HOT IRON # 119

February 2023

Table of Contents

CQ-CQ-CQ

An apology…

I've been ill recently, my having bronchitis (or 'COPD' as it's known nowadays) was caused - so I'm told - by a lifetime's inhalation of rosin flux fumes, tobacco smoke, electro-plating shop fumes, dichlorosilane and coal dust, and not necessarily in that order. This ended up with me in a local Hospital r4ecently, and on antibiotics to clear up a cracking good lung infection.

This came just after a death in the family before Christmas; so my usual Hot Iron writing time has been much truncated - this Hot Iron is briefer than usual, and I hope you don't mind. I've had some positive emails about Hot Iron (and its contents) which have helped frame out this edition; please keep the feedback - good or bad - coming, it's very welcome.

Radio links

Tom McKee K4ZAD sent me a link to an archived collection of radio information, from an old friend of Hot Iron, Roger Lapthorn, G3XBM:

https://archive.org/details/dlarc?query=G3XBM

In the archive you'll find Roger's notebooks and lots of his other links and ideas. Roger has always been an avid experimenter in all things radio; his circuits and results are superb and always worth reading, be it VLF to THz optical.

Touching outer space?

I spent a lot of my working life in Test Gear Maintenance, on-site breakdown service repairs, R&D and general production improvements and the like. I met many 'old hands' along the way whose guidance and experience rubbed off on me (or so I'd like to think!). One such was Ronnie B., who was the High Vacuum genius and very talented engineer who, by pointing out the basic skills of high vacuum engineering and pump maintenance, gave me my first glimpse of what outer space - and 10^{-8} Torr - looked like from a maintenance point of view. Ronnie was at home with high voltages, high currents and plasma etching, metal deposition, ion implanters and a host of other applications associated with semiconductor manufacture that involved the generation of vacuum conditions. Take for instance the plastic encapsulation around a semiconductor device - you'd think it was a simple enough task to encapsulate an IC or transistor chip, wouldn't you?

Consider this: the plastic encapsulation has to be applied in a Production line - i.e. quickly, hundreds if not thousands at a time, over and over again, without any human intervention. The molten plastic has to be as gentle a flow as possible, or the tiny bond wires that connect the chip to the outside world will get broken; it has to be an insulator par excellence, as good if not better than the finest glass; it has to be as cheap as chips and readily available to known electrical parameters - for instance, you can't get fast edges from a logic chip if the encapsulation has high ε_r, the stray capacitance would be too high. All in all, it's one massive engineering job to encapsulate a tiny SMT transistor , let alone a 500 point 'solder bump' processor chip and it was in this regard I first met Ronnie B.

Ronnie was struggling with a vacuum pump; it was refusing to start after he'd shut it down to replace a shaft seal (the bane of rotary pumps, a problem high vacuum engineers amongst us will recognise) and I was fixing a temperature controller which, for reasons I found out after much investigation, was becoming unstable in controlling the temperature of a moulding press platen - a block of precision milled steel that the lead frame of 64 devices slotted in, and a similar block that clamped down above it to create the mould chamber for each device. These steel blocks weighed upwards of 2 tonnes each; the press closed under 500 tonnes of hydraulic pressure to ensure no 'leaks' which show as side flashes in the product (you'll sometimes see the 'halfway' mark on IC's and plastic transistors, where the two mould halves fit together).

Ronnie was there as the mould platens MUST be pumped out to a low pressure - the hot liquefied plastic is injected under immense pressure into heated steel moulds, which, because they are under vacuum, draw in the molten plastic to the very edges and corners of the mould chambers - with NO AIR BUBBLES guaranteed.

Bubbles cause serious problems in encapsulating a device: a sudden discontinuity in the distributed capacitance of a device plays havoc with the high frequency capability, and air bubbles, no matter how hot they might be when encapsulated, contain water vapour which at -20°C on cold test will condense and cause electrical problems (water has $\varepsilon_r \sim 80$), not to mention possible future corrosion and premature failure. Ronnie B. was stumped; he couldn't use his leak detection equipment as the vacuum in a mould was nowhere near high enough to run his helium leak detector - typically needing 10^{-6} Torr to function.

It's always a fascinating moment to peep into a high vacuum system through an armoured glass window - pressures inside are often down to 10^{-8} and are those of space, and where electrons roam free. A beam of electrons, inside such a vacuum system, is a sight a high vacuum maintenance engineer will never forget - that thin ethereal blue light from electrons impinging on nitrogen atoms create is truly unique! Ronnie B. had to rely on his experience and to that end he was stripping out the shaft seal to replace it, working on the principle it was the only place the particular fault could be. I was nearby trying to find the source of instability in the mould platen temperature control circuits which maintained the mould platens at 210°C. ± 2°, and so Ronnie pointed me to his pump starting problem to be resolved as soon as I got a minute.

Ronnie, to aid his leak finding at mid vacuum pressures, developed a bit of kit to attach to his high vacuum helium mass spectrometer leak detector - a small aquarium air pump, and - as Ronnie so delicately put it - 'a calibrated hole', namely, a long, very small diameter coil of stainless tubing that could run a high vacuum on one end (the helium leak detector), and atmospheric pressure on t'other - allowing a 'sniff' of helium via the aquarium air pump, to be detected. Thus, Ronnie's 'sniffer' could be attached to the *exhaust* of the pump he repaired, and detect any hint of helium presented to the outside of any leaks. Ronnie thus gently played a stream of balloon gas (no point wasting 'six nines' helium for leak detecting) over his repaired shaft seal to test if indeed he had a good seal. recall, however, the pump wouldn't start! Every time he clicked the circuit breaker in, it immediately jumped out. It was one of a bank of the old style lever actuated sort, with a hole in the lever for a padlock. Ronnie called me over and asked if I'd anything to measure the start surge amps to the pump motor (20HP, 3 phase). I had; my Hall effect clip-on ammeter soon found the problem - there was no problem! The surge was ~ 80 amps, (later found to drop to ~ 30 amps once started) as expected and thus a dud circuit breaker diagnosed. A type "C" 40 amp MCB was jumpered in and the job left running for tidying up at the next production halt.

Thus was my fault found, too: the whole bank of circuit breakers had suffered much heat over the years living right next to the hot platens, and the temperature control MCB had gone intermittent: it would run for a few hours then give up the ghost. Just why was no issue; Production demanded we got the line running and so we did. And that's How I met Ronnie B.!

I did ask where Ronnie had got his micron sized bore tubing, to make his helium 'sniffer'. He looked at me with a slow sidelong glance, and said 'allow me some secrets, Peter…!'

Radio communications with ZERO power transmitter

Yes, you read that right… ZERO power transmitter. The technology is in it's infancy, just managing to send a signal across a 10 metre gap at 26 bits per minute - but it's a start, and it looks like a whole new territory of RF engineering is opening up. How does it work? It uses a natural phenomenon we'd all like to be without, given a choice: Thermal, or Johnson Noise, that's how.

Consider a transmitter, with resistors and the like: all components make thermal noise if they are above absolute zero temperature. What these RF explorers did was alternately connect a noise generating component (a 50 ohm resistor) to ground, then to a wideband microwave antenna in a code sequence. Result? In a "distant" receiver, the noise received on a wideband microwave receiver rose and fell as the "transmitter" was alternately 50 ohm terminated or 'radiating' .The noise levels received shifted in synchronisation with the 50 ohm load switching and data was thus transmitted with pure (random) noise as a carrier!

That lousy SMPS that wipes out the entire 80m band might - just *might* - have a new lease of life, if this principle can be refined - an amateur project if ever there was one!

