Christmas 2011
Issue No. 134

Radio Bygones

ISSN 0956-974X

Mobile And Portable Operation Of Amateur Radio Equipment In The 1960s

Servicing And Calibrating AVO Valve Characteristic Meters Mk1 and Mk2

An Original Wartime Paraset And A Forensic Investigation

Designing And Building A Quality Valve Amplifier – Part 2

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MUSEUM PIECES

Front panel view of the mobile/portable 2 metre transmitter, a conversion of a war-surplus 'Power Supply & LF Amplifier Units No. 2' described in the *Mobile And Portable Operation Of Amateur Radio In The 1960s* (Photos by Louis Meulstee)

The original 'Power Supply and LF Amplifier Units No. 2', developed for powering a Wireless Set No. 88 AFV in an armoured vehicle and interfacing to the No. 19 Set harness

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Editor
Mike Kenward

Editorial and Subscription Offices
Radio Bygones
Wimborne Publishing Ltd
113 Lynwood Drive
Merley
Wimborne
Dorset BH21 1UU
England

Telephone 01202 880299
Fax 01202 843233
Email
radiobygones@wimborne.co.uk
Website
www.radiobygones.com

Advertisement Manager
Stewart Kearn
113 Lynwood Drive
Merley
Wimborne
Dorset BH21 1UU

Telephone 01202 880299
Fax 01202 843233
Email
rbads@wimborne.co.uk

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ON OUR FRONT COVER
Mobile And Portable Operation Of Amateur Radio Equipment In The 1960s – see page 30

Cut Off

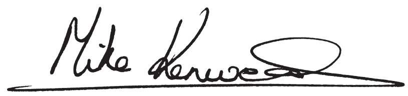
Two ‘incidents’ have recently brought home to me the ‘value’ of modern technology. A recent power cut during the evening, that only affected our home (due to the failure of a cable joint under the pavement, no doubt caused by lots of rain), made me realise just how much we rely on electrical power. We had no heat, no phone (except mobiles), no Internet, no ability to cook or make a cup of tea, or even see very well in the dark. Not even enough light to read or write by. Thankfully Scottish and Southern Energy (who are, incidentally, not our electricity supplier, but who are responsible for the distribution system) dug up the pavement at night and restored the power by 3.00am.

Unavailable

A recent overnight stay in a hotel also brought home how much we can also miss modern communications. I’m not one to always carry a mobile phone – I tend to see it as being for my convenience when I want to use it, not for everyone to be able to contact me anywhere, anytime.

However, when there was no phone signal in the hotel, no phone system that could connect you to another room – or to reception or room service – and wifi that was too weak to allow connection from our room, then one tends to feel rather cut-off from the rest of the world.

Maybe I should see it all as a blessing – at least a few hours of peace and quiet – but I guess I’m now so used to being able to communicate with anyone from anywhere – car, home, hotel and even a plane, that I do miss it, even if I don’t always welcome it.



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News & Events

For your diary

Bletchley Park Trust Secures £4.6 Million

A landmark victory for the Bletchley Park Trust was announced in October with a grant of £4.6 million from the Heritage Lottery Fund (HLF) towards the regeneration of Bletchley Park. The investment will enable the restoration of iconic Codebreaking Huts 1, 3 and 6 and create a world-class visitor centre and exhibition in the currently derelict Block C as soon as £1.7 million in match funding has been raised. Not only will this development allow the conservation of buildings of highly-significant heritage value, it will considerably improve the educational offering and visitor experience at Bletchley Park.

Bletchley Park, home of the Codebreakers, is arguably one of Britain's most important 20th century historical sites. When the Codebreakers wrote to Churchill, in October 1941, starved of resources to do their essential work, Churchill immediately ordered, "Action this day! Make sure they have all they want on extreme priority and report to me that this had been done". Exactly seventy years on it is resonant that the Heritage Lottery Fund are doing as Churchill asked. Their decision will be welcomed by the millions of people in this country and abroad who have supported the Park's restoration, and take pride in its achievements.

Bletchley Park helped to shape the course of the twentieth century by giving the allies a critical edge in WW2, and foreshadowing the technological revolution that was to follow. Throughout the war, against seemingly impossible odds and in total secrecy, the Bletchley Park Codebreakers systematically broke what was the backbone of Germany's communications cypher system – Enigma – and the even more complex cypher system used by Hitler and his High Command – Lorenz. Most historians agree that Bletchley Park shortened the war by perhaps two years, saving countless lives and changing the shape of the world that emerged from it.

For twenty years the Bletchley Park Trust has been devoted to ensuring that its achievements are recognised and the site developed, both to inspire and educate generations to come and as a permanent testament to the remarkable people who made those achievements possible. During its post-war years of secrecy and neglect, Bletchley Park and many of its codebreaking huts and blocks quietly descended into near-dereliction; today they welcome 130,000 visitors a year.

The late Professor Richard Holmes said, "The work here at Bletchley Park... was utterly fundamental to the survival of Britain and to the triumph of the West. I'm not actually sure that I can think of very many other places where I could say something as unequivocal as that. This is sacred ground. If this isn't worth preserving, what is?" The Heritage Lottery Fund has now made a huge contribution to that process. The Bletchley Park Trust will now aim to work with other funding bodies to secure the match funding needed to let work begin.

Carole Souter, Chief Executive of the Heritage Lottery Fund, said, "The complex story of Bletchley Park revolves around a group of dedicated men and women who quietly worked away with no expectation of public recognition. Now, more than sixty years later, the Trust will bring to life fascinating tales of the ground-breaking work that took place in this sprawling country estate. I cannot think of a better use of Heritage Lottery Fund money than to support this project and, in so doing, honour the memory of all who were involved."

Stephen Fry, British actor and author, welcomed the announcement saying, "Today marks a monumental triumph for the Bletchley Park Trust. This investment from the Heritage Lottery Fund will finally enable the Trust to do justice to this amazing place in tribute to the tremendous intellectual feat of those who worked there. Not only did these people alter the very course of history by helping to secure the allied victory, thereby quietly and modestly providing us with the free world, they also gave birth to the Information Age which underpins the way we all live today.....". The Bletchley Park Trust has launched the 'Action This Day' campaign to raise the match funding needed. Please go to **www.bletchleypark.org.uk** for details of how to support it. For visitor information, contact 01908 640404, **info@bletchleypark.org.uk**, or go to **www.bletchleypark.**

Servicing And Calibrating AVO Valve Characteristic Meters MkI And MkII

by Euan MacKenzie

The AVO VCMs MkI and MkII are quite similar in design, however the differences are easy to spot, the MkII version has a clip on the lid for the top cap lead, two 'rack handles' on the front instrument panel and two runners underneath, in order to provide a shelf for the AVO Valve Data Manual (VDM). These features are not present in the MkI.

Inside there are minor differences in the position of some components, as well as some minor circuit changes to stoppers under the valveholder panel. Neither Mark appears to have been issued with an identification label or a serial number; unlike AVO's later model VCMs.

Dismantling The VCM

The pressed aluminium case can be lifted off, when the two 2BA × 1½inch Allen head socket bolts are removed (using a 5/16inch Allen key) from each of the side handles. Essentially, the VCM consists of three sub-assemblies:

1. The instrument panel
2. The transformer panel
3. The valveholder panel

These sub-assemblies are mounted on two cast aluminium side frames, with 2BA × 5/8inch CH screws; unless otherwise mentioned, all screws have a shakeproof washer fitted. The valveholder panel is connected to the main unit by two 10-way tag strips (although only nine of them are actually used) which have their tags soldered together; this makes disconnecting them both difficult and tedious. They are best unsoldered, using plenty of Solderwick and a thin strip of steel between each tag as they are progressively unsoldered. A couple of warnings: on the MkI, that I have access to, the wire colours used on either side of the tag strips *do not match* (unlike AVO's later VCMs, where they do); so make a written note of the two colour sequences first.

The disassembly procedure does strain the individual tags, which are prone to break. Frankly, the whole assembly is best discarded and replaced with a suitable plug/socket terminal strip; for readers in the Antipodes, Jaycar's HM-3202; for readers in the UK, Maplin's FZ21X is probably equivalent. The valveholder panel can then be removed.

The unit can then be inverted and the rubber feet, now probably perished, and the base plate can be removed. The rubber feet are at the corners of the side frames, and are held by four 4BA × 5/8inch CSK screws, they have a plain ½inch washer under the screw head, and a plain 1inch washer between them and the base plate. Two more 4BA × 3/8inch RH screws, also

Fig.1. AVO MkI VCM

Fig.2. AVO MkII VCM

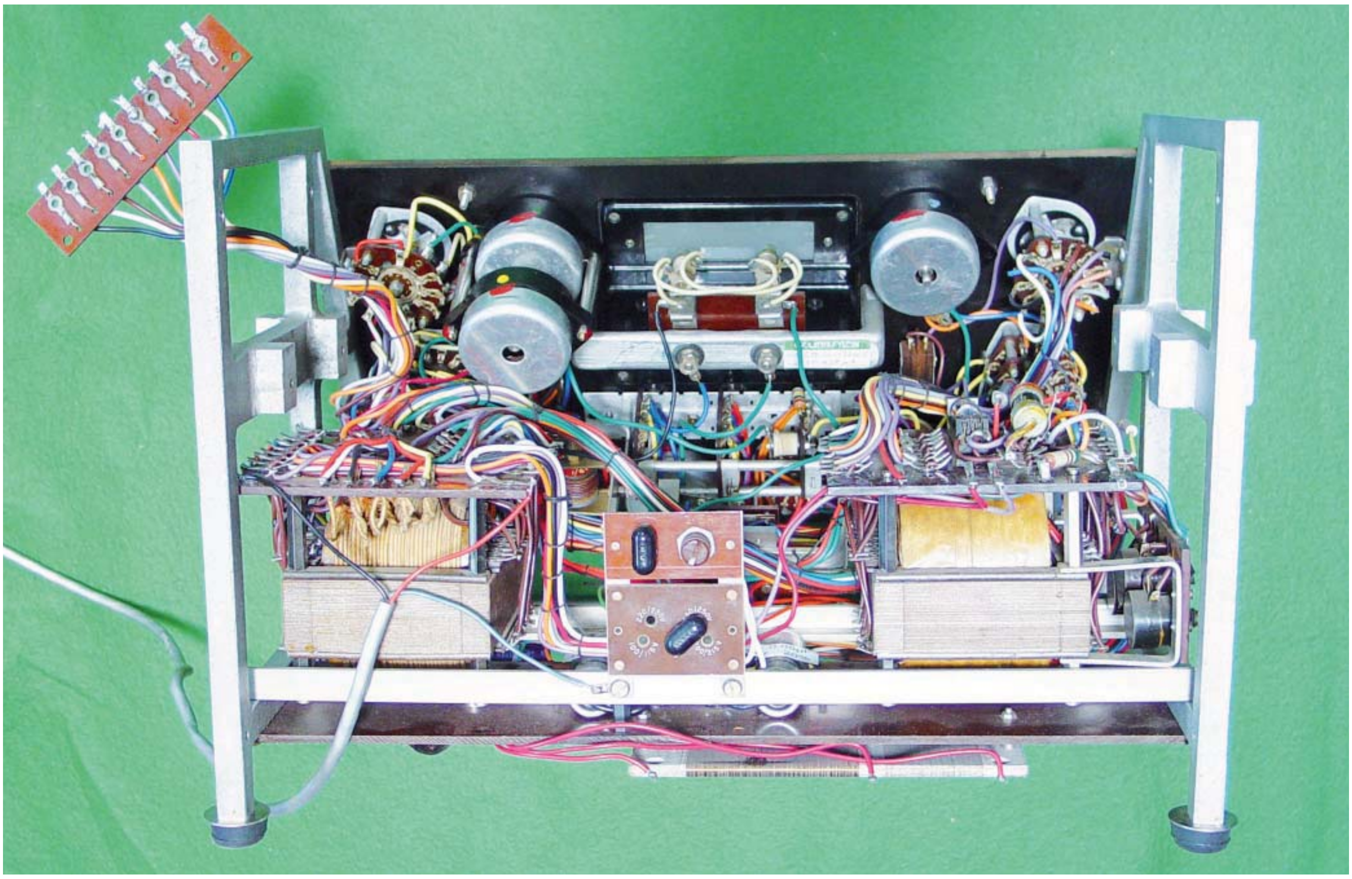
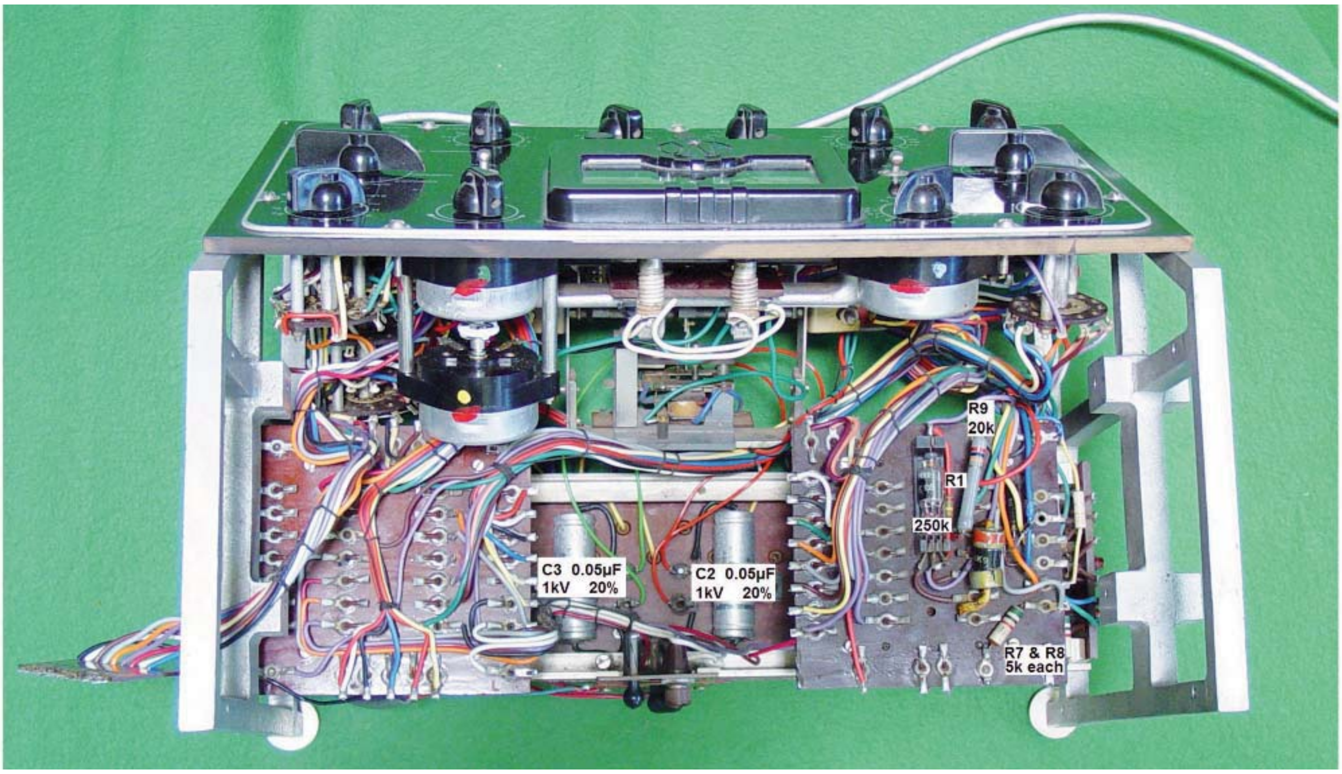


Fig.3. Back of MkI (above) *Fig.4. Back of MkII (below)*



with 1inch washers, are fitted to the centre of the side frames, but without rubber feet.

A 5/16inch diameter spacer bar, between the side frames at the front, can also be removed, it is held by two 4BA × 5/8inch CH screws.

The front panel assembly is held by four 4BA × 5/8inch ‘semi-instrument’ head screws (with no washers) at the sides and is located by two 1/8inch diameter dowel pins (which fall out easily and are just as easily lost) at the bottom of the ¼inch thick insulating panel, on which the instrument panel proper is screwed. The front panel can then be tilted forward onto its face. Warning: AVO used single strand ‘hook up’ wire; after sixty years or so, it has ‘age hardened’ and is very easily broken, so take care not to flex it any more than is absolutely necessary.

The transformer sub-assembly is mounted on two ½inch × ½inch angle aluminium channels, which are fastened at each end to a horizontal member on the

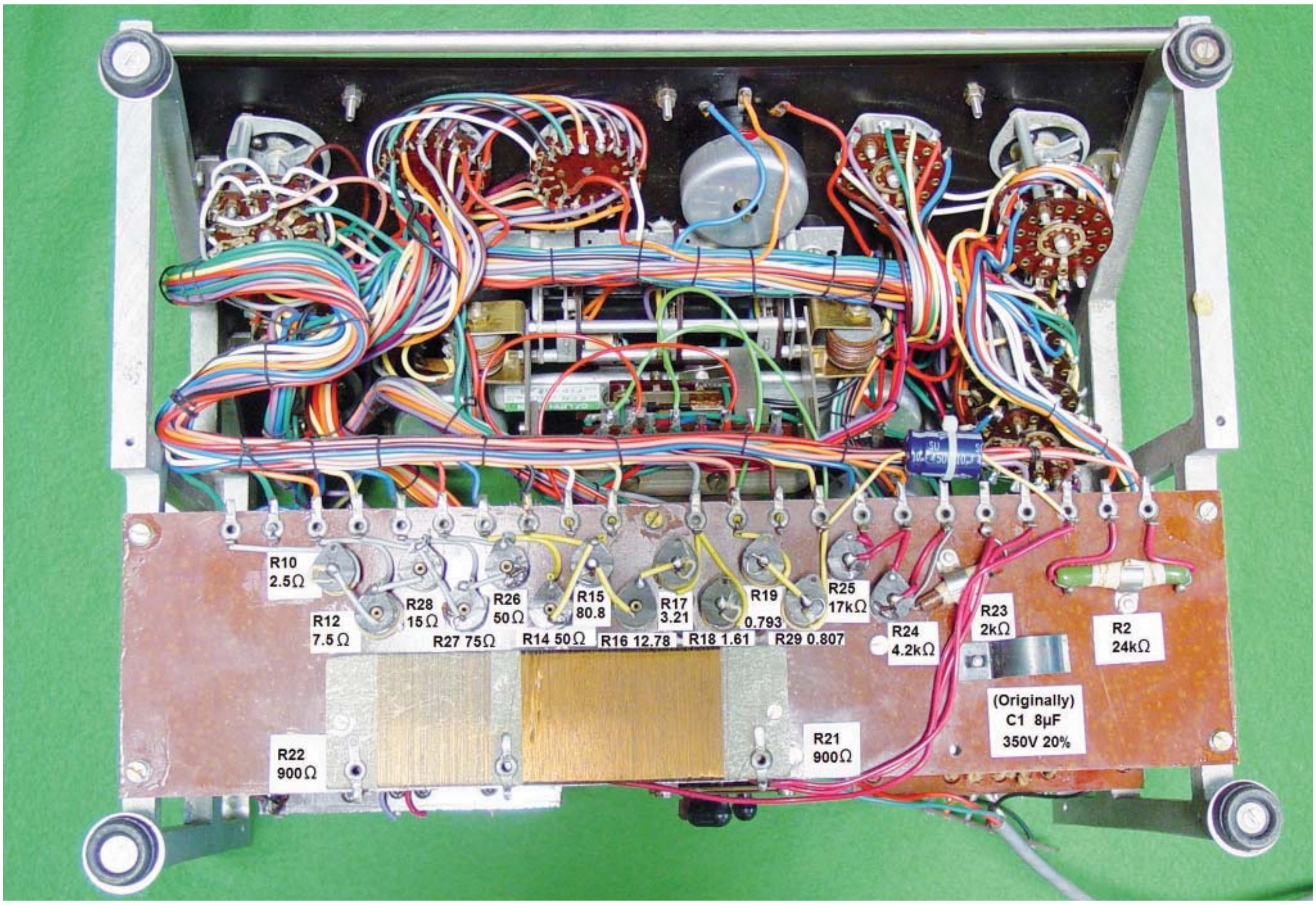
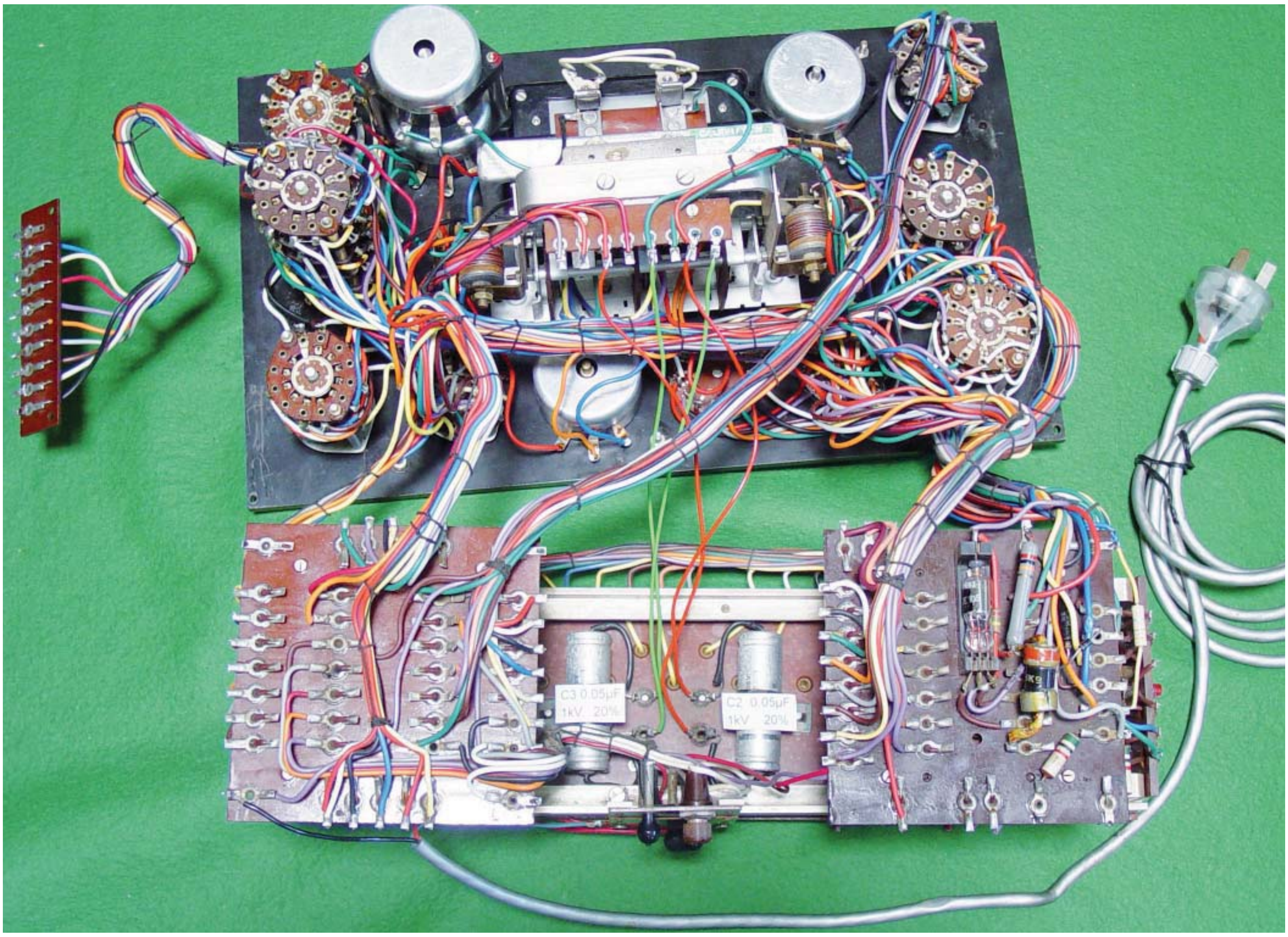


