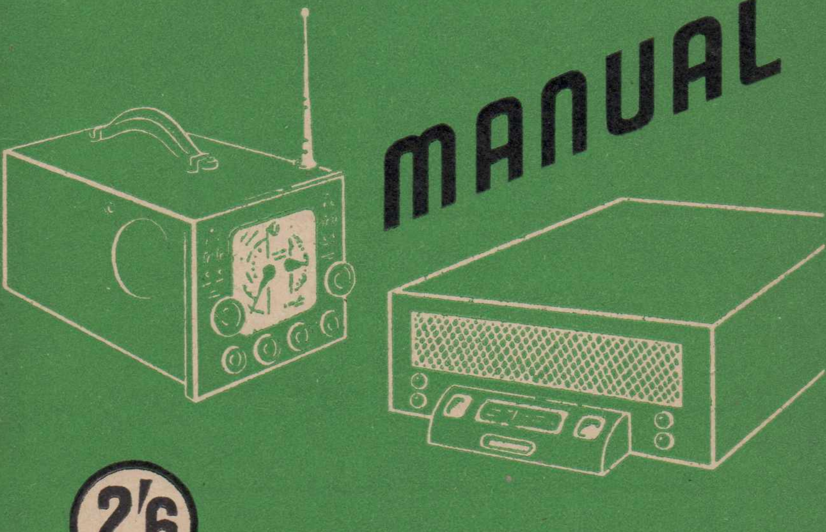
E.L.N.

CAR and PORTABLE RADIO CONSTRUCTORS MANUAL



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E. L. Nicholas

CAR AND PORTABLE RADIO CONSTRUCTORS MANUAL

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E.L.M.

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CAR RADIO SECTION

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INTRODUCTION

This small book is written with a view to adding to the rather sparse information easily available to the man in the street on the allied subjects of Car and Portable radio receivers.

Allied subjects, since although the car radio is far more selective and sensitive than the battery operated portable set, with a far greater audio power output, both types of receiver are designed to work under specialised conditions—either on the move or in the open air—and thus have rather different requirements from those pertaining to the home receiver.

The Manual is divided and the two types of set are treated separately for the car radio, whilst deriving its power supply from a storage battery, is essentially similar to a mains operated receiver. The portable, on the other hand, uses battery valves with as low a filament and H.T. consumption as possible.

Again, in the car radio section, the greater part of the text is concerned not with actual receiver circuits, although naturally these are shown and described, but upon the even more important details of power supplies and interference suppression. It has been borne in view that many readers will have, or intend to have, a ready-made or commercial receiver, and will be chiefly interested in its installation in the car.

In the portable radio section, however, the stress must be upon constructional and circuit details, especially as regards the frame aerial itself. The latest midget radios from America have demonstrated what can be done in the way of reducing the size of the receiver, and the day of the heavy suitcase type of portable is almost done. The battery manufacturers have played their part in pressing the development of a handy portable by producing layer-built batteries of remarkably small size and weight. These go admirably with the new lines of small valves with low consumption filaments, suited to work from dry cells rather than from bulky accumulators. It would, however, be of little practical value to show a series of circuits using nothing but these latest, and therefore more costly, components.

Accordingly, an effort has been made to design and explain circuits which include both modern and not so modern equipment, in the hope that by doing so something will be provided for everyone.

It should be added, here, that car owners who fit their vehicles with radio receiving gear must remember that a separate licence is required, and must be obtained from the Post Office before the gear is used.

Portable sets are covered by the existing home licence of the owner, since they are not fixed installations as are the car radios.

E. L. N.

CAR RADIO

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CHAPTER 1.

GENERAL CONSIDERATIONS.

As every owner of a television receiver, a short-wave set or a communications receiver knows only too well, the ordinary automobile is a most efficient generator of interference over a wide band of frequencies. Installing a receiver actually in a car is therefore not a task to undertake lightly, for unless reception is to be marred to the point of uselessness all the various causes of interference must be tracked and suppressed, whilst the receiver itself must be of a high sensitivity which increases the difficulty of the work.

The interference which shows itself on the television screen as a series of white flecks, or which is heard on the high or ultra high frequencies as a harsh crackle is almost entirely due to the ignition system. The spark and corresponding high frequency waves in the ignition wiring send out bursts of radio signals, but to a receiver in the automobile itself these are often the least of the disturbing factors. Practically all the electrical equipment of the car produces or draws current intermittently—even the dynamo, for example, though it is producing D.C. for storage battery charging, produces not a smooth voltage but a peaky output, the ripple depending upon the number of commutator bars and the speed of their revolution.

Nor is a device which draws a steady current above suspicion, for whilst it will not cause interference on its own account, the wiring which feeds it may be acting as a small transmitting aerial, into which is injected interference from a separate source. The roof light, for example, often needs suppression on this score.

For the moment, however, it will be sufficient to discuss the general electrical layout of the average automobile, leaving the suppression of all the various types of interference until a later chapter.

The vast majority of cars have as their electrical power supply a lead-acid storage battery or accumulator, so called since it may be recharged from the car dynamo, or, on the bench, from any source of direct current at the proper voltage. The battery consists of a number of cells, generally either 3 or 6, connected in series, and since each cell has a voltage of nominally 2 volts, the battery has an overall potential difference of 6 or 12 volts. In actual practice, the voltage is higher than this, since the potential difference across each cell, particularly when freshly charged, is more in the nature of 2.5 volts.

Each cell consists of two sets of plates which are made in the form of a framework of lead, the " windows " in the framework being filled with a tightly packed and pressed paste of lead oxide. After manufacture the plates are formed by being placed in the acid solution which acts as the electrolyte, current being passed from one plate through the electrolyte to the other plate. The resulting chemical change results in the positive plate's filling becoming lead peroxide, PbO_2, whilst the negative plate filling reduces to spongy lead, Pb, and this is the state of the cell when bought.

The electrolyte consists of a solution of pure sulphuric acid in distilled water, the specific gravity of the liquid in a charged cell being in the nature of 1.250 as measured by a commercially obtainable hydrometer. It should be pointed out straight away that this is a greater acid density than is used in small accumulators such as those supplying the filaments in a battery receiver, the acid density in these cells being generally of the order of 1.200, but it has been found advantageous to use the stronger acid in car batteries for the sake of greater capacity at the expense of a rather shorter life.

Each cell of the battery is a separate unit, containing its two sets of plates in their own electrolyte. The plates are intermeshed, and since it might be possible for them to buckle and thus touch each other, or for loose paste to fall across and bridge the gap between them, short circuits of this nature are generally prevented by including thin wooden separators between the plates. All the positive plates of a cell are cast or welded on to a main connecting lug, as are all the negative plates on to a second main lug, the two lugs being fitted into and retained by the moulded top of the cell. The internal resistance of each cell, and of the battery, is very low, so that high currents can be drawn for short periods under the stress of starting, etc.

All the connecting lugs and terminals of the battery itself should be of lead, and corrosion is prevented by smearing the terminals with vaseline. The battery should always be kept clean, spare electrolyte or spray on the top of the cells being cleaned off periodically.

As the battery discharges, the lead peroxide of the positive plates and the lead of the negative plates, together with the sulphuric acid, undergo a chemical change. The acid density drops towards that of water, showing that the acid is weakening, whilst the two plates form lead sulphate. Upon charge, however, the sulphate radicle is expelled from the plates, the specific gravity of the acid rises again and the plates resume their former condition.

Both charging and discharging should be at the specified rate, neither being carried to excess. Overworking or overcharging the battery causes buckling of the plates, loosening of the filling, the dropping of sediment to the bottom of the cell and the loss of acid by spraying. This last is a result of overcharging or recharging at too rapid a rate. The level of the acid should be topped up occasionally with distilled water, the specific gravity of the acid being checked from time to time.

As a last remark concerning the car battery, it might be stated that the capacity of a cell or battery is expressed in ampere-hours. For example, a 50 ampere-hour cell would supply a current of 1 ampere for 50 hours or a current of 50 amperes for 1 hour. It is of more value, especially when comparing different batteries, to use the watt-hour rating, which is simply the ampere-hour capacity multiplied by the battery voltage, the average voltage across the battery during discharge being taken.

The normal discharge rate for a battery, however, is given at a 10 or 20 hour rating. Thus, a 50 ampere-hour battery at a 20 hour rating would supply a current of 2.5 amperes.

When installing a car radio it is good practice to give the battery a thorough overhaul. The extra load taken by the receiver is approximately 35 to 40 watts, which corresponds to loads of about 6 amps on a 6 volt battery or about 3 amps on a 12 volt battery, when 12 volt receiving equipment is used in the latter case. Running a 6 volt receiver from a 12 volt battery causes an added complication, however, since it is undesirable to tap the receiver across the battery, for this obviously would cause uneven discharging. Accordingly, a dropping resistor is used in series with the receiver so that in this case the load rises to perhaps 70 watts, and the 12 volt battery is still supplying about 6 amperes.

These remarks apply more to vibrator power supplies which until now have been considered practically standard practice, but here again the war-time influence is felt. Genemotors have been used for the supply of power to mobile equipment throughout the Services with great success, and they are compared with vibrator power supplies in the chapter on the car radio power pack.

The receiver itself, as distinct from its accessories, has certain requirements which must be met. It must be perfectly shielded, being built in a metal or metal covered case with all sides bonded together. It must be of such a size that it will fit into such space as is available—generally into the dash pockets or under the dashboard with supporting brackets. Wherever possible it should be built to take the feed voltage from the battery direct, without the use of dropping resistors. Push button tuning, at least on the main stations, is highly desirable, although remote control of the manual tuning dial from a tuning box mounted on the steering wheel is also popular.

The receiver must be highly sensitive with good A.V.C. characteristics, although, since signal strength may fluctuate very rapidly, delayed A.V.C. system must have a short time constant. Finally, the output of the receiver must be powerful enough to overcome the mechanical noise of the vehicle, though never so overpowering that warnings cannot be heard.

THE AERIAL.

Whilst the aerial does not warrant a separate chapter, it must nevertheless receive careful attention, and is accordingly dealt with here. Car aerials fall into four main types, the roof aerial, the under-chassis aerial, the running-board aerial and the telescopic rod aerial, the latter probably being the most popular.

The sole virtue of the under-chassis aerial lies in the fact that it is inconspicuous, and where it is desirable or necessary to avoid altering the appearance of the vehicle either this type or the running-board aerial must be used. In either case, however, the aerial at best can only be a very short distance above ground with a consequently high capacity to earth so that it is probably more correct to speak of it as a counterpoise earth.

Another obvious disadvantage of these two types of aerial is the fouling they will suffer in bad weather, whilst both of them are in a position most prone to the picking up of interference from the car engine and mechanism.

Both the running-board and under-chassis aerial may consist of three or four wires running parallel to each other, connected at one end only both to each other and to the lead-in. In the case of the running-board aerial the wires can be stretched between stand-off insulators mounted at either end of the underside of the running-board, or the insulators can be screwed on to hardwood strips which in turn can be fastened in place by the running board fixing bolts. A heavy wire with a tough rubber sheathing is suitable, and as with all car radio equipment the working vibration must be borne in mind. To prevent loosening with consequent variations in signal strength and the introduction of rubbing contact noises, it is not sufficient to anchor the wire under the stand-off insulator nut. A measured length of wire could be twisted into a loop at each end, the loops being well tinned and fitted to the screwed threads of the stand-off insulators, or, better, a substantial lug might be soldered to either end of the wire, the lugs being drilled for fitting to the stand-offs.

The under-chassis aerial can be made in the same way, that is, by fitting stand-off insulators to hardwood strips, the strips being affixed to convenient bolts below the chassis, but a more convenient type of aerial to use is the horizontal V. For this aerial only two wires are used, connected at one end, the apex of the V generally at the front of the car, the wires separating as they proceed rearwards to two stand-off insulators on either side of the back axle, thus forming a V shape. The lead-in is taken from the junction of the two aerial wires, and the same remarks concerning rigidity and stout well-insulated wire apply. In some cases it is found necessary to mount one end of an under-chassis aerial by a strong tension spring, to take up play and vibration.

The fitting of the under-chassis aerial really requires an inspection pit, however, unlike the running-board aerial, which is simpler to fix, and, as already mentioned, it cannot really be recommended.

The roof aerial can be fitted either inside or outside the vehicle, the inside aerial preferably consisting of a sheet of copper gauze or a series of parallel wires. The outside aerial is generally decorative in shape, often consisting of a stout plated rod curved to suit the contour of the car roof with an ornamental " scroll " at the front.

The inside roof aerial should be fitted between the roof and the fabric lining if it is not to be unsightly, so that a good deal of work is required in the stripping and replacing of the roof fabric. Obviously the aerial, whether of the gauze sheet or multi-wire type, must be insulated from the metal work of the car body since this acts as the earth, so that, as in many other cases when dealing with car radio, actual details of how the work is to be done cannot be given since they will depend on the make of vehicle. It can only be said that if the copper gauze aerial is fitted the area of the gauze should be as large as is comfortably possible. A multi-wire aerial should consist of four or six parallel wires running the length of the roof, anchored where necessary by small insulators between roof and fabric. These insulators could conveniently be of bobbin form, made up of three paxolin or fibre washers, the outer two having a greater diameter than the central washer to form the bobbin.

A sunshine or folding roof will clearly complicate the position to such a degree that the interior roof aerial becomes impracticable. If a roof aerial is to be retained it must therefore be of the outside variety, and may be obtained commercially. This is perhaps the best plan where such an aerial is to be used, for not only will the equipment be bought to suit the car but it will also have suitable fixing bolts and washers with it. Aerials have been designed to fit to the outside of the car merely by the suction of vacuum cups, retained by an adhesive mixture, but a good bolted fitting is much more desirable. In any case, the car body must be drilled to take the lead-in, so that weather proofing is always an integral part of the fixing of an outside aerial.

In the case of a sliding roof the aerial must first be positioned in such a way that the roof action will not be impaired either by the aerial or by its fixing bolts, remembering that the bolt shank and nut will protrude a slight amount inside the car. When the roof is drilled and the aerial placed in position, the bolt holes must be fitted with washers both for insulation (though this should be provided by the supports purchased with the equipment) and also for weather proofing. In the case of a home-made aerial these washers are probably best made of rubber, but a leather washer with a fibre washer for insulation are quite suitable. The lead-in must be packed tightly into its hole, either with rubber sleeving or tape, and be made absolutely watertight.

The fixing of the telescopic rod type aerial is rather less difficult, but the positioning of the aerial needs careful thought. In some cases the rear bumper is chosen to carry the rod, but in this case it must be remembered that the lead-in has to be carried the length of the body to the receiver, thus being open to pick-up of interference. The majority of telescopic aerials are positioned on the near-side of the car just before the passenger's door, at such an angle that they are parallel to the door hinge line. This means that the lead-in can be kept short, whilst the bolt holes for the aerial supports are less troublesome to drill. Here again it is wise to buy a commercial type of aerial, for although a rod aerial can be made with simple tools, good telescopic action is not easy to achieve with the desired rigidity.

THE LEAD-IN.

Whatever type of aerial is used on the car, the lead-in must always be of screened cable of as low capacity as possible. Co-axial feeder line makes the best lead-in, the screening being earthed both at the aerial end and at the receiver where it is bonded into the cabinet screening. Since practically all car aerials exhibit high capacity effects, thus loading up the first tuned circuit of the receiver to a considerable degree, the lead-in capacity must be kept down. If, in spite of using screened cable, interference still breaks through on the lead-in, anti-noise transformers will have to be fitted, one at the aerial end and one inside the receiver. This step, however, should not be necessary in a properly carried out installation.

The lead-in must be firmly fixed at the aerial end, particularly in the case of the under-chassis or running-board aerial, where there will be considerable fouling of the connection. For these types of aerials the lead-in should be fitted with a soldered lug, this being bolted down into tight contact with the lug on the end of the aerial. The junction should then either be taped or given a coat of suitable weatherproof paint. Corrosion or vibration at the lead-in-aerial joint will give a great deal of trouble, since the noise resulting from the poor contact will probably be confused with electrical interference from the engine.

The aerials mentioned may be graded for efficiency roughly as follows: first, the roof aerial, inside or out; secondly, the telescopic rod; thirdly, the running-board aerial; and fourthly, the under-chassis, although, as already pointed out, both of these latter aerials are to be avoided wherever possible.

CHAPTER 2.

POWER SUPPLIES.

It has already been mentioned that for the car radio receiver the power must be supplied from the car battery, the H.T. voltage being obtained either through a vibrator system or through the use of a genemotor.

