Therefore a negative resistance can lead to amplification; but precautions are needed to prevent oscillation.

Equivalent Circuit

The equivalent circuit of a typical tunnel diode is shown in Fig. 16. The diode itself has a negative resistance in parallel with a capacity, but the leads have inductance and resistance.

Operating Conditions

There are two main ways in which tunnel diodes can be operated and in each case the biasing and circuit resistance are most important. One method causes the tunnel diode to operate as a switch whilst the other enables it to amplify, oscillate, etc.

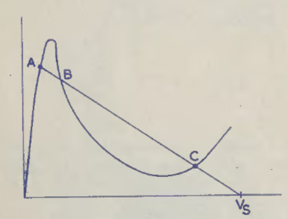


FIG.20
Load line for operation of tunnel diode as switch. M868

Amplifier or Oscillator

Any tunnel diode used as an amplifier or oscillator must be biased so that the operating point is on the negative resistance part of the curve. In addition the equivalent series resistance, R_s, of the circuit must be numerically less than the negative diode resistance, r, or switching will occur. The load line representing R_s (its slope$=1/R_s$) is then steeper than the slope of the diode characteristic (1/r) and consequently the load line can cut the characteristic in only one place (see Fig. 17). The type of circuit used is shown in Fig. 18 with some typical values, and its Thevenin equivalent circuit in Fig. 19. The d.c. resistance of the load must be less than 90Ω when the circuit values shown in Fig. 18 are used no matter whether the diode is used as an oscillator or as an amplifier. The total d.c. resistance must be negative.

The a.c. circuit resistance determines whether the tunnel diode circuit will amplify or oscillate, assuming that the necessary d.c. condition mentioned above has been fulfilled. Oscillation occurs if the total a.c. circuit resistance is negative and amplification if it is positive, but it is most important to note that the total a.c. resistance is the negative resistance of the tunnel diode ($-R_2$) in parallel with the circuit a.c. resistance (R_1). The resulting a.c. resistance is not therefore the series value of R_1–R_2, but the parallel value

$$\left(\frac{-R_1 R_2}{R_1-R_2}\right)$$

This is positive if R_1 is less than R_2 numerically and is negative if R_1 is numerically greater than R_2. A tunnel diode circuit will therefore oscillate if the negative resistance of the diode is numerically less than the circuit a.c. resistance. In order to avoid oscillation and obtain amplification, however, the numerical resistance of the diode must be greater than the a.c. circuit resistance. This is exactly opposite to the effect which would have been expected.

Another way of looking at the a.c. resistance problem is from the point of view of the load lines. If the load line of Fig. 20 represents the a.c. circuit resistance (dynamic load line), the circuit will oscillate between points A and C. The a.c. circuit resistance is greater than the numerical value of the tunnel diode negative resistance if the dynamic load line cuts the characteristic in more than one place. If the dynamic load line can be represented as in Fig. 17 and cuts the characteristic at a single point, amplification will occur.

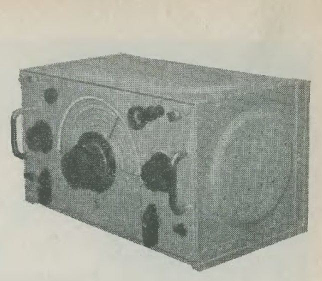
The adjustment of the tunnel diode circuit values is much more difficult for amplifier operation than it is for operation as an oscillator. It must be mentioned that the above discussion assumes that the operating frequency is not high enough for the diode reactances to affect the operation of the circuit.

Switching

A higher series resistance, R_s, is required in a tunnel diode switching circuit so that the slope of the load line is less; the load line can then cut the diode characteristic in three places (see Fig. 20). It is not difficult to see that the point B is unstable. If a minute increase in the voltage across the diode occurs so that B moves down the curve, the current will decrease and this will result in further voltage increase leading to a cumulative effect. Stability will be reached at point C. Alternatively the operating point at B may start to move up the curve and it will not then stop until it reaches A.

