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Editorial
Growth in the Electronics Industry

By John E. Remich
Manager, Technical Department

Probably no phase of the electronics industry affords a more graphic picture of the growth of the industry than television. In 1948, the presidential conventions were "live" telecast to only six cities in the United States, (Boston, New York, Philadelphia, Baltimore, Washington, and Richmond). Compared with this, the telecasts of the 1952 conventions will reach 68 major cities coast to coast, by means of a vast network of coaxial cables and microwave relays linking all but four of the 108 TV stations now operating in the U. S. A similar comparison is found in the small number of TV receivers available in 1948, as compared to the 18 million now in use.

In the short space of four years, then, this one phase of the electronics industry has expanded at least ten-fold, creating jobs for thousands of technicians and engineers, not only directly in television broadcasting activities, but also in the supporting fields of design, manufacture, and installation of receivers, transmitters, microwave and coaxial relay equipment, test equipment, and the like.

An even greater expansion in TV coverage can be anticipated for the next few years as a result of the lifting of the FCC "freeze" on the UHF TV band. Authorizations for the construction and operation of 1357 new stations in the UHF band (470 mc. to 890 mc.) have now been made available, as well as an additional 557 stations utilizing the present VHF channels. It has been predicted that a large percentage of these will be in operation within the next five years.

Of equal significance for the future is the widespread interest in color television. With at least three basic color systems already proved feasible, and with others currently being perfected in the laboratories, one can safely assume that as soon as the current defense effort ceases to limit the availability of essential materials, great emphasis will once more be placed on color transmission. Increased complexity of color transmission and reception equipment probably will require proportionately more and better trained technicians and engineers.

The same limitation on critical materials which presently is holding up the color program is affecting another phase of television expansion —industrial television. Although already proved in many applications, authorities in the field are confident that the surface has hardly been scratched.

Security regulations have allowed only brief glimpses to the public of the potential uses of television in the military field, but those few glimpses indicate a tremendous potential opportunity for trained electronics personnel.

Less dramatically but just as surely, the expansion in other phases of electronics continues to broaden the field of opportunity for the man with electronic know-how.

SYNC SEPARATION AND THE GATED-BEAM VACUUM TUBE

By Mark Flomenhoft
Technical Publications Department

A discussion of the gated-beam tube and its application to TV and FM circuitry.

One of the formidable problems of the television art is that of synchronizing the sweep generators in the receiver with the scanning generators at the transmitter. In this connection, the recently developed gated-beam vacuum tube has gained recognition as a superior sync-pulse separator. It it interesting to note, however, that the tube was originally developed for the purpose of combining in a single stage the dual functions of limiting and detecting an FM signal. Eventually, the remarkable limiting ability of the gated-beam tube foretold its value as a sync-pulse separator.

This background suggests the advisability of briefly discussing sweep synchronization, especially the difficulties presented by sync-pulse separation. An understanding of such considerations should then make clear the superiority of the gated-beam tube over conventional limiters.

TV SYNCHRONIZATION

Obviously, it is imperative that the many picture elements of the reproduced image be situated precisely in their correct positions. To this end, the electron beam of the kinescope is subjected to two scanning motions, one horizontal and the other vertical. It is fairly simple, of course, to generate voltage or current waveforms that effect linear deflection of the electron beam at a controllable rate. Therefore, by using identical rates of linear deflection at the transmitter and receiver, the scanning operation at the kinescope can be held in step with the scanning executed at the trans-

mitter *as long as proper timing is maintained.* Even a minute disparity between two related motions at transmitter and receiver can result in displaced picture elements or the pairing of interlaced lines. Consequently, the scanning motions must be synchronized to a high degree of precision.

For these reasons, the transmission of video intelligence is interrupted at regular intervals by synchronizing pulses, commonly referred to as *sync pulses.* The situation is illustrated in figure 1A. Note that the sync pulses are superimposed on a platform of constant amplitude called a *pedestal.* The function of the pedestal is to establish a signal reference level which is intended to coincide with the cut-off bias of the kinescope. In other words, the pedestal represents the black level of the picture signal. It follows that greater signal amplitudes, such as those of the sync pulses, will not be visible in the reproduced image. This explains why the sync pulses are said to be in the infra-black region of the signal.

SYNC SEPARATION

As might be expected, the video portion of the transmission never exceeds the pedestal in amplitude. It is possible, therefore, to extract the sync pulses from the transmission cleanly, without accompanying video intelligence. Naturally, the danger of contamination by interference signals that override the pedestal is still quite real, and, in fact, constitutes a separate problem. Disregarding interference, however, the demodulated waveform
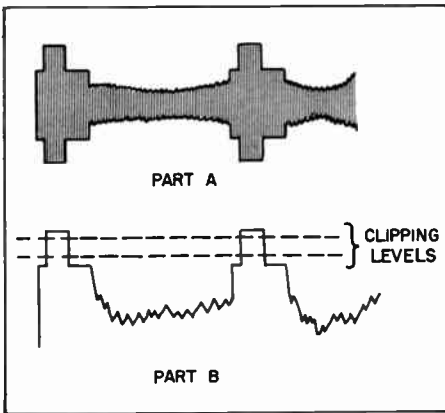
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PART A

PART B

} CLIPPING LEVELS

Figure 1. Nature of Composite Television Signal

of figure 1B suggests a method for obtaining highly dependable timing pulses from the transmission. Evidently, the signal should be demodulated and then applied to a tube that is biased to respond only to the portion of the signal between the dotted lines. This procedure will result in an output consisting of precisely timed impulses. Although only the lower clipping level is essential, subsequent discussion will explain how the gated-beam tube neatly "slices out" the segment of the sync pulse lying between the dotted lines of figure 1B.

There are a number of methods for separating the sync pulses from the demodulated output of the detector. Perhaps the most elementary arrangement is the one shown in figure 2. This circuit is actuated by a demodulated composite video signal of such polarity that the sync signal is negative going. The positive biasing voltage in series with the incoming signal must be equal in amplitude to the black level of the signal. When the signal impulses are less negative than the black level—in other words, lie in the picture-signal portion of the transmission—conditions of saturation will prevail. It follows that video signals merely cause changes in grid-current flow, and produce no discernible change in the plate voltage. The more negative sync pulses, on the
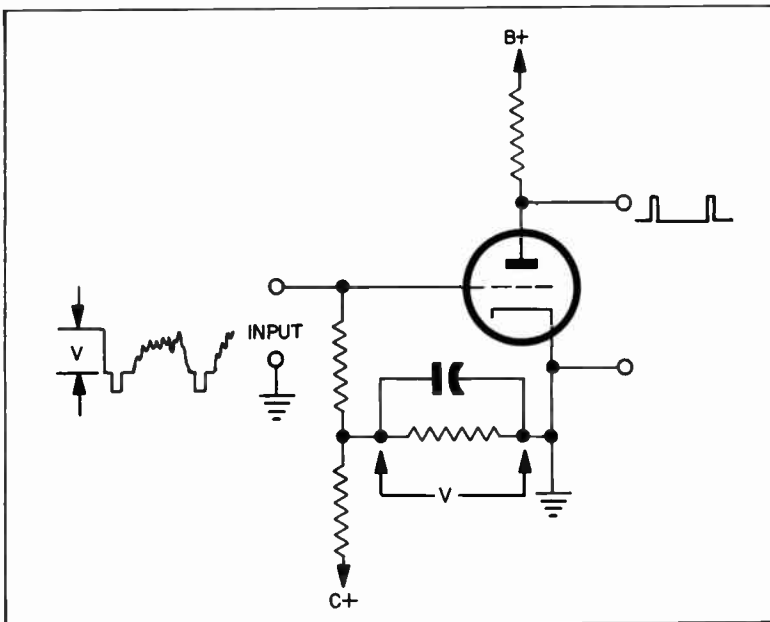

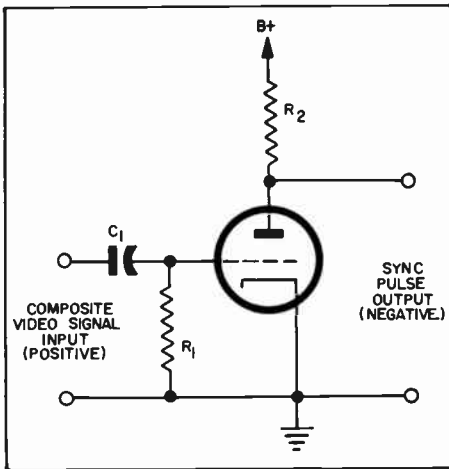**Figure 2. Elementary Sync Separator**

Figure 3. Grid-Leak Type of Limiter

other hand, are amplified in the ordinary way and appear as positive pulses in the output. Unfortunately, this type of limiting requires that the black level of the composite signal be fixed at a known amplitude prior to the separation process, regardless of fluctuations in received signal strength or the selection of another station. Owing to these requirements, the circuit has little value apart from showing how a limiter is capable of separating the sync pulses from the composite signal.

Apparently, some means must be devised for automatically adjusting the bias so that sync pulses can be recovered from any demodulated signal lying within reasonable limits. In contrast to the limiter of figure 2, the usual procedure is to apply a positive-going sync signal to a negatively biased stage that conducts only when the signal is in the infra-black region. The most widely used arrangement appears in figure 3. A grid-leak combination consisting of capacitor C and resistor R is placed in the input circuit of a suitable triode or pentode. The positive crests of the incoming signal cause the grid to draw electrons, and the capacitor

quickly charges. During the more negative portions of the signal, the capacitor discharges slowly through the grid-leak resistor and develops a negative operating bias. If circuit values are properly chosen, the operating bias will be such that the black level of the applied signal is more negative than the cutoff potential of the tube. This situation is illustrated in figure 4, the dotted line representing the operating bias of the stage. Camera signals, which are more negative than the black level of the transmission have no effect upon the amplifier, but the sync signals can cause plate current to flow. The surges of plate current develop negative pulses across load resistor R_2. At the peak value of the sync pulses, grid current flows into the capacitor and replenishes the charge it had lost while establishing a negative bias on the stage. In this manner, an output consisting exclusively of sync pulses is produced.