Fig.5. Underside of an unmodified MkI (above)

Fig.6. MkI with side frames removed (below)



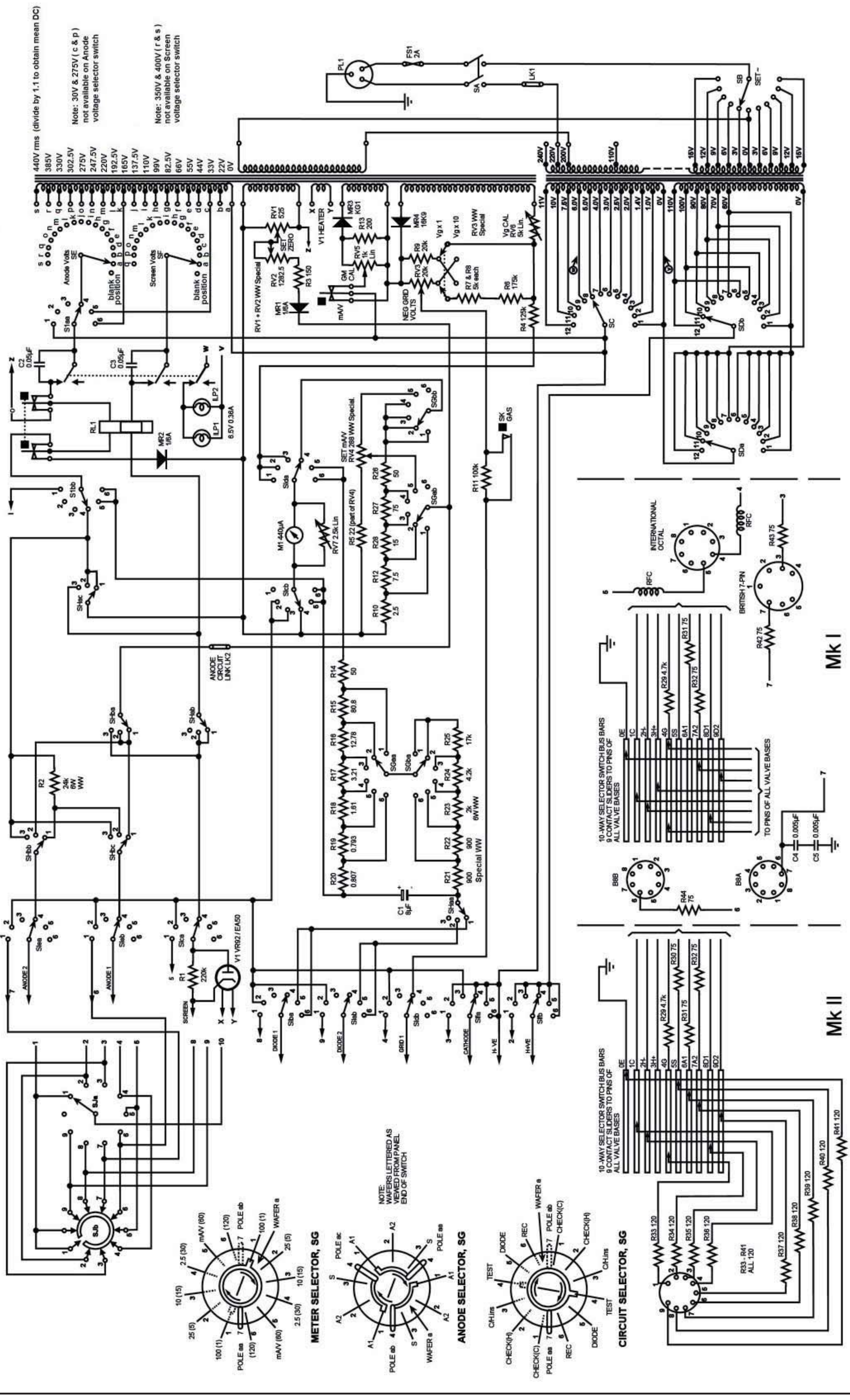


Fig.7. Circuit diagram of MkI and MkII. Drawn, with corrections, by Martin Forsberg. The original is copyright of Megger Limited, the successors of AVO International Limited

side frames, using two 4BA × 5/16inch CH screws. On the MkI, a 1/8inch thick insulated board is mounted, in a similar manner, to the underside of the same horizontal member, again using 4BA × 5/8inch CH screws. A lot of the discrete components; resistors and capacitors, are mounted on this board. On the MkI, the insulating board at the bottom was evidently dispensed with, and these components were ‘scattered around’, mainly on the transformer tagboards; so not all the tags on the transformer tagboard are actually connected to windings on the transformer.

Components

All the components are now sixty or so years old, and in that time there have been substantial improvements to components; there are two schools of thought here:

1. Retain as many as possible of the original components; in order to preserve its originality. If you opt for this category, then it absolutely essential that you do a full, component-by-component check, measuring the value of each one and comparing it with the component list. This will, in some cases, necessitate disconnecting one end of the resistor; if it is in parallel with others.

2. Replace as many as possible of the components with modern components, as these are more accurate, much less leaky and also will have a much longer life expectancy.

Whichever option you choose to follow, to assist in checking component values, the full, correct circuit diagram (covering both Marks) is shown in **Fig.7**, and the full component list is given opposite.

It is worth discussing the components by their groups:

1. Capacitors: by modern standards, these will be very leaky; indeed it is very likely that C1, the 8μF 350V electrolytic, has already been replaced; usually with a 10μF 450V one. This is 25% higher than AVO’s original value, and will therefore lead to a similar error in the diode/rectifier readings. You can still purchase 8μF 450V electrolytics, for example, at the time of writing Antique Electronics Supply sells 8μF 450V Sprague Atom electrolytics (**www.tubesandmore.com**). However, a much better option is to use an 8.2μF 630V polypropylene capacitor and permanently solve all the leakage and life expectancy problems; these are

Components

Circuit reference	Value	Tolerance and rating	Type
R1	220kΩ	10% ¼W	Carbon, insulated
R2	24kΩ	5% 6W	WW, vitreous
R3	150Ω	5% -	WW bobbin
R4	125kΩ	1% ½W	Carbon, non insulated
R5	22Ω	- -	Supplied part of RV4
R6	175kΩ	5% 1W	Carbon, non insulated
R7	4.7kΩ	10% ½W	Carbon, insulated
R8	4.7kΩ	10% ½W	Carbon, insulated
R9	20kΩ	10% ¾W	Carbon, non insulated
R10	2.5Ω	0.5% -	WW bobbin
R11	100kΩ	10% ½W	Carbon, insulated
R12	7.5Ω	0.5% -	WW bobbin
R13	200Ω	5% ¼W	Carbon, non insulated
R14	50Ω	0.5% -	WW bobbin
R15	80.8Ω	0.5% -	WW bobbin
R16	12.78Ω	0.5% -	WW bobbin
R17	3.21Ω	0.5% -	WW bobbin
R18	1.61Ω	0.5% -	WW bobbin
R19	0.793Ω	0.5% -	WW bobbin
R20	0.807Ω	0.5% -	WW bobbin
R21	900Ω	5% -	WW on ins. slab
R22	900Ω	5% -	WW on ins. slab
R23	2kΩ	5% 6W	WW, vitreous
R24	4.2kΩ	5% -	WW bobbin
R25	17kΩ	5% -	WW bobbin
R26	50Ω	0.5% -	WW bobbin
R27	75Ω	0.5% -	WW bobbin
R28	15Ω	0.5% -	WW bobbin
R29	4.7KΩ	10% ½W	Carbon, insulated
R30 #	75Ω	25% ½W	Carbon, insulated
R31	75Ω	25% ½W	Carbon, insulated
R32	75Ω	25% ½W	Carbon, insulated
R33	120Ω	10% ½W	Carbon, insulated
R34#	120Ω	10% ½W	Carbon, insulated
R35#	120Ω	10% ½W	Carbon, insulated
R36#	120Ω	10% ½W	Carbon, insulated
R37#	120Ω	10% ½W	Carbon, insulated
R38#	120Ω	10% ½W	Carbon, insulated
R39#	120Ω	10% ½W	Carbon, insulated
R40#	120Ω	10% ½W	Carbon, insulated
R41#	120Ω	10% ½W	Carbon, insulated
R42*	75Ω	25% ½W	Carbon, insulated
R43*	75Ω	25% ½W	Carbon, insulated
R44*	75Ω	25% ½W	Carbon, insulated
C1	8μF	20% 350V	Electrolytic
C2	0.05μF	20% 1kV	Paper
C3	0.05μF	20% 1kV	Paper
C4*	0.005μF	20% 750V	Paper
C5*	0.005μF	20% 750V	Paper

Not in the circuit of the Mk I instrument
* Not in the circuit of the Mk II instrument

RV1 + RV2	525Ω + 1282.5Ω	-	WW special
RV3	20.5kΩ + 500Ω	-	WW special
RV4	288Ω + 22Ω (R5)	-	WW special
RV5	1kΩ	1W	WW lin. min.
RV6	5kΩ	1W	WW lin. min.
RV7	2.5kΩ	1W	WW lin. min.
MR1	-	-	1/6A Metal rect.
MR2	-	-	1/6A Metal rect.
MR3	-	3.5V 5mA	KG1 Metal rect.
MR4	-	135V 8mA	16K9 Selenium
RL1	-	50 -70mA	Two coil, polarised relay
FS1	-	2.5A	Cartridge fuse
M1	-	440μA	3½” flush meter
T1	-	0 – 95/255V 0 - 16V + 0 - 116V	Heater Transformer
T2	-	200V Power, GB & HT Multi-tapped	HT Transformer
V1	-	VR92/CV1092/EA50	Valve, electronic
ILP1	-	6.5V 2.36W	MES filament lamp
ILP2	-	6.5V 2.36W	MES filament lamp
SA	-	250V 3A	Toggle, 2p 1w switch
SB	-	-	Rotary 1b 1p 11way
SC	-	-	Rotary 1b 1+1p 12 way
SD	-	-	Rotary 2b 2+2p 12w
SE	-	-	Rotary 1p 17w
SF	-	-	Rotary 1p 17w
SG	-	-	Rotary 2b 2+2p 6w

SH	-	-	Rotary 2b 3+3p 3w
SI	-	-	Rotary 6b 2x6p 6w
SJ	-	-	Rotary 1b 1+1p 9w
SK	-	-	Push button
SM			2+2+1 p 2w
SN	-	-	DP changeover
SO	-	-	Rotary 9 unit 1p 10 position

obtainable from Solen (**www.solen.ca**) as part number PPE820.

The remaining capacitors are all tubular waxed-paper capacitors in a metal can; (waxed-paper capacitors are also very leaky by modern standards): C2 and C3 are 0.05µF 1kV connected across the relay contacts, and C4 and C5 are 0.005µF 750V. Capacitors C4 and C5 are connected in series and hidden inside a tube; underneath the valveholder panel, and connected between pin 7 of the B8A (rimlock) socket and chassis; (C4 and C5 were not fitted in the MkII). Again, these are best replaced with polypropylene, which has a much lower dissipation factor than polyester; suitable values are 47nF 1kV, obtainable from Solen as PPM0047, and 4.7nF 630V axial polypropylene, available from (**www.justradios.com**) in Canada.

2. Diodes: AVO used four different types of diodes in the MkI and MkII:

Two 1/6A metal rectifiers, which are now museum pieces; as Morgan Jones observed "If they were any good, we'd still be using them". Some cynics have suggested that AVO must have bought truck loads of war surplus 1/6As, because AVO continued to use them, right up to, and including, their MkIV (in the backing off circuit). A copper oxide rectifier, KG1, is used to supply the GM voltage, which adds + 0.52V to the grid when mA/V button is pressed.

A Selenium rectifier, 16K9, is used to rectify the grid voltage supply, 0 to -100V; Selenium rectifiers have their problems (the 16K9 was listed as 'obsolete' in the 1961 *Wireless World Valve Data* book). They either short circuit and explode (complete with a particularly obnoxious smell); or the plates inside slowly corrode and force the end caps off, leading to an open circuit rectifier; so it might have been replaced already. Remember that you might be testing an expensive NOS GEC KT66, for example, when suddenly the grid voltage (via the 16K9) either becomes AC (ie, positive as well as negative) or completely disappears.

The remaining rectifier is a thermionic one, VR92/EA50, used to rectify the screen voltage; it was manufactured, by Mullard (and others), as a video detector diode for TV receivers. As such it has very low ratings: maximum forward current 5mA, maximum reverse voltage 50V. AVO chose to ignore this latter minor detail; admittedly they did place a 250kΩ resistor across it, presumably to stop it arcing internally on the maximum screen voltage, which is 330Vrms! By contrast, in the later CT160, they observed the reverse voltage limit, 330Vrms, but then proceeded to exceed the forward current limit (9mA) of the CV140/6AL5 diodes; which were designed as FM detector diodes, not as current rectifiers.

All five rectifiers should, therefore, be replaced by modern silicon diodes; and not the ubiquitous 1N4007, or worse still, any old silicon diodes that just happen to be lying in your scrap box. It is well worth fitting soft recovery types, eg Philips BYW96E, as these minimise circuit switching oscillations and EMI.

3. Resistors: these fall into two categories, wirewound and carbon film. In my experience, the wirewound types seldom give trouble, so provided the value is within tolerance, they may be left alone. However, with the passage of time, the carbon film type has not proved to have the high stability that was claimed for them, back in the fifties.

Several of them have been observed to drift high, and you may find that they already have been bridged to bring their value back within tolerance. Again, these are best replaced with modern metal film 1% resistors; however, these are only available in 0.5W or 0.6W, so check the original wattage; you may need to use two, of comparable value, in order to meet both the original value and wattage.

Component Layout

To assist in locating individual components, several photographs, which were taken of the MkI, are shown. In the MkI, in general, all the wirewound resistors and three of the capacitors are located on the insulated board, below the transformer panel; while most of the carbon film resistors are mounted on the transformer tagboards, some underneath, as well as top; along with three of the diodes, KG1, 16K9 and EA50. Remember that not all the tags on the transformer tagboard are connected to windings on the transformer.

As well as checking all the components, do not neglect to check the meter; early permanent magnets were not as good as modern ones at retaining their magnetic flux. If the flux has dropped then so will the sensitivity of the meter, so we should measure the FSD before attempting calibration. One side of the meter must

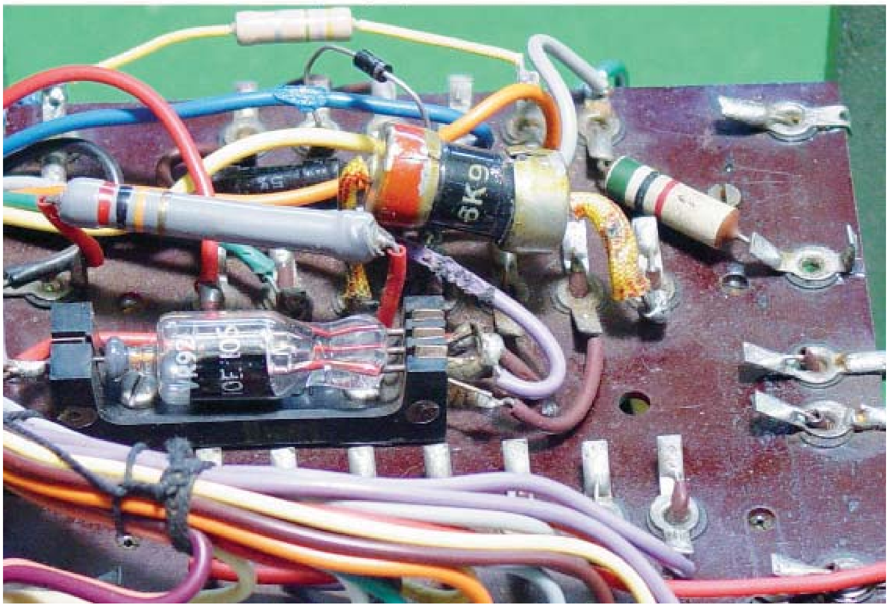


Fig.8. Top of the HT transformer, showing diodes (and pre-existing wiring damage). Note: KG1 had been replaced previously by a 1N4007, plus damage inflicted by a soldering iron in the process (by persons unknown). 16K9 end caps splitting. A 4.7MΩ across R6 (below tagboard) to restore value to 175k.

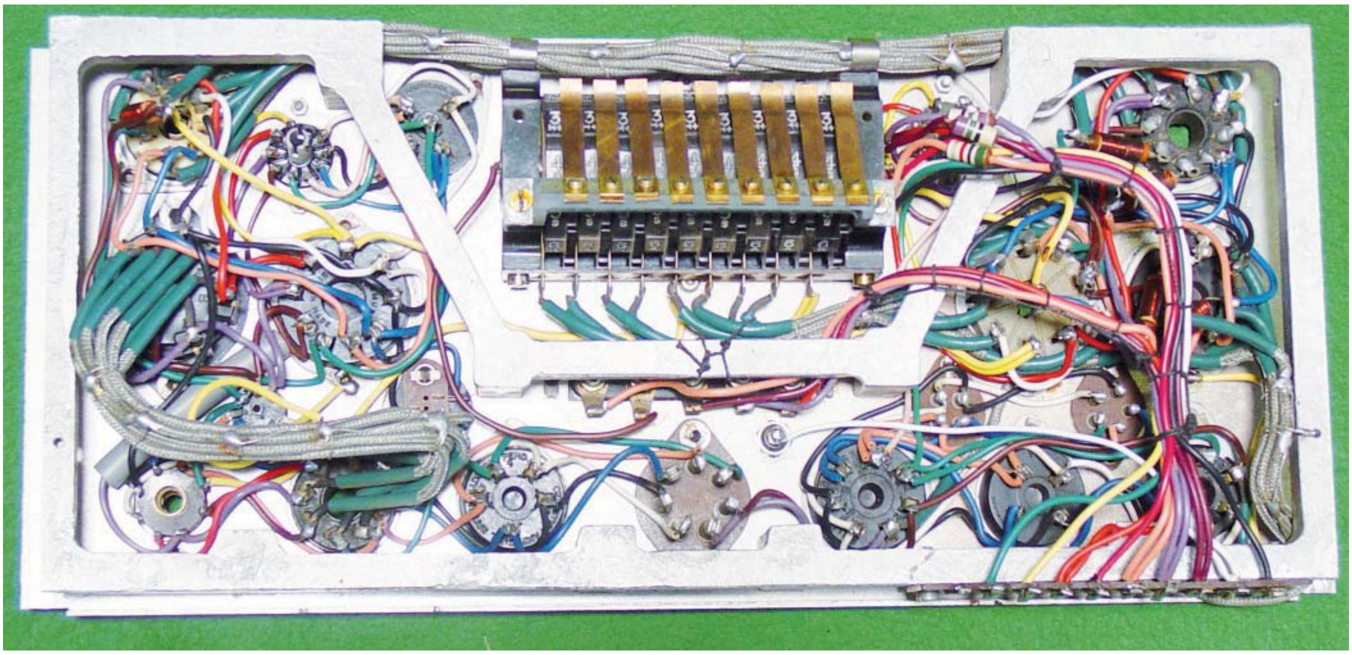


Fig.9. Underside of valveholder panel

be disconnected from the VCM, but leave the meter in its operating position in the sloping panel.

A suitable simple circuit consists of a high value resistor, eg 47kΩ, in series with a digital multimeter (DMM) on the 200µA range and the AVO VCM meter, and the whole series circuit is connected to a variable 0V to 30V regulated power supply, set to 0V. Slowly increase the output voltage, until FSD is reached, and observe the current indicated by the DMM. A more refined measurement would include an extra precision resistor from the RC55Y ± 0.1% range, in the vicinity of 100Ω, also in series. The value in itself is not important, as long as its resistance is accurately known.

