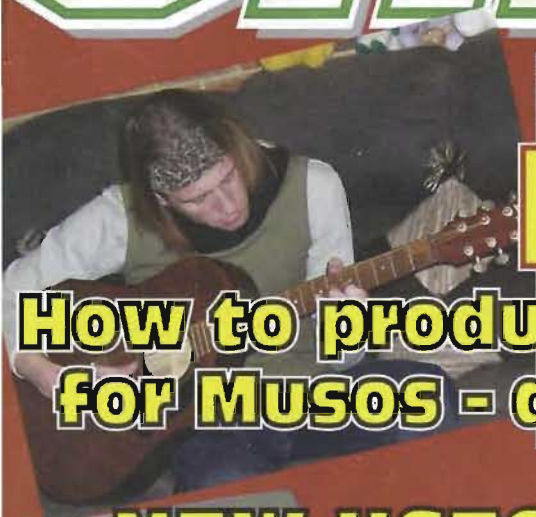
SILICON CHIP

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How to produce pro-quality audio CDs for Musos - at a fraction of the cost!

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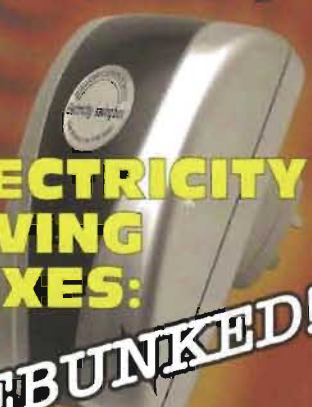
PIC-based Water Tank Level Meter with optional radio telemetry!



BUILD A UV LIGHTBOX WITH TIMER

and make your own Printed Circuit Boards at home:

WE SHOW YOU HOW!

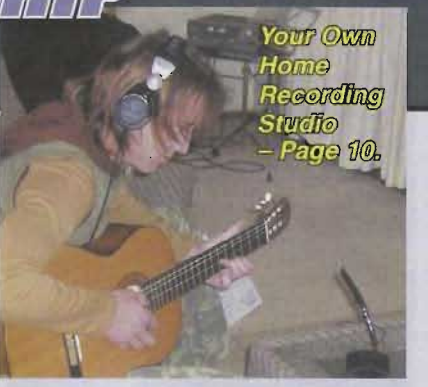


ELECTRICITY SAVING BOXES: DEBUNKED!

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Publisher & Editor-in-Chief
Leo Simpson, B.Bus., FAICD

Production Manager
Greg Swain, B.Sc.(Hons.)

Technical Staff
John Clarke, B.E.(Elec.)
Ross Tester
Jim Rowe, B.A., B.Sc, VK2ZLO
Mauro Grassi, B.Sc.(Hons.)

Photography
Ross Tester

Reader Services
Ann Morris

Advertising Enquiries
Glyn Smith

Phone (02) 9939 3295
Mobile 0431 792 293
glyn@siliconchip.com.au

Regular Contributors
Brendan Akhurst
Rodney Champness, VK3UG
Kevin Poulter
Mike Sheriff, B.Sc. VK2YFK
Stan Swan

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Editorial office:
Unit 1, 234 Harbord Rd,
Brookvale, NSW 2100.

Postal address: PO Box 139,
Collaroy Beach, NSW 2097.

Phone (02) 9939 3295.

Fax (02) 9939 2648.

E-mail: silicon@siliconchip.com.au

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Publisher's Letter

Now for the next 20 years



20 years have passed in the life of SILICON CHIP, its staff and those readers who read the first issue, back in November 1987. Actually, last month, October 2007 was the 240th issue of SILICON CHIP and I suppose we could have celebrated our 20th anniversary last month.

Our thanks to all those readers and advertisers who have supported us over the years. You have helped us grow and survive. Of all our advertisers, I must single out our three major supporters, Jaycar Electronics, Dick Smith Electronics and Altronics. Without your particular and consistent support, we certainly would not have survived. But thanks also to all our other advertisers – you all help contribute to the financial health of this publication which is vital for long-term survival and growth.

It has been a long haul for all concerned but very gratifying nonetheless. Who could possibly have imagined all the technological changes which would occur in those 20 years of publishing? There are so many that it is hard to nominate the most important changes but they have probably involved mobile phones, DVDs and the internet. All of these existed in some form or were being developed prior to 1987. Most other technology changes that we now use and take for granted are really just incremental.

What will happen in the next 20 years, as far as technology is concerned? If you could answer that question, you will be a real prophet. For our part, we will only nominate a few areas where technology changes are likely to be significant. The first of these will involve the production and use of electrical energy. We are bound to become much more efficient in our use of energy, right across all human activity. The same comment applies to the use of water. That will apply regardless of whether Australia becomes a lot drier in the years to come.

As far as video technology is concerned, it seems very likely that laser projectors will soon become available, as well as 3D TV (demo models are already in the research labs) and even fancier mobile phones with better screens, cameras and so on.

We also think that there will be drastic changes in medical technology in years to come and this will run the gamut of gene technology, DNA and stem cell technology, all sorts of electronic medical implants, robot medicine and so on. Sure, there will be lots of improvements in communications, speeds of computers and the internet, plus massive changes in software to do all sorts of stuff but really, all of that will be incremental. More than that, we just don't know.

As far as SILICON CHIP is concerned, we are preparing for the next 20 years. Back in 1987, we had three other direct competitors in the form of "Electronics Australia", "Electronics Today International" and "Australian Electronics Monthly" and a host of foreign magazines from Europe and the USA. All the local competitors have gone and so have most of the international magazines. Those that are left are generally only a shadow of their former selves, leaving SILICON CHIP as one of the very few magazines of its type in the world. We expect that SILICON CHIP will become even more select in the future.

With the continuing support of our tens of thousands of readers and our advertisers, we plan to grow and develop our special capabilities as a significant electronics publisher. It is bound to be an interesting and challenging ride.

Leo Simpson

BitScope USB Mixed Signal Oscilloscope

Analog + Digital

Digital Storage Oscilloscope
- Dual Channel Digital Scope with industry standard probes or POD connected analog inputs. Fully opto-isolated.

Mixed Signal Oscilloscope
- Capture and display analog and logic signals together with sophisticated cross-triggers for precise analog/logic timing.

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- Display analog waveforms and their spectra simultaneously. Base-band or RF displays with variable bandwidth control.

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- Eight logic/trigger channels with event capture to 25nS.

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- Built-in flash programmable DSP based function generator. Operates concurrently with waveform and logic capture.

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Inventing the future requires a lot of test gear...

...or a BitScope



BS100U Mixed Signal Storage Scope & Analyzer

Innovations in modern electronics engineering are leading the new wave of inventions that promise clean and energy efficient technologies that will change the way we live.

It's a sophisticated world mixing digital logic, complex analog signals and high speed events. To make sense of it all you need to see exactly what's going on in real-time.

BS100U combines analog and digital capture and analysis in one cost effective test and measurement package to give you the tools you need to navigate this exciting new frontier.



Standard 1M/20pF BNC inputs Smart POD Connector



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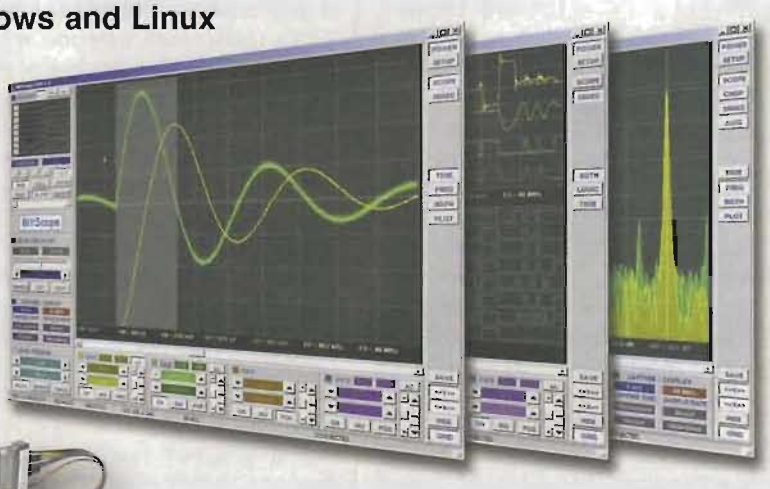
BitScope DSO Software for Windows and Linux

BS100U includes BitScope DSO the fast and intuitive multichannel test and measurement software for your PC or notebook.

Capture deep buffer one-shots, display waveforms and spectra real-time or capture mixed signal data to disk. Comprehensive integration means you can view analog and logic signals in many different ways all at the click of a button.

The software may also be used stand-alone to share data with colleagues, students or customers.

Waveforms may be exported as portable image files or live captures replayed on another PC as if a BS100U was locally connected.







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Sensor light with no manual over-ride

I wish to respond to the article in Ask Silicon Chip, page 97, May 2007 (and the response in Mailbag, page 5, July 2007), regarding sensor lights staying on due to intermittent power glitches.

There is an HPM brand sensor, model 630/3A, that is set-up to work in sensor mode only, with no built-in manual override (note: the 630/3 has the built-in manual override). Power glitches, brownouts or switching the power off, then on again within two seconds doesn't affect it.

If you wish to install a manual override on the 630/3A, you can simply add an external bypass switch.

Tony Cassaniti,
Garden Suburb, NSW.

Satisfaction with Nixie clock

I just had to let you know that the Nixie Clock published in the July & August 2007 issues is the best kit I have ever built. It took me about 10 hours to complete and I was very careful to ensure correct alignment of the various components.

My wife is so pleased and impressed by the Nixie Clock that she has made room for it in one of her glass display cases. The clear Perspex case really does make the Nixie Clock look incredible! Congratulations to David Whitby and Silicon Chip!

Dave Sargent,
Howard, Qld.

Simple tank indicator has drawback

The simple tank water level indicator presented by John Williamson in the September 2007 issue does indeed perform exactly as he says. However when I tried the very same idea a while ago the problem I had was that the water in the clear plastic tubing was then exposed to sunlight and began to grow some multi-coloured algae which I decided I didn't want in my drinking water.

Tony Ullman,
Georgica, NSW.

Comment: good point. The tube must not be exposed to sunlight.

Reason to invert a laptop display

I have been looking for a way to invert the screen of a laptop for about a year. I tried Google, online forums, etc and eventually gave up.

I therefore read the Serviceman's Log for September 2007 with great interest. It presented an easy solution to my needs.

Interestingly the Serviceman could not think of why anyone would use this. In my case, the application is to mount an old laptop upside down on the roof of my 4WD and use it to display navigation with a GPS and as a large roof-mounted DVD player.

Tony Wise,
Melbourne, Vic.

Speedo readings not good enough

I have read the recent letters regarding car speedo errors. I find it quite disconcerting that manufacturers are permitted such a large error. If I go into a supermarket and buy 100 grams of product, I expect to get very close to 100 grams (maybe ±1%). I would be very displeased to find that I only had 87.273 grams.

As you state, it must be very frustrating for heavy vehicles with speed limiters set at 100km/h to be stuck behind a line of cars all doing 88km/h even though their speedos are showing 100.

Your correspondent Adrian Leake (Silicon Chip, August 2007) asserts that odometers are calibrated to read accurately. My experience is that they read low. On several different 5km 'Speedo Check' zones my odometer read between 4.8km and 4.9km (2-4% low). A timed check of the speedo shows that 100km/h is indicated as 108km/h, a fact that I can testify can't be too much in error as I drive on the highway with the speedo indicating just below the 110km/h mark (approximate needle width) and have never had a speed camera ticket although I pass a large number of cameras on various highways.

Surely it is about time that car instrument manufacturers caught up with the rest of the world and made instruments that indicate more accurately the speed and distance. Perhaps even radar or GPS technology would beat the old mechanical devices running off the transmission.

Bill Neumann,
Yeerongpilly, Qld,

Climate change scepticism

There has never been any doubt that the publisher, Leo Simpson, stands on the conservative side of the political spectrum but I would call him a climate-sceptic rather than "denier" and some hard-nosed scepticism is certainly needed with some of the self-serving "solutions" on offer.

Changing the area lighting on a block of flats to CFLs saved considerable power but the biggest impact was from the longer life, meaning that visits from an electrician at $80 per blown light globe were cut to one-third, never mind better lighting. The much higher cost of the CFLs was recovered in only a few months.

I've installed and maintained some remote area solar power systems and I agree that they are quite uneconomic

Who wants a watch when they retire?

One of our Broadcast Engineers here at DMG Radio Australia (Kevin Stephens, pictured) recently retired from our company. I was at a loss as to what to buy him as a retirement gift.

Usually, a fine wristwatch is given to a faithful employee after many years of service. In this case, I was looking for something a little unusual and after reading the article about the Nixie Clock project in SILICON CHIP, I knew exactly what I would get him.

Kevin actually used Nixie tubes in the early part of his electronic career, so this was a perfect gift. I contacted David Whitby of Gless Audio who kindly agreed to assemble a Nixie Clock in time for Kevin's retirement party and presentation.



As you can see, the idea of a "retirement watch" was still adhered to. Kevin was delighted with his gift.

Steve Adler,
Technology Director,
DMG Radio Australia,
Adelaide, SA.

where mains power is available. There are still large gains to be made in household energy integration such as waste heat recovery from fridges.

The economy of solar-electric panels is reduced by charge regulators that simply disconnect all those expensive watts, rather than redirecting them to the fridge and homestead water pumps in a load-shed tree.

However, I am at a loss to understand your swipes at solar hot-water heating. If there is one thing that already significantly unloads the urban electrical system it has to be domestic solar hot-water heating. The daily shower gobbles a surprising amount of energy.

But it's not often that I get a good belly laugh from a SILICON CHIP editorial. After a couple of swipes at "environmentalists" (whatever that means these days), Leo Simpson goes on to demolish tree planting as a "net carbon sink".

Why I find this funny is that this very argument has been a mainstay of the native forest logging industry (misquoting a CSIRO study). Only a few years ago, it was "environmentalists" who were being derided for saying exactly what you go on to say – the mature carbon-sink trees would then have to be somehow totally removed from the eternal carbon cycle! That makes you as green as a "Forest Feral" Leo.

Sadly, the arguments for CO_2 as "landfill", electric motoring and the nuclear fuel cycle still need similar cold scrutiny. In contrast, geothermal power looks very hopeful at this point, not least because the "waste" is not the stuff of parental nightmares and terrorist dreams.

Roly Roper,
Ivanhoe, Vic.

Solar hot water systems should be booster-free

I have two comments on Peter Seligman's recent articles on how to cut greenhouse gas emissions. Firstly, concerning renewable energy from the electricity grid, when the renewable energy source is not generating, there is no electricity available from that source. Quite obvious really, so your energy consumption must fall to zero; ie, the light should go out.

If it doesn't, it must be coming from a non-renewable source or some form of magic! Worse still, a fossil fuel machine needs to be running, using fuel, waiting for the extra demand. This is known in the power industry as "spinning reserve."

Real renewable energy consumers

Atmel's AVR, from JED in Australia

JED has designed a range of single board computers and modules as a way of using the AVR without SMT board design



The AVR570 module (above) is a way of using an ATmega128 CPU on a user base board without having to lay out the intricate, surface-mounted surrounds of the CPU, and then having to manufacture your board on an SMT robot line. Instead you simply layout a square for four 0.1" spaced socket strips and plug in our pre-tested module. The module has the crystal, resetter, AVR-ISP programming header (and an optional JTAG ICE pad), as well as programming signal switching. For a little extra, we load a DS1305 RTC, crystal and Li battery underneath, which uses SPI and port G.

See JED's www site for a datasheet.

AVR573 Single Board Computer



This board uses the AVR570 module and adds 20 An./Dig. inputs, 12 FET outputs, LCD/Kbd, 2xRS232, 1xRS485, 1-Wire, power reg. etc. See www.jedmicro.com.au/avr.htm

$330 PC-PROM Programmer

This programmer plugs into a PC printer port and reads, writes and edits any 28 or 32-pin PROM. Comes with plug-pack, cable and software.



Also available is a multi-PROM UV eraser with timer, and a 32/32 PLCC converter.

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Mailbag: continued

Some stereo TVs don't reproduce stereo sound

Much has been discussed over the years about picture quality of LCD vs plasma television sets. But I am not sure if people are all that concerned about the quality of the audio from their new whiz-bang TV.

I recently discovered that at least one model of a well-known brand LCD is incapable of producing stereo on all TV channels. It consistently delivers dual monaural – ie, exactly the same sound from both channels – on Southern Cross High Definition. The problem is also evident on ABC HD, WIN HD and PRIME HD but it doesn't seem to be consistent.

I've checked three other examples of this particular model and this definitely seems to be not just a fault but a major design flaw in this TV. It could very well be that there are other brands and models with the same problem. My investigations have revealed that this model is incompatible with the various audio modes being broadcast (see **http://www.dba.org.au/index.asp?sectionID=14**).

So if you are concerned about the audio from your TV, then have a close listen. You might be surprised to find it is not performing as expected.

I wonder if people really do "listen with their eyes" and could be blissfully unaware of this problem.

Trevor Dalziell,
Symonston, ACT.

don't consume when the renewable energy is not there! Otherwise it is not renewable energy – it is a sham.

Secondly, concerning solar hot water systems, about 25 years ago I lived in Papua New Guinea and developed an interest in "alternative energy." My employer (Department of Civil Aviation) had numerous remote aircraft radio navigational beacons and many were solar-powered (photovoltaic with lead-acid batteries) and I had friends who were missionaries.

Most missionaries were in locations where there was no power grid. Some had no electricity at all and for others, diesel-powered generators met all electricity requirements.

Diesels have 40% or better full-load efficiency and could be a source of hot water from the "waste heat" in the cooling system. I never calculated overall efficiency but it would have come close to 50% at full load with the waste heat recovery factored in.

Unfortunately, no one ran their machines all day. (6:00am to 1:00pm, and 4:00pm or 5:00pm to 11:00pm was common). Cooking was usually solid fuelled (carbon neutral) and many stoves had a heating coil for hot water but this form of water heating is not really "waste heat recovery" and won't work between meals!

Solar heating was a viable alternative. Experience tells me that with a sufficient sized collector and tank, there was no requirement for a "booster". Most Australian commercially available solar hot-water systems at the time were adequate in PNG. At my own home, I covered one or two of the three collectors in the dry season as the water was too hot! I think it must have been designed for Melbourne!

After some design research, it became apparent that these same systems had a plate surface area that was about one third of that required for Perth latitudes and the tanks were too small for the planned consumption. My conclusion was that solar hot water systems designed for Perth were too small, and deliberately designed to be "boosted!" As a corollary, solar hot water systems, designed for the installation's latitude won't need boosting and therefore will be truly "carbon neutral" in their energy consumption.

Hence, booster-free solar hot water systems are the correct direction for reducing greenhouse emissions in domestic installations. Consumers need to become aware of the difference and government needs to promote the value of such systems.

Alan Johnson,
Greenmount, WA.

Are mobile phones a hazard?

Like many others in our industry over the years I have followed the debate over possible health implications associated with using mobile phones. My background included control, communications and radar from 10kHz up to 20GHz so I think I have sufficient knowledge to comment from a perspective of over 40 years. Recently, a thought occurred to me on the phone issue and I would like to put it out there for discussion.

Phone studies seem to vary from maybe there is to maybe there isn't a problem. In a similar manner to Scandinavia enforcing stringent standards on the zoo of signals associated with CRT monitors, perhaps it is time to examine how the phone studies were conducted and whether they were appropriate or sufficient. Some studies were based on statistical analysis of epidemiology data. Results were sometimes significant, others not conclusive.

I am cynical about any establishment and their ability to spin a story to put the best face to protect their interests. It occurred to me that physical studies were undertaken but very little detail of such tests is available. The thought was, "Did the test take into consideration close proximity of the mobile phones to the head?" I had been of the view that signal levels were at such a low level that the risk was higher from base stations. I did also consider a possibility existed that the pulse nature of the signal had an ability to force resonance and perhaps cause problems with some molecules.

We traditionally think in term of far field radiation and not the near field where the signal is launched, as is the case for mobile phones. Wavelengths used for mobile phones ranges from about 30cm down to about 5cm for some cordless phones. Purists will argue about the transition phase from near field to far field but for general discussion the conventional value of half a wavelength is sufficient. The near field for 900MHz phone services half is about 15cm and covers most of the brain cavity. This is also a problem for cordless phones at 25mm but less so.

In the near field, the magnetic component predominates and this is the issue that occurred to me. The near field being a magnetic field must interact with our blood due to its iron content. I would be interested to know if this has been considered. Any data obtained needs to reflect near field locations and not more conventional far field locations. Suitable data that may be available from radiography but such data would reflect a steady signal as compared to a predominantly pulse signal. Also the phone "duty cycle" would be higher. Have the hard yards been done or is part of our industry conveniently sticking its head in the sand?

Am I a technophobe? Far from it. It is important that we discuss such matters in a dispassionate way, unlike emotional mainstream press coverage. As technologists, we know that at some level hazard conditions start. Would a biologist studying radio illumination of a biological test subject even consider or be aware of the difference between near and far field conditions and possible differences in outcomes?

Brendan Falvey,
Gundaroo, NSW.

New Australian Vintage Radio Society

Your readers may be interested to hear about the formation of a new vintage radio organisation. The Australian Vintage Radio Society Inc is a not-for-profit organisation dedicated to the preservation of our radio and radio related electronic history.

Meetings are held on the fourth Saturday afternoon of the month and visitors are welcome. Most meetings include a talk by a presenter with experience in the field of restoration or history and a display of radios and related equipment of the era.

Other services available to members include a bi-monthly newsletter,



SBS is available from satellite

In the September 2007 issue on page 99 there is an item about poor UHF TV Reception from W. M., of Lesmurdie, WA. His problem was that he was unable to get SBS clearly in Perth, despite being just 6km from the transmitter.

My suggestion is to get either a 65cm or 85cm satellite dish and get SBS Free-to-Air (FTA) off the Optus B3 satellite with an FTA satellite set top box. Have a look at Christian Lyngmark's Lyngsat website (**http://www.lyngsat.com/optusb3.html**) which shows what is on all satellite TV feeds.

Also, have a look down the bottom of Optus B3 list and you will find Free-to-Air SBS with a KU spot beam over WA.

Tony Liolio VK2ZLT, via email.

technical assistance, restoration workshops, a valve and component bank and a circuit diagram service.

Further details can be obtained by contacting the secretary at: Australian Vintage Radio Society Inc, PO Box 3099, Syndal LPO Vic 3150. Or visit our website at **www.avrs.org.au**

Warwick Woods, President, AVRS.

50th anniversary of Sputnik I

1957 was the year I started school and the year space travel commenced. October 4th 2007 was the 50th anniversary of the 3-week long flight of Sputnik I.

At that time, my father was working as a scientist in the CSIRO's Radio Research Board (RRB) under Dr David F Martyn, based in the Sydney area. This research group was investigating the structure and behaviour of the upper atmosphere. The experimental side of this work involved transmitting radio signals up and observing the reflected signals returned. This meant that there was a selection of antennas, receivers and expertise available to receive signals from the first spacecraft.

One Saturday afternoon, Dad and I drove to a building in the grounds of the University of Sydney. I remember being in a room dimly lit by outside light through high-blinded windows. There were large grey equipment racks, some with dark knobs, glowing dials and lamps on front panels. I remember one with a round green CRT display. There was the dull red glow of valve heaters visible where there were no front panels.

On a work table there was an incomplete looking metalwork thing and some cylindrical objects with wire pigtails. I had seen a similar sight in a WWII bunker used by RRB near Camden Airport.





Various knobs were adjusted and then we waited, Dad attempting but failing to explain Sputnik to me. Then it started, "bleeep bleeep bleeep bleep". The explanations then became simpler. The sound was coming by radio from 90 miles above from the first man-made orbiting satellite.

My first thought was this was like many other bleeps I had heard while near equipment racks. But I then realised my usually unemotional Dad was keen to share both the facts and his excitement, about this scientific and technical advance.

My recollection is that Sputnik I was not visible to the unassisted eye due to its small size but that the final rocket stage was. However, Dad said, these didn't pass over Sydney at dusk or dawn and so he couldn't show it to me. I think the rocket stage was visible further south.

In the next month, on November 3rd, Sputnik II was launched. This was visible in the evening sky from my home. We saw its star-like appearance hurrying across the sky with its dog and, I assumed, bleeper.

Graham Harvey,
Toowoomba, Qld.

Comment: thanks for sharing your memories of Sputnik, Graham. It really does seem like a lifetime ago.

Refining the Studio Series Preamplifier

I have recently completed the Altronics kit for the complete Studio Series Stereo Preamp (SILICON CHIP, October & November 2005, April & July 2006) and was most impressed with the supplied parts and overall performance.

An article in the August 2007 issue of SILICON CHIP highlighted the superlative performance of the LM4562 op amp, even putting the OPA2134 (as used in the preamp) to shame! I purchased a quantity of the LM4562 and since it is a plug-in replacement, popped them in.

With the preamp connected to my AWA F242 Noise & Distortion measuring set, it was obvious that something wasn't quite right. Probing with a CRO revealed 10-30MHz parasitic oscillations around both IC sections. Both amplitude and frequency were dependent on volume control settings. Some lateral thinking suggested that the op amp output feeding the volume control via 100-150mm of screened cable (and hence 50pF of shunt capacitance) was the culprit. While the OPA has a gain-bandwidth product of 8MHz, the LM4562 tips the scale at more than 55MHz!

The cure was quite simple: insert a 100-220Ω resistor in IC1a's (and IC2a's) output feeding the volume control. This is easily accomplished by lifting the "pot" wire on the PC board connector and inserting the resistor in series with the screened cable and connector.

I was unable to measure any difference in distortion (little wonder!) but the preamp's total noise (20Hz - 20kHz, flat) was 6-8dB lower with the volume control at "max" using the LM4562 op amp; well worth $25 for two ICs.

I also did some work on the potentiometer drive motor. I purchased a dual 10kΩ ALPS Blue Velvet motorised pot (on eBay from Germany). However, I measured a considerable increase in output noise (still around -100dB) when the motor was activated. A few checks revealed that it was noise radiated from the motor body, not the DC wiring. Two turns of mu-metal "tape" around the motor body and secured with a cable tie removed the motor noise completely.

The supplied toroidal transformer in the Altronics kit was rotated to optimise the signal-to-noise ratio (SNR), there being a definite sweet spot. The measured SNR on the F242 in dB terms didn't show any reduction but the residual noise improved dramatically from a buzz to a hum.

To find the correct orientation, the F242's noise "monitoring output" was fed into an audio amplifier and the resultant noise (more like a raspy buzz caused by transformer stray leakage and/or magnetising currents and possibly the diode bridge switching transients) was monitored on a speaker. The toroid was gently (and carefully) rotated to null the resultant buzz (very obvious!) with the volume set to 50% – the most likely setting used. The final SNR was better than -105dB with a terminated input, the top cover in place and using the LM4562s.

Kit Scally,
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HOME RECORDING STUDIO

By MICHAEL GOEBEL

Learn how to produce audio CDs for musicians at a fraction of the cost of a recording studio

Want to make good-quality audio recordings in your own home? All you need is a PC, a hifi system, a good-quality microphone and some software.

DUE TO THE PRICES charged by professional recording studios (some in the region of hundreds of dollars per hour), many talented soloist and group musicians cannot afford the cost of producing their first CD. What's more, attempts at recording an entire performance using a single microphone invariably lead to very poor results – results that are so bad that reviewers cringe when hearing even the most promising artists.

But there is a way out. The latest PC recording software makes it possible to obtain surprisingly good results using relatively simple equipment in the comfort of your own home.

Before describing how you go about making such recording, let's take a look at the equipment you need. The list is as follows:

(1) A standard desktop computer (the faster, the better);

(2) A CD writer (writing speed not critical) and CD writing software;

(3) A good quality sound card (at least 16-bit) or on-board sound system;

(4) A good quality desktop microphone;

(5) Adobe Audition 1.0 (Win98 users can use CoolEdit and/or CoolEditPro or Diamond Cut;

(6) A home stereo system capable of good performance; and

(7) A hifi "sampler CD" of known high quality and containing material familiar to you

There are also a few important things to consider before you begin:

- This project is intended for those who are fairly proficient in the use of computers, Adobe Audition 1.0 and have some experience with audio.
- It is extremely unlikely that you will achieve adequate results using a bargain-basement laptop and/or a $99 combination CD/radio/cassette home "hifi" system. As with all systems, the chain is only as strong as its weakest link.
- This project is much more easily carried out with the help of an experienced musician, preferably someone who can play an instrument (eg, guitar) and sing.
- Screen resolutions of less than 1280x1024 will make it difficult to control and organise the program windows used in this project.
- An absolute minimum of background noise is essential to the recording process. If your computer has a noisy fan, then you should attend to this before embarking on this project.

Also, remember to take the phone off the hook and switch off your mobile phone prior to any recording.

- The objective is here is NOT to strive for bass levels that will rattle the windows or searing treble that causes bleeding from the ears. Instead, the aim is to achieve a well-balanced, pleasant and realistic level of sound.
- Many stereo systems possess lots of "effects" options and it is vital that they be bypassed (disabled). The same goes for any "effects" on the computer (eg, "3D Depth", "Stereo Enhancement", "Surround Sound", etc).
- For best results, all file operations for this project should be done in WAV format. Avoid the use of MP3 or any other type of sound file extension.
- If you are having trouble getting sufficient gain through the microphone, go to the volume control panel (Fig.1), select "Options", "Advanced Controls", then in the microphone section, click on "Advanced" and select "Mic Boost".
- In Adobe Audition 1.0, enable (tick the box marked) "Live update during recording" under "Options", "Settings". This will greatly facilitate monitoring the recording process.
- While this project only uses a 2-track performance as an example, the principles and methods outlined can be extended to include up to 128 performers and/or instruments, by switching to the "multitrack" mode of Adobe Audition.

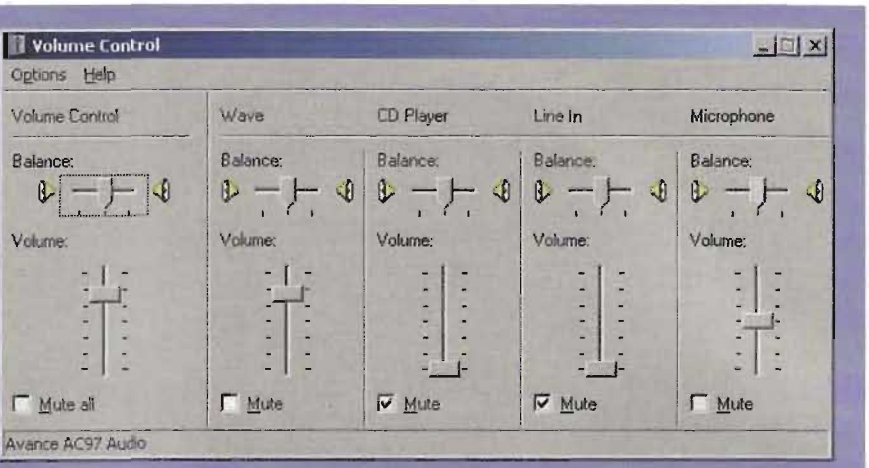


Fig.1: this is the Windows volume control mixer panel. Set both the "CD" and "wave" level controls to about 80% and the "master" or "volume control" to zero.

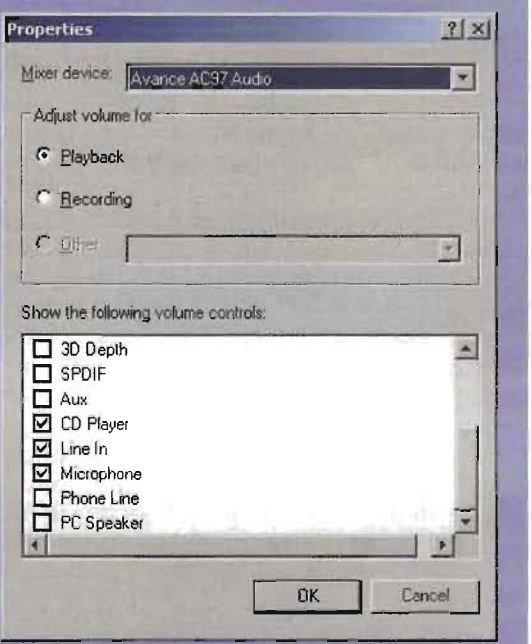


Fig.2: the Windows volume control mixer panel properties window. Be sure to select the Microphone option for recording.

Marrying a PC to your hifi

The purpose of this step is to ensure that the backbone of the system (ie, the computer and stereo system combo) is functioning properly.

First, connect the PC's sound card output to the "aux" input of your stereo system. Avoid using a cable longer than necessary or one of poor quality.

That done, boot the computer and once you are in Windows, power up the stereo system, select the "aux" input and set the system's volume control to roughly 10 o'clock. Now locate the computer's volume control panel (Fig.1), set both the "CD" and "wave" level controls to about 80% and the "master" or "volume control" to zero. Set all other level controls to zero.

Now play a CD through the computer's CD player, preferably one that has been well recorded and with which you are very familiar. Gradually increase the computer's main volume control and adjust the volume control on the stereo until you obtain maximum volume from the system (before the onset of noticeable distortion) when the computer's main volume is at 100%. Listen to the track in its entirety,

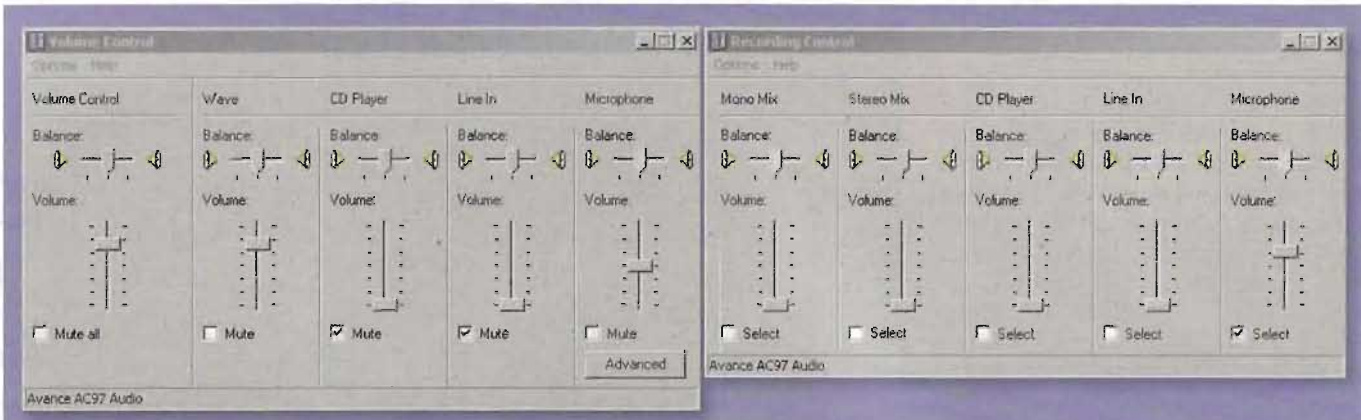


Fig.3: opening two instances of the Windows volume control mixer panel – one for playback and one for recording.

preferably from a comfortable position in the room's "sweet spot" and assess the quality of the sound.

Important: avoid setting the "wave" level control to greater than about 80% – this is likely to cause overloading (clipping) of the computer's audio system.

If your stereo system has a CD player, it is a good idea to compare the performance of the two (ie, with the CD ROM drive in the PC). If you cannot detect any audible differences between them, then this is a good sign that the computer's audio quality is adequate (it may also be a good sign that you have no ear for music, however!).

Now switch back to the computer and try different tracks and different CDs. If necessary, "fine-tune" the system with the stereo system's bass and treble controls (or equaliser) but avoid using any more boost or cut than is absolutely necessary. Do not use any equalisation facilities (or "effects") that may be available on the computer. Ensure that these are disabled.

Testing the PC's audio

A number of computer audio performance testing programs are available, with *RightMark Audio Analyser* (**http://audio.rightmark.org/download.shtml**) being the best tested by the author. This program will test the playback and recording capabilities of your PC's sound system and report such specifications as frequency response, distortion, hum and noise, stereo separation and more.

While considerable variations of performance will be found between various types of motherboards and sound cards, you should rely on your ears to make the final judgement. It is not much use having a system with superb specifications if it is not pleasing to listen to (it does happen).

If you are intending to use a laptop computer for this project, then it is highly recommended that you evaluate its performance using a program such as this. Some laptop computers, even fairly expensive ones, have relatively poor audio performance specifications and hence, poor sound quality.

Treating room acoustics

To measure the overall characteristics of the entire system (or of any audio system, for that matter), just follow these simple steps:

(1). Generate a 20Hz to 20kHz sine



Fig.4: setting the format of a new file in Adobe Audition. Choose the mono, 16-bit & 44,100Hz sample rate options for recording.

wave sweep @ -6dB of approximately 1-minute duration (you do this using the "Generate Tones" function in Adobe Audition).

(2). While playing the file at medium/high volume through the stereo system, listen carefully to the room (not the speakers). Record the results using a microphone placed roughly in the centre of the room.

In most cases quite a few rattles, buzzes and assorted resonances will make themselves annoyingly apparent at certain bass frequencies. Loose wall panels, windows, hanging pictures and various standalone appliance panels are usually the worst offenders, followed by such items as glasses and other objects on shelves, and even pens on a table.

Removing these resonances will greatly improve the sound quality (or "resolution") of the system. As with any audio system, the subject of room resonances is not to be treated lightly if the very best results are to be obtained (in fact, the best place for recording is outdoors but this is rarely convenient). One big problem is the standing-wave bass resonances present in any room. The room's dimensions determine these frequencies. To learn more, see **http://www.silcom.com/~aludwig/Room_acoustics.html**

In most cases, the effects of these resonances can be minimised by thoughtful equalisation.

Higher frequency resonances are also a problem. These are due to sound reflections from nearby objects which cause destructive interference. The more soft furnishings present in the room, the more these resonances will be attenuated.

Recording the instrument

The purpose here is to successfully record the performer's instrument and play it back with good fidelity. First, ensure that you have access to the microphone level control on your computer's volume control panel. If you cannot see it, go to "Options", then "Properties" and select "Microphone" (Fig.2). Do this for both the recording and playback modes.

The mode is again set using "Options", "Properties" and then selecting either "Playback" or "Recording" (Fig.2). If other options such as "surround", "3D depth", "subwoofer", etc are present, disable them to keep the control mixer panel simple.



Fig.5: an example of a track recorded at an optimum level. The waveform peaks should not exceed the -3dB levels shown on the righthand scale.

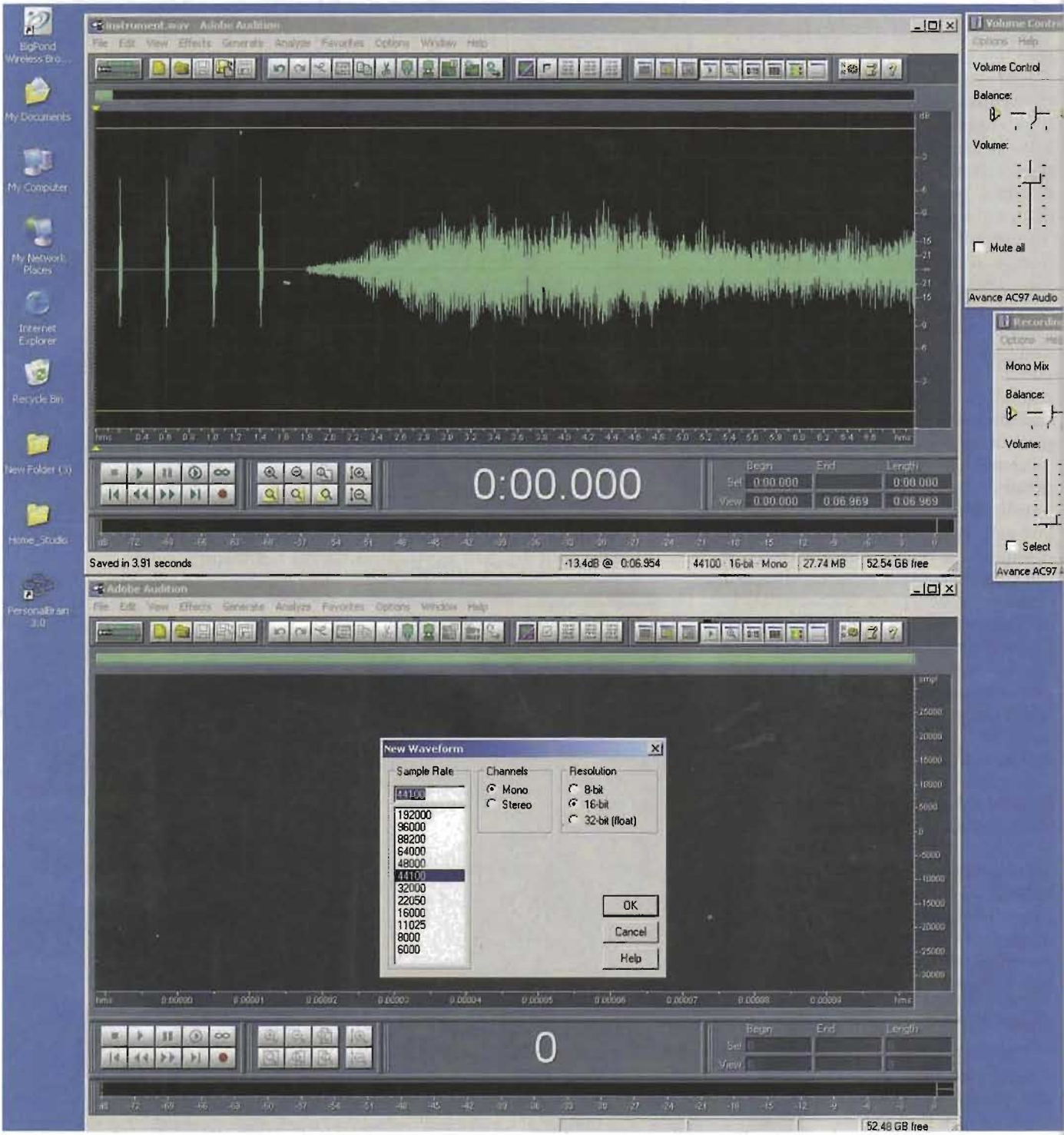


Fig.6: an example of a recorded instrument track complete with time markers. These timing reference points are used later on in order to synchronise the recorded tracks for mixing.

Now place the microphone in its intended position, preferably not too close to the speakers. That done, open two instances of the computer's volume control panel, one for playback mode and one for recording mode – see Fig.3.

Next, ensure that the main playback level control is set to zero, then set the microphone recording level to around 50%. When these settings are correct, open the Adobe Audition program and open a new file (mono, 16-bit, 44,100Hz) for recording – see Fig.4.

Now press the record button and have your assistant start playing approximately 30cm from the microphone. Watch the resulting waveform and adjust the microphone recording level so that the average level of the



waveform is as high as possible without the peaks exceeding -3dB. Fig.5 is a good example of a track that has been correctly recorded. As shown, the peaks do not exceed this value.

Note: ensure that the level scale on the righthand side of the window is in decibels. This is done by right clicking the scale and selecting "decibels".

If the recorded level exceeds -3dB at any time, stop and start again with a slightly reduced recording level. Let it record for about 30 seconds and then stop.

Now set the microphone playback level to around 80% and play back the recorded track. Set the main playback level control for a subjective loudness level similar to the original instrument's volume. The objective here is to obtain a crisp, clear reproduction of the original with (ideally) no detectable distortion, background noise or hum.