The grid-leak circuit is successful because the magnitude of the applied signal determines the amount of grid current that flows, and therefore the amount of bias produced. A small signal limits the amount of charge which the capacitor can receive, but a strong signal results in a substantial charge. In properly designed circuits, a departure from average signal conditions in either direction tends to produce a new bias voltage that maintains the black level of the incoming signal in excess of cutoff. It is important that the relatively small bias resulting from weak signals should not allow the picture-signal portion of the applied signal to be reproduced in the output of the stage. In other words, the bias must still be fairly large. This requirement means that resistor R_1 must be at least one megohm or greater. Although such a provision leads to erratic operation when gassy conditions in the tube
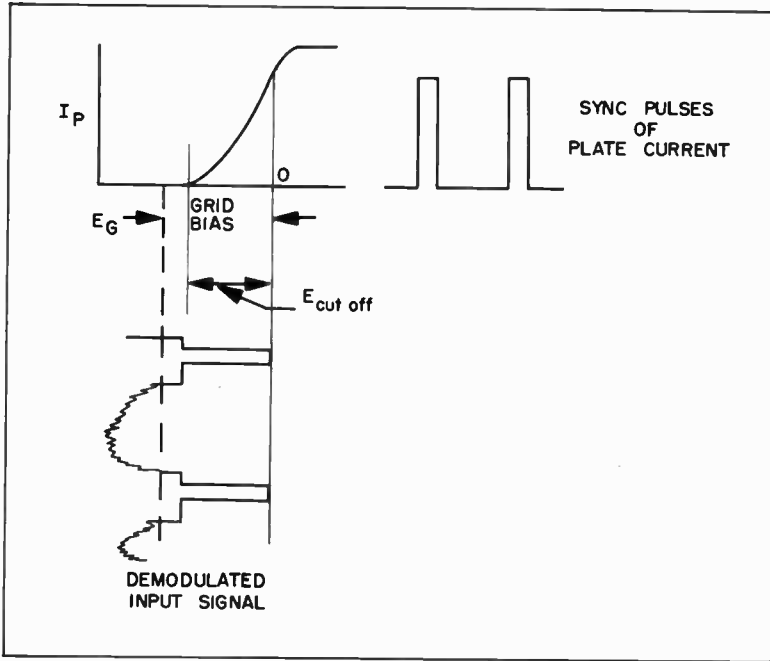
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Figure 4. Typical Limiter Transfer Characteristic

become troublesome, grid-leak biasing ordinarily is quite satisfactory. This is especially true in gated-beam circuits, for which grid-leak requirements are not severe.

In figure 5, several additional sync-separating circuits are shown. Since these arrangements are discussed in any basic text, no description of them is given here.

DESIRABLE SYNC-SEPARATOR CHARACTERISTICS

It is now possible to formulate the characteristics of an ideal limiter. Plainly, a low cutoff potential is one desirable property. Lower grid-leak resistances could then be utilized, making weak signals less of a problem as well as avoiding erratic operation due to gas in the tube. Another useful property is the ability to maintain a constant output amplitude despite variations in the magnitude of the input signal. To be sure, an output of irregular sync pulses can be ap-

plied to an additional limiting stage, but regardless of procedure the objective is constant-amplitude pulses resembling the output of figure 4. One result of this requirement is the need for a drastically sharp transition between the cutoff and high plate-current states of the tube. The matter may be expressed rather aptly by saying that the tube should act as a gate that passes an electron stream when open but shuts it off abruptly when closed.

In this regard, it should be recognized that a conventional tube is severely hampered as a limiter by the action of space charge, which surrounds the cathode except when saturation prevails. As the negative bias of the tube is increased, the electrons hovering over the cathode impede the escape of the newly released electrons. This effect makes the plate current taper off rather gradually before the cutoff is reached, as is shown in figure 4. A gradual transition from
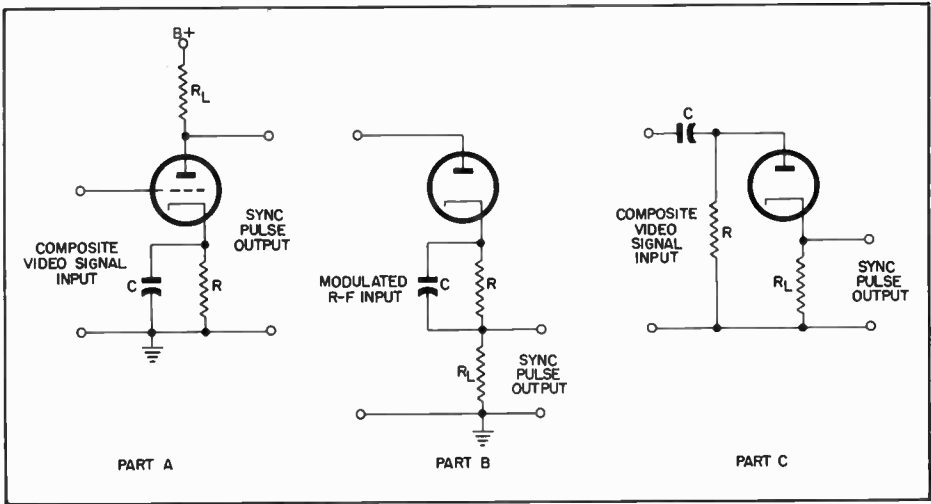
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Figure 5. Additional Sync Separating Circuits

tube saturation to cutoff is detrimental in a limiter.

A sharp transfer characteristic, however, should be supplemented by certain other properties. For example, once space-current saturation has been reached, it is desirable that no further increase of the current should

Figure 6. Type 6BN6 Gated-Beam Tube

occur, regardless of further increases in the magnitude of the input signal. This restriction would set an upper limit to the peak amplitude of the output signal. In conjunction with a sharp transfer characteristic, the existence of a fixed maximum amplitude of space current leads to output signals that have the same constant amplitude whether the input signal is large or small.

Another advantageous property is a reasonably low maximum grid current. This maximum should be reached, moreover, when the input signal is still fairly small. The benefit obtained is negligible loading of the input circuits, especially in the case of a moderately large input signal.

CHARACTERISTICS OF THE GATED-BEAM TUBE

Point for point, the gated-beam tube (figure 6) is admirably suited for limiting applications. To begin with, the transfer characteristic of the tube is exceptionally sharp. This is borne out by the static characteristic of a 6BN6 tube (figure 7A). The middle of the vertical portion of this curve corresponds to a negative 1 or
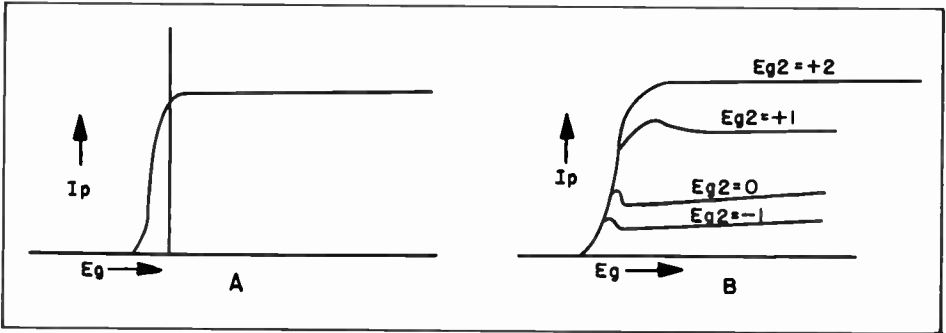
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Figure 7. Transfer Characteristics of Gated-Beam Tube

2 volts, and experience has proved this voltage to be optimum bias for circuit operation. If the composite input signal applied to a gated-beam limiter is between 20 and 80 volts (peak-to-peak), the 2-volt swing from cutoff to maximum space current enables a small section of the sync pulses to be sliced out, as mentioned earlier with regard to the dotted lines of figure 1B (sync pulses are equal to one quarter of the maximum amplitude of the composite video signal). In other words, the output pulses are limited to an unvarying maximum amplitude because tube saturation is quickly reached, while the camera signals are eliminated as a result of the exceptionally sharp cutoff characteristic.

EFFECT OF NOISE

If a noise spike larger than the sync pulses should be applied, as illustrated in figure 8, it will be limited to the same amplitude as the sync pulses. The construction of the 6BN6 is such that the sync pulses draw the maximum possible grid current of about 500 microamperes, and even the largest noise impulses do not draw any more current. Under most
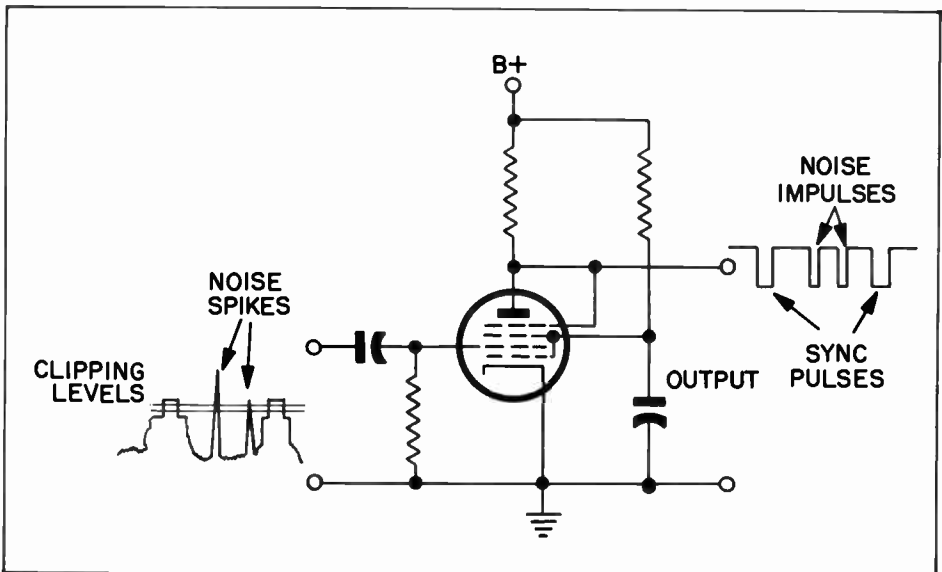

Figure 8. Gated-Beam Sync Separator

circumstances, therefore, the normal grid bias is not changed by large noise spikes any more than by minor ones.

As mentioned previously, the size of the grid-leak resistor in a sync separator determines the bias of the tube. Excessive grid-leak resistance causes a bias so large that only the peaks of the sync pulse will be capable of initiating plate-current flow. In the presence of noise, unfortunately, the effective amplitude of the sync pulses is usually erratic, so that a large bias will eliminate many of the smaller pulses from the output. To restore these smaller pulses, it is necessary only to reduce the bias. A grid-leak resistance of one megohm or slightly less results in the optimum negative bias of one to two volts. This resistance is low enough to eliminate most difficulties caused by gas in the tube. If the resistance is decreased further, however, camera signals will appear sporadically between the sync pulses, thereby defeating the purpose of sync separation.

LOADING EFFECTS

The loading imposed on an input circuit by the 6BN6 gated-beam tube depends upon the amplitude of the signal. In the presence of signals that are too small to be limited, there is no appreciable loading. The input resistance will begin to fall, however, if the amplitude peaks increase to about 1 volt, which is usually sufficient to initiate limiting. When the peaks increase further to somewhere between two and three volts, the input resistance passes through a minimum of about 20,000 ohms. As the signal strength becomes even greater, the input resistance rises once more toward infinity. This is attributable to the constant grid current that flows when the input signal is larger than about three volts. If 60 volts are applied to the accelerator (explained in the next paragraph), the grid current levels off at a maximum of about 500 microamperes. Consequently, there is little danger of overloading the tube or overdamping the driving circuits when the grid is driven positive. This property often proves valuable.

