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The History of Videotape

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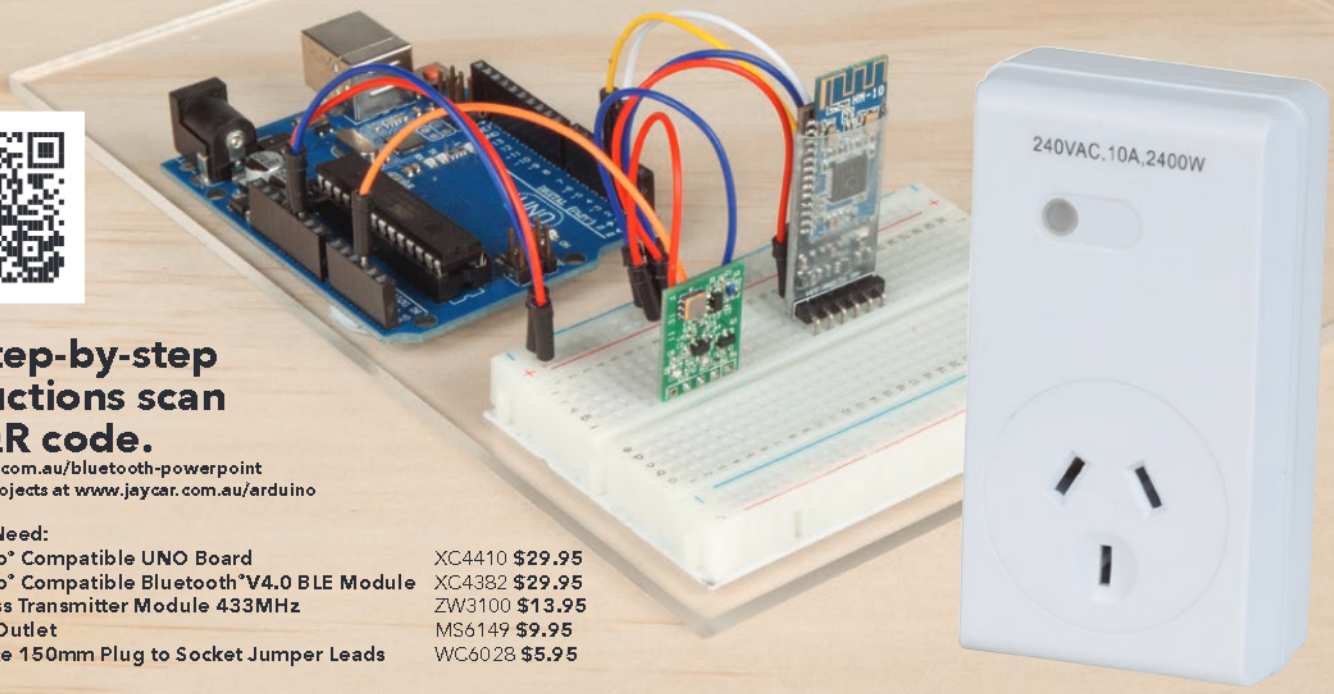

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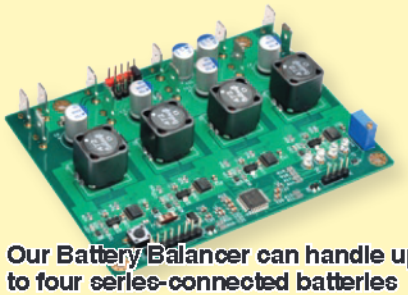
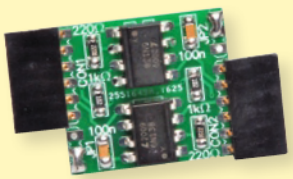
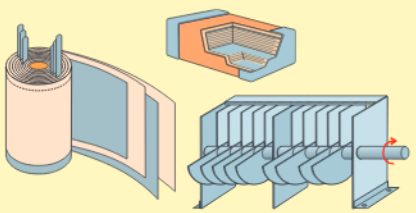


Our Battery Balancer can handle up to four series-connected batteries per unit, and suits most common battery types. It can handle batteries or cells from 2.5-15V, with a charging current up to 50A – Page 21

A look at the beginnings of videotape recording, starting with systems like the BBC's Vera and Ampex's quadruplex VR-1000A – Page 44



This Mini Isolated Serial Link can be used with our Battery Balancer to manage even more batteries or cells. But it's also useful any time you need to send isolated signals between two boards – Page 68



Capacitors come in all shapes and sizes, and because of this it is confusing trying to pick one. So we've detailed some of the important aspects of capacitors, such as dielectrics etc – Page 72

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Editorial Viewpoint

Older devices involved creative engineering

While I am not particularly into 'retro' electronics like vintage radios, vintage computers etc, I find some of the articles on these topics quite interesting. You can tell that the designers of these devices had to be very clever to use the meagre resources available to them to solve some quite tricky problems.

Take the four-part series of articles on Videotape Recording starting in this issue (on page 44). Younger readers (say, those under 30) probably don't remember much about videotape.

I was young when the VHS/Beta 'war' was raging, and by the time I was old enough to use a VCR, VHS had taken over. I remember the machines being quite finicky, and they would sometimes go wrong (in the worst case, 'eating' a tape) for no apparent reason. But for the most part, they worked quite well, albeit with video quality that I now consider awful.

Having read the articles mentioned above, I realise now how complicated the loading systems were. With so many parts having to move in concert, in a device produced at a relatively low cost, it's no wonder they went wrong sometimes! So my hat's off to the engineers that designed those mechanisms; it must have been a lot of effort to get them to work reliably.

Another thing that's apparent in reading these articles is how much 'outside-the-box' thinking went into developing the core technologies enabling video recording, especially helical scan. It seems kind of obvious in retrospect, but it took lots of smart people many years to develop a device which could record an hour or two of video on a reasonably compact, easy-to-use and low-cost cassette.

It was an incremental, evolutionary process too, as is so common with technological advancements. There were several generations of video recording between the first useful machines (Ampex quadruplex) and the final 'sorted' generation of consumer machines, which I guess you could say was hifi VHS.

Each generation made certain improvements, but often retaining shortcomings that would be addressed in future. It helped that the later semiconductor technology allowed more signal processing to be crammed into smaller machines.

I guess my point is that you might enjoy those articles even if you're too young to remember the technology being described, and aren't terribly interested in the topics themselves. You might still learn something and enjoy the journey of discovery.

I can make a similar comment about the article on Fetrons; they are interesting because they give you a glimpse of the transitional period when valves were being phased out in favour of transistors. Again, it took innovative engineering to make transistors operate like valves.

Also, consider some of the techniques described in our Vintage Radio columns like reflexing, combined mixers/oscillators and some of the design choices in early transistor sets. Even if you aren't really into radio, you can appreciate the amount of work that went into getting the most performance out of a few (then costly) active devices.

That's the sort of engineering that I really appreciate, and I think the people who came up with those ideas must have done a lot of brainstorming to reach those 'Eureka!' moments.

Nicholas Vinen

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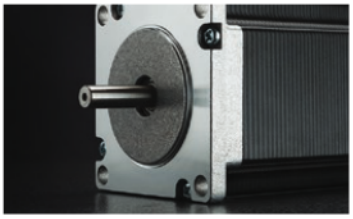
Mixed-Signal MCUs Redefined

Smaller Packages and Upgraded Peripherals for PIC32MK



PIC32MK is a performance-intensive 32-bit Microcontroller (MCU) family with seamlessly integrated analog. Expanding on the lineup of 100- and 64-pin packages, PIC32MK is also now available in a space-saving 48-pin QFN, measuring just 6 x 6 mm for size critical mixed-signal applications.

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Preview only.

HOARDING: URBAN ELECTRONIC ARCHAEOLOGY

Don't let this happen to you! If you have a large collection of anything (including electronics), you must have a succession plan. It would also be a good idea for you to periodically 'clean house' and allow collectors – young and old – to pick up items you don't absolutely need.

By Dr David Maddison

I recently had the task of sorting through an extensive collection of electronic items which were part of a deceased estate. As I had been a long-time friend of the deceased, I was permitted to 'rescue' any interesting items I found, as they would otherwise end up in a landfill.

There were a vast number of items in the hoard, but before I had a chance to go through it, drug addicts and other thieves were reported to have broken in and taken anything that could be sold on the street.

What remained (see opposite for an example) was of little-to-no monetary value, but still of interest to electronic enthusiasts. In fact, by taking items away, I was probably saving the estate the cost of disposing of them.

The collection was accumulated over a lifetime, mostly being purchased from second-hand markets, one being the well-known Laverton Market in Leakes Rd, Laverton, Vic.

Many of the other items seem to have been discarded by industrial or government laboratories.