Then using a second DMM, measure the voltage across the meter and then the across the precision resistor; then using the known value of the precision resistor and simple proportion, it is an easy matter to calculate the resistance of the VCM meter. In addition, using the precision resistance and the measured voltage drop across it, the current at FSD can be cross checked. In the MkI, that I have access to, I obtained values of 438µA and 116.4Ω

When the values of all the components have been checked, and either been confirmed as within tolerance, or been replaced; then the calibration can commence.

Calibration

Note: Items that are in bold print refer to the actual labels on the instrument.

The presence of a 'sensitivity' control, '**S**', consisting of RV7, 2.5kΩ, across the 440µA meter produces a 'chicken and egg' argument in the calibration procedure: AVO's procedure was to calibrate **SET ~** first; however, since the meter's sensitivity may be altered later, when the anode current check is made; it is better to defer this step, until all the other calibrations have been completed.

Connect a dummy load, consisting of a 1kV rated silicon diode, eg BYW96E, in series with a 3.9kΩ, minimum 10W, resistor and a 1kΩ, 3W WW variable, eg a Colvern CLR4001, potentiometer, across the anode and cathode pins; then insert a suitable current meter, which is known to be accurate, in the anode link. Set the VCM to **TEST** and Va to '0V', then switch on the VCM and slowly increase the anode voltage, carefully monitoring the anode current, up to '400V'; then adjust the potentiometer in the dummy load, to produce exactly 50mA on the external meter. Then, if necessary, adjust the sensitivity potentiometer, **S**, to give exactly 100mA (indicated) on the VCM meter.

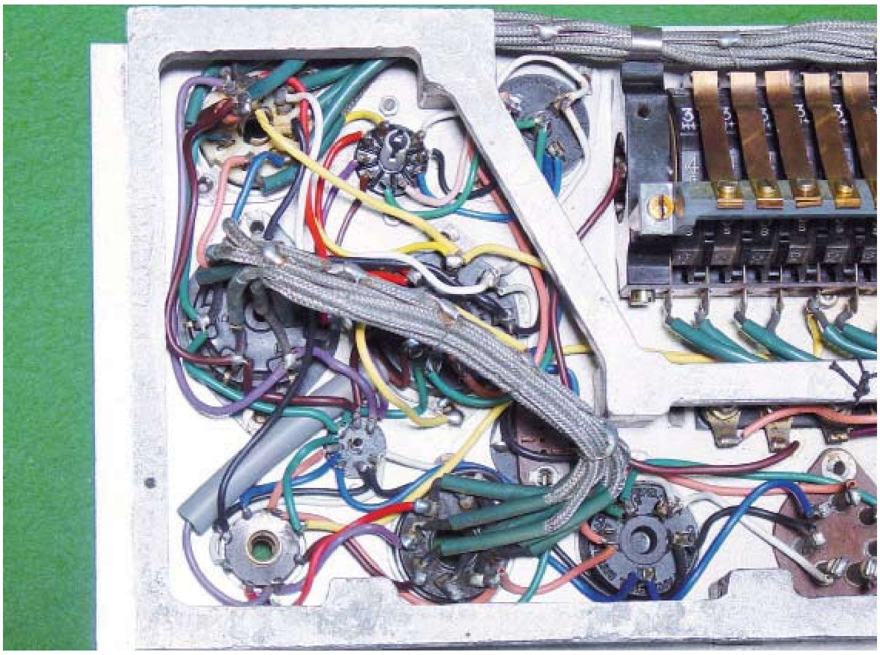


Fig.10. Underside of valveholder panel, showing tube for C4 and C5

Switch off, remove the dummy load and re-insert the anode link; then connect an accurate AC voltmeter to the anode and cathode pins; with Va set to '400V' and still on **TEST**, you should measure 444Vrms on the anode; if not adjust the mains tap, at the rear of the instrument, to obtain as close as possible to 444Vrms. AVO specified a tolerance of ±5% on the anode (and screen) voltages, this corresponds to 444 ± 22V on the '400V' setting. They claimed that their patent method of using AC for valve testing quote "Rendered regulation errors negligible" (p5 of the handbook issued with the MkII). With Va on the '400V' setting, on no load, I measured 442V; however, when a 50mA real (ie 100mA indicated) load was applied, it dropped to 421V; which corresponds to a regulation of 4.75%.

The next step is to check the accuracy of the grid voltage calibration: place an electronic or digital multimeter, DMM, across RV3, **NEG**. **GRID VOLTS**, set it to **'-10V'**, and switch to **Vg × 10**, thus giving '-100V'. This voltage has to be multiplied by the factor AVO specified in their patent, namely 0.52, giving -52V.

Two notes: first this cannot be measured accurately with an AVO Model 8 or any similar 20,000Ω per volt instrument; because it is a high impedance source, namely 20kΩ; so the minimum meter impedance should be 100 × 20kΩ, ie 2MΩ; (most DMMs are 10MΩ). Second, in spite of anecdotal opinion to the contrary, digital multimeters will give the correct, ie the mean, readings on the DC setting, when measuring half-wave rectified AC. However, if the DMM is of the automatic ranging type, you may have to override this facility, and set it to the 100V range, for example.

If the voltage is incorrect, adjust RV6, 5kΩ, marked **VG**, to give exactly -52V. Now switch to **Vg × 1**, leaving RV3 at -10V; the voltage across RV3 should now be -5.20V, if it is not, you will have to adjust the simple 'tap' that AVO provided, in the right-hand corner of the rear transformer tagboard. This consists of the main resistor, R6, 175kΩ, plus two smaller resistors, R7 and R8, both 5kΩ, in series; choose the best tap position; or better still, instead fit a 20-turn trimpot, say 10kΩ or 20kΩ, in lieu of R7 and R8.

Final Calibration

The final calibration is the **GM** voltage, which produces a change of +0.52V in the grid voltage, as measured between the grid and cathode sockets, when the **mA/V** button is pressed. If this is incorrect, adjust RV5, 1kΩ, to give exactly + 0.52V.

Now, we can check the SET ~ calibration: switch to **SET~**, and check the meter indication; if it is not correct on the red ~ mark, double check the value of R4, 125kΩ ± 1%. Assuming that all the previous calibration checks were correct, you may have to modify the value of R4, either by bridging it with a high value resistor, in the 1 to 10MΩ range, if the reading is too low; or alternatively adding a few kΩ in series, if the reading is too high. This then completes the calibration procedure.

AVO's Subsequent Improvements

AVO continued to improve their VCMs, right up until their last model, which was the VCM163. There is no reason why these improvements cannot be made to the MkI or MkII. The subsequent MkIII and the CT160 continued to use thermionic diodes (CV140 or D77); however, in the MkIV, AVO changed over to silicon diodes for the screen voltage rectifier. Subsequently, this was later followed by rectifying the anode voltage as well, in both the CT160A and the MkIV. The VCM163 also had both anode and screen voltages rectified.

In October 1960, AVO added protection for the more sensitive 30µA meter, which was used in the CT160, MkIII and MkIV. It consisted of back-to-back silicon diodes across the meter terminals, as well as an 8µF 12V electrolytic capacitor. AVO's idea of fitting a capacitor was basically sound, but the choice of an electrolytic was not a good idea; the very low voltage, <100mV, was insufficient to polarise the dielectric, leading to leakage, which obviously stole current from the microammeter. However, a low voltage polypropylene capacitor is a much better choice, the value is not critical, and so a modern 10µF would be quite suitable for the 30µA, 3250Ω meter.

Unfortunately, with the 440µA, ~ 100Ω meter in the MkI or MkII, we would need 325µF to achieve a similar time constant, which is 26ms. Again, there is anecdotal opinion that "fitting silicon diodes doesn't work, because they interfere with the meter"; all I can say is try it for yourself; set the meter to FSD (eg, as in the test above), you will observe that there is no detectable reduction in the deflection when back-to-back silicon diodes are connected directly across the meter terminals. However, germanium diodes do give a noticeable drop in deflection, so they should not be used.

If you do decide to incorporate anode and screen voltage rectification, you will need to fit a 100kΩ, 1W resistor to the common or 0V rail, after the diode, in each supply; just as AVO did, in order to prevent spurious voltage readings. Also, when you subsequently check either the anode or screen voltages, remember that you are now measuring the mean or DC value of a half-wave rectified sinewave; not the rms! Hence, the value of the voltage, that AVO labelled the selector switch with, is halved; ie '400V' will read 200V mean; this, of course, is also the reason why the indicated anode current is twice the real value.

To facilitate testing and calibration, the final modification is to drill a suitable hole in the valveholder panel, adjacent to the existing central strip of 3mm sockets (labelled **G1** to **D1**); in order to accommodate a 3mm socket, which should be connected to the cathode wiring.

Acknowledgements

This article was the result of an enquiry (to assist the owner of a MkII, whose VCM had some problems). It could not have been written, without the kind assistance of the following persons (listed in alphabetical order):

Jack Connell, in Port Willunga, South Australia; who kindly let me have his Mk I on long term loan, and furthermore, agreed to allow me to fit all of AVO's subsequent improvements to it.

Martin Forsberg, in Linköping, Sweden; who kindly drew the correct circuit diagram for the article (the original AVO MkI contains mistakes, the most notable one being that the backing off diode, is drawn the wrong way round!).

Peter Holtham, in Brisbane, Queensland; for his perseverance in tracking down the actual wiring of his MkII, for taking a photograph of it for this article, and also for kindly giving me a copy of his excellent book on restoring the Marconi R1155. ***RB***

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Crystals And Transmitters

by Ron

Many years before the mid 1920s, the Curies discovered the piezo-electric effect during their experiments, which involved the use of Rochelle salt. It was discovered that if a sample of this substance were to be placed between two metal electrodes as at **Figure 1**, connecting the two electrodes to a source of direct current could change its shape.

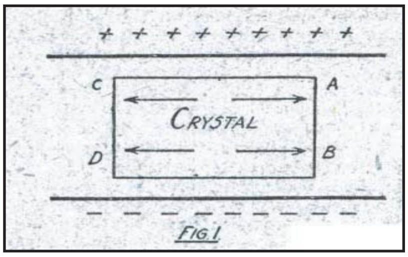


Fig.1. A crystal between two electrodes

When voltage is applied to the electrodes, the crystal is shortened over the lines A-B and C-D, and lengthened in direction of the arrows, i.e. if the crystal is shorter in one direction, it will become longer in the other.

Polarity

If we reverse the polarity of the charge on the electrodes, the mechanical strain on the crystal will also undergo a reversal. It was found that this particular phenomenon manifests itself in the opposite manner. That is to say, if the crystal is subjected to mechanical stress or surface pressure, its surfaces will take on an electrical charge, i.e. electrical stress causes a mechanical strain and vice-versa.

It was believed, during the initial experiments, that other specimens of crystal would exhibit the same effects, but it was found not to the same degree. Yet Rochelle salt are weak in their basic mechanical form; and due to moisture and absorption, the use in radio engineering is limited.

Quartz

Since the early days, the mineral quartz has been discovered to have superior properties. In oscillatory uses quartz exhibits its ability in the realms of frequency stability, in that when the electrodes come under stress, mechanically or by an applied voltage across the parent electrodes, the crystal, having undergone change, quickly returns to its normal dimensions. Then, overshooting the normality, it tries to return to normal size by expansion, and sweeping past its mark becomes larger etc.

This state of 'oscillation' whose frequency is determined by the physical proportions of the crystal, is consistent in vibration, but at a radio frequency.

Periodicity

Such a nice word for frequency – periodicity! But it can be adjusted by the thickness of the piece of quartz plate to the required 'frequency'; but now comes the difficult bit, the natural quartz must be cut along certain lines in order to obtain good oscillatory results.

Looking at **Figure 2**, which depicts a natural piece of quartz crystal exhibiting three important axes; these being X; Y and Z; dotted lines indicating the optical axis. There are other X and Y axes, but only one Z, this is indicated in **Figure 3**. Reference to Fig. 2. reveals how the quartz is cut from the natural crystal. Natural frequency is determined by the crystal's thickness. A thin crystal will function at a higher frequency.

Elasticity

As the modulus of elasticity varies between many specimens of quartz, it is not easy to estimate the frequency of different crystals. Early experiments in quartz crystals revealed an average value of a wavelength of 150 metres per millimetre in quartz thickness. At the beginning of quartz experimentation in oscillators, there was extreme difficulty in achieving oscillations below 100 metres, this being due to the fragility of the crystals after cutting. Over the years, improvements were made, but frequency multipliers were mainly employed by harmonics and overtones. Doublers and triplers following the fundamental crystal stage enabled

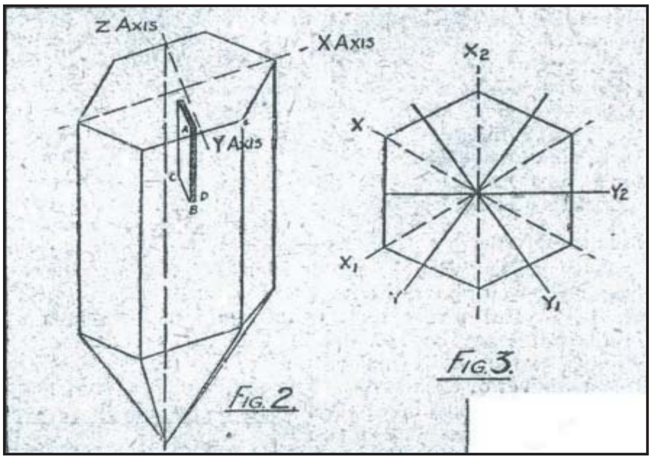


Fig.2. and Fig.3. The three axes of a crystal

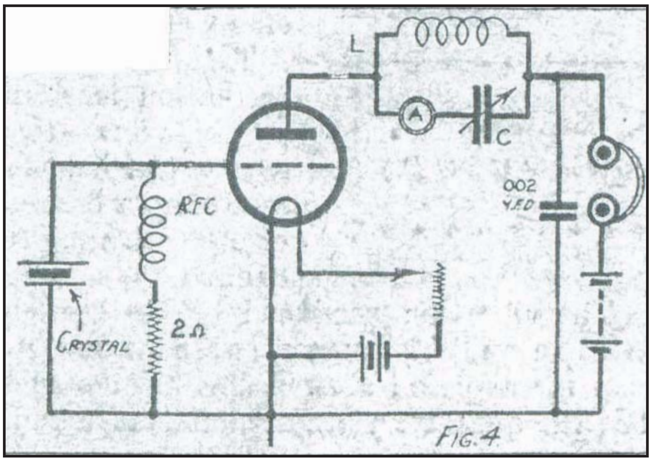


Fig.4. A simple valve circuit for testing a crystal

high frequencies to be reached when transmitting.

Figure 4 gives a serviceable circuit diagram for testing quartz crystal specimens. The valve may be one of many ordinary valves such as the old PM2DX with 60 to 90 volts on the anode; whereas the radio frequency choke (RFC) should be wound with fine wire, or selected from the normal RFC range. Such chokes are small in order to minimise coupling with the inductance L.

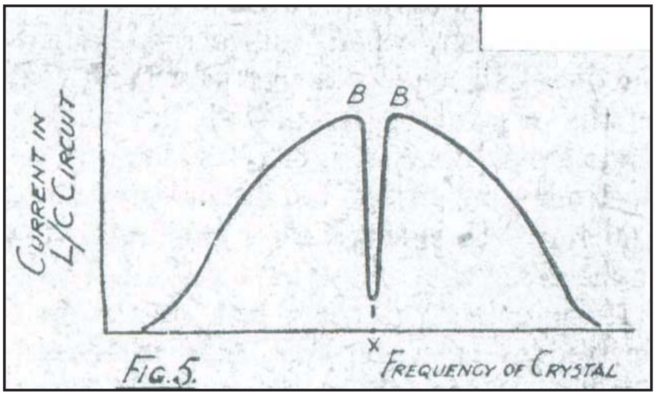
Natural Frequency

The RFC should be resonant substantially higher than the crystal itself. This is to avoid self-oscillation in the valve circuit which could be confused with the true crystal oscillation. LC values should be such that the combination should be tuned over the frequency range in which the crystal is expected to oscillate. Eventually, during the tuning sweep, current will start to fall until a dip appears on the meter. See **Figure 5**.

The ammeter A will indicate when the crystal is "in the mood to oscillate", this quotation is from the late G5LL who was a good teacher. The meter *per se* should be one of a range of 0 to 100mA, but at resonance the circuit current will probably be in the region of 20mA or less. Fig. 4. is a well tried circuit.

Stability

Frequency stability is typified by the figure + 10 parts/10^6/° Centigrade, but when used in a crystal oven of close control a reduction of + 2 parts/10^6 can be expected. That certainly is better than the average VFO; the disadvantage being that one is rock-bound. It is possible to obtain a slight variation of frequency by 'pulling' the crystal, i.e. using a tuned circuit in parallel with it.



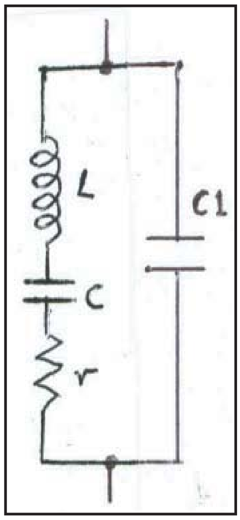


Fig.5. (above) Graph of meter reading from the circuit of Fig.4

Fig.6. (right) Equivalent circuit of a crystal resonator

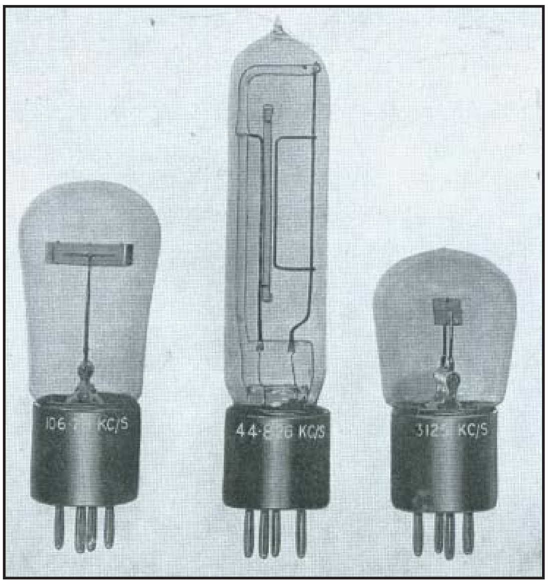
Figure 6 shows the equivalent circuit of a crystal resonator in which C1 represents the capacitance between the two electrodes; the crystal being the dielectric. Capacitor *C* inductor *L* and *r* represent the resilience mass and friction, i.e. damping losses in the crystal. The damping is small, therefore the Q of the circuit is very high being of the order of 2000 to 500,000, dependent on the cut of the crystal.

Series Or Parallel

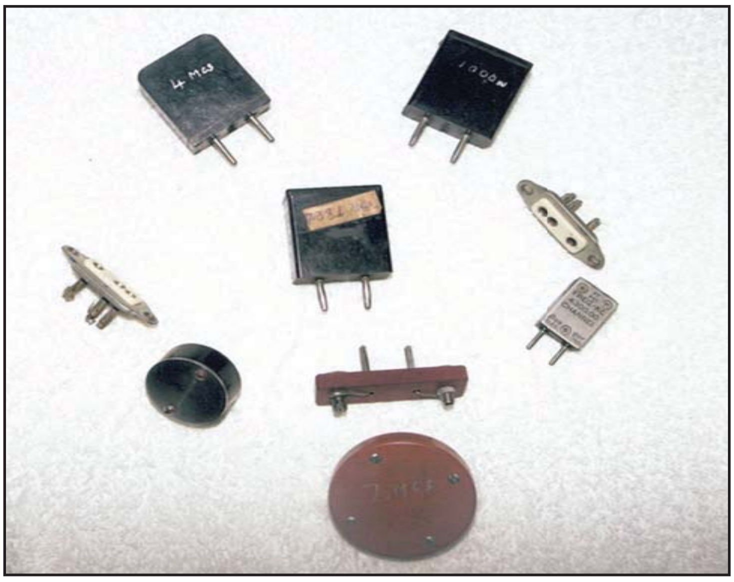
It's not unusual for the value of C to be lower than that of C1 in that L and C frequencies possess equal reactance, and that the impedance of the *LCr* part of the circuit is quite small, so that it's possible to ignore C1; *r* being low in value. In these circumstances the crystal functions as a series-tuned circuit; but as the frequency is increased, the series circuit *Z* will give an inductive appearance, thus causing the reactance to have a value equal to C1. The difference between the two resonant conditions is determined by the ratio of *C* to C1; but for frequencies off series or parallel resonance, the crystal acts as capacitance; its value being equal to C1.

Crystal Assemblies

Over the years various assemblies have been employed. The writer has several specimens in working condition, the early type being housed in glass, having valve-like appearance, some of which are quite large. By way of contrast, the WW2 American crystals having two pin contacts are quite small and easy to dismantle to change or repair. The English crystals are similar but much larger; whereas some of the early 1930s type are round; likewise the quartz insert. Modern crystals are quite small having wire contacts for soldering into circuit boards. ***RB***



Some early crystals – from 1938 Book II Admiralty Handbook, wireless transmitter crystals



A selection of crystals and crystal holders, including two round crystals (Photo by Robert Ibbotson)

An Original Wartime Paraset And A Forensic Investigation

by Ken Brooks G3XSJ

The Paraset, or Mk. VII, is a self-contained miniature radio station that was introduced in 1941. It was developed by MI6 SIS Section VIII at Whaddon Hall, but was also used by SOE. The Paraset has the integrated appearance of a transceiver, but actually comprises separate transmitter and receiver circuits. Early versions were supplied in wooden boxes while later versions, the Mk. VII/2 came in a hinged metal box which, when closed, bears no evidence of its clandestine wireless contents. The metal box version is very compact being just 221 × 141 × 116mm, and weighs in at around 2.5kg,

Information in *Wireless For The Warrior Volume 4* states that, 'its purpose was for agents and the resistance, and an accompanying photograph shows an accumulator powered Paraset being used in operational service in Norway'. As an illustration of the versatility of the Paraset, it appears that one was used by Edgar Harrison, wireless operator to Winston Churchill at a conference held in Mersin, eastern Turkey in 1943 [1]. The station enabled two way communications to be established with Cairo and London, a notable achievement bearing in mind the low transmitter power.

