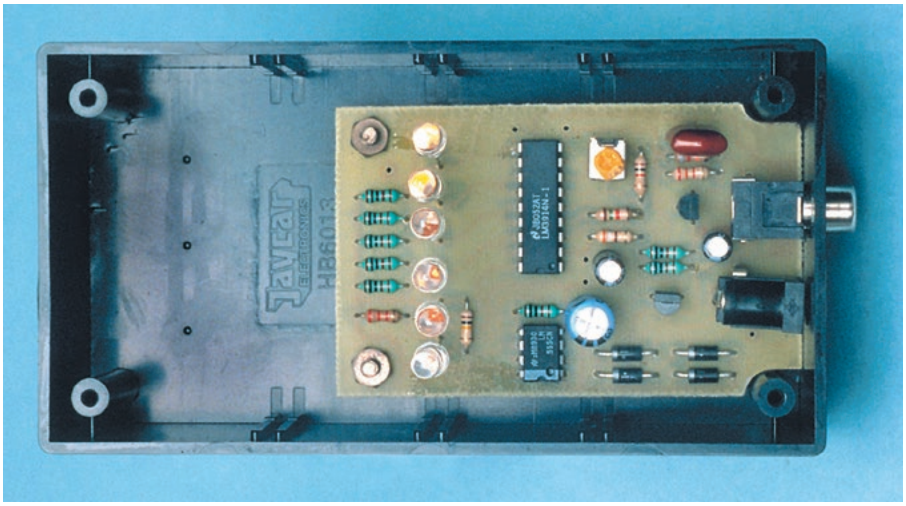
D1 remains in circuit to protect against reverse battery connection.

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 2-6 do not touch the walls of the tank. This can be done by slipping a length of 25mm-OD clear PVC tubing over the completed probe, securing it at the top so that the water inside can follow the level in the tank.



The power socket and RCA connector are both mounted directly on the PC board. Make sure that all parts are correctly oriented and that they are in the correct locations.


The PC board in secured to the bottom of the case using two 10mm standoffs at one end, while the RCA socket provides the support at the other end.

Final assembly

The PC board is mounted in the bottom of the case on two 10mm standoffs and is secured using 3mm machine screws, nuts and washers. Note that the corners at one end of the PC board must be removed to clear the pillars inside the case.

You will have to remove these corners yourself using a small hacksaw and rat-tile file if this hasn't already been done.

Fig.6 shows the locations of the two board mounting holes in the bottom of the case. You will also have 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).

The front-panel artwork (Fig.5) can be used as a template for drilling the front panel. There are six holes to be drilled here – one for each LED – and these are all 5mm-dia. It's a good idea to countersink these holes from the underside of the lid using a 6mm drill, so that the LEDs slip easily into position when the lid is fitted.

Sensor assembly

The sensor assembly is made by threading six lengths of 1mm enamelled copper wire through 8mm OD

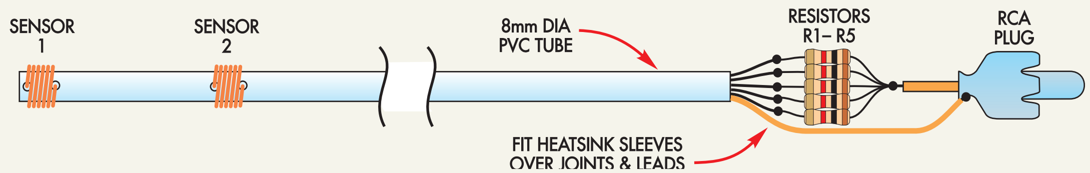


Fig.4: the water level sensor is made by threading six lengths of 1mm enamelled copper wire through 8mm OD clear PVC tubing (see text). The six sensors should be evenly spaced down the tube.

clear PVC tubing – see Fig.4. This tubing 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 plastic tube.

Parts List

1 PC board, code 05104021, 80 x 50mm
1 plastic case, 130 x 67 x 44mm
1 PC-mount RCA socket
1 RCA plug
1 2.5mm PC-mount power socket
1 12V AC 500mA plugpack
1 100gm spool 1.0mm enamelled copper wire
1 length 8mm-OD clear PVC tubing to match height of tank plus 200mm
2 3mm x 20mm screws and nuts
2 10mm spacers

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)
5 5mm green LEDs (LEDs1-5)
1 5mm red LED (LED6)

Capacitors
1 100µF 35VW PC electrolytic
1 47µF 16VW PC electrolytic
1 10µF 16VW PC electrolytic
1 0.1µF greencap

Resistors (0.25W, 1%)

1 820kΩ	1 82kΩ
1 680kΩ	2 2.2kΩ
1 560kΩ	1 1.5kΩ
1 330kΩ	9 1kΩ
1 220kΩ	1 390Ω
1 100kΩ	1 470Ω trimpot

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

The top sensor (S6) 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.

Begin by using a 1.0mm 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. That done, you can thread the wires through by pushing them through the drilled holes and then up the tube. You will find that the wire goes in more easily if the PVC tube is bent at an angle so that the drilled hole is in line with the bore of the tube.

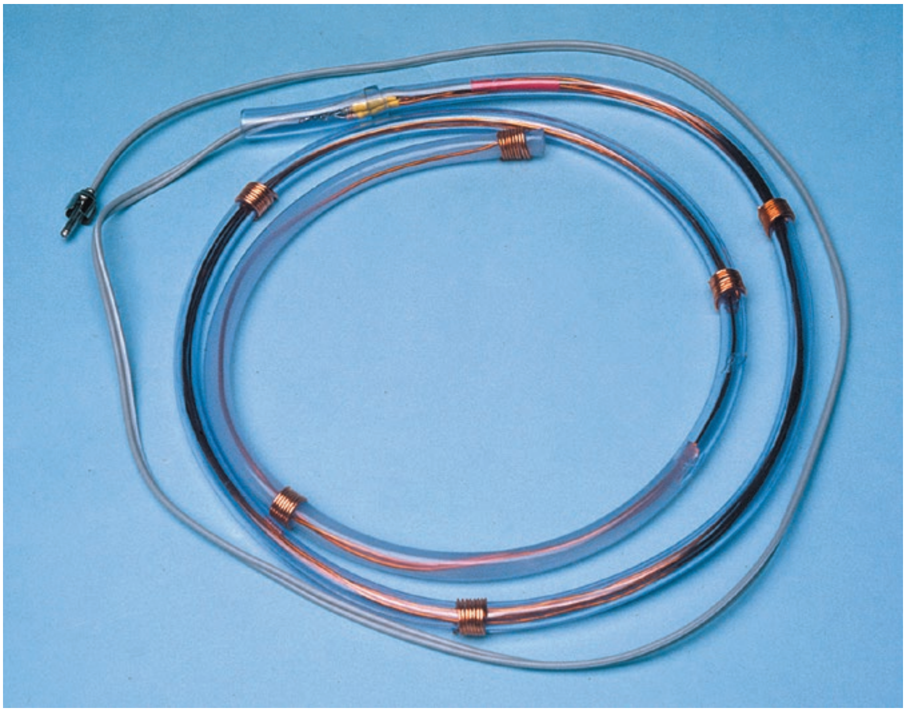
The end of each wire should also be smoothed before pushing it into the tube, to avoid scratching the enamel of the wires already in the tube. Leave about 150mm of wire on the outside of the tube at each point.

It's a good idea to trim each successive wire so that it protrudes 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 six 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 8mm tube, as shown in the photo.

When this process is complete, there will be five resistors protruding from the top of the 8mm tube. Their



This is the author's completed water level sensor. A weight can be attached to the bottom end to keep the plastic tube straight when it is immersed in the tank.

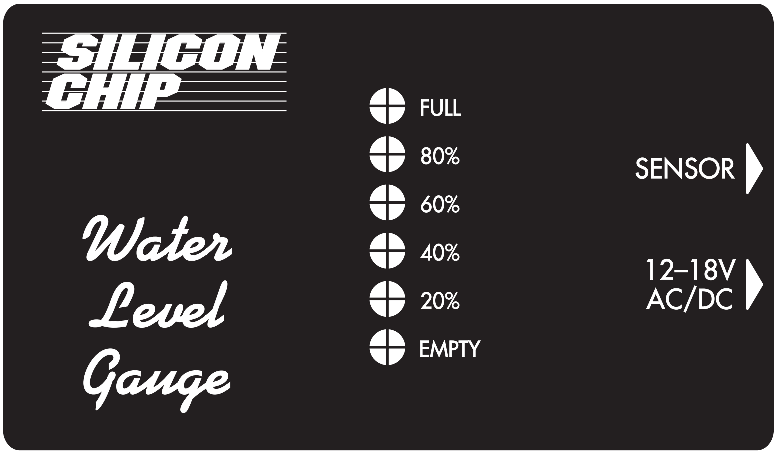


Fig.5: this full-size artwork can be used as a drilling template for the front panel.

Improved Water-Level Sensor

For a long-life water level sensor, Bob Barnes of RCS Radio suggests that the probe be made out of 19mm plastic conduit fitted with stainless-steel radiator or fuel pump hose-clamps for the sensors.

Suitably sleeved nichrome or stainless steel wire ("up the spout") can then be used to make the connections between the clamps and the resistors.

You will need to use Multicore Arax cored solder or Litton Arax cored solder (available from Mitre-10) when soldering nichrome or stainless steel wire (ie, a corrosive flux is needed). You can buy nichrome wire from Dick Smith Electronics or from Jaycar, while stainless steel wire should be available from boating suppliers.

The top of the water level sensor can be secured to the tank using a suitable bracket.

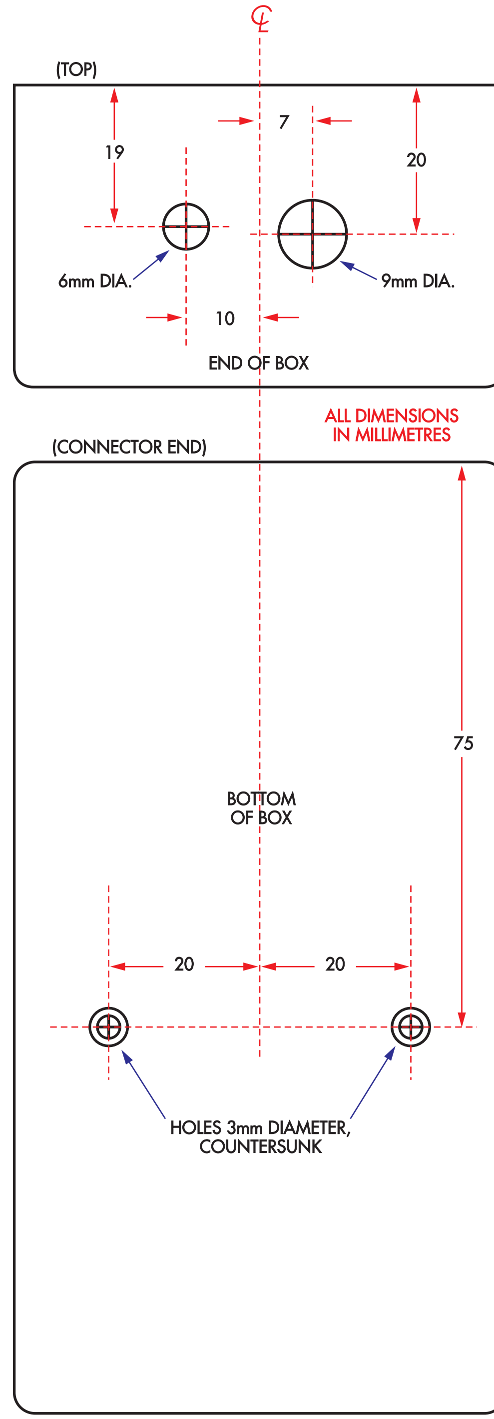


Fig.6: this diagram shows the drilling details for the plastic case.

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 12.5mm copper water pipe can be pushed over sensor 1 to add weight and increase the surface area if desired.

Note: on no account should solder be used on the submersible part because corrosion will result from galvanic action.

Finally, the end of the plastic tube and the holes can 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 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 plastic dish that's full of water. When sensor 1 and sensor 2 are immersed, LED6 should extinguish and LED5 should come on.

Similarly, when sensors 1, 2 & 3 are immersed, LEDs 5 & 4 should be on and so on until all five green 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. **SC**

SERVICEMAN'S LOG

Who said servicing was dying?

Well, maybe it is but my bench is still full. In fact, I have quite a collection of stories this month for no less than 10 different models. Fortunately, several were short and fairly straightforward.

I have a full house this month, starting with a 1999 Panasonic TC-14S15A (MX5 chassis). It was dead and the horizontal output transistor Q551 (2SD2499) was short circuit. A new one was fitted but it became extremely hot. The horizontal output transformer T501 was also replaced and all the components around the horizontal output stage were checked thoroughly. Nothing amiss was found but it was still blowing the transistor.

The only clue was a some ringing around the positive horizontal pulse on the collector of the horizontal output transistor. This problem was solved only when a sister set was brought in and the two compared. A smart pair of eyes noticed that there were four ferrite beads fitted on the good set – L552 in the emitter, L558 in the base and L551 & L557 in the collector. In the crook set, someone in the factory had left out L551 and L552 and fitted only links.