Most of the items were filthy, with 50 or so years of accumulated dust and grime, plus damage from being thrown into a heap rather than stacked correctly. To get the items shown here into presentable condition required extensive cleaning

Unlike some hoards, I did not find much actual rubbish, just a lot of 'stuff' in several general categories:

1) **A staggering number of generic desktop PCs**. These were mostly from the 1990s and 2000s, and not collectible computers (such as original IBM, Apple or Commodore PCs might be). He had told me that he usually paid $2-5 each for these at the weekend markets.
2) **Huge numbers of CDs and floppy disks**, mostly for computer games, likely never used.
3) **Many car parts**, mostly incomplete or used, mostly Holden-related and including at least two 'grey motors' and one 'red motor'.
4) **Lots of scrap metal**.
5) **Numerous pieces of electronic or mechanical equipment**, usually incomplete or broken, in various states of disassembly with components missing or, in the case of many electrical or electronic items, with the power cords cut off. This is likely because it is illegal in Victoria to sell electrical items without an electrical safety test, and for the low value of many items, that is not worthwhile.
6) **Many broken items**, as items covered the floor nearly everywhere. Apart from a few 'goat tracks' with limited visibility of the floor, mostly one had to walk on these items to move around the house. If they weren't broken when acquired, they soon would be. (Some rooms were unreachable due to items stacked floor to ceiling).

The full extent and composition of the hoard is not known at the time of writing, because what was recovered and presented here is only what was obvious and at the surface level. In many areas, the hoard was a metre or more thick.

A variety of older electronic items I found were handmade for various scientific or technical purposes. Back in the day, it was common for large government, university and com-

mercial laboratories to make their own equipment as it wasn't always commercially available, or it would take too long to order it from overseas.

The items I recovered represent an interesting cross-section of electronics for virtually the whole of the twentieth century. The collection of articles presented here also includes items he gave me while he was alive.

Where I found multiple similar items, I will show the Australian-made item if there is one.

Postscript

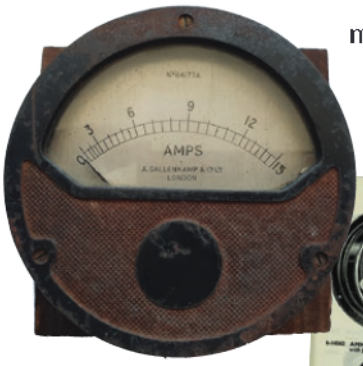
Although my friend was known by work colleagues to be brilliant, when he passed away, there were no funeral arrangements.

So besides showing some interesting items, this article also serves as something of a memorial or tribute to his life.

Appropriately for a collector of electronics, his initials were A. C.

Just a small part of what I was faced with . . . after drug addicts and thieves had already gone through it.

Vintage Gallenkamp switchboard ammeter (1910s)

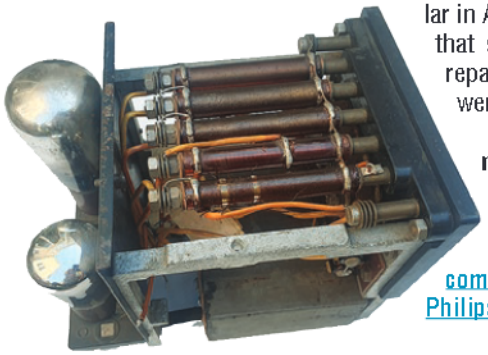


I found this Gallenkamp ammeter, estimated to be made around 1910, based on a very similar one I found in a catalog (see below). It was found half-immersed in water.

Philips valve radio 'battery eliminator' (1920s)

Valve radio batteries were expensive. These devices replaced two of the three battery types (the "B" and "C" batteries) with a mains supply. The technology at that time made it difficult to eliminate the "A" battery.

The one I found is a Philips 3003, made in Holland and very popular in Australia. It appears that somebody tried to repair it as many wires were disconnected.



For more information on this device, including a circuit diagram, see www.tuberadio.com/robinson/museum/Philips_3003/

Ormond variable condenser (capacitor) (1920s)

This was in a pile of rubbish, but it caught my attention because it had screw terminals. I measured its maximum capacitance as 450pF and determined it to be from the UK brand Ormond, and almost certainly the No. 3 model.

It featured "S.L.F." or "straight-line frequency". This meant that through the rotation of the dial, the corresponding frequencies would be linearly proportional to the dial position.

According to Radio Retailing magazine of December 1925, this "improves the tuning of a set and has been developed to meet conditions which were becoming almost intolerable, namely, the crowding of the stations in the lower part of the present broadcast range".

Headphone and headphone parts (1920s to 1940s)

The oldest such item I found was made by Brandes Ltd, London, and marked "superior matched tone". It is one driver from a pair of headphones. According to radiomuseum.org, this item dates from approximately 1924-1932. It is marked "BBC" (probably not the broadcaster) and "Made in England". Its nominal impedance is 1000Ω.

I also found a Brunet & Cie driver from their Casques et Écouteurs Type F model, dated around 1924 (according to radiomuseum.org). It was available with an impedance of either 500Ω or 2000Ω.

Another was a complete set of Australian-made Q-Plus brand headphones. I could not find any information online about them, but Q-Plus was an Australian manufacturer operating from 1947 to at least 1965.

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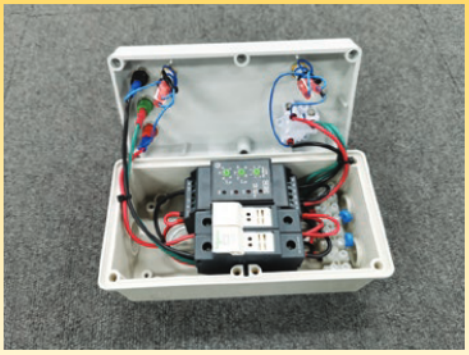

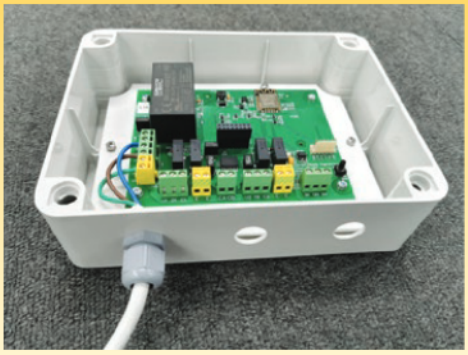

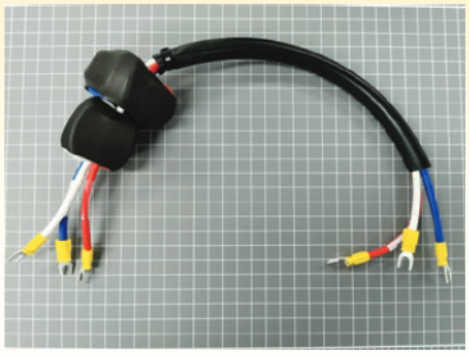

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Care for your rechargeable batteries. . .

High-current Battery Balancer

Part 1 - by Duraid Madina

Properly balancing batteries is critical for a long life, especially if they are lithium-based rechargeable types. But many balancers are inefficient, as they dump excess charge for a given cell, restricting how fast you can charge the batteries and wasting power. Not this one – it redirects that extra charge into other cells, so you can charge fast with little heat or waste!

Most rechargeable batteries consist of an array of nominally identical cells, connected in series, parallel or series/parallel to meet particular voltage, current, and capacity requirements.

Batteries with many series-connected cells often only expose the connections at the extreme ends.

For example, a typical lead-acid car battery has six cells (2V x 6 = 12V) but only two terminals.

To charge such a battery, we apply a higher voltage than the total of all the cells across those two terminals, and current flows through all six cells, increasing their state of charge.

But there is no guarantee that each cell starts with an identical voltage, and despite their identical construction, cell capacity can vary, especially as the battery ages.

This is not a big problem with car batteries because lead-acid cells tolerate slight overcharging well. By overcharging the battery a little, cells with a lower charge get a chance to 'catch up' to the others, while the most highly charged cells dissipate the charging current as heat.

Despite this, large lead-acid battery banks (as might be used in a renewable energy installation) will last longer if they are kept balanced. In this case, you might have several batteries in series, so not only do you need to be concerned about inter-cell balancing within a given battery, you also need to consider balancing the charge between batteries.

The fact that you might be using batteries with different ages and possibly even from different manufacturers makes this even more critical.

Then there is the case of lithium-ion and similar rechargeable cells. There is a great variety of lithium chemistries around, but many of them do not tolerate overcharging. They also can be easily damaged by over-discharging.

So keeping lithium rechargeable batteries balanced is even more crucial.

Since this Balancer can handle cell voltages as low as 3V and as high as 15V, it is suitable for a wide range of balancing tasks, including balancing the cells within a lithium-ion battery, or balancing individual lithium-ion or lead-acid batteries.

Each Balancer can handle up to four cells (or groups of cells) or batteries, and you can combine multiple balancers for larger installations.

