Vintage car radios

J. LeJeune takes a look at car radio design in the post-war period, up to the time when transistors came into use, and in particular considers the power supply arrangements

Today's car buyers expect a radio to be fitted. Fifty years ago however a car radio was a luxury, and often a liability for the unwary. Before transistors came along and altered electronic technology for ever, portable and mobile equipment was bulky, heavy and power-hungry. The valves used in a car radio needed heater power and an HT supply of something over 150V.

Basic models

Most vintage car radio designs use a standard valve line-up with three or four valves to provide the following functions: frequency changer, IF amplifier, detector, audio amplifier and audio output stage. A push-pull Class AB1 output stage was occasionally used to provide greater output power. The detector diode was usually incorporated in the IF or audio amplifier valve.

Power was obtained from the car battery of course, usually a 6V or 12V type. A vibrator unit with a step-up transformer produced the HT voltage required. It consisted of an oscillating-contact spring set that fed the DC input in alternate directions through the primary winding of the transformer, see Figure 1. With this type of vibrator arrangement the output would be rectified by either a valve rectifier such as the 6X4, a heaterless valve rectifier such as the OZ4 or a metal rectifier of the copper-oxide or selenium variety. The valve heaters were supplied by the battery directly: there were 6·3V and 12·6V valves to suit the battery in the car. Incidentally it has been said that these standard valve heater voltages were set by the requirements of lead-acid battery operation, being the voltages of car batteries in use and under partial-charging conditions.

Because of the very low voltage supply and the considerable power consumed by a receiver, it is not surprising that if someone decided to stop the car for a while and listen to the radio they may not have been able to get started again, as the battery had insufficient energy left to start the engine. Use of the starting handle would then be required. A typical current consumption with a 12V car radio of basic design was 6A: more sophisticated models took up to 10A.

Physical arrangements

The size of early models was such that much of the receiver was installed in the engine compartment, close to the battery to avoid the need for long cables. All that was visible inside the car was a control panel that included the tuning knob and illuminated dial, the on/off switch, a wavechange switch and the volume control. The tuning and wavechange functions were operated by Bowden cables, and a relay was used to switch on the supply to the receiver, avoiding the need for long power cables to the control panel. Later models brought the receiver unit inside the passenger compartment, leaving the power unit and audio output stage in the engine compartment.

A problem with all vehicle radios is ignition interference. Early attempts to obtain noise-free reception included resistive suppressors in the ignition leads and screened ignition leads. Subsequently the now common suppressor cable came into use. The dynamo used to maintain battery charge sometimes also required suppression: unsuppressed ones caused a sharp whine that varied with the engine revolutions. The vibrator unit in the receiver's power supply could also add to the general load of hash generated under the bonnet: spark-suppression capacitors were always fitted to damp the interference and prolong the life of the vibrator contacts.

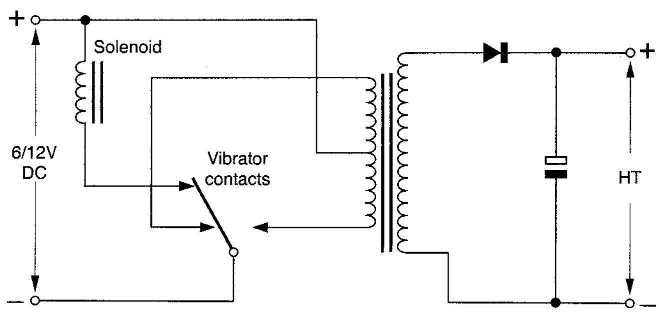


Figure 1: The basic vibrator power supply arrangement.

The vibrator

The vibrator was housed in a sealed can and consisted of a set of spring changeover contacts operated by an electromagnet (solenoid) that was connected to an auxiliary contact on the spring set, see Figure 1. The solenoid was thus energised when DC was applied to the unit. As a result the spring-set changeover contacts were moved to one side, connecting the supply across one half of the transformer's centre-tapped primary winding and at the same time breaking the connection to the solenoid. As the solenoid field collapsed, the contacts swung back again, connecting the other side of the primary winding to the supply and reconnecting the solenoid energising contact.

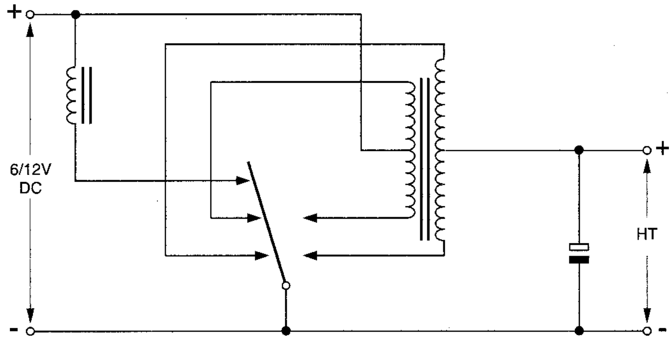


Figure. 2: The synchronous version of the vibrator power supply had an extra pair of contacts that did away with the need of a separate rectifier.

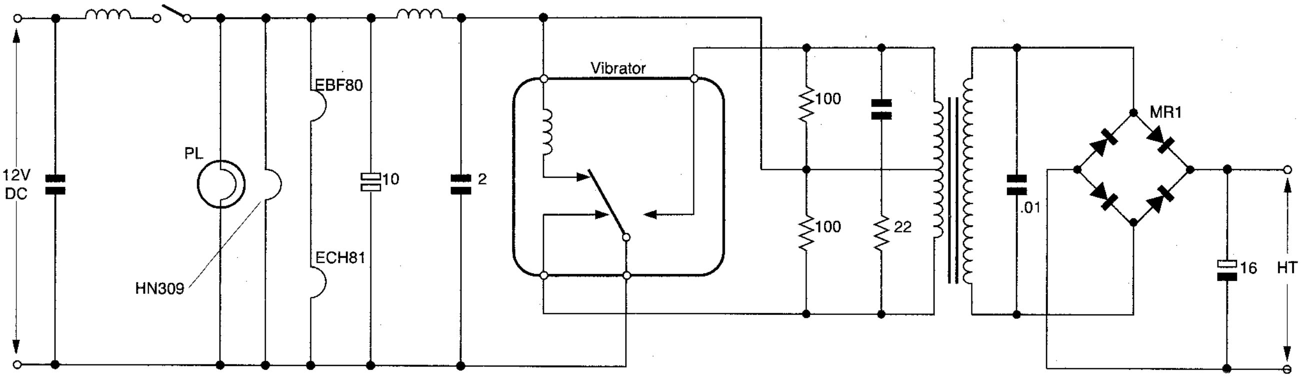


Figure. 3: Vibrator power supply used in the Radiomobile Model 20X.

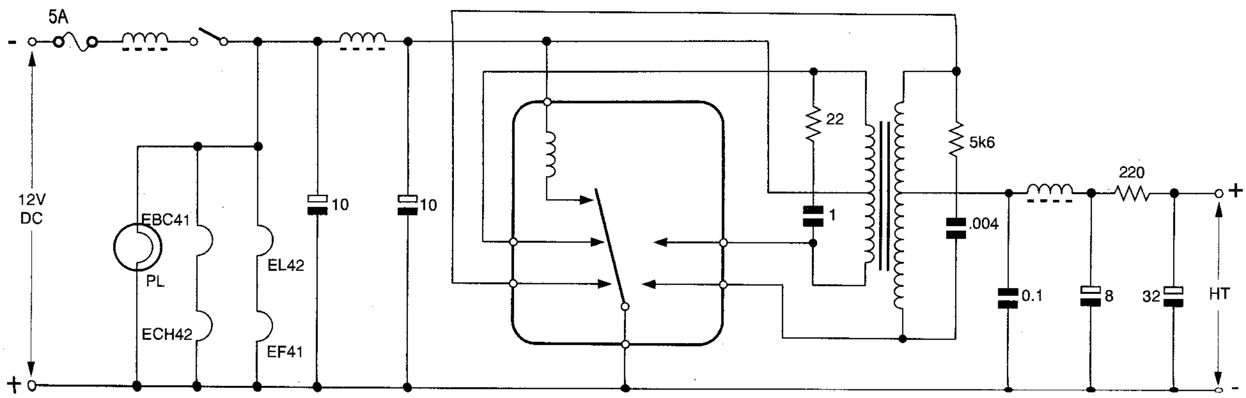


Figure 4: Synchronous vibrator power supply used in the Ekco Model CR280.

This 'buzzer' action sent current through the sections of the transformer's primary winding alternately, setting up an alternating flux in the core. The step-up transformer produced a high voltage across its secondary winding: after rectification, this provided the receiver's valves with their HT supply. Buzz it did, and one didn't need a keen ear to determine whether the vibrator supply was working or not.

Some vibrators, known as the synchronous type, had an extra pair of contacts that provided rectification. This arrangement is shown in Figure 2.

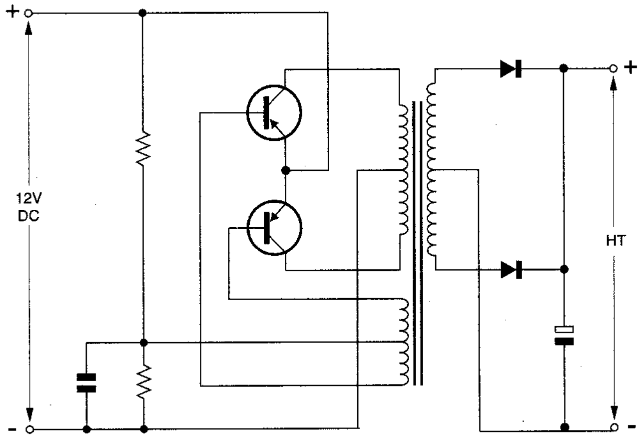
Figures 3 and 4 show practical non-synchronous and synchronous vibrator circuits.

Receiver circuitry

The receiver was generally a three- or four-valve unit that was tailored to provide extra performance from a small whip aerial under extremely variable signal conditions. AGC, which was sometimes delayed, was applied to the IF amplifier valve and the mixer section of the frequency-changer valve, a fast-operate, slow-release action being preferred.

Stable tuning was a number one priority. It was difficult to achieve, because of the high temperature range experienced by a receiver unit mounted in the engine compartment. Some early receiver manufacturers

Figure 5: Typical transistor converter circuit.



adopted permeability tuning because temperature compensation was easier to apply, using a fixed capacitor and variable inductance. This was cumbersome however with receivers that had more than one waveband. Superhet circuits were always employed, because of their superior performance, the ease of applying AGC, and their better stability. Extra sensitivity could be achieved by having an RF amplifier stage ahead of the frequency-changer stage or two instead of one IF stages.

The more 'de-luxe' the receiver, the higher the current consumption. But a push-pull output stage didn't significantly add to the overall battery drain unless the receiver was operated at high volume, as would have been the case had today's pop music then been around. Class AB1 or AB2 operation was popular for push-pull output stages, as the current consumption is to a large extent proportional to the audio-output level.

The Radiomobile 20X and Ekco Model CR280 were popular models from the 1957-8 period, both providing MW/LW reception. The former is a basic receiver designed for 12V operation only, with either positive- or negative-chassis electrical systems. Thpe power unit has a non-synchronous vibrator, the transformer's secondary winding being connected to a selenium bridge rectifier. The valve line-up is ECH81 frequency-changer, EBF80 IF amplifier and detector, and HN309 audio amplifier/output.

Permeability tuning was a feature of the CR280. Its power supply used a synchronous vibrator that was set for positive-chassis systems: changeover to negative-chassis use was achieved by reversing the leads connected to the transformer's primary winding. The valve line-up was ECH42 frequency changer, EF41 IF amplifier, EBC41 audio amplifier/detector and EL42 audio output. This model had a current consumption of only about 2A.

Progress

When transistor portables began to appear it was not unusual to see such sets hung by their carrying handles from the top of the driver's window, because their puny output was often insufficient to be heard above the engine and road noise in cars of that era. Having the radio hung by the driver's ear was the best way for him to hear it. The advent of power transistors such as the OC16 and OC25 transformed car radio, and led to the now universal fitting of radio receivers in cars.

There was an interim period during which hybrid receivers were used, with valves for the receiver section and a transistor audio section. The vibrator was designed out. There were two approaches to this. The first was to use a transistor converter, with two transistors to drive the step-up transformer. Figure 5 shows a typical circuit. The second was to use a range of valves that could provide reasonable performance with an 'HT' supply of only 12V!

Development of the AF116 and AF117 range of transistors sounded the death knell for the use of valves in cars, and car radio development went ahead rapidly.

Radio is as popular today as it has ever been. The introduction of viable FM receivers started a huge upswing in car radio, coupled with the excellent traffic reporting service for drivers supported by the major broadcasters. The introduction of a tape cassette playing facility and subsequently CD have added to the interest. It's now called "in-car entertainment". ■

Vintage radio: tuning indicators

Tuning indicators were often a feature of the more up-market receivers that graced the nation's homes from the Twenties to the Seventies. Several different types were used over the years. J. LeJeune describes their mode of operation and circuitry

Tuning indicators were never really necessary with the AM receivers that graced the nation's homes from the Twenties to the Seventies. They were nevertheless often a feature of the better class of receiver, along with push-pull output stages and, in later models, band-spread tuning on some wave ranges.

Early indicators

The very first indicator was the Tuneon. This was a long, thin neon lamp with two wire electrodes inside, a fairly short one and another that extended almost the length of the tube, see Fig. 1. One electrode was grounded while the other one was connected via a resistor to the anode of a variable-mu IF valve to which AVC (automatic volume control, i.e. AGC) was applied.

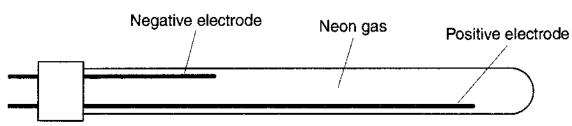


Fig. 1: The Tuneon neon tuning indicator.

The negative-going AVC voltage increased as a station was tuned in, biasing back the valve and thus reducing its anode current. As the valve's anode voltage rose, the length of the glowing neon gas increased. So you tuned in for maximum length of the orange-pink glow. The arrangement worked fairly well, but reduced the effectiveness of the AVC action because of the change in anode voltage required to operate the indicator.

Less troublesome was the simple current-meter connected in series with the anode of the gain-controlled IF valve, see Fig. 2. The meter was at full-scale deflection under no-signal conditions, the needle sliding back as a station was tuned in. You simply tuned for a minimum meter reading.

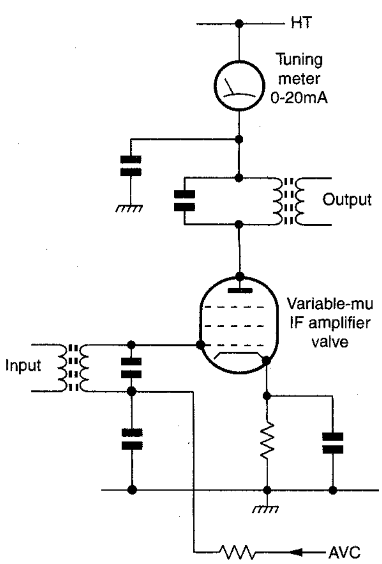


Fig. 2: Tuning meter in the anode circuit of a variable-mu IF amplifier valve.

The magic-eye

By the Thirties the magic-eye tuning indicator had become extremely popular. This was a thermionic device, basically a triode with a conical anode. The open end of the cone faced the top of the glass envelope, which was coated with a fluorescent powder on the inner surface, similarly to a CRT screen. The grid was a pair of wires or, sometimes, small blades that were spaced 180° apart and close to the cathode. It was connected to either the AGC line or the output from the AM detector circuit. The latter was generally preferred, a high-value resistor being included to reduce loading on the detector circuit. When the grid voltage became more negative, an increasing shadow was cast over the fluorescent anode coating. As a result the 'eye' closed. A small disc at the centre of the aperture hid the hot cathode from the user's view. Fig. 3 shows the display and Fig. 4 a typical circuit. The most common types used were the EM4, EM34 and Y61. After a time the fluorescent coating lost is brightness and the eye began to dim.

FM tuning indicators

A variation on the magic-eye device appeared in the US to enable FM receivers to be tuned accurately. Its type number was 6AL7GT. The end of the glass envelope was again coated with fluorescent powder, but inside there were two tetrode electron guns side by side. They produced a pair of illuminated green strips on the 'screen'. The anodes of the guns were connected to a supply of some 250V. Fig. 5 shows the idea. The grids controlled the brightness of the strips, while the deflection plates varied their length.

The grids were biased so that the beams were cut off when no signal was present. This was easy to arrange, using the AGC line and

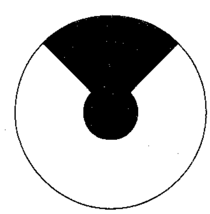


Fig. 3: The magic-eye display.

a polarity-inverter stage. When a viable signal was found the grids were driven positively and the screen was illuminated. The deflector electrodes were connected to each side of the FM ratio detector circuit so that, when the tuning was slightly off to one side of the centre frequency, one deflector was more positive than the other, making the illuminated strip longer. As the correct tuning point was reached, the two fluorescent strips became of equal length. Should the tuning drift to the other side of the centre frequency, the strips would change in length in the opposite sense. The user of this type of tuning indicator would know whether the receiver was tuned high or low of the correct point.

These indicators were never used in the UK, despite being a very useful addition to a domestic FM receiver. The moving-coil meter with a centre-zero took over from this indicator which, as with the magic-eye type, suffered from display fading with time. The meter arrangement is shown in Fig. 6.

Battery-operated receivers

Before the advent of the LED, battery-operated receivers used the DM70, DM71 and DM160 indicators, which had 1·4V filaments. The DM70 and DM71 had a display like an exclamation mark, which was actually the shape of the control-grid aperture through which the fluorescent strip could be seen. The single filament passed directly in front of the aperture, so that the fluorescent display was viewed through it.

The DM160 could be classed as a sub-miniature display and was again a triode. But instead of an aperture-plate grid it had a helical grid between the filament and the fluorescent anode. At only 5 x 25mm the DM160 fitted easily into the miniature receivers of the day. The DM70/71 were 9 x 45mm. Fig. 7 shows the two types with a Y61 magic-eye indicator for comparison.

Tape recorders

For a time these indicators and the EM80 series were very popular both as tuning indicators and as inexpensive recording-level indicators in domestic tape recorders. The EM80 had a fluorescent strip along the side of the envelope. This narrowed as bias was applied to the control grid. In tape recorders the two separate illuminated ends moved towards each other until the edges met, indicating excessive recording level.

In many recorders these devices were replaced by a cheap moving-coil meter movement, often driven from simple transistor circuitry. A meter didn't deteriorate and need replacement. The advent of reasonably good automatic level control in cassette recorders finally eliminated the need for a record-level meter.

Tuning-scale indication

There were other arrangements of course, but perhaps the one most worthy of mention was that used in some early valve receivers. It appeared as a strip of light across the top of the tuning scale. As a station was tuned in, the length of the strip varied. The shutter that produced it was a curved vane of lightweight material which was painted black. This was mounted on the needle of a moving-coil meter: when there was no signal, the vane (shutter) blocked the light from a dial bulb – the light from this was projected through a slot aperture on to the rear of the translucent tuning dial.

As a station was tuned in, the meter needle moved and the shutter allowed light to reach the tuning scale: the length of the illuminated strip varied with signal strength. The meter movement was, of course, included in the anode circuit of a variable-mu IF valve.

In conclusion

These are all now relics of a bygone age. In radio sets they were marks of a 'de-luxe' receiver, along with other desirable accessories that were aimed at tempting prospective purchasers to spend a little more than they had originally intended.

A look at today's audio equipment shows that little has changed in this respect. Marketing people call them "features" and, amongst themselves, speak of "bells and whistles", the product being a "mug's eyeful". Ostentatious in presentation, and when in operation flashing like a fairground in full spate, much modern consumer audio equipment works well enough without any need for such extras – which can make servicing a nightmare.

In comparison, the old tuning indicators were examples of good taste and moderately useful extras. ■

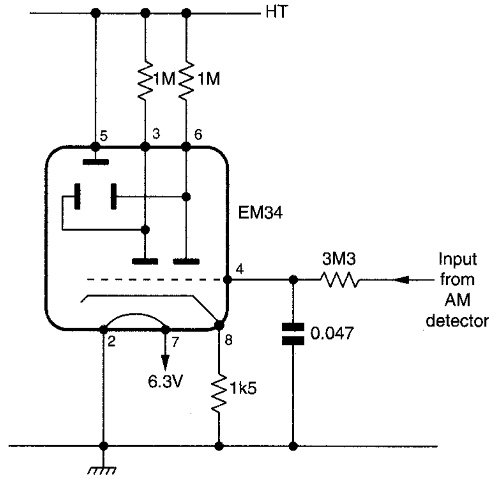


Fig. 4: Typical EM34 magic-eye indicator circuit. Grid drive could be obtained from the AVC line or the output from the AM detector.

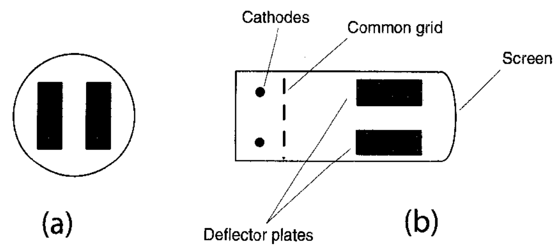


Fig. 5: The US dual-beam indicator for tuning FM receivers, (a) display, (b) internal arrangement of the indicator.

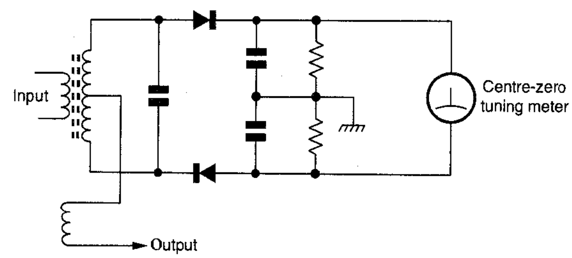


Fig. 6: FM tuning-meter connections in a ratio-detector circuit.