At this point, it is necessary to make it a habit to lead in any recording you do with a "1-2-3-4" (depending on the beat of the music). Use something that creates a sharp, short pulse in the recorded waveform as shown in Fig.6 (the author uses a pencil on the edge of a wooden table). This is very important, as later on you will need

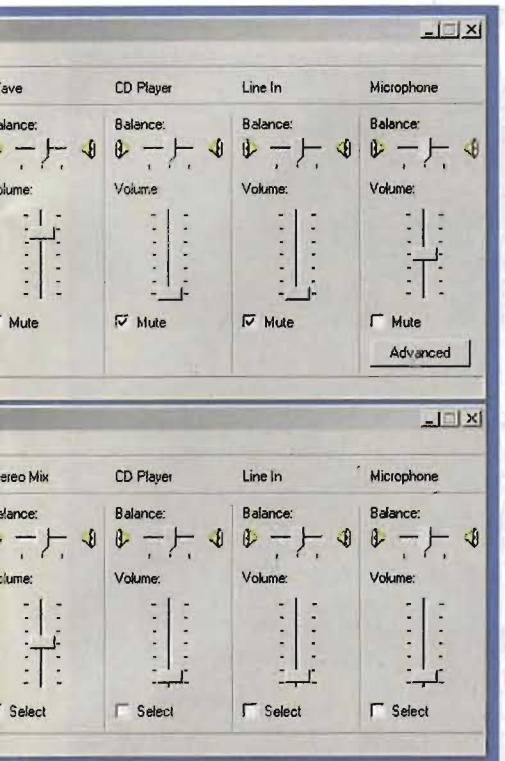
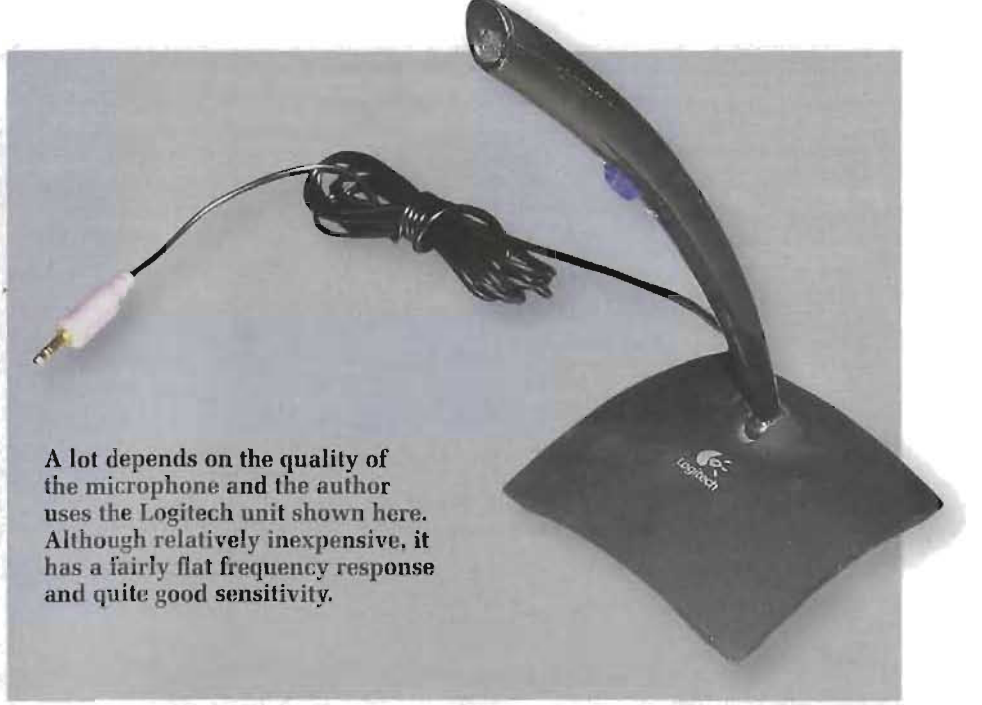


Fig.7 left & above: these are the windows required for ease of control in duplex mode. This involves opening two instances of Adobe Audition & setting one for playback and the other for recording. The playback & recording volume control panels must also be opened.



A lot depends on the quality of the microphone and the author uses the Logitech unit shown here. Although relatively inexpensive, it has a fairly flat frequency response and quite good sensitivity.

these timing reference points in your waveforms in order to synchronise them for mixing.

Recording the voice

The purpose of this stage is to successfully record and play back the singer's voice, again with good fidelity. Repeat the steps described above in "Recording the instrument".

A word of warning – advise the vocalist not to sing directly into the microphone as this can create "woofing" and "whooshing" artefacts that sound terrible and are impossible to edit out later. With practice, you should be able to record the performer's voice and play back a faithful replica at will.

Again, review each recording attempt in its entirety and only continue to the next stage when you have a satisfactory result. One indicator of success is when the performer likes what they hear.

Gain structure

The signal chain between the performer and the listener's ear consists of a number of stages, each of which has an effect on the overall gain (or amplification) of the system. Aside from the numerous volume controls, you must deal with and the original loudness levels of both the instrument and the voice, the distance between the microphone and the performer is another factor affecting gain.

It may take some practice to establish the correct level settings for each stage. The configuration of these settings is collectively referred to as the "gain structure" of the system. This is a subject of tremendous importance in sound engineering. There exist any number of combinations of settings that will result in the same apparent loudness but obtaining the best sound quality depends on finding the optimum settings for each control.

If, for instance, the microphone level is set too high, then distortion will result from overloading of that stage. Reducing the volume somewhere else cannot compensate for this. Do not move on to the next stage until you feel confident about the preceding stages. To learn more about gain structure, see **http://www.mmproductions.co.uk/gain1.html**

Duplex operation

We will now learn how to perform playback and recording simultaneously. This involves opening two instances of Adobe Audition and setting one up for playback and the other for recording. The playback and recording volume control panels must also be opened and the four windows arranged conveniently on the screen as shown in Fig.7.

It is necessary to become proficient

Extra Tips & Techniques

(1). A refinement of the duplexing technique described in this project is to play back the instrument to the performer through headphones and not via the main system. This eliminates any presence of the instrument track in the vocal track. Once again, it's best to let the performer decide which method they prefer.

(2). If you are experiencing burn speed/audio quality related problems, try lowering the burn speed when writing to the CD.

(3). Adobe Audition can also be used in 32-bit mode.

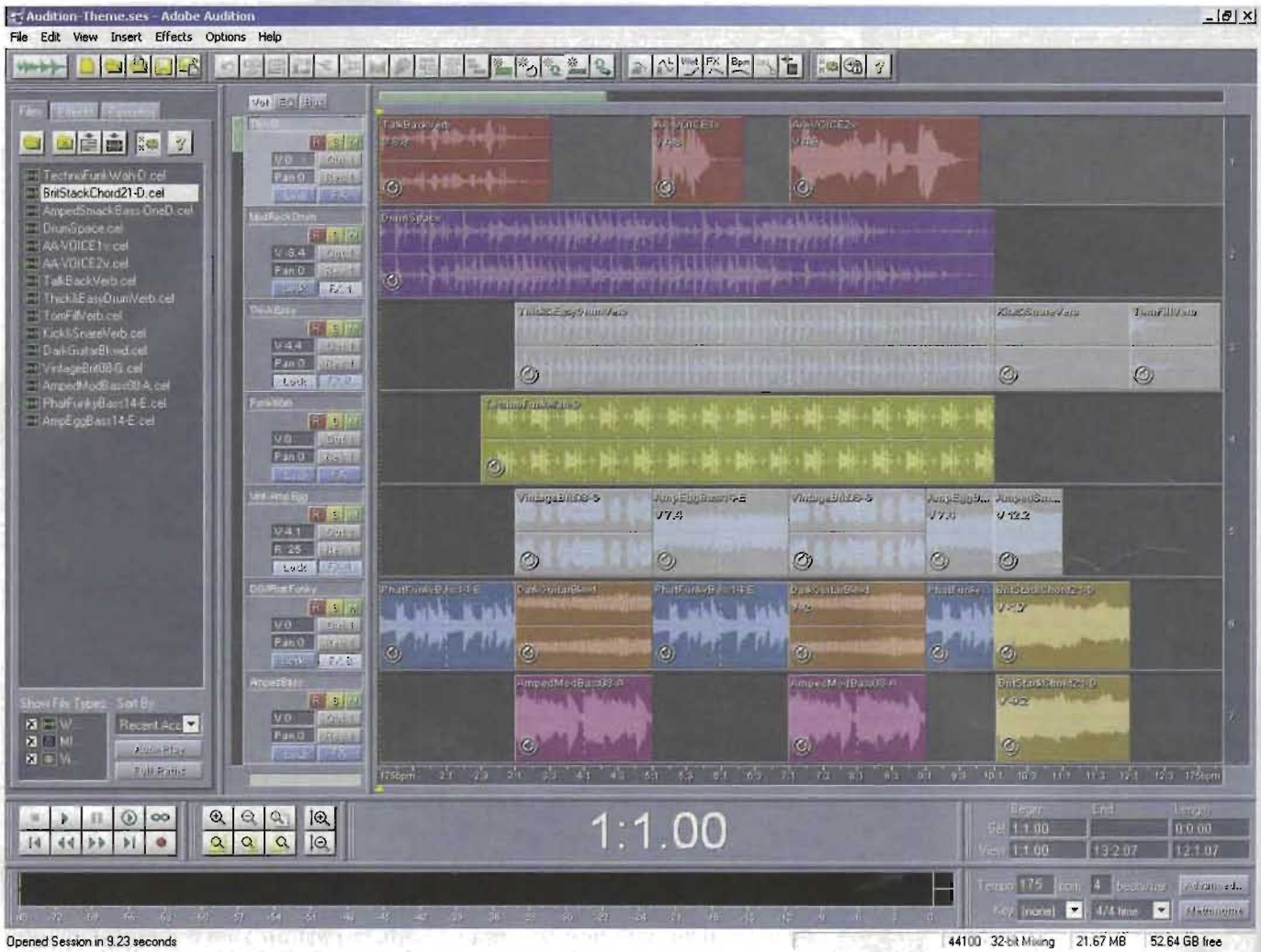


Fig.8: the "multi-track" mode of Adobe Audition 1.0. This gives access to no less than 128 tracks!

in setting up both recording and playback gain structures, starting both programs (recording first) and monitoring the process until completion of the recording. Sometimes, during a crescendo (a significant increase in "vocal level"), the waveform will overload (or "clip"). If this happens, the recording must be halted and the levels reset.

Remember that the distance between the performer and the microphone is an important factor. Only practice and patience will yield the optimum levels, placements and settings.

To perform this stage, open a new file in the recording instance of Adobe Audition (Fig.4) and start recording. Then open the playback instance containing the instrumental track, having first verified optimum levels.

Setting the marker

In order to set a synchronisation marker in the voice track, instruct the singer to tap the microphone lightly with a pencil **on the last** lead-in marker. The timing precision of this operation will determine the final accuracy of time-alignment (synchronisation) when mixing the two tracks later on.

The vocals should now commence and be recorded simultaneously with playback of the instrumental track. Note that the voice track will also contain a faint background signal of the instrumental track. While an equivalent, higher amplitude copy will later overlay it, it is suggested that the instrument playback level be as low as possible to minimise this effect.

This is usually no problem if the microphone is not too close to the speakers and the vocals have been adjusted to give a good strong recording signal.

At the conclusion, you will have two files, one of the instrument and one of the voice, both with accurate and clearly visible synchronisation markers. Both recorded tracks should be listened to and evaluated, particularly by the performer. Often the performer will recognise instances in either or both tracks where improvements could be made and ask to re-record them.

Remember that it is difficult for any performer to accurately perceive how they sound while they are actually performing.

Track signal processing

It's at this point that you may elect to process the tracks – eg, equalisation, noise reduction, dynamic range enhancement, reverb and echo, etc. Adobe Audition is a very powerful audio editing program, capable of generating studio-quality results if it is used competently.

However, it is suggested that a minimum of "special effects" be applied. Only use those necessary to correct obvious inadequacies or to add a bit

of "shine" to the performance (eg, a small amount of reverb for the singer's voice or a slight brightness boost for the instrument).

If you do choose to edit the tracks, be sure to first save copies of the original unedited tracks! While Adobe Audition allows you to "undo", you can quickly get lost, especially if you neglect to save and correctly name each track variation (remember to always use WAV format).

Synchronisation and mixing

When you are satisfied with the instrument and voice tracks and know that they both contain accurate timing markers, you are then ready to synchronise and mix them. The method of combining the separate tracks into one involves copying one track and "mix-pasting" it into the other track, positioning the cursor so that the two are in sync. This is where the lead-in markers are used.

Fig.6 shows a magnified portion of the start of the instrument track. First, position the cursor so that it aligns with the centre of the last lead-in marker, then select the track from there onwards to the end by holding down the <shift> key and then pressing the <end> key. Now copy the selection.

Next, go to the other instance of Adobe Audition and zoom in to the beginning of the voice track, where the marker should be clearly visible. Position the cursor directly in line with the marker and then select "mix-paste" from the EDIT menu.

After pasting, the resulting file will be a time-aligned mix of both instrument and voice. Again, it may need some practice to align the two files, however if the result is unsatisfactory, simply hit "UNDO" and try again. It is usually not necessary to align the tracks to any greater degree of accuracy than about one millisecond (1ms).

Now listen to the resulting mix to determine if the relative volume levels of the two components are in balance. If, for example, the voice is too loud, then simply apply an amplitude reduction to the original file (typically 2dB at a time) and try another mix. Remember to save the original file and rename the amplitude-edited version.

Writing to CD

It is now only necessary to write the mixed track to a CD and this can be done using almost any CD-burner program. Ensure that you use a good quality CD blank, though.

Although there's some debate over whether any CD could be "optimised for audio" (considering that all CDs store data in digital format), just choose the type that gives you the best subjective results. Also make sure that the burner program is configured to convert the WAV file to a CDA file before writing to the CD, otherwise normal stand-alone CD players will not be capable of reading it.

A nice touch is to fill in the title, artist and authoring information section. Even more swish is printing a label on the CD and making artwork for the CD cover.

A final evaluation of the overall tonal balance should be made by playing the CD on other systems. Sometimes it may be found that the entire track could benefit from a touch of equalisation.

Advanced functions

Adobe Audition has many advanced functions, including "DeDynamic" (a DirectX-based algorithm) which dynamically expands the dynamic range, effectively eliminating the cross-modulation problems associated with earlier analog expansion methods. Applying this transform to virtually any music track will make it seem "more alive".

If you are interested in the more advanced multi-track capabilities of Adobe Audition 1.0, switch to multi-track mode (press F12) and you will have access to 128 tracks (Fig.8). Examine the demonstration multi-track "ses" file and refer also to the Help section. SC

Frequently Asked Questions

Question: sometimes room resonances are easy to hear but difficult to locate and if the sweep time is made shorter, they disappear. What to do?
Answer: select a narrow band of frequencies either side of the frequency where the offending room resonance is being triggered and set Adobe Audition to "Loop Play".

Question: what do you do if the instrument is not acoustic (ie, electric)?
Answer: use the computer's "line input" and rig the system so that the performer can hear the instrument properly while they are playing it.

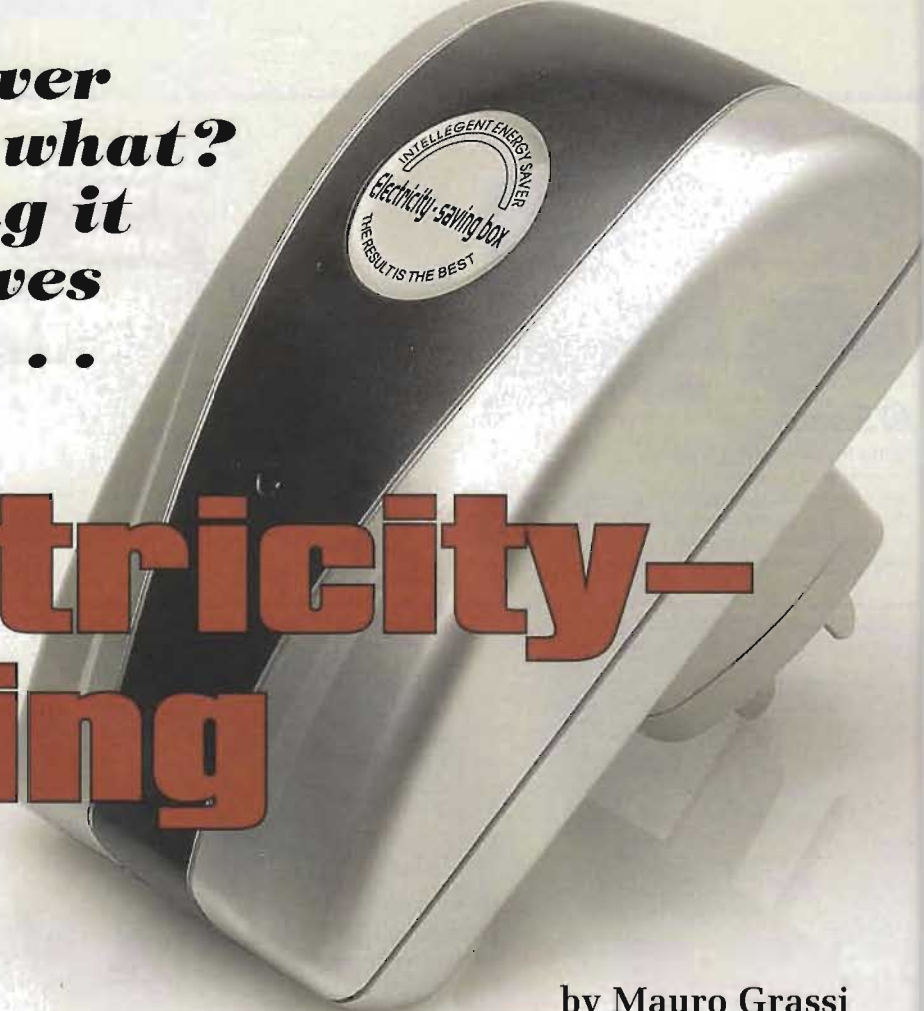
Question: when I do a sweep, the recorded result looks like a map of the Himalayas! Is the response of my system really that bad?
Answer: do a number of trials with the microphone in various positions throughout the room, take the average and only attempt to correct overall response imbalances. Do not worry too much about individual narrow peaks if they change when the microphone is moved. These are caused by room reflections and are of little concern. Concentrate on the most severe frequency anomalies and treat them via suitable equalisation.

Question: is it possible to analyse the finished product for frequency content (ie, do a frequency histogram of it)?
Answer: yes - select the entire waveform and go to "Frequency Analysis" under "Analyse". Higher FFT settings will increase the number of samples. (Select "advanced" in the analysis window to gain access to this).

Question: why this duplex business? Why not just make two tracks and mix them?
Answer: no performer, regardless of skill or ability, can sing a track and play it separately and maintain perfect timing (unless a metronome is used). The method adopted here (and found to be popular with musicians) is to record the instrument track first and then while playing it back, record the performer singing along to it, hence the need for the two instances of Adobe Audition.
The performer will find it much easier to sing along to the instrumental track than singing without accompaniment.

Question: I am getting feedback between the microphone and speakers, which I cannot eliminate.
Answer: at no time should you be using the microphone in playback mode through the speakers. Whether recording or playing, the microphone playback level control should be set to zero.

Is this a clever gimmick or what? You just plug it in and it saves you money . . .



Electricity-Saving Box

by Mauro Grassi

This all started out when a reader sent us a link to an item being offered on eBay. He wanted to know if the claims were true: could this little device really save money by reducing the amount of power used by your electrical appliances? Have Newton, Ohm, Kirchoff, Thevenin et al been wrong all along?

It's called, quite simply, an "Electricity-Saving Box". You simply plug it into the power outlet. . . and whenever you use any electrical/electronic device on that circuit you start saving energy (and therefore money).

But wait, there's more: it would protect all the mains powered devices you used. And if that weren't enough, it would even extend those device's lives. Wow!

We'd seen (and, we must admit, dismissed!) such claims before – but our reader wanted to know if somehow the supplier had rewritten the basic laws of physics. Could the claims possibly be true?

"Reduce the amount of electricity used by your appliances", they said.

"Begins to save you money the second you plug it in" Wow again!

"Save between 10% and 30% of the energy used depending on device"

"Uses no power itself"

"Prolong the life of your appliances" Really?

Hmm! Our experience is that if something sounds too good to be true, then it invariably is.

Therefore, we were dubious. Skeptical. Downright derisive, if you like. But hey, the price was only $25.00 including freight from China (where else, these days, on eBay?). So we hit the "Buy it Now" button and waited with bated breath for the magic device to arrive – which, in due course, it did.

Even before we plugged it in, we attacked it with our trusty company screwdriver to see what was inside. (Oh dear. Have we voided the warranty?)

The truth is, there's not a great deal

inside ! Our photos and the circuit we've drawn (Fig.1) show what you get for your money.

Fluoro clue

One of the claims on eBay gave us at least some clue to the theory behind this product. *"To test the device, fluorescent light tubes were used, however, please bear in mind that appliances used in the home may be different."*

A fluorescent light is a common inductive load, as shown in Fig.2. When power is applied a bimetallic strip in the starter heats up closing the switch. When this happens, the filament at either end of the tube receive current through an inductor and eventually the potential difference reaches a point at which the gas inside the tube ionises.

At this point, the tube fires and emits light and the starter opens again. This state will continue until the power is turned off.

The large capacitor is not necessary for its operation (its purpose will be explained shortly). Sometimes it is omitted.

Because fluorescent lights are common inductive loads, this suggested that the product was aimed at correcting the power factor of your household.

Let us explain. The "power factor" of a load is the ratio between the real power (that which the load can use to do work, measured in Watts) and the power that is supplied, also known as the apparent power (measured in volt-amps, or the product of the voltage and current it consumes). The power factor is therefore a number between zero and one since the real power is at most equal to the apparent power that is supplied, by conservation of energy. The further from one the power factor is, the more power losses are involved in supplying electricity and transmitting it over the power grid.

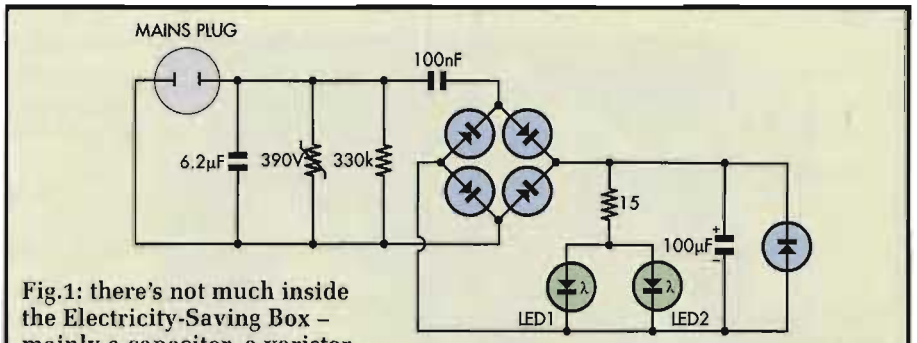


Fig.1: there's not much inside the Electricity-Saving Box – mainly a capacitor, a varistor and a power supply to light up a couple of LEDs. The claimed "intelligent and digital" circuitry (what else could that be but a microcontroller?) was obviously out to lunch on the day we opened up this can of worms!

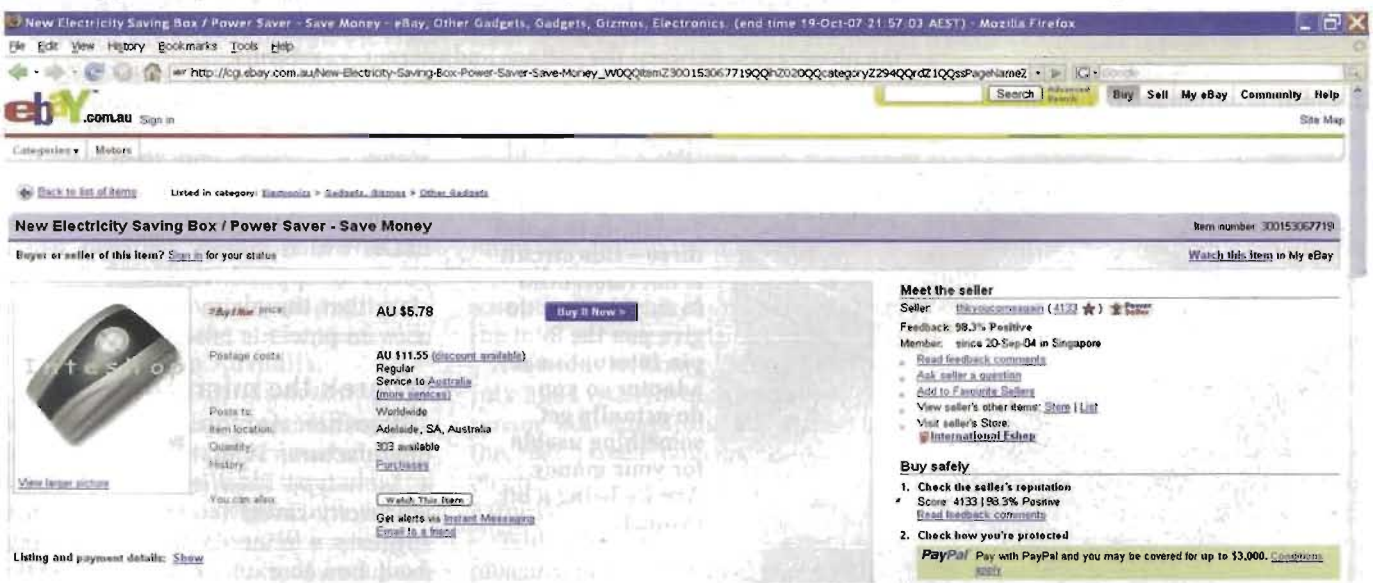
Now consider a sinusoidal voltage waveform. When the current waveform is in phase with the voltage waveform, the power factor is simply one. On the other hand, suppose the voltage waveform is 90° out of phase with the current waveform, as happens for an inductive load.

Since power is the product of voltage and current, it will happen that the power waveform is symmetrical about the time axis. This means that the average power, which represents the real power transferred to the load, is zero, meaning that the power factor is also zero. As the phase difference between the voltage and current waveforms varies between these extremes, the power factor varies between zero and one. Fig.3 shows the derivation of an expression for the power factor in terms of the phase difference, for sinusoidal waveforms. The calculations are more complex for other types of waveforms.

For a pure sine wave, it turns out that the power factor is the absolute value of the cosine of the phase difference between the voltage and current waveforms. Therefore, for an ideal inductive load, the power factor is zero, while for an ideal resistive load the power factor is one.

Now back to Fig.1. The large 6.2µF capacitor across the mains confirmed our initial suspicion that it is there to correct the power factor.

The term "power factor correc-



Hey, we wuz ripped off! This more recent eBay page has exactly the same product, purportedly from Adelaide (but look at where the seller is located!) for less than $18.00 including postage. The claims are the same, though (we haven't bored you with the rest of the page). And the good news is there is now a "2nd Generation" model. Hmmm – wonder what that has in it!

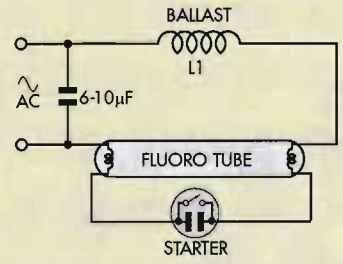


Fig 2: a simplified schematic of a typical fluorescent light, showing the in-built power factor correcting capacitor of around 6-10µF. The ballast inductor (L1) is typically around 10-15mH. It represents an inductive load, hence needs power factor correction.

tion" refers to using a circuit, usually something as simple as a capacitor in parallel with the inductive load to correct the phase difference between the voltage and current waveforms, since for a capacitor the current leads the voltage. This is why sometimes you see a capacitor being used in fluorescent lights (in fact, in offices and factories where there are large numbers of fluorescent lights, there will always be a power-factor-correcting capacitor).

Its purpose is to bring the current waveform closer into phase with the voltage waveform, thus increasing the power factor and minimising power losses. As can be seen from the schematic we traced out, this is one of the intentions of this product.

The varistor in parallel with the mains is meant to provide surge protection, another claim of the manufacturer. The 330kΩ resistor is used to discharge the 6.2µF capacitor when the unit is unplugged. The bridge is solely there to rectify the mains, which is substantially stepped down by the 100nF capacitor, and then used to drive the two LEDs. Finally, the 15Ω resistor limits the current through the LEDs, which simply light up when power is applied. It should now be clear that the claim that this device uses no power is false.

The derivation of the power factor is as follows.

Suppose we have sinusoidal voltage and current waveforms, which are out of phase by the angle ϕ, of amplitudes V_0 and I_0 respectively.

Hence we may write the instantaneous voltage and current as follows:

$$V(t) = V_0 \cos(\omega t)$$

$$I(t) = I_0 \cos(\omega t + \phi) = I_0(\cos(\omega t)\cos(\phi) - \sin(\omega t)\sin(\phi))$$

Let the instantaneous apparent power be:

$$P(t) = V(t)I(t) = V_0 I_0 \cos(\omega t)[\cos(\omega t)\cos(\phi) - \sin(\omega t)\sin(\phi)]$$

The average real power is therefore:

$$\frac{1}{2\pi}\int_0^{2\pi} P(t).dt$$

Since:

$$\int_0^{2\pi} \cos^2(\omega t).dt = \pi$$

and:

$$\int_0^{2\pi} \sin(2\omega t).dt = 0$$

It follows that the average real power is equal to:

$$\frac{1}{2\pi}\int_0^{2\pi} P(t).dt = \frac{V_0 I_0 \cos(\omega t)}{2}$$

Since the RMS voltage is $\frac{V_0}{\sqrt{2}}$ and the RMS current is $\frac{I_0}{\sqrt{2}}$, it follows that the average apparent power is the product of these, or: $\frac{V_0 I_0}{2}$. The power factor is the ratio of the average real power and the average apparent power, in other words it is:

$$\frac{V_0 I_0 \cos(\omega t).2}{V_0 I_0.2} = \cos(\omega t)$$

Fig 3: This shows a derivation from first principles of the power factor for a sinusoidal waveform. The power factor of the load turns out to be the cosine of the phase angle between the voltage and current waveforms.



Here's the back of the device showing the two mains plug pins (note two, not three – this circuit is not referenced to earth). They do give you the 3-pin international adaptor so you do actually get something usable for your money. Are we being a bit cynical?

Where's the microcontroller?

Another dubious claim of the manufacturer is that this product is a *"new-type intelligent and digital electricity-saved* (sic) *device"*. This suggests a microcontroller is being used, however, a look at the schematic reveals there is no intelligent or digital component there.

The more appealing claim of the

Load/Time (minutes)	0	5	10	15	20	25	30	35	40	45	Average
Fluorescent light	98.35W	98.62W	98.62W	98.71W	98.71W	98.50W	98.50W	98.50W	98.44W	98.44W	98.539W
Fluorescent light + Electricity saving box	98.65W	98.86W	98.88W	98.88W	98.78W	98.65W	98.86W	98.88W	98.78W	98.56W	98.778W
Fridge	142.61W	142.59W	142.83W	142.83W	142.34W	142.34W	142.35W	142.35W	141.64W	141.64W	142.352W
Fridge + Electricity saving box	143.28W	143.28W	142.91W	143.19W	143.19W	142.33W	142.33W	142.94W	142.94W	142.94W	142.933W

Table 1: the results of measurements of real power we made of two household inductive loads – a two-tube fluorescent batten and a domestic refrigerator. The table shows measurements of the instantaneous power consumption of the loads over ten consecutive 5-second intervals while the last column shows the average power consumption in watts. In every case, the real power consumption using the electricity saving box, representing the actual cost to you, is higher.

the electricity saving box and hence that the claims of the manufacturer that this product will save you money are false.

Given that it is clear that this device will not save you any money, the next question is whether it corrects the power factor.

To answer this, we must look at the voltage and current waveforms through a load. We chose to use the same fluorescent light we used in the measurements of real power, which did not have power factor correction built in. To obtain the current waveform, we measured the voltages at either end of a resistor and subtracted the waveforms using the maths function of the scope.

Fig.4 shows a scope grab of the mains voltage waveform (channel 3) and the mains current flowing through the fluorescent light (channel M). Note that the mains waveform is not a perfect sinusoid. Rather, it is an approximate sine wave with flattened peaks and troughs. This is because there are other appliances plugged into the same household circuit that perturb the mains waveform.

The RMS voltage is as expected at 241.9V and the frequency is 50Hz. The current waveform is obtained by subtracting two voltage waveforms across a 4.4Ω resistor on the neutral side.

The RMS voltage of the grey trace is measured to be 3.599V giving an RMS current of 818mA. The phase difference is shown to be around 59°.

Note that the apparent power is therefore 0.818x240 = 196 W, roughly twice that of the measured real power of 98W. This makes sense because the power factor is given by the cosine of the phase difference and this is approximately 0.5.

Fig 5 shows what happens when the electricity saving box is plugged in. Again, the mains voltage waveform and the mains current flowing through the fluorescent light are shown. In this case, the phase difference is shown to be around 37°. The RMS voltage of the grey trace is measured to be 2.063V giving an RMS current of 469mA. Note that the apparent power is therefore lower at 0.469x240 = 112.6W.

This suggests that the electricity saving box does indeed correct the power factor of this load, also apparent from the lower value of the phase difference. In fact, all this is consistent with the theory.

Fig 6 shows a calculation of the effect of adding a capacitor C in parallel with an inductive load L with series resistance R. The phase difference angles predicted from the equations are consistent with our measured values.

Suppose we consider a typical fluorescent light without power factor correction. We think of the load as a resistance in series with an inductor. A typical value for the series resistance of the inductor is $R = 1.8\Omega$ and a typical value for the inductance is $L = 10mH$ (these we measured using an LCR Analyzer).

It turns out that the expression:

$$\theta = \tan^{-1}\left(\frac{\omega L}{R}\right) = 60.18^\circ$$

measures the phase difference in the voltage and current waveforms for this load, where $\omega = 2\pi f$ where $f = 50Hz$, the mains frequency.

Now suppose we introduce a capacitor $C = 6.2\mu F$ in parallel with this load (which represents a typical fluorescent light).

Then it can be verified that the phase difference in this case will be:

$$\theta' = \tan^{-1}\left(\frac{\omega(L - \omega^2 CL^2 - \omega CR^2)}{R}\right) = 32.34^\circ$$

The corresponding power factors are the cosines of these angles or:

$$\cos(\theta) = 0.497$$

and

$$\cos(\theta') = 0.845$$

Compare these values with the measured values in Figures 4 and 5.

Fig 6: Theoretical calculation of phase difference between voltage and current waveforms, and hence power factor, for a typical inductive load with series resistance with and without a parallel capacitor. This setup roughly applies to the fluorescent light we used in our tests.

Conclusion

The Electricity-saving box will not save you any money. In fact, the op

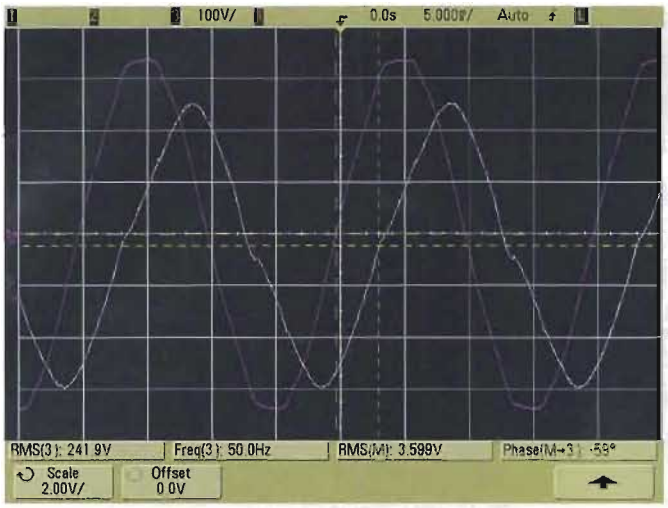


Fig 4: A scope grab of the mains voltage waveform (in purple) and the mains current (in grey) flowing through a fluorescent light (without power factor correction). The electricity saving box was not used. The RMS voltage is as expected at 241.9V and the frequency is 50Hz.

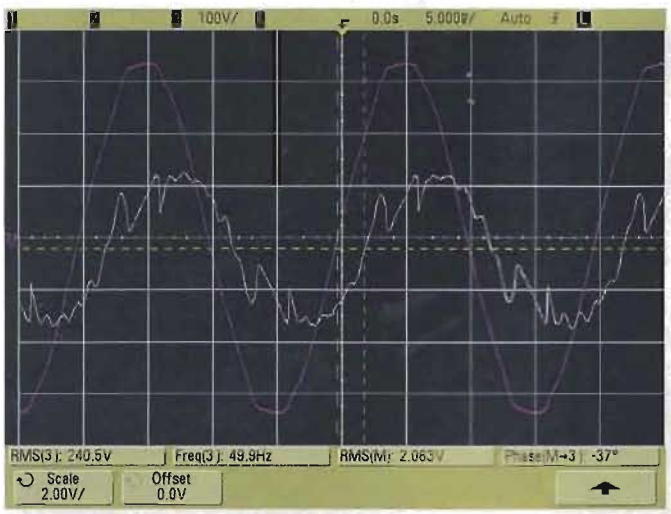


Fig 5: the mains voltage waveform shown in purple (with the electricity-saving box installed) and the mains current flowing through a fluorescent light without power factor correction is shown in grey.

posite is true – it will very slightly increase your electricity bill. However, it will have some effect on your household's overall power factor. While this may benefit your energy provider, this effect will become negligible whenever many loads are connected in your household's power circuit. This is because the value of the capacitor used (6.2µF) is simply too small for most households.

This will be especially true when these loads already have power factor correction. Normally, switchmode supplies used in computer power supplies and other appliances have power factor correction, as do many fluorescent lights. In this case, the electricity saving box will have a negligible effect on your power factor. Many of the claims made in the advertising for this product are simply false.

Since it will not save you any money and will have a negligible effect on your power factor, we see little reason to purchase this product. SC

They have arrived!



Fuel Cells

Off grid power for measurement, transportation, security and telecommunications industries

Generate electricity without combustion, without sunlight or wind, without pollution. Fuel cells are small, lightweight and portable, quiet, have no major moving parts and require no maintenance. They have an expected operational life exceeding 8000 hours of run time.

5 litre and 10 litre fuel cartridges are available. For example, an off-grid video camera will operate for up to 8 weeks on a single 10 litre fuel cartridge.

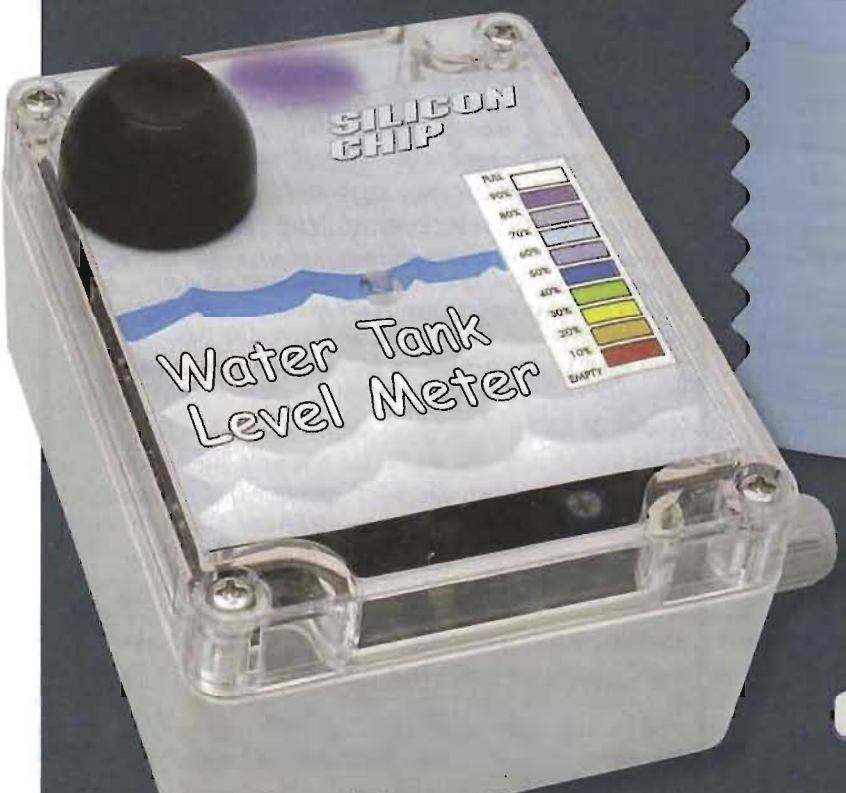
Technical data

Model	600	1200	1600
Charging capacity	600Wh/day 50Ah/day	1200Wh/day 100Ah/day	1600Wh/day 130Ah/day
Nominal Voltage *	12V	12V *24V available on request	12V
Nominal Power	25W	50W	65W
Nominal Current	2.1A	4.2A	5.4A
Fuel consumption	1.1 litres per kWh. 1.3 litres per 100Ah		
Weight	7.3kg	7.5kg	7.6kg
Dimensions	(L x W x H) 435mm x 200mm x 276mm		
Batteries	40 to 200AH recommended		

- **100% availability**
  Maintenance free and absolutely reliable. Even under extreme climate conditions it ensures 100% availability of your equipment. This is a decisive advantage, especially in hard-to-reach areas or with critical applications such as observation posts.
- **Fully automatic**
  Automatic charge control, continuously monitors battery status as it powers your electrical equipment. If the battery's voltage sinks below the level pre-programmed by the user, the fuel cell activates, charges the battery, and then automatically shuts itself off. And it does so without any user intervention.
- **Remote Control**
  Each fuel cell can be connected by an interface adapter to any RS232 interface and serviced/monitored using a cellphone, laptop or PC from the office.
- **Theft Proof**
  Solar cells need to be placed out in the open where it is difficult to protect them against theft and vandalism. The compact fuel cell can be integrated into any standard cabinet or box.
- **More Power**
  With the control interface you can operate up to 5 fuel cells in parallel, giving you a capacity of up to 8000Wh per day.

Contact: Siomar Battery Industries
Ph: (08) 9302 5444 Email: mark@siomar.com

PIC-Based Water Tank Level Meter



Pt.1: By JOHN CLARKE

Optional radio telemetry feature lets you remotely monitor up to 10 tanks & automatically control pumps

Looking for a water tank level meter that's easy to install? One that's accurate but doesn't need a complicated in-tank sensor? This PIC-based unit uses a pressure sensor to monitor water level and it displays tank level at the press of a switch. It can also send its readings to a base station with an LCD readout via an RF link.

RAINWATER TANKS are now all the go! Australia is one of the driest continents on Earth and faced with ongoing drought conditions, Australians are now rethinking the way water is managed.

In most parts of the country, dams have been at their lowest levels since construction and many towns and cities now have some form of water restrictions. Saving water is vital and using rainwater tanks to store otherwise wasted rainwater is becoming commonplace.

One traditional problem with water tanks is checking how much water is in them. That's because they are opaq and they are made that way to prot the water from sunlight which wou otherwise promote algae growth.

