BASIC RADIO

PART 2

PRICE $5.00

HEATHKIT

EDUCATIONAL SERIES

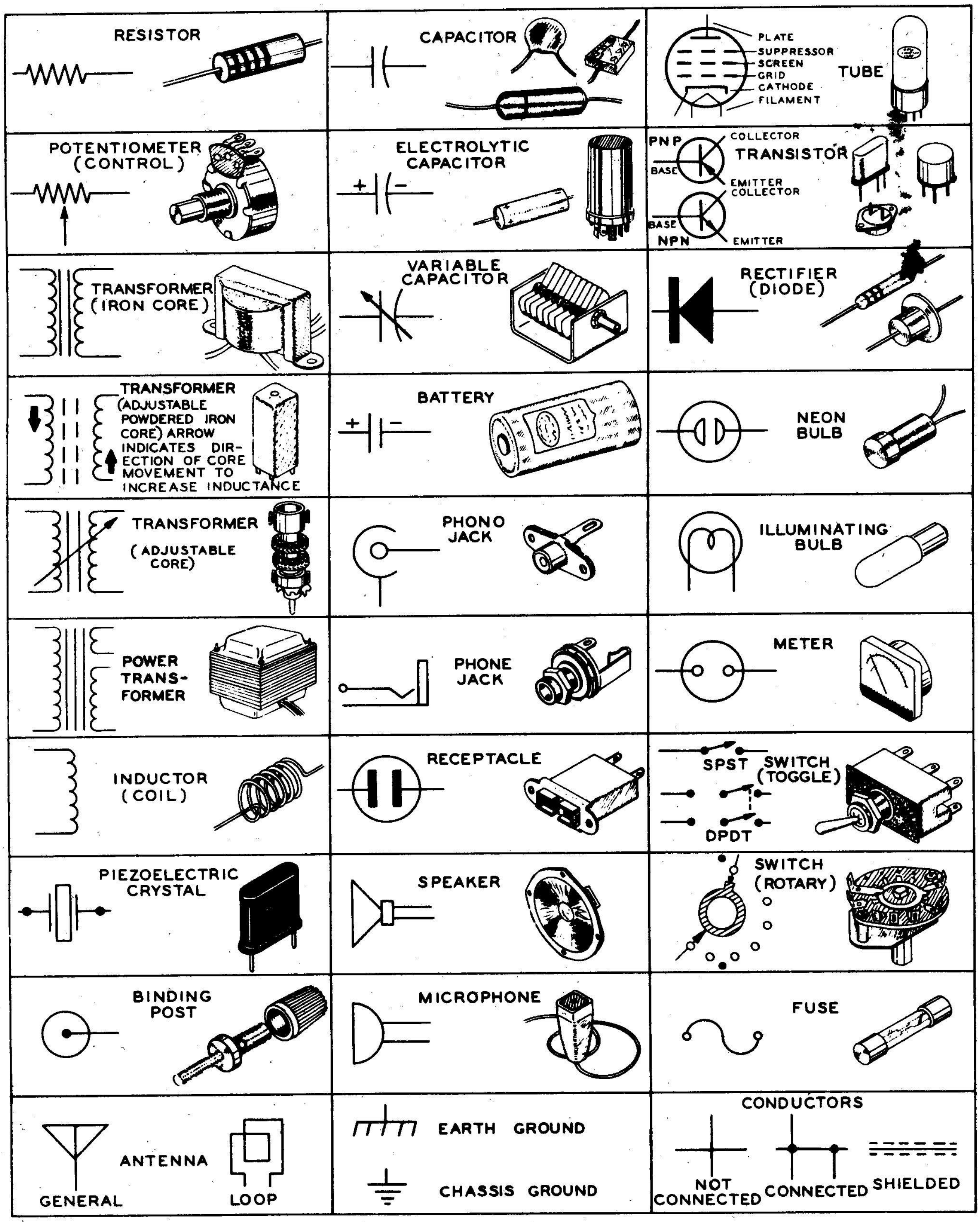
MODEL EK-2B

595-352

HEATH COMPANY BENTON HARBOR, MICHIGAN

TYPICAL COMPONENT TYPES

This chart is a guide to commonly used types of electronic components. The symbols and related illustrations should prove helpful in identifying most parts and reading the schematic diagrams.



BASIC RADIO

PART 2

★ ★

One of a series of Learn-by-Doing
EDUCATIONAL KITS
prepared especially for
Individual Home Study
or
Group Classroom Instruction

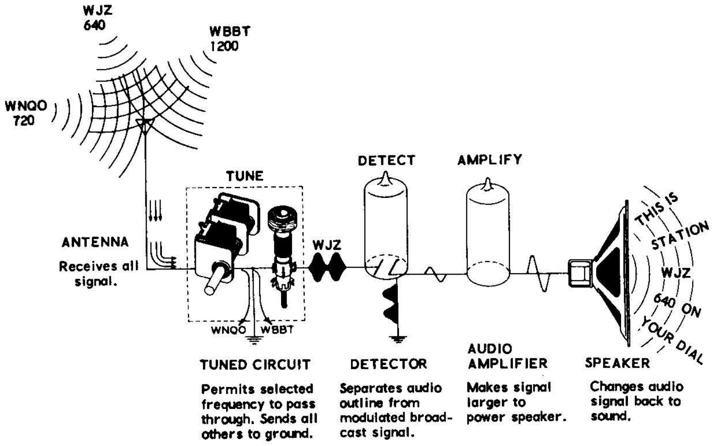
★ ★

HEATH COMPANY
Benton Harbor, Michigan

PRINTED IN THE UNITED STATES

OF AMERICA

12/28/64



INTRODUCTION

Since you have purchased the EK-2B it is quite obvious you wish to further expand your growing knowledge in the field of electronics. Your persistence will not go unrewarded. This new kit is presented to you in the same basic, easy-to-understand form as the EK-1 and EK-2A. Along with the many new parts that have been added, the same chassis and parts that were used for the EK-2A will also be employed. This feature not only saves you unnecessary expense, but it also helps you to recall the experiments performed in the EK-2A.

Before starting the EK-2B, you will find it helpful to review the EK-1 and the EK-2A. This will refresh your memory on the fundamentals needed in this course of instruction. The Technical Word Index of the EK-1 may also prove useful as a reference.

In the EK-1, Basic Electricity, you learned about the electron theory, meters and their uses, and basic DC circuits. In the EK-2A, Basic Radio-Part 1, you began a study of radio by learning the nature of broadcasting and receiving. You then learned the three basic functions of a receiver; tuning, detecting, and amplifying. The EK-2B Basic Radio-Part 2, will instruct you about all the additional circuits needed in a complete 2-band superheterodyne receiver.

You will find this a fascinating study since you will not only learn the interesting principles of how a radio receiver operates, but you will also build a complete 5-tube, 2-band receiver. Each Lesson will bring you another step closer to your goal of understanding the complete receiver. The electronic knowledge that you gain will put you on much firmer ground in dealing with the scientific concepts that are so much a part of this present age of space exploration and atomic energy.

TABLE OF CONTENTS

*Fold-out from page.

CONSTRUCTION NOTES

UNPACK THE KIT CAREFULLY AND CHECK EACH PART AGAINST THE PARTS LIST. In so doing, you will become acquainted with the parts. Refer to the charts and other information on the inside covers of the manual to help you identify the components. If some shortage or parts damage is found in checking the Parts List, please read the Replacement section and supply the information called for therein. Include all inspection slips in your letter to us.

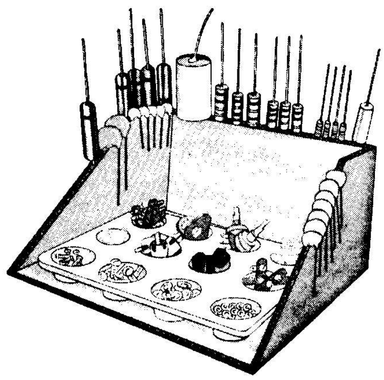
Resistors generally have a tolerance rating of 10% unless otherwise stated in the Parts List. Tolerances on capacitors are generally even greater. Limits of +100% and -50% are common for electrolytic capacitors.

We suggest that you do the following before work is started:

1. Lay out all parts so that they are readily available.

2. Provide yourself with good quality tools. Basic tool requirements consist of a screwdriver with a 1/4" blade; a small screwdriver with a 1/8" blade; long-nose pliers; wire cutters, preferably separate diagonal cutters; a pen knife or a tool for stripping insulation from wires; a soldering iron (or gun) and rosin core solder. A set of nut drivers and a nut starter, while not necessary, will aid extensively in construction of the kit.

Most kit builders find it helpful to separate the various parts into convenient categories. Muffin tins or molded egg cartons make convenient trays for small parts. Resistors and capacitors may be placed with their lead ends inserted in the edge of a piece of corrugated cardboard until they are needed. Values can be written on the cardboard next to each component. The illustration shows one method that may be used.



PARTS LIST

PART No.	PARTS Per Kit	DESCRIPTION
Resistors		
1-41	1	10 Ω 1/2 watt (brown-black-black)
1-2	1	68 Ω 1/2 watt (blue-gray-black)
1-20	1	10 KΩ 1/2 watt (brown-black-orange)
1-22	1	22 KΩ 1/2 watt (red-red-orange)
1-25	1	47 KΩ 1/2 watt (yellow-violet-orange)
1-26	2	100 KΩ 1/2 watt (brown-black-yellow)
1-31	1	330 KΩ 1/2 watt (orange-orange-yellow)
1-33	1	470 KΩ 1/2 watt (yellow-violet-yellow)
1-34	1	680 KΩ 1/2 watt (blue-gray-yellow)
1-37	1	2.2 megohm 1/2 watt (red-red-green)
1-71	1	4.7 megohm 1/2 watt (yellow-violet-green)
1A-20	1	330 Ω 1 watt (orange-orange-brown)
1A-24	1	4700 Ω 1 watt (yellow-violet-red)
Hardware		
250-16	1	8-32 setscrew
250-31	4	6-32 x 1/4" round head machine screw (RHMS)
250-32	4	6-32 x 3/8" flat head machine screw (FHMS)
250-49	2	3-48 x 1/4" binder head machine screw (BHMS)
250-89	10	6-32 x 3/8" binder head machine screw (BHMS)
252-1	2	3-48 nut
252-3	14	6-32 nut
252-7	1	Control nut
253-27	8	5/16" OD washer
253-28	2	Plastic "O" washer
254-1	11	#6 lockwasher
254-4	2	Control lockwasher
255-1	4	1/8" spacer
258-1	1	Dial cord spring
259-1	6	#6 solder lug
260-7	2	IF transformer mounting clip
Capacitors		
20-1	2	47 µµf mica
20-56	1	150 µµf mica

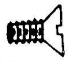
PART No.	PARTS Per Kit	DESCRIPTION
Capacitors (Cont'd.)		
20-40	1	470 µµf mica
20-72	1	2000 µµf mica
21-11	1	150 µµf disc ceramic
23-28	2	.1 µfd 200 volt tubular
23-34	1	.01 µfd 400 volt tubular
23-59	1	.05 µfd 200 volt tubular
25-4	1	10 µfd 25 volt electrolytic
28-1	1	2.2 µµf molded phenolic
31-11	2	3-30 µµf dual mica trimmer
Coils-Transformers-Switches		
40-77	1	BFO coil
141-22	1	Coil set
Consisting of one each:		
40-299	1	Broadcast antenna coil
40-300	1	Shortwave antenna coil
40-301	1	Broadcast oscillator coil
40-302	1	Shortwave oscillator coil
51-55	1	Output transformer
52-4	1	IF input transformer
52-5	1	IF output transformer
60-4	2	Slide switch, SPDT
63-230	1	Rotary switch, 2-section
Metal Parts		
100-M166	1	Dial cord drum
100-M255	1	Subpanel
100-M300	1	Front panel assembly
204-M295	1	Pilot lamp bracket
Miscellaneous		
100-M260	1	Dial cord assembly
344-59	1	Length hookup wire
346-1	1	Length insulating sleeving
401-21	1	Speaker
411-10	1	6AT6 tube*
411-60	1	6AQ5 tube
411-90	1	6BA6 tube
411-91	1	6BE6 tube
434-37	1	7-prong tube socket
446-16F314	1	Plastic window
453-19	1	Tuning shaft
455-13	1	Shaft bushing
462-111	1	Knob
463-11	1	Dial pointer
331-6		Solder
595-352	1	Manual

*The tube type markings for these tubes may or may not be followed by the letter "A." (Example, 6BA6 - 6BA6A.)

PARTS PICTORIAL

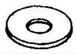

#250-16
8-32 SETSCREW


#250-31
6-32 x 1/4" ROUND HEAD
MACHINE SCREW (RHMS)


#250-32
6-32 x 3/8" FLAT HEAD
MACHINE SCREW (FHMS)

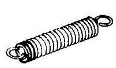

#250-49
3-48 x 1/4" BINDER HEAD
MACHINE SCREW (BHMS)

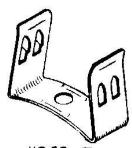

#250-89
6-32 x 3/8" BINDER HEAD
MACHINE SCREW (BHMS)

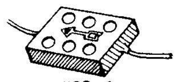

#253-27
5/16" OD WASHER


#253-28
PLASTIC "O" WASHER

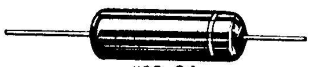

#255-1
1/8" SPACER

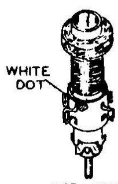

#258-1
DIAL CORD SPRING


#260-7
MOUNTING CLIP
IF TRANSFORMER

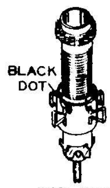

#20-1
47 $\mu\mu$f MICA CAPACITOR


#21-11
150 $\mu\mu$f DISC CERAMIC
CAPACITOR

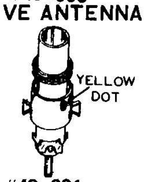

#23-34
.01 μfd 400 VOLT
TUBULAR CAPACITOR



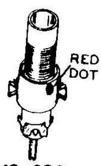
#40-299
BROADCAST ANTENNA COIL



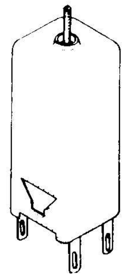
#40-300
SHORT WAVE ANTENNA COIL

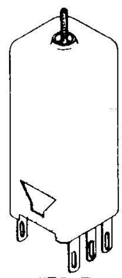


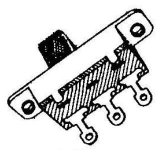
#40-301
BROADCAST OSCILLATOR COIL

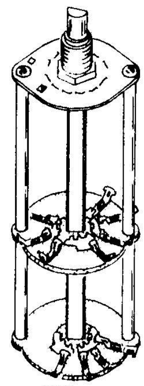


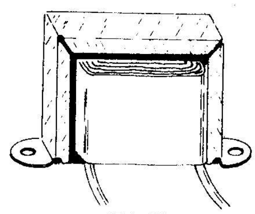
#40-302
SHORT WAVE OSCILLATOR COIL

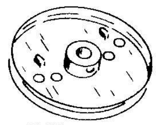

#52-4
IF INPUT TRANSFORMER

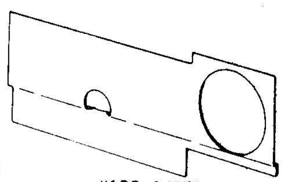

#52-5
IF OUTPUT TRANSFORMER

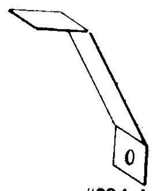

#60-4
SLIDE SWITCH, SPDT

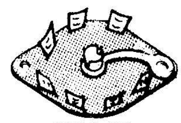

#63-230
ROTARY SWITCH,
2-SECTION


#51-55
OUTPUT TRANSFORMER


#100-M166
DIAL CORD DRUM


#100-M255
SUBPANEL


#204-M295
PILOT LAMP BRACKET


#434-37
7-PRONG TUBE SOCKET


#453-19
TUNING SHAFT

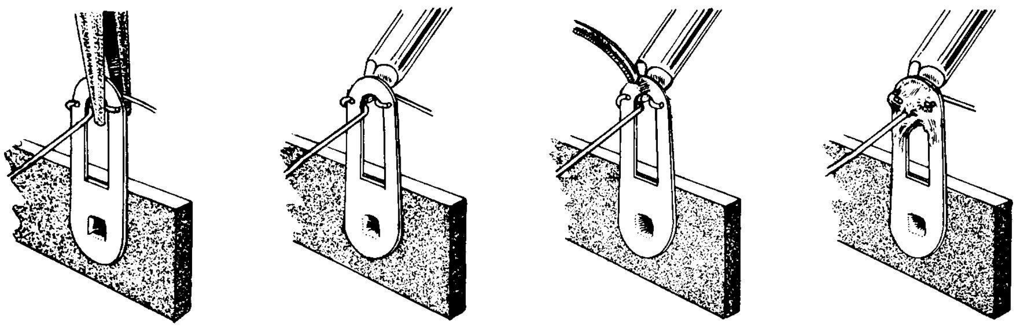

#455-13
SHAFT BUSHING

PROPER SOLDERING TECHNIQUES

DO NOT PROCEED UNTIL YOU READ THESE

Refer to the soldering instructions given in Basic Radio Part 1 and be sure to make a good solder connection as indicated there. A high percentage of the difficulties that cause faulty circuits are due to poor solder joints.

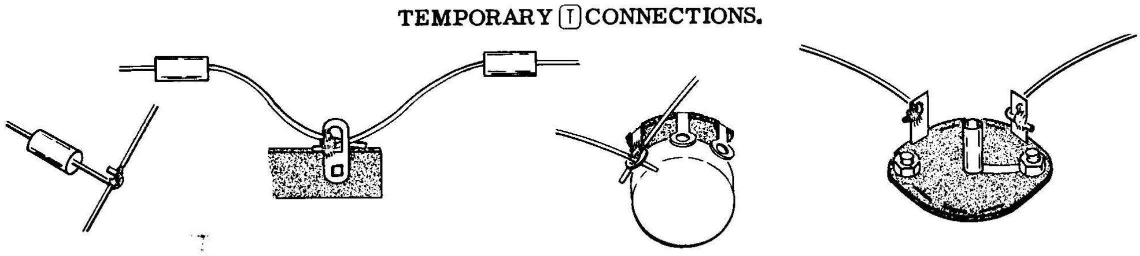
PERMANENT (P) CONNECTIONS



CRIMP WIRES   HEAT CONNECTION   APPLY SOLDER   ALLOW SOLDER TO FLOW

The letter (P) will be used to indicate a permanent connection. When it appears in a step it means that this will be the final position of this wire or component in the receiver. The leads may be shortened if necessary, and then they should be crimped to the terminal before they are soldered. The preceding illustration shows how to make permanent type solder connections.

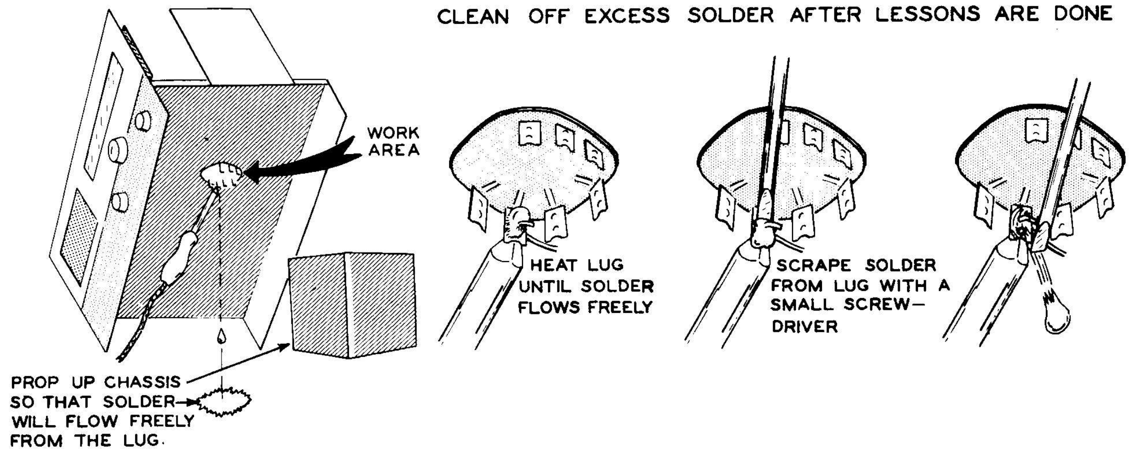
TEMPORARY (T) CONNECTIONS.



When the letter (T) appears in an instruction, it means that this will be a temporary connection; this part or wire will be removed again in another step. When making temporary connections with resistors or capacitors, <u>do not cut the leads.</u>

A temporary connection should be one that can be easily removed at a later time. It can usually be made in the form of a lap joint, but occasionally it may be necessary to put a loose bend around a terminal to hold a wire in place. The preceding illustration shows some methods by which temporary connections can be made. Be careful that the long wires used in these temporary connections do not cause short circuits by touching the chassis, or other lugs or wires. Each wire should only touch the connecting point indicated in the directions.

Soldering instructions have been added to your EK-2B Receiver to make the construction portions easier. The instruction given with each connection will be either to solder the connection (S), or not to solder the connection (NS). The instruction (S) will mean that no more connections will be made to this terminal at this time. The instruction (NS) will mean that more leads or wires will be connected to this lug before you start the next experiment.



You will find it necessary from time to time to remove the excess solder from a lug. The best method for doing this is shown in the preceding illustration. Be sure to place the heated lug in such a position so that the solder will fall from it by the force of gravity. Use a small screw-driver to scrape the solder from the lug, and from the holes in the lug.

ROSIN CORE SOLDER HAS BEEN SUPPLIED WITH THIS KIT. THIS TYPE OF SOLDER MUST BE USED FOR ALL SOLDERING IN THIS KIT. ALL GUARANTEES ARE VOIDED AND WE WILL NOT REPAIR OR SERVICE EQUIPMENT IN WHICH ACID CORE SOLDER OR PASTE FLUXES HAVE BEEN USED. IF ADDITIONAL SOLDER IS NEEDED, BE SURE TO PURCHASE ROSIN CORE (60:40 or 50:50 TIN-LEAD CONTENT) RADIO TYPE SOLDER.

LESSON I

WHAT IS A TRANSFORMER?

Your first exposure to a transformer was in Lesson IX of Basic Radio-Part 1. You learned that a transformer was a device consisting of two coils, used to couple AC signals. You also learned that DC did not pass through it from one coil to another.

At this time you will find it helpful to review "How the meter can indicate the rate of flow of electric current" in Chapter 2 of Basic Electricity. This chapter covers the theory of magnetic fields and magnetism. The magnetic fields generated in the coils of the EK-1 Meter are similar to the magnetic fields in the coils of the transformer.

The AC voltage used to power a radio receiver comes from the 117 volt power line. This voltage must be changed to voltages of different values to operate various parts of the receiver, and this job is done by the power transformer. Other types of transformers are also used in other parts of the receiver to adjust the signal voltages.

A transformer consists of two or more coils placed close together and wrapped around some kind of core material. The core may be made of iron, powdered iron, or air, depending on how the transformer is to be used. In coils that have a core of air or powdered iron, the coil is wound around a hollow tube (coil form). This coil form has no effect on the lines of force. Examples of two general types of transformer are shown in Figures 1A and 1B. Notice that the type of core is indicated by the schematic symbol, solid lines for an iron core, dotted lines for powdered iron, and no lines for an air core coil.

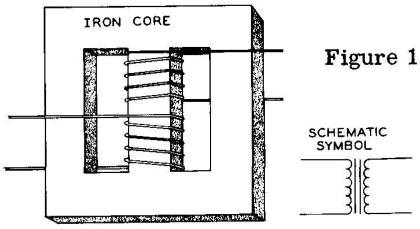


Figure 1A

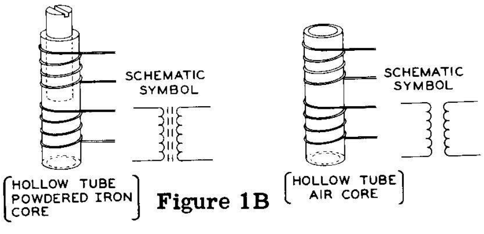
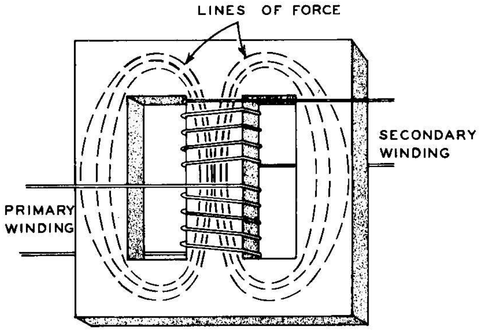


Figure 1B

Transformers are most often used to increase or decrease AC power supply voltages or AC signal voltages. They are also used quite often to keep the DC currents of different circuits separated, or "isolated." A current through one coil of a transformer creates a magnetic field around and through the coil. This magnetic field consists of lines, called "magnetic lines of force." These lines of force are somewhat like the waves that appear when a stone is dropped into a puddle of water.

While these lines of force are passing through another coil of the transformer, they induce a voltage in it. This is shown in Figure 1C. The coil that is connected to the source of voltage is called the primary winding and all other coils are called the secondary windings.



LINES OF FORCE CREATED BY THE PRIMARY MOVE THROUGH THE SECONDARY WINDING.

Figure 1C

Remember that voltage is induced only in the second coil while the lines of force are moving through it. The lines of force move only when the amount of voltage across the primary winding changes. Since DC, by its very nature does not change in amplitude, it will not pass from one winding to another of a transformer. Only the pulse caused by turning on the DC passes through the transformer. Conversely, since AC voltage is always changing, it is coupled through a transformer, from one winding to another. From this we see that a transformer is an AC device; except for the initial surge, DC voltage is blocked.

The amount of voltage in the secondary winding of a transformer, compared to the amount of voltage in the primary winding, is called the "voltage ratio." This voltage ratio, and therefore the amount of voltage in the secondary winding, depends on the proportion between the number of turns in the primary and the number of turns in the secondary of the transformer. This proportion is called the "turns ratio."

$$\text{Turns ratio} = \frac{\text{primary turns}}{\text{secondary turns}} = \frac{\text{primary voltage}}{\text{secondary voltage}}$$

In this manner the AC voltage at the secondary may be either stepped up (increased), or stepped down (decreased), depending on the turns ratio.

EXAMPLES:

-A step-up transformer has 10 turns in the primary and 100 turns in the secondary. This makes a step-up turns ratio of 1 to 10. Thus, if 15 volts were applied to the primary winding, 10 times as much voltage (or 150 volts) would appear at the secondary winding.

-A step-down transformer has 40 turns in the primary winding and 10 turns in the secondary winding. This makes a step-down turns ratio of 4 to 1. Thus, if 100 volts were applied to the primary winding, only 25 volts would appear at the secondary winding.

It may be helpful to you to remember that the higher voltage will always be at the winding with the greater number of turns.

The core material of a transformer depends on the frequency at which the transformer will be used. Iron core is for low frequencies, such as power transformers, because it helps the magnetic lines of force to flow more easily between the windings. Because of the iron core, the magnetic lines of force flow more easily between the windings, and the transformer operates more efficiently. This iron core is constructed in the form of laminations, which are thin sheets of iron stacked together to form a solid iron core. Powdered iron and air core transformers are used at radio frequencies (RF).

The uses of transformers are so numerous that it would be impractical to try to name them all. Four different types of transformers are used in the EK-2B; the RF transformer, the IF transformer, the audio transformer, and the power transformer. Each of these transformers will be explained further in the section in which it is used.

SUMMARY

Transformers are needed in the receiver both to change the size of the power line voltages, and also to change the signal voltages in various parts of the receiver. A transformer consists of two or more coils, placed close together, and wrapped around some kind of a coil form. The coil form, or the core, may be made of iron, powdered iron, or air. When a transformer has an air core, the coils are wound around some sort of hollow cardboard tube (which doesn't effect the magnetic field).

Transformers are generally used to either increase or decrease AC voltages. A transformer that increases the AC voltage is called a step-up transformer. A transformer that decreases the AC voltage is called a step-down transformer. How far the voltage is stepped up or stepped down, depends on the ratio of turns between the primary winding and the secondary winding.

Voltage is induced in the secondary coil because the magnetic lines of force from the primary coil pass through it. The voltage is only induced when these magnetic lines of force are moving through the secondary winding. The lines of force only move when the amount of voltage across the primary winding is changing. Since DC voltage does not change in amplitude it will not pass from one winding of a transformer to another. Only the initial pulses caused by connecting (or disconnecting) the DC will pass through the transformer.

The type of core material of the transformer is determined by the frequency at which the transformer will be used. The iron core is used for low frequencies, such as power transformers. Powdered iron core, and air core transformers are used at radio frequencies.

PUTTING THE TRANSFORMER TO WORK

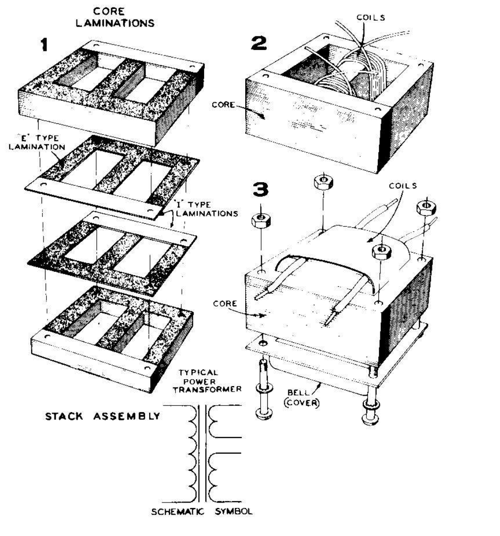
To show how a transformer reacts to DC and AC, and to demonstrate voltage step-up and step-down.

PARTS REQUIRED

1 EK-2A Final chassis
1 Battery with battery holder
(or with wires soldered to the battery terminals as used in Basic Radio-Part 1)
1 Crystal diode (from EK-2A)
1 Audio transformer #51-55
2 6-32 x 3/8" BHMS
2 6-32 nuts

BECOMING FAMILIAR WITH THE PARTS

Your POWER TRANSFORMER (mounted on the EK-2A final chassis) is constructed in the manner shown in Figure 1D. The core consists of iron laminations shaped like the letter E and the letter I. These laminations are placed in alternating directions, as shown, and stacked to the desired height.



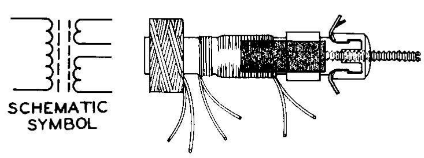
THE INTERNAL CONSTRUCTION OF THE POWER TRANSFORMER.

Figure 1D

The windings of the transformer are wound around the center leg of the core. This allows the lines of force to flow easily around the core in both directions. Each winding is then in the magnetic field of every other winding. In actual practice, sheets of insulating paper are placed between the different layers of wire and between the windings on the transformer. This same paper is also wrapped around the outside of the coil.

After the laminations have been installed on the coil, the bell (or cover) is placed on the transformer. The complete unit is then fastened together with the four screws.

The REGENERATIVE DETECTOR COIL is actually a TRANSFORMER and was described briefly in Lesson IX of the EK-2A. This transformer, shown in Figure 1E, is used at RF frequencies. The coils are wound on a hollow coil form containing the adjustable powdered iron core. When the adjustment screw is turned, the core moves in and out of the coil. Moving this core changes the number of lines of force that can pass from the primary to the secondary windings. This gradually changes, or adjusts, the overall amount of energy that can pass from the primary to the secondary windings. Maximum energy can pass from the primary to the other windings only when the core is all the way into the windings. Minimum energy will pass when the core is all the way out of the windings.



THE POWDERED IRON CORE ADJUSTS IN AND OUT OF THE REGENERATIVE TRANSFORMER.

Figure 1E

The AUDIO OUTPUT TRANSFORMER is just used temporarily in these experiments as a step-down transformer. It will be explained in detail later, when it is first used in its normal manner with audio signals.

PREPARING THE CHASSIS

NOTE: Although you are directed to use an EK-1 Meter a number of times in these lessons, a substitute meter with the correct voltage ranges can also be used. If a substitute meter is used, select the voltage range closest to the range given in the lesson; then follow the directions for connecting the positive and negative leads.

( ) Place the EK-2A in front of you as shown in Figure 1F.

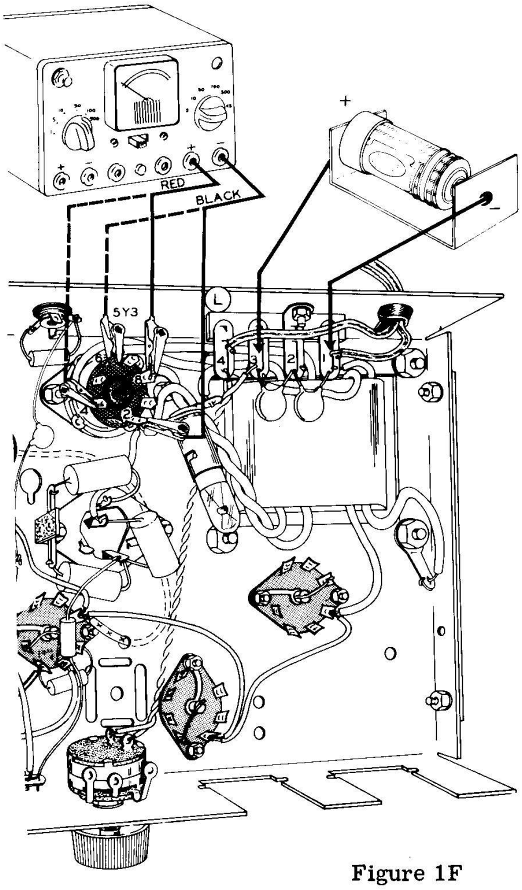
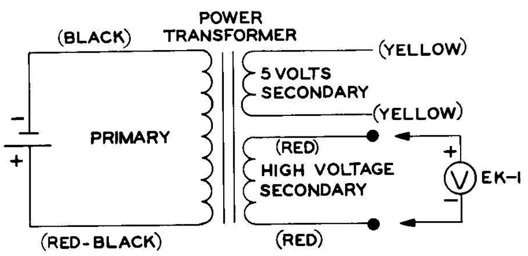


Figure 1F



( ) Make sure that the line cord is unplugged and that the switch is turned off.

( ) Remove the two tubes and the two pilot lamps.

NOTE: Before making any connections, you may wish to review the instructions for making permanent (P), and temporary (T) solder joints, given on Page VIII of this manual.

EXPERIMENT 1

To show that DC does not couple through the transformer.

( ) (T) Connect your EK-1 Meter across the high voltage secondary winding of the power transformer by clipping the black test lead to lug 6 and the red test lead to lug 4 of the 5Y3 tube socket.

( ) (T) Connect a length of hookup wire, about 5 inches long, to each lug of the battery holder (S).

( ) Turn the EK-1 Meter to the 5 volt range.

Note that the lugs referred to as L-1, L-2, L-3, and L-4 in Basic Radio-Part 1, will now be described as lug 1, lug 2, lug 3, and lug 4 of terminal strip L.

( ) Now, while watching the meter, momentarily touch one of the battery wires to lug 1 and touch the other to lug 3 of terminal strip L. (Do not leave the battery connected to these terminals very long, or it will be drained excessively.) Do not touch the bare part of the battery wires.

You have just applied the battery voltage to the primary of the transformer. Note that the needle of the meter (connected to the secondary) jumps when the battery is first connected, but then settles back and remains at zero until the battery is disconnected. This indicates that only the pulses created by connecting and disconnecting the DC pass through the transformer from primary to secondary; the DC voltage itself does not pass through.

If this or any other experiment or a circuit does not seem to operate properly, you may wish to refer to the IN CASE OF DIFFICULTY section on Page 118 of this manual.

EXPERIMENT 2

To show that AC does couple through a transformer, and may be changed by it.

Refer to Figure 1G for the following steps.

( ) Make sure that the line cord is unplugged and that the switch is turned off.

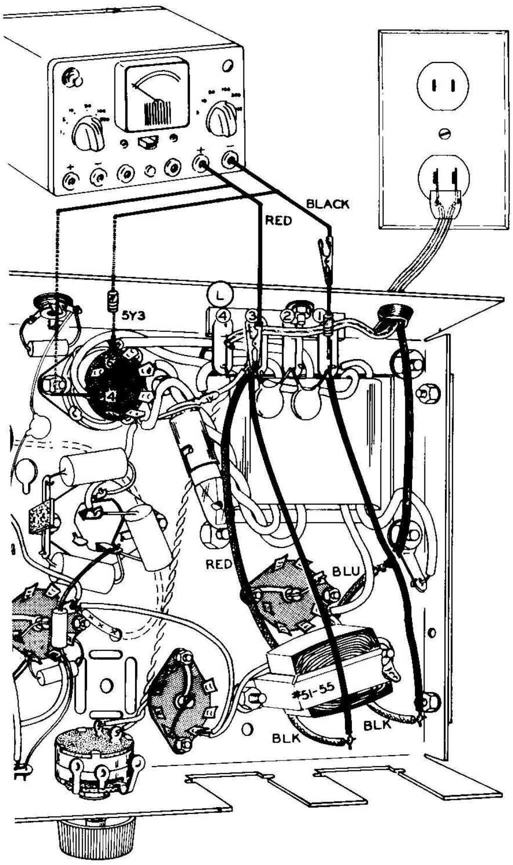
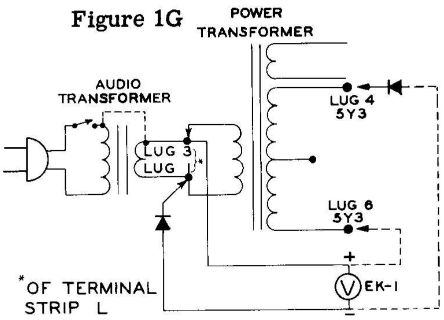


Figure 1G



NOTICE: In any circuit where the voltages are high enough to give you an electrical shock, we recommend that you do not work on the receiver with the circuit turned on or plugged in.

If an occasion should arise that would prompt you to disregard this suggestion, the danger of electrical shock is greatly lessened if you work on the circuit with only ONE HAND. An old axiom says, "When working on a circuit where shocking voltages are present, always keep one hand behind your back."

(✓) Disconnect the line cord from lug 1 of 4-lug terminal strip L.

(✓) Temporarily mount the audio transformer (#51-55) in position as shown in Figure 1G, using 6-32 x 3/8" screws and 6-32 nuts. Make sure that the transformer is mounted so that the leads face in the direction shown in Figure 1G.

NOTE: The audio transformer is used in Experiment 2 only as a step-down transformer. It supplies about 4 volts from the 117 volt power line for an input to the power transformer primary. This is done to make the voltages easier to measure on the EK-1 Meter.

(✓) [T] Connect the red audio transformer wire to lug 3 of terminal strip L (NS).

(✓) [T] Connect the free line cord lead to the blue wire of the audio transformer (S). If necessary, use a short length of hookup wire.

(✓) [T] Connect a length of hookup wire from either black lead of the audio transformer to lug 3 of 4-lug terminal strip L (S).

(✓) [T] Connect a length of hookup wire from the other black lead of the audio transformer to lug 1 of 4-lug terminal strip L (NS).

( ) Clip the lead of the crystal diode that is away from the color bands to the black lead of the EK-1. (This crystal diode will convert any AC voltage that is connected to it to PDC. This will allow the EK-1 to give an indication when it is connected to an AC voltage, since the EK-1 normally responds only to DC or PDC.)

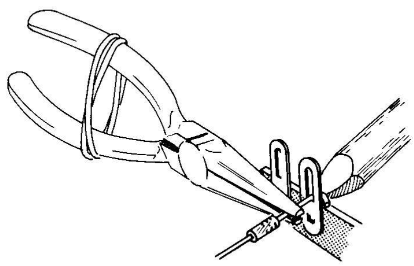


Figure 1H

NOTE: To keep the crystal diode from being damaged by excessive heat, always clamp long-nose pliers over the diode lead being soldered. The pliers will absorb the heat. Hold the lead (with the pliers) between the diode and the point being soldered. An easy way of doing this is by clamping the handle of the pliers with a rubber band as shown in Figure 1H.

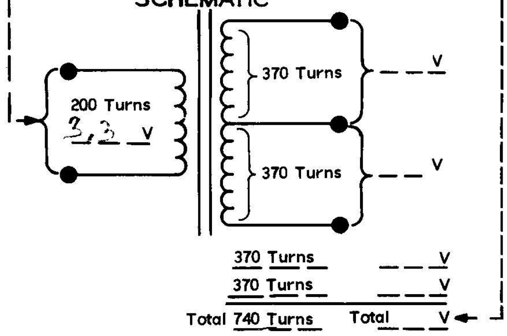
( ) Ⓣ Connect the other end (the end near the color bands) of this same crystal diode to lug 1 of 4-lug terminal strip L (S).

( ) Clip the other lead of the EK-1 to lug 3 of 4-lug terminal strip L. Make sure that the EK-1 is on the 5 volt range; it is now connected to indicate the voltage present at the primary of the power transformer. See Figure 1G.

CHART

	TURNS	VOLTS
Primary	200	1.2 V
Secondary	740	4 V
Ratio	3.7 to 1	1.8 to 1

SCHEMATIC



FILL IN THE BLANKS AND CALCULATE THE TURNS RATIO OF YOUR TRANSFORMER.

Figure 1J

( ) Plug in the line cord, turn on the switch, and note the reading on the EK-1. This reading will not give you an accurate measurement of the AC voltage, but it is intended only to give you an indication. Now write the reading in the primary voltage square in the chart in Figure 1J, and unplug the line cord.

( ) Disconnect the EK-1 leads (include the crystal diode as a part of the black lead) from the primary of the power transformer, lugs 1 and 3 of terminal strip L.

( ) Ⓣ Now connect the EK-1 leads, with the diode still in series with the black lead, as before, across the secondary of the power transformer (pins 4 and 6 of the 5Y3 socket, - either way is correct.

( ) Plug in the line cord and note the reading on the EK-1. Now write the reading down in the secondary voltage square of the chart in Figure 1J, and unplug the line cord.

( ) Disconnect the EK-1 leads from pins 4 and 6 of the 5Y3 socket.

( ) Ⓣ Connect the black lead of the EK-1 (with the diode in series as before) to the red-yellow transformer lead (connected to the pilot lamp under the chassis); this is the center tap of the high voltage secondary winding (S).

( ) Ⓣ Connect the red EK-1 lead to pin 4 of the 5Y3 socket. This connects the EK-1 Meter across one-half of the high voltage secondary winding.

( ) Plug in the line cord and note the reading on the meter. Write this voltage down for the voltage of the upper half of the secondary in the schematic of Figure 1J. Unplug the line cord.

( ) Ⓣ Now connect the red lead of the EK-1 to pin 6 of the 5Y3 socket.

( ) Plug in the line cord and read the meter. Write this voltage for the voltage of the lower half of the secondary in the schematic of Figure 1J. Unplug the line cord and disconnect the meter.

( ) Write the primary voltage down in the primary of the schematic in Figure 1J. You will find this voltage written in the chart above the schematic.

( ) Remove the two lengths of hookup wire used to connect the black leads of the audio transformer to lugs 1 and 3 of terminal strip L.

( ) Remove the red audio transformer lead from lug 3 of terminal strip L.

NOTE: Any wires that are connected permanently Ⓟ in the EK-2B should be routed close to the chassis, not up in the air.

( ) Disconnect the line cord lead from the blue lead of the audio transformer.

( ) Ⓟ Connect this line cord lead to lug 1 of terminal strip L.

( ) Remove the audio transformer from the chassis.

( ) Disconnect the crystal diode from the black lead of the EK-1 Meter.

DISCUSSION

The audio transformer was used in Experiment 2 only as a step-down transformer. It supplied about 4 volts from the 117 volt power line for an input voltage to the power transformer. This was done to make the voltages easier to measure on the EK-1 Meter.

In the first experiment, you attempted to measure DC through a transformer. You saw actual proof that the DC did not pass through the transformer. You also saw that the DC pulses, caused by connecting and disconnecting the DC voltage, did pass through a transformer.

In the second experiment, you connected the crystal diode in series with the EK-1 Meter. This rectified the AC voltage and allowed an indication to be given on the EK-1. Primary and secondary power transformer voltages were then marked in the chart of Figure 1J. The left-hand column gives the actual number of primary and secondary turns along with the turns ratio. Now divide your larger (secondary) voltage reading by the smaller (primary) voltage reading. Write the answer in the box for the voltage ratio. This should be the same (except for meter errors) as the turns ratio, 3.7 to 1. This furnishes us with experimental proof of our formula stating that the turns ratio is equal to the voltage ratio.

The voltage readings for the schematic of Figure 1J shows you again that voltage is proportional to the number of turns in a transformer; half the number of turns produces half the voltage, as shown on the secondary of the power transformer.

The power transformer is the very heart of the power supply in your receiver. As stated before, the power transformer supplies all the various voltages of different sizes to operate different parts of the receiver. The power supply filter circuit receives these voltages from the transformer, converts them to DC if necessary, and distributes them throughout the receiver. In Lesson II, you will learn how the complete power supply operates.

LESSON I

QUESTIONS

1. When a current is passed through a coil of a transformer a ________________ forms around and through the coil.

2. In the schematic symbol for a transformer, when two solid lines appear between the coils, it means that the transformer has an ________________.

3. What are power supply transformers used for?

4. A DC voltage (does, does not) couple through a transformer.

5. The amount of voltage in a secondary winding of a transformer depends on the amount of voltage at the primary winding and the ________ ________ between the primary and secondary windings.

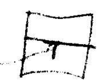
6. A transformer has 10 turns in the primary and 30 turns in the secondary. If 100 volts is applied to the primary winding, ________ volts will appear the the secondary winding.

7. A transformer has 120 turns on the primary and 40 turns on the secondary. If 75 volts is applied to the primary winding, ________ volts will appear at the secondary winding.

8. What determines the type of core material used in a transformer?

9. An iron core is made up of thin sheets of iron called ________________.

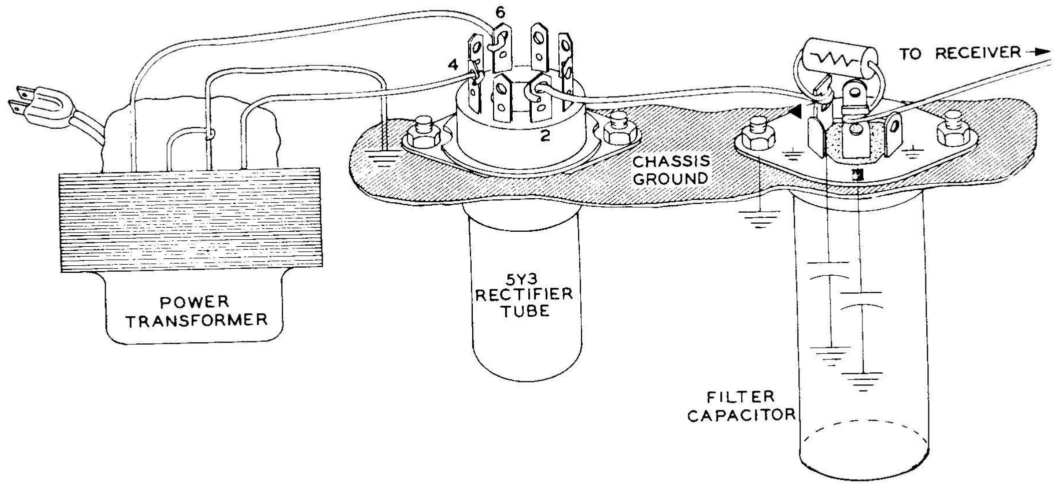
10. What part of the core are the windings wound around?



11. When the powdered iron core of an RF transformer is moved, it has the following result: It changes ________ of ________ that can pass from the primary winding to the secondary winding.

LESSON II

HOW THE RECEIVER POWER SUPPLY OPERATES



A receiver power supply, at its name implies, supplies energy, at different voltage levels, to the various parts of the receiver. These voltages take the form of both AC and DC. AC voltages are needed to operate the heaters of the tubes. DC voltages, such as a battery would supply, are needed to operate all the other parts of the tubes.

In order to eliminate the need for batteries, the power supply is used to change the AC power line voltage into DC voltage. In the early days of radio three different batteries had to be used to create these operating voltages. The first battery, called an "A" battery, supplied voltage to the heaters. The second battery, called a "C" battery, supplied a small amount of DC voltage (called "bias voltage") to the tubes. The third battery, called a "B" battery, supplied a high DC voltage to operate the plates of the tubes.

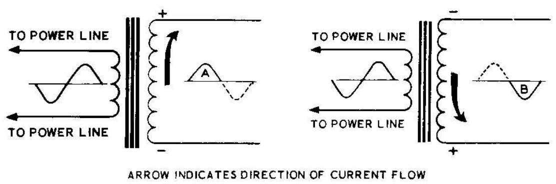
The term "B" voltage is still used today as a carry-over from the "B" battery. The plus (+) voltage, supplied by the power supply to the plates of the tubes, is called the B plus voltage (B+). The minus (-) voltage that connects throughout the receiver from the power supply, is called B minus (B-).

B- is also very often called ground in the receiver. You may already be familiar with its symbol ⏚. These B-, or ground connections, may or may not actually be connected to the earth itself. Instead, a ground connection usually means a connection to the metal chassis of the receiver. Electric currents then flow through the metal chassis from one ground point to another ground point. This eliminates the need for many extra wires that would otherwise have to be used. It also allows DC voltage to be measured easily anywhere in the set, by just clipping the minus (-) lead of the meter to the metal chassis of the receiver.

HALF-WAVE POWER SUPPLY

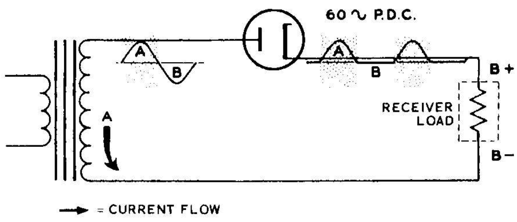
There are two general types of "B" voltage power supplies used to convert AC voltages to DC voltage. These are the half-wave power supply and the full-wave power supply. The half-wave power supply will be shown first since it is simpler.

The first part in a half-wave power supply is the power transformer. As you learned in Lesson I, a power transformer steps the AC line voltage up or down to give the desired amount of voltage in the secondary winding. This transformer could be elminated if the AC line voltage was already of the desired size. Figure 2A shows how current flows in a transformer on each half of the AC signal. During the positive half-cycle, "A", the bottom of the winding is minus (-) and the top of the winding is positive (+), so current flows through the winding as shown by the arrow. During the negative half-cycle, "B," the top of the winding is minus (-) and the bottom of the winding is positive, so current now flows



THE DIRECTION OF CURRENT FLOW IN A TRANSFORMER DURING THE POSITIVE AND NEGATIVE HALF CYCLES OF THE AC WAVEFORM.

Figure 2A



THE OUTPUT WAVEFORM AND DIRECTION OF CURRENT FLOW IN A HALF-WAVE RECTIFIER CIRCUIT.

Figure 2B

up through the winding. The voltage at the transformer constantly alternates back and forth in this same manner while AC line voltage is applied to it.

The voltage coming from the secondary of the transformer is then applied to the rectifier. Since current can only pass through a rectifier in one direction, the positive half-cycle, "A," flows through the receiver load while the negative half-cycle, "B," is blocked. The AC input signal is changed to pulsating DC (PDC) at the B+ side, or output side, of the rectifier.

Rectifiers, as you may recall from Lesson IV and Lesson VI of the EK-2A, always act as diodes. The main difference between the rectifier used in the power supply circuit, and the rectifiers used in the detector circuit, is the amount of power that each rectifier will handle. The type of rectifier used in the power supply is designed to handle large amounts of power and the type of rectifiers used in detector circuits are designed to handle small amounts of power. A large amount of power through one of these small rectifiers would cause it to overheat, and destroy itself.

In Figure 2B and other figures to follow, notice that a resistor has been placed in the schematic diagrams to take the place of the receiver circuits. This was done in order to make the diagrams more simple. Notice in Figure 2B, that the rectifier is supplying pulsating DC (PDC) to the receiver. This PDC must be smoothed out to operate the receiver. It is the job of the power supply filter circuit to smooth out this PDC.

