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In This Issue...

PHILCO
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BULLETIN

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Editorial . . .

by John E. Remich

Manager, Technical Department

THE PAST, PRESENT, AND FUTURE

On August 27, the TechRep Division reached a significant milestone. Fifteen years ago on that date, in 1941, our Vice President Mr. Robert F. Herr (then Manager, Parts and Service Division) founded an organization which has developed over the years into the present TechRep Division.

This organization was originated to meet the increasing demand for electronics personnel, brought about by the advent of radar and other electronic developments. Not long after the outbreak of hostilities in December, 1941, the Philco Training and Installation Division was established for the specific purpose of aiding the Armed Forces in the instruction of personnel, and in the installation and servicing of electronic equipments.

As early as February, 1942, Philco Field Engineers were initiating prototypes for future airborne radar installations; however, it was not until March, 1943, that the first Philco Field Engineer was sent on an overseas assignment.

These early events foreshadowed the trend of things to come. From this humble beginning has evolved the present TechRep Division, which has hundreds of TechRep Field Engineers in overseas assignments, in addition to those assigned to domestic locations.

The expansion and development of the TechRep Division is symbolic of the expansion and development of the electronics field in general. In the last 15 years many great new electronics developments have taken place. Among these are such major developments as radar, transistors, television, and computers, to name only a few.

The expansion and development of the electronics field is continuing at an increasing rate, and the demand for experienced electronics personnel is, of course, keeping pace. While no one can predict just how far electronics will have advanced by the end of the next 15 years—when the TechRep Division marks its 30th anniversary—the future of electronics certainly looks very promising.

LETTERS TO THE EDITORS

In continuation of the policy adopted in the last issue (July-August) of the BULLETIN, we are including in this column excerpts of some of the letters received by the Technical Information Section during the last two months.

"Admittedly my calculus is a little rusty, not having used it very often in the last four or five years, but I would bet that equation (4-2) on page 13 of the July-August 1956 issue of the BULLETIN should read as follows:

$$\frac{d^2i}{dt^2} + \frac{R}{L}\frac{di}{dt} + \frac{1}{LC}i = \frac{1}{L}\frac{d}{dt}E(t)."$$

U. J. Theriot
Philco TechRep Field Engineer

(You win the bet, U.J., and thanks for calling the mistake to our attention. Ed.)

"I don't know whether you accept requests for articles in the Philco TechRep Division BULLETIN or not; if you do . . . I would like to see an article on Radio-Frequency Propagation and Antenna Theory vs. Known Practical Results."

Lynn W. Russell
Philco TechRep Field Engineer

(We do accept requests for articles, but cannot always comply because of a lack of authors. This leads to a point which seems to require clarification; namely, what we mean by an author. As far as we are concerned, an author is anyone who submits an acceptable manuscript which he has personally prepared. To be acceptable, the manuscript must be readable, technically accurate, and concern a non-classified subject of general interest to BULLETIN readers. Ed.)

"I have just got 'round to reading the July-August issue of the TechRep Division BULLETIN, and I notice that Mr. H. W. Merrihew has his geography a bit mixed up. He states in his "Technical Sketch of James Clerk Maxwell" that Aberdeen is in England. Now this to a Scot is like a red rag to a bull. What makes it worse, Aberdeen is my original home—I was born there."

(According to our geography book you are absolutely correct. Please excuse the mistake, and accept our thanks for calling this matter to our attention. Ed.)

"I should like to request any information which you can supply concerning the construction and design of paraboloidal antennas."

W. Warriner McQueen
Philco TechRep Field Engineer

(We have no detailed information on this subject here at Headquarters other than that contained in the reference books in our library. We have examined most of these books and have found that the four listed below contain a considerable amount of information pertaining to the design of paraboloidal reflectors.

Microwave Antenna Theory and Design
MIT Radiation Lab Series—Volume 12
McGraw-Hill

Reference Data for Radio Engineers
(3rd Edition)
Federal Telephone and Radio Corp.
Pages 388—390

Antennas, Theory and Practice
Schelkunoff and Friis
Wiley, 1952

Principles of Radar
MIT Staff
McGraw-Hill

Very little general information pertaining to the construction of paraboloidal reflectors is available. The nature of the construction of these reflectors depends upon a great many variables, such as size, location, frequency, and application. For example, the construction of a reflector 60 feet in diameter for scatter propagation at VHF would be vastly different from that of a reflector used in an airborne fire control system. Information on a specific reflector may sometimes be obtained from the manufacturer. Ed.)

PRINCIPLES OF MAGNETIC AMPLIFIERS

by Edwin J. Pfiffner

Headquarters Technical Staff

GENERAL

A CONSTANT SEARCH FOR RELIABILITY in the operation of certain electronic equipments by various investigators has led to the introduction of a series of amplifiers based upon the nonlinear characteristic of magnetic core material. As units these magnetic amplifiers usually consist of such components as inductors, dry disk rectifiers, and resistors. When used within their design ratings, all of these components suffer practically no deterioration with time and therefore can be "potted" into one case. The resulting unit is very compact and ideally suited for use as servo amplifiers for fire control equipment where shock and vibration from gunfire would seriously reduce the reliability of vacuum-tube devices. Other possible uses for magnetic amplifiers include computers, switching devices, measuring instruments, motor control for automation, etc.

It is necessary to include at this point a short discussion of a characteristic of magnetic materials which is often unfamiliar, the B/H characteristic. Plotting this characteristic on a graph produces a curve which is known as the B/H curve, magnetization curve, or hysteresis loop. The B represents flux density, which is a measure of the amount of magnetization, and the H stands for the magnetizing force, or magnetic field intensity. These two quantities are related by an expression involving the permeability μ which may be written

$$B = \mu H$$

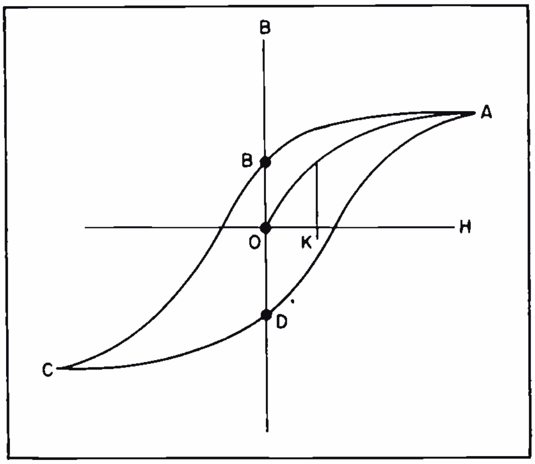


Figure 1. Typical B/H Characteristic Curve

If the magnetizing force H is increased from zero (point 0) to a value K, as shown in figure 1, the flux density increases linearly. However, as H is further increased, the core material becomes saturated, and a point is reached where a further increase in H gives no further increase in B. This condition is analagous to plate current saturation of a vacuum tube. If the magnetizing force is decreased to zero and increased in the opposite direction, the flux density will follow the curve ABC; finally, if the magnetizing force is again decreased to zero and increased in the original direction, the curve CDA results. The closed curve ABCDA is known as the B/H curve, magnetization curve, or hysteresis loop. It may have the form shown in figure 1, or figure 3, or it may assume other forms, depending on the material being magnetized.

The core material utilized in the construction of magnetic amplifiers should possess a B/H characteristic curve that is as close to a rectangular curve (considered ideal) as possible, it should have low eddy current losses, and it should have a high saturation flux density to permit maximum inductance. In addition, the material should possess a high degree of stability under conditions involving vibration, shock, and temperature extremes.

AMPLIFIER CIRCUITS WITHOUT FEEDBACK

Figure 2 shows a basic type of magnetic amplifier which has current gain characteristics. This type of circuit is useful in motor speed control applications and lighting control for public places.

The basic reactor (a name commonly used for the transformer of the magnetic amplifier) consists of three windings on an E-type core. The center winding is the control coil, and receives the control voltage. This voltage must be d.c. and is made variable by adding a rheostat to the circuit. The two outside windings are the controlled coils; they are connected in series aiding, and are placed in series with the load as shown. The magnetization curve for the core material should have a shape similar to that indicated in figure 3.

With no current flowing in the a-c control winding, the magnetizing current flowing in the a-c windings through the load would be small because of the large inductance exhibited by the reactor. This magnetizing current would provide the hysteresis loop shown in part A of figure 4. Since the reactor is not saturated during either half of the a-c cycle, the a-c windings present maximum impedance in series with the load. When a direct current is fed through the control winding, a residual flux appears in the core, and the center of the core magnetizing force shifts to the right, as shown in part B of figure 4. This magnetizing force is the resultant of both the a-c and d-c currents in the reactor. Since the hysteresis loop becomes smaller, the change in flux density decreases, resulting in a larger amount of a-c magnetizing current and less impedance to the load. By varying the d-c control current from zero to saturation, the impedance in the a-c circuit may be made to vary from a high value to almost zero. Any d-c current change in the control winding causes a corresponding a-c current change of greater value. Therefore, this circuit exhibits current gain characteristics. By connecting the two a-c windings in series aiding, the core flux due to alternating current will follow the path shown by the dotted line in figure 2. Under these conditions no a-c voltage will be induced into the control winding. The flux due to d-c magnetizing current will follow the solid line path. During any half cycle, the a-c flux aids the d-c flux in one leg of the core and

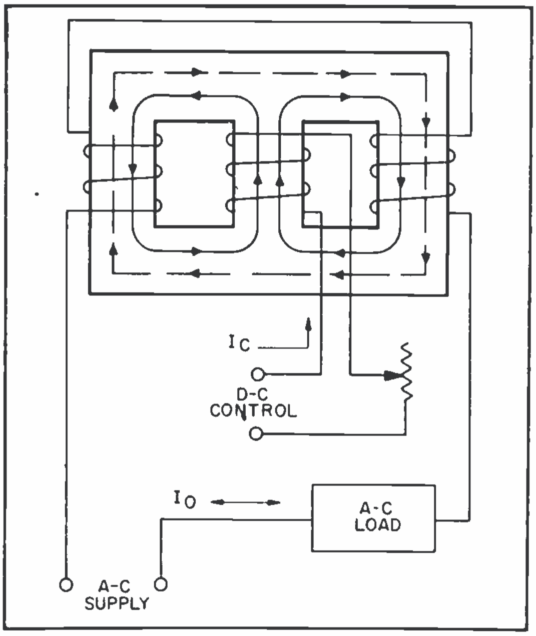


Figure 2. Simple Magnetic Amplifier Utilizing Series-Connected Windings

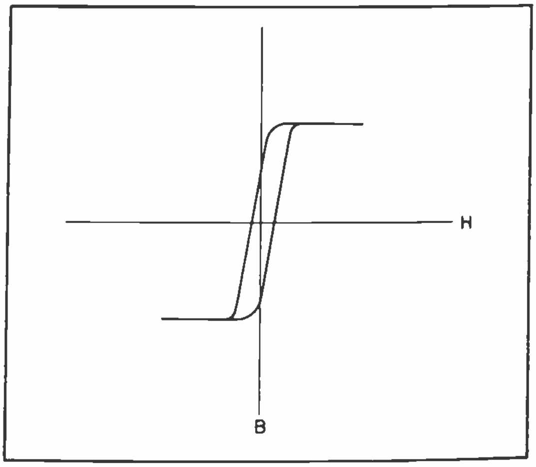


Figure 3. Typical B/H Characteristic Curve of Material Used in Magnetic Amplifier Cores

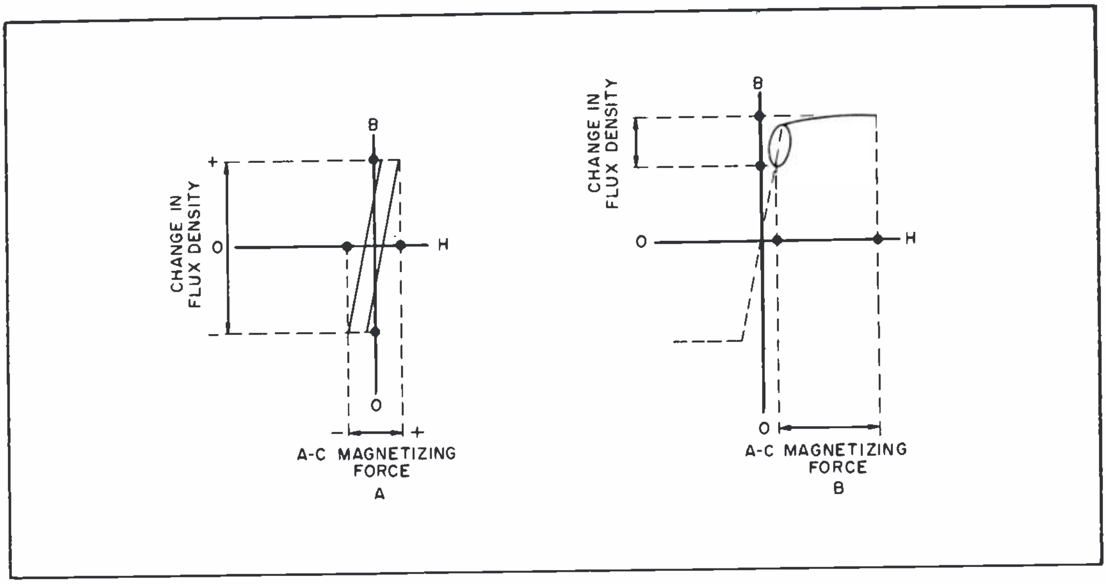


Figure 4. Operation of Magnetic Amplifier on the B/H Characteristic Curve

thus provides a high degree of saturation in that leg, but the two magnetizing forces oppose each other in the opposite leg. This condition would tend to restrict the minimum impedance to a value too high for practical use. It can be overcome by using a high value of ampere turns for the control winding, to prevent the peak a-c magnetomotive force from driving the flux density too far down from the knee of the B/H curve, on the side where the fluxes are opposing.

