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Was $449.00



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RESPONSE PRECISION





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$199.00 Cat: CS-2354



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6 x 9"
- 75WRMS, 4Ω
- 90dB SPL @ 1W, 1m
- 55Hz-20kHz ***Was $119.00***

Cat. CS-2374



SAVE $39.05

$79.95 Cat: CS-2374

RESPONSE PRECISION

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- 65Hz-20kHz ***Was $149.00***

Cat. CS-2378



SAVE $50

$99.00 Cat: CS-2378

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Was $385.00

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SAVE $$

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- Display format: 16 x 9
- Resolution: 480 x 234 pixels
- Power consumption: 24W
- Chassis dimensions: 182(W) x 53(H) x 161(D)mm

Was $229.00

$199.00 Cat: QM-3782



SAVE $30

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Was $24.95

$19.95 Cat: CS-2211



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Publisher's Letter

Oscilloscope probes are a vital link in looking at signals



In all fields of electronics, the oscilloscope is regarded as the tool of choice. It gives you a means of looking at a vast range of signals, both analog and digital, audio, radio and higher frequencies. While you can always take voltages around a circuit, the oscilloscope will give a clear indication of whether the device is actually working, whether it has a fault condition or whether it is dead.

Even if a circuit appears to be working perfectly, an oscilloscope can reveal if it has problems with a tendency to supersonic oscillation, for example, or whether it has overshoot, under-shoot, unduly long settling times or whatever.

No wonder technicians and engineers regard the oscilloscope as being so indispensable. Without it, you are virtually blind and you are forced into proxy methods to determine whether a circuit is working or not. And yet, most people using oscilloscopes are quite cavalier in their use of probes. This is odd, because if you do not understand and use oscilloscope probes correctly, you can greatly degrade the quality of your observations. In short, you can turn an expensive wideband oscilloscope into a very ordinary instrument.

Which is why we are pleased to feature this month's article on oscilloscope probes by Doug Ford. It gives a very good description of how scope probes work, moving from the over-simplified explanation that is commonly quoted in textbooks and technical articles to a more detailed description of their operation as transmission lines. In fact, it demonstrates that there is far more technology involved in high-performance probes than you would think. So that's why they can be so expensive to replace!

Rational climate change debate has yet to take hold

We are also very pleased to feature a long letter from Professor Ian Plimer in the Mailbag pages, on the subject of climate change. While many readers are probably sick of seeing references to the subject, we are extremely worried that moves to an emissions trading scheme (ETS), renewable energy targets (RET) and carbon pollution reduction scheme (CPRS) are extremely ill-conceived, will be expensive to implement and ultimately, will have zero effect on either carbon dioxide emissions from power stations, cars or any other human activity. Furthermore, they will have no effect on global warming, if in fact, it is still occurring or if it is anthropogenic (ie, caused by man's activities) – itself unknowable at this stage of our knowledge on long-term climate.

However, in virtually all of the debate on these measures, it seems to be accepted by most politicians and most of the media that global warming is definitely happening and furthermore, that it will be bad and must be stopped. Anyone that does not hold that view is likely to be pilloried as a "denier", a ratbag or with epithets that are much worse. For example, Senator Steve Fielding has been ridiculed for asking why global warming has apparently stopped when carbon dioxide continues to rise. Yet Steve Fielding is no fool and is a qualified engineer.

Professor Plimer's book demonstrates that there are vast mechanisms at work which control our climate, virtually none of which are discussed in the popular panic over climate change. Nor is he the only one who promotes the view that man's activities have negligible effect on our climate. There are thousands of scientists who agree with him.

The sooner that politicians and the media take these contrary views more seriously, the better off we will all be.

Leo Simpson

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Human-induced global warming: a load of hot air

The government's Carbon Pollution Reduction Scheme has the potential to ruin Australia's productive economies and to build an even greater bureaucracy. Even the name of this bill should ring warning bells as carbon is the foundation of life and is not a pollutant.

It is claimed that there is a scientific consensus about human-induced climate change. There is no consensus; consensus is a process of politics, not science. Science is married to evidence, no matter how uncomfortable.

Scientists who push the view that humans create climate change are young, trying to forge a career in a narrow field by fear, seek government and research grant favour and base their opinions on computer projections about the future. There are no scientists I know who have spent more than 40 years of integrated interdisciplinary science who argue that humans change climate.

To argue that temperature has increased 0.8°C since 1850 is misleading because the Little Ice Age ended in 1850 and it is absolutely no surprise that temperature increases after a long cold period. Since 1850, there has been temperature increase (1860-1880, 1910-1940, 1976-1998) and decrease (1880-1910, 1940-1976, 1998-present) and the rate of the three periods of temperature increase has been the same.

A simple question does not get asked: what part of warming and cooling since 1850 is natural? The first two warmings could not be related to human additions of CO_2 from industry hence why wouldn't the 1976-1998 warming also be due to natural processes?

It is claimed that, since 1950, human additions of CO_2 has been the dominant cause of warming. The scales and rates of temperature change in the past have been far greater than when humans emitted CO_2 from industry. What has caused the cooling (1940-1976 and 1998-present) or, by some tortured logic, is global cooling in this century actually global warming cunningly disguised?

At present, atmospheric temperature is decreasing and CO_2 is increasing, again showing that CO_2 is not the principal driver of climate change. Planet Earth is a warm wet greenhouse volcanic planet. The planet is dynamic; change is normal. Five of the six major ice ages occurred when the atmospheric CO_2 content was up to 1000 times higher than at present and for half of Earth's history CO_2 has been sequestered naturally into algal reefs, coral reefs, sediments, altered rocks, bacteria, plants, soils and oceans. This process is still taking place.

The hypothesis that high atmospheric CO_2 drives global warming is therefore invalid. The Earth's atmospheric CO_2 initially derived from volcanic degassing. Much of it still does and the rest is recycled CO_2 from the oceans, rocks and life.

The claim that warming will increase in the future has been disproved by the climate modellers' own data. Climate models of the 1990s did not predict the El Nino of 1998 or the cooling in the 21st century. If such models are inaccurate only 10 years into the future, how can they be accurate for longer-term predictions? Furthermore, when these models are run backwards, they cannot be used to identify climate-driving processes involving a huge transfer of energy (eg, El Nino), volcanoes, solar changes and supernovae.

Climate models tell us more about

KiCAD open-source CAD software

In your May issue of 2009, you mentioned some circuit design software for drawing schematics. However, most of this was based on software that, in your own words, was "a bit long in the tooth". The software I personally use is KiCAD http://www.lis.inpg.fr/realise_au_lis/kicad/

KiCAD is an open-source program (completely free) under active development. Not only does it include a schematic drawing application but it also includes a schematic symbol editor, a PC board layout application and a footprint editor. And it has the ability to hook up to Spice circuit simulators.

It also has an option to "print" copper layouts to "svg" files instead of normal printing. These files can then be edited using programs like Inkscape (http://www.inkscape.org/) or CorelDraw. I personally use this feature to make my boards nearly all copper, as I etch them at home using printer resist paper and have found this speeds the etching process up quite nicely.

The program is a bit fiddly to learn. As with most open-source programs, it's designed to give you flexibility and powerful options once you go beyond the basics. But the help menu opens up a nice pdf document that takes you step-by-step through the board-design process. I strongly suggest all new users read this document first.

KiCAD works on both Linux and Windows and has two sites: http://www.kicadlib.org/ and http://per.launay.free.fr/kicad/kicad_php/composant.php for additional component symbols and footprints.

Joal Heagney,
Whitfield, Qld.

Praise for the September issue

I have just opened my September copy of the magazine on the bus home from university (undertaking a B. Elec. Eng,) and I'm taken aback by the content of this issue. OLED displays put to work, some ingenious simulation software (Pebble), an excellent selection in the Circuit Notebook, a high-end DAC audio project and the review of the Salae Logic Analyser. I have heard of this device before but seeing a local review of such high praise has convinced me to order one.

I am impressed! These are the sort of nitty-gritty articles that make me proud that our hobbyists and industry are as strong in Australia as the rest of the world. Congratulations and keep up the good work. I hope one day to be a contributor to this great Australian magazine!

I also have a comment in regards to Steve Hodges' letter in this September issue ("Adapting To SMD Technology"). I too fear that the unknowns of SMD soldering are what hold most hobbyists back. TAFE offer excellent modules in soldering, both through-hole and SMD, and once completing these you will not look back from SMD soldering. I haven't! I have completed numerous small projects with SMD components and the process is so much faster, simpler, repeatable and reliable than through-hole soldering, when using the proper techniques.

Simple solder paste syringes can be used with great success when hand-assembling boards. In addition, all the expensive equipment can be dispensed with by modifying a cheap soldering iron and aquarium air pump or adapting a heat gun with a silicone extension tube and nozzle as hot air soldering tools.

Callum Martin,
Kent Town, SA.

the climatologists than they do about nature.

Another claim is that climate cannot be reversed. This invokes a non-dynamic planet. The fact that previous warmings with an atmospheric temperature some 5°C higher than now (eg, Minoan, Roman, Medieval) were reversed is conveniently ignored, as are the great climate cycles driven by the Sun, the Earth's orbit, tectonics and tides seen on modern, archaeological and geological time scales.

"Tipping points" are another sensationalist unsubstantiated claim. In past times when atmospheric CO_2 and temperature were far higher, there were no tipping points, climate disasters or runaway greenhouse. The climate catastrophists attempt to create fear by mentioning the carbon cycle but just happen to omit that significant oxygenation of the atmosphere took place when the planet was in middle age and this process of photosynthesis resulted in the recycling and sequestration of carbon.

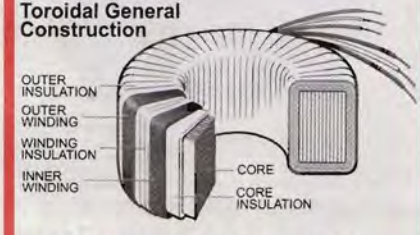
The atmosphere now contains 800 billion tonnes (800 Gt) of carbon as CO_2. Soils, vegetation and humus contain 2000 Gt of carbon in various compounds, the





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Mailbag: continued

Simple metal locator is most useful

The Metal Locator project which appeared in the July 2009 issue is both simple and useful. I have used similar devices in the past with varying degrees of success (mostly they work fine) but one thing that has always been a problem is marking the area of the wall of interest.

This device (and all the others I tried) rely on placing two marks on the wall, one on the top of the '+' sign and one (or two) on the cross bar, then removing the device and either using a ruler to mark the area that was shielded by the device or just guessing if accuracy is not critical.

The answer in this project is simple; drill a hole through the case to allow a pen, pencil or scribe to be passed through the centre of the coil to mark the wall. It wouldn't matter if it affected the operation of the device as we have already found our point. Another advantage of the hole is being able to see the area of interest.

Another solution, if the thickness of the case is a problem, would be to have the coil mounted on an arm which extends through the top of the case; again a hole needs to be through the centre of the coil and suitable protection covering it. This solution would have the advantage of more accurate placement and better visibility of the surrounding area. After all, we could be looking for a 10mm nail which is only 1mm thick.

Philip Chugg,
Rocherlea, Tasmania.

oceans contain 39,000 Gt and limestone, a rock that contains 44% CO_2, contains 65,000,000 Gt of carbon. The atmosphere contains only 0.001% of all carbon at the surface of the Earth and far greater quantities are present in the lower crust and mantle of the Earth.

Human additions of CO_2 to the atmosphere must be taken into perspective. Over the last 250 years, humans have added just one part of CO_2 in 10,000 to the atmosphere. One volcanic eruption can do this in a day.

Climate chestnuts about polar ice are commonly raised. What is not raised is that ice is dynamic; it advances and retreats. While the Arctic is warming, the Antarctic is cooling and vice versa and if ice did not retreat, then the planet would be covered in ice. For less than 20% of time Earth has had ice. The Antarctic ice sheet has been with us for 37 million years, during which time there were extended periods of warmth and the ice sheet did not disappear. So too with the Greenland ice sheet which has enjoyed nearly three million years of expansion and contraction, yet did not disappear in extended times far warmer than at present.

Sea level is also dynamic and has risen and fallen over time by at least 600 metres. Since the end of the glaciation 14,000 years ago, sea level has risen some 130 metres at almost 10mm per year. It is now rising at about 1mm per year. This sea level rise has flooded Bass Strait, the English Channel and destabilised the west Antarctic Ice Sheet. It is this sea level rise that has stimulated coral growth, created larger shallow water ecologies and changed the shape of landmasses.

The fear-mongering suggestion that oceans will become acid is also misleading. The oceans are buffered by sediments and volcanic rocks on the sea floor and even in past times when atmospheric temperature and CO_2 were far higher than at present, there were no acid oceans. If there had been, there would be no fossils with calcium carbonate shells. Although industrial aerosols are decreasing, the climate catastrophists omit to state that volcanic aerosols kill. At least three of the five major mass extinctions of complex life on Earth were probably due to aerosols emitted by volcanoes.

If our climate catastrophists want to twiddle the dials and stop climate change, they need to play God and change radiation in the galaxy, the Sun, the Earth's orbit, tidal cycles and plate tectonics. Once they have mastered volcanoes, then we can let

. . . continued on page 9

Tighten up those transistor mounting screws

I recently built two Ultra-LD Mk2 modules (SILICON CHIP, August 2008) for a stereo amplifier and ran into a problem with one of them.

The problem was that when I first applied the full supply voltage to it the drop across the emitter resistors was varying between about 25mV and 40mV. I increased Q7's emitter resistor several times until I ended up with 120Ω and it was still barely within the specified range. Worse, it still drifted around a lot.

Despite this, both amplifiers seemed to be working fine. I ran them for awhile until they got warm and unfortunately the one which had quiescent current instability blew its fuses. I measured the output transistors and one on each side had gone short circuit. I then built another module to replace it, thinking something was wrong with the original. Surprisingly, while the replacement module worked a lot better, it still suffered from fairly wild variations in quiescent current.

After having contacted SILICON CHIP for advice, I spent some time investigating what was going on based on that feedback. One of the suggestions led me to the solution. I had noticed that the driver transistors felt cooler than the power transistors. Note that I was very careful when touching them so as not to shock myself with 60V or worse, 120V DC!

However, it had been suggested that I check the tightness of the transistor mounting screws. While I had followed the instructions and done the screws up to what I would consider "tight", ie, they would not easily turn any more, I got a bigger screwdriver and applied more force. This allowed me to turn some of the screws another full turn. After this, the quiescent current was much closer to the 7-10mV range and more importantly, much more stable.

Hence, I would recommend that anybody building an Ultra-LD Mk2 amplifier module follow this piece of advice: when they say to do the screws up tight, they mean it. Don't use all your strength but make sure you use a proper large handled screwdriver and turn the screws tightly enough to compress the silicone rubber washers. You also need to make sure the transistors are sitting perfectly flat on the surface of the heatsink before you solder them.

Secondly, if the quiescent current is not in the expected range after removing the safety resistors but other indications are that the amplifier is working fine, the first thing to check should be the tightness of the screws. This includes both the power transistors and the drivers. It is critical that they are all in good thermal contact with the heatsink.

Next, monitor the quiescent current for awhile. Let it warm up, play some music through it for about 10 minutes, then remove the input signal and check the quiescent current. It is normal for the quiescent current to change slowly as the amplifier warms up and cools down but it should not have any wild or rapid excursions. If it does, the heatsinking of all the transistors should be checked.

In my experience you want to adjust the quiescent current while cold to be towards the lower end of the 70-100mA range as it will increase a little with temperature, due to slight differences in the temperature coefficients of the transistors (both power and drivers) and the integrated diodes.

If it becomes necessary to adjust Q7's emitter resistor to change the quiescent current, I find it's much easier to bend the leads of the resistor as you normally would, then cut them short after the bend and solder them onto the pads on the top of the board. Use tweezers to hold it in place, off to the side of the pads. This way you can easily change the resistor without having to remove the module from the case, at least until you have determined the optimal value for your particular module.

I have to say now that it's working it's a truly excellent amplifier, better than the commercial unit I bought a number of years ago for close to $2000.

Nicholas Vinen,
Randwick, NSW.

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Mailbag: continued

In praise of the cartoonist

There are so many things to be appreciative of in relation to the continuing longevity of SILICON CHIP magazine, especially when so many other electronics magazines in Australia and worldwide have bitten the dust. I am certainly not the first regular reader to write in praise and I hope the magazine well and truly outlives all its current readers.

However, this communication concerns SILICON CHIP's brilliant cartoonist, Brendan Akhurst. I can't hope to describe my gratitude for all the giggles, amazement and sheer joy that Brendan's cartoons have given me over many years, going way back to his wonderful efforts in ETI magazine.

One could say Brendan's cartoons are extremely clever, stylish and superbly drawn. But they are much more than that. Brendan is, quite simply, a genius and in each issue of SILICON CHIP he gives us yet another opportunity to enjoy that genius. His work is timeless.

Therefore, on my own behalf, and I'm sure on behalf of many other SILICON CHIP readers, I say a huge "THANK YOU" to Brendan for all the fun he has brought us over many years.

Otto Hoolhorst,
Brisbane, Qld.

Comment: we hope that Brendan Akhurst does not read the Mailbag pages for this month.

them loose on climate change.

Senator Wong, the Minister for Climate Change, argues that it is in the national interest to have a Carbon Pollution Reduction Scheme. Which nation does she refer to, because it is certainly not Australia?

Australia faces the biggest financial decision since Federation yet there has not been an independent scientific review or financial due diligence on an emissions trading scheme. All that there has been is spin. Even the Regulations for this legislation have not been drafted so how can Australia even contemplate an emission trading scheme when the legislators do not know the details?

It is this legislative time bomb that will destroy productive industries in rural and industrial Australia.

Professor Ian Plimer
Adelaide University,
Adelaide, SA.

Comment: Professor Ian Plimer's book "Heaven and Earth: Global Warming – The Missing Science" (Connor Court) is now number 14 on the Amazon book list.

Circuit breaker tripping can be cured

Regarding the 'Multiple CFLs Can Cause Switch-On Problems' topic in the "Ask SILICON CHIP" pages of the September 2009 issue, I am surprised at your suggestion in the last paragraph about increasing the size of the circuit breaker from 10A to 15A. This is a bit like saying "put a bigger nail in the fuse".

To your credit you did recommend consulting a licensed electrician. If you don't mind me putting my licensed electrician's hat on, I would suggest trying a 10A circuit breaker with a "D curve". These are for applications like motor starting where a large in-rush current occurs and might be the solution to the problem.

Bill Adams,
Sinnamon Park, Qld.

The role of carbon dioxide

After years of subscribing I find there is at last something I am sufficiently knowledgeable on to make a contribution to SILICON CHIP.

In response to Alan Swales' comments in the August 2009 Mailbag concerning photosynthesis, it should be noted that as long ago as 1941 it was discovered that WATER, not carbon dioxide, is the source of oxygen in photosynthesis. This had been postulated for some time by analogy with the biochemistry of sulphur-producing

bacteria,but it took the "discovery" of O_{18} and its use in biochemistry to provide the proof. The oxygen in carbon dioxide finishes up in carbohydrates.

David Yates,
The Gap, Qld.

DAB+ is a disappointment

I've read through your 5-part series on the new digital radio phenomenon (DAB+) but for all intents and purposes, apart from the added stations and the AM stations now coming in at better than 5kHz, is it really going to revolutionise our listening experience?

Up until 18 months ago, I used to install and maintain broadcast services from studio to transmitter for both AM and FM stations around NSW. These consisted of copper lines with amplifiers and equalisers, broadcast multiplexers or a combination of both, and even 128kbit/s ISDN2 services (ie, a rate equivalent to 128kbit/s MP3) with the appropriate analog codecs either end.

The links were bandwidth-restrict-

What happened to Nine Digital?

I don't know about the rest of the community but I am getting sick of the unprofessionalism of the commercial TV networks. They clearly believe that wasting everyone's time is OK. The constant time changes, late-starting programs and programs changed at the last minute are bad enough. It is no wonder TV guides are basically useless.

Now digital TV is getting the same treatment. I went to check out ACA during August, to be faced with no signal. Now I have seen more signal losses from digital than I have seen signal losses on analog TV for 30-odd years. So it did not seem unusual; just another network technical mix-up.

I subsequently checked during the evening and still no signal. As the other stations where fine and I knew my system was OK, I put it down to a big problem at Nine.

The next day, still no signal. However, when switching to SBS channel 350, I mistakenly went to 351 and low and behold there was "Channel Nine SD" with HD on 352. Why? They sure couldn't be bothered propagating this change to viewers.

One would think the intelligent and professional procedure would have been to display the change on 9 and 90 for a week say, before changing the signal.

Tony Joyce,
Macquarie Fields, NSW.

Comment: as discussed in the Serviceman pages this month, the Nine network neglected to tell its digital viewers that it was shifting its stations to allow for the new GO SD station.

Many digital TVs and STBs continued to work just fine but in some cases, you have to completely rescan all stations in order to find all the Nine stations.

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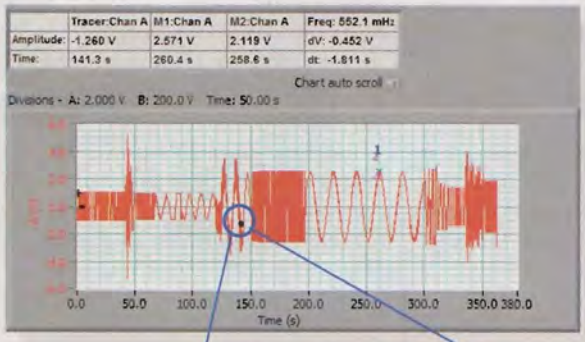
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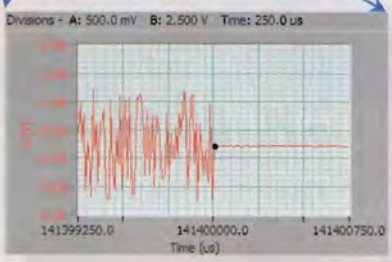
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Mailbag: continued

EVs and working close to home

I'd like to comment on George Ramsay's comments, in the Mailbag pages of the August 2009 issue, regarding electric vehicles being unnecessary and the desirability of living within 5km of your workplace.

I wonder what world he lives in. In my current job, the workplace is the closest to home that I have had and that is 13km away from home. Where on Earth could one get a job within 5km of home? Also public transport to this workplace or near to it is zero, so I need some sort of a car.

I have been an electronics technician since 1966 and have bought most, if not all, the Australian electronics magazines from "Electronics Australia" to SILICON CHIP. I have purchased and kept all issues of SILICON CHIP and really like your work and good information with these magazines.

Charlie Sims,
Canberra, ACT.

ed from 40Hz to 15kHz (flat to -1dB); signal-to-noise ratio -72dB (-55dBm to +17dBm) and maximum was 0.5% at 400Hz @ +17dBm.

In August I went to the launch of DAB+ at Martin Place in Sydney. I left very disappointed. I went around some of the radio stations and asked the technical people "How do you get the audio from the studio to the transmitter?" Everything was in the digital domain but the carriage of service varied from satellite, line-of-sight microwave, BDSL (dependent on distance from telephone exchange to transmitter) and ISDN2.

No one could tell me the bit rate they were using, especially those using 128kbits/s ISDN2.

I then visited the marquee showcasing the various companies and their products. The first receiver I looked at was a portable unit made by Sangean. I explained to the representative that I now work as a bus driver and my FM radio sits beside me while driving. I work around the eastern suburbs of Sydney and have reception problems around Clovelly, Bronte Beach, Maroubra and parts of North Bondi. In those areas, how cloudy the day is determines how good the signal is.

The Sangean representative tried assuring me that I should have minimal problems. At the time the unit was tuned to 2CH, so I picked it up, walked around the marquee and while tilting the radio off vertical, I noticed a significant drop in signal strength. The rep said best performance is at vertical, due to the way the signal is being transmitted, though as long as the signal strength did not drop below the minimum indicator, there should not be a problem.

I then decided to turn the radio upside down, so the antenna was vertical but pointing to the ground. The signal strength dropped below minimum and began muting the audio. And this was in the middle of Martin Place! What will it be like in a moving vehicle?

Switch on problems for school computers

I read with interest two items in "Ask SILICON CHIP" in the September 2009 issue. The first was from W. S. (Rockingham, WA) and concerned a power overload problem when switching on multiple laptops. The second was from Z. J. of Cordeaux Heights, NSW discussed a similar problem when switching on multiple CFLs.

You will recall that some time ago the Federal Government started handing out computers to all school students and this problem arose shortly thereafter. The students are forbidden from plugging the equipment into the mains themselves so, as I understand it, trolleys were provided with all the switchmode plugpacks pre-connected to a single 3-pin plug. At the end of the day, the students return the laptops to the trolley and plug in the yet unpowered low-voltage DC connector. The teacher then plugs in the single 3-pin mains plug and switches on the standard 10A GPO, more often than not with the same result as experienced by W. S.

We were approached over 12 months ago concerning this problem because readings of well over 25A were being recorded on standard tong testers before the 15A circuit breakers dropped out. What the actual peak current was is not known but it would have been significantly greater than the 25A displayed by the tong tester.

However, as W. S. discovered, should the breaker hold, the steady state current, even with all flat batteries, was well under the 10A rating of the GPO.

We solved the problem with a small soft-starter module that reduced the actual maximum initial surge to well below the 15A circuit breaker rating. We produced 40 units as a matter of some urgency back in October 2008.

We know that they work and I have had contact with the teachers that use them but we have never seen any follow up orders – a pity because there are a lot more than 40 schools out there.

John Jeffery,
Engineered Electronics,
Tasmania.

I tuned to other stations and had the same problem. He then came back with "the transmitters are only putting out ¼ power" but could not explain why the receiver faulted when upside down.

At least with FM, when the signal weakens, the audio starts to get noisy but you still get program. It is amazing how the human ear can tune out noise, especially when listening to a song you know. I believe that muting while on the move will really annoy the listener.

When working correctly, the unit sounded like my MP3 player when I had my headphones plugged in but it was like a $10 radio from the cheapie shops when listening via the small on-board speaker. Yes, the technology is new to Australia, however around $150 for a portable is pretty rich.

With no quiet room set-up, as you would have in a hifi store, I cannot comment on the audio quality of a home unit designed to be connected to a good-quality hifi system. At home, I have a couple of DVB set-top boxes, connected to the antenna with RG6 quad shield cable and the signal strength is excellent. When watching free-to-air TV via analog reception, it takes a super bolt of lightning to disturb the picture and sound.

Admittedly, the picture while watching digital is cleaner though something as simple as opening the fridge door or a small lightning bolt is enough to cause the picture to pixellate and the sound to squawk, especially on channels 7, 9, 10 and the ABC which are in VHF band 3. Will DAB+ operating in this frequency range have the same problem?

So overall, my first experience did nothing for me. Not convinced.

Simon Kareh,
Penshurst, NSW.

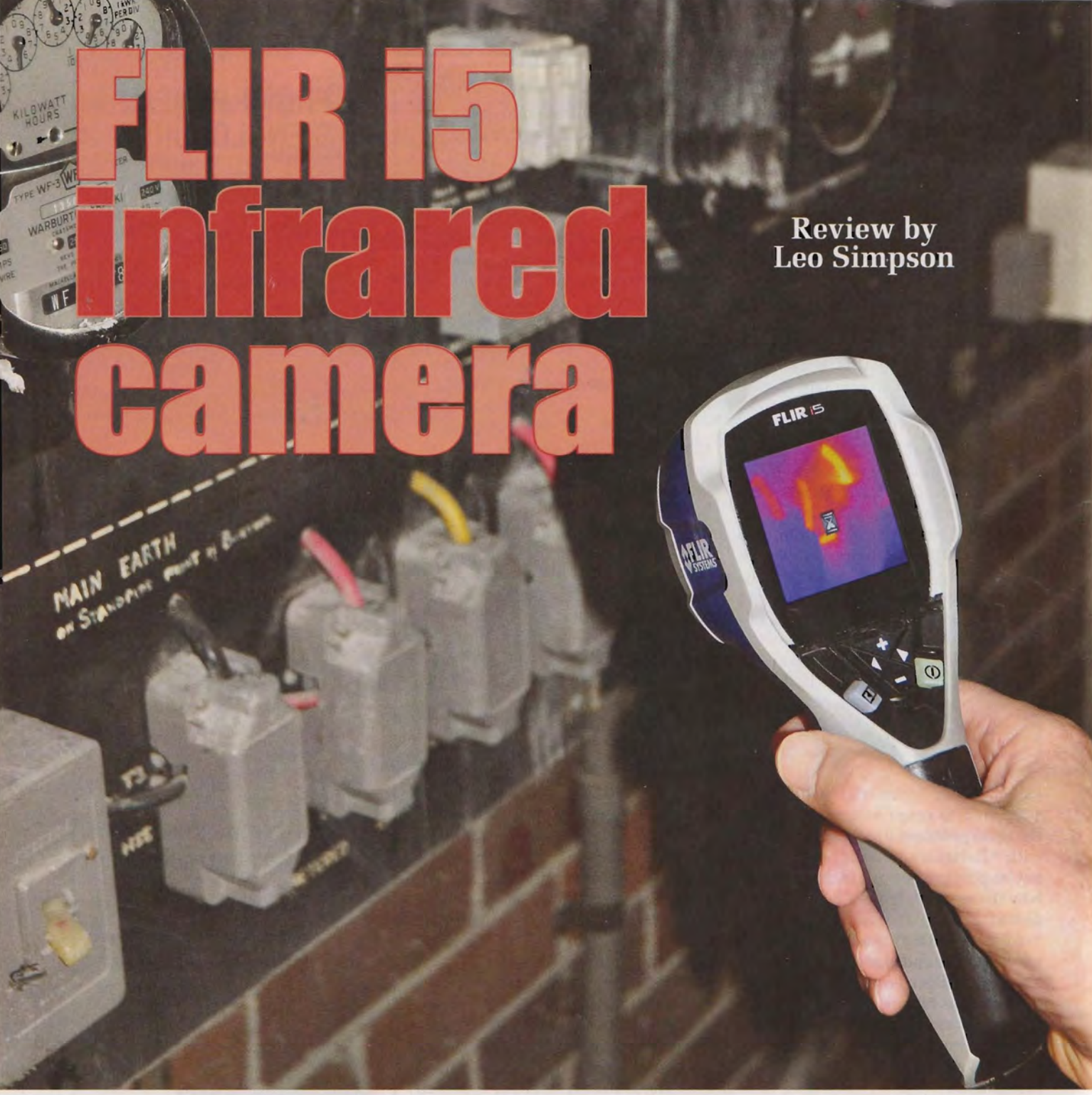
Comment: the sound quality from DAB+ broadcasts is fairly average at the moment. Perhaps it might improve if sampling rates are increased. SC





FLIR i5 infrared camera

Review by Leo Simpson



FLIR Systems' new i5 camera is a compact handheld instrument weighing only 340g. You just aim and shoot with it and the result is a false colour picture showing the temperature gradients of a building, machinery, electrical equipment, a human body or whatever. You can use it as a precise non-contact thermometer which will also show the full temperature range of everything in the camera's view.

Anyone familiar with infrared cameras will be surprised at the compact size, ease of use and precision measurements now available from this new FLIR Systems' i5 model.

It has a comfortable pistol grip and you can single-handedly aim, shoot and control all functions with your thumb and index finger.

The front of the pistol grip incorporates a large trigger button which you press to take a picture. At the side of the pistol grip is a rubber cover which conceals and protects the mini-SD memory card, the mini USB socket and the socket for battery charging.

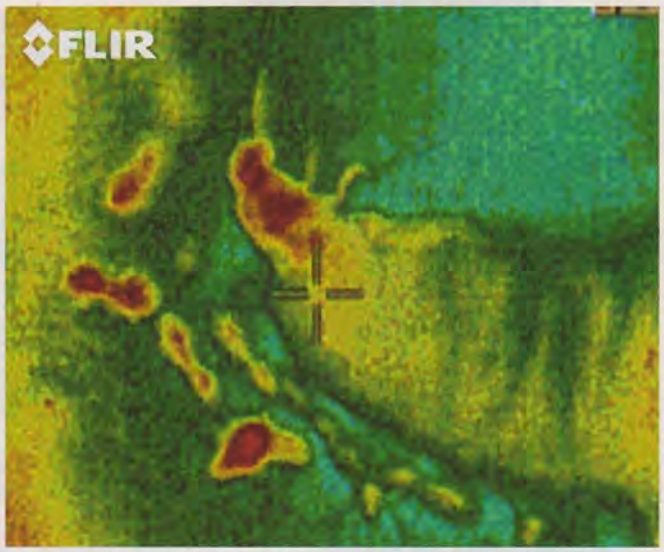
The camera screen measures 45 x 60mm although the recorded image is square, at 80 x 80 pixels. The unit is simple to use and is controlled by eight buttons just below the screen.

You turn it on by pressing the white power button on the right and use a small lever at the front of the camera to uncover the lens.

To review the images you have already taken, you press the white archive button on the left and then the plus and minus buttons to scroll down through the images.

Nine images in thumbnail format are displayed on the screen and you can examine individual images by clicking on them with the respective buttons. The left and right arrow buttons let you navigate through the various menu options as do the plus and minus buttons. The black buttons at left and right are "soft" or "context sensitive" and the changing labels at the bottom corners of the screen depict their functions.

For example, if you are reviewing the image file, the soft buttons will let you erase an image or close it.



Chomping their way through your money! Infrared cameras are becoming very popular in pest control – here's some termites making a meal of the studs and noggings inside a wall, with absolutely no evidence on the outside that anything is wrong.

You have two options for downloading images from the camera. The first is to use the supplied mini-USB to USB cable to connect the camera to your computer and then you can transfer images to a directory using Windows Explorer etc.

Second, you can download the images directly from the mini-SD card via an external card reader or the integral card reader on a laptop. The supplied mini-SD card is 512MB, enough for many thousands of which are stored in JPEG (.jpg) format with a typical file size of 25KB.

You can take thermal images in two false colour modes, so-called "iron bow" and "rainbow" as well as gray scale (ie, black & white).

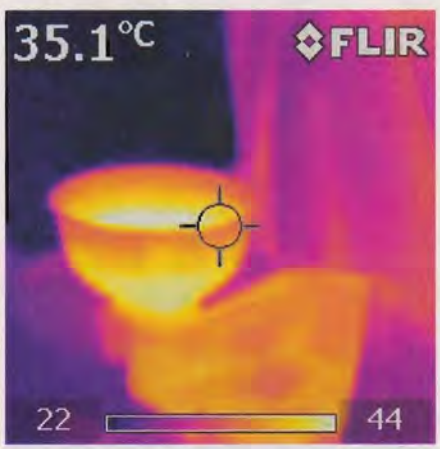
"Iron bow" is the conventional false colour mode which shows temperature gradients from white, ranging through yellow, orange and red to purple and black. The reference to iron, by the way, refers to the sequence of colours that a block of iron takes as it is heated up from cold to white hot.

However, that is where the connection ends because when iron is white hot it is liquid and at several thousand degrees, far hotter than this camera can depict.

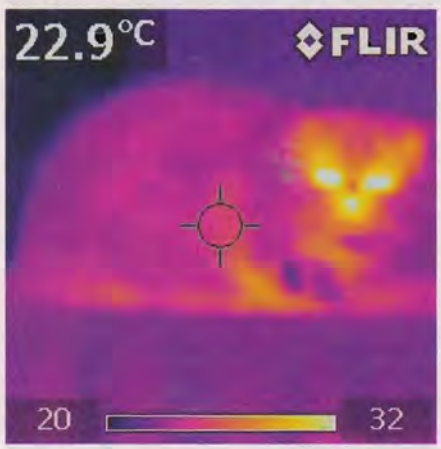
The overall temperature range in the image is indicated in a scale at the bottom of the picture. This means that the camera automatically scales the colours to suit the overall temperature range depicted, whether it is over a few degrees C or hundreds of degrees C.

You can turn off this automatic scaling function and lock the temperature for a series of images. This can be useful if you want to make direct comparisons of temperatures over the series of images.

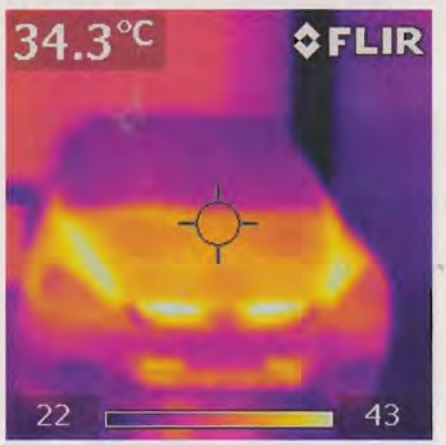
Each image also shows the temperature in the small central zone. If you are using the camera merely to observe heat gradients rather than



A few happy snaps of common objects around the home and office: here a cup of tea (note the warm hands!) . . .



. . . and here the family moggy. She's got very thick fur, so it's nowhere near as hot as her eyes . . .



. . . finally, no-one can argue that the car has been used recently. The whole engine bay is "glowing" with heat!





as 60cm. Naturally, the area of the picture you take will then depend on how far the camera is from the object being photographed.

The range of temperature measurement is 0°-250°C and accuracy is ±2°C or ±2% of reading over the range from 10°-35°C.

For some measurements you need to take into account the emissivity of surfaces and also their reflectivity. Going into the camera's menu allows you to compensate for these factors.

Images taken in rainbow mode highlight subtle transitions between hotter and warmer areas. By the way, it is possible to invert both the "iron bow" and "rainbow" palettes, if that is your preference. You might also wonder what is the point of having thermograms in a gray scale format. This is useful for people who are colour-blind.

A lithium-ion battery powers the camera and it is charged from an external mains power supply (included). Typical operating time with a fully charged battery is five hours.

Potential uses

The uses for this camera are much wider than you might first think. Sure, you can use it to check for hot spots in all sorts of equipment, electrical wiring, piping and so on. And if you take it outside a building or home on a cold day or night, you can quickly see where the heat is escaping, in spite of windows and doors being closed.

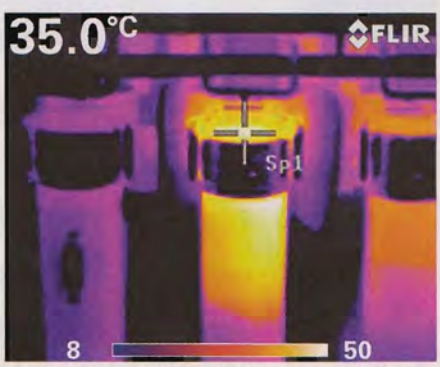
But a thermal imaging camera such as this can also be used to find water leaks in walls and floors, because the evaporation of water coming to the surface results in areas than are cooler than adjacent areas.

recording images, you can take precise temperature measurements by aiming the central cross-hairs on the screen at the point you want to measure.

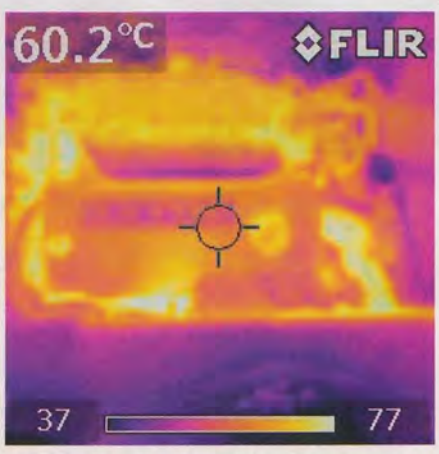
The fixed focus lens gives a field of view of 17° x 17° and it allows you to capture images at distances of as little



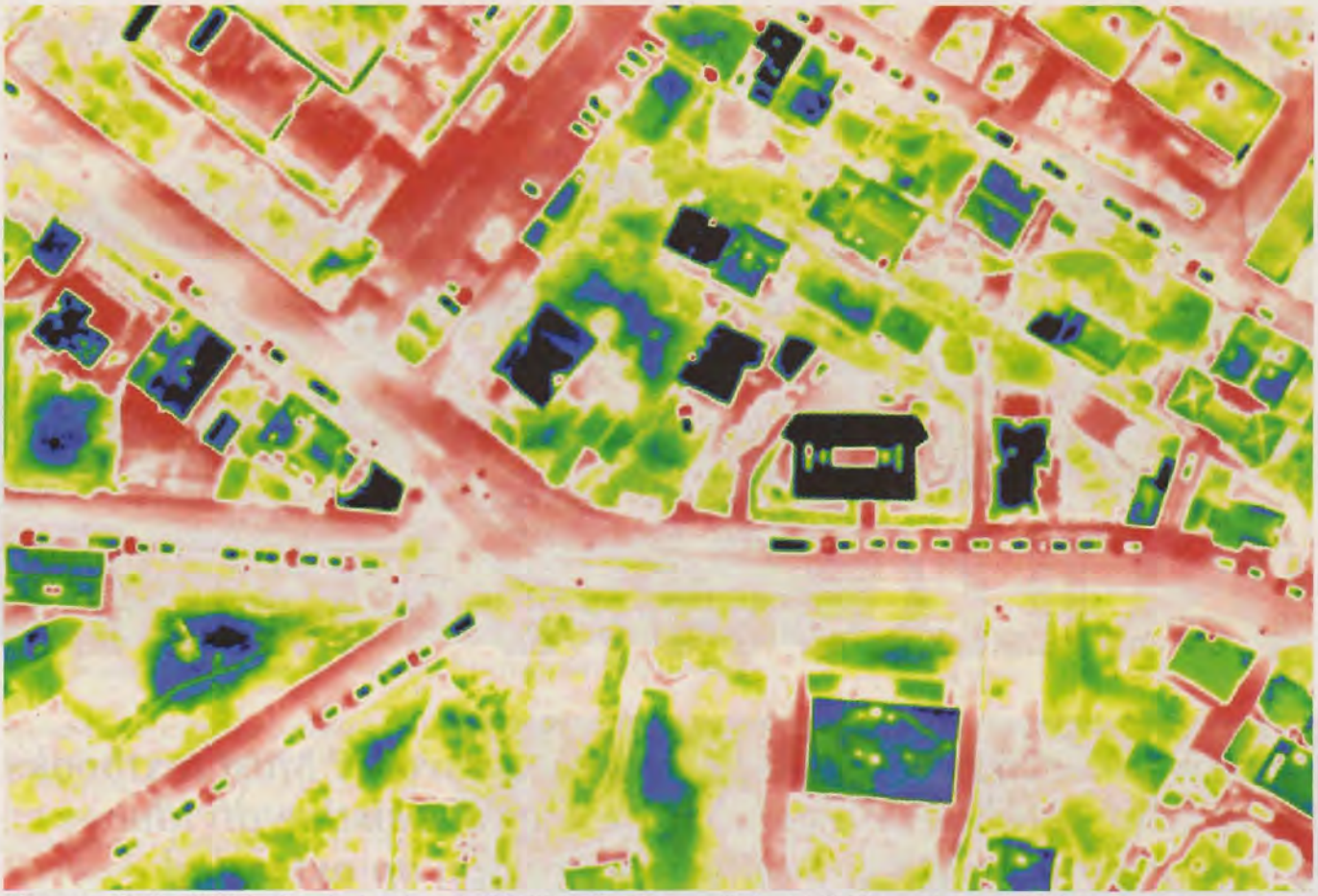
A "normal" photo of three intact cartridge fuses doesn't show much evidence of a problem . . .



. . . but the infrared photo certainly does. The fuse at left is cool but the other two are certainly very hot.



Another FLIR shot of the car overleaf, this time looking under the bonnet from the side. It's all heat!



They even had a FLIR in the air, to misquote CW McCall's "Convoy"! Aerial FLIR can show which houses are unoccupied, which vehicles have recently been running, vacant land and even people on the ground show a different colour.

As a matter of fact, during the period while we had this camera for review, the SILICON CHIP offices were inundated with water from a blocked roof drain in a severe storm.

We had to engage a firm to have the water sucked out of the carpets and then big fans were installed to dry the carpets out over a period of several days.

At the end of that period it was instructive to take shots around the office to see the areas which were still damp. They included the timber skirting boards and the base of a large bookshelf which had been made of particleboard – that stuff sucks water up like a sponge!

The camera could also be useful in medical diagnosis. It can detect areas of inflammation in muscles and can even help in the detection of cancers.

The FLIR i5 camera is supplied with a 100-230VAC switchmode plugpack charger, a mini-USB to USB cable, a 512MB mini-SD card, a mini-SD to SD card adaptor and a multi-language Getting Started Guide (with very small print!). There is also some very useful documentation on three CDs: a training guide with short flash video files, the same Getting Started Guide in PDF format and a very good User's Manual which includes sections on thermographic measurement techniques, building thermography and thermographic inspection of electrical installations.

