Hot Iron 105

August/ September 2019

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CQ-CQ-CQ

First of all, I'd like to offer a "thank you" to all those readers who have emailed me, on many topics, all of which I found very interesting and relevant. Please keep sending your emails, be they questions, requests, information, or whatever you find an interesting topic that is amateur radio related. All is fair grist to the mill, and very much appreciated. Hot Iron is yours!

Hot Iron 105 has a distinctly 'digital' flavour. This is because of the emails I've received asking or commenting about matters digital, but also because Moore's Law relating to the ever expanding complexity of microelectronics has some rather disturbing and unwarranted results - not always inside the ever smaller IC packages - that have a hefty bearing in an amateur shack and it's operations.

As an example, I can quote a few purely 'digital' problems I'm sure you'll have come across that are the equivalent of running into a brick wall, blocking further progress of a project, or, worse, doing damage to a vital piece of shack equipment.

For instance, I've been setting up some software defined radio projects, using the superb (and cheap!) RTL u.s.b. dongle. The dongle is an excellent piece of electronics, combining mixer, IF amplifier and many other functions in a bit of kit that costs (relatively) peanuts that plugs directly into a computer u.s.b. port; the computer then supplies all the other necessary functions such as filtering, bandwidth adjustments and audio processing, with a 'waterfall' display showing a slice of RF spectrum. By clicking the cursor onto the centre frequency of a signal in the frequency domain, it is demodulated, the mode selected being one of dozens of different modes as desired.

All well and good: but the receiver dongle has to marry up to the computer software that accepts the u.s.b. signals from the dongle and manipulates them via software to give the display, and that's the first major hurdle. Software isn't reliable. It is, just as it says on the tin, "soft". It's not "hard". More to the point, you can't find a dud bit of software with a meter. You can't remove a dud bit, byte or kilobyte and put a new bit in - not without losing all the "upgrades" in the rest of the system, leading to several days waiting whilst the whole software suite is reloaded and updated. That's why I run a Linux Ubuntu operating system on my shack computer, having had experience 'certain' (fenestration-like) operating systems for the past umpteen years driving me nuts (don't ask - but plenty of times in the "depths of a night shift", after 12+ hours of struggling to eliminate all the physical faults in a machine, find the software in the control computer has decided to do something barmy - everything else physically having been eliminated. As Sherlock Holmes said, "whatever is left after everything else has been eliminated is the culprit (then add "or Beelzebub has cast his spawn into the software").

When you issue, in a terminal programme, a very basic fundamental command like “change directory” and a string of errors comes back with no rational explanation as to why, it might be a simple matter of knowing the foibles of an unwieldy operating system, or the programme memory chip(s) - laughingly called “firmware” - are corrupted. Or the machine the computer is issuing contradictory commands to the power supply that cause rail-to-rail kilovolts output or swinging hundreds of amps, causing violent glitching and flashovers. Or the HV power supply’s safety earth shunts are shorting the HV stack to ground because the control computer’s lost it’s bl**dy marbles, or switching the HV output polarity from “+ve” to “-ve” without an appropriate discharging of the system smoothing capacitance. Not usually a major problem in an amateur shack, but this was an Ion Implanter 160kV DC accelerator supply and analyser magnet drive. Not funny!

Then, to add insult to injury, the Day Shift Production Manager is baying for blood, you try telling him (and all the day shift operatives) that the production line’s stopped because nothing’s actually broken, but a machine has gone gaa-gaa - it’s at that moment you realise the digital dream isn’t quite what it was cracked up to be, and you know exactly where you’d like to shove your logic probe (with the hook tip fitted, of course) if only you could get at the software designer who foisted this unstable string of algorithms, untested in real World conditions, on you and your fellow engineering brethren.

Of course, the machine manufacturer gave you on a disc or (even worse, on-line) back up files to reload the software; the moment you try a software reload the software in the host machine recognises that an older version of software is being loaded - and promptly spits it’s dummy out, refusing to accept the reload to revert to an older version. Or... if the control computer is firmly jammed in a never ending spiral of sub-routines and refuses to do any coherent activity, because a high voltage glitch has corrupted a few bits in the software, how do I connect to the manufacturer’s on-line back up file system? I can’t use any other computer as in his infinite wisdom the software designer has trapped out any attempt to download his software on anything but the original host computer, for “security” reasons” - which usually means “because the manufacturer wants to charge you an arm and leg for a set of new software discs”.

What brought this about was that I recently loaded into my shack Linux computer an SDR / RTL waterfall display / demodulating software suite to run the aforementioned RTL dongle. It didn’t work - well, not properly anyway - so I decided to purge it all out of memory, and load an alternative. It took me a week to get my computer back to rights. The dud software blocked a huge chunk of the operating system memory and wouldn’t allow removal - it stopped all attempts to remove it, even some powerful “super user” Linux terminal techniques. I eventually had to do a full reload of the operating system, do all the updates, and restore all my files from the back-up hard disc drive, which, thank Gaia, Linux does extremely well, and quickly too.

Software issues have bitten me for many industrial years; I can’t be the only one who has run into grief doing what should be a very simple job because some “disruptive technology” twerp in California has added so many bells and whistles to a software programme that it’s rendered nigh on useless, or has become a major ‘technology’ in it’s own right - needing an “IT” degree (now there’s an oxymoron if ever there was one) to use to it’s fullest extent. I don’t know if they put mind altering substances in the software writer's drinking water, but whoever dreamt up the programming software for PIC's, and other popular micro-controllers, was away with the fairies in my opinion. Or am I taking E.F. Schumacher's "Small is Beautiful" philosophy too liberally? - but I know from bitter practical experience (as does any engineer who's tried to get a plant running under extreme duress, whilst dog tired, without the spare parts warehouse every machine manufacturer assumes his customers hold) that "simple is as simple does" and it's alter ego: if it's simple then it's reliable. Maybe it's not quite as reliable as a purely electronic software combination; but for those mere mortals of us who have to live in the real World of a time and budget constrained environment, simple systems (i.e. non-software) are eminently fixable, adaptable, and substitution friendly beasts.

A 400kW / 200kHz RF generator I worked on often came in two variants: one was significantly cheaper than the other, and the cheaper proved version very much more reliable in the face of 3 phase supply glitches, lost phases and brown-outs. It wasn't a few percent more reliable: it was orders of magnitude more reliable, and the RF generator of choice for developing countries where 3 phase power was not as reliable as we are accustomed to here in Europe / North America. The more expensive version had data logging, statistical process control displays of any variable you can name and was intra-net capable so control from a central office was possible. This all-singing, all dancing version was useless outside Europe / North America; the cheaper version, with it's box of contactors and power transistors in the SCR power control box, ran year in, year out with basic routine servicing and general maintenance - and you could squeeze a few more kW's out the thing by carefully manually tuning the system (the more expensive version had "auto tuning", or as we very quickly found out, "auto mis-tuning", after changing the power grid tube a few times) - the auto tuning couldn't cope with connections in the RF circuit over a few µohms, a common problem in copper bus bars with thousands of RF amps flowing through them causing premature failure.

It has to be said that electronic software systems running "CANbus" control are reliable, as witness the far fewer car breakdowns seen nowadays, CANbus being the acronym for "Computer Automotive Network bus". That said, I went to a classic car exhibition last weekend: a Ford Model "T", with original "buzz-box" ignition system was chuffing around; an "Austin 7", running a 750cc side valve engine, with coil / distributor ignition - all original parts - was happily clocking up 250,000 miles on the original crankshaft bearings; a Velocette MSS 500cc single cylinder motorcycle, running on the original Miller magneto, never having had a new contact breaker fitted, the original being perfectly serviceable and repairable with a new contact breaker points made from 4mm brass bolts fitted every 20,000 miles. Fixable; reliable, and economical, not a sniff of software or LSI integrated circuits anywhere - but more than that, they did what they said on the tin, with without fuss, gadgets, bells, whistles or useless idiotic features only one in a thousand customers would find useful.

The moral is this, in my opinion: if you want functionality in adverse conditions (surely THE most common operating demand made on amateur radio gear) then simple is (usually) best. If you have budget and time to waste, then by all means, spend your mega $'s / £'s on the latest technical wizardry, but I'll bet a Penny to a Pound you'll learn a lot more building basic bits of kit, fixing them after pushing them a bit too hard, modifying them to get the features you want, not what some marketing psychologist tells me you *need.*

I make only few exceptions to the above, which I've mentioned in Hot Iron before: DDS and PLL digitally controlled VFO's. I've chatted with quite a few designers of these wondrous VFO's, about using digi-switches and the like to set up the command words, but really, they cry out for simple micro-controllers as they use serial "words" to input the frequency control command. I also have vast regard for the designers who give us modern versions of "classic" CMOS and TTL logic gates - the 74HC families and the like. These wondrous beasties breeze along at 50MHz and more, driving healthy output currents - ideal for switching power mosfets via simple gate driver circuits. Combine a digital VFO with an HC NOR gate for easy on / off keying, a common base fast gate driver feeding an HV power mosfet with a class "E" output network and you've a very potent AM* / CW transmitter with very few components, superb frequency control, and very high power efficiency. Just the job!

* *AM being produced by pulse width modulation (class D or E operation) of the HV supply to the class E power stage - very low loss, very efficient audio modulation but great care needed to eliminate any birdies from the PWM switching frequencies.*

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A rant by Jenny List (and a busted TV)

Here's a rant by Jenny List - which I (partly) agree with - that I saw recently, that certainly highlighted many a headache I've suffered both in professional RF engineering and amateur times too. The one thing Jenny doesn't comment on is how an amateur can design with the modern "system on a chip", or, in fact, do an amateur repair of a pcb containing one of these beasts. A good example of that is a flat screen TV I recently "inherited" - the fault being a "dead set". "Aha!" thinks I, "that's a power supply problem if ever I saw one!"

I opened the thing up: it has two pcb's, each the size of a playing card or small postcard (if you can remember them...). One was the entire power supply, mains in, low volts out; the other was the "AV" board, RF, HDMI, SCART, Audio, Video, USB ports x 2 and a few other I/O's, with a 15 way ribbon cable connected the two pcb's and a 24 way flat cable to the display - which had decoder / driver electronics built into the edges. The AV board did ALL the signal processing: it had one massive chip in the middle, taking RF from a tiny tuner module, as well as the audio amplifier driving stereo speakers, and the remote control functions too.

I searched on the web for information: I found a page which - without going too deep - said of a dead set - "check the power supply output; if the +12v and +5v are present, the AV board's faulty. If the voltages are missing, or wrong, the PSU board's faulty. Replace as required". In other words, TV repair is now board level: no diagrams, circuits or test points. Just "check and replace". I should add the display, a 21" LED job, works perfectly; and was probably more than 80% of the cost of the whole thing. Replacement pcb's searched for on favourite on-line auction supplier - "Obsolete". Stock next due in? "None Available for foreseen future".

The TV was just over 5 years old, and destined for the bin, discarding the most valuable part - the display - which is surely the most wasteful and useless policy I've come across to date. If this is the
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standard of modern electronics recycling useful materials, then the future is getting a bit gloomy for amateur repairers and constructors, who want to work to component level, not bung in another pcb.

"Zombie Components - those that never die"

"As a fresh-faced electronic engineering student while the first Gulf War was raging in a far-off desert, I learned my way through the different families of 74 logic at a university in the North of England. 74LS was the one to use, the story went, because it's quick and doesn't use much power. At the time, there was an upstart on the scene: 74HC. Now that's *really* quick. New. *Exotic*, even.

Thus an association was formed, when you want a quick logic function then 74HC is the modern one to go for. It could have been a lifelong love affair, but over twenty years, after many factors of speed increases and some RF tricks with gates we wouldn't have dreamed of back then, it's over. There is a whole world of newer logic families to choose from, and while HC is still good at what it does, it's well past time to admit that it may just have been superseded.

A tendency to cling to the past with logic families is pretty harmless. Like "TIP" power transistors they're pretty cheap, still very much in production, and still do most jobs demanded of them excellently. But what prompted this piece was a far more egregious example of an old component still being specified: the RCA 40673 dual-gate MOSFET. Launched in the mists of time when dinosaurs probably still roamed the earth, this static-sensitive four-pin TO72 found a home in a huge variety of RF amplifiers, oscillators, and mixers. It worked well, but as you might expect better devices came along, and the 40673 was withdrawn some time in the 1980s. Unfortunately, nobody seems to have told a section of the amateur radio community about the 40673's demise. Or perhaps nobody's told them that many scrap analogue TV tuners of a certain age will yield a perfectly good newer replacement for free. Because even today, thirty years after the 40673 shuffled off this mortal coil, you can still find people specifying it. If you have a stash of them in your junk box, they're worth a small fortune, and yours could be the bench with the throng of people at the next ham radio convention.

A different but equally annoying manifestation of the phenomenon comes when the device everyone likes to specify is not very old and very much still in production, but the designer hasn't taken the time required to check for a cheaper alternative. Nobody ever got fired for buying IBM, they say, but perhaps they should be fired for specifying an AD8307 logarithmic amplifier in an amateur radio power meter. Don't take this the wrong way, it's a beautiful chip and probably a lot of work at Analog Devices has gone into laser-trimming resistors to make it perform to an extremely demanding specification. But *eleven dollars* for a chip? When a cursory search will turn up Maxim's MAX9933 which does a perfectly good job in this application at well under two dollars? Someone isn't doing their homework.

