ISSUE 6

DU MONT Instrument Journal

DU MONT

INSTRUMENT DIVISION

DU MONT
Instrument
Journal

A PUBLICATION DEVOTED TO ELECTRONIC INSTRUMENTATION AND RELATED FIELDS, PROVIDING THE LATEST INFORMATION ON DEVELOPMENTS IN EQUIPMENT, APPLICATIONS AND TECHNIQUES. PERMISSION FOR REPRINTING ANY MATERIAL CONTAINED HEREIN MAY BE OBTAINED BY WRITING TO THE EDITOR AT THE ADDRESS BELOW.

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On The Cover

Electronic circle drawing helps Dr. Morgan Upton maintain rigid controls over subjects in group psychological testing at Rutgers University (New Brunswick, N. J.). Chairman of the State University's psychology department, Dr. Upton utilizes Du Mont Type 401 Oscilloscopes (featuring identical X and Y amplifiers) in these tests which are being made to determine the relation of what man thinks he perceives to what has actually been presented to him. Dr. Upton is shown obscuring a white disc stimulus after it has been exposed to the subject for a fixed period of time; then the subject attempts to duplicate what he thinks is the size of the disc by expanding or contracting the electronic circle on the oscilloscope screen by a simple turn of a knob.

The winner of our IRE Show Oscilloscope Pattern Contest is announced and introduced on page 6. Five runners-up, who will receive *Du Mont Instrument Journal* binders, are also mentioned.

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OSCILLOSCOPE PHOTOGRAPHY BY POLAROID-LAND PROCESS

by H. P. Mansberg
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A basic discourse on oscilloscope recording with Polaroid-Land photographic materials. Procedures for beginners are detailed, as well as pertinent information for the master. A discussion on writing rate parameters is given as well as the steps taken to obtain such figures. Primary types of Polaroid-Land photographic materials in their relation to end results is explained. To anyone working with or interested in such photography, the article will be of great informative value.

Part I

Although we have in the past published an extensive amount of information on conventional photorecording techniques, and many talks have been given on this subject, very little up-to-date information has so far been published on the specific subject of Polaroid-Land Oscilloscope Photography. Unquestionably the field of single frame photorecording of both stationary patterns and transients on the cathode-ray tube screen is now largely dominated by the Polaroid-Land photographic process. Improvements in both the quality and emulsion speed of Polaroid-Land materials have continued since the introduction of the Type 40 material just a few years ago. In fact, improvements have been so rapid that information which might have been published two years ago would probably be obsolete today.

The Polaroid-Land process (called a Diffusion-Transfer Reversal Process) is in reality a more conventional photographic process than the layman realizes (compared to techniques such as electrophotography, photosensitive glass and plastics, etc.). It is still basically a silver haloid process which is subject to some of the limitations and many of the advantages of conventional silver haloid photography. It also has a number of advantages not possessed by other photographic systems. The techniques which have been published, therefore, in the Du Mont *Oscillographer* and in our booklet *Techniques of Photo-Recording* still largely apply, but it is important to review some of these techniques, particularly stressing those factors which affect Polaroid-Land photography, and to present data and suggestions which we hope will be helpful to oscilloscope users.

Basically, the Polaroid-Land processing chemicals, in the pods attached to the film, are a thickened monobath mixture containing developing and silver halide solvent agents which cause silver reduction and fixing to proceed concurrently. The processing fluid is spread in a thin vis-

TABLE I

Relative Speeds of Polaroid Land Films for Oscilloscope Recording

Based on the Recording of Single Transients from P11 Phosphor Screens

Film Type	ASA Index (daylight)	Relative Speed* Normal	Prefogged
41, 31	100	1	10
42, 32	200	3	10
44	400	10	40
46, 46L	1000	10	30
Eastman Kodak** Tri-X Pan 35mm	250	60	—

*These numbers were arbitrarily assigned based on maximum photographic writing rates obtained using a Type 329-A Oscilloscope and Type 302 Camera with f/1.9 lens. Type 41 was assigned a value of 1 and the others followed by ratio of writing speeds obtained.

**Tri-X Pan film added to Table for comparison.

cous layer between sensitive and nonsensitive coated materials which are pressed together. Negative and positive images are formed concurrently, the negative on the sensitive layer and the positive on the nonsensitive layer. The reaction products of image formation in the viscous solution adhere to the negative so that when the positive is peeled off it contains only the transferred silver image which is permanent.

Those who have developed their own film, using conventional materials, may have observed that if the film was severely overexposed or exposed to light during development or before fixing, that an uncontrolled image reversal occurred. This effect sometimes called Solarization is one method of making direct positive images. The direct positive film for the black and white movies you take with your motion picture camera is also reversed during processing. The Polaroid-Land process however is unique in that it does not utilize a reversing exposure to produce a positive print, and that separate positive and negative images are concurrently produced.

Film Sensitivity

Although the effective sensitivity of the early Polaroid-Land materials to CRT traces was so low as to limit its usefulness to, almost entirely, recording stationary patterns, the ASA speed of the new materials such as Type 44 and 46L are as high or higher than those assigned to conventional high speed negative emulsions. However, the ASA speed index is not a suitable measure of the emulsion speed for transient oscilloscope recordings. A useful characteristic of Polaroid-Land film is that it responds very significantly to sensitization by prefogging, much more so than the ordinary negative film emulsions. More will be stated on this subject later. The availability of the new positive transparency Polaroid-Land material now makes it more likely than ever that crude sketches of oscilloscope waveforms in engineering reports and technical papers will be replaced by clear, reputable photorecordings. The ease with which prints can be made by dizaotype machines and the rapidity of preparing slides makes Oscilloscope Record cameras more useful than ever.

