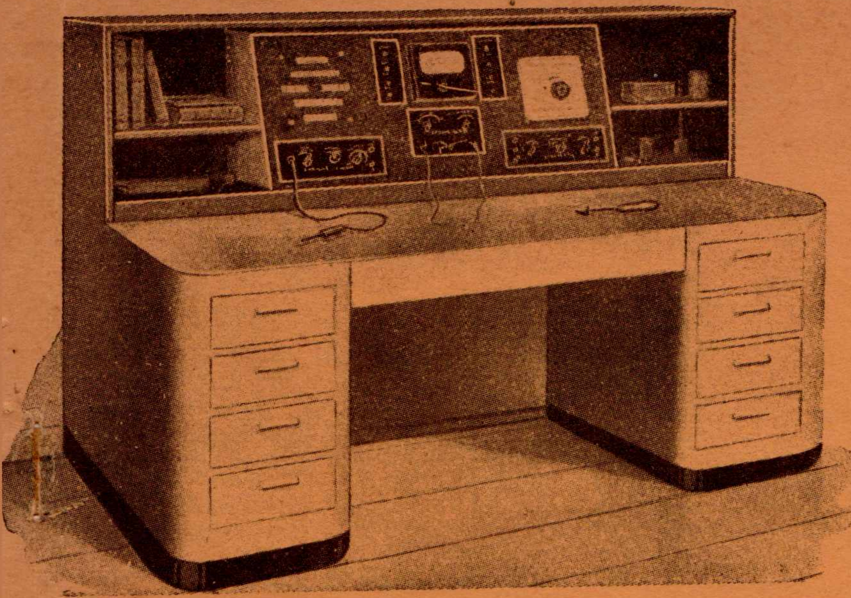


HOME PRACTICAL INSTRUCTION

LESSON No. 8

Contents . . . . .

SUPERHETERODYNE RECEIVER and TEST PANEL

This lesson will show you how to build and test—

AUSTRALIAN RADIO AND TELEVISION COLLEGE PTY. LTD.

206 BROADWAY, N.S.W., AUSTRALIA

HOME PRACTICAL INSTRUCTION.

LESSON No. 8.

In performing Radio Service work or for adjusting new receivers when completed, two instruments are essential to enable adjustments to be carried out efficiently. One of these is a Multimeter which we have already constructed and the second is an Oscillator.

Oscillators take a variety of forms and generally speaking may be defined as an instrument for generating a signal suitable for application to a receiver or amplifier to be tested. Oscillators in most common use are those which generate a radio frequency carrier wave which is modulated with a steady audio frequency tone so that the signal from the oscillator is easily recognised and is of steady strength at all times, to facilitate testing. You will thus see that a test oscillator usually consists of two sections, one section is an oscillator for generating a radio frequency carrier wave and the other section is an oscillator or source of alternating voltage at audio frequency which can be used for modulating the radio frequency carrier wave.

In addition, for testing the audio frequency amplifying stages of a receiver, or audio amplifiers in general, it is desirable to have available an audio frequency oscillator. This may be one portion of the modulated radio frequency oscillator, as described above, or may be a second instrument.

A large number of different circuit arrangements have been devised both for the generation of audio and radio frequency signals and we will examine some of these oscillator circuits in the earlier part of this lesson. Having constructed a suitable oscillator we will proceed to use it for making tests of audio frequency amplifying stages and later on we will experiment with a modulated RF oscillator and finally apply some further modifications to the receiver you constructed in earlier lesson papers.

The following materials are contained in Kit No. 8 and you should carefully check this list to see that everything is present.

1 -	1R5 valve.	1 -	.03 mfd. tubular condenser.
1 -	3S4 valve.	4 -	$1\frac{1}{4}$" x $\frac{1}{8}$" Whit Bolts.
1 -	Switch, 2 pole, 3 position.	12 -	$\frac{1}{8}$" Whit Nuts
2 -	Bantam 7 pin valve socket.	1 -	Metal switch collar.
1 -	Small pointer knob.	1 -	.01 mfd. tubular condenser.
1 -	.1 meg. $\frac{1}{2}$ watt resistor.	2 -	.001 " tubular condensers.
1 -	5 lug resistor panel.	6 -	$\frac{3}{8}$" x 8BA bolts and nuts.

Immediately upon unpacking the parts examine the two valves to see that the glass is not broken and also test the filament of each by applying the test leads from your ohmmeter to pins 1 and 7 in the case of the 1R5 and firstly to pins 1 and 5 and then to pins 5 and 7 in the case of the 3S4. The two tests are necessary for the 3S4 because its filament consists of two sections. The ohmmeter leads should be plugged into the sockets marked "low ohms" on your multimeter. The meter should indicate a resistance of approximately 20 ohms in the case of the 1R4 and 20 ohms for each section of the 3S4. Both valves have been carefully ~~tested~~ immediately before being packed for despatch to you so should arrive in perfect condition.

EXPERIMENT No. 1 A.F. OSCILLATOR.

A large number of experiments we will perform with this kit of parts will consist of making tests on audio frequency amplifiers and consequently we will need a source of audio frequency signals or in other words, an A.F. oscillator. We have already seen one type of A.F. oscillator in Lessons 5 and 7 but in this case we will construct an entirely different type to illustrate not only an alternative principle for generating audio frequency signals but also a principle which is widely used in superheterodyne receivers to enable frequency changing to be accomplished. This type of A.F. oscillator is known as a "beat frequency oscillator" and consists of generating audio frequency signals by mixing together in a valve, two separate radio frequency voltages. The principle involved is that if one frequency say 100 kilocycles per second is mixed with another frequency of say 99 kilocycles per second in an amplifying valve, coming out of the valve there will be the two original frequencies of 100 and 99 kc also a third frequency equal to the sum of the two which will be 199 kc and a fourth frequency which is equal to the difference between the two, or 100 minus 99 kc, which equals 1 kc. This 1 kc signal which you will realise, is within the audio frequency range, can be used as an audio frequency test voltage. By altering the difference between the two original radio frequencies, the frequency or pitch of the audio frequency signal will be altered.

(See A.R.T.C. Service Engineering Course lessons Nos. 21, 35 and 47.)

Figure 1 shows the circuit diagram of the beat frequency oscillator. In Figure 1, the 1S5 valve is made to act as a radio frequency oscillator in exactly the same fashion as was the valve in the audio frequency oscillator described in Lessons 5 and 7. In Figure 1 of Lesson 5, oscillation is produced by passing plate current through one half of the centre tapped transformer. This induces a voltage in the other half of the transformer which is applied to the grid of the valve. In the 1S5 valve, instead of using a centre-tapped transformer we employ a coil wound on one of the coil formers supplied to you. Current in passing through the plate winding generates a voltage in the secondary winding which is applied to the grid of the valve. So that the valve will generate one particular and definite value of radio frequency signal, the secondary winding of the coil is tuned by means of a .001 mfd. condenser and also one section of your tuning condenser gang. In this way, its frequency range will cover from approximately 350 kc, when the tuning condenser plates are fully out of mesh, to a value of approximately 338 kc when the tuning condenser plates are turned fully into mesh.

In addition to the plate and grid windings, there is also a 5 turn coil which takes some of the voltage from the 1S5 valve and applies it to one of the grids in the 1R5 where it is mixed with another radio frequency signal.

The second radio frequency signal is generated in the triode portion of the 1R5 valve.

The 1R5 valve is a type normally used as a frequency changer in superheterodyne receivers and in effect consists of two separate sets of elements inside the one glass envelope, for compactness and cheapness. The filament

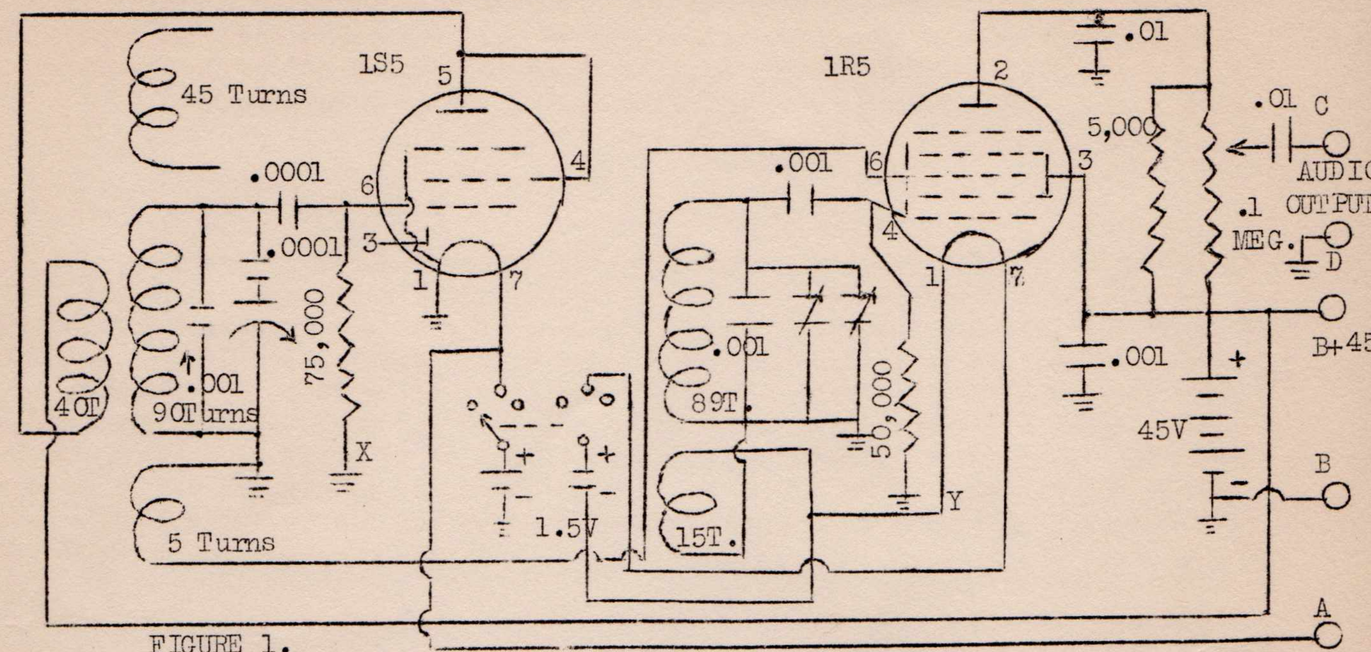


FIGURE 1.

of the valve, the first grid and the second grid act as the filament grid and plate of a triode valve. The second grid has a positive voltage applied to it which draws electrons out through the first grid and so these elements are able to amplify or act as an oscillator in the same way as any other triode valve. One difference between the oscillator circuit used for the triode section of the 1R5 and that used for the 1S5 is the fact that in the 1S5 the plate current is passed through a coil of wire connected between the plate and B plus. In the case of the 1R5 the plate should be connected directly to B plus, so as not to interfere with the action of the remaining elements in the valve and consequently in this case the electrons in the plate circuit pass through the 15 turn coil on their way back from the B battery through this coil to the filament of the valve. This coil is thus virtually in the plate circuit although it is actually connected between B minus and the filament, and the plate current, in flowing through it, generates voltages in the secondary winding which is tuned by a .001 mfd. condenser and also two small trimmer condensers. The signal voltages from this winding are then applied to grid No.1 in the valve. No variable condenser is used for tuning this oscillator because it is intended only to produce one frequency at all times.

The signal voltages generated in the oscillator section of the valve control the number of electrons passing through to the outer elements. Thus the electrons finally arriving at the plate vary in strength in accordance with the signal voltages from grid No.1. Simultaneously, the signal voltages from the 1S5 oscillator, acting on grid No.3 also influence the electrons passing through the 1R5 valve so that the plate current carries the combined effects of the two voltages. This causes the combination effect mentioned earlier, so that in the plate circuit of the valve, in addition to the two original frequencies, we have the sum frequency and also a frequency equal to the difference between the two which is the "beat" frequency and which can be an audio frequency.

The radio frequency signals in the plate circuit of the 1R5 are bypassed to the metal chassis by means of a .01 mfd. condenser connected from the plate to chassis. This condenser however has too high a reactance to bypass the audio frequencies and consequently the audio frequency signals present in this valve plate circuit are passed through the 5,000 ohm resistor and .1 megohm potentiometer and generate a voltage drop across these. When the arm on the potentiometer is moved to the bottom end there will be no output from the terminals at the right hand side of the diagram but as it is moved upwards, the output voltage will increase to a value of approximately .25 volts.

ASSEMBLING THE OSCILLATOR.

It is most important that the two radio frequency oscillators be isolated from one another as effectively as possible. If they are not, they will tend to operate always at the same frequency as one another and consequently there will be no difference frequency to produce any output. They can be most effectively isolated by moving the two coils to new positions on the chassis as far apart as possible. That is, they should be moved to diagonally opposite corners of the chassis as shown in Figure 2. The coil mounted near the front left hand corner of the chassis in Figure 2, is the coil which was previously the aerial coil in our receiver and the valve placed near it, on the left of Figure 2 is the 1R5.

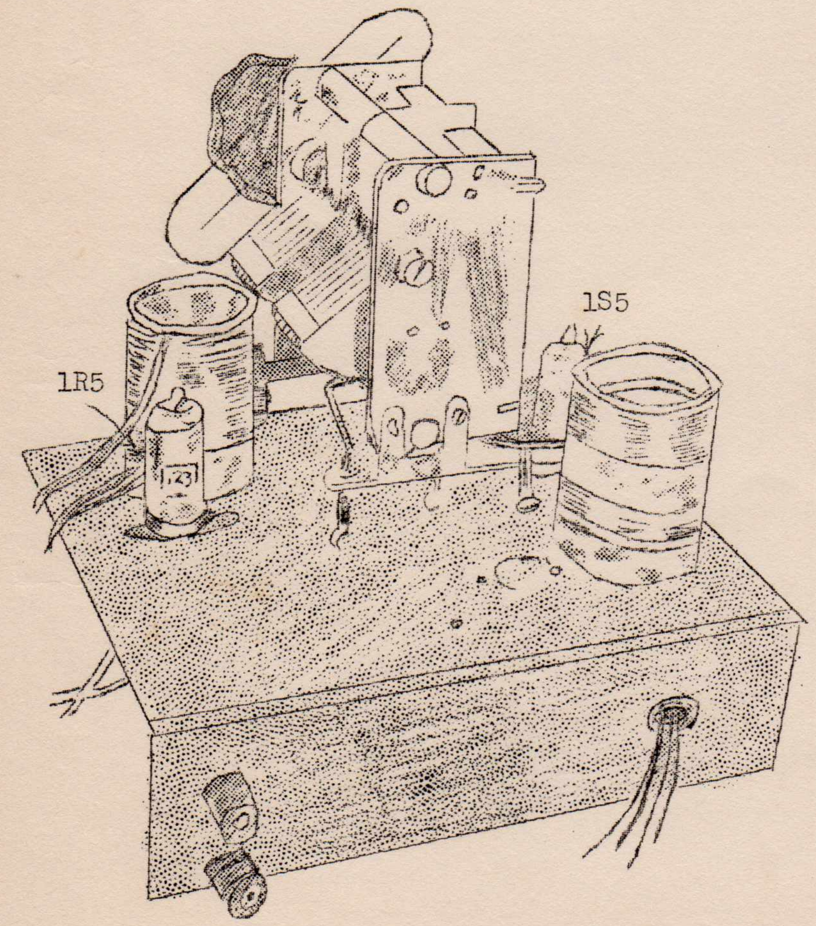


FIGURE 2.

The coil near the right hand corner of the chassis was the coil previously used to couple the RF amplifier to the detector in our receiver and the valve partly hidden behind it, in Figure 2 is the 1S5.

You will be able to determine the correct positions for the small parts and for the wiring from the wiring diagram which is drawn in Figure 3.

The wires extending from the coil connected to the 1R5 valve, will have to be brought around the edge of the chassis to reach the underneath of the socket and the trimmer condensers which are also mounted under the chassis. Similarly, the wire from socket contacts 5 and 6 on the 1S5 valve to the coil connecting to this valve can be brought around the other edge of the chassis.

Due to the fact that the filament of the 1R5 valve is not directly connected to the chassis but, instead, is connected to the chassis through the 15 turn winding on the coil,

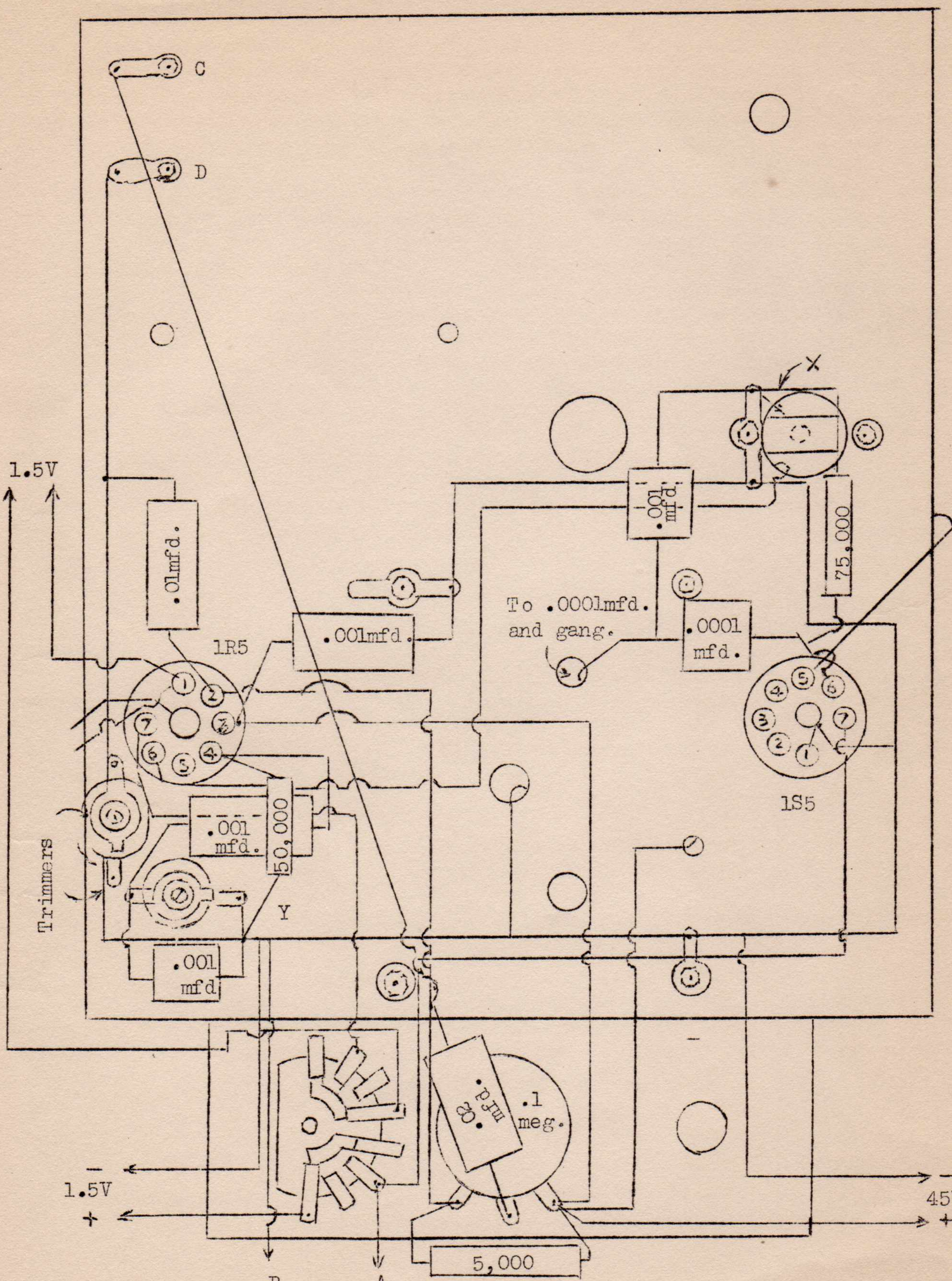

C
D
X
1.5V
.01mfd.
.001mfd.
.001 mfd.
75,000
To .0001mfd. and gang.
.0001 mfd.
1R5
1S5
.001 mfd.
50,000
Trimmers
Y
.001 mfd
.02 mfd.
.1 meg.
1.5V
45V
5,000
B
A

FIGURE 3.

it is not possible to use the one A battery to heat the filaments of both valves. This means that you should use a 1.5 volt cell for the filament of the 1R5 valve and the other 1.5 volt cell, borrowed from your ohmmeter after testing as explained below, for heating the filament of the 1S5 valve.