Sometimes there are components for which there are no perfect replacements. Germanium point-contact diodes, for example. 1N34As and OA91s are becoming like hen's teeth these days, and though Schottky diodes can replace them in many applications, there are still a few places if you're a radio person you'll hanker for the original. There are suppliers on Alibaba who claim to manufacture 1N34s, but the pictures always look suspiciously like 1N4148s, and anyway who can find a home for (a minimum order of) one hundred thousand diodes?

OK, maybe germanium diodes are an edge case and the examples above have a radio flavour, but you get the picture. What the full-blown rant in the previous paragraphs has been building up to is this: a plea for designers to do their homework. Please try to design every project for the next two decades, and as though any extras in the component price come from your company's bottom line. (We'll make exceptions for building something for which the whole point is a retro circuit. An Apple I replica like the Mimeo 1 [*click the link*] needs old logic chips for artistic purposes.)
Is there a vital electronic engineering skill that's being lost here perhaps? Back when the Internet was the sole preserve of boffins and Tim Berners-Lee hadn't yet plugged his hypertext ideas into it, we relied on catalogues. Big paper-bound books the size of telephone directories were our only window into the exciting world of electronic components. If you're an American yours was probably from Radio Shack, but for most UK-based hackers and makers who couldn't get their hands on a commercial account from RS or Farnell that meant the Maplin catalogue. Before they moved in a consumer-electronics direction, they were a component specialist whose catalogue with its distinctive spaceships on the cover could be bought at large news stands.
It's difficult to describe the impact of electronics catalogues in the '70s and '80s to someone who has known only the abundance of information from the web. These publications were our only window into the world of electronic components. They contained significant excerpts from semiconductor data sheets, and we read their wealth of information from cover to cover. We knew by heart what each device was capable of, and we eagerly devoured each new morsel of information as it arrived.

In short, when we specified a component, we did so with a pretty good knowledge of all the components that were available to us.

By comparison, nowadays we can quickly buy almost any device or component in production from a multitude of suppliers. There are millions more devices available, and if RS or Farnell don't have the part then Mouser or Digi-Key are sure to provide. The web allows us to find what we need in short order, and the miracle of global distribution means that we can have it delivered within 48 hours almost wherever we live.

Which means that all the new devices are available to us, but we've lost the ability to keep on top of them. We've become information rich, but knowledge poor. Printed catalogs still exist, but the sheer volume of information they contain forces brevity upon their entries and expands the size of the publication to the point at which it becomes an unwieldy work of reference. We therefore tend to stick with the devices and components we know, regardless of their cost or of whether they have been superseded, and our work is poorer for it.

We need to relearn the skill of inquisitiveness when it comes to the parts we use, and to rediscover the joy of just browsing, even if the medium is now a huge suppliers' web site rather than a paper catalogue. Otherwise we'll still be looking at circuit diagrams containing 74LS logic and 40673 MOSFETs in the 2030s, and that can't be a good thing!

There is of course also a slightly macabre alternative scenario. The highest online price we found for 40673s was over $30 each, so if a producer can make that kind of silly money then there's a danger that RCA's successors will see a business model in exhuming the corpse and re-animating it, thus ensuring that we'll **never** be free of the undead. We need to make sure that doesn't happen!"

[*My grateful thanks go to Jenny List for this excellent article. For those of us with a penchant for thermionics, though, it's a wise move to keep a weather eye open on solid state developments - before returning to sanity and simple, effective circuits that don't go up in a puff of smoke at the merest hint of overload or lightning strike a hundred miles away. I look forward with keen anticipation to the introduction of a solid state device of equal capability and price as a 4CX250! Mind you, at $30 for a 40673 it's very tempting to have a quiet word with some of my old pals in a wafer fab. Or... experiment with cascode connected BS170 / 2N7000 mosfets as a 40673 substitute? P. Th.*]

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Rx

A Franklin Receiver

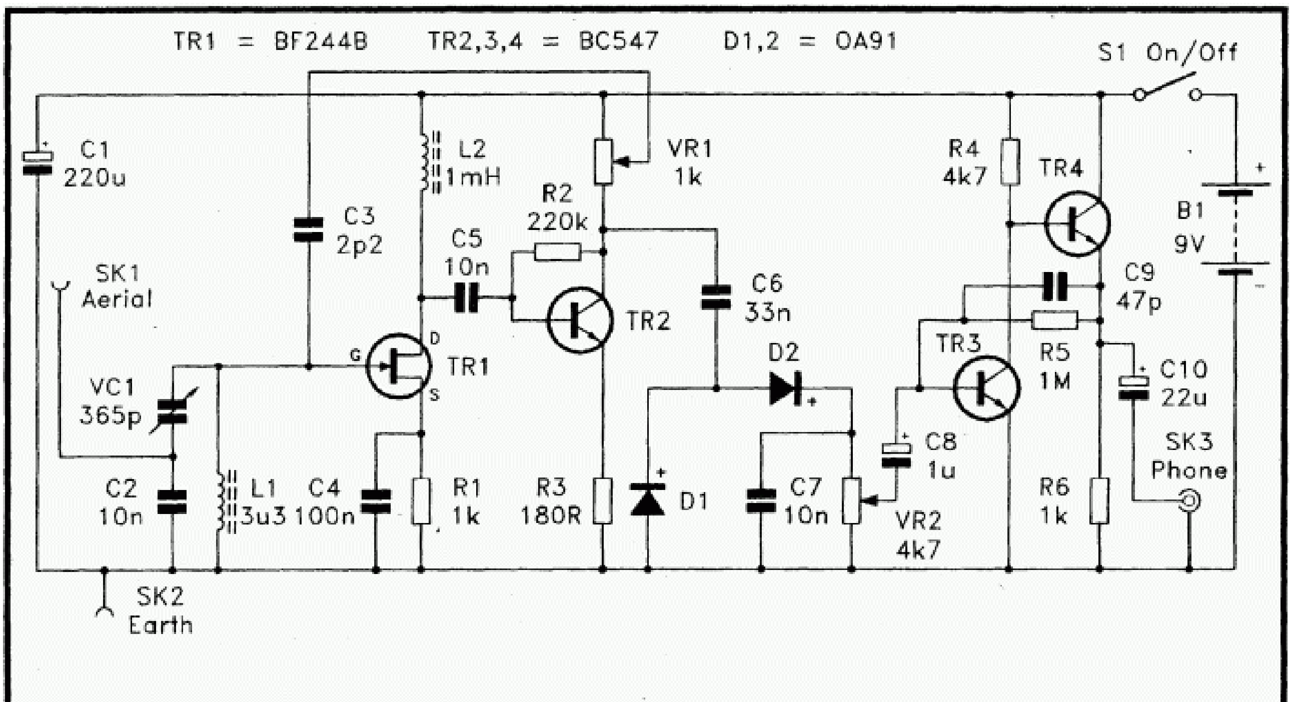
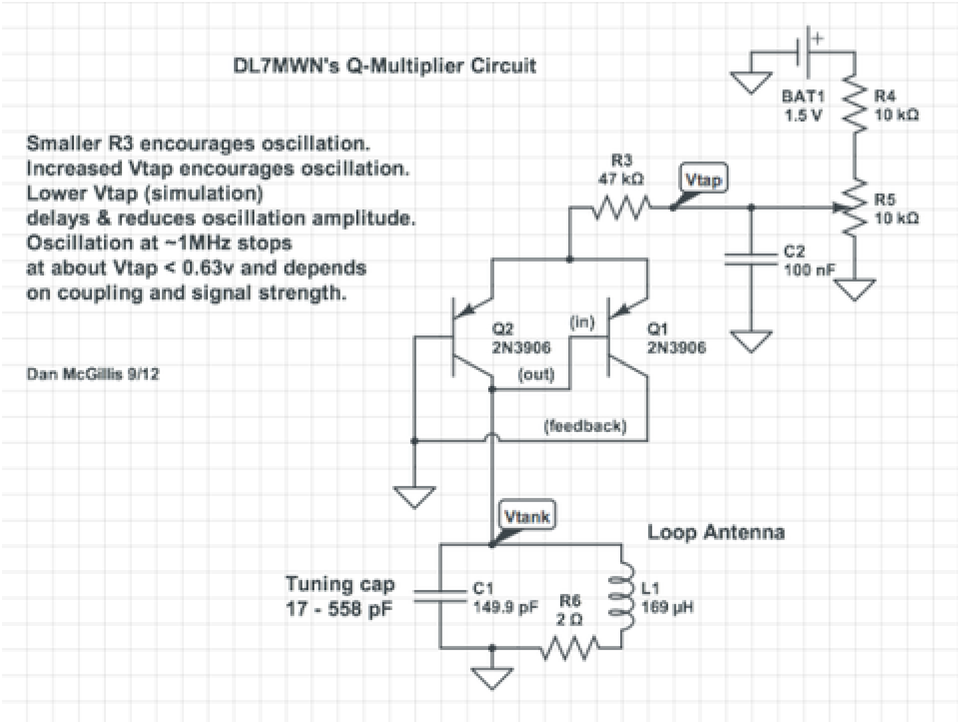


Fig.3.8 The circuit diagram for the s.w. t.r.f. receiver

The Franklin oscillator was a well known beast in the 1930's: using valves it was a very stable LC oscillator as the LC circuit is earthed at one end, and can be remote from the heat producing valves. The circuit was a derivative of the Eccles-Jordan flip flop; it's a multivibrator in disguise! Take a look at TR1 and TR2 in the above diagram (from the one and only R.A. Penfold; many similar found on the Internet).

A multivibrator is a pair of amplifier stages, the output of each stage feeding the input of the other - see below - and so you'll see in "the circuit diagram for the S.W. T.R.F. receiver" above: C5 feeds the base of TR2, C3 feeds the output of TR2 into the gate of TR1 - whose drain is connected to C5. Thus the loop is closed; the overall phase shift is a guaranteed 360° at all frequencies (within the parameters of the device's frequency responses, that is). VR1 picks off the signal at TR2 collector and controls the feedback to TR1 gate, via C3 which can be made very small - the loading on the LC circuit is minimal, so the circuit can be set just at the point of regeneration and the LC circuit Q factor kept as high as possible. The use of a jfet for TR1 is important: it reduces the loading on the LC tuning tank to almost negligible levels, allowing a very high Q and thus selectivity. A bipolar device in this position would significantly load the tuning tank as (without bootstrapping) the input impedance would be far lower.

The gain available in two devices as opposed to the usual one used in a regen detector receiver is far greater; and the phase shift around the amplifier loop is 360°, guaranteed by double inversion stages and not reliant on phase changes across inductors or capacitors. The nett result is that "two is better than one"; and if you look at some of the "Russian" two transistor oscillators and receivers by Viktor Polyakov you'll see they can be extremely simple and superbly effective- especially as add-on Q multipliers, needing only a 1.5v dry cell to power them, plus minimal power consumption.



Q1, Q2 form a multivibrator - note how the collector of each transistor feeds the base of the other - with an LC element frequency selective network (in this case, a loop antenna, but could be any LC network, or indeed, a quartz crystal) in the feedback path to force one frequency of oscillation; used here by Dan McGillis, and in many "Polyakov" designs. A low value resistor (say 27R?) in each emitter lead might "calm the beast", giving a more controllable oscillation onset: without a little degeneration, as Vtap reaches the Vbe of one transistor, the circuit suddenly comes alive; the added resistors give a little negative feedback to 'soften' the switching point.

In the Franklin the detection of A.M. is done by a voltage doubler circuit to feed the audio amplifier section, a standard two transistor design. I'd be tempted to fit modern very low noise audio transistors for TR3 / 4, I've seen references to ZTX851 transistors being ultra-low noise as the Rbb value (it's a power device) is around 2 -3 ohms, and the lower Rbb, the better for low noise. The ZTX851 has the added advantage of being a through hole E-Line device, so easily employed in amateur construction - and being a "ZTX" device, is as tough as old boots and very robust.

Of course, CW and SSB can be handled by allowing the Franklin to *just* oscillate; by adjusting the value of C3 by constructing it with a trimmer or even better, a few inches of hook up wire twisted together as a "gimmick" capacitor, that can be un-twisted little by little until the regeneration is silky smooth and only just capable of oscillation. Or of course, use an external carrier oscillator to introduce a sniff of carrier at signal frequency - a doddle for DDS / PIC VFO's.

You'll have noticed an anomaly in the Franklin diagram: the 10nF capacitor to ground below the tuning capacitor VC1 effectively shunts the antenna signal to ground. In my opinion, the antenna should be connected via a tiny capacitor to the gate side of VC1 - another “gimmick” capacitor is a great idea, or even a short wire close to C3. Adding a very low gain RF amplifier for isolation is a very good idea, capacitively feeding the gate circuit as suggested above.

For an interesting 160m / 80m receiver, the LC circuit can be constructed as a frame antenna, to give excellent directionality to null the thund’rous noise found nowadays on bands under 20m.

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RTL SDR receivers

I had an email recently asking about Software Derived Receivers and having had a ‘gross encounter of the worst kind’ with said SDR software, I dug out my notes and had another look. The very low cost ‘RTL’ USB computer dongle TV receiver has had much work centred around it, and probably represents the cheapest piece of powerful RF hardware you’ll find today in terms of bandwidth and capability. Whilst not the absolute ultimate in performance, it does a splendid job for very few £’s / $’s, **provided** you can get the driver software set up and stable on your computer.

