PHILCO

TECHREP DIVISION
BULLETIN

In This Issue...

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Editorial . . .

TECHNICAL   SKILL — AMERICA'S   HERITAGE

by John E. Remich
Manager, Technical Department

We, as Americans, have been accustomed to thinking of our technical aptitudes as an inheritance that will automatically care for our entire technical personnel requirements. It is a well-established fact that Americans have been blessed with aptitudes for technological skills that have been responsible for many new scientific developments. Our past has been brilliant, but we cannot rest on the laurels of the past and expect a brilliant future. In order to continue to expand our economy and maintain our security, we must have increasingly larger numbers of well-trained people in all the technical fields.

We have no automatic right to leadership in technical skill. It is something that can be retained only by careful planning for the future. Such plans must recognize that an expanding technology is making increasingly greater demands on technical personnel, and that more education and training are required to accomplish a given job. The plans must therefore provide for increased training facilities. Also necessary are methods of stimulating and maintaining the interest of ever-increasing numbers of younger people. As applied to electronics, the most productive method would be to introduce electronics training at high school and junior high school levels. In addition, interest in electronics hobbies, such as amateur radio, high fidelity, and radio control of models to name a few, should be stimulated by our schools and by the electronics industry in general.

The heritage of technical skill for the future must be built today—only by continuous effort can our technology continue to grow.

HYBRID JUNCTIONS

PART 1

by John E. Marchesano

Senior Engineer, Philco Research Division

This article is the first part of a two-part discussion of the construction and operation of the more common hybrid circuits used in radar applications.

THE OBJECTIVE OF THIS ARTICLE is to explain the operation of basic hybrid junctions and to discuss their applications, advantages, and limitations. First, a set of conclusions will be drawn in describing the operation of typical junctions. These conclusions will then be used to explain the operation of hybrids having such colorful names as the "Magic T" and the "Rat Race."

The explanations outlined herein are made on the assumption that the basic operation of waveguides is understood. For instance, that both E (electric) and H (magnetic) fields must be present in order to transfer energy; that no parallel E field and no perpendicular H field may exist at the waveguide walls; and that the field pattern of the E field in the fundamental mode is known.

In the development of the conclusions for hybrid circuit operation, only the E field will be considered. The presence of the H field will be taken for granted and it will not be shown nor mentioned except when necessary. This treatment is not intended to minimize the importance of the H field—it is an integral part of the operation of hybrid junctions, just as it is for waveguides.

THE E-TYPE T JUNCTION

The E-type T junction, shown in figure 1, is constructed by joining rectangular waveguides with an arm (labelled C) connected across the wide dimension of the main waveguide. The E-type T junction is so called because the arm of the junction extends from the main waveguide in the same direction as the E lines in the waveguide, with the resultant shape forming a T.
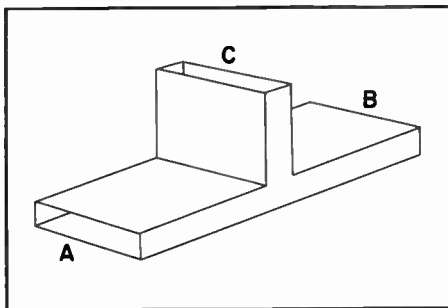

Figure 1.   The E-Type T-Junction

Figure 2 is a cutaway front view of the E-type T junction shown in figure 1. The drawing shows a signal being fed into arm A. The energy travels normally along the waveguide until it approaches the junction, where the fields must change to conform to the discontinuity. Arrows are used to show the direction and distortion of the E field, the direc-
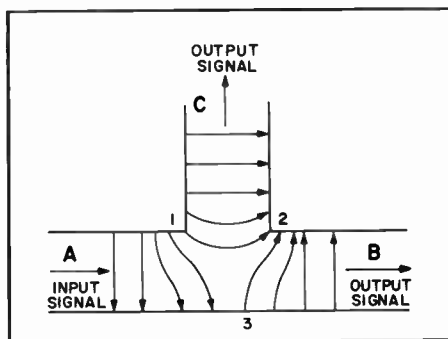

Figure 2.   E Fields in an E-Type T-Junction

tion of the arrows being from a positive to a negative potential. When the E field arrives at point 1, a positive charge will exist there. This charge induces, electrostatically, a negative charge at point 2, and an E field will exist between the two points as shown in the illustration. The induced negative charge at point 2 will, in turn, induce a positive charge on the wall below it, causing an E field between points 2 and 3, as indicated. These new E fields now proceed out through arms B and C. Note that the E field did not change polarity in going from arm A to arm C, but that it did change polarity in going from A to B. Thus the following conclusion with reference to figure 2 may be stated:

> When a signal is fed into (1) arm A of an E-type T junction, the ouput from arm B will be 180° out-of-phase with the input signal, and the ouput from arm C will be in-phase with the input signal.

From the symmetry of figure 2, it can be seen that if a signal were fed into arm B instead of arm A, a similar situation would exist. Therefore:

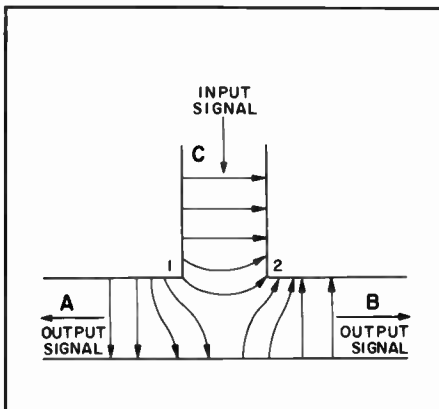> When a signal is fed into (2) arm B of an E-type T junction, the output from arm A will be 180° out-of-phase

with the input signal, and the output from arm C will be in-phase with the input signal.

Consider next the operation of the junction when a signal is fed into arm C, as shown in figure 3. When the E field arrives between points 1 and 2, point 1 will be positive and point 2 negative, as indicated. The positive charge at point 1 will induce a negative charge on the wall beneath it, and the negative charge at point 2 will induce a positive charge beneath point 2. Note that the resulting E fields indicate that signals will leave the two ends of the main waveguide 180 out-of-phase. This effect with reference to figure 3 may be stated as follows:

> When a signal is fed into (3) arm C of an E-type T junction, the outputs from the remaining two arms will be 180° out-of-phase with each other.
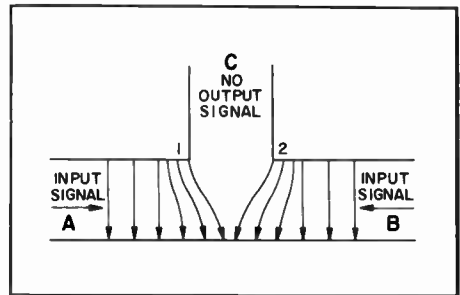

Figure 4. E Fields in an E-Type T-Junction with Signals Fed In-Phase into Arms A and B

Now, let it be assumed that equal signals of the same phase are fed into both arms A and B, as illustrated in figure 4. The two E fields arrive at points 1 and 2 in-phase, with both points being at the same positive potential. No E field develops in arm C since there is no difference in potential—hence, no energy will travel out of this arm.

When signals which are 180° out-of-phase with each other are fed into arms

Figure 3. E Fields in an E-Type T-Junction with a Signal Fed into Arm C

A and B, the result is as pictured in

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figure 5. It can be seen that the two E fields arrive at points 1 and 2 out-of-
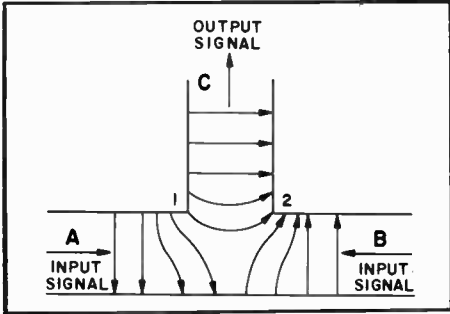
Figure 5. E Fields in an E-Type T-Junction with Signals Fed Out-of-Phase into Arms A and B

phase, with point 1 being positive and point 2 negative. As a result, an E field is present in arm C, and energy will travel out through this arm. Thus, the following conclusion may be drawn from observing the effects shown in figures 4 and 5:

> When signals are fed into (4) arms A and B of an E-type T junction, they must be 180° out-of-phase if energy is to be taken from arm C.
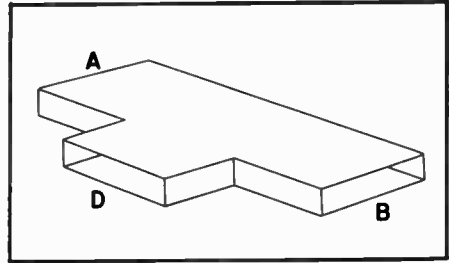

Figure 6. The H-Type T-Junction

THE H-TYPE T JUNCTION

The H-type T junction, shown in figure 6, is constructed by joining rectangular waveguides with an arm (labelled D) connected along the narrow dimension of the main waveguide. The H-type T junction is so called because the arm of the junction extends from the main waveguide in the plane in which the H lines lie in the main waveguide, with the resultant shape forming a T.

Figure 7 is a top view representation of an H-type T junction, showing a signal being fed into arm A. The figure shows the tails of the E field arrows as crosses, with lines joining the points of
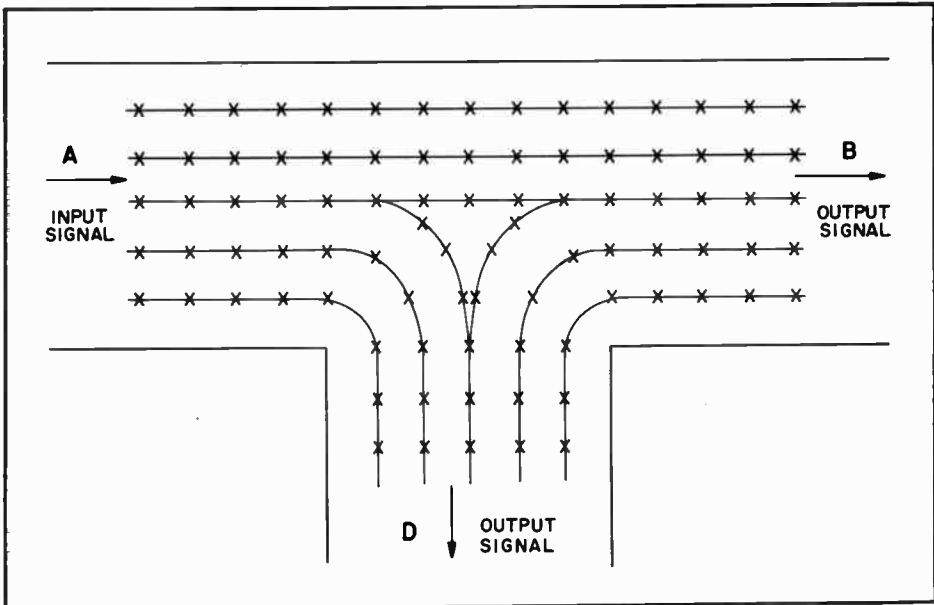

Figure 7. E Fields in an H-Type T-Junction with a Signal Fed into Arm A

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the same potential (equipotential lines). The energy moves normally along the main waveguide until it approaches the junction. At the junction, the E field will have to change in order to conform to the discontinuity. The potential difference between the upper and lower walls of the main waveguide at the A entrance end causes a potential difference to exist at the entrances to B and D. This condition results in the presence of an E field in both of these arms, and energy will move out of them without change of phase. Figure 8 is a pictorial representation of the contour described by the E
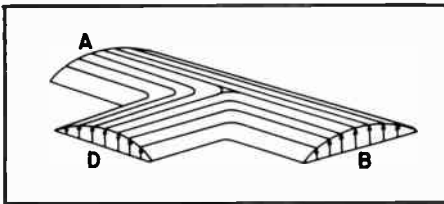

Figure 8. Pictorial Representation of the Surface Described by the E Field in Figure 7

field as it progresses through the junction. Note that the condition of zero E field at the surface of the narrow guide walls is always met. Since, like the E-type junction, the H-type junction is symmetrical, the same conditions will apply if the signal is fed into arm B. Furthermore, if the energy is fed into arm D, in-phase outputs are obtained from arms A and B. These facts may be

stated as follows:

> When a signal is fed into (5) any arm of an H-type T junction, outputs will be obtained from the remaining two arms and these outputs will be in-phase with the input signal.