You can read all about it at:

https://arxiv.org/pdf/2111.08629.pdf

The wonders of RF technology have many more amazing discoveries still to be explored; this is just another facet opening up. Who would have thought it?

Receivers

Oranje clandestine receivers

Radio Oranje was the clandestine radio transmission in Holland during WW2, the highlight for most listeners was when Queen Wilhelmina broadcast speeches to raise morale and the passing of covert information to the Dutch resistance movement. The transmitters of the BBC in London were used for these broadcasts, which were deliberately short (15 minutes or thereabouts) so those listening in could escape detection by radiated oscillations from simple regenerative recievers.

The occupying Nazi forces banished all radios, and listening the the BBC was illegal, with confiscation of equipment, severe fines and corporal punishment in some cases. Clandestine receivers, often powered by bicycle lamp batteries, were popular and the disguises were novel to say the least - food boxes, tins and anything into which a midget receiver could be squeezed was fair game for the constructors. The Philips employees and radio amateurs worked together in the Resistance movement to create these gems right under the Nazi occupier's noses - and what a great job they did of it, too.

The proximity of the Philips electronics factories to most Dutch civilians helped; no doubt plenty of 'moonlight' illicit components came out of those factories under the noses of the occupying forces. The receiver designs had to be physically small, economical in power consumption, and capable of decent (headphone) reproduction. These miniature receivers have always attracted my attention; anything with thermionic devices is by nature not very 'miniature'! For an example of these receivers, and amazing miniature construction, see:
https://www.cryptomuseum.com/spy/oranje/acorn.htm.
Just look at how the components are squeezed into every available corner - how this design ever worked without howl-round is a tribute to the constructors! Gives a clue though to the desperate ingenuity these constructors had to employ in those very trying times.

Mighty midget receivers

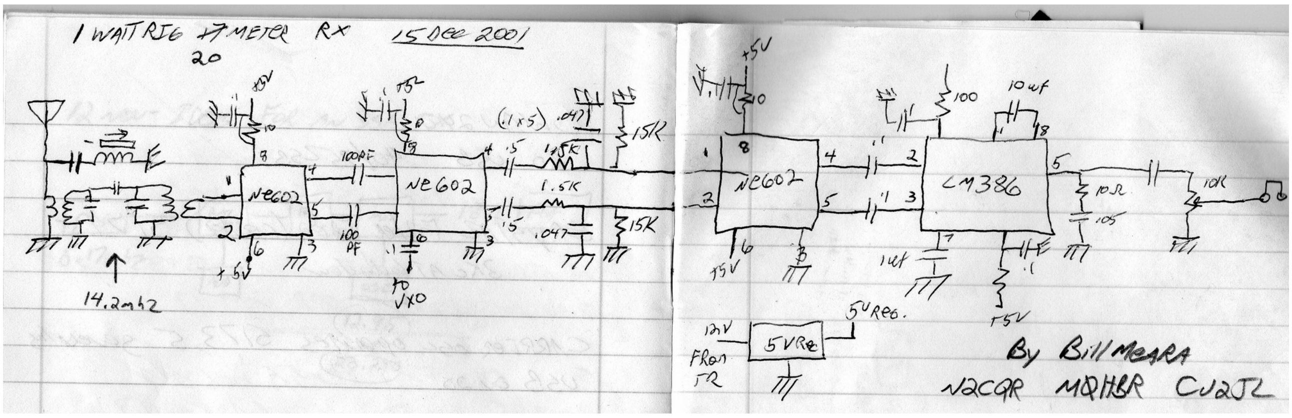
These are tour-de-force for small (but very potent) valve receivers and have been copied and duplicated many times. The design is straightforward; a goal not often witnessed when combined with the performance these simple receivers deliver. See:

https://www.jvgavila.com/mmrx.htm

The page has comprehensive links to the construction of these receivers; and to see folk of such standing as Bill Meara N2CQR involved then my attention is certainly piqued.

SA612 balanced mixer receivers

Talking of Bill Meara, you should know about Bill's SA612 direct conversion receiver: see Bill's sketch below:



The points to note in this superb fully balanced design are the use of the SA612 Gilbert Cell as a balanced RF amplifier; not only in the front end with a double tuned top coupled input section, but as an 'IF' amp too. I asked Bill about this circuit - he tells me (as far as he recalls) it's from a 'VK' operator; and apparently the circuit has appeared in the GQRP Club magazine, 'SPRAT'. If anyone has any links or information, I'd be most obliged if you'd let me know, so I can give credit appropriately.

The SA612 chips, superb as they are, have a hang-up: they don't like strong signals. SA612's are very susceptible to overload; adjacent strong signals can wreak havoc. Now this can't often be helped; the proximity of broadcast bands to amateur operation frequencies often means millivolts of A.M. are right alongside fragile µV's of amateur signals. The top coupled double tuned input filter will certainly help; as willm the series tuned trap, but no attenuation, right at the front end, means these powerful unwanted signals can get deep into the mixer and do their damnedest to upset the apple cart.

Help is to hand, however: PIN diode attenuation set up as front end AGC can help keep the leviathans out the goldfish bowl. Not got any PIN diodes? Oh dear, what a shame, never mind! Use 1N4148's as noted below, or try 1N4007's, they have a P-I-N structure to get a reverse bias stand-off of 1kV or more, and they could be useful on the lower bands (they are quite high capacitance). See: http://www.waveguide.se/?article=ne612-receiver-experiment

To implement this, you can pick off the signals required from the mixer chip output(s) and with a bit of juggling values so as not to mismatch the output too much. I'd bet this would turn a 'sovereign' receiver into a 'golden guinea' of a job!

Transmitters

We often need HV ceramic capacitors for tuning output networks, ATU's and the like: these capacitors are called on to handle, with low losses, hefty RF power. Even the QRP operators need low loss HV capacitors: not for the power handling, but to preserve every single μW of power by eliminating losses. A lot of amateurs equate high voltage ratings with low losses; 'taint necessarily so' The figure to look for is the 'tan δ' , the 'loss angle', Dissipation Factor, or 'ESR'.

Basic electrical theory tells us the perfect capacitor has current flowing which is 90° leading the applied voltage, but unfortunately in the real World, the angle between current and voltage is more often 89° or so: the 1° difference is the 'loss angle' of the capacitor, and tan δ is the trigonometric value of that angle, used to calculate the actual watts lost. A capacitor is made by setting conductive plates spaced apart by an insulator, and it's these metal plates that possess resistance - any current in the capacitor has to overcome the resistance of the plates and this represents ohmic loss.

These are capacitors I'm familiar with: https://www.vishay.com/docs/22168/715c-dk.pdf
You can see the Dissipation Factor (DF) is quoted at: 20×10^{-3} (1 kHz). Now we can calculate several important values:
ESR (Rs) = DF x Xc (capacitive reactance) and Q = Xc / ESR.

The actual watts lost in this capacitor is the $(ESR)^2$ x Current (RMS) i.e. the I^2R value. Note that in tuning and ATU work, the current is almost always considered as true sinusoidal; in DC power supplies, this can be very different, so average values can be used as an approximation.

A hybrid DSB Tx offers 'bombproof' simplicity

If you were to follow an SA612 balanced mixer with a grounded grid double triode, running 350 volts on the anodes, you get good linearity and unconditionally stable 3 - 5 watts output, top band to 6 metres (or more!).

