THE OSCILLOGRAPHER

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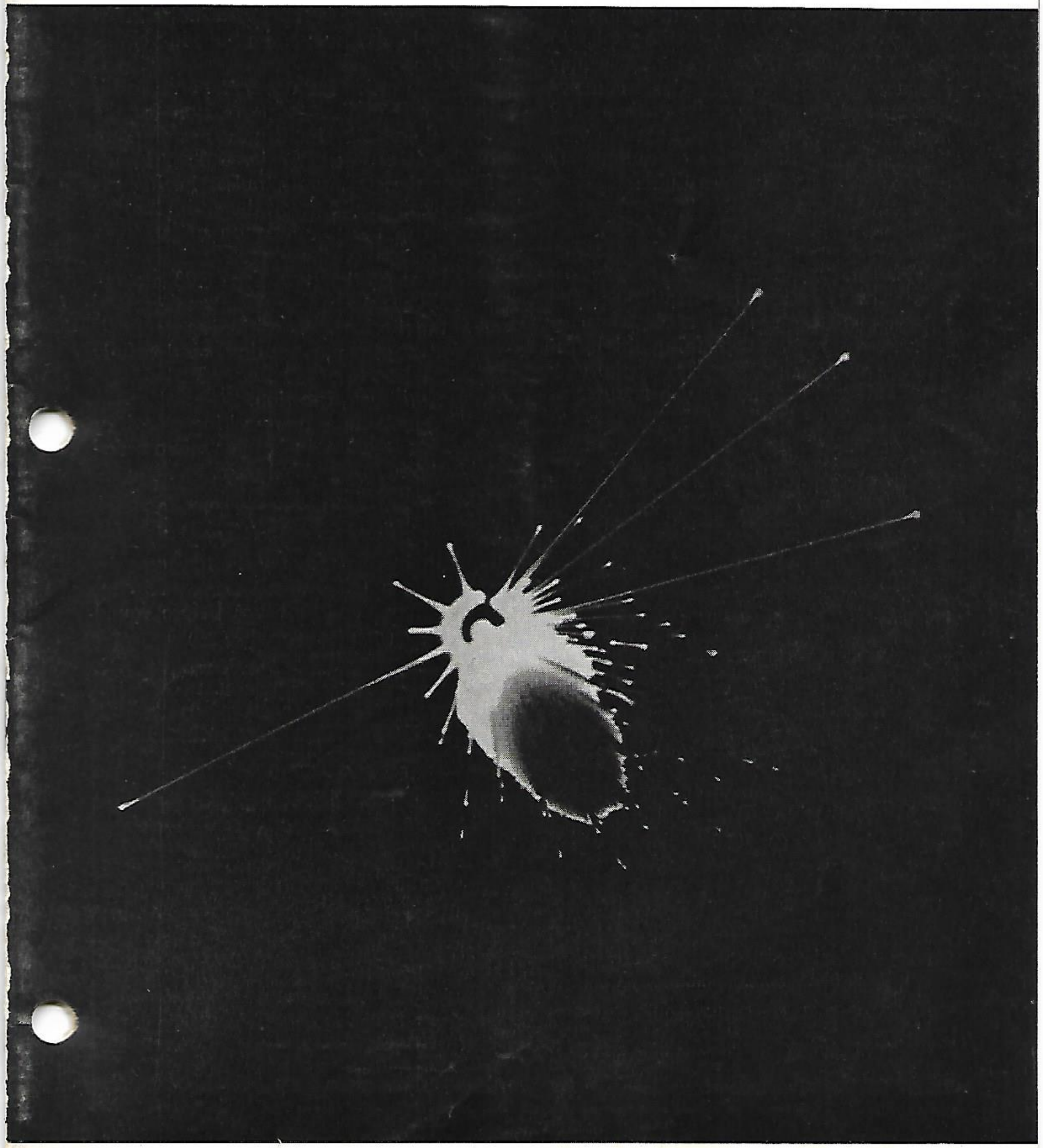

ELECTRONIC ENTOMOLOGY SEE PAGE 2

Du Mont "Spotlights the New" at the 1950 I.R.E. Show

The Radio Engineering Show of the I.R.E. will be held again this year at Grand Central Palace, New York City, from March 6 to 9. In keeping with the spirit of the 1950 Show to "Spotlight the New," the Instrument Division of Allen B. Du Mont Laboratories, Inc., will exhibit six wholly new cathode-ray oscillographs in booths 125, 126, 127, and 128. These new instruments, which cover the frequency spectrum from d-c to more than 100 megacycles per second, represent the very latest advances in the art of cathode-ray oscillography. On display will be:

1. *The NEW Du Mont Type* 303 *Cathode-ray Oscillograph*

This medium-price, 10-megacycle oscillograph is intended primarily for the investigation, both quantitative and qualitative, of signals containing high-frequency components. Displays of the new Type 303 will emphasize such features as the excellent response characteristics of the 10-megacycle vertical amplifier; vertical deflection factor of 0.1 volt per inch, with 2½ inches of undistorted deflection; driven and recurrent sweeps, continuously variable in duration from 0.1 second to 5 microseconds; sweep expansion; a built-in signal delay line; and a built-in voltage calibrator.

The specified frequency response, sensitivity, and undistorted deflection for the vertical amplifier include the performance of the delay line. The signal delay is sufficient that even with pulses having extremely short rise times, the entire leading portion of the phenomenon under study is reproduced on the trace.

Sweeps of the new Type 303 are expandable to six times full-screen diameter, and the horizontal positioning range is sufficient that any portion of the fully expanded trace may be examined on the screen, without distortion.

The maximum spot writing speed of the Type 303 is 5 inches per microsecond with the fully expanded trace.

2. *The NEW Du Mont Type* 304-H *Cathode-ray Oscillograph*[1]

This instrument, which replaces the well known Du Mont Type 208-B, contains many features never before found

(*Continued on Page* 23)

1 See "The New Du Mont Types 304-H and 304 Cathode-ray Oscillographs," by M. Maron in the OSCILLOGRAPHER, Vol. 11, No. 4, Oct.-Dec., 1949.

THE OSCILLOGRAPHER

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Neil Uptegrove - Editor

CONTENTS

ON THE COVER

This interesting and unusual pattern was recorded from the screen of a Du Mont polar-coordinate indicator, and shows the applied signal (low-amplitude radial deflections), upon which angle markers (high amplitude radial deflections, have been superimposed. In the words of Dr. P. S. Christaldi, Engineering Manager of the Instrument Division, this pattern demonstrates that even in the rare cases where the electronic engineer is unable to find "bugs" in his circuits, he is prepared to generate them electronically.

TYPE 292

Cathode-ray Oscillograph

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A Discussion of this New Instrument Which Sets a New High in Performance & Portability

By William J. O'Meara

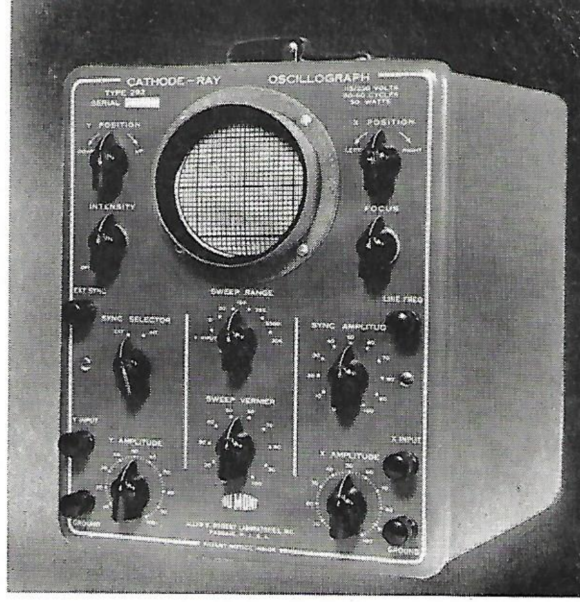


Figure 1. Du Mont Type 292 Cathode-ray Oscillograph

THE NEW Du Mont Type 292 Cathode-ray Oscillograph has taken its place in the Du Mont line of instruments, supplanting the well known Du Mont Type 164-E. This new three-inch oscillograph features extreme portability, combined with performance of an unusually high quality for an instrument its class. The rugged, compact design of the Type 292 suits it admirably to work in the field, while its excellent characteristics permit its use in many of the laboratory, industrial, and educational applications from which low-cost three-inch oscillographs have long been barred.

The compactness of the Type 292 is largely the result of the new type of cathode-ray tube with which it is equipped. This new tube, the Du Mont Type 3RP-A (See Figure 3), has an extremely short overall length (only 9⅛ inches) and has a flat face. The flat face permits the observation of wave forms with a minimum of error owing to paralax. And since the face is of uniform thickness, and is virtually free of blemishes, optical distortions are greatly reduced. To overcome the problem of pin cushion distortion usually associated with cathode-ray tubes of short length and large deflection angle, the vertical deflection plates are rounded (See Figure 4). Operated at an accelerating potential of 1000 volts in the Type 292, the Type 3RP-A displays a brilliant, well defined trace with extremely small spot size.

Deflection Amplifiers

Deflection factor on the Y axis of the Type 292, with the amplifier at full gain, is 0.40 rms volts per inch, and 22 rms volts per inch (±15%) when the signal is applied directly to the deflection plates. On the X axis, the deflection factor is 0.56 rms volt per inch with the amplifier at full gain, and with direct connection 31 rms volts (±15%). Sinusoidal frequency response of both X and Y amplifiers is uniform within 30% from 5 to 100,000 cps.

The horizontal and vertical deflection amplifiers of the Type 292 are similar (See Figure 5), and consist of dual-triodes connected to provide balanced output signals to the deflection plates of the cathode-ray tube. The use of balanced amplifiers improves performance in many respects (ie. amplitude linearity, freedom from astigmatism, and freedom from trapezoidal distortion).

The horizontal amplifier of the Type 292 may be used to amplify either the output of the time-base generator, or an external signal by proper adjustment of the coarse-frequency selector switch.

