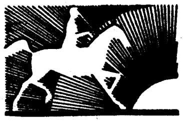
RIDER'S VOLUME XIX

HOW IT WORKS



JOHN F. RIDER PUBLISHER, INC.
480 Canal Street New York 13, N. Y.

Printed in the United States of America

PREFACE

Television is here to stay and from the reaction of many it appears to be chasing conventional radio out of its well established place in the nation's homes. As far as the conventional radio trade is concerned — that is, for a-m and f-m receivers — these receivers were here to stay quite a while ago and will remain for quite some time, notwithstanding the fact of the new boom in television.

Our *Volume XIX* and the accompanying *How It Works* book is a significant indication of the continuous flow of a-m and f-m receivers to the radio market. There are over 100 different manufacturers represented in this manual, which totals over 2100 pages. Numerous circuit innovations appear in many of the models included in this manual.

It is the purpose of this *How It Works* book to acquaint the radio technician with these new and interesting features so that he can have a better understanding of how they function. Besides discussing the underlying theory of these circuits, it is believed that this book will help the technician repair the receiver in less time than usual — especially if the fault lies within the new circuit that is being analyzed here.

We have included with this book discussion of different types of f-m circuits, specially constructed circuits, analysis of audio networks, tuning eye circuits, and automatic volume control circuits. With this *How It Works* book and the previous ones which accompanied Rider's Manuals the reader will have a ready reference on new and interesting circuits found in the radio receivers of today.

We wish to express our gratitude to the many manufacturers in supplying us with technical data on their products. We also wish to thank the members of the editorial department and those members of the technical writing section of John F. Rider Publisher, Inc. who cooperated in the preparation and writing of this book and whose names appear at the heads of each section.

John F. Rider

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F-M CIRCUIT FEATURES

By Seymour D. Uslan

A GREAT many of the new and interesting circuits can be found in the combination am-fm receivers and f-m tuners of today. In this section we are going to analyze a number of unique f-m features found in the radio service data incorporated in Rider's Volume XIX.

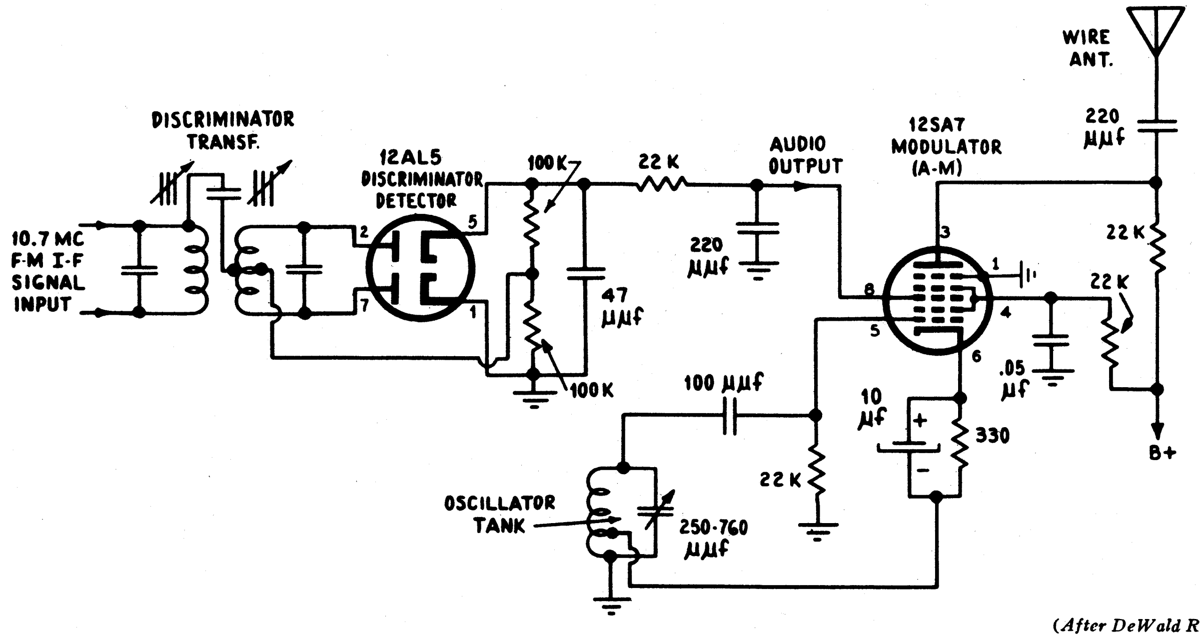
DeWald Model B-612

Over ten years ago wireless phonograph and record players found their way into the radio receiver market. The circuits of these units essentially consisted of a modulator tube, with perhaps an r-f amplifier, and an associated power supply. The modulator employed was usually of the pentagrid type where one grid was used as the phono input and another section of the tube used as the r-f oscillator.

The unit to be discussed now is also of the wireless type and it is something new. It is a *wireless f-m tuner,* DeWald Model B-612, appearing on pages 19-3 through 19-5 of Rider's Volume XIX. This wireless f-m tuner contains a complete f-m section (excluding audio amplifiers) and also a basic a-m modulator. The f-m tuner section employs the duo-triode 12AT7 tube as an r-f converter for the f-m band, a 12BA6 as an i-f amplifier (the i.f. is 10.7 mc), a 12BA6 as a limiter, a 12AL5 as a discriminator-detector and a 35W4 as a rectifier. This part of the unit is of the ordinary f-m tuner design and is tunable over the entire f-m broadcast band. An f-m signal picked up is fed to the input r-f stage and after the process of heterodyning, i-f amplification, limiting action, and f-m detection an audio signal appears in the output of the detector circuit.

A 12SA7 pentagrid tube is used as the a-m modulator. Its operation is very similar to those modulators employed in wireless phonograph players. In the latter type of unit, the audio modulating signal is obtained from the phono output but in the circuit under discussion the audio signal is obtained from the f-m detector circuit. The schematic diagram of the 12AL5 f-m detector and 12SA7 modulator is given in Fig. 1. The complete schematic of this wireless f-m tuner can be found on DeWald page 19-3 of Rider's Volume XIX.

Let us examine the diagram of Fig. 1 and see how it



(*After DeWald Radio*)

Fig. 1.—The discriminator detector and modulator stages of the DeWald wireless f-m tuner, Model B-612.

works. The supply voltage for the 12SA7 is obtained from the power supply used for the f-m section. The first and second grids of this tube in conjunction with the cathode function as an r-f oscillator of the Hartley type. The f-m detector is of the conventional discriminator type where an audio signal, which is the intelligence superimposed on the incoming f-m signal, appears in the output of the detector, as shown in Fig. 1. The output of the f-m detector is connected to the third grid, pin 8, of the 12SA7 tube. (This grid normally serves as the r-f signal grid when the 12SA7 tube is used as a converter.) Thus we see that the audio output from the f-m detector is fed to the input to the 12SA7 tube.

The r-f oscillator signal inside the 12SA7 tube is amplitude-modulated in direct accordance with the incoming audio signal applied to the third grid. This a-m signal is then electron-coupled to the plate of the tube. The 220-$\mu\mu f$ capacitor which is connected to the plate of the modulator serves to couple the a-m signal from the plate to the wire lead which serves as the antenna. In this manner the a-m signal is easily radiated. The frequency of the Hartley oscillator is pre-set to 540 kc at the factory, but the 250-760-$\mu\mu f$ trimmer capacitor in this circuit enables the oscillator to be variable, approximately between 500-750 kc.

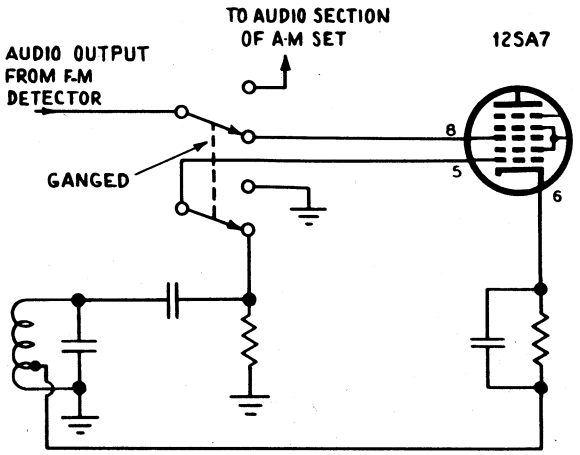


Fig. 2.—A method of connecting a double-pole double-throw switch into the modulator section of the DeWald B-612, so that the a-m modulator can be made inoperative if desired and the set used solely as an f-m tuner.

This oscillator is pre-set to about 540 kc, because this frequency is just below the lowest frequency (550 kc) of the a-m broadcast band. Thus, by tuning an a-m receiver just below 550 kc it is possible to pick up the a-m signal radiated from the unit.

This wireless f-m tuner can also be used simply as an f-m tuner by making the a-m modulator inoperative. Although there is no special switching section incorporated in this unit to make this possible, it can very easily be done by incorporating a separate switch. Any number of methods are available, one of which is shown in Fig. 2. In this circuit, a double-pole-double-throw switch is used. Only one terminal of the switch has to be attached to the a-m receiver. This attachment has to be made to the audio section of the receiver as indicated in the drawing. With the switch in the position shown, the unit operates as a wireless f-m tuner and with the switch thrown to its other position the oscillator grid, pin 5, is grounded and the oscillator becomes inoperative. At the same time the audio signal output from the f-m detector is fed to that section of the switch connected to the audio section of the a-m receiver instead of the input grid, pin 8, of the 12SA7 tube. Thus, in this latter position the set operates as a normal f-m tuner.

Farnsworth 400M Series

In tuning from one station to another on an f-m receiver a great deal of noise is usually heard in the output of the speaker. This noise is very objectionable to the user of the receivers, even though once on station the audio output may be practically free of noise. To overcome this undesired effect in the Farnsworth Model 400M Series (shown on pages 19-34 through 19-54 of Rider's Volume XIX) a special type of *squelch circuit* on the f-m band is employed.

The name squelch circuit, in general, is usually applied to any type of circuit that is employed to suppress or reduce the noise apparent in the output of a radio receiver when there is no carrier signal present at the input to the receiver. (When tuning from one station to another, it is assumed that no carrier is present.) Squelch circuits are not new. They have been used for quite some time in a-m receivers, especially those employing electro-mechanical push-button systems, to reduce noise when tuning between stations. Most squelch circuits work on the basis of driving the grid of the first audio stage beyond cutoff when no carrier signal is present at the input to the receiver.

Various different types of squelch circuits exist and the one to be discussed in this section is somewhat different from those normally encountered. This unique squelch circuit arrangement appears in Fig. 3. The complete schematic for this model appears on Farnsworth page 19-51,52 of Rider's Volume XIX. This squelch network employs a 6SN7GT duo-triode tube and, as mentioned previously, it is only operative on the f-m band of the receiver. Let us analyze this circuit

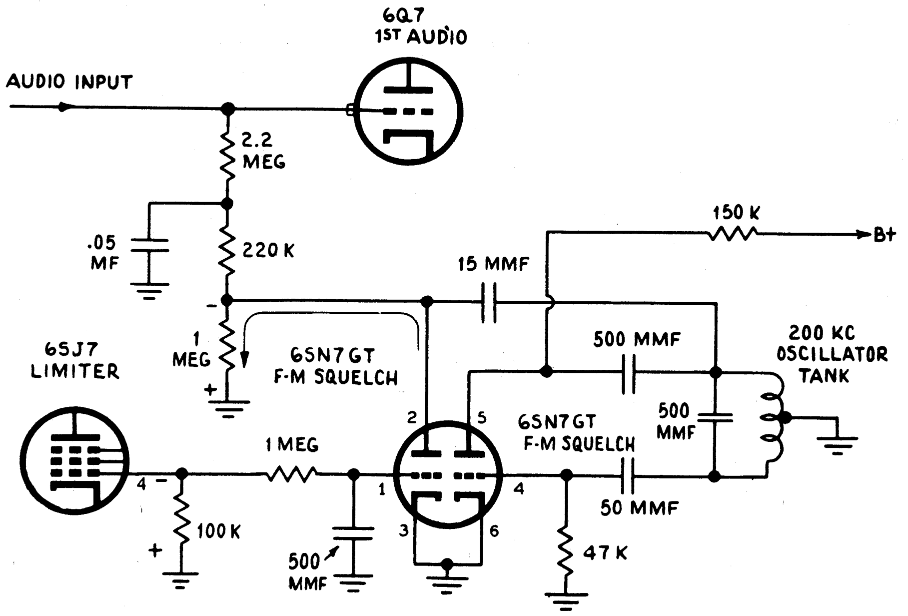


Fig. 3.—The squelch circuit incorporated in the Farnsworth 400M series. It is used only in f-m operation.

(After Farnsworth Telev. & Radio Corp.)

to see how it eliminates noise output from the receiver when tuning between f-m stations.

One triode section of this 6SN7GT squelch tube, (pins 4, 5, and 6) functions as a shunt-fed type of Hartley oscillator circuit, operating at a frequency of approximately 200 kc. The second triode section has its grid circuit connected to the limiter grid of the receiver and acts as a grid-controlled rectifier. Note that there is no B+ supply on the plate, pin 2, of the 6SN7GT tube. The oscillator voltage and the limiter grid voltage both play important roles in the operation of this circuit. One important thing to remember is that the oscillator section of the 6SN7GT tube is always in operation on the f-m band. Completely to understand the function of this circuit we have to consider its operation from two angles, when tuning between stations and then when the set is on station and a signal is being received.

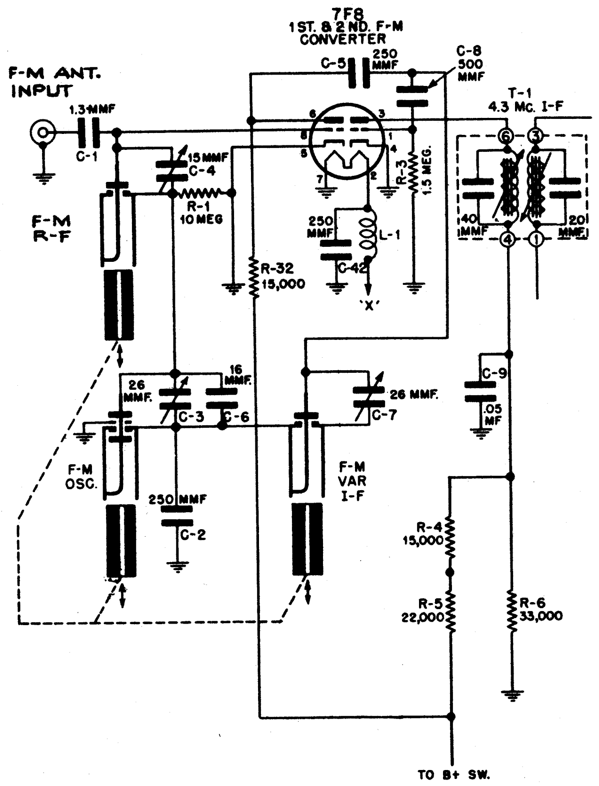
From the drawing of Fig. 3 you will notice that the oscillator tank circuit is coupled to the plate, pin 2, of the 6SN7GT tube through a 15-$\mu\mu f$ capacitor. Since the oscillator is continuously in operation, this means that pulses of oscillator frequency will always be present at the plate, pin 2. When tuning between stations no f-m signal is being received and, hence, there is no signal input to the limiter. This means there is no limiter current flow and no voltage drop across limiter grid resistor. The potential on the grid, pin 1, of the 6SN7GT tube is zero volt. Consequently, the plate and cathode of this triode section of the tube will act as a rectifier to the pulses of oscillator frequency.

When the plate is made more positive than the cathode, current will flow from the cathode to the plate (inside the tube), then through the 1-megohm resistor to ground and back to the cathode to complete its path. A d-c voltage drop occurs across this 1-megohm resistor with the potentials as shown in the drawing of Fig. 3. This voltage is applied to the grid of the first audio tube, a 6Q7, through a 220,000-ohm resistor and then through a 2.2-megohm resistor. This voltage drop is large enough to produce a negative potential at the audio grid to drive it beyond cutoff, thereby preventing the audio tube functioning during tuning between f-m stations. The 220,000-ohm resistor and 0.05-μf capacitor serve as a filter network to smooth out any ripple in the d-c voltage applied to audio grid, as well as a filter for any signal of 200 kc oscillator frequency.

When an f-m station is tuned in, this high bias on the audio tube has to be removed in order for the audio circuit to function. This is where the limiter grid voltage takes effect. When an f-m signal is received, grid current flows in the limiter circuit and a bias is developed at the limiter grid due to the voltage drop across the 100,000-ohm limiter grid resistor. The grid circuit of the rectifier section of the squelch tube is connected to the limiter grid and, hence, whatever bias appears on this grid also appears at the rectifier grid. The rectifier section of this squelch tube now becomes a *grid-controlled* rectifier with the bias on this grid, pin 1, high enough to cause the rectification action of this tube to become negligible. This means that the voltage drop across the 1-megohm plate resistor in the rectifier circuit is also considered negligible and the first audio tube is no longer biased beyond cutoff, but functions normally. Thus, when an f-m station is tuned in, the grid-controlled rectifier can be considered as being biased beyond its cutoff point.

Motorola E-33-T and E-34-T AM-FM Tuner

The Motorola company has manufactured some very interesting tuners for use in both a-m and combination am-fm receivers. Two of these tuners, Models E-33-T and E-34-T (appearing on pages 19-105 through 19-107 and 19-127 through 19-129 respectively of Rider's Volume XIX) have a unique f-m tuning section. The f-m tuning on each of these units are the same, so whatever is said about the circuit to be discussed will apply to both tuners. Many of the Motorola combination am-fm receivers shown in Volume XIX use these tuners.



(*Courtesy Motorola Inc.*)

Fig. 4.—Schematic diagram of the f-m section of the Motorola E-33-T and E-34-T tuners.

Let us examine the schematic diagram of the complete f-m tuner which appears in Fig. 4. From the drawing we see that the 7F8 duo-triode tube is used as a *first and second f-m converter*. This, of course, means that we have to deal with two intermediate frequencies. The tuning circuit is of a special mechanical construction too detailed to discuss here. Three separate tuning sections are employed, one for the r-f input signal, one for the local oscillator, and the other is used for a *variable i-f* signal. Thus, we see that one of the i.f.'s that we are to deal with can be varied, the other i.f., as will be seen later on, fixed in frequency — being 4.3 mc.

The drawing of Fig. 4 has been simplified into a more functional schematic diagram to make the analysis of this circuit easier to understand. The new schematic is illustrated in Fig. 5. One triode section of the 7F8 tube acts as the first converter, in which a separate oscillator tank circuit and r-f tuned circuit are employed. This triode section of the tube is designated as *T1*. The oscillator tank circuit is always tuned *below* the incoming r-f signal. Although the oscillator and r-f tanks are both in the grid circuit of *T1,* there is little interaction between the circuits that will cause undesired effects.

Both the r-f input signal and the oscillator signal are present at the grid of *T1*. The supply voltage and the bias for *T1* are such that the triode operates as a converter. Numerous frequencies appear in the plate circuit of this tube. These frequencies include the r-f and oscillator signal themselves plus the sum and difference frequencies between these two signals.

The frequency of the r-f tank, which is tuned to the incoming signal, and the frequency of the oscillator are *not always* separated by the same amount as in normal converter circuits. In other words, the (difference) intermediate frequency of this first converter is *not* constant. This difference frequency will at all times be *higher* than the oscillator frequency itself. In the plate circuit of *T1* there is a variable i-f transformer circuit. Note that the tuning unit of this circuit is ganged to that of the oscillator and r-f tuned circuits. Thus, when tuning in an r-f signal, the resonant frequency of the i-f tank is changed as well as that of the r-f and oscillator stages. Let us now see what the frequency relationships are between these circuits.