Available Polaroid-Land Films

The following paragraphs briefly describe the various Polaroid-Land films available and give some information about their characteristics. Table 1 also lists these films and provides a relative speed number which we have arbitrarily assigned to them on the basis of their maximum photographic writing rate capability for single transients. For comparison, a relative speed number is shown for a conventional high speed photographic film emulsion. (Tri-X)

Types 31 and 41 Film

This film is Orthochromatic, having its highest sensitivity in the blue-green region. It is very suitable for the recording of stationary patterns and slow speed transients, particularly on the P11 screen. For steady state patterns it is certainly suitable for most phosphor screens. This film would not be recommended for photographing just the long persistence component of screens such as the P2, P7, P14, P19 and P25. That is, an orange or red filter should not be used on the oscilloscope with Types 31 or 41 film. It is the slowest of all of the Polaroid-Land materials, for single transient recording, but it responds most to sensitization by prefogging, giving about a tenfold increase in writing rate over the unsensitized condition.

Types 32 and 42 Film

This is a Panchromatic emulsion, which means it is sensitized to the yellow, orange, and red portions of the spectrum, as well as to the blue and green. Therefore it can be used to photograph the yellow or orange afterglow of long persistence phosphors, even when these cathode-ray tubes are covered with an orange or amber filter. An important characteristic of this film is that it has a greater gray scale range (it has a greater linear portion in the Density vs. Log Exposure curve) than Type 41 film. This gives one a better chance of recording the higher writing speed portions of a trace without over exposing very low writing portions of the same trace. For example, in recording a square wave with Type 41 film, a normal exposure for the flat top portion often results in the rise and fall portions of the wave form being invisible. The Type 42 film, on the other hand, is more likely to produce a usable exposure for the higher writing rate rise and fall portions near the threshold of the D vs. log E curve. This film is also faster than Type 41, but it responds less to prefogging (see table 1). It is less expensive than the very fast films to be described next, but it is more expensive than Type 31 and 41. It is the film most likely to be found at the local photographic supply store.

Type 44 Film

This is a very fast Panchromatic emulsion, making it very useful with all of the cathode-ray tube phosphors. It is faster than Type 41 and Type 42, and it responds to sensitization by prefogging—but to a lesser extent than Type 41. It is always the preferred Polaroid film for high speed transients except where positive transparencies are required for printing or projection. It also has a better gray scale range than Type 41, giving it similar advantages to Type 42 for obtaining adequate exposure for high and low writing rate portions of a trace.

Types 46 and 46L Film

This is a very fast Panchromatic positive transparency film which produces good transparencies for printing on diazotype print machines or projection. It has an extended gray scale, nominal contrast and wide exposure latitude, giving it similar advantages to Type 42 and Type 44 film. It provides approximately the same maximum photographic writing speed as Type 44 and responds well to prefogging. Note (Table 1) that although this film has an ASA speed rating of 1000, it does not produce higher single transient writing speeds than the Type 44.

This film requires two minutes for full development rather than 1 minute as required for the other materials. The emulsion is very sensitive to scratching so that after drying it must be dipped in a special solution

(*continued on page* 16)

OSCILLOSCOPE PATTERN CONTEST RESULTS

At the 1958 I.R.E. Show, Du Mont presented the opportunity to all visitors to participate in a contest of technical "know-how". A simulated three dimensional display was presented on a Du Mont Type 401 Oscilloscope, and it was the task of contestants to describe how the display was created. The one person most closely describing the exact method was awarded a Du Mont portable television set.

Mr. A. D. Baker, of Rochester, N. Y., was adjudged to be the recipient of the TV set by the judging board. A short background story on Mr. Baker is given below, followed by the exact solution by Du Mont and the report of the judging board, and a condensation of Mr. Baker's solution.

Other gentlemen deserving honorable mention for "coming close" are: Mr. John W. Dozier, Baltimore, Md.; Mr. Sam Zaslavsky, Bronx, N. Y.; Mr. C. F. Verra, Rockville, Md.; Mr. Eugene J. D'Amato, Erlton, N. J.; and Mr. Douglas MacMaster, North Granby, Connecticut.

Mr. A. D. Baker

Mr. A. D. Baker has been an employee of Eastman Kodak Company, Rochester, N. Y., for over eleven years. He is an electronic engineer, designing cathode-ray and sundry electronic instruments for the company.

During World War II Mr. Baker was engaged in national defense work at John Hopkins Applied Physics Laboratories in Silver Spring, Maryland. Prior to that he worked seven years as a radio and television theory instructor for what is now Central Technical Institute, of Kansas City, Missouri. After having worked in the latter establishment for four years, he set up and supervised the school's airline radio maintenance training program.

According to one of his associates, Mr. Baker is an ardent TV viewer. In fact, the circuit diagram submitted with his solution to the contest was conceived by him while watching a television program in a hotel room. Mr. Baker claims that the complete solution took him about 1½ hours. Our congratulations on his success.

Description of Du Mont Three Dimensional Display

The cathode-ray oscilloscope is most commonly considered to be a device for displaying information in the form of one or more variables as a function of time. Yet osciloscopes are frequently used to display the output of one transducer against the output of another, e.g., in plotting stress-strain curves, hysteresis loops, vectorcardiograms, etc. Sometimes a third variable is superimposed in the form of intensity modulation or blanking marks.