Assume now that signals are fed in-phase into arms A and B, as shown in figure 9. When the E fields arrive at the junction, they will aid in producing the correct E field at the entrance to arm D. Thus energy will move out through arm D. In the alternate case, if the inputs to A and B are 180° out-of-phase, the signals will cancel at the junction, as illustrated in figure 10, and no energy will move out through arm D. The above facts may be stated as follows:

> When signals are fed into (6) arms A and B of the H-type T junction, they must be fed in-phase if energy is to be taken from arm D.
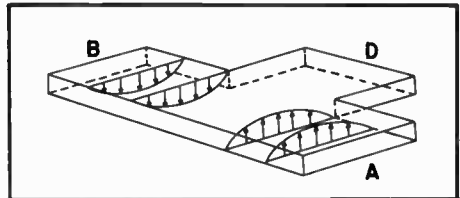

Figure 10. E Fields in an H-Type T-Junction with Signals Fed Out-of-Phase into Arms A and B
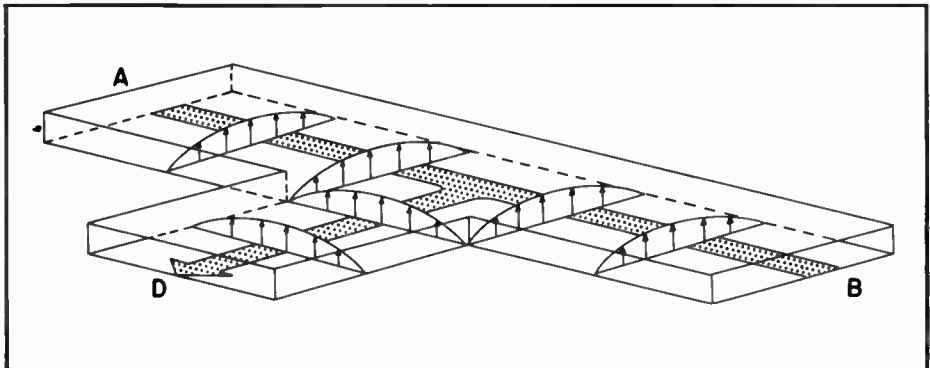

Figure 9. E Fields in an H-Type T-Junction with Signals Fed In-Phase into Arms A and B

THE MAGIC T

The magic T is constructed by combining E-type and H-type junctions, as shown in figure 11. As indicated in the
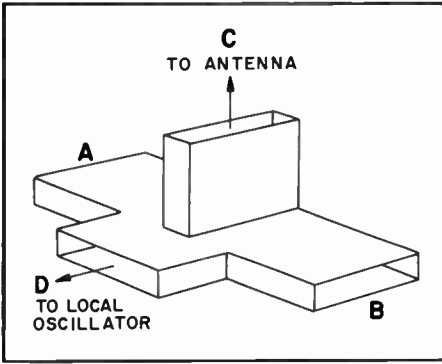

Figure 11. *The Magic T*

illustration, the magic T normally has two input signals applied to it—the local-oscillator signal, usually generated by a klystron tube, and the echo signals from the antenna. The frequencies of the two signals differ by an amount equal to the intermediate frequency.

Operation

Consider the operation of the magic T when a signal is fed into arm C, as shown in the side view of figure 12. From the operation of the E-type T junction, it can be seen that the signals travel out through arms A and B with opposite phases (conclusion 3), as indicated. However, no signal will travel out through arm D, because no potential difference will be present at the input to arm D. The reason for this lack of potential can be found by referring to the top view of the figure, in which the magnitude of the E field is indicated by the length of the arrows. Looking at the top view of the magic T, the E field in arm C is shown in the fundamental mode—maximum in the center and zero at the guide walls. Note that the entrance to arm D lies in the plane of the guide wall of arm C. Hence, no signal
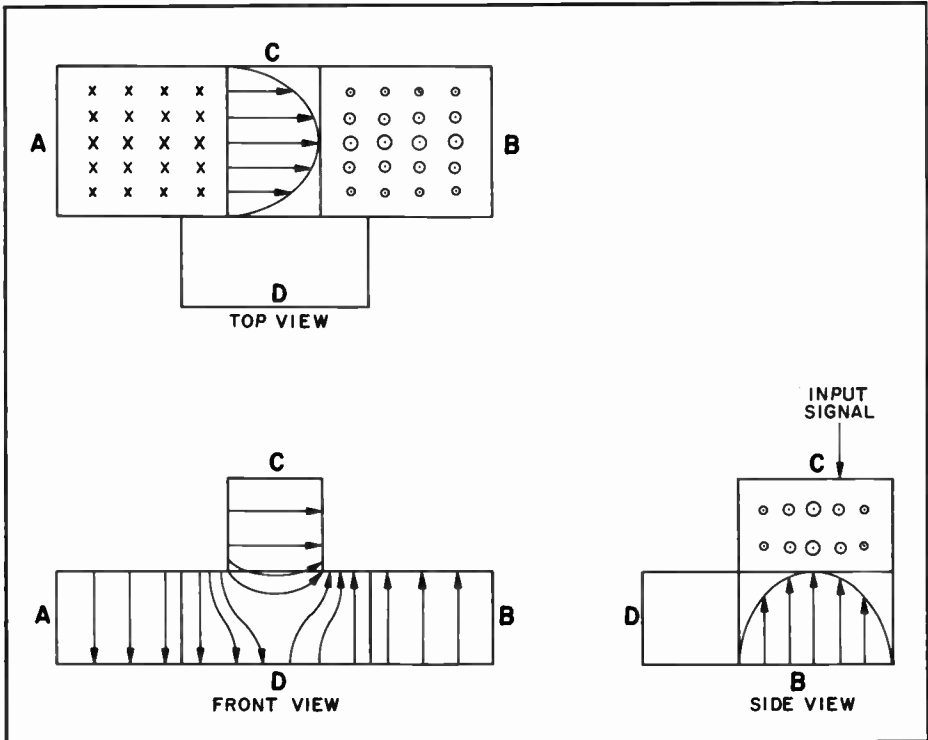

Figure 12. *E Fields in a Magic T with a Signal Fed into Arm C*

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will be impressed across the input to arm D from arm C. Looking at the side view of the magic T, the E field in arm B is also maximum at the center and zero at the guide walls. Note that the entrance to arm D also lies in the plane of the guide walls of arms A and B. Hence, no signal will be impressed across the input to arm D because of the operation of the junction. Therefore, the result of applying a signal to arm C may be stated as follows:

> When an input signal is ap- (7) plied to arm C of a magic T, the outputs from arms A and B will be 180° out-of-phase with each other, and no output will be obtained from arm D.

Consider next the operation of the magic T when a signal is fed into arm D, as shown in figure 13. From the operation of the H-type T junction, it can be seen that signals will travel out through arms A and B in-phase (conclusion 5). However, no signal will travel out through arm C, because there is no potential difference at the input to arm C. The reason for this lack of potential can be found by referring to figure 13. First, however, a brief explanation of the figure is in order. When a signal is applied to arm D, an E field will appear across this arm, and its components will have different magnitudes as shown by the associated vectors labelled 1. If one visualizes this E field progressing to the junction, and then out through arms A and B, a solid volume will be described as was shown in figure 8 for the H-type T junction. However, instead of showing the volume, slices of it have been drawn only at important points to indicate the shape of the field at those points. The large arrows indicate the direction in which the energy flows in passing through the junction. With this in mind, consider the slices labelled 2 and 3. Because of the symmetry of the magic T, the energy will divide equally into arms A and B, and the E fields on both sides of arm C will be identical in shape. Since the potentials on both sides of arm C are the
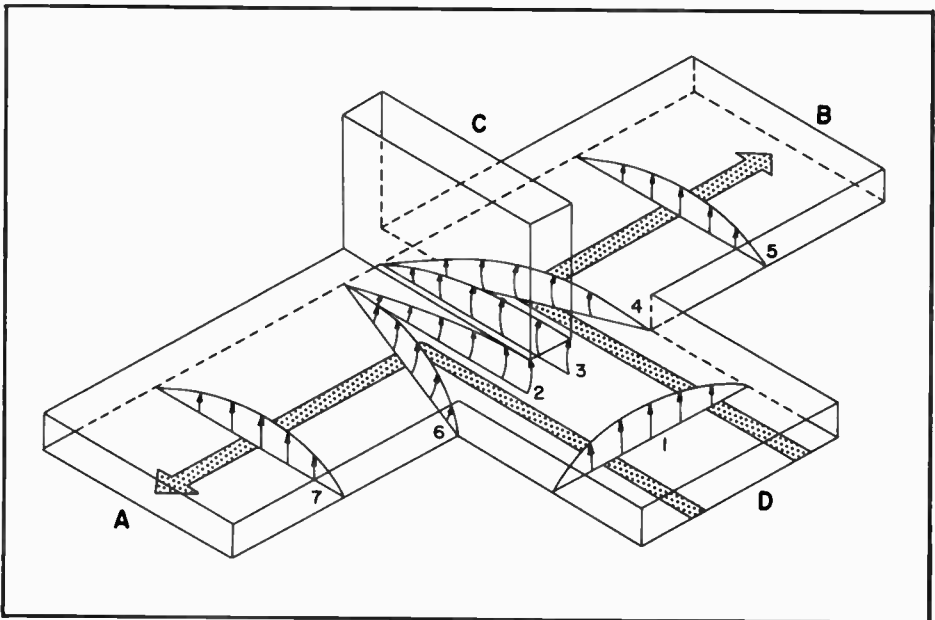

Figure 13. E Fields in a Magic T with a Signal Fed into Arm D

same, no potential difference will be impressed at the input of this arm, and no signal will travel out through arm C. The bending of the arrows is due to the fringing effect at the opening of the arm. E field slices 4 and 6 indicate the shape the field takes as it goes around the corners of the junction. E field slices 5 and 7 show the field returned to its normal shape as it is propagated out through arms A and B. The result of applying a signal to arm D may be stated as follows:

> When an input signal is ap-   (8)
> plied to arm D of a magic T,
> the outputs from arms A and
> B will be in-phase with the
> input signal, and no output
> will be obtained from arm C.