There are several other important ‘features’ of the RTL - SDR; and this being the Journal of the Constructor’s Club, those features and how to employ them will be my focus: the innards of the RTL dongle’s chips are well documented on-line, and since you can’t get inside the chips with a soldering iron and wire cutters, are not of much import at G6NGR. The drivers and software gimmicks that derive the performance are, however: but you’ve probably noted my distinct warnings about software earlier in this issue and I’m not including software as a ‘construction’ feature unless it’s got a direct relevance to the job in hand.

So to business. The RTL dongle is a radio receiver that covers (approximately) 24MHz to 1600MHz (depending on version, manufacturer and type) and outputs two quadrature signals to the USB port, as per the Direct Conversion principle of sideband selection / elimination, the “I” and “Q” signals. The software inside the host computer does the rest: the amplification, demodulation, filtering, buffering and audio. Using some software ‘tricks’ the Nyquist limit is (apparently) overcome resulting in full coverage without aliases and other sampling errors and foibles.

The RTL USB dongle has an antenna socket input, and being designed for TV reception, is of 75 ohm input impedance. You get a mini antenna with the dongle, a short length of micro-coax leading to a crimped plug that fits the dongle’s antenna socket. Obviously the mini antenna can be removed, and connected to a superior antenna, and of course you can fit an RF amp / filter section if desired, but it’s probably not required unless you have severe noise / interference issues at 24MHz and up.

By now you’ll have noticed the first snag: ‘24MHz and up’. Yes, the RTL doesn’t go below 24 MHz. Some sneaky software tricks can help, as can physically opening the dongle and altering the mini pcb inside; but help is at hand for the discerning user - an *up-converter*.

Simply stated, assuming you want to receive signals below 24MHz, you feed the incoming antenna signal into a mixer, and transform the signal upwards in frequency to somewhere more fitted to the RTL’s specification: 50MHz or 100MHz are common up-shifts. Thus an HF signal at 10MHz becomes 60MHz or 110MHz; and you can adjust the antenna signal’s RF gain and filtering
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externally to better suit your environment. There a many up-converters described on-line, using every variety of mixer you care to name; but for my money it's a pre-packaged diode ring mixer for wide bandwidth and strong signal capability. Note the local oscillator driving the mixer should be set exactly as the manufacturer states; the drive level has to be set properly if aliases and noise are to be eliminated (as far as is possible, that is) and an appropriate termination used for the mixer output. It's an interesting discussion point to compare diode ring mixer drive signal wave shapes: the diodes need switching well and truly on / off, so logic level drive is often advocated, but this then includes all the harmonics! Sine drive is effective too, but you need to be sure you have the milli-Watts of grunt to really switch the diodes properly.

The next caveat is the positioning of the RTL dongle. It's tempting to plug it into your computer and off you go: and there, for all to see, are the spikes of noise the zillions of transistors in your computer are spewing out. Computers are (in RF receiver terms) noisy beasts to say the least! It's like listening to a faint signal in a roaring gale, with somebody running an old petrol lawn mower right next to you. The partial answer is a USB extension cable: but again, a caveat strikes: it's got to be USB 2.0 (at least) capable, the fastest data rate possible. Which limits the cable length to 5m or so before the speed degrades! The way round this limit is a powered USB buffer hub, to then allow adding another 5m USB cable to be connected, to locate the RTL dongle far enough away from the computer to avoid the racket your computer kicks out.

By now, the SDR as an easy option 'plug-n-play' radio receiver is fast disappearing! The problems can be overcome; the issues can be resolved - but be prepared for the problems, it's not as easy as you might think.

There exists, however, what must be the cheapest way to listen on-air to amateur signals: no mixers, no software loading your computer, no antenna, no mucking about - use an internet connected "web SDR" radio receiver that you tune, control and set up - all online - and observe the waterfall display just as if it was your own computer, in your own shack. Take a look at these for starters:

1. websdr.org (just type this in the address bar of your web browser)
2. https://www.globaltuners.com/receiver/
3. https://www.dxzone.com/catalog/Internet_and_Radio/Online_Receivers/

These are just a few of many web SDR (and conventional Rx with remote control) receivers you can access in many parts of the World, just by signing up to an account. Now that's digital technology I like!

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Oscillators

A Sweeping Oscillator

Terry Mowles, VK5TM, has been up to his wonderful tricks again, and produced a design for a sweep frequency oscillator for alignment and other useful purposes (anybody for frequency agile communications on an amateur band?) The link to Terry's design is below:

https://www.vk5tm.com/homebrew/simple_sweep/simple_sweep.php

Terry's web pages are always an interesting read, and you can get pcb's from him, should you require them for his projects. Terry maintains a good outlook on his projects, they do exactly what it says on the tin, no more, no less: what more can you ask? And he dislikes software over-engineering and features added for little purpose, which makes him very much on my wavelength. If you're programming PIC's and the like, try to download and use older versions of the software for the job - the archived versions before the 'bells & whistles' brigade had been at them and added more useless (by the majority of users) "eye candy" features.

Andrew Woodfield's (ZL2PD) PLL VFO's

Andrew very kindly wrote to me commenting on my recent notes in Hot Iron #104 about DDS VFO's, and recommended I look at his design for a PLL VFO that fits in **half a matchbox (!!!)** including a mini OLED display - and added a few thoughts too. I strongly suggest you look up his web page www.zl2pd.com and his note to me is reproduced below:

"*Thanks for the copy of Hot Iron, Peter. The remarks in this issue about DDS oscillators spurred me to write.*

DDS is good, but fractional-N PLLs are arguably more compact and cheaper, such as the now famous si5351a chip. I have built a number of these now. They are super cheap, and it can provide three vfo outputs from 3.4kHz to 295MHz or so, with steps from 1hz to 10MHz or whatever you choose to program. See some examples on my website at www.zl2pd.com *(That's ZL2PD not the number 12 in that URL). Must remember to upload some more examples next week. And these vfo consume less than 30mA at 3.3V usually while being capable of driving diode DBMs directly.*

With SMD, I can build a great drift-free vfo for HF and VHF in half a matchbox. With a tiny 128x32 oled display on the outside. I don't bother trying that any more with analog(ue) or DDS. Well, maybe occasionally.

For completeness, you could also mention the very recent design by VU3XVR which uses an ATtiny13 with a potentiometer, but no display(!!), relying on the variable resistor for tuning, and presumably it's knob scale for frequency readout. Importantly, although not stated there, it would also presumably require a very stable voltage rail for the pot. The Tiny13 would shift with changes *in voltage using this very simple approach. (See http://www.siars.org.in/) However, it appears to be a very cheap replacement for a ceramic VXO tuned with the same pot. With si5351a chips down as low as 79p in the UK, this looks an interesting approach, with care.*

For more features, maybe filling the rest of the matchbox, aside from all my designs of course, there are also the compact ATmega-based VFO/si5351a designs from Peter, DK7IH. See the VFO section of his Micro24, for example, on https://radiotransmitter.)

Cheers
Andrew ZL2PD"

I can only say that "you pays your money, and makes your choice"! But... and here comes the caveat - you need some of that "spawn of Beelzebub" software to set up the control micro-controller. Don't say I didn't warn you!

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Tx

Frequency detecting PIC / rig control?

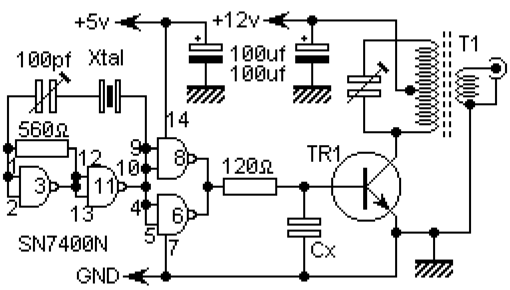
From VK5TM, Terry Mowles, comes yet another development using PIC's: a frequency switch that can be adapted for rig control too, sequentially switching bias supplies and the like. I won't waffle on about this as you can read the entire thing on Terry's web pages - click the link below:

https://www.vk5tm.com/homebrew/freq_switch/freq_switch.php

Terry is making some remarkable inroads to PIC applications; the next article is a project that would probably suit modern PIC technology very nicely. I must admit (and it's just my personal preference) fault finding with a meter and logic probe is a damn sight easier than trying to find an errant comma or other furtive software glitch!

SM0VPO's logic gate Tx

Whilst this must be one of the simplest and most effective transmitters ever devised, Harry's design lends itself to adding a few extras. Crystal control isn't everybody's cup of tea (but for QRP operators, working on an internationally known frequency whilst whispering into the ionospheric galleries is a definite advantage - QRP'ers know where to listen out for you) so some means of shifting frequency yet keeping "rock" solid stability is, for some, a *good thing*.



Of course, the modern DDS/PLL devices, with attendant microcontroller control, are superb, no doubt 'bout that - but for the meter and screwdriver dinosaurs like me, the following is a cracking
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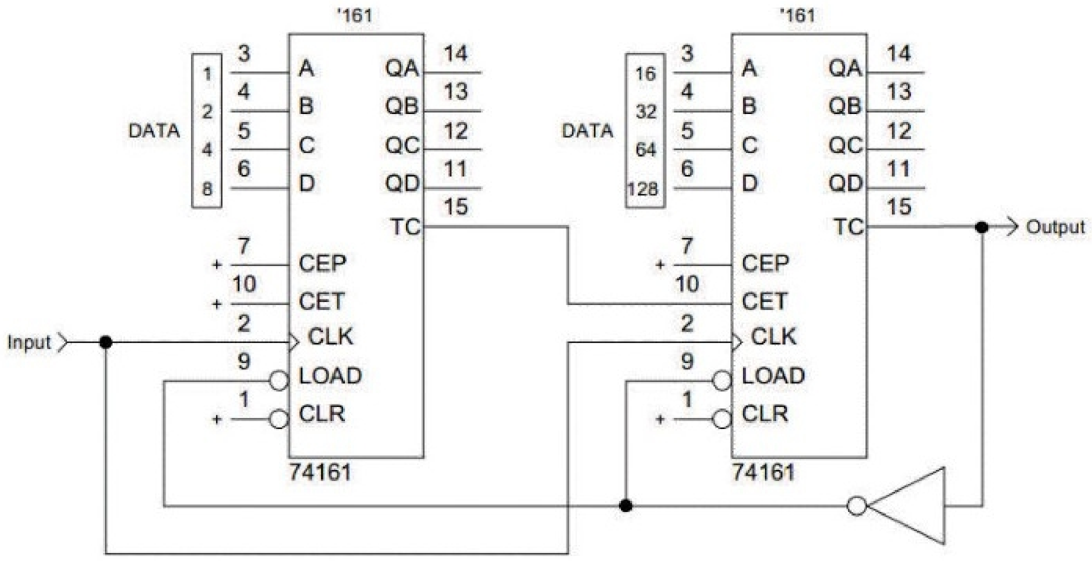
idea. I’ve always had vast respect for Chas. Wendel’s work: a true RF professional, he is a modest and helpful man - and if you stroll through the circuits he’s developed (many using only a couple of transistors!) you glimpse the humour in the man, and I await with bated breath his two transistor bread slicer! Below is a block diagram of my future investigations, once the Pink Brazilian transmitter has earned it’s stripes:

Divide by N Using the '161 Counter

Here is a simple circuit for obtaining divide-by-N from '161s. The technique will work for one, two, or more dividers to obtain the desired N value. One counter handles N values up to 16, two counters divide by N values up to 256, etc. The terminal count, TC, of the last divider is inverted and used to preset all of the counters. The other TC pins are connected to the following counter's CET input. The CET input of the first divider is connected to logic 1 (+VCC).



The data inputs are programmed for the desired division factor, N, using the equation:

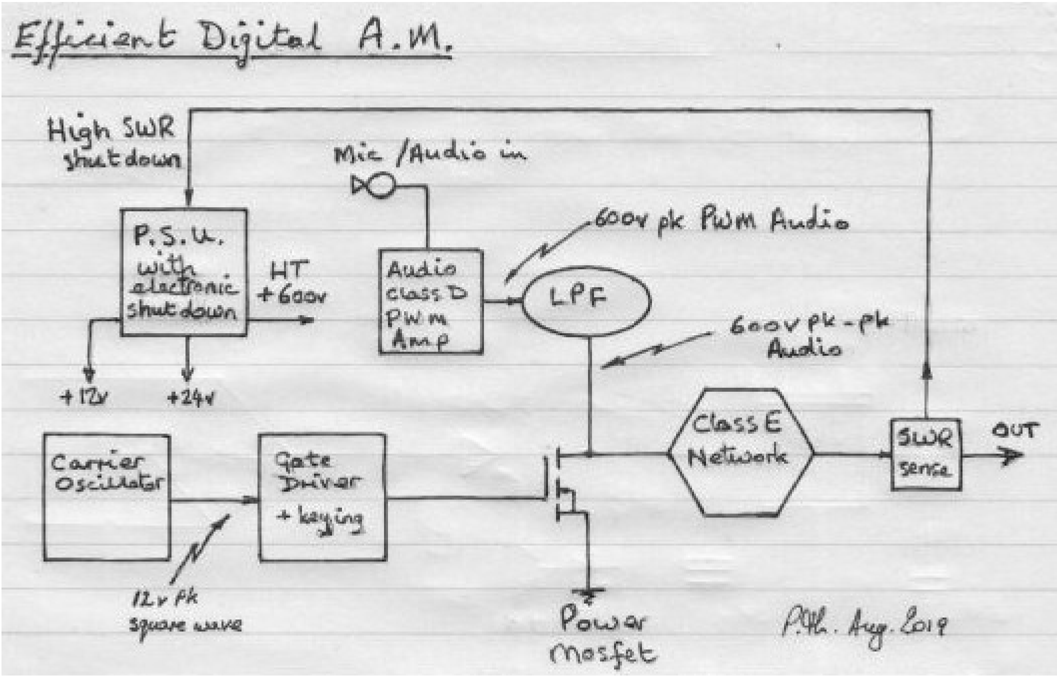
DATA = 256 - N.

with the value of each bit as shown in the boxes. For example, to divide by 183:

DATA = 256 - 183 = 73

And the binary representation of 73 is 01001001 (the first digit being pin 6 of the second '161 and the last digit being pin 3 of the first '161).