It has been shown, by a number of investigators, that simple electrical operations make it possible to represent functions of three variables in the form of an isometric, oblique projection or perspective picture on the

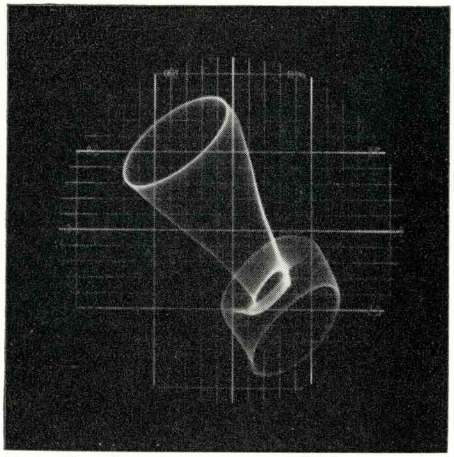

Figure 1. The simulated three-dimensional display pattern for the IRE contest.

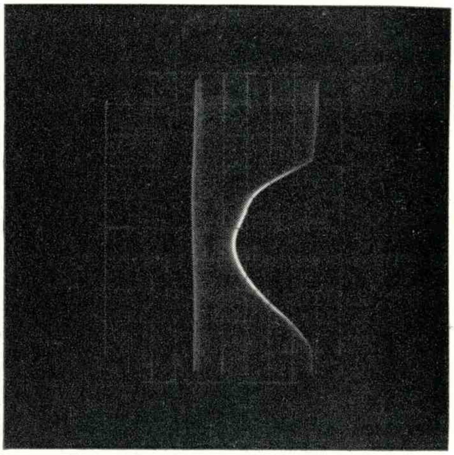

Figure 3. Modulated 10 kc signal.

cathode ray tube screen.[1-2-3] Such displays have applications in the fields of analog computers, radar, mechanical measurement, electromagnetic theory and others.

The object of the IRE display was to illustrate the usefulness of an oscilloscope, particularly one with equal gain -Y amplifiers, in plotting complex functions of three variables. For obvious reasons it was desirable also to present a pattern which had a recognizable shape and which would arouse interest.

Using techniques described in the reference the display pattern of Figure 1 was presented. The three signals were: a 10 KC sine wave, a 60 cps sawtooth voltage and a 60 cps sine wave. Referring to the block diagram of Figure 2, the output of a sinewave oscillator (10 KC) was modulated by a 60 cps sine wave obtained from a filament transformer. A very simple form of modulation was used (non-linear portion of diode characteristic) and the 10 KC carrier was partially clipped as shown in the modulation pattern of Figure 3. Careful inspection of the display pattern (Figure 1) will show a slight flattening at the neck of the cone and a

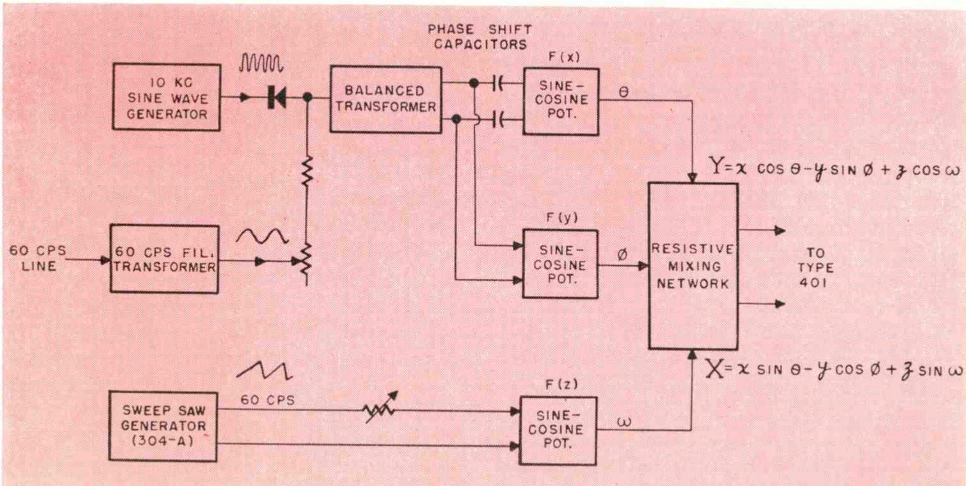

Figure 2. Block diagram of Du Mont method.

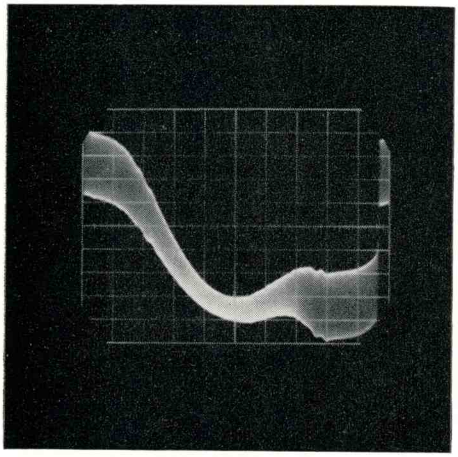

Figure 4. X-input to the Type 401 oscilloscope.