STRUCTURE OF GATED-BEAM TUBE
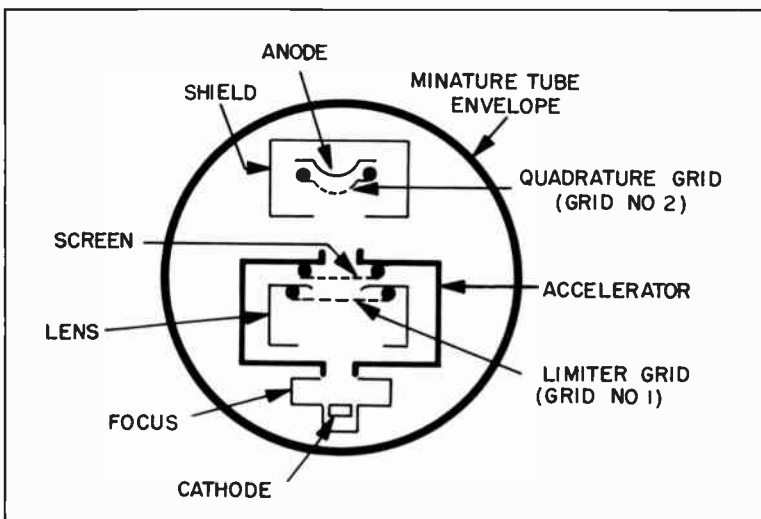
A schematic representation of a

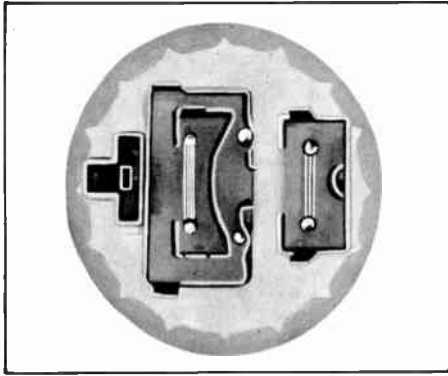*Figure 9. Schematic Representation of Gated-Beam Tube*

Figure 10A. Top View of Gated-Beam Tube

gated-beam tube appears in figure 9, while figure 10 shows an actual photograph of the tube elements. Note that two sections are present, although only one is needed in limiting applications. The additional section is included because the tube was originally developed as a single-stage FM limiter-detector, as mentioned earlier. Essentially, the operation of the tube is as follows:

The electrons emitted by the cathode are focussed into a sharply defined beam by the *focus* electrode; they pass through a narrow slot in a solid positive electrode called the *accelerator,* and are thereby collimated into an even sharper beam; this beam is in the form of a narrow sheet stream, the electrons of which proceed head-on to a control grid; lastly,

when the grid bias is not too negative, the electrons continue through a screen grid and on to an anode situated behind the grid (actually, the rear wall of the accelerator acts as the anode of the first section). These provisions result in an exceptionally rapid transition from tube cutoff to saturation. It is possible, in fact, to achieve transconductances in the order of several thousand micromhos per ma. of anode current. These properties are illustrated in figure 7B, which shows that the characteristic of grid voltage versus plate current is virtually step-shaped. Thus, the plate current rises abruptly from zero to a rigidly fixed maximum as the grid potential becomes increasingly positive. Observe in particular that after maximum current is attained, there is no further increase, regardless of how positive the grid potential swings. As a result of the action within a gated-beam tube, it is commonly referred to as an *electron-optic* device.

Electron behavior within the tube is illustrated in figure 11. In part A of the figure, attention is given to a single section in which conduction is assumed; in other words, the gate is open. In part B, the gate is closed, shown by the divergence of returning electrons. In order to understand this action, it is necessary to reconsider the internal construction of the tube.
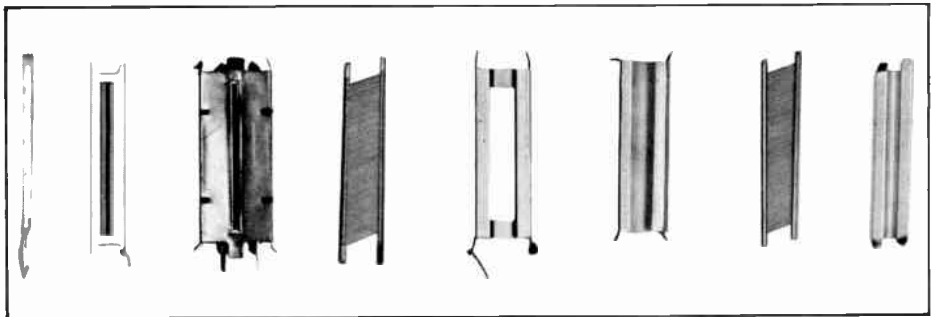

Figure 10B. Elements of Gated-Beam Tube (Left to Right:) Cathode, Focus Electrode, Accelerator, Control (#1) Grid, Lens, Shield (Rear Surface), Quadrature (#2) Grid, and Anode
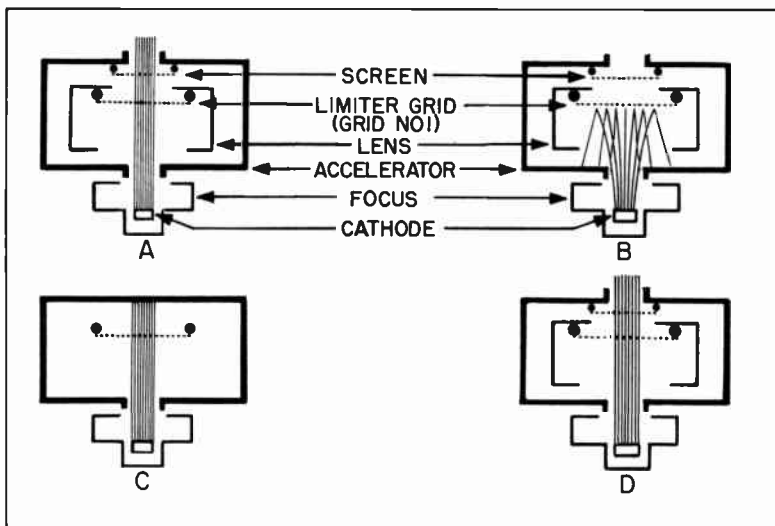
Figure 11. Electron Behavior in Gated-Beam Tube

Through the combined effect of the focus electrode and the slot in the accelerator, the electrons arrive at the first control grid "head-on," as stated previously. Expressed differently, it can be said that the lateral component of electron motion is negligible. Under this condition, the repulsion of an electron by the grid compels it to travel back along its original path. As more repulsed electrons collect in this region, the space charge in the vicinity of the grid increases enormously. Hence, there is a cumulative effect that rapidly causes many other electrons to reverse direction also. The narrow path to the grid is soon totally blocked.

Because of the concentration of space charge in the center of the path, the majority of electrons subsequently repelled are dispersed around the edges of the oncoming beam and fall back to the accelerator, for the most part missing the gap through which they emerged. In this way, the electrons are prevented from returning to the vicinity of the cathode. The situation is comparable to a hose squirting a narrow stream of water up through a manhole, so that the descending spray arcs around the main stream and falls to the sides. Pouring the repelled electrons back to the accelerator rather than returning them to the cathode is of the greatest importance. If, to the contrary, the returning electrons were to collect around the cathode, consistent with the action in tubes of conventional construction, the increase of space charge near the cathode would reduce the outgoing current. This would make the plate current taper off rather gradually before the cutoff point were reached, instead of diminishing abruptly as shown in figure 7B.

SECOND SECTION

For the tube to function as an f-m detector, another section duplicating the properties of the first must be added. Reference to figure 9 will show that the rear plate of the accelerator, which serves as the anode of the first section, contains a small slot. The electron stream is directed through this slot by a second electron lens and a screen grid; hence, the slot becomes the starting point of a second gated-beam section.
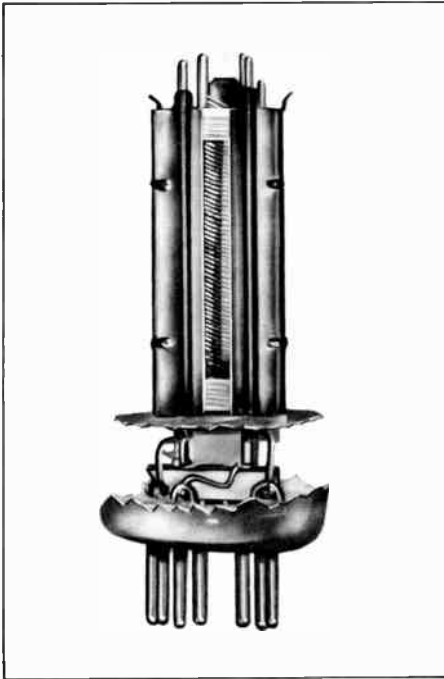
Figures 11C and 11D show the

Figure 12. Photograph Looking into
Second Section of Gated-Beam Tube

development of the second section. In C, electrons are pictured as traveling past the first control grid and proceeding to the anode. In D, a lens has been added in order to direct the thin, sheet-like stream of electrons through the slot now present in the former anode. A screen grid and the control grid (both physically curved) enhance the focussing action. The electrons remain focussed in sheet form; consequently, they may be directed against the second control grid and collected by a final anode with the identical results as before. The control grid of the second section and the final anode are situated within a shield box. Shield, focus, and lens electrodes are connected internally to the cathode, and the entire assembly is placed inside a 7-pin, miniature-tube envelope.

Since both sections of the tube have the same properties, the application of appropriate biasing potentials will enable either section to control the amplitude of the platform of the step-shaped characteristic. For example, suppose that saturation prevails in the first section of a 6BN6 tube. Under this condition a maximum number of electrons are transmitted from the first section to the second, and the platform of the characteristic relating the bias of the second control grid with plate current will attain maximum amplitude. As the bias of the first control grid is made increasingly negative, however, fewer electrons succeed in entering the second section. Therefore, the saturation current of the second section is reduced, producing a corresponding decrease in the platform level of its characteristic. In general, when a characteristic curve is obtained for the second section, variation of the bias applied to the first control grid within a small range of potentials near zero will control the level of the platform. Conversely, a variation of second-control-grid bias within a range close to zero has a similar influence on a characteristic obtained for the first section.