The IC's are of course the 74HC161 type; and my thanks go to Chas. Wendel for his superb work. Now consider: if we drive this circuit with a crystal oscillator, you can create almost any frequency you want, by selecting the division ratio, assuming you have a high enough frequency to start with and the '161's can clock at that rate. Now if we add a LOCO clock multiplier chip, we can divide and multiply by the integers available - LOCO clock multipliers can run to several hundred MHz, and offer ratios of 2,3,4,5,6,7,8 and more - and you can cascade them for even more numbers. With a bit of jiggery pokery you'll get virtually any frequency you want, crystal controlled, with a few tuppeny IC's. What's not to like? Combine this easy "bench" technology with efficient A.M. and you've a very potent phone transmitter indeed, reasonably simple, **no software**, which is a winner in my book!



(Many thanks to the http://www.classeradio.com/modulate.htm)

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Construction

Soldering technology

"Anybody can learn to make a perfect soldered joint; the trick is to make millions of perfect soldered joints, day in, day out". This was said to me at a World class soldering machine manufacturer's factory on a technical visit - and it sums up the job perfectly. There are many methods of automating soldering, including - but not exclusively - wave, reflow, vapour phase, inert atmosphere, vacuum, laser and many derivatives of these technologies. All rely on getting the joint hot enough to melt solder (note I say "joint", NOT "soldering iron") and removing surface oxides sufficiently to allow tin to dissolve copper to some extent. That's how soft solder works: tin dissolves a few atoms deep into the copper; copper dissolves a few atoms deep in the tin to make a
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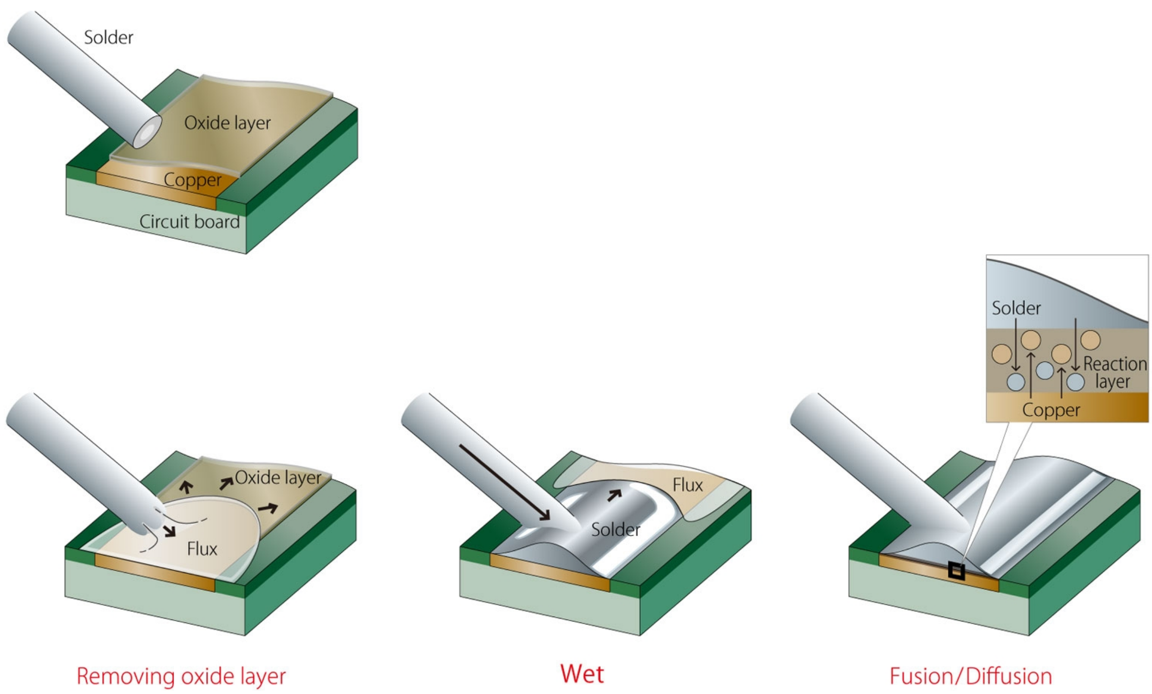
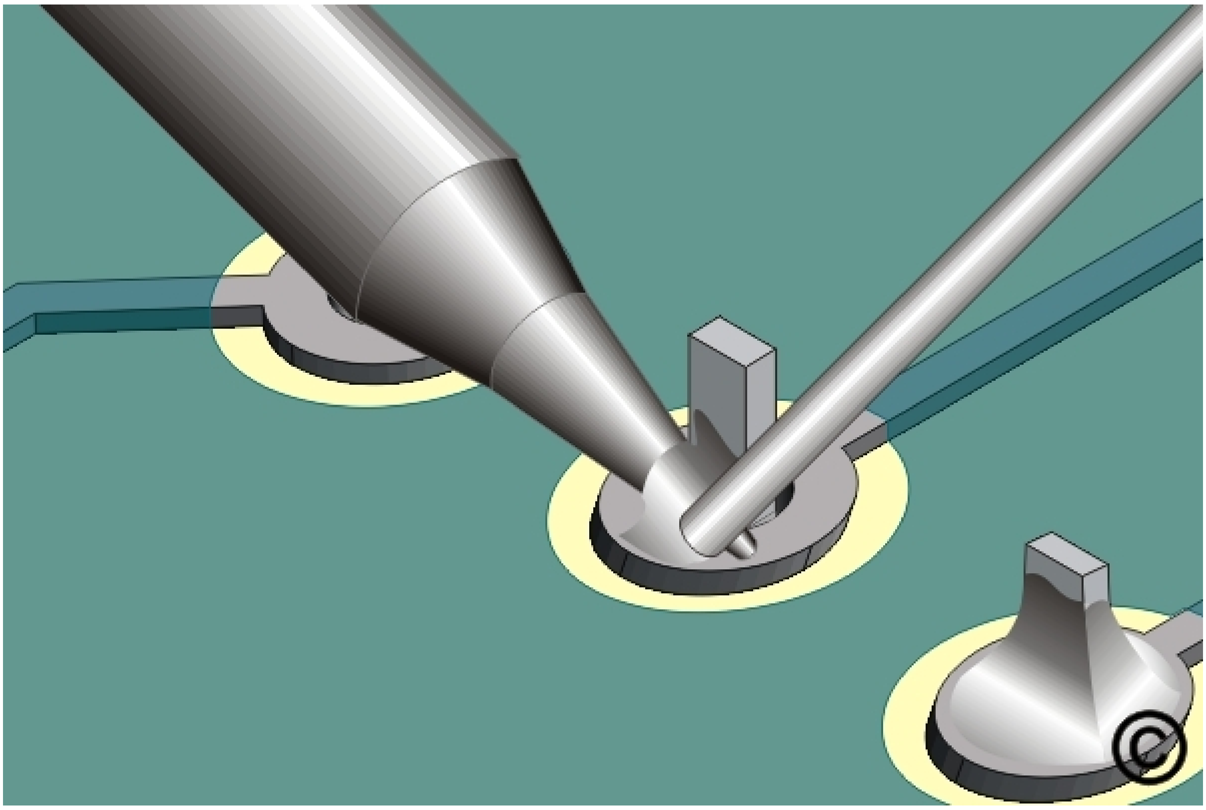
solute metal interstitial layer. After using such big words, a picture is perhaps a good idea. This series of images is from japanunix.com, and illustrates the creation of a soldered joint:



You’ll have to imagine the copper track has been heated by hot soldering iron contact.; the actual stages (you can actually see these stages down a microscope when hand soldering) are illustrated perfectly in the diagram. The stages are:

1. Flux cored solder wire is touched to the copper track
2. Flux melts from inside the cored solder onto the oxide layer, and strips the oxide layer away, exposing pure copper
3. The solder melts as heat is conducted from the copper track into the solder wire, and the flux is pushed along the copper track,much like a glacial moraine
4. The heat and time of contact (a fraction of a second) between the molten solder and unoxidised copper track allows the tin and copper to dissolve a few atoms deep - this is the mechanical and electrical connection.

The following illustration, from circuitrework.com, to whom I give my grateful thanks, shows a component lead being soldered - and illustrates vitally important features of a quality soldered joint:



Note how the soldering iron touches both the copper pad, and the component lead: the area of contact to each part of the joint determines how much heat is introduced to each part of the joint. The solder is applied to the pad, as this gets the flux to run directly onto the copper - if the solder wire was put onto the soldering iron bit, the flux would have cleaned (mostly) the bit, not the pad and lead! Note too the shape of the soldered joint to the right of the joint being soldered: it is truly concave, and uses a minimum amount of solder to cover the pad and most of the lead. Too much solder *does not improve the joint in any way*, and doing so may overheat the component. The soldering heat can only be tolerated by a component for so long before degradation of the semiconductor die inside occurs!

This last is a very important point in machine soldering: the time any component is withstanding the full heat of molten solder is a very important constraint. below is a diagram of a wave soldering machine, the most effective and cheapest mass soldering technology, where a bath of molten solder is pumped up to form an overflowing wave that contacts the underside of a printed circuit board. Flux applied prior to the solder bath is ‘activated’ i.e. removes the oxide from the pcb’s copper and component leads when the full heat of the solder is applied, thus the time of contact with the hot solder wave is critical for good joints every time.

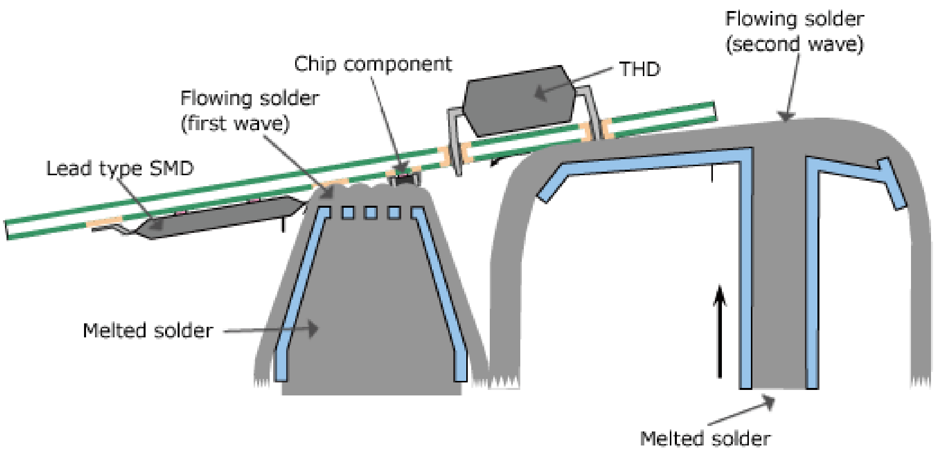


Figure 1.12 Flow (Wave Soldering) Method (Example)

This diagram is from edgar-blajec.squarespace.com, for which many thanks. The process is as follows; the circuit board and components are moving from left to right, along an inclined conveyor, the angle of which is critical:

1. The printed circuit boards, on entering the machine, are sprayed with flux which is then baked to remove the solvent and leave active flux evenly coated on the pcb.
2. The pcb is moved through the first ‘wave’, which is usually turbulent - you can see the multiple nozzles forming a ‘ripple’ wave which solders the intricate and shielded joints.
3. The pcb, now very hot, moves into the second, ‘flow’ wave, which solders the larger and more heat sinking components; you can see the actual region of contact of solder on the pcb is defined by the wave height (i.e. how fast the pumps push molten solder upwards to create the wave).
4. The pcb now leaves the flow wave, the solder peels off the underside cleanly, leaving soldered joint with a minimum of solder applied.
5. In some instances, a ‘hot air knife’ can be used to remove excess solder, immediately after the wave: this works by blowing an accurately defined stream of hot air (or nitrogen in some cases) to remove excess solder and drop it back into the solder bath below.

The temperatures, angle of conveyor, solder pump speeds, flux spray settings, pre-heat control are all specific to a particular pcb: it’s not often that two different pcb’s run the same machine settings unless they are remarkably similar. The ‘process recipes’ are usually held in the control computer, set up by running many trials until the optimum is found; as the production run continues, the solder in the baths becomes oxidised by being continually exposed to air. This produces ‘dross’, oxides of tin and dissolved copper, mixed with burnt excess flux and other contaminants that have to be removed. This is a continuous process; in some machines a nitrogen cover gas is applied to keep oxygen away from solder waves and pcb’s - this is known as ‘nitrogen inerting’ and is a very costly (in terms of nitrogen gas used) process, involving airlocks to get pcb’s in and out. Servicing is very difficult too, as all air has to be displaced by nitrogen before the process can be run after routine maintenance. I’m working on designing a much more efficient nitrogen inerting system, but that’s beyond the scope of Hot Iron: unless you’re planning on producing several million of your current radio project’s pcb’s that is!