Trying to look down through the w ter inlet into the dark interior does help much because this is invaria gauzed over to keep mosquitoes o

And although some large concrete tanks have a manhole, this usually takes some effort to remove, so it's not a convenient way to check the water level.

Add-on devices

Many ingenious devices have been developed over the years to show the water level in tanks. These include simple passive indicators that use clear tubing as a sight glass, mechanical floats and pulleys that move up and down with the water level, and the more complex electronic gauges.

Each has its advantages and disadvantages. For example, sight "glass" systems, although simple, eventually become impossible to read because of algae growth and discolouration of the transparent material due to minerals in the water. And if the tube is directly exposed to the sun, it tends to become brittle.

Similarly, mechanical float and pulley systems require regular maintenance otherwise they become jammed. In addition, none of these mechanical gauges easily provide for remote monitoring.

Electronic gauges are more complex, require power and are usually more costly. However, they can provide features that passive and mechanical gauges cannot. These features include reliability, accuracy and the ability to provide remote monitoring of one or more tanks at a time. In addition, provision is often made to include pump control.

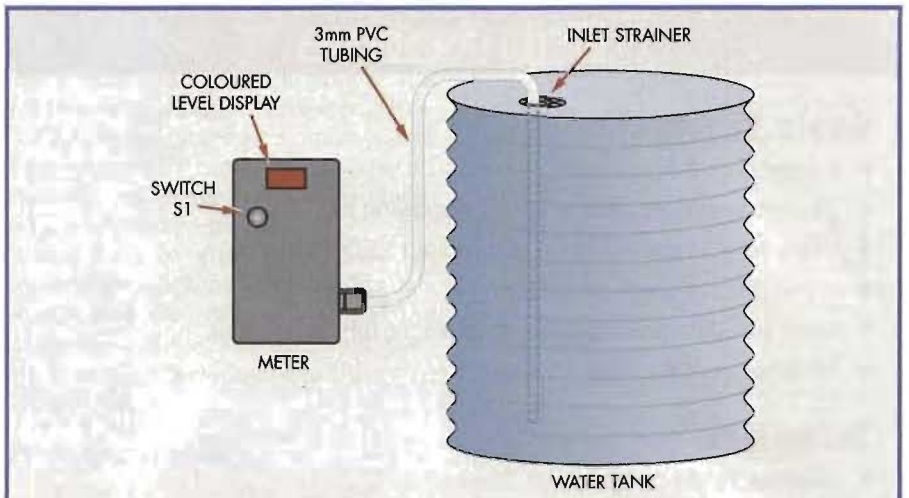
This new Water Tank Level Meter includes all those features and more.

Basic concept

The SILICON CHIP Water Tank Level Meter is a versatile unit that can be built in a number of different configurations. It suits all types of rainwater tanks, is easy to install and because it doesn't rely on mains power, can be installed just about anywhere.

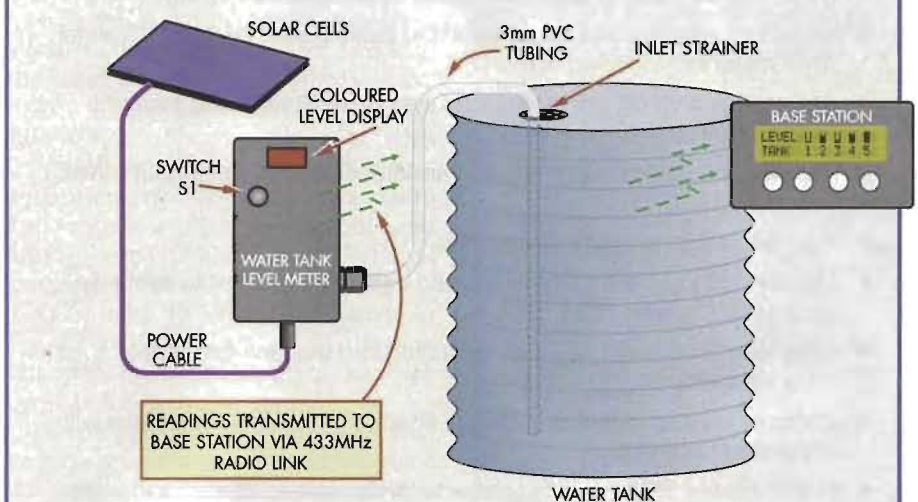
That last feature is particularly important because mains power is often not available adjacent to water tanks and this makes many electronic tank level meters impractical.

By contrast, the SILICON CHIP Water Tank Level Meter is powered from a single AA alkaline or rechargeable cell, making it independent of the mains. So it doesn't matter whether your tank is attached to the house, located next to a shed away from the house or situated half way up a hill to provide water pressure storage – this unit will still work.



BASIC WATER TANK LEVEL METER

Fig.1: in its most basic form, the Water Tank Level Meter is a standalone unit that sits next to the tank. The water level is sensed using a pressure sensor connected by a plastic tube.



TELEMETRY VERSION OF WATER TANK LEVEL METER

Fig.2: the telemetry version transmits its reading to a remote Base Station which can display a range of data. A solar cell panel recharges an internal NiMH or Nicad battery.

In its most basic form, this water level meter can be built as a standalone unit that's installed adjacent to a tank. The basic arrangement is shown in Fig.1.

All you have to do is press a pushbutton switch and a multi-coloured LED will display the water level. Water levels are displayed as a colour sequence, ranging over 10 colours from white through to violet, to violet/indigo, indigo, indigo/blue, blue, green, yellow, orange and red. Red indicates the lower 10% range followed by orange for the 10-20% range and so on up to violet for an 80-90% level and white for the 90-100% level – see Fig.3.

A single AA alkaline cell provides power for this basic version of the Water Tank Level Meter. The circuit draws no power until the pushbutton switch is pressed to activate the LED display. Actual cell life depends on usage but with one water level check per day, the cell should last for four years.

If you want higher water level resolution and remote monitoring, the unit can be upgraded to a telemetry unit. In this case, the tank level is transmitted to a separate (plugpack-powered) base station – see Fig.2. Note, however, that

Main Features

Basic Version

- Powered by a single cell
- Zero power consumption unless displaying the level
- Water level displayed using a 10-colour LED indicator
- Pushbutton initiates the display
- Easy installation using a length of plastic tubing into tank
- Weatherproof housing

Telemetry Version

- Alkaline, NiMH or Nicad cell powered
- Solar cell charging for rechargeable cell
- Pushbutton initiates the 10-colour level display
- Minimal power drawn from cell
- Radio transmission of tank level, temperature and cell voltage
- Up to 10 tanks can be monitored at the base station by using 10 water level meters
- Automatic pump control facility (requires Base Station and separate Pump Control unit)
- 16 encoding selections (prevents interference from a neighbour's Water Tank Level Meters)
- Four transmission update selections
- Update period differs slightly between each tank monitor to minimise data send clashes
- Easy installation using a length of tubing into the tank for height measurement
- Accurate measurement of regularly shaped tanks, including tanks with corrugated sides
- Weatherproof IP65 housing (protected from ingress of dust and water)

the tank level can still be checked using the LED display.

Base station

The base station shows levels in 1% increments from 0% through to above 100%. Why show levels above 100%? Well, most tanks are full when the water level reaches either the overflow outlet or the bottom of the inlet strainer when there is no overflow outlet. This is the 100% full level.

However, during periods of heavy rain or when the tank is being filled using a pump, the tank can overfill. It is this condition that can be monitored via the base station readout – ie, up to 110% in level.

Up to 10 tanks can be remotely monitored using the base station. To do this, each Water Tank Level Meter (one for each tank) uses an inbuilt radio transmitter to send the data to the base station. This transmitter operates on the licence-free LIPD 433MHz band.

The distance over which the data can be sent depends on the terrain. Our tests indicate a range of more than 250m in open country but this is reduced if the signal has to pass through a wall or roof to reach the base station, especially if there is corrugated iron in the transmission path.

The data is sent to the base station once every 16.8s, 33.5s, 67s or 268s (about 4½ minutes), depending on the set-up. This rate is selectable and depends on your installation.

For small tanks, you may want to choose a fast rate so that the reading updates can keep pace with the water level as the tank rapidly fills. The downside of a fast rate is that the circuit draws more power from the cell. So while an alkaline cell could be used to power each Water Tank Level Meter, the best power option for the telemetry version is to use a rechargeable cell, along with a solar cell to recharge it.

The slowest rate (ie, 268s) can be used to conserve power and is more suited for large tanks. It's also an acceptable update period for most other installations, where you just want to know the water level and don't have pump control.

Pump control

The base station not only shows water levels but can also independently control up to 10 electric water pumps. For example, the base station can be set up to switch off a given pump when the tank water drops below a preset level. This is useful when pumping out of a tank.

Alternatively, a pump can be switched off if the water rises above a preset level; eg, when filling a tank. A pump can also be switched off if the temperature drops below a preset value, to prevent the pump from running when the water is frozen.

In addition, the pump control includes brownout protection. We'll have more to say about this and pump control in a later article.

Water Tank Level Meter

Now that we've covered the basic features, let's go back and take a closer look at the Water Tank Level Meter.

Basically, you require one of these meters for each tank. As shown in the photos, the unit mounts in a weatherproof box with a clear lid to allow the coloured LED to be seen (for water level indication). The front panel carries a waterproof switch, while the plastic tube that is required for tank level measurement enters the box via a waterproof cable gland.

Unlike the basic version, the telemetry version uses a rechargeable cell and this is recharged by a separate solar cell panel during daylight hours. The leads from the solar panel enter through a waterproof cable gland on the bottom of the box.

Measurement techniques

Just about every water tank level meter on the market measures water height within the tank. They do not

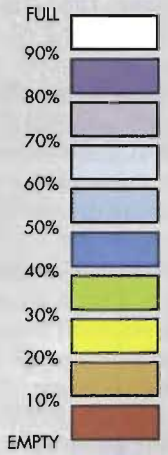


Fig.3: the water level in the basic version is displayed using a 10-colour sequence, ranging from red (0-10%) to white (90-100%). These colours are generated by a tri-colour LED.

measure water volume because that is difficult to do and because it is usually unnecessary.

If the tank is a regular shape with nominally straight sides and with the same shape and area at any horizontal cross section, then the water level gives a direct indication of water volume. By contrast, irregularly-shaped tanks such as those that have large indentations or are moulded to fit into an available space are not suited to accurate level measurement.

Tanks that taper slightly (in the vertical direction) due to the use of thicker material towards the base do not alter the accuracy markedly. Similarly, corrugations have only a small effect on accuracy, although this gets worse at very low water levels and where the tank diameter is small compared to the corrugation depth. In general though, the small non-linearity of volume with height does not matter.

There are several electronic techniques that are used to measure water level in a tank. One method is to use an in-tank sensor with a series of vertically-spaced metal contacts. As the water rises, current flows through each successive contact (because water is a good conductor) and the associated electronic circuit displays the level.

The resolution of this type of meter depends on the number of vertical contacts. This type of water level meter was described in the April 2002 and July 2007 issues of SILICON CHIP (five levels and 10 levels respectively).

Another method involves using an ultrasonic sensor to measure the distance from the top of the tank to the surface of the water. However, ultrasonic transducers require more power than we care to draw from an AA cell and the measurement is unreliable while the tank is filling.

Why is it unreliable? Well, as the water enters the tank inlet, the droplets scatter the ultrasonic signal and the measurement is lost. We published an ultrasonic level meter in the April 1994 issue.

Pressure sensor

Unlike our previous designs, the Water Tank Level Meter described here uses a pressure sensor to measure water height. This is a very simple method that provides excellent accuracy and is easy to install – all you have to do is connect the free end of a hose to the pressure sensor and feed the other end of the hose into a tank.

The technique relies on the fact that water pressure increases with increasing depth. For water, the pressure increases by 9.8kPa per metre and so there is approximately an extra atmosphere (1013hPa or 101.3kPa) of pressure for every 10.3m of depth.

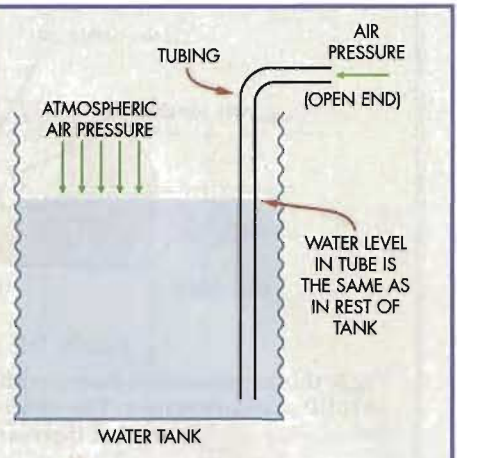
Refer now to Fig.4. As shown in Fig.4a, if the free end of the hose is left open, the hose will fill to the same level as the water in the tank.

However, if we first connect the free end to a pressure sensor and then place the hose in the tank, the water will still rise inside the tube but not to the water tank level (see Fig.4b). That's because it pressurises the air trapped inside the tube. In fact, the water level within the tube stabilises when the pressure inside the tube equals the water pressure at the bottom of the tube.

Fig.4c shows what happens if the water level drops below the bottom of the tube. In this case, the reading will be zero, since both inlet ports on the sensor are at atmospheric pressure (ie, the unit is calibrated to measure zero pressure when there is no water in the tank, with the pressure then progressively rising as the water level rises).

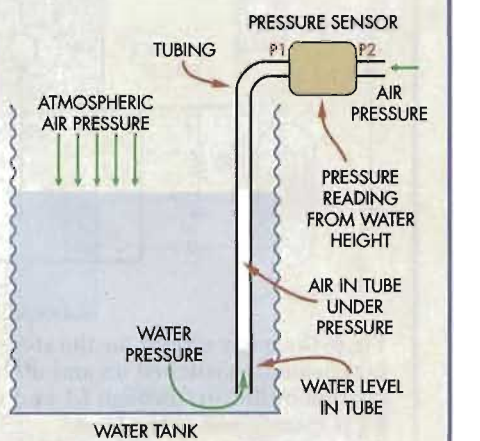
One problem with this scheme is that the tube will not stay down of its own accord but will float due to the air trapped inside it. Fortunately, that's easy to overcome by tying it to a length of PVC pipe. Alternatively, it can be tied down using a weight.

Another problem concerns the effect



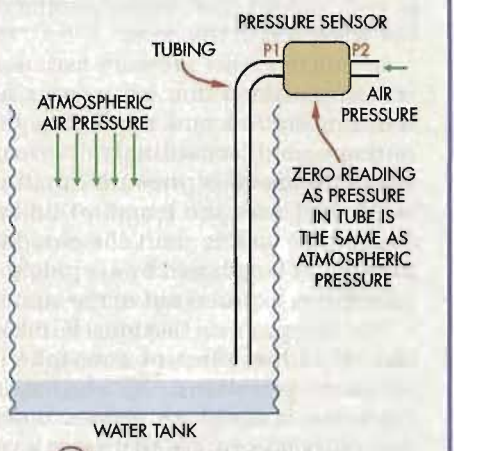
(A) TUBING WITH OPEN END

Fig.4a: if the free end of the tube (or hose) is left open, the tube fills to the same level as the tank.



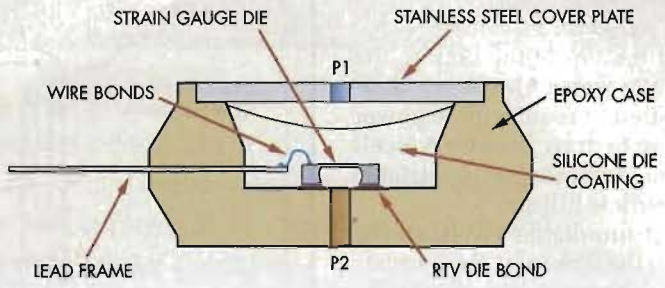
(B) WITH PRESSURE SENSOR, END OF TUBE NEAR TANK BOTTOM

Fig.4b: if one end of the tube is connected to a pressure sensor, the water pressurises the air in the tube.



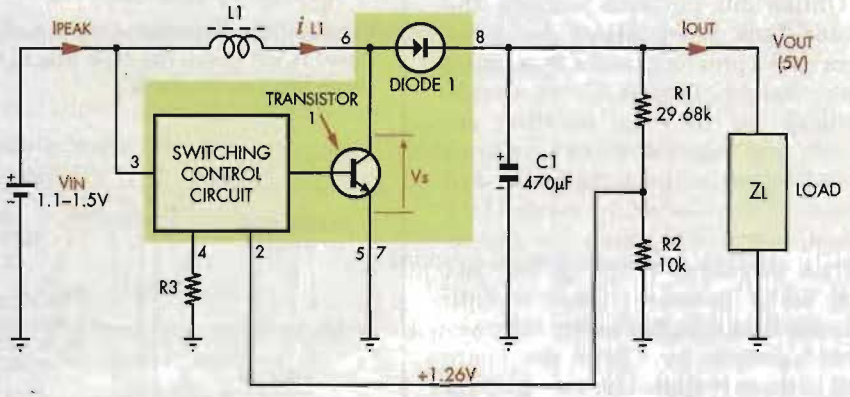
(C) WITH PRESSURE SENSOR, TUBE END AT SURFACE

Fig.4c: if the water level drops below the bottom of the tube, the reading will be zero since both sensor ports are at atmospheric pressure.



INSIDE THE PRESSURE SENSOR

Fig.5: this cross-section diagram shows the internal structure of the MPX-2010DP pressure sensor. The strain gauge varies its resistance according to the applied load. Note that there are two port openings (P1 & P2).



TL499A STEP UP CIRCUIT

Fig.6: the basic circuit for the step-up switching regulator. Transistor Q1 is repeatedly switched on and off by the control circuit. When it is on, the current builds up through L1 and when it switches off, the energy stored in L1 is transferred to the load.

of temperature variations on the air pressure inside the tube. For example, if the sun heats the tube, the air inside it will expand and displace some of the water out of the tube.

In practice, this pressure variation is compensated for by measuring the temperature and modifying the measurement accordingly. We can also minimise this pressure variation by making sure the length of tubing outside the tank is short compared to the overall length and by keeping the part that is exposed out of the sun.

Another problem that must be taken care of is the effect of atmospheric pressure variations. As shown in Fig.4, the atmosphere presses down onto the water and so the water level readings could vary markedly as the atmospheric air pressure changes.

The solution to this problem is simply to use a differential pressure sensor. This type of sensor is vented to the atmosphere, and so this variation is removed from the measurement.

In order to explain how the sensor ignores the atmospheric air pressure, let's take a look at its internal construction – see Fig.5.

The sensor used here is the MPX-2010DP from Freescale Semiconductor. Note that "RTV die bond" stands for "Room Temperature Vulcanising" bonding. In other words, silicone glue is used to bond the strain gauge die to the epoxy casing and is cured at room temperature.

Inside the sensor is a strain gauge that varies its resistance according to the applied load – ie, the air pressure exerted on the gauge. Note that there are two port openings to the strain gauge. One is on the top side and is designated port1 (P1), while the other is on the lower side and is designated Port 2 (P2).

If the same pressure is applied to both P1 and P2 then the strain gauge does not flex. However, if one port has more pressure than the other, the strain gauge bends and its resistance changes.

This particular sensor is called a differential type because it measures the difference in pressure between the two ports – ie, its output only changes when the pressure difference between the two ports changes.

The MPX2010DP is designed for the pressure at port 1 to be greater than or equal to the pressure at port 2. In addition, port 1 has a silicone gel protective layer to prevent moisture affecting the strain gauge element. This makes the sensor ideal for water level measurement, as the silicone barrier keeps the sensor free of the water vapour that results from condensation in the measuring tube.

By contrast, Port 2 is vented to the atmosphere, to balance the air pressure on both sides of the strain gauge element.

This sensor is specified for a 0-10kPa pressure range, with a maximum differential pressure of 75kPa. Using it above the 10kPa level degrades the linearity due to internal self-heating of the sensor. However, this limit is specified when running the sensor from a 10V supply. Since we are using a 5V supply, the self-heating will be considerably lower and so we can easily exert more pressure than 10kPa without loss of linearity.

When connected to measure water level, each metre of water adds 9.8kPa of pressure to the sensor. Most water tanks are equal to or less than about 2.2m in height because they are designed to fill from the rainwater guttering of a house. This means that, for a 2.2m tank, the maximum pressure applied to the sensor will be about 22kPa maximum. This is well below the 75kPa maximum allowable for the sensor.

The strain gauge element is temperature compensated within the sensor by connecting it in a balanced bridge arrangement and by laser trimming the elements during manufacture. In practice, the sensor is compensated over a 0-85°C range but can be operated from -40°C to +125°C.

Circuit details

As stated previously, the unit is powered from a single cell – either a 1.5V rail from a standard alkaline cell or a 1.25V rail from an NiMH (or Nicad) rechargeable cell. This voltage

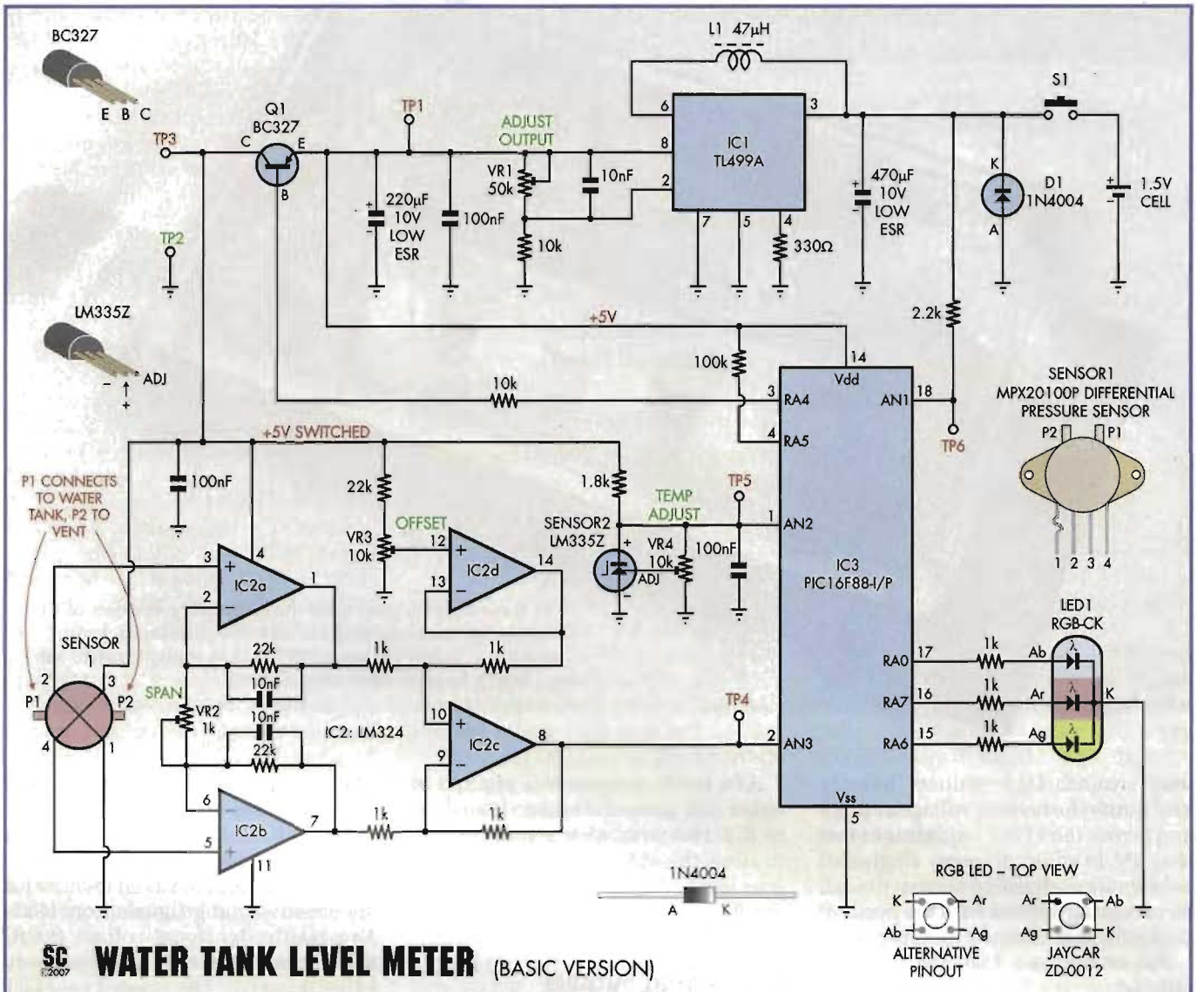


Fig.7: this is the circuit for the basic version of the Water Tank Level Meter. The differential outputs from the pressure sensor at pins 2 & 4 are buffered and amplified by op amps IC2a-IC2d and then fed to inputs AN2 & AN3 (pins 1 & 2) of a PIC18F88-I/P microcontroller (IC3). IC3 processes the data and drives a tri-colour LED at RA0, RA6 &RA7.

needs to be stepped up to 5V to run the microcontroller (IC1) and its associated circuitry

This voltage step-up is performed using a TL499A switching regulator (IC1), transistor Q1, inductor L1, a series diode (D1) and output filter capacitor C1. Fig.6 shows the details.

The circuit works like this: initially transistor Q1 is switched on and the current through inductor L1 builds up until it reaches a preset value, as set by the resistor connected to pin 4 of IC1. At that point, the transistor switches off and the energy stored in L1 is delivered to the load and to output capacitor C1 via the series diode (DIODE1). This process then repeats, with the transistor switching on again and recharging L1, then switching off again and transferring the charge in L1 to the load.

A voltage divider consisting of resistors R1 & R2 reduces the output level, while Q1's switching is controlled so as to maintain 1.26V at pin 2. Basically, the voltage divider values of 29.68kΩ and 10kΩ divide the output by 3.97 so the output will be at 5V when there is 1.26V at pin 2. Should the voltage rise slightly above 5V, transistor Q1 stops switching until the voltage falls slightly below the 5V level. Conversely, if the output voltage falls below 5V, the transistor switches on and off at a fast rate to increase the voltage.

Note that the 1.26V at pin 2 (necessary to maintain regulation) is only a nominal value and could in fact be anywhere between 1.2-1.32V, depending on the particular IC. As a result, resistor R1 needs to be adjustable so that the output voltage can be set precisely to +5V.

Refer now to Fig.7 for the circuit details of the Water Tank Level Meter (Basic Version).

As shown, power from the 1.5V cell is applied to pin 3 of step-up converter IC1 via switch S1. Diode D1 provides reverse polarity protection if the cell is inserted incorrectly, while a 470µF low-ESR capacitor bypasses the supply. This capacitor provides the necessary transient current for the inductor when Q1 switches on.

If the cell is connected the wrong



The Base Station goes with the Telemetry Version of the level meter and can display a range of data, including individual levels for up to 10 tanks & pump control set-up. It will be described next month.

way around, D1 conducts heavily and limits the reverse voltage at pin 3 and across the 470µF capacitor to less than 1V. In addition, many single cell holders are designed to prevent the cell from making contact with the positive contact if it is inserted incorrectly.

Power is drawn from the 1.5V cell only when switch S1 is pressed. This means that the cell should last for several years before it requires changing, depending on the amount of use. The current consumption from the cell when the switch is pressed with one or two LEDs alight is typically around 32mA.

IC1's output voltage appears at pin 8 and is sampled via trimpot VR1 and a 10kΩ resistor. This sampled voltage is then applied to pin 2.

In practice, VR1 is adjusted so that the output is exactly +5V. A 100nF ceramic capacitor and a low-ESR 220µF capacitor filter this supply rail which is then fed to pin 14 of microcontroller IC3. The +5V rail is also connected to the emitter of transistor Q1 (BC327).

When power is applied to IC3, its internal software program starts running. Initially, transistor Q1 is switched off because IC3's RA4 output (which drives the base via a 1kΩ resistor) is held at +5V.

As a result, no power is applied to either the pressure sensor (Sensor1) or IC2. However, after a short period to allow the +5V rail to stabilise, RA4 goes low and Q1 switches on. Sensor1 and IC2 are then powered up and begin operating.

Differential outputs

As shown in Fig.7, Sensor1 has differential outputs at pins 2 & 4. If the same pressure is applied to both ports, the voltages at pins 2 & 4 are nominally the same, at half supply voltage or 2.5V. However, if the pressure at port 1 is higher that at port 2, the voltage at pin 2 rises and the voltage at pin 4 falls. This change in voltage is actually quite small, amounting to around 12.5mV for a 10kPa pressure difference when the sensor is powered from a 5V rail.

The sensor's differential output signals at pins 2 & 4 are fed to op amps IC2a & IC2b respectively. These are each set up as non-inverting amplifiers with 22kΩ feedback resistors and with a 1kΩ trimpot (VR2) connected between their inverting inputs. The 10nF capacitors across the 22kΩ resistors, filter the signal by rolling off the high-frequency response.

The outputs from IC2a & IC2b appear at pins 1 & 7 respectively and are summed in unity gain differential amplifier IC2c. Basically, IC2c acts as a voltage follower for the positive-going signals from IC2a and as an inverter for the negative-going signals from IC2b. As a result, the signal voltage excursions from IC2a & IC2b are effectively added together. The overall gain is 1 + (22kΩ x 2/VR2).

Buffer stage

IC2d is wired as a buffer stage and applies an offset voltage to the non-inverting input of IC2c (pin 10) via a 1kΩ resistor. It obtains its reference voltage via a voltage divider from the +5V supply and this divider comprises trimpot VR3 and a 22kΩ resistor.

In practice, VR3 is adjusted so that IC2c's pin 14 output sits at 1V when the sensor has no pressure difference between the two inlet ports. By contrast, trimpot VR2 is adjusted to provide 3V at IC2c's pin 8 output when the sensor is measuring a full tank.

As a result, IC2c has a 2V range – ie, from 1-3V for a zero to full tank level measurement.

If the tank being monitored is 1m high, the sensor output will provide a 12.5mV signal when the tank is full. In this case, the signal must be ampl

fied by 160 to produce the required 2V swing and that means that VR2 would be set to 277Ω.

VR2's practical range from 1kΩ down to about 100Ω easily provides for tanks ranging in height from 3m down to 360mm. However, in the unlikely event that a tank is less than 360mm high, a 200Ω trimpot should be used for VR2 instead of the 1kΩ value specified on the circuit. This will allow the trimpot to be set below 100Ω without being too near its adjustment limit.

The reason we restrict IC2c's output to between 1-3V is so that the LM324 op amp can operate correctly within its output range. Typically, an LM324 can easily provide an output from 1-3V when powered from a 5V rail but it cannot provide a 0-5V output.

IC2c's output at pin 8 is applied to the AN3 input (pin 2) of IC3, a PIC16F88-I/P microcontroller. Note, however, that the 5V supply is applied to the sensor and to IC2 for about 64ms before the voltage at AN3 is measured. In operation, IC3 converts this applied voltage to a 10-bit digital value and this is then calculated as a percentage, with a 1V reading converted to 0% and a 3V reading converted to 100%. The 100% to 110% range covers input voltages between 3V and 3.2V.

The resulting percentage level is then used to determine what colour should be produced by the tri-colour (RGB) LED. This device basically includes separate red, green and blue LEDs and these are driven by the RA0, RA7 & RA6 outputs via 1kΩ resistors.

When all the LEDs in the package are powered, the LED colours mix to show white. If only two or one LED is lit, a different colour results. For example, to produce violet, the red and blue LEDs are lit. Similarly, yellow is displayed when the red and green LEDs are lit.

We can also obtain a range of in-between colours by reducing the light output of one of the LEDs. This is achieved by switching the LED on and off using a fast equal duty cycle waveform, so that it doesn't appear to flicker. For example to obtain orange, we switch the red LED on continuously while the green LED is rapidly switched on and off.

In practice, when switch S1 is momentarily pressed, the LED colour display comes on for about 2s to show the water level and then switches off again. At the same time, IC3's RA4 output goes high and switches off transistor Q1 to disconnect power to the pressure sensor and IC2. This conserves power should the switch be pressed longer than required.

The 2.2kΩ resistor at pin 18 (AN1) of IC3 ties this input to pin 3 of IC1 so that it is not left floating (this input is used in the telemetry version to measure cell voltage).

Specifications

Water Level Indication: White 90-100%, Violet 80-90%, violet/indigo 70-80%, indigo 60-70%, indigo/blue 50-60%, blue 40-50%, green 30-40%, yellow 20-30%, orange 10-20%, red 0-10%

Current – Basic Unit: 32mA typical when displaying level; 0mA when off.

Current – Telemetry Version: standby current drawn from 1.25V cell = 1mA; awake current during each start-up for 220ms = 24mA; average current = 314µA for 16.8s update; 157µA for 33.5s update; 79µA for 67s update; and 19µA for 268s update. Add an extra 8mA over 2s when one or two LEDs are lit

Solar cell charge current in winter time and in full sunlight: typically 30mA

Data transmission duration: 146ms

Transmission repeat: approximately 16.8s for encode 0-3, 33.5s for encode set at 4-7, 67 seconds for encode set at 8-B and 268s for C-F.

Transmit range: over 250m

Temperature sensing

The AN2 input (pin 1) monitors the temperature via an LM335Z temperature sensor (Sensor2). This produces a nominal output of 10mV/°C but with an offset of 2.73V at 0°C and is linear with temperature changes. The water level reading is then compensated for according to the measured temperature.

Trimpot VR4 is used to calibrate the sensor for 2.73V at 0°C or 2.98V at 25°C by altering the voltage at the ADJ terminal.

Clock signals for IC3 are provided by an internal oscillator that's set to run at 8MHz. Among other things, it runs the internal program at a constant rate to perform the A/D conversion and to drive the RGB LED for the set period.

Telemetry version

The telemetry version of the Water Tank Level Meter is almost the same as the standard version but adds a few extra parts, including a 433MHz transmitter and two rotary BCD switches. In addition, the power supply arrangement is slightly different.

As previously mentioned, this version is powered from a rechargeable NiMH (or NiCd) cell. This cell is in turn charged from a solar cell array via Schottky diode D2. This diode is required to stop the solar cell from discharging the NiMH cell when there is no sunlight.

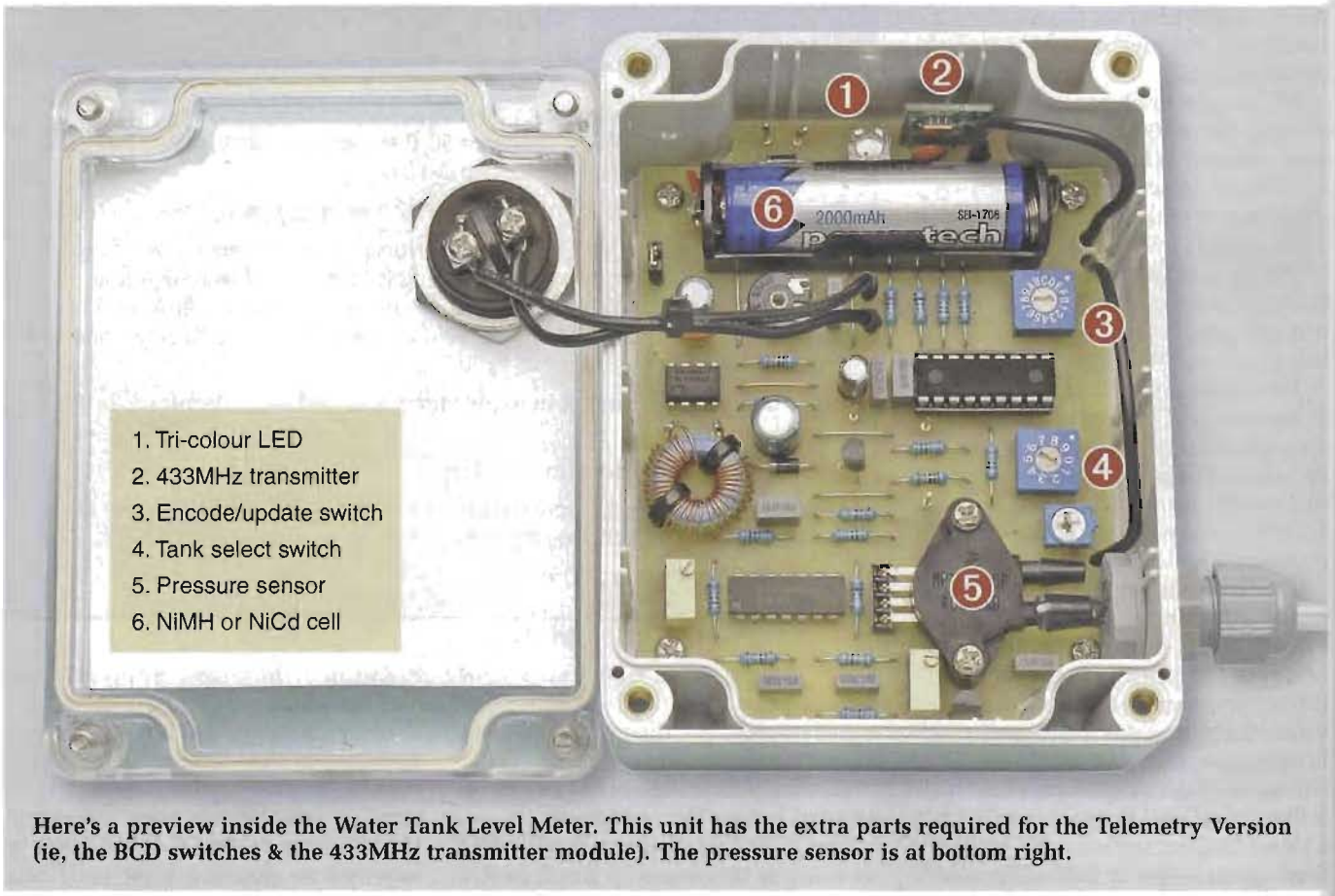
In case you are wondering, you could still use an alkaline cell to power the unit and do away with the solar cell charger. However, the cell would require changing every two months.

Another alternative is to run the circuit from a mains plugpack. In this case, an NiMH (or Nicad) cell must be used and this is recharged from the plugpack. In addition, diode D2 must be replaced with a 1kΩ 0.25W resistor.

Other supply changes to the circuit include moving S1 so that it now connects across transistor Q1. S1's previous position is now replaced by link LK1, which means that power is now continuously applied to step-up converter IC1 which in turn permanently powers the microcontroller (IC3).

To conserve power, IC3 is normally in a sleep mode; ie, its internal oscillator is stopped, its A/D converter is off and the program is halted. In this mode, IC3 typically draws just 11µA.

During this period, a watchdog timer is left running (more about this timer soon) and the RA4 output is set high so that transistor Q1 is off. As a result, there is normally no supply to



Here's a preview inside the Water Tank Level Meter. This unit has the extra parts required for the Telemetry Version (ie, the BCD switches & the 433MHz transmitter module). The pressure sensor is at bottom right.

Sensor1, ICs2a-2d, the 433MHz transmitter and all those other components that derive their supply from the +5V switched rail.

We have also minimised the current drain due to BCD switches BCD1 and BCD2. These switches can connect any of their '1', '2', '4' or '8' inputs to the common pin (C), depending on the switch setting.

These inputs are usually tied to +5V via internal pull-up resistors (typically 20kΩ) at the RB0-RB2 inputs for BCD1 and the RB3-RB6 inputs for BCD2. The RA5 input for BCD1 is pulled to +5V using an external 100kΩ resistor. The 1kΩ resistor between BCD1 and RA5 is necessary because this input is susceptible to currents that flow into or out of the pin when voltages go above or below the supply (these currents can reset IC3).

Normally, if IC3 is to determine which settings are selected for the BCD switches, their common (C) connections must be at ground level so any closed switch will pull the normally high input to ground. However, this would cause extra current flow because the corresponding pull-up resistors would be connected across the 5V supply and thus drawing up to 250µA extra current for each closed switch.

To prevent this current, we have connected the common pins to the RA4 output of IC3 instead. This output is high at +5V when the microcontroller is in sleep mode and so whether a switch is closed or not, the BCD switches will not add to power consumption. The RA4 output subsequently goes low when IC3 is awake to allow the switches to be read.

This also means that the switchmode step-up circuit comprising IC1 and its associated components does not need to supply much current to IC3 when it is in sleep mode. As a result, IC1 charges L1 for just 28µs once every 6ms and this is just enough to maintain the 5V supply. By contrast, when the supply is required to deliver current to the whole circuit, L1 is charged for 28µs every 150µs.

Reawakening IC3

IC3 will "wake up" on any one of two events. The main event is when the watchdog timer times out and wakes IC3 from its sleep. In this case, the oscillator starts up and the internal program starts running.

Basically, the watchdog timer will timeout every 16.8s, 33.5s, 67s or 268s, depending on the switch selection for BCD2. The period between "wake-ups" is basically the update period – each time IC3 wakes up, the water tank level is measured and the data transmitted to the base station. After sending this data, the microcontroller then returns to its sleep mode to conserve power.

Note that a watchdog wake-up does not light the tri-colour RGB LED and this is again done to conserve power.

In order to light the RGB LED for a tank level display, switch S1 (now in parallel with Q1) must be pressed. In addition, IC3 needs to be woken from its sleep independently from the watchdog timer through a different process.

Note that, during the sleep mode, the AN1 (pin 18) and AN2 (pin1) inputs of IC3 are set to connect to a comparator within IC3. The AN1 input is at the cell voltage (1.2V), while the AN2 input is at 0V because transis-

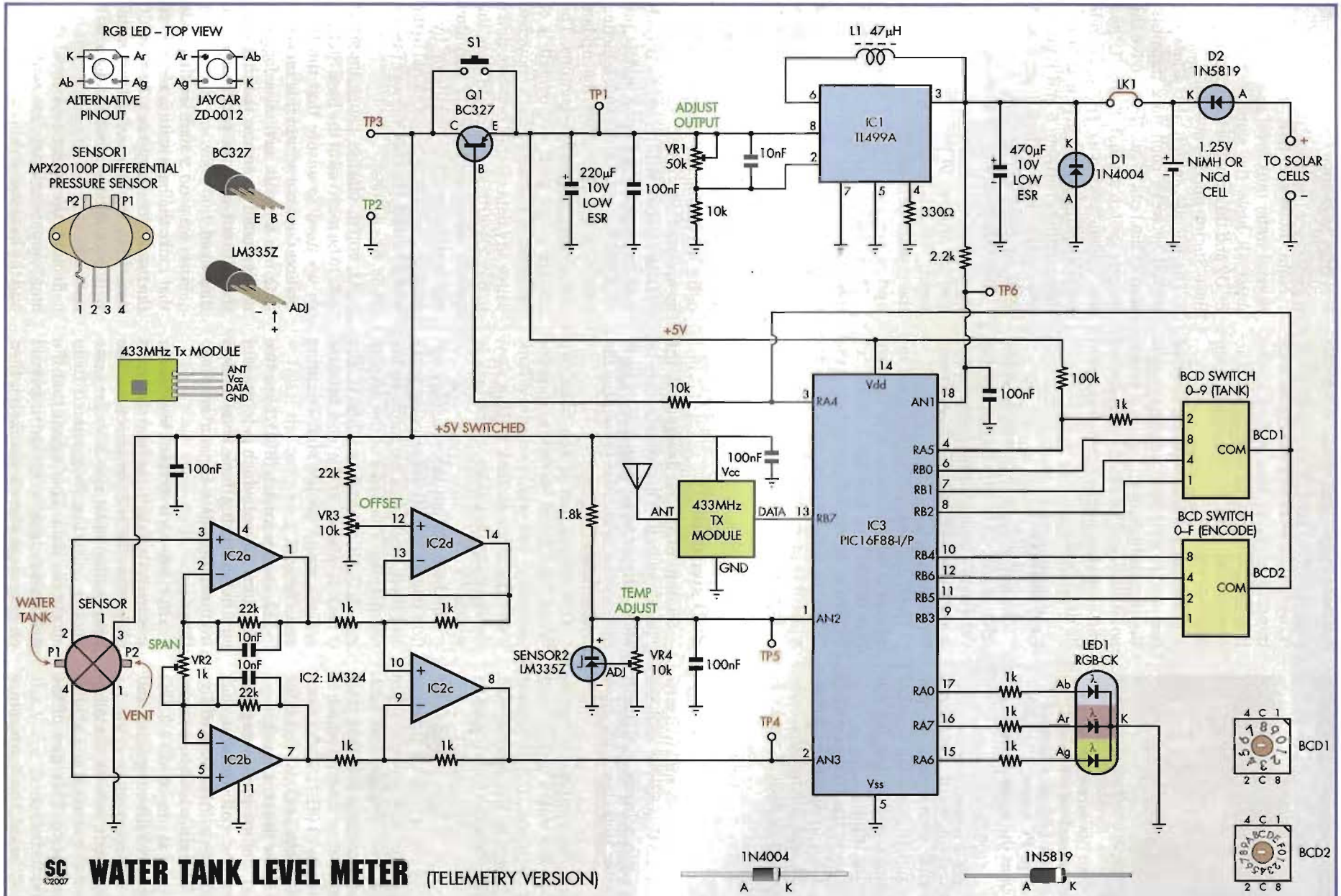
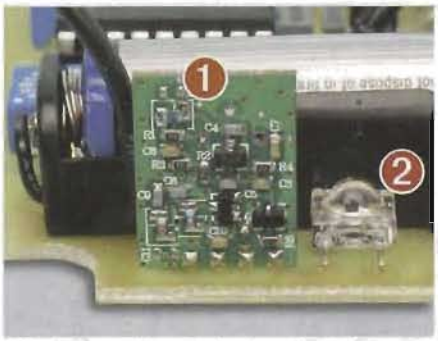


Fig.8: the Telemetry Version is similar to the Basic Version but adds in a couple of BCD switches and a 433MHz data transmitter module. The BCD switches allow tank selection and set the data update periods.