Valves

Three metal octal valves are used, which are stowed in spring clips inside the lid. The receiver uses two 6SK7s while the transmitter uses a single crystal controlled 6V6, a valve often seen in the audio output stage of domestic receivers. Two indicator lamps are used for tuning up the transmitter instead of the usual meter, as front panel space is limited. External power supplies enable operation from AC mains or a DC source.

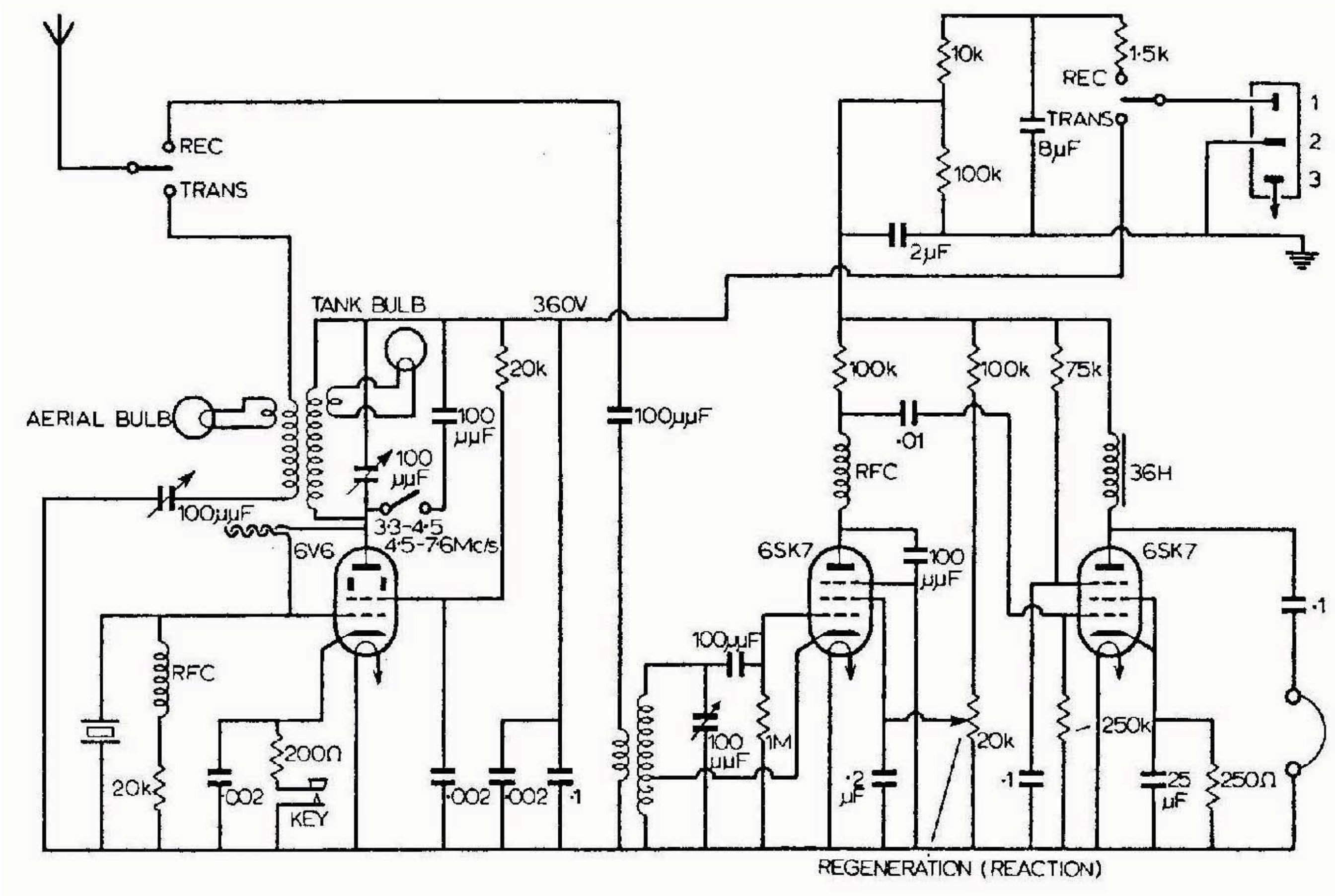
The transmitter covers 3.3MHz to 7.6MHz in two ranges, while the receiver covers a similar range in one band, this leading to observations that tuning the receiver, particularly at the high end, needs 'safecracker' fingers! The tuning control is not directly calibrated, being a simple 0 to 100 scale and calibration is effected by a separate individually prepared chart affixed inside the lid. A miniature Morse key is fitted in the lower right corner of the control panel. Only the knob is visible, the remainder of the mechanism, other than the gap adjustment control, being under the panel.

As a simple regenerative receiver, the Paraset can radiate signals on the receive frequency and using the receiver in occupied territories would have been hazardous. The design has a strong following and reproducing Parasets is popular with low power enthusiasts. Original examples are scarce. This project required the customary capacitor replacements for recommissioning, but it developed into an intriguing investigation working with a forensic science laboratory.

Internal Inspection

Some time ago I had the privilege of acquiring a Mk. VII/2, the later metal box version of the Paraset. On top of the box was the pencilled scribbled note "OK 16/11/58". First impressions were its diminutive size, and the grubby, unloved appearance, not improved by a yellowing varnish unevenly applied to the front panel. I was dismayed to notice a blank space where there should have been a serial number plate. This had been brutally removed, as the aluminium rivets which once held it in place were still present. Strangely, there were a pair of identical pitch holes just above the rivets as if the plate fixing holes had been incorrectly located at the first attempt.

Three sides of the stepped lid fit over the lower part of the box but, as with other Parasets of this style, there is no means of keeping the lid closed. This seems an unusual design omission.



Paraset circuit diagram (from Wireless For The Warrior *Vol 4)*

Upon removing the chassis from its container I noticed, with disapproval, a sizeable 8μF electrolytic capacitor hanging in place along with a smaller one, both held only by their supporting wires. A clamp would have prevented straining the mounting wires that is inevitable as portable equipment is moved about. These wires were clearly at risk of failure over time and the absence of any type of strain relief seemed to be a serious shortcoming. My misgivings were later confirmed when removing the two parts for refilling. Both negative leads terminate at a solder tag and had indeed fractured.

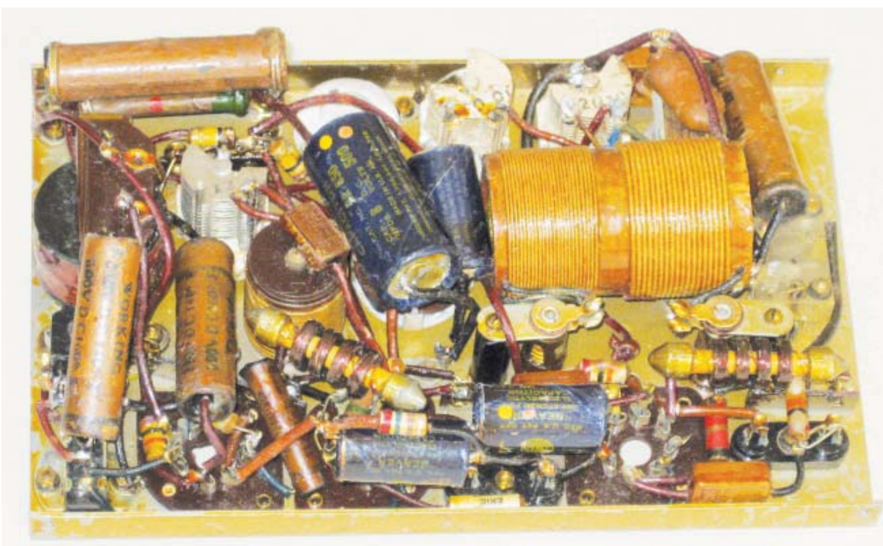
The yellowed varnish on the front panel extended to all the below chassis parts except the variable capacitors, reaction control, and key, suggesting that this was applied during manufacture. Other than that the construction style is conventional, if densely packed.

Something else that I noticed was the unequal height of control spindles. When subsequently removing some knobs crude hacksawed marks were visible where the spindles had been cut to length. I was surprised that no effort had been made to tidy up all the tool marks. With other evidence like the unevenly applied varnish and incorrect serial number plate mounting holes I surmised that this set was probably a production prototype of the Mk. 2 metal box style Paraset.

Unmolested

It was fascinating to inspect one of these hallowed chassis and marvel that a complete radio station had been shoehorned into such a compact assembly. Despite the rather tired app-earance, I was delighted to have an unmolested chassis with no evidence of any work or modifications other than one resistor being loose at one end, and a couple of wires soldered across the key contacts and brought out through the key aperture to allow the set to be used with an external Morse key.

To record the as found appearance, a series of photographs were taken. These would be used later to ensure that any replacement parts would be replaced in



Paraset chassis underside

exactly the same orientation as they had originally occupied. Before commencing any electrical work, a spot of machine oil was applied to moving parts and worked in around capacitor shafts and bearings to ensure that they were mechanically free.

There is clearly a balance in restoring old, historic equipment like a Paraset between keeping the original appearance and a wish to have the equipment working, rather than a lifeless exhibit. This apparent conundrum illustrates some subtle differences between restoration and conservation. We might all admire a classic or vintage car, but it inevitably will have many non-original parts like its tyres, battery, lamps, and probably hoses. Total originality seems to be unattainable for this type of product, unless, of course, something has been stored from new and its component parts have not deteriorated with age. The same difficulties apply to restorers of electronic equipment, especially with small parts that are likely to suffer age-related degradation and failure, like capacitors and resistors.

For less common equipment, I like to keep the original below chassis appearance and rather than simply replacing old capacitors with new, prefer to refill the old cases with new parts. This can be one of the most time consuming tasks of a refurbishment. Unless resistors have become open circuit it is very likely that the usual carbon examples have increased their value. On this chassis it was possible to measure most of the resistors with minimal effects from parallel circuits. Many had increased by around 30% which, although outside their original manufacturing tolerance, were left in place as the circuit did not appear to rely on any precision value resistors. I could always return to these if difficulties were encountered.

Testing And Refilling The Electrolytic Capacitors

The Paraset contains four electrolytic capacitors and these were expected to have failed because of their age. Reforming of one was attempted in the forlorn hope that if successful, originality could be retained. The sample responded by getting warm and on closer inspection an aged bulge was visible on the end cap, indicating a past failure. A replacement was obviously needed.

The electrolytic capacitors are cardboard sleeved ‘Beaver’ brand. In past work I have removed an end cap, but as they are visible on this set I tried a new method of capacitor replacement by gaining access under the cardboard sleeve. To do this I soaked the cardboard to soften it, eased up one end of the crimping and pushed out the can. Most responded well to this treatment, the sleeves sliding off with little resistance after initial loosening. Like fasteners, there always seems to be one that causes problems and, on the problem capacitor, the sleeve was particularly troublesome and only separated after considerable effort.

With a collection of metal capacitor cans now in hand, these were marked with their values and hacksawed in two. The internal parts were removed either by pulling out with a corkscrew used to grip the foil, or by picking at the foil and removing it piecemeal. The new capacitors that I intended using as replacements came with lead out wires of insufficient length, so I used the opportunity of extending the wires to match the wire gauge with that of the original parts.

To rebuild, a springy piece of shim coated with Araldite was lowered into one of the can halves with its new capacitor and the other half then offered up to close the can. When cured, the assembly was put back into the cardboard sleeve. I was feeling quite satisfied about all this until I tried crimping the cardboard outer back to its original shape. Working soggy old cardboard is not at all easy and only after considerable effort was a passable result obtained. In addition all the flexing had damaged the ink and lacquer, so a combination of black and blue inks was applied to conceal the damage, followed by protective varnish.

Replacing Paper Capacitors

Initial leakage testing with a digital multimeter seemed to suggest that the larger, paper capacitors might just be serviceable. I have found that these sometimes respond to conditioning with high voltage, but my quick test was not very convincing as the indicated leakage kept changing. I am, in any event, somewhat sceptical about the validity of a test carried out at low voltage when some functions need excellent insulation. The tests were, therefore, repeated with an electronic Megger on the 500V range. This severe leakage test gave much less optimistic results, and on that basis, the capacitors were duly condemned.

The Paraset contains three 0.1μF and one 0.01μF tubular paper capacitors. These were to be refilled and came apart easily after warming the cases to soften the wax. The new polyester

Rebuilt Paraset capacitors

capacitors did not have sufficiently long leads, so additional lengths of the correct gauge tinned copper wires were added before refitting them into the original cases. All this was very straightforward after working with the electrolytic capacitors and their difficult cardboard outers.

Incidentally, I stress tested the newly rebuilt capacitors with a Megger at 500V just to reassure myself of their quality, and after testing dropped them in a plastic tray ready for the next stage of work. When I came to install them a few days later I put a slightly damp hand in the tray of loose capacitors and received quite a jolt ! Measurement with a digital multimeter revealed a 0.1μF capacitor was still charged to over 200V, so the quality of insulation was certainly not in doubt. Next time, I will pay greater respect toward small capacitors after high voltage testing.

Testing And Operation

After replacing the leaking and failed capacitors, and having checked many resistors, I was hopeful that the set would work when power was applied. Both 6SK7 receiver valves came with the set, but the 6V6 transmitter valve was missing and a replacement was found from my small stock. All three valves are black painted metal octals, a type of valve that seems particularly neat and businesslike.

A variable voltage bench power supply was hooked up to the power lead, which terminates in a three-way male connector to mate with a socket on the Paraset chassis. This arrangement provides a tidy looking front panel when the power lead is removed, but if the power supply is live some 300V HT is exposed at the male pins of the connector. Nowadays, this arrangement would excite any health and safety inspector.

A typical hazard built into the Paraset design is that one side of the headphone jack is connected to the HT via a capacitor. This saves the cost, weight and volume of an output transformer, and works well, but is less than ideal from a safety perspective on present standards. When the set was new it probably represented a small risk to the user, but over the years the coupling capacitor may have degraded, increasing the risk. Unlike the exposed connector pins, this is what might be called a 'time bomb' hazard.

Awareness is *essential* when working on equipment which not only relied upon knowledge of the hazards to achieve electrical safety, but where insulation may have degraded over time. I rebuilt the coupling capacitor as it was already leaking, but in an endeavour to ensure personal safety had stress tested samples beyond normal HT voltage to satisfy myself that the set was safe to use with headphones.

To check the Paraset, an 80 metre crystal was plugged in to the crystal socket, and headphones and an aerial connected. LT volts were applied and after a short time the valve envelopes could be felt warming up. The HT was turned on, starting at zero volts, and gradually increased to 150V, which is about half the normal operating voltage.

As I did so, noises could be heard in the headphones and, by advancing the reaction control, signals started coming in. At 300V the set worked very well, with good headphone volume, while the current meter on the power supply was only registering a few mA. This was all very encouraging and I was keen to try the transmitter.

Transmitter Testing

A separate receiver was set up nearby to monitor the transmitter signal, and the aerial was switched to a dummy load. However, when the key was pressed nothing happened, and the current drain was zero. Testing with a meter showed that HT was reaching the 6V6 anode, so I turned to the cathode circuit. I had previously given the key contacts a wipe with very fine wet and dry paper so mentally discounted it and went in search of poor valve contacts and failed RF components.

After much checking these all seemed in order and I returned to the key, now noticing that the contacts were very oxidised despite earlier cleaning. A more vigorous clean had the key contacts working after a fashion, but further work was needed to bring them up to working condition as determined by an audible continuity tester.

Hopeful that the transmitter circuit would now work, I reapplied power and was rewarded with a current indication on the power supply. A little adjustment of the tuning controls soon had RF being delivered to the dummy load and I could hear a good note in my monitoring receiver. The two indicator lamps lit as the circuits were tuned through resonance.

Naturally, I wanted to see if any contacts could be made, and, switching back to my aerial, put out a call. Several attempts failed to produce any replies, but later in the day I did hear someone calling on 3.560MHz, and made a short contact in poor conditions. On the following day a further call was put out and a long contact established with a station in west Wales. This was very pleasing after all the refurbishment work. Bearing in mind the basic style of construction, I had expected the receiver to drift quite a lot, but on changing back from transmit to receive was pleasantly surprised at the stability. Operating the set from a stabilised power supply will have certainly helped in this regard.

In common with many other agent sets of its era, the Paraset does not have a netting facility to set the receiver to the transmitter frequency. Without some kind of aid, tuning the receiver to the transmit frequency can be a tedious procedure, needing another signal source and receiver. I built a separate crystal calibration checker based upon a Colpitts oscillator circuit found in an RSGB *Radio Communication Handbook*. A push-to-operate switch and LED battery indicator was added, and, other than the enclosure, was made up in a day from junk box parts.

After building it I picked up a tip that netting could be achieved by temporarily wiring the crystal in series with the aerial. I did try this and found that it works in an approximate sort of way. The calibration checker seems a better method and makes frequency changing very much easier than the cumbersome process used in the past.

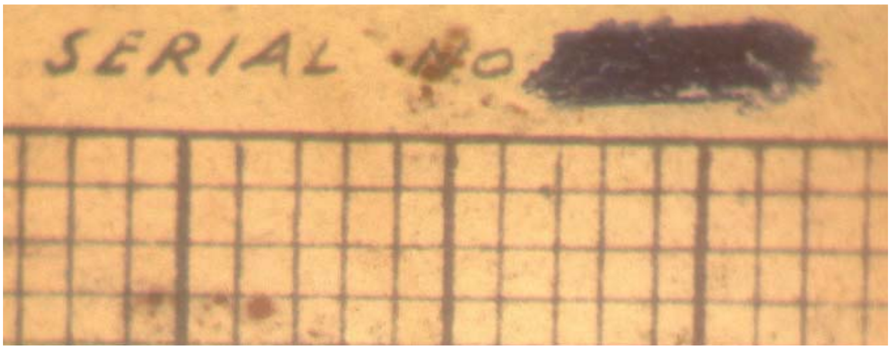
Missing Serial Number Plate

Some Parasets had their serial number plates removed [2] when released from official duties and mine appeared to be one of these as noted earlier. The serial number is repeated on a calibration chart glued to the inside the lid, but this is not easily separated. In an attempt to conceal the number, someone had obliterated it with a good dose of blue ink. As I wished to replace the missing serial number plate, preferably with its original number, thoughts turned to the possibility of discovering the serial number hidden under the layer of ink.

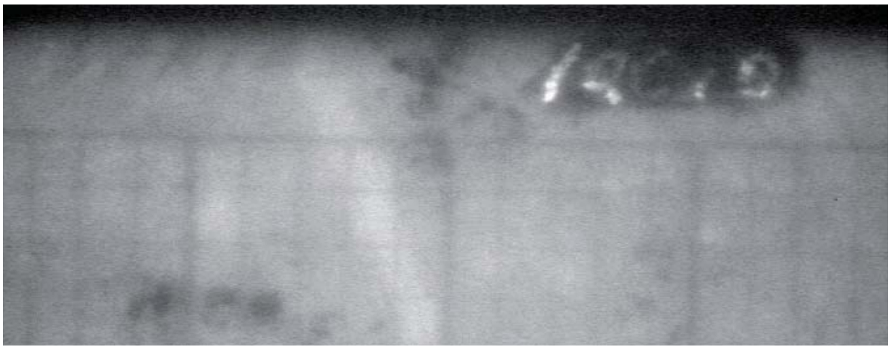
Knowing that art historians can reveal all manner of hidden detail in paintings from underneath layers of paint, my first line of enquiry was to approach the Bristol City Museum and Art Gallery. I spoke with their Paper Conservator who suggested techniques like infra red imaging, but as they were not equipped with this specialist equipment they were unable to help. Around this time the local *BBC News* ran an interview about forensic science facilities at UWE Bristol, the University of the West of England, and I made contact with them to see if they could help. During discussion with their specialists it appeared that the most appropriate technique would be to use a document examination instrument known as a Video Spectral Comparator or VSC.

After making a written proposal, UWE agreed that I could bring the Paraset along to their forensic laboratories. Fortunately, the Paraset just fitted within a machine designed for flat documents and, after some fiddling to get the lid horizontally aligned and consistently illuminated, the analysis began.

By illuminating the specimen with different colours of lighting and filtering the resultant image, the hidden serial number started to become visible. Image optimisation with red lighting revealed what initially looked like the number 12010, although a joint examination of the ‘2’ showed a stroke, possibly a random mark and heavier than the background number. We concluded that the second digit was probably a ‘0’, giving the serial number 10010.



Serial number obliterated by ink



Serial number revealed by Video Spectral Comparator

Better Clarity

Now that we had an image of the hidden number, I wondered if better clarity might be obtained if the layer of ink was removed with some solvent. Bristol City Museum had warned me to be very careful about doing this because it might well destroy the underlying image, but at this stage of the investigation it seemed worth trying. A little ethanol applied with a swab did indeed remove much of the ink, but further analysis in the VSC resulted in a lower quality image, as if some of the serial number ink had been removed along with the obscuring ink. We had reached the stage where as much information as possible had been extracted from the calibration chart.

