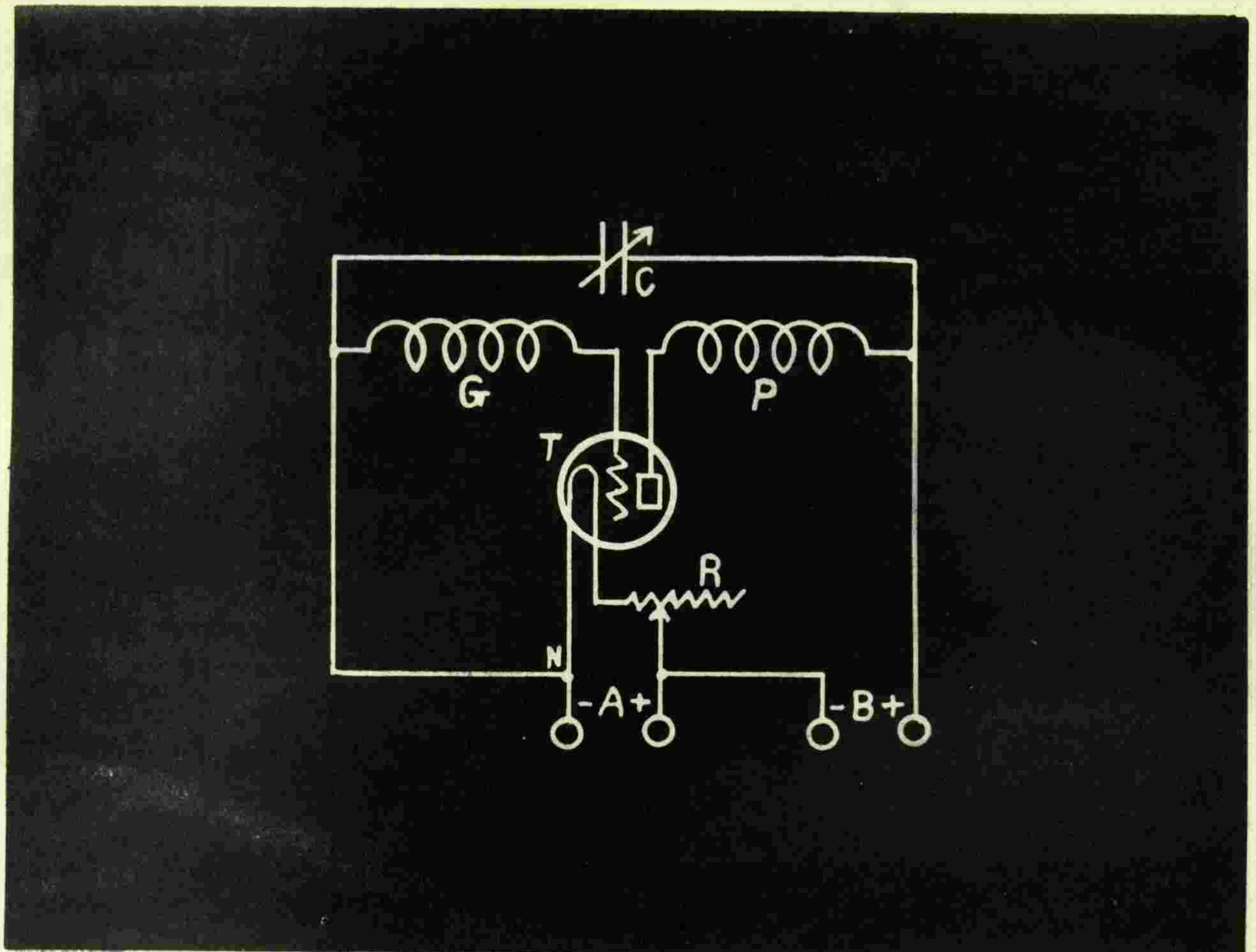

LESSON
35 R

THE VACUUM TUBE AS AN OSCILLATOR

RADIO-TELEVISION TRAINING SCHOOL, INC.
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THE VACUUM TUBE AS AN OSCILLATOR

When used as an oscillator, the triode vacuum tube acts as a generator of high frequency electric current oscillations. In other words, the energy that is supplied to the tube is transformed into an alternating current that oscillates at high frequencies. This transformation is accomplished by suitably coupling the grid and plate circuits of the tube, so that an interchange of energy can take place between these two circuits.

How a vacuum tube can operate as a generator of electric current oscillations can easily be understood with the aid of the circuit illustrated in Fig. 1. Here we have the tube "T" with the filament heated by the battery "A". The plate is given a positive potential with respect to the filament by means of the battery "B". The coils "G" and "P" are closely coupled so that they act like the primary and secondary of a transformer. Both coils are shunted by the variable condenser "C".