The question is, how did it last for so long before it reached this stage, because the transistor was very hot? Anyway, the ferrite beads fixed it quick smart and the transistor now runs quite cool.

Another Panasonic

At about the same time, a similarly aged (1999) Panasonic TV set also came in with a similar fault; ie, it was dead with the horizontal output transistor short circuit. This model was a more upmarket TAU set, model TX-79P100Z with an MD2 chassis, and advanced features such as computer and DVD inputs (B-Y & R-Y), etc, which one might expect at $4700.

The cause of the failure was unusual, as the frequency of the horizontal drive was far too high. In fact, it was double the correct frequency. Surprisingly, it wasn't the jungle IC that was the culprit. Rather, it was the Digibox that had somehow become stuck in the 100Hz mode. This module is non-serviceable and was replaced under warranty which fixed the problem.

A mysterious customer

Mr Armstrong was a rather mysterious customer. He was a single man in his late thirties and spent a lot of time travelling overseas. And he was on his way to another overseas trip so there was no forwarding address – just a mobile telephone number.

He brought in an Hitachi 5-inch LCD/Video Cassette Recorder VT-LC50EM (AU) which was completely dead. This is a rather nice little toy, consisting of a truly portable battery operated miniature multi-system TV receiver and VHS video system, all in a neat 370 x 90 x 220mm case. It was a set I had never seen before.

Mr Armstrong was convinced that it was just a fuse or switch and left it with me after I had checked the external AC adaptor/charger (VM-AC600EM) was delivering a healthy 9.6V DC from a rather frayed cord.

I knew immediately that this wasn't going to be simple; it was far too compact and it would be like a notebook computer – all surface mounted components and tricky access. I shot around to my mate who is an Hitachi agent and borrowed his service manual(s) – and that's when I started having second thoughts.

Maybe I had been too courageous in taking on this repair? Mr Armstrong had given me the impression that the unit was only a few years old and so I was rather disillusioned when I found out that it was in fact nearly 12 years old.

The first thing I did was to confirm that the 2Ah 9.6V nicad battery, VM-BP63, was completely shot and that a new one was rather expensive and obtainable only from Hitachi.

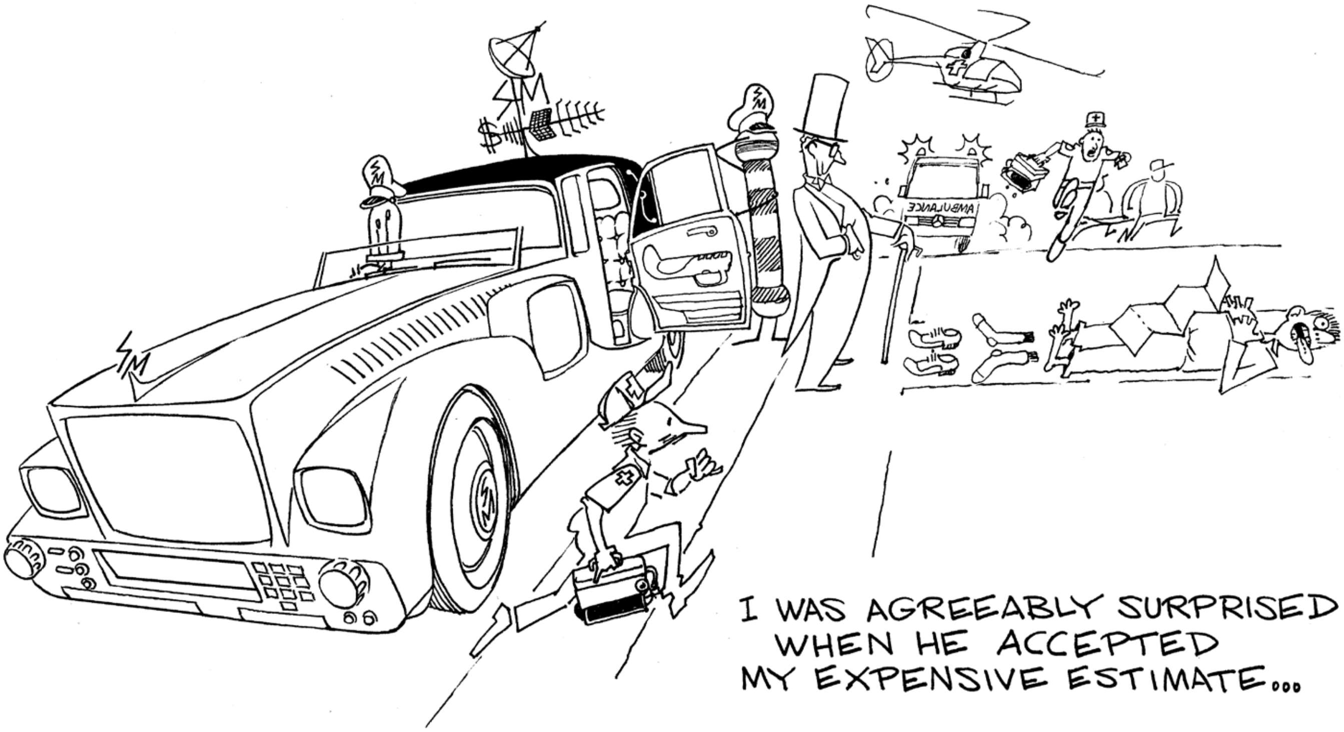
A tape was also stuck inside but the video cassette was unable to eject it or even show any signs of life.

I removed the bottom cover by undoing seven screws to reveal just what I had expected – a fair whack of miniature electronics in a small box. After a little careful reconnaissance and surfing the service manual, I discovered that there are two main boards on the left looking from underneath – ie, PC boards JAS and TTS – plus a further board (SWS) on the right under the video deck. The TTS board could be unclipped and folded upwards to give access to the JAS board below.

Of course, the boards were double-sided with surface-mount components – but the thing I noticed most, which filled me with fear, was the vast number of subminiature electro-

Items Covered This Month

- Panasonic TC-14S1SA TV set (MX5 chassis)
- Panasonic TX-79P100Z TV set (MD2 chassis)
- Hitachi 5-inch VT-LC50EM (AU)
- Sony KV-XF29M35 TV set
- Panasonic NV-FS90A TV set
- Sony KV-XF29M35 TV set
- Philips 28CE1965 TV set
- Philips 28GR6775/75R TV set
- Sony KV-1415AS TV set
- NEC N-3452 VCR



lytic capacitors, many of which were leaking electrolyte on all the boards.

At this stage, all I was intending to do was to diagnose the fault(s) so that I could give Mr Armstrong a quote for the repair cost. I already had a good idea what had happened but I was determined to cross a few "t"s and dot a few "i"s. And I needed to know where the power came in and where it went, which I thought was going to be fairly simple.

It wasn't. The circuit was very complex and it took a long time to work out that the AC adaptor came in via JK1501. The battery came in via PG502 and the line then went via fuses FU1501 and FU501. These are 2A picofuses and both had blown.

The fuses, which look like resistors, were located some distance away from the DC jack and battery input. Unfortunately, it was too difficult to trace the path, not only because the board was double-sided but also because the parts were tightly packed.

Even with the fuses blown, there were voltages that could be measured at random on all the boards at places that were accessible. Unfortunately, replacing the fuses had no positive effect – the unit was still as dead as a doornail.

Next, I followed one rail from the fuses to the TTS board and then to another switchmode power supply. In the process, I checked a lot of other fuses but I was getting nowhere.

By now, I was feeling rather frustrated. All I had achieved so far was to find two open circuit fuses and determine that there was no 5.1V where it should have been. Nor was the 9.6V reaching pin 11 of IC581, the switching regulator. What's more, there were a lot of electrolytic capacitors to replace.

I then checked some of the IC regulators that fed the microcontrollers, to find they were OK (eg, IC1902 that fed IC1901 on the TTS board; and IC906 to IC901 on the SWS board which controls the power-on function).

By now, I could see that a lot of work was needed to replace the electros and possibly fix the corroded tracks underneath them. Then there was the NiCad battery, plus the memory back-up lithium battery. After adding 10% GST, I thought it hardly worth continuing with what was essentially a toy.

Anyway, I had to wait a few months before I could finally contact Mr Armstrong, when he resurfaced back in Australia. I was agreeably surprised when he accepted my expensive estimate. I guess he is one of those blokes who doesn't have many other interests and this was one of the luxuries he felt he had to have.

While waiting for his verdict, I had been planning my campaign of attack and now I was ready to go. First, I removed his jammed video tape by unplugging the loading motor (CN904) and connecting a 9V battery to it to release the tape.

That done, I concentrated on changing the worst of the electrolytic capacitors. There were 10 brown electrolytics, eight of which were 47µF 16V (C584, C587, C588, C589, C597, C1855, C1857 & C1939) and there were also two at 100µF (C585 and C586). C1855 and C1857 had corroded the tracks badly underneath and it took a lot of effort to work out which "micro-thin" tracks were which. The main one was VDET from PG1902-6 to pin 22 of IC1901 via R1958 and pin 1 of D1901.

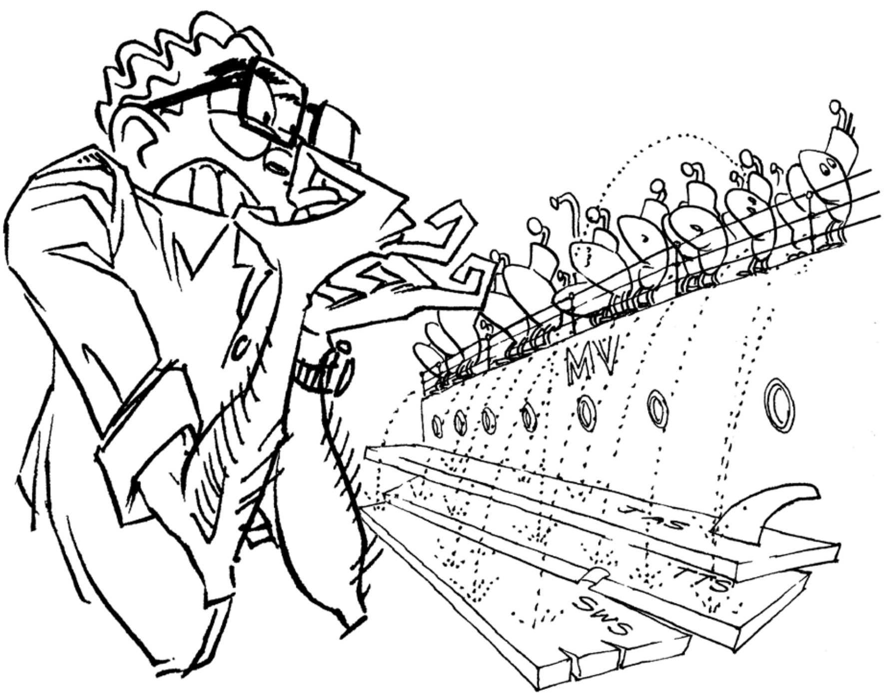
Unfortunately, I wasn't having much luck and still couldn't get the power switch to work – or even get the power-on LED to light.

I have to confess that much of my work was done with the unit upside down and I was operating the power switch by toggling it with my fingers under the half-opened LCD screen lid. After changing a few more electros, it was getting late so I thought I would clear the bench and partially reassemble the unit, ready for the next day.

That done, I turned the unit over, opened the lid fully and was staring at it hatefully while I again hopelessly pushed the power switch. To my total amazement, the whole lot came on – even the video system was working. I tuned in a channel (when I worked out how to do it!) and the picture and sound were perfect.

When I came in the next day, I couldn't help feeling that it had all been a mirage – but it was still working!

What I hadn't realised before was that the set would only work when



BUT THE THING WHICH FILLED ME WITH FEAR WAS THE MILLIONS OF SUBMINIATURE ELECTROLYTIC CAPACITORS LEAKING ELECTROLYTE ON ALL THE BOARDS...

the screen was fully opened. There is another panel switch (S2801) – not mentioned in the manual – on the LCD board that controls pin 17 of IC1901. So I'm no too sure just when the set had actually been fixed as I worked on it.

There was no question that the screen was fully open at the start and the set was definitely "no go" then!

The problem was that the power switch doesn't just switch the power straight on. The power switch (S017, FSW board) controls IC1901-18 on the TTS board which, if everything is OK, will somehow talk to IC901. IC1901-61 then "wakes up" Q904 and activates IC901-49 on the SWS board. And that in turn switches on Q581, Q585, Q582 and IC581 on the JAS board which then switches on regulator transistors Q588-Q591

Of course, that's all assuming that nothing is wrong and that the protection circuits don't switch on!

In the future, jobs like this are definitely for the birds.

Seaside problems

Disasters can happen to everyone and to every type and make of set. Mr Byron had one such experience with a newish (1999) Sony KV-XF29M35, which lived with him in a stylish mansion by the sea.

I guess one can have too much of a good thing, because the humid salty sea breeze plays havoc with anything containing metal and electricity.

Inevitably, his set died prematurely and ended up on my bench. The power supply was dead and blowing IC601 (STR-F6656) repeatedly. I checked for shorts on the secondary of the chopper transformer and found the horizontal output transistor, Q511 (2SC4927-01), was short circuit also but this didn't stop the switchmode control IC from destroying itself. It was only after I had committed the third IC to the bin that I woke up to the fact that the sensor amplifier, SE-135N (IC602), was giving incorrect feedback information.