These sections will be most useful to anyone involved in building inspections, particularly with respect to building efficiency, home insulation and so on.

Finally, there is a CD with FLIR's ThermaCAM QuickReport software, enabling you to present all your images and measurements in a professional format.

Using it

We found the camera very simple to use, with just one proviso. When you are reasonably close to an object and you press the trigger button to take a picture, it is all too easy to find that the camera has jerked away from the target. Even if you hold the pistol grip with two hands and then carefully squeeze the trigger, it is difficult to hold it precisely on target, especially if you want the central cursor on a particular hot spot in the image, to show the temperature.

However, it turns out that if you have recorded an image where the central cross-hairs have drifted off the wanted spot, you can then use the ThermaCAM software to move the cursor around on the image to indicate temperatures at will. Brilliant!

Apart from that small quibble, this camera is likely to be a boon for those working in the building industry, particularly involved in building inspections. And it has very wide applications across many fields, in electrical installations, machinery and so on.

Recommended retail price is $5550 plus GST. For further information, contact Trio Smartcal, 3 Byfield Street, North Ryde, NSW 2113. Phone 1300 853 407, website **www.triosmartcal.com.au**.

In New Zealand, contact RF Test Solutions Ltd, PO Box 6844 Wellington, 6141. Phone 0800 738 378, website **www.rftest.co.nz** SC

THE SECRET WORLD OF OSCILLOSCOPE PROBES



Ever wondered how scope probes really work? Most textbooks treat scope probes as a combination of a resistive divider in combination with capacitors to provide an extended frequency response. But as will be revealed, the reality is that they are much more complex in principle. Read on.

By Doug Ford

The oscilloscope is an essential tool for anyone working in electronics. Whether you're working in electronics service, production, testing R&D or in your home workshop, you need an oscilloscope.

If you listen to a bunch of technical people chatting about their scopes, they'll talk about their bandwidth or whether they have colour displays, depth of memory or portability but the probes rarely get mentioned.

In fact, most users don't think about their probes until they hear the sickening crunch underfoot which tells them they shouldn't have left them dangling off the bench onto the floor.

There are many varieties of "specialist" probes: active-FET probes, differential-floating probes, current-sensing probes are just some we could mention.

They all have their uses but by far the most common is the "times ten" (x10) passive voltage probe. Typically, you're given two of them free with every oscilloscope.

But how much do you really know about these probes?

A few hours of Googling will yield countless explanations about basic operation (voltage division and capacitance compensation) but you are unlikely to find explanations which show the probe's transmission-line properties.

Nor will you find any adequate description of the design differences between inexpensive 40MHz probes and much dearer 350MHz probes.

Conventional explanations

Conventional wisdom explains the operation of a x10 probe with the equivalent circuit in Fig.1 (above right).

The scope's input impedance is assumed to be 1MΩ in parallel with a small capacitance (somewhere between 10pF and 50pF). Low-bandwidth scopes generally have higher input capacitances.

The capacitance of the probe cable may be from 60pF (for a high bandwidth probe) to 200pF (for a pretty average probe).

The factor-of-ten voltage division is determined at lower frequencies by the divider formed by the 9MΩ resistor in the tip of the probe and the 1MΩ scope input resistance.

The compensation capacitor across the 9MΩ probe resistor is trimmed to be 1/9th the combined capacitances of the scope input and the probe cable. In the case above, the scope-plus-cable

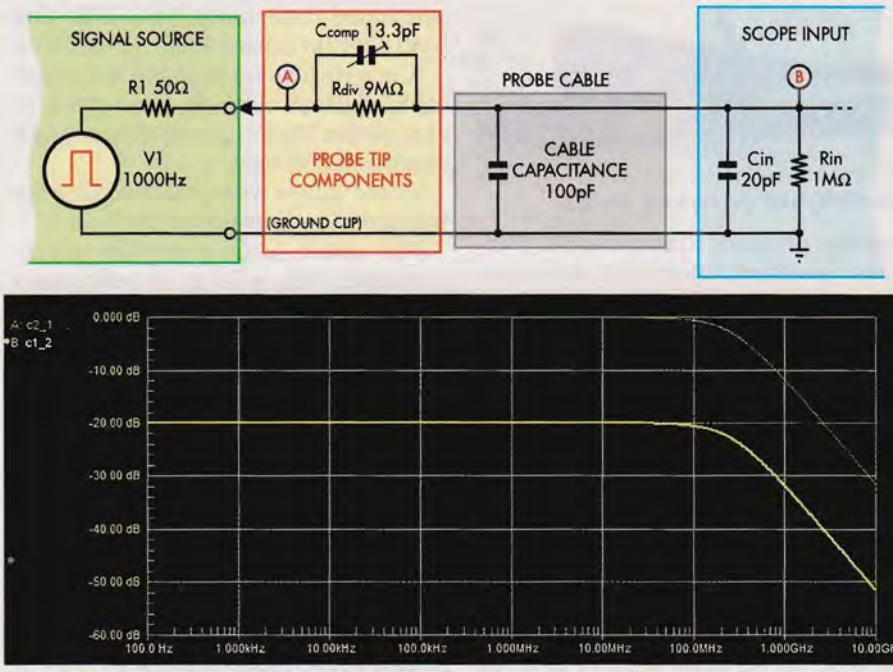


Fig.1: Circuit and response of x10 probe ("Conventional" explanation).

capacitance is 120pF, so the compensation cap is trimmed to (120/9) = 13.3pF.

When the capacitive divider formed by C_{COMP} and C_{IN}//C~~CBL~~ has the same 1:10 ratio as the resistive divider formed by Rin and Rdiv, the frequency response of the probe should be flat from DC to ultraviolet.

The only limitation to high-frequency bandwidth should be the interaction of the source impedance (shown here as 50Ω) with the effective capacitance of the probe tip (12pF), giving a –3dB point of 265MHz.

Note that the frequency scale of the simulation extends from 10Hz to 10GHz. We don't want to miss any interesting artefacts, do we?

Trimming the compensation capacitor

The effect of trimming the compensation capacitor on frequency response is shown in Fig.2 The capacitor has been varied from 8pF to 18pF in 1pF steps.

Note that the gain is unaffected at frequencies below 300Hz but gain errors in the 3kHz ~ 100MHz range are large and consistent.

Oscilloscopes are fitted with an internal square-wave generator which feeds a "calibration" terminal on the front panel.

This calibration signal is provided specifically for the purpose of trimming probes. The calibration signal frequency is usually 1kHz with an amplitude of 1V peak-to-peak. The probe is connected to the calibration terminal and adjusted to achieve the "squarest" waveform display.

Anyone who has trimmed a x10 probe will be familiar with the scope waveform seen during trimming, as in Fig.3.

While Fig.1 shows the compensation trim capacitor connected across the 9MΩ probe resistor this is actually very rare.

More typically, the capacitor across the 9MΩ resistor has a fixed value and trimming is achieved by a trimmer connected in parallel with the probe cable and scope input capacitances, as shown in Fig.4.

At this stage, there doesn't appear to be much difference between probes with tip-end or scope-end trimming. Both types of probe are available, with bandwidths from 20MHz to 300MHz.

However, higher bandwidth probes

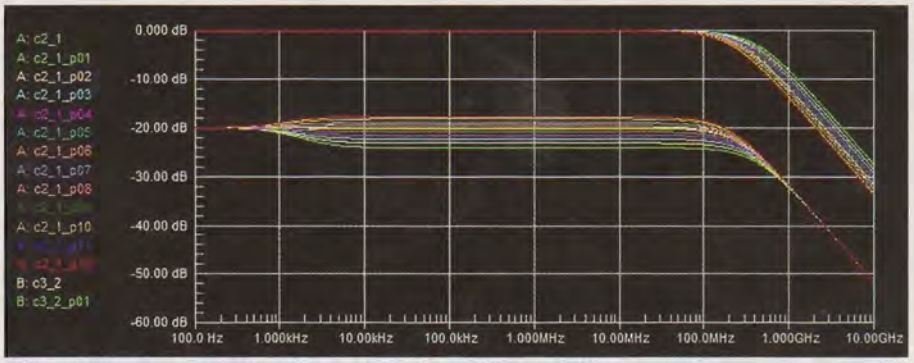


Fig.2: How compensation trimming affects frequency response.

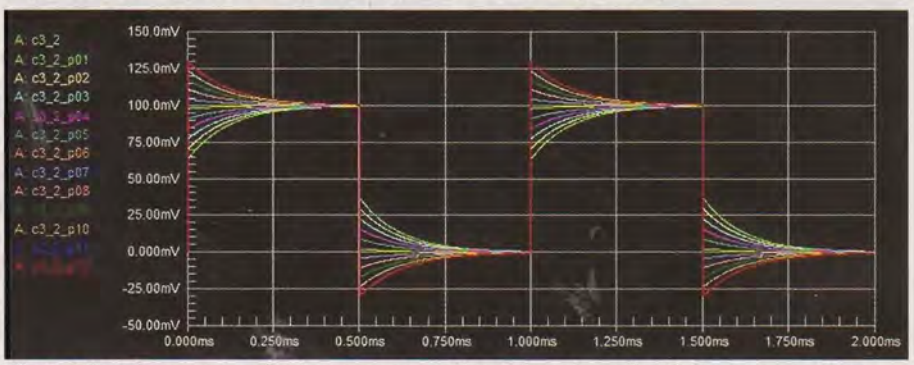


Fig.3: Waveforms seen during compensation trimming of a 1kHz square-wave.

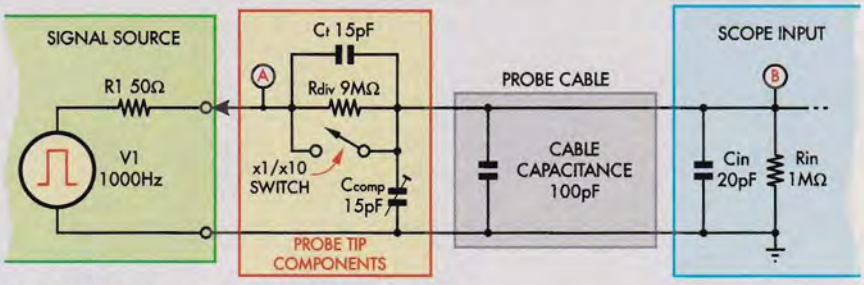


Fig. 4: Probe circuit with fixed tip capacitor.



Fig.5: compensation trimmer at the scope end (left) and probe end (right).

(350MHz and higher) tend to have their compensation trimmers at the scope end of the cable.

So far, we have given a fairly simple description of probe operation using standard textbook explanations. But this ignores the fact that the probe's cable is NOT a simple lumped capacitance; it is a transmission line!

The probe's coaxial cable has length, distributed inductance and capacitance, propagation delay and signal reflections from unterminated ends. What's the effect of these properties on the behaviour of a probe?

So let's replace the lumped cable capacitance in our previous simulation with a transmission line and see what happens!

Simulator software

CircuitMaker is a schematic layout and simulator program originally released by Microcode.

I've been told that Microcode bought the Autotrax franchise from Protel in the early 90's. In 1998, Protel bought Microcode, then changed its name to Altium in 2001. So, CircuitMaker became an Altium product, until Altium discontinued it in 2001.

This is a pity, because this excellent simulator was bundled with the PCB drafting program Traxmaker (a Windows version of Autotrax) and a Gerber file reader at a very reasonable price.

Simulating a probe's cable

We'll replace the single 100pF cable capacitance with a transmission line in the circuit simulator. The circuit simulator can simulate any transmission line, but we need to make a few guesses about the circuit values to enter into the simulator.

Typical probe cables are around 1.2m long, although they can be up to 1.8m. The total capacitance of my 250MHz probes is 85pF, according to their manufacturer's specifications. The specified capacitance is 128pF for my 60MHz probes, although these actually measured closer to 170pF. We will use 100pF in simulations for now, to maintain parity with the previous simulations of Fig.1 and Fig.4. Our cable capacitance will thus be 83pF/m for a 1.2m cable.

We will assume that the cable's characteristic impedance is 50Ω for the moment. The cable inductance (per unit length) can be calculated from: $Z_O = \sqrt{(L/C)}$, where L = inductance per unit length and C = capacitance per unit length. It doesn't matter what your unit length is; we're using metres here. The calculated inductance, for a 50Ω line with 83pF/m capacitance, is 208nH/m.

Since we haven't changed the 100pF cable capacitance, we don't need to change the 15pF tip capacitor or 15pF compensation trim.

These values were punched into the transmission line shown in Fig.6:

The result is an awful frequency response! The effects of reflections from the unterminated transmission line will give huge response variations at the scope above 20MHz (green trace). The effects of probe loading on the signal generator (yellow trace) are similarly large.

So what do probe and scope designers do to address this problem?

I have looked inside several scopes and probes over the years. And I've trodden on a few probes in my time, resulting in some sad post-mortems and furtive probe replacements.

Most probes have a discrete low-value resistor built into the probe tip extremity, located at the tip in front of the 9MΩ divider resistor and x1/x10 switch.

I measured the end-to-end resistance of some probes (in x1 setting) and found values in the range 180Ω ~ 270Ω. OK, we will include some probe-tip resistance, say 250Ω in the simulation.

Similarly, I have seen that in some older scopes, there is a series 50Ω resistor between the BNC input socket and the range switch. We will include this, as well. See Fig.7.

The frequency response (green) is obviously smoother than in Fig.4 and the loading effect on the source (yellow) is

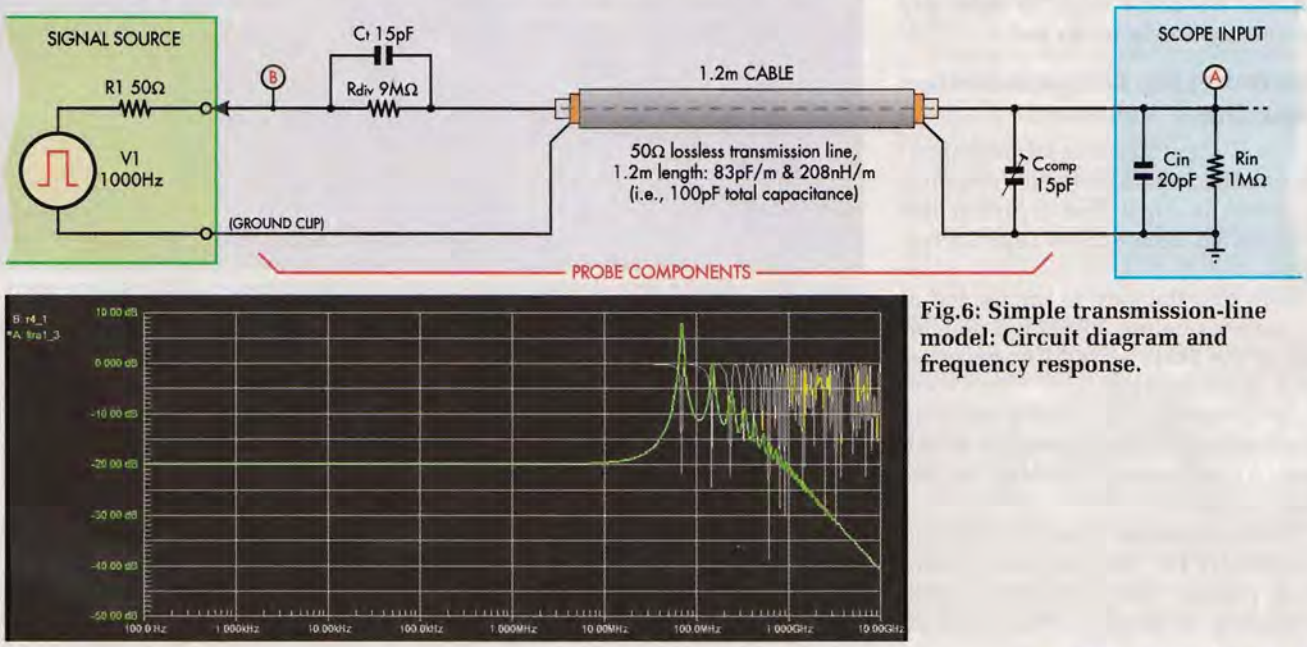


Fig.6: Simple transmission-line model: Circuit diagram and frequency response.

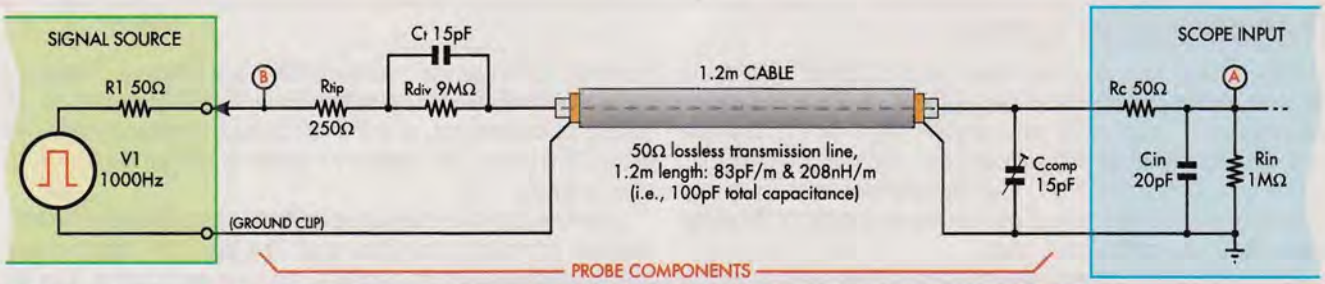
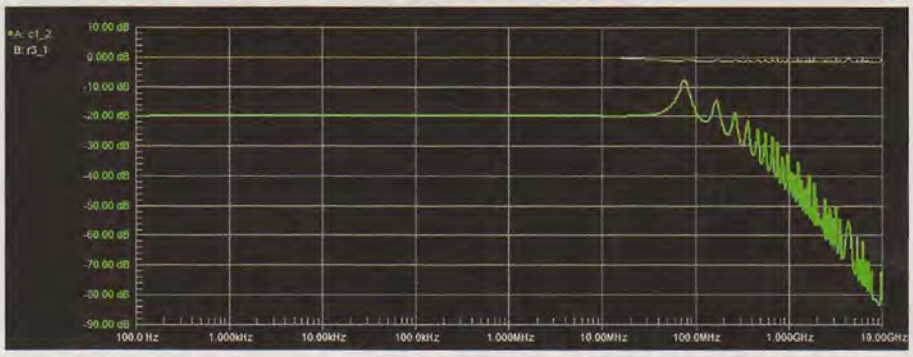


Fig.7: Simple TL model with added probe & scope resistances: circuit and frequency response



lower. But the usable bandwidth is still less than 40MHz. Even if there was a clever way to smooth the response, it would still only get to maybe 100MHz before rolling off.

Tweaking the compensation capacitor has little effect on the frequency response or the transmission-line resonance effects. So it is obvious that the transmission-line characteristics of the probe cable are potentially responsible for some serious bandwidth and frequency-response limitations. So, what is the secret behind the design of my 250MHz probes, and even my junkbox 60MHz probes? How DO probe manufacturers manage to get extreme bandwidths from probes?

I tried all kinds of tricks in simulator-land to see how the transmission line could be tamed and how the response could be extended. I tried variations to the cable's characteristic impedance, various component combinations at the tip or at the scope end of the cable; all to little effect.

I eventually resorted to examination of the cable from a defunct probe. I discovered that the cable centre core had a surprisingly high resistance.

I dissected the cable further and was surprised to discover that the core wire appeared to be very thin resistance wire, with a resistance of around 100 ~ 200Ω per metre! See Fig.8.

This very fine core wire appears to be made from a single strand and is "crinkled" – presumably to provide tolerance to repeated flexing. I'm guessing that the white foam core insulation gives low dielectric loss, while the black PVC around the foam gives mechanical support to the foam (and no, the black stuff isn't conductive. I checked!).

The high resistance of the core wire was the clue I needed. This coax cable is NOT low-loss; it has been made deliberately lossy, to reduce the effects of end-to-end transmission-line reflections!

I now wanted to know the identity of the unknown, unsung genius who developed this trick.

So, back to simulator-land. This time, we'll give the coaxial cable a resistance of 165Ω/m (200Ω total). We'll also reduce the value of the probe-tip resistor from 250Ω to 50Ω. The overall probe series resistance is still 250Ω, as before.

Also, I'm pretty sure that most modern scopes don't use 50Ω series resistors any more, because modern high bandwidth scopes have very low input capacitances (10pF ~ 15pF). This renders the scope's 50Ω series terminator pretty useless at frequencies around 80MHz, where transmission-line end-to-end resonance is most problematic. It's irrelevant so let's get rid of it from simulations.

Fig.9 shows the magic result: a smooth and monotonic response, which is -3dB down at 65MHz with no nasty reflections or response anomalies – just a smooth, usable response!

Even more interesting: the response of this simulation conforms quite nicely to the behaviour of a typical 60MHz probe!

OK, so now we know the secret to designing a probe: use lossy transmission-line cable! But how can the response be extended?

First: I'll assume that modern high-bandwidth scopes don't have 50Ω series termination.

Secondly: I'll use the manufacturers' specs for a 100MHz oscilloscope and 250MHz probe in the simulator.

Thirdly: I'll assume a low-impedance source, instead of the 50Ω source impedance used so far.

Fourthly: when I dissected the scope-end compensation trim of the cable shown in Fig.8, I found that the trimmer capacitor was connected in series



Fig.8: probe cable dissection – note the crinkled inner wire.

Transmission Lines

Transmission lines may take many physical forms: They be in the form of single conductors near a ground return, such as copper tracks on PC boards, PC striplines and single-wire rural phone lines. They may be in the form of wire pairs, such as figure-8 cable, twisted wire pairs or overhead power transmission lines. They may be in the form of coaxial cables, whether single-conductor, stranded conductor or shielded twisted pairs.

As a rough rule of thumb, wire conductors will begin to exhibit transmission-line effects when their length becomes greater than one-tenth of a wavelength while conductors longer than a quarter wavelength show definite transmission-line effects.

Mains power lines operating at 50Hz are treated as transmission lines if their length exceeds a few hundred kilometres. Phone lines with 3kHz bandwidth are treated as transmission lines if they are longer than a few kilometres. At 10MHz, any conductor longer than 30cm must be treated as a transmission line!

A property of a transmission line is its characteristic impedance. When a transmission line is loaded at its far end by a resistor of the same value as its characteristic impedance, all signals fed into the line are absorbed by this resistor. If the load at the far end is not the same as the line's characteristic impedance, signals will be reflected from the far end back to the signal source.

If the line is fed with signals via a resistance equal to the characteristic impedance, it doesn't matter if the far end is not terminated by the correct resistance; Any reflections from the far end will be absorbed by the source resistance.

If a line is terminated by mismatched impedances at both ends (for example, driven at one end from a very low impedance source,and open-circuit or short-circuit at the far end) then signals can ping-pong up and down the line many times before they are slowly absorbed by line losses.

Video distribution systems, which send high-frequency signals through long coaxial cables, terminate both ends of each cable. Signals are sent into a cable via a series terminating resistor and the far end of the cable is terminated by a resistor in the appliance (TV or whatever). This system ensures that a cable is terminated even when an appliance is unplugged from the far end.

The transmission-line characteristics (including characteristic impedance) of a conductor are defined by four basic properties of the wire:

- R, the resistance per unit length (Ω/m)
- L, the inductance per unit length (H/m)
- G, the conductance of the dielectric (insulation) per unit length (m/Ω)
- C, the capacitance per unit length (F/m)

The conductor resistance (R) and insulation conductance (G) determine the losses in the transmission line. The conductance is usually low, but can become very significant in coaxial cable if the insulation becomes waterlogged.

You can calculate the line's characteristic impedance (Z_0) from the inductance and capacitance: $Z_0 = \sqrt{(L/C)}$.

In a coaxial cable, L and C are defined by the cable geometry and materials (core diameter, outer diameter and insulation material). If you make the core wire smaller, you increase its inductance and reduce its capacitance, so the characteristic impedance becomes higher. This is why 75Ω coax has a smaller wire diameter than 50Ω coax of similar size.

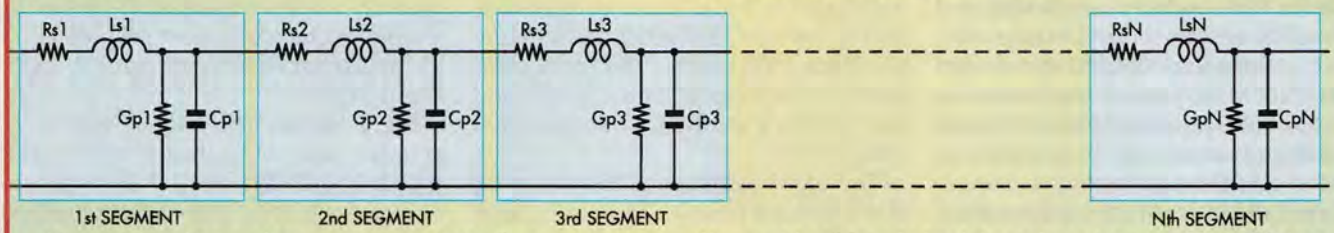
Low-loss coaxial cables usually use foamed insulation around the core, rather than solid insulation. The gas in the foam reduces the insulation's dielectric constant, reducing capacitance. This allows thicker core wire to be used to achieve the right characteristic impedance, giving lower resistance and lower loss. In addition, the foam insulation can sometimes have lower conductivity (lower loss) than its solid counterpart – at least, until moisture seeps in...

When you are simulating or measuring the effects of a cable at low frequencies where no transmission-line effects are seen, you will be dealing with the "bulk" cable properties. The bulk properties of total resistance, total capacitance and total inductance will be all you require to determine cable effects.

For example, if you're feeding audio signals into a 100m cable (with 100pF/m capacitance) from a 100Ω output source, you would estimate that the high frequency response would be 3dB down at $F = 1/2\pi RC$ (where R=100Ω and C = 10nF), or around 160kHz; good enough for audio!

However, if you were actually going to feed a 160kHz signal down this same cable, you might want to see if transmission-line effects are likely. Calculate the wavelength from: Wavelength = Velocity/Frequency. Velocity of signals in a cable are around 80% of light-speed (rule of thumb!) or about 250 million meters per second. You don't need much precision for such calculations; just enough information to tell you if you DO need to resort to more elaborate analysis!

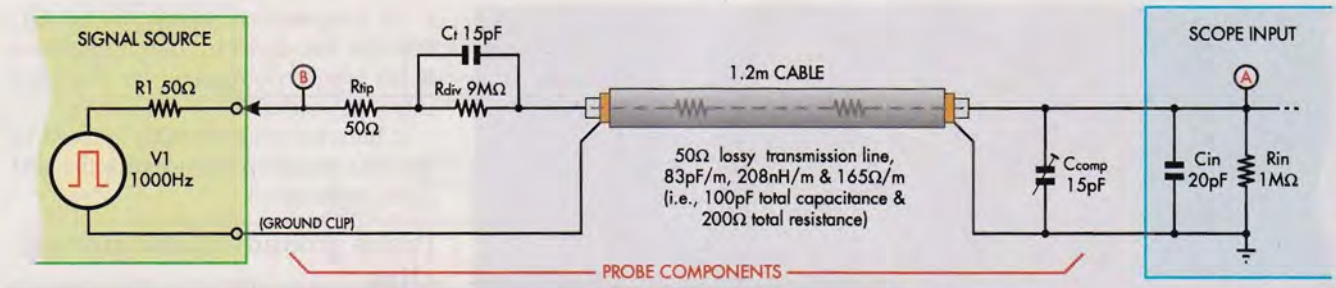
At 160kHz, one wavelength = 250,000,000/160,000 = 1500-odd metres. So your 100m cable is one-fifteenth of a wavelength long; You might not have to treat it as a transmission line at 160kHz but you certainly would if your signal had higher harmonics which needed to be preserved.



Transmission-line effects can be simulated and/or calculated by dividing the line into many smaller segments. The inductance, resistance, conductance and capacitance of each segment is given by "quantity per unit length" times cable length, divided by the number of segments. This approach is called the "lumped parameter" method. The equivalent circuit of a lumped-parameter transmission line is shown below.

The number of segments (lumps?) you use for your simulation will determine how closely it corresponds with reality. Ten segments will give only moderate accuracy; Several hundred segments will give a very high degree of accuracy to simulations and calculations, but netlist size and computation time can become prohibitive.

Transmission lines are generally modelled in SPICE simulators by matrix mathematics and recursive convolution, rather than by the lumped-parameter approach. These methods require much less computation time than lumped-parameter methods. The maths is beyond me, but the transmission-line model used by CircuitMaker certainly responds correctly to "test questions" which I've posed.



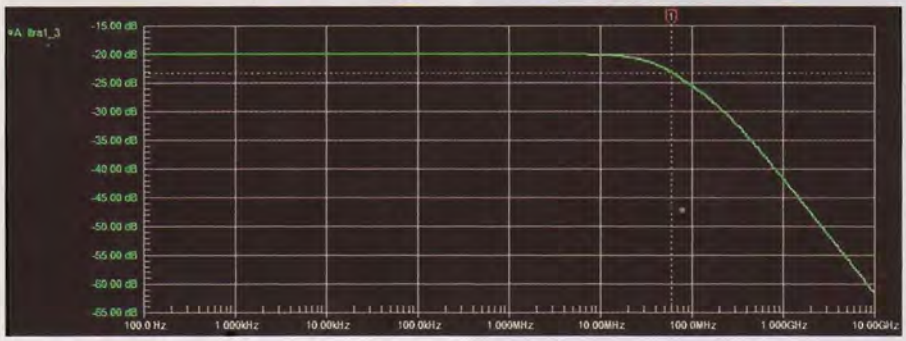


Fig.9: "lossy transmission-line" model and frequency response

with a 68Ω resistor. I'll include this resistor in simulations and find out what it does.

Then we'll juggle the series resistance of the transmission line in the simulator to see what happens!

A 100MHz scope has an input capacitance of 15pF, so we'll use this value at C_{IN}.

My 250MHz probe has a specified capacitance of 85pF (x1 setting), so we'll set the transmission line capacitance to 71pF/m. For a 50Ω cable, the calculated inductance must be 177nH/m.

This probe has a specified capacitance of 15pF (x10 setting), so we'll leave the value of the tip capacitor at 15pF. However, we'll increase the value of the compensation trim to 35pF, because of the lower cable capacitance (85pF vs 100pF).

The simulator circuit using these values is shown in Fig.10.

The transmission-line resistance in this circuit was varied from 50Ω/m to 200Ω/m. This is the kind of experiment where simulators become so incredibly useful. It would be a horribly expensive exercise to obtain the various lossy cables which would be needed to conduct this series of experiments at the test bench.

The effect of varying the cable resistance over the range 50Ω ~ 200Ω per meter can also be seen in Fig.10. Low resistances (50Ω/m) allow transmission-line reflections to build up, giving a peaking response. Larger resistances (200Ω/m) give an overdamped, sagging response.

The optimum cable resistance was found to be around 115Ω/m. This gave a response which is substantially flat to nearly 600MHz!

The real bandwidth of my 250MHz probes would be 250MHz, rather than the 600MHz shown by the simulator. I haven't simulated the small stray capacitances from each component to ground or the stray capacitance across each component, which would reduce the real bandwidth.

The resistor in series with the

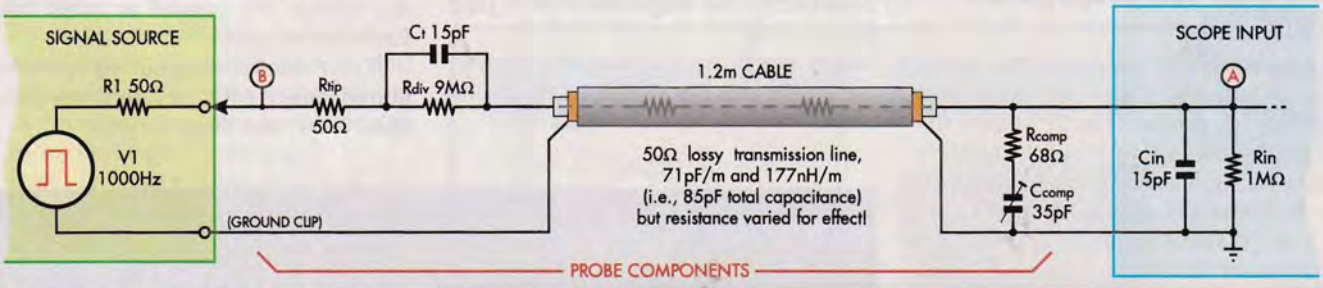
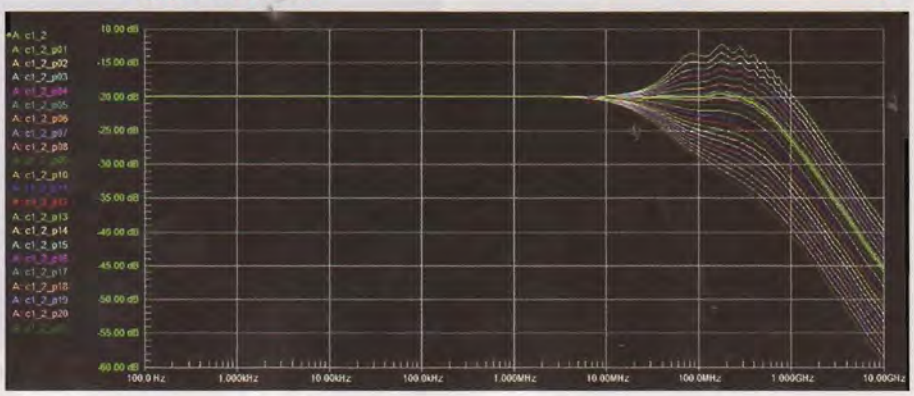


Fig.10: circuit for "high bandwidth" probe transmission-line model, with the response at right.



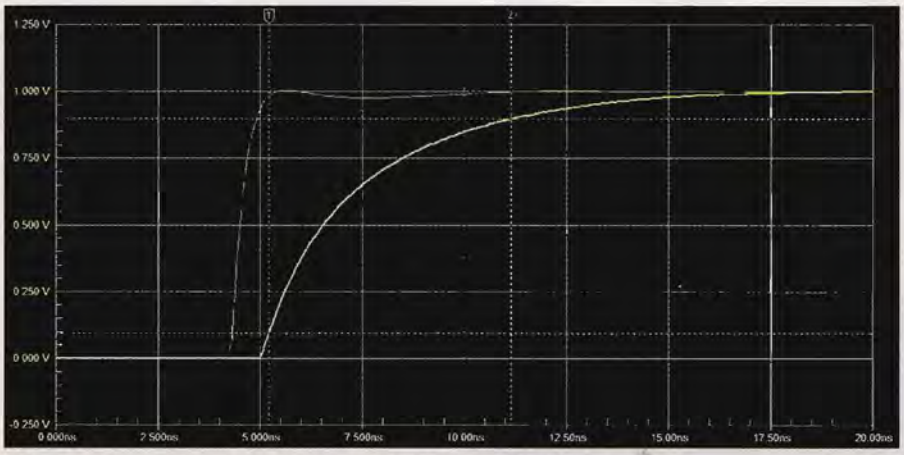


Fig.11: time-domain responses of 60MHz and 600MHz probes.

compensation trim (R_{COMP} in Fig.10) appears to play a significant role. It appears to terminate the lossy transmission line.

For example, if this resistor is shorted, the –3dB bandwidth is reduced to 180MHz and the optimum transmission line resistance is 110Ω/m instead of 115Ω/m. If R_{COMP} is increased above 68Ω to (say) 150Ω, the frequency response shows several dB of peaking at 200MHz.

Interestingly, it makes little difference whether the compensation trimmer and its 68Ω resistor are positioned at the scope end or probe end of the transmission line.

This indicates that the choice of trimmer location is probably a manufacturing decision rather than performance issue.

Rise-time and propagation delay

It is useful to compare the delay (propagation) times of different bandwidth probes. Fig.11 shows the response to a 10V pulse of the 60MHz probe of Fig.9, and the 250MHz probe (with 600MHz bandwidth!) of Fig.10.

The "600MHz" probe (green) has a propagation delay of around 4.2ns while the 60MHz probe (yellow) has around 5.1ns delay.

The propagation delay is the time between the input pulse edge and the start of the pulse edge at the scope end of the cable.

A difference of less than a nanosecond might not seem much, until you're chasing race conditions in logic circuits with mismatched probes.

The rise-time of the scope end waveform is the time taken for the voltage to go from 10% to 90% of the final value. The simulated 60MHz probe shows 5.9ns rise-time; the "600MHz" probe shows 0.7ns rise time.

The effects of faster or slower rise times are in proportion to the nature of the signals you're observing. Nanosecond differences in rise time are irrelevant if you're observing the squarewave response of audio op amps with microsecond rise time but they become vital if you're chasing problems in high-speed digital circuits.

Probe impedance

Does your x10 probe actually have a 10MΩ input impedance? Yes – but only at low frequencies.

Fig.12 shows the input impedance in "dB re 1Ω" of the 60MHz probe of Fig.9. The impedance is 140dB (10MΩ) below 1kHz but the capacitance of the compensation cap determines the impedance at higher frequencies.

It is worth noting that when probing audio circuits at 20kHz, the probe impedance is less than 1MΩ.

At frequencies above the probe's 60MHz bandwidth, the impedance is no longer dominated by the 15pF input capacitance.

It flattens out at 100Ω, dictated by the 50Ω probe tip resistor plus the 50Ω coax impedance.

Probe grounding and ground clips

How "grounded" is the ground clip on your probe?

A typical probe ground wire with alligator clip is around 150mm long. Typical wire inductance is around 1nH/mm, so the ground lead exhibits 150nH of inductance. The probe tip's separation from its ground-lead attachment will add another 50nH or so. This ground inductance was added to the high-bandwidth probe circuit, shown in Fig.13.

The frequency response of this circuit can be compared to the "natural" response of the probe. So our nice, flat 600MHz probe's response has been peaked at 100MHz, with premature rolloff above this.

The transient response isn't pretty either, as seen in Fig.14.

It is worth noting that since most x10 probes have similar input capacitance (10pF to 25pF) and most ground clip leads have a similar length, they will all exhibit peaking around 100MHz, irrespective of probe bandwidth.

For this reason, high-bandwidth probes are generally supplied with a kit of attachments which allow the probe ground to be connected to the circuit via coaxial or other low-inductance paths.

If you're measuring circuit operation above tens of MHz or rise times faster than 50ns, use these fittings!

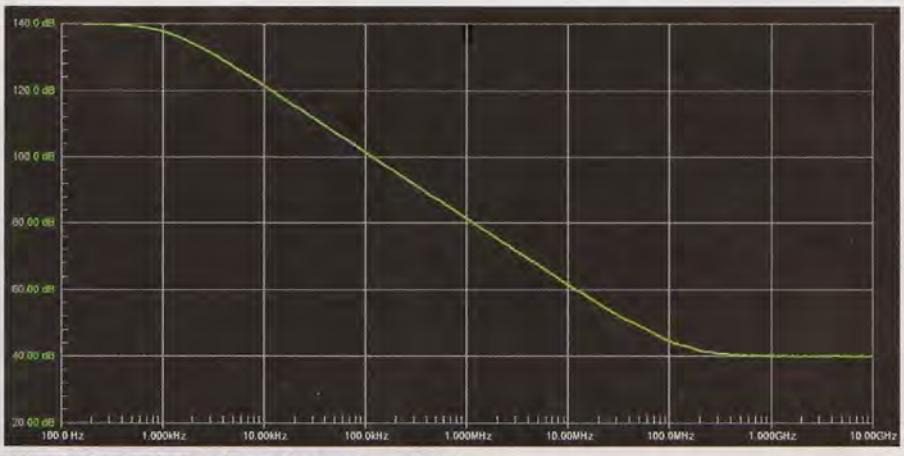


Fig.12: Probe input impedance magnitude.

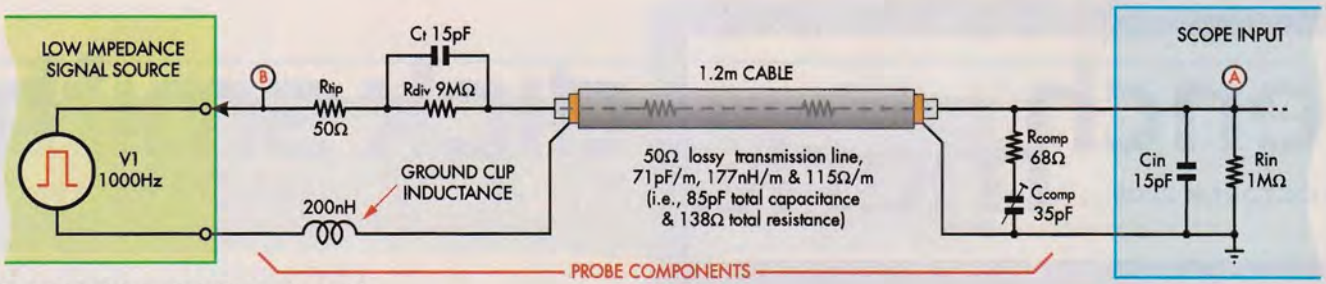
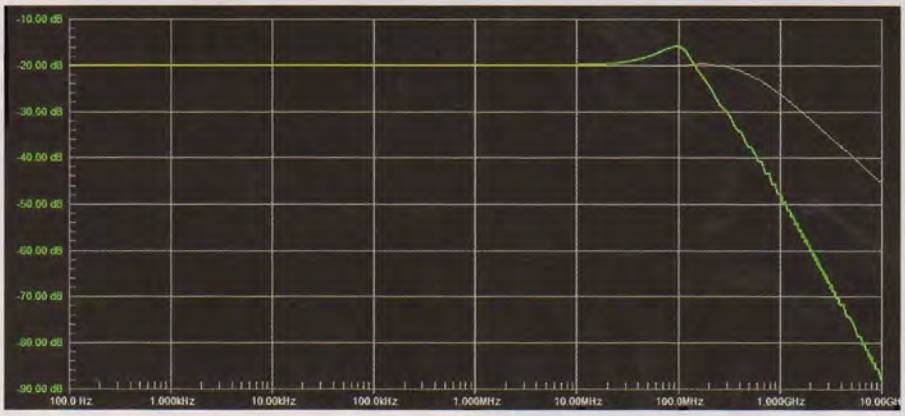


Fig.13: high-bandwidth probe with added ground-clip inductance, with response at right.



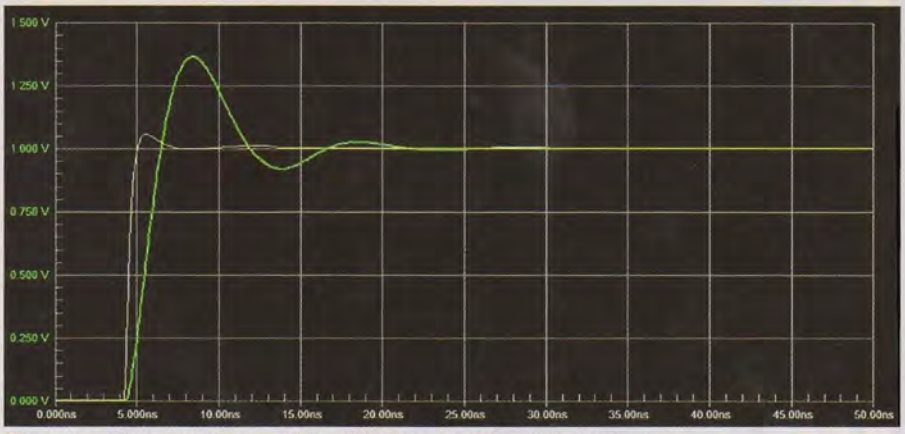


Fig.14: probe waveform with added ground-lead inductance.

Conclusions

The morals of this tale are:

- Trim your probe's compensation capacitor!
- Textbook analyses of probe operation rarely mention transmission-line effects but these are fundamental to the design of a probe.
- There IS a difference between low-bandwidth and high-bandwidth probes. High-bandwidth probes are designed with carefully tailored transmission-line cable and to minimise the effects of end-to-end transmission-line reflections. Much more attention is paid to stray capacitances and build quality.
- A x10 probe will only exhibit 10MΩ impedance at low frequencies. The impedance at higher frequencies is mainly determined by the probe compensating capacitance.
- Use identical probes with equal rise time and bandwidth when inter-channel timing is important (eg, chasing race conditions or clock skew).
- Probe ground-lead inductance can destroy waveform fidelity and bandwidth. Use the kit of adaptors in your probe's pouch to ensure low inductance probe grounds!
- Don't let your probes dangle off the test-bench. Even the good ones break when you tread on them or run your office chair over them!

