RADIO-ELECTRONIC *Engineering* SECTION

RADIO & TELEVISION NEWS

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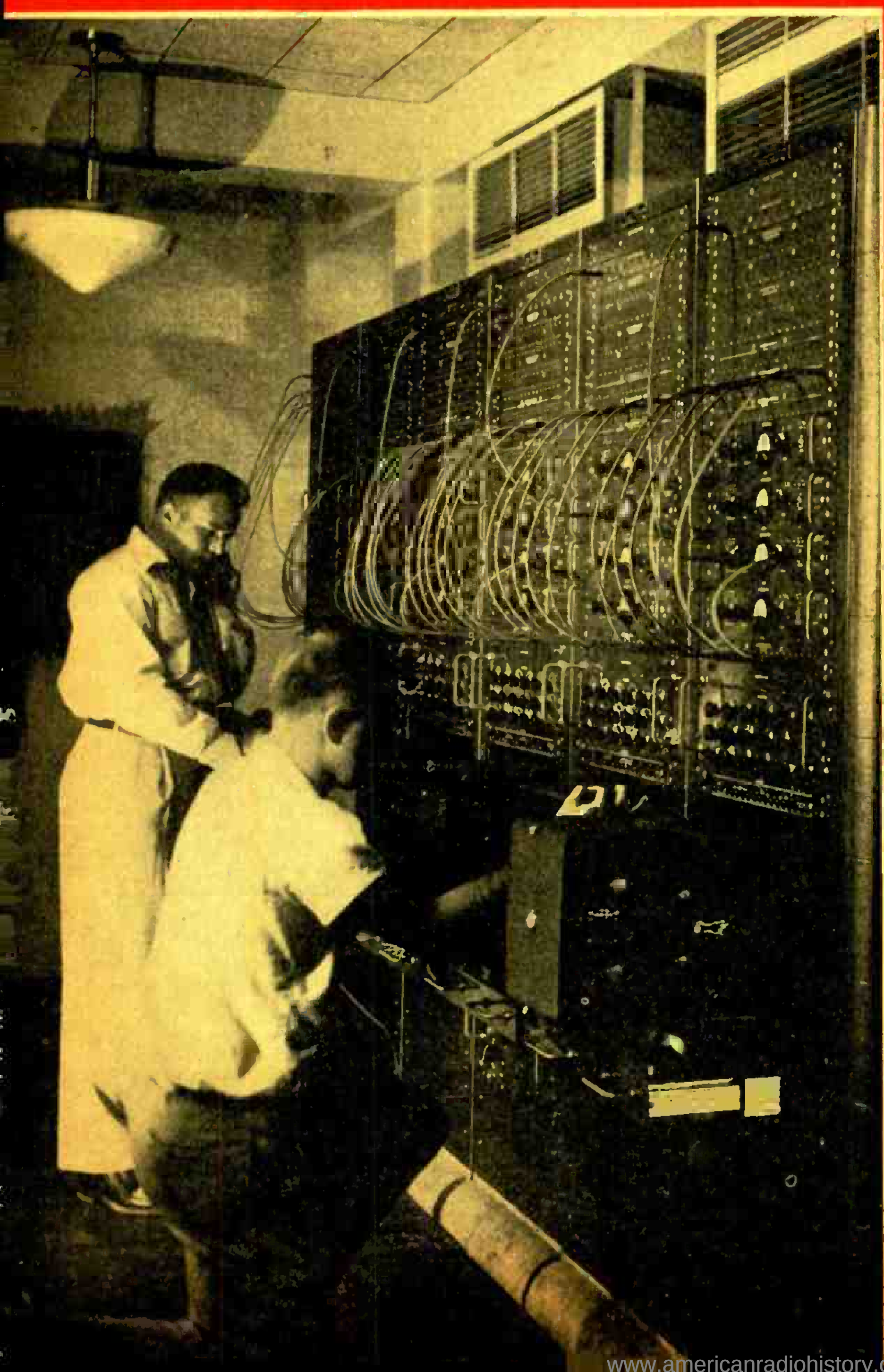

FEBRUARY, 1953

DEPARTMENTS

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Edited by H. S. RENNE
and the Radio & Television News Staff

Technicians making final oscillograph calibration adjustments on guided missile data recording equipment at Patrick Air Force Missile Test Center. Mr. J. Wynn, Jr., co-author of article on P. 3, is at left.