However, I wasn't completely out of the woods. The picture was extremely dark, with no contrast. And the horizontal output transformer, T503, was looking particularly dodgy, as it was hissing and spluttering.

While a new one was on order, I decided to chase the ABL circuit and see if there was anything untoward there. It turned out to be a fairly involved circuit but my hunch was correct in the end – several surface mount components on the A board, including Q312 (2SA1162-G), D315 (ISS3565) and D316 (a 6.8V zener diode), were faulty. This was rather surprising because I would have expected Q512 to have been destroyed as well but it was OK.

The new horizontal output transformer finally restored the set until the next onshore sea breeze. And the customer was happy.

The SAMPO chassis

The Philips Group has produced over 5000 different models of colour TV sets in the last 30 years. Almost all have been designed and made by the company but there are a few that have been made outside.

Two that come to mind are made in Taiwan – the SAMPO-1 and SAMPO-2 chassis (Models 26CE1991 and 28CE-1965). Anyway, Mr Tennant phoned for a home service call on his Philips set, a 28CE1965, complaining that when it was cold it was hard to start. And he was convinced that it was the on/off switch. Well, of course – if it isn't the fuse, the switch or the tube – it can't be anything else!

When I arrived, he had the set on and so it was switching on and off perfectly every time. I just couldn't accept that the switch was faulty only when it was cold, so I told him that I suspected the power supply and probably the electrolytic capacitors in it and that it would have to go to the workshop.

Back at the workshop with the back off, I could see the set was very well made and that it used a Toshiba IC chip set. There is no master power switch – the set is controlled by a subminiature push switch going to a microprocessor and then a relay.

I found and replaced capacitors C713, C714, C717, C735 in the power supply which were dried out. I then put it back into operation and left it to soak test on the bench but with back off just in case I had to do any further work. After a few days, it was still working correctly and so I put the back on.

However, with the back on, I found it difficult to turn the set off with the remote control. I didn't discover this until it had run all day and it was time to turn it off, so I wondered whether this new problem might be caused by additional heat affecting something. I tried it for another day, before opening it again. And with the back off, I couldn't fault it, so I was even more suspicious of the heat factor and replaced even more capacitors – C740, C741, C744 & C745 – in the auxiliary power supply for the relay and microprocessor.

Well, I still couldn't fault it with the back off but once back in its case, the set intermittently wouldn't switch off with the remote control, even when it was cold. However, it did respond to the switch on the set.

Consistent with my old age, it took a while for the cause to sink in. The chassis slides in from the back, on plastic rails, until the escutcheon mounted pushbutton controls just touch the push switches. However, the combination of the chassis being pushed too far forward and a slightly distorted power knob meant that the microswitch was permanently switched on. So, when the remote control was used, it could only mute the sound but not turn the relay off. However, when the switch itself was pressed, it released itself properly.

So Mr Tennant was right; or at least partially – there was a problem with the switch assembly.

Another Philips

I had a Philips 28GR6775/75R G110-S chassis in for repair at about the same time. This model was very popular in Australia and there are a lot of them about.

Mr Brady brought this one in and, originally, it had intermittent vertical deflection and linearity but the fault was now permanent.

I replaced capacitors C2813 and C8214 (both 1500μF 40V electrolytics), which were leaking badly and thought that that would fix it. However, before replacing them, I had to clean off the excess electrolyte on the board. It had even leaked underneath the chassis but no visual damage to anything was apparent. Unfortunately, having done all this, the fault was still there.

I measured everything in sight with the ohmmeter but could find nothing wrong. I then spotted a surface mount component link (4815) under C2813 and C2814. This had 000 printed on it, denoting zero ohms, and connects C2813 and C2814 together.

Anyway, when I measured this, it did indeed measure zero ohms but when I hit it with freezer, while the set was on, the vertical timebase began to scan. I felt that it was telling lies and linked it out with a fair dinkum wire link. This fixed the fault completely and when I measured the surface-mount link again, I found it was high resistance.

I can only assume that the corrosion from the electrolyte had damaged it in a manner such that it failed under load.

Dark NEC

A Thai-built NEC portable 34cm remote control TV set was brought with a dull dark picture. It was an N-3452 model with PWT-101A chassis.

The voltage on TP91 was only 85V when on but shot up to 143V on stand-by. It should have been 116.5V so something was very wrong. The power supply uses an STK 730-80 (IC601) and I noticed that it raised the voltage when hit with freezer.

The voltage input across capacitor C604 was a very healthy 320V.

I then started looking for any electros in the primary or control section of the power supply and at first didn't see any. But then I spied C610 (10μF, 50V) on the circuit although I couldn't see it on the board. I finally found it tucked up tight behind IC601 and replaced it.

This was indeed lucky as it was the culprit and not the expensive IC I was about to order and replace.

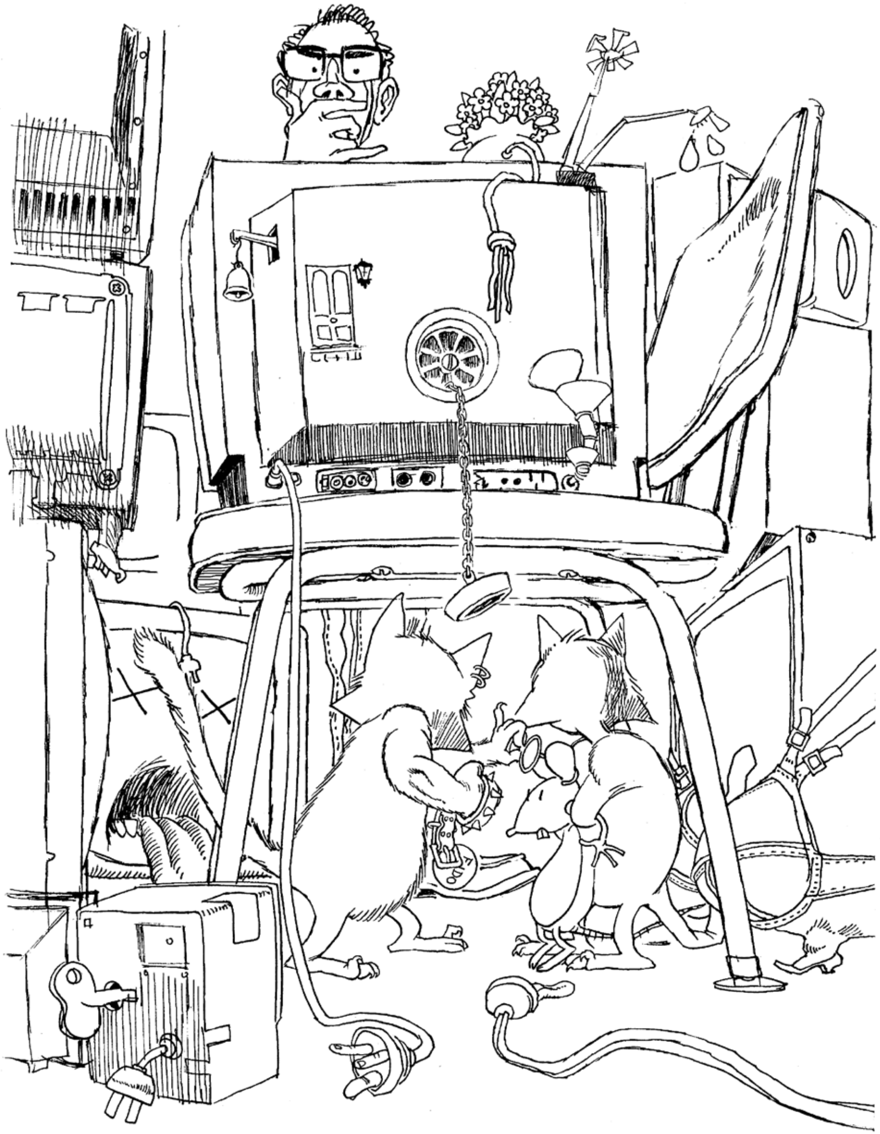
A crook guess

I don't appear to be very good at guessing which jobs look easy and which don't. Mrs Lyon's Sony KV-1415AS (SCC-F35A, G3E chassis) had a very small dark picture and for all the world it looked like the main HT was low, which would be relatively easy to repair.

However, after I had taken the back off, I measured the HT and it was spot on at 115V, on the cathode of D608. So my main theory was quickly dissolved.

I moved to my fall-back position – when in doubt, measure all the power rails. This I did, and realised fairly quickly that all the secondaries of the horizontal output transformer were low and the EHT was down to about 15kV. There are three main voltages from the transformer: 200V for the CRT video outputs, 26V for the vertical output and 15V for all the ancillary circuits. I started with the latter by disconnecting the output of IC851, a 9V IC regulator, to see if the rail would come up when the load was removed.

I was back on track again! Disconnecting the 9V rail brought all the secondaries up to normal – but what was loading it? There were no shorts on the 9V rail but when it was reconnected, the 9V dropped to 6V.



THIS WAS REALLY ONE OF THOSE SETS THAT WASN'T WORTH FIXING...

Unfortunately for me, the 9V rail goes everywhere in the set. So in the absence of any other brainwave, there was nothing for it but to progressively disconnect the devices being fed by the 9V rail and keep track of its value.

Much later, I found that desoldering the links to Q851 (2SA1162), a surface-mount PNP regulator, made a significant difference, even though the device itself was perfectly OK. I then found that disconnecting diode D251 (ISS119) in series with the collector of this transistor restored everything.

That surprised me, as both these devices are minute and yet were holding this rail down by one third! I measured D251 to find it too was perfect – so where to now? D251 fed the bases of the two transistors, Q251 and Q252, which apply audio muting to IC251 (the audio output IC).

Once again, I had to disconnect components to find out where the current was going. I desoldered Q251 and Q252 in turn but found that it was D250, another ISS119, that was causing the problem. It was leaky and replacing it fixed the set completely.

So what was the significance of D250? As already stated, its cathode (along with D251) fed the two muting transistors. The anode goes to the emitter of Q2004, which is in the power on/standby circuit and feeds horizontal drive transistor Q801 via R057 (1kΩ).

Not being a circuit designer, my hypothesis is that a leaky diode reduced the drive to the horizontal output stage. And it was this that was causing the low output rather than a current overload problem.

It was an interesting case but unfinancial as far as I was concerned. Mrs Lyons' set had been fixed at a significant discount but she still thought it was too expensive!

Panasonic VCR

With the low cost of VCRs, I am getting less and less to repair, the exception being the more expensive hifi and SVHS machines. Recently, I had a Panasonic NV-FS90A with no TV reception – the tape would play OK and all the other functions were fine.

Unlike most similarly dated SVHS machines from Panasonic, this model selected AV via the program selector in sequential order, or it could be selected on the remote control. Other models have a switch on the front panel offering Tuner, Simulcast or Auxiliary inputs.

This set was stuck in the AV mode and wouldn't switch to TV at all. I took a long time studying the service manual and in the course of tracing the circuit, discovered that C1003, the memory back-up capacitor, had leaked electrolyte onto the main board, corroding at least three tracks.

I thought that linking the broken tracks would fix the problem but it wasn't to be. The critical point was pin 4 of the microprocessor (IC6001, MN188166VDU) which should have 5V on it for the TV function.

It took a long time to realise that the corroded tracks were not the only problem. IC6001 itself was also faulty but only on pin 4. But why had such a complex microprocessor failed only on one pin. The reason, I suspect, was because the electrolyte from the leaking capacitor had shorted the nearby -20V to pin 4.

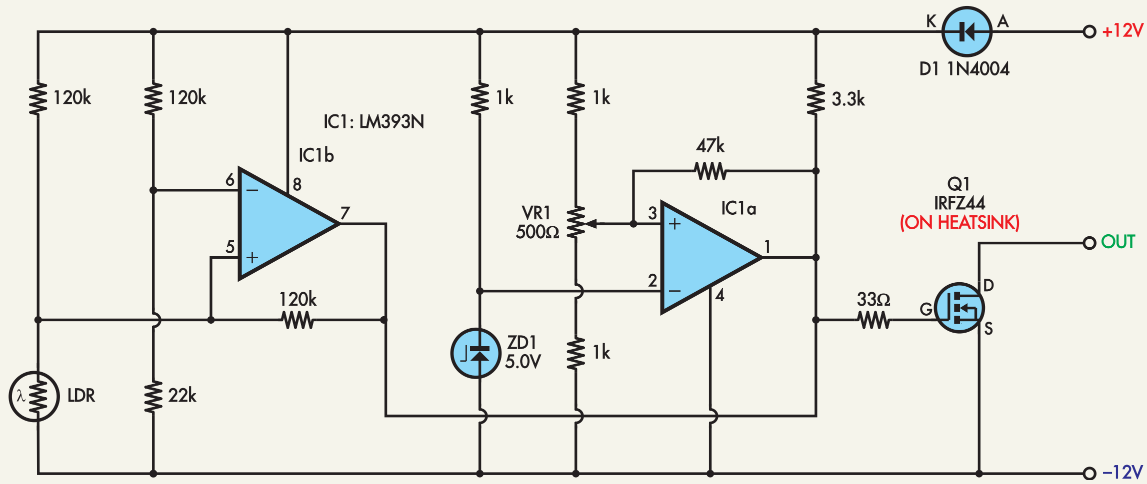
I worked out a fix by shorting Q607's base and collector, to hold this rail at 5V. But this fix was incomplete – it fixed the TV problem but only at the expense of the AV function.