Avoiding cell damage

One conservative option would be to immediately stop charging as soon as any cell reached its maximum permissible voltage, but that would leave the remainder of the cells not quite fully charged.

Left unchecked, what might start as

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Preview only.

Not quite vintage radio . . . or is it?

by Dr Hugo Holden

The Fetron . . .

and the one and only all-Fetron radio

You would probably be aware that there are some similarities between valves (aka vacuum tubes) and field-effect transistors, or FETs. You may also know that some people have created valve-equivalent devices based on FETs.
But did you know that there were commercially-made semiconductor-based triode and pentode equivalents known as "Fetrons"?
I am fascinated by these, so I built a superhet using little else.

The Fetron, a unique combination of N-channel Junction Field Effect Transistors (JFETs), using the Cascode configuration, was a product of research and development in the Aerospace and Avionics industry (by the Teledyne Company in the USA) in the early 1970s.

They were built primarily as a plug-in valve or solid-state pentode replacement, although triode equivalents were also made.

The basic idea behind the Fetron was to have the electrical properties of a pentode, but no microphony and no heater power consumption, along with the other advantages of semiconductors: greater efficiency and reliability, with lower noise and higher gain.

Fetrons usually had a much higher amplification factor than the valve they replaced. Teledyne also produced a range of semiconductor devices such as high-voltage Junction FETs and they still produce beyond excellent-quality miniature RF relays.

Every Teledyne product I have inspected and used has always impressed me with its innovative nature, outstanding manufacturing quality, excellent physical appearance and electrical performance.

Because of this, I decided to engineer a multi-band radio composed of entirely Fetrons, powered by a single 90V battery or DC supply, and incorporating some of my other favourite Teledyne devices.

Replacing valves with semiconductors

The idea of replacing a valve with a plug-in transistor substitute has occurred to many people since the invention of the transistor.

Although there are mathematical models for transistors as voltage-to-current control devices, fundamentally, they are current-to-current control devices.

Reproduced rather significantly larger than life size, this is the TS6AK5 used in the Fetron Receiver. The type number is designed to show its equivalence to the 6AK5 valve.

I know that some people disagree with this (for example, audio guru Douglas Self), but it is generally accepted to be true.

In most instances, the input (base-emitter) current controls the output (collector-emitter) current.

Valves, on the other hand, are voltage-to-current control devices or transconductance amplifiers, where usually the grid-to-cathode voltage controls the anode-to-cathode current.

Transistors in the grounded-emitter configuration have a much lower input resistance than valves in the grounded-cathode configuration.

When high-voltage JFETs arrived on the scene, they were possible substitutes for the triode valve. They had a similar transfer function of gate voltage versus drain current, compared to grid voltage versus anode current for the triode. Also, JFETs have a similarly high input impedance to a valve.

In the grounded-source or grounded-cathode circuit, both the JFET and the triode are influenced by the effective amplification of the drain-to-gate (or anode-to-grid) capacitance – known as the Miller effect.

This capacitance, which is intrinsic to the device, is multiplied by its amplification factor. This limits the high-frequency response and results in significant input to output feedback as the operating frequency increases.

In triode circuits, if a tuned circuit with a similar resonant frequency is placed in both the grid and the anode circuit, oscillations occur due to the feedback capacitance and the two resonant circuits exchanging energy with each other.

Historically, the Miller capacitance problem was solved with an added neutralisation capacitor feeding back an out-of-phase signal from a coil extension on the anode resonant circuit to the grid (or to the base in a transistor circuit) via a small adjustable capacitor.

In early transistor radios, intermediate frequency (IF) amplifiers using devices such as the OC45, which had a sizeable internal feedback capacitance, required neutralisation.

Later, better transistors such as the OC169, AF117 or AF127 had a much lower feedback capacitance and didn't require neutralising in 455kHz IF stages.

In vintage TRF radios based on triode valves, the added neutralising capacitor was called a Neutrodon and

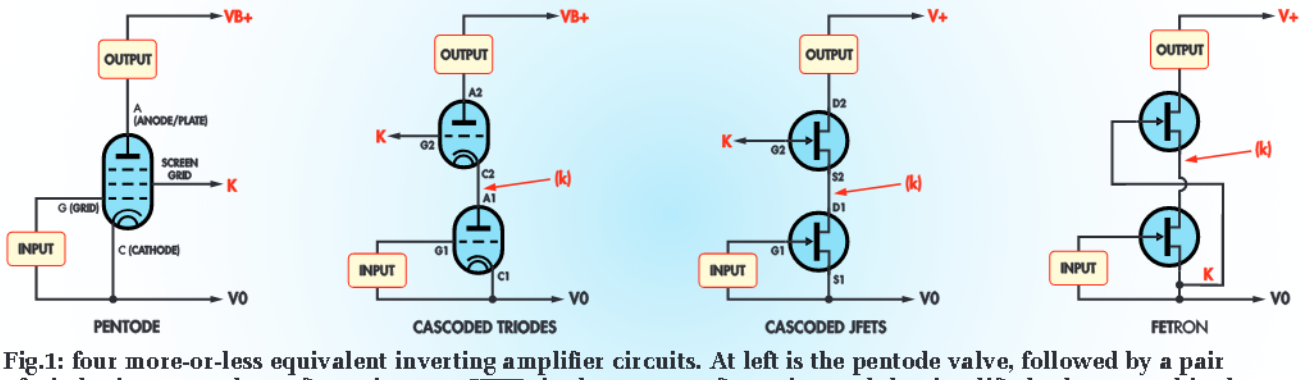

Fig.1: four more-or-less equivalent inverting amplifier circuits. At left is the pentode valve, followed by a pair of triodes in a cascode configuration, two JFETs in the same configuration and the simplified scheme used in the Fetron (which requires specific JFET characteristics).

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The History of Videotape – part 1
Quadruplex

By Ian Batty, Andre Switzer & Rod Humphris

Analog videotape is now obsolete. But it was state-of-the-art for many decades, and during that time, a video recorder was arguably the most advanced piece of electronic equipment in many homes. The history of video recording is quite fascinating, and this series of articles provides an in-depth explanation of how it came about and changed over the years.

www.historyofrecording.com/ampexvrx1000aniv.html

Audiotape recording and playback predate videotape, with early magnetic recording of audio demonstrated in 1898. Oxide tape was invented in Germany in 1928. By the time serious work on videotape recording started in the 1950s, audiotape was already widely used.

Audiotape use amplitude-based recording; a stronger signal creates proportionally stronger magnetic patterns on the tape. Audio signals are in the frequency range of 20Hz to 20kHz, a range of ten octaves or three decades. This is not especially difficult to achieve with magnetic tape.

Videotape, however, needs to cover the range of 60Hz to at least 4.2MHz for the US NTSC standard, or 50Hz to 5MHz for CCIR/PAL (see Fig.1). This is a range approaching 17 octaves. That's a much bigger challenge.

On playback, tape head output doubles for every doubling in frequency (ie, output increases at 6dB/octave).

Let's say that we can get away with a video signal that has a signal-to-noise ratio (SNR) of 40dB. From 50Hz to 5MHz, the signal ratio due to the 6dB/octave effect is 100dB! That means that our tape system SNR needs to be at least 140dB (Fig.2). That is simply not possible. So video signals cannot be recorded and played back using conventional amplitude recording.

Another reason why amplitude recording cannot be used for video is that any tiny variations in tape-to-head contact (dropouts) would severely affect the replayed picture (Fig.3). Variations in the tape's oxide layer would also cause major visual disruptions, especially if the signal level falls and the synchronising signals cannot be detected.

Tape-to-head speeds

Tape systems work well up to a frequency where the wavelength of the recorded magnetic pattern approaches the width of the tape head's magnetic

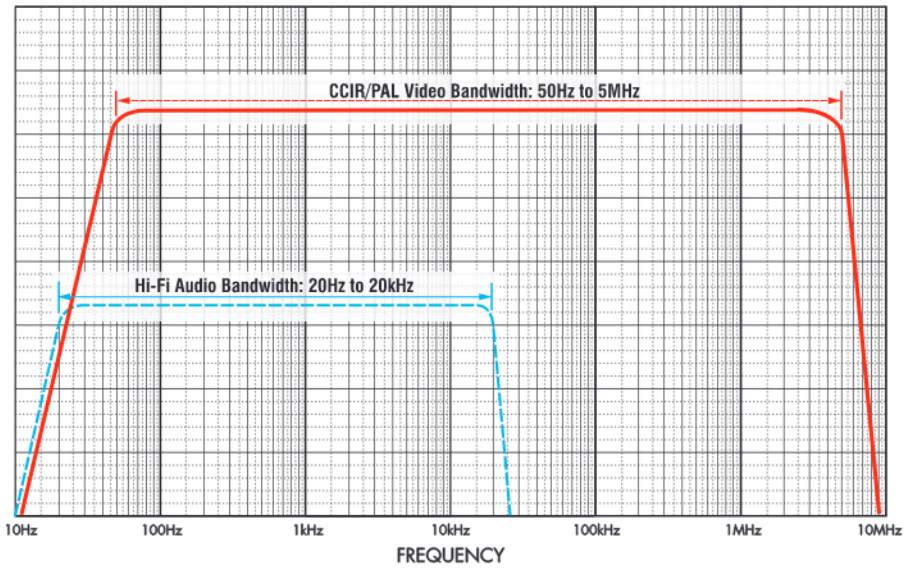

Fig.1: the recording bandwidth needed for a direct (linear) analog transcription of standard audio and video (PAL) signals. The horizontal axis is logarithmic; video covers 16.5 octaves (five decades) while audio covers 10 octaves (three decades).