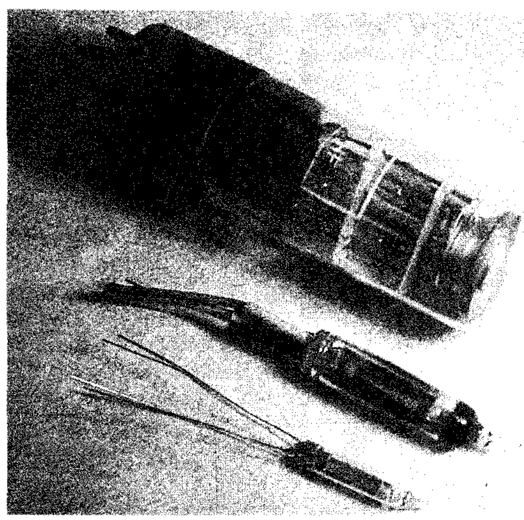


Fig. 7: Three generations of thermionic tuning indicator: a Y61 (top), a DM70/71 type (centre) and a DM160 (bottom).

Table 1: European DAB multiplex frequency allocations

Multiplex	Frequency	Multiplex	Frequency
5A	174·928MHz	12D	229·072MHz
5B	176·640MHz	13A	230·784MHz
5C	178·352MHz	13B	232·496MHz
5D	180·064MHz	13C	234·208MHz
6A	181·936MHz	13D	235·776MHz
6B	183·648MHz	13E	237·488MHz
6C	185·360MHz	13F	239·200MHz
6D	187·072MHz		
7A	188·928MHz	LA	1·452960GHz
7B	190·640MHz	LB	1·454672GHz
7C	192·352MHz	LC	1·456384GHz
7D	194·064MHz	LD	1·458096GHz
8A	195·936MHz	LE	1·459808GHz
8B	197·648MHz	LF	1·461520GHz
8C	199·360MHz	LG	1·463232GHz
8D	201·072MHz	LH	1·464944GHz
9A	202·928MHz	LI	1·466656GHz
9B	204·640MHz	LJ	1·468368GHz
9C	206·352MHz	LK	1·470080GHz
9D	208·064MHz	LL	1·471792GHz
10A	209·936MHz	LM	1·473504GHz
10B	211·648MHz	LN	1·475216GHz
10C	213·360MHz	LO	1·476928GHz
10D	215·072MHz	LP	1·478640GHz
11A	216·928MHz	LQ	1·480352GHz
11B	218·640MHz	LR	1·482064GHz
11C	220·352MHz	LS	1·483776GHz
11D	222·064MHz	LT	1·485488GHz
12A	223·936MHz	LU	1·487200GHz
12B	225·648MHz	LV	1·488912GHz
12C	227·360MHz	LW	1·490624GHz

Vintage radio repairs

Yura/Microsonic keyring radios

These little Soviet radios were imported in large quantities during the late Fifties. They use six germanium transistors and provide MW reception only. Pete Roberts describes the sorts of faults you can expect to find and ways of dealing with them

Above – Photo 1: External view of a Yuri-badged keyring radio dating from the late Fifties.

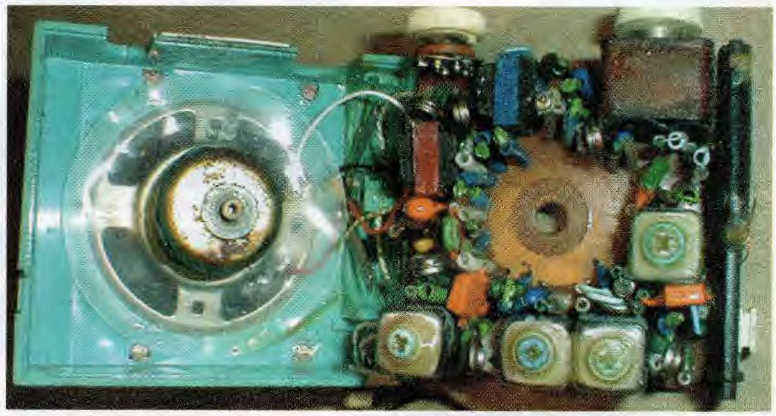
Right – Photo 2: Internal view, showing the PCB and cabinet speaker.

Many of these small Soviet-made keyring radios were imported under the Yura brand by Technical and Optical Equipment of London during the late 1950s. T&OE was at the time the sole importer of Soviet radio and camera equipment. It was also reputed to be the KGB's UK headquarters: whether that's just an urban myth I don't know! The radios were also imported via Hong Kong, badged "Microsonic – Made in Hong Kong", despite being of obviously Soviet manufacture. This might have had something to do with Cold War politics, but was more likely to be a dodge to avoid import duties, from which Crown Colony products were exempt.

Basic details

Photo 1 shows an external view of a Yura-badged version, Photo 2 the PCB and cabinet speaker, and Photo 3 the front of the case, with speaker and battery terminals. Despite their small size, these sets were not toys. They used six germanium transistors in a medium-wave only (550-1,640kHz) superhet circuit, the line-up consisting of a self-oscillating mixer, two IF stages, a germanium-diode detector, an audio amplifier/driver and a transformer-driven balanced push-pull output stage. Some versions even have negative feedback! Two different IFs appear to have been used, 455 or 470kHz.

Power, at 2·4V, is provided by two series-connected 125mAh NiCad button cells. These give about six hours' use per charge,



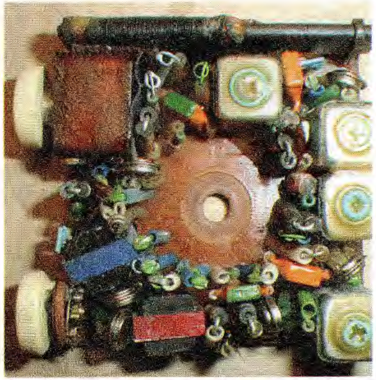
depending on volume. Each radio came with four cells and a charger, the idea being to have two cells on charge while the other pair was in use. The chargers don't use a mains transformer. Instead, a 'lossless' dropper capacitor fed the rectifier. Unfortunately these units have a tendency to explode while in use!

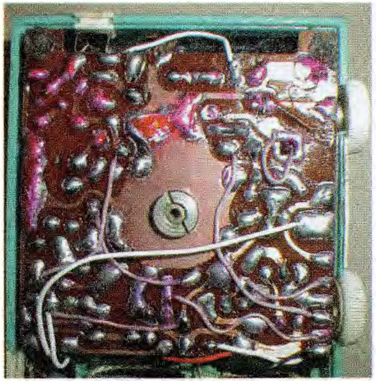
Repairs

I've had a few of these radios to fix. The usual cause of a dead set is the electrolytics. These are tiny axial capacitors with a voltage rating of 3V or 6V. You will find them all very leaky or even short-circuit. Values vary, the most common being 3μF, 5μF and 0·5μF. In view of the low voltage rating, I use match-head sized tantalum-bead replacements, fitting the closest E12 value (3·3μF, 4·7μF and 0·47μF). It seems to be difficult to obtain miniature aluminium electrolytics with these values and a working voltage rating of less than 40V, and running such capacitors at a volt or so can result in loss of polarisation. Solid tantalum capacitors aren't affected adversely by being used at very low DC voltages.

With a recent set, see Photos 4 and 5, replacement of the electrolytics failed to restore normal operation and a quick check around the circuit revealed that the various voltages were much as they should be. After checking the various wire links at the rear of the PCB for continuity and dry-joints, I decided to use 'heuristic signal injection': I touched the collector and base connections of each transistor in turn with a metal screwdriver blade in contact with a finger, working back towards the mixer. Using this technique in an IF stage you should hear fluorescent tube buzz, static or even strong local station breakthrough.

Although its DC voltages appeared to be correct, the first IF transistor wasn't amplifying. As I had a donor chassis, I was able to





Far left – Photo 3: Front of the case, showing the peaker and battery terminals.

Centre – Photo 4: Front of the PCB before repair.

Left – Photo 5: Rear of the PCB with wire links.

fit the correct replacement. This restored normal operation. If original transistors aren't to hand, an OC44M can be used in the mixer stage, the OC45M is suitable as an IF amplifier, and all AF devices can be replaced with an AC128, an AC125 or an AC153. This applies with most of the germanium transistors used in Russian receivers, the exception being SW and FM models. These require the higher-frequency AF125 or AF127 in the RF and IF stages.

Should you come across one of these sets that has been stored with the batteries in place, the contact springs will have become corroded. These are glued into the case. If a good wire-brushing doesn't do the trick, the PCB, speaker and metal trim will have to be stripped out. The springs can then be given an overnight soak in spirit (clear) vinegar, followed by a good wash with warm, soapy water. Don't put the used vinegar on your chips!

Performance

These sets are capable of really good performance, being superior to contemporary Far Eastern pocket receivers. They are very sensitive, selective and have effective AGC. The only real niggle is the tiny tuning knob, which is mounted directly on the shaft of the tuning capacitor. It makes finding closely-spaced stations difficult.

Batteries

The original batteries are no longer available, and there is no modern equivalent. But similarly-sized NiCad or NiMH replacements will fit, held in place with a bit of packing if necessary. Alternatively a couple of non-rechargeable button cells could be used, or two AA cells in an external holder can be connected to the set using a pair of crocodile clips. I've found however that some sets are prone to instability when run at 3V.

Vintage repair: the PYE P202BQ pocket radio

Pete Roberts on restoring life to one of these transistor pocket radios

Pete Roberts in his workshop.

The Pye P202BQ is a British-made transistor pocket radio receiver that dates from about 1962. The one that arrived recently for repair was a non-worker. Circuitry is fairly standard – it's a six-transistor superhet. There are five pnp transistors and an npn one, germanium types supplied by Newmarket Transistors. Do you remember them? They were housed in distinctive oblong cans. The name comes from the famous horseracing town, and the company had been taken over by Pye.

It's nominally a two-band receiver, with the long-wave fix-tuned to Droitwich. The *Trader* service sheet for this model shows a balanced push-pull output stage with driver and output transformers. But this set was an 'issue 2' version with a transformerless complementary-symmetry output stage, see Fig. 1. The full circuit diagram is shown on page 267 of the 1962-63 volume in the *Radio and Television Servicing* series of books. It also applies to Models P200BQ and P201BQ. The receiver is powered by a 9V battery of the PP3 type.

Testing and initial repair

I fed 9V from my bench power to the set and, after ensuring that the current taken was not excessive (it was about 5mA), started to check various voltages. The output stage's centre voltage was decidedly low at just over 1V. The cause was the NKT258 driver transistor VT4, which was leaky. An AC125 replacement restored a more realistic 4·7V centre voltage and some signs of life.

After looking askance at the several small low-voltage electrolytic capacitors on the board, and taking into account their 40 years' hard labour, I decided to replace all the decouplers. Tantalum-bead types were fitted as they wouldn't detract too much from the original appearance of the chassis. A conventional subminiature aluminium electrolytic was used to replace the speaker coupling/boostrap capacitor C27 (50μF): a tantalum bead capacitor can't be used in this position as any appreciable ripple current will damage it.

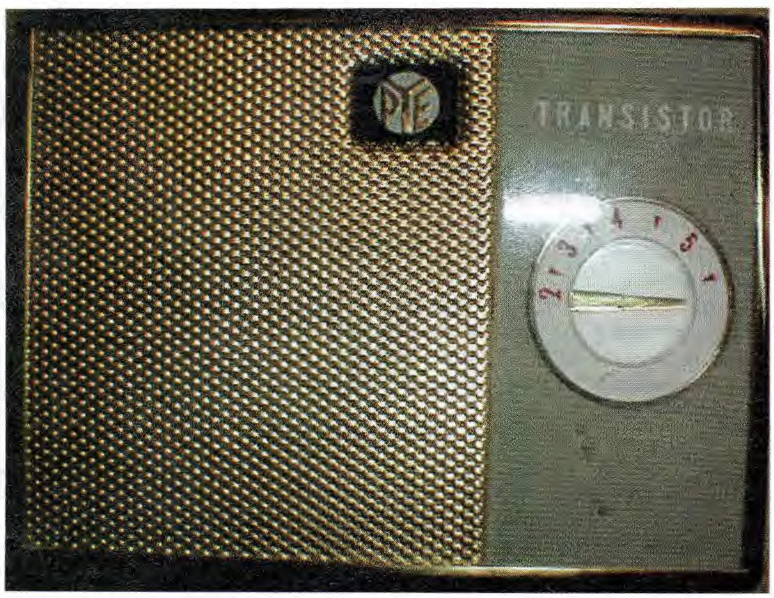


Photo 1: Appearance of the Pye Model P202BQ transistor pocket radio receiver, which dates from about 1962.

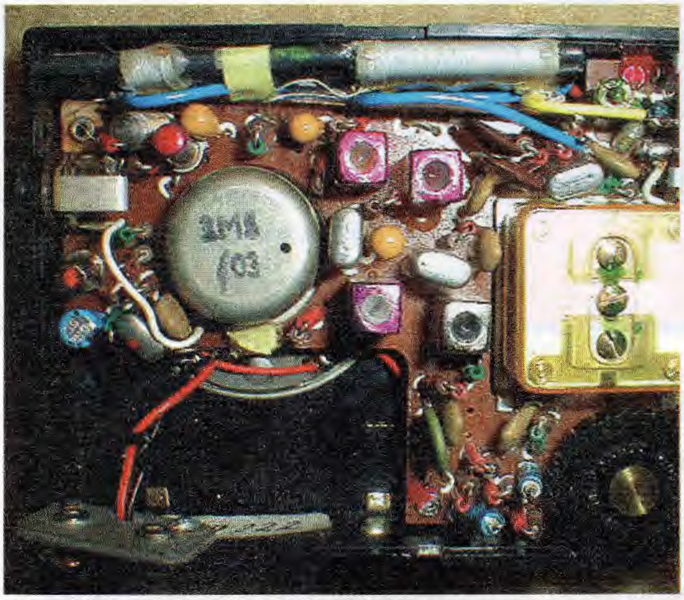


Photo 2: Component side of the PCB, with replacement tantalum-bead electrolytic capacitors fitted.

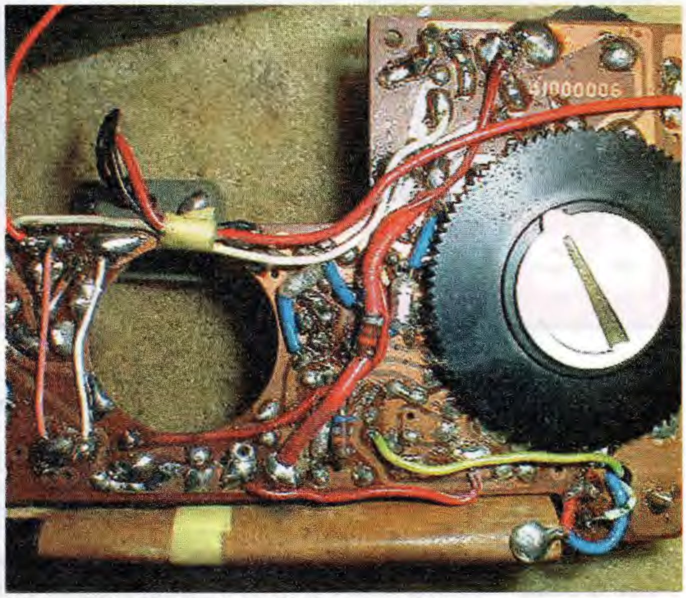


Photo 3: Track side of the PCB – some of the components are mounted on this side.

Alignment

I now had reception of sorts, and on closer examination it was obvious that the IF cores had been disturbed. Time to reach for my trusty Advance E2 signal generator. I had a cuppa while waiting for it to warm up – the recommendation is to allow twenty minutes after switching on. With the tuning capacitor fully closed I injected 470kHz via a loop round the ferrite-rod aerial. The three tiny IF transformers were considerably off tune and needed careful adjustment, reducing the generator's output as the gain came up to prevent the AGC action masking the signal peak. The signal level should be just sufficient for it to be heard over the background noise. When tuning by ear, use of an earpiece may be helpful.

It's essential to use a proper trimming tool for this task, otherwise there is a real risk of cracking the cores.

These radio sets don't have a tuning scale as such, so it was only necessary to ensure that I had full MW coverage then slightly move the aerial coil along the ferrite slab for maximum sensitivity at the LF end of the band. The cause of sudden loss of reception at the HF end of the band was traced to someone having tampered with the solid-dielectric tuning capacitor's centre bearing screw, the result possibly being vane fouling. I slackened it off a fraction of a turn, then tweaked the oscillator and aerial trimmer screws.

All that was needed to finish off was a slight tweak of the LW oscillator trimmer to repeak reception of Radio 4, which is now at 198kHz of course. I finally ran a small amount of hot paraffin wax into the IF and oscillator cans to secure the cores and discourage any further 'user adjustments'.

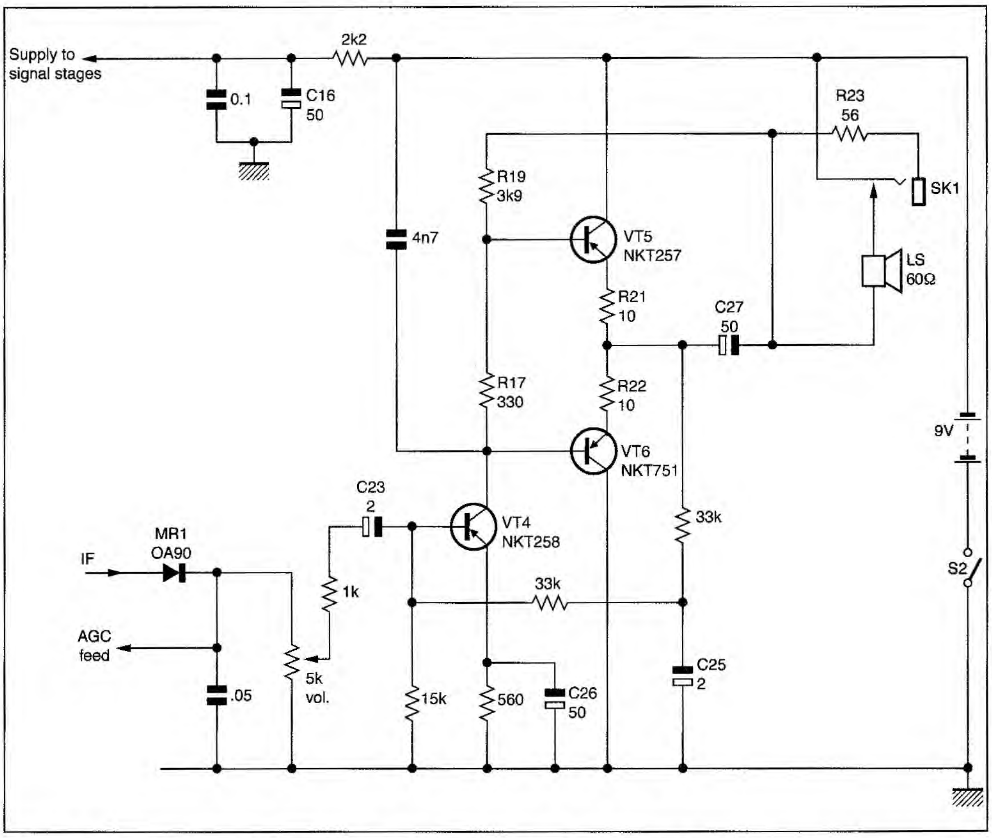


Fig. 1: Audio circuitry used in the issue 2 version of the Pye Model P202BQ, with driver transistor VT4 and complementary-symmetry output transistors VT5/6. The value of R23 seems to have been different in the set Pete Roberts had for repair.

In conclusion

After giving the set a soak test I boxed it up and returned it to its owner.

Incidentally the set had a 1·5k Ω bypass resistor (R23) which is switched in when an earpiece is used.

This provides a DC path to the driver stage with the speaker out of circuit, presumably to allow the use of a crystal earpiece.

I didn't try a magnetic earpiece, but a crystal unit sounded very clear indeed.

Vintage repair: the Ferguson Model 352U

Appearance of the Ferguson Model 352U table radio receiver, with its distinctive cabinet and tuning knob.

Malcolm Burrell describes the steps he took to make an otherwise worthless set usable and presentable

At first glance I didn't think this little radio set, which dates from about 1955, would be worthy of restoration. So it haunted the workshop for three or four years, gathering further layers of dirt and barely escaping the dustbin. One control knob and the trim from the tuning knob were missing; there were no rear or bottom covers; and the audio was exceedingly indistinct. As my interest in vintage radio sets grew however, it became increasingly clear that it would be necessary to be able to make parts that were missing. The 352U seemed an ideal test bed for the purpose – but by this time its loudspeaker had been consigned to another set!

I recalled from early sales literature that the exterior design of the set was distinctive (see heading photo), particularly the tuning knob in the centre with its domed gold trim. The other two controls would have been recessed into the sides of the plastic cabinet, volume/on-off to the right and the wavechange switch to the left, but the latter was missing.

Little service data is available. No *Trader* sheet seems to have been issued, but the circuit diagram (see Fig. 1) is in the 1956-7 volume of *Radio and Television Servicing*. Most Trader sheets provided a photograph to show the model covered. I would like to express appreciation of those who managed to cram complex circuit and layout diagrams, technical descriptions and voltage and alignment information into the extremely limited space of the *Trader* service sheets.

Description

Basically, the Ferguson Model 352U is housed in a mauve plastic cabinet with a beige loudspeaker grill, uses three valves, covers the long and medium wavebands and has a 3Ω, 6 x 4in. loudspeaker. A Westinghouse metal rectifier is used in the HT supply. Each valve in the economical AC/DC design has a dual function, so it's equivalent to a set with six valves. AGC is applied via R6 to the IF amplifier stage and also via R2 to the frequency changer stage.

The wavechange knob

The first task was to try to construct a replacement wavechange knob. If this was not possible, the project would be at an end. But experience gained in making a replica would help with other vintage radio and TV set restorations. As the wavechange switch had a similar 1/4in. (8mm) shaft to the volume control, I assumed that the shape, size and design of the surviving knob would provide a pattern for moulding a replacement.

When a wavechange switch is operated considerable stress is often applied to the stem of the control knob. So this is a common point where damage occurs. Modern fibreglass and polyester materials are durable but cannot always duplicate the strength of the material they might be used to replace. Some plastics are extremely hard but retain a little flexibility. Polyester tends to crack or crumble instead of flexing. It's often better therefore to find a disused knob and slice the shaft from it for use with a new creation. Provide as large a cross-sectional area as possible to bond with the stem of the replacement, in order to distribute the operating stress.

Making the mould

Several materials could be useful for creating the mould required. No doubt a good craft shop would be able to offer some advice on this. The material should inflict minimum damage on the original, but modelling clay and putty were dismissed because they never harden fully. That would cause warp and result in distortion. As I had decided to use polyester filler for the final product (the knob), it seemed unwise to use this to create the mould — in case it became fused with the cast.

