

**AUTOMATIC TUNING
CONTROL SYSTEMS**

35FR-1

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Study Schedule No. 35

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind, then answer the Lesson Questions specified for that step. Study each other step in this same way.

1. Introduction; Automatic Tuning Systems; Problems of Automatic Tuning; Mechanical Automatic Tuning Systems - - - Pages 1-9

This lesson, which completes the foundation of your Radio career, contains a wealth of thoroughly practical information on push-button tuning systems. Only fundamental facts are given—basic knowledge which will enable you to master in a jiffy the intricacies of any specific system you may encounter in your work. Answer Lesson Questions 1, 2 and 3.

2. Electrical Automatic Tuning Systems - - - - - Pages 9-14

The first time you work on a set employing this system of tuning, you'll see the importance of the fundamental facts in this section. Pay particular attention to the material dealing with adjustment of trimmer condensers. Answer Lesson Question 4.

3. Electro-Mechanical Automatic Tuning Systems - - - - - Pages 14-18

The various types of motor-driven tuning systems are classified here in such a way that you can readily recognize each type in an actual receiver and quickly figure out how it should work. Some of the most fascinating mechanisms in Radio are described here. Answer Lesson Questions 5 and 6.

4. Audio-Silencing and A.F.C.-Releasing Switches for Electro-mechanical Systems - - - - - Pages 18-23

When you tune a receiver manually, one station after another blasts from the loudspeaker. When a motor does the job, however, a simple switch keeps the set silent until the desired station is tuned in. You learn how this is done, and also study two complete electro-mechanical systems which are presented as examples. Answer Lesson Question 7.

5. Tuning Motors - - - - - Pages 23-28

Although you will invariably replace defective tuning motors rather than attempt to repair them, a knowledge of how they work is interesting and useful background information for a Radio man. Pay particular attention to the methods used for reversing these motors, because trouble often develops in the reversing switches. Answer Lesson Questions 8, 9 and 10.

6. Mail your Answers for this Lesson to N.R.I. for Grading.

7. Typical Receiver Diagrams and How to Analyze Them - - Reference Text 35X

Study carefully now the explanation of the a.c.-battery portable receiver on pages 1-6, so as to familiarize yourself with these recently-developed sets which operate from a single self-contained storage battery.

Plan to study the other circuits in this text along with the first five lessons of your Advanced Course, one circuit per lesson.

8. Start Studying the Next Lesson.

Automatic Tuning Control Systems

Introduction

AUTOMATIC tuning, which permits tuning in a desired station accurately and more or less instantly simply by pressing a lever or button, is rapidly reaching the point where it is being considered essential in a receiver. The average listener soon learns that he can obtain practically all desired programs from a few nearby broadcasting stations, with a clarity and freedom from interference which cannot be obtained in the case of distant or foreign stations. This listener then wants to be able to change quickly from one station to another without having to bother with accurate tuning, so he can choose the most interesting program. In making these things possible, automatic tuning has fulfilled a real need among radio listeners.

Automatic Tuning Systems

Although manufacturers are using many different schemes for providing automatic tuning, we can divide these into three groups according to the operating principle employed, as follows:

1. *Mechanical Automatic Tuning Systems.* By pressing a button or rotating a telephone-type dial, the listener himself provides the force required to rotate the gang tuning condenser to the setting for a desired station. This is a purely mechanical action, with no electrical switching whatsoever; tuning is essentially instantaneous.

2. *Electrical Automatic Tuning Systems.* Pressing a button switches an entirely new set of condensers, pre-adjusted to a particular station, into the tuning circuit of the receiver in place of the gang tuning condenser. The action here is entirely electrical, hence tuning is instantaneous.

3. *Electro-Mechanical Automatic Tuning Systems.* Pressing a button closes the circuit to a small electric motor, which then rotates

the gang tuning condenser to a desired station. Electrical switching here causes a mechanical force to be applied to the gang tuning condenser. A certain amount of time is required, once a button is pressed, for the motor to complete the tuning process.

In all three systems, the initial adjustments which insure accurate automatic tuning to desired stations must be made by the radio dealer at the time of the installation. Printed tabs having the call letters of the desired stations are attached to the push-buttons themselves or to the escutcheon surrounding the buttons, to identify the station selected by each button.

Problems of Automatic Tuning

Proper design and installation of an automatic tuning device does not insure accurate automatic tuning indefinitely; many other factors must be considered in the tuning device itself and in the circuits which are controlled.

Mechanical Vibration. All three automatic tuning systems are subject to vibrations and jars, especially at the time the buttons are pressed, which may alter the initial adjustments. The inaccuracies of tuning introduced by vibration may not be noticeable when local stations are tuned in on a receiver having a reasonably broad response, but when automatic tuning is employed on a highly selective receiver for the reception of semi-local or distant stations we really have a serious problem. Automatic frequency control (A.F.C.) is an effective solution, though somewhat expensive; improvements in the mechanical design of the automatic tuning system can greatly reduce undesirable effects of vibra-

tion, making tuning sufficiently accurate without A.F.C. provided that automatic tuning is restricted to local stations.

Frequency Drift. Changes in the output frequency of the local oscillator due to changes in temperature present another serious automatic tuning system problem, particularly when A.F.C. is not used. Oscillator frequency drift is most noticeable in the high-frequency bands of an all-wave receiver, but there can be appreciable frequency drift in the broadcast band as well. In a conventional manually tuned receiver, this frequency drift can be compensated for by shifting the tuning dial setting slightly after the receiver has warmed up and reached a constant internal temperature, but with automatic tuning systems the listener has no means of correcting for this drift.

Investigation has revealed that the chief cause of oscillator frequency drift in an ordinary superheterodyne receiver is *the fact that a rise in temperature will increase the dielectric constants of insulating materials which are present in the oscillator circuit.** Some dielectric materials are affected more than others by changes in temperature; when materials such as molded plastics, bakelite, low-grade rubber insulation and waxed paper insulation are present in the oscillator circuit, the result is an increase in the effective capacity in the oscillator tuning circuit as temperature goes up, producing a reduction in the oscillator output frequency

* As you will recall from earlier lessons, the dielectric constant of a material is equal to the capacity of a condenser with that material between its plates divided by the capacity of the same condenser when only air is between the plates. The higher the dielectric constant of the material used in a condenser, the higher will be its capacity.

and consequently lowering the I.F. signal frequency.

By using only dielectric materials like mica and ceramics (which are little affected by temperature) for oscillator circuit parts, engineers have succeeded in reducing frequency drift. In addition, special temperature-compensating condensers are often shunted across the regular condensers in the oscillator tuning circuit. These condensers are each made up of a fixed metal plate and a movable plate to which is connected a bi-metallic strip. Air forms the dielectric between the two plates of this compensating condenser. Increases in temperature cause corresponding changes in the shape of the bi-metallic strip, and these in turn cause the movable plate to move farther away from the fixed plate, reducing the capacity. The amount and nature of compensation required to offset frequency drift due to temperature changes varies with each receiver design.

Muting. In some mechanical and electro-mechanical tuning systems the receiver is tuned quite slowly through many stations before the desired one is reached, creating an annoying situation if the receiver is not silenced in some way during the actual tuning process. It is for this reason that the audio system is often silenced or muted during the time the tuning mechanism is being rotated.

Eliminating A.F.C. While Tuning. An A.F.C. circuit tends to hold on to stations while passing through them, so it is perfectly possible for a receiver to "hang on" to a station adjacent to that corresponding to a particular push button. For this reason a switch is built into the automatic tuning mechanism to disconnect the A.F.C. system temporarily while the station is being tuned in.

Mechanical Automatic Tuning Systems

Mechanical automatic tuning systems may be divided into two general groups according to the manner in which they are operated by the listener:

1. *Rotary or telephone dial types*, in which the listener himself provides the rotary motion which turns the tuning mechanism to the correct setting for a desired station. Automatic stops prevent him from moving beyond the correct setting.

2. *Direct push types*, in which the listener applies a direct push or force to a button or lever. Either a gear, cam or lever arrangement is used to convert this force into the rotary motion required to turn the tuning condenser to the correct setting for a desired station.

Telephone Dial Type. The basic principles involved in a telephone dial type of mechanical automatic tuning system are illustrated in Fig. 1. An analysis of the problems involved in this purely imaginary system will make it easier for you to understand the more complicated systems actually used.

In Fig. 1A the rotor and stator of a conventional tuning condenser are shown in the minimum-capacity or highest-frequency position. As the rotor meshes more and more with the stator plates, the capacity increases and the receiver tunes to a lower frequency. A circular metal disc, on the rear side of which are several metal pins or pegs, is attached to the shaft of this tuning condenser. Suppose that a 1300 kc. station can be tuned in by rotating the rotor clockwise through the angle marked θ_1 ; if the pin on this circular metal disc makes contact with a stop stud the instant this tuning condenser setting is reached, we can readily see that this 1300 kc. station will be tuned in automatically.

Now suppose that turning the tun-

ing condenser rotor through an angle θ_2 tunes in a 1100 kc. signal. A pin placed at the position marked 1100 on this circular disc will automatically stop the rotor at the correct position for this station. As many additional pins as are desired can be placed upon the circular metal disc, one for each station.

At once we see a mechanical difficulty. The pin for the 1300 kc. station will prevent the rotor from turn-

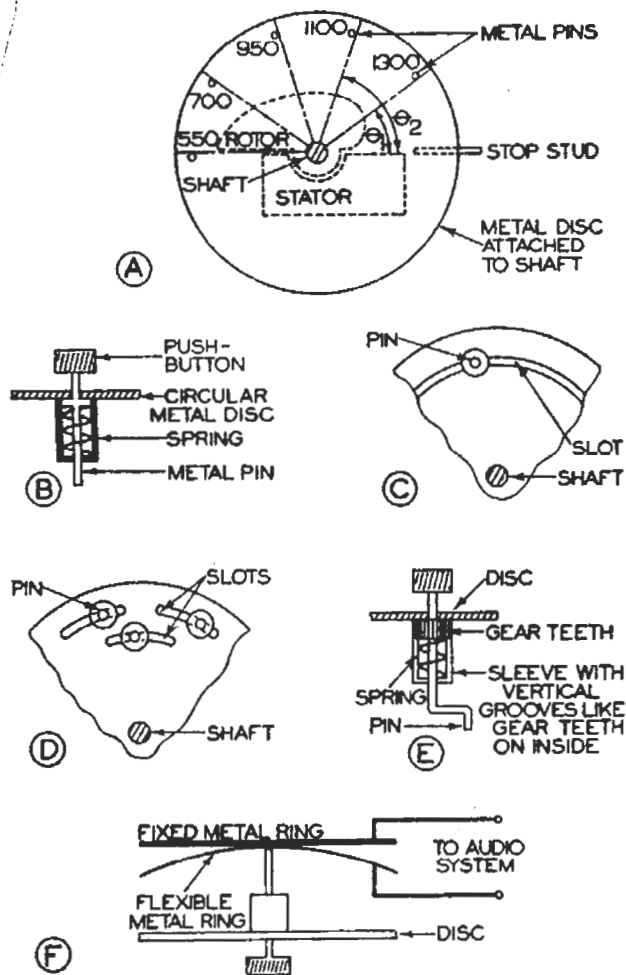


FIG. 1. Basic principles of the telephone-dial type mechanical automatic tuning system.

ing to the positions required for lower-frequency signals. Suppose, however, that the pin is made in the manner shown in Fig. 1B, with a spring which normally holds the pin outward so it can pass over the stop stud. Pressing in the button and rotating the entire mechanism clockwise causes this pin to strike the stop stud, stopping the rotor at exactly the correct position for a desired station.

Still another mechanical difficulty arises. With the construction shown in Fig. 1A, the positions of the pins cannot be changed and consequently the choice of stations is limited to those selected at the time of construction. We could eliminate this objection by mounting the pins in a circular slot like that shown in Fig. 1C, so they could be moved to the correct position for a desired station. This arrangement prevents selecting adjacent stations, however (each push-

pin is made in the form of a crank arm which can be rotated to any desired position when the button assembly with its gear teeth is pulled out of the correspondingly grooved sleeve. In this way the effective end portion of the pin can be set at any position within the swing area of this crank arm, eliminating entirely the need for slots in the circular metal disc.