Finally, consider the operation of the magic T when a signal is applied either to arm A or arm B (because of the symmetry of the magic T, the operation will be the same for either arm). Assuming that the signal is applied to arm A, as indicated in figure 14, it will be found that outputs will be obtained from arms C and D, but not from B. The reason for this may be determined by referring to figure 14 and recalling the rules for the operation of basic T junctions. In order to determine the resulting outputs,

it will first be assumed that arm D is not present, making the magic T a simple E-type T junction. From conclusion 1, it is known that the output from arm C will be in-phase with the input signal, whereas the output from arm B will be displaced 180°. Next assume that arm C is not present, making the magic T a simple H-type T junction. From conclusion 5, it is known that the outputs from arms B and D will be in-phase with the input signal. Now, when the resulting fields are combined in the magic T, it can be seen that the two component fields in arm B are opposite in phase, causing a cancellation of the signal and zero output from arm B. These facts may be stated as follows:

> When a signal is applied   (9)
> either to arm A or arm B of
> a magic T, outputs that are
> in-phase with the input sig-
> nal will be obtained from
> arms C and D, but no output
> will be realized from the re-
> maining arm.

Application of the Magic T

The principal application of the magic T is that of a balanced mixer. Before going into the mixer operation, however, the problem of noise in a radar system should be explored, in order to aid in
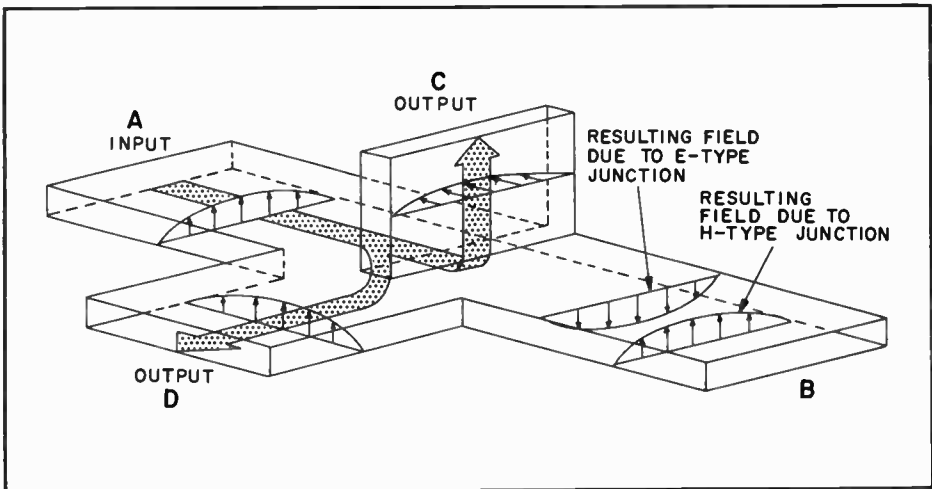

Figure 14.   E Fields in a Magic T with a Signal Fed into Arm A

understanding and appreciating the advantages of the magic T.

Signals received by the radar set are reflections of the transmitted radio energy, but their energy constitutes only a very small fraction of the total transmitted energy. Signals on the order of a few microvolts are received by the radar antenna, and they must be amplified many times before they can be used to give indications on the radar indicators. Noise at radar frequencies is caused principally by random thermal agitation of electrons in conductors, vacuum tubes, and other components. The utmost care is taken in design to ensure that the barest minimum of noise is introduced into the first stages of a radar receiving system, because the signal at this point has not had the benefit of amplification and the noise would be comparable to the signal in magnitude. In a radar receiver, it has been found that no significant noise is introduced preceding the mixer stage. However, in the mixer stage, rather serious noise contributions will be made by the local oscillator, especially above 3000 mc. It is desirable, therefore, to use a device which will permit mixing but which will eliminate the local-oscillator noise. A balanced mixer, one form of which is the magic T, is such a device.
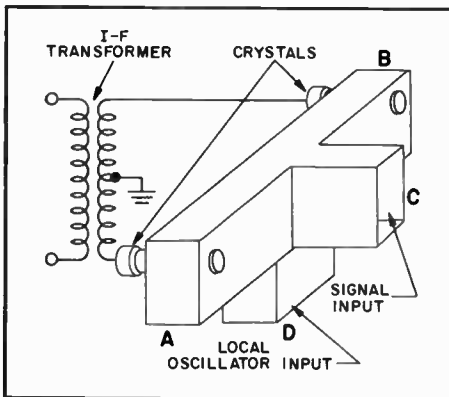
Figure 15 shows the magic T constructed as a balanced mixer, with crystals mounted in two opposite arms, which are closed at the ends. The returning echo signals enter arm C (E plane), and the local-oscillator signal enters arm D (H plane), as shown. Assume first that no local-oscillator noise is present. From the discussion of the magic T, it can be seen that the local-oscillator signal will divide and the two portions will pass out, in-phase, through arms A and B to the crystals. The signal from the antenna will also divide and the two portions pass out through arms A and B, but with opposite phases.

The waveforms of figure 16 show the resultant of the local-oscillator and echo signals applied to the two crystals. Note that the amplitude of the local-oscillator signal is greater than that of
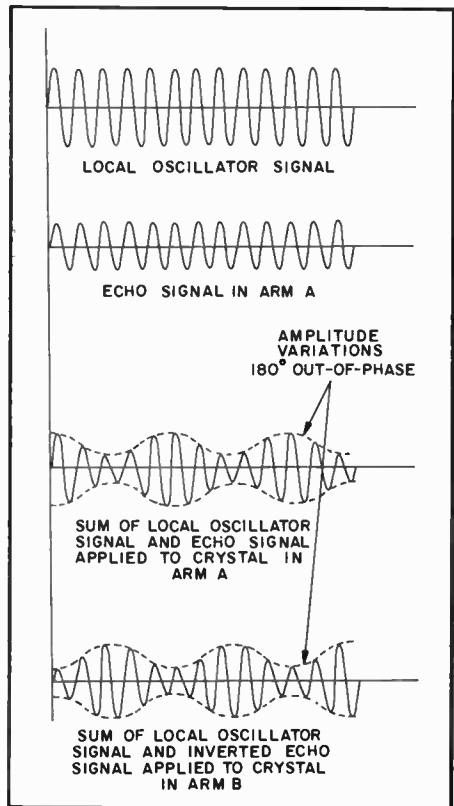

Figure 15. *The Magic T as a Balanced Mixer*

Figure 16. *The Resultant Signals Applied to the Crystals of a Magic T Balanced Mixer*

the echo signal, and that the amplitude of the resultant signal varies as the difference between the two frequencies. In addition, because of the opposite phases of the echo signal, the resultant amplitude variations will occur 180° out-of-phase in the two arms.

In order to obtain the beat frequency, which will be used as the i.f., the signals are passed through the crystals, which are nonlinear devices. The crystals can be assumed to be rectifiers having the characteristic shown in figure 17. This figure shows the resultant output waveforms that are applied to the i-f transformer. No voltage can be induced in the secondary of the i-f transformer unless a voltage difference exists across the primary. Since the pulses that come from both crystals occur in-phase and only the amplitude changes occur out-of-phase, the only signal coupled to the secondary will be that which is caused by the difference in amplitude. Thus the output pulses from the i-f transformer will vary in amplitude in accordance with the beat frequency. (In practice, the signals are fed to a tuned circuit, which makes the output a sine wave instead of a series of pulses; however, the use of this circuit has no bearing on the fundamental explanation and will not be discussed further.)

Noise will appear as random fluctuations of the local-oscillator frequency. For explanation purposes, let it be assumed that the noise occurs in pulses shaped like a square wave. Since the noise adds energy to the signal, it will increase the amplitude of the signal, as shown in figure 18. Note that the noise signal has the same phase in both arms of the mixer (since it arises in the local oscillator). When the combination antenna and oscillator-noise signals pass through the crystals, the resulting sig-
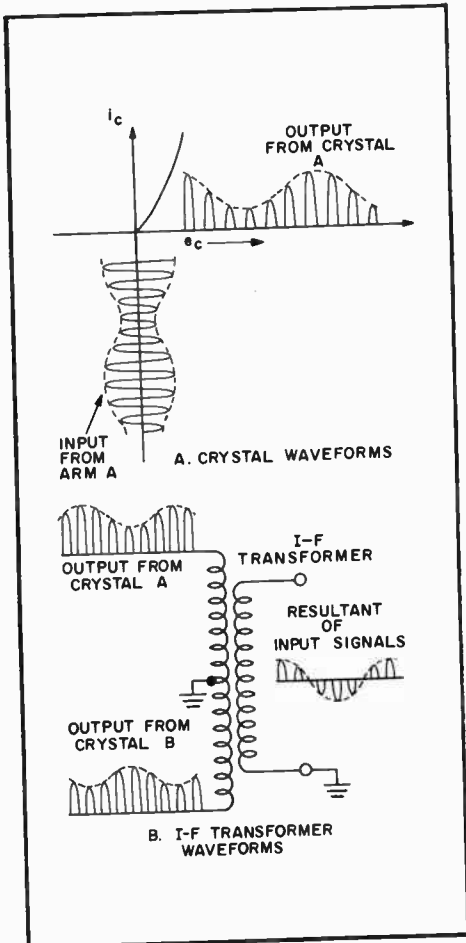

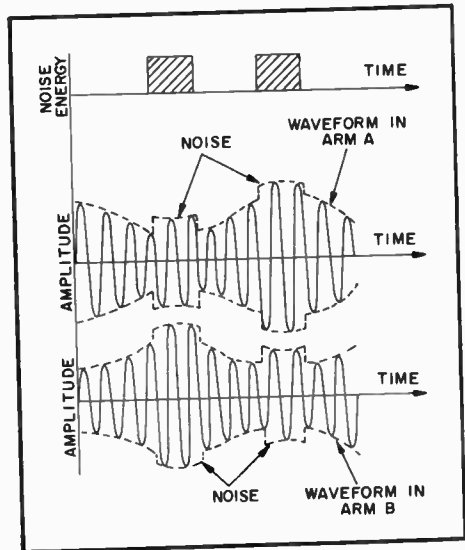Figure 17. Output Waveforms from the Balanced Mixer Crystals

Figure 18. The Effect of Noise on Signal in Mixer Arms

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nal applied to the transformer will appear as shown in figure 19. It can be seen that the increase in the amplitude of the pulses, caused by the noise, is the same on both sides of the transformer. Hence, no noise signal will appear in the output because the noise pulses do not cause a potential difference across the transformer primary. The beat frequency, however, still causes a potential difference, and the output will contain this signal.

Reflections in the Magic T

Unfortunately, when a signal is applied to any arm of a magic T, the flow of energy into the output arms is adversely affected by the junction discontinuity, which produces reflections. These reflections cause the two major disadvantages found in the use of the magic T. First, the reflections represent a power loss, since all of the energy fed into the junction does not go to the load. Second, the reflections give rise to standing waves, just as they do on a transmission line which is operated into a mismatched load. The standing waves cause voltages higher than the applied voltage to exist along the guide, and can
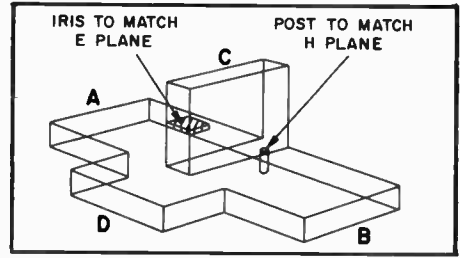
Figure 20.   Matching Device for a Magic T

result in arc-overs, which cause improper system operation. Thus the power that the system can carry is seriously reduced. In order to reduce the reflections, some means of matching at the junction is needed which will not destroy the symmetry. Pound* suggested a solution which proved satisfactory for a 3-centimeter magic T. A post was used to match the H plane, and an iris to match the E plane, located as shown in figure 20. However, even though a good match can be obtained by this method, the post and iris reduce the breakdown voltage rating of the junction by reducing the breakdown distance.