Refer to https://frank.pocnet.net/sheets/184/1/12AT7.pdf , for full data sheets showing grounded grid push pull operation.

figure 313.69, top right. The grounded grid push-pull amplifier as described in paragraph 4.51, where the input impedance of the grounded grid configuration is given as roughly 180 ohms (~ $1/G_m$) for the 12AT7. The SA612 output transformer, probably a toroid, would interface an SA612 output very nicely into the cathodes of a 12AT7; thus a simple hybrid DSB transmitter could be built, that offers the unconditionally stable performance of grounded grid push-pull, capable of 3 - 5 watts clean output and not be bothered in the slightest with mismatched loads or other 'experimental' situations - unlike a solid state version!

It would be advisable to employ careful screening round the SA612 section to prevent unintentional feedback; but the (low-ish) input impedance of the push-pull P.A. at 180 ohms will tend to reject feedback.

Terra Tertia RF Communications

(literal translation: "1/3 rd. of the earth") - radio through solid ground!

https://pe2bz.philpem.me.uk/Comm/-%20ELF-VLF/-%20ELF-Theory/Th-115-EarthCurrents/com.pdf the best I've found on this topic

The professional approach - and very useful to those on low bands, LF and VLF:

https://www.vermilliontesting.co.uk/globalassets/get-connected/cic/icpsidnos/g81-library/new-pages/planning-and-design/cp333-earthing-design-distribution-networks.pdf

https://icestuff.com/~energy21/roger.htm

is a simple practical approach

https://pe2bz.philpem.me.uk/Comm/-%20ELF-VLF/-%20ELF-Theory/-%20CaveTheory/CaveRadio1/radio1.htm is cave radio and proven technology

Earth injection 'Terra Tertia' of VLF // LF cave radio at 70kHz SSB // Earth telegraphy - what an experiment! Inject (say) 30Hz - 30kHz at 1kW between two wide spread earth electrodes, what received signals miles away on widely separated earth electrodes? Nicola system et al is worth investigatring.

https://nvlpubs.nist.gov/nistpubs/jres/65D/jresv65Dn2p189_A1b.pdf

A Classic Tx - and all the construction notes you could ever desire!

W1TS vintage Tx (and notes):

http://www.arrl.org/files/file/QST%20Binaries/Jan2012/w1ts_project.pdf

Contact bounce, CW and CdS photocells…

Hard to believe, but it's true: metal contacts, as in relays, contactors and Morse keys, exhibit a characteristic known as contact 'bounce'. The metal contacts touch, bounce off, re-touch and repeat a several times. You can see this with a decent oscilloscope; you can use logic circuits (typically a SR bistable or a Monostable) to eliminate the 'bounce', but that rather defeats the object in a simple CW transmitter. You might describe the 'bounce' a key click; you can apply a CR snubber circuit to slug the HF components created in the 'bounce', but again, that doesn't really solve the problem, but rather partially remove it and hope for the best. Well engineered keys are designed to minimise 'bounce' but not everyone has Vibroplex and the like kicking about the shack, or willing to throw them around when outdoors! No matter how well a key is made, 'bounce' is a physical property of metal contacts impacting, mechanical solutions involve dash pots, dampers, spring tensioners and other mechanical methods to 'kill the click'. The situation with 'logic gate' keying is a similar case to direct keying of an amplifier stage; the bounce is squared up by the gate and the keying again becomes 'clicky'.

Here's a neat rick that you can try to defeat the 'bounce' and give almost perfect control of a transmitter: use a photocell and an LED as a 'break-beam' system, so your Morse key interrupts the light from the LED reaching the photocell. Which type of photocell to use, though: yes, you can make a miniature photocell with integral photo-transistors and LED's, or you can make a very simple add-on unit to fit your Morse key - and being crafty, you might choose a Cadmium Sulphide photocell.

Why Cadmium Sulphide (CdS)? because CdS is slow (in electronic terms!) to respond; you get a sweet edge that's bounce free with beautifully shaped edges containing few HF components. As a guide, any switching edge has a relationship between bandwidth and edge speed, i.e. $F_{bw} = 2 / T_{edge}$ so as an illustration, an edge speed of 1mS requires bandwidth of 2 / 1mS = 2kHz! No wonder your key generates 'clicks', each 'bounce' (and 5 - 10 bounces are not uncommon) is another edge full of HF frequency components. CdS cells are photo-resistors: dark they are high resistance; illuminated, low resistance (resistance change depending on levels of illumination and colour). Typically a CdS cell takes a good few mS to switch, depending on frequency and intensity of illumination.

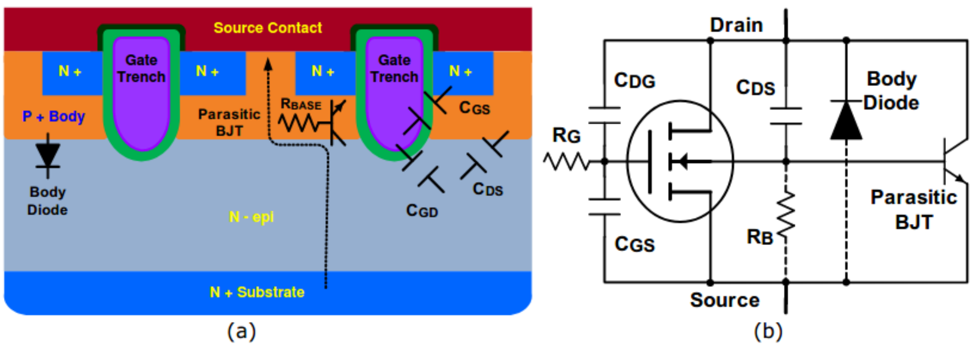
Another reason CdS optical switches as described reduce clicks is that *the beam isn't broken instantly*. The flag (or key arm if you build it so it fits your key) that interrupts the light falling on the CdS photocell moves *across* the light path at a speed determined by your keying - thus the keyed edge is a ramp, not a fast (or 'bouncy') edge. The timing is set by the physics of the system and key clicks from 'bounce' are thus non-existent. You can tweak the ramp times by altering the illumination intensity too: the brighter the LED, the slower the CdS photocell switches ('stored charges' I'm told), allowing adjustable edges to suit your keying. Keep in mind too that the set-up needs to eliminate ambient light affecting the CdS photocell; a used ball point pen body (the black tubular type) cut down and mounted makes a great collimating tube! Or - consider this: just mount the CdS photocell close the the key arm, and let ambient light do the illumination. What could be simpler for your next SOTA expedition? Build the photocell buffer transistor into your Tx, and you've got a neat combined system. A small CdS cell, a few odd components added to a transistor or two, controlled by the CdS photocell - is sufficient.

MOSFET's and all that…

Whilst it would seem a relatively simple job to make a mosfet P.A. stage to deliver 4 - 5 watts from a 13.5v supply rail, these little darlings can be very frustrating: they are lightning fast devices, and given the least opportunity, will be off and away in self oscillation - 'Hooting'. Most people imagine the innards of a mosfet are simple: just a lump of silicon, an SiO_2 insulating layer and a few bits of wire and that's it.

Well, a recent flurry of emails caused me to recall the non-linearities inherent in the capacitances inside a mosfet. These can behave as varactors; as volts change, so the energy stored can make it's presence felt by oscillations at particular points in a waveform, where dV/dT is changing dramatically. Below is the innards of a 'simple' trench gate mosfet… not perhaps as simple as you imagine! Taken from:

http://www.how2power.com/pdf_view.php_url=/newsletters/1703/articles/H2PToday1702_design_VishaySiliconix.pdf



Illustrates clearly the parasitic devices created when constructing the device in silicon. Not perhaps as simple as you expected? And then you wonder why this thing 'hoots' at many MHz with a sniff of feedback and a few pF's and µH's?!