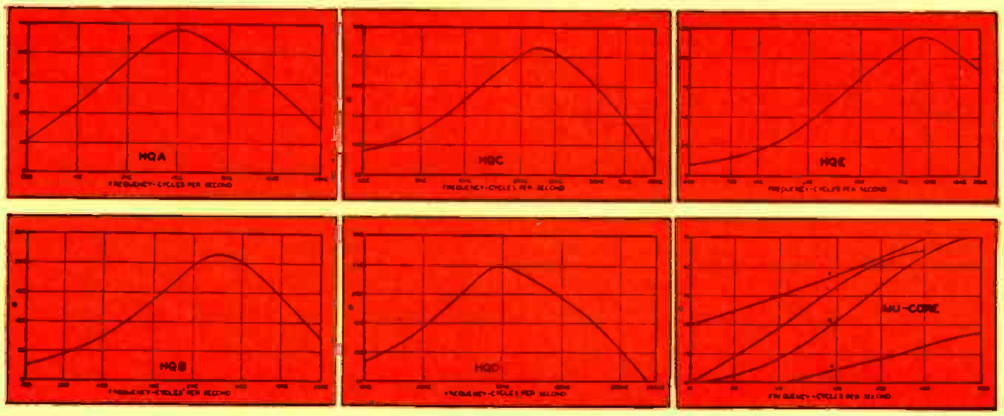
PERMALLOY DUST TOROIDS FOR MAXIMUM STABILITY...

The UTC type HQ permalloy dust toroids are ideal for all audio, carrier and supersonic applications. HQA coils have Q over 100 at 5,000 cycles...HQB coils, Q over 200 at 4,000 cycles...HQC coils, Q over 200 at 30 KC...HQD coils, Q over 200 at 60 KC...HQE (miniature) coils, Q over 120 at 10 KC. The toroid dust core provides very low hum pickup...excellent stability with voltage change...negligible inductance change with temperature, etc. Precision adjusted to 1% tolerance. Hermetically sealed.

HQA, HQC, HQD CASE
1 13/16" Dia. x 1 3/16" High

HQB CASE
1 5/8" x 2 5/8" x 2 1/2" High

HQE CASE
1/2" x 1 5/16" x 1 3/16" High



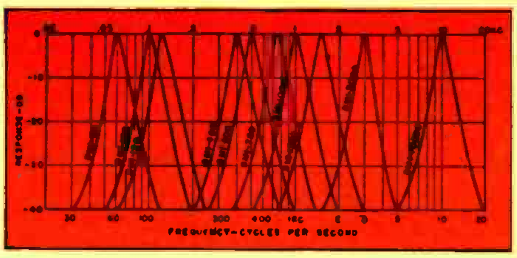
Type No.	Inductance Value	Net Price
HQA-1	5 mhy.	$7.00
HQA-2	12.5 mhy.	7.00
HQA-3	20 mhy.	7.50
HQA-4	30 mhy.	7.50
HQA-5	50 mhy.	8.00
HQA-6	80 mhy.	8.00
HQA-7	125 mhy.	9.00
HQA-8	200 mhy.	9.00
HQA-9	300 mhy.	10.00
HQA-10	.5 hy.	10.00
HQA-11	.75 hy.	10.00
HQA-12	1.25 hy.	11.00
HQA-13	2. hy.	11.00
HQA-14	3. hy.	13.00
HQA-15	5. hy.	14.00

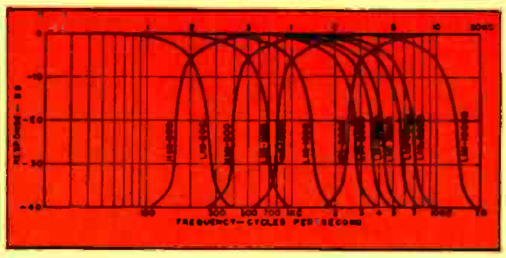
Type No.	Inductance Value	Net Price
HQA-16	7.5 hy.	$15.00
HQA-17	10. hy.	16.00
HQA-18	15. hy.	17.00
HQB-1	10 mhy.	16.00
HQB-2	30 mhy.	16.00
HQB-3	70 mhy.	16.00
HQB-4	120 mhy.	17.00
HQB-5	.5 hy.	17.00
HQB-6	1. hy.	18.00
HQB-7	2. hy.	19.00
HQB-8	3.5 hy.	20.00
HQB-9	7.5 hy.	21.00
HQB-10	12. hy.	22.00
HQB-11	18. hy.	23.00
HQB-12	25. hy.	24.00

Type No.	Inductance Value	Net Price
HQC-1	1 mhy.	$13.00
HQC-2	2.5 mhy.	13.00
HQC-3	5 mhy.	13.00
HQC-4	10 mhy.	13.00
HQC-5	20 mhy.	13.00
HQD-1	.4 mhy.	15.00
HQD-2	1 mhy.	15.00
HQD-3	2.5 mhy.	15.00
HQD-4	5 mhy.	15.00
HQD-5	15 mhy.	15.00
HQE-1	5 mhy.	6.00
HQE-2	10 mhy.	6.00
HQE-3	50 mhy.	7.00
HQE-4	100 mhy.	7.50
HQE-5	200 mhy.	8.00