To silence or mute the receiver when a button is pressed and the mechanism rotated, the pin could well

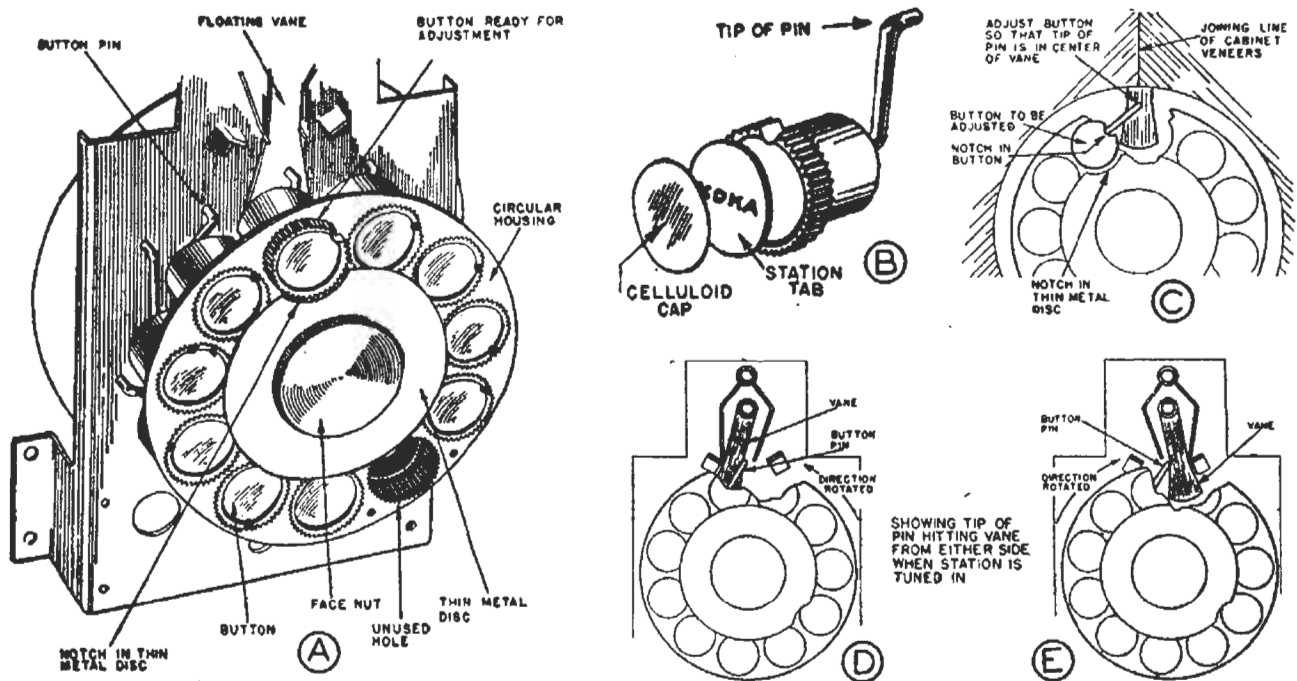


FIG. 2. Constructional details of the Emerson automatic dial mechanism as used in models AT-170, AT-181 and other Emerson receivers. When a station is tuned in, the button selected for that station will be near the top of the dial. One of the eleven holes shown at A is not used, and is covered by a blank space on the bakelite cover plate. When operating this dial mechanism, the direction in which the dial is rotated must be such that the blank space does not have to pass across the top of the dial, for the rotor plates are then either completely meshed or completely unmeshed, and cannot be rotated farther. Since this dial rotates through 360°, and ordinary tuning condensers rotate only through 180°, it is obvious that a gear drive is used between the dial shaft and the condenser shaft.

button has a certain minimum thickness), but we could overcome this difficulty with a staggered arrangement of slots, as illustrated in Fig. 1D.

Obviously, a staggered slot arrangement would not give a pleasing arrangement of push-buttons on the receiver dial. A symmetrical arrangement can be secured, however, by utilizing the construction shown in Fig. 1E; here the position of the button is fixed on the metal disc, and the

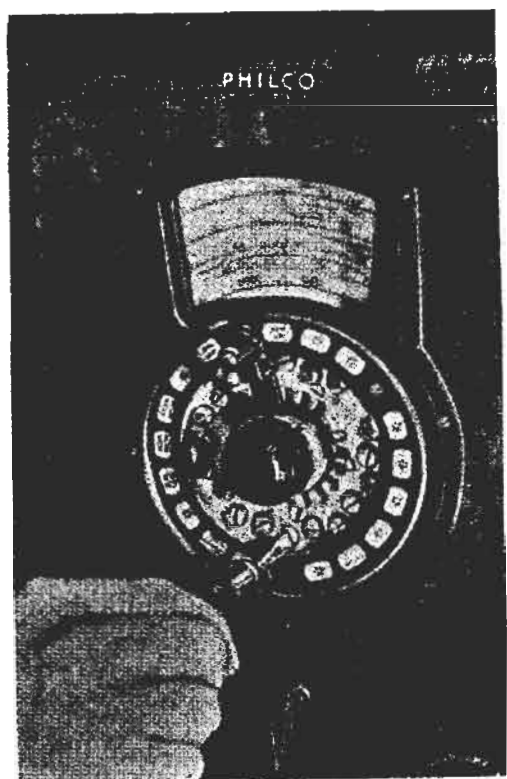
be made to depress a flexible metal ring as it moves, causing this ring to contact a fixed metal ring behind and thus short the input of an audio amplifier stage, as illustrated in Fig. 1F. Releasing of the push-button after the station setting has been reached would open the audio circuit muting switch.

Emerson Automatic Dial. A mechanical automatic tuning system of the telephone dial type is used on a number of Emerson receivers. The

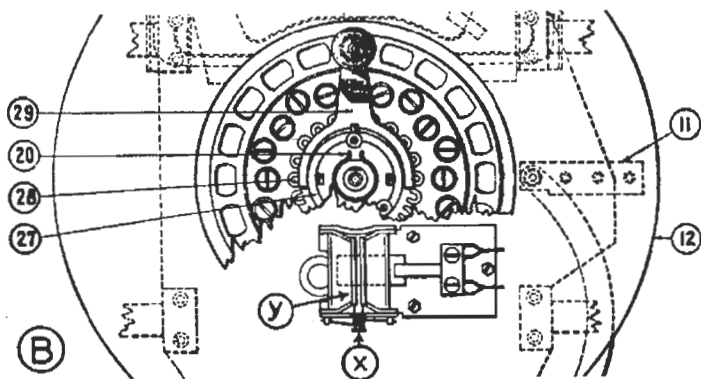
operating principle is essentially the same as that illustrated in Fig. 1E.

Constructional details of this Emerson automatic dial mechanism are shown in Fig. 2A. A number of push-buttons, each mounted on a pin which is shaped like a crank arm (see Fig. 2B), are arranged symmetrically on the circular dial. A station call letter tab, protected by a transparent celluloid cap, fits into a circular recess in the top of each button. The

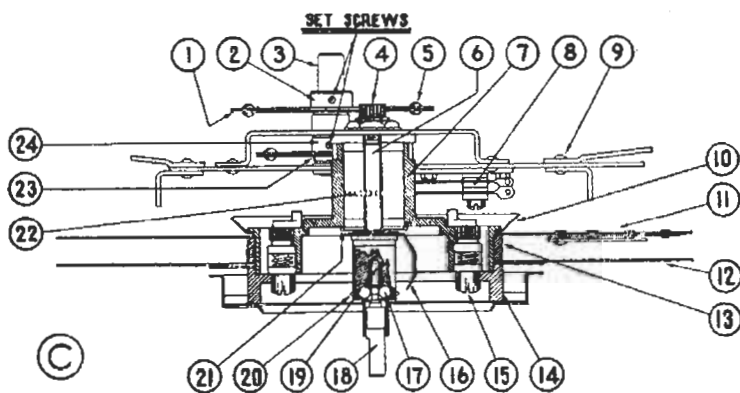
genious pivoted or floating vane serves to stop the tuning condenser assembly at exactly the same point regardless of the direction in which the dial mechanism is rotated. A spring normally holds the vane in the middle position shown in Fig. 2C, and serves also to absorb the shock when the button pin is suddenly forced against the vane. Fixed stops, shown on each side of the vane in Figs. 2D and 2E, prevent the vane from swing-



A



B



C

Courtesy Philco Radio & Television Corp.

FIG. 3. Three views of an automatic tuning system used on a number of Philco receivers which also have A.F.C. The numbered parts on these diagrams are all identified in the Philco service bulletin on automatic tuning; the important parts are also identified in this lesson.

sides of each button are grooved in much the same manner as a gear, as also are the holes in which the buttons slide; this procedure prevents a button from turning in its hole yet allows it to be moved in or out.

To operate this Emerson automatic tuning dial, the button corresponding to the desired station is pressed and the entire dial then rotated until the pin hits a stop which prevents further rotation; this tunes in the desired station correctly. In this unit an in-

ing beyond a definitely limited angle.

Since this particular mechanism is used chiefly on inexpensive receivers which do not employ A.F.C., no provisions are made for blocking the audio system or shorting the A.F.C. system during the tuning process.

Philco Automatic Tuning Dial. The general appearance of the Philco telephone type automatic tuning dial with cover plate removed is shown in Fig. 3A. In using this unit, the lever arm is swung to the position corre-

sponding to the call letters of the desired station, the knob on the end of the lever is pushed in (engaging the lever with the tuning dial) and the entire mechanism is rotated in either a clockwise or counter-clockwise direction (only one direction will be correct) until a stop is reached. A click will be heard an instant before the knob reaches its final position, signifying that a spring-operated

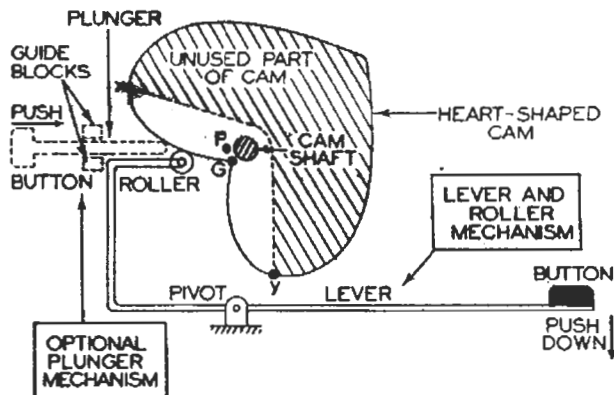


FIG. 4A. Operating principles of direct push types of mechanical automatic tuning systems employing a cam with either a lever and roller or a plunger. Pressure on the button in the direction indicated by the heavy arrow serves to rotate the gang tuning condenser (geared to the cam shaft) to the correct setting for the station assigned to that button.

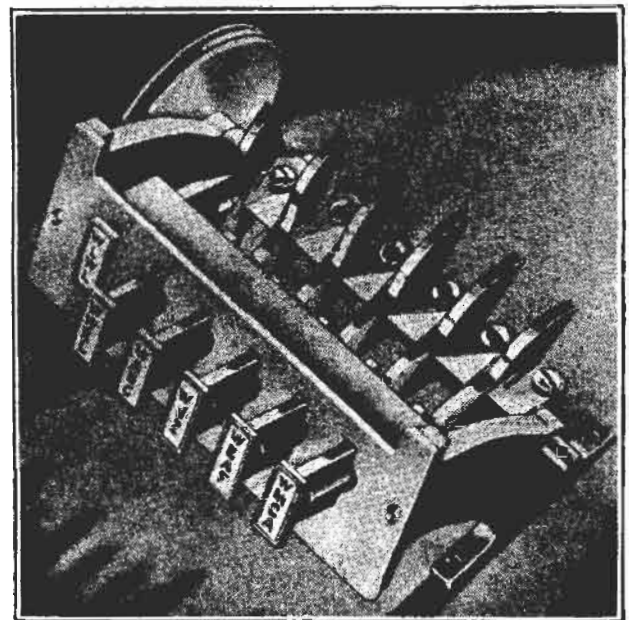
switch has temporarily shorted the A.F.C. system in order to allow the desired station to "take hold."

Constructional details of this mechanism can be seen by studying the front-view diagram of Fig. 3B and the cross-section view in Fig. 3C. Pushing in the knob at the upper or outer end of the lever 29 does three things: 1, it causes a metal pin on this lever to set itself in one of the holes marked 28 (Fig. 3B); 2, it depresses the key corresponding to the desired station (one of these keys is shown as item 15 in Fig. 3C); 3, it causes insulated switch blade 16 to make contact with shaft bushing 19, thus shorting the audio system during the tuning process.

With the lever button depressed, the entire dial mechanism is rotated until the depressed key engages with the stop assembly (x in Fig. 3B).

Note the long slit which locks the key pin. On this assembly, item y is a pivoted flapper; movement of the pin over this closes switch contacts 8 in Fig. 3C, shorting the A.F.C. system temporarily. When the pin falls into the recess between the two flappers, this switch opens, and the A.F.C. system then makes the final correction in tuning. Releasing the pressure on the knob and lever opens the audio shorting switch, making the program audible.

In setting up this Philco automatic dial tuning system, a station is first



Courtesy A. W. Franklin Mfg. Corp.

FIG. 4B. Franklin direct push type automatic tuning unit, an example of the mechanism shown in dotted lines at the left in Fig. 4A. Note that all cams are on the same cam shaft, with a separate locking screw holding each cam in its correct position for a particular station. The cams used here have the same shape as that shown in Fig. 4A, except that the unused part of each cam (the shaded portion in Fig. 4A) is cut away.

tuned in the conventional manner, with the A.F.C. or magnetic tuning control in its "out" position. The key (item 15) at the bottom of the dial is then adjusted by inserting a screw driver in its slot, pressing the key in slightly so it is free to rotate, then turning the key until a click is heard. The receiver is now tuned for maximum output by turning the key back and forth slightly. This procedure is

repeated for each other station selected.

Direct Push Types of Mechanical Automatic Tuning Systems. A number of different mechanisms are being used to convert an ordinary direct push on a button into rotation of a tuning condenser to the correct setting for a desired station; let us look over a few of them.

First of all, keep in mind that a gang tuning condenser must be rotated through an angle of 180° (one-half of a complete revolution) to cover an entire tuning band. Because of the mechanical difficulties involved in converting a direct push into a full 180° of rotation, it is customary to use an auxiliary shaft which can be rotated through a maximum angle of 90° or less, with the gears between this shaft and the tuning condenser shaft to step up this rotation to the required amount.