Figure 5 illustrates an arrangement with the a-c windings connected in parallel. This circuit is usually employed to handle loads with medium to high current consumption, but has a somewhat slower response characteristic than the series circuit.

Figure 6 shows a variation that permits the use of a d-c load. In this amplifier a bridge rectifier is utilized in the a-c circuit to provide d.c. to the load while keeping any d-c component of current out of the a-c windings, thus preventing self-saturation.

Since a d-c voltage is applied to the control winding, it is possible to connect two d-c output amplifiers in cascade to increase the gain, as illustrated in figure 7. This circuit has a disadvan-

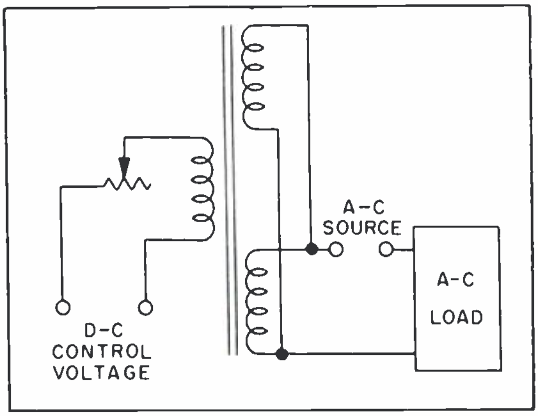


Figure 5. Magnetic Amplifier Utilizing Parallel-Connected Windings

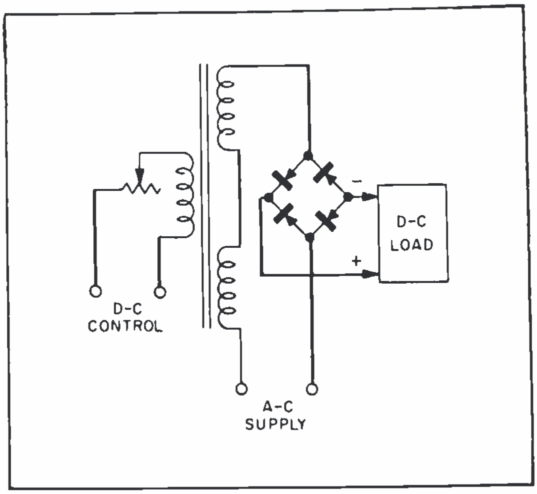


Figure 6. Bridge Rectifier Circuit Used with a D-C Load

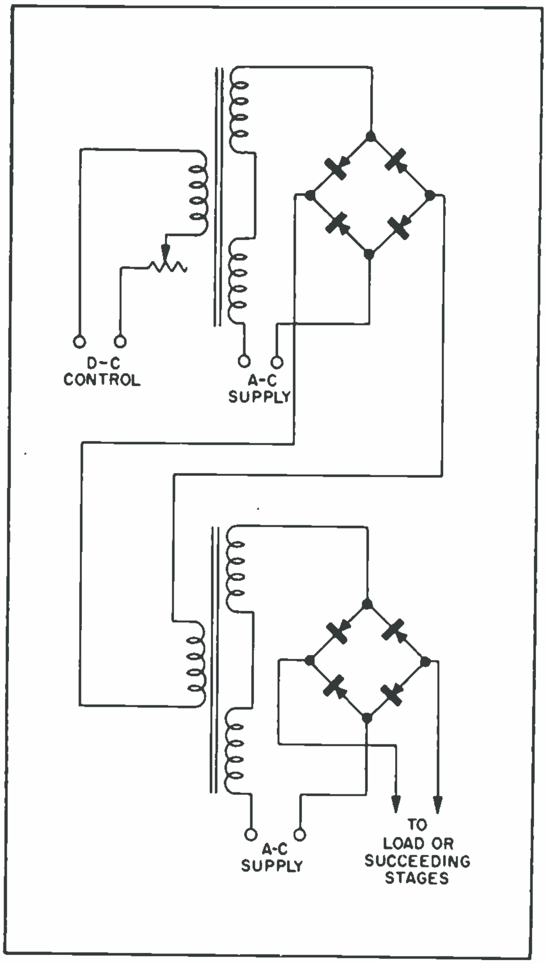


Figure 7. Two-Stage Cascaded Magnetic Amplifier

tage arising from the fact that an a-c current always flows in the a-c winding, and this rectified current is applied to the control coil of the succeeding stage. This factor limits the number of stages that can be connected in cascade, because the control windings of succeeding stages would saturate the core with the "no-signal" current, and the amplifier would effectively become blocked. This disadvantage can be overcome by using the a-c winding of an amplifier in a bridge circuit to cancel out the residual flow of current in the load. Figure 8 illustrates this type of connection. In this circuit the a-c windings (A and B) of the reactor form one leg of the bridge. Choke L1, which has the same inductance as the a-c winding of the reactor without control current flowing, forms the second leg. The third and fourth legs (C and D) are formed by the secondary of a center-tapped isolation transformer used to supply a-c voltage to the circuit. With no control current input, zero current will flow in the control windings of the succeeding stage, making possible the use of many stages in cascade for increased current amplification. The control current in this type of amplifier may be taken from a thermocouple or photocell to actuate motors, relays, etc.

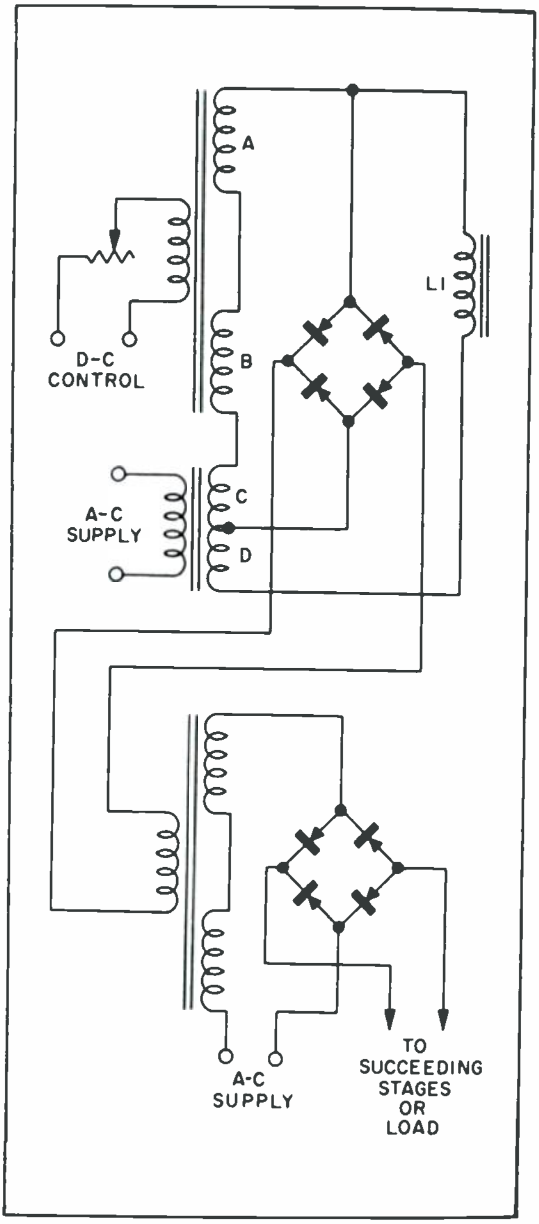


Figure 8. Magnetic Amplifier with Bridge Circuit Incorporated to Cancel Residual Current Flow in the Load

The operation and sensitivity of magnetic amplifiers can be improved by utilizing push-pull operation and by biasing of the magnetic cores to the knee of the B/H curve with a special bias winding located on the same leg of the core as the control winding, as illustrated in figure 9. In this type of amplifier equal a-c voltages are applied to the a-c coils of two reactors. The outputs are rectified and applied to a load in the conventional manner. The circuit is polarized so that, when the inductances of both reactors are equal, the resultant output voltage is zero. The above is true when zero control current is flowing. A d-c voltage applied to the bias windings causes current to flow in the same direction in both of these windings. The bias current is adjustable so that the core may be brought to the high-sensitivity portion of the magnetization curve. The control coils are connected in such a manner that when current flows in the control circuit, the bias flux in one reactor will aid the control flux, causing saturation, while the bias flux in the other reactor will oppose the control flux. This condition will cause an unbalance in the a-c windings of the two reactors and will result in a d-c voltage output. If the polarity of the control voltage is reversed, the action just described will result in an output voltage of the opposite polarity. This circuit, therefore, can be used as a d-c amplifier, since the output polarity is a function of the control voltage polarity. Amplifiers of this type have been constructed which have gains in the vicinity of 23 db with power inputs on the order of 400 microwatts.

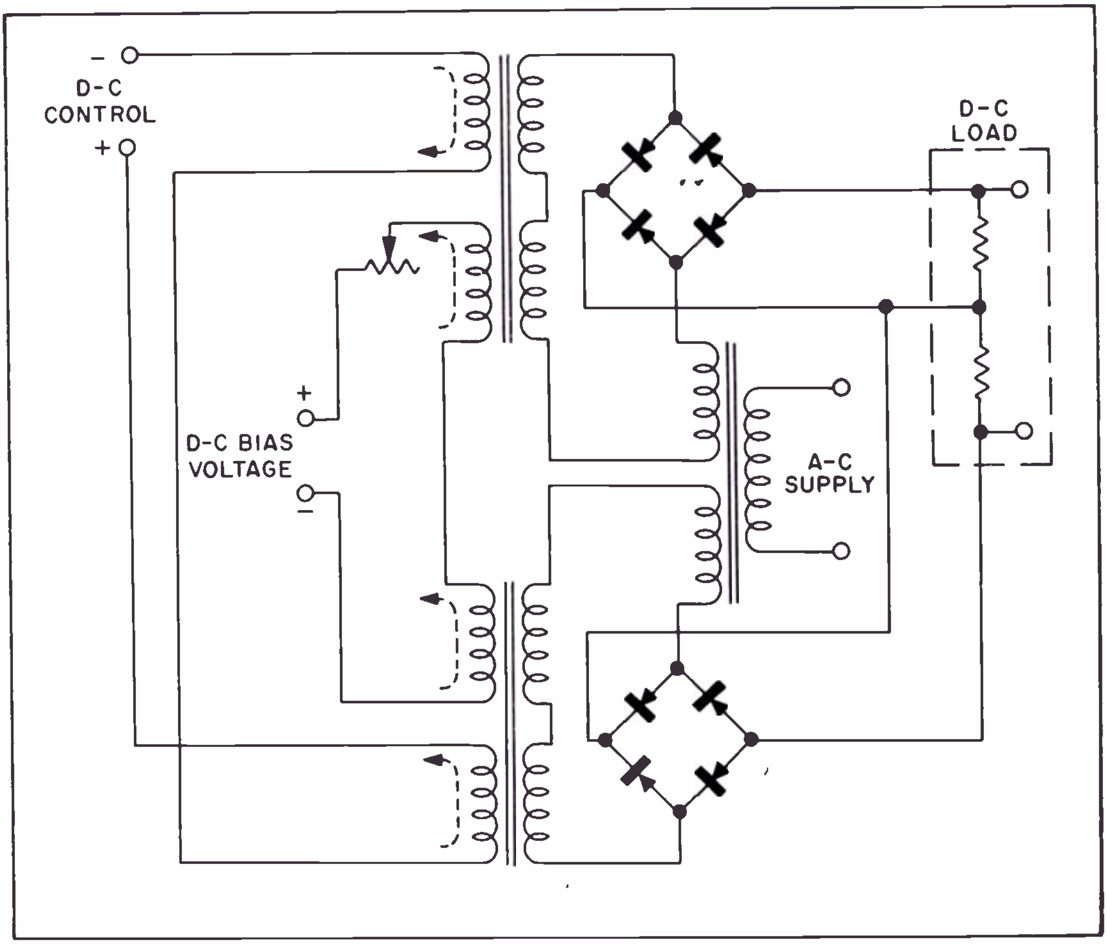


Figure 9. Balanced Magnetic Amplifier with Bias Current

AMPLIFIER CIRCUITS WITH FEEDBACK

By providing regenerative feedback in a single-stage magnetic amplifier, it is possible to obtain a considerable increase in power gain over that of a single-stage non-feedback circuit. Basically, regeneration is accomplished by combining a portion of the output power of the single stage with the input power so that addition of the two results in a higher power gain. Positive feedback may be provided in two different ways. One method consists of feeding a portion of the output power into a special feedback winding so that the feedback flux will aid the control flux. This type of feedback is usually referred to as external feedback. Another method makes use of a half-wave rectifier in series with the load so that a d-c current component will flow in the a-c winding circuit. This type of feedback is referred to as self-saturation or internal feedback. By the use of regenerative feedback, the power gain of a single-stage amplifier may reach 40 to 50 db. Both types of feedback may also be used simultaneously if desired.

