RCA

Fundamental Radio

Physics Course

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Radio Physics

FUNDAMENTAL RADIO COURSE

Lecture No. 1

Nature of Electricity

1. Molecule, made up of atoms.
2. Atom, smallest particle of any element, made up of electrons and protons. Number and arrangement of electrons and protons determines nature of element.
3. Nucleus of atom made up of protons and electrons - positive charge.
4. Protons - positive charge.
5. Electrons - negative charge.
6. In normal atom, number of electrons equals number of protons and charges cancel each other, leaving atom uncharged.
7. Body having shortage of electrons - positively charged.
8. Body having excess of electrons - negatively charged.
9. Electrons and protons balanced - uncharged or neutral body.
10. Laws of electrical charges - (a) Unlike charges attract.
    - (b) Like charges repel.
11. Flow of electricity - flow of electrons - negative to positive.
    - flow of current - positive to negative.
12. Conductor - Material in which electrons move freely from atom to atom. Used to carry an electric current.
13. Insulator - Material in which electrons move with difficulty from atom to atom. Used to prevent the flow of an electric current.

Electrical Circuit

1. In order to have a flow of electricity (electrons) a path of conducting material must be provided for the flow. This path is called a circuit. In order to start and maintain the current flow an external force must be applied. (Battery, electric generator, etc.)
2. Closed circuit - Complete path from negative to positive, necessary for flow of current.
3. Short circuit - Extremely short closed circuit, usually undesirable as it by-passes the flow of current and prevents it flowing in the proper circuit.
4. Open circuit - Incomplete or broken path, permits no flow of current in circuit.
5. Series circuit - Circuit in which two or more pieces of electrical equipment are connected together in such a way that the current must flow through all units in order to flow through any one, if the circuit through one unit is broken, there will be no current flow through any of the others.
6. Parallel circuit - Circuit in which two or more pieces of electrical equipment are connected together in such a way that the current flows through each unit without depending upon any other unit to complete the circuit. If the circuit through one unit is broken, the current flow through the other units will not be affected.

MR:dw
Oct. 31/49.

FUNDAMENTAL RADIO

MAGNETISM

1. Natural magnets - lodestones.

2. Poles of magnet - north and south.

3. Magnetic substances - iron, steel, nickel, cobalt, alloys.

4. Non-magnetic substances - copper, brass, aluminum, non-metals, etc.

5. Retentivity - ability to retain magnetic state-residual magnetism. iron lowest steel highest

6. Permeability - ease with which magnetic lines of force can permeate substance can be magnetised. iron most affected

7. Laws of magnetic attraction and repulsion.
   (a) Unlike poles attract, like poles repel.
   (b) Force between magnetic poles varies inversely as the square of the distance between them.

8. Magnetic lines of force, magnetic field, flux. imaginary lines

9. Magnetic shielding.

10. Molecular theory of magnetism.

ELECTRO-MAGNETISM

1. Magnetic field set up in conductor carrying a current.

2. Direction of field about a conductor depends upon direction of current flow. Right-hand rule - grasp conductor with right hand with thumb pointing in direction of current flow. Fingers will point in direction of magnetic field.

3. Strength of field depends upon strength of current flow.

4. Conductor in form of coil - solenoid.
   (a) Much stronger magnetic field.
   (b) Field similar to bar magnet with north and south poles.
   (c) Field strength depends upon (b) number of turns on coil (2) strength of current (3) closeness together of turns.
   (d) Strength of electro-magnet measured in ampere-turns (amperes X turns).
   (e) Introduction of core of magnetic material greatly strengthens magnetic field.
   (f) Direction of field about solenoid depends upon direction of current flow. Right hand rule - grasp solenoid with right hand so that fingers point in direction of current flow in each turn. Thumb will point to north pole.

5. Strength of magnetic field - flux density - number of lines of force per unit area.

MR:dw
Nov. 9/49.

FUNDAMENTAL THEORY

Units.	
Coulomb.	Quantity of current.
Ampere.	Unit of current flow.
Milliampere. 1/1000 of an ampere	
Volt.	Unit of pressure.
Kilovolt. 1000 volts	
Millivolt.	
Microvolt.	
Ohm.	Unit of resistance.
Megohm.	
Resistivity.	Formula.