Let the frequency of the oscillator be designated as F_o, the resonant frequency of the r-f tank as F_s (that of the incoming signal), and F_1 the resonant frequency of the variable i-f tank. The mechanical design of this unit is such that at any one instant of time the resonant frequency of the variable i-f tank is equal to the oscillator frequency plus 4.3 mc. In simplified form this means $F_1 = 4.3 + F_o$. Thus, we see that the oscillator is *always tuned below* the variable i-f tank by 4.3 mc. Since the variable i.f. is, at any one instant of time, equal to the difference between the oscillator and signal frequencies; that is, $F_1 = F_s - F_o$, then the frequency of the incoming signal is equal to twice the oscillator frequency plus 4.3 mc. In mathematical terms we have $F_s = 4.3 + 2F_o$.

If the incoming signal, F_s, is equal to 100 mc, the oscillator frequency, F_o would be equal to 47.85 mc and

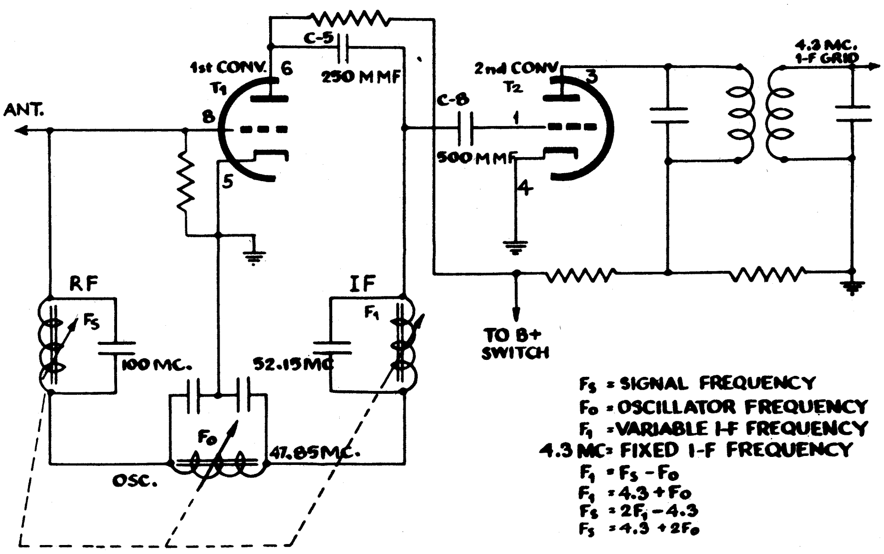


Fig. 5. — Simplified schematic of the f-m section of the Motorola E-33-T and E-34-T tuners.

(After Motorola Inc.)

the first intermediate frequency, F_1, output from the first converter tube *T1* is equal to 52.15 mc. These frequencies are given on the drawing. If the incoming r-f signal is equal to 93 mc, then F_o would equal 44.35 mc and F_1 would be 48.65 mc. The incoming and oscillator signals beat within *T1* and in the output of this tube the difference frequency is always selected by the i-f transformer in the plate circuit of *T1*. It should be remembered that, even though a new i.f. is produced by *T1* every time a different station is tuned in, the tuning of the (first) i-f transformer is also varied and the change is such that its new resonant frequency will always be equal to the i.f. produced within *T1*.

The i.f. produced in *T1* and then selected by the variable i-f transformer is coupled to the grid circuit of *T2* via the 500-$\mu\mu f$ capacitor *C-8*. The oscillator signal also finds its way into the grid circuit of *T2*. This oscillator signal, which also appears in the plate circuit of *T1* is coupled to the grid of *T2* directly through the coupling capacitors *C-5* and *C-8*. The i-f tank can be considered as offering some selectivity to the oscillator signal because the resonant frequency of the oscillator and that of the variable i-f tank are not far apart.

These two signals, F_o and F_1, beat inside *T2*, the second converter, to produce a new i.f. No matter what the frequency of the incoming signal, oscillator signal, or first i.f., the i-f output from the second converter will be constant and always equal to 4.3 mc. ($F_1 = 4.3 + F_o$ as shown previously.) A double-tuned 4.3-mc i-f transformer in the output of this second converter selects the new i.f.

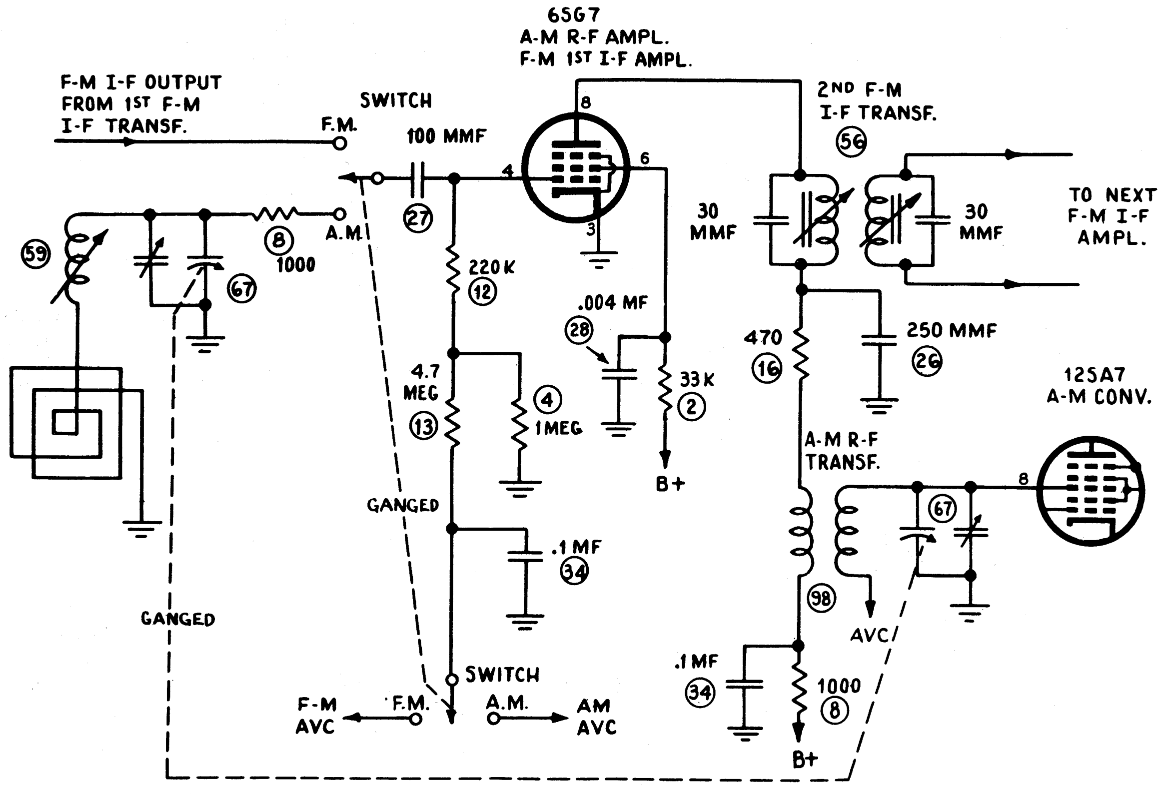
There are a number of advantageous features to this system but the most important is that variations in oscillator frequency due to changes in tube and circuit capacitances during warm-up are negligible. This is easily explained when one realizes the fact that the oscillator frequency is tuned below the incoming signal by a very appreciable amount, by more than half the frequency of the incoming signal. This means that the oscillator tank circuit can be resonated with a high capacitance (250-$\mu\mu f$ in this case, see Fig. 4) and, therefore, small changes in circuit and tube capacitances of the oscillator will produce a percentage change in the over-all tank capacitance that will have negligible effect on the oscillator frequency.

Farnsworth Models N4, P4

In many of the combination am-fm receivers, one tube serves a dual function — operating on both the a-m and f-m band. It is common to find the same tube acting as the converter for both bands, also one tube being used for amplification of both i-f signals, and the same audio tubes are almost always used on both bands. The type of dual function tubes, that are more interesting than these others are those used to perform a *different* function on each band.

Many of the combination receivers found in Rider's Manual XIX, employ such tube circuits. Interesting articles on similar circuits found in earlier models are included in previous "How It Works" books. In this section, we are going to discuss the 6SG7 tube circuit of the Farnsworth combination am-fm receiver, models N4 and P4, appearing on page 19-10 through 19-18 of Rider's Volume XIX. This tube, in conjunction with its associated circuit, functions as an r-f amplifier on the a-m band and as the first i-f amplifier on the f-m band.

The simplified schematic diagram for this section of the receiver is illustrated in Fig. 6. When the receiver



(After Farnsworth Telev. & Radio Corp.)

Fig. 6.—Simplified schematic of the 6SG7 tube circuit in the Farnsworth Models N4 and P4. This tube performs the dual function of a-m r-f amplification and f-m i-f amplification.

selector switch is in the f-m position, the 6SG7 tube functions as the first f-m i-f amplifier. The f-m i-f signal output from the first f-m i-f transformer is coupled to the control grid circuit of the 6SG7 tube through the switch. At the same time, another section of the selector switch enables avc voltage from the ratio-detector circuit of the receiver to be applied to the control grid of the 6SG7 tube.

When in the a-m position, the switch in the grid circuit of the tube connects to the a-m antenna tuned circuit, as can be seen in Fig. 6. The other switch section in the grid circuit that previously helped apply f-m avc voltage to the grid of the 6SG7 tube, now allows a-m avc voltage to this grid circuit. In this manner the tube operates as an a-m r-f amplifier.

The output circuit of this combination tube is interesting because there is no switching involved as in the grid circuit; the output circuit remains the same for both bands. Both the second f-m i-f transformer and also an a-m r-f tuned circuit appear in the plate circuit of the 6SG7 tube. When the receiver is switched to the f-m band, the 2nd f-m i-f transformer functions in the normal manner by selecting the i-f signal output and coupling it to the following i-f amplification stage. The primary of the a-m r-f tuned circuit (98) does not have any detuning or loading effect on the f-m i-f transformer, because the 250-$\mu\mu f$ capacitor (26) bypasses the f-m i-f signal to ground. Therefore, the a-m r-f transformer is not an effective part of the f-m signal circuit. The primary of this transformer, nevertheless, is in the d-c path from the plate of the 6SG7 tube to the B+ supply.

When the set is switched to the a-m band, the primary coil of the f-m i-f transformer remains in the circiut, but it has a negligible reactive effect at the frequencies of the a-m band and is considered to be virtually a short circuit at these frequencies. Consequently, the a-m r-f signal output from the 6SG7 amplifier is coupled to the signal-grid circuit of the 6SA7 a-m converter via the r-f tuned circuit (98). Note that the tuning capacitor in this r-f tuned circuit is ganged to the tuning capacitor in the antenna input circuit of the a-m band.

SPECIAL CIRCUIT CONSTRUCTIONS

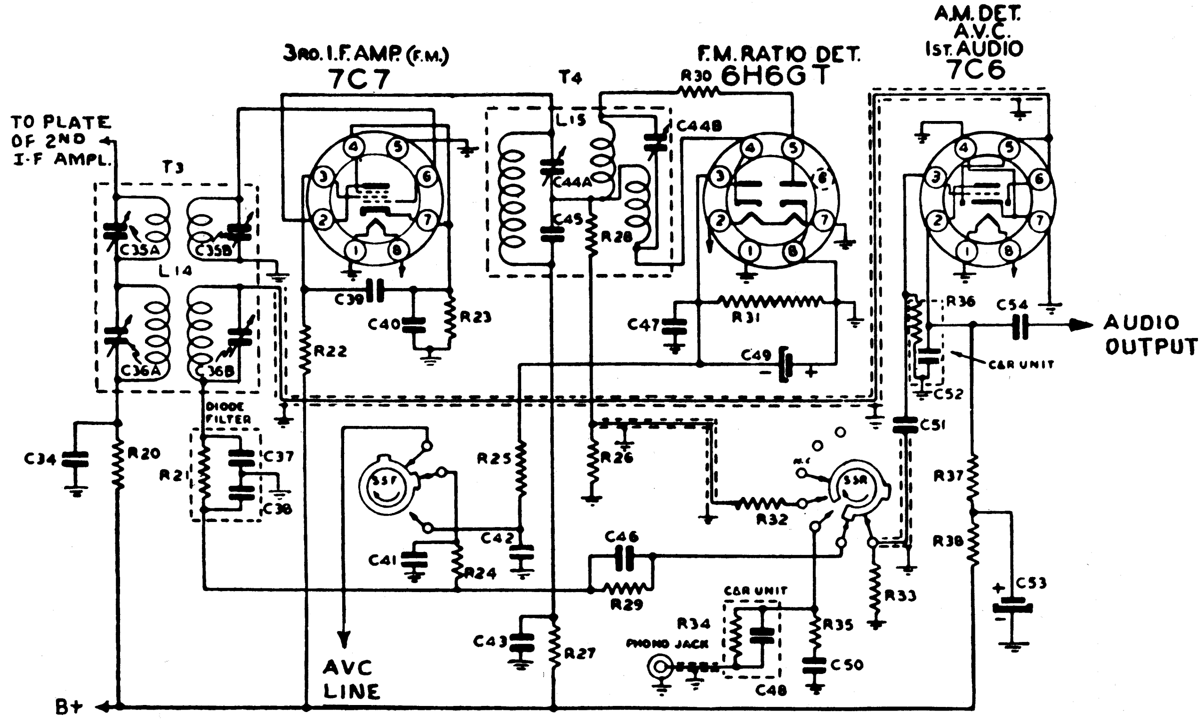
By Seymour D. Uslan

FROM the point of view of the man who traces out the troubles in radio receivers and repairs them, variations in electrical and mechanical design always present a problem. He must acquaint himself with these innovations so that he can do a better job. Do you remember those unconnected wires in certain sections of radio receivers that were thought by many to be due to faulty manufacturing but were found to be really intentional — serving as "gimmicks" to produce the effective capacitance?* The trend toward the use of new circuit constructions in the electronic equipment of today is on the increase.

It is the purpose of this section to acquaint the reader with those special constructions that are used in the radio receivers of today.

Sparton 9L8 and 12L7

In these Sparks-Withington chassis 9L8 and 12L7 (appearing on pages 19-14 through 19-22 and 19-5,6 through 19-13 respectively) there are employed specially constructed resistance and capacitance units, called "C and R units." Most of these units are shown schematically as representing a single resistor and capacitor but there are some that are shown representing two capacitors and one resistor. These units are *not* printed circuits, but rather separate resistors and



(*Courtesy of The Sparks-Withington Co.*)

Fig. 1.—Special "C & R" units are used in the circuit of the Sparks-Withington chassis 12L7 as illustrated in this partial schematic diagram.

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*A complete discussion of circuits employing "gimmicks" can be found in the *"HOW IT WORKS" book for Rider's Volume XV.*

ceramic capacitors so mechanically arranged into a single unit that it might at first be difficult for the radio serviceman to realize that more than one circuit element is represented by this unit.

The schematic diagram for a section of chassis 12L7 is illustrated in Fig. 1. The complete schematic diagram for this model can be found on pages 19-5,6 in *Rider's Volume XIX*. The units of interest to us are shown enclosed in dashed boxes and are represented by the resistor-capacitor combinations of *R36-C52, R34-C48,* and *R21-C37-C38*. The relationship between the schematic representation and the physical unit is somewhat puzzling. In order to visualize the tie-in between the schematic drawing and the unit itself, we will study the construction of each of these three units.

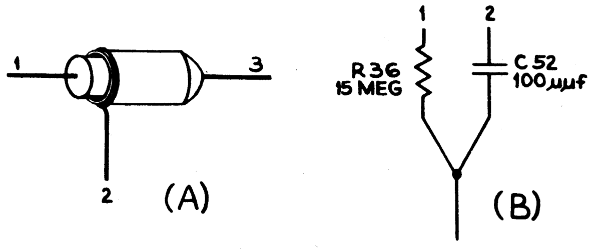


Fig. 2.—(A) Drawing of the *R36-C52* unit as it appears in the receiver. (B) Schematic representation of this unit.

Each unit consists of a single carbon resistor in conjunction with a ceramic capacitor. A drawing of the *R36-C52* unit as it appears in the receiver is illustrated in Fig. 2 (A) and the schematic representation for this unit is shown in Fig. 2 (B). This unit consists of a 15-megohm carbon resistor inserted inside a ceramic capacitor. One end of the resistor is soldered to one plate of the capacitor and this connection brought out as a single lead, number 3 in Fig. 2 (A). Lead number 1 acts as the other end of the resistor and lead number 2 is the other end of the capacitor.

In the circuit of Fig. 1 the common lead (3) of the *R36-C52* unit is grounded, the other end of the resistor is connected to the grid of the 7C6 tube, and the other end of the capacitor is connected to the plate of this tube. In order to understand fully the way the capacitor and resistor are combined, let us refer to the enlarged drawing of this C and R unit as illustrated in Fig. 3. From this isometric cross-sectional drawing the individual resistor and capacitor are readily evident.

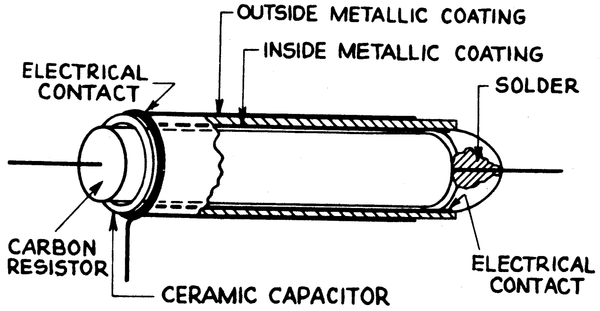


Fig. 3.—Enlarged isometric cross-section of the *R36-C52* unit.

The interesting constructional details of this unit, as well as of the others, is the ceramic capacitor. The capacitor has two separate metallic coatings. One coating is on the inside of the ceramic cylinder and the other coating on the outside of the ceramic. These two metallic coatings represent the plates of the capacitor. The exact amount of capacitance represented by this capacitor is determined by a number of factors. One factor is the dielectric material separating the two metallic coatings, which in this case is, of course, the ceramic material. The distance of separation between the metallic plates is another factor — the smaller the distance, the greater the capacitance. For the capacitor under discussion this means the smaller the thickness of the ceramic cylinder, the larger the capacitance. The final factor in determining the value of the capacitance is the common area between the two metallic plates; the greater this area, the higher the capacitance. Since we are dealing with a cylindrical capacitor, this area is dependent upon two dimensions — the length of the metallic coatings that are common to each other and the diameter of the ceramic cylinder. The greater this length and the larger the diameter, the greater the area will be and, hence, the larger the capacitance.

Coming back to Fig. 3, it can be seen that the resistor is not inserted all the way into the ceramic capacitor. At the right-hand end of the unit some solder is inserted into the ceramic cylinder and takes on the approximate shape shown in the drawing. This solder is used to make electrical contact between the metal end of the resistor and the inside metallic plate of the capacitor. In this manner one end of the resistor and one end of the capacitor are tied together. At the left-hand side of the ceramic, a piece of wire is wrapped around the outside of the capacitor a few times and then soldered to the outside metallic plate of the ceramic cylinder. This connection serves as the other lead of the capacitor. The metallic plates do not necessarily cover the whole length of the ceramic. The exact length is determined by the amount of capacitance desired.

In the drawing of Fig. 3, the heavy lines indicate the metallic coatings of the capacitor. After assembly this completed C and R unit is covered with a white coating of some insulating material.

A drawing of the *R34-C48* unit as it normally appears is shown at (A) in Fig. 4, in conjunction with its schematic diagram which appears in part (B). This

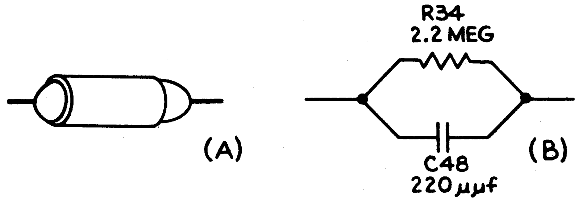


Fig. 4.—(A) Drawing of the *R34-C48* unit as it appears in the receiver. (B) Schematic representation of this unit.

parallel R-C unit is used as a phono input equalizer. It, also, consists of a single carbon resistor inserted inside a ceramic capacitor. In this unit, however, there are only two exposed leads indicating that the resistor and capacitor are already in parallel. Each end of the resistor is soldered to a different plate of the capacitor. A detailed isometric cross-sectional drawing of this unit appears in Fig. 5. The heavy lines on the ceramic indicate the metallic plate of the capacitor. The interesting detail about this unit is the method of making contact between each end of the resistor and the plates of the capacitor.