I eventually decided to try standard, water-based multipurpose filler of the type used for household decoration, e.g. Polyfilla. This proved to be surprisingly successful. Water-based 'wood filler' would no doubt prove to be an acceptable substitute. The mould would be a 'negative' form of the original knob, with the cavities standing proud. I decided make it in two halves, the circular rear portion and the front section with its indentations.

A barrier of petroleum jelly was smeared over the entire surface of the knob to be reproduced. A secondary barrier of thin, absorbent tissue paper (e.g. toilet paper) was then pressed on to the surface. After that the filler paste was inserted into the front of the knob and the crevices. It was important to place a control shaft into the

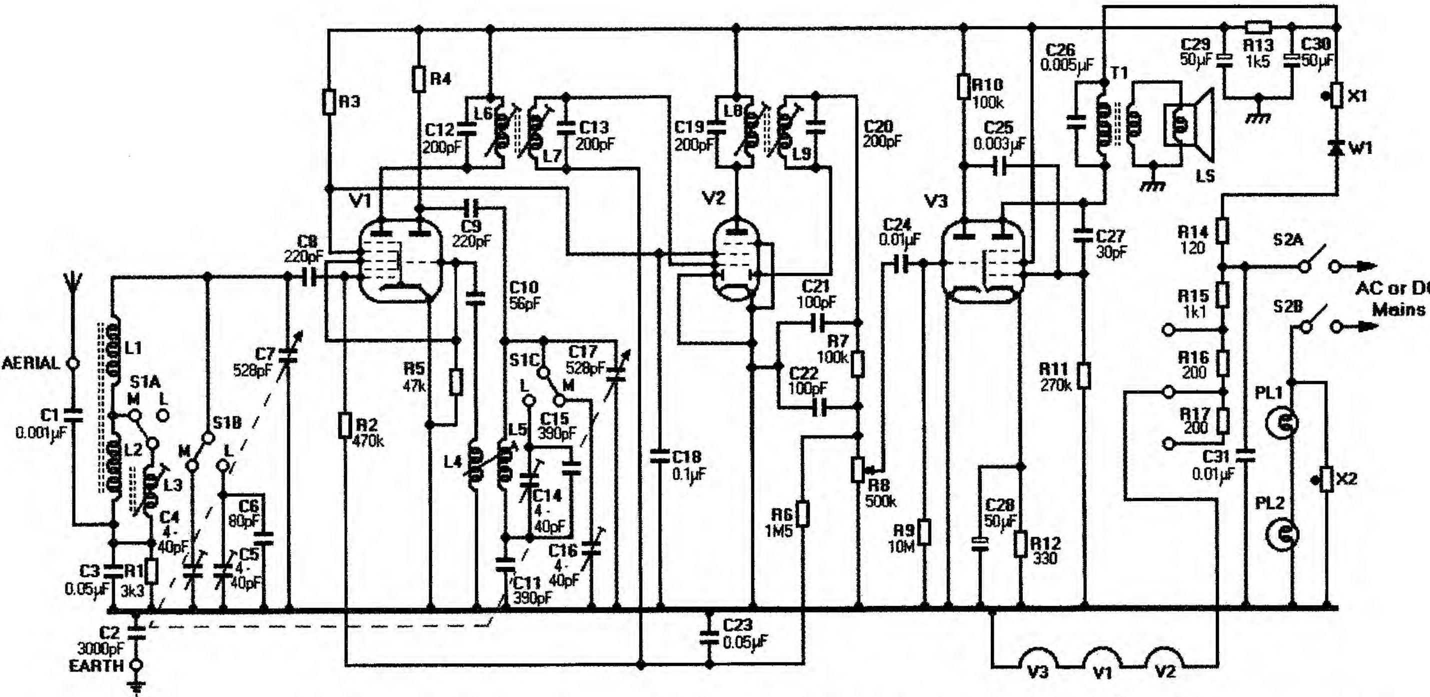


Fig. 1: Circuit diagram of the Ferguson Model 352U. V1 UCH81, V2 UBF80, V3 UCL83. W1 is a Westinghouse contact-cooled metal rectifier. L4/5 should be shown with a ferrite core.

mould to ensure that a suitable aperture would remain, see Photo 1. Finally, loops of wire were inserted at convenient points to facilitate easy withdrawal.

Once it had hardened, the mould for the front of the knob was separated and fragments of tissue paper were removed. I then found it necessary to allow some hours for it to dry fully before attempting further work. Meanwhile the back of the know was coated with barriers of petroleum jelly and tissue paper, and a layer of water-based filler was built around it in the same way as before.

Photo 2 shows the original Ferguson 352U volume/on-off control knob and the moulds made from it. The quality of the cast (the new knob) depends on that of the mould. Some additional filling, correction and smoothing were needed.

Making the cast

Once an acceptable mould had been created, both halves were coated with petroleum jelly. This time, tissue paper was not used. I then mixed some polyester filler and impacted it into each half – firmly, to avoid air pockets. The two halves were then brought together until the filler hardened, whereupon a tag on the loops of wire separated them (there was some risk of the moulds being fractured). I now had a knob that was a reasonable facsimile of the original one, see Photo 3.

But there were imperfections – minute holes and jagged edges. These were made good using fine wet-and-dry paper, filling where necessary. I strongly advise that you make this a gradual process, viewing the cast at different times under various lighting conditions. Like writing, painting and sculpture, today's success might come to be seen as tomorrow's failure! The attempt to achieve perfection is exceedingly tedious. Compromise is, with patience, a little more easily achieved!

As previously mentioned, I considered it better to slice the shaft from another control knob rather than replicate the original. If the control spindle is to pass into the body of the new knob, it should be smeared with petroleum jelly, inserted through the new shaft then into the knob, to ensure correct positioning – particularly when the spindle has a 'flat'. A disused potentiometer is suitable for this propose.

A thin layer of polyester was used to attach the new shaft to the new knob. Once the filler had hardened, the spindle was retrieved and the entire assembly was inspected prior to being painted – with a modelling enamel of the correct hue, in this case mauve mixed with dark brown. The enamel tended to flow over most of the remaining imperfections, giving a smooth, glossy finish. See Photos 4 and 5.

Photo 1: Shaft attached to the moulding for the new wavechange switch knob.

Tuning control trim

The trim at the centre of the tuning knob was clearly essential to the appearance of the set. It was specially shaped into a shallow, conical 'dome' in bright bronze or gold. I decided to experiment with polyester filler to provide a substitute.

A sheet of paper was laid across the surface of the inner tuning knob and scored to indicate the ridge that defines the circumference of the trim. When the paper was removed the ridge was outlined in ink then cut out. Filler was used to form a tough dome on the paper. This was contoured, using sandpaper, prior to being sprayed with bronze paint. The result was smoothed with fine

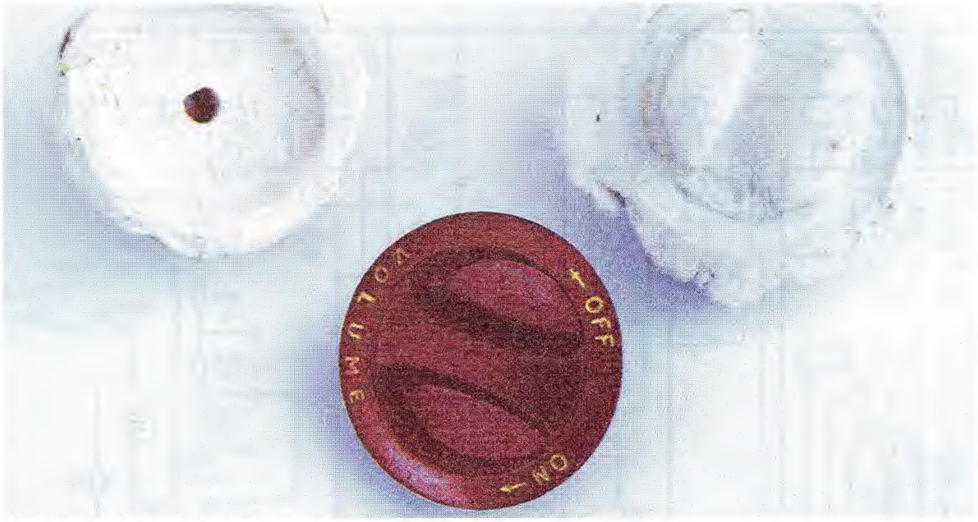
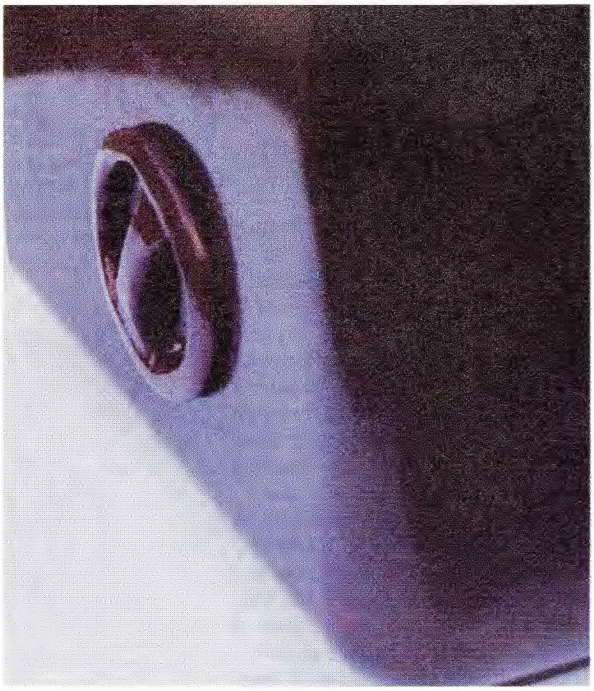


Photo 2: The original Ferguson 352U volume/on-off control knob and the moulds taken from it.

Photo 4: The new wavechange switch knob when painted.

Photo 5: The new knob fitted to the radio.



wet-and-dry paper. Although the finish was not the original mirror one, it provided an acceptable addition to the tuning knob.

Back and bottom covers

Back and bottom covers were considered obligatory, to protect the receiver as well as for the safety of potential users. The originals would undoubtedly have been made of dark brown fibreboard, embossed with the Ferguson logo in silver. A reasonable substitute would have been a form of drilled hardboard known as peg-board. This now seems to be impossible to obtain however. So there was little alternative to shaping a sheet of standard hardboard to fit the cabinet, then drilling holes to facilitate free air circulation.

Surprisingly, the new covers seemed neither superfluous nor ugly. A dedicated restorer would have scoured the world for the correct type, but the set seemed happy with what had been made for it.

The electronics

Operation of the circuit is fairly simple. V1 (UCH81) is a triode-heptode that's used as oscillator, mixer and first IF stage. The following UBF80 (V2) is the second IF amplifier and detector while V3 (UCL83) is the audio amplifier and output valve.

One of the dial lamps was open-circuit and the other one blackened. The HT supply at the cathode of the contact-cooled rectifier W1 seemed to be about right at some 185V. But when I switched to LW reception there were simply rather poor MW signals!

After much investigation I concluded that the front-end alignment must have been disturbed. MW needed adjustment – in particular

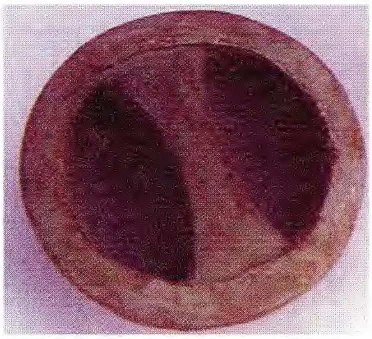


Photo 3: The cast for the new knob.

L3 needed to be carefully reset for optimum results. Once this was achieved, C5 and C14 were adjusted for optimum reception of BBC Radio 4 at 198kHz (1,500m).

The components, including the electrolytic capacitors, all seemed to be in order, but replacement of the audio coupler C24 produced some improvement. Presumably the original capacitor had fallen in value. Coupler C25 was also replaced, as any leakage would destroy the output valve.

Replacement dial lamps produced a substantial improvement in the performance – they provide the mains neutral connection to chassis, in parallel with thermistor X2. A new UCH81 valve further enhanced the sensitivity.

In conclusion

The measures outlined above made an otherwise worthless piece of equipment usable and presentable. Similar moulding techniques could be used for the replication of other items – no doubt small knobs for TV receiver preset controls could be created simply from a clay impression, provided allowance is made for the control spindle. Some presentation parts might also be made in this way.

Replacement of the dial lamps in the 352U also produced a pleasant surprise when the chassis was refitted in the cabinet. Because of their position on the chassis, I had assumed that they were simply intended to provide stray light through the outer tuning scale. In fact they also light the white, translucent rim of the tuning knob, producing a very attractive glow. The set had certainly come to life!

There is a problem with involvement in a restoration project such as this – one becomes attached to the set. It's extremely unlikely that this one will be consigned anywhere other than the shelf used to exhibit and demonstrate my vintage receivers! ■

Meteor III bakelite kit radio

By Ray Porter MSc CEng MIEE

The primary reason for the work that is done on equipment that subsequently becomes described in Television is usually to restore full operation for the user.

The reason for doing the work in this case was to satisfy both the curiosity of a friend and my interest in valve radios. The Meteor III bakelite kit radio that I examined was found in a cupboard when my friend had to clear the contents of his father's house.

In the 50's and early 60's, before Japanese transistor radio production swamped the world, home constructors with mechanical and soldering ability were keen to buy valve radio kits from radio and electrical parts suppliers and then assemble them for domestic use.

This was attractive as at that time the shop price of a brand name radio was high enough for it to be considered a luxury item. Big cities usually had several of these radio parts shops located in a specific area; some sold ex-government electronics surplus as well as new parts.

Tottenham Court Road in London and Hurst Street in Birmingham are two examples of radio and electronics goodies 'ghettos' of that era.

My friend could just remember, as a child, that his father had built the kit, but wanted to know when that would have been. I enthusiastically suggested that it also might be interesting to find out if the set worked, realising that I had now committed myself to help out.

The kit and its designer

The kit assembly instructions, circuit diagram and parts list were also found in the house, but were not dated.

Figure 1 shows the front page of the instructions. This gave me a lead to start the research.

An internet search using the designer's name returned a reference to Tom Gamble at: www.virtualbrum.co.uk/oldads1968.htm. However I was sure that the radio dated from much earlier than 1968.

A picture of Tom is shown in Figure 2 as he was then as the service manager at Curry's Superstore in Birmingham's Martineau Way.

The website also reported that Tom was the first manager at the kit's suppliers, Norman H Field, who still have a shop in Hurst Street in central Birmingham, although now at a different street number.

Figure 3 shows the circuit diagram (as hand written in the instructions because there were no schematic capture software drawing packages in those days) and after looking at the two valve set up, I was impressed by the claims in the instruction book of 'strong reception of local and foreign stations on a few feet of aerial' and eagerly wanted to see if that could be verified in practice.

The parts list made interesting reading: Cabinets were available in cream or brown, the speaker cost 16s 6d (83p), resistors were 4d (2p) and SP41 valves were 7/- (35p).

Each part in the kit could be bought separately for a total of £5 13s 5d (£5.68) or all together for £4s 17s 6d (£4.87) plus 2s 6d (13p) postage.

Technical advice included "reverse the mains plug if there is excessive hum". This referred to the common usage of non-polarised two pin non-fused 5A (or 15A) plugs or lampholder plugs that replaced bulbs in domestic installations.

EASY TO FOLLOW INSTRUCTIONS . . .
MAKE THE
"METEOR III"
A.C. MAINS
INSTRUCTIONS 1/- PRICE
Designed by - - Mr. T. A. Gamble G3DBL
A really Good Kit with High Quality Results.
PARTS OBTAINABLE ONLY FROM
NORMAN H. FIELD (ELECTRONICS)
68 HURST STREET, BIRMINGHAM 5
BIRMINGHAM'S LEADING HOME CONSTRUCTORS STORE

Figure 1. Front page of the instructions.

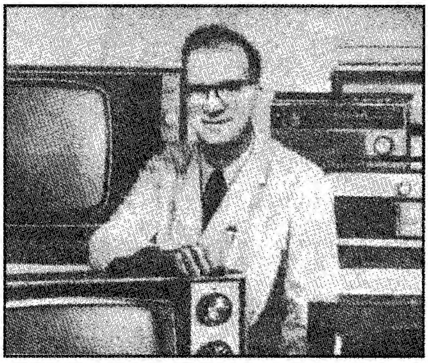


Figure 2. Tom Gamble.

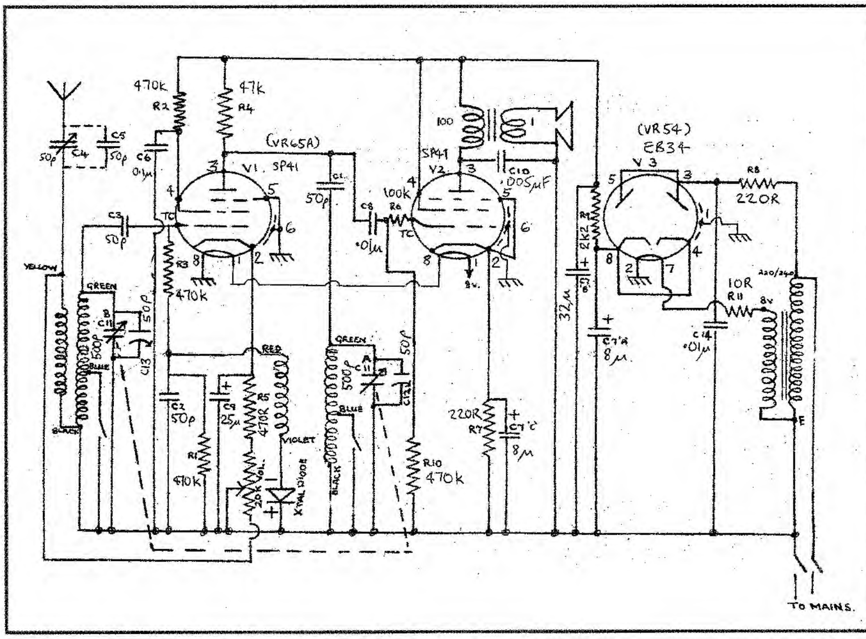


Figure 3. Circuit diagram.

The kit did not contain a mains plug, as mains equipment was not supplied with plugs until that was relatively recently legislated.

A caution notice advised that the chassis was connected to the mains, and that the exposed chassis fixing screws could become live, and that the grub screw holes on the knobs must be filled with wax to avoid shocks.

We have come a long way in electrical safety since then, designing in double insulation seems such an obvious safety precaution.

The kit was guaranteed: 100% refund if unused within 7 days, if the constructor couldn't get it to work then a repair would cost 10/- (50p) plus parts, if still not satisfied then 80% refund would be given.

Those were outstanding customer protection terms in those times, several decades before superstores introduced no quibble guarantees.

Taking a closer look

The style and appearance of the bakelite cabinet made the finished kit look acceptable in the living rooms of the time.

My next step was to look at the internals, shown in figure 4. There was very little dust, but there was some rust on the steel parts; the drive cord was intact and the tuning mechanism worked.

The fixing lugs of the polystyrene coil formers had cracked, so that the coils were not firmly fixed to the chassis.

All valves were fitted and their part numbers agreed with the assembly instructions. A 13A plug (I had to replace the 13A fuse with a 3A one!) was fitted to the mains lead, and thankfully the neutral was connected to the chassis.

The next task was to look for date markings. Pencilled onto the external metallising screen of V1 was '1955', which was also hand written onto the chassis.

There is a good chance that this was the year of construction as 'Apr 55' and 'Aug 54' were marked on two of the electrolytics by the capacitors' manufacturer.

About ten years later on a ready built pocket transistor radio with ferrite rod aerial could be bought for the price of this kit.

Figure 4. The internals.

Reception possible

Now I had to be able to show my friend if it worked. My first task was to reform the electrolytics, as that is what restoration experts say you must do.

Is it a myth that electrolytics lose their aluminium oxide layer with time?

I isolated the HT circuits and applied a variable DC voltage through a current limiting resistor to C7a and C7b only and never saw a value of leakage current that made me think that these capacitors were anything but immediately serviceable, even with full HT applied.

I did leave them with full voltage applied via the resistor for an hour in case flash over was going to occur, and all was well.

A quick check on their values gave some low readings, but there was no need to replace them unless there was hum that masked reception completely.

Three capacitors that I didn't trust were C6, C8 and C14. These were all subject to high voltage stress, and I knew from past experience that their waxed paper construction deteriorates and loses insulation resistance.

I replaced these with new modern types as visible in figure 5, before I applied mains to the transformer via a variac and saw the welcoming glow of all the valve heaters when the variac was at 100%.

After reconnecting the HT circuit, I wound the variac up to 100% again, and was pleased to get good MW reception (at 10 miles from Droitwich) on a metre of wire hanging from the aerial socket.

LW reception was also good, but slightly intermittent and tapping the aerial coil would make it cut out completely.

Well done Tom Gamble

My friend was pleased to see that his heirloom was still capable of working after 40 years, and said that he would treasure it rather than attempt to use it.

I have to agree with him that there is something comfortable about the appearance of bakelite radios. Perhaps it is the associated childhood memories that are so cosy.

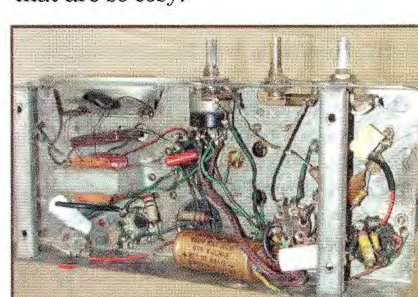


Figure 5. Capacitors.

Ekco U29 small table set

The Ekco U29 is better described as a small table set rather than a midget because although modest in outside dimensions, inside it has a chassis that is little smaller than a conventional table model and is exceedingly well put together. Chas Miller reports.

A 'short' superhet for AC/DC mains, the Ekco U29 was originally released in June 1946. It is totally inconceivable that anyone at the time could have anticipated that it could offer excellent performance nearly sixty years later, for that is exactly what our particular example did after a commendably small amount of necessary repair work had been carried out.

Externally this set looked very clean and tidy. It was not too bad inside either but there was evidence of previous repair work having been carried out many years ago, some more recently.

In the first category was the replacement HT smoothing choke of Radiospares manufacture and evidently an 'exact replacement' type because it was equipped with the two lugs on its shell to which the HT fuse panel is bolted.

