VOL. 3, NOS. 6 and 7

DU MONT

OSCILLOGRAPHER

AUG.-SEPT., 1939

THE AMPLIFICATION OF DIRECT-CURRENT SIGNALS THROUGH ALTERNATING-CURRENT CIRCUITS

SUMMARY: ***A means is described for amplifying small direct-current signals through conventional alternating-current amplifiers. Important applications are the measurements of signals containing both d.c. and a.c. components and the study of the modulation characteristics of radio transmissions at the transmitter or at remote locations.***

DUE to the unique features of the Du Mont Type 185 Electronic Switch, it is possible to amplify direct-current signals first through the amplifiers of this electronic switch and then through the conventional resistance-capacitance coupled amplifiers which are normally used in standard cathode-ray oscillographs. In this manner, both qualitative and quantitative measurements of small d.c. potentials may be made without the necessity of unwieldy and expensive high-gain d.c. amplifiers. Also, the stability problem normally encountered in d.c. amplifiers does not exist.

The general principles involved in this amplification of direct-current signals through a.c. amplifiers have been tried many times, but, with the advent of the Type 185 Electronic Switch and Square-Wave Generator, it is now possible to obtain standard equipment which will produce these desired results. It is suggested that the electronic switch will be extremely useful for this application when used in conjunction with an oscillograph such as the Du Mont Types 168, 175, or 175-A, or any other good cathode-ray oscillograph containing sensitive a.c. amplifiers.

Amplification of direct-current signals may be obtained with such circuits by electrically chopping the signal and subsequently passing the chopped signals through standard a.c. amplifiers. Many experimenters have adopted this method, using mechanical devices in conjunction with thermo-couple outputs, photo-electric-cell outputs, and the like, but such equipment is handicapped by mechanically moving parts and serious limitations due to varying contact potentials of metallic parts. The electronic switch accomplishes this chopping essentially by means of an electronic multivibrator circuit which makes the amplifier to which the desired d.c. signals are applied sensitive and insensitive in rapid succession, and with a periodicity sufficiently high so that the resulting square-waves, of suitable frequency, may be transmitted by conventional resistance-capacitance coupled amplifiers. This amplification of d.c., by means of the elec-

tronic switch and the cathode-ray oscillograph, is only a special case; but since this special case is of extreme value it is deemed attention should be drawn to this use of the equipment.

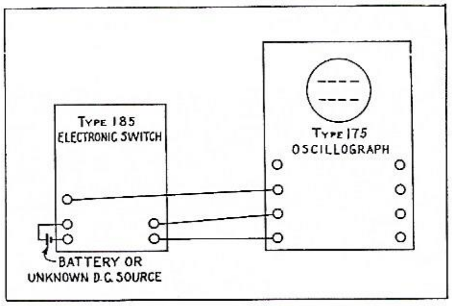


Figure 1. *Block diagram showing application of Type* 185 *Electronic Switch and Type* 175 *Cathode-Ray Oscillograph to the amplification of direct-current signals.*

Figure 1 shows a typical group of equipment suitable for measuring small d.c. potentials. The signal to be measured is applied to the input A of the Type 185 Electronic Switch. For identification purposes of the resulting signals, it may also be desirable to insert an a.c. signal, for example, a small sixty-cycle voltage from the post provided on the front panel of the Type 175 Cathode-Ray Oscillograph, at the input B. With the gain controls for both amplifiers A and B completely retarded, and with the oscillograph amplifier set at some reasonable gain, the electronic switch will produce a square-wave output signal. Adjustment of the balance control on the Type 185 instrument will now reduce the amplitude of the square-wave output to zero, as shown by a straight line on the screen of the cathode-ray oscillograph. It is possible, of course, to utilize so much gain in the amplifier of the cathode-ray oscillograph that the slight irregularities in output caused by power-supply hum and mismatch of tubes in the electronic switch show up in such a manner that it is impossible to obtain a perfectly straight line at even the best balance point of the square-wave balance control. Generally, however, such gain in the cathode-ray oscillograph is not necessary, and a reduction of the amplifier gain in this instrument will eliminate this disturbing residual ripple. A slow advance of gain control A, on the electronic switch, will now displace one-half of the square wave, and the displacement will be proportional to the d.c. signal which is applied by this advance. A slight advance of gain control B will insert the sixty-cycle reference signal on the portion of the square-wave which has not been displaced, and this signal may be used to identify the zero reference-line. An application of this sixty-cycle signal, by momentarily turning up the gain control B and returning it again to zero, will identify the zero- or reference-line from which the d.c. signal represented by the other line should be measured. In this connection, it must be pointed out that true d.c. measurements cannot be made with reference to, say, a fixed line across the center of the cathode-ray tube, but they must rather be made with reference to this fixed-half of the square-wave. The reason for this is obvious, since it is considered that, due to condenser coupling, the fixed line will be displaced downward while the d.c. line is displaced upward because of the fact the the coupling condensers will charge to an average potential making the signal center about a zero-line on the cathode-ray tube chosen by the positioning circuits of the cathode-ray oscillograph.