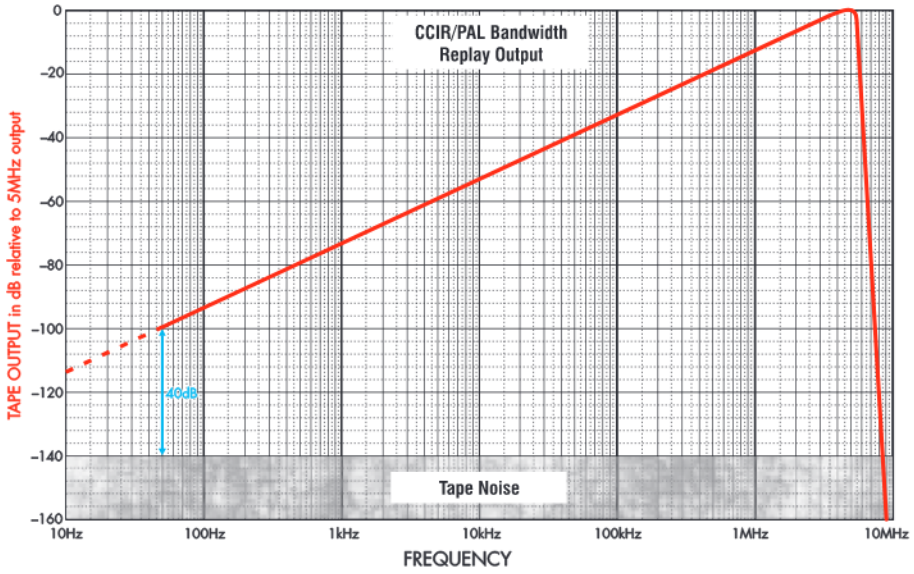

Fig.2: the signal from the tape head increases by 6dB for every doubling in frequency. This shows the impossibility of recording a video signal directly to tape, since to avoid saturation at 5MHz and signals below 50Hz being lost in the noise, the system would need an impossibly high dynamic range of 140dB.

The BBC's Video Electronic Recording Apparatus (VERA) was an attempt to record video onto tape in a similar manner to audio. It used stationary heads and a very high tape speed, necessitating huge tape reels. Despite their size, each reel only lasted 15 minutes! *Source:* www.vtoldboys.com

Ampex's Harold Lindsay (left) and Alexander M. Poniatoff (right) with the well-regarded Ampex 200 audiotape recorder. *Source:* www.historyofrecording.com

gap. At precisely one wavelength, the signal on one side of the head has the same amplitude and polarity as that on the other side. With no difference in the magnetic field, there is no output from the head.

So the combination of head gap width and tape speed determines the frequency at which head output falls to zero, and thus the maximum recordable frequency.

For the NTSC limit of 4.2MHz and a practical head gap of only 2.5µm, the required tape speed is 21 metres/sec ($2 \times 2.5 \times 10^{-6} \times 4.2 \times 10^{6} \times 10^{3}$). That's the entire length of an old-fashioned 2400 foot/731m reel in about 35 seconds! It's worse for the CCIR/PAL bandwidth of 5MHz, needing a tape speed of 25m/s, giving a reel playtime under 30 seconds. So it is not practical to use linear tape recording for video recording.

VERA

Despite all these apparent problems, some hardy folks did give amplitude recording a try. The BBC's Video Electronic Recording Apparatus (VERA) from 1952 took on the challenge, using stationary heads and a very high tape speed.

Unable to accommodate the required 405-line standard's bandwidth of 3MHz with amplitude recording, Dr Peter Axon's team ingeniously split the entire signal into three bands.

Band A contained signals 50Hz~100 kHz (including synchronising signals), frequency modulated onto a 1MHz carrier. Band B contained signals 100kHz~3MHz using amplitude modulation. Band C frequency-modulated the audio signal onto a 250kHz carrier.

Splitting the video bandwidth did allow the 405-line bandwidth of 3MHz to be accommodated, and demonstrated the principle of recording video on tape.

VERA's development lasted until 1956, by which time US company

...continued on page 48

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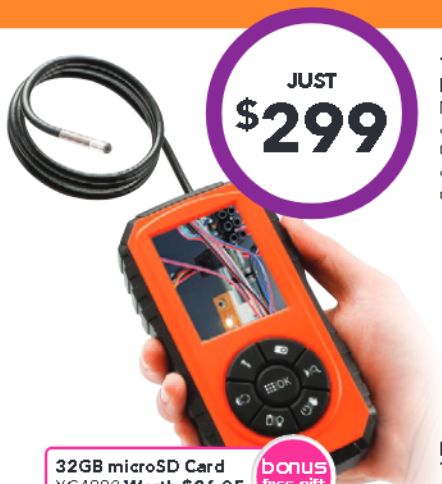

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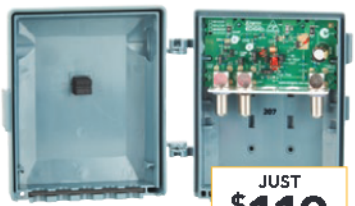

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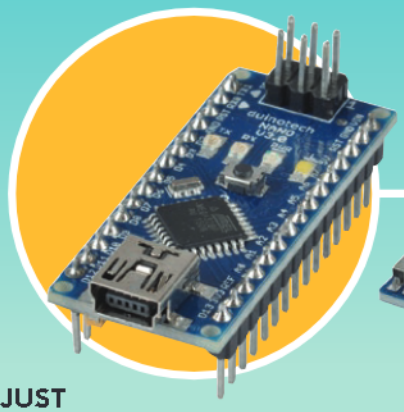

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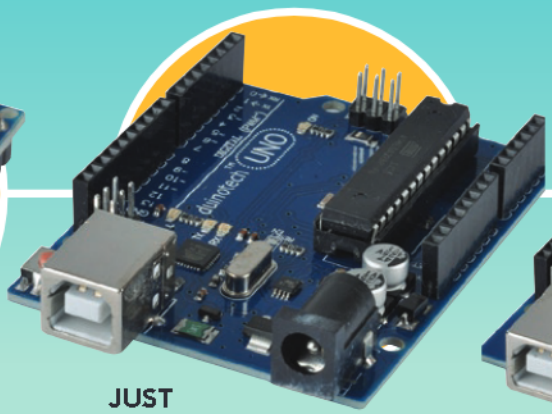

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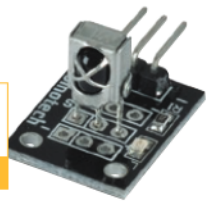

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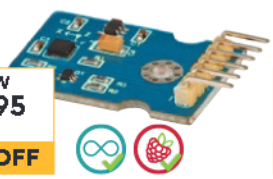

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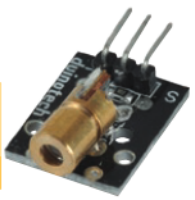

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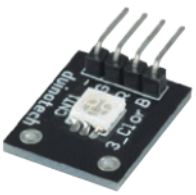

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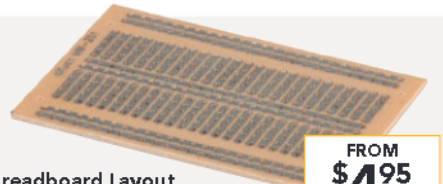

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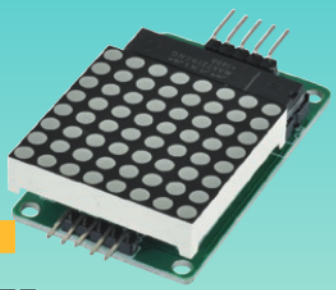

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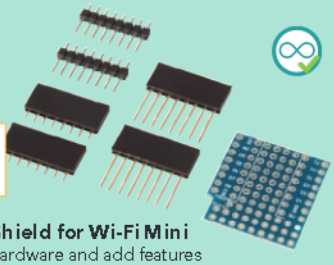

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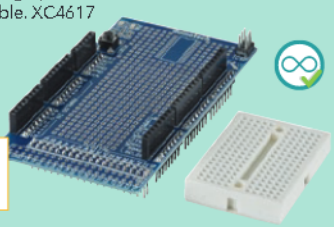