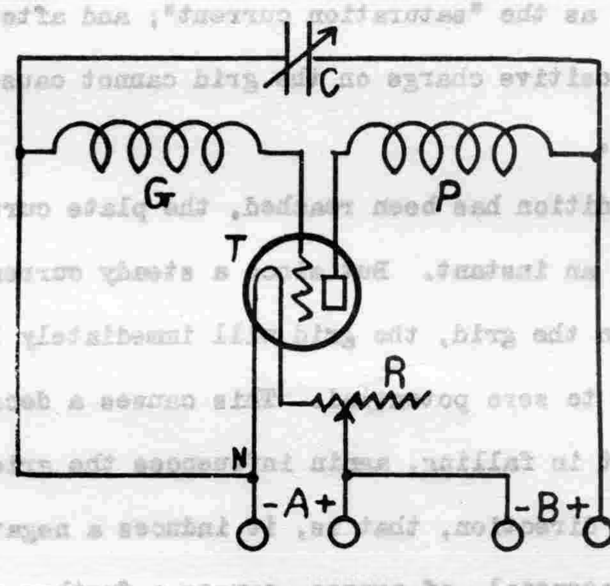


Fig. 1

The oscillating action of this circuit arrangement depends upon the fact that a variable current flowing in either one of the two coils will cause a current to be induced in the other one; but as long as the current flow is steady, no such inductive action can take place. In other words, a rising or falling current in the plate circuit induces a voltage in the coil "G" and thus influences the potential of the grid. An important point to remember is that the negative end of the filament, that is "N" in the figure, is always considered the starting point or point of zero potential in vacuum tube work.

When the circuit is closed, current begins to flow in coil "P". This rising current induces a voltage in coil "G". The coils must always be connected so that this induced voltage will make the grid positive with respect to the filament while the plate current is rising. But a positive charge on the grid causes a further increase of plate current, and this in turn induces an increased positive charge on the grid. This accumulative increase in plate current and grid potential continues until a maximum condition is reached, that is, all the electrons given off by the filament are reaching the plate as fast as they are being emitted. This is known as the "saturation current"; and after this point has been reached, a further positive charge on the grid cannot cause any further increase in the plate current.

When this saturation condition has been reached, the plate current is steady at its maximum value for just an instant. But since a steady current in coil "P" produces no induced voltage on the grid, the grid will immediately lose its positive charge and drop back to zero potential. This causes a decrease in plate current; and the plate current in falling, again influences the grid potential - but this time in the opposite direction, that is, it induces a negative charge on the grid. This negative potential, of course, causes a further drop in plate current, and the decrease continues until the current is nearly zero. At the instant the plate current reaches zero, its inductive action on coil "G" again ceases, the grid potential immediately returns to zero, and everything is set for the entire action to be repeated.

The plate current thus rises and falls as a result of its influence on the grid in causing its potential to swing back and forth between a positive and a negative value. The frequency of the oscillations set up in the plate circuit, depends on the inductance and capacity of the circuits containing "P" and "G". Any desired frequency can be obtained by adjusting the relative number of turns in coils "P" and "G" or by adjusting the variable condenser "C". Although some oscillating circuitsmay differ somewhat from the one described here, they all operate on the same general principle; and if the operation of this circuit is clearly understood, it will be a simple matter to see through any of the others.

SOME COMMONLY USED OCILLATOR CIRCUITS

There are numerous vacuum tube oscillator circuits in use today, as in oscillating wave meters, heterodynes and superheterodynes, bridge measurements, etc. Some of the more common circuit arrangements are illustrated in Fig. 2 and are explained in the following paragraphs.