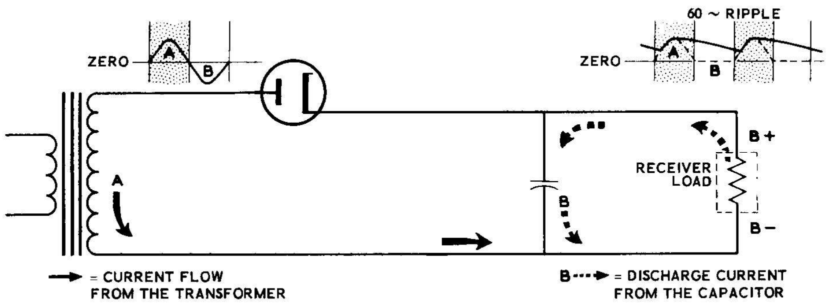
POWER SUPPLY FILTER

To operate the receiver properly, the filter circuit must change the PDC into a pure (smooth) DC like the DC from a battery.

Notice in Figure 2C that a capacitor has now been added to the circuit across the load of the rectifier tube. During the positive half of the input cycle (A), the current flows from the transformer up through the receiver load, through the rectifier tube, and back to the transformer to complete the circuit. Some of the electrons of this charging current (indicated by the solid line) also flow onto the minus (-) plate of the capacitor, causing it to become charged.

During the negative half of the input cycle, when the current cannot flow through the rectifier tube, the excess electrons from the minus plate of the capacitor flow through the receiver load and around to the positive plate of the capacitor. This current flow is indicated by the dotted lines in Figure 2C. While this large capacitor slowly discharges through the receiver, the voltage across it gradually decreases as shown at half-cycle B on the 60 cycle ripple. The capacitor, then acts as a source of current for the receiver load between the PDC pulses (at "B," when the current from the transformer is blocked by the rectifier). The capacitor is charged again each time a pulse of current passes through the rectifier tube.

The 60 cycle ripple waveform, shown at the receiver load, appears on top of the DC voltage



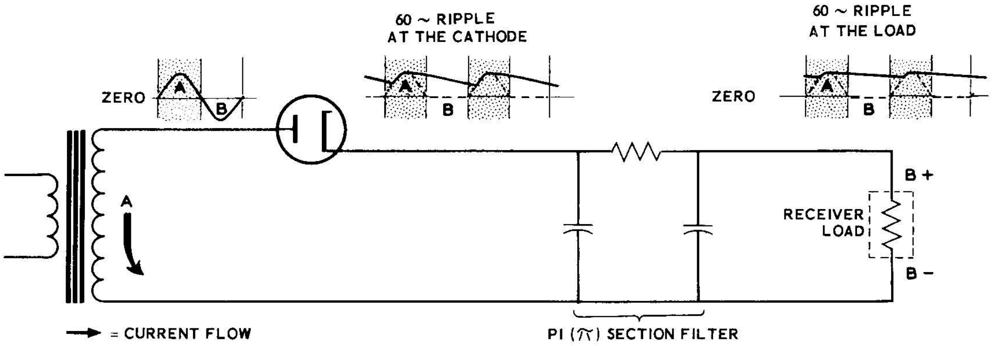
ADDING A SIMPLE FILTER TO THE HALF-WAVE RECTIFIER CIRCUIT.

Figure 2C

as a result of the filtering action. This waveform, although much closer to smooth DC, is still not as flat as we would like to have it.

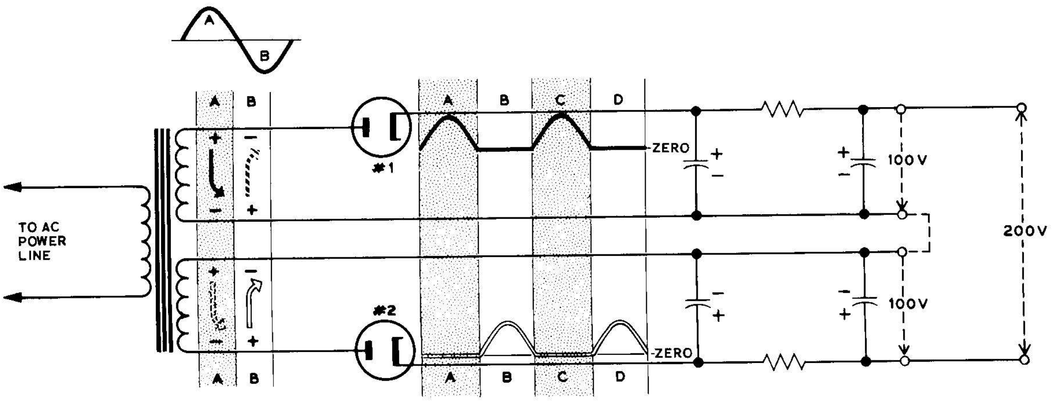
The irregularities still remaining in this waveform, even after the capacitor fills the gaps between pulses, are called ripple, and in this half-wave circuit it still occurs at a 60 cycle rate. Hence, it is known as 60 cycle ripple. You can check the 60 cycle frequency of this ripple by noticing that it makes one complete alternation (one swing, in each direction) in the same length of time as the input voltage did, only now the waveform is not a pure sine wave as it was at the input.

In Figure 2D, a second capacitor and a resistor have been added to the simple filter of Figure 2C. This complete filter is called a pi-section filter because it resembles the Greek letter pi (π). The second capacitor, in conjunction with the resistor, reduces the 60 cycle ripple much further, until it is so small it will not interfere with receiver operation. This voltage, which is now for all practical purposes a pure DC voltage, is then used to operate the receiver.



ADDING A COMPLETE π-SECTION FILTER TO THE HALF-WAVE RECTIFIER CIRCUIT.

Figure 2D



CONNECTING TWO HALF-WAVE RECTIFIER CIRCUITS ON DIFFERENT WINDINGS OF THE SAME TRANSFORMER.

Figure 2E

FULL-WAVE POWER SUPPLY

In Figure 2E, two half-wave rectifier circuits have been drawn; one is placed directly above the other. In each circuit the transformer windings are exactly the same size and give exactly the same voltage. The solid arrows at the transformer's secondary windings indicate a current that flows through the rectifier and around the circuit; the dotted arrows indicate that the current is blocked by the rectifier.

During half-cycle A, current flows through the circuit of rectifier #1, while the current in the lower circuit is blocked by rectifier #2. This causes a pulse to appear at the cathode side of rectifier #1, and no pulse at rectifier #2. (these pulses are shown not filtered so that the circuit action will be easier to follow.)

During half-cycle B, current is blocked by rectifier #1, and passes through the circuit of rectifier #2, thus causing a pulse to appear at the cathode side of rectifier #2.

Notice that rectifier #1 and rectifier #2 take turns conducting. In the full-wave rectifier, a way has been found to combine these two half-wave rectifiers into one circuit so that both halves of the input AC waveform are used. This full-wave rectifier is shown in Figure 2F.

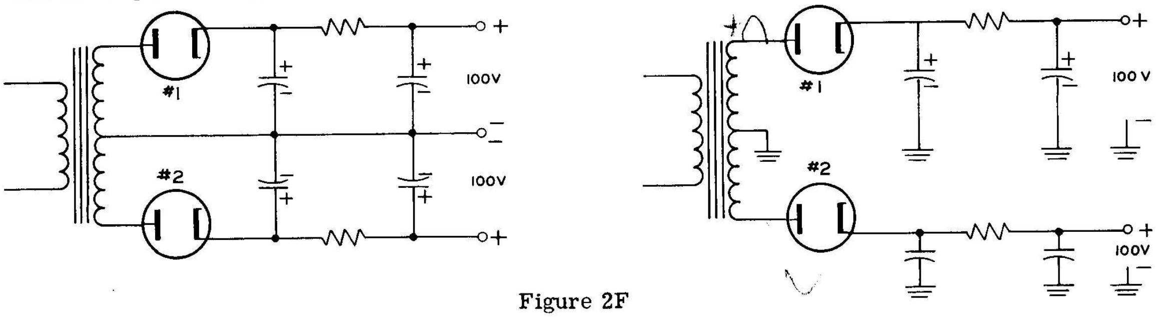


Figure 2F

In Part (1) of Figure 2F, the center connections of the two equal windings of Figure 2E have been connected together. The rectifier circuits still work in exactly the same way, only both currents now use a common center wire.

In Part (2) of Figure 2F, the common center wire has been replaced by ground (chassis ground) connections (see Page 9). In addition, the filter circuit for rectifier #2 has been turned over and drawn just like the filter circuit for rectifier #1. Both rectifier circuits still work in exactly the same way.

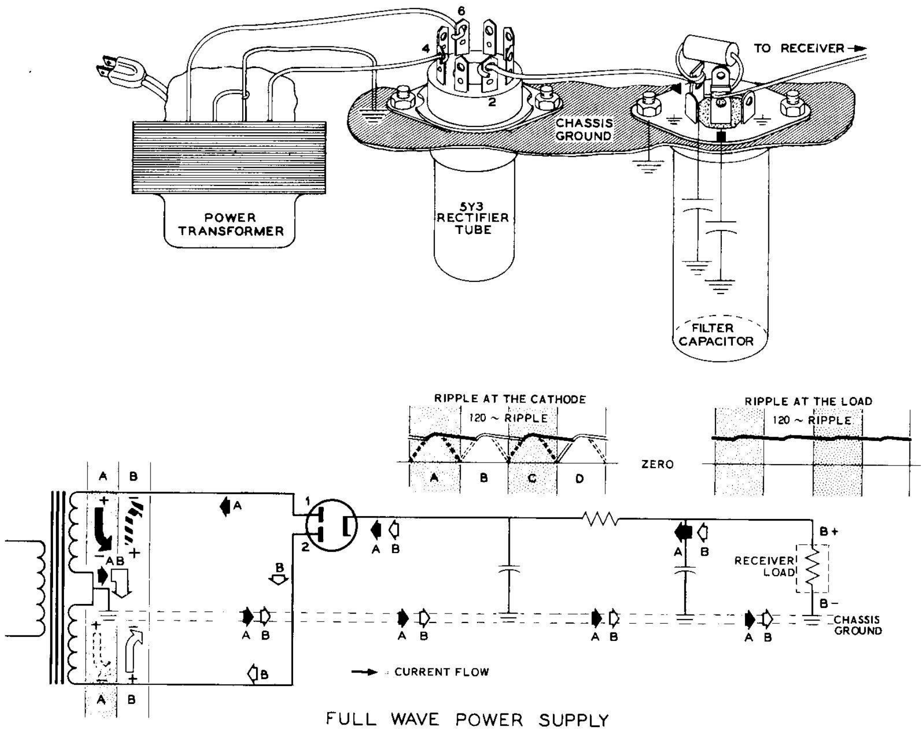
In the schematic of Figure 2G, rectifier #1 and rectifier #2 have been combined into a single rectifier that contains two plates and one cathode. The filter circuit used with rectifier #2 is also eliminated, since one filter circuit will now do the work of both.

During Time A in Figure 2E, the current (black arrows) flows through rectifier plate #1 and is blocked by rectifier plate #2; this causes the first output pulse at the cathode during time A. This current flowing from the cathode to rectifier plate #1, flows through the upper half of the secondary winding to ground; from there it flows through the chassis, up through the receiver load, and back to the cathode to complete the circuit.

During Time B, current (white arrows) flows to rectifier plate #2, while rectifier plate #1 blocks the current from flowing in the upper half of the secondary winding. This current at Time B flows through the bottom half of the secondary winding to the ground connection, through the chassis, and up through the receiver load to the cathode. At Time C the input waveform has reversed again and the circuit works just as it did in Time A.

The resulting waveform is shown near the cathode of the rectifier tube. Because the rectifier plates take turns conducting, there are twice as many pulses here as there are with a half-wave rectifier (both halves of the AC input are used) and the filter circuit operates much more efficiently. The filter capacitors are charged with a new pulse of current before they have time to discharge very far. Because of this, a full-wave power supply is both more efficient than a half-wave power supply and it also has a smoother output voltage.

Notice that the ripple that remains on top of the DC voltage in the full-wave rectifier has doubled in frequency from 60 cycle to 120 cycle. You can check this by noticing that two complete cycles of ripple appear, one at Time A and one at Time B (A and B represent only one cycle of the input signal).

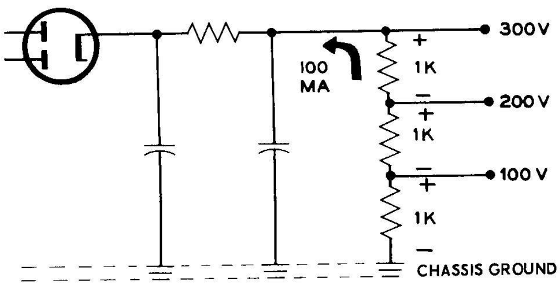


COMBINING THE TWO HALF-WAVE RECTIFIER CIRCUITS OF FIGURE 2E INTO ONE FULL-WAVE RECTIFIER CIRCUIT.

Figure 2G

BLEEDERS AND VOLTAGE DIVIDERS

A voltage divider, such as the one shown in Figure 2H, is a series of resistors connected between the output of the filter and ground. By using Ohm's Law (Chapter 2, EK-1), the values of the resistors can be calculated so that they will provide voltages of different sizes to be used throughout the receiver.



A VOLTAGE DIVIDER THAT PROVIDES VOLTAGES OF THREE DIFFERENT VALUES.

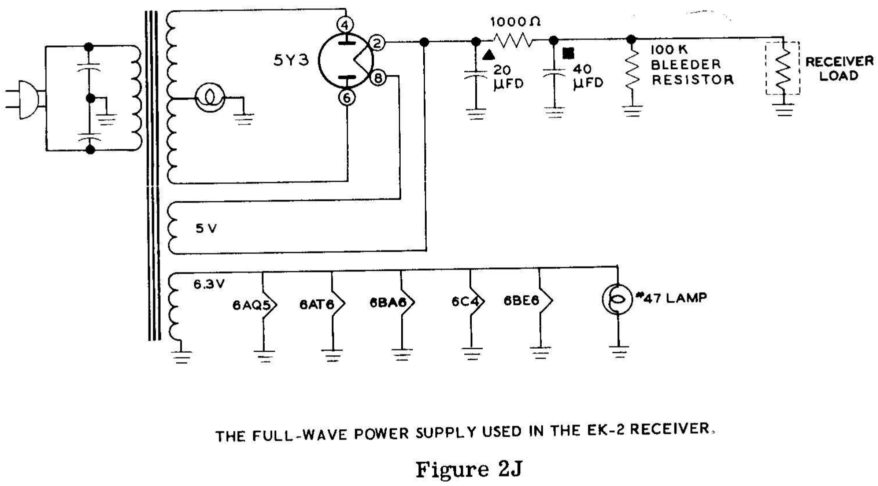
Figure 2H

A bleeder resistor is a resistor connected from the output of the power supply filter (B+) to ground. This resistor lessens the danger of electrical shock after the receiver has been turned off by allowing the filter capacitors to discharge through it. It also helps to stabilize the B+ voltage by keeping a small constant load on the power supply. The 100 KΩ resistor in Figure 2J, is the bleeder resistor that will be used in the power supply of your EK-2.

Figure 2J, shows the final power supply schematic as it will appear in the EK-2B. The most noticeable difference between this full-wave rectifier and the ones we have been studying is that there is no cathode in the rectifier tube. In this type of "directly heated" tube, the filament itself emits the electrons, so no cathode is necessary. The transformer contains a separate winding so that this filament may be heated separately. It may be helpful for you to think of the two currents, the filament current and the B+ current, as being two completely separate currents. The 5 volt filament current flows only from the 5 volt winding, through the filament of the rectifier, and back to the other side of the 5 volt winding. The B+ current flows up through the bleeder resistor and the load, flows from the filament to one of the rectifier plates, and then through one-half of the high voltage secondary winding to ground. The 6 volt lamp that is connected at the center tap of the secondary winding is used only as a fuse.

The power transformer also contains a 6.3 volt winding which supplies power to the filaments of all the other tubes in the receiver. Often the need for a second wire in this filament circuit is elminated by connecting one end of the winding and one end of each of the filaments to ground.

The experiments for Lesson II will show the voltage difference between half-wave and full-wave power supplies. They will also show the different ripple frequencies present in the two types of power supply circuits.



THE FULL-WAVE POWER SUPPLY USED IN THE EK-2 RECEIVER.

Figure 2J

SUMMARY

The receiver power supply supplies voltages to the various parts of the receiver. AC voltages are sent directly from the power transformer to the circuits where they are needed. The DC voltages needed in various parts of the receiver are produced by the rectifier and filter network.

The large positive voltage needed to operate the tubes throughout the receiver is called the "B" voltage. The positive connection of the "B" supply is called B+, and the negative connection is called B-. The B voltage power supply is used to replace the large B battery that would otherwise be needed to supply the large DC voltage.

Since the rectifier tube is a one-way current device, one-half of the AC voltage applied to it is blocked, and will not flow through the circuit. The half-cycle which flows through the circuit is the positive half-cycle. With just the rectifier tube in the circuit we would have PDC voltage. The valleys between these pulses in the PDC voltages are filled in by the power supply filter.

Two main types of power supplies are used, the full-wave power supply and the half-wave power supply. The half-wave power supply, using one rectifier, is able to use only the positive half of the waveform from the power transformer. The full-wave power supply, by connecting two rectifiers in the circuit; is able to use both the positive and the negative half-cycle of voltage received from the power transformer.

The small irregularities that still appear on top of the DC voltage at the output of the power supply filter are called "ripple". In a half-wave power supply this ripple occurs at a 60 cycle rate. In a full-wave power supply this ripple occurs at a 120 cycle rate.

A bleeder resistor, or a voltage divider, is often connected from the output of the power supply filter to ground. A bleeder resistor allows the filter capacitors to discharge, after the receiver has been turned off. It also helps to stabilize the B+ voltage. A voltage divider divides the B+ voltage into various values that can be used in different places in the receiver.

TESTING THE EK-2B POWER SUPPLY

To show the increase of voltage and the change of hum frequency from the half-wave power supply to the full-wave power supply.

PARTS REQUIRED

1 EK-1 meter, or its equivalent
1 EK-2
1 Earphone
2 #47 bulbs
1 5Y3 rectifier tube

BECOMING FAMILIAR WITH THE NEW PARTS

ELECTROLYTIC CAPACITORS. The ordinary types of capacitors, like those explained in Lesson V of the EK-2A, are not large enough to be used as power supply filter capacitors, so a special type, called electrolytic capacitors, are used. Because of the manner in which they are constructed, these electrolytic capacitors are much larger in electrical size (microfarads) than other types of capacitors.

Like the other types of capacitors, the electrolytic capacitor also has two plates that are separated by layers of insulating material. One plate consists of metal foil as before. The other plate is made from a liquid chemical (called electrolyte) that is soaked into a gauze-like material. A chemical reaction causes a microscopically thin coating of oxide to form on the metal foil, and this oxide coating acts as the insulator between the two plates. Because the insulating layer is so thin (the oxide coating on the metal foil), a very large amount of capacity is obtained by a small amount of plate area.

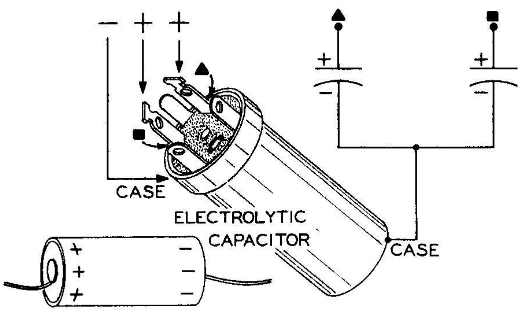


Figure 2K

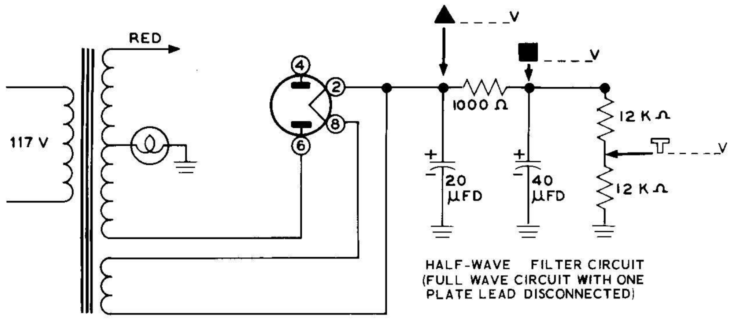


Figure 2L

Current can flow safely in only one direction through an electrolytic capacitor. If current should flow in the other direction the capacitor will be ruined. Because of this, electrolytic capacitors are always marked in one way or another, so that the minus and the plus end of the capacitor can be readily identified.

Common types of electrolytic capacitors are shown in Figure 2K. Notice that two different electrolytic capacitors are combined in one metal can in the larger capacitor like the one used in the EK-2B. Notice also that these two capacitors are each identified by a marking, either a circle or a square or a triangle, at the base of the lug.

EXPERIMENT 1

To show the voltage differences between a half-wave and a full-wave power supply.

(✓) Make sure the line cord of the receiver is unplugged and the switch is turned OFF.

Δ - 210
□ - 315
T - 100

( ) Disconnect the red transformer lead from pin 4 of the 5Y3 socket. Place tape over the bare wire at the end of this lead.

( ) Plug the 5Y3 tube into its socket. Install the two #47 bulbs in their sockets.

(✓) Ⓣ Connect the black (-) lead of the EK-1 to the EK-2 chassis (ground). Set the EK-1 on the 500 volt range (since you will measure DC voltage, the crystal diode will not be used in this test).

(✓) Plug in the line cord of the EK-2 and turn the switch ON.

NOTICE: In any circuit where the voltages are high enough to give you an electrical shock, we recommend that you do not work on the receiver with the circuit turned on. If an occasion should arise that would prompt you to disregard this suggestion, you should work on the circuit with only one hand to lessen the danger of electrical shock.

NOTE: The pilot lamp does not glow full brilliance in any experiment.

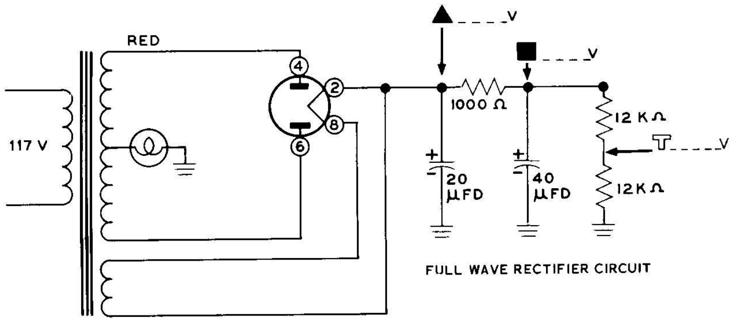


Figure 2M

( ) Figure 2L shows your power supply circuit as it is now connected, as a half-wave rectifier. Very carefully measure each of the three voltages at the points indicated, and write each voltage down in its proper blank.

( ) Unplug the line cord of the EK-2B and turn the switch OFF.

( ) Ⓣ Temporarily, reconnect the red transformer lead to pin 4 of the 5Y3 socket (S).

( ) Plug in the line cord of the EK-2B and turn on the switch.

( ) Figure 2M shows your power supply circuit as it is now connected, as a full-wave rectifier. Once again, very carefully measure each of the three voltages at the indicated points, and write each voltage down in its proper blank.

( ) Turn the switch off and unplug the line cord.

Δ- 235
□ = 220
T = 100

EXPERIMENT 2

To show the difference in hum frequency (60 cycle-120 cycle between the half-wave and full-wave power supply.

( ) Note the .005 μfd capacitor that connects to lug 1 of the earphone socket. Disconnect the end of this capacitor from the hookup wire that connects it to dual-lug terminal T-3.

( ) Ⓣ Now connect the free lead of this .005 μfd capacitor to lug 2 of the 5Y3 socket (S).

( ) Disconnect the red wire from pin 4 of the 5Y3 socket, and place tape over it as you did before. This has returned the circuit to the half-wave circuit of Figure 2L.

( ) Plug in the earphone.

( ) Plug in the receiver and turn ON the switch.

( ) Listen in the earphones and note the sound of the 60 cycle hum.

( ) Turn the unit OFF and unplug the line cord.

( ) [P] Remove the tape and reconnect the red transformer lead to pin 4 of the 5Y3 socket (S). Plug in the receiver and turn on the power.

( ) Listen in the earphones and note that the hum now has a much higher tone (frequency).

( ) This is because the hum (or ripple) in this full-wave rectifier circuit is at a frequency of 120 cycles. (The hum from the half-wave circuit was at 60 cycles.)

( ) Turn the unit OFF and pull the plug.

( ) Unplug the earphone.

NOTE: You may wish to repeat this experiment in order to impress this difference in frequency (or tone) more firmly in your mind.

( ) [P] Reconnect and solder the red lead to pin 4 of the 5Y3 socket (if necessary).

( ) [T] Disconnect the .005 μfd capacitor from pin 2 of the 5Y3 socket. Now reconnect the free lead of the capacitor to the jumper wire that connects it once again to dual-lug terminal T-3 (S).

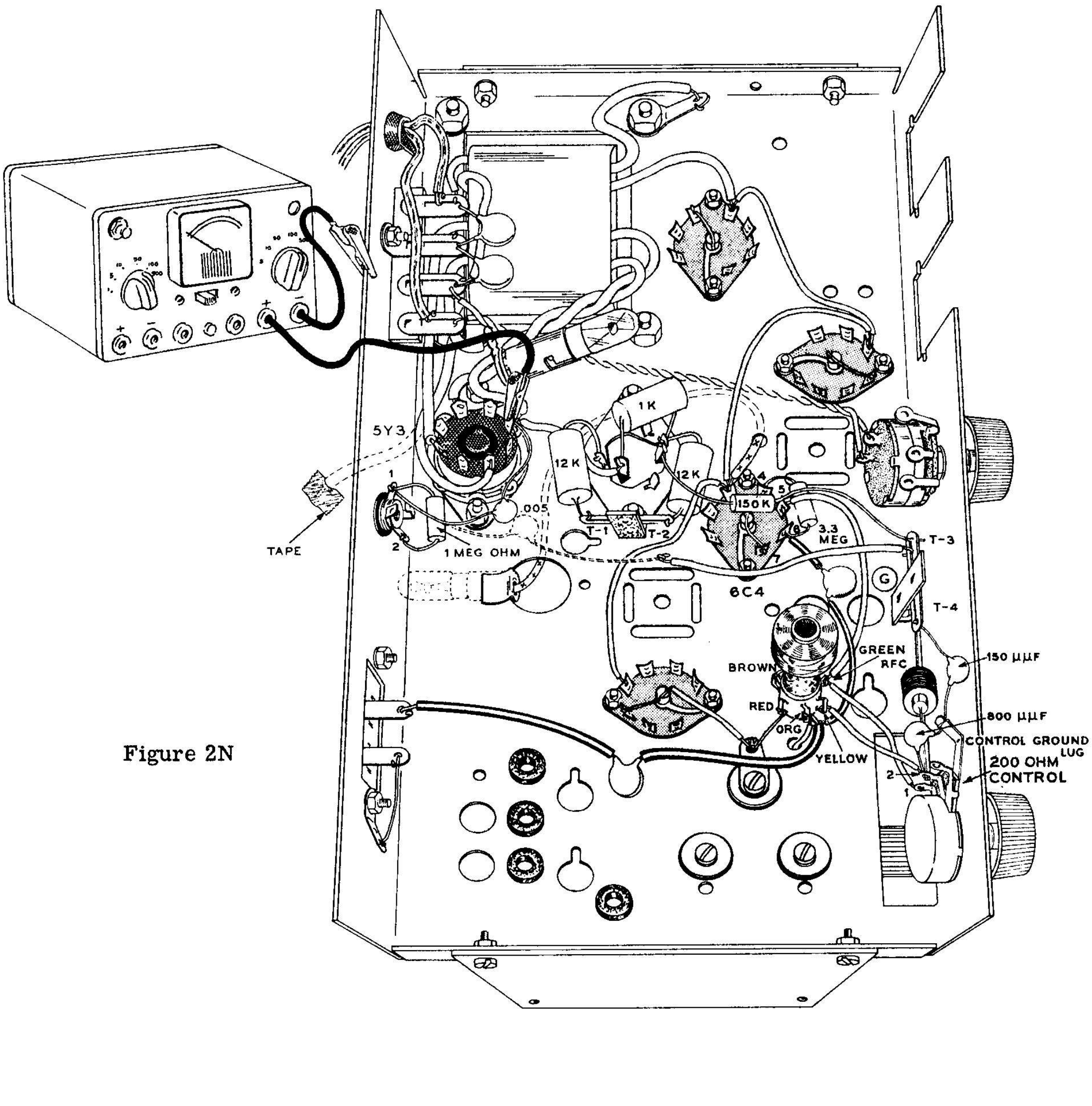


Figure 2N

DISCUSSION

Experiment 1 showed you that a higher output voltage is obtained from a full-wave power supply circuit than is obtained from a half-wave power supply circuit. Compare the voltage that you wrote down in Figure 2L and Figure 2M. Notice that each of these voltages has become larger in Figure 2M the full-wave power supply. Remember the reason for the increase in voltage that was given when you were studying the full-wave power supply of Figure 2G. Filter capacitors were not able to discharge as quickly because twice as many pulses were present at the output of the full-wave rectifier. Thus the circuit became much more efficient. This also caused the ripple to be lower in amplitude than the ripple in the half-wave circuit.

By the listening test in Experiment 2, you actually heard the 60 cycle ripple present in the half-wave rectifier circuit. Then you heard the 120 cycle ripple present at the rectifier tube of a full-wave rectifier circuit. Limitations present in the earphone itself prevented you from hearing the difference in volume level between the two ripples, but the tone (frequency) difference was quite noticeable. Remember, as stated with the full-wave rectifier of Figure 2G, that one of the properties of a full-wave rectifier circuit is that the ripple remaining at its output is at a frequency of 120 cycles.

Lesson III will show you how vacuum tube circuits make use of these voltages provided by the power supply. These power supply voltages may be compared to the power line voltage that comes into your home and operates all your electrical devices like your radio, TV, stove, etc. Learn how these power supply voltages are used in the amplifier circuits in Lesson III.

LESSON II

QUESTIONS

1. The plus (+) voltage supplied to the plates of the tubes is called the B+ voltage.

2. How do ground currents get from one ground point to another in a receiver?
Chassis

3. If chassis ground connections were not used, many more wire would be needed in receivers.

4. In a half-wave power supply, during the half-cycle when the rectifier is cut off, current is supplied to the receiver load by the unloading of the filter.

5. The output of a half-wave power supply contains DC with 60 cycle ripple remaining on top of it.

6. The output of a full-wave power supply contains DC with 120 cycle ripple remaining on top of it.

7. A full-wave power supply is much (more, less) efficient than a half-wave power supply.

8. In Figure 2P use ohms law to calculate and fill in the three voltages on the voltage divider.

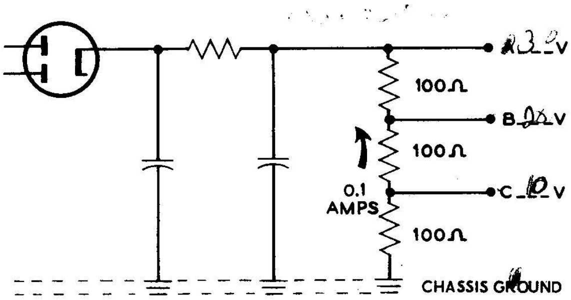


Figure 2P

9. The filament of the 5Y3 rectifier tube used in your EK-2B power supply is also called a cathode because electrons are emitted directly from it.

LESSON III

HOW TUBES USE OPERATING VOLTAGES

The basic operation of vacuum tubes was discussed at length in Lessons VI, VII, and VIII of Basic Radio - Part 1. An excellent preparation for this chapter would be to review these three lessons to prepare for the more advanced ideas presented here in Basic Radio-Part 2.

The operating voltages of a vacuum tube are the voltages applied to it by the power supply to allow it to operate. First, the tube needs heater voltage. Almost all vacuum tubes must have heater voltages supplied to them so that electrons can be boiled off of their cathodes. "B" voltage is also needed to furnish the electrical pressure that will cause a stream of electrons (or current) to flow through the tube.

In Lesson VI of Basic Radio - Part 1, you learned that the vacuum tube diode rectifier, like the crystal diode, is a one-way current device. The two main elements of the vacuum tube rectifier are the cathode and the plate. Heater voltage is supplied to the heater by the power supply to raise the temperature of the cathode of the tube. Heating the cathode causes electrons to boil from the surface of the cathode. A positive voltage on the plate of the tube causes these electrons to flow from the cathode to the plate. When a negative voltage is on the plate, it keeps these electrons from flowing.

Figure 3A shows a circuit containing a vacuum tube rectifier. During Time A, when a positive voltage is applied to the plate, current flows through the circuit. During Time B, when a

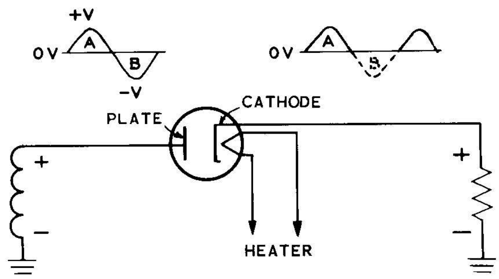


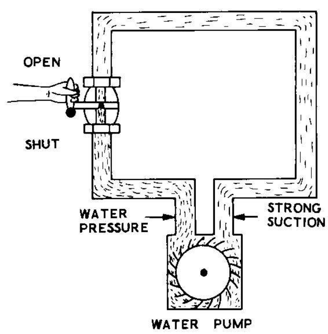
Figure 3A

negative voltage is applied to the plate, the diode blocks the current from flowing in the circuit. As a result, only the positive (A) portions of the input waveform appear at the cathode of the diode.

TRIODES AND THEIR OPERATING VOLTAGES

A triode tube is like a diode with one more element added to it. This new element, called the grid, is placed between the cathode and the plate of the tube (Figure 3C).

Figures 3B and 3C show how the grid in the triode operates. The grid of the triode in Figure 3C controls the flow of electrons through the tube in the same manner that the valve controls the flow of water through the pipes in Figure 3B. The water pump functions like a power supply, and tries to push water up through the valve. The other side of the pump tries to draw the water back in again. The opening or shutting of the valve allows a smaller or larger amount of water to flow through the circuit.



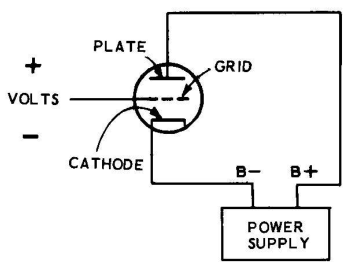


Figure 3B

THE VALVE CONTROLS THE FLOW OF WATER IN THE SAME WAY THAT THE GRID CONTROLS THE FLOW OF ELECTRONS.

Figure 3C

In the triode circuit of Figure 3C, the power supply tries to push the electrons from B- up through the tube, from the cathode to the plate. B+, at the power supply, tries to draw these electrons back to it again. The grid of the tube acts like the valve did, and allows a larger or smaller stream of electrons to flow through the tube. When the voltage on the grid of the tube becomes negative (-), it repels the electrons and tends to make them stay on the cathode of the tube. When the voltage on the grid becomes more positive, it acts in the same manner as opening the valve did, and allows the electrons to flow through the tube.

The way that this grid controls the flow of electrons or current in the triode is the key to how the circuit amplifies. A very small signal at the grid can control a large amount of current flowing through the tube.

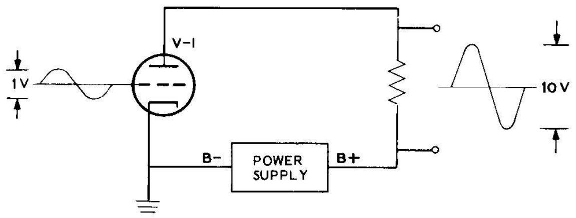
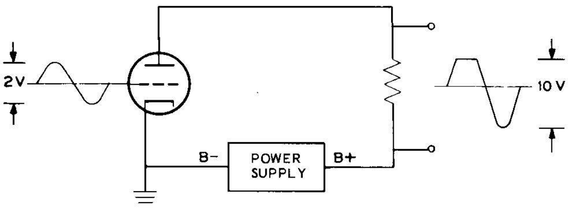


Figure 3D

The circuit of Figure 3D shows how a triode amplifier circuit was presented to you in Basic Radio-Part 1. The small 1 volt signal at the grid of the triode allows larger or smaller amounts of current to flow through the tube. As these larger or smaller amounts of current flow through the plate resistor, the same signal appears across the resistor in the form of voltage, only now it is much larger.

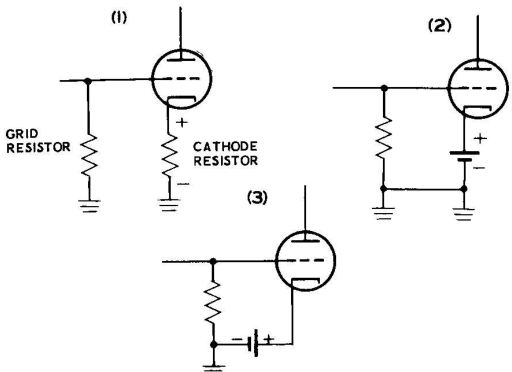
Grid bias should also be briefly reviewed at this point. Lesson VII of Basic Radio-Part 1 informed you that the grid bias voltage is a small amount of voltage applied between the grid and the cathode in order to adjust the tube to its best operating range. This might be compared to turning the water valve of Figure 3B to some point in the middle of its range, in order to give a particular amount of water flow. An input signal would then open the valve slightly wider, and then slightly narrower than this "bias" (or center) setting. Placing this bias voltage on the control grid keeps the input signal from being distorted. If the input signal were to turn the tube off too soon, the resulting signal at the output would be flat on one side. This is illustrated in Figure 3E. The proper amount of bias voltage needed for each tube and type of circuit depends on many things; the physical construction of the tube itself, the size of the resistors used in the circuit, and the amount of B+ voltage applied to the circuit, and many others.



IMPROPER BIAS WILL CAUSE THE WAVEFORM TO BE DISTORTED AT THE OUTPUT OF THE CIRCUIT.

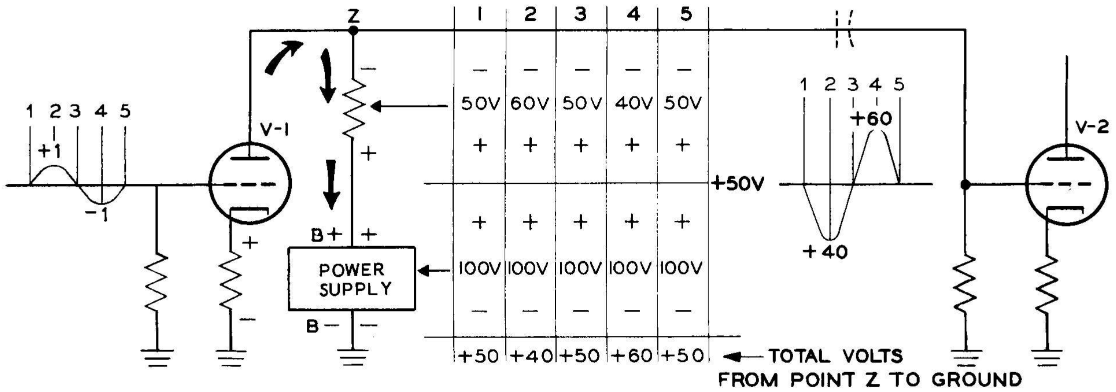
Figure 3E

The normal means of developing bias for an amplifier is by the self-bias method shown in part (1) of Figure 3F. The current that flows through the cathode resistor causes a voltage to be developed across it. This voltage works just like the battery shown in part (2) of Figure 3F. The control grid will be at the same voltage as the bottom and the cathode will be at the same voltage as the top of the cathode resistor (or battery). This results in always keeping the grid of the tube at a minus voltage compared to the cathode of the tube. The amount of this minus (bias) voltage is the amount of voltage developed across the cathode resistor, which



THE BIAS VOLTAGE DEVELOPED ACROSS THE CATHODE RESISTOR APPEARS BETWEEN THE GRID AND THE CATHODE OF THE TUBE, JUST LIKE A BATTERY WOULD.

Figure 3F



HOW THE OUTPUT WAVEFORM OF AN AMPLIFIER IS AMPLIFIED AND INVERTED.

Figure 3G

depends on the size of the resistor and the current flowing through it. Part (3) of Figure 3F shows the same bias battery circuit drawn a little differently in order to make the bias voltage to the grid of the tube easier to see.

In Figure 3G the amplifier circuit of Figure 3D has been redrawn in a slightly different manner, and the second tube, V2, has been added to the circuit. A resistor has also been added in the cathode of V1 to ~~supply bias to the~~ tube. Notice that redrawing the circuit makes it more apparent that the power supply is actually in series with the plate resistor. By measuring from point Z to ground, the voltage you would read would be the difference between the voltage across the plate resistor and the B voltage. Notice that the signal at point Z (and also at the grid of V2) is inverted, or turned over, from the way it was at the grid of V1. The reason for this signal being inverted becomes clear when you see what happens at point Z as the control grid of V1 swings plus (+) and minus (-) with the signal voltage. The signal voltage will now be examined at five different points along the cycle to make this clear to you.

At Time 1, there is 0 volts at the grid of V1. The voltages in the plate circuit at this same time are shown at Time 1 (near the plate resistor). Enough current is flowing in the circuit so that 50 volts is developed across the resistor. This 50 volts is in series with, but opposite to the 100 volts in the power supply. The resulting voltage that would appear between point Z and ground would be 50 volts because opposite voltages cancel. This same larger signal voltage appears at the grid of tube V2, and is shown at Time 1 on the large signal voltage near V2.

At Time 2 of the input waveform, +1 volt appears on the grid of V1, causing an increase of current through V1. This increase in current, at Time 2, causes a greater voltage, 60 volts, to be developed across the plate resistor. When this -60 volts is subtracted from the +100 volts of the power supply, the total voltage that appears between point Z (the grid of V2) and ground at Time 2 is +40 volts.

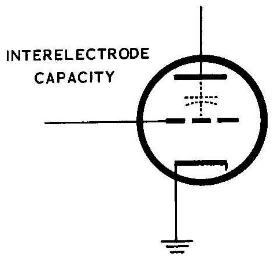
At Time 3, the input voltage has again returned to zero; the voltage that appears at point Z (and the grid of V2) is the same as it was at Time 1, +50 volts.

At Time 4, the voltage at the grid of V1 has decreased to -1 volt, causing the current through tube V1 to decrease. The decrease in current through tube V1 causes a smaller voltage to appear across the plate resistor, 40 volts. When this -40 volts is subtracted from the opposing +100 volts of the power supply, the resulting voltage at Time 4 at point Z, and the grid of V2, is +60 volts.

At Time 5 the input voltage at the grid of V1 has again returned to zero. This returns the voltage at point Z, and at the grid of V2, to the same voltage that appeared at Time 1 and Time 3, +50 volts. Each of these five voltages that appear at point Z and the grid of V2 are drawn in graphic form near the grid of V2. Notice that this signal is now ten times as large as the input signal to the grid of V1. It also has been inverted (turned upside down). Actually, a capacitor (shown dotted in near the grid of V2) would be used in this circuit. It would keep DC voltage from appearing on the grid of V2, but allow the signal voltages to pass through it. This will be explained further in Lesson IV.

TETRODES

A disadvantage of the triode tube that tends to limit its operating range is the small amount of capacity that is created between the plate and the control grid of the tube. This small amount of capacity (called interelectrode capacity) is developed because the plate and the grid of the triode act like the two plates of a capacitor. This capacity, shown in Figure 3H, is a very serious disadvantage in the operation of some circuits.



THE PLATE AND THE GRID OF THE TUBE ACT LIKE THE PLATES OF A CAPACITOR, AND A SMALL AMOUNT OF CAPACITY APPEARS BETWEEN THEM.

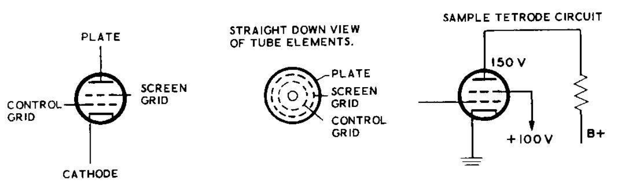
Figure 3H

The tetrode tube decreases this interelectrode capacity and makes the tube operate more efficiently by adding another grid between the control grid and the plate of the triode. This new grid that has been added to the tube is called the screen grid. The physical construction of the tetrode, along with its schematic symbol, is shown in Figure 3J.

A positive voltage, usually smaller than the voltage on the plate, is applied to the screen grid of this tube. This screen grid can be placed closer to the control grid than the plate can, with less ill effects. The large positive voltage on the screen grid pulls the electrons from the cathode, and since the screen grid is made of a fine wire, the great majority of these electrons flow through the screen grid to the plate of the tube. This allows much greater amplification to occur in the tube. Also, the screen grid shields the plate of the tube from the control grid, causing the interelectrode capacity between these two elements to be much smaller. This improvement allows the tetrode to be used much more widely in circuits where interelectrode capacity is such a serious problem.

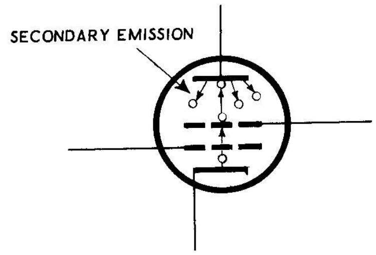
The tetrode is very seldom used today. It has been explained to you mainly to provide a stepping stone between the triode and the pentode tube. The pentode tube is used widely in almost all types of electronic circuits.

The main disadvantage of the tetrode tube is the effect shown in Figure 3K called "secondary emission." When electrons from the cathode are accelerated by the screen grid, they hit the plate at a high rate of speed and tend to knock other electrons loose from the plate. Many of these electrons that are knocked loose from the plate can be attracted to the screen grid, because the screen grid has a highly positive voltage on it. The number of these electrons that go to the screen grid, and the number that are returned to the plate, depends on the voltage on the plate compared to the voltage on the screen grid. If there is a higher voltage on the plate, then most of the electrons will return to the plate. If there is a higher voltage on the screen grid, then a great many of these electrons will go to the screen grid. The results of this "secondary emission"



THE TETRODE TUBE ADDS AN ADDITIONAL ELEMENT, CALLED A SCREEN GRID, TO THE TUBE.

Figure 3J

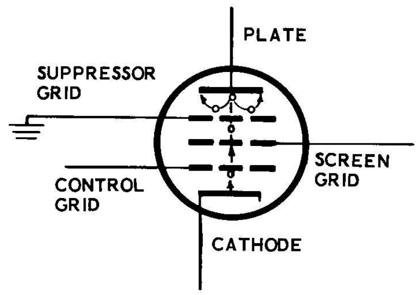


IN A TETRODE THE ELECTRONS KNOCKED FROM THE PLATE OF THE TUBE CAN BECOME A SERIOUS PROBLEM.

Figure 3K

in the tetrode can be serious distortion or lower amplification than would otherwise be possible. The third grid that is added in the pentode tube eliminates this secondary emission.

THE PENTODE



ANOTHER GRID, CALLED A SUPPRESSOR GRID, IS ADDED IN THE PENTODE TUBE.

Figure 3L

In the pentode tube a third grid, called the suppressor grid, has been added. This suppressor grid is placed between the screen grid and the plate of the tube and is used to isolate the screen grid from the plate of the tube. It is generally connected to ground or to the cathode of the tube. Now, the electrons that are knocked loose from the plate are prevented by the negative voltage at the supressor grid from traveling to the screen grid. This forces them to return to the plate.

Since the suppressor grid is made from fine mesh wire, the electrons traveling from the cathode to the plate tend to pass right through it. Because it has a high negative voltage compared to the plate, the suppressor repels the electrons that tend to bounce from the plate. The screen grid would now be isolated from the plate, therefore a much higher voltage can be placed on it. This causes the pentode to be much more efficient than either the tetrode or the triode.

Because the cathode of the tube is very close to ground potential, the suppressor grid is quite often connected to it instead of to ground. This is done mainly for convenience, since the cathode connection of the tube is often closer to the suppressor grid than a ground connection. In some pentodes, the suppressor is connected to the cathode inside the tube.

SUMMARY

You have learned in this lesson that many operating voltages are needed to make vacuum tubes work. The first of these was the filament or heater voltage, which was used to bring the cathode of the tube up to operating temperature. This heater, or filament voltage, can be either AC or DC. Filament voltage is usually AC because AC is easily obtained from the power transformer.

DC voltages of many different sizes must be applied to the other elements of the tube. High DC voltage must be applied to the plate, and the bias voltage must be applied between the grid and the cathode of the tube, in order to insure proper operation. In a tetrode or pentode tube, a high DC voltage must be applied to the screen grid.

A short review of the theory of the vacuum tube rectifier reminded you that it was a one-way current device. Current can only flow from its cathode to its plate, causing the tube to rectify any signal that is applied to it.

In a triode, the grid acts like a valve and allows either more or less current to flow through the tube from the cathode to the plate. Because a small signal at the grid of the tube can control a large amount of current flowing through the tube, the grid signal is made much larger in the plate circuit of the tube. This is called amplification.

When the tetrode was developed it offered some advantages over the triode tubes. The tetrode added a new grid, called a screen grid, which helped draw electrons to the plate. This new grid also decreased the interelectrode capacity between the control grid and the plate of the tube by isolating them from each other. The main disadvantage of the tetrode was the undesirable effects caused by secondary emission from the plate of the tube.

The pentode added a third grid called a suppressor grid to the tube. This grid eliminated the secondary emission previously mentioned. The pentode has a higher amplification than the triode.

Now proceed to the Experiment section of Lesson III. These experiments will give you a practical demonstration of amplifiers in action.

USING THE TRIODE AND PENTODE AMPLIFIERS

To show that the grid signal is amplified and inverted in the plate circuit of an amplifier, and to use an audio amplifier containing a triode and a pentode with the regenerative receiver circuit.

PARTS REQUIRED

NOTE: To identify some of these parts it may be helpful to refer to the Parts Pictorial on Page VII.

1 Front panel
1 Subpanel
1 Dial light bracket
1 Plastic dial window
1 Dial cord drum
1 6AQ5 tube
1 Knob
1 Speaker
1 Dial pointer
1 Dial cord
2 Plastic "O" washers
1 Shaft bushing
1 Tuning shaft
2 Slide switches
1 Dial cord spring
4 6-32 x 1/4" RHMS (Round Head Machine Screws)
4 6-32 x 3/8" FHMS (Flat Head Machine Screws)
7 6-32 x 3/8" BHMS (Binder Head Machine Screws)
1 8-32 x 3/16" setscrew
4 1/8" spacers
8 5/16" OD washers
2 #6 solder lugs
10 #6 lockwashers
11 6-32 nuts
1 Control lockwasher
1 Control nut
1 10 Ω resistor (brown-black-black)
1 10 KΩ resistor (brown-black-orange)
1 470 KΩ resistor (yellow-violet-yellow)
1 330 Ω 1 watt resistor (orange-orange-brown)
1 10 μfd, 25 volt electrolytic capacitor
1 .005 μfd disc capacitor (now connected to the earphone jack)
1 .01 μfd tubular capacitor
1 Output transformer (#51-55)
1 6C4 tube
1 EK-2 chassis
1 EK-1 meter (or equivalent)
2 1-1/2 volt batteries

PREPARING THE CHASSIS

In order to prepare for the experiments, the complete front panel and speaker assembly must first be assembled. Refer to Figure 3M for the following steps.

(✓) Place the speaker OFF-ON switch over the mounting holes on the front apron of the chassis. Install 6-32 x 1/4" screws through 1/8" spacers and through the chassis apron into the tapped holes on the OFF-ON switch.

(✓) In the same manner, using 6-32 x 1/4" screws and 1/8" spacers, install the BFO switch.

(✓) Install the output transformer in position, using 6-32 x 3/8" (BHMS) screws and 6-32 nuts. Be sure that the red and blue leads face toward tube socket V4. Put a #6 lockwasher under the nut for the mounting foot near V3. Put two #6 solder lugs, one above and one below the chassis, on the screw of the other mounting foot.

