Re-creating John Scott-Taggart's ST300 of 1932

It is now 57 years since Mr Scott-Taggart's three-valve receiver design, the ST300, came into being. Robert A. Wilson decided it might be nice to re-live those halcyon days and so, after obtaining a blueprint for this classic receiver, he set about building a modern replica.

For a long time I had wanted to own a baseboard-built set, but unfortunately such things are few and far between these days.

After reading the test reports and studying the plans of the ST300 I decided that a replica of the set could be made, although a certain amount of guesswork would be required on some components. My own early days in radio had led me to believe that not much in the way of performance could be expected from three valves and relatively few components. At best I had expected one or two stations at medium to loud headphone strength, but rather low for a speaker. When the set was completed I was not only surprised - I was astonished! The performance was far superior to what I had expected. A number of stations were picked up at such a volume that the set could be heard some seventy feet down the garden with the ST300 inside the house. After dark a number of Continental stations were picked up also at good loudspeaker volume.

Although the set has relatively few components, it has rather a lot of panel controls. It is therefore not a simple matter of switching on, tuning in and adjusting the volume. As can be seen in the circuit diagram Fig. 1, there are five variable capacitors, each to be tuned carefully. They control the aerial, the r.f. amplifier, the detector, the anode coupling and reaction. With careful use of all these controls, a station may be picked up faintly beneath interference - amplified and isolated until it is at full strength.

The tone is sharp, but clear, no doubt it could be deepened with the addition of a tone control circuit. Battery consumption is low, being about 300mA for the filaments, 15mA for the h.t. and nil for the grid bias.

Building such a receiver as the ST300 in 1980s may seem a backward step to some. It is not. Amongst other things it shows what can result from a few components in a carefully designed circuit.

The biggest problem any present day constructor of the ST300 will come up against will be with the components. Many of them may be found in attics or markets, but often have suffered through age. Capacitors (condensers) will often have developed short circuits, chokes and coils gone open circuit and other components may have suffered insulation failure. It is therefore very necessary to check thoroughly any original components which you may find.

Fortunately the most important components, which are no longer manufactured, do not appear to suffer unduly with age. I refer now to the valves. As long as the glass envelope is not broken the valve is protected by its vacuum. Do not purchase or use any valve which has a milky white look inside it, this indicates that air has somehow got inside. Even if the valve itself in undamaged it will not work if the glass has broken or air has leaked in. A mirror-like burn inside the glass envelope is normal and indicates that the vacuum has been maintained. All the valves quoted in this article are still available.

The following notes are to help the present day constructor assemble all the various components for the receiver. Where certain items are no longer available, instructions are given as to how to construct them, or to modify modern equivalents to look like their 50-year-old counterparts.

Components

The following description of each individual component tells how to either obtain originals or fabricate replicas from modern components.

The ST300 was built on a wooden base measuring 406 x 254 x 12mm (16 x 10 x 0.5in). This, of course, poses no problem at all. In my own version, rather than using a plain piece of timber I obtained a piece of particle board (chipboard) with a dark-wood veneer with a fine grained finish. The sides of the base were covered with matching strips of iron-on veneer to hide the rough internal texture of the particle board.

Originally the front panel was of either ebonite or Paxolin, as was the terminal strip along the back. Rather than go to the expense and trouble of finding the correct material and having it cut and drilled I settled for a thin sheet of three-ply painted black. Both the panel and the terminal strip were drilled before fitting the baseboard.

Batteries

Three batteries were used to power the ST300. These are known as the high tension (h.t.), the low tension (l.t.) and grid bias (g.b.). In the 1930s the l.t. was provided by a 2V accumulator, whilst the g.b. and h.t. supplies were dry cells made up into blocks. All three batteries used in the replica I made up myself using modern-day dry cells.

The ST300 requires a h.t battery of 120 volts with at least two lower voltage tappings. The home-made battery consisted of fourteen 9V batteries wired in series as shown in Fig. 2. Tappings were made at the 5th battery (45V), 7th (63V) and 10th (90V) with the maximum h.t. at 126V. The batteries were encased in a