Ohms Law.	
Voltage drop.	
Resistors.	
Color code.	
Power.	
Watt.	Unit of power.
Kilowatt. 1000 Watts	
Power rating.	

RESISTOR COLOR CODE

Black	0	Blue	6
Brown	1	Violet	7
Red	2	Grey	8
Orange	3	White	9
Yellow	4		
Green	5		

Each resistor has 3 color bands.
The first represents a digit.
The second represents a digit.
The third represents the number of zeros to be added.

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FUNDAMENTAL RADIO

Lecture No.4

Electro-magnetic Induction

1. Magnetic lines of force cutting across a conductor induce a current in the conductor. (Magnetic field must be moving with relation to the conductor in such a way that conductor passes through lines of force).

2. Direction of current flow depends upon direction of motion of magnetic field cutting conductor.

3. Strength of current depends upon -
   1. Strength of magnetic field.
   2. Rate at which lines of force cut conductor.

4. Stronger current induced by using solenoid and causing the turns of the solenoid to be cut by a magnetic field, either by moving the coil or the magnetic field.

5. Strength of current induced in a solenoid depends upon -
   1. Strength of magnetic field.
   2. Rate at which magnetic field cuts conductors.
   3. Number of turns being cut by magnetic field.

6. Lenz' Law - In every case of electro-magnetic induction the induced current sets up a magnetic field opposing the motion of the inducing field. In no case is the induced electrical energy greater than the mechanical energy used to induce it.

7. Application of electro-magnetic induction - electric generator, dynamo.

Alternating Current

1. Direct current is a current that flows always in one direction. There are definite positive and negative terminals to the voltage source. Example - batteries.

2. Alternating current is a current that is continually changing its direction of flow. There are no definite positive or negative terminals to the voltage source. Example - voltage from a generator in which the conductors are first cutting the magnetic field in one direction and then in the opposite direction.

3. Cycle - One complete change in direction of flow.

4. Frequency - Number of cycles per second.

5. Peak voltage or current (AC) - highest value reached during cycle.

Alternating Current (cont'd.)

6. R.M.S. voltage or current (AC) - one ampere (R.M.S.) is that current that will produce the same amount of heat as one ampere DC.
   R.M.S. voltage or current = .707 x peak voltage or current.
   e.g. - If peak voltage is 100 volts, R.M.S. voltage = .707 x 100 = 70.7 volts.

Transformers

1. Voltage is induced in one coil by placing it in the magnetic field of another coil through which AC is flowing.

2. Primary - Coil to which AC is applied.
   Secondary - Coil in which voltage is induced.

3. In iron core transformers volts per turn in secondary is equal to volts per turn in primary.
   e.g. - Primary turns = 100 - Primary volts = 200
   Primary volts per turn = $\frac{200}{100}$ = 2
   Secondary volts per turn = 2

4. Voltage induced in secondary (voltage and turns on primary fixed) depends upon number of turns on secondary.
   e.g. - In above example - Secondary volts per turn = 2
   Therefore, total secondary voltage = no. of turns x 2
   or secondary voltage = secondary turns x $\frac{\text{primary voltage}}{\text{primary turns}}$

5. Step-up or step-down transformers.

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bd/Nov.23/49 W. Moore

INDUCTORS

When the current flowing in a conductor varies the field varies. The changing field at all times tries to oppose the variations in the current. For example, if a current builds up a field and suddenly reverses direction, the field before dying out and changing its direction will resist the change, as if it had inertia because of a counter EMF or induced voltage. This property of a circuit, opposing change of current because of induced counter voltage, is called self inductance.

This EMF is made much stronger when the conductor is wound in the form of a coil. Inductance is desired in radio circuits and are deliberately inserted in the form of coils.

The unit of inductance is one <u>Henry</u>. When a current change of <u>one ampere per second</u> produces in it an induced voltage of 1 volt, the circuit has an inductance of one Henry.

The inductance of a coil is fixed by its design and varies with the following factors:

$$L = N \times d^2 n^2 \, l \, k \text{ Henries}$$

N = constant number
d = diameter
n = no. turns
l = length
K = form factor (ratio $\frac{L}{D}$)

$$\text{Millihenries} = \frac{\text{Henries}}{1000}$$

$$\text{Microhenries} = \frac{\text{Henries}}{1{,}000{,}000}$$

The above formula applies to an air core coil only. When an iron core is used the inductance may be increased as much as 25,000/1. In the case of air inductance remains constant. In the case of an iron core inductance may vary depending on the extent of saturation of the core.