Basically, of course, the answer was to replace IC6001. But I hesitated. It was a large and fairly expensive unit and, with labour costs, would make a costly exercise. And I sensed that the customer was worried about further costs. As an alternative, I suggested that I could fit a toggle switch so that he could switch between the AV and TV inputs. However, he ultimately decided that he really had no further use of the AV inputs and that a switch would look out of place.

So we left it at that. The customer was happy and I was happy. What more could one want? **SC**

CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions from readers are welcome and will be paid for at standard rates.



Solar battery protector prevents excessive discharge

This circuit prevents the battery in a solar lighting system from being excessively discharged. It's for small systems with less than 100W of lighting, such as several fluorescent lights, although with a higher rated Mosfet at the output, it could switch larger loads.

The circuit has two comparators based on an LM393 dual op amp. One monitors the ambient light so that lamps cannot be turned on during the day. The second monitors the battery voltage, to prevent it from being excessively discharged.

IC1b monitors the ambient light by virtue of the light dependent resistor connected to its non-inverting input. When exposed to light, the resistance of the LDR is low and so the output at pin 7 is low.

IC1a monitors the battery voltage via a voltage divider connected to its non-inverting input. Its inverting input is connected to a reference voltage provided by ZD1. Trimpot VR1 is set so that when the battery is charged, the output at pin 1 is high and so Mosfet Q1 turns on to operate the lights.

The two comparator outputs are connected together in OR gate fashion, which is permissible because they are open-collector outputs. Therefore, if either comparator output is low (ie, the internal output transistor is on) then the Mosfet (Q1) is prevented from turning on.

In practice, VR1 would be set to turn off the Mosfet if the battery voltage falls below 12V.

The suggested LDR is a NORP12, a weather resistant type available from Farnell Electronic Components Pty Ltd.

Michael Moore,
Beecroft, NSW.

Radio controlled electronic flash

A radio controlled electronic flash is a useful item in any photographer's kit. Professionals use them all the time. For example, a wedding photographer would put one behind the bride to back-light her gown and veil. You don't want wires showing in a shot like that.

To build this control you will need an old R/C car (the simplest sort) in which the car runs in reverse at switch-on and goes ahead only when the remote is operated. They can be picked up cheaply as school fetes and garage sales. A typical car will run from 3V (two cells) and use 9V in the transmitter.

Before proceeding, make sure that the electronics in the car are operating. It doesn't matter if the wheels are broken or the motor is dead. You need to gain access to the leads to the motor. Normally (ie, without the remote operating), one is positive with respect to the other. Label them accordingly. On pressing the remote button, the polarity of the motor leads should swap.

You will also need a flash ex-

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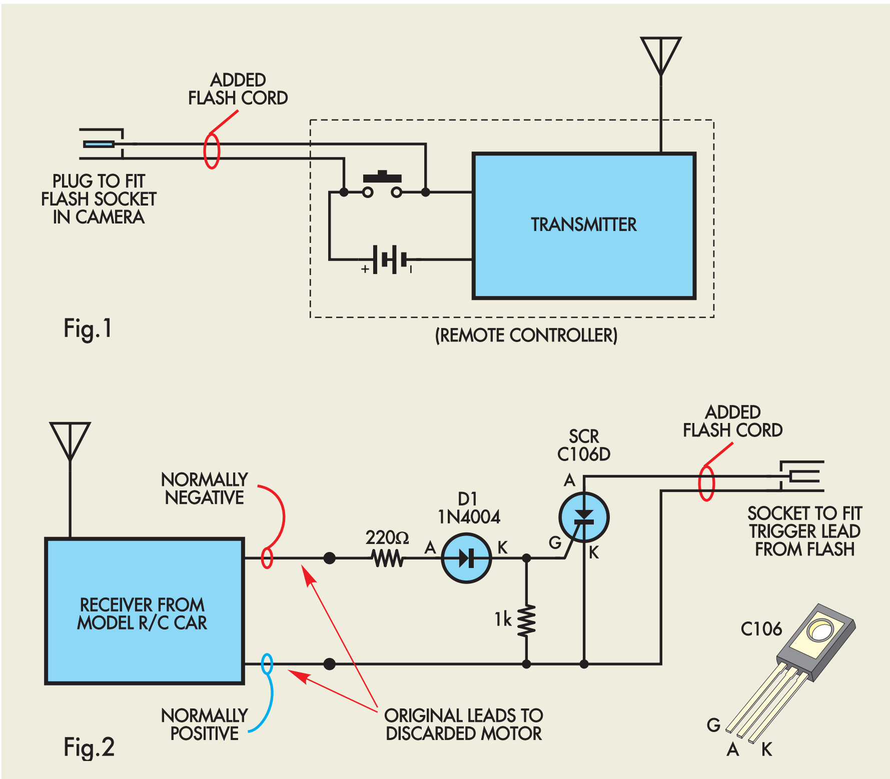


Radio controlled electronic flash: continued from page 45

tension cord you can cut into two sections.

At the transmitter, the camera end of the extension cord is fed into the case and soldered to the control button contacts, as shown in Fig.1. The contacts are in series with the battery supply, so if you don't want to open the transmitter, just cut one of the battery leads and connect the flash extension cord into the gap so created.

You will then need to tape down the remote button so that it is permanently operated (ie, closed).

All that needs to be done at the receiver end is to connect the normally negative motor lead to the gate circuit of an SCR, as shown in Fig.2, while the normally positive lead goes to the cathode of the SCR. Now, when the transmitter is operated by the camera's contacts, the lead polarity is reversed and the SCR acts as a switch to fire a portable electronic flash via the other half of the flash extension cord.

The transmitter can be attached to the camera via a flash bracket or a screw into the tripod socket, depending on what is the most convenient arrangement.

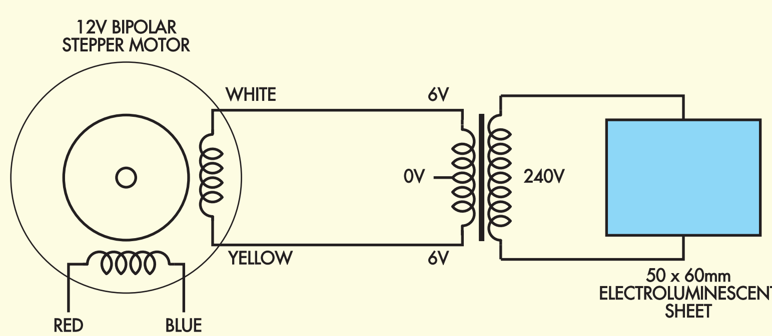
The added components in the receiver can be mounted on Veroboard and housed in the space where the electric motor was. If appearance is a primary consideration, the receiver and the added components could be mounted in a standard jiffy box.

Finally, a note of caution: when connecting the flash end half of the extension cord to the SCR, make sure that it is the positive wire which goes to the anode of the SCR. Flash cords do not always have the centre wire connected to the centre pin of the plug. The centre pin of the lead on the flash unit will be positive and this must connect to the anode of the SCR via the lead connected to the R/C receiver.

A. J. Lowe,
Bardon, Qld. ($40)

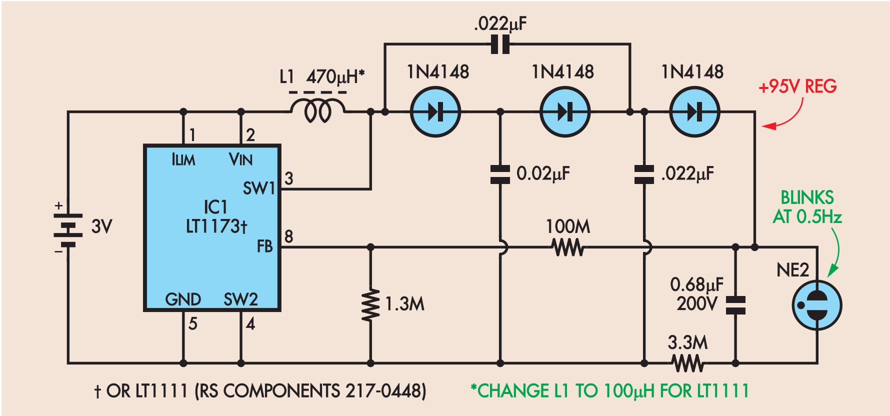
Luminescent generator

When spun rapidly between the fingers, a bipolar stepper motor will generate around 10VAC. If this is stepped up with a small 240V to 6-0-6V transformer in reverse (with series connected secondaries), a small bipolar stepper motor is capable of powering a standard 5cm by 6cm luminescent sheet at full brightness. These are designed to be powered from 20V to 200VAC (typically 115VAC), producing 1.5 candelas of light – which will dimly light the average room, or adequately light a camp table. They are manufactured by Seikosha (RS Components Cat. 267-8726).



The transformer should be a small one (around 100mA or so), otherwise efficiency is compromised. The wires of the motor's two phases are usually paired white & yellow and red & blue. Just one of these phases is employed in the circuit. If a small bipolar stepper motor from a discarded 3.5-inch disk drive is used, the Luminescent Generator may be built into a very small enclosure. To sustain rapid, smooth spinning of the motor, a geared handle may be added.

Thomas Scarborough,
Cape Town, SA. ($30)



Neon flasher runs from 3V supply

A neon indicator typically requires at least 70V to fire it and normally would not be contemplated in a battery circuit. However, this little switchmode circuit from the Linear Technology website (www.linear-tech.com) steps up the 3V battery supply to around 95V or so, to drive a neon with ease.

The circuit has two parts: IC1 operating as step-up converter at around 75kHz and a diode pump, consisting of three 1N4148 diodes and associated .022µF capacitors. The 3.3MΩ resistor and the 0.68µF capacitor set the flashing rate to about once every two seconds.

The average DC level from the diode pump is set to about 95V by the 100MΩ feedback resistor to pin 8.

The circuit could also use an LT1111 (RS Components Cat 217-0448) which would run at about 20kHz so L1 could be reduced to 100µH and use a powdered iron toroid core from Neosid or Jaycar.

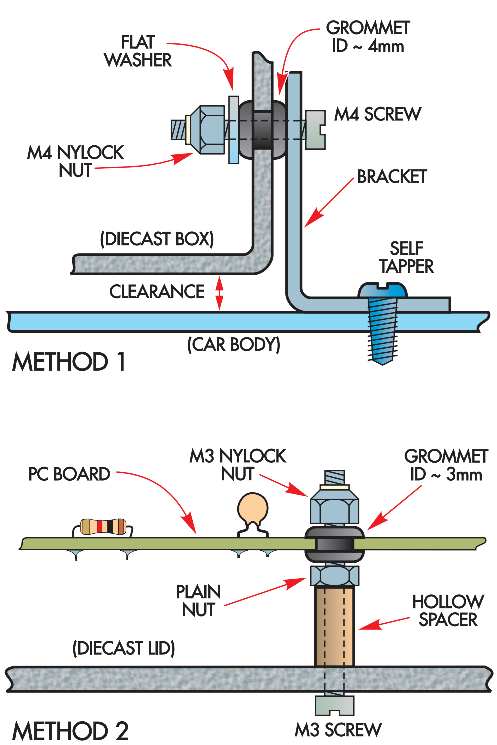
Silicon Chip.

Isolation for PC boards in cars

These two mounting methods were devised to protect PC boards from vibration when installed in the engine compartment of a car. They could also be used in other applications where vibration is a problem.

Method 1 involves rigidly mounting the PC board inside a diecast box and then mounting the box itself to provide vibration isolation. As shown, small grommets are installed in suitably sized holes in the sides of the box. The box is then secured to angle mounting brackets using M4 screws, washers and nylock nuts.

Method 2 involves mounting the diecast case onto the chassis of the car and then mounting the PC board as shown, using M3 screws, grommets, hollow spacers and nylock nuts. In this case, the grommets are fitted into suitably sized holes in the PC board itself. Once the nuts are tightened, the PC board should be able to move slightly, relative to the box.



If there is not enough space on the board to fit the grommets, then Method 1 is the way to do it.

David Boyes,
Gordon, ACT. ($35)

MULTI-POWER

An easy-to-build bench power supply

This handy bench power supply has no expensive meters and offers six fixed dual-polarity supply voltages: ±3V, ±5V, ±6V, ±9V, ±12V and ±15V DC. And for added flexibility, you can use any of the first three outputs and any of the second three at the same time.

By JIM ROWE

FULLY VARIABLE DC bench supplies with voltage and current meters are great for checking circuits that operate from odd-ball voltages. They're also essential for checking the voltage range over which a circuit operates correctly. However, for a lot of work, they can represent overkill.

Some of the bells and whistles on a typical supply can even be a drawback, when you're simply trying out an idea for a circuit that must work from a bog-standard supply rail. For example, on many low-cost bench supplies, the meters are either too small or too inaccurate to allow you to properly check that the output is set within tolerance. So you generally have to reach for your DMM and check the voltages anyway, before even connecting the supply to your circuit.