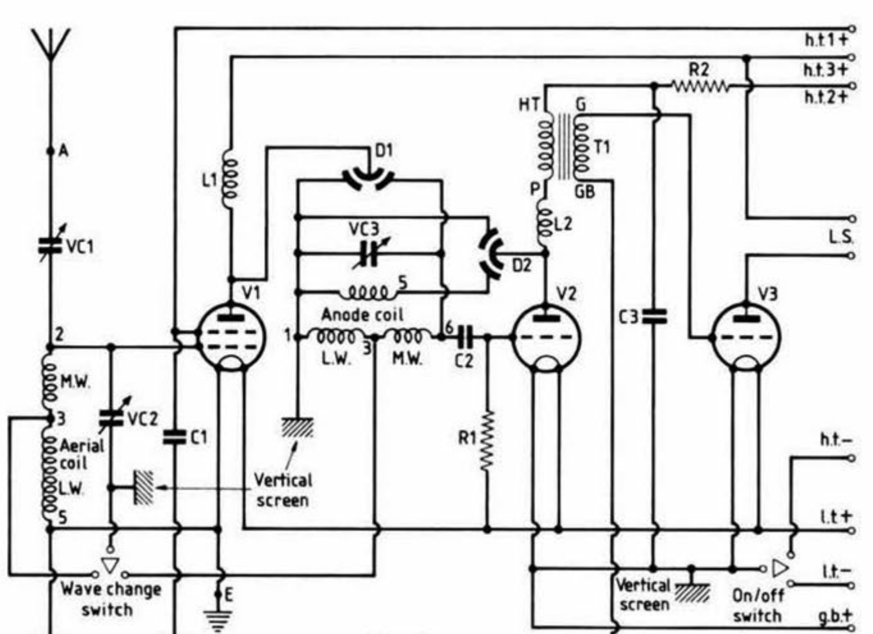


Fig. 1: ST300 Circuit Diagram. Note D1 and D2 denote differential capacitors and not diodes

small wooden box measuring 152 x 152 x 51mm (6 x 6 x 2in). The top was fitted with sockets labelled Negative, 45V+, 63V+, 90V+ and 126V+.

The l.t. requirement (valve filament supplies) is met by wiring two 1.5 volt batteries in series, giving 3 volts. Although this is one volt too much there is very little danger of damaging the valves. I have been using 2V valves on 3V supplies for years with no fatalities. These two cells should be the larger torch size as each valve takes about 0.1 amp for its filament, giving a total consumption of 0.3 amps.

The g.b. battery consists of four penlight cells wired as shown in Fig. 2 and enclosed in a small wooden box measuring 114 x 35.5 x 58mm (4.5 x 1.375 x 2.25in). This box has the positive terminal coming out of the back about 6mm (0.25in) above the bottom of the box. The other five terminals 0V, 1.5V-, 3V-, 4.5V- and 6V- are along the top of the box. The grid bias lead is connected to whichever terminal gives the best results.

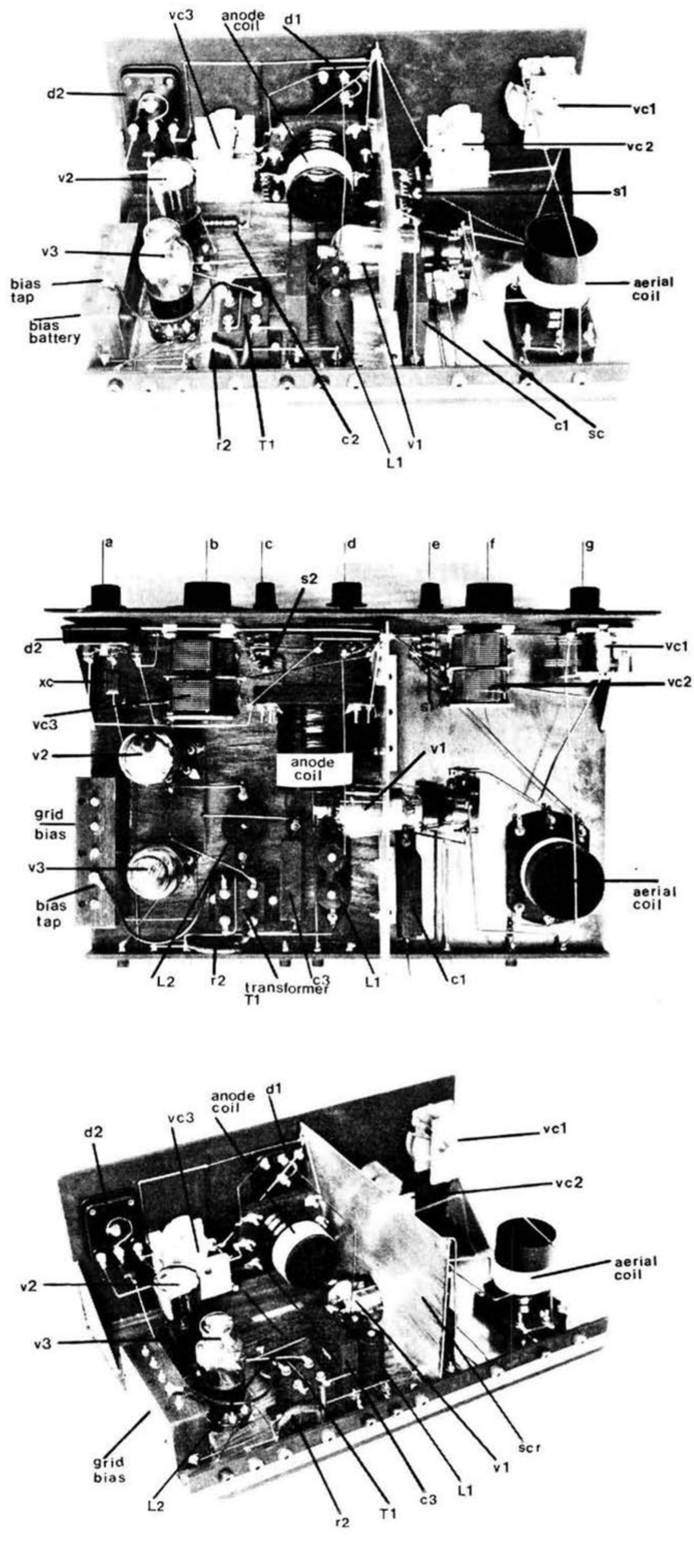
The g.b. battery may use miniature cells as there is virtually no current drawn from it. It merely supplies a negative potential to the grid of the output valve V3. This battery is not switched, but can be left safely in circuit all the time, hence its inclusion on the baseboard of the set.