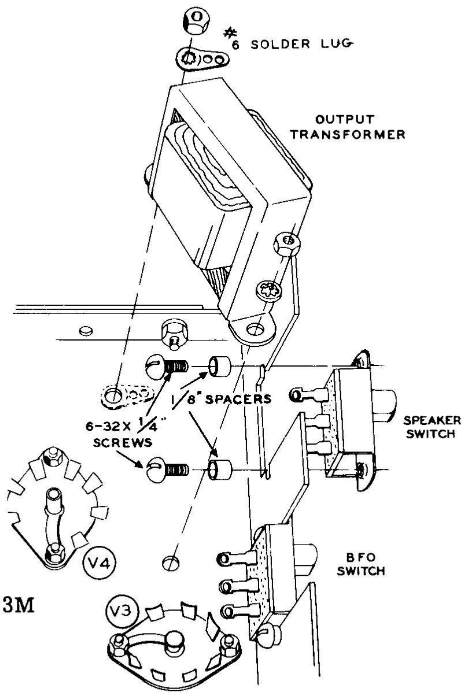


Figure 3M

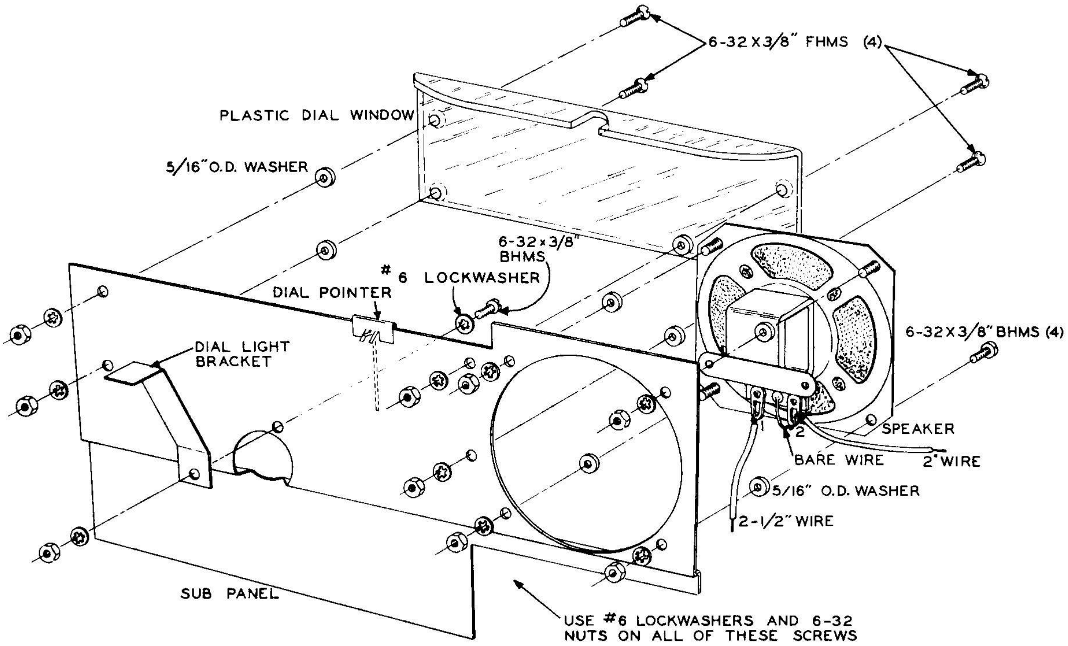


Figure 3N

Refer to Figure 3N for the following steps.

( ) Install the dial light bracket in position using a 6-32 x 3/8" BHMS, two #6 lockwashers, and a 6-32 nut.

( ) It may help the dial pointer to slide more smoothly if you rub the top edge of the subpanel lightly with sandpaper, before you install the pointer.

( ) Place the dial pointer in position over the top edge of the subpanel. The pointer itself should be on the front (black) side of the subpanel as shown in Figure 3N.

( ) Install the plastic dial window in place at the top edge of the subpanel. Use four 6-32 x 3/8" FHMS, one in each corner of the window. Place a 5/16" OD washer on each screw between the plastic dial window and the subpanel as shown. Secure these four 6-32 screws and #6 lockwashers and 6-32 nuts, at the rear of the subpanel.

( ) (P) Solder a short length of wire from lug #2 of the speaker to the center (ground) connection of the speaker.

( ) (P) Solder one end of a 2-1/2" wire to lug 1 of the speaker.

( ) (P) Solder one end of a 2" wire to lug 2 of the speaker.

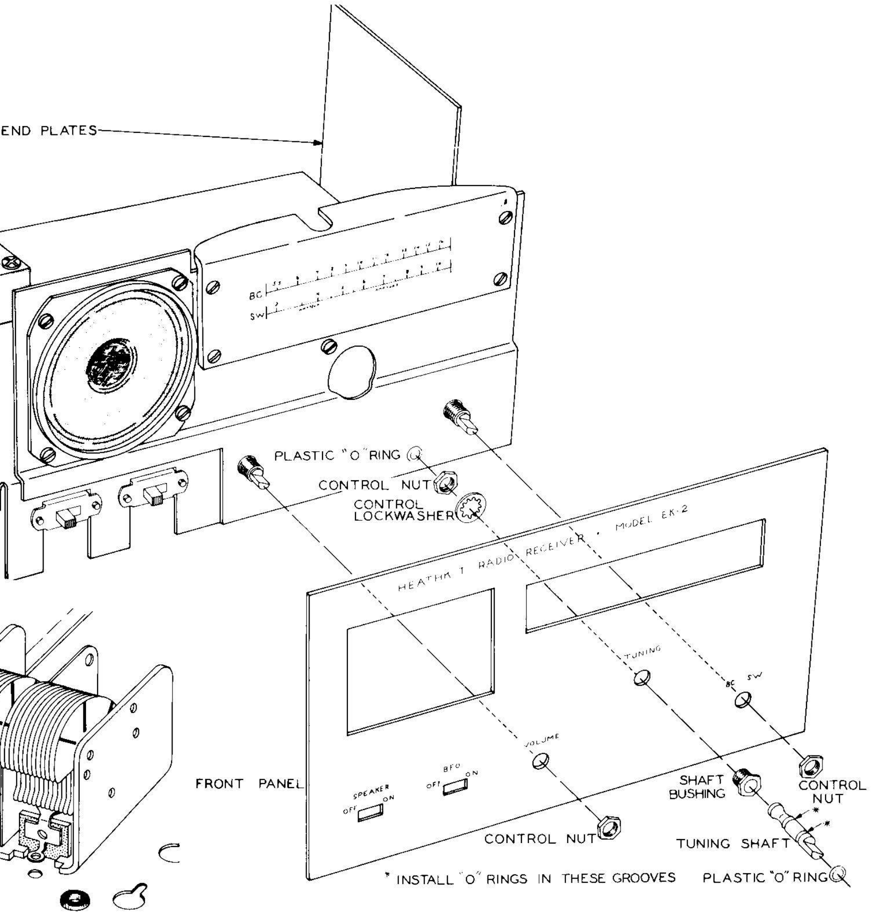
( ) Install the speaker in position on the subpanel as shown in Figure 3N (make sure that the speaker wires also pass through the speaker mounting hole). Use 6-32 x 3/8" BHMS, #6 lockwashers, and 6-32 nuts. Place a 5/16" OD washer on each screw between the speaker and the subpanel as shown in Figure 3N.

( ) Install the setscrew in the dial cord drum.

( ) Turn the tuning capacitor to the fully open position, as shown in Figure 3P and then remove the knob from its shaft.

( ) Install the dial cord drum on the end of the tuning gang shaft, as shown in Figure 3P, with the bushing part of the drum toward the capacitor itself. The outside of the dial cord drum should be set back about 1/16" from the end of the tuning capacitor shaft.

( ) With the tuning capacitor plates still full open and the dial cord drum positioned as shown in Figure 3P, tighten the setscrew.



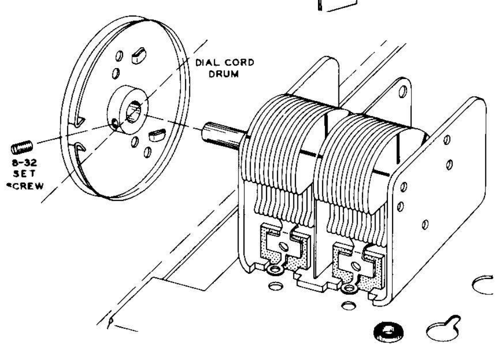


Figure 3P

Figure 3Q

Refer to Figure 3Q for the following steps.

( ) Install the shaft bushing in the hole below the word TUNING on the front panel; use a control lockwasher and control nut at the rear of the panel to tighten the bushing in place.

( ) Notice the two small grooves in the tuning shaft. Slide one of the plastic "O" washers over the rear (the end away from the flat end) of the tuning shaft until it snaps into position in the first of these grooves.

( ) Now slide the tuning shaft through the bushing from the rear of the front panel. Lock the tuning shaft in place by sliding the other plastic "O" washer over the front of the tuning shaft until it locks in place in the remaining small groove of the tuning shaft.

( ) Remove the knobs and the control nuts on the two front panel controls on the EK-2 chassis.

( ) Place the subpanel in position over the controls on the front apron of the chassis. Make sure that the speaker wires do not get caught between the subpanel and the chassis. Insert the wire from lug 1 of the speaker through the hole just below it in the chassis.

( ) Now install the front panel in position over these same controls. Fasten both panels firmly in position by replacing the nuts on the two front panel controls.

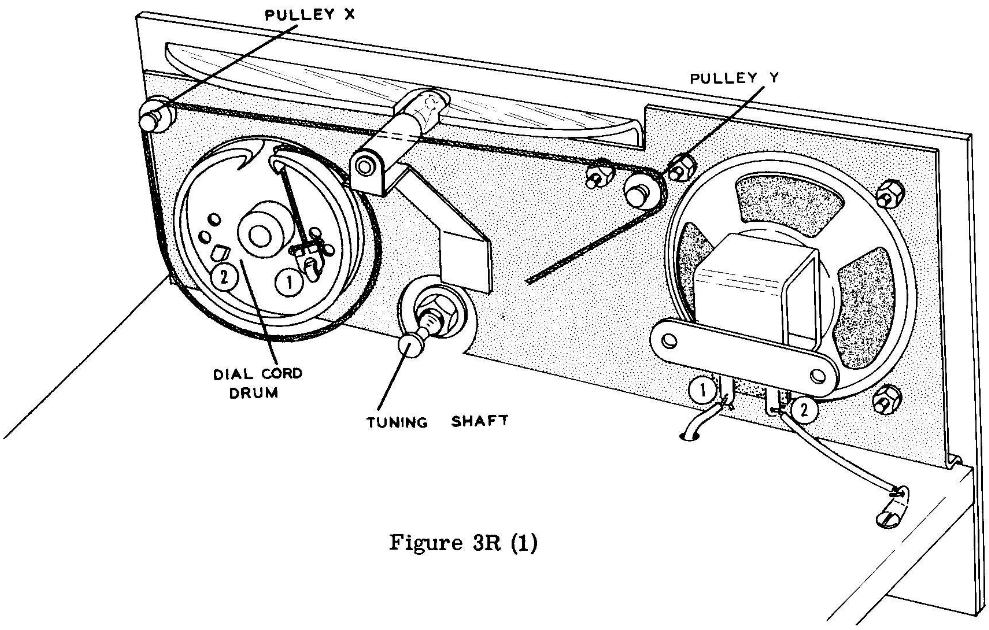


Figure 3R (1)

( ) Reinstall the two small knobs on the two lower shafts. Install the large knob on the tuning shaft.

( ) Remove one of the end plates from the chassis. Now rotate this plate 90 degrees and remount it at the end of the chassis, using the narrower mounting holes this time. Use the same two screws to remount the end plates. The top of this end plate should be just about even with the top of the front panel.

( ) Remove the other end plate and rotate it 90 degrees in the same manner.

Refer to Figure 3R (1) for the following steps.

( ) Ⓟ Connect the 2" wire from lug 2 of the speaker to the solder lug near the edge of the chassis (S).

( ) Place the chassis in front of you as shown in Figure 3R, and make sure that the dial cord drum is in the position shown.

( ) Hook one end of the dial cord over lug 1 of the dial cord drum. Route the dial cord out through the opening and around the top of the dial cord drum.

( ) Continue routing the dial cord around the dial cord drum, up around pulley X, across the top of the subpanel, and around pulley Y.

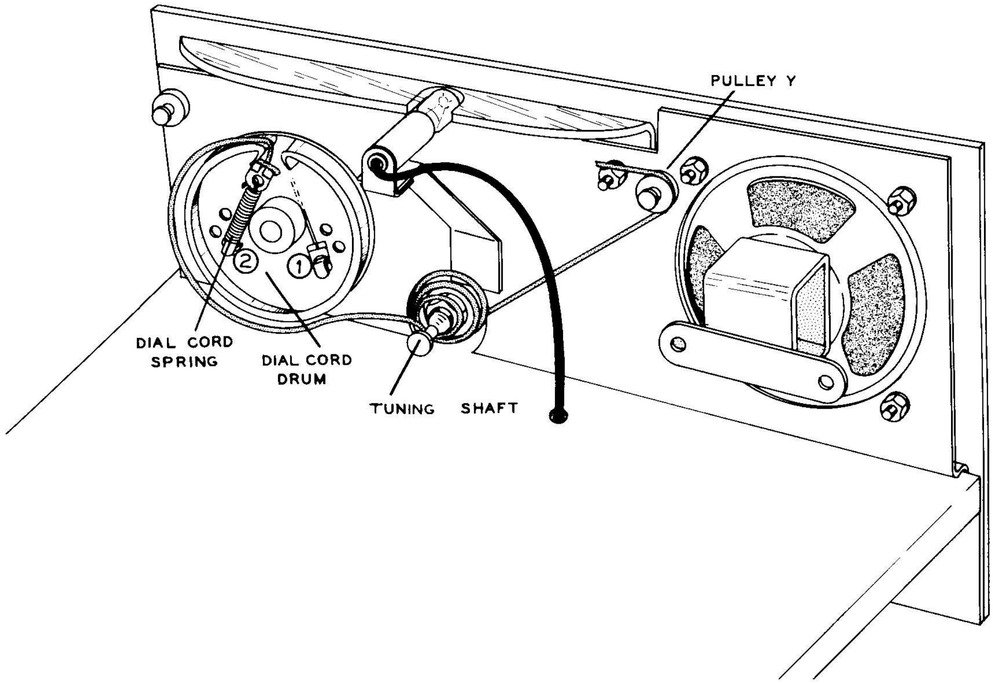


Figure 3R (2)

Refer to Figure 3R (2) for the following steps.

( ) Now route the dial cord below the tuning shaft, and wrap it around the tuning shaft three times.

( ) Route the end of the dial cord string coming from the tuning shaft around the bottom of the dial cord drum, and in through the opening of the drum, toward lug 2. Install one end of the dial cord spring over lug 2 of the dial cord drum. Connect the free end of the dial cord to the other end of this dial cord spring.

( ) Remove the pilot lamp socket from V5 tube socket hole (see Figure 3S). Now mount it on the dial light bracket so that the #47 lamp fits into the slot in the plastic dial window as it is shown in Figure 3R.

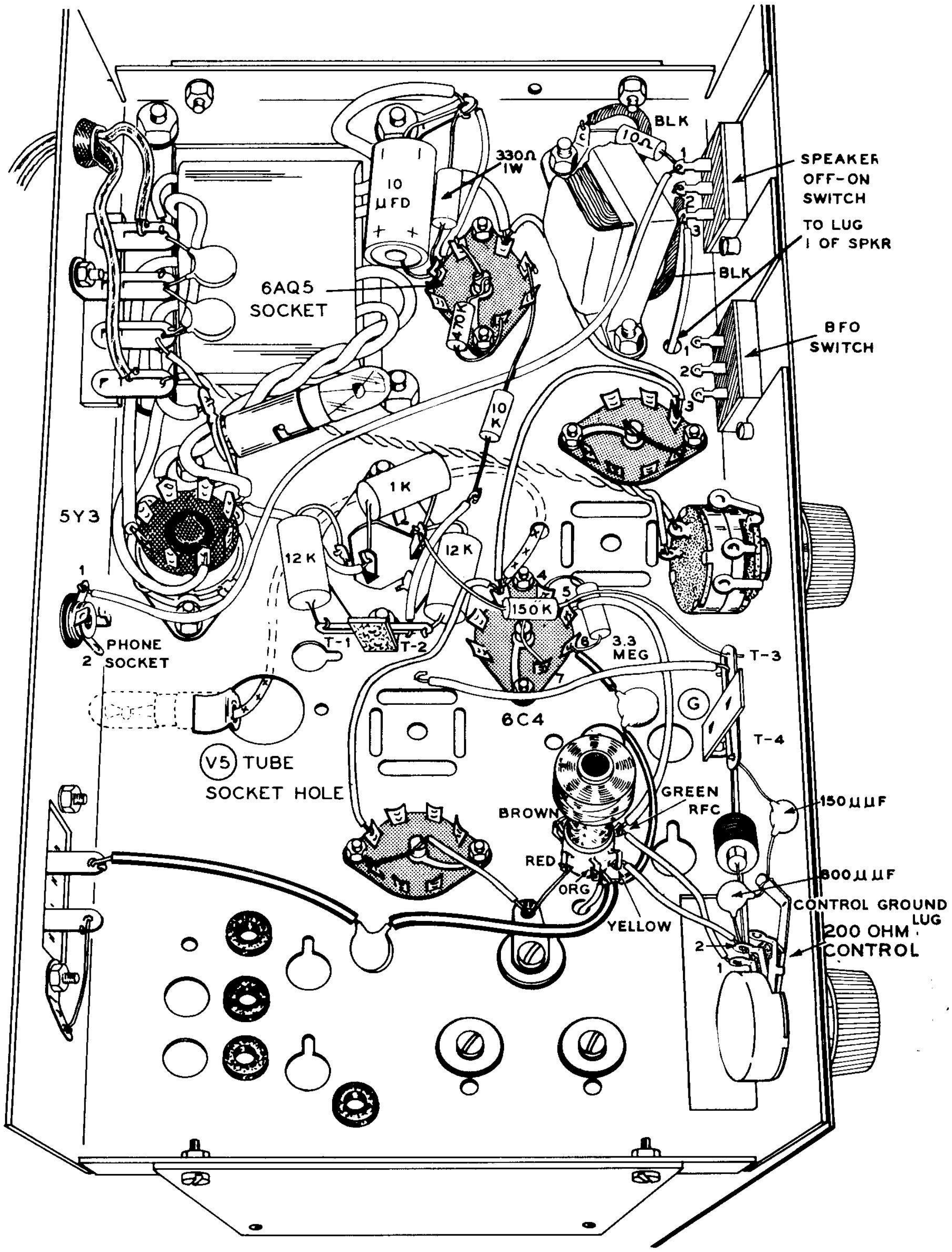

BLK
330Ω
1W
10
μFD
10Ω
SPEAKER
OFF-ON
SWITCH
TO LUG
1 OF SPKR
6AQ5
SOCKET
BLK
BFO
SWITCH
10
K
1K
5Y3
12K
12K
150K
3.3
MEG
PHONE
SOCKET
T-1
T-2
T-3
T-4
6C4
V5 TUBE
SOCKET HOLE
BROWN
GREEN
RFC
150μμF
RED
ORG
YELLOW
500μμF
CONTROL GROUND
LUG
200 OHM
CONTROL

Figure 3S

Refer to Figure 3S for the following steps.

( ) Remove the 1 megohm resistor that is connected across the phone socket.

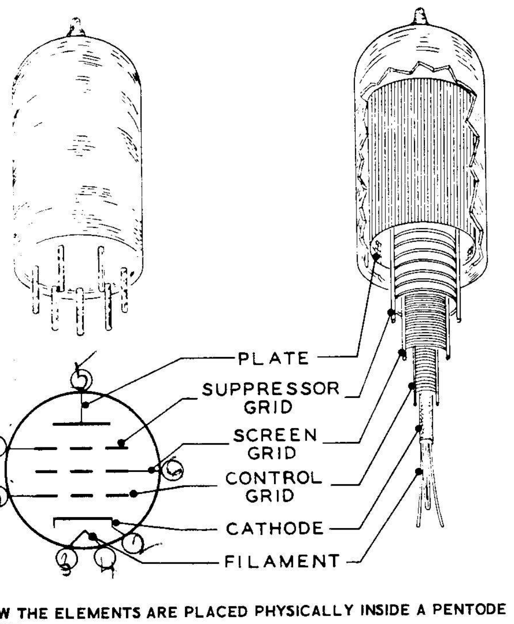
( ) Disconnect both ends of the .005 μfd disc capacitor that is connected to lug 1 of the phone socket. Remove the length of hookup wire that went from this .005 μfd capacitor to dual lug terminal T3.

( ) (P) Connect the positive lead of the 10 μfd 25 volt electrolytic capacitor to lug 2 of the 6AQ5 socket (NS).

( ) (P) Connect the negative lead of this capacitor to the ground lug near the edge of the chassis (NS).

( ) (P) Connect the 330 Ω 1 watt resistor from lug 2 of the 6AQ5 socket (NS) to the ground lug near the edge of the chassis (NS).

( ) (T) Connect a short length of hookup wire from lug 2 of the 6AQ5 socket (S) to the ground lug near the edge of the chassis (S).



HOW THE ELEMENTS ARE PLACED PHYSICALLY INSIDE A PENTODE TUBE.

Figure 3T

( ) (P) Connect one lead of a 470 KΩ resistor to the center lug of the 6AQ5 socket (S). Connect the other lead of the 470 KΩ resistor to lug 7 of the 6AQ5 socket(S).

( ) (T) Insert one lead of a 10 KΩ 1/2 watt resistor through lug 6 to lug 5 of the 6AQ5 socket (S). Use a short length of hookup wire to connect the other end of this resistor to dual-lug terminal T-2(S).

( ) Cut the two black transformer leads to 2". Strip 1/4" insulation from the end of each lead and tin. "Tin" means to melt a small amount of solder on the exposed lead end.

( ) (P) Connect one of the black leads of the output transformer to the #6 solder lug on the mounting foot of the transformer (S).

( ) (P) Connect the other black lead of the output transformer to the center lug of the speaker OFF-ON switch (S).

( ) (P) Connect a 9" length of hookup wire to lug 1 of the speaker OFF-ON switch (NS).

( ) (T) Connect the other end of this 9" wire to lug 1 of the phone socket (S).

( ) (P) Insert the previously connected 2-1/2" length of hookup wire from lug 1 of the speaker through the hole in the chassis near the output transformer, and connect it to lug 3 of the speaker OFF-ON switch (S).

( ) (P) Connect a 10 Ω 1/2 watt resistor from lug 1 of the speaker OFF-ON switch (S) to the ground lug on the mounting foot of the output transformer (S).

BECOMING FAMILIAR WITH THE NEW PARTS

The construction of the PENTODE tube, along with its schematic symbol, is shown in Figure 3T. Physically, the tube is constructed much like the triode tube. The plate of the tube is the outermost element and it may be easily seen through the glass envelope of the tube. Each of the other elements fit inside the plate assembly; each element is made in the form of a tube with the smaller elements placed inside it. The element at the center of the assembly is the heater, which is placed inside of the cathode. A short length of wire connects each of these elements to one of the pins on the base of the tube.

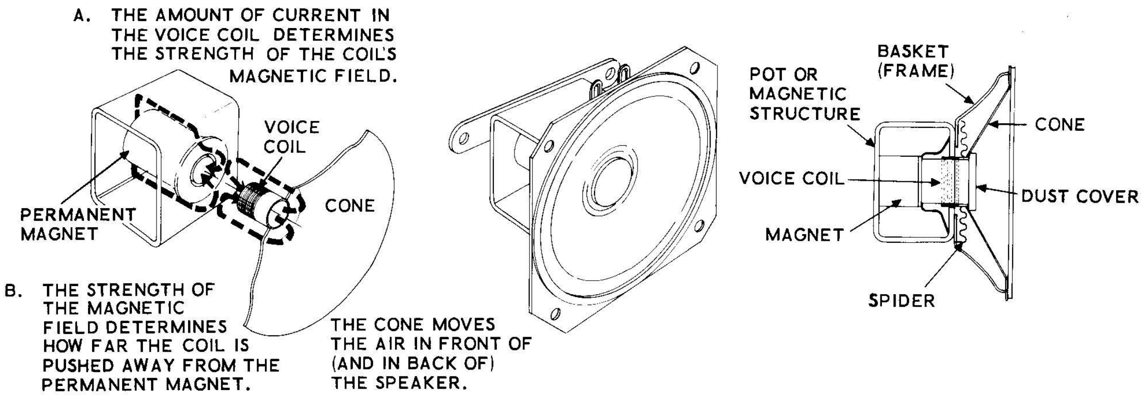


Figure 3U

The construction and operation of the SPEAKER is shown in Figure 3U. The speaker operates somewhat like the meter described in Chapter 2 of the EK-1, in that both make use of the magnetic fields of a coil and a permanent magnet. The magnetic field of the coil, caused by the current through it from the audio signal, pushes against the magnetic field of the permanent magnet which is located at the rear of the speaker. The audio signal from the amplifier is connected to the coil, and the coil is connected to the cone of the speaker. The amount of current in the coil, which changes with the audio signal, determines the strength of the magnetic field around the coil. As the strength of the magnetic field becomes larger and smaller with the changes in the audio signal, the coil pushes back and forth against the magnetic field of the permanent magnet.

The paper cone moves back and forth with the coil causing the air in front of the cone to move; thus the cone moves back and forth in a manner that matches the audio signal passing through the coil. These movements of air from the speaker are the sounds that you hear coming from the speaker.

The following are the main parts of the speaker.

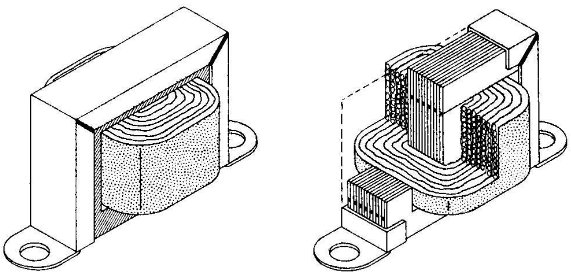
The CONE moves the air in front of the speaker. The dust cover, at the center of the speaker, keeps dust from getting inside the speaker and hampering its performance.

The MAGNET and the POT (or magnetic structure) create the permanent magnetic field.

The SPIDER is used to hold the coil in the center of the opening in the magnetic structure to keep it from rubbing on the pot.

The BASKET (or frame) is used to hold the cone in position.

The construction of the OUTPUT TRANSFORMER is shown in Figure 3V. The core of the transformer, like the power transformer, is made of laminations which are shaped like the letter E and the letter I. These laminations are placed in alternating directions as with the power transformer.



THE INTERNAL CONSTRUCTION OF THE OUTPUT TRANSFORMER.

Figure 3V

The primary winding and the secondary winding of the transformer are wound around the center leg of the core. This allows the magnetic lines of force to flow easily around the coils in both directions. A further explanation of how this output transformer is used in the circuit, is contained in the next lesson on the audio amplifier section of the receiver. Although the coil and the laminations are constructed like the power transformer, this transformer is fastened to the chas-

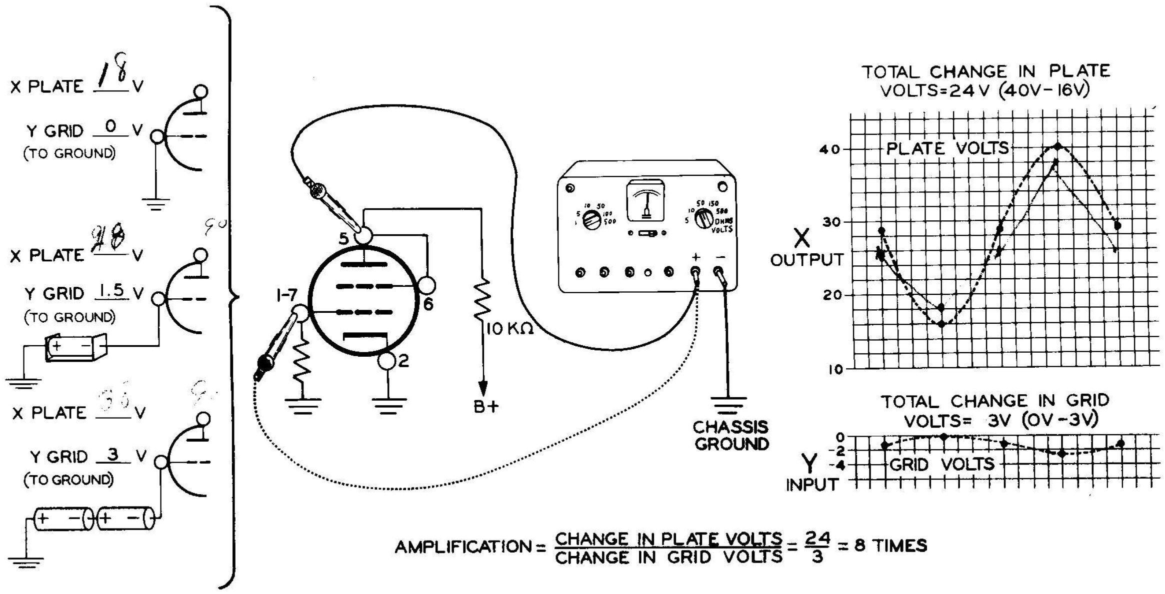


Figure 3W

sis in a different manner. Instead of using bell type covers, a strip of metal is wrapped around the outside edges of the core. Tabs are bent out at the bottom of this strip of metal to provide mounting holes.

EXPERIMENT 1

To show that a triode amplifier, such as those studied in this lesson, amplifies and inverts (or "turns over") the input signal applied to it.

Figure 3W shows the 6AQ5 pentode connected as a triode. The screen grid of the tube, pin 6, has been connected to pin 5 (the plate of the tube). This makes the tube act like a triode (the suppressor grid will not be able to perform in its normal manner).

In this experiment, 1-1/2 volt batteries connected to the grid of the triode will be used to simulate a signal at the grid. Changing the number of batteries (and therefore the voltage) at the grid, changes the plate current just as an AC signal would. The three voltages at the grid (input), indicated by the letter Y, are plotted on Graph Y at the lower right of the meter in Figure 3W. The three voltage readings at the plate (output), indicated by the letter X, are shown in Graph X to the right of the meter.

Only three voltages were applied to the grid of the tube and only three voltages were taken at the plate of the tube. The middle voltage in each of these two waveforms is recorded on the graph three different times in order to simulate a sine wave of AC voltage. The sine wave that each of these two signals represents has been traced on the graph by connecting the dots together.

Since the operating voltages of different circuits usually vary slightly, the voltage readings that you will take in your 6AQ5 amplifier stage will probably differ slightly from the amplifier readings already shown in the graph at X. Notice that each vertical square of Graph X and of Graph Y represents a voltage change of 2 volts. Since this is the case, the output waveform at X, the plate waveform, will show you the actual amount of amplification your amplifier has. The input grid voltage at Y has altered a total of 3 volts. On the plate waveform, the bottom dot is at 16 volts, the center dot is at 29 volts, and the top dot is at 40 volts; this gives us a total voltage change of 24 volts in the plate circuit of the amplifier. Therefore, since a 3 volt change in the grid circuit has given a 24 volt change in the plate, this amplifier must be amplifying the input signal 8 times.

( ) Install the 6AQ5 tube in its socket.

( ) (T) Connect the negative lead of your EK-1 Meter to the chassis of your EK-2 Receiver. Switch the EK-1 Meter to the 100 volt range.

( ) (T) Connect the positive lead of the EK-1 Meter to pin 5 of the 6AQ5 socket.

( ) (T) Connect a short length of hookup wire from pin 1 (S) to the center ground lug (S) of the 6AQ5 socket.

( ) Plug in the EK-2 and turn on the switch. Allow about 1 minute for warmup. The voltage indicated on the EK-1 Meter is the plate voltage for that condition where you have 0 grid volts. Read this voltage on the meter and write it down in the proper space on the chart on Page 33.

( ) Turn off the switch and remove the plug.

( ) Remove the wire connecting pin 1 of the 6AQ5 socket to the center ground lug.

NOTE: In connecting flashlight cells to the grid of the 6AQ5, use either the battery holders from the EK-1 kit or solder hookup wire directly to the cells.

( ) (T) Connect the negative lead of a flashlight cell to pin 1 of the 6AQ5 (S). Connect the positive lead of this flashlight cell to the chassis of the EK-2 (S).

( ) You now have applied a grid voltage of -1-1/2 volts to the 6AQ5 amplifier. Plug in your EK-2 Receiver and turn on the switch. Note the reading on the EK-1 Meter and mark it down in its proper place on the chart.

( ) Turn off the EK-2 and remove the plug. Now disconnect the negative lead of the flashlight cell from pin 1 of the 6AQ5.

( ) (T) Connect a second flashlight cell in series with this first flashlight cell, by connecting the negative lead of the new cell to pin 1 of the 6AQ5 socket (S). Connect the positive lead of the new cell to the negative lead of the first cell (S).

( ) Plug in the EK-2 and turn on the switch.

( ) You now have placed -3 volts on the grid of the 6AQ5. Note the reading on the EK-1 Meter and mark it down in its proper square on the chart. Turn off the EK-2 and remove the plug.

( ) Disconnect the two batteries from the 6AQ5 tube and from each other.

( ) Now mark a dot for each of your voltage readings in the proper positions in waveform X of Figure 3W. Mark the dot that represents the middle voltage reading down three times just as in the waveform now indicated on Graph X. Now connect your five dots together to give you the correct simulated sine wave for your amplifier stage.

( ) Now find the amplification of your circuit by dividing your output (change in plate volts) signal by your input (change in grid volts = 3 volts) signal.

EXPERIMENT 2

Listening tests with the regenerative receiver to show the difference between triode and pentode operation.

Refer to Figure 3X for the following steps.

( ) Remove the short length of wire that connects lug 2 of the 6AQ5 socket to the ground lug.

( ) Disconnect the 10 KΩ 1/2 watt resistor from lugs 5 and 6 of the 6AQ5 socket. Disconnect and remove the length of hookup wire that now connects from the 10 KΩ resistor to dual lug terminal T-2.

( ) (P) Cut the blue lead of the audio output transformer to 2" and tin. Connect this blue lead to lug 5 of the 6AQ5 socket (NS).

( ) (P) Connect a .005 μfd disc capacitor from lug 5 (NS) to lug 6 (NS) of the 6AQ5 socket.

( ) (T) Use a 3" length of hookup wire to connect lug 6 (S) to lug 5 (S) of the 6AQ5 socket.

( ) (P) Connect the red lead of the audio output transformer to the triangular marked lug of the electrolytic filter capacitor.

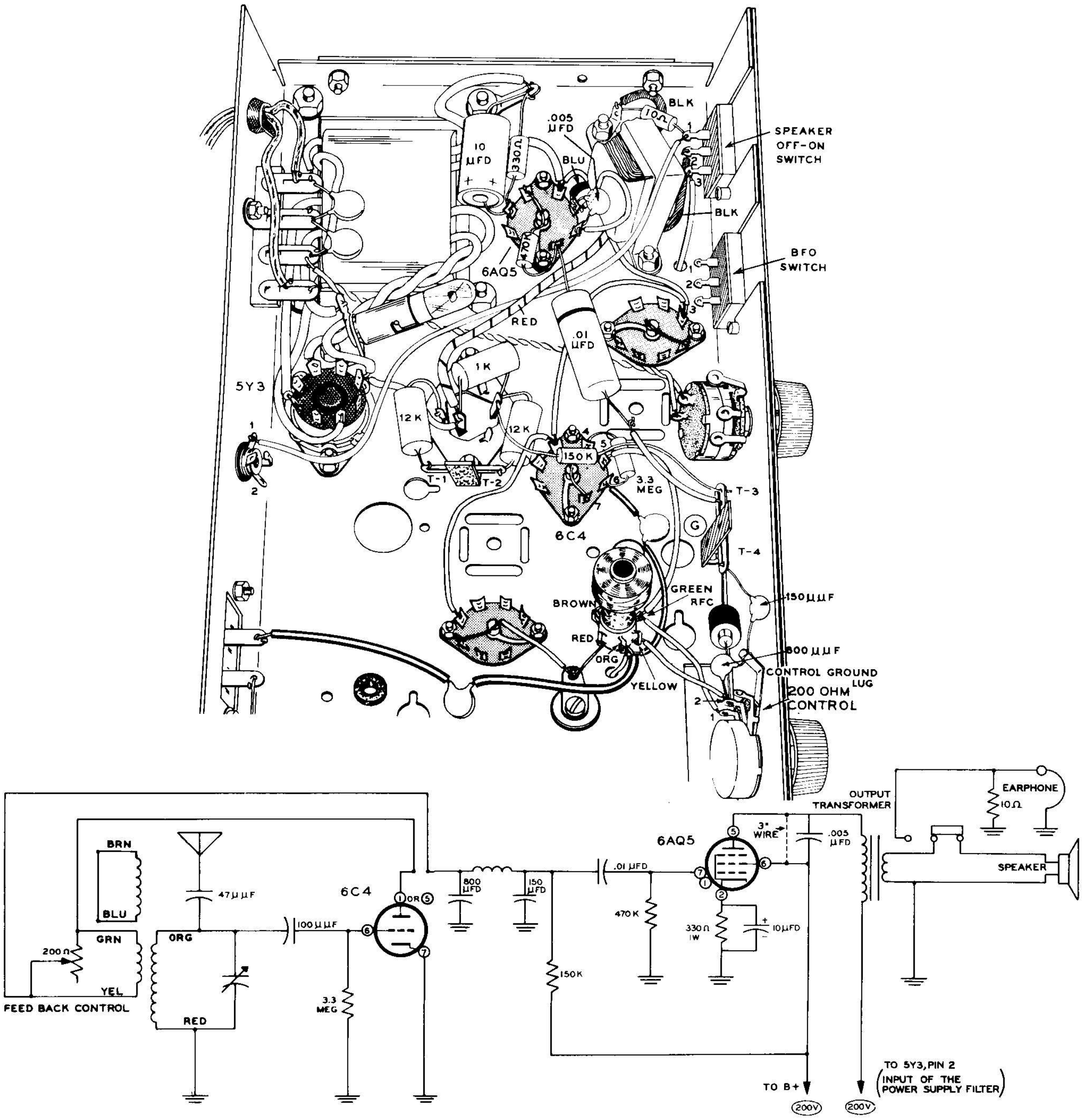


Figure 3X

(✓) Connect one lead of the .01 μfd tubular capacitor to the length of wire coming from terminal T-3 (S). Connect the other end of this tubular capacitor to pin 7 of the 6AQ5 (S). Place this capacitor down against the chassis.

( ) Plug in the 6C4 tube.

NOTE: The 6AQ5 amplifier is now connected as a triode as it is shown in the schematic of Figure 3X. The regenerative receiver from Lesson IX of Basic Radio-Part 1 is now connected through this triode amplifier to the speaker.

( ) Make sure that the speaker switch is in the ON position. Connect your antenna and ground lead to the terminals at the rear of the EK-2 chassis.

( ) Plug in the line cord and turn on the switch. You should now be able to tune in stations and hear them on the speaker. Note the loudness of these stations.

( ) Turn off the switch and pull out the plug.

( ) Disconnect the 3" wire from pin 5 of the 6AQ5 socket.

( ) (P) Now connect this end of the 3" wire to the lug of the electrolytic filter capacitor that is marked with a square ■ (S). Route this wire along the chassis.

( ) This last step has connected the screen of the 6AQ5 amplifier socket to a separate B+ supply voltage, thus changing it over from triode operation to pentode operation. Now plug in the EK-2 and turn on the switch.

Notice how much louder the stations are now, since you have the extra gain of the pentode. This completes Experiment 2.

DISCUSSION

In Experiment 1 you used the flashlight cells to simulate an AC signal at the grid (input) of the triode amplifier stage. You then plotted the output at the plate of the amplifier in Graph X. The difference between Graph X and Graph Y showed you two things; it showed you that the input signal was amplified about eight times, and it also showed you the input signal was inverted, or turned over, from the way that it appeared at the grid of the amplifier. Each grid voltage marked in Graph Y has the voltage at the plate of the tube, at that same time, marked directly above it in Graph X. As a result, the waveform at the output of the amplifier (X), is shown directly above the waveform at the input of the amplifier (Y).

In Experiment 2 you connected the output of the amplifier to the output transformer, and therefore to the speaker. When you disconnected the wire from pin 2 of the tube to ground, you put the cathode bias resistor back in the circuit, creating a bias for this tube. By connecting a coupling capacitor to the output of the regenerative receiver, you were able to hear radio stations through the speaker of your EK-2.

First, you tuned in stations with the 6AQ5 amplifier connected as a triode. Next you reconnected the 6AQ5 amplifier as a pentode, and tuned in the stations again; this gave you a much louder signal on all stations. This experiment gave you an actual, practical, demonstration of the increase in gain in a pentode amplifier compared to a triode amplifier.

LESSON III
QUESTIONS

1. The grid of a tube controls the flow of electrons, just like a valve controls the flow of water in a pipe.
2. A large negative voltage on the grid of the tube stops the flow of electrons.
3. Bias voltage is a small amount of voltage applied between the grid and the cathode of a tube.
4. Bias is used to adjust the tube to the best amplification without distortion.
5. An amplifier stage, such as the ones studied in this lesson, both increases and invert the signals presented to its grid.
6. When the tetrode tube was developed, it decreased the interelectrode capacity between the grid and the plate of the triode.
7. The main disadvantage of the tetrode tube is its secondary [illegible].
8. In a pentode a third element called a suppressor grid has been added.
9. This third grid of the pentode is used to (increase, decrease) secondary emission.
10. In a speaker the magnetic field of the voice [illegible] pushes against the magnetic field of the permanent magnet.

LESSON IV

WHAT DOES THE AUDIO SECTION OF THE RECEIVER DO?

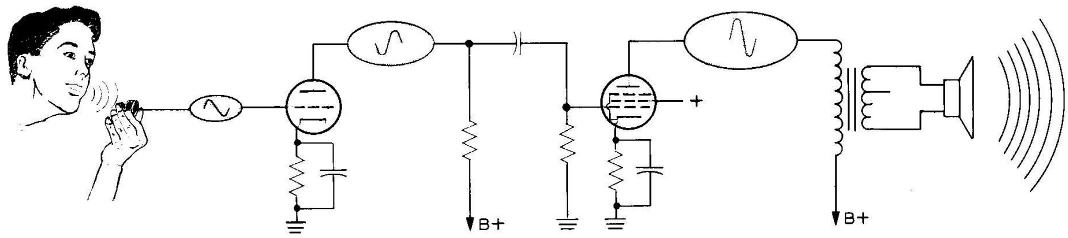


Figure 4A

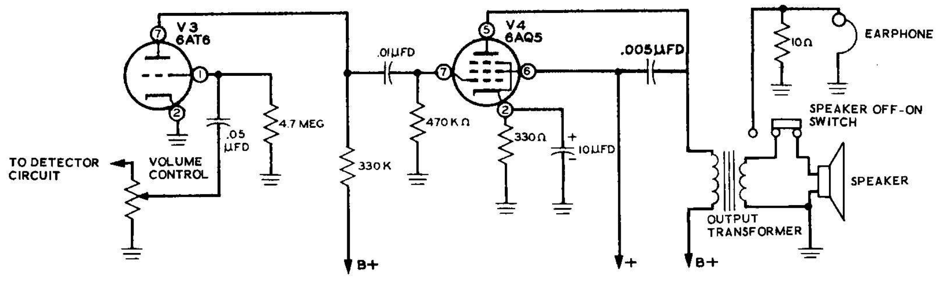
In learning about the audio section of your receiver, you will put to use all of the information learned in the last three lessons. The audio output transformer will call to mind your lesson on transformers. The triode voltage amplifier and the pentode output amplifier will put your knowledge of amplifiers to use. The power supply that you studied in Lesson II will supply all the necessary voltages to operate the audio section of the receiver.

This lesson is intended to show you how the audio section of your receiver operates. It will show you that the audio section of your receiver is an audio amplifier, much like the audio amplifier in a Hi-Fi system.

The audio section of your receiver, shown in the Schematic of Figure 4B, extends from the volume control, to the speaker of the receiver. Review for a moment just what an audio signal is. In Lesson II of Basic Radio-Part 1, you were instructed that an audio signal (AF) was sound in the form of an AC current of 20 cycles to 20,000 cycles per second. Then you were told that this audio frequency signal was used to control the amount (modulate) of radio frequency (RF) signal sent out from the transmitter. Lesson III of Basic Radio-Part 1 informed you that this audio signal was removed (detected or demodulated) from the radio frequency signal in the detector circuit. This signal, received from the detector circuit, is an audio signal. The audio amplifier receives this signal, amplifies it, and changes it back into sound by applying it to the speaker.

An audio amplifier, whether it is in a receiver or in a Hi-Fi amplifier, does the same job, it amplifies the signal and then applies it to the speaker. A Hi-Fi amplifier would compare to the amplifier of a receiver just like an expensive car would compare with one of the lower priced cars. A Hi-Fi amplifier is an audio amplifier that has been designed to give the best possible reproduction of sound.

The quality of an audio amplifier depends on how faithfully it reproduces the audio signals that are presented to it. How faithfully an audio amplifier reproduces the signal presented to it depends on the frequency response of the amplifier and the distortion created in the signal by the amplifier. It would be well at this time to explain these two terms briefly.



THE AUDIO AMPLIFIER CIRCUIT OF THE EK-2B RECEIVER.

Figure 4B

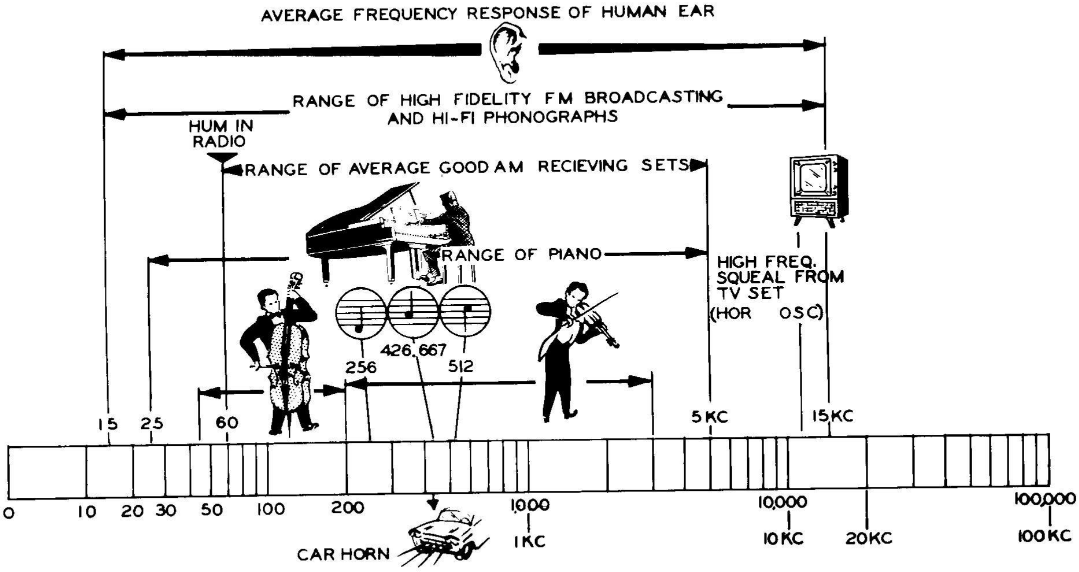


Figure 4C

Frequency response - The average human ear hears frequencies from about 20 cycles to approximately 15,000 cycles. Each sound that is created has its frequency or group of frequencies. The frequency response of an amplifier tells us how many of these frequencies the amplifier will be able to reproduce. The audio amplifier of a radio receiver may be able to reproduce the range of frequencies from about 100 cycles to approximately 6000 cycles. The expensive parts used in a Hi-Fi amplifier are needed to reproduce the low frequencies that approach 20 cycles and the high frequencies that approach 20,000 cycles.

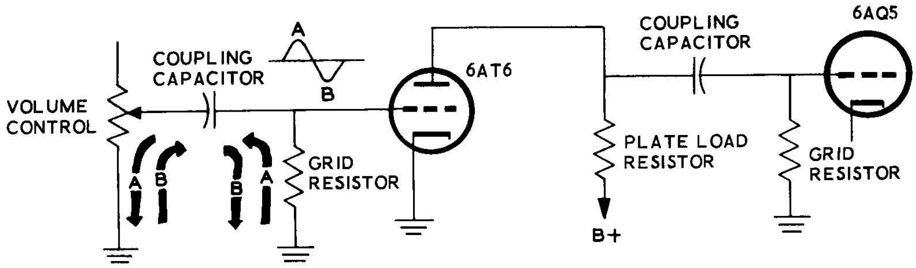
Distortion - Distortion, generally speaking, is caused by any part, or circuit, in the amplifier that changes the original sound. Any hums or buzzes that you hear in a radio receiver are types of distortion. Any audio waveform that is bent out of its original shape, either by the amplifier or by the speaker, would be distorted.

Thus far, Lesson IV has described the general considerations of audio amplifiers. Now refer to Figure 4B, which is the schematic of the audio section of your receiver. The three stages of your audio circuitry are the 6AT6 voltage amplifier, the 6AQ5 power amplifier, and the speaker.

Trace the path that the audio signal takes as it passes through the amplifier circuit. The audio signal is received from the detector circuit at the volume control, and the volume control applies a part of the signal to the grid of the voltage amplifier, the 6AT6. The signal is amplified by the voltage amplifier and passes on to the grid of the 6AQ5. The 6AQ5 amplifies the signal again and couples it to the primary of the output transformer. The output transformer couples the signal to the speaker where it is changed into sound.

THE VOLTAGE AMPLIFIER

Figure 4D is the schematic diagram of the voltage amplifier circuit. The name of each part is also marked in the schematic so that the part names will become familiar to you. The volume control is used to select the desired amount of signal voltage and apply it to the voltage amplifier grid. The complete signal would be coupled to the amplifier if the arm were near the top of the volume control. If the arm were at the bottom of the volume control, it would be connected to ground and no signal at all would be sent to the voltage amplifier. In between these two extremes, the volume control acts like an adjustable voltage divider and selects either a larger or a smaller portion of the audio signal.



THE NAMES OF THE PARTS USED IN THE VOLTAGE AMPLIFIER CIRCUIT.

Figure 4D

The audio signal is coupled to the grid of the voltage amplifier through a coupling capacitor. It is the job of the coupling capacitor to allow the AC signal voltage to appear on the grid, while it blocks the DC voltage from previous circuits from appearing on the grid. As the input signal is applied to it, the coupling capacitor charges and discharges slightly through the volume control and the grid resistor. This charging and discharging action causes the input signal to appear across the grid resistor of the voltage amplifier. The input signal that appears at the top of this grid resistor is applied directly to the grid of the tube.

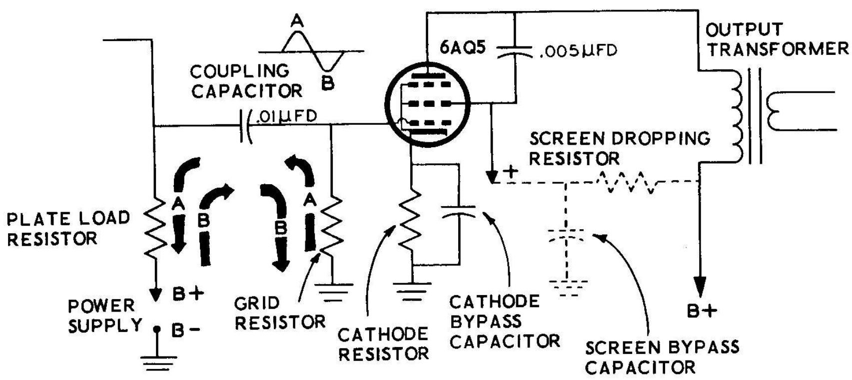
The current flowing to the plate circuit of the 6AT6 is controlled by the signal voltage at its grid. This plate current then flows through the plate load resistor, causing the amplified signal to appear across it. This amplified signal is then coupled through the .01 μfd coupling capacitor to the grid circuit of the 6AQ5.

POWER AMPLIFIER

The last amplifier stage in an amplifier (in this receiver the 6AQ5 stage) is usually called the power amplifier because it supplies the power to operate the speaker. The audio signal is coupled to the grid of the power amplifier through the .01 μfd coupling capacitor from the plate circuit of the voltage amplifier. The signal passes through this coupling capacitor in the same manner that is passed through the coupling capacitor of the voltage amplifier circuit. The coupling capacitor charges and discharges a slight amount through the grid resistor, through the power supply, and through the plate load resistor of the voltage amplifier. This charging and discharging action places the signal across the grid resistor of the 6AQ5, which causes it to appear on the grid of the tube.

It is the purpose of the cathode resistor to provide bias for the tube. This DC bias keeps the

THE POWER AMPLIFIER



THE NAMES OF THE PARTS USED IN THE POWER AMPLIFIER CIRCUIT.