There can also be a problem when it comes to trying out a circuit that needs multiple supply rails. Most bench supplies have two outputs at most and even these are generally balanced – ie, the positive and negative outputs closely track each other. That's great when you do want balanced supply rails but not so useful if you want say +12V and -5V. In that case, you generally need a second supply altogether.

In fact, if you need three rails – say +5V, -5V and +12V – there's usually no option but to use a second supply. And if you need a fourth rail, you might well have to use either a third supply or at the very least, two different balanced twin supplies.

All of which demonstrates the truth of that old saying in electronics: "you can never have too many power supplies!"

Multiple fixed outputs

For a lot of day-to-day bench work, what would be really handy is a small supply with four outputs – especially if these outputs could be easily switched to select commonly used fixed voltages. Such a supply wouldn't need any voltmeters, because of the fixed outputs, and for a lot of work it wouldn't need current metering either. And none of the outputs would need to have a high current/power rating, since most bench work now involves very low power circuitry.

This line of thinking culminated in the compact, low-cost four-in-one bench supply described in the January 1998 issue of "Electronics Australia". It was a very handy little supply and quite popular too but it did turn out to have a few shortcomings. For example, it had a choice of only four output voltages: ±5V and ±12V. Obviously, there are situations where other voltages are required.

The other "shortcoming" was that it was not suitable for beginners, because of the transformer and mains wiring inside the case.

The idea behind this new design has been to come up with a supply that's not only more flexible than the 1998 version but easier and safer to build as well. It still offers only four output voltages at once (two bipolar pairs) but these can now each be switched between three pairs of voltages. You can have either ±3V, ±5V or ±6V from one set of outputs and either ±9V, ±12V or ±15V from the other set.

Despite this extra flexibility it's even easier to build than before, because all of the internal wiring is on two PC boards which connect directly together. There's really no off-board wiring at all.

There are no safety worries for beginners either, because the supply gets all its power at very low voltage from an external 9V/1A AC plugpack. The highest voltages anywhere inside the case are only 9VAC and 27V DC.

Like the earlier design though, it won't deliver really high currents. You can draw up to about 750mA at ±3V, 550mA at ±5V, 450mA at ±6V, 600mA at ±9V, 500mA at ±12V and 350mA at ±15V. This is for each output used singly of course but the figures don't "droop" too rapidly when multiple outputs are in use – the main limitation is the regulation of the AC plugpack.

Fig.1 shows the performance details in graphical form (see also the accompanying specifications panel).

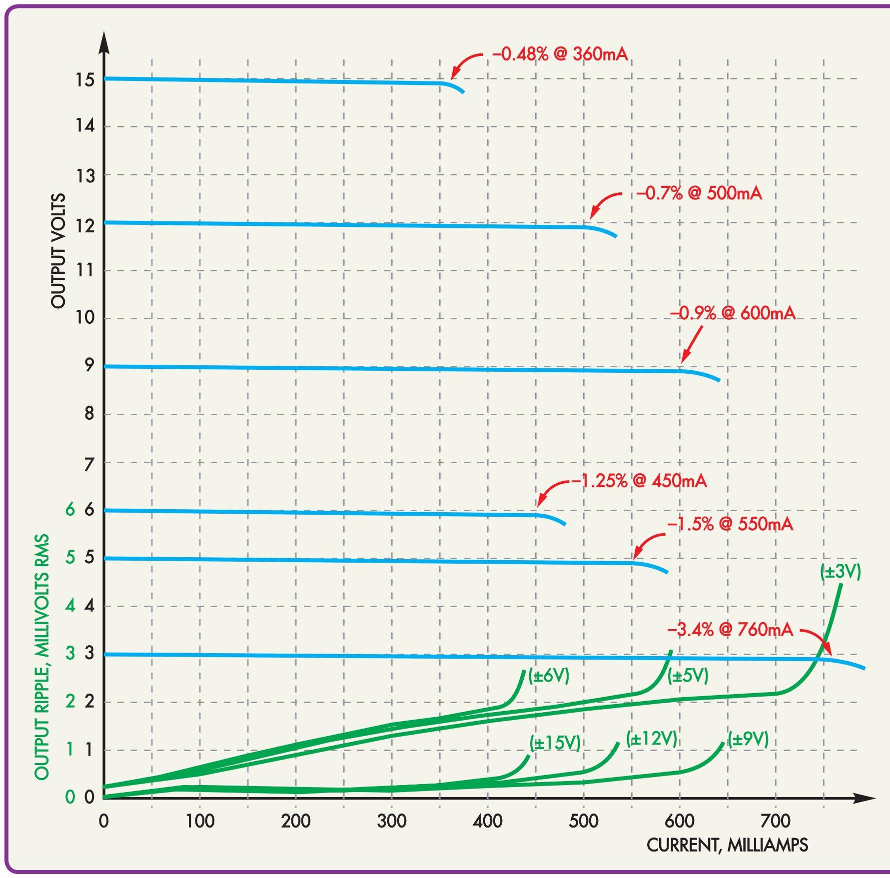


Fig.1: this graph shows the output current capabilities (blue) for the various fixed voltage outputs. The ripple performance is also plotted (green).

As you can see, it still has enough "grunt" for most experimental bench work. So although it deliberately lacks a lot of the traditional bells and whistles, it's still a surprisingly practical unit. The outputs are overload and short-circuit protected and the output terminals are spaced on standard 19mm centres to allow the use of dual banana plugs if desired.

The circuit

Refer now to Fig.2 for the circuit details. It may seem a bit daunting at first glance but it's really very straightforward.

First, there are four simple rectifier and filter circuits producing raw DC rails from the 9V AC delivered from the plugpack. Each rectifier then drives an adjustable 3-terminal regulator with a switch to select one of three regulated output voltages. It's mainly the plugpack which sets the unit's total power rating of around 9W (9V x 1A).

The two low-voltage rectifiers are standard half-wave circuits, each based on a single 1N5404 power diode (D1 & D2) feeding a pair of 2200µF filter capacitors. These rectifiers produce about ±13V of unregulated DC under no-load conditions, drooping down to

SPECIFICATIONS

Outputs: 2 x dual-polarity pairs (VA & VB) plus two common terminals.

Output Voltages: 3 x dual polarity low-voltage outputs (VA); 3 x dual-polarity high-voltage outputs (VB), as follows:

- **(1) Low-voltage switch (VA):** ±3V @ 750mA; ±5V @ 550mA; & ±6V @ 450mA
- **(2) High-voltage switch (VB):** ±9V @ 600mA; ±12V @ 500mA; & ±15V @ 350mA

Power supply: 9VAC 1A plugpack

Overload and power indication: 4 x 3mm LEDs

Load switching: independent toggle switches for each output pair lower voltages as current is drawn. The 1N5404 diodes have a current rating of 3A continuous and 200A peak, so they should be virtually "unbreakable" here.

For the higher voltage outputs, we use half-wave voltage doubling rectifiers, each with a 2200μF series capacitor, a pair of 1N5404 power diodes (D3 & D4 and D5 & D6) and a pair of 1000μF filter capacitors. These rectifiers produce about ±27V of unregulated DC under no-load conditions, which again droops as current is drawn.

By the way, the relatively poor regulation of the half-wave rectifiers doesn't pose a problem. In fact, it helps keep the power dissipation of the regulators down to an acceptable level, by lowering the voltage across the regulators at higher load currents.

The maximum power dissipated by any of the regulators is 3.5W, which is reached by the high-voltage regulators when delivering ±9V at 400-450mA. This is acceptable because the regulators are all mounted on a reasonably good heatsink (the rear panel) and have inbuilt thermal overload protection anyway. If they do get too hot, they automatically shut down for a while to cool off.

As shown on Fig.2, the positive 3-terminal regulators are LM317T devices while the negative regulators are LM337Ts. Both of these regulator ICs are capable of handling up to 1.5A of current so, like the rectifier diodes, they're being used quite conservatively here.

The regulator circuits all use virtually the same configuration. This is because the LM317 and LM337 regulators work in the same way, acting to maintain a fixed voltage across the resistor connected between their "output" and "adjust' terminals (240Ω for the positive regulators and 120Ω for the negative regulators).

In each case, the regulator keeps the voltage across these resistors fixed at 1.25V.

Because virtually all of the current through these resistors comes from the output terminal and almost no current flows in or out of the adjust terminal, virtually the same current flows in any resistance we connect between the adjust terminal and ground. So we are able to set the actual output voltage of the regulator by adjusting this lower resistance value, to set up a "bootstrap" voltage drop that's equal to the desired output voltage less the 1.25V that's maintained across the upper resistor.

For example, in the low-voltage positive regulator (REG1), the series 470Ω and 430Ω resistors give a total of 900Ω, which produces +4.75V between the adjust pin and ground. As a result, the regulator's output is +6.0V (4.75 + 1.25) when these resistors are in circuit alone. Similarly, for REG2, the 1.5kΩ and 1.1kΩ resistors alone give an output of +15V, while the 270Ω and 180Ω resistors in the REG3 circuit give an output of -6V, and so on.

To set the two lower output voltages for each regulator, we simply switch in additional shunt resistors across these lower resistors, to reduce their value and hence the voltage drop.

For example, in the REG1 circuit, we switch in a 3.3kΩ resistor to lower the regulator's output voltage to +5V, or the parallel 2.2kΩ and 680Ω resistors to bring it down to +3V. Exactly the same arrangement is used for the other three regulators.

Note that the two low-voltage regulator outputs (REG1 & REG3) are set using switches S3a & S3b, while the high-voltage regulator outputs (REG2 & REG4) are set using S4a & S4b – ie, each pair of outputs is tied together. As a result, S3 and S4 are respectively marked "VA SELECT" and "VB SELECT" on the front panel, to ensure easy operation.

In addition, load switches S1a & S1b allow you to switch the two low voltage outputs together, while S2a & S2b perform the same role for the two high-voltage outputs. These switches are miniature toggle types and are positioned quite close to each other on the front panel. So with a little dexterity, it's quite easy to switch all four outputs on or off within a few milliseconds of each other.

As shown in Fig.2, each regulator has a 100μF filter capacitor across its output and a 10μF capacitor from its adjust pin to ground to provide additional filtering. There are also reverse-biased diodes connected between each regulator's output and input (D7, D9, D11 & D13) and between the output and adjust terminals (D8, D10, D12 & D14).

Fig.2 (facing page): the circuit uses four simple rectifier and filter circuits to produce raw DC rails from the 9V AC delivered from the plugpack. Each rectifier then drives an adjustable 3-terminal regulator to derive the fixed output voltages.

Parts List

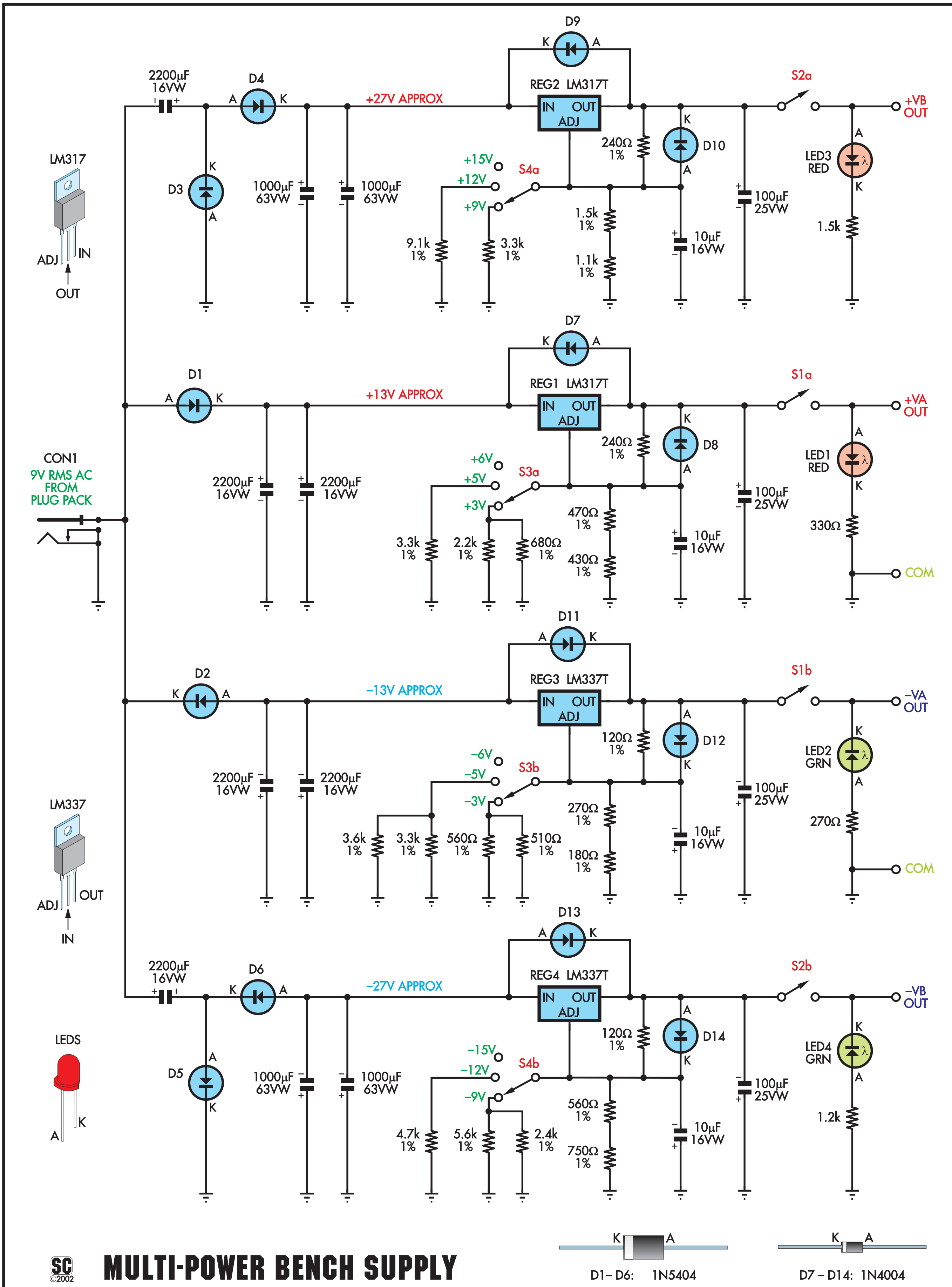
- 1 plastic instrument case, 155 x 160 x 64mm, with metal rear panel (2mm thick aluminium)
- 2 PC boards, code 04104021 (119 x 124mm) and code 04104022 (134 x 48mm)
- 6 banana jack screw terminals (2 red, 2 black, 2 green)
- 2 DPDT miniature toggle switches (S1, S2)
- 2 2-pole, 3-position rotary switches (S3, S4)
- 1 DC power socket, 2.6mm (PC-mount)
- 1 9V 1A AC plugpack
- 23 PC terminal pins, 1mm diameter round type
- 4 TO-220 insulating kits
- 4 M3 x 12mm round head machine screws
- 4 M3 nuts, flat washers and star lockwashers
- 2 instrument knobs, 19mm dia.