The latter situation is illustrated in figure 7B, which shows characteristic curves for the 6BN6 tube with various biasing potentials applied to the second control grid. When this grid is
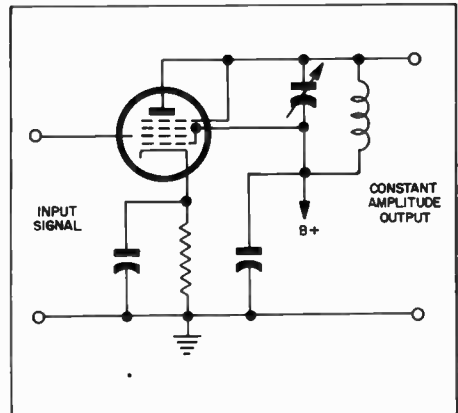

Figure 13. Limiter Circuit Incorporating
6BN6

at a potential of approximately $+2$ volts, the amplitude of the platform is maximum; that is, maximum plate current is flowing. This current can be a little more than 3 ma. when $+60$ volts are applied to the accelerator. The corresponding cathode current is 5 ma. As an illustration of the sharp switching action of the tube, the plate current is nearly maximum with the first grid at zero potential and the second grid at $+2$ volts, while a negative bias of slightly more than 2 volts on the first grid results in cutoff.

LIMITING AND SYNC SEPARATION

Use of the gated-beam tube as a limiter only is even more straightforward than operation as a sync separator. If the tube is connected simply as a linear amplifier, the E_g-I_p characteristic shown in figure 6B will cause limiting on both the positive and negative swings of a sufficiently large input signal. A typical circuit is shown in figure 13. Again, a constant negative bias of 1 or 2 volts should be employed. Since the second control grid is not required in limiting circuits, it may be tied either to the plate or to ground. A larger output signal will be obtained with the second grid connected to the plate as shown in figure 10, but grounding the second grid will enable smaller input signals to be completely limited. The first control grid should be returned to ground through a low d-c resistance such as a coil. By avoiding the use of energy storage, such as provided by a grid-leak resistor and capacitor, each cycle of the signal is unaffected by preceding ones. Under these circumstances, impulse noise and adjacent channel interference are suppressed with unusual effectiveness.

Operation of the gated-beam tube as a sync separator is similar to that of straight limiting. Therefore, the second grid should be connected to the plate when maximum output is desired, and to ground or a fixed d-c potential if more definite clipping of the pulse tips is advantageous. Sometimes a gating signal is applied to the second control grid so that noise not coinciding with sync pulses will be suppressed. In a gated-beam circuit, it is possible to obtain positive as well as negative sync output pulses—a feature which greatly simplifies separation of the horizontal and vertical sync pulses. This capability is due to the fact that a rise in the plate current is always accompanied by a decrease in the accelerator current (cathode current is constant). In practice, however, it is feasible to derive only the vertical sync pulses from the accelerator. This is accomplished by connecting an appropriate integrating capacitor between the accelerator and ground. Horizontal pulses, on the other hand, are preferably taken from the anode circuit.

FM DETECTION

A typical circuit in which the 6BN6 is employed as an FM limiter-detector is shown in figure 14. The first control grid performs the limiting operation. It is biased near the mid-point of its control characteristic, so that the applied wave is subjected to both positive and negative clipping. As determined by the E_g-I_p characteristic, the amplitude of current admitted to the second section will remain fixed at a certain maximum amplitude, regardless of amplitude changes in the applied signal. (This assumes a signal large enough to drive the first section well into saturation.)

In proceeding to the anode, the electrons develop a periodically varying space charge in the region surrounding the second control grid. As a result of electrostatic induction, frequently termed space-charge coupling,
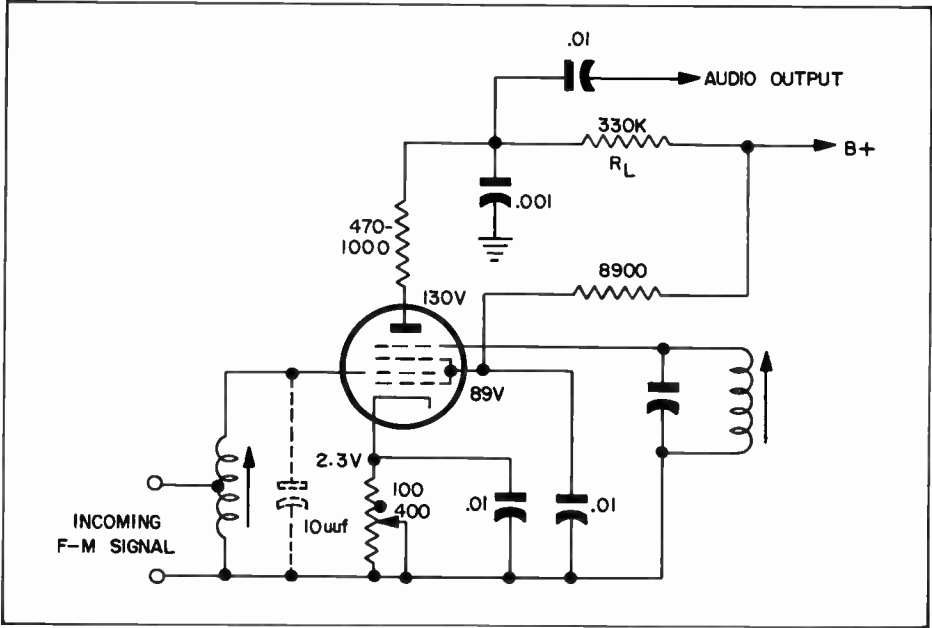
Figure 14. FM Limiter-Detector Circuit

a periodically varying potential difference is induced between the second control grid and ground. A tuned circuit is therefore connected between this grid and ground. When the resonant frequency of the tuned circuit is the same as that of the incoming signal, the voltage across the tuned circuit lags the applied signal by 90°. Owing to this phase relationship, the tuned circuit is usually called the *quadrature* circuit. The phase lag causes the second grid to act as a delayed gate that repeats the alternate opening and closing action of the first gate (grid). It is apparent that both gates must be open for the electron beam to reach the anode. Consequently, plate current begins when the second gate opens, and stops when the first gate closes.

The frequency of the signal induced in the quadrature circuit is the same as that of the incoming signal. It is important to remember that a 90° phase lag occurs only when the signal frequency is exactly equal to the reso-

nant frequency of the quadrature circuit. Since the frequency of the incoming signal changes, the phase difference between the signals on the two grids changes also. It is the phase difference that governs the width of the plate-current pulses that are passed during each r-f cycle. The varying pulse width, in turn, causes the average value of the plate current
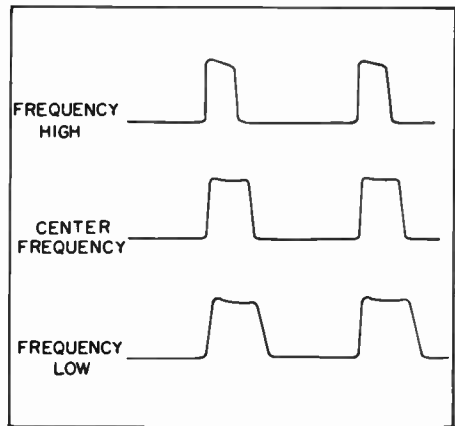

Figure 15. Effect of Incoming Frequency on Width of Plate-Current Pulses

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to change in accordance with the incoming frequency variations.

To illustrate the variation of pulse width, three sets of pulses are shown in figure 15. In one instance, the frequency of the incoming signal is relatively high; in another, the center frequency prevails; and in the last, the frequency is low. The resulting variations in the average value of the plate current cause an audio output signal to be developed across load resistor, R_L. A frequency characteristic curve typical of gated-beam discriminators appears in figure 16.

Figure 16. Frequency Characteristic of Gated-Beam FM Detector

INCREASING BANDWIDTH

The useful bandwidth of the frequency characteristic is proportional to the bandwidth of the quadrature circuit. One acceptable means of increasing the bandwidth of this circuit is to make its L/C ratio as high as possible. The ordinary method of increased damping, however, adversely affects the audio output, and impairs AM suppression. To avoid such difficulties, a small resistance in the range of 300 to 1000 ohms is connected between the plate and the load resistor. An i-f component of voltage will appear at the plate and be coupled into the quadrature circuit through the interelectrode capacitance between the anode and quadrature grid. Fortunately, the phase relationships are such that the small voltage reinforces the quadrature voltage produced by electrostatic induction. At the same time, the anode-grid capacitance, which contributes to the tuning of the quadrature circuit, occasions a damping effect because it is now in series with a resistance. Thus, the voltage developed in the quadrature circuit remains constant or even rises despite the increase of bandwidth. The benefits obtained are good audio output, improved AM suppression, and an increase in the bandwidth of the circuit.

Operated as a limiter only, the gated-beam tube suppresses amplitude modulation even more effectively than a conventional grid-bias limiter. This capability is due largely to the elimination of energy storage in a gated-beam limiter. Nevertheless, the superiority continues throughout low modulation frequencies, at which grid-bias operation of ordinary tubes is not yet impaired by time-constant disturbances. As a limiter-discriminator, however, the ability of the gated-beam tube to suppress amplitude modulation is less spectacular. Since audio output is developed in the plate circuit, signals corresponding to amplitude modulation can be present owing to unwanted plate-bend (saturation) detection. An obvious way of curing this tendency is to choose the limiter-grid bias carefully by proper adjustment of the cathode resistor. (The tube is designed so that the two grids require the same biasing voltage; consequently, bias for both can be provided by a single cathode resistor.) By exercising due care, it is possible to raise the AM suppression of the gated-beam circuit to a point where

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MARK FLOMENHOFT, born in Philadelphia on February 22, 1922, received his B. S. in Electrical Engineering at the University of Pennsylvania in February, 1943. During the following year, he was able to use his training to advantage in his position with the Hazeltine Electronics Corporation, at Little Neck, N. Y. In 1944, he entered the service of the U. S. Navy, where he spent two years as an ETM.

Following his discharge, Mr. Flomenhoft spent a year with the Transvision Company, where he wrote assembly instructions, servicing data, and sales literature for the company's TV kit. From 1947 to 1948, a new field of activity was entered—work in the computer field, as a member of the "logic" branch of project Whirlwind, at M. I. T., provided a valuable background in this subject. Upon completion of the computer project, he moved back into the writing field where he wrote Armed Services Manuals for the Cushing and Nevell Company, of New York.

He joined the Publications Department of the TechRep Division, in September, 1950. Since this time, he has been engaged in a major Government Manual project. He is now completing the writing of the latest manual in the Philco training series (Measurements in Radio Communications). This manual can be expected in the field shortly.

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it is on a par with other commercial FM detectors. In the suppression of noise impulses, the gated-beam detector is clearly superior, since it is less susceptible to bias disturbances than the older circuits.

If there is stray coupling between the two control grids, or between their associated tuned circuits, amplitude variations of the incoming signal may "leak through" to the second grid. This would seriously reduce the AM suppression provided by the detector. In the absence of excessive stray coupling, a substantially constant voltage is induced in the quadrature circuit. Stray coupling effects, however, may be noticeable when the input signal is very large.