*R. V. Pound, Radiation Laboratory Report 662, August 1945.

Figure 19.   Mixer Signal Plus Noise Waveforms Applied to I-F Transformer

SWITCHING UNIT FOR RT-66 ALIGNMENT

by James F. Mayo
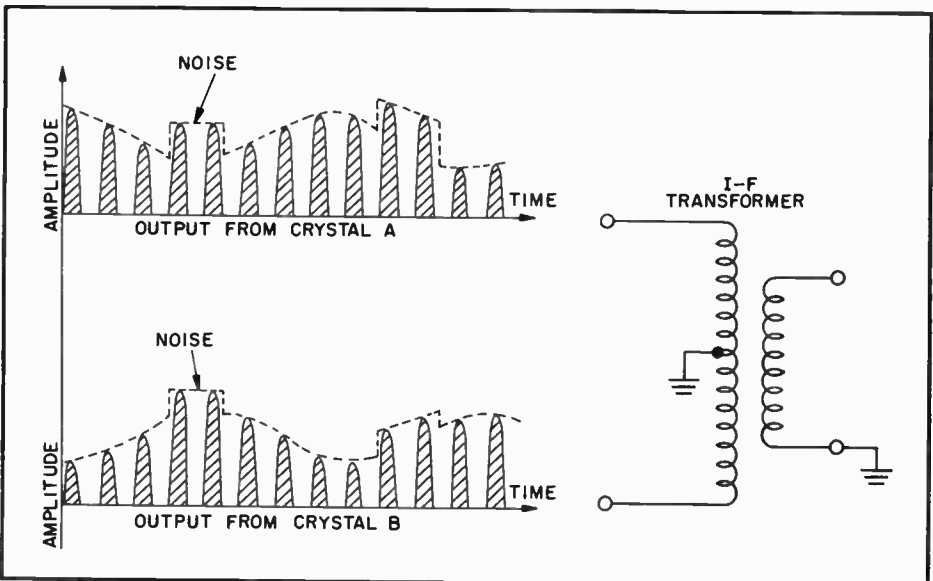Philco Field Engineer

An easily constructed device which simplifies alignment procedures on the RT-66/GRC, RT-67/GRC, and RT-68/GRC receiver-transmitter equipments.

IN THE DESIGN of the receiver-transmitter equipments RT-66/GRC, RT-67/GRC, and RT-68/GRC, many of the test points are brought out to two metering sockets, X200 and J3. While this feature in itself simplifies alignment procedures to some extent, it is still quite inconvenient to transfer meter probes around to the various socket pins. Moreover, it is necessary to turn over the chassis several times during alignment. This presents a problem in that the meter probes tend to fall out of the test sockets, or they may break in the turnover process.

The switching unit, illustrated in figure 1, overcomes the haphazard probe-contact problem, and has the added advantage of leaving both hands of the technician free to make the required adjustments. The switching unit is designed so that plugs may be inserted into the metering sockets, thereby bringing the test points into a switch box. When the VTVM leads are connected to two binding posts on the box, the meter may be connected to the desired test points through the manipulation of two selector switches.

Receiver-transmitter test points, used in the alignment procedure and brought out to test sockets, are pins 1, 2, 5, 6, 7, and 8 on socket X200, and E9F, E9G, E9H, and E9J on socket J3. Test socket X200 is an octal tube socket, while J3 is a 4-pin socket of the crystal holder type.

MATERIALS REQUIRED

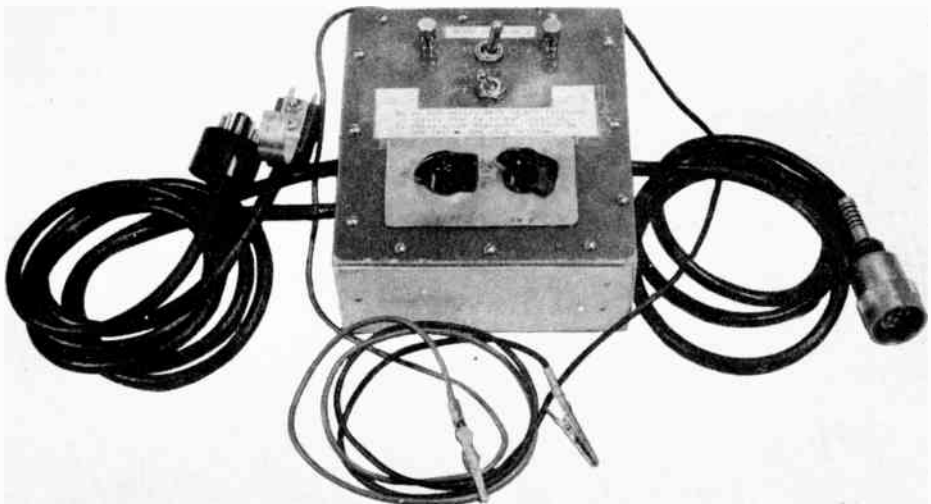As shown in the photograph and in the schematic diagram of figure 2, the

Figure 1. Photograph of Switching Unit Built by Author

switching unit is equipped with three plugs. The plug for test socket X200 is made from an old octal tube base. The plug for test socket J3 is constructed from two old crystal holders fastened together, while the transmitter keying plug is an H-33/PT audio connector.

SW1 is a 7-position rotary switch and SW2 is a 5-position rotary switch. Two toggle switches are used—an SPST keying switch and a DPST meter disconnect switch.

All cords used are discarded H-33/PT handset cords. Two test leads, the switch box, panel, binding posts, and control knobs complete the list of materials needed for fabrication.

SWITCHING FEATURES

The ground position of SW2 (negative terminal of the VTVM) is connected to pin 1 of socket X200, which is grounded internally. The positive VTVM terminal can be switched through SW1 to all of the other test points previously mentioned.

Since it is sometimes necessary to connect the negative lead of the VTVM to points above ground for some of the adjustments, this terminal can be switched through SW2 to pin 2 of X200 and to points E9G and E9H of J3.

Because several other test points are not brought out to test sockets, provision is made in both SW1 and SW2 for switching the meter terminals directly to the two test leads which are equipped with alligator clips. Some of these test points are E4H, E2L, E6A, E6B, E7B, and E8G. When it is necessary to measure from one of these points to ground, only the positive probe need be used, since SW2 is left in the ground position. When it is desired to measure between two of these test points, both switches are turned to PROBE position and both probes are used.

For the protection of the VTVM, the meter disconnect switch is provided to isolate the binding posts from all switch positions. This switch should always be in the OFF position when the SW1 and SW2 positions are changed.
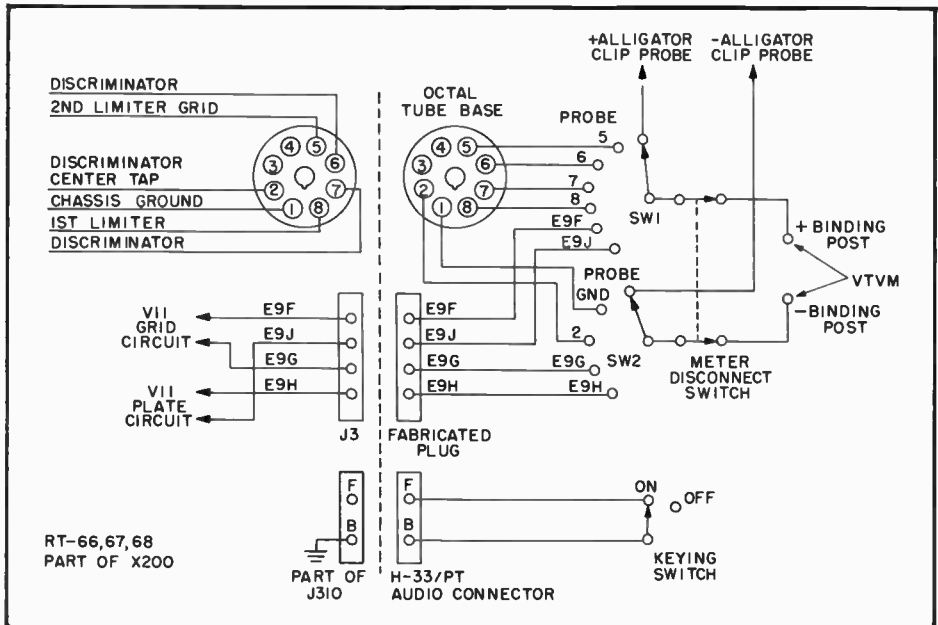

Figure 2. Schematic Diagram of Switching Unit

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It is necessary to add one note of caution in the operation of the switching unit. E9F and E9G are across R50, and E9H and E9J are across R53, the resistors being current metering resistors in the respective grid and plate circuits of the transmitter final amplifier. Therefore, SW1 should never be turned to position E9J *unless* SW2 is first placed in the E9H position. This prevents 450 volts from being applied to the meter when it might be set for a low-voltage scale; this would occur if SW1 was on E9J and SW2 was turned to GROUND position. For this reason, the front panel should carry the following legend:

CAUTION
1. Do not switch SW1 to E9J position unless SW2 is in E9H position.
2. Throw meter disconnect switch to OFF before changing rotary switch positions.

PHILCO TRANSISTORIZED PHONOGRAPH

THE FIRST COMPLETELY TRANSISTORIZED phonograph has been developed by Philco Corporation. In addition to being transistorized, this phonograph is also fully portable.

Philco engineers report that the transistor phonograph, which uses three transistors, will play up to 3000 standard 45 r.p.m. records using only four standard flashlight batteries. Because of the low power drain, 150 hours of continuous operation is possible.

Components in the new transistorized phonograph are radically different from those in a conventional phonograph. The set has the smallest turntable motor of any phonograph on the market—a 4-volt motor which weighs less than three ounces and which is approximately one-fifth the size of the conventional motor.

A speed control was developed to compensate for any loss of power due to aging of the batteries. Special provisions have also been engineered in the phonograph's chassis so that fresh batteries can be quickly inserted through a trap door at the bottom of the cabinet. The transistor phonograph uses a printed-wired chassis and a 4-inch speaker. The phonograph tone arm incorporates an on-off switch, which automatically stops the turntable and turns off the set after each record, to eliminate excess waste of battery power. No warm-up time is required, and records can be played with the cabinet lid closed.

This phonograph is the second completely transistorized entertainment appliance Philco has made available to the public within a few months. Only recently, Philco and Chrysler Corporation announced a completely transistorized auto radio.

RADAR RECEIVER A-F-C SYSTEMS

PART 2

by H. W. Merrihew
Headquarters Technical Staff

This article is the second of a series of three on radar a-f-c systems. The first article of this series appeared in the July and August, 1955 issue of the BULLETIN. The reader should be familiar with the first installment and have it available for reference in reading the discussion that follows.