As a postscript to this article, I received news of the clever fellow who pioneered the use of lossy cable in oscilloscope probes.

It was the invention of John Kobbe, from the halcyon days of Tektronix in the early years. His patent is long expired.

I take my hat off to this gentleman who would have been working without the benefit of PCs and simulator software. SC

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Open-USB-IO: a universal I/O solution

This hardware I/O board will let you drive a host of digital and analog I/O (input/outputs) via the USB interface on your laptop or desktop computer. Based on an Atmel Atmega32 microprocessor and not much else, it works on Windows, Linux and Macs.

In the days of Windows 98 and DOS, you could directly write to the hardware ports on your computer, typically to the parallel printer port and serial port. This was great for hobbyists and many good projects were built around programs which directly accessed hardware.

I built a very useful logic analyser that worked at 1MHz just by reading the digital inputs of the parallel port. I also controlled a bank of relays with C code, writing to the parallel port.

Then came Windows XP, a great improvement over Windows 98, except that it blocked direct access to hardware ports. There was a quick and dirty fix called giveio.sys but it wasn't always reliable.

Next, parallel and serial ports started to disappear from laptops and even desktop PCs. Finally, along came Window Vista which has completely blocked I/O access. Thus hobbyists have been deprived of a powerful, simple, and cheap way to access hardware from program code.

This inability to easily control hardware is not just a problem for hobbyists. At RMIT University where I lecture, we had the same problem with our labs and major projects.

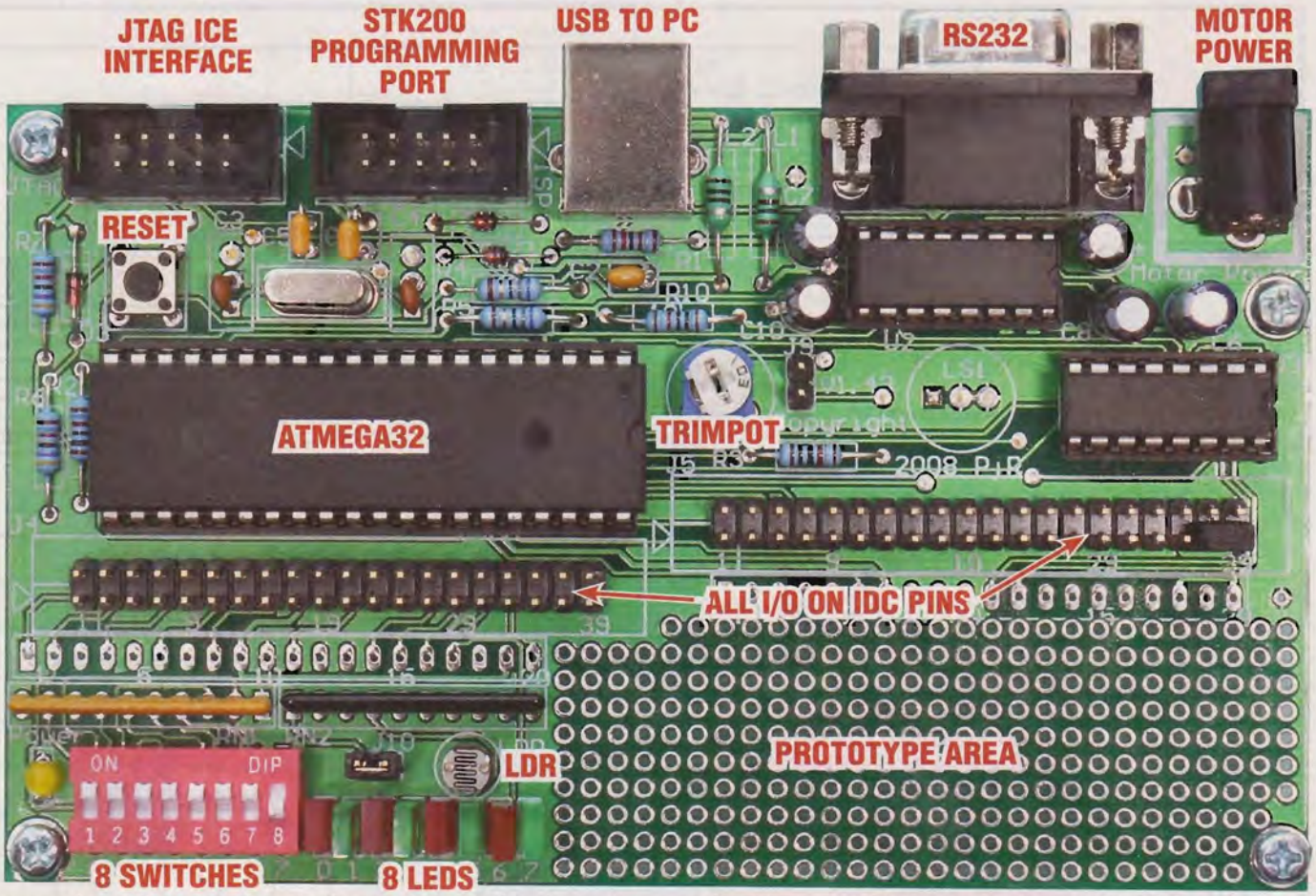
In the Computer and Networks degree, students need to become familiar with hardware, software, networks and the interaction between hardware and software (optional in Electrical and Electronic and Communications degrees).

In our quest to find ways for software to control hardware we found several USB boards that allowed digital input and output (I/O) but they were either expensive, didn't do all we wanted, didn't work on Windows and Linux and Macs or needed special drivers to be installed.

We drew up the specifications for our ideal hardware I/O board:

- Cheap, under $50 in bulk.
- Lots of digital I/O, analog inputs and PWM outputs.
- Basic I/O: LEDs, a Light Dependent Resistor (LDR) and a trimpot for simple analog work.
- An RS-232 serial data port not used for any system function such as programming.
- The ability to drive DC motors or stepper motors (at least 500mA and 50V each).
- USB-driven, with no special drivers for Windows, Linux and Mac.
- Hardware I/O can be controlled from the PC via a GUI, command line or program code.
- Some prototyping area.
- Interface with simple hardware using easy-hooks, or complex hardware with a cable.
- All ICs in sockets to allow easy repair if they are damaged.
- Users must be able to download their own code into a powerful microprocessor. Hardware can thus be controlled direct from the microprocessor with the USB just providing power.

By
Dr Pj Radcliffe
Senior Lecturer, School of Electrical & Computer Engineering, RMIT University.



Reproduced here significantly larger-than-life for clarity (it's actually 125mm wide), this is the Open-USB-I/O Board showing key interfaces.

- The whole thing should be Open Source and GPL for both software and hardware. This makes it easy for anyone to modify and extend the hardware or software but they must release these changes back into the public domain. It also keeps the price down as no one manufacturer can have a monopoly on the board.

The result is the Open-USB-I/O board. Let's look at its key features and then see how to drive it.

What's on the Open-USB-I/O

The compact PC board packs a lot of features. Its heart is an Atmel ATMEGA32 microprocessor with 32KB of code memory, 1KB of EEPROM and 2KB of RAM. You can do a lot with 32KB of code memory!

It also has three timers, four PWM (Pulse Width Modulation) lines, eight A-D converter ports with 10-bit accuracy, serial data ports, digital I/O ports and much more.

Open-USB-I/O makes many of these available to the user but a few must be kept to drive the interfaces such as the USB and the programming port.

The board has eight LEDs and eight switches which can also be used as eight digital inputs and eight digital outputs. In fact these 16 lines can be used as any combination of inputs and outputs by reprogramming the data direction registers in the microprocessor.

Above the LED array there is a LDR (light dependent resistor) which is read via one of the analog inputs on the microprocessor. The LDR can sense the output of nearby LEDs which gives interesting possibilities, including an optical oscillator.

The trimpot in the middle of the board is connected to another analog port and provides a convenient variable analog input. Near the trimpot is a space where the user can add an additional 2-pin device, such as a buzzer.

Circuit description

The full circuit of the Open-USB-I/O board is shown in Fig.1. Only three IC packages are used: IC1 is the MAX-232ACPE RS232 interface chip; IC2 is the Atmel Atmega32 microprocessor and IC3 is the ULN2003A Darlington array.

The top left shows the USB interface where the zener diodes ZD1 and ZD2 act as voltage limiters while the 68Ω resistors present the correct load to the PC USB port. The USB lines carry both DC power and high frequency data signals. Inductor L1 and the associated capacitors filter out noise to provide the DC rail, V_{CC}.

On a desktop computer the USB port can supply up to 500mA but laptops can provide rather less. V_{CC} is clean enough for digital circuits but has too much noise for analog circuitry so the combination of inductor L2 and the 100nF capacitor gives extra filtering to provide the AV_{CC} rail which is used for all the analog circuits in IC1.

The USB data interface is handled by firmware on the ATMEGA32 which uses interrupt PD2 and pin PD7 to receive or drive signals to the USB line.

The bottom right of the circuit has S2-S9, a bank of eight switches which can be read by the microprocessor. The

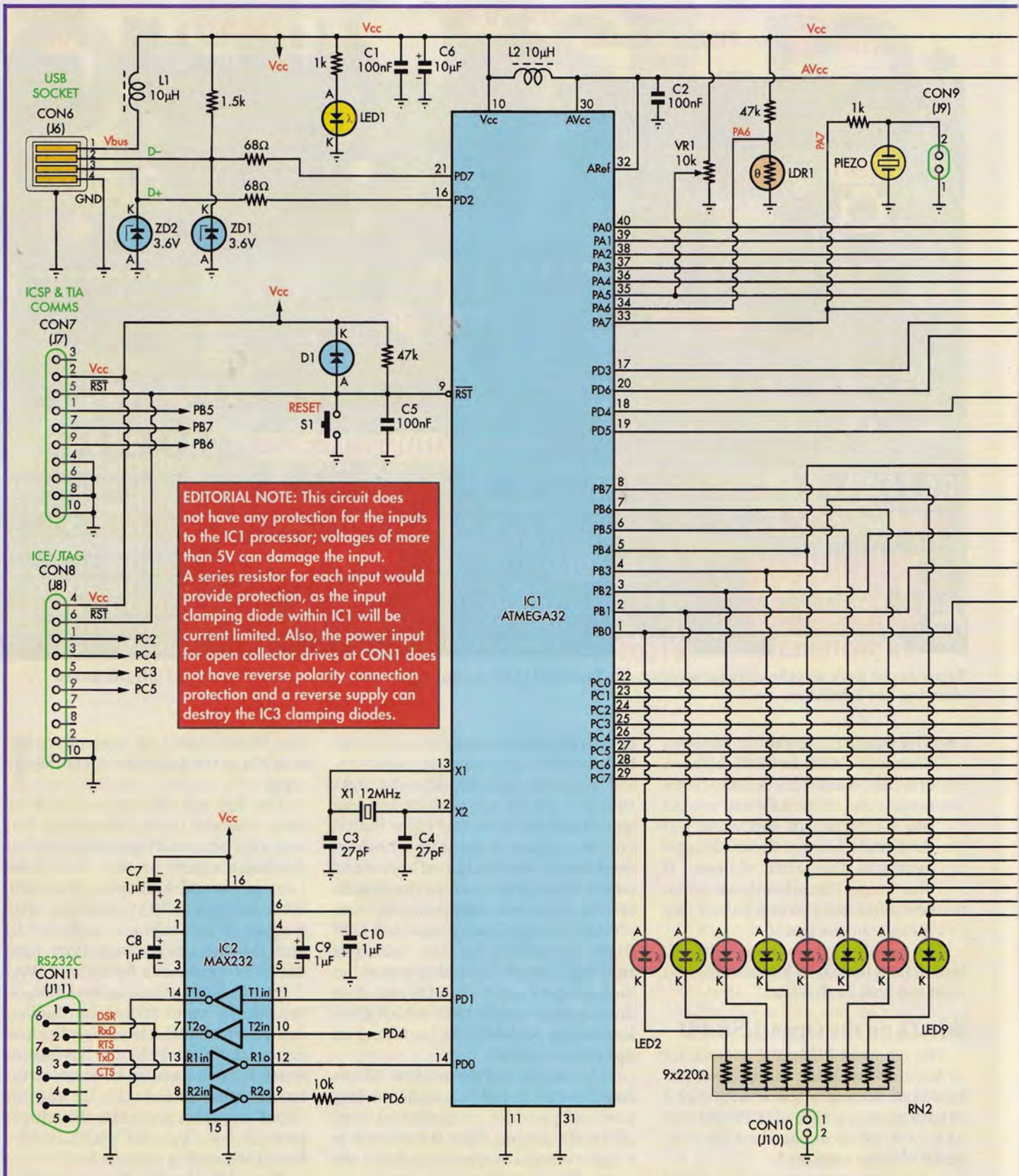
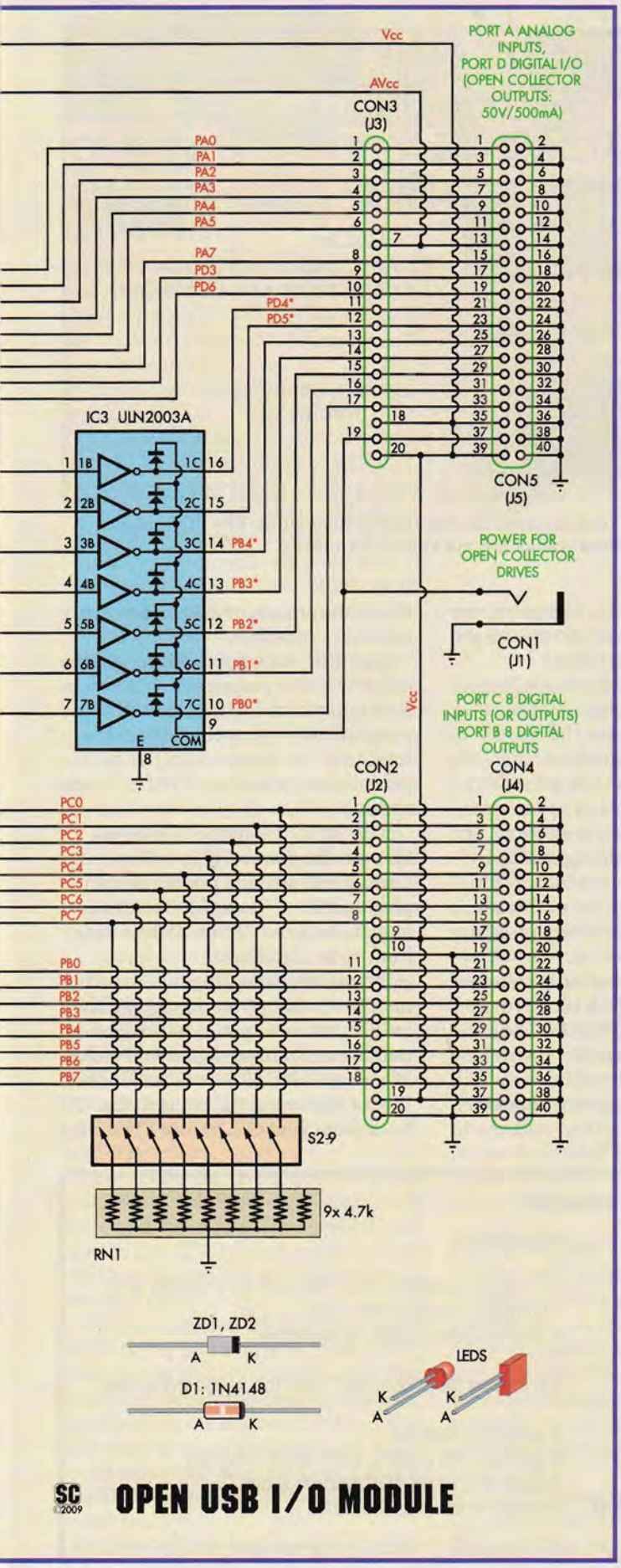


Fig.1: the circuit diagram for the Open USB I/O module shows it is primarily based on a programmed ATMEGA32 along with several input/output devices and LED indicators. The various input/output and power connectors are labelled here as CON1, CON2, etc, as is our normal practice. However, on the PC board overlay and in the text of this article they are labelled J1, J2 etc, so we have shown both to avoid any confusion.



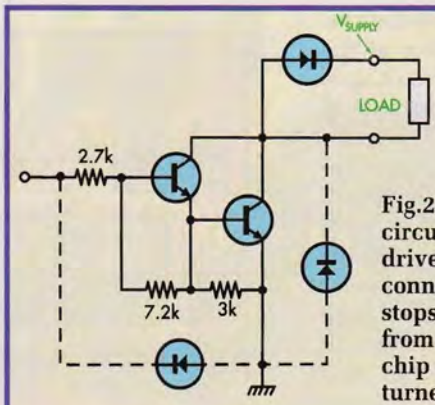


Fig.2: the internal circuit of one ULN2003 driver. The diode connected to V_{SUPPLY} stops inductive spikes from destroying the chip when a load is turned off.

microprocessor provides internal 100kΩ pull-up resistors on each port C pin. These set each port C pin to logic high when the associated switch is open and logic low then the switch is closed, bringing the external 4.7kΩ pull-down resistor (resistor array RN1) into play.

These inputs are available on the J4 connector (and the J2 holes below the connector). Any external output capable of driving the 4.7kΩ resistor could be connected here and be read by the microprocessor. If all the switches were set to off the external input would only have to drive the 100kΩ pull-up resistor.

Port B of the microprocessor drives eight LEDs (LED2-9, labelled on the PC board DS2-DS9) through a 220Ω resistor array and then via link J10 to 0V. If the link is removed the LEDs will not light. This can be useful if port B pins on connector J5 are intended to drive external devices.

Alternatively, the LEDs may be left connected when driving external circuitry, as the ATMEGA32 outputs are capable of driving 20mA and the LEDs only take around 12mA, thus leaving spare drive for external devices.

The ATMEGA32 should not drive more than 200mA for the entire chip as an absolute maximum but given the chip only requires some 12mA for its internal uses this leaves a

Controlling Open-USB-I/O from the command line

```
[user]$ ousb io PORTB 85
 PORTB = 85
[user]$ ousb io PORTB 0xff
 PORTB = 255
[user]$ ousb io PINC
 PINC = 1
[user]$ ousb -h io PINC
 PINC = 0x1
[user]$ ousb -b io PINC
 PINC = 0b00000001
[user]$ ousb adc 6
 ADC6 = 119
[user]$ ousb adc 5
 ADC5 = 481
[user]$ ousb io PORTB 0
 PORTB = 0
 [user]$ ousb pwm-freq 1 7000
  PWM #1 on pin 4 operating at 5859.375000 Hz
 [user]$ ousb pwm 1 30
  PWM #1 on pin 4 operating at a duty cycle of 0.301961
```

SC 2009 **OPEN USB I/O MODULE**

lot of drive for external devices.

The RS232 interface at the bottom left of the circuit uses a standard MAX232 chip to interface to the RS232 lines and to provide the ±3V power supplies needed to drive the RS232 outputs. The device not only handles transmit and receive but also one status line in and one status line out. If the RS232 port is not needed for serial data, then the two output lines can be used as general purpose outputs that drive around +3V and –3V.

The right side of the circuit shows the open-collector drive chip, ULN2003A, which has seven open-collector drivers.

Fig.2 shows the circuit of one of the Darlington drivers. An input of 3V or more applied to the 2.7kΩ resistor will turn on the Darlington transistor and current can flow from V_{SUPPLY} through the load to ground. If the input goes to 0V the Darlington turns off and the load current drops to zero.

If the load is inductive, the built-in diode connected to the positive supply will short-circuit the inductive current and ensure there are no large voltage spikes that could destroy the chip.

V_{SUPPLY} is not tied in any way to the board +5V and can range from 0V to 50V. The Darlingtons can handle 500mA and so each of the seven drivers can control a small DC motor or a coil in a stepper motor.

Our students at RMIT have used such a configuration to drive one 6-wire stepper motor (using four outputs) and three DC motors or servo units. The power for these motors is usually connected to the 2.5mm DC socket (centre pin positive) which corresponds to V_{SUPPLY} above.

If you use the USB +5V as described above and your commands to Open-USB-I/O start to generate errors, then it is likely that the output devices are drawing too much current from the USB port.

The two 20-pin IDC connectors, J4 & J5, provide access to most of the microprocessor pins and all the open-collector drivers. The back row of these pins are all connected to 0V. When a cable is connected this means each signal wire has a 0V wire on each side. This helps to stop interference both to and from the signal wire. Without such an arrangement a signal on one wire will usually create glitches on the wire next to it in the cable.

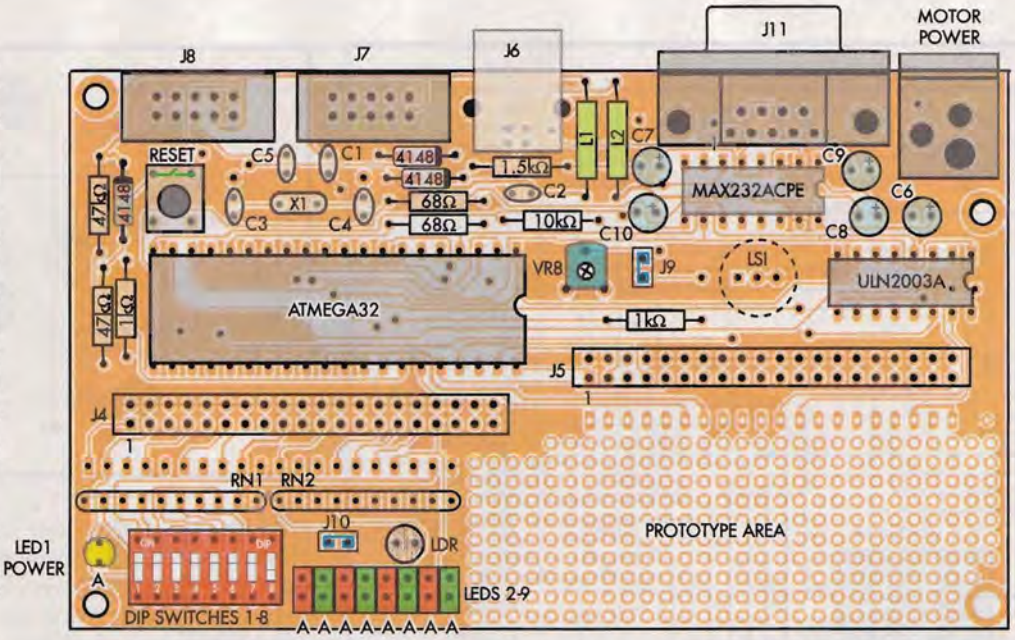


Fig.3: PC board layout, looking from the top (component side). The PC board is double-sided but the bottom tracks are not shown for clarity.

The pins on the 20-pin IDC arrays can be connected via easy-hooks or a proper cable, as can be found in older computers (often on the side of the road) that use IDE drives. The right connector also has seven open-collector drivers powered from the motor power plug (top right of board).

The RS232 port provides a serial data link that is entirely at the user's control; it's not used for any programming or control function.

The USB socket takes a standard USB A-B printer cable which provides +5V power from the PC. Code on the microprocessor enables the board to act as a standard USB device and allows the ousb program on the PC to directly control every register in the microprocessor and hence every hardware interface.

The ISP socket conforms to the older STK-200 programming interface standard which is supported by many programmers. Using this you can download your own code into the microprocessor or reload our USB interface code.

The JTAG interface allows an In Circuit Emulator (ICE) to be connected and provide powerful debugging facilities. Such ICE devices cost anywhere from about $50 to many hundreds of dollars.

If you are doing serious development work that needs debugging, then an ICE can save you a lot of time by making it much quicker to find errors. You won't need either of these sockets if you just want to control the I/O ports from your PC. (Editor's Note: for

BASH script file example

```
                        #!/bin/bash
                        #
                        #----- BASH script to read the LDR light sensor and
                          write the value to the LEDs.
set –u                  # stop autodeclaration of variables.
LDR=
until [ 0 != 0 ]        # A forever loop, control-C from the keyboard to stop.
do
sleep 0.3               # pause for 300 ms.
LDR=$(ousb adc 6)       # get the LDR reading from Open-USB-I/O
let "LDR = LDR/4"       # scale the 10 bit ADC back to 8 bits.
ousb io PORTB $LDR      # write the value to the LEDs
done
```

more on JTAG see the review article on pages 44-48 of the August 2009 issue of SILICON CHIP).

Lastly, the prototype area is big enough to add your own hardware, for example a motor, a relay or a number of opto-isolators.

Obtaining the software and hardware

There are several key resources that will help you understand much more about Open-USB-I/O and provide all the required hardware, programs and circuit diagrams.

The web site **http://pjradcliffe.wordpress.com/** has:

- A reference manual which covers the USB commands in more detail, how to program the board from script files (.bat under Windows or BASH under Linux), how to write and download your own C programs onto the ATMEGA32 and a description of various development tool chains.
- The Windows and Linux programs that give the ousb command line functionality described later in this article. Normally the firmware is pre-programmed into the Open-USB-I/O board but the web site has the firmware and instructions on how to program it into the board.
- Hardware circuit diagrams for the Open-USB-I/O board and a simple programming cable which enables you to download your own programs into the board.

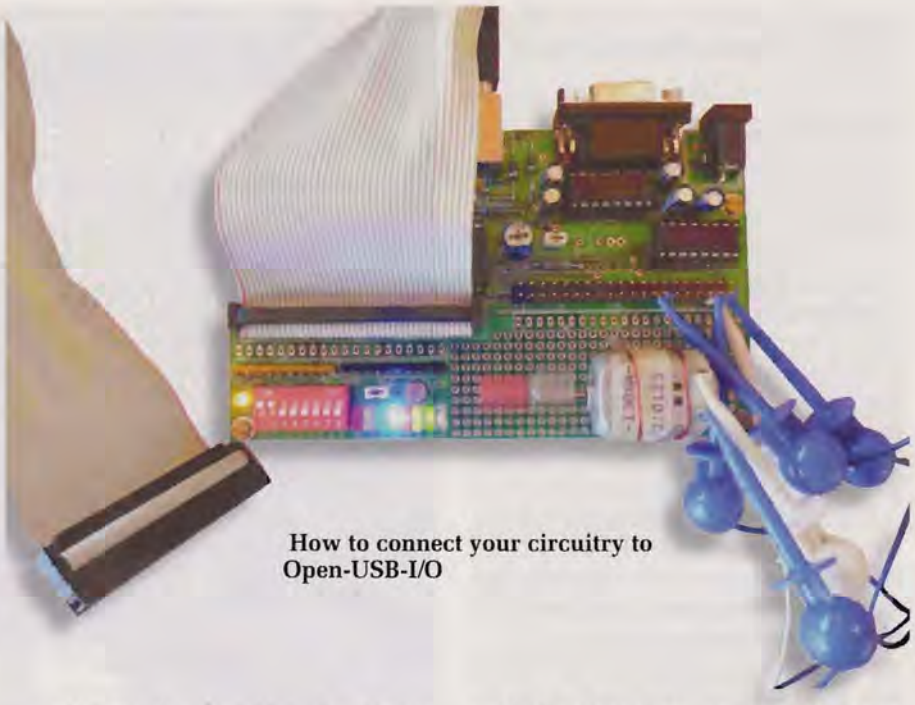
The web site **http://interestingbytes.wordpress.com/** supplies the Open-USB-I/O boards and also has a live-DVD with a huge range of development tools. This bootable DVD provides an excellent and surprisingly easy to use Linux system running straight off the DVD.

Live-DVDs do not touch the hard disk, they run from just your DVD drive and the RAM. However, if you like the live-DVD then it takes only 15 minutes to install it as a dual boot to the hard drive.

To boot the live-DVD ensure your BIOS is set to boot first from DVD, then put in the DVD and restart the computer. When the desktop appears double click on the readme.html file and read through the help and how-to information. Key features on the live-DVD related to the Open-USB-I/O board include:

- Code editors and avr-gcc C compiler and assembler for Atmel microprocessors.
- The VMLAB emulator that enables you to simulate your code, including hardware, before downloading the code to real hardware.
- An excellent set of examples which can serve as the basis of your own projects.
- A variety of useful documentation, including all data sheets for the ATMEGA32 and Open-USB-I/O board.

The live-DVD has an extensive array of other development tools for Linux including the Eclipse IDE for C, C++, java, python, Perl, and C for the ATMEGA32. Other tools include Apache web server, MySQL database server, PHP, web editors such as Kompozer, Qt Designer for GUI development and much more. There is also a whole range of network tools, drawing tools, Open Office, audio-visual programs, and a few games.



How to connect your circuitry to Open-USB-I/O

Construction

The Open-USB-I/O is available in kit form or built and tested. The pre-assembled version is only slightly more expensive than the kit version and available from **http://interestingbytes.wordpress.com/**. However, any hobbyist with reasonable soldering skills should be able to build the board themselves.

The following is for those constructing from a kit. Using the component layout of the PC board (Fig.3), start with the IC sockets, ensuring that pin 1 of each is properly orientated. The notch at one end of the socket should match the notch in the socket outline on the board.

Next, solder in the sockets on the back edge of the board, the two shrouded IDC connectors, the USB connector, the RS-232 connector and the DC power connector. Note that the notch in the two shrouded IDC connectors should face the outside of the board.

As you solder in the two 20-way IDC connectors, be careful that they are sitting flush to the board and solder one pin on each end first.

Do not apply heat for too long to any pin as the plastic can melt and the pin will shift, making it impossible to place a plug into the socket.

Now it is simply a matter of placing and soldering in the rest of the components, starting on one side of the board and moving to the other side.

Be especially careful with all polarised devices such as electrolytic capacitors and LEDs.

Finally, insert the ICs into their respective sockets (again watch the polarity) and do a careful visual inspection, checking the board against the photos and the overlay diagram of Fig.3. Don't forget to put in link J10 directly above the LEDs or the LEDs will not light!

Power up by connecting the board, via a USB cable, to a powered-up computer. The yellow power LED should

immediately light. If not, check for shorts between +5V and ground on the board.

Start playing

The simplest way to control the Open-USB-I/O board is via the command line.

On a Windows computer copy the ousb.exe file from http://pjradcliffe.wordpress.com/ to My Documents. Start a terminal by clicking the start icon, select Run, then type cmd in the command box and hit enter. Use the command cd "My Documents" (change directory) to move to where you have saved the ousb.exe file.

For Linux, copy the ousb file to some where convenient. The location /usr/local/bin is a good place for programs as this is in the path. Another good place is your home directory.

Check the program works by typing just ousb in the command window, help information should be displayed (if you are using your home directory on Linux use ./ousb).

To begin, let's control the LEDs. First, ensure link J1 directly above the LEDs is plugged in. Type the command ***ousb io PORT B 85*** and every alternate LED should be lit. This command is writing to PORTB of the microprocessor which is connected to the LEDs.

Now try ***ousb io PORTB 0xFF*** which will light all LEDs and uses a hexadecimal number with all bits set high. To turn off the LEDs, use the number 0. Next try reading the switches, first set all switches to ON and try the command ***ousb io PINC***. The result should be zero. Now try setting any switch and issue the command again. The result should show a one bit for each switch turned off.

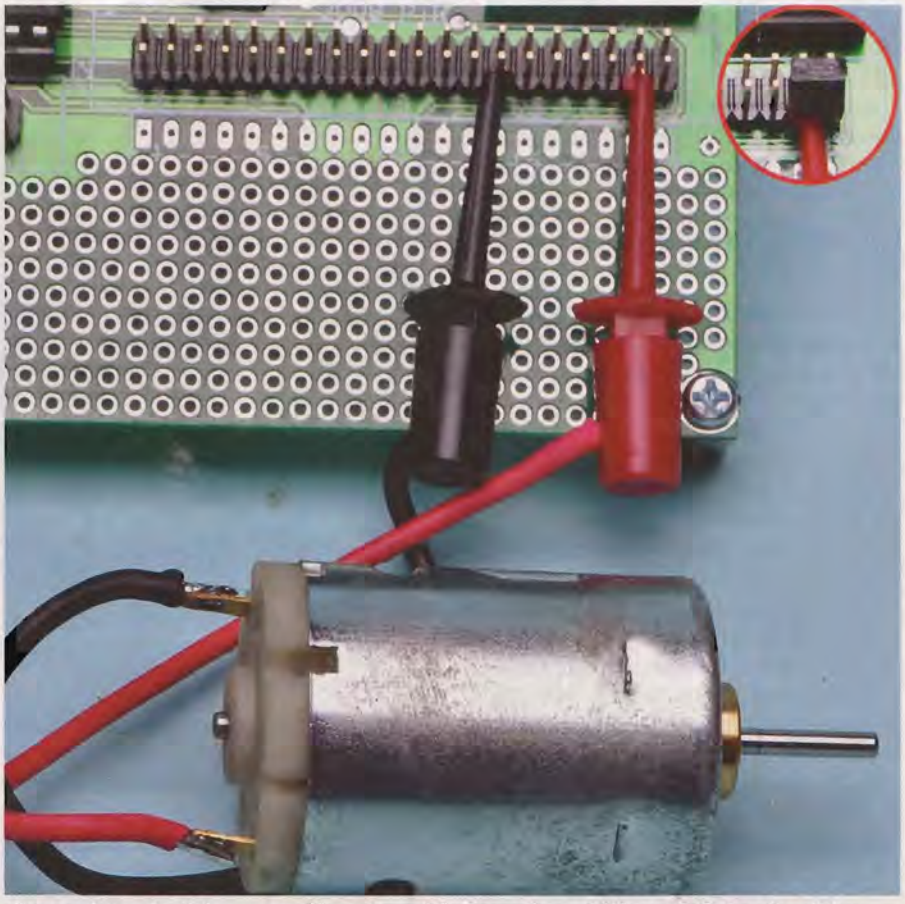
To view it in hexadecimal try ***ousb –h io PINC***, to see the result in binary try ***ousb –b io PINC***.

The LDR is a slow responding light detector. Try the command ***ousb ADC 6*** to see the light level. Try different light levels and turning the LEDs on and off, to see changes in the reading.

The trimpot provides a convenient analog input, use the command ***ousb adc 5*** to read the setting. Try moving the pot and note the reading changes.

If you have some easy-hooks and a small DC motor then you can use the PWM and the motor drivers. PWM generates a fixed frequency square wave but varies the 'on' period (duty cycle).

A motor responds to the effective average voltage so if the duty cycle is 10% then the effective voltage to the motor is 0.5V and the motor will probably not even move. However, for a duty cycle of 90% (which translates to an average voltage of 4.5V), your motor will spin freely.



Connections to drive a small motor with the pulse width modulator. Inset top right is the J5 37-39 jumper required to drive the motor from USB port +5V.

There are two ways to get power for the motor. The first is to use an external power source that plugs into the 2.5mm DC socket (centre pin positive) on the board – in this case the motor can be connected between pins 27 and 37 of J5.

The second approach is to use the +5V supplied by the USB which should be OK for a small DC motor. If you are using this method you will need to link pins 39 and 37 of J5.

The photograph above shows both options. Note that the red and black connections are required for both, while the jumper between pins 39 and 37 of J5 (inset in red) is only required for option 2, in order to use the USB +5V to drive the motor.

The first PWM output can only operate at four set frequencies and the output is connected to LED3 as well as an open collector driver.

First set the LEDs to off using the command ***ousb io PORTB 0*** and then set the frequency of the PWM to say 7kHz using the command ***ousb pwm-freq 1 7000***. Note the frequency will be rounded to one of the several fixed values available.

Now set the duty cycle to 50% with the following command: ***ousb pwm 1 50***. LED2 should now be at half intensity. Try other duty cycles to see the intensity change, or if you have a motor connected then the motor speed will vary as the duty cycle changes.

Advanced play

The ***ousb io*** command allows the user to access any register in the microprocessor and so gain full access to all the on-chip peripherals which include extra timers, I^2C interfaces, more PWMs, interrupts, input time capture, the RS232 interface and more.

As an example let's take port B which is an output by default and then make it an input.

First use the command ***ousb io PORTB 255*** to turn on all the LEDs.

Next, the data direction register for port B must be altered – use ***ousb io DDRB*** to read the current value, then ***ousb io DDRB 0*** to turn all the pins to inputs which should turn off all the LEDs. Add the command ***ousb io PORTB 0*** to turn off the microprocessor's 100kΩ pull-up resistors which may cause the LEDs to glow dimly.

Now try the command ***ousb io PINB*** to read the inputs. Use an easy-hook or similar to connect the J4 pin for port B bit 0 (pin 21) to +5V (pin 37) or 0V (any even pin). Read the value of the pin using ***ousb io PINB***. To restore the microprocessor to its default state first remove all connections and then hit the reset button.

Any ousb command can be placed in a script file; a .bat file for Windows or a BASH script file under Linux or Macs.

The Windows .bat files are not very powerful compared to Linux BASH script files. Under Windows you can download a package called cygwin (www.cygwin.com). This gives you a Linux command line and BASH script capability on Windows.

With a BASH script you can now write complex programs to control your Open-USB-I/O board. For example, the bash script file earlier reads the Light Dependent Resistor and writes the reading to the LEDs.

Starter projects to power projects

The ATMEGA32 is a cheap yet very powerful microprocessor and quite amazing things can be done with it. The web is filled with the hardware and software that you can download for free.

For example, Neil Franklin on his website http://neil.franklin.ch/Projects/SoftVGA/ shows how to drive a VGA display from the ATMEGA 32 with just six resistors. Austin Lu and Albert Ren show to build an iPod interface (http://dev.emcelettronica.com/how-to-control-ipod-atmel-mega32). Perhaps you are just beginning, how about just flashing a LED (at www.dharmanitech.com/2008/10/adc-project-with-atmega32.html).

Some of the best projects and information can be found at www.avrfreaks.net; here you can find tools, data sheets, getting started information and projects ranging from the simple to the extreme.

Low speed activities (below 1kHz) can be driven from the PC via command line, script, or C/C++ code. Higher speed activities need to be programmed directly on the ATMEGA32 microprocessor.

Conclusion

The Open-USB-I/O board is an easy and inexpensive way to achieve digital and analog I/O from your laptop or desktop using just the USB port. It will work on Windows XP, Vista, Mac OSX, Linux and other POSIX operating systems without the need for special drivers.

The board contains a whole range of I/O pins, Pulse Width Modulators, analog inputs, motor drive pins, and more. The board also contains the powerful ATMEGA32 microprocessor and using the live-DVD you can write your own assembler or C code then download it into the ATMEGA32. The live-DVD has several project examples which can serve as the basis of your own projects.

We have found the Open-USB-I/O board very useful at the School of Electrical and Computer Engineering at RMIT University (Melbourne, Australia). It can be used in simple first year programming activities right up to final year microprocessor subjects that require students to use the full complexity of the ATMEGA32.

The board is used in our major project activities which are both fun and very important to our students (employers want evidence that students can achieve things not just be good at passing exams!). Hopefully you will find Open-USB-I/O as useful as we have.

We are developing more useful tools based around Open-USB-I/O including a GUI controller and the ability to program the ATMEGA32 just through the USB connection.

Check the websites below in the near future to get these tools. SC

Where do you get it?

See www.interestingbytes.wordpress.com to purchase an Open-USB-IO board and the live-DVD which contains development tools and example projects.

See www.pjradcliffe.wordpress.com for a detailed reference manual, and all the programs that you will need.

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A high-quality stereo DAC for superb sound from your DVD player

Second article has the board assembly details



Pt.2: by NICHOLAS VINEN

Last month, we introduced our new high-quality Stereo Digital-To-Analog Converter (DAC) and described the circuit. This month, we show you how to build the various modules and make the header cables.



Where To Buy Kits For The Stereo DAC

Both Jaycar and Altronics will be supplying kits for this project and both companies will be supplying the Input and DAC Boards with the surface-mount ICs (IC3 & IC6) already soldered in place. This is a real bonus as it will save you the hassle of having to solder these small devices in by hand and risk ruining the boards.

The Jaycar kit will be in short form only and will consist of the Input, DAC and Front Panel Boards plus all on-board parts. A kit for the Power Supply Board is available separately (Cat. KC-5418).

The Altronics kit will be complete and will include all the modules, the power supply components (including the transformer) and a laser-cut custom steel case with screened lettering. The modules will not be available separately except for the Power Supply Board (Cat. K-5501) and the remote control is not included.

TOSLINK Receivers

Jaycar ZL-3003 TOSLINK receivers were specified for this project in the parts list published last month. However, Altronics also sell TOSLINK receivers (Cat. Z-1602) which are pin-compatible with the Jaycar receivers.

The only problem is that the Jaycar units run off 5V, whereas the Altronics units require a 3V rail. As a result, we have slightly modified the PC board so that either receiver can be used. This involved fitting a 3-pin header near TOSLINK1 on the Input Board, so that a shorting jumper can be used to select between +5V and +3.3V rails (3.3V is close enough).

It's just a matter of fitting the jumper to select the +5V rail if you are using Jaycar ZL-3003 receivers or fitting it to select 3.3V if you are using Altronics Z-1602 receivers. The two types offer equivalent performance.

Check carefully if you buy TOSLINK receivers elsewhere – not only can their supply requirements vary but they may not have the same pinouts.

AS SHOWN IN the photos, our prototype DAC was built into a 1-unit high rack case with internal rails from Jaycar. However, we recommend against using this case, as the internal rails (used to secure the panels) make it difficult to mount the two main PC board assemblies. In the prototype, these boards were mounted on the rails but it really is an exercise in frustration when it comes to fitting the nuts to the mounting screws.

What's more, once they are in and the case is fully assembled, it's a big job to remove them again.

Another problem is the sub-panel that runs just behind the front panel. This complicates matters when it comes to mounting both the mains power switch and the Front Panel Switch Board because it means that additional cut-outs are necessary.

Finally, making sure that all the panels and rails are properly earthed is a difficult and time-consuming task.

For all those reasons, if you are not buying a complete kit, we recommend that you build your Stereo DAC into the Altronics H-5035 rack case instead. It doesn't have internal rails or a sub-panel and so the Input and DAC Boards can be mounted on tapped spacers, making them easy to install and remove for service.

PC board assembly

As stated last month, the Stereo DAC is built on four PC boards: (1) an Input Board, (2) a DAC Board, (3) a Front Panel Switch Board and (4) a Power Supply Board. They are all straightforward to assemble although there are two surface-mount ICs (IC3 & IC6) to consider, one on the Input Board and the other on the DAC Board.

The good news here is that both the Jaycar and Altronics kits for this project will be supplied with the surface-mount ICs already installed on the boards – see panel. This is a worthwhile feature that will save you lots of time.

However, if you elect not to buy a kit, it is possible to reliably hand-solder these TSSOP (Thin Shrink Small Outline Package) parts. The following article titled "How To Hand Solder Very Small Surface-Mount ICs" describes how it is done.

Begin by carefully inspecting all four boards for possible defects. Make sure that there are no shorted or broken tracks and check that all the holes have been drilled. In particular, pay special attention to the area immediately surrounding the surface-mount ICs on the Input and DAC Boards, as these have very fine tracks and close track clearances.