This larger than life-size view shows the 433MHz transmitter module (1) and the tri-colour LED (2) mounted at one end of the PC board. The LED colour indicates the water level.

tor Q1 is off. As a result, the output of the internal comparator is low because the pin 18 inverting input of the comparator is higher than the pin 1 non-inverting input.

That leads us to the second way of waking up IC3 – by manually pressing switch S1 and forcing the comparator output to go high. It works as follows.

When S1 is pressed, it bypasses Q1 and supplies power to the temperature sensor (Sensor2) via a 1.8kΩ resistor. With power applied, Sensor2 will now have at least 2.5V across it and the comparator's pin 1 input (AN2) will now be greater than the 1.2V from the cell.

As a result, the comparator output goes high and this wakes up IC3. And when that happens, the processor maintains power to the sensors and the 433MHz transmitter by bringing its RA4 output low to turn on Q1.

Regardless as to how it wakes up (ie, either via the watchdog timer or by pressing S1), IC3 measures the temperature, cell voltage and tank level. It then transmits this data via a 433MHz transmitter module which is connected to pin 13 (RB7). At the same time, the tri-colour LED also lights for about 2s to show the tank level.

Note that before measuring the temperature and cell voltages, IC3 changes its AN1 and AN2 ports to digital inputs. This allows IC3 to measure the cell voltage at pin 18 via a 2.2kΩ resistor and 100nF filter capacitor and to monitor the temperature at pin 1.

As with the basic version, the temperature is monitored using an LM335Z temperature sensor. This part of the circuit works as before.

At the AN2 input, the temperature sensor voltage is converted to a 10-bit digital value. This is then converted to °C by the software and the digital data transmitted to the base station where it is displayed on the LCD panel. The temperature can be displayed from -99°C to 100°C.

Note that the temperature reading can used to switch off a pump should the temperature drop below a preset point. This is done via the base station and a separate pump control circuit to be described.

Cell voltage

The cell voltage is measured at the AN1 input. This input converts the voltage to a 10-bit digital value which is again transmitted to the Base Station for display.

The displayed voltage is a good indicator of battery charge. A cell voltage that is 1.15V or less has a small "x" located at the top left corner before the "1" in the display reading, to indicate a possible problem with the cell.

Typically, a fully-charged NiMH cell will show more that 1.25V on the Base Station display.

BCD switches

Switch BCD1 is designated the "Tank" switch. This switch can be set to any number from 1-9 or to 0, the number selected representing the tank number.

This means that if you have two Water Tank Level Meters (to monitor two tanks), you would set one as Tank 1 and the other as Tank 2. That way, the base station knows which tank is which.

The base station has a display option that shows all the selected tanks and their levels as a bargraph on the one display. The order of the display is 1, 2, 3, etc up to 9 and then 0. The 0 tank is placed at the end because not too many people start counting tanks from 0!

The encode switch (BCD2) has two functions, one of which is to prevent any neighbouring tank level meters from sending data to your base station.

Thus, when a water tank level meter transmits its data to the base station, it also sends the encode selection. The Base Station must also have the same encode selection programmed in to accept the data. This means that if a neighbour's tank levels are displayed on your base station (unlikely), then it is time to change the encode selection.

Note, however, that if you have several water tank level meters, these must all have the same setting for BCD2 and this must be identical to the Base Station encode switch.

The encode switch also alters the period between each data transmission of the tank level. If you have the encode switch set to 0, 1, 2 or 3, then the update period is 16.8s. Encode switch settings of 4-7 give a 33.5s update; settings between 8 and B give a 67s update; and settings from C to F 268s, or about 4.5 minutes.

The selection you choose depends on the size of the tank to some extent and the number of tanks being monitored. The fewer the tanks, the faster the update periods can be. A slower update rate avoids data clashes.

Data clashes occur when one tank transmits its data during the same time period as another. This will cause incorrect data reception at the Base Station and the data will be rejected. The more tanks that are monitored the greater the likelihood of clashes. So we need to minimise these clashes or the data at the Base Station will not be updated very often.

Data clashes will be worse if each tank has exactly the same update period. For this reason, the tank selection switch BCD1 also alters the update rate slightly between selections. The change is not great and overall is of the order of ±12% but that's enough to cause any data clashes between tanks to quickly drift apart. In addition, the encode selections at BCD2 also alter the watchdog timer oscillator by a small amount (this is additional to the widely-spaced update values of 16.7s, 33.5s, 67s & 268s).

As noted, clashes cause incorrect data to be received at the Base Station so we need to ensure that the Base Station does not accept this incorrect data. As a result, several safeguards are included to ensure the that only the correct data is processed and displayed.

First, we send a start locking code that locks the base station receiver to the transmitter frequency. As a result data from another water tank meter will be a different rate and so will not lock.

Second, the water tank level data and temperature data are sent twice and the base station checks if the data

Parts List

Basic unit

1 PC board, code 04111071, 104 x 79mm
1 IP65 sealed polycarbonate enclosure with clear lid, 115 x 90 x 55mm (Jaycar HB-6246 or equivalent)
1 MPX2010DP Freescale Semiconductor 0-10kPa differential temperature compensated pressure sensor (Jaycar ZD-1904 or equivalent) (Sensor1)
1 SPST waterproof momentary switch (Jaycar SP-0732 or equivalent) (S1)
1 18 x 8 x 6.5mm iron-powdered core (Jaycar LO-1242 or equivalent) (L1)
1 3-6.5mm diameter IP68 waterproof cable gland
1 AA cell – see text
1 AA cell holder (Jaycar PH-9203 or equivalent)
1 2-way pin header with 2.54mm spacing
1 18-pin DIL IC socket
1 4-way SIL socket (made from a cut down DIP8 socket)
2 M3 x 15mm screws
2 M3 nuts
2 No.4 x 6mm self-tapping screws
10 PC stakes
1 1.5m length of 0.5mm enamelled copper wire
1 150mm length of medium-duty hookup wire
1 270mm length of 0.8mm tinned copper wire
2 100mm cable ties
1 length of 3mm ID clear vinyl tube (length to suit water tank depth and installation)
1 length of 25mm PVC tubing to support the tubing or a suitable weight
4 200mm cable ties

Semiconductors

1 TL499A power supply controller (IC1)
1 LM324N quad op amp (IC2)
1 PIC16F88-I/P microcontroller programmed with "water tank level meter.hex" (IC3)
1 LM335Z temperature sensor (Sensor2)
1 BC327 PNP transistor (Q1)
1 1N4004 1A diode (D1)
1 common cathode RGB LED (Jaycar ZD-0012 or equivalent) (LED1)

Capacitors

1 470µF 10V PC low-ESR electrolytic
1 220µF 10V PC low-ESR electrolytic
1 100µF 16V PC electrolytic
3 100nF MKT polyester
1 100nF ceramic
3 10nF MKT polyester

Resistors (0.25W 1%)

1 100kΩ
3 22kΩ
2 10kΩ
1 2.2kΩ
1 1.8kΩ
7 1kΩ
1 330Ω

Trimpots

1 50kΩ horizontal trimpot (code 503) (VR1)
1 1kΩ multi-turn top adjust trimpot (code 102) (VR2)
1 10kΩ multi-turn top adjust trimpot (code 103) (VR3)
1 10kΩ horizontal trimpot (code 103) (VR4)

Extra Parts For Telemetry Version

1 BCD 0-9 DIL rotary switch (BCD1) (Jaycar SR-1222 or equivalent)
1 BCD 0-F DIL rotary switch (BCD2) (Jaycar SR-1220 or equivalent)
1 433MHz transmitter module (Jaycar ZW-3100)
1 6.5mm diameter IP68 waterproof cable gland
3 PC stakes
1 2.54mm jumper shunt
1 Solar garden light (Homemaker Lifestyle (Kmart) or equivalent – this includes the solar cell, an AA NiMH or NiCd cell & the 1N5819 Schottky diode (D2))
1 100nF MKT polyester capacitor
1 100nF ceramic capacitor
1 1kΩ 0.25W 1% resistor
1 length of single core shielded microphone cable (length to suit installation)

Extra parts if pressure sensor mounted inside tank

1 bulkhead box, 65 x 38 x 17mm
1 4-way header with 2.54mm pin spacing
2 M3 x 15mm Nylon screws
2 M3 x 6mm Nylon screws
2 M3 x 9mm tapped Nylon spacers
1 2-pair (4-wire) sheathed telephone cable (to suit installation)
5 100mm Nylon cable ties
Neutral-cure silicone sealant

is the same for both transmissions before it accepts it as valid. In addition, the encoding selections for the Water Tank Level Meter and the Base Station must match, the water tank level must not be more than 110% and the stop bit encoding must be correct.

The protocol for sending data is as follows: initially, the Water Tank Level Meter sends a 50ms transmission to set up the receiver to be ready to accept data. A 16ms locking signal is then sent, followed by a 4-bit encode signal and the 4-bit tank number.

Next, the 8-bit tank level is sent, followed by the temperature (eight bits with bit 7 as a sign bit), cell volts (8 bits) and then the 8-bit water level again and the temperature again.

The 8-bit stop code which has a value of 170 is then sent. These stop bits indicate that the signal is a water tank signal. A different stop bit sequence is used for the water pump control transmission.

Note that the locking sequence is included at the start of each transmission because the oscillator rate is slightly different for each tank selection. In operation, the receiver must lock onto the transmission rate or the data will be read incorrectly.

The data from the 433MHz transmitter is sent at a nominal 1k bits per second. The receiver in the Base Station detects the signal and delivers the same data at its output.

That's all for this month. Next month, we'll show you how to build both versions (Basic & Telemetry) of the Water Tank Level Meter and describe the Base Station. SC



Playback adapter for CD-ROM drives

Ever wanted to use an old CD-ROM drive as a CD player for audio playback? Now you can do it, with this nifty CD-ROM Playback Adapter. It can control one or two CD-ROM drives and has an infrared remote control. A 16x2 line LCD screen provides track information and other data.

WE HAVE OFTEN been asked how to interface a hard drive or computer CD-ROM drive to a microcontroller. This is an interesting question, since there are countless old CD-ROM drives out there that are still in perfect functioning order but they are "obsolete". Instead of letting them end up in landfill, you could do your bit and build this project.

As well, this project will be good experience for those readers who wish to learn more about the ATA interface and who want to use hard drives and CD-ROM drives in their own projects. The interface can be easily modified to suit any other micro and only requires a few I/O ports and a reasonably fast processing core.

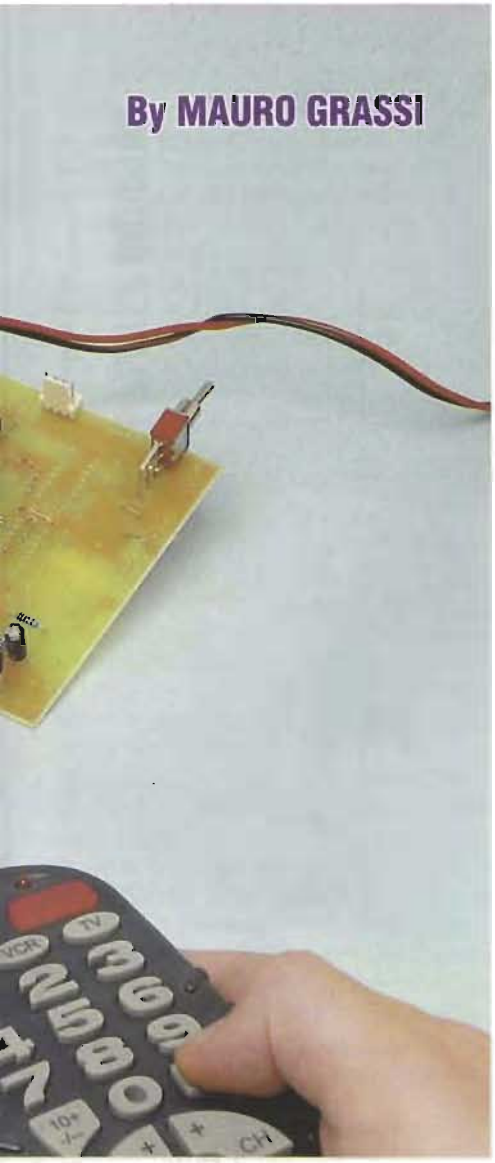
The main features of the Playback Adapter are listed below:

(1) Can connect up to two ATAPI CD-ROM drives.
(2) Auto detection of up to two connected drives.
(3) Plays your favourite CDs.
(4) Random play and repeat modes.
(5) Controls volume (16 levels) and balance digitally.
(6) Remote control with user-selectable key definitions.
(7) Works with any RC5 remote control.
(8) ISP (in-system programmable) if you wish to experiment with the firmware.
(9) The CD is automatically locked when playing
(10) LCD screen.

Accessing an ATAPI device

The CD-ROM Playback Adapter

By MAURO GRASSI



/CS1	/CS0	A2	A1	A0	/RD	/WR
1	0	0	0	0	Data	Data
1	0	0	0	1	Error	Features
1	0	0	1	0	Sector Count	Sector Count
1	0	0	1	1	Sector Number	Sector Number
1	0	1	0	0	Cylinder Low	Cylinder Low
1	0	1	0	1	Cylinder High	Cylinder High
1	0	1	1	0	Device/Head	Device/Head
1	0	1	1	1	Status	Command
0	1	1	1	0	Alt Status	Device Control

Table 1: the ATAPI register file. All ATA and ATAPI devices are controlled by reading and writing to these registers.

presented here lets you connect one or two drives and control each independently using a standard RC5 remote control.

CD-ROM drives that conform to the parallel ATA (AT attachment) standard can be used with the adapter and most old drives fall in this category. In fact, most CD-ROMs will be ATAPI devices, which is a superset of ATA. It just means they support the packet interface, a feature that was added to the original ATA interface.

The resulting protocol was renamed ATAPI, with the 'PI' standing for packet interface. Most CD-ROMs, as well as DVD drives, are ATAPI devices, although others conform to different standards, like SCSI and SATA (serial ATA). These have a different connector and are not compatible with this project.

Interfacing to an ATAPI device is simple because most of the work is done inside the drive. In effect, it acts as a black box. It conforms to a standard and the internal implementation is left to the manufacturer. That is why the standard was originally called IDE (integrated drive/device electronics). It just means that a lot of the complexity of the interface is in the drive and the drive responds to a uniform set of commands.

It speaks well of the design that one of the easiest parts of a computer to get working is the hard drive or CD-ROM/DVD drive. Plug any drive into any motherboard and it will usually work first time.

Overview of the ATA interface

The ATA interface is register-based. There are essentially two banks of eight registers, although only one of the eight registers in the second bank is ever used.

The interface consists of two chip select lines, called /CS0 and /CS1 which are active low. There are three address lines designated A0, A1 & A2, as well as the read and write control lines. The latter are designated /RD and /WR respectively and are also active low.

In order to access a register, one sets the register address given by [A2:A0] and then brings either /CS0 or /CS1 low (but not both). Then it is a matter of bringing either /RD or /WR low and reading or writing the data through data port D7:D0.

Note that the data bus width is actually 16 bits but for accessing the ATA registers, only the lower eight bits are used. However, the full width of the bus is used for data transfers.

Note also that the name of the register sometimes changes depending on whether you are reading from or writing to the specific address. For example, at address 110b and with /CS1 low and /CS0 high, reading will give the Alternate Status register (a read only register), while writing will affect the Device Control Register (a write only register).

All commands to control the drive are sent through the register file (ie, the set of ATA registers). For example, the Command Register can be written with the opcode for a particular operation – eg, "SLEEP" - and the drive will respond by going into power saving mode, barring any errors.

Note: the order in which you assert the control lines on the ATAPI/IDE bus is important. For example, you would think that you could assert /RD or /WR first and then bring /CS1 or /CS0 low. However, this approach does NOT work on all drives.

The correct procedure is to assert /CS1 or /CS0 first, then to assert either /RD or /WR. Of course, because we are using a general-purpose micro and these pins are on different ports, it is impossible to assert them simultaneously. This is not required however, but would be closer to a native IDE/ATAPI port interface.

Low level drivers

It is relatively simple to write to an ATAPI device. As explained, you first prepare the data and the address, bring the chip select line low and then apply either the read or write signal.

This is the minimum you would need to interface to an ATA device like a hard drive. It would not be the fastest interface possible - you'd have to get

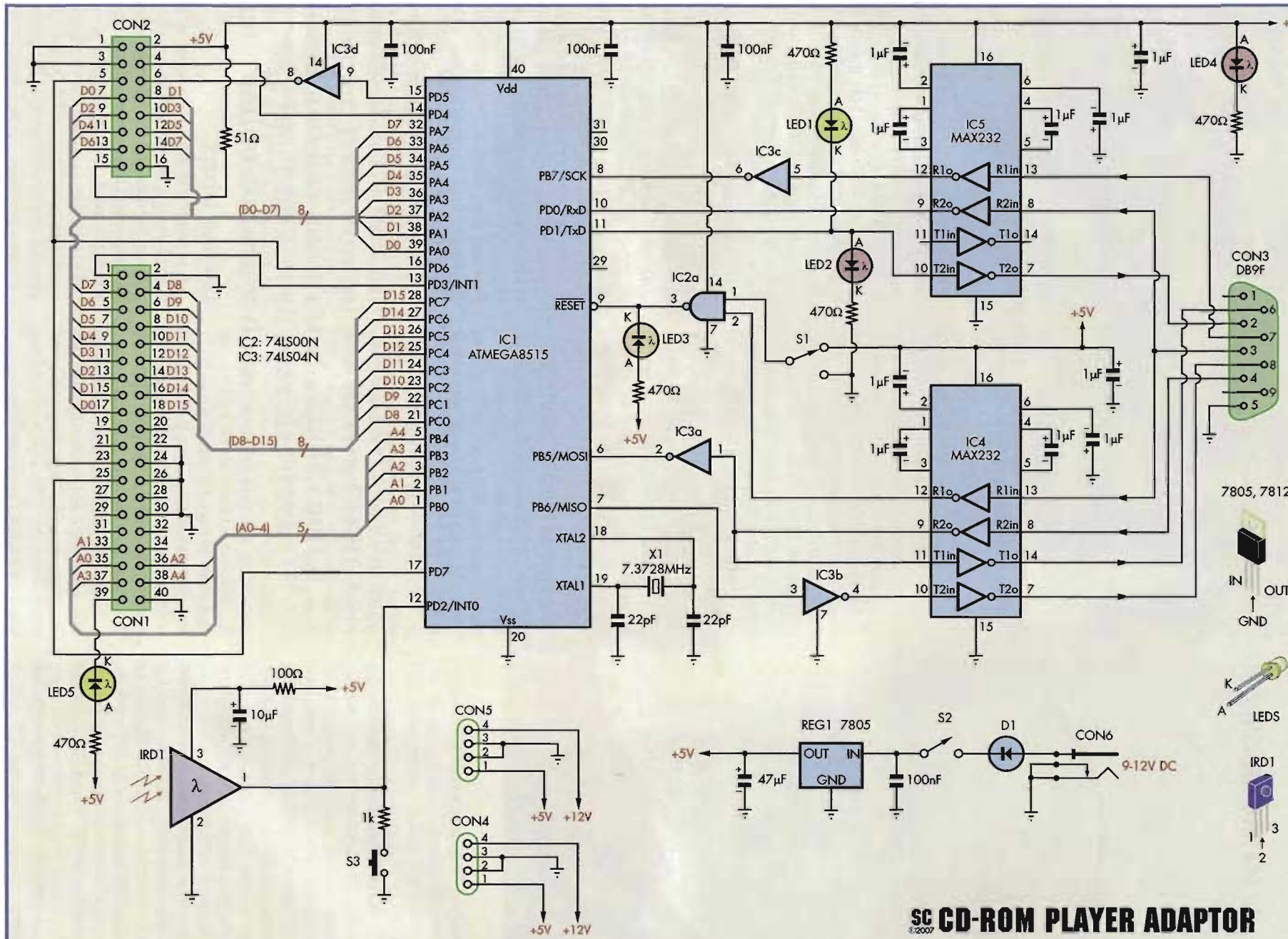


Fig.1: the circuit uses an Atmel ATmega8515 microcontroller (IC1) to interface to the CD-ROM drives (via CON1) and the LCD module (via CON2). IC4, IC5 and CON3 are optional, to provide in-circuit programming for the microcontroller.

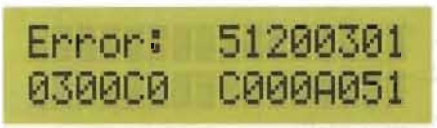


Fig.2: the Error Screen. The numbers give information about the state of the program and the drive when the error occurred.

involved in DMA (direct memory access) for that - but it would work.

With ATAPI devices like CD-ROM drives, most operations are initiated by writing packets rather than single byte commands. A packet is a string of 12 or sometimes 16 bytes that are sent to the drive in sequence.

In order to send packets, a more involved algorithm than just writing to the register file is needed. Here you have to worry about bus timings and whether the drive is busy or requesting data. There is a well-defined protocol for PIO (peripheral input output) access to an ATAPI device.

Feedback is provided by the bits BSY (bit 7) and DRQ (bit 3) in the Status register, which can be polled to determine the current state of the drive. When the drive shows BSY=1 it does not respond to commands and reading any register except the Status register is undefined. In other words, the only valid information that can be read from the drive is bit 7 (BSY) of the status or alternate status registers (when it is busy).

As an example, the packet to open the tray of the drive is given by the 12-byte string: 0x1B, 0x00, 0x00, 0x00, 0x02, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00. To send this packet, you first send the PACKET command 0xA0 to the command register and then follow the packet protocol, as outlined in Flowchart 1.

The protocol begins with a packet being written to the drive. Optionally, there may follow a data read or write transfer, depending on the packet written to the drive.

The CoD (command/data) and IO (input/output) bits are in the Sector Count ATA register (also known as the Interrupt Reason Register in ATAPI devices). CoD is bit 0 and IO is bit 1. When CoD is 0, data is being transferred and when it is 1, a command (packet) is being transferred.

The IO bit indicates the direction of transfer. When IO is 0 the host writes to the drive and when it is 1 the host reads from the drive.

Pin	Name	Description
1	/RESET	A low level on this pin resets all connected drives.
2, 19, 22, 24, 26, 30, 40	GND	All these pins are connected to the common ground plane.
3, 5, 7, 9, 11, 13, 15, 17	[D7:D0]	3=D7, 5=D6 ..... 15=D1, 17=D0 These are the eight least significant bits of the data bus.
4, 6, 8, 10, 12, 14, 16, 18	[D15:D8]	4=D8, 6=D9 ..... 16=D14, 18=D15 These are the eight least significant bits of the data bus.
20	KEY	This pin is not connected and is used to prevent the cable being connected the wrong way around.
21	DDRQ	Data request pin – not used in this project.
23	/WR	Write strobe, active low.
25	/RD	Read strobe, active low.
27	/IOREADY	Device ready pin, active low, not used in this project. Used to slow a controller if it is too fast for the drive.
28	ALE	Address latch enable – not used in this project.
31	IRQ	Interrupt request – not used in this project.
32	IO16	Obsolete since ATA-3 – not used in this project.
33, 35, 36	[A2:A0]	35=A0; 33=A1; 36=A2. Address bus
37	/CS0	Chip select 0
38	/CS1	Chip select 1
39	/ACT	A low level on this pin indicates that the drive is working. It can be connected directly to a LED to show drive activity.

Table 2: this table shows the pin-outs of the ATAPI interface. Note that this project leaves many pins ususued, as they are unnecessary for PIO transfer.

When the above packet has been successfully processed by the drive, it will respond by opening the tray. This packet does not require any extra data transfer but other commands, such as reading the CD TOC (table of contents), do require reading from the drive. Other packet commands such as setting the volume require both reading and writing to the drive (refer to the ATAPI specification for the relevant packet codes).

The firmware

The main component of this project is the firmware, as the hardware is little more than a Atmel microcontroller. The firmware is responsible for interfacing to the drives, decoding the remote control signals, auto detecting the connected drives and controlling playback and volume, among other things.

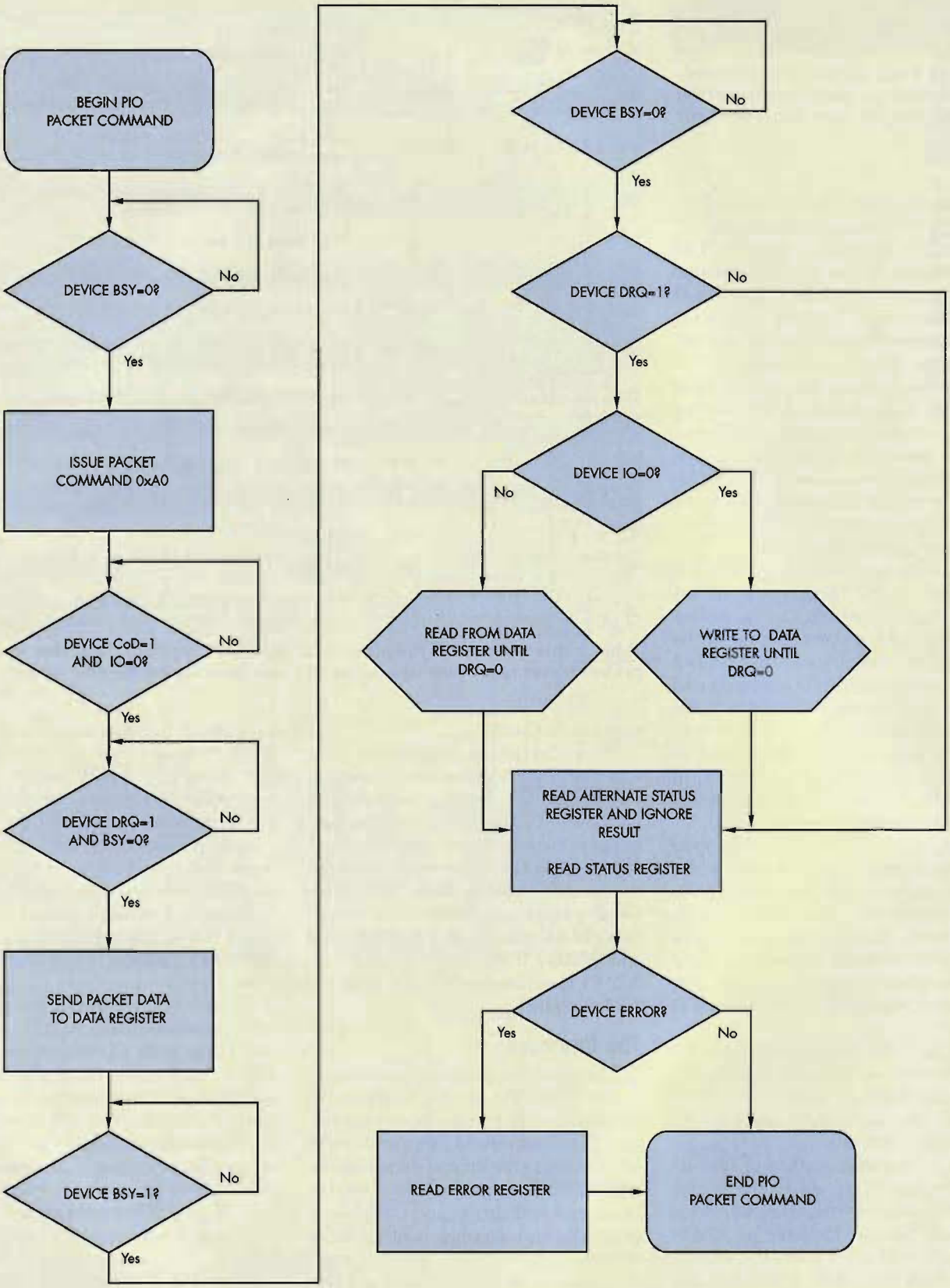
All this is done with only 512 bytes of .RAM! The firmware size is approximately 7.2KB and fits inside the micro's 8KB flash memory.

ATA and ATAPI commands are either "Mandatory", "Optional" or not supported. To make sure that the CD-ROM Playback Adapter works with just about any ATAPI device, we've used only "Mandatory" commands as per the specification (rev 2.6 1996).

Note, however, that we cannot guarantee that it will work correctly with all ATAPI devices. Some are buggy and the standard covers a period of many years. We've also come across drives that don't conform to the standard in every detail.

In our case, we tested the adapter with seven different ATAPI devices, including both CD-ROMs and DVD drives, and it worked correctly with six of these. The seventh drive had a problem in that it was not detected by the firmware and closer inspection and debugging revealed that the micro was unable to write to the drive's register file. Thus it failed the first test of the auto detect subroutine, as explained below.

Basically, if a particular CD-ROM or DVD drive is not detected by the firmware on start-up, it will not be functional with the adapter. In that case, try using a different drive. Conversely, if the drive is correctly detect-



Flowchart 1: this is the packet writing routine used in the firmware. The interrupt signal INTRQ, intended for PCI buses on computers, is not used and a method of polling for DRQ and BSY is used in its place.

ed, there is a high chance that it will work correctly with this adapter.

How it works

Refer now to Fig.1 for the circuit details. The circuit is essentially just an Atmel ATmega8515 microcontroller (IC1) with its general IO pins configured to read and write to up to two drives. It also controls the LCD screen and reads the remote control sensor. Add in a power supply and a few support chips and that's about it.

ICs4 & 5 are MAX232 line drivers and are used to interface the microcontroller to the serial port of a computer (RS-232). These devices are optional and are only needed if you are planning to experiment by writing your own firmware. Basically, they allow the board to be connected to a PC's serial port so that the microcontroller can be programmed in-circuit. The software to use for this job is called "Pony Prog 2000" and is free for download from **www.lancos.com/ppwin95.html**.

ICs2 & 3 are simple logic gates, used here as "glue logic" for the interface. These devices are 74LS00 and 74LS04 quad NAND gates and hex NOT gates respectively but only one NAND gate and four NOT gates are used from these devices.

Infrared receiver

IRD1 is an infrared receiver module, containing a photodiode, amplifier, filter and demodulator all in a compact package. It accepts a modulated infrared signal on a 38kHz carrier and outputs a demodulated TTL level serial stream.

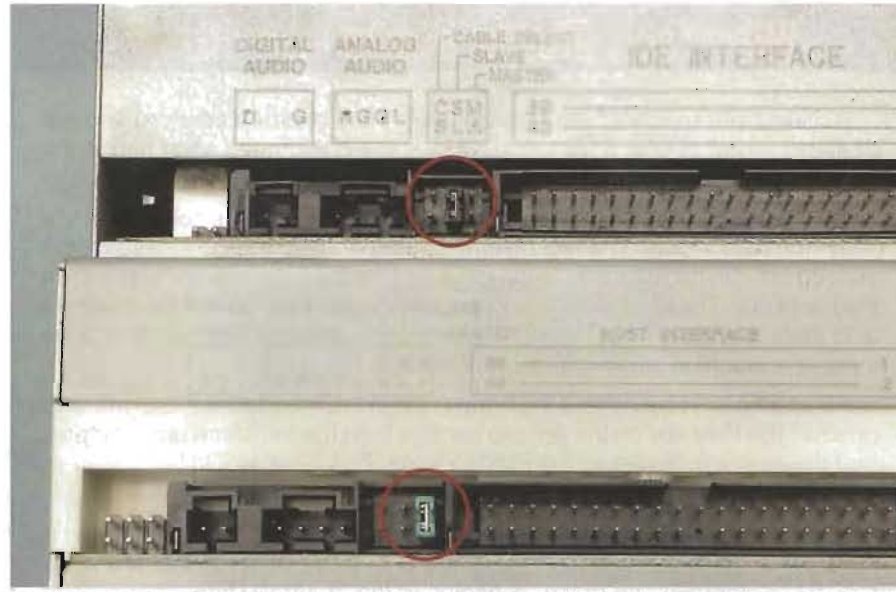
This stream is fed to pin 12 of IC1 and is decoded by the firmware in the microcontroller. Note that IRD1's output is usually high (around +5V) and varies as a square wave when an infrared input is received.

S3 is used to select the remote control setup option at boot time. For normal operation it is open and this allows the signal from IRD1 to pass to the microcontroller for decoding the remote control signals. Conversely, when S3 is pressed, it temporarily pulls this line low via a 1kΩ resistor to allow remote control set-up.

There are five indicator LEDs on the board. LED4 (red) is the power LED, while LED3 (orange) lights when the micro is being programmed or is in the reset state. This state can be entered using switch S1.

LED1 (green) shows the activity of the currently selected drive.

Finally, LED2 & LED5 make a pair. Only one will be lit at any one time. LED5 (green) indicates that the MASTER device is being controlled, while LED2 (red) indicates that the SLAVE device is being controlled. If you have two drives connected, you may toggle between them using the Line-In button on the remote.



CD-ROM drives have three sets of jumper pins at the back to configure the drive. If you have just one drive, it can be configured as either a master (MA) or a slave (SL) using the jumper link. However, if you are using two drives, then one must be configured as a master and the other as a slave, as shown here.

Power supply

In order to power the drives, you will need a power supply capable of delivering +12V at 2A and +5V at 2A (eg, a computer power supply). By contrast, the board requires a +5V supply and draws just 200mA.

Basically, you've got two choices when it comes to the power supply. The first option is to power the PC board directly from a 9-12V plugpack supply and power the drives separately. In this case, the board supply is fed in via CON6 and is regulated to +5V using 3-terminal regulator REG1. Diode D1 provides reverse polarity protection, in case the supply is connected the wrong way around.

The second option is to plug a +12V/+5V supply into either CON4 or CON5 on the PC board. The board will then be directly powered from this supply, while the supply for the drives can then be taken from the unused connector. Note that you will need a Y-splitter cable if there are two drives.

In this case, you can use a surplus computer power supply to power both the boards and the drives. This will simply plug straight into either CON4 or CON5. Another option is to use a ready-made adapter like the Jentec JTA0202Y (from Taiwan). This unit supplies +12V and +5V at 2A each, which is enough to power two drives and the PC board. It also comes with the proper plug, so all you need then is a Y-splitter cable.

Setting up the drives

The two drives must be configured before being installed. Specifically, if you wish to connect only one drive, it can be configured as either a slave or master device.

Usually this is accomplished by a jumper setting on the back of the drive. The drive will usually have a label indicating the appropriate position of the jumper.

If you wish to use two drives, however, make sure that one is configured as a master while the other is configured as a slave. It doesn't matter which is which as long as they are not both slaves or both masters.

How auto-detection works

Let's now see how the micro detects any connected ATAPI devices at boot up.

First, a simple test is done. The mi-

What's A Finite State Machine?

A finite state machine (also known as a finite state automaton) is a set of states together with a transition table and a designated state that is the "initial state".

The transition table can be thought of as a table with three columns and a finite number of rows. The first column corresponds to the current state, the second column corresponds to the input and the third column corresponds to the next state. These triplets (X, I, Y) are interpreted as follows: if the machine is in state X and an input I is received, it moves to state Y. While there is no input, the machine stays in its current state.

For example, in our case, if the firmware is in the neutral state, and the user presses the Play key on the remote control, then the transition table dictates that the machine moves to the Playing state. This "rule" would be written as the triplet ("Neutral", "PLAY", "Playing").

The user interface of this playback adapter is simply implemented as a finite state machine, meaning there are a number of rules that make up the transition table. The machine begins in the "neutral" state, after a short initialisation.

Flowchart 2 shows the finite state machine implemented in the firmware. The transitions correspond to arrows, while the blue blocks are the possible states.

cro writes a known value to an ATA register and then attempts to read that value. If the value read is the same as that written, the auto detect subroutine goes to the next stage.

Conversely, if the drive fails this test, it is assumed to be absent. Instead, 0xFF is returned as the value read due to internal pull-ups on all inputs (which incidentally, is not the value that is written).

The next stage of auto-detection involves searching for the signature that all ATAPI devices are required to have (according to the standard). In fact, all ATAPI devices have a unique signature of 0x14 and 0xEB (notice that 0x14 + 0xEB = 0xFF) in the Count Low and Count High registers on start up.

The inquiry command of the ATA interface, while mandatory for ATA devices, is actually aborted by ATAPI devices. Instead, the effect of this ATA command on ATAPI devices is to put the ATAPI signature word in the Count Low and Count High registers. What is mandatory for ATAPI devices is to support the ATAPI inquiry command.

The algorithm for detecting the drives is as follows:

(1) Perform a simple read-write test. Abort if this test fails, otherwise continue.

(2) Select the drive by writing to the drive/head register.

(3) Issue an ATA identify device command.

(4) If the signature 0x14 0xEB in the Count Low and Count High registers is present, go to step 5.

(5) If this signature is not present, the device is either absent or it is not an ATAPI device. Therefore, we may assume that no ATAPI device is present and terminate.

(6) If the ATAPI signature is detected, we issue an ATAPI inquiry command to get further information about the drive and conclude that an ATAPI device is connected. The test is then terminated.

Firmware operation

Flowchart 2 shows the structure of the firmware. After initialisation, the program can optionally jump to a subroutine to set-up the remote control.

This should be done at least once, preferably the first time the program is run. Once the remote control has been successfully set up, the adapter is ready to be used.

The next stage in the firmware is the auto detection of the drives. Up to two drives can be connected and they should be configured correctly as master or slave as detailed previously.

The firmware then enters a "finite state machine" by going to the neutral (or initial) state. It then listens for activity on the infrared port an responds to the remote control com mands.

There are three playing modes: (the default mode, (2) the repeat mod and (3) the random mode. In defau mode, the adapter will play the curre track and when that is done, will jum to the next track.

In repeat mode, the adapter pla the current track and then repeats over and over. This mode is indicat by the digit '1' appearing as the l character of the first line of the displ in playing mode.

Finally, in random mode, t adapter will play the current track a then select the next track random This mode is indicated by the let 'R' appearing as the last character the first line of the display in playi mode.

In operation, the user can scr between the default, repeat and ra dom modes by pressing the 'Reco button on the remote control dur play mode.

The volume is controlled by Volume Up and Volume Down butt on the remote. Up to 16 levels rang from muted (0) to full volume (15) be selected.

The 'Mute' button has the us effect of storing the current volu and then setting the volume to 0 pressed again when the volume i the original volume level is restor The percentage balance of the right left audio channels can be modi by the user, by pressing the Chan Up and Channel Down buttons on remote. The percentages range f 0-100% in steps of 5%.

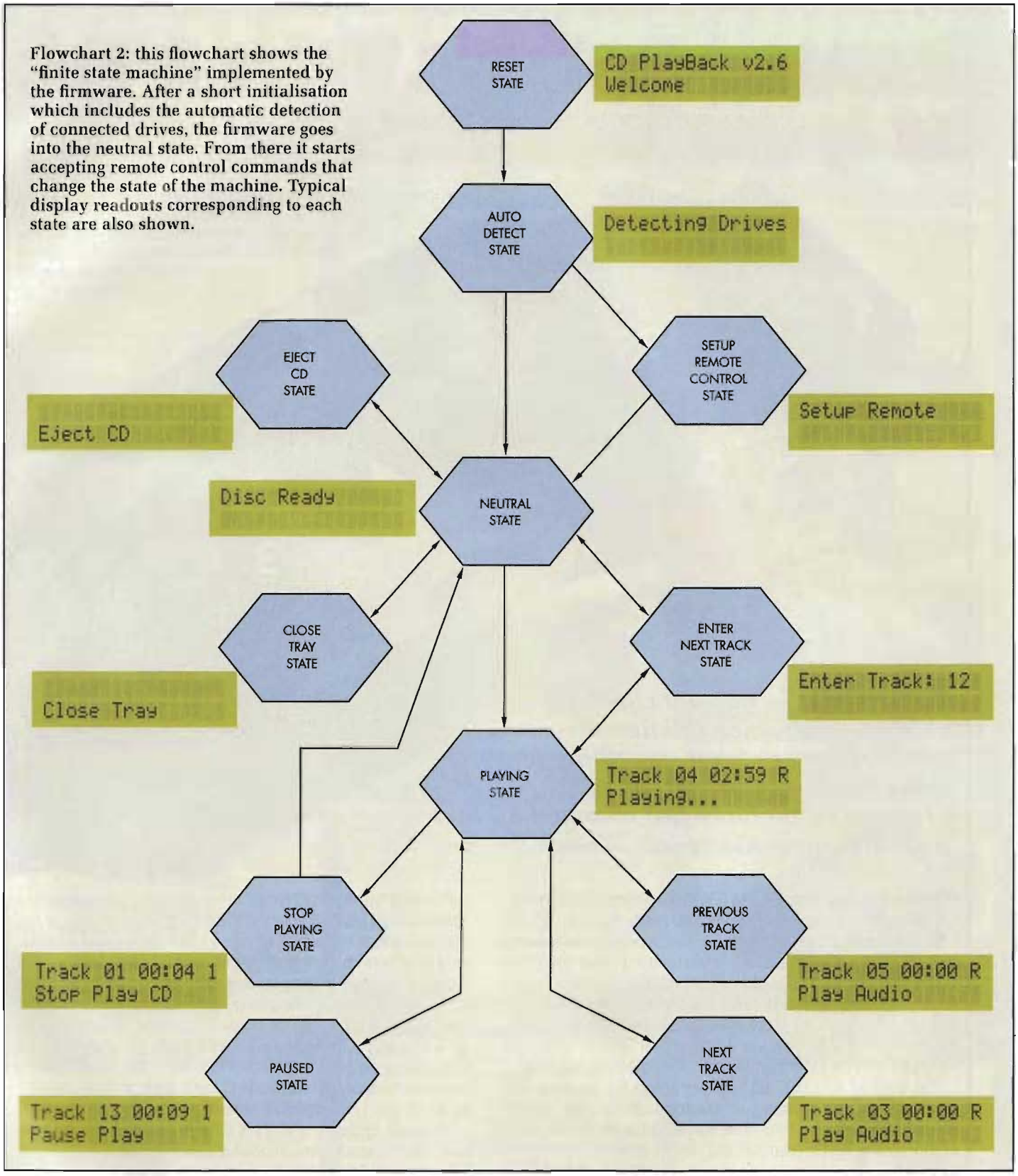
The volume for each channel is t calculated in terms of the balance ing a simple formula:

(1) Volume (Left) = (Balance Left) x Volume Level

(2) Volume (Right) = (Balance Right) x Volume Level

In playing mode, there are the u control options like going to the track (pressing the Fast Forward ton) or to the previous track (pres the Rewind button). You can pause playing (by pressing Paus stop playing (by pressing Stop).