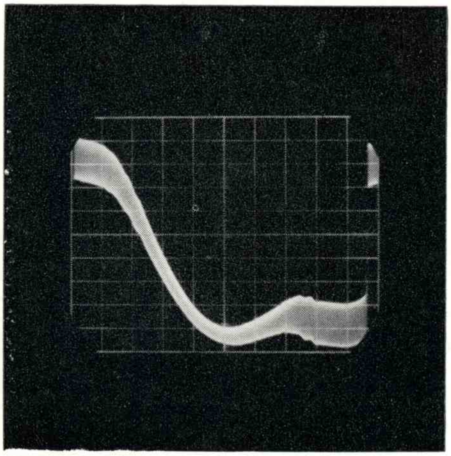

Figure 5. Y-input to the Type 401 oscilloscope.

corresponding bright edge all along that side of the cone, caused by this distortion. None of the contestants seemed to notice this effect as judged by the entries.

The modulated high frequency signal was then coupled through phase shifting capacitors to a sine-cosine potentiometer labeled **F** (x) and directly to another sine-cosine potentiometer labeled **F** (y). A 60 cps sawtooth waveform synchronized to the line frequency was fed to another sine-cosine potentiometer, **F** (z). The capacitors in combination with the resistance value of the sine-cosine potentiometers produced a phase shift of approximately 40° to give the elliptical shope.

To represent three coordinate electrical data or the x, y, and z coordinates of a point in three dimensional space, on a single plane, the signals may be resolved into **X-Y** plane projections by the use of sine-cosine functions of the angles made with this plane. Detailed discussions and mathematical derivations concerning these transformations may be found in the references cited.

Although any type of sine-cosine resolver can be used for the purpose (and similar patterns can be produced without such resolvers) sine-cosine potentiometers were used for convenience and relative independence of frequency. The use of three sine-cosine potentiometers makes it simple to rotate the entire figure into any quadrant of space and to view it from any "angle".

Finally a resistive mixing network was connected to the output of the resolvers to obtain the **X** and **Y** summations shown in Figure 2. The waveforms obtained at the **X** and **Y** inputs respectively, of the Type 401 are shown in Figure 4 and 5. These **X** and **Y** signals consist of 10 KC sine waves modulated by a 60 cycle sine wave to which a 60 cps sawtooth waveform is added. The actual appearance of the display depends on the portion of the 60 cps sine wave to which the sawtooth is synchronized and the setting of the three resolvers. For example, if the sawtooth is allowed to drift out of synchronization the pattern drifts through the stages shown in Figures 6 and 7.

Description of Winning Entry

Although none of the contestants produced explanations and circuit configurations identical with those described above a number showed that combinations of two sawtooth voltages and a higher frequency sine wave would produce a similar pattern. The earliest postmarked and one of the best detailed of these entries was that of Mr. A. D. Baker. Portions of his description and circuit diagrams are shown below:

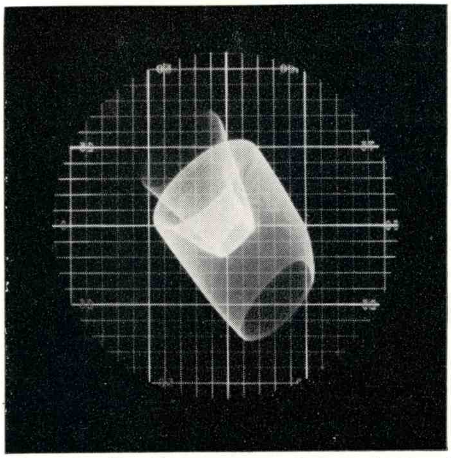

Figure 6. The display pattern of Figure 1 allowed to drift.

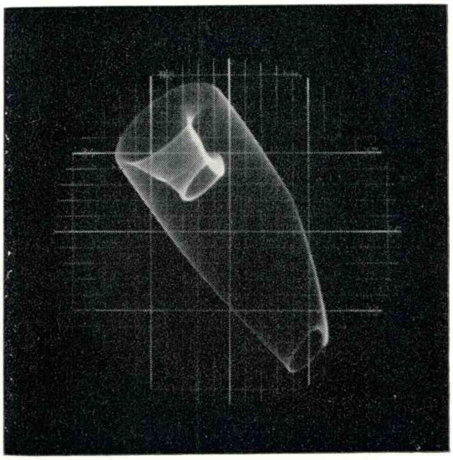

Figure 7. Another stage of the display pattern of Figure 1 if allowed to drift.

"The pattern appears to be that of a circular sweep as produced by two sine waves phase shifted 90° modulated approximately 33% by a sawtooth wave. The three dimensional effect may be produced by adding the modulating sawtooth component to the higher frequency modulated components. Phase shifting the modulating sawtooth component relative to the added sawtooth component will produce the effect of the ring around the apex of the cone. Except for the 90° phase shift between the wave components, identical signals are fed to both deflection amplifiers."

The block diagram submitted by Mr. Baker is shown in Figure 8.

(*continued on page* 15)