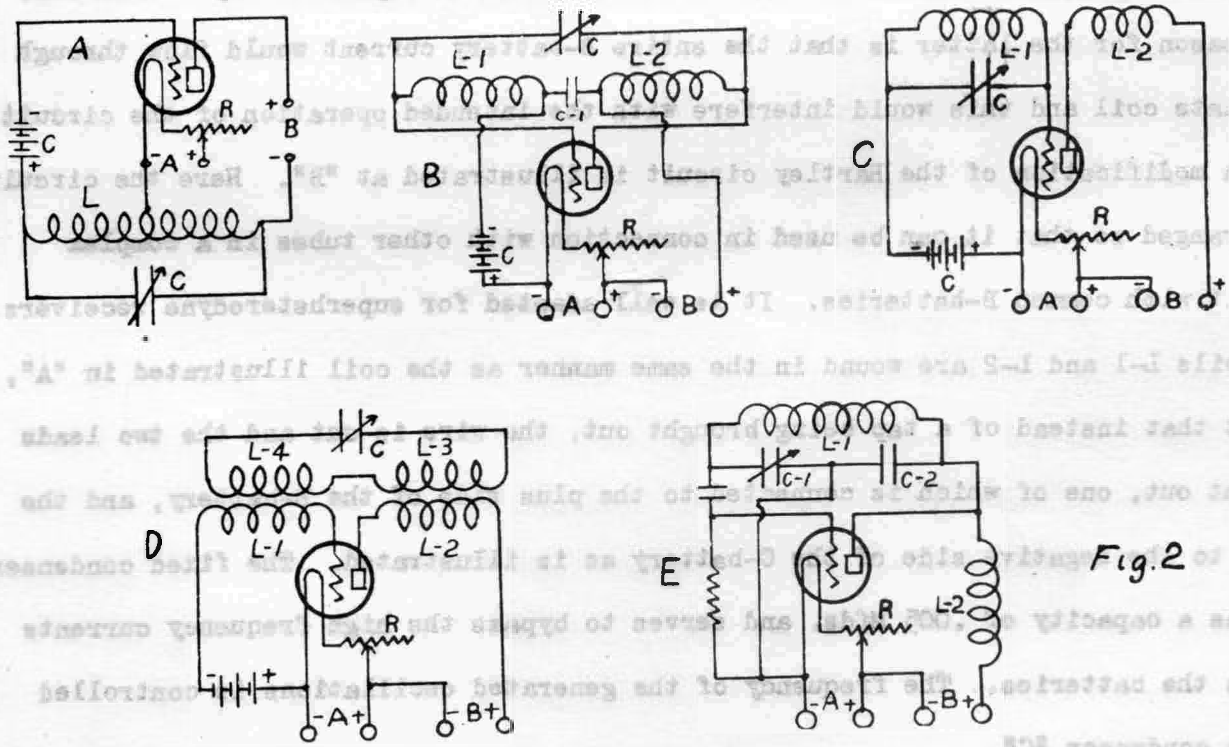


Fig. 2

The coil data given is for frequencies from 550 to 1500 kilocycles, the broadcasting frequency range. Although batteries are illustrated supplying the necessary operating potentials, the same circuits would be used for electric power operated systems.

One of the most familiar oscillators is the Hartley circuit illustrated at "A". It consists of a single triode vacuum tube, an A-battery for heating the filament, a B-battery for supplying the plate pressure, a C-battery for biasing the grid, a rheostat for controlling the filament temperature, and a tuned circuit consisting of the coil "L" and the variable condenser "C". The coil consists of 50 turns of No. 24 double cotton covered wire wound on a 3-inch bakelite tube, with a tap brought out at the 29th turn from the plate end. The value of the inductance is about 200 microhenries. The condenser has a capacity of 0.0005 microfarads. This circuit is suitable for oscillating wave meters or as a generator of radio frequency oscillations, but is not adapted for superheterodyne circuits. The reason for the latter is that the entire B-battery current would flow through the plate coil and this would interfere with the intended operation of the circuit.

A modification of the Hartley circuit is illustrated at "B". Here the circuit is arranged so that it can be used in connection with other tubes in a complex circuit with common B-batteries. It is well adapted for superheterodyne receivers. The coils L-1 and L-2 are wound in the same manner as the coil illustrated in "A", except that instead of a tap being brought out, the wire is cut and the two leads brought out, one of which is connected to the plus side of the B-battery, and the other to the negative side of the C-battery as is illustrated. The fixed condenser C-1 has a capacity of .005 Mfds. and serves to bypass the high frequency currents across the batteries. The frequency of the generated oscillations is controlled by the condenser "C".

An oscillator that is used very frequently in superheterodyne receivers is illustrated at "C". This is very similar to the familiar tickler regenerative circuit employing a tuned grid, and is arranged so that it can be used with other tubes on common B-batteries. The grid coil L-1 consists of 50 turns of No. 24 D. C. C. wire wound on a 3-inch tube, and is shunted by a 0.0005 Mfd. tuning condenser. The plate or tickler coil consists of 40 turns of wire wound on the same tube but separated from the grid coil by one-fourth inch. For best operation the plate and grid should be connected to the outer ends of the coils and the batteries to the inner or adjacent coil ends. Some oscillator coils designed for this circuit have the plate coil wound on a rotor at the grid end of the tuned coil so that a variable coupling is had between the two coils. The tickler can then be set in the position in which the oscillator functions best.

The Meissner oscillator circuit is illustrated at "D". Here the tuned circuit is an independent circuit coupled to both the grid and plate coils. With this arrangement a very constant frequency and pure wave form can be generated. The coils L-3 and L-4 each consist of 35 turns of No. 24 wire wound on 3-inch tubes. Coil L-2 consists of 20 turns and is wound on the same tube as L-3, while the coil L-1 consists of 50 turns and is wound on the same tube as L-4. A good arrangement is to have the two sets of coils mounted so that the distance between them can be changed for variable coupling.

The Colpitts oscillator circuit is illustrated at "E". Here electrostatic (capacity) coupling is used between the plate and grid circuits to obtain oscillation. This circuit is used chiefly in transmitters where a practically fixed frequency is generated. It is not so well adapted for receiving circuits or measuring instruments. The oscillating circuit consists of the coil L-1 and the two condensers C-1 and C-2. L-2 is an R.F. choke.

THE PENTAGRID CONVERTER - 2A7 AND 6A7

The pentagrid converter is a multi-electrode tube designed to perform simultaneously the functions of first detector and oscillator in a super-heterodyne receiver. It is a direct outgrowth of the successive attempts that had been made to improve the performance of the superheterodyne and to increase its operating efficiency by reducing the number of tubes required. Through a special arrangement of the internal elements in this tube it became possible to realize more fully the four operating features that were being sought, namely, more stable oscillator action, better modulation, higher conversion gain, and grid bias gain control. The tube is of an entirely new type and has circuit applications quite different from those of any other tube.