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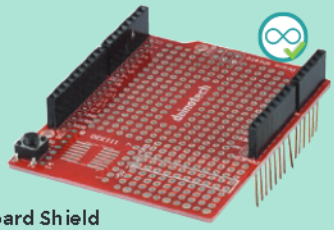

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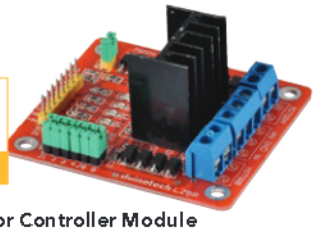

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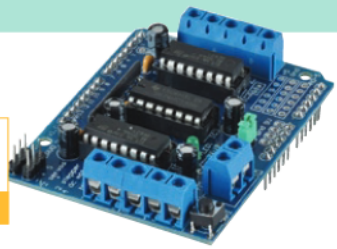

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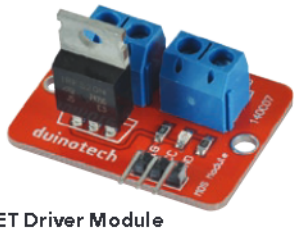

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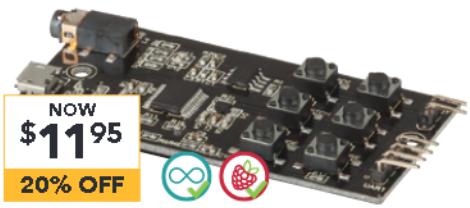

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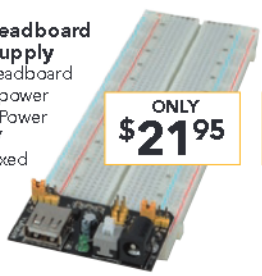

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SERVICEMAN'S LOG

If it isn't one thing, it's another

Dave Thompson

Sometimes, even when there are no customers lining up, work comes along anyway. It isn't always welcome, but when your tools go down, you have to fix them. It doesn't help that I'm afflicted with the Serviceman's Curse, so I'm allergic to paying for replacement tools when it's possible to (uneconomically) fix them!

Over the past year, plenty of local businesses have folded; there simply isn't the customer traffic to keep the doors open any more due to lockdowns and general economic malaise.

While our overall revenue has dropped, as you would expect with a lot less work coming in, the silver lining is that I finally have some free time to get onto those little jobs that I'd been putting off.

Those of you who live the rock and roll life of a serviceman know that sometimes things don't go according to plan. An anticipated five-minute job can easily turn into a two-day mission in the flash of a shorted battery connector or a clumsily-placed screwdriver. That sort of thing doesn't happen to me, of course! But I do hear rumours that it happens to other, less-careful people.

The first small job created itself when I went to use my soldering station, and the pencil was still cold 10 minutes after I switched it on. The astute among you will know soldering irons are meant to be hot, so the fact that I could hold on to the wrong end of it without being burnt told me that something was up!

Items Covered This Month

- It's always the other thing
- Coin counter repair
- Alternative security systems
- LED rose garden repair
- Electric fence energiser repair

*Dave Thompson runs PC Anytime in Christchurch, NZ.

Website: www.pcanytime.co.nz
Email: dave@pcanytime.co.nz

The pencil connects to the soldering station using one of those multi-pin screw-on plugs, sometimes called a GX-16 series connector. I removed and re-connected it, and it seemed sound, so I guessed that the pencil's element had gone open-circuit.

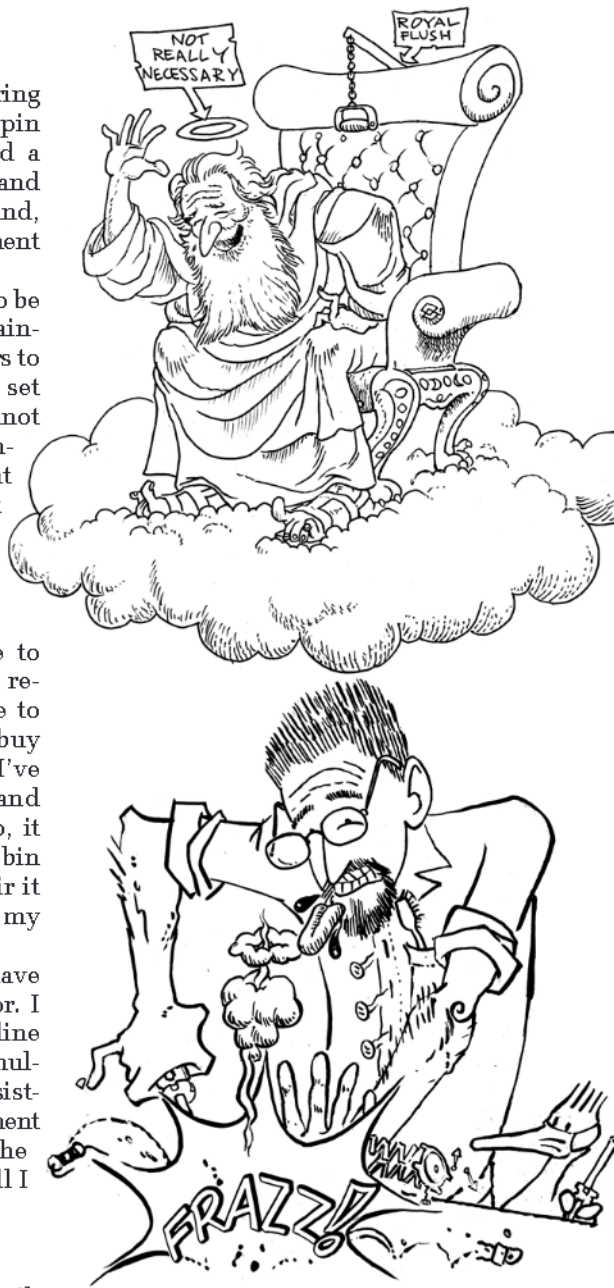
Confirming this theory proved to be more difficult than I imagined, mainly because the pencil itself appears to be a moulded unit. Everything is set into it at manufacture, and it cannot be disassembled to reveal the innards. The cable stress reliever at the bottom can be prised out, but the element appears to have no means of being removed, other than by cutting into the pencil's plastic body.

This makes them inexpensive to manufacture, but not great for repairs. I think they expect people to throw away the dead pencil and buy a new one. The problem is that I've used this pencil for a while now and having just 'broken in' a new tip, it is perfect for the work I do. To bin it without at least trying to repair it would be, well, frankly against my serviceman's code!

So electrical checks would have to be made via the GX connector. I searched for circuit diagrams online for my model. Once located, my multimeter confirmed there was no resistance or continuity through the element from any of the pins, let alone the designated ones, which told me all I needed to know. It was dead!

Borrowing a spare

Fortunately, I have a spare pencil. But when I say spare pencil, I mean spare soldering station. While it is very much like my usual one, I originally



SOMETIMES THINGS DON'T GO ACCORDING TO PLAN (serviceman plans, God laughs)

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Mini Isolated Serial Link

This tiny module (about the size of a postage stamp) provides bidirectional, isolated, full-duplex serial communication. That makes it ideal for when two (or more) boards running from separate supplies need to pass information to each other. It can also carry isolated logic signals. Among its many other uses, it can be used to join two of the Battery Balancers (described in this issue).

By Tim Blythman

The High-current Four Battery Balancer project starting on page 21 can handle more than four batteries (or cells) by stacking multiple units.

But for that to work, they need to communicate with each other, even though their ground potentials will be quite different; possibly as much as 60V DC apart.

To connect their onboard serial links so they can work as a single unit, a serial isolator is needed. This little device uses optoisolators to provide thousands of volts of effective isolation while allowing the serial data to pass through unchanged.

Another important use for a device like this is connecting a computer to a device that you're testing, to prevent any possibility of damage should the device malfunction and feed a high voltage to its serial pins.

If you have a single Battery Balancer and wish to monitor or control its operation on a computer, it would be a good idea to use this isolator between the two, for safety.

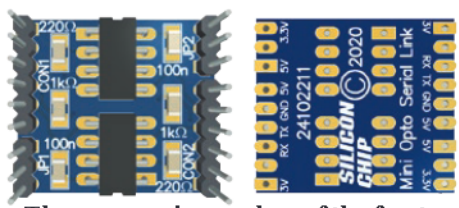
We already published the Zero Risk Serial Link in January 2019 (siliconchip.com.au/Article/11360) for this purpose, but that board includes a power supply for the isolated device, which often isn't necessary.

That makes the board much larger and more complicated than necessary. In cases where both communicating devices have individual power supplies, this design is a better choice.

New design

By dispensing with the power circuitry and using six passive SMDs, we've managed to squeeze the required circuitry into a PCB that measures just 26.5 x 23.5mm.