The 20+ button on the remote c used to either eject the CD or clos tray (depending on whether the is already closed or open). The In button is used to switch bet master and slave devices, if two d



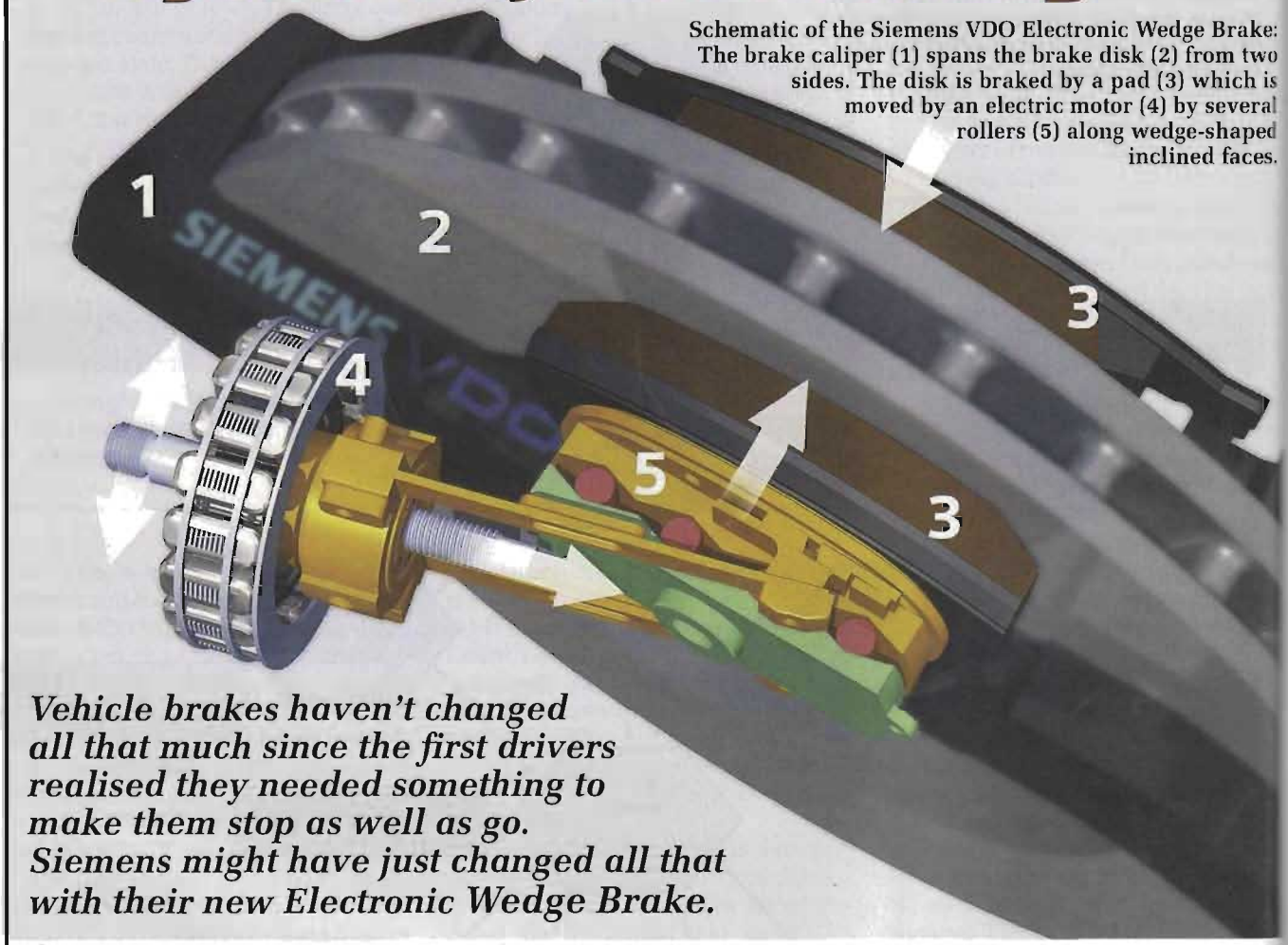
Flowchart 2: this flowchart shows the "finite state machine" implemented by the firmware. After a short initialisation which includes the automatic detection of connected drives, the firmware goes into the neutral state. From there it starts accepting remote control commands that change the state of the machine. Typical display readouts corresponding to each state are also shown.

are connected and have been correctly detected by the firmware.

The 0-9 number buttons are used to select a particular track number to play. Simply press the correct number (which will be shown on the screen) and then press Play to play the selected track number.

As you can see, the user interface has been kept deliberately simple and intuitive. By the way, you can use virtually any RC5-compatible remote control since you can assign the buttons during the set-up procedure (more on this next month). **SC**

Siemens' Electronic Wedge Brake: no hydraulics, better braking



Schematic of the Siemens VDO Electronic Wedge Brake: The brake caliper (1) spans the brake disk (2) from two sides. The disk is braked by a pad (3) which is moved by an electric motor (4) by several rollers (5) along wedge-shaped inclined faces.

Vehicle brakes haven't changed all that much since the first drivers realised they needed something to make them stop as well as go. Siemens might have just changed all that with their new Electronic Wedge Brake.

The electronic wedge brake (EWB) from Siemens can reduce braking distance on snowy and icy roads by up to 15%. In tests conducted in northern Sweden, a prototype required a distance of 64.5m to bring a vehicle traveling at a speed of 80km/h to a halt. A comparable vehicle equipped with hydraulic brakes and the anti-locking system ABS needs around 75m on average to brake when traveling at the same speed. This means that such a vehicle will still be traveling at a speed of 30km/h when one equipped with the EWB has already come to a complete stop.

The tests were carried out by experts from the Siemens VDO automotive supply company in the town of Arjeplog, located around 100km south of the Arctic Circle and some 900km north of Stockholm. Test procedures and results were also monitored by staff from the international safety service provider DEKRA. Up until now, the EWB system's ability to shorten braking distance had only been demonstrated in simulations. The tests impressively confirmed the computer results. Siemens VDO will channel the knowledge gained from the tests into the further development of the EWB, which is expected to be ready for series production in three years.

The EWB represents a revolution in brake technology because it works without any hydraulic systems. Each wheel on the car has its own separate unit equipped with a brake caliper, disk and pad, all of which are controlled electronically. At the heart of the EWB system is a wedge-bearing mechanism whose special geometric shape results in a self-energising effect. Here, an electric motor that moves the roller bearing is able to generate a strong braking force with only a minimal amount of energy. The electric motor holds the brake pad on the roller bearing in the exact position necessary to apply optimal braking force, while sensors monitor the brake pad 1,000 times per second.

Hydraulic systems, which are used in practically all vehicles today, tend to react more sluggishly than the EWB, despite being linked with ABS and brake force boosters. Valuable milliseconds are lost in the time it takes the pressure applied to the brake pedal to be transferred to the hydraulic system. With EWB everything occurs electronically. Introduction of the EWB would also eliminate the need to produce brake fluid. An estimated 5.4 million litres of brake fluid are required each year in Germany for new vehicles alone.

SERVICEMAN'S LOG

Fire, foam & computer hard drives

Some days bad things just happen. A fire can occur at any time and when it does, recovering valuable data from computer hard drives can be a real challenge.

Items Covered This Month

- Grundig ST84-796-9 TOP LOG (CUC 6380 chassis)
- Grundig Vision II LXW 68-9620 Dolby G1 chassis
- Hewlett Packard f1703 (P9620A) computer monitor
- Apple Mac Studio Display 17-inch monitor M7649

It was a beautiful spring morning and I was sitting outside the workshop enjoying a cup of coffee and a chat with a friend. Suddenly, someone shouted "FIRE!" and all hell broke loose. It was my neighbour's factory unit and it had smoke pouring out of the roof and from the gaps around the closed doors and windows.

I didn't have my neighbour's mobile number but someone else did and called him. Naturally, the fire brigade was also called and while we waited, a few of the other unit owners managed to organise some water hoses.

The problem was that the place was fully locked with the roller door in the closed position, so all anybody could do was to cool the building from the outside with the water hoses. It didn't take long for the fire brigade to arrive and they were about to break down the door with a battering ram when the owner screeched to a halt outside. He got out and unlocked the door for them and was immediately enveloped in thick acrid smoke.

The fire brigade took over from there and several men wearing breathing apparatus entered the building dragging fire hoses. They quickly extinguished the fire which was on the mezzanine floor and within about 10 minutes, the roller door was pulled up and the windows opened.

None of us in the now sizeable audience outside actually saw any flames but it was fairly obvious that the fire was now out and it was just a matter of clearing up and blowing out the smoke. After the firemen had finished, the forensic police went in and then later on the insurance assessor arrived.

It wasn't until four hours later that I was allowed in to see the damage. Downstairs it looked as though nothing had happened but upstairs was like Armageddon. Though no-one could actually swear to it, it looked as though a mains plugpack or an extension lead had been the cause but there just wasn't enough evidence left to confirm this.

Immediately adjacent to the seat of the fire were the remains of an elaborate computer system. I was asked to give an insurance estimate for some of the items that were damaged and was also asked to see if I could recover any of the data on some of the computers.

The first item was a 2Gb USB2 fast external hard drive in an aluminium case. This had copped a lot of heat and the plastic had melted and burnt on both ends of the metal case and had to be cut away. Eventually, I extracted





the IBM IDE hard drive and most of the controller card.

The USB socket was too badly fried but I managed to get a new one and fit that. I also had to replace the red HDD activity LED, which had melted.

After some cleaning, the controller card came up looking pretty good. I then connected it to one of my computers with one of my hard drives and was delighted to see that it worked OK.

Next, I turned my attention to the hard disk drive inside the case. This was still wet and was covered with all sorts of powdered debris, despite being deep inside the machine. I took it out and cleaned it up using brushes and an air compressor. It came up looking quite good on the outside so I connected it to the USB controller card and plugged it into my computer.

All I got were a few faint noises from the drive but no action. I then decided to remove the drive's PC board which was held in place by six Torx screws. Once it was out, I was annoyed to see even more wet ash on the inside. How on earth did this get there?

After delicately brushing out the debris and flushing it with compressed air, I sprayed the corroded areas with a light penetrating oil and then blew the excess off. I then reassembled the hard drive and reconnected it.

This time the noise was somewhat louder but still nowhere near that of a working hard drive. I wasn't game to remove the main cover on the hard drive itself as I figured this was airtight. My feeling was that the motor wasn't spinning correctly and nothing more could be done by me. An expert would have to do the rest.

Desktop computer

The desktop computer was a Dell and had really copped a lot of heat.

Inside, the motherboard didn't look too bad. The DVD and floppy drives had been destroyed but the hard drive looked OK. Connected to another computer, it immediately spun up OK and the data was readable.

Unfortunately, the 20-inch Mitsubishi monitor had been totalled, along with the keyboard and mouse , and was simply chucked into the skip.

There were also a couple of notebooks in the room, one of which was a write off. The other, a HP Pavilion dv9000, was borderline. It had been saturated with fire retardant but because the lid was down, it looked as though only the sides needed cleaning.

After a brief clean, it actually booted up and seemed to be working fine. However, because it had been saturated with fire retardant, I was asked to strip it down and clean it out.

That wasn't as easy as it sounds. First, nobody ever tells you about the lingering sweet, sickly smell that permeates everything touched by smoke or fire. Second, I hate doing notebook computers at the best of times as there are always concealed clips and screws plus there are millions of different screws which all look very similar but can only go back into their original holes.

Anyway, I downloaded the maintenance and service guide (some 30 pages) and printed out the relevant removal and replacement procedures.

Because the notebook was working I decided to strip it down just enough so that I could see inside it and see whether it really was damaged or not. The really difficult part involved removing the keyboard and later, if necessary, the display screen, system board and power supply.

To get to the keyboard, you first have to remove all the drives and accessories and then remove the switch cover on the top at the rear. This assembly is held on by six screws in the battery compartment and then by a lot of clips.

Once the cover was off, I could access the keyboard mounting screw and remove it. I could then see about 50% of the computer and it didn't look too bad. However, the USB socket and other sockets on the side of the case were already beginning to corrode.

What is it with this fire retardant foam that the fire brigade use? It is unbelievably corrosive and conductive too. It may put out the fire but everything else that it touches is ruined.

Once again, I used brushes and an air-gun to clean out the gunk and afterwards applied a minute film of oil over the contacts and metal brackets. I then reassembled the computer and replaced the battery. And that's when my worst nightmare started. As soon as the battery was replaced, smoke started to pour out the lefthand side of the computer near the VGA socket.

Unfortunately, the battery fitted to this notebook is not one you can unplug and remove easily, as there is no finger grip available. Instead, you have to release the battery lock, hold the computer horizontally and literally let the battery drop out.

Once the new fire had subsided



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I examined the relevant area very carefully but just could not find the source of the smoke. I then gingerly connected the external DC power supply and noticed smoke begin to come from under the VGA socket before I unplugged it.

At this stage, I really had no idea what was causing this problem except that it had to be in the power supply on the system board. So there was nothing for it but to disassemble the whole thing.

Referring to the guide, there were four major assemblies to remove. In addition, I had to unplug lots of extra module accessories. I started at section 5.4 and worked through to section 5.25. Each time I took out a part, I placed it in a box together with a bag holding the appropriate screws.

As I peeled off the layers and got deeper and deeper into the works, I began to see all the areas I had missed when cleaning, especially around the edges. Eventually, I got the system board out and removed the heatsinks and then the insulating tape covering the power supply next to the VGA board.

Well, I looked and looked but I couldn't see any sign of a hot spot or fire. In fact, I had to power the system board up again to finally locate the source of the trouble. It was a tiny dag on the VGA support bracket that was just touching a PC board track.

Access was very difficult but I cleaned the area up meticulously and angle ground the metal dags off the bracket so it didn't touch. This stopped the pyrotechnics in their tracks – but had the computer's electronics been damaged? I wouldn't be able to tell until after another two to three hours of re-assembly.

Next I paid attention to the other areas of corrosion. The audio board was badly corroded in and around its connection plug and one of the tracks had actually been "etched" open circuit by the foam. I bridged this gap and cleaned it thoroughly.

Similarly, the power input socket and some of the extra sockets and assemblies all around the edge of the case required attention. That done, I then started the tedious task of re-assembly.

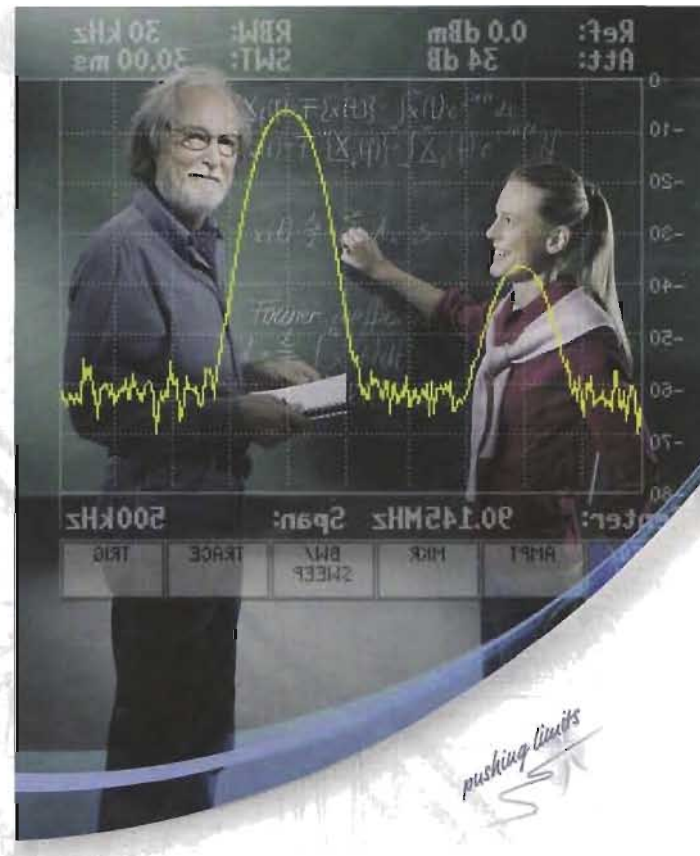
However, despite all the precautions of saving the screws with their assemblies, I found there were discrepancies between the service manual and reality. Also many of the screws looked very similar but weren't. Then I had the hassle of reconnecting all the miniature plugs and sockets. Some of the ribbon cables were very fiddly to plug in.

Finally, when it was all back together, I had one screw and one socket left. The only trouble was the screw didn't match the socket! Anyway, the notebook was solid – nothing rattled – it would just have to work without it.

And fortunately it did – all the functions seemed to test OK.

It was only now that I could prepare an estimate of the cost. I also realised that I couldn't possibly guarantee that the chemical reaction from the foam would stop right there and then. In fact, it was quite likely that this computer, now working, would be unreliable, with repetitive failures due to continuing corrosion.

In the end, I decided that the only way out would be to replace both the system and audio boards. However,



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this would be more expensive than a replacement notebook. All that hard work for nothing!

LCD TVs & monitors

Repair work on LCD TVs and monitors is now increasing, with most repairs involving the backlight inverter power supplies. These power supplies provide the backlights with high voltage and also crudely control their brightness levels. As yet, I haven't actually had any backlights fail unless they have been smashed due to some sort of accident.

Recently, I had a Grundig Vision II LXW 68-9620 Dolby using a G1 chassis come in with "no-picture" symptoms. However, if you shone a torch at the right angle to the screen, you could just discern an image.

This set has quite a large inverter board as it had a lot of backlights. Unfortunately though, the service manual shows no part of this circuit board as it is part and parcel of the display panel. In other words, if you can't fix this board, you will have to replace the panel, which is uneconomical.

Fortunately, I could not detect +24V on the BUI-27 connector to the inverters. This was due to a dry joint on one side of the diode that supplies this rail on the main board and resoldering this fixed the problem.

I had similar symptoms on an HP f1703 (P9620A, probably made by Liteon) LCD computer monitor, except that the picture was intermittent. It would come on for 15-30 seconds and then go off.

This monitor used an external 12V power supply which was OK. When I stripped it down, there were only two boards inside for the inverters and the video processing and scalar drivers.

I immediately went for the inverter board, looking for dry joints on the coils, but could find nothing. I then searched the internet for a circuit diagram or service manual but again found nothing. However, I did find a lot of hits for this very problem from other owners.

Next, I tried to contact HP but only got through to an Indian call centre. They knew nothing about this problem and could only suggest I check my screen saver. They did however "cherish" the opportunity to help and wished me a "blessed" day!

Almost all the hardware fixes on the net involved completely resoldering the four copper coils, which I did by first removing them from their silicone rubber bed and then resoldering them back in position. This didn't work and without access to another f1703 monitor to compare voltages, I can only conclude that it is probably something to do with the processor board switching the inverters off.

I don't have a circuit either and so have been left in a rather frustrating cleft stick – at least for the time being.

Similarly, Apple has had problems with their Studio Display 17-inch monitors (M7649). The symptoms with these are uneven dull pictures and the power light flashing.

Once again it is the inverter board that is the problem but the modified replacement (V041063.00M3S by MonitorServ) costs US$110 plus freight.

Why can't these companies offer free circuit diagrams with detailed information on how to repair or modify these products once they are out of warranty? If an owner doesn't have the technical ability to do the repairs, at least he can supply the information to someone who is competent to do the work. Wishing people a blessed day doesn't quite cut it.

Grundig TV set

I was asked to do a service call on a Grundig ST84-796-9 TOP LOG (CUC 6380 chassis) TV set. I don't normally do service calls but I made an exception in this case. This large 80cm CRT TV was located in a home unit and was simply too heavy to lift and take to the workshop.

I was asked to phone before I arrived at the block of units because of their secure internal parking arrangements. When I arrived, it wasn't hard to see

why – the location was right in the middle of a large shopping centre with no on-street parking.

Once inside the unit, I was surprised at how quiet and secluded it was despite its location. I was also filled with dismay when I realised the set was situated in one of those much-dreaded entertainment cabinets, with very little access.

The problem was no sound which is an unusual fault these days. Fortunately, I could see the cause as soon as I got close to the TV.

What happened was that the mains power on/off switch had been giving trouble and wouldn't latch in the on position. So, to keep the set on, the owner had jammed a match splinter in the side of the on/off button.

Unfortunately, he didn't realise that this switch also has a momentary switch built in. This normally resets the microprocessor and mutes the sound to prevent unnecessary noises when switching the set on or off.

I proved the point by removing the match and pushing the switch in far enough for the set to come on then releasing it slightly so that the momentary switch was no longer on. This brought the sound on with the picture.

I told the client that I would have to order the switch in from Grundig and it would take time. In the event, the switch (part no. 297032917200) was no longer available but as luck would have it, I did have a 297032917204 switch in stock.

Back at the customer's unit, I managed to rotate the set in the entertainment cabinet and remove the back and the main chassis. I then had to remove the control and display chassis to gain access to the switch. Finally, I removed the whole assembly and examined it carefully.

It was indeed a very special switch with a solenoid built in. It had three functions – On, Standby and Full Off – which could be controlled by the remote. You only had to push the switch in to go into either the full On or Standby modes which are controlled by the remote. If you pressed the remote's Off button once, it would go to Standby. If you pressed it twice, it would pop the switch out to Off using the solenoid.

The original switch looked identical to the one I had (thank goodness) but it also looked as though there was nothing wrong with it as it was now latching properly every time outside the cabinet.

What was crook was the power on/off button itself which had cracked and so was not sitting on the switch properly. Once again I was left with a dilemma. The faulty knob would probably work perfectly well super-glued to its original switch. However I could only go down that path once. The knob was no longer available and once superglued on, you would never be able to remove it if the switch failed.

In the end, I decided to replace the switch just to make sure and superglued the knob onto it. This fully restored the sound and it was a win-win situation all around. SC

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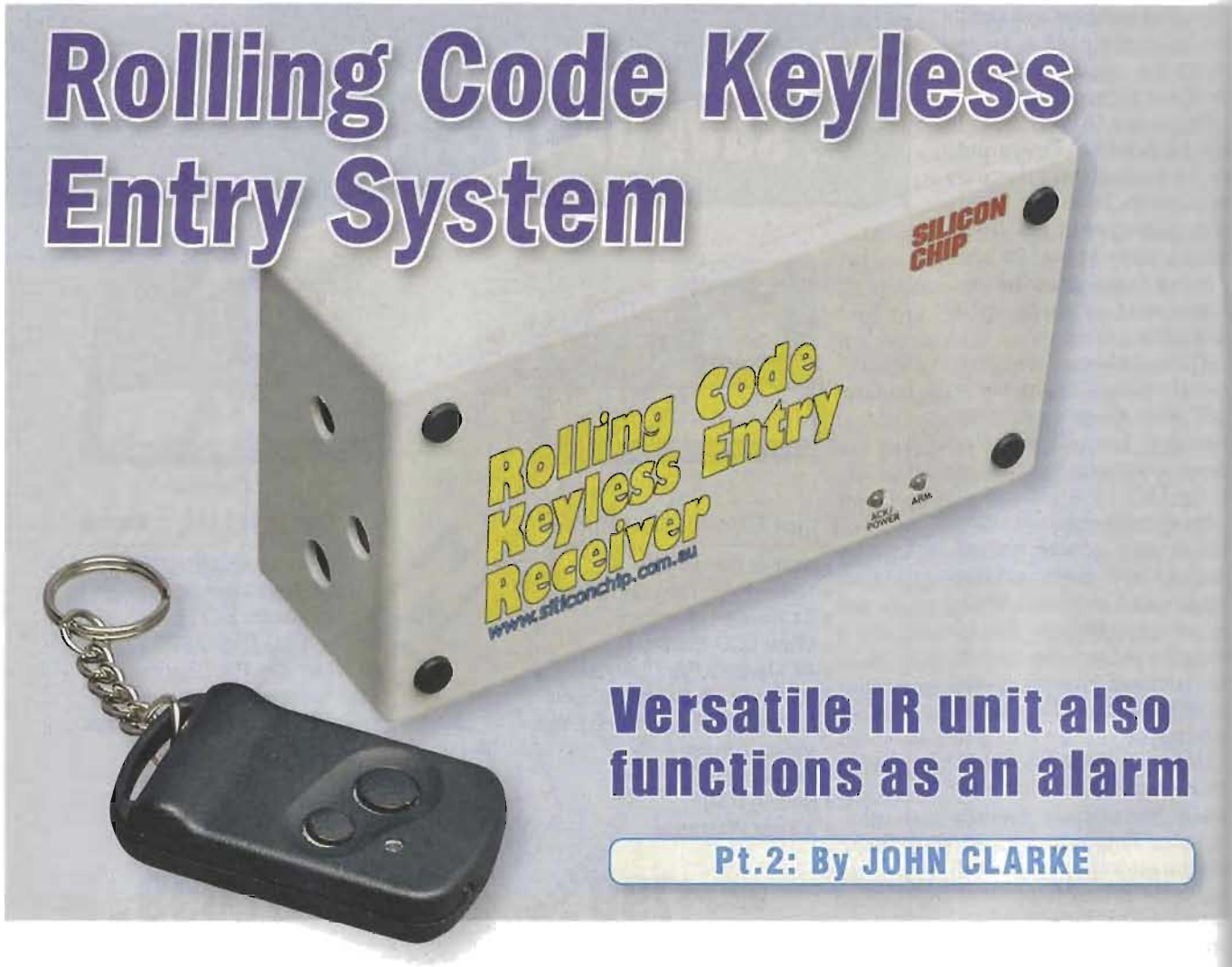
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Rolling Code Keyless Entry System



Versatile IR unit also functions as an alarm

Pt.2: By JOHN CLARKE

Last month, we described the circuitry and gave the PC board assembly details for our new Rolling Code Keyless Entry System. This month, we cover the installation and setting-up procedures and describe the optional SOIC adaptor board, so that you can program the PIC micro out of circuit.

HAVING COMPLETED THE RECEIVER board assembly, as described last month, it can be housed in a UB3-size utility box. As shown in the photo last month, it simply clips into place but first you will need to drill a hole in one end for IRD1, plus a hole in the other end for the external wiring.

You will also have to drill matching holes in the lid for the Ack/Power and Arm LEDs (LEDs1 & 2).

Now for the initial set-up. First, install a jumper link in the minus (-) position for LK2. This will set the Strike2 output to toggle mode (note: LK2 must always have a jumper connection, either to the "+" or "-" position). Leave jumpers LK1, LK3 & LK4 out for now.

Next, set trimpots VR1 & VR2 to mid-range. These trimpots are later used to set the various time periods.

Transmitter set-up

At this stage, the transmitter is already partially set up because it identity is selected during construction. If the transmitter's PIC microcontroller has not been programmed then program it now via the ICSP connection. This connection can be made by soldering five leads to the transmitter's ICSP pins and then connecting the other ends of these leads to a 5-way ICSP socket to plug into the PIC programmer.

After the IC has been programmed clip in the 12V battery and check that the green acknowledge LED lights when a switch is pressed.

Of course, if you buy a complete kit, the PIC microcontroller (and the PIC in the receiver) will be supplied pre-programmed so you won't have to worry about that last step.

Testing the receiver

The receiver can now be tested. First, with IC1 out of its socket, connect a 12V power source that can supply at least 60mA. That does

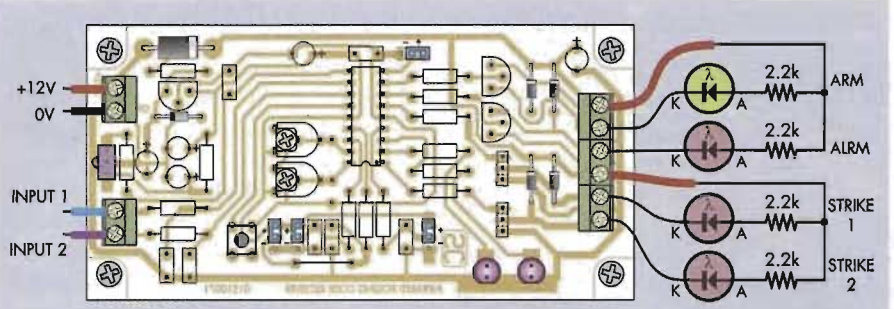


Fig.6: the test LEDs are connected to the receiver as shown here. Follow the procedure in the text to synchronise the transmitters and test the receiver.

switch on and check that there is 5V between pins 14 & 5 of the IC socket. If this is within 10% of 5V (4.5V to 5.5V), switch off and plug IC1 into its socket, making sure that it is correctly orientated.

Next, wire up the test LEDs as shown in Fig.6. These are all wired in series with 2.2kΩ current limiting resistors. Once the LEDs are wired up, apply power and check that the receiver's power LED flashes briefly at about once per second. If it does, then so far so good.

The transmitter must now be randomised and then synchronised with the receiver. Let's now take a look at these two procedures.

Randomising

Randomisation of the transmitter ensures that it uses a unique set of parameters to calculate the rolling code. This procedure is important because the original parameters programmed in are the same for every transmitter.

Basically, you need to personalise the parameters to prevent another transmitter that has the same identity from operating your receiver. If randomisation is not done, there is the real risk that someone else's transmitter that has also not been randomised will operate your receiver.

To randomise a transmitter, simply connect pins 3 & 5 of its ICSP connector together and then press switch S2. The transmit LED will flash at a 1-second rate for the duration. Release the switch when you are ready after anywhere from several seconds to several minutes.

The parameters are all altered every 40µs (that's 25,000 times a second), so they will be different for each transmitter after even short presses.

Synchronising

After randomising, the transmitter must then be synchronised with the receiver. To do this, disconnect pins 3 & 5 of the ICSP header and connect pins 3 & 4 together instead. That done, press and hold down S1 on the receiver and then press one of the switches on the transmitter.

The transmit LED will now flash twice momentarily and the receiver's

Rolling Code Protection: Keeping It Secret

As previously noted, the Rolling Code Keyless Entry System provides a high level of security because the transmitted code changes each time it is sent. However, to further improve security, we have also included code protection for both the transmitter and receiver.

Basically, code protection prevents the program and data within the PIC microcontrollers from being read by a PIC programmer. As a result, the parameters used to calculate successive rolling codes are kept safe within the microcontrollers. In particular, this effectively prevents a transmitter from being "interrogated", in order to make a duplicate transmitter that will operate the door lock.

So while the hex files can be used to program the microcontrollers, they cannot be read back once programming has been verified. The parameters used for calculating the rolling code are then randomised in the transmitter using the set-up procedure already described. It is these parameter and rolling code seed values that are hidden by the code protection.

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Table 1: Strike1 Operation (LK1)

LK1	+	-	Open
Strike1 operates on	Arm Only	Disarm Only	Arm & Disarm

Table 2: Strike2 Operation (LK2)

LK2	+	-	Open
Strike2 operation	Momentary	Toggle	Not valid

Table 3: LK3, VR1 & VR2 Settings

LK3	+	-	Open
Operates when S1 pressed	VR1 sets Strike1 period VR2 sets Strike2 period	VR1 sets Input1 delay VR2 sets Input2 delay	VR1 sets alarm period
Notes	5V sets 64s 2.5V sets 32s 1.25V sets 16s 0.625V sets 8s 0.313V sets 4s 0.156Vsets 2s	5V sets 64s 2.5V sets 32s 1.25V sets 16s 0.625V sets 8s 0.313V sets 4s 0.156Vsets 2s	5V sets 128s 2.5V sets 64s 1.25V sets 32s 0.625V sets 18s 0.313V sets 8s 0.156Vsets 4s

acknowledge LED will flash on and off at a 1-second rate until switch S1 on the receiver is released.

Now remove the link between pins 3 & 4 on the transmitter's ICSP header. Once that's done, you should now find that the transmitter operates the receiver. If it doesn't, try synchronising again and make sure that the IR receiver has a clear "view" of the transmitting LED.

The above randomisation and synchronisation procedures must be done for each new transmitter. Note that a transmitter that has not been synchronised will not be able to operate its receiver, even if their rolling codes are the same. Note also that synchronising a new transmitter prevents the use of a previously synchronised transmitter that has the same identity.

Next, press the main switch on the transmitter and check that the receiver's Strike1 LED lights for about five seconds. The external Arm LED should also light, while the receiver's on-board Arm LED should flash with an even on-off duty cycle. This flashing shows the exit delay.

After about 20s, the exit delay should expire and the Arm LED should then flash briefly once per second.

Now check the operation of the second (smaller) switch on the transmitter. This switch should toggle the strike2 LED on and off with successive pressings.

Testing the alarm

To test the alarm, arm the unit and short Input1 on the receiver to ground (0V) using a clip lead. The external alarm (ALRM) LED should light after 20s and should then stay on for 60s.

You can check the operation of the delayed exit by arming the unit and momentarily shorting Input1 or Input2 to 0V during the exit period. The alarm LED should not light after the exit period has expired.

Receiver options

The receiver can be powered from a 12V DC plugpack or a 12V battery. When powered by a plugpack, make sure it can supply the necessary current for the electric striker and a alarm siren if fitted. Many electri strikes draw around 800mA, so a 1 plugpack will be required.

Note that the armed status is store so that if power goes off, the arme or disarmed mode will be returne when power is reconnected. So if th receiver was armed when power wa lost, then the armed mode will be re stored when power is returned.

When powering from a 12V battery a charger should also be connected t maintain battery charge – see Fig.7. A 12V 350mA charger for sealed lead acid batteries would be suitable. Thes chargers are fully automatic – the charge the battery when required an maintain full charge with a trickl current. Two suitable chargers are th Jaycar Cat. MB-3517 and Altronic Cat. M 8520.

Depending on your applicatio Strike1 can be optioned to operate o arming, on disarming or on both arm ing and disarming. These options a selected using link LK1. Table 1 show what each link connection does. Yo may also wish to place a small buzz across the door strike connection t give an audible indication of doo strike operation.

The Strike2 output can be momenta ily activated when ever the secondar switch on the transmitter is presse Alternatively, it can be toggled on o off with each switch pressing. Lin LK2 selects these options.

Receiver time periods

Trimpots VR1 and VR2 are use to set the time periods for Strike1 Strike2, the exit and entry delays f Input1 & Input2, and the alarm perio Link LK3 provides the means to s each time period – see Table 3.

With LK3 in the "+" position, VR and VR2 set the strike period f Strike1 and Strike2 respectivel Table 3 shows the various vol ages that VR1 & VR2 can provid to set the strike periods. The voltages can be measured at TP for VR1 and at TP2 for VR2.

To set the strike periods, sim ply adjust VR1 & VR2 to the volta settings required and press the sy chronise switch (S1) on the receiv board.

The delayed inputs (ie, the ent delays for Input1 & Input2) are s when LK3 is in the "-" position. On again, it's simply a matter of setting t

Where To Get The Bits

Suitable reed switch assemblies, door strikes and sirens are available from Jaycar and Altronics.

The parts available from Jaycar include: (1) the LA-5072 normally closed (NC) reed switch magnet assembly; (2) the LA-5078 door strike; and (3) the LA-5255 and LA-5256 piezo sirens.

Altronics has the following: (1) the S-5173 reed switch assemblies; and (2) the S-6120A or S-6127 siren. Altronics also stock two different door strikes – the S-5385 for wooden door-frames and the S-5387 for metal frames.



Above right: door strikes are available from both Jaycar and Altronics.

Calculating The Rolling Code

The rolling code for the infrared transmitter comprises four start bits, a 48-bit code and four stop bits.

A calculation comprising a multiplier and an increment value is used to generate the 48-bit code. First, you start with a number (called the seed), then you multiply this seed by the multiplier and then add the increment. The result becomes the next value for random code.

Normally, if the calculation is continued, the random code will become larger and larger as we multiply and then add the increment value. However, this is prevented by limiting the actual seed value used in the calculation to a certain width – 32 bits in this case.

In practice then, the 24-bit multiplier multiplies the 32-bit seed. The 8-bit increment value is then added and the result is limited to 48-bits by eliminating the more significant bits. This resulting 48-bit code is the code used for the rolling code transmission. In addition, the order of transmission for these bits is jumbled using an 8-bit scramble code with 32 possible combinations.

The calculations do not necessarily produce random numbers but they do produce variations from one transmission to the next. However, in some cases, the result could converge to settle at the same value so it is important to check this and make sure the calculations do give diverging values each time.

To do this, the result of each calculation is compared to the last value to ensure it is not repeated. If the result is the same as before, the duplicate code is not transmitted and a new calculation is made after incrementing the result. Subsequent calculations will then begin to diverge.

Randomisation

To avoid conflict, each transmitter must have a unique set of parameters for making the rolling code calculations. As a result, we have included a "randomisation" function, whereby the multiplier value, the increment value, the scramble value and the seed value are all changed in a relatively random way.

There are 16.7 million multipliers available and 54 possible increment values. Together with the 32 scramble variations, these provide 29 billion different combinations. In addition, the minimum multiplier value is 8192 to ensure a significant change in value with each calculation.

Even if two transmitters do end up with the same parameter values, the fact that the seed value is a part of the calculation means that you need to be within 200 values of the correct value in order to unlock someone else's lock. The probability of this is 2^{24} divided by 200 or one in 83,000. This is in addition to the one in 29 billion chance of having the same parameter values!

There are up to 16 different transmitters that can be used with the one receiver and each transmitter uses a different set of seed, multiplier, increment and scramble values. The transmitter sends out its identification code that is embedded in the rolling code, so the receiver knows which set of values it must use in the calculation for each transmitter.

When the transmitter is sending synchronising code to the receiver, it sends the 8-bit identifier, the 24-bit seed, the 24-bit multiplier, the 8-bit increment value and the 8-bit scramble values. The identifier value is also stored so that the receiver knows that this identity has been synchronised. An identity that has not been synchronised will not operate the receiver.

Once the receiver has these parameters, the transmitter and receiver will remain in lock because they use the same calculation values.

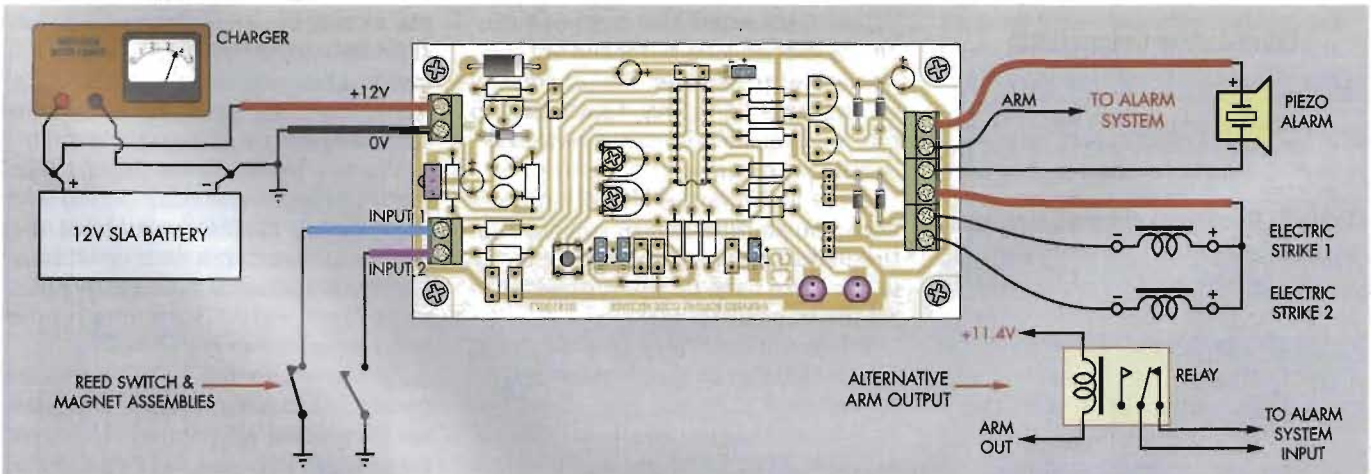


Fig.7: here's how to connect the receiver in a typical installation. Note that you can use both NO (normally open) and NC (normally closed) sensors on the alarm inputs (Input1 & Input2). The battery charger keeps the battery topped up.

voltages at TP1 & TP2 and pressing S1 to set the values.

Finally, when LK3 is out, VR1 sets the alarm period (VR2's setting is ignored). Just set the required voltage at TP1 and press S1 to program the period in.

Note that because pressing switch S1 programs in the timing adjustments, synchronisation will also alter the timing. This means that if you synchronise a transmitter to the receiver at a later date, you will have to make sure that VR1 & VR2 are in the correct positions for the LK3 option selected before pressing S1.

In practice, this just means leaving VR1, VR2 and LK3 in their final positions after you finish the timing adjustments. That way, if you synchronise a transmitter later on, the last set

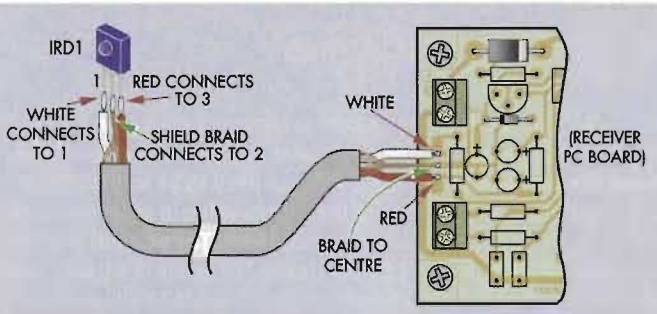


Fig.8: the IR receiver (IRD1) can be connected via twin-core shielded cable as shown here.



Above: you can buy both NO & NC reed switch assemblies.

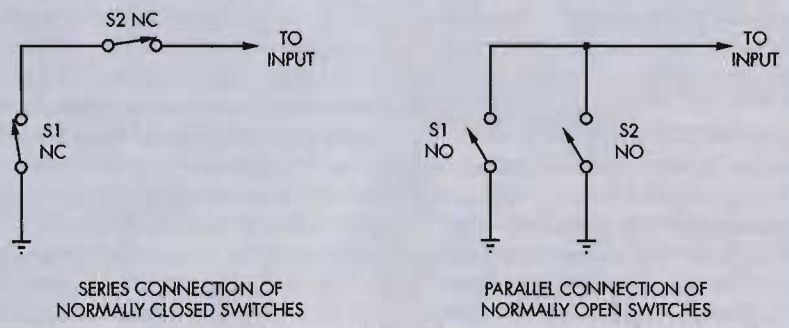


Fig.9: here's how to wire the two different sensor types (NO & NC) to the alarm inputs on the receiver board.

timing values are simply reset to the same values.