Figure 4E

tube operating between the two extremes of its operating range. The negative extreme would be where the input signal makes the tube stop conducting, thus distorting the output waveform. (When negative voltage stops a tube from conducting in this manner, the tube is usually referred to as being "cut off.") The positive extreme of the tubes operating range would be that point where electrons start to flow into the control grid circuit, again distorting the output waveform.

The bias of a tube must be a DC voltage. If the bias of the tube were allowed to move about with the AC input voltage, it could easily cause the tube to wander out of its proper operating range. It is the purpose of the cathode bypass capacitor to allow the AC current to pass around the cathode resistor without disturbing the DC voltage that appears across it.

The screen grid of the 6AQ5 power amplifier tube is connected to a positive voltage in the power supply. The screen grid resistor and the screen bypass capacitor are shown, dotted in, connected to the screen of the tube, because the screen of the tube is so often connected in this manner. The screen grid resistor drops the B+ voltage to a lower voltage than appears on the plate. The screen bypass capacitor connects to ground any AC currents that may appear on the screen grid of the tube.

The plate of the 6AQ5 connects through the primary of the output transformer to B+. The output transformer steps the voltage down to the proper voltage needed to operate the speaker. The output transformer also keeps the DC voltage in the plate circuit of the 6AQ5 from appearing at the speaker since DC current does not pass through a transformer. The .005 μfd capacitor that connects from the plate to the screen of the 6AQ5 is used to help give the correct tone to the output signal.

Figure 4F shows the speaker and earphone circuits of the receiver. The switch that is connected to the secondary of the output transformer switches the output signal either to the earphone or to the speaker. The earphone and the speaker both convert the signal into sound. A 10 Ω resistor is connected across the earphone so that either position of the switch will present about the same load to the secondary of the output transformer.

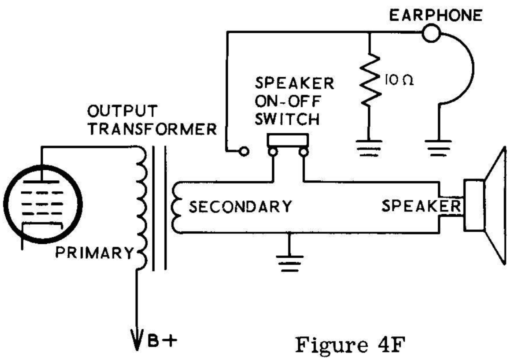


Figure 4F

When the signal is applied to the earphone it causes the crystal inside the earphone to vibrate at the signal frequency. The vibrating crystal moves a small amount of air inside the earphone which you hear in your ear as sound.

The signal from the secondary of the output transformer is applied to the voice coil inside the speaker, thus creating a magnetic field around the coil. The magnetic field of this coil pushes against the magnetic field of the permanent magnet which is connected to the frame of the speaker. The coil of wire is connected to the paper cone of the speaker and the field of this coil pushes against the permanent magnet. This moves the paper cone at the same rate as the input signal supplied from the transformer, creating sounds. The speaker moves a much larger volume of air than the earphone, and hence, can be heard by many people at once in the area in which it is operating.

Figure 4G shows a "block diagram" of the EK-2B Receiver as it will appear at the end of this lesson. Block diagrams are often used to describe electronic equipment to present a quick, simple description of the type of circuits used, and the manner in which they are connected together.

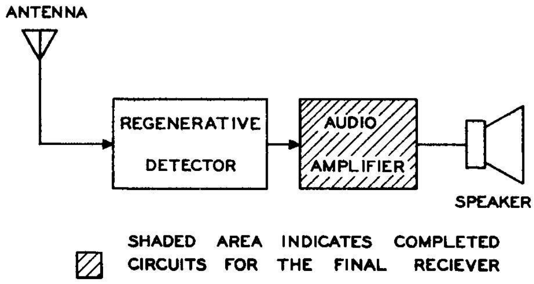


Figure 4G

SUMMARY

The audio section of your receiver is that section between the volume control and the speaker. The quality of the signal amplified by this audio amplifier depends on how faithfully it reproduces the signals presented to it. The main measurement of the quality of reproduction of the amplifier is the frequency response of the amplifier, and how cleanly it reproduces the signal. The smaller the distortion of the amplifier, the cleaner it will amplify the signals presented to it.

Signal is coupled through the coupling capacitor from the volume control to the 6AT6 voltage amplifier. The slight charge and discharge action of the coupling capacitor recreates the signal in the grid resistor of the 6AT6 and thus, applies it to the grid of the tube.

The amplified signal from the 6AT6 voltage amplifier couples through the .01 μfd coupling capacitor to the grid of the 6AQ5 power amplifier. The cathode resistor of the power amplifier creates DC bias for the tube while the cathode bypass capacitor bypasses the AC signal around the cathode resistor. The screen of the 6AQ5 is returned to B+ in the power supply. The plate of the 6AQ5 couples the signal to the output transformer. The output transformer couples the signal to either the earphone or to the speaker, which converts the signal back into sound.

TESTING THE AUDIO AMPLIFIER

To demonstrate the amplification of the 6AT6 amplifier stage, and to use the audio amplifier as a public address amplifier.

PARTS REQUIRED

1 7-lug tube socket
2 3-48 screws
2 3-48 nuts
1 IF transformer (part #52-5)
1 Transformer clip
1 330 KΩ resistor (orange-orange-yellow)
1 4.7 megohm resistor (yellow-violet-green)
1 .05 μfd 200 volt capacitor
1 .01 μfd 400 volt capacitor (now connected to lug 7 of V4)
1 0.1 μfd 200 volt capacitor
1 6AT6 tube
1 Earphone (received with Basic Radio-Part 1)
1 EK-2 chassis

BECOMING FAMILIAR WITH THE NEW PARTS

NOTE: Although the IF transformer is a new part, it will not be explained until it is used in the circuit of a later lesson.

PREPARING THE CHASSIS

Refer to Figure 4H for the following steps.

( ) Mount 7-lug tube socket V5, using two 3-48 screws and two 3-48 nuts. Be sure to mount the socket so that the pins face as shown in Figure 4H.

( ) Mount the IF transformer (#52-5) in position behind the volume control as shown in Detail 4J. Be sure that the side of the transformer with two lugs faces toward tube socket V3. Hold the transformer in place with one hand and push the mounting clip through from the bottom until each side engages.

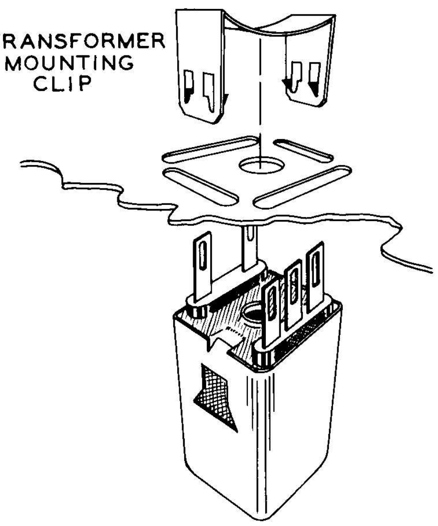


Figure 4J

( ) Disconnect the .01 μfd tubular capacitor from lug 7 of tube socket V4 and from the wire to terminal T-3.

( ) Ⓟ Connect a length of hookup wire from lug 4 of tube socket V3 (S) to lug 1 of the volume control (S).

( ) Ⓟ Insert one lead of a 4.7 megohm 1/2 watt resistor through lug 2 to the center post of tube socket V3. Now solder both connections (S).

( ) Ⓟ Connect the other end of this resistor to lug 1 of tube socket V3 (NS).

( ) Ⓟ Connect a 330 KΩ 1/2 watt resistor from lug 7 of tube socket V3 (NS) to lug 1 of the IF transformer (NS).

( ) Ⓟ Connect a short length of hookup wire from lug 1 of the IF transformer (S) to the nearest power supply filter capacitor lug, the one marked with the square ■ (S).

( ) Ⓟ Connect a .01 μfd 400 volt tubular capacitor from lug 7 of tube socket V3 (S) to lug 7 of tube socket V4 (S).

( ) Ⓟ Connect a .05 μfd 200 volt capacitor from lug 1 of tube socket V3 (S) to lug 2 of the volume control (S). Use sleeving on the lead connected to the volume control.

( ) Install the 6AT6 tube, V3, in its socket.

The audio amplifier circuit is now hooked up and ready for operation.

EXPERIMENT 1

To demonstrate the amplification present in the 6AT6 amplifier stage.

( ) Ⓣ Connect one lead of the .1 μfd capacitor to the wire connected to terminal T-3. Connect the other capacitor lead to lug 7 of tube socket V4 (S). (This lead is now shown going to lug 1 of V3.)

( ) Plug in your receiver and turn on the switch. Now tune in a station and notice how loud it sounds in the speaker.

( ) Turn the switch off and pull the plug of the receiver. Now disconnect the free lead of the .1 μfd capacitor from pin 7 of tube socket V4 (this is the capacitor that is connected to terminal T-3).

( ) Ⓣ Now connect this lead to lug 1 of V3 (S).

( ) Plug in the receiver and turn on the switch. Notice how much louder the stations are now that the 6AT6 amplifier is connected in the circuit.

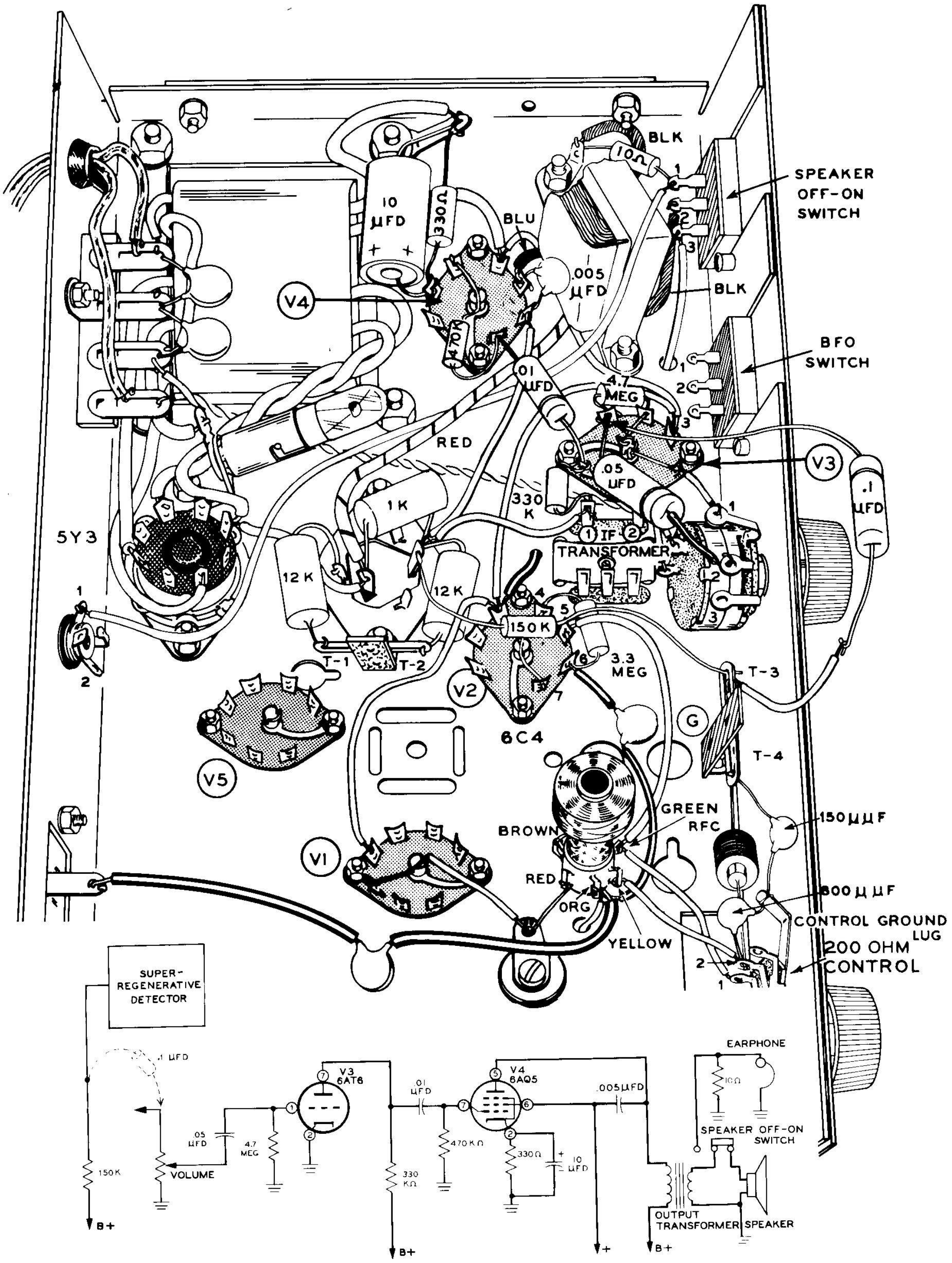

SPEAKER OFF-ON SWITCH
BLK
10Ω
10 μFD
330Ω
BLU
.005 μFD
V4
470K
BLK
BFO SWITCH
.01 μFD
4.7 MEG
RED
V3
.1 μFD
.05 μFD
1K
330 K
IF TRANSFORMER
5Y3
12 K
12 K
150 K
T-1
T-2
3.3 MEG
T-3
V2
6C4
G
T-4
V5
GREEN
RFC
BROWN
150 μμF
V1
RED
500 μμF
ORG
CONTROL GROUND LUG
YELLOW
200 OHM CONTROL
SUPER-REGENERATIVE DETECTOR
.1 μFD
V3 6AT6
.01 μFD
V4 6AQ5
.005 μFD
EARPHONE
10Ω
.05 μFD
4.7 MEG
470 KΩ
330Ω
10 μFD
SPEAKER OFF-ON SWITCH
150K
VOLUME
330 KΩ
OUTPUT TRANSFORMER
SPEAKER
B+

Figure 4H

( ) Turn the receiver off and pull out the plug. Now disconnect this .1 μfd capacitor lead from lug 1 of tube socket V3.

( ) Ⓣ Now connect this lead to lug 3 of the volume control (S).

( ) Turn on the receiver and plug it in. Now notice the action of the volume control -- turning the volume control up and down increases and decreases the loudness of the signal in your speaker. Turn the receiver off.

EXPERIMENT 2

To use the audio amplifier as a public address (PA) amplifier.

Refer to Figure 4K for the following steps.

( ) Unplug the receiver.

( ) Disconnect the wire connected to lug 1 of the earphone socket.

( ) Disconnect the .1 μfd capacitor connected to lug 3 of the volume control.

( ) Ⓣ Now connect a wire from lug 1 of the earphone socket (S) to lug 3 of the volume control (S).

( ) Plug the earphone into the earphone socket.

( ) Plug in the receiver and turn on the switch. Now speak into the earphone and notice that you can hear your voice coming from the speaker. The volume control will control how loud your voice comes from the speaker.

( ) Turn the receiver off, and pull the plug.

( ) Return the receiver to its original condition (before this experiment) by disconnecting the wire from lug 1 of the earphone socket to lug 3 of the volume control.

( ) Ⓟ Reconnect the wire (from the speaker OFF-ON switch) formerly connected to the phone socket (S).

DISCUSSION

The first experiment in Lesson IV gave you a practical demonstration of the different stages of amplification in your receiver's audio amplifier section. It also demonstrated one of the practical ways of testing an amplifier. In this method, a noise or a signal is introduced at the grid of the last tube (or "output" stage). If this sound is heard in the speaker, then the same noise is introduced at the grid of the previous amplifier stage. When you come to a grid where no sound is heard, then you know that the fault lies between that grid and the last grid where you were able to hear the sound.

Experiment 2 demonstrated one of the many common uses of audio amplifiers, the public address amplifier. This same amplifier could also reproduce the output of a crystal phonograph arm if it were connected to a phonograph.

This lesson, Lesson IV, has demonstrated the audio amplifier section of your receiver. In Lesson V, you will study the circuit that sends the signal to the audio amplifier section, the detector circuit.

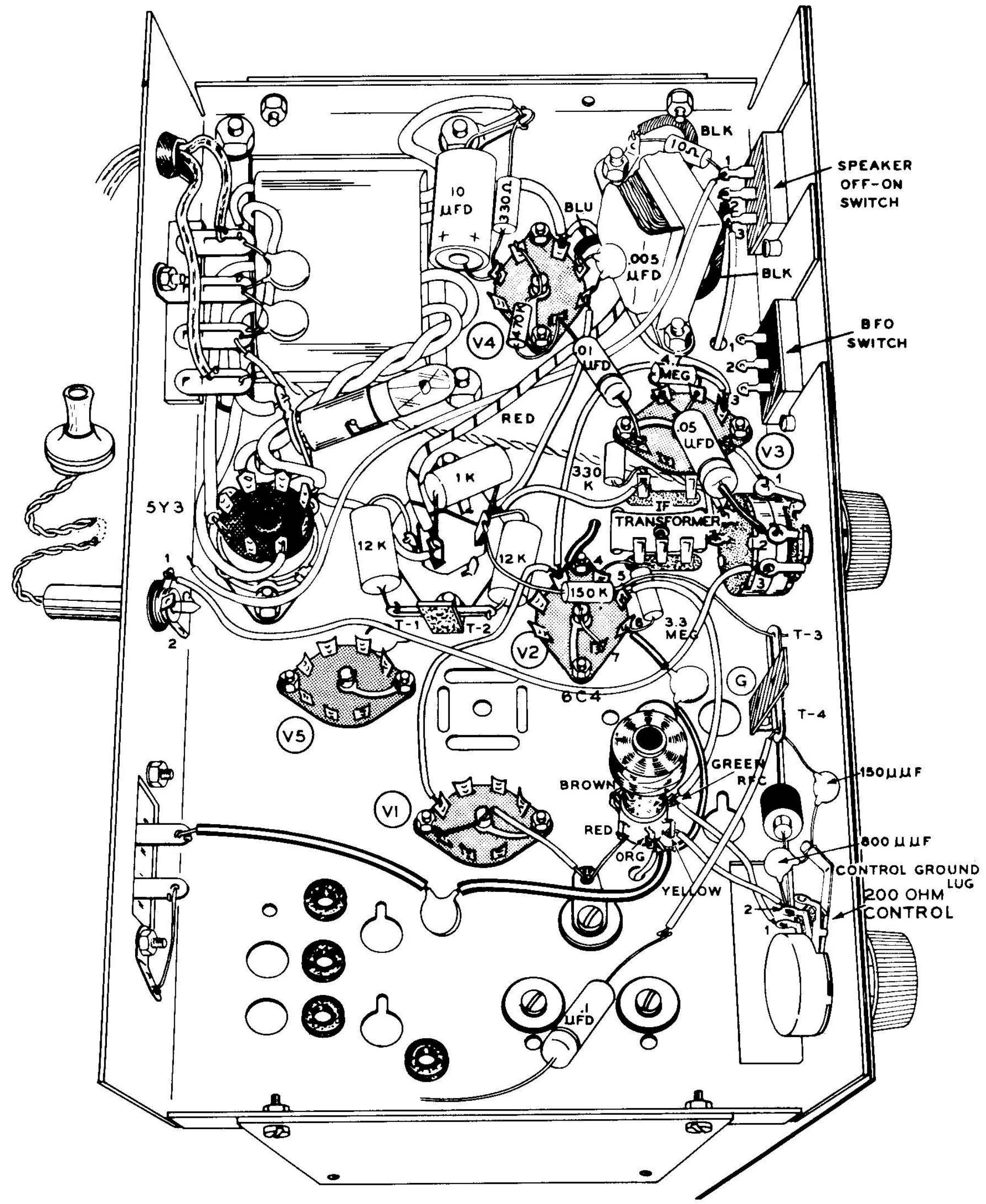

SPEAKER
OFF-ON
SWITCH
BFO
SWITCH
BLK
10Ω
BLU
10
μFD
330Ω
.005
μFD
BLK
V4
.01
μFD
4.7
MEG
RED
.05
μFD
V3
330
K
1K
IF
TRANSFORMER
5Y3
12 K
12 K
150 K
3.3
MEG
T-1
T-2
T-3
T-4
V2
6C4
G
V5
GREEN
RFC
150μμF
BROWN
V1
RED
ORG
YELLOW
800 μμF
CONTROL GROUND
LUG
200 OHM
CONTROL
.1
μFD

Figure 4K

LESSON IV

QUESTIONS

1. An audio amplifier makes the audio signal (larger, smaller), and then applies it to the speaker.

2. On what does the quality of an audio amplifier depend?

3. The term "frequency response" means how wide a band of vibration an amplifier is able to reproduce without distortion.

4. The name of the circuit that contains the 6AT6 triode amplifier is the Voltage amplifier.

5. The audio signal is coupled to the grid of the voltage amplifier through a coupling capacitor

6. The power amplifier in the EK-2B Receiver uses a type 6AQ5 tube.

7. It is the purpose of the cathode bypass capacitor to allow the AC to pass around the cathode resistor.

8. The output transformer steps the voltage (up, down) to the level needed to operate the speaker.

9. Both the earphone and the speaker are used to convert the audio signal into vibrations.

LESSON V

HOW THE DETECTOR CIRCUIT OPERATES

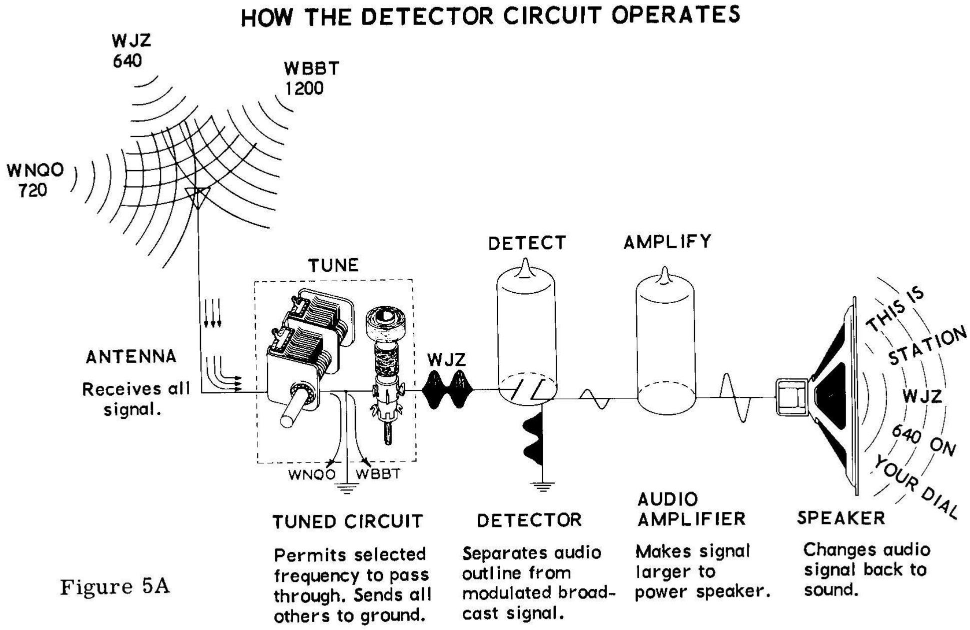


Figure 5A

Basic Radio- Part 1 instructed you that there were three basic requirements of a broadcast receiver; it must tune, detect, and amplify. The previous lesson, Lesson IV, showed you how the audio amplifier section of your receiver operates. This lesson will instruct you in the next basic need of your receiver, detecting the radio signal. The third basic requirement of a receiver, tuning, will be covered in a later lesson.

A review of what you learned about the detector circuit in Lesson IV of Basic Radio-Part 1 is in order at this time. First, refer to the modulated broadcast signal, shown in Figure 5B, that is received by the detector circuit. You will no doubt recall that the audio signal is carried to your receiver by the radio frequency signal, since it is impractical to broadcast a pure audio signal. The radio frequency signal is needed to carry the audio information through the air to your receiver. This audio signal appears in the RF signal in the form of the swells, shown in Figure 5B.

It is the purpose of the detector circuit to remove this audio signal from the RF signal and present it to the audio amplifier.

The audio signal is necessary because the speaker or earphone will not respond to an RF signal.

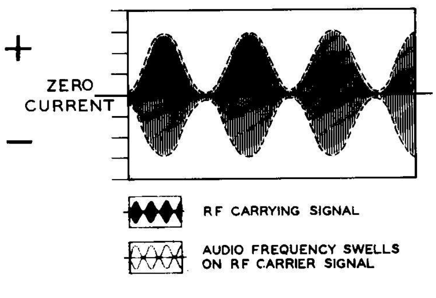
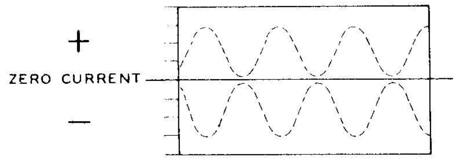


Figure 5B

Figure 5C shows the audio outline of the modulated broadcast signal. A careful examination shows that at the same time the signal is swelling in the positive direction, it also swells in the negative direction. These two opposing swells would cancel each other out, because they are exactly equal and opposite.



AMPLITUDE CHANGES IN THE SIGNAL ARE DUPLICATED, PLUS AND MINUS, RESULTING IN CANCELLATION.

Figure 5C

The job of the detector circuit consists in rectifying and filtering the modulated broadcast signal that is applied to it. Rectifying, which removes one-half of the signal, prevents the positive and negative swells from cancelling each other out. The filtering removes the RF signal itself, leaving only the audio shell of the RF signal to be amplified by the audio amplifier.

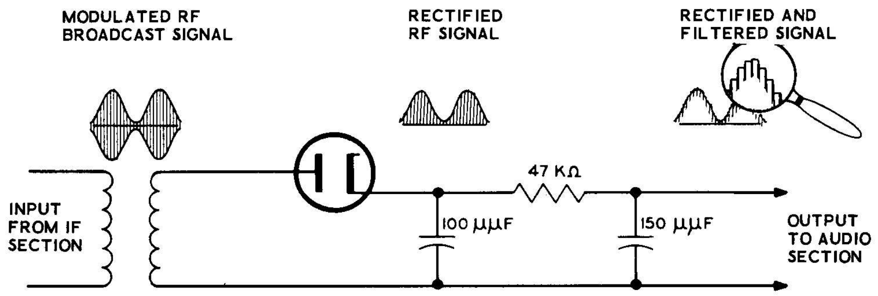
Figure 5D shows the detector circuit in operation. The modulated broadcast signal is received through the transformer from the previous circuit. Since current can flow in only one way through a diode, only one-half of this signal appears at the other side of the diode rectifier. Thus, the first need of a detector circuit has been accomplished, one-half of the input signal has been eliminated, now there are no equal and opposite swells to cancel each other out.

The rectified signal from the diode is then applied to the filter circuit. The filter circuit removes the radio frequency signal, leaving only the audio shell to be applied to the audio amplifier section. The filter circuit looks much like the filter circuit that was used in the power supply of Lesson II, only now the size of the capacitors is much smaller. Since these filter capacitors are very small, they can only flatten out the short spaces in between the cycles of the RF signal. Very large filter capacitors, like those used in the power supply section, can store up a great many electrons, and thus will slowly discharge across the far apart peaks of the low frequency signal from the power line.

The small capacitors used in this filter circuit can only hold a small number of electrons; thus, although they can discharge slowly between the close together peaks of the radio frequency signal, they will not hold enough electrons to flatten out the spaces between the far apart peaks of the audio signal. The waveform shown above the filter in Figure 5D shows how the filter circuit fills in the spaces between the RF peaks of the waveform. The small pulses shown on top of the filtered waveform are actually so small that they cause no difficulty whatsoever in the audio amplifier circuits.

Figure 5E is divided into four parts; part (4) shows the final detector circuit of your EK-2B Receiver as it appears in the schematic. Parts (1), (2), and (3) show that this circuit is actually only slightly changed from the detector circuit you studied in Figure 5D. In all four circuits the small capacitor across the transformer winding tunes the IF transformer; its function will be explained in more detail when the IF circuits are studied in later lessons.

Part (1) of Figure 5E shows the same circuit you studied in Figure 5D. In Part (2) of Figure



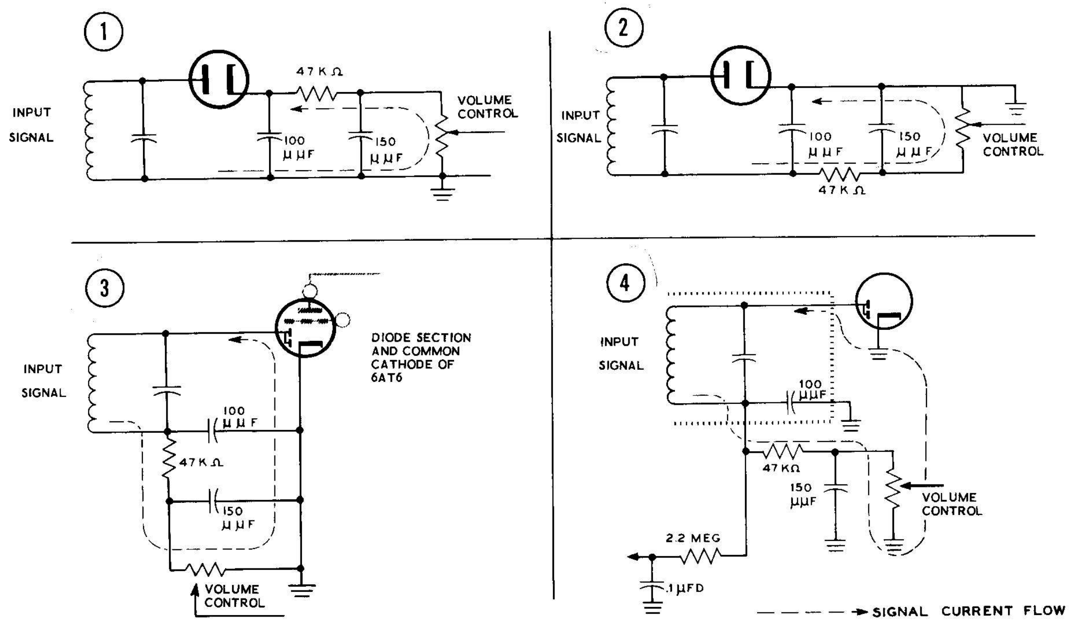
THE DETECTOR CIRCUIT RECTIFIES AND FILTERS THE MODULATED RF BROADCAST SIGNAL - THEN SENDS IT TO THE AUDIO AMPLIFIER.

Figure 5D

5E, the resistor and the ground connection have been moved. Because the rectifier has caused a one-way current to flow all through the circuit, this circuit works exactly the same as the circuit of Part (1).

Parts (2), (3), and (4) are actually the same circuit drawn three different ways. In Part (3), the filter circuit and volume control part of the schematic have been bent down so that the capacitors are now drawn horizontally instead of vertically. In Part (4) the circuit is still the same, only the filter circuit has once again been turned around to face in a different direction.

The diode that is used in this circuit (shown in Parts (3) and (4) of Figure 5E) is actually included in the same tube as the 6AT6 amplifier tube, in order to eliminate the need of one more tube in the circuit. Although the same cathode is used for both the diode and triode parts of the tube, they work just like two separate tubes.



THE DEVELOPMENT OF THE EK-2B DETECTOR CIRCUIT.

Figure 5E

Although two separate diode plates are included in the tube, they are connected together in this circuit and work just like one big plate.

In this circuit (Part (4), Figure 5E), the rectified signal is taken from the bottom of the IF transformer. The rectified signal is then applied to the filter circuit. From the filter circuit it is applied to the volume control.

THE AVC CIRCUIT

Notice that a separate 2.2 megohm resistor and a .1 μfd capacitor are connected to the bottom of the transformer and lead off to the left. This circuit is called the automatic volume control circuit, or the "AVC" circuit. This AVC circuit is used to turn the volume of the receiver up or down automatically, by creating a DC controlling voltage. This DC controlling voltage is then applied to the circuits in the radio frequency (RF) sections of the receiver where it controls the amount of signal sent to the detector.

The AVC control voltage is developed from the rectified RF signal in the detector circuit. The 2.2 megohm resistor and the .1 μfd capacitor act as an audio filter circuit, which converts the rectified RF signal into this well filtered DC automatic volume control voltage.

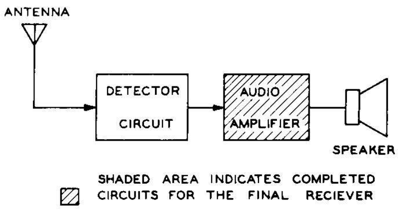


Figure 5F

More details on the operation of the AVC circuit will have to be given in a later lesson when the radio frequency amplifiers are studied. It would be well for you though, at this time, to learn some of the basic principles of the AVC circuit.

The DC voltage developed by this AVC circuit is developed at the output of the AVC filter, which is indicated by the arrow in Figure 5E. This DC voltage which was developed from the rectified RF signal will be quite large when a large signal is received from the front sections of the receiver. When a small signal from a weak station is received from the front of the receiver, only a small amount of DC voltage will be developed at the output of the AVC filter circuit. This larger or smaller DC voltage automatically turns up or turns down the volume of the signal in the RF and IF amplifiers. Exactly how this DC voltage controls the volume in the RF sections will be explained in later lessons where the radio frequency circuits are explained.

Figure 5F shows the block diagram of your EK-2 Receiver as it will appear when the construction is completed at the end of this lesson. At this time you have the antenna connected to the detector circuit. The detector circuit is connected to the audio amplifier which, of course, is connected to the speaker. Lesson VI will expand this block diagram one step further to include the radio frequency amplifier circuit.

SUMMARY

Now review briefly the facts about the detector circuit that you have learned in this lesson. Remember that the modulated broadcast signal is applied to the detector circuit where it must be rectified and filtered before it can be applied to the audio circuit. Since the rectifier tube is a one-way current device, it rectifies the signal by eliminating one-half of it; this prevents the equal and opposite swells from cancelling each other out at the output of the circuit.

The filter circuit eliminates the RF signals due to the filter capacitors discharging and filling in the blank spaces between the individual peaks of the RF waveform. The audio signal thus obtained is then presented to the volume control, which couples it to the audio amplifier.

The AVC filter circuit creates a DC voltage from the rectified RF signal from the detector circuit. This automatic volume control voltage gets larger when the received signal gets larger, and it gets smaller when the received signal gets smaller. This larger or smaller AVC voltage is then applied to the RF circuits, where it automatically turns up or turns down the volume of the signal.

HOW TO BUILD A DETECTOR CIRCUIT

PARTS REQUIRED

1 EK-2 chassis
1 22 KΩ resistor (red-red-orange)
1 150 μμf disc capacitor (now connected to dual lug terminal T-4)
1 100 μμf disc capacitor (now connected to lug 6 of V2)

PREPARING THE CHASSIS

Refer to Figure 5G for the following steps.

(✓) Remove the 800 μμf disc capacitor that is connected from the control ground lug to the center lug of the 200 Ω control.
(✓) Disconnect all wires and parts from dual lug terminals T-3 and T-4.
(✓) Disconnect the 150 μμf capacitor from the control ground lug.
(✓) Disconnect the choke (RFC) from the center lug of the 200 Ω control.
(✓) Disconnect the wires that connect to lug 1 and lug 2 of the 200 Ω control.

NOTE: Remember when you are connecting to the antenna coil lugs, that each of these lugs is identified by a spot of paint at the lug itself; use this spot of paint to identify each individual lug.

( ) Disconnect both wires from the green lug of the antenna coil.

( ) Disconnect the wire connected to the yellow lug of the antenna coil.

( ) Disconnect and remove the wire connecting the center post of tube socket V1 to the tuning capacitor solder lug.

( ) Disconnect and remove the 100 $\mu\mu$f disc capacitor connected from lug 6 of tube socket V2 to the orange lug of the antenna coil.

( ) Disconnect and remove the 150 KΩ resistor connected between dual lug terminal T-3 and the filter capacitor lug marked with a square ■.

( ) Disconnect and remove the 3.3 megohm resistor connected from lug 4 to lug 6 of tube socket V2.

( ) Remove the 6C4 tube from tube socket V2.

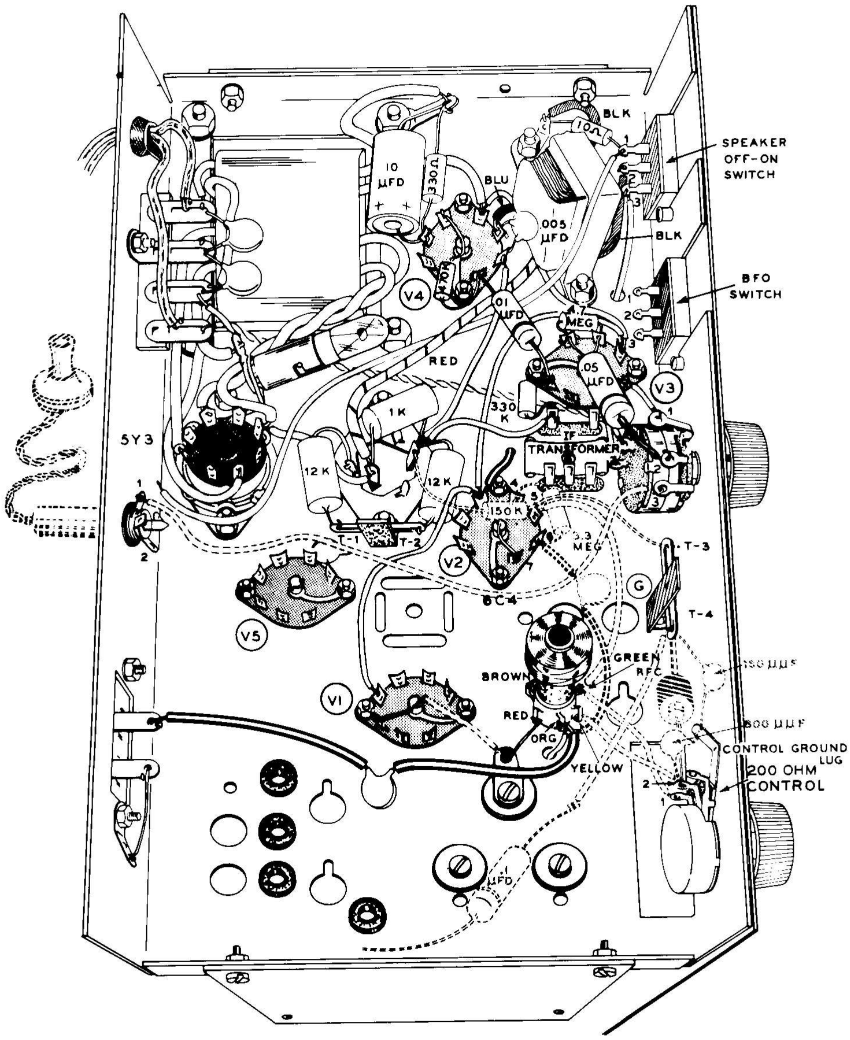


Figure 5G

EXPERIMENT 1

To build the type of detector circuit normally used in a radio receiver, and to listen to it in operation.

Refer to Figure 5H for the following steps.

(✓) Ⓣ Connect one end of a length of hookup wire through lug 6 to lug 5 of tube socket V3 (S). Connect the other end of this wire to the orange lug of the antenna coil (S).

(✓) Ⓣ Connect a length of hookup wire from the tuning capacitor solder lug (S) to dual lug terminal T-4 (S).

(✓) Ⓣ Connect a 22 KΩ 1/2 watt resistor from lug 3 of the volume control (NS) to dual lug terminal T-4 (S).

( ) Ⓣ Connect a 100 μμf disc capacitor from dual lug terminal T-3 (S) to lug 1 of the volume control (NS).

(✓) Ⓟ Connect a 150 μμf disc capacitor from lug 1 (S) to lug 3 (S) of the volume control.

(✓) Ⓣ Connect your antenna lead and ground lead to the proper terminals on your EK-2 Receiver.

( ) Plug in the receiver and turn on the switch. Now tune in some station to see that your detector circuit is operating properly. You will find that this detector is much weaker than the superregenerative detector used in the previous lessons.

DISCUSSION

In the experiment for Lesson V, the regenerative detector circuit, which is not commonly used in home radio receivers, was dismantled. In its place, in Experiment 1 you constructed the type of detector circuit that is normally used in home radio receivers (except for the input tuned circuit).

The only difference between this detector circuit of Experiment 1 and the detector circuit studied on Page 49, is that the input tuned circuit uses the antenna coil and the tuning capacitor in place of the IF transformer. The antenna coil has been used because the IF transformer is a special type of transformer that would not readily tune the incoming RF signals. The complete use of the IF transformer will be covered in a later lesson.

The incoming radio signal to your receiver is coupled from the antenna to the antenna coil and tuning capacitor. The antenna coil and tuning capacitor form a resonant circuit which selects only one of the many incoming radio signals, and sends this signal on to the detector circuit. (Remember the resonant circuits studied in Lesson V of Basic Radio- Part 1?)

The incoming modulated broadcast signal is detected by the diode portion of the 6AT6 tube. The detected signal is then filtered and applied to the volume control which couples it to the audio amplifier section.

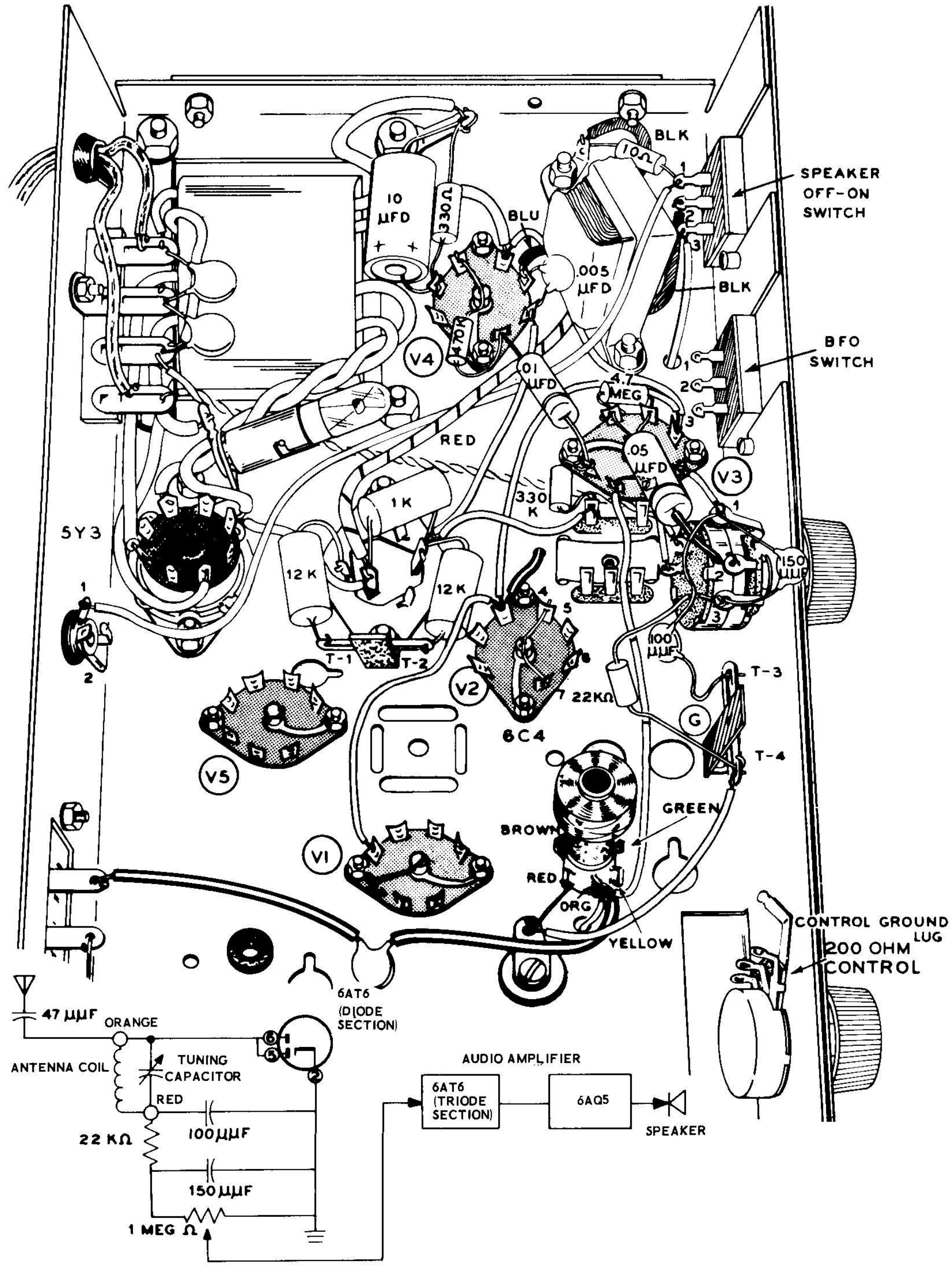

SPEAKER OFF-ON SWITCH
BFO SWITCH
BLK
10 µFD
330Ω
BLU
.005 µFD
V4
.01 µFD
4.7 MEG
RED
.05 µFD
V3
1 K
330 K
5Y3
12 K
12 K
150 µµF
100 µµF
T-1
T-2
V2
22 KΩ
T-3
G
6C4
T-4
V5
GREEN
BROWN
V1
RED
ORG
YELLOW
CONTROL GROUND LUG
200 OHM CONTROL
6AT6 (DIODE SECTION)
47 µµF
ORANGE
ANTENNA COIL
TUNING CAPACITOR
RED
22 KΩ
100µµF
150µµF
1 MEG Ω
AUDIO AMPLIFIER
6AT6 (TRIODE SECTION)
6AQ5
SPEAKER

Figure 5H

LESSON V

QUESTIONS

1. The three basic requirements of a broadcast receiver are, it must __________, __________, and __________.

2. The audio signal appears in the form of __________ in the modulated broadcast signal.

3. The detector circuit removes the __________ signal from the modulated broadcast signal and presents it to the __________ __________.

4. The purpose of the detector circuit is to __________ and __________ the modulated RF signal.

5. Rectifying the signal with the diode keeps the __________ and __________ from cancelling each other out.

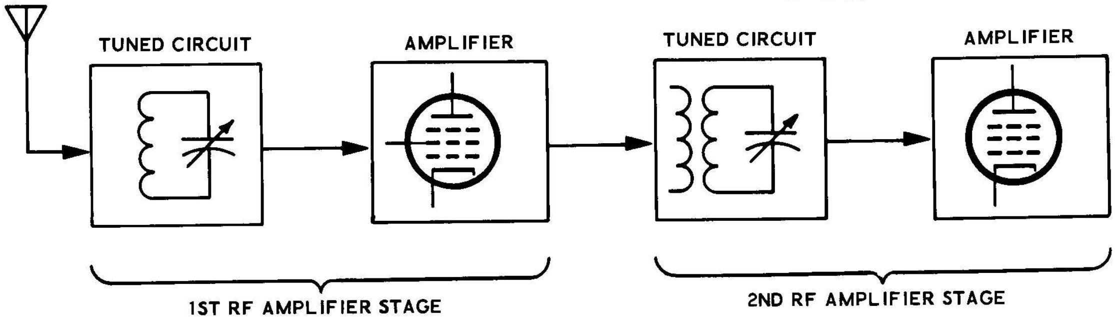
6. What parts of the signal does the filter circuit "fill-in?"

7. The diode and the triode portions of the 6AT6 tube have an element in common, the __________.

8. The circuit that automatically turns the volume of the receiver up and down by using a rectified audio signal from the detector circuit is called the __________ circuit.

LESSON VI

WHAT DOES THE RF SECTION OF A RECEIVER DO?



A BLOCK DIAGRAM OF TWO TUNED RF AMPLIFIERS

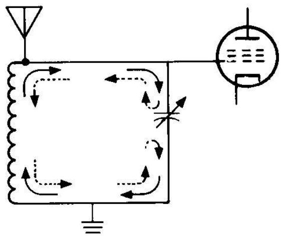
Figure 6A

The main function of an RF section of a receiver is to tune (or select) the desired signal, and to amplify it, before sending it to the following circuit. Previous lessons traced the signal through the detector circuit and through the audio amplifier circuits. This lesson will show you how the RF amplifier tunes only one of the many signals that it receives from the antenna, amplifies it, and sends it to the detector circuit.

A single RF amplifier circuit may be divided into two parts, the amplifier portion which amplifies the signal and the tuned circuit which selects the desired signal. An RF amplifier section containing two stages of amplification, is shown in Figure 6A. The tuned circuit of an RF amplifier selects the desired signal and rejects all other signals. The amplifier portion of the circuit makes the input RF signal larger, just like the audio amplifier amplifies the signals in the audio section.

The modulated broadcast signal can be amplified by any number of RF amplifier stages before it is sent to the detector circuit. While Figure 6A shows two complete RF amplifier stages, there could be more, or less, depending on the design of the radio. These amplifiers are also called "tuned radio frequency amplifiers" because each uses a tuned circuit. Since the tuned circuit is such a basic part of the RF amplifier, you would do well to review Lesson V of Basic Radio-Part 1, "What Is A Tuned Circuit."

A tuned circuit, such as the one shown in Figure 6B, consists of a coil and a capacitor connected in parallel. This capacitor, like all capacitors, is able to store a charge of electrons on its plates. This coil, like all other coils, is also able to store energy by expanding the magnetic field that surrounds it. Each of these parts, when it has stored energy, tries to release it across the other part; this is also called "kick-back" action.



CURRENT IN A TUNED CIRCUIT FLOWS BACK AND FORTH AT THE RESONANT FREQUENCY BETWEEN THE COIL AND THE CAPACITOR.

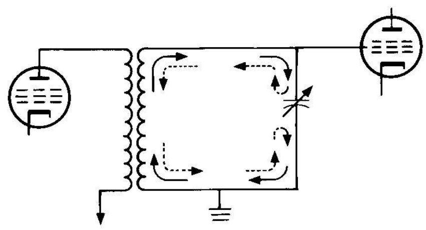
Figure 6B

At one certain frequency, determined by the size of the coil and the size of the capacitor, an interesting effect called "resonance" occurs. The frequency at which resonance occurs, is called the "resonant" frequency. At this resonant frequency, the current circulates back and forth from the capacitor to the coil, and from the coil to the capacitor. The discharge current from the capacitor causes energy to be stored in (the field of) the coil; when the magnetic field of the coil collapses, it places a charge on the capacitor again. In this resonant condition, once the initial charge of energy has been placed in this tuned circuit, only a small electrical signal at the resonant frequency will keep a much larger current flowing back and forth in the tuned circuit between the coil and the capacitor.

The resonant frequency of this tuned circuit can usually be changed by changing the size of either the coil or the capacitor. In most home radio receivers, the capacitor is usually made variable. It might help you to think of the capacitor and the coil as being like two small buckets, with one of the buckets full of water. If both of the buckets were quite small (small coil and small capacitor), the water could be poured back and forth from one bucket to the other quickly; this would be like a higher frequency. If both of the buckets were quite a bit larger (large coil and large capacitor), it would then be a much slower job to pour the water from one bucket to the other; this would be like a lower frequency.

Suppose a tuned circuit is connected to the antenna of a receiver. At the tuned (resonant) frequency a very weak signal from the antenna can keep a much larger current flowing back and forth in the tuned circuit.

In the RF amplifier circuits of this lesson, the coil of the tuned circuit is actually the secondary winding of an RF (air core) transformer and the tuned circuit still acts in exactly the same way. Figure 6C shows the secondary winding of a transformer being used as the coil in a tuned circuit. The magnetic field from the primary couples the signal into the secondary of the transformer, and therefore into the tuned circuit.



THE TUNED CIRCUIT OF AN RF AMPLIFIER IS USUALLY ONE WINDING OF AN RF TRANSFORMER.

Figure 6C

When the signal coupled to this tuned circuit is at the resonant frequency, it sets up a high circulating current in the tuned circuit. This high circulating current causes the signal to appear across the grid resistor of the RF amplifier, and thus it is amplified by the tube. A signal that is not at the resonant frequency of the tuned circuit will not be able to set up this high circulating current in the tuned circuit. Little or no signal will appear across the grid resistor and at the grid of the tube if the signal is not at the resonant frequency.