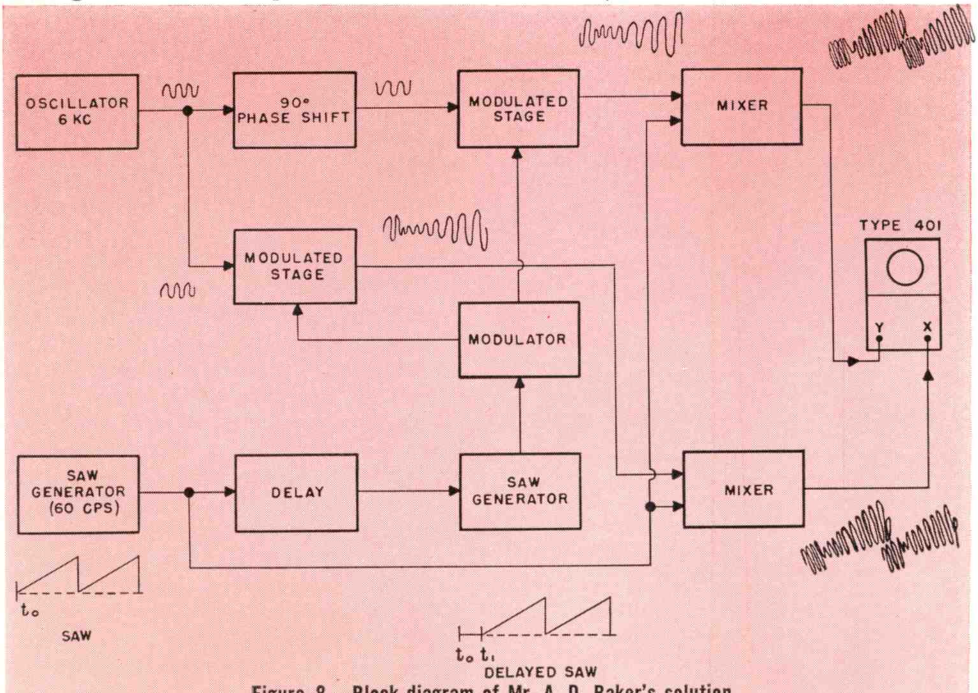

Figure 8. Block diagram of Mr. A. D. Baker's solution.

CONCERNING PULSE CHANNELS

Particularly Those in Oscilloscopes

by: William J. Judge

Section Manager: High-Frequency Instruments

Du Mont Instrument Division

Part II

Part I of this two-part article appears in Issue 5 of the Du Mont Instrument Journal.

D. Delay Distortion - Phase Bandwidth

In the development of an expression for the maximum build-up rate in the previous section the sine components of the step-wave were assumed to be in the phase at $t = 0$; i.e., they were in time coincidence. As a practical matter the time of coincidence, say t_D, need not be zero, but any value. Now any channel consisting partially of reactances developes an apparent time delay by virtue of its phase-shift characteristics, although a time delay as such does not really exist. Time delay implies a finite velocity of propagation taken over some path length, such as in free space or transmission line propagation.

In a lumped circuit the idea of velocity is meaningless since length is not one of the circuit parameters. The lumped circuit will always develop an instantaneous response at its output coincidentally with the application across its input terminals of some driving force; the response will generally be rather small until a certain time, t_D, has elapsed, after which a normal build-up occurs. This virtual delay time, t_D, being a function of the phase shift characteristics of the lumped circuit, is more appropriately denoted as the phase delay — given mathematically

$$t_D = \frac{\phi(\omega)}{\omega} \qquad (11)$$

where $\phi(\omega)$ is the channel phase characteristic. If $\phi(\omega)$ is a linear function the phase delay will be a constant. Obviously this is the most desirable situation since with the constant phase delay all the frequency components of the driving force will be in time coincidence at the channel output terminals.

Since the primary interest here is confined to low-pass channels, the value of $\phi(\omega)$ will always be equal to zero at zero frequency. The phase delay, t_D, however, has a finite value at zero frequency and this may be

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Mr. William J. Judge is manager of the high-frequency instrument section of Du Mont's Instrument Engineering Department. During his six years with Du Mont, Bill also had extensive engineering experience in the Television Transmitter Department—serving there as senior engineer. Although he holds a B.S. degree in Mathematics, his endeavors and interest have been in electronic development. He is a member of the IRE. He has written several articles in the electronic field for professional trade publications, and we are pleased to present his latest written contribution to the industry.

simply illustrated by considering the network of Figure 2. The phase-shift is given by the expression

$$\phi(\omega) = \arctan \omega RC$$

and the phase delay by

$$t_D = \frac{\phi(\omega)}{\omega} = \frac{\arctan \omega RC}{\omega}. \quad (12)$$

Although this latter expression becomes indeterminate at $\omega = 0$, its value is readily found via L'Hospital's rule, thus —

$$t_D = \lim_{\omega \to 0} \frac{\phi(\omega)}{\omega}$$

$$= \lim_{\omega \to 0} \frac{RC}{(1+\omega^2R^2C^2)} = RC.$$

Likewise ,as the frequency becomes undefined, equation (12) approaches zero as an upper limit since its numerator is bounded. Now all physical lumped channels exhibit the identical characteristic — i.e. — the phase delay is finite at zero and zero at undefined frequency. This is because the phase-shift is a function of the number of reactances in the circuit and so long as that number is finite, $\phi(\omega)$ is always bounded—hence the zero phase delay limit.

The significant point, therefore, is that in a physical lumped channel constant phase delay may not be realized over the whole energy spectrum. Of even more significance then, is the departure from constant phase delay, the relative phase delay, for a channel having relative phase delay different from zero no longer has its minimum build-up time equal to equation (10) — since all the frequency components of the driving force are not in time coincidence at the channel output terminals. The relative phase delay, thus, is the measure of delay distortion in a channel.