Figure 10 illustrates a basic type of circuit involving internal feedback. When the control current of this amplifier is increased, a larger value of pulsating load current will flow in the a-c windings, bringing the core to saturation more quickly. This circuit is bidirectional as far as transfer characteristics are concerned. Replacing the load with a suitable meter would make the circuit adaptable as an extremely sensitive zero center d-c voltmeter.

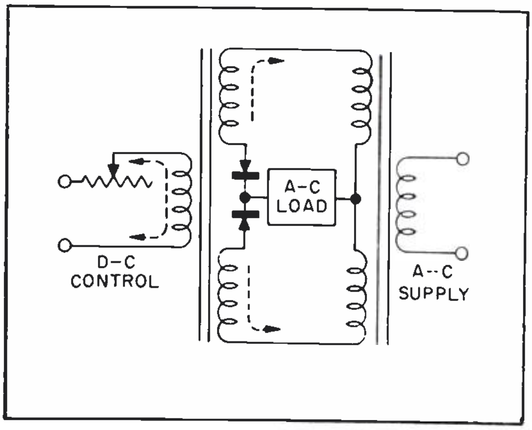


Figure 10. Magnetic Amplifier Using Internal Feedback

In figure 11 an amplifier which incorporates an external feedback circuit is shown. In this amplifier a d-c voltage from the bridge rectifier connected in the a-c circuit is returned to a feedback winding located on the same leg of the core as the control coil. As the control current is increased, the feedback voltage is also increased. Flux from the feedback winding will reinforce the control winding flux, and saturation will occur rapidly. The control current must flow in the direction as shown for the circuit to be regenerative; if the control current is reversed, degeneration will result. This circuit is representative of the polarized type of magnetic amplifier.

CONSTRUCTION

The method of construction of magnetic amplifiers with respect to core assembly differs considerably from practices utilized in ordinary transformer construction. Standard E cores using staggered butt joints are unsatisfactory, because much of the flux crosses the many small air gaps provided by the

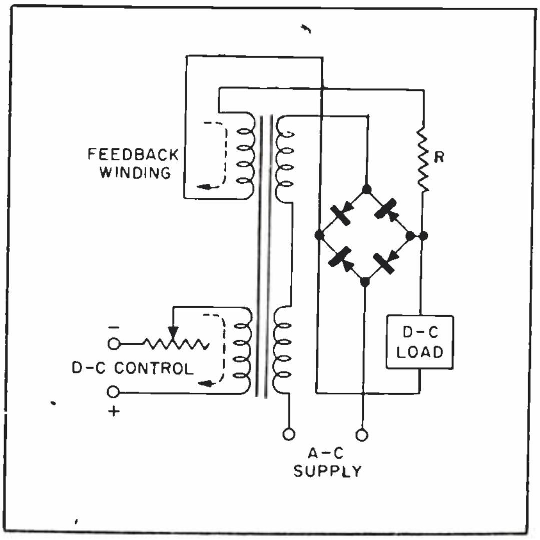


Figure 11. Magnetic Amplifier Using External Feedback

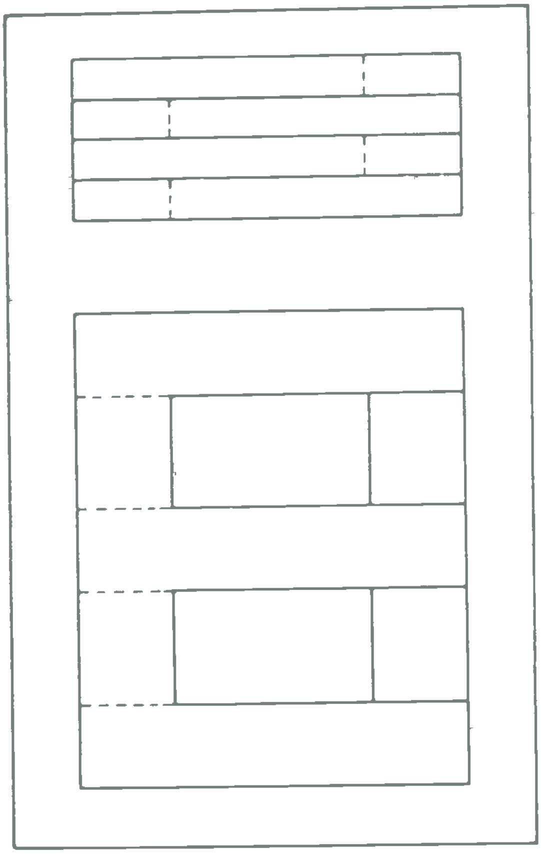


Figure 12. Construction of a Satisfactory E Core

butt joints. Considerable improvement can be had by using the E core arrangement illustrated in figure 12. Here the laminations are overlapped for a greater portion of the magnetic path, resulting in a sharper knee in the magnetization curve. This type of construction lends itself to uniformity of core characteristics. Another method of construction rapidly becoming popular makes use of toroidal cores spirally wound with silicon steel tape. Two spirally wound cores would be required in the average amplifier since there is no center leg. A circuit using these cores is illustrated in figure 13. The two control windings are connected in series-aiding so that both cores can be saturated by a common control current. The two a-c windings are connected in series-opposing so that negligible alternating current will appear in the control circuit as a result of transformer action. With slight circuit variations, the twin-core method is adaptable to all of the previously discussed amplifier circuits.

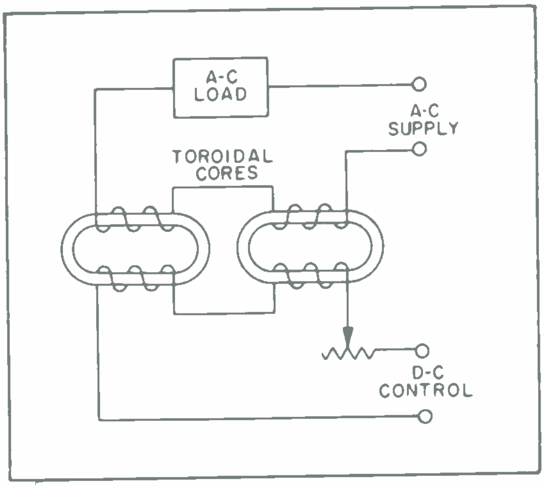


Figure 13. Spirally Wound Toroidal Cores Used in a Magnetic Amplifier

AMPLIFIERS USING TWIN TOROIDAL CORES

The full-wave amplifier shown in figure 10 may also be constructed using toroidal cores, as shown in figure 14. The use of two cores requires that a high a-c impedance be connected in series with the control winding. As in the case of the amplifier using the E core, the output voltage across the load is a.c., and one of the rectifiers is conducting on each half cycle.

Dependence on Rectifier Characteristics

It has been assumed so far that the rectifiers have zero forward resistance and infinite back resistance. Unfortunately, this assumption is not valid for practical rectifiers, because the back resistance is not infinite. By examination of figure 14, it can be seen that any back current flowing through the rectifier during its "nonconducting" half cycle will tend to drive the core out of saturation and thus reduce the gain of the amplifier. One method of counteracting this effect is by the addition of a "crossover winding" on each core, as illustrated in figure 15.

Operation of the Crossover Windings

Assume that during the first half

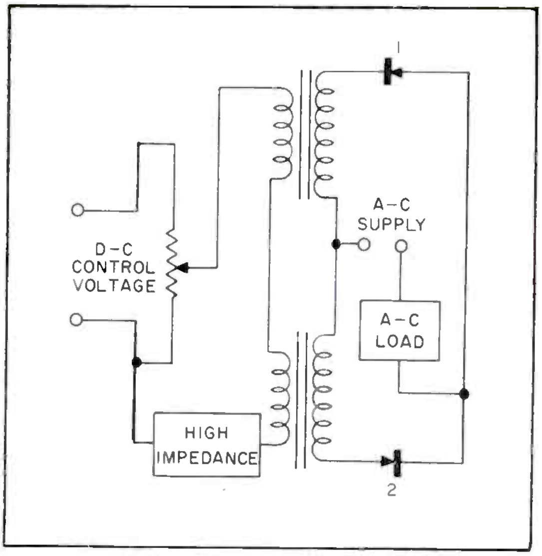


Figure 14. Amplifier Utilizing Toroidal Cores and Internal Feedback

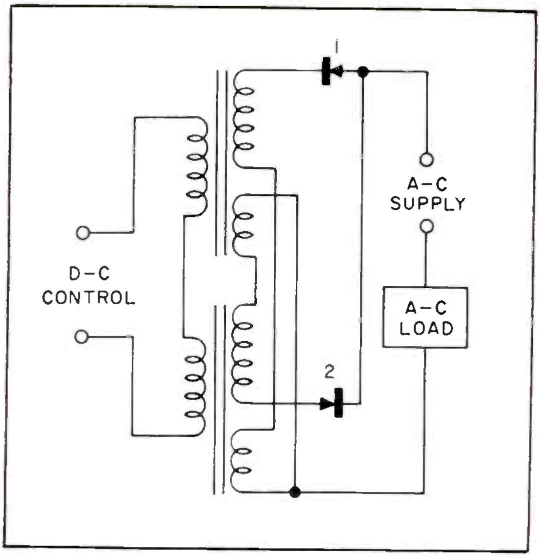


Figure 15. Amplifier Utilizing Crossover Windings

cycle of the a-c supply voltage, rectifier 2 is conducting in the forward direction. The heavy current which flows through rectifier 2 and the main winding of the core associated with it, also flows through the crossover winding of the other core. This crossover winding consists of a few turns which produces a field in a direction opposite to that produced by back current in rectifier 1 in the main winding of the core. The large current flow through a small number of turns cancels the effect of a small current flow through a large number of turns. Similarly, a cancellation is achieved on the second half cycle of the a-c supply voltage by the other crossover winding.

Variation in Back Resistance

If the back resistance is constant, the circuit shown in figure 15 is excellent, and the effect of the back resistance can be cancelled at all times by the crossover winding. However, the back resistance will vary considerably with changes in applied voltage and temperature, or with a change of the rectifier. To overcome this disadvantage, the back resistance, which is high but variable, is shunted by a small constant resistance R, as shown in figure 16. In this circuit each rectifier is shunted, during its nonconducting half cycle, by the series combination of R and the conducting rectifier.