The oscillator tuning coil for the 1S5 will require one alteration before you secure it on the chassis. As used in the receivers described in Lesson 7 it has a 45 turn tickler coil, a 90 turn secondary winding, a 5 turn winding at the bottom and an overwound primary of 30 turns. The alteration is that you will need to increase the turns on the overwound primary from 30 to 40 turns. You can do this by unwinding the 30 turns and winding on a complete new coil of 40 turns or else you can do it by soldering another length of 34 gauge wire to the upper end of the 30 turn winding and merely adding on the extra 10. If by any chance you are short of wire for winding this coil then you could unwind the 45 turn tickler coil and use this wire for winding the 40 turn primary.

In connecting the coil to the 1S5, it is more important that the upper end of the 90 turn winding connect to the .0001 mfd. condenser and that the lower end of the 40 turn primary winding connect to the plate of the 1S5 valve. If you reverse the connections to the 40 turn windings so that the plate connects to the top instead of the bottom of it the valve will not oscillate.

(See A.R.T.C.Service Engineering Course Lesson No.35.)

The 90 turn winding is tuned by a .001 mfd. fixed condenser and also one section of the variable condenser which has a .0001 mfd. condenser in series with it, the two being connected in parallel with the .001 mfd. unit. When the tuning condenser plates are fully out of mesh, the .001 mfd. condenser will tune the coil to a frequency of approximately 350 kc. When the plates are turned fully into mesh the frequency will decrease to a value of approximately 338 kc. due to the increased capacity.

(See A.R.T.C. Service Engineering Course Lesson No.15.)

The 89 turn winding on the coil connected to the triode portion of the 1R5 valve is tuned also by a .001 mfd. condenser and in addition, there are two trimmer condensers connected in parallel with this .001 mfd. unit. This valve will oscillate always at a frequency of approximately 350 kc., the exact value being determined by the settings of the trimmer condensers.

The trimmer condensers are provided because of the fact that even with the variable condenser gang plates fully out of mesh, the variable condenser will still have some capacity and where we require the two oscillatorsto operate at the same frequency, the minimum capacity of the variable condenser has to be equalled by the capacity of the two trimmer condensers connected to the coil of the fixed frequency oscillator.

TESTING.

After having wired the instrument, and before plugging in the valves, apply your ohmmeter leads to the three sets of battery wires shown near bottom of Figure 1 and make sure that no short circuits exist which would damage the batteries. If your ohmmeter shows that there are no short circuits present you can connect up the two A batteries and the B battery. You should then proceed to test the voltages existing at the various pins of the valve sockets. Clip the negative test lead of your voltmeter on to the chassis of the receiver and have the positive test lead inserted in the "plus 50 socket".

Touch the positive test lead to the various pins of the 1S5 valve socket. On pins 4 and 5 you should obtain a reading of approximately 45 volts on 1, 3 and 6 no reading at all, and on pin 7 a movement of approximately $1\frac{1}{2}$ graduations on the meter scale.

In applying the positive test lead to the 1R5 valve socket you should obtain a reading of approximately 45 volts on pin 3, a reading of approximately 40 volts on pin 2, no reading on pins 1, 4 or 6, and a reading of about $1\frac{1}{2}$ graduations on pin 7. Of course, the readings on pins 7 on both valve sockets will only be obtained with the filament switch turned "on".

If the voltages are correct, insert the valves, being sure to plug the valves in their right socket only. If by any chance you plug the valves into the wrong sockets you will damage both valves. The correct positions are shown in Figure 2. When the valves are oscillating, the output voltage at the terminal at the rear of the chassis will only be about .25 volts and this is not sufficient to produce an audible sound from the loudspeaker so that we are not yet in a position to test the oscillator until we have built an audio frequency amplifier so that the signals from the oscillator can be sent through this amplifier and will then become strong enough to drive the loudspeaker.

EXPERIMENT No. 2 TRANSFORMER COUPLED A.F. AMPLIFIER.

On the second chassis supplied to you, you should mount three valve sockets in the positions shown in Figure 4. The circuit diagram of the amplifier is shown in the lefthand portion of Figure 5. In this case we use the 1T4 valve as a first audio frequency amplifying stage and the signals from this valve are coupled to the 3S4 power output valve by means of the iron cored transformer. Signals emerging from the 3S4 valve will be heard from the loudspeaker and in addition, so that we may be able to learn something of the performance of the amplifier the output signals from the plate of the 3S4 valve are also applied through the .1 mfd. condenser to a second

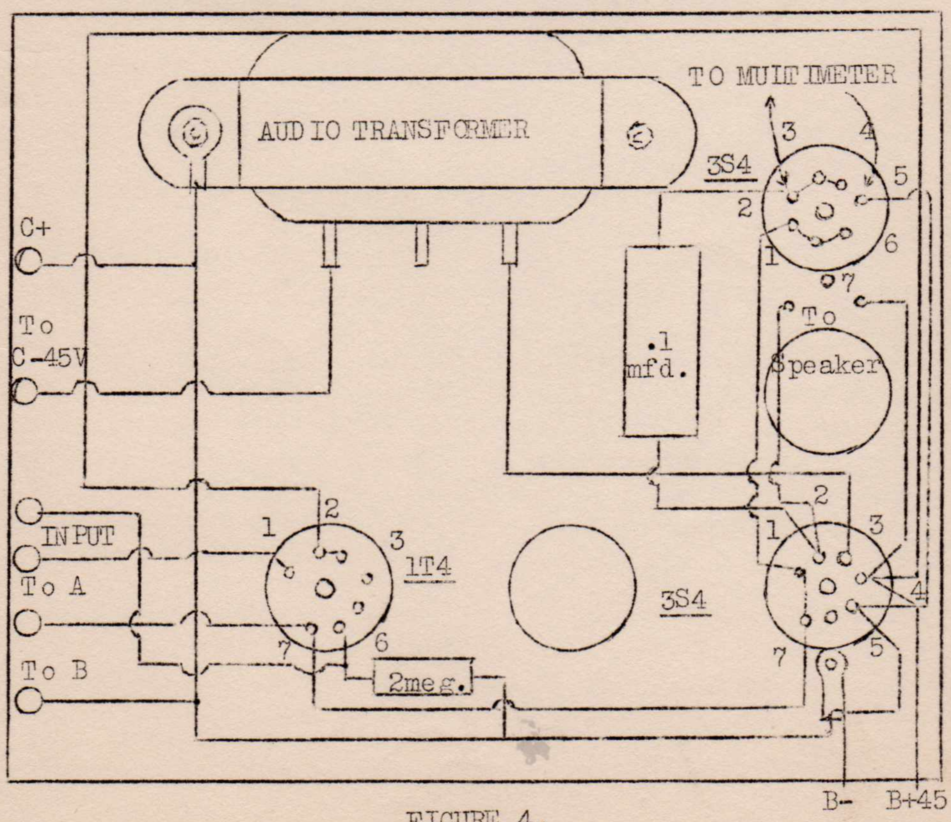


FIGURE 4.

3S4 valve which acts as a diode rectifier, as explained in Figure 20 of practical instruction lesson No. 4.

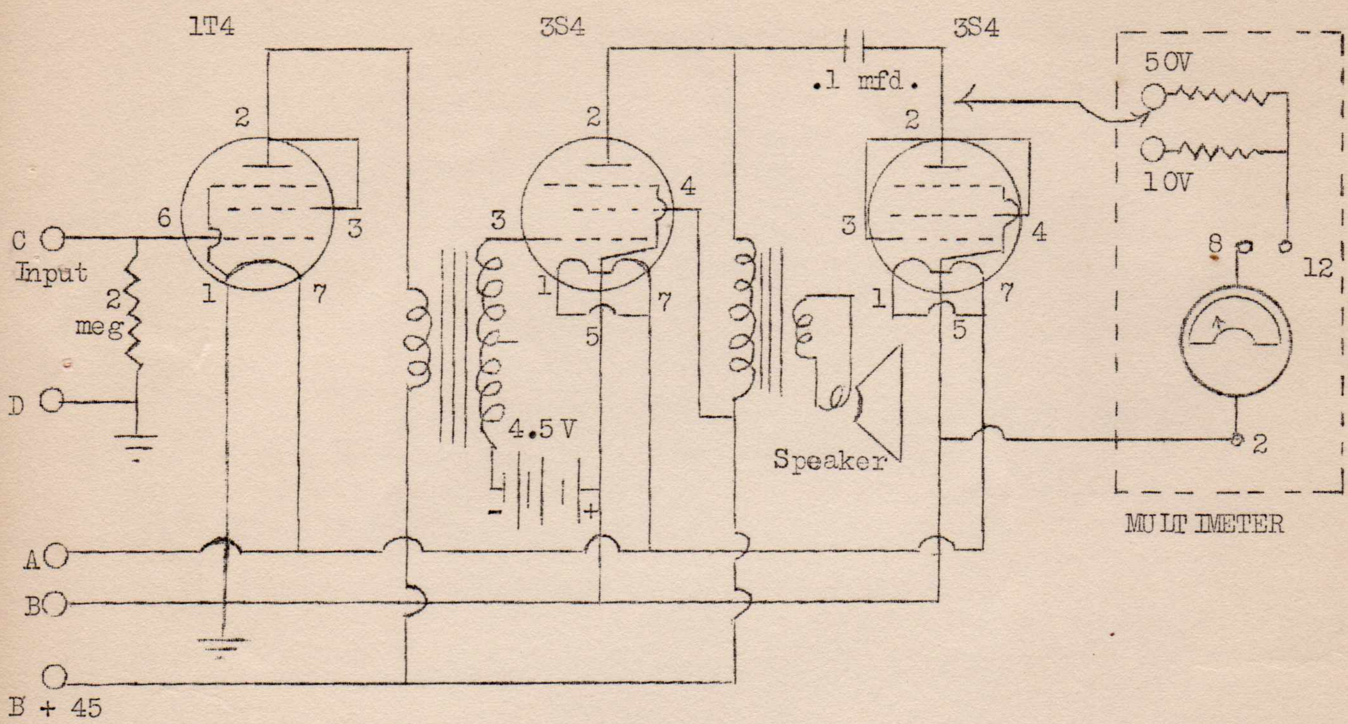


FIGURE 5.

This valve is wired in a slightly different fashion from that illustrated in Figure 20 of Lesson 4 to enable filament pin No. 1 to be connected to the chassis, so that it may be operated from the same 1.5 volt battery which applies filament voltage to the filament of the 1S5 and also to the valves in the amplifier.

The 3S4 shown at the right hand side of Figure 5 will not amplify or strengthen the signals in any way but will merely rectify the signals reaching it through the .1 mfd. condenser, converting the alternating signal voltages to direct voltage which can be registered on your multimeter.

In connecting up the transformer, the two rather thick enamel covered wires emerging from the transformer and normally intended for connecting to a voice coil of a speaker are connected, one to the plate of the 1T4 and one to the positive terminal of the B battery. The grid of the 3S4 valve is connected to one of the outer wires moulded in the plastic former and the negative terminal of the B battery is connected to the other outer terminal. The centre tap of the secondary winding on the transformer is not used.

After completing the wiring, connect wires marked "A"and "B" in Fig.5 to points marked "A"and "B"on the oscillator circuit of Figure 1. Wire marked "B+45" on Fig.5 can connect to the positive terminal of the B battery. You should next connect the negative test lead of your Multimeter to chassis of the amplifier and with the positive test lead plugged into socket marked"+50v"touch the test prod to the pins of the valve socket. When touching the prod to the socket for the 1T4 valve you should obtain a reading of approximately $1\frac{1}{2}$ graduations at pin 7, when the switch on the oscillator is turned on.

In the case of the 3S4 in the amplifier, you should obtain a reading of approximately 45 volts at pins 2 and 4 and a reading of about $1\frac{1}{2}$ graduations at pins 1 and 7 by reversing the test leads so that the positive lead is touched to the chassis and the negative lead touched to pin 3 you should obtain a reading of approximately 4 graduations at pin 3.

In the case of the 3S4 diode valve there should be no readings on any pins with the exception of a movement of about $1\frac{1}{2}$ graduations on pins 1 and 7.

If all these readings are correct you may insert the valves in their sockets, again being careful to see that the 1T4 is not plugged into the socket intended for the 3S4 valve.

In order to employ the 3S4 valve, at the right of figure 5, as an output meter, it will be necessary to make one additional connection in your multimeter. This consists of joining together switch contacts 12 and 8 shown on figures 4 and 5 of practical instruction lesson No.4. Also, in place of the negative test lead, you should use a length of hook-up wire, one end of which is soldered to switch contact 2 and the other end to pin No.1 on the 3S4 socket, as shown at the right of figure 5 in this lesson. The numbers near the meter symbol in figure 5 are the multimeter switch contact numbers shown in figures 4 and 5 of lesson 4. The positive lead may be plugged into either the 10 or 50 volt socket depending upon which voltage range is to be employed. When the lead is plugged into the 10 volt socket, readings should be made on the lower scale of the instrument face. When plugged into the 50 volt socket, readings should be made on the middle scale on the instrument face. The switch on the multimeter should be turned to the position marked "A.C.". The prod end of the positive test lead should be clipped on to socket pin 2, 3 or 4 on the 3S4 valve socket shown at the right hand side of figure 5.

When an alternating signal voltage from the plate of the amplifying 3S4, is applied through the .1 mfd. condenser to the 3S4 rectifying valve, this positive pulsation of signal will cause electrons to leave the filament of the 3S4 and to be attracted across to the grid, screen grid and plate. From this point they cannot pass through the .1 mfd. condenser and so must pass through the positive test lead, the voltage multiplying resistor in the multimeter to switch contacts 12 and 8 on the multimeter, then to the negative terminal of the meter itself and out from the positive meter terminal, through switch contact 1 to 2 and from 2 to the negative filament terminal on the 3S4 valve socket.

TESTING THE AMPLIFIER.

Once you have followed the procedure explained so far, and have all the valves inserted in their sockets; - if the switch is turned on and the potentiometer on the oscillator rotated,you should hear some sort of audio frequency note from the loudspeaker and obtain an indication of its strength on the meter scale. The pitch of the note will be determined by the setting of the tuning condenser gang plates. When the plates are turned fully out of mesh, the pitch should be very low and will represent a bass note whereas, as the plates are turned further into mesh, the pitch will become higher and higher representing shrill treble notes. If the tuning condenser plates are turned fully into mesh the difference between the two radio frequency signals will produce a beat frequency which will be about 10,000 cycles per second and will be so high in pitch that you may not hear them, as many people's ears will not detect sounds higher than 10,000 cycles in frequency.

If you have followed the instructions carefully and have made no mistakes in your wiring, the equipment should operate when first turned on and tried however, if you fail to obtain an audio frequency note it will be necessary to use your multimeter for testing to determine whether each oscillator valve is functioning.

To do this turn the switch on the face of the multimeter back to the position marked "D.C." and insert the test leads in the negative socket and in the socket marked "plus 1 MA". These leads may now be used to connect the multimeter in series with the 75,000 ohms grid leak for the 1S5 valve at the point marked X on Figure 1, by disconnecting the earth end of the 75,000 ohm resistor from the chassis and connecting the end to the negative lead from the multimeter instead. The positive multimeter test lead should be clipped on to the chassis.

In a similar fashion, you may test and see whether the triode section of the 1R5 valve is oscillating by reconnecting the 75,000 ohm resistor in the normal fashion and instead disconnecting the earth end of the 50,000 ohm resistor from the chassis and inserting the multimeter at the point marked "Y" in Figure 1. In both cases, if the valve is oscillating, there should be a movement of approximately 1 graduation on the meter scale whereas, if the valves are not oscillating the meter needle will rest at zero or will move only about a $\frac{1}{4}$ of a graduation across the scale.

If you do not obtain an indication of approximately one or more graduations on the meter scale and if this does not vary somewhat as the tuning condenser plates are rotated, it suggests that the valve in whose grid circuit it is connected is not oscillating. If you obtain a satisfactory indication at each of these points and still no signals are heard from the loudspeaker, then this suggests a fault in the plate circuit of the 1R5 valve or that you have failed to connect the output terminals of the oscillator to the input terminals of the amplifier. The output terminal marked "C" should connect to the amplifier input terminal marked "C", in Figure 5 and similarly, the output terminal "D" should connect to the input terminal "D" in Figure 5.

Again, if there is no result although these connections are correct, there may be a fault in the audio amplifier and this should be carefully checked to see that it is wired correctly.

One quick way of telling whether failure to operate is caused by a fault in the oscillator or amplifier is to disconnect the wire which joins terminal "C" on the oscillator to terminal "C" on the amplifier and touch point "C" on the amplifier with your finger or with a piece of metal held in your hand. As you touch the terminal, or as you touch a piece of metal to the terminal, there should be a distinct click or possibly a hum or squealing noise from the loudspeaker. If there is no sound whatsoever when you touch point "C" on the amplifier then this indicates that a fault almost certainly exists in the amplifier. On the other hand, if you do hear a noise when you touch point "C" then this suggests that the amplifier is capable of responding to signals applied to this point and should function if the oscillator is working.

ANALYSING OSCILLATOR FAULTS.

If no result can be obtained, the next test to apply is to use your multimeter as an ordinary DC voltmeter to measure the voltage of the B battery and the voltage of the two A batteries under their actual working load. The voltages we checked previously, at the valve sockets, were measured before the valves were inserted and although these may have been correct without any load, the insertion of the valves in the sockets would cause a drain of current on the batteries and this would cause their voltage to decrease somewhat. If the batteries are approaching the end of their life then their voltages might decrease to such a degree that they are incapable of supplying enough current to cause the valves to oscillate. On measuring the B battery voltage before the valves are inserted, the instrument should give an indication of at least 35 volts. When the valves are inserted in their sockets this reading should not drop below 32 volts.

Similarly, the 1.5 volt A battery should provide a reading of at least 1.4 volts before the valves are inserted and should provide at least 1.1 volt when the valves are plugged in and the equipment switched on. If either voltage is lower than those suggested above, it will be necessary for you to procure new batteries before you proceed.