The tube has an indirectly heated cathode, a plate, and five operating grids, therefore the term pentagrid (penta meaning five). Since with its associated circuits it forms a complete frequency conversion unit, it is called the pentagrid converter. The arrangement of the elements in the tube from the heater outward is as follows: Cathode, oscillator grid or grid No. 1, anode grid or grid No. 2, screen grid or grid No. 3, control grid (modulator grid) or grid No. 4, another screen grid or grid No. 5 (internally connected to grid No. 3), and the plate.

The 2A7 and 6A7 tubes have a small 7-pin base with the following connections (looking at the bottom of the base and proceeding clockwise from the left heater pin): Heater, plate, screen grids (No. 3 and 5), anode grid (No. 2), oscillator grid (No. 1), cathode, heater. The top cap on the tube is the modulator grid (No. 4) connection.

ACTION OF THE PENTAGRID CONVERTER

The arrangement of the elements within the pentagrid converter and the customary method of connecting these elements into a circuit system are illustrated in the diagram in Fig. 3. The cathode "K" is raised to an emitting temperature by the filament or heater "H". Next to the cathode is grid No. 1 generally called the oscillator grid, and surrounding it is grid No. 2 known as the anode grid. The two screen grids, No. 3 and No. 5, that are connected together within the tube, serve to decrease the control grid to plate capacity as in any screen grid tube, and grid No. 4 or the control grid receives the incoming radio frequency signals.

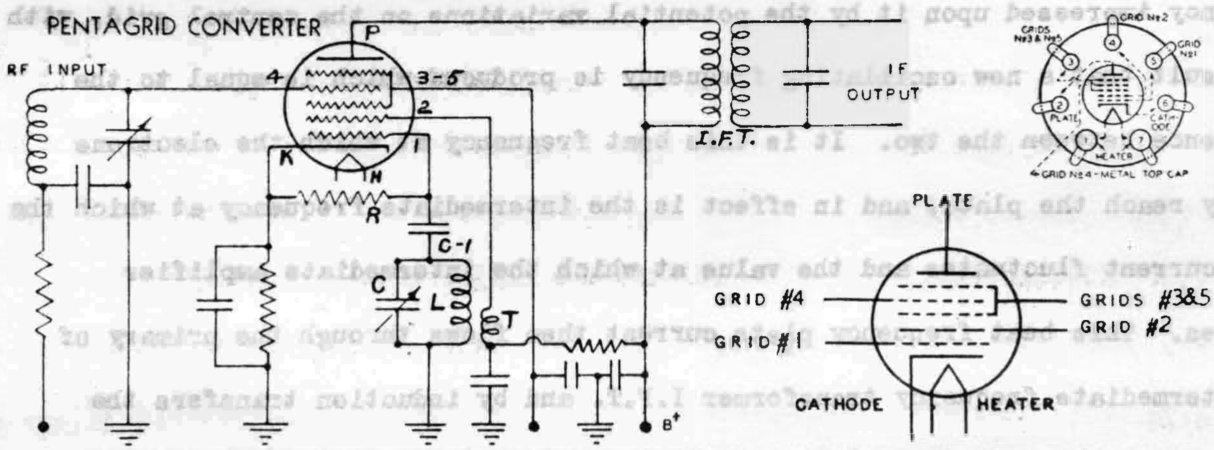


Fig. 3. Illustrates skeleton construction of 2A7 pentagrid converter and typical converter circuit system.