Power Supplies

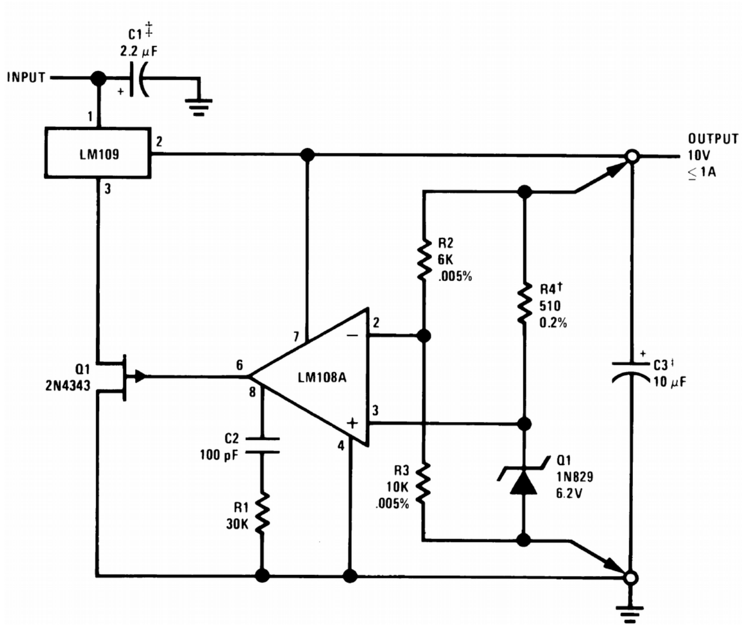
Discrete regulators to improve 78XX outputs

Monolithic voltage regulators do an amazing job, no doubt about that: day in, day out, they deliver the power that makes all the rest of a circuit function. The power supply and regulator(s) are probably the most stressed parts of a circuit - even power amplifier components get a rest between peaks, but the power supply soldiers on.

Good though they are, it's possible to improve the 78XX (and 79XX) types with a bit of external circuitry. From:

https://www.edn.com/simple-circuits-reduce-regulator-noise-floor/

This little add-on will give substantially improved performance. Note the zener D1 can be a far better component: a band gap reference, like LM4040 from Diodes Inc.



Constant current supplies for fault finding

An honest opinion: a modern ‘surface mount’ pcb isn’t for your convenience. No, they are purely for profit, manufacturers love ‘em, they are like printing money! You get a microscopic (compared to through hole or - dare I say it - thermionics on a chassis) assembly that works miracles. But you try fixing it when that ‘miracle’ goes AWOL!

The moist common fault seems to be any component that is connected *directly* between power supply rails: decoupling capacitors, voltage regulators, IC’s, and the like. Think of a simple switching transistor circuit: there is usually another component between the device and one power rail - a collector resistor for instance. The resistor precludes a *direct* connection between the power rails. If however that resistor is a choke, then yes, you have a *direct* connection (for DC) between the power (DC!) rails, and thus a short circuit for DC power.

Finding these faults is a bitch. And that’s putting it mildly; I’ve spent hours trying to find power rail shorts with a multimeter; even on lowest ‘ohms’ you’ll get a vague indication but you’ll not pin down the offending component. The favourite candidates for ‘short circuit’ failures from my experience are:

1. SMT Decoupling capacitors
2. Voltage regulators
3. LSI chips (the rarer and most expensive inevitably fail first)
4. Mosfets and bipolar transistors in RF circuits with choke loads (as noted above)

Under such fault conditions the unit’s power supply will either:

1. Shut down safely
2. Destroy itself as the designer couldn’t be bothered to fit a fuse or current limit
3. Set the pcb on fire

(1) and (2) above are common; I've known a few (3) scenarios, where I've sawn off the burned bits of PCB and fitted an external replacement (good if you've got room or safe enclosures).

All are utterly useless for fault finding - see later in 'Fault Finding' section.

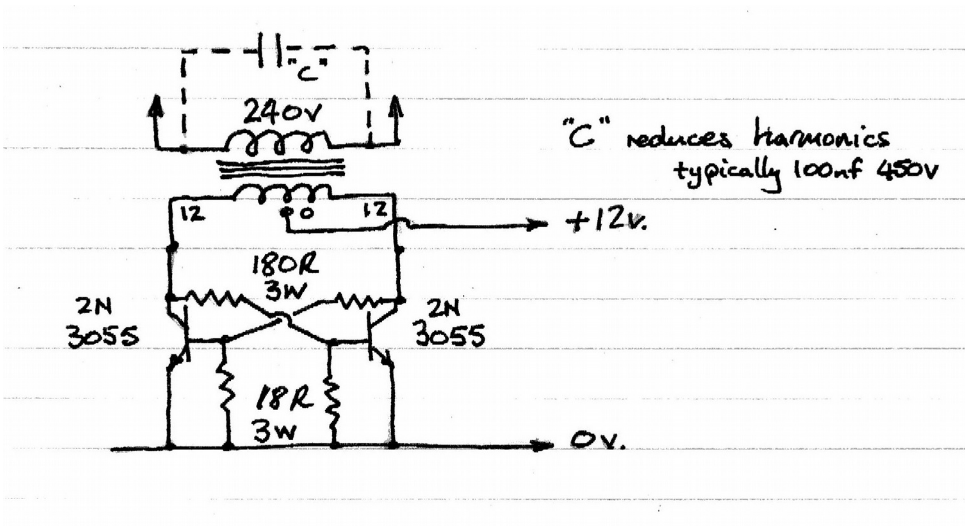
Vibrator Power Supplies

These are found in ancient bits of RF gear (like WW2 wireless set No. 19, for instance) running from batteries: they are akin to a buzzing relay, switching battery volts alternately one way then then other across a centre tapped transformer primary to simulate 'AC' inputs; the secondary being the HV to be rectified for B+ supplies.

These being electro-mechanical, and umpteen years old, they are worn out - ne'er any buzz left in them. Some crafty designers soon spotted power transistors could be coerced into doing this job, at a similar standing burden power too: the coil drive amps of the mechanical job roughly equal to the base currents needed in power transistors. What the original transistor men missed though was the 'dead time' taken for the contacts to cross the gap between 'open' and 'closed': this dead time gave far better output waveforms and saved a lot of wasted power in forcing flux reversals before the natural decay of core flux had taken place in 'dead time'.

The design below is an absolute beauty: it mimics perfectly the mechanical switching dead times by crafty design. Don't try substituting mosfets in this circuit: use bipolars as shown and you'll answer all your battery powered thermionic needs (I suspect the back biased base emitter breakdown volts of silicon transistors at ~ 7v sets the dead time along with the resistor selection).

Mount the circuit in an old vibrator housing (use the biggest heatsink you can fit!) and you've a plug in replacement for easy servicing; try various transformers as the core iron differs widely in transformers; being driven like this might not suit one transformer but happily drive another. As always, it's a question of suck it and see!