The switching-frequency chosen in the Type 185 Electronic Switch and the sweep-frequency chosen in the cathode-ray oscillograph determine the actual appearance of the patterns. In many applications, pure d.c. may be applied at the input A, but more often the signal applied at A will contain both d.c. and a.c. components, whereas a conventional oscillograph alone, with capacitative input eliminates

the d.c. signal and, indeed, other very low-frequency components. The combination of the Type 185 Electronic Switch and the Type 175 Cathode-Ray Oscillograph enables faithful reproduction of frequencies from d.c. to well beyond audio frequencies, and it is limited only by the characteristics of the amplifiers in the electronic switch and the cathode-ray oscillograph.

When an input signal contains both d.c. and a.c. components, it is probably desirable to feed a portion of this signal to the external-synchronizing binding post on the Type 175 Cathode-Ray Oscillograph through the synchronizing-signal switch on the front panel for external synchronization and then adjust the sweep-circuit frequency so that it locks in step with the a.c. component of the signal under investigation. In this way, the a.c. waveform may be made to appear as stationary for the most satisfactory analysis, independently of the actual switching-rate chosen.

With the circuits described above, the input signals are applied directly to the input potentiometer of 100,000 ohms on the Type 185 instrument, and they are fed directly from the rotor of this potentiometer to the grid of the first amplifier tube in this instrument. The electronic switch itself utilizes a single stage of amplification for each channel, and it is entirely d.c. coupled from the input binding post to the output binding post. Figure 2 shows a schematic diagram illustrating the essential features of this d.c. amplifier in the Type 185 Electronic Switch. The switching arrangement, for illustration, is shown here as a mechanical device to eliminate the complexity of the multivibrator circuits.

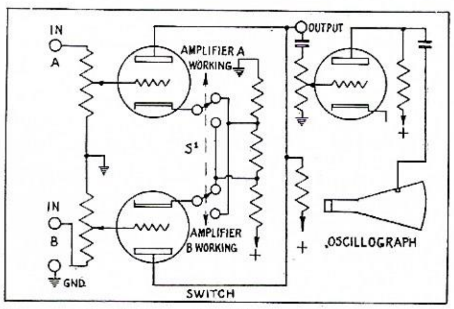


Figure 2. Schematic diagram of elctronic switch and cathode-ray oscillograph for amplifying direct-current signals. The switch, S, is actually a rapid electronic circuit.

Applications of this d.c. amplification feature are numerous. The standard oscillograph, as mentioned above, is of little use in determining d.c. potentials in circuits. By virtue of the 100,000 ohm gain control on the input circuit of the Type 185 Electronic Switch, the combination here described may be utilized for measuring d.c. potentials over a range from 0.01 volt to several hundred volts. It is advantageous, when used in this manner, in determining cathode biases, battery potentials, and bleeder voltages. A minor disadvantage of the standard circuit usually employed in the instrument is the low input-impedance, which was chosen, during design, in order to maintain essentially uniform frequency-response well above audio frequencies when using a simple potentiometer attenuator. If one wishes to employ these principles for high-impedance d.c. measurements, however, the grid of the input tube may then be disconnected, brought out directly from the instrument, and whatever grid leak is desired may be connected to ground. With this change, it is possible to work with input-impedances up to ten megohms without serious disturbances due to grid current in the input tube.