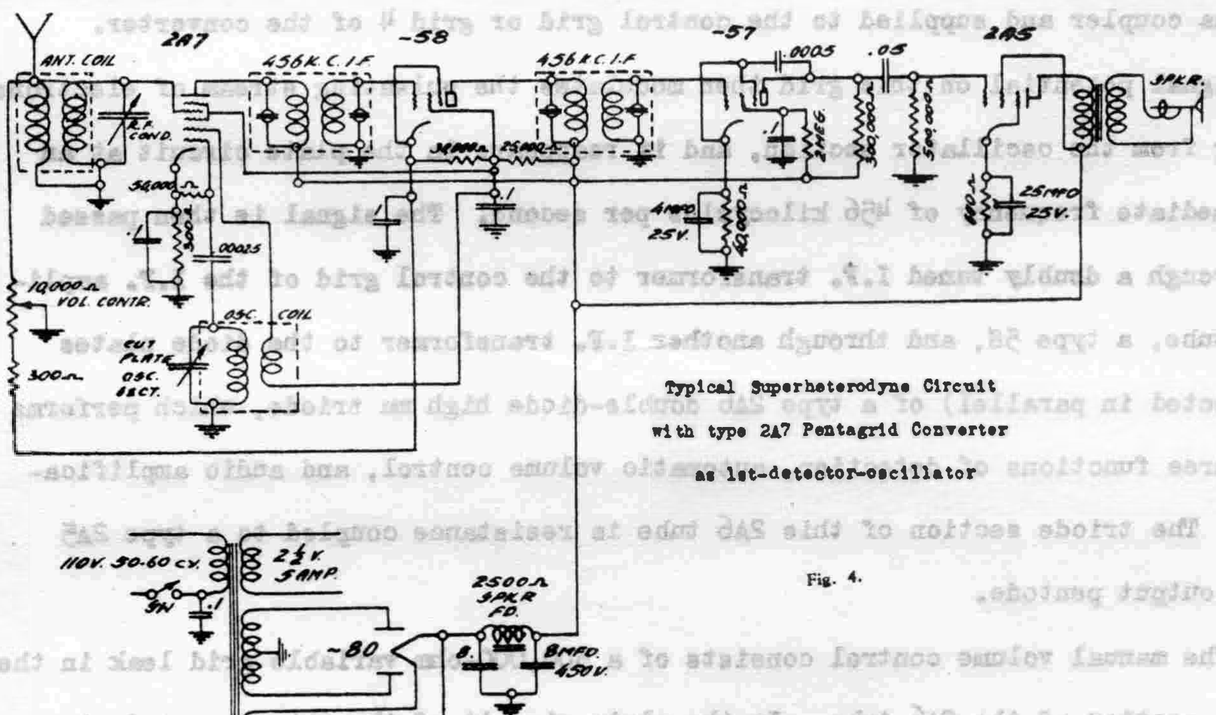
The action within the tube is of a peculiar dual nature. The cathode and grids No. 1 and No. 2 operate in one associated group and function as a triode, with grid No. 1 acting as the normal or oscillator grid and grid No. 2 as the plate. Grid No. 2 provides the feedback effect and carries a positive potential. It is therefore referred to as the anode grid. As illustrated in Fig. 3, these three elements are connected into a standard feedback oscillator system in which "L" is the tank coil tuned by condenser "C". Condenser C-1 and resistor "R" form the grid condenser and leak, while "T" is the tickler coil. The oscillation frequency is determined by the value of "L" and "C". As a result of the oscillator action, a continuously pulsating stream of electrons is emitted that fluctuates according to the oscillation frequency. In other words, these three elements act like a composite cathode that emits or supplies a variable pulsating stream of electrons, with the outbursts or puffs of electrons occurring at a frequency that is determined by the oscillator tuning.

The received signal comes in through the radio frequency tuner R.F.T. and is impressed on the control grid or grid No. 4 of the converter tube. As the pulsating stream of electrons coming from the oscillator section travels toward the plate, it is further influenced or modulated by the signal voltage on grid 4. In other words, the electron stream which is already oscillating has an additional frequency impressed upon it by the potential variations on the control grid, with the result that a new oscillating frequency is produced which is equal to the difference between the two. It is this beat frequency at which the electrons finally reach the plate, and in effect is the intermediate frequency at which the plate current fluctuates and the value at which the intermediate amplifier operates. This beat frequency plate current then flows through the primary of the intermediate frequency transformer I.F.T. and by induction transfers the signal on to the secondary circuit to be impressed on the grid of the intermediate frequency amplifier tube.

TYPICAL PENTAGRID-CONVERTER CIRCUIT SYSTEM

A typical superheterodyne circuit system employing the pentagrid converter in a combination first detector-oscillator stage is illustrated in Fig. 4.

A standard feedback oscillator system is employed, with the anode grid (grid No. 2) providing the feedback action. This grid in effect acts like the plate of an ordinary triode; that is why it is termed the anode grid. The incoming signal is received through the tuned antenna coil and impressed on the control grid (grid No. 4) of the converter tube. The pulsating stream of electrons coming from the triode oscillator section is then further modulated by the signal potential on grid 4, and an intermediate or beat frequency of 456 kilocycles per second is produced. This frequency is then passed on through the doubly tuned I.F. transformer to the control grid of the type 58 intermediate amplifier tube. Volume is controlled manually by means of a 10,000-ohm potentiometer that regulates simultaneously the bias on the grid of the intermediate amplifier tube and on the control grid of the modulator section of the pentagrid converter. By increasing or decreasing the bias on grid 4 of the converter the modulating effect of the incoming signal voltage on the variable electron stream is weakened or strengthened.



Typical Superheterodyne Circuit
with type 2A7 Pentagrid Converter
as 1st-detector-oscillator

Fig. 4.

The remainder of the circuit is of standard design and varies in different commercial receivers according to the desires of the manufacturers. Some circuit systems, it will be seen in the next paragraphs, employ a tuned radio frequency stage ahead of the pentagrid converter stage, but that does not affect the functioning of the oscillator-mixing system.