Heart-Shaped Cam with Lever and Roller. In receivers employing this

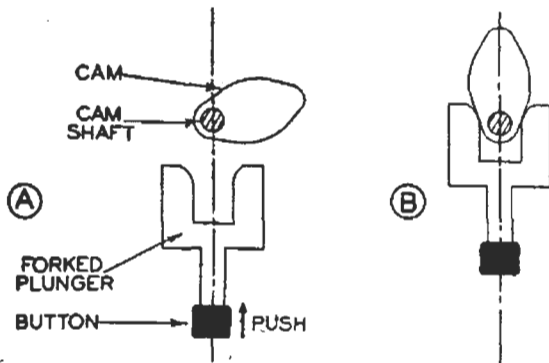


FIG. 5. Egg-shaped cam and plunger mechanism used in the mechanical automatic tuning systems of some Philco receivers.

particular tuning unit, there will be one complete set of parts like those in Fig. 4A for each station which is to be tuned automatically. A downward pressure on the station-selecting button is applied to the heart-shaped cam through a roller at the other end of the lever arm, forcing the cam to rotate to a position which brings the roller to point G, closest to the center of the shaft. For example, with the

cam in the position shown, pressure on the button will cause the cam and shaft to rotate clockwise. The cams for the different stations are mounted side by side on a cam shaft which is geared to the tuning condenser shaft,

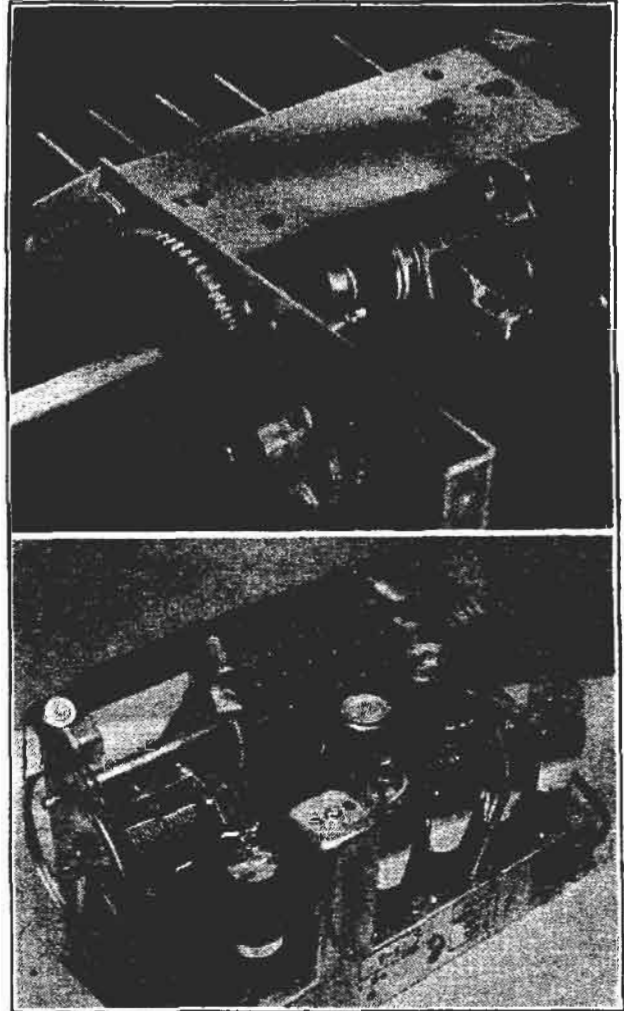
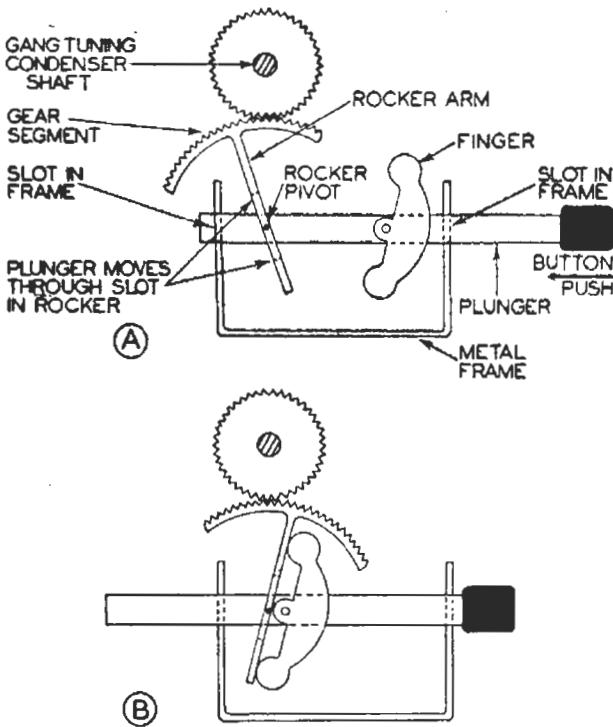


FIG. 6A (above). Mechanical automatic tuning unit used in a number of Philco receivers. One plunger is in its depressed position, and its forked end is holding the corresponding cam in the position shown in Fig. 5B.

FIG. 6B (below). Chassis of Philco model 39-17 superheterodyne receiver, with automatic tuning mechanism visible at the right of the gang tuning condenser. Bakelite buttons are pushed over the ends of the six plungers after the chassis is mounted in its cabinet. Note the gear drive between the cam shaft and the tuning condenser shaft. The tuning control knob is placed on the cam shaft; the locking screw which holds all cams rigidly in position (by friction with spacing washers) fits into the center of this knob.

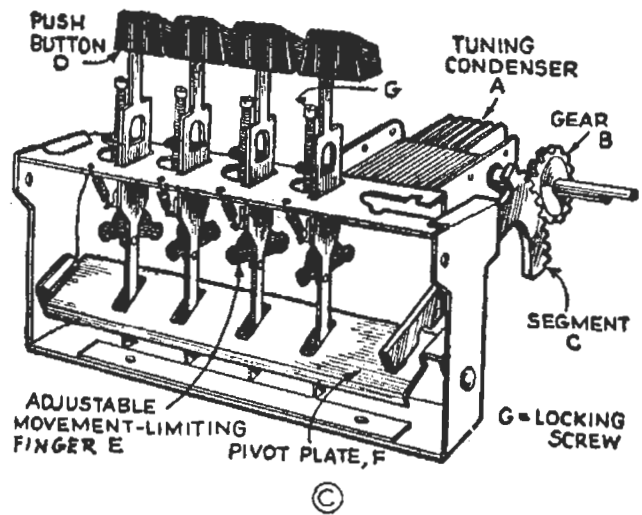
the cams being separated by spacing washers and held in position by friction. A mechanical locking device is provided for locking each cam rigidly in position once it is adjusted for a station.

Cam with Plunger. In some systems a straight plunger, with or without a roller, is used in place of the lever, as indicated by the dotted lines at the left in Fig. 4A. The push-button tuner shown in Fig. 4B is an example of this particular mechanism; a $\frac{5}{8}$ -inch movement of the button here provides a 60° maximum rotation of the cam shaft, and this can be stepped up to 180° with a 3-to-1 gear ratio.



tween the cam shaft and the tuning condenser shaft is clearly visible in this photo.

Finger and Rocker. A finger and rocker mechanism which provides mechanical tuning in still another manner is illustrated in Figs. 7A and 7B, "a sketch of this unit" is shown in Fig. 7C. For each station there is a plunger (flat metal strip) sliding freely through two slots in opposite sides of a metal frame. At



Courtesy Radiocraft.

FIG. 7. The diagrams at A and B show one of the finger and rocker units used in the mechanical automatic tuning systems of some Crosley receivers (including the Crosley Safety-Tune auto radio), while the sketch at C shows the complete tuning unit with a gear drive to a gang tuning condenser. Tightening the screw on the plunger locks the finger rigidly in position. To set up a button for a station, this screw is loosened so the finger can rotate, the button is pushed all the way in, the station is tuned in manually, and the screw is tightened to lock the finger at the correct angle. A spring returns the button to its normal position when pressure is released, leaving the tuning condenser at the correct setting for the desired station.

Egg-Shaped Cam with Forked Plunger. In another system of the direct push type, illustrated in Fig. 5A, the cam is somewhat egg-shaped and the roller is replaced by a U-shaped or forked metal piece. Pressing the button makes the forked plunger take the position shown in Fig. 5B, holding the cam in a definite position. Photographs of the Philco version of this arrangement appear in Figs. 6A and 6B. The gear drive be-

one end of this plunger is the push-button; clamped to one face of the plunger is a metal "finger" which can be set at any desired angle to the plunger and held in position by a locking screw and clamp arrangement (omitted from Figs. 7A and 7B to simplify the diagrams, but shown in Fig. 7C). Pressing in a button makes the rocker rotate to the same angle as the finger; on the rocker is a gear segment which meshes with a gear on

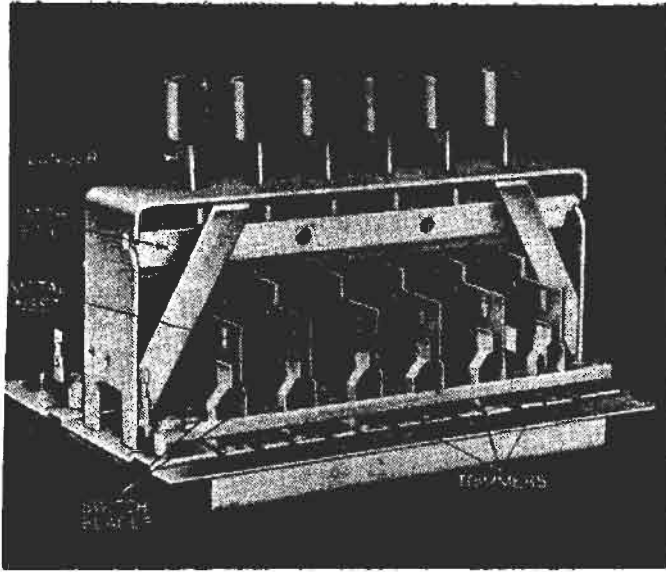


FIG. 8A. Sprague electrical automatic tuning unit with built-in trimmer condensers. The switch blades in the foreground are normally held apart by the strip of insulating material mounted on each plunger; when a button is pressed, the metal inset moves down between the blades, shorting them and closing the circuit to one set of trimmer condensers.



Courtesy Sprague Products Co.

FIG. 8B. Bottom view of the Sprague unit, showing the trimmer condensers and their adjusting screws. Each push-button controls one upper and one lower trimmer on this gang assembly. One terminal of each trimmer is grounded to the frame of the unit, and this frame is in turn grounded to the receiver chassis.

the tuning condenser shaft and thus provides the correct tuning condenser setting for the station assigned to that button.

In many of the receivers which incorporate a mechanical automatic tuning system, some form of compensating condenser is employed in the oscillator circuit to compensate for temperature changes which might otherwise alter the accuracy of the automatic tuning system. The tuning action is so rapid that audio silencing switches are usually omitted.

Electrical Automatic Tuning Systems

Instead of rotating the tuning condenser when a new station is desired,

electric automatic tuning actually removes the variable condensers in the tuned circuits and replaces them with new condensers which were previously adjusted to the correct values for that particular desired station.

Push-button switching mechanisms like that shown in Fig. 8A are used in electrical automatic tuning systems. When one of the buttons on this unit is pressed down, the button which formerly was down is released, removing that set of condensers, and an entirely new set of condensers is switched in. The entire process of switching is practically instantaneous. It is common practice to mount the set of pre-adjusted condensers right on the switching mechanism. In Fig.

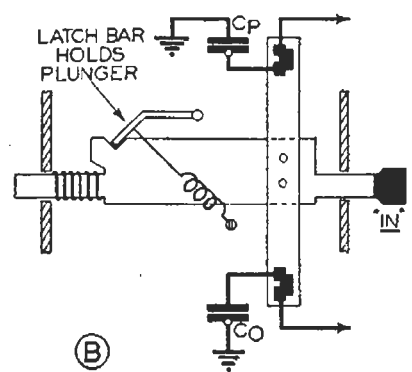
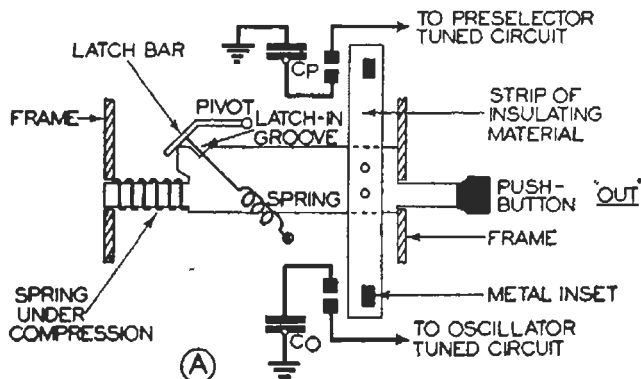


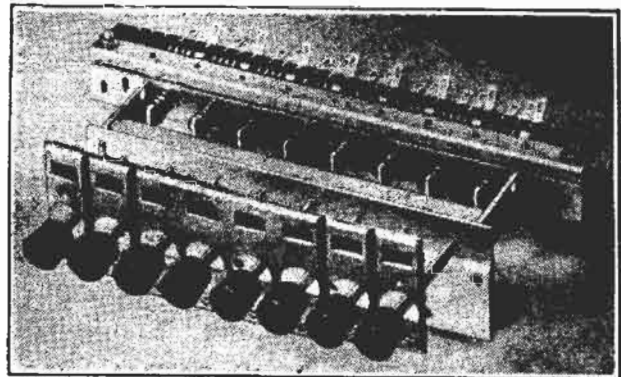
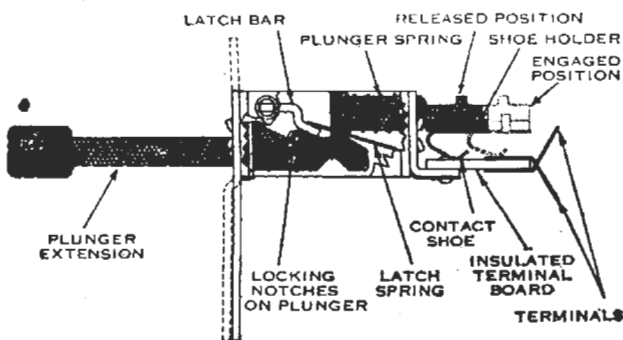
FIG. 9. These two diagrams show the construction of one of the push-button assemblies in the Sprague unit (Fig. 8) and also show the relative positions of the parts when the button is in its normal or "out" position (A) and when the button is pushed "in" (B).

8B is a bottom view of the unit in Fig. 8A; as you can see, there are two trimmer condensers, each adjusted by a screw, for each of the buttons on the unit.