Having done this, start the assem-

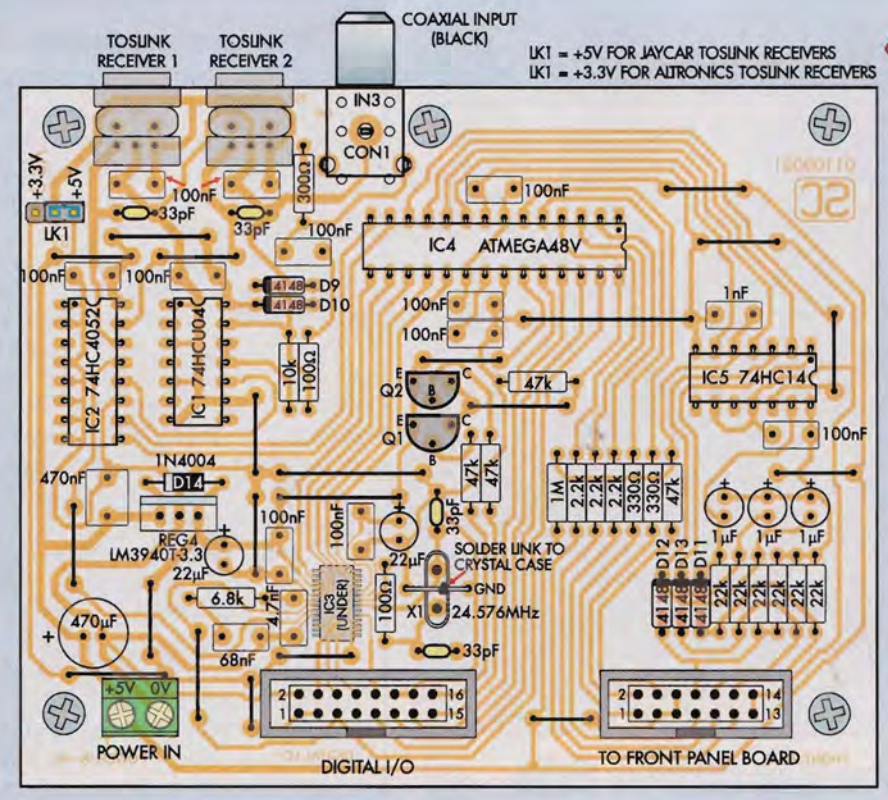
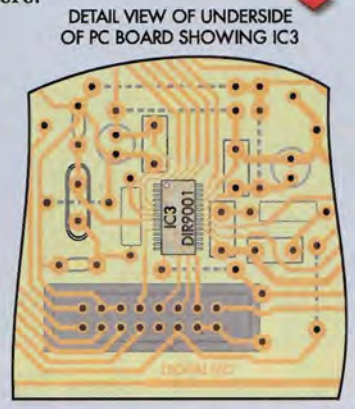


Fig.5: the parts layout on the Input Board. Make sure the SMD device (IC3) is installed first (see Fig.6) and be sure to select the correct supply rail option to suit your TOSLINK receivers.

Fig.6: if you buy a kit, IC3 will be supplied soldered in position. If not, you will have to carefully solder it in by hand as shown here.



bly by building the Input Board. This board is coded 01109091 and measures 113 x 93mm. Fig.5 shows the assembly details.

As stated, if you purchase a kit (recommended), IC3 will already be mounted on the board. Alternatively, if you're not building from a kit, the first step is to install IC3. This is a 28-pin TSSOP SMD, which has a 0.65mm pin pitch (ie, there is 0.65mm between the centres of adjacent pins). The clearance between the pins is a mere 0.35mm which means that it is almost impossible to manually solder the pins one at a time without bridging them.

Fig.6 shows where IC3 is installed. This SMD part is mounted on the copper side of the board and must be oriented with its pin 1 at upper left, as shown. It's easy to identify pin 1 – it's adjacent to a small dot in the body at one end of the IC. Refer to the following article titled "How To Hand-Solder Very Small Surface-Mount ICs" for all the details on soldering it into place.

Fig.5 shows how the rest of the parts are installed. Start by installing the 21 wire links (use 0.71mm tinned copper wire), then install the resistors. Table 1 shows the resistor colour codes for this board but check each one using a digital multimeter before installing it, just to make sure.

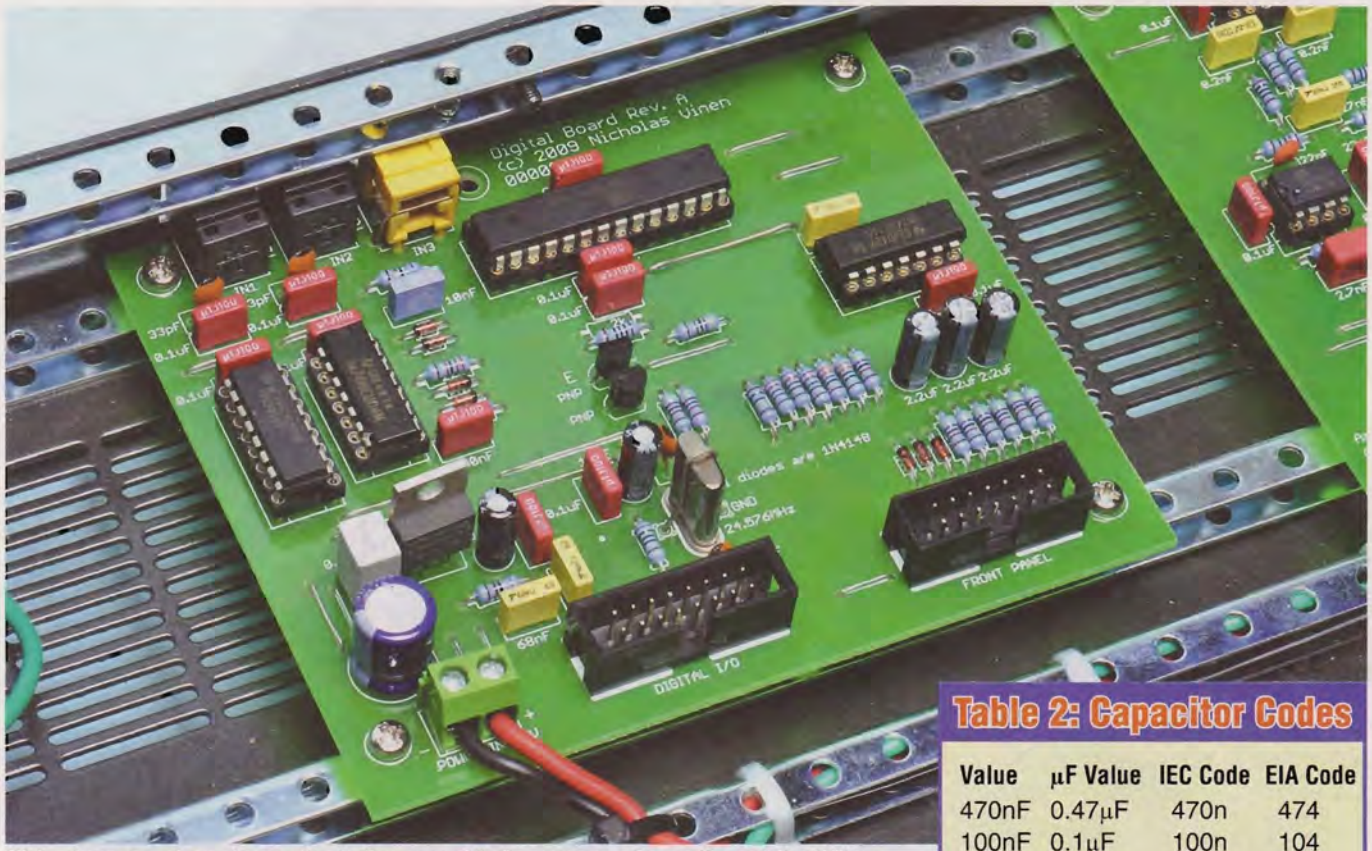
Follow these parts with the diodes. These are all 1N4148s except for D14 which must be a 1N4004. Check that they are all correctly oriented before soldering their leads.

The four IC sockets are next on the list. Install these with notched ends matching the notches on the overlay. In each case, it's usually easier to first solder two pins at opposite corners, then check that the socket is sitting flat against the PC board before soldering the remaining pins.

The two IDC sockets (14-pin & 16 pin) go in with their notched sides oriented as shown (ie, towards the edge of the PC board). Don't get them in the wrong way around. Alternatively, you can use DIL pin headers (0.1-inch spacing) instead of the IDC sockets

Table 1: Resistor Colour Codes – Input Board

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	1MΩ	brown black green brown	brown black black yellow brown
❑	4	47kΩ	yellow violet orange brown	yellow violet black red brown
❑	6	22kΩ	red red orange brown	red red black red brown
❑	1	10kΩ	brown black orange brown	brown black black red brown
❑	1	6.8kΩ	blue grey red brown	blue grey black brown brown
❑	3	2.2kΩ	red red red brown	red red black brown brown
❑	2	330Ω	orange orange brown brown	orange orange black black brown
❑	1	300Ω	orange black brown brown	orange black black black brown
❑	2	100Ω	brown black brown brown	brown black black black brown



This close-up view shows the fully-assembled prototype Input Board (it differs slightly from the final version) Take care with component orientation.

although these make it possible to plug a connector in backwards, which could damage some components.

Once these parts are in, install the 2-way screw terminal block, then install all the MKT and ceramic capacitors. If your 33pF ceramic capacitors have a 0.2-inch (5.08mm) pin spacing they will fit right into the holes. If not, use a pair of pliers to carefully bend the legs out at approximately 45° and then parallel again so that they fit.

Follow with the six electrolytic capacitors (make sure they are correctly oriented) and the two BC327 transistors (Q1 & Q2). Just line up the flat sides of the transistors as shown on Fig.5 and you can't go wrong.

TOSLINK receivers

The two TOSLINK receivers go in at top left of the board and can only go in one way. They should be installed one at a time. In each case, after you insert the five pins through the holes, gently push the module towards the middle of the board. This will ensure that the plastic feet correctly sit near the edge of the board and that the face is parallel with the edge.

Solder the two thicker pins closer to the PC board edge first, then check that it is sitting flush against the board and is correctly aligned. Adjust it if necessary before soldering the remaining three pins.

The 3-pin header (near TOSLINK1) can now go in. This header allows you to select the supply rail for the TOSLINK receiver using a shorting jumper. **Place the jumper in the 5V position (as shown on Fig.5) if you have the Jaycar ZL-3003 receivers.**

Alternatively, fit the jumper to the 3.3V position if you have the Altronics Z-1602 receivers.

A black RCA socket is used for the coaxial input and this can be a little tricky to fit. You may have to press it fairly hard into the holes to get it to sit properly. Note that the six plastic posts don't actually go down very far into the holes – the metal flange on the centre pin usually limits this. Adjust it so that it is at right angles to the PC board, then solder the two pins on either side. That done, recheck the orientation before soldering the third pin.

Next on the list is the 24.576MHz crystal. Once you have soldered its leads to the board, cut a length of 0.71mm tinned copper wire and bend it into a U-shape. Insert the ends of this wire into the holes on either side of the crystal and push it down so that the "U" sits flat against the top of the crystal case. Finally, solder both ends of the wire to their PC pads, then solder the top of the "U" to the case to ensure good electrical contact.

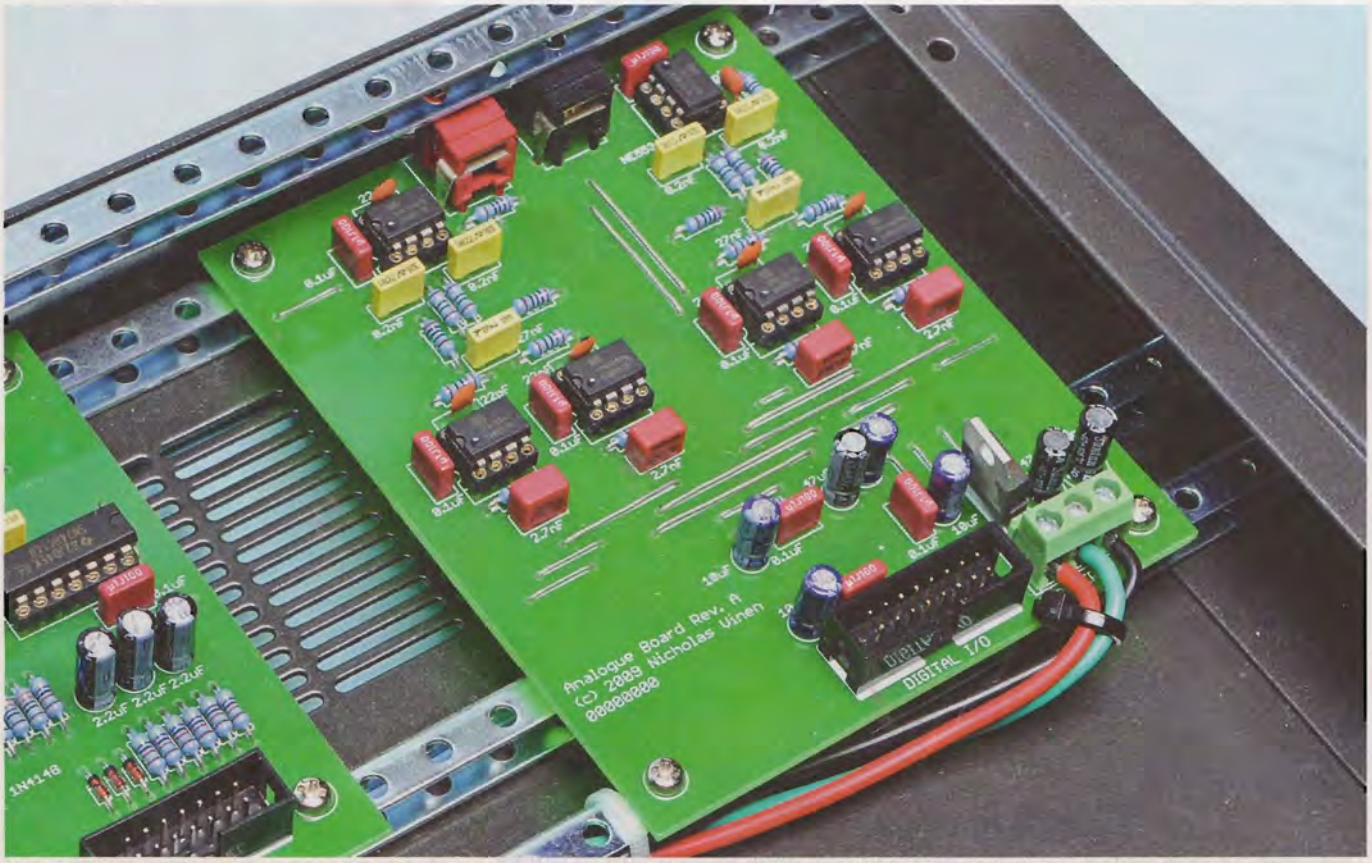
Doing this grounds the metal case and reduces RF interference.

The Input Board assembly can now be completed by installing regulator REG4 and by plugging the ICs into their sockets. Note that REG4 goes in with its metal tab towards diode D4. Push it down onto the PC board as far as it will comfortably go before soldering its leads.

Take care when fitting the ICs – they must be fitted with the notched ends oriented as shown. Be careful also not

Table 2: Capacitor Codes

Value	µF Value	IEC Code	EIA Code
470nF	0.47µF	470n	474
100nF	0.1µF	100n	104
68nF	.068µF	68n	683
27nF	.027µF	27n	273
10nF	.01µF	10n	103
8.2nF	.0082µF	8n2	822
4.7nF	.0047µF	4n7	472
2.7nF	.0027µF	2n7	272
2.2nF	.0022µF	2n2	222
1nF	.001µF	1n0	102
33pF	NA	33p	331
22pF	NA	22p	221



The DAC board is mounted in the rear righthand corner of the case. Use a white RCA socket for the left output and red for the right (not red & black as fitted to the prototype).

to get IC1 and IC5 mixed up, as they are both 14-pin devices.

Building the DAC Board

Refer now to the diagram of Fig.7 to build the DAC Board. This board is coded 01109092 (94 x 110mm) and is assembled in exactly the same manner as the Input Board.

Once again, if you buy a kit, the DAC Board will be supplied with the SMD IC (DSD1796) soldered into place. If not, you will have to install it as shown in Fig.8. As before, this device is mounted on the copper side of the PC board and is installed in exactly the same manner as IC3 (see following article). Make sure that it's mounted with pin 1 at lower left, as indicated by Fig.8.

That done, install the wire links, resistors, IC sockets and capacitors. Diode D15 (1N4004) and regulator REG5 can then be installed, making sure they are oriented as shown.

Follow these parts with the 16-pin IDC header and the two RCA output connectors. Be sure to follow convention and use a red RCA socket for the right output and a white socket for the left output. Check that the RCA sockets sit flush against the PC board and are aligned at right angles to it before soldering their leads.

Finally, complete the DAC Board assembly by fitting the ICs to their sockets. **OPA134 op amps are recommended for ICs7-12 but you can also use NE5534s for slightly reduced performance.**

Front Panel Switch Board

This board is coded 01109093 (103 x 34mm) and carries only a handful of parts: the three pushbutton switches, two 5mm LEDs, infrared receiver IRD1, a 100nF capacitor and a 14-pin DIL header. In addition, you have to install two wire links.

It should only take you about 15 minutes to assemble but note that the switches, IRD1 and the two LEDs are all installed on the copper (track) side of the PC board. Fig.9 shows the details.

Begin by installing the two wire links, the IDC socket and the 100nF MKT capacitor on the non-copper side of the PC board. **Be sure to orient the IDC socket correctly, ie, notched side towards the top of the board.**

Once these parts are in, temporarily install an M3 x 10mm tapped spacer

Parts List Additions & Changes

(1) The Input Board has been modified to also accept the Altronics 3V TOSLINK receivers. As a result, the following parts should be added to the parts list: 1 x 3-pin header and 1 x jumper link.

(2) The four M3 x 10mm tapped spacers specified for the Power Supply Board should be changed to 4 x 6mm untapped Nylon spacers.

(3) Add 2 x 100µF 25V electrolytic capacitors & 4 x 47µF 16V electrolytic capacitors to the parts list for the DAC Board. Delete the 1 x 47µF 6.3V electrolytic capacitor and reduce the number of 10µF 6.3V electrolytic capacitors to one.

(4) The DAC Board now measures 94 x 110mm, while the Front Panel Switch Board now measures 103 x 34mm.

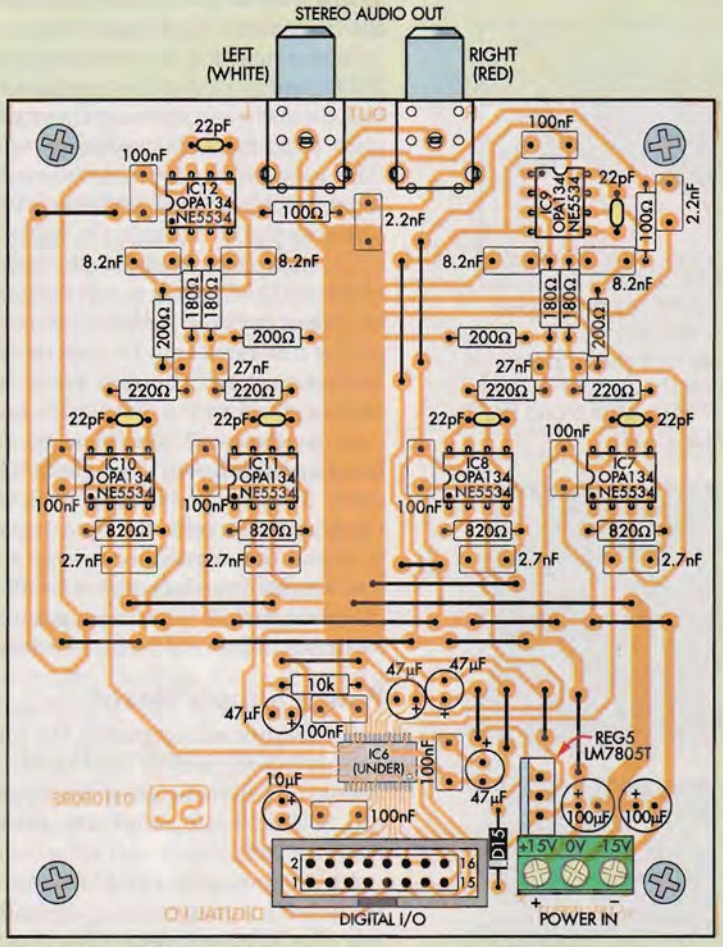


Fig.7: the DAC/output Board is easy to assemble but again make sure that the SMD (IC6) is installed first.

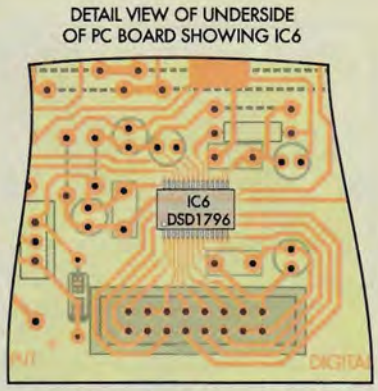


Fig.8: if you don't buy a kit, then install IC6 on the copper side of the PC board as shown here.

Power Supply Refinements

Our tests of several protoypes of this unit have shown that the brand of 7805 regulator on the DAC Board may slightly affect the THD performance. To remove this variability, the 47µF capacitors on the ±15V rails have been increased to 100µF 25V, while the three 10µF capacitors on the output of the 7805 regulator (REG5) have all been increased to 47µF.

These changes are all included on the parts layout diagram of Fig.7.

at each corner, with the spacers on the non-copper side and M3 machine screws passing through from the copper side (you can use the spacers that will later be fitted to the Input or DAC boards). This will ensure that the assembly will now sit level on your workbench and will make it easier to install the pushbutton switches.

Installing the three pushbuttons on the copper side of the board is the next step. These have angled pins at each corner plus two straight pins for the integral blue LED. The anode of the LED is longer than the cathode and must go into the hole marked "A" on the overlay (ie, towards the DIL header).

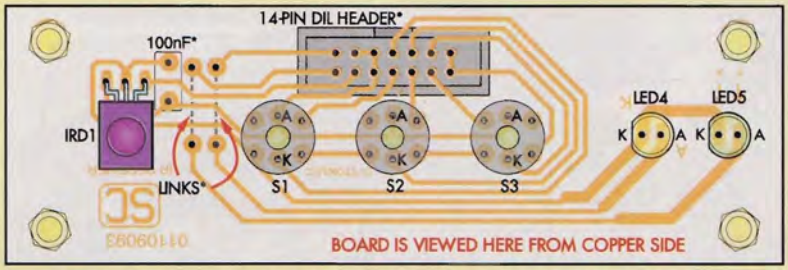
Once the pins are inserted through the holes, press the buttons down gently. Because of the way the corner pins are bent, they should not go all the way through. If one of the buttons doesn't sit parallel with the board, its pins have been bent, so adjust them using needle-nose pliers and try again.

Having fitted the switches to the board, place the flat face of a ruler along the top of the buttons and check that they all line up. That done, carefully solder two diagonally opposite pins for each button without disturbing them, then test fit the board to the front panel on 6mm spacers to make sure the buttons are all correctly aligned. Adjust them as necessary, then solder the remaining pins.

Next install the two 5mm LEDs. These are also inserted from the copper side with the green LED closest to the edge of the board and the yellow LED nearest the centre. The tops of the LEDs must sit 11mm above the board,

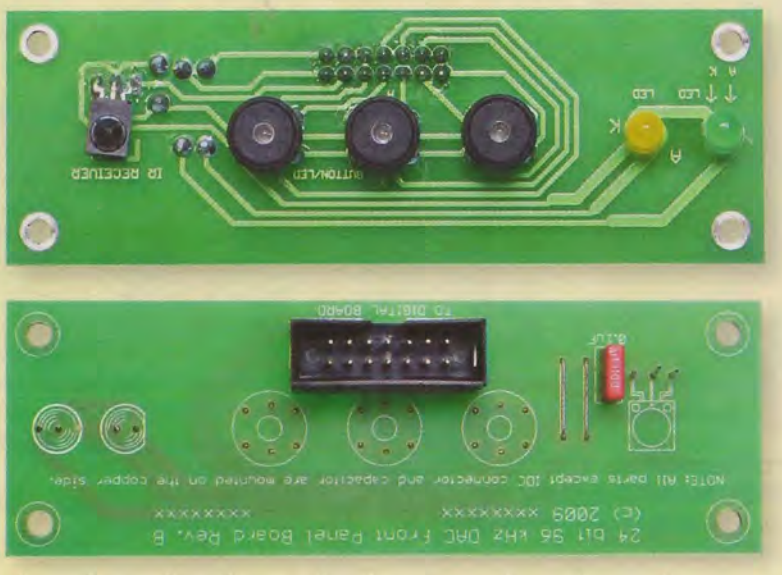
Table 3: Resistor Colour Codes – DAC Board

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	10kΩ	brown black orange brown	brown black black red brown
❑	4	820Ω	grey red brown brown	grey red black black brown
❑	4	220Ω	red red brown brown	red red black black brown
❑	4	200Ω	red black brown brown	red black black black brown
❑	4	180Ω	brown grey brown brown	brown grey black black brown
❑	2	100Ω	brown black brown brown	brown black black black brown



*NOTE: IRD1, SWITCHES S1-S3 AND LEDS 4 & 5 MOUNT ON COPPER SIDE OF THE BOARD. THE 100nF CAPACITOR, DIL HEADER & WIRE LINKS ARE ON OTHER SIDE.

Fig.9: the Front Panel Switch Board assembly. Note that the infrared receiver (IRD1), switches and LEDs are mounted on the copper (track) side of the PC board. The header, links and 100nF capacitor go on the other side. Take care with the switch orientation (see text).



These photos show the completed Front Panel Switch Board. Be sure to mount the IDC header with the orientation shown (ie, notch towards the edge of the PC board).

so that they will later protrude through the front panel by about 2mm.

In practice, this means mounting the LEDs 2mm proud of the board and this can be done by pushing them down onto a 2mm-thick cardboard spacer (slid between the leads) before soldering them. Make sure they are correctly oriented (ie, cathode to the left).

The last part to install is the infrared receiver (IRD1). This must be oriented as shown in Fig.9, with its domed lens facing outwards and in line with the switch centres. The rear of its body should sit about 1mm above the board.

In practice, all you have to do is bend its leads down through 90° about 2mm from its body, then push it all the way down onto the board against a 1mm-thick cardboard spacer to set the height. It's then just a matter of checking that its lens lines up with the switches before soldering the leads.

Power Supply Board

As mentioned last month, the power supply board used in the Stereo DAC was originally designed for the Studio Series Preamplifier described in October 2005.

Fig.11 shows the parts layout on the PC board (code 01109052). Install the low-profile components first, starting with the single wire link, resistors and diodes. To aid heat dissipation, the two 5W resistors should be mounted about 2mm proud of the board surface.

Take care with the orientation of the electrolytic capacitors and be sure

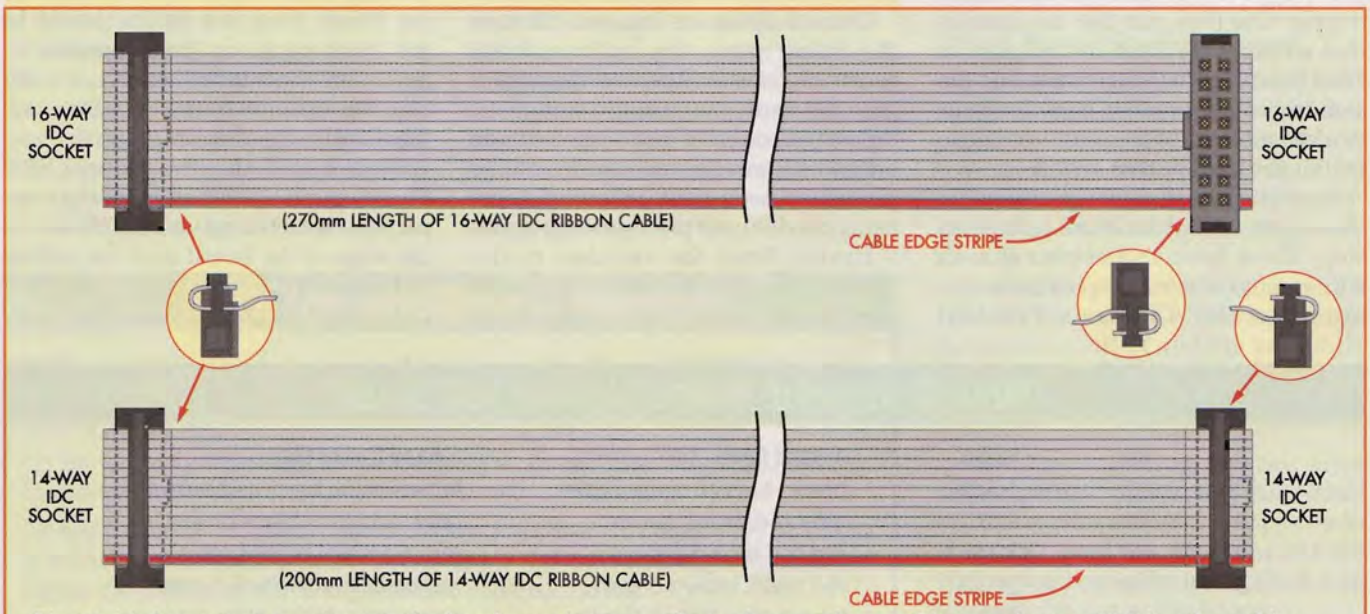


Fig.10: it's important to orientate the header sockets exactly as shown when making up the two IDC header cables. You must also leave about 15mm at each end so that it can be looped back and clamped with the locking bar.

not to interchange regulators REG1 and REG2. Note also that they face in opposite directions! It's not necessary to fit heatsinks to either of these two regulators, although they were fitted to the supply in the prototype (they came with the kit).

Unlike REG1 & REG2, regulator REG3 mounts horizontally and must be fitted with a heatsink. Bend its leads down 90° about 5mm from its body and trial fit it in position to verify that the hole in the tab lines up with its hole in the board. Adjust as necessary, then slide a TO-220 heatsink between the regulator and the PC board after applying a thin smear of heatsink compound to the mating surfaces.

Secure the assembly to the board using an M3 x 10mm screw, flat washer & nut. Don't solder the regulator's leads until after the screw has been tightened, otherwise the PC board tracks or the regulator package (or both) could be damaged.

Making the ribbon cables

Now for the two IDC cable assemblies. Fig.10 shows the details.

Start with the 16-way cable. First, cut this cable to a length of 270mm, then clamp a 16-pin IDC header socket (rectangular locating tab facing inwards) to one end, with the red strip going to pin 1. You can do this by sandwiching the assembly together in a vice or by using a crimping tool such as the Altronics T-1540. Be sure to leave about 15mm free at this end so that it can be looped back and clamped with the locking bar.

That done, fit a 16-pin header socket to the other end. This header must go on the opposite side of the cable, with the red cable strip again going to pin 1. As before, its locating spigot should again face inwards.

Basically, it's just a matter of orienting the headers at each end exactly as shown in Fig.10. Note that pin 1 on the header sockets is indicated by a small triangle in the plastic moulding.

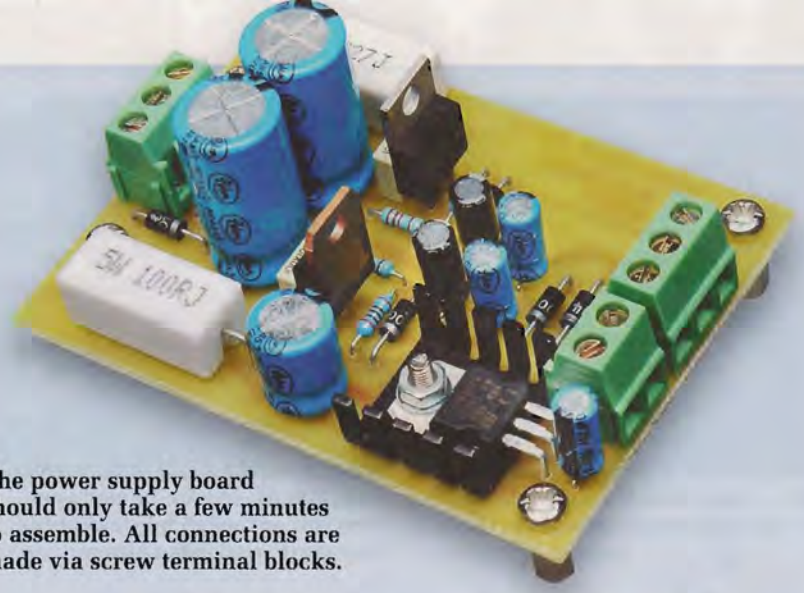
The 14-way cable is slightly different – see Fig.10. Begin by cutting the cable to 200mm and attaching a header socket to one end with its spigot facing inwards. That done, fit the second header socket to the other end of the cable on the same side. It should be oriented the same way as the first, with its locating spigot facing outwards.

Having completed the cables, it's vital to check that they have been properly terminated. If they are not crimped correctly, then some of the pins may be open circuit because the "blades" in the header sockets haven't fully pierced the cable insulation.

The best way to check them is to connect the PC boards together and then use a multimeter to check for continuity between the corresponding header pins on each board. If you do find any open circuits, then that cable should be discarded and a new one made up.

This procedure will also reveal if any of the header sockets has been incorrectly oriented.

That's it for this month. Next month, we'll show you how to assemble the modules into a steel case and get it all going. We'll also show you how to customise the remote control codes and the various software options. SC



The power supply board should only take a few minutes to assemble. All connections are made via screw terminal blocks.

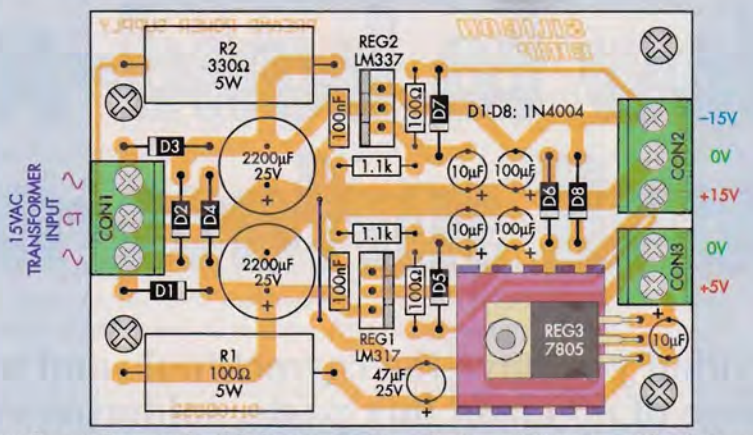
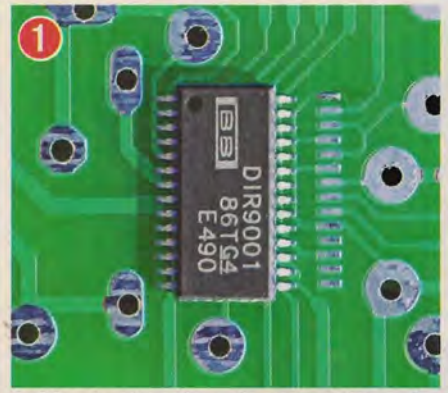


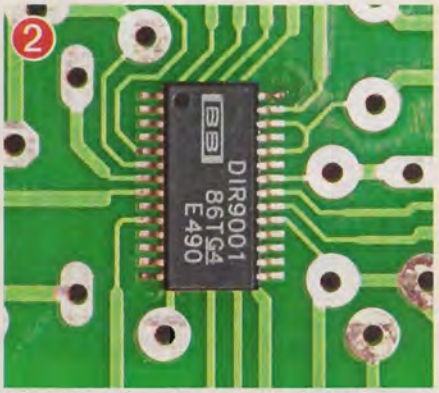
Fig.11: here's how to build the Power Supply Board. Don't get the 3-terminal regulators mixed up and note that REG3 is fitted with a heatsink.

Table 4: Resistor Colour Codes – Power Supply Board

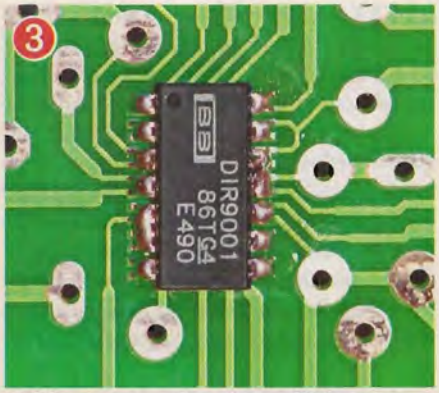
❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	2	1.1kΩ	brown brown red brown	brown brown black brown brown
❑	2	100Ω	brown black brown brown	brown black black black brown
❑	1	330Ω	orange orange brown brown	orange orange black black brown
❑	1	100Ω	brown black brown brown	brown black black black brown



Solder is placed on the top-right pad & the IC is positioned alongside the pad.



The IC is placed on the pads and then solder tacked in place at two diagonally opposite corners.



Solder is now placed on all the pins. The substance around the IC is flux from the solder.

How to hand-solder very small surface-mount ICs

Provided you have the correct tools and a syringe of no-clean flux paste, soldering very small SMDs (eg, TSSOP devices) into place is easier than you think. Here's how to do it.

By NICHOLAS VINEN

YOU HAVE TWO choices when it comes to soldering in the two surface-mount ICs used in the Stereo Digital-To-Analog Converter described in the previous article: either hand-solder them or use a homebuilt reflow oven.

In the latter case, you'll need to follow the instructions in the article titled "How to Solder Surface Mount Devices", SILICON CHIP, March 2008. However, not many constructors will go to the trouble of setting up a home-built reflow oven unless they handle surface-mount devices (SMDs) on a regular basis.

Fortunately, hand-soldering fine-pitch SMDs only requires a few basic tools and a little care. At the very least, you will need a small temperature-controlled soldering iron, a magnifying glass (preferably a magnifying lamp), some desoldering braid (or solder wick) and a syringe of no-clean flux paste (Altronics Cat. H-1650). You'll also need two pairs of tweezers, one straight and the other pair with angled tips.

Don't try to attempt the job without these basic tools, otherwise you could wreck both the ICs and the boards.

It's also vital to have lots of patience. You must treat each IC gently and avoid applying heat for long durations (more than 3-4 seconds at a time). The pins on TSSOP and SSOP devices are quite thin – in fact, they are noticeably easier to bend than larger surface-mount packages like SOIC/SOP (let alone DIP).

Soldering iron

A temperature-controlled soldering iron is the best iron to use here. Set the temperature to somewhere in the 350-400°C range. The lower end of that range is appropriate when applying solder while temperatures around 400°C should be used when heating the solder wick, as described later.

You don't need to use a very thin tip on the soldering iron. In fact, using a thin tip can actually make the process more difficult when it comes to applying enough heat to the solder wick and getting the solder to reflow properly. The standard tip supplied with most good irons should be sufficient and a medium to fine conical tip works well.

Be sure also to use fine, good quality solder (eg, 0.71mm diameter).

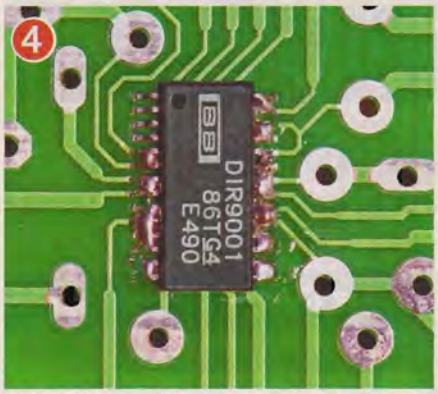
Step-by-step procedure

The step-by-step procedure for soldering in each SMD IC is as follows:

(1) Place the board flat on the workbench, copper side up.

(2) Apply a tiny amount of solder to the top right pad (top left if you are left-handed). To do this, briefly touch the pad with the soldering iron and add a dab of solder – just enough so that you can see smoke from the flux – then quickly remove the iron.

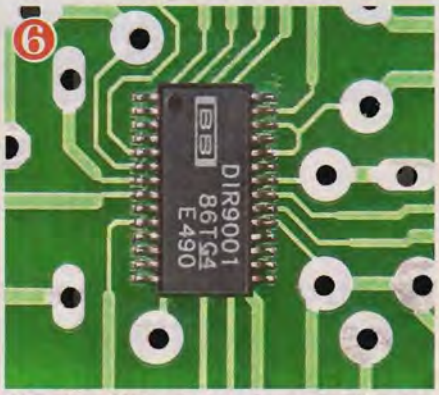
You should now be able to see a small solder bulge on that pad (check with



A thin layer of flux is applied to the pins & the excess solder removed using solder wick (eg, four pins at a time).



This shows the IC after the remaining pins have been cleared of the excess solder using solder wick.



Here the IC has been cleaned with isopropyl alcohol, to remove the flux residue (optional).

a magnifying glass if you are unsure).
(3) Clean the tip of the iron with a damp sponge to remove any excess solder.
(4) Place the IC next to (but not on) the pads. If you are right-handed, place it slightly to the left of the pads and vice versa. Ensure that the dot or divot in the corner of the IC (nearest pin 1) is oriented correctly.
(5) Grab the IC by the ends using a pair of tweezers.
(6) Use the soldering iron to melt the solder on the top-right pad, then gently slide the IC along the board and into place. Remove the soldering iron immediately it's in place. This process should only take a couple of seconds, to avoid overheating the pad.

Don't worry about getting it in exactly the right place the first time. Just try to avoid getting any solder on the other pins. As long as you do that, repositioning the IC is easy.
(7) If the IC is not exactly lined up with the pads, simply re-melt the solder and nudge the IC until it is. Wait a few seconds between each attempt. You need to get three things right: the vertical position, horizontal position and rotation. When it's correctly lined up, the pins will all be centred on the pads.
(8) Once you are happy with the alignment, rotate the board 180° and solder the pin at the diagonally opposite corner. The IC may still move a little during this step, so check the alignment again and adjust it as necessary.
(9) Now solder the remaining pins. Start in one of the two remaining unsoldered corners and apply solder to each pin. Do not worry about bridging them – in fact the simplest technique is to apply a small blob of solder between each pair. Make sure that all pads have solder flowed onto them but don't go overboard as you need to remove the excess later.
(10) Once all pins are soldered, apply a thin layer of flux paste along both rows towards the outside. A thin layer should be enough (you can always add more later if necessary).
(11) You now have to remove the excess solder. Begin by placing a length of solder wick immediately alongside (but not on top of) some of the pads. Now place the soldering iron on top of the solder wick, pressing it down onto the board, while gently sliding the wick towards the solder on the pads.

As the wick heats, it will start to melt the flux and the excess solder, creating visible smoke. At that point you can slide it right up against the pins. Most of the excess solder should then be sucked into the braid. Finally, slide the wick along the board away from the pads and lift it and the soldering iron off the board.

Do not apply any pressure directly onto the IC pins during this procedure. At all times, you should be pressing down onto the PC board only while sliding the wick along it. The whole process should take no more than about 5-6 seconds.

Don't worry if some solder is left behind – rather than applying the heat for too long, it's best to remove what's left with a second pass. When you are finished, the pins should be left with a near-perfect amount of solder and no bridges (see photos).
(12) Repeat this process all the way along both edges of the IC, moving the wick along a few pins each time. Don't do it twice on the same set of pins as most of the flux is used up in the process and the solder won't flow properly without it.
(13) Once you have gone around the entire IC, inspect the pins using a magnifying glass to check for any remaining solder bridges. There will likely still be some bridges after the first pass. Be sure to check high up on the pins where they enter the package, as sometimes solder can find its way up there.

If there are solder bridges, apply a little more flux to the affected pins and then repeat the process with the solder wick. Do this until all the pins are clear.

If you are using no-clean flux (ie, the recommended type) then you don't need to remove the flux residue. However, if you really want to, pure alcohol will dissolve it. SC



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SERVICEMAN'S LOG

Weird faults from car electronics

Electronic and electrical faults in cars can give rise to all sorts of weird faults. Often though, the fault itself is really quite simple although tracking it down can be quite a challenge.

Items Covered This Month

- Limping VR Statesman
- The Pulsar that wouldn't reverse
- What happened to Nine Digital?
- Komatsu dump truck Tiptronic gear selector

Back in the July issue, a colleague of mine related some interesting service stories on car electronics. This month, he's got several more interesting stories on car electronics to tell so I'll let him tell them in his own words.

The limping Statesman

One of our long-time customers recently brought in a Holden VR Statesman with what appeared to be serious automatic transmission issues. The car had all of a sudden gone into "limp" mode or more correctly, "limp home" mode. What happens is that whenever the control computer (ECU) loses any major inputs or detects a circuit malfunction, the transmission reverts to "third gear only" operation when drive is selected.

This allows the car to be driven, rather than towed, to a repair shop.

To explain this more fully, the VR series (1993 on) was the first Holden to utilise the electronically-controlled 4L60-E transmission behind their V6 and V8 engines. The 4L60-E was similar to the previous model's hydraulic unit (the 4L60), the difference being that gear shifts were now initiated by a series of 12V solenoid valves rather than the old method of complicated hydraulic hardware.

The transmission solenoids are operated by the same ECU that controls the engine's EFI system and other ancillaries. This was easily achieved because the engine and transmission shared many of the inputs required for their operation. The most important data comes from the TPS (throttle position sensor), the MAP (manifold air pressure) sensor and from temperature, road speed and engine RPM sensors. TPS and MAP are important in this instance, as they monitor accelerator position and engine load to enable correctly timed (and smooth) gear-changes – just as the old-style transmissions were controlled by a kick-down cable and vacuum modulator.