Soldering is very much taken for granted when knocking a few boards together in the amateur workshop - but look around at the electronics in your home and workplace and give a thought for all the people and technology involved in bringing you modern electronics at such low prices.

Soldering Flux

From bitter experience, you MUST keep adequate ventilation and fume extraction at all times when soldering. IT IS DANGEROUS TO INHALE FLUX FUMES OF ANY SORT. You won’t feel ill right away; but in time it can be - you may have permanent lung damage, including COPD / asthma.

I shudder to recall - in years gone by we smoked cigarettes whilst using resin cored solder at the bench, used Baker’s Fluid (a barbarous mixture of metallic zinc chippings and hydrochloric acid), a proprietary brand of rosin flux(ite), and stainless steel flux containing phosphoric acid. That doesn’t include silver soldering and brazing, both done with raw borax powder as flux and oxy-acetylene torches. We thought nothing of it at the time...

From article by Jeff Johnson, https://www.pcbtoolexpert.com/best-flux-for-soldering-electronics

“*The Best Flux for soldering Electronics*

If you work with electronics, you know that soldering is an essential part of your job. However, improper soldering can lead to bad joints or even no joints at all. To help increase the likelihood of a good solder, professionals recommend the use of a flux.

What is Flux?

When solder is melted down to form a joint between two opposing metal surfaces, it crease what is referred to as a metallurgical bond. In other words, the solder chemically reacts with other metal surfaces to create a joint. For a solid bond, there are two main things you need. The first is a solder that is compatible, in a metallurgical sense, with the types of metals you are bonding. Secondly, the metal surfaces that are to be jointed should be free of oxides, dust, and other such particles that can damage the integrity of the solder joint. While cleaning metal surfaces can easily remove the dust and grime, oxides are a different story.

Oxides

When a metal surface comes into contact with oxygen, it creates a chemical reaction. This reaction creates metal oxides on the surface of your material and can impact conductivity, current flow, and your solder. Rust on iron, for example, is a visible iron oxide created by this process. Tin, aluminum, copper and almost all other metal surfaces are susceptible to oxidation. When you metals are coated in oxides, soldering can become difficult, if not impossible. We live in a world supported by oxygen, so you will never be able to have a metal surface completely devoid of all oxides. When you solder, you apply high heat to the area. Oxidation occurs much faster when this type of heat is applied. By using flux, however, on the metal surface, you can prevent the growth of additional oxides while applying heat to your solder joint.

What Flux Does

The flux you choose is a chemical component that is vital to a successful solder. Flux should provide three key things. First, it should chemically clean your metal surfaces, help with the flow-ability of your filler materials over the base metals, and provide a protective barrier between the metal and your soldering heat. Second, flux should assist with the heat transfer between the metal surface and your soldering heat source. Third, your flux should help to reduce and remove any surface metal oxides currently sitting on your metal surfaces.

Types of Flux for Soldering

In certain cases, the flux that is typically included within the core of a solder wire is good enough. However, there are certain situations where the use of an additional flux is beneficial. This includes things like surface mount soldering as well as de-soldering. Regardless of the reason you are using a flux, the most ideal product is the one that is the least acidic but still works on any oxidation on the surface of your component. With that, it is important to point out that there are different types of flux to choose from.

Rosin Flux

One of the oldest types of flux is based off of rosin. (Rosin is a refined and purified pine sap.) While rosin flux still exists today, it contains a blend of fluxes instead of just pure pine sap. This helps to optimize the flux and increase its performance and characteristics. One of the great features of a rosin flux is that it potent and acidic only when in its liquid (hot) state. When it cools, however, it becomes solid and inert. Because it becomes inert when cold, rosin flux can be left in place when your soldering is complete. (That is unless the printed circuit board (PCB) or other surface heats to the point of melting the resin flax while in use. Should this occur, the resin can actually begin to eat away at the connection.) While a resin flux does become inert, it is always recommended that you remove it once your solder is done anyway. Rosin flux can be easily removed with alcohol.

Organic Acid Flux

Organic acid (OA) flux is extremely popular. OA flux is actually a water soluble flux. OA fluxes use common, but weak, acids. This includes things like citric, lactic, or stearic acids. These weak acids are then combined with other solvents, such as isopropyl alcohol or water. The phrase "weak acids" may make these fluxes seem weaker than other types. However, OA fluxes are stronger than resin versions. The acids in an OA flux work to clean oxides from metal surfaces much more quickly. Because these fluxes are water soluble, they are easier to clean up and remove. In fact, they can be removed with just water. Unlike resin fluxes, which become inert and could potentially be left on the surface of your PCB, OA products must be removed. (OA flux is electronically conductive and can affect the performance of a PCB if left behind.)

Inorganic Acid Flux

If an OA flux uses "weak acids", an inorganic flux uses much stronger ones. Typically, inorganic fluxes will use a blend that includes an acid like hydrochloric acid, zinc chloride, or ammonium chloride. Inorganic must be removed from your metal surfaces after use. Because of the stronger acids, inorganic flux can be extremely corrosive if left behind after use. This can destroy your solder joint. (Inorganic flux should never be used for electronic assemblies or electrical work due to its highly corrosive nature!)

A Note on Solder Fumes

Fluxes contain many chemical compounds. When soldering, the smoke and fumes that are emitted are dangerous. In fact, inhaling soldering fumes has been linked to asthma. Make sure you solder only in a well ventilated area. Additionally, it is important to take proper safety measures to ensure you remove any fumes or chemicals from your skin. This includes wearing a mask, thoroughly washing your hands and face, and avoiding eating or drinking in an area where soldering is performed.
In addition to this, some soldering fluxes will include the phrase "RoHS compliant." RoHS is short for "Restriction of Hazardous Substances." RoHS, which came from the European Union's Directive 2002/95/EC, restrict the use of certain materials that have been deemed hazardous when used in and for electrical and electronic products."

Diecast Box lid screws

[With obligatory 'Elf - N - Safety' note...]

Yes, those tri-lobe self tappers beloved of the diecast box manufacturers - those little beggars can be done up tight - tighter than a crab's b*m, and that's water tight. Help is to hand however: more oft than not, a kettle of boiling water poured over the box corner (or in the oven, get it really hot), then attack the screws with the appropriate screwdriver - new, not at all worn - and a good sharp twist usually shifts 'em. For this job you ideally need one of those screwdrivers with exchangeable bits, get the best you can from a good quality tool stockist.

And... it's vital to get the right screwdriver bit. Look for #2 Posidrive in Europe, #2 Philips in the USA / Canada (usually).

Any lid screws refusing to co-operate after this treatment - give 'em another kettle full of boiling first oxide of hydrogen, set them on a solid bench or block, put a new screwdriver bit in the head socket and, whilst holding the bit with long nose pliers, clout the bit short and sharp with a light hammer. The bit will stick tight in the head recess; then promptly fit the screwdriver handle without moving the bit. Keep all dead plumb vertical, give her a solid twist and out the offending screw comes.

<u>Compulsory Health and Safety warning:</u> *boiling water is hot, and can cause severe scalds as well as making good tea or coffee. Use a suitable insulating medium to grip the box once it's hot. Ensure the hot water flowing off the box does not run into / onto your hands, boots, pockets, sleeves, or the cat (or any other domestic / agricultural animal, reptile or other sentient being). Do not miss the box with the boiling water from the kettle. Do not hold any part of the kettle other than that which the manufacturer has designated specifically for that purpose. Always unplug the kettle if you are unsure of it's purpose, use and storage, and call for a competent person to assist. If in doubt, don't do it. Whatever 'it' is.*

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Power Supplies

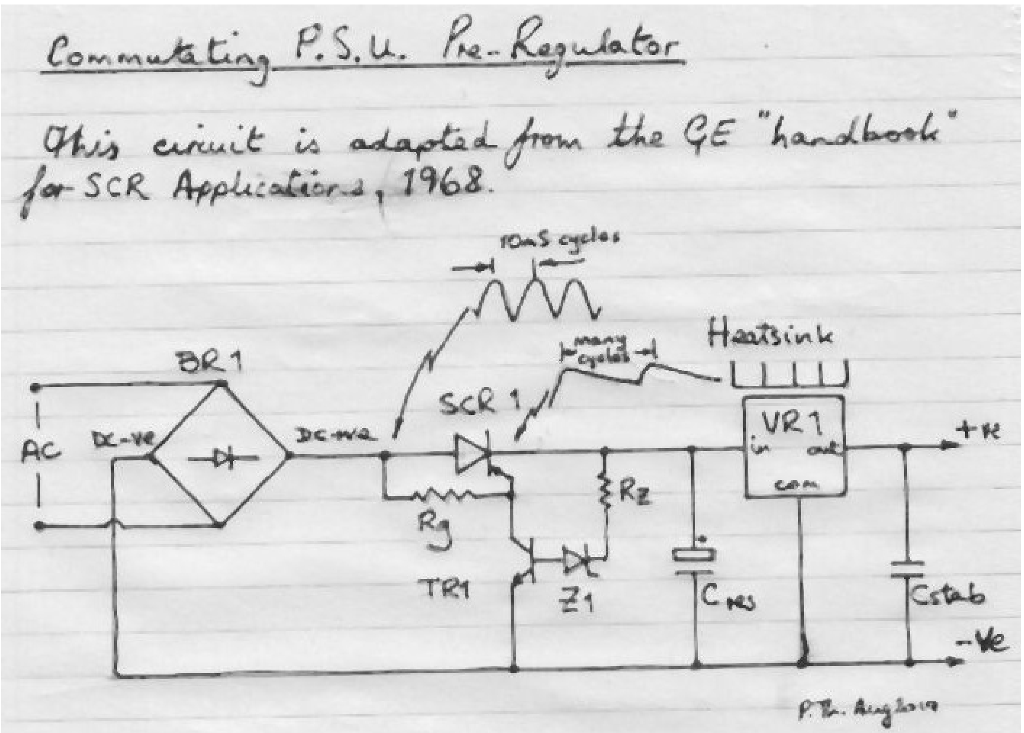
Commutating Pre-Regulators (2)

I had an email (thanks, Mike) about that perennial problem, generating 5 volts DC at some hefty amps from a 13.8v DC bench power supply.

The easy (but inefficient) answer is a linear regulator; but, as Mike points out, his regulator is cooking - it's dissipating (at 5 amps load current) over 35 watts. Using a decent sized power resistor as a dropper feeding the DC into the 5v regulator reduces the watts the linear regulator has to dissipate - but this arrangement merely moves the dissipated watts to the power resistor, and in these energy conscious days, is strictly verboten.

The circuit below has been built hundreds of times and has proved simple, robust and extremely reliable - it does what it says on the tin, and saves power using ultimate simplicity.

It's a good bet that if you can get into the bench power supply you can get to the mains transformer, and find the secondary (low volts) output terminals. A couple of extra wires are attached to the secondary, and brought out to a separate circuit comprising bridge rectifier, SCR and reservoir electrolytic capacitor to form a commutating pre-regulator, the SCR being controlled by a small auxiliary circuit board containing a resistor, zener and transistor, circuit schematic below:



The SCR fires via the gate feed resistor Rg if - and only if - the reservoir capacitor is discharged below a voltage equal to the zener plus one base - emitter volt drop. Make the zener equal to the drop-out voltage of the linear regulator, plus a volt or two for a comfortable operating point, and the SCR will fire only when the voltage on the reservoir capacitor approaches the drop-out voltage for the regulator. One or two half cycles from the transformer via the bridge completely recharge the electrolytic capacitor to the bridge output peak voltage, less the forward drop of the SCR (usually

1.2v or so) - leaving the linear regulator to discharge the reservoir electrolytic as the load current is supplied, and taking no power from the transformer. Result: far lower losses in the linear regulator and less power wasted.

Good, but not perfect, though, as the peak volts from the bridge exceeds the 5v regulator's drop out voltage - but far less power wasted than if the 5v regulator had to do all the dissipation. The commutating supply does not cause any RF noise; the switching is close to zero volts (actually about + 0.55 volts, the gate voltage required to turn on the SCR) and only repeats as and when the reservoir capacitor voltage drops to the zener plus base-emitter volts of the control transistor - certainly not every half cycle if the reservoir is of sufficient capacity. I've seen many other 'SCR' regulated PSU's on the web - almost all use some (complicated!) form of phase angle firing for regulation; this isn't at all satisfactory in the amateur shack. The noise created by non-zero cross switching is horrendous and exactly what you don't want within a mile of your super doozy Rx.

A simple approximation of Cres capacitance required can be made from considering the charge in Coulombs held in the reservoir: CV = Coulombs = iT, where C is capacitance in Farads, V is volts DC across the capacitor, I is the load current drawn from the capacitor and T is the time to discharge the capacitor in seconds. Assume the peak output volts of the secondary after rectification = 20 volts or so, and the drop out voltage of the external regulator is (say) 7.5 volts, then the capacitor feeding 5 amps load, on 50Hz mains, this works out to C = iT/V = 5 x 10mSecs / (20v - 7.5v) which is 0.5/12.5 = 1/25 Farad = 4,000µF. This is an approximation; we don't know how often the SCR fires, so the "T" value might not be anywhere near 10mS - it could be much longer. So the formula gives an absolute minimum "C" value, double that and add more µF's if required after testing.