THE FAIRBANKS-MORSE MODEL 51 CHASSIS

The Fairbanks-Morse Model 51 chassis which is used in a number of their receivers, employs a 5-tube superheterodyne circuit with a type 2A7 tube in a combination 1st-detector-oscillator stage. The circuit arrangement is illustrated in Fig. 5. The cathode and grids No. 1 and 2 comprise a typical triode oscillator system of the feedback type. The incoming signal is received through a tuned antenna coupler and supplied to the control grid or grid 4 of the converter. The signal potential on this grid then modulates the pulsating stream of electrons coming from the oscillator section, and it reappears in the plate circuit at an intermediate frequency of 456 kilocycles per second. The signal is then passed on through a doubly tuned I.F. transformer to the control grid of the I.F. amplifier tube, a type 58, and through another I.F. transformer to the diode plates (connected in parallel) of a type 2A6 double-diode high mu triode, which performs the three functions of detection, automatic volume control, and audio amplification. The triode section of this 2A6 tube is resistance coupled to a type 2A5 power output pentode.

The manual volume control consists of a 500,000-ohm variable grid leak in the triode section of the 2A6 tube. In the plate circuit of the output pentode is a tone control consisting of a .05-mfd. condenser in series with a 50,000-ohm variable resistor. An interesting feature of the circuit is the wave trap across the antenna primary. This trap is tuned to 456 kilocycles, the operating frequency of the intermediate amplifier. Its function is to trap out the signals from commercial stations which are operating near 456 kilocycles so that interference from these stations will not be experienced as does happen in many cases when these signals leak through the input tuning system.

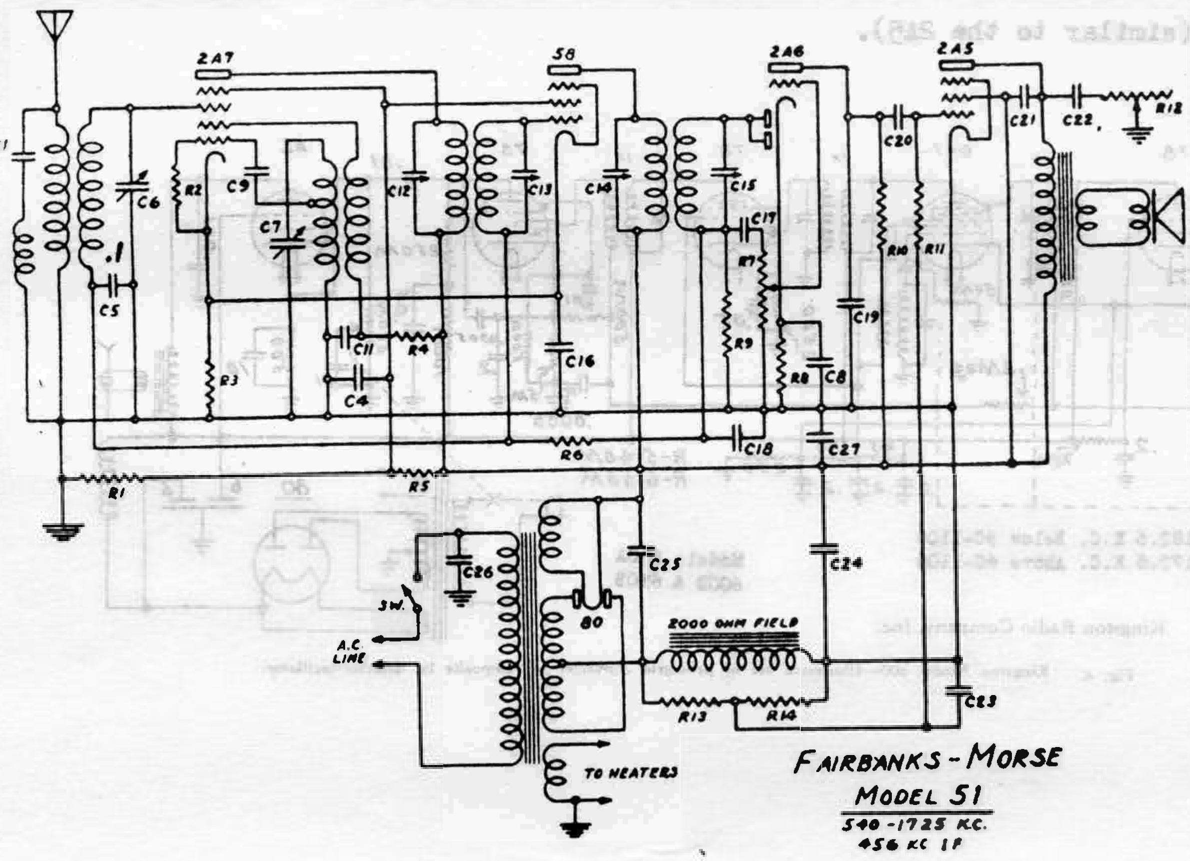


Fig. 5. Fairbanks-Morse Model 51—Illustrates use of 2A7 pentagrid converter as composite 1st detector-oscillator.