When the filtered output voltage of the power supply is high, as is usually the case in a television receiver, an audio signal as large as 15 volts rms can be obtained for an input FM signal with a deviation of 25 kc. This order of amplitude is usually sufficient to drive a class-A power output stage directly. For the same deviation, smaller audio output voltages are obtained when the well-filtered detector plate-supply voltage is low, such as the usual 80-100 volts found in small home FM receivers. However, the reduction of output due to the low plate-supply voltage is offset by the larger frequency deviation of FM transmission; namely, 75 kc. The input signal must be roughly 1 volt rms or more.

ALIGNMENT

Alignment of a gated-beam FM detector is quite simple. An amplitude-modulated signal at the intermediate frequency of the receiver under adjustment should be applied to the first control grid. The following steps should then be performed:

1. Reduce the amplitude of the signal until a definite hiss or tone is heard in the output of the receiver.

2. Adjust the setting of the cathode resistor so that minimum hiss is heard in the output. If it is possible to make the hiss vanish entirely, reduce the amplitude of the applied signal until the hiss reappears. Then readjust the cathode resistor. The correct adjustment is one for which hiss is minimum but not completely suppressed.

3. Tune the quadrature circuit for maximum sound in the output of the receiver. If the input of the limiter section is tunable, adjust it for maximum sound output also.

CONCLUSION

In addition to the previously described circuit functions, the gated-beam tube has been utilized successfully as a coincidence detector in computer circuits and as a "slicer" in phase modulators. Although unexpected, the impressive versatility of the gated-beam tube should not come altogether as a surprise, since research conducted for a single purpose has often culminated in many additional applications. Indeed, it appears safe to anticipate even further exploitation of the electron-optic principle, so that the gated-beam tube may well prove the forerunner of a new design trend.

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In Coming Issues

If you've ever wondered about radar operation in arctic regions, and about the appearance of ice and snow-covered areas viewed on a radar screen, don't miss Bud M. Compton's "Radar Interpretation in the Northland," due to appear shortly.

Also coming up in an early issue is another of Gail W. Woodward's very practical articles, this one entitled "Theory and Application of the Magic T." The article contains a wealth of data on such novel devices as the balanced microwave duplexer, the microwave discriminator, and the "rat race," and is, in our opinion, one of his best.

USE OF THE SLIDE RULE
FOR FREQUENCY CALCULATIONS

By Norman Wasser and George James

Philco Field Engineers

**A simple method of converting an ordinary slide rule
for operation of an LC scale.**
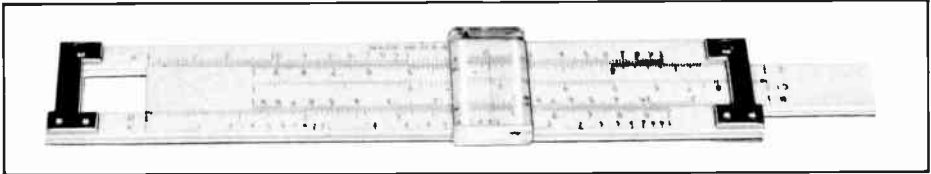
Determining the resonant frequencies of circuits is a relatively simple matter using a Cooke slide rule which is equipped with an LC scale. It seemed logical that one of the scales on an ordinary slide rule could, by manipulation, be used as an LC scale. This would make it easy to determine resonant frequencies on any slide rule.

Since the LC product is inversely proportional to the square of the frequency, and since the B scale is the square of the D scale, it is evident that the proper relationship will exist if the reciprocal of the B scale is used with the D scale. However, these scales must be made to coincide by modifying the result by a constant. In actuality, the LC scale on a Cooke slide rule is folded at the point of this constant.

To establish these conditions with an ordinary slide rule, remove the slide, turn it end-for-end, and re-insert it in the rule. The B scale is now inverted and adjacent to the D scale. The proper relationship is achieved by setting one index of the D scale on 2.53 of the B scale. This constant of 2.53 can be worked out mathematically from the term $\left(\dfrac{10}{2\pi}\right)^2$, but the authors found it the easy way by locating the point where the LC scale on a Cooke slide rule was folded.

This was done by comparing the LC scale with the index of the A scale. This point may also be determined by setting up on the rule several cases for which the LC product is known for a given frequency. It will be found in each case that one of the indices of the D scale will correspond to 2.53 on the B scale.

After the rule has been prepared as above, it can be used for determining resonant frequencies or LC products. Frequencies are read on the D scale, and LC products are read on the B scale. Let the left index of the D scale represent 1000 kc. and the right index, 10,000 kc. (The D scale can accommodate any 10-to-1 range in the frequency spectrum.) The LC product is read on the B scale directly above the frequency on the D scale. In placing the decimal point it should be remembered that for a frequency in the region of 1000 kc., the LC product will be approximately 25,000. At the 10,000-kc. end of the scale, the LC product will be about 250, while in the middle of the scale, the product is 2500. (With these figures, L is in microhenries and C is in micromicrofarads.) Knowing the LC product and either L or C, the unknown component can be quickly determined without returning the slide to its original position, by simply

using the CI and the D scales in the usual manner for multiplying or dividing.

In some cases, the slide of the rule will not fit in the inverted position described because of misalignment of the grooves and runners. For these cases, the same net effect can be produced in the following manner:

From the foregoing discussion of the relationship between the frequency and the LC product, it is apparent that the significant figures of the LC product will be obtained if the frequency is squared and the reciprocal of this result is multiplied by 2.53. The equation for this is:

$$LC = \frac{1}{F^2} \times 2.53$$

or

$$LC = \frac{2.53}{F^2}$$

This operation can be done directly on the slide rule. First, set the frequency on the D scale, and then read the frequency squared on the A scale. Next, under the frequency squared on the A scale, set 2.53 on the B scale. Then the LC product is read on the B scale under the A-scale index. Naturally the process can be reversed, and, with any known LC, the resonant frequency can be determined, or, with a fixed L and variable C, the frequency limits can be determined in less than 30 seconds.

$Solution$ to . . .

Last Month's "What's Your Answer?"

In considering last month's problem, it will be noted that the four capacitors form a balanced bridge across the generator. The variable inductor is connected at the null points of the bridge—thus, no current will flow in the variable inductor. This means that the variable inductor can be removed with no effect, and the circuit becomes a simple parallel circuit with 100 $\mu\mu$f. of capacitance (four 100-$\mu\mu$f. capacitors in series-parallel) shunting a 1-mh. inductor.

Accordingly, the resonant frequency is 500 kc. for all values of the variable inductor.

EFFECTS OF ELECTRIC SHOCK ON THE HUMAN BODY

By George J. Nichols, M.D.

A cardiologist discusses the effects of the passage of electric current through the human body, and the various ways in which injury or death may result.

Historians of the future will probably say that the strategic interference in the return of an electric current to ground has marked man's achievement in electricity. When this interference has not been so strategic, and man himself has been the conductor, the result has been injury or death. Yet at the present day, when we look around us, we find that electric shock as a part of our electrical training is disgracefully neglected. We are all aware of the tragic accidents which have happened to fellow technicians. Many of these have been instances of carelessness, possibly born of an incomplete understanding of the dangers inherent in every electrical circuit. It is the purpose of this article to shed some light on the relationship of electric shock and the human organism.

THE CAUSES OF DEATH

Two terms will be used frequently in this discussion which have intimate connections with the death-producing property of an electric current. They are: *ventricular fibrillation* and *respiratory-center paralysis*. To understand and appreciate ventricular fibrillation it is necessary to have a brief understanding of the structure and operation of the human heart. A heart-structure diagram is shown in figure 1. Normally, the stimulus which causes the heart to contract rhythmically is a minute electric current arising periodically in an area in the right auricle (sinus node). This minute electric current spreads over the entire auricle as an excitation wave, and engages the specialized heart conduction system at the junction of the right auricle and right ventricle (A-V node). The stimulus then proceeds along and branches into the right and left bundles of the conducting system (Purkinje network) and reaches the arborized endings where it is transferred to the ventricular musculature and causes them to contract. If this conduction system is paralyzed, the heart muscles may respond in a haphazard fashion, the effect being a quivering and discordant contraction, which renders the ventricles incapable of supplying the oxygenated blood to the rest of the body. This purposeless muscle activity is called ventricular fibrillation. The occurrence of ventricular fibrillation in man usually causes death, as recovery from this phenomenon has been recorded only in rare instances.

The second most lethal effect of an electric current on the human organism is respiratory-center paralysis. Normal respiration is governed by a
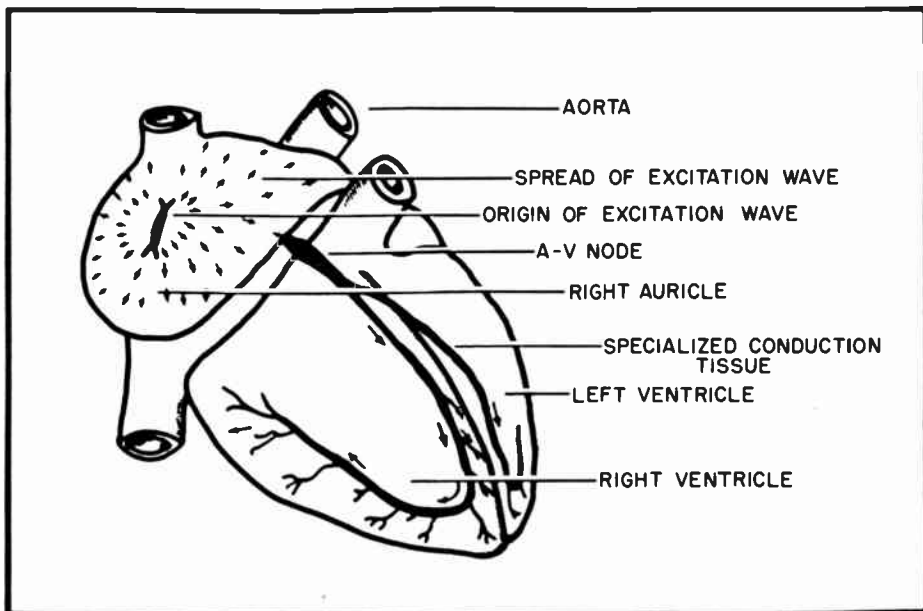
Figure 1. Heart Structure Diagram (The rythmic heart beat is controlled by a minute electric current generated in the right auricle. The current spreads over the auricle and flows into the specialized conduction system to the main pumping chambers—the ventricles. Any other electric current interfering with the minute heart current may produce deadly ventricular fibrillation if sufficiently strong.)

respiratory center located in the medulla-oblongata portion of the hind brain. It is here that the stimulus to breathe arises, day in and day out, year after year without cessation, and is sent over a complex nerve network to the breathing muscles and the lungs. Naturally, anything interfering with the function of such an important regulating mechanism, directly or by reflex action, as in the case of an electrical shock, is life-endangering. Death from electric shock may be caused by either of these two effects, or by a combination of both.