Use of Two or More Inputs

The use of toroidal cores makes possible two or more inputs, with the amplifier producing an output proportional to the vector sum of the inputs. A common circuit is shown in figure 17, which shows a bias winding and two control windings. After the main and crossover windings are put on the cores,

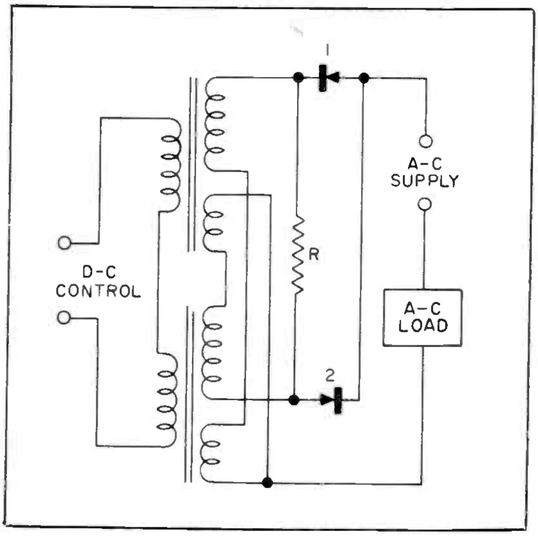


Figure 16. Amplifier Utilizing Crossover Windings and Shunt Resistance

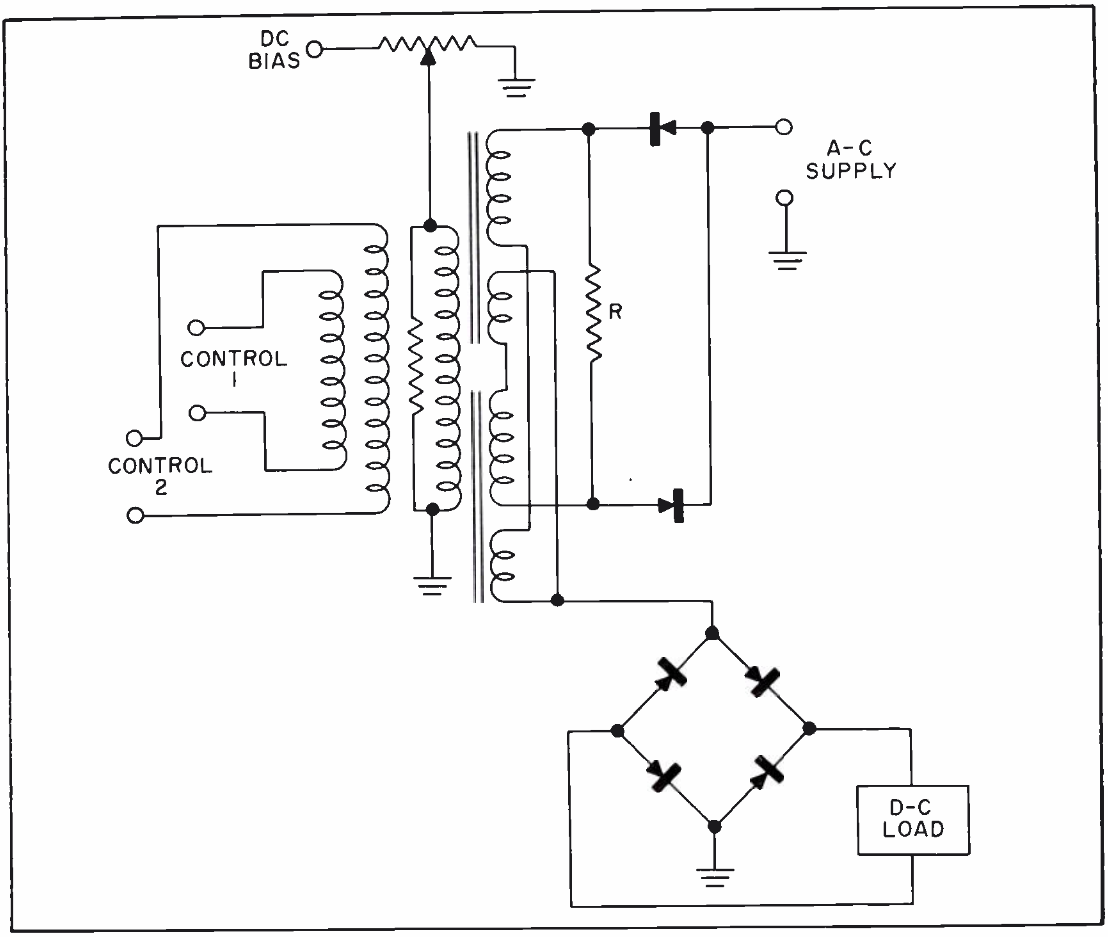


Figure 17. Common Type of Magnetic Amplifier

the cores may then be stacked and wound with common control and bias windings.

CONCLUSIONS

Magnetic amplifiers lend themselves well to a wide variety of uses, as indicated by some of the following advantages:

1. Extremely high gain.
2. Complete isolation between input and output circuits.
3. No deterioration.
4. Potted type construction.
5. No warm-up time.
6. Rugged—will withstand extreme shock and vibration.
7. High stability as a d-c amplifier.

The response of the average amplifier at present is approximately 2 to 60 cycles of power supply frequency. At present, research is being conducted on amplifiers with power supply frequencies of about 15 kc., to improve response and make possible the amplification of audio frequencies.

THE PHILCO AUDIPAGE SYSTEM

The Philco Audipage is a personal one-way communication system wherein only those persons wearing the small Audipage receivers are able to hear the messages. The system utilizes the principle of magnetic induction to eliminate connecting cables, thus providing complete freedom of movement, while at the same time sidestepping the disadvantages of a public address system.

The Audipage receiver will receive only within the limits of an audio-frequency magnetic field set up by a wire loop radiating element which encloses the listening area. The wire loop is fed from any radio, television receiver, record player, or audio amplifier which has a power output of at least 100 milliwatts and an output impedance of less than 10 ohms. The maximum area that can be covered is determined essentially by the amount of available audio power. The power required for a given area may be estimated from figure 1.

The loop should always be installed in a horizontal plane, and it should be no larger than necessary. Multiple loops should be used for areas greater than 20,000 sq. ft. See figure 3. For optimum results, the loop shape should not exceed 400 feet in length and 50 feet in width. Wire size may be determined from figure 2.

A multiloop configuration confines the magnetic field within the loops, while a single loop allows the magnetic field to extend a short distance outside. Magnetic field distribution within the loop area is more uniform in a multiloop configuration. Because of this more uniform distribution, the multiloop input power requirement is lower than that of a single loop. Several multiloop configurations are shown in figure 4.

For best performance, loop wire should be strung no closer than 3 feet

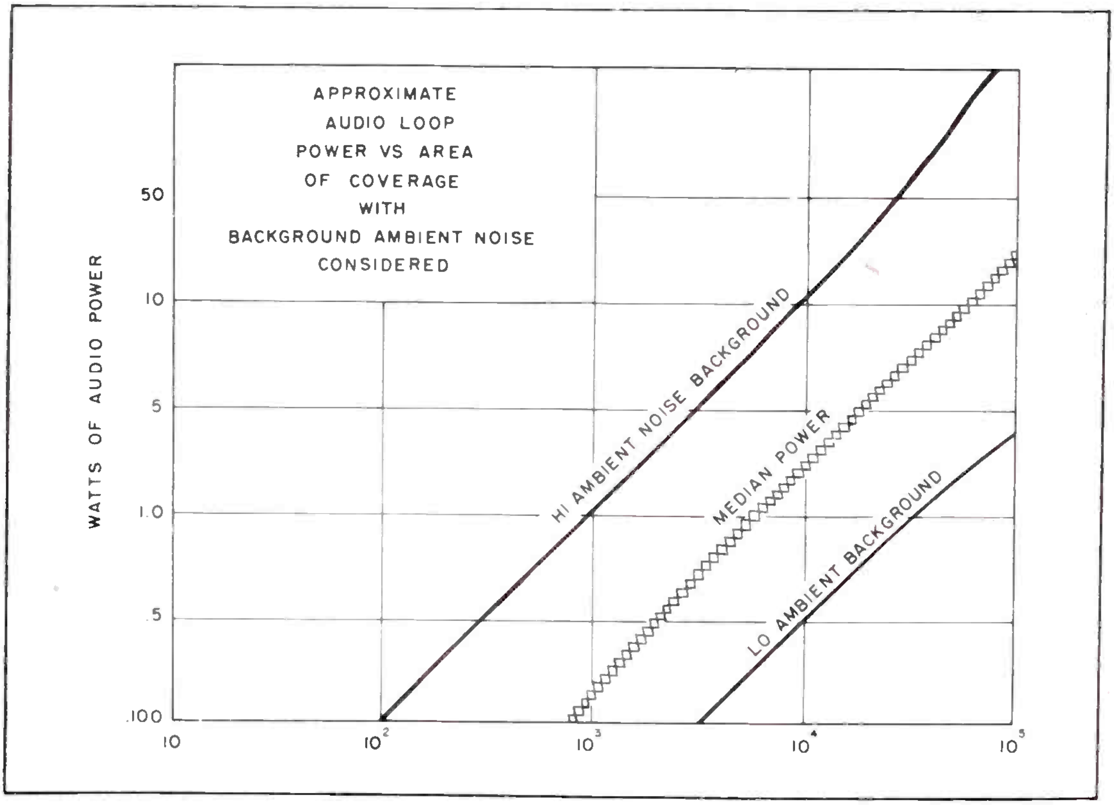


Figure 1. Graph of Audio Loop Power Versus Area Coverage

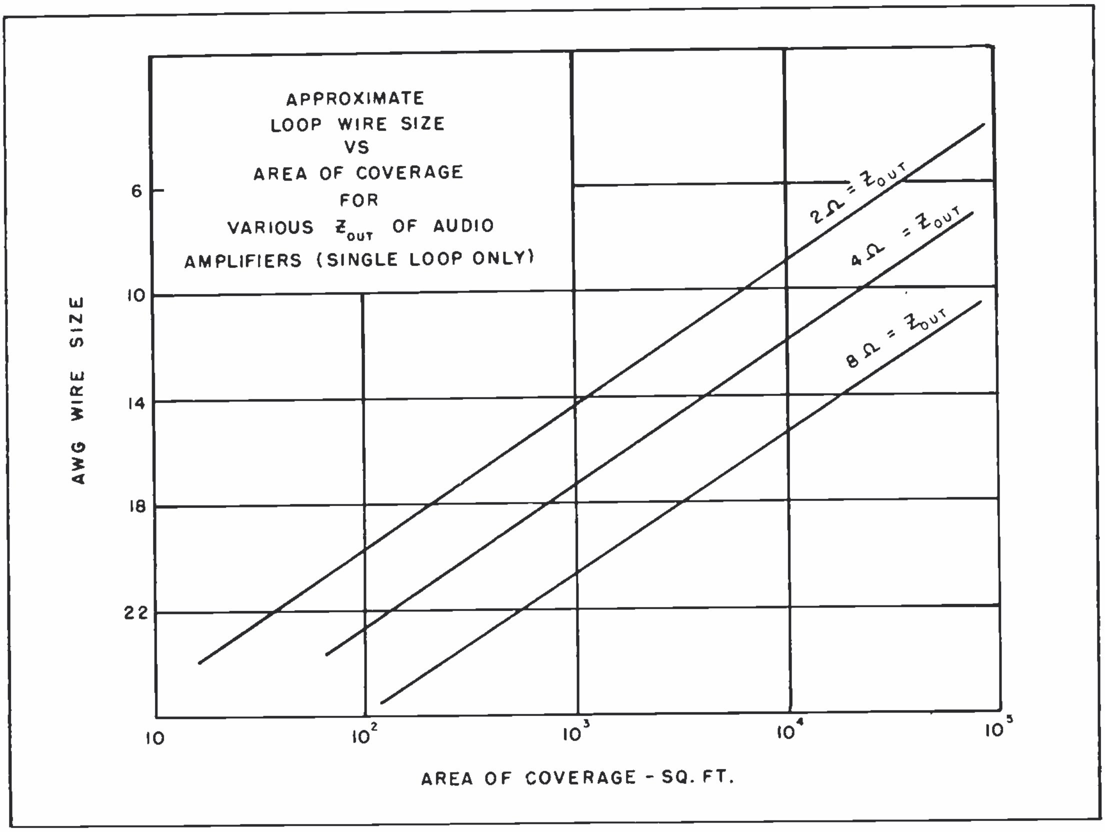


Figure 2. Graph of AWG Wire Size Versus Area Coverage

to parallel steel beams, waterpipes, reinforcing rods, or other steel structures that might form a closed magnetic circuit.

The loop connection to an audio source (leads marked "A" in figures 3 and 4) is made by removing the two speaker voice coil leads and connecting the two loop leads. In the case of an audio amplifier, the ends of the loop are connected to the amplifier output terminals. When both speakers and loop are included in an installation, a double-pole, double-throw switch may be installed as illustrated in figure 5, to facilitate switching between speakers and loop. Figure 6 illustrates a method of connecting speakers and loop in parallel.