A GAS TUBE A-F-C CIRCUIT

Figure 4 of the first installment showed the block diagram of a search and tracking system using gas tubes. The schematic diagram of the system, part A of figure 1, shows only those elements of the a-f-c system which make it different from the tracking system previously described; thus, only the pulse amplifier, the control tube, and the search tube are shown.

This a-f-c circuit utilizes two thyratrons for the search and control functions. When the system is turned on, the control thyratron (tetrode type) will not conduct until positive pulses are applied to its control grid from the discriminator. The search tube (triode type), however, will conduct as soon as C_1 has charged to a sufficiently high value. The conduction of the search tube will rapidly discharge C_1, and the cycle will be repeated, as shown by the waveforms in part B of figure 1. This constitutes the search action, which occurs at a rate of about 1 cycle per second.

When the control tube is fired, search operation ceases, and the repeller voltage is rapidly varied over a small range. This occurs at a rate of 200 to 400 cycles per second, and constitutes the tracking action. The start of this action is indicated in part B of figure 1.

Part A of figure 2 shows the locus of the klystron frequency as the action shown in part B of figure 1 takes place. When C_1 is completely discharged, the
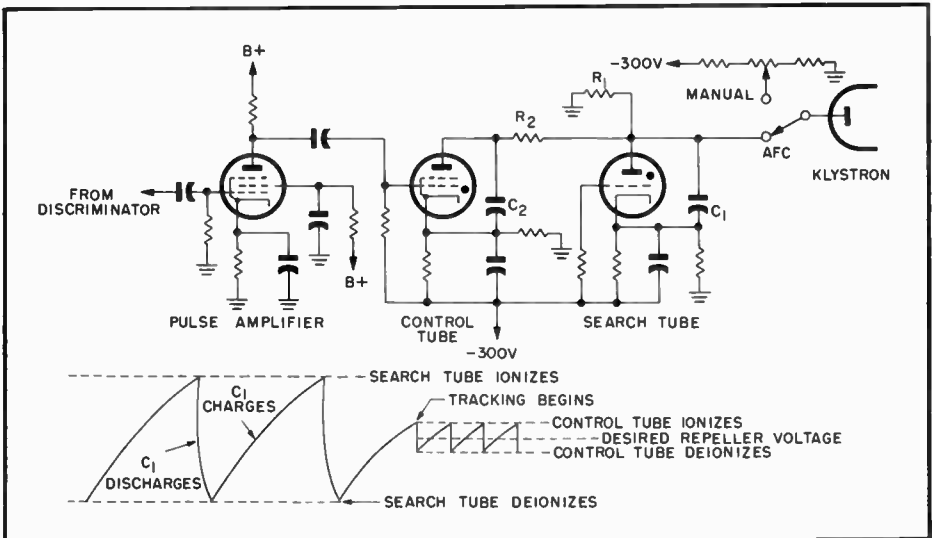

Figure 1. *Gas Tube A-F-C Circuit and Waveforms*

repeller of the klystron is at its most negative potential, and the klystron frequency is at its highest value. As C_1 charges, the frequency is gradually lowered until the klystron frequency reaches a value where i-f signals begin to appear. With additional change, the output of the discriminator will consist of positive pulses followed by negative pulses, as the i.f. passes through the 30-mc. frequency. This condition is illustrated in part B of figure 2.

The positive output pulses from the discriminator are amplified and inverted by the pulse amplifier. The resulting negative pulses are applied to the grid of the control tube, but have no effect since positive pulses are required to make this tube conduct. As the klystron frequency decreases and the i.f. reaches 30 mc., the discriminator output becomes zero. When the i.f. exceeds 30 mc., negative pulses appear at the discriminator output. These pulses are amplified, inverted, and applied to the grid

of the control tube. The control tube now conducts and discharges C_2. The resulting drop in potential is applied to the repeller of the klystron, causing the frequency to increase slightly. The positive pulses disappear, the control tube de-ionizes, and C_1 and C_2 commence charging again. When positive pulses again appear at the grid of the control tube, the tube conducts and C_2 is again discharged. This sequence of actions is shown in part A of figure 2. The repeller voltage oscillates about a level which holds the average klystron frequency at the correct level. In a typical circuit the value of C_1 is large, about .5µf., and the value of C_2 is relatively small, about .05µf. C_2 is decoupled from C_1 by R_2.

Figure 3 shows a simplified equivalent of a gas tube a-f-c circuit. C_1 charges toward ground until C_2 is discharged by S_2, at which time the charging process is momentarily halted. When S_2 opens, C_1 and C_2 once again begin to charge. The search thyratron will not fire dur-
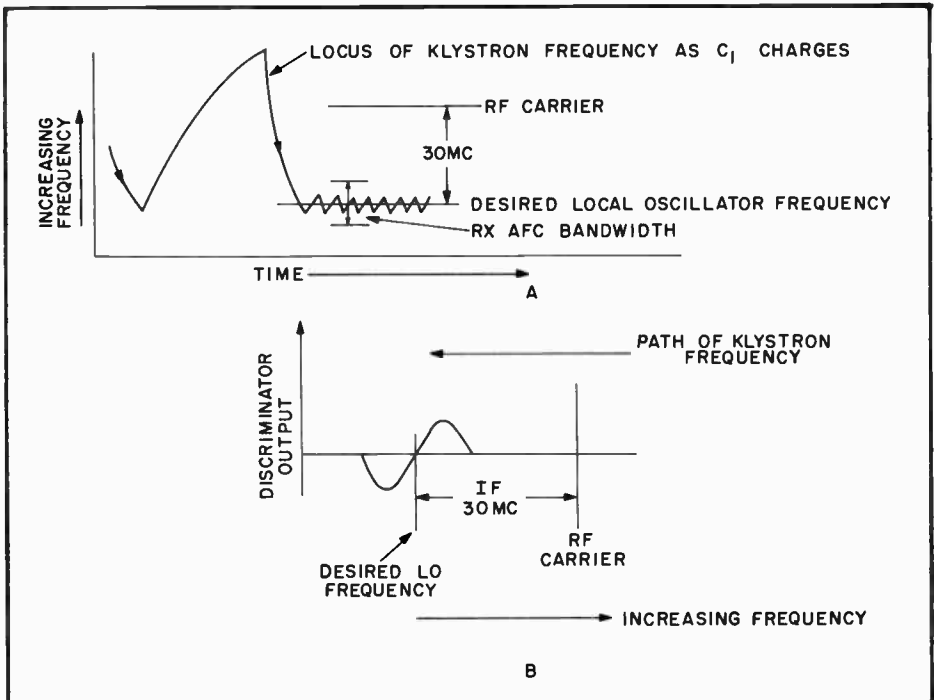

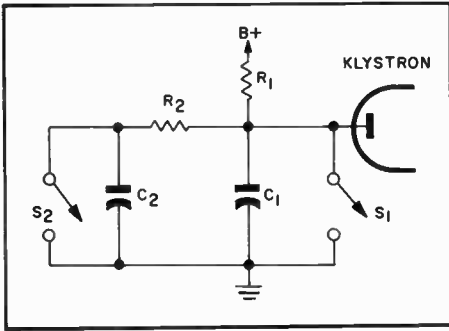Figure 2. Local-Oscillator Frequency Diagrams

Figure 3. Equivalent of the Gas Tube Circuit

ing the tracking process because the voltage across it never reaches the ionization potential. The closing of S_1 corresponds to the firing of the search tube.

If a change in the klystron or magnetron frequency makes it necessary to lower the klystron frequency, C_1 will commence charging and continue to charge until the desired lower frequency is reached. This action is illustrated in figure 4, points A to B.

If it becomes necessary to raise the klystron frequency, C_1 will charge until the search tube fires and raises the klystron frequency to its highest value. The charging of C_1 then gradually lowers the frequency until the correct value is obtained. This action is shown in figure 5 from points A to B. The system

searches for the correct frequency and locks in by the tracking action described above.

THE PHANTASTRON CIRCUIT

The phantastron circuit also incorporates a search feature. It is not necessary to manually tune the klystron to the exact freqency desired, although it is necessary for the resonator tuning to be in the desired region. As shown in figure 6, a Weiss discriminator is used. The operation of this circuit is similar to that of the discriminator circuit described previously except that the capacitor is tapped instead of the inductor. The analysis is similar. The discriminator output circuit is of the short-time-constant type, and produces positive or negative pulses to operate the lock-in feature.

Assuming that the a.f.c. is to lock the local-oscillator signal at a frequency 30 mc. below the transmitter frequency, the search action is as follows: The application of $B+$ causes the plate to draw current, which decreases the plate voltage abruptly. This drop is applied by C_3 to the control grid. The control-grid voltage will not decrease far enough to cut off the plate current since the source of voltage is in the plate circuit. The plate voltage now begins to decrease
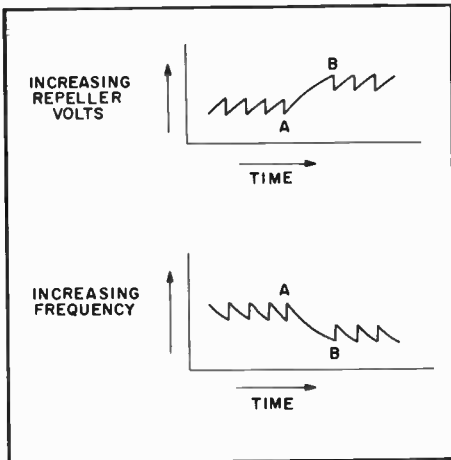

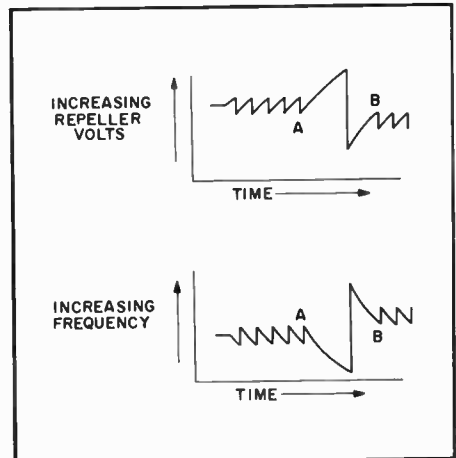**Figure 4. Circuit Waveforms for a Decrease of Klystron Frequency**

Figure 5. Circuit Waveforms for an Increase of Klystron Frequency
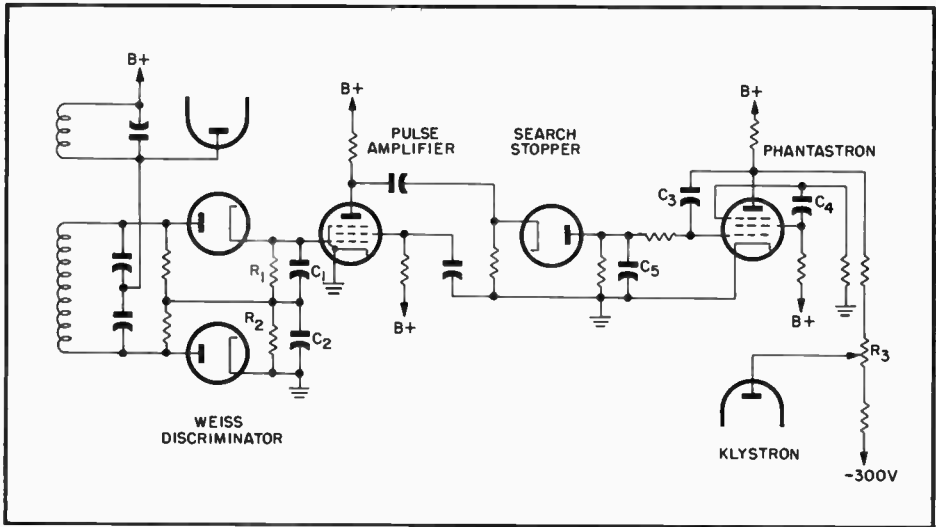
17