Whatever power supplying device is used, its function obviously is to step up the available 6 or 12 volts to something like 300 volts at a current depending upon the needs of the receiver. A current of 85 milliamps might easily be required by a conventional chain of valves, however, so that it can be seen straight away that a robust power pack assembly is a necessity, both electrically and mechanically.

Moreover, the smoothing of the power supplies is highly important, since there is always the chance of injecting interference into the receiver through the power leads, whilst the vibrator is capable of causing a good deal of interference on its own account.

Whilst the action of the genemotor is obvious from its title—a motor winding drives, on the same shaft, a generator winding which supplies through a separate commutator the H.T. current—the action of the vibrator is not so clear, and is therefore dealt with in greater detail.

The genemotor has been but little used for ordinary car radio purposes in this country, but providing that room and mounting space are available for the instrument there is no reason why it should not give excellent performance. At the time of writing, quite a wide selection of machines are available through ordinary radio channels as Government surplus, one example giving for a 6 volt input an output of 250 volts at 72 milliamps. A receiver could be built down to this figure without difficulty, when the current drawn from a 6 volt battery supplying the input power would be somewhere in the nature of 5 amperes after allowing for an efficiency figure of 60%.

When working out the current drains taken by different forms of converting apparatus, the efficiency of the power supply gear must be calculated into the final result. The input current is arrived at by comparing the watts input with the watts output, allowing for the efficiency of the system which for a genemotor is in the nature of the stated 60%. Thus, the calculation for the above example is:—

$$\text{Battery current} = \frac{250 \times 0.072 \times \frac{100}{60}}{6}$$

remembering to bring the output current, expressed in milliamps, to amperes by dividing by 1,000.

The smoothing required to render the output power suitable for feeding the receiver will vary with the make of machine obtained, and with some types it is possible to use very little smoothing at all. The ripple frequency superimposed on the D.C. output is directly proportional to the number of commutator bars and the speed at which the genemotor runs. Perhaps the best plan, therefore, before installing the gear in the car is to make a trial bench run. The receiver is used with H.T. from the genemotor which in turn is supplied from the battery, the valve heaters also drawing their power from the same battery. With no smoothing at all there will probably be whine or hum in the loudspeaker, although any sparking at the commutator will be introduced as interference. The smoothing may now be inserted in the H.T. supply leads, an R.F. choke being installed immediately before the receiver if it is not integral with the power leads inside the set. For the smoothing proper, the genemotor may be treated as is a domestic D.C. supply, a low resistance choke being by-passed with capacities best found by experiment, although nominal values are shown in Fig. 1. In a few cases a condenser directly across the output of the machine is all that is required, and is fitted by some manufacturers.

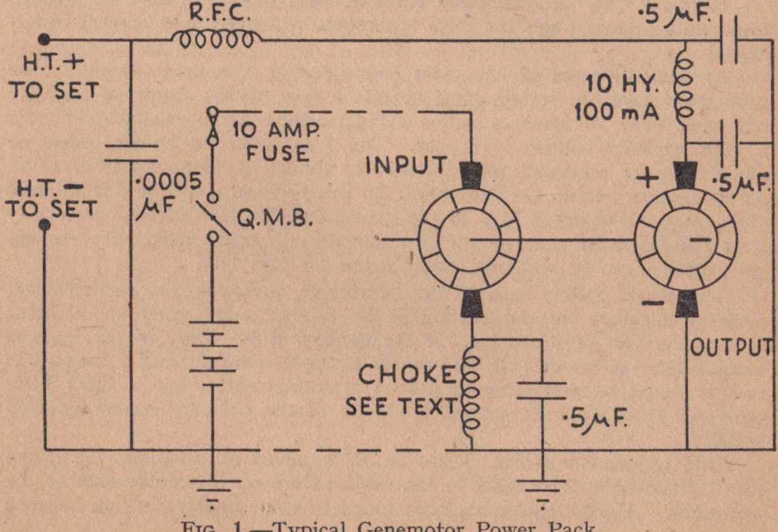

FIG. 1.—Typical Genemotor Power Pack.

The R.F. choke may seem an unnecessary refinement, but it must be remembered that ignition interference can be picked up by the H.T. leads, as well as passing into them via the battery leads and the genemotor. It must be capable of carrying the full H.T. current, but since this will rarely be greater than about 80 milliamps no difficulty should be met with on this score.

Fig. 1 shows the genemotor circuit complete with conventional smoothing as installed in the car. Since the machine may require to be some distance from the battery, really heavy leads must be used to supply the input current, the switch being a Q.M.B. type capable of carrying over the 5 amps.—a 10 amp. rating would be preferable. The leads must be as direct as possible, since at a current of 5 amps. a lead resistance of only 0.1 ohm causes a voltage drop of 0.5 volt. For this reason the genemotor is sometimes switched in by relay, but since this causes an extra current drain on the battery whenever the relay is energised, the simple switch seems preferable.

The H.T. leads can be as long as required, within reason, if the R.F. chokes, with their by-pass condensers, are included at the receiver end.

All the earth returns at the genemotor should be brought to one single point, which is then bonded by stout copper braid to the chassis.

Whether room is found for the machine under the bonnet or whether it is installed, as in some cases, in the rear luggage compartment, it should be mounted to a firm base by rubber shock absorbers with the spindle horizontal. The bearings on a new machine should be run in on the bench, and should always receive proper care and attention, being regularly greased and inspected. The genemotor must be mounted where it is clear of damp or petrol or oil, and the commutators must be kept clean, with true running brushgear to avoid sparking.

Bad sparking, after lengthy running, will most probably be due to commutator wear, when the mica separators will need very careful under-cutting.

As with all types of car radio power supply, the input wiring to the genemotor from the battery must include a fuse, with a rating of certainly not more than 10 amperes unless a big machine doing special duty from a high capacity battery is in use. The fuse, with its holder, must be mounted in an accessible place, and room should be found for it, if at all possible, on or behind the dashboard. In this position it will be conveniently wired into the switched lead to the genemotor, the lead coming preferably from the discharge side of the car ammeter, in order that extra current consumption can be watched, or from the car fuse box.

The single battery lead to the genemotor, presuming an earth return, must be adequate for the current to be carried, and should be insulated to suit the run of the cable. If the genemotor is placed in the luggage compartment at the rear of the car, for example, necessitating a long cable run, it would be preferable to use an armoured cable, but a short lead, protected throughout its length, could be of the ordinary rubber covered variety.

One component in Fig. 1 has as yet received no mention, the choke with its associated condenser in the earth return on the motor side of the genemotor. A small choke has been found of value in this position in some cases, especially where the receiver operates on the short-wave bands. Naturally, since the choke has to carry the full driving current of the machine it can consist of only a few turns of heavy wire, but in some cases it will be found to cut out any " hash " that might occur. If it is found desirable to include this choke-condenser combination, an ordinary 0.5 mfd. condenser is connected across 60 turns of 14 S.W.G. enamelled copper wire wound on a 1″ diameter former such as wooden dowelling, the turns touching.

The smaller components of the H.T. power supply, including this last choke, should be mounted within a screened box for best results, this box being bonded to earth via the common copper braid earth lead.

VIBRATOR POWER SUPPLIES.

The underlying principle of the vibrator type of power pack is to interrupt the D.C. supply from the battery into the primary winding of a transformer similar to the mains transformer of an A.C. receiver. In this way the primary current is stopped and recommenced at a fairly high rate so that the transformer has a correspondingly varying magnetic flux. An alternating current is thereby induced in the secondary windings of the transformer, this current being rectified either in the usual way, by a valve, or by the vibrator itself.

The self-rectifying vibrator is known as the synchronous type, the straightforward vibrator where valve rectification is used as the a-synchronous type.

In both cases the vibrator may be likened to the armature of an electric bell or buzzer, working on the simple principle of an electromagnet which attracts a springy arm whenever current is supplied to the coil. The attraction of the arm, however, causes the circuit of the energising coil to be broken, so that the arm springs back and the circuit is re-made, setting up attraction once more, the cycle of operation being repeated at the natural frequency of the vibrator for as long as the supply is connected.

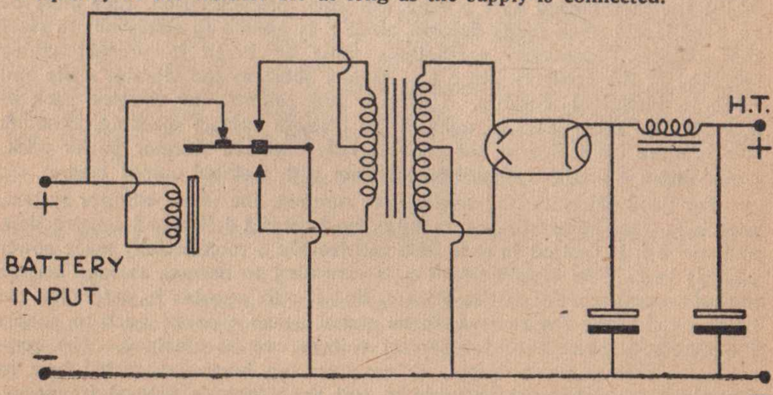

FIG. 2A.—Basic A-synchronous Vibrator Circuit.

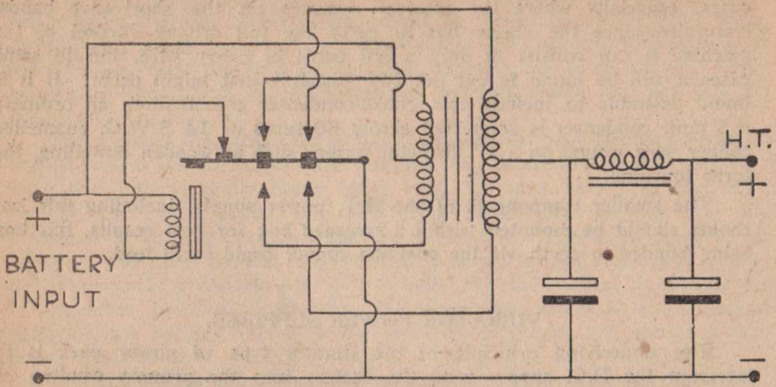

FIG. 2B.—Basic Synchronous or Self Rectifying Vibrator Circuit.

Fig. 2 shows the contacts in diagram form on both the a-synchronous and synchronous types of vibrator, feeding into a transformer in the first case and both feeding in and rectifying the output in the second case. It will be seen that in both types of rectifier the D.C. input to the primary winding is reversed at each interruption, since there is a contact on either side of the vibrating armature, the transformer primary being centre-tapped to permit correct feeding.

The synchronous vibrator has two further contacts, however, the secondary output being fed to these, and since the alternations of polarity in the secondary winding depend on the vibrations of the armature, it can easily be seen that the switching of first one side of the secondary winding to the output line, then the other, leads to the rectification of the H.T. supply.

The adjustments of the vibrator are very delicate and easily upset, and whilst the instruments have a long life when properly used, they must be replaced if and when faults develop, since it is useless to endeavour to reset the contacts. Moreover, precautions must be taken to prevent undue sparking at the contacts, since this rapidly shortens the vibrator's life and leads to inefficient working. Under or over-running the vibrator pack as a whole also often leads to reduced life through contact sparking, although this is more applicable to the commercially obtained vibrator power pack, containing a specially designed transformer with a stated output load.

For good efficiency and trouble-free running, the whole vibrator system, especially when self-rectifying, requires most careful design and construction, and where it is desired to save time and trouble a commercially made power pack is best. The supply situation is returning to normal, various makers having several models on the market, and it only remains to determine the input required by the receiver to be stated, when a power pack to supply the necessary current at the correct voltage can be obtained. The commercial vibratory power supply scores over the home-constructed type in that the transformer can be made to suit the vibrator's natural frequency, the transformer thus being resonant to the vibrator. Obviously, when this is the case the system as a whole has greater efficiency, there is less sparking trouble, and the suppression of interference becomes easier. The unit is also compact and screened, and ready to mount.

Vibrators are also readily obtainable, however, and many constructors will undoubtedly require details of the construction of a power pack using ordinary components. The points to bear in mind are that the vibrator is a very efficient spark transmitter, so that it must be built in a screened box made solidly of sheet metal with all joins bonded, that R.F. filtering as well as hum filtering must be provided and that buffer condensers which regulate the contact sparking must be carefully chosen, preferably with the aid of an oscilloscope whenever possible.

For home construction it will probably be simpler to use valve rectification, although the use of a synchonous vibrator does not present great difficulties so long as some method of determining the requisite buffer condensers is to hand. Failing the oscilloscope test, the vibrator can may be removed in the last resort, and the condenser values discovered by trial and error whilst actually watching the contact sparking.

In Figs. 3 and 4 two practical circuits are shown using valve and self-rectification respectively. Before discussing the smaller points, the transformer common to each circuit must be explained, and its method of construction outlined. (Transformers suitable for vibrator power packs are obtainable from Messrs. Bulgin and Co., Ltd.)

The primary of the transformer is to be supplied with switched D.C. from the vibrator, at either 6 or 12 volts, depending on the car system. Since the primary is centre-tapped this means that each side of the winding must be wound for either 6 or 12 volts, so that immediately the 6 volt system is seen to have advantages. In this case it is often possible to utilise a mains transformer without any modifications, since one possessing three 4 volt windings, one of them being centre-tapped, or a transformer with two similarly rated 6 volt windings will suit the case, so long as these low voltage windings can safely carry the current it is required to pass.

The first problem, then, is to calculate the primary current which once again depends on the output required from the secondary. Presuming the transformer to have the usual H.T. secondary rated at 350-0-350 volts, 100 mA., it should be possible to obtain a 300 volt output, the current still being rated at 100 mA. to keep the theoretical primary demand high. This being the case, the output in volt-amps. will be 300×0.1 or 30 v.a., and, assuming an efficiency for the system of 60%, the primary load will be $30 \times \frac{100}{60}$ or 50 v.a. The primary current is thus $\frac{50}{6}$ amps. for a 6 volt supply or $\frac{50}{12}$ for a 12 volt supply, that is, 8.3 amps. and 4.15 amps. approx. respectively.

The primary winding is centre-tapped, however, which means that the average current throughout the whole winding is roughly half of the stated current, since the primary has only one-half of the winding working at a time. Thus, the primary needs to be wound for, say, 4.5 amps. for 6 volt batteries and 2.5 amps. for 12 volt batteries, and, in the former

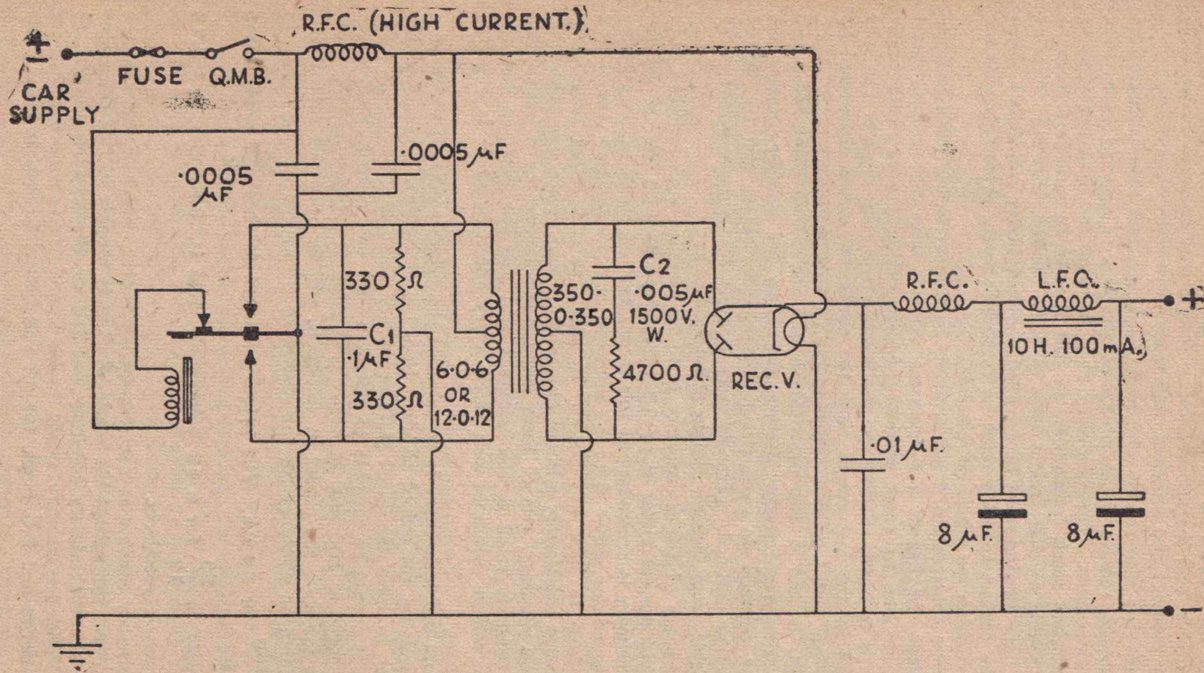

FIG. 3.—Valve Rectifying Vibrator Power Supply.
For details of choice and adjustment of C_1 and C_2, see text.