For those interested in the technique, the VSC equipment is described in the panel opposite. During my appointment I enjoyed a mini teach-in on the forensic science courses run by UWE, and got to see some of their very specialised laboratory equipment. I asked about a prominent blood stain on the back of a laboratory door but was reassured that it was only fake blood made up from food colouring!

Returning to interpretation of the VSC results, a low serial number, or one containing many zeroes might be expected because this set, with its incorrectly placed holes, unequal height control spindles bearing tool marks, and poorly applied varnish suggests a prototype. A more presentable production standard Paraset inspected in the past bore a five digit serial number commencing 103xx, as does the Paraset so expertly drawn in *Secret Warfare* [3], while another in the possession of *Radio Bygones* contributor and clandestine radio enthusiast John Elgar-Whinney bears the sequence 104xx.

A prototype would have been built earlier in time and on the balance of probability the serial number of my

The Video Spectral Comparator, VSC.

The VSC is an instrument generally used for examining documents. Unlike some forensic testing, the VSC is non-destructive and sample preparation is not required.

There are three principal features in the VSC – light sources, image capture by means of an overhead digital camera, and software driven image analysis on a conventional PC. Illumination of the document is by means of differing light sources and filters. The light source can range from ultra violet to infra red, and when suitably illuminated some inks will fluoresce strongly. Lighting is normally overhead, but documents may be viewed with low-angle side lighting to reveal indented or embossed writing. The overhead digital camera can be adjusted remotely by the software in much the same way as a conventional camera. Sophisticated image processing is available and the system offers filtering and integration to optimise results. Stored images may be compared, rotated, scaled and mirrored as required.

The system used for this work was the VSC2000 made by Foster+Freeman of Evesham, England.

example appears much more likely to be 10010 than 12010. It is not known if production numbers reached the quantities indicated by a serial number 12010, but it is believed that production quantities were modest.

The output of the forensic study, and comparison with three other sets, enabled recovery of what is thought to be the original serial number. An accurately dimensioned reproduction serial number plate was therefore designed with a computer graphics package based upon the plate fitted to a wartime SIS Mk. 33 transmitter. With this affixed the original appearance of the Paraset was reinstated.

Conclusion

Restoring an unmolested prototype Paraset is a rare privilege and I enjoyed this project immensely. The work took me outside the usual comfort zone of component replacement and into the realms of forensic science. All this was a most interesting challenge that has resulted in a fully functioning Paraset used on the 80 metre amateur band.

The Paraset is pleasant to use with smooth reaction. The tiny Morse key seems a little daunting at first but one soon becomes used to it. Crouching over the chassis and watching the little lamps flash as the 6V6 does its work is all part of the Paraset experience. Every radio contact is challenging and rewarding. This is proper radio at its best.

Paraset in the Video Spectral Comparator

Acknowledgements

Recovery of the serial number could not have taken place without facilities made available by the Department of Applied Sciences, UWE Bristol. Their cooperation is gratefully acknowledged and thanks are due to Kevin Sudlow for the forensic expertise so readily offered.

Particular thanks are also due to Mr D Thom, G3NKS and Mr T Woolford, G3SNN for making the Paraset available to the author.

References

1. *Edgar Harrison Soldier – Patriot and Ultra Wireless Operator to Winston Churchill*. Arundel Books, 2008.

2. Private correspondence, Rev. Adrian Heath, G4GDR, January 2011

3. *Secret Warfare – The arms and techniques of the resistance*. Pierre Lorain 1972

RB

Designing And Building A Quality Valve Amplifier – Part 2

by Tony Thompson, BSc

Having investigated the circuit design in Part 1, we now continue with the details of the amplifier construction.

Circuit Points

Mullard state that of the two 100kΩ resistors – 5% tolerance – used to supply the ECC83 anodes, the one feeding anode 2 (pin 6) should ideally be the higher in value of the two, due to the action of the cathode-coupled splitter (requiring, for perfect balance, that the 'earthy' triode section have a slightly higher anode load resistance). The easiest way to ensure this is to check your resistors individually, preferably using a digital ohmmeter.

The two 680kΩ 6V6 grid resistors also should be closely matched.

The two 10Ω resistors chosen as current limiters for the rectifier are slightly over-rated at 7W, but they were used because they were to hand. In truth, they are not essential because the high voltage secondary winding of most mains transformers will possess winding impedances in the order of 130Ω or more and, as the Philips data for the GZ34 suggests a minimum resistance for each anode of 100Ω with an AC of 350V, there was already likely to be more than sufficient resistance present; however, I felt it was best to be prudent and fit them.

The balance control circuitry is a little more involved than the commonly-used single high-value pot across the two input signals, with the slider to chassis; an arrangement I do not care for. This circuit provides a very smooth shifting left or right of the sound stage but cuts neither channel completely off. There is some loss of maximum output associated with this circuit; see alternatives (below) for other balance methods.

The 1kΩ resistor across the secondary of each of the output transformers offers a measure of protection to the output stage components should a loudspeaker become disconnected.

Of the options available for push-pull, distributed loading was chosen, with output transformer primary taps at 20%. This reduces power output slightly, but also reduces distortion at all reasonable listening levels compared with normal loading (ie, with the screen grid resistors tied directly to HT+ instead of the 20% primary taps).

All HT+ line electrolytic capacitors used in the prototype are metal-can double types, cans being negative. As the cans were covered by a plastics sleeve, there was no likelihood of grounding the negative poles by contact to the chassis, when they were clamped into place. Earth returns were made to the common bus-bar, which is earthed to the chassis only at the phono input sockets.

Regulator

Designed to supply the heaters of the two EF86 valves with direct current, the regulator circuit is based around a pair of 78S05 regulator ICs in TO-220 packages. This is a fixed +5V type, but is made to provide approximately 6.3V at its output by the addition of the two 1N4001 diodes in series with the ground return. The PCB is powered by a small transformer of the standard clamp type with its double 20V secondaries in parallel, used because it was to hand. Note that 20V is rather high and to prevent stressing of the 4700μF reservoir capacitor, the prototype board use a 15Ω wirewound resistor in series with the bridge rectifier to generate the necessary DC for the regulator. I would advise the use of a 15V secondary transformer instead.

The PCB itself is a small independent board, mounted close by its dedicated transformer. As mentioned earlier the use of this regulator is optional; Mullard never employed them in their 5-10s but then, these dedicated ICs were not around at the time, but it isn't beyond the bounds of possibility that had they been, their design engineers could have used them.

Note that the heatsink 'solder pads' shown on the track pattern on each side of the 78S05 regulator may need adjustment to suit differing heatsink designs. They are only there to provide additional support and are not part of the circuit. They do not need to be soldered unless the heatsink is of a type that requires it. The aluminium ones used here were twist-lock types, locked into slots created by double-drilling and enlarging with a needle file.

Valve Voltages

Typical valve voltages, taken with digital and analogue meters. (AVO 8 readings are in brackets). Volume control at zero setting.

	ANODE	SCREEN GRID	CATHODE
EF86	60 (60)	62 (60)	1.2 (1)
ECC83	150 (140)both anodes	-	60 (60)
6V6GT	240 (230)	248 (233)	12 (12)

Board Design

The adapted schematic circuit and the new power supply circuitry were drawn using Express SCH, and the board layouts were created with Express PCB. Both programs come as a free download. There are some limitations with both but, for ease of use, they are hard to beat. Once each layout was completed and a satisfactory track pattern created, the design was printed at a large scale and checked against the schematic by the time-honoured method of scribbling along each checked track using a coloured felt tip pen.

Though they are not especially complex boards, it is still all too easy to make an error and thorough checking is absolutely essential should you choose to design your own track pattern. If you opt to use the patterns provided, each one must be printed full-scale; the AF board print should measure 96.5mm × 125mm, the tone control board print should measure 160mm × 31mm and the regulator board print should measure 93mm × 36.5mm, all measurements are from edge to edge of the grey border lines.

Making The PCBs

If you possess or can obtain a copy of *EPE* for August 2010 you might care to read up on my article entitled *Make Your Own PCBs*. If not, here is a brief summary of the process I use and recommend:

The track design was printed in black at high density (set printer to high quality) onto Hewlett Packard premium inkjet film. Each film should be run through the printer at least three times and preferably more – allowing a minute or so for each layer of ink to dry – to ensure the essential opaque black. Most printers will handle this procedure quite well, though poor registration of the image can occur, in which case the only answer is to try again.

The most important thing is to ensure that the input tray guides are set correctly, allowing the film a minimum of free side play. The printer I used was a Canon Pixma IP5200. I cannot stress strongly enough the need for a dense pattern. Attempts to make a PCB with a less than opaque print will fail.

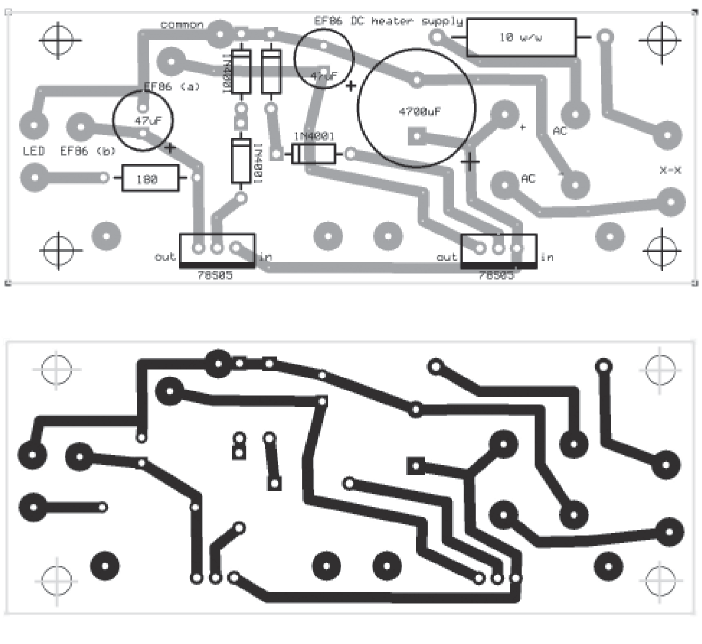
Standard 160mm × 100mm single-sided glassfibre boards were used to make the two AF amplifier PCBs, the regulator PCB and control panel PCB. Glassfibre board produced to the FR-4 standard (woven glassfibre in epoxy resin) is better than the 'economy' SRBP, both in terms of dielectric strength, toughness and increased insulation properties, and also has better fire-resistance. The ready-sensitized board comes with a black plastic protective film. When you are ready to use it – and not before – peel away the film, taking care not to scratch the light-sensitive coating. Exposure of the boards was carried out using a home-built low-voltage UV exposure box, but this is not essential as sunlight provides a good source of UV light, albeit somewhat variable.

Exposure To UV

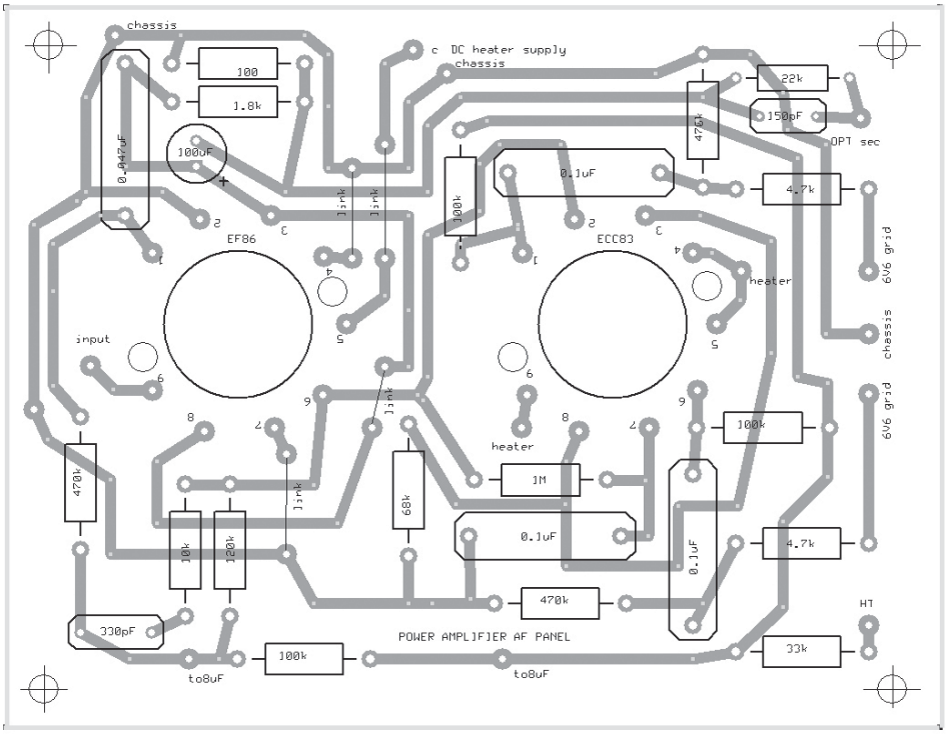
To prevent slips, use masking tape to attach the transparency to the board, with printed side in contact and avoiding masking any areas of print. Tape this assemblage to a south-facing window in full sunlight, keeping pressure on to ensure close contact between film and board. Arms can tire, so it is better to lean a heavy wooden batten or something similar to apply pressure to the back of the board.

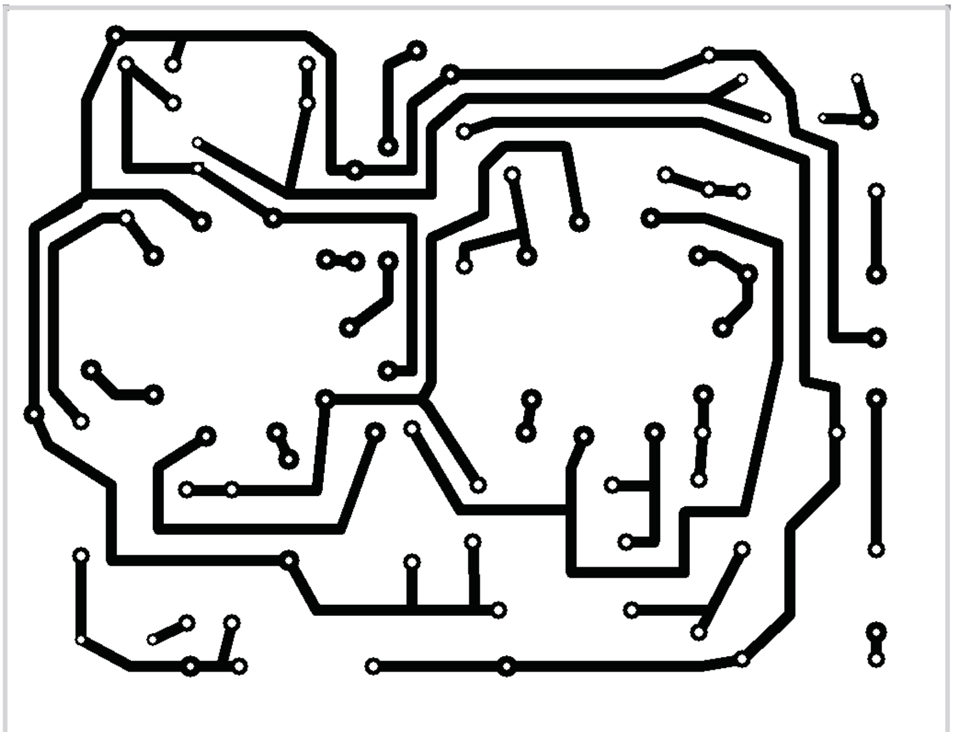
Four to five minutes exposure should suffice, but if the sunlight is a little weak, longer is advised – in fact, to avoid wastage of board it is useful to produce test strips of board offcuts, sequentially exposing through a printed transparency using a strip of card that can be slid down in timed periods of, say, one minute to six minutes. Develop the strip to select the most suitable time period to use for the main board exposure.

To develop the exposed boards you can choose either to use a proprietory chemical and develop in a shallow tray



Regulator PCB design shown full size





(an emptied ice cream carton is OK) or use a ‘Sena’ developer applicator (no tray needed, just a pad of old newspaper). Wash very gently in luke-warm water after the waste has been removed between the tracks.

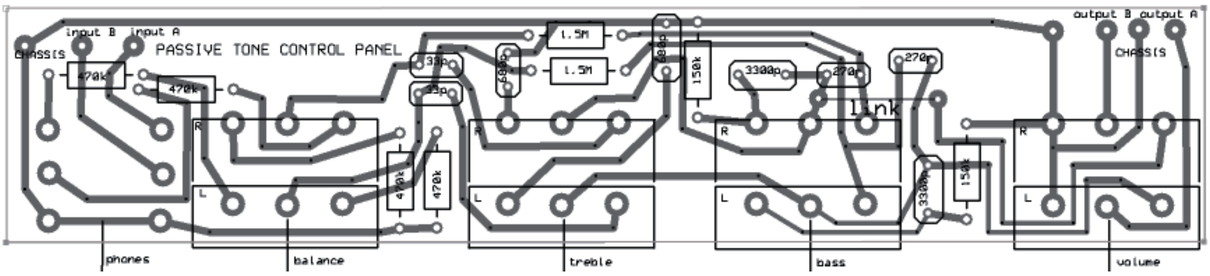
Ferric Chloride

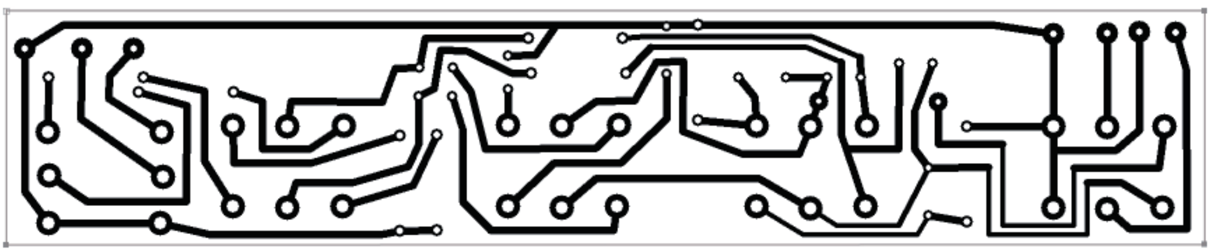
Etching is conveniently carried out with Ferric Chloride. This messy acid isn’t especially dangerous, but it can ruin clothing and it stains surfaces if left for long in a sink or tray. It is particularly troublesome when left in contact with a stainless steel sink. The best advice is to work steadily and avoid any splashes. Follow the instructions to melt the crystals or pellets to create a brown semi-opaque liquid. Immerse the board in the liquid (I find an empty ice-cream carton useful for this, too) while rocking gently to prevent a build-up of residue.

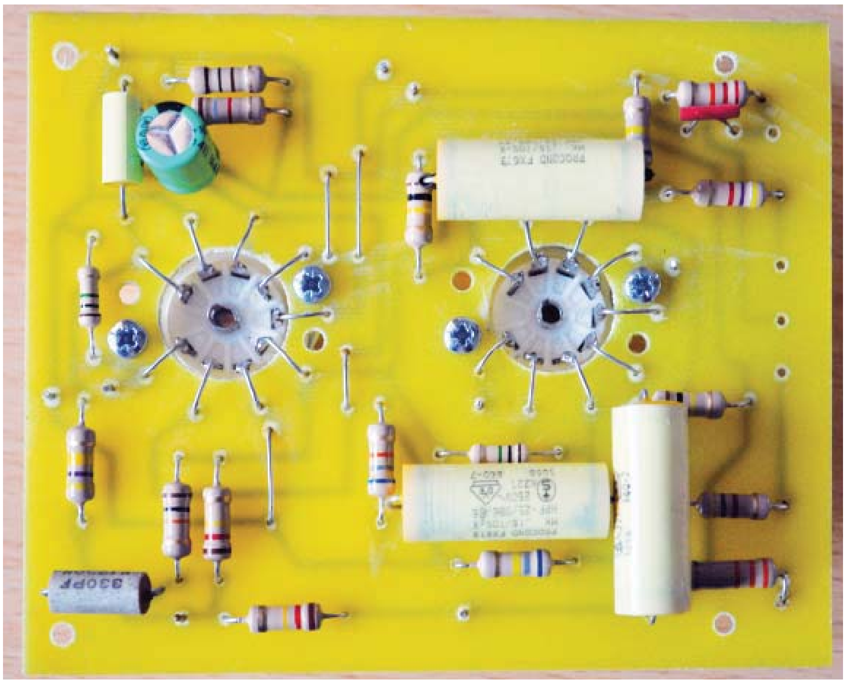
You will see when the board is fully etched – the process can take at least ten minutes and possibly much longer as it is very dependent upon warmth and acid mixture strength. The mix can be kept warm by floating the tray containing the acid in a bowl filled by an inch or so of hot water.

Wash the board and all areas around the sink thoroughly (really, very thoroughly) and do wear latex gloves to prevent staining of your fingers. Eye protection is sensible, too. The acid can be kept in a sealed-top glass container such as a jam or pickle jar

Amplifier PCB (left) and control PCB (below) shown full size







for re-use. It will last at least three weeks or more, though etching times will extend excessively as it ages.

At this point, fine grade wire wool may be used to strip away the remaining acid resist covering the tracks, but Seno make a very good resist stripper and other Seno products can be used to clean and protect the exposed track surfaces; the prototype stripped boards were coated with *Seno* flux lacquer.

Though far from essential, it may be found useful to paste a printout of the component positions on the blank side of the board. At least have a printout of the component positions to hand when populating the board. I find a magnifying headband of considerable help.

Drilling can be carried out using a 1mm drill, preferably in a small drill press for greater accuracy (the potentiometer tags will require a 2-2.5mm hole). The large holes for the valveholder connections can be made either with a chassis cutter (glassfibre board punches quite cleanly without cracking) or chain-drilled and filed.