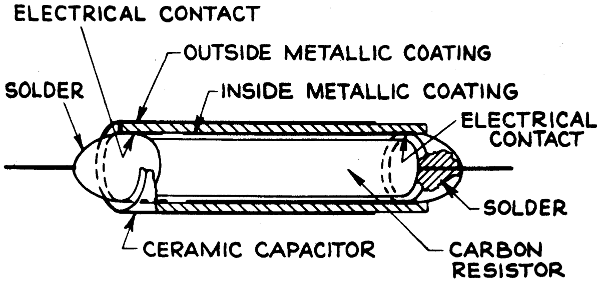


Fig. 5.—Detailed isometric cross-section of the *R34-C48* unit.

At the right-hand end, the solder which is inserted inside the capacitor makes electrical contact between the inside plate of the capacitor and the resistor. The left-hand end of the unit has the same physical appearance as the right end. However, from Fig. 5 we see that the outside metallic plate of the capacitor is *flush* to the left-hand end of the ceramic and continues for a short distance on the inside of the ceramic, but does not make contact with the inside metallic coating. By placing some solder inside this end of the capacitor, there is effectively an electrical contact between the outside plate and the other end of the resistor. This C and R unit is also covered with a white coating of some insulating material. The capacitance of the capacitor is determined in the same manner as that of Fig. 3.

The third unit of interest to us electrically consists of two capacitors and one resistor. From the actual drawing of this unit as shown in Fig. 6 (A), it is difficult to conceive how it is equivalent to these three circuit components. The schematic diagram of this unit appears in Fig. 6 (B). This three-element unit only has three external leads. Lead number 1, around the middle of the unit, represents the common connection between the two capacitor components. Each of the other two leads represents the connection between one end of the resistor and one plate of the capacitor. Thus, there is a capacitance of 100 µµ*f* between leads 1 and 2 and also between leads 1 and 3 of the drawing of Fig. 6. A 47,000-ohm resistance can be measured between leads 2 and 3.

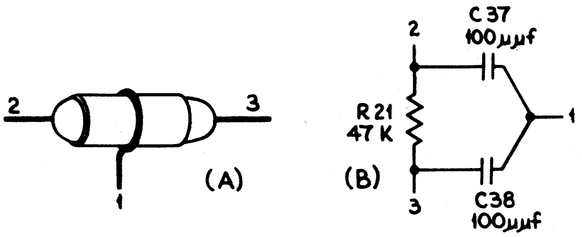


Fig. 6.—(A) Drawing of a unit composed of two capacitors and one resistor. (B) Schematic representation of this unit.

This unit is employed as the diode filter in the a-m detector circuit of the receiver, as can be seen in Fig. 1. When wiring this special construction into the circuit, lead number 1 must be grounded. Since each capacitor is 100 µµ*f* in value, it does not matter which of the other leads is connected to the detector transformer; even if leads 2 and 3 were interchanged, the circuit of this unit would still be the same.

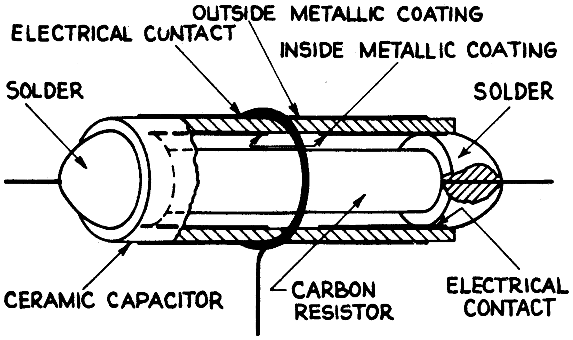


Fig. 7.—Detailed isometric cross-section of the unit composed of two capacitors and one resistor.

Let us examine the construction of this double capacitor and resistor combination. A detailed isometric cross-sectional drawing appears in Fig. 7. A single carbon resistor and one ceramic cylinder is used to form this special filter network. The interesting thing about this unit is the method of plating the ceramic.

The outside of the ceramic is covered with a metallic coating, as shown by the heavy solid line in the drawing. The inside of the ceramic also has a metallic coating, as indicated by the heavy lines; however, this coating is *not continuous* but is split at the center. Considering the ceramic capacitor as is, we find that we have three separate plates.

Centered inside the ceramic cylinder is the carbon resistor. At each end of the unit some solder is inserted, similar to the C and R unit of Fig. 5. Each end of the resistor, therefore, makes electrical contact with a separate metallic plate at the inside of the ceramic. A piece of wire is wound around the outside of the ceramic and soldered to the metallic coating. This latter wire is centered on the unit. From this drawing of Fig. 7 we find:

1. That the outside metallic coating represents the common plate of the two capacitors, with the center wound wire as its connecting lead.
2. That a capacitance exists between either end of the unit (which represents a connection between one end of the resistor and one of the other plates of the capacitor) and the center lead. This capacitance is determined primarily by the common area of the two metallic plates of the capacitor, the distance between the plates, and the length of the inside metallic plate.

After assembly this unit is covered with a white insulating coating similar to the other C and R units.

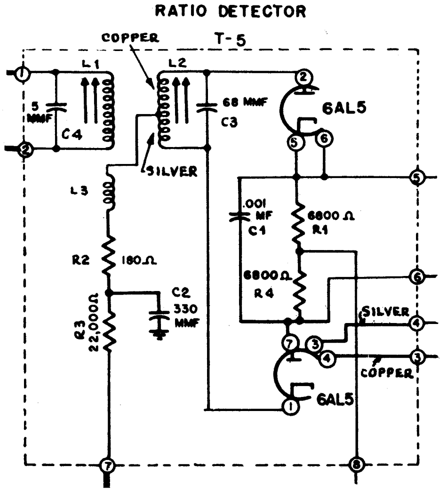
Units such as these will probably be used in greater quantities as time goes on. From the manufacturing viewpoint, their use saves time in assembly operations. For example, the three components of the diode filter of Fig. 6 would normally require 6 separate connections, 2 for each component; but only 3 connections are required with this special construction.

This also means that the serviceman would have less work to do if all of the components have to be changed. However, this is not the usual case. Thus, if any one element in these special C and R units were to become defective, the complete unit would have to be changed. If these special units are not available, then standard components of proper size and ratings can be used if there is enough space for them.

Stromberg-Carlson Models 1406PLA, 1407PFM, 1409M-2W

The arrangements of most i-f cans usually consist of the i-f tuned transformer and the associated resistors and capacitors, with about four or five external connections necessary. Of course, there have been some deviations in these circuits. It has been the policy of these "How It Works" books to illustrate the innovations, both mechanical and electrical, that appear in the radio receivers of today. In the "How It Works" books of *Volumes XV* and *XVII,* we discussed numerous features of special i-f transformer arrangements. In this present book we are going to discuss a new and unique type of i-f circuit construction.

The f-m section of the Stromberg-Carlson combination am-fm receivers, Models 1406PLA, 1407PFM, and 1409M-2W, employs a specially constructed ratio detector assembly, including the detector tube, inside a single can. Complete schematic diagrams for each of these receivers can be found on pages 19-1,2; 19-9,10 and 19-11,12, respectively, of *Rider's Volume XIX.* This complete ratio-detector circuit is designated as T-5 in the schematic diagrams of these models.

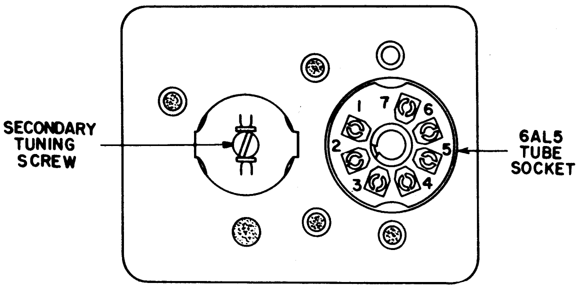


(*Courtesy of Stromberg-Carlson*)

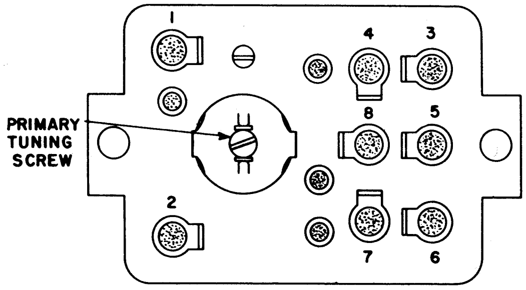
Fig. 8.—Ratio detector circuit of the Stromberg-Carlson 1406PLA, 1407PFM, and 1409M-2W receivers.

The schematic diagram of the circuit in question is illustrated in Fig. 8. The letters designating the components are ours and not the manufacturers and are inserted for ease of discussion. The dashed box indicates the shield-can around the unit and all the components inside this box are included inside the can assembly. From this circuit diagram we find that the complete ratio-detector transformer is included in the can, along with the detector tube circuit and many associated components. The electrolytic capacitor, which is usually connected across the output detector load is not included inside the can because of the large size of such a component. After this T-5 unit is attached to the chassis, a 5-μf electrolytic capacitor is connected across the output of the detector to terminals provided in the physical construction. These terminals are designated as 5 and 6 in Fig. 8; terminal 5 is grounded to the chassis.

To understand fully the mechanical construction of this unit, how the various circuit components inside are wired, and how connections are made to the remainder of the receiver, we have made a number of drawings of this special construction. All of these drawings are made with the shield can removed.



TOP VIEW
(A)



BOTTOM VIEW
(B)

Fig. 9 (A and B).—The top and bottom views of the ratio-detector unit as used in the Stromberg-Carlson Models 1406PLA, 1407PFM, and 1409M-2W. The 6AL5 miniature tube socket may be seen in the top view.

The top and bottom view of the unit appears in Fig. 9. The top view (A) shows the detector tube socket and the secondary tuning screw, and the bottom view (B) shows the primary tuning screw and eight terminals by which the ratio detector circuit is connected to the remainder of the receiver. Besides these parts, small solder connections (shown in stippled form) can be seen in both views. These represent small rivets and serve as tie points for the leads of certain components and also for pieces of bus bar. This bus bar, in turn, also serves as tie points for electrical connection between components.

Although not apparent from the drawing of the top view, the 6AL5 tube can be inserted into its socket through the top of the shield-can. This shield-can has two holes on top, a small one for the secondary tuning screw and a larger one so that the miniature 6AL5 tube can be inserted into the tube socket. With the tube in its socket, about half of it protrudes from the top of the can; hence, the tube can be easily pulled out. At first one might think that since the tube socket and associated circuit is inside the shield, it might be inconvenient to take voltage measurements usually made at the tube socket. However, in this unit all necessary voltage measurements can be made at the terminals at the bottom of the assembly. If any defect in this assembly is suspected, it is suggested that the unit be returned to the manufacurer for replacement.

The numbers next to the terminals on the bottom view of Fig. 9 (B) correspond to those circled numbers around the periphery of the dashed box of the schematic circuit of Fig. 8. Terminals 3 and 4 represent the filament of the 6AL5 tube and by placing a suitable voltmeter across these terminals, one can test for filament voltage. In the actual circuit hookup, terminal 4 is grounded and terminal 3 is connected to the high side of the 6.3-volt secondary winding of the power transformer. The stippling effect seen on the terminals and

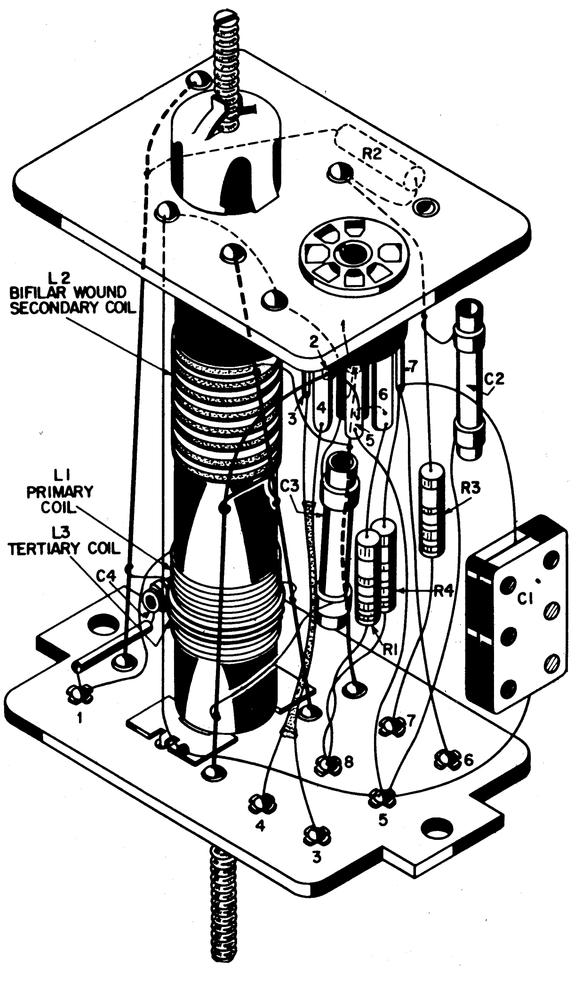


Fig. 10.—Isometric view of the complete ratio-detector circuit, including the detector transformer, of the Stromberg-Carlson Models 1406PLA, 1407PFM and 1409M-2W.

other parts of the two views of Fig. 9 indicate soldered connections at these points.

Now let us look at the isometric view of the complete ratio detector assembly in Fig. 10. The picture appears quite complicated, but by carefully tracing all the components, their connections can be discerned. Four resistors and four capacitors are included inside this assembly. The transformer coil form with its associated windings, as well as the underside of the detector tube socket, can easily be seen. The thick heavy wires are pieces of bus bar which are used as tie points for interconnections of the circuit components.

In analyzing this construction, constant reference should be made to the schematic of Fig. 8 for the proper correlation of wiring and components. The lettered components of Fig. 10 are the same as those of Fig. 8.

It should be remembered that certain parts of the drawing are somewhat exaggerated and that some of the components are shifted slightly from their normal placement to show more clearly all the components and wiring.

The ground connections inside this unit are quite interesting. Aside from the ground connection of one end of the 6AL5 filament, which is made to terminal 4, all the other components and parts that have to be grounded are all interwired within the unit and finally end at terminal 5. (Remember that these terminals are at the bottom of the assembly and do not represent the pin numbers of the tube socket). Terminal 5 is grounded to the chassis of the receiver after the ratio-detector assembly is inserted inside the receiver.

Tracing these ground connections from terminal 5, we find four leads, one lead going directly to pin 5 of the tube socket. From pin 5 there are two other leads, one going through the metallic center-pin of the tube socket to pin 6 of the socket to which one end of resistor *R1* is also connected. The other lead from pin 5 is soldered to the rivet which holds the metallic support of the tube socket (this metallic support is not shown in the drawing), and from this point the lead continues and is soldered to both metallic supports of the transformer coil form and then comes back to terminal 5. Thus we have accounted for two of the leads coming out of terminal 5. One of the remaining two leads is connected to one side of mica capacitor *C1* and the other lead is attached to one side of ceramic capacitor *C2*

From pin 3, one end of the tube filament, a (silver-colored) lead connects directly to terminal 4. From pin 4, the other end of the filament, a (copper-colored) lead connects directly to terminal 3. These two leads are part of a special type of wire, wherein both leads are very close together and are separated only by a plastic insulator, as can be seen in Fig. 10.

This same type of wire is also used for the secondary winding, *L2,* of the ratio-detector transformer. To differentiate between the two lead colors in the drawing, the copper-colored wire is drawn heavier than the other; this also enables the reader to trace the wires easily. This part of the transformer is *bifilar wound,* as is usually necessary in ratio-detector transformers.

The top lead of this coil (the thinner wire) is connected to a bus bar which in turn is connected to pin 1 of the tube socket. Tracing this part of coil *L2,* we find that the other end, at the bottom of the coil, is connected to another bus bar. This connection represents the tapped center point of the secondary coil, *L2.* The top end of the copper-colored lead of coil *L2* and also one end of the fine-wired tertiary coil, *L3* is also connected to this bus bar. The lower end of the copper wire of *L2* is connected to another bus bar which, in turn, is connected to pin 2 of the tube socket. This completes the circuit of the bifilar-wound secondary coil, *L2* (a truer representation of how a bifilar wound secondary coil should appear schematically can be found in Fig. 6 on page 14 of the "How It Works" book for Rider's Volume XVII.

One end of ceramic capacitor *C3* is connected to pin 1 of the tube socket and the other end of this capacitor is connected to the same bus wire which is connected to pin 2. Thus, this capacitor is across the secondary coil, *L2.*

The primary coil, *L1,* of the unit appears at the lower end of the transformer coil form. The upper end of this coil is soldered to terminal 1 and the lower end to terminal 2. (This latter terminal is not shown in the illustration.) A small 5-$\mu\mu f$ ceramic capacitor, *C4,* has one lead soldered to terminal 1 and the other end soldered to terminal 2. The lead of this capacitor going to terminal 1 has a piece of "spaghetti" around it for insulating purposes.

Wound around the bottom part of primary coil *L1* is the tertiary winding, *L3.* Although not shown, a piece of insulating material lies in between coil windings *L1* and *L3.* We have already indicated how one end of coil *L3* is attached to the center tap of coil *L2.* The other end of coil *L3* is soldered to the lower end of a bus bar, as seen on the left side of the drawing. To the upper part of this same bus bar one end of resistor *R2* is connected. The other end of this resistor is soldered to a rivet tie point at the top of the assembly. To this tie point there is also connected one end of resistor *R3* and the other end of ceramic capacitor *C2;* the other end of this capacitor is grounded, as mentioned previously. The other end of resistor *R3* is soldered to terminal 7.

To complete the analysis of the wiring of this unit, it will be seen that the remaining end of resistor *R1* (the other end is grounded as mentioned previously) is twisted together with one lead of resistor *R4* and these twisted leads are soldered to terminal 8. The other end of resistor *R4*, as well as the other end of mica capacitor *C1*, is connected to pin 7 of the tube socket. From pin 7 a separate lead can be seen going to terminal 6 at the base of the unit. This completes the wiring of the special ratio detector assembly.

Printed Circuits

In the "How It Works" book of Rider's Volume XVIII there was an article on the application of printed circuits in radio receivers. Because of their growing use in radio receivers, it was felt that further discussion about printed circuits are in order. A printed circuit is defined as being printed when it is produced on a special insulating base by any one of a number of processes. Thus, it should be remembered that a printed circuit in one piece of electronic equipment may be reproduced by a completely different method than a printed circuit in some other equipment.

Below is an excerpt from the National Bureau of Standards Circular 468 titled *Printed Circuit Techniques* written by Cledo Brunetti and Roger W. Curtis. This circular describes the methods by which printed circuits can be produced.

"Printed circuits fall into six main classifications: painting, spraying, chemical deposition, vacuum processes, die-stamping and dusting. Some of the processes are new, some have been used for years, others have not been applied to production of electronic circuits but are included because they point the way to new techniques.

"All are methods of reproducing a circuit design upon a surface and as such fall under the general classification of printing processes. Electronic circuits produced by any of these methods will be called printed electronic circuits. The processes differ mainly in the manner in which the conductors* are produced. Resistors and capacitors are applied by methods that in general may be used interchangeably with any of the processes.

"*Painting.* Metallic paints for conductors, inductors and shields are made by mixing a metal powder with a liquid binder to hold the particles together and a solvent to control the viscosity. Resistance paints are made in somewhat the same manner, using carbon or metallic powders. The circuit is painted on the surface by brush or stencil. It is fired at elevated temperatures. Tiny capacitors and subminiature tubes are added to complete the electronic unit.