Now let us see exactly what happens when one of the push-buttons in the unit shown in Fig. 8 is pressed. The diagram in Fig. 9A gives a side view of the button assembly in its *out* and *open* position, while that in Fig. 9B shows the same assembly with the button pushed in. First of all, observe that the button is on the end of a sheet metal plunger which slides freely in and out through slots in the frame of the switching unit. A spring

tuned circuit of the receiver. The fact that one terminal of each tuning condenser section in a receiver is grounded makes it possible to use this simple switching system.

A separate push-button and plunger assembly like that shown in Fig. 9A is required for each station which is to be automatically tuned, but only one latch bar is needed for the complete switching mechanism. Pressing of any button lifts up the latch bar; this serves to release any other plunger which may have been previously pushed in and held by the latch bar. Since stations can be tuned in just as fast as the buttons can be



Courtesy P. R. Mallory & Co., Inc.

FIG. 10. Photo and cross-section diagram of Mallory-Yaxley multiple push-button switch. Trimmer condensers are not built into this unit, but can be mounted either on the sides or at the rear of the unit; each trimmer must then be connected to one of the soldering lugs on the insulated terminal board. This unit is available with many different combinations of contacts and terminals, and can be used to switch in three trimmer condensers at a time in receivers having three tuned circuits.

under compression, acting between the plunger and the left-hand frame in Fig. 9A, normally holds the plunger entirely out. When the button is pushed in, a pivoted flapper or latch bar falls into a groove in the plunger, as indicated in Fig. 9B, preventing the plunger from returning to its normal *out* position.

A strip of insulating material, with a U-shaped metal piece set into each end, is attached to the plunger. Pressing in the button causes each metal piece to move between a pair of switch contacts, shorting the contacts and thus inserting a set of pre-adjusted trimmer condensers in the

pressed, there is no need for audio silencing switches or A.F.C. releasing switches.

Although many different forms of switching mechanisms are being used for condenser substitution purposes in electrical automatic tuning systems, all have essentially the same construction as that shown in Fig. 9. There will be some form of plunger for each push-button, with switching contacts or blades mounted on the plunger but usually insulated from it. Likewise there will always be a latch bar to hold a plunger in when a button is pressed. A photograph of one other switching mechanism employing

these principles, together with diagrams showing its construction, are given in Fig. 10.

Typical Circuits. In Fig. 11 is shown the circuit for the preselector and oscillator sections of a typical superheterodyne receiver employing two tuned sections. Tube *VT* is a conventional pentagrid converter. Condenser C_P of the gang tuning condenser tunes the preselector coil L_2 to resonance, while C_O tunes the oscillator coil L_3 . Only three connections need be made to this circuit to incorporate electrical automatic tuning; one lead from the push-button switching mechanism goes to point *x*, which is the stator terminal for preselector tuning condenser C_P . Another lead goes to point *y*, which is the stator terminal of the oscillator tuning condenser C_O , and the third lead is grounded to the tuning condenser frame or to the chassis.

Semi-Automatic Connection. Observe that the gang tuning condenser section in Fig. 11 is still present in the circuit after the push-button pushing mechanism is connected; this is known as a semi-automatic connection, because the gang tuning condenser must be turned to its minimum-capacity (highest frequency) setting before automatic tuning can be used. When this is done, pressing of any one of the four station buttons serves to tune in a station. For example, pressing button 1 places trimmer condenser C_{P1} across the preselector tuned circuit and places trimmer condenser C_{O1} across the oscillator tuned circuit.

Since an automatic tuning system provides for reception of only a limited number of stations, it is obvious that some means for restoring manual tuning must be incorporated in the receiver. (Manual tuning cannot be used when the automatic tun-

ing system is connected, because of the fact that one set of trimmer condensers will always be in shunt with the gang tuning condenser section.) An extra button is often provided on a push-button tuning for the sole purpose of restoring manual tuning. This button is designated as *M* in Fig. 11, and serves to open the two ungrounded leads to the push-button switching mechanism. Pressing button *M*, which is often marked

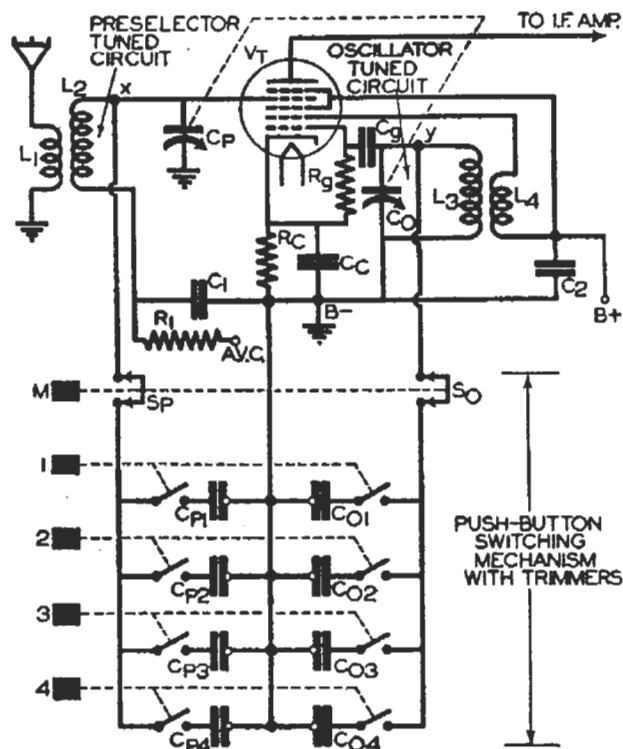


FIG. 11. This circuit shows a semi-automatic connection of an electrical automatic tuning unit to a superheterodyne receiver employing a pentagrid converter tube. Pressing button *M* restores manual tuning; pressing any other button inserts a set of preadjusted trimmer condensers (one trimmer for the oscillator tuning circuit and one for the preselector) in the tuning circuits of the receiver, after first breaking previous trimmer connections. Each set of trimmers is adjusted initially to exact resonance for one desired station.

MANUAL, opens switches S_P and S_O and at the same time releases any other button which may have been pressed in.

Full-Automatic Connection. Naturally, it is somewhat of a nuisance to turn the tuning dial to its highest frequency setting whenever automatic tuning is desired. This undesirable characteristic of the semi-automatic connection can be eliminated by

modifying the switching mechanism so it will disconnect both sections of the gang tuning condenser from the receiver circuit whenever automatic tuning is used. Fig. 12A illustrates one way in which this can be accomplished, and Fig. 12B shows how the MANUAL button could provide the required double-pole, double-throw switch action.

Oftentimes it is undesirable to have long leads running from the receiver chassis to the push-button tuning mechanism (because of the inductance of these leads); for this reason

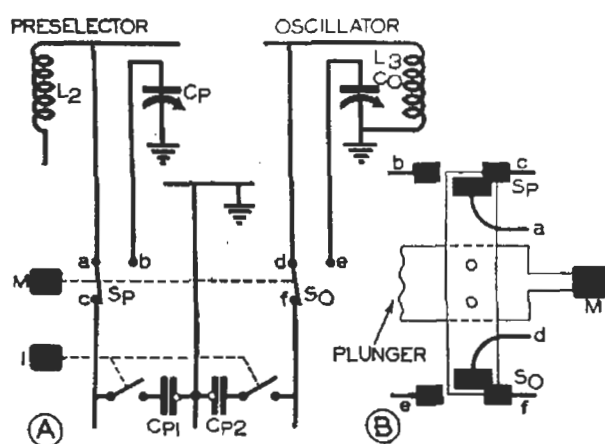


FIG. 12. At A is a simplified circuit showing a full-automatic connection of an electrical automatic tuning unit to a superheterodyne receiver having two tuned stages. Pressing button M restores the gang tuning condenser connections and breaks the two connections to the tuning unit; pressing any other button releases M, disconnecting the gang tuning condenser sections, and inserts a set of trimmers in the tuned circuits. The sketch at B shows how this switching could be accomplished with a plunger like that in Fig. 9.

the manual-tuning switch is sometimes incorporated in the band-changing switch. In this case one setting of the switch might be labeled BROADCAST MANUAL and another setting labeled BROADCAST AUTOMATIC. In one receiver the change-over from manual to automatic operation is accomplished by pushing the wave band switch knob in or out; this particular switch also operates dial lights which illuminate the words *automatic* or *manual* to indicate which particular tuning system is being used.

Tuning by Coil Substitution. Just as with mechanical automatic tuning systems, the oscillator tuned circuit can be the cause of frequency drift in an electrical automatic tuning system. To secure better frequency stability, some manufacturers are using a push-button switching system to substitute adjustable coils instead of trimmer condensers in the oscillator tuned circuit. Special coils employing pulverized iron cores which can be moved by means of an adjusting screw to change the inductance of the coil are used for this purpose. A fixed condenser, usually of the temperature-compensating type, provides the necessary capacity for the oscillator circuit. Because of the higher cost of variable-permeability iron core coils, they are usually used only in the oscillator circuit. A slight change in trimmer condenser capacity will have far more de-tuning effect in the oscillator tuned circuit than in a preselector tuned circuit.

Initial Adjustments. It is neither advisable nor necessary to make each adjustable part in an electrical automatic tuning system cover the entire 540 to 1500 kc. broadcast band. A more economical and stable construction is secured by limiting the tuning range of each adjustable coil or trimmer condenser to a definite section of the broadcast band; for example, one set of adjustable parts may be designed to tune from 540 to 900 kc., another set may cover the range from 700 to 1300 kc., and the third and final set might cover the range from 1000 to 1500 kc. Notice that there is enough overlapping between these three groups so that a station near the limit of one group may also be tuned in by another group.

Receivers employing electrical automatic tuning are usually adjusted by the servicemen as a part of the

installation job, rather than by the listener. First of all, it is wise to prepare a list of the stations which have been selected by the listener for automatic reception. Assign one push-button to each of these stations, making sure that each button is in the proper frequency group, as specified in the instruction manual supplied with the set. The station call letter tabs, also supplied by the manufacturer, can now be affixed to the buttons or the escutcheon. The receiver should be turned on during this preliminary work, so it can warm up for twenty to thirty minutes and reach its stable operating temperature. If you suspect that the I.F. amplifier may be out of alignment, be sure to check this and realign if necessary before making any preselector and oscillator adjustments.

To set up a button for a station, tune in the station manually and note the nature of its program at that time. Now push in the button assigned to that station (if a semi-automatic connection is used, be sure to turn the tuning condenser to its minimum-capacity position before adjusting any trimmer condensers); locate the oscillator trimmer condenser or variable inductance controlled by that button, and adjust until the desired station is heard with maximum audio output. For best results do not depend upon your ears, but use an output indicator or the tuning indicator in the receiver (if available). With this done, locate the preselector trimmer condenser which is controlled by this button and adjust for maximum output in the same manner; you will note that this adjustment is quite broad, whereas the setting of the oscillator trimmer was quite critical. Repeat this procedure for each other push-button.

Radiotricians sometimes prefer to

use a signal generator which is set to the station frequency and fed into the receiver input as a guide for initial adjustments of the trimmer condensers; if the signal generator is quite accurately calibrated, only slight additional adjustments of the trimmers will be needed after the signal generator is removed.

Oftentimes the initial adjustments will change slightly during the first

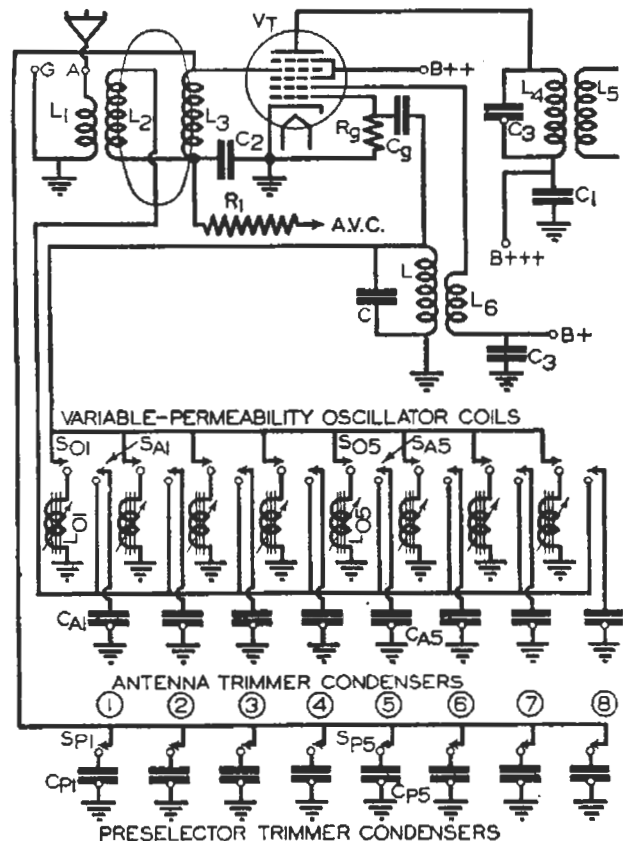


FIG. 13. Circuit diagram of the tuned sections of the RCA-Victor model HF-1 high-fidelity broadcast band superheterodyne receiver, designed for automatic reception of eight different local stations. Eight push-buttons control the electrical automatic tuning system; there is no tuning dial or knob.

few days after they have been made. When the receiver does not have A.F.C., it is a good idea to return in about a week and make final adjustments which will correct for any changes which may have occurred.

RCA-VICTOR Model HF-1. This is an excellent example of a receiver employing a push-button switching mechanism for substituting a pre-adjusted variable inductance in the

oscillator tuned circuit and substituting a pre-adjusted trimmer condenser in each of the two preselector tuned circuits. No manual tuning control is provided. The circuit diagram for the tuned sections of this receiver is given in Fig. 13; vacuum tube *VT* is a conventional pentagrid converter tube, with the first two grids acting as the oscillator grid and plate respectively. The oscillator tuned circuit is made up of condenser *C*, fixed inductance *L*, and one of the adjustable-core oscillator coils shown just below in the diagram. Coil *L* acting alone with condenser *C* resonates below the correct frequency, and the pre-adjusted coil which is shunted across *L* by the switching mechanism lowers the net inductance in the circuit exactly the correct amount for a particular station. Coil *L₆* serves as the oscillator feed-back coil.