All investigators agree that there are certain governing factors which influence the injurious effect of electricity on the human body. They are: current, voltage, body resistance, duration of contact, type of current, path of current, and susceptibility of the organism at the time of contact. It is impossible to select any one of these factors and say that it is entirely responsible for injurious effect. It must be remembered that all factors operate simultaneously and each factor is interdependent on all others. Voltage itself does not cause death, but produces the flow of current which is, of course, determined by the resistance that varies with the circumstances of each individual contact with the charged conductors.

Current is the most important single factor in determining the overall effects of an electric shock. Skin resistance at the point of contact and voltage may be at wide variance and different in each case, but the intensity of current and the path it takes

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through the body are the criteria for judging injurious effect.

Alexander[1] gives us an idea of what the intensities of an electric current must be to produce the so-called shock. He states that ". . . an electric current of 0.2 to 0.3 ma. is felt by humans as a tap, one of 0.75 ma. as a pinch, a current of 1.0 ma. as a grip, one of 5.0 to 15.0 ma. causes unpleasant stimulation of the muscles, one of 15.0 to 19.0 ma. and above stimulates and at the same time paralyzes, or rather blocks for voluntary action the muscles and nerves through which it flows for the duration of the contact, one of 25.0 ma. and above may produce permanent damage, especially to nerve tissues and blood vessels, and one of 70.0 to 90.0 ma. and above may be fatal."

From the above statements we can also see why it is believed by some that a charged conductor has the power of "drawing" or holding its victim, or that in some instances the victim is believed to be "thrown" away from the conductors. Actually, of course, this is not the case. When the current flowing through the muscles and nerves is sufficiently strong (above 15 ma.), it causes a contraction of muscles and paralysis of the nerves involved, and thus it is impossible for the victim to "let go" because he has no control over these muscles during the time that the current passes through his body. If a sufficiently large number of muscles are stimulated by the electric shock, the sudden violent contraction of the muscles produces a "throwing" or "knocking" effect. This is secondary to muscle stimulation, and is not a property of the charged conductor. Therefore, the victim actually throws himself, which may cause serious and painful injuries.

It is evident that the amperage required to cause death need not be very high. As matter of fact, a current flow of 70 ma. at the ridiculously low value of 25 volts is capable of causing death due to ventricular fibrillation if passed directly through the chest. Higher current values (1 to 6 amperes) do not appear to have the tendency to produce ventricular fibrillation when passing through the heart. Such higher currents cause a sustained violent contraction of all musculature, including the heart. As mentioned before, ventricular fibrillation is a chaotic and purposeless contraction of heart muscles. If the current is of sufficient strength, the heart muscles are thrown into a state of complete contraction, thus preventing the phenomenon of fibrillation from occuring. Provided the victim is released from the shocking source within a short time (3 to 4 minutes at the very most), the inherent irritability property of the heart muscles may cause it to resume normal rhythmic contractions, particularly if the heart is stimulated by artificial respiration (or directly by cardiac massage).*

THE FACTOR OF VOLTAGE

In certain selected cases, the optimum lethal current value of 70 to 90 ma. may be higher than necessary to indirectly cause death. That is, if a current of the magnitude of 15 to 20 ma. passes from hand to hand through the chest, the victim is incapable of

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*Ventricular fibrillation also occurs in patients undergoing surgical operations. Beck ("Diagnosis and Treatment of Cardiovascular Diseases," Vol. 2, 1940, pp. 1181-2) has discussed an operation where fibrillation was stopped by subjecting the heart muscle to a shocking current of about 1.5 amperes for a very short time, thus causing sudden total contraction of all heart muscle. This electric shock and sudden contraction stopped the fibrillation of the heart muscle.
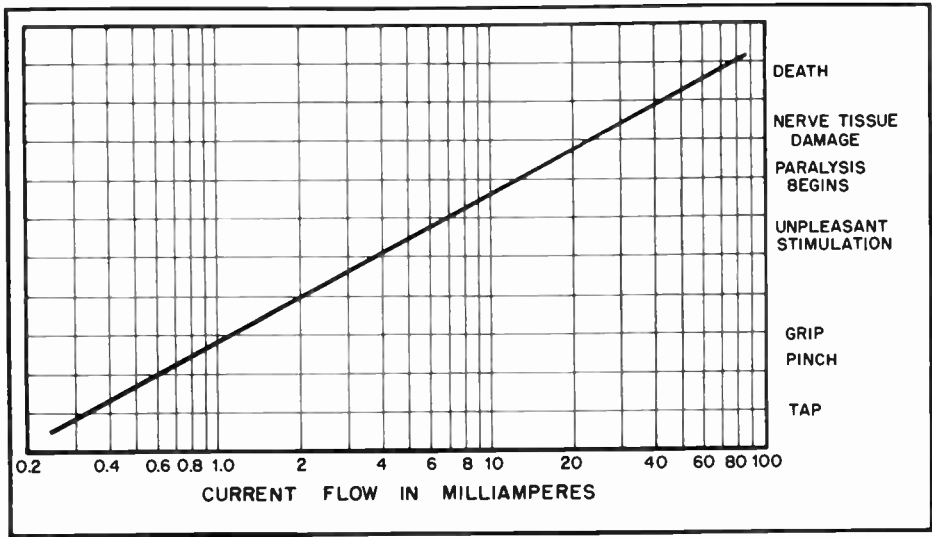
Figure 2. Physical Effects Produced by Body Currents of Various Intensities (Note the sequence of effects with the increase in current. Death generally occurs from ventricular fibrillation at a current of between 70 and 90 ma.)

releasing himself from the circuit. Furthermore, the path of the current may cause the muscles of the diaphram to be stimulated to contraction.

The continued spasm or contraction of the diaphram muscles and the victim's inability to "let go" can cause death from asphyxia even though the heart or the respiratory center may not be seriously involved.

Inasmuch as a considerable amount of data has been accumulated using voltage as the criterion of judgment in electric-shock cases, it might be well to discuss this factor. We must, however, continue to bear in mind that the combination of voltage and skin resistance produces the all-important current flow through the body.

The question always arises—how many volts will kill me? Upon examination of medical records it was found that there were cases in which death was attributed to the relatively low voltage of 45 to 60 volts.

Naturally, all other factors had been optimum. But even so, it is worthy of consideration that from a medical viewpoint many authorities regard any potential above 25 volts as dangerous to human life.

With changes in the voltage level, there appears to be a change in the manner in which electricity causes death. At the ordinary house-current frequency of 60 cycles, charged conductors carrying voltages below 220 volts are considered extremely dangerous since they tend to produce the deadly ventricular fibrillation phenomenon in the heart. Contact with conductors carrying 220 to 1000 volts is especially dangerous, since in addition to producing ventricular fibrillation there is also a tendency to produce respiratory-center paralysis in the brain, a combination which materially lessens chances of recovery.

Pearl[2], in discussing effects of voltages above 1000 volts, cites a series of cases in which the recovery

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rate of victims rendered unconscious by electrocution was 62%. When the victim was rendered unconscious by exposure to much lower voltages, the recovery rate was only 39%. From these and many similar recorded data it can be safely presumed that shock produced by contact with voltages in excess of 1000 volts tends to produce respiratory-center paralysis alone. This is probably due to the same reasoning as given under the discussion of current, whereby the heart muscles go into a state of complete contraction (precluding ventricular fibrillation) because of the excessive current flow. Voltages below 1000 volts, and especially those common to household distribution circuits, cause fibrillation and a proportionally greater number of deaths.

Within recent years some authors have advanced the theory that there is a substantial additional e.m.f. produced in the body tissue by the interruption of the flow of the shocking electric current. This has given rise to the erroneous conception that the interruption of an electric current flowing through the human body can produce a state of ventricular fibrillation in a heart not otherwise undergoing this phenomenon. This has been called counter-shock. Conversely, they maintain that a heart exhibiting fibrillation can be jolted back to normal rhythm by this means. However, this suggestion violates elementary laws since in order to produce a transient e.m.f. in the body tissue we must have considerable inductance. The inductance of the human body is far too small to be capable of producing the appreciable e.m.f. needed to cause fibrillation.

SKIN RESISTANCE AND DURATION OF CONTACT

Skin resistance is an extremely variable but important factor in considering the injurious effect of an electric current. It is the first barrier of defense of the human organism. Bone, muscle, and nerve tissue are comparatively much lower in resistance than the skin. Consequently, the skin becomes the limiting resistance in the passage of an electric current through the body. Skin resistance may vary from one megohm in the case of a calloused dry hand to 300 ohms in the instance of skin wet with saline perspiration. The average hand-to-hand resistance is about 50,000 ohms.

The duration of contact is intimately related to skin resistance since as contact time increases, the skin resistance rapidly decreases. This is most likely due to the stimulation of sweat glands which produces greater perfectness of contact. By application of Ohm's Law, it can be seen why a potential of 30 volts can cause a lethal current of 70 ma. to pass through the body. When we consider that the potential of 110 volts is most frequently contacted, current through the body can easily reach a dangerous level of 100 ma. in passage through the chest when the dry-skin resistance is as high as 100,000 ohms. This because the initial burning of the flesh at the point of contact and exit will cause carbonization of the tissue and reduce the skin resistance to a very low value. Skin resistance can be easily measured with an ohmmeter. When the occasion arises again for you to use this instrument it will prove interesting to note the variation of resistance from hand to hand and from different degrees of pressure on the electrodes. Also note the very appreciable reduction in skin resistance obtained when the contact areas are moistened.

PATH OF CURRENT

The path by which an electric current traverses the human body is largely responsible for its injurious effects. For all practical purposes, the human body can be considered a heterogeneous conductor of electricity, there being every little difference in the conductivity of bone, nerve, muscle, or blood tissue. Furthermore, the path of the current is the most direct one from the point of contact to the point of exit. The current does not, as is generally believed, follow the so-called "salty" blood stream. Any pathway involving the heart or brain is considered dangerous. Head to left leg is particularly dangerous since it involves both the brain and the heart. Arm-to-arm, arm-to-leg, and chest contacts bring the heart into the path, consequently causing ventricular fibrillation from abnormal stimulation of the heart at low current levels. Except for secondary tissue damage, leg-to-leg contacts are not particularly dangerous since no vital organs are traversed by this route.

Schudde[3], reports an interesting series of post-mortem examinations on persons killed by contacts with circuits carrying a voltage not greater than 250 volts. He found burns of the left hand in 90% of these victims. Remember that little rule of keeping one hand in the pocket while working on operating equipment? Try to make sure it is the left hand. Of course, a good ground predisposes to accidents. A damp concrete cellar floor with damp shoes and a myriad of shoe nails to help make contact more sure is a combination of circumstances to which many experimenters are constantly exposed. It is significant that when one reads accounts of electrical accidents, in many instances a concrete floor is men-

tioned. The account of the electrocution of Philip Murray (W9VYU, Dec. 7, 1938) suggested a concrete floor, and even mentioned a small puddle of water. It definitely behooves anyone working around electricity to have an insulated platform of flooring or dry wood. Rubber mats are not always safe, since some rubber products have an appreciable lampblack content which makes the rubber a fairly good conductor.