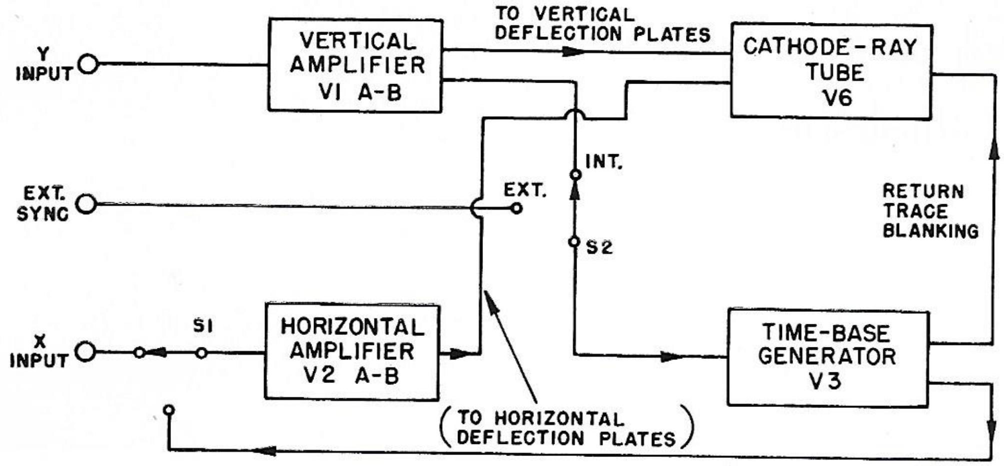


Figure 2. Block diagram of the Du Mont Type 292 Cathode-ray Oscillograph

In order to reduce the input capacitance of the amplifier, cross-coupled feedback is employed. This permits the input capacitance of a triode to approach that of a pentode.

Figure 5b is a simplified schematic of the amplifier, showing the feedback capacitance, C_f, from the plate of the second section of the tube to the grid of the first section, as well as the arbitrary positive directions of the grid and plate voltages at a given instant of time.

The important interelectrode capacitances of a dual triode are indicated on Figure 6. From this, it can be shown how neutralization or cross-coupled feedback is used to reduce the input capacitance.

Let C_f in the I_3 branch of Figure 6 be the feedback capacitance from the second plate to the first grid. It will be assumed that the circuit is symmetrical.

$$I_g = I_1 + I_2 + I_3 \quad (1)$$

The input admittance becomes:

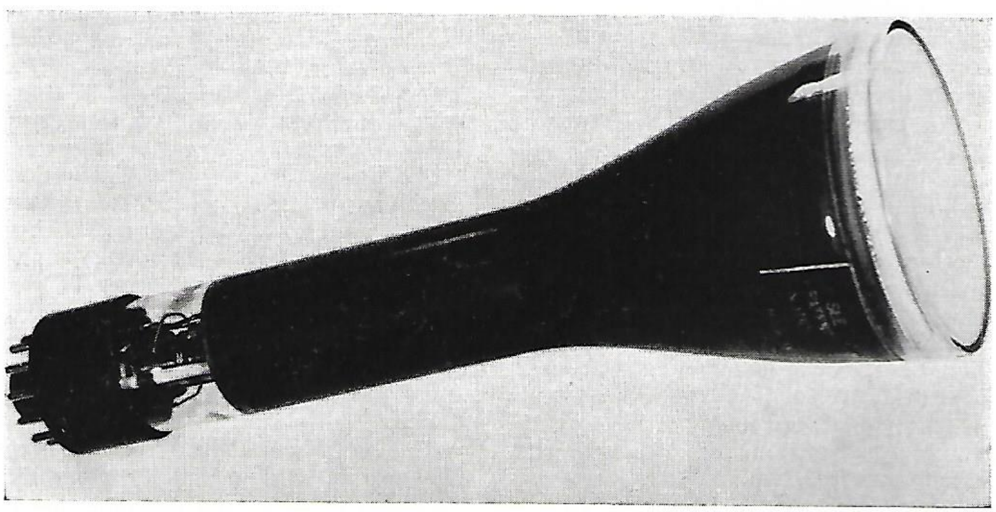


Figure 3. Du Mont Type 3RP-A Cathode-ray Tube. Note flat face and short overall length

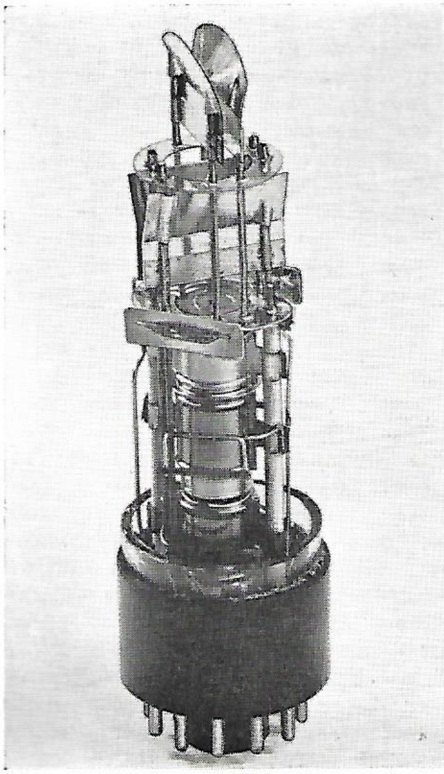


Figure 4. Electron-gun and deflection-plate structure of Type 3RP-A

$$Y_g = \frac{I_g}{E_g} = G_g + jB_g$$

$$= \frac{I_1}{E_g} + \frac{I_2}{E_g} + \frac{I_3}{E_g} =$$

$$= j\omega C_{gk} + \frac{I_2}{E_g} + \frac{I_3}{E_g} \qquad (2)$$

The following loop equations may be solved for the currents I_2 and I_3:

$$E_g - \frac{I_2}{j\omega C_{gp}} - E_p = O \qquad (3)$$

$$E_g - \frac{I_3}{j\omega C_f} - E'_p = O \qquad (4)$$

Then:

$$I_2 = (E_g - E_p)\, j\omega C_{gp} \qquad (5)$$

$$I_3 = (E_g - E'_p)\, j\omega C_f \qquad (6)$$

Substituting equations (5) and (6) into equations (2), the input admittance is given by:

$$Y_g = j\omega C_{gk} + \frac{(E_g - E_p)\; j\omega C_{gp} + (E_g - E'_p)\; j\omega C_f}{E_g}$$

$$= j\omega C_{gk} + \left(1 - \frac{E_p}{E_g}\right) j\omega C_{gp} + \left(1 - \frac{E'_p}{E_g}\right) j\omega C_f \qquad (7)$$

Let the gain of the first section be A and the gain of the second section be A′, which, when referred to the grid of section one is —A.

$$A = \frac{E_p}{E_g} = A_r + jA_i,$$

$$A' = \frac{E'_p}{E_g} = A'_r + jA'_i,$$

But since $E_g = -E'_g$,

$$A' = -(A_r + jA_i),$$

where the r and i subscripts refer to the real and imaginary parts respectively. Substituting this information in equation (7), we obtain:

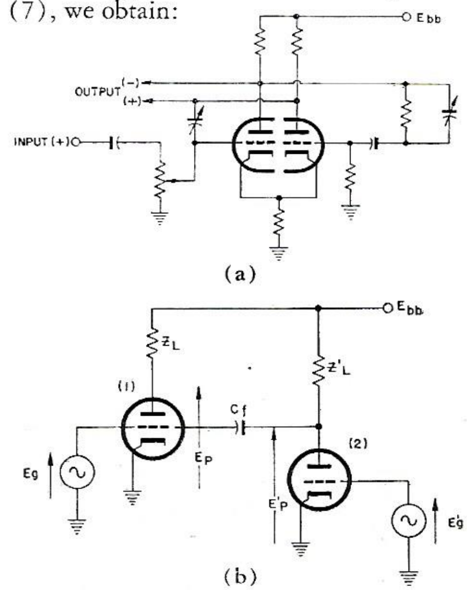


Figure 5. (a) Schematic of deflection amplifier of Type 292, (b) simplified version of same schematic, showing neutralizing capacitance, C_f, and the arbitrary positive direction of the input and output voltages

$$Y_g = j\omega C_{gk} + (1 - A_r - jA_i)\,j\omega C_{gp} + (1 + A_r + jA_i)\,j\omega C_f \quad (8)$$

In terms of A, the gain of the first section:

$$Y_g = (\omega C_{gp} - \omega C_f)\,A_i + j\omega\,[C_{gk} + C_{gp}\,(1 - A_r) + C_f\,(1 + A_r)] \quad (9)$$

When $C_f = C_{gp}$ the input capacitance of section one becomes:

$$C_{inf} = \frac{B_g}{j\omega} = C_{gk} + C_{gp}\,(1 + |A_r|) + C_f\,(1 - |A_r|) = C_{gk} + 2C_{gp} \quad (10)$$

The input capacitance of section one without the feedback capacitance may be arrived at by setting C_f equal to zero in equation (9):

$$C_{in} = C_{gk} + C_{gp}\,(1 + |A_r|) \quad (11)$$

Although equation (10) indicates a large reduction in input capacitance, this particular balanced amplifier will oscillate in a fashion somewhat similar to a multivibrator before this theoretical value of input capacitance is achieved. The value of C_f can, however, be made large enough to reduce the input capacitance substantially.

It is well to note here a caution concerning certain type 12AX7 dual triodes. Some early production lots of this Type, owing to faulty plate-structure design, were troubled with electron coupling between the sections as a result of cross-emission. Most offending tubes may be singled out by noting the plate surfaces which face each other. Those tubes whose plate structures contain small cutouts at the top and bottom of the inner plate surfaces will, in all probability, exhibit this coupling characteristic. Most manufacturers recognized this condition several months ago, and have corrected it. When observing a pattern on the screen of the cathode-ray tube, the effects of this electron coupling are visible as a bunching of the signal at the center of the pattern, similar to the origin distortion of early gas-filled cathode-ray tubes.

The outputs of the amplifiers are capacitively coupled to the deflection plates of the cathode-ray tube through a terminal board at the rear of the instrument. Since all the deflection plates of the cathode-ray tube are brought out to this terminal board, potentials may be applied directly to the deflection plates. When feeding signals directly to a deflection-plate pair, the signal source must provide the necessary ground path and positioning potential.