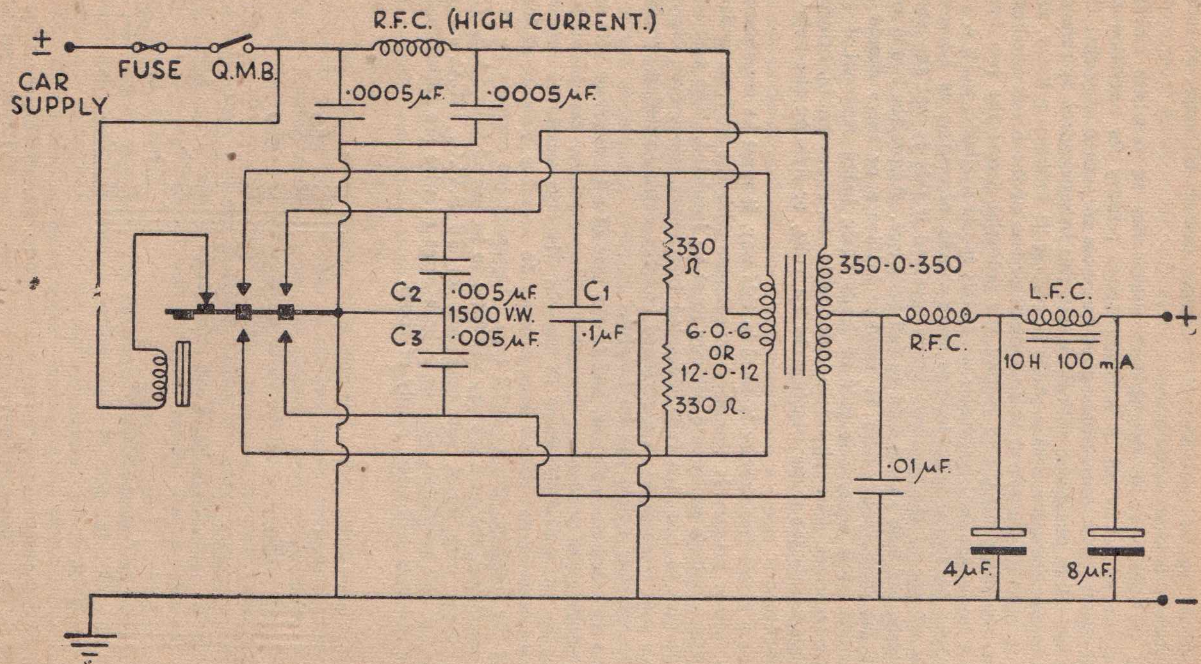

FIG. 4.—Synchronous Vibrator Power Supply.
For details of choice and adjustment of C_1, C_2 and C_3 see text.

case, a transformer with low voltage windings rated at 4.5 amps. or more can be used without modification.

Figs. 5a and b show how 4 volt secondaries of requisite current capacities are joined to act as a centre-tapped primary for operation on a 6 volt circuit. The connections must be made in such a way that the windings are all in phase one with the other, this being checked by running the transformer from the 240 v. A.C. supply on its ordinary primary, and connecting together the two 6 volt windings or two of the 4 volt windings, whichever are being used, and testing the potential across the two open ends by a low range A.C. voltmeter or, if this is not available, a 12 v. car bulb. Across the two 6 volt windings there should, of course, be 12 volts, the leads of one of the windings being reversed if this is not the case. Alternatively, the bulb should light to full brilliance. Across the two 4 volt windings the bulb should light to medium brilliance or there should be an indication of 8 volts, one pair of leads again being reversed if the phasing is incorrect. The third 4 volt winding is now connected in, bringing the voltage across the three windings to 12 volts, or lighting the bulb to full brilliance.

When a mains transformer is used in this way, it must be remembered that the 240 v. primary is energised in common with the H.T. secondary, so that the terminals of the old primary must be insulated. The best type of transformer to use is a fully shrouded instrument, since even though the whole unit is enclosed in a screened box the extra screening provided by the transformer shield will be helpful.

For a 12 volt battery circuit, and in the case of a transformer with low voltage windings of inadequate current carrying capacity, the instrument will have to be re-wound. Some of the old windings should be removed and their place taken with a new primary to suit the new conditions, either of the 6-0-6 or the 12-0-12 type. Assuming the currents to be as already calculated, the new primary will have to be wound with 14 S.W.G. D.C.C. copper wire for 6 volt operation, or 16 S.W.G. D.C.C. copper wire for 12 volt operation, and since both sizes of wire are rather bulky the new windings will need plenty of room.

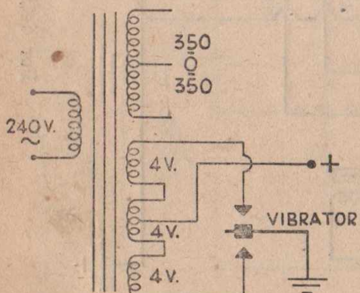

FIG. 5A.—4 volt windings as Vibrator primary.

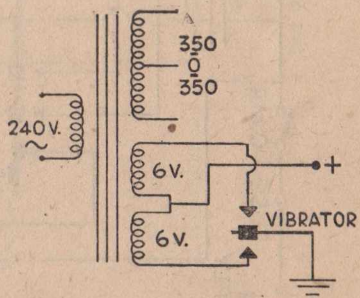

FIG. 5B.—6 volt windings as Vibrator primary.

On the transformer, however, the old low voltage windings can be scrapped, giving a fair degree of winding space, and, if necessary the old 240 volt primary can also be stripped off, leaving the 350-0-350 secondary.

Unfortunately, the primary is generally the lowest winding on the majority of transformers, although by removing one cheek of the core, taking care not to disturb any of the secondary windings, the primary can sometimes be stripped out of the centre of the windings.

The first operation, however, is to remove the old low voltage secondaries, almost always on the outside of the transformer, counting the number of turns per volt as the first is being removed. Thus, for a 4 volt winding with 24 turns the turns per volt would be 6, and when the new winding is put on the same figure will apply. In such a case, for example, a 6-0-6 volt winding would consist of 72 turns centre-tapped, whilst a 12-0-12 volt winding would have 144 turns centre-tapped. The lower the turns per volt figure is, so the more convenient will be the re-winding of the transformer, and since the turns per volt depends largely upon the cross-sectional area of the transformer core a large transformer will be more readily adapted than a small one.

If the whole of the new winding can be put on in place of the old low voltage secondaries the task will be simple, but if the original primary has to be removed the new primary will best be wound in two halves, one half in place of the old primary and the other in place of the low voltage secondaries. These halves will then be connected in series as before, properly phased so that when one half of the 350-0-350 volt secondary is connected to the 240 volt mains a 6-0-6 volt primary will show approximately 8 volts on an A.C. voltmeter across the whole winding, and a 12-0-12 primary will show approximately 16 or 17 volts.

Insulation between primary and secondary windings must, of course, be perfect, especially in view of the fact that high self-inducted voltages can be set up due to the fact that the transformer is not working on a sine wave, but rather on a modified square wave. Both windings have a common connection to the earth line through the vibrator, so that any leaks would be very serious.

The transformer having been supplied, other points in the two types of power pack can be noted. A rectifier valve, when used, must have its heater highly insulated from the cathode, since the cathode is at high positive potential whilst the heater is connected to the earth line. A similar state of affairs exists in A.C./D.C. receivers, however, and a range of suitable valves includes the 6X5, which is readily obtainable at the time of writing and is rated for 350 volts per anode at 75 mA. When in supply, the 84 can also be used with excellent results, and is rated at 350 volts per anode, 50 mA.

It will be seen from the diagrams that when the synchronous or self-rectifying vibrator is used a rather unusual state of affairs in the H.T. section is encountered. In the first place, the rectifying is performed by switching the ends of the secondary winding at the same time as the current flow in the primary is reversed, so that the induced reversed current in the secondary is always fed to the output of the power pack in the correct manner. This, however, means that the centre tap on the secondary is positive with the ends being alternately earthed for the negative side of the supply, which also means that the current in the primary must at any moment be flowing in the correct direction to cause this state of affairs.

In a home-constructed rectifier this can be tested for in the building, preferably before the unit is finally assembled, any necessary adjustment being made by reversing the secondary leads to the vibrator rectifying contacts. In a commercial unit, however, the working of the vibrator depends upon which side of the car battery is earthed, since if the unit is made for a negatively earthed battery, connecting it to a system with a positively earthed battery will result in the wrong direction of current flow. In many cases this may be compensated for by removing the vibrator from its socket, turning through a specified angle and replacing it in the new position. In any case, the manufacturer's instructions will include details of adjusting for either positive or negative earthing, but it must be remembered at all times that the polarity must be corrected before any electrolytic condensers are connected in circuit.

As has already been mentioned, the buffer condensers distributed throughout the two types of circuit are required to damp the contact sparking which is caused by the abrupt nature of the alternations of polarity. In Fig. 6 are superimposed the curves of the primary and secondary voltages across the transformer windings, the narrow high peaks in the dashed line showing the high Back E.M.F.s which occur in the secondary,

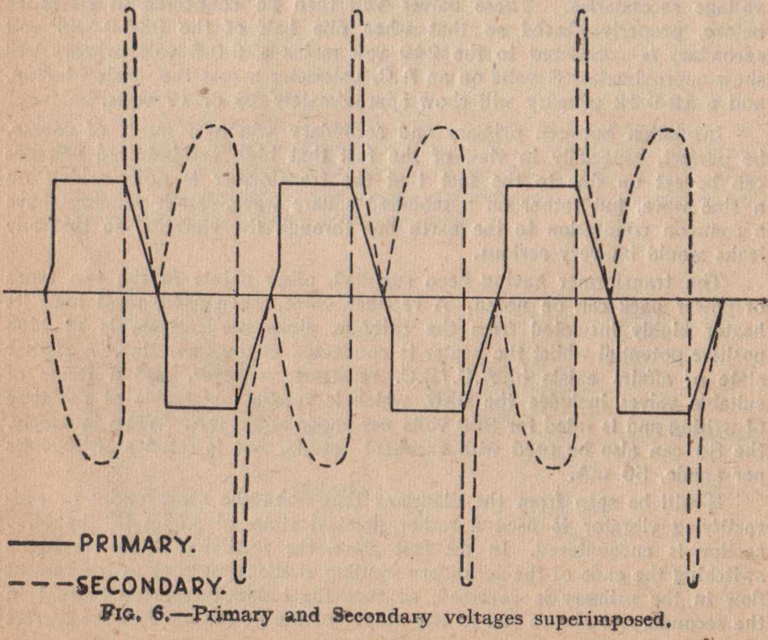

FIG. 6.—Primary and Secondary voltages superimposed.

and which have to be absorbed. It will be realised, of course, that the solid line and the dashed line of the figure are drawn to different voltage scales.

The high voltage rating of the secondary condensers is immediately explained by the high peak voltage, although the primary condenser, of 0.1 mfd. capacity in the diagrams of Figs. 3 and 4, is rated at the ordinary working voltage of approximately 350 volts.

The capacities shown in the figures are only nominal, and their final values are dependent upon the transformer and the working of the vibrator itself. The 4,700 ohm resistor in series with the condenser in Fig. 3 is a precaution against breakdown in order that the full secondary load shall not be short-circuited if the condenser insulation fails, and similar precautions may be taken if desired in the circuit of Fig. 4. If resistors are included, the condenser values must be determined with the resistors in circuit.

Assuming that an oscilloscope is obtainable, connect its input leads across the full primary winding, and with the capacities as shown, switch on the vibrator power pack, working into its receiver in order that it may be properly loaded.

A common frequency for vibrator armatures is 100 to 115 cycles per second, and with the time base running at a suitable rate the curve obtained should be similar to the solid line of Fig. 6. The primary condenser is variable within fairly wide limits, but appreciable changes will be caused in the trace by altering the capacity of the secondary condenser, and it should be simple to discover an optimum value where the curve is like that shown, watching in particular the slanting line connecting each half-cycle to the next, the slanting portion taking up 60% of the whole connecting line.

If the vibrator is easily opened, the contacts themselves can be inspected under operating conditions. With no secondary capacity there will be a practically continuous arc which, with the correct capacity, will become only an occasional spark. The vibrator case must be treated carefully, and proper metal to metal contact re-established when the can is replaced on the base, since the screening must be as good as possible. On no account must the contacts be touched, since it is upon their correct timing, relative one to the other as regards making and breaking primary and secondary circuits, that the smooth running of the whole unit depends.

The heavy current R.F. choke shown in each diagram is made in the same way as that specified for the genemotor equipment, by winding 60 turns of 14 S.W.G. copper wire, enamelled, on to a 1" former, the turns touching in a single layer. The purpose of the choke is to prevent vibrator hash from feeding back into the battery, whence it might be transmitted to the heaters of the receiver valves.

The placing of the whole power unit requires some thought, and wherever possible it is wise to remove it some distance from the radio set, taking the supply via a shielded cable to the input terminals. Since in some commercial car radio receivers the vibrator unit is integral with the rest of the equipment, this may be thought to be an unnecessary precaution, but in practice it is found to be worth while. The actual position of the power pack will depend on the make of car, but in some cases a corner of the tool box can be spared whilst in others a corner of the shielded box might be bolted on to the side of the battery container. A protected situation under the bonnet and close to the bulkhead is probably the best, in order that all leads may be as short and direct as possible.

The D.C. output in both the a-synchronous and synchronous power packs is shown filtered for both L.F. and R.F. components, and no interference from the power supply itself should pass into the receiver circuits. A further 0.0005 mfd. condenser may be shunted directly across the output terminals if required to by-pass any remaining trace of R.F. interference.

All components used should be of good quality, the smaller condensers being of the mica type and any paper condensers tested for leakage. The L.F. chokes must have as low a resistance as possible, 100 ohms being a suitable value, and the fuse in the main battery circuit should be rated to blow at not more than 10 amps.

In some cases the vibrator energising winding may require a dropping resistor in series between it and the supply line, but maker's instructions must be followed in this detail.

The Q.M.B. switch must handle 5 amps. at least, and a switch with a higher rating is preferable so long as it can be mounted in the space available. Where the same switch controls the receiver valve heater line a 10 amp. switch is essential.

In the next chapter it will be shown that a suitable series of receiver valves can be arranged in such a way that 6 volt heater valves can be supplied directly from a 12 volt battery without the use of a dropping resistor. Insofar as the rectifier valve is concerned, however, this is not the case, for it cannot be included in the receiver heater chain for obvious reasons, both on the score of safety and also to prevent the feed-through of interference.

When it is required to use a 6 volt rectifier valve with a 12 volt circuit, therefore, the valve must have its own series resistor in the heater circuit, the resistance required being simply calculated by dividing the voltage to be dropped by the working current drawn by the valve heater. In the case of the 6X5, calling the battery voltage 12.6 volts, it would be required to drop 6.3 volts at 0.6 amp. The resistance is thus $\frac{6.3}{0.6}$ or 10.5 ohms, the rating being approximately 4 watts.

The last note with reference to the power pack, *of any type,* relates to its connection to the car circuit. On no account should the input circuit of the receiver supply system be connected to the car battery direct, since this will interfere with any voltage regulation device fitted to the vehicle, thus upsetting the correct running of the whole battery charging system. The power pack input current may be taken either directly from the discharge side of the ammeter, from the fusebox terminal marked " A," supplying the ammeter, or from the fusebox terminal marked " Auxiliary," providing this fuse will stand up to the extra receiver drain. The receiver fuse must still be used when this last connection is the one chosen.

CHAPTER 3.

THE RECEIVER.

The commercially built car radio receiver is a sensitive superheterodyne with a powerful output stage, the whole circuit hardly ever consisting of less than 4 valves and with often as many as 7, where a push-pull output is provided. Several receivers include a tuned R.F. stage for the sake of the extra sensitivity and selectivity thus provided, and the general circuit layout, when this is the case, is as follows: R.F. stage, Oscillator-mixer, I.F. stage, Diode detector and A.V.C., Triode audio amplifier, Output stage.

The detector, A.V.C. diode and triode amplifier usually take the form of a double-diode-triode, with consequent saving in expense and space.

Wherever possible, the use of metal valves in a car radio receiver has much to recommend it, for not only are they exceptionally robust, but they are also more compact than the glass type and are very well shielded—an important point.