That's small enough to be connected inline with your serial link and encased in a short length of large diameter heatshrink tubing. Despite this small size, it isn't hard to build.



These same-size renders of the front (left) and rear (right) of the Isolated Serial Link PCB show just how tiny it is. Whether you use vertical header pins, as shown here, or horizontal, as shown in our photos, is up to you. Incidentally, the renders were taken directly from the new Altium Designer 21, which we reviewed in January (siliconchip.com.au/article/14705).

Fig.1 is the complete circuit diagram. The operation is simple. On the transmitting side, a current loop is formed between the TX pin and the selected supply rail (3.3V or 5V) via one optoisolator LED (OPTO2 for CON1 and OPTO1 for CON2). This is via a 220Ω current-limiting series resistor.

So when the TX pin is high, no current flows through the LED, and when it is low, about 10mA (for a 3.3V supply) or 18mA flows. This pulls the RX pin at the opposite end low by activating the Darlington transistor in the other half of the optoisolator.

When no current is flowing through the LED, the Darlington is off, so that pin is held high by a 1kΩ pull-up resistor.

The configuration is identical for data flowing from CON2's TX pin to CON1's RX pin as it is in the other direction. A 100nF bypass capacitor stabilises the voltage across the Darlington on either side.

Pin headers CON1 and CON2 are identical, and could be soldered directly to one of the communicating boards (eg, a Battery Balancer) using four of the six pins.

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Preview only.

All About Capacitors

Capacitors are probably the most misunderstood of the passive components, due to the many different types available, their many parameters and greatly varying performance. This article should give you an understanding of the most common types, how they differ, and how to choose the right ones for your design.

By Nicholas Vinen

Capacitors come in all shapes and sizes. Some are much smaller than a grain of rice, while others are huge and used in banks to launch aircraft weighing many tonnes into the air!

Because there are so many different types, it can be very confusing trying to choose one. Even if you know what capacitance and voltage rating you need, there could be hundreds or even thousands of matching parts. Some of those might not work at all in your circuit, while others might work but not very well, and some will be very expensive. You need to narrow the choice down to just a handful and then pick one.

We have tried to break the following descriptions into digestible sections, despite their complexity. If you find yourself overwhelmed, give yourself time to digest what you have read so far, then read the rest later.

Capacitor dielectrics

Fundamentally, a capacitor is just two conductors (originally flat plates) separated by an insulator (the "dielectric"). But because the area of the plates required for any significant capacitance is quite large, modern capacitors are typically arranged as many layers of smaller conductors and insulators connected in parallel, allowing for a more compact package.

In some cases, the 'plates' are not even flat but instead are spiral coils, or 3D structures such as the etched surface of a metal foil or granular materials.

Etched or granular materials have a much higher capacitance per volume, as capacitance is proportional to surface area and inversely proportional to the distance between the plates.

This creates a tradeoff; thinner dielectrics give more capacitance, but have a lower breakdown voltage, so the maximum voltage applied to the capacitor must be kept lower. This is the main reason that a capacitor with a higher voltage rating, but the same capacitance, tends to be physically larger; its dielectric layer(s) need to be thicker.

The type of insulating (dielectric) material used has a strong effect on capacitor behaviour, and for this reason, capacitors are mostly categorised by the dielectric type. Different dielectric types have their own trade-offs in terms of capacitance, voltage ratings, linearity, current handling and more.

Some widely used dielectric materials for capacitors are:

- Ceramics (typically metal oxides)
- Metal oxide layers (in electrolytic capacitors)
- Plastic films
- Mica
- Paper
- A Helmholtz plane of solvent molecules (as in 'double layer' super/ultracapacitors)

The most common types of capacitors in use today are ceramic and electrolytic, followed by plastic film types. These three types of capacitors have important sub-categories which strongly affect their behaviour.

One property of all dielectric materials is the dielectric constant ("K"). The larger this number, the higher the capacitance for a similarly constructed device. K can vary with temperature, voltage, age and other properties. While high K values make for greater capacitances in a small volume, there are significant penalties in other areas, as we describe below.

Ceramic capacitors

If you look at the PCB of just about any modern electronic device, you will find it covered in ceramic capacitors. They are cheap, reliable, perform very well and are available in a wide range of capacitances and voltage ratings.

Because modern ceramic capacitors are fabricated in bulk, they can have anywhere from one to many thousands of layers. This gives them a wide capacitance range, from fractions of a picofarad up to hundreds of microfarads, in a small package – see Figs.1-3.

Ceramic capacitors are typically robust and long-lasting, and are not polarised (they can handle negative or positive voltages).

Ceramic capacitors are available with voltage ratings from just a few volts up to several kilovolts. Ceramic capacitors with voltage ratings above 500V tend to use different types of ceramic to those below 500V, and have slightly different properties.

The most common ceramics used are based on titanium dioxide (TiO_2) or barium titanate ($BaTiO_3$) with additives to tweak their properties.

As there are so many different possible combinations, they are arranged in various categories based on their performance. The categories are based on the initial tolerance of the capacitor (ie, the variation of real samples from the rated value), how the capacitance changes with temperature (the temperature coefficient) and how it changes with applied voltage (the voltage coefficient).

The most common type codes are NP0 or C0G (different names for the same category), JB, SL0, X5R, X5S, X6S, X7R, X7S, X8L, Y5V and Z5U.

To take three examples, NP0/C0G types have very close tolerances and no or minimal capacitance variation with temperature or voltage. They also have a low dielectric constant, so they are relatively large for a given capacitance value and voltage rating. As a result, they are also quite expensive.

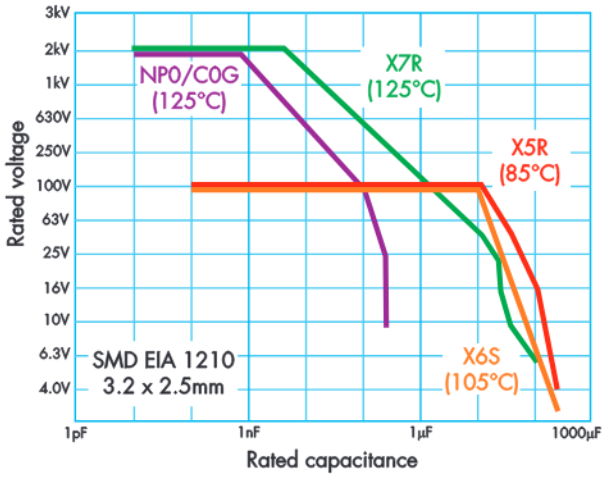

Fig.1: the range of capacitances and voltages available in 3.2 x 2.5mm SMD ceramic capacitors today. Both larger and smaller sizes are available, extending the range of values down to 0.1pF (1.6 x 0.8mm) and up to 470µF (4.5 x 3.2mm). Note how some types of ceramic dielectric are available to higher working voltages, and others to a higher maximum capacitance. *(original source: Wikipedia)*

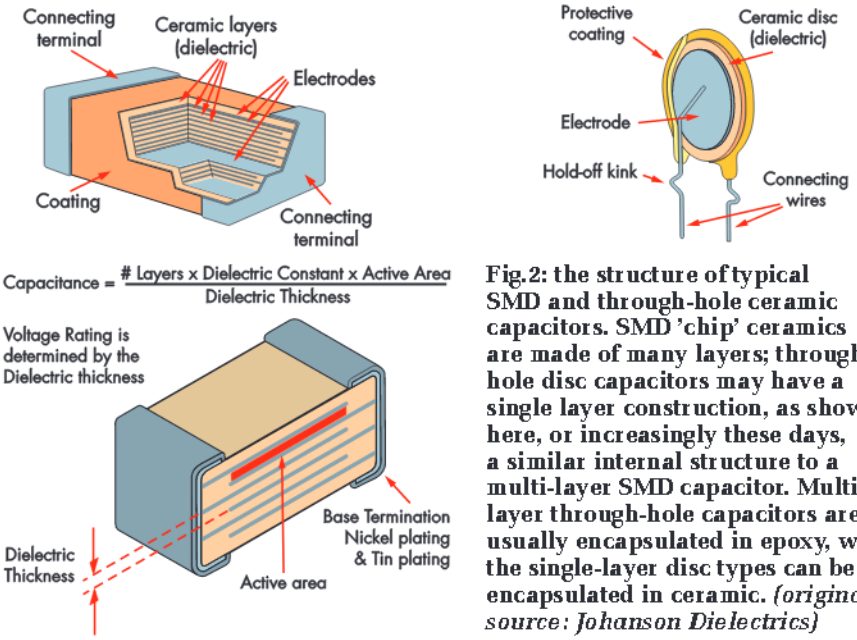

Fig.2: the structure of typical SMD and through-hole ceramic capacitors. SMD 'chip' ceramics are made of many layers; through-hole disc capacitors may have a single layer construction, as shown here, or increasingly these days, a similar internal structure to a multi-layer SMD capacitor. Multi-layer through-hole capacitors are usually encapsulated in epoxy, while the single-layer disc types can be encapsulated in ceramic. *(original source: Johanson Dielectrics)*