Chassis Work

Though believed to be accurate, all measurements given here and on the drawings should be taken as being approximate. Dimensions are in millimetres. The chassis consists of two main components: the chassis proper and the transformer housing, the latter having two internal screening plates and provision for ventilation.

No specific size has been shown for the octal valveholders as these vary and so should be obtained before the chassis is punched; the same applies to the phono inputs and the loudspeaker connections. Do NOT mount individual phono sockets directly onto the chassis metal.

There are grommets fitted through the chassis deck for leads to the transformers. The main chassis is cut from a panel of aluminium sheet 450mm × 430mm × 1.2mm, which only just allows for sides of the 70mm depth required to house the smoothing choke; but when fitted the bottom tray cover provides a more than adequate air gap.

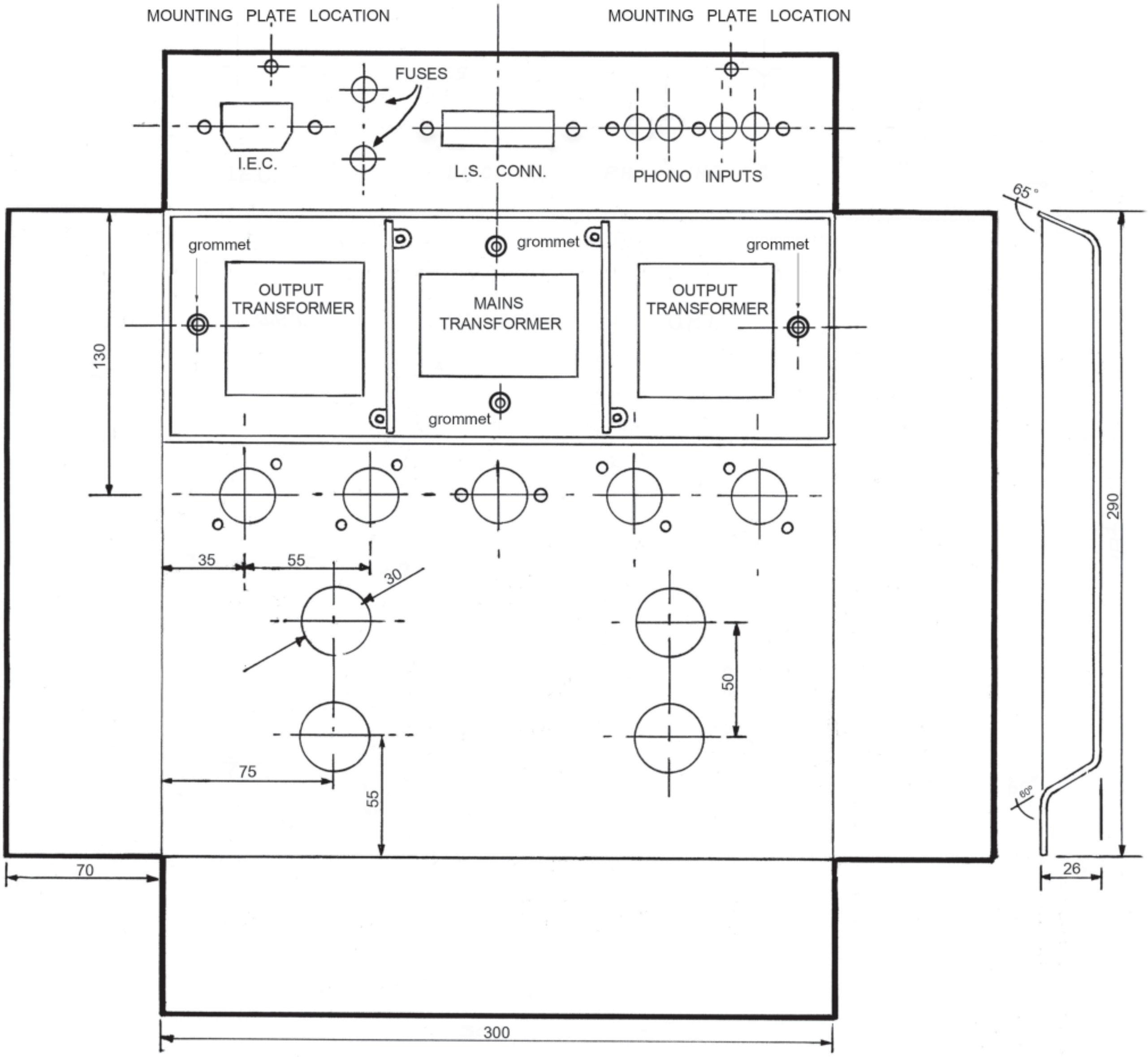
When folded, the chassis created is a box form with an open base 310mm wide × 290mm long × 70mm deep (external measurements). The corners on the prototype were simply folded to butt up, leaving a slight bevelled gap for the Durafix soldering process described below. Corner plates to take the screws for the bottom cover were pop-riveted in place.

The chassis base plate is formed from an aluminium sheet 332mm × 300mm, folded as shown in the diagram. The 'recess' toward the front is there for visual reduction of the front panel depth. The shallow sides are filled with aluminium strip, soldered in place. The base is fixed by four small countersunk self-tap screws, one through each of the chassis front corner brackets and one through each of two small fixing plates at the rear – see photograph – screwed into the back chassis wall.

The chassis was drilled and punched using Maxi-Q chassis cutters after a process of fine-tuning component locations was carried out. Alternatives to the cutters include chain-drilling and filing, a tank cutter or hole saws. The cutouts on the rear chassis wall to take the IEC input plug and the loudspeaker connection panel were drilled, sawn and filed to shape. The phono input strip was punched with chassis punches to a clearance size and the holes for the fuseholders were also punched.

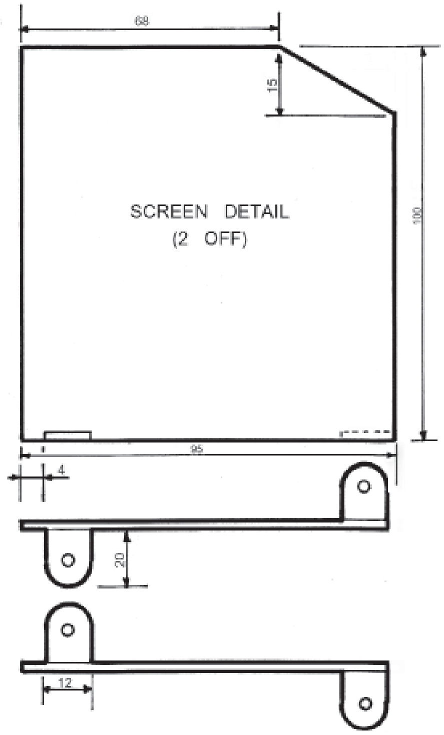
Transformer Screening

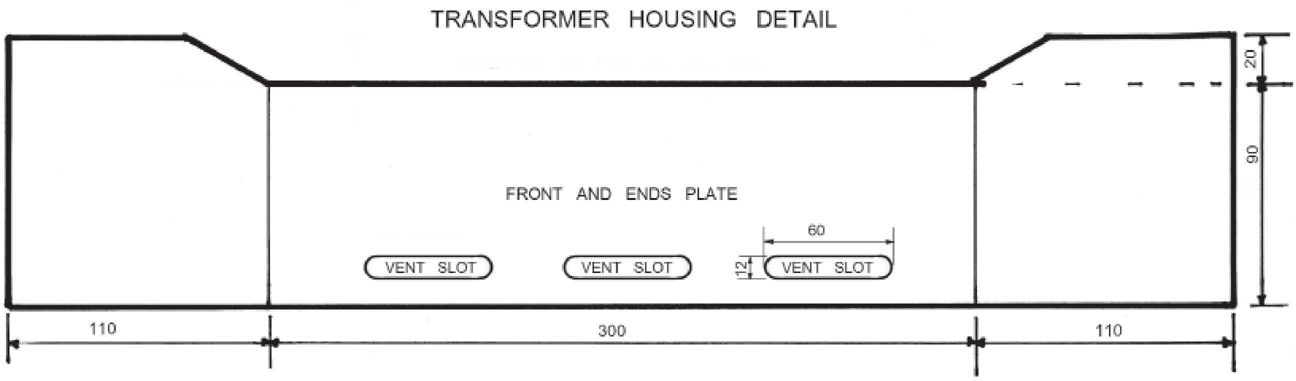
The transformer screening box was created in two main sections, one panel of 110mm high × 490mm long being cut to shape as shown in the diagram, then folded to create the front and the two ends and the other panel being cut to 110mm × 300mm, minus the thickness of the aluminium sheet and folded to fit on the inside edges of the folded front/side plate to create the top and back.

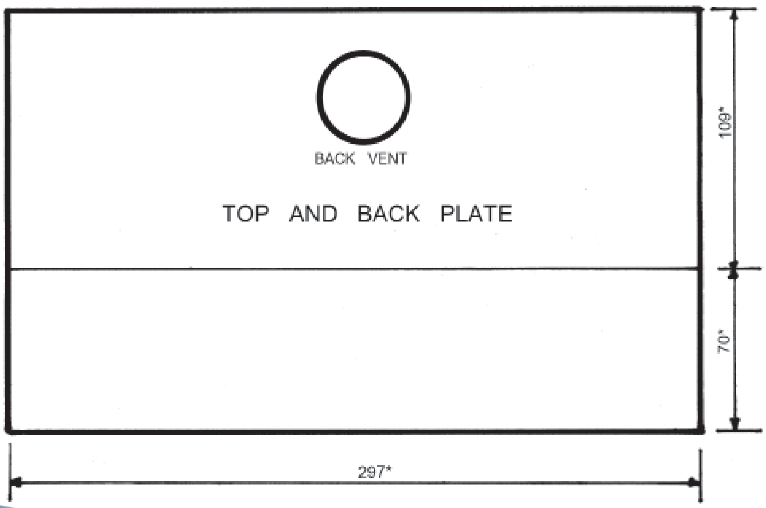


PLAN VIEW OF CHASSIS TOP

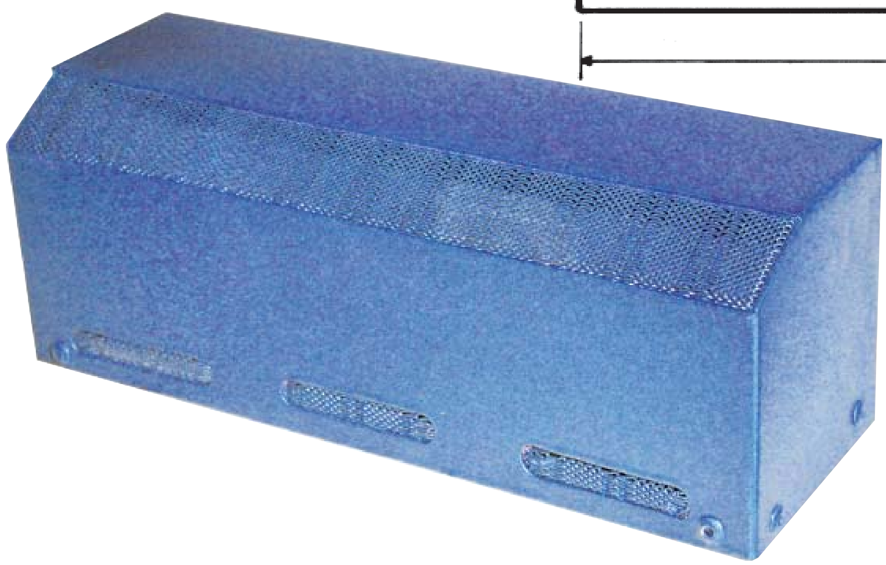
Chassis cutting and drilling details. The base plate design is shown on the right-hand side of the diagram above







The angled gap between the top and front was filled with a pre-folded strip of expanded aluminium grille with 20mm overlaps, easily bonded into place on the inside by means of double-sided foam tape of the automotive type. This grille material was also used for the single punched ventilation hole in the back plate and the two slots in the front, fixed by using a glue gun.



Two additional screening plates of 100mm high × 95mm wide overall (see drawing showing opposed mounting feet) were cut to fit between the transformers and mounted on the chassis by means of M3 metal screws through the 90 degree feet. The edges of the box were joined by Durafix soldering in the same manner as the main chassis. The box itself was fitted with pop-riveted corner mounting plates of the same type as those used for the main chassis inner corners. Self-tap screws from below the chassis deck pass through these to secure the box in place.

Front Panel

The front panel is a simple twin assembly of 4mm clear acrylic (Perspex), both in construction and visually. The two 297mm × 70mm acrylic plates were drilled to match the spindle, jack and indicator locations using a flat bit at medium speed in a drill press. The back plate holes were made larger than the front ones in order to clear the control mounting nuts and it was also countersunk to clear the chassis corner rivets.

The cut edges of the plastic were smoothed and the outer edge of the

Components

Control Panel

(both channels)

Resistors: 4 × 470kΩ. 2 × 150kΩ. 2 × 1.5MΩ. ¼ or ½ W.

Capacitors: 2 × 33pF. 2 × 680pF. 2 × 270pF. 2 × 3300pF.

Potentiometers: 2 × 2MΩ PCB mount double-ganged potentiometers, log law (bass and treble)

1 × 1MΩ PCB mount double-ganged potentiometer, log law (volume)

1 × 1MΩ PCB mount double-ganged potentiometer, linear law (balance)

Miscellaneous: 1 × rotary switch, 2-pole 6-way with adjustable stop.

Stereo jack socket, panel mounting PCB type.

Main Amplifier

(per channel)

Resistors: 2 × 47Ω, 100Ω, 1.8kΩ, 2 × 4.7kΩ, 10kΩ, 22kΩ, 33kΩ, , 2 × 100kΩ, 2 × 120kΩ, 470kΩ, 2 × 680kΩ, 1MΩ, 2MΩ. 2 × 270Ω 3W (6V6GT cathodes). 68kΩ 1W (ECC83 cathode). All half-watt unless otherwise stated.

Capacitors: 150pF, 330pF, 0.047μF, 3 × 0.1μF capacitors. 100μF, 2 × 47μF electrolytic capacitors. 1 × 8μF × 8μF 500VW can-type electrolytic capacitor. 1 × 16μF × 16μF 500VW can-type electrolytic capacitor for smoothing and reservoir, common to both channels.

Power Supply

Mains transformer: VVT VTH15651-1200. Output transformers (2 off): VVT VTP12566-1200. Choke: VVT VTL12158-1200. 1 × 10VA mains transformer, 230V primary, 2 × 15V secondary.

Resistors: 2 × 10Ω 7 watt wirewound 1 × 180Ω.

Miscellaneous: 1 × 3mm green LED. 4 × 1N4001 diodes. 1 × bridge rectifier. 2 × 47μF electrolytic, 25 VW. 1 × 4700μF electrolytic, 30VW.2 × 78S05 regulator chips, TO-220 package. 2 × heatsinks for regulators. 2 × 20mm panel mount fuse-holders. 1 × 250mA 20mm fuse. 1 × 2.5A 20mm fuse.

Valves

1 × GZ34. 2 × EF86. 2 × ECC83/12AX7. 4 × 6V6GT.

Sundries

Quantity of single-sided PCB pins. Quantity of 3mm and 4mm machine screws, countersunk and dome heads, and nuts, washers and star washers to suit. Quantity of threaded octagonal stand-offs for board supports. 2 × 160mm × 100mm Fibreglass pre-sensitised PCB panels for main amplifier. 1 × 150mm × 100mm fibreglass pre-sensitised PCB panel for control board and regulator. Aluminium sheet, approx. 16 gauge, for chassis, base and transformer cover. Metal expanded mesh for transformer cover air vents. Length of 16 gauge solid tinned copper wire for bus bar. 2 × tag boards to take output stage components. 1 × stereo loudspeaker connector plate, chassis mount type. 1 × twin stereo phono input plate, chassis mount or discrete phono sockets. 1 × IEC mains socket, chassis mount. 1 × two-pole rotary mains switch. 1 × 3mm LED holder, chrome type, panel mounting. 4 × B9A valveholders, chassis mount, with lower screens. 5 × International Octal valveholders, chassis mounting. Suitable knobs for controls.

Sources for components and materials

It pays to shop around for valves. They can be found from the usual suppliers, one of which is **www.sequoia.co.uk/shop/browse.php?d=40**. This link will take you directly to the Sequoia valve list, which is hard to find from their home page. Sequoia Technology Ltd., Basingstoke Road, Spencers Wood, Reading, Berkshire RG7 1PW.

Some of the smaller items of hardware were sourced from eBay.

www.esr.co.uk. PCB and Seno materials, components and hardware. Station Road, Cullercoates, Tyne and Wear NE30 4PQ.

www.cricklewoodelectronics.com. Valves, valve holders, fixed regulators, general components. 40-42 Cricklewood Broadway, London NW2 3ET.

www.bitsbox.co.uk. General components, some useful hardware items. 41 Warwick Road, Olton, Solihull B92 7HS.

www.thesitebox.com. Nuts, bolts etc. Tones Ties Ltd., Unit 5 Bearsted Green Business Centre, Bearsted, Maidstone, Kent ME14 4DF.

www.vvttransformers.co.uk. Output and mains transformers, smoothing chokes. Sales Department (W42). Variable Voltage Technology Ltd., Unit 3B Sheat Manor Farm, Chillerton, Newport, Isle of Wight, PO30 3HP.

www.blore-Ed.com. Potentiometers. 25 Aberaman Industrial Estate, Aberdare, Mid Glamorgan, South Wales CF44 6DA.

www.dukeriesengineering.com. Durafix aluminium solder. Dukeries Engineering, Quick-Fix solutions, Unit 7 Canal terrace, Worksop S80 2DF Tel 01909 477955.

www.vvttransformers.co.uk/drb12919_mullard_amps/drb12919_dhn.htm. Scans of the complete original *Mullard Circuits For Audio Amplifiers* Book.

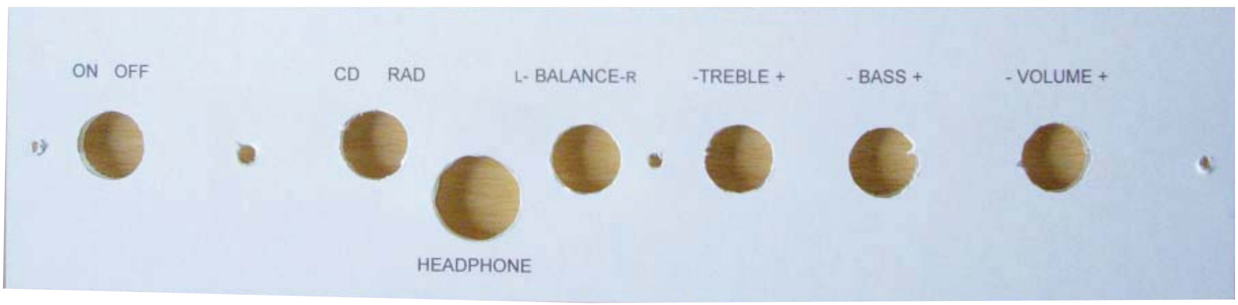
www.r-type.org/static/mull-cir.htm. This website carries selected scans of Mullard amplifier data.

www.dukeriesengineering.com. Durafix aluminium welding kits.

www.plasti-kote.co.uk. Information on their range of aerosol finishes and stockists.

www.letraset.com. Rub-on self-adhesive lettering system.

www.maplin.co.uk. Control knobs.



front plate was bevelled with fine wet and dry paper used wet and wrapped around a block, then all edges and faces were polished with Brasso. A white card computer-printed with control identification was sandwiched between the two plates. The card was cut slightly smaller all round than the acrylic and attached to the back-plate by double-sided adhesive tape. The assembly was fixed to the chassis front by means of three countersunk self-tapping screws, one each end and one roughly central.

Finishing Touches

All external, and therefore visible chassis and transformer housing surfaces, were well flatted with wet/dry paper and slight imperfections, scratches, filing marks and the like were filled with cellulose knifing putty of the type used in car paint shops. This putty must be applied in very thin coats and allowed to dry for several days before being levelled with the wet/dry paper. Time consuming but worth while for the superior finish attainable.

After a few light coats of grey primer, spraying continued using Plasti-kote 'Velvet Touch' velour effect, a textured spray aerosol. Several coats gradually produced a good coverage, but the nozzle constantly blocked during the spraying, a problem I put down to the added body of the paint. When this was hard dry (no flatting required) the final coats of paint were applied to all surfaces.

The texture paint was claimed to be a dark red from the blurb on the can, but when applied it presented as a rather unpleasant pinkish shade (Plasti-cote 4321), hence the use of an additional dark blue finish. The paint chosen for this was Plasti-kote satin super project paint in aerosol form and the colour was 'night navy' (Plasti-kote 2112 – see the back cover for a colour photo). The underside of the chassis was also sprayed dark blue but not textured, with just the selected chassis grounding point protected from the insulating paint coat by a masking tape disk. The resultant finish on the visible surfaces is not unlike a fine version of the 'wrinkle' finish that was once popular for some items of electrical and electronic equipment: movie and still film projectors, valve testers and industrial/military gear, for example.

The same procedure was used to finish the transformer housing. By way of a contrast, the chassis bottom cover was sprayed smooth silver.

White 5mm Helvetica rubdown 'Letraset' was used on the back chassis upright to identify the loudspeaker connectors, the two fuses and their values and the phono sockets for CD and radio input. A printed card plate was added to the transformer housing providing brief information about the maker and the date.