Both 6.3 and 12.6 volt heater valves are on the market, and where a receiver is being built the choice will obviously depend upon the car battery voltage. It has already been shown that dropping the voltage from a 12 volt battery to 6 volts to run a 6 volt receiver doubles the battery drain, and it is therefore highly desirable to design the receiver to suit the car. On the other hand, a chain of 6 volt valves can often be arranged in such a way as to present a 12 volt circuit at the input point, the method being apparent in Fig. 7. The valves are arranged in series-parallel, it being necessary only to balance the currents of valves in series so that each valve of a pair draws the same current. It must always be remembered that the

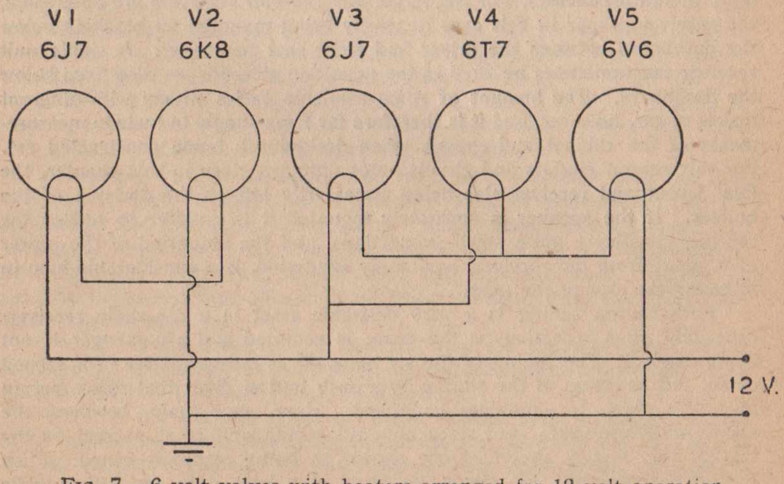

FIG. 7.—6 volt valves with heaters arranged for 12 volt operation.

rectifier cannot be included in the chain, and that where a 6 volt rectifier is to be used on a 12 volt circuit, it must be provided with its own dropping resistor, as already explained.

In the diagram the first two valves require 0.3 amps. and are in series, whilst the third and fourth valves require 0.3 and 0.15 amps. respectively. They are therefore placed in parallel so that their total demand is 0.45 amps. at 6 volts, the parallel combination being placed in series with a 6V6 output valve, which is also rated at 0.45 amps. The chain of 6 volt valves is thus suitable for connection across a 12 volt battery without the use of dropping resistors, except in the rectifier circuit.

One disadvantage of the series-parallel valve combination is that not all the valve heaters are directly earthed, although this is so unimportant for most cases that it is scarcely worth mentioning. Another disadvantage is that in the event of a heater failure in the parallel combination of V3 and V4 the remaining heater takes a heavier load. Heater failures are far from common, however, and since the receiver would give no output and would, presumably, be switched off, probably little damage would be done.

When designing a car radio receiver it is wise to restrict the tuning to the medium waveband. Longwave programmes will be received only poorly on a car aerial unless conditions are more than usually favourable, whilst so far as the B.B.C. programmes are concerned there is at least one station which may be considered as local in most parts of the country on the medium waveband. Short wave reception is so subject to interference that provision for the higher frequencies is of little value unless their reception is especially required, when more stringent interference suppression will be necessary. Even so, there will be serious interference from other cars on the road.

A commercially built car radio receiver will obviously be chosen to fit the car, since a range of set sizes will be available when the industry is once more in full production. For the larger car two-unit receivers are obtainable, the receiver proper in this case generally being mounted on brackets below the dashboard between the driver and front seat passenger. A single unit receiver can sometimes be fixed in the near-side glovebox, or also fixed below the dashboard. The amount of room available varies widely with different makes of car, however, and it is therefore far from simple to include measurements of the cabinet and chassis when designing a home constructed set. For this reason circuits and circuit notes only are given in this chapter, the final layout and receiver size being necessarily left to the decision of the builder. If the speaker is separately mounted it is possible to reduce the receiver chassis to quite small proportions, and the mounting of the power pack apart from the receiver, as already suggested, is a considerable help in reducing the size of the gear.

Push button tuning is a very desirable asset in a car radio receiver, especially when reception on the move is required and a passenger is not being carried. The tuning of the set manually is only a matter of a second or so, but selection of the station by a push button gives that extra margin of safety which is sometimes important. Here, once again, however, the supply question arises, and since no push button unit is at present on the market the circuits described are shown as being manually tuned. Push button tuning could, of course, be fitted at a later date or, with a little ingenuity, remote control tuning might be fitted, the tuning head being placed on the steering column or in some other position ready to hand. A further note will appear on remote control tuning.

In Fig. 8 is shown a 5-valve receiver circuit, using the valve chain already mentioned in connection with Fig. 7, the valve heaters being connected either in parallel for 6 volt operation or in the series-parallel chain for 12 volt working.

As will be seen from the diagram, three tuned circuits are ganged to a single tuning control, a midget type three gang condenser being used. A.V.C. is applied to the R.F. stage and to the I.F. stage, but not to the oscillator-mixer, whilst iron cored I.F. transformers are used. A double-diode-triode demodulates the signal and provides A.V.C. as well as giving one stage of audio amplification, which drives the output valve. At the given voltages this stage should provide 4 watts into a 5,000 ohm speaker load, an adequate output for practically any type of vehicle.

Inter-stage screening, as applied to components and valves, must be as good as possible. The metal case for the receiver, which is essential, prevents the injection of interference, but the circuit has such a high overall gain that all precautions against feedback must be taken, so that not only must the coils be built into screening compartments, but the leads in all R.F. and I.F. stages must be as short and direct as possible to guard against regeneration. The valves of these stages are operated with screen voltages of no more than 100 volts, which in individual cases may be reduced even further if necessary. Some loss in gain is consequent upon a lower screen voltage, but stability is much improved.

The aerial coupling is shown as either of the aperiodic or condenser type, and here again this must be chosen by actual tests, the results depending both on the efficiency of the receiver and the exact aerial on the car. The rather high capacity of the aerial and the screened lead-in has a loading effect in some cases which makes the accurate trimming of the R.F. stage somewhat difficult, and it is in such a circumstance that the aperiodic coupling scores. At the same time, reception may vary appreciably over the medium waveband, there being a marked discrepancy between the high and low frequency ends of the tuning range, and in this case the effect of a mixed coupling might be tried with a very small condenser between the aerial and grid coil together with the aperiodic arrangement.

Where the receiver is to be used in a good reception area the R.F. stage can be omitted altogether, although it must be remembered that the omission of the first valve will upset any series-parallel heater connections. As shown, the mixer is fed from the first stage via an R.F. transformer, and where the R.F. stage is not used this coupling would become an aperiodic aerial coupling, an aerial coil being substituted for the R.F. transformer type of coil.

It must also be remembered, however, that the signal-to-noise ratio is improved by the use of the R.F. stage, and where stations other than locals are required this is of considerable importance.

Whatever the size and shape of chassis decided upon, the stages should be arranged in sequence, somewhat in the manner shown in Fig. 9. In this way the chance of feedback is minimised and the leads to the components are as direct as possible.

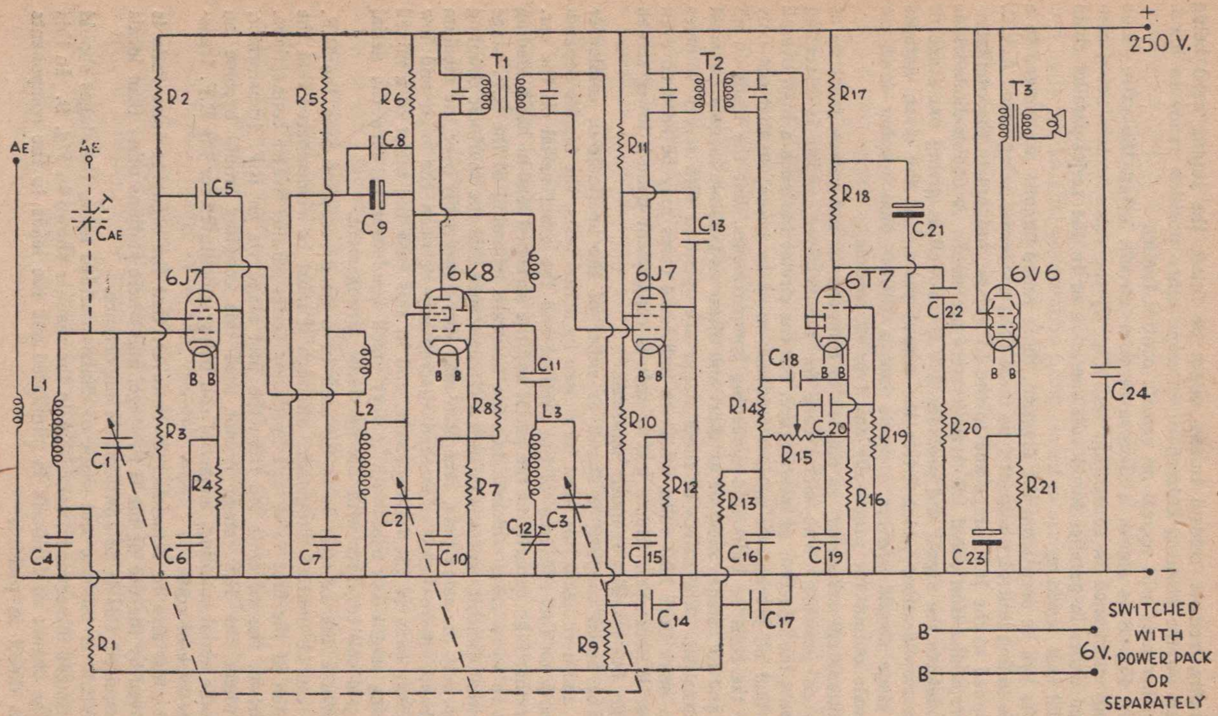

FIG. 8.—A 5 valve Car Radio Receiver.

The screening box into which the whole set is built is most simply made by cutting the sides of the box separately to the required size in sheet iron, assembling the whole into shape by the use of 90° angle brass strips at each corner. The sides should be drilled along each edge for 6 bolts, the right-angle bracketing strips being clamped to the side whilst this operation is carried out, and then, with the pair still clamped together, the holes should be tapped for 6 B.A. screws. The tapping drill for 6 B.A. threads is size 44, whilst the clearing drill, if required, is 33.

This method of building the box ensures excellent electrical contact at all junctions, as well as providing perfect mechanical rigidity. The receiver case, whether on a commercial or home-constructed set, must always be bonded to the chassis by copper braid.

Since chassis construction is necessary, the box will need to have a bottom, acting as a screen, with a false bottom, acting as the chassis, 2″ or 2½″ higher. A lesser separation could be used where the overall space is restricted, but is not advised. With a number of valves operating in such a cabinet, provision clearly must be made for ventilation, for if the heat generated is not led away not only will there be a likelihood of

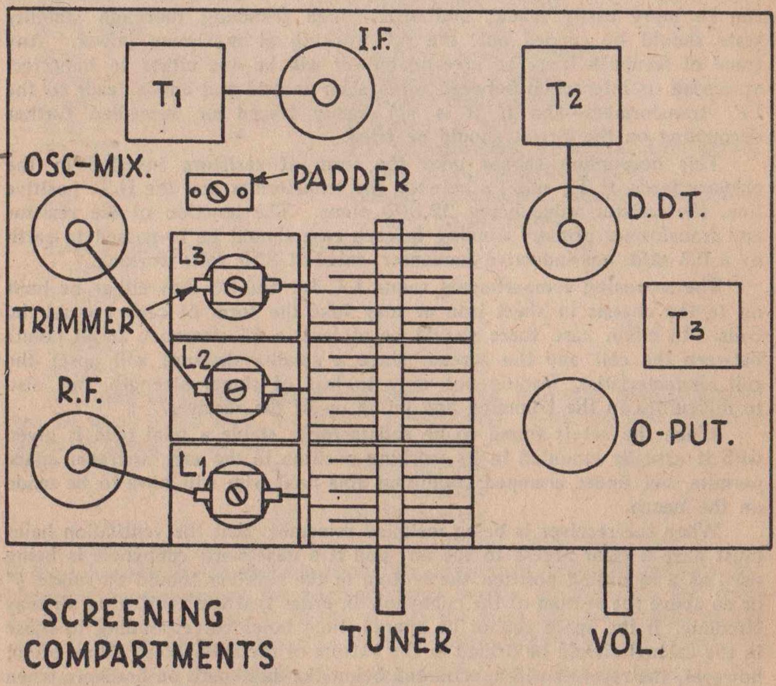

FIG. 9.—General Schematic Layout of 5 valve Receiver.

frequency drifting, but some components might easily suffer, in particular, items like electrolytic condensers.

The ventilation should take the form of a clear flow of air provided by convection currents, drawn in at the bottom of the cabinet, up through the chassis and out at the top. Holes must be drilled for this airflow, the positioning depending upon the valve spacing inside the box. Undoubtedly the best arrangement is to have a ½″ hole in the bottom of the box directly beneath each valve, there being at least 4 holes drilled in the chassis around each valveholder to allow the airflow to pass directly up the sides of the valve screening can. These chassis holes should be $\frac{1}{16}$″ in diameter. At the top of the cabinet a further set of holes, one above each valve, may be provided or a louvre can be cut to give a general outlet. The holes in the top and bottom of the box must be covered, on the inside, with suitable pieces of copper gauze of fairly open mesh, the gauze being sweated on to the sheet iron or otherwise fastened to give good electrical contact. The holes are thus protected so that nothing can project or be dropped through them to cause damage to the receiver, and at the same time the screening of the whole box is not impaired.

All receiver tests must be made with the box assembled round the chassis and closed down on top (a hinged lid is an asset, since adjustments can be more easily made), and after rough trimming thorough stability tests should be carried out, the set working at maximum power. Any trace of feedback must be investigated—it will be due either to imperfect screening or interaction between wires such as grid and anode leads to the I.F. transformers—and if it is not easily traced or remedied further decoupling on the circuit should be tried.

This decoupling should take the form of resistors inserted in the primary leads of T1 and T2 between the transformer and the H.T. positive line, the resistor value being 22,000 ohms. The junction of the resistor and transformer primary winding in each case should be by-passed to earth by a 0.1 mfd. non-inductive condenser, rated at 350 volts working.

The screening compartments round L1, L2 and L3 may either be built on to the chassis in sheet iron or may take the form of cans around the coils. In either case there should be at least a ½″ clearance at all points between the coil and the screen, since a smaller distance will upset the coil characteristics, leading not only to loss of signal strength, but also to difficulties in the trimming and lining up of the receiver.

When the set is found to be satisfactorily stable a final trim is given with it actually mounted in its working position in the car, wherever space permits, but under cramped conditions this final trim will have to be made on the bench.

When the receiver is being installed remember that the ventilation holes must have a clear access to the air, and if a dashboard cubbyhole is being used as a mounting position the bottom of the receiver should be raised ½″ or so above the bottom of the cubbyhole in order that the ventilating air may circulate. If the space cannot be spared, then holes corresponding to those in the cabinet should be drilled in the bottom of the cubbyhole. More often, however, the receiver will be mounted below the dashboard on brackets, when the air supply will be automatically provided.

The components list for the receiver of Fig. 8 is as follows :—

Components List for Circuit of Fig 8.

L1	PA2, Wearite.
L2	PHF2, Wearite.
L3	PO2, Wearite.
C1, C2, C3	0.0005 mfd. Triple Gang Variable condenser, Midget, with trimmers.
C4, C14, C17, C20	0.05 mfd. Noninductive, 350 v.w.
C5, C6, C7, C8, C10, C13, C15, C22, C24	0.1 mfd. Noninductive, 350 v.w.
C9, C21	8 mfd. Electrolytic, 350 v.w.
C11, C16, C18	0.0001 mfd. Mica.
C12	300-500 m.mfd. Padder.
C19	0.5 mfd. Noninductive, 350 v.w.
C23	25 mfd. 25 v.w. Electrolytic.
R1, R2, R3, R9, R10, R11	100,000 ohms, ½ watt.
R4, R12	1,200 ohms, ½ watt.
R5, R14, R17	22,000 ohms, ½ watt.
R6	15,000 ohms, ½ watt.
R7, R21	270 ohms, 1 watt.
R8	51,000 ohms, ¼ watt.
R13, R19	1 meg., ½ watt.
R15	0.5 meg. Volume control.
R16	5,000 ohms, ½ watt.
R18	250,000 ohms, ½ watt.
R20	0.5 meg., ½ watt.
T1, T2	I.F. transformers, 465 KCs. Iron cored, plug tuned, Wearite M400.
T3	Output transformer, loading into output stage, 5,000 ohms.