Semiconductors
- 2 LM317T 3-terminal regulators (REG1, REG2)
- 2 LM337T 3-terminal regulators (REG3, REG4)
- 6 1N5404 3A power diodes (D1-D6)
- 8 1N4004 1A power diodes (D7-D14)
- 2 3mm red LEDs (LEDs 1 & 3)
- 2 3mm green LEDs (LEDs 2 & 4)

Capacitors
- 6 2200μF 16VW RB electrolytic
- 4 1000μF 63VW RB electrolytic
- 4 100μF 25VW RB electrolytic
- 4 10μF 16VW RB electrolytic

Resistors (0.25W, 1%)

1 9.1kΩ	1 680Ω
1 5.6kΩ	2 560Ω
1 4.7kΩ	1 510Ω
1 3.6kΩ	1 470Ω
3 3.3kΩ	1 430Ω
1 2.4kΩ	1 330Ω
1 2.2kΩ	2 270Ω
2 1.5kΩ	2 240Ω
1 1.2kΩ	1 180Ω
1 1.1kΩ	2 120Ω
1 750Ω	



MULTI-POWER BENCH SUPPLY

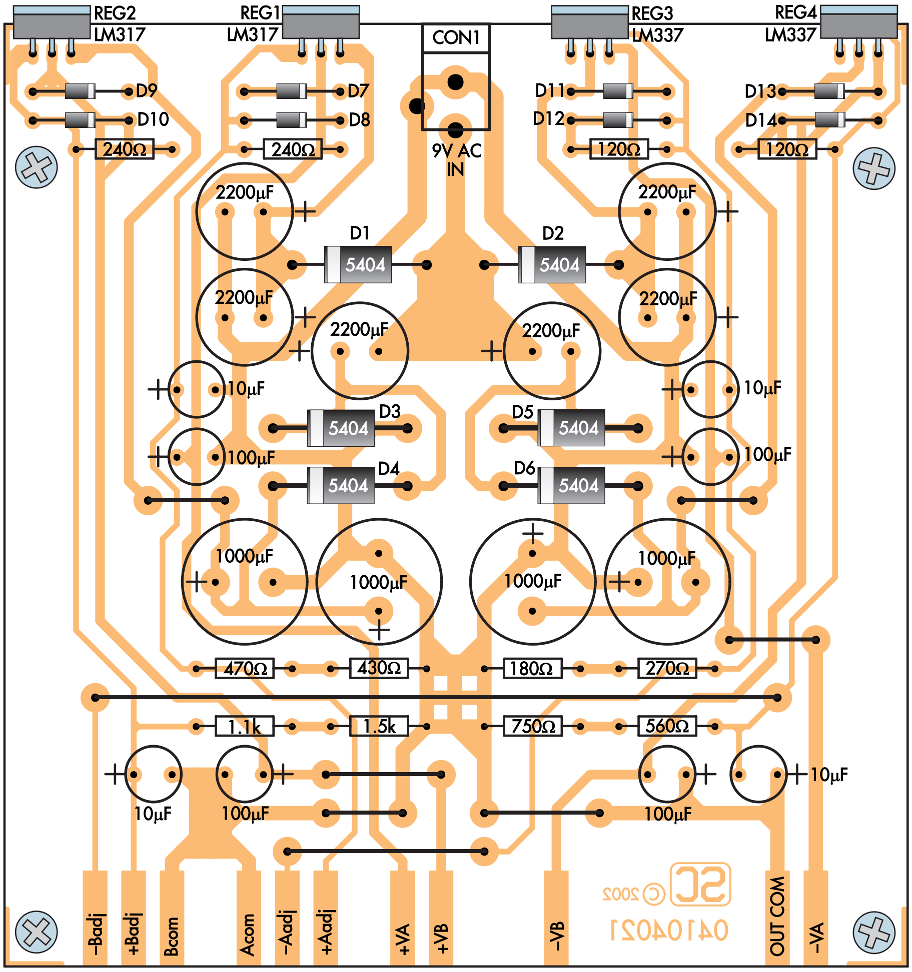


Fig.3: install the parts on the main PC board as shown in this diagram. Note, however, that REG1-REG4 are not installed directly on the board – instead, you have to install PC stakes at each of their lead positions and the regulators are then later soldered to these stakes (after mounting them on the rear panel).

The "upper" diodes are included to protect the regulators against damage if the outputs are accidentally connected to a voltage higher than that across their input filter capacitors. This can happen, for example, if you turn off the power to the supply's plugpack and then suddenly turn on one of the two load switches, thus connecting its regulator outputs to charged bypass capacitors in an external circuit.

The "lower" diodes similarly protect the regulators from damage due to any charge remaining in the 10µF filter capacitors when the AC input power is removed.

To save costs and keep the circuitry as simple as possible, there's no current monitoring or limiting, apart from that provided inside the regulator chips themselves. However, each of the four outputs has a simple LED status indicator, based on LEDs 1-4 and their series resistors. This means that should one of the regulators begin to shut down in response to an overload, that output's LED will become dim – so you'll at least be warned of an overload situation. That's the cue to hit the appropriate switch and investigate the cause of the overload!

This simple system works quite well in practice, despite its low cost.

Construction

The complete supply is housed in a standard plastic instrument case measuring 160 x 155 x 65mm. Inside the case, everything is mounted on two compact PC boards which solder together at right angles: a main board which is mounted horizontally in the lower half of the case and a switch/output terminal board which mounts vertically behind the front panel.

The main board is coded 04104021 (119 x 124mm) and carries all the components used in the rectifiers. The four 3-terminal regulators also mount along its rear edge, so they can be bolted to the rear panel which acts as the heatsink (the usual plastic rear panel is replaced by a 2mm-thick aluminium plate). Also on this board are the basic components used in each regulator circuit and the power supply AC input connector (CON1).

The vertical PC board is coded 04104022) (134 x 48mm) and supports mainly the front-panel components: ie, voltage selector switches S3 & S4, load switches S1 & S2, the six output terminals and the four indicator LEDs. Also on this board are the LED series resistors and the voltage selection resistors switched into the regulator circuits by S3 & S4.

The connections between the two boards are made via 11 PC terminal pins, which solder to circular pads near the bottom of the vertical board

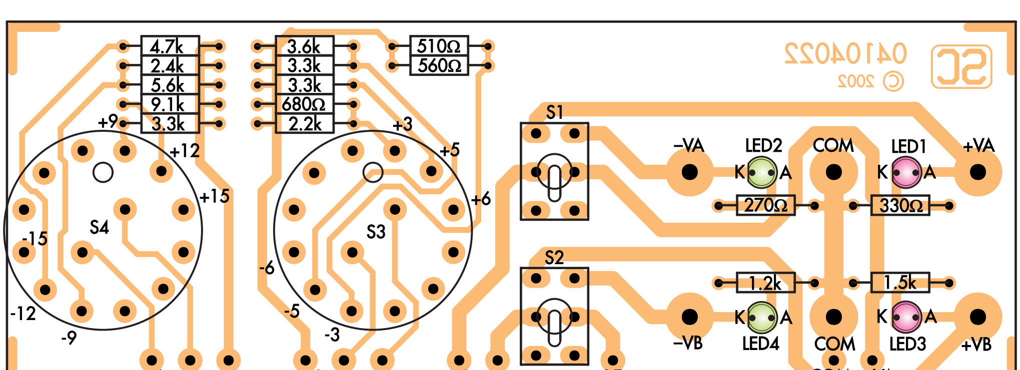
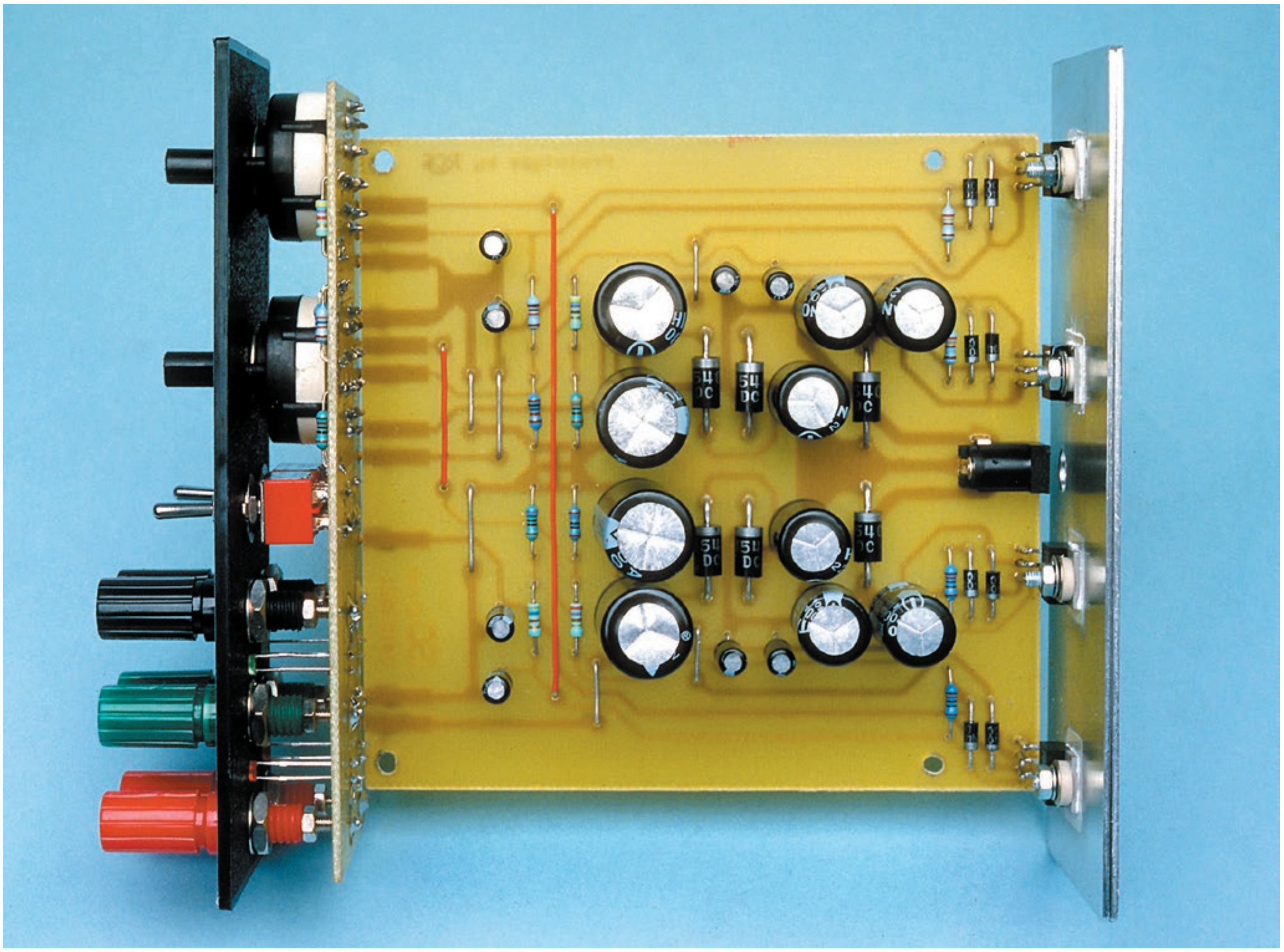


Fig.4: this is the parts layout for the vertical PC board. Refer to the text for the details on mounting rotary switches S3 & S4. Eleven PC stakes have to be soldered to the otherwise vacant pads along the bottom of the board. These are installed from the copper side and connect to matching pads on the main PC board (see Fig.5).