"*Spraying.* Molten metal or paint is sprayed onto an insulating surface with a spray gun. In some processes, metals in the form of wire, powder or solutions are supplied to the gun and sprayed directly on the surfaces through stencils to form the conductors and to fasten in place resistors, capacitors, and other electronic components that have previously been placed in depressions on the surface. Resistance paints may also be sprayed. Chemical spraying is possible using a spray gun with two openings, one ejecting silvering material and the other a reducing liquid. In another method, a metallic film on an insulated surface is subjected to an abrasive blast through a stencil bearing the circuit pattern. Included in this classification is the die-casting method. A special low-melting point alloy is cast directly into grooves in the insulating surface. Expansion on cooling holds the metal in place.

"*Chemical deposition.* A metallic solution, such as silver for example, is prepared by adding ammonium hydroxide to a solution of silver nitrate. A reducing agent is used to precipitate metallic silver on the insulating surface. A stencil is employed to define the circuit. Thin films are formed that may serve as resistors or conductors. Electroplating is used to increase the conductance of the part of the wiring serving as the conductors.

"*Vacuum processes.* The coating metal is made up in the form of a cathode or placed in a container in an evacuated chamber opposite the plate on which the pattern is to appear. Raising the metal to proper temperature distills it onto the plate through a suitable stencil to define the circuit. Resistors as well as conductors are made this way.

"*Die-stamping.* Circuit wiring is punched out of metal foil and attached to one or both sides of an insulating panel. A variation is to use a heated die with the circuit wiring pattern on its face. Pressing the die on a thin sheet of metal foil over a plastic surface prints the complete wiring in a single step. The heat causes the foil to adhere strongly to the surface. The process is applicable to production of inductors and resistors.

"*Dusting.* Metallic powders with or without a binder are dusted onto a surface in a wiring pattern and fired. The powder may be held to the surface by coating the latter with an adhesive through a circuit defining stencil. The powder adheres to the surface in the desired circuit pattern and fuzes strongly to it on firing. An electrostatic method of holding the powder on prior

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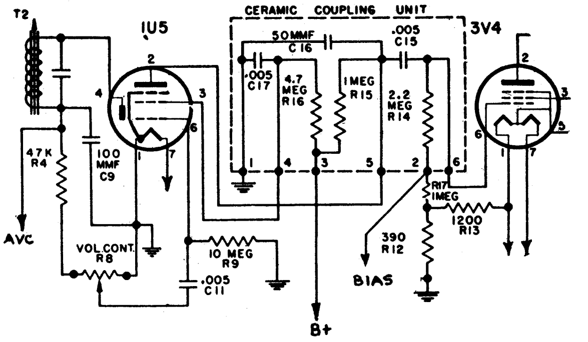
*The term "conductors" herein is used to denote the leads or that part of the circuit wiring which connects the electronic components such as the resistors, inductors, etc.

to firing or flashing has been developed. The process is adaptable to making resistors and conductors. Electroplating may be used to increase the conductance where necessary.

"In this country considerable interest is being displayed in the painting, spraying, and die-stamping methods. A good deal of experience has been accumulated and practical methods of operation adaptable to mass production worked out. Review of progress in foreign countries also reveals development and usage of some of the methods, particularly in England and Germany. The literature is replete with methods of depositing metals on non-metallic materials. A large number have been patented long ago and the patents expired. Early methods consisted of applying finely divided graphite or metal powders to wax coatings on the surfaces. The chemical reduction methods were probably the first to be used for producing thin metallic films on non-conducting surfaces for decorative arts. Some have been used for over 100 years. The resulting films were usually very thin, and plating was used to increase the thickness.

"Not all the components of an electronic circuit may be printed. The practice is adaptable to conductors, resistors, capacitors, inductors, shields, and antennas. By printing the circuit on a base plate of high dielectric constant one may print the capacitors, wiring, and inductors all in a single operation. The capacitors in this case may be made up by silvering equal areas on opposite sides of the plate. This practice is applicable to uses where high capacity between leads and components may be tolerated, such as in phase shift networks comprising only resistor and capacitor elements. It is desirable that the circuits and components adhere strongly to the base plate. The wiring should be of low resistance and of sufficient size to carry large currents without appreciable heating. The resistors and other printed components should be stable under rated electrical loads and should show a minimum aging effect. The complete printed circuit should withstand fairly severe temperature and humidity exposures, rough handling, and mechanical abuse."

In quite a few of the radio receivers appearing in Rider's Volume XIX, printed circuits are used. In this section we are going to discuss one of these printed circuits which appears in Firestone Model 4-C-13 (appearing on page 19-41 through 19-43) but can be representative of those used in many other receivers. The manufacturer of this printed circuit is Centralab Division of Globe-Union, Inc. The printed circuit we have in mind is used as the coupling unit between the pentode audio voltage amplifier section of the 1U5 tube and the 3V4 audio power amplifier. That part of the circuit of interest to us is illustrated in Fig. 11. The printed circuit shown in schematic form is enclosed in the dashed box and is termed "ceramic coupling unit." The supplier of this unit calls it a "standard pentode couplate."



(*Courtesy Firestone Tire & Rubber Co.*)

Fig. 11.—The printed circuit appearing in the Firestone 4-C-13 contains three resistors and three capacitors.

From the schematic of this unit we see that six components are included, three resistors and three capacitors. For the 1U5 tube, the one-megohm resistor, *R15,* is used as the plate load, the 4.7-megohm resistor, *R16,* is used as the screen dropping resistor, the 0.005-μf capacitor, *C17,* is used as the screen by-pass and the 50-$\mu\mu f$ capacitor, *C16,* is used as the plate r-f bypass. The 0.005-μf capacitor, *C15,* is the audio coupling between the plate of the 1U5 tube and the control grid of the 3V4 tube, and the 2.2-megohm resistor, *R14,* is the grid resistor for the 3V4 tube. The resistors are each rated at 1/5 watt and the d-c working voltage of the capacitors are rated at 450 volts. Each resistor has a tolerance of ±20%.

A drawing of this printed circuit including its actual dimensions is shown in Fig. 12. There are six tinned copper leads coming out of the unit. These leads are

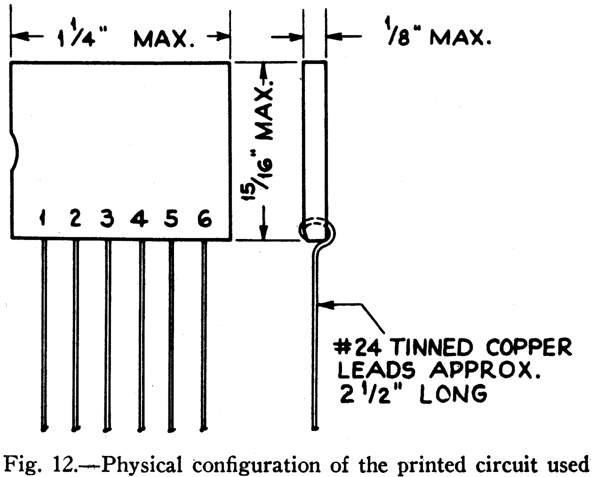
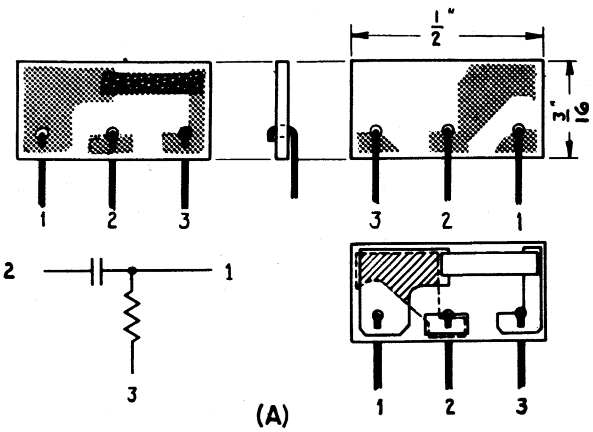


Fig. 12.—Physical configuration of the printed circuit used in the Firestone 4-C-13.

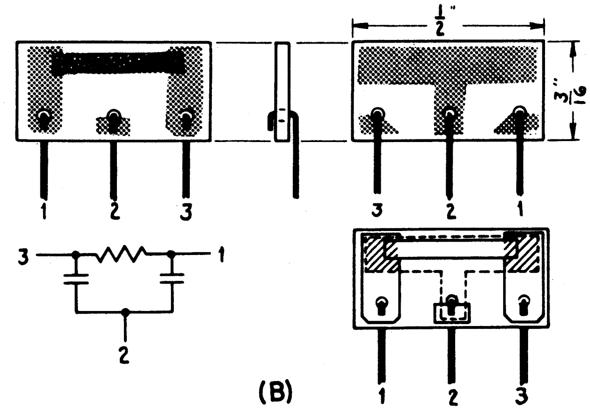
numbered one through six on the coating of the printed circuit, as shown. These numbers tie-in with those illustrated in the schematic drawing of Fig. 11. Lead 1 is grounded, lead 2 is connected to a bias-supply point and also to a 1-megohm resistor, *R17*. Lead 3 is connected to the B+ supply, leads 4 and 5 are connected to the screen and plate of the 1U5 tube respectively, and lead 6 is connected to the control grid of the 3V4 power output tube.

To present a fair idea of the techniques used in the assembly of these printed circuits, we have reprinted below part of an article written by A. S. Kouri of the Centralab Division of Globe-Union, Inc. This article describes some of the techniques involved in this company's production of printed circuits, and was taken from the National Bureau of Standards Miscellaneous Publication 192 titled "New Advances in Printed Circuits." Wherever it was felt necessary, we have supplemented the material contained in this article.

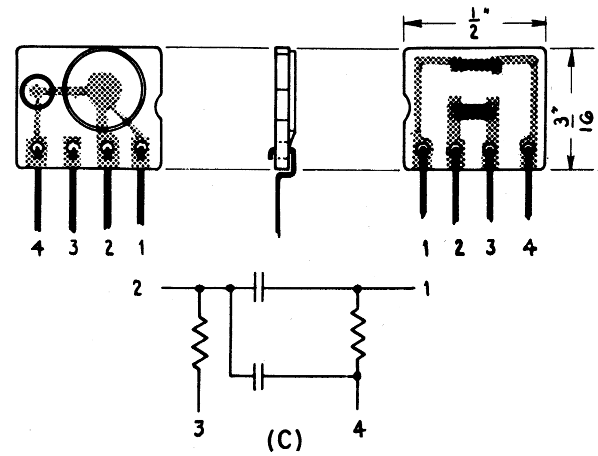
"An important question at this moment is 'What do the basic everyday circuits look like when printed?' Both simple and complex circuits have been reduced in size and complexity of construction by the techniques now used in manufacturing at Centralab. Some of these techniques are illustrated in Fig. 13. In part (A) the units shown represents a simple RC coupler. Correlation between the four different views of the unit can easily be made. In the composite view we have indicated, by the cross-hatched lines, that portion of the silvered plates that are effective in producing the desired capacitance. This composite drawing is nothing more than an overlapping of the front and rear views on this printed circuit in order to show areas that are common to each other. The leads 1, 2, and 3 indicate the external connections of the circuit. Various more complicated coupling and filter circuits can be made using two or more of the units. The layout in part (B) of Fig. 13 includes two capacitors and one resistor and can be used as a diode filter. The composite view in this drawing also indicates by cross-hatched lines those parts of the silvered plates that are effective in producing the desired capacitance. An important point to note is that the ceramic plate serves as a base for the circuit and resistors and as the dielectric for the capacitors. Both parts (A) and (B) of Fig. 13 use a ceramic plate as the base for the circuit and components.



(A)
LAYOUT OF R.C. COUPLER- "KUPEC"



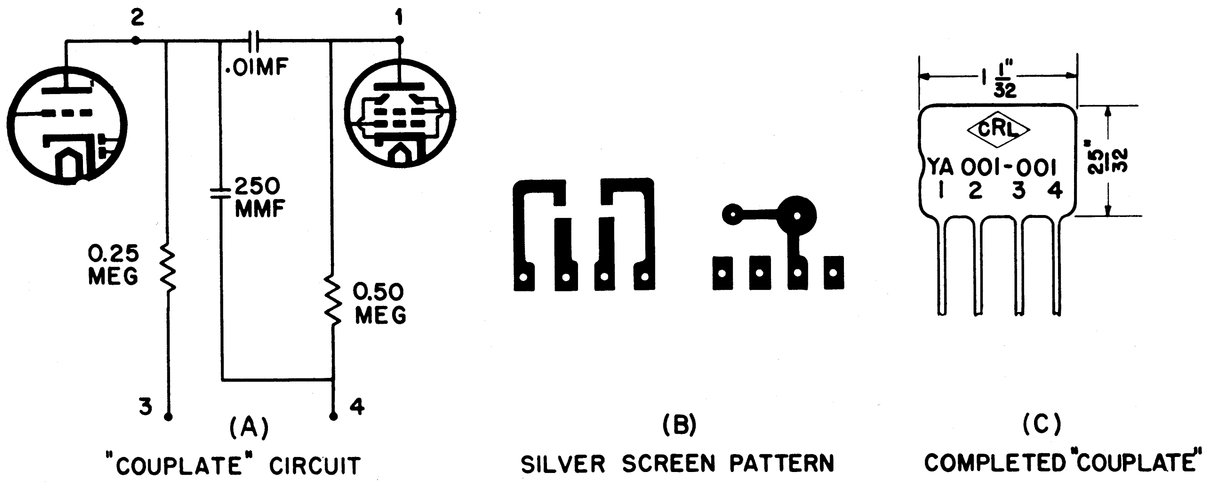
(B)
LAYOUT OF DIODE FILTER- "FILPEC"



(C)
LAYOUT OF INTERSTAGE COUPLING-
"COUPLATE"

Fig. 13.—The construction and schematic representation of three types of printed circuits are shown in parts (A), (B), and (C).

"In part (C) of the figure we see a layout for an intra-stage coupler which is termed the 'Couplate.' This latter unit employs a steatite plate as a base for the circuit and resistors, and the capacitors are thin, silvered disks of high dielectric ceramic soldered flat against the plate. These three items illustrate the two basic methods we employ at Centralab. Each has its advantages. But it is important to note, however, that when a high dielectric constant plate is used for the circuit and resistor base as well as for the dielectric for the capacitors, (as that used for the printed circuits of (A) and



(A)
"COUPLATE" CIRCUIT

(B)
SILVER SCREEN PATTERN

(C)
COMPLETED "COUPLATE"

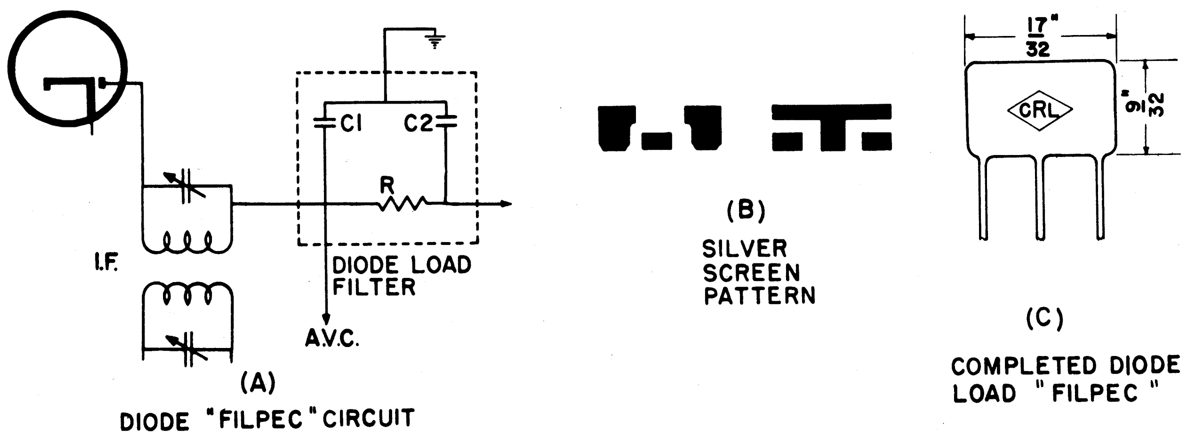
Fig. 14.—Schematic representation, silver screen pattern, and completed printed circuit for a coupling circuit are shown in parts (A), (B), and (C), respectivly.

(B) of Fig. 11) a high degree of sometimes undesired coupling of components presents a problem. Where this coupling cannot be minimized to a negligible effect by proper spacing, layout and other expedients, it becomes necessary to use the method illustrated with the Couplate printed circuit of part (C) of Fig. 11; that is, attaching wafer-thin ceramic capacitor disks separately to a steatite plate having a low K instead of a high K. (K means dielectric constant.)

"Together with a general idea of the appearance of some commercial applications of printed circuits, we will attempt to answer another question arising in your mind, that is, 'How do we manufacture printed circuits at Centralab?' Starting with a schematic drawing of the circuit, as shown in part (A) of Fig. 14, the shape and size of a base plate is determined, and a layout drawing is made.

"The layout drawing is accurately made to enlarged scale and photographed. From the layout photographs, which are reduced to actual size, screens are made, as shown in part (B) of Fig. 14, which are used to apply the circuitry and resistors. A silver paint used for the circuitry is fired at approximately 1,400° F. to bond it to the ceramic and to render it conductive. For the resistors, a carbon-resin dispersion is used which is baked at a moderate temperature to stabilize it against the effects of mechanical abrasion and humidity. After resistors are applied, wire leads and capacitors are soldered to the plate to complete the assembly. A phenolic coating is used to provide insulation and additional protection against humidity and abrasion. In part (C) of Fig. 14 a line drawing of this completed Couplate is shown including its dimensions.

"For a simple RC circuit, such as the diode filter of



(A)
DIODE "FILPEC" CIRCUIT

(B)
SILVER
SCREEN
PATTERN

(C)
COMPLETED DIODE
LOAD "FILPEC"

Fig. 15.—Schematic representation, silver screen pattern, and completed printed circuit of a diode load filter are shown in parts (A), (B), and (C), respectively.

Fig. 15 (A), a high K base is used as the dielectric for the capacitor. Silver and resistor screening are done in the same manner as illustrated before. However, it is unnecessary to attach external capacitors since they are included as an integral part of the unit in this design, the screening pattern is shown in part (B) and the completed unit illustrated in part (C) of Fig. 15. If this circuit had been more complex and intercoupling of components had to be reduced to a minimum, then it would have been preferable to use a steatite base with wafer-type capacitors attached separately. In either case, the ceramics used for the base plate and the capacitors are dense bodies, impervious to moisture, and have excellent dielectric properties.

"How these ceramics are made is another question, since it is a science all its own. In producing either steatite or high K ceramic, careful laboratory control precedes all operations such as mixing, molding, and firing.

"The screens used to deposit the circuit pattern and the resistors are an important part of printed circuit equipment, and their manufacture requires considerable skill, especially for small and intricate layouts. Either silk or steel mesh screen is used. The choice depends on first cost, expected life, and quality of work. After a photosensitive emulsion is applied to the surface of the screen it is exposed to light against the photographic positive of the circuit layout. After washing the unexposed sections of the screen it is checked for accuracy and is then ready for use.

"In order to deposit the circuit pattern or the resistors, a small amount of paint is poured over the screen and a rubber squeegee moved over the surface of the screen forces paint through the pattern openings onto the ceramic plate below.

"Let us examine each of the four types of circuit components that can be made by our printed circuit technique in order to determine what these printed circuits can do and how they perform.

"The conductors of 'wires' are silver normally applied in widths from 0.010 in to 0.060 in. and approximately 0.003 in. thick. A 1-in. length of conductor 0.030 in. wide will have a resistance of approximately 0.1 ohm. Humidity, load life, noise, and voltage coefficient data for a 1-megohm resistor 1/4 in. long and 5/64 in. wide may be seen in Table 1.

"The ceramic dielectrics used for the printed circuit capacitors have a number of important characteristics. Of first importance is the simple parallel plate construction which allows the capacitors to be made wafer thin so that they can be mounted flat against the printed circuit plate, retaining the two dimensional nature of the circuit and resistors. Typical temperature coefficient and aging curves are shown in Fig. 16.