Fixed Capacitors

Only three fixed capacitors (Fig. 3) were used in the design. Capacitors of this age are seldom in perfect condition so it is not recommended that they are used even if they are available. Fortunately the required values are still in common use, namely C2 0.0001mfd (100pF) and C1 and C3 both 1mfd (1µF). Capacitors C1 and C3 should have a working voltage of at least the h.t. voltage used, in our case 126 volts. Capacitor C2, being a grid capacitor, can be one of the small low voltage types.

Having obtained these three capacitors it is then necessary to change their modern appearance to what they would have looked like in 1932. This is not a difficult job as the two larger ones are identical. The drawing shows the dimensions of C1 and C3. The body of the replica capacitor is made from a solid block of wood. On the underside a space is cut out with a chisel and the modern capacitor inserted. The base consists of two identical sheets of wood as shown. The first one is glued to the base of the capacitor and the two terminal bolts put through it at the ends. The concealed capacitor is wired to these terminals. The second piece of wood has two "dimples" bored into the ends to accommodate the protruding heads of the terminal screws. The whole lot is glued together and painted either black or brown. I then added the value, "1MFD" to the outside in white dry rub-down lettering.

Capacitor C2 is much simpler, being a smaller component measuring approximately 38 x 15 x 6mm. Again it is a block of wood with a hollow cut underneath to house the modern



Three interior shots of the authors' replica receiver to assist with component placement