This isn't too much to ask nowadays - but you'll need capacitors with good ripple current ratings and low ESR: 2 x 4700µF in parallel should do the job, as you want the SCR not to fire too often for low power loss. Be aware too the bridge and SCR will need to be hefty: they both have to carry the half cycle inrush current of the first half cycle, and that's going to be a large current! Assume a minimum of 25 amp continuous rating and the surge capacity will be at least 250 amps. The transformer secondary winding resistance will limit the current well below that, in most cases, it will take a couple of cycles to fill the reservoir capacitor - you'll certainly hear the start-up "whump" of the transformer core! This soon settles to a "ping" of half cycles as the system settles into full running conditions.

USA vs. Euro Transformers... another good point

From Ross Whenmouth, ZL2WRW. Readers may recall in Hot Iron # 104 I reproduced a note from Martin Boardman, of Boardman Transformers, regarding the use of USA transformers on 50 Hz, rather than 60Hz - and the difference in flux density in the cores. Ross comments:

"Hi Peter,

Re: USA vs. European Mains transformers

In response to Martin Boardman's article on page 23 of Hot Iron #104:

I understand that a common industrial voltage in North America is 480V 3-phase 60Hz with 277V line-neutral voltage. A transformer with a winding rated 277V 60Hz should be quite happy with 230V 50Hz energisation because both the voltage and frequency are reduced by ~ 20% - thus the core flux density will be same as when energised with 277V 60Hz. However, the output voltage will unavoidably be reduced by 20% (but maybe you can get lucky and source a 277V to [desired output + 20%] transformer ?)

73 ZL2WRW
Ross Whenmouth"

My grateful thanks got to Ross, I'm always happy to hear alternative views and helpful information.

The 50Hz / 60Hz issue has been kicking the dust up for as long as I can remember; my experience was with USA manufactured 25kV 2Amp HV transformers in Perkin-Elmer electron beam crucibles for tungsten / nickel back coating of silicon wafers, to prevent back face gold migrating into the active regions. When we really pushed the power to the maximum (nickel and tungsten are a b*gger to evaporate) the transformers cooked - the cores were sizzling hot. We dumped the transformers into tanks filled with transformer oil, and fitted fans on the convection pipes on the outside (yes, those are the pipes you see on substation transformers). 50kW electron beams evaporated tungsten, but the deposition rate was low, so we switched to metal sputtering using RF plasmas in magnetron sputter heads running 8kV, 15amps of RF. Think on that next time you pick up a tuppeny transistor!

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Antennas

Antenna advice - and very true

For casual use with a simple receiver you don't need to worry too much about antenna wire length. Too long a piece of wire will diminish the performance of your receiver as it will provide more energy than your receiver can comfortably handle. The symptoms of this are hearing stations outside of the band, such as nearby AM short wave broadcasters. Too short a wire will not provide enough signal - the receiver will appear "deaf". So you should experiment and find out what's right for you. Sometimes 20 meters is dead (you won't be able to hear many signals because the atmospheric conditions are poor) so try your experiments a few times, until you find a convenient and effective length.

Or... take some advice from the very early days of radio.... below.

The Loose Coupler

This device came from the very earliest days of "tunable" radio operations, and is just as useful nowadays as it was then - eliminating overload whilst improving receiver selectivity and reducing noise by closing the received bandwidth down *before* the mixer or RF amplifier, following the principles of rejecting what you don't want, enhancing what you do. A close relative is the popular
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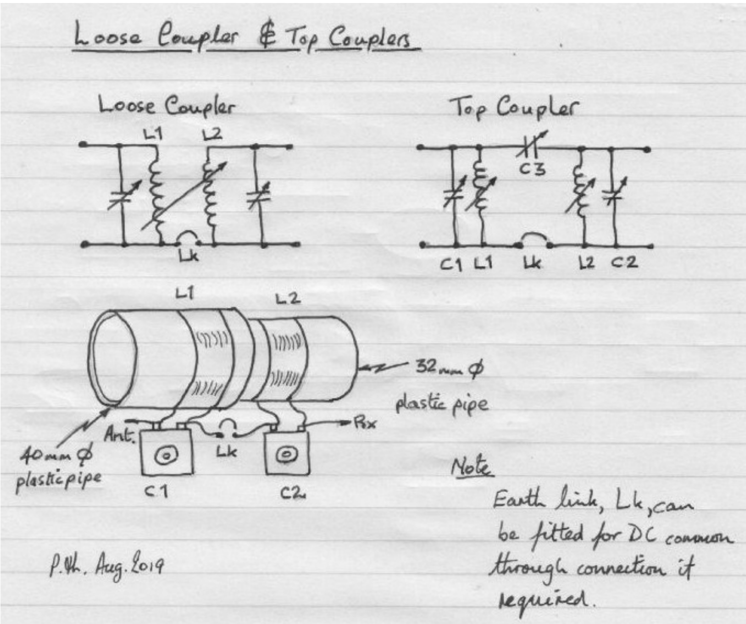
top coupled double tuned circuit - “top coupler” - which can, if constructed with commercial (TOKO style) coils, be effective if the top coupling capacitor is made variable, but that’s the rub. Making controllable, stable and easily adjustable pF capacitors *can* be done, but varying the coupling between the coils is far easier for the home constructor. Having said that, the loose coupler is probably the best bet for lower bands, under 20m perhaps, whereas the top coupler scores all the way to VHF, but is a bit more hassle to adjust (3 capacitors plus 2 coils).

Bearing in mind though the poor ionospheric conditions currently for the higher HF bands, the lower amateur bands are coming into their own: if - and it’s a big “if” - you can work in the crashing noise prevalent nowadays on the bands under 20m. The loose coupler can bring wanted signals out of noise, but the wideband nature of the interference (a deliberate design policy to avoid having to meet noise level tests conducted at spot frequencies - spread the noise far and wide, it becomes as Marmite - “spread exceeding thin” - but enough to overwhelm that tasty weak signal.

Regenerative receivers generally demand an attenuator (usually a potentiometer of some sort, as an “RF gain control”) at the antenna input, otherwise they easily overload with consequent drastic loss of selectivity; but the RF Gain controlled this way loses as much of the signal you want as well as the interference, but the loose coupler can control gain, *without losing any of the desired signal or selectivity*. A loose coupler enhances the signal you want, and can be used on several bands if designed with tapped coils and switched capacitors for tuning. You only need to fit a loose coupler prior to your receiver, peak it up on receive and adjust the RF input to the receiver by varying the coupling for best results.

The principle uses mutual inductance, in which two coupled coils become a transformer. If the coupling between the coils is made variable (i.e. varying the mutual coupling co-efficient, “k”), then the incoming signal can be readily controlled both in level and selectivity without sacrificing sensitivity.

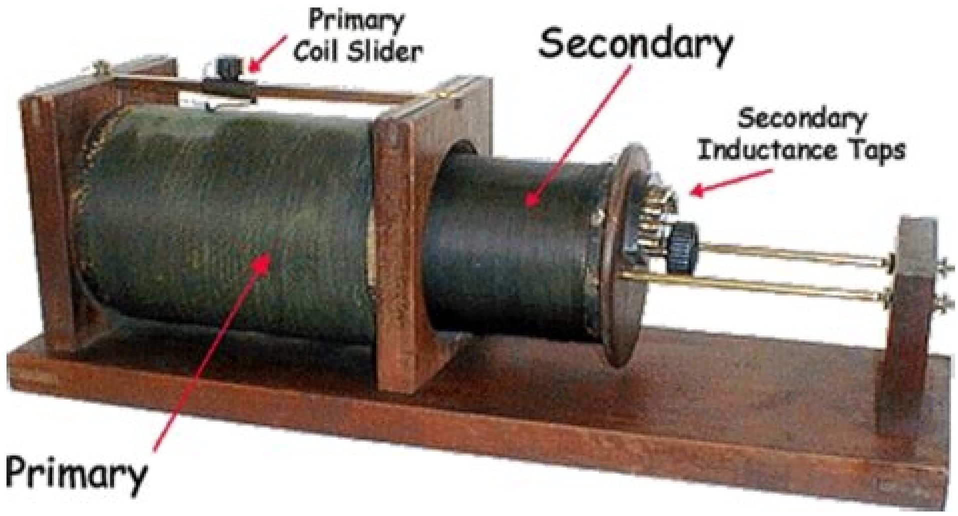
This is my loose coupler at G6NGR, using common UK waste pipe sizes:



The links shown as “Lk” are useful if

you have separate antenna and shack earths - or if earth lines are introducing noise into your shack. Fit as required.

A lovely “spark era” loose coupler (courtesy sparkmuseum.com) is below:



This was built for long waves, you don’t need anything like this number of turns for 160 / 80 / 60 / 40m! You’ll note that no variable capacitors are fitted: this is actually a variable transformer; the only resonances are from the coil inductance and capacitance. For amateur bands nowadays, make both primary and secondary tunable by shunting the coils with a suitable variable capacitor - a 365pF polyvaricon does nicely and they are readily available for very low cost.

A small antenna for 80m

Below is a link for a really effective transmitting antenna by Mike Dennis, G7FEK that covers a good few bands - and is of such a scale it should fit into small gardens.

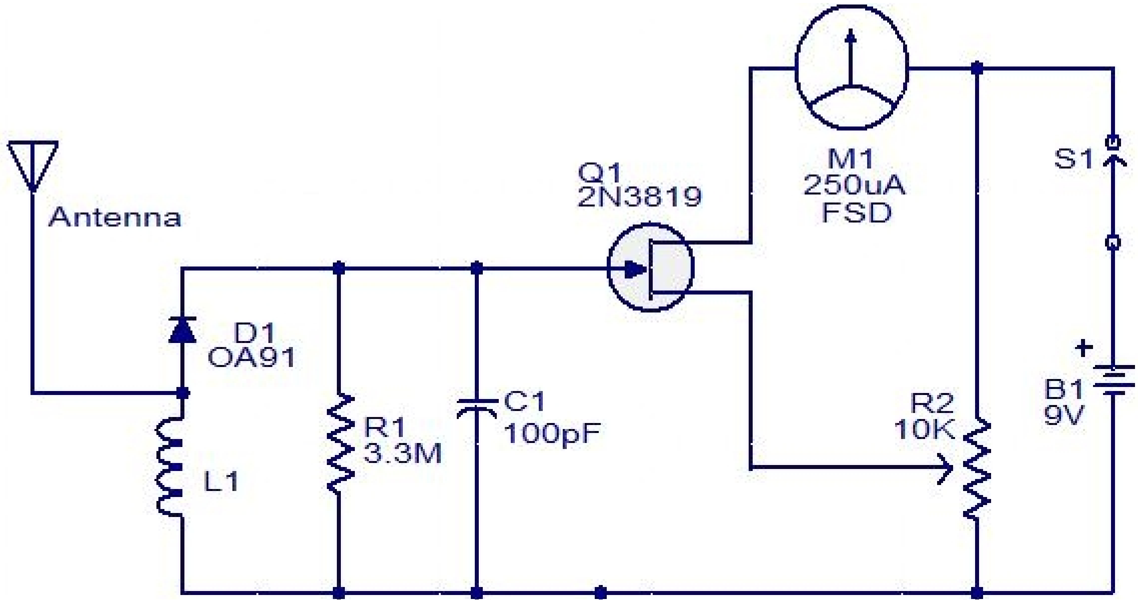
http://www.g7fek.co.uk/blogus/newsshow.php?page=80m_Antenna_for_small_gar_49493

Mike gives a comprehensive construction guide: a very thoroughly engineered job indeed in every aspect. Mike makes some excellent observations - that extra length isn’t always a good idea, for instance - as he’s worked out the resonant lengths just right. And he points out the oft forgotten component - the counterpoise(s)* play a significant part. I’ve found slightly elevated counterpoises work best - threaded around garden fences out of the way of mowers, footballs, washing line (the last being a critical point to observe in any antenna installation....). The point is clearly illustrated: a Marconi vertical radiator, with resonant top loading elements, counterpoise to match, give very good results in a very small space. Take my word for it: Mike’s antenna is a very good example of sound RF engineering.

*Mike comments that a separate and carefully arranged RF earths are the “make or break” for Marconi antennas. This is always a good principle to follow. A (series) tuned counterpoise network of multiple wires fanned out can help if you’re stuck for space; but be prepared for some “cut and try” with your earthing, especially on short antennas. The counterpoise(s) / RF earth is as important as the radiators!