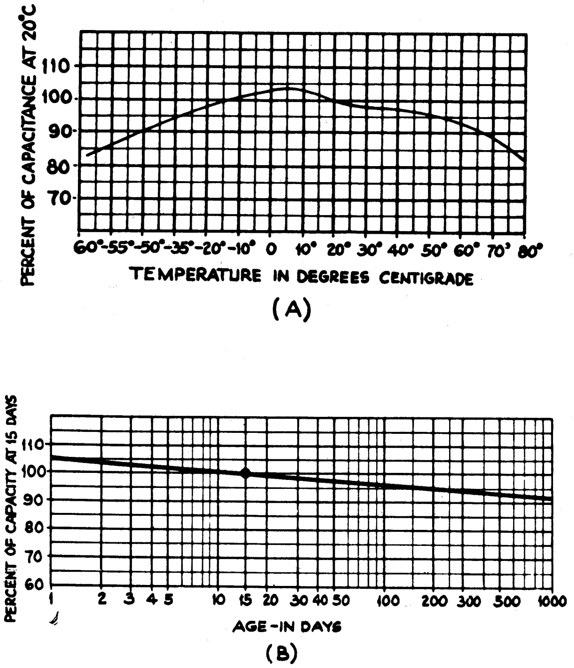


Fig. 16.—Typical temperature and aging curves of the ceramic dielectric used in manufacturing printed circuits are shown in parts (A) and (B), respectively.

"Inductances are applied either as spiral conductors on a flat surface, the maximum inductance practical to obtain in this manner being approximately 0.1 micro-

TABLE 1.—*Electrical characteristics of printed resistors*
Example: 1 Megohm Resistor, 1/4 in. × 5/64 in.

	Humidity	Load life	Noise	Voltage coefficient
Duration and type of test	96 hours at 90%-95% relative humidity, and 40° C.	1,000 hr. intermittent (1½ hr. on, ½ hr. off). Total power dissipated 0.5 watt.		
Change immediately following test	+11%	—4.7%	4 db over equivalent composition type resistor.	0.007% per volt.
Permanent change following test	—1%			

henry with a Q of 150, or as parallel lines having lower inductance but higher Q. In general, resonant circuits can be handled over the range from 25 to 509 mc. It is important to note, since the ceramics used have a temperature coefficient of linear expansion one-half or less than that of good metallic conductors, that an inductance which is bonded to the ceramic and constrained to expand with the ceramic base will have at least half the temperature coefficient of inductance of a similar, form-wound inductance. Also, this type of inductance has greater stability when exposed to repeated temperature cyclings than it is possible to obtain with either air or form-wound types.

"Wherever it is desired to miniaturize a circuit, printed circuit techniques should be considered. For instance, it is possible to make a printed circuit having 15 capacitors and 15 resistors, or more, a total of 30 components, and associated wiring, on a plate 3/4 sq. in. in area and 1/16 in. thick. Uniformity in performance and appearance of printed circuits produced in quantity is an important advantage to consider. Since all components are integrally bonded to the base plate, there can be no movement of parts relative to one another due to vibration or shock. Because of the dense nature of steatite and the ceramics used for capacitors, printed circuits are impervious to the effects of high humidity, and consequently, they should be useful in equipment destined for tropical use.

"Circuits which can be treated as a unit lend themselves ideally to printed circuit techniques. In this case the circuit can be molded or potted as a unit section and provided with plug connections to the remainder of the circuit. Servicing them becomes a matter of locating the faulty section and plugging in a new unit.

"A single three-stage miniature amplifier, mass produced at low cost, can be used in various applications. It can be used wherever a small 'packaged amplifier' is needed such as in a stethoscope, hearing aid, pocket signal-tracer, or pocket transceiver.

"There is no question of greater importance to the prospective commercial user of printed circuits than that of cost. At the present time printed circuits are competitive with and sometimes cheaper than circuits using standard components, providing, the intangible considerations such as savings in labor, wiring mistakes, purchasing, inventory, and stock handling, are given their proper weight. The arithmetic illustrating the economics involved for the Couplate, a single component with 4 leads replacing 4 separate components with 8 leads is shown in simple tabular form in Table 2. A similar analysis can be made for any of the other printed circuit items discussed in this paper."

TABLE 2.—*Printed electronic circuit costs*

By comparative ratio computed from averaged cost analyses supplied by Couplate users

	ORDINARY COMPONENTS	*Index*		COUPLATE EQUIVALENT	*Index*
1.	4 Separate components	9.0	1.	Multiunit component	10.0
2.	8 Soldered joints	2.0	2.	4 Soldered joints	1.0
3.	Wiring mistakes	1.5	3.	Wiring mistakes	0.75
4.	Purchasing	1.0	4.	Purchasing	0.5
5.	Inventory, storage, and stock handling	1.0	5.	Inventory, storage, and stock handling	0.5
	Total	14.5		Total	12.75

For further information relative to printed circuits, it is suggested that the reader consult the two National Bureau of Standards publications mentioned in this discussion.

The biggest problem is raised by the serviceman repairing a receiver containing such printed circuit units. If he finds the trouble exists inside the printed circuit, all he need do is replace it with a new one. All good and well, but this still means replacing a complete new unit, equivalent, say, to six separate components such as the one discussed in Figs. 11 and 12, even if *only one* of the components is defective. The complete cost of the printed circuit must be borne, compared to that for a single resistor or capacitor (or whatever the defective element may be). Aside from this, there is also the amount of repair time that has to be considered; it will take a serviceman longer to wire, say a six lead printed circuit than two leads for a single component.

If the over-all picture relative to the cost to the consumer as charged by the serviceman for the parts used and time rendered is only a few cents different from that charged for a single component change, then there may not be many protests. However, if there is, in the final analysis, a difference in price that is considered appreciable, there will be quite a few customer complaints.

AUTOMATIC VOLUME CONTROL (AVC) AND TUNING EYE CIRCUITS

By Willard Moody

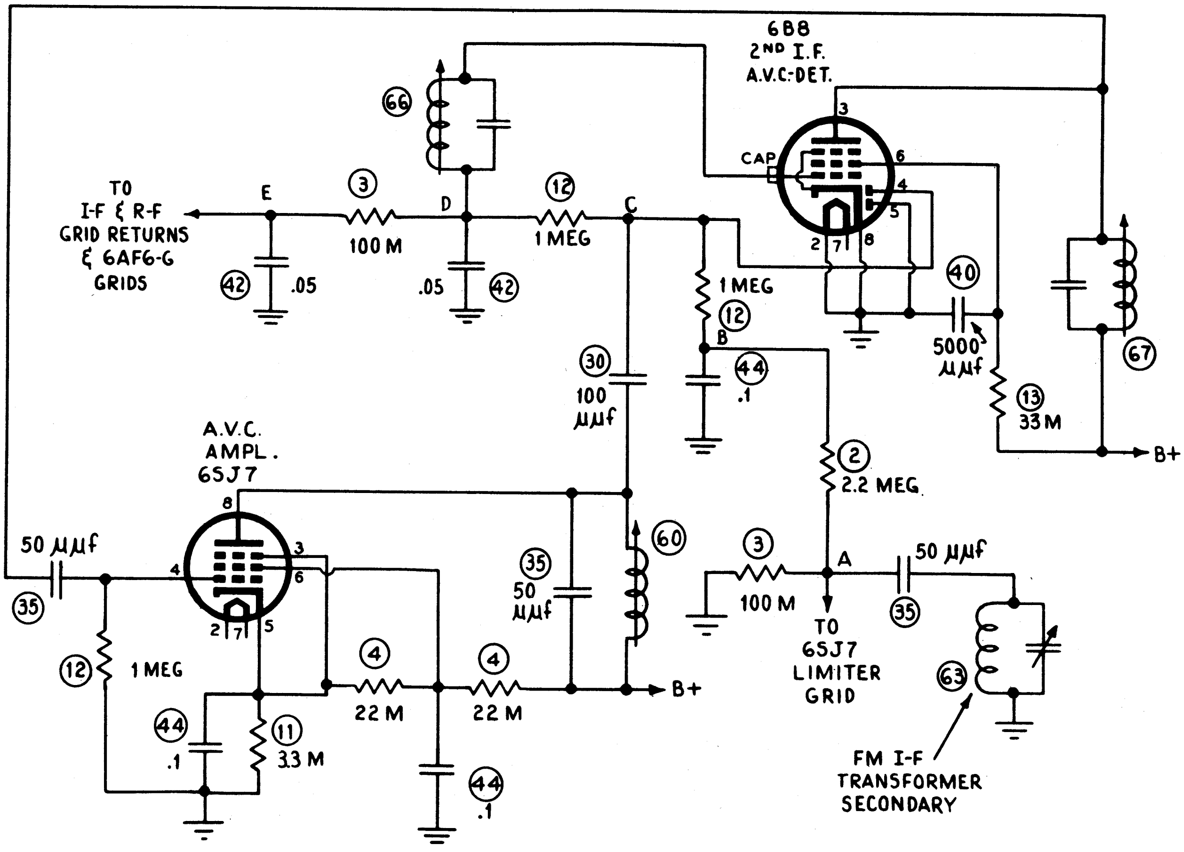
MODERN radio receivers often use extremely ingenious and interesting circuits. The circuits to be described in this section are of that type and include such circuit arrangements as those designed to permit ready switching from a-m diode-detector bias to f-m ratio-detector avc bias. In one receiver, the limiter grid current flowing in a grid resistor provides an automatic bias proportional to signal strength, and the ratio detector bias circuit is not used.

The fact that, contrary to general practice, a limiter is used ahead of the ratio detector is in itself an interesting innovation and departure from conventional circuit design.

The use of amplified avc is rather uncommon, and this type of a circuit will be discussed. When the manufacturer incorporates an amplified avc system in his receiver to obtain greater sensitivity in the tuning eye circuit, rather than in the avc circuit, the circuit is referred to as tuning eye type. A receiver incorporating this type of circuit will also be discussed.

Farnsworth Model 400M

Amplified avc is not widely used, but, when properly designed, it affords greater sensitivity and wider range — at additional expense — than ordinary avc circuits. The Farnsworth Model 400M appearing on *pages*



(After Farnsworth Telev. & Radio Corp.)

Fig. 1.—A breakdown of the avc circuit of the Farnsworth 400M.

19-34 through 19-54 of Rider's Volume XIX uses such a system.

In this set, a 6B8 tube functions as a combined 2nd detector, second i-f, and avc stage. A type 6SJ7 functions as an amplifier which amplifies the i-f signal and feeds it to the avc circuit.

In Fig. 1, a breakdown circuit of the Farnsworth 400M avc arrangement is illustrated. The complete circuit is given in *Rider's Vol. XIX, pages 19-51,52.* The 6H6 ratio detector supplies avc bias on the f-m band. In addition, an unusual tuning indicator arrangement is employed.

The circuit operation is not particularly complex. An i-f signal voltage appearing across the secondary circuit of the a-m i-f transformer (66) is applied to the grid input circuit of the 6B8 tube and is amplified by this tube. The resulting, larger signal potential appearing in the plate circuit is applied through a 50-$\mu\mu f$ capacitor (35) to the grid of the 6SJ7 avc amplifier, is amplified, and then applied to the 6B8 diode plate, pin 4, through the 100-$\mu\mu f$ capacitor (30).

The diode rectifies this signal and a d-c voltage is developed between pin 4 of the 6B8 and ground. This potential is applied through resistors 12 and 3 to the 0.05-μf capacitor 42, (points *C, D,* and *E*) and hence to the grid circuits of the avc-controlled tubes: the 6AB7 r-f tube, 6SA7 mixer, and 6SG7 i-f tube.

The negative d-c avc voltage is also applied to the grids of the 6AF6-G tuning indicator tube, point E in the diagram.

The voltage is a maximum at resonance, when a station is tuned in on the receiver, and drops sharply off-resonance, just as it does in any avc circuit. The range, or limits, over which this avc circuit operates, however, is greater than in the ordinary avc circuit because of the amplification afforded by the 6SJ7 avc amplifier stage.

The diode load resistance is the impedance between pin 4 and ground in the 6B8 stage. The d-c return path for the diode is through resistors 12, 2, and 3, of 1-megohm, 2.2-megohm and 100,000-ohm value respectively. Resistor 12 (1 megohm and capacitor 42 (0.05 μf) are the elements of an r-f filter used for circuit stability, with reference to points *C* and *D.*

It should be noted that the 6B8 diode is used as an avc detector or r-f rectifier at the i.f. and does not supply an a-f signal to the audio amplifier.

The 6SQ7 diode, pin 4, (shown in the complete schematic, pages 19-51,52 of Rider's Volume XIX) is the diode detector used for an audio source to the a-f amplifier section of the receiver on a-m operation.

AVC For the F-M Band

On f-m operation, signal voltage is developed in the grid circuit of the 6SJ7 limiter (not shown in Fig. 1). This tube has no cathode resistor and no fixed bias, thus it draws maximum grid current on positive signal peaks and capacitor 35 becomes charged. The average grid potential thus becomes negative as the grid capacitor-resistor time constant is so chosen as to permit a bias voltage to be developed on the limiter. As this bias potential is proportional to the amplitude of the incoming signal voltage, it may be used for avc purposes and is so used in this receiver.

The negative d-c voltage across resistor 3 (100,000 ohms) is applied to the avc circuit and capacitor 42 (0.05 μf) through resistors 2, 12, and 3, (through points *A-B-C-D-E* on the drawing).

On the f-m, the band diode formed between pins 4 and 8 of the 6B8 merely functions as a "gas gate," not a rectifier. If the diode plate (pin 4) should "go positive" with respect to ground, because of a gassy *controlled* tube, the diode would conduct and short out the positive bias, thus protecting the other avc controlled tubes from possibly damage.

Similarly, if strong noise pulses should exceed the bias on an avc controlled tube on positive peaks, the 6B8 diode would act as a noise limiter and tend to damp the circuit and prevent the avc line from going positive.

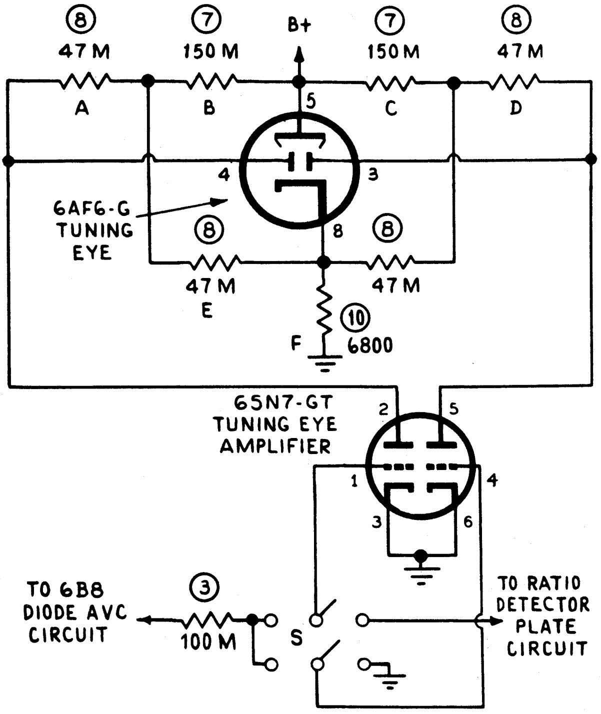
In this set a limiter is used before the ratio detector. This is a departure from conventional practice. The ratio detector was originally developed so that the limiter tube could be eliminated. The use of a limiter before the ratio detector, although not necessary, does improve the signal-to-noise ratio of the receiver. However, it adds to the cost of the receiver and for that reason is generally omitted.

While the use of the limiter improves the signal-to-noise ratio of the receiver, it is also a convenient and practical source of avc voltage on f-m operation. The switching circuits acts in such manner that, on a.m., no signal voltage appears across transformer 63 and the limiter grid circuit. Therefore, there is no interference between the a-m and f-m avc circuits.

Similarly, no a-m signal voltage is applied to diode plate 4, through capacitor 30, from the 6SJ7 plate, on a.m. and, there is no reaction of a.m. on f.m. bias.

Further, the usual practice of deriving avc bias, for f.m., from the ratio detector, has not been followed.

Another innovation is the employment of a 6AF6-G. This tuning eye, or indicator, is a special tube used in an unusual circuit. This special circuit is shown in Fig. 2. However, before proceeding to a discussion of this circuit, some attention will be given to the 6AF6-G tube.



(After Farnsworth Telev. & Radio Corp.)
Fig. 2.—The tuning eye circuit of the Farnsworth 400M.

The 6AF6-G,* fundamentally, is a high-vacuum, heater-cathode type of tube designed to respond visually, by means of two shadows on a fluorescent target, to changes in the voltages applied to the control electrodes. These electrodes connect to pin terminals 3 and 4 of the 6AF6-G tube. The tube performs, therefore, as a voltage indicator and is useful as a convenient and non-mechanical means to indicate accurate tuning of the receiver to the desired station.

Structurally, the 6AF6-G tube has a heater, a cathode, two ray-control electrodes, and a fluorescent target. Electrically, however, the 6AF6-G may be considered as two separate electron-ray tubes in one bulb, the cathode and target being common to both. Each control electrode can perform independently of the other to produce a separate shadow. The control electrodes may be connected in parallel to give twin shadows or connected separately to give two independently controlled shadows. The voltage or voltages generally speaking, required for control, are supplied to the 6AF6-G through one or more voltage amplifier tubes.

In the circuit of the Farnsworth 400M, a 6SN7 duotriode tube is used as a d-c amplifier. Using the ray control electrodes of the 6AF6-G tube in parallel, the twin patterns vary from shaded angles of 100 degrees with no controlling voltage (off tune) to shaded angles of approximately zero degrees at resonance, with a strong carrier. Exact tuning is indicated by the narrowest shaded angles that can be obtained; the stronger the carrier, the narrower the angle.

In the circuit shown in Fig. 2, the grid of the right hand portion of the 6SN7-GT (pin 4) is switched automatically to ground f-m operation; on a-m operation this grid is switched to resistor 3 and the grid circuit of the 6D8 tube. The grid of the left-hand portion of the 6SN7-GT tube (pin 1) is switched from the ratio detector plate circuit (negative voltage source) on f-m operation to resistor 3 and the common grid circuit of the 6B8 tube on a-m operation.

Thus, on a-m operation both tuning eye grids connect to the avc source, and on f-m operation one tuning

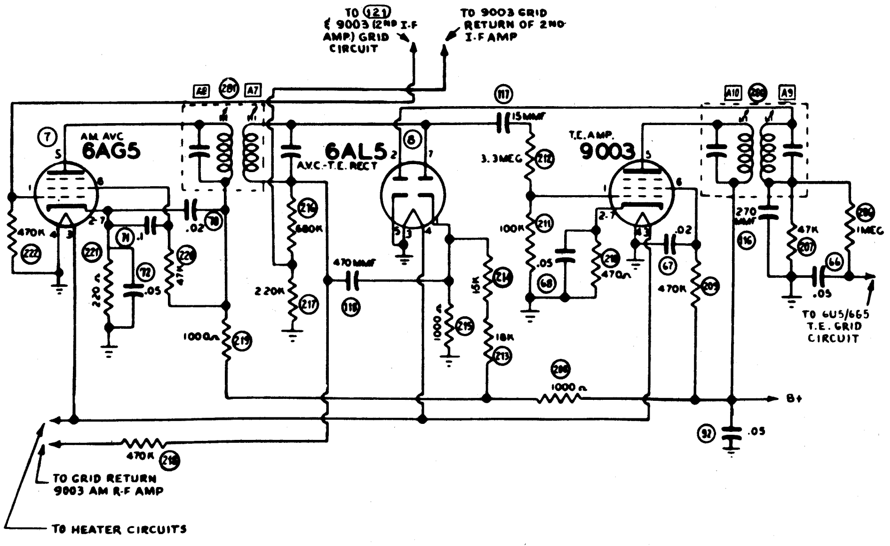


Fig. 3—The tuning eye circuit of the Meissner Model 2961.

(Courtesy Meissner Mfg. Div., Maguire Industries, Inc.)

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*RCA Patent Note 6AF6-G-5-38

eye grid is at ground potential while the other is at a negative potential at resonance, due to standard ratio detector action.