Figure 6D shows three RF amplifier stages and the detector circuit in block diagram form. If a graph were to be made of the amount of signal received by the detector circuit, as each

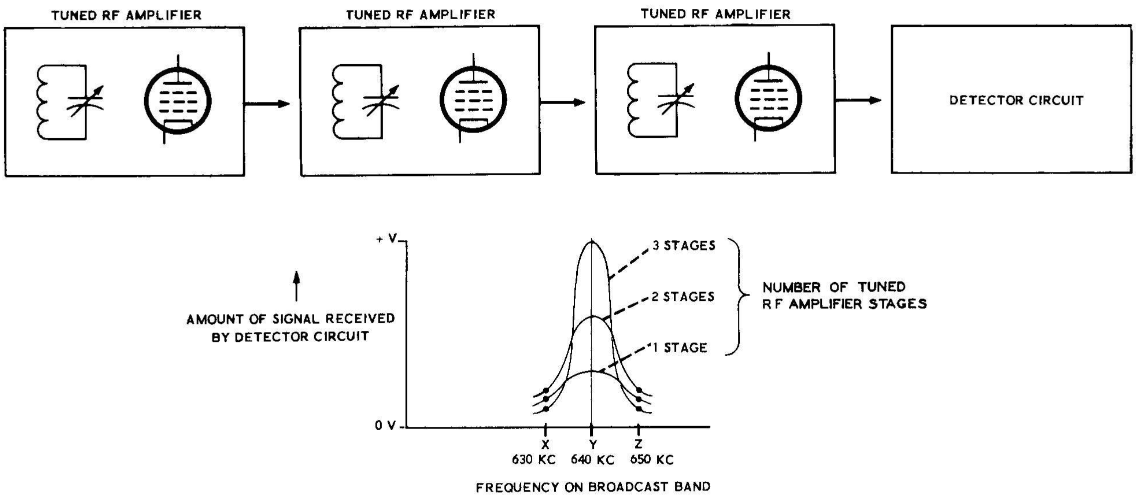
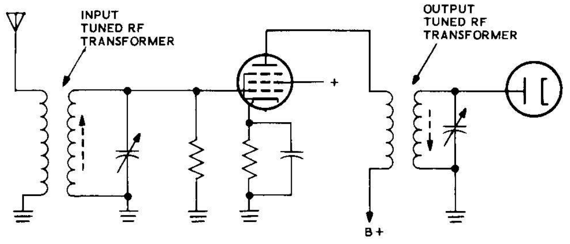


Figure 6D

THE GRAPH SHOWS HOW MUCH SIGNAL THE DETECTOR CIRCUIT WOULD RECEIVE FROM STATIONS X, Y, AND Z, WITH EITHER ONE, OR TWO, OR THREE TUNED RF AMPLIFIERS.



A TYPICAL RF AMPLIFIER STAGE.

Figure 6E

amplifier is added to the circuit, it would appear as shown in Figure 6D. Along the bottom of the graph the frequencies of the three different, close-together, radio stations are shown. The amount of signal received at the detector circuit is shown vertically in the graph. In this graph, consider that each of the tuned circuits is tuned to the station at 640 kc. Notice how much sharper the tuning gets as each additional RF amplifier is added to the receiver.

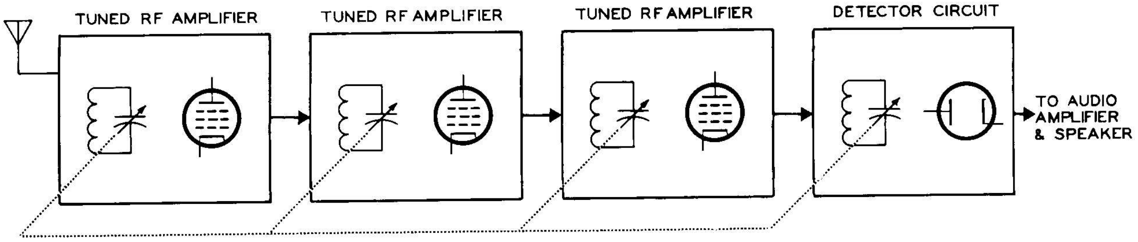
How sharply a receiver will tune is called "selectivity." With only one RF amplifier stage, stations X and Z are amplified almost half as much as the desired station, at Y. With two RF amplifier stages this condition has been improved some; now station Y is amplified four or five times more than stations X and Z. When three RF amplifier stages are used, station Y is amplified many, many times and the stations at X and Z are hardly amplified at all. In this case, very little, if any, of the programs being broadcast on station Z would be heard.

The RF amplifier tube amplifies the RF signal in the same manner that the audio amplifier amplified its signal. The small RF signal at the grid controls the plate current of the tube. The plate current of the tube couples the signal through the output tuned RF transformer. A plate load resistor and a coupling capacitor, like those used in the audio amplifiers, could be used in this RF amplifier instead of the tuned circuits. The reason tuned circuits are almost always used, is so that the circuit will select the proper signal, and reject the other signals.

Figure 6E shows a typical RF amplifier stage. Notice that, except for the input and output connections, it looks just like the pentode amplifier of the audio section. The desired signal from the antenna is selected by the input tuned RF transformer, and applied to the grid of the tube. The tuned signal is then amplified in the tube and applied to the output tuned RF transformer which again tunes the desired signal, rejects any other signals that are still present, and sends it to the tube of the next circuit.

The input and the output tuned RF transformers of Figure 6E must, of course, be tuned to the same frequency. Usually, the tuning capacitors are turned at the same time by connecting both capacitors to the same shaft; this type of capacitor is usually called a "ganged" variable capacitor. The capacitor used in your EK-2 Receiver is a 2-gang capacitor; in other words it has two sections that turn simultaneously.

A very small capacitor, called a trimmer capacitor, is usually connected across each section of a variable ganged capacitor. These trimmer capacitors are used as an adjustment, so that the different sections of the ganged capacitor can be adjusted to tune their individual circuits to exactly the same frequency at the same time.



A FOUR-SECTION TUNING CAPACITOR WOULD BE NEEDED TO TUNE THIS TRF RECEIVER.

Figure 6F

Figure 6F shows a block diagram of a radio receiver with three tuned RF amplifiers. The dashed lines in the diagram show that the capacitors are ganged, and therefore tune together. This type of receiver, used very commonly in the early days of radio, is usually called a "tuned radio frequency" receiver, or "TRF" receiver.

Notice that four different tuned circuits must be ganged together and tuned at the same time. It is quite a difficult process to make all of these tuned circuits tune to exactly the same frequency at exactly the same time all the way across the broadcast band. It is also quite expensive to manufacture a tuning gang with this many sections in it. To adjust the trimming capacitor for each section of this tuning gang, so that all four sections will tune together all the way across the broadcast band, is a very difficult feat indeed.

A second difficulty encountered with TRF receivers is found in the coils themselves. Some of the current applied to a coil is always wasted because it is consumed in heat and produces no energy in the magnetic field of the coil. In a high quality (high Q) coil this waste is held to an absolute minimum. Because the tuned circuits of the TRF receiver must tune over so wide a range of frequencies, it is impossible to design very high quality coils to be used in tuning such a wide range. High quality coils would make the tuned circuits tune much more sharply. A coil with a high Q at the high end of the broadcast band would work well there, but would work poorly at the low end of the dial. The opposite would be true for a coil with a high Q at the low end of the broadcast band. How these difficulties of the TRF receiver can be overcome will be explained in later lessons when you study how the superheterodyne receiver operates.

SUMMARY

The RF section of your broadcast receiver has two functions. It will select the proper modulated broadcast signal and it will also amplify it. While the audio amplifier will amplify all the frequencies within the audio range, the tuned RF amplifier will amplify only the signal from a single station; it will reject all other signals.

At the resonant frequency of a tuned circuit, a relatively large current flows back and forth between the coil and the capacitor. A very small amount of current at this same resonant frequency, from an external source such as an antenna, will keep this larger current circulating. At all other frequencies, this high circulating current condition does not occur. This high circulating current in the tuned circuit, causes a signal voltage to appear across the grid resistor of the amplifier tube, therefore at the grid of the tube.

By connecting several tuned RF amplifiers in series it is possible to tune signals much sharper, and stronger than with just one tuned RF amplifier. To achieve this goal of much sharper tuning, each tuned circuit must be tuned to exactly the same frequency as the others.

The type of receiver that uses a number of tuned RF amplifier stages is called a "tuned radio frequency" or TRF receiver. One disadvantage of this type of receiver is the need for a many-sectioned variable capacitor. This type of ganged capacitor is very expensive to produce. It is also difficult to adjust the sections to keep all of the tuned circuits synchronized to exactly the same frequency.

A second disadvantage of the TRF receiver is in the coils themselves. When a coil is designed to tune well, all the way across the broadcast band, its design is a compromise. The coil will have high internal losses compared to a coil designed for a narrow band of frequencies. These "higher-loss" type of coils used in the TRF, will not tune as sharply as a coil designed for a narrower band of frequencies.

HOW TO BUILD AN RF AMPLIFIER

Showing how to make the tuned circuits tune to the same frequency, or "track," all the way across the broadcast band of a TRF receiver.

PARTS REQUIRED

1 EK-2 chassis
2 6-32 x 3/8" screws
2 6-32 nuts
3 #6 solder lugs
1 Dual trimmer capacitor
1 Broadcast antenna coil (#40-299)
1 Crystal diode (from Basic Radio-Part 1)
1 68 Ω resistor (blue-gray-black)
1 .1 μfd 200 V tubular capacitor
1 47 KΩ resistor (yellow-violet-orange)
1 6BA6 tube

BECOMING FAMILIAR WITH THE NEW PARTS

The BROADCAST ANTENNA COIL is very similar to the other adjustable coil studied previously. The main difference between this coil and the other coil (now used as the tuned RF transformer) is the size of the coils.

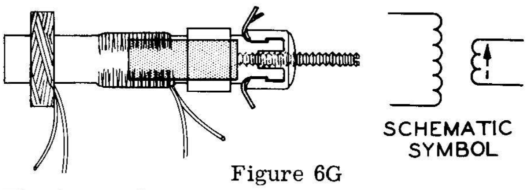


Figure 6G

The two coils are wound around a hollow cardboard tube. Metal tabs are placed at the base of the cardboard tube and the wires from the ends of the coils are connected to the tabs. A powdered iron slug can be adjusted in and out of the two windings. This changes the amount of coupling between the primary winding and the secondary winding of the transformer. It also changes the inductance (electrical size) of the coils.

The dual TRIMMER CAPACITOR is constructed as shown in Figure 6H. Two metal plates, insulated by a thin sheet of transparent mica material, are mounted on each trimmer capacitor. The bottom plate is permanently fastened to the porcelain base. The top plate is constructed of spring-like material that allows it to rise from the lower plate, as the screw is turned out. The screw itself is insulated from touching either plate. Varying the space between the two plates of this trimmer capacitor, changes the amount of capacity of the trimmer capacitor from 3 μμf to 30 μμf.

The complete assembly is mounted to the frame by a metal strap, but like the screws, the strap does not come into contact with either plate of the capacitor.

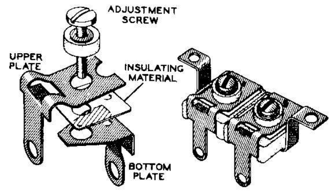
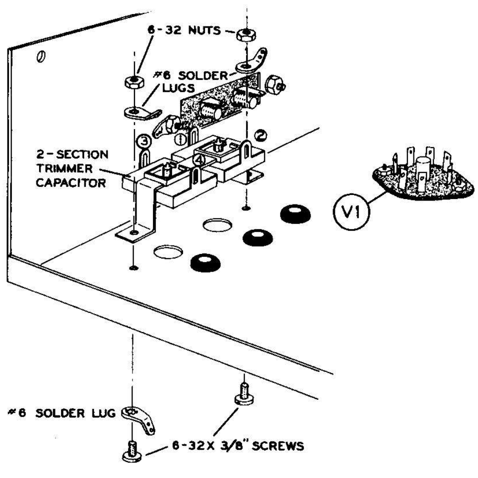


Figure 6H

PREPARING THE CHASSIS

Refer to Detail 6J for the following steps.

( ) Mount the 2-section trimmer capacitor near the antenna terminals in the following manner so that the upper plates (see Figure 6H) are in the position of lugs 1 and 3. Use 6-32 x 3/8" screws and 6-32 nuts. Mount a #6 solder lug under the nut that holds the mounting foot nearest tube socket V1. Mount two #6 solder lugs, one below the chassis and one above the chassis, at the other mounting foot of the trimmer capacitor.



MOUNTING THE TRIMMER CAPACITOR.
Figure 6J

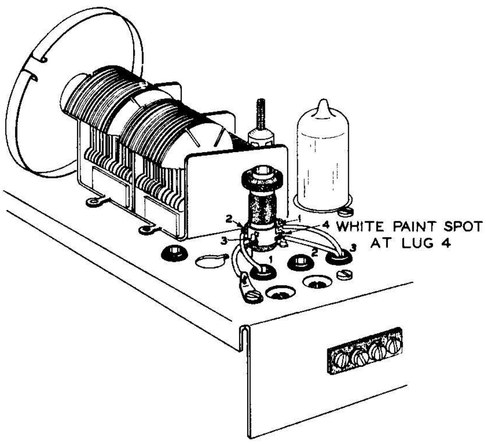
( ) Remove and set aside the 47 $\mu\mu f$ disc capacitor that is connected from the antenna terminal to the orange lug of the tuned RF transformer.

( ) Remove and discard the wire that is connected from dual lug terminal T-4 to the tuning capacitor solder lug.

( ) Remove and set aside the wire that is connected from lugs 5 and 6 of tube socket V3 to the orange lug of the tuned RF transformer.

( ) Remove and discard the short wire that connects between the brown and blue lugs of the tuned RF transformer.

See Detail 6K.



MOUNTING AND WIRING THE BROADCAST ANTENNA COIL.

Figure 6K

( ) Mount the broadcast antenna coil (#40-299 in position as shown in Detail 6K.

( ) [P] Connect a 2" length of wire from lug 3 of the broadcast antenna coil (S) to the #6 solder lug (S).

( ) [T] Connect a 4" length of hookup wire to lug 2 of the broadcast antenna coil (S). Insert the other end of this wire down through grommet 1.

( ) [T] Connect a 1-3/4" length of hookup wire to lug 1 of the broadcast antenna coil (S). Insert this wire down through grommet 3.

( ) [T] Connect a 3" length of hookup wire to lug 4 of the broadcast antenna coil (S) and insert the other end of this wire down through grommet 3.

Refer to Figure 6L for the following steps.

( ) [T] Insert one stripped end of a 2-3/4" length of hookup wire through the hole (indicated in Figure 6L) located near the mounting screw for the tuning gang. Connect this wire to the tuning capacitor lug above this hole on top of the chassis (S).

( ) [T] Connect the other end of this 2-3/4" wire to lug 1 of tube socketV1 (NS).

( ) [P] Connect a short length of bare wire (remove all the insulation from a length of hookup wire) from lug 4 to the center post (S) of tube socket V5.

( ) [P] Connect a 2-1/2" length of hookup wire from lug 4 of tube socket V1 (S) to lug 3 of tube socket V5 (S).

( ) [T] Connect a length of bare wire from lug 2 (S) to the center post (S) of tube socket V1.

NOTE: The coil near the tube socket V1 on the bottom of the chassis is being used as a tuned RF transformer in this experiment. This is the name it will be called by when it is mentioned in the construction and in the experiment. Remember that the lugs of this coil are identified by the colors marked at the lugs.

( ) [T] Connect a length of hookup wire from the blue lug of the tuned RF transformer (NS) to the power supply filter capacitor lug marked by the square ■.

( ) [T] Connect a length of hookup wire from lug 5 of tube socket V1 (S) to the brown lug of the tuned RF transformer (S).

( ) [T] Connect the short wire coming through grommet 3, to the ground lug beside grommet 3 (NS).

( ) [T] Connect the long wire coming up from grommet 3 to lug 1 of tube socket V1 (NS).

( ) [T] Connect the long wire coming up from grommet 1 to the antenna lug on the rear of the chassis (S).

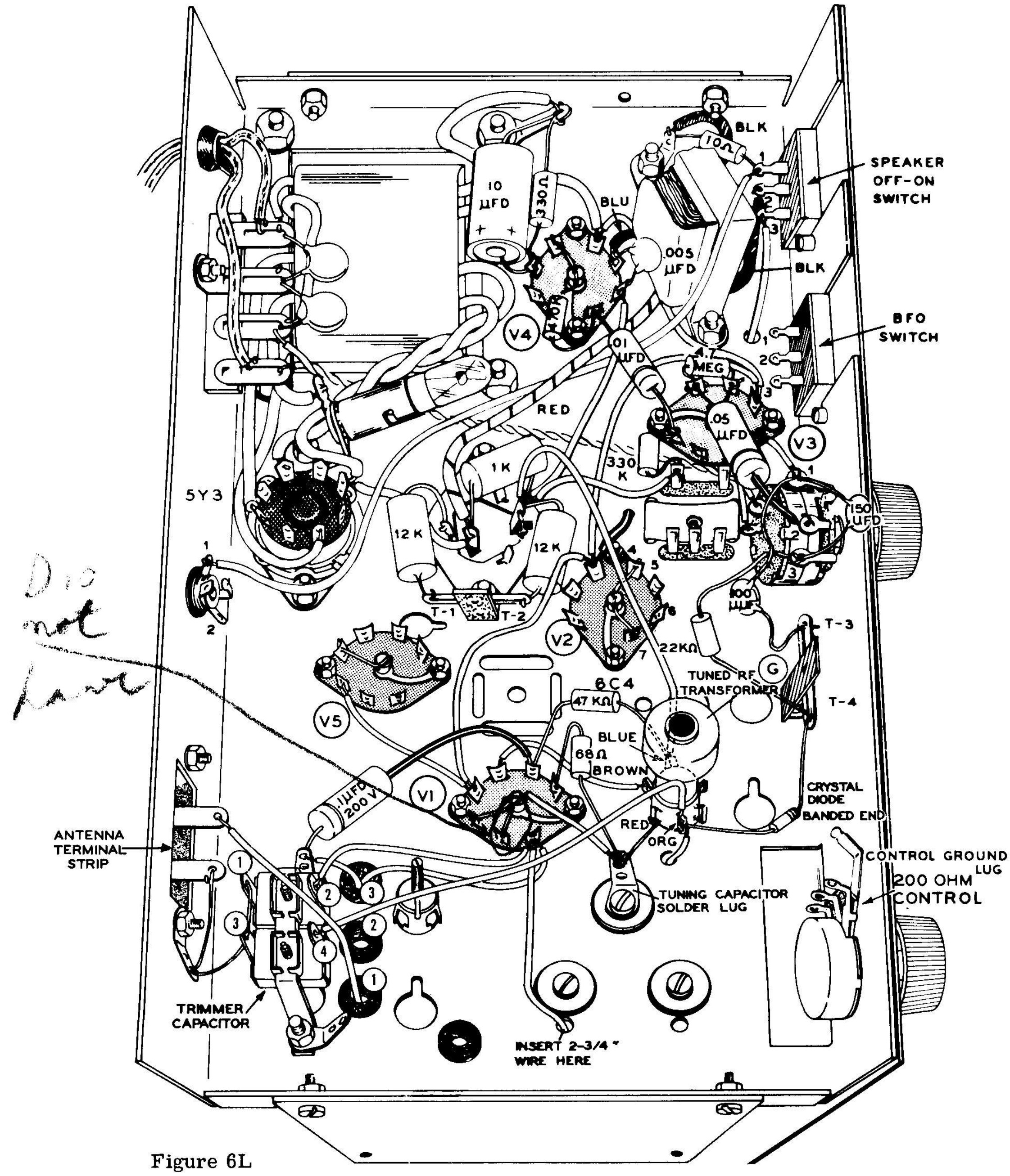


Figure 6L

A PICTORIAL VIEW OF THE CHASSIS.

(✓) (P) Connect a length of bare wire from lug 1(S) and lug 3 (S) of the trimmer capacitor to the nearest ground lug (S).

(✓) (P) Connect a length of hookup wire from lug 2 (S) of the trimmer capacitor to lug 1 of tube socket V1 (S).

( ) Ⓣ Connect a length of hookup wire from lug 4 of the trimmer capacitor (S) to the orange lug of the tuned RF transformer (NS).

( ) Ⓟ Connect a length of hookup wire from the center post of tube socket V1 (S) to the tuning capacitor solder lug (NS).

( ) Ⓣ Connect a 47 KΩ 1/2 watt resistor from lug 6 of tube socket V1 (NS) to the blue lug of the tuned RF transformer (S).

( ) Ⓣ Connect a 68 Ω 1/2 watt resistor from lug 7 of the tube socket V1 (S) to the tuning capacitor solder lug (S).

( ) Ⓟ Connect a .1 μfd 200 V tubular capacitor from lug 6 of the tube socket V1 (S) to the ground solder lug near lugs 1 and 2 of the trimmer capacitor (S). Use sleeving on the lead that is connected to lug 6 of V1, if it looks like it may touch any other lead, or the chassis.

NOTE: Remember when soldering the crystal diode that a pair of long-nose pliers should be connected to the lead of the diode. Connect the pliers between the diode and the solder point as shown in Detail 6M. This is done to keep heat from ruining the diode.

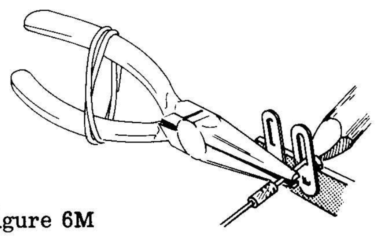


Figure 6M

( ) Connect the banded end of the crystal diode to dual lug terminal T-4 (S). Connect the other end of the crystal diode to the orange lug of the tuned RF transformer (S).

( ) Insert the 6BA6 tube in socket V1.

EXPERIMENT 1

To adjust this TRF receiver for the best tracking from the low end to the high end of the broadcast band.

( ) Turn the tuning knob counterclockwise until the tuning capacitor plates are fully meshed, as they are shown in Figure 6P.

( ) Connect the dial pointer to the dial cord as shown in Detail 6N. Place the pointer behind the dial marking that marks the low end of the band. Now fasten the dial cord between the prongs at the rear of the pointer, and bend the prongs slightly to hold the dial cord in place.

NOTE: In the following steps refer to Figures 6P, 6Q, and 6R. Figures 6P and 6Q show the adjustments for the tuned circuits as they appear on the chassis. Figure 6R shows the schematic of the circuit. As you make each adjustment on the chassis, refer to the schematic so that you will know which part of the circuit you are actually tuning.

( ) Connect your antenna and ground leads to the terminals on the rear of your EK-2B Receiver. Plug in the line cord and turn ON the receiver.

NOTE: You will not receive as many stations and the stations will not be so loud on this TRF receiver as with the regenerative receiver. This is because the RF amplifier does not have the exceptionally high gain of the regenerative receiver.

( ) Tune to a station at the low end of the band (indicated in Figure 6P). Determine the frequency of this station from its call letters; they will be given during the station breaks between programs. Now look up the frequency of this station; it is usually given on the radio page of your local newspaper.

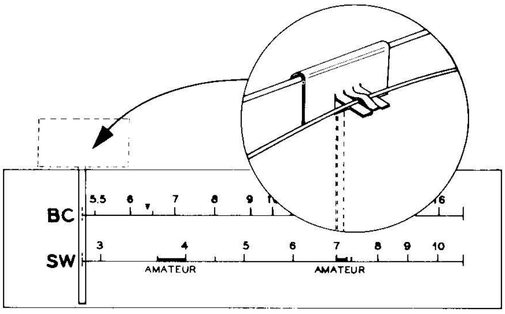
( ) Adjust the tuned RF transformer and the broadcast antenna coil (Figure 6P) to move the dial pointer to its correct position on the dial. This can best be accomplished by tuning each of these coils only a little at a time, and retuning the receiver slightly after each adjustment.

( ) Tune the receiver to a station at the high end of the band (shown in Figure 6Q).

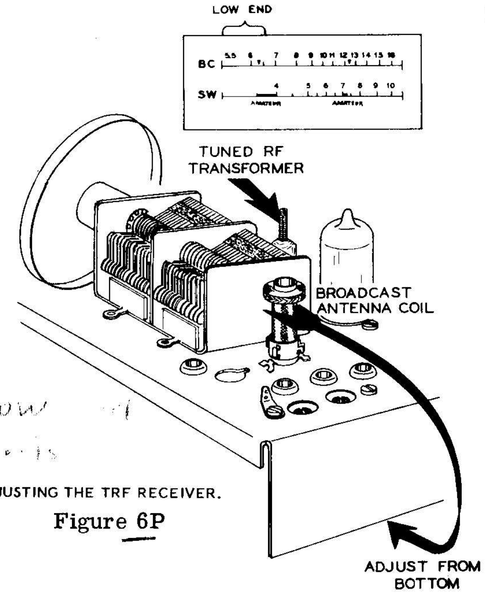
( ) Find the correct frequency of this station in the same manner as before.

( ) Adjust the two trimmers, the antenna trimmer and the detector circuit input trimmer, to bring the dial pointer to the proper frequency marking on the dial.

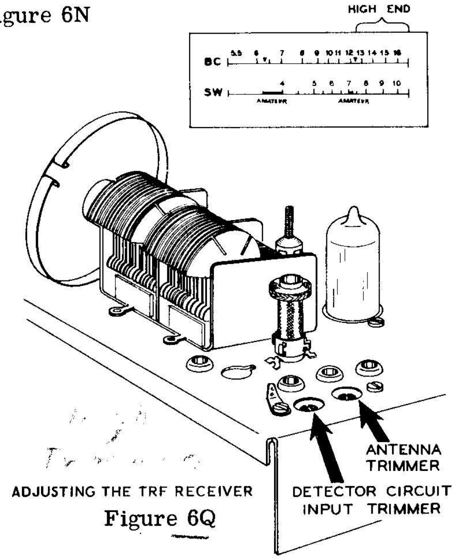
( ) You may find that this last adjustment has slightly moved the previous adjustment at the low end of the band. It may be neces-



CONNECTING THE DIAL POINTER.
Figure 6N



ADJUSTING THE TRF RECEIVER.
Figure 6P



ADJUSTING THE TRF RECEIVER
Figure 6Q

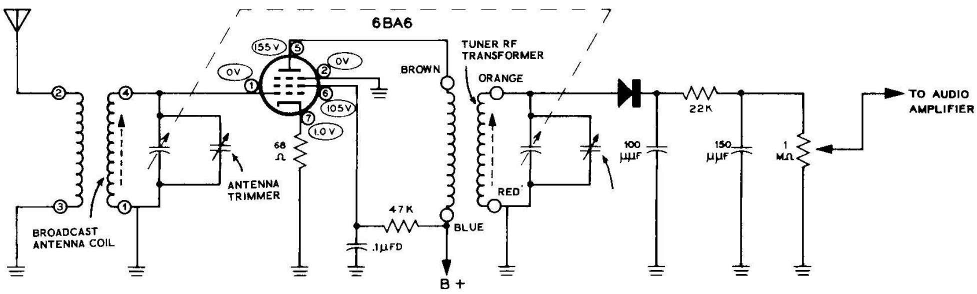


Figure 6R

sary to repeat the adjustments at the low end and at the high end of the band for best results.

( ) When the adjustment procedure has been completed, tune in all the stations you can receive, all the way across the broadcast band, in order to become familiar with how sharp the receiver tunes.

DISCUSSION

In this experiment you learned how to adjust a tuned radio frequency, or TRF receiver. In actual practice this TRF receiver would very likely have more RF amplifier stages, making adjustment more difficult.

The two coils have more effect at the low end of the band, so they are adjusted there. The two trimmer capacitors have more effect at the high end of the band, so they are adjusted at the high end. Once the two tuned circuits have been synchronized at the extreme ends of the broadcast band, the receiver will tune the correct frequencies all the way across the band.

Notice that this TRF receiver has much greater selectivity than any of your previous receivers. Notice also, that you can now separate close-together stations much more easily than before; this is because of the selective amplification of the RF amplifier circuit. As stated earlier in this lesson, the RF amplifier not only amplifies, but it also selects. Only the desired signal is amplified, the undesired signals are not amplified. Refer once again to Figure 6D to see the effect the different tuned circuits have on the amount of signal received by the detector circuit.

LESSON VI

QUESTIONS

1. The main function of the RF section of your receiver is to tune and amplify the desired broadcast signal.

2. A tuned circuit such as those used in the EK-2B Receiver consists of a coil and a capacitor connected in shunt.

3. In a tuned circuit the kick-back action of the coil is equal to the kick-back action of the capacitor at resonance.

4. A weak signal from the antenna can keep a much (larger, smaller) current flowing in the input tuned circuit.

5. Two tuned RF amplifier stages would tune much (more sharply, less sharply) than a single tuned RF amplifier stage.

6. A variable capacitor that contains two or three sections is usually called a Ganged variable capacitor.

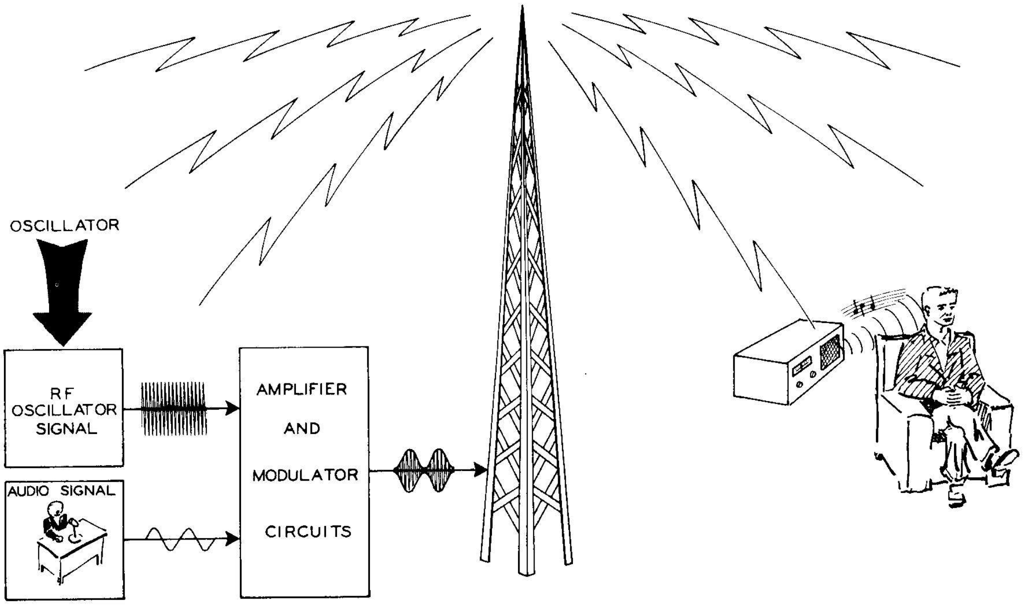
7. The type of receiver that was constructed in the experiment of this lesson is usually referred to as a TRF receiver.

8. Referring to the type of receiver mentioned in Question 7, what are the two main reasons this receiver is not used extensively today?

   too hard to tune, and variable capacitor too expensive. [illegible] Coil will not adjust over whole band.

LESSON VII

WHAT IS AN OSCILLATOR AND HOW DOES IT WORK?



AN OSCILLATOR CIRCUIT IS USED AT THE HEART OF A RADIO TRANSMITTER.

Figure 7A

An oscillator is the circuit that is used to create an AC signal. This AC signal may be either an audio signal or an RF signal. The RF signal, used by the radio stations in their modulated broadcast signal, is created by an RF oscillator circuit. Oscillators are also used widely in all types of radio transmitters, television, and in many other types of electronic equipment.

Figure 7B shows two test oscillators used to design and repair radio receivers, and other types of electronic equipment. The audio oscillator creates a signal that can be used in testing audio circuits. The RF oscillator creates signals that can be used to test RF circuits. The meter for each oscillator shows how large the signal from the oscillator is. The knobs for these oscillators are used to adjust the oscillator for a larger or smaller signal; they are also used to adjust the frequency of the signal.

This lesson will show you how the oscillator circuit creates a signal. Subsequent lessons will show the use of an oscillator circuit in the superheterodyne receiver.

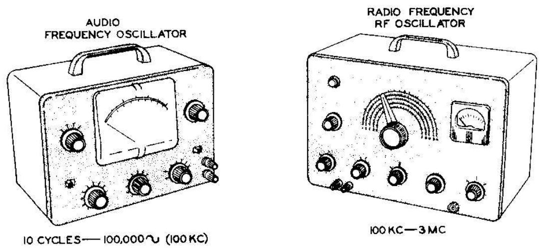
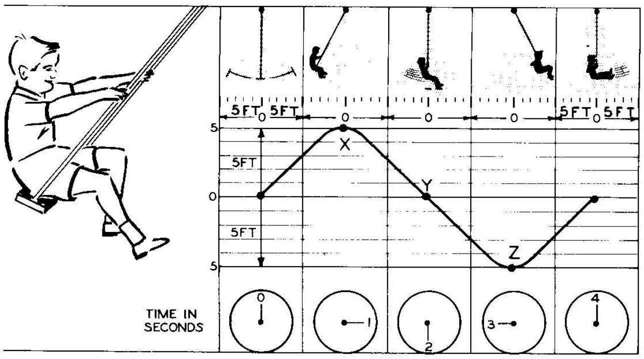


Figure 7B



THE MOTION OF THE BOY ON THE SWING PRESENTED IN GRAPH FORM.

Figure 7C

By definition, to oscillate means to swing back and forth. A common example of this is a child on a swing or the pendulum in a clock. The graph in Figure 7C shows the motion of the swing in graphic form. Four seconds of time is shown horizontally (on the clocks), and the distance the swing moves is shown vertically. One complete cycle of oscillation of the swing is shown, starting at the center position, "Y" (or "O").

The swing starts at the center position, and in one second it has moved back five feet, to position "X." At the end of two seconds it moves back again to the center position, "Y." At the end of three seconds the swing moves forward to position "Z," and at the end of four seconds the swing returns to position "Y," where the cycle begins all over again.

Notice that the graph also shows how fast the swing moves. The swing moves fastest as it moves past "Y", in the center of its range; this is shown by the slanted line in the graph.

The swing is not moving at all at position "X", or at position "Z"; this is because the line is not increasing or decreasing for one instant, as it moves through these two points. From this analysis of a swing's motion, we can say that it is oscillating back and forth at a rate of one cycle in four seconds.

If the swing in Figure 7C were allowed to swing freely, without being touched by any outside force, it would gradually slow down and then stop. If this motion of the swing were drawn as a waveform, it would appear like the gradually diminishing, or "damped," waveform in Figure 7D. Notice that the time of each complete cycle of the waveform (frequency) is still the same, four seconds, but the distance that the swing moves gets a little shorter with each cycle.

If a little push were given to the swing at the proper moment of each cycle, the same amount of motion would be maintained for every cycle. If this bit of energy were added to each cycle,

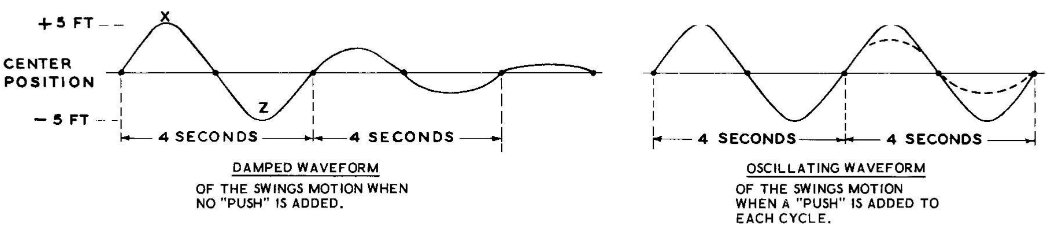
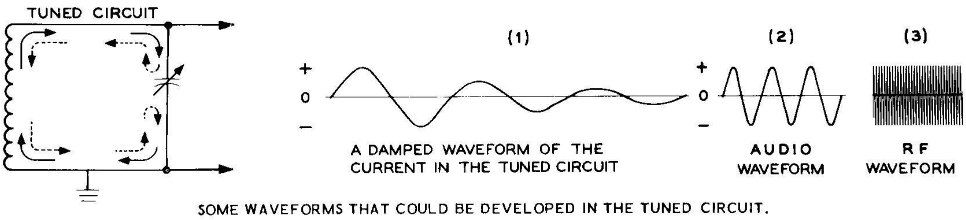


Figure 7D



SOME WAVEFORMS THAT COULD BE DEVELOPED IN THE TUNED CIRCUIT.

Figure 7E

the resulting waveform would look like the second waveform of Figure 7D. This physical motion of the swing is like the electrical action in an oscillator circuit.

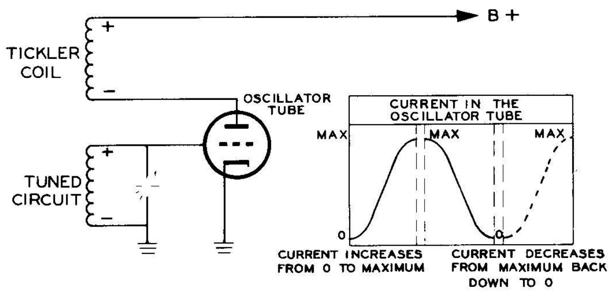
Figure 7E shows the tuned circuit explained in previous lessons, along with its circulating currents. It also shows some other waveforms that could be produced by this tuned circuit. Refer to waveform 1, the damped waveform. Notice that this damped waveform of voltage is much like the damped waveform made by the swing in Figure 7D.

If a charge of current, from an outside source, were placed into the tuned circuit, and then the source was taken away, circulating currents, or an "oscillation," would start. This oscillation in the tuned circuit would gradually decrease with each cycle, just like the motion of the swing decreased. Each cycle of the current becomes weaker, and the tuned circuit loses just a little bit more energy. If a small electrical "push" could be supplied to the tuned circuit at the right moment on each cycle of oscillation, the waveform could be kept at the same amplitude. The purpose of an oscillator circuit is to provide this small electrical push that will keep the oscillation going.

An oscillator circuit, such as the one shown in Figure 7F, oscillates because it adds new energy into the tuned circuit during each cycle. An additional coil, called a tickler coil, is wound on the same form with the coil of the tuned circuit. This tickler coil, along with the action of the triode, couples energy from the plate circuit of the triode (output) back into the tuned circuit (input to the triode) coil. This energy is coupled from the tickler coil to the tuned circuit coil by transformer action. The magnetic field of the tickler coil couples the energy back into the coil of the tuned circuit.

When the circuit of Figure 7F is first turned on, B+ is applied to the plate, and current begins to flow through the tube. As this current begins to flow through the tickler coil, it creates a field around the tickler coil. The field of the tickler coil induces a voltage in the tuned circuit coil.

The two coils are wound so that this voltage, induced in the tuned circuit coil puts a positive voltage on the grid of the triode. This positive voltage causes more current to flow through the triode, causing the magnetic field of the tickler coil to expand even further. As the magnetic field of the tickler coil expands fur-



A BASIC OSCILLATOR CIRCUIT

THE TICKLER COIL FEEDS ENERGY BACK FROM THE PLATE CIRCUIT INTO THE TUNED CIRCUIT.

Figure 7F

ther, it induces an even larger voltage in the tuned circuit coil, placing still more voltage at the grid of the triode. As you can see, this action multiplies itself many times, until the tube is said to be in "saturation." Saturation takes place when the maximum amount of current flows through the tube, this is the point where further increases in positive grid voltage will not increase plate current.

So far you have learned how the current through the tube increases from zero up to maximum amount the tube can conduct; now see how the circuit reverses itself, and the current through the tube begins to decrease to zero.

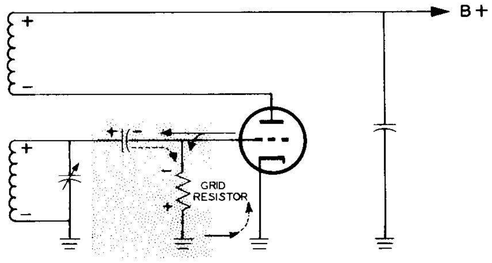
When the maximum amount of current is flowing through the tube (at saturation) the current through the tickler coil stops increasing; this causes the magnetic field of the tickler coil to stop expanding. As the magnetic lines of force stop moving through the tuned circuit coil, the voltage across the tuned circuit coil begins to decrease.

As the voltage across the tuned circuit decreases, the voltage at the grid of the triode becomes less positive, or in other words, more negative. As the voltage at the grid of the tube becomes more negative (less positive), less current flows through the tube and through the tickler coil. Less current through the tickler coil causes the magnetic field of the tickler coil to become smaller. As the magnetic field of the tickler coil becomes smaller and starts to collapse, it causes voltage to be induced in the tuned circuit coil, that is even more negative. This negative voltage decreases the tube current still further. This effect keeps multiplying, as before, until the voltage on the grid causes the tube to be completely cut off. In other words, the grid becomes so negative that the electrons cannot flow from the cathode to the plate.

The circuit has now reached the point where it is the same as it was before it was turned on; now the entire action starts all over again.

This whole cascading series of actions keeps repeating itself, first in the positive direction and then in the negative direction, resulting in an oscillation and an AC waveform. The tuned circuit determines the frequency of the oscillations.

Figure 7G shows the same oscillator circuit with some additional parts. Because the oscillator circuit of Figure 7F does not produce a good waveform, a grid leak bias circuit has been added. This grid leak bias circuit is created by using carefully selected values for the coupling capacitor and the grid resistor of the triode. The values of these two parts ~~are selected~~ so that a negative bias voltage will be maintained at the grid of the oscillator tube.



A GRID LEAK BIAS CIRCUIT (SHOWN IN THE SHADED PORTION) IS ADDED TO THE OSCILLATOR CIRCUIT.

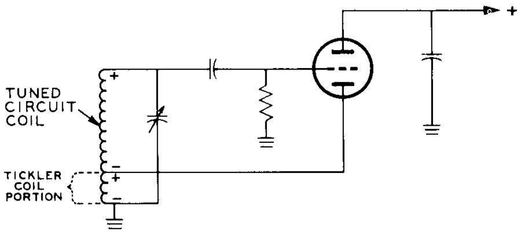
Figure 7G

For a small part of each cycle, current flows to the grid of the triode. From the grid it flows down through the large grid resistor. It also flows through the coupling capacitor, causing a charge to appear as shown on the capacitor. During the part of the cycle when the grid current does not flow, the capacitor attempts to discharge down through the grid resistor and up through the tuned circuit.

The capacitor is not able to discharge very much because the grid resistor is too large. As a result of this filtering action, a DC voltage is maintained across the grid resistor. This voltage acts as a bias for the tube. The bias voltage causes the tube to operate so that the waveform of the oscillator is not distorted by the tube.

The small capacitor, that connects from the B+ connection to ground, is used to keep the oscillating currents from this oscillator circuit from coupling back to B+, or to other circuits connected to B+.

Figure 7H shows the type of oscillator circuit that you will construct in your EK-2B Receiver in a later lesson. Although this circuit may appear to be quite different, it operates in essentially the same manner as the previous circuits. When B+ voltage is applied to the tube, current begins to flow through the tube, and also through the tickler coil portion of the tuned circuit coil. This part of the coil through which the current is flowing, acts like the primary of the transformer; it induces a voltage in a proper direction in the upper part of the tuned circuit coil.



A TYPE OF OSCILLATOR CIRCUIT THAT IS USED IN THE EK-2B RECEIVER.

Figure 7H

The voltage induced in the upper portion of the tuned circuit coil places a positive voltage on the grid of the triode. This positive voltage at the grid of the tube causes even more current to flow through the tickler coil part of the tuned circuit coil. The field from the tickler coil then expands further, and induces more voltage in the upper portion of the coil. This action multiplies itself, as it did in the previous circuit, until the tube has become saturated.

The circuit of Figure 7H reverses itself just like the basic oscillator circuit of Figure 7F. When the current through the tube has become maximum, the field of the tickler coil stops moving. When the magnetic field of the tickler coil stops moving through the upper portion of the tuned circuit coil, the voltage across the upper portion of the coil begins to decrease. As the voltage across the upper portion of the coil decreases it places a more negative voltage on the grid of the triode. The more negative voltage starts to cut off the current in the triode, and decreases the current flowing through the tickler coil even further. This action multiplies until the tube becomes completely cut off.

The waveform that results from this oscillator is a sine wave, whose amplitude is held constant by the action of the circuit. The frequency at which this sine wave occurs, whether it is an audio frequency or RF, depends on the size of coil and the capacitor in the tuned circuit.

Figure 7J shows the type 6BE6 pentagrid converter tube, which will be used in your EK-2B Receiver. The pentagrid converter was developed so that two different signals, one on each control grid, could be introduced in the same tube; both signals control the cathode-to-plate current of the tube.

The first control grid is placed in the normal position next to the cathode. The second control grid, which is the center of the five grids, is placed in between two separate screen grids, tied together. Two grids are used for the screen grid so that the action of control grid 2 will be isolated from the action of control grid 1. Further details on the operation of this tube will be given in later lessons.

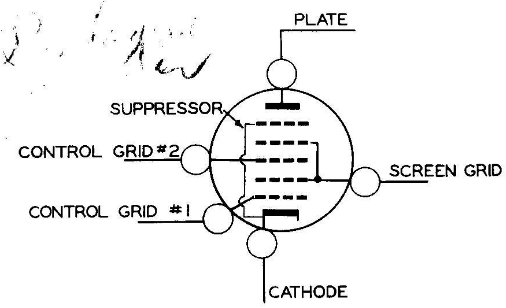
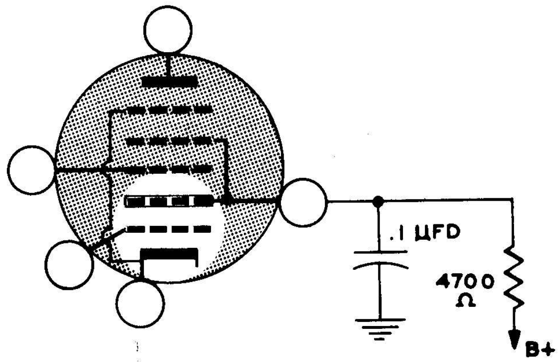


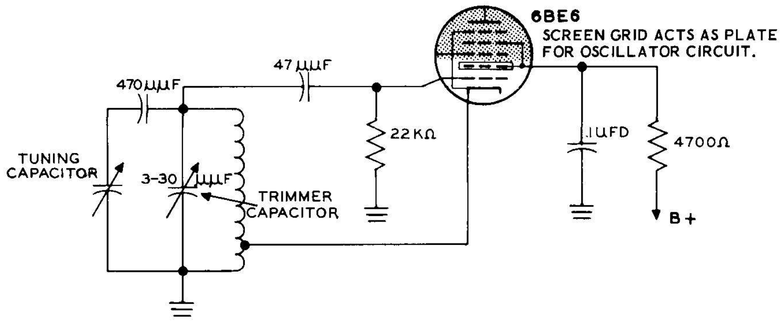
Figure 7J

Figure 7K shows the pentagrid converter tube of the EK-2B Receiver, as it would seem to the oscillator circuit. Since the screen grid of the tube is at a steady DC voltage, it acts just like a plate, as far as the action of the control grid 1 is concerned. Any signal that appears at the screen grid of the pentagrid converter is shorted to ground by the .1 μfd capacitor. This portion of the pentagrid converter, the common cathode, control grid 1, and the screen grid, are the parts of the tube that are used as a triode for the EK-2B oscillator circuit.



THE PENTAGRID CONVERTER TUBE AS IT APPEARS TO THE OSCILLATOR CIRCUIT.

Figure 7K



THE ACTUAL OSCILLATOR CIRCUIT OF THE EK-2B RECEIVER WITH THE SWITCHES REMOVED.

Figure 7L

Figure 7L shows the actual oscillator circuit of your EK-2B Receiver, when it is drawn with the switches removed. By tracing the circuit in the large schematic of the EK-2B Receiver on Page 123, you should be able to follow the circuit connections. Note that when the switch is in the broadcast position, the connections are the same as those of Figure 7L.

The few differences between the circuit of Figure 7L, and the circuit of Figure 7H are minor. The most obvious difference between this circuit and the circuit of Figure 7H, of course, is in the use of the pentagrid converter, which has already been explained. The 470 $\mu\mu$f capacitor, in series with the tuning capacitor, is used to adjust the tuning capacitor to the proper range, so that it will tune as it should in the broadcast band. The 3 to 30 $\mu\mu$f trimmer capacitor is used as a fine adjustment of the oscillator circuit, so it will tune exactly as it should in the broadcast band.

SUMMARY

The purpose of an oscillator circuit is to create an AC signal, either an audio signal or an RF signal. Common examples of oscillators in use are in transmitters, test equipment, television, and many other places.

Common examples of physical oscillators would be a pendulum, or a boy on a swing; each complete cycle of the swing or the pendulum from start to finish can be compared to the oscillation in electrical oscillator circuits. If new energy is not added during each cycle of oscillation, then the swing will gradually move over a shorter and shorter distance, until it stops.

In a basic oscillator circuit an additional coil, called a tickler coil, is wound very close to the coil of the tuned circuit. When the triode is added to this circuit, the tickler coil inserts energy from the plate circuit back into the tuned circuit, located at the grid of the tube. The actions and reactions of these two coils cause the current through the triode, first to increase to its maximum, and then to decrease to minimum. The result of this is that the circuit oscillates between the two extreme limits of the tube's operating range, and an AC waveform results. The frequency of the AC waveform is determined by the tuned circuit.

The oscillator circuit used in the EK-2B Receiver is slightly changed from the basic oscillator circuit. Instead of two separate windings there is now only one winding tapped near the bottom. This winding, instead of being in the plate circuit of the tube, is between the grid of the tube, the cathode, and ground. Except for this slightly different arrangement of the coils, the circuit action is essentially the same.

The actual oscillator circuit of the EK-2B Receiver also contains a type of tube known as a pentagrid converter. The reason that a tube is needed that can accept two separate signals, will be explained in the next lesson when the superheterodyne receiver is studied. The oscillator circuit of the EK-2B Receiver uses only the lower portion of this pentagrid converter tube, which acts just like a triode as far as operation of the oscillator circuit is concerned.

HOW TO TEST AN OSCILLATOR CIRCUIT

To test the oscillator with the meter, and to test the oscillator by tuning in its signal on another receiver.

PARTS REQUIRED

1 4700 Ω 1 watt resistor (yellow-violet-red)
1 22 KΩ resistor, 1/2 watt (red-red-orange)
1 100 KΩ 1/2 watt resistor (brown-black-yellow)
1 47 µµf mica capacitor
1 Dual trimmer capacitor, 3-30 µµf
1 Broadcast oscillator coil (#40-301)
2 6-32 x 3/8" screws
2 6-32 nuts
1 #6 lockwasher
1 #6 solder lug
1 6BE6 tube
1 EK-2B chassis

BECOMING FAMILIAR WITH THE NEW PARTS

The MICA CAPACITOR is a high quality capacitor that is used in higher frequency circuits. Its manner of construction and its marking system are shown in Figure 7M.

Thin plates, made from either metal foil or silver, are sandwiched between layers of insulating mica. Each plate is offset in the opposite direction from the plates on each side of it. This results in two complete sets of plates, much like the two complete sets of plates on the tuning capacitor. A terminal clamp, with a wire attached, makes contact to the sets of plates at each end of the assembly. The whole capacitor is then sealed in a molded plastic case.

Complete data on the marking system for mica capacitors is given inside the front cover of this manual. At this time, a short review of the marking system used for the type of mica capacitors in your EK-2B should be helpful.

Place the mica capacitor in front of you with the identifying arrow pointing to your right. The three dots that show the size of the capacitor will be the upper center dot, the upper right dot and the lower right dot. The color code for the upper center dot identifies the first number in the size of the capacitor. The color code for the upper right dot identifies the second number in the size of the capacitor. The color of the lower right dot identifies the number of zeros, if any, that will be placed after the first two numbers. The size of these capacitors is always read in micromicrofarads, µµf.

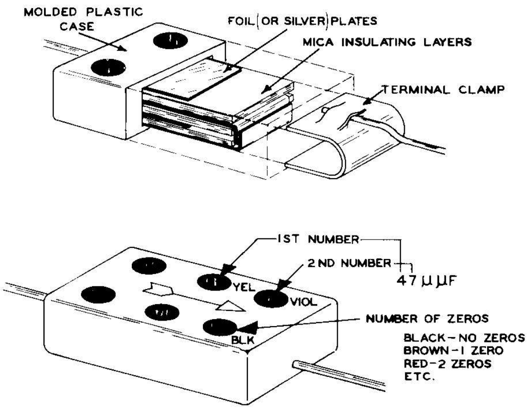


Figure 7M

PREPARING THE CHASSIS

Refer to Figure 7N for the following steps.

( ) Remove the 6BA6 from tube socket V1.

( ) Disconnect and remove the 47 KΩ 1/2 watt resistor that is connected from lug 6 of tube socket V1 to the blue lug of the tuned RF transformer.

( ) Disconnect and remove the wire that is now connected from lug 4 of the dual trimmer capacitor to the orange lug of the tuned RF transformer.