Figure 6. The Phantastron A-F-C Circuit

gradually. The discharge of C_3 allows the control-grid voltage to rise slowly (see figure 7), causing the plate voltage to continue to drop. The plate current is passed to C_3 and is the source of current for its discharge. Since the plate current of a pentode is nearly constant over this range of plate voltage, the discharge of C_3 is fairly linear. When the plate current drops to the bend or knee in the E_p-I_p characteristic curve, the plate current decreases (see the characteristic curve in figure 7). Since the cathode current of the phantastron is essentially fixed, the screen grid draws the current not being drawn by the plate, and the screen voltage drops. This drop in screen voltage is applied to the suppressor grid and causes an additional drop in plate current. The process is regenerative and soon cuts off the plate current. The current remains cut off until C_4 has discharged sufficiently to allow the plate to start drawing current again. During plate current cutoff, C_3 charges. The circuit repeats this action at a rate of about 1 cycle per second. The negative-going sawtooth at the plate is fed via the divider to the repeller of the klystron. As the voltage becomes more negative, the klystron frequency increases. As the proper operating frequency is approached, the i.f. will be greater than 30 mc. The discriminator is connected to produce negative pulses for an i.f. greater than 30 mc. These pulses have no effect since they are inverted by the pulse amplifier, and are not passed by the search stopper. The klystron frequency continues to rise until the i.f. becomes less than 30 mc., whereupon the output of the discriminator becomes positive.

At this point the locking action begins to take place. The positive pulses are amplified and inverted by the pulse amplifier, and output negative pulses appear at the cathode of the search stopper. These pulses charge capacitor C_5, and after a few pulses sufficient charge appears on C_5 to hold the phantastron grid bias constant. The gradual decrease of plate voltage ceases, and the repeller voltage is held constant at this point. A small displacement of the i.f. from 30 mc. will exist in order to maintain a charge on C_5, and keep the phantastron plate at the desired potential.

If the i.f. becomes greater than 30 mc., because of a decrease in klystron frequency or an increase in magnetron frequency, the a-f-c circuit must increase

the local-oscillator frequency, to return the i.f. to the correct value. This is done as follows: The bias pulses are removed from the search stopper, and the plate voltage begins a gradual decrease as before. The dropping plate voltage causes the repeller to become more negative, thus raising the klystron frequency and once again producing the correct i.f. The action for an i.f. of less than 30 mc. is similar.

A CAVITY AND REPELLER TUNING SYSTEM

The next a-f-c circuit to be discussed involves a scheme for tuning the klystron resonator cavity and repeller. The circuit diagram is shown in figure 8.
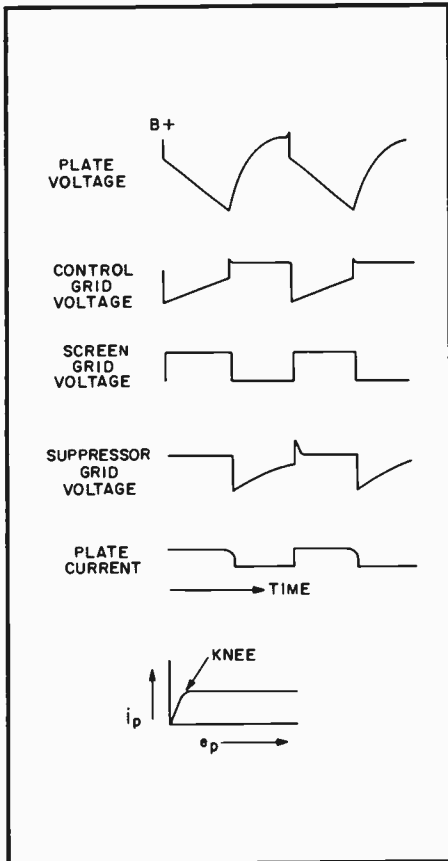

Figure 7. Waveforms and Tube Characteristic for the Phantastron Circuit

The discriminator is a Travis inductively coupled type, and incorporates three tuned circuits. The primary is tuned to 30 mc., the upper secondary to 27 mc., and the lower secondary to 33 mc. The primary tuning is made quite broad in order to cover the 6 mc. difference between the secondary windings. This is accomplished by placing a resistor in parallel with the primary. In figure 9 the response curve of each secondary winding is shown. Consider the individual response curve as indicative of the voltage applied to the diode associated with that secondary. At 30 mc. the output of the diodes is equal and the resultant voltage between points A and B is zero.

Any increase or decrease of the input frequency to the discriminator will cause the output of one diode to become larger than the output of the other. This causes the net voltage between points A and B to be either positive or negative, as illustrated in figure 10. The output voltage of the discriminator is fed to the differential d-c amplifier identified as (1) in figure 8. The selector switch in the output is used to change the direction of the swing in the correction voltage applied to cathode follower (1). If the switch is in the position shown, the output to the cathode follower will become more positive for an i-f signal that is increasing in frequency. This will ultimately cause the local-oscillator frequency to be raised, so that the local oscillator will lock in 30 mc. below the transmitter frequency. If the switch is placed in the opposite position, an increase in the frequency of the i-f signal produces a negative-going signal, which is applied to cathode follower (1) and which will ultimately cause the local-oscillator frequency to be lowered. In this position, the switch must be used for lock in at 30 mc. above the transmitter frequency.

The output of cathode follower (1)

operates servo control amplifier (1). The servo control amplifier supplies current to the d-c coil of relay K_1. This relay has a permanent magnet for bias; that is, a quiescent current through the d-c coil is necessary to hold the contactor in the center position. Thus a current of about 10 ma. supplied by the servo control tube would hold the contactor in the center position except for the effect of the a-c winding. The a-c winding is en-ergized by a 60-cycle voltage, which causes the contactor to vibrate at a frequency of 60 cycles per second. If the d-c current varies from 10 ma., the contactor rests longer against one contact than against the other.

Figure 11 illustrates the circuit conditions that exist for each position of the relay contactor, and shows the effect of each condition on the motor stator cur-
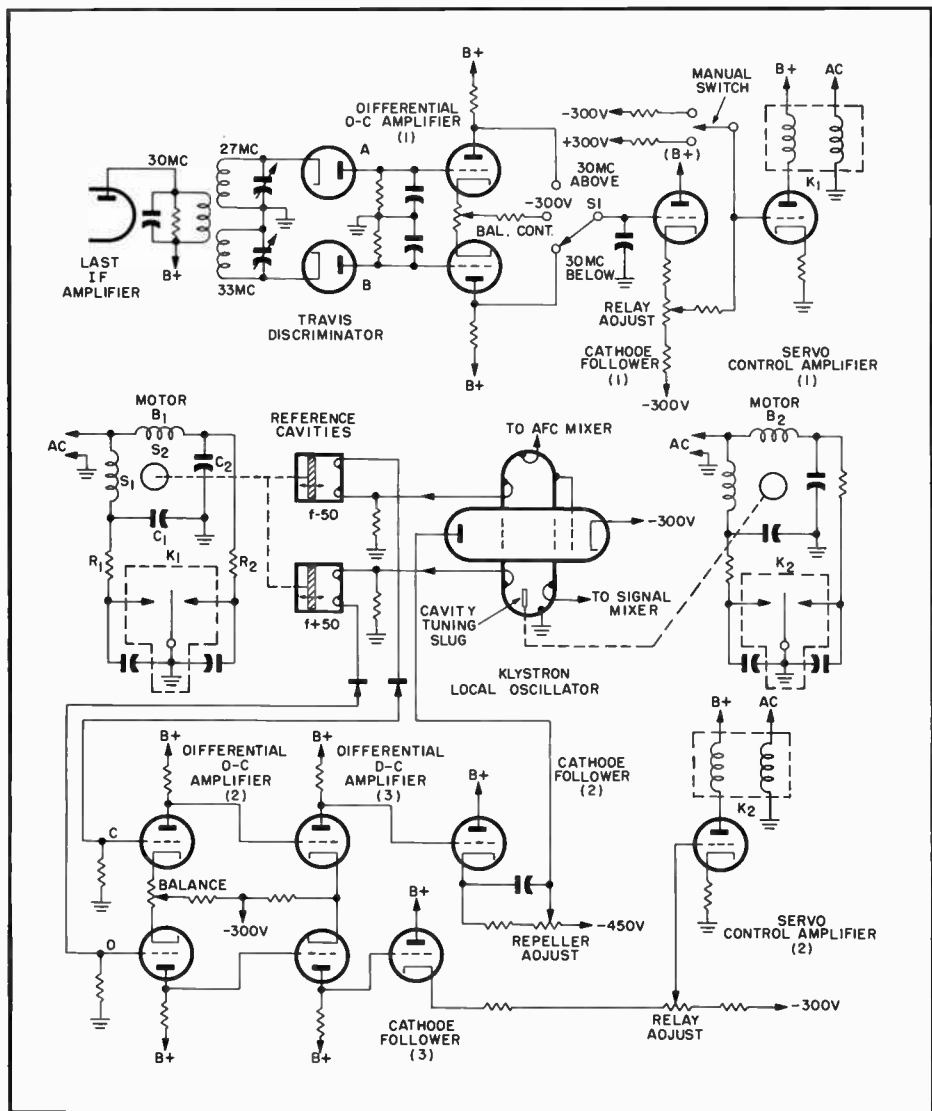

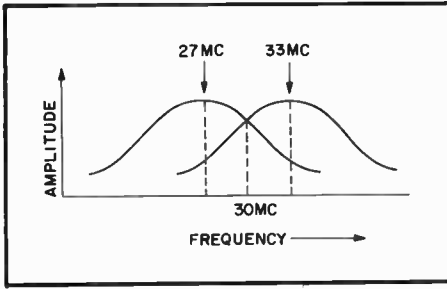*Figure 8.   Circuit for Control of Klystron Cavity and Repeller*

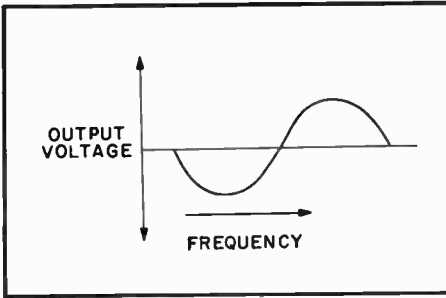**Figure 9.** *Response Curves for Travis Discriminator Secondary Windings*