Examples of coils used in sets are -

1. Antenna coils.
2. Oscillator coils.
3. I.F. coils.
4. Choke coils.
R. F Coils

We have thus far only considered the effects of self inductance. Of equal importance is the effect of mutual inductance. As the magnetic field varies it induces a voltage in any other winding which happens to be in its path. This effect is called mutual inductance and the value depends on the distance between the coils. Such coils are said to be coupled together and the distance between them is very important in determining the best value of coupling.

D.C. flow	-	no opposition.
A.C. flow	-	varying opposition.
Frequency	-	cycles per second.

Reactance in ohms:

$X_l = 2\pi F L$ ohms.
F in cycles per second.
L inductance in Henries.
π is constant factor = 3.1416.

Lag.
Phase.
Power factor.
Power consumed.
Reasons for use in radio set.

MR:dw
Nov. 29, 1949.

FUNDAMENTAL RADIO COURSE

Lecture No. 6

Capacitors

1. Elementary form - two metal plates separated by an insulator called the dielectric.

2. Capacitor is able to hold electrical charge, as positive charge on one plate attracts and holds electrons in opposite plate.

3. Unit of capacity - farad (microfarad and micromicrofarad).

4. Capacity of capacitor depends upon -
   1 - Area of plates. Greater area, greater capacity.
   2 - Thickness of dielectric. Thicker the dielectric, lower the capacity.
   3 - Nature of dielectric. Higher the dielectric constant, greater the capacity.

5. Breakdown voltage - highest voltage that dielectric will stand without breaking down. *should be higher than capacity voltage being used*

6. Capacitor will prevent flow of DC, but permit flow of AC.

7. Capacitative Reactance (X_c) depends upon -
   1 - Capacity of capacitor. Higher the capacity, lower the reactance.
   2 - Frequency of AC. Higher the freq., lower the reactance.

$$X_c \text{ (ohms)} = \frac{1}{2\pi F \text{ (cycles)} \times C \text{ (farads)}}$$

6.28

8. Types of capacitors -

   Fixed - paper, mica, electrolytic.
   Variable - gangs, trimmers.

9. Uses of capacitors -
   1 - Filter capacitor - stores up electrical charges.
   2 - Blocking or coupling capacitor - blocks flow of DC while allowing flow of AC.
   3 - By-pass capacitor - provides low reactance path for AC without affecting the DC characteristics of the circuit.
   4 - Tuning capacitor - forms part of a resonant circuit.

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bd
Dec.7/49

W. Moore

$$2\pi FL = \frac{1}{2\pi FC}$$

$$F = \frac{1}{2\pi L \times 2\pi FC}$$

$$F^2 = \frac{1}{2\pi \times 2\pi \times L \times C}$$

$$F = \frac{1}{2\pi \sqrt{LC}}$$

Resonant Frequency

FUNDAMENTAL RADIO

Lecture No. 7

1. Sound waves (audio frequencies) - 16 to 20,000 cycles per sec.

2. Radio waves (radio frequencies) - 20 - 3,000,000 kilocycles per sec.

3. Carrier wave - radio frequency signal sent out by transmitting station.

4. Modulation - introduction of sound wave into carrier wave at transmitter.

5. Demodulation or detection - separation of sound wave from carrier at receiver.

6. Amplitude modulation - modulation of carrier by changing its amplitude (strength).

7. Frequency modulation - modulation of carrier by changing its frequency.

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Dec. 28/49

W. Moore

VACUUM TUBE THEORY

Vacuum tube operation depends on the action of electrons. As energy is applied to the conductor in the form of heat, electrons start to move. If enough heat is applied, the conductor becomes red or white hot and electrons break through the surface and escape into space. This is called Thermionic Emission. (No. of Electrons)

This emission of electrons depends on the following:-

(1) Area of emitter. Fixed
(2) Nature of material. Fixed
(3) Temperature.
(4) Nature of medium surrounding the conductor. Fixed

The number of electrons emitted varies directly as the area. In vacuum tubes the area is fixed by design. The best known materials are thorium, tungsten or oxide coatings, or a thorium tungsten mixture. The temperature is very important since the electron flow varies directly as the temperature. In tubes the heat is applied by means of an electric current. It is therefore important to have control over the current flowing so that the temperature will be known.