( ) Disconnect and remove the crystal diode that is now connected from the orange lug of the tuned RF transformer to dual-lug terminal T-4.

( ) Disconnect and remove the 100 μμf capacitor that is now connected from lug 1 of the volume control to dual-lug terminal T-3.

( ) Disconnect and remove the 22 KΩ 1/2 watt resistor that is now connected from lug 3 of the volume control to dual-lug terminal T-4.

( ) Disconnect and remove the wire that connects pin 2 to the center post of tube socket V1.

( ) Disconnect and remove the wire that is now connected from the orange lug of the tuned RF transformer, through the hole in the chassis, to the tuning capacitor lug.

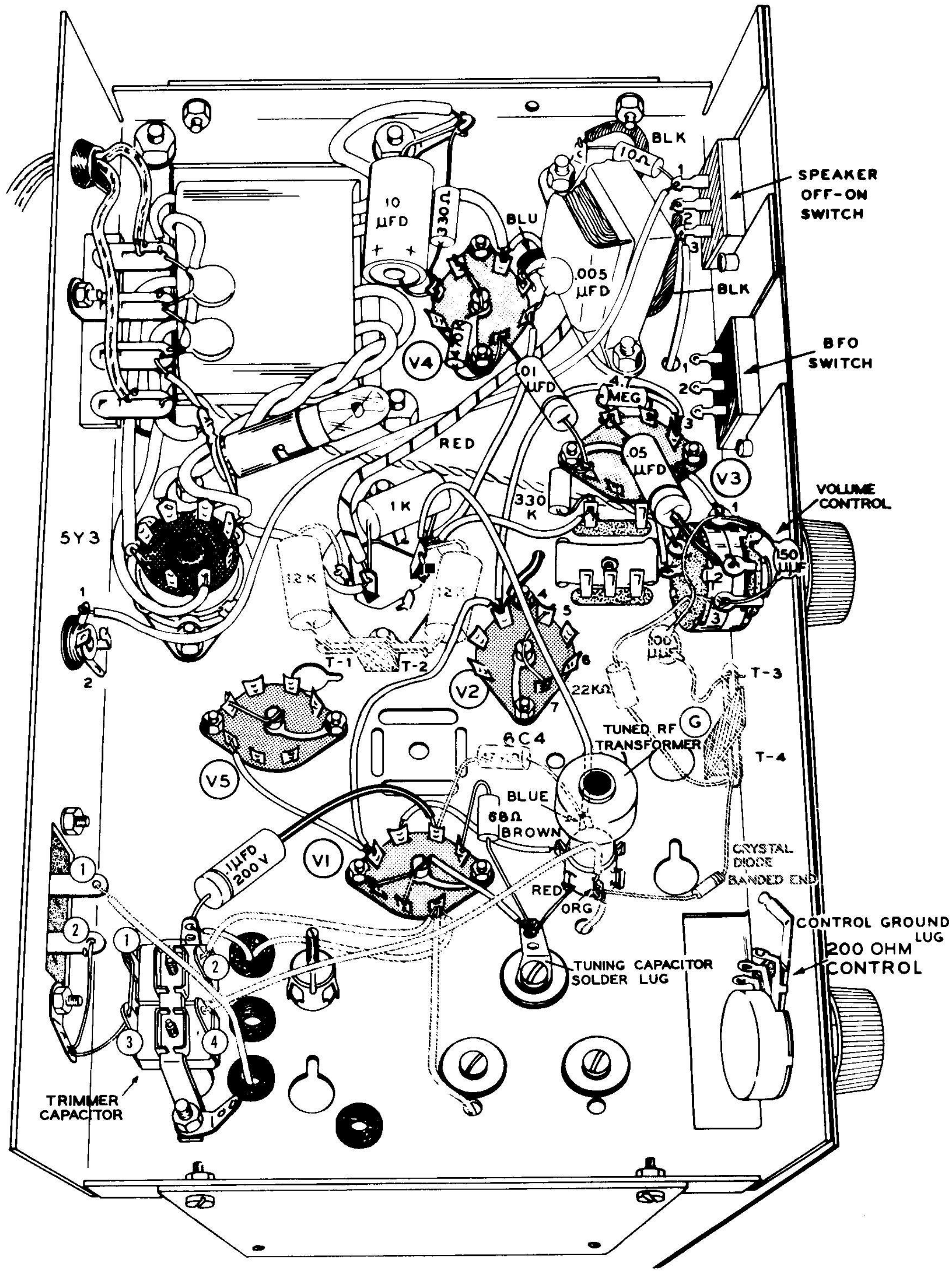
( ) Disconnect the three wires that are now connected to pin 1 of tube socket V1. Now disconnect the other end of each of these three wires, one from the tuning capacitor lug, one from lug 2 of the dual trimmer capacitor, and the other from lug 4 of the broadcast antenna coil.

( ) Disconnect and remove the length of hookup wire that is now connected from lug 1 of the antenna terminal strip to lug 2 of the broadcast antenna coil.

( ) Disconnect and remove the two 12 KΩ 2 watt resistors that now connect from dual-lug terminal strip T-1 and T-2 to the lugs at the power supply filter capacitor.

( ) Remove the dual-lug terminal strip that contains terminal T-1 and T-2. Do this by removing the nut, taking the terminal strip off, and then replacing the nut and the lockwasher.

( ) Remove the dual-lug terminal strip that contains terminals T-3 and T-4.



REMOVE THE DOTTED-IN PARTS FOR LESSON VII

Figure 7N

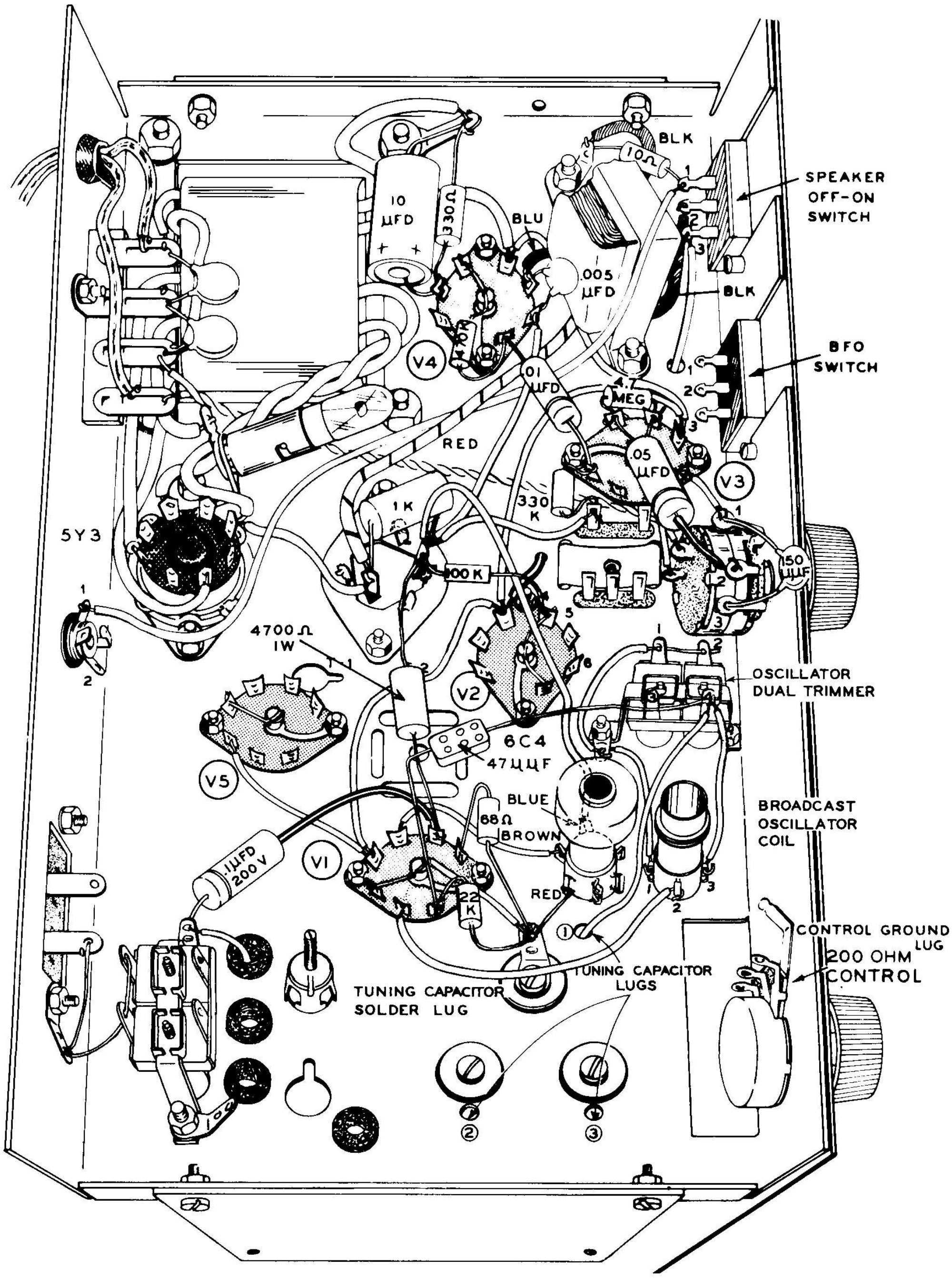

BLK
10Ω
SPEAKER
OFF-ON
SWITCH
10
µFD
330Ω
BLU
.005
µFD
BLK
V4
.01
µFD
4.7
MEG
BFO
SWITCH
RED
.05
µFD
V3
1K
330
K
5Y3
100 K
150
µµF
4700Ω
1W
V2
OSCILLATOR
DUAL TRIMMER
V5
6C4
47µµF
BLUE
68Ω
BROWN
BROADCAST
OSCILLATOR
COIL
.1µFD
200V
V1
22
K
RED
CONTROL GROUND
LUG
200 OHM
CONTROL
TUNING CAPACITOR
LUGS
TUNING CAPACITOR
SOLDER LUG

Figure 7P

BUILDING THE OSCILLATOR CIRCUIT

Refer to Figure 7P for the following steps.

( ) Mount the oscillator dual trimmer capacitor as shown in Detail 7Q. Use 6-32 x 3/8" screws and 6-32 nuts and place the trimmer so that the upper plates (see Figure 6H) are in the position of lugs 1 and 2. Use a #6 lockwasher under the nut closest to the front of the chassis, and place a #6 solder lug under the nut closest to tube socket V2.

( ) Install the broadcast oscillator coil (#40-301) as shown in Detail 7Q.

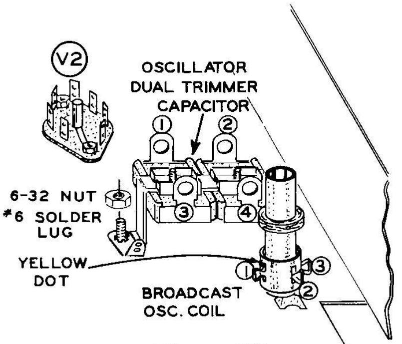


Figure 7Q

NOTE: In all steps referring to the dual trimmer capacitor in this lesson, perform the wiring operations on the dual trimmer capacitor that you just installed, the oscillator trimmer.

( ) Ⓟ Strip about 1" of insulation from the end of a 2-1/2" length of hookup wire. Insert this 1" stripped end of the hookup wire through lug 1 to lug 2 of the dual trimmer capacitor (S). Connect the other end of this wire to the solder lug at the mounting foot of the trimmer capacitor (NS).

( ) Ⓟ Connect a 1-1/2" length of hookup wire from this same ground lug (S) to lug 1 of the broadcast oscillator coil (S).

( ) Ⓟ Connect a 1-1/2" length of hookup wire from lug 4 of the dual trimmer capacitor (NS) to lug 3 of the broadcast oscillator coil (S).

( ) Ⓣ Connect a 2-1/2" length of hookup wire to lug 1 (S) of the tuning capacitor (through the hole in the chassis near the orange lug of the tuned RF transformer). Connect the other end of this wire to lug 4 of the dual trimmer capacitor (NS).

( ) Ⓣ Connect a length of hookup wire from lug 2 of tube socket V1 (S) to lug 2 of the broadcast oscillator coil (S).

( ) Ⓣ Connect the 4700 Ω 1 watt resistor from lug 6 of tube socket V1 (S) to the filter capacitor lug marked with a square ■ (NS).

( ) Ⓟ Connect a 100 KΩ 1/2 watt resistor from the filter capacitor lug marked with a square ■ (S) to lug 4 of tube socket V2 (S).

( ) Ⓣ Connect a 47 μμf mica capacitor from lug 1 of tube socket V1 (NS) to lug 4 of the dual trimmer capacitor (S).

( ) Ⓣ Connect a 22 KΩ 1/2 watt resistor from lug 1 of tube socket V1 (S) to the tuning capacitor solder lug (S).

EXPERIMENT 1

To determine if the circuit oscillates by using a voltmeter.

NOTE: Find the locations of the various coil and trimmer adjustments by referring to Figure 7R.

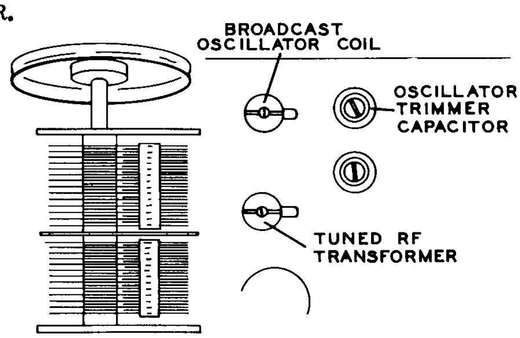


Figure 7R

( ) Tighten the adjustment screw of the oscillator trimmer capacitor until it stops turning easily. Do not overtighten this adjustment.

( ) Turn the adjustment screws for the tuned RF transformer and the broadcast oscillator coil all the way in. At this point only about 1/8" of the adjustment screw should be protruding above the coil.

( ) Plug the 6BE6 tube into tube socket V1.

( ) Place the chassis on its side as shown in Figure 7S.

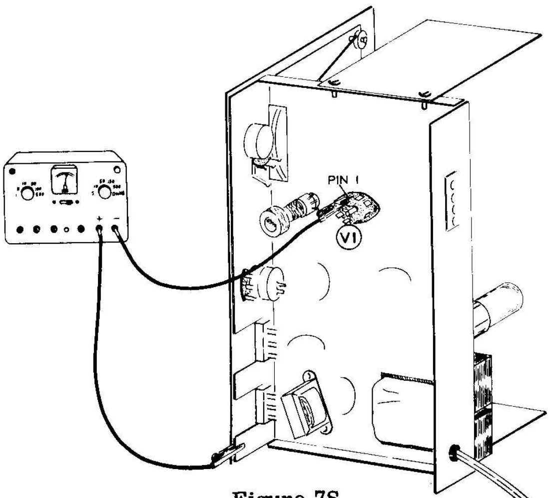


Figure 7S

( ) Connect the red positive lead of your EK-1 Voltmeter to the chassis of your EK-2B Receiver.

( ) Connect the black negative lead of your EK-1 Voltmeter to pin 1 of tube socket V1. Make sure that this voltmeter lead does not lean over and touch or short out any other connections that may be near pin 1.

( ) Turn the range switch of your EK-1 Voltmeter to the 50 volt range.

( ) Plug in your EK-2B Receiver, and turn on the switch.

( ) Adjust the tuning capacitor until it is about one-half way open.

( ) Note the reading on your EK-1 Meter. It reads about 10 volts. This is the bias voltage that the oscillator creates at the oscillator grid of the converter tube (no voltage would mean that the circuit is not oscillating).

( ) Short pin 2, the cathode of the pentagrid converter tube, to chassis ground with a screwdriver and notice that this causes the voltage read by the EK-1 Meter to decrease to zero. The voltage has decreased to zero because you have disabled the oscillator circuit (shorted out the tickler winding), so no bias is developed at the oscillator grid.

( ) Turn off the receiver.

EXPERIMENT 2

To show that the oscillator is working by tuning it in on a different receiver.

( ) Disconnect both leads of the EK-1 Meter from the EK-2B Receiver.

( ) Place the EK-2B Receiver and another radio receiver close together and turn on both of them.

( ) Tune the other receiver carefully through the broadcast band; notice that at some point above 650 kc on the dial, the receiver tunes through a point that is either very quiet, or a whistle is heard. This point is caused by the oscillator signal from the EK-2B Receiver.

( ) Short the cathode (pin 2) to ground, for a moment, ~~and note that the~~ above effects disappear.

( ) Turn the EK-2B tuning capacitor a little way (in either direction) from its present position, and notice that the receiver again sounds normal.

( ) Now retune the other receiver and notice that the quiet spot on the dial has moved.

( ) Notice that by tuning the frequency of the EK-2B oscillator in this manner that its position can be shifted almost all of the way up and down the broadcast band of the other radio.

( ) Tune in a radio station on the other receiver. Now tune the EK-2B until a whistle is heard on the other receiver. This whistle comes from the EK-2B oscillator signal being mixed with the signal in the other receiver. When your EK-2B oscillator is at the exact same frequency as the signal in the other receiver, the whistle will stop. This is sometimes called the "zero beat" between two frequencies. As you tune your EK-2B oscillator to either side of this zero beat point, the whistle will gradually change in tone, from a very low note to a very high note.

( ) Turn off the receiver and unplug it.

DISCUSSION

Figure 7T is the schematic diagram for the oscillator circuit used in the experiments you have just completed. This is the same type of oscillator used in the complete EK-2B Receiver. As explained in the early parts of this lesson, the oscillator circuit uses the cathode, grid 1, and the screen grid of the pentagrid converter tube. This part of the converter tube operates like a regular triode tube.

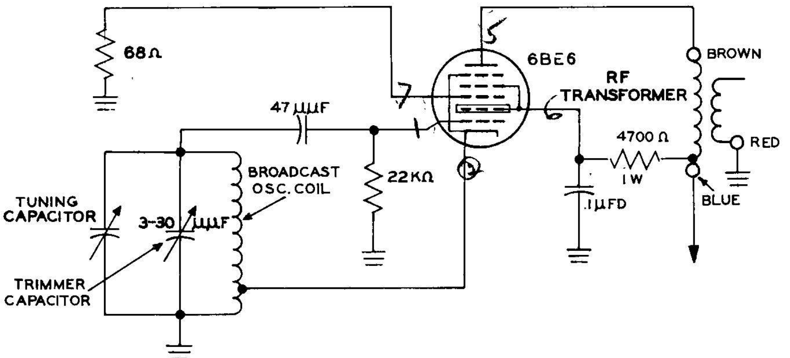
The RF transformer is used as a plate load for the circuit. The 4700 Ω 1 watt resistor is used to lower the B+ voltage before it is applied to the screen grid of the tube. The .1 μfd capacitor is used to ground out the AC variations from the oscillator that appear on the screen grid. The 68 Ω resistor connected to control grid 2 helps keep this grid ineffective for the purpose of this experiment.

In Experiment 1 you measured the bias voltage (developed across the grid resistor) at the oscillator grid (grid 1) of the converter tube. This is one of the ways to test an oscillator circuit to see if it is working. Since the bias at this grid is created by the oscillation current flowing in the grid resistor, if the oscillator is not working, there will be no bias, as indicated by shorting pin 2 of V1 to ground. (Refer to the explanation for grid leak bias on Page 68 of this lesson.)

The signals from this oscillator circuit are broadcast from your EK-2B Receiver, for a short distance, just like the signal that is broadcast from a radio station. In Experiment 2 you tuned in this oscillator signal on another receiver. Since there is no modulation on the oscillator signal, it appears as a quiet point when it is tuned in on the dial.

If a station is tuned in on the other receiver, a whistling noise is heard when you tune your EK-2B Receiver near the frequency of this station. This whistling noise is created because the frequency of the oscillator in the EK-2B combines with the frequency of the signal from the radio station in the other receiver. This creates the whistling noise, which changes in tone as you tune closer to, and further away from the frequency of the station.

Lesson VII has explained how the oscillator circuit operates. In Lesson VIII you will learn how the oscillator signal combines with the signal from a radio station in the converter tube of a superheterodyne receiver.



A SCHEMATIC DIAGRAM OF THE OSCILLATOR CIRCUIT USED FOR THE EXPERIMENTS IN LESSON VII.

Figure 7T

LESSON VII

QUESTIONS

1. An oscillator is a circuit that is used to create wave form AC Signal.

2. The definition of the word "oscillate" means to [illegible] back & forth.

3. If some electrical energy were placed in a tuned circuit, and then the source of the energy was taken away, the waveform would gradually die down in amplitude. This would be called a dampened wave-form.

4. The coil, or coil winding that causes the output energy to feed back into the input tuned circuit of the basic oscillator (Figure 7F), is called the tickler coil.

5. The current flow in the tube of the basic oscillator circuit is constantly changing. It oscillates back and forth between the maximum and the minimum current that the tube can conduct.

6. Usually grid leak bias is created at the grid (across the grid resistor) of the oscillator tube.

7. In the oscillator circuit of the EK-2B Receiver (Figure 7T), the portion of the oscillator coil that has the same function as the tickler coil in the basic oscillator, is that part of the coil between the cathode of the tube and ground.

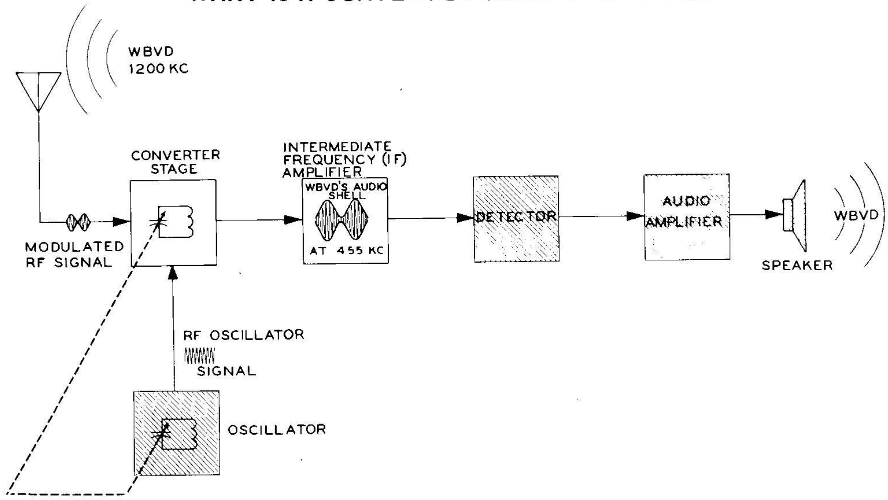
8. To the oscillator circuit, the screen grid of the pentagrid converter tube acts just like the plate of the tube.

9. One way to see if an oscillator tube is working is to measure the -bias voltage at the grid of the oscillator tube.

oscillator

LESSON VIII

WHAT IS A CONVERTER CIRCUIT USED FOR?



A BLOCK DIAGRAM OF THE SUPERHETERODYNE RECEIVER SHOWING THE DIFFERENT STAGES OF THE RECEIVER AND THE SIGNALS PRESENT.

Figure 8A

A converter circuit fills one of the basic needs of the superheterodyne receiver by combining ~~two~~ different signals in the same tube. One of these signals is from the radio station, and the other signal is from the oscillator circuit in the receiver.

This combining action may be done by several methods. One method is by using a pentagrid converter tube which does all of the oscillating and combining in the same tube. In another method two separate tubes may be used; the tube that does the combining is called a "mixer" tube, and the tube for the oscillator circuit is the oscillator tube.

The last lesson, Lesson VII, showed you how the oscillator worked. This lesson will show you how the oscillator signal and the signal received from the antenna are combined in the converter, in order to overcome some of the disadvantages of TRF receivers.

GENERAL SUPERHETERODYNE THEORY

In Lesson VI you learned two disadvantages of the TRF receiver. One disadvantage was the need for a many-sectioned variable capacitor, which creates the problem of keeping the many capacitor sections adjusted to exactly the same frequency. The other difficulty with the TRF receiver was in the coils themselves. If a tuned circuit coil is to tune well all the way across the broadcast band, it must be a "low-Q" type of coil, which is a compromise, and will have high internal losses. The superheterodyne receiver goes a long way toward overcoming these two difficulties.

Figure 8A shows a block diagram of a superheterodyne receiver. The new stages you have not studied are, the combining stage (which is the mixer or converter stage, sometimes called the first detector), and the intermediate amplifier (or IF) stage. The boxes of the stages that you have studied in previous lessons are shaded.

The antenna, along with the input tuned circuit, sends the desired broadcast signal to control grid #2 of the converter stage. The oscillator section also sends an RF signal into the converter stage (control grid #1). As a result, when both of these two signals are present in the same tube, additional signals are produced, one of which is coupled to the intermediate amplifier stage.

As a result of the combining action, this signal that is coupled to the IF amplifier stage contains the audio modulation from the desired broadcast signal.

This modulated IF signal is then amplified and sent on to the detector circuit.

The two-section tuning capacitor makes the input tuned circuit of the converter stage and the tuned circuit of the oscillator turn together. This mechanical connection that makes the two sections of the tuning capacitor tune together is indicated by the dotted line in Figure 8A. Tuning both circuits simultaneously causes the IF signal created in the converter stage to stay at the same frequency at all times. In other words, the frequency of the oscillator and the frequency of the input tuned circuit are always separated by the same number of kilocycles (kc).

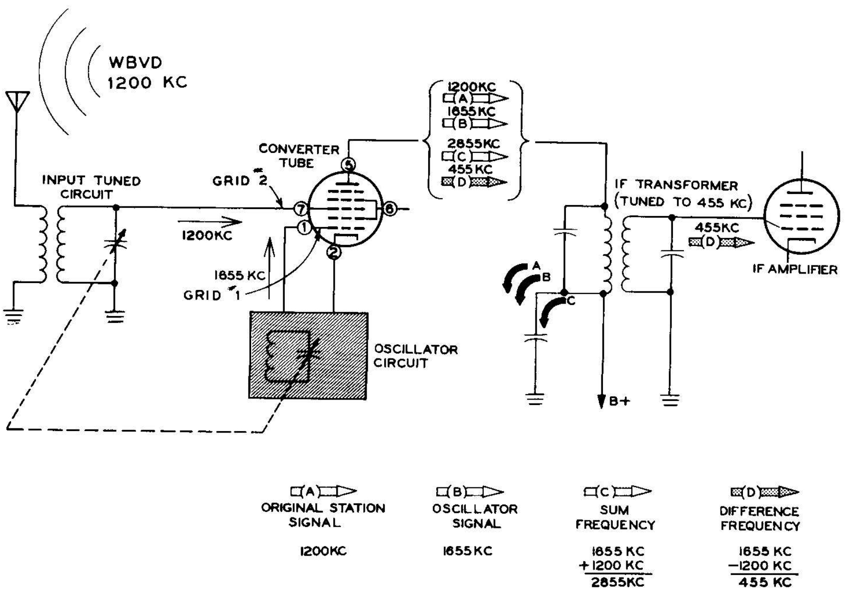
Both of the disadvantages of TRF receiver (see Page 58) that were mentioned previously, have now been overcome. The first disadvantage has been overcome because only one 2-section tuning capacitor is now needed, one section for the converter stage and one section for the oscillator stage. More stages (IF amplifiers) could now be added without adding gangs to the tuning capacitor, because the IF's are always tuned to the same frequency.

The superheterodyne receiver also overcomes the coil difficulty. Since the coils of the IF amplifier stage always operate at the same frequency, no compromise has to be made when they are designed. The IF coils can be designed to be very high quality (high-Q) coils, because they just have to operate at one frequency, 455 kc. Since high-Q coils can be used in this IF amplifier stage, the stage can amplify signals a greater number of times than the RF amplifier stages of the TRF receiver.

COMBINING SIGNALS

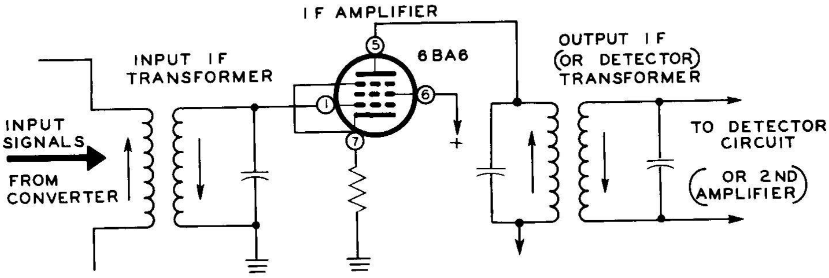
Figure 8B shows the input and output signals in the converter circuit of the superheterodyne receiver. The desired signal shown at 1200 kc is received from the antenna by the input tuned circuit, and coupled to the converter tube. The signal from the oscillator circuit shown at 1655 kc is coupled to the other grid of the converter tube.

Both of these signals, the 1200 kc input signal and the oscillator signal, control the cathode-to-plate current of the converter tube. The result of combining these frequencies in one tube is shown by the arrows in the plate circuit of the tube.



FOUR DIFFERENT SIGNALS ARE PRESENT IN THE PLATE CIRCUIT OF THE CONVERTER TUBE.

Figure 8B



A SCHEMATIC DIAGRAM OF A TYPICAL IF AMPLIFIER.

Figure 8C

If the total output signal in the plate of the converter tube were analyzed, we would find four different signals present there. These four signals are shown by arrows A, B, C, and D. Arrow A shows the original station signal at 1200 kc. Arrow B shows the original oscillator signal at 1655 kc. Arrow C is a signal that results from the sum of these two frequencies, 2855 kc. Arrow D is a frequency that results from the difference between the two frequencies, this frequency is at 455 kc. The signal at 455 kc, Arrow D, is the signal selected by the IF amplifier.

The IF transformer is tuned to 455 kc, therefore only that frequency is selected and sent to the IF amplifier. All three of the other frequencies are shorted to ground. The 455 kc IF signal has the same modulation envelope that was present on the original signal.

The tuning capacitor for the oscillator circuit and the tuning capacitor for the input tuned circuit turn together, so that there is always a 455 kc difference between these two frequencies at any setting of the tuning gang. This allows the IF transformers to be designed with a very high quality (high-Q), causing the IF amplifiers to have a very high amplification. If you tune a station at the low end of the broadcast band, say at 650 kc, the oscillator will be 455 kc higher, or at 1005 kc. If you tune a station at the high end of the broadcast band, 1600 kc for example, then the oscillator circuit will be tuned to 1955 kc. The difference frequency stays at 455 kc.

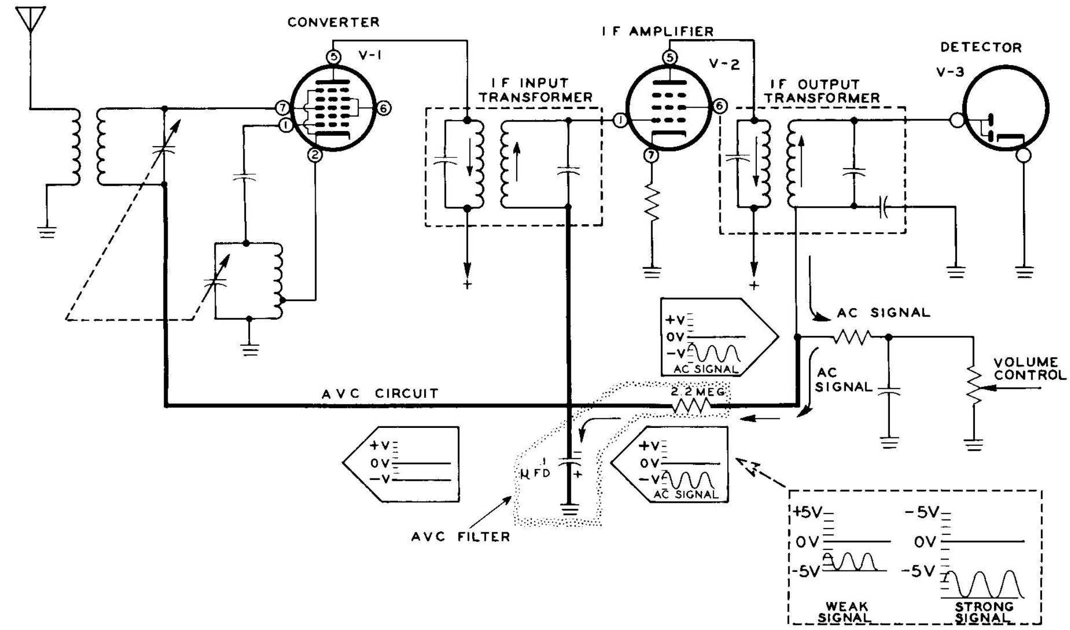
The oscillator tuned circuit and the input tuned circuit must be adjusted carefully so that the difference between the two frequencies will always be 455 kc. The adjustment procedure to insure that these two circuits tune properly all the way across the broadcast band, is called the "alignment," or "tracking" procedure. This will be discussed further in Lesson IX.

THE IF AMPLIFIER

The IF amplifier amplifies a signal in the same manner the RF amplifier did. The main difference is that the IF amplifier is much more efficient, because it amplifies only one frequency, 455 kc all the time. In some cases, where greater amplification is desired, two or even three IF amplifier stages can be used.

Notice the arrows in the primary and secondary windings of the IF transformers in Figure 8C. Each of these arrows indicates an adjustable powdered iron core in the transformer. The IF transformer has a separate adjustable core for each winding. One of these adjustments tunes from the top of the transformer, and the other adjustment tunes from the bottom of the transformer, as indicated by the arrows.

These adjustments tune each coil of each transformer to compensate for the minor differences between circuits. During the alignment procedure for the receiver, each of these transformer windings is adjusted so that the amplifier will best amplify 455 kc.



A SCHEMATIC DIAGRAM OF THE COMPLETE AVC CIRCUIT. THE SMALL ARROWS TRACE THE FLOW OF SIGNAL CURRENT AND THE LARGE ARROWS SHOW THE DEVELOPMENT OF THE AVC VOLTAGE.

Figure 8D

THE AVC CIRCUIT

How the automatic volume control voltage or AVC voltage is developed, in order to keep the volume of the receiver at about the same listening level, was discussed in Lesson V. The complete AVC circuit is shown in Figure 8D. This AVC circuit is used to adjust the volume of the receiver up or down automatically, by creating a DC controlling voltage.

This DC controlling voltage, or AVC voltage, is created from the rectified RF signal in the detector circuit. It is then applied to the IF and RF amplifier sections of the receiver as grid bias, where it controls the amplification of these two tubes.

The signal from the detector circuit, as shown in Figure 8D, is always at a negative voltage level; in other words it is a negative PDC signal. This negative PDC signal flows from the detector circuit to the AVC filter circuit (which consists of the 2.2 megohm resistor and the .1 µfd capacitor). The AVC filter circuit changes the negative PDC voltage into a negative DC voltage, which is equal to the peak negative value of the AC signal.

When a weak signal is received at the detector circuit this negative voltage will be small, therefore a small negative voltage will appear across the .1 µfd capacitor of the AVC filter. When a large signal is received at the detector circuit, a large negative voltage appears across the .1 µfd capacitor. The voltage across this capacitor, then, is quite large when a strong station is being received, and it is quite small when a weak station is being received by the receiver.

This negative AVC voltage that appears across the .1 µfd capacitor, controls the amount of amplification in both the pentagrid converter tube and in the IF amplifier tube by regulating their bias voltage. When the negative bias voltage on these tubes (the AVC voltage) becomes large, the tube will amplify less. When the negative bias voltage (AVC voltage) becomes smaller, or less negative, the tubes amplify more.

Since the negative AVC voltage that appears across the .1 µfd capacitor is connected to each of these two grids, through the transformer windings, the amount that each of these two tubes amplify will change with the amount of negative voltage across the .1 μfd capacitor.

Now trace the action of the AVC circuit for a strong signal and then for a weak signal. When a strong signal is received at the antenna, the signal is amplified by the converter tube and the IF amplifier, and then it creates a large signal at the detector circuit. The large signal from the detector circuit creates a large negative PDC signal at the output of the detector.This large negative PDC signal causes a large DC voltage to appear across the .1 μfd capacitor. This large negative voltage across the .1 μfd capacitor is applied as bias to the grid of the IF amplifier, and to the grid of the pentagrid converter; then the amount that these two tubes amplify is reduced and less signal is coupled to the detector.

If a weak signal is now presented to the tuning circuits of the receiver, either by tuning a new station, or by the previous signal fading out, the AVC circuit has the opposite effect on the receiver. The smaller signal will cause a smaller signal to appear at the output of a detector circuit. This smaller negative PDC signal will cause a smaller negative DC signal to appear across the .1 μfd capacitor. This smaller (less negative) signal across the .1 μfd capacitor will present a less negative bias voltage at the grid of the pentagrid converter and the IF amplifier tubes. This smaller bias voltage would cause both of these two amplifier tubes to amplify the weak signal a greater number of times,. thus presenting a larger signal to the detector.

This AVC circuit, of course, will not do the job of the volume control. The volume control can be thought of as setting the level in the speaker that you wish to listen to. The AVC circuit may be thought of as helping to keep the signal at this same level, and not allowing atmospheric conditions to constantly change the volume. This changing volume effect can still be noticed sometimes, but it would be much worse if no AVC were used in the receiver.

SUMMARY

The converter circuit is used to combine two signals. These two signals are the input broadcast signal from the antenna, and the RF signal from the oscillator circuit. By controlling the stream of electrons from the cathode to the plate of the converter tube with these two different signals, four different signals occur in the plate circuit of the tube.

These four signals are, the original signal from the antenna, the original oscillator signal, the sum of these two signals, and the difference between these two signals. The signal that is selected, and used by the IF amplifier circuits, is the difference signal, usually 455 kc in home receivers. This type of receiver, where an IF signal is created, is called a superheterodyne receiver.

The tuning capacitor for the oscillator circuit and the tuning capacitor for the input tuned circuit are mechanically connected, and turn together, so that there is always 455 kc difference between the two frequencies. As the result of this, at any place on the dial of the receiver a 455 kc difference frequency will be created between these two circuits. This 455 kc frequency, or IF frequency is then amplified by the IF amplifiers.

Only two sections of the tuning capacitor are usually needed for superheterodyne receivers, where many more were usually used in the TRF receiver. Another big advantage of the superheterodyne receiver is in the coils of the IF amplifier circuit. Since the IF amplifier circuits always amplify the same frequency, 455 kc, very high quality (high-Q) coils can be used, and the gain of these amplifiers will be very high. Each IF transformer contains a tuned circuit in the primary, and a tuned circuit in the secondary that tune to 455 kc.

The AVC circuit automatically increases or decreases the amount of amplification of the converter stage and the IF amplifier stage. This automatic volume control, or AVC, tends to hold the volume of the receiver at a constant level, even when atmospheric conditions cause fading and surging, which increases or decreases the amount of signal received from the antenna.

HOW TO BUILD A SUPERHETERODYNE RECEIVER

To show the difference in operation between a superheterodyne receiver, and all previous receivers built in the EK-2B up to this time.

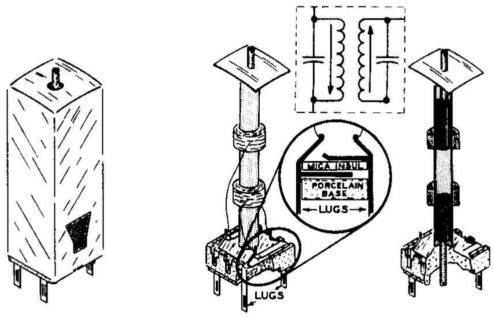
PARTS REQUIRED

1 68 Ω 1/2 watt resistor (blue-gray-black)
1 47 KΩ 1/2 watt resistor (yellow-violet-orange)
1 2.2 megohm 1/2 watt resistor (red-red-green)
1 4700 Ω 1 watt resistor (yellow-violet-red) (now mounted on the chassis)
1 470 μμf mica capacitor
1 .1 μfd tubular capacitor
1 IF transformer (#52-4)
1 6BA6 tube
1 EK-2B chassis
1 IF transformer mounting clip

BECOMING FAMILIAR WITH THE NEW PARTS

The IF transformers are used to couple signals into and out of IF amplifier stages. Two high quality (high-Q) coils are wound on a hollow cardboard tube, at the proper distance from each other. The hollow cardboard tube, with the two windings on it, is then mounted on a porcelain or plastic base assembly containing four contacts. The wires from each coil are then connected across a pair of the contacts.

Notice that the upper part of each of these contacts is folded over the plastic base. Notice also that an insulating layer is placed between the pairs of contacts, forming a small capacitor between each pair of contacts. These small capacitors are the capacitors shown on the schematic diagram; they are used to tune the coil to the proper frequency, in this case 455 kc.



THE IF TRANSFORMER AND ITS SCHEMATIC SYMBOL.

Figure 8E

Two powdered iron slugs are introduced into the coils, one from the top of the assembly and one from the bottom of the assembly. These two adjustments align each coil separately so that each can be tuned to exactly 455 kc after the IF transformer is mounted in the receiver.

PREPARING THE CHASSIS

Refer to Figure 8F for the following steps.

( ) Disconnect the 4700 Ω 1 watt resistor that is connected from lug 6 of tube socket V1 to the filter capacitor lug marked with the square ■. Set this resistor to one side, as it will be wired back into the circuit later in a different position.

( ) Disconnect and remove the hookup wire that now connects from the blue lug of the tuned RF transformer to the filter capacitor lug marked with the square ■.

( ) Disconnect and remove the 68 Ω 1/2 watt resistor that is now connected from lug 7 of tube socket V1 to the tuning capacitor solder lug.

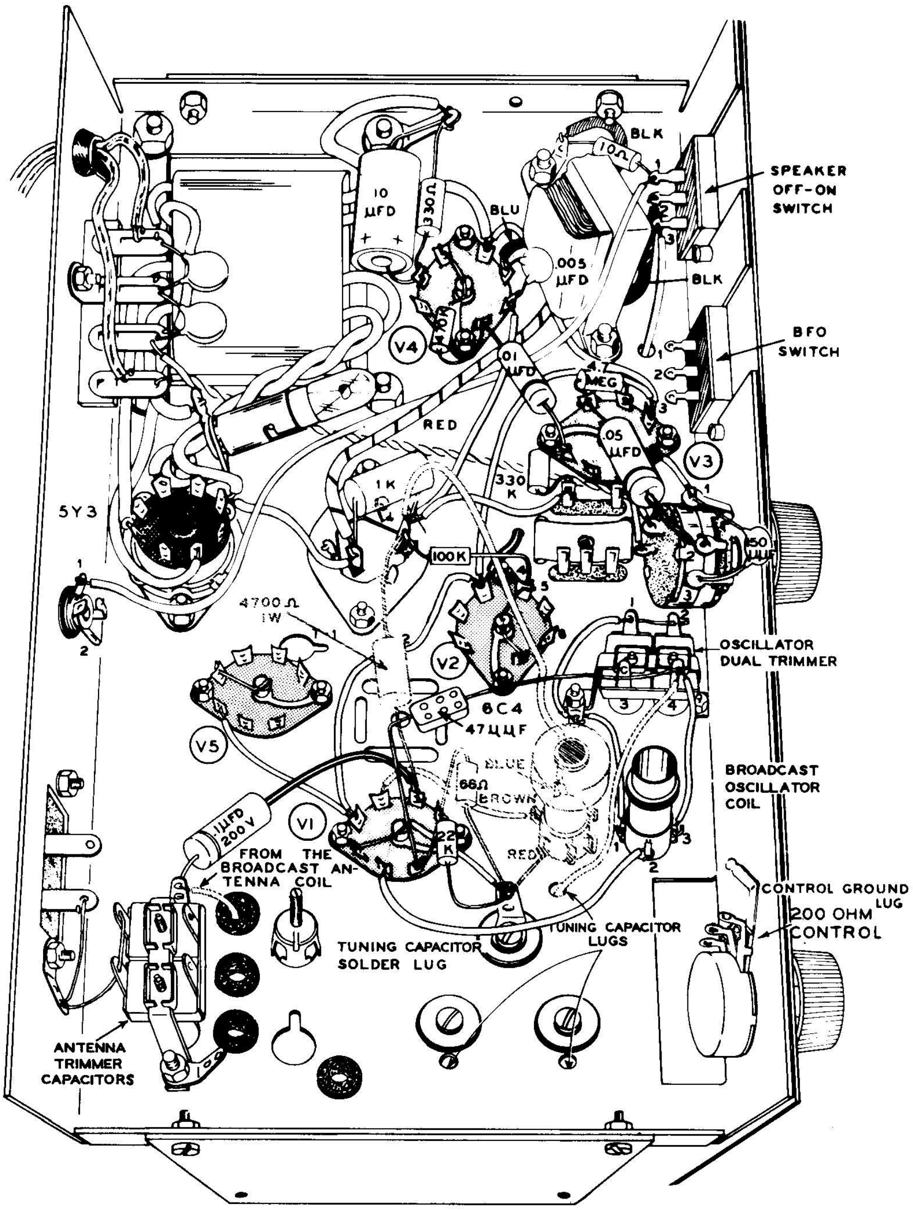
( ) Disconnect and remove the short length of wire that is connected between the red lug of the tuned RF transformer and the tuning capacitor solder lug.

( ) Disconnect and remove length of hookup wire that is connected between lug 5 of tube socket V1 and the brown lug of the tuned RF transformer.

( ) Remove and discard the wire that is connected from pin 7 to the center post of tube socket V2. Do not discard the part of the wire that connects lug 4 to the center post.

( ) Remove the tuned RF transformer from the chassis. This can be done easily by squeezing the two tabs that hold it in position above the chassis, and then pulling the transformer downward.

NOTE: Wiring will be done on both sets of dual trimmers in this lesson. The dual trimmer that is mounted near tube socket V1 and the oscillator coil will be known as the oscillator trimmer. The dual trimmer mounted near the antenna terminals will be known as the antenna trimmer.



PICTORIAL VIEW OF THE CHASSIS-REMOVING THE PARTS.

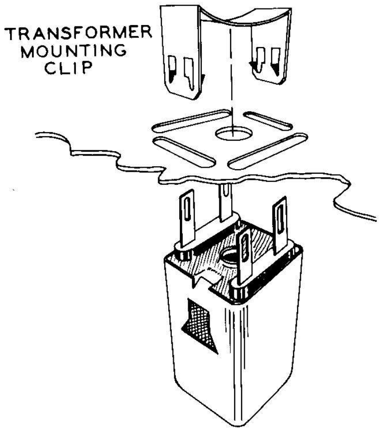
Figure 8F

(✓) Disconnect the wire that connects from lug 4 of the oscillator trimmer down through the hole in the chassis. Disconnect the other end of this wire from the tuning capacitor lug above the chassis.

(✓) Remove the length of hookup wire that connects from lug 1 of the broadcast antenna coil (on top of the chassis) through grommet 3 to the solder lug below the chassis.

Refer to Figure 8G for the following steps.

( ) Mount the IF transformer (#52-4) in position between tube sockets V1 and V2 as shown in Detail 8H. Notice that the transformer is installed so that the green paint spot is positioned near lug 5 of tube socket V1.



MOUNTING THE IF TRANSFORMER.

Figure 8H

( ) [P] Insert a short length of bare wire through lug 6 to lug 5 of tube socket V3 (S). Connect the other end of this short bare wire to lug 2 of the IF output transformer (S).

( ) [P] Connect a 47 KΩ 1/2 watt resistor from lug 5 of the IF output transformer (NS) to lug 3 of the volume control (S).

( ) [P] Bend over lug 3 of the IF output transformer to touch lug 5 of tube socket V2. Now solder these two lugs together (S).

( ) [P] Insert a short length of bare wire from lug 4 of tube socket V2 (S) to lug 4 of the IF output transformer (S).

( ) [P] Bend over lug 1 of tube socket V2 to touch lug 2 of the IF input transformer. Now solder these two lugs together (S).

( ) [P] Connect a length of hookup wire from lug 1 of the IF input transformer (NS) to the filter capacitor solder lug marked with the square ■ (S).

( ) [P] Connect a length of hookup wire from lug 6 of tube socket V1 (NS) to lug 6 of tube socket V2 (S).

( ) [P] Insert one lead of a 68 Ω 1/2 watt resistor through lug 2 to the center post of tube socket V2 (S). Connect the other lead of this resistor to lug 7 of tube socket V2 (S).

( ) [P] Connect a 2.2 megohm 1/2 watt resistor from lug 5 of the IF output transformer (S) to lug 4 of the IF input transformer (NS). Use sleeving on both of these leads.

( ) [P] Bend over lug 5 of the tube socket V1 to touch lug 3 of the IF input transformer. Now solder these two lugs together (S).

( ) [P] Connect a 4700 Ω 1 watt resistor from lug 1 of the IF input transformer (S) to lug 6 of tube socket V1 (S). Position this resistor so the bottom slug of the transformer is not hidden under it.

( ) [T] Connect a 470 μμf (.00047) mica capacitor to oscillator trimmer lug 4 (S). Connect the other lead through the chassis hole to tuning capacitor lug 1 (S). Use sleeving.

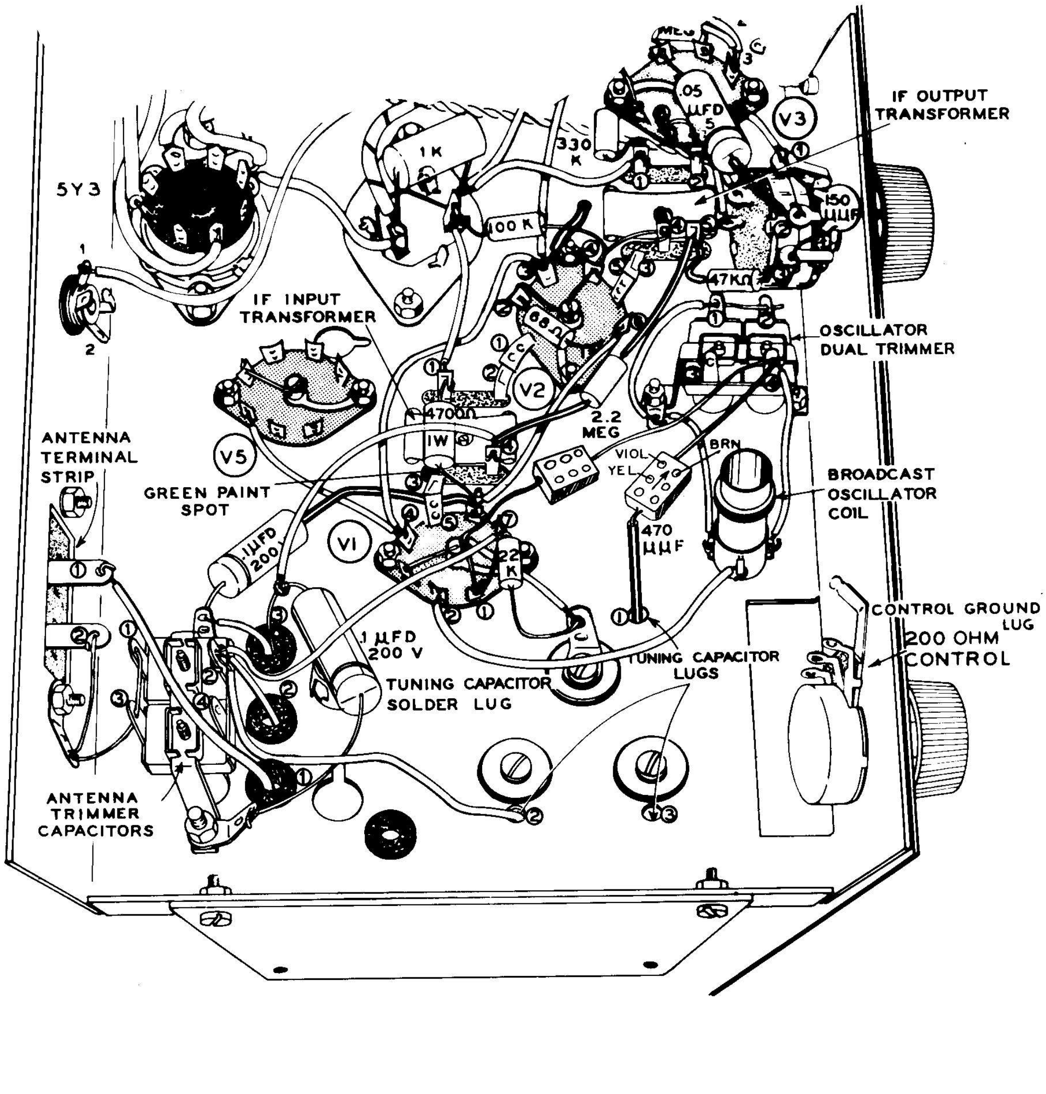
( ) [T] Connect a length of hookup wire from lug 2 of the antenna trimmer capacitor (NS), through the chassis hole, to tuning capacitor lug 2 (S).