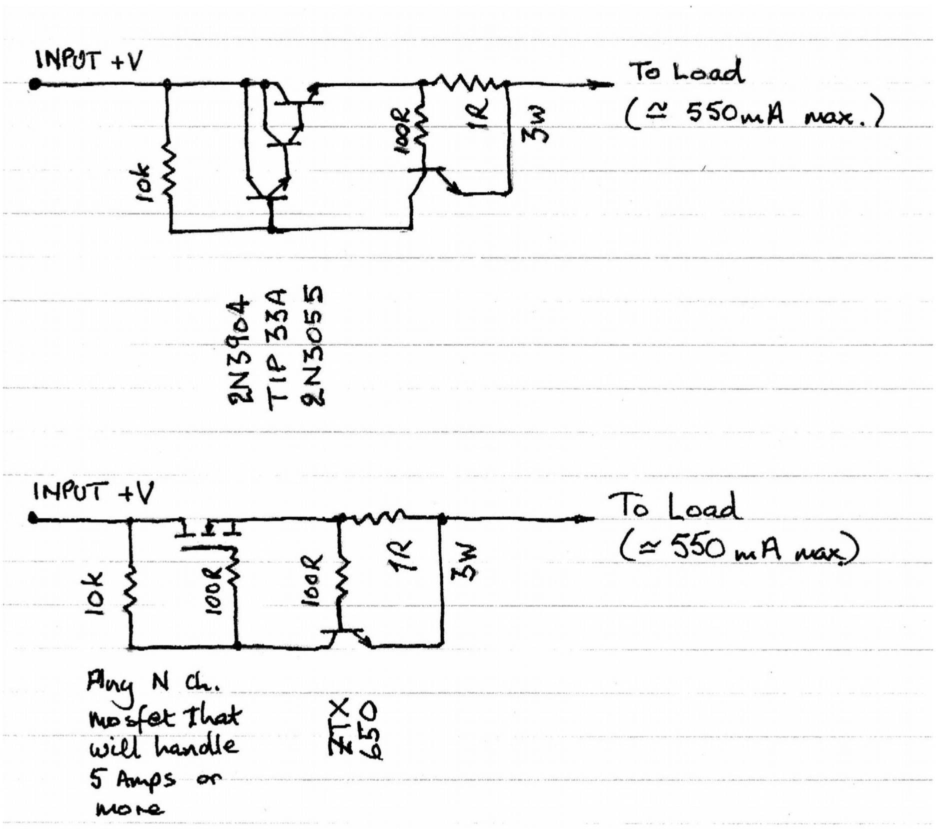
Test Gear & Fault Finding

AD9851#

type dds dip oscillators from a sig gen: https://www.george-smart.co.uk/arduino/arduino_ad9851/
Removes the annoying “pulling” as you approach resonance(s)...

Voltage Injection to find shorts

Using voltage injection into identifiable pins on a micro controller or IC can really help find a shorted component on a pcb. Most of us have a bench DC power supply, but not all PSU’s have a current limit function - so an add-on current regulator is a useful item. Below are two very functional implementations of such an add-on, that you can fit to your 5 volt bench power supply:



The current output is set by the sense resistor, 1 ohm. The current = 0.55volts / 1 ohm = 0.55 amps, where 0.55 volts represents the base - emitter drop. A 2 ohm sense resistor would yield 0.275 amps, and so on. One thing to keep in mind is the maximum output voltage, so as to not over-volts a sensitive chip on the pcb. This is approximately 2.2volts (for the three base emitter drops plus 0.55 volts for the sense resistor drop) deducted from the input voltage. Suppose for instance you want no more than 3 volts to be applied to your PCB; thus set your input +V to (3 + 2.2) = ~ 5Volts. You can do a similar calculation for a mosfet limiter, where you need the turn on Vg-s for your mosfet to take into account.

IR viewing screens are expensive but worthwhile if you've lots of surface mount pcb's to fix; IPA to find hot spots with current limited voltage injection can be a useful substitute. The general idea is to set up a test current into a PCB with a shorted component, then find which component is getting hot.

The canny amongst us use fingers, or iso-propyl alcohol on a cotton bud, to see where the heat is: your finger tip will certainly let you know you've touched a hot spot! The iso-propyl alcohol will do the same (without destroying your finger tips) by sizzling and evaporating very rapidly.

The components I've found to be likely culprits of a rail to rail short are: smt de-coupling capacitors, voltage regulator chips, many-legged IC's, and melted wire insulation in the centre of bundled cables. Finding a melted wire in the middle of a bundle need careful opening out of the wires; you're looking for the pair that are stuck together but these can be infuriatingly intermittent.

Isolation Transformer safety

Most people think that an isolating transformer is guaranteed freedom from electric shock: true if either of the output wires have absolutely NO connection - a megohm at least - to ground. In a typical amateur shack that is far from easy to assure!

There are literally hundreds of paths to earth that might not be obvious: Stan M. taught me this by pointing out how power line filters, often inmtegral in "IEC" power input sockets, have bleed resistors across their filter capacitors, thus giving a path to earth on the output of an isolating transformer. Fit an ELCB (earth leakage circuit breaker) to the isolating transformer output so any imbalance exceeding the milliamp rating of the device will disconnect safely.

Be aware the defibrillation current of a human heart can be as low as 2 -5 mA, and you'll struggle to find an ELCB that sensitive. Fit the lowest trip current ELCB you can find, and remember the old adage still applies: for voltages above 50v RMS, keep one hand tucked behind you in your belt!

AVO meter, anybody?

You might like to consider, when studying the voltage chart of that vintage valve radio chassis you're resurrecting, making an add-on to present the same 'loading' to the circuit when diagnosing faults with a modern 10M digital multi-meter. Knowing a little about the meter used to make the voltage charts, often quoted for reference, you can soon make loading resistance to mimic the original and get 'true' readings. It's worth noting too that despite what a modern digital multimeter might infer; those dancing mV's are of no account whatsoever; the original value noted was written by estimating from an analogue scale so an accuracy of ± 10% might well be more applicable!

One major point to consider is adding damping capacitors to such loading circuits. This removes those confounded dancing mV's, which are not relevant in any case, and allows much more stable peaks (or minimums) to be set up - a job a digital multimeter is exceptionally useless at doing.

The value of loading resistors is easily found: take for instance if the voltage chart specified "measurements made with an AVO Model 7" which is 1000 "ohms per volt" on DC ranges - so if I set the meter to "300 volts" full scale deflection (commonly termed FSD) then the meter represents a loading of 1000 ohms/ volt x 300 volts fsd. = 300,000 ohms, 300kΩ. I made up a shunt resistor of

300k by paralleling 270k, 27k, 2k7 and 330Ω (near enough!) and shunted this with a 450v 0.47μF capacitor with 10k in series to reduce initial current draw. I fitted this in a small box, with 4mm test plugs and sockets for easy test lead connection. I made up loading resistors for other common ranges required and thus my 10Megohm digital multimeter mimicked the AVO 7 loading for the job in hand.

The capacitor proved very useful; the digital multimeter gave damped steady readings on peaking (or minimising) circuit adjustments. Stan preferred faster readings; he fitted 0.1μF, 450v capacitors + 10k limiting resistor to his load box. I didn't bother with most lower voltage ranges; the typical voltage charts covered 90 - 800 volts so I made up loads and dampers to suit the ranges I wanted. It made repairing ancient (but unbeatable performance) GenRad Z-bridges used in manufacturing 10GHz varactor diodes an absolute doddle!

A curious "C-Beeper"

An interesting "C-Beeper" can be made with a 555 timer; it effectively uses the timing capacitor to integrate the leakage current, until the threshold switching point is reached and the output gives a pulse. See:

https://www.ti.com/lit/ds/symlink/lmc555.pdf?ts=1674234794921&ref_url=https%253A%252F%252Fwww.google.com%252F

I first saw this technique years ago when testing the reverse leakage of silicon and GaAs diodes. Using a long integrating time allows very tiny currents to be gauged reliably without needing instruments capable of Atto-amp (10^{-18} amp) resolution, by measuring the time to charge an integrating capacitor to a known trip voltage.