Meissner Model 2961

The service data for this receiver appears in Volume XIX on pages 19-7,8 through 19-21. The tuning eye amplifier circuit of this receiver is shown in Fig. 3. This receiver utilizes an unusual a-m avc and tuning eye amplifier circuit. The circuit consists essentially of a 6AG5 a-m avc stage, a 6AL5 avc and tuning eye, rectifier, and a 9003 tuning eye amplifier. Instead of the 6AF6 tuning indicator which was discussed previously, a 6U5/655-tuning indicator is used.

An i-f signal voltage at the grid (pin 1) of the 9003 2nd i-f amplifier, is applied to the grid of the 6AG5 a-m avc tube across the 470,000-ohm resistor (*222*). The signal is amplified by the 6AG5 tube and fed to the plate, pin *7*, of the second 6AL5 diode. This second diode rectifies the signal and current flow through resistors 216 and 217 to ground.

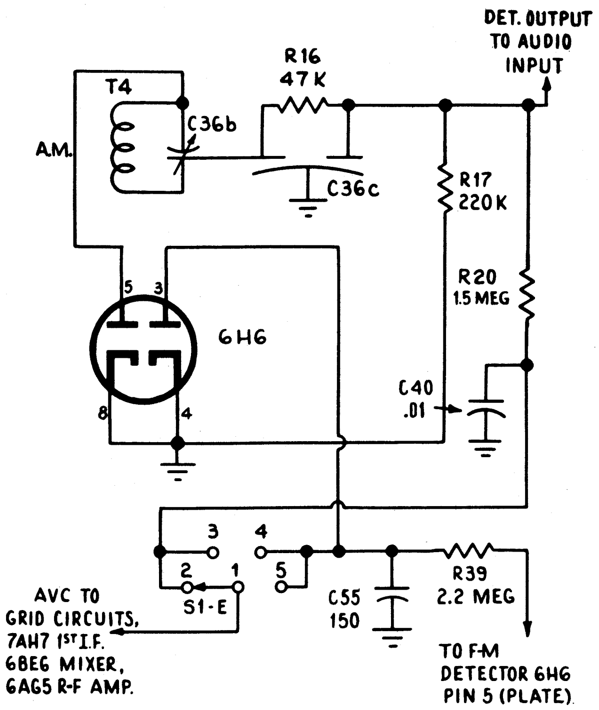
The d-c potential across the 220,000-ohm resistor, (217) is then applied to the grid circuit of the 9003 2nd i-f amplifier tube. This tube, incidentally, is not widely used and its inclusion in this receiver is a mark of difference from conventional design.

The i-f signal voltage available at the plate of the second section of the 6AL5 is also applied through the 15-$\mu\mu f$ capacitor (117) to the grid circuit of the 9003 tuning eye amplifier tube. This signal voltage appears across resistor 211, which has a value of 100,000 ohms.

The 9003 eye amplifier then amplifies the signal and couples it, through i-f transformer 280, to the other half of the 6AL5 duo-diode type; specifically, to pins 2 and 5. The electron flow through the 47,000-ohm resistor (207) makes the junction point of this resistor, and the transformer secondary terminal connected to 207, negative with respect to ground. This negative potential is applied through a 1-megohm resistor (206) to the grid circuit of the tuning eye, a type 6U5/655 tube. The arrowhead shows the point in question.

The full d-c voltage across resistor 216 and 217 is applied through the 470,000-ohm resistor (218) to the first i-f and a-m r-f grid circuits.

The tuning eye grid circuit is shifted by the switching system from the 6AL5 tuning eye rectifier to the grid circuit of the f-m limiter. Limiter grid current in a gridleak resistor causes the development of a bias in the presence of an f-m input signal. This particular circuit is shown in pages 19-9,10 of Rider's Vol. XIX.



(*Courtesy Bendix Radio Div.*)

Fig. 4.—AVC circuit of the Bendix Models 1217B and 1217D.

Bendix Models 1217B and 1217D

Modern receivers often differ in basic circuit designs that provide equivalent functions. In the Bendix 1217B and 1217D, a circuit arrangement is used that is different from any so far discussed.

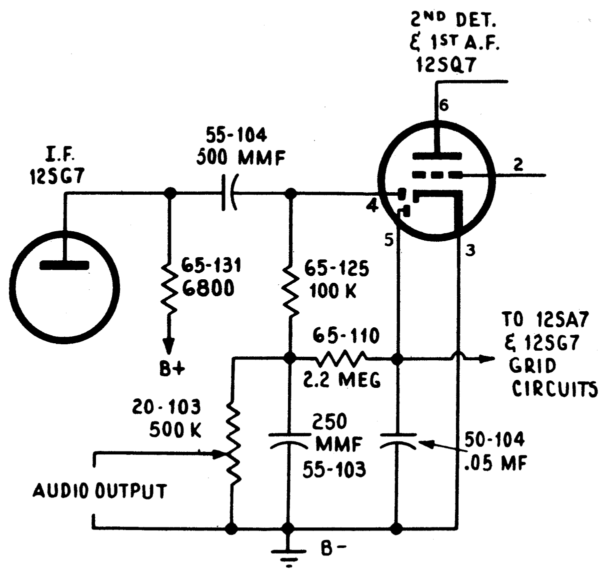
On a-m operation the avc circuit of this set uses a 6H6 rectifier. Ratio detector plate circuit bias, for avc, is used on the f-m band. A circuit for analysis appears in Fig. 4. The complete service data appears in Rider's Vol. XIX, pages 19-9 through 19-33.

Plate 5 is the a-m diode plate and is connected to the secondary of a-m i-f transformer *T4*. An i-f signal voltage appearing across the secondary is rectified and a d-c voltage appears across resistor *R17*. This negative voltage is applied through resistor *R20* and contacts 2 or 3 of switch *S1-E* on a-m operation to the 7AH7, 6BE6, and 6AG5 grid circuits. The other section of the 6H6 is disconnected on a-m operation.

On f-m operation, switch *S1-E* switches the 7AH7, 6BE6, and 6AG5 grid circuits to contacts 4 or 5 and to the ratio detector circuit.

The negative at resonance voltage of the ratio detector plate is applied through resistor *R39* to *S1-E* and the grid circuits of the avc controlled tubes.

The right half of the 6H6 is shunted across capacitor *C55*. If plate 3 becomes positive for any reason, the



(*After Regal Electronics Corp.*)

Fig. 5.—Partial circuit of the Regal 7251.

diode conducts and shorts out *C55* so that a positive voltage does not act in the avc circuit. A gassy tube or high intensity noise pulse might cause the avc "line" to go positive .The diode, then, would conduct and protect the avc controlled tubes.

Regal Model 7251

This receiver uses a 12SQ7 which is a commonly used tube in combination diode-triode detector and audio circuits. However, the method of using the diode elements in this circuit is somewhat unusual. The complete circuit appears in Rider's Volume XIX, on page 19-11. The circuit sketched for analysis is shown in Fig. 5.

The signal voltage at the plate of the 12SG7 i-f tube is applied through a 500-μf capacitor (55-104), to the diode plate, pin 4 of the 12SQ7, and is rectified. A d-c voltage is developed across the diode load resistor, 20-103. The negative d-c output voltage is applied through the 2.2-megohm resistor (65-110) to the grid circuits of the 12SA7 and 12SG7 tubes. The audio component is picked off a 500,000-ohm potentiometer (20-103).

Capacitor 50-104 is the usual 0.05-μf avc capacitor and diode plate 5 is a shunted across the avc circuit, in the same manner as was described in the previous section. Resistor 650131 (6800 ohms) is the plate-load resistor for the i-f stage.

General Electric Models 354, 355

In a receiver such as the Regal 7251 the circuit is relatively simple. A more complex circuit is often found in an am-fm set. The circuit of the General Electric 354 and 355, for example, uses a switching system to vary the avc circuit arrangement.

These receivers use two different circuit arrangements to provide a-m avc and f-m avc. The service data appears in Rider's Volume XIX on pages 19-28 through 19-35. The functional circuit of the a-m avc circuit is shown in Fig. 6.

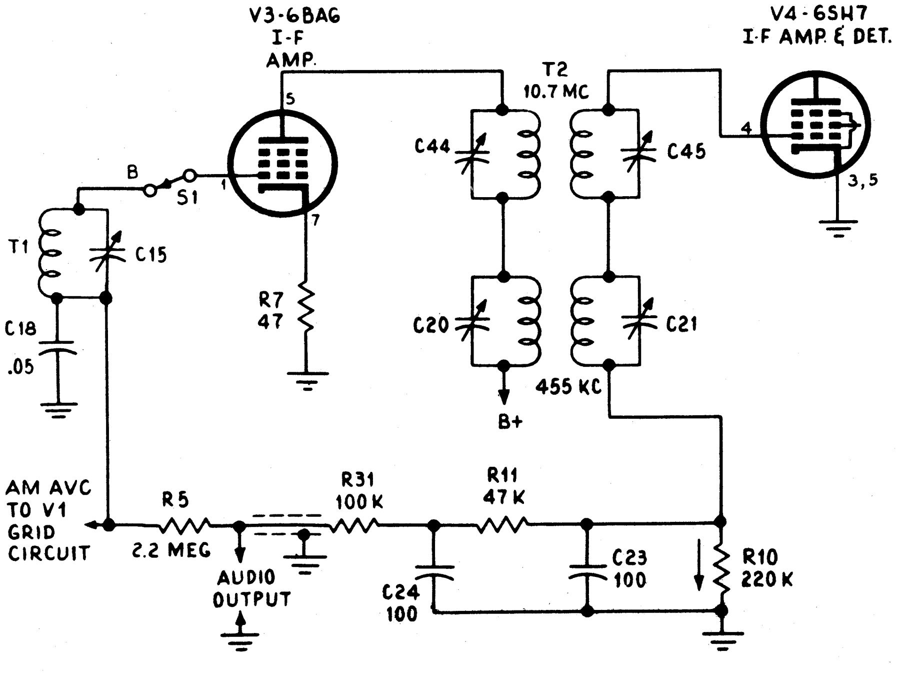


Fig. 6.—Functional circuit of the a-m avc circuit of the GE Models 354 and 355.

(*After General Electric Co.*)

This section of the circuit uses a 6BA6 i-f amplifier, *V3,* and a 6SH7, second detector *V4.* The plate and screen voltages of the tube *V4* are removed on a-m operation by opening a switch. This switch is omitted in Fig. 6, for the sake of simplicity. *V4* then functions as a diode detector with the first grid serving as the diode plate. On f-m operation, the switch is closed and *V4* functions as an i-f stage, with normal plate and screen potentials applied to it.

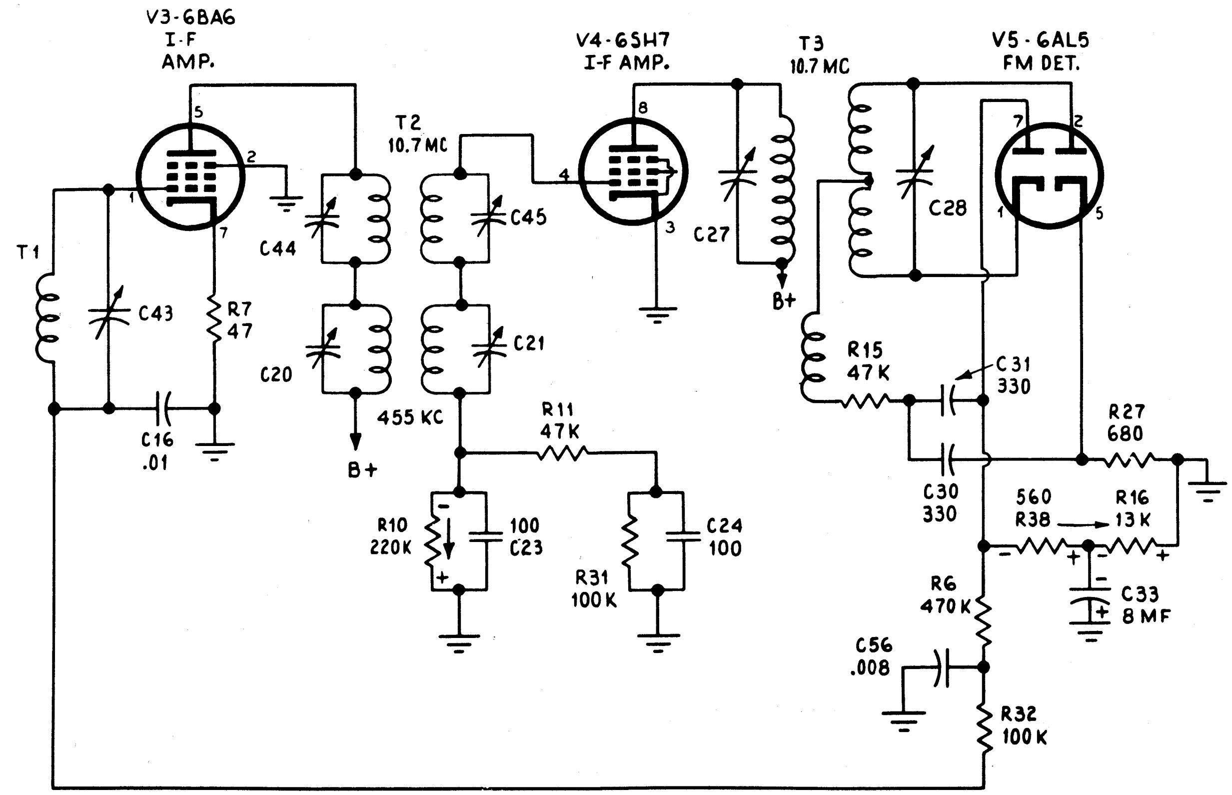
The electron flow to ground through the 220,000-ohm resistor, *R10,* in the *V4* grid return circuit, develops a negative avc bias potential across capacitor *C23.* This voltage is applied to the grid circuits of *V1* and *V3* through resistor *R5.* The audio output voltage is obtained at the junction point of resistors *R5* and *R31.*

T1 is the first i-f transformer and capacitor *C15* is placed across the a-m 455-kc secondary winding. Switch *S1,* in the grid circuit of *V3,* is shown in the a-m broadcast position. Capacitors *C44* and *C45* in the *V3* plate circuit and the *V4* grid circuit, respectively, are the 10.7-mc f-m i-f trimmers and capacitors *C20* and *C21* are the 455-kc a-m i-f trimmers.

The mode of operation on the f-m band is quite different from the a-m operation of this receiver. On the f-m band, *V3* is an i-f amplifier, as in a-m operation, but *V4* is no longer an a-m detector. Instead, it functions as an f-m i-f amplifier and drives *V5,* which is used in a ratio detector circuit. The equivalent circuit is shown in Fig. 7. Switching circuits have been eliminated in this functional diagram to secure clarity.

The grid return of *V3* now connects to *R32* and the circuit traces back through *R6* to the plate, pin 7, of the 6AL5 ratio detector circuit. The plate of *V5* assumes a maximum negative potential, with respect to ground, at resonance. This occurs when an f-m station is tuned in on the receiver. This negative potential serves as the avc bias since it is proportional to signal amplitude and it is applied to the grid circuit of *V3.*

The grid return of *V4* connects to resistor *R10.* On a-m operation, resistor *R31* is not grounded and the resistance to ground for the *V4* grid is higher than it is on f-m operation. On f-m operation, resistors *R11* and *R31* are in series and across resistor *R10,* making the net circuit resistance lower. The electron flow in resistor *R10* is shown by the arrow. Hence, the junction of capacitors *C21* and *C23* is negative to ground, and this is the automatic bias potential for *V4.* In essence, capacitor *C23* is a grid capacitor and the resistance across it is a gridleak on f-m operation.



(*After General Electric Co.*)

Fig. 7.—I-F amplifier and ratio detector circuits of GE Models 354 and 355.

AUDIO CIRCUIT FEATURES

By Willard Moody

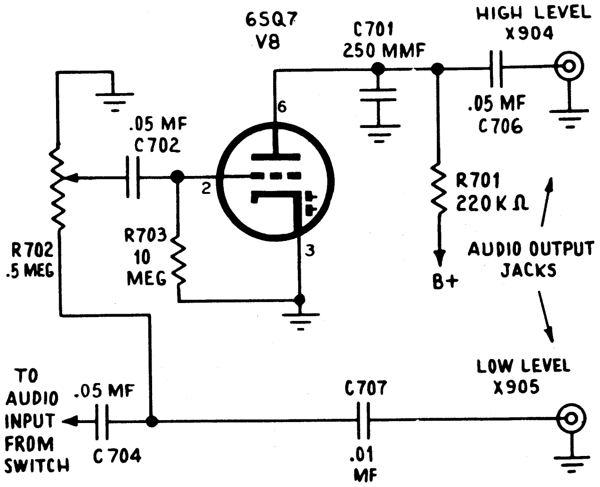
MODERN radio receivers often incorporate unique circuit arrangements that are interesting to examine and study. A number of such circuits is included in this discussion, ranging from those of a-m and f-m models to that of an auto radio receiver using a special tone control system.

Espey Model 512

Audio jacks are not uncommon in receiver circuits. Usually they are used to permit the ready connection of a record player to the audio amplifier input circuit of the receiver, but in the circuit of the Espey 512 f-m tuner they are employed for a different purpose—to pick off the desired signal voltage rather than to introduce it. This f-m tuner can be used to drive a good quality audio amplifier for effective reproduction of f-m programs. Two jacks provide low-level and high-level signals.

The service data for the Espey 512 appears on *pages 19-11,12 of Rider's Volume XIX.* A partial schematic, including the previously mentioned output jacks, is given in Fig. 1.

An audio amplifier may require more or less signal voltage to its input circuit, according to its inherent gain, and either the low- or high-level jacks of this tuner can be used.



(After Espey Mfg. Co., Inc.)

Fig. 1.—Part of the audio system of the Espey Model 512, showing the audio output jacks.

Jack *X905* (low level) is connected to *R702,* the audio volume control through a 0.01-μf capacitor. The audio output at jack *X905* is not controlled by *R702.* A low-level audio output signal can thus be taken off the f-m tuner at this point, and fed through a suitable connecting cable to the input circuit of an audio amplifier. This amplifier might be the audio section of an a-m receiver to be used for f-m reception, a public-address amplifier, or a phono amplifier in the home.

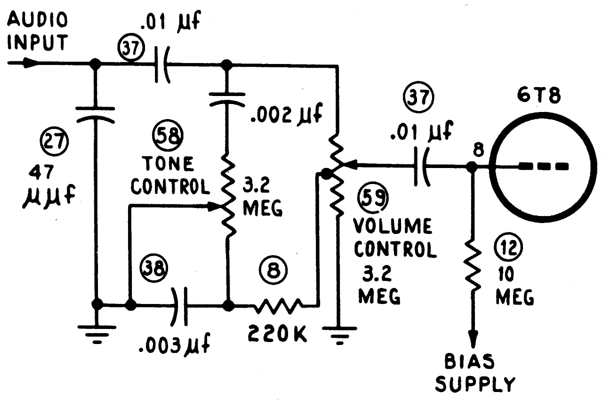
If a higher level audio signal is required to drive the audio amplifier, it is available at jack *X904.* The added gain is afforded by the 6SQ7 tube, *V8,* and is controllable by means of *R702.*

It is possible, it should be noted, to feed in a signal from a mike or phono pickup to the grid of *V8* through *X905, C707, R702,* and *C702.* The gain of the 6SQ7 tube could then be usefully employed to obtain a larger signal potential at jack *X904.*

Farnsworth Model P7

The magnetic pickup was one of the early developments in phono reproduction. Weight was a disadvantage, and soon the magnetic pickup gave way to the inexpensive, simple crystal variety. We have now witnessed another swing in the cycle with the development of the modern magnetic pickup having superior frequency and low inherent distortion, as well as ruggedness and strength, and the ability to withstand temperature changes.