Here's what the completed assembly looks like before it's installed in the case. We sandwiched two 1mm-thick aluminium panels together to make up the rear-panel heatsink but you can use a single 2mm-thick panel.

and to rectangular pads along the front edge of the main board. As well as making the connections, these pins also hold the two boards together at 90°.

Putting it together

Assembling the supply is easy, particularly if you tackle it in the following order.

First, inspect both PC boards and make sure they've been trimmed to the correct sizes and that there are no solder bridges between tracks. This done, begin the main board assembly (Fig.3) by fitting three PC terminal pins to each regulator position along the rear edge – ie, 12 pins in all.

Next, fit the 2.6mm power connector CON1 to the board, followed by the eight wire links. Note that most of the links can be made using bare tinned copper wire (eg, component lead offcuts) but the two longest links should be made using insulated hookup wire.

With the links in place, you can then fit the resistors, 1N4004 diodes and finally the larger 1N5404 power diodes. Make sure the diodes are all fitted with the correct polarity, as shown in the overlay diagram, and be sure to fit the correct diode in each location.

Once the diodes are fitted you can fit the electrolytic capacitors, again taking care with their polarity. Your main board should then be complete and you can put it aside while you work on the second board.

Begin the assembly of this board (Fig.4) by checking that the holes have been drilled to the correct sizes to accept the larger items, such as the rear of the output terminals and the rotary switch connection lugs. That done, fit all of the resistors, again using the overlay diagram as a guide.

The only other items to fit to the board at this stage are the two rotary switches but first you have to trim their control shafts to about 10mm from the threaded mounting ferrule. That done, rotate each switch shaft fully anticlockwise, remove its locking nut and star washer, and move the indexing collar three positions anticlockwise. Finally, replace the star washers and mounting nuts to lock the collars down.

Each switch should now operate over three positions (instead of six).

You might also want to file a "flat" on each switch shaft (if one isn't already present), to help prevent the knobs from working loose later. The flat should be diametrically opposite the switch locating spigot, when the rotor is in its centre position

After the shafts have been trimmed and given flats, both switches can be fitted to the board, with their locating spigots directly above the shafts (see Fig.4). You may need to straighten their lugs a little, to allow them to mate with all of the board holes correctly.

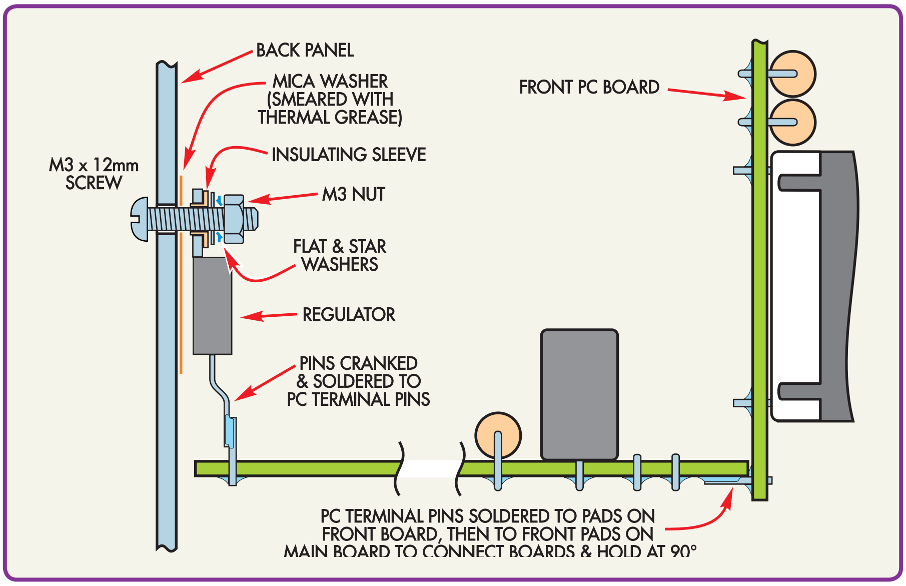


Fig.5: this cross-section diagram shows how the 3-terminal regulators are attached to the rear panel (using TO-220 insulating kits) and their leads bent so that they can be soldered to the matching PC stakes on the PC board. The diagram also shows how the two PC boards are connected together.

That done, solder all the lugs to the board's copper pads, with the switch body in contact with the front of the board.

The next step is to fit the four LEDs in their correct positions, as shown in Fig.4. Just tack-solder one lead of each LED at this stage and DON'T cut any of their leads short – they're just being positioned for final mounting later. Take care to ensure that the LEDs are correctly oriented – the anode lead is the longer of the two (see Fig.2).

Before you can proceed any further with this board, you have to prepare the front panel (that's because they combine to form an integrated assembly). So the next step is to drill and/or ream the holes in the front panel, using a copy of the artwork as a template. It's also a good idea to file the holes for the output terminals with "flats" on each side as suggested by the artwork, to prevent them rotating and working loose later.

You may also want to provide small "blind" holes above the main mounting holes for switches S3 and S4, to accept the switch locating spigots.

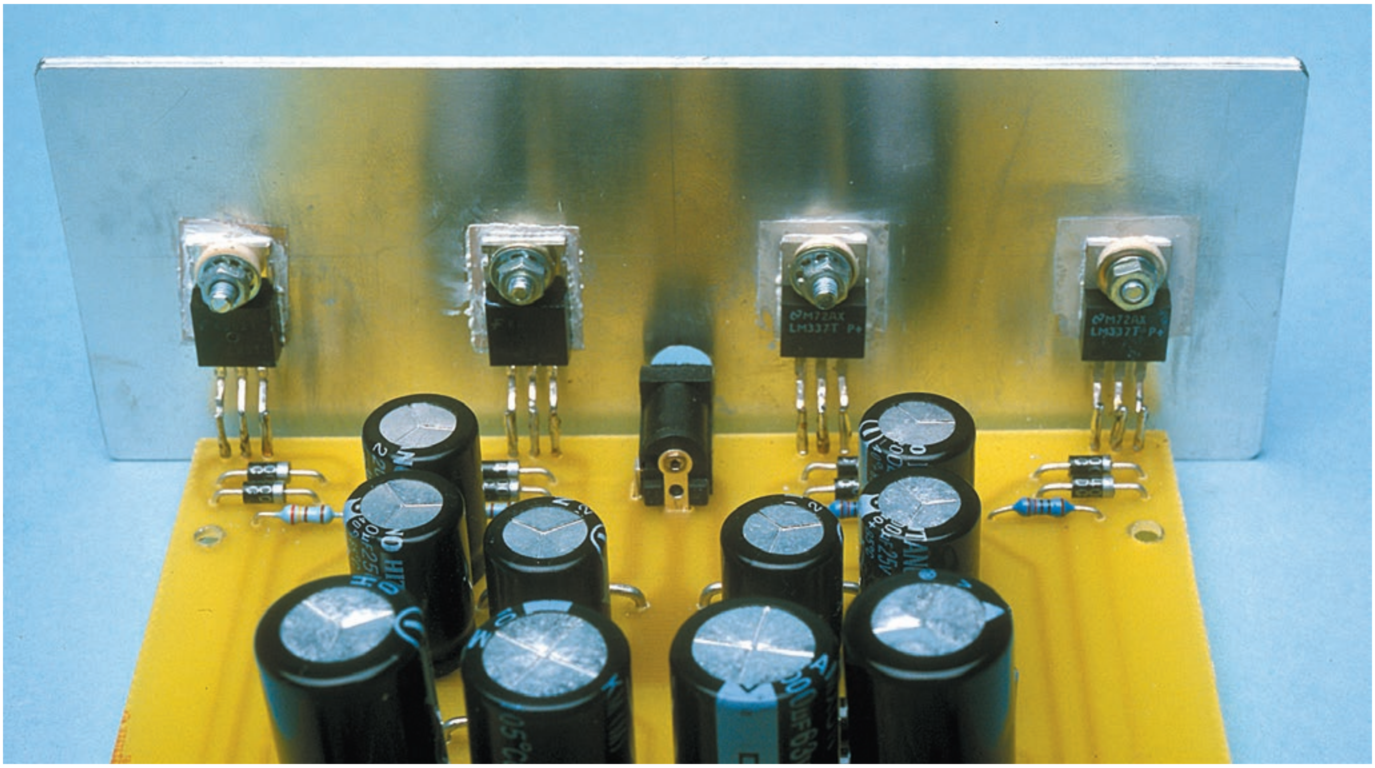
Check also that the holes for the 3mm LEDs will in fact accept the LED bodies without too much force. The ideal hole size is where the LED will just fit snugly, without being loose.

The adhesive label can now be attached to the front panel and the holes cut out using a sharp utility knife. This done, mount the toggle switches and output terminals. The switches should be fitted with the nuts adjusted so that the switch bodies are reasonably close to the panel, with the threaded ferrules protruding 1.5mm or so beyond the front nuts (this is to facilitate board mounting later on). The green terminals are fitted in the two centre "Common" positions, with the black terminals for the negative outputs and the red terminals for the positive outputs.

If your toggle switches are fitted with standard "solder lug" terminals instead of PC terminals pins, now is the time to fit short lengths (say 20mm) of tinned copper wire to the

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	9.1kΩ	white brown red brown	white brown black brown brown
❑	1	5.6kΩ	green blue red brown	green blue black brown brown
❑	1	4.7kΩ	yellow violet red brown	yellow violet black brown brown
❑	1	3.6kΩ	orange blue red brown	orange blue black brown brown
❑	3	3.3kΩ	orange orange red brown	orange orange black brown brown
❑	1	2.4kΩ	red yellow red brown	red yellow black brown brown
❑	1	2.2kΩ	red red red brown	red red black brown brown
❑	2	1.5kΩ	brown green red brown	brown green black brown brown
❑	1	1.2kΩ	brown red red brown	brown red black brown brown
❑	1	1.1kΩ	brown brown red brown	brown brown black brown brown
❑	1	750Ω	violet green brown brown	violet green black black brown
❑	1	680Ω	blue grey brown brown	blue grey black black brown
❑	2	560Ω	green blue brown brown	green blue black black brown
❑	1	510Ω	green brown brown brown	green brown black black brown
❑	1	470Ω	yellow violet brown brown	yellow violet black black brown
❑	1	430Ω	yellow orange brown brown	yellow orange black black brown
❑	1	330Ω	orange orange brown brown	orange orange black black brown
❑	2	270Ω	red violet brown brown	red violet black black brown
❑	2	240Ω	red yellow brown brown	red yellow black black brown
❑	1	180Ω	brown grey brown brown	brown grey black black brown
❑	2	120Ω	brown red brown brown	brown red black black brown



This close-up view of the rear panel shows how the four 3-terminal regulators are mounted. Note that the regulators must all be electrically isolated from the rear panel using TO-220 insulating kits (see Fig.5). They are connected into circuit by soldering their leads to matching PC stakes on the main PC board.

top four lugs of each, pointing directly backwards along the lug axis but with a small loop around the side of each lug before soldering – to make sure it can't drop off when you later solder it to the PC board pad.

You should now be ready to mate the front panel and the vertical PC board together. This involves pushing the rotary switch shafts and their threaded ferrules through the front panel holes (you have to remove the locking nuts first) and at the same time pushing the rear spigots of the output terminals and the leads on the rear of the toggle switches through the corresponding holes in the board. It's a bit fiddly but not too difficult if you take it carefully.

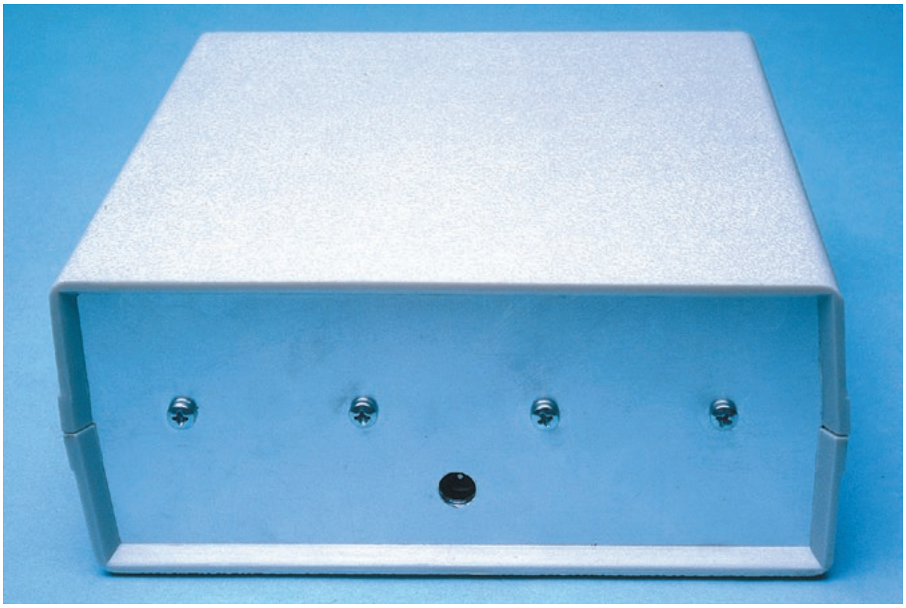
Once the two are mated together, you may need to adjust the positions of the mounting nuts and washers for the toggle switches so that the switch positions fore-and-aft will allow both panel and board to be truly parallel to each other, with a space of very close to 16.5mm between them everywhere. Tighten the toggle switch nuts at this point, followed by the rotary switch nuts – but carefully, so you don't strip the plastic threads or slip and scratch the front panel.