THE KINGSTON MODEL 600A

The Kingston Models 600A, 600B and 610B radio receivers manufactured by the Kingston Radio Company at Kokomo, Indiana, employ a 6-tube superheterodyne circuit with a type 6A7 pentagrid converter in a combined first detector-oscillator stage. The incoming signal is received through a tuned antenna coupler and sent through a preliminary radio frequency amplifier stage equipped with a type 78 pentode before it is impressed on the control grid (grid 4) of the modulator section of the converter tube. The oscillator section, consisting of the cathode and grids 1 and 2, is connected into a typical feedback type oscillator system. A single intermediate-frequency stage is used, also equipped with a type 78 pentode, and this is coupled to a type 75 duo-diode (similar to the 2A6), which performs the three functions of detector, automatic volume control, and audio amplifier. The triode section of this tube is coupled to a type 42 power output pentode (similar to the 2A5).

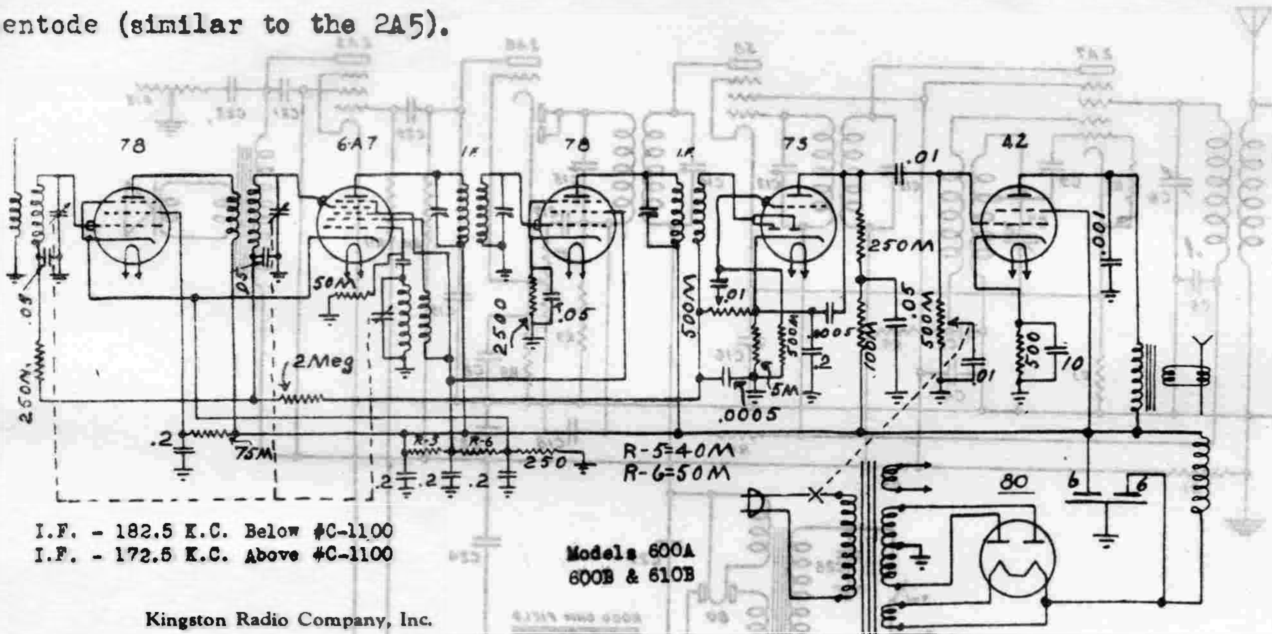


Fig. 6. Kingston Model 600—Illustrates use of pentagrid converter as composite 1st detector-oscillator.

THE STEWART-WARNER R-123 CHASSIS

The Stewart-Warner Model R-123 chassis which is used in their receiver models 1231 to 1239, employs both the 6A7 and the 6F7 tubes in an interesting arrangement. The circuit is illustrated in Fig. 7. The 6A7 pentagrid converter is used in the customary combined first detector-oscillator stage, with the triode section (cathode and grids 1 an d 2) connected into the familiar feedback oscillator system. The incoming signal is received through a tuned antenna coupler and impressed on the control grid (grid 4) of the modulator section, where it further modulates the pulsating electron stream and reappears in the plate circuit at an intermediate frequency of 456 kilocycles. It is then transferred through a doubly tuned I.F. transformer to the input circuit of the next tube.