For minimum phase shift networks $\phi(\omega)$ is fixed by the prescribed attenuation characteristic $R(\omega)$, and if one is varied so is the other. These networks, furthermore, exhibit a reactance characteristic analogous to the concept of equal energy spectra for equal C described previously—i.e. — the area under the reactance characteristic is simply determined by the real part of the channel characteristic at zero frequency. Thus, if we again consider the network of Figure 2

$$\int_0^\infty \frac{X}{\omega} d\omega = -R_L \left[\arctan \omega RC\right]_0^\infty$$

$$= -\frac{\pi R_L}{2} \quad (13),$$

which also holds when any minimum phase non-dissipative coupling network N (Figure 3) is included. What equation (13) says is that the total area under the imaginary characteristic is determined only by the values assumed by the real characteristic at zero and undefined frequency—i.e.— the integral is independent of path. This leads to the obvious conclusion that if the major change in the real component is confined to a small frequency interval of the channel energy spectrum, then a pronounced change

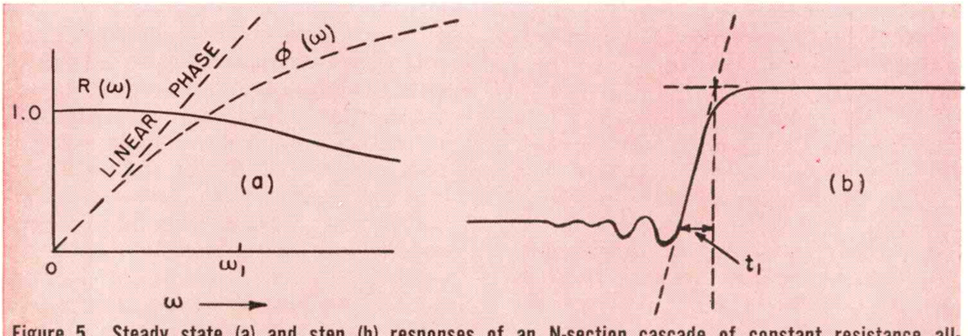

Figure 5. Steady state (a) and step (b) responses of an N-section cascade of constant resistance all-pass networks having a monotonic delay characteristic.

in phase shift occurs over the same interval; in the same way, if the real characteristic is gradually decreasing (curve 2, Figure 4) $\phi(\omega)$ describes a broad curve. The relative phase delay of a minimum phase shift channel having such a monotonically decreasing envelope shape will consequently contribute little in the way of delay distortion since a large portion of the phase area exists over that part of the energy spectrum where the real part is quite small.[5]

Certain low-pass channels, however, may consist of a large number of non-minimum phase shift networks in cascade (viz: a virtual delay line). It is quite common for these channels to exhibit severe departures from constant phase delay over portions of the spectrum where the attenuation is negligible. As an example, consider an n-section cascade of constant resistance all-pass networks having the characteristic shown in Figure 5a. At the frequency ω_1, the relative phase shift is $\frac{\pi}{2}$ and the attenuation is about 10%. (Theoretically, of course, an all-pass network is lossless. The finite Qs of the physical network reactances, nevertheless, account for a gradual attenuation.) The step response (Figure 5b) indicates a build-up time

$t_1 = \frac{\pi}{\omega_1}$ between steady-state levels

and a preceding oscillation of frequency f_1. Thus, the build-up time is determined here by the relative delay characteristic and not the channel energy spectrum. We may say that this channel has a *phase bandwidth* of f_1 — certainly the amplitude bandwidth is much greater.

The significance of the $\frac{\pi}{2}$ relative phase shift frequency becomes intuitive if one considers the time position of the inflection point of any sine component, of the step-wave, occurring at a frequency greater than f_1. These components, having a relative phase shift greater than $\frac{\pi}{2}$, do not contribute to a faster build-up, but rather account for the preswings.

Summarizing, delay distortion has the following deleterious effects on the channel response:

a. introduces an assymetrical component into the transient response which is subjectively poor (Figure 5b)
b. limits the speed with which the channel can transmit information (the phase bandwidth) and consequently reduces the maximum rate of build-up.

In general, the phase bandwidth of pulse channels has not received the engineering consideration it deserves, although its presence has been recognized inadvertently; namely, through manifestation of longer build-up time than calculated (or measured) from the amplitude response, and via transient assymetry. A well designed channel will minimize the assymetry through linearization of $\phi(\omega)$ to some compromise frequency.

E. Optimizing the Channel Characteristic

A linear channel will be distortionless only if its input and output waveforms are identical. Since the input waveform may be analyzed into a spectrum of sinusoidal terms, the channel must not discriminate against any term, i. e., it shall not be frequency selective. Frequency selection can occur in two ways — effecting either the relative amplitude or phase (or both) of any term in the waveform spectrum. Physical channels, of course, exhibit both types of selection and the engineering problem is to optimize the channel capabilities consistent with the application.

Conventionally, the pulse, (or vertical) channel of an oscilloscope is expected to exhibit distortion only in

5. Bode, H. W., Network Analysis & Feedback Amplifier Design, pp 286.

regard to build-up time (Fig. 1b). This imposes definite restrictions on the channel characteristics which have been generally set down in section A (Issue 5, page 3) and it seems desirable at this time to elaborate a bit more on those three requirements. The necessity for constant phase delay should now be obvious in view of the discussion contained in the previous section. As a practical matter, the phase characteristic will be linearized to some compromise frequency such that the economics of the situation are satisfied.

For example, in a channel consisting only of minimum phase networks the amplitude and phase characteristics are interdependent and the best possible compromise must be realized. When non-minimum phase networks are present*, a much simpler situation exists since those networks permit adjustment of the phase without effecting the amplitude characteristic.