The points A and C can both be made stable, so that the tunnel diode forms a useful "flip flop" switch with a switching time as little as a milli-microsecond. This is about 100 times faster than the best transistor. The tunnel diode switching circuit will certainly be useful in computers, etc. *(To be concluded)*

The R1155 as a General Purpose Receiver



By D. Easterling **Part 2**

Modification Procedure

The first step is to remove all unwanted components, most of this work concerning the d.f. circuits. At first glance the constructor may well assume that the work is going to become very complicated if the removal of wanted parts of the circuit is to be avoided. Actually the process is relatively simple, since unwanted sections are nearly completely independent. Being drastic, therefore, all components below the tuning indicator are removed, including Jones sockets, valveholders, originally taking the two VR99 or VR99A triode hexode d.f. valves, several metal can condensers, various chokes and transformers, and the master switch assembly. One valveholder is refitted later for the rectifier.

The tuning indicator may be temporarily unbolted from the front panel at this stage. It will be refitted later with the new panel.

Next comes the clearance of the front panel with the removal of the following controls: METER BALANCE, FILTER IN, METER AMPLITUDE (to be re-installed later as the new r.f. gain control VR_2), METER DEFLECTION, AURAL SENSE, and SWITCH SPEED. Also to be removed from the front panel is the wiring running in ducts at the top and bottom. Some of this wiring goes to tag-strips leading to components mounted in a screen behind the b.f.o. compartment. These parts, although not used in the modified version, can be left in position, as space here is not essential. Other wiring goes to the valveholder shown in Fig. 5 as V_6. This takes the VR102 double triode valve which is no longer required, the valveholder being used for the 6G6 output stage instead; thus heater leads going to pins 2 and 7 can be retained. Where wiring appears to go into wanted sections of the circuit, it should be left hanging for the time being, as it can be easily identified and linked up later.

With regard to the clearance of unwanted parts to the left, or volume control side of

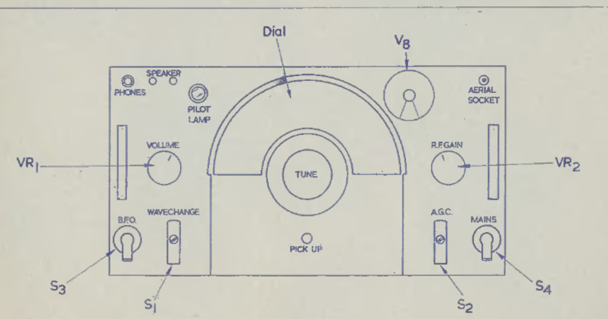
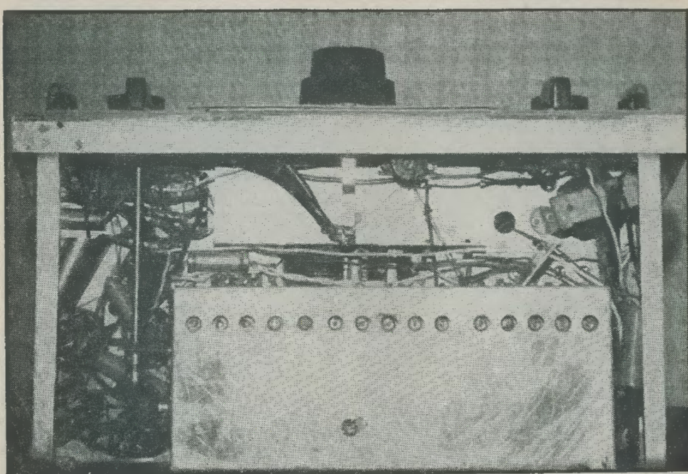


FIG.6
Front View
M835



Under-chassis view of the R1155. Compare with Fig. 7

the receiver, more caution should be exercised. First comes the filter inductor assembly mounted immediately behind the volume control, and associated with the FILTER IN switch. This should be removed complete with attached components, the latter being put carefully on one side, as some will be re-installed later. Last component to be removed is the original output transformer, which is mounted below chassis next to the switched marked HET (S_3 in Fig. 1).

With all the above components removed, space should now be available in between the r.f. transformers associated with the tuning heart and the front panel, on the chassis below the tuning indicator, and below chassis to the side and front of the tuning heart. With regard to the latter position, some receivers are fitted with a single h.f. coil. This is part of a filter circuit connected with the tuning heart, and should, therefore, be retained.

Fitting the New Front Panel

Before proceeding to link up the circuit, the additional major components and new front panel must be installed. First the front panel.