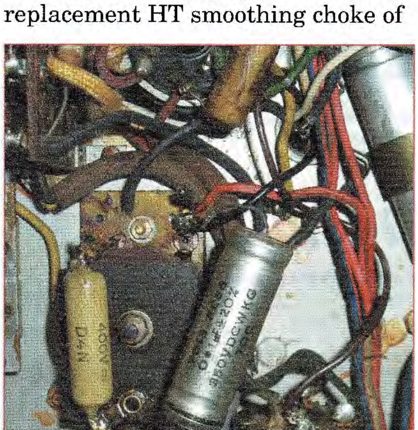
We would guess that this dates from not less than forty years ago. The recent work was the replacement of the original mains filter condensers by two unsuitable modern types, one of which was non-connected to a solder tag by as fine an example of a 'dry' joint as one might meet in a month of Sundays.

Not being attracted by the use of 250V DC working condensers at mains voltages, we removed them and fitted in their place a couple with a more reassuring 1kV rating.

In the U29 we have an excellent example of how Messrs. EK Cole took great care in mains filters in AC/DC receivers by using close-coupled RF chokes designed mutually to cancel out noise.

The valve line-up of the U29, according to the Trader service sheet, consisted of a CCH35 frequency-changer, EF39 IF amplifier, Pen453DD double-diode output pentode and CY31 half-wave rectifier.

However, in this example and in all the others we can remember servicing, the DDP is a CBL31. The two types differ considerably in characteristics, particularly in respect of grid bias voltage and optimum anode load and are not directly interchangeable.



Above: The front of the Ekco U29.

Left: The look of the mains filter did not inspire confidence.

Bias grid error

It should also be recorded that there is an error in the Trader circuit diagram regarding the bias on the grid of the DDP, whichever type might be fitted, that needs to be corrected before a discussion of our work on this set may be carried out.

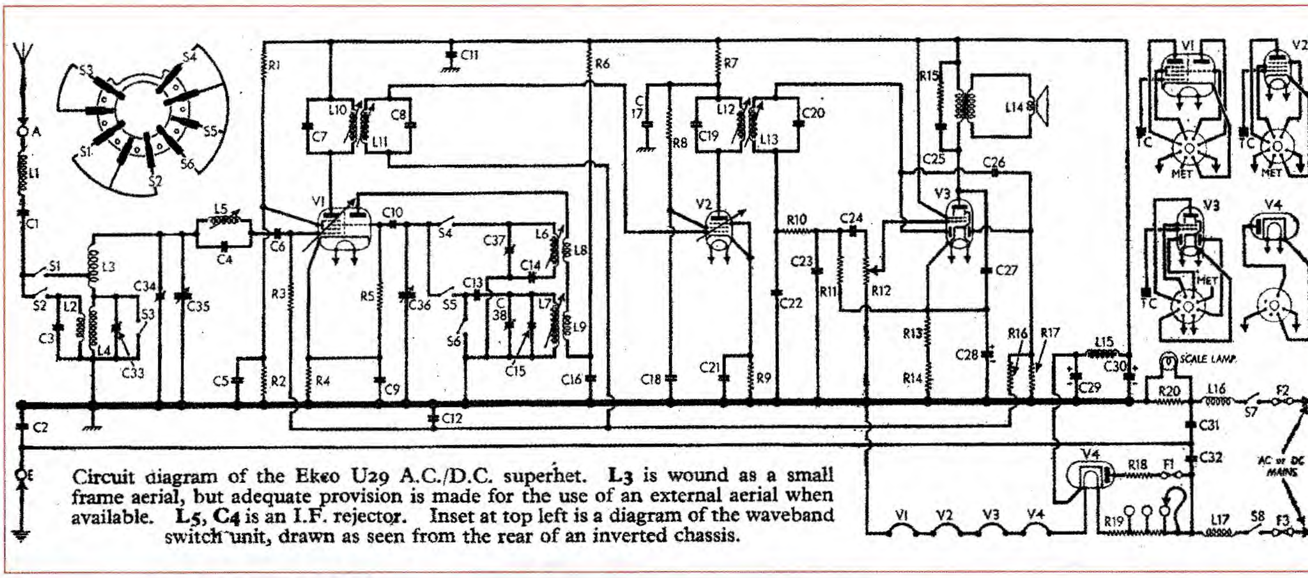
In fact, this is no bad thing as a thorough understanding of how the DDP works in a short superhet is essential for servicing purposes and this gives us the opportunity for a detailed description.

In order to obtain sufficient AF input to load fully the output pentode a high degree of AVC delay has to be employed. This is obtained by raising the cathode voltage to a considerably higher potential than is necessary for grid bias purposes, by inserting another resistor in series with that used for the latter. The values used in the U29 are entirely typical at 150Ω for grid bias with an extra 330Ω for the AVC delay bias.

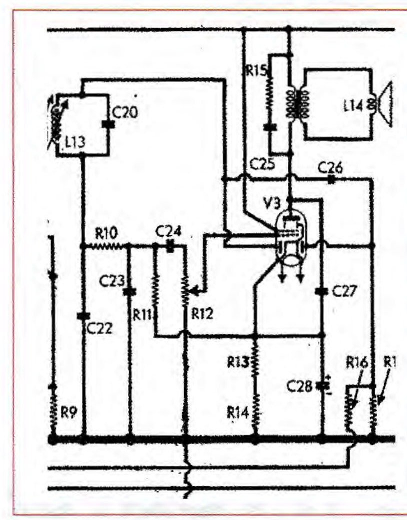
Now, a situation arises in which three different electrodes in the output valve have to receive different bias voltages: the maximum available for the AVC diode, about one third for the pentode grid and zero for the detector diode.

These voltages are obtained by returning the AVC diode direct to chassis, the grid to the junction of the bias and AVC cathode resistors and the detector diode to the cathode itself.

Reference to the corrected circuit will show that the AVC diode returns to chassis via its load



Circuit diagram of the Ekco U29 A.C./D.C. superhet. L3 is wound as a small frame aerial, but adequate provision is made for the use of an external aerial when available. L5, C4 is an I.F. rejector. Inset at top left is a diagram of the waveband switch unit, drawn as seen from the rear of an inverted chassis.



Above: The original circuit as it appears in Trader Sheet 799. Compare this with the enlarged and corrected section in the next image, in which the bottom of R12 goes to the junction of R13 and R14.

Right: The corrected circuit of the detector and output stages.

resistor, R17, 1.5MΩΩ; the grid returns via the volume control, R12, 1MΩ, to the junction of R13, 330ΩΩ and R14, 150Ω; and the detector diode returns to cathode via the IF stopper R10, 100kΩ and its load resistor R11, 560kΩ to the cathode.

In order to separate the bias voltages on the detector diode and grid the top of the volume control is fed with AF signals via the DC blocking condenser C24, 0.01μFd.

Waxed paper condensors

With this firmly in mind, let us return to repairing the U29. Apart from the two condensers already mentioned, all the original waxed paper types were in situ, and so were all the electrolytics, come to that.

We should, in our preamble, have eliminated any urge to change all the condensers before proceeding, so we will get on with the business of educated diagnosis.

Having checked for continuity through the mains dropper and heaters, for a reasonably high resistance between HT+ and chassis and for the correct disposition of the mains connector for the chassis to be neutral, we plugged the set straight into the mains.

At this stage, let us remind persons addicted to variacs that it would not be a scrap of good endeavouring to 'run up', as they quaintly call it, a U29 by the use of one of those curious devices.

The CY31 rectifier inherited the cast-iron cathode of its ancestor the CY1 and on a good day with full heater voltage and the wind behind it takes a good three minutes to stagger slowly into life.

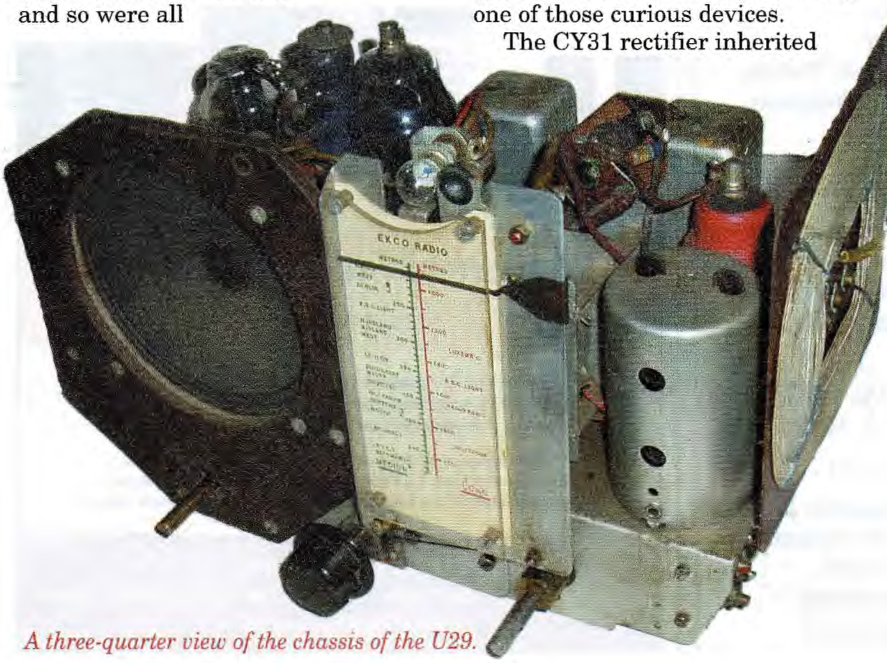
With anything much less than 20V you could wait all day for something to happen and professionals don't have the time to spare for such fripperies.

On the initial test run the set hesitated a little then eventually started to produce sounds as we tuned along the medium wave band. This was on its frame aerial and a number of stations came in at reasonable strength but rather questionable quality.

The usual dodge

When we tried the usual dodge of applying the palm of one hand to the frame aerial to apply more signals to it, the volume soared up but with much distortion.

This is where you use your deductive powers. If, as appears likely, the detector was being overloaded it suggests that the AVC



A three-quarter view of the chassis of the U29.

A rear view of the U29.

was not operating correctly and experience in turn suggests that the most likely cause is a leaky decoupling condenser.

It was not hard to locate the 0.1µF used in the U29 for this purpose then to snip off one end and measure its DC resistance as about 500kΩ – not a large leakage but sufficient to drain down the AVC bias.

Replacing this condenser eliminated the overloading on strong signals but left the output still sounding a little distorted.

Again you need to use your deductive powers to suggest a cause and you should be suspecting the bias on either or both the detector diode and the grid of the output valve.

We have already discussed the purpose of C24 as a DC blocker and it ought to be apparent that if it should leak it would have two unwanted effects.

By introducing a DC path between the detector diode and the grid return of the CBL1 it will simultaneously reduce or even remove altogether the bias on the latter and also put some negative bias on the former, which is pretty darn clever when you come to think about it.

Again, snipping off one end of C24 and measuring it for DC resistance immediately proved the diagnosis correct.

A replacement resulted in great improvement in sensitivity and sound quality and the repair might well have been considered complete; but in the event we checked the rest of the voltages throughout the set and found just one discrepancy - that on the output valve cathode was a little higher than specified.

A possible reason for this suggested itself as the fixed tone corrector condenser 'twixt anode and cathode of the CBL1 leaking and once again a simple test proved this to be so.

This final replacement brought the performance right up to standard and the U29 is now a firm favourite for workshop listening.

This article first appeared in Issue Number 104 of The Radiophile.
More details from Chas Miller on 01785 284696.

Restoring vintage radio sets

Valve radio sets are becoming rare. Many enthusiasts and collectors are prepared to pay good money for those still around to be restored. So here's another source of profitable work. It requires an understanding of how such sets work and how they were designed. Ian Rees provides a detailed guide to circuit operation and restoration techniques

The number of valve radio receivers that turn up at car boot sales and auctions is gradually dwindling. As a result, prices are rising – even for sets in very poor, non-working condition. Collectors and dealers are usually able to cope with the cosmetic side of restoration, but often have difficulty finding someone with the know-how to get a set to work. Money spent on this greatly adds to the set's value. It's ironical that while we turn away so much modern equipment the repair of these old sets has once again become viable.

Restoration differs from overhaul, repair and rebuilding. Elements of all three contribute to restoration, but I personally take the view that the repairer has a responsibility to maintain the context, spirit and appearance of the item being restored, even though the work may be hidden from view. Modern safety requirements place a large responsibility on the restorer however: achieving a balance between old practices, new regulations and historic accuracy is, unfortunately, not always possible.

It's sometimes better to disable a vintage radio, leaving the original build and appearance as they were. When a working restoration is required however I try as far as possible to keep to the spirit of the original construction and layout, while making sure that it will be safe to use. Mains cable type, anchorage, cover fixing/protection, insulation and isolation are a few of the things that have to be considered. Once you have restored the set as a working item, these must all conform to modern safety requirements.

Inspection

Initially, a vintage radio receiver can be treated like any other piece of faulty equipment that arrives in the workshop. Obtaining information on its background and symptoms is very important – the customer is unlikely to have resisted the urge to plug it in and try it out.

Genuine collectors know the score about electrical restoration. A customer who has been given a set or got it cheap and wants it patched up is a menace. In this situation it's vital to make clear what is likely to be involved. I insist on providing an estimate, which must be paid for in advance. If the estimate is accepted, its cost is absorbed in the overall charge. This saves wasted workshop time, and makes clear to a customer the risks involved in having the repairwork carried out.

I recommend that a set is dismantled and inspected visually before any functional checks are attempted.

Once a set has been removed from its cabinet it is vulnerable to damage. Always close the air-spaced tuning gang to protect its vanes. Glass scales, knobs and fittings are usually irreplaceable, so keep them safe.

With valve equipment there are often visual symptoms to aid diagnosis. Sweaty carbon resistors, flaking wirewound ones, leaking electrolytic capacitors and melting wax from chokes and transformers can all indicate the presence of problems. Your nose will often verify what your eyes see. Paxolin has a very distinctive acrid smell when it overheats or burns. Tagstrips, switches and valvebases were often made of it. Valves should have mirror silvering (the result of gettering) inside the top of the glass. Any sign of a misty, white deposit inside the top of the glass indicates that the vacuum has been broken – this is not always obvious however. Fabric and rubber sleeving on wires can crumble when moved, causing shorts.

Once the overall condition has been assessed, safety insulation and continuity checks can be carried out. The primary winding of the mains transformer in an AC set should provide a DC resistance reading of about 25Ω when set for 220V operation and 30Ω when set for 250V. A check on the resistance between the HT line and chassis is recommended before a functional test is carried out. Expect a reading of anything from 50kΩ to infinity once the smoothing capacitors have charged.

Functional test

I carry out all functional tests with the set powered via an isolation transformer and a variac. By using the latter to increase the mains input slowly, any problems not found during the initial inspection will show up before damage is done. This time your nose rather than your eyes will probably be the best means of detecting the presence of problems.

Connection of a multimeter to the HT line, switched to its high DC voltage range, will provide a useful indication that everything is holding its own when mains voltage is applied to the set. Excluding battery-operated equipment, an AC or AC/DC radio will normally greet you with a show of pilot lights at switch on. As the set warms up, the HT voltage reading will rise, settling down at between 150V and 450V DC depending on the type of power supply. Many of the valve heaters should glow visibly, followed by a faint hum from the loudspeaker and, maybe, stations on one or more bands with the volume control turned up fully.

Each movement of the wavechange switch should give at least a click, if nothing else. A short throw-out aerial will be required if the set doesn't incorporate a frame aerial.

Apart from a completely dead set, likely symptoms include mains hum, motor-boating (instability), distortion, loss of one or more of the wavebands (in part or whole), lack of sensitivity and interference of various kinds. I hesitate to suggest, at this point, the use of a wet finger (and the other hand in a pocket) to check stage operation, because of modern workshop safety practice.

It's desirable to have a few items of test equipment in addition to a multimeter. These are an AF/RF signal generator, an oscilloscope and an insulation tester.

Power and audio stages

Most of the problems in an old radio receiver are likely to be in the power or audio sections. Fig. 1 shows a typical AC radio receiver power supply and audio circuit of the early Fifties. The valves have international octal bases. V3, a 5Z4 rectifier used to provide the HT supply, has a directly-heated cathode, requiring a separate 5V AC heater winding on the mains transformer T2. The other valve heaters and the pilot lights are connected to a 6·3V AC winding, one side of which is connected to the earthed chassis.

The electrolytic capacitors C7 and C3 are the HT reservoir and smoothing capacitors respectively. They will either dry out and loose their capacitance or leak, causing mains hum or voltage loading. The rectifier valve is very rugged, but can suffer from interelectrode arcing shorts or low cathode emission. Insulation breakdown or shorted-turns in the mains transformer T2 is not uncommon. Problems with the HT smoothing choke CH1 are unusual (you will often find a low-value power resistor in this position).

The audio output stage consists of a 6V6 beam-tetrode valve that operates under class A bias conditions (standard with a single output valve). It can deliver about 4W RMS via the output transformer T1 to the loudspeaker. A top-cut tone control network (C6 and RV2) is connected between the valve's anode and chassis. The audio input is coupled by an *RC* network, C2 and R4. Cathode bias is provided by resistor R5, which is decoupled by C5.

A fault from which most valve equipment of this age suffers is leaky waxed-paper or moulded capacitors. All such capacitors should be replaced on sight, without question. If C2 in Fig. 1 is

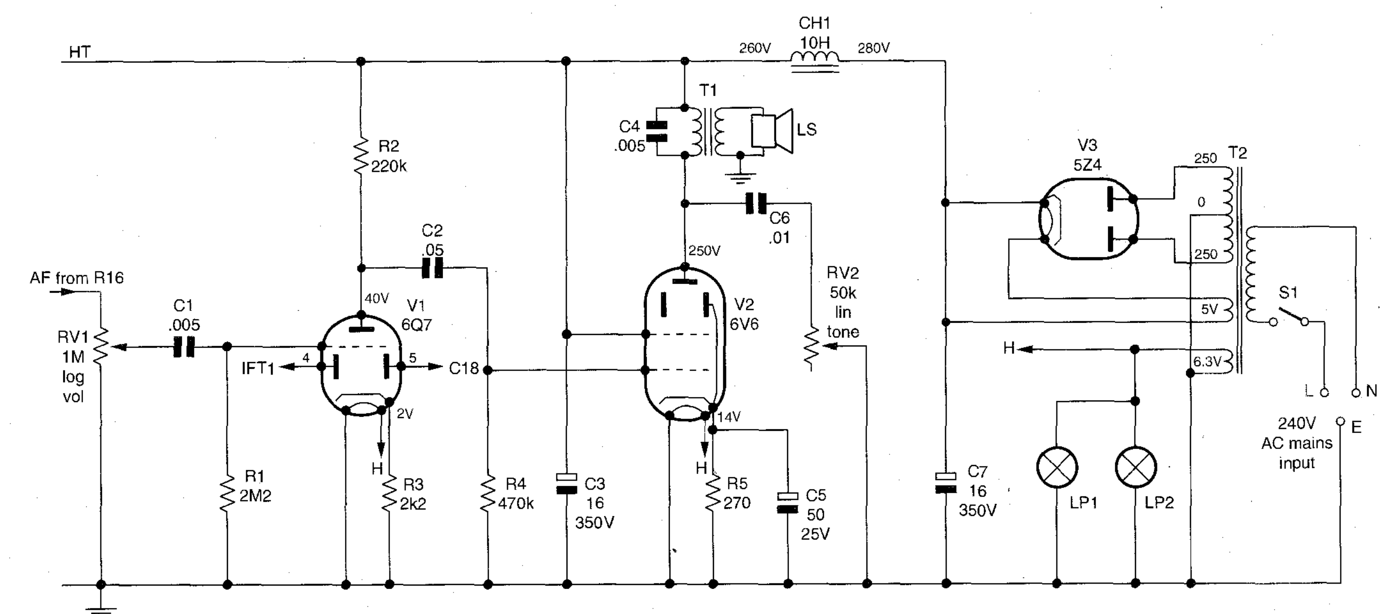


Fig. 1: Typical power supply and audio circuitry in an AC mains valve radio receiver.

leaky for example V2 will pass excessive current, because the positive voltage at the anode of V1 will be present, attenuated by the degree of C2's leakage, at the control grid of V2. Not only may V2's anode glow red, which is not good for it, but T1, R5, C5 and the power supply will all be stressed. If C6 is leaky the track of RV2 will be damaged, making it noisy, and the load on the output transformer T1 will be increased. Paper capacitor C4 can go short-circuit, with the result that there's minimal output via T1 while V2 will be overloaded, or may arc internally at high volume. If C5 dries out V2's gain will be lowered, because of the negative feedback introduced by R5 when it's without decoupling.

The 6Q7 valve V1 is actually three valves in one, two diodes and a triode. The two diodes are used for demodulation of the signal and the generation of an AGC voltage, while the triode provides voltage amplification of the demodulated audio signal. The amplifier stage gives few problems apart from the load resistor R2 going high in value. This reduces the audio output.

Signal injection was the usual method of checking when there's no audio output. Check at each side of C2 then each side of C1. Since a 6Q7 valve has its control grid connected to its top cap, this is an easy place at which carry out a signal-injection check.

A common fault with audio valves, though not particularly the 6Q7, is microphony. This is caused by mechanical vibration within the valve and produces a sound like a string on a musical instrument being plucked. If the effect is loud enough there will be sustained audio feedback. Replacement of the valve is the only cure. As a check, gently tapping the valve's glass envelope will instigate the condition. Note that some valvebases are mounted on rubber grommets to reduce the effect. Check that the rubber hasn't perished and that the base is free to move.

C1, which couples the audio signal from the volume control RV1 to the grid of V1, is probably another waxed-paper capacitor that's likely to be leaky. The result will be distortion and crackles from the volume control.

The volume and tone controls RV1 and RV2 tend to become noisy, especially when a mains on/off switch is built in (this is common with volume controls). Switch cleaner is very effective, provided you can find a way to get the spray to the track.

Negative feedback is generally applied somewhere in the audio circuitry to improve the sound quality by reducing harmonic distortion. In Fig. 1 R3 is not decoupled. This is a simple way of providing negative feedback in a single amplifier stage. There are various other ways of applying negative feedback in this sort of circuitry. For example a high-value resistor could be connected between the anode of V2 and V1, or a considerably-lower value resistor between the secondary winding on the output transformer and the cathode of V1. If this latter technique is employed it's possible, when working on the output transformer, to get the winding used for the feedback reversed. The result is positive feedback, whose symptoms are distortion or sustained audio oscillation.

Where breakthrough from taxi and other mobile services is a problem, connecting a 5nF ceramic capacitor across the volume control generally provides a cure.