You should now be able to solder the ends of the output terminal spigots to their large pads on the PC board. The toggle switch leads can then also be soldered to their respective pads.

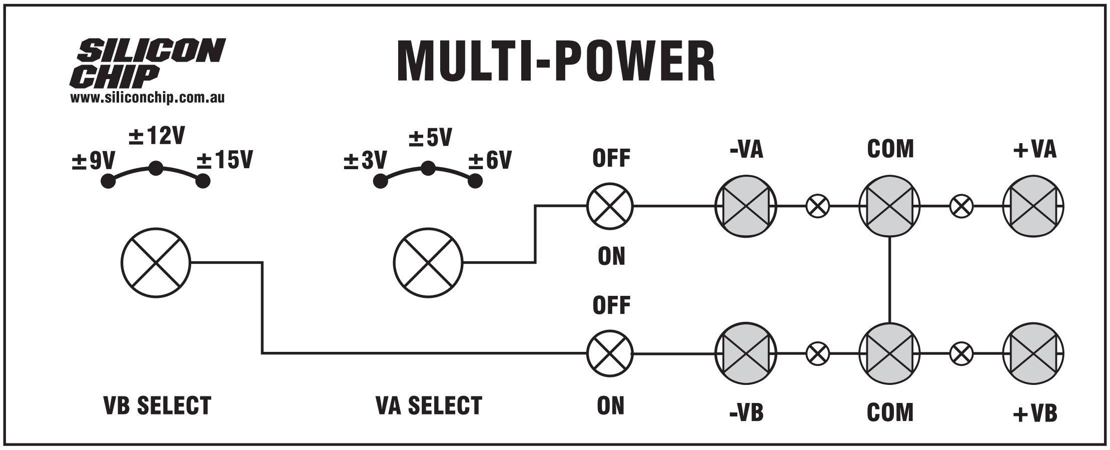
That done, you can untack each LED from its initial position and carefully push it forward until its body fits snugly in the corresponding front panel hole. Its leads can then be soldered properly to the board pads and any excess finally trimmed off.

The next step in preparing this board/panel assembly is to lay it face down on the bench and fit the 11 PC terminal pins which will connect it to the main board. These are all fitted from the copper side, so their main length protrudes backwards from the board. Solder each one carefully to its pad.

The two boards can now be mated



The rear panel is pretty uninspiring – just the four screws that secure the regulators plus a hole for the power socket.



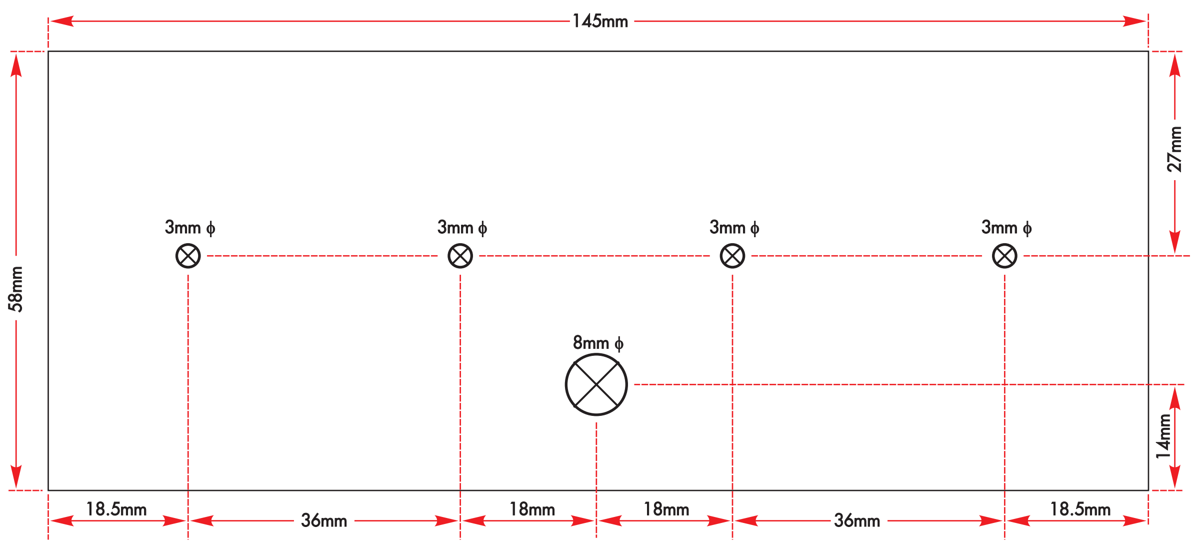


Fig.6: these full-size artworks can be used a templates for drilling the front and rear panels. Note that the holes for the for the banana jack terminals have straight sides, so profile these carefully.

together, by soldering these same 11 terminal pins to the rectangular pads along the front of the horizontal board. This is best done with the main board upside down (ie, copper side up) and with the other board/panel assembly also upside down but held at right angles using a small strip of 18 x 32mm wood or similar as a guide.

It's a good idea to just tack solder the pins at each end first and then make sure everything is aligned properly in terms of both the 90° angle and the side-to-side positioning. Once all is well, you can then solder all the pins to their pads to complete the assembly.

At this point, you can fit the control knobs to the rotary switch shafts, ready to adjust the output voltages. The module is now essentially finished (apart from the regulators which are fitted during the final assembly) and can be put aside while you prepare the rear panel.

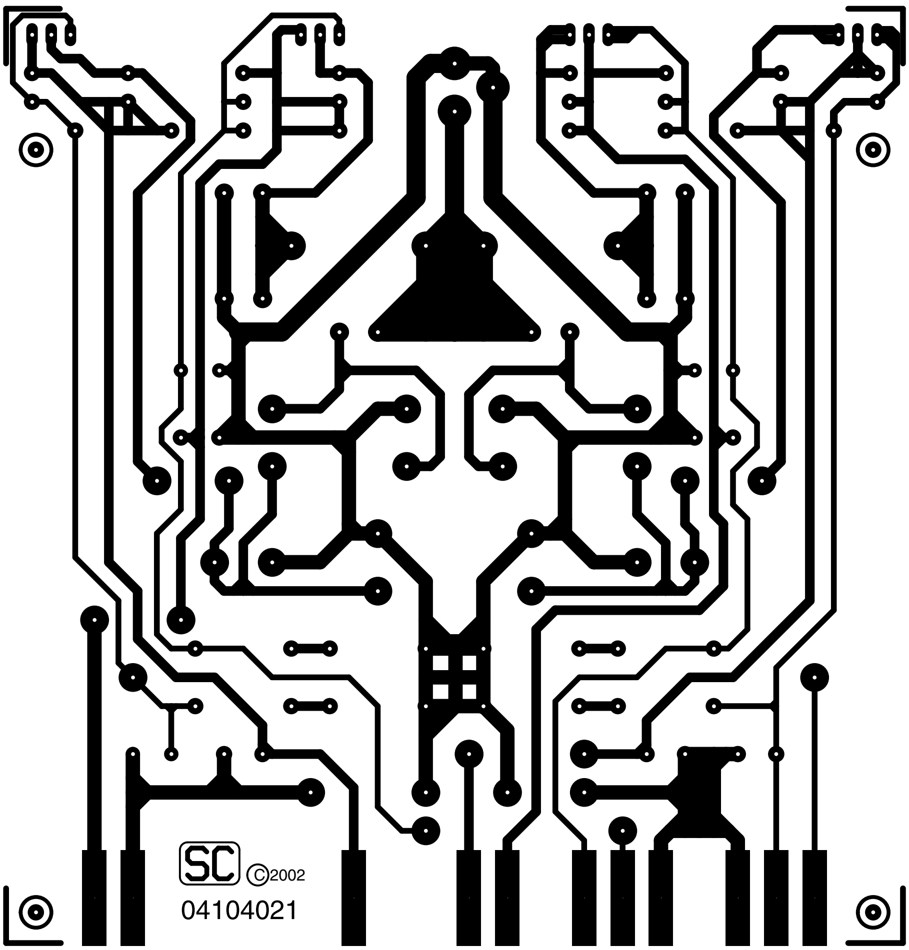
Rear panel work

In order to provide reasonable heatsinking for the four regulators, the rear panel should ideally be made from 2mm-thick aluminium sheet. I didn't have this available so I used two 1mm-thick pieces in "parallel".

There are only five holes to drill/ream in the rear panel – 4 x 3mm-diameter holes for the regulator mounting screws and 1 x 8mm-diameter hole to clear the power input socket. Their positions are shown in Fig.6, so there shouldn't be any problems with them. Just make sure you don't leave any burrs around the 3mm holes in particular. A countersink bit or a large drill bit can be used to remove any metal swarf and make the edges smooth.

With the rear panel drilled, the next step is to crank the three leads of each regulator IC forward, so that they end up immediately behind the terminal pins on the rear of the main PC board after final assembly. This is done by gripping each regulator's leads with a pair of needlenose pliers about 4mm from the body (just after the leads narrow) and then bending all three upwards at 45°. The pliers are then used to grip them a further 5mm along, after which they are bent back down again by 45° (see Fig.5).

The four regulators can now be fitted to the rear panel but first make sure that all the mounting holes are smooth and free of metal swarf. Fig.5 shows the mounting details. Note that each regulator must be electrically isolated from the rear panel using insulating bushes and mica washers. Smear all mating surfaces with silicone grease



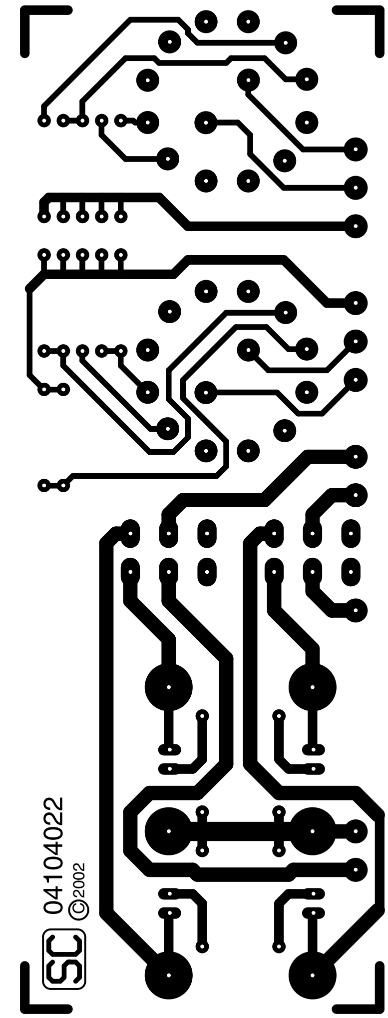


Fig.7: these are the full-size etching patterns for the two PC boards. Check your etched boards carefully for any defects before installing the parts.

before bolting the regulators down.

Alternatively, you can use silicone-impregnated thermal washers instead of the mica washers, in which case you don't need the thermal grease.

Make sure that you mount each regulator in the correct location – the two LM317Ts mount on the lefthand side of Fig.3, while the LM337Ts are on the right-hand side.

When you have fitted them all, it's a good idea to check with a DMM or ohmmeter to ensure that there's no connection between any of the regulator leads and the panel. If you do find a short between any of the leads and the rear panel, remove the regulator and locate the source of the problem before refitting it.

Final assembly

The next step is to fit the board and front panel module into the lower half of the case. You do that by sliding the ends of the front panel carefully down into the front case slot. This should allow the main board to sit flat on the case support spigots, with the mounting holes located over the centre hole in each spigot.

If the alignment isn't quite right, you may need to remove the board assembly again so that you can enlarge one or two of the board holes in the required direction. That done, refit the board assembly and install four 6mm x M3 self-tappers to hold it in position.

The rear panel (and its 3-terminal regulators) can now be installed in the rear case slot. This should position each set of cranked regulator leads behind their corresponding PC terminal pins (in fact, they should be just touching).

Check that all the leads are correctly aligned before soldering them to their respective PC pins.

Checkout time

If you've followed these instructions carefully, your supply should work correctly as soon as you plug the lead from the 9V AC plugpack into CON1.

Each of the two pairs of LEDs should glow as soon as you switch on each pair of supply outputs using the two toggle switches. You can then check each of the output voltage pairs using your DMM. Check that you get the correct readings for each position of the two rotary switches – all voltages should be within about ±1% of their nominal values, under no load conditions.

About the only possibilities for error are fitting the electrolytic capacitors or diodes incorrectly to the main PC board; mounting the regulators in the wrong positions on the rear panel; mixing up some of the resistors on the vertical PC board, or fitting one or more of the LEDs the wrong way around. So if your supply doesn't work properly, check these possibilities first after quickly switching off.

And that's it – you've just finished making yourself a very handy little four-in-one bench supply. All that should remain is fitting the top of the case and putting it to use! SC