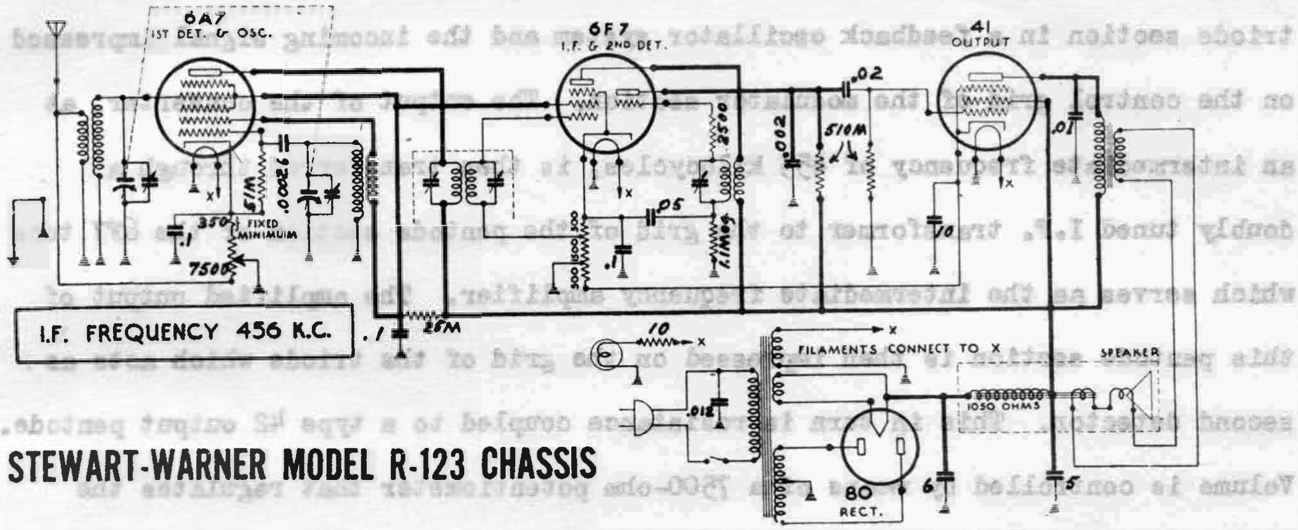


Fig. 7. Stewart-Warner Model R-123—Illustrates use of 6A7 pentagrid converter as composite 1st detector-oscillator and also the 6F7 as I. F. amplifier and 2nd deector.

The second tube, the 6F7 triode-pentode, is also used in a dual role, but this time as an intermediate frequency amplifier and second detector. From the secondary of the I.F. transformer the signal is impressed on the control grid of the pentode section. Here it is amplified and passed on through the second I.F. transformer to the grid of the triode section, the latter now acting as second detector or demodulator. It is resistance coupled to a type 41 power output pentode.

The manual volume control consists of a 7500-ohm potentiometer in series with a 350-ohm limiting resistor. This potentiometer controls both the antenna input to the receiver as well as the bias on the control grid of the modulator section of the 6A7 tube. Varying the bias on this grid controls its effectiveness in modulating the stream of electrons coming from the oscillator section and in this manner controls the volume of the receiver.

GRUNOW MODEL 460 RECEIVER

The Grunow Model 460 radio receiver also employs the type 6A7 and 6F7 tubes in a novel circuit system. A circuit diagram of the receiver is given in Fig. 8. The pentagrid converter is connected in the usual manner with the triode section in a feedback oscillator system and the incoming signal impressed on the control grid of the modulator section. The output of the converter, at an intermediate frequency of 455 kilocycles, is then transferred through a doubly tuned I.F. transformer to the grid of the pentode section of the 6F7 tube which serves as the intermediate frequency amplifier. The amplified output of this pentode section is then impressed on the grid of the triode which acts as second detector. This in turn is resistance coupled to a type 42 output pentode. Volume is controlled by means of a 7500-ohm potentiometer that regulates the antenna input and the bias on the control grid of the modulator section of the 6A7 tube.

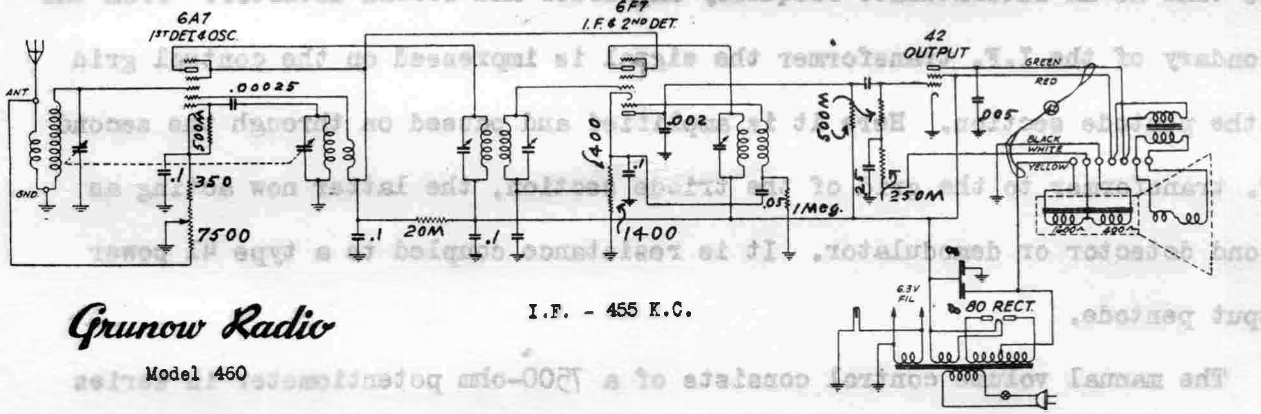


Fig. 8. Grunow Model 460—Illustrates use of 6A7 converter as composite 1st detector-oscillator and 6F7 as composite I. F. amplifier and 2nd detector.