As the existing panel carries all the weight, the new panel which will be fitted on top need not be of heavy material; actually 22 gauge aluminium is adequate. Before it can be mounted, however, the existing front panel has to be cleared of parts such as handles, control labels, and so on. Controls which will remain in the modified version will have to be slipped back on their wiring by releasing the securing nuts. The wavechange spindle is difficult to remove, and should be allowed to remain with the spindle bush slipped back. Also to be temporarily removed are the tuning dial escutcheon, this being accomplished by removal of all perimeter screws and five 4BA bolts visible from the front, and the fixed knob scale (although the tuning knobs themselves can stay put).*

The new front panel must be made to exactly fit the existing one and, as the latter is not necessarily square, it is advisable to cut slightly larger to begin with (say 16⅜ x 8⅝in) and, when the panels are firmly fixed together, remove the surplus with a file. In order to fit the new panel initially, however, a hole for the wavechange switch spindle, and a cut-out for the dial and tuning assembly must be made. The dial cut-out should be marked out on the new panel using the dial escutcheon as a guide. The cut-out is then made ⅜in inside the marking so that the escutcheon covers the join. When the cut-out has been made, the panel will have an appearance similar to a railway tunnel entrance.

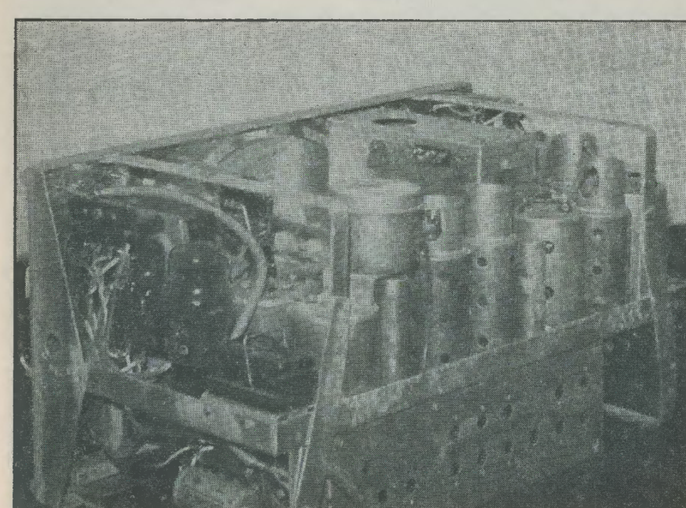
Once the plate has been made to lay flat on the existing front panel, it should be firmly secured, first by the wavechange switch spindle, and then by four 4BA nuts and bolts, which temporarily replace the case securing bolts. To ensure that the holes in the new panel line up with those in the existing one it is recommended that a fine pilot drill be used first, followed by one of the correct size. The latter will guide itself into the correct position.

With the new panel secured, fit the escutcheon plate in place and check that the pointer assembly does not foul. Then, using the same method as suggested for the corner bolts, bore the five 4BA holes used to secure the escutcheon. Next the smaller holes to take the self-tapping screws round the dial perimeter may be drilled. It was found that the original self-tapping screws were not quite long enough, consequently they should be replaced by ⅜in 6BA self tapping screws (obtainable from radio dealers). The original screws may be used later for further strengthening around the panel edge.

Using the pilot drill method, holes may now be drilled for switch S_3 (HET); the volume control, handles, tuning indicator, and original master switch position. The latter will now accommodate the new r.f. gain control. A series of small pilot holes can be used for the tuning indicator hole, these being linked up with a rat-tail file to produce the large cut-out.

New holes are required for the pilot lamp (situated on the side of the tuning scale opposite the tuning indicator), the a.g.c. switch S_2, and mains switch S_4 (situated on the right hand side of the receiver to balance the wavechange switch and b.f.o. switch S_3). Attention should also be given to the connecting arrangements for loudspeaker, phones, aerial, and pick-up. Fig. 6 illustrates where these are positioned in the writer's receiver. Individual constructors, however, may wish to preserve a less cluttered front panel by mounting the sockets either at the side or back of the equipment, in which case special mounting panels will have to be provided and corresponding holes cut in the case. Finally, provision has to be made for the output transformer, which is also mounted on the front panel just above the volume control.

Certain controls, removed from the receiver earlier, are re-installed in new parts of the circuit, and in new positions on the front panel. First the r.f. gain control, VR_2.



