RADIO-ELECTRONIC *Engineering* SECTION

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DEPARTMENTS

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CONTRAST MEASUREMENT In TV Images

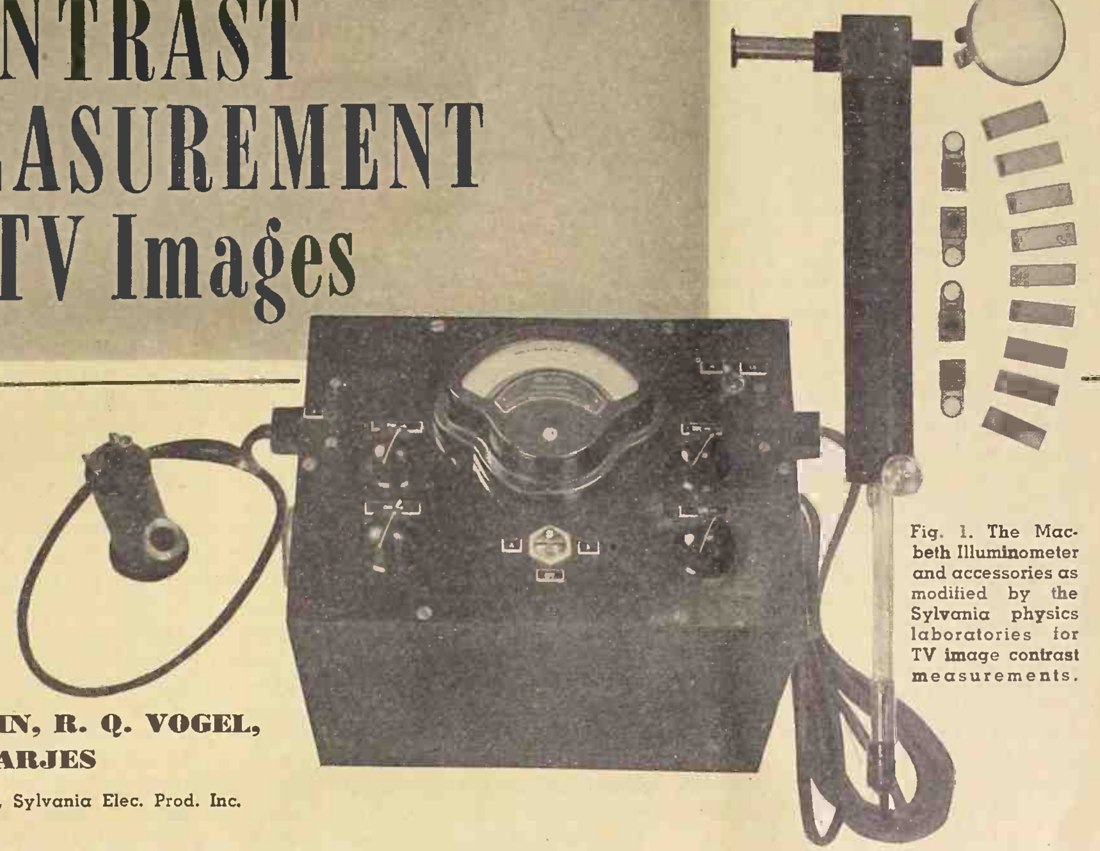


Fig. 1. The Macbeth Illuminometer and accessories as modified by the Sylvania physics laboratories for TV image contrast measurements.

A. E. MARTIN, R. Q. VOGEL, and F. W. HARJES

Physics Laboratories, Sylvania Elec. Prod. Inc.

A modified Macbeth Illuminometer can be used to measure large area contrast in TV images.

CONTRAST in television images is a characteristic which is gradually receiving more attention as a part of engineering specifications for television picture tubes. It is a quantity which is affected not only by the electrical parameters of receiver operation and by ambient lighting, but also by many recent efforts directed specifically toward improving its value. Examples of the latter are: viewing filters (colored, gray, and polarizing), neutral filter face plate glass, and anti-reflection processing of face plates. At the 1950 IRE National Convention it was pointed out by one of the present authors that, "the television industry . . . . . has not yet established specifications for either the amount of contrast which should exist in a television image or for means of measuring it." More recently the Joint Electron Tube Engineering Council Subcommittee, 6.3, on Cathode Ray Tube Phosphor and Screen Characteristics has undertaken a study of methods of measuring large area (range) contrast.

In the *Sylvania* physics laboratories systematic studies of contrast have been made for the past two years. The present paper is a report in part on this work. In attempting to examine a variety of approaches to the measurement of large area contrast from the viewpoint of the optical physicist, it aims to weigh the advantages and disadvantages of each.

Large area (or range) contrast may be defined as the brightness ratio existing between the lightest white and the darkest black areas in a television image. Zworykin and Morton have pointed out that a complete determination of contrast requires in addition a value for small area (or detail) contrast. At the present time the authors know of no proven method for measuring this latter, although several have been suggested. Therefore the present discussion will be concerned solely with large area contrast. The experimental methods to be considered may be classified as being visual, photoelectric, or photographic in character. They will be discussed in that order in what follows. Their evaluation will be based on three criteria:

(a) accuracy;
(b) simplicity; and
(c) adaptability to production or laboratory use.

Visual photometers are not generally known for high accuracy, and in many ways television only exaggerates their defects. Pending the development and construction of a good photoelectric photometer with small angle of view and sufficient sensitivity for operation at a considerable distance from the dark portions of a cathode-ray tube, the Macbeth Illuminometer has been extensively used in the *Sylvania* physics laboratories for the measurement of contrast in television images. This instrument is primarily adapted for use on incandescent sources. It therefore has certain inadequacies when used on television rasters. If these are not properly accounted for, serious errors in measured results occur. Only after the Macbeth was modified to overcome some of these inadequacies were satisfactory results obtained. It is the purpose of the authors to outline these modifications as a guide to others using such an instrument.

The Macbeth Illuminometer as shown schematically in Fig. 2 is manufactured by the *Leeds and Northrup Company.* It is a portable photometer utilizing a Lummer-Brodhun cube and featuring a totally enclosed working standard lamp movable with respect to the cube by means of a rack and pinion coupled with an inverse square scale of brightness. A visual photometric match with the unknown source is achieved by positioning this lamp. The range of the instrument can be greatly extended in either direction by means of neutral density filters which can be mounted in front of either the test source or the standard lamp. The illuminometer is

	Observer 1	Observer 2	Observer 3	Mean
RASTER				
a) no color filter	19.8	26.8	25.0	23.9
b) yellow filter	21.4	25.5	24.8	23.9
c) blue filter	24.3	25.0	23.9	24.4
BACKGROUND				
a) no color filter	.342	.359	.334	.345
c) blue filter	.244	.255	.256	.252
b) yellow filter	.333	.332	.360	.342

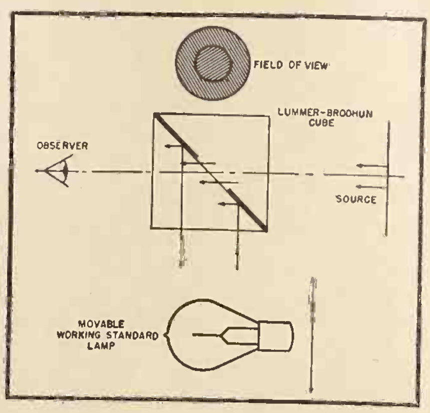
Table 1. Brightness in foot-lamberts with a screen brightness of 24 foot-lamberts.

periodically calibrated by the operator by comparison with the brightness produced by a certified reference standard lamp operating under fixed conditions. Such a standard is supplied with the instrument. The equipment as furnished by *Leeds and Northrup* is shown in Fig. 3. The usual calibration procedure is to make the instrument direct reading by presetting the scale to the value of the reference standard brightness and obtaining the visual photometric balance by adjustment of the current through the working standard. This current is then maintained for all readings on the unknown source.

The color of the working standard, of course, varies with the lamp current. The eye is influenced by this and will therefore select a balance point which is a compromise between a brightness match and a color match with the reference standard. This varies with the individual and the particular lamps, and can introduce an error of a few per-cent.

At a sacrifice of the direct-reading feature of the illuminometer, this error has been eliminated by operation of the working standard lamp at a fixed color temperature equal to that of the reference standard (2360° K) and obtaining a brightness match solely by positioning the working standard. To obtain brightness, readings must then be multiplied by the ratio of the certified calibrating brightness to the original balance reading. In contrast determination, however, the ratio of light and dark readings would be unaffected by omission of this step.

Fig. 2. Schematic representation of the Macbeth Illuminometer.



After the illuminometer has been standardized, the television raster is viewed. It becomes immediately apparent that no accurate brightness match is possible because of the large color difference between the raster at color temperatures of approximately 5000°K to 9000°K and the working standard lamp at 2360°K color temperature. These manifest themselves as separate blue and orange areas in the visual field of the instrument. Under these conditions each observer's readings cover a considerable range, and there are large differences among observers. Especially under incandescent ambient light conditions, there is the further complication that the dark portion of the tube is still another color, yielding a different error in reading. This rules out the hopeful assumption that the contrast (*i.e.*, the brightness ratio) would be unaffected by poor color matches.

An amber filter (probably a Wratten No. 86) is obtainable with the Macbeth Illuminometer. It is intended to be placed in front of a daylight test source. An acceptable color match is possible once the blue component of the daylight is filtered out. This filter, when used in cathode-ray tube photometry, causes additional errors. Its visual transmission is about 3 to 7 per-cent less for standard P-4 phosphor radiation within the proposed color limits of the Joint Electron Tube Engineering Council than for the standard radiation for which the filter is calibrated. The exact difference depends on the spectral distribution of the particular tube. Since in general the light and dark portions of the tube have different spectral distributions also, cancellation of errors again could not be relied upon to improve contrast determinations.

Accuracy cannot be achieved with certainty unless the visual transmission of the filter for the particular incident radiation is known. To do so entails knowing both the filter transmission and relative energy in each source for every wavelength in the visible spectrum. This is an impractical task when the filter is used before different tubes.

This problem has been solved at *Sylvania* by the use of blue photometric filters (Wratten Series 78) between the Lummer-Brodhun cube and the working standard lamp to achieve a good color match by reducing the red in this incandescent source. The five individual filters in this series were cemented between glass cut to fit the Macbeth neutral density filter holders. The color temperature of the working standard as used is the same as that of the reference standard (2360°K), so its relative spectral distribution can be obtained from tables of Planck's Law. This, together with the spectral transmissions of the filters, obtained spectrophotometrically, enables calculation of the integrated visual transmission of each filter for this radiation. The filters appear very stable after two years. Their use enables the attainment of a close color match while the absorption of the filters is accurately known.

Unfortunately, the visual transmission of blue filters to incandescent light is so low that for adequate illumination in the photometric field a brighter working standard had to be substituted in the illuminometer. The higher current and voltage needed by this lamp necessitated the construction of a new controller, patterned after the original but with a higher range meter and more rugged resistors. The Macbeth Illuminometer as modified by the *Sylvania* physics laboratories is shown in Fig. 1.

The use of the modified Macbeth Illuminometer for brightness measurements is then as follows:

(a) In standardizing, the working standard lamp current that gives an exact color match with the reference standard is determined once and for all, and the lamp is always run at this current. The standardizing balance point is then periodically and easily checked by racking the working standard lamp with respect to the tube.

(b) A color match is next achieved with the television raster by insertion of the appropriate Wratten Series 78 filter in front of the working standard. The balance is determined as usual, using a neutral density filter to extend the range if needed.

(c) The brightness of the image is calculated by the relationship

$$B = r \times \frac{S}{r_s} \times \frac{t}{\tau} \quad \text{.............. (1)}$$

where r = balance point for the television raster;

r_s = standardizing balance point;

S = standardization brightness;

τ = transmission of any filter used in front of the television raster. Since only neutral density filters are used in this position, knowledge of the spectral energy distribution of the raster is unnecessary.

t = integrated visual transmission of any filter used between the cube and working standard. It is predetermined independently for each filter as described.

If the brightness ratio (contrast) only is desired, preliminary standardization is unnecessary since the contrasts drop out, leaving:

$$\text{Contrast} = \frac{r_1}{r_2} \times \frac{\tau_2}{\tau_1} \times \frac{t_1}{t_2} \quad (2)$$

where the subscripts 1 and 2 refer to the light and dark portions of the tube, respectively. τ_2 is usually $= 1$ and t_1 sometimes equals t_2, resulting in greater simplification.

Actual use tests of the modified Macbeth Illuminometer showed very good performance. A screen brightness of 24 foot lamberts was set up on a standard television tube. This brightness was determined by a *Weston* Model 756 Television Tube Brightness Meter whose calibration had been independently verified. Three trained observers were used. With the Macbeth, each repeatedly photometered the bright and dark portions of the tube face both with and without ambient illumination. The Macbeth was used in its usual and modified versions for these tests:

(a) Without color correction filters;
(b) With the Macbeth yellow "daylight" filter when it improved the color match; and
(c) With a Wratten Series 78 blue photometric filter, when the use of one of them improved the color match.

The reproducibility of readings was significantly increased as the color match improved. For each of the above conditions, the coefficient of variation, which is the standard deviation expressed as a percentage of the mean value, was computed for each observer. With no color correction filters this coefficient averaged 5.8% for the three observers. In the cases when the color match was improved by the use of the Macbeth yellow "daylight" filter the coefficient of variation was lowered to an average of 3.2%. Achieving good color matches with filters from the Wratten No. 78 blue photometric series further lowered this coefficient to an average of 2.2% for the three observers. It is thus apparent that better color matches yield much more reproducible readings.

More important is the fact that the correct highlight brightness, as determined by the *Weston* meter, was obtained by all three observers only when they made use of the blue filters to obtain good color matches. The same background brightness and contrast determinations by all observers were likewise obtained only under these conditions.

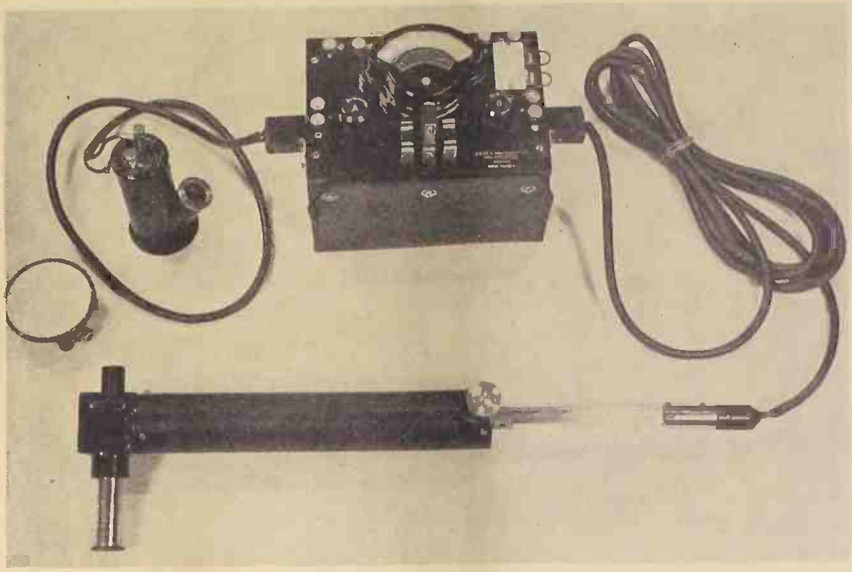


Fig. 3. The Macbeth Illuminometer as furnished by Leeds and Northrup.

Tables 1 and 2 show the results for the condition of no ambient light on the tube.

The readings taken under incandescent ambient light conditions show a similar but smaller effect, because of the better color matches obtained when the bluish raster light was diluted with the reddish incandescent light.

This data clearly shows that consistent and accurate brightness and contrast determinations on television images cannot be made using the Macbeth Illuminometer without first eliminating some of the large errors due to physiological and psychological differences among observers. It is the major aim of this paper to show how this has been accomplished in the *Sylvania* physics laboratories. Results are still somewhat dependent on the individual observer's eye characteristics, although to a much smaller extent than previously. This follows from the fact that only a visual color match and not a spectral energy distribution match is achieved by the filters. Readings show a much smaller range than previously, and variations among observers have been materially reduced by elimination of the personal judgment needed for a brightness match of two different colors. The additional effort required by this method is largely in preliminary calibrations, and is subsequently repaid manyfold in increased accuracy, lower eye fatigue, and quicker balances once these have been accomplished.

One device for eliminating color differences in heterochromatic photometry is the flicker photometer. As distinguished from steady comparison methods, the flicker photometer does not depend on a brightness match between two adjacent fields. Instead, the test and comparison fields are viewed alternately and in rapid succession. The visual processes are such that, above a given frequency, any color difference between two sources being compared will disappear. Then, by use of the inverse square law for illumination from a point source, a brightness match may be obtained. When this occurs the flicker in the viewing field will also disappear.

Although flicker photometry seems to offer certain advantages where color differences exist, it has remained a research technique. There are several reasons for this condition. First, the equipment needed is generally more complex than that for direct comparison and, since it is usually possible to obtain a color match with appropriate filters, direct comparison methods have been used most often. Second, the observations in flicker photometry are extremely tiring, hence this method is not adaptable to routine measurements. Finally, if good agreement between dif-

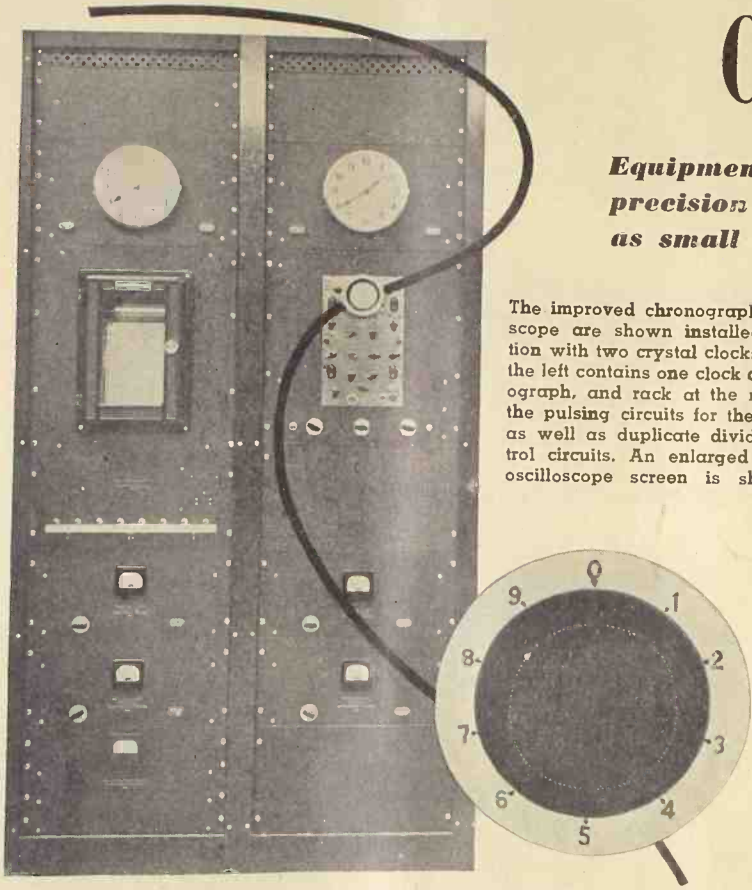
(*Continued on page* 27)

Table 2. Contrast determinations as recorded by different observers.

	Observer 1	Observer 2	Observer 3	Mean
a) no color filter	57.9	75.0	75.0	69.3
b) yellow filter	64.3	76.8	68.9	70.0
c) blue filter	99.5	98.0	93.5	97.0

SPARK CHRONOGRAPH and CHRONOSCOPE

Equipment developed at NBS for monitoring precision clocks will record time differences as small as twenty millionths of a second.



The improved chronograph and chronoscope are shown installed in conjunction with two crystal clocks. The rack at the left contains one clock and the chronograph, and rack at the right contains the pulsing circuits for the chronoscope as well as duplicate dividing and control circuits. An enlarged view of the oscilloscope screen is shown below.

THE National Bureau of Standards' system for monitoring the precision timekeeping of a group of standard crystal clocks has been further refined by J. M. Shaull and C. M. Kortman of the Bureau staff. This refinement consists of an improved spark chronograph and chronoscope which together record time differences as small as 20 millionths of a second. The new development may be easily applied to checking stability of oscillators and frequency dividers and rating clocks and chronometers over long periods of time. The method is now being applied, in principle, by watchmakers for the rapid adjustment of watches and clocks.