Figure 10. *Over-all Response Curve for Travis Discriminator*

rents. Circuit condition A causes I_1 to lead I_2 by 90 degrees, and would produce clockwise rotation of the motor. Circuit condition B causes I_2 to lead I_1 by 90 degrees, and would produce counterclockwise rotation of the motor. If these conditions last for equal time intervals during an a-c cycle, the motor will not develop sufficient torque to overcome its inertia and start. Anytime that condition C exists, I_1 and I_2 are in phase. Since for a motor of this type to operate, the field stator currents must be approximately 90 degrees out-of-phase, condition C contributes nothing to the motor rotation. The motor runs when an error signal appears at the servo control amplifier. This error voltage causes the plate current to shift from its 10-ma. quiescent value. When the control-amplifier current decreases, the contacts of K_1 will spend more time in the A condition. This causes the motor to rotate in a clockwise direction, since the net rotating field in the motor is
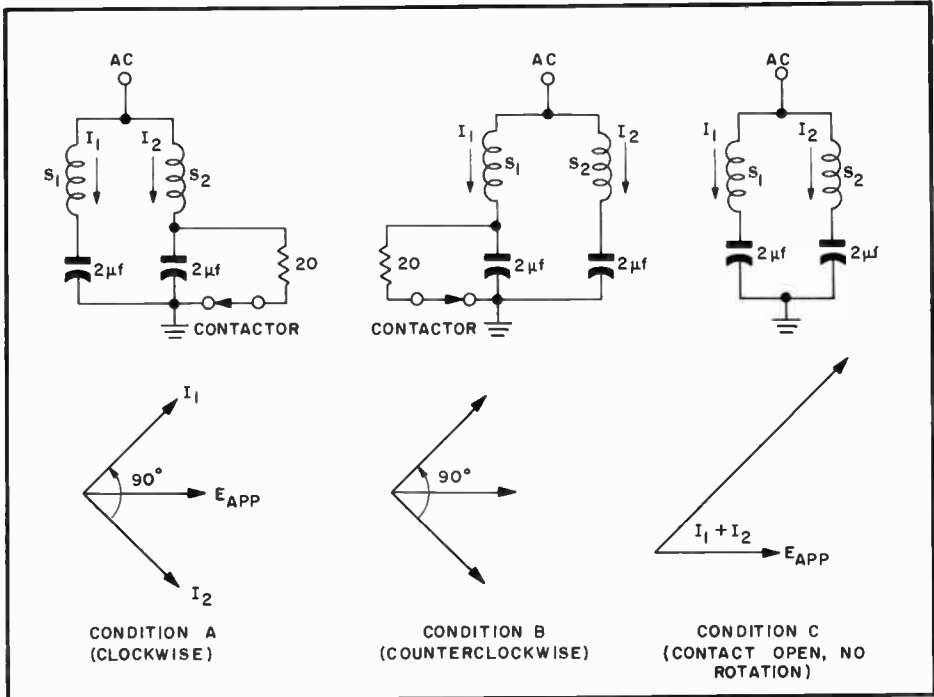

Figure 11. *Control Relay and Motor Circuit Conditions*

produced by the phase relation indicated in condition A. It is possible for the plate current to decrease to the point where the relay remains in the A condition continually. When this happens, the motor develops its greatest torque. A similar situation prevails for an increase in plate current, where condition B controls the rotation, which is in a counterclockwise direction.

The motor tunes two reference cavities; for the A condition the frequencies of the cavities will be lowered, and for the B condition the frequencies of the cavities will be raised. This is stipulated for S_1 in the "30 mc. below" position. The reference cavities are excited by the local-oscillator signal, and the resonant frequencies of the cavities are separated by 100 kc. Figure 12 illustrates the condition of the system at rest. Symbol F_0 represents the local-oscillator frequency, and the cavity frequencies are displaced from F_0 by 50 kc. Whenever an error signal causes motor B_1 to rotate, the cavities will be tuned, but the local-oscillator frequency will remain the same. Hence, the cavity response curves shift so that they are no longer symmetrically spaced with respect to F_0.

The cavities and the crystal detectors in their output circuits may be thought of as a discriminator. For the condition given in figure 12, which shows the frequency of each cavity displaced from the local-oscillator frequency by 50 kc., the crystal outputs are equal and no error signal is sent to the differential d-c amplifier (2). But if the cavities are tuned away from this position by an error signal applied to the servo control amplifier (1), the outputs of the crystals will be different and an error signal will be applied to the grids of the d-c amplifier (2). This error may cause point C to go positive with respect to point D, or vice versa.

The output of the upper portion of the d-c amplifier (2) is coupled to a second d-c amplifier (3), and the amplifier in turn is coupled to cathode fol-
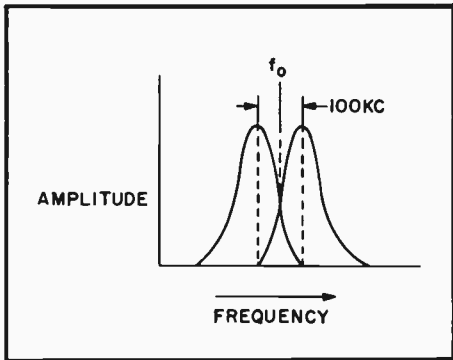

Figure 12. Relation of Cavity Response Curves to Local-Oscillator Frequency

lower (2). The output of the latter stage varies the repeller voltage of the klystron to make the necessary frequency correction. From the lower section of d-c amplifier (2) an output is coupled to the lower section of d-c amplifier (3), and then to the cathode follower (3). The output of this cathode follower controls the grid voltage of servo control amplifier (2). Control amplifier (2) operates a relay system (relay K_2 and motor B_2) which is identical in operation to that described previously. Motor B_2 mechanically varies the klystron resonator tuning. The system comes to rest when the output of the Travis discriminator is zero, and when the frequencies of the reference cavities are symmetrically spaced on either side of the local-oscillator signal.

A typical case is now illustrated: Assume that the local-oscillator frequency is supposed to be 30 mc. below the transmitter frequency and that it becomes necessary to raise the local-oscillator frequency. The following steps take place:

1. The i.f. becomes greater than 30 mc.
2. The output of the Travis discriminator causes the servo control amplifier plate current to increase.
3. Condition B occurs at motor B_1, and the motor raises the cavity frequencies.
4. The output of the lower cavity rectifier becomes less negative.

5. The output of the upper cavity rectifier becomes more negative.
6. The rectifier output of the upper cavity is fed to the klystron repeller, making it more negative and raising the klystron frequency.
7. The rectifier output of the lower cavity is fed to the second servo control amplifier, and the plate current of this amplifier increases.
8. Condition B occurs at motor B_2, and the motor increases the resonator frequency of the klystron.
9. The system comes to rest at the new frequency.

Manual tuning of the local oscillator is accomplished by inserting a d-c error voltage at the grid of servo control amplifier (1).

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ERRATA (July-August Issue)

"Radar Receiver A-F-C Systems (Part 1)" Article

1. The diagrams shown in figures 4 and 5 should be interchanged; i.e., the diagram shown on page 5 is figure 5; while the diagram shown on page 6 is figure 4.

2. On page 12, the capacitors are incorrectly designated. Change C1 to C2 and change C2 to C3.

SIMPLE ADJUSTABLE POWER SUPPLY

by T/Sgt. David D. Blackmer

A useful device for those installations where several different B+ voltages may be required in the course of daily maintenance.

MANY TIMES THERE IS A NEED for a source of two or more B+ voltages at the same time for experimental or operational use. No doubt this need has presented a real problem in the past; and has resulted in the rifling of many signal residues (polite for junk box), in an effort to find dropping resistors or combinations of VR tubes that could be used to accomplish the job.

There is a relatively easy way of overcoming this problem, as illustrated by the diagrams shown in figures 1 and 2. Several possible solutions to the problem will suggest themselves after a study is made of these two circuits. Figure 1 assumes that a good standard power supply is available, to which can be added one or more circuits to provide adjustable B+ voltages. It also assumes that vacuum tubes can be used as variable resistors. If the control resistor, R_1
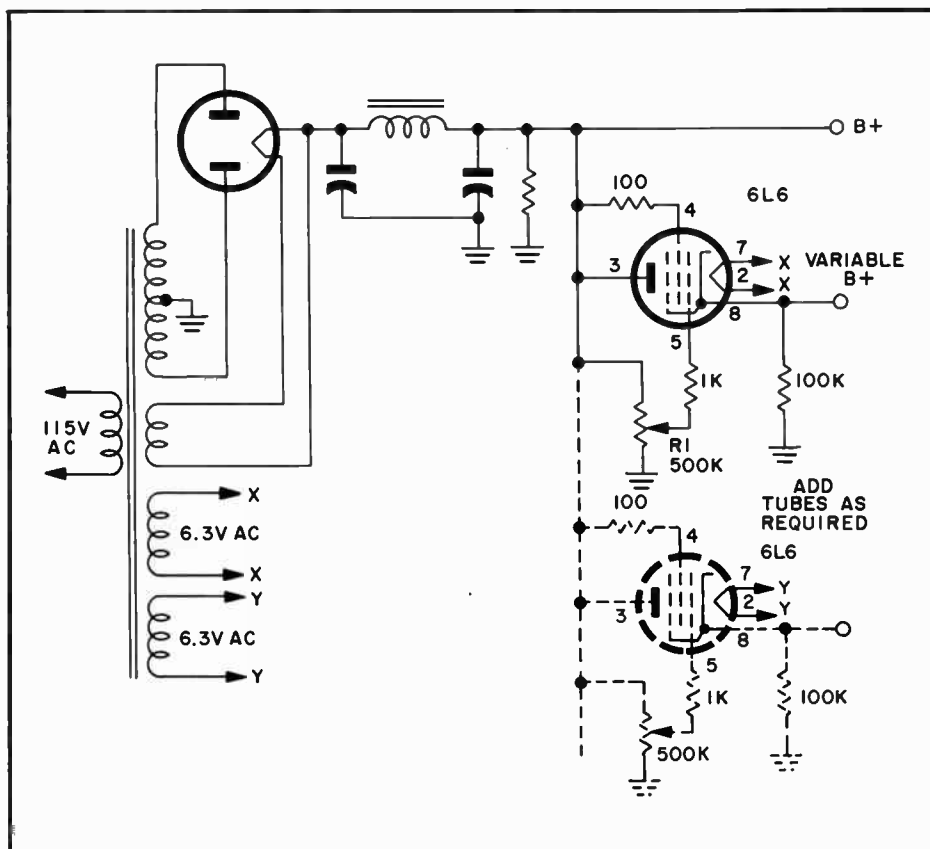

Figure 1. *Schematic Diagram of Standard Power Supply with Additional Circuits for Supplying Variable B+ Voltages*
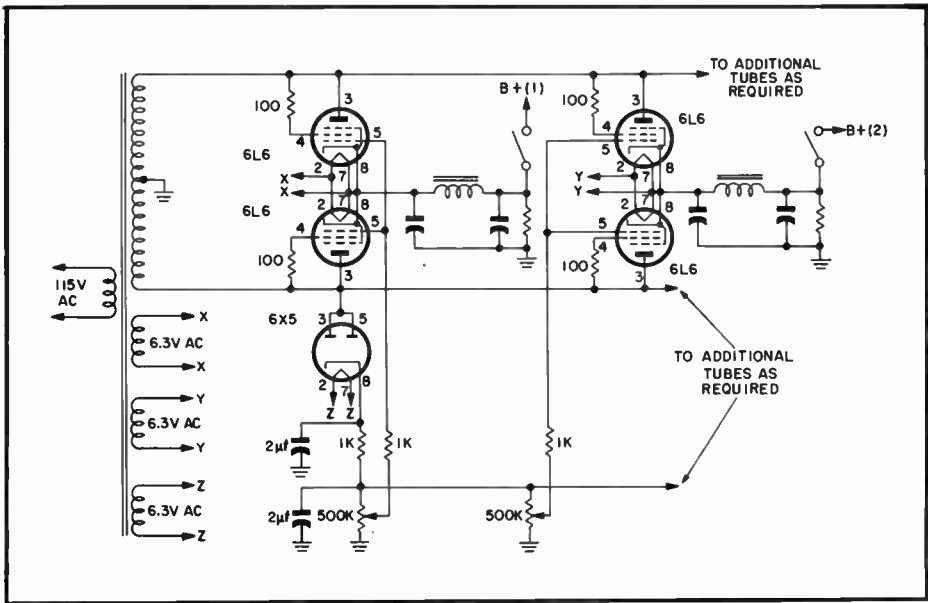
Figure 2. Schematic Diagram of the Adjustable Power Supply

of figure 1, is set with the variable control at the ground end, electron flow from cathode to plate causes the cathode to go positive, but only to the point that the bias causes cutoff. If R_1 is adjusted in a positive direction, the cathode potential will rise. The maximum value is limited only by the applied B+ voltage and the IR drop in the tube; therefore, by the twist of a knob, a continuously variable voltage is obtained from about 45 volts up to the full B+, less the voltage drop across the tube. The tube thus becomes a deluxe variable resistor. Additional tubes may be added as required, as long as the current drawn by the various circuits to which power is supplied does not exceed the rating of the power supply used. A 6L6 tube will draw about 50 ma.; two such tubes may be used in parallel for added current drain, as illustrated in figure 2.