General view of the chassis

*This comment applies to R1155,s in which the knobs are coupled direct to the tuning condenser spindle instead of being mounted lower and coupled thereto by slow-motion gearing.—*Editor.*

This was formerly the section of the ganged volume control located furthest from the front panel which is not employed in the modified circuit. The control occupying the METER AMPLITUDE position is now fitted in the VR_2 position. With regard to the mains switch S_4, the switch occupying the old SWITCH SPEED position is re-employed. For the a.v.c. switch S_2, a single pole change-over wafer type is required but, if it is to match the range switch opposite the knob arrangement should be similar. The easiest solution is to dismantle the original master switch and, after shortening the operating spindle and inserting a new stop to provide only two positions of the index (a 6BA self tapping screw may be used for this), re-assemble the switch with one wafer only. All controls should now be fitted in the positions indicated in Fig. 6.

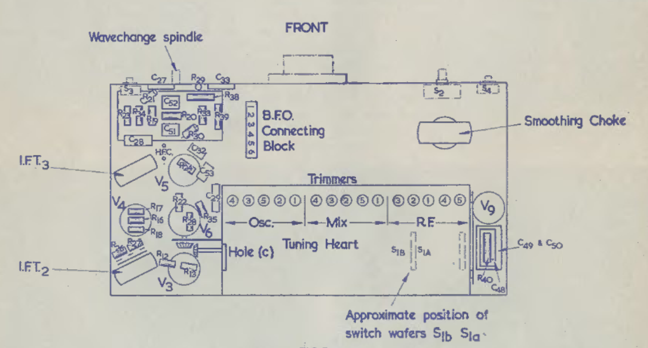


FIG.7.
Under-chassis Component Positioning

Now comes the mounting of internal major components, the biggest of these being the mains transformer. The best position for this component is below, and to the right of the tuning indicator. In order to prevent the necessity of large chassis drilling operations a component with upright fixing brackets is preferable to the "drop-through" type. A transformer measuring 7 x 3 x 3in was easily accommodated, although it was necessary to fit the r.f. gain control first.

One of the original d.f. valveholders is used for the rectifier valve, and a two-way fuse bridge can be accommodated in the other valve position. The rectifier valve-holder should be minus the screening can base, otherwise the 5Z4G valve cannot be inserted.

The smoothing choke goes below chassis just behind switches S_2 and S_4. Close to the smoothing choke, mounted on the side of the tuning heart, is a tagboard with several small condensers. These are removed and the tag strip is later used to mount components C_{49}, C_{50}, C_{48}, and R_{40}.

Above chassis, between the tuning condenser and the mains transformer, should be mounted a small tagstrip to hold condensers C_1 and C_2. This can be fabricated from parts previously removed from the receiver. A further pair of tags are required on the inside of the front panel adjacent to switch S_3 for securing resistor R_{21} and condenser C_{27}. Finally to complete the metal work, a ⅜in hole should be drilled in the rear of the case in order to admit the mains lead adjacent to the power unit.

With the above work completed, a suitable stage is reached for the painting process. A Valspar battleship grey was used by the writer. Also painted was the whole case exterior. No attempt was made to remove the previous black crackle finish, which was is fairly good condition; and the crackle effect came through the grey to enhance the finish.

Wiring Up

When wiring a completely new piece of equipment it is wise to follow through the circuits in a logical fashion; starting with the power unit and heater supplies first, then proceeding through the circuit one stage at a time. In the case of an extensive modification process, as in this instance, similar techniques are best followed. Before commencing, however, it is useful to know the simple wiring colour code adopted, which is as follows: Red—h.t. positive; Blue—l.t. positive; Yellow—h.t. negative; Black—earth; Green—grids.

Starting at the mains lead, the neutral connection is taken direct to one side of the mains transformer primary, while the live lead goes via S_4 and the mains fuse carrier to the transformer adjuster strip. Note that the switch used is actually a changeover type; thus it can only be used to break one lead.

The l.t. secondaries are next, with the 5V winding taken to pins 8 and 2 of V_9, while the 6.3V heater chain goes, via a twisted pair, to pins 2 and 7 of V_6. From here the remaining valve heater chain may be traced through the various stages until it disappears through the hole marked (*c*) in Fig. 7. As the interior of the tuning heart has not been touched, it may be assumed to be in order.