If the battery voltages are satisfactory, then a fault may exist in one of the valves. If you suspect this, it would be advisable to test the valve as explained in experiment 8 of practical lesson No.7. An emission test only will be necessary as this will reveal if there is any material change in the valve characteristics. Instructions for testing the type 1S5, 1T4 and 3S4 valves are contained in practical lesson 7. In testing the 1R5, the procedure will be very similar to that indicated in figure 14 of practical lesson 7. The A battery will be applied between pins 1 and 7 and the negative lead from the meter should be connected to pins 2, 3, 4 and 6 which are all joined to one another. The correct size of resistance to use is 2,000 ohms.

If the valves appear to be in good order then check carefully the connection to the coils. As previously mentioned, it is most important that the top of the tuned windings connect through the small condensers to the grids of the valves at socket contact 6 for the 1S5 and 4 for the 1R5 and also, that the lower end of the 40 turn winding connect to the plate of the 1S5 valve and the lower end of the 15 turn winding connect to earth in the case of the 1R5 valve. It is also important to check and see that both windings on each coil are wound in the same direction as one another. If by any chance you have accidentally wound one coil in a clockwise direction and the other coil in an anticlockwise direction, on the same former, then you may be able to make the equipment oscillate by switching over the leads to the 40 turn coil or 15 turn coil. That is, in the case of the 40 turn coil the top end would connect to pin 5 on the valve socket and the bottom end to the positive terminal of the 45 volt battery. Similarly, in the case of the 15 turn coil the top end would be earthed and the bottom end connected to valve socket pin No.1 on the 1R5 valve. Of course, if both windings on each coil former are wound in the same direction as one another this reversal will not be necessary.

If all these checks have failed to reveal why the oscillator will not function, then the only remaining procedure is to add additional turns to the 40 turn coil if you cannot obtain a satisfactory indication of current when the meter is inserted at point "X" on Figure 1, and this number can be increased up to 50 or even 60 in an attempt to make the valve oscillate. Again, if you cannot obtain any satisfactory movement of the pointer at position "Y", you could add additional turns to the 15 turn coil and increase here up to 20, 25 or even 30.

The analysis above covers almost completely, possible reasons for failure of the equipment to operate and if you have checked the various points outlined one by one, then I feel sure that you will have discovered any possible troubles and have rectified them. We are now in a position to proceed further with our adjustments.

OSCILLATOR FREQUENCY RANGE.

When first turned on, it is unlikely that the audio frequency notes produced by the oscillator will cover from a deep bass note, when the tuning condenser plates are turned fully out of mesh, to a shrill treble note when they are turned fully into mesh.

The purpose of the trimmer condensers indicated in Figure 1 is to adjust the frequency of the fixed frequency oscillator so that it is equal to that of the variable frequency oscillator when the tuning condenser plates are turned fully out of mesh. Consequently, you should rotate the tuning condenser until its plates are fully out and then adjust, by means of a screwdriver, either one or both of the trimmer condensers until the pitch of the note decreases to its lowest value. You will then find that rotating the tuning condenser plate inward causes the pitch to increase to a shrill whistle when the tuning condenser plates are turned fully in.

Due to imperfect shielding and incomplete isolation between the two oscillator circuits, it will not be possible for your oscillator to operate so that it produces audio frequencies right down to very deep bass notes approaching zero frequency. You will probably find that the pitch of the note decreases down to a certain value and then suddenly stops. At the point where the pitch of the note suddenly stops the frequency will probably be well below 400 cycles per second and we will use this as our lowest test frequency. With the tuning condenser plates turned approximately half way in, the pitch of the frequency should be somewhere about 3,000 cycles per second and with the tuning condenser plates turned fully in, the pitch should be 10,000 cycles per second.

In beat frequency oscillators produced commercially for use as reliable test instruments, a great deal of care is taken to see that the strength of audio frequency signals provided by the oscillator is constant throughout its range of operation. This means that regardless of whether the instrument is producing bass notes or treble notes the output voltage should be constant. In our case, it is impossible to fit all the necessary refinements to assure this and consequently you will find that the oscillator will produce far stronger signals at 400 cycles per second than it will at the higher frequencies. You will be able to obtain some idea of the way in which the strength of the signals from the oscillator varies by temporarily disconnecting the input lead of your 3S4 rectifier valve from the plate of the 3S4 amplifier and instead touching the lead from the .1 mfd. condenser to the oscillator output terminal "C". When the oscillator is functioning, the output meter should give an indication of about half a graduation when the positive test lead is inserted in the 10 volt socket. This output will be obtained at about 400 cycles per second and you will notice that although the reading is very small the needle will drop off towards zero as the plates are turned further into mesh to produce higher frequencies.

Now restore the connection from the .1 mfd. condenser to the plate of the 3S4 valve and we will be in a position to check the output voltages after they have been amplified.

For this test, you should have the positive test lead plugged into the 50 volt range on your multimeter. At 400 cycles you will probably obtain an output reading of about 4 graduations on the meter face. At 3,000 cycles the meter needle should rise a little to about 6 graduations and with the condenser plates turned fully into mesh the reading should fall again to about 1 graduation. The actual readings you obtain may differ quite appreciably from those just mentioned because there is so much possibility of variations in the individual valves, transformers and other parts involved that it is improbable that any two amplifiers and oscillators will perform exactly the same as one another. Although these figures have been obtained at the College, it does not necessarily follow that you will obtain exactly the same readings but you should notice that the output from the amplifier is moderately strong on bass notes, rises on middle pitch notes falls off again on treble notes. This is due to the characteristics of audio frequency transformers. These transformers have a reactance which decreases at low frequencies, causing the drop in bass notes. The capacity between the turns and also losses in the iron core causes a decrease in efficiency at the extremely shrill notes and consequently a transformer causes the greatest amplification of middle pitched notes. The bass notes will really be much weaker than they would appear from this experiment because you must remember that your oscillator is providing bass notes which are much stronger than middle pitched notes, consequently one would expect the bass notes to still be stronger than the middle pitched notes after passing through the amplifier. Due to the small inductance of the transformer primary however, the bass notes will not be amplified to the same degree as the higher pitched notes.

(See A.R.T.C. Service Engineering Course - Lesson 27)

The transformer supplied to you and which you are using for this experiment is not really designed to couple the plate circuit of one valve to the grid of the next. A good quality inter-stage audio frequency transformer would provide a greater degree of amplification and more even results than the transformer you are using. However, the principles are illustrated quite well by this equipment.

EXPERIMENT 3. RESISTANCE COUPLED TRIODE AMPLIFIER.

It is interesting now to substitute resistance coupling for the transformer and to check the performance of the resistance coupling unit in comparison with that of the transformer.

Firstly we will set up the 1T4 valve as a triode as shown in Figure 6. There is nothing at all unusual about this arrangement and consequently you should be able to substitute the resistance coupling unit for the transformer from the information contained in Figure 6 without any further instruction. It is most important of course, to disconnect the B battery before you make any alterations to avoid any chance of your soldering iron or stray pieces of wire, short circuiting the positive terminal of the B battery to the filaments of the valves and thereby burning them out. As the alterations are few it is not necessary to disconnect the A batteries and these may be left connected although of course the switch on the oscillator should be turned off.

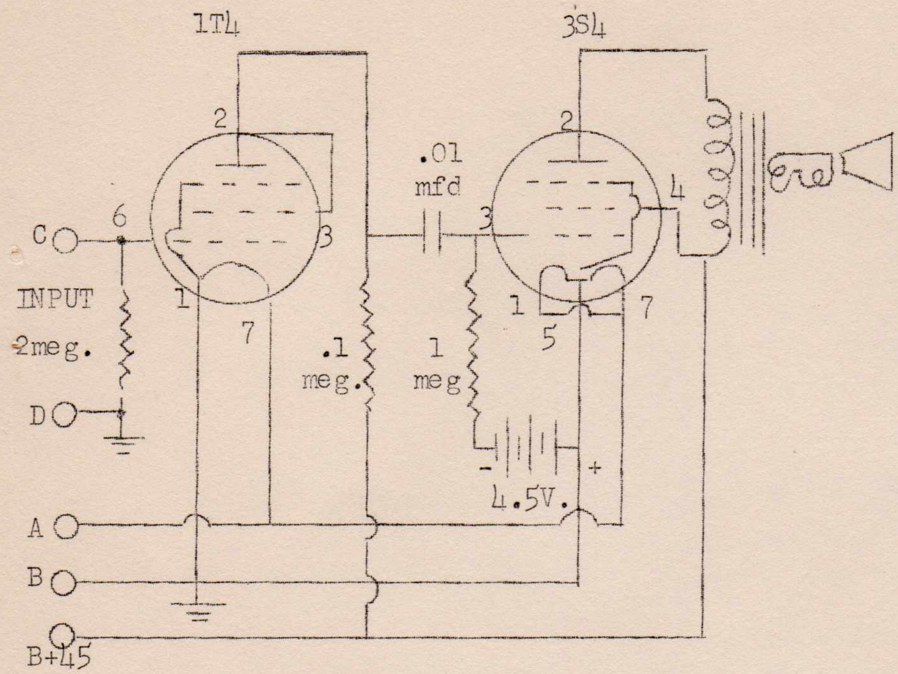


FIGURE 6.

After completing your connections, check them very carefully before reconnecting the B battery and switching on again.

If you now repeat the measurements at the three frequencies you used previously, you will probably find that the strength of bass notes is many times stronger than it was. You will probably obtain a reading of about 26 volts output at 400 cycles, a reading of about 4 volts at 3,000 cycles and a reading of about 5 volts at 10,000 cycles. In order to make possible a satisfactory comparison of results with the previous results, it is desirable for you to set the tuning condenser plates to the same position on each of these tests and therefore you should fit a piece of paper or cardboard behind the tuning condenser dial, marking the various positions on it for the three test frequencies. Alternatively, it is possible to make a pencil line directly on the tuning condenser plates. If you do this, you will be able to reset the condensers to the same position each time you make tests on a new amplifier circuit.

The considerable increase in the strength of bass notes does not mean that a resistance coupled amplifier tends to over-emphasise the bass notes at the expense of the higher frequencies but simply indicates that your beat frequency oscillator is providing a greater signal output at the bass frequency. The strength of middle pitched and very high pitched notes will be much the same, as a resistance coupled amplifier provides an almost uniform degree of amplification throughout the audio frequency range.

On comparing the results from the resistance coupled amplifier with that from the transformer, you will realise how inefficient the transformer is in handling bass notes and also the way in which its response falls off at very high pitched notes such as 10,000 cycles per second.

(See A.R.T.C. Service Engineering Course - Lessons 27 and 28.)

EXPERIMENT 4. RESISTANCE COUPLED PENTODE AMPLIFIER.

In the last experiment, illustrated by figure 6, the 1T4 valve is used as a triode and under these conditions its amplification factor will be 10 but in practice you will realise a little less than this. We will now alter the connections to the 1T4 valve socket so that it acts as a pentode valve and we will determine the actual increase in amplification achieved by this. Figure 7 shows the altered connection. You will observe that the only alterations necessary are to disconnect the screen grid, connecting to pin No.3 on the 1T4 valve socket from the plate, and connect it instead to a .5 meg. resistor and .02 mfd. condenser.

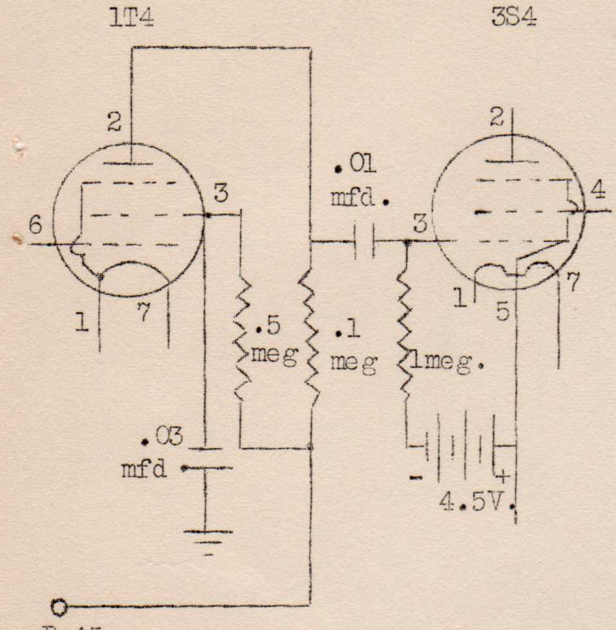


FIGURE 7.

Once you have made these alterations you should repeat the tests at the three different audio frequencies and again observe the output strengths. You will find that at low frequencies the output should be somewhere about 37 volts, at 3,000 cycles approximately 10 volts and at 10,000 cycles approximately 12 volts. You will notice, at the middle and high frequencies the increase of amplification is about twice that obtained when the valve is acting as a triode. Under more ideal conditions, with a higher value of plate voltage, an even greater increase in amplification can be obtained by using a valve such as the 1T4 as a pentode instead of as a triode.

The increase of amplification at bass frequencies is not double as great as that when the valve was used as a triode because the valve is overloaded with signals under these conditions. If the signals were weaker, you would find that the amplification at bass frequencies would be greater. This can be checked by turning down the output control on the oscillator so that the oscillator furnishes a weaker signal for the amplifier. If you turn down this control while the oscillator is producing a 3,000 cycle signal until the output meter reading is just half of what it was during your first test, then check the results of the other two frequencies, you will find that the signals at 10,000 cycles will also be about half as strong as before but the bass notes willbe more than half as strong as before, indicating that the valve was being overloaded in the first case.

The change from triode to pentode will not materially alter the frequency response, that is, will not alter the way in which the amplifier handles the various audio frequencies, if the signals are kept weak enough to prevent overloading.

EXPERIMENT 5. INVERSE FEEDBACK.

In experiment 2 of practical lesson 7, you learned something of the use of inverse feedback to provide a method of tone control. Even when a tone control system is not required, inverse feedback is frequently used to improve the uniformity of amplification of amplifiers over a wide frequency range.

By feeding back signals from the plate circuit of a valve to its own grid circuit, or to an earlier point in the system, so that the signals fed back tend to weaken or cancel the original signal, the amplification of an amplifier is somewhat reduced but the distortion is also reduced and uniformity of amplification is improved. As a result, many high quality amplifiers now use a system such as this. A very simple method of obtaining inverse feedback is indicated in Figure 8. It will be seen that a 2 megohm resistor is simply connected from the plate of the 3S4 valve to the plate of the 1T4 so that signals passing back through it are again applied to the grid of the 3S4 through the .01 mfd. condenser.

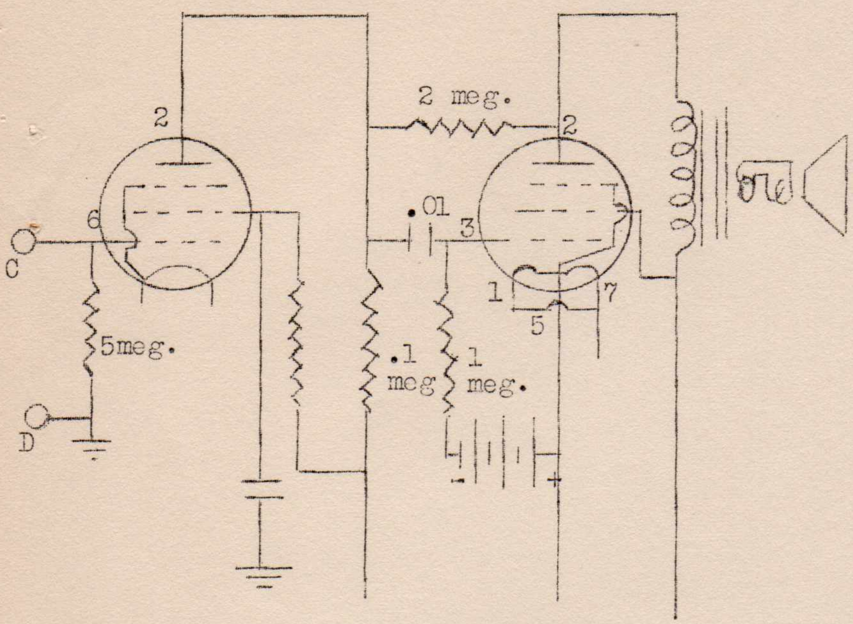


FIGURE 8.

If you now repeat your check at the three frequencies when this resistor is in place, you will find that there is a reduction in output voltage. With the full output of the audio oscillator applied you will still obtain about 37 volts at 400 cycles but you will obtain only about 8 volts at 3000 cycles and about 8 volts at 10,000 cycles. The reduction in output is due to the presence of the inverse feedback circuit. If you repeat the tests also, with weaker signals, you will find that the bass notes are reduced in the same proportion as the higher pitched notes as you then avoid overloading the 3S4 output valve.

You will not notice any particular improvement in uniformity of amplification when you use the inverse feedback because the output strength of signals from the oscillator varies so much that it is difficult to judge whether the use of inverse feedback provides any more uniform degree of amplification or not, in this type of experiment. When high quality test instruments and carefully designed amplifiers are used however, an inverse feedback system makes a worthwhile improvement in frequency response and reduction of distortion.

(See A.R.T.C. Service Engineering Course - Lesson 28).

EXPERIMENT 6. AUTO-TRANSFORMER COUPLING.

Although transformer coupling and resistance coupling are the two most commonly used methods for applying signals from the plate of one valve to the grid of the next there are various other coupling methods also in use. Still another method is indicated in Figure 9. This type of coupling is known as auto-transformer coupling because the transformer used need have only one winding, provided that this winding has a tapping on it, instead of the two separate windings we used previously. You will notice, in Figure 9, the secondary winding of the transformer, that is the thick wire, is not used. For this experiment the screen grid of the 1T4 is connected to the plate once again so that the valve acts as a triode. The plate current of the valve flows from the B battery through the lower half only of the transformer winding to the plate. This lower half of the transformer therefore acts as the primary winding of a transformer. In passing through these turns the current fluctuation, due to the signals acting on the grid of the 1T4 induces a voltage in the other half of the transformer winding and the voltage at the top of this winding is equal to the voltages of the two halves added together. In other words the signal voltage at the top of the transformer will be equal to twice the signal voltage present at the plate of the 1T4 because the transformer is tapped at the centre and so the two voltages are equal and when added provide a total twice that present at the 1T4 plate. This strong voltage is then applied through the .01 mfd. condenser to the grid of the 3S4 and on repeating your tests as made previously, you will note that although the tube is now operating as a triode again, the output voltage will be as strong as, or probably stronger than, that obtained when the 1T4 was used as a pentode with resistance coupling. You can expect an output of about 40 volts at 400 cycles, about 12 volts at 3,000 cycles and about 13 volts at 10,000 cycles.