Chas. Wenzel in: http://techlib.com/Electronics/c_beeper.html

has described various discrete circuits to do a similar job (and that's where the term "C-Beeper" came from, incidentally) and the 555 version is usefully transmuted into the C-MOS 555 version for far lower input current to the comparator section in the 555; this allows remarkably low currents to be gauged, as, for instance testing the insulation of antenna assemblies and strung wire antennas.

One point to note that will make far more capable circuits at the extremes of measurements, is to build the circuits 'dead bug' over an FR4 pcb material ground plane, using super glue or wax to set the IC's into place; building upside down 'in fresh air' over FR4 ground plane allows ultra high resistance checks as fresh air and wide component spacing reduces leakage to a fraction of that found in strip board or other 'perf. board' constructions, on DC and LF testing.

Capacitor test kits

...are available for home assembly with far more functions than mere capacitance measurement: they will measure ESR (equivalent series resistance) and tan δ (dissipation factor). But, the mere presence of such information doesn't tell you whether or not a capacitor under test is 'good to go' or fit for the bin!

A useful guide for electrolytics (our favourite component for replacement) can be taken from the manufacturer's obligations: a capacitor, marked as 470 μF, will always be equal to or above that nominal value. A reduction of nominal µF's greater than ~ 10% and raised ESR surely indicates a worn out capacitor! It's important to note the capacitor value and voltage rating affects the ESR characteristics: gauge the validity of your decision by referring to an ESR table online, like https://www.jestineyong.com/wp-content/uploads/2012/05/ESRTable1.jpg) .

Construction

Superb mini boxes: https://community.element14.com/technologies/open-source-hardware/b/blog/posts/making-mini-circuits-style-tiny-metal-boxes---rf-module-enclosures from square section ally extruded stock; search for "aluminium extruded box section online suppliers"

And… https://hackaday.com/2021/09/15/the-many-ways-to-solve-your-enclosure-problems/

Boxes… https://www.youtube.com/watch?v=yrb1Oh0aJM4&ab_channel=PaskMakes

Soldering stainless steel

It's not often radio amateurs need to solder stainless steel; special fluxes are available to facilitate this, and they come with 'special prices' too. Try Phosphoric acid mixed with 10% water (from de-rusting fluids) or Boric acid (from borax dissolved in water, NOT borax substitute!). A close look at the ingredients list on the containers will show these ingredients, as will the safety requirements . But… I emphasise most strongly DO NOT INHALE THE FUMES from these materials.

Desoldering SMT components without specialist hot air guns

We've discussed these methods previously but I was reminded of some other tricks of the trade in an email (thanks, Bob). As well as a modelling clay barrier around a chip, filled with liquid solder, you can use two cheap irons set side by side with a jury-rigged clamp to get the right spacing (for shifting RF power transistor tabs) and brass blocks or plates clamped to a 200 watt iron bit to get the heat exactly where you want it.

One caveat: be highly aware of the damage done to components and pcb's when keeping the heat on for more than a few seconds. Semiconductors abhor heat; in reflow soldering it's vital that the process engineer sets the time in the hot reflow zone to be less than the manufacturer allows, often 200°C for no more than 20 seconds.

One answer: practice on pcb's from the scrap bin!

Antennas

That chunky high wattage rheostat with burned out windings at the radio rally sale can be a very useful component: substitute a toroid core for the original ceramic former, and add multiple turns of heavy gauge enamelled copper wire to replace the resistance wire and use the rotary mechanical contact assembly to make a variable auto transformer, with which you can easily adjust the turns ratio to match those ‘difficult’ loads. make sure the enamel is removed to allow the sliding contact get a low ohms contact.

One point to note: extend the control shaft with a perspex or tufnol rod to avoid RF flash-overs to your hand!

Location, Location, Location

...of an antenna is more important than any modelling and keep to mind that in the UK we don’t often have prairie sized gardens - so try folded designs, and keep the folded sections as far from high current point as best you can. failing that, go up in frequency to adopt shorter dipole lengths - but you can usefully allow the outer 20% ends of a dipole droop down without too much loss; and the centre can be bent out of straight without too much waste.

For those who are blessed with acres of garden, the old motto of ‘high, wide and handsome’ almost guarantees good performance - if:

- you adopt ‘kW’ wire sizes to minimise copper loss
- set as high and clear as possible
- are carefully matched and loaded (this is vital)

...are a good solution for small spaces; loft loops similarly set up can squeeze into a ‘hidden’ QTH.

Accept, once and for all, there is NO magic design that can work anywhere, on any band and have lots of gain and bandwidth.

An old article…

Though still very appropriate!

TRANSMITTING TOPICS

LOADED AERIALS FOR TOPBAND

By O. J. Russell, B.Sc.(Hons.), G3BHJ

CORRESPONDENCE has shows that there is a very great interest in the question of loaded aerials for topband use. This interest is not unnaturally greatest among the citybound amateurs who are anxious to improve the radiation efficiency of their installation upon topband. In view of the fact that a 10-watt topband transmitter may be reduced to the level of a transistor QRP rig by an inefficient aerial, attention to the topband aerial system is in order. As previously stated, the actual earth resistance is an integral part of the Marconi system, and every effort to obtain a really low resistance earth is necessary, including the provision of multiple earth rods spaced over the ground area available. It will be assumed that a really low-resistance earth system can be achieved. An earth resistance of 10 ohms represents a good earth *effective* resistance, and this value will be assumed.

Where multiple earths are in existence, the amateur can readily determine the resistance value by measurements. The use of a resistance meter, such as an AVO meter on the low-resistance range is satisfactory, if only a brief reading is taken. The meter should not be connected longer than is necessary, as polarisation effects may occur due to soil electrolysis. The simple A.C. bridges available will enable resistance readings to be taken without trouble from polarisation effects. However, a "spot" reading with the usual multimeter on its resistance range will enable sufficiently accurate measurements to be made.

Fig. 1 shows the set-up necessary for earth resistance measurements. Three separate earth connections are required, as the return connection to any earth rod can only be effected by using a further earth rod as the return. As the resistance of the earth rod is initially unknown, the actual earth resistance must be calculated from cross measurements made on the three earthed rods. Four or more earthed rods may be employed, and in this case alternative checks can be obtained from the resistance figures.

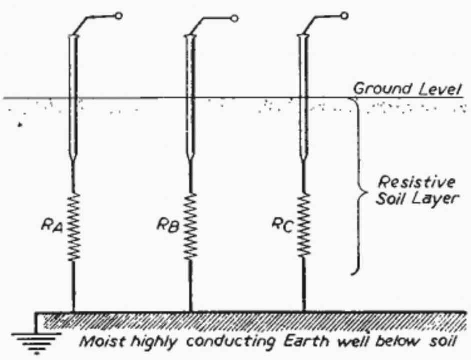


Fig. 1.—The arrangement necessary for measuring earth resistance.