The medium must be a vacuum or very close to it. If air is present it will speed combustion and burn up the conductor. If gases are present, they will offer resistance to the flow of electrons.

Cathode - The emitter in a tube is called the cathode. It can be directly, or indirectly, heated. In the case of direct heating, the coating which gives off electrons is painted on the conductor through which current flows. Emission is instantaneous and these tubes are usually used in battery sets. In indirect heating, the conductor is surrounded by the plate which gives off the electrons, but not in contact with it. It takes a few seconds for the emission to start. This type is used on A.C. currents.

Space Charge - Electrons constitute a negative charge of electricity. As more electrons leave, the cathode becomes more positive. After a short time, a negative charge accumulates in the tube a short distance from the cathode which tends to repel electrons back. The cathode also tends to attract electrons back. Therefore, many electrons will return unless other attractions or forces are provided. The negative charge present in space is called the Space Charge.

Suppose a plate were added in the tube. If there was no charge on it electrons would not be attracted or repelled. There would be no difference. If the plate is negative it will repel electrons back into the space charge. But if it is made positive it will attract electrons, and if the plate circuit is complete, current will flow. Electrons will reach the plate and continue through the circuit back to the cathode. Current will actually flow from plate to cathode and is called plate current. The strength of the current depends on both the plate attraction and the temperature of the emitter. Usually the latter is fixed so that the plate current depends on the value of positive plate voltage. As plate voltage increases the plate current increases; i.e. more electrons are attracted to the plate. This will continue until all the electrons emitted are being absorbed. There can be no further increase and a condition of saturation exists.

Two Electrode Tube - A tube containing only a cathode and a plate is called a diode. When positive voltage is applied to the plate, electrons will flow into the plate circuit. When the plate is negative, it repels electrons and no current flows. If A.C. is applied, it is alternately positive and negative. Current flows out of the tube only during positive half cycles. Therefore, A.C. is converted to D.C. or rectified. This tube is called a rectifier. There is no amplification.

Three Electrode Tube - This tube is called a triode and makes amplification possible. The third electrode is called a grid and consists of a coil of wire. It is located so that all the electrons must flow through it. When the grid has no charge, it does not affect the flow. When it is positive it neutralizes the space charge and plate current increases. When it is negative, it aids the space charge and plate current decreases. The grid can be made negative enough so that all electrons will be repelled. It therefore acts as a valve and controls the flow of electrons. Since it is closer to the cathode than the plate, it has a much stronger control than the plate and makes amplification possible. There is one weakness in this type of tube - capacity exists between the electrodes; i.e. between plate and grid, plate and cathode, and grid and cathode. This causes feedback and instability and limits the usefulness of the triode.

Four Electrode Tube or Tetrode - The capacity between grid and plate is very important and must be kept very low. It can be reduced by adding a screen grid between the grid and the plate. This acts as an electrostatic shield and reduces the capacity by about 1,000 to 1. The screen is operated at positive potential and helps the plate attract electrons. Most of these pass through the grid to the plate. It makes higher gain possible due to this action. The objection to this tube is that some electrons bounce back from the plate to the screen due to secondary emission and Ip is reduced.

Five Electrode Tube or Pentode - To reduce secondary emission a fifth electrode called a suppressor grid is placed between the plate and the screen, and connected to ground. Electrons emitted from the plate will be shielded from the screen and return to the plate. This tube provides maximum gain and stability, and is most commonly used.

M. Rolbin:dw

FUNDAMENTAL RADIO COURSE

LECTURE #9

The Radio Receiver

1. The crystal set.

2. The tuned radio frequency (T.R.F.) receiver.

3. The superheterodyne -
   (a) Antenna stage tuned to desired station frequency.
   (b) Intermediate frequency (I.F.) amplifier tuned to fixed frequency (usually 455 Kc).
   (c) Local oscillator tuned to frequency equal to sum of station + I.F. frequencies. Oscillator frequency determines to what station frequency receiver will respond.
   (d) Second detector demodulates signal (i.e. removes modulation from carrier).
   (e) First audio frequency (AF) amplifier amplifies AF modulation.
   (f) Power amplifier steps up power of AF modulation to drive loudspeaker.