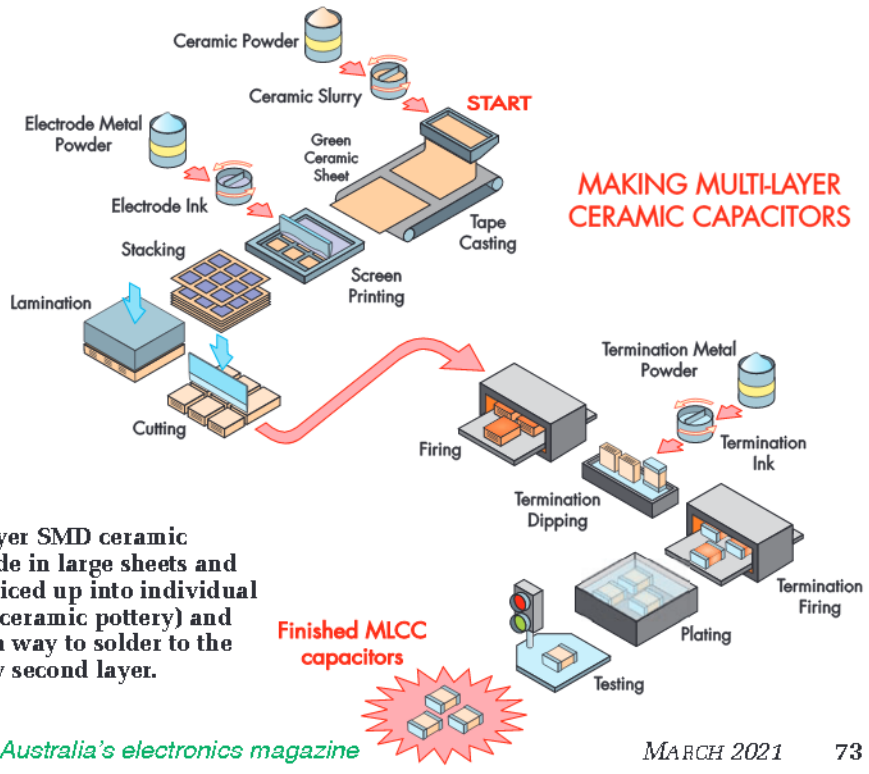

Fig.3: the manufacturing process for multi-layer SMD ceramic capacitors. To keep the cost low, they are made in large sheets and after lamination is complete, the sheets are sliced up into individual capacitors. Those are then fired (similarly to ceramic pottery) and the end terminals are added, which provide a way to solder to the capacitor while also electrically joining every second layer. *(original source: Johanson Dielectrics)*

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• Monitor up to 3 batteries from 6 to 100V • Currents to 10A (or 100A+ with shunt)

VERSATILE BATTERY MULTI-LOGGER WITH TOUCHSCREEN LCD

Part 2 – By TIM BLYTHMAN

In Part 1 of our new Battery Multi-Logger last month, we described how it combines the functions of a Micromite LCD BackPack along with voltage and current sensing hardware, and power-saving techniques, all on a single PCB. Now we'll go over the construction, testing, setup and calibration procedures so you can build and use it.

Before getting to the assembly instructions, let's quickly review the Logger's capabilities.

- It can handle batteries from 6-100V and monitor up to three bidirectional currents of up to 10A using its onboard shunts, or much more (to 100A or beyond) using external shunts.
- Its own power consumption is less than 1mA while actively logging with the screen off.
- It can display the current and historical data on a 2.8-inch backlit LCD touchscreen, and the data can also be downloaded to a computer over USB for further analysis.
- It tracks the current battery state-of-charge in both amp-hours (Ah) and watt-hours (Wh), and it has a current measurement resolution of around 0.1% of full-scale, which equates to 10mA steps when using the internal shunts.

All of these functions are built onto a small PCB. As all the user interface features are accessed via the touchscreen, it can easily be integrated into other devices through a rectangular cutout in the case.

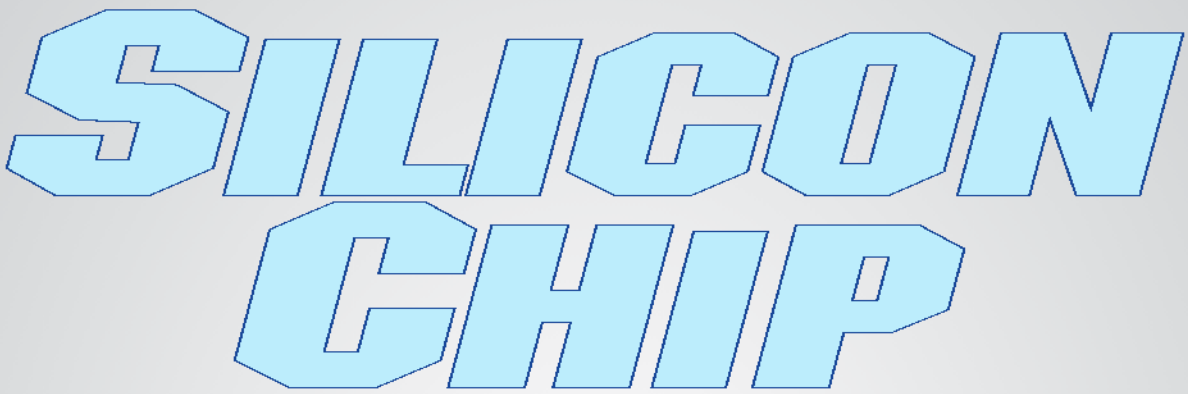
Construction

The Battery Logger is built on an 86mm x 50mm double-sided PCB coded 11106201. Fig.5 shows where the components go, on both sides of the board.

As usual for assembling a board with many SMDs, it is useful to have the following on hand: flux paste, solder braid (wick), a magnifier, tweezers and an adjustable temperature iron. The smallest parts have pad spacing under 1mm, so solder bridges are almost inevitable, hence the need for flux paste and solder wick.

Since flux tends to generate smoke, use a fume extraction hood or work in an outdoor area, where the smoke can more easily dissipate.

One of the most fiddly parts is the USB socket, CON5, so start by fitting that. Dispense flux onto the pads and then sit the USB socket in place; it should lock into the holes in the PCB. Add some more flux to the tops of the pins.



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ELECTRONIC Wind Chimes

Part 2: finishing it off – by John Clarke

Last month, we described how our new Electronic Wind Chime worked, and how to build the electronics. Now we get to the tricky bit – modifying the wind chime itself so it can be driven by a series of solenoids. Fear not, because we have detailed instructions on how to accomplish this, and finish the build by putting it all together and setting up the electronics.

Our finished Electronic Wind Chime. It's based on a commercial wind chime but ours works when there's no wind.

We modified a Carson Home Accents "Amazing Grace" 640mm Sonnet Wind Chime to incorporate the solenoid drivers.

It is a 5-chime type with 31.5mm outside diameter tubes. The longest tube is 590mm and shortest at 450mm.

The solenoids are supported on a circular ring made from 9mm MDF (medium-density fibreboard). This ring is held in place with an inverted U-shaped piece made from MDF and a couple of right-angle brackets. The whole frame is attached to the wind chime's attachment hook with an M5 screw and nut.

For our prototype, the clapper plate was made using an 80mm diameter piece of 1mm aluminium sheet. The plate (shown in Fig.7) is designed to cater for the 5-chimes arranged 72° apart around the diameter.

The plate includes holes for the strings and a slot to allow the clapper plate to be placed over the clapper while its central support string is still attached.

The frame needs to be sized so the base plate can be positioned at a height where the solenoids and levers are in-line with the top of the clapper plate.

There are two holes for the string attaching each solenoid to its chime. These need to be far enough apart so that the string does not touch the chime tube when pulled taut. This clapper plate can be glued in place, or held with a small self-tapping screw into the clapper after the string has been threaded.

The 100mm x 10mm rectangular solenoid levers are made from 1mm aluminium sheet; the two end holes are 3mm in diameter. Note that two holes are not centred, but placed close to one side, to give the best rotational movement when attached to the solenoid plunger.

The pivot point is a wood screw into the base plate. This should be long enough and screwed in sufficiently for the lever to sit horizontally, without being too tight to move.

The hole in the solenoid plunger was drilled to 2.5mm and then tapped for an M3 thread. That allows the lever to be secured at the fulcrum with just a 10mm-long M3 screw and no nut, with the screw acting as a bearing. Alternatively, you could drill 3mm diameter holes and secure them with machine screws and nuts.

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VINTAGE RADIO

Kriesler's 41-21 mantel/portable set

By Ian Batty

The Kriesler "Triplex" 41-21 is an all-transistor, battery-powered radio which uses reflexing. It was produced in the late 50s/early 60s and was sold with a plastic case that came in one of three colours (pink, brown or red).