Earth Rod

Referring to Fig. 1, it is assumed that each earth rod has an unknown resistance connected to an ideal buried earth under the soil of zero resistance. Thus the resistance of Rod A is R_A, of Rod B is R_B and of Rod C, R_C. The resistance measured from Rod A to Rod B is thus R_A plus R_B, and so on for the three possible pairs of earth rod connections. Let the measured values of resistance be X, Y and Z, so that we have :—

$$X = R_A + R_B$$
$$Y = R_A + R_C$$
$$Z = R_B + R_C$$

The following simple algebraic manipulation enables the values of all the resistances to be determined. First of all add X and Y. This gives us $X + Y = 2R_A + R_B + R_C$. However as $Z = R_B + R_C$, we have only to subtract Z to determine R_A. Thus $X + Y - Z = 2R_A$. In other words we have now $R_A = \frac{1}{2}(X + Y - Z)$. Thus having determined R_A, we can find the values of the other resistances in turn by using the value of R_A to find R_B, and then using the value of R_B to determine R_C.

A numerical example may help those whose algebra is a little rusty. Thus in one case X was 25 ohms, Y was 30 ohms and Z 35 ohms. Hence R_A was $\frac{1}{2}(25 + 30 - 35)$ ohms, that is $\frac{1}{2}(55-35)$ ohms $= \frac{1}{2}(20)$ ohms $= 10$ ohms. As Y is R_A plus R_C and we now know R_A is 10 ohms, clearly as Y is 30 ohms, then R_C must be 20 ohms. Similarly as $Z = R_B$ plus $R_C = 35$ ohms, and we now know R_C is 20 ohms, then clearly R_B must be 15 ohms in value. As earth resistance values from 10 ohms up to 50 ohms may be encountered in practice, figures of the above order will be obtained on resistance meter tests. Three average-to-good garden earths of say 30 ohms apiece, if paralleled, will give a final effective earth resistance of 10 ohms, so that it really is necessary to employ at least three widely spaced garden earth rods if a satisfactorily low earth resistance is to be achieved ! To make a reasonable earth, several feet of copper rod or tube should be driven into the soil. Six to 10ft. is about the minimum, and even greater depths are desirable. It should be noted that the efficiency of an earth connection to the waterpipes can be readily checked by the resistance method. All that is needed is the provision of two auxiliary earths, so that the requisite three resistance readings can be taken. A few tests with a resistance meter may provide a few shocks for those amateurs who have assumed that their earth connections are above suspicion. It may also provide a clue to those missing topband contacts, and the solution is obvious!

While it may seem paradoxical to devote attention to the *earth* as a part of the aerial system, it should be noted that generally this is a very much neglected part of the Marconi type of topband aerial. Moreover it represents a major source of loss that must be attended to if improvements elsewhere are to be worth-while. Thus an 8ft. whip aerial on topband has a radiation resistance of 1/10 of an ohm, so that even with an earth resistance of 10 ohms.

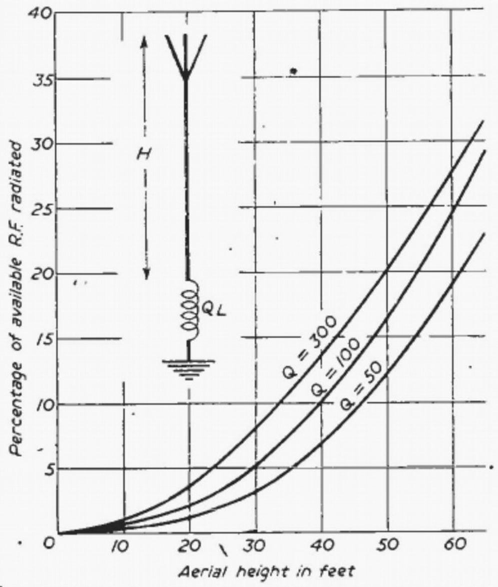


Fig. 3.—Efficiency of vertical aerials on topband. The curves show the percentage of R.F. radiated for loading coils of various Q values, and a ground resistance of 10 *ohms.*

and with a perfect loading coil the efficiency is only 1 per cent., so that a typical 10-watt rig supplying 7 watts of R.F. to the whip would actually result in the radiation of only .07 watts of R.F., that is 70 milliwatts! Even in the case of a 32ft. vertical, the radiation resistance is only 2 ohms or so, so that with a 10 ohm earth resistance, only 17 per cent. of the R.F. available is radiated, so that our typical 10-watt rig would only radiate about 1.2 watts. However, this is a vast improvement, some 12 db, or two S points above the 8ft. whip case. Increasing the aerial to a 60ft. vertical would add another S point.

Loading Coil

However, these figures assume a perfect loading coil of zero resistance. Practically, of course, a loading coil has a definite R.F. resistance. As shown in the April, 1955, issue of this journal, the aerial radiation resistance, the earth resistance and the loading coil resistance are all in series, so that the reduction of earth and coil resistances is essential for efficiency. Unfortunately, in the case of coils we are unlikely to exceed a Q figure of 300 even by using 14 gauge wire on a ceramic former. For the 8ft. whip, a base loading coil of 350 microhenries (approximately) is required. A really high Q design of loading coil with a Q of 300, has an effective R.F. resistance of 14 ohms, so that with an earth resistance of 10 ohms, the radiation resistance of 1/10th of an ohm now represents an efficiency of less than ½ of 1 per cent. Should we build a coil with a Q of 100, this will have a resistance of 40 ohms, so that our overall figure would become one fifth of 1 per cent.

The contention that "every foot of height counts" is borne out by the fact that a 40ft. vertical only requires a coil of about quarter the inductance, and hence (for the same Q value) of one quarter the effective series resistance. Thus, with a Q of 300 this means approximately 3 ohms of coil resistance. Also the radiation resistance of the 40ft. vertical is 2 ohms, so that with a coil resistance of 3 ohms, and an earth resistance of 10 ohms, we have 13 ohms of wasteful resistance in series with the 2 ohms of useful radiation resistance of the aerial. Thus, 2/15th of the total R.F. power will be radiated, an efficiency of some 13.3 per cent. This is a vast improvmént over the ½ per cent. possible with an 8ft. whip using the best coil we can make!

The lesson is obvious. After we have installed multiple earths to reduce earth resistance to the lowest practicable level, we must think in terms of ceramic coil formers and thick wire. Number 14 or even 12 gauge wire, spaced by approximately the wire diameter on a low-loss former, or self supported, is necessary for obtaining high values of Q. Optimum Q values are obtained when the length to diameter ratio is approximately two, and long coils of small diameter should not be used.

Fig. 2 shows the typical base-loaded antenna set-up, and Fig. 3 gives the approximate radiation efficiency with coils of various Q values, with an assumed earth resistance of 10 ohms. What is startling, is that efficiency may vary over a range of some 300 to 1 when considering aerials ranging from an 8ft. whip loaded by a coil of Q=50, up to a 64ft. aerial with a high Q coil of Q=300. However, even a change from a 16ft. vertical to a 24ft. vertical can make nearly an S point (four-to-one power change) difference. This is a welcome bonus for a mere 8ft. of height increase. While the curves are derived from approximate calculations they should serve to highlight the necessity for extreme care in loading up an aerial for topband. Obviously a makeshift aerial system is unlikely to be efficient. Also, of course, the actual aerial wire itself is relatively unimportant in view of the huge losses that can be introduced by the earthing system and by the loading coil system. Moreover, these losses are "hidden" losses, as even a high-resistance earth and a poor loading coil will tune up in what appears to be a normal fashion.

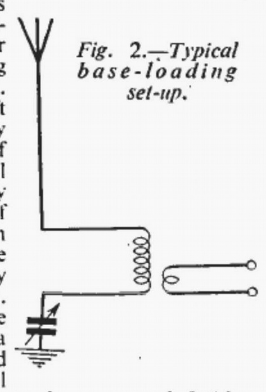


Fig. 2.—Typical base-loading set-up.