Example:

Receiver I.F. frequency (as determined in design) = 455 Kc.
Frequency of station to be received (carrier freq.) = 600 Kc.
Modulation on station carrier = 1000 cycles.

1. Ant. stage tuned to 600 Kc, thereby strengthening signals of this frequency and weakening all others.
2. Local oscillator tuned to 600 Kc + 455 Kc = 1055 Kc, thereby producing a beat frequency of 455 Kc.
3. Beat frequency of 455 Kc amplified by I.F. amplifier which is tuned to this frequency.
4. 455 Kc signal goes to second detector where the 1000 cycle modulation is removed from the 600 Kc carrier.
5. The 455 Kc is eliminated and the 1000 cycle signal is amplified by the 1st AF amplifier.
6. The 1000 cy. is further amplified and the power increased by the power amplifier.
7. The 1000 cy. is then fed to the speaker and is reproduced as a 1000 cycle sound wave.

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W. Moore
Radio Inspection

WM:bd
Jan.11/50

FUNDAMENTAL RADIO

POWER SUPPLY

1. Voltage requirements in a radio set are for Plate, Screen, Filament and Grid.

2. A.C. supply must be changed to D.C.

3. Transformers.

4. Rectifiers.

5. Filters.

6. Voltage regulators.

7. D.C. supply.

8. Voltage doublers.

9. Vibrator.

10. Wiring.

M. Rolbin:dw
January 18, 1950.

FUNDAMENTAL RADIO LECTURE # 11

A M P L I F I E R S

1. Uses in Radio receivers.

    (a) RF
    (b) IF
    (c) Voltage
    (d) Power

2. Types of tubes used. Triodes. Pentodes.

3. Voltages required. Plate, screen, grid.

4. Automatic grid brasing.

5. Amplification.

6. Tube constants.

7. Relation between grid voltage, plate current, plate voltage.

8. Output.

9. Coupling.

10. Tuning.

M. Rolbin:dw
January 25. 1950.

O S C I L L A T O R S

Fundamental Radio # 12.

1. An oscillator tube converts D.C. to A.C.

2. Requirements for oscillation -

   (a) Feedback in proper phase.
   (b) Resonant circuit.
   (c) Ability to amplify.

3. Tank circuit, grid bias, wave form, time constant, amplitude, harmonics.

4. Frequency stability, temperature compensation, voltage regulation, rigidity.

5. Hartley oscillator.

6. Colpitts oscillator.

7. Tuned plate oscillator.

8. Meissner oscillator.

9. Electron coupled oscillator.

10. Crystal oscillator.

11. Audio oscillator.

12. Pentagrid converter.

13. Mixer.

14. Tracking.

M. Rolbin:dw

February 21st., 1950.

LECTURE No. 13

Second Detector

Diode rectifier that rectifies modulated carrier, thereby making modulation available for audio amplification.

Automatic Volume Control (A.V.C.)

When the carrier is rectified in the second detector a D.C. voltage is created, the strength of which depends upon the strength of the carrier. This voltage (negative) is fed back to the control grids of the R.F. and I.F. amplifier tubes. The gain of these tubes is affected by the amount of this negative voltage applied to the grids; the higher the voltage, the lower the gain. Therefore, with a strong signal a high voltage is developed and the amplifier gain is reduced. With a weak signal the voltage is lower and the amplifier gain higher. This tends to keep the signal coming out of the amplifier at a nearly constant level in spite of variations in strength of the signal being fed in.

WM:bd
Mar.1/50

W. Moore

RESISTOR COLOUR CODE

0	Black
1	Brown
2	Red
3	Orange
4	Yellow
5	Green
6	Blue
7	Violet
8	Grey
9	White

Resistors are usually marked with three bands. Starting with the band closest to the end, these indicate values as follows:

First band	represents	a digit (from 1 to 9)
Second "	"	" " (" 0 " 9)
Third "	"	the number of zeros to be added (from 0 to 9).

e.g. If the resistor has three bands, Red-Orange-Blue, the value would be 2 . 3 . 000000 or 23 million ohms.