This was a perfect opportunity to use our diagnostic scanning tool. You just plug it in, read the codes, diagnose the problem, quote the job, order and fit the parts required and the customer is back on the road. Well, that's the theory and I wish it was always that

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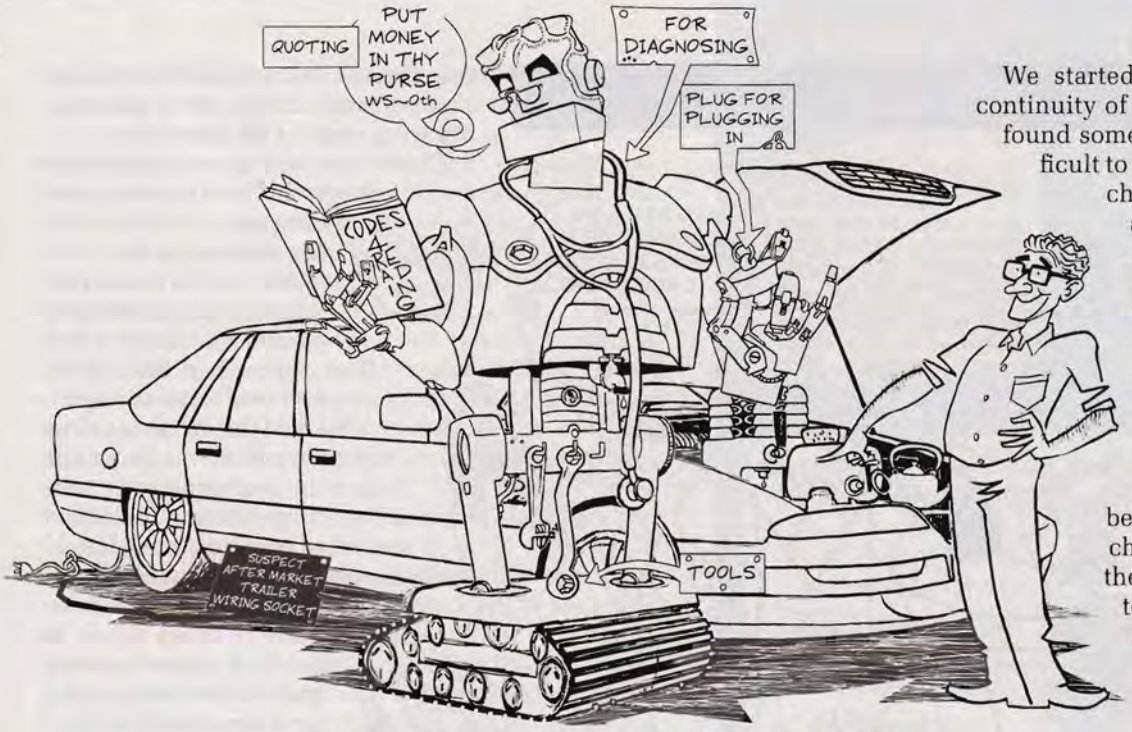
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simple! More often than not, it just doesn't pan out that way.

In this case, a fault code had been recorded for just about every device in the system. So how could you believe the readouts? Was every solenoid and sensor really faulty? I don't think so!

The first thing to check was that the wiring harness to the transmission had not been damaged or become unplugged? This was checked out but everything was intact so we erased all of the codes that had been recorded, then switched on the ignition to see which codes (if any) would log again. And immediately, the same mass of fault codes reappeared.

To coin a phrase: "Houston, we have a problem".

At this stage, we asked the owner if the car had been in an accident or had had any other work performed on it which could have led to this. We also wanted to know when the problem first manifested itself and under what circumstances.

Unfortunately, this provided no real clues. "It just happened all of a sudden yesterday", was the reply.

In cases like this, it's well worth starting with the basics, especially with Holdens (and other designs from manufacturers of US origin). Their electrical design is usually far more logical in layout and operation than the designs seen in many European and Asian cars.

Once the correct wiring schematic had been procured, it became clear than the circuit was very simple. All the transmission solenoids had +12V directly supplied to them and each one was then earth-switched by the control module, as and when required.

We started out by checking the continuity of the various circuits but found some of the pins a little difficult to access. In the end, these checks revealed nothing and once again I found myself wondering why so many fault codes were present. Other than the ECU, what is one common component that could cause these problems?

At this stage, I thought it might be better to change tack and chase some voltages with the good old multimeter, to see if that would shed some light on all of this. To my surprise, nowhere in the transmission control circuit was there any supply voltage present. Not one volt! Yet the car still started and drove well (except for the lack of gear changes).

A quick look at the circuit diagram showed that the common link was, in fact, a solitary 15A fuse for whole transmission. A blown fuse! – could it really be that simple or had we found the solution to one problem only to uncover yet another?

Fuses are inexpensive devices so the quick "fix" is to fit a new fuse, stand clear and see what happens. Well that seemed to be it. The replacement fuse didn't blow, the voltages were now all present and a quick scan revealed no fault codes. The engine was then started and we now had first gear when drive was selected.

It was time to take the Statesman for a test drive. The car now drove well, with all forward gear ratios being correctly selected. But the $64,000 question was "why had the fuse blown

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and would it blow again"?

It didn't take long to find out. The Statesman only managed to get about 1.5km into its test drive before suddenly reverting to limp mode again. Yes, the fuse had blown again so now we had to find out why.

The first thing to check was the possibility of damage to the wiring harness. Our experience has shown that short circuits in wiring harnesses can often be traced back to a collision or some other accident (eg, during major repairs). However, this car, even though it was now 14 years old, was in pristine condition. It was a "one-owner" vehicle with an immaculate service history and no previous collision damage or faults that required major repairs, so scratch that theory.

According to the wiring schematic, the fuse in question only supplied power to the automatic transmission and not much else. The only other item connected to this same fuse was the reversing light circuit. We replaced the fuse again, selected reverse and followed the reverse light wiring in an effort to locate the short.

No amount of tapping or pulling the wiring harness caused any problems until we got to the rear of the car. There, one firm knock on the rear bumper immediately blew the fuse. We were close to the money.

Closer inspection revealed some very suspect aftermarket wiring to the trailer-wiring socket. In fact, this turned out to be the root cause of the problem but why did it occur just now? This socket had been fitted and wired over a decade ago.

We asked the owner to tell us exactly what he was doing just before the fault emerged. After some thought, he finally realised that it had occurred immediately after he had disconnected his trailer from the car, following his monthly jaunt to the local waste transfer station (the modern day term for a rubbish tip).

It didn't take an Einstein to subsequently figure out what had happened. When the trailer plug had been removed, a retaining grub screw in the socket had been dislodged. This, in turn, allowed the bare pins to come into contact with the metal lid of the socket. You can guess which pin was shorted to earth as soon as reverse gear was selected!

A quick tidy up of the wiring socket plus a dob of "Loctite" on the grub screw solved the problem. If there's a moral to this story, it's to ask the client more questions than seem necessary at the time.

But why did the ECU log fault codes for all the solenoids, etc. The reason is that because the 12V supply was absent, the ECU detected and logged a fault for each branch of the transmission control circuit!

Smoothing a transmission

Fortunately, not all cars that come into the workshop are difficult to

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repair. Sometimes, quick and simple solutions are all that are necessary to fix the most hideous problems.

An old Nissan N13 Pulsar that paid us a visit a few months ago was a case in point. The complaint was that the car would not operate in reverse gear. It was fitted with an automatic transmission and when ever reverse gear was selected, the engine would suddenly shut down. This would happen even with the accelerator pressed down slightly.

The owner had thought the worst and was looking at the possibility of an automatic transmission overhaul costing several thousands of dollars. That's one of the downsides of front-wheel drive vehicles – transmission repairs are much more costly than in their rear-wheel drive counterparts.

Upon inspection, we found that on this model car, the air-conditioning compressor is wired so that it is switched on each time reverse is selected. This happens even if the air-conditioning system itself is switched off and is done to alleviate the age-old problem of the seals in the compressor drying out due to lack of use.

The problem in this case was that the compressor had completely seized some time ago and so each time it was switched on (ie, whenever reverse was selected), the engine was forced to stop rotating. The owner knew the compressor was shot, so he knew not to switch on the air-conditioner. But little did he realise that this was in fact the same issue.

He was short of funds and the car was in its twilight years, so the quick fix was to remove the drive belt to the compressor with the aid of a pair of side-cutters. Problem solved – the car now reverses superbly.

We didn't make any money out of this one. In the interests of customer goodwill, we performed this repair "on the house" but he duly rewarded us with a case of 24 small bottles filled with a tasty amber fluid.

What happened to Nine Digital?

So that's the car electronics business. I'm really missing out on something here – no-one ever rewards me with a case of beer, so it looks like I'm in the wrong game.

OK, time for some stories of my own. We'll start with what happened to the Channel 9 digital signals a few months ago.

On August 5th (a Wednesday), TCN Channel Nine altered the Service Information Parameters (SI or service ID) of its digital television multiplex signal that's transmitted Free-to-Air (FETA). I'm unsure as to the exact technical reasons for this but apparently it was necessary to support Nine's new Standard Definition channel called "GO!"

Unfortunately, this change also upset the tuning on many digital TVs and set-top boxes (STBs). As a result, what's left of the TV service industry was inundated with calls from viewers complaining that they either couldn't get Channel 9 or that there was no sound on Channel 9 or that the picture was pixellating and dropping out. These problems affected the digital channels only of course, with analog reception being unaffected.

However, these symptoms didn't affect all sets and STBs equally, with many sets not being affected at all. Many such sets just automatically retuned (or tuned)



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This close-up view shows the optocoupler and slotted metal skirt interruptor in the Komatsu's electronic transmission selector. The slot in the skirt is arrowed.

to channels 350, 351 and 352 for Nine Digital, Nine HD and GO! Respectively – corresponding to digital channels 9, 90 and 99 (8, 80 and 88 regional).

Of course it's an ill wind that does nobody any good and we made some money retuning sets for lots of customers. It's surprising how many people have no idea how to do this themselves or are completely unwilling to give it a go. Inevitably, some customers with new TVs tried to argue that this should be done under warranty but no-one was wearing that argument.

In the process, we also found that very few people had managed to tune in ONE HD which had also recently been introduced. In fact, many people are still unaware of its existence, despite the publicity.

At present, there are officially 13 FETA (Free-To-Air) stations (depending on the region) in the Sydney area – eight of these standard definition and five high definition. They are SBS ONE, 7 Digital, 9 Digital, 10 Digital, ONE HD, ABC HDTV, ABC1, ABC2, SBS HD, SBS TWO, 7 HD Digital, NINE HD Digital and GO!

These should, where possible, be selected as "Favourites" and the rest skipped. This is best done after first doing a full factory reset to erase the old stations and then a full SEARCH/AUTO TUNE – unless, of course, you particularly like watching Teachers TV or Parliament or listening to the radio on your TV!

In the midst of all this chaos, we encountered further problems. Many people are able to receive identical channels from a number of different transmitters. With a full AUTO TUNE, it is not unusual to finish up with 50-100 channels. If any of these signals has a signal strength less than about 24dB or is otherwise of poor quality, the channel will pixellate and the sound will drop out intermittently.

Unfortunately, determining the good-quality signals and deleting the poor-quality ones is very time-consuming and, at times, confusing process.

Also some TVs and STBs use complicated menus to navigate through. Many people just do not understand the concept of "Favourite" channels and its purpose of allowing you to quickly select your favourite stations. In our case, we simply find it easier to delete or skip unwanted channels.

My final job in this saga was to retune Channel 9 for some pensioners at a large retirement village. It took me a very long time to find out what almost everyone else already knew. The village uses a "channelised" distribution system and apparently the Ch9 amplifier had gone down (what timing!). If only I had asked at the office first!

The antenna contractor fixed it. Perhaps it just needed rescanning as well.

Dump truck

I'm now also getting my fair share of car computers with leaky electros, dry joints and corrosion. These jobs are usually routine but one interesting repair that I did involved a dump truck – you know, one of those big yellow things they use in open cut mines.

It was actually a 9-metre Komatsu Dump Truck (HD65-5) with a faulty Tiptronic electronic gear shifter that was dropping out of Neutral and Reverse. The shifter was dropped into my workshop and I could see as I dismantled it how well made it was, with beautifully welded and machined parts.

The circuit on the PC board was simple enough. At its heart were seven optocouplers arranged in a semicircular pattern. These were interrupted by a metal skirt with a slot attached to the gear lever. Depending on which gear was selected, this slot provided a light path for one of the optocouplers, allowing it to switch on.

Five of the outputs from these optocouplers feed a Darlington driver IC, which then drives solenoid relays in the gearbox. Fortunately, none of these were faulty. Similarly, the Reverse and Neutral optocouplers drive power transistors which in turn drive their relevant gearbox solenoids.

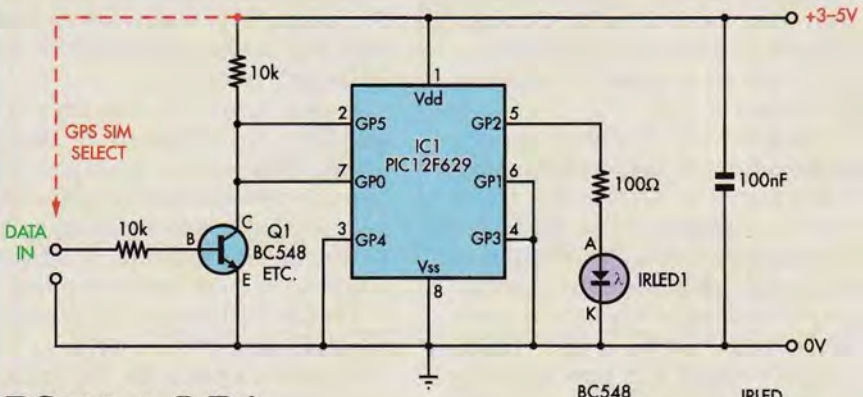
At first, I tested the unit with a digital multimeter and a 12V power supply and it all seemed to work OK. However, when I swapped the multimeter for a 12V lamp, anomalies started to appear due to the increased load of the lamp.

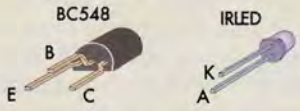
Eventually, I discovered that although the PC board looked OK, some of its tracks were intermittently open circuit due to hairline cracks. These could only be seen after I cleaned the tracks with a glass-fibre pen and took a close look at them through a magnifying glass.

Reworking the solder joints on the board and repairing the tracks solved all the problems. For good measure, I also replaced the sole electrolytic capacitor on the board and tested it thoroughly before returning it to the auto-electrician for re-installation in the dump truck. 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.





RS232 to IrDA transmitter

This circuit converts an RS232 signal into an IrDA transmission. Its purpose is to transmit 4800 baud NMEA sentences from an OEM GPS module into the infrared port of a PC or PDA. There are two versions: one with the converter function only and one with a GPS simulation function.

The input transistor isolates the negative-going RS232 signal from the PIC12F629 microcontroller. The PIC converts the signal by checking the input (GP5) and controlling the LED. The LED emits a pulse for logic lows. The PIC goes to sleep if no data is detected for 10 seconds and wakes up when data input resumes. Sleep mode removes the need for a power switch.

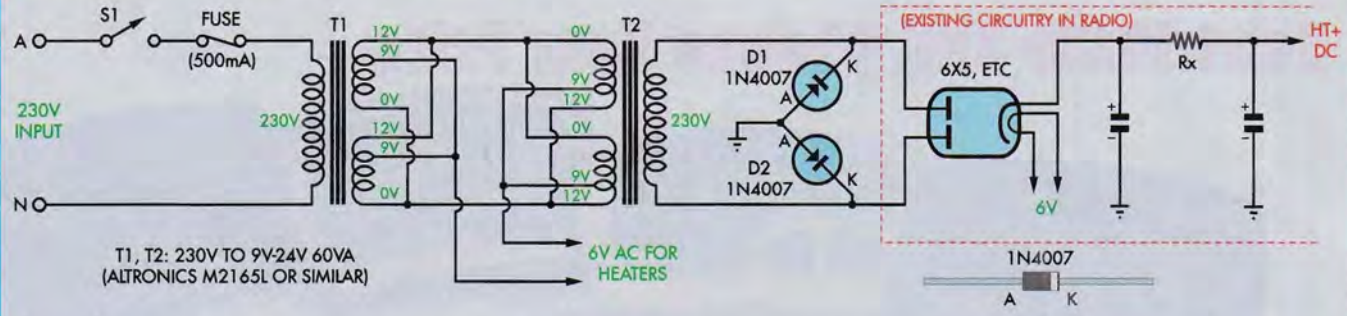
Simulation mode transmits a few basic NMEA sentences. It is entered by placing and holding Vdd on the input when the PIC is in sleep mode. Simulation mode is useful for software and IrDA port testing without a GPS. The simulated present position is Brisbane Airport. Edit the LAT/LONG data in the GGA and RMC sentences to change the position.

The circuit operates from 3-5V DC. The prototype used a 3.7V lithium-polymer battery from a cheap RC helicopter that was smashed. Current drain in operation is a few milliamps and is negligible in sleep mode.

For visual indication, a high-brightness red LED can be used instead of the IR LED but range is reduced.

Before programming the PIC, it is important to read the calibration value located at address 3FFh. This value should be entered during programming for accurate timing. The software (IrDA.hex & IrDA.asm) is available from the SILICON CHIP website.

Greg Poole, Oakey, Qld. ($40)



Replacement for a power transformer in a valve radio

This circuit uses two off-the-shelf transformers to replace a power transformer that had burnt out in a valve radio. The original transformer is no longer available and so there is no easy drop-in replacement.

The two transformers are standard types with two 12V windings tapped at 9V. In each case, the two 12V windings are connected in parallel as shown. With the low voltage secondary of transformer T1 driving the low voltage windings of T2, the two 9V windings will have a difference between them of 6V AC which can be used to drive the valve heaters.

Transformer T2 is driven back-to-front so that its 230VAC winding becomes the output to drive the plates of the rectifier valve. This is used in conjunction with two 1N4007 diodes to provide bridge rectifier operation – the original transformer had a centre-tapped secondary winding and only required the two diodes in the valve rectifier. The value of the dropping resistor Rx, between the two existing filter capacitors in the radio chassis may need to be varied to obtain the correct HT DC voltage for the radio.

Naturally, you will need to ensure that the radio chassis has enough space to mount the two transformers. The specified transformer is Altronics Cat. M2165L or equivalent.

Roderick Wall,
Dandenong, Vic. ($35)

Audio power meter with programmable load

This circuit will measure the RMS output power of an amplifier and display the result on a digital multimeter set to read DC volts. The resistance load for the amplifier is shown as 8Ω but the circuit can also accommodate 4Ω and 2Ω loads. It will also measure the output of an audio amplifier with a bridged output.

The circuit combines logarithm and exponential functions to achieve the result. It can be broken down into three converter stages:

(1) an AC-DC converter based on IC2a, IC2b and diodes D1 & D2;

(2) a logarithm converter based on IC1b & IC1c, together with transistors Q1 & Q2; and

(3) an exponential converter based on IC3b & IC3c, transistors Q3 & Q4 and three attenuators.

Starting at the input, the AC signal from the audio amplifier is fed into an 8Ω 100W resistor. From there, the voltage is divided by 10 and buffered by voltage follower IC1a. The output from the voltage follower then feeds the AC-DC converter and a DC replica of the AC input signal appears at its output, pin 7 of IC2b. This DC voltage is coupled into the logarithm converter via slide switch S3. This converter performs the function $-\log_2 N$ where N is the DC voltage at the output of IC2b.

The resulting DC voltage appears at the output of the logarithm converter (pin 8 of IC1c) and is fed to inverting amplifier IC3a which has a voltage gain of -2. The output of this amplifier follows the function $\log_2 N^2$ or $2\log_2 N$ where N is again the DC voltage at the output of IC2b.

IC3a's output is in turn fed to the exponential converter based on the remaining op amps in IC3. This converter performs the function 2^N where N is the DC voltage at pin 1 of IC3a. An overall measurement function of N^2 now appears at pin 8 of IC3c.

This DC voltage is coupled to the second attenuator via switch S1. This attenuator divides the voltage at its input by a factor of 8 (for the 8Ω setting). Letting N = V then gives the expression $V^2/8$ which is the equation this circuit uses to compute the RMS power of the audio amplifier. This attenuator is buffered by op amp IC3d which drives an attenuator associated with switch S4 and which has a division ratio of 10.

This results in an overall measurement function of power P = 1mV/W. For example, if the power is 50W, then the voltage displayed by the DMM will be 50mV.

Switch S4 is used when the audio amplifier is configured in bridge mode. This setting multiples the circuit's measurement function by four so that when measuring the power in bridge mode, the DMM will display four times the power.

The Cal/Test position of switch S3 enables selection of a range of test voltages via switch S2. Calibration needs to be done at a set temperature, ideally 25°C.

To calibrate, set switch S2 to 2V and switch S3 to Cal/Test. Then adjust trimpot VR1 until the output of the logarithm converter (pin 8 of IC1c) reads -1V. Then adjust trimpot VR2 until the voltage at pin 8 of IC3c is 4V. The accuracy of the power measurements will depend on the tolerance of the resistors and the accuracy of the digital multimeter.

Malcolm Sharp,
Berala, NSW. ($70)

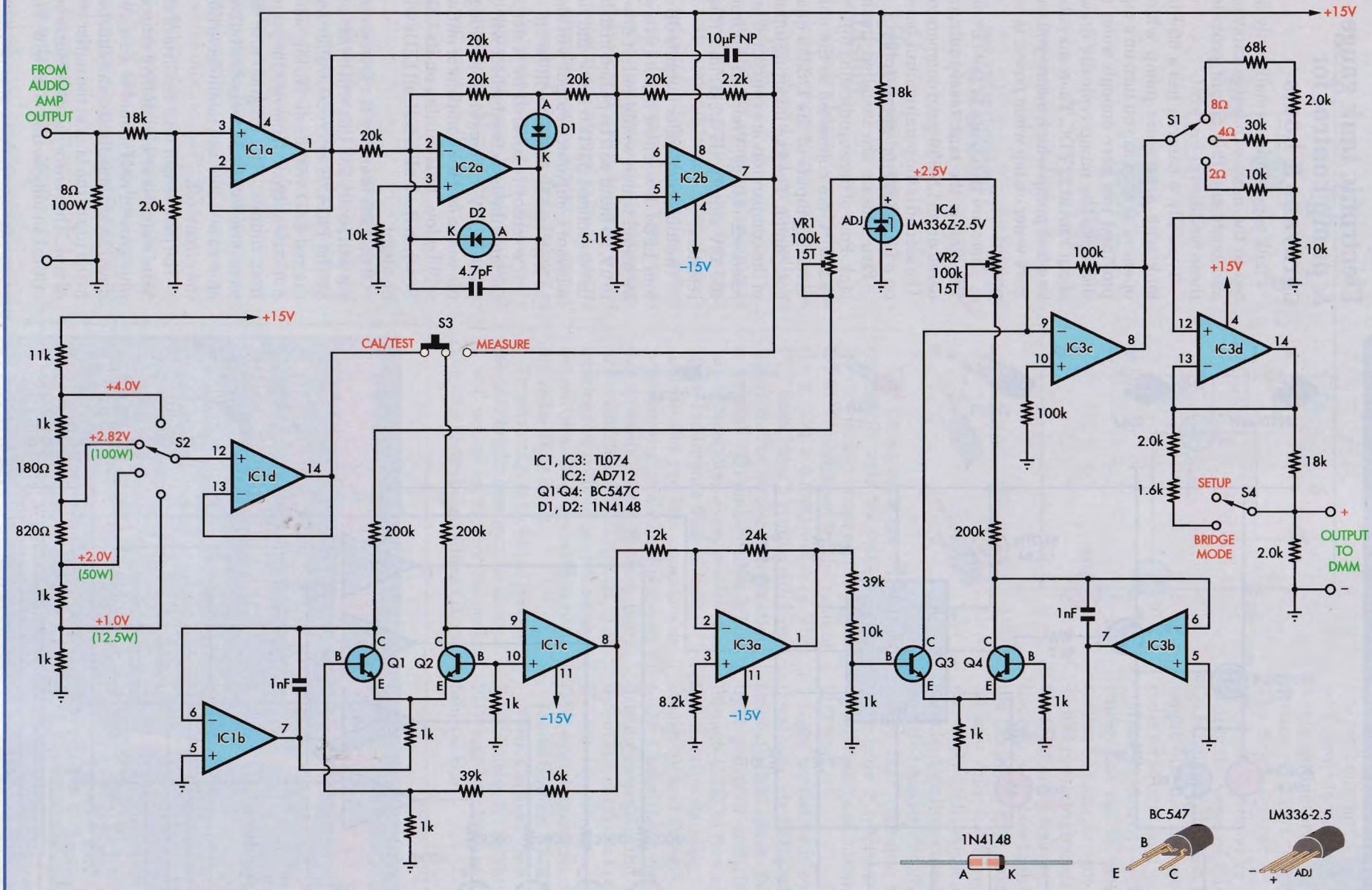
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The Audio Power Meter circuit can be broken down into three converter stages: (1) an AC-DC converter based on IC2a, IC2b and diodes D1 & D2; (2) a logarithm converter based on IC1b & IC1c, together with transistors Q1 & Q2; and (3) an exponential converter based on IC3b & IC3c, transistors Q3 & Q4 and three attenuators.

Electronic tank gauge & pump control for caravans & boats

Tank gauges are normally only fitted to the more expensive caravans and boats and this circuit provides these facilities at low cost.

Typically, a caravan has a 60-litre tank with a pressure pump which operates as soon as you turn on a tap, provided you have enough water in the tank. The pump typically draws about 1.8A at 12V DC. There may also be a foot pump which means you can have water on tap when power is not present.

There are two parts to the circuit. The first is the tank level indicator based on an LM339 quad comparator. The second is the pump control, based on a PICAXE08 microcontroller.

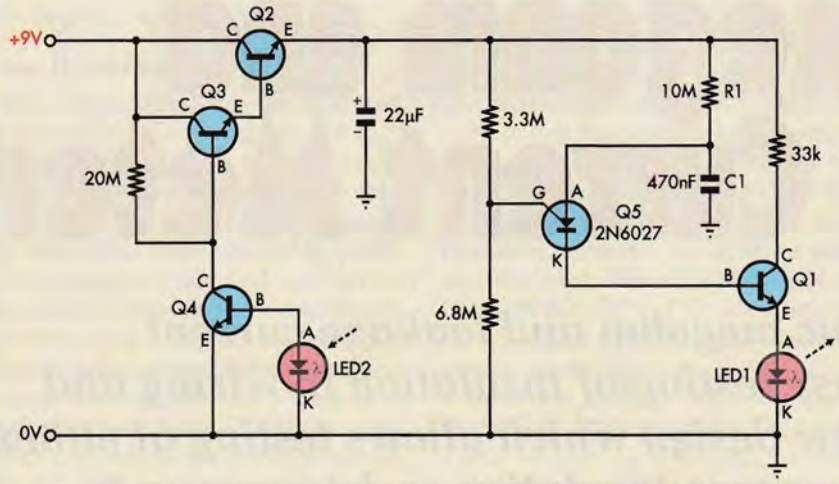
Five sensors are installed in the tank. Four of these, indicating full, ¾, ½ and ¼, are connected to the non-inverting inputs of the LM339 quad comparator. The four inverting inputs of the comparators are connected to a reference voltage, Vref, derived from the 12V supply via 3.3kΩ and 10kΩ resistors.

The four comparator outputs drive four LEDs. If a sensor is not covered by water, which would pull it down to 0V, its input will be pulled high by the associated 33kΩ resistor and the relevant comparator output will also be high and so its LED will be off.

If a sensor is covered by water in the tank, the associated sensor will be pulled to 0V, via conduction through the water, and the comparator output will be low, thus turning on its LED. So when the tank is full, all LEDs will be alight.

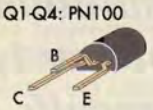
If the tank is empty, the lowest sensor will be dry and this will be sensed by the PICAXE microcontroller and the red LED will flash. At the same time, the micro will prevent the pump from running. The program also detects no activity and sounds a buzzer after 15 minutes, as a reminder to turn the circuit off.

The tank sensor unit consists of six 5mm stainless steel rods (five sensors plus ground rod) mounted on a cut-down Nylon breadboard and attached to the top of the tank at the outlet end of tank. The sensor rod diameter is not critical so long as they are rigid. The



LED1: JAYCAR ZD-0283 (RED) OR ZD-0282 (GREEN)
LED2: JAYCAR ZD-0283







Ultra-low power flasher

Here is a flasher circuit which has very low current drain, such that the battery should last for virtually its shelf-life.

CMOS IC timer are commonly used for this purpose but they typically draw 50-200µA, most of which is used to control the timing rather than to generate light. This circuit uses a programmable unijunction transistor (PUT) to generate a brief repetitive pulse of current and is notable because almost no energy is wasted. Current drain is kept to a minimum by the use of unusually high resistance values but the circuit is quite reliable and the average current drawn is about 4µA.

The timing capacitor C1 charges through R1 until the voltage across it exceeds the voltage on the gate of the PUT, as defined by the ratio of the 3.3MΩ & 6.8MΩ resistors. The PUT then "fires", rapidly discharging C1 via the base-emitter junction of transistor Q1 and the ultra-bright LED1, generating a very brief (about 10ms) but intense flash of light.

Since the eye has considerable persistence after a stimulus ceases, the intensity of the flash is more important than its duration. The flashing rate is about one per second but can be easily adjusted by varying the value of R1 or C1.

Transistor Q1 is included to boost the LED brightness even further, as it will act as an emitter follower. The discharge pulse turns Q1 on and extra current will flow via its 33kΩ collector resistor to LED1. The brightness of the flash can be set by adjusting the value of this resistor. If Q1 is omitted, the flash is still quite bright but the average current is reduced to only 2µA.

If flashing is only required at night, battery life can be extended even further by a simple light-suppressed switch involving transistors Q2-Q4. Q2 & Q3 are connected as Darlington pair, with bias to the base of Q3 via the 20MΩ (2 x 10MΩ) resistor. Because only 4µA is required, this extremely high resistance provides sufficient emitter current in Q2 to drive the flasher circuit.

The 22µF capacitor is essential to provide a reservoir to supply the brief surge of current when the PUT fires.

Light regulation is obtained in a novel way, via LED2 which senses ambient light. Even dull ambient light provides sufficient current through LED2 to turn on transistor Q4, to bring its collector down to almost 0V and thereby turn off Q2 & Q3. Under these conditions, the flashing ceases and the daytime quiescent current drops to about 0.5µA. If light regulation is not needed, Q2-Q4 can be omitted.

James Goding, VK3DM,
North Carlton, Vic.

Editor's note: the 2N6027 or 2N6028 PUT can be obtained from www.futurlec.com

James Goding is this month's winner of a Peak Atlas Test Instrument

breadboard or other non-conductive material (about 12mm thick) is used to give stability to the rods, as the tank top is not thick enough.

If the tank is used for rain water, which has less conductivity than town water, the 33kΩ resistors at the non-inverting pins of the comparator and the input to the PICAXE08 should be 56kΩ to ensure reliable detection.

The software required for the PICAXE (Manpump1.bas) can be downloaded from the SILICON CHIP website.

Ray Sonter,
Bundaberg, Qld. ($50)

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Digital Megohm and Leakage Current Meter

Looking for an electronic megohm and leakage current meter, for quick and easy testing of insulation in wiring and equipment? Here's a new design which allows testing at either 500V or 1000V. It can measure insulation resistances up to 999MΩ and leakage currents to below 1μA. It uses a PIC microcontroller and displays the results on a 2-line LCD panel.

By JIM ROWE

Domestic and industrial equipment operating from the 230V or 400V AC power mains needs to have its insulation checked regularly, so that users can be assured that it doesn't pose a shock hazard. After all, exposure to voltages of this magnitude can be fatal!

But what sort of test gear do you need to carry out this type of safety check? You'll get a fair idea by reading the text in the Insulation Testing panel on the opposite page.

In a nutshell, you need a portable and isolated meter that is capable of providing a nominal test voltage of 500V or 1000V DC and able to measure leakage current or insulation resistance or both.

Our new Megohm and Leakage Current meter design is intended to meet these requirements. It is compact, portable and isolated and provides a choice of either 500V or 1000V DC as the test voltage.

It also allows you to measure insulation resistances from below 1MΩ up to virtually 999MΩ, as well as leakage currents from below 1μA to over 100μA (103μA, to be precise).

We should point out that because it can only measure leakage currents up to 103μA, it will indicate that Class I equipment (with earthed external metalwork) is effectively unsafe if it has a leakage current of more than 100μA – even though, strictly speaking, this kind of equipment is still regarded as 'safe' providing its leakage current is below 5mA.

So the test performed by this meter is more rigorous than the official safety standards – but where safety is involved it's better to be too tough than not tough enough, surely?

The new meter is easy to build, with most of the major components mounted on a small PC board. This fits inside a compact UB1 size jiffy box, along with a small power transformer used in the test voltage generation circuit and the 4-AA battery holder used to supply the meter's power. It can be built up in a couple of hours and for a much

lower outlay than commercially available megohm meters.

How it works

The block diagram, Fig.1, shows what is inside the new meter. It's split into two distinct sections: that on the left-hand side generates the test voltage of 500V or 1000V, while the metering section on the right-hand side is used to measure any leakage current which flows between the test terminals and from this calculate the external resistance connected between them.

In more detail, the test voltage generation section has a DC-AC inverter which converts 6V DC from the battery into AC, so it can be stepped up to a few hundred volts AC. This is fed to a voltage-multiplying rectifier circuit to produce the 500V or 1000V DC test voltage.

We use a negative feedback loop to control the inverter's operation and maintain its output voltage to the correct level.

This works by using a high-ratio voltage divider (RD1 and RD2) to feed a small proportion of the high voltage DC output back to one input of comparator IC2b, where it is compared with a 2.50V voltage reference.

The comparator is then used to turn off the DC/AC inverter when the high voltage reaches the correct level and to turn the inverter on again when the voltage is below the correct level.

The basic voltage divider using RD1 and RD2 alone is used to set the high voltage level to 500V, with multi-turn trimpot VR1 allowing the voltage to be set very closely to this level.

To change the test voltage level to 1000V, switch S1 is used to connect RD3 in parallel with RD2, doubling the division ratio of the divider and hence doubling the output voltage maintained by the feedback loop.

Note that the inverter only operates to generate the 500V or 1000V test voltage when TEST button switch S2 is pressed and held down. As soon as the button is released, the inverter stops and the high voltage leaks away via RD1 and RD2/RD3. This is a safety feature and also a simple way to achieve maximum battery life.

Referring back to Fig.1, the meter section is at lower right. It uses a 10kΩ resistor as a 'shunt', to sense any leakage current (I_L) which may flow between the test terminals. Since the shunt has a value of 10kΩ, this means that a leakage current of 100µA produces a voltage drop of 1.00V. It is the voltage across this resistor which we measure, to determine the leakage current.

First the voltage is fed through a DC amplifier (IC2a), where it is given a voltage gain A of 3.1 times. Then it is passed to IC3, a PIC16F88 microcontroller which is used here as a 'smart' digital voltmeter.

The amplified voltage from IC2a is fed to one input of the ADC (analog to digital converter) inside the micro (IC3), where it is compared with a reference voltage of 3.2V.

The digital output of the ADC is then mathematically scaled, to calculate the level of the leakage current in microamps (µA). The micro is then also able to use this calculated current level to work out the insulation resistance, because it can sense the position of

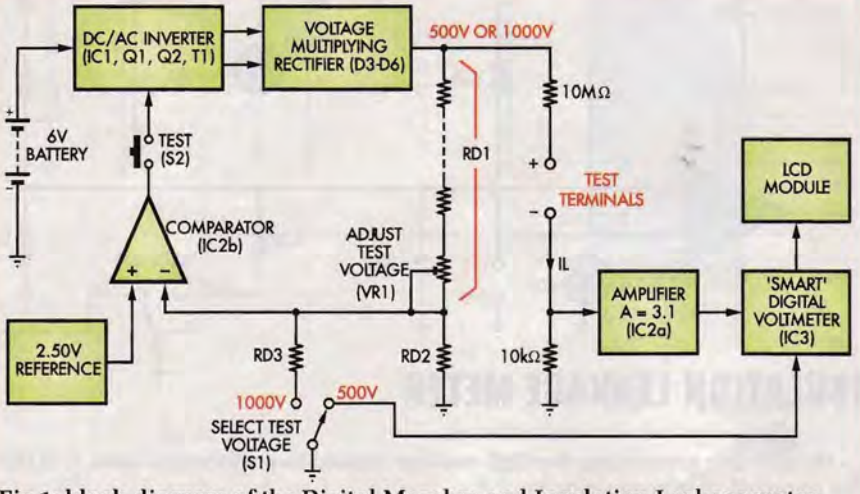


Fig.1: block diagram of the Digital Megohm and Insulation Leakage meter.

Insulation Testing

Testing the insulation of mains powered cables & equipment is an important step in ensuring that they are safe to use and don't pose a shock hazard.

According to the Australian and New Zealand standards for safety inspection and testing of electrical equipment (AS/NZS 3760:2003), tests on the insulation of 'domestic' cables and equipment operating from 230VAC should be carried out with a testing voltage of 500V DC. Similarly the recommended testing voltage for insulation tests on 'industrial' equipment like ovens, motors and power converters operating from 3-phase 400VAC is 1000V DC.

Insulation tests on domestic 230VAC equipment can be performed by measuring either the leakage current or the insulation resistance. For Class I equipment with accessible earthed metal parts, the leakage current should be no greater than 5mA, except for portable RCDs (residual current devices) where it should not be greater than 2.5mA. The insulation resistance for these devices should be not less than 1MΩ, or not less than 100kΩ for a portable RCD.

For Class II (double insulated) equipment, the insulation resistance with the power switch 'on' measured between the live supply conductors (connected together) and external unearthed metal parts should again be not less than 1MΩ.

The same insulation resistance figure of 1MΩ applies to extension cables and power boards (between the live conductors and the earth conductor), to power packs (between the live input pins and both output connections) and also to portable isolation transformers (between the primary winding and external earthed or unearthed metal parts, between primary and secondary windings, and also between the secondary winding and external earthed or unearthed metal parts).

switch S1 and hence 'knows' whether the test voltage being used is 500V or 1000V.

So all it has to do is calculate the total resistance which will draw that level of leakage current from the known test voltage, and then subtract the 'internal' 10MΩ and 10kΩ resistors from this total value to find the external resistance between the test terminals.

The calculated leakage current and insulation resistance values are then displayed on the LCD panel, along with the test voltage of 500V or 1000V.

The 10MΩ resistor connected between the high voltage generation circuit and the positive test terminal (ie, inside the meter), is included mainly to limit the maximum current that can be drawn from the HV generator – even in the event of a short circuit between the test terminals.

In fact it's the 10MΩ resistor which limits the maximum current to 100µA with the 1000V test voltage, or 50µA at 500V.

Another function of the 10MΩ resistor is to make the meter safer to use; if you accidentally become connected between the test terminals yourself, you will get a shock but it won't kill you. Mind you, that shouldn't happen, because you would have to be simultaneously holding down the TEST button to get a shock.

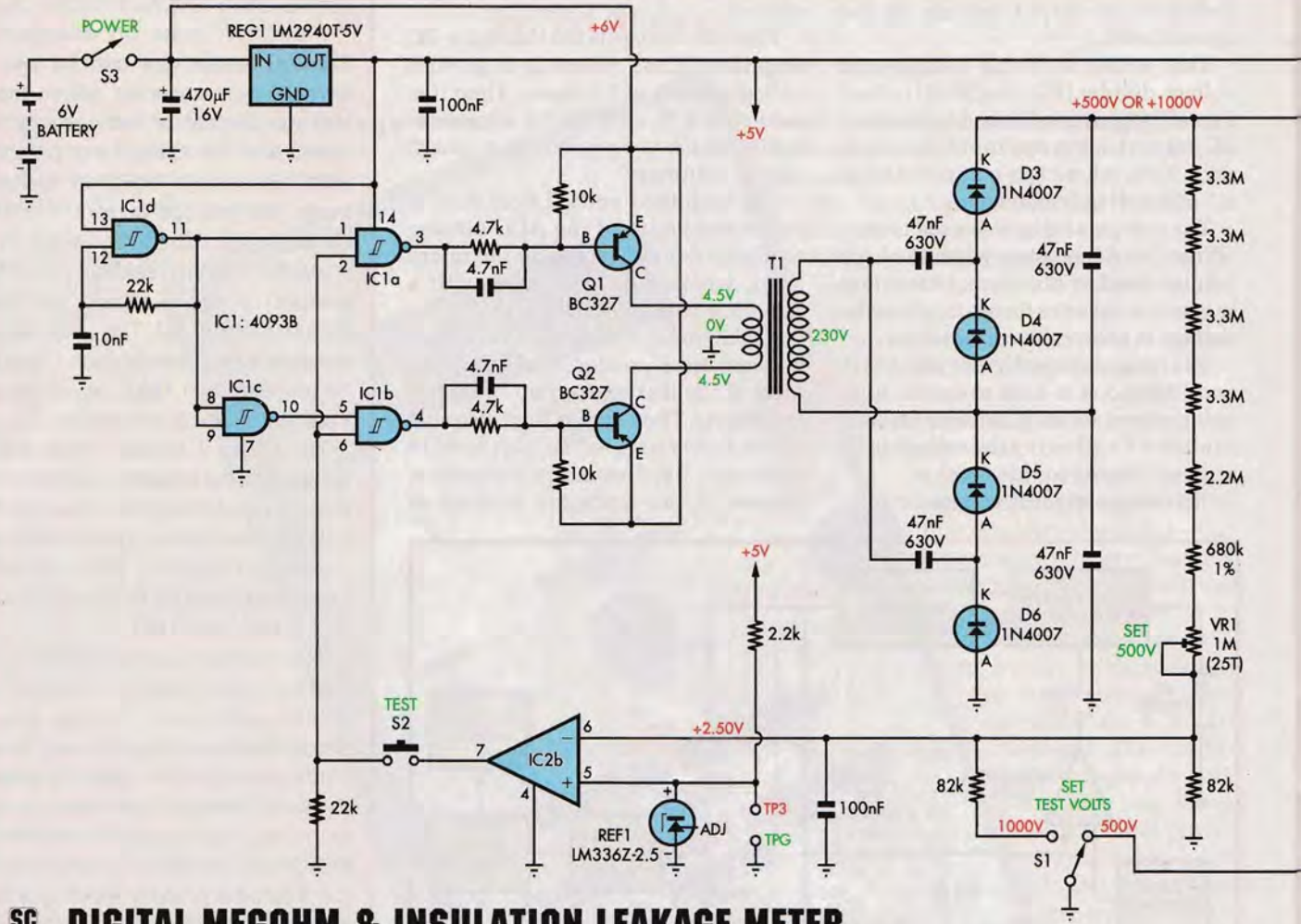
As you can see from the above explanation of the way the meter's smart voltmeter works, there is no problem having the 10MΩ current limiting resistor in series with the test terminals, just as there's no problem using a 10kΩ current measuring 'shunt'. The program inside the PIC knows that both of these resistors are in series with the external resistance being measured and simply subtracts 10.01MΩ from the total resistance to find the external value.

Circuit details

Fig.2 shows the full circuit. The DC/AC inverter section of the circuit uses IC1, a quad Schmitt NAND gate, to drive switching transistors Q1 and Q2. When the inverter is operating the transistors switch about 5.6V DC alternately to either end of the low voltage winding of a standard mains transformer, T1.

This is used as a step-up to produce a much higher AC voltage to feed the voltage-multiplying rectifier comprising diodes D3-D6 and their associated 47nF/630V capacitors.

Oscillator IC1d runs continuously at about 6kHz and its output is inverted by IC1a & IC1c. IC1c drives inverter IC1b while IC1a and IC1b apply the alternating signals to the bases of transistors Q1 & Q2. But gates IC1a & IC1b



SC 2009 **DIGITAL MEGOHM & INSULATION LEAKAGE METER**

Fig.2: the circuit is essentially two parts – the left side generating the high voltage needed to perform the tests and the right side using this voltage to perform the required measurements.

have their pins 2 & 6 pulled down by a common 22kΩ resistor and so they are disabled until the TEST button (S2) is pressed.

When that happens, comparator IC2b will pull IC1a's pin 2 and IC1b's pin 6 high and the inverter will run until the output of the voltage multiplying rectifier reaches the correct voltage level. As soon as the high voltage output reaches the correct level, the comparator's output will switch low and gates IC1a and IC1b will be turned off, stopping the inverter even if S2 is still being held down. The feedback network will maintain this process as long as S2 is pressed.