Base-loading Coil

As explained previously, the function of the base-loading coil is to tune the effective capacity of the aerial to resonance, so that power may be loaded into the aerial. The capacity of the aerial varies with the wire diameter slightly. Thick aerials have slightly more capacity than thin wires. Fig. 4 shows the approximate capacity of short vertical aerials made of wire, that is "thin" aerials. The approximate inductance required to load these aerials at the base for resonance in the topband is shown in Fig. 5. In practice, of course, a series aerial tuning condenser is often employed to adjust the "effective inductance" of the loading coil to exact resonance. This obviates any difficulty with taps on the coil, or with unused turns. Even with the low power of 10 watts, high circulating currents and high R.F. voltages are developed across the loading coil and the loading condenser. It is, in fact, the high currents circulating that cause appreciable losses with even high Q loading coils. The fact that a neon lamp lights brightly when placed on the loading coil or series resonating condenser is heart-warming to the true amateur. Unfortunately, it is also literally a "red light" warning of the high losses inevitable with Marconi-type systems, unless every precaution is taken to reduce sources of R.F. loss in every element of the aerial system.

An Example

A true story illustrates this. In the shack of a well-known topband exponent, an emergency loading coil was wound with enamel wire on a cardboard former. After some tinkering to load up the aerial system on topband, satisfactory results were obtained. After an interval for tea and refreshment, a return was made to the shack, where it was found that the aerial current was greatly down, and a local contact reported a much reduced signal strength. In the course of the QS0, the aerial current slowly crept back to its orginal value, and the signals were reported increasing in signal strength. The cardboard former was then found to be appreciably warm. The solution was that the cardboard had absorbed atmospheric moisture, and its R.F. losses had sharply increased during the interval for tea. The heat dissipated due to the losses automatically dried out the cardboard during the QS0, so that the losses decreased, with a consequent rise in aerial current and radiated signal! It is needless to add that the temporary coil was rapidly substituted by a coil wound with thicker wire on a ceramic former!

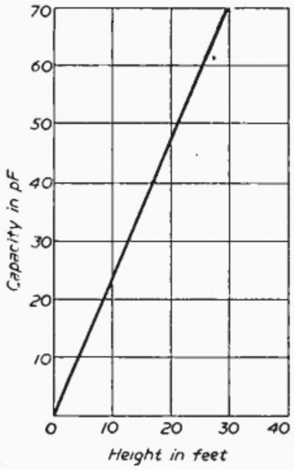


Fig. 4.—Approximate capacity of vertical wire aerials.

While a cardboard former is unlikely to be used for a permanent topband loading coil, it is a graphic example of the dramatic improvement possible by the reduction of losses. While it may seem reminiscent of 1920 practice to use heavy wire and large ceramic formers, it should be remembered that the topband is truly the "long waveband," and to amateurs in restricted locations it offers a severe problem from the aerial point of view. Those fortunate enough to

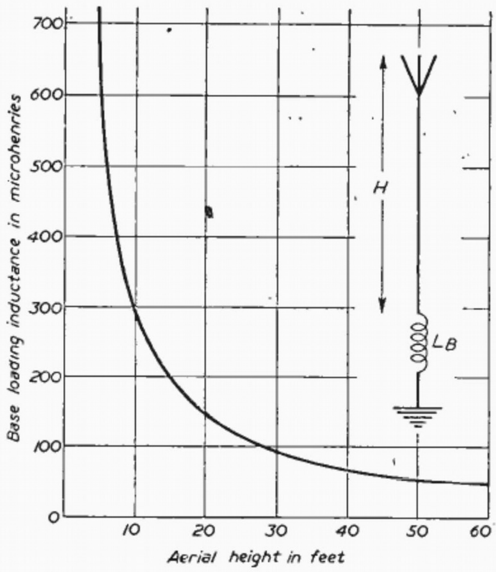


Fig. 5.—Approximate inductance values for resonating vertical aerials to the topband. In practice, slightly larger coils should be used and resonated by the usual series condenser.

have ample space for long wires and high masts are the fortunate few indeed as far as topband is concerned. Even here, however, if a Marconi system, such as a 132ft. against ground is used, the earth resistance is still important. Radiation efficiency with a 30 ohm ground resistance means only 40 per cent. of the power is radiated. Also if most of the 132 ft. is horizontal, efficiency may be much lower still, a factor that may be considered in a later article, as height rather than length is the important factor in topband aerials.

My thanks to the original publisher(s) and authors. This describes the fundamentals of radio transmission, the fundamental feature of radio transmission.

Stop Press

One thing Stan taught me…

I was struggling with an Ft measurement test rig; an oscillator running 40MHz, 5 watts into an attenuator (for isolation) feeding the transistor under test via matching networks, the output being detected for amplitude driving a 50 ohm dummy load, again via a matching network. One thing bothered me: the output seemed wander erratically, up and down, even though the drive and power supplies checked out fine.

After a few hours checking power supplies, instruments and attenuators, led me to an SCR controlled water pump on the floor below; running the pump which delivered de-ionised water at a constant delivery pressure to the clean room processing areas on the floors above. This was 3φ 50 kW rated; it worked hard for a living, delivering 17 -20 tonnes of DI water per hour. I had a quick chat with Stan at brew time - he reckoned a double section LC high pass filter to pass the wanted 40MHz signal and reject the interfering radiation from the nearby (unscreened) 3φ cable feeding the pump would do the job, to cut the interference getting into the measurement circuits. I reached for filter design tables; and Stan dug out some likely looking inductors from the workshop "glory bin", added a couple of pF capacitors and had a high pass two section LC filter knocked up in minutes. 'No point pontificating, just try and see how it goes', and, yes, it did the trick. Stan added three off 100 watt, 100 ohm wire wound resistors in series with with 0.1µF / 600volt paper capacitors as 3φ snubbers in a centre earthed star across the lines - hey presto! No more wandering readings, job done.

'Remember the old radio men didn't waste time on abstruse maths: they had to get back on the air quick sharp rapid' quoth Stan; 'the niceties of design are fine if you've time but odds on you'll still need 'cut and try'. No point working out exact numbers; we wouldn't have the special value components anyway'.

Stan proved right (as usual…), and it's good advice: forget the long complex calculations, just make a rough approximation and cut and try. You'll learn the old art of Radio very quickly that way!

Wanted...

Further to my scribbles in the CQ section of this edition of Hot Iron, I have been told, in no uncertain terms, that I'm to avoid soldering, brazing or welding flux fumes, fine particles and other toxic dust by-products which are, for me, strictly 'verboten' - and a face mask restricts my breathing to such an extent I find them intolerable.

I'm told exercise in open air with vigorous exercise will help keep my lungs clear. I already spend a fair bit of my time rock climbing, walking ' o'er hill and dale' in my native Lancashire but I must increase this activity if I'm to enjoy a reasonable later life. I have been given various inhalers and other palliative measures, but practically speaking, I would much rather take outdoor exercise than using chemicals and potions. My being prescribed blood pressure tablets I take as a warning and I don’t intend ignoring it. The hardest bit of this is that I cannot continue to spend the hours indoors I currently do, building experimental circuits, test gear and researching Hot Iron.

Therefore Hot Iron needs co-authors, writers and radio builders / operators to help produce future editions: you know the open framework of Hot Iron and anything you have to say or report about RF is grist for the mill.

So there you have it: if you can offer any help in writing Hot Iron, be it basic thoughts or fully detailed articles, operating advantages, microwaves to milli Hertz, whatever, please let me know.