Two tuned circuits in the preselector make up a band pass tuner. In one of these circuits is fixed inductance *L₂* and one of the pre-adjusted antenna trimmer condensers which is controlled by the push-button switching mechanism; the other preselector tuned circuit is made up of coil *L₃* and one of the trimmer condensers. All three input circuit coils, *L₁*, *L₂* and *L₃*, are mutually coupled inductively.

Provisions are made for automatic tuning of eight different stations. The switching action is as follows: Pressing button 1 closes switch *S₀₁*, shunting *L₀₁* across oscillator coil *L*, and simultaneously closes switches *S_{A1}* and *S_{P1}*, inserting pre-adjusted trimmer condensers *C_{A1}* and *C_{P1}* in their respective preselector tuned circuits. Pushing in button 5 would first release all switches controlled by button 1, then close switches *S₀₅*, *S_{A5}* and *S_{P5}*, which would place parts *L₀₅*, *C_{A5}* and *C_{P5}* in the tuned circuit.

Electro-Mechanical Automatic Tuning Systems

Electro-mechanical automatic tuning systems can be divided into two general types according to the method of operation involved: 1, *the non-homing system*; 2, *the self-homing system*. Each type will generally include the following sections:

1. A small electric motor which drives the gang tuning condenser through speed-reducing gears and which can be reversed by means of a switch.

2. A switching mechanism which can be adjusted to stop the driving motor at predetermined positions which correspond to the gang tuning condenser settings for desired stations.

3. A group of push-button-controlled switches, each of which starts the motor and connects into the motor circuit the proper switch mechanism for stopping the motor at the correct point (these may be located at any reasonable distance away from the receiver, making remote control tuning possible).

4. A means for silencing the audio system of the receiver during the interval when the motor is driving the tuning condenser, in order to prevent annoying blasts of sound as the receiver is tuned past strong undesired stations; a means for releasing temporarily the A.F.C. system while the tuning motor is in motion or just after it stops, in order to allow the desired station to "take hold" of the A.F.C. system.

In the non-homing system the motor always drives the variable condenser in the same direction in which it was rotated by the previous automatic tuning action. If this direction is toward the desired station, the motor stops when it has driven the tuning condenser to its correct setting. If the direction is away from the desired station, the motor is automatically reversed when the tuning condenser reaches the limit of its rotation, and the condenser is then driven past its original setting to the desired new setting. In this non-homing system it is important that the motor stop instantly when its circuit is

opened by the switching mechanism, for otherwise it might coast long enough while power is off to drive the tuning condenser beyond the correct setting. This is called a non-homing system because the motor does not always "go home" to the correct new setting immediately.

In the self-homing system, the electric motor always travels in the correct direction to bring the tuning condenser to the desired new setting in the quickest possible time; if the

Variable condensers can be made which will rotate through a full revolution, but it then becomes difficult and costly to make the rotor plates sufficiently rigid.

Non-Homing Electro-Mechanical Tuning Systems. The essential features of a non-homing system are illustrated in Fig. 14. First of all, observe that a small reversible electric motor drives the shaft of the main tuning condenser through a chain of speed-reducing gears. These gears

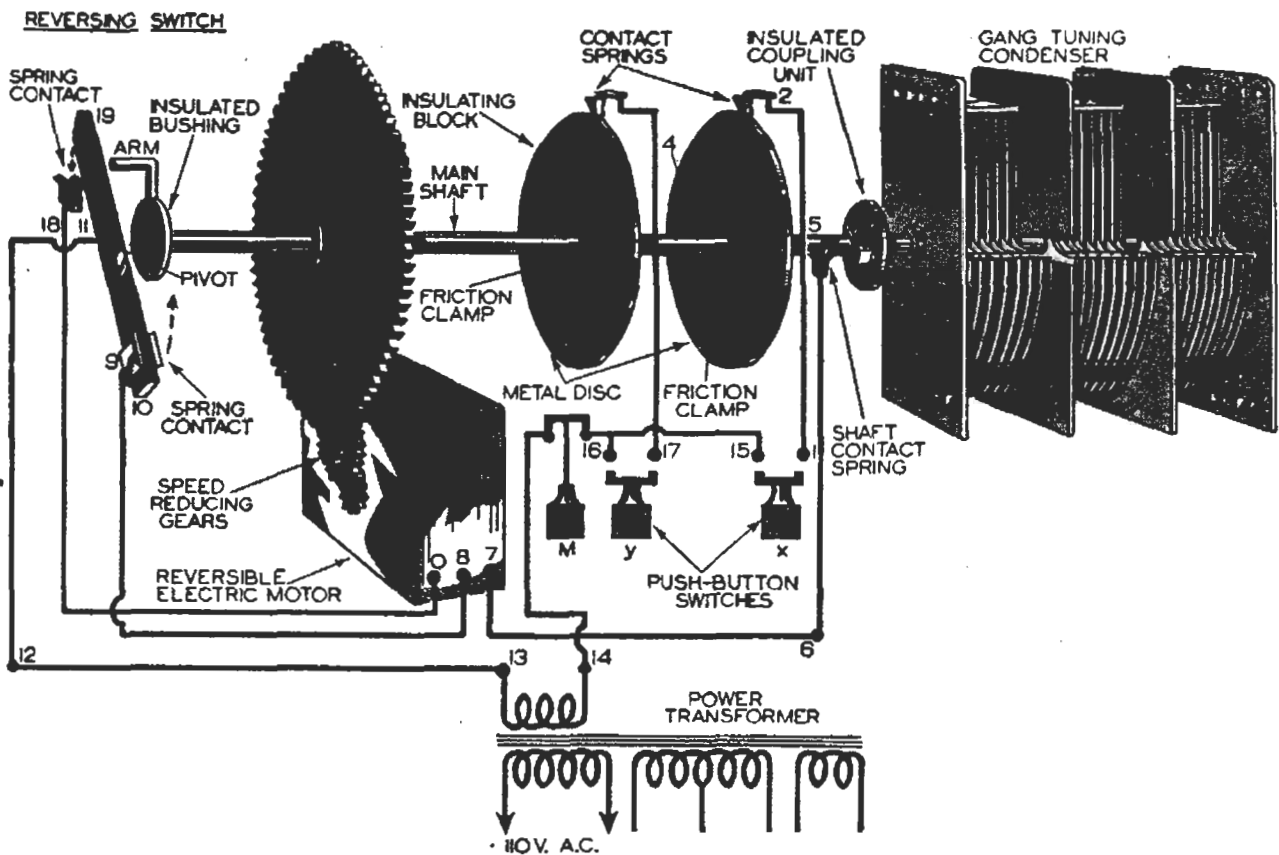


FIG. 14. Essential features of a non-homing electro-mechanical automatic tuning system.

motor overruns the proper stopping position because of inertia after power has been cut off, it will instantly reverse and correct its error automatically.

In both the self-homing and non-homing systems the variable tuning condenser cannot swing through more than 180° (one-half of a complete revolution), because the rotor plates of the tuning condensers used in modern receivers are given added rigidity by a metal strip at one end.

are necessary because the midget motors used in these systems rotate at a speed higher than one thousand revolutions per minute, a speed which is far too great for tuning purposes.

For simplicity we will consider a system having only two station-selecting buttons, designed as *x* and *y* in Fig. 14. For each button there is one metal disc on the extended tuning condenser shaft, held rigidly in place by a friction clamp. A small block of insulating material is set into the circumfer-

ence of each disc, as indicated. Above each disc is a contact spring which normally makes contact with the disc but which is insulated from the disc whenever the insulating block is directly under the spring. Each contact spring is connected to the switch controlled by its push-button; the push-button switching mechanism is the same as that used in electrical automatic tuning systems, with a latch bar serving to release a previously pushed button before holding in the button for a desired station.

Now let us see what happens in this non-homing electro-mechanical system when button *x* is pushed in. We see immediately that the switch controlled by this button shorts together points 1 and 15, so let us start at point 1 and trace the circuit through the motor to point 15 again. Follow through from point 1 to point 2, then through the contact spring to point 3 and the metal disc provided for this button. From the disc we trace through the tuning condenser shaft from point 4 to point 5 and then through a shaft contact spring to points 6 and 7. From point 7 we know that current must flow through the motor and come out either at point 0 or point 8. Tracing from point 0, we find an open circuit at point 18 and know that current cannot flow over this path at this time. We therefore trace from point 8 to point 9 and then to point 10, the other terminal of the reversing switch. From 10 we go through the metal arm of the reversing switch to point 11, to point 12, to point 13, through a secondary winding on the power transformer (which provides the required voltage for the motor) to point 14, through manual tuning switch *M*, and finally we are back at points 15 and 1 again.

With this complete circuit for the

motor between its terminals and the source of power, the motor begins to rotate, and the direction will be such that the tuning condenser shaft and the metal disc will rotate in a counter-clockwise direction (as indicated by the arrow on the metal disc) until the insulating block in this disc comes directly under the contact spring. This breaks the circuit between points 2 and 3, opening the motor circuit and stopping the motor. If the position of this metal disc on the condenser shaft is properly chosen, the tuning condenser setting will now be exactly correct for receiving the station assigned to button *x*.

Now suppose that we desire to receive the station assigned to button *y*. We push in this button, and the latch bar lifts just enough to release button *x* and open the circuit between points 1 and 15. The latch bar then holds in button *y*, and the corresponding switch shorts points 16 and 17. Since the arm at the left end of the condenser shaft has not yet touched the reversing switch, contacts 9 and 10 are still together and the circuit traces from point 17 through the left-hand metal disc, through the shaft, through the shaft contact spring to point 7, through the motor to point 8, through contacts 9 and 10 and the reversing switch to point 11, and then through the power transformer winding and switch *M* to points 16 and 17. The motor rotates in the same direction as it did for button *x*, and the insulating block on this metal disc moves away from its contact spring. The motor continues rotating in this counter-clockwise direction until the arm at the end of the shaft flips the reversing switch over to a position which opens the circuit between points 9 and 10 and closes the circuit between points 18 and 19. Now the circuit through the motor is from point

7 to point *O* and the internal connections of the motor are such that this reverses the direction of rotation, making the tuning condenser rotate in a clockwise direction. This continues until the insulating block has moved under the contact spring and opened the motor circuit.

The speed of the motor is so high that this tuning action takes place in a few seconds. During the tuning process, the station-selecting knob on the panel of the receiver is rotating and the dial pointer is moving, since both are driven by the tuning condensershaft. (For simplicity, the manual tuning mechanism has been omitted from the diagram in Fig. 14.)

Self-Homing Electro-Mechanical Automatic Tuning Systems. The basic features of a self-homing system are shown in Fig. 15. First of all, we note that there is no separate reversing switch for the motor; an ingenious switching mechanism automatically starts the motor in the correct direction, eliminating the need for reversing the motor during the tuning process.

In this mechanism, a single circular disc of insulating material is permanently and rigidly mounted on the tuning condenser shaft. To the edges of this disc are fastened two semi-circular metal segments, with their ends separated by insulating segments *J* and *K* so there is no electrical circuit between them. The lead marked 6 connects metal segment *v* to one metal slip ring which is mounted on but insulated from the tuning condenser shaft, and the lead marked 9 connects the other metal segment (*w*) to the other metal slip ring. Surrounding and resting upon the two semi-circular metal segments are a number of sliding contacts or brushes, one for each push-button, which can be set at any required position along

the circumference of this disc.

Now let us push in button *x* and trace through the motor circuit to see what will happen. The switch controlled by button *x* has only two terminals, 11 and 1, which are shorted together when the button is held in by the latch bar. Starting at terminal 1, we trace to point 2 and through the manual tuning switch *M*, through power transformer winding *S_M* and then to terminal 3 on the motor. If terminal 4 is the other motor terminal in the circuit, we get a clockwise rotation of the tuning condenser shaft, and if terminal *O* is in the circuit we

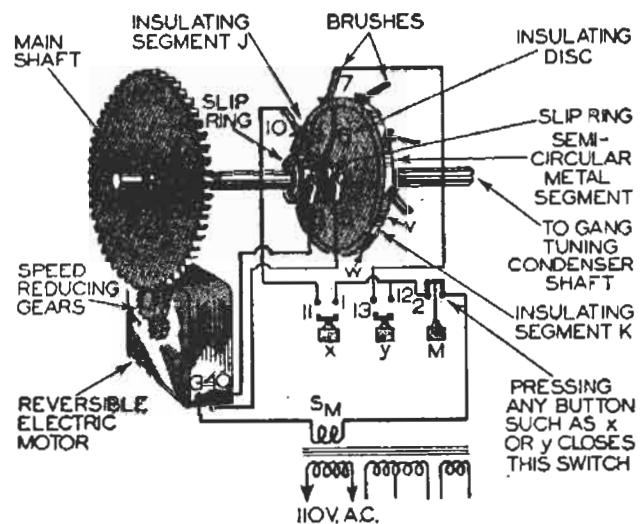


FIG. 15. Essential features of a self-homing electro-mechanical automatic tuning system.

get a counter-clockwise rotation of the shaft. Let us trace from point 4 first; we go to slip ring contact 5, then through the slip ring and through connecting lead 6 to metal segment *v* on the disc. None of the brushes which are resting on this disc provides a closed circuit to point 1 again, so we know that motor current does not take this path.

Returning to the motor, we trace from point *O* to slip ring contact 8 and through this slip ring and connecting lead 9 to metal segment *w*. Brush 10, resting on this metal segment, connects directly to point 11, which is shorted to point 1 by the

switch, and hence we have a closed circuit for the motor. The motor rotates the shaft in a counter-clockwise direction until brush 10 is directly over insulating segment *J*. This breaks the circuit, and the motor stops. If the motor coasts far enough after the circuit is broken so that brush 10 touches metal segment *v*, the motor circuit is instantly closed through its other path (4, 5, 6, 10, and 11 to 1) and the motor starts up in the reverse direction rotating the shaft in a clockwise direction. This quickly returns brush 10 to its position above the insulating segment, and since the motor has not had a chance to build up speed, it stops instantly. If brush 10 is properly located, a station will now be tuned in correctly.