Linear Time Base

Sweeps of the Type 292 are continuously variable from 8 to 30,000 cps. The sweep voltage is generated by a conventional gas-tube circuit, employing a type 884 gas triode (See Figure 7). The return trace of the sweep is blanked out by differentiating the sweep "flyback" and

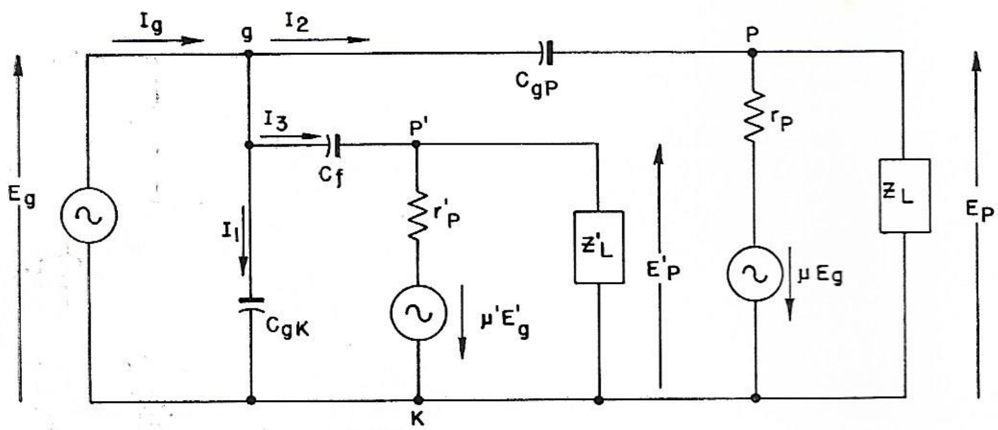


Figure 6. Equivalent circuit of amplifier showing important interelectrode capacitances

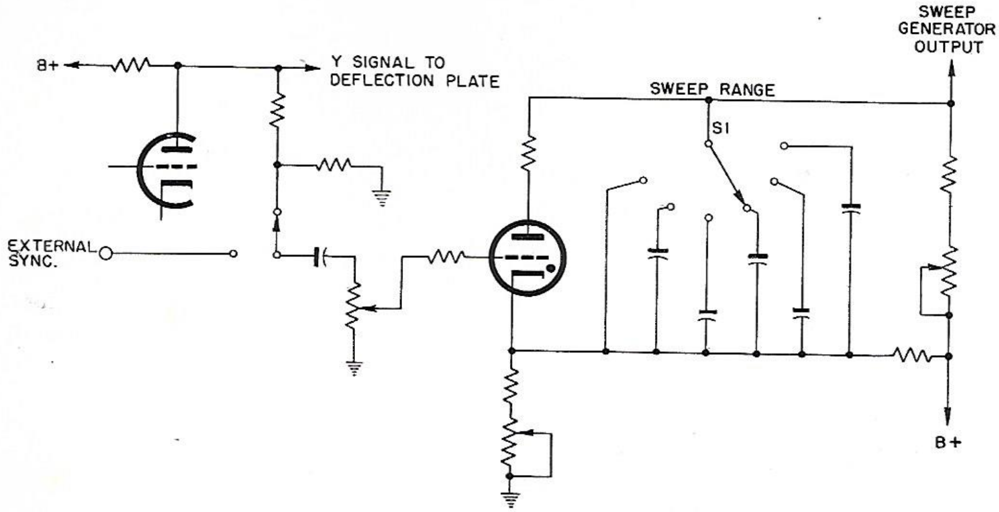


Figure 7. Schematic of sweep generator of the Du Mont Type 292

applying it to the grid of the cathode-ray tube.

The sweep may be synchronized internally by a signal obtained from the vertical amplifier, or by an external signal. A front-panel switch selects the synchronizing signal source. A signal at power-line frequency is brought out to a front-panel terminal post. This test voltage is convenient for checking the operation of electronic circuits, and also, for synchronizing the sweep at power-line frequency.

Mechanical Features

The compact mechanical design of the Du Mont Type 292 combines the desirable features of ruggedness and portability. This is possible by using, as stated above, the new, short Type 3RP-A Cathode-ray Tube, and by employing a die-formed front panel, together with a mating cabinet. The circuit layout provides for a unique location of the power transformer, in that the mechanical balance of the instrument is preserved, while the magnetic field of the transformer causes minimum deflection of the electron beam of the cathode-ray tube.

A magnetic shield encloses the Type 3RP-A Cathode-ray Tube completely in this instrument. The front portion of the shield extends through the front panel, offering some shielding from ambient light, as well as mechanical protection of the cathode-ray tube.

A Du Mont Type 216-A Calibrated Scale is supplied with the instrument. This scale is made of clear, laminated Vinylite, with black calibrations every 0.1 inch, vertically and horizontally, with each inch line accentuated. The scale is held in place by four Vinylite tabs, spaced equally around the circumference, which grip the sides of the tube. The scale may thus be easily attached or removed as desired.

The instrument's panel is finished in blue-gray enamel with white silk-screened markings, while the sturdy cabinet and the cathode-ray-tube shield are finished in blue-gray wrinkle.

The Type 292 is equipped with a comfortable, plastic carrying handle, an attached power cord, and a winding cleat. Another convenient feature is the provision of the die-formed feet on the bottom of the cabinet, which permit the instrument to be moved about easily, without its "digging in" to the surface of the working area.

Applications

The Du Mont Type 292 Cathode-ray Oscillograph was designed with maximum portability, consistent with good performance, as the goal. The Type 292 will be found particularly useful in the radio servicing field, for such operations as aligning and trouble shooting both a-m and f-m receivers. The Type 292 may also be used in radio-transmitter applications for aligning and neutralizing the transmitter, checking the a-f channel, monitoring transmitter output, as well as general trouble shooting. Here, the small size and light weight of the Type 292 make it extremely useful for work in the field, on remote receiving and transmitting equipment. Also, the compact and versatile Type 292 is well suited for the maintenance of remote electronic indicating and controlling devices in industrial establishments. In short, the Type 292 is to be recommended wherever a portable general purpose three-inch cathode-ray oscillograph is required.

* * *

William J. O'Meara, Intermediate Electronic Engineer with the Development Engineering Section of the Instrument Engineering Dept., Instrument Division, Allen B. Du Mont Laboratories, Inc., is the designer of the Du Mont Type 292 Cathode-ray Oscillograph.

SPECIFICATIONS

CATHODE-RAY TUBE
- Type 3RP-A
- Accelerating potential .... 1000 volts

VERTICAL AXIS
- Deflection Factor
  - Full Gain .... 0.40 rms v/in.
  - Direct .... 22 rms v/in. ± 15%
- Sinusoidal Frequency Response, uniform within 30% from 5 to 100,000 cps.

Maximum input potential 400 rms volts
600 d-c volts
600 peak volts

- Input Impedance
  - (unbalanced) Direct
    4.7 megohms max; 25μμf
  - Amplifier .... 1 megohm; 70 μμf

HORIZONTAL AXIS
- Deflection Factor
  - Full Gain .... 0.56 rms v/in.
  - Direct .... 31 rms v/in. ± 15%
- Sinusoidal frequency response, uniform within 30% from 5 to 100,000 cps.
- Maximum Input Potential 400 rms volts
  600 d-c volts
  600 peak volts
- Input Impedance
  - (unbalanced) Direct
    4.7 megohms; 25 μμf
  - Amplifier .... 1 megohm; 70 μμf

LINEAR TIME BASE
- Gas Triode .... Type 884
- Sweep-frequency range 8 to 30,000 cps

MISCELLANEOUS
- Test Signals on front panel at line frequency, approximately 6.3 rms volts.
- Minimum of three inches of positioning available when using amplifiers.

POWER SUPPLY
- Primary-Power Potential
  115 or 230 rms v. ± 10%
- Frequency .... 50-60 cps
- Power Consumption
  50 watts (approx.)
- Fuse Protection .... 1 ampere

TUBE COMPLEMENT
- 2 — 12AX7
- 1 — 884 Sweep Generator
- 2 — 80 rectifiers

PHYSICAL SPECIFICATIONS
- Height .... 10⅞″
- Width .... 8⅛″
- Depth .... 11″
- Weight .... 21 lbs.

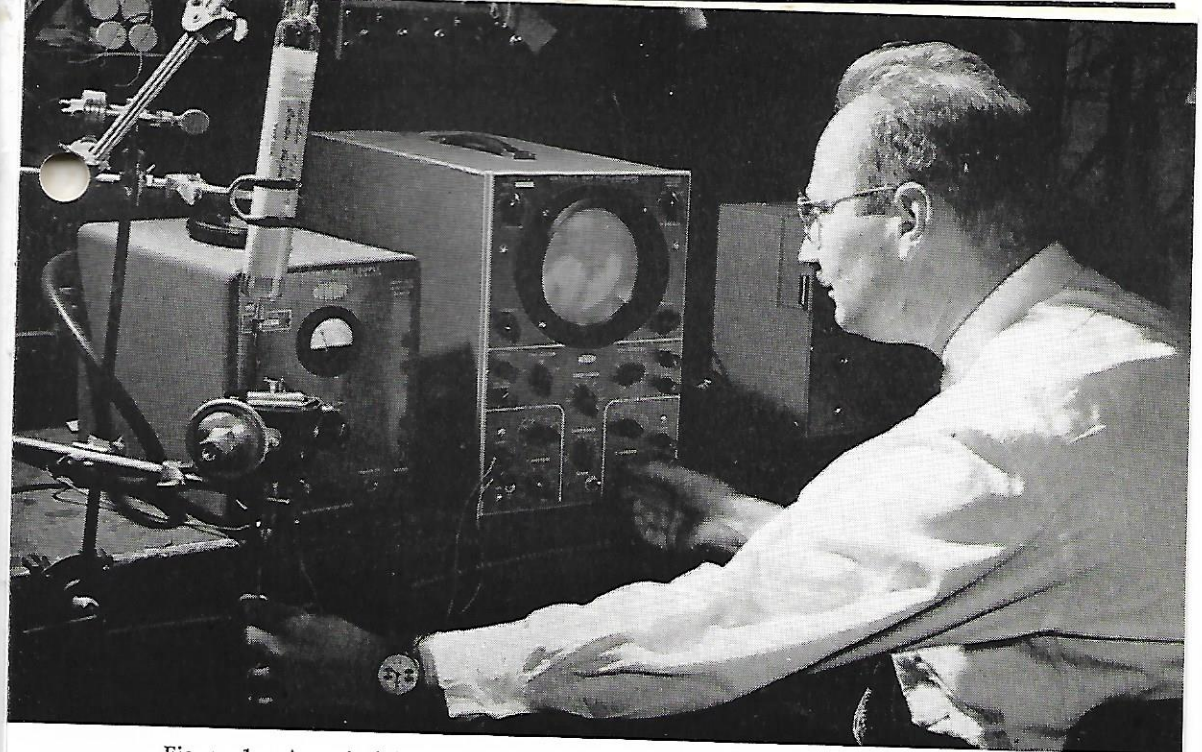


Figure 1. A typical laboratory setup, in which a Geiger-Mueller tube is used as a transducer with a Du Mont Type 304-H Cathode-ray Oscillograph, to check auto distributor contacts for X-ray emission

TRANSDUCERS

A Review of the Design and Applications of Transducers for Oscillography

By Carl Berkley

Basically, the cathode-ray oscillograph is a device which plots one electrical voltage as a function of another. From this definition, it would seem logical to infer that the oscillograph is exclusively a tool of the electrical or electronic engineer. And this assumption would be correct were it not for the TRANSDUCER.