Engineers are a chummy lot. During my Air Force days, I encountered a variety of engineering types needed to keep an aircraft flying: mechanical engineers for the engines, airframes and controls, electrical engineers for the electrical systems and controls, electronics engineers for the radio, radar navigation and instrument systems, and commerce types for supplying all the parts needed.

But when I took a look at the Kriesler 41-21 (manufactured from 1959 to 1961), I started wondering whether the mechanical engineering folks at Kreisler were 'in dispute' with the electronics engineer cohort.

Surely no-one could have come up with the labyrinthine dial drive in this otherwise fine set unless they had some axe to grind. Yes, I get that it's a way of accommodating a 130mm long dial with a 41mm diameter drum on the tuning gang, when an 82mm diameter drum would otherwise be needed. But I would have put in a 2:1 gear set to the drum and simplified the rest of the arrangement.

Electrically, the set is also somewhat interesting. It uses a reflexed second intermediate frequency (IF) amplifier, with that transistor also acting as an audio preamp. The design is similar to the Philips MT4 that I described in September 2017 (siliconchip.com.au/Article/10806).

Like that set, the reflexed stage needs carefully-managed signal levels, so the 41-21 has a two-gang volume control potentiometer. More on that later.

So despite its dial drive, it's an Australian set worth an article.

First appearances

The curved, rippled front with its coloured inset and black case rear is a pleasing alternative to the "square black box" so often resorted to in the late 50s/early 60s.

The "slide rule" dial is some 130mm long; plenty of space to list all the stations of the day. The side-mounted volume control is placed for easy adjustment. The separate on/off switch eases the load on the volume control; ie, it doesn't need to be rotated every time you turn the set on or off, giving a longer trouble-free life.

Circuit details

The set's circuit is shown in Fig.1. The main difference between the 41-21 and the identically-cased 41-21A is the 21A's use of a single-tuned third IF transformer.

All transistors are Philips/Mullard "OC" series germanium PNPs, with a negative power supply (ie, positive ground).

Ferrite rod L2 is tuned by the antenna section of the tuning gang, C3A. A low-impedance secondary matches to the base of the converter via capacitor C2, in parallel with 2.2kΩ resistor R1 (the bottom half of the converter's bias divider). C2 is there to overcome the resistance of R1 at radio frequencies

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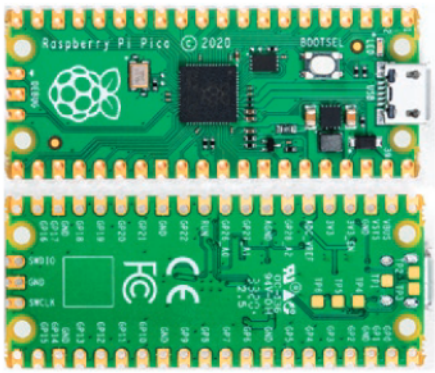
PRODUCT SHOWCASE

Raspberry Pi Pico – available from element14

element14 has announced the availability of the first product built on Raspberry Pi-designed silicon: Raspberry Pi Pico. This new product brings high performance, low cost, and ease of use to the microcontroller market, in a $5 development kit.

The Raspberry Pi Pico is available to purchase from https://au.element14.com/3643332



At the heart of the Raspberry Pi Pico is the RP2040, a Raspberry Pi-designed micro. It features two 133MHz ARM Cortex-M0+ cores; 264KB of on-chip SRAM; 26 GPIO pins; dedicated hardware for commonly used peripherals and a programmable I/O subsystem for extended peripheral support; a 4-channel ADC with internal temperature sensor; and built-in USB 1.1 with host and device support.

The RP2040 microcontroller offers high performance for integer workloads, a large on-chip memory, and a wide range of I/O options, making it a flexible solution for a wide range of microcontroller applications.

Key features include:

Memory: 264KB of on-chip SRAM; 2MB of on-board QSPI Flash.

Interfacing and mechanicals: 26 GPIO pins, of which three can be used as analog inputs. 0.1-inch through-hole pads with castellated edges for SMT assembly.

Power: on-board power supply to generate 3.3V for the RP2040 and external circuitry. Wide input voltage range, from 1.8V to 5.5V, giving designers the flexibility to select their preferred power source.

Developer tools: simple drag and drop programming via micro-USB. 3-pin Serial Wire Debug (SWD) for interactive debugging. C-based SDK, MicroPython port, and extensive examples and documentation.

To find out more about the Raspberry Pi Pico, visit www.element14.com/community/docs/DOC-96021/

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Crocus CT220 – the industry's first TMR contactless current sensors

Mouser is now stocking the CT220 XtremeSense contactless current sensors from Crocus Technology.

The CT220 sensors are powered by Crocus' XtremeSense tunnel magnetoresistance (TMR) 1D technology, which enables them to detect slight changes in AC or DC. The sensors offer a 2.7V to 5.5V supply voltage range and 1.2mA supply current rating in a 5-lead SOT23 package. It measures the magnetic field of the current flowing through a busbar or PCB trace and converts it to an analog output voltage that represents the field and current.

These sensors achieve a typical total output error of ±0.5% while sensing fields as low as 5mA. CT220 current sensors feature an inherently high isolation, making them the ideal solution for applications where product safety compliance is a requirement.

These applications include motor controls, solar inverters, power distribution units and power supplies, and Internet of Things (IoT) devices.

To learn more, visit www.mouser.com/new/crocus-technology/crocus-ct220-xtremesense-sensors/

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Postponement of ElectroneX to September 2021

AEE, organisers of ElectroneX, have been closely monitoring the COVID-19 situation and following recent outbreaks and border closures over the Christmas period, and have made the decision to postpone ElectroneX (Electronics Design and Assembly Expo) at Rosehill Gardens in Sydney until 15-16 September 2021 which also brings the Expo back into the normal September timeframe.

This cautious approach will provide sufficient time for the vaccine roll-out to be implemented and for state governments to provide more certainty in relation to their border closure policies which is currently having a major impact on interstate business.

Due to the lead time that is required for the promotion of the show and the need for companies and visitors to be able to freely travel to NSW, we believe this is the best decision to help ensure the overall success of the Expo.

In accordance with the terms and conditions, all contracts and payments that have been made will be transferred to the rescheduled dates.

If you have any questions in relation to the rescheduling please contact Noel Gray on 0407 943 817 or Vee Johnson on 0422 399 818.

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electronics design & assembly expo

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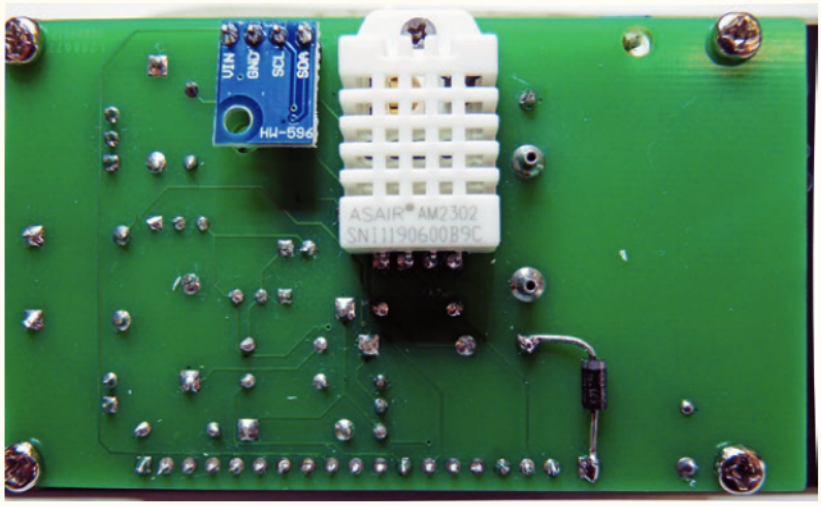
Notes & Errata

USB SuperCodec, August-October 2020: in the Fig.13 circuit diagram on page 88 of the September 2020 issue, pin 12 of IC7 (SDOUT) should not be shown connected to pin 9 of IC6. Instead, it goes to the I2S_ADC1 connection at the right edge of Fig.12 on p86.

Car Altimeter, May 2020: the design is missing one schottky diode (D8) which connects from the cathode of ZD1 (schottky anode) to the positive terminal of the battery (schottky cathode). This is needed to charge the battery. It can be added to the underside of the PCB, as shown in the accompanying photograph.



6GHz Touchscreen Frequency Counter, October-December 2017: in the circuit diagram on pages 30 & 31 of the October 2017 issue, a 1µF bypass capacitor is missing between the anode and cathode of REF1. Also, in the overlay diagram (Fig.3) on p86 of the November 2017 issue, the board shown is RevA; the final (RevB) board adds a 100µF capacitor just to the left of REG2, with its positive lead towards the regulator.

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