Construction

Durafix aluminium solder kits are obtainable from the source mentioned in the 'Components' panel and come with a stainless steel brush (essential, as a standard wire brush will contaminate the metal and prevent the solder from adhering) and instructions. In brief, the procedure is as follows: the butting edges need to be bevelled at 45 degrees to form a groove for the solder. After using the stainless steel wire brush to scrub the heated joint free from oxidation, continue to heat the area to be joined until the relatively low temperature of 720˚F. is achieved, then rub the Durafix rod along the joint, allowing the hot metal – and not the flame – to melt the rod. No flux is used.

A brisk additional rub with the stainless steel wire brush may not be necessary but it ensures adhesion of the filler rod to the joint surfaces. This is then followed by application of the rod to fill the gap in the joint. That's the process in a nutshell; the finished joint is strong and can be cleaned up with a file. I found it helpful to heat the joint from the inside of the box as this encouraged penetration of the solder through the butted joint. Anyone considering attempting this is advised to watch the video demonstration on the supplier's website.

Aluminium soldering is definitely not essential; the chassis may be assembled by mechanical means (nuts and bolts, self-tap screws or pop rivets). If this is the intention, it may be convenient to leave small tabs at the corners.

Transformer And Choke

The axes of the output transformers are set at right angles to the mains transformer axis to minimise field interaction. The transformers used are fitted with tag connections, so they are boxed-in for safety, but the use of shrouded transformers would render the box uneccessary. The two rectifier current limiter wirewound resistors are located on tag strips, one on each side of the mains transformer. The ventilation provided to the lower front panel and the lower back edge is there to encourage convection flow and keep both the transformers and the resistors cool.

Both the regulator transformer and the smoothing choke are fitted below the chassis deck in order to use the available space to the fullest extent and to help reduce the overall chassis size. The on-off switch is deliberately separate to the volume control, both to minimise hum pick-up and also for convenience – the volume can remain set at a preferred level.

The wiring to the transformers and the choke was carried out using stranded insulated wire stripped from 5A flexible mains cable. The live tags on the mains input socket, transformers and fuse-holders were insulated with short heat-shrink sleeves to prevent inadvertent hand or finger contact and, in the case of the mains and output transformers, to stop accidental contact with the protective housing.

Input Panel

The phono input panel is made from a scrap of protoboard with the copper stripped from it, cut to a suitable size and shape to take the four phono sockets. These single sockets were designed to be individually chassis fitted, with a ground return automatically made via the mounting bush, but as just one chassis return point is used in this design, to prevent any possibility of hum due to multiple grounding points, the plain board provides the needed insulation. There are ready-made socket strips available, but it was preferred to make one up to suit the purpose.

Output Stages And General Layout

The 6V6GT cathode and screen components fit on small multi-way tag boards, one for each channel, located conveniently close to the valves on the underside of the chassis deck. The EF86 heater regulator board is located on the chassis wall near the LT supply transformer.

All chassis (common) returns are made to a bus bar, made using solid 16swg tinned copper wire and only connected to the chassis at a single tag on one of the input panel mounting screws. The mains earth is also connected to the bus. The EF86 and ECC83 valveholder central spigots are connected by lengths of the same wire linked to the main bus and each screened base is grounded to the bar by a wire loop beneath a holder fixing screw. The 'loose' end of the bus bar is anchored to the chassis tag on the LT regulator board. The use of a single return minimises the possibility of hum-producing currents occurring in the chassis.

Heat-shrink sleeving was also used on the connections to the poles of the rotary switch, to add stiffness and support the delicate inner of the screened wire.

Alternatives

If it is preferred to wire the entire amplifier in the conventional manner, the bulk of the components may be mounted on tag boards or between tag strips. If this method is chosen you would do well to obtain details of the original Mullard data and follow their layout recommendations closely. A web address displaying the data is listed in the 'Components' box.

When wiring the balance control as shown in the diagram, note that the two tracks are symmetrical, i.e. mirrors of each other. Alternative balance controls are the original Mullard log/antilog option, which requires a special ganged potentiometer, or a linear law twin-gang pot wired in the log/anti-log manner (this results in some loss of gain as, because of the linear law, the panning effect is uneven across the sound stage), or a fixed single-gang linear law 1MΩ or 2MΩ potentiometer with slider to chassis and track ends respectively to right and left channel inputs. The original Mullard balance method is the best of these alternatives.

Component Selection

Finding a reliable supplier for the transformers was not easy. There are some very expensive transformers on the market, the cost of which may be hard to justify. Alternatively, there are some relatively inexpensive types that at first sight appear to be a bargain, but check carefully as you may find these have been designed for use with guitar amplification and their cores will saturate too readily and perhaps intentionally, resulting in distortion. After all, that's the effect many guitarists apparently seek. The source listed can be relied upon to provide good transformers and chokes at a reasonable price.

Use only modern resistor types. Old carbon resistors tend to generate noise, especially noticeable in the front-ends of amplifiers such as this. The main smoothing and reservoir electrolytic must be capable of withstanding a high ripple current and it is preferable that the subsidiary HT filter electrolytics have a good ripple rating also.

Chassis Finishing

Once all the spray painting has been completed and a suitable period for hardening of the finish is allowed, assembly can start. I prefer to secure the transformers before fitting the rest of the components. It should be noted, however, that the mounting holes for the screws securing the mains transformer can be obscured when fixing the choke in place. One easy way around this is to Araldite the transformer screws into their countersinks. Care should be taken at this stage to prevent cross-threading and damage to visible screw heads.

The AF panels and control panel were fitted after completion of the wiring to the power supply, output stages and input switch.

It is best not to fit the delicate acrylic control panel at this stage and fit temporary knobs until full testing of the wired chassis is completed. The LED panel-mounted holder should be fitted last, attached to the front panel rather than the chassis front upright.

Some protection and support will be needed when the chassis is inverted on the bench for assembly and wiring. A thick newspaper pad and a cork sanding block were found useful in this respect.

Once the wiring of the power supply and output stages was completed the opportunity was taken to test them before further assembly. Cold resistance checks revealed a problem with one of the 10Ω wirewound limiting resistors supplying the rectifier anodes. It was open-circuit; a brand new component that had been carefully handled and soldered. A replacement solved the problem and once power was applied with only the rectifier valve in place, a healthily high HT was found to be present at the smoothing capacitors and the output valve anodes and screens.

Testing

The amplifier was powered up on the bench, connected to a venerable old CD player and a couple of large Leak three-way loudspeakers of early 1980s vintage. The results were impressive. Plenty of volume to spare, truly stunning sound quality and a hum level so low that there was virtual silence between tracks.

As can be expected of Mullard design, the treble and bass controls work well within the expected limits of a passive network. The somewhat novel balance control smoothly shifts the stereo image. The mains transformer required setting to 220V input on the primary before 6.3V was reached on the heater winding, but then the mains in this area rarely seem to exceed 228V. Would I build this again? Most definitely.

Mistakes, Mistakes

In case anyone thinks that I am in some way gifted and never make a mistake, let me assure you that I am – more or less – human and I do indeed commit often silly errors, most of which, in the case of this project, were to do with the chassis construction. From the outset I had no wish to create folded tabs to take self-tap screws, machine screws and nuts, or pop rivets, as the plan was to have a smooth sided and sleek chassis devoid of such fixings. With that intention, I purchased some lengths of aluminium solder and a small container of flux from an Internet source.

This proved to be a mistake. Using a hand torch and a gas canister of butane/propane mix I was able to heat the aluminium sufficiently to melt the solder (high temperature, similar to silver soldering), but I could not persuade the molten solder to flow along the seam, despite cleaning as per the instructions. I tried several times and only stopped after I had partially melted one of the corners. Heating to such a high temperature also annealed the metal, making it very soft and too easily malleable. This problem needed correction by planishing (hammering).

On the basis that 'If at first you don't succeed…' I then turned to Durafix as mentioned earlier, and this not only secured the corners but also repaired the melted and missing area. It should be noted, however, that the soldering process requires a lot of heat and as aluminium is a very good conductor of heat, the entire chassis will rapidly become too hot to touch. The advice must be to use eye protection, clamp the chassis to the bench and quench comprehensively in cold water when completed.

The heating will cause the metal to soften but it will work-harden from mallet or hammer blows and also should age-harden to some extent. If you use a hammer, whether for bending the metal or hardening it, smooth any marks from the hammer face with fine wet and dry paper before you begin, or every imperfection on the hammer will be transferred to the aluminium.

Photographs were taken as an aide memoire when the components were placed temporarily in their approximate locations within the chassis; but I found when drilling for mounting that difficulties arose, necessitating the 'fine tuning' of some component positions with the result that I ended up with several more holes than required. Most of these were filled with two-part putty, hiding the mistakes once the chassis was spray painted

Another problem developed when the first regulator board was tested. This used a single 1.5A regulator chip to supply DC to both EF86 valve heaters. According to the Brimar manual, the EF86 heater current requirement is a modest 0.2A. The assumption was made that a 1.5A regulator would be easily capable of meeting this need. In the event, it couldn't. I still do not understand this, but the fact remains, one valve: no problem. Two: voltage virtually disappeared. Another example where theory and practice disagree, I suspect. The redesigned board uses the identical power source arrangement but supplying twin regulators, one per channel.

Reference Sources

Circuits for Audio Amplifiers. Mullard Ltd., 1959

Brimar Valve and Teletube Manual No.9. Thorn-AEI radio Valves and Tubes, 1961

Douglas Self: Audio Power Amplifier Design Book (4th Ed.) Newnes, 2006

RB

Mobile And Portable Operation Of Amateur Radio Equipment In The 1960s

by Louis Meulstee, PA0PCR

It was during last summer that I received an email from Graham Vine in Essex, who was planning the layout of his Wireless Set No.19/88AFV setup. He hoped eventually to obtain a 'Power Supply and LF Amplifier Units No. 2' to interface correctly, but, in the meantime, he wished to build a box to do the interfacing. For that reason he asked me about the size of the front panel of the 'No. 2'.

This appeared to be a manageable task, as I remembered having this unit somewhere in my inventory. Come to think of it, I had two of these 'Power Supply and LF Amplifier Units No. 2', which I bought as a lad in the 1950s. One of them was never touched and kept as a possible enclosure for another project, the second one was 'converted' into a mobile/portable 2 metre AM transmitter. Although I had neither seen nor used this transmitter for decades, I assumed that it was still wrapped in plastic foil, since a previous move of home in the 1970s, and was lying dormant somewhere.

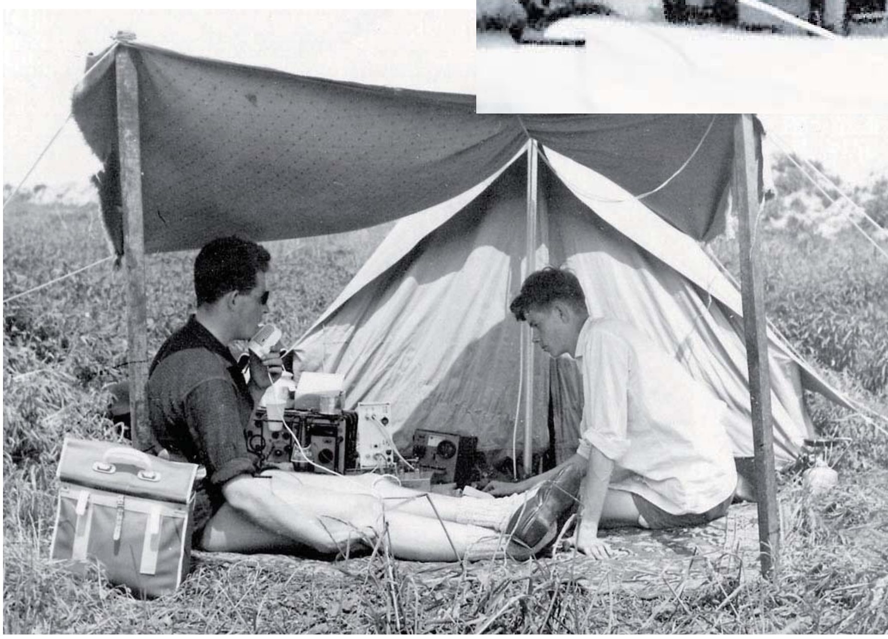
It also sprung to mind that, at the time of the conversion, I had saved the original identification and serial number plate of the converted unit. I eventually found this plate (now in the hands of Graham) along with the unmodified 'Power Supply and LF Amplifier Units No. 2', and, to my surprise, the transmitter. The cases and front panels of both sets showed little trace of rust, mainly due to the thorough packing in plastic foil and taping up of the edges. See the colour illustrations of both units in *Museum Pieces*.

Being a systematic person, I had coiled up and packed the power cable, receiver muting cable, valves and fuses spare box, canvas carrying bag and microphone in the same cardboard box in which both the units were packed. It therefore took me little time to connect the 2 metre transmitter to a 6V mains power unit, as I was rather curious whether it still worked.

The original working frequency crystal (for operation on 145.320MHz) and two spare alternative frequency crystals were still in their holders as I never needed them for other projects. After allowing the valves to warm up, I pressed the microphone button and, to my utter surprise, about three watts were indicated on my RF test set, to be increased to six watts after having made a few alignments to the intermediate stages and RF power amplifier.

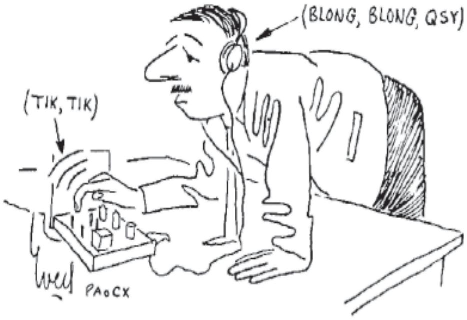
First Attempts With Portable Equipment

Already being occupied with the construction of radio receivers for a considerable time, with varying but still progressive results, it was about 1957



Portable operation (left) during an amateur radio field day at a very favourable location in the hot summer of 1962, showing Leen PA0ARF (left) and myself under an improvised tarpaulin

Enlarged cut-out: (above) note the Reception Set R109 (left) and Power Supply Unit No. 4 (right) originating from a Wireless Set No. 22, powering....

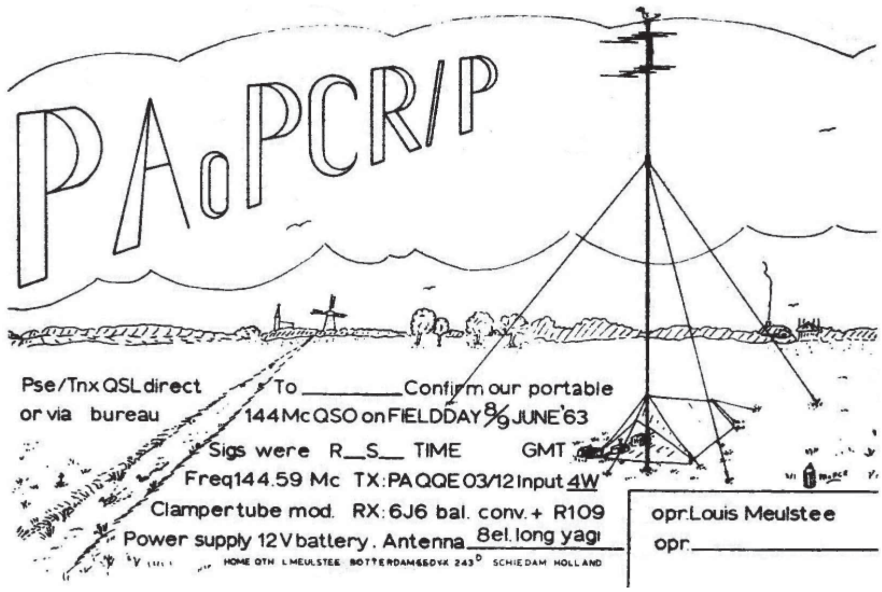


...a 2 metre convertor with continuous tuning.

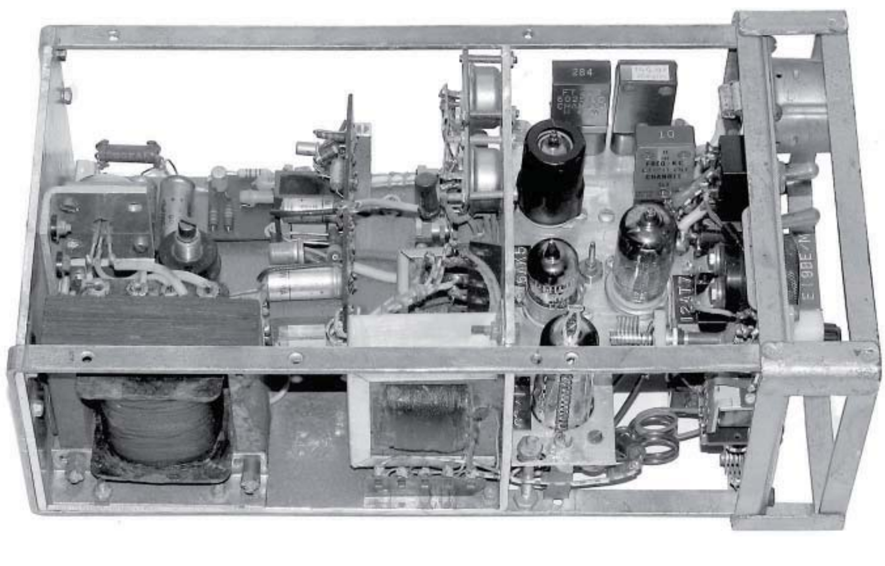
that I acquired a Reception Set R109. This was, to me at that time, the ultimate receiver, and particularly useful during holidays and weekends spent with the family at our allotment garden outside town. This receiver was bought at a local surplus store along with three unused two-volt 16Ah 'unspillable' Army accumulators (they were definitely not unspillable, which I found out eventually, much to my mum's regret...).

This battery arrangement allowed me to listen for a day or two, recharging taking place overnight at our home. After passing my amateur radio examinations in early 1962, the R109 came into use as my main receiver during summer field days, along with home-brew transmitters.

Factory built amateur radio equipment was, for most people in the 1950s and 1960s, not affordable and home-brew construction the only option. Fortunately, war-surplus radio stores (I had the choice of six different shops within reasonable distance) usually offered suitable parts for a modest sum, although I must stress that this was not always as cheap as believed nowadays. In particular, desirable items such as mains-operated shortwave receivers and equipment, which would not require much conversion, were expensive and (to me) unattainable.



Home-made QSL card: field day June '63



View of the mobile transmitter constructed in a stripped 'Power Unit and LF Amplifier Units No. 2'. Right: transmitter compartment: 12AT7: crystal oscillator/doubler and tripler, 6AK5: tripler, QQE03/12: RF power amplifier. Spare 6AK5 valve in screening can. Centre: AM modulator comprising a pair of AD103 transistors connected in push/pull and microphone amplifier. Left: HT inverter with a pair of AD103M transistors in push/pull. The transformers for the modulator and HT inverter were all re-wound, originating from salvaged broadcast radios

Amateur Operation On 2 Metre

In Holland, being a relatively flat country with an active amateur community, operation on 2 metre had become quite popular in the 1950s and 60s. Of course, transmitters were amplitude modulated and, in most cases, crystal controlled, operating on a fixed frequency. The latter was dependent on what you could lay your hands on, quite popular were 6MHz and 8MHz surplus FT-234 crystals, and as there was no such thing as a band plan there was plenty of space. Receivers for 2 metre often comprised a home-brew crystal controlled convertor with a shortwave receiver as tuneable intermediate frequency, although many people used a convertor with continuous tuning connected to a shortwave receiver.

Portable operation on this band, usually during summer amateur radio field days, was relatively easy, apart from the heavy accumulators, but working mobile was a different matter. In particular, the receiver caused practical problems, not only with the stability, but also being bulky and power greedy. I had solved this in about 1965 when a home-built fully transistorised receiver for 2 metre was successfully completed.

The New Mobile Set: A Hybrid

With the availability of suitable and affordable power transistors around 1964-65, I experimented with transistorised HT inverters and modulator amplifiers. As this appeared to be successful, I decided to rebuild the existing mobile/portable transmitter which was rather inefficient and quite bulky.

Camping in the Wicklow Mountains during the summer holidays of 1966. While brewing a late cup of tea, Leen (PA0ARF) is listening for amateurs from the direction of Dublin. You can just make out the transmitter, receiver and accesories used during that trip to the right of the aerial mast

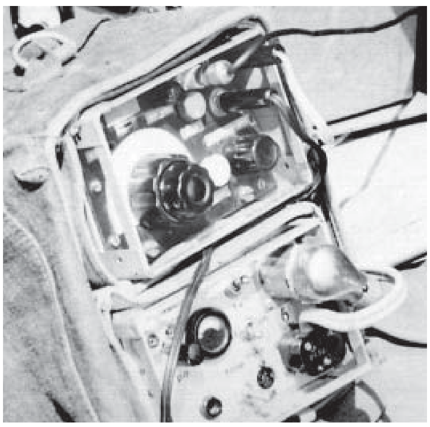
The experimental transistorised HT inverter and modulator unit did not occupy much space, so for an enclosure I considered using one of the two 'Power Supply and LF Amplifier Units No. 2', which I had bought in about 1956, but so far found unsuitable for any practical use. This was a major project, in particular the mechanical part, starting with the removal of the original components of the 'No. 2'. This resulted in an empty front panel, its louvered case and the two U-shaped chassis suspending strips. I still remember this being a difficult job, which may be a compliment to the maker. But at that time I had already acquired much experience with dozens of similar war-surplus conversion projects, so that this was just a question of persistence.

Most of the parts were taken from my old transmitter, a common practise in those days and probably the reason why I haven't many of the units I constructed still in my possession

That this transmitter survived over the years is partly because in the late 1960s I constructed a fully transistorised SSB/AM/FM transmitter with about 10W RF output which required totally different components, but also, and foremost, that I wanted to keep the little hybrid transmitter as a spare, as it never let me down and it did not occupy much space. However, with the advent of repeater stations and the consequent rise of FM on 2 metre it was never used again.