Apart from the power supply, in which differences will be found (see later), the above fault conditions also affect AC/DC mains receivers and battery portables.

RF/IF circuitry

Fault diagnosis in the RF and IF sections of a valve radio receiver can be much more difficult than in the power and audio sections. Fig. 2 shows typical RF and IF circuitry. For simplicity, bandswitching is not included. We'll assume that medium-wave reception only is provided.

The aerial coil L1 and oscillator coil L2 are tuneable across the band by the ganged capacitor VCa/b. The two IF transformers IFT1 and IFT2 are generally tuned to some point in the range 450-470kHz (many US sets use 110kHz). The frequency changer (oscillator/mixer) valve V4 and IF amplifier valve V5 are variable-mu (gain) types, to which automatic gain control (AGC) is applied. The negative-going control voltage is produced by one of the rectifier diodes in V1 (Fig. 1), at anode pin 5, and is applied to the control grid of the mixer section of V4 via R14, R6 and L1, and to the control grid of the IF amplifier V5 via R14 and IFT1. Smoothing is provided by C8 and C11. C18 couples the IF signal to the AGC detector diode. With a strong signal, the receiver's gain is reduced by an increased negative AGC voltage in order to prevent signal overload. The AGC voltage falls when a weak signal is being received, increasing the overall gain of the set's RF/IF stages. The IF signal produced by V5/IFT2 is also fed to the anode of the other diode in V1, at pin 4. This diode demodulates the signal, producing an AF output across its load, which consists of R16 and the volume control RV1 (Fig. 1). C19 provides RF filtering. The audio tapped from RV1 is fed via C1 to the grid of the triode section of V1.

Many problems will be cured by replacing the waxed-paper capacitors in these stages. C8 and C11 can cause instability when faulty, while C9, C10,

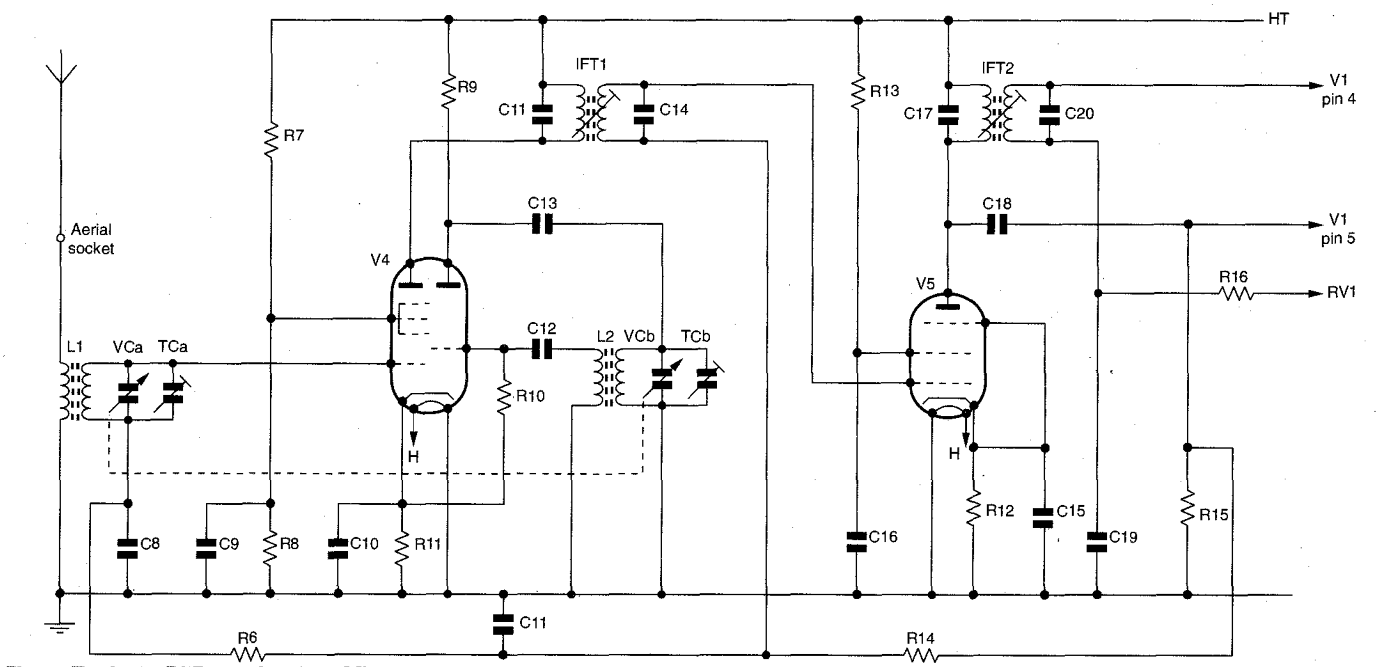


Fig. 2: Typical RF/IF circuitry in a MW superhet valve radio receiver.

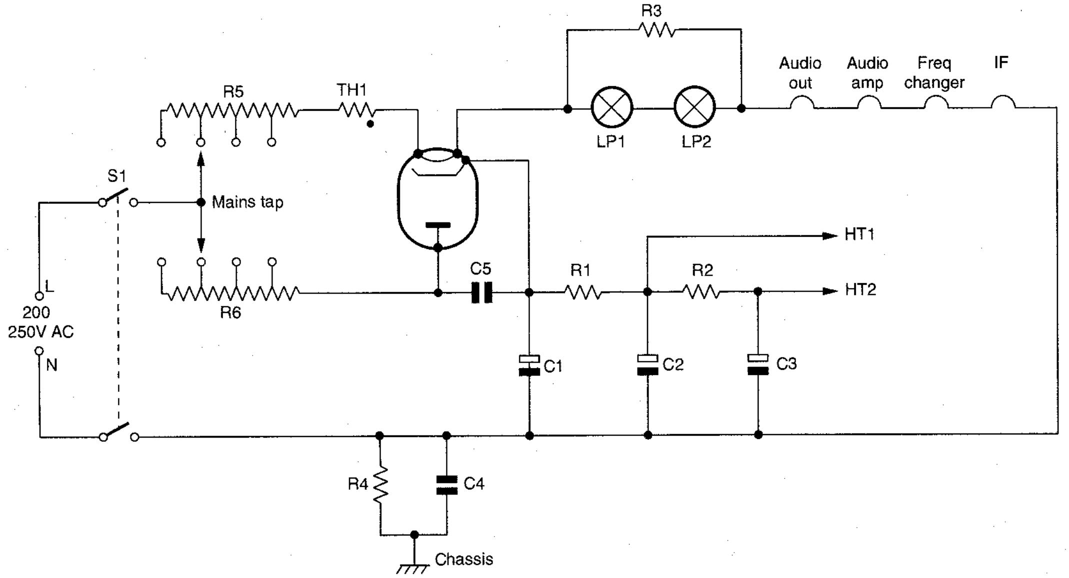


Fig. 3: Typical power supply arrangement in an AC/DC valve radio receiver.

C18 and C19 can be responsible for lack of gain or no oscillation. C13 and C8 will probably be mica or ceramic capacitors, though low-value paper types can be found in these positions as well. If C13 is faulty V4 will cease to oscillate and there will be no IF signal. Oscillation can be seen by connecting an oscilloscope to V4's triode grid, at the junction of R10 and C12. If an oscilloscope is not available, connect a multimeter to this point, switched to its DC voltage range. It will show a negative voltage when the valve is oscillating.

Tuneable hum with some distortion of the signal occurred with quite a few mains-powered valve radio receivers. Unlike mains hum in the power supply, this is present only when a station is tuned in: off tune, no hum is heard. Check all the resistors associated with V1, especially those in the AGC circuit (R6, R14 and R15). Alternatively heater-cathode leakage in V4, V5 or V1 could be the cause.

Tuneable hum with strong local stations calls for a modification, which would be carried out as a matter of course when a set that exhibited this symptom came in for repair. It's caused by the mains lead acting as an aerial, introducing 50Hz modulation on to the carrier. The cure is to add an 0·02μF, 1kV capacitor – C5 in Fig. 3 – between the anode and cathode of each power supply rectifier. AC-only sets had an 0·1μF capacitor added between the cathode of each power supply rectifier and chassis.

Probably because this was the era of DIY radio, it seemed that everyone who owned a small screwdriver would jump in the back of a receiver and tighten up every preset they could find. RF alignment problems were common. It is important that the aerial and oscillator tuning should keep in step across the whole tuning band, so that a constant IF difference signal is produced. In Fig. 2 the tuning gang capacitors VCa/b have small trimmer capacitors, TCa/b, in parallel for alignment. IFT1 and IFT2 are shown with fixed tuning capacitors (C11, C14, C17 and C20) and tuneable dust cores. They could just as likely have fixed cores and adjustable preset capacitors. These alignment adjustments were often the first targets of the twiddler. Refer to the section on alignment before you attempt any adjustments in the RF/IF circuits.

Microphony can also affect the valves in the RF/IF section. Replacement is the only cure. Low emission is something else to expect. When V4 starts to lose emission it may stop oscillating across all or part of the band. Interelectrode shorts or leakage in RF/IF valves is common. Substitute or test to confirm.

AC/DC radios

The AC/DC radio followed the AC-only era, lasting into the Seventies. This was not because such sets had the added virtue of being able to work with a DC mains supply – such supplies had long since disappeared in the UK – but because this approach did away with the expensive mains transformer. Early versions used large wirewound dropper resistors in the power supply to provide the large heater currents: these dropper resistors radiated a lot of heat, which would burn the cabinet.

Fig. 3 shows a typical AC/DC radio receiver power supply. Note that there is no earth connection, only mains neutral and live. Half-wave rectifiers such as the UY41 were introduced, with improved heater-cathode insulation and a higher heater voltage and lower heater current, better suited for use with series-connected valve heaters.

Before this the normal heater voltage for most valves was 6·3V at 300mA. Later AC/DC radio sets have valves with a heater current rating of 100mA and a variety of voltage ratings from around 4V to 100V (the UY41 had a 31V, 100mA heater requirement), connected in series as shown in Fig. 3. As with the lights in a Christmas tree, when one heater failed they all went out. Also used for a time was a device that looks like a household light bulb and is called a Barretter. This found favour because it not only worked as a dropper resistor that provided a constant-current output but, in addition, its glow could be used to illuminate the tuning scale.

Many dropper resistors (R5, R6 in Fig. 3) have fixed or movable taps to provide adjustment for different mains supply voltages. It is not unusual to come across a set in which the taps have been set for a lower than correct mains voltage in order to boost flagging performance – a stressed valve may not work with the correct tapping. The only answer is to replace the valves and reset the taps.

Just to add further confusion, in some sets the valve heaters are wired in a series/parallel arrangement, with resistors across some of the heaters to balance the current. This can give you the impression that a valve has developed a heater-cathode short when, in fact, one of the balancing resistors has gone open-circuit with the result that the associated valve glows very brightly as it takes the strain.

An alternative to the hot dropper resistor was a type of mains cable called a line cord, which we first encountered in small sets imported from the US. The line-cord mains cable was usually cotton covered and had, in addition to the live and neutral conductors, an asbestos cord that had resistance wire, coiled in a continuous spiral, along its length. One end of the resistance wire was terminated at the live pin of the mains plug, the other end going to the valve at the beginning of the heater chain.

Because of the resistance contributed by its inner core, the length of the line cord is critical. As the UK's mains voltages are double that in the US, the lead could be quite long. Owners irritated by its length would shorten it, with disastrous results.

It's normal for the cable to run quite warm in use. A few working sets with a line-cord cable are still found. Alas the cord is harder to find, and you may have

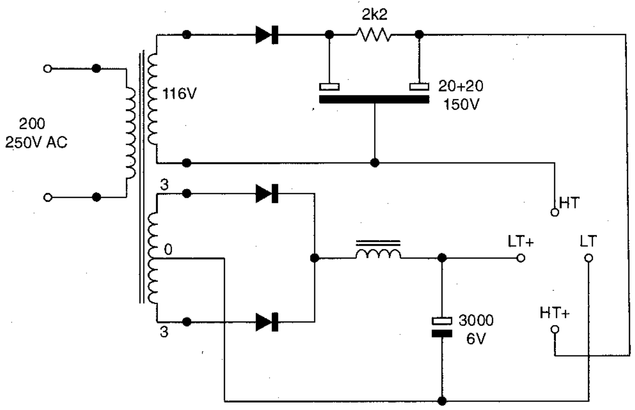


Fig. 4: An original battery eliminator circuit.

to resort to a transformer or dropper resistor in an external box to get such a set to work.

You may find two small rings of tinned copper wire hanging in mid air and no heater voltage at the valves. This will be the home of a missing thermistor, TH1 in Fig. 3, which is incorporated to protect the heaters against the high switch-on surge. You may find that the thermistor's body is lying in the bottom of the cabinet. If it is intact and has not lost its tinning, it can be resoldered to the ring connections. If a replacement isn't available, fit a 50Ω, 5W wirewound resistor.

The use of half-wave instead of full-wave rectification calls for higher-capacitance smoothing and reservoir capacitors (C1, C2 and C3 in Fig. 3) and higher-value smoothing resistors (R1 and R2).

The dial bulbs LP1 and LP2 are connected in series, with a bypass resistor R3 in parallel. This lengthens their life, as they are under-run, and enables the set to continue in operation should they blow. The position of the valves in the heater chain is important. A common arrangement, from the live mains supply end to chassis, would be HT rectifier, audio output valve, audio amplifier/detector valve, frequency changer then finally the IF amplifier. In some sets you might find that the dial lamps are wired in series with the HT rail. Wherever they are connected, the set must be switched off to replace them.

It's important to ensure that mains live is not connected to chassis. Most of us at the time carried a neon test screwdriver and dabbed it on the metalwork to check. Some manufacturers didn't connect the metalwork directly to the mains supply but chose to use it as a ground plane, with isolation via a small capacitor and a 1-10MΩ discharge resistor (R4 and C4 in Fig. 3). In this event using the metalwork as one connection for a multimeter can produce bewildering readings!

Heat dissipation inside these sets can be very high. Cardboard backs became brittle and were easily damaged, and their screw fixings became worn and insecure. Some US sets had an unearthed metal case that was covered with cloth or a crackle-finish paint. Their 'live' chassis were insulated from the case with thin strips of wood or Paxolin. These tend to be the most difficult to raise to a modern standard of safety. Although brittle, Bakelite cases keep their good looks. As with other cabinets the back covers and fixings are a weak point. Where an oversize screw has been used, cracking the brittle case, the damage can be repaired with Epoxy resin. Once hardened, the Epoxy can be drilled and tapped to take a new screw.

The grub screws that secure the control knobs are often overlooked with AC/DC radio receivers. They bite down on to the exposed live shaft of the control. The manufacturer would recess the screw well into the hole in its knob, then fill the hole with wax. An oversized screw that sticks out from the knob is a dangerous shock hazard if the mains input is reversed. An insecure knob may leave a live shaft when pulled off. Some shafts were insulated with special insulated coupling extensions. Later, fully insulated shafts were introduced.

A tip for removing a knob that's jammed on its shaft is to wrap a pocket handkerchief round the back of it. Once the circle of wrap has been completed, gather the handkerchief and gently but firmly rock the knob from side to side while pulling. Thats should get it off.

Battery sets

Battery sets were actually the first to come into general use, because in the early days of radio batteries were the most convenient form of power. Early radio was rather a DIY sort of thing, with lots of hands-on coil winding and experimentation. The battery valves of the period were of the directly-heated type,

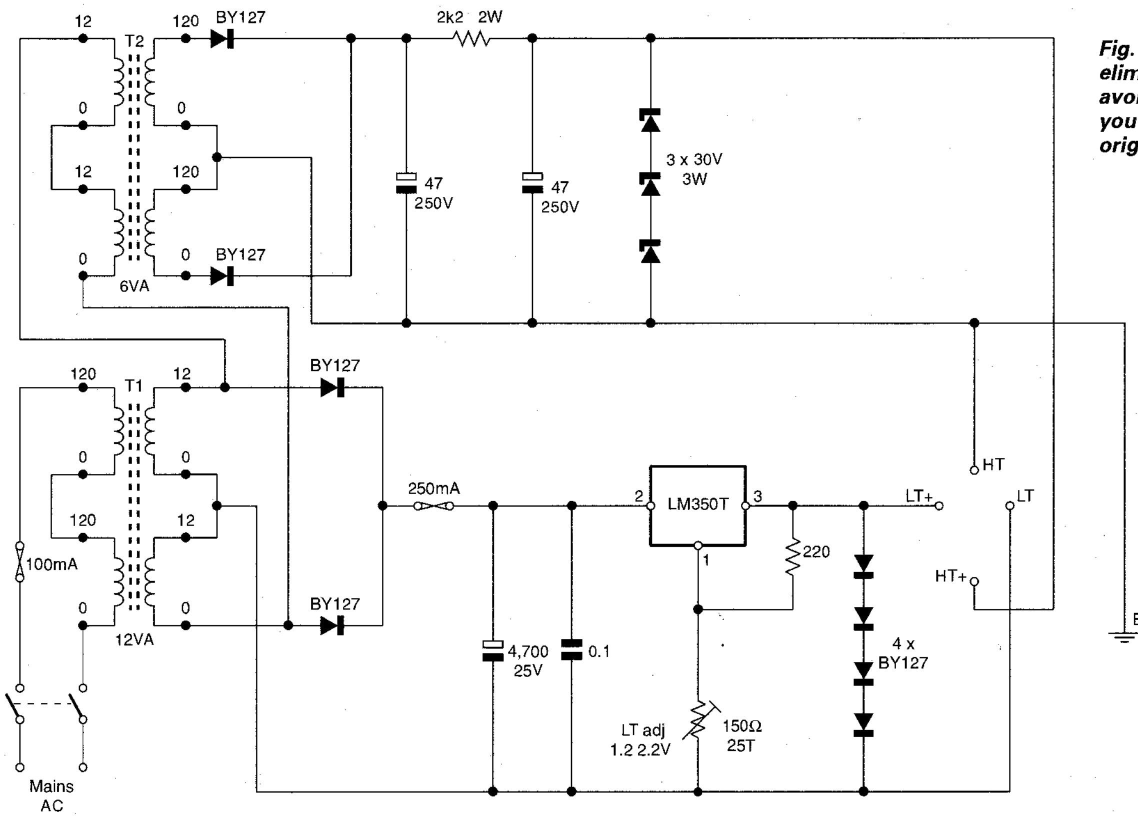


Fig. 5: This battery eliminator circuit avoids the problems you can get with original designs.

where the heater is the cathode. The sets used a varying number of valves, from one to five. Some provided an output for headphones only. These were of the metal-diaphragm type, with an impedance of 500Ω to 1kΩ.

The first sets used three batteries. There was a 2V rechargeable lead-acid accumulator for the heaters, a large HT battery that provided between 45-120V, and finally a 9V battery to provide the valves with grid bias. The HT and GB batteries consisted of banks of dry cells in a cardboard box, with taps to supply intermediate voltages. When, as the technology developed, 'automatic bias' was introduced, the grid-bias battery was dispensed with. Lead-acid accumulators were phased out as more economical valves became available. Only dry cells were then used to provide power. This was really the start of large-scale production and sale of battery-portable sets. Many examples are still around, such as the Pye P114BQ.

Even the more economical battery-operated valve sets were expensive to run, so battery-eliminator units were introduced. These little steel boxes took an input from the mains supply and supplied the DC voltages required to run the set, via sockets that took the original battery plugs. A cottage industry grew up from the high demand that developed. Kits of parts were sold, but the build standard of these is likely to be very poor verging on dangerous. Fig. 4 shows the circuit of one such unit that I happened to have in the workshop as part of a restoration.

Battery set on/off switches control only the battery side, so unplugging the eliminator or switching off at the mains is the only way of isolating the unit. A problem arises when the radio set is switched off using its own on/off switch. My tests showed that, unloaded, the HT supply from the eliminator rose to 156V, exceeding the 150V DC working voltage rating of its combined HT reservoir/smoothing electrolytic capacitor. The heater voltage also rose, to 3·5V. This is not a good situation. Even if the electrolytics don't break down, the set will have to absorb a high switch-on current when it's switched on again with the eliminator powered.

A strong smell of bad eggs coming from the eliminator means that the original selenium rectifier diodes are either under stress or on their way out. Don't just replace them with silicon diodes. A selenium rectifier has a higher internal forward resistance than a silicon diode, and the result will be far higher output voltages unless compensation resistors are added in series.

The mains lead attached to my sample eliminator is a thin figure-of-eight bell flex, with the ubiquitous knot to prevent it being yanked out of the case through the bare hole in the metalwork. Inside there's a bird's nest of wiring, with few supported joints other than those on the mounted components. Dating from the time when mechanical joints were the belt and soldering the braces, this little flash-bang abounds with lightest-touch only soldered connections. Sorting it out is a must.

Unless you manufacture your own batteries, you will need to continue to use these eliminators. Even when loaded they tend to provide voltage outputs that are too high. While a slightly increased HT voltage is not a major problem, overrunning the heaters of valves will considerably shorten their lives. Battery valves that have been overrun may not work when correct voltages are applied.

The margin for valves with 2V heaters is ±7 per cent, but ±10 per cent is acceptable. Valves with 1·4V heaters were designed to work with 1·5V cells: if damage is to be avoided, on no account should the voltage exceed 1·6V. Unfortunately, underrunning some valves can also shorten their lives.

Eliminators are vintage in their own right, but date from a later period than the sets themselves. A choice has to be made to either discard an eliminator; use a safe, modern circuit; or strip it and build a modern circuit in the old box.

I designed the battery-eliminator circuit shown in Fig. 5 for workshop use. The LT supply is stabilised by the LM350T IC. Adjustment of the 150Ω preset (25-turn wirewound) connected to pin 1 enables the heater supply to be set up for 2V or 1·5V. I couldn't find a small transformer with a suitable secondary winding for use in this circuit, so I used two transformers connected back-to-back. The mains input transformer T1 is rated at 12VA. It feeds the HT transformer T2 and the LT circuit. T1's primary winding is 0-120V/0-120V, its secondary winding being 0-12V/0-12V. Connected as shown, it provides full-wave (bi-phase) HT and LT rectification.

The LM350T IC has its tab connected to pin 3 (LT+), so it will have to be insulated if bolted to an earthed heatsink. The HT output is limited to 90V by the three 30V, 3W zener diodes. The four BY127 diodes across the LT supply, and the 250mA fuse, were added after I accidentally touched between HT+ and LT+ (the IC went short-circuit and the 1·4V supply shot up to 17V!). The four series-connected diodes clamp the LT output at a maximum of 2·4V: should the IC go short-circuit the fuse will blow.