Now suppose we wanted to receive the station assigned to button *y*. We press in this button, releasing button *x* and shorting points 12 and 13. Current now flows over the path 12-2-3-4-5-6-7-13-12, and the motor turns the tuning condenser shaft in a clockwise direction until brush 7 is directly over insulating segment *J*. If the motor "over-runs" the insulating segment, brush 7 will contact segment *w* and the motor will be reversed just long enough to correct the error. In this way a self-homing or self-correcting automatic tuning action is obtained.

Although only two station-selecting buttons have been shown in Figs. 14 and 15, as many additional buttons can be used in both these systems as are desired. In each case, one additional manual tuning button *M* must be pressed to open the main motor supply lead when manual tuning is desired. Since the common latch bar acts upon all buttons, the mere act of pressing a station button releases the manual tuning button, closing its

switch and restoring automatic tuning.

With non-homing systems, one metal disc with its insulating block is required for each station which is to be automatically tuned; with self-homing systems only one large disc is required, with one brush resting on the metal segments of this disc for each station which is to be automatically tuned. The metal segments may be made wide enough so that two brushes can rest side by side or very close together on it, permitting automatic tuning of stations which are only 10 kc. apart.

Audio-Silencing and A.F.C.-Releasing Switches for Electro-Mechanical Systems

There are five methods in general use for silencing the audio system, of which the first is the most common:

1. Grounding the grid of an audio tube.
2. Shorting the terminals of the loudspeaker voice coil or shorting the primary winding of the output transformer.
3. Shorting the diode load resistor in the second detector circuit.
4. Applying a large negative C bias to an audio tube in order to block the tube.
5. Applying a large negative C bias to the tubes in the frequency converter and the I.F. stages of a superheterodyne in order to reduce the sensitivity of the R.F. system.

Two methods are in general use for removing A.F.C. action while the tuning mechanism is in operation or for temporarily releasing the A.F.C. system when tuning is completed:

1. Shorting the output of the A.F.C. discriminator sections.
2. Applying a large negative C bias to the tubes in the frequency converter and I.F. stages. (Reducing the input voltage to the A.F.C. system in this manner prevents the system from holding a station which is even a small amount off resonance.) This method also provides audio silencing.

Regardless of which method is used for silencing the audio system and releasing A.F.C. action, the switches

used must be interlocked with the automatic tuning mechanism. The switches can be actuated either by mechanical movement of some part of the tuning system or by the flow of current through the motor circuit.

Switch Control by Motor Shaft Movement. An electric motor consists essentially of a rotating part, called the armature or rotor, and a stationary part called the stator. The interaction of the magnetic fields produced by these two parts causes rotation. For greatest rotating force, the rotor must be exactly in the center

receiver operation and A.F.C. action.

When voltage is applied to the motor, the rotor instantly centers itself by moving to the right, as indicated in Fig. 16B. This causes a collar on the shaft of the motor to press against a lever arm which actuates a multi-contact spring switch, shorting all contacts to ground and thus grounding the audio grid and shorting the discriminator output resistor. When current through the motor is interrupted, the rotor-centering force disappears and the spring again pushes the rotor to the position

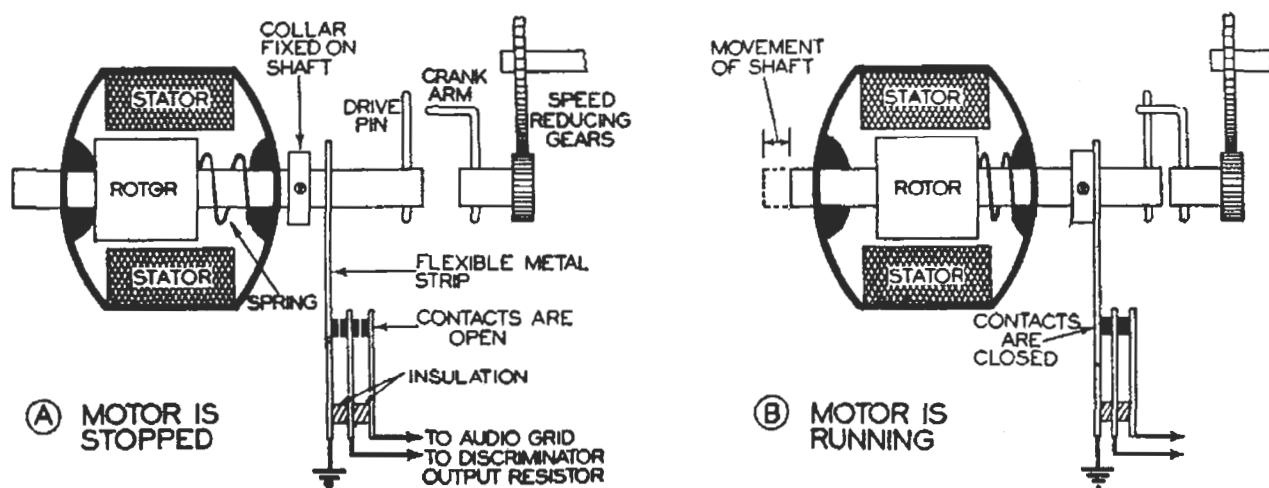


FIG. 16. Details of audio-silencing and A.F.C.-releasing switches which are actuated by thrust (end-wise movement) of the motor shaft when voltage is applied to the motor of an electro-mechanical automatic tuning system.

of the stator; if the rotor is off center to one end or the other, it will be magnetically pulled into the center whenever voltage is applied to the motor. This endwise movement of the rotor is used in some electromechanical automatic tuning systems to actuate the audio silencing and A.F.C. releasing switches.

The arrangements of parts for a switch control action of this type is shown in Fig. 16A. A spring on the rotor shaft, pressing between the rotor and the frame of the motor, serves to push the rotor off center when the motor is stopped. Under this condition the contacts of the switches are open, permitting normal

shown in Fig. 16A, opening the audio and A.F.C. circuits.

The end movement of the rotor shaft is also used to engage the motor with the speed-reducing gears which drive the gang tuning condenser shaft. The movement of the rotor shaft to the right when voltage is first applied causes a drive pin on the motor shaft to engage with a crank arm on the shaft of the smaller gear, as indicated in Fig. 16B. When current to the motor is interrupted by the station-selecting system, the drive pin moves away from the crank arm, allowing the motor to coast to a stop without causing undesirable rotation of the gang tuning condenser. The

friction load on the gang tuning condenser itself is sufficient to make it stop instantly when the driving force is removed. The switches shown in Fig. 16 may, of course, be used for any of the other audio silencing and

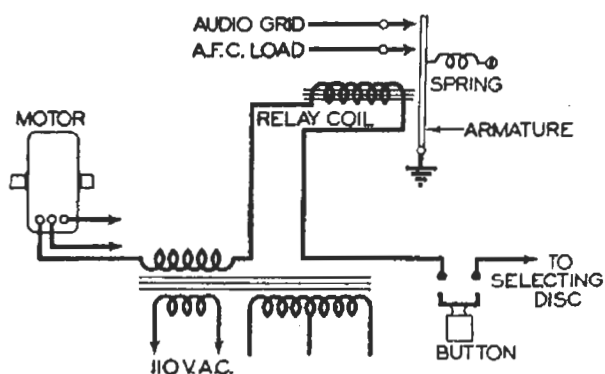


FIG. 17. Method of using a relay in the motor circuit to actuate audio-silencing and A.F.C.-releasing switches in an electro-mechanical automatic tuning system.

A.F.C. releasing methods which are employed by receiver designers.

Switch Control with Electro-Magnetic Relays. The flow of current in the main lead to the motor of an electro-mechanical automatic tuning

of any station-selecting button sends current through the relay coil as well as the motor. The relay armature is attracted to the relay core by the magnetic flux created by the relay coil, and this movement of the armature causes the audio grid and A.F.C. load contacts to be grounded. When the station-selecting mechanism interrupts the current to the motor, the current flow through the relay likewise stops, allowing the spring to move the armature away from the core and open the audio and A.F.C. circuits.

Electrical Circuit (without Switches) for Audio Silencing and A.F.C. Releasing. In this circuit, the A.C. voltage for the A.C. motor is also applied to a twin rectifier stage, and the resulting D.C. voltages are made to increase the negative C bias on an audio amplifier tube enough to silence the audio system, and to increase the negative C bias on the

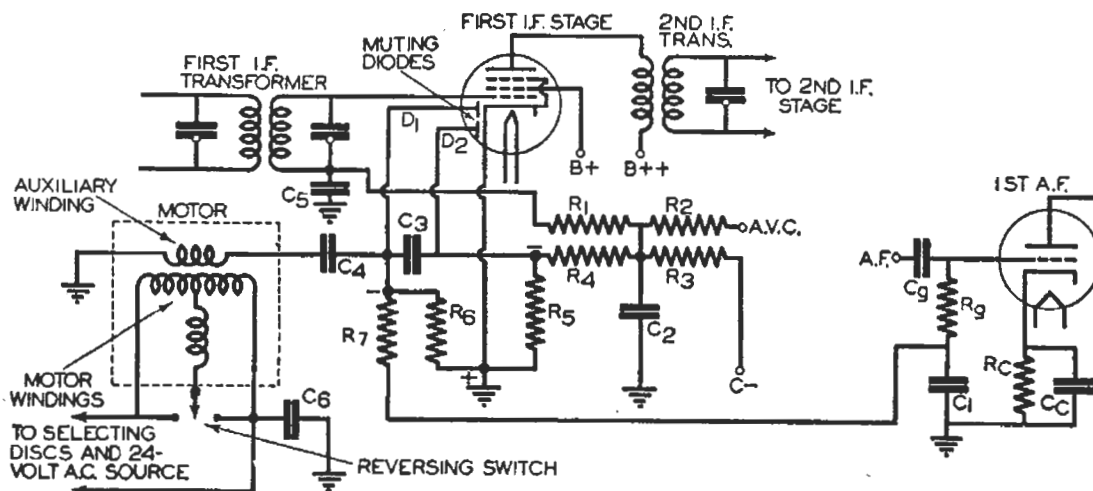


FIG. 18. Circuit diagram showing connections for an electrical system which silences the audio amplifier and releases the A.F.C. system during the operation of the electro-mechanical automatic tuning system. This scheme is used in some Motorola receivers. The use of a duo-diode-pentode in the first I.F. stage eliminates the need for an extra muting tube.

system can be used to actuate an ordinary A.C. relay having contacts which are connected to silence the audio system and release the A.F.C. system, since this motor current flows only during the tuning operation. The circuit arrangement is quite simple and is shown in Fig. 17; the pressing

I.F. stages in order to prevent the A.F.C. system from acting during the tuning operation.

A typical circuit arrangement is shown in Fig. 18; the A.C. voltage developed by an auxiliary winding on the motor core is applied to the two diode plates of the first I.F. tube

through D.C. blocking condensers C_4 and C_3 , the return path being from the grounded cathode to the grounded end of the auxiliary winding. On alternate half cycles the diode sections act as shorts across resistors R_5 and R_6 , and the current pulses flowing through these resistors on the remaining half cycles produce rectified voltage drops across them.

The D.C. voltage across R_6 acts in series with the normal C bias on

the I.F. tube grids. Condenser C_6 places the motor circuit at R.F. ground potential.

RCA Electro-Mechanical Automatic Tuning System. This electro-mechanical system is of the non-homing type, and consequently the motor will sometimes drive the gang tuning condenser away from a desired setting until the limit of condenser rotation is reached and a reversing switch is tripped. A top view

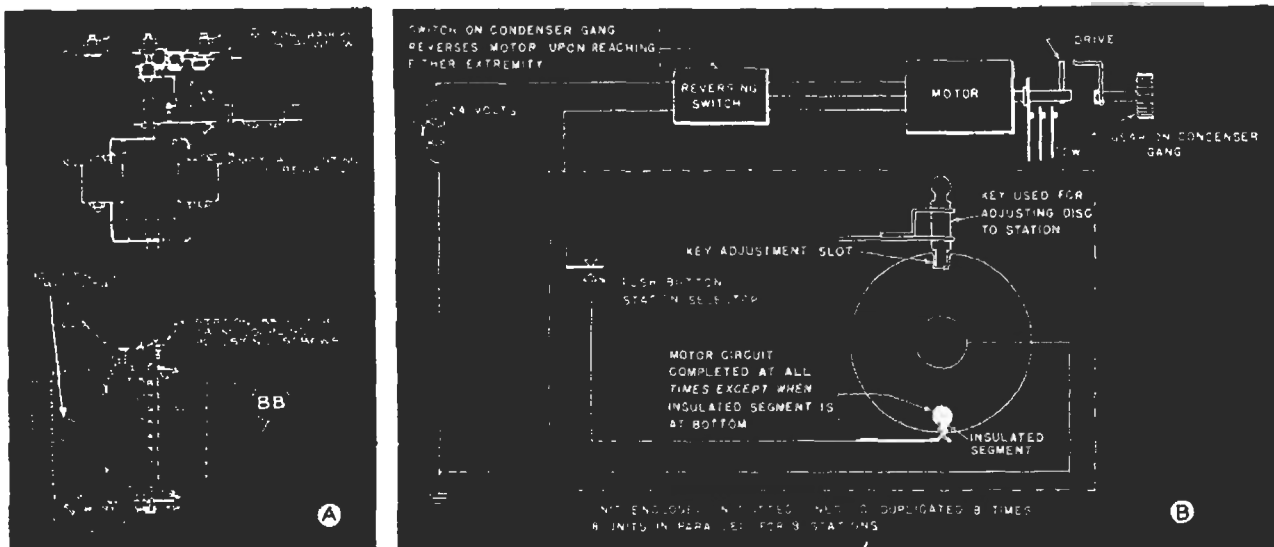


FIG. 19. RCA electro-mechanical automatic tuning system of the non-homing type. Shaft coupling units are designated as BB.

the first A.F. tube, driving this tube sufficiently negative to prevent audio amplification. Condenser C_1 and resistor R_7 make up a filter which smooths out ripples in the rectified D.C. voltage across R_6 .