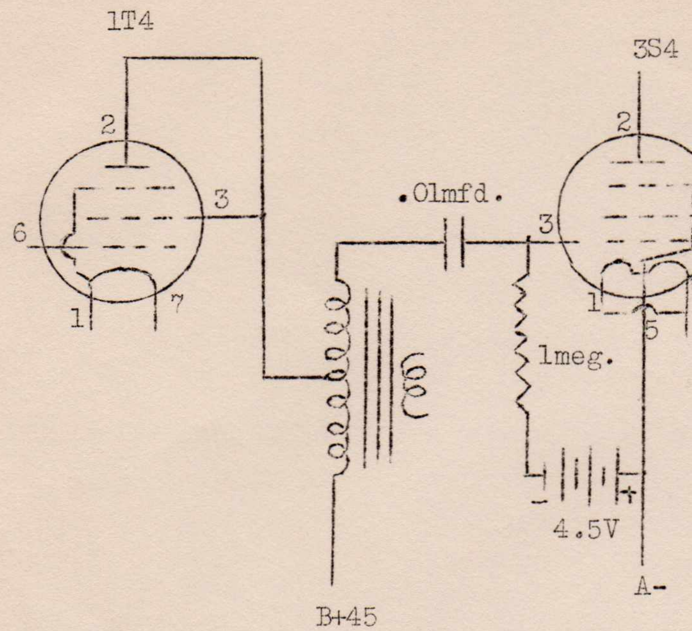


FIGURE 9.

When making any alteration to the amplifier in changing from one experiment to the other, do not forget to disconnect the B battery every time, before you make any alteration and examine the wiring very carefully to see that it is done correctly, before reconnecting the B battery.

EXPERIMENT 7.

Another method of using the step up of 2 to 1 provided by an auto transformer is to connect it in the grid circuit of the 3S4 valve. This is indicated in Figure 10. In this case, current for the 1T4 valve is applied to the plate and screen grid by means of a .1 megohm resistor as in Experiment 3.

On making your tests, you can expect an output of about 12 volts at 400 cycles, about 4 volts at 3,000 cycles and about 2 or 3 volts at 10,000 cycles.

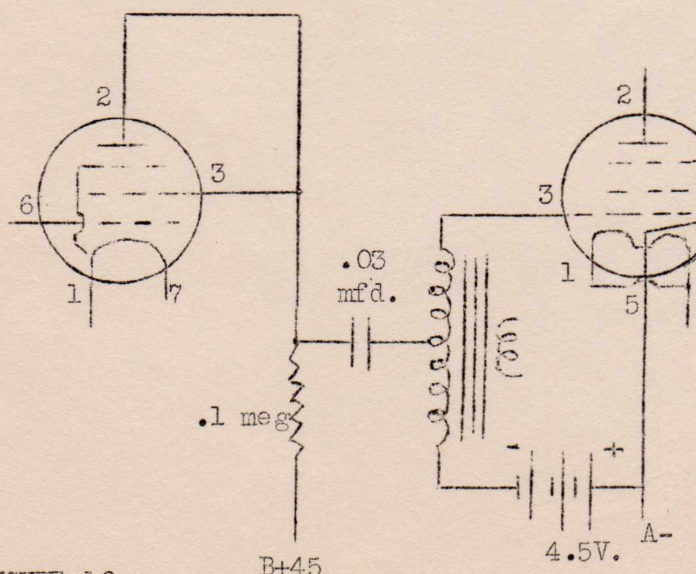


FIGURE 10.

The reason why the amplification in this experiment is not as high as in the last experiment is due to the fact that the plate voltage of the 1T4 valve is not reduced appreciably by the auto-transformer, when used as shown in Figure 9, because the transformer winding has very little resistance and consequently the 1T4 receives almost the full 45 volts and operates fairly efficiently under these conditions.

When we switch the transformer over into the grid circuit of the 3S4 and place a .1 megohm resistor in the plate circuit of the 1T4 this resistance causes an appreciable drop of voltage, when the 1T4's plate current passes through it, so that the 1T4 valve has a plate voltage of only about 20 volts left and under these conditions it does not amplify as well. This drop in plate voltage for the 1T4 valve causes its efficiency to drop to such a degree that no real advantage is obtained by using the auto-transformer in the grid circuit of the 3S4 and results are much the same as those obtained with a less expensive resistor as shown in Figure 6.

(A more complete explanation of the actions of these various circuits is contained in A.R.T.C. Service Engineering Course - Lesson No. 28.)

EXPERIMENT 8. CATHODE FOLLOWERS.

The general characteristics of cathode follower amplifiers is explained in A.R.T.C. Service Engineering Course - Lesson No. 28. In this lesson you read that a valve operated with all of the plate load contained in the cathode circuit, between the cathode of a valve and B minus, is capable of a very faithful reproduction of signals applied to the grid circuit. Unfortunately however, when all of the plate load resistance is placed in the cathode circuit of the valve the voltage drops across the cathode resistor, representing the signal changes, counteract the signals applied to the grid so that the output voltage is always slightly less than the signal voltage applied to the grid circuit of the valve. This means that the valve's amplification is a little less than one and in practice, is generally .9 or .95 times. In this way, the output signal is a little weaker than the input signal so the advantages of the cathode follower are not always apparent. Its principal advantage is that it offers a very high impedance to the source of signals applied to its grid but yet offers a low impedance to the following circuits. In this way it acts in very much the same way as a step down transformer but without the reduction in voltage which occurs when a step down transformer is employed.

It is possible to set up the 1T4 valve in your amplifier, as a cathode follower, in order to study its behaviour. A circuit diagram showing this arrangement is illustrated in Figure 11. In this diagram you will see that the plate of the valve is joined directly to the screen grid so that the valve acts as a triode and these parts are connected directly to the positive terminal of the B battery. However, the complete plate circuit must be continued through the B battery until the electrons return to the negative filament terminal and you will notice that on the path back from B minus, electrons must pass upwards through the .1 megohm resistor in order to flow back to the cathode and to be emitted once more to the plate. Thus, the .1 megohm resistor is really the plate load of the valve although it is connected between the filament negative terminal and chassis.

Because the filament of the 1T4 valve will be several volts positive compared with the chassis, due to the voltage drop across the .1 megohm resistor, it will be necessary to use a separate filament battery for this valve. In AC operated equipment, where the cathode of the valve is isolated from the filament or heater circuit, a separate source of heater voltage is not required. However, with battery valves, where no indirectly heated cathode is available, we must use a separate A battery.

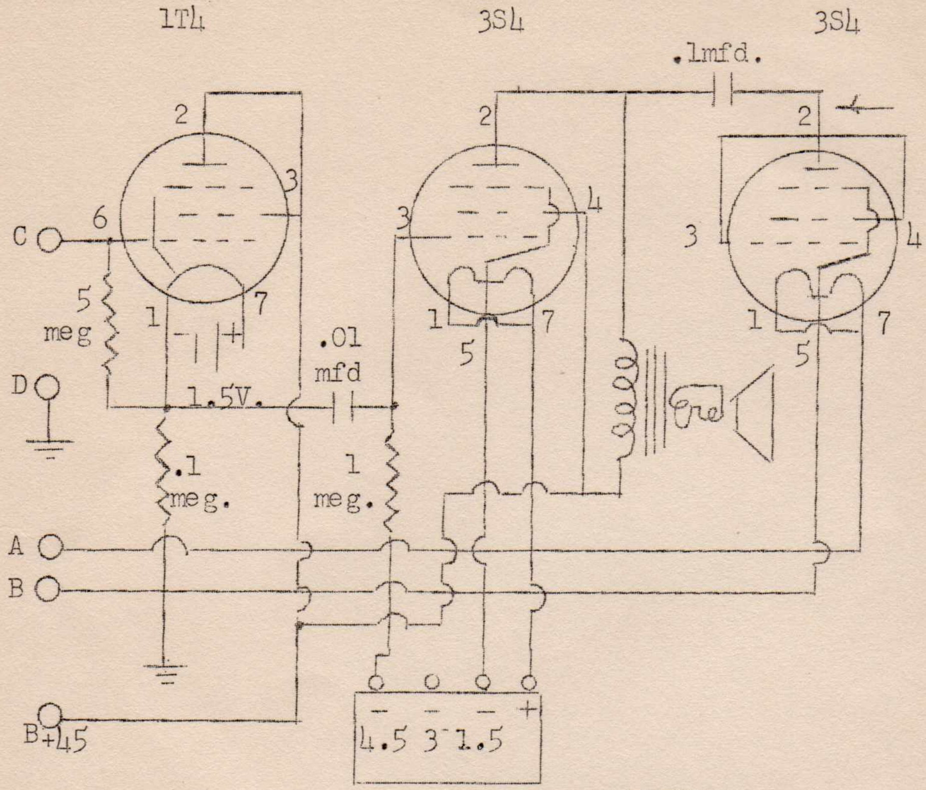


FIGURE 11.

You are already employing one of your 1.5 volt cells for heating the filament of the 1R5 valve in the oscillator. The second 1.5 volt cell was used for heating the 1S5 valve and the amplifier valve. It will be necessary instead to use this cell for heating the filament of the 1T4 valve. The heating current for the 3S4 output valve, the 3S4 rectifying valve, and the 1S5 valve in the oscillator can be provided by one section of the $4\frac{1}{2}$ volt C battery. Of course, if you happen to have an extra 1.5 volt cell available, you could use the extra cell for heating the filament of the 1T4 without disturbing the wiring of the oscillator and amplifier but unless you have this extra cell you should wire the 4.5 volt battery as shown in Figure 11. If you follow the wiring of this battery you will observe that the cell connecting between the positive terminal and the terminal marked minus 1.5, furnishes filament current for the 3S4 valve in the amplifier and also applies voltage back to terminals "A" and "B" which in turn, will carry current through terminals "A" and "B" on the oscillator to the 1S5 valve.

The remaining cells in the 4.5 volt battery will furnish negative grid bias through the 1 megohm resistor to the grid of the 3S4. As the negative filament terminal of the 3S4 is connected to the minus 1.5 volt terminal and the grid is connected to the minus 4.5 volt terminal, the difference in voltage between these points is only 3 volts and so the valve will be operating with 3 volts bias. However, this will be quite sufficient to enable the valve to perform satisfactorily.

After having made the alterations indicated in Figure 11, reconnect the batteries, and before re-inserting the 1T4 and 3S4 valves in their sockets measure the voltages existing between the pins.

With your multimeter switch turned to the "D.C." position and the test leads inserted in the negative socket and the socket marked "+50 volts", touch the negative test lead to pin No. 1 and the positive test lead in turn to the other pins. On pin 7 you should obtain a reading of $1\frac{1}{2}$ graduations indicating the filament voltage. On pin 6 there should be no reading and on pins 2 and 3 there should be a reading of approximately 15 volts. This reading is obtained because of the presence of the .1 megohm resistor in the circuit, through which current must flow on its way back to the B battery, when the meter is connected.

In the case of the 3S4 amplifying valve, with the negative test lead touched to the metal chassis and the positive lead applied to the socket contacts in turn, there should be a reading of $1\frac{1}{2}$ graduations at pins 1 and 7, a reading of almost the full 45 volts at pins 2 and 4 and a very slight backward movement of the needle below zero when the prod is touched to pin 3.

If these voltage readings are obtained satisfactorily, carefully insert the 1T4 and 3S4 in their correct sockets. The filament switch on the oscillator must be turned "on" to apply filament voltage to the 1R5 valve, although of course filament current will reach the 1S5 all of the time from the 4.5 volt battery. For this reason, whenever you are not using the equipment make sure that you disconnect the wire from the positive terminal of the 4.5 volt battery in order to switch off the equipment as well as turning off the switch on the oscillator. Otherwise, the valve filaments will always be heated from the 4.5 volt battery and this battery will be run down very quickly.

When the equipment is operating, you will find that the loudness of signals from the loudspeaker is much weaker than with the previous tests because, as explained earlier, the 1T4 valve instead of strengthening the signals will very slightly weaken them and the signals leaving the top end of the .1 megohm resistor and passing through the .01 mfd. condenser to the grid of the 3S4 valve will be slightly weaker than those applied to pin 6 of the 1T4. In order to observe the strength of signals, switch your multimeter to the position marked "AC" then insert the positive test lead in the "10 volt" socket. You can expect an output of approximately 1.4 volts at the low frequency end of the oscillator tuning condenser setting, a reading of approximately .3 volts at about 3,000 cycles and a reading of approximately .25 volts at the high frequency end. In this case, the signals from the oscillator although being very slightly weakened by the 1T4 are still being amplified by the 3S4 but the total amplification is of course nowhere near as great as that experienced in experiments 3, 4, 5, 6 and 7.

Whilst the equipment is working, you should also switch your multimeter back to the position marked "DC" and with the positive test lead inserted in the "+50 volt" socket, observe the voltage at the plate of the 1T4 and at the filament of the 1T4. With the negative test lead connected on to the chassis of the amplifier you should obtain a reading at the plate of the 1T4 equal to the full B battery voltage.

When measuring the voltage at the negative filament terminal of the valve you will probably obtain a reading of about 15 volts due to the plate current of the 1T4 passing through the .1 meg. resistor and instrument. Although the negative filament terminal of the 1T4 is about 15 volts positive compared with the chassis, the valve filament will not be damaged in any way because the voltage difference, between pins 1 and 7 on the valve socket, is only 1.5 volts and it is this voltage difference which determines the heat of the filament.

If you touch the positive test lead of your instrument to pin No. 6 you will find that there is a slight positive voltage recorded. The movement of the needle will be very small due to the presence of the 2 megohm resistor in the grid circuit of the valve. The indication of a positive voltage at pin 6 does not mean that the valve is operating with a positive grid bias, because the grid will be at a voltage slightly below that of pin No.1 and consequently the grid will be negative compared with the filament of the valve. This means the valve will actually have a negative grid bias and will perform normally.

EXPERIMENT 9. PHASE SPLITTER AND PUSH-PULL AMPLIFIER.

The advantage of push-pull operation of output valves has been explained thoroughly in A.R.T.C. Service Engineering Lesson No. 27 so that it will now be interesting to build up an amplifier employing output valves operating in push-pull to gain some practical experience of this type of amplifier.

Figure 12 shows the circuit diagram and it will be seen that the output stage consists of the two 3S4 valves. The use of the 3S4, which was previously associated with the multimeter to enable it to operate as an output meter will

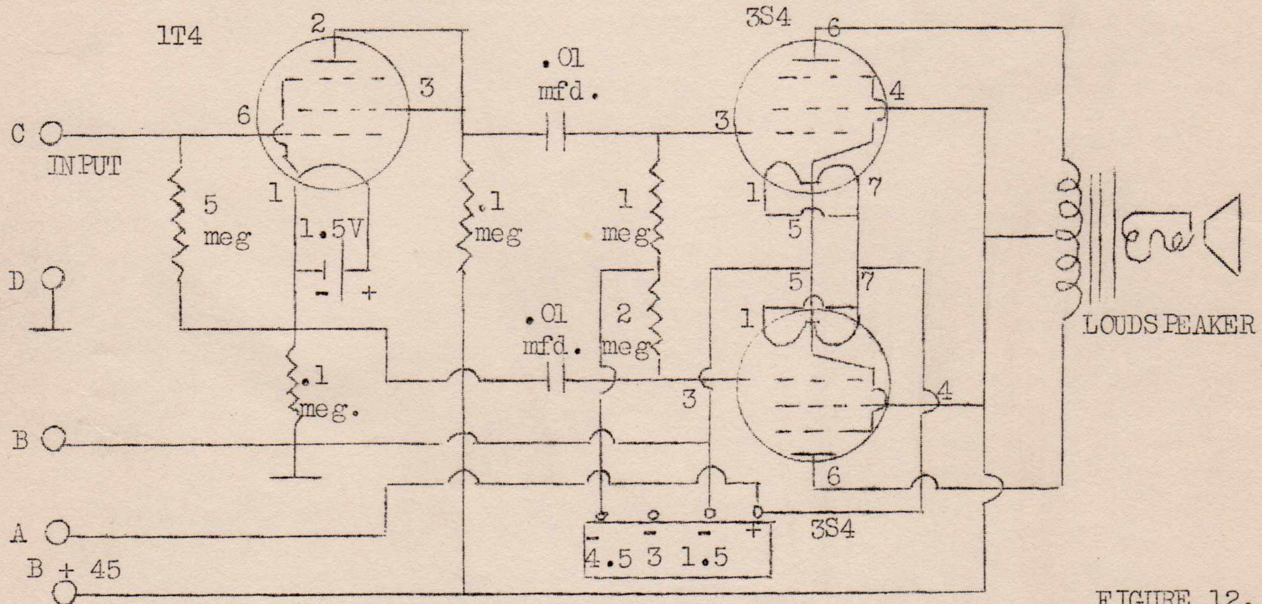


FIGURE 12.

mean that we will not be able to measure the strength of the audio frequency signals during this and the following two or three experiments and so we will have to judge the results solely by ear.

You will notice from Figure 12 that the output transformer has three connections to its primary. In other words, the primary must be centre tapped and as the transformer originally supplied with the speaker has only two connections it will be necessary to use the separate centre tapped transformer to operate the speaker. The method of disconnecting the original transformer from the speaker voice coil was explained on page 59 of Practical Instruction Lesson No. 7. The centre tapped transformer can be bolted on to the amplifier chassis or bolted to the loudspeaker frame, whichever you prefer. You will probably find it easier to bolt it to the amplifier chassis and extend the enamel covered secondary wires with pieces of hook-up wire so that they are long enough to reach to the small eyelet to which the voice coil winding of the loudspeaker connects.

After soldering the pieces of hook-up wire to the enamel covered secondary winding of the transformer, you should cover the soldered joints with small pieces of insulation tape and then tie the hook-up wire through a hole in the back of the chassis and around one end, so that any pull on the wire will not break the enamel covered wire away from the transformer.

One of the problems with a push-pull amplifier is to provide two equal signal voltages 180° out of phase for the grids of the output tubes. One method of doing this is by means of a centre tapped transformer but as we only have one centre tapped transformer and it is used for coupling the plates of the output tubes to the loudspeaker, we cannot build this.

One of the most popular methods of providing the equal and out of phase signals is by means of a "phase splitter". In its most common form, this consists of a triode valve with half of the plate load in the normal position, between the plate and B+ and the other half of the plate load between the cathode or filament negative terminal and B-. In Figure 12, you will see that the total plate load for the 1T4 is .2 megohms and is divided into two halves so that a .1 megohm resistor is in the plate circuit and a .1 meg resistor also in the path between filament minus and B minus. In an indirectly heated tube this resistor would be in the cathode load.

The electrons comprising the plate current, are emitted from the filament, pass across to the plate, from the plate through the .1 meg resistor to B+, then back through the battery to B minus, to the chassis of the amplifier and then up through the .1 meg resistor to filament minus again. When signal voltages are applied to the control grid of the tube the fluctuations in plate current representing the signal must pass through both resistors and because the resistors are equal in value the signal voltage drop across each will be equal. A rise in plate current will cause the voltage at the plate of the 1T4 to drop, representing a negative signal impulse, while the same rise in plate current will cause the voltage at the negative filament terminal of the 1T4 to rise, representing a positive signal impulse. Thus, the signals applied through the two .01 mfd. condensers to the grids of the 3S4 valves will be 180° out of phase.

You will notice also that the fact that part of the plate load is in the cathode circuit causes the 1T4 valve to act in a fashion very similar to the cathode follower illustrated in Figure 11. This valve again requires a separate filament battery, due to the fact that it is a directly heated valve and once again the 3S4 valves must be operated from one section of the 4.5 volt battery. The filament arrangement is thus similar to the last experiment.