The collectors of Q1 & Q2 are supplied with the full battery voltage. All of the remaining circuitry in the meter operates from a regulated +5V supply line, derived from the battery via an LM2940 regulator, REG1.

The metering side of the circuit is performed by the PIC16F88 micro, IC3. The voltage developed across the 10kΩ 'shunt' resistor (in response to the current between the test terminals) is amplified by op amp IC2a which has a gain of 3.1.

The amplified voltage is fed to pin 1 of IC3 (AN2) which is configured as an ADC input. The 3.2V reference voltage for the ADC is fed to pin 2 of IC3, being derived from the 5.0V supply line via the voltage divider using the 3.3kΩ, 5.6kΩ and 270Ω resistors.

As noted before, the ADC inside IC3 measures the voltage applied to pin 1 by comparing it with the reference voltage fed to pin 2. The micro then calculates the leakage current through the test terminals.

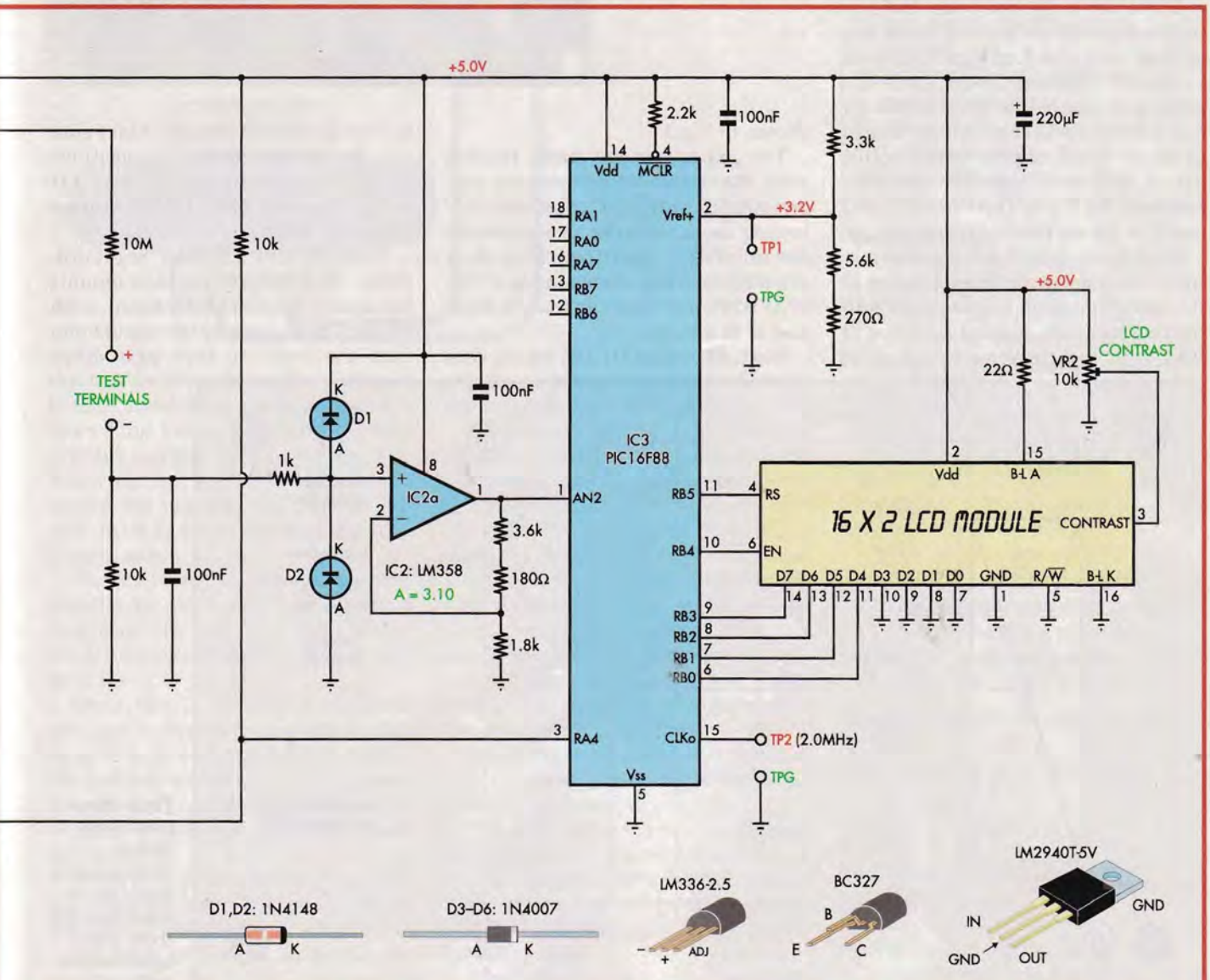
Because it is able to sense the position of test voltage selector switch S1 (high or low) via pin 3 (RA4), it is able to deduce the actual test voltage (500V or 1000V) and hence calculate the total resistance connected across it via the test terminals. Then finally it works out the external resistance between the terminals by subtracting the 10.01MΩ internal resistance.

The calculated current and resistance values are then displayed on the LCD module, along with the test voltage being used.

In this circuit IC3 is using its internal clock oscillator, running at very close to 8MHz. This gives an instruction cycle time of 2MHz, which may be monitored using a scope or frequency counter at test point TP2.

The micro drives the LCD module in the standard 'four bit nibble' fashion, which involves a minimum of external components.

Trimpot VR2 allows the LCD module's contrast to be adjusted for opti-



mum visibility, while the 22Ω resistor connected to pin 15 sets the current level for the module's inbuilt LED back-lighting. This was chosen as a compromise between display brightness and battery life.

Construction

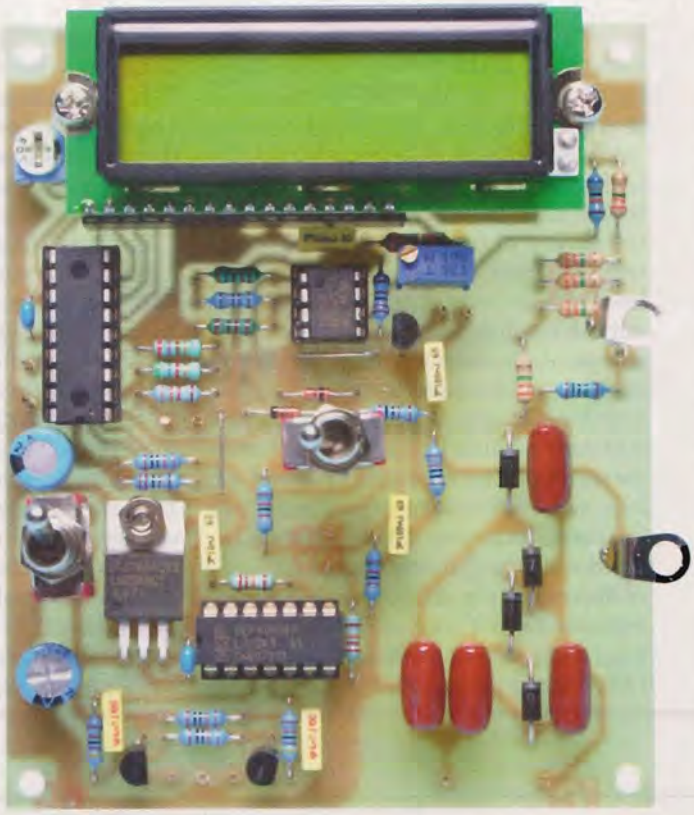
Most of the components are mounted directly on the PC board. This measures 84 x 102mm and is coded 04110091. The only components not mounted on the board are transformer T1 and the 6V battery holder, which are both mounted in the lower part of the case, the test terminals and switches S1-S3. The board assembly mounts behind the lid via four 25mm long tapped spacers.

The diagram of Fig.3 shows all of the components mounted on the board, together with the wiring to the transformer.

There are only two wire links to be fitted and these are best fitted first so they won't be forgotten. One goes to the left of board centre, while the other goes just below the position for IC2. After both links are fitted you can fit the six terminal pins for test points TP1-3 and their reference grounds, followed by the sockets for IC1, IC2 and IC3, taking care with orientation.

Next, fit all of the fixed resistors, taking particular care to fit each value in its correct position. Follow these with the two trimpots, making sure you fit VR1 with the correct orientation as shown in Fig.3.

At right is a same-size photo of the PC board, assembled and ready for mounting in the box. The two test terminals and the "TEST" pushbutton switch are not shown here as they mount on the front panel and connect by wires. Compare this photo to Fig.3, far right, which shows the complete component layout/wiring (in this case with the test terminals and "TEST" switch).



The capacitors are next, starting with the lower value ceramic and metallised polyester caps and following these with the two polarised electrolytics – again matching their orientation to that shown in Fig.3. The 47nF 630V polyester caps can be fitted also at this stage.

Next, fit diodes D1-D6, taking care to orientate them correctly. Make sure you fit 1N4007 diodes in positions D3-D6. Then install transistors Q1 & Q2, plus the LM336Z-2.5 voltage reference, REF1.

Then fit the LM2940 regulator, REG1. This TO-220 package mounts flat against the top of the board, with its leads bent down by 90° about 6mm from the body, so they pass down

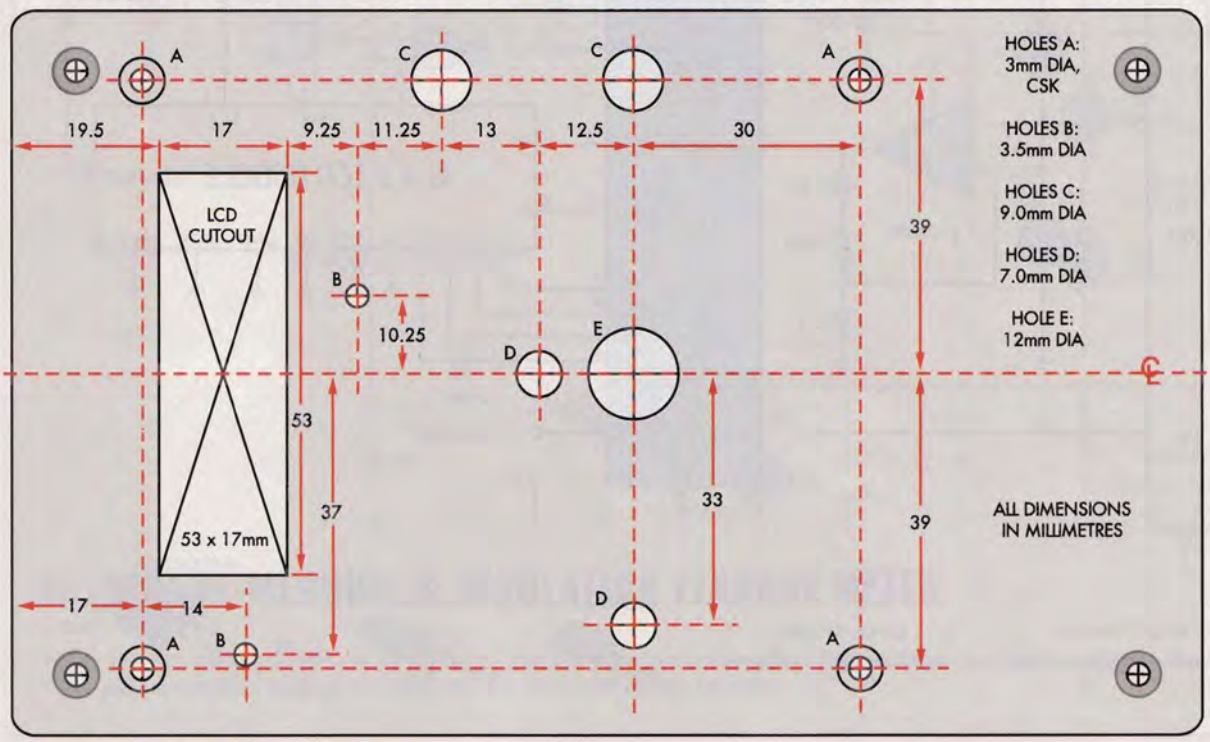
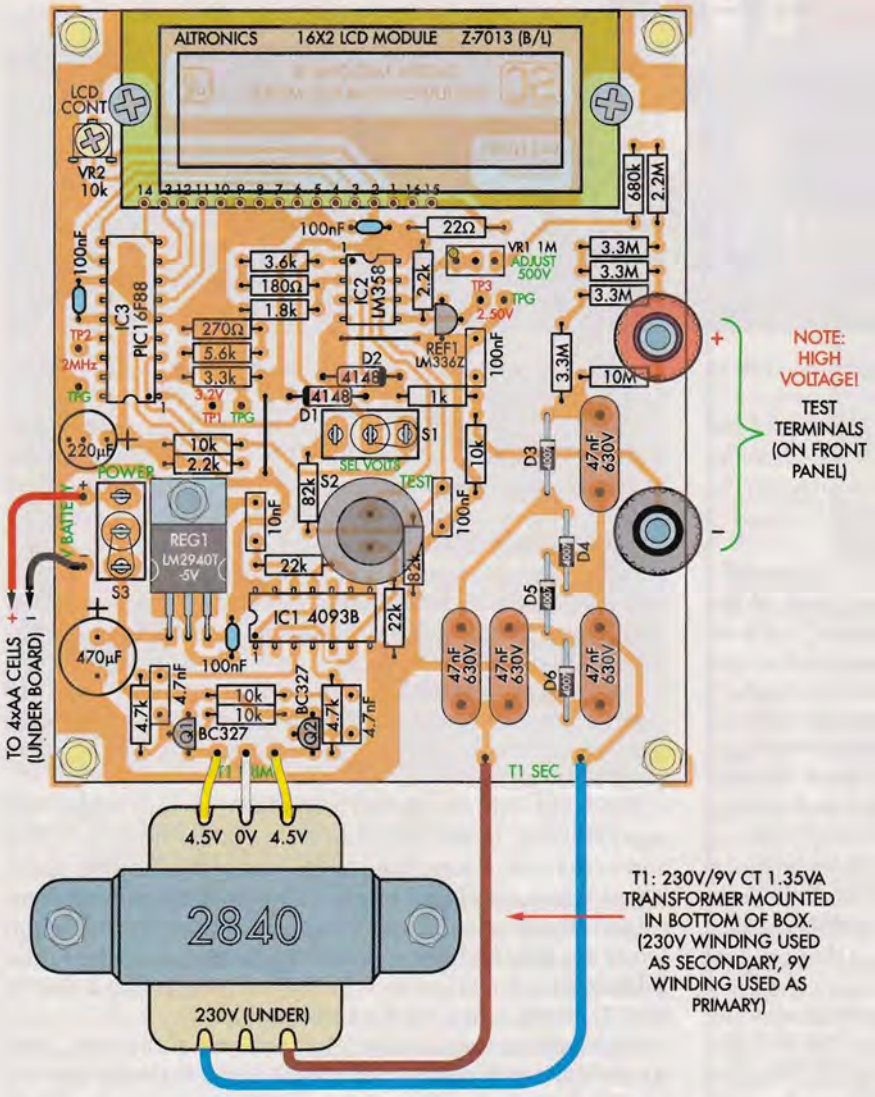


Fig.4: use a photocopy of this diagram as a template to mark out the front panel holes before drilling.



through the board holes. The regulator is then attached to the board using a 6mm long M3 screw and nut, passing through the hole in its tab. The screw and nut should be tightened to secure the regulator in position before its leads are soldered to the pads underneath.

The final component to be mounted directly on the board is the 16-way length of SIL (single in-line) socket strip, used as the 'socket' for the LCD module.

Once this is fitted and soldered, you can fasten two 12mm long M3 tapped Nylon spacers to the board in the module mounting positions (one at each end) using a 6mm M3 screw passing up through the board from underneath.

Then plug a 16-way length of SIL pin strip into the socket strip you have just fitted to the board. Make sure the longer ends of the pin strip pins are mating with the socket, leaving the shorter ends uppermost to mate with the holes in the LCD module.

Next, remove the LCD module from its protective bag, taking care to hold it between the two ends so you don't touch the board copper. Lower it carefully onto the main board so the holes along its lower front edge mate with the pins of the pin strip, allowing the module to rest on the tops of the two 12mm long Nylon spacers. Then you can fit another 6mm M3 screw to each end of the module, passing through the slots in the module and mating with the spacers.

When the screws are tightened (not over tightened!) the module should be securely mounted in position.

The final step is to use a fine-tipped soldering iron to solder each of the 16 pins of the pin strip to the pads on the module, to complete its interconnections. Check that there are no shorts between pads.

After this is done, you can plug

PARTS LIST

1 UB1 size jiffy box, 157 x 95 x 53mm
1 PC board, code 04110091, 84 x 102mm
1 LCD module, 2 lines x 16 chars, with LED back-lighting (Altronics Z-7013 or equivalent)
1 power transformer, 9V CT secondary at 150mA or 1.35VA (eg 2840 type)
4 AA cell battery holder, flat type, with battery snap lead
2 mini SPDT toggle switch (S1, S3)
1 SPST pushbutton switch (S2)
2 binding post/banana jacks (1 red, 1 black)
2 4mm solder lugs
1 16-pin length of SIL socket strip
1 16-pin length of SIL pin strip
1 18-pin IC socket
1 14-pin IC socket
1 8-pin IC socket
4 25mm long M3 tapped metal spacers
2 12mm long M3 tapped Nylon spacers
9 6mm long M3 machine screws, pan head
4 6mm long M3 machine screws, countersunk head
2 10mm long M3 machine screws, countersunk head
3 M3 nuts with star lockwashers
6 1mm diameter PC board terminal pins

Semiconductors

1 4093B quad Schmitt NAND gate (IC1)
1 LM358 dual op amp (IC2)
1 PIC16F88 microcontroller (IC3, programmed with 0411009a.hex)
1 LM2940T LDO +5V regulator (REG1)
1 LM336Z-2.5 +2.5V reference (REF1)
2 BC327 PNP transistors (Q1,Q2)
2 1N4148 signal diodes (D1,D2)
4 1N4007 1000V/1A diodes (D3-D6)

Capacitors

1 470µF 16V RB electrolytic
1 220µF 16V RB electrolytic
2 100nF MKT metallised polyester
3 100nF multilayer monolithic ceramic
4 47nF 630V metallised polyester
1 10nF MKT metallised polyester
2 4.7nF MKT metallised polyester

Resistors (0.25W 1% unless specified)

1 10MΩ	1 680kΩ	2 82kΩ
2 22kΩ	4 10kΩ	1 5.6kΩ
2 4.7kΩ	1 3.6kΩ	1 3.3kΩ
2 2.2kΩ	1 1.8kΩ	1 1kΩ
1 270Ω	1 180Ω	

4 3.3MΩ 5% carbon film 0.5W
1 2.2MΩ 5% carbon film 0.5W
1 22Ω 5% carbon film 0.5W
1 1MΩ 25-turn trimpot, top adj. (VR1)
1 10kΩ mini horizontal trimpot (VR2)



The assembled PC board "hangs" from the front panel via four threaded spacers. Follow the text to ensure the right assembly order is achieved!

the three ICs into their respective sockets, making sure to orientate them all as shown in Fig.3.

Attach a 25mm long mounting spacer to the top of the board in each corner, using 6mm long M3 screws. Then the board assembly can be placed aside while you prepare the case and its lid.

Preparing the case

Two holes need to be drilled in the lower part of the case, to take the mounting screws for transformer T1. These should be 3mm in diameter, spaced 47mm apart and 20mm up from the end of the case which will become the meter's lower end. The battery holder can be held securely in place using two strips of 'industrial' double-sided adhesive foam.

The lid needs to have a larger number of holes drilled, plus a rectangular cut-out near the upper end for viewing the LCD. The location and dimensions of all these holes are shown in the diagram of Fig.4. You can use a photocopy of it as a drilling template. The 12mm hole for S2 and the 9mm holes for the test terminals are easily made by drilling then first with a 7mm twist drill and then enlarging them to size carefully using a tapered reamer.

The easiest way to make the rectangular LCD viewing window is to drill a series of closely-spaced 3mm holes around just inside the hole outline, and then cut between the holes using a sharp chisel or hobby knife. Then the sides of the hole can be smoothed using a medium file.

The artwork of Fig.6 can be used as the front panel label. This can be photocopied from the magazine or downloaded as a PDF file from our website and then printed out. The resulting copy can be laminated and attached to the front of the lid (or covered with self-adhesive clear film) for protection against finger grease, etc.

You might also like to attach a 60 x 30mm rectangle of 1-2mm thick clear plastic behind the LCD viewing window, to protect the LCD from dirt and physical damage. The 'window pane' can be attached to the rear of the lid using either adhesive tape or epoxy cement.

Once your lid/front panel is finished, you can mount switches S1-S3 on it using the nuts and washers supplied with them. These can be followed by the binding post terminals. Tighten the binding post mounting nuts quite firmly, to make sure that they don't come loose with use. Then use each post's second nut to attach a 4mm solder lug to each, together with a 4mm lockwasher to make sure they don't work loose either.

Now you can turn the lid assembly over and solder 'extension wires' to the connection lugs of the three switches and to the solder lugs fitted to the rear of the binding posts. These wires should all be about 30mm long and cut from tinned copper wire (about 0.7mm diameter). Once all of the wires are attached, they should be dressed vertical to the lid/panel so they'll mate with the corresponding holes in the PC board, when the two are combined.

Next, mount transformer T1 at one end of the case, with its low voltage winding connections towards the top and the high voltage connections towards the bottom, as in Fig.5. Secure the transformer in position using two 10mm long M3 machine screws with flat washers, star lockwashers and M3 nuts, tightening both firmly to make sure the transformer cannot work loose.

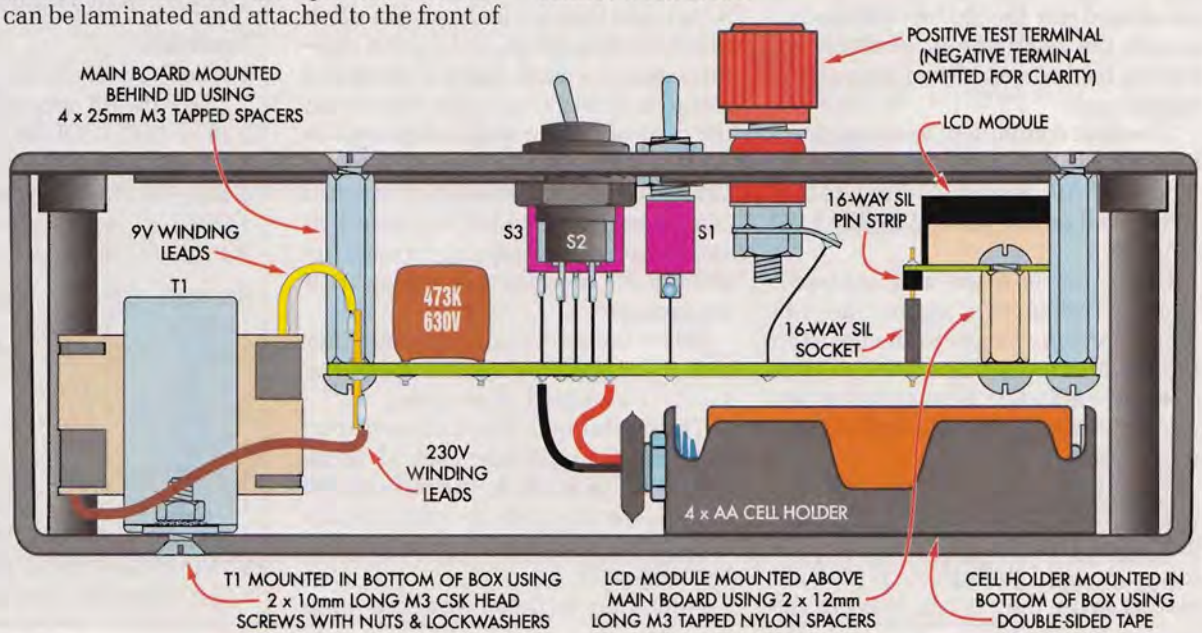
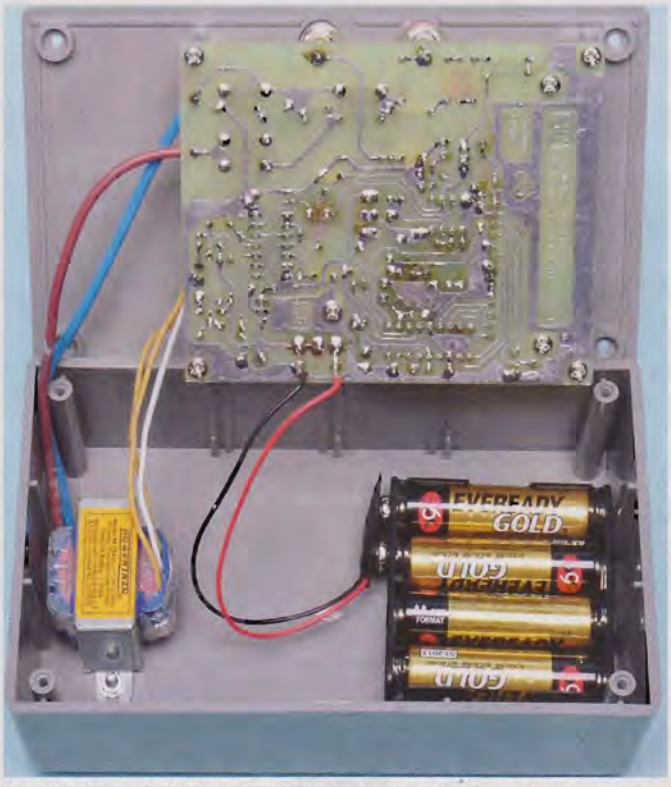


Fig.5: the assembled project inside a UB1 Jiffy Box. Note that this does not show the negative test terminal (which would hide S2 and S3).



Here's how it all fits together inside a UB1 box. The power transformer and battery holder are the only components not mounted on the PC board.

The 4-AA cell battery holder can also be mounted in the upper end of the case using double-sided adhesive foam, with its battery snap connections at the lower end.

Next solder the bared ends of the battery clip lead wires to their connection pads on the PC board, just to the left of the position for power switch S3. The leads from transformer T1 can also be connected to the connection pads along the lower edge of the PC board, with the three low voltage winding leads connecting to the pads on the left and the two high voltage winding leads to the pads on the right, as shown in Fig.3.

Now you can attach the PC board assembly to the rear of the lid/front panel. You have to line up all of the extension wires from switches S1-S3 and the two test terminals with their matching holes in the PC board, as you bring the lid and board together. Then you can secure the two together using four 6mm long countersink head machine screws.

Then turn the complete assembly over and solder each of the switch and terminal extension wires to their board pads.

Fit four AA alkaline cells into the battery holder and your new Megohm/Insulation Meter should be ready for its initial checkout.

Initial checkout

If you set switch S3 to its ON position, a reassuring glow should appear from the LCD display window — from the LCD module's back-lighting and should also see the Meter's initial greeting 'screen'. You may need to adjust contrast trimpot VR2, until you get a clear and easily visible display. (VR2 is adjusted through the small hole just to the left of the LCD window.)

After a few seconds, the LCD should change to the Meter's measurement 'screen', where it displays the current test

ADVANCED BATTERY TESTER

MBT-2LA



Easy to understand LED display

12 test modes

Simple operation Test results in 15 seconds



Rugged NBR rubber sleeve

Internal cooling fan



48" interchangeable test leads

Features

- **Computes State of Charge for lead acid battery types (SLA, AGM, Gel, Flooded)**
- **Test battery condition – quickly and easily identifies weak or failing batteries**
- **Patented high accuracy Pulse Load test – battery safe, non-invasive**
- **Test 2-volt, 4-volt, 6,volt, 8-volt, 12-volt**
- **Measures battery performance under load, not just voltage or internal resistance**
- **Ideal for battery management & cell matching – reduce costs and increase reliability**

Description

The MBT-LA2 provides a comprehensive means of testing the state of charge and battery condition for 2-volt, 4-volt, 6,volt, 8-volt and 12-volt lead acid battery types (SLA, AGM, Gel, Wet). Lightweight, compact design make it an ideal tool for anyone working with lead acid batteries. The microprocessor-controlled instrument tests popular batteries using a patented, high-accuracy pulse load tests. After a fully automatic test cycle, percentage of remaining battery capacity is indicated on the LED bar display. Test results are easy to understand. An integrated cooling fan dissipates heat from testing, and the circuit is protected against over-voltage. Rugged NBR rubber sleeve protects against impact. Includes 48" removeable test leads with sold copper clamps. The accessory kit (K-MBTLA2) includes a hanging strap & magnet for hands-free operation, and a protective soft case. Requires 4AA batteries (not included).

Applications

- Fire/security
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- Industrial
- Lighting
- Telecom
- Mobility
- Inspection
- Military
- Safety
- Service
- IT
- Access control
- Auto/marine/RV
- Manufacturing
- Utilities

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voltage setting together with the measured leakage current and resistance (as shown in the opening photograph).

At this stage it will show a leakage current of 000µA and a resistance of 999MΩ, for two reasons: (1) because the test voltage isn't actually generated until you press the TEST button and (2) you haven't connected anything between the two test terminals at this stage, to draw any current.

Just to make sure though, try switching voltage selector switch S1 to the other position. You should find that the test voltage setting displayed on the top line of the LCD screen changes to match. If so, it will show that your Megohm/Insulation Meter is working correctly.

This being the case, switch off the power and complete the final assembly by lowering the lid/PC board assembly into the case and securing the two together using the four small self-tapping screws supplied.

Setting the test voltages

The test voltage levels are set with trimpot VR1. This is adjusted via a small screwdriver, through the small hole just below the LCD window. But how do we get the meter to measure the test voltages itself? Simply by connecting a short piece of wire between the two test terminals, as a short circuit. This temporarily changes the meter into a 0-1000V voltmeter, to read the test voltage on the leakage current range.

So to set the test voltages, fit the shorting wire between the test terminals and then switch S1 to the '1000V' position. Then switch the Meter on, and once it is displaying the measurements screen press and hold down the TEST button (S2). The LCD should show a 'current' of close to 100µA, corresponding to a test voltage of 1000V. If it indicates a figure either higher or lower than this, all you have to do is adjust trimpot VR1 with a small screwdriver until the reading changes to 100µA (=1000V).

To make sure that you have made the setting correctly, try switching voltage selector switch S1 to the '500V' position. You should find that the LCD reading changes to 50µA(=500V). If so, your meter is now fully set up.

Remove the short circuit between the test terminals and your meter is ready for use. SC

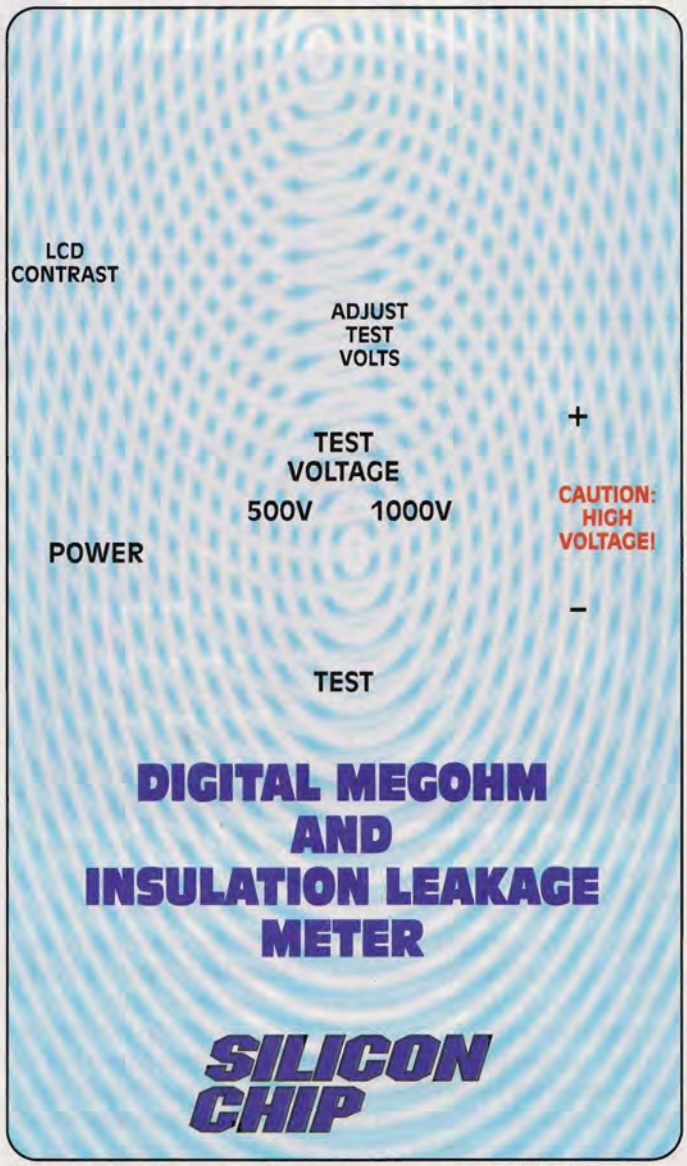


Fig.6: same-size artwork for the front panel. This does not have the hole positions shown so all screws are hidden once it is glued in place.

Resistor Colour Codes

	No.	Value		4-Band Code (1%)	5-Band Code (1%)
❑	1	10MΩ		brown black blue brown	brown black black green brown
❑	4	3.3MΩ	(0.5W)	orange orange green brown	orange orange black yellow brown
❑	1	2.2MΩ	(0.5W)	red red green brown	red red black yellow brown
❑	1	680kΩ		blue grey yellow brown	blue grey black orange brown
❑	2	82kΩ		grey red orange brown	grey red black red brown
❑	2	22kΩ		red red orange brown	red red black red brown
❑	4	10kΩ		brown black orange brown	brown black black red brown
❑	1	5.6kΩ		green blue red brown	green blue black brown brown
❑	2	4.7kΩ		yellow violet red brown	yellow violet black brown brown
❑	1	3.6kΩ		orange blue red brown	orange blue black brown brown
❑	1	3.3kΩ		orange orange red brown	orange orange black brown brown
❑	2	2.2kΩ		red red red brown	red red black brown brown
❑	1	1.8kΩ		brown grey red brown	brown grey black brown brown
❑	1	1kΩ		brown black red brown	brown black black brown brown
❑	1	270Ω		red violet brown brown	red violet black black brown
❑	1	180Ω		brown grey brown brown	brown grey black black brown
❑	1	22Ω	(0.5W)	red red black brown	red red black gold brown

PRODUCT SHOWCASE

ShiftBrite RGB LED module allows large displays



The ShiftBrite RGB LED modules from Ocean Controls have a built-in driver featuring 10-bit digital brightness control on each colour channel (over one billion colours).

Multiple ShiftBrite modules can be easily chained together and connected to a single microcontroller to create large LED displays.

The ShiftBrite is a module by Macetech that integrates the Allegro A6281 3-channel constant current LED driver with a large, high-brightness RGB LED. Using just three digital output pins and a simple protocol, microcontrollers can control a long chain of ShiftBrites.

Each ShiftBrite in the chain can be independently changed to any of the 1,073,741,824 possible colours to create dynamic displays and decorations. Over-temperature shutdown protects the LED driver from overheating.

The pins of the ShiftBrite are spaced 0.1" apart, making them compatible with breadboards and perfboards.

Check out the Shiftbrite on YouTube, – there are several movies showing Shiftbrites in action.

Contact:
Ocean Controls
PO Box 2191, Seaford Busn Centre, Vic 3198
Tel: (03) 9782 5882 **Fax:** (03) 9782 5517
Website: www.oceancontrols.com.au

New DMMs from Kyoritsu



Eaton has introduced a new high performance Digital Multimeter range.

Models 1051 and 1052 are both CAT IV 600V TRMS while the 1052 is selectable for both TRMS and MEAN measurements.

Both models have low pass filters for motor drive applications, data-logging capability with the ability to upload and live monitor results on PC.

Models 1061 and 1062, the professional series, have dual-readout display capability on the large LCD screen. The 1061 and 1062 have faster peak hold response times and higher AC bandwidths.

All models communicate to PC or laptop via USB and include USB interface and data-logging/monitoring software.

The range of high performance multimeters has colour coded range selection switches and function buttons for ease of use.

Contact:
Eaton Industries Pty Ltd
10 Kent Road, Mascot NSW 2020
Tel: (02) 9693 4333 **Fax:** (02) 9667 3820
Website: www.eatonelectric.com.au

New Australian distributor for Mouser Electronics



Active Components has been appointed the official Australasian distributor for Mouser Electronics, a large Texas-based supplier of electronic components. Mouser's product line has over a million electronic parts, from more than 366 leading manufacturers such as Farichild, Microchip, Atmel, and Zilog.

Active's locally stocked range, along with Mouser's products, can be purchased online at the website below.

Contact:
Active Components
PO Box 1351, Parramatta NSW 2150
Tel AU: (02) 9893 9400 **Fax:** (02) 9891 9322
Tel NZ: (09) 443 9500 **Fax:** (02) 443 9502
Website: www.activecomponents.com

Microchip's Australia and New Zealand embedded designer's forums

Registrations are now open for Microchip's Embedded Designer's Forum (EDF), a worldwide series of technical learning events focused on innovative technologies that will help designers stay ahead in today's competitive environment.

Showcasing the latest PIC microcontroller (MCU) technologies, the Embedded Designer's Forums will teach designers how to add more features and functionality to their designs, for lower system costs and faster time to market.

The forums will run in Australia and New Zealand during October and November in Sydney, Melbourne, Adelaide, Auckland and Christchurch.

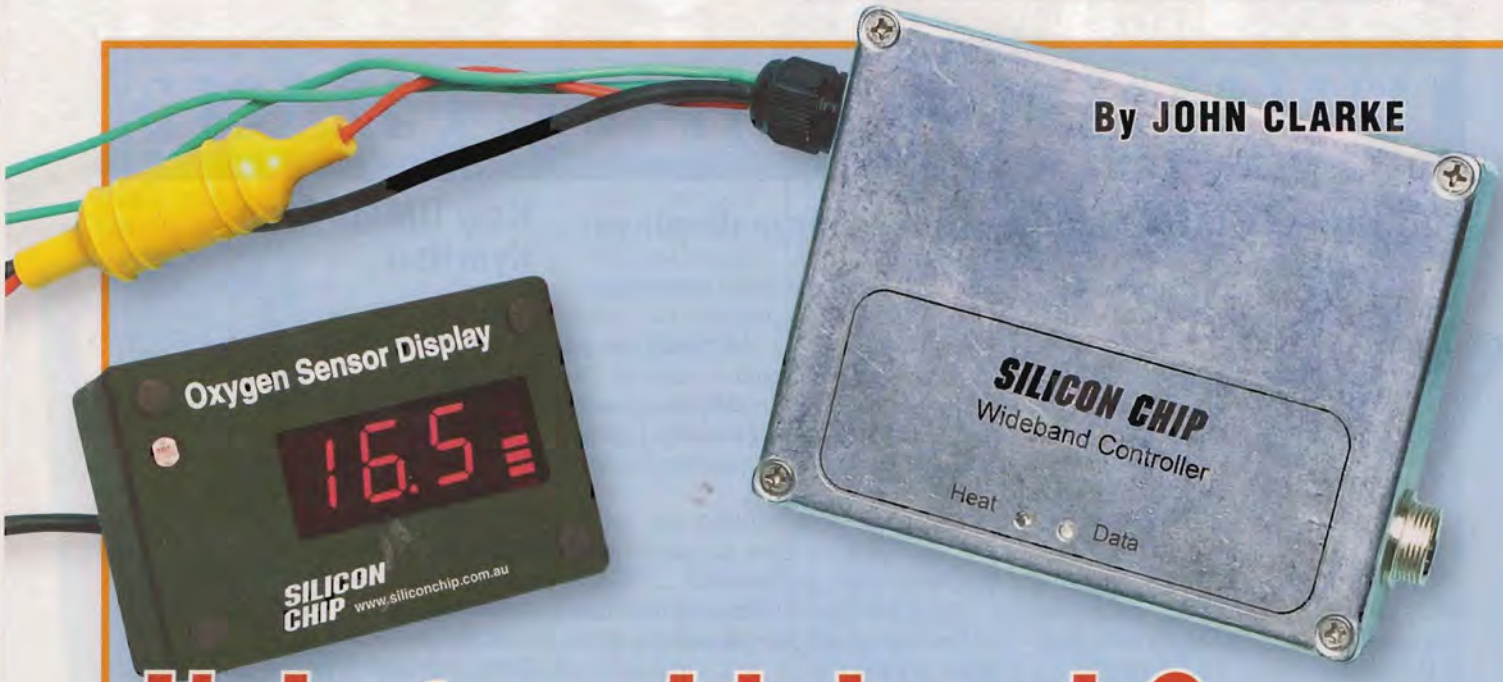
Each forum will include the following sessions:

- Lower your system power with the World's Lowest Sleep Power MCU
- Getting the most out of the new 32MHz PIC16F enhanced 8-bit core MCUs
- Expand your application with PIC32 32-bit performance
- Add LCD and graphics displays to your products
- Improve your user interfaces using TouchSense technology
- Integrate USB connectivity into your embedded design

All attendees will receive a substantial discount on select Microchip development tools.

To register or for more information, please visit the website below. SC

Contact:
Microchip Technology Australia
PO Box 260, Epping, NSW 1710.
Tel:(02) 9868 6733 **Fax:**(02) 9868 6755
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By JOHN CLARKE

Using a wideband O_2 sensor in your car, Pt.2

Construction and installation details

Last month, we introduced our new Wideband Oxygen Sensor Controller and described the circuit. This month, we show you how to build it and give the test and installation details.

BUILDING THE Wideband Controller is straightforward. All the parts, except for the wideband oxygen sensor, are mounted on a PC board coded 05110091 and measuring 112 x 87mm. This is housed in a diecast box measuring 119 x 94 x 34mm.

An 8-pin circular multi-pole panel plug connector is used to provide the interface to the external wideband sensor. This sensor is mounted on the exhaust (either directly or via an adaptor pipe) and connects to the controller via a 7-way extension cable. In addition, the controller is fed with power via leads which enter via a cable gland and these wires terminate into an on-board screw terminal block. The 3-wire connection to the optional Wideband Display Unit also passes through this cable gland.

Refer to Fig.13 for the parts layout on the PC board. Begin by checking the board for any defects such as shorted tracks or breaks in the copper. Check that the corners have been shaped to clear the internal corner pillars of the box by test fitting it in place. Similarly, check that the board has had rectangular sections removed from either side so that it will later clear the nuts used to secure the multi-pole connector and the cable gland.

The shape required is indicated using thin tracks on the underside of the PC board.

Now start the parts assembly. Insert the wire links and resistors first, taking care to place each in its correct place. Table 1 shows the resistor colour codes but you should also check each one using a digital multimeter before soldering it in place. The 0.1Ω 5W resistor runs cold and can be mounted flush against the PC board.

Next, install the diodes, zener diodes and the ICs but don't install IC1 (the PIC micro). Instead, install a socket at its location. Make sure that this socket and the other ICs are all oriented correctly (ie, notched ends towards the top of the PC board).

Follow with the capacitors, taking care to install the electrolytic types with the polarity indicated. That done, install REG1, REG2 and Q1. These parts are all mounted flat against the

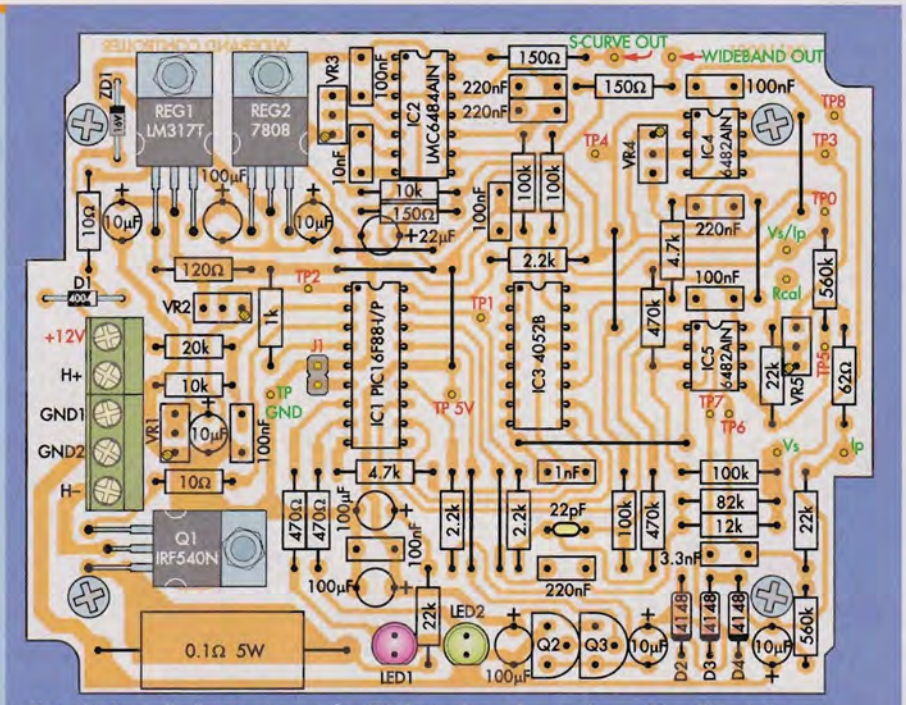


Fig.13: install the parts on the PC board as shown here. Use PC stakes at all the test points (TP0-TP8) and make sure that the semiconductors and electrolytic capacitors are all oriented correctly.