The spark chronograph records time differences of two clocks to one millisecond by linearly sweeping a spark discharge point across the waxed paper strip of a specially designed recorder. The chronoscope uses the visual characteristics of the cathode-ray tube to increase the resolution of the chronograph to 0.02 milliseconds. Together these instruments constitute a reference clock with which all other crystal clocks comprising the primary standard, including those of the NBS radio station, WWV, may be intercompared.

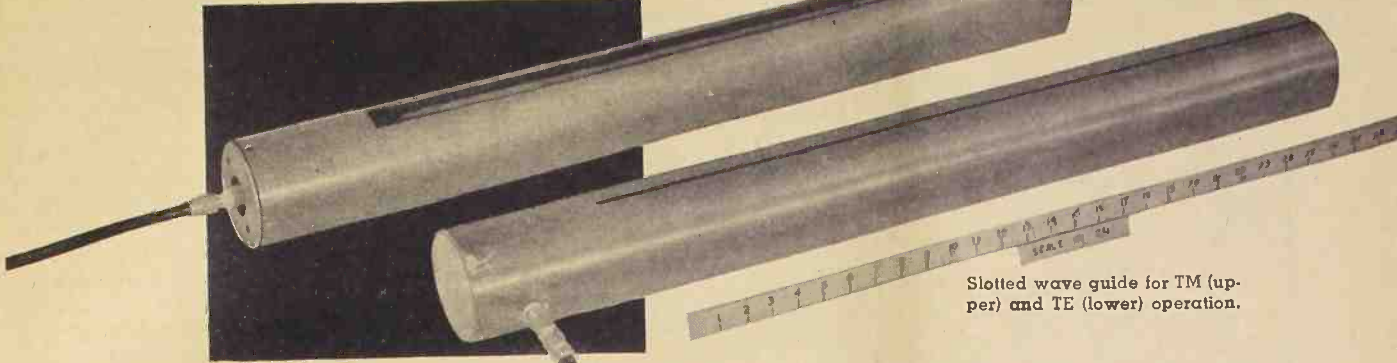
The improved spark chronograph includes a single-turn helix wound on a rotating drum driven by a synchronous motor. Beneath the drum is an insulated knife edge over which a strip of waxed paper slowly passes. A high-voltage pulse causes a spark to jump from the knife edge to the nearest point of the helix, perforating the paper, melting the wax, and thus leaving a permanent record. Should the motor driving the drum be supplied by subfrequencies from a standard oscillator while the high-voltage pulse is controlled by another crystal clock, a recorded picture of the relative rates is readily obtained. If the drum-control frequency is equal to the spark-control frequency, each time a spark occurs the rotating drum turns through an angle which is an exact multiple of 360°. Thus the same point on the helix will be opposite the knife edge, and the record on the waxed paper will be a straight line running vertically up the chart. However, should there be a difference in frequencies, the drum will rotate through a greater or smaller angle, causing a different point on the helix to be nearest the knife edge at the time of the spark. As a result, the record will slope to the right if the clock controlling the spark is running faster, or to the left if the clock is running slower. The difference in rates may be evaluated by measuring the amount of displacement over a given period. If the spark generating equipment is switched, in turn, to each of several clocks, the chronograph provides a convenient method of intercomparing and recording their operation. In practice, a motor-driven switching unit connects each clock to the spark generator every 15 minutes. In addition, push-buttons permit manual checking of a particular clock at any time.

The rotating drum is made of stainless steel; a helical groove is cut into its surface, and a steel spline is soldered into this groove. The synchronous motor drives the drum at a rate of ten revolutions per second causing the helix to cover a time interval of 0.1 second per sweep. The length of the drum is five inches, and the paper is of the same width; thus 0.001 second is represented by 0.05 inch across the paper chart. The chart is ruled with 10 lines per inch, and values are easily interpolated to the nearest millisecond.

Because the drum rotates at ten revolutions per second, some method is needed to indicate in which tenth of a second the helix is turning. For this purpose, a smaller drum is mounted above the major one and is geared down to rotate at a speed one-tenth as great, and passes over another knife edge which is divided into ten parts. A switch is provided so that the high-voltage pulses can be applied to the smaller drum and the tenths position noted visually.

A pulse-shaping circuit provides the desired pulse for spark generation with different types of input signals. Tests with sine-wave input have shown that the circuit will operate between 10 and 400 cycles when less than ten volts r.m.s. is applied, and over a much wider range with greater amplitude.

(Continued on page 26)



Slotted wave guide for TM (upper) and TE (lower) operation.

By D. R. RHODES

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SLOT ANTENNA DEVELOPMENTS

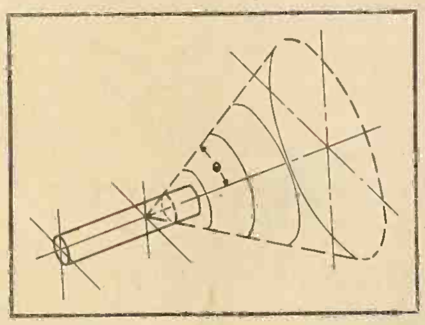
Part 2 discusses slotted wave guides, radiation patterns, side lobe control, and slot arrays.

THE PRESENT day emphasis on slot antennas is the result of a progressive trend toward development of antennas for operation in the microwave region which can be mounted flush with a conducting surface and which, at the same time, possess certain prescribed radiation characteristics required for the many diverse applications. In addition to the primary requirement that the antenna be flush mounted, another important requirement is that the radiation pattern of the antenna should not change radically with a change of operating frequency. Although a specified radiation pattern can be obtained by the practical method of arraying resonant half wavelength slot radiators properly located in the walls of ordinary wave guides,[1] arrays of this type are quite sensitive to changes in frequency. For a co-linear array of resonant slots in the broad face of a wave guide, which at present is the only practical type of wave guide fed resonant slot array for producing an arbitrary pattern, the relative amplitude in each slot is a function of displacement of the slot from the wave guide axis, and the relative phase is a function of the phase velocity in the wave guide, both being undesirable functions of frequency. On the other hand it has been found that a wave guide in which a single long, continuous slot is cut parallel to the wave guide axis is a very simple and effective microwave antenna, and furthermore is more flexible in its radiation properties than discrete arrays of resonant slots. Although the directivity of a slotted wave guide antenna is also frequency sensitive, the change in the radiation pattern can be determined from rather simple considerations.

Analog of Long Wire

Perhaps the simplest form of traveling wave slot antenna is the slot analog of the ordinary traveling wave wire antenna. A single, straight wire several wavelengths long when fed at one end and terminated in a matched load at the other end has a single traveling wave of current propagating from the feed end toward the load. The three dimensional radiation pattern of such a long wire is well-known to be a pattern of revolution consisting of a main lobe in the forward direction together with a number of side lobes, where the beam angle of the main lobe with respect to the direction of current flow decreases with increasing wire length. When the load is removed from the end fed wire a reflected current wave is set up on the wire, resulting in a superposition of the original pattern with a similar pattern in the backward direction. Loss of power due to radiation causes an exponential attenuation of current along the wire, and hence a reduction in the amplitude of the backward radiation pattern. These properties apply equally well to a slot several wavelengths long cut in a large conducting plane and fed near one end of the slot, usually a quarter wavelength from the end, when radiation from the slot is confined to one side of the plane.

Fig. 1. Each mode in a slotted wave guide radiates maximum power in a cone of constant angle θ about the wave guide axis.



Slotted Wave Guides

The axially slotted wave guide is a more useful form of traveling wave slot antenna for most practical applications because of its compactness and wide range of pattern control. Structurally it is the very essence of simplicity, consisting of an ordinary hollow metallic wave guide, closed at the ends, with a slot milled parallel to the axis as in Fig. 2A and fed near one end in the manner of one of the usual *TE* or *TM* wave guide modes. The usual fields in a wave guide are disturbed when a slot is cut, so that the fields deviate somewhat from the ordinary wave guide modes. It is this disturbance, in fact, that is responsible for the radiating currents flowing on the walls of the wave guide; as the slot width decreases to zero, the radiating currents vanish and the antenna reduces to an ordinary wave guide. To insure the existence of a single wave guide mode it is customary to choose the wave guide cross-section and method of excitation in such a way that only the principal *TE* or *TM* mode can exist. The principal modes, *i.e.*, the modes having the lowest cut-off wavelength

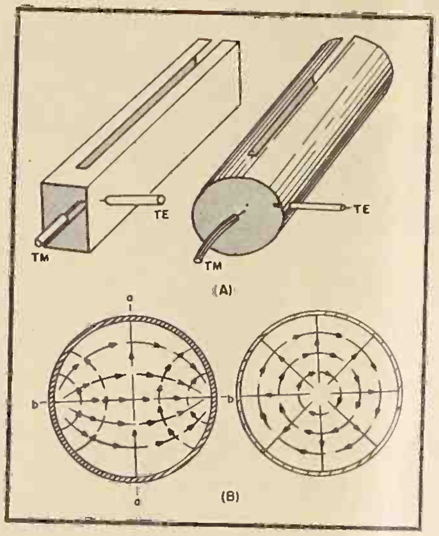


Fig. 2. (A) Traveling wave slots milled parallel to the axis of rectangular and circular wave guides. Location of exciting probes for TM and TE modes are shown. (B) Electric (solid) and magnetic (dotted) fields in a plane cross-section of a circular wave guide for the (a) TE_{11} and (b) TM_{01} modes.

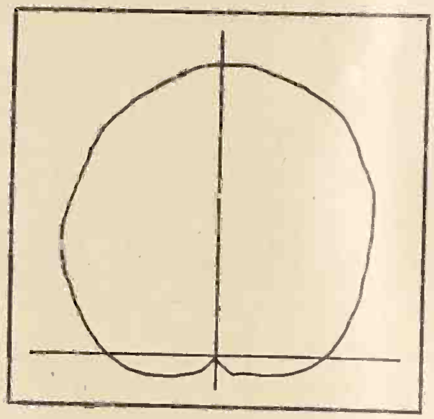


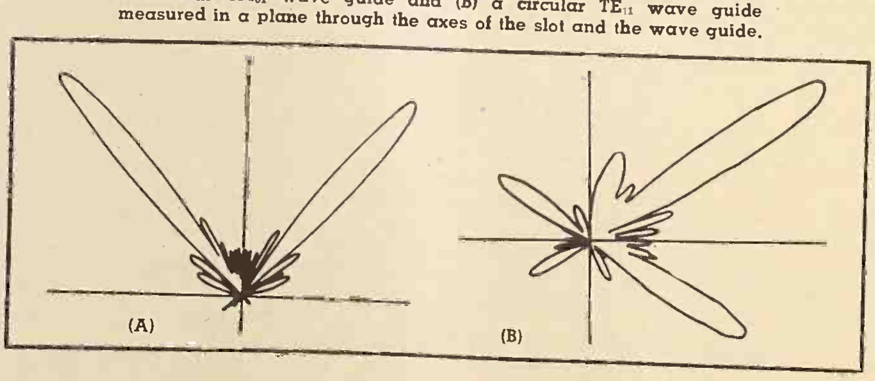
Fig. 3. Radiation pattern of a single traveling wave slot in a circular TM_{01} wave guide measured in the cone of maximum radiation about the wave guide axis.

for a given cross-section, are the TE_{01} and TM_{11} modes in rectangular wave guides, and the TE_{11} and TM_{01} modes in circular wave guides. The field distribution of the principal modes in a plane perpendicular to the axis of a circular wave guide are shown in Fig. 2B; the general characteristics of the modes shown are also present in the corresponding rectangular wave guide modes. Both of these modes can be excited by means of a stub extending radially in the wave guide; this is the usual method of exciting the TE_{11} mode, but in the case of the TM_{01} mode it is best to excite the guide by means of a stub directed along the cylinder axis to insure the unique existence of that mode in the wave guide. With the stub extending radially in the guide, TE_{11} mode adjusts itself in such a way that the stub is located at point a with respect to the field configuration. For the configuration shown, the slot should be cut at point b in order to preserve the mode. Because of complete symmetry of the TM_{01} mode set up by an axial stub, there is no preferred position at which the slot should be located.

Radiation from an axially slotted wave guide is polarized according to the type of mode set up in the guide. Transverse electric modes always radiate energy polarized at right angles to the axis of the wave guide, while transverse magnetic modes always radiate energy polarized parallel to the axis of the wave guide.

When a slot in a wave guide is narrow, the fields in the wave guide are very close to being the actual wave guide modes; as the slot width increases, the fields deviate more and more from the wave guide modes. The width of the slot controls the rate at which power leaks from the wave guide and is radiated into space, which in turn determines the rate of attenuation of power propagating along the wave guide. When the total attenuation over the length of the aperture is made sufficiently great, the power reflected from the closed ends becomes insignificant. This constitutes a uniformly distributed load on the wave traveling down the aperture, with the result that the side lobe level is lower and the efficiency is greater than for a traveling wave radiator whose load is concentrated at one end.

Fig. 4. Radiation patterns of a single traveling wave slot in (A) a circular TM_{01} wave guide and (B) a circular TE_{11} wave guide measured in a plane through the axes of the slot and the wave guide.



An essential difference in principle exists between the mechanism of operation of an end fed wire, or the equivalent slot in a conducting plane, and a continuously slotted wave guide. The wave traveling along an end fed wire propagates at a velocity near that of light, hence the angle (with respect to the wire) of the main beam is completely dependent on the length of the wire. The wave traveling along a continuously slotted wave guide, however, propagates at a velocity determined by the wave guide cross-section, and by proper choice of cross-section any desired phase velocity above the velocity of light can be easily attained independently of the length of the slot aperture. By increasing the slot length and decreasing the slot width, the radiation directivity can be increased to any desired value without effectively changing the angular direction of the beam. No independent control of directivity is possible for the end fed wire.

The energy radiated by a continuously slotted wave guide several wavelengths long lies in a sharp cone about the wave guide axis, accompanied by smaller conical side lobes. If the amplitude reduces to a small value at the far end, *i.e.*, if nearly all the power is radiated when the wave leaving the feed end passes over the total length of the aperture, then the field in the slot aperture is a simple exponentially attenuated traveling wave. Radiation from a wave traveling with a uniform velocity in a slotted wave guide is concentrated in a right circular cone in the forward direction of the wave, as shown in Fig. 1. The angle between the axis of the wave guide and elements of the cone is related to the velocity of the wave traveling along the aperture by:[2]

$$\cos \theta = c/v \quad \ldots\ldots \quad (1)$$

where v is the velocity of the wave in the aperture, which is just the phase velocity of the mode in the wave guide, and c is the familiar velocity of light in free space, numerically equal to 3×10^8 meters per second. This simple relationship for the angle at which maximum power is radiated from a continuously slotted wave guide is a well-known expression for determining the angle of maximum constructive interference from any uniform traveling wave, whether it is a sound wave in a perforated tube, an electromagnetic wave in a dielectric rod, a wave of electric current on a wire, or a wave in a slotted wave guide. Although the expression is exact only when the attenuation of the wave, due to radiation or other losses, is zero, the expression is a very close approximation for most practical cases in which the attenuation is small. Only when the slot aperture is quite wide, or when several parallel slots are cut in a wave guide, does the observed angle differ appreciably from that predicted by Eqt. (1).

The ratio of the velocity of light in free space to the phase velocity of a given mode in a wave guide is related to the cut-off wavelength of that mode by:

$$\frac{c}{v} = \sqrt{1 - \left(\frac{\lambda}{\lambda_c}\right)^2} \quad . \quad . \quad . \quad (2)$$

where λ_c is the cut-off wavelength for the particular mode in the guide. From Eqts. (1) and (2) it is seen that the conical angle of maximum radiation is given for any particular mode by:

$$\sin \theta = \lambda/\lambda_c \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Equation (3) is a general relation for a wave guide of any arbitrary cross-section. For the two simplest cross-sections, namely rectangular and circular, the cut-off wavelengths are given by the following.[3] For the TE_{mn} or TM_{mn} mode in a rectangular wave guide:

$$\lambda_c = \frac{2\,a\,b}{\sqrt{(mb)^2 + (na)^2}} \quad . \quad . \quad (4)$$

where a and b are the wave guide cross-sectional dimensions, and for the TE_{mn} or TM_{mn} mode in a circular wave guide:

$$\lambda_c = \frac{2\,\pi\,r}{p_{mn}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

where r is the radius of the guide, and p_{mn} is the n^{th} root of the m^{th} order Bessel function for the TM_{mn} mode, or the n^{th} root of the first derivative of the m^{th} order Bessel function for the TE_{mn} mode. For the principal TE and TM modes in rectangular wave guides, namely TE_{01} and TM_{11}, the cut-off wavelengths reduce to $2a$ and $2ab/\sqrt{a^2 + b^2}$, respectively; in a circular wave guide, the cut-off wavelengths for the TE_{11} and TM_{01} modes reduce to $3.41r$ and $2.61r$, respectively.

For every TE mode in a rectangular wave guide there corresponds a TM mode having the same cut-off wavelength, and hence the two modes will have maximum radiation at the same conical angle. On the other hand the cut-off wavelengths of all circular wave guide modes are separate and distinct, with the exception of the TE_{0m} and TM_{1m} modes. This is of some importance, for example, when designing an antenna that must be linearly polarized in a particular cone.

Radiation Patterns

To illustrate some of the observed characteristics of radiation from a slotted wave guide, the pattern of a slotted cylindrical wave guide excited by the TM_{01} mode is indicated in Figs. 3 and 4A. The cylinder chosen had an inside diameter of 1½ inches, or one wavelength at the measuring wavelength of 3.82 cm., and contained a slot 30 cm. long by 1.27 cm. (0.33 wavelengths) wide. The pattern in Fig. 4A was measured in a plane containing the axes of the cylinder and the slot, while the pattern in Fig. 3 was measured by moving a probe in a cone of maximum radiation (constant θ) about the cylinder axis. The conical angle of maximum radiation is about 49.9°, which compares favorably with a calculated value of 50.1°. A backward lobe of slightly less intensity than the lobe in the forward direction of current flow is seen to exist. Its presence is due to the fact that a large proportion of the power transmitted along the wave guide is reflected back from the short circuited end because of relatively small radiation losses. Comparatively little power is radiated from any slot of width less than half a wavelength when excited by the TM_{01} circular mode. By widening the slot it is possible to reduce the backward radiation, but at the expense of increasing the beam width. The backward radiation could be reduced without an increase in beam width by placing a resistance load at the far end; however, the antenna would be relatively inefficient, since the power radiated from the waves set up by multiple reflections from the two closed ends would then be dissipated in the load.

An interesting property of the conical pattern of a cylinder containing a given array of axial slots is the fact that the pattern is an inherent characteristic of the wave guide mode, *i.e.*, that the pattern is fixed for any particular mode and array of slots, and is completely independent of the frequency or the cylinder diameter. This was first shown theoretically[4] for infinitely long conducting cylinders and has since been shown to be a good approximation experimentally.

When a second slot is cut diametrically opposite to the original slot in the cylindrical wave guide excited by the TM_{01} mode, the pattern becomes that shown in Figs. 5A and 8. The cylinder and slots have the same dimensions as were used to measure the patterns in Figs. 3 and 4A, although the

(*Continued on page* 29)

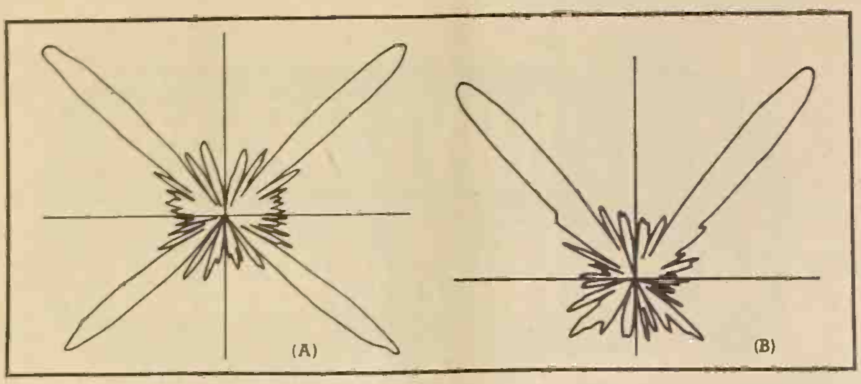
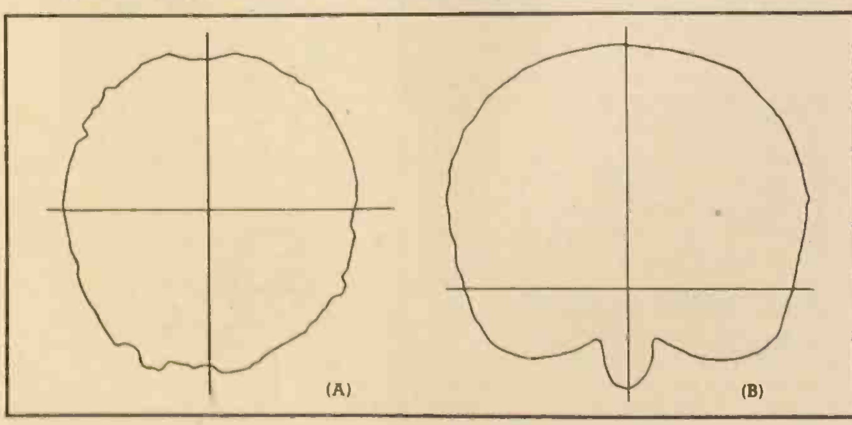


Fig. 5. (A) Radiation pattern of two diametrically opposed traveling wave slots in a circular TM_{01} wave guide measured in a plane through the axes of the slot and the guide. (B) Pattern of eight traveling wave slots in a circular TM_{01} wave guide constructed of eight parallel wires measured in a plane through the wave guide axis.