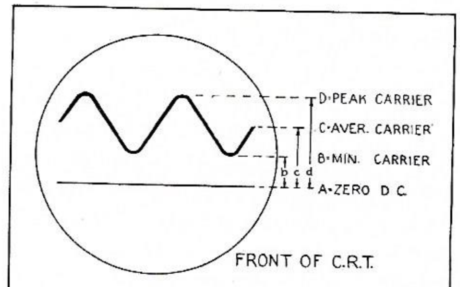


Figure 3. Method for measuring modulation percentage of a radio signal at the receiver.

A particularly useful application of this circuit arrangement is found in connection with the observation of signals at the detector of radio receivers. With this feature, the d.c. and a.c. components of a radio signal may be observed. It further allows a simple means of studying the modulation percentage employed at the transmitting station. Figure 3 illustrates the signals observed in the load circuit of a detector when receiving a broadcast sound program. In this case, the sound signal, represented by the sine wave, is producing only 50% modulation of the carrier at the transmitter. The equations for calculation of modulation percentage are as follows:

The level A represents the zero- or reference-line on the cathode-ray tube screen.

The level B represents the minimum carrier during a cycle of the audio tone.

The level C represents the average carrier.

The level D represents the peak carrier.

In other words, if the modulation were removed, and the carrier alone were transmitted, the oscillograph would indicate a straight line at A as the zero-line and another straight line at C which represents the rectifier d.c. potential generated by the unmodulated carrier. The modulation percentage is now derived from the following expression: Let b represent the d.c. proportional to the minimum carrier. Let c represent the d.c. proportional to the average carrier. Let d represent the d.c. proportional to the peak carrier. In practice, it is not easy to measure c. It is, however, practical to determine b and d. Further, let M represent the percent modulation.

Then:

$$M = 100 \frac{c - b}{c}$$

but:

$$c = \frac{d + b}{2}$$

and thus:

$$M = 100 \frac{d + b}{d - b}$$

The above expressions are based entirely upon the assumption of symmetrical modulating signals. Interpretations must necessarily be different when, for example, something such as a television video signal is being investigated. The circuit, however, is very valuable in determining what level of the carrier is continuously provided into which region the modulation never dips. The circuit also makes it possible to examine the steadiness of the pedestals, or of the blanking and synchronizing levels of television transmissions even while the picture components are going through extreme changes.

The combination of the Type 185 Electronic Switch and a cathode-ray oscillograph should prove very valuable in monitoring the modulation characteristics of radio transmitters at remote points in the field. It must be pointed out, however, that, for precise measurements at low signal levels, a correction must be made for the small d.c. potential developed across the diode load. This correction, in general, is small and of course it is unnecessary when working with levels of a volt or more at the detector.

In regard to calibration of the d.c. signals measured in the above-described manner, the convenience of the electronic switch, allows the calibrating signal to be applied at the other input circuit of the instrument which has been provided for the second channel, since the amplifiers are accurately balanced in gain. In this manner, for example, one can obtain a deflection with an unknown signal applied at input A. A d.c. signal may, then, be applied at input B which is of just sufficient magnitude and polarity to bring the zero-line to coincide with the line displaced by the unknown d.c. In this way, the applied standardizing signal is exactly equal to the unknown signal. Another method of calibration is the use of an a.c. signal, available, for example, from the sixty-cycle output post on the front panel of the Type 175 Cathode-Ray Oscillograph. An initial calibration of the a.c. potential applied at input B will provide a method of determining in absolute units the d.c. potential from the unknown source. For many purposes, the accuracy of the attenuator and dial, that is, gain control B, will be sufficient. It must be remembered, however, that measurements of the signal at input B obtained with normal voltmeters will be an r.m.s. indication, whereas, the indications suggested above involve the peak voltage. As an example, let us say five volts, r.m.s., at sixty-cycles, is applied from the ground post to the input post B. The distance from the zero-line to the peak of the a.c. signal will be actually represented, now, by the following expression:

Peak d.c. volts $=\sqrt{2}$ (r.m.s. volts)
Let E represent the r.m.s. potential applied at input B. Let S represent the dial setting of the main control B. Let V equal the d.c. potential represented by the distance

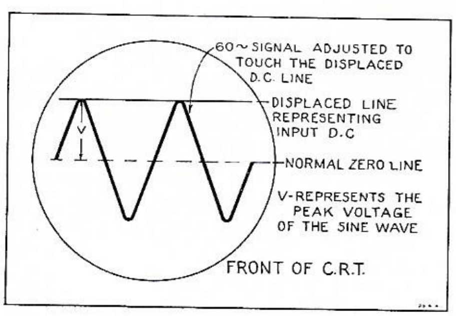


Figure 4. Method for calibration of the equipment for measurement of d.c. signals.

from the zero-line to the peak of the sixty-cycle wave. Figure 4 will show these details more clearly. When the circuit is used as suggested above, this value, V, will be equal to the actual d.c. potential applied at the other input post A.

Now:

$$V=\frac{S}{100}E\sqrt{2}$$

In general, the square-root factor can be incorporated once and for all as a multiple of E, if this be accurately measured, and therefore the equation becomes:

$$V=\frac{S}{100}K$$

where:

$$K=1.41\ E$$

or, for the above example:

$$K=(1.41)5=7.05.$$

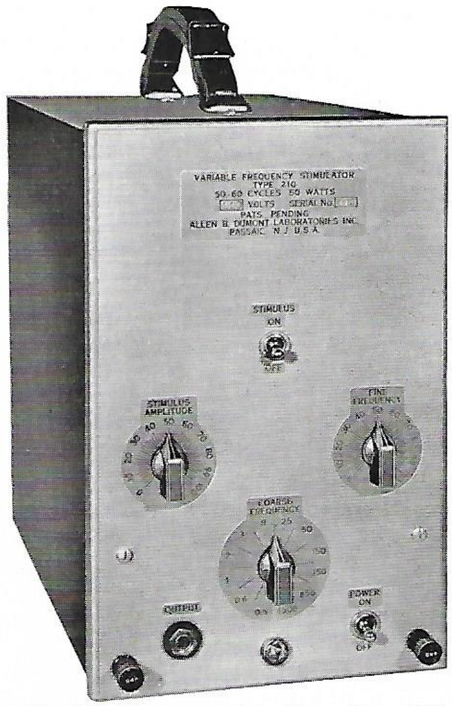
For some purposes, where the accuracy of a known external signal is not required, it is possible to calibrate the balance control in a manner suitable for the absolute value of the d.c. signals, since this control varies the relative biases on the two parallel amplifiers of the Type 185 Electronic Switch at their operating point.

It is suggested that the features of the above circuits may prove of extreme value when it is desirable to measure d.c. potentials in circuits where the application of any measuring instrument at once initiates a change in circuit characteristics, so that the use of normally-sluggish d'Arsonval-type meters is made impossible. Circuits, for example, involving a charged capacitance which will discharge to a value quite appreciably different from its initial value before a moving needle d.c. meter could become stable, may be measured at their original value by the means described here. Its application in connection with piezo-electric crystal circuits should also prove valuable.

—*Thos. T. Goldsmith, Jr., Ph.D.*

A NEW STIMULATOR FOR BRAIN-SURGERY AND RESEARCH

The Du Mont Variable-Frequency Stimulator, Type 210, has been designed for use in stimulation of



Variable-Frequency Stimulator, Type 210

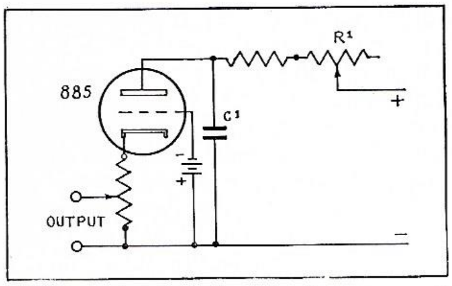
the cortex in neuro-surgery, and for use in any type of experimental work where it is desirable to supply a stimulating current accurately controlled in both frequency and amplitude.