By this term, transducer, is meant what is known in the audio field as a pickup, or in the industrial instrumentation field as a sensing or controlling element. In short, the transducer may be defined as any device which converts a phenomenon into a proportional electrical voltage, so that it may be displayed on the cathode-ray oscillograph. Through the medium of the transducer, the range of application of the cathode-ray oscillograph is expanded to embrace virtually every phase of modern science, technology, and industry. In nearly twenty years of oscillography, Du Mont Laboratories has yet to find a phenomenon which is incapable of conversion into a suitable electrical signal.

The problem of selecting the right transducer for a particular application is an important one, and one which deserved considerable attention, if the best results are to be obtained. Some points to consider in such a selection are:

1. *Method of energizing* — The most desirable transducer is one which is a small, self-contained unit, requiring no bulky, external power supply. Thus transducers such as those employing piezo-

electric crystals, which generate the signal voltage without need for a power supply are in common use for many applications. Should a source of power be essential, however, it is advisable to avoid the use of batteries, wet or dry, since these frequently fail or give rise to noise signals in the output at the most inconvenient times.

2. *Transfer characteristic* — An important attribute of a transducer is the relationship between its input and output. In most cases this relationship should be a linear one, a certain change in the input producing a corresponding change in the output, whether this change be an incremental one or a large one. In some cases it is desirable to have a non-linear relationship between input and output, as, for example, in measuring a phenomenon related to any of the human senses. The relationship between input and output then should usually be exponential, in order to conform with the Weber-Fechner law. In some cases it is desirable to have a logarithmic variation of output with input. An example of this is found where one must measure a very wide range of values, and display them all on the limited scale of the cathode-ray tube. Such a condition exists in the measurement of photographic densities where a range of 1000 to 1 in transmission is not unusual. This corresponds to a density range of only 0 to 3.

Sometimes it is desirable to have a trigonometric relationship between input and output. For example one may be interested in displaying the relation between some harmonic and linear motions which are sinusoidally related.

3. *Output Impedance* — If, for a given output voltage, one has the choice between low and high impedance in a transducer, low impedance is to be preferred, particularly if the output leads have any considerable length from the transducer to the oscillograph. High-impedance leads may be used since cathode-ray oscillographs in general have a sufficiently high input impedance that they will not load the usual transducer sources. But difficulty is encountered in long leads with extraneous electrostatic and magnetic pickup, requiring careful shielding, which usually deteriorates the high-frequency response of the transducer due to the capacity loading of the shield on the transducer.

4. *Amplitude Range* — The amplitude range of a transducer should be such that it will not be exceeded by the phen-

Figure 2. With many transducers, such as this one, it is important that the amplitude range not be exceeded

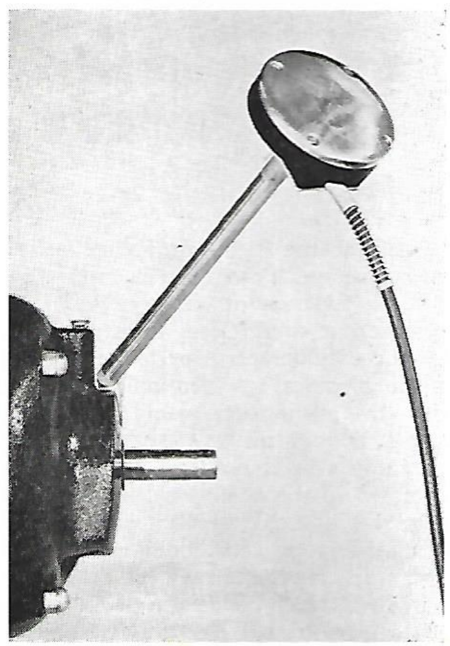


Figure 3. Hand-held, probe-type transducers such as this Du Mont Type VP-5 Vibration Pickup are most convenient

omenon under test. If this is unavoidable, then the output of the transducer should cut off in such a manner that it introduces no spurious signals. For example, the transducer of Figure 2 is subject to the defect that if its amplitude range is suddenly exceeded, the output oscillates at the resonant frequency of certain of the elements within it. This frequency bears no relation to the input.

Transducers should also be designed so that off-scale readings will not injure the transducer or cause a change in its zero. This is a typical defect that occurs when the basic element in the transducer is a mechanical one having an elastic limit.

5. *Sensitivity* — It is desirable to have the output of the transducer sufficiently high that it may be applied directly to a medium-gain oscillograph without the necessity of preamplifiers. Resistive strain gages, for example, while excellent transducers in other respects, suffer from the defect of low output, requiring tuned carrier preamplifiers for the oscillograph, with the resulting difficulties in the requirements of the amplifier bandwidth.

6. *Frequency Response* — Just as in the design of vacuum-tube amplifiers, a good transducer should have a frequency, phase, and amplitude response sufficient to display the phenomenon under study without distortion.

7. *Mounting Methods* — The most convenient and most widely applicable transducer would be in the form of a probe which could be hand-held and inserted into or touched to the object being tested. Many transducers, for example, the Du Mont Type VP-5 (see Figure 3) and the Western Electric WE79B are of this type. Probes are convenient for determining the time of occurrence or the wave shape of some devices, but inconvenient when reproducible measurements are to be made. A wide variety of attachment means may be used for transducers. They may be screwed directly to the object under test if such attachment will not load the source driving the transducer. Where screws are used in the form of clamps, it is important to determine that excessive tightening of the screws will not distort the phenomenon. Otherwise a slipping or ratcheted clamp must be provided, permitting the tightening to be reproducible. Some types of transducers, such as strain gages, may be cemented directly to the test object. These transducers must then be left permanently attached. Often it is desirable to be able to move a particular experimental transducer from place to place and attach it in a wide variety of orientations. For such cases, we have found standard chemical laboratory clamps and fittings of great utility. These are nothing more than glorified erector-set components, but they save many hours of construction of special fittings for special locations. In some cases, where a production test is necessary, in which an operator goes from one machine to an identical machine, considerable time may be saved by the construction of special fittings capable of being quickly attached or detached to particular portions of the machine. For gaging purposes, it is sometimes desirable to build directly into these, clamp-attachments accessory units such as micrometer heads, which can be used to displace the transducer a specific amount, and the output then adjusted to a specific value of the deflection on the oscillograph.

8. *Other Important Characteristics* — The weight of the transducer should be kept to a minimum, since, although a transducer may be designed for measuring the vibration of a massive object such as a beam, it will sooner or later be found desirable to use it for relatively light structures. The size of the transducer should be kept to a minimum for reasons similar to the above. Therefore the use of subminiature tubes is indicated wherever possible. The shape of the transducer should be such that it can be mounted conveniently with screws, for example, or held by chemical clamps for the sake of versatility. The direction of response of the transducer should be taken into account, since in some cases it is desirable to obtain pickup in a preferred direction to the exclusion of others. Some types of transducers, for example, magnetic coils, have relatively poor directional characteristics in this respect.

A transducer should be designed so as to be capable of continuous operation under the conditions of use without changing its calibration or without deterioration. For example, Rochelle salt crystals and photocells are not capable of long operation under high ambient temperatures and most types of gas-filled photocells are subject to fatigue.

9. *Additional Requirements* — Because of the fact that oscillographs are potentially capable of displaying much more information than other types of recorders, the use of an oscillograph with a particular transducer frequently shows up previously hidden defects in the transducer's output. For example, a microphone used with a sound or film recorder may give perfectly adequate recordings of the peak amplitude of the wave, which is essentially what the ear reacts to. Upon examining the individual waveshapes closely with the oscillograph, all sorts of distortions and phase shifts in the recorded wave may be seen. Many transducers are not properly damped for the frequencies one is interested in studying. This gives rise to under- or over-shoots in the oscillograph pattern. One of the best single tests of the frequency-response damping, and phase shift characteristics of a transducer is the application of a single step function to it. This should be made part of the final test for a transducer before it is put into use. Examination of the output with an oscillograph will usually show up defects in the shielding of many transducers. The pickup requiring shielding is usually some multiple of the power-line frequency, and does not

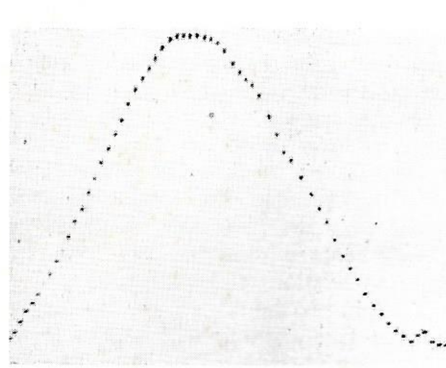


Figure 5. Oscillogram of shed-aperture vs. time, obtained by use of transducer of Fig. 4

appear on the average recorder which either does not respond to this frequency or integrates the frequency in order to read only the average, rms or slowly varying value of the phenomenon. A meter, for example, reading the output of an unfiltered power supply will read only the average d-c value; an oscillograph will show the ripple in the output. The same considerations hold for the signal-to-noise ratio of most transducers. In the case of a low-level transducer, such as a pyrometer thermocouple, a perfectly satisfactory reading is obtained on an ordinary meter, but the oscillograph shows all the thermal agitation noise which obscures the output reading. In general, it is desirable to choose the transducer such that the signal-to-noise ratio is high enough that gain may be reduced in order that the noise level is limited to value of about the width of the trace on the cathode-ray tube. It is possible in some cases to use long persistent screens or photographic methods to integrate out the noise from a repetitive pattern.