Don't be tempted to link the HT– and LT– lines. In many sets there are special biasing and other functions that require them to be separate.

I obtained the zener diodes, IC and transformers from CPC (Preston, Lancs).

Next month

So much for basic circuitry, power supply arrangements and fault conditions. Next month we'll consider the tricky subject of component replacement in vintage equipment, and also look at tuning drives and alignment.

Restoring vintage radio sets

In this concluding instalment of his series Ian Rees deals with tuning drive cord replacement and RF/IF circuit alignment

A task that most engineers in the vintage years used to hate was stringing cord drives. Early sets tended to have some form of mechanical reduction drive, which enabled fine tuning to be carried out. There was often in addition a 'bandspread' control. This was a small, auxiliary tuning capacitor that moved the tuning a few kHz either side of the main setting. Subsequently large tuning scales with station names, rather than arbitrary log or degree marking, were introduced, bringing with them a whole new cat's-cradle of string technology. The waxed string used at the time is long gone. For replacement purposes white nylon cord of the type used for sail making can be purchased by the spool from boat chandlers in a variety of sizes. It's stronger and better than the original.

Restringing

Provided you plan the direction the cord has to travel, restringing a drive without instructions is not that difficult. With the gang fully closed, the pointer will be positioned at the low-frequency end of the dial. With this in mind, you have to visualise which way the cord will come off the tuning drum. Follow its direction on to the pulleys, considering the direction – left to right or top to bottom. The direction around the tuning knob shaft is important: it is most disconcerting to turn the knob clockwise and watch the pointer go from right to left. Finally, its journey around the remaining guides or pulleys and back on to the tuning drum has to be in the correct direction. Sometimes more than one cord is used. In this case life can be simpler.

There are many ways of stringing the same drive. The end test is: does the pointer track smoothly with the tuning knob, following its direction? And when the end of the scale is reached, will the cord stay in place if the knob is turned farther? It's no good setting up a drive if someone comes along, cranks it past the end stop and the whole lot then ends up as a tangle of string inside the set. What's required is enough slippage on the tuning spindle to prevent excessive pressure at scale end. At the same time there must be enough friction to propel the pointer and gang efficiently to their tuning points.

Cord thickness, the number of turns around the tuning shaft and system tension all matter. A bad fault is to allow cord turns to overlap when spooling. This will at best result in a twang and pointer judder, at worst a total lock-up or dismounting of the drive. A small misalignment of the pulleys or too many turns around the drum can be the cause. Cord of the wrong gauge can be the problem, or maybe a wrong pulley direction has been chosen.

As with most things in restoration work, patience is required.

Suggested procedure

My approach is to start with the gang fully open or closed, make a small loop in the cord, and attach the end to one of the tags on the tuning drum. If there isn't a tag, tie the cord to the locking screw on the drum shaft. Feed the cord through the slot in the drum's groove, in the opposite direction it will be feeding off. Estimate how much cord will be required around the drum to reach the first pulley and go that way. Note that the cord has not yet been cut. Continue feeding the cord around the pulleys. Make two-three turns around the tuning shaft, in the correct direction. Continue around the rest of the pulleys, finally arriving at the tuning drum from the opposite direction. Again estimate the amount of cord that will be required.

At this point it's possible, gripping the cord and the edge of the drum in one hand and turning the tuning drive with the other, to see if everything is going in the right direction. If all is well, a spring is usually attached to the tuning drum and the end of the cord is fixed to it. When tying the cord to the spring, a small amount of tension is applied. The action of the drive can now be checked from end to end. The final step is to attach the pointer – this may add a bit more tension to the system. Note that some makers fit the spring or another spring in the cord length.

I use the method described above where I have partial or no knowledge of how the dial is strung. Sometimes the old drive is in place but not working, or is hung loosely, broken. In such a case I try to copy the original arrangement. The best situation of all is where a plan of the cord drive exists, complete with directions and the turns around the shafts and drums.

When you are satisfied that the stringing works correctly, it's a good idea to put a small spot of glue on each knot, to prevent them coming loose.

Note that later sets employ a solid, stepped pulley design. The purpose is to alter the gearing ratio between the stepped pulleys.

The pointer will usually still be attached to either the cord or the scale pan. When it's totally missing, it is worth making one. A piece of 2·5mm copper wire, from a piece of twin and earth cable, formed into an L shape can easily be made to ride the string.

Alignment

Like restringing, alignment is as much an art as a science. The principles of alignment are easy to understand and to carry out. But doing so does not always provide the hoped for results. Empirical methods and compromise then have to be adopted. If the manufacturer's instructions are available, follow them. Otherwise the following is a guide to the process.

Before you touch anything, consider whether the set's performance is poor enough to warrant adjustment. Symptoms blamed on misalignment often have their roots elsewhere, so you have to be sure that all other possibilities have been taken into account. Even valve replacement has little effect on alignment. Few other faults apart from human intervention will move the factory settings.

Some cheap radio receivers were not very good when new. There is little to be gained by trying to tweak the tuned circuits if this fails to provide any improvement. If the waveband calibration and sensitivity are sufficient to provide reception of the main stations at reasonable volume without interference, leave the alignment alone. Many manufacturers painted or wax-locked the preset cores and trimmers after setting up. Where this locking is intact, I would be very reluctant to break the seals.

Equipment required

It's important to have the correct non-inductive trimming tools before you start, otherwise damage to the delicate dust cores etc. is guaranteed. A wallet containing all the tools you will need can be obtained very cheaply from CPC and other sources. Made of plastic, the tools are themselves very delicate and are easily broken in use. But I would rather break the tool than the trimmer being adjusted. Plastic knitting needles filed down to fit the cores are useful. When they break the end can be remade. Never use a metal blade.

Tuning wands are a help. Fig. 6 shows how easily they can be made. The first wand (a) consists of an insulated plastic shaft (knitting needle, ballpoint pen body etc.) with a small ferrite core at one end and a piece of brass screw studding at the other end. The ferrite can consist of several beads or an old IF core. The shaft serves as a handle. The cores at each end are glued in place. Inserting the wand's ferrite core in the former of an RF or IF coil increases the inductance: inserting the brass core reduces it. A change in sensitivity or tuning can indicate whether adjustment of the set's RF/IF core is warranted.

The second wand (b) is for use with ferrite-rod aerials. This time a piece of bare 3/8th inch diameter ferrite rod aerial a few inches long is required. Attach a 1in. loop of stiff insulated wire at one end with tape. Strip and twist together the ends of the wire so that it forms a shorted turn. Moving a coil that is paint- or wax-locked to a ferrite aerial is difficult. You can check whether a coil needs to be moved by putting the end of the wand's rod (the end where the coil is mounted) to the end of the aerial ferrite rod. On contact, the inductance increases: looping the shorted turn over the aerial coil reduces the inductance. Any improvement or otherwise shows whether the aerial coils need to be moved farther towards the centre of the rod (increased inductance) or away from the centre towards the end (reduced inductance).

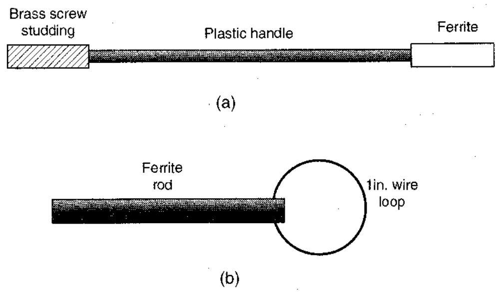


Fig. 6: Simple-to-make tuning wands, (a) for checking tuned transformers and (b) for checking a ferrite-rod aerial circuit.

Both wands provide a non-intrusive method of performance assessment.

There can be as many as twenty or more coil and capacitor adjustments in the average AM radio receiver. Some interact with each other. Without a calibrated RF signal generator and some form of output indicator, obtaining optimum performance is purely guesswork.

I use an old Nobrex 42 AM signal generator, which is as basic as things can be. But backed up with a frequency meter it gives an accurate signal.

Tuning for maximum output from the loudspeaker can be tiring and not very accurate. It's much better to disconnect the loudspeaker and connect an AC meter across the output terminals. I prefer to use an oscilloscope to monitor the signal across the volume control however. This enables the signal and noise to be seen separately, and the volume control can be turned down.

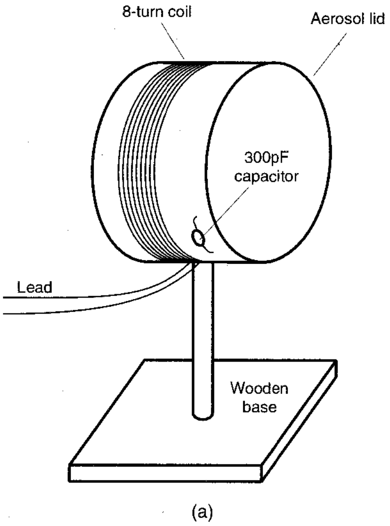
Manufacturers probably used a wobbulator for receiver alignment. The spot-frequency method is slow but can give just as good results.

There are several ways of feeding an alignment signal into a set. Inductive coupling is the best method if no instructions are available, as it requires no direct connection. Frame and ferrite aerials will pick up the signal directly. If the set is not fitted with an aerial of this type, the signal can be picked up by positioning it close to the set's tuning coil. Where the set's sensitivity is very poor, a direct connection to the aerial socket or the first grid of the frequency-changer valve will have to be made.

The construction of an alignment-signal coupling coil is shown in Fig. 7. It consists of eight turns of insulated 22 SWG wire wound on the 2in. diameter plastic lid of an aerosol can. Use PVC tape to hold the coil in place. A 300pF capacitor is connected in series with the coil and the inner conductor of the screened lead that connects the signal. The coil and capacitor leadouts are threaded through holes pierced in the plastic lid.

IF alignment

The starting point with receiver alignment is the IF transformers.



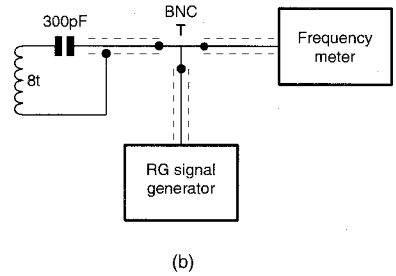


Fig. 7: Construction of an RF aerial coupling coil (a), with its connections shown at (b).

It's a good idea to check the tuning curve of the transformers first. It should have the classic steep sides and narrow peak. Set the signal generator to provide a 30 per cent amplitude-modulated IF signal – the usual receiver IF is 470kHz. Tune the radio to near the centre of its MW band (find a quiet spot). Position the coupling coil so that a clean, low-level signal can be seen or heard at the radio receiver's output. To prevent AGC action, keep the RF input signal very low. Otherwise, short out C11 (Fig. 2, page 528, July). If this causes problems, apply a small, adjustable negative bias voltage of about 0-3V DC. Swing the output from the signal generator slowly through the receiver's passband, and watch that it peaks at the correct centre frequency and falls away rapidly, by equal amounts, at each side until lost. If the tuning band is broad, skewed, kinked or off-frequency, the IF alignment may need to be set up.

With the arrangement as described above, alignment can begin. Start by adjusting the cores or trimmers of the final IF transformer (IFT2 in Fig. 2). Tune them for maximum output. Move to IFT1 and repeat. Do not allow the AGC to operate. Go back to IFT2, and repeat the procedure with the two transformers a couple of times until no further improvement can be achieved.

Hopefully, when the signal is removed and the set is tuned across its bands many stations will be received. If there is still room for improvement, RF alignment will be required.

RF alignment

RF alignment is not quite as easy as IF alignment. Before you commence, ensure that the station pointer is set correctly. Tuning scales often have marks that show where the pointer should come to rest at the ends of the scale. Datum settings, in kHz or metres, can also be found on scales and on the tuning drum (to enable setting up to be carried out when the chassis is out of its case and away from the tuning scale). The tuning scales will almost certainly be calibrated in wavelength (metres) rather than frequency (kHz, MHz). To convert wavelength to frequency, in kHz, simply divide 300,000 by the number of metres. For example 300,000/250 = 1,200kHz.

Before you start, it's a good idea to draw a layout that shows where the various trimmers and coils are and what they adjust.

Set the signal generator to 1,200kHz and connect its output as for IF alignment. Switch the set to the medium-wave band. Tune first at the HF end of the scale, at 250m. Adjust the oscillator preset trimmer (TCb, Fig. 2) for maximum output, then repeat with the aerial trimmer (TCa). Next set the signal generator's output at 600kHz and adjust the radio receiver's tuning at the LF end of the dial, at 500m. Adjust the oscillator coil (L2) for maximum output, then repeat with the aerial coil (L1). Keep the signal input below the AGC threshold by adjusting the coupling loop's position or using the signal generator's attenuator control. Repeat the adjustments a couple of times, or until no improvement can be achieved. Wax lock all the items adjusted.

Use the same procedure for the long-wave band. The preset oscillator and aerial trimmers will be found somewhere else in the coil pack. Don't touch the MW trimmers you have just set.

For short-wave alignment it's best to inject the signal via the banana aerial socket at the back. The principle is that same as with MW and LW alignment, but to be effective your signal generator will have to be a good one with an accurate attenuator and good screening.

TRF radio receivers

TRF radio receivers can be as complex as superhet ones. Some are multi-band and have three tuned stages ganged together. The waveband switching is awesome, as are the layout problems. A reaction control enabled positive feedback to be applied to sharpen the tuning, thus improving the selectivity and sensitivity. The volume control is often the reaction control. With simpler sets the oscillation could radiate and interfere with neighbouring radio receivers.

Alignment is similar to RF alignment with a superhet receiver. A badly-aligned TRF receiver may give no output at all. In this case the signal may have to be injected at the last RF stage first, followed by adjustment, then working back to the aerial input, aligning each stage in turn.

Reaction should be well backed off and the bandspread (if fitted) centred before you start. Each stage will be heavily screened, and great care must be taken not to disturb the wiring, otherwise instability may occur.

Not all RF stages will be tuned. A buffer valve is often included between the aerial and the first RF stage. It provides little gain and is present to prevent the set from radiating when the reaction control is close to critical.

A TRF receiver's audio stages are very similar to those already described.

Detection is usually carried out by the last RF valve, using a method called "leaky-grid detection". The valve concerned will be *RC*-coupled to the previous stage by means of a small-value capacitor (about 100pF) and the grid resistor (about 2MΩ). Detection is carried out by the valve's control grid acting as a diode anode. A choke or resistor in the valve's anode circuit blocks RF and allows only the demodulated audio to pass to the AF stages.

TRF receivers may be battery, AC or AC/DC operated, using power supply circuits similar to those previously described.

Valves and service data

The following firms can be tried for any valve requirements:

Colomor (Electronics) Ltd., Unit 5, Huffwood Trading Estate, Brookers Road, Billingshurst, West Sussex. Tel. 01403 786 559.

Langrex Supplies Ltd., 1 Mayo Road, Croydon, Surrey CR0 2QP. Tel. 020 8684 1166.

PM Components Ltd., Selectron House, Unit A, Jenkins Dale Industrial Estate, Chatham, Kent ME4 5RD. Tel. 01634 848 500.

Valve and Tube Supplies, Woodland Vale House, Calthorpe Road, Ryde, Isle of Wight PO33 1PR. Tel. 01983 811 386.

For service data, try the following:

Mauritron Technical Services, 8 Cherry Tree Road, Chinnor, Oxon OX9 4QY. Tel. 01844 351 694.

Savoy Hill Publications, 50 Meddon Street, Bideford, Devon EX39 2EQ. Tel. 01237 424 280 (phone/fax) or e-mail savoy.hill@lineone.net ■

FM stereo radio tends to be taken for granted, so much so that many technicians have little understanding of what it involves.

Keith Cummins describes the technology, including decoder circuit operation and the radio data system (RDS) that was added in the Eighties

FM stereo radio and RDS

FM stereo radio transmissions have been available in the UK since the Sixties. They have become part of everyday life, so much so that the technology is taken for granted and little understood. This article describes the basic Zenith-GE system, which became a world standard (including the French for once!), and also takes a look at the basics of RDS (Radio Data System), a later development that was added to FM stereo transmissions in the Eighties.

Precursors

Before FM stereo became available there was FM mono, which provided a better audio bandwidth and interference immunity than AM radio broadcasting on the medium and long waves. The FM audio bandwidth was 15kHz, which compares with 4·5kHz for the AM broadcasts. Because the maximum FM deviation was 75kHz, the receiver bandwidth needed to be at least 150kHz, which is why FM was transmitted at VHF where there's enough 'elbow room' for the signal.

One potential problem with FM is the fact that the noise level increases with the square of the bandwidth. A process called pre-emphasis is used to improve the signal-to-noise ratio: it increases the level of the higher audio modulation frequencies to compensate for the higher noise level. The pre-emphasis characteristic is defined as being identical to the admittance-frequency curve of a parallel resistance-capacitance network with (for the UK and Europe) a time-constant of 50µsec. If you do the sums, it works out at a lift of 3dB at 3·18kHz and 6dB per octave thereafter. At the receiving end a series *RC* network with a 50µsec time-constant restores a level frequency response while reducing the upper (15kHz) audio noise by 13dB.

A 20·5MHz band, from 87·5-108MHz, is assigned to FM transmissions by international agreement. This has been adhered to by all except some Eastern European countries prior to the break up of the Soviet Union – they used frequencies around 65MHz.

Advent of stereo

It was only a matter of time before methods were sought to enable stereo signals to be broadcast. There

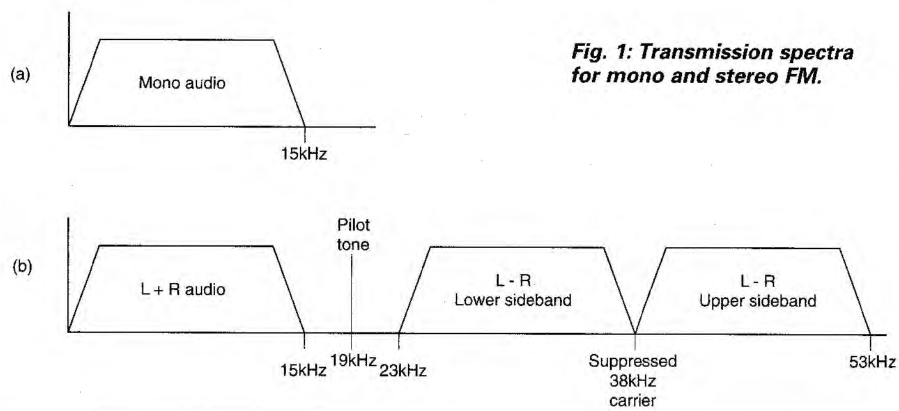


Fig. 1: Transmission spectra for mono and stereo FM.

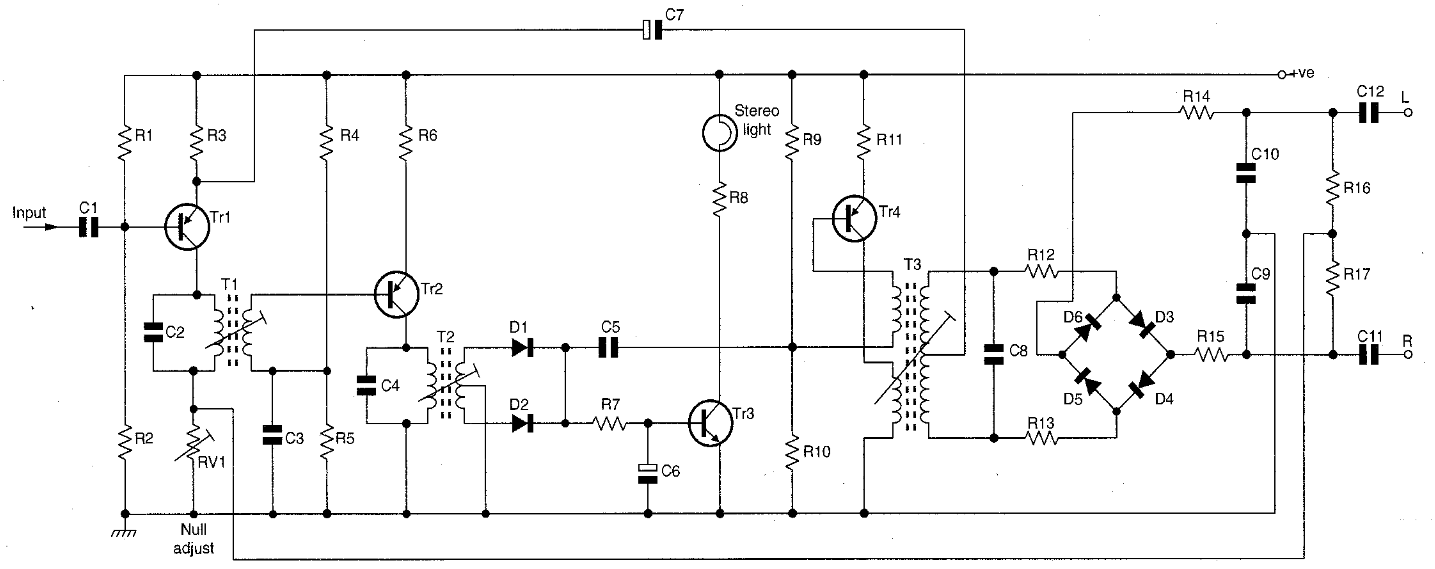


Fig. 2: Typical early stereo decoder circuit, simplified.

was insufficient bandwidth at the time in the AM bands, and no technically viable method of transmitting AM stereo was available or, because of the bandwidth limitations, considered desirable. It was therefore decided that the possibility of transmitting stereo within a single FM channel should be investigated.

A prerequisite was that the transmission method had to be compatible, i.e. a mono receiver could receive a stereo broadcast as if it was a mono signal, with imperceptible reduction in audio quality. The Zenith-GE system was devised in the US to meet this requirement. As its name suggests, it was the result of co-operative development by the two companies. Because the system was so successful, it was adopted worldwide.

There's a price to be paid however: the system introduces a 22dB deterioration in the signal-to-noise ratio, which means that a higher aerial signal level is required to obtain the same signal-to-noise ratio as with a mono signal. Most of you will probably have experienced noisy FM stereo reception, and will know that in this situation the signal-to-noise ratio can be improved significantly by switching the receiver to the mono mode. The reason for this will become clear later.