However, special circuits are required to take full advantage of the inherent properties of these magnetic pickups and this is done in the Farnsworth P7 equalizer circuit to be described. Both low- and high-frequency corrective networks are employed; low-frequency compensation to take care of the recording characteristic and play-back action, and high-frequency compensation to reduce the high-frequency response and thus cut down "scratch noise" in reproduction. The over-all, or equalized, effect provided by the equalizer is one of improved fidelity and greater faithfulness of reproduction than was possible in the past using less modern magnetic pickup devices.



(*Courtesy Farnsworth Telev. & Radio Corp.*)

Fig. 2.—The volume control circuit of the Farnsworth Model P7.

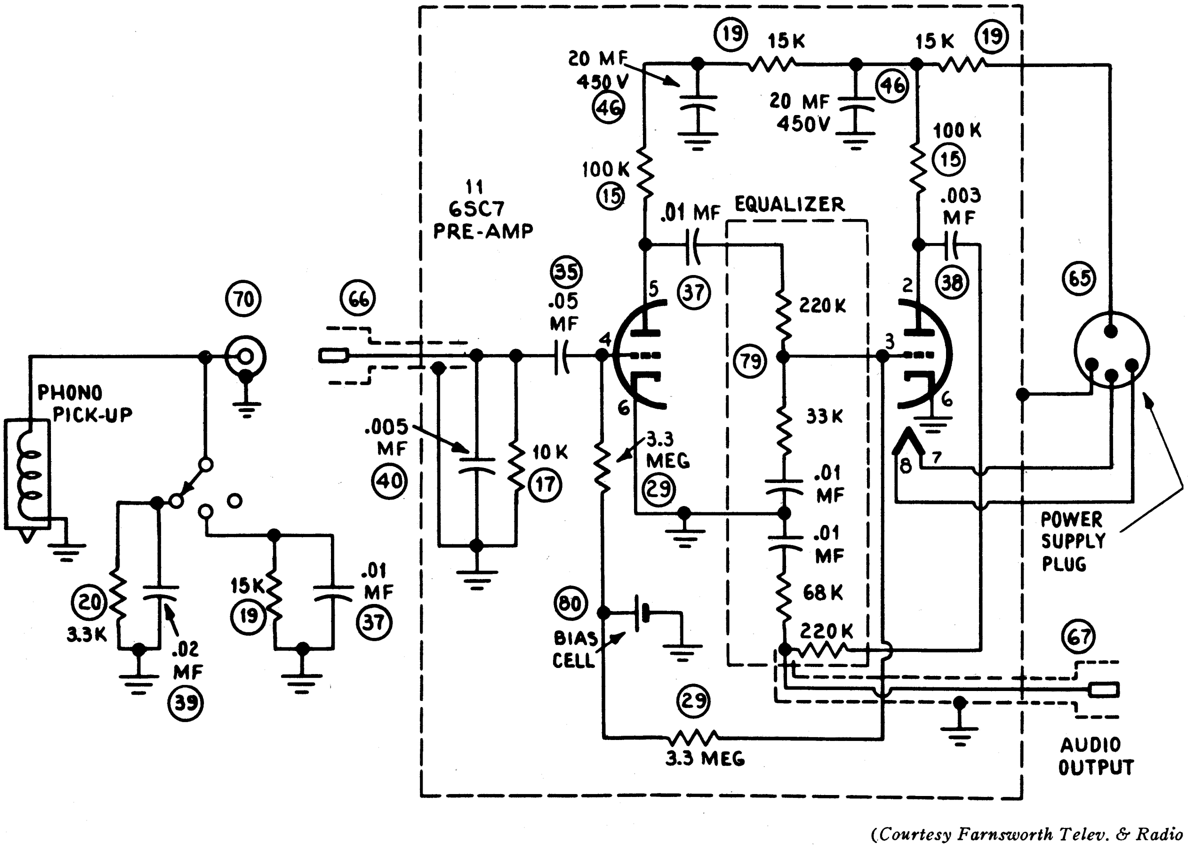
The low level of the pickup, (that is, reduction in output obtained at the expense of improved fidelity) makes necessary higher gain audio amplifiers which then present problems of hum minimization and special design. These electronic challenges have been successfully met by the designers in creating the low circuit arrangements that will be shown.

The Farnsworth P7 contains two unusual sections, the volume control input circuit and the phono equalization stage. The service data for this receiver appears on *pages 19-19 through 19-33 of Rider's Volume XIX.* The circuits to be described are shown in Fig. 2 and Fig. 3.

The volume control, 59, a 3.2-megohm variable unit (see Fig. 2), in the 6T8 grid input circuit, is of conventional design and is coupled through capacitor 37 to the 6T8 grid. A tap on the control is connected to the series circuit, resistor 8 and capacitor 38, and thence to ground.

If the arm of volume control 59 is set to the tap-spot position, the resistance-capacitance combination, 8 and 38, is a direct shunt across the input circuit of the 6T8 tube. As the impedance of resistor 8 is the same at all audio frequencies, while that of the 0.003-µf capacitor, 38, varies inversely as the frequency, the net impedance of the input circuit is noticeably reduced at the medium and high frequencies.

Conversely, the impedance of capacitor 38 (0.003-µf) is high at low frequencies, where the bass notes in music are found. The input circuit impedance, therefore, rises at low frequencies; increased gain is secured in the 6T8 triode section, and we have, in effect, "bass compensation."



(*Courtesy Farnsworth Telev. & Radio Corp.*)

Fig. 3.—The phono equalization circuit of the Farnsworth Model P7. This equalization circuit compensates for the recording characteristics.

This feature is useful since it prevents a thinning out effect, or weakening, of the bass tones with a reduction in volume level. This weakening effect is due to the characteristics of the human ear, which is less responsive at low-power levels and low frequencies. Without bass compensation, the bass would seem to "drop out" and not be evident to the ear in as great a degree as desired. The tonal quality, however, is further variable by means of 58, a 3.2-megohm potentiometer.

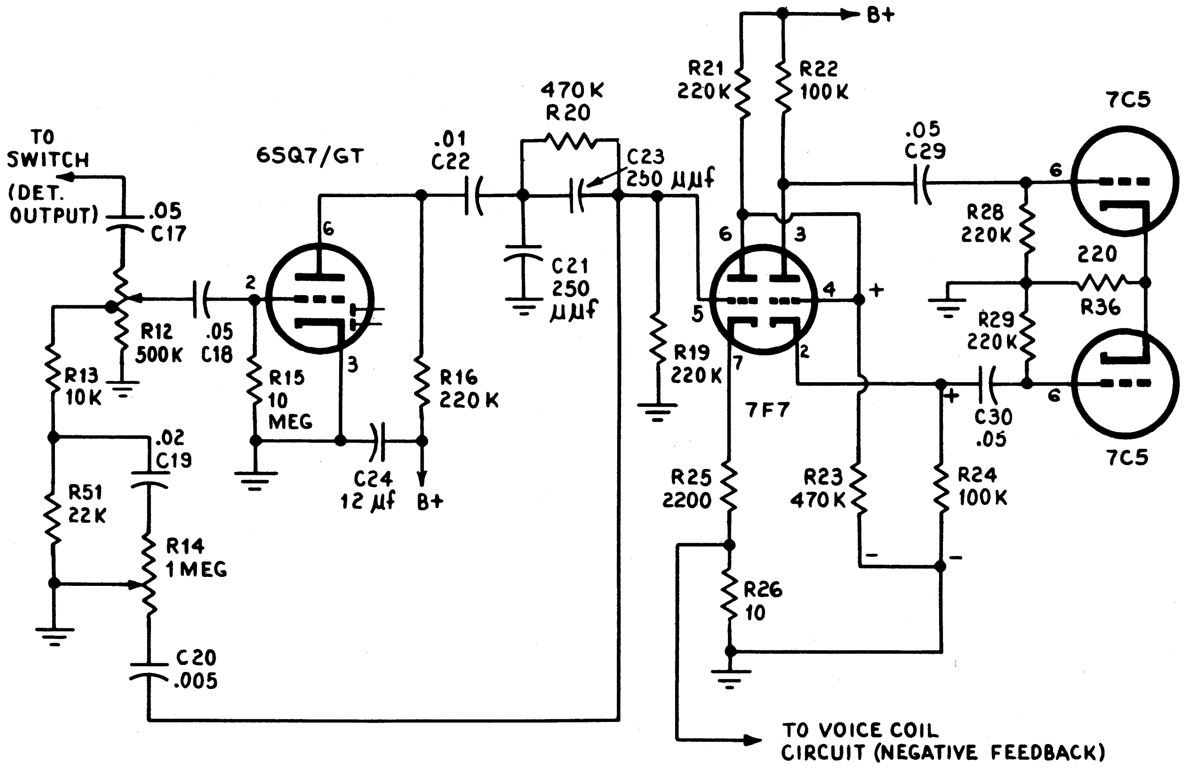
An examination of this circuit indicates that the resistance of tone control 58 is a variable shunt across capacitor 38. If the arm of tone control 58 is set so that there is a very low resistance across capacitor 38, the bass compensation effect of capacitor 38 will be nullified. Conversely, if the arm is set so that the resistance across capacitor 38 is high, the bass compensation effect will be enhanced.

With lowered resistance across capacitor 38, we also have increased the resistance between the 0.002-μf capacitor and ground. The result is that this capacitor has less shunting effect on the volume control, and the high-frequency gain of the audio amplifier is increased. The effect of capacitor 27 is to limit the entrance of i-f or r-f signals into the audio input circuit.

The phono equalizer stage of this receiver is shown in Fig. 3. Basically, the equalizer stage consists of a frequency-compensated, two-stage, resistance-capacitance coupled audio amplifier. This amplifier affords the additional gain required with the low-level phono pickup employed and also provides a low-frequency boosting action to compensate for the recording characteristic of the record played on the record player.

The high-frequency shunting effect can be varied by adjustment of the switch connected to jack 70 in the phono pickup circuit. The high-frequency response is reduced to cut out needle scratch. The amount of reduction is controlled by the switch setting in the phono circuit.

The nature of the recording process, however, is such that there tends to be a loss of induced voltage in the magnetic pickup as the recording frequency is reduced. With constant amplitude and lowered frequency in recording, the amount of flux linkage is reduced so that the voltage induced in the pickup coil is cut down. To compensate for this loss at low frequencies, suitable resistance-capacitance networks are included. These are the 33,000-ohm, 0.01-μf, and 68,000-ohm elements in the grid input and plate output circuits of the second half of the 6SC7, pins 2, 3, and 6.



(Courtesy Lear, Inc.)

Fig. 4.—Part of the audio circuits of the Lear Models 861-PC and 281-PC, showing the phase inverter circuit.

The 33,000-ohm resistor, in series with a 0.01-μf capacitor is connected from grid to ground in the 6SC7 stage. As a result, the impedance of the grid input circuit of the tube is increased at low frequencies and the input impedance goes up. Similarly, the plate output circuit impedance of the tube is increased at low frequencies, because a similar network is connected between the plate load circuit and ground. This results in low-frequency boost or compensation.

It should be noted that a common bias arrangement is used, the grid returns connecting to the common bias cell. This eliminates the high-resistance grid circuits, commonly used for convection bias, and permits grounding the cathodes which reduces the possibility of hum troubles due to grid-to-cathode heater leakage.

The 220,000-ohm resistor connected between pin 3 of the 6SC7 tube and the 0.01-μf capacitor (37) in the plate circuit of the preceding triode amplifier, (the first half of the 6SC7) is a decoupling resistor which limits the shunting effect on the grid circuit on the preceding plate circuit.

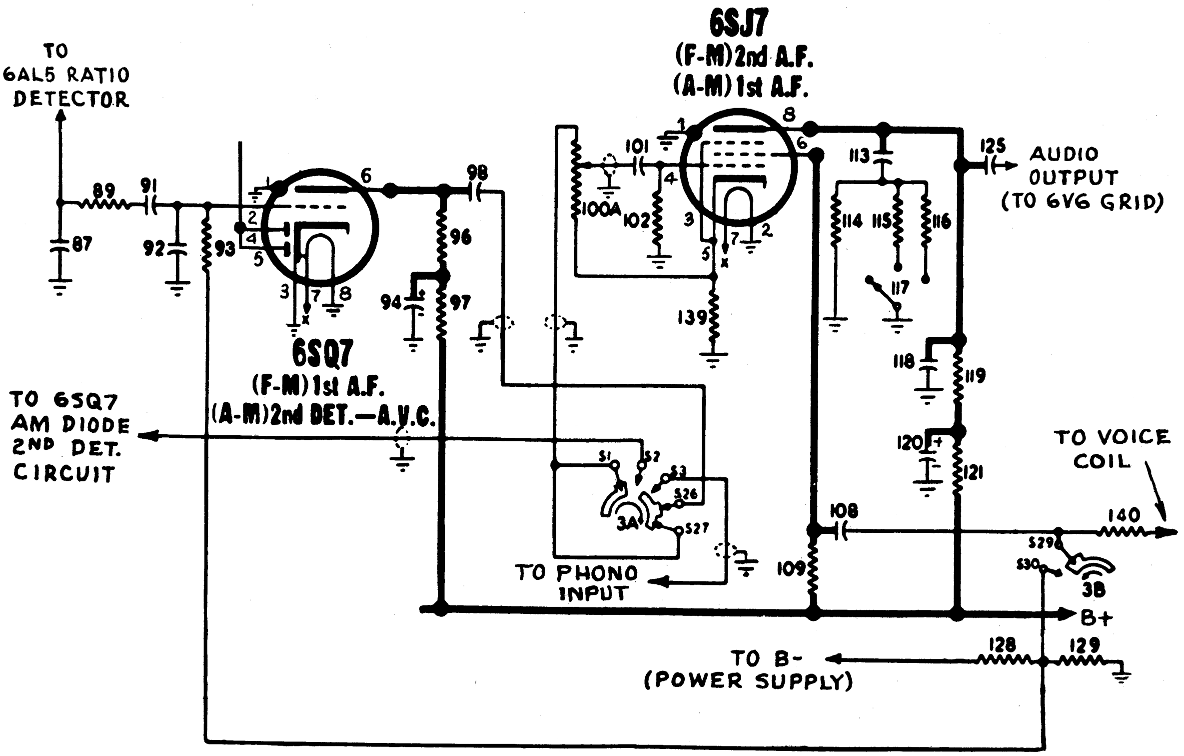
Cable 64 connects the pre-amplifier input circuit to the phono pickup circuit and cable 67 connects the pre-amplifier output circuit to the phono input jack, 70, and thence to switch circuit *F*, section 3, rear.

Lear Models 861-PC, 281-PC

In the old days of radio, when audio amplifier development was literally in its infancy, the Loftin-White direct coupled amplifier was hailed as an improvement in quality. However, it fell into discard as less critical circuits giving good performance were developed. Like the early loop antenna of radio which was discarded only to return later in modern portables as a highly developed and modern device, the d-c coupled amplifier has also returned in modern guise, and is used in these Lear receivers. But, to make it even more unusual, this circuit is a phase inverter, not merely a simple amplifier.

A simplified schematic of part of the audio circuits is given in Fig. 4. The complete data for these receivers may be found on pages 19-1 through 19-5 of Rider's Volume XIX.

The electron flow through *R24* is in a direction towards the cathode of the 7F7, pin 2. Therefore, the cathode is positive with respect to ground. The plate, pin 6, and grid, pin 4, are also positive with respect to ground. Pin 4, however, is negative with respect to 2, because the d-c voltage drop across *R24* is greater than that across *R23* by an amount equal to the bias potential.



(*Courtesy Firestone Tire & Rubber Co.*)

Fig. 5.—Switching circuits in the audio stages of the Firestone Model 4-A-60.

The operation of the phase inverter is standard and will not be discussed. Fundamentally, it is no different from that of the usual RC coupled audio amplifier except for the omission of the usual coupling capacitor.

D-C coupling results in better low-frequency response and lowered distortion. In an ordinary audio stage, the connection between pins 6 and 4 of the 7F7 tube would be replaced with a 0.01-μf coupling capacitor and the resistance values in the stage would be different.

The tone control system is not out of the ordinary, the tone being governed by adjustment of *R14*. *R14* varies the input impedance of the 7F7, pin 5, to ground, or the volume control circuit impedance, according to the setting of the arm on the 1-megohm potentiometer.

The network combination *R20-C23* forms a simple high-pass filter between the 6SQ7-GT stage and the 7F7. By its action, the low and middle frequencies are attenuated. This tends to emphasize, relatively, the high-frequency response to make up for high-frequency loss elsewhere in the receiver. *C21*, for example, eliminates r.f. in the input of the 7F7 but also attenuates the high audio frequencies and *R20-C23* may be used to achieve an equalization or compensation effect to offset such losses.

Firestone Model 4-A-60

Unusual switching circuits are not too common in receiver circuitry, but every so often an unusual design is seen, as in the Firestone 4-A-60. A means is provided for switching in or out a 6SQ7 audio stage, and for switching from f.m. to a.m. or phono, using a special three position rotary switch. The negative feedback is automatically varied, uniquely, by switching action, taking into account the phase shift that occurs as a tube is switched in and out of an audio amplifier system.

The service data appears in Rider's Volume XIX on pages 19-2 through 19-15 and a schematic of the circuits to be described is given in Fig. 5. The switch section marked *3A* performs the necessary switching operations.

With the switch in the position shown, the grid input circuit of the 6SJ7, through volume control 100A, is connected to capacitor 98 and to the 6SQ7 plate circuit. The triode grid of the 6SQ7 is connected to the ratio detector circuit through capacitor 91 and resistor 89. This switch setting is, therefore, used for f-m operation.

If the switch is now rotated clockwise to the succeeding position, the contact marked *S1* is connected to *S2* and the 6SJ7 grid circuit no longer is connected to the 6SQ7 plate circuit. It is connected, instead, to the a-m diode, second detector circuit. Switch connection *S2* traces to resistor *77*, the secondary circuit of the a-m section of i-f transformer 74 and to the diode plates, pins 4 and 5, of the 6SQ7. These connections are omitted in Fig. 5, for simplicity, but are shown in the complete schematic on pages 19-11,12 of Volume XIX.

It can also be seen that the switch segment of *3A* which formerly (first position) connected *S26* and *S27* no longer connects them and, therefore, the 6SQ7 plate circuit is not connected to the 6SJ7 grid circuit.

A serviceman finding interference between a-m and f-m programs might well look for trouble in this section, *S26-S27*, since a short circuit at this point would cause this sort of difficulty. Wires touching, or a spot of solder in the switch, could cause the trouble.

It should also be observed that as *3A* moves clockwise, *3B* moves counter-clockwise. On the first switch position, then, when f.m. is obtained, capacitor 108 is not connected directly to ground through resistor 129. This capacitor is connected to resistor 140 and the voice coil circuit. Some audio from the 6SJ7 screen is bypassed to ground through resistor 140, and through the voice-coil circuit impedance, which is relatively low.

There is no audio voltage fed back from the voice-coil circuit to resistor 129 and the 6SQ7 grid circuit. If there were such feedback present, its phase would be positive and this positive feedback would cause the audio amplifier to oscillate. Instead, the negative feedback action is obtained by introducing a portion of the voice-coil voltage into the 6SJ7 screen circuit on f-m operation.

For other switch positions, *3B* is shorted and the negative feedback voltage from the voice-coil circuit is applied to resistor 129 and the 6SQ7 grid circuit through resistor 140 and switch *3B*. On the third position of *3A, S1* is connected to *S3,* and, therefore, to the phono circuit through resistor 19. The phono cable plugs into the jack connected to resistor to 19.

Philco P-4735 Packard

This receiver is an auto radio. Its circuit is more or less standard except for a unique tone control system. Ordinary tone controls do not depend upon negative feedback action. This tone control varies the plate circuit impedance of an audio voltage amplifier (the 7B6 triode) and in addition varies the amount of negative feedback from the voice-coil circuit to the 7B6 cathode.

The service data for this receiver appears on pages 19-24 through 19-29,30 of Rider's Volume XIX. A breakdown circuit is illustrated in Fig. 6.