The circuit of figure 2 uses a pair of tubes as rectifiers and "variable resistors" at the same time. As indicated in the discussion above, more than one pair of tubes may be used to supply additional voltages as required; however, care must be exercised not to overload the circuit. As shown in figure 2, a separate filament winding should be used for each pair of tubes, to avoid possible internal voltage breakdown between cathode and filament due to voltage differential between these elements. The 6X5 rectifier tube is used to produce the d-c bias voltage which is applied to the control grids of the 6L6 tubes. The resistor and capacitor components in the cathode circuit of the 6X5 tube act as an a-c filter, to provide a fairly steady d-c voltage. The 100-ohm resistor in the screen-grid circuit of each 6L6 tube is used to supress parasitic oscillations which may be generated within the circuit. The filter components in the B+ circuits are standard values, and any number of value combinations can be used.

Figures 3 and 4, top and front views, respectively, are photographs of the power supply built by the author. This supply is identical schematically with the one shown in figure 2. The d-c outputs, as well as the a-c filament voltage, can be connected through permanent wiring to a number of work benches,
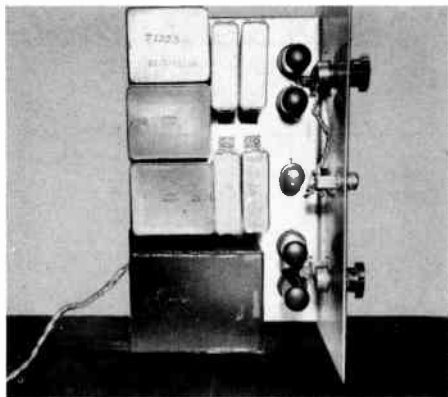
Figure 4. *Front View of the Adjustable Power Supply*

Figure 3. *Top View of the Adjustable Power Supply*

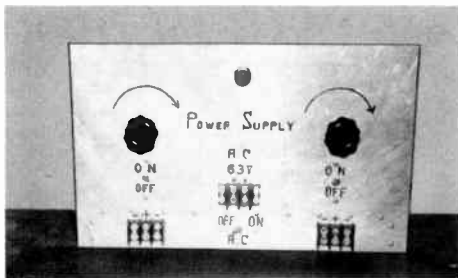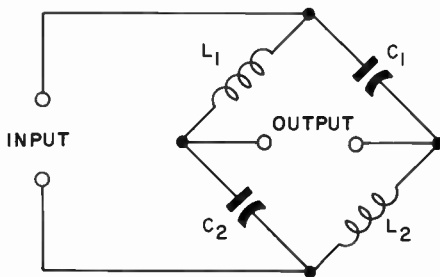and the power supply left at a central location. The power supply illustrated has been in use for several months to power different types of frequency meters and other bench test equipment. Such a supply should prove especially useful in areas where batteries are hard to obtain.

Solution to . . . July-August "What's Your Answer?"

When the circuit is redrawn, as in the accompanying diagram, it is seen to be a bridge, which must be connected to a high-impedance source in order to attenuate an applied signal. The bridge had been connected to a low-impedance transformer winding and therefore was unsatisfactory. It will also be seen that when C_1 and L_2 are interchanged, the bridge becomes balanced at all frequencies and, consequently, provides zero output voltage at all frequencies.

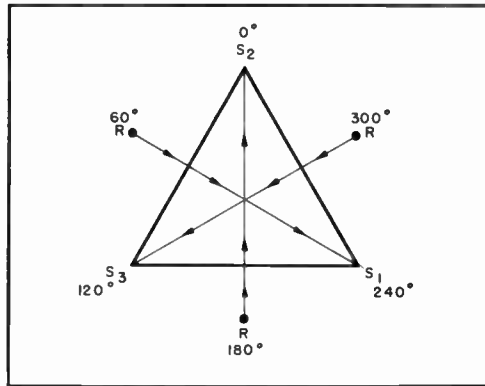# A SIMPLE METHOD FOR DETERMINING PROPER SELSYN CONNECTIONS

Figure 1.

By USING FIGURE 1, anyone familiar with selsyns can readily determine what connections must be changed in a selsyn system when only "crossed wiring" troubles exist. This figure can be memorized or carried in a pocket notebook.

DIRECTIONS FOR USE OF FIGURE

Suppose that the transmitter selsyn is set at zero degrees and the rotation is clockwise, and that the receiver reads 300 degrees and also rotates clockwise. In order to determine what connections must be changed in order to zero the receiver and maintain proper rotation, proceed as follows:

1. Place a pencil point at R 300 degrees on figure 1 and follow the arrows to S3. This means that reversing the rotor connections will cause the receiver to read 120 degrees.

2. Place a pencil point at S3 120 degrees and note that the shortest distance to 0 degrees is from S3 to S2. This means that connections S3 and S2 must be reversed in order to make the receiver read 0 degrees. It should be understood that reversing any two stator connections will reverse the direction of rotation; therefore connections S3 and

S1 must now be reversed in order to correct the rotation without changing the zero reading of the receiver.

To use figure 1, always start at the point representing the reading of the receiver selsyn (with the transmitter selsyn at zero) and follow the arrows and lines to 0 degrees taking the shortest route. If the starting point on the figure is R 300, R 180, or R 60 degrees, the rotor connections must be reversed in order to arrive at a stator point on the diagram. The appropriate stator connections may then be reversed, if required.

SUMMARY

If receiver reads:

60 degrees	reverse	R1 & R2
		S1 & S2
300 degrees	reverse	R1 & R2
		S3 & S2
180 degrees	reverse	R1 & R2
240 degrees	reverse	S1 & S2
120 degrees	reverse	S3 & S2

To correct rotation only, reverse S3 and S1.

Frank DiGenova
Philco Field Engineer

MORE CONCERNING THE ELECTRONIC COLLISION COURSE COMPUTER

*(Editor's Note: Since the publication of the Electronic
Collision Course Computer article by Russell Wolfram, in
the January and February 1955 issue of the BULLETIN,
it has been learned that the circuit, when put to practical
use, had certain faults. It was felt that the computer story
would not be complete without the publication of com-
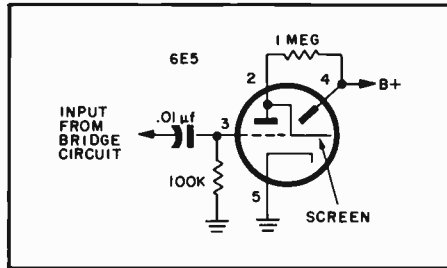ments by someone who has actually built and used the
computer.)*

**Figure 1.   Revision to Electronics Collision Course Computer Circuit**

I N THE ORIGINAL SCHEMATIC diagram of the electronic colli-
sion course computer the B + voltage was shown connected to
the plate (pin 2) of the 6E5 electric eye tube. The B + voltage
should be connected to the target anode (pin 4) of the tube.
A better method of showing the elements of the 6E5 tube is
presented in figure 1, which also shows the correction described.
Note that the 1-megohm resistor remains connected between
the target indicator and the plate. This resistor provides a dif-
ference of potential between the screen and the target anode
so that any variation in output from the d-c amplifier portion
of the tube may be seen as a light-angle variation on the screen.

The original value of the grid-leak combination was given
as .01μf. and 10 megohms. With this combination the response
was found to be too sluggish to give an indication of change
in the bridge circuit, and the 10-megohm resistor was there-
fore changed to 100K as a corrective means. This change is also
shown in figure 1.

When the changes described above are made, the computer
will do an excellent job of providing an approximate collision
intercept course.

Bobby C. Conner
Philco Field Engineer

"What's Your Answer?"
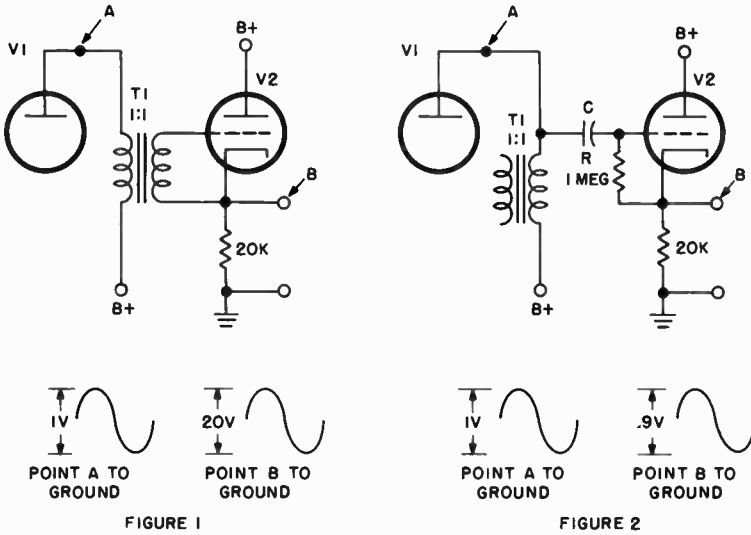
FIGURE I

FIGURE 2

This edition's problem was submitted by Bob Hunter, a recent addition to our Headquarters staff. Perhaps you'll find the problem as interesting and instructive as we did.

During normal operation, the circuit shown in figure 1 develops an output from V_2 as shown. A defect in the circuit reduces the output to zero, and subsequent troubleshooting establishes that the primary of T_1 has been burned open by a short in V_1. In an attempt to effect an emergency repair, a technician rewires the circuit as in figure 2, after replacing V_1. (The impedance of C is insignificant with respect to the resistance of R.)

When the rewired circuit is checked, the output from V_2 is found to be considerably lower than normal, although the output from V_1 is normal. All components are good and of the values indicated. Why is the output from V_2 lower than normal?

(Solution next issue...)

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