Fig. 7. (A) Radiation pattern of eight traveling wave slots in a circular TM_{01} wave guide constructed of eight parallel wires, measured in the cone of maximum radiation about the wave guide axis. (B) Pattern of single traveling wave slot in circular TE_{11} guide measured in the cone of maximum radiation about the wave guide axis.



IMPROVEMENTS In Audio Amplifiers

By **ULRIC J. CHILDS,**
Audio Engineer, and

RICHARD H. DORF,
Audio Consultant

The cross-coupled phase inverter, driver stage requirements, and inverse feedback are discussed.

AUDIO reproduction has made giant strides in the last few years in the development and commercial production of quality components, especially pickups and loudspeakers. Progress in amplifiers has kept pace in the sense the circuitry capable of full-range, almost distortion-free amplification exists. Many amplifiers used in high-quality systems, however, while good, are not as good as they could be, simply because certain circuit arrangements have not been publicized and used sufficiently.

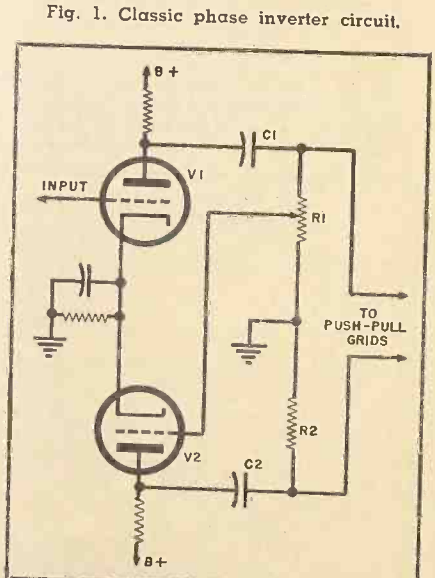
The aim of the conscientious amplifier designer is to be able to say, "What goes in comes out." That is, the least possible distortion and range restriction should be added to the sound by the amplifier. The writers do not believe that trick circuits or peculiar effects have any place in a good amplifier. The job is simply to design a unit which amplifies—and basically does nothing more.

Compensation of two types has a definite place in amplifiers, but only in the early stages. The output of phonograph pickups should be equalized to complement as nearly as possible the characteristic used in recording. And deficiencies of the human ear at lower volume levels makes the use of a loudness control very beneficial.

Further "compensation"—specifically the use of continuously variable tone controls—is not suitable for high-quality reproduction. Obviously the sound from a single speaker system cannot equal the spatial distribution of a full orchestra. Equally obvious is the fact that the acoustic characteristics of the listening room are probably not the same in any case as those in which the recording or broadcast takes place. But tone controls cannot clear up these defects. To take an extreme attitude, the audio engineer who is satisfied with nothing less than perfect reproduction will sell his equipment and become a concert-ticket broker!

Trick circuits are not only unnecessary but harmful. As the art is today, perfectly simple, straightforward methods can be used to obtain distortion-free reproduction at any power level. Trick circuits in amplifiers can be justified only on the same basis as table-model receivers—there is neither space nor money to do better. Circuits that try to squeeze more performance out of a system for less money usually cause trouble. They are likely to operate components at or too near the very limits of their capabilities or they may depend on fairly exact adjustments and calibrations. In either case, they are usually not so reliable as the simpler approaches.

Fig. 1. Classic phase inverter circuit.



Phase-Inversion

One of the most common stumbling blocks in audio amplifiers is the phase inverter. It is safe to say that the only kind of phase inverter which is inherently incapable of unbalance at any frequency is a transformer of high quality with a secondary winding which is tapped in the precise center. Transformers are expensive, however, and they can pick up hum. Consequently they are not commonly used today. The vacuum-tube inverters which substitute for the transformer are all inherently incapable of balance over the entire frequency range, with the exception of the cross-coupled circuit.

The problem of achieving balance at medium frequencies is easily solved by even the classic inverter circuit of Fig. 1. Tube V_1 amplifies the input signal and feeds it to one grid of the push-pull power stage. The grid V_2 is tapped down on the push-pull grid resistor to the point where the voltage applied to it is the same as that applied to the grid of V_2. Then, if the gain and input and output resistances of the two triodes are equal, the plate signals are equal and opposite in sign.

The input and output impedances of a vacuum tube are not entirely resistive, however, but capacitive as well, due in practice to interelectrode capacitances, Miller effect, and stray wiring capacitances. The output circuit of V_1 is of high impedance and the capacitance across it reduces the high-frequency response to some extent. That altered-response output is now put through V_2, which operates under the same conditions—its own output circuit reduces highs still further. Thus the signal reaching the lower grid of the push-pull stage is more deficient in high frequencies than that fed to the upper tube and balance is destroyed in the treble range.

Balance is not inherently good at low frequencies either. The plate output of V_1 passes through only one frequency-discriminating (and phase-shifting) network C_1-R_1. But the signal reaching the lower push-pull tube goes through two—C_1-R_1 and C_2-R_2. The low-frequency signals reaching the two push-pull grids are therefore unequal. At both ends of the range, then, the unbalance creates even-harmonic distortion which the push-pull stages are powerless to cancel.

The so-called self-balancing inverter, in which the grid of V_2 (Fig. 1) is connected to the junction of R_1 and R_2 and a resistor is placed between that point and ground, is even worse. Even at mid-frequencies balance cannot be good, for as balance is approached the correction voltage passing through the grounded resistor diminishes and loses its ability to balance.

The long-tailed or split-load inverter of Fig. 2 is also a bad frequency discriminator at the higher frequencies. At mid-frequencies splitting the load resistance equally between plate and cathode does give good balance. The actual maximum cathode impedance, however, is not determined by the value of the cathode resistor; it remains at a value in the neighborhood of 500 to 800 ohms in any practicable tube and the resistor merely shunts it to lower the impedance. At high frequencies interelectrode and stray capacitances cause a drop in the response of the plate output but because the cathode output is of much lower impedance the stray capacitances have almost no effect on its response. The result again is unbalance.

Each of the other usual phase inverters could be diagrammed here, broken down, and shown to lack balance at one or both ends of the spectrum. But one single cause can in all cases be traced as the cause of the frequency-balance relationship—the asymmetry of the circuit as far as the complex input and output impedances are concerned.

This gives all the information necessary to plan an approach to the problem of eliminating unbalance. That approach, illustrated in basic form, appears in Fig. 3. The first requirement is a generator of low (preferably zero) impedance. Second, the same signal must be fed to both inverter tubes—not a recaptured signal from another point nor a replica of the original signal, but the identical signal. That can easily be done by feeding one tube in the usual manner, between grid and cathode, and inverting similar connections to the other tube. The reason for having a low-impedance generator is to swamp out incidental capacitances. Such capacitances would have little effect on the input to V_2 because a grounded-grid, cathode-fed amplifier has a low-impedance input itself. V_1, however, is being fed in its grid circuit, which is of high impedance. Then the low impedance of the generator reduces the effective input impedance of V_1 until it is approximately equal to that of V_2 and stray losses are negligible (zero if the generator is of zero impedance). If the g_m and output impedance (complex) of both tubes are similar the output signals are balanced perfectly throughout the entire range.

Unfortunately the simplicity of the basic idea of Fig. 3 must be sacrificed in practice, for some means of biasing the tubes is necessary. The bias should be adjustable so that small inherent unbalances in the tubes themselves can be cancelled, and the use of blocking capacitors is undesirable because they produce phase shift at low frequencies. The final solution is the cross-coupled input circuit described by J. N. Van Scoyoc in the November, 1948 issue of RADIO-ELECTRONIC ENGINEERING. It is diagrammed in Fig. 4. Four triodes are necessary, preferably in the form of two duo-triodes because of the better inherent long-term balance of triodes in the same envelope.

A cursory glance at the diagram shows that the circuit is symmetrical, but let us analyze it. A single ended input signal is applied to the grid of V_1-A—across R_1. V_1-A is a cathode follower, so its output appears between its cathode and the grounded arm of R_4.

The cathode of V_2-A is tied to that of V_1-A through R_6, across which there is no audio voltage drop resulting from the output signal of V_1-A. The grid of V_2-A is tied to the cathode of V_1-B, which is at a d.c. potential equal to that of V_1-A. The cathode of V_2-A, however, is more positive than its grid because of the flow of V_2-A plate current through R_6. The net cathode-grid bias of V_2-A, therefore, is equal to the d.c. drop across R_6, since its grid is tied to a point of d.c. potential identical to that at the V_1-A end of R_6. For audio, the grid of V_2-A is effectively grounded, since there is no a.f. drop through R_5 and the lower half of R_4.

The output of V_1-A is also coupled directly to the grid of V_2-B. The d.c. circuit of V_2-B is identical to that of V_2-A because of the circuit's symmetry.

We have thus fulfilled the conditions for a perfectly balanced cathode follower if the characteristics of V_2-A and V_2-B are similar. A low-impedance source (the cathode of V_1-A) is feeding the identical signal to the cathode of V_2-A and the grid of V_2-B. The input impedances of V_2-A and V_2-B are almost entirely controlled by the output impedance of V_1-A, which is in shunt with both, and the grid impedance of V_2-A is held down to the same value by the cathode circuit of V_1-B, which is identical to that of V_1-A. The output impedances of V_2-A and V_2-B are equal simply because they are identical tubes. They are exactly opposite in phase because of the transposition of input

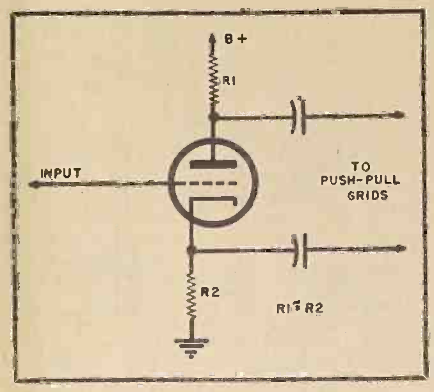


Fig. 2. Split-load phase inverter circuit.

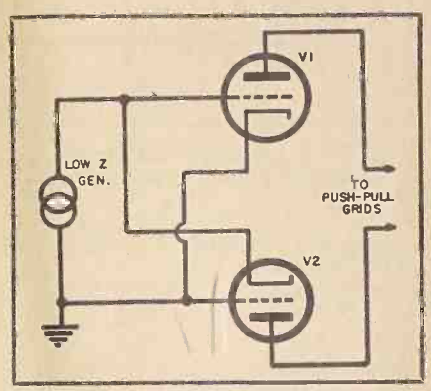
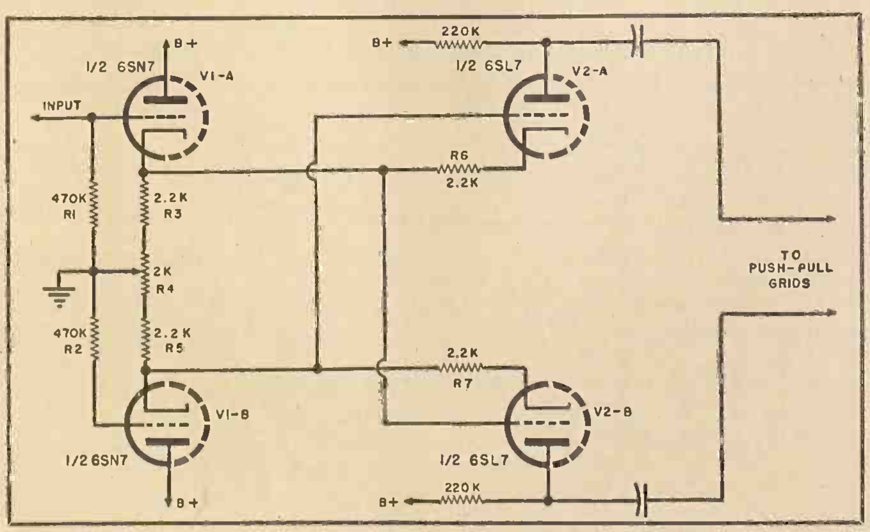


Fig. 3. An approach to the problem of eliminating unbalance in phase inverters.

Fig. 4. Basic circuit of the cross-coupled phase inverter circuit.



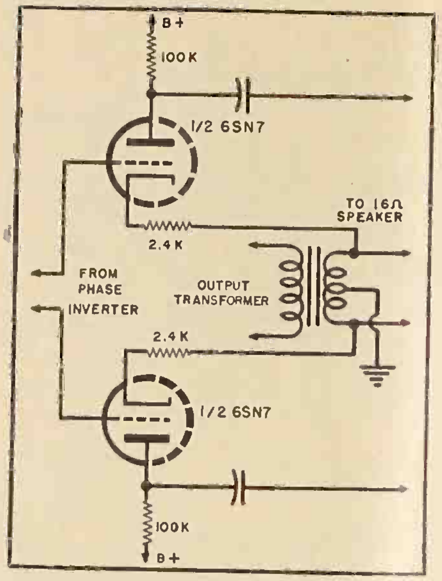


Fig. 5. A very simple and satisfactory method of adding inverse feedback.

signal polarities between grids and cathodes.

Since the gain of the two triodes in the 6SL7-GT envelope may not be quite equal, R_4 is provided to vary the biases applied to the two grids and cathodes. Once the bias is set so that both 6SL7-GT triodes amplify equally, the only remaining cause of unbalance is the difference between the output capacitances of the two triodes. This amounts to a fraction of a micromicrofarad and the result is insignificant up to almost 1 mc.

The input signal for the cross-coupled circuit may be applied to either grid of the 6SN7-GT or a balanced signal may be applied to both. Two separate unbalanced signals may also be applied to the two grids and the circuit used as a two-position mixer by replacing R_1 and R_2 with potentiometers.

A signal will sound the same no matter to which grid it is applied, but the phase of the output signal from the amplifier is reversed if the input is switched from one grid to the other. This fact makes the balance adjustment a very simple one. If a single unbalanced signal is simultaneously applied to both grids (grids connected together) and the circuit is perfectly balanced the signals from the cathodes of V_1-A and V_1-B will cancel. In balancing, then, the V_1-A and V_1-B grids are shorted and fed a signal and R_4 is adjusted for zero amplifier output. Because the two triodes of each tube are in the same envelope, balance in practice has been observed to remain almost perfect for many hundreds of hours of operation.

A simple and effective rebalancing arrangement, however, can be provided by mounting a normally-open pushbutton switch on the chassis. Every so often the button can be pushed and R_4 readjusted for no signal.

The over-all gain of the circuit with the values shown in Fig. 4 is approximately 25. The maximum output voltage before distortion becomes serious is 72 v. (r.m.s.) but it is preferable to operate the stage so that the output does not exceed about 50 volts from plate to plate. This restricts the input to about 2 volts.

Additional Amplification

The 50-volt safe output of the cross-coupled circuit is not high enough to drive a reasonable-power output stage fully and additional amplification is needed, especially if considerable negative feedback is used in the amplifier. A single low-mu triode on each side of the push-pull arrangement is entirely sufficient.

The triode, however, is bound to introduce some frequency discrimination due to Miller effect if it feeds the power stage directly. It is advisable to use two stages, therefore, between the cross-coupled inverter and the power stage. Miller effect is negligible in the inverter because each of the output tubes (the 6SL7-GT triodes) is fed by a low-impedance source.

A somewhat similar solution suggests itself for the amplifier stage. A 6SN7-GT can follow the 6SL7-GT of the inverter, giving a voltage gain of approximately 13 on each push-pull side or about 26 over-all. Such a gain would be far too high normally, for the output capability for push-pull low-mu triodes is only about 30 volts each or 60 volts total. A good amplifier incorporates negative feedback, however, and this should be fed to the inverter stage. As a result, the actual voltage present at the inverter output will be very much lower. As will be shown, feedback may be introduced into the amplifier stage as well.

The amplifier stage is best followed by a balanced cathode-follower stage, as shown in Fig. 6. This cathode follower has two advantages. First, it minimizes the effects of amplifier-stage output capacitances, and second, it presents a low-impedance signal source to the power-stage grids, minimizing Miller effect in it. The cathode follower also is a part of a very effective bias arrangement for the final stage which allows direct coupling to keep down the number of blocking capacitors in the amplifier.

Fixed-Bias Power Stage

The merits of fixed versus cathode bias have been discussed loudly and long and there is little point in continuing the argument. As a matter of principle some designers will continue to use fixed bias and some will never do so. It has certain advantages, however, in itself, and in conjunction with the cathode-follower driver of Fig. 6 it has even more.

The advantage of the cathode follower was described above. In the arrangement of Fig. 6 the cathode return of the tubes is to the C-minus point, a regulated 105 volts in the *Childs* amplifier. This effectively increases the applied plate voltage by 105 volts which adds greatly to the undistorted output capability of the cathode follower. The use of fixed bias also enables the cathode follower to be direct-coupled to the power stage, eliminating one frequency discriminating network composed of a blocking capacitor and grid resistor on each push-pull side.

The grids of the cathode-follower stage are returned to the arm of a potentiometer R_1 connected across the bias supply. Adjustment of R_1 controls the cathode currents of the 6SN7-GT triodes. The cathode current determines the cathode voltage, which, because of the drop through R_2 and R_3, is much less negative with respect to

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Fig. 6. Circuit of a balanced cathode-follower driver stage.

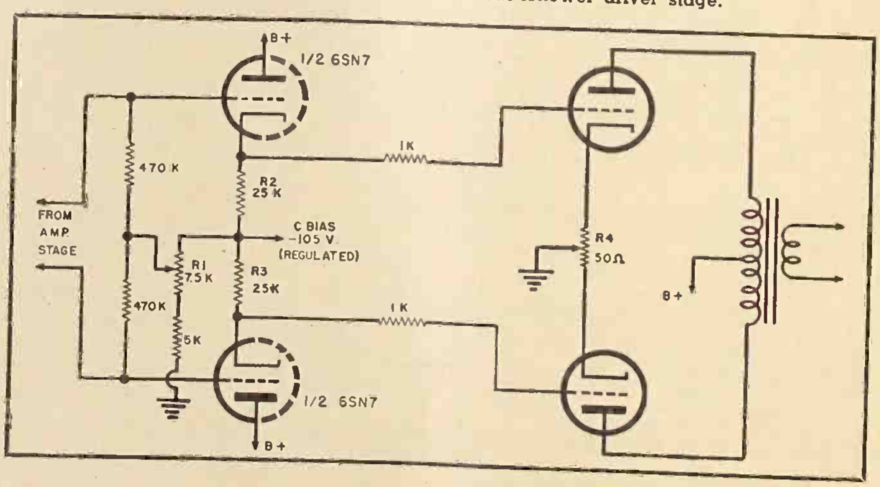


Fig. 1. A panel having stamped circuits on both sides, produced for use in an electronic business machine. Bases for 8 tubes are applied with eyelets.

The STAMPED CIRCUIT PROCESS

By
HERBERT CHASE

Savings in labor costs, greater compactness, and neater assemblies are advantages of this process.

APPLIED electronics can and does accomplish remarkable and frequently somewhat astounding results. Yet the gap between what can be done and what proves feasible from an economic standpoint is often so wide that the accomplishment either remains in the laboratory stage or attains only pilot production at a cost that is prohibitive, save for comparatively few customers. Even when quantity production is attained, costs are often so high that markets are greatly restricted.