The D.C. voltage developed across R_6 when the motor is operating acts upon the grid of the I.F. tube through resistors R_4 and R_1 , and drives this grid sufficiently negative to reduce the strength of the I.F. carrier signal and thus release the A.F.C. system. Note that this A.F.C. releasing voltage acts in shunt with the A.V.C. voltage and the normal C bias voltage for the I.F. tube. Condensers C_2 and C_3 are filter condensers, while resistors R_2 , R_3 and R_4 serve to isolate the various negative voltage sources acting upon

of the tuning mechanism is shown in Fig 19A; the motor, the speed-reducing gears, the A.F.C. and A.F. shorting switches, and the pin and crank arm drive are all essentially the same as for the system shown in Fig. 16, while the reversing switch is like that shown in Fig. 14.

The simplified diagram in Fig. 19B shows how this system operates. The metal disc with an insulated segment and a slot on opposite sides is one of eight discs which are mounted on a common shaft and held in position by friction; beneath each disc is a spring contact. During manual tuning the metal discs turn with the gang tuning condenser but the electric motor remains motionless since the pin on its shaft is not engaged with

the crank arm on the speed-reducing gear.

To make the preliminary station-setting adjustment for this RCA mechanism, one of the buttons is pressed, and after the motor has stopped, an adjusting key (provided with the unit, and kept in a special adjusting key receptacle when not in use) is inserted in the adjusting hole corresponding to this button; this places the key in the slot on the metal disc, exactly as shown in Fig. 19B. The A.F.C. system is turned off by means of a switch on the receiver panel, and the receiver is now tuned manually to the station desired for that button. Removal of the adjusting key com-

shorting switches are closed. The motor stops when the metal disc has turned to the position where the contact spring is over the insulated segment; if the gang tuning condenser reaches the limit of its travel before this occurs, the reversing switch changes the direction of motor rotation.

General Electric Electro-Mechanical Automatic Tuning System. Diagrams for this non-homing system are given in Fig. 20. As you can see, no metal station-selecting discs are used; instead, a metal arm with a knife-edge spring contact is mounted on the tuning condenser shaft, and swings over a number of metal contact but-

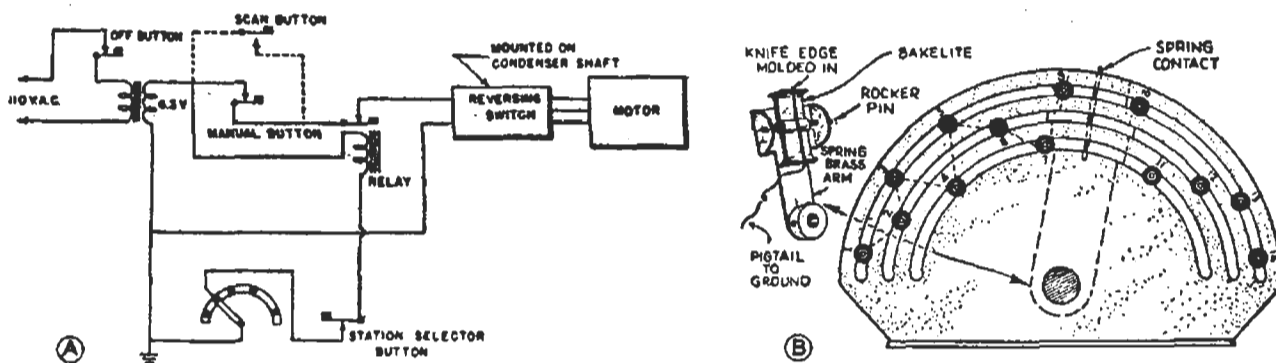


FIG. 20. General Electric non-homing electro-mechanical automatic tuning system.

pletes the adjustment for this station; the process is then repeated for each other button. It is not necessary to lock the metal discs in position, since there is sufficient friction to prevent them from slipping during normal receiver operation.

The operation of this automatic tuning system is as follows: The pressing of the push-button station selector in Fig. 19B closes the circuit to the motor through the reversing switch and through the contact spring and metal disc; the motor starts up in the direction of its previous rotation, with its rotor automatically centering in the stator so that the drive pin engages with the crank arm on the gear and the A.F.C. and A.F.

tons which are set into slots in an insulating panel. The tuning motor drives the tuning condenser shaft through reducing gears; when the limit of rotation is reached, a reversing switch changes the motor direction and starts the contact arm moving back over the contacts again. All this is shown in Fig. 20A.

The circuit connections for one contact button are indicated in Fig. 20B; here is how the system works. When the *MANUAL BUTTON* is pressed, it opens the motor supply circuit and raises the latch bar enough to release all other push buttons. The latch bar also releases the *OFF BUTTON* at this time, thus closing the primary circuit of the power transformer.

Under this condition neither the relay nor the motor gets power (because all station selector button switches as well as the manual button switch are open), and the receiver can be tuned manually.

When the *STATION SELECTOR BUTTON* is pressed, the latch bar releases the *MANUAL BUTTON*, closing its circuit. Power is thus applied to the motor, and it rotates the gang tuning condenser and the rotating contact arm until this arm is directly over the contact button corresponding to the station selector button which has been pressed. This closes the relay circuit, and its armature pulls in, opening the motor circuit and stopping the motor. The relay remains closed until the pressing of another station selector button switch opens its circuit. The A.F. system is silenced and the A.F.C. system is temporarily released by means of a conventional switching arrangement operated by the end-thrust action of the motor (this is not shown in Fig. 20).

Another interesting feature of this General Electric system is the non-latching *SCAN BUTTON*. When manual tuning is in use, pushing of the scan button will close the motor circuit, and it will continue to rotate the gang tuning condenser back and forth through its entire 180° of rotation as long as the button is pressed. In this way stations can be tuned in roughly without the trouble of turning a manual tuning knob, and when a desired station is heard the scan button can be released. Accurate final tuning can then be done manually if necessary, but usually the A.F.C. system will be able to take hold instantly and tune in the desired station when the scan button is released.

To set up any station selector but-

ton, the desired station is tuned in manually while the manual button is depressed. A contact button near the contact arm is now loosened and moved directly under this arm. Labeling the station selector button with the call letters of the station tuned in completes the setting up process; this is repeated for each other button.

Tuning Motors

Despite their small size, tuning motors require careful design and construction. They must operate

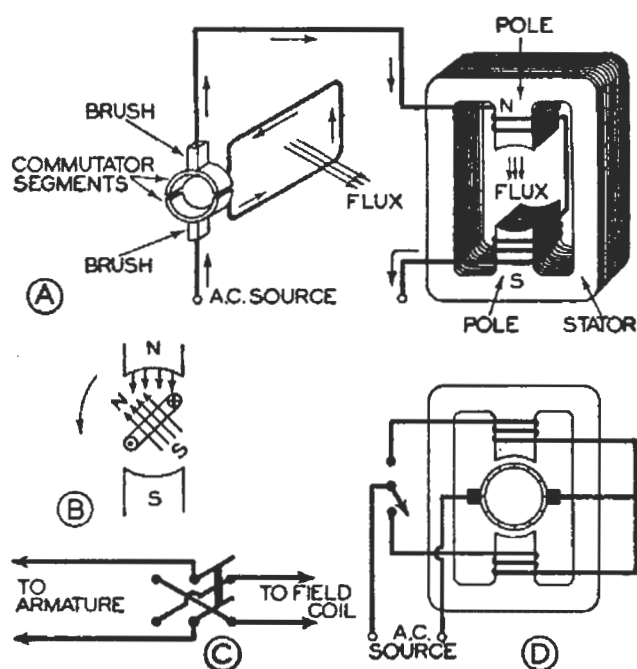


FIG. 21. Details of a series-wound tuning motor. Short arrows indicate direction of current flow for one half of cycle. Plus sign in wire indicates current flow into paper; dot in wire indicates current flow out of paper.

with as little noise as possible, must operate with little or no oiling, must not heat up excessively while in use, and must operate from an A.C. source. Usually they are designed for 6.3 volt operation, in which case they can be connected in shunt with the filament supply of the receiver; some motors are designed for higher voltages, however, and for these an extra secondary winding must be provided on the power transformer.

There are two types of small A.C. motors in general use in automatic

tuning systems: 1, series motors; 2, induction motors. The fundamental operating principles of each will be discussed.

Series Motors. In Fig. 21 is a simplified diagram illustrating the operating principles of a series motor. For convenience, the armature is shown as a single loop of wire whose ends are connected to two semi-circular commutator segments; in an actual motor, there will be many loops of wire and many more commutator segments, and the entire armature will be mounted in the center of the stator, between the pole pieces. Two fixed brushes make contact with the commutator segments as indicated. The armature loop and the field coils are connected *in series* across the A.C. source, as you can easily see by tracing the current from one source terminal through the circuit as indicated by arrows to the other source terminal; all motors having the armature and field coils connected in this way are known as *series motors*. In an actual series motor the wire loop is wound around a cylindrical soft iron core whose shaft is free to revolve in bearings at each end. The stator (the stationary part of the motor) is usually made from sheet metal laminations to reduce eddy current losses. Field coils are wound over the poles of the stator, and are connected together in such a way that both will produce flux in the same direction at any instant. When current flows through this motor in the direction indicated by arrows, the loop of wire on the armature will set up a magnetic flux in the direction indicated, and the field coils will likewise set up a magnetic flux which makes one pole north and the other pole south in polarity, as indicated.

Naturally the magnetic fields produced by the armature and stator will

interact with each other when the armature is inside the stator. For the armature position and direction of current flow shown in Fig. 21B, the armature will act as a pivoted magnet having the indicated polarity. The armature N pole will be repelled by the stator N pole and attracted by the stator S pole, and likewise the armature S pole will be repelled by the stator S pole and attracted by the stator N pole, causing counter-clockwise rotation. Since the like poles are closest together now in Fig. 21B, the repelling action will be strongest; when the armature has rotated a bit farther, the unlike poles will be closer together and the attractive force will be the strongest, reach-

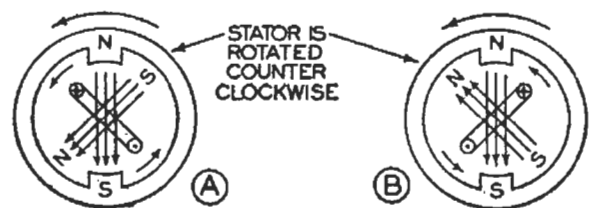


FIG. 22. Simplified diagram showing the operating principles of an induction motor.

ing a maximum when the armature N pole is next to the stator S pole. At this time the current through the armature loop is reversed in direction by the commutator, and the entire process of repulsion and attraction repeats itself, causing the armature to continue rotating in the same direction until it is again horizontal and current flow is again reversed by the commutator.

Reversing a Series Motor. With a given connection of armature and field coils, as indicated in Fig. 21A, the armature will revolve in a certain direction; to reverse this direction of rotation it is necessary to reverse the direction of current flow through *either* the field coil *or* the armature (*but not through both*). This can be done by inserting a double-pole,

double-throw switch in the circuit as shown in Fig. 21C. If, however, a center-tap field coil arrangement like that shown in Fig. 21D is used, a single-pole, double-throw switch will serve for reversing purposes. Note that with this arrangement only one field coil is carrying current and producing magnetic flux at any one time.

A series motor operates on either an A.C. or D.C. source, since the reversal of current flow through both the field coils and the armature does not change the direction or magnitude of the forces acting on the armature.

Induction Motors. All induction motors operate on the principle that when a closed or shorted loop of wire is pivoted in the center of a rotating magnetic field, the loop will rotate in the same direction as the field. Let us see why this statement is true.

Suppose we have a magnetic field like that shown in Fig. 22A, made up of an *N* pole and an *S* pole, which is being rotated by some mechanical means in the counter-clockwise direction indicated. Between these two poles is a shorted copper loop or ring which is pivoted at its center and is therefore free to turn. If the initial positions of the loop and magnetic field are as shown in Fig. 22A, a certain amount of magnetic flux will pass through the loop. When the magnetic field begins to rotate counter-clockwise, however, the amount of flux through the ring will be reduced and consequently the flux linkage in this coil or loop will be reduced. From Lenz's law we know that whenever there is a change in flux linkage in a coil, a voltage is induced in the coil in such a direction as to *oppose the original change in flux linkage*. This means that the loop in Fig. 22A will set up a flux to aid the original flux, and the coil

will act as a small magnet having the polarity indicated. Since like magnetic poles repel and unlike poles attract, we can readily see that the coil will rotate in the same direction as the magnetic field, as indicated by the arrows.

The shorted loop cannot rotate at exactly the same speed as the magnetic field, for then there would be no change in flux through the loop. The loop is continually slipping or lagging behind the magnetic field, but even when it slips past the pole pieces it is still forced in the same direction of rotation. Suppose that the relative positions of the coil and magnetic field

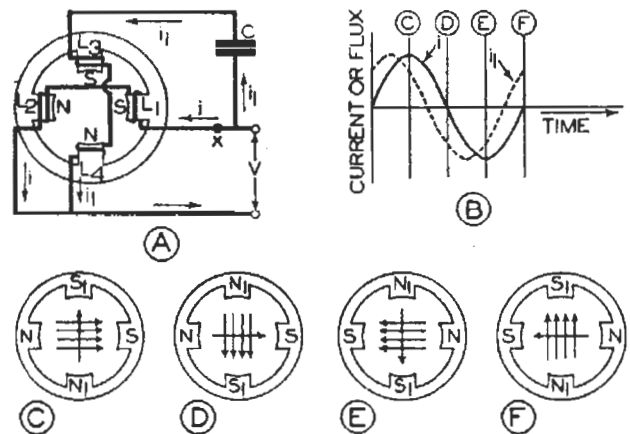


FIG. 23. These diagrams show how a condenser can be made to produce a clockwise-rotating magnetic field for a split-phase induction motor. Short arrows indicate current flow.

are as indicated in Fig. 22B at one instant, with the field traveling faster than the loop. The number of flux linkages in the loop will now be increasing, and consequently the loop will set up a flux to oppose the original flux, in an attempt to maintain a constant number of flux linkages. The polarity of the loop will be as indicated, and since like poles repel we still have the loop rotating in the direction of the magnetic field. In a practical induction motor there are a large number of shorted loops mounted on the armature, each contributing a rotational force.