In this case, because only half of the load is in the cathode circuit the valve can amplify the signals slightly. If a 1 volt signal is applied between the input terminals "C" and "D", there will be a signal output of a little less than 1 volt at the filament of the 1T4 and also a signal of a little less than 1 volt at the plate of the 1T4. The total output voltage would be about the same as in Experiment 8. The signals actually will be a little louder because the two 3S4s will both be feeding signals through the centre tapped transformer to the loudspeaker.

One 3S4 valve alone, operating with 45 volts from the B battery can provide approximately 60 milliwatts of power output and the two valves, because they are operating in a push-pull circuit could supply a little more than 120 milliwatts. However, in our case, due to the fact that the 1T4 is providing an amplification of only about 1.8 or 1.9 times, we cannot furnish a strong enough signal for the grids of the 3S4's to produce this full amount of output.

After wiring up the equipment in accordance with Figure 12, reconnect the 4.5 volt battery and B battery and check the voltages applied to the valve sockets with your multimeter. The meter should be set with the switch pointing to "D.C." The negative test lead should be in the negative socket and the positive test lead in the socket marked "+50 Volts".

With the negative terminal of the meter connected to the chassis and the positive test lead touched to the prongs of the 1T4 socket you should obtain a reading of approximately 15 volts at pins 2 and 3 and before the valve is plugged in, there should be no reading at terminals 1 and 6. A very slight movement of the pointer may be noticed at pin 7.

In the case of the 3S4's, there should be a reading of 1½ graduations at pins 1 and 7, no reading at pin 5, a slight backward movement of the needle at pin 3 and a reading of full B battery voltage at pins 6 and 4. If these voltages prove to be correct, carefully insert the valves in their sockets and again check the voltages at pin 1 on the 1T4 socket. You should now obtain a reading of between 5 and 10 volts at this point.

Due to the low amplification provided by the 1T4, the signals from the loudspeaker will not be very loud but you will be able to determine whether the two output valves are working properly and aiding one another in producing the output, by removing firstly one 3S4 valve from its socket and noting that the signal drops a little in loudness. If this first 3S4 is then replaced and the second one withdrawn, there should again be a similar and exactly equal drop in loudness.

Removing one of the 3S4 valves will decrease the power output to half of what it is with both valves working. The signals will not appear to be half as loud to your ears because of the peculiarity of the ear in being very insensitive to increases or decreases in loudness. You will in fact, hardly notice the decrease in loudness when you remove one of the valves and may thus form the opinion that the additional cost of a push-pull circuit is not warranted. However, the advantages of push-pull are not only in providing louder signals but also in eliminating distortion and in A.C. operated equipment-hum. These advantages are set out clearly in A.R.T.C. Service Engineering Course - Lesson No. 27.

When the 3S4 valves are operated with either 3 or 4.5 volt negative grid bias they are employing the normal amount of negative grid bias which means that they are working under "Class A" conditions.

Class B and Class C amplification cannot be used with a single output valve, as used in all previous experiments but class B amplification could be used with push-pull output valves. However, we are unable to carry out any experiments with this system of amplification due to the fact that we do not have sufficient negative grid bias available to reduce the plate current of the 3S4 valves almost to zero, nor do we have a suitable transformer for applying signals to the grids of the valves. To operate these 3S4 valves under Class B conditions with a B battery of 45 volts would require approximately 9 volts negative grid bias.

Class C amplification is only used in radio transmitters and would consist of applying even more negative grid bias to the valve. Class C amplification is not normally used for radio receiver work.

EXPERIMENT 10. PHASE INVERTER WITH PUSH-PULL AMPLIFIER.

The phase splitter illustrated at the left of Figure 12 is not the only method of providing equal signals 180° out of phase for the output valve's grids.

Figure 13 illustrates the 1T4 valve providing the out of phase signals, by a different method. The signal from the oscillator is applied directly through input connection "C" to the grid of one 3S4 valve. Our problem now is to provide an exactly equal but out of phase signal for the grid of the other 3S4 valve. If we take portion of the signal for the first 3S4 and pass it through the 1T4 valve this will have the effect of providing, from the plate of the 1T4, a signal which is 180° out of phase with that applied to its grid. Whenever signals pass through a resistance coupled amplifier they are changed in phase by 180°. In other words, a positive impulse of signal applied to the grid of a valve produces a negative signal impulse from its plate circuit.

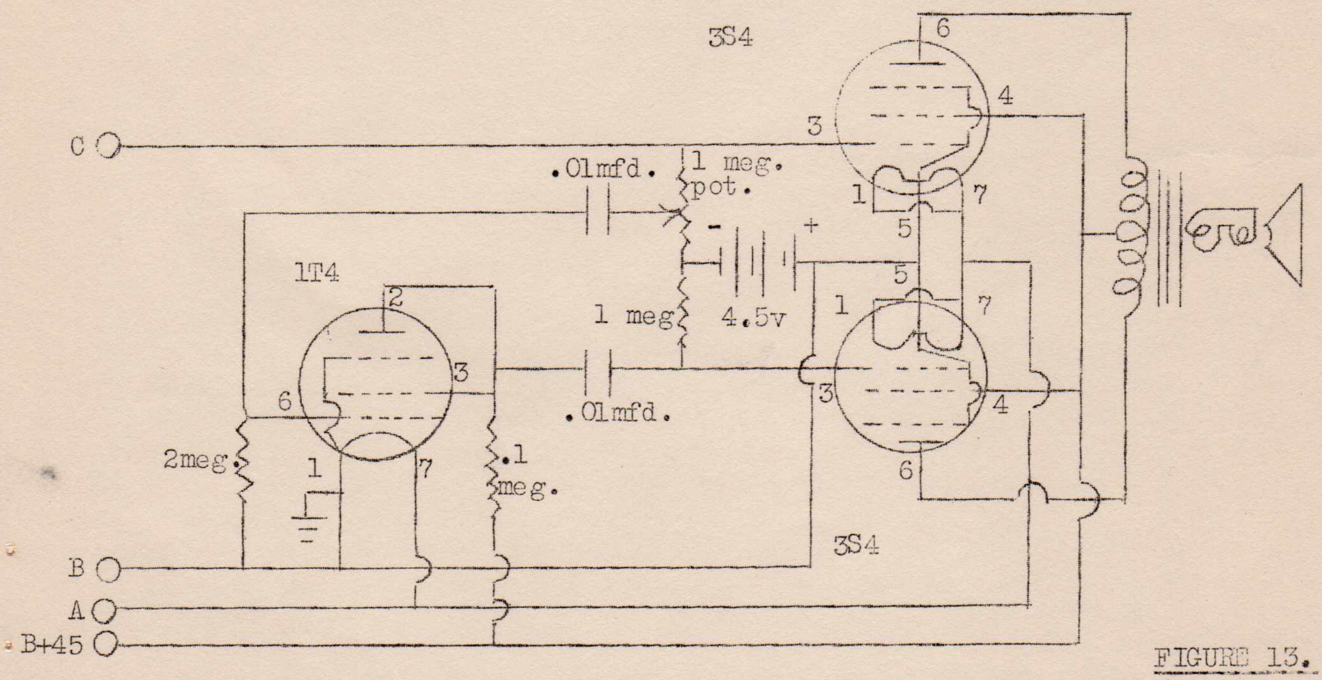


FIGURE 13.

If the full signal voltages applied to the first 3S4 were also applied to the grid of the 1T4 the signals from its plate circuit would be far stronger than those applied to the first valve and so the two push-pull valves would not receive equal signal strength. For this reason, it is necessary to apply only a small portion of the signal reaching the first output valve's grid to the grid of the 1T4. This reduction in signal strength is obtained by using the 1 megohm potentiometer as the grid leak for the first 3S4 valve. The 1T4 valve, operated as a resistance coupled triode valve will provide an amplification of approximately 8 times and, therefore, if the signal at its plate circuit is to be equal to that at pin 3 on the first 3S4 valve, it will be necessary to reduce the signal reaching the grid of this 1T4 valve to about $\frac{1}{8}$ of the strength of that present at the grid of the 3S4. We must thus adjust the 1 megohm potentiometer until the signals leaving the moving arm of it are only $\frac{1}{8}$ as strong as those applied to its upper end.

In actual practice, it is common to use two fixed resistors, rather than a potentiometer to reduce the voltage in this way. If two separate resistors were used the upper one would have a resistance value about seven times as great as the lower one so that the voltage at their junction would be $\frac{1}{8}$ of the total input voltage. When this weak voltage is applied to the grid of the 1T4, it will be amplified and the signals available at the plate of this valve will be equal to those reaching the grid of the first 3S4. This means that our output valves will have signals of equal strength and 180° out of phase.

After completing the wiring and reconnecting the batteries, the voltage readings for the 3S4 valves should be the same as in the last experiment whereas the positive test lead from the multimeter, applied to the 1T4 socket should give a reading of plus $1\frac{1}{2}$ volts at pin 7, no reading at 6, and a reading of approximately 15 volts at pins 2 and 3. You will notice that in this case, the 1T4 valve does not require a separate filament battery and so the second 1.5 volt cell can again be connected between the switch and earth, in the oscillator circuit of Figure 1, so that the 1T4 and two 3S4s receive their filament current through terminals "A" and "B" from the oscillator. The full 4.5 volts negative bias can now be applied to the grid circuits of the 3S4s once more.

If the voltages are in order, you can insert the valves in their sockets and you will notice that the signals appear to be much the same as in the case of the last experiment. Although the 1T4 is capable of providing a greater degree of amplification in itself, the fact that the signals are reduced to $\frac{1}{8}$ of their strength by means of the 1 megohm potentiometer means that no real amplification is obtained from the 1T4 stage. This method of providing the change of phase, results in performance almost exactly the same with that of Figure 12, as you will be able to judge by the loudness of signals from the loudspeaker. To set the potentiometer at the right position, you should start off with it turned fully off, and on removing firstly one 3S4 and then the other you will notice that with the upper valve operating the signals have a certain loudness and with the upper valve removed there will be no output.

You should now turn on the 1 megohm potentiometer a little at a time, as you continue to remove first one 3S4 valve and then another. The correct position of the potentiometer is when the signals are of uniform loudness regardless of which 3S4 valve is in its socket. If you turn up the potentiometer too far, a loud howling noise may result due to oscillation occurring.

There are a few other methods of obtaining the necessary phase change to enable output valves to operate in push-pull but the two methods illustrated in Figures 12 and 13, together with transformer coupling are by far the most commonly used methods of achieving this.

EXPERIMENT 11. PARALLEL OUTPUT.

A signal power output twice as great as that available from one output valve can be produced by operating two output valves in parallel instead of push-pull. Operation of output valves in parallel however, does not provide the cancellation of distortion, hum, and other advantages associated with push-pull amplification. However, when the two tubes are operated in parallel it is not necessary to employ a valve as a phase splitter or phase inverter as the two valves can be operated by an ordinary signal voltage and do not need equal signal voltages out of phase with one another.

In Figure 14 you will observe that the 1T4 valve is operating in the normal fashion as a resistance coupled triode amplifier. The output valves have all their elements connected in parallel with one another. That is, the filaments are connected in parallel, the grid of each valve is connected to one another, similarly, the two plates are joined to one another and the two screen grids are joined.

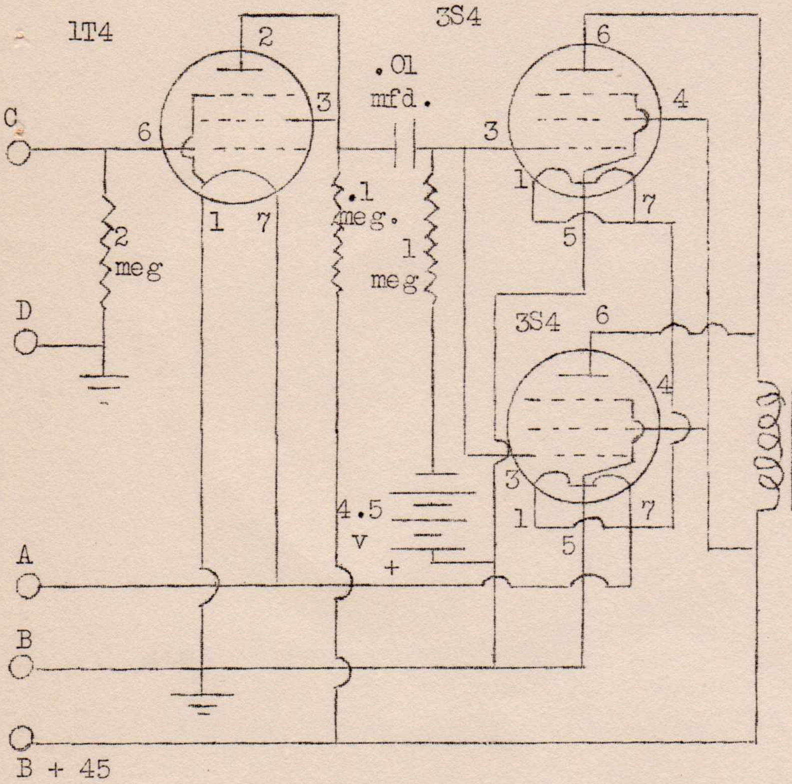


FIGURE 14.

After wiring up the arrangement as illustrated in Figure 14, you should measure the voltages present at the valve sockets after the batteries have been reconnected. With the valves removed from their sockets you should obtain a reading of approximately 15 volts at pin 2 of the 1T4, the same reading at pin 3, no movement at pin 6, and a movement of $1\frac{1}{2}$ graduations at pin 7. In the case of the 3S4 sockets, you should obtain a reading equal to the full battery voltage at pins 2 and 4 on each socket and a slight backward movement of the needle at pin 3 at each socket. You should obtain a reading of plus $1\frac{1}{2}$ volts at pins 1 and 7 on each socket.

On inserting the valves, you will notice that the signals are very much louder than in the case of experiments 9 and 10, this being due to the fact that the 1T4 valve is now capable of providing a really worthwhile amount of amplification. This valve will now provide an amplification of about 8 times, so the signals will appear very much louder from the loudspeaker. Once again, you can judge the way in which each 3S4 valve contributes to the power output by removing firstly one and then the other from its valve socket. As you remove one valve you will find that the power output drops by half but although there will be a slight decrease in loudness from the speaker it will not appear to be only half as loud to your ear. However, this is normal as explained earlier.

EXPERIMENT 12. R.C. OSCILLATOR

In all our tests up to date we have been employing the beat frequency oscillator as a source of signals.

There are several other methods which can be employed for producing audio frequency signals and an alternative form of audio frequency oscillator is indicated in Figure 15. The two tubes at the left-hand side of the diagram act as the oscillator and the 3S4 at the right is merely an amplifying valve to make the signals from the oscillator loud enough to operate your loudspeaker.

This principle, of using two equal resistors, marked "P" and "Q" on the diagram and two equal condensers marked, "R" and "S", for providing a change in the phase of signals passing back from the plate of the 3S4 valve, through the .1 mfd. condenser to the grid of the 1R5 is known as a resistance-capacity network and is quite often used in test instruments and other applications. Many good quality audio frequency oscillators employ this principle. As the two equal condensers, "R" and "S" in Figure 15 are portions of the variable tuning condenser it will be possible to alter the pitch of the audio frequency note over a range of about 10 to 1 as the tuning condenser dial is rotated.

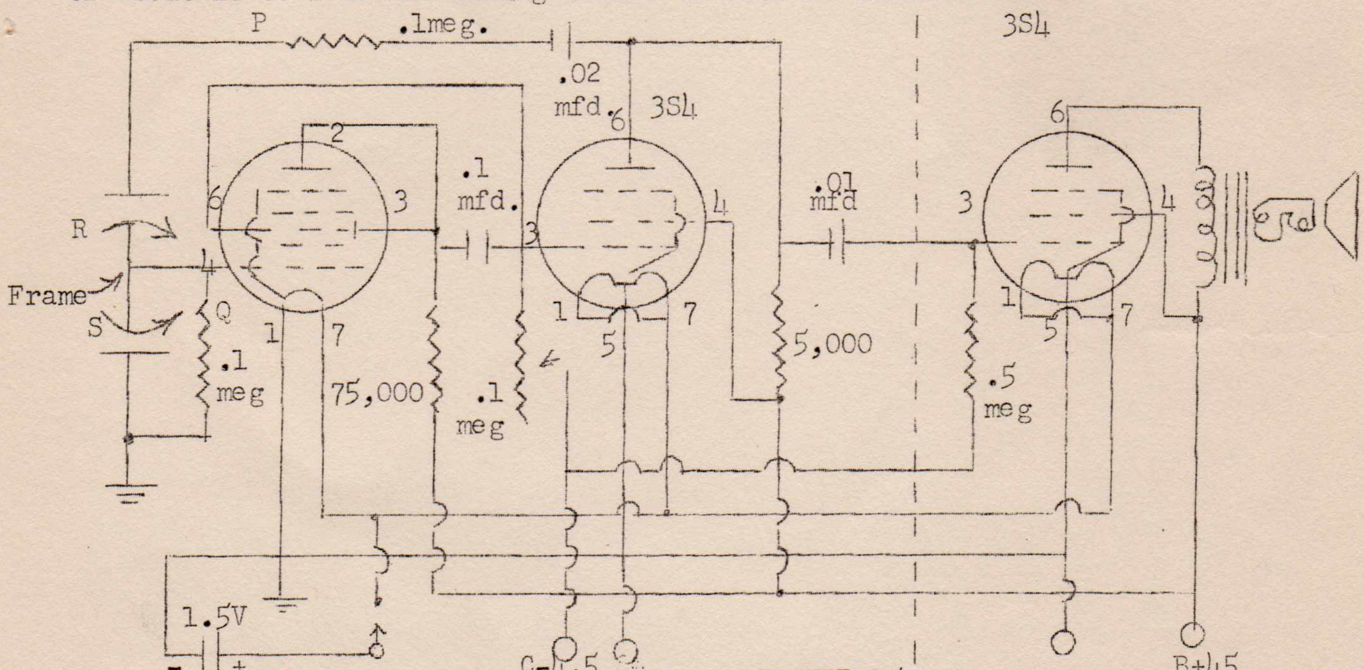


FIGURE 15.

As you have now finished with the beat frequency oscillator, you can build up the equipment illustrated in Figure 15 on the chassis you previously used for it. You will notice in Figure 15, that the rotor plates of the tuning condenser, illustrated by curved arrows on Figure 15, are no longer connected to the metal chassis. Instead, the rotor plates of the condensers connect to grid No.1 of the 1R5 valve and this means that the tuning condenser must be unbolted from the chassis and insulated from it. If you simply remove the condenser from the four long bolts you were previously using to hold it on the chassis and place it on top of a piece of cardboard or other insulating material such as several thicknesses of paper, it will operate satisfactorily without being bolted down. On no account try to secure it in place by passing a bolt through the condenser mounting brackets and on through the chassis as this bolt will connect the rotor plates to the chassis and prevent the oscillator from operating.

For your first experiment with this oscillator, you should employ the two .1 megohm resistors in the positions marked "P" and "Q".

The 1R5 valve may be left in the position on the chassis in which it has been used up to the present. Although the two coils will not be required in this oscillator, they may be left bolted in position but of course, the coil wires must be disconnected from the valve sockets. One 3S4 valve can fit in the socket previously used for the 1S5 and a socket for the second 3S4 valve can be fitted in the hole immediately behind the tuning condenser gang. The 3S4 valve illustrated in the centre of Figure 15 should be fitted in this socket.