The other two requirements concern the transfer modulus and merely state that the channel shall exhibit a monotonic attenuation characteristic (drooling roll-off). Convention appears to be completely in charge here, but not without virtue. Such a characteristic — a. permits derivation of a step response having a single pronounced inflection point (Fig. 1C) which is subjectively good. b. simplifies the analysis of complex waveforms whose spectra lie mostly within the channel transfer modulus. c. extends the high frequency usefulness of the channel well past the half power frequency. d. develops a near constant phase delay and simplifies the correction problem. The principle objections to the monotonic shape are its inability to realize the minimum 10-90% build-up time within the confines of the channel capabilities, and the shape itself (for sinusoidal or narrow band† measurements a flat response is more desirable).

*Usually in the form of an all-pass virtual delay line.

†Such as an amplitude modulated carrier.

6. Kenney, J. F. *Mathematics of Statistics*

The limiting envelope shapes for a family of monotonic responses having identical energy spectra are illustrated by Fig. 4, where curve #2 is the uncompensated RC case. The corresponding step responses (due to R (ω) only — the phase delay is assumed to be constant) indicate somewhat different build-up paths except at the half amplitude points where the maximum rate of build-up is encountered. Of particular significance is the difference in the so called rise time†† which is $0.8\pi/\omega$, for the flat-top versus $1.7\pi/\omega$, for curve #2. Thus, envelope shapes belonging to the same family can exhibit rise times which differ by more than two to one.

The problem, therefore, is to obtain an envelope shape having the same finite bandwidth as those in Fig. 4 and a minimized rise time consistent with the distortion requirements. Obviously, neither of the responses of Fig. 4 are satisfactory — one suffers from ringing, the other from smear. Now since an indefinite number of monotonic envelope shapes may exist, for a given energy spectrum, it follows that their corresponding step responses may take on any form intermediate to those of Figure 4. Intuitively, then, there must exist a response which exhibits the fastest rise time without preswing and overswing, and likewise a response with a minute amount of both and still faster rise time. The latter case would appear to be more desirable in spite of Fig. 1b since conventionally some overswing is always specified and the rise time advantage is important. The monotonic shapes responsible for the aforementioned step responses are fairly well known as the Gaussian and "Cosine-Squared" curves respectively. Let us consider both in detail.

The normal curve of De Moirve is represented by the expression[6]

$$Y = \exp(-h^2 x^2) \qquad (14)$$

††Build-up time measured between 10% & 90% points of transition.

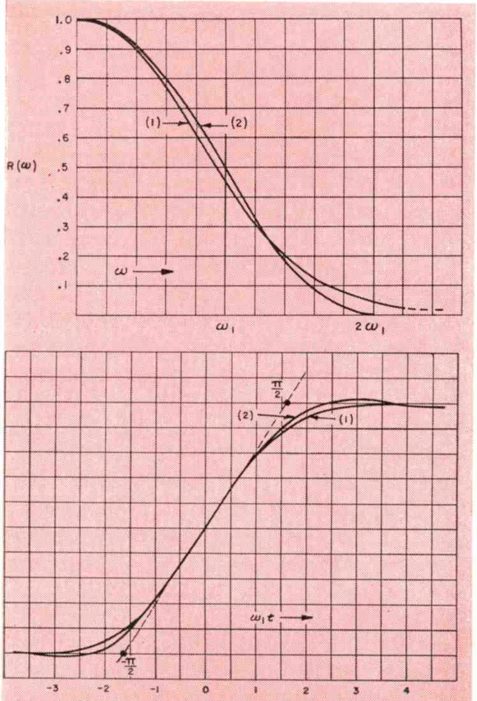

Figure 6. Steady state (a) and step (b) responses of two channels having equal energy spectra, and respectively — Gaussian (1) and Cosine-Squared (2) envelope shapes.

and the area $\int_0^\infty y dx$

is found by not so simple integration[7]

$$A = \frac{\sqrt{\pi}}{2h} \qquad (15)$$

The Gaussian curve is a special case thereof and exists for a certain value of h. It may not be realized physically but is approximated closely in an n-stage constant current RC amplifier when n is large (ten or more). As the number of stages is passed to the upper limit, the real part of the transfer characteristic is given by

$$R(\omega) = \exp\left(-\omega^2/k^2\omega_0^2\right) \qquad (16)$$

where

$k = 1.2$

$\omega_0 =$ half power frequency.

Equation (16) may be derived without too much difficulty[8] and is left as an exercise for the student. Consider a Gaussian curve belonging to the family of Fig. 4 and thus having an area

$$A = \int_0^\infty R(\omega)\, d\omega = \frac{\pi}{2}.$$

It follows, then, from (15) and (16) that the half power frequency

$$\omega_0 = \frac{\sqrt{\pi}}{K} = 1.48 = .94\omega_1.$$

The curve and its corresponding step response is illustrated by Figure 6.

Significantly, a rise time of $\frac{1.03\pi}{\omega_1}$ is obtained without preswing and overswing.

A further improvement over Gaussian response is obtained via the Cosine-Squared curve (Fig. 6) at the expense of slightly less than 2% preswing and overswing. This shape, which may be considered the optimum for an oscilloscope pulse channel, exhibits the form of one complete cycle of a cosine curve and has as it equation

$$R(\omega) = \tfrac{1}{2}\left[1 + \cos\frac{\pi\omega}{2\,\omega_1}\right]. \qquad (17)$$

The step response has a rise time of $\frac{.92\pi}{\omega_1}$, a speed-up of 1.12 over the Gaussian although its conventional bandwidth (3DB frequency) shows an improvement of only 6%. The Cosine-Squared curve, like the Gaussian, is non-physical but may likewise be closely approximated in physical systems. It is an easy curve to work with since its half amplitude point coincides with that of a flat-top and the 3DB and 6DB points are nearly reciprocally related.