Tuning dial, octal valve holders, wire, etc.

2 6J7
1 6K8
1 6T7
1 6V6

NOTE :—

A tuning condenser without trimmers, or one with only small trimmers may be used if the coils are trimmed separately. The required trimming values as given by the coil manufacturers are :—

L1	15-60 m.mfds.
L2	15-60 m.mfds.
L3	30-90 m.mfds.

In some cases the adjustments to the circuits will be more simply made if the trimmers on the variable condenser are left at minimum capacity and trimming condensers of the postage stamp variety are fitted to the coils. The trimmers are soldered directly across the main connecting tags on the coils, their adjusting screws then being directly accessible from above.

In cases where the coils are mounted below the chassis, however, this method will be inconvenient, and the trimmers will require to be mounted separately.

The small condenser used for direct aerial coupling to V1, marked CAE, should be found experimentally. Its value will be between 0.0001 and 0.0003 mfds. for most types of aerial.

ADJUSTING THE RECEIVER.

The lining up of the receiver is carried out in the usual manner, using a signal generator covering the medium wave band and the I.F. of 465 KCs.

With the receiver switched on, and with the output either into the speaker or to an output meter, tune the signal generator to 465 KCs and feed the signal into the grid of the hexode portion of the 6K8. Bypass the grid of the oscillator portion to earth via a 0.1 mfd. condenser to prevent oscillation. Turn the volume control of the receiver to maximum output, and, for best results, short the junction of R1 and R9 with R13 to earth, thereby putting the A.V.C. out of action (this step is not necessary when using an output meter).

A signal should be heard from the loudspeaker when the output control of the signal generator is advanced, the signal being kept at the lowest audible volume whilst adjustments are being made. If the signal cannot be

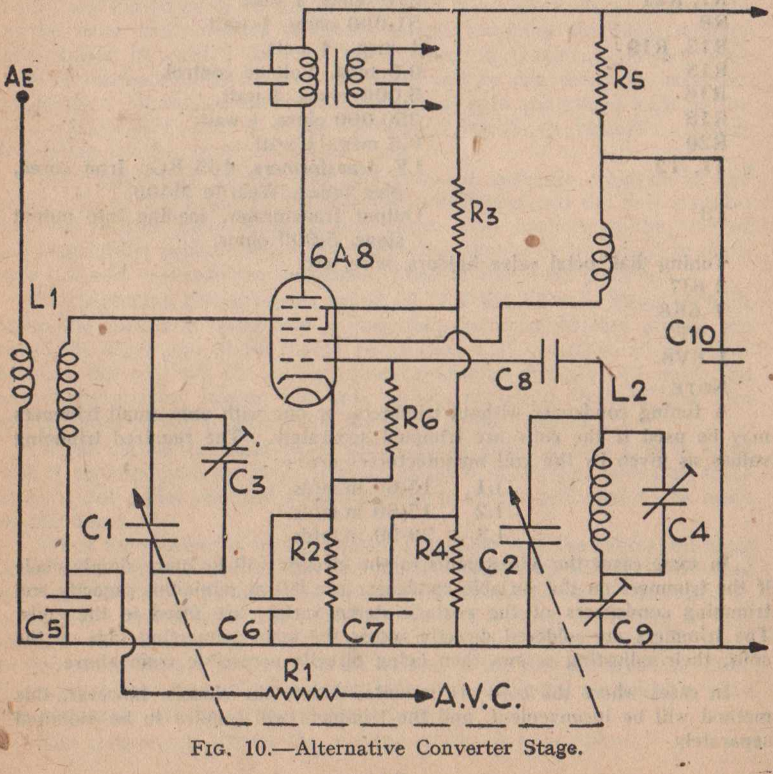

FIG. 10.—Alternative Converter Stage.

heard with full output from the generator the I.F. transformers are considerably out of trim, and it may be necessary to transfer the generator feed from the 6K8 grid to the grid of the 6J7 I.F. amplifier. In either case, commence trimming the transformers from the diode detector back towards the mixer, setting each winding adjustment to give greatest volume, reducing the generator output as the stages come into line.

The I.F. of the receiver is now set, and should not require any further attention.

Remove the temporary condenser across the oscillator grid, set all trimmers at half capacity and the padder at minimum capacity. Tune the receiver and signal generator to 250 metres and transfer the generator connections to the aerial and earth sockets of the receiver. Roughly trim the first stage to the point where a signal is heard, reducing the generator output to the lowest possible to give audibility, and trim the circuits of L2 and L3 to give greatest volume. Retune to 550 metres on both set and generator, and pad the oscillator by means of C12 to greatest volume. Retuning to 250 metres will probably show a loss of volume, requiring a readjustment on the trimmer of L3, and also on the trimmer of L2 in some cases. Repeat these trimming and padding operations until the set is tracking correctly over the waverange, and finally trim L1 to greatest volume. In many cases, however, L1 will require a final trim when the receiver is coupled to the actual aerial, when a weak station at about 250 metres should be used as the test signal.

Remove the shorting link from the A.V.C. circuit.

In cases where only strong local stations are required, the R.F. stage may be omitted from the circuit of Fig. 8, the signal being fed to the grid of the 6K8 by substituting a PA2 coil for the PHF2 coil specified. Alternatively, a different oscillator-mixer circuit might be preferred, and in Fig. 10 is shown a pentagrid converter stage, the rest of the circuit being as already shown in Fig. 8.

In either case, where no R.F. stage is used, the mixer should be connected to the A.V.C. line.

Components List for Circuit of Fig. 10.

L1	PA2, Wearite.
L2	PO2, Wearite.
C1, C2	0.0005 mfd. Double gang condenser.
C3	15-60 m.mfd. Trimmer.
C4	30-90 m.mfd. Trimmer.
C5	0.05 mfd. Noninductive, 350 v.w.
C6, C7, C10	0.1 mfd. Noninductive, 350 v.w.
C8	0.0001 mfd. Mica.
C9	300-500 m.mfd. Padder.
R1	100,000 ohms, ½ watt.
R2	300 ohms, ½ watt.
R3	30,000 ohms, ½ watt.
R4	47,000 ohms, ½ watt.
R5	22,000 ohms, ½ watt.
R6	51,000 ohms, ½ watt.
1 6A8	

The lining up of the superhet circuit with the R.F. stage omitted is carried out in the same manner as already described, the I.F. stages being set to the frequency of 465 KCs. with the oscillator trimmed and padded and the first tuned circuit trimmed afterwards, the trimming on L1, C1 being corrected if necessary on the actual aerial to be used with the receiver in situ.

REMOTE CONTROL.

Remote control is an integral feature of some commercial receivers, and a remote control system can be added to a home-built receiver if it is thought to be worth while. In places where the set is mounted in such a way that there is ready access to the controls, remote operation is probably not worth while, but if, by its use, the receiver can be mounted in a more convenient position, the use of such a control might be worth considering.

The controlling head, in most systems, is mounted on the steering column so that it is immediately to hand, and from the head run as many control cables as are required. In the case of the receiver of Fig. 8, or modified with the converter of Fig. 9, only two control cables are needed, one for tuning one one for the volume control.

By cables are meant Bowden cables for the direct control of rotating mechanisms. The on-off switches could also be mounted on the remote control head if desired, in which case fairly heavy current leads would be involved. A neater installation would result by keeping these switches on the dashboard, or on an operating panel, reserving the remote control head for the tuning and volume knobs.

For this type of operating the variable condenser should be of the type with integral slow motion, for the smoothest tuning. Bowden cable core is then attached to the inner spindle, the outer cable casing being held rigidly by a bracket attached to the receiver box. Rotating the far end of the cable core, therefore, results in the rotation of the condenser, the volume control operating in the same fashion through a second cable. Obviously the moving parts should all be free and without friction, and lubricated with the minimum amount of light oil.

The control head itself is the most difficult part of the apparatus to build, for it must provide good bearings for the operating knobs and spindles to which the ends of the cables are attached. The spindles themselves may be obtained by sawing off the spare ends of long-spindle volume controls, when at 2″ length of brass rod will be available without impairing the volume control in any way. In most cases the rod will have a diameter of ¼″, so that ordinary radio knobs of any pattern may be used. To provide suitable bearings for these spindles the control head will require to be thick, and possibly the simplest construction will take the form of two brass plates separated by distance pieces, as shown in Fig. 11. The whole bolts together in the manner of a box with the spindles held in position by collars, two on each spindle, grubscrewed in place and acting as bearing pieces against the inner walls of the box. If the distance piece between the front and back plates is cut from wood it will also act as a protecting continuous side to the box.

It will be seen that both plates are drilled with two ¼″ holes to take the spindles, which, therefore, protrude on either side of the assembly. On

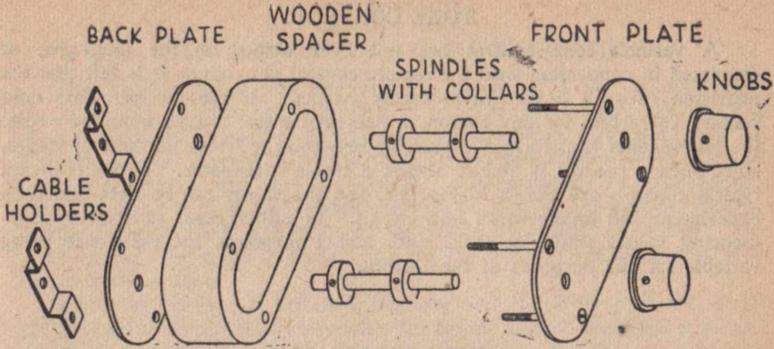

FIG. 11.—Simple Remote Control Head.

to the front projections are mounted the operating knobs, whilst at the rear the spindles are drilled centrally to a depth of ½", the hole being of such a diameter that the cable core can be inserted and sweated into place, thus becoming a fixed extension of the spindle. The outer case of the cable is held by a bent brass strip held at the back of the control head by the nuts on the fastening bolts. The cable passes through a hole in the centre of the strip in each case, and the outer case is soldered or threaded into the bent strip. This will prevent it turning with the rotation of the core.

The whole head is mounted on to the steering column or any other convenient fixing place by further straps attached to the brass strips, the straps being made of springy brass and provided with a screw clamping device.

At the receiver end it will be preferable to attach the control cables to the condenser and volume control spindles in such a way that they can be easily detached for servicing. The simplest method is that of soldering a ½" length of ¼" diameter brass rod to each cable, again drilling the rod along its central axis and sweating the cable core into the hole. The cables are thus given plug ends, which can be coupled with the receiver controls by the use of flexible couplings as made by Eddystone. The cable casings must be held in brackets made of stout brass strips screwed to the receiver case and giving sufficient clearance for the couplings to rotate.

Using the head as described means that the tuning dial reading is still shown on the receiver, and not on the control head. If station indications on the head itself are required, the head must be enlarged to take a small slow-motion dial, the drive being taken through the cable to the condenser, which should now be directly driven without further speed reduction. The head and the condenser must be ganged by tuning in a station on the receiver with the control cable detached, setting the control head dial to indicate that station, and then coupling the control cable to the condenser.

The cables will be satisfactorily earthed at the receiver, but the control head must also be earthed through its clamping strips to the steering column or to whatever mounting point is used. If the head is mounted on wood, or on a metal part insulated by enamel or paint, a bonding strip of copper braid must be run by as short a route as possible to the nearest earthing point electrically in contact with the car chassis.

TONE CONTROL.

A variable tone control has not been shown on the diagrams, or discussed in connection with the remote control gear, since it is felt that the provision of such a control is hardly needed. If the receiver tone does require correction for any reason, a present control can be mounted across the loudspeaker transformer primary or between the triode and output stages, since such a control is almost always a treble attenuator. Two circuits of typical controls are shown in Fig. 12, and the values can be determined by experiment and finally wired into circuit. In either case, satisfactory commencing values would be 0.02 mfd. and 1 megohm, the resistance being variable for the purposes of the testing.

THE LOUDSPEAKER.

Whilst there are special car radio loudspeakers available, fitted with energised fields to run, in most cases, direct from the car battery, their use is by no means essential, and a good permanent magnet speaker will give just as good results with less current consumption. The ordinary energised field speaker cannot, of course, be used since, in general, the field resistance is much too high for the limited voltage drop allowable when running from vibrator power supplies. The size of the speaker will depend on the room which can be provided for it, and, naturally, as large a speaker as can be used will be fitted. Whatever cabinet or box it is fitted into should have a drilled or openwork back, and for this reason, with others, it is not recommended that the speaker be fitted into the receiver case. Before it is finally mounted it will be as well to test it in the car with passengers in all the seats to ensure proper sound distribution, the test being made on the move.

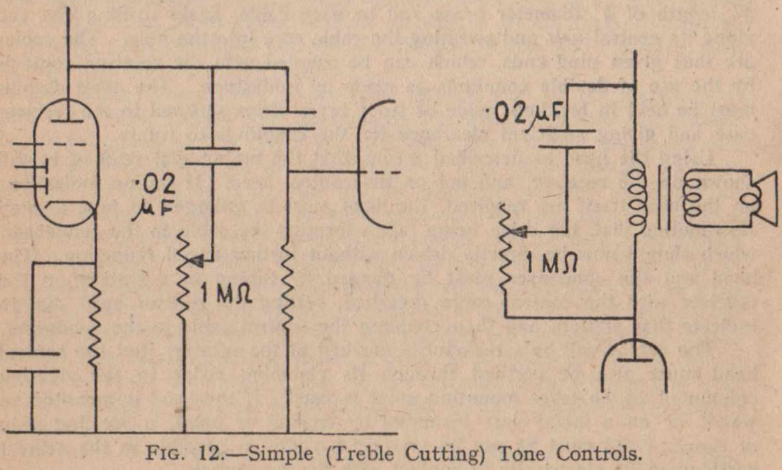

FIG. 12.—Simple (Treble Cutting) Tone Controls.

CHAPTER 4.

THE SUPPRESSION OF INTERFERENCE.

The suppression of interference is so important a part of installing a car radio that it must be dealt with at some length, and an enumeration of all the possible causes of interference would form a very impressive list. It should not be thought, however, that all the precautions to be described have to be taken in the case of every car. Circumstances vary considerably and cases have been known where the introduction of one resistor into the distributor head wiring has rendered the whole installation noise free. This is, of course, the other extreme, and on the average vehicle rather more work has to be done.

When the receiver is installed, together with its power pack and aerial, and has been proved satisfactory with the engine and all electrical apparatus switched off, testing for interference may commence, but the set must have this static test first in order to ensure that no noise is arising from the vibrator or is inherent in the receiver itself. It is advisable, also, to make the test outside the garage since on the rather inefficient aerials which have to feed most car receivers, the screening of a steel framed or iron roofed building can have considerable effect.

With these points attended to, the interference tests can commence. The set should be working at ordinary listening volume on a station not subject to fading effects, and the car doors should be closed. Switch on the ignition, ignoring for the moment any noise which might arise as soon as the key is turned, and start the engine.

Almost certainly there will be an outburst of staccato crackling, superimposed on the speaker sound, the rhythm of the crackle varying as the engine speed is varied. Two types of suppression are used, often together, to overcome ignition interference which is the cause of the crackle. The first, and almost always necessary course, being to fit a resistor in the lead from the coil or magneto to the distributor, the second being the fitting of resistors in the leads from the distributor to the plugs.

If possible, a set of plug resistors should be borrowed, since in some cases they appear to increase rather than suppress the interference, and if this can be ascertained before buying some expense will be spared.

In any case, both for the distributor and plug resistors, correct automobile components should be used. Ordinary carbon resistors are not suitable either for insertion into the car wiring or for undergoing the mechanical and electrical stresses involved. Car resistors are made with correct end fittings (lugs, in the case of the plug resistors), which fit the sparking plug terminals and screw ends (in the case of the distributor resistors), which actually screw directly into the lead.

Fit the distributor suppressing resistor (with a value of about 10,000 ohms) first, cutting the lead to the distributor as close to the head as possible and screwing the resistor home in series with the lead. If the lead is long, and goes to the distributor by an indirect route, it should be shortened, leaving sufficient slack to take up vibration. Test for interference again (it should be considerably reduced) and then, bearing in mind as clearly as possible the new interference level, fit the sparking plug resistors. These are mounted by their lugs directly on to the plug, the lead being taken to the binding post on the top of the resistor, which in each case has a value of approximately 15,000 ohms. Test once more (remembering to close the bonnet after each change).

The benefit may be apparent as soon as the engine is switched on, the ignition interference having vanished and given way to other types of noise, but in some cases it may be at a higher level with the resistors in place. If so they must be removed.