Analysis of the reasons for this situation reveals that the number of small parts is excessive and especially that their assembly requires so many relatively slow hand operations that labor charges skyrocket. Makers of small components, including tubes, tube bases, capacitors, inductors, resistors, and the like, have done much to lower costs by applying quantity production methods, but examination of consumer electronic equipment reveals complexities, especially in major assemblies, that must be overcome to bring costs in line with market requirements. This paper will discuss one process that attempts to achieve that end—the stamping process.

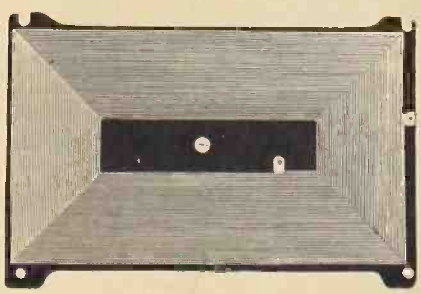
The general idea behind stamped circuits is quite old and, to the production engineer, at least, almost obvious. Until recently, however, desired results have not been forthcoming because certain requirements were overlooked. Further studies and research by the *Franklin Airloop Corp.* have unearthed wide electronic applications for this process.

This is true not only in respect to the product termed "Airloop", of which several million have been manufactured and applied as rear panels for table radios, but to what are called "wired" circuits, though these circuits are not made from wire. Actually, these stamped circuits are blanked from thin sheet metal and, at the same time, are applied to one or both sides of dielectric panels. This is done on a high production basis, sometimes almost completely mechanized, so that labor charges are exceedingly low. Processing involves the following steps:

(1) Coiled strip metal, usually 0.004 to 0.010 in. thick, is roller coated on one side with a thermoplastic adhesive which is dried by infrared radiation before the metal is recoiled.

(2) Dielectric panels, such as Masonite, tag board or laminated phenolic plastic, are blanked in a punch press from sheet or strip stock to desired size and contour.

Fig. 2. Typical Franklin Airloop. Up to 30 turns per inch may be applied.



(3) The coiled metal and the dielectric panels are run between a heated die made to the circuit shape specified and a flat plate in a press. There, the coated side of the metal is pressed against the panel and is heated by the die, adhering to the panel only where pressure is applied. At the same time, the metal is sheared to form a circuit or circuits of the same pattern as the die and is also sheared from the strip, after which the panel is removed from the die. This can be done at the rate of 25 panels a minute in a semiautomatic setup in which the operator merely keeps a magazine filled with panels and watches the press to see that it operates as required.

(4) Panels coming from the press are transferred to a bench where that part of the metal not pressed against the panel (and hence not heated enough to soften the adhesive) is stripped off by hand and becomes scrap. Metal forming the circuit or circuits adheres to the panel because the adhesive, softened by heat and again cooled, causes this metal to stick tightly. Pressure applied by the press is sufficient to force edges of the metal into the panel and there is mechanical as well as adhesive anchorage.

(5) Panels with circuits applied are then pierced in a punch press with such holes as may have to pass through the metal and panel, say for eyelets or pins, and with such other holes as may be needed for tube bases or other components, these then being applied by conventional means.

It is noteworthy that each step in this process is a very rapid one and can be done on a semiautomatic or very rapid basis. Consequently, the labor cost is minimized. Moreover, the basic circuits are completed and no wires have to be applied later except to connect such components as the stamped circuit itself does not include. Attachment of such components as tube bases and switch parts can be done with eyelets

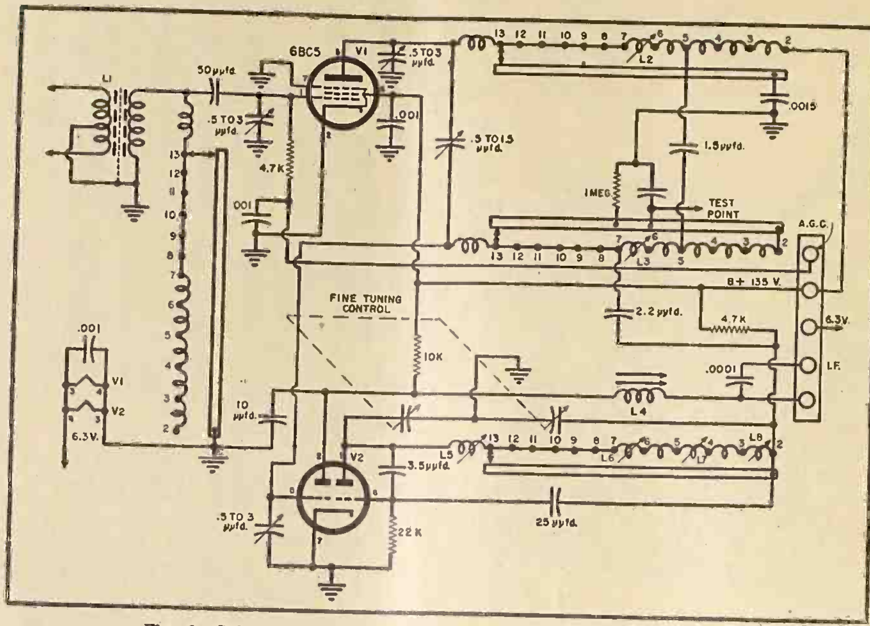


Fig. 3. Schematic of the stamped circuit tuner shown in Fig. 5.

or pins, some of which effect connections to the stamped circuit and others for fastening purposes only.

If circuits are needed on both sides of the panel, step (3) is repeated to apply the circuits for the other side using another die of appropriate design. Eyelets or pins are then usually applied to make connections from circuits on one side of the panel to those on the other side. Because the panel is a dielectric, circuits on one side can cross those on the reverse side but not make electrical contact at the crossovers.

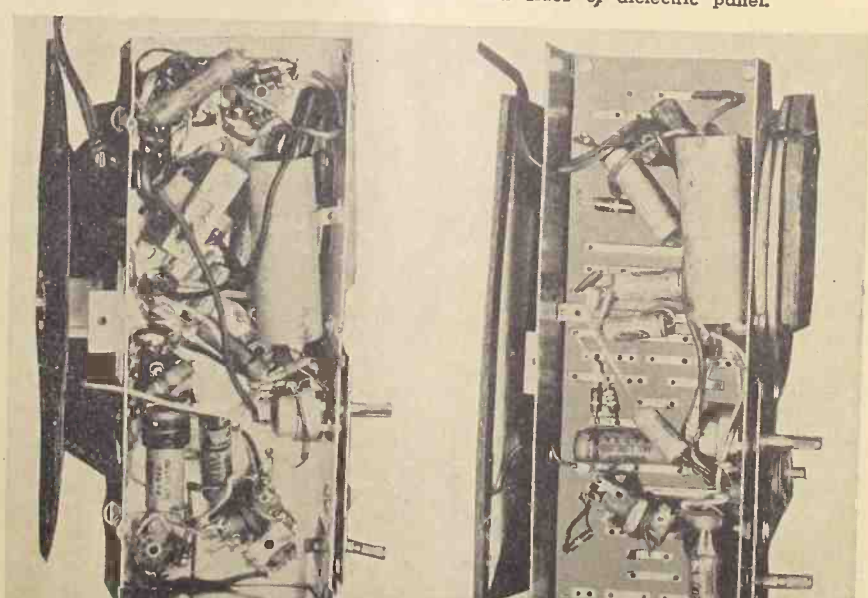
The circuits, as stamped, can include, besides the mere conductors, inductors and, in some cases, even resistors that are applied to the panel and so need not be furnished and applied separately. Stamped inductors are important components of the stamped circuits on panels of the television tuner described later and not only lower its cost but help make it more convenient to adjust if required during installation.

Gridlike stamped resistors have also been produced. If made of good conductors, such as copper, their resistance is low but they can be stamped (separately from other parts of the circuit) from high resistance alloys, if desired. As the stamped resistors and inductors are applied directly to the panel, they take up little space and do not require separate connection by wires.

Every designer of electronic equipment employs neat rectilinear diagrams of the circuits used but when these diagrams are converted into actual circuits the usual result is a complex maze of wires, most of which have to be insulated. Often, complexity is so great that insulation of various colors has to be used to make circuits easier to trace. With stamped circuits, however, the rectilinear diagram is often transferred more or less as such to the actual panel, the "lines" then being stamped strips of conductor fastened to the panel and very easy to follow. This is apparent in Fig. 1.

It should not be concluded, however, that the stamped circuit is a cure-all or that it eliminates all supplementary parts and all hand operations. Commonly it is necessary to attach resistors, capacitors, and large inductors, among other components, but the work of doing this is much reduced and a far neater assembly results as Fig. 4 shows.

Fig. 4. Left, small radio set wired in the conventional manner. Right, same set with circuits stamped on both sides of dielectric panel.



It is possible to solder wires and other connections directly to stamped circuits but, unless an eyelet, pin or equivalent fastening is attached to the joint, the heat applied may loosen the adhesive at this point. For this reason, eyelets or pins are commonly employed where soldering is done and it is often advisable to employ a tinned metal for the circuit. Eyelets or pins may also have to be tinned or plated.

Heating for soldering can be done with an iron, by carbon electrodes or by induction equipment. If circuits and mating components are properly arranged, dip soldering can be done at many points in one operation. Resistance welded joints can also be made if design is such that electrodes can be brought to bear where required.

In the *Franklin* system, the conductors are fixed to dielectric panels and so are not subject to relative motion in assembly or service. This makes it possible to operate tubes nearer the "spill over" or "hot" point and thus to improve performance. Feedback, pickup, parasitic oscillation and other interactions of circuits such as often occur in equipment wired in the ordinary way can be avoided or minimized and kept from varying by correct original design of the stamped circuit. If needed, a grounded lead can be stamped between two other leads and will then act as an electrostatic shield much as the screen of a tube. Hum can thus be reduced by shielding grid leads from filament leads.

At this writing, the largest use of stamped *Franklin* circuits has been in the production of loops, Fig. 2, applied to removable panels of table and portable radios. These loops are, of course, fixed inductances and comprise many turns of conductors applied in oblong spiral arrangements because this makes optimum use of the space available. Masonite panels about 1/8 in. thick have been most used for this purpose but any dielectric having suitable properties can be employed.

Stamped circuits can include radio frequency transformers and coils having two or three windings in parallel. Coupling between stamped spiral inductors on opposite faces of panels can be effected by mounting in the axial plane a compressed powdered metal slug. If adjustably mounted, the slug can alter the adjustment of coupling. Variable tuning can also be done by stamping an inductor on a separate wafer or panel and so mounting the latter that it can be moved relative to the stamped coil with which tuning is desired.

Parallel conductors produced by stamping can be applied to panels of any length that can be accommodated within die and press limits and then can be used for connection to other units. Such panels can serve in place of a bundle of insulated wires. Wherever such groups of conductors take the place of a cable or "harness" or of a wound and laced inductor or "loop", they are much simpler and faster to fabricate and possess all the advantages of other stamped circuits.

Another important application of stamped circuits is found in panels, Fig. 1, for electronic calculating machines. These panels, about 6 x 8 in. in size are 3/32-in. XXP laminated Bakelite and have stamped circuits on both sides, the metal being tinned copper 0.004 in. thick. Each panel has two sets of pierced holes for a total of eight tube bases attached by eyelets, some of which pass through stamped conductors, the tube terminals being soldered to the eyelets.

Such assemblies are not only neat and compact but save a great deal of wiring and hand soldering. Jack sockets on each panel permit ready substitution of a duplicate panel or of one with altered circuits in service and are a great convenience in the field as well as in simplifying initial fabrication. Characteristics of the stamped circuits themselves are fixed for a given design but can be altered as desired by applying inductors, capacitors, resistors, etc. just as for conventionally wired circuits except that the simplicity of the panel (with its eyelets for soldering) facilitate the application of accessory items.

Of particular interest to designers of television equipment is the *Franklin* television tuner, Fig. 5, partly because it includes four small panels or wafers having stamped circuits on both faces. There is one panel each for input, r.f., oscillator and converter. Each wafer includes several stamped inductor coils that are joined by parts of the stamped circuits to the fixed rotary switch elements near the center of each panel. A shaft runs through the four rotary switch elements, as in conventional units, but the stamped circuits save a great amount of hand wiring that would be needed otherwise on both sides of each panel.

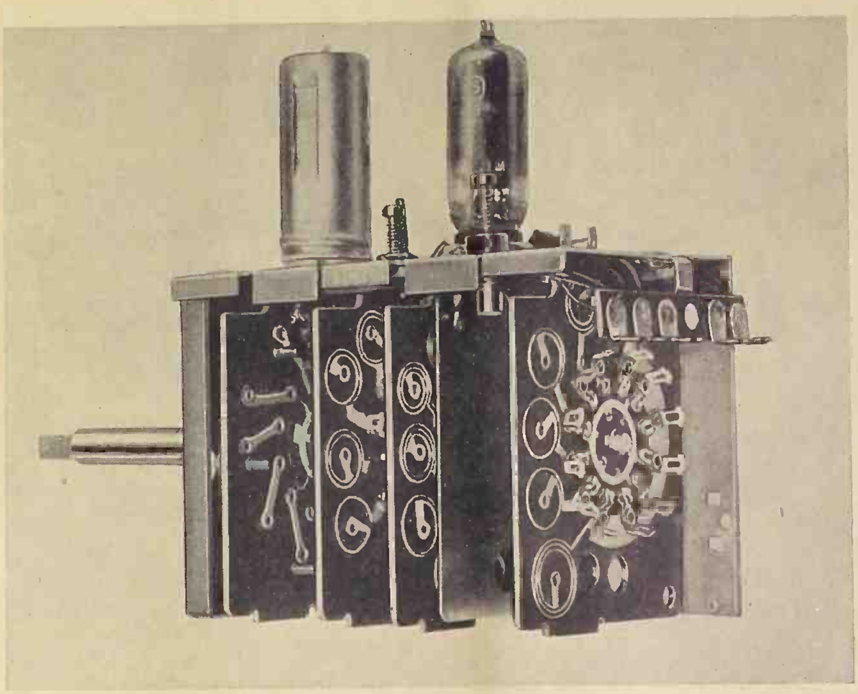


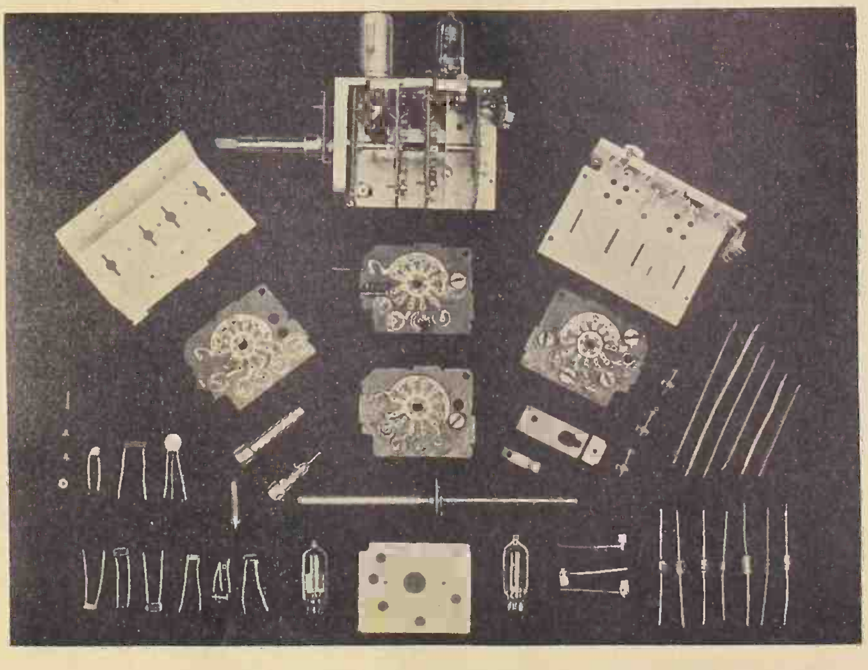
Fig. 5. Over-all view of the stamped circuit television tuner.

As it is, the only separate wires (not stamped) are those that join the stamped circuits to other components of the major assembly. Actually, even these hand applied wires could have been avoided had the components of the panel supporting the tubes been designed to include stamped wiring. Specifications imposed by purchasers made it necessary to follow a more conventional method in fabricating this side panel, which happens to be steel anyway.

The important gain in simplicity and lowering of cost, however, occurs in the wafers having the stamped circuits. Three of these panels have, as part of the stamped circuits, one or more in-

(*Continued on page* 30)

Fig. 6. Assembled and disassembled views of the TV tuner.



IMPULSE NOISE LIMITERS

By
ROBERT C. MOSES

Qualitative and quantitative characteristics of three circuits for reducing noise interference.

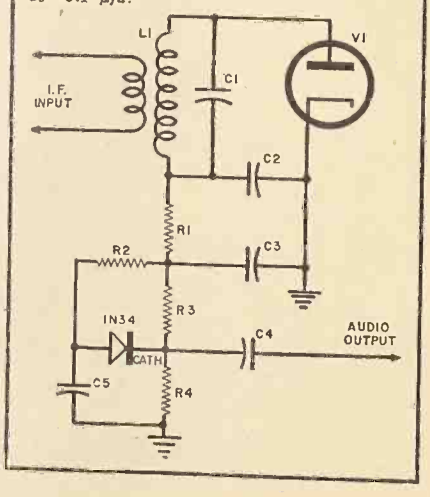
NOISE reduction in radio communications systems has long been a problem facing engineers in this field. Modern information theory has disclosed the fundamental benefits of various new types of modulation in obtaining an advantage over random noise. In many cases, however, it is necessary to maintain a communications channel with existing amplitude modulation equipment under variable and often severe conditions of interference from man-made noise. To assist in the preservation of readability in such cases, it is frequently possible to render the receiving equipment less susceptible to certain types of interference through the use of one of a number of noise reducing devices.

Before proceeding with a discussion of such devices and their application to communications receiving equipment, it might be well to touch briefly upon some of the more important sources of interfering noise. It is well-known that the limiting sensitivity of any receiving system is governed by the absolute magnitude of the noise voltages developed within or admitted by the receiver. In the complete absence of externally caused noise voltages, either picked up by the antenna or otherwise injected into the r.f. circuits, the sensitivity of the receiver is limited by its own internal noise; that due to thermal agitation and tube noises developed in the very first stages. On the assumption that the over-all gain of the receiver is sufficient to make these noise voltages audible, any further gain is not useful, because beyond this point, signal and noise are amplified together. It can be said therefore, that providing the gain of the first stage is reasonably high, the absolute signal-to-noise ratio and consequently the maximum sensitivity is determined in the input amplifier stage and its associated antenna coupling circuit. The problem of realizing maximum inherent signal-to-noise ratio within the receiver resolves itself into obtaining highest effective front-end gain together with lowest internally developed noise. The design of low-noise front-end circuits is beyond the scope of this paper; however, it is desirable to point out that this limitation does exist.

Fig. 1. Circuit of shunt diode limiter.

TYPICAL VALUES

R_1—47,000 ohms R_2—1 megohm
R_3—220,000 ohms (see text)
R_4—330,000 ohms (see text)
C_2, C_3—47 μμfd.
C_4—.05 μfd.
C_5—0.1 μfd.



Although it is readily possible to make a receiver of communications bandwidth to have an inherent noise figure such that signals as small as one microvolt or less are detectable, as pointed out previously, such sensitivities are realized only in the complete absence of external noise. This condition seldom exists in practice however, and it is frequently found that the level of the external noise far exceeds that of the receiver noise. In order to approach the ultimate sensitivity of which the receiver is capable, it then becomes necessary to resort to special antenna systems together with noise reducing circuits which will improve the apparent signal-to-noise ratio in the presence of certain types of externally caused interference.

External noise may be classified into two general types—the more or less continuous "hiss" type, the source of which has been attributed to cosmic disturbances; and the discontinuous or impulse type caused by static discharges, electrical machinery, automotive ignition systems, and the like. Of the two types, natural electrical discharges and man-made disturbances are by far the greatest source of interference in a communications channel, and any means taken for reduction of this type of interference will almost certainly result in an improvement in the apparent signal-to-noise ratio of the system.