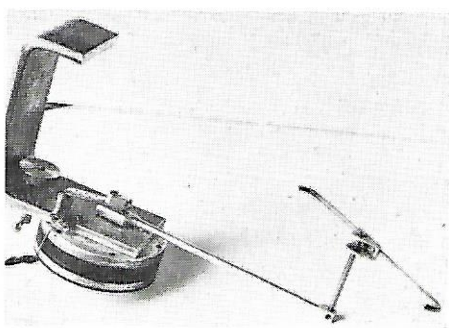


Figure 4. A typical resistive transducer, for measuring the shed aperture on a loom

TYPES OF TRANSDUCERS

Transducers may be divided into the following classifications:

1. *Resistive* — The simplest type of transducer is a linear resistor whose resistance is made to change in some manner by the phenomenon under study. The most convenient method of obtaining the change in resistance is to make the resistor a part of a potentiometer or rheostat which is, for example, mechanically

coupled to a machine. Figure 4 shows such a typical resistive transducer, designed for measuring the aperture or "shed," between certain crossed threads on a loom. The right-angled foot with upturned edges rests upon a group of threads and reads their average position by varying the resistance of the potentiometer. It is usually convenient to use direct current for energizing the potentiometer, although alternating current may be used if only an a-c amplifier is available, or if no source of d-c is available. The line-voltage output available on standard oscillographs is convenient for this purpose. Figure 5 shows a typical shed aperture vs. time curve obtained from this transducer. Angular timing markers have been superimposed on the pattern by means of beam modulation.

Potentiometers suffer from the defect that at high frequencies the potentiometer arm tends to bounce from wire to wire of the card, giving rise to discontinuities in the output. This can be eliminated in some cases by a shunting condenser, but this tends to cause phase shifts in the output. Carbon potentiometers may also be used, but these tend to wear out rapidly with continuous use. A better solution is the use of single slide wires for the potentiometer. Such slide wires are capable of being made as long as desired or arbitrarily shaped to fit a particular machine disposition.

Resistive transducers need not be wires. For example, a humidity transducer has been made by using a strip of cotton

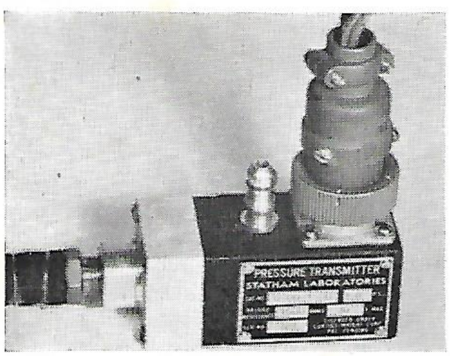


Figure 6. Typical strain gage, employing a non-linear resistance

fibers impregnated with a saline solution, which either effloresces or deliquesces, depending upon ambient humidity. Such a sensing element has been used in meteorological balloons to determine cloud heights. Non-linear resistors also form suitable transducer elements in many cases. The strain gage is an example of such a transducer. The cross section of the gage wire, which is closely bonded to an element whose strain is being measured, changes with extension or compression of the measured member, resulting in a variation in electrical output. Such strain gages have been either bonded directly to objects being measured, such as girders or incorporated upon extensible gage elements. A typical example of such a strain gage transducer in which the elements are mounted upon a deformable diaphragm is shown in Figure 6. One defect of resistance strain gages is that the percentage of change in resistance with elongation is small and this requires the use of a balanced bridge to avoid stray pickup, and the use of carrier signals to obtain high amplification with tuned amplifiers. D-C may be used where careful attention is paid to the shielding and where large signal amplitudes are expected. The frequency range of this type of transducer is normally of the order of a few kc. Recently developed types of conductive rubber (U. S. Rubber Company) show some promise in the design of non-linear resistive transducers capable of wider ranges of elongation. When using a bridge type of strain gage carrier modulator, it is desirable to know whether the unbalanced output indicates compression or extension of the gage. This may be done conveniently by marking a particular portion of the carrier phase with a blanking dot. The carrier then has a dark or bright line on the top or bottom half of the wave for compression or extension.

Coil springs which unwind progressively, one coil at a time, have been studied by the National Bureau of Standards, and appear to be capable of use as non-linear resistors over a wide range of amplitudes and resistances.[1]

1 N.B.S. Tech. News Bull., Oct. '48, #10, pg. 122.

Varistors are another type of resistive element which change in resistance, depending upon the impressed voltage or current. These are useful as current or voltage transducers over a wide range of magnitudes in order to display overall values on the face of the tube.

Thermistors are similar variable resistances which change value with temperature. These are, therefore, capable of use as sensing elements for changes in temperature. They also are more sensitive in bridge circuits. Various effects other than temperature may be measured by means of the change they produce in the temperature of some object. For use with an oscillograph, a thermistor to measure temperature may merely be connected between the input of the scope and a source of supply voltage applied through a resistor whose value is made as high as practicable, consistent with the amplification of the oscillograph and the pickup encountered. The supply voltage may be either d-c, a carrier frequency, or the 60-cycle test signal supplied by the oscillograph. Thermistors may be obtained with time constants due to thermal lag of as low as 1/10 second.

Switches are convenient transducers for many oscillographic tests. (We have classified them here under resistors, considering that they produce a change in internal resistance from zero to infinity.) Vibrating switches are sometimes useful as choppers for a d-c signal, in order to enable its amplification through an a-c coupled amplifier. This use is in general limited to very low frequencies however, where the advantage of the oscillograph is not so apparent. At high frequencies, the switch cannot be made to operate efficiently and electronic switches must be used. Switches are also useful to produce markers upon the trace indicating the instant of operation of some portion of a machine. By means of differentiating and integrating circuits, the pulses from various switches may be given different wave shapes or characters in order to enable a large number of phenomena to be displayed upon a single time base.

2. *Electrostatic Transducers* — A variation in capacitance may also be used to produce an electrical signal. From the formula $Q = CE$, either Q, C or E may be changed to produce an indication on the oscillograph. One of the first transducers used was the condenser microphone. This consists of a thin diaphragm vibrated by the sound which has a capacity to the grid of a vacuum tube amplifier. With a change on the diaphragm, its motion induces a resultant motion of the electrons to and from the grid of the tube giving rise to the voice modulated signal. This effect increases in sensitivity as the spacing is made smaller and increases with the applied voltage. This effect is, therefore, most suitable for small spacings. Vibrating reed condensers in conjunction with a-c operated amplifiers have also been used to amplify d-c signals which are impressed upon the capacitance. Condensers have been used as transducers in oscillators whose frequency is varied by the capacitance. The oscillator frequency may be varied by the space between the plates measuring a distance or by the change in the dielectric constant or dipole moment of the substance between the electrodes.

Condensers cut in special orientations are also used as transducers in sweep frequency generators, in which the rotation of the condenser or displacement is made a function of the desired frequency. Specially cut condensers of this type have also been used as continuously variable phase shifters for cathode-ray tube presentations. Such transducers can be made to have a phase shift which is accurately proportional to the angle through which a shaft is turned.

Another type of transducer which may be classified here is the mechano-electronic transducer. This produces a variable output depending upon the position of a magnetically variable plate in a triode tube. This transducer is quite sensitive to small angular or linear displacement but suffers from the defect mentioned above, that when its elastic limit is exceeded, which can be done quite readily, it does not return to zero. The frequency response of this unit is of the order of 12kc. Many phenomena can be converted to a mechanical displacement and, therefore, measured with this transducer.

3. *Electromagnetic Transducers* — A coil moving in a magnetic field can obviously be used as a source of electrical voltage. This voltage is usually proportional to the velocity or rate of change of the motion and, therefore, requires integration in order to produce a true indication of displacement.

Another type of magnetic transducer depending upon the motion of a moving permanent magnetic field and a stationary coil is a two phase a-c generator used to transduce rotational speed. The a-c output of this pickup is accurately proportional to the speed of its center shaft. The generator has two phases which are 90° apart and is, therefore, useful in generating a circle on a cathode-ray tube which rotates at the same speed as a machine to which it is coupled, giving an automatically synchronized circular sweep.

There are many types of magnetic transducers. A simple coil can detect the motion of most ferrous objects due to their residual magnetism. The characteristics of a ferromagnetic material are not usually altered for industrial purposes if it is magnetized in order to enable electrical pickup of its motion. For example, a steel projectile may be magnetized and its time of passage through two coils generate two marker voltages which enable an accurate determination of the shell's muzzle velocity. In a similar manner to that for condenser transducers, a variable coil may be made the frequency determining element in an oscillator. If desired, the oscillator may also be varied over a range of frequencies and the response of the part under test noted to be compared with a standard material. This is done in the Du Mont Cyclograph.[2] In order to obtain a linear response from a variable-coil-determined oscillator, the output is generally detected using a detector operating on the linear portion of the response curve of the output transformer.

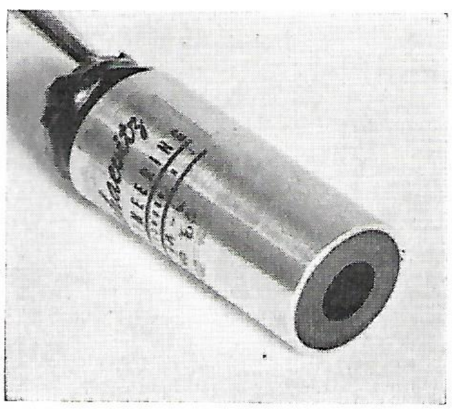


Figure 7. A typical differential transformer

Most types of transformers can be used as electromagnetic transducers in one fashion or another. A variometer whose output is proportional to some function of its angle may be used to detect the motion of some object or machine. The common selsyns may be used as such transducers with the restriction that the output is a sinusoidal function of the angle through which the shaft is turned. A particularly useful type of transformer transducer is the differential transformer (See Figure 7). These transformers are available in a wide variety of shapes and capacities. They consist of a single primary and two symmetrically wound, opposed secondaries. These transducers may be used, for example, to detect slight changes in some material capable of producing an inductive effect. If the material is uniform and the transformer balanced for zero output, then the output will remain zero unless a change in the characteristics of a portion of the material running through the transformer occurs. This particular transducer will work just as well on magnetic and non-magnetic metallic materials. The non-magnetic materials act as shorted turns, which have identical effects on both ends of the transformer. This type of transducer can also be used as a position transducer in which a slug of material is brought closer to one coil than another. It can also be used to detect changes in the thickness of materials by placing one end of the transducer against the material and having it run past.

2 The Oscillographer, Vol. 7, No. 6, Nov.-Dec. 1945.

Saturable reactors of various types can be used as transducers for small currents or changes in reluctance to produce relatively large voltage changes which are capable of display on oscillographs. Such saturable reactors generally have a rather poor frequency response for oscillographic purposes, but have the advantages of great ruggedness for industrial applications and the fact that they do not require any vacuum tubes for their operation.