If the ignition interference is further reduced by the use of the plug resistors, but is still audible, or if the resistors have to be removed, the next step is to bond the whole engine to the chassis. This may seem an unnecessary procedure, since the engine is already bolted to the car frame, but the contacts may be electrically poor. The bonding takes the form of a length of heavy copper braid, 2″ or 3″ wide, the ends being well tinned over a hot flame so that solder lugs are formed. These are drilled to take the shank of whatever bolts are conveniently placed on both engine and chassis, the braid being bolted down under bright metal washers at either end. The engine and frame should be cleaned to receive it and to ensure first-class contact.

Ignition interference should now practically have vanished, but if it persists the exhaust pipe should be bonded to the chassis also, for in some cases a surprising degree of interference comes from this source. The aerial lead-in screening should also be bonded to the chassis at points along its length.

With these precautions taken, the remaining interference will be coming from the rest of the electrical apparatus, which must be dealt with by by-passing every suspect component by a condenser of 0.5 mfd. or 1.0 mfd. capacity. Here, again, the correct equipment as made for the work should be obtained, and ordinary radio type condensers are not suitable. The car type suppressor condenser is a non-inductive capacitor in a metal case which acts as the earthed connection, a lug being fitted so that in the bolting of the condenser to the car frame, or to the component to be suppressed, the earth connection is made automatically. The live connection to the condenser is made by a flexible pigtail, so that the condenser should be mounted under a bolt as near as possible to the live terminal to which the pigtail connection is to be made. The metal below the bolt should be cleaned and a bright metal washer may be used between the bolt head and the condenser casing lug, a shakeproof washer being used if necessary.

As with the distributor and plug suppressing resistors, the condensers should be coupled into the car electrical circuits one by one in order that the functioning of each may be checked. Almost certainly the dynamo and petrol pump will require suppression, so that two condensers should be fitted for a start, one between the dynamo charging current terminal and earth and one between the petrol pump live terminal and earth. In the unlikely event of the car's having a two-wire system it is probable that a condenser will be required between each terminal and earth.

With these condensers fitted, the receiver should again be tested with the engine running. The starter will probably cause considerable noise, but since this will only affect reception at the commencement of a journey, when the receiver in all likelihood will be off, there is no need to endeavour to correct this interference.

Presuming a diminution of noise, continue to hunt out the circuits still introducing interference. A condenser will probably be needed across the primary of the ignition coil, and whilst in some cases it is sufficient to connect this across the ignition switch, in others it is necessary to go directly to the coil itself. An electrical petrol gauge with a floating unit in the tank connected via a long lead to the dashboard indicator, can introduce noise, best suppressed by connecting the condenser across the indicating instrument. Other instruments should be tested for noise introduction at the same time, condensers being connected across the oil gauge, the clock and the other electrically-operated devices on the panel.

If noise is still present attention must now be turned to the lighting circuits, for, although a loose or intermittent connection might introduce a crackle on its own account, the lighting wiring can also act as an aerial for interference generated elsewhere. Switch on all lights, listening for any increase in noise as each circuit comes into operation, and working on any circuit where the interference is increased. In the event of there being no increase in noise, however, each circuit must be tested by connecting a condenser between the live wire and earth. This should not be done at the lamp itself, for that would leave the cable still acting as an aerial, but the condensers should go into circuit directly at the switch. In the case of stubborn noise in a lighting circuit, the interference being diminished, but not totally overcome by a condenser, a choke should be added, made in the same manner as those described in Chapters 1 and 2, by winding 50 or 60 turns of enamelled copper wire on to a 1″ diameter wooden former. The gauge of the wire can be chosen with respect to the current in that particular lighting circuit, 16 S.W.G. being adequate for a 3 amp. loading, but 14 or even 12 gauge being required for 6 amps.

Along with the lighting wiring may be tested the circuits to such auxiliary gear as the windscreen-wiper, the horn, direction indicators, etc., and with all these points attended to, and the set functioning well with the engine running, the car being at rest, the time has arrived to make trials with the car on the move.

In an unlucky case an entirely fresh batch of noises may make their appearance as soon as the vehicle is well under way, particularly in the form of brushing or scratching sounds. These are due to movement between the metal parts of the car frame and body, and no forecast can be made as regards their likelihood in any make or age of car. The remedy is bonding at all likely points, especially in so far as the bodywork of the car is concerned. The noise is due to static charges on the metal work, panels of sheet metal, for instance, touching intermittently and discharging one into the other, so that the various parts of the body and chassis must be brought into electrical contact to preserve an even charge throughout.

Suggested bonding points include the steering column to chassis, car body to chassis at one or two points along each side, bonnet and radiator to chassis, metal tool box to chassis, metal dashboard or instrument panel to chassis, separate body panels to each other and chassis, wings to chassis, and so on. The amount of work would appear to be never ending, but it will be appreciated that these bonds would only be needed in their entirety on a very bad case. The bonds are made as already described in the example of the engine, by forming a sweated lug at each end of a length of broad copper braid, the lugs being drilled and held under convenient fixing bolts, the metal first being scratch cleaned.

One further test still remains when the bonding on the framework and chassis of the car is satisfactory. There is still a possibility of wheel noise, caused by static charges set up on the wheels, or, more likely, in the brake drums by uneven brakelinings rubbing on their rims. The test should be made from the top of a gradient down which the car can coast with the engine shut off and all electrical equipment dead. Any noise due to wheel static will increase as the car gathers speed and will die away as the vehicle slows down at the foot of the slope and comes to a stop. Gently applying the brakes should show whether the brakelinings are actually the cause of the noise, since it should increase, when the remedy is obvious—the linings require attention—but true wheel static, caused by charges generated on the wheels themselves, is not simple to cure. Sets of discs are obtainable which are fitted into the wheel hubs to ensure good electrical contact with the rest of the frame, but there is generally some uncertainty about their proper functioning. Fortunately the interference does not often arise, and so far as this country is concerned neither does another static charge trouble, that of charges on the tyres themselves, since this noise source is more likely in a hot climate.

With all these sources of noise investigated and eliminated there is still one further chance of ignition interference remaking an appearance when the car is carrying passengers. If this does occur the passengers are acting as aerials and are retransmitting the noise. The fault is found most often in cars with wooden or insulated floors, the remedy being to add screening, in the form of a metal mesh, preferably copper gauze, beneath the matting on the floor, the net being bonded by braid in the usual way to the chassis at two opposite corners.

PORTABLE RADIO

CHAPTER 1.

GENERAL CONSIDERATIONS.

Portable radio types, from the point of view of the constructor, can be divided, broadly, into two main classes, those containing a frame aerial and those designed to work with an outside aerial—that is, an aerial carried with the set but, under working conditions, not enclosed inside the set cabinet as is the frame aerial.

The external aerial has really made its appearance by reason of the extreme smallness and light weight of some modern sets, since a frame aerial in the cabinets of such receivers would be little more than an ordinary tuning coil, with poor pick-up qualities. Two external aerials recently described are very novel, in one case the aerial being integral with the leads to a single light-weight earpiece and in the other being enclosed in a shoulder strap by which the set is carried. (It should be remembered that both these aerials are protected by patents.)

It should perhaps be remarked at this point that the frame aerial is no more than a tuning coil, generally the first tuned circuit of the receiver, feeding into an R.F. stage. The coil is made large and wound on a rigid frame, in order that it also may perform the functions of an aerial, although the output, expressed in millivolts due to wave induced energy, is very small since the frame aeral is inefficient on several counts.

An external aerial is not very much more efficient, however, if it is to be of convenient size. A rod aerial made to protrude from, say, the top of the set will require to be collapsible for easy packing and still will not have great pick-up qualities even when fully extended, whilst an aerial which is also used as, or built into, a carrying handle, 'phone cord or some similar device, will be close to the body, giving it a fairly high capacitance, and will be subject to a varying degree of pick-up as it is moved, besides being likely to introduce mis-tuning or fading effects into the receiver. So far as the choice between the two types of aerial is concerned, therefore, it would appear that the frame aerial is the more convenient whenever the receiver is to be of such a size that the frame can be made to give worthwhile sensitivity.

In the old suitcase type of portable, in which the frame and loudspeaker were contained in a hinged lid, the receiver and battery compartment being in the base, the frame itself was usually about 14″ square. There is no need for such a large loop as this, and the writer has conducted experiments aimed at discovering a frame size which will be more convenient to the builder and yet still keep its pick-up qualities at a reasonable level. As the frame size diminishes there is an undoubted loss in output, but a frame measuring 10″ high and 6″ broad gave quite a good signal, a 12″ square giving a rather better performance apparently by reason of its shape, as well as greater size. It would appear that a rectangular frame should work with the long side vertical—this might seem an obvious fact, using the reasoning of the explanation attached to Fig. 1, but since radio waves are subject to changes in polarisation and also angle of arrival, it is as well to confirm theory by practice.

Using a 0.0005 mfd. variable condenser, the two frames mentioned had satisfactory tuning ranges when the 10″×6″ frame was wound with 18 turns of wire and the 12″ square was wound with 12 turns. Extending the experiments to other sizes and shapes of frame, it was found that, as a generalisation, the aerial would have an approximately correct tuning range when 50 feet of wire was used for the winding, allowing for the medium wave band.

At this point, however, it is necessary to consider the frame aerial with respect to the circuit which follows it, and which it feeds. Either the frame aerial or external aerial type of portable can be further divided into straight T.R.F. or superhet receivers, the superhet as well as the straight receiver preferably being provided with an R.F. amplifying stage. So far as the frame aerial is concerned, then, it is the tuned circuit of this R.F. stage, a second tuned circuit following it in either type of receiver.

This means that for the two tuning circuits to be in gang in order that a two-gang variable condenser may be used, the frame aerial has to be matched to the tuning coil, which is sometimes not a simple matter. The self-capacity of the frame is generally greater than that of the coil in

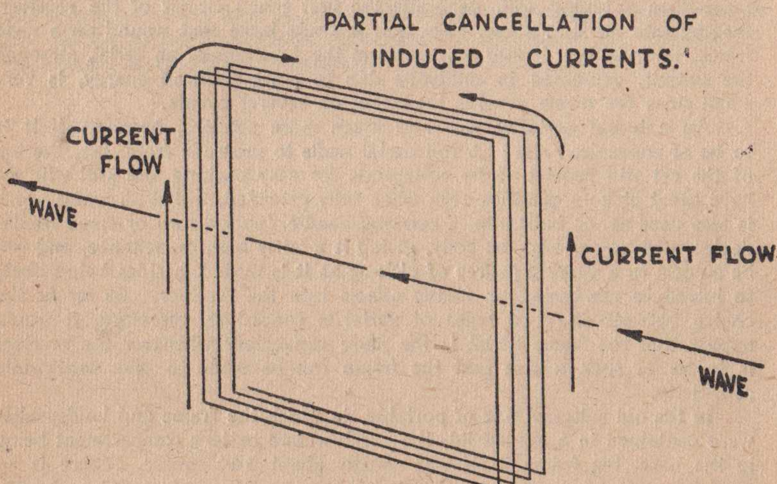

FIG. 1.—Demonstrating the partial cancellation of currents in the Frame Aerial.

the second circuit, but if an attempt is made to correct this by widely spacing the turns of the frame, the inductance is reduced disproportionately. Moreover, the frame aerial tunes fairly sharply, so that little error is permissible before losses through misalignment become serious. In the older type of portable the problem was easily solved by using two separate tuning condensers with no attempt at ganging, this method, of course, still being available to the constructor and providing at least good tuning of the receiver. Where space is at a premium, however, a ganged condenser is almost essential, the panel layout also becoming much neater, so that it remains necessary to review the methods of bringing the frame aerial tuning and the coil tuning of the next stage into line.

Fairly common commercial practice is to trim the tuning condensers with rather larger trimming condensers than are used in the ordinary domestic receiver, although too large a value will cause the tuning range to be cramped, giving small station separation. In addition to the extra trimming, the frame aerial is sometimes shunted by a resistance of approximately 20,000 to 50,000 ohms value, the effect being to broaden the tuning of the frame so that station selection is less critical. At the same time, of course, a certain degree of attenuation is introduced.

Besides these two correcting methods, the ganged condenser may be fitted with a variable trimmer which is brought out to a small control knob concentric with the larger tuning knob, the trimming being performed generally on the second tuned circuit, but above all the frame aerial should be wound to suit the tuning coil as used in the second stage of the receiver.

So far as the two frames mentioned are concerned, the 12″ square frame with 12 turns of wire agrees quite well with the Wearite PHF2 coil in the second stage, whilst the 10″×6″ frame lines up with the Wearite PHF7 coil, but since it is quite likely that the constructor will desire, in many cases at least, to use an existing case or box for the set, some experiment with the number of frame aerial turns should be made, using the basic figure of 50 feet of wire as a guide.

The best plan is to wind on at least 60 feet, and to reduce the number of turns one by one to bring the circuits into line, using either a signal generator or a station some distance away so that a rather weak signal is heard as a test signal.

In both the T.R.F. and superhet circuits some precautions must be taken against the introduction of feed-back into the frame windings, especially since a reacting detector or a local oscillator are used respectively. The receiver therefore should be built on a metal chassis, preferably of aluminium, with the second stage coils mounted inside a screening can, there being good circuit decoupling so far as the power supplies are concerned.

Inspection of the circuits which appear on subsequent pages will show that in the majority of cases tuned anode coupling is used, the second tuned stage being in the anode circuit of the R.F. valve. The question of efficient coupling of stages is thus answered in the simplest manner, since the only coupling into the detector stage is the grid condenser, whilst the secondary winding of the coil is kept free for introducing reaction. Naturally, other coils can be used, a third or H.F. transformer winding being put into service as an inter-stage coupling where it is provided, and if desired, but there can be no doubt as to the efficiency of the system shown.

Under ordinary circumstances the tuned anode can be troublesome, since with an ordinary coil and condenser tuned circuit in the grid of the valve it is quite likely that a trace of feed-back will set up oscillating conditions, as in the old T.P.T.G. oscillator, but with the frame aerial the unstable condition is far less likely to occur, allowing the circuit to be used without trouble.

As in the case of car radio reception, it is strongly advised that the tuning range of the portable should be restricted to the medium wave band, especially where a superhet circuit is to be used, or where a ganged tuning condenser is necessary. If a long-wave winding is required, the frame will be rather more tedious to make and to adjust, whilst the single trimmer, shown across each tuning condenser section, will need to be replaced by two trimmers in each stage, the trimmers being mounted across the frame sections, medium and long, in the first tuned circuit and across the two coils, medium and long, in the second stage. The wave-bands should be controlled by shorting the long-wave winding, so far as the frame aerial is concerned, and using a selecting switch to connect in either of the two coils to the second stage. As usual, the band switching may be performed by either a two-leaf or a two-circuit single-leaf Yaxley type switch.

The extra winding on the frame should consist of a further 150 feet of wire, wound on in the same direction as the medium wave winding. The wire gauge, for the two windings, is not of great importance, although the resistance of the winding should of course be kept low. Wire insulated by both a coat of enamel with a single or double winding of cotton is best, to give the frame as much protection as possible, and 22 or 24 S.W.G. is suitable for the medium wave coil, whilst the long-wave winding, if put on, may consist of 30 S.W.G. wire.

When adjusting the frame windings to line up with the coil or coils used in the tuning of the second stage, probably the best method, with signals either from a signal generator or from a broadcasting station, is to check both the coil and the frame winding across the same tuning condenser, using a tuning dial marked in degrees. The coil and condenser unit should be connected across grid and earth of a triode detector stage, via a grid condenser of 0.0005 mfd. capacity and a 1 megohm grid leak, a pair of headphones being in series with the anode. The output from a signal generator, or a short aerial, is connected to the grid end of the coil, and a station or signal at the low-wave end of the band is tuned in, noting the reading on the dial. The frame aerial is now substituted for the coil, and the same signal is retuned, noting the new reading. If the condenser has been turned to a lower setting (*i.e.*, the vanes are meshed to a lesser degree), one turn at a time must be removed from the frame until the tuning condenser is returned to its original reading. A higher setting of the dial, when the frame aerial is substituted for the coil will, of course, mean that more turns on the frame are required.

With the circuits in gang at the high frequency end of the band, they should now be tested at the lower frequency end (frequencies of 1,200 kilocycles and 600 kilocycles respectively are ideal for these tests, and are readily obtainable when using a signal generator). First tune the coil to a signal at the lower frequency, noting the reading, and repeat the process once more with the frame aerial. Any discrepancy will be taken up by the trimming condensers, a higher condenser setting for the frame aerial than that for the coil indicating that the coil trimmer must have a greater capacity than the frame trimmer, and vice versa.