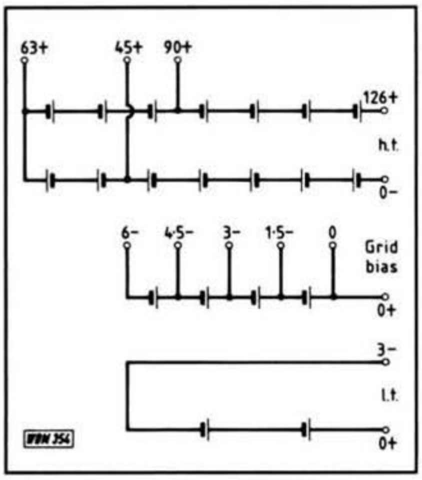


Fig. 2: Batteries

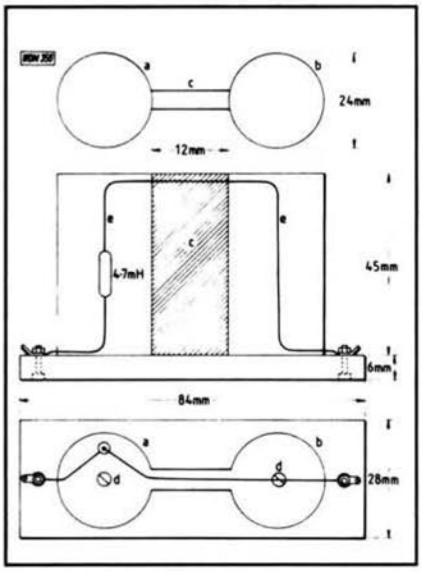


Fig. 4: Screen grid choke L1

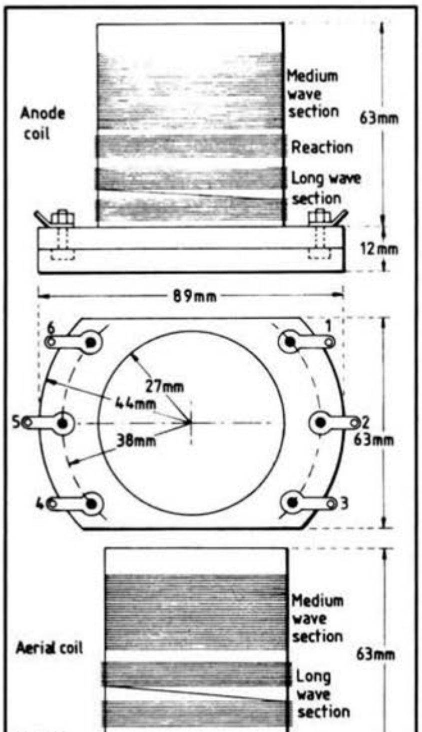


Fig. 6: Anode and aerial coils

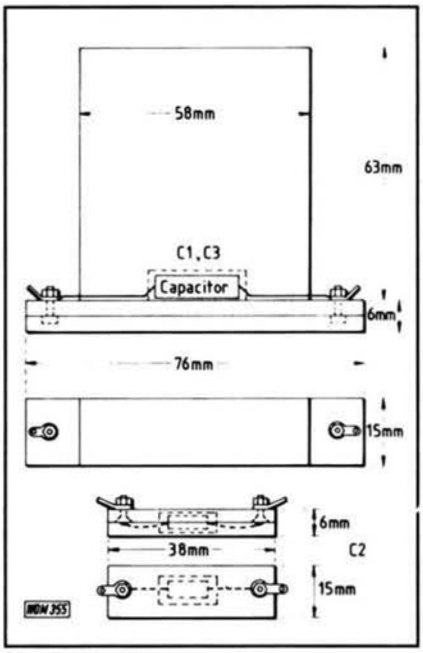


Fig. 3: Replica capacitors

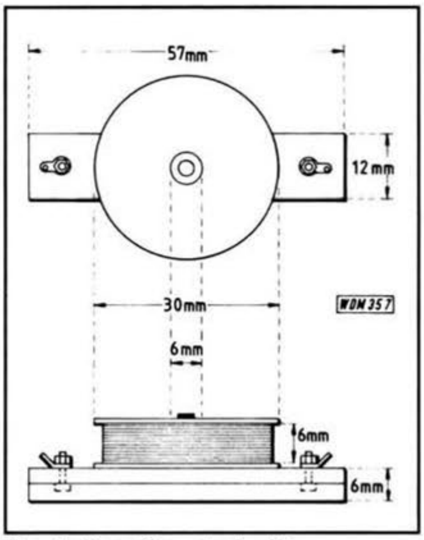


Fig. 5: Reaction choke L2

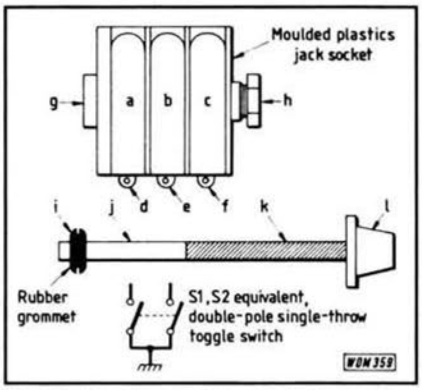


Fig. 7: Replica pull-switch for wave-change and power

components. Rather than have this wire-ended I fixed two solder tags in the ends of the block and soldered the leads to them. Again with rubdown lettering, the value 0.0001MFD was added to the completed capacitor.

Note that no fixing holes were provided in these components. When they were fitted they were held in position by contact adhesive.

Variable Capacitors

The ST300 uses five variable capacitors, three conventional ones and two differential. The aerial coupler is VC1 and has a value of 0.00004mfd (40pF). For this I used a standard modern capacitor of 174pF. Despite being of considerably higher value than the specification, this control is a very effective one.

The next two variable capacitors, VC2 and VC3, are 500pF. They form the tuning controls and at first I was tempted to use a modern ganged capacitor to take the place of two components. This would not have worked, however, as any adjustment of the anode coupler capacitor would have moved the set off tune, VC2 and VC3 must be kept separate. As I was unable to find two single 500pF capacitors I used two twin-ganged ones using only one set of blades of each. Ideally these capacitors should be identical, but again I was unable to find two matching ones and had to compromise, VC2 being slightly smaller than VC3. This does not affect performance.