Basics

Fig. 1 shows at (a) the transmission spectrum for a mono FM signal and at (b) the transmission spectrum for stereo FM. The mono part of the transmission is still present in the stereo version: it consists of the left and right channels added together (L + R) and divided by two. The bandwidth of this part of the transmission is limited to 15kHz. An unmodulated pilot tone is transmitted at 19kHz, at a level of –20dB relative to the signal required to produce the maximum ±75kHz deviation of the main carrier. At 38kHz there's a suppressed amplitude-modulated subcarrier*, whose symmetrical sidebands carry a difference signal which is obtained by subtracting the left and right channels and again dividing by two, i.e. (L – R)/2. The bandwidth is ±15kHz, centred on 38kHz, so the overall difference signal occupies the frequency range 23-53kHz. A mono receiver will not respond to the pilot tone and the difference subcarrier, simply reproducing the sum signal as mono sound. Thus compatibility is maintained.

Once you have the sum and difference of the left and right signals, the original L and R information can be recovered by simple mathematical manipulation. Think for a moment about two figures, say 12 and 2. The question is, which two numbers when added make 12 and when subtracted leave 2? You can do it in your head. The answer is 7 and 5. The stereo decoder has to carry out a similar manipulation.

To put it algebraically, we have (L + R)/2 and (L – R)/2. Adding these gives us (L/2) + (L/2) + (R/2) – (R/2) = L. Then, if we reverse the phase of L – R and make the equation (L + R)/2 minus (L – R)/2 we get (L/2) – (L/2) + (R/2) + (R/2) = R.

So simple processing can be used to recover the original L and R signals. I'll describe the basic circuit that achieves this later, after explaining why the 38kHz subcarrier is suppressed and why there's a pilot tone.

The subcarrier

Consider the situation where L = R, i.e. the sound is coming from midway between the stereo speakers. The signal is effectively a mono one, and L – R = 0. Thus there's no modulation of the L – R subcarrier which, being suppressed and having no modulation sidebands, simply vanishes. This means that in the mono state no subcarrier energy is used and the difference signal is significant only when the difference between the R and L channels is large.

The most dramatic and unlikely situation would be the very odd one where L = –R or R = –L. In this case the mono sum signal L + R vanishes, which means that a non-stereo receiver would be silent! The broadcasters could not allow this, so the difference subcarrier always represents a lower energy level than the sum signal, especially as the subcarrier is suppressed. This helps maintain mono compatibility.

The pilot tone

The pilot tone has two functions. One is as a 'flag', to indicate that the transmission is a stereo one: it's the pilot tone that turns on the

*With FM the deviation is proportional to the amplitude of the modulating signal.

stereo light. Secondly and most importantly, the pilot tone provides the means of recovering the difference subcarrier modulation.

To do this the missing 38kHz subcarrier has to be regenerated in the receiver. So the 19kHz pilot tone is passed through a frequency doubler to produce, or synchronise, the 38kHz carrier needed for demodulation of the difference signal.

The relative phasing of the pilot tone and the subcarrier is important and is defined in terms of L and R, so that if L is positive and R is equally negative the subcarrier crosses the zero line in a positive direction each time the pilot tone passes through zero. The phase tolerance is ±3°.

Noise level

Earlier I mentioned that stereo transmission incurs a degradation of the signal-to-noise ratio compared with a mono transmission, and that the noise level with FM increases with the square of the bandwidth. For mono the bandwidth is 15kHz, while for stereo it widens to 53kHz.

For a first-order approximation we can write

$$20\log_{10}(15/53)^2.$$

So the change in signal-to-noise ratio, in dB, is –21·92dB, the minus sign indicating deterioration. Peter Eckersley, the first Chief Engineer of the BBC, put this well when he commented "the wider you open the window, the more dirt blows in!".

SCA

Before providing a description of the basic FM stereo decoder I should mention SCA, which stands for Subsidiary Communications Authority. This function is part of the Zenith-GE system as used in the US and consists of a further subcarrier at 67kHz, frequency modulated by a maximum of 4kHz with ±3·5kHz deviation and 150μsec pre-emphasis. This narrow-bandwidth audio channel is used for distribution of Musak to hotels and supermarkets and is sometimes called Storecasting. I have not heard of the system being used in the UK. It has been used for radio paging in some areas of the USA.

Stereo decoder operation

Today FM stereo decoders (or FM multiplex decoders as they are alternatively called) generally reside inside a chip. If the stereo radio chip fails you replace it, end of story. It was not always so of course: early decoders used discrete circuitry. Fig. 2 shows a typical, simplified circuit to illustrate how the decoder works.

C1 couples the stereo input signal to Tr1, which is basically an emitter-follower with a 19kHz tuned circuit, C2 and T1, connected in series with its collector. The tuned circuit picks out the pilot tone, which is amplified by Tr2 then passed via T2 to the full-wave rectifier circuit D1, D2. When a pilot tone is present, filtered (R7, C6) DC from D1 and D2 turns Tr3 on and the stereo lamp lights.

The ripple at the cathodes of D1 and D2 is at 38kHz. This signal is used to synchronise an oscillator circuit which consists of Tr4 and T3, providing a switching signal for the diode ring demodulator D3, D4, D5 and D6. The stereo signal's L + R and L – R components are fed via C7 from the emitter of Tr1 to the centre tap of T3's secondary winding and then to the diode ring. A clever thing happens here. The diode ring action simultaneously demodulates the subcarrier and demultiplexes the L + R and L – R signals. So the L and R signals are recovered in one hit. They are de-emphasised by R14/C10 and R15/C9 respectively and fed out via C12 and C11.

In the absence of a stereo signal Tr4 and T3 oscillate unsynchronised and continue to switch the diode ring which produces L + R (mono) at each output.

What about the feedback from R16/R17? Because bandwidth limitations at the transmitter cause attenuation of the subcarrier harmonics, the received L – R signal is reduced by a factor of 2/π. To compensate for this, the L + R signal is reduced accordingly by introducing a partial cancelling signal, which is set by RV1 for optimum channel separation – with this type of circuit about 30dB.

Chip-based decoders use a phase-locked loop to regenerate the suppressed subcarrier, and typically achieve a 50dB channel separation which is consistent and largely independent of any setting up. The output from a 76kHz master oscillator is divided by two to provide 38kHz. A further division by two produces 19kHz, which is frequency and phase compared with the transmitted pilot tone to provide AFC for the master oscillator.

RDS

Many tuners and car radios now include RDS (Radio Data System) facilities. The system provides identification of transmissions, types of programme and time. It also enables a car radio to change frequency automatically to maintain optimum reception of a given programme while driving through different transmission areas. The system is complex: the European Standard EN50067 "Specification

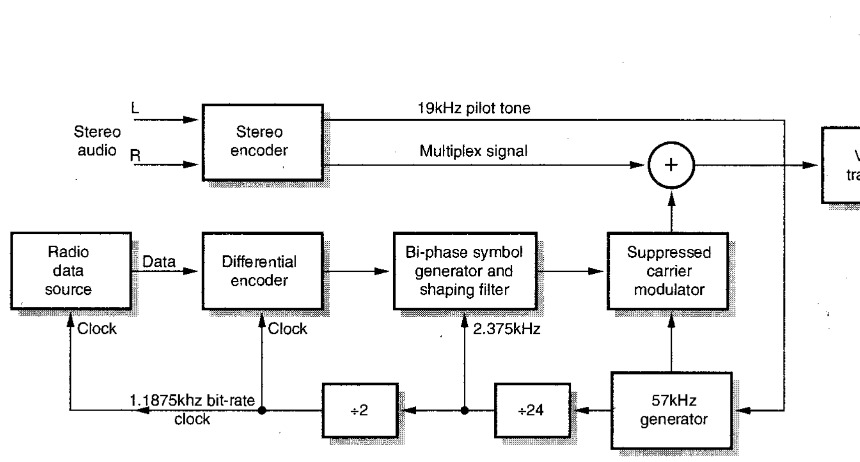


Fig. 3: Block diagram of the RDS encoding process.

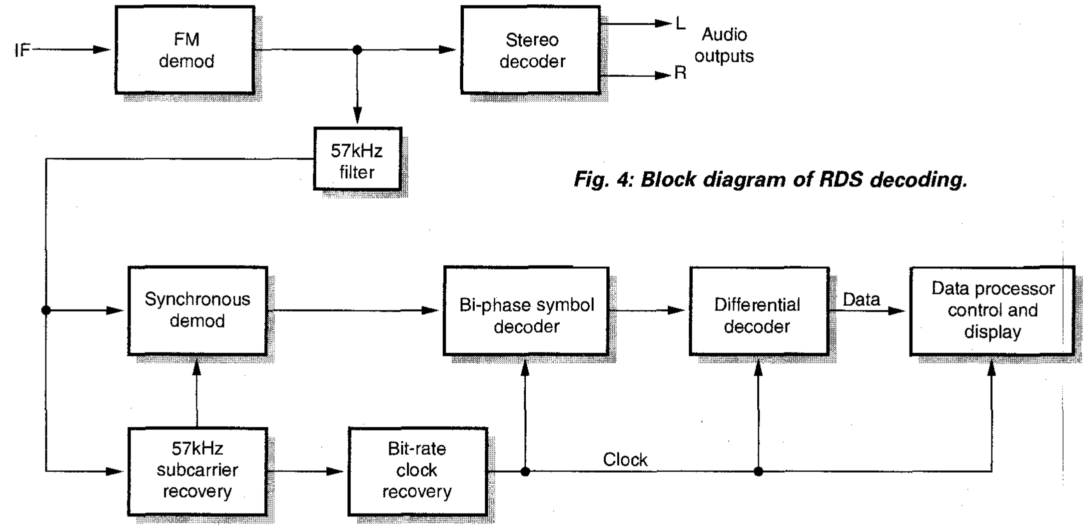


Fig. 4: Block diagram of RDS decoding.

of the Radio Data System (RDS) for VHF/FM sound broadcasting in the frequency range from 87·5 to 108·0MHz" is a weighty document that runs to 132 pages. Furthermore copyright is involved, so my description of RDS must be confined to the method of modulation, data recovery and the basic coding involved.

RDS uses a second subcarrier at 57kHz, locked to the third harmonic of the 19kHz stereo pilot tone. The 57kHz subcarrier is also suppressed. Its sidebands contribute a maximum deviation of the main VHF carrier of ±2kHz. The maximum permitted deviation of the overall multiplex signal remains at ±75kHz. The suppressed subcarrier is amplitude modulated by a shaped and bi-phase coded signal which is derived from the radio data source.

Fig. 3 shows the transmission system in block diagram form. The signal from the data source is differentially encoded, such that when the input data level is zero the encoder's output remains unchanged from the previous output bit and when an input one bit appears the new output bit is the complement of the previous output bit. The receiver decodes the data by applying the reverse process, and the data is correctly decoded whether or not the demodulated signal is inverted.

The power of the data signal around the 57kHz subcarrier is minimised by coding each data bit as a bi-phase signal. This prevents disruption by crosstalk in phase-locked loop stereo decoders.

The 57kHz generator is locked to the 19kHz pilot tone. Its output is divided by 24 to produce 2·375kHz and then by two to produce the 1·1875kHz bit-rate clock. The 2·375kHz signal is used for bi-phase generation.

A typical decoder block diagram is shown in Fig. 4. Note that because this is a digital system the 57kHz signal is embedded in the bit stream, from which it can be recovered, rather than employing the third harmonic of the pilot tone. The rest of the circuit is basically complementary to the transmission chain shown in Fig. 3.

The transmitted coding pattern consists of four data blocks that each contain 26 bits. Each block consists of a 16-bit information word, with the remaining 10 bits constituting a checkword for error correction. The first block in each group of four always contains a programme identification code. The first four bits of each second block comprise a code that specifies the application of the group. The remainder of the data provides specific information, e.g. type of programme, traffic announcement, frequencies, time etc., and alternative frequency details. The level of functionality provided would not be viable without the use of LSI chips dedicated to the system.

From the servicing point of view it's a matter of checking and replacing chips. In all likelihood the precise nature of a fault may never be known. Such is the complexity we now have to live with, be it car radios or digiboxes!

Acknowledgement

My thanks to David Thorpe, Engineering Field Officer for the Radio Authority, for his assistance in providing information that enabled me to write this article. ■

Vintage repair:

A Bush VTR103 radio

Pete Roberts tackles an AM/FM radio that failed to provide reception in any of the bands. The use of germanium transistors had some advantages in terms of performance quality

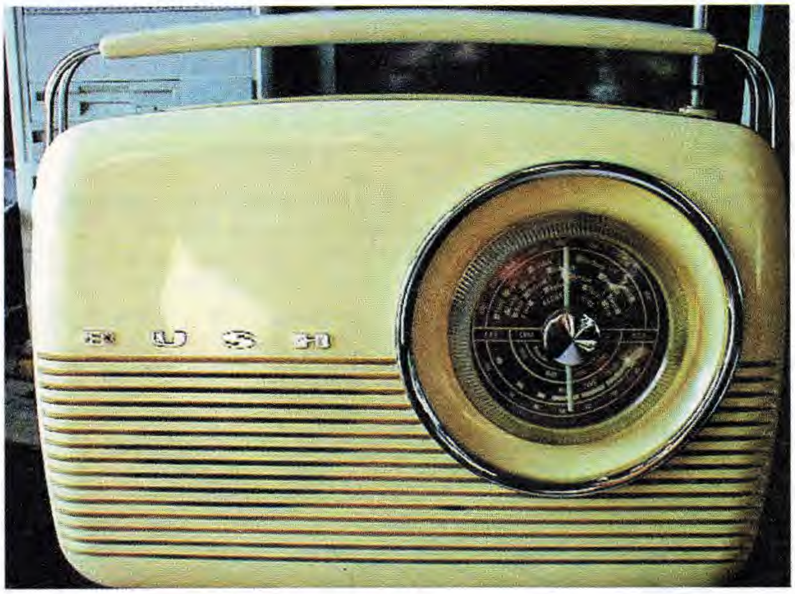


Photo 1: Appearance of the Bush Model VTR103, an AM/FM receiver that dates from 1962.

How's this for a classic? A three-band Bush radio Model VTR103 dating from 1962, with VHF coverage 88-100Mc/s (we'll drop Hz this time to keep in the spirit of things). Photo 1 shows the receiver, and Photo 2 the internal layout. The fault report was no reception, just crackling. I connected the receiver to my bench power supply, set for 9V output, and found that the current consumption was 20mA (spot on for MW/LW reception). So there was obviously nothing seriously wrong.

Circuitry

The set is fairly complex compared to most radios of the time. Unlike the two-band TR82, the RF/IF stages use the then new Mullard alloy-diffused junction transistors. Starting from the front end, the VHF tuner has an AF114 RF amplifier followed by an AF115 self-oscillating mixer, both operated in the common-base mode. The MW/LW mixer/oscillator, which acts as the first IF amplifier for VHF reception, and the two following IF stages all use AF116 transistors. The VHF IF is 10Mc/s, the AM IF 470kc/s. An OA90 diode is used for AM detection while a pair of OA79 diodes is used in the FM ratio-detector circuit.

The audio section starts with an OC71 preamplifier transistor which is followed by an OC81D driver transistor. This is transformer-coupled to the OC81 output transistors, the secondary winding on the driver transformer having a centre-tap that's connected to chassis. The output stage is very nice: it's a balanced push-pull type with a meaty valve-radio sized output transformer. The transistors are pnp types throughout, with their emitters fed from the 9V rail.

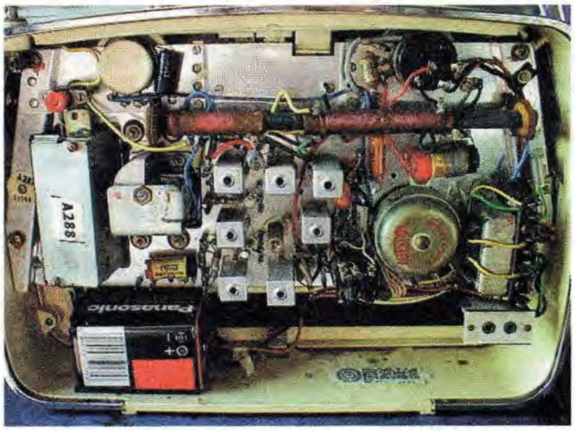


Photo 2: Internal layout of the VTR103.

Fault finding

I decided to tackle the loss of AM signals first. Touching the wiper of the volume-control potentiometer produced a healthy mains hum, so the audio stages were working – it never ceases to amaze me how quiet germanium amplifiers can be compared with modern silicon circuitry. Measurements around the three AF116 transistors produced voltage readings close to those shown on the circuit diagram.

The AF11X range of transistors are housed in large TO7 cans. They all suffer from a peculiar problem: the collector develops a short-circuit to the case. This is caused by a conductive whisker forming in the silicone compound that's used to protect the transistor wafer. The transistors in the VTR103 were all OK in this respect however.

Further experimental signal injection (touching various points with a screwdriver in contact with my finger) produced hash when the base of the final IF amplifier transistor was contacted but nothing when the base of the transistor in the previous stage was contacted. So I replaced the first IF transistor, using an AF126. This is the later version of the AF116, in the much larger TO74 can. Voila – up came medium- and long-wave reception., But there was still no VHF reception.

When the set is switched to VHF, signal injection of the type just described should result in short-wave noise (10·7Mc/s is about 30 metres). But I couldn't raise a cheep anywhere while poking about in the RF/IF stages. So I decided to adopt the 'official' approach and brought out my trusty Advance E2 valve signal generator, allowing it to warm up for the recommended twenty minutes! While waiting, I checked the two OA79 diodes in the ratio-detector circuit: they were both OK.

When I injected a high-level amplitude-modulated 10·7Mc/s signal at the collector of the final IF amplifier transistor there was the expected distorted 400c/s tone, but silence when the probe was transferred to the transistor's base. What sort of transistor fault can give correct DC conditions and satisfactory operation at 470kc/s but no results at 10·7Mc/s? I've long given up applying what some call "logical deduction of fault conditions". In went another AF126, and the result was short-wave noise when I touched the VHF tuner's IF output. But still no VHF reception.

The VHF tuner is in a separate screening can and uses permeability tuning, with an RF amplifier stage and a self-oscillating mixer. Access is easy: undo two 6BA nuts and the tuner housing can be slid off, revealing both sides of the PCB and the permeability tuner with its cord-tensioning spring, see Photo 3. Once again voltage checks around the two transistors produced readings close to those shown on the circuit diagram.

Now where I live, at Runcorn, I am not only at the top of a multi-story building which is itself sited on top of a hill, but I'm also in the primary service area of the Holme Moss transmitter and surrounded by strong local-radio transmitters. So I have to be very careful when servicing VHF/FM receivers as the signals here are so strong across the band that a set with a dead RF amplifier can still hit the limiting level. Thus in my workshop a VHF radio with working IF stages means just one thing: a dead mixer/oscillator.

After replacing the AF115 mixer/oscillator transistor with an AF125 I was rewarded with excellent VHF reception and, surprisingly, no realignment was required despite fitting the physically much smaller AF125 – all stations appeared at the correct points on the alignment check dial (see Photo 4).

Something else that surprises me is how low the inter-station noise is with these old receivers. I've noticed this with most of the early Sixties gear I've serviced: there's nothing like the raucous hash you get with modern equipment. One thing I did notice, with our crowded VHF band, was 'birdying' because of poor image rejection, though this was significantly reduced when the tuner's screening can had been refitted. Of course this forty-year old radio receiver was originally designed to receive just three widely-separated stations at nothing like the field strengths we have today.

Capacitors

The electrolytic capacitors in this Bush receiver are all those attractive two-tone Plessey ones I liked as a boy and still like now. Even the labels were in good nick. Experience has shown that these capacitors continue to be pretty reliable even after all these years. The low quiescent current proved that none of the decouplers were leaky, so I left them all in place.

Likewise the Hunts moulded capacitors. Now I know that these had a very bad reputation when used in valve radios and TV sets: the cases crack and the paper dielectric becomes leaky. I remember, when I were but a lad, watching Hunts Supamolds going up in a puff of smoke when a particularly ratty old radio was first plugged in after years of disuse. In a transistor set however the capacitors aren't subjected to the high temperatures that damage the moulded casing, nor are they run at anything near their rated voltage. I've never had reason to replace a Hunts moulded capacitor in a transistor radio.

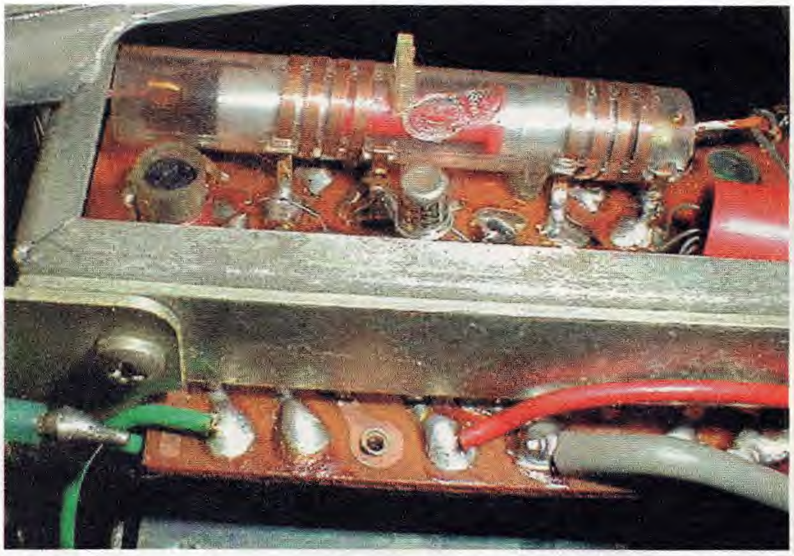


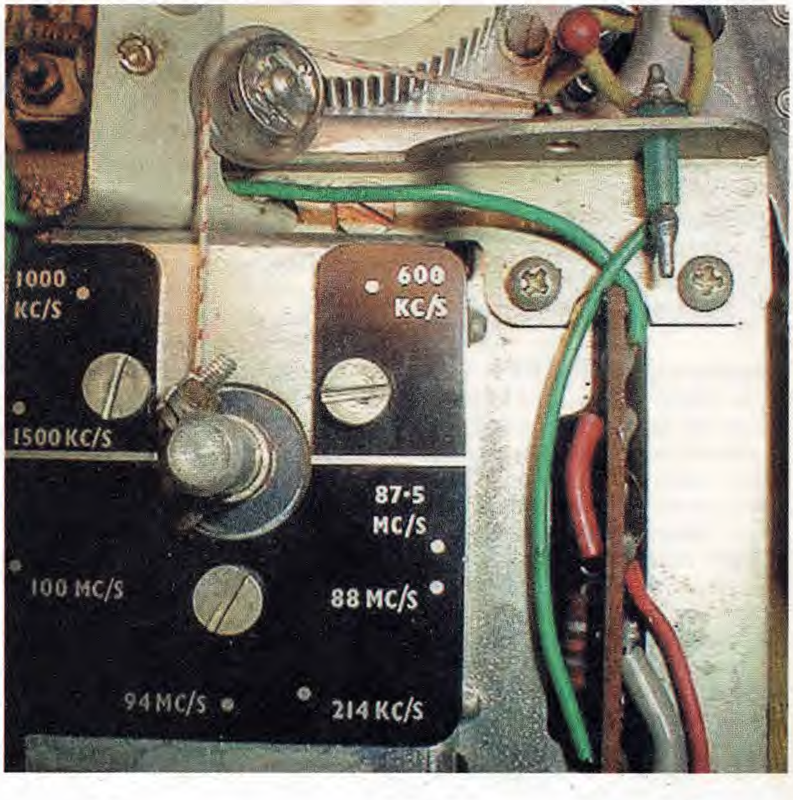
Photo 3: The VHF tuner, after removal of its screening can.