Arm output option

Link LK4 sets the arm output option – see Table 4. When LK4 is in the "+" position, the Arm output is low on arm and open on disarm. Conversely, when LK4 is in the "–" position, the Arm output is open on arm and low on disarm. It all depends on how you intend to use this output as to which option you choose.

Table 4: Arm Output (LK2)

LK4	+	-
	Arm output low on arm, open on disarm	Arm output open on arm, low on disarm

Table 5: Receiver Lockout Selections

Lockout Identity	LK1	LK2	LK3	LK4
1	+	+	+	+
2	+	+	+	-
3	+	+	-	+
4	+	+	-	-
5	+	-	+	+
6	+	-	+	-
7	+	-	-	+
8	+	-	-	-
9	-	+	+	+
10	-	+	+	-
11	-	+	-	+
12	-	+	-	
13	-	-	+	+
14	-	-	+	-
15	-	-	-	+
16	-	-	-	-

Receiver lockout

Any transmitter that has been synchronised can later be locked out from operating the receiver. This is done by setting links LK1, LK2, LK3 & LK4 in the receiver and pressing switch S1 during power up.

Table 5 shows the link options for each transmitter identity. Note that these link settings correspond exactly to the links used in the transmitter to set the transmitter identity

When lockout is performed, the power LED flashes the identity number to indicate that the procedure has been successfully completed. So, for example, if you lock-out an identity 3 transmitter, the power LED will flash three times at a nominal 1s rate before a 4s break until S1 is released.

When S1 is released, the receiver then operates normally but with the selected transmitter now locked out.

If S1 is held closed, the cycle of LED flashing continues. At the end of the third cycle, all identities will be locked out and the power LED will stay lit until S1 is released. This feature is included as a short cut to locking out all identities.

If one transmitter is locked out and a second one also needs to be locked out, the power will have to be switched off and links LK1-LK4 repositioned for that transmitter identity. The power must then be re-applied with S1 pressed.

Once the lockout procedure has been completed, you must relocate links LK1-LK4 to their correct positions for the receiver functions that you wish to select. It is then best to test that everything is correct by pressing the switches on another (non-locked-out) transmitter and verifying that the receiver operates as expected.

Undoing lockout

It's easy to get a locked out transmitter to operate the receiver again (ie, to unlock it). Just synchronise the transmitter with the receiver and all will be back to normal.

Installation

The Rolling Code Keyless Entry System is suitable for use in homes, factories and cars. Fig.7 shows how to wire the unit for a typical installation. **Note that IRD1 must be shielded from direct sunlight, otherwise the reception range will be severely affected.**

In some cases, it may be necessary to connect the infrared receiver (IRD1) via extended leads using twin-core shielded cable (eg, if the receiver is mounted on one side of a wall but infrared reception is needed on the other side). Fig.8 shows how this is done.

The two alarm inputs (Input1 & Input2) can be used in conjunction with reed switch magnet assemblies that change state when a door or window is opened or closed. You can use either normally closed (NC) or normally open (NO) types.

As shown in Fig.9, NC types are connected in series, while NO types are connected in parallel. However for best security use only one sensor per input.

Alternatively, you can use a PIR detector or a glass breakage detector on one or both of the inputs.

Errata: the PIC16F828A-20/SO specified for IC1 in the transmitter parts list last month should be a PIC16F628A-20/SO. Also, IC1 on the receiver parts overlay (Fig.6) should be a PIC16F88-I/P (not PIC18F88-I/P).

PIC Programmer SOIC Converter

Programming 18-lead surface-mount SOIC PIC microcontrollers can be a quite difficult because access to the leads is not that easy. This adaptor PC board accepts 18-pin SOIC PIC microcontrollers and plugs directly into a conventional PIC programmer.

Most people will buy a kit for this project and the PIC micros used in the transmitter and receiver will come pre-programmed. But what if you want to program them yourself?

One way of programming the SOIC (surface-mount) PIC16F628A –20/SO used in the transmitter is to use the In-Circuit Serial Programming (ICSP) header on the PC board. Basically, you have to connect the Vdd, Vss, MCLR, RB6 & RB7 pins on the processor to the +5V, 0V, Vpp, clock and data ICSP connections on a PIC programmer. However, this technique is only good for assembled PC boards (assuming ICSP connections are available on the PIC programmer).

Converter board

If you want to program an SOIC PIC out of circuit (eg, for production runs) some other method is needed. This SOIC Converter board solves the problem. It provides a means to connect the pins on the SOIC PIC to a standard 18-pin DIP socket on a PIC programmer.

In use, the SOIC PIC is positioned on the converter board and held in place using a spring-loaded clip (eg, a clothes peg or a bulldog clip). The SOIC Converter then plugs into the PIC programmer, after which programming is carried out in the normal manner.

Parts List

1 PC board, code 04211071, 29 x 48mm
1 100nF monolithic ceramic capacitor (code 104 or 100n)
2 9-way header strips with 2.54mm spacing
1 80mm length of 0.7mm tinned copper wire

Circuit details

Fig.10 shows the circuit for the SOIC Converter. There's not much to it – just two 9-pin SIL headers and a 100nF capacitor. The SIL header pins connect to the Vss, Vdd, Vpp, RB6 & RB7 pins of the SOIC device.

No provision has been made for Low Voltage Programming because the LVP pin varies between different processors. The 100nF capacitor bypasses the 5V supply.

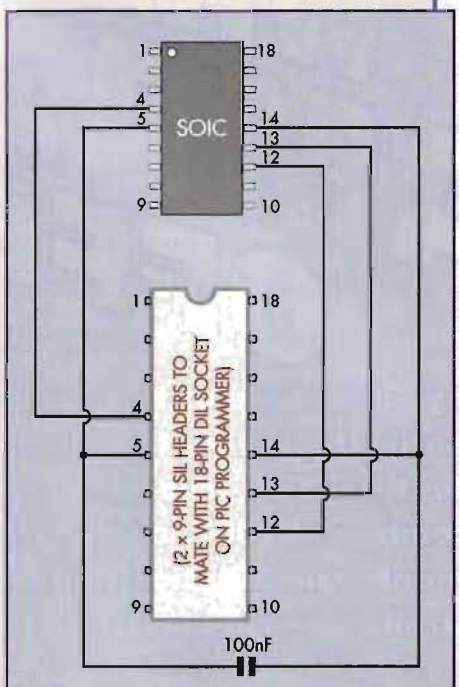
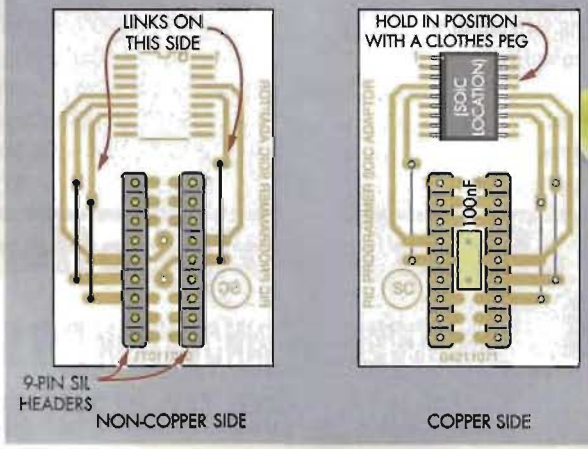


Fig.10: the SOIC Converter uses just two 9-pin SIL headers and a 100nF capacitor.

The PC board (coded 04211071 and measuring 29 x 48mm) is assembled by first installing the three links on the non-copper side of the PC board – see Fig.11. The two 9-way header strips are then installed and soldered in place.

Finally, the 100nF capacitor is mounted on from the copper side of the board – see photo.

Note that the power must always be off when mounting the SOIC device or removing it from the board. SC



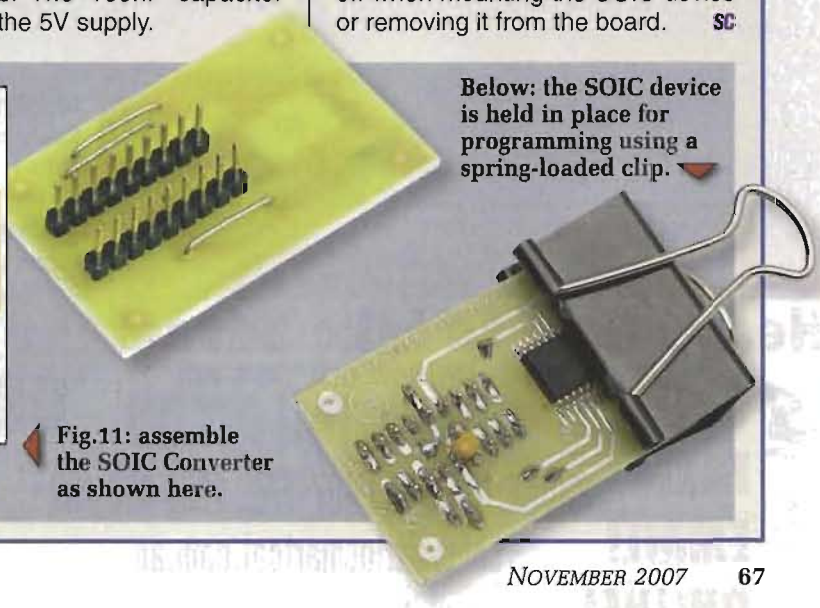
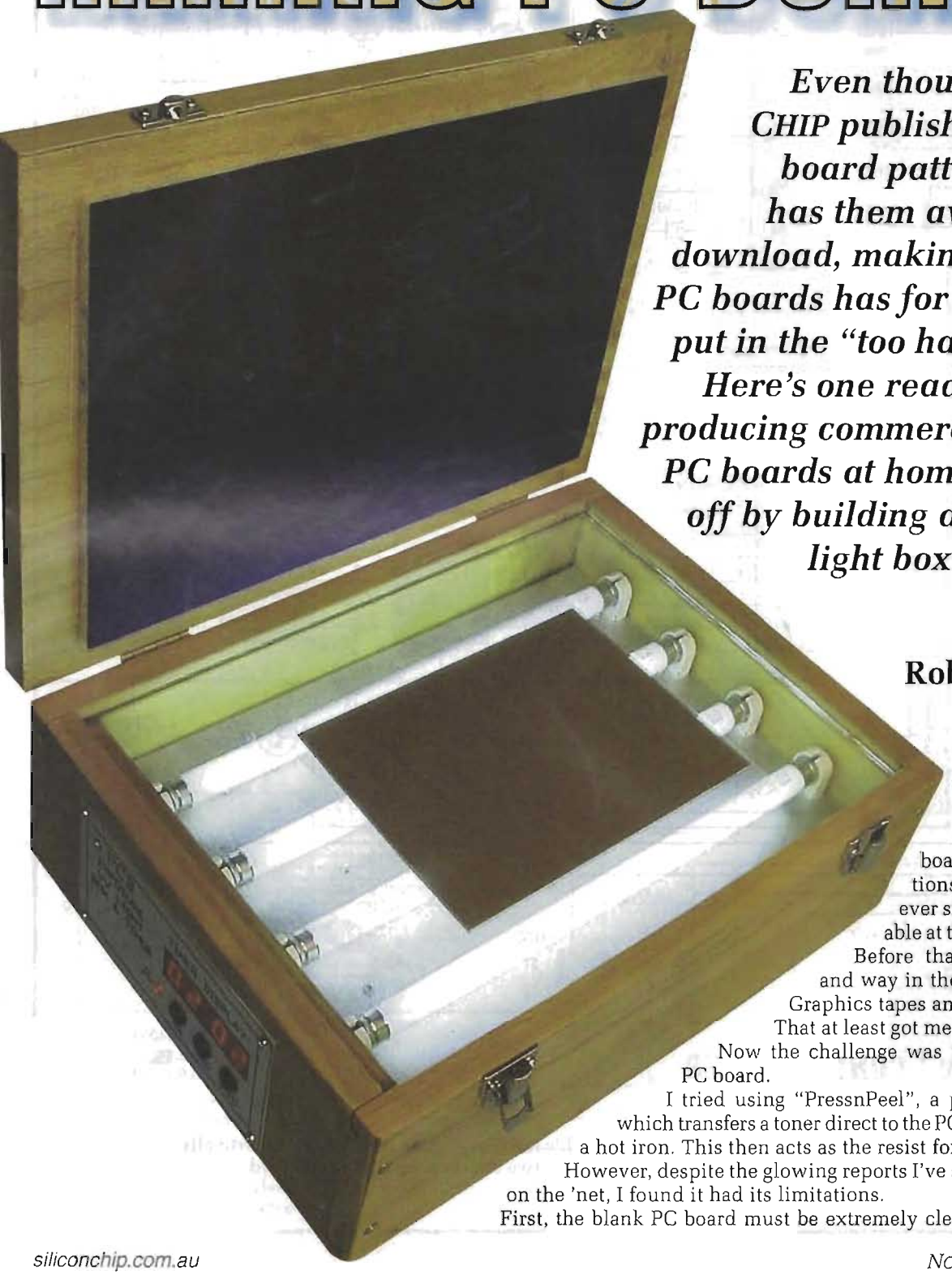


Fig.11: assemble the SOIC Converter as shown here.

Below: the SOIC device is held in place for programming using a spring-loaded clip.

A UV LIGHT BOX FOR MAKING PC BOARDS



Even though SILICON CHIP publishes most PC board patterns and/or has them available for download, making your own PC boards has for many been put in the "too hard" basket. Here's one reader's way of producing commercial-quality PC boards at home. He starts off by building an exposure light box with timer.

by Robert Scott

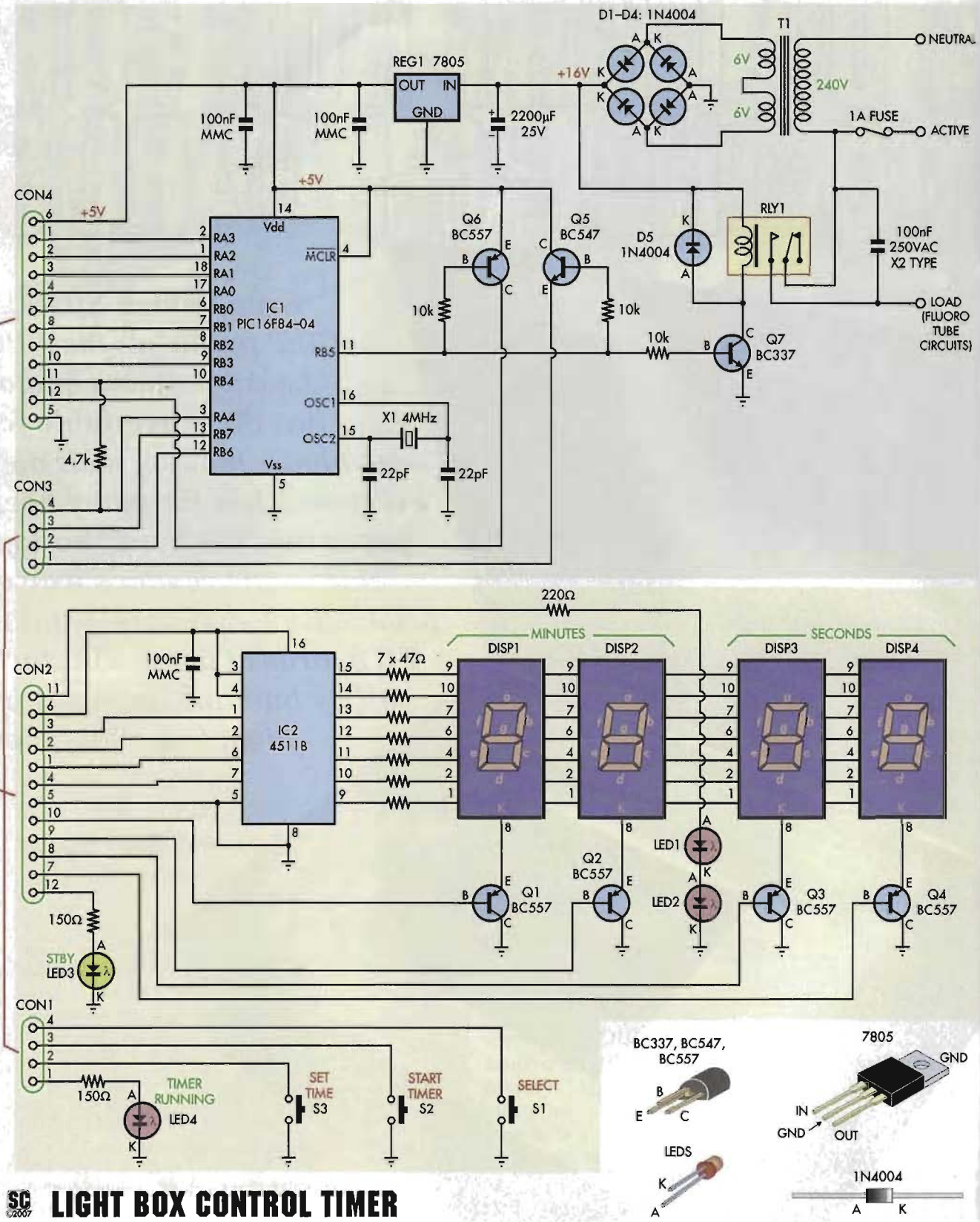
I have been using Autotrax* 1.61 to design PC boards for my own creations for a few years now, ever since it became available at the right price (free!). Before that I used Easytrax* and way in the past I used Bishop Graphics tapes and pads.

That at least got me a PC board artwork. Now the challenge was to convert that to a PC board.

I tried using "PressnPeel", a photo-sensitive film which transfers a toner direct to the PC board surface using a hot iron. This then acts as the resist for etching.

However, despite the glowing reports I've seen on this product on the 'net, I found it had its limitations.

First, the blank PC board must be extremely clean for the toner im-



LIGHT BOX CONTROL TIMER

Fig.1: the light box controller is built on two PC boards and this circuit diagram is split in two vertically, each part containing the contents of one of the boards. They are joined by two short cables, one 4-way and one 12-way, which plug into connectors 1/3 and 2/4 respectively.

age on the film to stick to it. Second, if the PC board artwork is quite a bit larger than the iron then it is hard to get the blank board up to the correct temperature all over for the toner to stick again.

Quite often you would pull away the film only to be left with a result where, Dalo pen in hand, you would have to repair the pattern as best you could.

It wasn't a very satisfactory situation and to make matters worse, PressnPeel at a retail level adds quite a lot to the finished board cost.

Pre-coated boards

I had been looking for a source of relatively cheap, photo-resist coated blank board and found it in "Kinsten" positive acting photo-resist coated PC board.

Kinsten coated PC boards are available in both SRBP and fiberglass, single or double-sided and in a variety of sizes, from several sources – I obtained mine from KALEX (718 High Street Rd Glen Waverley Vic 3150. Ph 03 98020788). They can also supply via mail order.

Also available from Kalex are the 8W UV lamps used in this project at $9.75 each plus GST. The developing solution for this resist is available too. While it appears to be just plain old sodium hydroxide (NaOH; caustic soda), it is actually sodium metasilicate, mixed at 50g per litre of water. A 50g pack will cost $2.50 plus GST.

The good news is that I have heard sodium hydroxide works just as well. The bad news is that I have not been able to get sodium hydroxide anywhere down here in Tasmania yet so I cannot verify if the above is true.

Editor's note: at SILICON CHIP we have been producing one-off PC boards using Kinsten pre-coated blanks for some years (in fact, we published a feature on it in March 2001) and had heard exactly the same thing.

We can confirm that properly diluted sodium hydroxide will develop Kinsten boards perfectly. Too strong a solution and the whole image washes straight off. Too weak and nothing happens. Experimentation is a wonderful teacher. Incidentally, we found that sodium hydroxide is not difficult to obtain from specialist chemical supply houses here in Sydney.

OK, with the availability of the blank board and suitable UV lamps the next step was finding a way to transfer the computer-generated PC board pattern to a transparency through which the Kinsten coated blank boards could be exposed. The idea is to have as high a contrast as possible – black blacks and clear "whites".

The problem with most printers, especially printing onto transparency film (eg, overhead projector film) is that the blacks are anything but. Hold one up to the light and you'll see what I mean.

If you are very accurate, to some degree this can be alleviated by using two sheets. I get very good results from two toner-coated transparencies from a laser printer stuck together with thin double sided tape. I haven't tried inkjet transparencies or even know if this is possible with inkjet. I find a good HP or Canon laser printer such as the LaserJet 4 or Cannon LBP 1260 does the job admirably.

I have one of each of these; even the LaserJet II or III will do. These can be obtained quite cheaply second-hand and refurbishing the cartridge is quite easy, even if rather messy.

Editor's note: inkjet prints can be just as good as, if not better than, laser prints. However, the problem of non-black blacks still exists. Incidentally, great results can be achieved by printing onto plain bond paper – with an appropriate increase in exposure time.

Exposing PC boards

The Kinsten coated boards are exposed by shining UV light through the artwork transparency. The clear part of the transparency "softens" the emulsion on the PC board, which is then "developed" away with the sodium hydroxide solution mentioned earlier.

Two problems exist. One is to keep the PC board pattern transparency in intimate contact with the board so that there is no light "scatter", causing break-up of tracks. Even the thickness of the film itself can cause problems, so the image on the film should always be

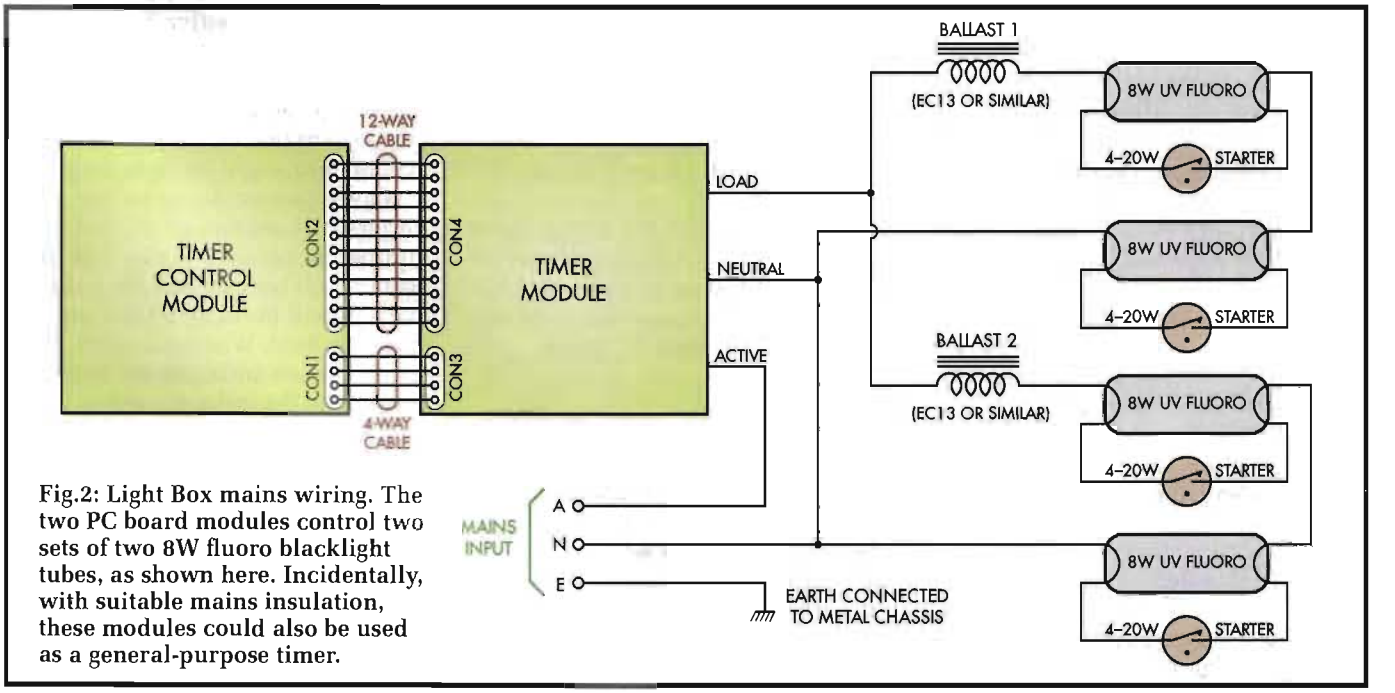


Fig.2: Light Box mains wiring. The two PC board modules control two sets of two 8W fluoro blacklight tubes, as shown here. Incidentally, with suitable mains insulation, these modules could also be used as a general-purpose timer.

on the PC board side, ie, "emulsion to emulsion."

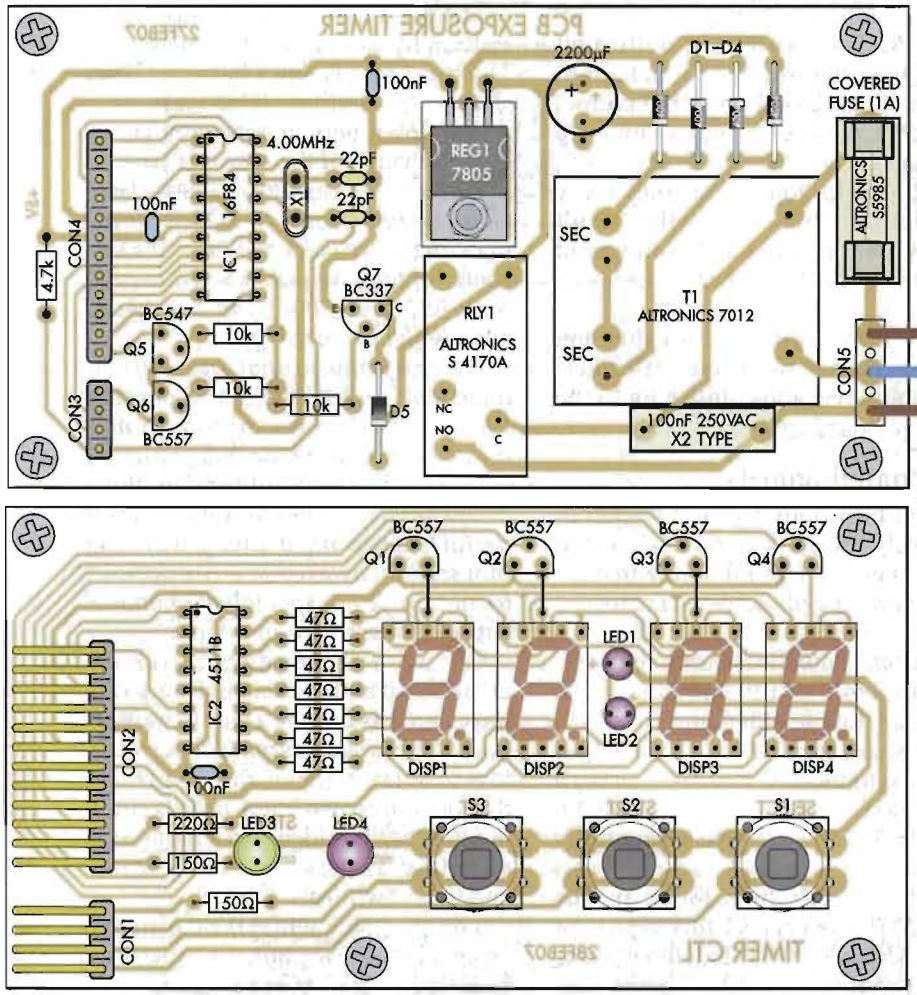
The second problem is to keep the amount of UV exposure constant in both time and strength, so that results are consistent.

Various methods of exposure have been tried over the years – including using the very high UV content of sunlight. But this highlights problem two – the sun's strength varies according to time of day, cloud cover, latitude, pollution levels, etc!

The answer is to use a dedicated light box. With a timer, the exposure could be set. With pressure applied to the transparency, the two parts could be held together properly.

I thought I would see if a light box project was feasible. First thing? Check the net!

There appeared to be a lot of info but only one with anything like what I was looking for. It consisted of a PIC16F84 programmed as a timer with a basic circuit displaying on 7 segment displays. While it held promise, I believed that with redesign of the firmware for the PIC and particularly the hardware would make it much better.



Figs 3 & 4, the component overlays for the Exposure Controller (top) and the display board/timer controller (bottom).

Outline of the project

The electronics side of the project consists of two PC boards, each 120 x 64mm. One is for the timer lamp control and power supply, the other the timer control and display panel.

One of these is mounted on standoffs on the underside of a folded aluminium chassis, which also contains the fluorescent tube ballasts and starters. The other is mounted on the side of (and through) the lightbox so that its LED displays and setting pushbuttons are all accessible and viewable from outside.

On the top side of the chassis are mounted the eight "tombstones" which hold four 8W NEC fluorescent "blacklight" (UV) tubes. These are not like the deep purple (almost black) blacklight tubes you see in clubs and discos. Instead, these are described as "actinic blue" and appear white when off but are very strong in UV as well as visible blue light when on.

This chassis is secured by screws in a wooden box, outside dimensions 360 x 120 x 100mm, which has a 6mm glass pane located in a channel in the sides of the box, which places it about 25mm above the fluorescent tubes. There is a hinged lid on the box which has a piece of 6mm foam covered with felt glued to its underside. When the lid is locked closed, the foam and felt force the PC board (and the transparency underneath it) hard against the glass pane.

This ensures that the blank board and the transparency have intimate contact with one another so that the image on the transparency accurately transfers to the blank PC board.

The circuit

Fig.1 shows the wiring of the exposure lamps, ballasts and starters, under the control of the timer PC board.

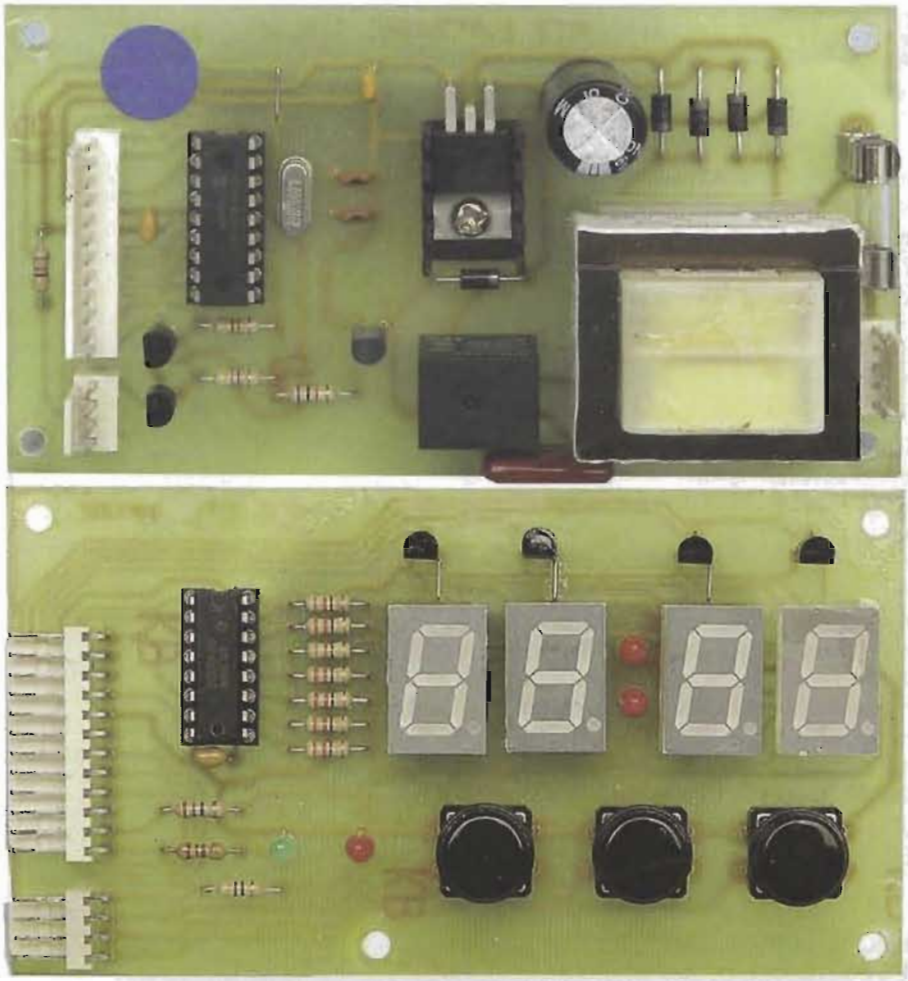
Power is switched to the fluoro tubes via a mains-rated relay, under the control of the PIC and switching transistors.

The four UV tubes are arranged in two identical parallel circuits, shown in Fig.2. Each one consist of two lamps, two starters and a ba last all in series. The starters are th 4-20W (more sensitive type) for th lower level currents involved wit 8W tubes.

It's a little unusual to have tw tubes share one ballast, so a word o explanation might be necessary.

When power is applied, bot starters will arc and close due to th internal bimetallic strip. The tub heaters will heat up and the inducto (ballast) will build up a 50Hz varyin magnetic field. When one of the start ers cool down and open the magneti field round the inductor will collaps causing a somewhat large EMF to b developed across the inductor. Thi will appear across the open starte and its associated tube.

The gas inside the tube will ionis and the tube will strike. Once an fluorescent tube strikes, the voltag dropped across it due to current flow ing through it is much reduced. If th



Here are the matching same-size photos of the PC boards to assist you with construction. The fuse shown here has been changed to a fully covered type.

other starter then opens induced EMF across the inductor again will strike the second tube.

All this happens rather fast and both tubes should be glowing within a second or so.

Sometimes both starters open nearly simultaneously and the startup strikes occur together. This type of circuit is possible with low wattage tubes as the distance between tube heaters is small compared to say, a 36W standard lighting fluorescent and the voltage drop is small.

The PC boards

Two PC boards are used, sharing functions between them.

The control/display PC board is connected to the timer board with 12-way and 4-way cables. I used these as it was easier to design and make single-sided PC boards to suit these than it was to make a double-sided board with a dual-in-line 16-pin plug. Because these are all on the low-voltage side of the circuit, ordinary hookup wire or even rainbow cable can be used here.

The timer PC board is screwed to a small panel of 1mm aluminium with stand-off's. Cutouts and holes are required in the panel for the stand-off's, LEDs, 7-segment displays and pushbutton switches. This panel is then screwed to the left side of the light box with a cutout to suit.

Looking now at Figs. 2 and 3, power is supplied to the circuit via a 1A fuse, PC-mounted transformer, (240V to two 6V windings, eg, Altronics 7012). Both 6V windings are connected in series, rectified and filtered, resulting in an unregulated DC supply of about 16V or so.

The unregulated supply is used to power the switching relay and also fed to a 5V voltage regulator (REG1, 7805). This provides the timer with a 5V regulated supply.

Most of the timer operation is carried out by the programmed PIC16F84 so the circuit is not as complicated as it would otherwise be if hardware alone did the task.

The PIC's clock is set at 4MHz by crystal X1. Pins 17,18,1,2 (RA0 to RA3) send multiplexed BCD data to the display board via P4-P2. Pins 6 to 9 (RB0 to RB3) send multiplexed data to transistors Q1 to Q4 (display drivers) on the display board via P4-P2. Pin 11, RB5, is normally held low in standby.

When the timer is counting down it goes high, biasing on Q7 (BC337) which pulls in RLY1 (supplying power to the fluorescent tubes), at the same time biasing Q5 (BC547) on and Q6 (BC557) off.

These in turn extinguish standby LED3 and turn on running LED4.

When the timer has completed the countdown RB5 goes low, which turns off Q7 and turns on Q5 and Q6. Relay RL1 opens, the timer LED4 goes out and standby LED3 comes back on.

Pin 3, RA4, connects to the select switch via P3-P1; a pull-up resistor is required here. Pin 12, 13 (RB6, RB7) connect to the set and start switches (S3, S2) respectively.

Pin 10 (RB4) provides a positive pulse every second while the timer is active and this pulse is fed to two LEDs in series via a 220Ω resistor. These form a "colon" between the minutes and seconds LCD digits.

Making the chassis

Aluminium was chosen for the chassis as it is easy to work with and some UV light will reflect from this, distributing the UV fairly well through the artwork. The chassis is bent in a "U" shape with holes and slots cut out for the various components.

The layout is shown in Fig. 7, reproduced a little under half size. Ideally, the chassis should be bent to shape with a sheet metal folder but good results can be had with 25mm angle iron and a sturdy vice.

The aluminium sheet size is 320 x 265mm and the sheet can be 1 to 1.6 mm thick.

Making the Box

Once the chassis is made then the box can be made to fit. I made my box from 17mm plywood, 100mm high. A plywood lid was made to suit from the same material.

A sheet just over 600 x 470mm (to allow for saw cuts) will achieve mini-

Parts List – PC Board Light Box

1 PC board, 120 x 64mm, code 10111071
1 PC board, 120 x 64mm, code 10111072
1 aluminium sheet, 155 x 80mm x ~1-1.5mm (for front panel) with label
1 aluminium sheet, 300 x 320mm (thickness 1-1.6mm) (for chassis)
1 240V to 12V (2x6V) PC board mounting mains transformer (eg, Altronics M-7012A)
1 12V SPDT PC board-mounting relay with mains-rated contacts (eg, Altronics S-4170A)
1 4MHz crystal (X1)
1 covered M205 fuseholder, PC board mounting (eg Altronics S5985)
1 1A M205 fuse
3 pushbutton membrane switches, PC board mounting (eg, Altronics S-1135)
3 1 16-pin machine IC socket
1 18-pin machine IC socket
1 4-pin 90° PC board male socket (eg, Altronics P5514)
1 12-pin 90° PC board male socket (eg, Altronics P5522)
1 4-pin straight PC board male socket (eg, Altronics P5494)
1 12-pin straight PC board male socket (eg, Altronics P5502)
2 4-pin plugs
2 12-pin plugs
1 300mm length 4-wire cable (either rainbow cable or individual wires)
1 300mm length 12-wire cable (either rainbow cable or individual wires)
1 3-way mains-rated PC board mounting terminal block (eg, Altronics P2035A)
1 sheet 17mm plywood, ~600 x 470mm and 17mm iron-on edge veneer
1 sheet 3mm plywood, ~360 x 270mm (for base)
1 sheet 335 x 245 x 6mm clear glass (no flaws, scratches or tinting)
1 sheet 320 x 230 x ~7mm foam plastic (high density if possible)
1 sheet 320 x 230mm felt
1 piece red transparent plastic, 65 x 20 x ~1.5mm (for display lens)
2 hinges for lid
4 rubber feet
4 8W UV (actinic blue) fluorescent tubes (eg, NEC blacklight FL8BL or similar)
8 miniature fluoro tube holders, type ST 268 (known as "tombstones"),
4 fluorescent starter holders (HPM 390 or similar)
4 4-20W fluorescent starters (Osram ST151 or similar)
2 13W fluorescent ballasts (EC13 or similar)
1 3-core mains lead fitted with 3-pin plug.
1 mains cord clamp
1 earth lead lug (crimp-on preferred)
Lengths mains-rated hookup wire for fluoro tube, ballast and starter wiring

Semiconductors
1 PIC16F84-4, loaded with light_box_timer.hex (IC1)
1 4511 7-segment display driver (IC2)
1 7805 5V regulator (REG1) with U-shaped heatsink
5 BC557 or BC558 transistors (Q1-Q4, Q6)
1 BC547 or BC548 transistor (Q5)
1 BC337 or BC338 transistor (Q7)
2 3mm red LEDs (LED1, 2)
1 5mm green LED (LED3)
1 5mm red LED (LED4)
4 1N4004 1A silicon diodes (D1-D4)
4 0.5-inch 7-segment common cathode displays (DISP1-4) (eg, Jaycar ZD1855 or Altronics Z0190)

Capacitors
1 2200µF 25V electrolytic
4 100nF monolithic
1 100nF 250VAC X2 TYPE
2 22pF ceramic

Resistors (0.5W, 1%)
3 10kΩ 1 4.7kΩ 1 220Ω 1 150Ω 8 47Ω

Electrical parts, including the miniature tube holders ("tombstones"), ballasts, etc are fairly common items available from (or ordered via) most electrical wholesalers.

The 8W "blacklight" fluorescent tubes are not so common but should also be available from major electrical wholesalers (even if on special order). Those used in the prototype were obtained from KALEX, 718 High St, Glen Waverley, Vic 3150. Tel (03) 9802 0788.

* Autotrax and Easytrax PC board layout software are available as free downloads from www.altium.com/Community/Support/Downloads/

mum wastage. The two sides and two ends need a slot cut in them, about 7mm down from the top, to accommodate the glass plate.

There has to be a slot about 6mm down from the top of the box to fit the glass plate. This is best done with a router using a ¼" (6.5mm) bit. Cut the slot about the same depth (6.5mm). As you are not removing much wood this can be done with one cut. The slot can also be cut with a circular saw if you are experienced enough – a router is better though and they can be obtained very cheaply these days.

As the smallest router bit I had was ¼", the glass plate had to be the same thickness, ¼" or 6.5mm. This was a fortunate accident, because that's about the right thickness for stability but not too thick to have to worry about UV absorption in the glass. It is important that the glass does not have any scratches or imperfections as these will surely show up in your finished PC boards.

Is Ultraviolet light dangerous?

From time to time warnings appear about the dangers of UV light. Even as we go to press, UV tanning salons have been implicated in at least one recent death through melanoma (skin cancer).

From the outset, let's state that staring at any light, especially intense light, is not good for the eyes. Very bright light, especially if strong in ultraviolet wavelengths in particular, is known to cause eye discomfort and damage.

Ultraviolet light is generally regarded as having a wavelength from about 200 to 400nm (nanometres). This is further divided into three sub-bands, UV-C, UV-B and UV-A.

UV-C (200-280nm) has the shortest wavelength and is often used as a germ killer or steriliser. It is regarded as dangerous stuff! Anything which emits UV-C usually has interlocks to prevent accidental exposure to the eyes or skin.

UV-B (280-320nm) has a longer wavelength and is considered less dangerous but exposure can redden and possibly burn the skin and may cause damage to the retina.

UV-A has a longer wavelength again (320 to 400nm) and is considered less dangerous again.