SUSCEPTIBILITY TO ELECTRIC SHOCK

There are a number of less important factors which can influence the effect of an electric current. Perhaps the one which might concern us most is fatigue. Aiello[4] points out that fatigue increases the susceptibility of the body to electricity. Statistics have confirmed the fact that the greater number of accidental electrocutions have occured during periods of maximum fatigue. Many of us attempt to construct and repair our apparatus during the time of maximum fatigue. In itself, this may not be a dangerous procedure, but couple it with the lack of precaution, exposed wiring, high voltages, and, what is worse, haste, with its consequent tendency towards carelessness, and we have a serious threat to human life. Otherwise, however, it is difficult to prove from available data and from the results of electrical experiments that pre-existing diseases or conditions of the body increase the susceptibility to electrocution.

As to the type of current, it has been found that a.c. at ordinary household frequencies (25-150 cycles) is roughly three times more dangerous than a d.c. of the same potential. However, Pearl states that d.c. is capable of producing a much more intense nervous inhibition and tends to produce ventricular fibrillation in

a much shorter time. When all factors are considered, it probably matters little whether a.c. at the household frequencies or d.c. is the shocking source—the overall effects are about equal.

As the frequency of a.c. increases, the injurious effects decrease. Animal hearts subjected to a.c. were found to be much more sensitive to lower frequencies. For instance, a dog's heart was found to be 20 times more sensitive to a 150-cycle current than to one of 1750 cycles. When alternating currents reach the radio-frequency level (above 10 kc.), the currents, even though they may be of the magnitude of several amperes, produce no muscle or nerve stimulation, the effect being one of heat. This is the principle involved in all medical diathermy machines. Increasing the current further produces destruction of living tissue by burning, this being the process akin to the "electric knife."

Caution must be exercised in the use of diathermy machines by the laity, since the heating effect takes place through the entire tissue. While the skin nerves are able to distinguish between "hot" and "cold," the central nerve tissues or body organs may be unknowingly injured by excessive heating.

DELAYED EFFECTS OF ELECTRIC SHOCK

The fact that we survive after contact with electricity does not always preclude escape from injury. There are certain effects which an electric current is capable of producing in the human body as an aftermath of the electric shock. The knowledge of these effects, unfortunately, is not general, and the impression which prevails is that if a victim survives an electric shock there are no subsequent sequelae to fear. Such is definitely not the case.

Most of us, at one time or another, have contacted a conductor inadvertently, and have received a so-called "nip" or "bite." How many of us considered the possibility that these painless shocks may have very serious after-effects? MacLachlan[5] points out that one of the most seriously incapacitating and most common delayed results of electric shocks of "house-circuit" intensity is a wasting away of muscle (atrophy) in the limb involved. This is caused by the effect of the current on the delicate nerve cells in the spinal cord. It is a slow, progressive, and intractable disturbance, and may not appear until weeks or even months after the date of the contact. Other reported delayed reactions are insanity, personality changes, amnesia, mental inertia, diseases of the blood vessels, eye cataracts, nerve disturbances of varied natures, and disturbances in the heart conduction system. It can now be seen why electric shock is regarded as a real industrial hazard.

A relatively new complication of electric shock has been brought to our attention by Glazer[6]. He records three separate cases in which extensive destruction of the tissues of the pancreas had been found by autopsy. While it is unlikely that the immediate death would be from this cause, it is well known among physicians that pancreatic destruction, regardless of the cause, is attended with an extremely high mortality rate.

WHEN ELECTRIC SHOCK OCCURS

A big question in our minds is what should be done for a victim rendered unconscious by electricity? Too often, accidental electrocution has been considered solely a problem for a
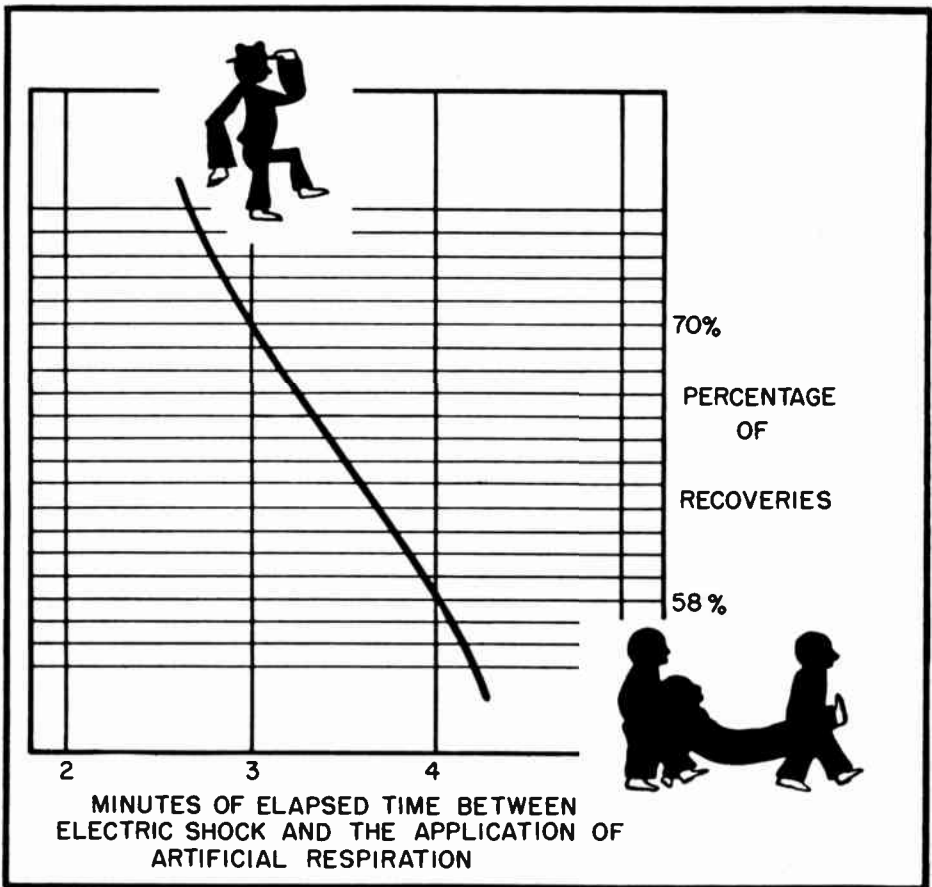
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Figure 3. Graph of Recovery From Electric Shock Plotted Against Time Between Shock and Start of Artificial Respiration (In an examination of some 600 cases of accidental electrocution, MacLachlan found that the averaged elapsed time between the shock and the application of artificial respiration was the determining factor in recoveries. When artificial respiration was applied in less than three minutes after the shock, the recovery was 70%. When artificial respiration was applied in less than four minutes, the recovery was only 58%. Death generally occurs in the absence of heart and respiratory action within 5 or 6 minutes.)

physician, and much precious time has been lost by waiting for one to arrive at the scene. In the meantime, however, the victim has died, because nothing was being done for him.

The death rate in accidental electrocution can be lowered only by the layman. Fortunately, the most effective treatment for electric shock so far known is artificial respiration by the prone-pressure method. It exceeds the efficiency of pressure-operated mechanical respirators, which, if used by unskilled operators, can do considerable damage and even cause death. Every electronics technician should acquaint himself with the Schaefer technique of artificial respiration. Many lives have been lost

because of the ignorance of this simple procedure.

To be effective, artificial respiration must be applied as soon as possible after the victim is rendered unconscious. One precaution should be taken, and that is preventing electrocution of the rescuer. Break the lethal circuit as quickly as possible. If you are alone with the victim, do not take time to send for help, but immediately apply artificial respiration, and keep doing so uninterruptedly. Shout, whistle, or scream to attract attention for more help, but do nothing that will interfere with the rhythmic motions of artificial respiration. In a case like this—you and you alone can save another person's life —do not become panic stricken. If the victim can be resuscitated, you can do it as well as anyone else.

Never take the responsibility of pronouncing a victim dead because he is not capable of breathing of his own accord—to do this makes one guilty of a crime just short of murder. There are cases on record in which artificial respiration has been continuously applied for as long as 8 hours before the victim was able to resume normal respiration. In the average case of unconsciousness due to electric shock, all signs which would ordinarily indicate death will be present. These signs are lack of pulse, absence of heart beat, no response to stimulations, and no respiration. Even though all these signs are present, the victim may still be alive, and artificial respiration is the only way in which he can be kept alive until his body processes are again capable of functioning.

The only absolute sign of death in a body rendered unconscious by electric shock (or by drowning or gas asphyxiation) is the appearance of rigor mortis (post-mortem phenomena due to coagulation, or jelling, of protoplasm). It is a sign to be interpreted only by a physician or by one acquainted with such phenomena —until this sure evidence of death occurs there is a possibility that the victim may be revived. Never attempt to administer stimulants or water by mouth to an unconscious person, because the swallowing reflex will be absent and anything given by mouth will go directly into the lungs, further lessening the victim's chance of recovery.

In an unconscious state where there is no heart action or respiration, death occurs in about 5 minutes because of the lack of oxygen and subsequent damage to body cells. For this reason, it is extremely important to start artificial respiration as soon as humanly possible. The highest percentage of recoveries exists in those cases in which artificial respiration was started almost immediately after the accident. The number of successful recoveries obtained when artificial respiration was started after 3 minutes is markedly reduced, and if it is not started before 5 minutes have elapsed, death will surely occur.

CONCLUSION

The main causes of death by electric shock are ventricular fibrillation, respiratory-center paralysis, or a combination of both. Currents at ordinary household voltages and frequencies are considered to be the most dangerous. The magnitude of the current and the path it takes through the human body are the most important factors to consider in the severity of an electric shock. There are serious latent effects of electricity which may well be incapacitating. Artificial respiration is the most effective means of reviving a victim, and it must be applied promptly and continued until

there is no question of death. Consider any potential above 25 volts as dangerous to human life, and never willfully subject yourself to electric shock.

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AN EASILY CONSTRUCTED TRIMMER CAPACITOR

Here is an item which has been used successfully by the author in the construction of high-frequency equipment.

The object of the device is a compact, simple, easily constructed, low-cost trimmer capacitor. The trimmer is constructed as shown in the figure; capacity values are determined by the size of the hole, the size of the plate, and the dielectric plate material and its thickness.

Since the shape of the hole determines the capacity-versus-rotation curve, it is evident that any desired curve can be obtained with a little experimental effort.

The small size of vhf and uhf trimmers, combined with the wide use of series-tuned circuits, make the practical value of this gadget obvious.