On completing the wiring of the oscillator in accordance with Figure 15, you should first of all test for short circuits between the end of the wires provided for battery connections so that the batteries will not be damaged if a wrong connection exists. If you obtain no indication of a circuit when you measure between the wires marked "B+ and B-" and also between the wires for "A+ and A-" you may safely connect the batteries. You should then use your multimeter on the 50 volt range, with the negative test lead clipped to the chassis, to check the voltage existing at the various valve sockets. When touching the positive prod to the pins of the 1R5 valve socket you should obtain no reading at points 1, 4 and 5, you should obtain a reading of $1\frac{1}{2}$ graduations at pin 7, a slight backward reading at pin 6, a reading of approximately 18 volts at pin 3, and a reading of about 18 volts at pin 2. On both 3S4 sockets you should obtain no reading at pin 5, a reading of $1\frac{1}{2}$ graduations at pins 1 and 7, a slight backward reading at pin 3, full B battery voltage at pin 4 and almost full B battery voltage at pin 6.

If these voltages all appear to be in order, you may safely insert the valves in their sockets, but be careful to fit the valves in the sockets intended for them and not in the incorrect sockets. On turning on the filament switch and rotating the .1 megohm potentiometer to a position about half way on, you should find that as you vary the setting of the tuning condenser, you hear an audio frequency note which varies in pitch from an extremely shrill treble note, which may even be above audibility when the tuning condenser plates are turned fully out, down to a much lower pitch. Once you have obtained an audio frequency signal from the equipment you should reduce the resistance of the .1 meg potentiometer to a value which just allows the oscillator to function without stopping. If too low a resistance is employed the oscillator will cease to operate and if too high a resistance is used the note, instead of being a pure pleasant sound, will become harsh and buzzing in nature indicating the presence of harmonic distortion.

The range of audio frequencies can be extended down to still lower values by using higher values of resistance in the positions marked "P" and "Q" on Figure 15. The next test is to substitute a 1 megohm resistor for each of the .1 meg resistors and to note the effect. The 1 meg. 1 watt resistor you have can be substituted at position "P" and in position "Q" you may use the 1 megohm potentiometer by connecting only to the two outer lugs and disregarding the centre connection. With these 1 megohm resistors in place, you will find that the pitch of the notes produced is much lower than in the previous example.

If we had available a pair of still higher valued resistors it would be possible to make the oscillator produce still lower pitched notes, right down to deep bass notes and it is the ability of this class of oscillator to produce very deep bass notes with extremely pure wave-form, that makes it popular for audio frequency testing purposes.

If by any chance you are unable to obtain a squealing sound from the oscillator when it is turned on, this will indicate that signals are not finding their way back from the plate of the first 3S4 valve back to grid No.1 on the 1R5 valve. Failure for the signals to pass back in this fashion may be due to the fact that the tuning condenser frame is touching the metal chassis and you should examine carefully to see that there is no connection between the tuning condenser frame and the chassis.

By using still smaller values of resistors in the positions "P" and "Q" the oscillator could be used to produce frequencies above audio frequency range and this type of oscillator is often used up to about 200 kilocycles per second. However, there is little point in conducting any experiments with lower values of resistors because the signals would exceed the frequencies which your ears could detect from the loudspeaker.

EXPERIMENT 13. BLOCKING R.F.OSCILLATOR.

The next series of experiments will consist of measurements to determine the relative sensitivity of various types of detectors. In order to provide a source of modulated radio frequency signals, so that the various detector circuits may be tested, it is first necessary to construct a modulated R.F. oscillator.

There are a large number of possible ways of connecting a radio valve to act as a radio frequency oscillator but in this lesson we will use one of the simplest possible types of circuits which will furnish a radio frequency carrier wave, modulated by an audio frequency tone, so that signals from the oscillator will be audible from the loudspeaker. In the following lesson you will see other methods of achieving this.

The circuit diagram for the "Blocking R.F. oscillator", or, as it is sometimes called a "Squegging R.F. oscillator" is shown in Figure No. 16.

The 3S4 valve is made to oscillate, and produce a radio frequency signal by feeding energy from its plate circuit back to its grid circuit by means of a reaction winding similar to that used with the detector tube used in your experiments in Kits 6 and 7. The energy sent back from the 45 turn coil in the plate circuit of the 3S4 generates a voltage in the 90 turn winding and this winding is tuned by a .0001 mfd. condenser. An alternating voltage is developed in this circuit at the frequency at which the .0001 mfd. condenser makes the 90 turn winding resonant and this voltage acts through the two .001 mfd. condensers to the grid of the 3S4 . As the result of the repeated feeding back of energy from the plate circuits to the grid circuit, the valve will generate a radio frequency voltage in the 90 turn winding and the lines of force from this winding will induce a small voltage in the 5 turn winding which we can use as our radio frequency output. The strength of the radio frequency voltage can be regulated by means of the 2,000 ohm potentiometer and the required signal strength applied, by means of terminal "C" in Figure 16, to the circuit being tested.

You will notice that the grid leak for the 3S4 valve has an unusually high value, being 5 megohms. Also, the condenser feeding signals from the 90 turn coil to the grid of the 3S4 has an actual capacity of .0005 mfd. due to the fact that the two .001 mfd. condensers are connected in series. This combination of a large capacity with a large grid leak resistance causes the oscillator to periodically block, due to the development of a high negative voltage at the grid of the 3S4, so that in effect, the oscillator stops and starts oscillating at an audio frequency rate. When you hear the signals from this oscillator through the equipment to be described in the next experiment or through a receiver, you will be able to hear this audio frequency sound as a high pitched buzzing sound. It is due to the periodical blocking of the plate current of the 3S4 and then the discharging of the voltage from the right hand plate of the .0005 mfd. grid condenser that the name "blocking oscillator" is derived.

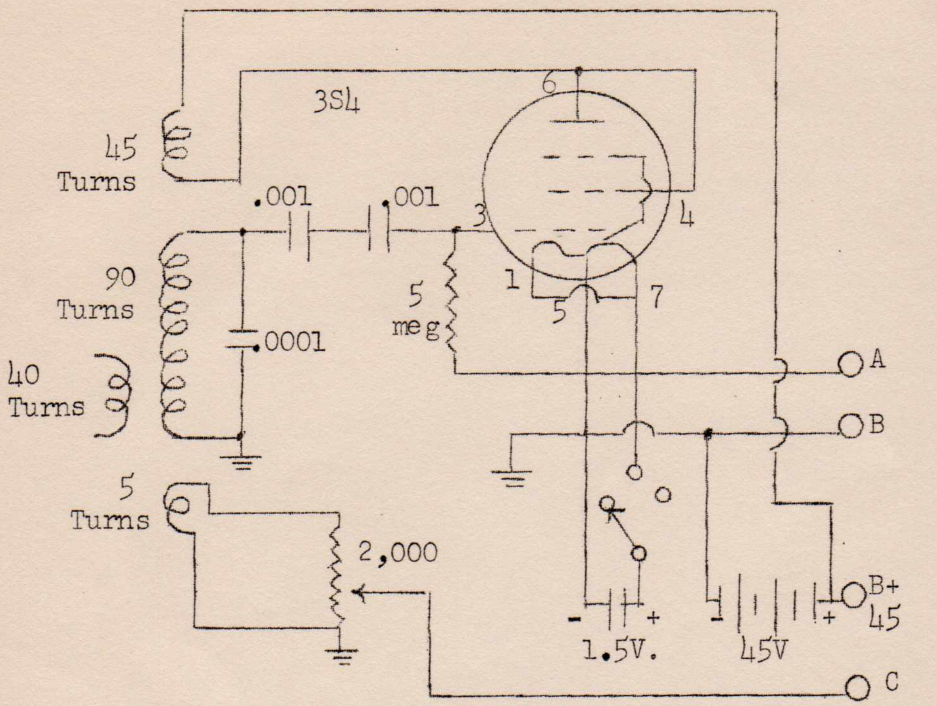


FIGURE 16.

The blocking oscillator should be built on the smaller of the two chassis supplied to you. There are four valve socket holes available in this chassis and it does not matter which of these holes you employ for the 3S4 valve socket. The coil with the 45 turn reaction winding and 5 turn winding at the bottom can also be mounted on this chassis over any one of the other valve socket holes. The wiring and placement of parts is not at all critical so you should experience no difficulty in making the circuit operate.

After completing the wiring, use your multimeter to test for short circuits between the "A" battery and "B" battery wires and if there are no short circuits, connect the wires to the A and B batteries. Next, before you insert the valve in the socket, use your multimeter, on its 50 volt range, for measuring the voltages present at the socket pins. With the negative test lead clipped to the metal chassis there should be a reading of $1\frac{1}{2}$ graduations at pins 1 and 7, no movement at pins 5 or 3 and full "B" battery voltage at pins 6 and 4. It is preferable to use pin 6 for the plate connection as it is easier to solder to this pin than pin 2.

If you have a radio receiver available, you can test the oscillator before proceeding to construct the equipment outlined in the next experiment. The .0001 mfd. condenser will tune the oscillator to a frequency of approximately 1,300 kc. If you connect point "C" on Figure 16, to the aerial terminal of your receiver and connect the chassis or point "B" to the chassis of the receiver, -switch on the oscillator and tune your receiver to approximately 1300 kc., you should hear the peculiar buzzing note from the oscillator, through the receiver's loudspeaker. If you do not hear any sound at all when the tuning dial of the receiver is moved to various frequencies around about 1300 kc., this indicates that the oscillator is not functioning and you should carefully check the circuit arrangement once more and also see that the lower end of the 45 turn coil is connected to the plate of the 3S4 at pin 6, and the upper end of the 90 turn coil is connected through the two .001 mfd. condensers to the grid of the 3S4.

EXPERIMENT 14. RECEIVER WITH GRID LEAK DETECTOR.

Figure 17 shows a circuit diagram of a three valve receiver employing a grid leak detector, which will be the first type of detector to be tested. You will notice that the circuit diagram of Figure 17 is almost identical with that of Figure 1 of Practical Instruction Lesson No. 7, with the exception that the 1S5 valve is not fitted with a system of regeneration in this lesson, as regeneration would cause a variation in amplification of the valve, dependent upon the setting of the 2,000 ohm potentiometer, and so would give us results which would vary according to the amount of regeneration used.

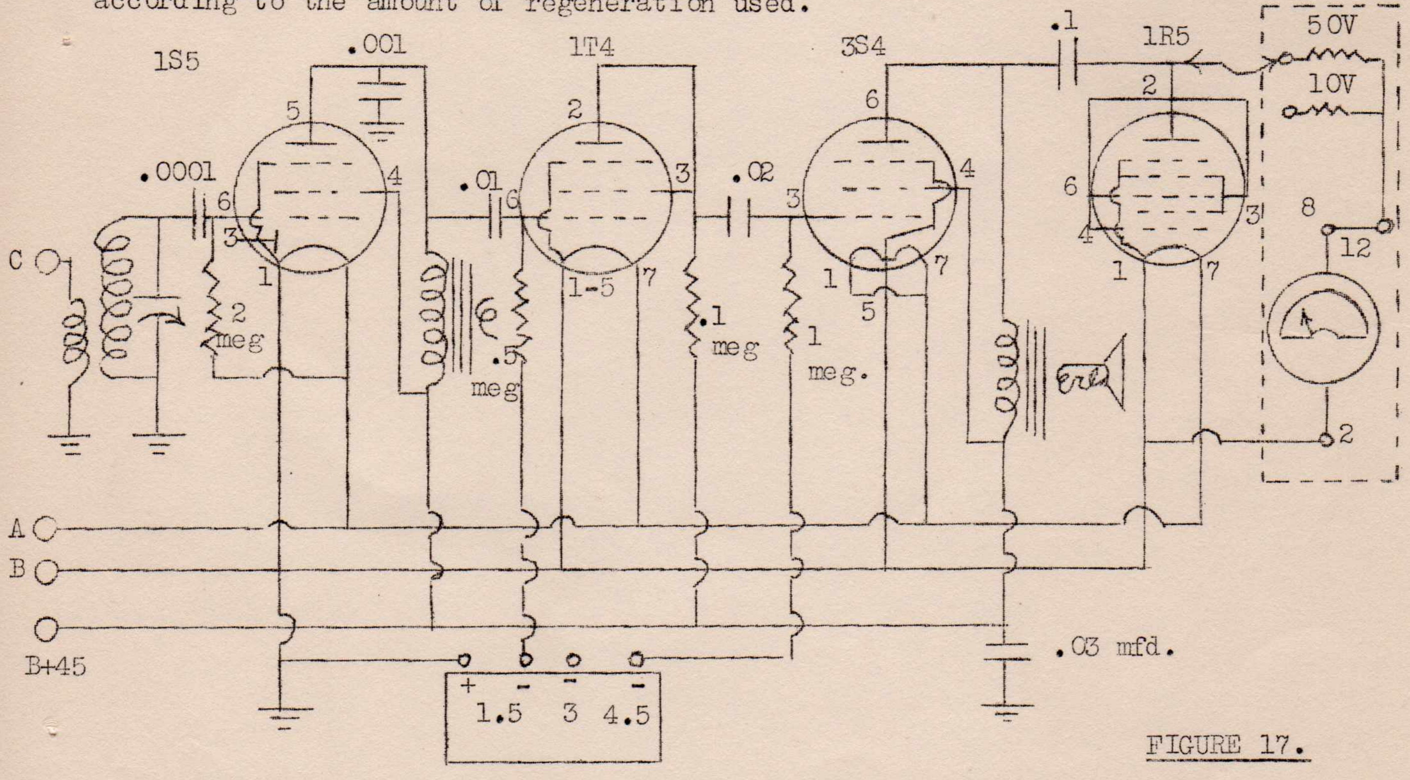


FIGURE 17.

You already have a coil with a 15 turn and 89 turn winding on it so that you may use this for feeding signals to the grid of the 1S5 valve.

The receiver should be built on the larger chassis and the location of parts may be determined by reference to Figures 2 and 3 of Practical Instruction Lesson 7. The "A" battery switch and the 2,000 ohm potentiometer are, in this case, mounted on the oscillator chassis so that they will not be fitted on the front flange of the receiver chassis. In addition, apart from the fact that there is no reaction provided in the circuit of Figure 17, there are one or two other minor alterations; so on no account should you attempt to wire the equipment from Figure 3 of Lesson 7. Instead you must wire it from the circuit diagram of Figure 17. Figures 2 and 3 of Lesson 7 will be valuable however, in suggesting where to place the parts.

On completing the wiring of Figure 17, and checking the voltages on the

50 volt range of your multimeter, you should obtain approximately the following figures. In the case of the 1S5 socket, 1½ graduations at pin 7, no reading at pins 1, 3, or 6, full B battery voltage at pin 4 and almost full voltage at pin 5. In the case of the 1T4 socket a reading of 1½ graduations at pin 7, no reading at pins 1 or 5, a very slight backward reading at pin 6, although this may not even be noticeable as it will be so small, and a reading of approximately 15 volts at pins 2 and 3.

In the case of the 3S4 socket, there should be a reading of 1½ graduations at pins 1 and 7, no reading at pin 5, a very slight backward movement at pin 3 and full "B" battery voltage at pins 4 and 6.

In the case of the 1R5 valve socket there should be a reading of 1½ graduations at pin 7, and no reading at any of the other pins.

If the voltages all check correctly, insert the valves and rotate the tuning condenser so that the signal from the oscillator is heard from the loudspeaker.

If you do not hear any sound from the speaker, thismay indicate a fault in the receiver you have just constructed or, if you have not already tested your R.F. oscillator by trying it on an ordinary radio receiver, it may indicate that the oscillator is not functioning.

You will be able to obtain a fairly good idea of whether your receiver is in working order or not, by touching your finger to pin 6 of the 1S5 valve socket. When you touch your finger on this point you should hear a distinct click, hum or squeal from the loudspeaker. Perhaps an even better method is to hold a short piece of bare wire or a bare screwdriver in your hand and touch this to pin 6 on the 1S5 socket. There should be quite a distinct sound from the loudspeaker when you do this and if you do hear the click, it indicates that signals reaching the grid of the 1S5 will be able to pass on through to the loudspeaker. If you hear no sound at all it indicates a fault in the receiver which must be located before you proceed further.

If you cannot obtain any results when touching the grid of the 1S5 then it will be necessary to carefully recheck the wiring of the circuit arrangement and also recheck the voltages mentioned above and see that they are correct.

When the equipment is working satisfactorily, you will find that you are able to vary the strength of signals from the loudspeaker by rotating the 2,000 ohm potentiometer fitted to the oscillator. As the signals vary in loudness the output meter will record the variations in strength. You should operate your output meter with the switch turned to the "A.C." position and the positive test lead inserted in the 50 volt socket, the negative meter connection being by means of a length of wire joining lug 2 on the switch, to pin 1 on the 1R5 valve socket as explained in connection with Figure 5 of this lesson. In order to establish a basis for comparison of the other detector circuitswith the grid leak detector, you should adjust the 2,000 ohm potentiometer until the strength of signals from the loudspeaker results in a reading of 20 volts. Of course, when using your meter as an output meter it is measuring alternating voltages and you should observe the reading on the row of graduations marked "50V.A.C. and up".

EXPERIMENT 15. RECEIVER WITH BIASED DETECTOR.

To convert the circuit from a grid leak detector to a biased detector involves alterations only to the 1S5 valve. These alterations are indicated in Figure 18. In place of the grid leak and condenser in the grid circuit of the 1S5, a .01 mfd. condenser is included in the tuning circuit and a connection taken from the lower end of the 89 turn coil to the 3 volt tapping on the "C" battery. In this way, the valve receives a large amount of negative bias so that it amplifies the positive half cycles of signal voltage reaching it and suppresses the negative half cycles. This causes it to act as a detector but you will find that it does not give quite as great a degree of amplification as did the grid leak detector.

Before making any alterations to the wiring of the 1S5 valve, be sure to disconnect the "B" battery wires and turn off the switch on the oscillator. It is not necessary to remove all tubes but it is advisable to remove the 1S5. After making the alterations, switch your multimeter to "D.C.", plug the negative test lead in the minus socket and clip this to the chassis of the receiver. With the positive test lead, measure the voltages at the pins of the 1S5. At pin 7 there should be a reading of 1.5 volts when the switch on the oscillator is turned on. At pins 4 and 5 there should be full B battery voltage and at pin 6 the needle should move backward. To measure this voltage, clip the positive test lead to the metal chassis and touch pin 6 on the socket with the negative test lead. The meter should indicate a value of 3 volts by the needle moving three graduations across the scale.