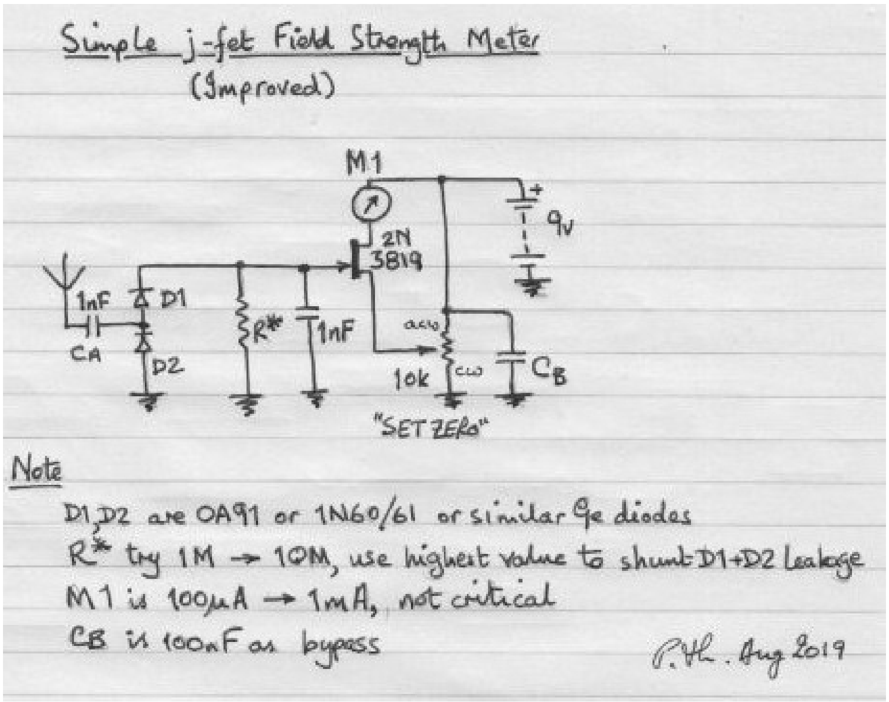
A simple very sensitive field strength meter

This schematic diagram has been floating around for years now; and is instantly recognisable by those who have 'the knack' - as one to avoid! The problem in this design is the inductor, L1. If you design it for, say, the 80m / 60m bands, at 20m and up L1 parasitic coil resonances cause weird readings. Similarly, if you size the inductor for, say, 15m/12m/10m, it's nigh on useless anywhere



under 20m. But... the simple j-fet amplifier is a real boon for the QRP / QRPp operators, so below is a simple modification to get this little rascal back to sanity. Discard L1; add Ca and D2. This creates a voltage doubler rectifier, increasing sensitivity, as does a higher value gate resistor, R*. Fit 1M - 10M, whatever value works that gives reasonably stable meter deflection; R* also provides the DC reference for the j-fet gate. The 1nF capacitors Ca and the j-fet gate capacitor suit low band HF operation; increase to 10nF / 47nF for LF, and reduce to 220pF - 27pF for 6 /10 / 12/ 15m.

Note the pot wiring - make a habit of turning the pot fully anti-clock and unplug the battery when not in use, or fit a power switch.



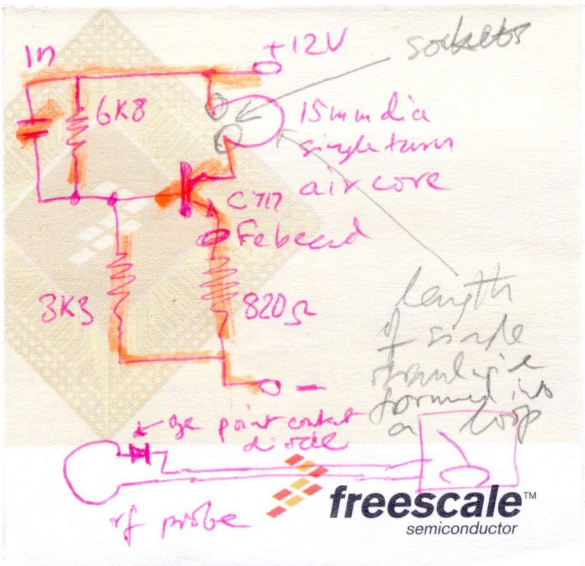
Conundrum Corner....

RF electricity does funny things! Inductance, capacitance mysteriously appear like mushrooms springing up to kibosh your latest design. It seems to have neither rhyme nor reason; touch an RF “hot” contact, and you don’t get electrocuted - just fried skin, as the RF stays in the very outer layers of the body, and makes notoriously difficult to heal deep burns. Make a transmitting antenna for LF, and the top glows blue with St. Elmo’s Fire (corona discharge) at night, even running just a few watts; at 160m or higher you’ll see nothing. Odd!

Sometimes seemingly simple devices can produce remarkable effects you can’t even detect: an RF transistor, energised, but with no drive, gets mysteriously hot. “Aha! parasitic oscillation!” is the thought; but any attempt to measure the frequency yields nothing; the moment you touch a probe to any terminal, the oscillatory heating stops. Adding extra capacitors doesn’t help, merely turns the continuous oscillation into “motor boating”!

Step in old hand who has seen all this before: “it’s inductance in the emitter lead / cathode wiring / source wires (delete as appropriate). The active device, with an Ft of maybe a few hundred MHz, is oscillating at GHz as the parasitic circuit elements surrounding the device have created a common base / grid / gate (delete as appropriate) oscillator, and once power’s applied, off she jolly well goes.

A circuit I came across years ago illustrates this nicely, it’s a UHF / µ-wave oscillator:



If you build this circuit with absolute minimal lead lengths, on a scrap of FR4 copper clad board you’ll see the oscillation way above the Ft value of the transistor. Transistors with Ft 0f 300MHz will easily achieve GHz frequencies - IF (and only IF) the construction is of absolutely minimal lead length and size. Ideally, surface mount components and chip capacitors if you can - and this thing will achieve Ft x 10 or more; the simple Ge diode and meter circuit detect the GHz's and display them as meter deflection. This little circuit is good fun to use with Lecher lines to find the frequency of oscillation. Incidentally, with OA91's (as pointed out earlier in this edition of Hot Iron) are as rare as hen's teeth nowadays - but a dig into any ancient volume of Towers International Transistor and Diode Selector book will find dozens of Ge diodes just as capable and often very cheaply available at out favourite on-line auction house. I'd suggest you find (and keep - never loan it out!) a copy of Towers - the useful parameters of millions of transistors are easily found as are substitutes, very useful in amateur (ahemm! and professional...) workshops.

Which leads very nicely to a conundrum! You may have heard of "mercury wetted" reed relays, a device first made in the early 1900's, I believe. These have a tiny, tiny drop of liquid mercury on the contacts - it really is a tiny drop, maybe thousandth of an inch high, such that as the contacts are closed, the circuit is made through the Palladium relay contacts as usual; but on opening, the drops of mercury on the contacts exhibit surface tension (as any liquid does), and the mercury between the contacts maintains the circuit closed until the mercury surface tension collapses the column of mercury and the circuit opens, very quickly - very quickly indeed. The mercury maintains the circuit until a single atom of mercury on each contact is the only link, then opens virtually instantaneously. I'm told it's the time it takes for electrons in the outer shell of the mercury atoms making the circuit to go into quantum exclusion, and open the circuit. The only thing that slows down the opening circuit electrical signal is the surrounding capacitance and inductance of the mercury columns, and, of course, the mounting wires and any oscilloscope probes (or whatever) connected to measure the moment of disconnection.

Here's a question: how fast does the mercury contact open, ignoring the external influences from leads, probes, etc.? It's been mooted (and up to now, as far as I know, nobody's disproved it) the speed of opening is - - - - less than 10^{-20} seconds! It's related to the outer shell electron orbit times of mercury; or, if you swing that way, to the frequency of the DeBroglie pilot wave the electrons dance round.

The practical application of this effect is used in very high speed pulse generators using charged transmission lines and sampling scopes to measure the propagation delay of gates and other devices. The mercury wetted relays are switched at about 10kHz so the sampling scopes can build a picture up within a few seconds.

Similar switching speeds are achieved in air gap triggertrons, used to pulse lasers, by switching 16kV charged capacitors into the flash tubes to pump the laser element. The triggertron uses two tungsten electrodes, spaced a few mm apart, with a third tungsten needle tip just to one side of the electrode space. A 100kV pulse is applied to the needle, the ensuing spark to both electrodes ionises the gap and *BANG* the capacitors discharge through the flash tube in very quick order. Below is a good description of a triggertron, from https://core.ac.uk/download/pdf/18320788.pdf

"Triggering of the output was accomplished by a triggertron high voltage spark gap switch. The triggertron is a three-port device and consists of a pair of rounded electrodes separated by a gap of about 1 cm. There is a hole in the center of one of the electrodes, which has the pin of a small spark plug peeking up through it. [Fig 3-5] When the two electrodes are at their charged potential there is

not enough voltage to cause a breakdown between the them. To trigger the device (to switch it on) a spark is created between the spark plug pin and the surrounding electrode by the triggering circuit. This spark releases ions into the space between the electrodes, triggering a breakdown between the two rounded electrodes activating the switch closure."

To conclude: if the mercury wetted contacts open in 10^{-20} seconds, what bandwidth must the connecting circuitry have to faithfully reproduce (i.e. not slow down) the switched edge? I'll give a clue: it might not be possible with current materials and technologies...! And it makes the fastest computer processors available today appear pedestrian. Don't forget that free space, with no wires, nor anything else, has capacitance and inductance, so that $1 / (\varepsilon_o \times \mu_o)^{-2} = C$, the speed of light, and the Zo of free space is 377 ohms.

You're well into the realms of experimental physics here: fast edges, of high voltage and current, are just as mysterious as the electromagnetic wave itself. Described by Maxwell's equations, we radio amateur disregard the many solutions of Maxwell's equations, choosing the one that seems to work for us (the "forward" solution) whilst ignoring the "retarded" solution - which describes how an equal but opposite wave to our transmitted wave comes racing backwards towards our antennas when we key.

There are other solutions too... but not for talking about now. The mathematics of fast edges are the very useful Laplace transforms, so useful for solving circuit and control theory differential equations; but maths allows infinities and zero time - the real World doesn't, and it's this difference that makes fast edge physics such an interesting research topic.

Data and Information

This information is for guidance only – you MUST comply with your local Regulations! I have included information about AC power systems and conventions, as equipment can often be bought from overseas nowadays and it's important that we know exactly how to connect it and control theory to our "home" supplies - but suffice to say, if there's any doubt - - - GET PROFESSIONAL, COMPETENT HELP BEFORE YOU CONNECT TO ANY ELECTRICAL SUPPLY!

Wire Information...

AWG Table

1 AWG is 289.3 thousandths of an inch
2 AWG is 257.6 thousandths of an inch
5 AWG is 181.9 thousandths of an inch
10 AWG is 101.9 thousandths of an inch
20 AWG is 32.0 thousandths of an inch
30 AWG is 10.0 thousandths of an inch
40 AWG is 3.1 thousandths of an inch

The table in ARRL handbook warns that the figures are approximate and may vary dependent on the manufacturing tolerances. If you don't have a chart handy, you don't really need a formula.
There's several handy tricks:
Solid wire diameters increases/decreases by a factor of 2 every 6 gauges,
" " " " " 3 every 10 gauges,
" " " " " 4 every 12 gauges,
" " " " " 5 every 14 gauges,
" " " " " 10 every 20 gauges,
" " " " " 100 every 40 gauges,

With these, you can get around a lot of different AWGs and they cross check against one another. Start with solid 50 AWG having a 1 mil diameter.
So, 30 AWG should have a diameter of ~ 10 mils.

36 AWG should have a diameter of ~ 5 mils.	Dead on.
24 AWG should have a diameter of ~ 20 mils.	Actually ~ 20.1
16 AWG should have a diameter of ~ 50 mils.	Actually ~ 50.8
10 AWG should have a diameter of ~ 100 mils.	Actually ~ 101.9

If you are more interested in current carrying ability than physical size, then also remember that a change of 3 AWG numbers equals a doubling or halving of the circular mills (the cross sectional area). Thus, if 10 AWG is safe for 30 amps, then 13 AWG (hard to find) is ok for 15 amps and 16 AWG is good for 7.5 amps.
The wire gauge is a logarithmic scale base on the cross sectional area of the wire. Each 3-gauge step in size corresponds to a doubling or halving of the cross sectional area. For example, going from 20 gauge to 17 gauge doubles the cross sectional area (which, by the way, halves the DC resistance).
So, one simple result of this is that if you take two strands the same gauge, it's the equivalent of a single wire that's 3 gauges lower. So two 20 gauge strands is equivalent to 1 17 gauge.

Wire Gauge Resistance per foot

4	.000292
6	.000465
8	.000739
10	.00118
12	.00187
14	.00297
16	.00473
18	.00751
20	.0119
22	.0190
24	.0302
26	.0480
28	.0764

Current ratings

Most current ratings for wires (except magnet wires) are based on permissible voltage drop, not temperature rise. For example, 0.5 mm^2 wire is rated at 3A in some applications but will carry over 8 A in free air without overheating. You will find tables of permitted maximum current in national electrical codes, but these are based on voltage drop. Here is a current and AWG table.

AWG	dia mils	circ mils	open air Amp	cable Amp	ft/lb bare	ohms/1000’
10	101.9	10380	55	33	31.82	1.018
12	80.8	6530	41	23	50.59	1.619
14	64.1	4107	32	17	80.44	2.575

Mils are .001". "open air A" is a continuous rating for a single conductor with insulation in open air. "cable amp" is for in multiple conductor cables. Disregard the amperage ratings for household use.
To calculate voltage drop, plug in the values:
V = DIR/1000
Where I is the amperage, R is from the ohms/1000' column above, and D is the total distance the current travels (don't forget to add the length of the neutral and live together - ie: usually double cable length).
Design rules call for a maximum voltage drop of 6% (7V on 120V circuit).