Magnetic field strength detectors are frequently desired to measure the strength of a steady or d-c magnetic field in space. This is difficult to do in a continuous fashion. One simple method is to rotate a coil in the field and measure on an oscillograph the peak value of the induced voltage. The value of the field can then be calculated from an observation of the variation of the output with the angle of the coil on the oscillograph. The cathode-ray tube itself can be used as a d-c magnetic probe but is usually relatively large for this purpose.

A small magnetic transducer accomplishing the desired variation of output with magnetic field indensity is the magnetically controlled diode. This is a simple diode in which the variation of plate current with ambient field indensity is roughly linear over a certain range. This can be used, for example, as a position transducer by having the position of a small bar or horseshoe magnet in the vicinity change its position with respect to the tube. It may be used as a pressure transducer too, for example, by attaching a small magnet to the end of a Bourdon tube placed near the diode.

Figure 8. A typical piezoelectric transducer, the Du Mont Type DP-1 Displacement Pickup

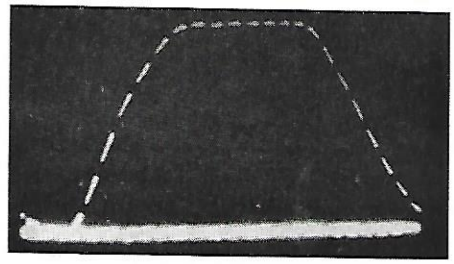


Figure 9. Oscillogram indicating camera shutter opening vs. time, obtained by use of a photoelectric transducer

4. *Piezoelectric Transducers* — The piezoelectric crystal is one of the earliest forms of transducers. Either natural or synthetic crystals may be used. The natural crystals have the advantages of very low leakage which with an electrometer input enables the measurements of very slowly varying pressures. These natural crystals, however, have the disadvantage of very low sensitivity. The natural crystals are to be preferred where vary hard usage is to be encountered, or where high temperatures or sudden shocks occur. The synthetic crystals have the advantage of very high output for a given displacement, pressure, or strain but these are usually temperature sensitive and are not as capable of withstanding high applied forces without fracture. The natural crystals in general have a higher frequency response, while synthetic crystals may be made quite large and, therefore can be used, for example, as frequency determining elements in relatively-low-frequency oscillators.

A new class of synthetic materials such as the barium titanates has recently become commercially available, and has been very widely used in phonograph pickup transducers. This material has the advantage for transducing, that it may be readily formed into special shapes which make it adaptable, for example, to the design of hemispheric-shaped sound transducers for concentrating their attention

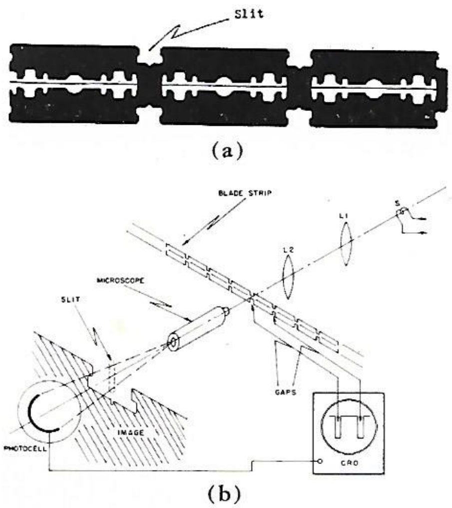


Figure 10. (a) Razor-blade strip. (b) The optical arrangement for scanning razor blade strip

upon a small area at the focus of the sphere. These synthetic materials are also relatively fragile and temperature-sensitive. Figure 8 shows a typical piezoelectric transducer, the Du Mont Type DP-1, which is capable of very low frequency response and is used as a displacement pickup. This does not produce any differentiation for frequencies down to a few cycles.

5. *Thermoelectric Transducers* — The thermoelectric effect is another capable of being used for transducers. The thermocouple or the optical pyrometer, in which the image of the furnace is focused upon the couple are two examples. The difficulty with most thermocouples is their heat lag, which rules them out for any high-frequency heat changes. A photocell pyrometer is usually to be preferred, if the temperature is such that the photocell effect can be used.

6. *Photocell Transducers* — The photocell is probably the most versatile transducer known. A photon causes the least loading upon the source, compared to any other transducer effect. Photocells of the barrier layer type, such as the Weston Photronic Cell, have the disadvantage of low voltage sensitivity and poor frequency response, but have the advantage of very good stability for industrial applications. Resistive photocells, such as the selenium type, which are too unstable for direct calibration, and the gas or vacuum field photocells which are subject to the usual gas oscillations and fatigue are to be avoided in general. Vacuum photocells are most suitable for oscillographic use. They may be obtained in a range of sensitivities from the small probe-type 1P42 units, to the high-sensitivity multiplier photocells. In designing a photocell transducer for oscillographic use, account should be taken of the electrode capacity of the photocells, since the high-value load resistors used with the cells may be shunted appreciably, even at fairly low frequencies. Care should also be taken in designing the light sources for photocells than even illumination for the cathodes is provided to avoid variations in signal resulting from variations in sensitivity of portions of the cathode surface. The obvious applications for a photocell on the oscillograph is to show light output vs. time curves. A typical curve of shutter opening vs. time is shown in Figure 9.

It is frequently convenient to scan an

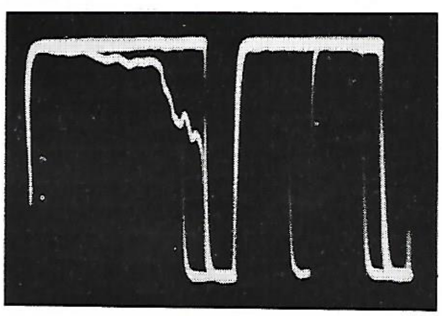


Figure 11. Oscillogram showing razor-blade edges, some of which are nicked

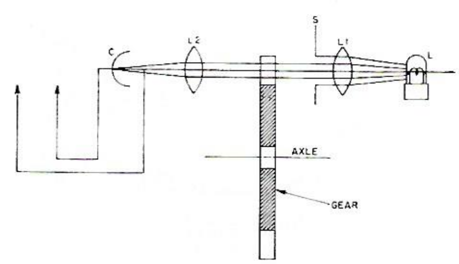


Figure 12. Optical setup for inspecting gear teeth

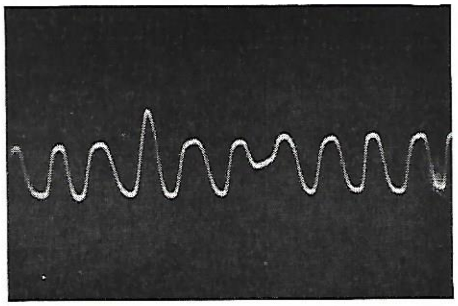


Figure 13. Oscillogram made from setup of Fig. 12, showing that two of the gear teeth are deflective

object, outline, or surface, using photocells. Figure 10 illustrates such an instance. Here, the outlines of razor blades which are prepared in a continuous strip are examined by moving them past the photocell. Figure 10b shows the optical setup for scanning the razor blade edges using a microscope to magnify the images and a slit for examining a small portion of the edge at any instant. Figure 11 shows a typical oscillogram made from razor-blade edges, revealing a number of nicks and other defects. Figure 12 shows another photocell scanning method for testing a rotating gear, in which the optical system is so arranged that the output of the photocell is proportional to the height of each gear tooth above the base circle of the gear. Figure 13 shows a typical oscillogram showing the waveshape from a number of teeth, two of which are defective. With a more rapid sweep, synchronized with the repetition rate of the gear teeth, we obtain the patterns of Figure 14, enabling the comparison for congruence of all the teeth.

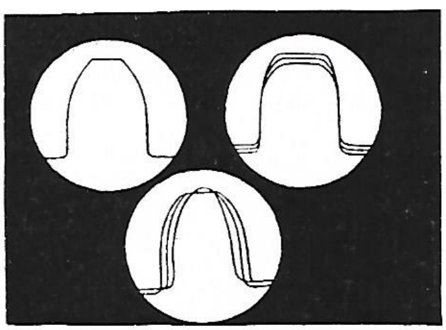


Figure 14. More rapid sweep enables comparison of patterns for congruence of teeth. Top left, perfect gear; top right, eccentric shaft; below, irregular teeth

In photography it is desirable to draw automatically H and D curves, illustrating the variation in density of sensitometric strips. It is desirable also to obtain this information indicating how this density varies during development. Figure 15 shows an experimental setup for H and D curve tracing of a circular strip rotated together with a mechanically linked potentiometer used as an angle transducer. A photocell operating on nonactinic light is used to pick up the reflectance of the paper sensitometric strip. Figure 16 shows two sets of typical H and D curves obtained during development.

An oscillograph and photocell offer a convenient combination for plotting the light distribution curves of various surfaces. Figure 17 shows such a typical light distribution curve in polar coordinates made on a Du Mont Type 275-A Polar-Coordinate Indicator.

A convenient method of scanning sur-

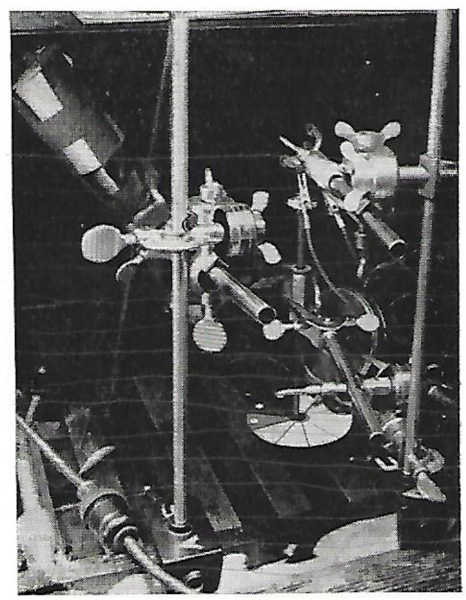


Figure 15. Experimental setup for tracing H and D curves

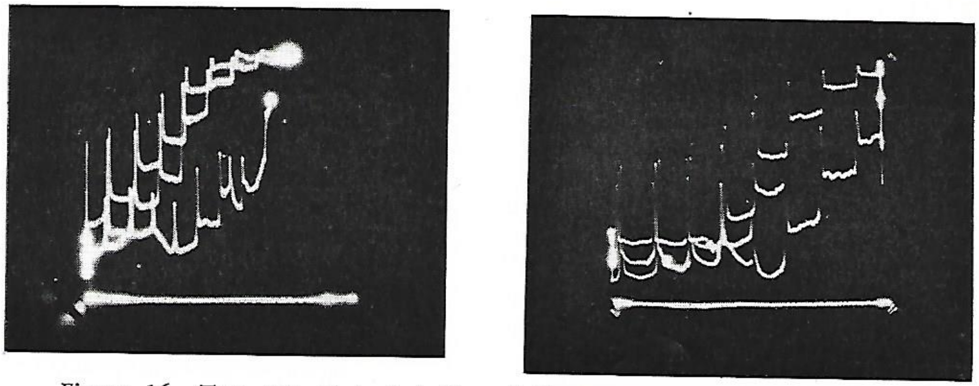


Figure 16. Two sets of typical H and D curves obtained during paper development

faces is a vibrating mirror. This mirror is mounted on a tuned resonant reed, oscillating at the power-line frequency. Figure 18 shows typical light-distribution curves made in this manner, from glossy and matte surfaces.