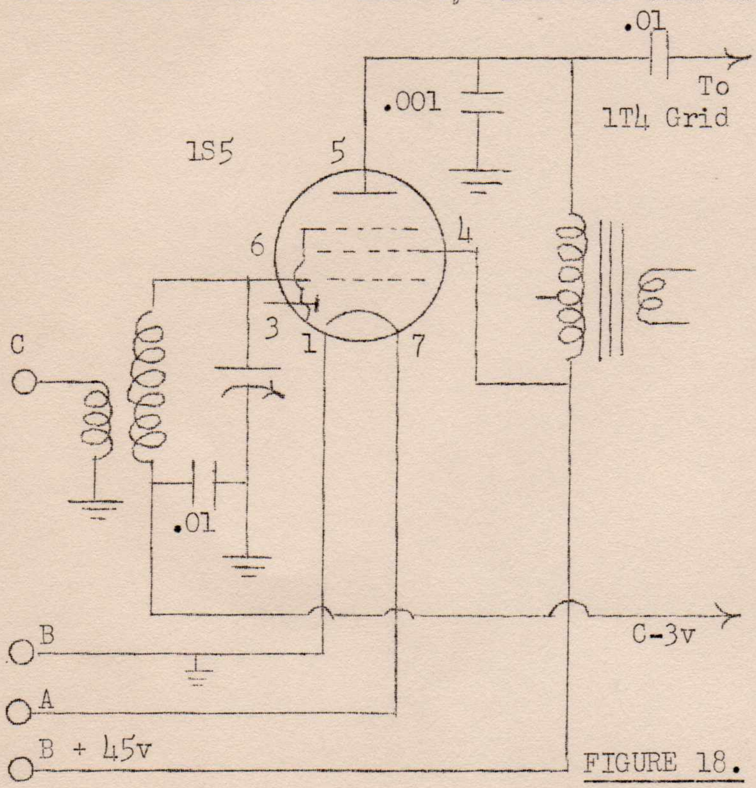


FIGURE 18.

If these voltages check correctly, you should remove the negative test lead from the multimeter, switch it back to "A.C.", clip the positive test lead back to one of the pins on the 1R5 valve socket, such as pin 2, plug in the 1S5 valve and observe the output signal strength. On no account should you alter the setting of the 2,000 ohm potentiometer on the oscillator, otherwise you will not be able to compare the output voltage obtained in this and the succeeding experiment with that obtained in experiment 14. When you switch on the equipment, you will probably hear the signals from the oscillator coming through weakly but it will be necessary to readjust the tuning condenser on the receiver, to tune the signals to their maximum strength once more, before you judge the strength of output obtained. The presence of the .01 mfd. condenser in the tuning circuit will slightly alter the position at which the signals will be received with maximum strength. In moving the tuning knob you will notice that the signals from the oscillator do not spread over as broad an area of tuning condenser rotation as in the case of the grid leak detector. This indicates that biased detectors do not impose such a load on the tuning circuit as grid leak detectors and consequently result in a greater degree of selectivity.

(See A.R.T.C. Service Engineering Course - Lesson No.32.)

When you have tuned the signals to maximum strength, you will probably obtain a reading of about 17 volts output on the 50 volt A.C. range of your multimeter.

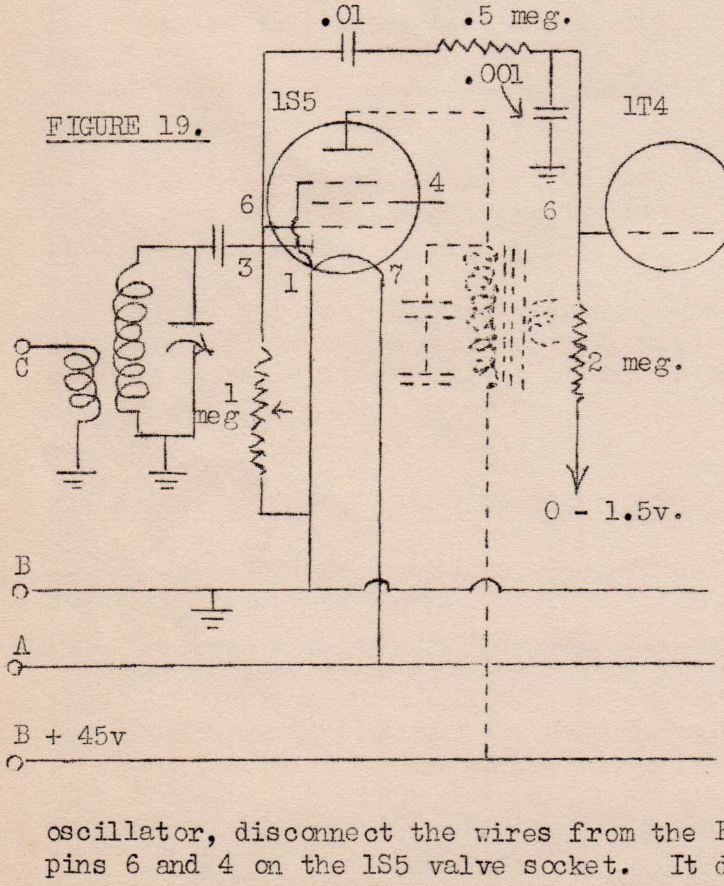
As a point of interest, you should experiment by touching the lead from the lower end of the 89 turn coil to various other tappings on the "C" battery. You may possibly find that you obtain slightly better results by using the 1.5volt tapping, but when connecting to the positive terminal, or to the minus 4.5 volt terminal, the results will not be as good.

EXPERIMENT 16. RECEIVER WITH DIODE DETECTOR.

This experiment consists of rewiring the 1S5 valve so that the diode detector element is used.

From Figure 19 you will observe that signals are applied to the diode plate by means of the .0001 mfd. condenser and that the two outer terminals of the 1 megohm potentiometer are used to connect it between the diode plate and pin 1 on the valve socket so that it acts as a diode load. There should be no connection to the centre lug on the potentiometer. Another alteration is to substitute the 2 megohm resistor for the .5 meg resistor previously connecting to pin 6 on the 1T4 valve socket, as shown in Figure 17, so that the .5 meg. resistor becomes available to use as a radio frequency filter, in conjunction with the .001 mfd. condenser drawn near the top of Figure 19.

FIGURE 19.



The action of this circuit is that the modulated R.F. signals applied to the diode plate are detected and an audio frequency voltage,together with the radio frequency signal voltage,is available at pin 3 on the 1S5 socket. We do not wish the radio frequency voltage to pass on to the audio amplifying stages and although both signals are applied through the .01mfd. condenser and .5meg resistor, the reactance of the .001 mfd.condenser following this resistance,is so low that the R.F. signals are bypassed through it to chassis, where they have no effect. The audio frequency signals experience a high reactance in the condenser,due to their lower frequency, and consequently cannot pass through it but instead are applied to the grid of the 1T4 and eventually reach the loudspeaker. To carry out the alterations, you should turn off the switch on the oscillator, disconnect the wires from the B battery and disconnect any wires from pins 6 and 4 on the 1S5 valve socket. It does not matter if the wire from pin 5 on this socket is left connected to the .001 mfd. condenser and iron cored transformer as these parts will not influence the performance of the diode detector in any way. For this reason, they are shown in dotted lines in Figure 19.

On completing the alterations, you may connect the B battery and turn on the switch. On measuring the voltages, you should obtain a reading of $1\frac{1}{2}$ graduations at pin 7, no reading at pins 1, 3, 6 or 4, but there will of course still be a voltage at pin 5, obtained through the choke.

If the voltages are correct, plug in the 1S5 valve and again carefully readjust the tuning condenser for loudest signals before judging their strength on the scale of your output meter. Due to the fact that a diode detector does not provide any amplification of the signals, the signals will be much weaker than in the previous experiments and you can expect an output voltage of only about 1 volt on your output meter scale. As this voltage is so small the needle will not move far, but do not plug the positive test lead into the 10 volt socket instead of the 50 volt socket for this will alter the load imposed by the meter on the 3S4 output valve and will not provide a fair comparison between the results.

(See A.R.T.C. Service Engineering Course - Lesson No. 32.)

EXPERIMENT 17. RECEIVER WITH DIODE DETECTOR AND A.F. AMPLIFIER.

In order to compensate for the fact that a diode detector will not amplify signals, it is customary practice to have diode detectors built into the same glass envelope as a triode or pentode amplifier. The relatively weak signal output from the diode detector can be amplified by the pentode section of the 1S5 before being applied to the 1T4 and 3S4. Figure 20 shows how the 1S5 should be wired to accomplish this. You will notice that the signals emerging from the .5 meg resistor and .001 mfd. condenser, instead of being applied directly to the grid of the 1T4, are now applied to the grid of the 1S5 at pin No.6. This valve will then amplify the signals and they will emerge from the plate of the 1S5 to be applied to the grid of the 1T4.

Observe the usual precaution of disconnecting the B battery wires and after making the alterations, check the voltages at the pins of the 1S5 socket. There should be no reading at pins 1, 3 or 6 and there should be full "B" battery voltage at pin 4 and almost full voltage at pin 5.

Reset your multimeter as an output meter, plug in the 1S5 and once again readjust the tuning condenser dial to bring the signals to their greatest strength. In this case, you can expect an output of approximately 11 volts, indicating that the pentode section of the 1S5 has amplified the signals about 11 times.

If the valve were operated under more ideal conditions, with a higher B battery voltage and a high resistance in the plate circuit as a plate load, the amplification achieved would be much greater than 11 times and in actual practice it is customary to obtain just as strong a signal output from a diode and A.F. amplifier stage as is available from a grid leak detector.

EXPERIMENT 18. INFINITE IMPEDANCE DETECTOR.

A type of detector which is occasionally found in receivers designed for high quality reproduction is known as the "infinite impedance detector" and works along the lines of a cathode follower amplifier. The audio frequency load resistor is placed in the cathode or B minus circuit instead of being connected directly in the plate circuit. Figure 21 shows how the 1S5 pentode section may be wired to operate in this fashion. Once again, it will be necessary to employ the 1.5 volt cell, normally used for the ohms ranges of your multimeter, for furnishing "A" battery current for the 1S5.

The valve really acts in a way as a biased detector, the bias being provided by the voltage drop due to plate current passing through the .5 meg. resistor connected between the valve filament and chassis.

On making the alterations, and checking voltages, there should be no reading on pins 1, 7, 3 or 6 but a reading of full battery voltage at pins 4 and 5. If these readings are correct, plug in the valve and again measure the voltage at pins 1 and 7. In this case you will obtain a reading of a few volts due to the voltage drop across the .5 meg. resistor when the tube's plate current passes through it.

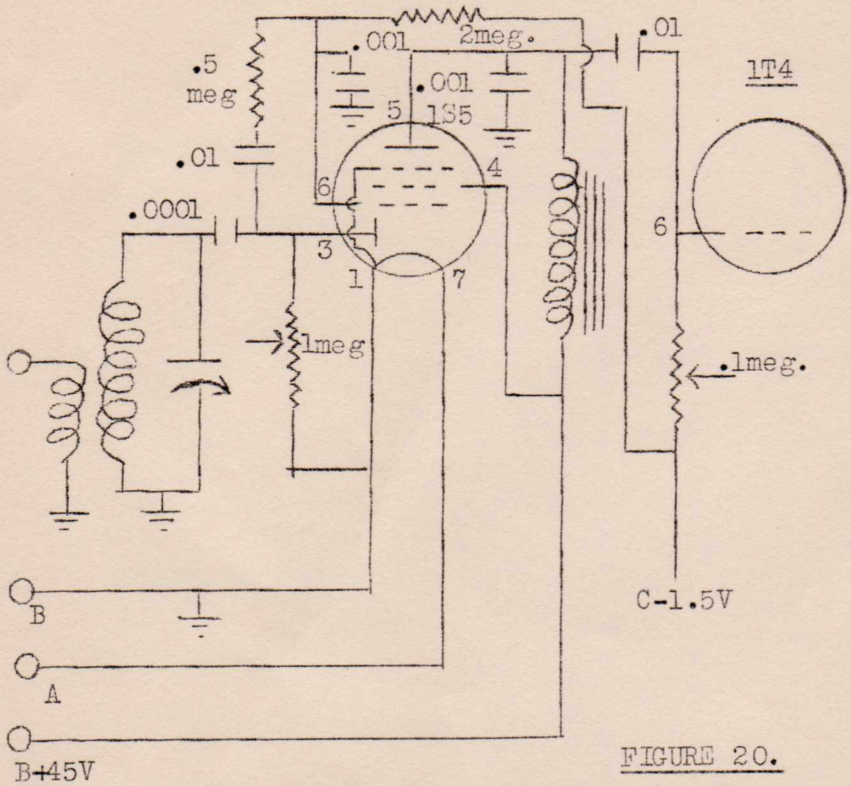


FIGURE 20.

With the oscillator switched on, retune to produce maximum output and in this case you will find a reading much the same as that obtained with a diode detector. You will probably get a reading of about .95 volts, indicating that although we are using the pentode section of the tube it provides no audio frequency amplification due to the fact that all of the load resistance is in the cathode circuit and so, like a cathode follower A.F. amplifier, the valve will not amplify signals at all. Because of this lack of amplification, the circuit arrangement is not often used but it is capable of providing better detection, with greater freedom from distortion than can be obtained even with a diode detector.

EXPERIMENT 19. MULTI-VIBRATOR.

The A.F. and R.F. oscillators we have constructed up to date have all been designed to produce signals at one particular frequency. However, it is possible to set up a pair of valves in what is called a "multi-vibrator circuit" which will provide signals over an enormous range of frequencies simultaneously. The frequency range covers not only the audio frequency band but also the radio frequency band. A circuit diagram for achieving this is shown in Figure 22. The purpose of a multivibrator is to simplify the adjustment of padding condensers in superheterodyne receivers. The normal method of aligning the padding condenser with an ordinary test oscillator is somewhat tedious and is explained in A.R.T.C.Service Engineering Course Lesson 49. A quicker way is to use a multi-vibrator as a source of signals and simply to adjust the padding condenser until the strongest sounds are heard from the receiver's loudspeaker. Although we have not constructed a superheterodyne receiver to employ the multi-vibrator with, it is interesting to build it to hear the type of sound which emerges from it and to confirm the fact that its signals spread throughout the full tuning range of an ordinary receiver.

You have now completed your tests with the blocking oscillator and so the multi-vibrator may be built on the small chassis. You will not require the rectifying tube for the output meter range of your multimeter for any further experiments in this lesson, so you can use the two valve sockets on the small chassis for the two tubes indicated in Figure 22.

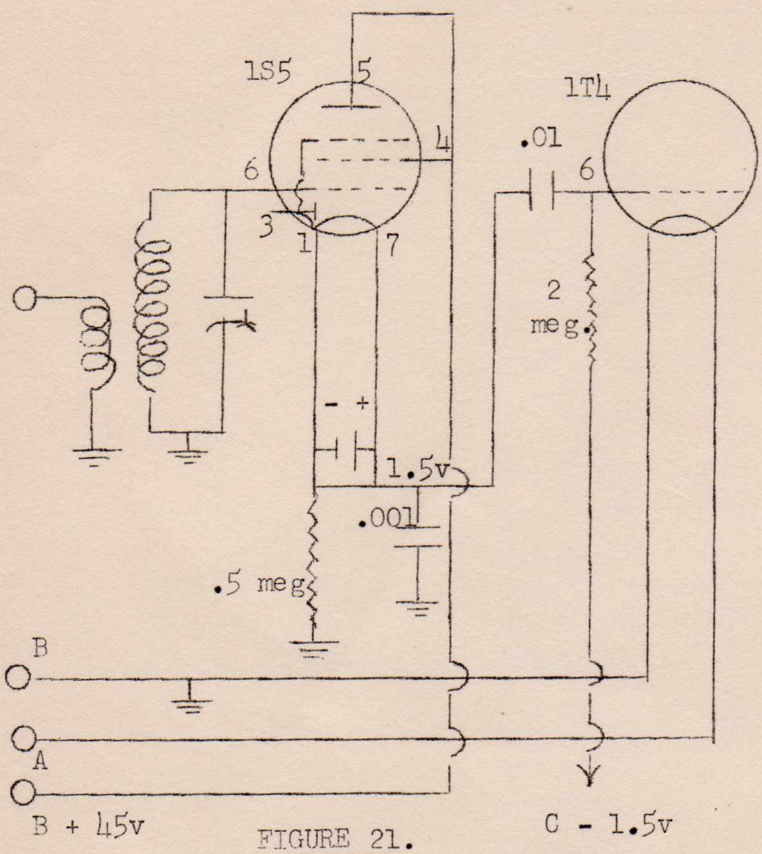


FIGURE 21.

After wiring up the equipment, connect the batteries and before inserting the valves measure the voltages. On the 1R5 socket the readings should be 1.5 volt at pin 7, no readings at pins 4 and 6, approximately 17 volts at pins 2 and 3. In the case of the 3S4 there should be 1.5 volts at pins 1 and 7, no reading at pin 3, and approximately 15 volts at pins 4 and 6.

If you have an ordinary radio receiver available, you may test the output of the multi-vibrator by connecting the point marked "C" on Figure 22 to the aerial terminal of the receiver. If the receiver is switched on, you will find that you can rotate its tuning condenser from one end of the range to the other and that you will hear the signals with approximately equal loudness throughout this range. This indicates that the multi-vibrator is providing signals at all frequencies throughout the broadcast band. The 1 meg potentiometer can be adjusted to a position which allows the greatest output signal strength from the unit.

If you do not have an ordinary radio receiver you can test the output of the multi-vibrator by applying the signals from terminal "C" on Figure 22 to point "C" on the receiver consisting of the infinite impedance detector in Figure 21 and the following two stages of audio amplification, you have just been using.One alteration you will have to make in this case is to wire the 5 megohm resistor to the grid circuit of the 1T4 valve in place of the 2 meg resistor, as the 2 meg resistor is required in the multi-vibrator.

If the signals are not very loud when using the infinite impedance detector as shown in Figure 21, you can increase their loudness considerably by altering the detector circuit of the receiver back again to a biased detector as shown in Figure 18. Once again, you should notice that the signals of the multi-vibrator are heard at approximately constant loudness regardless of the setting of the tuning condenser.

EXPERIMENT 20. FOUR-VALVE RECEIVER.

Our final experiment in this lesson is to construct a 4-valve receiver of the tuned radio frequency type which should enable reception of signals from broadcasting stations operating on frequencies between 550 and 1,500 kilocycles, provided the stations are not more than about 50 miles away in daytime or more than 200 or 300 miles distant at night.