The completed PC board is mounted inside a diecast metal case on plastic stand-offs.

PC board, so you will have to bend their leads down through 90° to get them to fit. This involves bending the two outer leads of each device down about 8mm from its body, while the inner lead is bent down about 6mm away.

Secure the metal tabs of these devices to the board using an M3 x 6mm screw & nut before soldering their leads to the PC board. Don't solder the leads first, otherwise you could crack the PC board pattern as the screw is tightened down. Be sure to install the correct part at each location.

Transistors Q2 and Q3 can go in next. **Be sure to use a BC327 for Q2 and a BC337 for Q3. Do not get these two transistors mixed up.** Once they are in, install the 2-way pin header for JP1, then install PC stakes at the external wiring positions (see Fig.14).

LEDs 1 & 2 are next on the list. These must be installed with the top of each LED exactly 24mm above the PC board. You can set their height by pushing each LED down onto a 19mm cardboard spacer that's slid between its leads. In each case, the anode (longer lead) must go towards the top of the PC board.

The three trimpots (VR1-VR4) can now go in. Be sure to use the correct value at each location and orient each one with its adjusting screw as shown on Fig.13 (this ensures that the voltages at their wipers increase with clockwise rotation). Note that these trimpots may be marked with a code other than the actual resistance value in ohms, ie, the 500Ω trimpot may be coded as 501, the 5kΩ trimpots may be coded as 502 and the 1kΩ trimpot may be coded as 102.

Finally complete the PC board assembly by installing the 3-way & 2-way screw terminal blocks. These must be dovetailed together to form a 5-way block before installing them on the PC board. Make sure that the wiring access holes face towards the edge of the PC board.

Boxing it up

The PC board is mounted inside the case on M3 x 6mm tapped Nylon spacers and secured using M3 x 4mm screws. Before doing this though, you will need to drill all the necessary holes.

First, position the PC board inside the base and use it as a template to mark out its four corner mounting holes. That done, remove the board and drill these holes to 3mm diameter. Deburr them using an oversize drill.

Next, you need to drill holes in the ends of the box to accept the cable gland and the 8-pin circular connector (see photo). The location and diameters of these holes is indicated on Fig.14. They are best made by using a small pilot drill to begin with, then carefully enlarging each to its correct size using a tapered reamer.

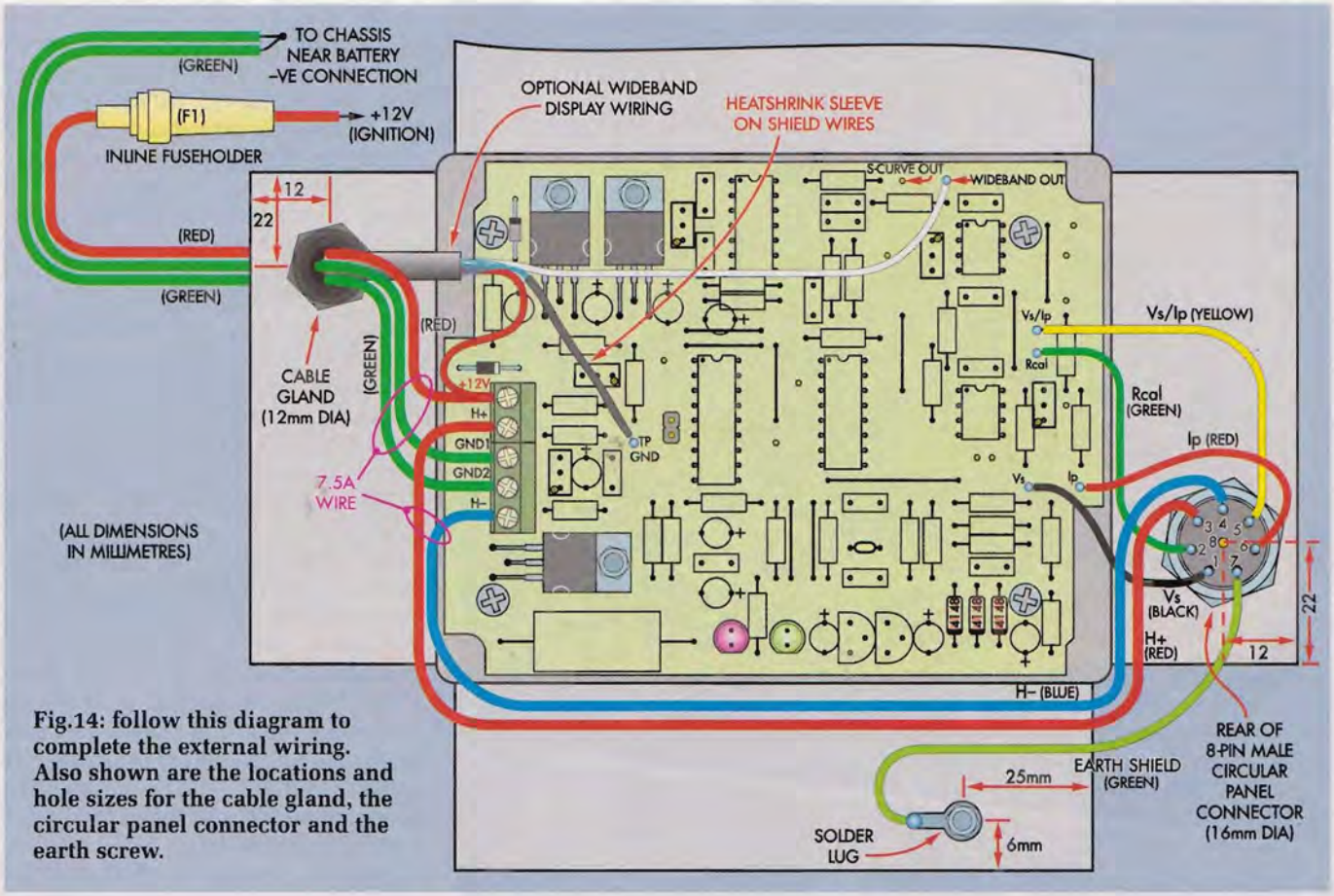


Fig.14: follow this diagram to complete the external wiring. Also shown are the locations and hole sizes for the cable gland, the circular panel connector and the earth screw.

Finally, you will need to drill a 3mm hole in the front side of the case to anchor the earth solder lug.

Once all the holes have been drilled, secure the board in position, then run the wiring as shown in Fig.14. Note that you must use 7.5A rated wire as marked on the diagram for the 12V supply, ground and heater wires, since these carry heavy currents.

The 8-pole circular panel connector is wired by first connecting the sensor wires to the PC stakes on the PC board and the heater wires to the screw terminal block. The wires are then fed through the nut and washer for the circular connector and then through the mounting hole before soldering them to the connector itself.

Note that each soldered pin is covered with heatshrink tubing to avoid shorts and to prevent the wires from breaking. This means you will have to slide a length of heatshrink over each wire before soldering it to the connector. After soldering, the heatshrink is pushed over the connection and shrunk down with a hot-air gun.

Similarly, the leads for the power supply should be fed through the cable gland before connecting them to the screw terminal block. If you are using the wideband and S-curve outputs, these wires also go through the gland. For the Wideband Display Unit, the 0V rail can be obtained from the TP GND pin, while the +12V supply can be picked up from the +12V terminal on the 5-way terminal block.

Note that the +12V supply lead requires an in-line fuseholder and 5A fuse. This supply is obtained from the vehicle's ignition circuit. **Note that, because of the currents involved in the heater circuit, two earth wires must be used as shown in Fig.14.** These connect together at the vehicle's chassis.

For temporary use, the cigarette lighter socket can be used to provide power via a lighter plug connector.

Sensor extension cable

The sensor extension cable is wired as shown in Fig.15. Make sure that the wiring is correct and use heavy-duty cable for the H+ and H- leads.

The wiring is shown from the back of each connector, so be sure to follow this carefully. Note that the 6-pin connector includes wire-sealing glands and these are placed over each lead before it is attached to the 2.8mm female crimp spade terminals.

That completes the assembly. Now for the setting-up procedure.

Setting up & testing

It's best to initially configure the Wideband Controller to measure the oxygen content of the air. That way, the controller can be tested with a known gas, ie, one that comprises 20.9% oxygen in fresh air.

This test requires the installation of two extra 560kΩ resistors in parallel with the 560kΩ resistors associated with IC5b (ie, one across the existing resistor to pin 5 and the other added across the existing resistor between pins 6 & 7). The Vs/Ip and offset voltage set by VR4 is also different compared to the normal set-up for measuring exhaust gas.

If you prefer to skip the above step in the setting-up procedure, leave the extra resistors out and simply connect your multimeter between TP3 and Rcal. Set the meter to read ohms and adjust trimpot VR5 for a reading of 311Ω. That done, skip directly to



Above: this view shows the completed extension cable with the sensor attached.

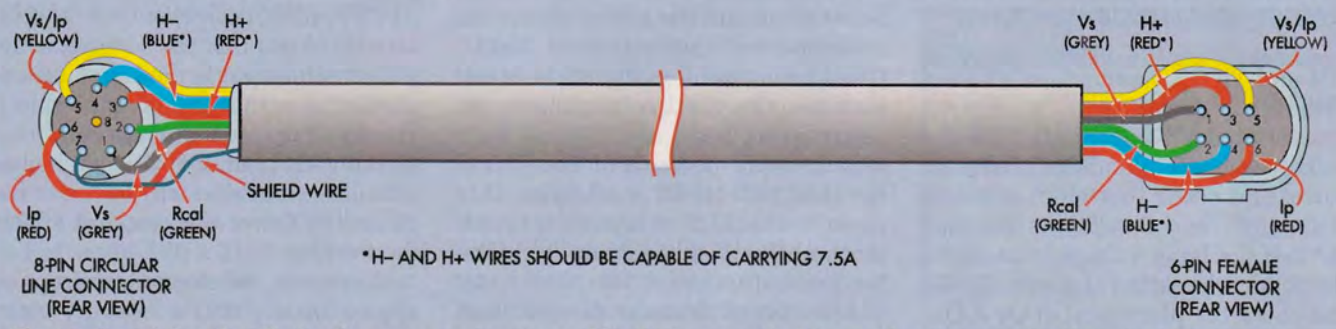


Fig.15: the wiring details for the sensor extension cable. Make sure that the wiring is correct, otherwise the sensor could be damaged. Be sure also to use heavy-duty cable for the heater H+ and H- leads and note that the 6-pin female connector at right is shown from the rear.

the "Engine exhaust readings setup" procedure and ignore the instruction to remove the 560kΩ resistors between TP0 & TP5 and between TP6 & TP7.

Oxygen concentration settings

If you do intend to first measure the oxygen content of the air, just follow this step-by-step procedure:

Step 1: solder one 560kΩ resistor between TP0 and TP5 and a second 560kΩ resistor between TP6 and TP7.

Step 2: remove the jumper plug from J1 and connect a multimeter between TP3 and Rcal. Set the multimeter to read ohms.

Step 3: adjust VR5 for a reading of 311Ω.



This view shows female 6-pin connector (left) at the end of the extension cable and the matching male plug that comes fitted to the sensor (right).

Mounting The Oxygen Sensor

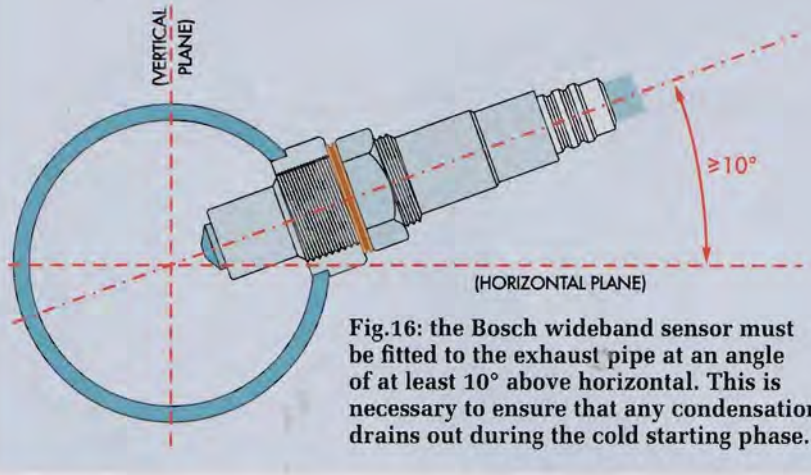


Fig.16: the Bosch wideband sensor must be fitted to the exhaust pipe at an angle of at least 10° above horizontal. This is necessary to ensure that any condensation drains out during the cold starting phase.

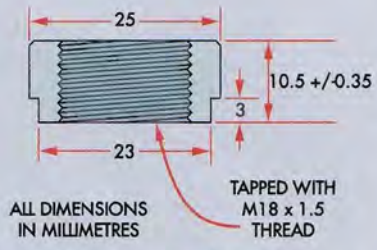


Fig.17: this diagram shows the dimensions of the threaded boss that's used to attach the sensor. It must be made of stainless steel and should cover the sensor's thread completely. The tightening torque is from 40-60 Nm.

Step 4: check that IC1 is still out of its socket and that the sensor is unplugged, then apply power (12V) to the circuit. Monitor the voltage between TP 5V and TP GND and adjust VR1 for a reading of 5.00V.

Step 5: monitor the voltage between Vs/Ip and TP GND and adjust VR3 for a reading of 2.00V.

Step 6: monitor the voltage between TP4 and TP GND and adjust VR4 for a reading of 2.343V.

Step 7: switch off and install IC1 in its socket (watch its orientation). Reapply power and check that pin 8 of IC4 is at about 8V and that TP8 is at about -2.5V. If the latter voltage is positive, check the orientation of diodes D2-D4 and check the placement of Q2 & Q3. Check the orientation of the 10µF and 100µF capacitors as well.

Step 8: now you are ready to test the operation with the oxygen sensor connected. Switch off and connect the sensor to the Wideband Controller. Before switching on, check that there is resistance between H+ and H-. It should be about 3.2Ω at 20°C.

Note that the sensor will get hot and so the plastic protective cap should be removed and the sensor placed on a surface that can withstand 200°C. Glass cookware (eg, Pyrex) is ideal. Note also that the tip of the heater can become very hot.

Step 9: apply power and check that the Heat LED (LED1, red) lights. If is doesn't, check its orientation. Check that both the Wideband output and the S-curve output are at 0V.

After about 20-seconds, the Heat LED should start flashing and the Data LED should light. The flashing Heat LED indicates that the sensor has reached operating temperature, while the lit Data LED indicates that the Wideband Controller is measuring the oxygen content in the air and that the reading is available at the wideband output.

The wideband output voltage will be proportional to the oxygen content. A 2.09V reading corresponds to 20.9%.

Step 10: check that the voltage at the wideband output is close to 2.09V. It should be within 1% of this value if you are at sea level and the measured air is not in a confined space. At higher altitudes, the value will be lower because the lower air pressure affects the reading.

In practice, the air pressure drops by approximately 10hPa for every 100m above sea level, starting from a standard pressure of 1013.25hPa. However, this pressure decrease rate does not apply for altitudes above 2000m where the rate becomes non-linear. And, of course, weather conditions also affect air pressure.

For more detail, refer to the *Ip versus Pressure* graph (Fig.11) published last month. Typically, the reading will be 4% less at an altitude of 1000m above sea level. Since the oxygen concentration versus Ip current is almost linear, the graph can also be interpreted as the change in oxygen concentration reading with pressure. The oxygen concentration in percent is the reading from the Wideband Controller.

Step 11: if the reading is nowhere near the expected value, check the resistor values on the PC board. Although adjusting the value of the 62Ω resistor can recalibrate the reading, this should not

How To Remove The Narrowband Sensor

It is highly unlikely that an open-ended 22mm spanner will be sufficient to remove the original oxygen sensor. Instead, it will be so tight that the nut will refuse to budge and will simply start to "round off" under the spanner.

Basically, you will require a special oxygen sensor removal tool. This comprises a 22mm socket that has a slit along one side to allow for the oxygen sensor wires to protrude.

Even with this tool, we found that the oxygen sensor was difficult to remove. Initially, no amount of force would budge it as it was seized solidly in place. In the end, we used "Loctite Freeze & Release Lubricant" (Part No. FAR IDH1024403) to help free it. This "shock cools" and penetrates and lubricates the screw threads and this allowed us to eventually remove the sensor.

Note that special high-temperature grease must be used on the screw threads if you refit the existing sensor. A new sensor (such as the Bosch wideband sensor) will be supplied with this grease already applied to the thread.

be necessary and we have not provided for trimming this resistor.

Step 12: this step adjusts trimpot VR5 to give the best operating conditions for the Wideband Controller and to obtain the highest resolution available. To do this, measure the voltage at TP3 and adjust VR5 so that the voltage is at about 4.8V.

This setting now suits the particular sensor connected. If you change the sensor, this adjustment will have to be repeated. Alternatively, you can just leave VR5 set at 311Ω to suit all LSU4.2 sensors.

Step 13: check the various operating voltages The voltage between Vs and TP GND should be 2.450V, while the voltage between Vs/Ip and Vs should be 450mV. The voltage between TP7 and TP GND should be 2.5V.

There may be small variations here as the controller continually adjusts the current to maintain these voltages. If you have an oscilloscope, you will be able to see the 177mVp-p square wave imposed on the Vs voltage used for sensor impedance measurement.

Engine exhaust readings set-up

Having checked that the Wideband Controller accurately measures the O_2 content in air, you now have to readjust it to give accurate engine exhaust measurements. Here's what to do:

Step 1: switch off and remove the extra 560kΩ resistors between TP0 & TP5 and between TP6 & TP7.

Step 2: disconnect the sensor, then reapply power and adjust VR3 for a reading of 3.30V between the Vs/Ip terminal & TP GND.

Step 3: adjust VR4 for a reading of 3.92V between TP4 and TP GND, then check the voltage on TP1. This should be 0.385V with the sensor disconnected. This voltage can be adjusted by tweaking VR4 but the TP4 reading should still be at or very close to 3.92V.

Step 4: disconnect power and reconnect the sensor. Apply power again and check that the Heat LED is fully lit. Once this LED flashes, the Data LED will also flash at the same rate, indicating that the gas under measurement (air) is too lean for the lambda range of up to 1.84 (air has a lambda of 207).

Step 5: check that the wideband output is close to 5V and that the S-curve output is close to 0V.

Step 6: fit jumper JP1 to the 2-pin header. The Wideband Controller is now ready to measure exhaust gas.

Sensor installation

As mentioned in Pt.1, the Bosch LSU4.2 wideband sensor can be installed in the exhaust pipe using a suitable threaded boss. This should be as close to the engine as possible.

Note, however, that the exhaust gas temperature under all engine-operating conditions at the sensor position must be less than 850°C. In general, installing the wideband sensor in the same position as the existing narrowband sensor will be OK.

The following points should also be taken into consideration:

(1) The sensor must not be mounted in the exhaust manifold of a turbocharged engine. Instead, it must be installed after the turbocharger.

(2) The exhaust pipe section prior to the sensor should not contain any pockets, projections, protrusions, edges or flex-tubes etc, to avoid the accumulation of condensation water. Locating the sensor on a "downhill slope" of the pipe is recommended.

(3) Make sure that the front hole of the sensor's double protection tube does not point directly into the exhaust gas stream. Instead, mount the sensor



A Bosch LSU4.2 wideband sensor is used with the Wideband Controller. Note that other wideband sensors are not suitable for use with this controller.

Table 2: Capacitor Codes

Value	µF Value	IEC Code	EIA Code
220nF	0.22µF	220n	224
100nF	0.1µF	100n	104
10nF	.01µF	10n	103
3.3nF	.0033µF	3n3	332
1nF	.001µF	1n0	102
22pF	NA	22p	22

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	4	560kΩ	green blue yellow brown	green blue black orange brown
❑	2	470kΩ	yellow violet yellow brown	yellow violet black orange brown
❑	4	100kΩ	brown black yellow brown	brown black black orange brown
❑	1	82kΩ	grey red orange brown	grey red black red brown
❑	3	22kΩ	red red orange brown	red red black red brown
❑	1	20kΩ	red black orange brown	red black black red brown
❑	1	12kΩ	brown red orange brown	brown red black red brown
❑	2	10kΩ	brown black orange brown	brown black black red brown
❑	2	4.7kΩ	yellow violet red brown	yellow violet black brown brown
❑	3	2.2kΩ	red red red brown	red red black brown brown
❑	1	1kΩ	brown black red brown	brown black black brown brown
❑	2	470Ω	yellow violet brown brown	yellow violet black black brown
❑	3	150Ω	brown green brown brown	brown green black black brown
❑	1	120Ω	brown red brown brown	brown red black black brown
❑	1	62Ω	blue red black brown	blue red black gold brown
❑	2	10Ω	brown black black brown	brown black black gold brown

Tailpipe Sensing

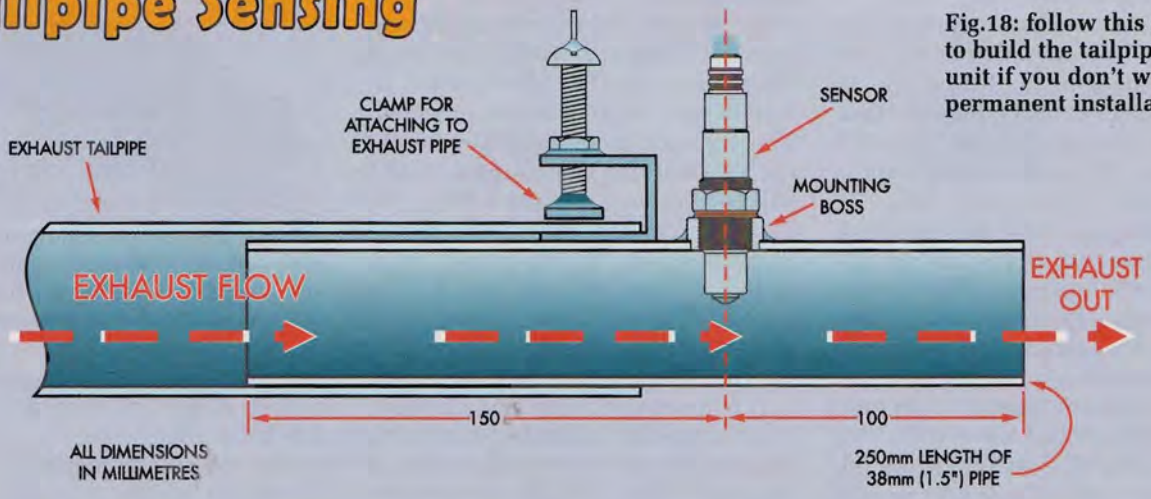


Fig.18: follow this diagram to build the tailpipe sensor unit if you don't want a permanent installation.

IF YOU DON'T WISH to install the wideband sensor permanently, an alternative is to mount it in a tailpipe extension. This tailpipe extension can then be slid over the end of the tailpipe and clamped in position – see Fig.18.

Note, however, that any readings obtained using this method will be affected by the catalytic converter and so won't be as accurate. That's because the catalytic converter reacts with the exhaust gas and changes the oxygen content. In addition, some catalytic converters include an air bleed to feed oxygen into the exhaust to allow full catalytic operation with rich gases.

Of course, this won't be a problem in older cars that don't have a catalytic converter. However, the sensor must be placed so that the exhaust is not diluted by air. Note also that exposing the sensor's leads to exhaust gas may alter the reference air composition of the sensor and give false readings.

Fig.18 should be followed quite closely if you intend mounting the sensor in a tailpipe extension. By using the dimensions shown, the sampled exhaust gas is taken sufficiently upstream from the end of the tailpipe to prevent dilution with outside air.

The pipe and clamp materials can be made of steel or brass but use a stainless-steel boss for mounting the sensor.

perpendicular to the exhaust stream so that it can constantly monitor fresh exhaust gas.

(4) Never switch on the sensor heating until the engine starts. **This means that jumper J1 must be installed to ensure heating does not begin until 13V has been measured on the battery supply. Check that this jumper is installed.**

(5) The sensor must be mounted so that it is inclined at least 10° from horizontal (electrical connection upwards) – see Fig.16. This is necessary to prevent liquid collecting between the sensor housing and the element during the cold start phase.

(6) The sensor receives reference air through the connection cable. For this reason, DO NOT use cleaning fluids or grease at the sensor plug connection.

(7) The recommended material to use for the threaded boss in the exhaust pipe is temperature-resistant stainless steel to the following standards: DIN 174401.4301 or 1.4303, SAE 30304 or 30305 (US). Fig.17 shows the thread boss dimensions. **Note that the sensor thread must be covered completely.**

(8) The use of high-temperature-resistant grease on the screw-in thread of the boss is recommended. The tightening torque is from 40-60 Nm.

(9) The sensor must be protected if an underseal such as wax or tar or spray oil is applied to the vehicle.

(10) The sensor must not be exposed to strong mechanical shocks (eg, during installation). If it is, the element could crack without visible damage to the housing.

(11) Both the sensor and its connecting cable should be positioned to avoid damage due to stones or other debris thrown up by the wheels.



The Wideband Controller mates with the Wideband Oxygen Sensor Display unit described in the November 2008 issue.

Frequently Asked Questions

Q: Can a wideband sensor directly replace a narrowband sensor?
A: No, a wideband sensor must be used in conjunction with a Wideband Controller. If the Wideband Controller has a simulated narrowband output, then this scan usually be connected to the ECU's oxygen sensor input instead of the narrowband sensor.

Q: I have heard that narrowband oxygen sensor (S-curve) simulators are not recognised as a valid sensor by the ECU which records a diagnostics fault code. Will the narrowband output of the Wideband Controller be recognised correctly as a valid sensor?
A: Yes, usually it will. Narrowband sensor simulators usually comprise an oscillator that delivers a voltage centred about 450mV, with a sinusoidal variation of about 50mV above and below 450mV. However, these simulators oscillate continuously regardless of mixture and do not respond in the usual manner to mixture changes (ie, where a rich mixture cause the sensor output to rise above the 450mV stoichiometric point and a lean mixture cause it to fall below this point).

By contrast, the Wideband Controller's S-curve output simulates the response of a narrowband sensor and it bases its output voltage on the actual mixture readings. So a lean mixture will cause the narrowband output to fall and a rich mixture will cause the narrowband output to rise above the 450mV stoichiometric point. Consequently, the ECU will recognise the signal as valid because it responds to mixture variations correctly.

Q: Can I use a different wideband sensor with the Silicon Chip Wideband Controller?
A: No, only the Bosch LSU4.2 is suitable.

Q: When the wideband sensor is installed in the exhaust pipe are there any special precautions to prevent sensor damage?
A: Yes. First, the controller must not be switched on until after the engine has started in order to remove any condensation within the sensor before it is electrically heated. In addition, the sensor must be mounted more than 10° from horizontal to allow moisture to run out. The sensor must also be installed where the exhaust gas heats the sensor quickly but where it does not go above 850°C.

Q: Can a wideband sensor be left installed in the exhaust pipe without a controller?
A: Yes, but only for a short duration. Otherwise you should remove the unused sensor and plug the exhaust hole if the sensor is not connected to a controller.
Q: Can the sensor and controller be used with a 24V supply?
A: No, the sensor is not been designed to cater for 24V operation and using it at this voltage would result in excessive heater element current.

Q: Can the sensor run from a 9V (216) battery?
A: No, the heater current is too high for a 216 type 9V battery. Also a 9V supply not may be sufficient for the heater to reach the required operating temperature.

Q: I want to monitor the Heat and Data LEDs inside the car. Can these LEDs be external to the wideband controller and connected to the controller using long wires?
A: Yes.

Q: If I unplug or plug-in the wideband sensor to the controller while the controller is still powered will it damage the sensor?
A: There is a possibility the sensor will be damaged, due to reverse Ip current. It's also possible that the ceramic material may crack due to incorrect heating up from cold.

Q: What is the life of the sensor?
A: Typically 10,000 hours or 160,000km if handled and installed correctly.

Q: How long after the controller is switched on before the air/fuel readings are available?
A: Less than 22 seconds with a 20°C gas temperature.

(12) Do not expose the sensor to water drips from the air-conditioner or from sources such as windscreen run-off during rain or when using the windscreen washer. The resulting thermal stress could damage of the sensor.

Fast preheat

Provided the sensor is correctly installed in the exhaust pipe and is rapidly heated by the exhaust, it can be preheated more quickly by starting at a higher effective heater voltage.

To do this, the code for the Wideband Controller requires a small change. This as at line 706 and involves removing the semicolon (;) from the beginning of line 706 – ie, from in front of "btfsc PORTB,0". The file then needs to be saved, reassembled and used to reprogram the PIC micro (IC1).

This change is only recommended if all mounting requirements are met. In addition, jumper J1 will need to be installed for the fast start preheat to take effect.

The Wideband Controller assumes an initial temperature of -40°C for pre-heating. This ensures that the sensor is not heated too rapidly for any initial temperature that's likely to be encountered.

Using the S-curve output

As mentioned, the S-curve output from the Wideband Controller can be used to replace the existing narrowband signal. However, the vehicle must be currently using a zirconia-type narrowband oxygen sensor. If the vehicle already has a wideband sensor, then this sensor should not be replaced with the S-curve signal.

A less common type of narrowband lambda sensor has a ceramic element made of titanium dioxide. This type does not generate a voltage but instead changes its resistance according to the oxygen concentration. Once again, this type cannot be simulated using the S-curve signal.

Identifying the sensor leads

In order replace the existing sensor with the S-curve output from the Wideband Controller, you first need to identify the leads running from the sensor to the ECU.

Basically, there are four narrowband sensor variations:
(1) If the sensor has one lead this will be the signal wire and the sensor body will be ground.
(2) If the sensor has two leads, one will be the signal lead and the other will either be a +12V heater supply or the

Parts List For The WideBand Controller

1 diecast metal box, 119 x 94 x 34mm (Jaycar Cat HB-5067)
1 PC board, code 05110091, 112 x 87mm
1 8-pin circular multi-pole panel plug connector (microphone type)
1 3AG in-line fuse holder
1 5A 3AG fuse (F1)
1 DIP18 IC socket
1 2-way PC mount screw terminals (5.04mm spacing)
1 3-way PC mount screw terminals (5.04mm spacing)
12 M3 x 4mm screws
4 M3 nuts
4 M3 x 6mm tapped Nylon spacers (do not use metal types)
1 3-6.5mm cable gland
17 PC stakes
1 2-way pin header with 2.54mm spacing
1 jumper for pin header
1 solder lug
1 50mm length of yellow medium duty (2A) hookup wire
1 50mm length of red medium duty (2A) hookup wire
1 50mm length of black medium duty (2A) hookup wire
1 100mm length of green medium duty (2A) hookup wire
1 150mm length of light blue heavy duty (7.5A) hookup wire
1 4m length of green heavy duty (7.5A) hookup wire
1 2m length of red heavy duty (7.5A) hookup wire
1 250mm length of 0.7mm tinned copper wire (or 9 zero ohm links)
1 140mm length of 3mm heatshrink tubing (or 20mm yellow, 40mm red, 40mm black, 40mm green)

Semiconductors
1 PIC16F88-I/P microcontroller programmed with 0511009A (IC1)
1 LMC6484AIN quad CMOS op amp (IC2)
1 CD4052BCN 1-to-4 CMOS analog multiplexer (IC3)
2 LMC6482AIN dual CMOS op amps (IC4,IC5)
1 LM317T adjustable regulator (REG1)
1 7808 8V regulator (REG2)
1 IRF540N 100V 33A N channel Mosfet (Q1)
1 BC327 PNP transistor (Q2)
1 BC337 NPN transistor (Q3)
2 3mm red LEDs (LED1,LED2)
1 16V 1W zener diode (ZD1)
1 1N4004 1A diode (D1)
3 1N4148 switching diodes (D2-D4)

Capacitors
5 100µF 16V PC electrolytic
1 22µF 16V PC electrolytic
4 10µF 16V PC electrolytic
4 220nF MKT polyester
4 100nF MKT polyester
1 10nF MKT polyester
1 3.3nF MKT polyester
1 1nF MKT polyester
1 22pF ceramic

Trimpots
1 500Ω multi-turn trimpot (3296W type) (Code 501) (VR1)
3 5kΩ multi-turn trimpot (3296W type) (Code 502) (VR2-VR4)
2 1kΩ multi-turn trimpot (3296W type) (Code 102) (VR5)

Resistors (0.25W, 1%)

4 560kΩ*	3 2.2kΩ
2 470kΩ	1 1kΩ
4 100kΩ	2 470Ω
1 82kΩ	3 150Ω
3 22kΩ	1 120Ω
1 20kΩ	1 62Ω
1 12kΩ	2 10Ω
2 10kΩ	1 0.1Ω 5W
2 4.7kΩ	

*(Two used for % oxygen in air readings)

Sensor Parts
1 Bosch LSU4.2 broadband oxygen sensor
Available from: TechEdge (http://wbo2.com/lsu/sensors.htm part # [07200])

signal common. For a heated sensor, the body will be a common ground for both the signal and heater circuits. (3) A 3-wire sensor has Heater+ (H+), Heater- (H-) and sensor signal leads, with the body as the signal ground. (4) The 4-wire sensor is similar to the 3-wire sensor but with an extra ground lead for the signal ground.

In each case, the leads are quite easy to identify but first a word of warning. **Do not measure the narrowband sensor impedance with a multimeter. The reason for this is that the current produced by the meter for resistance measurements will damage the sensor.**

Note also that the maximum loading for the sensor is ±1µA. **This means that to measure the voltage produced by a narrowband sensor, the meter must have an input impedance higher than 1MΩ.** Digital multimeters generally have an input impedance much higher than 1MΩ and so they can be used to measure the sensor's output voltage. However, the input impedance of an analog meter may not be high enough.

The first step in identifying the leads is to set your DMM to DC volts (eg, 20V), then connect the negative lead of the DMM to chassis. That done, it's a matter of starting the engine and probing the sensor's leads with the DMM's positive lead (a pin can be used to pierce the wire insulation but seal any holes with silicone afterwards to prevent corrosion). The sensor's H+ lead will be at +12V, while its signal voltage lead will be at about 450mV.

Once these two leads have been identified, switch off the engine and unplug the sensor. The H- terminal can now be identified – it's the one that gives a resistance reading of typically 5Ω (and usually less than 10Ω) to the previously identified H+ terminal **(warning: do not connect the meter probe to the previously identified signal terminal when making resistance measurements).**

The ground terminal is the one remaining.

With Bosch sensors, two white leads are used for the heater, while a black lead is used for the signal and a grey lead is used for sensor ground. However, this does not apply in all cases.

In some cars, the ECU will check that the sensor is connected and produce an error code if it detects that anything is amiss. In most cases, however, the S-curve signal from the Wideband Controller will be accepted

Bosch. Part # 0 258 007 200
Audi/VW Part # 021-906-262-B.
1 6-pin female connector for the sensor including 6 x 2.8mm female crimp spade terminals plus 6 end seals
Available from: Techedge (http://wbo2.com/cable/lsuconns.htm part # [CNK7200])
Or VW Part # 1J0-973-733 for the plastic shell only, type FEP FKG6-2,8/2FEP42122200.

1 8-pin circular multipole line socket
Available from:TechEdge (http://wbo2.com/cable/connkit.htm part # [P8PIN]
Or www.farnell.com.au cat #804-1563

1 6-way sheathed and shielded lead with 2x7.5A wires for heater.
Available from: Techedge (http://wbo2.com/cable/default.htm part # [DIY26CBL] for 2.6m long or part # [DIY40CBL] 4m long. Both parts include the 8-pin circular multi-pole line socket

1 8-pin circular multi-pole panel plug connector (microphone)
Available from: Techedge (http://wbo2.com/cable/connkit.htm part # [S8PIN]
Or www.farnell.com.au cat #804-1709

as valid but there are exceptions.

First, the ECU may check the sensor's impedance to determine if it is sufficiently heated (ie, when its impedance falls below a particular value). However, the impedance the ECU will measure at the Wideband Controller's S-curve output will be 150Ω and this may be incorrect for some sensors. For the Bosch LSM11 narrowband sensor, the impedance is less than 250Ω when heated and so the 150Ω impedance for the S-curve output should be satisfactory.

Other sensors may differ, however, and so the 150Ω output resistor may have to be changed to prevent an error code.

No provision has been made to vary the S-curve output impedance to simulate the heating of the sensor over time (ie, from a high value when cold to around 150Ω when hot). Usually, for a cold engine start, the ECU will wait until the engine is warm (as indicated by the temperature sensor in the cooling system) before readings from the oxygen sensor take place. By this time, the sensor will also be warm, with the S-curve output responding as it should to mixture variations and having a low impedance as expected by the ECU.

Conversely, the sensor will already be hot for a warm engine start.

If the ECU expects the S-curve output impedance to be high at engine start-up, then a timer such as the Flexitimer (SILICON CHIP, June 2008) can be used. This can be set to provide an open circuit connection between the S-curve output and the ECU for about 20 seconds after engine start, at which time the timer's relay contacts close to make the connection.

Heater fault indications

Some ECUs will indicate a fault if the heater leads to the oxygen sensor are disconnected. In this case, you will have to keep the original heater connection to the old oxygen sensor and mount it in a convenient place (eg, against the firewall). Just make sure that the heated sensor cannot be accidentally touched, as it can run very hot.

Alternatively, you can make up a resistance box that has the same nominal resistance as the sensor's heater element when hot. This should go in a diecast case and you would need to use resistors rated for the power.

The power rating is calculated by assuming a 14.8V maximum supply and a 50% derating. For example, if the heater resistance is 12Ω, then $14.8V^2$ divided by 12Ω gives 18.25W. In practice, a 40W resistor would thus be required.

A 12Ω 40W heater resistance could be simulated by connecting four 10W 47Ω resistors in parallel.

Sensor response rate

Another ECU check may involve the way the sensor responds to mixture changes in the exhaust gas. The ECU will expect the sensor output to be higher than 450mV for rich mixtures and less than 450mV for lean mixtures and the sensor's response rate may be tested.

For optimal set-up of the delay, the

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http://wbo2.com/diy

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Using A Wideband Sensor In A Permanent Installation

As a test, we substituted a wideband sensor for the narrowband sensor in a 2004 Holden Astra. The S-curve output from the Wideband Controller was then fed to the car's ECU (in place of the output from the original sensor).

This worked OK and no error codes were produced by the ECU. However, we did have to keep the heater circuit to the original narrowband sensor connected to achieve this result.

In operation, the narrowband signal from the Wideband Controller cycles correctly above and below stoichiometric but it appears to be twice as slow in its response as the original narrowband sensor. A new narrowband sensor also had a slower response than the original sensor.

The differences in the sensors are in the way the sensor is vented to the exhaust gas, the original narrowband sensor having side slits to allow fast gas entry. By contrast, the new narrowband sensor has its entry slits on the end while the wideband sensor uses small holes which are also at the end. As a result, the latter two sensors have a slower response because the gas is not replaced as quickly.

So using a wideband sensor as a permanent installation may not be ideal in all cases but will be OK for testing mixtures. Whether or not it is completely successful as a permanent installation will depend on the sensor orientation to the exhaust gas flow.

S-curve output from the Wideband Controller can be set to match the response of the original narrowband sensor. This adjustment is made using VR2 and can be as fast as the overall wideband response of <250ms when VR2 is adjusted for 0V on TP2. This can be increased up to an extra 1.2s when VR2 is set to that TP2 is at 5V, with shorter delays in between.

For example, a setting of 2.5V will increase the overall wideband response delay by 600ms (ie, to 250 + 600 = 850ms).

The correct setting for your vehicle can be easily determined if you have an oscilloscope. To do the test, make sure the original narrowband sensor is installed and connect the scope probe to the sensor's output signal. Alternatively, an OBD (On-Board Diagnostics) scan tool that shows live or real-time parameter data can be used to monitor the sensor voltage if this feature is supported on your vehicle.

When the engine is warm and idling, the sensor reading should oscillate above and below 450mV at a rate dependent on the sensor's response rate and the ECU. By using the oscilloscope, the frequency of oscillation and the voltage can be directly measured.

A typical narrowband sensor response is shown in Fig.19.

Now replace the narrowband sensor with the wideband sensor and connect the S-curve output from the Wideband Controller to the sensor+ signal input of the ECU.That done, adjust VR2 so that the response appears to be similar to that from the narrowband sensor. Note that adjustments to VR2 can take up to 5s to have any effect, so take it slowly.

If you don't have an oscilloscope, monitor the narrowband sensor output using a DMM and then try to match the response when the Wideband Controller's S-curve output is substituted. This method will not be very accurate, however.

Alternatively, you may prefer not to bother trying to match the response time. In that case, set VR2 so that TP2 is at 1.25V. This will increase the normal Wideband Controller response by about 300ms (ie, to about 550ms), which should suit most vehicles.

By the way, oxygen sensors do have a slower response as they age. This means that a faster response from the Wideband Controller can be used to simulate the narrowband sensor's output when it was new.

Finally, if the S-curve simulation proves unsuccessful, either because the engine runs poorly or the ECU logs a fault regardless of any attempts to match the response, then the narrowband sensor will have to be reinstalled. The Wideband Sensor will then have to be installed in a separate position.

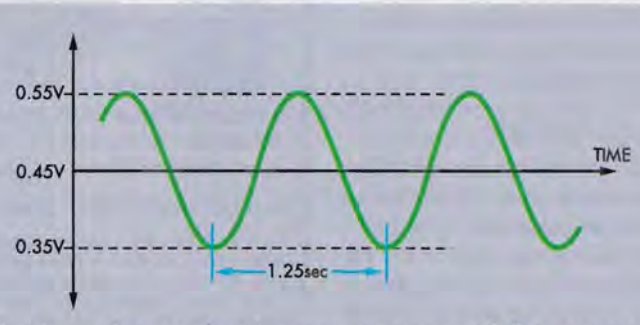


Fig.19: a typical narrowband sensor response with the engine warm and idling. The output oscillates above and below 450mV and can vary from just a few millivolts to about ±400mV (±100mV shown here).

Other applications

As indicated earlier in this article, the Wideband Controller can be set up to monitor the oxygen content in air. It can measure oxygen concentrations ranging from beyond the standard 20.9% in normal air right down to 0%. That makes it ideal for checking the oxygen content of the air in enclosed spaces such as fire bunkers and walk-in cold storage containers, where the oxygen content can be depleted due to human respiration.

Another application includes areas where oxygen is depleted due to combustion. This includes areas heated with gas, oil, coal or wood fires. Other instruments should also be used to ensure clean air, including those for monitoring carbon monoxide (CO) and flammable gases.

In order to correctly read the oxygen content, the tip of the sensor must be exposed to the air under being monitored while the "lead end" of the sensor must be exposed to normal air. In other words, the sensor has to be able to use normal air as a reference.

This means that the sensor must be mounted in the outer wall of the enclosed space, with its top section exposed to the outside air.

The voltage output from the Wideband Controller is directly proportional to the oxygen content in percent. So a 2.09V reading represents an oxygen content of 20.9%, which is the oxygen content of normal outside air. SC



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Vintage Radio



By RODNEY CHAMPNESS, VK3UG

The development of AC mains power supplies, Pt.1

The development of AC mains power supplies was an important step in the evolution of domestic radio receivers. Understanding how they work is important for vintage radio restorers, especially if the power supply has to be modified in some way.



This photo shows two common mains transformer styles from the valve radio era. The one on the left is an above-chassis mounting type while the other is a through-chassis type.

PERHAPS THE MOST common modification to a vintage radio's power supply is the substitution of a different rectifier valve. This may be necessary if the original type is no longer available or is difficult to obtain. Before substituting a rectifier valve though, it's important to first determine if the replacement is indeed suitable.

Considerable care is also necessary if a valve rectifier is to removed and converted to a solid-state circuit using diodes.