The two remaining variable capacitors are of the differential type D1 and D2. That is to say they have two opposed sets of fixed blades. As the moving blades move out of one set of fixed ones they move into the opposing set. Their values are 100pF and 150pF. As far as I know such components are not manufactured today. Fortunately two components of the correct value were obtained from The Vintage Wireless Company of Bristol [1].

Chokes

In the anode circuit of V1 is a screen grid choke L1, mechanical details are shown in Fig. 4. The name screen grid choke may seem a rather an odd name for a device that is connected in the anode cicuit of a valve. However, the definition of this device is; a coil of wire connected in the anode lead of a screen-grid valve to offer high impedance to h.f. current.

Chokes of this type are still available, but can be rather expensive. A substitute can be made in a similar manner to the fixed capacitors. Screen grid choke L1 appears on the replica as two vertical tubes mounted on a base about half an inch apart. The windings are inside. The base of the simulated choke was made from a thin sheet of wood fitted with terminals at each end. The two tubes were cut from a length of plastics tubing obtained from a do-it-yourself store. The two 46mm (1.8in) lengths "a" and "b" were glued to the base with contact adhesive. A thin piece of wood "c" was glued between them. The actual choke "L", a Siemens B78108S 4.7mH[2], was concealed inside one of the tubes. The lead "e" comes through of the top of the tube and out to the terminal. The open tops of the tubes were filled with resin filler and smoothed off after it had hardened. In the drawing two screw heads "d" can be seen on top of each tube of L1. These are only for effect. They have been sawn off and glued flat on top of the component.

The second choke, L2 is the reaction choke, the mechanical details of which are shown in Fig. 5. This component is still available, but again I decided to wind my own. First a bobbin was made from two 30mm (1.2in) diameter circles of Paxolin, with a hole in the centre and a 6mm (0.25in) length of 6mm (0.25in) dia. dowel glued in between. When the glue had set a hole was drilled through the centre of the bobbin.

The choke was formed by filling the bobbin to the edge with 34 s.w.g. enamelled copper wire. This was not as tedious as it may appear. A long nut and bolt was put through the centre hole, and the protruding end of the bolt was put in a wheel-brace chuck. The handle of the brace was then placed in a vice. The start of the winding was threaded through a hole in the centre of the bobbin and the wheel-brace was then turned by one hand while the other was used to guide the wire onto the choke. In this way the winding was completed in a few minutes. The d.c. resistance of the completed reaction choke was then found to be 300Ω. The wound bobbin was fixed to a strip of wood with a terminal in each end and painted black. The component was screwed to the baseboard through the central hole using a brass screw.

Coils

There are two main tuning coils in the ST300, the aerial coil and the anode coil, mechanical details of which are shown in Fig. 6. Neither is available, so they must both be made from scratch. Fortunately, both formers and bases are identical which makes things somewhat easier. The aerial coil consists of a medium and a long wave winding. The anode coil consists of two identical windings, but with an additional reaction winding in between. Each coil has six terminals, but in the aerial coil only three are used and in the anode coil only four are used. Both of my coils were fitted with the full six terminals purely for aesthetic reasons.

Each coil base consists of two 89 x 63 x 6mm (3.5 x 2.5 x 0.25in) sheets of obeche wood. This type of timber can be obtained from model shops in sheet form. The ends are curved to the radius shown in Fig. 6.

When the two halves of each base have been cut to size the nuts, bolts and solder tags can be fitted. Then the lower halves, with holes drilled to take the protruding screw heads, may be glued on. The bases should be painted either black or brown.

I thought the actual former might

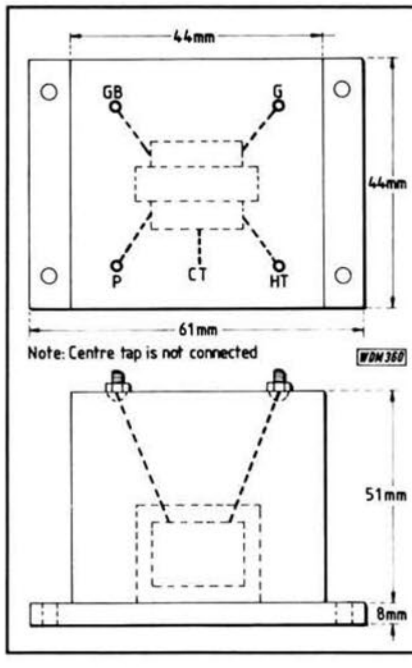


Fig. 8: Intervalve transformer. Note the centre tap of LT44 transformer is not used

prove a problem, but in the end it did not. A suitable plastics container was found in the form of a small tub containing dried parsley, available at most big grocers. The former of the anode coil must be cut down to a length of 63mm (2.5in) otherwise it will be in the way of the screen grid valve. Each former has eight vertical ribs.