METHOD OF OPERATION

Fundamentally, it is desirable in any stimulator, that the nature of the individual stimuli and the repetition-rate be independently variable. It is essential, if studies are to be made of the effect of various frequencies of stimulation, that the form and amplitude of the individual stimuli remain constant at a preset value throughout the frequency range; or that, in studies of the effects of various stimulus amplitudes, the frequency remain constant throughout the amplitude range.

The Harvard inductorium, which has long been used for stimulation, does not provide for such non-dependent changes in control of the stimulus. A more satisfactory arrangement, which has been widely used, is a single gas-discharge tube functioning as a relaxation oscillator of variable frequency. In this type of instrument, a portion of the discharge current of the tube is utilized for the stimulus. A typical simplified circuit is shown in Figure 1. The range of such an instrument is limited by a number of factors. The charging current to the condenser has a definite maximum value above which the discharge-tube will fail to dionize, and a definite minimum value below which the circuit becomes unstable due to the effectively increased leakage. For a given value of C_1, therefore, there is a definite and fairly narrow range of frequencies for which the circuit will function. If the value of C_1 be changed, to extend the frequency range, the form and amplitude of the stimulus will be altered.

The principle employed in the Du Mont Variable-Frequency Stimulator is to use a pulse generator, similar in principle to that outlined above, to trigger a gas-discharge tube in which the grid bias has been placed so high that discharge will not occur until a pulse from a preceding pulse-generator is placed upon its grid. With this type of circuit, the shape of the pulse received from the trigger pulse generator is unimportant so long as it is not of sufficient duration to trigger two impulses from the gas triode. It has been possible, therefore, in this instrument to provide a wide frequency-range by the use of various-sized condensers in the triggering pulse generator without altering the final stimulus shape. The output amplifier is resistance-capacity coupled to the output to prevent any direct-current component from reaching the subject between stimuli.

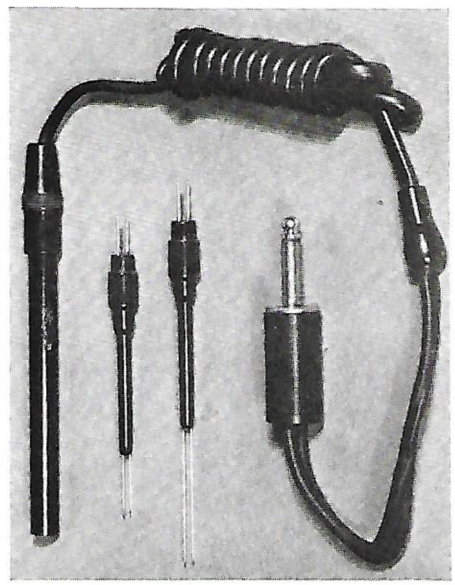


The circuit of this instrument, then, consists of three major components: 1. a triggering impulse generator of variable frequency controlling the repetition-rate of the stimulus; 2. a gas-discharge stimulus generator producing stimuli of fixed form under control of the triggering impulse generator; and, 3. an output amplifier to bring these stimuli to the required strength. While a gas-discharge tube in a circuit similar to that of Figure 1 could have been used for the triggering impulse generator, the characteristics of such a tube are subject to considerable variation with time. This instrument, therefore, employs two high-vacuum tubes in a special oscillator circuit to provide the triggering pulses with a much higher degree of frequency stability. The particular circuit which has been employed provides exceptionally satisfactory independence of frequency from line-voltage changes.