Electric motor design engineers

have devised a number of simple ways for producing a rotating magnetic field by electrical means in a single-phase A.C. induction motor (the induction motors used for radio tuning purposes will operate on a two-wire, single-phase, A.C. power line, and hence are often called single-phase motors).

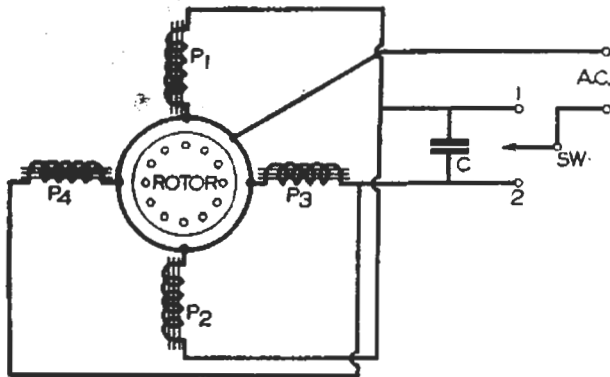


FIG. 24. Circuit of General Electric condenser split-phase induction motor as used in a number of automatic tuning systems. When switch SW is set at contact 1, current to poles P_3 and P_4 (which are connected together in parallel rather than in series) must flow through C; when SW is at 2, current to P_1 and P_2 flows through C, reversing the direction of the rotating magnetic field and thus reversing the direction of motor rotation.

Capacitor Split-Phase Induction Motor. In Fig. 23 is shown a method of producing a rotating magnetic field by means of a four-pole stator, with a coil wound on each pole and a condenser connected in series with two opposite coils to make them draw a current which is approximately 90° out of phase with the current through the other coils.

A.C. voltage V , applied to the motor terminals, sends a current i through field coils L_1 and L_2 , and the flux produced by this current is *in phase* with the current. The current which voltage source V sends through field coils L_3 and L_4 must pass through high-capacity condenser C and the capacitive reactance of this condenser is so high with respect to the inductive reactance of these coils that current i_1 leads the A.C. voltage V by almost 90° . The curves in Fig. 23B give the phase relationship of the two currents, i and i_1 , and show that

i_1 leads i by almost 90° ; since a flux is always in phase with the current which produces it, these curves can also represent the flux produced by each pair of poles.

You can readily see that sine wave alternating current i , flowing through the horizontal pair of poles, will cause the flux to reach a maximum in one direction (Fig. 23C), drop almost to zero (Fig. 23D), reach a maximum in the opposite direction (Fig. 23E), and again drop almost to zero (Fig. 23F). The vertical pair of poles is going through this same complete cycle of changes in flux, but the flux is here 90° ahead of that for the horizontal poles. At each instant, the fluxes produced by the two pairs of poles combine, and it is the resultant flux which acts upon the shorted loops of wire on the armature. Referring to Figs. 23C, D, E, and F, you can see that the weaker flux in each case (shown by a single arrow line), will have little effect upon the stronger flux. Furthermore, the position of the stronger flux at each quarter-cycle is such that we have the same effect as was produced by the rotating magnetic field in Fig. 22,

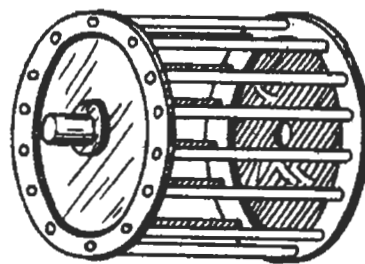


FIG. 25. Typical rotor of an induction motor, made up of copper rods which are riveted and soldered at each end to circular copper discs mounted on the rotor shaft. Before assembly, laminated sheet steel discs having slots for the copper rods are placed on the shaft inside this "squirrel-cage"; this steel core serves to reduce the reluctance of the path for the rotating magnetic flux and for the fluxes set up by the many shorted loops in the rotor.

with our magnetic field rotating in a clockwise direction in this particular case.

A counter-clockwise rotation of the magnetic field could be secured in

Fig. 23 simply by inserting the condenser in series with the other pair of coils, such as at point x . Since in tuning motors it is usually necessary to have a reversing switch, this particular type of induction motor will usually be found connected as shown in Fig. 24, with a single-pole, double-throw switch arranged to change the condenser from one circuit to the other. The condenser could just as well be replaced by a high-inductance coil, making current i_1 in Fig. 23A lag rather than lead current i , for it is the difference in phase which creates the rotating magnetic field. The rotors used in this and all other types of induction motors are much the same in construction and appearance, resembling that shown in Fig. 25.

Shaded-Pole Induction Motor. Another method of producing a revolving magnetic field is shown in Fig. 26A. Alternating current is fed through coil L_1 , which is wound on one of the poles of the motor, with the result that an alternating flux θ_1 is produced at the pole face. A short-circuited coil L_2 is wound around one portion of the pole; when flux θ_1 is increasing, that portion of

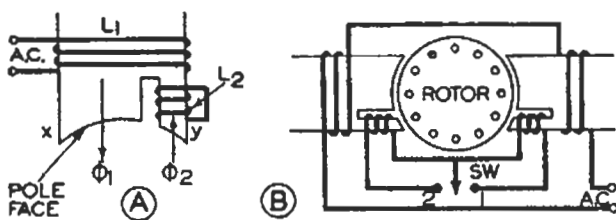
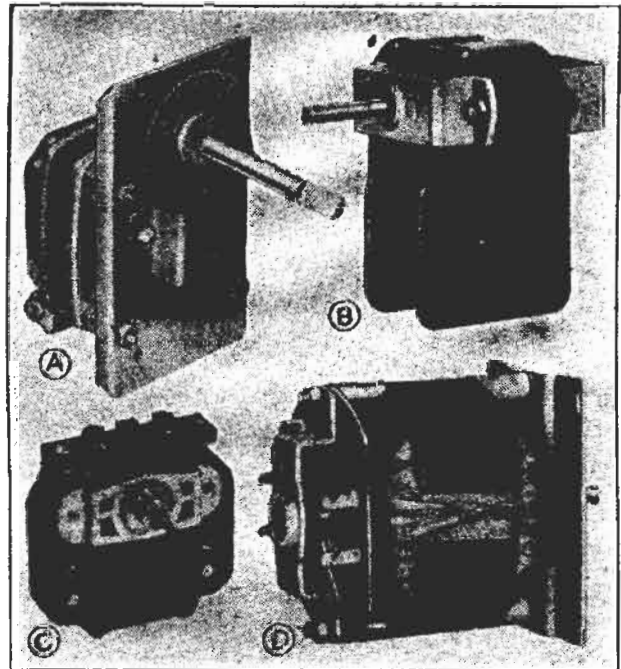


FIG. 26. Diagrams showing principles of a shaded-pole type induction motor.

θ_1 which passes through coil L_2 will likewise be increasing. The result is that a voltage will be induced in L_2 , and this will set up a flux θ_2 which tends to oppose any change in the flux through this coil. In other words, when θ_1 is increasing, θ_2 will oppose the main flux θ_1 and the flux near point y on the pole face will be quite weak. When θ_1 is decreasing, θ_2

will attempt to prevent this decrease by aiding the main flux, and under this condition there will be a stronger flux at point y than at point x . During one-half of a cycle the region of



Typical examples of motors used in electro-mechanical automatic tuning systems.

Courtesy Alliance Mfg. Co.
A—Alliance Model R shaded-pole induction motor. The shading coils are connected according to the diagram in Fig. 26B, and motor is therefore reversible. Note the speed-reducing gear assembly mounted directly on the motor.

Courtesy Delco Appliance Div., General Motors Sales Corp.
B—Delco split-phase (reversible) induction motor; this unit employs the auxiliary high-inductance winding shown in Fig. 27 to produce the out-of-phase flux required for a rotating magnetic field. These motors are made for 5, 20 or 115 volt A.C. operation.

Courtesy Barber-Colman Co.
C—Reversible single-phase, shaded-pole Barcol induction motor designed for 110-volt A.C. operation. A single main coil serves for both poles; separate shading coils are wound around a portion of each pole and connected as in Fig. 26B to permit reversal of the motor.

Courtesy Delco Appliance Division
D—Delco reversible series motor. Two brushes resting on the commutator feed current to the armature windings in the correct direction. Field coil connections are as shown in Fig. 21D, permitting reversal of the motor with a simple single-pole, double-throw switch.

maximum flux travels from x to y ; during the next half cycle this process repeats itself, with the point of maximum flux again moving from point x to point y . We thus have a maximum flux rotating always in the same direction across this pole face,

from the main pole toward the shorted coil, which is known as a shading coil. The rotor will follow this rotating flux, and consequently the rotor of an induction motor will always rotate toward a shading coil.

The direction of rotation can be reversed by placing a shading coil on each pole of the motor, with the various coils connected together in the manner shown in Fig. 26B. When switch *SW* is at contact 1, only the right-hand shading coil will be shorted and effective, and the rotor will rotate in a clockwise direction, toward this shading coil. When switch *SW* is at contact 2, the left-hand shading coil will be shorted and the direction of rotation will be counter-clockwise.

Instead of short-circuiting the shading coils, as was done in Fig. 26B, they may be connected together and to the main voltage supply. Since their reactances will be different from the reactances of the main field coils, the shading coils will produce fluxes which are out of phase with the main fluxes, thus giving a rotating magnetic field.

Split-Phase Induction Motor with Reactive Winding. Another way of producing a rotating magnetic field is that shown in Fig. 27, which involves using an extra pole on which is wound a coil (L_3) having a high inductive reactance. The A.C. line current flowing through the regular field coils L_1 and L_2 produces a pulsating A.C. magnetic flux, which alone is not sufficient to cause rotation. When switch *SW* is set at contact 2, placing L_3 across L_2 , the current through high-inductance coil L_3 will lag the current through low-inductance coil L_2 by almost 90° , and consequently the flux produced by L_3 will lag the flux from L_2 by almost 90° . This phase relationship will be maintained as each flux increases and decreases in a sine wave

manner, with the result that we have the required rotating magnetic field. When switch *SW* is set at contact 1, shunting L_3 across L_1 , we secure this same phase relationship between the fluxes but now the resultant or combined flux will rotate in the opposite

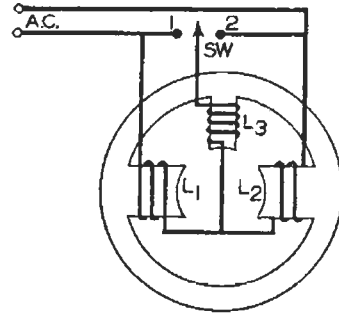


FIG. 27. Simplified diagram of a split-phase induction motor employing an auxiliary pole with high-inductance winding L_3 for producing the required rotating magnetic field.

direction, causing reversed rotation of the rotor.

Speed. The maximum speed at which an induction motor can operate is of course the rotational speed of the rotating magnetic field. The motor can approach this speed only under no load conditions, and will slow down (due to increased slippage) as a load is applied. The maximum speed can easily be computed; the speed in revolutions per second is equal to the frequency of the alternating current in cycles per second divided by the number of pairs of poles.

The tuning motors used in radio receivers ordinarily have two poles, forming a single pair, since this construction has been found efficient as well as economical in cost. For 60-cycle current, then, the speed will be 60 divided by 1, or 60 revolutions per second. To obtain the speed in revolutions per minute (r.p.m.) we multiply by 60, getting 3600 r.p.m. as the maximum speed of an induction tuning motor. If a gang tuning condenser were driven directly by such a motor, the required half-revolution would take only a little more than

1/200 of a second; obviously this is far too fast. Speed-reducing gears must therefore be used with induction motors; ordinarily they are designed to give a reduction in speed of at least 100 to 1, which means that the longest time required for a motor to tune in a station will be only a few seconds.

TEST QUESTIONS

Be sure to number your Answer Sheet 35FR-1.

Place your Student Number on every Answer Sheet.

Never hold up one set of lesson answers until you have another ready to send in. Send each lesson in by itself before you start on the next lesson. In this way we will be able to work together much more closely, you'll get more out of your Course, and you will receive the best possible lesson service.

1. Into what three groups (each having a different operating principle) can automatic tuning systems be divided? *P1*
2. What is the chief cause of oscillator frequency drift in an ordinary super-heterodyne receiver? *P2*
3. Into what two general groups can mechanical automatic tuning systems be divided according to the manner in which they are operated by the listener? *P3*
4. Where will a slight change in trimmer condenser capacity have more de-tuning effect—in a preselector tuned circuit or in the oscillator tuned circuit?
5. Name the two general types of electro-mechanical automatic tuning systems. *P14*
6. In an electro-mechanical automatic tuning system, why is the A.F.C. system released temporarily while the tuning motor is in motion or just after it stops? *P14*
7. What method of removing A.F.C. action during a tuning operation also provides audio silencing? *P18*
8. What two types of small A.C. motors are in general use in automatic tuning systems? *Series motor & induction motor*
9. How can the direction of rotation be reversed in a series motor?
current flow thru the field coil or the armature must be reversed
10. In what direction will the rotor of a shaded-pole induction motor rotate?
Toward the shading ~~coil~~ ^{pole}