Now the h.t. wiring, with the ends of the mains secondary going to pins 4 and 6 of V_9, while the centre tap is taken to a convenient tag on the strip mounted on the side of the tuning heart near the smoothing choke. Components C_{48}, C_{49}, C_{50}, and R_{40} may now be fitted in place. Next the h.t. line is completed from pin 8 on V_9 to C_{50}, thence to the smoothing choke, and from the other side to C_{49}; continuing to the inner tag on R_{39}, then to the pole of switch S_3.

At this stage it would perhaps be best to trace the circuit through from the aerial terminal. A screened lead is fitted from the aerial socket to condensers C_1 and C_2 mounted on the tagstrip to the front of the r.f. transformers. From the other side of C_1 and C_2 connection is made to the leads protruding through the hole marked (*b*) in Fig. 5. If necessary, these leads can be traced to the relevant switch wafers as illustrated in Fig. 7 and Fig. 1.

While the tuning heart is opened for the above investigation, an ideal opportunity arises to remove unwanted leads originating from this unit at their source. Leads appearing at hole (*c*) in Fig. 7 and hole (*a*) in Fig. 5 should be left connected however. At this point the tuning heart may be closed.

The lead originating through hole (*a*) in Fig. 5 is the gain control line, and may be connected to the wiper of switch S_2.

Four leads emerge through hole (*c*) in Fig. 7. The brown lead should already be connected to the earthing tag on V_3, while the blue carries the heater supply, connecting to pin 7 of V_6. One yellow lead carries the bias supply, and goes to the outer tag of R_{26} (see Fig. 7); while the other carries h.t. from a centre tag on i.f.t.$_2$. Following this lead through further it will be noticed that R_{12} and R_{13} feed the screen of V_3 (the anode decoupling resistor R_{14} is inside i.f.t.$_2$); while the h.t. lead continues to pin 1 on V_4, where resistors R_{16} and R_{18} are supplied. From this pin, the h.t. lead reconnects to pin 4 of V_6, and from here joins up with the main h.t. connection at R_{39}.

The signal wiring between V_3 and V_4 i.f. stages is straightforward and should not have been disturbed, but it may be checked by reference to the diagrams.

The a.f. signal emerges from i.f.t.$_3$ and is taken to the filter network of which R_{19} is a part; then to the coupling condenser C_{27} and through the chassis to the top of VR_1 volume control, which is the section nearest the front panel. From the wiper of VR_1, a screened lead is taken to the grid cap of V_5; and from the bottom connection, a lead is taken to the junction of C_{28} and R_{24}.

Referring now to V_5, a check should be made to ensure that C_{53} is still connected to pin 3. Resistor R_{22} should now be inserted along with condenser C_{29}. Resistor R_{22} takes its h.t. from pin 4 of V_6, while the other side of C_{29} takes the a.f. signal to the grid of V_6 (pin 5). The bottom connection of the grid leak R_{28}, along with the cathode bias network C_{30}, R_{35}, is taken to the negative bias line at pin 6 of V_5.

Connection to the output transformer primary (made by a twisted pair from pins 3 and 4 of V_6), and output connections from the secondary winding, complete the a.f. wiring.

The a.g.c. and biasing network comes next, starting from pin 6 of V_5, where a lead is taken to the bottom end of the r.f. gain control VR_2, and thence to the junction of R_{40}, C_{48}, C_{49}, and C_{50}. From pin 6 of V_5 also check connections to R_{23}, R_{24}, and R_{34}. From the other side of R_{34}, the intermediate bias line connects to R_{33} and R_{27}, and should also be linked to the top end of VR_2. The slider of VR_2 goes to one of the contacts on switch S_2; the other contact being taken to the a.g.c. line which is picked up at the junction of R_{30} and C_{33}.

Now the tuning indicator and pilot lamp can be connected, with the l.t. voltage for both being taken from the 6.3V heater winding on the mains transformer. The h.t. connection to V_8 runs direct to C_{49} and the smoothing choke, with R_{41} wired to the valve holder as before. The cathode connection is made direct to the top end of VR_2, and finally the grid is connected to the a.g.c. contact on S_2.

If the pick-up jack facility is required, screened leads should be used to connect it to R_{21} and C_{27}, as illustrated in Fig. 4, where it will be seen that the insertion of the jack plug disconnects the receiver signal automatically. Some breakthrough may be experienced, but can be overcome by setting S_2 to OFF and VR_2 to minimum signal.