Mobile Operation In Ireland

In 1966 we decided to spend our summer holidays in Ireland, and after having made successful enquiries whether we could apply for a reciprocal amateur radio licence, we decided to bring along the little 2 metre set which we had found to be so successful for mobile operation. Little did we know that 2 metre activity in Ireland was principally concentrated in and around the larger towns, but in spite of this, we still managed to make contacts with our EI9BE/M call.



Slyne Head Revisited

Having been rather disappointed with the lack of 2 metre amateur radio activity in Ireland during our previous holiday, we still wanted to go back the next year, with the main object of exploring just a small part of the west coast, in particular Connemara and The Burren area, which we passed during the coastal tour the year before. As we were still keen to operate on the amateur radio bands we worked out a plan to set up camp only at a few spots which would allow us to explore the area by foot or car during the day, and to work on 80 and 40 metre in the early morning hours and evenings, again as EI9BE.

After we had acquired a rather battered, but still complete 150 watt PE-162 petrol electric generator set, it was just a matter of purchasing a readily available war-surplus Command Set BC-456 AM modulator and matching 80 metre (BC-696) and 40 metre (BC-459) transmitters at one of the local

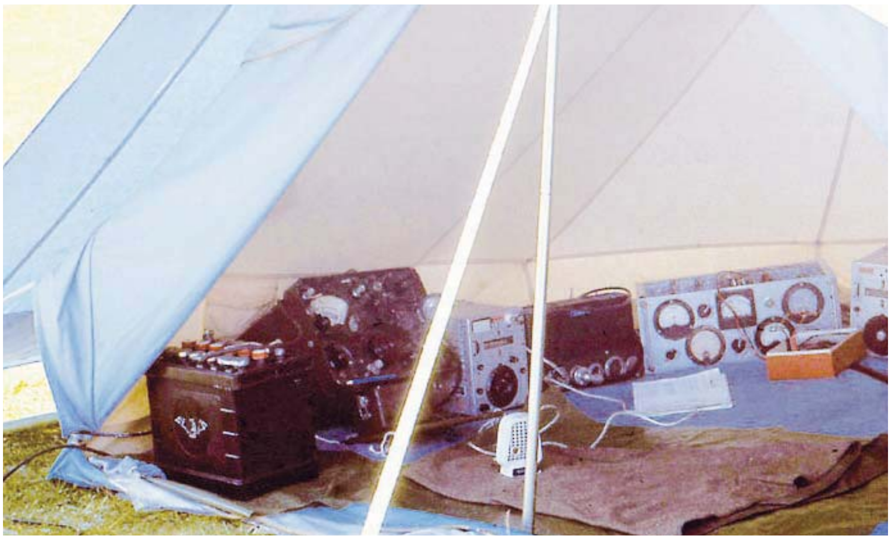
Amateur radio field-day 1966. Equipment (transistor receiver on top and transmitter below) and operation position on a 1200ft hilltop in Connemara on the west coast of Ireland. Note that the transmitter is not yet connected up

The Power Unit PE-162 was originally developed for powering American WW2 field radio sets SCR-284 and SCR-694, and later AN/GRC-9. It was used during our vacation on the west coast of Ireland in 1967, and many amateur radio field days later in Holland. PA0ARF had just started the engine (some exhaust fumes are still visible) and is busy adjusting the governor. Leen (PA0ARF) who was a genius in these matters had put much effort in the overhaul of the engine, which was a bit temperamental during start-up, but otherwise gave excellent service. Note the wooden structure over the generator set which was intended to support a small tarpaulin to protect it against the rain

My 2 metre portable/mobile amateur radio station (below) as I found it in the loft after 40 years. The transmitter (lower unit) untouched as described in this article. But the individual modules and boards of the original transistorised receiver, which was part of the station, had been used in another, now long forgotten project, and its enclosure (yes, I admit, a stripped 'Power Supply and LF Amplifier Unit No. 1', part of Wireless Set No. 38 AFV) was made to house an universal power unit allowing the transmitter to be operated from AC mains and 12/24V DC (the top unit).

Note the original canvas bag, microphone (from a salvaged Philips radiotelephone) and spare valves/fuses box (originating from a Wireless Set No. 31) still having its contents from the 1960s.

I did not have to look far for the loudspeaker in its wooden box (with protecting grille from an American BC-603), as this is still in almost daily use in my workshop.



Camping on the Atlantic Coast at Slyne Head (near Bunowen, Connemara) showing the inside of the radio tent comprising (from left to right): buffer accumulator, R209 Mk.1, 80 metre Command set transmitter, Command set modulator, home brew generator set interface and metering unit, and 40 metre Command set transmitter. We discovered this place accidentally during our first trip through Ireland, and stayed there again the next year

surplus shops. This was an obvious choice, as these sets (previously used in aircraft) were cheap, small and light, and could be stowed independently. They had a rather good and stable VFO, and were capable of producing sufficient power output.

The trusty old R109 receiver was replaced by a smaller and more selective R209 Mk.1, which I got cheap because of an intermittent fault. This was easily traced to a badly soldered ground joint and I recall that the R209 was an excellent little receiver for our purpose. Changing band from 80 to 40 metre was a relatively easy task, comprising the exchange of the Command transmitter unit, lowering the dipole aerial and removing two links.

Conclusions

Looking back, I must say that I've been lucky to have been brought up at a time when, if you wanted to be a licenced radio amateur, certain (mechanical) skills and a bit of determination were the basic requirements. During my later career in radio communication this proficiency, and being able to improvise, have been a great asset.

The nearly inexhaustible amount of war-surplus material was, to almost any radio amateur in the 1950s and 1960s, the major source for components and is well covered in this story. It was also the reason for my later interest in the technical development of British Army radio communication equipment.

That the little 2 metre transmitter and most of the accessories described in this article survived over the years, which included four moves of home, may be a wonder, and I did not really expect it to function. But it did!

No doubt many a reader of this article recognise in this story their own experiences with mobile and portable amateur radio operation, and maybe still have some of their old gear hidden in the loft. I shall be very pleased to read their stories in *Radio Bygones* one day, preferably with a few 'then and now' photos!

I am grateful to Hans Evers PA0CX for his permission to use one of his excellent drawings, previously published in *Electron*, the magazine of the VERON. Particular thanks goes to Tor Marthinsen for his advice and corrections on the manuscript. Without Graham Vine's email this account would probably never have been written, and the little transmitter might still be lying packed in the loft gathering dust. ***RB***

Feedback...

...where you can air your views

Letters should be original and not copied to or from other publications.
The views expressed are not necessarily those of the Editor

DC Heaters, Regulators etc

The use of DC heaters in valved circuits is fairly rare (Valve Amplifier *RB133*), as until relatively recently it was not that easy to get low voltage at relatively high current rectifiers. Remember the need for low hum amplifiers goes back well before the silicon diode. The use of oxide rectifiers was possible, but expensive, they had high forward loss, and took up a lot of space. As to regulation, that was really out of the question, with the possible exception of constant-voltage transformers.

Tony Thompson notes there is an audible difference in hum in his design; but wouldn't the use of a twisted-pair have done the job, and AC? The traditional way, apart from that; of reducing hum further, remembering that the EF86 is specifically designed with a hum-cancelling heater, is the use of a 'hum-buck' (potentiometer) across the heater winding to allow adjustment to null. Before the EF86, there was the EF37 and EF37A. As this is an (approximately) line-level input amplifier, and as a traditional microphone pre-amp would have 50 or 60dB more gain, but still no audible hum, I think it is overkill. A tape-head pre-amp would have a lot more gain still at low frequency, as would a moving coil disc pick-up.

To then use separate regulators for each valve despite their taking only 0.2A each, and the regulators being rated at 1A, or more depending on specific type, is also hard to understand.

The use of a 15V transformer suggests about 21V DC across the reservoir capacitor. Yet the maximum required input voltage is three volts over the output (but note: this is the voltage at the trough of the ripple), so a ten volt transformer would give more than adequate output. Most modern IC regulators take less than three volts, and the slightly more expensive LDO, that is low drop-out voltage, variants, take much less than 1V. Further saving in energy could be made by using the specified transformer type with a centre-tap, and only two diodes – as per the HT arrangement.

If one is going to go the DC route, then seriesing the valves to give 12.6V will do wonders for efficiency: the voltage loss across the regulator and diodes is constant, but the current is halved.

These regulators like to have a small capacitor very close to their inputs and outputs, 0.1µF will normally do. Otherwise they can be unstable. Note they often oscillate at low amplitude at 3MHz to 4MHz, anyway, and that is normal.

In a previous article in *RB* about a battery replacement supply Tony had trouble with ripple using a 317 regulator. I suspect that was because the reservoir capacitor in that design was too small. It was made up for by a large one on the output; that is the wrong way round. Providing the 3V minimum is provided, the ripple rejection ratio of these regulators is excellent. However, as heaters are OK with ± 5%, it would appear that if one does go the DC route, simple *RC* smoothing would be good enough. Again seriesing would work better.

These IC regulators work very well, are cheap, need little heatsinking normally, and are very reliable. I see very many in things I repair, and it is rare for them to fail without serious provocation.

What I think many of us are intrigued to know is if Tony has discovered a source of high-quality transformers that we won't need mortgages for!

Lastly on this subject, be warned that the break-contacts in jacks are likely to go intermittent. I see large numbers of these in studio mixers, where they are used for effects insertion points, and in instrument amplifiers.

Finally, regarding other matters, I have to say that comments on articles starting with "absolute rubbish" really are not called for and add nothing to the subject, or dignity of our fraternity. If one wishes to disagree with what one has read, one should keep to the technicalities.

Phil Moss, via email

Reply from Tony Thompson:

First, a single transformer of the low voltage type will not, in general, require a mortgage to purchase – think around £6 (I've just done a quick check on the Internet) but in any case, as I pointed out in the article, I used the transformer because I had it to hand and for no other reason. If I'd bought one I would have found something better. The output and high-voltage mains transformers – well, now you are talking serious money.

Second, as for using two regulators, I was well aware that the current ratings were above the two valve's heater ratings, but those ratings expect AC and a hot heater, not DC and at DC the cold heater of an EF86 measures, in round terms, five ohms. Present that to a 6V regulator and the instantaneous current requirement (before heating of the element occurs) is higher, over 1A I imagine, certainly enough to cause the regulator to self-limit. Whatever the case, I found in my empirical tests that one *regulator would not function properly when driving the heaters of two valves. Empirical, true – but practical as always, I prefer to go by experiments. When I put an item forward for construction I have to be sure, in my own mind, that it will work as stated.*

Regulators are very cheap to buy. Two regulators were still therefore cheap (actually I bought a batch – cheaply!) and, of course, using two means very cool running. I had the maker's literature to hand and I followed their recommendations. If constructors follow my PCB layout there is no need for additional damping capacitors.

Third, the use of a block diode instead of a full-wave rectifier circuit was again because I had a bridge rectifier to hand. I agree that full-wave would have worked perfectly well. Of course it would... but my prototype used a block and that is why I left it in on the design as published.

Fourth, I have not seen the old hum-bucking resistor method used on a modern valve amplifier, nor would I ever wish to use it. I do know all about twisted heater leads and I repeat what I found to be the case, that (and by the way, despite having used twisted leads) the already very slight hum level was reduced by the use of regulators. It is entirely a matter of choice for the constructor and that has been made clear already, I hope. I chose to leave the regulators in place.

By the way, it isn't simply a matter of keeping hum out of the EF86 stages; the use of DC means that the heater leads are no longer a source of hum, twisted or not. I have simply presented the amplifier exactly as I built it. I would, however, point out that there is the possibility that 'modern' copy EF86s may not be quite as efficient at hum rejection as the original Mullard valves were.

Finally, I believe the power supply design being referred to was the one I put forward a year or so ago in a Sky Queen *article. I do agree that the reservoir and smoothing capacitor values would be better changed around. In fact, I can't think why I built it that way at the time, except that it worked. An oversight on my part, for sure. It may be worth mentioning here that in a later power supply design the problem was corrected. Although it should be obvious, let me repeat for clarity that anyone intent on building this design is free to change it in any way they wish, provided they accept the responsibility for the changes. The design as published works.*

Tony Thompson, via email

The Thing Is...

I enjoyed the article in *RB132* by Brian Austin on microwave cavity resonators, which I found to be well-written, interesting and informative. Naturally, one must expect that any analysis of this type may not be accurate in every respect, and so it is useful that John Gibson was able to provide another perspective (*RB133*). However, I found the tone of Mr Gibson's letter offensive, in particular the first sentence, and I think you should not have published it in this form. In my view such a response lowers the tone of the discussion and could create the risk that readers are discouraged from attempting to contribute.

Dr Roy Miller, Boston Lincs

Point taken, on reflection I should have deleted part of John's first sentence – Ed.

Vibrator Replacement

I would like to thank Ben Nock, G4BXD, for his interesting article regarding replacing a vibrator in a ZC1 MkI transceiver (*RB133*).

I am the fortunate owner of a ZC1 MkII, which was kindly given to me by a ZL ham. The set arrived from ZL in good condition, except that although there were few modifications, (modification of ZC1s is a time-honoured ZL tradition) the set would not fire up. No vibrator hum. Well after 60 or so years, it is a bit much to expect these war-time vibrators still to be in tip-top condition. I opened the unit, freed the sticking contact, cleaned the contacts and put the unit back in.

This time it fired up. However, knowing, as Ben pointed out, that these repairs are likely to be short lived, and not wishing to burn out a scarce ZC1 vibrator transformer, I resolved to cobble together a solid-state unit.

Several circuits were available from old copies of *Break-In*, the journal of the NZART, however, they all used bipolar transistors. These circuits apparently work fine, but I wanted something that would have a lower switch-on resistance. It seemed that MOSFETs would be the answer.

So a circuit was cobbled together using a 555 timer IC as an oscillator, followed by a flip-flop divide-by-two to provide a symmetrical waveform. The outputs of the flip-flops were used to drive the gates of the MOSFETs. However, one MOSFET stayed on and quickly destroyed itself. I came to the conclusion that the capacitance of the MOSFET gate was the problem, and that it was easy to switch the MOSFET on, however, when switching it off, the charge on the gate would have to be dumped to ground very quickly. Perhaps a complementary pair bipolar transistor gate driver would be the answer (I beleive this is called a 'totem pole').

Meantime, being an impatient chap, I settled for a solid-state replacement from Antique Electronic Supply, a P-V2015N 12volt, 4-pin, negative ground device for USD29.95. As the ZC1 MK II vibrator is a synchronous type, the power supply circuit needed a couple of silicon diodes to perform the HT rectification. The vibrator socket was replaced with a 4-pin ceramic tube socket, diodes installed, buffer capacitor replaced, and power applied.

The HT output voltage was satisfactory, even though the various waveforms were anything but square. One had to be very careful with the polarity of the silicon diodes because of the peculiarities of the ZC1 power supply circuit.

Well one day, I will return to experimenting with MOSFETs after I find my round tuitt.

Many thanks for the interesting articles that appear month after month.

Kevin B G Luxford, VK3DAP/ZL2DAP, via email from Australia

Tuning Lamp

Regarding the letter and photo from Malcolm Haskard in *RB129* asking for information on a tuning lamp, I have an Electradix catalogue No.72 which shows a picture of an almost identical looking item (the photo is not very clear) advertised as a 0-80 ohm resistance switch, maker R W Paul. The photo shows a switch with the same number of ways, and the box on the front has the same number of screws and everything on the unit, including the lampholder (no lamp) is in the same position. The unit does not have the back board which Mr Haskard thought was not original and the catalogue does not state it's original use.

I would date the catalogue to around 1926 from the later items shown in it, although it still contains adverts for many WW1 surplus items.

M J Butt, via email

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Any cables, plugs, sockets for R107 or WS12 sets. Also type F aerial coupling unit, R107 valve tin or other accessories. Bob 01329 834032 (Southampton)

FOR SALE

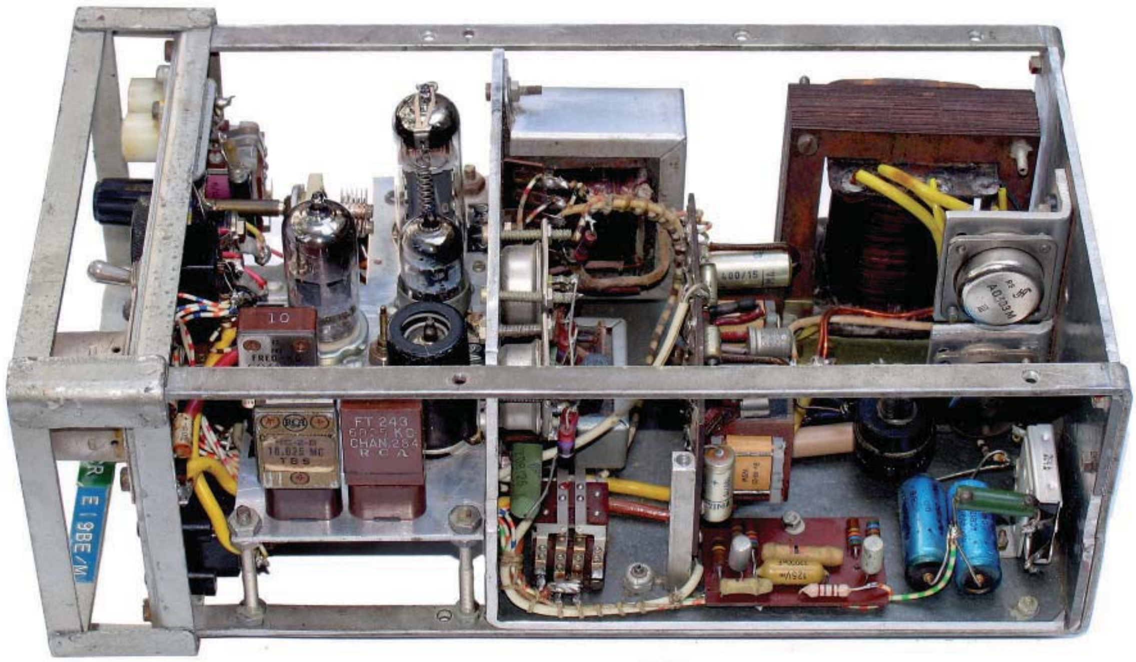
Free for collection, or the cost of postage, any of the following reference books: Television Engineers' Servicing Manual 1952; Radio and Television Servicing 1956-57 (Newnes), 1957-58 (Newnes), 1965-66 (International Learning Systems), 1967-68 (ILS), 1971-72 (ILS), 1973-74 (ILS), 1981-82 (Macdonald). Tony Noble, Tel. 01684 290 297 (Tewkesbury, Gloucestershire).

Eddystone 840A receiver – £70.00 ONO, also, Eddystone 680X – £150.00 ONO, both with manuals. Phone for more details. Tel. 0161 4560814. Brian Collier (Stockport).

Back Issues of *Radio Bygones*. Numbers; 4, 15, 16, 17, 18, 19, 55, 70, 99, 117 and 126. Phone David on 01481 201142 (Guernsey). Sensible offers and postage appreciated.

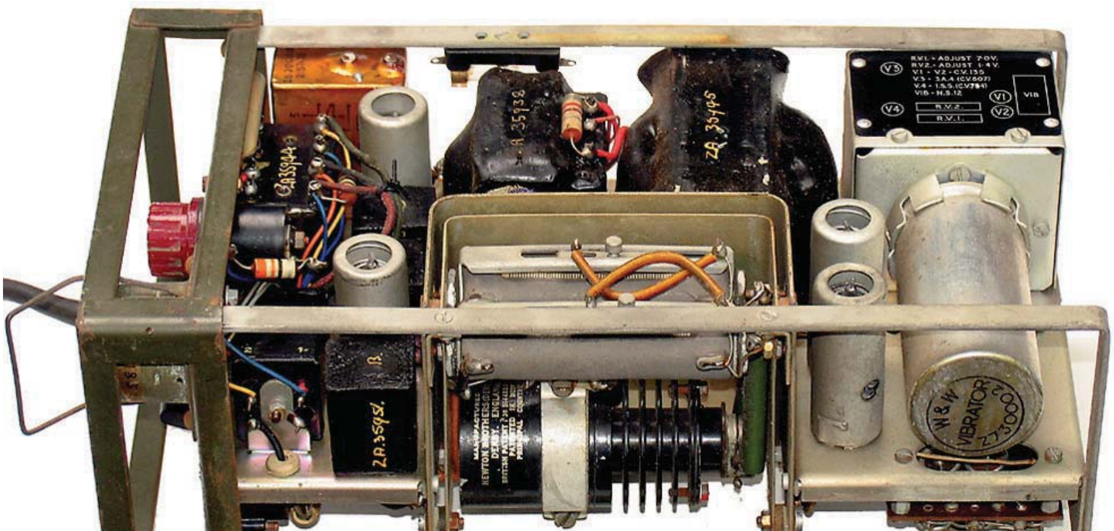
One transistor radio kit. Series tuned regenerative reflex medium-wave radio receiver kit using only one BC182 transistor and one BAT85 diode. All complete with ready wound ferrite rod aerial, case, battery and earphones. £6.99 plus £1.72 postage. Cheque or postal to B A Jackson, 32 Seymour Street, Peterlee, SR8 4EN.

Bush DAC90A (working) KW103 SWR Power meter. Tel. 01308 897625 (Dorset).



Internal view of the mobile/portable 2 metre AM hybrid transmitter, showing RF chassis with one working and two spare crystals (left), transistor modulator and microphone amplifier (centre) and transistor HT inverter (right)

MUSEUM PIECES



Internal view of the ‘Power Supply and LF Amplifier Units No. 2’

Two photos of Tony Thompson's Quality Valve Amplifier showing the construction, wiring and finish of the amp