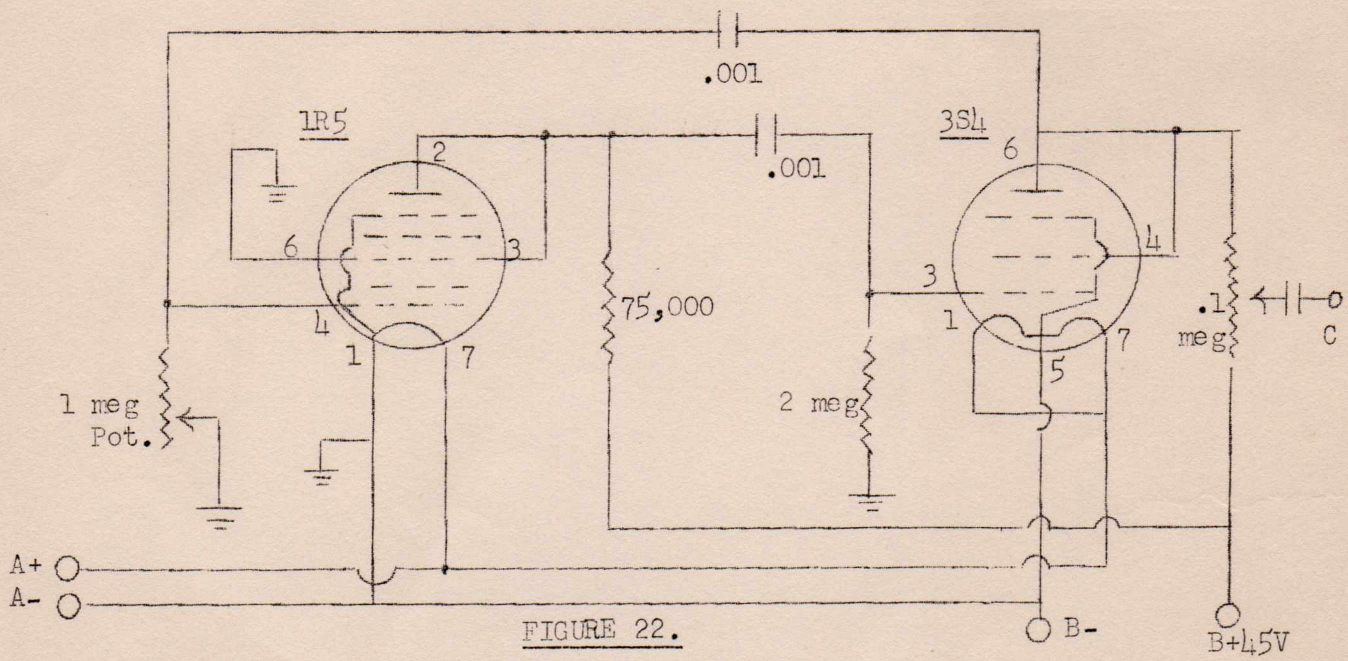


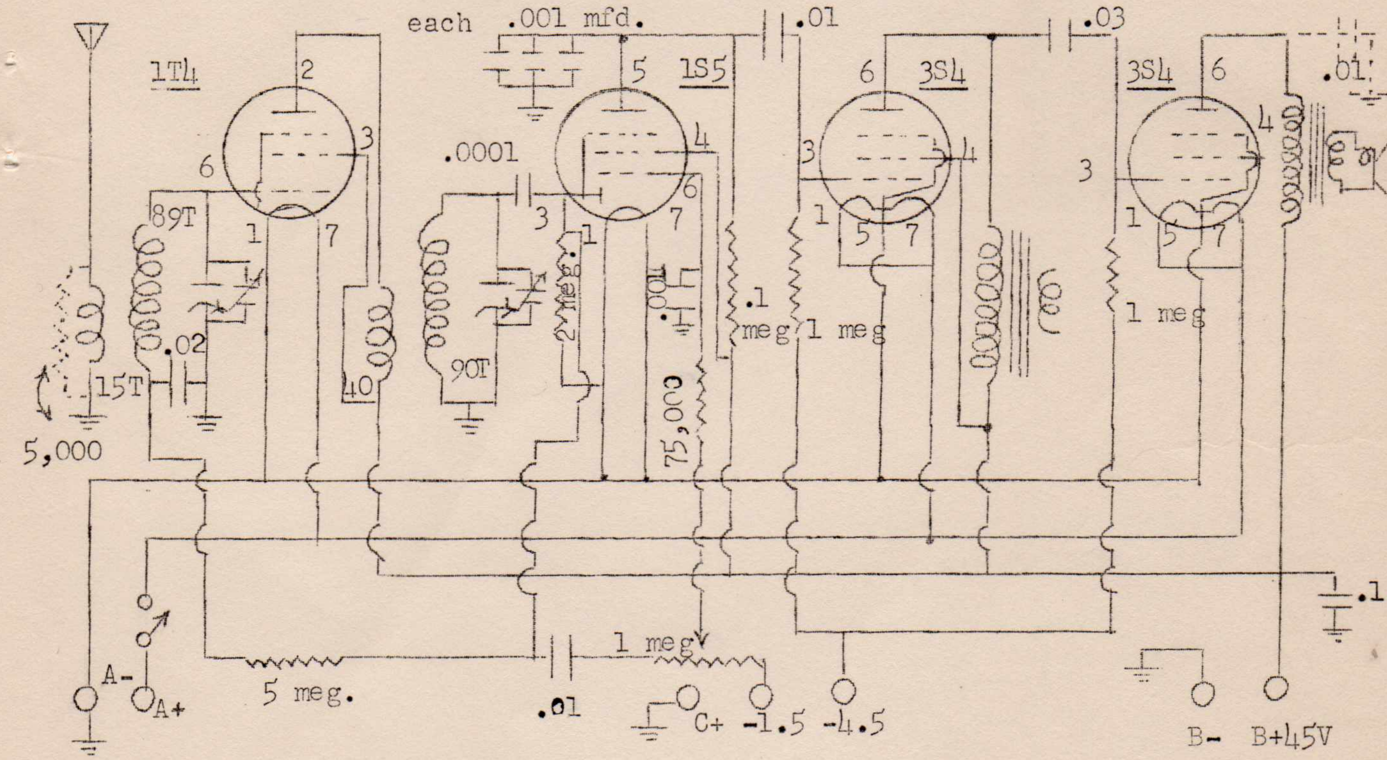
FIGURE 22.

The circuit arrangement of the receiver is indicated in Figure 23. You will notice that the 1T4 valve is used as a tuned RF amplifier, to amplify signals received from the aerial and earth system before these are applied to the diode detector element contained in the 1S5. After the diode plate has detected the signals, the audio frequency voltages are fed through the 1 megohm volume control to the grid of the 1S5 which acts as an audio frequency amplifier. This tube strengthens the signals which are then passed, by resistance coupling, to the grid of a 3S4 and this tube in turn is choke coupled to the grid of the final 3S4 which passes the signals into the loudspeaker.

Automatic Volume Control is used, employing a circuit similar to that indicated in Figure 13 of Practical Lesson 7. In fact, the circuit of the 1T4 and detector portion of the 1S5 is identical with Figure 13 of Practical Lesson 7.

In laying out the parts for the receiver, you will be able to obtain quite a lot of guidance from Figure 3 of Practical Lesson 7. The socket for the 1S5 and for the 3S4 second audio amplifying stage will be mounted in the positions marked on Figure 3 of Lesson 7 while the socket for the 3S4 output valve, feeding the loudspeaker, will be mounted in the position where the 1T4 valve socket is shown on Figure 3. The choke and A battery switch should be mounted in the position illustrated and the 1 megohm potentiometer will be fitted in the position occupied by the 2,000 ohm potentiometer on Figure 3.

The aerial coil, consisting of the 15 turn and 89 turn windings, will remain in the position indicated in Figure 2 of this lesson, that is, near the front corner of the chassis but the other coil, consisting of the 40 turn, 90 turn and 45 turn windings will be moved from the position shown in Figure 2 to the other front corner of the chassis, being mounted in position by means of a bolt passing down through the hole in the chassis near the 1S5 valve socket. In mounting the coil, be careful to rotate it so that the upper end of the 90 turn winding is not



jammed against the metal frame of the tuning condenser gang. If the frame of the gang presses firmly against the wire it may damage the enamel insulation and short circuit this coil to the chassis. This would prevent the receiver operating. You will be able to rotate the coil slightly so that it is moved over as close as possible against the 1S5 valve and in this way it will just clear the metal frame of the tuning condenser. If there is any chance of the condenser pressing against the top of the coil you should place a piece of the varnished insulating tape or a piece of cardboard between the coil and the condenser.

The bolt which holds the aerial coil in position near the 1T4 valve socket should be removed and replaced by one of the $1\frac{1}{4}$" long bolts supplied with this kit. This long bolt is required to support the piece of 5 lug resistor panel, which will be needed to hold the ends of some of the resistors so that they are firmly supported and cannot move about to cause accidental short circuits which might damage valves or batteries.

You should complete the wiring of the 1T4 and 1S5 valve sockets before mounting the resistor panel in position, otherwise you will find it difficult to pass the wires to and fro underneath the resistor panel.

WIRING.

When you have mounted the various parts in position, you should commence the wiring by completing the connections to the 1T4 valve socket first of all. To avoid annoying whistles whenever the receiver is tuned to a station, it is most important to keep the diode circuit of the 1S5 valve and plate circuit of the 1T4 as far away as possible from the grid wire of the 1T4. To provide the greatest possible separation between the two, the grid lead for the 1T4 should extend from pin 6 around the end of the chassis to the top and then pass across in front of the aerial coil to the long lug protruding down from the front section of the tuning condenser gang. This long lug is relatively close to the R.F. coil, connected to the diode of the 1S5 and consequently, to provide as much separation as possible between this lug and the coil the lug should be gently bent towards the aerial coil, thus shortening the grid wire from the 1T4 by half an inch or so and at the same time providing the maximum possible separation between this point and the R.F. coil. The upper end of the 89 turn tuned winding on the aerial coil should be passed directly from the top of the coil former to the lug on the tuning condenser making this lead as short and direct as possible.

The upper end of the 40 turn winding on the R.F. coil should be passed down around the front corner of the chassis, near the 1 megohm potentiometer, and continued across under the chassis to the plate contact, No.2, on the 1T4 valve socket.

The other connections to the 1T4 valve socket are not critical but do not forget to see that the centre metal sleeve of the socket is connected to pin No.1 and then on to the earth wire which is used to link up all the points shown with an earth symbol on Figure 23.

The wires connecting to the diode plate of the 1S5, that is pin No.3 should be kept as short as possible. The .0001 mfd. condenser should be mounted in the position indicated in Figure 3 of Practical Lesson 7, the lead from one end passing up through the hole in the chassis to the long lug protruding downward from the rear section of the tuning condenser. The upper end of the 90 turn winding should pass straight across from the top end of the coil to this same tuning condenser lug in such a fashion that it is as far removed as possible from the other lug protruding down from the front section of the gang and connecting to the grid of the 1T4.

The lower end of the 90 turn coil may be passed down through the hole immediately under the centre of the front section of the condenser gang, and can be soldered on to the bare 18 gauge copper earth wire passing near this point on the chassis. The lower end of the 40 turn coil can be threaded through insulating tubing and either passed around the edge of the chassis or through the hole under the centre of the front section of the condenser to pin No.4 on the 1S5 valve socket. This pin is connected to the positive terminal of the B battery and so plate voltage for the 1T4 can be derived through the 40 turn coil from this point.

The upper end of the 15 turn aerial primary winding can be passed around the edge of the chassis to the aerial terminal which is mounted in the position shown in Figure 3 of Lesson 7 and the lower end of this coil can be passed around the edge of the chassis and connected to the bare 18 gauge wire at any convenient point.

Once the wiring has been completed up to this stage, you should mount the 5 lug resistor strip in position under the chassis, on the end of the long $1\frac{1}{4}$" bolt protruding downward from the aerial coil. The bolt should be passed through a nut, then one of the holes in the strip near one end, then another nut and the strip should extend along, parallel to the front flange of the chassis, toward the 1S5 valve socket.

It will be necessary to bend up the two lugs on the resistor panel nearest to the battery switch to prevent these lugs from short circuiting to the battery switch contacts. One of these bent up lugs can be used for terminating the wire from the bottom end of the 89 turn tuned winding on the aerial coil. This wire should be passed through insulated sleeving and brought around the front corner of the chassis to reach one of the bent up lugs. The .02 mfd. condenser can be connected with one end to this lug and the other end connected to the earth wire. In most tubular condensers one end is marked "outside foil" or has a heavy black line marked around it. This is the end which should connect to the earth wire.

One end of the 5 meg resistor should be soldered directly to pin No.3 on the 1S5 valve socket and its other end can be extended, by means of a piece of hook-up wire or bare wire covered with insulating tubing, to reach the point where the lead from the lower end of the 89 turn coil connects to the resistor panel. It is important to place the 5 meg resistor as close as possible to pin 3 on the 1S5 valve socket. The .01 mfd. condenser coupling audio frequency signals from pin 3 on the 1S5 socket to the 1 megohm potentiometer should have one end directly soldered to lug 3 on the valve socket and the end marked "outside foil" soldered to one of the outer lugs on the 1 megohm potentiometer. The lug used should be the one in the position corresponding to the unused lug on the 2,000 ohm potentiometer illustrated in Figure 3 of Lesson 7. That is, the left hand lug.

The location of the other parts, associated with the plate of the 1S5 and the two 3S4 valves, is not at all important and the parts may be fitted in in the most convenient positions.

The 1 meg and .1 megohm resistors connecting to the control grids of the 3S4 valves should have one end directly soldered on to the valve sockets at lug 3 and the other ends, which are to be connected to the $4\frac{1}{2}$ volt negative terminal of The C battery can be soldered to two of the lugs on the resistor panel to support the resistors securely. A length of hook-up wire can then be extended from the resistor panel to the C battery so that any pull on this wire will not dislodge the resistors.

It will be noticed that three .001 mfd. condensers are connected from the plate of the 1S5 to the chassis. These condensers are necessary to bypass any radio frequency signals which may reach the plate of this valve as the filter in the grid circuit, consisting of the 75,000 ohm resistor and .0001 mfd. condenser will not be completely effective in removing carrier voltage from the grid of the 1S5.

When first wiring the receiver, do not include the 5,000 ohm resistor shown at the extreme left of Figure 23 nor the .01 mfd. condenser shown in dotted lines at the extreme right.

Once you have completed the wiring, check it through very carefully again in conjunction with Figure 23, to see that it is carried out correctly and that all wires are included. It is quite a good idea to put a pencil mark on each part shown in Figure 23 and on each wire as you proceed with the wiring. In this way, in checking over, if you find any parts or wires on the circuit which are not marked, this will indicate that you may have forgotten to include them in the receiver.

CHECKING.

Before using your multimeter for checking the circuit, restore it to its original condition by removing the piece of wire joining lugs 8 and 12 on the multimeter switch and also remove any wire which may be connected to lug No. 2 on this switch. Also, you should connect one of your 1.5 volt cells back into the ohmmeter circuit of your multimeter.

Before connecting the batteries or inserting the valves, plug your test leads in the sockets on the multimeter marked "High Ohms" and adjust the ohmmeter needle to zero by touching the leads together. Next clip one of the leads to the metal chassis of the receiver or to the bare earth wire so that it makes a good connection. Touch the other ohmmeter lead to the lengths of hook-up wire you have brought out for connection to the batteries. This lead when touched to the wire for the positive terminal of the B battery, the positive terminal of the A battery or the negative terminals of the C battery should give no reading. If there is a reading obtained at any of these points, it indicates a short circuit in your wiring which must be corrected before you connect the batteries.

If no short circuits are indicated, you may connect the batteries to the leads and measure the voltages at the various pins on the valve sockets.

If your wiring is correct, you should obtain the following readings when the multimeter switch is turned to the position marked "+50 volts".

1T4. Pins 1, 5, 4 and 6 no reading. Pin 7, 1.5 volts. Pins 2 and 3, 45 volts.

1S5. Pins 1, 2, 3 no reading. Pin 4, 45 volts. Pin 5 approximately 15 volts. Pin 6, no movement or a very slight backward movement which will alter slightly in value as the 1 megohm potentiometer is rotated.

3S4. Pin 5, no reading. Pins 1 and 7, 1½ volts. Pin 3, a very slight backward movement of the needle. Pin 6, 1 or 2 volts less than full B battery voltage. Pin 4, full B battery voltage. The readings obtained when checking the voltages on the socket for the second 3S4 valve should be the same as those for the first 3S4 with the exception that the backward movement of the needle at lug 3 should be slightly greater.

If you obtain an indication which does not agree with the figures listed above, carefully check through the wiring associated with the particular valve socket contact at which the wrong reading is obtained, to locate where the fault exists.

After you have obtained readings similar to those mentioned above, you may safely insert the valves but make sure that you only place the valves in the sockets intended for them. Inserting a valve in the wrong socket could possibly damage the valve.

On connecting an aerial and earth to the receiver, it should be capable of reproducing signals from any broadcasting station within a distance of about 40 or 50 miles in daylight, although this range will be considerably increased at night time due to the fact that signals from broadcasting stations are not attenuated as rapidly at night as in the daytime and consequently cover greater distances.

If you obtain a squeal or whistle as you tune into each broadcasting station, you should firstly check to see that the metal sleeve in the centre of each valve socket is connected to the earth wire and also to see that the grid wire of the 1T4 valve is separated as much as possible from the plate wire of this valve or the diode load of the 1S5. Connecting a 5,000 ohm resistor between the aerial and earth terminals, as indicated by dotted lines at the left of Figure 23, may prove effective in preventing oscillation without substantially weakening signal strength. If the presence of this resistor does not eliminate the whistle then it will be necessary for you to connect the 50,000 ohm resistor from pin 6 on the 1T4 valve socket to the lower end of the 89 turn coil, where this is soldered onto the resistor panel. In other words, you connect the 50,000 ohm resistor in parallel with the 89 turn winding on the aerial coil. The presence of this resistor will reduce the coil's efficiency so that the selectivity of the receiver will not be as great but it will almost certainly eliminate any whistles.

As an alternative, the 50,000 ohm resistor could be connected across the 90 turn winding by soldering one end on to the centre top lug protruding from the top of the rear section of the tuning condenser and the other end of the resistor to the frame of the condenser. In this position,,it will not decrease the selectivity quite as much as when connected across the 89 turn coil nor will it be quite as effective in eliminating whistles. If it is necessary to use this 50,000 ohm resistor it should be tried in both positions to determine where it is most effective without reducing the receiver's selectivity to an unnecessarily great degree.

ALIGNMENT.

If your receiver is capable of picking up signals from a number of stations, you should choose a station which can be received with the tuning condenser plates turned as far as possible out of mesh. You should then adjust the trimmer condensers mounted on top of the tuning condenser gang, as explained in connection with experiment 3 of Practical Lesson 7, until the signals are received as loudly as possible. If either of the trimmer condensers has to be screwed fully up, you should move the main tuning condenser plates a little further into mesh and then readjust both trimmers. Similarly, if either of the trimmer condensers needs to be fully unscrewed, you should turn the tuning condenser plates a little further out of mesh and then readjust both trimmers.

When the receiver is operating, you should tune in the signals from a broadcasting station and connect the .01 mfd. condenser, shown in dotted lines at the right hand side of Figure 23, from pin 6 on the output 3S4 to chassis. When you connect the condenser you will find that the treble notes are reduced somewhat in loudness but the tone quality may be more pleasing under these conditions than with the condenser omitted. You may then please yourself whether you solder in the .01 mfd. condenser or not.

Although only a 45 volt B battery is furnished with your course, you can considerably increase the loudness of sounds from the receiver by operating the set with a $67\frac{1}{2}$ volt supply. This can be achieved by either purchasing a $22\frac{1}{2}$ volt battery or a $67\frac{1}{2}$ volt battery to replace the 45 volt unit. If the B battery voltage is increased to $67\frac{1}{2}$ volts, it will also be necessary to increase the C battery voltage applied to the grids of the 3S4 valves, from $4\frac{1}{2}$ volts to 7.5 volts. This will necessitate purchasing a 9 volt C battery as well.

If you have wound the coils carefully and followed the instructions in this lesson accurately, your receiver should perform quite well and compare with any other 4 - valve TRF type of receiver. However, the sensitivity will not be quite as great as that obtained with commercial 4 - valve superheterodyne receivers.