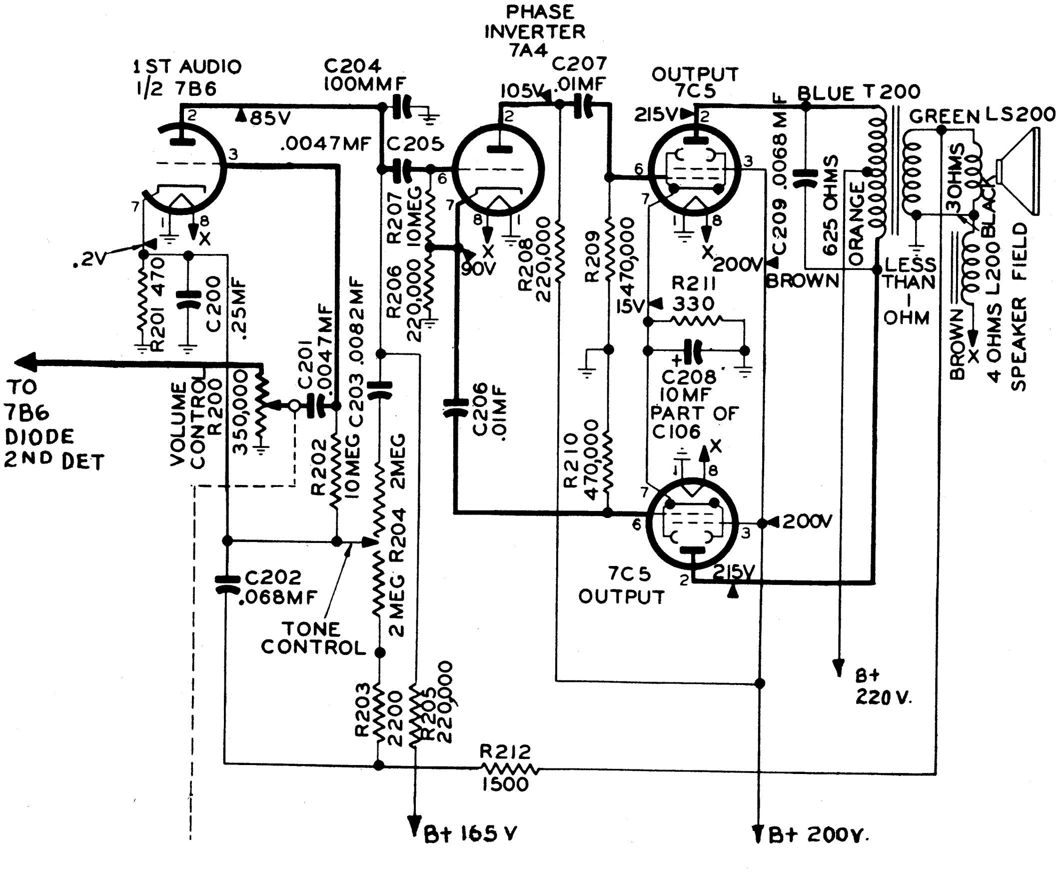
The grid, pin 3, of the 7B6 connects to a 0.0047-μf capacitor, *C207,* and through it to the 350,000-ohm volume control, *R200.* The 10-megohm grid resistor, *R207,* provides convection current bias for the 7B6 grid and returns directly to the cathode, pin 7.

The peculiar part of the circuit is that made up of *R201,* a 470-ohm resistor, and *C200,* a 0.25-μf capacitor. At first glance, this might appear to be a biasing arrangement. Actually, it is part of the negative feedback circuit. The impedance of the 0.25-μf capacitor will be low for medium and high audio frequencies, but not negligible for low audio frequencies. Consequently, a negative feedback voltage will be developed across *C200* at low frequencies.

This feedback potential is derived from the voice coil circuit through *R212,* a 1,500-ohm resistor, and the parallel network made up of *C202* (0.068 μf) and that portion of *R204* which forms a shunt across it, limited by *R203,* a 2,200-ohm resistor. The minimum resistance in shunt with *C202,* therefore, is 2,200 ohms.

With the arm of *R204* set to the lowest position, 2,200 ohms are obtained. With the arm set to the highest position, the shunt resistance across *C202* is made very high and the network effectively transmits only high-frequency and medium-frequency negative feedback—not the low frequencies. The result is attenuation of the "highs" and accentuation of the bass response. The reasons are easy to see. Suppose, for example, that at some instant of time the ungrounded terminal of the voice coil becomes positive with respect to ground during the signal cycle. The cathode potential of the 7B6, pin 7, will go up, corresponding to increased bias potential across *R201.* The decreased plate current will cause a decreased voltage drop in the 220,000-ohm plate-load resistor, *R205,* and a positive pulse will be developed in the plate circuit as the plate potential of the 7B6 rises.

This signal is now communicated to the 7A4 grid through *C205* and is shifted in phase by this tube. The



(*Courtesy Philco Corp.*)

Fig. 6.—The tone control and phase inverter circuits of the Philco Model P-4735 Packard.

output of the 7A4 is coupled through *C207* to the 7C5 grid and the 7C5 causes an additional phase shift.

Output transformer *T200* couples the 7C5 plate to the voice coil and causes an additional phase shift so that the feedback signal is of opposite (negative) phase with respect to the original voice coil signal and subtracts from it, thereby reducing the audio output at feedback frequencies. As this feedback, for the example given, occurs at medium and high frequencies, the bass is accentuated and the "highs" are cut down.

If, however, *R204* is set so that the shunt resistance across *C202* is low, the network of *C202* and *R203* will pass the low as well as the high frequencies and there will be little frequency discrimination at this point. However, low-frequency feedback voltage (not high-frequency) is developed across *C200* and there is, then, a reduction of bass response.

At the same time, the increased series impedance of the tone control and *C203* (0.0082-μf) will result in less high-frequency shunting of the 7B6 plate circuit. The high-frequency response, therefore, will be "picked up" or made greater in magnitude.

It can be seen that the section of the tone control resistance between the arm and 7B6 cathode is in series with *C203*. If this resistance is low, *C203* shunts the plate-cathode impedance of the 7B6 triode, pins 2 and 7, and attenuates the high-frequency signals. At the opposite setting of *R204, C203* is not effective as a 7B6 plate shunt and the high-frequency attenuation action is reduced to a negligible value.

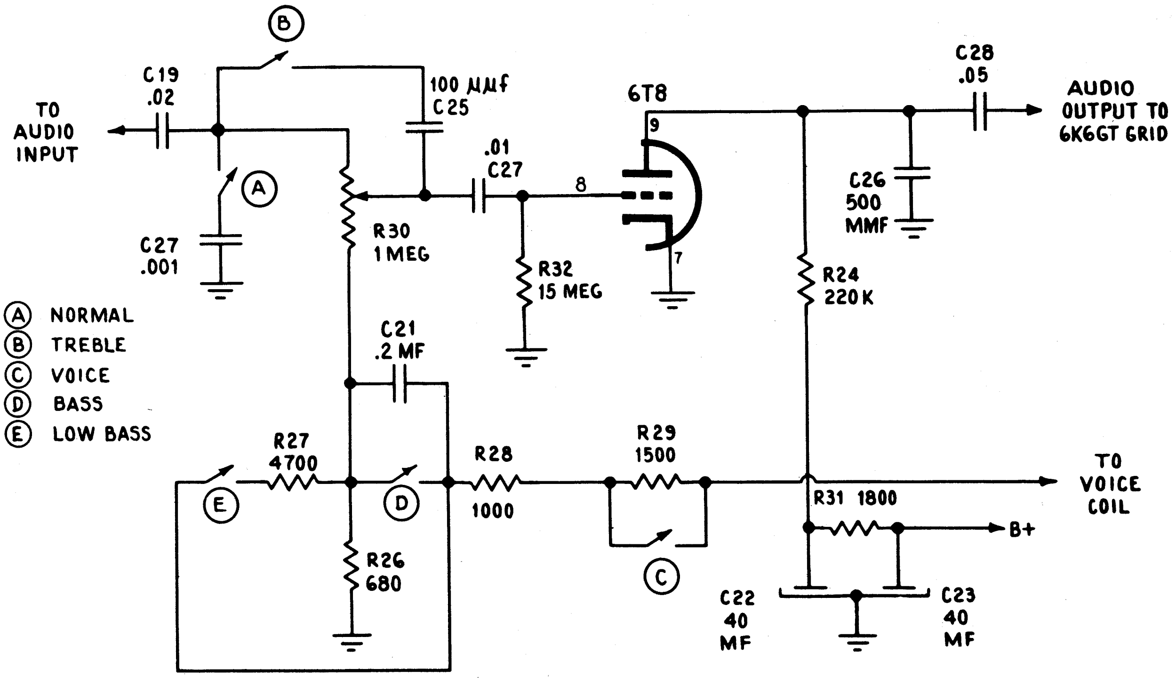
As *C200* is fairly large in size and is shunted by a 470-ohm resistor, *R201*, this combination has very little high-frequency impedance and the signal potentials developed across it occur primarily at low or "bass" frequencies when *R204* acts, with *R203*, as a shunt across *C202*. Then, the low-frequency gain and audio output are reduced, as previously mentioned.

Summing up, negative feedback from the voice coil circuit to the 7B6 cathode circuit is used for low-frequency attenuation (not medium and high frequencies).High-frequency attenuation is due to the shunting effect of *C203* when *R204* is adjusted so that *C203* is effective as a shunting element across the 7B6 plate-cathode impedance.

Zenith 9F22

Another combined form of multiplex tone control, using negative feedback in conjunction with RC components, is the Zenith chassis 9F22. Service data for this receiver appears on pages 19-31,32 through 19-35 of Rider's Volume XIX. A breakdown of the tone control circuit is illustrated in Fig. 7.

Fundamentally, the tone control system consists of five pushbutton switches in conjunction with various resistances and capacitances, that selectively (with frequency) vary either the amount of negative feed-



(*After Zenith Radio Corp.*)

Fig. 7.—A simplified schematic of the tone control circuit of the Zenith Model 9F22.

back or the impedance in a signal circuit path. This network is in the input circuit of the 6T8 audio voltage amplifier tube.

On the original diagram, the pushbuttons are marked LO Bass (closed), Bass (open), Voice (open), Treble (open), and Normal (open). The corresponding letter symbols in Fig. 7 are *E, D, C, B,* and *A*. *E* is open, on the diagram, for LO Bass, etc. The various pushbuttons may be used to obtain various degrees of tone control. The buttons are entirely independent of each other.

Button *A* switches *C27* in or out of the circuit. When in, the circuit, *C27* acts as a high-frequency shunt and the "highs," are cut down. Opening *A* boosts the high-frequency output.

B opens or closes the *C25* circuit. If *B* is closed, for the usual setting of *R30,* at medium or low volume, *C25* acts as a high-frequency path from *C19* to the 6T8 grid. The treble response is then accentuated. Opening *B* has the opposite effect — loss of treble output.

A and *B* do not depend upon negative feedback for tone control action; *C, D,* and *E* do. This can easily be seen by examination of Fig. 7.

With *C* open, the amount of negative feedback is reduced. The negative feedback voltage from the loudspeaker voice coil is applied to *R26* through *R28* and *C21*. *C21* can be shorted out by *D*. The impedance of the *C21* circuit can also be reduced by closing *E* and, thereby, shunting *C21* with *R27*. These actions result in circuit-impedance and negative-feedback voltage changes which cause tone variations.

C21 acts as a medium and high-pass filter. It possesses a considerable amount of impedance at low frequencies compared to the resistance values in the same circuit. When the amount of low-frequency negative feedback is reduced, the low-frequency gain and output of the audio amplifier system is made greater. Shorting *C21* by closing *D* makes the bass response drop off. Closing *E* will have a similar, but less pronounced, effect.

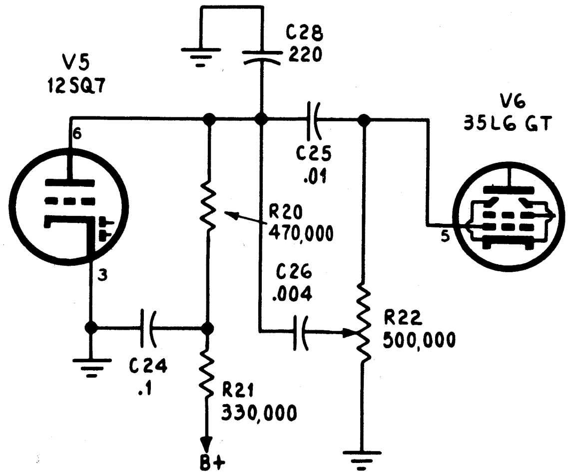
This tone control system is extremely flexible because five variables are involved, one for each pushbutton, and a great many combinations of pushbutton settings are possible.

Montgomery Ward Model 84HA-1810A

The circuit just discussed is relatively complex. By comparison, the circuit of the Montgomery Ward 84HA-1810A is simple. However, it is not quite so simple as it might appear to be at first glance.

The service data for this receiver is given in Rider's Volume XIX on pages 19-38 through 19-41. The tone control circuit is illustrated in Fig. 8. The essential elements of the control are *C26* and *R22*. *R22* also serves as the grid resistor of the *V6* stage.

When the arm of *R22* is at ground potential, *C26* forms a high-frequency shunt on the *V5* plate, and reduces the high-frequency response. When the arm is at the grid potential of *V6, C26* shunts *C25* is low at medium and high audio frequencies, it is not negligible at low audio frequencies. Shunting *C25* with *C26* results in an equivalent maximum capacitance of 0.014 μf instead of 0.01 μf, and this increase is sufficient to change the tone by a noticeable amount.



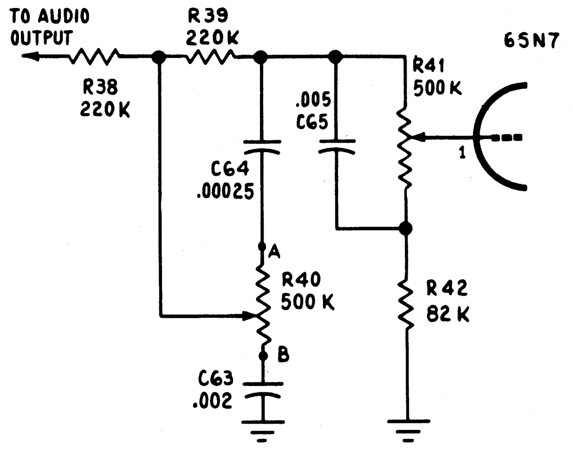
(After Montgomery Ward)

Fig. 8.—The tone control circuit of the Montgomery Ward Model 84HA-1810A.

Wilcox-Gay Models 7D42, 7D44

Another example of the use of variable impedance coupling to control tone is that in the Wilcox-Gay 7D42 and 7D44. The service data appears on pages 19-1,2 of Rider's Volume XIX and a simplified equivalent schematic of the tone control circuit is given in Fig. 9.

C64, R40, and *C63* are in series. When the arm of *R40* is moved to *A, C64* shunts *R39* and the high-frequency response is increased. When the arm is set at *B*, the high-frequency response is reduced. *C64* no longer shunts *R39*. *C63,* in series with *R40,* is a high-frequency shunt to ground, thus reducing the high-frequency response.

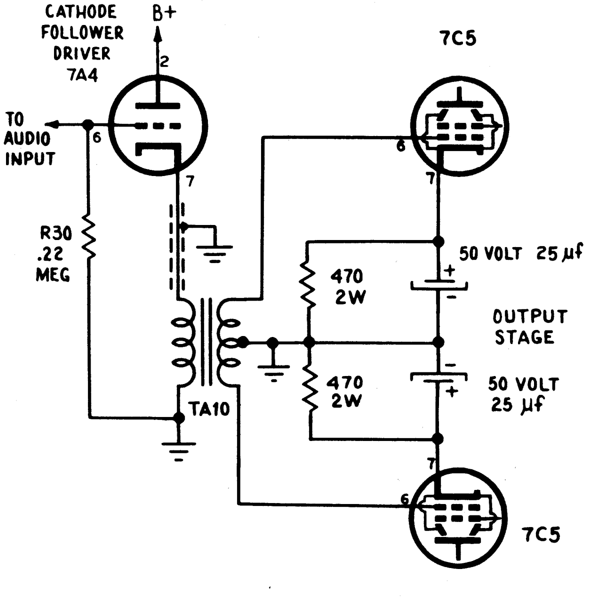


(*After Wilcox-Gay Corp.*)
Fig. 9.—Simplified schematic of the tone control circuit of the Wilcox-Gay Models 7D42 and 7D44.

Templetone G-1430

The preceding discussions have centered on tone-control circuits. Other unique audio circuits may be used as drivers or, in output stages, a peculiar circuit may be encountered. In the Templetone G-1430, the driver stage uses a cathode follower circuit. The service data for this receiver appears on pages 19-7,8 through 19-10 of Rider's Volume XIX. The equivalent circuit of the driver stage is shown in Fig. 10.

The 7A4 is used as a cathode follower. Transformer *TA10* has a low-impedance primary circuit to match the low output impedance of the cathode follower.

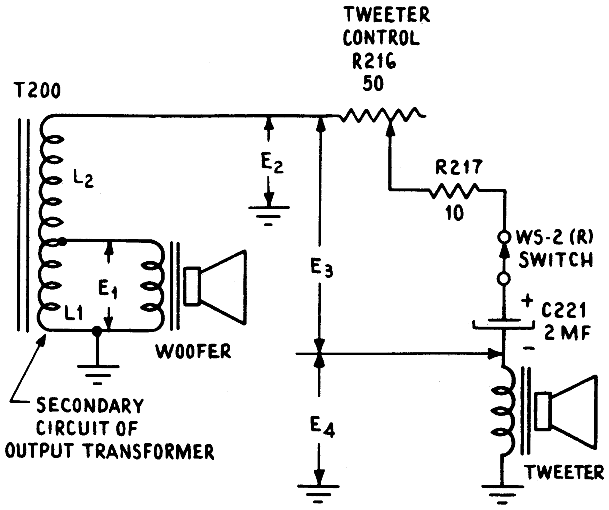


(*After Templetone Radio Mfg. Corp.*)
Fig. 10.—The driver stage of the Templetone Model G-1430 uses a cathode follower circuit.

Using low impedance circuits, class AB operation of the 7C5 beam-power pushpull tubes may be used without causing excessive distortion. The cathode follower circuit permits better regulation of the driver output due to the inherent low self-impedance of the cathode follower. A single, common resistor for the pushpull output stage is the usual rule. In this set, however, two resistors are used — one for each 7C5 cathode.

Philco 48-1274

The audio output section of the Philco 48-1274 uses an unusual tweeter circuit. The complete service data for this receiver is given on pages 19-108 through 19-129 of Rider's Volume XIX. The tweeter circuit is illustrated in Fig. 11.



(*After Philco Corp.*)
Fig. 11.—The tweeter circuit of the Philco Model 48-1274.

Basically, this circuit consists of a special secondary winding on the output transformer, the standard secondary winding, *R216* (a 50-ohm rheostat) a switch, and a 2-μf capacitor, *C221*. The regular voice coil winding, *L1*, has a signal voltage induced in it by transformer action. This voltage is applied to the woofer voice-coil circuit which handles the medium and bass frequencies.

The tweeter winding is *L2*. The voltages across L_1 and L_2 are additive, so that the voltage E_2 is considerably larger than E_1. The larger voltage is necessary to compensate for the total voltage drop, E_3, which is due to the current flowing in the series impedance circuit of *R216, R217,* and *C221*. This impedance, and, hence, the voltage, E_4, is variable by means of *R216*.

As the frequency is increased, the impedance of the tweeter voice coil rises, and less current flows in it, generally speaking, if the coil is connected to a source of emf having theoretically zero impedance. Therefore, less sound output at high frequencies is obtained. This is exactly the condition not desired. *C221* is used to compensate for this. Its impedance and voltage drop tend to decrease with frequency, equalizing the previous effect of coil impedance.

But *C221* performs still another function. At low frequencies, the tweeter voice coil impedance drops. This, for a constant voltage source, would mean a greater current and more power drawn by the tweeter. The tweeter, then, might overload, rattle badly, and produce considerable distortion. The increased impedance of *C221* at low frequencies results in controlling the amount of power fed to the tweeter and prevents overload. Further adjustments of power can be made with *R216*.