These can be formed by sticking thin strips of wood up the sides of the formers. The positions can be marked on the tubs by holding them over the full sized blueprint[1]. When all the ribs are on, paint the formers the same colour as the bases. In the photographs it may be noticed that my coils do not have ribs. The first two coils I made did, but unfortunately the numbers of turns were way out and they were a long way off frequency. The coils shown are the second lot of experimental ones which were not ribbed in order to save time. Now that the correct number of turns have been sorted out I will be able to make the better looking ribbed variety.

Windings on both coils are wound from the bottom of the formers towards the top using 32 s.w.g. enamelled copper wire wound in the same direction.

Details of the anode coil are as follows; thread the end of the wire through a hole in the bottom of the former and label "1". Wind 60 turns of wire on to the former in a pile about 6mm (0.25in) wide. Without breaking the wire leave a small gap and then wind another 60 turns on the former in another pile. Thread the end through the former and label it "3". This is the long-wave winding.

About 6mm (0.25in) above this winding thread the wire through a hole and label it "1". Wind 50 turns of wire in a pile about 6mm (0.25in) wide and thread through a hole in the former labelling it "5". This is the reaction winding.

About 6mm (0.25in) above the reaction winding thread the wire through the former and label it "3". Then carefully wind 80 turns of wire on to the former with the windings touching but NOT piled on top of each other. Thread the end through a hole and label "6". This is the medium-wave winding.

Clean all the ends of the wires and solder them to their correct number tags shown on the drawing. Note that the lower end of the long-wave coil and the lower end of the reaction coil both go to terminal "1". The top end of the long-wave winding and the bottom end of the medium-wave winding both go to "3". The top end of the reaction coil goes to "5" and the top end of the medium-wave goes to "6". The former may now be glued to the base and the anode coil is complete.

Winding details of the aerial coil are as follows; thread the wire through a hole in the bottom of the former and label "5". Wind 60 turns on to the former in a band 6mm (0.25in) wide, leave a gap and wind another 60 turns on. Thread the end through a hole and label "3". This is the long-wave coil which is identical to the long-wave section of the anode coil apart from the numbering of its wires.

Thread the wire through a hole and label "3". Wind 80 turns on the former touching and NOT piled up. Thread the end through a hole and label "2". Again the medium-wave winding is identical to the one on the anode coil, apart from the wire numbering.

Clean the wire ends and solder to their appropriate tags. Note that the bottom end of the long-wave winding goes to "5". The top end of the long-wave and the bottom end of the medium-wave both go to "3" and the top end of the medium-wave winding goes to "2". Glue the former to the base and the aerial coil is now complete. Both coils should be checked for continuity on a meter in case a winding has a break or there is a bad soldered joint.

Control Knobs

Plain black modern knobs will look correct on all but the two main tuning controls. The two tuning knobs, however, were 3in diameter types calibrated from 0 to 180 degrees. Replicas of the original knobs are available from Vintage Wireless Company[1] and add a look of authenticity to the set.

Loudspeaker

A standard modern loudspeaker and matching transformer is quite adequate for the set. I removed a six inch speaker and its transformer from an old set and enclosed them in a wooden cabinet to the style shown in the constructional details.

Resistors

The circuit uses only two resistors, a 1MΩ grid leak and a 20kΩ spaghetti. Although both original types can be obtained it is just as easy to make your own. Conveniently the grid leak is the same diameter as a plastics ball-pen barrel.

Cut a piece from a ball-pen barrel 44mm (1.75in) long. Inside it insert a modern 1MΩ resistor and add a screw terminal at each end. The completed resistor may then be painted black.

A spaghetti resistance is one of the flexible type about 75mm (3in) long. It can be formed by threading a modern resistor into a piece of sleeving. As 20kΩ is not a common value these days I used two 10kΩ resistors in series.

Screens

The aerial circuit of the set is separated from the rest of receiver by a vertical screen "scr". This is a piece of thin aluminium with a right angled bracket along the bottom to screw it down. The horizontally mounted screen-grid valve V1 protrudes through a 44mm (1.75in) diameter hole. Only two wires pass through this screen. Suitable holes can be drilled and fitted with rubber grommets before fixing the screen in position.