PROTECTIVE FEATURES

In designing the protective features of this instrument, much consideration has been given to the remotest possibilities of accident, and it is felt that this instrument provides a greater degree of safety to the patient than does even the simplest battery-operated stimulating device. With any device, in which wiring of any sort is brought into contact with a patient, there is always danger that some portion of the wiring may accidentally become crossed with a high-voltage circuit and that, in such a case, if the patient be grounded, he may receive a severe shock. It seems desirable to provide, therefore, as a final protective device which will operate in remote instances where the stimulating device may accidentally come into contact with high-voltage and where conditions may be of such a nature as to make such contact dangerous, fuses of extremely small capacity in series with the leads to the patient. Furthermore, it must be borne in mind that if any portion of the wiring between the patient and the fuses is exposed, contact of this wiring with high-voltage would not be subject to protection. In this instrument, the output jack and the output fuses have been completely enclosed in bakelite shells which mechanically and electrically isolate the output leads from any possible contact.

Most electrodes on the market are equipped with a type of plug



Electrode Holder and Tips

Electrode tips fit snugly into their holder, providing a vacuum-fit and precluding the possibility of the electrodes falling out during use. The entire electrode assembly, including the lead cord and plug, may be sterilized by boiling. Illustrated above are the Type 56 Electrode Handle and Cord, with the Type 56-E short-tip bipolar electrode, and the Type 56-F long-tip bipolar electrode.

in which one connection is made to the sleeve of the jack. With this type of plug and the ordinary type of jack mounting, one lead from the patient is connected to the metal case of the instrument. With such an arrangement, contact of a high-voltage circuit with any part of the metal case would constitute a potential source of danger to the patient. In this instrument, the usually grounded frame of the jack has been insulated from the case and a fuse inserted between it and the connection to the case which is normally grounded. This fused circuit is completely isolated in bakelite as is the other output lead. In this way, in addition to the normal protection afforded by grounding the case, sensitive fuse protection is provided for those rare instances where the ground connection is imperfect and accidental contact has occurred.

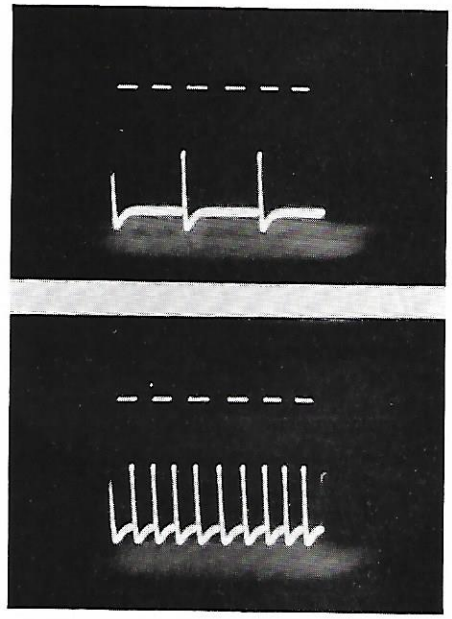
APPLICATION

The Type 210 Variable-Frequency Stimulator has been designed primarily for stimulation of the cortex in neuro-surgery, and for stimulation of nerve-muscle and other in-vitro tissue preparations in experimental work. The maximum output is not great enough for excitation of muscles through the skin, as it was felt that with such an output available, there would be the possibility of its accidental application to the exposed brain.

The Type 210 Variable-Frequency Stimulator lends itself well to stimulation of heart and nerve-muscle preparations in the physiological laboratory. The frequency-range has been extended to repetition-rates as low as one stimulus each two seconds for stimulation of heart preparations. Tetanizing stimuli for nerve-muscle preparations are well within the range of the instrument.

Since the choice of electrode types will vary with the use to which the instrument is to be applied and with the surgeon's preferences, electrodes are not included as standard equipment with the instrument. Readily-sterilizable high-quality electrode-holders and removable electrode tips are available. Special electrode types, in accordance with individual specifications, may be obtained upon request. A connection plug is supplied with the instrument to permit the use of any type of electrode which the individual may have.

The unretouched oscillographic records reproduced here illustrate



Oscillograms of stimuli showing constancy of form and amplitude. Time intervals: one millisecond.

the independence of stimulus amplitude, frequency, and waveform. With this type of performance from a stimulator, the operator is assured that his results are independent of any instrument variations.

ALLEN B. DU MONT LABORATORIES, INC.
2 MAIN AVE., PASSAIC, NEW JERSEY

Printed in U.S.A.