A fourth band, either silver or gold, may be added to indicate tolerance as follows:

Gold	5%
Silver	10%
Plain	20%

MR/bd
Apr.5/50

M. Rolbin
Radio Inspection

1. Mount output transformer.

2. " electrolytic.

3. " first I.F. Part 1

4. " second I.F. " 2

5. Capacitor .05 35Z5 pins 8 to (5 to 3).

6. " .03 from T.B. to 50L6 pin 3.

7. Resistor 220,000 from 50L6 pin 4 to 12SQ7 pin 6.

8. " 1200 ohms. from T.B. to 12SK7 pin 6.

9. Output Red to pin 8 35Z5.

10. Brown to T.B.

11. Blue " 50L6 pin 3.

12. Electrolytic Red to pin 6 50L6.

13. Green to pin 4 50L6.

14. Black to lower terminal V.C.

15. ≠ B Red leads from 35Z5 pin 8 to 50L6 pin 6.

16. 12SK7 " 6 " 50L6 " 4.

17. 12SK7 " 6 " 1st I.F.

18. 12SA7 " 4 " 1st I.F.

19. 12SA7 " 3 " 1st I.F.

20. 12SK7 " 8 " 2nd I.F.

21. 50L6 " 4 " 2nd I.F.

22. Common Black V. Control lower terminal to 12SK7 pin 5.

23. " " " " 12SQ7 " 3.

24. 12SQ7 pin 3 to 2nd I.F. middle terminal.

25. Bottom lug of V.C. to bottom Lug on Switch

Add black lead

MR:bd

FUNDAMENTAL RADIO WIRING

1. Mount oscillator coil with terminals to left.
   Count terminals from 1 to 4 from top, counter clockwise.

2. Connect oscillator terminals as follows:
   #1 Blue to oscillator section of gauge.

3. #1 56 capacitor to 12SA7 pin 5.

4. #2 Wire to 12SA7 pin 6.

5. #3 1 megohm resistor to first IF bottom right.

6. #3 Yellow wire to lance on gauge.

7. #3 · 3.3 megohm to second IF top left.

8. #3 .025 capacitor to 12SQ7 pin 5.

9. #4 Bus to 12SK7 pin 3.

10. ✓ 12SA7 Pin #8 Connect to green of ant. section of gauge.

11. ✓ 12SK7 Pin #1 220,000 ohm to pin #3 to pin #5.

12. ✓ 12SK7 Pin #1 .025 capacitor to pin #3.

13. ✓ 12SK7 Pin #4 Green to 1st IF top right.

14. 12SK7 Pin #5 .005 capacitor to 1st IF bottom right.

15. ✓ 12SQ7 Pin #4 Connect to 2nd IF bottom left.

FUNDAMENTAL RADIO

1. Assemble gauge to bracket using 3 grommets, 3 washers, 3 screws, and 1 ground lance.

2. Connect 2 green stranded wires approx. 4" and 5" to bottom lug of antenna section.

3. Connect 1 blue stranded wire approx. 2½" long to bottom lug of oscillator section.

4. Connect yellow wire approx. 2½" to lance.

5. Mount bracket to chassis using 2 large washers and 2 screws.

6. Mount speaker using 2 screws.

7. Connect 2 leads from output transformer to speaker terminal board.

8. 12SA7 pin 1 to ground on socket.

9. 12SK7 pin 1 to " " "

10. 12SQ7 pin 1 to " " "

11. 50L6 pin 8 connect 180 ohm resistor to 12SQ7 pin 8 to pin 5.

12. 12SA7 pin 6 connect 22000 ohm resistor to pin 5.

13. 12SA7 pin 6 connect wire 1½" long. Leave other end loose.

14. 12SA7 pin 5 connect 56 cap. Leave other end loose.

15. 12SQ7 pin 6 330 cap to 12SQ7 pin 3.

16. 12SQ7 pin 6 connect .0025 cap to 50L6 pin 5.

17. 50L6 pin 5 " 470,000 ohm res. to 12SK7 pin 5.

18. Volume control centre tap connect .01 to 12SQ7 pin 2.

19. 12SQ7 pin 2 " 4.7 meg. to 12SQ7 pin 3.

20. " " " " 150 cap to pin 5.

21. 12SQ7 pin 4 " to 2nd IF, bottom left.

22. Volume control top " yellow to 2nd IF, top left.