( ) [T] Connect one lead of a .1 μfd 200 volt tubular capacitor through grommet 3 to lug 1 of the broadcast antenna coil (S) (see Figure 6K). Connect the other lead of this capacitor to the ground lug at the mounting foot of the antenna trimmer (S).

( ) [T] Connect a length of hookup wire from lug 4 of the IF input transformer (S) to the capacitor lead that goes down through grommet 3 (S).

( ) [T] Connect a length of hookup wire from lug 7 of tube socket V1 (S) to lug 2 of the antenna trimmer (NS).

( ) [T] Connect a 4" length of hookup wire to lug 1, the antenna lug, of the antenna terminal strip (S). Insert the other end of this wire down through grommet 1 and connect it to lug 2 of the broadcast antenna coil (S) (see Figure 6K).

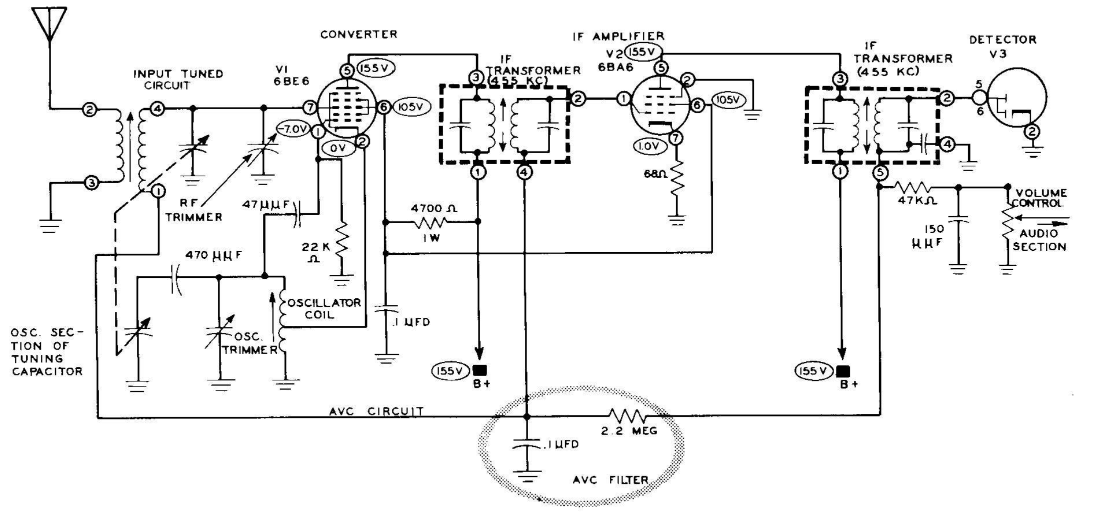


PICTORIAL VIEW OF THE CHASS-MOUNTING THE NEW PARTS.

Figure 8G

(✓) Ⓟ Connect one end of a short length of hookup wire to lug 2 of the antenna trimmers (S). Insert the other end of this wire through grommet 2, and connect it to lug 4 of the broadcast antenna coil (S) (see Figure 6K).

( ) Install a 6BA6 tube in tube socket V2.



A SCHEMATIC DIAGRAM OF THE EK-2B SUPERHETERODYNE RECEIVER, INCLUDING THE OSCILLATOR, CONVERTER, AND IF AMPLIFIERS.

Figure 8J

EXPERIMENT 1

To demonstrate that no signal is received when the oscillator is disabled, and to compare the sensitivity and the tuning of this receiver to the previous receivers.

( ) Connect your antenna leads and ground lead to the terminals at the rear of your EK-2B Receiver.

( ) Plug in the receiver and turn on the switch. Tune in a station on the receiver.

Figure 8J shows the schematic diagram of your EK-2B superheterodyne receiver as it is now connected. The complete detector circuit and the audic circuits have not been shown, since they are the same as before. Trace the different circuits of Figure 8J and make sure that you know the function of each one. The pentagrid converter tube, V1, contains the oscillator circuit, and the converting or mixing circuit. Tube V2, along with the IF input transformer and the IF output transformer, make up the IF amplifier stage.

( ) Now touch a screwdriver blade from pin 1 of tube socket V1 to the chassis. Notice that this stops the station from being heard in the receiver. Notice also, in Figure 8J, that this has grounded out the grid of the oscillator section of the converter tube.

( ) Remove the screwdriver shorting out grid 1. Now tune all of the different stations that you can receive on your EK-2B Receiver. Note the difference in sensitivity and the selectivity of this receiver compared with the previous receivers you have constructed. Greater sensitivity should be shown by the number of stations that you receive, and by how strongly they are received. Greater selectivity should be observed by noting that each station tunes more sharply than before, and also, close-together stations can be separated more easily.

DISCUSSION

In the experiments of Lesson VIII you have constructed a complete superheterodyne receiver. By shorting the grid of the oscillator to ground, the oscillator circuit ceases to function. This eliminates one of the frequencies to be combined in the converter tube. When no oscillator signal is combined with the input broadcast signal, no 455 kc difference frequency is created, therefore, there is no IF frequency and nothing is heard at the output of the receiver.

Tuning stations all across the broadcast band helped show you the difference between the superheterodyne receiver and the previous receivers. The selectivity of the superheterodyne receiver is greater. Not only are close-together stations easier to separate, but stations all the way across the broadcast band can be tuned more sharply than before.

Greater sensitivity should be noticed with the superheterodyne receiver, because more stations should have been received than with previous circuits. Greater sensitivity should also have been noticed when stations that were formerly rather weak became stronger. You may also have heard new stations that you didn't hear before.

In Lesson VII and Lesson VIII you have learned how the superheterodyne receiver operates. Lesson IX will show you the proper adjustment, or "alignment," procedure for all of these circuits. This alignment procedure is necessary so that the best performance can be obtained from the receiver.

LESSON VIII

QUESTIONS

1. A converter circuit combines ______ ______ in the same tube.
2. The signal from the oscillator circuit and the signal from the input tuned circuit mix in the pentagrid converter. As a result of this mixing action, 4 different signals are present in the plate circuit of the converter tube.
3. List the signals present in the plate circuit of the converter tube.
4. The signal from the converter tube that is coupled to the IF amplifier is the 455 frequency between the two original signals.
5. The modulation present on the input signal from the antenna circuit (is, is not) present on the IF signal.
6. True or false? As you tune the superheterodyne receiver from one station to another, the IF frequency changes.
7. Why can high quality IF transformer coils be made for the superheterodyne receiver, but not in the TRF receiver?
8. The tuning capacitors for the input tuned circuit and oscillator tuned circuit turn together. The difference between the frequencies of these two tuned circuits should always be 455.
9. Each IF transformer has (one adjustment for both coils, one adjustment for each coil).
10. The received signal actually becomes a negative PDC signal at the input of the AVC filter. The signal at the output of the AVC circuit is a (negative, positive) DC voltage.
11. True or false? The AVC voltage developed across the .1 μfd capacitor controls the amount of amplification in the pentagrid converter and IF amplifier tubes.

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LESSON IX

WHAT DOES ALIGNMENT MEAN?

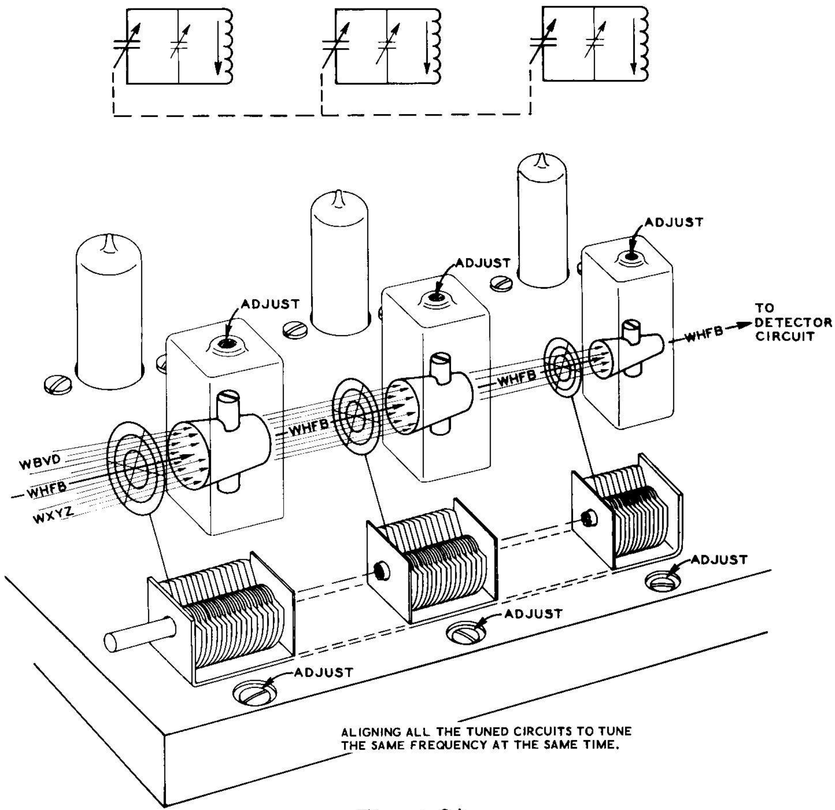
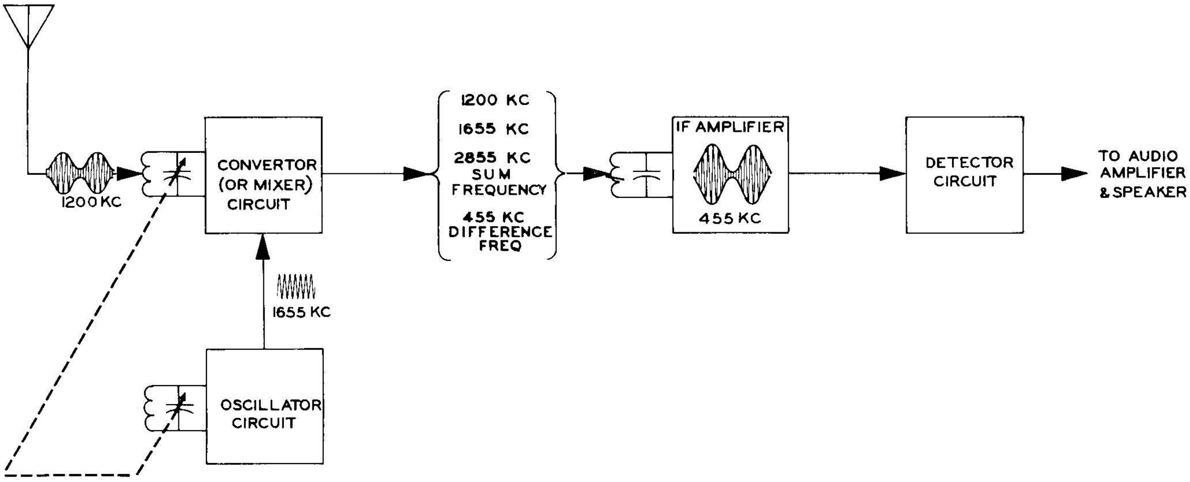


Figure 9A

To align a receiver means to adjust all of the circuits in which RF signals are present for the best operation of the receiver all through its tuning range. In superheterodyne receivers, the IF circuits, the oscillator circuit, and the mixing circuit are also adjusted for best receiver performance.

Lesson VIII explained the operation of the converter circuit and the various signals present in the superheterodyne receiver. Since Lesson IX deals with alignment procedures for the superheterodyne receiver, a review of how this superheterodyne receiver operates is in order at this time.



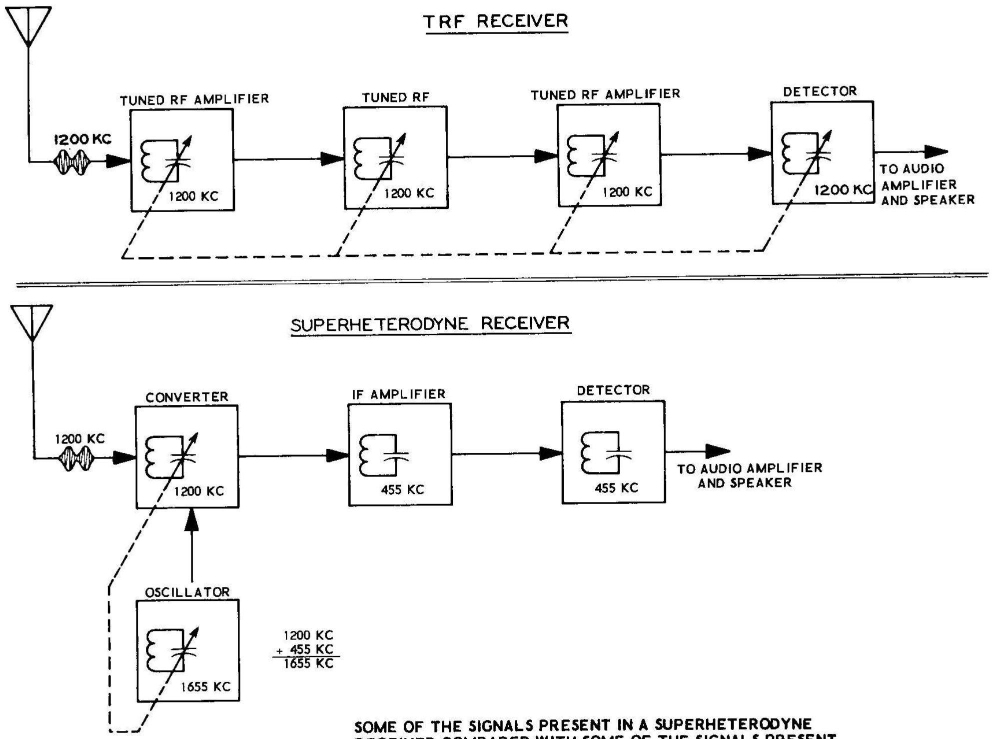
SOME OF THE SIGNALS THAT WOULD BE PRESENT IN A SUPERHETERODYNE RECEIVER TUNED TO 1200 KC.

Figure 9B

Figure 9B shows a block diagram of the RF circuits of a superheterodyne receiver, along with the various signals present. A 1200 kc signal is being selected by the input tuned circuit and sent to the converter tube. At this same time a 1655 kc signal is generated by the oscillator circuit. This 1655 kc oscillator signal is sent to the converter tube.

The result of mixing these two frequencies, is that four different frequencies appear in the plate circuit of the converter tube. The tuned circuit for the IF amplifier is tuned so that only one of these four frequencies can be accepted. The frequency that is coupled to the IF amplifier is the difference frequency, 455 kc. This 455 kc signal is then amplified in the IF amplifier and coupled to the detector circuit by the IF output transformer.

The difference between the frequency of the input tuned circuit and the frequency of the oscillator must always stay the same, 455 kc. The IF amplifier then can always amplify the same frequency.



SOME OF THE SIGNALS PRESENT IN A SUPERHETERODYNE RECEIVER COMPARED WITH SOME OF THE SIGNALS PRESENT IN A TRF RECEIVER. BOTH RECEIVERS TUNED TO 1200 KC. NOTE THAT FOUR GANGED CAPACITORS ARE NEEDED FOR THE TRF RECEIVER, AND ONLY TWO ARE NEEDED FOR THE SUPERHETERODYNE RECEIVER

Figure 9C

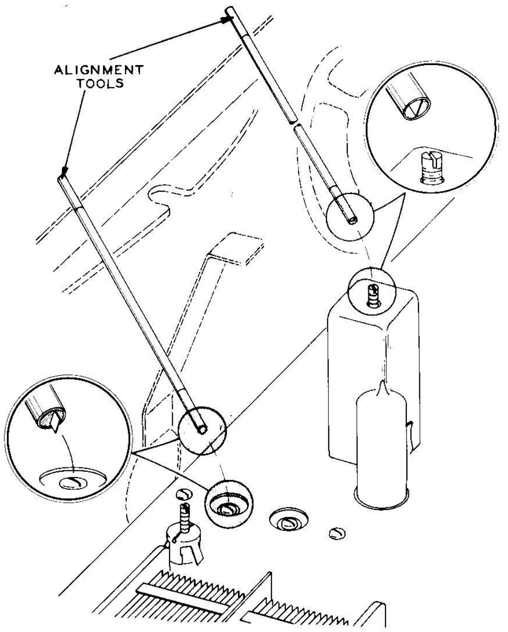
The reason for aligning a receiver is to adjust all of the tuned circuits for the best overall operation. Figure 9C shows block diagrams for both a TRF receiver and a superheterodyne receiver, along with the signals present in each.

In the TRF receiver of Figure 9C, all four of the tuned circuits would have to be adjusted to tune to exactly the same frequency. In the superheterodyne receiver, a different type of adjustment is needed. The mixing circuit (input tuned circuit) must be tuned to the frequency of the received signal. The oscillator circuit must be tuned to the frequency of the received signal plus 455 kc. The IF amplifiers must be tuned to 455 kc. The input tuned circuit and the oscillator tuned circuit must be adjusted very carefully, so that there is always a 455 kc difference between their frequencies, no matter where the receiver is tuned on the broadcast band.

ALIGNMENT OF THE SUPERHETERODYNE RECEIVER

Stated simply, there are two main objectives in the alignment of a superheterodyne receiver. The first objective is to align all the tuned circuits in the IF amplifiers so that they tune to exactly 455 kc. The second, and more complicated objective of this alignment, is to adjust the frequency of the oscillator and the frequency of the input tuned circuit so that they "track" together. To track means to adjust these two tuned circuits so that there will always be a difference of 455 kc between their frequencies. This difference frequency must always be 455 kc from the low end to the high end of the broadcast band.

Figure 9D shows some common types of alignment tools used by radio servicemen for the alignment of receivers. A small piece of metal is mounted in a hollow plastic tube. This small



SPECIAL TOOLS CALLED ALIGNMENT TOOLS TO ALIGN RECEIVERS.

Figure 9D

piece of metal is used like a screwdriver on the adjustments and the hollow plastic tube that encircles the piece of metal keeps the tip of the alignment tool from sliding off the adjustment. Often, the metal tip is also placed on the end of the alignment tool, without the hollow tubing around it. This part of the tool can be used like a screwdriver to adjust the trimmer capacitor screws. A large metal screwdriver might cause the circuit to become detuned, because the metal of the screwdriver would add capacity to the trimmer when touched to the trimmer screw. A plastic alignment tool would not affect the circuit at all.

ALIGNMENT PROCEDURES

There are two general types of procedures used for the alignment of superheterodyne receivers. One of these procedures does not use instruments, but instead, aligns the receiver by tuning in stations on the receiver. This is the type of alignment procedure that you will use to align the EK-2B Receiver in the Experiment section of Lesson IX.

The second alignment procedure is the one using test instruments. This procedure is more exact than the first type of alignment, and there is less chance for error.

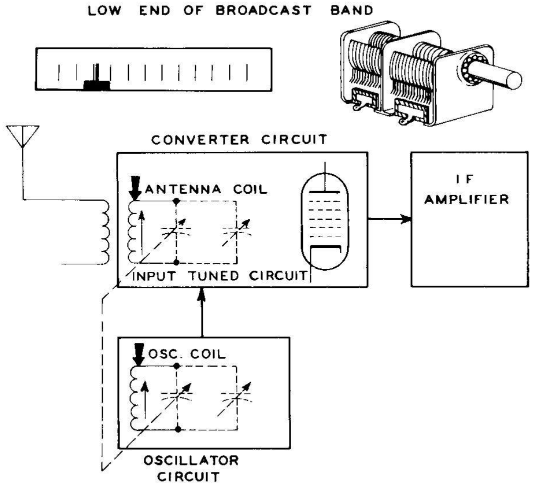
In both of these procedures, tracking of the receiver is adjusted at the low end, and then at the high end of the broadcast band. The coil adjustments for both the oscillator circuit and the input tuned circuit are always made at the low end of the broadcast band. They are adjusted at this end of the band because here they have a much greater effect on the frequency than the trimmer capacitors would have.

The trimmer capacitors for the input tuned circuit and the oscillator tuned circuit are adjusted at the high end of the broadcast band. At the high end of the broadcast band, the trimmers have a large effect on the frequency.

ALIGNMENT PROCEDURE WITHOUT INSTRUMENTS

Broadcast stations at the extreme ends of the dial are used when aligning a receiver without instruments. The converter circuit and the oscillator circuit must be adjusted to the point where they give the best signal to the IF amplifiers. In other words, they must "track." For this reason, when using this method of alignment, the IF transformers must be assumed to be properly aligned to 455 kc at the factory.

No matter which method of alignment is used, the first step that should be taken would be to set the dial pointer at the proper position on the cord.



THE LARGE ARROWS INDICATE THE PROPER ADJUSTMENTS TO BE MADE WITH THE RECEIVER TUNED TO THE LOW END OF THE BROADCAST BAND.

Figure 9E

The large arrows of Figure 9E and 9F show the proper adjustments that would be made at the low end and at the high end of the broadcast band. A station would be tuned at the low end of the broadcast band, preferably from 600 kc to 700 kc, and the correct frequency of this station would be determined by looking it up in the local newspaper. The following steps would then be taken:

1. The oscillator coil would be adjusted and the receiver retuned a little at a time until the dial pointer agreed with the actual frequency of the station.

2. The antenna coil (the coil of the input tuned circuit) would be tuned for the loudest signal from the station. In some cases when tuning for maximum loudness, it would be best to have the volume of the receiver turned low, to make it easier to judge the difference in volume levels.

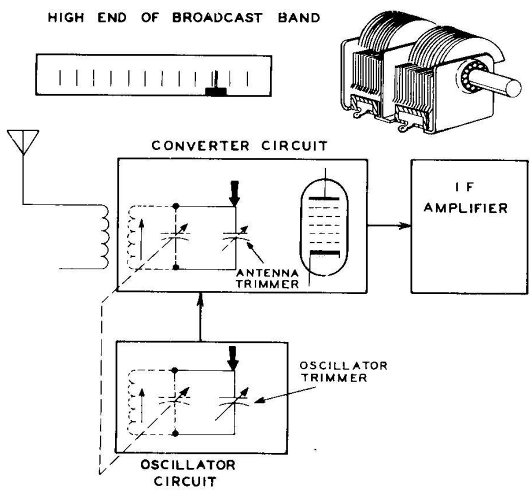
Now a station would be tuned at the high end of the band, preferably between 1200 kc and 1400 kc, and the correct frequency would be found as with the first station.

1. Now, while the receiver was tuned, the trimmer of the oscillator circuit would be adjusted until the dial pointer was moved to its correct position (the correct frequency of the station).

2. The trimmer of the antenna circuit would then be adjusted for maximum volume.

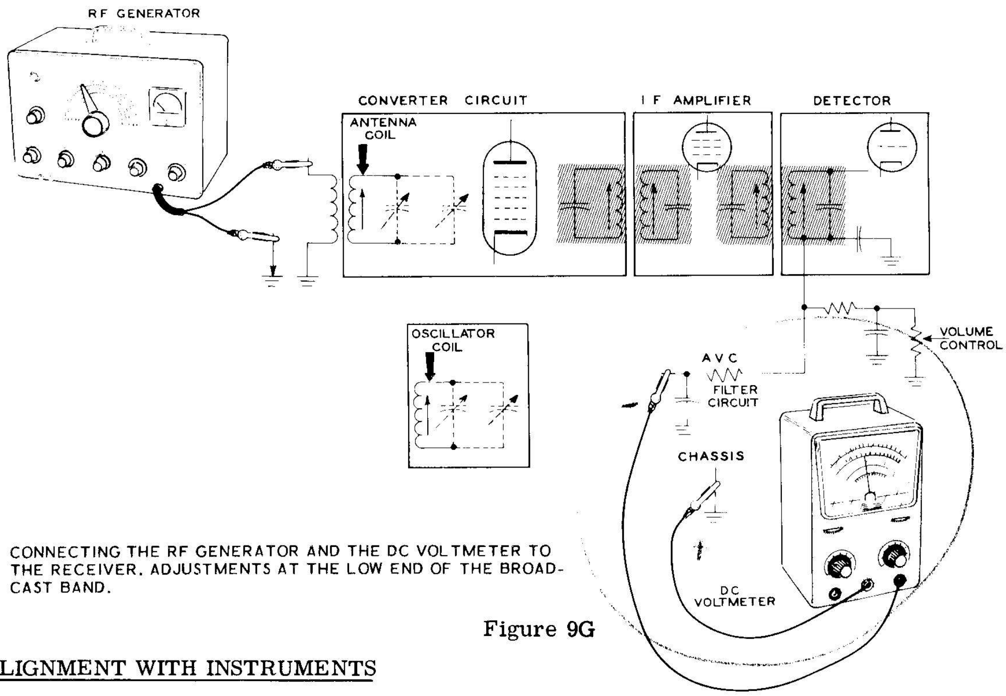
Now, tuning back to the same station at the low end of the dial would probably show that this station moved slightly from where it had been set previously. This movement would be the reaction from adjusting the high end of the band. Each set of adjustments of the coils and the trimmers have some effect at the opposite end of the band. For this reason, it is always best to repeat the whole process of adjustment until the station at the high end of the band and the station at the low end of the band both tune correctly at their proper frequencies on the dial.

The top and bottom slugs of each IF transformer would be adjusted next for maximum volume in the receiver.



THE LARGE ARROWS SHOW THE PROPER ADJUSTMENTS TO BE MADE WITH THE RECEIVER TUNED TO THE HIGH END OF THE BROADCAST BAND.

Figure 9F



CONNECTING THE RF GENERATOR AND THE DC VOLTMETER TO THE RECEIVER. ADJUSTMENTS AT THE LOW END OF THE BROADCAST BAND.

Figure 9G

ALIGNMENT WITH INSTRUMENTS

The two instruments that are generally used for this type of alignment procedure are an RF signal generator and a sensitive professional type voltmeter. The RF signal generator creates signals to take the places of the signals from the broadcast station. The signal generator can create a signal at either the broadcast frequency for aligning the input circuits, or at the IF frequency for aligning the IF amplifier circuits.

A professional type voltmeter would be used to measure the amount of signal received by the detector circuits or audio circuits of the receiver. This voltmeter is usually connected to measure the DC voltage at the output of the AVC filter (this is the DC voltage developed across the .1 μfd capacitor in the EK-2B Receiver).

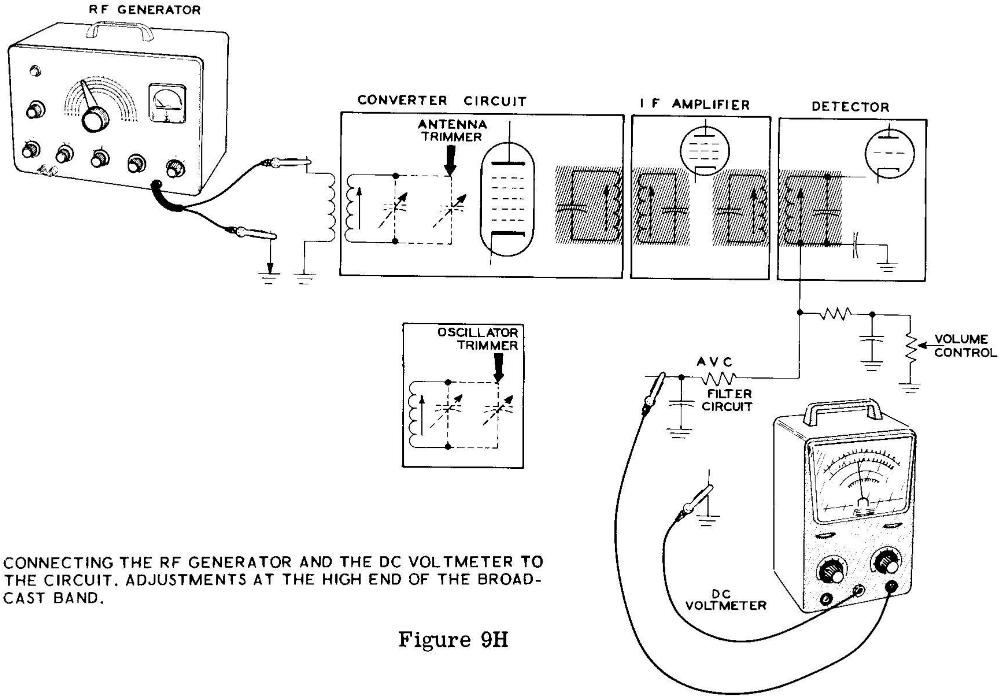
As you will recall from Lesson VIII, a large signal from the detector circuit will give a large amount of negative DC voltage across the .1 μfd capacitor. A small signal from the detector circuit will give a small amount of negative DC voltage across the .1 μfd capacitor. The amount of signal received by the detector circuit could also be determined by how loud the signal is in the speaker, but using the meter is a more exact method.

The first step in this alignment procedure, just like in the other alignment procedure, would be to set the pointer to travel the proper distance from end to end of the dial. The next step would be to tune the radio to some place on the dial where there is no station (a signal received from a station would interfere with the signals from the generator).

The next step in this alignment procedure is aligning the IF amplifiers to tune to exactly 455 kc. These adjustments are included in the shaded portions of Figure 9G. If two IF amplifier stages were used in the receiver, the process would still be the same, but an additional transformer would be aligned.

The alignment procedure itself would begin by connecting the two instruments to the receiver. You would connect the positive lead of the DC voltmeter to the chassis ground of the receiver, and the negative lead to the output of the AVC filter circuit.

The RF generator must be connected to insert a signal into the input of the receiver. This is done by connecting the negative lead of the RF generator to ground and by connecting the positive lead to the antenna terminal of the receiver.



CONNECTING THE RF GENERATOR AND THE DC VOLTMETER TO THE CIRCUIT. ADJUSTMENTS AT THE HIGH END OF THE BROADCAST BAND.

Figure 9H

The output of the generator would now be switched to create a 455 kc IF signal. Each slug of each IF transformer, starting with the last transformer and working toward the first, would be adjusted for the largest negative DC voltage on the meter. Since these adjustments interact with each other, this process should be repeated a couple of times for best results. This would complete the adjustment of the IF amplifiers.

Now the generator should be set to produce a signal at 600 kc and the dial of the receiver should be pointing to 600 kc. Refer to Figure 9G. Now the slug of the oscillator coil would be tuned for maximum reading on the DC voltmeter (maximum signal = maximum DC voltage at 600 kc). Next, the slug of the antenna coil would be tuned (input tuned circuit) for maximum reading on the DC voltmeter.

Refer to Figure 9H. The RF generator would next be set to 1400 kc and the dial of the receiver would also be set at 1400 kc. Then the oscillator trimmer capacitor would be tuned for the maximum negative voltage reading on the DC voltmeter. Next, the antenna trimmer would be tuned (in the input tuned circuit) for maximum negative DC voltage.

Just like the other method of adjustment, this process, because of interaction, would also have to be repeated a number of times until the dial tuned to exactly 1400 kc and 600 kc.

SUMMARY

The reason that alignment is needed in a receiver is so that it will tune properly, or track, all the way across the broadcast band and send the largest amount of signal to the IF amplifier circuits. There are two general areas of adjustment in the alignment procedure. The first section of the receiver that needs adjustment is the IF amplifier circuit. The second section is the converter circuit, which must be adjusted so that the difference frequency, 455 kc, is always created, regardless of the receiver's dial setting.

There are two general types of alignment procedure. The first of these uses the broadcast stations themselves. The IF amplifiers are presumed to be adjusted to the correct frequency from their adjustment at the factory. Stations are then tuned in at the low and high ends of the broadcast band. The receiver is then adjusted so that it will track properly at both of these stations. This results in proper receiver tracking between these two stations, or all the way across the broadcast band. The last step is to touch up the adjustments of the IF transformers to give peak performance.

The second alignment procedure uses instruments; an RF generator and a sensitive professional type voltmeter. The RF generator is used in place of the signals from the broadcast station. The voltmeter is used to tell how much signal is received at the detector circuit and at the audio circuits of the receiver.

The first adjustments in this method are to adjust the IF amplifiers so that they will amplify at exactly 455 kc. The converter circuit and the oscillator circuit are then tracked, using signals from the RF generator at 600 kc and at 1400 kc. This completes the alignment procedure.

HOW TO ALIGN YOUR SUPERHETERODYNE RECEIVER

To make the receiver track properly.

PARTS REQUIRED

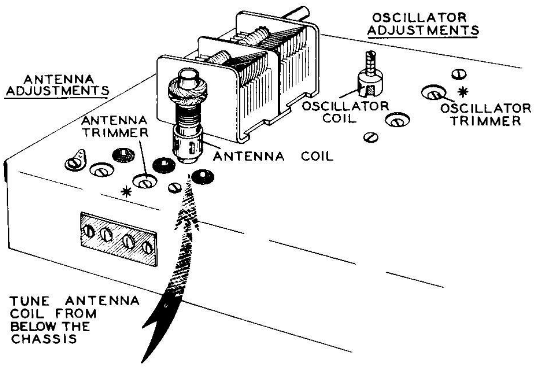
The only part required for this experiment is the EK-2B Receiver from Lesson VIII. No additional wiring on the chassis is needed.

EXPERIMENT 1

To align the EK-2B Receiver, using the signals received from broadcast stations.

NOTE: As you learned earlier in this lesson, the IF transformers must be considered to be properly aligned at the factory for this type of alignment procedure.

( ) Place your EK-2B chassis in front of you as shown in Figure 9J. Locate the positions of the adjustments to be made.



THE POSITION OF THE VARIOUS ADJUSTMENTS USED IN THE ALIGNMENT PROCEDURE FOR THE BROADCAST BAND.

Figure 9J

( ) To avoid confusion later when making trimmer adjustments, it may be best to place a mark on the chassis with a soft pencil, or a grease pencil, beside both the antenna trimmer adjustment and the oscillator trimmer adjustment. This will also be helpful in Lesson X when the other capacitor of each of these dual trimmers must be adjusted.

( ) Turn the dial pointer to either end of the broadcast band, and make sure that the pointer falls directly behind the marker that designates the end of the broadcast band. If it is not in the right place, the pointer should be moved on the string until it is exactly behind the marker.

( ) Now tune the dial pointer to the opposite end of the broadcast band and make sure that the pointer is lined up with the marker that designates this end of the band. Pinch the tabs together tightly (but not so tightly as to cut the cord) so the pointer will not slip. A drop of household glue on the tabs would be an extra precaution to prevent the pointer from slipping.

( ) Connect the antenna and turn on the receiver.

( ) Tune in a station at the low end of the broadcast band, below 700 kc if possible. Now determine the correct frequency for this station by looking it up in your local newspaper.

( ) Move the position of this station to its correct place on the dial by turning the slug of the oscillator coil a little bit at a time with a small screwdriver. Retune the receiver after each turn of the slug. It may be necessary to turn the slug a number of times until the station is moved to its proper position.

( ) Tune the slug of the antenna coil to where the signal is loudest in the speaker. You may find it necessary to turn the volume of the receiver rather low for this test to best tell exactly where the loudest point is.

( ) Tune in a station at the high end of the band, preferably one between 1300 kc and 1500 kc. Find the correct frequency for this station as you did with the station at the low end of the band.

( ) Move the position of this station to its place position on the dial by turning the screw of the oscillator trimmer. It may be necessary to tune this trimmer a little bit at a time, retuning the receiver after each slight adjustment.

( ) After the dial pointer is in its proper position, adjust the antenna trimmer capacitor for the loudest signal from the receiver.

NOTE: This completes the tracking adjustments for the receiver, but for best results the entire series of adjustments should be repeated one or two more times.

( ) Tune once again to the station at the low end of the band. You may find that the position of the station has been moved slightly due to the adjustment of the trimmer capacitor. Adjust the slug of the oscillator coil again to move the dial pointer to its proper position on the dial. Then adjust the antenna coil for maximum signal in the speaker.

( ) Tune again to the station at the high end of the broadcast band and note whether it has moved or not. If it has, repeat the adjustments for the oscillator trimmer and the antenna trimmer.

( ) Now tune each slug of each IF transformer for maximum volume. Start with the output IF transformer.

This completes the alignment procedure for your EK-2B Receiver.

DISCUSSION

Figure 9K shows a schematic diagram of your EK-2B Superheterodyne Receiver. Locate the positions in the schematic diagram of the various coils and trimmers that you have adjusted in the alignment procedure.

For the type of alignment procedure just completed, using broadcast stations, the IF transformers are considered to be correctly aligned to 455 kc as they are received from the factory.

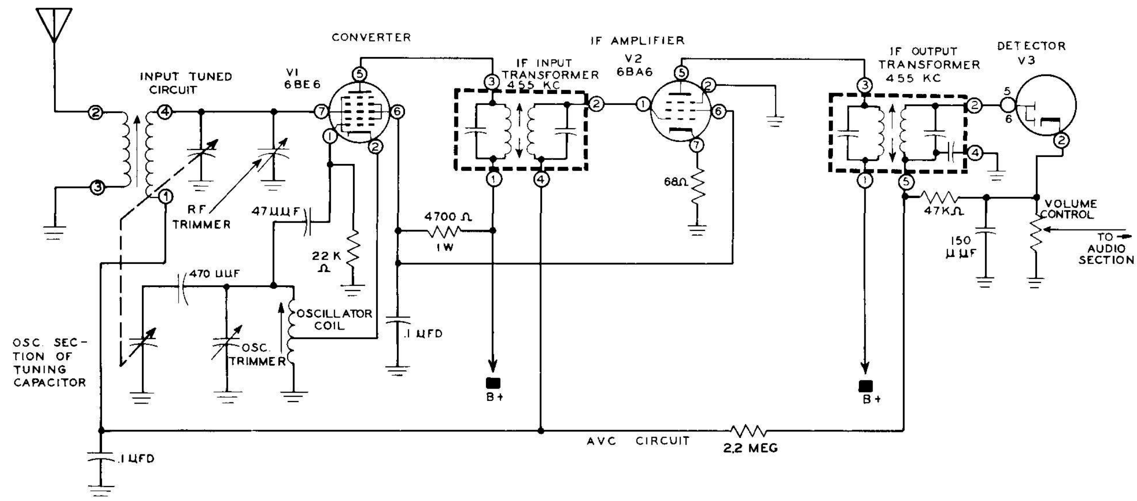


Figure 9K

The alignment procedure began with the tracking adjustments. First you placed the dial pointer at its proper position on the dial, and turned the oscillator coil adjustment until the proper IF frequency of 455 kc was created in the converter tube.

Tuning the antenna coil then caused the input tuned circuit to be exactly tuned to the station at the new setting of the tuning capacitor.

Turning to a station at the high end of the broadcast band, and repeating the adjustment procedure, adjusted the oscillator tuned circuit and the input tuned circuit to create the proper 455 kc IF frequency at this end of the band. Tuning the antenna trimmer capacitor adjusted the input tuned circuit to the exact frequency of the station. This gave maximum volume in the receiver.

After adjusting the receiver to give a 455 kc signal at the low end of the band, you then adjusted the receiver to give a 455 kc signal at the high end of the band. As a result, a 455 kc IF signal would now be created when the receiver was tuned between these two points. In other words, the receiver was set to track properly. The complete alignment procedure was repeated a number of times in order to compensate for the interactions between the adjustments from one end of the band to the other. Finally, the IF transformers were adjusted for peak performance.

A more exact adjustment for the IF amplifiers would have consisted in introducing a 455 kc signal into the receiver, using an RF signal generator. The upper and the lower adjustment slug of each IF transformer would then have been turned to give the maximum signal from the detector circuit.

LESSON IX

QUESTIONS

1. The converter circuit mixes the signal from the ______________ and the signal from the ______________.
2. The two signals mixed together in the converter circuit result in four different signals in the plate circuit of the converter. The signal used by the IF amplifier is the ______________ frequency, usually 455 kc.
3. There must always be a ______________ difference between the frequency of the input signal and the oscillator frequency.
4. When the tracking of the receiver is adjusted, two tuned circuits are adjusted. What are these tuned circuits? ______________
5. The coils are always adjusted at the (low end, high end) of the broadcast band.
6. The trimmer capacitors are always adjusted and have the most effect at the (low end, high end) of the broadcast band.
7. The two instruments used in the instrument alignment of the receiver are ______________ and ______________.

LESSON X

WHAT ARE SHORT WAVE SIGNALS?

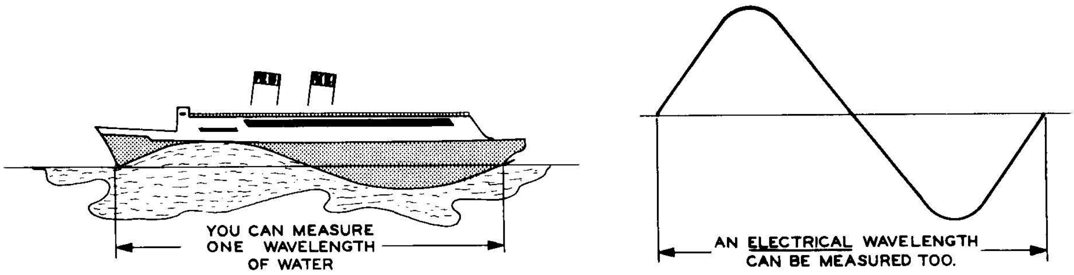


Figure 10A

Lessons VIII and IX showed you how the superheterodyne receiver operates and how it is adjusted for proper operation. Until now, all of the receivers you have studied have only tuned the frequencies within the broadcast band. Lesson X will add tuned circuits for the oscillator and antenna circuits in order to make your receiver tune short wave signals.

The difference between a broadcast signal and a short wave signal can be explained in the following manner. The actual length in inches of one cycle of a radio wave can be calculated using mathematical formulas. As the frequency of the waveforms get higher, the length of the waveform becomes shorter. Instead of in inches or in feet, the length of a signal is usually specified in "meters," a common unit of measurement in most European countries. A meter is equal to about 39 inches.

The term "short wave" came into use in the early days of radio to describe those signals higher in frequency than signals in the broadcast band. Since the frequencies of these communications signals are higher, the wavelengths of the signals are shorter than that of broadcast signals.

Figure 10B shows the length of one cycle of various radio waves. The longest of these signals would be found at 1500 kc (1.5 megacycles) on the broadcast band. The two shorter signals would be found at 3 megacycles and at 6 megacycles in the short wave band.

Figure 10C shows a block diagram of the EK-2B Receiver, along with the switching necessary to change the receiver from the broadcast band to the short wave band. When you switch to the short wave band the circuit of the receiver stays exactly the same. Only the antenna tuned circuit and the oscillator tuned circuit have been changed in order to tune to the new band of frequencies.

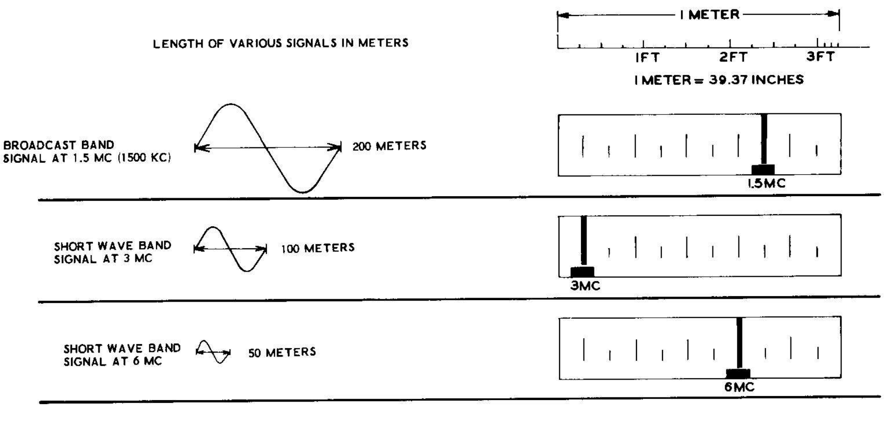
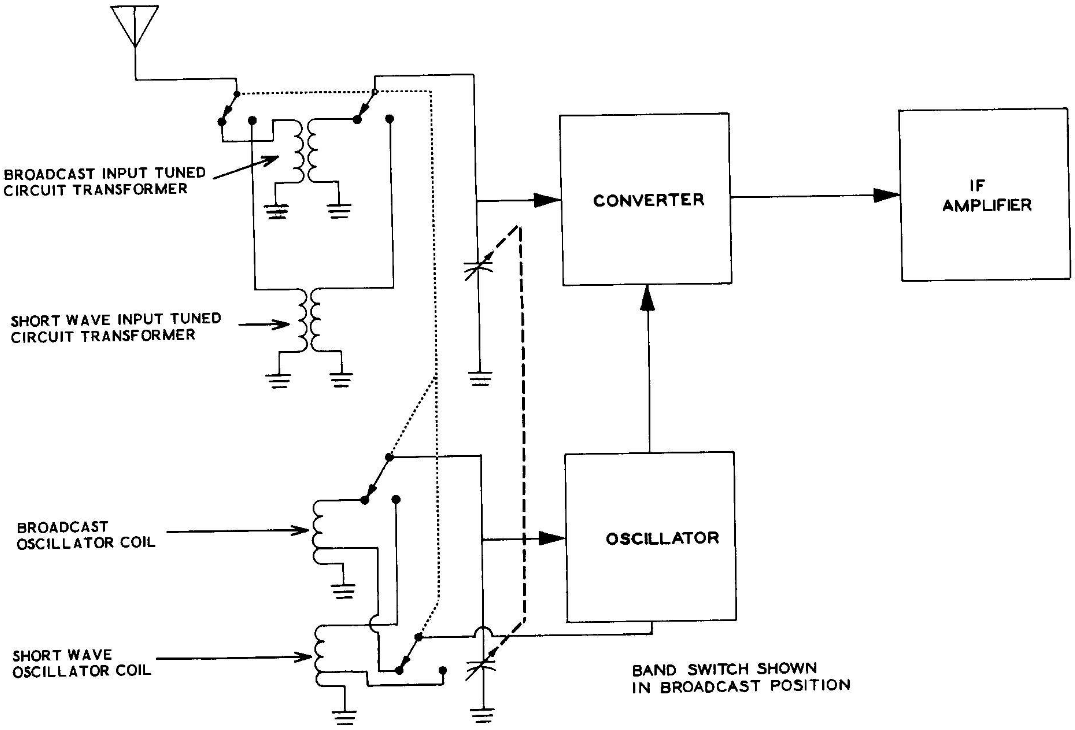


Figure 10B THE LENGTH IN METERS (39.37 INCHES) OF VARIOUS RADIO SIGNALS.

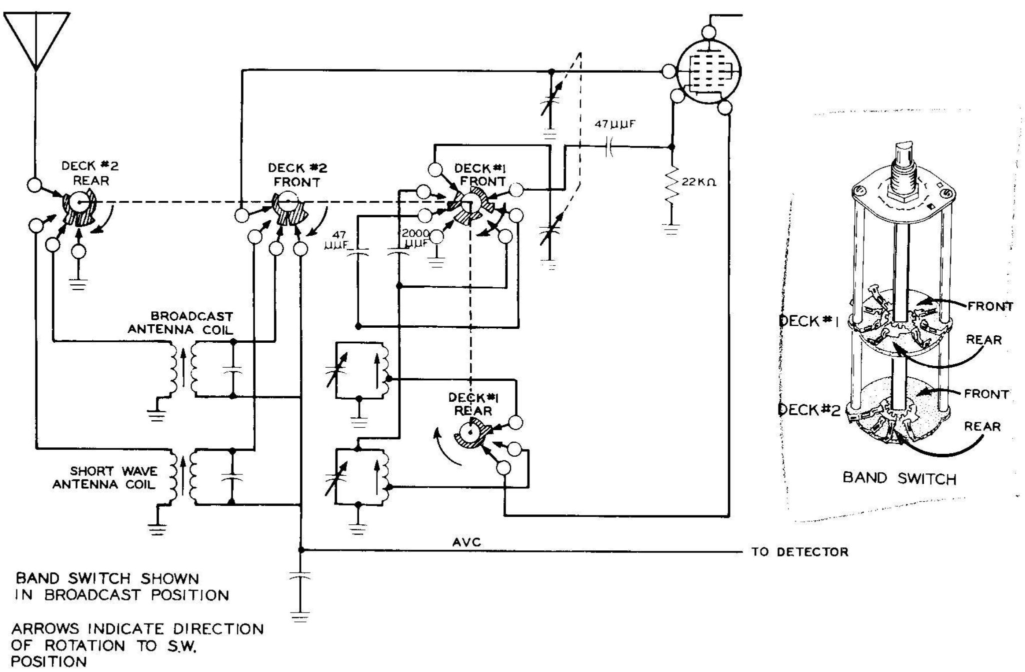


THE SWITCHING NECESSARY TO CHANGE THE RECEIVER FROM THE BROADCAST BAND TO THE SHORT WAVE BAND.

Figure 10C

If a schematic of the complete circuit were drawn, showing no switches, it would look exactly like the superheterodyne receivers shown in Lessons VIII and IX; only the electrical sizes of the two coils would be different.

Notice in Figure 10C that many different wires must be switched to change the circuit from one band to another. One large switch, called a band switch, does all of these switching operations at the same time. A dotted line shows the different sections of the switch that are connected together on the same shaft.



THE BAND SWITCH FOR THE EK-2B RECEIVER AND THE CIRCUITS THAT IT SWITCHES.

Figure 10D

Figure 10D shows the band switch for the EK-2B Receiver, along with a schematic diagram of the circuits it switches. The band switch is composed of two decks, and each deck has a switch on the front of it and another switch on the back of it. Notice that the location of each part of this switch is marked on the schematic. Look at the band switch itself and then look at the schematic diagram and notice that the segments for each switch are drawn on the schematic just as they actually appear on the switch.

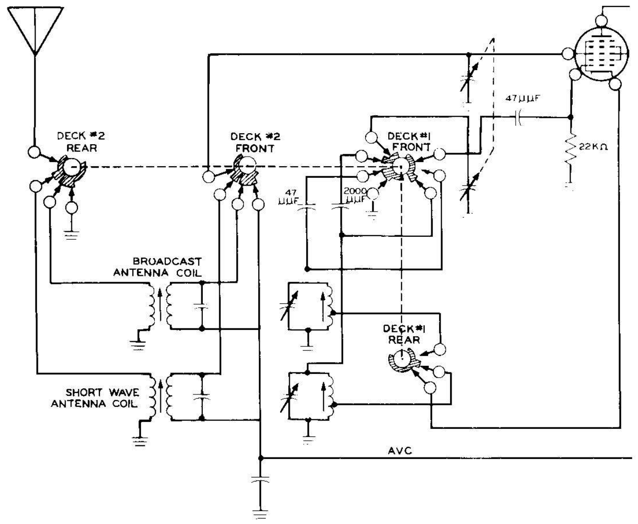
Examine the different sections of the switch. The arrows indicate the contacts of the switch; the dark portions between the contacts are the segments that connect the contacts together. The longer arrows indicate a contact that always touches a switch segment, and the shorter arrows are for contacts that are only connected when the segment is turned to their positions. Each part of the switch may have either one or two, or even three, separate segments.

All four sections of this switch are now shown in the broadcast band position. If you examine each part of the switch as it appears in the schematic you will see which part of the circuit it actually switches.

The first segment of the first deck (as shown in the schematic), deck #2-rear, switches the antenna from the input tuned circuit of the broadcast band to the input tuned circuit of the short wave band. The right-hand segment of this same switch deck is completely separate from the segment shown at the left. This segment has a wide connecting piece that is used to connect the top of the broadcast input tuned circuit transformer to ground, when the switch is in the other (short wave) position.

The front portion of deck #2 is used to switch from the secondary winding of the broadcast input transformer, to the secondary winding of the short wave input transformer. The left-hand segment of this deck connects the signal grid of the converter tube to the desired secondary.

The wider, right-hand, portion of this switch shorts out the broadcast coil when the switch is in the other (short wave) position.



THE BAND SWITCH CIRCUITS OF THE EK-2B RECEIVER IN THE SHORT WAVE POSITION.

Figure 10E

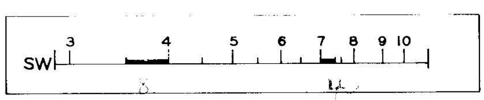
The next section of the switch (as it is presented in the schematic diagram of Figure 10D) is the switch at the front of deck #1. This section of the switch performs three different functions. The segment of the switch shown at the left connects the top of the desired oscillator coil to the oscillator grid of the converter tube. The segment of this switch shown at the right connects the oscillator portion of the tuning capacitor (through a calibrating capacitor) to the desired oscillator coil. The segment of the switch shown at the bottom shorts out the broadcast oscillator coil when the switch is in the other (short wave) position.