Resistivities at room temp:

Element	Electrical resistivity (micro-ohm-cm)
Aluminium	2.655
Copper	1.678
Gold	2.24
Silver	1.586
Platinum	10.5

This clearly puts silver as the number one conductor and gold has higher resistance than silver or copper. It's desirable in connectors because it does not oxidise so remains clean at the surface. It also has the capability to adhere to itself (touch pure gold to pure gold and it sticks) which makes for very reliable connections.

Thermal conductivity at room temperature

	$W/cm^2/°C$
silver	4.08
copper	3.94
gold	2.96
platinum	0.69
diamond	0.24
bismuth	0.084
iodine	43.5E-4

This explains why diamonds are being used for high power substrates now. That's man-made diamonds. Natural diamonds contain enough flaws in the lattice that the phonons (heat conductors) get scattered and substantially reduce the ability to transport the heat.

Copper wire resistance table

AWG	Feet/Ohm	Ohms/100ft	Ampacity	$(mm^{2)}$	Meters/Ohm	Ohms/100M
10	490.2	.204	30	2.588	149.5	.669
12	308.7	.324	20	2.053	94.1	1.06
14	193.8	.516	15	1.628	59.1	1.69
16	122.3	.818	10	1.291	37.3	2.68

18	76.8	1.30	5	1.024	23.4	4.27
20	48.1	2.08	3.3	0.812	14.7	6.82
22	30.3	3.30	2.1	0.644	9.24	10.8
24	19.1	5.24	1.3	0.511	5.82	17.2
26	12.0	8.32	0.8	0.405	3.66	27.3
28	7.55	13.2	0.5	0.321	2.30	43.4

These Ohms / Distance figures are for a round trip circuit. Specifications are for copper wire at 77 degrees Fahrenheit or 25 degrees Celsius.

Wire current handling capacity values

mm2	R/m-ohm/m	I/A
6	3.0	55
10	1.8	76
16	1.1	105
25	0.73	140
35	0.52	173
50	0.38	205
70	0.27	265

Mains wiring current ratings

In mains wiring there are two considerations, voltage drop and heat build up. The smaller the wire is, the higher the resistance is. When the resistance is higher, the wire heats up more, and there is more voltage drop in the wiring. The former is why you need higher-temperature insulation and/or bigger wires for use in conduit; the latter is why you should use larger wire for long runs. Neither effect is very significant over very short distances. There are some very specific exceptions, where use of smaller wire is allowed. The obvious one is the line cord on most lamps. Don't try this unless you're certain that your use fits one of those exceptions; you can never go wrong by using larger wire. This is a table apparently from BS6500, reproduced in the IEE Wiring Regs which describes the maximum fuse sizes for different conductor sizes:

Cross-section CSA / area	Overload current rating
0.5mm²	3A
0.75mm²	6A
1mm²	10A
1.25mm²	13A
1.5mm²	16A

Typical current ratings for mains wiring

Inside wall

mm^2	Amps
1.5	10
2.5	16

Equipment wires

mm^2	A
0.5	3
0.75	6
1.0	10
1.5	16
2.5	25

Wire sizes used in USA inside wall

For a 20 amp circuit, use 12 gauge wire. For a 15 amp circuit, you can use 14 gauge wire (in most locales). For a long run, though, you should use the next larger size wire, to avoid voltage drops. Here's a quick table for normal situations. Go up a size for more than 100 foot runs, when the cable is in conduit, or ganged with other wires in a place where they can't dissipate heat easily:

Gauge	Amps
14	15
12	20
10	30
8	40
6	65

PCB track widths

For a 10 degree C temp rise, minimum track widths are:

Current	width in inches
0.5A	0.008"
0.75A	0.012"
1.25A	0.020"
2.5A	0.050"
4.0A	0.100"
7.0A	0.200"
10.0A	0.325"

Equipment wires in Europe

3 core equipment mains cable

Current	3A	6A	10A	13A	16A
Conductor size (mm)	16*0.2	24*0.2	32*0.2	40*0.2	48*0.2
Copper area (mm^2)	0.5	0.75	1.0	1.25	1.5

Cable ratings for 3A, 6A and 13A are based on BS6500 1995 specifications and are for stranded thick PVC insulated cables.

Insulated hook-up wire in circuits (DEF61-12)

Max. current	1.4A	3A	6A
Max. working voltage (V)	1000	1000	1000
PVC sheat thickness (mm)	0.3	0.3	0.45
Conductor size (mm)	7*0.2	16*0.2	24*0.2

Conductor area (mm^2)	0.22	0.5	0.75
Overall diameter (mm)	1.2	1.6	2.05

Common Cable colour Codes

American electrical contractors and electricians are required to follow the National Electrical Code ("NEC") with regard to wiring colours. NEC imposes the following electrical wiring colour standards:

- **Ground wires:** green, green with a yellow stripe, or bare copper
- **Neutral wires:** white or gray

In theory, wiring conducting live current in the U.S. is permitted to be any other colour, although in practice, electrical contractors and electricians follow these local conventions:

- **Single phase live wires:** black (or red for a second "hot" wire)
- **3-phase live wires:** black, red and blue for 208 VAC; brown, yellow, purple for 480 VAC

Most countries in Europe, including the U.K., now follow the colour conventions established by the International Electrotechnical Commission ("IEC"). These colour conventions are as follows:

- **Earth wires** (called ground wires in the U.S. and Canada): green with a yellow stripe
- **Neutral wires:** blue
- **Single phase live wires:** brown
- **3-phase live wires:** brown, black and gray

Electrical wiring in Canada is governed by the Canadian Electric Code ("CEC"). The following wiring colour requirements apply in Canada:

- **Ground wires:** green, or green with a yellow stripe
- **Neutral wires:** white
- **Single phase live wires:** black (or red for a second live wire)
- **3-phase live wires:** red, black and blue

It's important to remember that the above colour information applies only to AC circuits.

A.M. Frequency slots in Amateur HF Bands

All Frequencies in MHz

160 Metres: 1.885, 1.900, 1.945, 1.985 (USA)

1.850 (W. Europe)

1.933, 1.963 (UK)

1.843 (Australia)

80 Metres: 3.530, 3650 (South America)

3615, 3625 (in the UK)

3705 (W. Europe)

3.690 (AM Calling Frequency, Australia)

75 Metres: 3.825, 3.870 (West Coast), 3.880, 3.885 (USA)

60 Metres : 5.317

40 Metres: 7.070 (Southern Europe)

7.120, 7.300 (South America)

7.175, 7.290, 7.295 (USA)

7.143, 7.159 (UK)

7.146 (AM Calling, Australia)

20 Metres: 14.286

17 Metres: 18.150

15 Metres: 21.285, 21.425

10 Metres: 29.000-29.200

6 Metres: 50.4 (generally), 50.250 Northern CO

2 Metres: 144.4 (Northwest)

144.425 (Massachusetts)

144.28 (NYC-Long Island)

144.45 (California)

144.265 (Los Angeles, CA)

Other AM Activity Frequencies

AM activity is increasingly found on a number of other bands, in particular: 5317KHz, 7143KHz, 14286KHz, 21425KHz and 29000 - 29150KHz.
There are several local AM nets in the UK on top band.

FM Frequencies

For mobiles working into VMARS events, 2m calling in on 145.500MHz (S20) is usual, before QSY to a working frequency. At event locations where military equipment is in use, suggested FM "Centres of Activity" on VHF are 51.700Mhz, 70.425MHz (70.450MHz calling).

VMARS RECOMMENDED FREQUENCIES

3615 Khz	Saturday AM net 08:30 – 10:30
3615 Khz	Wednesday USB net for military equipment 20:00 – 21:00
3615 Khz	Friday LSB net 19:30 – 20:30
3615 Khz	Regular informal net from around 07:30 - 08:30
3577 Khz	Regular Sunday CW net 09:00

5317 Khz Regular AM QSO's, usually late afternoon

7073 Khz Wednesday LSB 13:30; Collins 618T special interest group

7143 Khz VMARS AM operating frequency

51.700 MHz VMARS FM operating frequency, also rallies and events

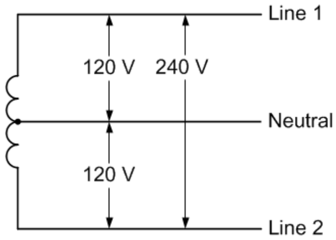
70.425 MHz VMARS FM operating frequency, also rallies and events

Electrical Supplies - Courtesy LEGRAND equipment

Common Electrical Services & Loads

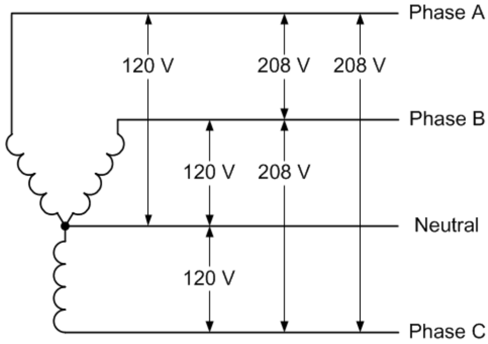
In the following drawings, the coil symbols represent the secondary winding of a utility service transformer or other step down transformer. Electrical code regulations in most jurisdictions require that the neutral conductor be bonded (connected) to the earth safety ground at the electrical service entrance.

Single Phase Three Wire



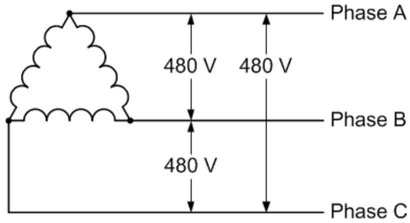
Also known as an Edison system, split-phase or centre-tapped neutral. This is the most common residential service in North America. Line 1 to neutral and Line 2 to neutral are used to power 120 volt lighting and plug loads. Line 1 to Line 2 is used to power 240 volt single phase loads such as a water heater, electric range, or air conditioner.

Three Phase Four Wire Wye



The most common commercial building electric service in North America is 120/208 volt wye, which is used to power 120 volt plug loads, lighting, and smaller HVAC systems. In larger facilities the voltage is 277/480 volt and used to power single phase 277 volt lighting and larger HVAC loads. In western Canada 347/600V is common.

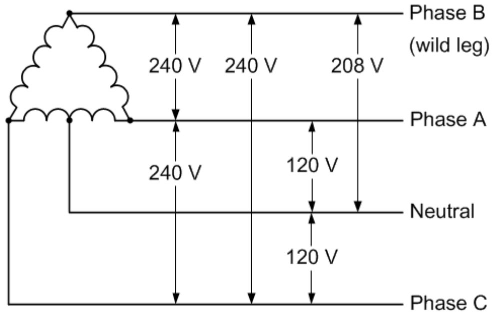
Three Phase Three Wire Delta



Used primarily in industrial facilities to provide power for three-phase motor loads, and in utility power distribution applications. Nominal service voltages of 240, 400, 480, 600, and higher are typical.

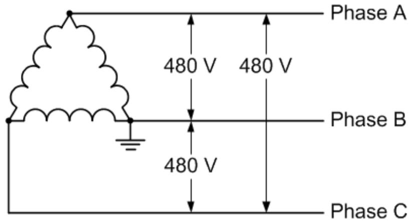
Uncommon Electrical Services

Three Phase Four Wire Delta



Also known as a high-leg or wild-leg delta system. Used in older manufacturing facilities with mostly three-phase motor loads and some 120 volt single-phase lighting and plug loads. Similar to the Three Phase Three Wire Delta discussed above but with a centre-tap on one of the transformer winding to create neutral for 120 volt single-phase loads. Motors are connected to phase A, B, and C, while single-phase loads are connected to either phase A or C and to neutral. Phase B, the high or wild leg, is not used as the voltage to neutral is 208 volt.

Three Phase Two Wire Corner-Grounded Delta



Used to reduce wiring costs by using a service cable with only two insulated conductors rather then the three insulated conductors used in a convention three phase service entrance.

International Electrical Distribution Systems

Description	L–N Vac	L–L Vac	Countries
1-Phase, 2-Wire 120 V with neutral	120	–	US
1-Phase, 2-Wire 230 V with neutral	230	–	EU, UK, Scandinavia
1-Phase, 2-Wire 208 V (No neutral)	–	208	US
1-Phase, 2-Wire 240 V (No neutral)	–	240	US
1-Phase, 3-Wire 120/240 V	120	240	US
3-Phase, 3-Wire 208 V Delta (No neutral)	–	208	US
3-Phase, 3-Wire 230 V Delta (No neutral)	–	230	Norway

3-Phase, 3-Wire 400 V Delta (No neutral)	–	400	EU, UK, Scandinavia
3-Phase, 3-Wire 480 V Delta (No neutral)	–	480	US
3-Phase, 3-Wire 600 V Delta (No neutral)	–	600	US, Canada
3-Phase, 4-Wire 208Y/120 V	120	208	US
3-Phase, 4-Wire 400Y/230 V	230	400	EU, UK, Scandinavia
3-Phase, 4-Wire 415Y/240 V	240	415	Australia
3-Phase, 4-Wire 480Y/277 V	277	480	US
3-Phase, 4-Wire 600Y/347 V	347	600	US, Canada
3-Phase 4-Wire Delta 120/208/240 Wild Phase	120, 208	240	US
3-Phase 4-Wire Delta 240/415/480 Wild Phase	240, 415	480	US
3-Phase Corner-Grounded Delta 208/240	–	240	US
3-Phase Corner-Grounded Delta 415/480	–	480	US

Note: regional variations may exist: if in ANY doubt, consult your Electrical Supply Authority.