The choice of Gaussian versus Co-

7. Wilson, E. B. *Advanced Calculus*
8. Cherry, C. *Pulses and Transients in Communications Circuits*

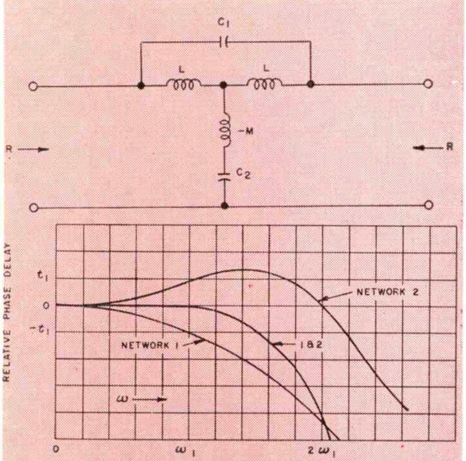

Figure 7. (a) The constant resistance all-pass filter network, (b) relative delay of two networks having the same driving resistance but different parameters, and relative delay of those two networks in cascade.

sine-Squared curves will depend upon the type of physical channel involved. Channels consisting simply of minimum-phase networks will, in general, exhibit a constant phase delay with a Gaussian response whereas the Cosine-Squared develops a lagging phase error. Consequently, little or no improvement in rise time is obtained since the requisite preswing cannot be realized and the step response is not skew-symmetrical. For those channels utilizing partially non-minimum phase networks, the Cosine-Squared response appears to be the better choice since its phase error may be corrected; i. e., the phase bandwidth of the channel is extended high enough in frequency such that a skew-symmetrical step response is developed and the superior rise time of the Cosine-Squared shape obtained.

The non-minimum phase networks are generally present in the form of a virtual delay line consisting of constant resistance all-pass filter sections. Networks of this type (Fig. 7) can have negligible attenuation over the useful part of the channel energy spectrum and yet develop a wide variety of relative phase delay characteristics dependent on the choice of network parameters[9]. By appropriate cascading of networks having the same driving resistance but dissimilar relative phase delays, the phase bandwidth of the line may be extended almost indefinitely. Furthermore, relative phase delay errors developed in that part of the channel consisting of minimum phase networks may be corrected to some compromise frequency by purposely introducing an opposite error in the virtual delay line. This principle is simply demonstrated with two networks by Figure 7. where, significantly, the phase bandwidth of a channel consisting of network #1 only is improved 50% by the addition of network #2.

9. Judge, W. J. "Simplifying Phase Equalizer Design." *Electronic Industries and Tele-Tech,* (May 1958)

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"Contest" (continued from page 9)

We congratulate Mr. Baker and wish him enjoyment in the use of his Du Mont Television set.

Judging Board

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OSCILLOSCOPE PHOTOGRAPHY BY POLAROID-LAND PROCESS

(*continued from page* 5)

to harden it. This is available in a very convenient plastic container called a "Dippit" which only requires a few seconds to use.

The transparency should be viewed by means of a strong uniformly diffused source of white light. For projection in standard 3¼ x 4 inch projectors, plastic frames are available, such that the positive transparency can be prepared for projection, within a few seconds, by snapping into one of these frames. A word of caution regarding projection is in order. When the transparency is mounted in these plastic frames it does not have the protection usually provided by standard lantern slides with cover glass. Therefore projectors with inadequate cooling, or very long projection exposure times will cause the film to buckle. For permanent lantern slides the positive transparency may be bound between standard 3¼″ x 4″ lantern slide cover glasses.

Which Film to Use in Du Mont Oscilloscope Cameras

The Type 302 Camera — Uses Types 41, 42, 44, 46 and 46L film. The Type 46 film provides 2¼″ x 2¼″ transparencies while the 46L provides 3¼″ x 4″ transparencies.

The Type 339 Camera — Uses Types 31 and 32 film.

Part II of the article, discussing actual photographing techniques, the determination of photographic writing rates, presensitizing films and other techniques, will appear in issue 7 of the *Du Mont Instrument Journal.*

The Engineer Speaks

Dear Sir:

"The writer was especially interested in the article entitled 'Oscilloscopes Invade the Automotive Industry' (Issue 3, page 12) because of a long-standing conviction that modern technology and engineering could make significant contributions to the automotive service field, particularly in diagnosing faulty operation, performance testing and evaluation of mechanical condition, by providing equipment for doing the job better, quicker, in quantitative terms and preferably in the form of graphical recordings. Your EnginScope is an outstanding example of this general type of equipment. However, there are several other automotive testing jobs for which currently available equipment is relatively inadequate. For example, there is a need for a good, quick-acting recording chassis dynamometer; a cylinder pressure recorder that will produce a record, in one minute, of the variations of pressure (and vacuum), at cranking speeds, within each cylinder of a 4-, 6- or 8-cylinder engine; a good reliable meter for indicating instantaneous values of fuel consumption rates in miles per gallon at various engine speeds and loads, etc., etc. For some time the writer has been working with a local automotive service engineering firm interested in using such equipment for quickly and accurately evaluating the condition and performance of used cars and fleet vehicles. It has turned out to be a long, uphill pull because suitable devices just don't seem to be available. Perhaps some of your readers are familiar with equipment of components adaptable for this purpose. If so, any relevant information or suggestions would be very gratefully received. There might even be enough available to constitute material for a future article on this subject in your interesting Journal!"

Sincerely yours,
W. Julian King
Professor of Engineering
University of California

Editor's Note: We're ready — send us the stuff.