The X-Y presentation on a cathode-ray oscillograph enables the simultaneous presentation of two values, which is of advantage in a particular photocell application which presents both the brightness and color of a surface as indicated by the X-Y position of the spot on the cathode-ray tube. This is similar to the I. C. I. presentation of color coordinates, except that the color primaries have been chosen arbitrarily. Figure 19 shows schematically the type of connections required for the three photocells, two of which read color, the third one luminosity.

The above mentioned applications which have necessarily been considered briefly, show a wide range of problems to which photocell transducers have been applied. These illustrations represent only a small fraction of the potential ones.

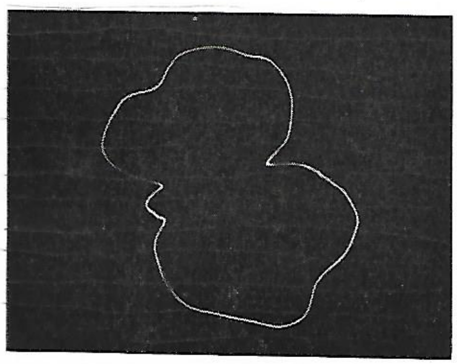


Figure 17. A typical polar-coordinate light distribution pattern

8. *Other Electronic Effects* — There are many effects associated with every occurrence in the universe. These effects are in many cases electrical in nature. But in all cases, they can be converted into electrical form by means of some transducer. Only a few of these other effects can be mentioned here.

In inorganic chemical analysis, for example, each ion component of a solution has a particular potential at which it will start to conduct. If the potential is slowly raised across a solution synchronous with the operation of a sweep on the oscillograph, the current will experience certain jumps at certain potentials characteristic of each ion. This is the basis for polarographic analysis which with the aid of an oscillograph in timing intervals has a time as short as 1/60 of a second for a complete analysis.[3] A somewhat similar situation exists in the analysis of gases. If the voltage across a gas is slowly raised synchronous with the operation of the sweep of an oscillograph, the gas will conduct at various levels depending upon the components within it. These potentials are known as the ionization potentials of the gas. This makes possible the chemi-

3 J. E. B. Randles, "A Cathode Ray Polarograph", Trans. Farad. Soc. #305, Vol. XLIV, Pt. 5, May '48, pp. 322-27.

cal analysis of gases merely by noting the ionization potentials. Since the ionization voltage is a function of pressure, this method may also be used to obtain a continuous pressure graph by sweeping through the voltage range of a gas repetitively and since the ionization potential is also a function of the electrode spacing, such a transducer could also be used to measure changes of spacing at a fixed temperature or pressure. Many other physical effects will be found, which are capable of use as in the design of transducers. We have already mentioned a few of these, such as the Einstein photoelectric effect, thermoelectric effect, the chemo-electrical polarization effect, magnetomotive effects, and the Piezoelectric effect. Other effects which show some promise are the electro-optical effect, magneto-optical effect, the De Broglie effect, the Doppler effect, and the Zeeman effect. Numerous other effects will be found in the physical literature.

In many cases it will be found that an effect already electrical in nature accompanies the phenomena being studied. This obviates or simplifies the need for a transducer since the oscillograph may then be connected directly, or sometimes, with a preamplifier. Such cases are in the streaming potentials (electrokinetic) encountered due to capilary sources in biological systems and the other biological potentials such as muscle action potentials, nerve potentials, and encephalic potentials. There are a wide variety of electrically operated machines to which oscillograph probes may be applied directly without further ado. Among such devices are: relays, motors, switches, filters, ignition systems, corona generating systems, lightning protectors, RF heaters and fence controllers. Voltage in these devices is measured by direct connection to the device. Current may be measured by putting a small series resistor in the lead whose current is to be measured. In order to cause minimum disturbance of the circuit, it is desirable that the resistor be of as low a value as possible consistent with the gain of the oscillograph.

Care must be taken in devices connected to the power line to use suitable isolation transformers to avoid difficulties due to

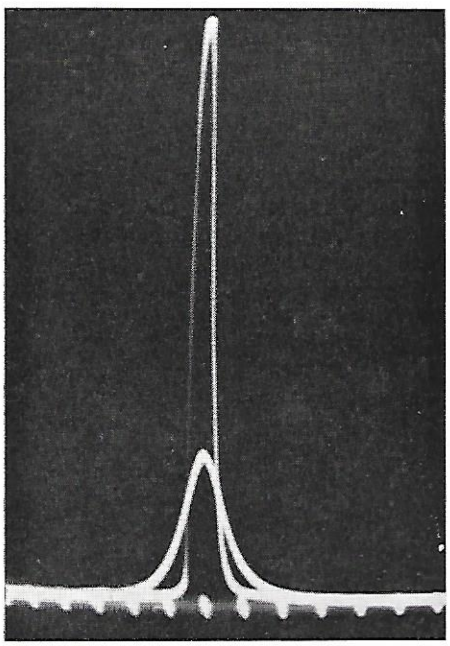


Figure 18. Two superimposed light distribution curves, one from a matte surface, the other from a glossy surface

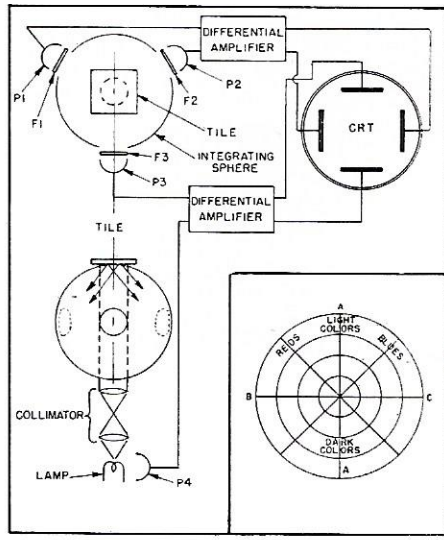


Figure 19. Schematic diagram of connections required for three photocells, two reading color, and one reading luminosity

simultaneous grounding of these devices and the oscillograph.

Choice of Transducers — As should now be obvious, for any particular application one has the choice of a wide variety of transducers or a wide variety of electrical or related effects to choose from in measuring any phenomenon. In choosing the best transducer, the points mentioned at the beginning of this article: method of energizing, transfer characteristic, output impedance, amplitude range, sensitivity, frequency response, mounting method, size, weight, shape, durability, and signal-to-noise ratio should be considered in order to obtain optimum results. Let us apply some of these criteria to the measurement of typical phenomena, which arise similarly in many related fields, in order to determine which type of transducer would be most suitable.

1. *Displacement* — Displacement may be measured by means of a slide wire, but the frequency response may not be sufficient. If the amplitude range is important, however, a differential transformer might be indicated. But this also has limited frequency response. A seismic suspension might be used with a piezocrystal, but this will not be suitable if it is desired to measure a d-c displacement. Such a seismic pickup as well as the previous ones mentioned may cause too much loading upon the source. It may, therefore, be desirable to use a photocell and optical system.

2. *Vibration* — Similarly to displacement, vibration may be measured photoelectrically, piezoelectrically, magnetoelectrically or electrostatically. The most convenient method will depend upon the conditions of the particular problem.

3. *Light* — The only suitable method for measuring light for oscillographic purposes is by means of a photocell.

4. *Temperature* — Temperature could be measured by means of the thermoelectric effect, a thermistor, or a photocell. Again the photocell is to be preferred if rapid changes are expected or if the temperature is such as to radiate detectable wavelengths.

5. *Pressure* — Pressure may be measured by means of strain gages, by the gas-tube transducer, or by means of a photocell and diaphragm-actuated mirror.

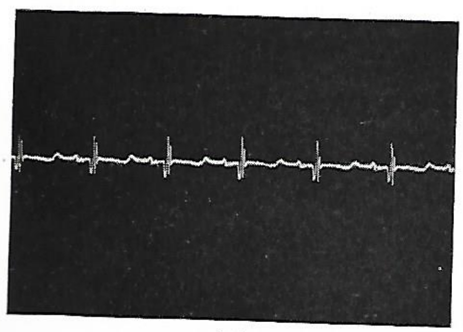
6. *Humidity* — Humidity as indicated above can be measured either photoelectrically by means of a mirror upon which condensation takes place, or by means of a variable resistance salted fibre.

7. *Vapor Pressure* — Vapor Pressure might be measured by means of the Toricelli vacuum displacement, either with a photocell or by having the mercury column control and oscillator, or the output of a differential transformer.

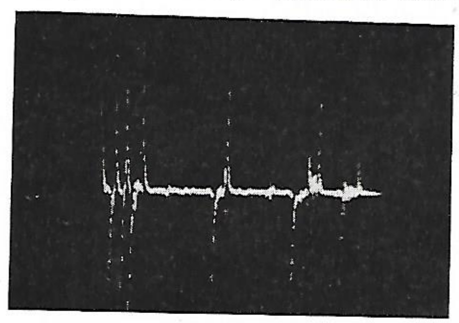
8. *Sound* may be measured by a diaphragm actuating a magnetic, electrostatic, or photoelectric transducer.

9. *Strain* may be measured either resistively, capacitively, or magnetically.