In Figs. 2a and 2b are shown two methods of winding the frame, the first being that usually employed in the older type of portable. The lid was provided with a set of false sides which slipped into the actual sides and retained by spacing pieces. On this framework the aerial was wound in two sections where two wave-bands were provided, the loudspeaker being central with the aerial. The second diagram shows a method for use in a more modern type of set where the opening lid is dispensed with, the frame aerial being wound in cleats on the front panel, the speaker again being central with the frame. It will be noticed in some of the receiver circuits that the loudspeaker is shown as having an earthed secondary winding and transformer core. This is to prevent the (rather unlikely) chance of feed-back to the frame by R.F. currents appearing in the output circuits.

The batteries for the portable receiver will obviously be selected to suit the valves, the larger 2 volt valves requiring an accumulator for filament heating with a standard 90 volt H.T. battery. It is only with the smaller 1.5 volt and 0.75 volt valves that layer batteries can be used, their current drain being limited to 4 or 5 milliamps, and then the provision for adequately loading a loudspeaker is rather difficult. For certain types of set, especially that used for high frequency operation, earphones are often more convenient, but for general entertainment loudspeaker reception is essential. Standard batteries for the H.T. supplies, together with as large a dry cell as can be accommodated for filament heating is therefore recommended for use with the smaller valves.

Moving coil loudspeakers with powerful permanent magnets should always be used in the portable receiver, for not only is their tone far better than that of the majority of moving iron speakers, but they can be more accurately matched to the characteristics of the output valve, with the result

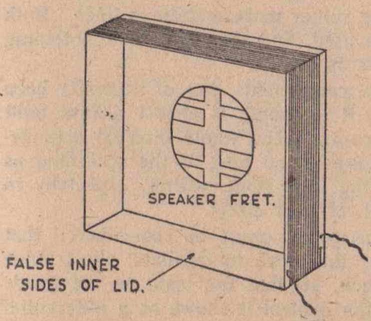

FIG. 2A.—Common method of winding Frame Aerial.

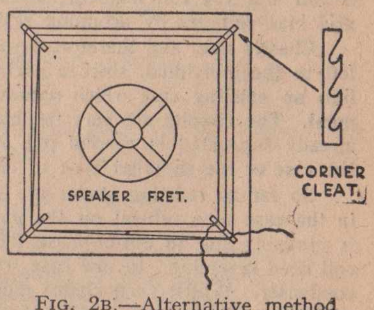

FIG. 2B.—Alternative method of winding Frame Aerial.

that there is no loss of output power. When the larger battery valves are to be incorporated in the set, a double output valve of the Class B or QPP type is a definite advantage, since excellent output with only slightly increased battery drain is available, although it must be remembered that in both cases a special driving transformer and a triode stage are required.

The grid bias battery may be eliminated by including a dropping resistor in the H.T. negative lead of such a value that the current flow through the resistor creates a potential drop across its ends equal to the highest grid bias voltage required. Other voltages may then be tapped off at suitable points. The resistor must be by-passed for audio-frequencies to prevent feed-back which may result in oscillation, motor-boating or loss of volume, and there is the slight disadvantage that the available H.T. voltage is reduced by the amount of the dropped voltage, but in most cases this will be negligible.

Whatever the form of the internal construction of the portable, the battery compartment should be kept on a lower level than that of the receiver, especially when an accumulator is used. A jelly acid accumulator is essential to prevent spilling or seepage of liquid, and a protective layer of lead foil in the battery compartment is well worth while to prevent corrosion. If the receiver is made in such a way that the frame aerial comes close to the batteries, it must be protected by a plywood partition, whilst the whole of the instrument should be weatherproof. The life of the batteries, and indeed the whole set, will be greatly shortened if any part is allowed to become damp, and receivers used in coastal districts require extra protection against sea air.

The circuits following show both frame and external aerial circuits of the T.R.F. and superhet type.

CHAPTER 2.

FRAME AERIAL RECEIVERS.

Figures 3 to 6 inclusive show circuit diagrams of receivers designed to work with frame aerials wound as already described in Chapter 1, the first three circuits showing T.R.F. or " straight " sets with similar basic designs, and the fourth a superhet along rather more ambitious lines. Both 2 volt and 1.4 volt filament valves are used, and the method of obtaining grid bias voltages by dropping resistors is shown.

Chassis size, and therefore layout of components, has of necessity been left to the individual, since a portable, it is found, is almost always built into an existing case which naturally controls the whole internal arrangement. The circuits are very flexible, however, so long as the screening as already suggested is carried out and the inter-stage wiring, especially in the case of the superhet type of circuit, is kept direct.

So far as reacting stages are concerned, it must be remembered that in the case of a refusal on the part of the valve to oscillate, the trouble is probably due to out-of-phase feed-back, so that the leads to the anode coil need reversing. In one case, reaction control is shown as a differential condenser. Whilst such claims must always remain a question of personal preference, many builders claim that this reaction control gives a very smooth performance, and it may be substituted for the simple condenser control shown in the other circuits if desired. In the same diagram, a grid leak return from the detector grid is centre-tapped via resistors to the filament, and this scheme may also be tried in other circuits.

Transformer and R.C.C. couplings are shown, between the output and penultimate stages, and in this case circuit details must be strictly adhered to, the type of coupling depending on the characteristics of both the coupled valves.

Three-point switches should be used to isolate all the power supplies from the chassis when in the OFF position, in order that any chance leakage in the circuit shall not cause the batteries to deteriorate. A volume control is shown only in the superhet circuit, since in the T.R.F. circuits volume is controlled by the reaction.

There follow lists of components for the diagrammed circuits.

Components for Circuit of Fig. 3.

L1,	Frame.
L2,	PHF2, Wearite, or medium wave coil.
C1, C2,	0.0005 mfd. 2-gang condenser.
C3, C4,	0.0001 mfd. max. Trimmer.
C5,	0.1 mfd. Noninductive.
C6,	0.0003 mfd. Mica.
C7,	0.0003 mfd. Differential reaction condenser.
C8,	0.5 mfd. Noninductive.
R1, R4,	47,000 ohms, ½ watt.
R2, R3,	2.2 megohms, ,,
R.F.C.	Screened broadcast band choke.
T1,	3 : 1 Intervalve transformer.
S1,	3-point ON-OFF switch.

V1, HP210c.
V2, HR210.
V3, PP2.
1 7-pin chassis mounting valveholder.
1 4-pin ,, ,, ,,
1 5-pin ,, ,, ,,
Tuning dial, chassis, Permanent magnet loudspeaker, etc.
Total H.T. consumption, 8-12 mA. for H.T. of 90-120 volts.
Use standard size battery.
Total filament consumption, 0.36 amps. at 2 volts.
Use jelly acid accumulator.
Grid bias voltage, 4.5 volts.
Load loudspeaker transformer into 19,000 ohms, *i.e.,* for 3 ohm speech coil use transformer with ratio of 80 : 1.

Components for Circuit of Fig. 4.

L1,	Frame.
L2,	PHF2, Wearite, or medium wave coil.
C1, C2,	0.0005 mfd. 2-gang condenser.
C3, C4,	0.0001 mfd. max. Trimmer.

ERRATUM. In Figs. 3, 4, 5, pages 46, 47, 49, the bottom end of C2 should be connected to L.T. and H.T. —ve., **not** to L2.

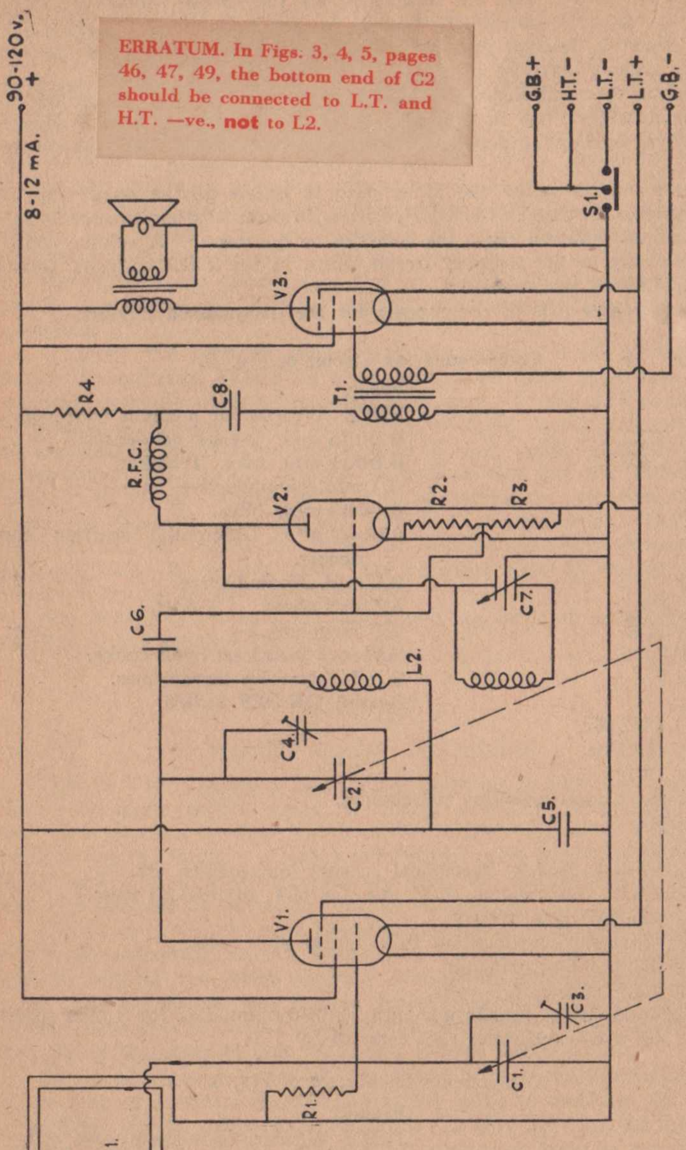

FIG. 3.—Simple 3 valve Portable, using 2 volt valves.

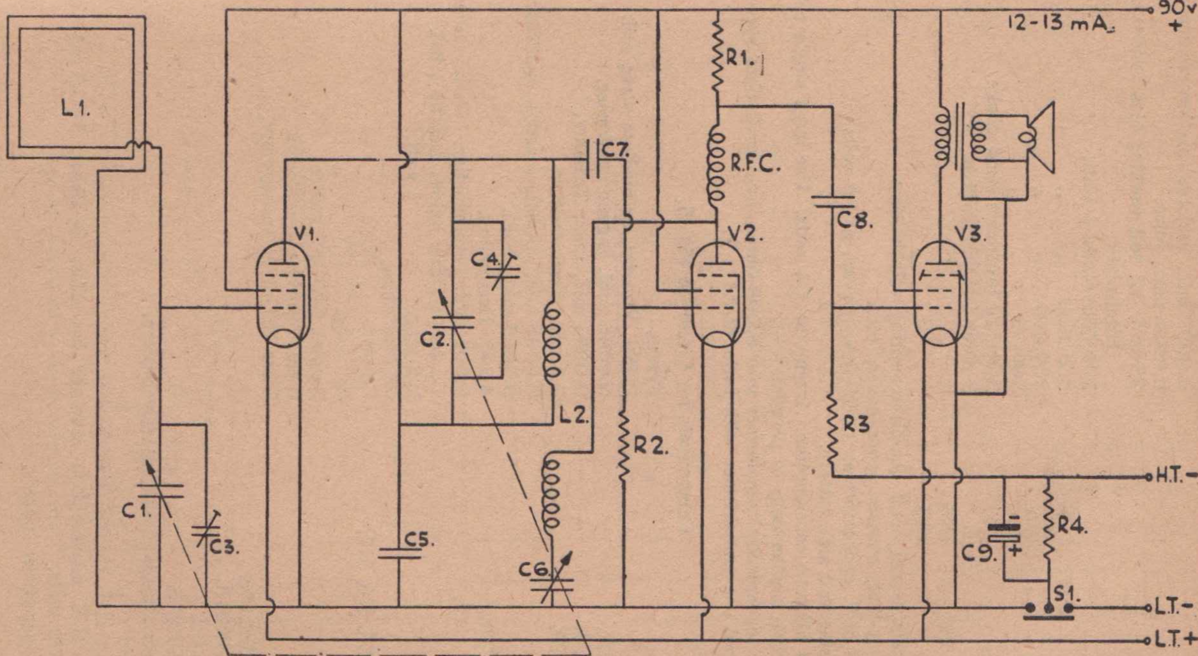

FIG. 4.—3 valve Portable, using 1.4 volt valves.

C5, C8,	0.1 mfd. Noninductive.
C6,	0.0003 mfd. variable reaction condenser.
C7,	0.0003 mfd. Mica.
C9,	25 mfd. 12 volt working bias condenser. Electrolytic.
R1,	100,000 ohms, ½ watt.
R2,	2.2 meg. ,, ,,
R3,	250,000 ,, ,,
R4,	360 ,, ,,
R.F.C.	Screened broadcast band choke.
S1,	3-point ON-OFF switch.

V1, V2, 1N5.
V3, 1Q5.
3 International octal chassis mounting valveholders.
Tuning dial, chassis, loudspeaker, etc.
Total H.T. consumption, 12-13 mA. approx. at 90 volts.
Use standard size battery.
Total filament consumption, .2 amp. at 1.4 volts. Use large single cell, or two smaller cells *in parallel.*
Load loudspeaker transformer into 8,000 ohms, *i.e.,* for 3 ohm speech coil use transformer with ratio of 51 : 1.

Components for Circuit of Fig. 5.

L1,	Frame.
L2,	PHF2, Wearite, or medium wave coil.
C1, C2,	0.0005 mfd. 2-gang condenser.
C3, C4,	0.0001 mfd. max. Trimmer.
C5, C9,	0.1 mfd. Noninductive.
C6,	0.0003 mfd. variable reaction condenser.
C7,	0.0003 mfd. Mica.
C8, C10,	4 mfd. Decoupling.
C11, C12,	0.001 mfd. Noninductive. Tone correctors. Other values may be tried.
R1,	2.2 meg. ½ watt.
R2,	68,000 ohms, ,,
R3, R5, R6, R7,	10,000 ,, ,,
R4,	0.5 meg. ,,
S1,	3-point ON-OFF switch.
T1,	Class B Driver transformer.
T2,	Class B Output transformer.

V1, HP210c.
V2, HR210.
V3, LL2.
V4, CB215.
2 7-pin chassis mounting valveholders.
2 4-pin ,, ,, ,,
Tuning dial, chassis, loudspeaker, etc.
Total H.T. consumption (average for Class B stage), 16-18 mA. at 120 volts.
Use super-power battery.

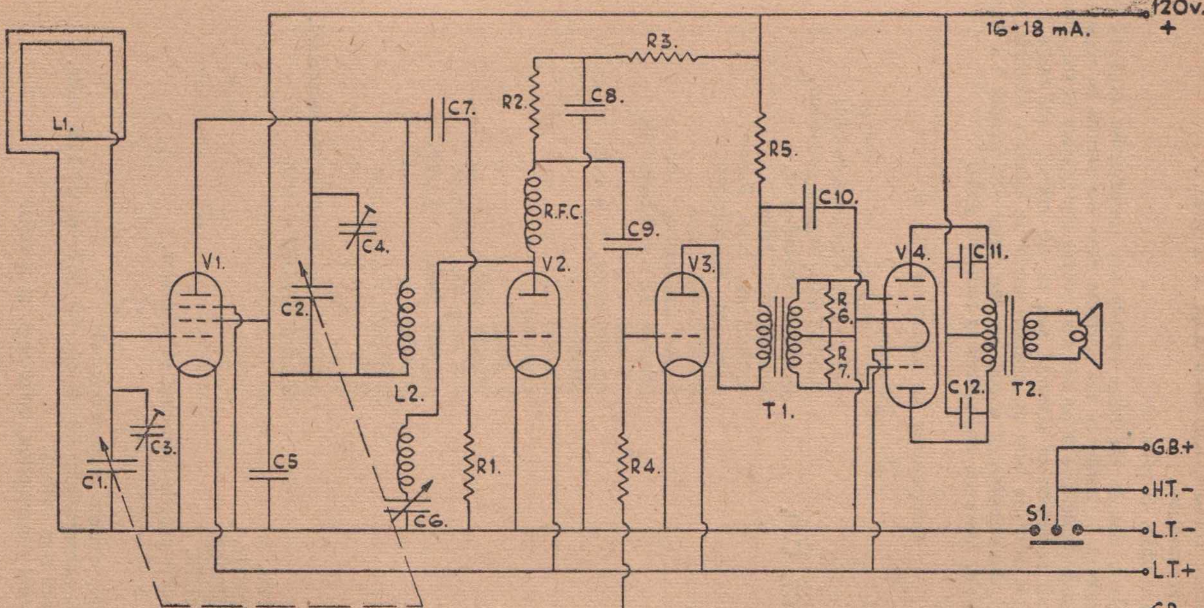

Fig. 5.—Class B Portable.