In dealing with the latter type of interference, two considerations may serve to determine a basis upon which noise reduction can be accomplished. First, natural electrical discharges as well as nearly all types of man-made disturbances are of a discontinuous or pulse-like nature. The actual duration of any one pulse is extremely short, seldom greater than about 2 microseconds, while the interval between pulses is very many times longer. This means that although the peak noise voltages may be several hundred times greater than the amplitude of the received signal, the actual energy content integrated over a period of time is quite small. Second, the noise pulse itself, though of extremely high peak amplitude, is not of sufficient duration to produce an appreciable effect in the audio circuits of the receiver. The high amplitude pulse does, however, shock excite the tuned circuits into damped oscillation at their own natural frequencies, and the effect of this is to prolong the pulse so that it becomes apparent at the receiver output. Neglecting considerations of bandwidth for the moment, a very selective receiver in which a large number of high Q resonant circuits are employed might be expected to perform rather poorly in

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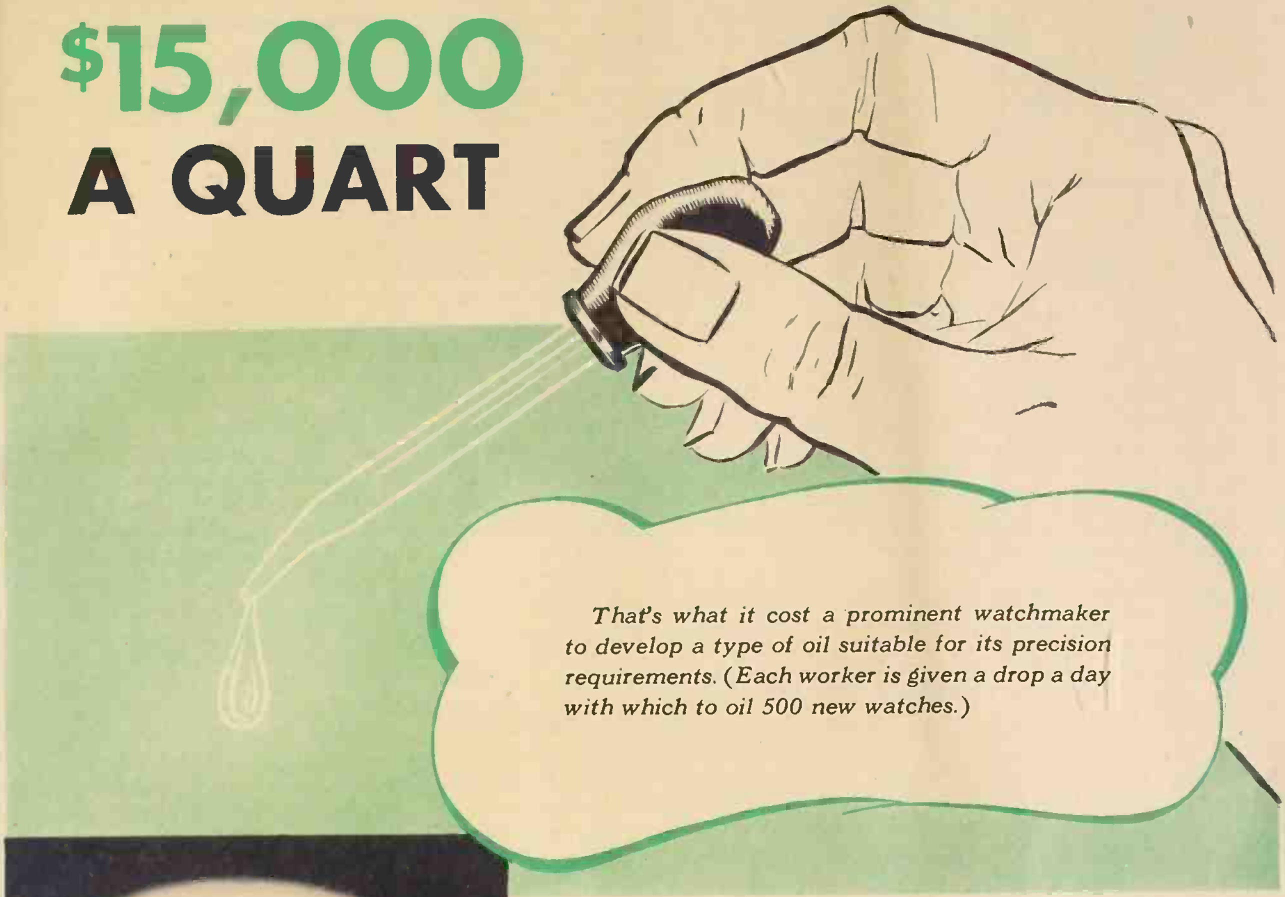

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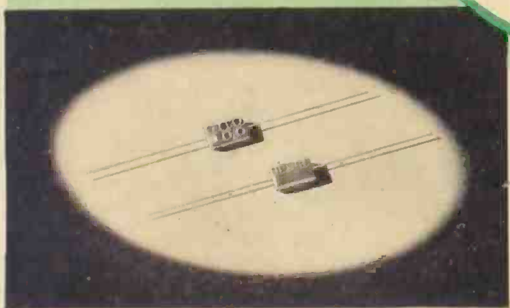

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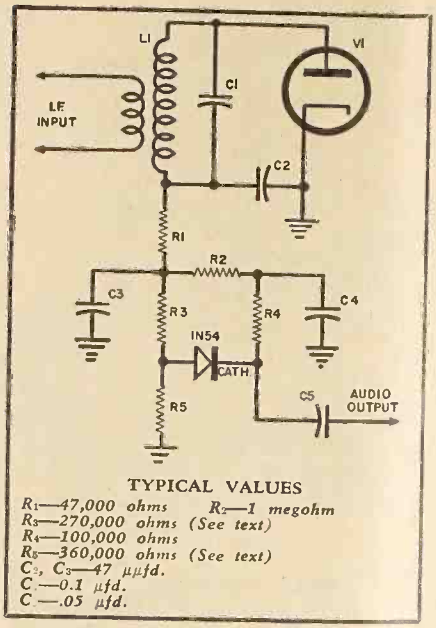


Fig. 2. Circuit of series diode limiter.

the presence of high amplitude impulse interference. This is because the low decrement tuned circuits tend to lengthen each impulse until the intereference assumes a more or less continuous nature. Fortunately, however, the narrow-band characteristics of such a receiver will admit a smaller percentage of the total noise spectrum so that the net effect will be not too greatly different.

Other than special antennas and certain interference balancing systems, noise reducing circuits used at the present time depend for their operation upon the noise impulses being discontinuous and of much greater peak amplitude than that of the desired signal. These characteristics have suggested two basic methods of noise reduction; that of "hole punching" or totally disabling the receiver for the duration of the pulse, and that of sharply clipping or amplitude limiting the pulse at a level equal to or slightly below the level of the received signal. It should be noted that both of these systems are applicable only to the reception of c.w. or amplitude modulated signals, and both introduce appreciable audio distortion at high modulation percentages.

Of these two systems, the first, while quite satisfactory in operation, is relatively complex in that it requires at least two additional tubes and a rather large number of components. Furthermore, this system is not easily adapted to existing receivers, since it requires that essentially complete and instantaneous gating action be applied to the signal channels. This necessitates a break into the normal amplifier chain. On the other hand, the second noise reducing system can be installed in virtually any receiver having a diode second detector with a minimum of circuit changes or additional components. On a comparative basis, it has been found that the results obtained with either type of system are nearly equivalent, and in view of the simplicity and versatility of the clipper type of noise reducing circuit, the latter has merited considerable attention.

Limiter Circuits

Noise clipper or limiter circuits can be divided into three general types, differing from each other primarily in the manner of connection of the clipper elements. The latter are usually biased diodes, and may be arranged in shunt, in series, or in compound configurations. Limiting action occurs in the audio channel and is applied at a point immediately following the demodulator. The circuits may then be designed so that the clipping level adjusts itself automatically to the level of the received signal, thus eliminating the need for manual adjustments.

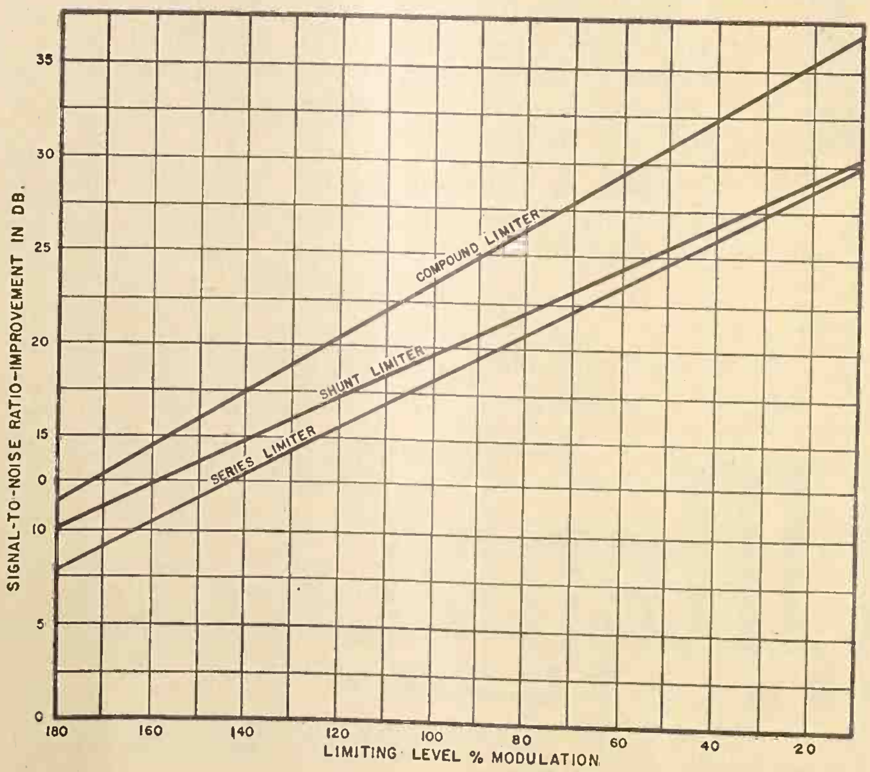
The simplicity and ease of installation of any of the three circuits to be described is greatly increased through the use of germanium diodes for the clipper elements. Compact, rugged, and requiring no heater supply, germanium diodes eliminate the necessity for mounting an additional tube in an already crowded receiver chassis. In addition, the higher conductance, lower capacitance, and freedom from contact potential effects provide improved circuit operation. The circuits presented are designed to take full advantage of these characteristics.

Shunt Diode Limiter

In the shunt limiter circuit of Fig. 1, V_1 is the demodulator diode which can be any of the types normally employed. The load circuit for this diode consists of capacitors C_2 and C_3, together with the series resistor combination R_1, R_3, and R_4. C_2, C_3, and R_1 are the usual r.f. filter elements. Capacitors C_2 and C_3, however, are given special values as described later. The series combination of resistor R_2 and capacitor C_5 has a time constant long with respect to the period of the lowest audio frequency to be passed, but sufficiently short to allow the d.c. voltage at the anode of the clipper diode to follow normal changes in carrier level. Resistors R_3 and R_4 constitute an audio voltage divider having a ratio such that under 100% modulation conditions, the d.c. plus peak audio voltage at the cathode of the clipper diode approximates the fixed d.c. voltage at its anode.

In operation, a rectified voltage approximating the peak of the applied carrier, together with any modulation and noise components, appears across the combined load resistance R_1, R_3, and R_4. Capacitors C_2 and C_3, together with resistor R_1, filter out the r.f. in the conventional manner. This leaves only a d.c. voltage which varies in accordance with the audio frequency en-

Fig. 3. Signal-to-noise ratio vs. limiting level. Two volt peak signal, 75% modulated; peak noise 38 db. above signal; pulse duration, 2 μsec.; repetition rate, 10 p.p.s.



velope of the applied signal, with any noise pulses superimposed. Since R_1 is very much smaller than the combined resistances of R_3 and R_4, the d.c. plus audio voltage at the junction of R_1 and R_3 is nearly equal to that across the total load. Capacitor C_5 is charged through resistor R_2 to approximately this potential, but due to the long time constant of R_2 and C_5, the anode of 1N34 is unable to follow the modulation and noise components. Present at this point, therefore, is a d.c. voltage free of audio and proportional only to the average carrier level. The anode of the 1N34 is held at a fixed negative potential with respect to its cathode, since the latter is tapped onto the combined load resistance at a point which is less negative than the junction of R_1 and R_3. Hence the diode is normally non-conductive. The cathode of 1N34 is free to follow the audio modulation and noise components. Since these are acting against a d.c. axis which approximates one-half of the voltage at the anode of 1N34, any negative going a.c. components exceeding twice this d.c. axis will cause the diode to become momentarily conductive. These components are therefore shunted to ground through the low impedance of capacitor C_5. The clipper thus acts in a direction corresponding to maximum modulation of the r.f. carrier.

The audio level relative to the carrier at which clipping commences is determined by the ratio of the d.c. plus peak audio voltage at the cathode of the 1N34 to the fixed d.c. voltage at its anode. Since with 100% positive modulation these two voltages will be equal, the cathode of the diode is returned to the approximate mid-point of the audio load resistance. The audio voltage division established by R_3 and R_4 is such as to provide a limiting level suitable for high modulation percentages. In practice, the adjustment of the resistor values must be so made that satisfactory limiting consistent with a tolerable level of audio distortion is obtained. Furthermore, the effective values of the several resistances in the circuit are reduced slightly by the shunting effect of the diode reverse resistance, so that the actual values of R_3 and R_4 will not necessarily be equal.

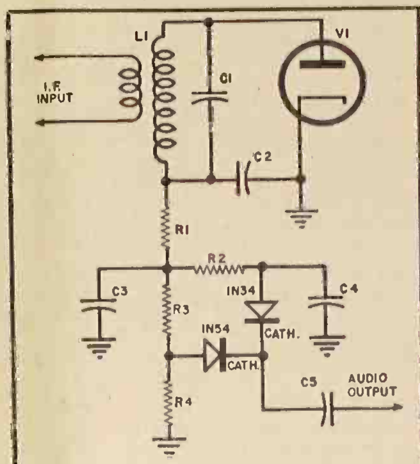
The absolute noise attenuation provided by the shunt clipper is dependent largely upon the relation of the clipper diode forward resistance to the effective impedance of the audio load including R_4, C_4, and the following grid circuit. For optimum results, the a.f. impedance of the shunt path provided by capacitor C_5 and the 1N34 diode when conducting should be as small as possible; conversely the shunting impedance around the audio load resistor R_4 should be kept large. Furthermore, any a.c. shunting across R_4 should remain reasonably constant since variations in the audio load impedance such as might result from controlling volume at this point are apt to introduce a variability in the clipping level.

A further consideration lies in the selection of time constants for the r.f. filter R_1, C_2, and C_3. Excessive time constants in the r.f. load circuit will introduce a positive transient of moderate amplitude immediately following the noise pulse. Due to its polarity, the clipper diode is unable to limit this transient, the effect of which is to produce a dull "thud" in the output. Although of considerably less amplitude than the original noise pulse, this effect is almost as objectionable. To minimize the transient, it is necessary to restrict the energy storage in the r.f. filter, a procedure most easily accomplished by the use of relatively small capacitors. It has been found that load capacitances as small as 47 µµfd. will not too greatly affect the detector efficiency at the i.f. frequencies normally encountered, but will reduce the amplitude of the transient to a very small value.

Series Diode Limiter

The series diode limiter of Fig. 2 is less critical to audio load impedance variations than the shunt type and is therefore, somewhat more flexible. However, the absolute noise attenuation provided by this circuit is not so great as that of the shunt type, since it is limited by the reverse characteristics of the particular diode used. A high reverse resistance diode is therefore advisable.

Essentially, this circuit consists of a series gate, the diode element of which



TYPICAL VALUES
R_1—47,000 ohms R_2—1 megohm
R_3—220,000 ohms (see text)
R_4—270,000 ohms (see text)
C_2, C_3—47 µµfd.
C_4—0.1 µfd.
C_5—.05 µfd.

Fig. 4. Circuit diagram of the compound or shunt-series limiter.

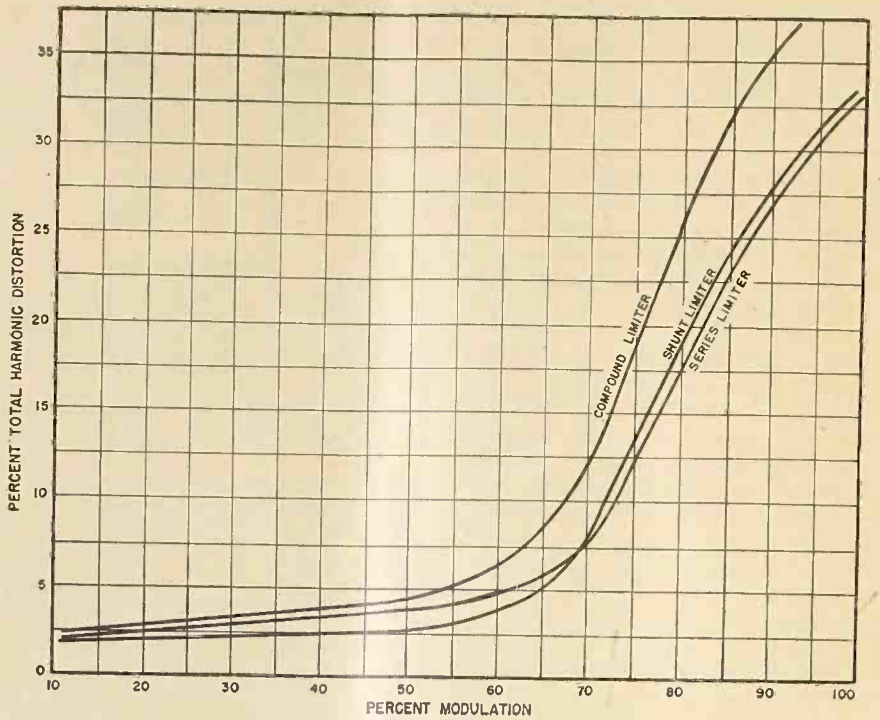


Fig. 5. Total harmonic distortion vs. percentage 400 cycle sine wave modulation. Signal voltage 2 v. peak at detector; limiting level 70% modulation.

is normally conductive due to the fixed negative potential at its cathode. In the same manner as in the shunt diode circuit, this potential is proportional to the average signal level since it is obtained from the rectified carrier voltage through the audio filter R_2, C_4. Resistor R_4 is an isolating resistor which acts in conjunction with R_5 as part of the audio load when the diode is conducting. The voltage division afforded by R_3 and R_5 is such that under 100% modulation conditions the d.c. plus peak audio voltage at the anode of the diode is approximately equal to the fixed d.c. voltage at its cathode. Instantaneous audio peaks in excess of this level will drive the anode negative with respect to the cathode and cause the diode to become momentarily non-conductive. This effectively opens the audio circuit to the following stage.

As in the shunt diode limiter, the clipping level is established by the ratio of the two voltages mentioned above. In practice, this ratio is set up by adjustment of the position of the tap on the audio load resistance R_3-R_5. The noise attenuation provided by this circuit is determined primarily by the relation of the diode resistance in the reverse direction (cathode positive) to the effective audio terminating impedance at the cathode of the diode. Unlike the shunt limiter, more effective limiting is obtained with relatively low terminating impedance. For this reason, minor variations in the latter will exercise little effect upon the operation of the circuit since the maximum terminating impedance under any conditions is limited by the resistance of R_4.