10. *Torque* may be measured magnetically by the Cox torque transducer which



(a)



(b)

Figure 20. Operation of many electrical devices may be studied on the oscillograph without transducers. Examples are: (a) indication of ignition noise; and (b) indication of arcing in a switch.

consists of two spring-coupled rotating masses, magnetically coupled. Variation of torque causes a relative motion of the masses which gives rise to an electrical signal. Torque may also be measured photoelectrically. The bar or shaft whose torque is to be measured has connected to it two crossed polaroids, with a light beam to a photocell passing through them. Torque in the bar causes a twist of the polaroids which gives rise to sinusoidal variation in light intensity with torque.

In addition to the solution of particular problems or the measurement of particular quantities by means of a variety of transducers, each particular transducer may be used to measure a variety of phenomena. For example, a slide wire in addition to being used as a position transformer may be used with a spring for weighing. A differential transformer, in addition to being used for magnetic tests, can be used for comparing the resistance of two materials as shorted turns for the primaries. A photocell may be used for a wide variety of tests. A thermistor, in addition to a temperature measuring device, may be used as a flow transducer, the amount of flow causing more or less cooling of one of the arms of a bridge. A Geiger-Mueller counter (see Figure 1) intended primarily for use as a radiation transducer may be employed as a thickness gage or as a flaw detector with a radioactive source.

Any phenomenon can be transduced into an electrical signal. Many transducers are available for converting most phenomena. The choice of a particular transducer for a particular application will depend upon the choice between a number of desirable and undesirable characteristics, as enumerated above.

The Instrument Division welcomes the opportunity of lending assistance in the selection or design of transducers for use in cathode-ray oscillography. Requests for information should be addressed to the Instrument Division, Allen B. Du Mont Laboratories, Inc., 1000 Main Avenue, Clifton, New Jersey.

* * *

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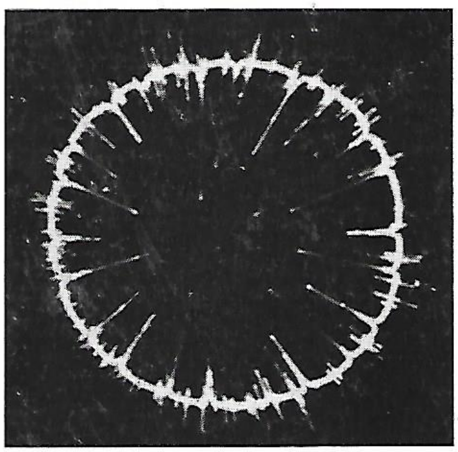
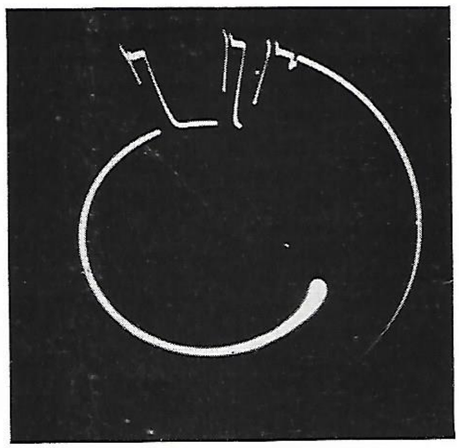
This article was adapted from a paper delivered by Mr. Berkley during a Symposium on Oscillography, conducted by Allen B. Du Mont Laboratories, Inc. for the New Jersey Chapter of the A. I. E. E. in October, 1949.



(a)



(b)

Figure 21. (a) Indication of noise in electric-motor brushes, and (b) indication of the bouncing of a relay arm. Both of these oscillograms, like those of Figure 20, were made without the use of transducers.

(*Continued from Page 2*)

in low-cost oscillographs. Both X and Y axes are equipped with highly stable, high-gain a-c and d-c amplifiers which have negligible microphonics and drift. Both driven and recurrent sweeps, continuously variable in frequency from 2 to 30,000 cps, are provided, and sweeps of much longer duration, down to 10 seconds, or more, are possible by attaching capacitance externally at the X-input terminals. Sweeps of the Type 304-H may be expanded up to 6 times full-screen diameter, with horizontal positioning available over the entire fully expanded trace.

Sync limiting is included in the Type 304-H; this prevents variations in signal level from affecting either sweep length or synchronization.

The accelerating potential of the Type 304-H is unusually high (3000 volts) for an instrument of the low-price range. The intensity of the fluorescent trace of the instrument may be modulated by applying an intensity modulation signal to the Z-axis input terminal on the front panel.

The Du Mont Type 304-H made its debut in late September of 1949, and in only five months, has gained wide-spread popularity, proving itself a worthy successor to the time-honored Type 208-B.

3. *The NEW Du Mont Type 294 Cathode-ray Oscillograph*

Replacing the Du Mont Type 248-A, the new Type 294 is a high-voltage, 15-megacycle oscillograph, designed for the detailed analysis of high-frequency signals. The band-width of its vertical amplifier extends to 15 megacycles, and a pulse having a rise time of 0.01 microsecond or less will appear at the output of the amplifier with a rise time of no more than 0.03 microsecond. A built-in signal delay line affords sufficient time for the sweep to start before the signal is applied to the vertical deflection plates.

The vertical deflection factor of the Type 294 is 0.15 rms volts per inch, with the cathode-ray tube operated at an overall accelerating potential of 12,000 volts. At this voltage, undistorted deflection of 1.7 inches — limited by the characteristics of the cathode-ray tube — is obtainable with unidirectional impulses. For symmetrical signals, correspondingly greater deflection voltages are available, permitting signal expansion in conjunction with the vertical positioning control. At the lower accelerating potential, the available undistorted deflection is well over 2 inches.

The specified frequency response, sensitivity, and undistorted deflection for the vertical channel include the performance of the built-in delay line.

Driven sweeps of the Type 294 are continuously variable in duration from 100,000 to 2 microseconds, and recurrent sweeps are continuously variable in frequency from 10 to 200,000 cps.

The Type 294 employs a Du Mont Type 5XP- Cathode-ray Tube, operated at overall accelerating potentials of either 7000 or 12,000 volts, with the change of voltage accomplished by a switch on the indicator. The high-voltage power supply for the intensifier potential is built into the indicator unit, while the low-voltage power supply, which provides the remaining voltages for operation of the instrument, is packaged as a separate unit. The high light output of the Type 5XP- Cathode-ray Tube, resulting from the high accelerating potential, is provided to permit the display or photographic recording of high-speed transients, or other signals having high writing rates.

Internally generated timing markers, indicating intervals of 1, 10, or 100 microseconds, may be selected and applied to the trace by means of a front-panel switch.

4. *The NEW Type 292 Du Mont Cathode-ray Oscillograph*

This low-price instrument sets a new high in portability and performance. Equipped with the new Du Mont Type 3RP-A Cathode-ray Tube, the Type 292 employs balanced deflection for minimum distortion of the trace. Pattern distortion is further reduced by the flat face of the new tube, as well as by its unique electron-gun design. The shorter overall length of the Type 3RP-A permits a smaller, more compact design. For addi-

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tional details on the Type 292, see the article beginning on page 3 of this issue of the OSCILLOGRAPHER.

5. *The NEW Du Mont Type 250-AH Cathode-ray Oscillograph*

The Type 250-AH, replacing the Du Mont Type 250-H, is a highly versatile, high-voltage instrument for general purpose use. This new instrument features a-c and d-c amplifiers on both X and Y axes, automatic beam blanking, a Type 5RP-A Cathode-ray Tube operated at potentials of up to 13,500 volts (used in conjunction with the Du Mont Type 263-B High-voltage Power Supply), a built-in voltage calibrator, and driven and recurrent sweeps continuously variable in duration from 5 seconds to 10 microseconds. The high-voltage feature of the Type 250-AH permits the use of the instrument in many low-frequency applications, where extremely long persistence is necessary, as well as in applications where high light output is required, as, for example, in the observation of high-speed single transients.

6. *Special Du Mont High-Frequency Cathode-ray Oscillograph*

An unique and extremely interesting exhibit will be the actual measurement of the velocity of propagation of an electromagnetic wave by a specially built cathode-ray oscillograph.

This instrument employs a new Du Mont high-gain, wide-band amplifier, which has a bandwidth of from d-c to more than 100 megacycles per second, and which provides balanced deflection signals for pulses of either polarity to the Du Mont Type 5XP- Cathode-ray Tube. A 100-megacycle sine wave of 2-inch amplitude will be superimposed upon the pattern for calibration, and will also demonstrate the undistorted-deflection capabilities of the amplifier.

The sweep of the special oscillograph will operate at approximately 100 inches per microsecond.

All of these exhibits, spotlighting the newest in the realm of cathode-ray oscillography, provide a striking example of the pioneering by Du Mont, which is so largely responsible for this company's position of leadership as designers and manufacturers of cathode-ray oscillographs and allied equipment.

As stated above, these exhibits will be found at Booths 125, 126, 127, and 128. The Tube and Electronic Parts Divisions of Allen B. Du Mont Laboratories, Inc. will have displays at Booth 25, while the Transmitter Division will occupy Booths 240, 241, 242, 243, and 244.

BIBLIOGRAPHY

The following bibliography of contemporary publications, prepared from abstract bulletins compiled by Du Mont's Technical Library may be of interest to those engaged in the application of the cathode-ray oscillograph.

"Miniature Portable Cathode-Ray Oscillograph Recorder", by C. F. Johnson in INSTRUMENTS, Volume 22, No. 9, pp. 800-801, Sept. 1949.

"Use of Cathode Ray Oscillograph in Measurement of Metal Areas and Kinetics of Electrode Reactions," by A. Hutcheon and C. Winkler in CANADIAN JOURNAL OF RESEARCH, Volume 27, No. 4, (Sec. B) pp. 353-360, April 1949.

"On a New Electron Gun for High-Voltage Tubes", by M. Bricka, and H. Bruck in ANNUAL RADIOELECTRICITE (In French), Volume 3, pp. 339-342, Oct. 1948.

"The Preparation of Luminescent Screens", by M. J. Sadowsky in ELECTROCHEMICAL SOCIETY, Volume 95, pp. 112-128, March 1949.

"High-Speed Recording of Optical and Electrical Transients", in PROCEEDINGS OF THE I. E. E., Volume 96, Part II (Power Engineering) No. 52, pp. 669-670, Aug. 1949.

C. R. T. Designed for Wide-Band Oscilloscopes", by K. A. Hoagland in COMMUNICATIONS, Volume 29, pp. 12-13.30, May 1949.

"New Method of Expanding Scale of Magnetic Oscillograph". by R. L. Goetzenberger, Jr. in INSTRUMENTS, Volume 22, No. 5, p. 405, May 1949.