The Audipage receiver, illustrated in figure 7, incorporates an induction pick-up coil, which provides the input to a three-stage transistor audio amplifier. The output of the amplifier is fed to the miniature speaker, which is similar to the earpiece of a hearing aid. A block diagram of the receiver is shown in figure 8. Power is provided by a tiny 1.3-volt mercury storage battery, which gives 100 hours of operation, and the entire Audipage receiver weighs only one ounce. The developmental models are 1⅝" long, 1½" wide, and ½" deep. Final production models may be considerably smaller in size. This small size may be attributed to the use of Philco miniature alloy junction transistors in

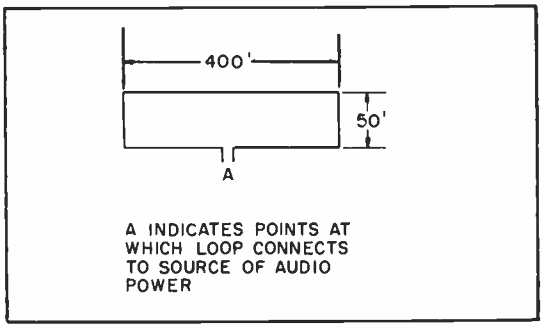


Figure 3. Single Loop Configuration and Maximum Dimensions

place of vacuum tubes. Transistors do not create heat; they are extremely rugged, long lived, and lightweight; and they require only minute amounts of power.

This new system of "silent" paging should find wide use in many different locations where small size and portability are necessary. Its ability to operate under severe noise conditions is an asset in many other locations.

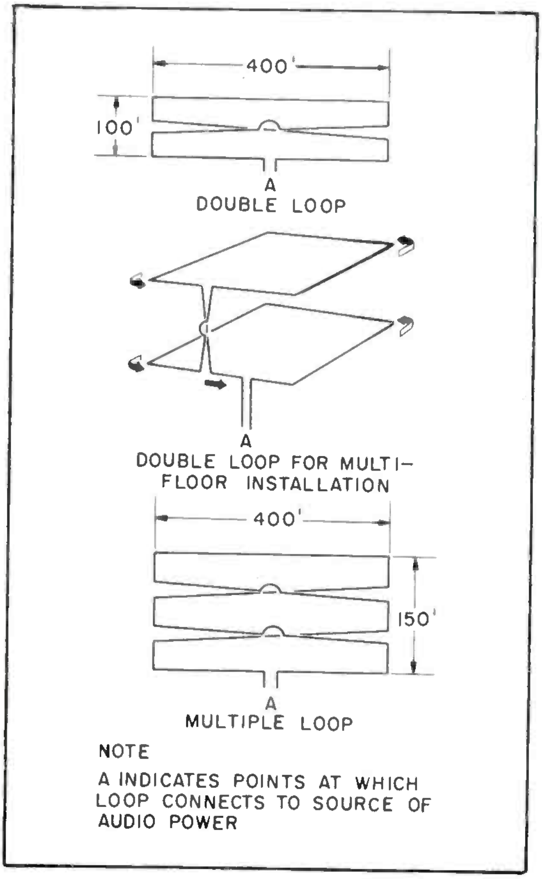


Figure 4. Multiloop Configurations

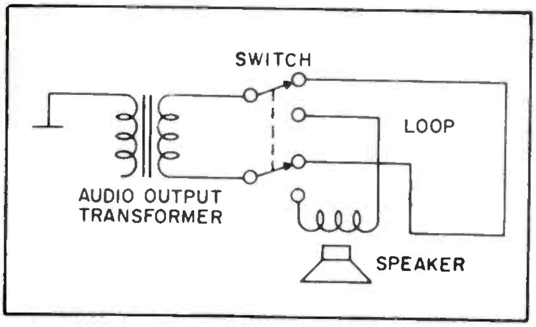


Figure 5. Switching Diagram for Loop or Speaker Operation

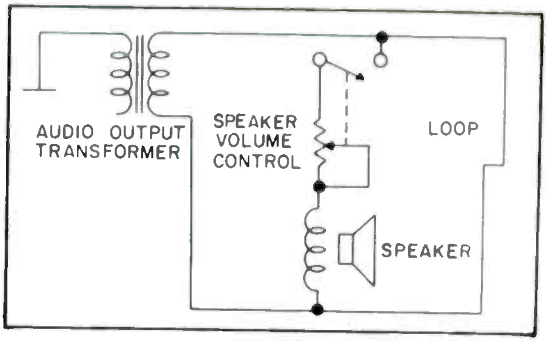


Figure 6. Parallel Loop and Speaker Operation, Showing Volume Control and Switch for Removing the Speaker From the Circuit

Figure 7. Audipage Receiver and Earpiece

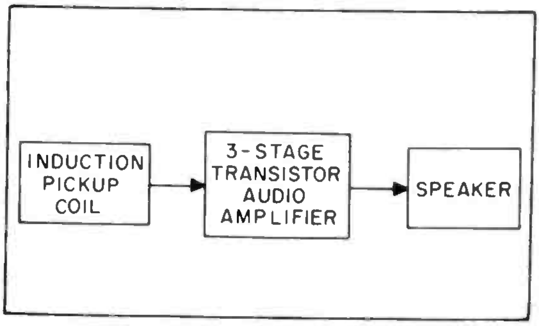


Figure 8. Block Diagram of Audipage Receiver and Earpiece

AN/ARC-27 SIGNAL TRACER

by Julian M. Myers
Philco TechRep Field Engineer

The signal tracer described in this article is an extremely simple device constructed from a few items normally available, and much of its value is derived from this simplicity.

In trouble-shooting the ARC-27 UHF transmitter-receiver, it is occasionally difficult to localize the trouble. As is always the case, a technician with considerable experience on the ARC-27 is normally able to localize the trouble to a particular unit by analyzing the symptoms and using his past experience, together with a few simple checks. However, the technician who is acquainted with the theory of operation but has had little practical experience with the equipment often has difficulty in isolating the trouble. The ARC-27 has been designed with a number of built-in test points, to make trouble-shooting as simple as possible; the purpose of this discussion is not to replace the test procedure involving the use of those test points, but to supplement it by providing checks at other points in the circuit. The signal tracer is also useful for line maintenance, because of its small size and portability, and requires for its operation only a d-c voltmeter (such as the PSM-6) and a pair of test leads.

The signal tracer (see figures 1 and 2) consists of a small coil of two turns, a capacitor, and a crystal. The coil, which has a diameter slightly larger than that of a seven-pin miniature tube, should preferably be formed from stiff wire, to eliminate the need for a support. It is mounted on a small strip of plexiglass or other insulating board. The capacitor

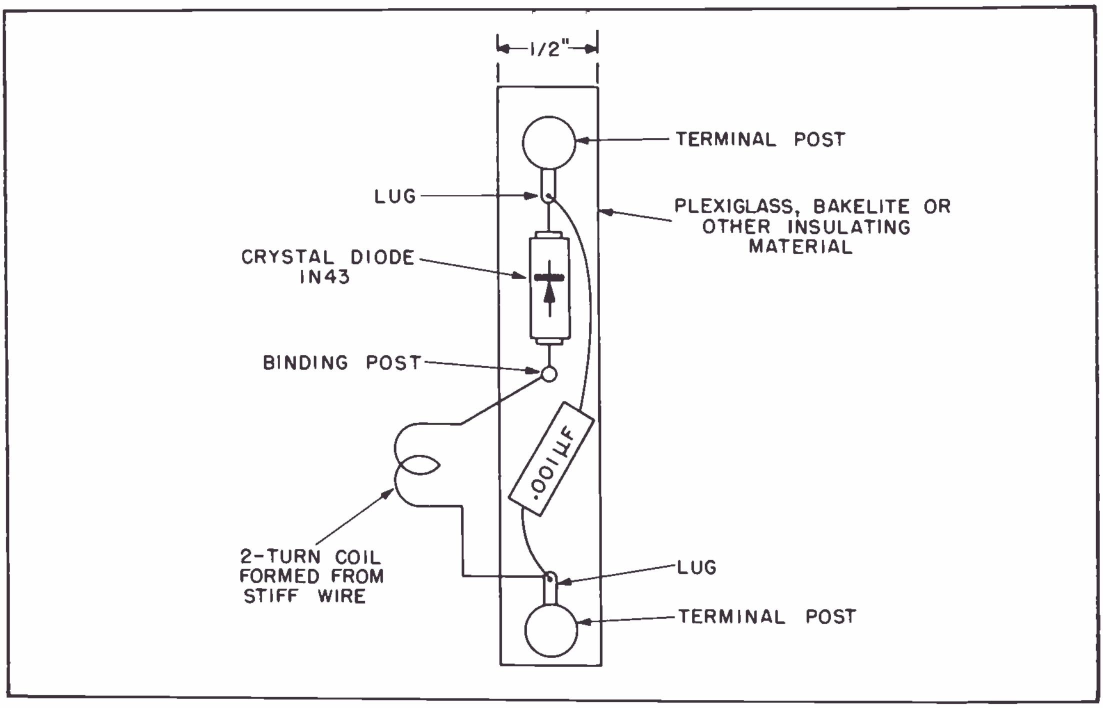


Figure 1. Parts Layout of ARC-27 Signal Tracer

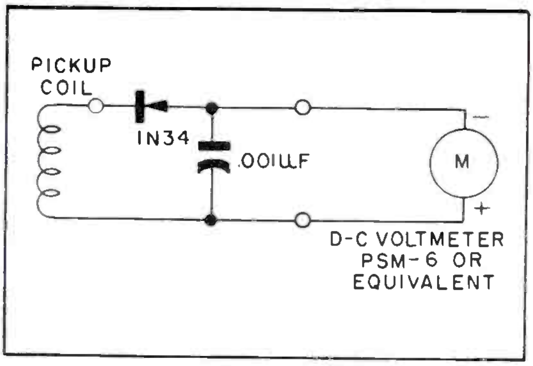


Figure 2. ARC-27 Signal Tracer Schematic Diagram

and crystal are mounted with small bolts, and connected as shown. The crystal used was a 1N43, but any similar crystal (such as a 1N34A) may be employed. In view of the limited space available in the ARC-27, it is advisable to make the width of the plexiglass strip ½ inch or less. The signal tracer on which this article is based had the test-lead posts mounted on the strip. This arrangement tends to hinder the use of the instrument, however, because the test leads get in the way in some locations. Further refinements, such as the use of an inverted L-shaped mounting with shielded leads brought from the coil to components mounted on the top, can undoubtedly be devised.

The procedure for using the signal tracer can best be illustrated by describing its use in connection with a hypothetical case of trouble. Given an ARC-27 which does not have any power output, the trouble-shooting procedure using the signal tracer is as follows:

Connect the ARC-27 on the mock-up as in any other test procedure, connect an absorption wattmeter to the output, and allow the set to warm up. In the meantime, provide the signal tracer with suitable test leads, and connect a d-c voltmeter to its output.

The first step in isolating the trouble is to determine whether or not the spectrum system is in operation by measuring the d-c voltage at C510, using a vacuum-tube voltmeter. A check of the spectrum system operation can also be accomplished by removing the tube shield from V502, slipping the signal-tracer coil over V502, and measuring the resulting voltage at the output terminals of the signal tracer. The voltage as read on the meter will depend to some extent upon the signal-tracer construction and the type of meter used; however, a reading on the meter is an indication of an output from the spectrum system. (A similar measurement should be made on an equipment known to be in proper operating condition to obtain a rough idea of what the reading should be.) Assuming that these indications show that the spectrum oscillator and spectrum amplifier are in proper operating condition, the next step is to eliminate mixer V503 and selective amplifier V504 and V505. If the indications show that either the spectrum oscillator or amplifier is not operating correctly, use the signal tracer to check V501; if no indication is obtained, check V401, V402, and V403.

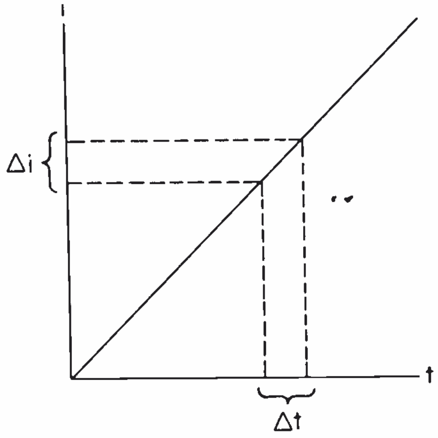
At transmitter mixer V506, when using either the vacuum-tube voltmeter or the signal tracer, doubt may arise as to whether the signal reading is due to the signal from the spectrum system or to the signal from the 20—30-mc. amplifier. This doubt can be dispelled with the signal tracer by slipping its coil over receiver mixer tube V103. The signal which is indicated at this tube comes only from the 20—30-mc. amplifier. Hence, a no-signal indication points to trouble in the 20—30-mc. amplifier or the i-f and audio chassis. Since it is a simple matter to replace the i-f and audio chassis with one that is known to be good, trouble in the 20—30-mc. amplifier can be determined or eliminated very conveniently. I-F amplifiers V302 and V304 cannot be checked by use of the signal tracer because of the effects of stray coupling from the power amplifier. However, they can be easily eliminated by using the vacuum-tube voltmeter first at test points E317 and

E318 and then at the transmitter mixer on the 20—30-mc. amplifier. Effects of stray pickup from the power amplifier probably could be eliminated by using a shield around the pickup loop. However, difficulty is encountered in fabricating such a shield without causing a short circuit across the coil.