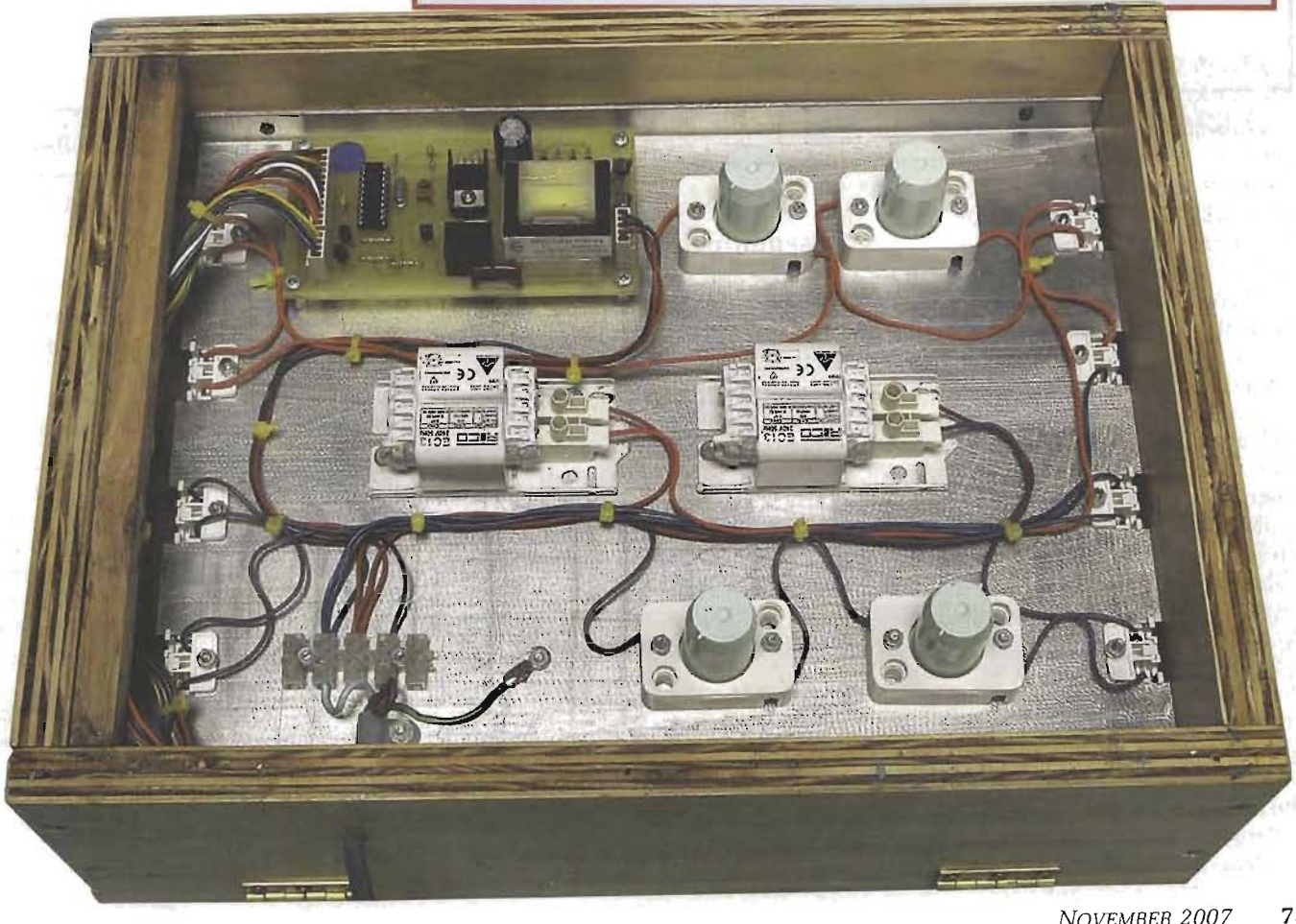
Prolonged exposure to UV-B and perhaps to UV-A are acknowledged to cause skin damage and possibly promote skin cancers as well as eye damage. But the vast majority of references point to UV-B light as the bogey.

The NEC FL8BL blacklight lamps used in this project emit mostly UV-A, with a peak wavelength of 365nm (which also explains why there is so much visible blue light from them). They are in fact the same as (or similar to) the blue lamps used in bug zappers.

Ideally, you should avoid long exposure, especially of the eyes, to any UV (or indeed any strong light). But the high wavelength of these tubes, their low power (all four combined are less than a single 36W fluoro tube), the fact that there is a sheet of UV-absorbing glass above them and the very intermittent nature of exposing PC boards using them means that they are reasonably safe.

Having said all that, keep children away and don't let your teenage daughter use this as a mini face-tanning centre! If you are still concerned, a mains-rated interlock switch (eg, a microswitch operated by the lid) could be fitted in series with the active wires going to the ballasts.

Below: the completed Light Box with its plywood base removed. The second PC board is on the left side.



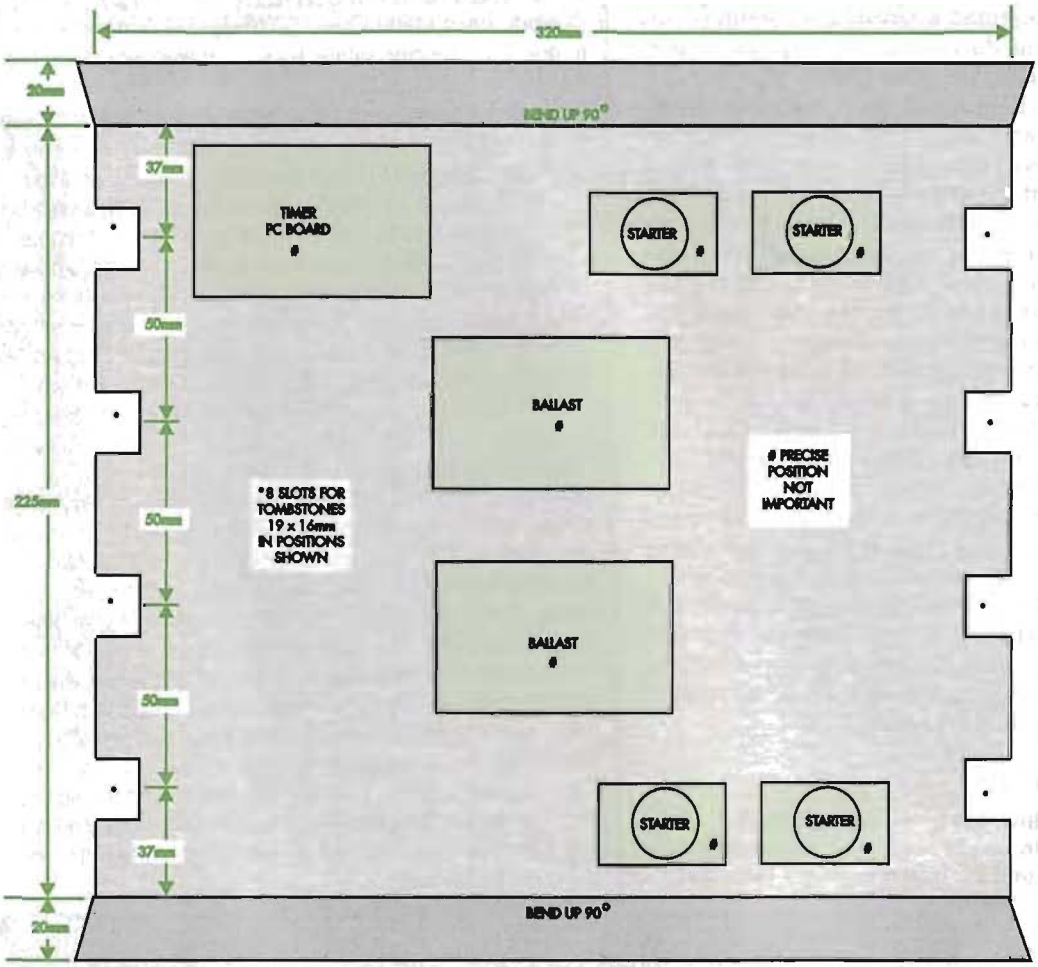


Fig. 7: here's how to fold and cut the aluminium chassis, looking from the underside. The only critical positions are the notches for the tombstones which must of course line up with each other. The PC board, ballasts and starter holders can be placed in approximately the positions shown.

With the dimensions shown, the glass plate will be 6mm all round greater than the box internal, the chassis is 225mm wide by 320mm long, therefore it follows that the glass plate will be 237 x 332mm.

Of course this all depends on your carpentry skills. I used iron-on veneer on the cut edges of plywood and varnished the whole assembly with Estapol. This makes the job attractive as well as functional. Ply was used rather than straight wood as this tends to be truer so the pieces fit together better.

The lid is a single piece of plywood, the same size as the box and again finished with iron-on veneer. It is attached to the box with two medium-sized hinges.

Inside the lid a piece of 6mm high density foam plastic, covered with self-adhesive felt on one side, was stuck into place with double sided tape to fit into the space between the top of the box and the glass.

Its size, 320 x 230mm, allows it to clear the box edges as the lid is closed and press down hard on the blank PC board to hold it flat against the artwork.

Assembling the PC boards

Solder the 3 links on the display board first, followed by the resistors, IC socket, displays, sockets and capacitors.

The same order applies for the timer/power supply – the lowest profile components first and highest last. 300mm lengths of 12-wire cable and 4-wire cables using rainbow cable or single hookup wire lengths has to be made in order to connect the display/control board to the timer board.

Do not solder the LEDs into the display PC board yet.

Putting it all together

All components can now be fitted to the chassis as per Fig.4 and wired as per wiring schematic Fig.3. Be very careful in wiring the mains-carrying cable – that is to all the fluorescent tube holders, starters and ballasts.

Mains wiring may be taken directly to the block connector on the timer PC board, with the switched active connected to the rest of the circuit. Use single-core 10A lighting wire for wiring the lighting circuit up. That's not because there are heavy currents involved, it's for the safety afforded by the cable's insulation.

Connections to the tombstones are achieved by pushing the stripped cable into the hole provided. The wires are locked into place by a spring loaded clamp and once they are in it is difficult to pull them back out again so try not to make mistakes. Make doubly and triply sure, however, that all strands of the wires have gone into the hole and none poke out to possibly short to the chassis.

Make sure you earth the chassis via the earth wire on the mains 3-core cable and plug.

The connections to the starter holders are achieved by a clamping screw.

A rectangular cutout will have to b

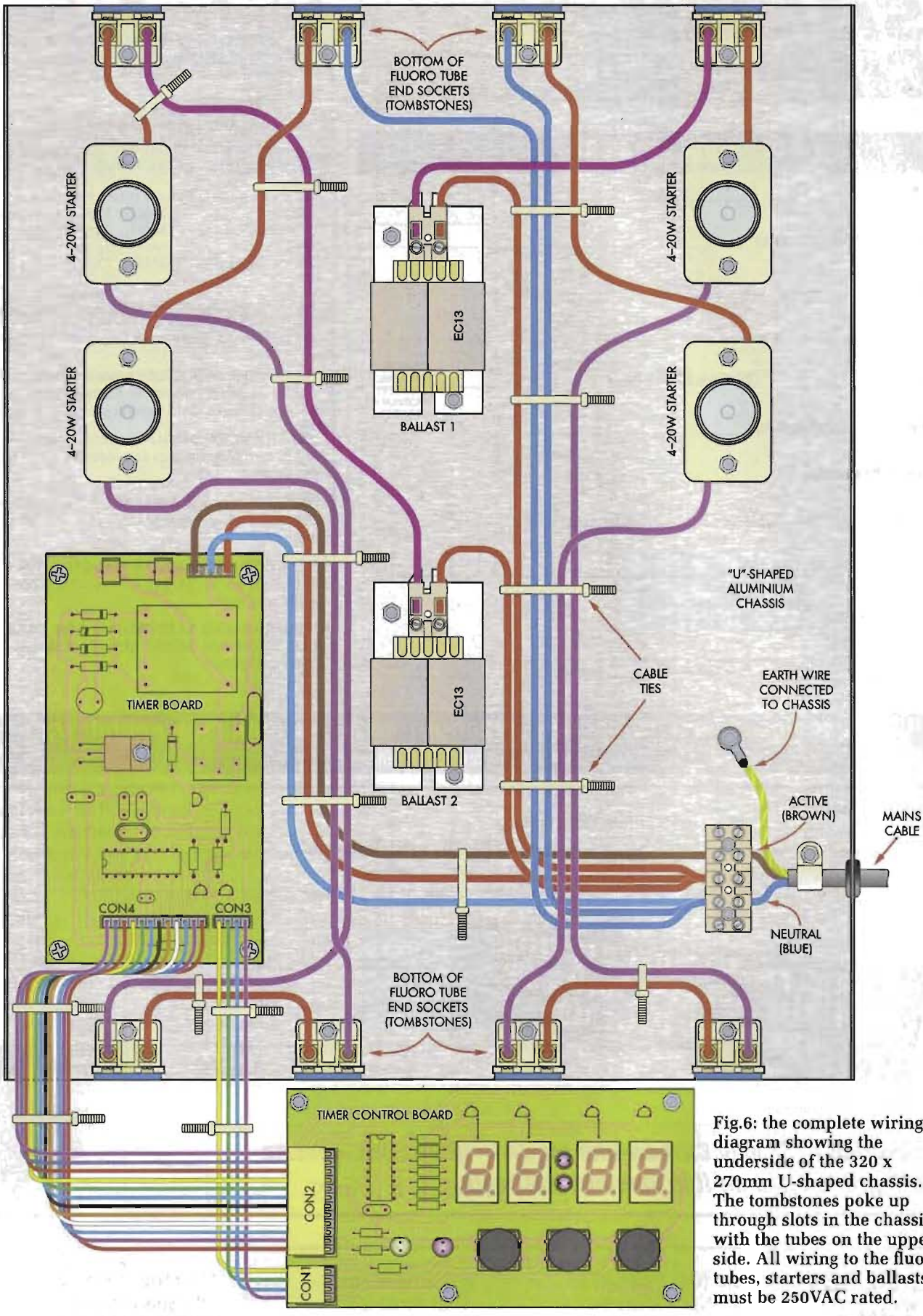


Fig.6: the complete wiring diagram showing the underside of the 320 x 270mm U-shaped chassis. The tombstones poke up through slots in the chassis with the tubes on the upper side. All wiring to the fluoro tubes, starters and ballasts must be 250VAC rated.

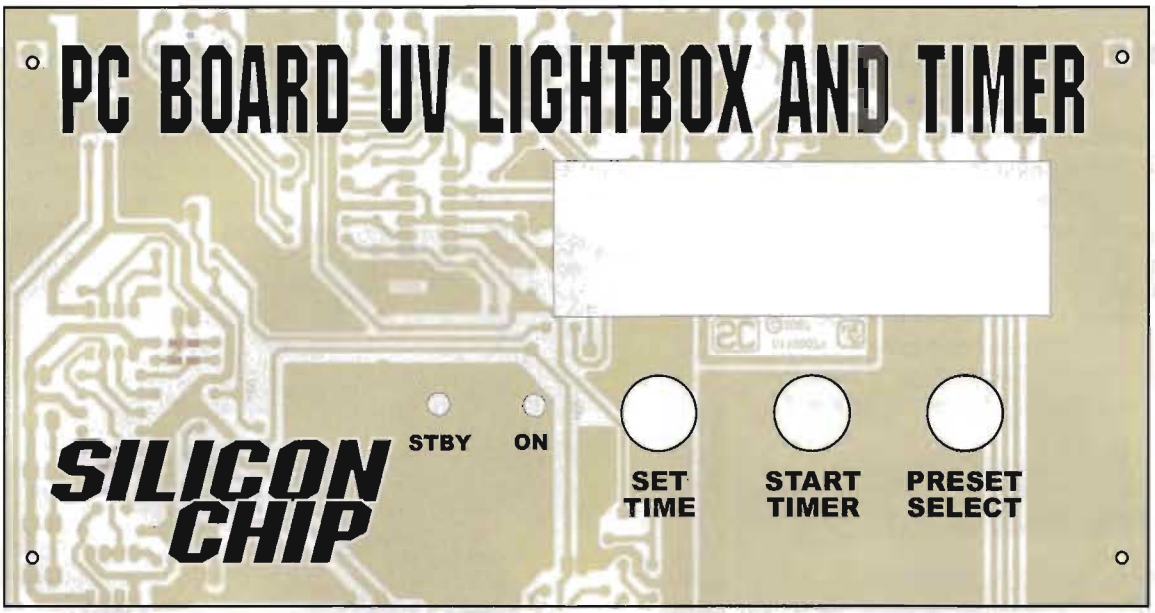


Fig.7: same-size artwork for the Lightbox front panel. Photocopy this and use as a template for drilling the holes in the aluminium sheet.

made for the control /display board on its mounting plate either in the front of the box or as I have done in the left side.

I have specified insulated stand-offs to mount the PC boards but metal ones could be used **except** for the one on the mains entry side of the timer/power supply board.

Display PC board

The display PC board is mounted to a small piece of ~1mm aluminium with holes drilled for the LEDs and switches along with a cutout for the display.

A piece of 1mm reddish plastic was glued into the cutout as a protective screen for the 7-segment displays and seconds LEDs. Use a small quantity of slow setting epoxy for this. The "Five Minute" type sets too quickly and is not as strong.

Drill PC board mounting holes in the panel by placing a photocopy of the display board overlay on the panel, lining up the 7-segment displays in the cut out and marking the center of the holes to be drilled with a prick punch or scriber.

I used 2mm mounting screws, nuts and washers. The stand-offs should be 8mm to allow the push-button switches to sit proud of the front panel.

If using 2mm screws you may have to make your own from 2mm brass tubing available from model aircraft stores. The 2mm screws don't stand out on the front panel as much as 3mm.

Countersunk screws could be used and the front panel artwork fixed to the aluminium over the screw heads.

Testing.

It's best to test the timer out before you wire it in on the chassis. Plug the two boards together and wire the main board temporarily to the timer board. Do not plug the IC's in both boards as yet, that is the 4511 and the 16F84A. Make sure you have double checked everything especially the timer/power supply with its mains wiring.

In the interests of safety, cover the fuse and fuseholder with some insulation tape while testing. It's the only section of the top of the PC board that's likely to bite you – but if you contact it, it will do just that!

Switch on power, measure to see if you have approx +16V and a regulated +5V where marked on the power supply; also that +5V appears on pin 16 with respect to pin 8 on the 4511 socket and between pins 14 to 5 on the 16F84A socket. If all is well and you have no burning smells switch off and remove the mains plug from the power socket. Wait a short time for the electrolytic capacitors to discharge and insert the two ICs

Reconnect and switch power back on. You should get a readout of 00:30 on the display board. The relay should not be energized and the green standby LED should be illuminated. If you do not have this, switch off and recheck your work.

Hopefully all should be well and you can proceed to check the timer operation. Press the start button, the green led should go out and the red one should illuminate, at the same time the relay will energise and the display will begin to count down from 30 seconds to 0.

When the timer reaches 0 the relay will drop out, the red LED will extinguish and the green one will come back on. Pressing the start button again will bring back the 00:30 readout again.

Press the select button and the display should change to a different time setting. Do this 15 times. There are 16 timer settings stored in EEPROM in the programmed 16F84A.

You can change any or all of these if you so desire by the doing the following: select a setting to change by pressing the select button until the display is reading the setting you want to change.

Press the set button. The seconds will start flashing, incrementing one more every second, when the time in seconds is reading your requirement press set again. The single minute digit will start to flash incrementing as before, again when your desired time is reached press set again. The tens of seconds will start to flash incrementing as the single minute digit did.

Again, when your requirement is reached press set again. The timer will be set in EEPROM to your keyed-in time.

If you make a mistake then you will have to go through the entire procedure again. Usually you will only need to do this once or twice.

If all is well checking the timer then it can be wired into the chassis and the rest of the wiring completed.

Using your new light box to make a printed circuit board . . .

Exposing the image

To make boards from Kinsten stock the manufacturer's recommend exposure time is 60 to 90 seconds using a high-contrast film. Set the timer for 1 minute 15 seconds using a test artwork. You may need to do a few test exposures and increase or decrease exposure times as required. Too long and you will end up with all the resist washed away, too short and it will be under developed with the "clear" areas not washing away.

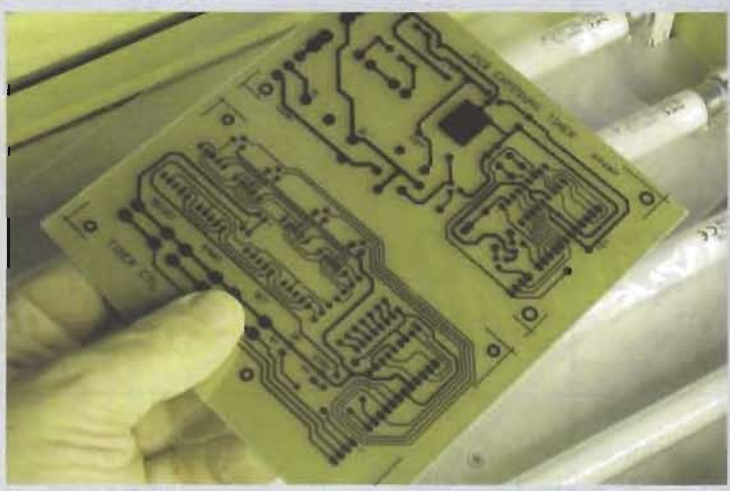
Using this presensitized PC board I found the latitude is about 10 seconds either way but you may find it different.

You could use Riston negative-acting pre-coated board but it is more expensive and so is the special developer and stripper. Also you will require a negative of your artwork.

To give you an idea of cost, a fibreglass pre-coated Kinsten-board, 150mm x 300mm from Kalex costs $16.50 plus $2.75 for developer. The same size Riston board (from Jaycar) will cost you $49.95 plus $7.95 for developer and $8.95 for stripper (you will never get it off easily otherwise).

Kinsten resist can be removed with 00 gauge steel wool or acetone.

As you can see Kinsten is about one third the cost taking everything into consideration.



Getting a black black is actually more important that getting a clear white (believe it or not, you can expose through bond paper!). The pattern should be on the bottom side of the film, so it is intimate contact with the photo-sensitive emulsion.

Developing the exposed board

As we mentioned eariler, the proprietary developer is easy to mix and use but we have also had success using a weak caustic soda brew. You'll soon know if you've made it too strong or too weak – if it's too strong the resist will all wash off (including the bits you want!) and if it's too weak nothing will wash off.

The same tray can be used to develop the board and to etch it – just make sure you wash the tray out between times.

Developing is achieved by full immersion, emulsion-side up, and gently rocking the tray so the developer "washes" over the resist. Rotate the tray as you go so the washing is even.

Brushing the board lightly with a soft brush (a makeup brush is ideal) can assist developing but be careful – it can result in flaws in the resist.

Before very long (a minute or so if your exposure is correct) you should see patches of developer starting to wash away from the board. It doesn't take too much longer for development to be complete, with all unwanted areas (ie, between tracks, component holes etc) now cleared of developer.

Development time will increase with lower temperatures so down here in Tassie I heat up the developer with an old microwave oven for about a minute. Be careful – too hot and you will be left with no image either (it will all dissolve).

When finished, rinse it in cool fresh water.

Until it dries, the resist is normally fairly soft. The board can either be air-dried (say an hour or so), dried in direct sunlight (half an hour) or baked in a just-warm oven (an electric frypan is also good!) for maybe ten to fifteen minutes.

Developing a Kinsten pre-coated board. The clear areas in the transparency have been washed away leaving the resist to protect the wanted areas from the etchant. Yes, this is a different board to those shown above!



Etching the developed Board

If you don't make many boards then the easiest way to etch the board is to place it upside down in a plastic container of ferric chloride in solution for 10 to 30 minutes, depending on the temperature, or rocked in a large tray.

If you make a number of boards, a better way is to purchase an etching tank, fish tank water heater & air pump. The tank is available at both Jaycar & Altronics or you can make your own from glass or Perspex. This way boards can be etched in less than 10 minutes depending on the strength of the solution.

An alternative etchant is ammonium persulphate but this needs to be heated to around 50°C plus before it will work and standard fish tank heaters will only heat the etching solution to 30°C (tropical fish don't like it much hotter than that). Also, ammonium persulphate is theoretically a use once solution so etching using this can be expensive. However, we've been able to use stored ammonium persulphate etchant many times over a few weeks.



For very occasional PC boards, tray etching is quite practical. Etching needs to be helped along by rocking or sloshed with a non-metal soft brush. The etchant shown here is actually ammonium persulphate – it's a lot cleaner to use than ferric chloride but must be heated first to 50-60°C to be usable. This board is about 90% etched – most of the inter-track copper is gone with just a few larger areas to go.
Below: if you're making several PC boards, this commercial etching tank, heater and air pump is definitely the way to go.

By the way, the cheapest and best way to buy ferric chloride is in hydrated granules. This is available from RS Electronics in 2kg containers (Cat 551-277). Virtually everything I get for this hobby has to be mail order down here, so there is no point in paying postage for water.

Mix 500g per litre of water and to clear the solution a little add 5g of sodium chloride (common salt.) Add the ferric chloride to the water not the other way around.

It takes 2.5 litres of solution to fill the Altronics/Jaycar etch tank but this lasts for quite a time, I have etched over 50 large and small boards in the one batch I have mixed up and it still etches quite well under 10 minutes.

One problem is that it ferric chloride is messy – don't wear your favourite clothes – and after a while sediment builds up at the bottom of the tank. I wait until all the sediment settles overnight, then drain the etching solution off into a large plastic container leaving the sediment behind and then clean out the tank.

I then pour the solution back into the tank topping up with fresh solution if required. There's not much evaporation down here where I live in Tassie any time of the year, so the level in the tank doesn't go down much. Once the board is etched and the etch solution is washed off then it is ready for drilling and finishing.



Finishing the completed board.

Don't use a hobby PC board drill press as these just haven't the torque required. Buy yourself a cheap Chinese drill press with ½" chuck, replace the bearings with good Australian-made ones and use tungsten carbide bits.

These are quite readily available, from 0.45mm to 6.31mm. These bits won't dull on fibreglass but they are very hard and brittle so they are easily broken. With this in mind, buy more that one of each size.

The resist can be left on while drilling to protect the board from oxidising. When you have completed drilling holes, scrub off the resist with 00 steel wool and dishwashing detergent.

Once you have done that dry the board thoroughly and cut it to size with a hacksaw and finish with a file. Then give it a couple of coats of liquid resin flux from a Solder flux pen (Jaycar cat TS-1512)

This will help in soldering and also give the board protection from oxidation.

A methylated spirit/resin flux used to be available but I haven't seen the product anywhere for years. However, you can make your own with Rosin (buy it at a specialist music shop – it is used on violin bows). Crush it then dissolve it in metho until no more will dissolve.

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.

PIC-controlled SLA battery capacity meter

Sealed lead acid (SLA) batteries are ideal for wide variety of applications and they are maintenance-free. With correct charging and use, they can last for many years on standby and hundreds of discharge cycles.

However, if they are deeply discharged, over-charged or left discharged, their life can be greatly reduced. And even with proper care, all SLA batteries eventually need replacing but how do you work out when? You could try a number of load cycles to estimate the battery's capacity but unless this is carefully controlled, you can very easily end up with a completely discharged battery which will never recover.

The solution is this battery capacity meter built around a PIC16F877A microcontroller. The circuit monitors the battery under test and terminates the discharge at a user-defined voltage. It also computes the battery capacity in amp-hours (Ah) as it goes. It allows the discharge rate to be varied between 0.25A and 2A to cater for different battery sizes. Even when the battery voltage drops to a level where it cannot deliver the set current into the load, the circuit constantly monitors the current so it can correctly calculate the battery capacity.

In operation, the PIC measures the battery voltage using the internal ADC at pin 2 via a potential divider. The PIC produces a range of analog control voltages between 0.25V and 2V using a resistor ladder (pins 15-18 & 23-26). The output voltage of this ladder is varied by grounding it at various PIC pins.

The control voltage is fed to the non-inverting input of op amp IC2 which controls power FET Q4. This controls the current flowing through Lamp1. The voltage across Q4's 1Ω source resistor is fed to the inverting input of IC2 to provide precise current control. A second ADC at pin 5 measures this voltage and therefore the current.

The PIC keeps track of time using integral interrupts and it drives the LCD panel to show the cumulative battery capacity, the instantaneous current, battery voltage and elapsed time. Once the voltage drops to the threshold value, the discharge is terminated and measurements are displayed. An audible beep indicates the end of test.

David Mitchell is this month's winner of a Peak Atlas Test Instrument

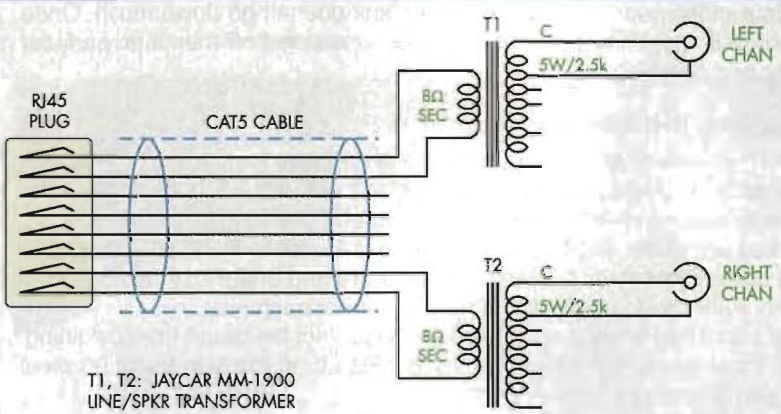
The load is one of four different wattage 12V lamps, selected to suit the required discharge current and so minimise the power dissipated in Q4. Settings are stored in the PIC's EEPROM for subsequent recall. The user is prompted via the LCD interface, with control via two pushbuttons for selecting discharge settings and modes.

The software will be available on the SILICON CHIP website at **www.siliconchip.com.au**

David Mitchell
Figtree, NSW.

Audio link via Cat.5 cable

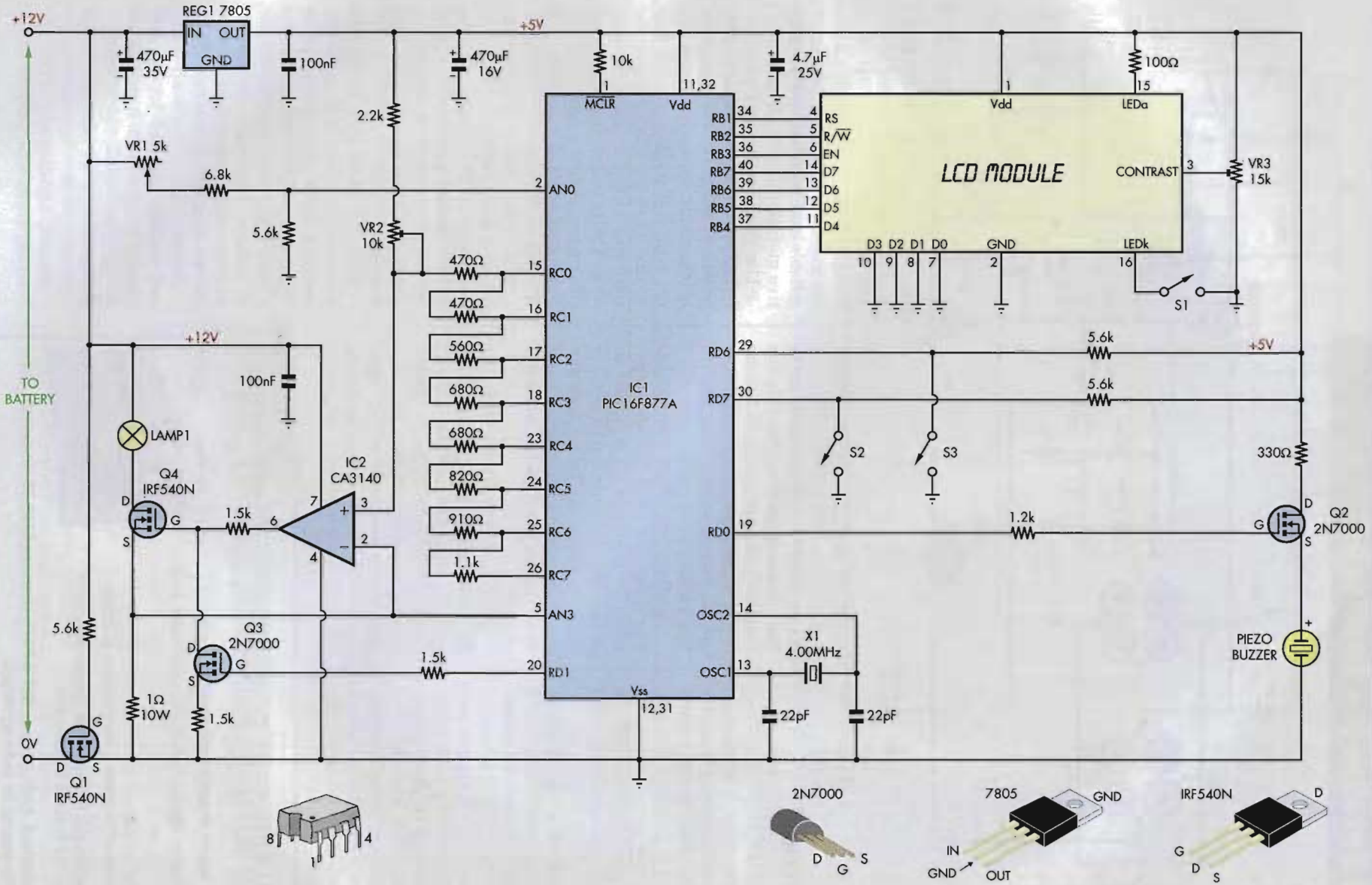
This novel adaptor was developed in order to transmit a good quality audio signal, to feed music (including streaming audio) from a PC to the family audio system. Since RF senders can be unreliable over distances of tens of metres, Cat.5 cable was the obvious choice. However, this would normally be done via commercial baluns, costing around $100 for each end.



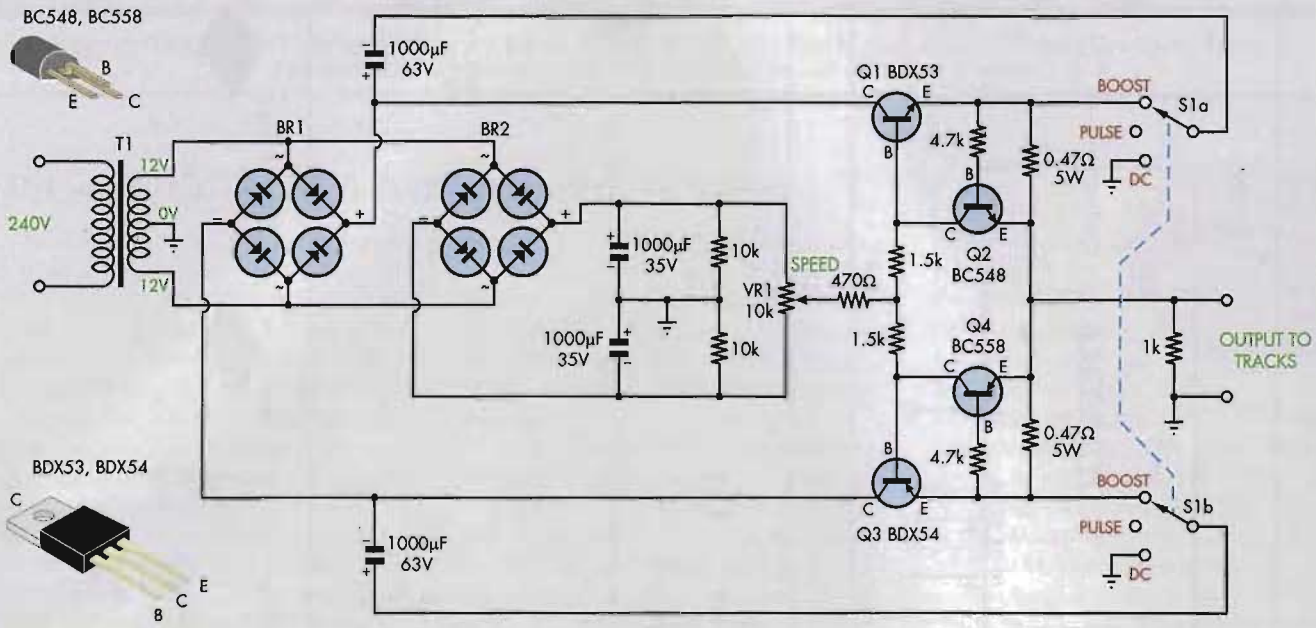
The accompanying circuit was tried using standard line output transformers and was found to work well. Two identical adapters are required, one for each end of the circuit. A 2-metre Cat.5 lead is cut in half and each resulting lead was clamped and terminated to the transformer secondaries in a Jaycar HB6011 Jiffy box. Each box was fitted with two Jaycar M1900 line transformers (one for each channel). Each box mounts two RCA chassis line sockets, with a transformer primary (5W tap) wired to each. The transformers were mounted at right angles to reduce crosstalk, although this is probably unnecessary.

Apart from a slight rolloff in lower bass, the quality is good and adding a small bass boost via the PC's sound card gives an excellent end result.

Fred Arden,
Melbourne, Vic. ($35)



PIC-CONTROLLED SLA BATTERY CAPACITY METER



Simple model train controller

This simple train controller is based on complementary Darlington transistors (Q1 & Q3) which are connected as emitter followers. Both their bases are connected to the wiper of potentiometer VR1 via 1.5kΩ resistors and a common 470Ω resistor.

VR1 is connected across a DC supply rail of about 36V, produced by bridge rectifier BR1 and the associated 1000µF electrolytic capacitors. The collectors of Q1 & Q3 are connected to the positive and negative raw (ie, unfiltered) DC from bridge rectifier BR1. This assumes that switch S1 is in the "pulse" setting.

In effect, when VR1's wiper is moved beyond the centre point (ie, more positive), Q1 is turned on to feed positive 100Hz pulses to the locomotive motor (track). When the wiper is centred, both transistors are off, and no voltage is applied to the tracks.

Finally, when VR1's is moved below the centre point (ie, more negative), Q1 is off and Q3 is turned on to feed negative 100Hz pulses to the track, to drive the locomotive motor in the reverse direction. Hence, this circuit requires no reversing switch.

When switch S1 is placed in the DC setting, two 1000µF capacitors are switched into circuit to filter the previously unfiltered DC. In this condition, smoothed DC is fed to the locomotive motor which may result in smoother and quieter operation for "can" motors but may not give as reliable starting for cheaper locomotive motors.

The third position of S1 is referred to as "boost" and in this position, each 1000µF capacitor is effectively connected across the collector and emitter of each Darlington transistor. Depending on the setting of VR1, the capacitors feed more 100Hz pulses to the locomotive motor. (Editor's note: we have some doubts about the efficacy of this circuit feature).

Transistors Q2 & Q4, in conjunction with the 0.47Ω resistors, provide current limiting for the circuit and thus protect against short-circuits across the tracks. As shown, the current will be limited to about 2A peak.

Both the Darlington transistors will need to be mounted on a finned heatsink. Note that they must be isolated from the heatsink with the usual mica washers and hardware. With larger heatsinks, the current capacity could be doubled by reducing the emitter resistors to 0.22Ω.

Switch S1 is a centre-off toggle and should be rated for the full current of the circuit. It should not be operated while the circuit is powered up, otherwise substantial currents will flow through it.

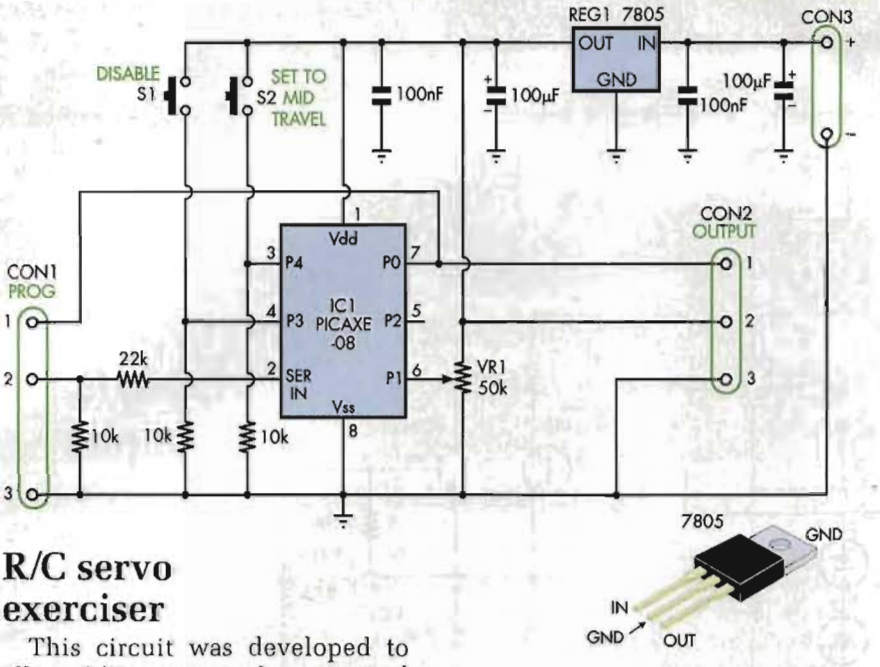
Hugh T. Middleton,
Lower Hutt, NZ. ($45)

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R/C servo exerciser

This circuit was developed to allow R/C servos to be exercised without the need for a radio control transceiver. Instead, it produces the required 1ms pulses directly using a PICAXE03M micro.

The circuit is powered from a 6-15V rail and the PICAXE chip is fed from the 7805 5V regulator. Potentiometer VR1 sets the pulse width and the servo responds in direct proportion to the deflection of the wiper from the centre position.

Switch S2 sets the servo to mid travel while switch S1 can be used to disable the pulse output.

The micro is programmed via the resistor network connected to pin 2.

Listing

```
main:
        if pin4 = 1 then
        low 0
        let b5 = 0
        let b8 = 0
        else if pin3 = 1 then
                if b5 = 0 then
                servo 0,150
                let b5 = 1
                let b8 = 0
                endif
        else
        readadc 1,b0
                if b0 > b6 or b0 < b7 or b8 = 0 then
                let w1 = b0 * 100 / 255
                let b4 = b2 + 100
                servo 0,b4
                let b6 = b0 + 5
                let b7 = b0 - 5
                endif
        let b5 = 0
        let b8 = 1
        endif
        goto main
```

The programming software is available on line (**http://www.rev-ed.co.uk/picaxe**).

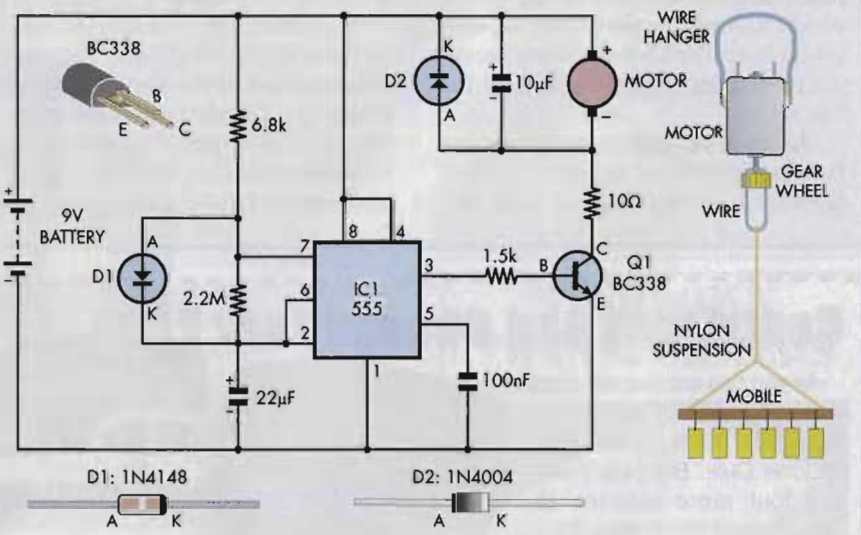
Robert Budniak,
Ryde, NSW. ($40)

Animation for mobiles

This is not about mobile phones but those visual distractions which hang from the ceiling waiting for a breeze to set them spinning. Breezes are seldom experienced in most rooms so mobiles are usually immobile; ie, static. This simple device adds a motor to provide a little animation.