By Harold Reynolds
Headquarters Technical Staff
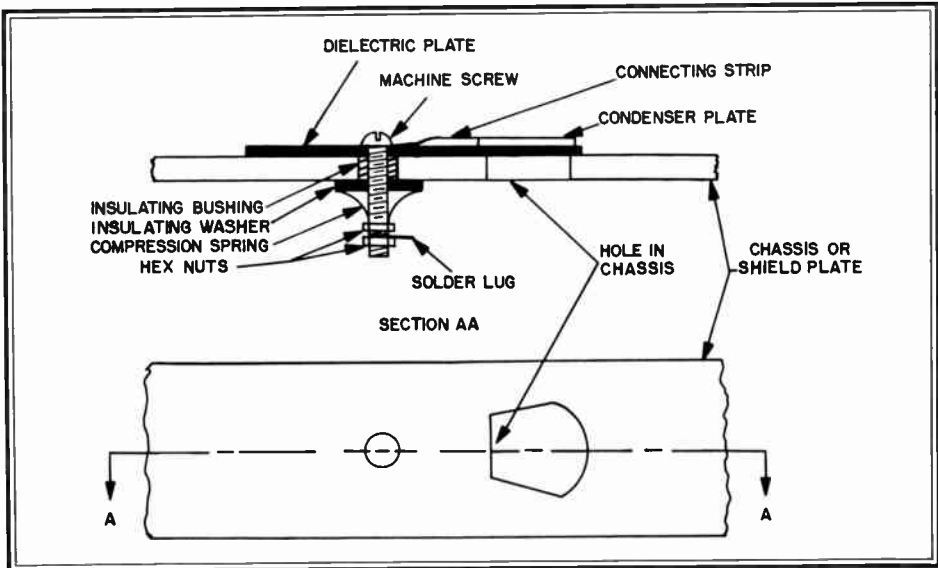
Simultaneous Interference-Free Operation of Two Adjacent Radars

By Louis A. Messer
Philco Field Engineer

A simple method for the elimination of mutual interference between adjacent radar sets.

A problem which frequently arises is that of operating two similar radars in proximity to each other without producing mutual interference. This situation is especially likely to occur with heavy ground radar sets because of their high system sensitivity. Normally, an interference blanker is used to suppress the video of the offended radar for the duration of the interfering pulse. Aside from being a relatively scarce item, the interference blanker eliminates only incident "main-bang" pulses, but not energy arriving over reflection paths. That this type of interference occurs may be readily demonstrated by rotating the antennas of two proximate radars at different speeds. Over a period of time, mutual interference will be observed on all azimuths, and, even with the reflectors positioned back to back, interference will still be visible as a result of multiple reflections from the surrounding terrain.

SYNCHRONIZATION

Fortunately, a simple and foolproof method of interference elimination is readily adaptable to heavy ground radar sets—namely, that of synchronizing the pulse-repetition frequency of one set with that of the other. To accomplish this, the ratio of the pulse-repetition frequencies of the two radar sets must be no greater than 4:3, and the radar with the lowest p.r.f., hereafter called the "slave," must have a gas-thyratron type of modulator which is externally pulsed. Furthermore, the slave p.r.f. generator must distribute trigger (not gating) pulses throughout the system. This type of trigger generator is usually a free-running blocking oscillator which easily synchronizes with positive trigger pulses of a slightly higher frequency. An MTI-equipped heavy ground radar is ideal as a slave unit because it meets the foregoing conditions. The various indicators, the range-mark generator, and the modulator are complete in themselves, and, with the possible exception of the modulator, all the components will operate quite stably over a wide range of p.r.f.'s. The average modulator will safely withstand an increase of not more than 33 percent in its duty cycle.

The problem of interference is most likely to occur when an older radar is replaced by a newer unit of similar design and radio frequency. Usually the p.r.f.'s of two such units will fall within the 4:3 ratio, especially if one set is equipped with MTI, because two p.r.f.'s are available on such an MTI-equipped unit. When two radars are synchronized, MTI reception will be possible on only the "master" (that is, free-running) radar, because the p.r.f. of a moving-target indicator must be determined by an accurately timed circulating trigger pulse passed through a mercury delay line. If MTI action is desired at any time on the slave radar, it is a simple matter to disconnect the synchronizing signal and switch to the fast p.r.f. If one radar set uses a rotary spark-gap
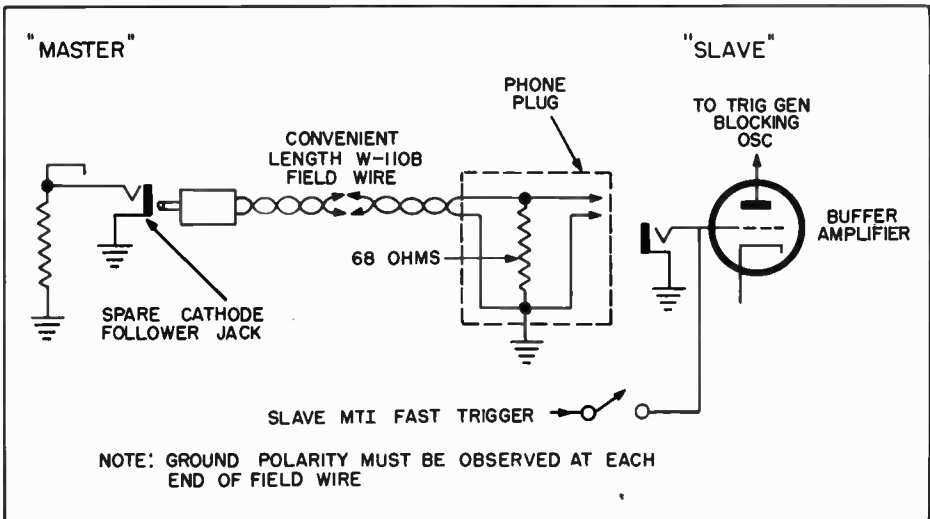
Figure 1. Schematic, Showing Method of Interconnection

modulator, this set must be used as the master, and no MTI reception will be possible while the radars are synchronized.

CIRCUITRY

In a typical example, radar "A" (the master) had a p.r.f. of 400 p.p.s. in MTI operation, and a p.r.f. of 200 p.p.s. in normal operation. Radar "B" (the slave) had a p.r.f. of 600 p.p.s. on MTI, and a p.r.f. of 300 p.p.s. on normal. Before this system was used, mutual interference was heavy, and operation of the sets at opposite ends of the L_K band did not reduce the interference below the tolerable level, even though the sets were a mile apart. In operation, set "A" was operated on MTI and set "B" on normal, which provided a 4:3 ratio of their p.r.f.'s. A synchronizing signal was obtained from a spare cathode-follower jack on set "A", and fed to set "B" by means of W-110B field wire. Referring to figure 1, it can be seen that the 300-p.p.s. trigger generator of the slave set consists

of a free-running blocking oscillator. For MTI operation, the blocking oscillator is triggered at twice its natural frequency by a faster trigger pulse fed to it through a buffer amplifier. A jack in the grid circuit of the buffer amplifier makes a convenient connection for the telephone line. The phone plug at the slave end of the line contains a 68-ohm line-terminating resistor. The buffer amplifier effectively isolates the blocking oscillator from the line, and, when MTI operation is desired on the slave set, it is only necessary to remove the phone plug from the jack. Synchronization is automatic upon connecting the line to both sets. The only noticeable change is the jumping in of the "second bang" on the slave set from 310 to 233 miles, and the complete elimination of mutual interference.

TRANSMISSION LINE

The use of field wire to carry pulse voltage may be questioned, but if the line is fed from a cathode follower, and is terminated in its characteristic impedance, the only detrimental effect on the trigger pulse is the loss of sharp corners. This
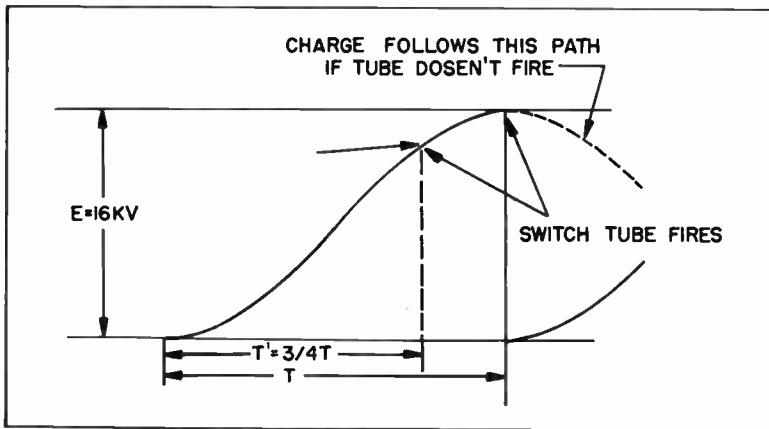
Figure 2. Graph Showing Charging Curve of Pulse-Forming Network in Radar Modulator

effect, which has been found to be unimportant, is due to the fact that the attenuation of this type of line increases rapidly with frequency. In one case, measured loss through one mile of W-110B field wire was found to be 17.4 db. Signal-to-hum ratio at the terminated end was 28 db, even though no special precautions were taken to isolate the line from power wires. The 4.5-volt trigger amplitude across the terminating resistor was ample for positive synchronization.

RADAR MODULATOR

The reader may also question the operating of a high-powered radar modulator at higher than its designed p.r.f., but, by referring to figure 2, it can be seen that increasing the duty cycle by 4/3 increases the average power by much less than this. This is so because the switch tube (gas thyratron) discharges the pulse-forming network at an earlier time (and, consequently, at a lower voltage) on the sinusoidal charging curve. (*Editor's Note: This action results in the application of a lower pulse voltage to the magnetron. However, where a line-voltage control is*

available, the a-c input to the modulator can be increased slightly to restore normal magnetron operation.) In the example cited by the writer, the average modulator current did not increase enough to trip the overload relay, which operates on a 43% increase. The slave was run for hundreds of hours at 4/3 its normal p.r.f. without causing a noticeable shortening of tube life.

CONCLUSION

Although this system of interference elimination has its maximum usefulness with heavy ground radars (because of their systems of trigger distribution), other radars may prove to be equally adaptable. The writer does not wish to convey the idea that the utility of this system applies only to the given example, but rather to present a general picture of the problems which may be encountered with most types of radars upon which the system might be used. If the slave radar is not seriously affected by the necessary increase in p.r.f., synchronization to another radar offers the most positive and readily adaptable solution in the field for the elimination of mutual interference.

WHAT'S YOUR ANSWER?

Here is a clever problem submitted by Philco Field Engineer Paul E. Burke.

The problem consists of two boxes connected to the 115-volt line as shown in the figure. One box contains two s-p-s-t switches, and the other box contains two lamps.

The objective is to add parts and circuitry *inside* the two boxes so that each switch will control a different light. The two switches must act independently.

(Solution next month)