As with any testing device, practice and experience will quickly show what the signal tracer will or will not do. It is believed that this device will be very helpful in many situations that arise in working on the ARC-27, and it should prove to be valuable in working on other sets.

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

Kirchhoff's law states that the sum of the voltage differences around any closed loop is zero. Therefore, the voltage across L at any time is E. Since in a pure inductance the rate of change of current $\frac{\Delta i}{\Delta t}$ is proportional to the applied voltage, the current wave form is a straight line, as shown below.



$$L\frac{\Delta i}{\Delta t}=E$$

$$\text{THEREFORE } \frac{\Delta i}{\Delta t}=\frac{E}{L}$$

The slope of the current waveform (the rate at which the current rises) depends on both the inductance and the applied voltage.

This condition arises in electromagnetic deflection systems, where a linear sawtooth current waveform provides a linear deflection. For best linearity it is desirable to have a large $\frac{L}{R}$ ratio unless some method of compensating for the effect of resistance is used.

SOME ASPECTS OF RADAR COVERAGE

by Samuel M. Moss
Philco TechRep Field Engineer

This article describes the principles of the "quality control" method of measuring and monitoring ground radar station performance, and discusses the effect of the weather on these measurements in areas where the atmosphere is nonstandard.

IN THE PAST, the evaluation of radar sites as they were installed consisted in part of determining the vertical radiation pattern of the radar by flying a sufficient number of flights of B-29 type aircraft, or in some cases smaller jet aircraft, at various altitudes in order to obtain an adequate statistical sample of the radar's capability to detect and track the aircraft. From this information a contour lobe of the radar beam was constructed to depict its coverage in the vertical plane. After the vertical coverage had been determined, supplemental flights were made to check radar line-of-sight predictions and horizontal coverage.

In accordance with standard calibration techniques at the time, the results of the flights were plotted on a vertical profile chart with range as the abscissa and altitude as the ordinate. Constant altitude lines on this chart are drawn according to the equation:

$$R = 1.23\sqrt{h}\,, \qquad (1)$$

where R is the range in nautical miles and h is the altitude in feet. This is a form of the well-known line-of-sight equation:

$$R = \sqrt{2h}\,, \qquad (2)$$

where R is the range in statute miles. In the derivation of these equations, a factor has been included which increases the radius of curvature of the altitude lines to 4/3 of their actual curvature. The inclusion of this factor is equivalent to increasing the earth's radius by 4/3. This factor was selected on the basis of an average refractive index gradient for a so-called standard atmosphere. By increasing the radius of the earth by 4/3 on this chart, the paths taken by radiated energy may be drawn as straight lines, instead of the curved paths which it actually follows in space. It should be noted that equations (1) and (2) are the equations of a parabola, and not of a circle, which would ordinarily be used as the equation of the earth's curve from a cosmic point of view. This discrepancy arises from a convenient simplification in the derivation of these equations, but the error committed in using them is small at the ranges and altitudes usually involved.

Existing quality control techniques for radar evaluation employ a lobe computer against which routine and random radar tracks are compared to determine the radar station performance. The computer consists, in part, of a chart on which a number of contour lines are drawn, the pattern of the lobes being determined by the particular type of radar employed, each line being assigned a somewhat arbitrary decibel level based on a prior knowledge of the radar set capabilities under normal conditions. For example, a zero db reference level is assigned to one of the contour lines; this level may represent the detection capability of the radar for some particular aircraft for which sufficient echo reflection data have been accumulated to allow fairly accurate pick-up ranges to be computed.

Radar pickup (detection) is a function of many variables which cannot be controlled and to which no definite values can readily be assigned. Radar pickup thus becomes a statistical quantity and must be regarded as such; hence, the db contours on a lobe computer which are assigned to different aircraft must represent some average or mean value of pickup (or fade) for those aircraft. The station performance is measured in terms of the ratio of the actual pickup range to the pickup range predicted by the computer, and for the purpose of this article will not include the operator factor. This ratio, after being converted to a percentage, is often referred to as the *quality control percentage.* From the above, it follows that the station performance is a statistical quantity also. As such, actual radar detection data plotted against deviations from a predicted value give rise to a Gaussian-like error curve, which will probably be asymmetrical or skewed (see figure 1). If arbitrary limits are selected so that the radar pickup range exceeds a certain deviation from the predicted pickup range, the positions of the limits on the downward slope of the bell-shaped curve will depend upon the range of swing of the variables governing pickup, i.e., set performance, antenna rotation rate, propagation, etc. Normally a system is established whereby some action is taken when the pickup falls outside of the selected limits. Consequently, the limits are not really arbitrary, but must be determined in terms of the variables governing detection and in terms of the mission of the radar set.

Preliminary findings from radar evaluations and quality control data indicate that variation in propagation is one of the serious offenders in causing wide variation in detection. Although lobe computers are based on weather conditions for standard propagation which represent an average of world-wide atmospheric soundings, the conditions in any particular locality may vary significantly from those for standard propagation. In fact, it is possible that the average conditions at a given locality may include a "radio hole" in the area of coverage. Assuming such to be the case, there would not necessarily be an unduly high power density gradient in the vicinity of the hole which could be detected by a measurement of field strength as a function of range and altitude. Further, the hole would not be

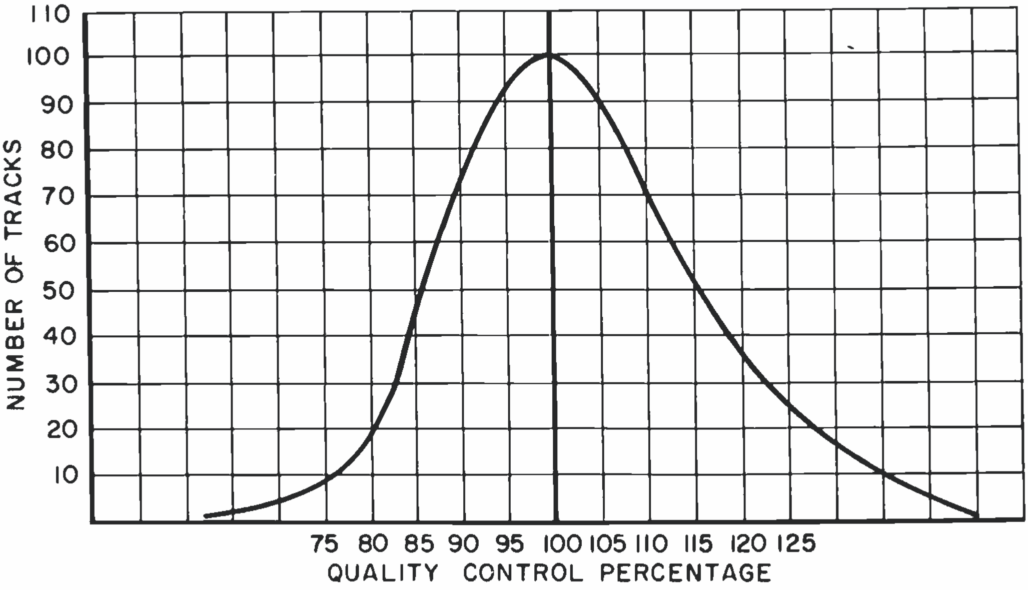


Figure 1. A Typical Gaussian Error Distribution Curve

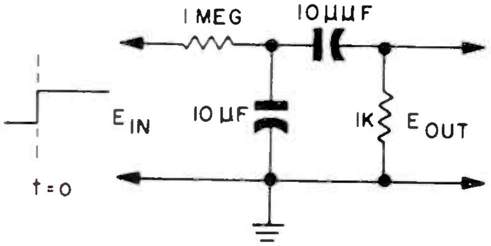
easily detectable from limited radar tracking information if it were in an area having a blip/scan ratio appreciably less than unity, because of the other variables affecting detection previously mentioned. The hole may appear in quality control data as higher quality control percentages for low-altitude tracks than those obtained for high flying aircraft.

In closing, it should be noted that any atmosphere which has a refractive index gradient differing from a constant value may give rise to a "radio hole" of minor proportions in radar coverage.

"What's Your Answer?"

This "What's Your Answer?" problem appears to be as simple as can be obtained—only four components are involved and all have even values. Even the explanation of the problem is short. Is the answer also?

A "step function" voltage at time $t = 0$ is applied to the circuit shown in the accompanying illustration. How will the output voltage look from the time $t = 0$ until 100 μsec. later?



HIGH-DENSITY TAPE RECORDING FOR DIGITAL COMPUTERS

GENERAL

The National Bureau of Standards has recently developed a method for closely packing digital pulses on magnetic tape. This method promises future useful application in the field of electronic computers. Such high-density storage can greatly reduce problem solution time by providing more rapid access to information recorded on external magnetic tape units. In a series of experiments performed in the Bureau's data processing laboratory, both continuous-current and pulse techniques were investigated to achieve densities in the range of 500 to 700 pulses per inch. Recording and reading circuitry was also developed to provide large-amplitude playback signals with error-free differentiation between binary *ones* and *zeroes.*

ADVANTAGES OF NBS TAPE RECORDING METHOD

An integral part of many large high-speed electronic computers is some type of magnetic tape or wire storage system which serves as an input-output means, as an external low-speed memory, or in some cases as both. Many types of mathematical problems require extensive use of an external storage system. In solving these problems relatively little actual computation is performed, but a great deal of data must be handled and assimilated by the computer. Ideally, the magnetic tape system would supply or receive data from the machine fast enough so that the computer could proceed with the problem solution at its normal rate. In reality, however, the maximum rate at which information can be accommodated by the tape unit is usually very slow compared to the speed of the machine because of tape speed limitations and the comparatively low density at which information is commonly stored on the tape. As a consequence, most of the problem solution time is spent not in computation, but in the performance of input-output or tape storage operations. The Bureau's investigation has been directed toward improving magnetic tape storage techniques to permit more rapid transmission of information to the computer by increasing the number of digital pulses recorded on each inch of the tape, thereby increasing the over-all efficiency of the machine. The electronic computer accessory, shown in figure 1, can reduce problem solution time by providing more rapid access to information recorded on external tape units. The reading and recording circuitry (top) will provide large-amplitude playback signals when 500 to 700 pulses per inch are recorded on the tape. The tape transport mechanism (bottom) is a modification of a commercially available model.

Sprocket pulses, indicated in figure 2, provide exact timing and spacing of information pulses. "Ones input" is for information pulses, and "reset input" is a pulse that occurs at the beginning of each information word. In operation, a pulse is recorded every time there is a sprocket pulse; if a binary *one* (information) is to be recorded, the pulse that is recorded is of opposite polarity to the previous pulse recorded. When a binary *zero* is to be recorded, a pulse of the same polarity as the previous pulse is recorded.