Total filament consumption, 0.64 amp. at 2 volts.

Use large accumulator.

Grid bias voltage, 3 volts.

This receiver, due to the large battery and accumulator required for economical working, is hardly in the portable class but should be regarded rather as a transportable. Use of an ordinary tuning coil in place of the frame, with consequent reduction of trimmer size to 60 mmfd., will make it a receiver suitable for use with an outdoor aerial in country districts and similar places. Substitution of a coil for the frame will render V1 more likely to oscillate, however, and screening must be good.

Components for Circuit of Fig. 6.

L1,	Frame.
L2,	PO2 Wearite.
CT.	See end of Components List.
C1, C2,	0.0005 mfd. 2-gang condenser.
C3, C6, C7, C13,	0.1 mfd. Noninductive.
C4,	0.0001 mfd. Mica.
C5,	0.0005 mfd. max. Padder.
C8, C11,	0.05 mfd. Noninductive.
C9, C10,	0.0002 mfd. Mica.
C12,	2 mfd. Decoupling.
C14,	25 mfd. 12 v.w. Electrolytic.
C15,	12 mfd. ,, ,,
R1,	62,000 ohms, ½ watt.
R2,	30,000 ,, ,,
R3,	33,000 ,, ,,
R4,	100,000 ,, ,,
R5, R10,	1 meg. ,,
R6,	22,000 ohms. ,,
R7,	0.5 meg. Vol. Control.
R8,	10,000 ohms, ½ watt.
R9,	51,000 ,, ,,
R11,	250,000 ,, ,,
R12,	330 ,, ,,
R13,	130 ,, ,,
T1, T2,	465 kcs. Iron-cored I.F. transformers.
S1,	3-point ON-OFF switch.

V1, TP26.
V2, HP211c.
V3, HL21DD.
V4, Pen 25.

2 Mazda octal chassis mounting valveholders.
1 7-pin ,, ,, ,, ,,
1 5-pin ,, ,, ,, ,,

Tuning dial, chassis, loudspeaker, etc.

Total H.T. consumption, 10-12 mA. for H.T. of 90-120 volts.

Use standard size battery.

Total filament consumption, 0.62 amp. at 2 volts.

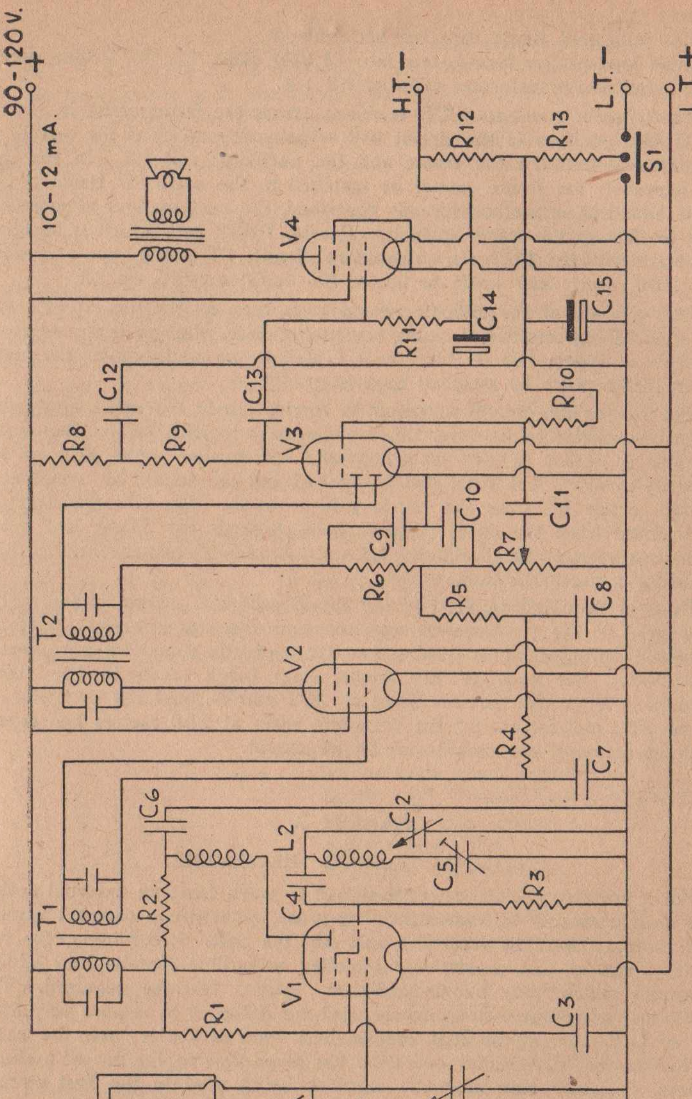

FIG. 6.—Portable Superhet.

Use jelly acid (large capacity) accumulator.

Load loudspeaker transformer into 14,000 ohms, *i.e.*, for 3 ohm speech coil use transformer ratio of 68 : 1.

The trimmer condenser, CT, is shown across the frame aerial in Fig. 6, but its final position in the circuit will actually depend upon the quality of the matching between the frame and the oscillator coil L2. In the case of a superhet, the frame cannot be matched to the oscillator tuned circuit by the substitution method already described, the best method of matching being to line up the frame against a Wearite PHF2 coil, which is designed to operate with the PO2. In an ordinary circuit, CT would have a capacity of 70-100 mmfd. and would be across the oscillator grid, on L2.

One way out of the difficulty would be to tune up the two circuits with individual tuning condensers, using two tuning dials, when accurate matching would be obtained, but if this course is felt to be undesirable, the aerial and oscillator must be matched experimentally.

The rest of the circuit alignment is carried out in the usual way, using a signal generator to line the I.F. transformers to 465 KCs. The signal generator is tuned to this frequency and fed to the signal grid of the frequency-changer, the oscillator being put out of action by coupling a 0.1 mfd. condenser from the triode grid to earth. The I.F. transformers are adjusted from the diode detector back towards the TP26, and when set the two variable tuned circuits, L1 and L2, must be trimmed and padded for tracking over the band.

Trim at 250 metres, feeding the signal generator output either to the signal grid of the frequency-changer or into the frame aerial, using an inductive coupling made by winding two turns of wire round the frame aerial compartment, the ends of the double loop being taken to the signal generator. When the circuits gang at 250 metres, pad the oscillator at 500 or 550 metres, correct the trimming again at 250 metres and repeat the processes until the circuits are in alignment.

CHAPTER 3.

EXTERNAL AERIAL RECEIVERS.

For a portable radio receiver designed to work from an external aerial, there must obviously be some special purpose, otherwise a compact version of an ordinary domestic receiver would suit the case. Accordingly, the two circuits given in this chapter are intended as outline circuits into which, or around which, may be designed any special features required. The circuits are, of course, self-contained, and are designed to require very little H.T. or L.T. current, so that the smallest type of battery may be used, and to this end loudspeaker operation has given way to the use of a single earpiece, a 2,000 ohm magnetic earpiece being used in the first circuit, that of a T.R.F. receiver, and a crystal earpiece being used in the second receiver, a superhet with the output taken directly from a diode-triode.

The aerials are shown with two input circuits, an aperiodic coil coupling and a capacity coupling, the final type of coupling being chosen by trial, whilst the aerial itself must also be tested experimentally. A rod aerial can be tried, as also can a length of wire attached to the clothing, results obviously depending on the district and distance from transmitters.

The T.R.F. circuit uses a new range of valves marketed by Park Royal Scientific Instruments, Ltd., the valves being of very small size and intended for direct wiring into circuit. The size of the Midgetron 500 is 35×12 millimetres, whilst that of the 501 is 43×12 millimetres, so that if all components are kept small it is possible to build an extremely compact receiver.

Whilst the superhet receiver cannot be built to occupy such a small space as the straight receiver, the smallness of the batteries still enables it to take up little room, and it is possible to construct the set to be carried comfortably on a shoulder strap.

One likely requirement of this type of circuit is that it shall be adapted for short wave reception over short distances, as a liaison or experimental receiver. Both of the circuits shown are adaptable for this purpose, provided that due care is taken with lining up and ganging. The superhet, being provided with an R.F. stage, should have more than sufficient selectivity to overcome second channel interference, so that there is no need to change over to a higher Intermediate Frequency, whilst the T.R.F. receiver is shown with a potentiometer reaction control, which obviates any hand capacity effects or mistuning on reaction.

Both receivers should be built into metal cases, the tuned coils being provided with screening compartments or else arranged so that they are on different sides of the chassis. In the case of the superhet the oscillator coil should be well screened, as also should the I.F. transformers, and in all cases wiring should be direct and as short as possible.

The lining up procedure with the superhet is as already described.

Components for the Circuit of Fig. 7.

L1,	PA2, Wearite.
L2,	PHF2, Wearite.
C1,	0.0003 mfd. max. Trimmer.
C2, C3,	0.0005 mfd. Midget 2-gang condenser.
C4, C5,	60 m.mfd. max. Trimmer.
C6, C7, C9,	0.0005 mfd. Mica.
C8, C10, C11,	0.05 mfd. Noninductive.
R1,	2.2 meg., ½ watt.
R2,	100,000 ohms, ½ watt.
R3,	0.1 meg. Potentiometer.
R4,	1 meg., ½ watt.
RFC1, RFC2,	Broadcast chokes, midget.
S1,	3-point ON-OFF Switch.
E,	2,000 ohm Earpiece.

V1, V2, Midgetron 500.
V3, Midgetron 501.
Tuning dial, chassis, etc.
Total H.T. consumption, 3-4 mA. for H.T. of 45 volts.
Use Ever-Ready Layer built battery.
Total filament consumption, 0.1 amp. at 1.4 volts.
Use single dry cell.

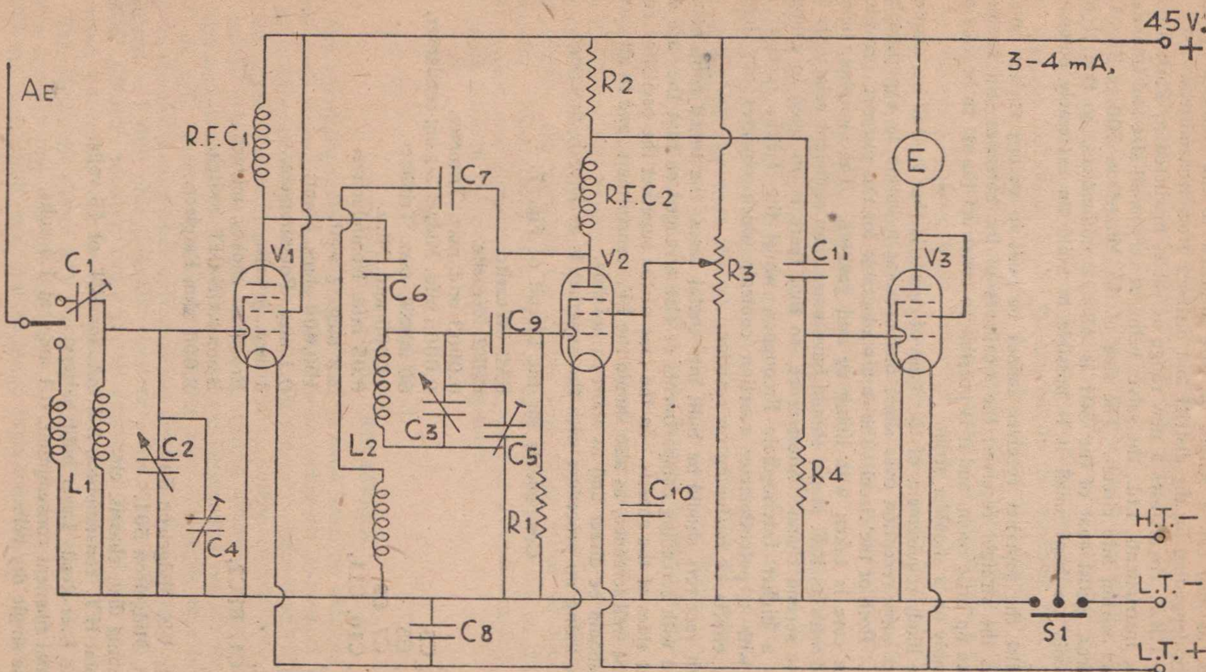

FIG. 7.—Midget T.R.F. Receiver.

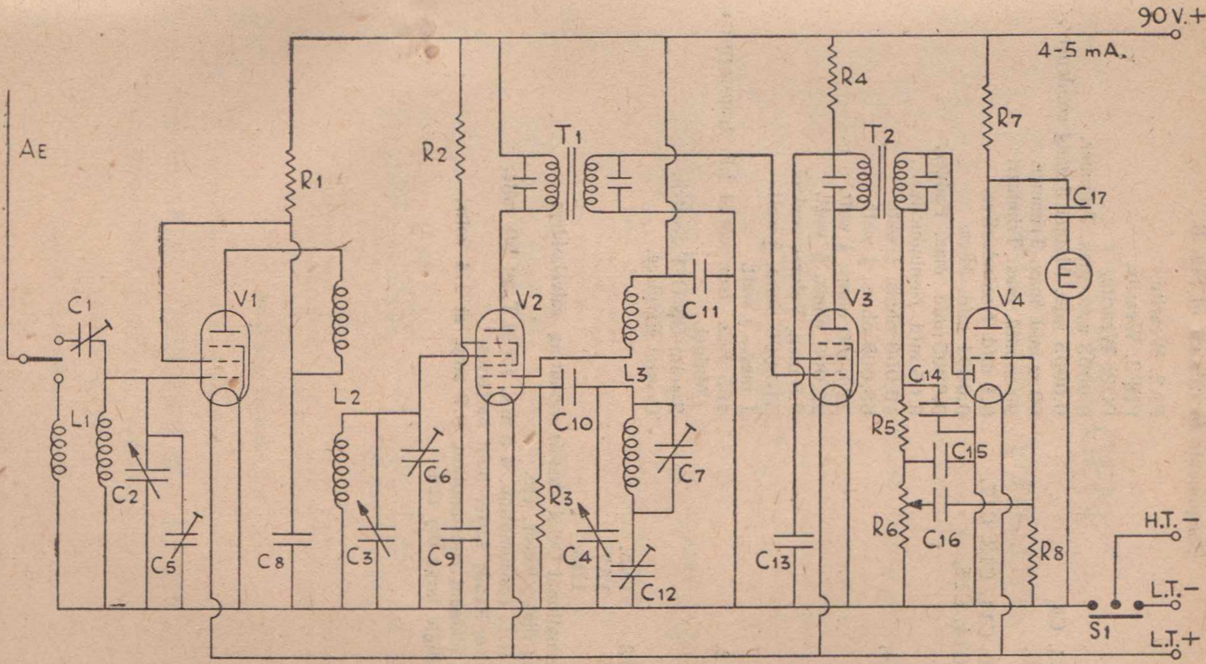

FIG. 8.—Low-consumption Superhet.

Components for Circuit of Fig. 8.

L1,	PA2, Wearite.
L2,	PHF2, Wearite.
L3,	PO2, Wearite.
C1,	0.0003 mfd. max. Trimmer.
C2, C3, C4,	0.0005 mfd. Midget 3-gang condenser.
C5, C6,	60 m.mfd. max. Trimmer.
C7,	90 m.mfd. max. Trimmer.
C8, C9, C11, C13, C17,	0.1 mfd. Noninductive.
C10, C14, C15,	0.0001 mfd. Mica.
C12,	0.0005 mfd. max. Padder.
C16,	0.05 mfd. Noninductive.
R1, R4,	10,000 ohms, ½ watt.
R2,	68,000 ohms, ½ watt.
R3,	220,000 ohms, ½ watt.
R5,	22,000 ohms, ½ watt.
R6,	0.5 meg. Volume control.
R7,	510,000 ohms, ½ watt.
R8,	1 meg., ½ watt.
T1, T2,	465 KCs. Iron cored I.F. transformers, Midget.
S1,	3-point ON-OFF Switch.
E,	Crystal Earpiece.

V1, V3, 1N5.
V2, 1A7.
V4, 1H5.

4 International Octal chassis mounting valveholders.
Tuning dial, chassis, etc.
Total H.T. consumption, 4-5 mA. for H.T. of 90 volts.
Use Ever-Ready Layer built batteries.
Total filament consumption, 0.2 amp. at 1.4 volts.
Use single large dry cell.