Chassis removal

I really dreaded one part of the job: removing the chassis. This is held in place by four screws that are easy to remove, but you also have to pull off that tuning knob! And after forty years it was tight. The recommended method of removal is to pull it off with a sink plunger but, having run out of these, I had to resort to other methods.

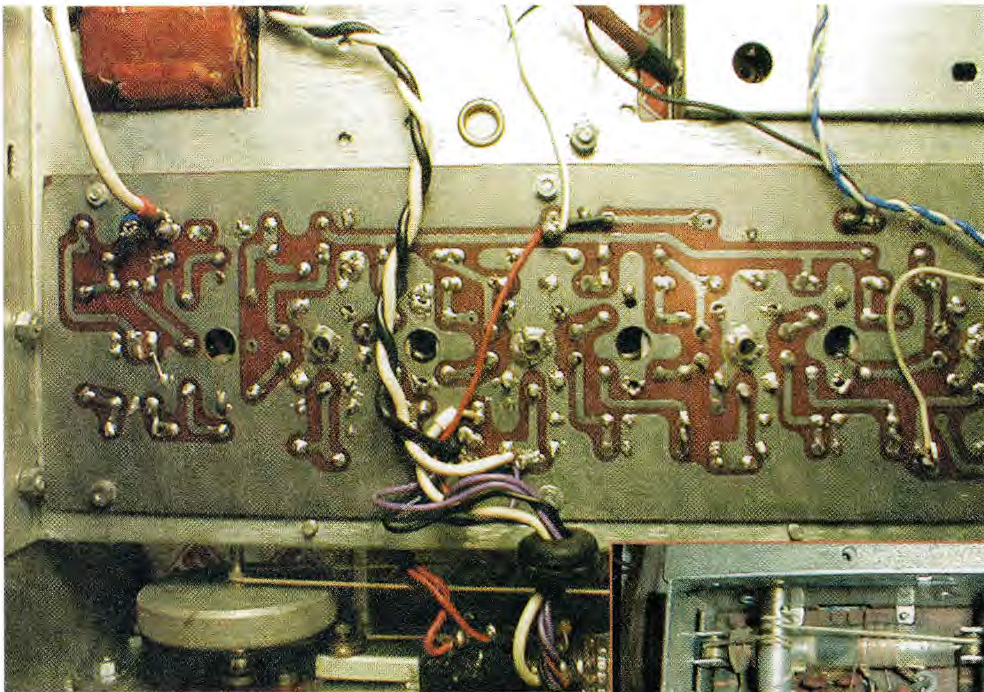
One thing you must never do is to try to prise the knob off with a screwdriver – that approach is guaranteed to crack it. I had to ease my not particularly dainty fingers under the knob, helped a bit by longish nails, then slowly and carefully rock it back and forth while pulling it gently. After about five minutes the knob relinquished its grip on the tuning gang's shaft. This particular radio is of great sentimental value to its owner, so I had to take the greatest care. There's a moral here: avoid trimming your nails before dismantling a Bush radio! ■

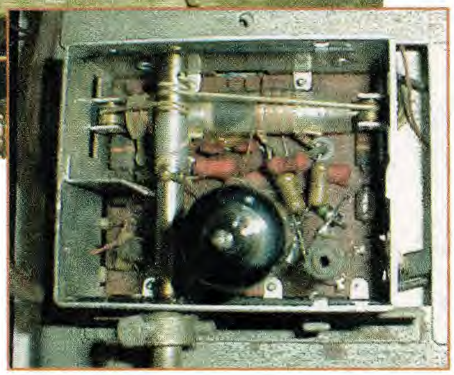
Photo 4: The alignment check dial.



Vintage repairs

Pete Roberts describes a couple of 'no-reception' faults with vintage radio equipment, a Radford FM tuner and a Motorola car radio.





The IF strip in the Radford FM tuner.

Inset: the tuner head in the Radford Model FMT1.

My latest vintage equipment servicing efforts involved two nice items, a Radford hybrid FM tuner, Model FMT1, and a Motorola 124 car radio. The latter was typical of dozens I repaired as a callow youth about thirty years ago. The problem with both was said to be "no reception".

The FM tuner

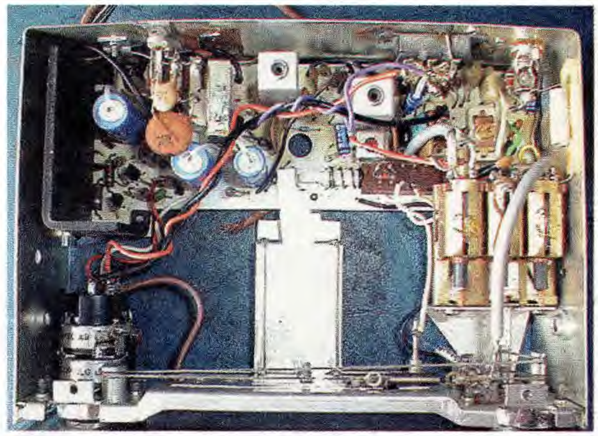
The Radford tuner matches in appearance the firm's contemporary preamplifier/control unit and power amplifier. That is, it's housed in a strong battleship-grey metal cabinet and weighs as much as a light destroyer. Going by the date codes on the electrolytic capacitors, I assume that this particular example hailed from the mid-Sixties. The valve line-up is as follows: an ECC85 RF amplifier/mixer-oscillator; three EF89 vari-mu IF amplifiers; an EF80 limiter; and an EM87 tuning indicator. Two germanium diodes are used for demodulation, which is followed by a two-transistor audio amplifier that uses an odd Texas Instruments device with an unreadable number and an AC128. The IF strip and audio amplifier are both built on PCBs that are mounted on cut-puts in the metal chassis. The RF amplifier and self-oscillating mixer stages are contained in a screened, permeability-tuned tuner head.

After checking for any obvious faults I applied power and switched on. The heaters all came up to normal brightness, but the magic-eye's display was very dim and showed no movement as I spun the dial across the band. I'd already checked that the permeability tuner's cores were free and moving. Then I saw it, balefully staring at me from the centre of the chassis: a Sen-Ter-Cel selenium bridge-rectifier block. So out came the meter, which showed that the HT supply was less than 90V – with an input from the mains transformer of about 250V AC! Knowing these things from long ago, I discharged the HT reservoir and smoothing capacitors (3 x 16+16μF, 350V wkg, 450V surge, with each having both sections wired in parallel) and measured their capacitances. 32μF in each case – not bad for 35-year old capacitors!

Suspicions confirmed, out came the selenium rectifier block: old hands may recall that meter checks on this type of rectifier could never be relied upon. I just happened to have a fairly substantial 1kV, 8A silicon bridge in stock. So in it went, with a 1,000pF, 250V AC class Y ceramic capacitor wired across the AC input to protect it from transients – always advisable when using silicon rectifiers with a transformer-derived high-voltage supply. OK, so 8A is a bit over the top, but it saved having to use tagstrip to mount a 1A part. After fitting it I was rewarded with success. With the valves heated the HT was now at about 270V, confirmed by a nice, bright magic-eye. Better still, the display flickered when I spun the tuning knob. As the magic-eye's control voltage is derived from the ratio-detector circuit, audio should have been present. But there was still silence.

Audio section

This tuner's audio section is odd to say the least. The post-detector transistor audio amplifier's output goes to a 5-pin DIN socket which is mounted on the rear panel. The twin-gang front-panel volume control is connected to the same socket, via a pair of screened leads. Another pair of screened leads connects a set of phono sockets, again mounted at the rear, to the wipers of the ganged volume-control potentiometers. My customer told



me that he took the mono signal from the DIN socket, which is obviously there to connect an external stereo decoder – bearing in mind that this tuner was built a couple of years before stereo transmissions started in the UK. Needless to say the volume control has no effect when the output is taken in this way.

The loss of audio was caused by a broken transistor lead. After repairing this I was able to tune across an FM band solid with signals. The audio amplifier is powered from the main HT line via a 2W carbon resistor that was rather cooked. When measured, the amplifier's supply was found to be 34V. As the AC128 transistor has a maximum Vce of 32V, I decided that this was not a good idea! I don't have a circuit diagram, and couldn't make out the original value of the dropper resistor (it measured 27kΩ). So I replaced it with a 33kΩ, 3W flameproof metal-film resistor mounted well off the preamplifier's little PCB. The audio amplifier's supply then measured 28V. With the replacement resistor running just comfortably warm and the audio quality unaffected, I decided to leave it at that. Reasonable longevity should be assured. I wonder why Radford didn't stabilise the preamplifier's supply with a zener diode?

Quite a few soldered joints on the IF amplifier PCB looked a bit past their best, so I did a blanket resoldering job, taking particular care to make good the joints that secure the valveholders. The unit was soak tested for a fortnight, then parcelled up for its journey home to the north of Scotland.

The Motorola

The Motorola 124 car radio was in excellent cosmetic condition for its age. It was one of the later all-silicon models made during the very late Sixties, with an output stage that features those odd little Motorola 'liquorice allsort' power transistors that have a distinctive, gold-plated heatsink tab. There's an RF amplifier stage prior to the mixer/oscillator stage, both being permeability tuned to provide full LW and MW coverage. The IF is 470kHz, and the single IF amplifier stage has two double-tuned IF transformers.

The reported fault was "no reception", but when I connected a speaker and my 13·8V bench power supply there was the usual MW noise – though not very much. After a few minutes even this disappeared, but wiggling the aerial plug in its socket would bring the set back to life. No need to 'hunt the fault' here: the symptoms were those of a duff detector diode. A new OA90 diode restored reception.

But the sound was thin and the volume a bit low. Turning up the wick produced obvious clipping at a still modest level. The output stage is of the familiar complementary-symmetry 'totem-pole' type, with capacitive coupling to the speaker. The 1,000μF, 25V coupling capacitor was the cause of the trouble, being almost open-circuit.

The electrolytic capacitors were all those nice golden and usually very reliable German Frako types. But the radio had no doubt been regularly toasted during its thirty odd summers, so I thought it prudent to replace them all. When refurbishing old radios I find that modern radial electrolytics aren't right from the appearance point of view. So I use those awfully nice blue BC Components axial capacitors which, though smaller, otherwise look just like their Sixties Philips predecessors. To many vintage radio enthusiasts the appearance of "the works" is as important as that of the case.

Dry-joints are a common fault with these radios. The PCBs appear to be flow-soldered and, sometimes, there are just minimal amounts of solder with the component leads clearly visible. So I undertook a blanket resoldering. This is particularly important as car radios are subject to vibration, which can also shift cores. Because of this I checked the alignment – a tweak of the IF cores provided a useful increase in gain.

Finally, never forget to check the voltage and polarity before applying power when repairing a vintage car radio: 6V radios weren't all that rare, and most Sixties models will be set for positive earth. The polarity setting is usually indicated by the position of a switch, but Radiomobile models use soldered links on the PCB – the position of these will need to be checked. Always ensure that the polarity is set as originally. It might be a good idea to note the polarity on the customer's invoice. Impress on the owner the need to fit a suitably-rated fuse in the supply lead. A 3A rating is adequate for most radios of the period.

***Top left:* The Motorola car radio Model 124.**

***Top right:* Internal view of the Motorola Model 124.**

***Below:* Electrolytics in the Motorola 124.**

Vintage radio repair

Pete Roberts tackles a couple of vintage transistor radios, an Ekco Nautilus Model PT310 that dates from the early Seventies and an original Roberts R700 that was built in 1968

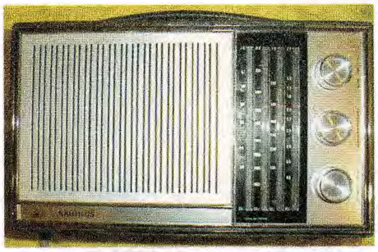


Photo 1: External view of the Ekco Nautilus Model PT310.

Welcome again to the vintage page. Here's some real nostalgia from the days of the Light Programme, Home Service and Luxembourg on 208! I tend to concentrate on transistor radios from the Fab Fifties and Swinging Sixties, but table and portable valve receivers also grace my workbench, not to mention period hi-fi gear.

The Ekco Nautilus Model PT310

The first patient this time is an Ekco Nautilus Model PT310, see Photo 1, which was made in Japan and released by the Pye/Invicta group in the early Seventies. It has a complement of eleven transistors (a mixture of germanium and silicon types), six diodes (including one varicap) and a bridge rectifier. Power is taken from either four C cells or the AC mains supply. Band coverage is long, medium and short plus FM. Photo 2 shows an internal view.

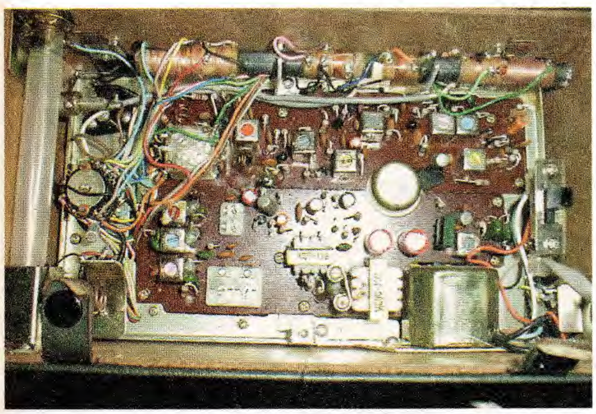


Photo 2: Internal view of the Ekco Nautilus Model PT310.

Unusually, this model has completely separate IF strips for AM and FM reception, with only the audio stages being common to both. The FM section uses silicon transistors throughout while, with the exception of the mixer/oscillator, the AM and audio sections use germanium devices. There's a balanced push-pull output stage, with driver and output transformers. The varicap diode is used for AFC with FM reception. The chassis and ground rail are connected to the positive side of the supply.

The radio came in with very noisy volume and wave-change controls and, as I discovered later, intermittent FM reception. The first job was to clean the controls with a shot of switch cleaner. This was completely successful, and I was rewarded with clear reception on all three AM wavebands. I noticed a distinct background hum, which was cured by replacing the mains bridge rectifier's reservoir capacitor. Bearing in mind the age of the set, some thirty years, I thought it best to replace all the electrolytics. FM reception worked only intermittently, and it turned out that there were two faults.

Dismantling the set is a fairly complex job that involves removal of many unmarked screws. The FM aerial lead (blue) has to be unsoldered from the telescopic aerial, likewise the brown 'live' and black earth leads from the external aerial socket. After removing the knobs the chassis can be withdrawn, leaving the speaker leads connected. "Chassis" is the right word to use too – this radio is built like many TV sets of the time, with PCBs mounted on a metal framework. In fact there are two PCBs, an upper one that carries the FM circuitry and a lower one for the AM section, the audio stages and the bridge rectifier for the mains supply. Several wire links interconnect the panels. These are a possible source of problems.

The FM reception problem

Needless to say the VHF RF section of the PCB was all under the tuning capacitor's pulley, so I had to remove the tuning scale, the drive cord and the pulley. My first check was for IF strip operation, by holding a screwdriver blade and touching the tip on the FM mixer/oscillator transistor's collector pad, i.e. using myself as an aerial. Safety note: tests of this sort should not be undertaken with valve radios, as there is a risk of getting a nasty shock. There was silence initially, but by pressing lightly on the board I obtained the expected short-wave noise (the 10·7MHz FM IF corresponds to about 28m in the short-wave band). Further careful tapping narrowed the cause of the problem to a dry-jointed diode lead in the ratio-detector circuit. Once this and a few other dodgy-looking joints had been resoldered the IF section worked steadily.

But FM reception had now failed completely. If the RF amplifier fails, the characteristic FM 'hash' is present and the strongest stations will still be heard. A general absence of life, when the IF stages are known to be working, is almost always caused by failure of the local oscillator. I checked various voltages in the stage, then decided to replace the transistor.

A 2N2222 produced no joy, so I tried a BF180. Again no luck. Unfortunately, because of the current obsession with surface-mounted devices, the range of leaded RF transistors listed by mainstream stockists is now quite limited. Of those listed the ZTX320, a tiny 'E-line' VHF transistor, seemed to be a good compromise between price and performance. It's a high-gain device with a cut-off frequency (ft) of 600MHz. I fitted one and, at last, had success. I also replaced the 5pF collector-emitter coupling capacitor, just in case. According to my Peak DCA50 component tester the original transistor was OK, with an Hfe of 55. That's what you would expect from a run-of-the-mill small-signal RF transistor. The ZTX320's measured Hfe of 150 is considerably higher.

After a few hours' soak testing I reassembled the tuning drive and refitted the chassis in its case. According to the tuning scale the alignment of the FM oscillator was way out. To restore Radio 2 to its correct position (88·9MHz from Holme Moss) I had to squeeze the turns of the oscillator coil closer together. Strangely, no adjustment was needed at the top end of the band: all my local radio stations were in their correct places. The new transistor's internal capacitances were obviously lower than those of the original device, requiring an increase in the inductance of the oscillator coil to compensate.

After that FM reception was every bit as good as with a contemporary receiver. To finish off, a small amount of paraffin was melted around the oscillator coil and the replacement transistor to prevent movement and possible microphony.

A Roberts R700

Next an original Roberts Model R700. Manufactured in 1968, this LW/MW/FM receiver uses 14 germanium transistors, including seven AF11X alloy-diffused types, and eight diodes including a varicap. The faults reported were loss of AM followed by FM failure. Again, this set is actually two receivers in one, with completely separate FM and AM sections and a common audio circuit. The output stage is of the transformerless complementary-symmetry type.

The FM front-end has an AF180 RF amplifier and an AF114 mixer-oscillator, both of which are operated in the common-base mode. This is followed by three IF amplifier stages

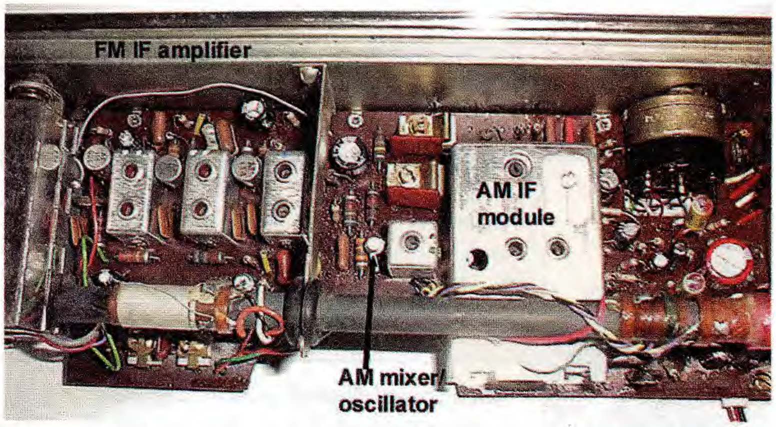


Photo 3: The IF section in the Roberts Model R700.

that use AF114 transistors, and a conventional ratio detector. The AM section starts with an AF117 mixer-oscillator, which is followed by a module that contains a two-stage IF amplifier and a diode detector. Depending on the position of the wave-change switches, the output from the appropriate detector is fed via the volume control to the audio stages. Although more expensive to produce, this arrangement avoids the compromises inherent in the design of common AM/FM stages.

The Roberts Model R700, which is two receivers in one.

This model uses two PP9 batteries in series to provide an 18V supply. When I connected my bench power supply I was surprised to see a quiescent current consumption of 80mA. There was FM reception but it was very faint and distorted, as if one of the output pair of transistors was open-circuit. As nothing seemed to be suffering from any distress, and the heatsink for the output transistors was cool, I left the power on and started to poke around with the test leads – in a logical sequence of course!

Troubleshooting with these sets can be confusing, as the circuitry is 'upside down' – in most radios that use germanium pnp transistors the positive rail is chassis. However the chassis line with the R700 is negative, which means that DC-wise the emitters of most of the transistors are 'hot'.

Some of the plastic-cased Plessey electrolytics looked a bit iffy. So, taking into account the advanced age of the set, I decided to replace the lot. This was a wise decision as it turned out. After fitting the replacements the quiescent current was only about 20mA, but there was still faint, scratchy sound, and the mid-point in the output stage was at almost the full supply voltage. Suspecting a faulty transistor, I was prodding with my test leads when a sudden surge of volume frightened the life out of me. Yes, there was a poor connection, specifically a break in a small piece of print. After attending to this fault FM reception was excellent. But there was still no LW or MW reception.

IF transistor replacement

Voltage checks showed that the supply to the AM IF module and mixer-oscillator stage was very low. Photo 3 shows the physical arrangement. The cause couldn't have been the supply decoupler, because this had been replaced along with all the other electrolytics. To cut a long story short, the problem was the usual collector-to-case short in the AF117 AM mixer-oscillator transistor. Fortunately it was the one I could get at, not one of the pair in the AM IF module.

A word of warning here. The AF239S is often listed as a suitable replacement for the AF11X range. It isn't, as I found out the hard way. The AF239S is a UHF transistor and, like most transistors of this type, it has a low Hfe – typically 10. The Hfe of an AF11X type transistor is anything from 50 upwards. The AF127 is a suitable replacement – it's basically an AF117 in a small TO74 can (TO18 but with four leads).

If an AF11X transistor fails with a collector-to-case short, you can often get away with just snipping the case lead. In some sets however this can lead to instability.

Finally, don't forget that heat-shunt when soldering germanium transistors. If there's insufficient room to clip one on, make the joint with a hot iron applied for the shortest time required to make a sound joint. You could also pre-cool the transistor's body with freezer immediately prior to soldering it.