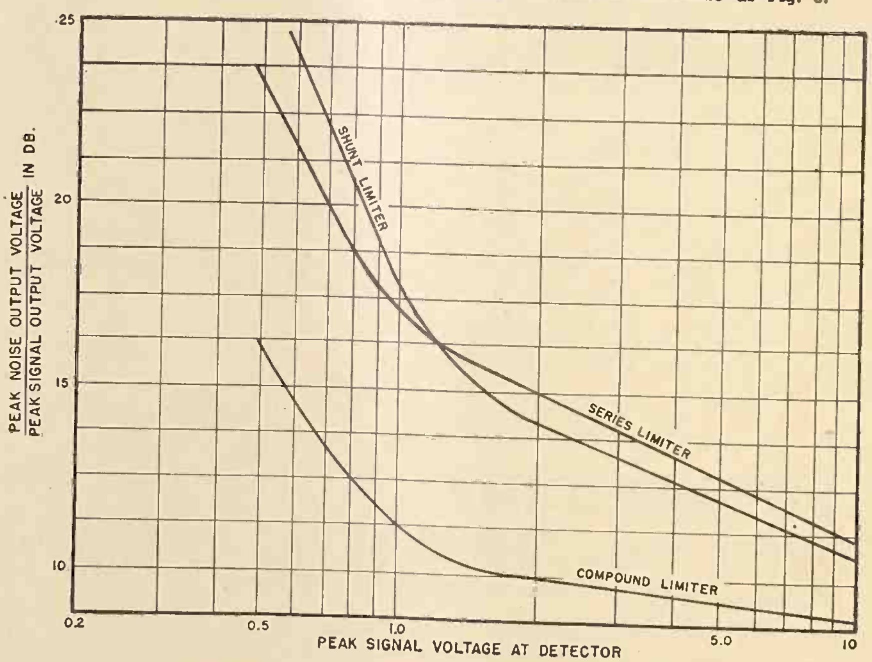
Compound Limiter

By properly combining the shunt diode limiter of Fig. 1 with the series diode limiter of Fig. 2, the advantages of both circuits may be realized in an arrangement known as the compound or shunt-series limiter. This is shown schematically in Fig. 4. The absolute noise attenuation provided by this circuit is substantially greater than that of either the shunt or series diode limiters. At the same time, the compound limiter requires no increase over the series diode circuit in the total number of components.

In this circuit, 1N34 is the shunt diode and the 1N54 is the series element. The r.f. filter as before consists of capacitors C_2 and C_3 together with resistor R_1. The same considerations of r.f. filter time constant as in the shunt and series circuits apply in this case. The audio filter R_2 and C_4 and the audio voltage divider are common to the circuits described previously. The audio isolation resistor R_4 of Fig. 2 is replaced in this circuit by the reverse resistance of the 1N34 shunt diode.

The manner of operation of the clipper elements is essentially the same as has been described individually in connection with the shunt and series type limiters. The fixed negative biasing voltage which results from rectification of the carrier and subsequent audio filtering is applied to the anode of the 1N34 and through the reverse resistance of this diode to the cathode of the 1N54. The 1N34 shunt diode is therefore non-conductive and the 1N54 series diode conductive so long as the sum of the d.c. and peak audio voltages at the junction of R_3 and R_4 does not exceed the d.c. axis so established. Instantaneous audio voltage excursions at this point of sufficient amplitude to exceed the negative d.c. bias cause the 1N54 series diode to become non-conductive. This diode, however, exhibits a finite although high resistance when non-conducting; therefore in the presence of high amplitude impulse in-

Fig. 6. Peak noise-to-signal ratio vs. signal voltage. Signal modulated 75% at 400 c.p.s. Limiting level set at 70% modulation. Other conditions same as Fig. 3.



terference, the noise attenuation at its cathode is not infinite. The partially limited pulse voltage at the 1N34 cathode causes the instantaneous potential at this point to drop below the fixed voltage at its anode. The 1N34 therefore becomes conductive for the duration of the pulse.

The a.c. equivalent circuit insofar as audio components are concerned consists of a generator in series with the relatively high impedance R_4. Shunting R_4 is a constant impedance variable ratio voltage divider made up of the non-linear elements 1N34 and 1N54. The load is connected across the 1N34.

The characteristics of the divider are such that at some arbitrary signal level, the voltage division ratio changes abruptly from very nearly unity to a value of the order of 5000 to 1. The divider insertion loss may therefore vary from essentially zero db. to a theoretical maximum of about 54 db. In the absence of noise, the attenuation through the divider is negligible since the load impedance in parallel with the reverse resistance of the 1N34 is at least several hundred times larger than the conducting resistance of the 1N54. When the 1N54 becomes cut off and the 1N34 conducts during a noise pulse, the high reverse resistance of the 1N54 is terminated by the low conducting resistance of the 1N34, and the attenuation through the divider approaches the theoretical maximum indicated above. The net result is that the degree of noise limiting provided by the compound limiter is substantially greater than would be obtained with either shunt or series diode alone.

In addition, the performance of the limiter as a whole is no longer a function of the terminating impedances. Due to the shunting effect of the diode reverse resistances upon the several resistive elements of the circuit, the clipping level of the series diode is somewhat lower than that of the shunt element. This allows the limiter to function effectively over an extremely wide range of signal and noise amplitudes. Furthermore, in the absence of a carrier, a very effective audio squelch action is obtained.

Because of the slight variations in reverse resistances between individual germanium diodes, it is somewhat difficult to state in terms of the ratio of resistors R_3 and R_4 the absolute percentage of modulation at which limiting commences. While it would be convenient to define the limit level in terms of these resistor values, in practice it may be found that some variation from the values given will be required in order to obtain most effective limiting together with reasonably low audio distortion. In certain instances, it may be desirable therefore to provide a semi-variable adjustment of the audio takeoff tap on the load resistor.

Comparison of Circuits

In conclusion, a comparison may be drawn between the performance of the three types of limiters described. Of particular interest is the relative improvement in the apparent signal-to-noise ratio afforded by each of these circuits, and the amount of audio distortion introduced by each for various modulation percentages. In addition, a knowledge of the limiter performance over a range of r.f. signal input levels is useful. The following data taken on a typical communications receiver is based upon a peak noise voltage 38 db. above peak signal measured with no limiting applied to the audio circuits. The noise pulse duration was approximately 2 microseconds, and the pulse repetition frequency 10 p.p.s.

In Fig. 3, the improvement in signal-to-noise ratio is plotted as a function of limiting level, the latter expressed as the percentage of modulation at which limiting sets in. It can be seen from the curves that the compound limiter is capable of effecting as much as 6 db. improvement over the shunt type and slightly more over the series limiter. In Fig. 5, the total audio distortion introduced by each is shown as a function of modulation percentage. The clipping level in each case was adjusted initially to 70%. The total harmonic distortion produced by the shunt and series limiters varies in essentially the same manner, while that introduced by the compound limiter increases more rapidly and becomes somewhat higher at high modulation levels. This is due to the sharper clipping action obtained. In Fig. 6, the output noise-to-signal ratio for a constant peak noise voltage input is plotted against r.f. signal input. For the same clipping level adjustment, the compound limiter surpasses the others with its ability to effect materially better limiting action at low levels.

The limiting sensitivity of any receiving system is determined by the absolute level of the random noise components developed within or admitted by the receiver. Three methods of reducing these random noise components have been described.

In the light of the data presented above, the practical choice between the three circuits must be governed by such factors as the noise conditions likely to be encountered, the range of input signal levels over which the receiver will be used, and the permissible audio distortion at its output.

NEW PRODUCTS

PULSE GENERATOR

The development of an electronic marker whose pulse duration, as well as repetition rate, is crystal-controlled

has been announced by *The Davies Laboratories, Inc.*, 4705 Queensbury Rd., Riverdale, Md.

The Timing Pulse Generator is a convenient time-marker source for cathode-ray oscilloscope presentations. Its peak output of 120 volts at one watt is sufficient to operate up to four argon lamps as timing indicators for action being recorded on motion picture film or for stroboscopic study of rotating apparatus.

Available in two models, Model 809C is supplied as a single rack-mounting unit with integral power supply. Model 809B is intended primarily for use in aircraft and comprises a separate power supply and pulse generator unit.

Specifications and prices may be obtained direct from the manufacturer.

PRESSURE AND VACUUM PUMPS

George A. Thiberg of Cedar Knolls, New Jersey is producing pressure and vacuum pumps which are small, compact, and silent in operation. *Boonton Molding Company* molds the housing

parts with *American Cyanamid Company's* Beetle Plastic.

These pumps are available in two models. Model 1 can be obtained either as an air pressure pump or as a vacuum type, and delivers approximately 800 c.c. per minute and has a maximum pressure of about four to six pounds. As a vacuum pump, Model 1 is used in the surgical and hospital fields. It creates a vacuum of about twelve feet of water and has proved useful as a pump for circulating air or gases in a closed vessel.

Model 2 is an air pressure type in a larger size and delivers approximately 3000 c.c. per minute and will give a maximum pressure of eight to ten pounds.

METER AND PROBE UNIT

A pocket-size pH meter and companion probe unit which permits instant, on-the-spot pH determinations anywhere is now available from *Analytical Measurements, Inc.*, 585 Main St., Chatham, New Jersey.

Completely self-contained with batteries, this instrument is furnished in an ever-ready case with novel plastic tubes of buffer and KCl solutions. Supports and beakers are completely eliminated by combining the calomel and glass electrodes with the sample holder, in a single polyethylene probe unit.

The meter is scaled from 2 to 12 pH for easy reading, and a simple adjustment gives readings from 0 to 14. Accuracy of 0.1 pH is obtainable. The electrometer tube, switch and input connector are sealed in a single unit to ensure freedom from high humidity difficulties.

LOAD CELLS

A new U-1 series of SR-4 universal (tension-compression) load cells is announced by *Baldwin-Lima-Hamilton Corp.*, Philadelphia 42, Pa. This series replaces the Type U cells as standard units.

Rated load capacities of type U-1 load cells are 500, 1000, 2000, 5000, 10,000, 20,000, and 50,000 pounds. Accuracy of load measurements is within ± ¼% of full range at any load within rated capacity. Relative sizes of the load cells are illustrated, the largest being only 6½ inches in diameter and 11½ inches high. Load cells may be used with indicating, recording, or controlling instruments. Input current may be a.c. or d.c. at 4 to 8 volts.

FREQUENCY MONITOR

The Engineering Products Department of *Radio Corporation of America*, Camden, N. J., has announced an FCC approved frequency deviation monitor for use in broadcast stations. The company stated that *RCA* Type BW-11A monitor is an improved instrument capable of handling a wide r.f. input range, and providing greater sensitivity than earlier models.

This monitor will continuously and directly indicate in cycles-per-second the magnitude and direction of any departure of the transmitter frequency from its assigned channel in the range of 500 to 2000 kc. It reveals deviation range (readable to 1 cycle) of plus or minus 30 cycles with an accuracy of plus or minus 10 parts per million.

The necessary r.f. pickup can be obtained either by direct connection to the transmitter or by use of a short length of wire attached to the input terminals to serve as an antenna.

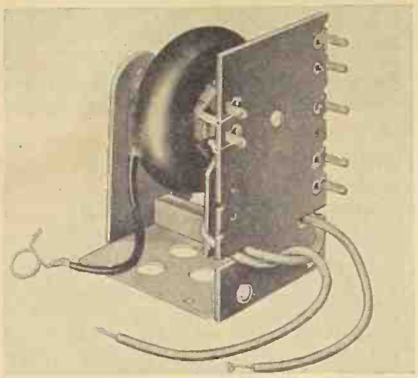
SWEEP OSCILLATOR

Kay Electric Company, Pine Brook, N. J., is now manufacturing a wide band sweeping oscillator called the Marka-sweep-model video to speed up and at the same time give more accurate alignment of video and other amplifiers over wide bands.

The many features of this unit include two bands selectable by front panel switch, 50 kc. to 10 mc. and 50 kc. to 20 mc., pulse type markers connected directly to oscilloscope crystal positioned at 1, 2, 5, 10, 15, 20 mc., output of 0.3 volts, 72 ohm output, and an all-electronic sawtooth sweep. Sawtooth is available for sweeping oscilloscope. Output is flat within 0.1 db. per megacycle.

TRANSFORMER

The Tube Department of *RCA*, Harrison, N. J., is offering the 225T1 horizontal-deflection-output and high voltage transformer for use with the 17CP4, 19A-types, 20CP4, and similar picture tubes having a horizontal deflection angle of about 66° and operating at a zero-load anode potential of 16 kilovolts.



The 225T1, which utilizes a ferrite core, is designed for use with a single, horizontal-deflection amplifier tube which may be either a 6BQ6-GT or a 6AU5-GT; a single, high-voltage rectifier tube such as the 1B3-GT; and the magnetic deflecting yoke *RCA*-209D1 which also has a ferrite core. In properly designed circuits, the 225T1 can supply up to 16 kilovolts at no load, has good regulation, and can provide good deflection linearity.

TURRET LATHE

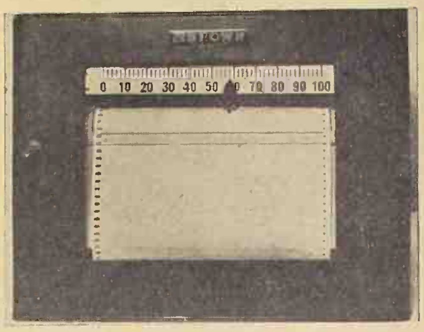
Rivett Lathe & Grinder, Inc., Brighton 35, Boston, Massachusetts, is now offering a 9" turret lathe for fast production of small duplicate parts to interchangeable limits.

Well-grouped controls permit instant selection of variable cutting speeds from 90 to 3750 r.p.m., and a convenient automatic chuck closer with switch controls spindle drive and brake. Spindle is dynamically balanced on super-precision, grease-sealed ball bearings, mounted to incur no thermal stresses.

Full information on the *Rivett* 918-S Turret Lathe may be obtained by writing the company for Catalog 918-ST.

FUNCTION PLOTTER

An automatic electronic instrument for compiling two measurements and plotting a curve to show their interrelationship has been developed by *Minneapolis-Honeywell Regulator Company*, Brown Instruments Division, Wayne & Windrim Avenues, Philadelphia 44, Pa.



Known as the Brown ElectroniK function plotter, the instrument incorporates two measuring systems, one of which actuates the recorder pen while the other motivates the instrument chart. The chart is driven up and down in response to the changes in one variable simultaneously with the movement of the pen in response to changes in a second variable.

Laboratory or over-all industrial investigations, involving such interdependent non-linear variables, are greatly facilitated with this function plotter. Measurements over the entire curve are continuous; no interpolation is needed to complete data between points of measurement.

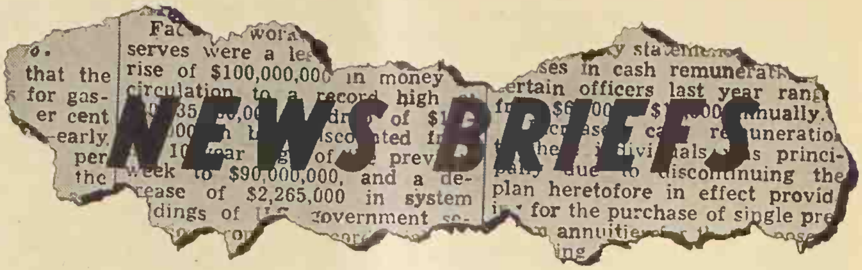
D.C. AMPLIFIER

The Model 1411 Inductronic d.c. amplifier introduced by *Weston Electrical Instrument Corp.*, 641 Frelinghuysen Ave., Newark 5, N. J., is particularly suited to d.c. measurement and control operations in industrial processes requiring continuity of service.

This amplifier is a versatile instrument capable of measuring as an automatic process the related physical quantities of input devices such as thermocouples, radiation receivers, strain gauge bridges, resistance thermometers, and photocells.

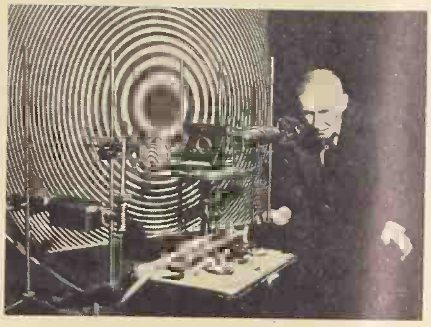
A precise regulation of d.c. current or voltage by reference against a standard cell is possible within 0.01 per-cent. With r.m.s. a.c. regulation using special thermocouples, a sensitivity of 0.02

(*Continued on page* 31)



ATOMIC STANDARDS OF LENGTH

The National Bureau of Standards and the Atomic Energy Commission have announced the availability of an



ultimate standard of length. The standards consist of spectroscopic lamps containing a single pure isotope of mercury. These lamps enable any research organization which has the auxiliary optical equipment to have for the first time an ultimate primary standard of length in its own laboratories.

The NBS-Meggers Mercury 198 Lamps, prepared under the direction of Dr. W. F. Meggers, Chief of the NBS Spectroscopy Laboratory, contain about one milligram of mercury of atomic weight 198. Dr. Meggers is shown positioning the eyepiece of the optical train prior to observation of the circular interference fringes of green light from the electrodeless Hg 198 lamp (left foreground). Length measurements based on this interference pattern (background) can be made with an accuracy of one part in 100 million.

Distribution of the lamps will be handled by NBS and will be available to qualified government, industrial, and educational laboratories both in this country and abroad engaged in precision length measurements and related research. All requests for information and applications should be addressed to the Coordinator of Atomic Energy Commission Projects, National Bureau of Standards, Washington 25, D. C.

NEW WESTINGHOUSE SITE

Elmira, N. Y. has been chosen as the site for the headquarters plant and engineering laboratories of *Westinghouse Electric Corporation's* new Electronic Tube Division.

Located on a 100-acre tract four miles northwest of Elmira, the plant will produce electronic tubes for the military services and defense industries, and will provide 1000 new jobs. Two complete factories will be in a brick one-story manufacturing building containing six times as much area for the manufacture of electronic tubes as is now available in the company's Lamp Division plant at Bloomfield, N. J.

Completion of construction work is scheduled for early next fall.

MOBILE MOLDING SHOP

A mobile unit which is a plastic molding shop on wheels has begun touring the nation to demonstrate a new approach to production of plastic parts. The mobile unit, a project of the Plaskon Division, *Libbey-Owens-*

Ford Glass Company, is a converted van-type trailer and tractor that carries everything needed to be a business concern in itself. The mobile unit drives into a prospect's plant, plugs in its electrical cable, and two presses are soon molding commercial parts for household fuses and at a rate of 4000 per hour.

The trailer also has a lounge area where visitors can sit and discuss the exhibit, see a display of successful uses of the alkyd material, its properties, and watch a dramatic, high-voltage test that demonstrates the alkyd plastics' electrical properties. An engineer-demonstrator travels with the trailer to explain the molding operation and the plastic material to visitors.

APPOINTEES OF ATOMIC PROJECT

The newly reorganized Engineering Divisions of the Knolls Atomic Power Laboratory, operated by the *General Electric Company* for the Atomic Energy Commission, recently announced the men appointed to head the various divisions.

Seated right to left are: William W. Kuyper, Engineering Manager, Harold

N. Hackett, assistant, and David Cochran, Divisions Engineer of the Development and Design Engineering Divisions.

Standing right to left are: Kenneth A. Kesselring, Engineer of the Reactor Engineering Division, and Thomas Trocki, Engineer of the Heat Transfer Engineering Division.

BRITISH ENGINEERS CONVENTION

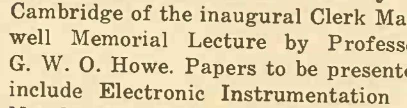
The British Institution of Radio Engineers has planned six separate sessions covering the whole field of radio and electronic engineering to take place during the Festival of Britain from July to September.

Formal papers, discussions, demonstrations, visits to places of technical interest, and social functions will contribute to the Convention. An outstanding feature will be the delivery at Cambridge of the inaugural Clerk Maxwell Memorial Lecture by Professor G. W. O. Howe. Papers to be presented include Electronic Instrumentation in Neucleonics, July 3-4; Valve Technology and Manufacture, July 5-6; Radio Communication and Broadcasting, July 24-25; Radio Aids to Navigation, July 26-27; Television Engineering, Aug. 21-24; and Audio Frequency Engineering, Sept. 4-6.

It is hoped that the spacing of the sessions will permit overseas members to attend at least some of the sessions. Overseas members are asked to communicate with the secretary of the Institution, 9 Bedford Square, London, WC1, England.

NOISE FIGURE STANDARDS

The National Bureau of Standards is offering a calibration service for the

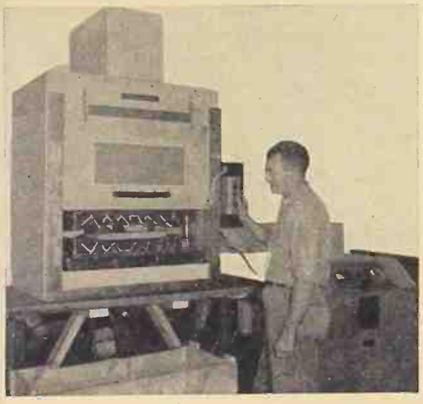


noise figure in the frequency range of 500 kc. to 30 mc. Standards for this purpose have been developed by M. Solow, I. W. Hammer, and P. H. Hass of the Bureau's Central Radio Propagation Laboratory.