APPLICATION OF DIGITAL PULSE TECHNIQUE

One variation of the non-return-to-zero (NRZ) system of tape recording was selected for the present investigation. In this system, as ordinarily applied, current sufficient to saturate the

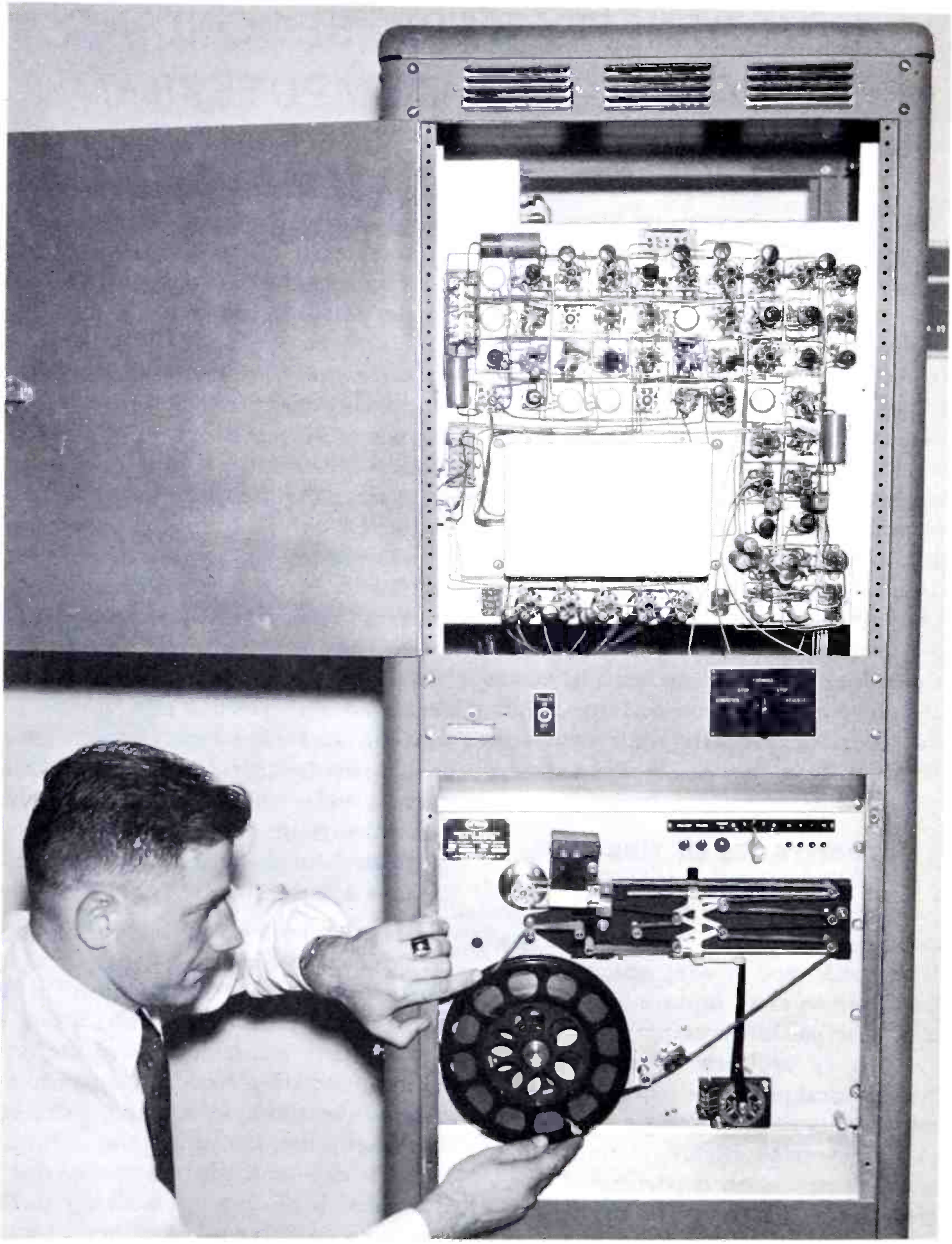


Figure 1. Equipment Developed at the National Bureau of Standards for Closely Packing Digital Pulses on Magnetic Tape

tape is maintained in the recording head at all times, but the polarity is changed each time a binary *one* is to be recorded. When a binary *zero* is to be recorded, the current is not changed. This type of recording produces a single change in magnetic flux on the tape for each binary *one* and no change in flux for a *zero,* so that on playback a voltage is produced only when a *one* is read. Disadvantages of this method are that a continuous current must be maintained in the head

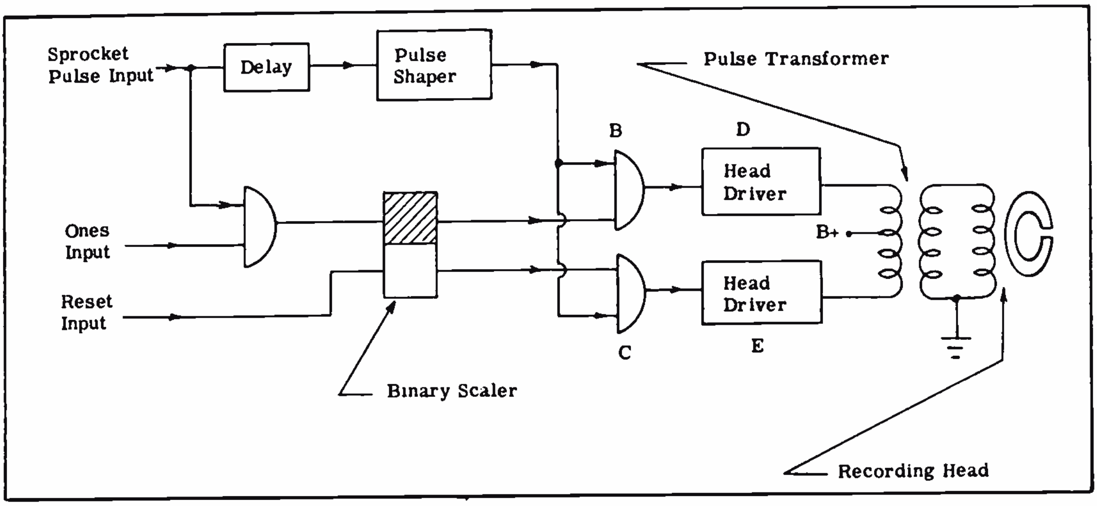


Figure 2. Logical Diagram of the High-Density Tape Recording System Developed at NBS

during recording and that the polarity of the current must be switched rapidly. Unless center-tapped head windings are used, these requirements often lead to rather complicated driver circuits that consume considerable power. To overcome these drawbacks, the Bureau used a digital pulse technique, instead of the continuous current method, to achieve NRZ tape magnetization.

In application, the pulse technique is analogous to the continuous current method. To record a binary *one* with the pulse technique, a pulse of opposite polarity to the previous pulse is recorded. To record a binary *zero,* a pulse of the same polarity as the previous one is recorded. Thus, on playback, there is a single voltage swing for each recorded *one,* and no voltage for a *zero.*

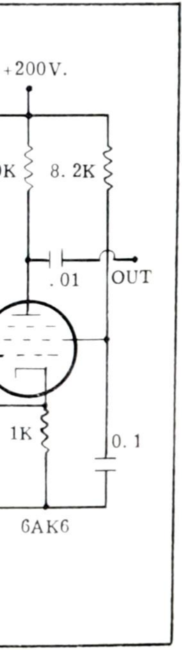
METHOD OF DETERMINING MAXIMUM USABLE PULSE DENSITY

To find the maximum usable pulse density, a number of recordings were made on tapes that had previously been erased with alternating current. See figure 3. For each recording the tape speed was held constant, the pulse duration was 2 μsec., and the pulse current was 60 ma. The only parameter that was changed was the pulse repetition rate; this was increased so that for successive recordings the pulses were crowded closer and closer together. When the recordings were read back, it was found that the playback voltage increased with pulse density until a maximum of 440 pulses per inch was reached, as shown in figure 3. The voltage then began to decrease for greater densities, but so slowly that even at 735 pulses per inch the output signal amplitude was still usable.

USE OF SPROCKET TIMING PULSES

In the NBS recording system, the recording rate and the exact location of each recorded digit are determined by timing pulses derived from a "sprocket" channel, shown schematically in figure 4, prepared in advance of the recording operation. The word length can be chosen arbitrarily, depending on the equipment with which the storage system is to be used. If the number of digits per word is n, then the sprocket channel must provide n + 1 timing pulses per word. The extra pulse is used to set up a reference condition at the beginning of each word. In preparing the sprocket channel, it is also necessary to consider the speed and acceleration time of the tape drive so that a sufficient gap can be left between words or groups of words for starting and stopping the tape without missing information.

usly Erased Tape



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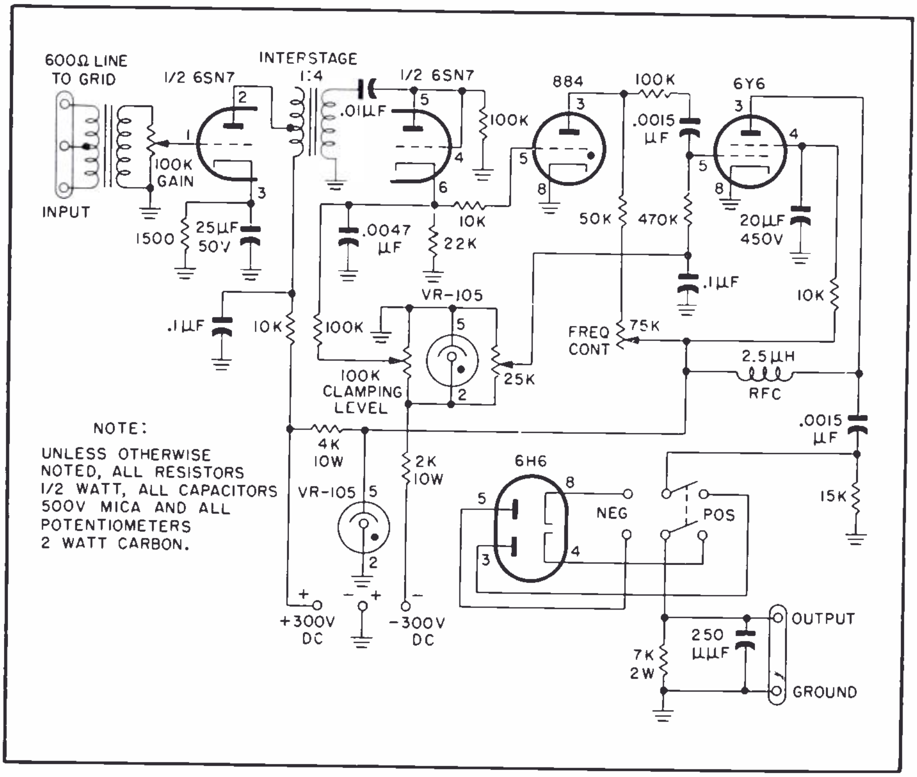
ION OF CROSSTALK OCKET CHANNEL

orage system such as this,
cket channel (shown in
sed both to interpret the
als from the information

fields to cancel. However, some crosstalk was still present because of slight geometric differences between the heads, minor differences in the signal levels, and a small capacitive coupling to the sprocket head. In order to suppress further the effects of the crosstalk signal, advantage was taken of the fact that the two signals with which the sprocket channel amplifier is concerned are made up of widely different frequency components. The desired signal from the tape consists of packets of nearly pure sine waves, whereas the undesired crosstalk signal is made up primarily of much higher-frequency components since it is induced by a recording pulse which is only 2 μsec. in duration. This knowledge was used to design and build a low-pass amplifier for the sprocket channel. At the output of this amplifier, the cross-

The amplifier output is transformer-coupled to a diode-connected triode, which acts effectively as a clamper circuit, with the level determined by the setting of a potentiometer in the cathode circuit. During the time of a high-amplitude input, the positive peaks of the 1800 c.p.s. signal are used to trigger the sawtooth generator stage, to provide an 1800 c.p.s. sawtooth output. During the time of a no-signal input, the negative grid bias holds this generator in a cutoff condition. Frequency shift control is achieved by providing a potentiometer to control the peak amplitude of the sawtooth generator output. This output is then fed to a switch and either one of two diodes, which provides either a positive or negative output with respect to ground. A filter is included to eliminate the 1800 c.p.s. component, leaving only a pulsed d.c. of the correct amplitude at the output. This is fed to the teletype transmitter to control the frequency shift.



The circuit seems unduly complex to perform a simple task, but it has the advantage that line noise pickup will not produce an output during a no-signal period unless the noise is of nearly the same amplitude as the signal, and that noise pickup during a signal period will not affect the output. Thus the output, used to control the transmitter frequency shift, is very nearly noise-free.

TECHNICAL SKETCH OF OLIVER HEAVISIDE
(1850-1925)

EDUCATION

Heaviside was reluctant to speak of his personal history; however, it is believed that the majority of his education was obtained through self-study and that he formally completed only high school.

In his early twenties Heaviside became aware of Maxwell's work, and he began a systematic study of *A Treatise on Electricity and Magnetism* by Maxwell. Heaviside supplied some excellent constructive criticism of Maxwell's work.

MAJOR SCIENTIFIC CONTRIBUTIONS

1. Interpretation of Maxwell's *Treatise.*
2. Developed methods of vector algebra.
3. Developed method of operators.
4. Used divergent series to solve differential equation.
5. Critic extraordinary. Heaviside pointed out errors in the work of P. G. Tait, J. J. Thomson and Lord Kelvin.
6. Put Maxwell's equations in a simplified form.
7. Introduced the idea of characteristic impedance of a transmission line.
8. Pointed out the existence of an ionized layer above the earth.

Heaviside was a mathematical physicist of the first rank. If Heaviside obtained accurate results with a specific mathematical approach, he felt that this was sufficient proof of the validity of the scheme rather than the formal rigorous proof of mathematical reasoning. For this viewpoint Heaviside was frequently criticized by mathematicians. Heaviside seldom produced rigorous proofs, but he was the originator of many new ideas in analysis that later were given rigorous proofs by the mathematicians. These innovations now form the basis of our modern operational mathematics.