Different voltages

Valve radio receivers invariably require a number of different voltage rails to supply various parts of the circuit. What's more, the current requirements for these voltage rails can vary widely, depending on the circuitry that's being powered.

Originally, the necessary voltages in radio receivers were supplied by primary and secondary batteries. The capacity of the batteries depended on the current drain at the particular voltage required. For example, many old radios typically needed just 10mA at 90V for the high tension (HT) voltage supply, whereas a current of 2-3A may have been required to heat the filaments (usually at voltages of 1-5V).

As a result, the HT battery consisted of many small cells of limited capacity in series, while the filament or low-tension (LT) battery commonly used two or three large wet cells with perhaps 100 amp-hours (Ah) capacity.

In short, batteries were used to power the earliest valve radios and also to power the various valve portable radios that were later developed.

Unfortunately, the high power consumption of battery valve receivers meant that the cost of powering such receivers was quite high (this also applied to the later portable sets with their specially-designed "battery valves"). As a result, set manufacturers and experimenters looked at ways of supplying the necessary power to a radio from the mains. In the end, a fairly standard circuit quickly evolved and this was used in a wide range of receivers during the valve radio era.

Of course, running a set from the mains supply restricts where the set can be used. In most cases though, that didn't matter because the set was installed in a fixed location and the aim was to eliminate the use of batteries which were expensive.

Early mains supplies

As already mentioned, the early battery receivers used quite a bit of power to heat the valve filaments. However, these valves could not be powered from the AC mains via a transformer for a very simple reason: the cyclic current variations over a full mains cycle meant that the filament emissions and thus the HT current drain varied in sympathy.

Although the mains frequency in Australia, New Zealand and most of Europe is 50Hz, the severe hum heard in the audio output is at 100Hz. This occurs because the mains waveform reaches two peaks per cycle – see Fig.1. Similarly, in North America the mains frequency is 60Hz and so the hum occurs at 120Hz.

Converting the raw AC to DC was initially achieved using selenium or copper oxide rectifiers and devices called Tungar rectifiers. These were used to charge secondary cells/batteries but the hum they produced was intolerable for powering the valve filaments.

Because these problems were not immediately solvable, the filaments were supplied from batteries, usually wet-cell lead-acid types. However, it was possible to power the filaments while the batteries were on charge although some hum was still likely. Another problem was that as the battery neared the end of its charge, its output voltage could exceed the filament voltage rating of particular valves.

In short, this was a messy solution that required careful attention during the charging part of the cycle.

By contrast, deriving HT supplies was not as difficult as the currents were quite modest. In fact, Philips and other manufacturers made battery eliminators that could be used in place of the HT batteries in early receivers. The transformer was wound with either a centre-tapped secondary winding or a single winding. Its output was then rectified and filtered to provide the correct HT voltage for the plate circuits.

The early rectifiers were solid-state types but the 280 (also known as the 80 and the 5Y3GT) eventually made its appearance. This was used as a "bi-phase" (or full wave) rectifier, its two plates (the anodes) being connected to opposite ends of a centre-tapped secondary transformer winding – see Fig.2. The centre tap of the transformer was usually connected to earth.

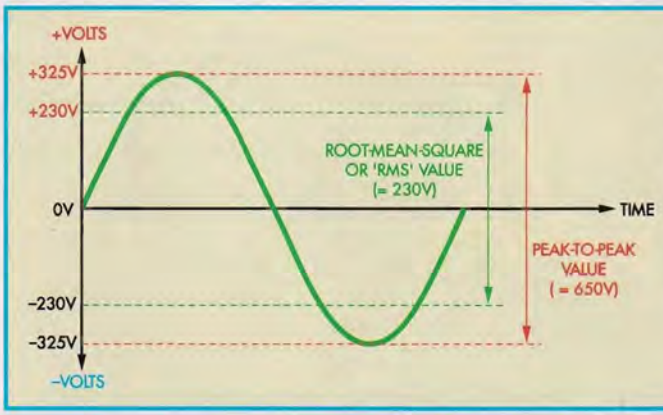


Fig.1: the AC-mains waveform. There are two peaks per cycle and this can give rise to 100Hz hum unless proper design precautions are taken.

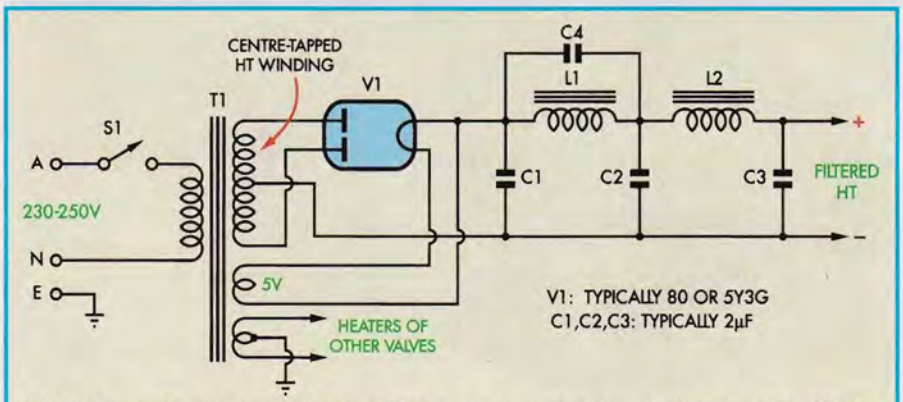


Fig.2: an early mains-derived radio power supply circuit. Because the filter capacitor values were so low, two chokes (L1 & L2) were used in series to achieve adequate filtering.

The 100Hz pulsating DC output from the rectifier cathode/filament was applied to a high-voltage paper capacitor of around 2µF, wired between the cathode and the centre-tap of the transformer winding. This reduced the hum somewhat. Following this capacitor, a choke of 10-30 Henries was placed in series with the HT+ and its output in turn applied to a second 2µF paper capacitor wired between HT+ and HT-.

An additional stage consisting of a further 2µF capacitor and large inductance choke was also often used and with this amount of filtering, the HT voltage was near enough to pure DC. It might be thought that having two chokes and three capacitors was a case of overkill. This was not so, as electrolytic capacitors were not available and manufacturers had to make do with low-value, high-voltage paper capacitors.

Valves with AC filaments

Having successfully come up with a scheme of deriving filtered HT from the mains, the manufacturers next at-

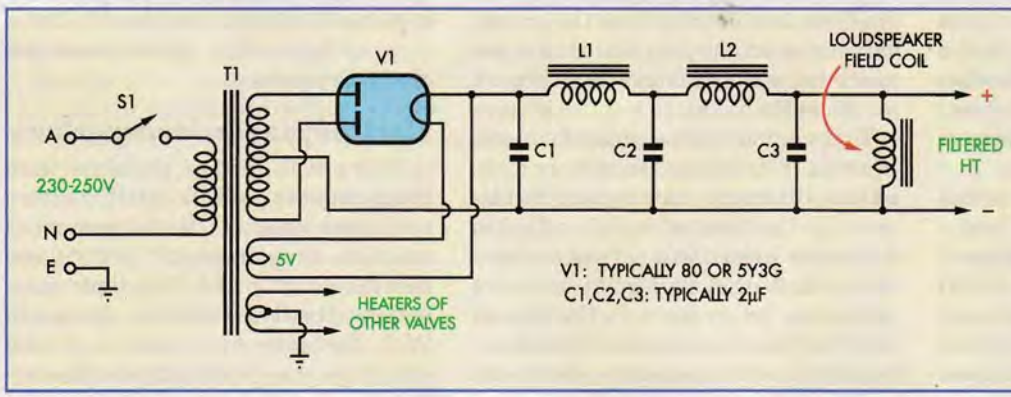


Fig.3: the field coil of early electrodynamic speakers was powered by connecting it across the filtered HT line. In later sets, the field coil performed a dual role and was placed in series with the HT line, taking the place of one of the filter chokes.

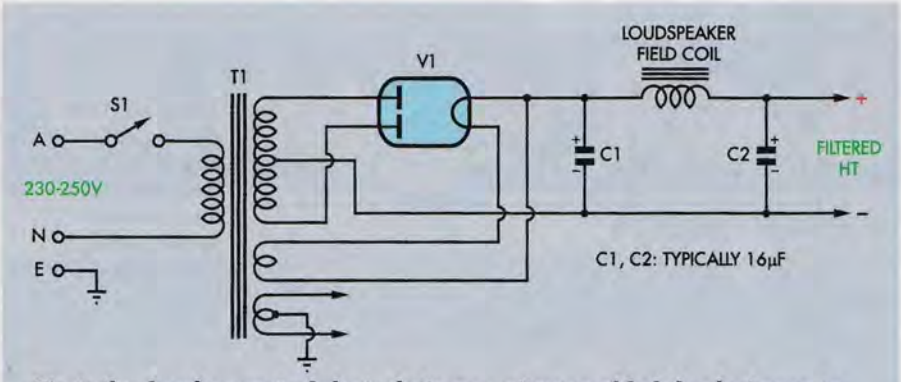


Fig.4: the development of electrolytic capacitors enabled the designers to use just one HT filter choke. This could be either a separate choke or the field coil of an electrodynamic loudspeaker.

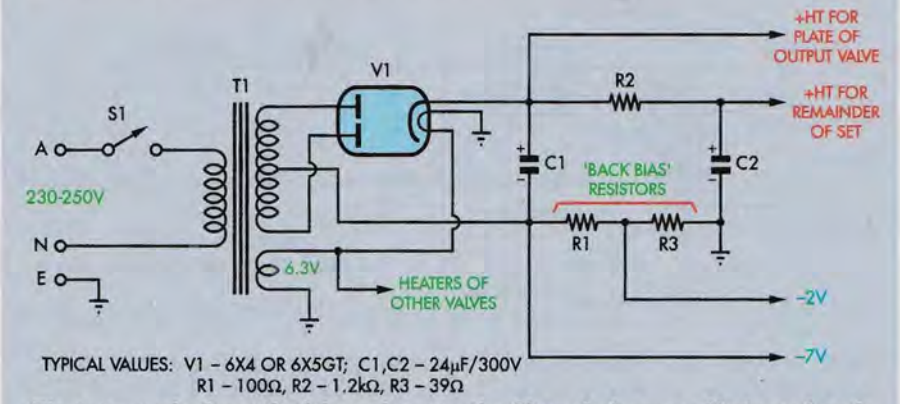


Fig.5: towards the end of the valve era, the filter choke was eliminated and was replaced by a resistor (R2). The HT for the output valve was derived directly from the first filter capacitor – see text.

tacked the problem of hum from the valve filaments.

This was done in several in several ways. First, for the power output valves, they reduced the filament voltage (2.5V was common) while increasing the current. This had the effect of increasing the thermal inertia of the filaments so that they didn't cool significantly between each peak of the mains cycle. This in turn meant that there was less variation in the current drawn by the valve over a mains cycle and so hum was reduced.

However, by itself, this was often not enough and so the 2.5V heater lines were often centre-tapped, with the centre tap going to chassis to further reduce the hum. The 2A3 is a typical example of a valve built to minimise the hum problem.

In other cases, where no centre tap was provided on the 2.5V heater line, a device called a "hum-dinger" was fitted. This consisted of a 6-25Ω wirewound potentiometer, which was connected across the 2.5V transformer winding. The pot's moving arm was connected to earth, either directly or via a resistor.

In practice, the potentiometer was adjusted so that hum in the output was minimised. This "hum-dinger" arrangement was also used in later high-performance valve audio amplifiers (also referred to as "hum-bucker" but see reference below) to minimise residual hum, even with indirectly heated, low-noise valves.

However, the same method of reducing hum from the filaments in earlier stages of a receiver or amplifier was impractical. That's because their heaters drew less current than the output valve and so they cooled down too much between each successive peak on the 50Hz mains.

To overcome this, manufacturers eventually developed indirectly heated valve filaments. In this case, the filament (or the "heater" as it is called in indirectly-heated valves) was encased in a sheath that had good emissive properties when heated. The sheath and the filament/heater are insulated from each other and so the sheath has considerable thermal inertia.

This thermal inertia is the reason it takes so long for an indirectly-heated valve to start operating after power is applied. The average time is 10-15 seconds, which is much slower than the fraction of a second it takes for a battery valve to start operating.

As a result, indirectly-heated valves (ie, valves with indirectly-heated cathodes) generate very little hum although it did take the manufacturers some years to achieve consistently low levels. Eventually, some valves were designed to have extremely low heater hum, such as the low-noise EF86 pentode.

Towards the end of the valve era, the designers of low-voltage power supplies were able to provide much better filtering as high-value electrolytic capacitors became available. Some hifi manufacturers even supplied the heaters in the preamplifier valves of audio amplifiers with well-filtered low-voltage DC to largely eliminate residual hum.

More economical filtering

Indirectly heating the valve cathodes using low-voltage AC largely solved the hum problem, at least as far as the valve heaters were concerned. In fact, during the 1930s, the filament/heater voltage was increased to 6.3V and directly-heated output valves were phased out. A 6.3V heater rating meant that they could be used in car radios, as most cars had 6V batteries at that time (ie, three cells at a nominal 2.1V per cell).

During this time, there were also further developments in filtering the HT voltage. Electrolytic capacitors were becoming quite common so instead of having a filter with three 2µF capacitors and two 10-30H chokes, it was now possible to use two 8µF or 16µF electrolytic capacitors separated by just one filter choke. This provided superior filtering at considerably lower cost, as large-value chokes were not cheap to produce.

Electrodynamic loudspeakers

There was also a problem with loudspeakers. While early battery sets used speakers with permanent magnets, they were not particularly sensitive and could lose their magnetism if badly treated (eg, dropped). With the advent of mains-operated sets, it became practical to employ so-

called electrodynamic loudspeakers. These used an electromagnet instead of a permanent magnet. However, the electromagnet had to be fed with well-filtered DC otherwise hum would once again be prevalent in the audio output.

In the early days, the electromagnet was fed with DC from the output of the power supply filter network. However, it was soon realised that the electromagnet could serve a dual purpose as both the HT filter choke and as the speaker magnet.

Unfortunately, this wasn't without its own problems initially, as the first filter capacitor is unable to remove all the ripple from the HT line before it is fed to the electromagnet's coil (or voice coil).

To overcome this problem, manufacturers developed a simple yet effective fix. A small coil called a "hum-bucking coil" was connected in series with the voice coil. The two were basically wired in anti-phase and this arrangement effectively cancelled out any hum produced by variations in the voice coil's magnetic field due to ripple on the HT line. For this reason, if you ever send away an electrodynamic speaker for repair and remove the output transformer, make sure that the leads to the hum-bucking coil are reconnected correctly when re-installing the unit.



A typical electrodynamic loudspeaker, this one from a 1920s Lyric 8-valve console. In this case, the iron-cored chokes and the speaker transformer are attached to the unit to form a single assembly.

Indirectly heated rectifiers

By now, most of the problems with mains supplies had been solved. However, there was one last problem to be solved – excessive HT voltage immediately after switch on.

To explain, considerable power is used to energise the field coil and so the voltage dropped across it when the set is operating is normally around 100V or more. However, at switch on, a directly-heated rectifier such as an 80 conducts within about a second while all the other (indirectly-heated) valves in the set take at least 10 seconds to start conducting.

During this warm-up period, the electrolytic capacitors will be fully charged and the rectifier will have virtually no load. As a result, the voltage on the HT line feeding the valves (ie, following the HT filter network) may be up to 200V higher than when the set is operating. This in turn meant that the components in such sets had to be rated to withstand this high voltage for a short period.

This problem was eventually overcome by using indirectly-heated rectifiers, larger value electrolytic capacitors and efficient permanent magnet loudspeakers. In addition, several further refinements were made which reduced the need for a filter choke.

First, the plate (anode) of the receiver's audio output stage was connected directly to the junction of the first electrolytic filter capacitor (C1), the cathode of the rectifier and a resistor between that point and the second filter capacitor (C2) – see Fig.5. The HT at the junction of R2 & C2 is then fed to the rest of the set.

Typically, a resistor of 1000-2000Ω separated the two 24μF electrolytic capacitors and this combination provided very effective HT filtering. However, the output valve's plate can be fed directly from the rectifier because the plate circuit has no gain. This means that the ripple with a high-value filter capacitor is reasonably low.

Most sets by now used a tetrode or pentode output valve and the plate current of such valves is controlled mainly by their screen and grid voltages. These voltages are well-filtered and are nearly pure DC. In addition, the low-frequency audio response of mantel sets was deliberately restricted so that hum was rarely a problem.

Finally, another innovation introduced at about the same time involved applying an anti-phase hum signal to the grid of the output valve (more on this later).

Power transformers

The power transformers used in domestic radio receivers came in many different shapes and sizes. In particular, the transformers used in older, larger receivers were often equipped with a primary winding which had several tappings to accommodate a variety of mains voltages, both locally and overseas. In Australia, most locations had AC mains voltages of between 200V and 250V.

In addition, there could be up to half a dozen secondary windings or more. In fact, four separate heater windings were not uncommon, some of them centre-tapped. In addition, there was usually one high-voltage centre-tapped winding (eg, 285V or more) and sometimes also an addi-



The filter chokes used in valve radios looked very much like small transformers. A typical unit is shown here, together with several electrolytic capacitors.

tional secondary winding to provide bias voltages for the receiver.

Towards the end of the valve era, the primary transformer winding was untapped as the nominal supply voltage at that time was 240V AC (it is now 230V AC). The secondary windings usually consisted of one 6.3V filament winding rated at around 3A plus a single untapped high-tension (HT) winding of 110V (eg, as used in the Kriesler 11-99).

In keeping with the construction techniques then used, the transformers were designed for chassis-mounting, with the laminations either parallel or at right angles to the chassis. Various techniques were used to prevent the transformers from generating circulating currents into the chassis, which reduces their efficiency.

In addition, because there was often quite a bit of electrical interference on the mains in earlier times, an electrostatic shield was commonly fitted between the primary and secondary windings. This greatly reduced the interference that could be inducted from the primary into the secondaries and hence the signal circuits of the receiver.

Electrostatic shields were more prevalent in earlier transformers andwere not used towards the end of the valve era.

Transformer temperature

Power transformers become warm during normal operation and later models often become warmer than earlier ones. There are a couple of reasons for this. First, the insulation on the windings in later models could withstand higher temperatures and this allowed the manufacturers to compromise on the materials used. This meant they could build smaller, lighter transformers which ran warmer for the same power output as earlier designs.

This also allowed manufacturers to save on the cost of materials.

By the way, anyone who has an American receiver will probably find that its transformer gets quite warm if run from 115V 50Hz AC. That's because it was designed for 60Hz mains and the transformer windings have a lower impedance at 50Hz. Because of this, it's prudent to operate such a set from about 105V AC if possible, to minimise transformer heating.

The power that can be drawn from a transformer is measured in volt-amps (VA). For example, the ubiquitous 2155 15V 1A multi-tapped transformer is rated at 15VA. Simply, it is just 15V x 1A = 15VA (or 15 watts for a purely resistive load)!

If the 15V AC output is rectified by a bridge rectifier and filtered, the DC output voltage at low load will be about 21V (less the voltage across the rectifier block). This voltage is simply the peak voltage of the AC sinewave and is 1.414 x the root mean square (RMS) voltage (the AC voltage measured on a typical digital multimeter). Note, however, that the DC voltage reduces as the current drawn increases (ie, as the load increases).

Note also that we cannot draw 1A from this power supply if the transformer is not to be overloaded. Instead, the maximum current drawn needs to be reduced to 1/1.414 x 1 = 0.7A. This ensures that the transformer's rating isn't exceeded since 21V x 0.7A = 15W (approximately).

However, that's really not the end of the matter because quite high peak currents are drawn from the transformer by the rectifier and filter capacitors. This in turn causes increased heating of the transformer. As a result, it's good practice to derate the maximum DC current to around 0.6 of the transformer's current rating.

Many transformers these days come with a built-in thermal fuse. If you do exceed the transformer's current rating, this fuse can blow and the transformer will cease to work.

By contrast, the transformers in valve radios are usually rated somewhat differently to the 2155. The heater windings are usually rated in terms of voltage and current, while the HT secondary winding is rated indirectly. For example, the HT secondary may be rated at (say) 300V at 100mA DC, following the rectifier and choke-capacitor filter network.

However, this is not a purely resistive load due to the charging current involved, as discussed above. In fact, the DC output of the power supply can be as high as 424V DC (at the input to the first choke) and if it can supply 100mA at this voltage, then the VA rating of the winding is around 42.4W. If the winding is only feeding a pure resistive load with no rectifier and filter network, the current that can be drawn will be 141.4mA x 300V = 42.4W.

In short, it's important to keep the VA ratings of a transformer in mind when you have to modify a power supply. This will ensure that the transformer operates within its rating and doesn't fail prematurely.

That's all for this month. Next month in Pt.2, we'll look at how to maintain vintage radio power supplies so that they continue to work well, despite being 70 years old or more. This is particularly important when the original parts are no longer available and substitutes must be used to keep a receiver operational. SC

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Speed control for a 110V movie projector

Would either of the universal motor speed controller circuits published this year (February or May 2009) be suitable for running a 110V AC motor. Could they be easily adapted?

The application is a French Pathe 9.5mm film projector, circa 1950, that runs off 110V AC via a stepdown transformer. The motor speed control (not original) is currently via a series wirewound pot. (P. H., Warwick, Qld).

● The May 2009 motor speed control would be suitable. One of the 4.7kΩ 5W resistors supplying the 15V supply would need to be replaced with a wire link to provide the necessary current from 110VAC.

Power supply needed for Mighty Midget

I have recently built the Mighty Midget power amplifier published in March 2002 and I am having trouble getting it going. I have music going in but I am only getting half a watt out. The sound is distorted and crackly and it starts oscillating.

I have checked all solder joints and tested the power consumption (110-150mA) and all checks out OK. I am running it off my lab power supply at 13.8V with a 4-ohm loudspeaker.

I am pretty sure that the TDA1562Q chip was not heat-damaged by my soldering iron. Can you help? It could have some thing to do with the muting feature inside the TDA1562Q. (R. C., Menai NSW).

● The power supply needs to be hefty enough to prevent the voltage dropping under load when driving the speaker. It should work with a 12V car battery or with a power supply that has sufficient current capability (4A). Some 2200µF capacitors across the power supply will help.

Audio power meter modifications

I am wondering if it is possible to modify the Appliance Power Meter (SILICON CHIP, July & August 2004) so it can measure audio power through a resistive load? (G. M., via email).

● It is possible. The voltage inputs connecting pins 6 & 7 of IC1 to the mains supply (via 2.2MΩ and 1kΩ resistor dividers) would need to be disconnected from the mains supply and connected to the amplifier output. Similarly, the current measurement resistors R1 and R2 (going to inputs at pins 4 and 5 of IC1) would need to be disconnected from the mains and connected so that the amplifier load current flows through the sense resistor, R1.

Optimising Ultra-LD bias and offset

I recently built a stereo version of the Ultra-LD Mk.2 Amplifier (SILICON CHIP, August & September 2008) and all is working as it should except that the bias current is still too low on both boards even though I built them with a 47Ω emitter resistor for Q7.

Your update on this in the September 2008 issue states do not reduce the resistor below 47Ω, yet that would be my next step. I am a bit of a perfectionist and will not be happy until I see 8.5mV across the 0.1Ω resistors. What do you suggest? Why do you say do not to go below 47Ω?

Also one of the channels has 34mV on the output while the other is just 4mV. As the perfectionist I want to see less than 10mV here and I think 34mV is way too high. I would reduce the resistance slightly of one of the Q1/Q2 emitter resistors to adjust this. Is this the best way? Is it safe?

I have let the amplifier warm up without the 68Ω resistors and replaced the fuses but the voltages are as stable as a rock; that is very encouraging but still not at the correct levels. (R. P., Horley, UK).

● We do not recommend going too low in resistance for Q7's emitter because it can cause heating in transistors Q7 and Q9. Instead, the bias current can be increased to the correct level by adding a low-value resistor (usually between 5-10Ω) in series with the diodes in output transistors Q12-Q15. There is a track between Q13 and Q14 which can be cut to accommodate this.

The output offset can be adjusted by balancing the emitter currents in Q1 and Q2. You could adjust it using

Occasional Switching Problem With Tempmaster

I have built the Tempmaster Mk2 project and have been having problems where occasionally, when it switches the relay on, there is a great amount of chattering and the freezer I am using shuts down. Could this be a comparator oscillation problem when it switches sometimes? (J. S., Newcastle, NSW).

● We doubt if the comparator in your Tempmaster is oscillating only occasionally. If there was any tendency to oscillate it would probably be occurring every time the comparator switched, not just occasionally.

Because of the occasional nature of the problem, its cause may be "spikes" on the mains generated by the inductance of the compressor motor windings. If this is the case, it should respond to either connecting a mains filter between the Tempmaster's output GPO and the compressor motor, or connecting a 47nF "X2" 250VAC rated capacitor across the relay contacts.

If you try the latter approach, make sure that you insulate the capacitor leads carefully to prevent accidental shocks.

Honda Cylinder Deactivation Comments

Your article on Honda's cylinder deactivation system (SILICON CHIP, January 2009) answered questions I had on just how it was done. Since retiring from the motor trade, I've had no opportunity to find out.

The article brought to mind characteristics of piston engines not usually known. First, they are ideally suited for compression. As the pressure rises, the crankshaft leverage over the piston is increasing, both reaching a maximum value at TDC. However, as a power producer the system fails awfully, because at the top of the down stroke when pressure is very high, the piston has very little leverage over the crank. Maximum leverage doesn't occur until just before half stroke, when the pressure is at a very low value.

The amount before half stroke at which this occurs is a function of con-rod stroke ratio or con-rod angularity. The shorter the rod, the earlier the maximum leverage occurs and this is also the point of maximum piston speed. This gives rise to the piston on the down stroke having less than 90° in which to reach maximum speed but more than 90° in which to slow to a stop. It has longer to accelerate to maximum speed and less to decelerate to a stop on the up-stroke. This is one cause of vibration.

All piston rings leak a slight amount, as shown by our engine oil becoming black. The piston rings act as a labyrinth seal. Pressure which passes the first ring expands in the inter-ring space and so there is less leakage past the next and subsequent rings. However, as the pressure in the cylinder reduces, it would take less power to compress and expand the same air. Another aspect is that high compression ratios are also high expansion ratios and it is only because combustion is still occurring that there is any pressure left to do any work.

I have often wondered if more power could be obtained by using a very low compression ratio but bringing the pressure up to a higher figure by supercharging or turbocharging. Variable valve timing which is the flavour of the moment has been used by steam locomotives for over 100 years. (R. M., via email).

● In fact, the cylinder pressure is not maximum at TDC (top dead centre). Engine spark timing is adjusted over the rev range to allow for the flame-front to generate maximum pressure when the piston has moved past TDC, even though the spark occurs well before TDC. That is why the ignition is advanced as the RPM rises. And whether the motor is a long-stroke or short-stroke is immaterial. Maximum cylinder pressure occurs as the piston is travelling down, just as it should be.

Maximum piston speed always occurs half-way down the cylinder, ie, half the stroke, regardless of con-rod length and engine type. After all, the piston is exhibiting simple harmonic motion, ie, a sinusoidal function.

Variable valve timing in steam engines has more to do with sharp steam cut-off than it has in IC engines with their overlapping of inlet and exhaust valves.

Variable compression engines are now being developed by companies such as Peugeot and Lotus.

a low-value trimpot in series with one of the 100Ω emitter resistors. You may have to swap the trimpot to the other emitter resistor if the effect of adjustment makes the offset worse.

DC-DC converter wanted

I need a DC-DC converter that delivers 27V from a 9V alkaline battery. Can you help? (R. R., via email).

● A DC-DC converter was published in the June 2003 issue of SILICON CHIP. The output could be increased to 27V by changing the 1.2kΩ resistor at pin 5 of IC1 to 820Ω. Its output current capability would be around 1A at that voltage.

Note that the input current would exceed 4A when delivering 1A at 27V from a 9V input. You may wish to short out diode D3 at the input to reduce current drain on the 9V battery.

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Measuring capacity in a horizontal tank

Referring to the LED Water Level Indicator Kit (SILICON CHIP, July 2007), if used in a horizontal round tank, the liquid level is not proportional to the volume (contents). Are the incremental level divisions separately adjustable/controllable to allow for this? (R. P., via email).

● If you want the level indicator to show capacity rather than water level, you will need to calculate the required

PICAXE Datalogger Question

I have assembled the PICAXE-18X 4-Channel Data Logger Unit (SILICON CHIP, January 2004). The light sensor is fine but the temperature produces a straight line two divisions up the 260 vertical scale, regardless of temperature.

I believe the DS18B20 sensor is defective. I get a variable voltage on terminal CT6 with slight changes in light but there is no change on terminal CT5 "data" with changes in temperature. I have no idea of the temperature range but did go to 80°C. Now that I have some results I have a few questions:

(1) What is the temperature range of the unit?

(2) Are the two spare inputs ready for use as is or do they require some programming?

(3) If I purchase the Honeywell humidity sensor, would any programming be required? (L. W., via email).

• We asked Clive Seager, from Revolution Education Ltd in the UK, to reply to your question. His reply is as follows:

The temperature sensor, a DS18-B20, is an "intelligent" digital sensor that communicates serially, so you will not see any voltage change on the pin as you will with an analog sensor like the LDR. It's rated from about -20°C to +80°C.

The sensors are very robust. So as long as it is connected around the correct way it is likely to work! They do look like transistors so make sure the correct number is printed on the device – DS18B20!

Also make sure you select the correct temperature sensor when running the program generation wizard. The spare inputs are ready to go, eg, with the humidity sensor. Simply enable them during the software wizard.

locations of the sensor contacts and then space them accordingly.

Source for FX2242 pot cores

I am trying to source an FX2242 pot core assembly featured in the Circuit Notebook pages of your May 2009 issue. Are you able to advise where this part may be obtained? I have found that most suppliers only stock the smaller FX2240 part. (D. H., via email).

• Contact Neosid, 23-25 Percival Street, NSW 2040. Phone 02 96604566. Or **www.neosid.com.au/pots.html**

They have the 26mm (OD) x 16mm (H) (FX2240 equivalent) pot cores through to 30mm (OD) x 19mm (H) and 36mm (OD) x 22mm sizes of pot cores.

Noise in voice recorder module

I recently constructed the 45-Second Voice Recorder Module (SILICON CHIP, May 2005 & December 2007). After setting it up and plugging it into the CHAMP amplifier I am getting a repetitive click and hiss in the playback.

I am powering both the voice module and the amplifier off the same 9V regulator circuit. I am fairly certain that the click is coming from the strobe LED. If I remove it, will the kit still be operational? (N. R., via email).

• Noise and clicks are probably caused by the supply earthing. Make sure the earth to the CHAMP is directly at the supply input earth connection.

The 9V supply to the CHAMP could be isolated from the voice recorder via a 100Ω resistor to help reduce the noise. Taking the LED out of circuit will not affect the unit's operation.

Igniter for pilot on Stanley Steamer

I am looking for a CDI unit that will give me a continuous spark from a battery power source at a spark rate of about one second continuous. It is needed to make sure that the pilot burner on my 1909 Stanley Steamer car is kept alight at all times, as they have a habit of going out occasionally when the main burner is ignited.

These old Stanleys had no electrical system originally but I have a 12V battery to supply power for stop lights. (G. M., Christchurch, NZ).

• The Jacobs Ladder Mk.2 kit from the April 2007 issue will provide a continuous spark. It is also sold as a kit by Jaycar (KC5445). The spark rate is set at 75 times per second. This can be slowed to around one a second by changing the 18kΩ resistor between pin 7 of IC1 and pins 4 and 8. A value of 1MΩ should be suitable.

Digital signal strength indicator wanted

I am interested in the Digital RF Level & Power Meter (SILICON CHIP, October 2008). I am a caravanner and am having trouble picking up digital stations when camping.

Recently at Port Macquarie, when pointing to both Taree and Coffs Harbour, my digital LCD with built-in tuner pixellated at will, sometimes though a perfect picture. I thought this project may be useful for eliminating signal strength as the culprit; either too weak or too strong. If it can detect signal strength for TV tuners, it could be used to manually tune the antenna to the strongest signal source at each camp, for instance, as well.

I have had my Happy Wanderer amplified antenna tested and it is OK so either I was getting a poor signal or my built-in tuner in my cheap Conia is faulty. If this project isn't exactly suitable for my needs, I'm sure you would make a lot of campers happy if you could design a kit for taking on the road to help with tuning our TVs. (G. C., Woonona, NSW).

• Sorry to disappoint you but the Digital RF Level and Power Meter would not be suitable for your digital TV signal strength application. Its range only extends up to about 500MHz and most of the FTA digital TV stations use higher frequencies. Nor is it tunable, which would be a requirement if it was going to be able to indicate the signal strength of a particular channel.

Unfortunately, there is no simple solution although AvComm have the DigiAir dB meter for $448.00 – see **avcomm.com.au**

Tester for ignition control modules

I would like to build a simple test unit for the Ignition Control Modules that were used in older European cars (VW/Audi/Porsche) and more specifically, the "2-valve" BMW motorcycles; specifically, a signal generator to simulate the signal from the Hall Effect sending unit.

The compatible Hall Units are Bosch

Rebuilding A Li-ion Battery Charger For A Camera

I was given the task of repairing my granddaughter's Olympus camera's charger but alas that proved to be a hopeless job as the faulty components were not available. A replacement charger was nearly the cost of a new camera and would have to be ordered in from the importers.

As a result, I am building a new charger board to fit the old case, using some of the circuits that you used in the "Mega Fast Charger" that was in the June 1988 issue of SILICON CHIP. As you well know it uses the drop in voltage of the Nicad battery to turn the charger off.

What I would like to know is, as I am charging a 3.7V/1090mA Li-Ion battery not a Nicad, when is the battery fully charged?

The charger I am making uses fixed current which I can adjust from 400-50mA and the switch "OFF" voltage is also adjustable from 4.2V down to 2.0V. Most Li-Ion batteries have three terminals; the third terminal measures about 0.36V less than the positive supply. What is the third terminal used for?

Unfortunately, I have not been able to get any data sheets on Li-Ion batteries. Can you help me? (M. M., via email).

• Most Lithium-ion cells are charged to 4.20V, with a tolerance of ±0.05V/cell. Charging to only 4.10V reduces the capacity by 10% but provides a longer service life.

Smaller batteries used for cell phones can be charged at 1C; the larger cells should be charged at 0.8C or less. The charge efficiency is 99.9% and the battery remains cool during charge. Full charge is attained after the voltage threshold has been reached and the current has dropped to 3% of the rated current or has levelled off.

No trickle charge is applied because Li-Ion cells are unable to absorb overcharge. So avoid overcharging. Commercial Li-Ion packs contain a protection circuit to limit the charge voltage to 4.30V/cell. That is 0.10V higher than the voltage threshold of the charger.

Temperature sensing disconnects the charge if the cell temperature approaches 90°C. More information can be found at **http://batteryuniversity.com/partone-12.htm**

The third terminal on the battery is probably a thermistor or diode connection (between battery positive and the third terminal) for temperature sensing.

0 232 101 020 (1 237 011 052, Siemens HKZ101 and/or Honeywell 2AV54. Many of these ICMs are interchangeable with only minor differences.

For a "load bank" (to simulate the ignition coil(s)) I intend to use 10 x 10Ω 10W ceramic resistors with a cooling fan (from a PC power supply). This will give a resistance of 1Ω which is a compromise between the older 2 x 6V ignition coils (wired in series for a total approximate resistance of 1.5Ω which was the minimum for the older Ignition Control Modules) and the newer "dual tower" ignition coils that typically had a resistance of about 0.7Ω.

I have modified a 250W PC supply for some testing (such as low-resistance measurement, using an LM317T and 1.25Ω "adjust" resistor to measure millivolts at 1A and then Ohms Law to convert to ohms – versus big money for a small-ohm DVM). However, the current limit for 12V on the power supply is 10A and therefore I will probably just use an old car battery. I have one DVM that measures frequency and another "automotive" DVM that measures dwell.

First, I would like to test ICM turn-on/turn-off function/times. Some of the older ICMs turned on with the ignition key and stayed on. This sometimes would trigger an initial spark at turn-on and if the ignition was left on without starting, would overheat the ignition coil. In later versions of the ICM, to protect the ignition coil from overheating, current to the ignition coil would be turned on with the ignition key but then turn off after about 1.2s or 5s. This was determined by whether the motorcycle had a kick starter or not (the extended 5s period was for models with a kick starter).

Later, the Ignition Control Modules would not apply current to the ignition coils at all until after first receiving one, two or even three signals from the Hall Sending Unit and in turn, turn off after about 1.2s; a problem for kick-start models that could, at best, be compensated for by repeatedly switching the ignition on and off – a bit of an act when balancing a fully-loaded R100GS in the muddy jungles of Guatemala! This particular function could be tested with a simple momentary button and observing either a DVM or indicator LED.

Another spec to measure, and the primary reason for my letter, is to check for differences in dwell of the

How To Drive A Fisher & Paykel Motor

I recently removed a brushless motor from a old Fisher & Paykel washing machine. I have searched far and wide for information on a simple kit to drive it, as I am unsure of how to do this.

On the web there is lots of information regarding generator/alternator modifications but I wish to use this on an electric pushbike project running off a 12V or 24V battery.

I think these are fantastic motors which should not go to waste and with an appropriate DC driver could find their way into a variety of applications. (A. M., via email).

• While it is relatively simple to rewind/rewire these motors to drive diodes and generate power, it is much more complex to use them as a motor. In effect, you need a variable frequency, variable voltage DC-to-AC inverter. Unfortunately, we have not produced a suitable circuit for that application.

As a starting point, you could have a look at the solar powered fountain driver published in the Circuit Notebook pages of the March 2009 issue. This circuit would need to be substantially modified to suit your washing machine motor.

Notes & Errata

Battery Zapper, July 2007: the BY-229 fast recovery diode D3 is wrongly specified as a BT229 in the parts list on page 28.

6-Digit GPS Clock, May-June 2009: as Mr Kevin Olds noted in the August 2009 issue (page 9), the seconds display updating was delayed by about 300ms every five seconds when the clock was being driven by the EM-408 GPS receiver module. This was due to the extra "GPGSV" or "GPS satellites in view" data sentences inserted by the EM-408 module into its data stream output every fifth second, ahead of the GPRMC sentence from which we were extracting the UTC time information.

The method chosen by Mr Olds to avoid this delay was to reprogram the EM-408 from his PC so that it no longer inserted the GPGSV sentences into the data stream every five seconds. This certainly solves the problem but other readers found the method unappealing because it involves sending commands to the EM-408 module from their PC, via an RS-232 serial link.

That being the case, designer Jim Rowe has found another way of solving the problem: by modifying the firmware in the GPS Clock's PIC micro so that it extracts the time information from the GPGGA sentences instead of the GPRMC sentences. This prevents the inserted GPGSV sentences from delaying the seconds display updating, because the EM-408 module sends out the GPGGA sentences at the start of each second's data stream.

The revised "Version 3" firmware for the GPS Clock's PIC controller will be available from the SILICON CHIP website by the time this note is published, for free downloading. Those who find the "short delay every five seconds" too irritating can therefore remove it, simply by reprogramming their PIC16F877A micro with this new Version 3 firmware.

various ICMs. I am searching for a relatively simple method to simulate the Hall Sending Unit signal. A sweepable range of 900 RPM to approximately 3000-4000 RPM would be nice but switchable for 900-1100 RPM (idle speed), 1400-1800 RPM, 2200-2800 RPM, 3200-3600 RPM and 4000 RPM would also work. These ranges are based on experience while riding my motorcycles.

Naturally, the frequencies would be half of the desired RPM ranges. I assume that the signal tends to be more of a "Schmitt Trigger" signal than a sine signal. I am not sure of the diameter of the vane/wheel or the width of the windows on the vane/wheel and therefore am unsure of the pulse widths. I have made exhaustive efforts to find these specifications from the OEMs – Bosch, Telefunken, AEG, Fairchild, Siemens and TEMIC but all to no avail. (J. H., Wroclaw, Poland).

● The output from Hall Effect sensors such as the Siemens HKZ101 is usually just a square wave. This is because the vane used to break the magnetic flux comprises a gap to vane ratio that is equal. So a signal generator producing a square wave can be used to simulate the signal.

The only addition would be a transistor output that can be made up using a BC337 transistor with emitter to the ground, collector to the ignition input (simulating the Hall Effect open-collector output) and the base connected to the signal generator output via a 4.7kΩ resistor.

Idiot's guide to programming

Can you recommend an idiot's guide to programming PICs? By that I mean if I built a programmer (eg, the design in SILICON CHIP, May 2008) how do I go from there, assuming all I want to do is download the software from the SILICON CHIP site and load it onto an appropriate PIC?

I presume I need the hardware, a lead to connect to my PC and software (WinPic?). I really don't want to write my own programs, just load PICs for projects. (J. G., via email).

● Most books about PICs will go into how to program them as well as how to write programs (the latter you don't seem to be interested in). That being the case, to program a PIC you require:
(1) a hex file (extension .hex);
(2) some programming software to run on a PC, like WinPic;
(3) a cable to connect your PC to a programmer;
(4) a programmer like the dsPIC/PIC serial programmer featured in the May 2008 issue of SILICON CHIP.

You simply need to then connect the programmer to your PC using the cable, run WinPIC and import the hex

... continued on page 103

WARNING!

SILICON CHIP magazine regularly describes projects which employ a mains power supply or produce high voltage. All such projects should be considered dangerous or even lethal if not used safely.

Readers are warned that high voltage wiring should be carried out according to the instructions in the articles. When working on these projects use extreme care to ensure that you do not accidentally come into contact with mains AC voltages or high voltage DC. If you are not confident about working with projects employing mains voltages or other high voltages, you are advised not to attempt work on them. Silicon Chip Publications Pty Ltd disclaims any liability for damages should anyone be killed or injured while working on a project or circuit described in any issue of SILICON CHIP magazine.

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Ask SILICON CHIP – continued

Spring reverberation – an oldie but a goodie

I am planning to build the "Spring Reverberation Module" from SILICON CHIP, January 2000. I have been able to source a different spring tank than the one in the article and I was wondering what circuit changes need to be made to accommodate this unit.

What I have is an "Accutronics 4DB2C1D" which is a 2-spring tank which has a 250Ω DC input resistance and 2250Ω output. I know this is a big ask but I am hoping that you will be able to provide assistance. (M. B., via email).

● The reverb unit you have is quite different in impedances compared to the specified 80Ω/800Ω unit we used. Consequently, the driver amplifier may have to be altered to suit the frequency response of your 250Ω spring reverb input and the recovery amplifier may require altering in gain.

Basically, the 16kHz high-pass filter of the driver amplifier may need shifting to a lower frequency. This is determined by the 10nF capacitor in series with the 1kΩ resistor at pin 6 of IC1a. A larger value will give a lower frequency.

The recovery amplifier will need a gain change if the signal level at the output is either too low or too high. This can be altered by changing the 820kΩ resistor between pins 6 & 7 of IC2a. A smaller value gives less gain. Some experimentation will be required.

. . . continued from page 103

file and set the PIC device (eg, 16F88).

For the dsPIC/PIC Programmer in the May 2008 issue you also need to set the jumpers correctly, as explained in the article. Then WinPIC will program and verify the PIC, etc. You then have a programmed PIC.

Amplifier temperature cut-out is too sensitive

I have found that the speaker protection circuit in the 20W Class-A Amplifier cuts the speakers off due to heat. Is the temperature control really necessary or can it be made less sensitive? I have built the amplifier with the heatsinks outside its case. (P. W., via email).

● As described in the July 2007 article, although the speaker protection circuit has provision for over-temperature cut-out, this facility is not used for the Class-A Amplifier because the heatsinks DO get hot. The answer to your problem is simply to disconnect the temperature sensor. This assumes of course, that the operating current of the amplifier is quite stable and not showing signs of thermal runaway.

Spark plug tester wanted

I was looking for a circuit diagram or kit to construct a spark plug tester. The unit would just be enclosed in a box with a pushbutton and some way of attaching the plug.

Commercial units cost about $300 and I am sure one could be made for much less. (D. S., Kempsey, NSW).

● The Jacobs Ladder project from the April 2007 issue would do the job. It uses an automotive ignition coil and this is driven via a circuit that rapidly charges and fires the coil. The output can then drive a spark plug.

However, a spark plug also needs testing under pressure and heat to simulate cylinder conditions. SC

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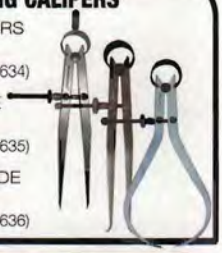
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