Shown is a schematic diagram of the Bureau's noise figure measuring apparatus. This system is used in the Bureau's calibration service for measuring noise figures of linear electrical networks. The technique is valid for both matched and unmatched input impedance and yields calibration to ±0.2 decibels at frequencies from 500 kc. to 30 mc. Work is still in progress to extend noise figure standards to 300 mc.

TECHNIQUE FOR SHUTTLE BONDING

Westinghouse Electric Corporation has adapted electronic dielectric heating techniques to shuttle bonding to improve the quality of the bond, reduce its cost, and increase production. Use of a radio frequency generator for heating plus an automatic hydraulic press produces a uniform bond the length of the shuttle.



The new technique uses "Stray Field Heating" with electrodes embedded in rubber on the surface of thick rubber dies to heat the glue line for the purpose of polymerizing the thermosetting plastic glue used with the new process. A radio frequency generator supplies the required dielectric heat at a frequency of approximately 13.6 mc. A standard steel die set, used in a hydraulic arbor press, makes up the upper and lower platens on which are mounted the electrodes and rubber dies.

The total curing time required is only 90 seconds, compared to previous methods requiring perhaps four hours or longer. The time saving is actually greater than the 90 seconds indicate, since more than one shuttle can be bonded at the same time.

STUDY FISSION PRODUCTS

The Stanford Research Institute of California, on behalf of the U. S. Atomic Energy Commission, is conducting an investigation on the industrial uses for by-products of the atomic energy program through the medium of large-scale employment of fission products. The immediate objectives of the study are to acquaint industrial concerns with the characteristics of fission products and to obtain the cooperation of industry and a limited supply of copies their possible utilization.

The scope and objects of this fact-finding program are described in detail in a descriptive booklet entitled "Industrial Utilization of Fission Products —A Prospectus for Management." The Institute will distribute the prospectus to a representative sample of U. S. industry and a limited supply of copies will also be available for other interested concerns. They may be obtained by writing to Project 361, Dept. of Business and Industrial Economics, Stanford Research Institute, Stanford, Calif.

NEW LITERATURE

Table of Powers of Complex Numbers

This table has been published by the National Bureau of Standards to meet the needs of engineers, mathematicians, and scientists who are working on problems in fields as diverse as alternating-current circuits, number theory, and exterior ballistics. It is especially useful in the treatment of Taylor series involving complex variables.

Exact values of powers of complex numbers are given in Cartesian form for powers from 1 through 25 and for arguments with real and imaginary parts ranging separately from 0 to 10 in unit steps. The table is arranged essentially in order to magnitude of the distances of the argument values from the origin in the complex plane.

National Bureau of Standards Applied Mathematics Series AMS8, Table of Powers of Complex Numbers, is available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., for 25c a copy.

Edvac Booklet

A complete description of the EDVAC, the electronic digital computer developed by the University of Pennsylvania for the Army Ordnance Department, is now available to the public.

The report, comprising over 400 pages of text, diagrams and tables in two volumes plus an Errata Section, presents a logical description of the various components. Main parts of the report cover the general principles of the EDVAC, the dispatcher, the EDVAC control, the computer, the memory, the reader-recorder, the timer, the power supply, and switchgear.

Copies of "A Functional Description of the EDVAC" may be obtained from the Moore School of Electrical Engineering, the University of Pennsylvania, Philadelphia 4, Pa., at $9.00 complete.

Personals

HENRY L. CROWLEY has received the honorary degree of Doctor of Engineering from his alma mater, the Stevens Institute of Technology, for his extraordinary contributions to the ceramic and metallurgical arts. Dr. Crowley heads *Henry L. Crowley & Company, Inc.* of West Orange, N. J., manufacturers of steatite parts and powdered-iron cores which supplied the armed forces and was among the first to earn the Army-Navy "E" award.

ROBERT B. DOME, *General Electric* consulting engineer at the Electronics Park plant in Syracuse, received the IRE Morris Liebman Memorial Prize for 1951. Cited for his contributions to the inter-carrier sound system of TV reception, wide-band phase-shift networks, and various simplifying innovations in FM receiver circuits, Mr. Dome has received 64 patents covering his electronic developments, and has twice received the Charles A. Coffin award.

H. E. FARRER has joined the Electrical Department Staff of the American Standards Association. Mr. Farrer retired in 1948 as assistant to the secretary of the American Institute of Electrical Engineers, and is thoroughly acquainted with standards in the electrical field. A member of the AIEE for thirty-three years, Mr. Farrer served as secretary of the AIEE Standards Committee and acted as AIEE representative on the Electrical Standards Committee of the ASA.

ALFRED C. HAEMER, JR., a member of the National Research and Development Board, has been named head of *General Precision Laboratory's* field engineering department. Mr. Haemer received his Bachelor of Electrical Engineering degree from Brooklyn Polytechnic Institute in 1943 while serving as a development and design engineer for the *Fairchild Camera and Instrument Corporation.* He later served as general manager of the *Stanley F. Chamberlain Co.*

W. B. WHALLEY, engineering specialist for *Sylvania Electric Products Inc.*, has been officially appointed Adjunct Professor in Electrical Engineering for the Polytechnic Institute of Brooklyn. Formerly assistant professor of engineering physics at Cornell University, Professor Whalley received his B.A. Sc. degree from the University of Toronto in 1932 and served on the University's department of electrical engineering staff for four years.

DR. R. M. ZABEL has been appointed manager of engineering for the *Westinghouse* Lamp Division in Bloomfield N. J. Dr. Zabel joined *Westinghouse* in 1947 after 11 years as chief engineer of the Lamp Division of *Sylvania Electric Products, Inc.* An active member of the Illuminating Engineering Society, Dr. Zabel is I.E.S. representative on President Truman's National safety committee, and is a member of the Society's technical papers committee.

Spark Chronograph

(*Continued from page* 6)

Since the chronograph records only to 0.5 millisecond, the chronoscope was developed primarily as a vernier device to permit the determination of long intervals with greater accuracy. In this instrument, the output of one crystal clock and frequency divider is used to produce a circular sweep with small, fixed marker dots on the face of a 3-inch cathode-ray tube. A pulse from another crystal clock produces a large bright spot on the sweep. By observing the position of this spot in relation to the marker dots, it is possible to measure relative time changes within a very small fraction of the interval required for one circular sweep. The time base and marker frequencies are obtained from the same frequency dividers that supply the chronograph drive so that the chronograph and chronoscope are locked in time phase just as are the minute and sweep-second hands of a conventional clock mechanism.

The circular sweep is obtained by applying 100-cycle voltages in phase quadrature to the deflection plates of the cathode-ray tube. Thus a 360° sweep is accomplished in 0.01 second. The grid of the cathode-ray tube is biased below cut-off so that no trace appears on the face of the tube except when a positive pulse is applied with sufficient amplitude to let the tube conduct. A 10 kc. signal applied to the grid therefore produces a circle composed of 100 dots, each 0.1 millisecond apart. Reference points are produced by a 1 kc. sine wave shaped to give negative pulses just wide enough to blank out every tenth one of the 10 kc. dots. Thus the cathode-ray tube shows ten groups of nine dots, each separated by a blank space. The signal to be measured is fed to the chronoscope as a strong positive pulse which places an enlarged dot on the face of the tube. The entire circular sweep represents 0.01 second while the distance between dots corresponds to an interval of 0.1 millisecond. By estimating fifths between the small dots, the position of the larger dot may be determined with sufficient accuracy to measure the change in relative time, as kept by two clocks, within 0.02 millisecond.

For greater resolution a larger cathode-ray tube may be used to increase the span between adjacent markers. For greater accuracy, 100 kc. markers could also be added. Another possibility is the use of a second chronoscope starting with either a 1 kc. or 10 kc. time base and using 100 kc. or 1 mc. markers to permit higher resolution.

Precise measurements of time and

frequency are becoming increasingly important in many technical fields—for example, in long-range radio navigation systems, in the upper range of the microwave region where atomic systems can serve as electronic components, and in basic research in microwave spectroscopy and molecular structure.

Contrast Meas.

(*Continued from page* 5)

ferent observers is desired, it has been found necessary to calibrate the color response for each observer.[1,2]

Another device which could conceivably be used for television photometry and contrast measurements is the Luckiesh-Taylor brightness meter.[3] This instrument is similar in principle and application to the Macbeth Illuminometer except that a circular photographic wedge is used to vary the intensity of the comparison lamp. There are two main objections to the use of this tool for television work. First, it is difficult to interpose color correcting filters in the comparison beam. As has been pointed out above, color correction is very important for accurate work. Secondly, the angle of view of the Luckiesh-Taylor instrument is very small (such that at 5 feet the field has a width of approximately 0.12 inches). Thus, for convenience, the Macbeth Illuminometer is probably better suited for the purpose of television photometry than is the Luckiesh-Taylor brightness meter.

In any attempt by photoelectric means to measure the necessary brightness levels from which large area contrast values are computed one soon becomes impressed with certain existing limitations:

(a) The very lowest light levels demand a really high order of absolute photoelectric sensitivity,

(b) The relative spectral response of the photoelectric device should be identical with the luminosity curve of the human eye,

(c) The viewing angle of the photocell must be suitably restricted.

It follows in practice then that item (a) eliminates most photocells from further consideration. They simply do not have the requisite sensitivity to permit their use with rugged microammeters or galvanometers to measure the brightness of a "dark" area in a television raster which might be as low as 0.028 foot-lamberts.

Item (b) also poses a problem to the experimenter in that, while he can obtain photocells which are nominally filter-adjusted to visual luminosity, these have already been ruled out on grounds of sensitivity. Now what about phototubes? Absolute sensitivity, while not quite adequate in the case of ordinary gas or vacuum phototubes, is wholly satisfactory for multiplier phototubes. These latter work well into rugged meters—a feature of great importance in connection with the suitability of equipment for use by production groups. The matter of color correction of multiplier phototubes has no stock solution. In their authoritative book, "Photoelectricity and Its Applications," Zworykin and Ramberg mention the use of a Wratten No. 11 (X-1) filter for color correction of a type 931-A multiplier phototube. The method for extending this to other multiplier phototubes is clear. One must measure the spectral sensitivity of the tube to visible light. A filter must then be selected whose spectral transmission when multiplied at each wavelength by the phototube sensitivity yields the visual luminosity function. Clearly this is primarily an optical laboratory problem. Solutions are possible, but for specific cases only.

In making television tube brightness measurements photoelectrically it is imperative that the viewing (or acceptance) angle of the photocell or phototube be properly restricted. If this is not done large errors arise because: (1) the photosensitive surface may receive light from areas in the field of view other than the one being measured; and (2) proper brightness calibrations may only be made from luminous surfaces whose radiant distribution follows Lambert's Law (*i.e.*, the surfaces must be practically perfectly diffusing). Quantitative account needs to be taken of these factors—a matter which goes unrealized far too often.

Regarding photoelectric means of contrast measurement, one may now reasonably conclude that they are at present chiefly laboratory devices whose accuracy depends upon the experimenter's skill. This fact by no means depreciates their value but simply renders them undesirable as production quality control devices. If contrast measurements did not involve accurate low-level brightness determinations, existing commercially available photoelectric television tube brightness meters could assume an extra duty. However this is not possible at present.

It is possible to conceive of photographic methods for determining large area contrast in television images. Associated with any of them though there would be a number of technical problems as follows:

(1) A study of the H and D curves for the various photographic materials listed in the Kodak Reference Handbook indicates that with any of them one is restricted to a maximum density range of 2. Therefore, such a material would accurately register light intensities over a range of 100:1.

(2) This fact would prevent contrast measurements being made on a number of types of aluminized as well as gray face plate television picture tubes with which we are familiar because their contrast values are, in some cases, as large as 300:1.

(3) To minimize areas in densitometering the photographic plate, its size should probably be at least 4" x 5". If smaller picture sizes are used, photographic enlargement, while possible, does not seem to be desirable because of the introduction of additional variables during the enlargement process.

(4) The use of any photographic method for this purpose must ultimately be based on individual plate calibration and extremely careful control of processing conditions. The latter is, of course, not impossible but would probably be the source of considerable difficulty.

(5) Any photographic-densitometric method for determining contrast would be more time consuming than the direct photoelectric method previously discussed.

REFERENCES

1. *I.E.S. Lighting Handbook*, 1947, pp. 5-23.
2. *Taylor, A. H., "The Validity of Flicker Photometer Measurements in Heterochromatic Photometry," Journal of the Optical Society of America*, 1926, pp. 193-203.
3. *Luckiesh, Mathew and Taylor, A.H., "A Brightness Meter", Journal of the Optical Society of America, Vol. 27*, 1937, p. 132.

TECHNICAL BOOKS

"PULSE TECHNIQUES" by Sidney Moskowitz and Joseph Racker. Published by *Prentice-Hall, Inc.*, 70 Fifth Avenue, New York, N. Y. 300 pages. $6.65.

This book is an elaboration of a series of articles prepared by the authors for the RADIO-ELECTRONIC ENGINEERING section of RADIO & TELEVISION NEWS. The primary objective of the text is to enable individuals with an electrical engineering background to analyze and design circuits for transmission and utilization of pulses.

Special mathematical tools, known as Fourier and Laplacian Transforms, are derived and their uses in transient response analysis are thoroughly discussed. The transition from conventional theory is gradual, enabling those readers who are not familiar with these new tools to readily assimilate them. Using these transform methods, the pulse response of linear networks is developed, followed by a description and analysis of many non-linear networks.

Subjects covered include the design of pulse networks, linear pulse amplifiers, pulse-shaping and clamp circuits, pulse generation, pulse measurements and instruments, and pulse communication systems. The final chapter covers aerial navigation aids. An appendix serves as a review of complex-variable theory, and presents the response of cascaded filters and transmission lines.

"THEORY AND APPLICATION OF INDUSTRIAL ELECTRONICS" by Prof. John M. Cage, Purdue University. Published by *The McGraw-Hill Book Company*, 330 West 42nd St., New York 18, N. Y. 290 pages. $4.75.

Written primarily for college graduate and undergraduate courses in industrial electronics, this is an integrated treatment of electronic circuits and devices outside of the field of communications. Practicing engineers should also find this text valuable for reviewing the principles of the electronic art.

The material covers electronic instrumentation of both electrical and non-electrical quantities, electronic control including servomechanisms, and electronic power, including d.c. power, induction heating, and dielectric heating. Many applications are described and the theoretical approach is sound.

Photographs and drawings are used liberally to illustrate specific points, and problems at the end of the chapters combine theory with simple workable applications.

Improvements

(*Continued from page* 12)

ground than 105 volts, and is positive with respect to the 6SN7-GT grids, thus creating the correct operating conditions for the cathode followers.

At the same time adjustment of R_1 controls the bias voltage placed on the grids of the power tubes, since they are direct-coupled to the 6SN7-GT cathodes. Though the *Childs* amplifier employs push-pull parallel triode-connected 807's in the power stage, the arrangement is equally useful for other tubes. In each case, the correct bias can be obtained with R_1. The 1000-ohm grid resistors are simply parasitic suppressors. The power tubes are balanced with the 50-ohm potentiometer R_4 by placing a current meter in series with each cathode. It is a good idea to provide jacks for the purpose.

Inverse Feedback

The amount of inverse feedback applied in an amplifier determines the effective output impedance. The more feedback the lower the impedance and the better the speaker damping and power regulation.

Feedback is the primary reason for the care which must be exercised throughout the design in keeping response flat to as high a frequency as possible, preferably to 100,000 cycles or more. A drop in response at either end of the range is evidenced by phase shift long before the response turnover is reached. Since feedback requires a shift of exactly 180 degrees for ideally stable, oscillation-free cancellation of distortion, the amount of feedback is sharply limited if the basic response is not excellent.

An amplifier using all the circuits described in this article would have four stages—the cross-coupled input, an amplifier, a cathode follower, and a final. Because each stage is designed, either in itself or in conjunction with the following one, for minimum frequency nonlinearity and phase shift, the feedback can be carried from the last back to the first stage without difficulty. If an excellent output transformer is employed, the feedback voltage can be taken from the transformer secondary so as to include the transformer itself in the loop, and can be balanced so as to enhance the inherent balance of each stage. The additional fact that all stages have minimum distortion and maximum balance adds to the effectiveness of the feedback, for obviously the end result of a given percentage of feedback cannot be as low a distortion figure when there is more inherent distortion to correct. An amplifier with the circuits of this article and 20 to 30 db. of feedback in addition operates as an absolutely stable, tightly self-controlled unit which is simply incapable of adding more than the very minimum of distortion which the "state of the art" makes unavoidable.

The origination point for the feedback may be the output transformer secondary. Most, but not all, high-quality transformers can be connected for balanced output if the correct taps are found by simple voltage tests. A 16-ohm balanced arrangement, 8 ohms each side of center, is usually satisfactory.

When the cross-coupled input circuit is used one end of the transformer secondary may be connected through a resistor to the cathode of V_1-A in Fig. 4. It is not necessary to make a connection to the cathode of V_1-B from the other side of the transformer, for any signal fed back to V_1-A will give balanced results for the same reason that the output of V_1-A itself does. The value of the series resistor can be determined experimentally with the aid of a variable resistor, adjusting it for the minimum resistance which still allows stable operation and sufficient over-all gain.

Feedback to the cross-coupled input need not, of course, be taken from a balanced transformer secondary—a single-ended one will do just as well. It need not be taken from the secondary either, but if taken from a point where d.c. exists, a series blocking capacitor will be necessary. This and the resistance of the feedback loop will form a frequency discriminator, limiting the amount of feedback and introducing the probability of accentuated highs in the loop and depressed highs in the final output.

Additional feedback may be applied in a balanced manner to the amplifier stage following the inverter. That is so because no matter how carefully an amplifier is built, there is some phase shift at the end frequencies between stages. The amplifier stage, being nearer the output, has a response which matches more closely that of the output.

A very simple and satisfactory way of adding feedback to the amplifier stage is illustrated in Fig. 5. The cathodes are connected through d.c. bias resistors to the output transformer secondary. The amount of feedback introduced in this way depends almost entirely on the output impedance of the transformer. If it is too great a lower-impedance pair of taps will reduce it, while the desired taps may still be used to drive the speaker. It is necessary, of course, that the transformer be center-tapped almost precisely (not true of all transformers) and that the tubes be symmetrical. Tubes need not be specially selected, however, for the arrangement tends to correct any small residual unbalance.

One more cause of instability sometimes plagues designers—the common power supply used for the entire amplifier. With careful design and good filter components, the power supply impedance can be reduced to a low value and interstage coupling through it reduced to a minimum. In an amplifier using the circuits of this article, however, response is so good and phase shift so small down to so low a frequency that some coupling through a common supply is almost inevitable. The resultant motorboating may be at a sub-audible frequency but is a clear cause of inferior performance. By far the best solution is to employ separate power supplies, one for the inverter and amplifier stages and a higher-voltage one for the driver and final. No interaction is to be expected through the bias supply so that may be obtained from the same circuit which supplies power to the early tubes.

Each of the circuits described here is highly suitable for individual use in amplifiers incorporating other features. They have also been employed as a group in the Childs amplifier, a construction article on which may be found in a future issue of RADIO & TELEVISION NEWS.

Slot Antenna

(*Continued from page* 9)

wavelength is shifted slightly to 3.86 cm. From the size of the backward main lobe it is seen that there is still relatively little power being radiated per unit distance traveled by waves in the wave guide. Because of circular symmetry of the TM_{01} mode all slots on the cylinder periphery are excited with nearly the same amplitude and phase, which results in an increasingly omnidirectional conical pattern as the number of slots is increased. The maximum variation in the conical pattern for the cylinder containing two diametrically opposed slots is only about 7 db. as compared with over 30 db. for a single slot. By increasing the number of slots it is possible to produce a nearly uniform conical pattern without radically altering the sharpness of the cone. The pattern of an array of eight slots all with the same length, in a cylinder with the same diameter as before, is shown in Figs. 5B and 7A, measured at a wavelength of 3.86 cm. The slots were separated by wires one sixteenth inch in diameter, so that the antenna has the appearance of an elongated bird cage. Although each slot is still only one third wavelength wide, the power radiated by eight slots combined is sufficient to reduce considerably the backward radiation.