PROFESSIONAL CAREER

Heaviside spent most of his adult life in retirement. He was in seclusion for about 50 years and seldom allowed visitors or personal interviews; hence, very little is known of his personal background. Heaviside was a nephew of Sir Charles Wheatstone, and some of his practical genius was probably inherited from this branch of the family.

PUBLISHED WORKS

Electromagnetic Theory—Three volumes.

Heaviside's works are, in addition to their scientific excellence, extremely well written and contain some philosophy and humor plus criticism of contemporary scientific persons. Heaviside was judged, by those who knew him well, as kind and generous with an artistic bent.

Such scientific notables as Professors V. Bush and E. J. Berg have written books containing the ideas of operational calculus worked out by Heaviside.

H. W. MERRIHEW
Headquarters Technical Staff

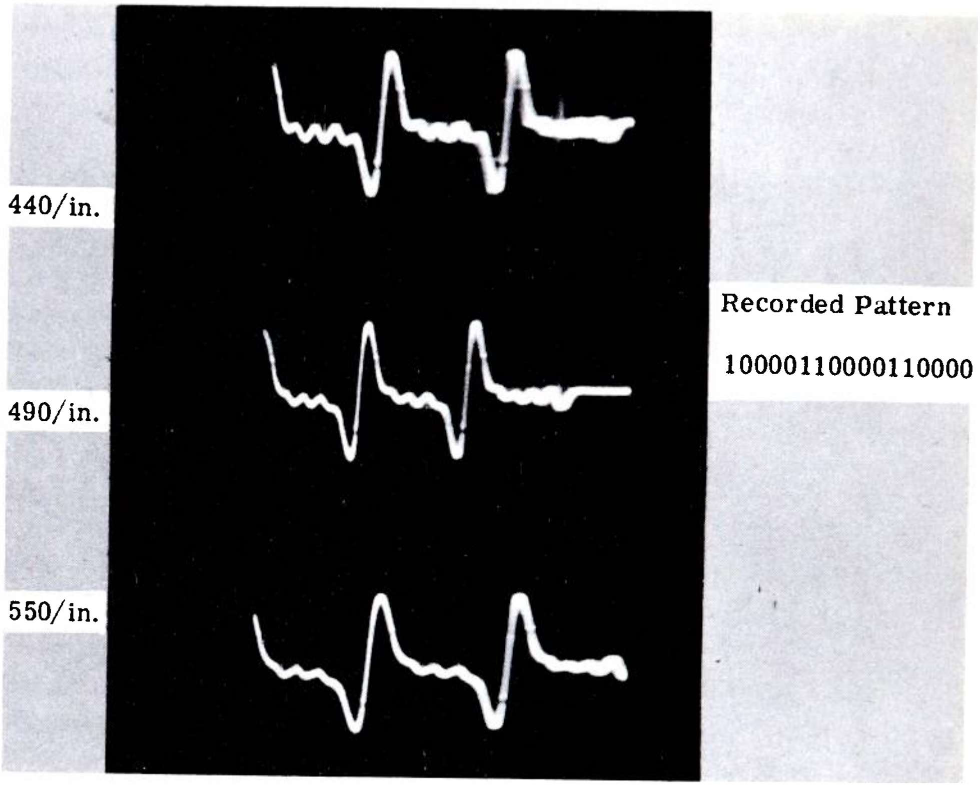


Figure 5. Typical Playback Signals From an Information Channel Where High-Density Recording Methods Have Been Used

talk signal is reduced to only one-fifth the amplitude of the tape signal. Thus attenuated, the crosstalk presents no further problem since it is now within the range of conventional amplitude discrimination means.

INFORMATION AND SPROCKET CHANNEL DIFFERENCES

The information channel circuitry is nearly identical to the sprocket channel circuitry; the main difference is in the reading amplifiers. While the sprocket channel amplifier was purposely designed to suppress the high-frequency response, the information channel amplifier had no such requirement. A satisfactory design was achieved simply by reproducing the sprocket channel amplifier with the low-pass filter omitted. As shown in figure 5, each lobe of the signal represents a binary *one* and is easily read and differentiated from the binary *zeroes* by the reading circuitry.

CONCLUSIONS

Although this tape storage system has not yet been completely and rigorously tested with a computer under actual operating conditions, it has been given extensive laboratory trials to determine the reliability of the reading and recording circuitry at different recording densities. For these tests the sprocket channel was recorded and used as it would be in actual operating conditions to control the recording and reading of the information channels. By recording words of information that contain a known number of *ones* and *zeroes,* it was possible to obtain a fair check of the performance of the system by counting the number of *ones* or *zeroes* on playback. Without taking any precautions to prevent errors from tape flaws, several runs of one to three million digits were recorded and read at densities of 500 to 600 digits per inch without apparent errors.

Although the phase shift characteristics of a transformer and the measurement and calculation of these characteristics and their variation with load are primarily of concern to the design engineer, questions regarding the accurate measurement of phase shift are frequently asked. F. J. Hoban, a BULLETIN reader, has submitted the following method of obtaining these phase angles by simple measurements and calculations.

If the wattmeter voltage coil is connected across the primary and the current coil connected in series with the secondary, then it is possible to determine the phase shift under any load conditions. The ratio of the wattmeter reading to the volt-amperes (obtained by conventional methods) will be the cosine of the phase angle between the primary voltage and the reverse secondary current. The angle between the primary voltage and the secondary current is then given by the relationship $180° - \cos^{-1}\frac{P}{EI}$, where P is the wattmeter reading, E the r-m-s primary voltage, and I the r-m-s secondary current. The readings are not in themselves significant, but their ratio can be used to give the phase angle. Thus, within the wattmeter frequency range, its fairly high accuracy can be used to obtain phase relationships under any load.

This is one answer. Do you have a better method?

– – – – –

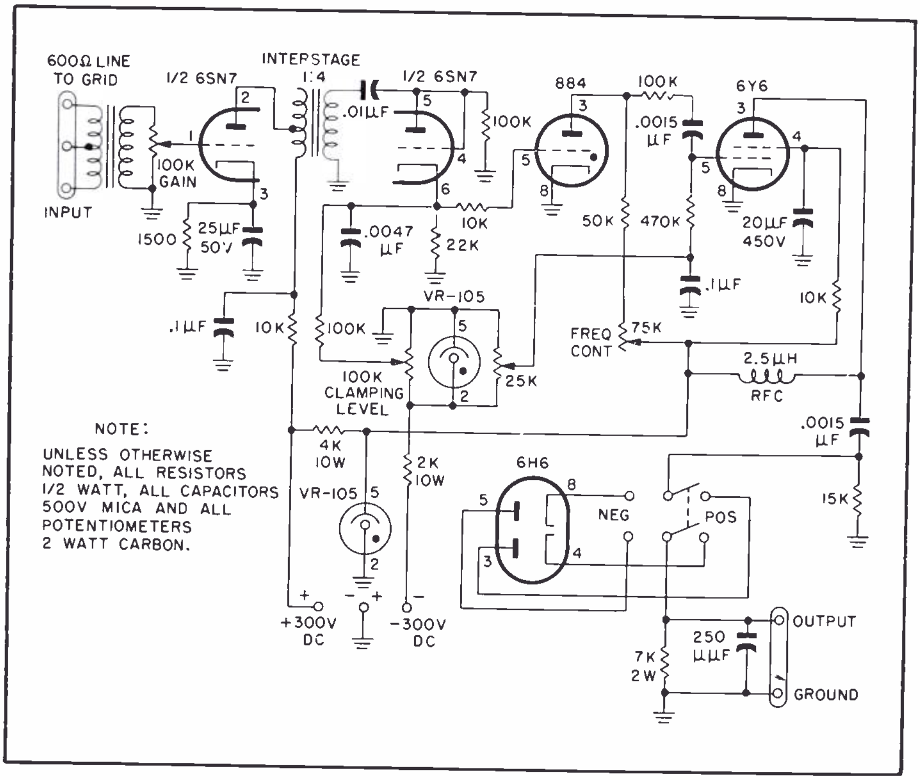
The following problem and its solution were submitted by Morton J. Zucker, a Philco TechRep Field Engineer with AACS.

It was found essential to transmit facsimile information from a transmitter normally used for frequency-shift teletype transmission. The material to be sent via the system consisted of weather maps, and at the transmitting site no commercial keying units were available. Therefore, it was found necessary to design and construct a simple keying unit for temporary use in accomplishing the specific objective of transmission of weather maps. Fortunately, weather maps do not contain halftones (shading) and therefore a "go, no-go" type of device could be used. The keying unit had to be compatible with the available equipment, a TXC-1 facsimile unit, which has an 1800 c.p.s. amplitude-modulated output, and an FRT-15A teletype transmitter using, for facsimile, a d-c input to produce frequency shift. This transmitter requires an input signal of +1 to +20 volts to provide maximum phase shift.

Here is the solution given by M. J. Zucker.

The circuit shown in the accompanying illustration was constructed to act as a keyer, using voltages available at the teletype transmitter. The input obtained from the TXC-1 facsimile unit is an 1800 c.p.s. amplitude-modulated signal. Since only black and white information was to be transmitted, the amplitude modulation is actually in the form of pulse modulation, with pulses of varying time duration. The first triode is a voltage amplifier with gain control at the input.

The amplifier output is transformer-coupled to a diode-connected triode, which acts effectively as a clamper circuit, with the level determined by the setting of a potentiometer in the cathode circuit. During the time of a high-amplitude input, the positive peaks of the 1800 c.p.s. signal are used to trigger the sawtooth generator stage, to provide an 1800 c.p.s. sawtooth output. During the time of a no-signal input, the negative grid bias holds this generator in a cutoff condition. Frequency shift control is achieved by providing a potentiometer to control the peak amplitude of the sawtooth generator output. This output is then fed to a switch and either one of two diodes, which provides either a positive or negative output with respect to ground. A filter is included to eliminate the 1800 c.p.s. component, leaving only a pulsed d.c. of the correct amplitude at the output. This is fed to the teletype transmitter to control the frequency shift.



The circuit seems unduly complex to perform a simple task, but it has the advantage that line noise pickup will not produce an output during a no-signal period unless the noise is of nearly the same amplitude as the signal, and that noise pickup during a signal period will not affect the output. Thus the output, used to control the transmitter frequency shift, is very nearly noise-free.

TECHNICAL SKETCH OF OLIVER HEAVISIDE (1850-1925)

EDUCATION

Heaviside was reluctant to speak of his personal history; however, it is believed that the majority of his education was obtained through self-study and that he formally completed only high school.

In his early twenties Heaviside became aware of Maxwell's work, and he began a systematic study of *A Treatise on Electricity and Magnetism* by Maxwell. Heaviside supplied some excellent constructive criticism of Maxwell's work.

MAJOR SCIENTIFIC CONTRIBUTIONS

1. Interpretation of Maxwell's *Treatise.*
2. Developed methods of vector algebra.
3. Developed method of operators.
4. Used divergent series to solve differential equation.
5. Critic extraordinary, Heaviside pointed out errors in the work of P. G. Tait, J. J. Thomson and Lord Kelvin.
6. Put Maxwell's equations in a simplified form.
7. Introduced the idea of characteristic impedance of a transmission line.
8. Pointed out the existence of an ionized layer above the earth.

Heaviside was a mathematical physicist of the first rank. If Heaviside obtained accurate results with a specific mathematical approach, he felt that this was sufficient proof of the validity of the scheme rather than the formal rigorous proof of mathematical reasoning. For this viewpoint Heaviside was frequently criticized by mathematicians. Heaviside seldom produced rigorous proofs, but he was the originator of many new ideas in analysis that later were given rigorous proofs by the mathematicians. These innovations now form the basis of our modern operational mathematics.

PROFESSIONAL CAREER

Heaviside spent most of his adult life in retirement. He was in seclusion for about 50 years and seldom allowed visitors or personal interviews; hence, very little is known of his personal background. Heaviside was a nephew of Sir Charles Wheatstone, and some of his practical genius was probably inherited from this branch of the family.

PUBLISHED WORKS

Electromagnetic Theory—Three volumes.

Heaviside's works are, in addition to their scientific excellence, extremely well written and contain some philosophy and humor plus criticism of contemporary scientific persons. Heaviside was judged, by those who knew him well, as kind and generous with an artistic bent.

Such scientific notables as Professors V. Bush and E. J. Berg have written books containing the ideas of operational calculus worked out by Heaviside.

H. W. MERRIHEW
Headquarters Technical Staff

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