NOTE: When the receiver is tuned to the short wave band, all broadcast coils are shorted out, or connected to ground, so that broadcast stations cannot possibly interfere with short wave operation.

The fourth part of the switch shown on the schematic is the portion at the rear of deck #1. This part of the switch switches the cathode of the converter tube to the correct tap, on either the broadcast oscillator coil, or the short wave oscillator coil.

Figure 10E shows the same schematic diagram as Figure 10D, but now the switch is shown in the short wave position. Trace through each segment of each switch. Notice that the short wave input transformer and the short wave oscillator coil are now connected in the circuit. Notice also, that the wide portions of the switch segments have shorted out, or grounded out, both windings of the broadcast input transformer and the broadcast oscillator coil.

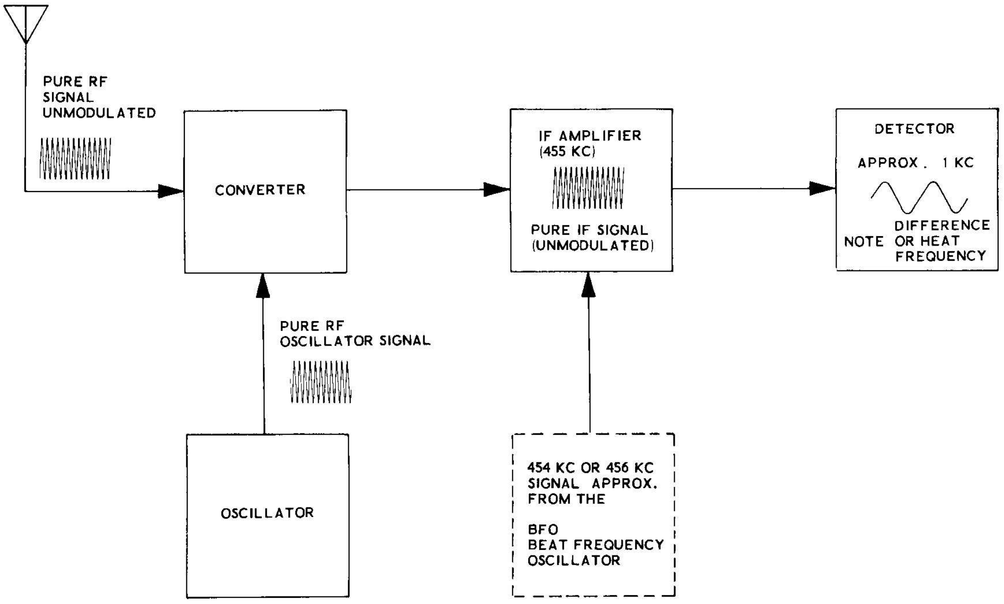
How wide a band of frequencies a short wave band will cover depends on the purpose for which the short wave band is intended. In your EK-2B Receiver a band of frequencies from approximately 3 megacycles to 10 megacycles is covered. This is illustrated in Figure 10F.



THE SHORT WAVE BAND OF THE EK-2B RECEIVER.

Figure 10F

Different services have different bands of frequencies allotted to them. The short wave band of your EK-2B Receiver includes two different bands of frequencies used by amateur radio operators. One of these bands near 7 megacycles is known as the "40 meter band," and the other near 4 megacycles is known as the "80 meter band." The term "80 meter" and "40 meter" bands are given to these two bands because of the approximate wavelength of the signals at those frequencies.



THE SIGNALS PRESENT IN THE EK-2B RECEIVER WHEN A MORSE CODE (CW) SIGNAL IS BEING RECEIVED.

Figure 10G

At exactly 5 megacycles and 10 megacycles on your short wave band, precise time signals are broadcast by station WWV. Station WWV is a Government station whose only purpose is to broadcast ultra-precise frequency and time signals. These time signals are used as the ultimate standard for all clocks (and all other applications that require very precise time checks) in the United States. Not only is the exact time broadcast from this station each minute, but each minute is also divided up into different precision sounds and signals from the station.

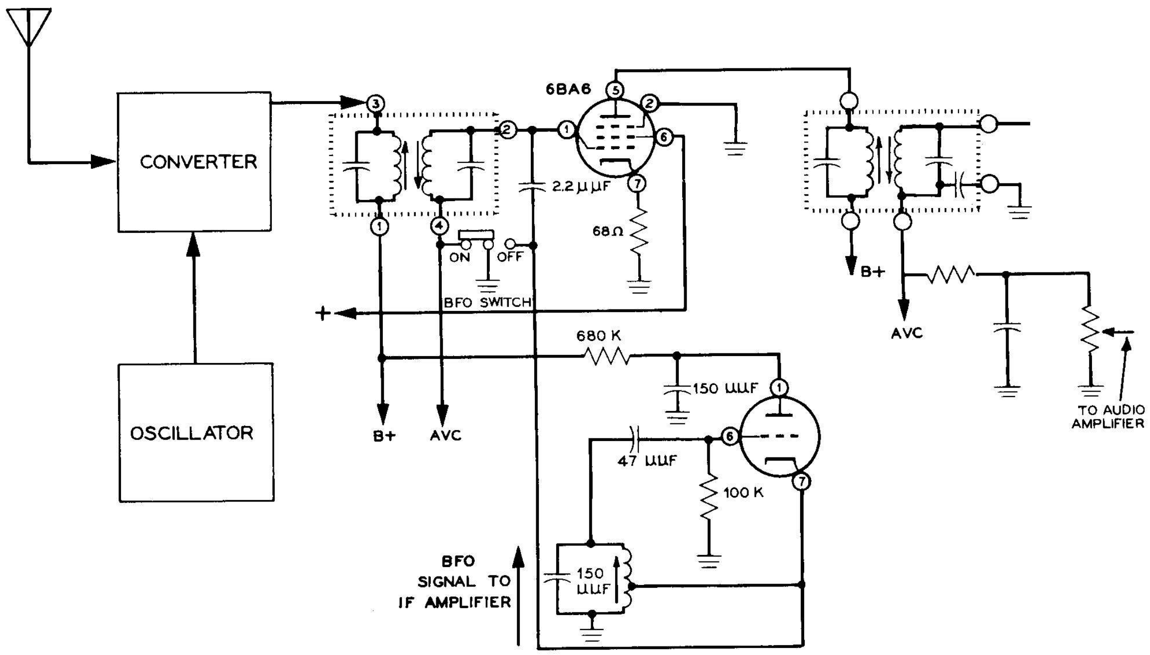
Another type of radio signal commonly found in the short wave band are Morse Code signals. These Morse Code signals are usually called "CW" (continuous wave) signals. The name "continuous wave" or "CW " refers to the fact that no audio modulation is placed on the RF signal. The dots and dashes of signal in Morse Code carry the intelligence from the transmitter to the receiver by interrupting the transmission, whereas an audio signal is carried from the transmitter to the receiver by the modulated RF signal. When a CW signal is detected, no audio signal results, so no sound is heard in the speaker (except perhaps some quieting due to AVC action).

Figure 10G shows a block diagram of a receiver as a CW signal is being received. You may find it easier to follow the action of the circuits if you think of this signal as being the burst of energy, for one dash of Morse Code. Now a circuit must be developed in the receiver which will make the dots and dashes of CW audible in the receiver.

The unmodulated input signal is coupled to the converter tube, where the oscillator signal beats against it, creating an IF difference frequency of 455 kc. Since there was no modulation on the input signal, there is no modulation on the IF signal. If this unmodulated IF signal were sent on to the detector circuit, no audio would be present, so no sound would be heard.

In order to create an audio signal from this pure RF code signal, a new oscillator, called the "beat frequency (BFO) oscillator," is introduced.

To create an audio tone, the BFO oscillator generates a new frequency very close to the frequency of the IF amplifier signals. This new oscillator signal has a frequency of about 454 kc or 456 kc, which is coupled to the grid of the IF amplifier tube. A mixing or beating process takes place in the IF amplifier, much like the



THE SCHEMATIC DIAGRAM OF THE IF AMPLIFIER AND BFO CIRCUITS.

Figure 10H

mixing process that takes place in the converter tube. A difference frequency is created between the IF signal at 455 kc and the BFO signal at 454 kc (or 456 kc). This difference frequency, 1 kc (1000 cycles) is then coupled to the detector and the audio circuits. The result of this mixing then, is the creation of the 1 kc audio note, which you hear from the speaker of the receiver.

During the time <u>between</u> the dots and the dashes, no signal is being received by the receiver. When no signal is received, no 455 kc IF signal is being created, so the signal from the beat frequency oscillator has nothing to beat against and no 1000 cycle note can be created. Since the 454 kc signal from the beat frequency oscillator has no modulation on it, it cannot create an audio signal in the detector circuit by itself.

Figure 10H shows the circuit diagram of the IF amplifier and the beat frequency oscillator circuit. The oscillator circuit is just like the other oscillator circuit of the receiver. Notice that the tapped coil in the grid and cathode circuits of the beat frequency oscillator is just like the other two oscillator coils.

The 454 kc (or 456 kc) signal is coupled through the 2.2 $\mu\mu$f capacitor from the cathode of the BFO oscillator to the grid of the IF amplifier. A BFO switch turns the beat frequency oscillator off and on by shorting the cathode of the tube to ground. This shorts out the bottom of the oscillator coil and prevents oscillations from taking place. This BFO circuit is only turned on when you want to hear Morse Code signals on the receiver.

SUMMARY

The term short wave refers to the actual length of 1-cycle of the radio wave in meters or inches. In practice, the length of these waveforms is usually specified in meters. The higher the signal is in frequency, the shorter the <u>length</u> of the waveform.

Except for the antenna and the oscillator tuned circuits, the circuits of the EK-2B Receiver stay exactly the same when it is switched to the short wave band. All circuits work in exactly the same way as they do on the broadcast band. Only the band of frequencies which the receiver tunes to, is changed.

Many different leads must be switched at one time to change all the connections of the tuned circuits from one tuning range to another. To perform this multiple switching function, the EK-2B Receiver uses a large switch, called a "band switch." This band switch contains four different sections to perform all of the actual switching operations. One section of this switch is used to change the input and the output connections of each coil.

The beat frequency oscillator, or BFO, section of the receiver is a circuit that allows Morse Code signals to be heard. Since a Morse Code signal is a pure RF signal with no modulation on it, no sound would ordinarily be heard in the speaker. The BFO creates an RF signal that is close in frequency to the IF signal and injects this signal into the IF amplifier. The BFO signal and the IF signal beat together, resulting in a difference frequency which is heard in the audio part of the receiver.

HOW TO ADD A SHORT WAVE BAND AND BFO TO YOUR RECEIVER

To complete the construction of the EK-2B Receiver.

PARTS REQUIRED

1 22 KΩ 1/2 watt resistor (red-red-orange)
1 100 KΩ 1/2 watt resistor (brown-black-yellow)
1 680 KΩ 1/2 watt resistor (blue-gray-yellow)
1 2.2 μμf tubular capacitor (red-red-white)
2 47 μμf mica capacitors (one of these is now mounted on the chassis)
1 150 μμf mica capacitor
1 150 μμf disc capacitor
1 470 μμf mica capacitor (now mounted on the chassis)
1 2000 μμf mica capacitor
1 .1 μfd tubular capacitor (now mounted on the chassis)
1 BFO coil (#40-77)
1 Short wave antenna coil (#40-300)
1 Short wave oscillator coil (#40-302)
1 Rotary switch (#63-230)
1 Control nut (now mounted on regeneration control)
1 Control lockwasher
1 6C4 tube
1 EK-2B Receiver

BECOMING FAMILIAR WITH THE NEW PARTS

Figure 10J shows the construction of the rotary switch or band switch. The switch is divided into two main sections, deck #1 and deck #2. Each deck has switch sections on both the front and back of it.

A close view at one of the decks, in this case the front of deck #1, is also presented in Figure 10J. Both long and short lugs are placed around the outside of the deck. Connections are made between these lugs by the metal segments in the center part of the deck. There may be any number of segments on each deck, depending on how many switching operations are desired.

The front of deck #1 contains three segments. The long contacts are always in contact with a segment; the short contacts only connect to a segment when it is turned to their position.

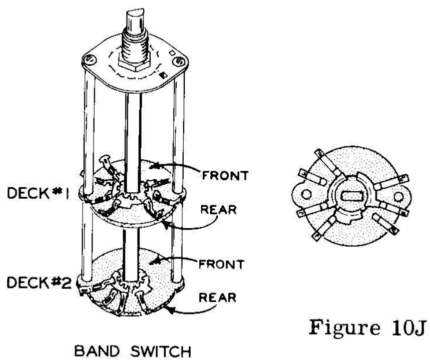


Figure 10J

PREPARING THE CHASSIS

Refer to Figure 10K for the following steps.

( ) Remove the knob from the regeneration control. Now remove the regeneration (200-ohm) control from the chassis.

( ) Unsolder and remove the 22 KΩ 1/2 watt resistor now connected from lug 1 of V1 to the tuning capacitor solder lug.

( ) Unsolder and remove the 47 μμf mica capacitor now connected from lug 1 of tube socket V1 to lug 4 of the oscillator trimmer capacitor.

( ) Unsolder and remove the 470 μμf mica capacitor now connected from lug 4 of the oscillator trimmer capacitor to lug 1 of the tuning capacitor.

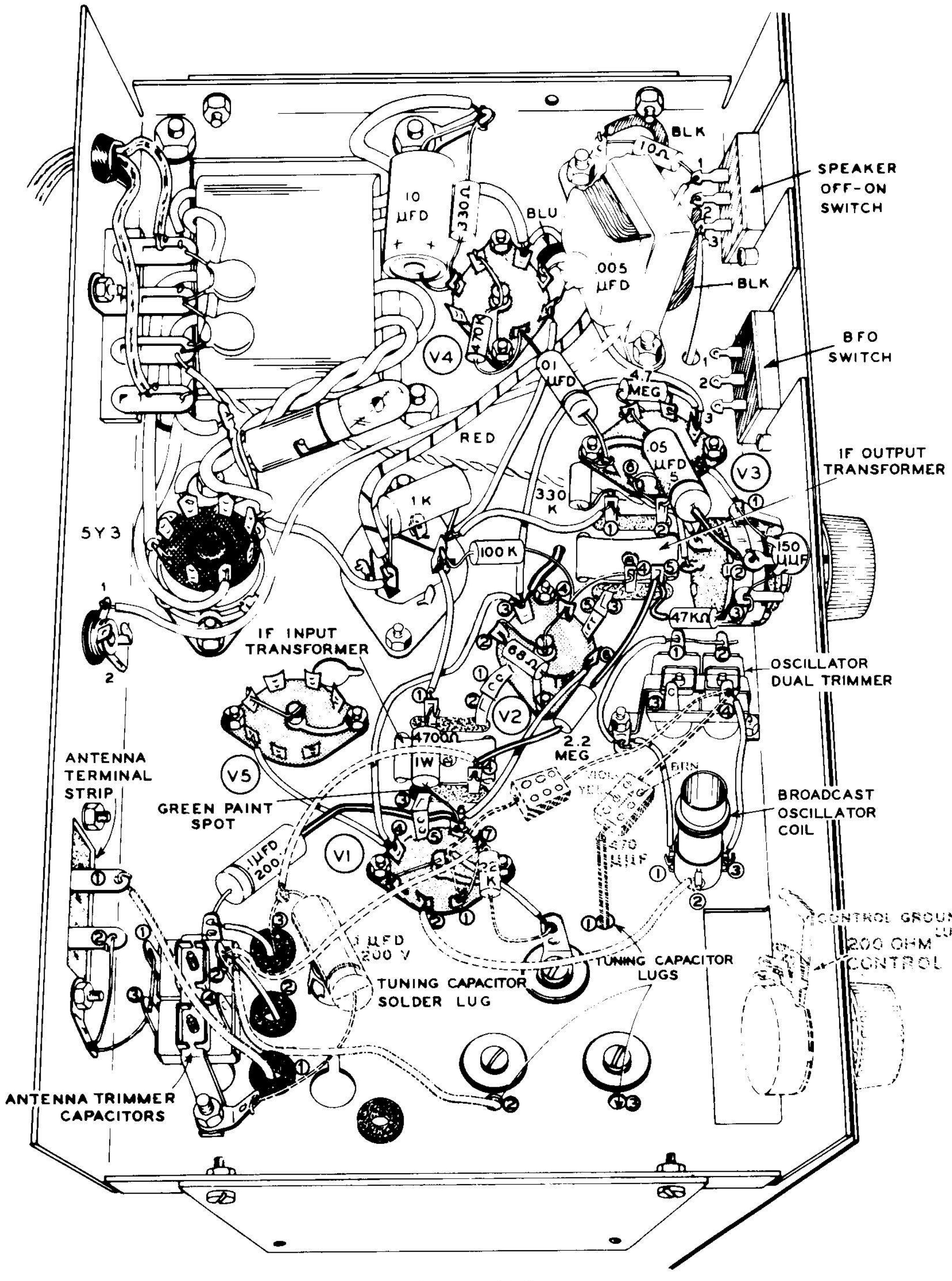


Figure 10K

(✓) Unsolder and discard the wire that is now connected from lug 2 of tube socket V1 to lug 2 of the oscillator coil.

(✓) Unsolder and discard the wire that now connects from lug 4 of the IF transformer to the lead of the .1 μfd capacitor that goes down through grommet 3.

( ) Disconnect and remove the length of hookup wire that now connects from lug 7 of tube socket V1 to lug 2 of the antenna trimmer capacitor.

( ) Disconnect and remove the length of hookup wire that now connects from lug 2 of the antenna trimmer capacitor to tuning capacitor lug 2.

( ) Disconnect and remove the wire that now connects from antenna lug 1, down through grommet 1, to lug 2 of the broadcast antenna and transformer.

( ) Disconnect and set aside the .1 μfd capacitor that connects from the ground lug at the base of the antenna trimmer capacitor, through grommet 3, to lug 1 of the broadcast input transformer.

Refer to Figure 10L for the following steps.

( ) Ⓟ Using sleeving on both leads, connect a 2000 μμf mica capacitor from lug 3 (NS) to lug 6 (S) on side A of the band switch.

( ) Ⓟ Using sleeving on both leads, connect a .00047 μfd (470 μμf) mica capacitor from lug 2 (NS) to lug 5 (S) on side A of the band switch. This capacitor may have the color dots to identify it, or it may have .00047 (or just 470) printed on it. See the detail drawing in Figure 10L.

( ) Ⓟ Connect a 3-1/2" length of hookup wire to lug 3 of side A of the band switch (S).

( ) Ⓟ Connect a 4" length of hookup wire to lug 2 of side A of the band switch (S).

( ) Ⓟ Connect a 3-1/2" length of hookup wire to lug 4 of side A of the band switch (S).

( ) Ⓟ Connect two 4" lengths of hookup wire to lug 1 of side C of the band switch (S).

( ) Ⓟ Connect a 3" length of hookup wire to lug 2 of side C of the band switch (S).

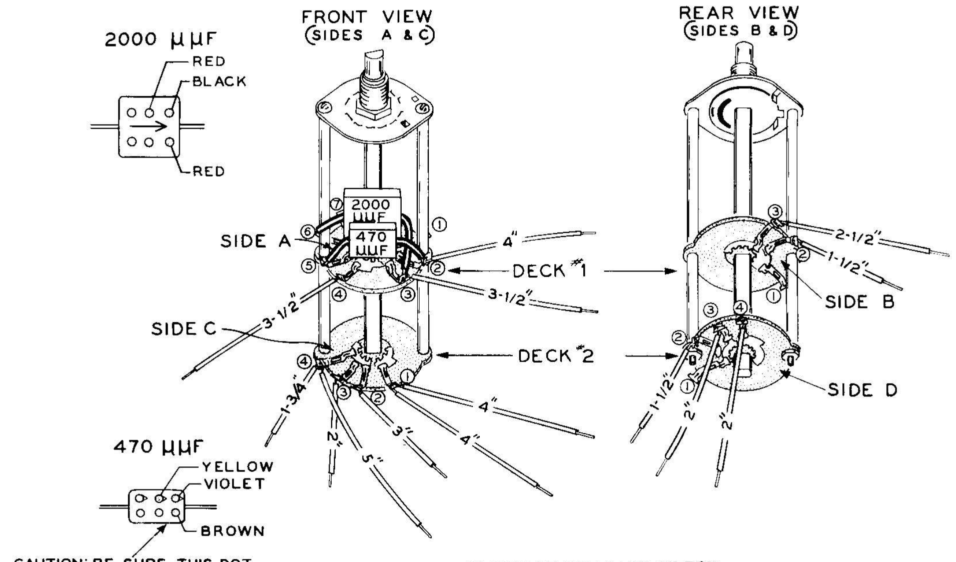
( ) Ⓟ Connect a 3-1/2" length of hookup wire to lug 3 of side C of the band switch (S).

( ) Ⓟ Connect a 1-3/4" length of hookup wire to lug 4 of side C of the band switch (NS).

( ) Ⓟ Connect a 4-1/4" length of hookup wire to lug 4 of side C of the band switch (S).

( ) Ⓟ Connect a 1-1/2" length of hookup wire to lug 2 of side B of the band switch (S).

( ) Ⓟ Connect a 2-1/2" length of hookup wire to lug 3 of side B of the band switch (S).



PRELIMINARY WIRING OF THE BAND SWITCH.

Figure 10L

( ) (P) Connect a 2" length of hookup wire to lug 4 of side D of the band switch (S).

( ) (P) Connect a 2" length of hookup wire to lug 3 of side D of the band switch (S).

( ) (P) Connect a 1-1/2" length of hookup wire to lug 2 of side D of the band switch (S).

( ) Mount the short wave antenna input transformer (#40-300) in position as shown in Figure 10M. Note that there is a black dot on the coil to identify lug 4.

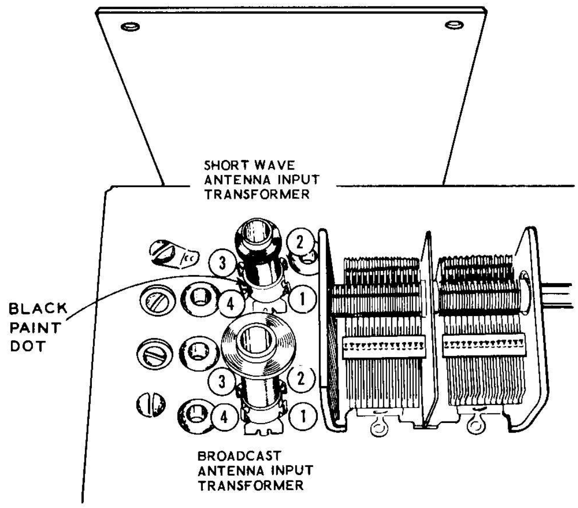


Figure 10M

Refer to Figure 10N for the following steps.

( ) Mount the short wave oscillator coil (#40-302) in position near the oscillator trimmer capacitor. The lug with the red paint spot should be mounted near tube socket V1.

NOTE: Remember the letter Ⓟ before a step means that this is to be a permanent connection. Route all wires close to the chassis, including the wires from the band switch.

( ) Ⓟ Connect a length of bare wire from lug 1 of the short wave oscillator coil (S) to the ground lug at the oscillator trimmer capacitor (S).

( ) Ⓟ Connect a short length of bare wire from lug 3 of the short wave oscillator coil (S) to lug 3 of the oscillator trimmer capacitor (NS).

( ) Ⓟ Install the BFO coil (#40-77) in position near tube socket V5.

( ) Ⓟ Connect a length of hookup wire from lug 1 of the BFO switch (S), across the chassis, to lug 7 of tube socket V5 (NS).

( ) Ⓟ Connect a 100 KΩ 1/2 watt resistor from lug 4 (S) to lug 6 (NS) of tube socket V5.

( ) Ⓟ Connect a 47 μμf mica capacitor from lug 6 of tube socket V5 (S) to lug 3 of the BFO coil (NS).

( ) Ⓟ Connect a short length of hookup wire from lug 1 of the BFO coil (NS) to the center post of tube socket V5 (NS).

( ) Ⓟ Connect a 150 μμf mica capacitor from lug 1 (S) to lug 3 (S) of the BFO coil.

( ) Ⓟ Connect a short length of hookup wire from lug 7 of tube socket V5 (NS) to lug 2 of the BFO coil (S).

( ) Ⓟ Connect a 2.2 μμf molded phenolic capacitor from lug 7 of tube socket V5 (S) to lug 1 of tube socket V2 (S). Use sleeving on both leads.

( ) Ⓟ Connect a 680 KΩ 1/2 watt resistor from lug 1 of tube socket V5 (NS) to lug 1 of the input IF transformer (S).

( ) Ⓟ Connect a 150 μμf disc capacitor from lug 1 (S) to the center post (S) of tube socket V5.

( ) Ⓟ Connect a length of bare wire from lug 2 of tube socket V3 (S) to lug 2 of the BFO switch (S).

( ) Ⓟ Connect a length of hookup wire from lug 3 of the BFO switch (S) to lug 4 of the input IF transformer (NS).

( ) Ⓟ Connect the lead at the banded end of a .1 μfd 200 volt tubular capacitor to the tuning capacitor solder lug (S). Connect the other lead of this capacitor through grommet 3, to lug 1 of the broadcast antenna input transformer (NS). See Figure 10P.

( ) Ⓟ Place the wires connected to lugs 2 and 3 of side D of the band switch down through grommet 4, and then install the band switch in position as it is shown in Figure 10N. Use a control lockwasher inside the chassis and a control nut on the front panel to secure the switch. Now install the knob on the switch.

( ) Ⓟ Connect a 2" length of hookup wire to lug 7 of side A of the band switch (S). Insert the other end of this wire down through the hole in the chassis to lug 3 of the tuning capacitor (S).

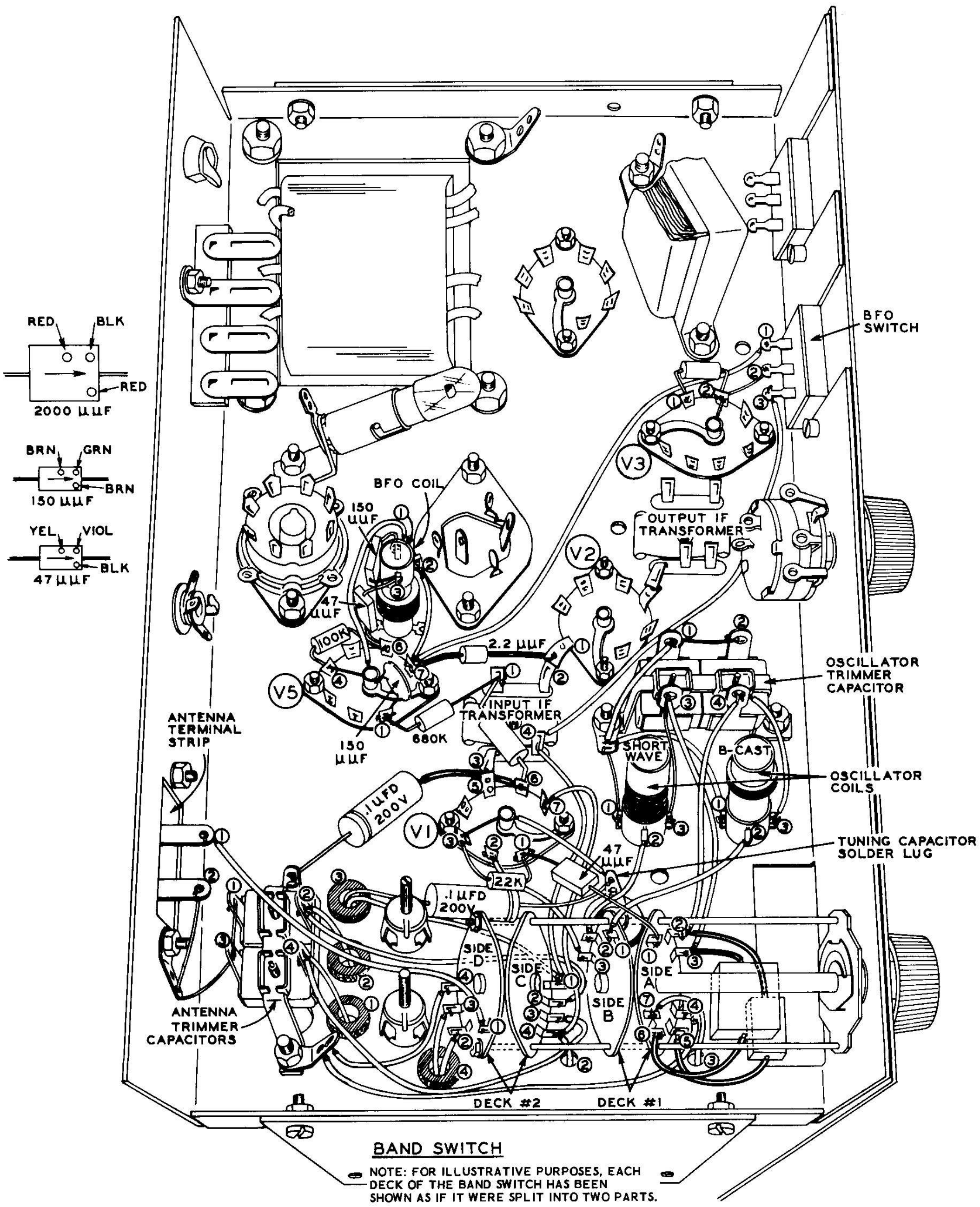
( ) Ⓟ Insert the short wire from lug 4 of side C of the band switch down through the chassis hole to lug 2 of the tuning capacitor (S).

( ) Ⓟ Insert one of the wires from lug 1 of side C of the band switch through grommet 3.

( ) Ⓟ Connect the wire from lug 2 of side A of the band switch to lug 4 of the oscillator trimmer capacitor (S).

( ) Ⓟ Connect the wire from lug 3 of side A of the band switch to lug 3 of the oscillator trimmer capacitor (S).

( ) Ⓟ Connect the hookup wire from lug 4 of side A of the band switch to the solder lug at the antenna trimmer capacitor (NS).



FINAL PARTS MOUNTING IN THE EK-2B RECEIVER.

Figure 10N

( ) Ⓟ Connect the wire from lug 3 of side B of the band switch to lug 2 of tube socket V1 (S).

( ) Ⓟ Connect the wire from lug 2 of side B of the band switch to lug 2 of the short wave oscillator coil (S).

( ) Ⓟ Connect a 3" length of hookup wire from lug 1 of side B of the band switch (S) to lug 2 of the broadcast oscillator coil (S).

( ) Ⓟ Connect the remaining lead from lug 1 of side C of the band switch to lug 4 of the IF input transformer (S).

( ) Ⓟ Connect the remaining lead from lug 4 of side C of the band switch to lug 7 of the tube socket V1 (S).

( ) Ⓟ Connect the wire from lug 3 of side C of the band switch to lug 4 of the antenna trimmer capacitor (NS).

( ) Ⓟ Connect a 2" length of hookup wire to lug 4 of the antenna trimmer capacitor (S). Insert the other end of this hookup wire down through grommet 1.

( ) Ⓟ Connect the wire from lug 2 of side C of the band switch to lug 2 of the antenna trimmer capacitor (S).

( ) Ⓟ Connect the wire from lug 4 of side D of the band switch to the solder lug at the foot of the antenna trimmer capacitor (S).

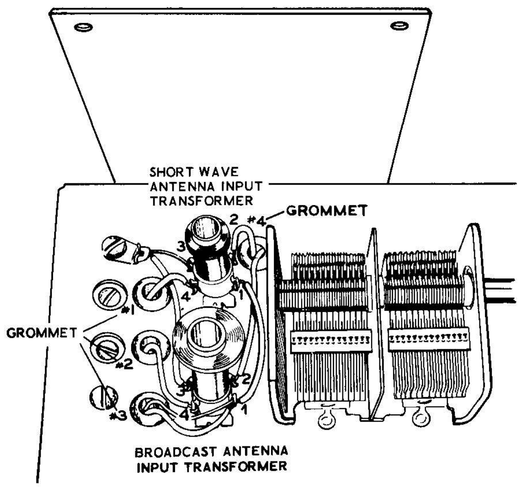
( ) Ⓟ Connect a length of hookup wire from lug 1 of side D of the band switch (S) to lug 1 of the antenna terminal strip (S).

( ) Ⓟ Connect a 22 KΩ 1/2 watt resistor from lug 1 (NS) to lug 3 (S) of tube socket V1.

( ) Ⓟ Connect a 47 $\mu\mu$f mica capacitor from lug 1 of tube socket V1 (S) to lug 1 of side A of the band switch (S).

Refer to Figure 10P for the following steps.

( ) Ⓟ Connect the short hookup wire coming up through grommet 4 to lug 2 of the short wave antenna input transformer (S).



WIRING THE ANTENNA INPUT TRANSFORMERS.

Figure 10P

( ) Ⓟ Connect a short length of bare wire from lug 3 of the short wave antenna input transformer (S) to the ground lug near it (S).

( ) Ⓟ Connect the length of hookup wire coming up through grommet 1 to lug 4 of the short wave antenna input transformer (S).

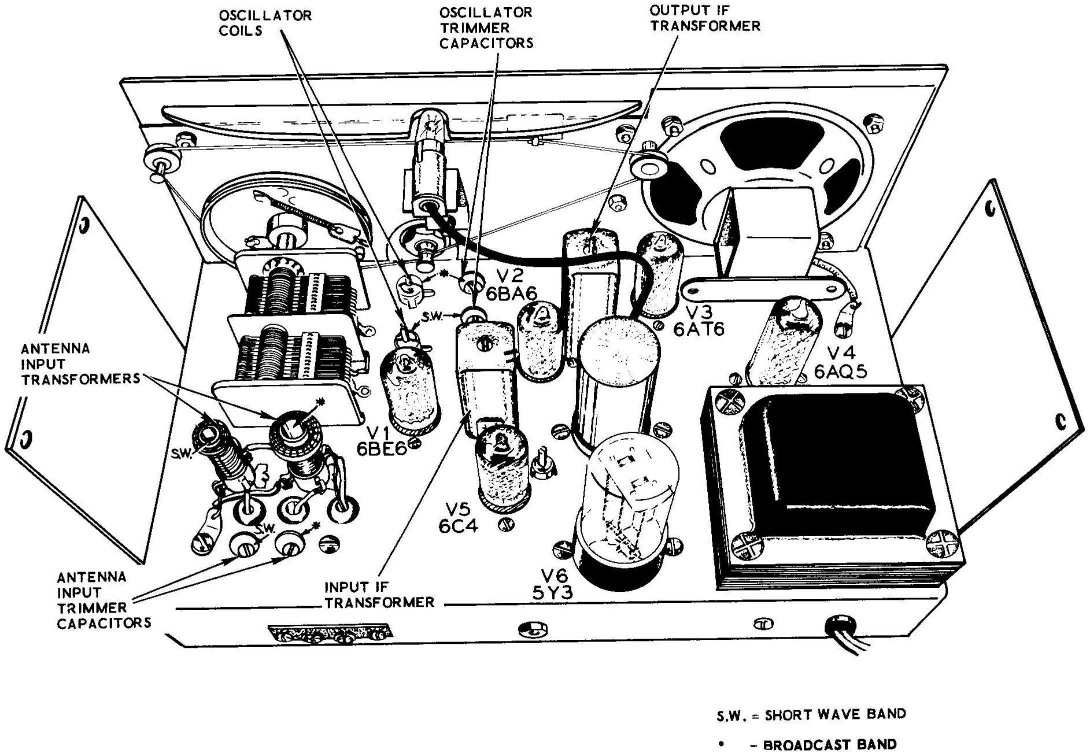
( ) Ⓟ Connect the long hookup wire coming up through grommet 4 to lug 2 of the broadcast antenna input transformer (S).

( ) Ⓟ Connect a 1-1/2" length of hookup wire from lug 1 of the short wave antenna input transformer (S) to lug 1 of the broadcast antenna input transformer (NS).

( ) Ⓟ Connect the length of hookup wire coming up through grommet 3 to lug 1 of the broadcast antenna input transformer (S).

( ) Insert V5, the 6C4 tube, in its socket.

This completes the construction of your EK-2B Receiver. Check carefully to see that there are no solder splashes, shorting out lugs or components. Check to make sure that none of the lugs of the band switch are touching the chassis.



THE TUBE NUMBERS AND THE ADJUSTMENT POINTS FOR THE EK-2B RECEIVER.

Figure 10Q

EXPERIMENT 1

To check the performance and realign the broadcast band.

( ) Connect the antenna and ground leads to your EK-2B Receiver and turn the receiver ON.

( ) Turn the BFO switch to the OFF position. Turn the broadcast-short wave (BC-SW) switch to the broadcast position. Make sure the SPEAKER switch is in the ON position.

( ) Now tune through the broadcast band to see how many stations you can receive.

( ) The receiver may not tune very many stations because its sensitivity has probably decreased. If this is the case, the receiver needs to be aligned again. When you wired the RF and IF amplifier circuits, the small changes in capacity introduced by changing the wiring and adding the band switch caused the circuit to become detuned.

( ) Now refer back to Page 90 in Lesson IX and go through the alignment procedure for the broadcast band.

( ) After you have aligned the broadcast band of the receiver, tune back and forth to see how many stations you can receive. Notice the difference in sensitivity of the receiver between the way it operates now, and the way it operated before it was realigned.

EXPERIMENT 2

To check the performance of the short wave band.

( ) Turn the band switch to the short wave position. Now tune through the short wave band and see how many stations you can receive. Many more stations will probably be received at night than will be received during the day time.

( ) Now turn the BFO switch ON and tune to the short wave band to see if any CW stations can be received.

( ) Just like the broadcast band the sensitivity of the short wave can be greatly improved by alignment process. To adjust the beat frequency oscillator, turn the BFO switch ON and tune to a station on either band of the receiver.

( ) The BFO should now be causing distorted tones to be heard on the station you are tuned to. If the sounds from a station are not distorted, turn the slug of the BFO coil until this distortion occurs.

( ) Now tune to a CW station on the short wave band. Tune the BFO coil until the tone is the sound that seems most pleasing to listen to. This completes the adjustment of the beat frequency oscillator.

SHORT WAVE ALIGNMENT PROCEDURE

Aligning the short wave band of your EK-2B Receiver is done by using the same two types of procedure that would be used to align a broadcast band. These two procedures are the alignment without instruments, or the alignment with instruments.

The easiest way of aligning the short wave band of your receiver is by using an RF generator as a substitute for a signal from a station. A professional type voltmeter could be used to check the AVC voltage just as you did in aligning the broadcast band. If a professional type voltmeter is not available, you could also align the short wave band by listening to the changes in the volume of the signal in the speaker. To align the short wave band of your receiver you must be able to tune stations at both the high end and at the low end of the short wave band. You must also be able to determine the frequency of each of these stations.

At the high end of the broadcast band, near 10 megacycles, you should be able to tune station WWV. You can recognize station WWV by the time signal that is given once a minute or by the ticking sound, like the ticking of a clock.

You may find it quite difficult to find a station at the low end of the band and determine its frequency. You would have to determine the frequency of the station, as you did before, by listening to the station until its frequency was given. If no station can be found at the low end of the band, then a signal generator would have to be used to align the receiver.

The procedure used to align the short wave band would be the same as the alignment procedure used to adjust the broadcast band. The complete procedure can be broken down into the following four steps:

1. Set the generator (or tune the station) at the low end of the short wave band (3 to 4 megacycles).

   a. Turn the slug of the short wave oscillator coil, while adjusting the tuning, in order to move the pointer to its correct place on the dial.

   b. Align the short wave antenna input transformer for maximum signal in the speaker, or on the meter.

2. Set the generator (or tune a station) at the high end of the short wave band. Set the generator at 8.5 megacycles, or tune in WWV at 10 megacycles.

   a. Turn the short wave oscillator trimmer capacitor, and adjust the tuning of the receiver to move the pointer to its correct place on the dial.

   b. Tune the short wave antenna trimmer capacitor for maximum signal.

3. Do not align the IF transformers, they should remain as you aligned them for the broadcast band.

4. Repeat the complete process starting with Step 1 and Step 2, until the station at the low end, and the station at the high end of the band are tuned at their proper frequencies.

DISCUSSION

In the Experiment section of Lesson X you have completed the construction for your EK-2B Receiver. The complete Schematic Diagram for the EK-2B Receiver is shown in Figure 10R (fold-out from Page 121). Study this complete Schematic Diagram and make sure that you recognize what each stage of the receiver does, and also what each part in each stage is used for.

The circuit of the short wave band of the EK-2B Receiver is exactly the same as the circuit of the broadcast band, as far as the operation of the receiver is concerned. When the receiver is switched to the short wave band, the only parts of the receiver that are changed are the input tuned circuit and the short wave oscillator coil. The size of these two components are changed, so that the converter circuit and the oscillator circuit will tune to a different band of frequencies.

Study the band switching section of the EK-2B Schematic. Deck #2-rear switches the antenna between the two primaries of the input transformers. Deck #2-front section switches the grid of the converter between the secondaries of the input transformers. The front of deck #1 switches the proper oscillator coil into the circuit. The rear section of deck #1 switches the correct tap of the oscillator coil into the circuit.

V5, the beat frequency oscillator, allows Morse Code (CW) signals to be heard on the EK-2B Receiver. It creates a frequency that beats against the IF frequency, creating the tone that is heard in the audio output of the receiver.

LESSON X
QUESTIONS

1. The length of a radio wave is usually given in ______________________.

2. A short wave signal is one which is (higher, lower) in frequency than the signal from a station in the broadcast band.

3. (True or false) When you switch a receiver to the short wave band it becomes a TRF receiver.

4. The large switch that switches the receiver from one band to another band is called a ______________________ switch.

5. The rear part of deck #1 of the band switch, switches ______________ ______________ ______________ ______________.

6. When the receiver is in the short wave position, the top (the ungrounded end) of the broadcast oscillator coil is connected to ______________________.

7. What are the names that are usually given to the two amateur radio bands shown on the short wave band of your EK-2B Receiver?

8. Precision time signals are received at 5 megacycles and 10 megacycles on the short wave band from government station________.

9. Morse Code signals are usually called ______________________ signals.

10. To receive Morse Code signals on the receiver it is necessary to have a ________ circuit.

WHERE DO YOU GO FROM HERE?

The EK series kits have given you an introduction to the fundamentals of radio. Now that you have these fundamentals firmly in mind, it should be easy for you to expand your knowledge of electronics even further. Even if your knowledge of electronics is never used as a trade or profession, it is still a very worthwhile subject to be familiar with in this scientific age.

In the future the Heath Company has plans for introducing a wide range of educational products. They will encompass many different subjects in the field of electronics. Watch for further announcements of these products in your Heath flyers. In the meantime, do not overlook the many fine electronic textbooks that are available in your local library.

SERVICE INFORMATION

SERVICE

If continued operational difficulties are experienced with the completed EK-2B Receiver, the facilities of the Heath Company Service Department are at your disposal, or you may contact our Technical Consultation Depatment by mail. Local Service is available in some areas through authorized HEATHKIT Service Centers. Should you choose to return the unit to the Heath Company for inspection, repair, and adjustment, you will be charged a minimal service fee, plus the price of any additional parts or material required. However, if the completed kit is returned within the Warranty period, parts charges will be governed by the terms of the Warranty. State the date of purchase, if possible. THIS SERVICE POLICY APPLIES ONLY TO THE COMPLETED CIRCUIT OF LESSON 10, CONSTRUCTED IN ACCORDANCE WITH THE INSTRUCTIONS AS STATED IN THIS MANUAL. Kits that are not entirely completed or that are modified in design will not be accepted for repair. Kits showing evidence of acid core solder or paste fluxes will be returned NOT REPAIRED.

REPLACEMENTS

Material supplied with HEATHKIT products has been carefully selected to meet design requirements and ordinarily will fulfill its function without difficulty. Occasionally improper instrument operation can be traced to a faulty component. Should inspection reveal the necessity for replacement, write to the Heath Company and supply all of the following information:

A. Thoroughly identify the part in question by using the part number and description found in the manual Parts List.

B. Identify the type and model number of kit in which it is used.

C. Mention date of purchase.

D. Describe the nature of defect or reason for requesting replacement.

The Heath Company will promptly supply the necessary replacement. Please do not return the original component until specifically requested to do so. Do not dismantel the component in question as this will voide the guarantee. This replacement policy does not cover the free replacement of parts that may have been broken or damaged through carelessness on the part of the kit builder.

SHIPPING INSTRUCTIONS

In the event that your Receivèr must be returned for service, these instructions should be carefully followed.

ATTACH A TAG TO THE CHASSIS BEARING YOUR NAME, COMPLETE ADDRESS, INVOICE NUMBER ON WHICH THE KIT WAS PURCHASED, AND A BRIEF DESCRIPTION OF THE DIFFICULTY ENCOUNTERED. Wrap the chassis in heavy paper, exercising care to prevent damage. Place the wrapped chassis in a stout carton of such size that at least three inches of shredded paper, excelsior, or other resilient packing material can be placed between all sides of the chassis and the carton. Close and seal the carton with gummed paper tape, or alternately, tie securely with stout cord. Clear ly print the address on the carton as follows:

To: HEATH COMPANY
Benton Harbor, Mich.

Include your name and return address on the outside of the carton. Preferably affix one or more "Fragile" or "Handle With Care" labels to the carton, or otherwise so mark with a crayon of bright color. Ship by insured parcel post or prepaid express; note that a carrier cannot be held responsible for damage in transit if, in HIS OPINION, the article is inadequately packed for shipment.

SPECIFICATION CHANGES

All prices are subject to change without notice. The Heath Company reserves the right to discontinue instruments and to change specifications at any time without incurring any obligation to incorporate new features in instruments previously sold.

IN CASE OF DIFFICULTY

Finding the cause of the trouble in a receiver or in a particular circuit is like a detective trying to solve a crime, the trouble most often can be found by the clues you find in the circuit. For this reason it is a very good idea to review how the circuit operates before trying to find the trouble.

Finding your difficulty can be divided into two general parts. The first part (Steps 1, 2, 3, and 4) are general checks where you try to find the trouble by looking for visible errors or difficulties. In the second part (Steps 6 and 7) you try to locate the trouble by finding the clues with your meter. First you locate the area (or stage) the trouble is in and then you track down the offending part itself.

1. Recheck your wiring against the wiring shown in the Figures and the wiring given in the step-by-step instructions. Often if someone else looks at the unit they will notice something that you have consistently overlooked. Check to see that no two wires are shorting, or touching each other or the chassis. Check to make sure that you have the proper part values in the proper places.

2. Check the solder connections. Poor solder connections are responsible for a great many difficulties. Often troubles can be eliminated by reheating all questionable connections. Clean off excess solder from any lugs where it might be causing a short circuit or a poor connection.

3. Check the tubes. Check to make sure that all tubes are in their proper location and make sure that all tubes light properly. A bad tube can be located by testing it in a tube tester or by substituting a tube of the same type, that is known to be good, in its position.

4. Check for bits of solder or pieces of wire which may be lodged in the wiring beneath the chassis.

5. Try to locate which stage or which circuit the trouble is in. This can be done by turning the receiver on and scratching the grids of the different tubes. Listen to hear the scratch in the speaker. Start with the last tube first (V4), and scratch each grid in turn, working toward V1. Usually the trouble can be found in the circuits of the tube where the scratching noise stops. In the audio amplifiers it will help to put your finger on the shaft of the screwdriver when it is touching the grid, this will help couple the signal into the audio circuits.

6. Try to locate the trouble itself by checking for the proper voltages in the stage where the trouble seems to exist. Normal voltages will vary plus or minus 10% from the voltage shown on the schematic. If the trouble seems to be narrowed down to a certain area, turn off the power and pull the plug; then check the resistors and the coils in that area to make sure that they have not opened or burned out.

ANSWERS FOR LESSON I

1. magnetic field
2. iron core
3. Power supply transformers are most often used to increase or decrease AC voltages.
4. A DC voltage does not couple through a transformer.
5. turns ratio
6. 300 volts
7. 25 volts
8. The frequency at which the transformer will be used.
9. laminations
10. the center leg of the core
11. amount of energy

ANSWERS FOR LESSON II

1. B+ voltage
2. Ground current flow across the metal of the chassis.
3. wires
4. discharge of the capacitors
5. 60 cycle ripple
6. 120 cycle ripple
7. more
8. A - 30 volts
   B - 20 volts
   C - 10 volts
9. directly heated

ANSWERS FOR LESSON III

1. electrons
2. stops
3. grid and the cathode
4. operating range
5. amplifies and inverts
6. interelectrode capacity
7. secondary emission
8. suppressor
9. decrease
10. voice coil

ANSWERS FOR LESSON IV

1. larger
2. The quality of an audio amplifier depends on how faithfully it reproduces the signals presented to it.
3. range of frequencies
4. voltage amplifier
5. coupling capacitor
6. 6AQ5
7. AC current
8. down
9. audio ---- sound

ANSWERS FOR LESSON V

1. tune, detect, and amplify
2. swells
3. audio - audio amplifier
4. rectify and filter
5. equal and opposite swells
6. The filter circuit can fill in only the short spaces between individual cycles of the RF signal.
7. the cathode
8. AVC

ANSWERS FOR LESSON VI

1. tune and amplify
2. parallel
3. resonance
4. (larger)
5. (more sharply)
6. ganged
7. TRF
8. Part 1 - The many sectioned tuning gang is expensive and difficult to adjust properly.

   Part 2 - A high quality coil will not adjust over so wide a frequency range, as the whole broadcast band.

ANSWERS FOR LESSON VII

1. an AC signal
2. swing back and forth
3. damped
4. tickler
5. maximum and minimum
6. grid leak
7. cathode
8. plate
9. bias - - grid

ANSWERS FOR LESSON VIII

1. two signals
2. four
3. original station signal, original oscillator signal, the sum frequency, and the difference frequency.
4. difference
5. is
6. false
7. High-Q coils can be used in the oscillator coils of superheterodyne receivers because the IF amplifiers only amplify one frequency, usually 455 kc in home-type receivers.
8. 455 kc, the IF frequency
9. one adjustment for each coil
10. negative
11. true

ANSWERS FOR LESSON IX

1. oscillator - station
2. difference
3. 455 kc
4. the input tuned circuit and the oscillator tuned circuit
5. low end
6. high end
7. a voltmeter and an RF generator

ANSWERS FOR LESSON X

1. meters
2. higher
3. false
4. band
5. the tap of the oscillator coils
6. ground
7. 80 meter band
   40 meter band
8. WWV
9. CW
10. BFO

SPECIFICATIONS

Frequency Range:.	Broadcast band - 540 to 1600 kc. Short wave band - 3 to 10 mc.
Intermediate Frequency:.	455 kc.
BFO:.	Variable (approximately 455 kc).
Bandwidth (6 db down):.	8 kc.
Sensitivity (10 db S/N; 400 cycle modulation 30%; 50 mw output):.	20 mv at 1000 kc and 6 mc.
Controls:.	Band switch, TUNING, AC ON-OFF-VOLUME, BFO ON-OFF, and SPEAKER ON-OFF.
Tube Complement:.	1 - 6BE6 converter 1 - 6AA6 IF amplifier 1 - 6AT6 detector and 1st audio amplifier 1 - 6AQ5 audio power amplifier 1 - 6C4 BFO 1 - 5Y3 full wave rectifier
Power Requirements;	105-125 volts AC, 50/60 cycles, 40 watts.
Dimensions (In Cabinet):.	11-1/2" wide, 6-1/2" high, 7-1/2" deep.
Shipping Weight (Less Cabinet):.	4 lbs.

WARRANTY

Heath Company warrants that all Heathkit parts shall be free of all defects in materials and workmanship under normal use and service, and in fulfillment of such warranty Heath Company will, for a period of three months from the date of shipment, replace any part upon verification that it is defective.

The foregoing warranty shall apply only to the original buyer, and is and shall be in lieu of all other warranties, whether express or implied and of all other obligations or liabilities on the part of Heath Company and in no event shall Heath Company be liable for any anticipated profits, consequential damages, loss of time or other losses incurred by the buyer in connection with the purchase, assembly or operation of Heathkits or components thereof. No replacement shall be made of parts damaged by the buyer in the course of handling or assembling Heathkit equipment.

The foregoing warranty is completely void if corrosive solder or fluxes have been used in wiring the equipment. Heath Company will not replace or repair any equipment in which corrosive solder or fluxes have been used.

This warranty applies only to Heath equipment sold and shipped within the continental United States including APO and FPO shipments. Warranty replacements for Heathkit equipment outside the United States is on a f.o.b. factory basis. Contact the Heathkit authorized distributor in your country or write: Heath Company, International Division, Benton Harbor, Michigan, U.S.A.

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