The other screen is the plate "sc" which covers the base of the set containing the aerial coil. For this screen I used a blank piece of copper-clad printed circuit board, copper side up. The p.c.b. material was glued to the base with contact adhesive.

Switches

The on/off and wavechange switches are identical and are shown in Fig. 6. They have three connections which are all either made or broken. The originals were of the push-in, pull-out types. Although they are still available I found it a simple matter to make my own from two 0.25in moulded stereo jack sockets as shown in the drawing. Metal contact springs "a", "b", "c" are connected to the tags "d", "e" and "f" respectively. Fixing nut "h" is the point through which the stereo plug would normally pass. The only modification to the socket is to cut the end stop "g" off to give a hole right the way through the socket. The shaft of the switch is made from a length of 0.25in brass tubing "k" into which a length of wooden dowel "j" has been fitted. Push the shaft into the jack socket until the three tags "d", "e" and "f" are all shorted out by the brass rod. Cut the protruding end of the brass rod off so that the knob "i" is pressed right up to the fixing nut "h". Pull the knob out carefully until "d", "e" and "f" are electrically separate. Then glue a rubber grommet "i" on to the wooden dowel making sure that it is pressed up to the body of the socket.

This makes a very effective three-way switch.

Terminal Panel

The terminal strip was originally made of Paxolin or ebonite and measured 406 x 38mm (16 x 1.5in). In my own receiver I used plywood painted black.

The ten terminals were found to be available at most electronics shops for about 20p each.

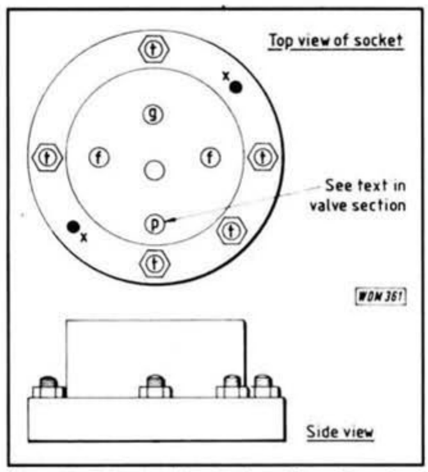


Fig. 9: Mechanical details of valve holders

Transformer

This component is just listed as an l.f. transformer in the parts list. Such transformers are still available, but can be expensive. I therefore decided to try a modern one concealed in a wooden mock-up of the original (Fig. 7). The drawing shows the dimensions of the box which was constructed out of thin sheet wood obtained from a model shop.

The transformer itself is an Eagle LT44[3] transistor driver transformer. It has a 20kΩ impedance primary winding and a 1kΩ impedance centre tapped secondary. For intervalve use, however, its connections were reversed. The centre-tapped secondary became the primary with the centre tap "CT" unused. The original primary then became the secondary. This component is only 19.5mm (0.75in) square and so it was supported inside its new case by its own leads as shown.

Valves

The ST300 uses three valves, a screen-grid tetrode, followed by two triodes. Valve types are not specified in the circuit details. The ones I chose were SG215(st) for the screen grid (V1), 210HL for the detector (V2) and HL2 for the output valve (V3). Triodes V2 and V3 are more or less interchangeable with each other depending on results. The "st" in brackets after SG215 refers only to the shape of the glass envelope, hence an SG215 is the same thing, but may be a different shape. All three valves are available along with baseboard mounting holders from The Vintage Wireless Company. Diagram Fig. 8 shows a typical baseboard type holder. The fixing holes are marked "x" whilst the connections are set around the base at points "t". These older type valve holders could usually take both four-or five-pin valves, hence the central hole and the extra terminal. In our case the fifth pin is unused and can be ignored. The four sockets "f", "g", "f", "p" stand for filament, grid, filament and plate. Plate is the old word for anode. These old valve holders can be made from wood, but it is easier to purchase them. The holder for the screen grid valve V1 should be a side mounting type. As mine were all vertical types I simply made an aluminium bracket for the S.G. valve holder.

Note: The S.G. valve holder connections are slightly different, "P" is the screen-grid terminal. The top cap of the valve is the anode or "P" connection.

Wiring

The leads used for connections between the terminal panel and batteries, etc., were normal flexible leads fitted with plugs at each end. The actual wiring of old-time sets such as the ST300 was usually of quite heavy gauge wire with all the angles bent neatly in the wire rather than going direct from component to component.

This is frowned upon today, but the ST300 was so well spaced out and screened that wiring in this manner does not have any adverse effect.