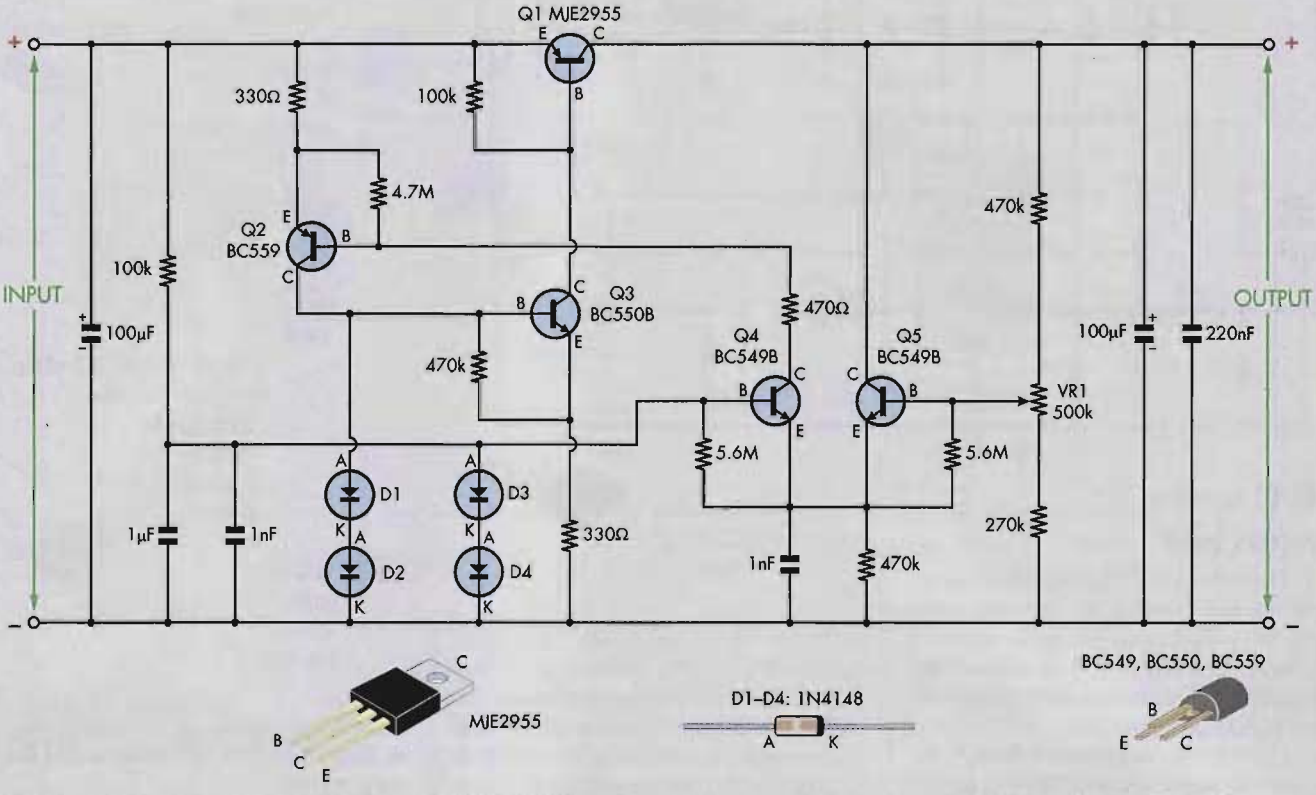
Instead of hanging the mobile directly from the ceiling, a small motor is inserted between the suspension hook and the Nylon line for the mobile. The motor is given a 10 millisecond burst of power every 40 seconds or so and this twists the suspension line so that it stores energy. This energy is slowly dissipated as the mobile twirls to and fro.

The suspension line should be Nylon filament in an inverted-Y arrangement, with the vertical section about 25cm long. The motor is attached via a wire hanger and a wire hanger is fitted to its output shaft so that the Nylon filament can be easily attached. As mobiles vary in mass and moment of inertia, some adjustment may be needed to the suspension or to the circuit, to increase or reduce the frequency of power bursts to the motor.



The circuit consists of a 555 timer (IC1) operating in astable mode and connected to give short bursts of power at intervals of about 40 seconds or so. The motor current is limited by the 10Ω series resistor.

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



Discrete component low dropout regulator

This low dropout regulator uses discrete parts and was designed for use with microcontrollers which, when in the low power sleep mode, only need very low current from the battery.

Q1 is the series pass transistor and it is controlled by transistors Q4 & Q5 which function as the error amplifier. The voltage setting provided by VR1 is compared to the reference voltage provided by signal diodes D3 & D4. These are biased at low current by a 100kΩ resistor.

Transistor Q4 controls Q2 which in turn, controls Q3 and hence the base current to the series pass transistor Q1. Q3 also provides current limiting, by comparing the voltage developed across its 330Ω emitter resistor with the reference voltage provided by diodes D1 & D2.

The actual current limit will depend on the current gain (h_{FE}) of transistor Q1. Q4 & Q5 need to be a matched pair (equal current gain) and should be in thermal contact with each other.

The input voltage would normally not exceed 12V and Q1 will require a heatsink.

Philip Foote,
Dianella, WA. ($45)

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As you can see, we pay good money for each of the "Circuit Notebook" items published in Silicon Chip. But now there are four more reasons to send in your circuit idea. Each month, the best contribution published will entitle the author to choose the prize: an LCR40 LCR meter, a DCA55 Semiconductor Component Analyser, an ESR60 Equivalent Series Resistance Analyser or an SCR100 Thyristor & Triac Analyser, with the compliments of Peak Electronic Design Ltd **www.peakelec.co.uk**

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PRODUCT SHOWCASE



Educational Trainers from Scientech

Scientech has introduced two trainer products – ST 2272 Satellite communication trainer and ST 2303 LVDT trainer – to their range of educational trainers.

Satellite Communication Trainer ST2272 consisting of uplink transmitter, satellite link and a downlink receiver facilitates in-depth study of basic Satellite communication system.

LVDT Trainer ST2303 is designed to teach LVDT (Linear Variable Differential Transformer) characteristics The trainer has a LED display showing displacement in mm with a sensitivity of 10mV/mm in the range of 10mm.

These trainers from Scientech provide a very convenient platform in teaching technology by eliminating the need for hardwiring components for conducting experiments.

Contact:
Geo Electronics
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Much more than an oscilloscope . . .

CircuitMaster 4000M

Precision Active Oscilloscope



The CircuitMaster 4000M from UK-based ABI Electronics is designed for testing circuit boards.

An active oscilloscope differs from a conventional (passive) oscilloscope in that the inputs can be internally driven. This is particularly useful for diagnosing electronic circuit problems.

Suppose you have a digital input to some complex IC that's suspected of causing intermittent faults. If you were to measure the voltage at the input pin with a normal oscilloscope or multimeter, you would measure close to 0V in the following three cases:

(1) When the input was shorted to ground;
(2) When the input was shorted to ground through a 1kΩ resistor and
(3) When the input was shorted to ground through a 10kΩ resistor.

This is because there is negligible current flowing into the device, as its input impedance is extremely high. Hence, with a passive oscilloscope or multimeter, you would not be able to differentiate the three situations by measuring the voltage at the input pin.

With an active oscilloscope, you can differentiate the situations as follows.

In active mode, the CircuitMaster 4000 can apply a small DC current through the probe and measure the resulting voltage drop. The situation is now as in Fig 1. Since the voltage drop will be proportional to the resistance, scenarios (1)-(3) above can be differentiated quite easily according to the measured voltage drop.

The CircuitMaster 4000M in detail

There are two analog channels accessed by BNC sockets (as in a conventional oscilloscope) and another BNC socket for an external trigger.

A 50-pin connector allows digital signals to be analysed. It is supplied with special clips (up to 40 pins) that can attach to ICs in-circuit. These are well suited to DIP ICs and modestly spaced surface-mount devices like TQFP but would be difficult to use with very fine pitch surface mount devices or BGA.

The signals are multiplexed and the voltages on all 40 pins can be acquired to internal memory. The bandwidth in this mode is naturally lower than the unit's native 100MHz due to the multiplexing.

At the rear, there is a socket for connecting the included foot switch, useful for capturing waveforms while concentrating on the PC board rather than the display of the oscilloscope.

The display is of relatively low resolution at 320x240 (quarter VGA). There is a brightness control but it didn't seem to have much effect. Fig. 2 shows a typical screenshot.

This instrument is well suited to analysing both analog and digital circuits. Up to two analog and four digital signals can be displayed simultaneously on the screen. For greater numbers of digital signals, multiplexing can be employed.

For digital circuits, TTL, CMOS and low-voltage TTL are standard options. For other logic families, the user can set the threshold voltage levels. The voltage ranges are shown on the Y-axis in different colours according to whether the signal is considered high or low (or neither – called no man's land). This is a handy feature that will quickly tell you whether your board is producing an "undefined" logic level, which could cause all sorts of unpredictable results in its operation.

It can operate in standard mode, akin to a normal passive oscilloscope but without some of the fancier options like FFT and maths functions. It also lacks an "Auto-Set" feature making it a little more difficult to use than a dedicated oscilloscope.

The other three modes are Active, FirmFlex and V-I curve. In FirmFlex mode, the "strength" of a node can be measured. This is a measure of its impedance. It is accomplished by outputting a small DC current (suitable for working on powered circuit boards) and the resulting voltage drop is measured. The strength of the node is indicated on the display by its background colour, changing from yellow to red to purple as the strength of the node increases.

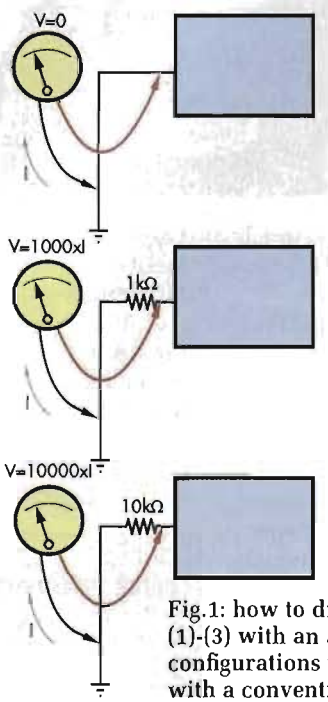


Fig.1: how to differentiate the three conditions (1)-(3) with an active oscilloscope. These three configurations would all measure the same with a conventional passive oscilloscope.

In Active mode, the source impedance can be set in decades from 100Ω to 1MΩ and the signal can be DC or AC with controllable frequency and peak-to-peak amplitude. This mode is particularly handy for test-

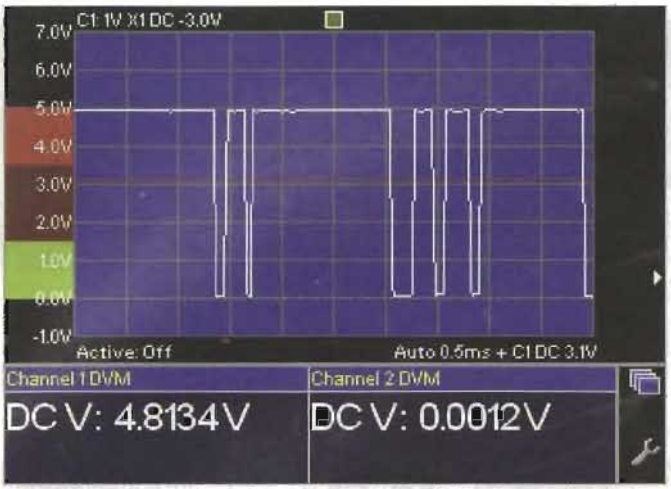


Fig.2: this screen shot shows a TTL signal from an infrared remote control in standard mode. On the y-axis, the red represents a high level, green represents a low level and maroon represents an "undefined" logic level. The DVM (digital volt meter) display can also be seen, showing a signal level of around 4.8V.

ing circuit boards relative to a known good board. The pass/fail feature will be appreciated by test technicians. A mask can be set from a known good board and other boards can be compared to it. The target pass percentage can be set by the user.

As its name suggests, the V-I curve mode plots voltage vs current for the component under test. Its main purpose is to check that components are working correctly and it is not intended as a measurement tool as the axes are not well labelled, making precise measurements difficult. If you had a suspected faulty diode, for example, you could quickly diagnose whether it was working correctly or not using this mode. This is something that a passive oscilloscope simply cannot do.

While offering many useful features, we thought the user interface could be improved to make it a little more friendly. This is a common complaint on a lot of high-end test equipment and is mainly a problem for first-time users. As you become more aware of its features, this would cease to be such a problem.

In a similar vein, some of the default options could be improved.

In addition, the screen background is set to blue and cannot be changed. This makes it difficult to see some fine traces on the display, even if you change the colour of the trace itself. However, we have been advised that the screen background colour can be changed at the factory.

We assume that the manufacturer does provide progressive firmware upgrades, which can be done via the USB port.

In conclusion, the CircuitMaster 4000M is a valuable special-purpose instrument designed to debug a faulty circuit board in ways that a passive oscilloscope simply cannot. Few instruments possess as many test features and all of this in a compact desktop unit.

Distributed in Australia by Tekmark, the CircuitMaster 4000M retails for $5,200 plus GST. (MG)

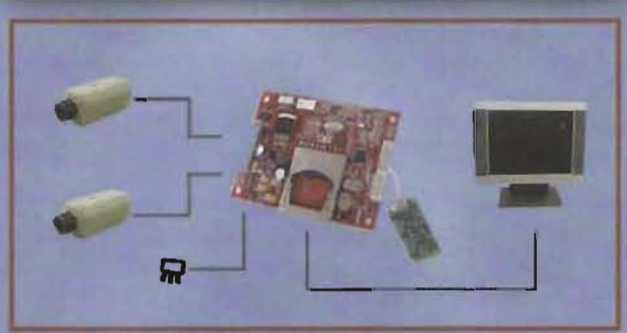
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Vintage Radio



By RODNEY CHAMPNESS, VK3UG

Pocket-sized valve portable radios

During the era before transistors took over, manufacturers went to extraordinary lengths to produce portable valve radio receivers. None went further than the Japanese, although their miniature valve portable receivers were never marketed in Australia.

"Portable" radios first started to appear in numbers in the 1930s, although a few innovative portables did appear as early as the mid 1920s. These early sets were quite bulky and heavy and by today's standards, were portable in name only.

Some of those original sets used 2V valves and required a 2V wet cell (A battery) for the filaments. They also required around 135V from a dry battery pack (B battery) for the high-tension (HT) plate and screen voltages. Certainly, people had to be serious about their desire to have radio "wherever they went". Radio stations of the time were fairly low-powered and programming was limited, which restricted the usefulness of early portable sets.

In addition, the battery requirements were quite onerous. The wet cell required regular maintenance and care, including measuring the specific gravity of the electrolyte, keeping the top clean and dry, recharging it at regular intervals and making sure the set was not tipped over.

Tipping the cell (battery) over meant that acid would leak out of the battery and damage the set as well as the battery itself (sulphuric acid is quite corrosive). By contrast, the better designs used dry batteries for the filaments, usually two 1.5V cells in series. The 2V supply for the valve filaments was obtained simply by connecting a resistor in series with this 3V supply.

The dry batteries used for the HT supply required no special maintenance. However, they were heavy and expensive to replace.



This is the view inside the Global miniature portable. The components are tightly packed together.

Portables become portable

In Australia, sets that could truly be classed as "portable" started to appear around 1938. This coincided with the introduction of battery valves which were designed to work from 1.5V and 90V filament and HT voltages. These sets were still quite a struggle to lug around but they were much easier to use than the earlier sets and the battery life was much longer than in sets using valves with 2V filaments.

Although these sets were a big improvement on the original portables, people really wanted something even smaller. As a result, a size of around 350 x 160 x 230mm (W x D x H) became the standard for portable receivers during the late 1940s and the 1950s. Even then, the weight of the sets with an AC power supply and batteries could be as much as 7kg. That said, these sets performed well and had a reasonable battery life of around 300 hours.

Getting smaller

The demand for even smaller sets during this period forced a few compromises. The antenna loop was made smaller by necessity, the sets generally had no RF stage and they used quite small batteries. In fact, the batteries only lasted 30-40 hours before needing replacement.

A typical "miniature" receiver of

this type was the Breville 801, which was featured in the February 2007 issue. This radio measured just 120 x 120 x 160mm – about a fifth the size of the larger sets. These radios enjoyed only a short period of popularity due to their lack of sensitivity and high battery costs.

By contrast, the larger portable sets continued right through until the advent of transistor receivers.

Japanese miniatures

In the years preceding the introduction of transistor receivers, Japanese manufacturers revisited the idea of producing miniature valve sets. As a result, they produced sets that were roughly the same size as the pocket transistor receivers we marvelled at in the late 1950s and early 60s.

These miniature valve sets had four valves in a conventional superheterodyne circuit. This consisted of a 1R5 converter stage, a 1T4 intermediate frequency (IF) amplifier, a 1S5 as a combined detector, AGC diode and pentode audio amplifier, and a 3S4 audio output stage which fed a speaker or headphones/earpiece.

So how well did these little receivers perform? The critical component that affects performance in such small sets is the antenna. In these radios, the ferrite rod antenna varied from quite small to some that ran nearly the length of the case and were from 6-9mm in diameter. Those sets with the larger rod antennas were likely have been better performers – certainly better than the older Australian-manufactured miniature portables of the late 1940s and early 1950s.

Personally, I can not remember seeing any of these miniature Japanese sets on the Australian market. In fact, I had seen only one of these really tiny sets before until the HRSA 25th anniversary celebrations, where I saw several in Laurie Harris's display. Apparently, they were used only in Japan (where they were manufactured) and in the USA. The 10 sets in Laurie's collection came from the estate of another collector.

Small is beautiful

So just how small were the Japanese miniature sets? Well, let's compare the size of the smallest set – the Global – with an AWA 450P miniature portable. The AWA set is 115mm wide x 115mm deep x 240mm high, while the Global is 145mm wide x 50mm deep x 95mm high. This means that the AWA set is 4.6 times the size of the Global, while the standard portable is nearly 19 times the size of the tiny Global.

Australian manufacturers such as Astor, AWA and Breville built these small sets for just a few years. They probably stopped making them because the batteries were relatively expensive and didn't last all that long, plus the performance of these radios left quite a bit to be desired.

By contrast, the performance limitations were not such a problem overseas, as AM broadcasting stations were much closer together than in Australia. The battery life would still have been a problem but affluent Americans didn't worry about that and the Japanese liked gimmicky sets, so the battery cost was not a major concern there either.

At the time, we were impressed at the way AWA, Astor and Breville managed to pack the necessary parts into the space available for their portable sets. This initially makes you wonder how the Japanese got all the parts and valves in the cabinet, along with a reasonable loop antenna and a set of batteries.

In fact, the Global is only marginally larger than the ubiquitous No.482, 45V battery of the 1950s and 1960s!

The answer is that most of the parts have been miniaturised to some extent. However, instead of using hearing-aid style valves as you might expect, the



Inside the Olympic #450 4-valve miniature receiver. The ferrite rod antenna is similar to that used later in transistor radios.



Removing the HT battery gives good access to the under-chassis parts in the Olympic #450. There's some chassis corrosion but the set is otherwise in good condition.



These 10 miniature valve portable radios are all owned by Australian collector Laurie Harris. They were sold only in Japan (where they were manufactured) and in the USA.

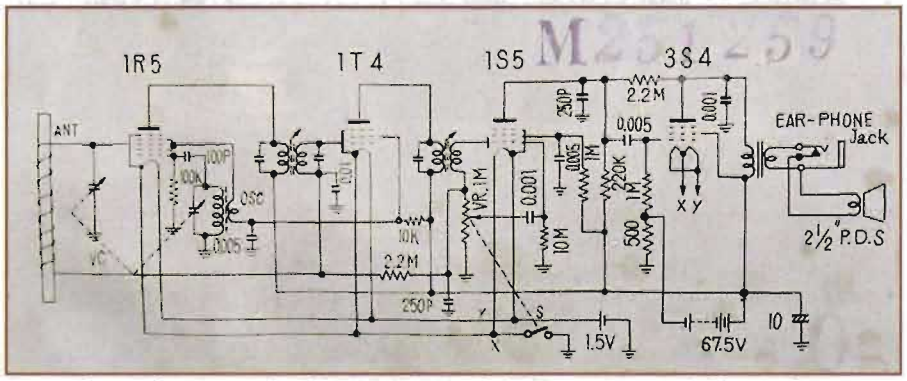


Fig.1: this is the circuit for the Harpers Model GK-501. It is a full superhet circuit with four valves: a 1R5 converter stage, a 1T4 IF amplifier, a 1S5 detector/AGC diode/audio amplifier and a 3S4 audio output stage.

Japanese manufacturers chose to use the normal miniature series valves, as mentioned earlier; ie, 1R5 converter, 1T4 intermediate frequency (IF) amplifier, 1S5 detector and first audio stage, and 3S4 audio output stage. In addition, the ferrite rod loop antennas used in the "larger" miniature receivers were of quite reasonable dimensions.

By contrast, the tuning gangs are miniature air-spaced types rather than the plastic film types used later in transistor receivers. The coils and transformers, although miniature, are not as small as those used later in transistor receivers, while the loudspeakers used were normal 50-75mm round units.

Battery life

Although parts miniaturisation was well done, shrinking the battery sizes meant that the battery life was severely reduced. In the Australian miniature portables, the 1.5V filament "A" battery was usually two D cells (950) in parallel. By contrast, the Japanese miniature sets use either a single 1.5V "D" cell or, in the smallest sets, a "C" cell.

In practice, a single "D" cell would last a little under half the time that two of these cells would working together, while a "C" cell would last perhaps 1/5th of the time that two D cells would. In fact, the life of a "C" cell may have been as little as five hours of continuous operation, while a single "D" cell would probably have lasted about 12 hours.

The 67.5V and 45V high-tension (B) batteries used would have had quite a short life too – probably much the same as the C-size cell. The smallest of these miniature batteries was around the size of three 216 batteries end-to-end.

These batteries were probably more energy dense than the Australian equivalents, the larger miniature batteries probably lasting about 15 hours and the smaller units no more than about five hours. Certainly, the owners of these sets would have soon become rather tired of buying and changing batteries.

The current drain in most units is about 250mA for the filaments and around 9mA for the HT. However, one unit (the Global) has a means of reducing the filament current to 150mA, as described later.

Miniature receivers

The 10 miniature portables owned by Laurie Harris are all shown in an accompanying photograph. The top row, starting at the left, shows the Fleetwood case, then the Fleetwood (one of the larger units) and the Global (the smallest).

In the second row (left to right) are the Olympic #450, the Standard "Muse" SR220E and the Crown PR530. Below these are a Zephyr RN7, a selection of miniature batteries as used in these sets and a Hilton 3672.

The bottom row houses a Continental, a Harpers GK501 and a Harpers GK301 which has the same chassis as the Crown PR530.

These sets all appear to have been predominantly for the American market. How many other makes and models appeared on the market is unknown. It is rather surprising that none (or very few) appear to have been imported into Australia.

The view inside

Several other photographs clearly show what these little receivers were like inside. The small Global would probably have been the worst per-



A selection of miniature valve portable radios and batteries at a recent HRSA display. The radios could easily be mistaken for the portable transistor radios that appeared a few years later.

former, with probably the shortest battery life. Close inspection shows that the components are laid out quite logically, with considerable thought given to keeping everything compact with little waste space between the parts.

The rod antenna for the Global is also quite small, so its performance would not have been outstanding when it came to sensitivity or audio output. It really is a "personal portable".

There are a couple of interesting design features in this set which are worth mentioning. The HT comes from a 45V miniature battery which would have a longer life than a similar-sized 67.5V battery. The filament battery is, however, only a "C"-size cell, so its life would be quite short. If the cell were a premium grade item, a life of perhaps 10 hours could be obtained but a generic standard quality item may only last around five hours or so.

However, this little set had one trick up its sleeve when it came to battery life. When an earpiece was connected, the plug open-circuited the filament line to the 3S4 which reduced the filament current drain to 150mA, at the same time removing the HT current drawn by this valve.

This meant that when the set was used with an earpiece, the life of the batteries was probably doubled.



Inside the Harpers GK501 miniature valve portable. The layout is similar to the other sets, with the parts all packed tightly together.

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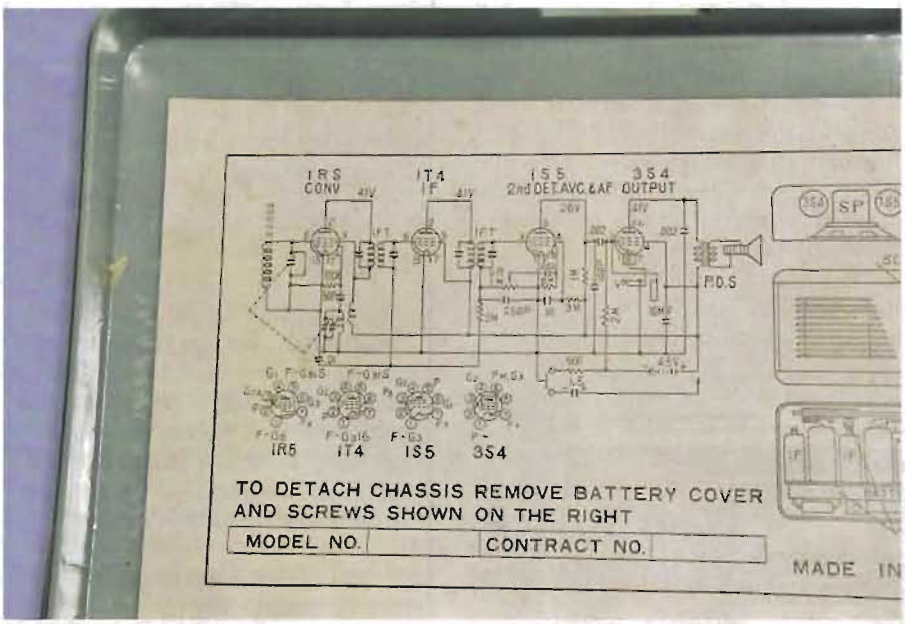
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The largest and the smallest compared: the Fleetwood (left) is the largest of the 4-valve miniature portables, while the Global (right) is the smallest.



A label affixed to the inside back of the Global miniature portable shows the circuit diagram and other information. The earpiece disconnects the filament supply to the output valve when it is plugged in, to reduce current drain.

By the way, the earpiece would have been a high-impedance crystal type. Crystal earpieces were common back in the 1960s but can be difficult to source today.

The Fleetwood is the largest of the sets and would probably be the best performer. There is a remarkable amount of room in the set for the valves and other components, along with room for a reasonably-sized 67.5V battery (around half the volume of a No.467 battery). The filament voltage comes from a single premium D cell.

The largish ferrite rod antenna sits behind the HT battery towards the front of the set. Unlike the previous set, the headphone socket is on the output side of the speaker transformer and all stages remain in operation when using an earpiece. However, the circuit trick used in the Global to reduce current drain when using an earpiece would have been a good idea in this set and in all the other sets.

Overall, this set would have been a much better performer than the Global and may have even been a better performer than the AWA and Astor 1940s equivalents. However, its battery life would have been much less.

Surprisingly, this receiver also appears to have provision for 110V mains input. However, from what Laurie and I could see, the 110V lead would have had a plug at both ends which would have been quite dangerous, if not potentially lethal, in use.

Another interesting receiver is the Olympic. The views under the chassis and in the back of the set reveal that it is remarkably easy to gain access to important items for servicing. In fact, the underchassis wiring, although tight, is not any harder to access for service than in many larger receivers.

The lack of suitable batteries has forced Laurie to make up batteries to power some of these sets. On the day

of my visit, only one radio had a set of useable batteries. The performance was quite satisfactory and is a tribute to the designers.

Conventional circuits

Some of the receivers have their circuits and other general information pasted inside the back cover. The circuits of all these sets are quite conventional. The only variation is the power consumption savings with the Global when it is used with an earpiece.

The Global receiver was of particular interest to me because of the extent of its miniaturisation and the use of only 45V for the HT. Its audio output would probably be somewhere around 100mW with a new battery.

The component count is also quite low, the set using just seven fixed resistors and eight fixed capacitors. All of the sets appear to have used padderless tuning capacitors.

Summary

These miniature 4-valve portables really are fascinating little receivers. The manufacturers did an excellent job in getting the best out of them, although they would have been mediocre performers in the Australian environment. However, in their intended market – ie, the USA – their performance would have been quite satisfactory.

These little sets really show how far the Japanese manufacturers were prepared to go to miniaturise their sets in the era before transistors took over. They would be a worthwhile addition to a vintage radio enthusiast's collection but being so rare, not many collectors will have the opportunity to own them. SC

Photo Gallery: Philips 1203 3-Valve TRF



RELEASED BY PHILIPS LAMPS (AUSTRALIA) LTD IN 1931, the model 1203 had a selling price of 24 pounds and 10 shillings which was many weeks wages at that time. The adverts described the piano-finished cabinet as representing the ultimate in consoles "at home in any home"

The set was a 3-valve TRF and the valve line-up was as follows: E442S detector, C443 audio output and 506 rectifier. Photo: Historical Radio Society of Australia, Inc.

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Headlight reminder for cars

I have just had an embarrassing situation in that the internal lights on my car were left on for three days, flattening the battery. This has cost me a new battery, a lot of lost time, plus the wrath of the other family member. So after a cursory examination of the "Headlight Reminder For Cars" kit (SILICON CHIP, August 2001) at my local Jaycar store, I purchased one.

However, I now believe it will not do what is required of it. I have three separate circuits in the car which need monitoring: headlights, parking lights and interior lights, as these are on separate switches, as well as the door switches.

The first two I can monitor by taking a feed off the instrument lights. I do not know about the third circuit but I wondered what would happen if I put a diode between the door switch circuit and the light circuit. Please advise (P. D., via email).

● A diode from the door switch and another from the interior light switch could be used to detect when any light is on. The direction (polarity) of the diodes depends on the car wiring.

If one side of the lamps is directly connected to the chassis, then the diodes connect with their anodes to the lamps where they are powered by 12V. The cathodes connect together and form the connection for the door switch input on the Headlight Reminder. In this case LK3 is out, LK4 is in and LK5 is out.

Conversely, if one side of the lamps is directly connected to 12V, the diodes are connected with their cathodes to the negative side of the lamps. The anodes form the connection to the Headlight Reminder and LK3 is in, LK4 is out and LK5 is out.

Extending the SC480's low-frequency response

I am using a pair of SC480 amplifier modules from the January & February 2003 issues of SILICON CHIP. I know that the SC480 module has excellent low-frequency response but I am hoping to improve the response at near DC to facilitate another mode of testing. I've built a vibration-testing platform and I am using the SC480s to drive the actuators.

Studying the circuit diagram, I can't find the components that are limiting the low frequency gain. Any help on this matter would be very much appreciated. (J. M., via email).

● Improving the bass response below the existing -1dB point at 14Hz is simple. Just increase the input 1µF BP capacitor to 2.2µF or 4.7µF. Similarly, increase the 47µF BP feedback capacitor to 100µF or 220µF.

Using the Guitar Jammer with a PC

I purchased and built your Guitar Jammer kit from the October 2000 issue and have used it with great success over the years.

I was wondering if it was possible to use the audio output from my PC's sound card instead of a CD player to mix with my guitar? I have a PC program called "Guitar Pro" and I would like to jam to that. Would the CD input resistor values need to be changed? Would it still work OK using a regulated 9V plugpack? (J. R., Deer Park, Vic).

● No changes are necessary to your Guitar Jammer. Any high level or line level signal can be used.

Multimedia amplifier and speakers

Some time ago, SILICON CHIP did a Multimedia Amplifier that fitted inside a computer. Would it be possible to use this externally, ie, not powered from the computer? My idea is to use the amplifier and two speakers, with the line inputs of the amplifier fed from

Battery Zapper Won't Check 6V Batteries

When I connect a 6V battery and use the Battery Condition option on the Deluxe Lead-Acid Battery Zapper (SILICON CHIP, May 2006), all the LEDs light up and stay on. The unit works fine on 12V and 24V batteries though.

I use deep-cycle 6V batteries (two in series for 12V), so the unit works fine on them (all LEDs light, then slowly go off when I press the button). However, a single 6V battery will keep all the LEDs lit.

Secondly, is it OK to use a conventional charger on a battery without the conventional charger going through the Battery Zapper? In other words, can I have the leads of the Zapper connected at the same time I have the leads from a conventional charger connected at the same time?

● We are not sure why your Deluxe Battery Zapper isn't working properly with single 6V batteries. Perhaps the 470µF 25V electro between pins 6 & 8 of IC5 is leaky and is pulling down the reference voltage for IC5, or the 1kΩ resistor in series with D12 is abnormally high in value – just enough to cause trouble when testing 6V batteries.

It's not a good idea to connect a charger directly to a battery when the zapper is connected to it and operating, because the charger can shunt the zapping pulses and prevent them "doing their work". That's why we incorporated inductor L3 into the zapper – to increase the effective AC impedance of the charger and prevent it from shunting the pulses.

a DVD, etc. (R. M., via email).

● It would be feasible to build the Multimedia Amplifier and Speakers (described in the October & November 1996 issues) as you suggest. However, a computer power supply would probably be the most economical way to supply them.

Ultrasonic leak tester for braking systems

I work as a diesel mechanic and because of acute hearing loss I am having problems detecting air leaks in the braking systems on trucks. I was wondering if you have ever published an article to detect air leaks or could you advise of another project that may be modified to do this?

Because of restricted access, the use of headphones is not really practical and I was thinking of something with a speaker type output. (H. H., Toowoomba, Qld).

● One possibility is to use an ultrasonic leak detector. This detects ultrasonic frequencies, such as the squeak emitted by a high-pressure leak, and shifts it down to the audible spectrum so you can hear it via headphones. Note that even this circuit concept is not practical with a loudspeaker. We published an Ultrasonic Eavesdropper project in the August 2006 issue.

Fuel Flow Sensors Wanted

A long time back, SILICON CHIP had an article on the Oztrip Car Computer. Do you know where I can get cheap petrol fuel flow sensors? I was thinking of building a PICAXE project with them. (K. W., via email).

● The Oztrip Car Computer was featured in the March & April 2000 issues.

We don't know of any cheap fuel-flow sensors. However, a liquid flow sensor suitable for petrol (10-bar maximum pressure) is available from Farnell (**www.farnellinone.com.au** – Cat 178-923) but is it not cheap at $360 plus GST. A possible alternative is the 560-121 at $157 plus GST. This is stated to be suitable for most liquids with a 20-bar maximum pressure.

Another, much cheaper, option to sense fuel flow is to monitor the duty cycle of the engine's fuel injectors as a guide to fuel usage. You would need to do tests to find the precise fuel flow with regard to duty cycle.

A further complication is that in some cars, each injector may need to be monitored if the duty cycle varies between cylinders.

Vintage car radio & Bluetooth CD player

I am restoring a car radio in a 1974 Rolls Royce Silver Shadow. It is connected to an 8-track cassette player which has controls for front & rear volume/tone control, etc. In my case, the equipment was top-of-the range German car audio at the time.

All the vintage car clubs are looking for a way to have the original equipment connected to a Bluetooth

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µVGA-PICASOMD1-UB	PICASO µVGA Base Board
GOLDELOX-MD1	Tiny OLED-LCD Graphics Controller with micro-SD
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Even if you're just an electronics dabbler, there's something here to interest you.

NB: Requires a computer with DVD reader to view – will not work on a standard audio/video DVD player

Use the handy order form on page 77 of this issue

Is Cathode Poisoning A Problem?

Regarding the Nixie Clock (SILICON CHIP, July & August 2007), I notice there is no provision for preventing poisoning of the unused cathodes. Initially, I did not see this as a problem as I thought it would be a simple matter to rotate the tubes occasionally but now I see that they are soldered in.

Most Nixie clock designs these days provide for cycling of the "unused" cathodes. The main reason for this, as I see it, is that if at some stage in the future, the seconds units digit was to fail (for example), it would allow one of the hour tubes to be swapped into that position. Of course this assumes all digits of the replacement are available and haven't been "poisoned". (L. W., via email).

● We put your question to the designer of the project, David Whitby, and this is his answer.

Cathode poisoning only occurs when minute amounts of material from a lit digit strike an adjacent unused (or hardly ever used) digit and build up on that unused digit over a long period of time, in the places where the two digits coincide. Where the required tube digits are being lit in cycles, even occasionally, the problem is minimal.

Frequently used digits, especially cycled digits, are not affected and the problem can only be seen on the usually unlit digit as faded areas and only when it is finally lit.

In the NX14 Nixie Clock, the digits which will never be used are digits 6-9 in the tens of minutes and tens of seconds tubes and all digits except 1 in the tens of hours tube. Since these digits are never lit, the effect will never be seen, so why worry?

Some Nixie clock designs now purport to have circuits to minimise cathode poisoning by occasional fast cycling through the digits (we only need to cycle through the used clock digits, not the unused ones which are never seen). This is simple to do on the NX14 Nixie Clock – just cycle it through all the clock digits by holding in the fast time-set button for a few minutes every now and then. But really, it is not a problem.

or wired device which will allow a discrete CD player to be connected to the existing system.

Presumably if a Bluetooth receiver could be connected in-line somewhere, at least to the speakers (perhaps with a separate amplifier?), an iPod and all the other gizmos would work with it as well. (J. M., Khancoban, NSW).

● Provided your car radio has an FM stereo tuner, the easiest way is to connect the audio signals from a CD player to an FM stereo transmitter. Have a look at our "FM Minimitter" described in the April 2001 issue.

Query on preamplifier board

I am interested in building the 20W Class-A Stereo Amplifier recently described in SILICON CHIP. On page 20 of the June edition, the photo shows a preamp board at the front which is quite different to that shown on page 24 of the August issue. Do I presume that the component shown in June is a module for the power amp only and that details will be published at a later date? I have a very good valve preamp, so I would only be requiring the kit as purely a power amplifier. (K. P., via email).

● We had to discard the original preamplifier shown in the June 2007 issue – it just did not perform well enough. However, you can build the amplifier without a preamplifier, as was noted in the final article in the September 2007 issue.

By the way, using a valve preamplifier will significantly degrade the sound quality of the amplifier.

Water level indicator query

Regarding the Tank Water Level Indicator in SILICON CHIP, July 2007), I was wondering how far the water tank can be from the electronic unit. If the figure-8 wire has to be extended to reach from the tank to a room in a house, what type of wire can I use? I assume that a Nylon tube with 2.5mm internal diameter is for the wire to go into and then be suspended vertically into the water? (J. F., via email).

● This is not something we have tested but it should be good for at least 20 metres of cable. Just use general-purpose figure-8 mains cable.

Battery checker for motor bike

I have a 1985 Yamaha motorcycle. It has a battery level sensor which plugs into the third battery cap, which in essence, is 6V DC.

My problem is that the new sealed batteries don't have caps. If I use a zener diode circuit to fool the input with 6V DC, how exactly do it? It most likely only needs a couple of milliamps. Any help will be greatly appreciated. (B. S., Hatfield, Pa, USA).

● A zener diode won't do the job. You need a voltage divider across the battery (such as two 1kΩ resistors in series) and then feed the battery sensor circuit from the midpoint of the two resistors. The voltage divider should only be switched across the battery when the ignition is turned on, to avoid unnecessary current drain.

24V variant of Voltage Switch

Can you please advise the component changes required to enable your 12V Voltage Switch to operate at 24V. It was featured in your book, "Performance Electronics For Cars". (N. S., Kaitaia, NZ).

● There are a number of changes required:

(1) Change the relay to a 24V DPDT type (eg, Jaycar SY-4053).

(2) Change both ZD1 and ZD2 to 33V 1W (1N4752).

(3) Change the two 100µF 16V and the 10µF 16V electrolytic capacitors to 100µF 35V and 10µF 35V (the 10µF capacitor at REG1's output can remain a 16V type).

(4) Change the 1MΩ input resistor to 2.2MΩ (0.25W).

(5) Change the 1.8kΩ resistor for LED1 to 3.9kΩ (0.5W).

How to eliminate DC plugpacks

I've noticed that many people have multiple 240VAC plugpacks in the

one location so I thought I'd suggest a replacement to be featured in SILICON CHIP. For example, at my computer I have eight such plugpacks of different voltages (phone, router, switch, printer, ext speakers, VOIP adaptor, etc) so would dearly love to have just one unit that could power all this equipment. It might even save in standby power costs.

Of course, each output would have to be voltage and polarity switchable but I figure that wouldn't be too hard to manage. (T. S., Devonport, Tas).

● We published a project along these lines in December 1999 – the PC Powerhouse. It derived rails of 5V, 12V, 6V and 9V and took the form of a card which plugged into your computer's motherboard.

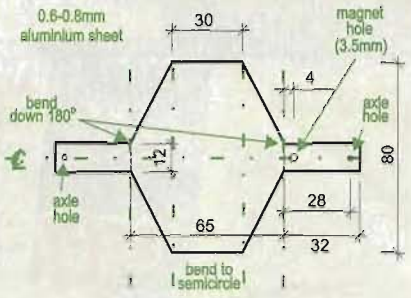
Query on the SMS Controller

I have assembled the SMS Controller kit (SILICON CHIP, October & November 2004) but I find that the commands to switch the eight outputs are not working. I get a positive signal on the selected input pins of IC4 (ULN2803) but no signal on the corresponding output pins.

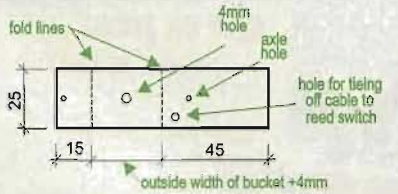
I suspect that pin 10 "COM" should be connected via the zener diode 36V ZD7 to +12V DC, not 0V. Can you comment please? (F. J., via email).

● Both the circuit and the wiring diagram of this project are correct, as published. Note that if you have nothing connected to the output pins, there will be no voltage there. Each output is the collector of a transistor and if it is not connected to anything, it does nothing. For suggested output configurations, see Fig.6. SC

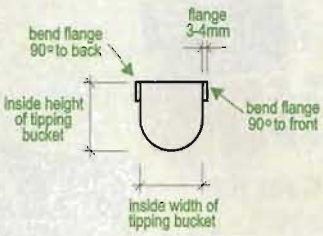
Notes & Errata



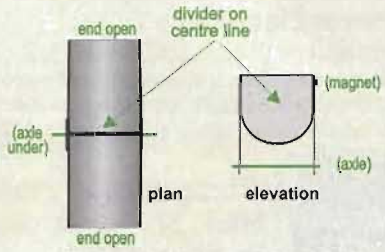
TIPPING BUCKET TEMPLATE



TIPPING BUCKET BRACKET TEMPLATE



TIPPING BUCKET DIVIDER TEMPLATE



TIPPING BUCKET ASSEMBLED

Fig.1: follow this diagram to make the tipping bucket assembly for the Simple Data Logging Weather Station.

Simple Data Logging Weather Station, September & October 2007: the diagram giving details of the tipping bucket assembly was omitted from the second article. Fig.1 (above) shows the missing diagram.

Versatile 4-Input Mixer, June 2007: the PC board pattern as published (01106071.PCB) has the connections reversed for input connectors CON1-CON4 and the reversed connections were also present in the board overlay diagram on page 66. A corrected version of the board pattern has been sent to manufacturers. Operation can be achieved with boards etched from the original pattern by removing the contact clips from CON1-CON4 and fitting them on the opposite sides of the connectors.

Programmable Ignition for Cars, March, April & May 2007: the link **http://www.pgmfi.org/twiki/bin/view/Library/MapSensor** giving pinout information on the MAP sensors is now unavailable. The information can now be found at: **http://web.archive.org/web/20050906201309/www.pgmfi.org/twiki/bin/view/Library/MapSensor**

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. Devices or circuits described in SILICON CHIP may be covered by patents. SILICON CHIP disclaims any liability for the infringement of such patents by the manufacturing or selling of any such equipment. SILICON CHIP also disclaims any liability for projects which are used in such a way as to infringe relevant government regulations and by-laws.

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