Radiation is much stronger from a slot excited by a *TE* mode than by a *TM* mode, as can be seen in the pattern in Figs. 3 and 4B of a slot 30 cm. long by 0.16 cm. (0.030 wavelengths) wide in a cylinder 3.82 cm. in diameter when excited by the TE_{11} mode. The rapid rate of radiation makes necessary the use of relatively narrow slots, and consequently requires greater accuracy in construction than is necessary for *TM* slots.

Slots of either the *TE* or *TM* type in rectangular or circular wave guides can be mounted in a conducting surface by electrically joining the slot in the wave guide to a similar aperture in the surface. As in the case of wave guide fed resonant slots in conducting surfaces, the wave guide serves to isolate the high frequency fields from any disturbing objects inside the surface.

Side Lobe Control

All of the slotted wave guide antennas considered above have been of the simplest type, namely, one or more slots of uniform width milled in the wall of a wave guide of uniform cross-section. For many applications this type of antenna is quite satisfactory since it can be used to produce almost any required directivity (if the slot length is sufficiently great) and can be faired into a conducting surface without appreciably changing its radiation properties, and either horizontal or vertical polarization can be had by exciting the wave guide in a *TE* or *TM* mode, depending on the orientation of the wave guide. However, the side lobe level is frequently quite high for a slot aperture containing the exponentially attenuated field distribution which results from these simple slotted wave guides. From theoretical considerations it is known that an amplitude distribution which is maximum at the center of the slot and which tapers on either side of center to some small value can produce a sharp main beam with considerably smaller side lobes than is possible for an exponential distribution.

Tapered aperture distributions have been obtained experimentally by means of slots whose width varies along the length of the wave guide.[5] A slot of increasing width over half of its length and of uniform width over the remaining half produces the desired distribution. The actual shape of the slot required to produce a particular field distribution is usually determined empirically by a cut-and-try process. In addition to suppressing side lobes, wave guides with tapered apertures retain their essential properties over rather wide frequency ranges.

Slot Arrays

Arrays of traveling wave slots in conducting surfaces have been found very effective for concentrating power in a particular direction. As in the case of resonant slots all wire arrays have their slot analogs, which immediately makes available a number of slot arrays whose properties are well-known. For example, parallel arrays of *TE* slots have been used successfully to increase the directivity of the conical pattern. The familiar "V" type array has also been constructed using two *TE* slots mounted in a plane and joined

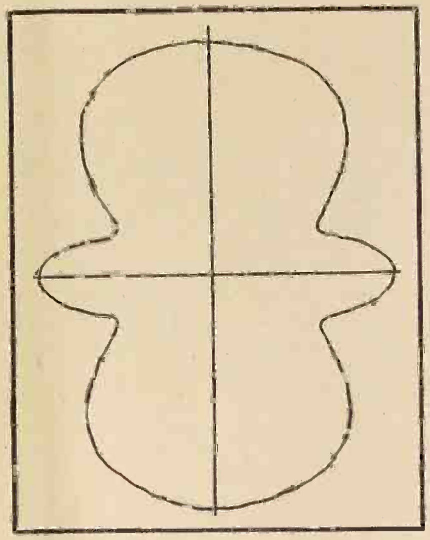
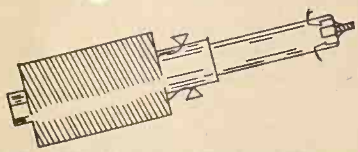


Fig. 8. Radiation pattern of two diametrically opposed traveling wave slots in a circular TM_{01} wave guide measured in a plane perpendicular to the wave guide axis.



together at the apex, at which point the slots were fed, with the result that radiation from the two slots added together to form a strong beam along the bisector of the "V" in the plane of the conductor. Similarly four slots could be joined together to form a rhombic array.

Another type of slot array is the slot fed horn, or "slorn," developed by C. H. Walter.[5] A sectoral horn joined to a continuously slotted wave guide at the slot aperture tends to concentrate the radiated power into a pencil type beam by increasing the effective width of the slot aperture. Such a radiating aperture may be thought of as a very large number of ordinary traveling wave slots, parallel to each other, and very close together. This antenna is more properly a diffraction type array since it depends on a continuous aperture distribution rather than discrete elements contained in the usual interference type array.

BIBLIOGRAPHY

1. *Rhodes, D. R. "Slot Antennas", Part I.*
2. *Hansen, W. W. U. S. Patent No. 2402622.*
3. *Ramo and Whinnery, "Fields and Waves in Modern Radio," Wiley and Sons, Inc., New York* 1944, *articles* 9.03 *and* 9.04.
4. *Rhodes, D. R. "Theory of Axially Slitted Circular and Elliptic Cylinder Antennas", Jour. App. Physics, vol.* 21, *p.* 1181, *November*, 1950.
5. *Hines, Krausz, Rhodes, Rumsey, and Walter, "Traveling Wave Slot Antennas", Proc. I.R.E. (to be published).*

Stamped Circuits

(*Continued from page* 15)

ductors whose inductance has to be adjustable. This is accomplished by a very simple means. Each such flat spiral inductor has passing through it a self-tapping brass screw whose head includes a disc about ½ in. in diameter. Shanks of the screws pass through holes in the panel but do not make contact with the inductors. As the screws are turned, the disc heads are brought as close to the flat coils as desired and alter the coil inductance accordingly. There are six of these screws and each is reached by a screwdriver either from the front or rear of the assembled tuner, hence inductance adjustment of the six corresponding coils is possible.

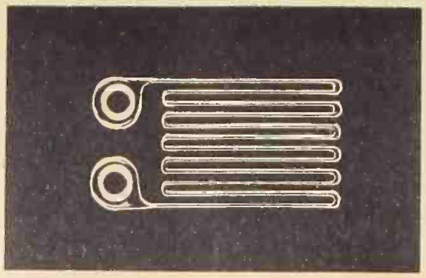
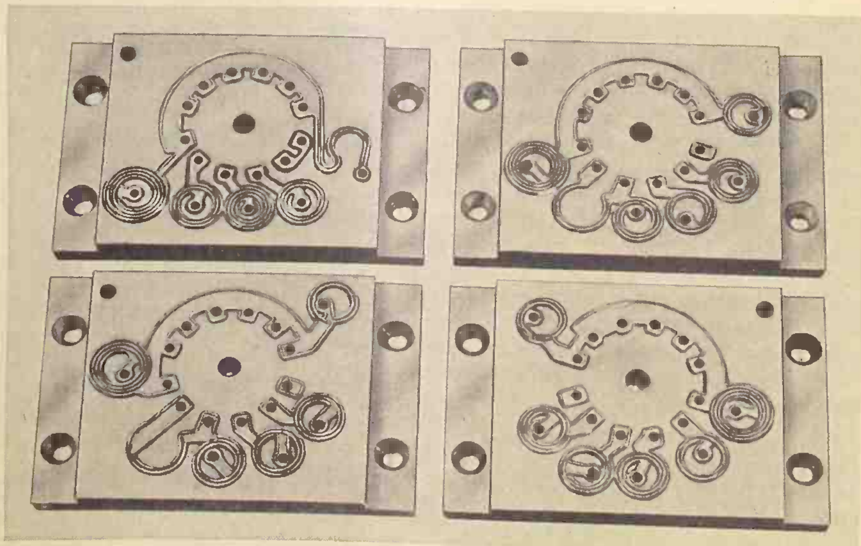


Fig. 8. This low resistance grid-type resistor is stamped and at the same time applied to a panel in a single operation.

To facilitate grounding of one of the stamped circuits of the tuner, the metal is left extending over an ear at one end of the wafer and is folded over this ear at assembly, when the ear is passed through a slot in the metal panel carrying the tubes. Solder is then applied to bond the copper to the plated steel and thus effects the ground.

Reference to the accompanying schematic diagram (Fig. 3) provides a good indication of the types of circuits employed. The tuner is designed to operate in a set using 105 to 124 v. at 60 c.p.s. and requires 6.3 v.a.c. at 750 ma. and 130 v.d.c. at 20 ma. Starting of the oscillator occurs on any channel with a set potential as low as 90 v. Long-time maximum oscillator frequency drift is 10 kc./volt (channel 13). Maximum oscillator radiation is 7500 microvolts at antenna terminals. Maximum bandwidth is 11 mc. for any channel at 3 db. down. Sound and picture carriers are within 3 db. of maximum point of r.f. response, maximum depth of valley being 3 db.

Fig. 7. Hardened steel die typical of those employed in producing stamped circuits. The die is heated and so softens the glue as well as shearing the metal.



Any metals available in coils, strip or sheet form can be employed in stamped circuits, but good conductors are commonly chosen. Pure rolled copper has been most used but tinned or plated copper, aluminum and silver have been employed. Cost, availability, conductance, ease of soldering and resistance to corrosion are among the factors affecting the choice. To date, only gauges between 0.010 and 0.004 in. have been applied commercially but thicker metal can be used if required for higher current capacity.

Increase in width of the flat conductors increases their conductance, of course, and the fact that they are flat helps to promote heat dissipation. Skin effects may be less. Because conductors lie flat against the panel to which they are applied, the space taken is small and is all in the planes of panel faces.

Adhesive employed in cementing the stamped circuits to panels is called Kotol (made by *U.S. Rubber Co.*) and is a thermoplastic that dries quickly but is softened subsequently by heat applied in the stamping die. Undoubtedly other adhesives could be used and thermosetting types (that do not soften when once set by heat) may well prove useful, especially where soldering must be done directly to conductors without using eyelets. Only further experiments and experience in commercial use can determine certainly which adhesive is best for specific conditions.

Dielectric panels can be of any type that will withstand the pressure applied and provide also the dielectric properties needed. To date, the materials used commercially include Masonite, laminated phenolics, tag board, and some forms of paper. Several plastics, such as those made from methylmethacrylate, styrene, urea, and melamine resins have been tried with good success. Choice hinges upon cost, ease of working, dielectric properties, hygroscopic properties, dimensional stability, and the like.

Tooling costs, especially for dies, are moderate and, in general, are quickly amortized through savings in other costs, especially in reduced hand labor. The stamping dies are made from steel and hardened but have proved to be good for at least 250,000 impressions. Such dies are made by the pantograph engraving method, using a master, usually several times actual size, laid out by drafting methods and cut from plastic sheet. This method is rapid and minimizes die costs. Dies having primarily parallel V-shape grooves (as for making Airloops or groups of parallel conductors) can be crush ground in replaceable sections at moderate cost.

By proper design and use of stamped circuits it is unquestionable that the number of soldered joints necessary to the production of the average radio and television set could be greatly decreased. It is thus apparent that both designers and producers of electronic equipment should study the adaptability of stamped circuits in developing new designs. This is particularly true in considering the developing of microwave equipment where compactness of design is so necessary.

New Products

(*Continued from page* 23)

per-cent can be achieved. The amplifier output is a current having a range of 1 milliampere into a total load burden not exceeding 5000 ohms (5 volts).

RADIOCHEMICALS

Nuclear Instrument and Chemical Corporation, 229 West Erie St., Chicago 10, Illinois, has expanded its facilities and services to include the availability of radioactive carbon compounds from its newly set up chemistry laboratory. These radiochemicals are the radioactive counterparts of compounds supplied in stable form through other sources. As a result of the radioactive labeling, the finished product continuously emits rays which can be detected and measured with the use of special electronic equipment.

While many of *Nuclear's* tagged compounds will be produced by chemical synthesis, the present major emphasis of the company will be in providing chemicals produced by the forces of nature in living plants and tissues, and known as "biosynthesized chemicals."

THERMOSTATS

Stevens Manufacturing Company, Inc., 69 South Walnut St., Mansfield, Ohio, is announcing a line of snap-acting bimetal strip thermostats for use in appliances and other devices requiring sensitive, precise control of high-wattage heater loads.

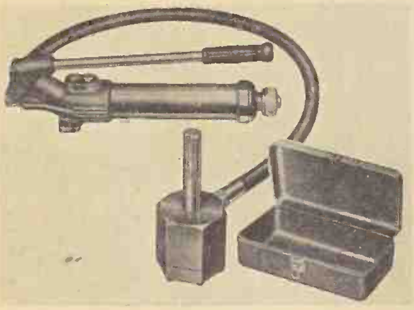
These units, designated as Type W Snap-Action Thermostats, are available in either adjustable or non-adjustable styles, each with a variety of terminal arrangements. According to the manufacturer, the advantages of these units over others of approximately the same size and with which Type W thermostats are interchangeable include operation with a fixed differential as close as 5°F in a 400°F temperature range. In addition, these thermostats are non-radio-interfering.

Featuring an electrically independent bimetal that effectively eliminates artificial cycling and "jitters," Type W thermostats closely follow the temperature of the controlled device and respond rapidly to temperature changes.

Technical data, including electrical ratings and engineering drawings, are available upon request.

DRAW BAR

The pump operated Ohio draw bar marketed by *Patterson Equipment Co.*, P. O. Box 163, Denair, California, pulls ½" to 4" size holes in sheet metal,



switchgear housing, and outlet boxes without manual exertion. Originally designed to replace laborious hand-operated knockout punches, this draw bar is now employed for a variety of industrial purposes.

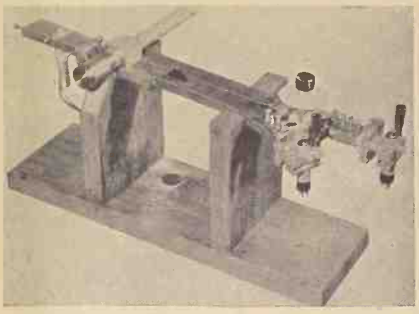
A thirty pound pressure on the handle produces 12,000 lb. pressure on cutting surfaces and cuts a clean, smooth-edge hole in less than a minute. It is said to perform efficiently in any desired position with pump at vertical or horizontal angles and may be employed wherever space allows hole pulling operations by present methods.

Detailed mechanical specifications and a list of standard attachments may be obtained from the company upon request.

SWEEP OSCILLATOR

Kay Electric Company of Pine Brook, N. J., is manufacturing a sweeping oscillator for the u.h.f. and microwave ranges.

To be known as the Super-Sweep, this instrument features a frequency range of 500 to 2000 mc. and up with a sweep width 30 mc. and up. Output



is approximately 0.5 volt maximum from 50 ohm internal impedance. Also featured is an accurate absorption type wavemeter for measuring and setting frequency.

STRIP-CHART RECORDER

Baldwin-Lima-Hamilton Corporation, Philadelphia 42, Pa. has announced a self-contained and portable strip-chart recorder of the "X-Y" type for plotting automatically on rectangular coordinates the simultaneous relationship between any two variables that can be made to actuate Microformers.

The recorder, identified as the MD-2, is similar in size and appearance to other models designed for attachment to B-T-E testing machines. It may also be used with any testing machine in which hydrostatic pressure in either the loading or weighing system is proportional to load applied to the specimen. For these applications separate Bourdon tube units are available for permanent attachment to the hydraulic system of each testing machine with which the recorder may be used.

Microformers are miniature variable transformers having usable core movements of 0.120 inch. Sensing Microformer core movements of 0.03 in. and 0.06 in. can produce full scale (10 in.) displacement of the stylus and core movements of 0.03 in., 0.06 in., and 0.120 in. can produce drum rotation of 10 in. Each of the recording elements, when used with an external Microformer of standard precision type, has a recording sensitivity of 0.000015 inch. Movement of the external Microformer core can be recorded to an accuracy within 0.2% of the recorder scale range.

CALENDAR of Coming Events

MAY 23-25—1951 IRE Technical Conference on Airborne Electronics, Biltmore Hotel, Dayton, Ohio.

JUNE 20-22—IRE Seventh Regional Conference, Seattle, Washington.

JUNE 25-29—1951 Summer General Meeting of AIEE, Royal York Hotel, Toronto, Canada.

AUG. 22-24—7th Annual Pacific Electronic Exhibit, San Francisco Civic Auditorium, San Francisco, Calif.

OCT. 22-24—7th Annual National Electronics Conference, Edgewater Beach Hotel, Chicago.

PHOTO CREDITS

3, 5 . . . . Sylvania Elec. Prod. Inc.
6 . . . . Nat. Bureau of Stds.
7 . . . . Ohio State U. Research Foundation
13, 14, 15, 30 . . . . Franklin Airloop Corp.

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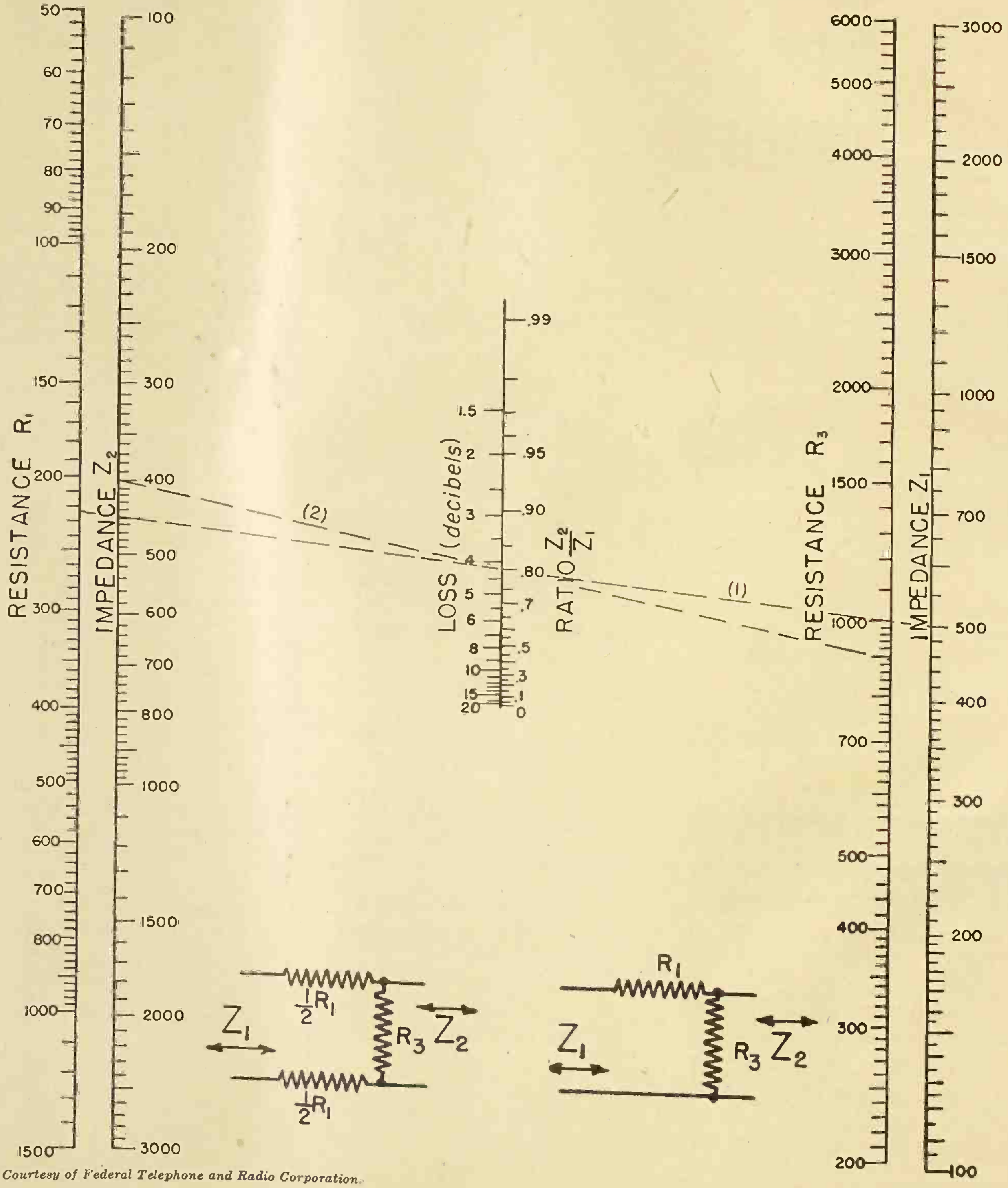
The nomograph is entered at the proper point on the "Ratio Z_2/Z_1," scale. A straight line through this point and the proper point on the Z_1 scale intersects the R_1 scale at the correct value for R_1. Similarly, a straight line through the same point on the "Ratio Z_2/Z_1" scale and the proper point on the Z_2 scale intersects the R_3 scale at the correct value for R_3. The loss in the pad is given on the "Loss" scale.



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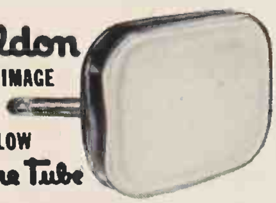

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