The wiring I used was bare copper wire of heavy gauge. Actually it was offcuts of modern house wiring cable. Before the wire can be used it should be straightened. To do this put one end in a vice, take the other end in a pair of pliers and pull it so that it stretches slightly. This stretching will make it perfectly straight. The angles can be bent in it with pliers and the wire cut to the correct length with clippers.

Panel Controls

Referring to the photograph, a is the Reaction control, b the anode tuning, c the on/off switch, d the anode coupler, e the wave change switch, f the aerial tuning and g the aerial coupler

When the set is switched on the required waveband should be selected first. It is best to make a start on medium wave until one is used to the operation. There are more stations available there.

The reaction control should be adjusted to minimum to begin with. If it is turned up too far the set will oscillate. When I first constructed my ST300 I found that the reaction was at minimum when the control was fully clockwise. The reaction condenser "D2" was therefore turned upside down so that the two sets of fixed blades became reversed (wires remained on same sides, but lower down). This put the minimum reaction at anti-clockwise.

Find a station by moving one or both tuning controls "b" and "f". Once a station is located it can be peaked with these two controls. Then an adjustment of the anode coupler "d" will improve it or remove interfering stations. The aerial coupler "g" may then be adjusted to increase volume. Once the station has been tuned in as well as possible with the two main tuning controls, plus anode coupler and aerial coupler, the reaction control can be turned slowly up. As reaction is increased, the signal strength will get louder until the set bursts into oscillation, the reaction should then be turned back again until oscillation ceases. Even then there is still scope for improvement and this is where practice by trial and error comes in.

Notes

A small fixed capacitor "xc" is visible in the photograph connected to the moving blades of the reaction control. This is not shown in the circuit diagram. The reaction condenser "D2" is a differential with a value of 0.00015mfd (150pF). The condenser which I obtained although labelled correctly showed a capacitance of 0.00025mfd (250pF) on a capacitance meter. I had hoped that it would not make any difference, but it was so high that the set oscillated all the time. The introduction of "xc", a 0.0001mfd (100pF) capacitor cured this by lowering the effective capacitance of D2.

A low value aerial coupler VC1 could not be found. Several moving blades were pulled out of a normal one to reduce its capacitance. This is obvious in the photograph. If you have occasion to pull blades out do it one by one, they can't be put back again!

The medium wave sections of both coils were covered in white insulation tape simply to increase the general contrast. A more effective way is to use the brightly coloured enamelled copper wire for the windings. Also the inclusion of the vertical ribs on the coil formers improves looks.

The top cap of the screen grid valve V1 is a plain metal stud. Do not solder direct to this or you may burst the glass envelope. Make a push-on clip. Some older types of valves have a screw terminal for a top cap.

Be very careful when plugging the batteries in. If you connect the high tension battery to the low tension sockets on the terminal panel, all three valves will be destroyed immediately the set is switched on.

Trial and error will find what tappings to plug h.t.1, h.t.2 and h.t.3 into on the high tension battery. No harm will be done if either h.t.1, 2 or 3 share any particular tapping - it really depends on what type of valve you use.

The valves shown in the prototype are "bright emitters". This doesn't mean that they light up like lamps. They only have a dull glow which can be difficult to see in daylight. Valves V2 and V3, both being triodes can be changed round to see which performs best in which socket.

Experiments

As a number of component values were guessed at in my ST300, it is possible that improvements may be obtained by trying different values. The areas of experimentation are as follows:

Anode and Aerial Coils: The wavebands covered may be altered by using either greater or lesser number of turns. Whatever number you choose, both medium-wave windings and both long-wave windings should be the same on each coil.

Reaction and Screen Grid (S.G.) Choke: The number of turns and inductance of these two components was pure guesswork and perhaps modern r.f. chokes would be worth trying.

Valves: Different types of valves can be tried provided, of course, that the bases/anode cap are of the correct configuration.

Intervalve Transformer: Ratios of normal intervalve transformers of the 1930s seemed to vary between about 1:2 and 1:6. The transformer eventually used in the replica was way out of this range, but seemed to work well. Other transformers may be tried to advantage.

Once the ST300 is working it makes one wonder what could be achieved with modern components and valves. It would be interesting to construct a set based on this design, but modernised by thirty years or so.

One final point. Over the years, family and friends may have become rather bored with your obsession with radio construction. When you embark on an ST300 it is amazing how tolerant amusement can turn into amazement when the relic bursts into operation with a volume that certainly cannot be ignored. If nothing else, it is certainly a talking point for everyone. ***PW***

(1) The Vintage Wireless Company Ltd.
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Bristol BS17 3EN
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