UTC INTERSTAGE AND LINE FILTERS

FILTER CASE M
1 3/16 x 1 11/16, 1 5/8 x 2 1/2 High





These U.T.C. stock units take care of most common filter applications. The interstage filters, BMI (band pass), HMI (high pass), and LMI (low pass), have a nominal impedance at 10,000 ohms. The line filters, BML (band pass), HML (high pass), and LML (low pass), are intended for use in 500/600 ohm circuits. All units are shielded for low pickup (150 mv/gauss) and are hermetically sealed.

STOCK FREQUENCIES
(Number after letters is frequency)
Net Price $25.00

BMI-60	BMI-1500	LMI-200	BML-400
BMI-100	BMI-3000	LMI-500	BML-1000
BMI-120	BMI-10000	LMI-1000	HML-200
BMI-400	HMI-200	LMI-2000	HML-500
BMI-500	HMI-500	LMI-3000	LML-1000
BMI-750	HMI-1000	LMI-5000	LML-2500
BMI-1000	HMI-3000	LMI-10000	LML-4000
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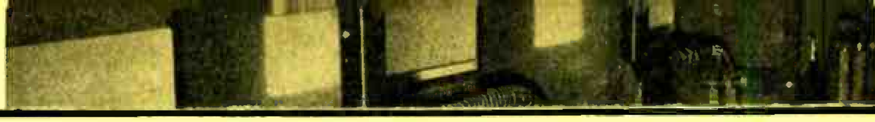
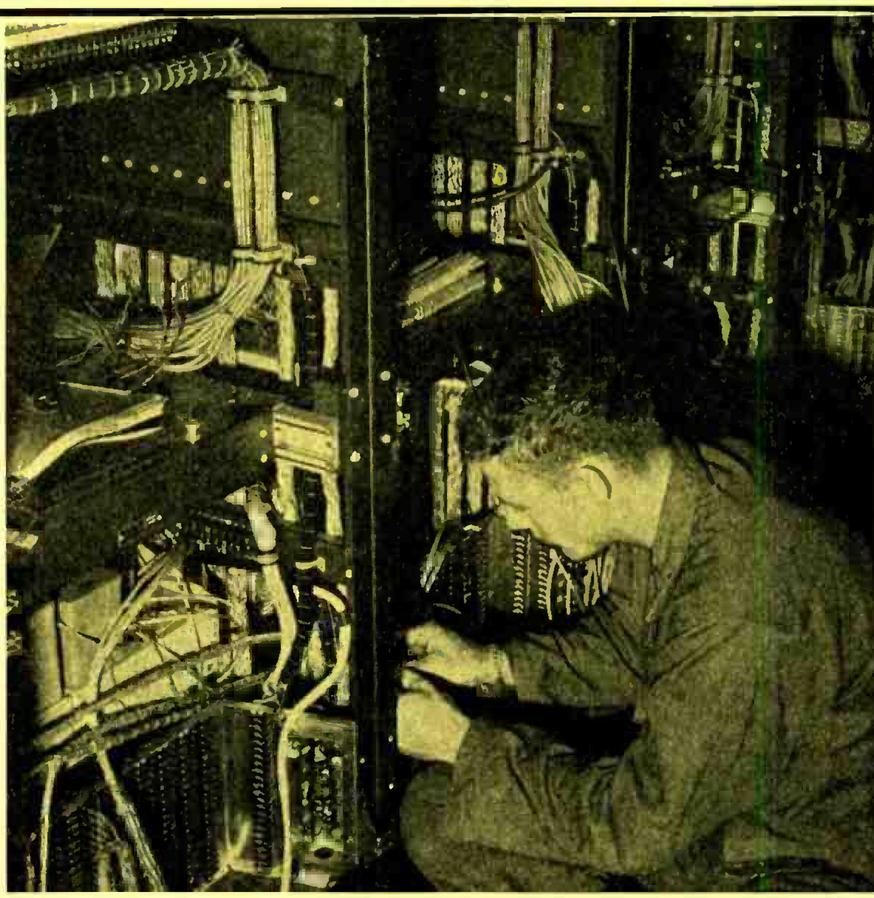


GUIDED MISSILE DATA RECORDING



A bay of oscillograph racks being installed at the telemetry receiving site.

Photographic oscillographs are widely used to record data obtained from telemetering systems.

By

JAMES B. WYNN, JR.*

and

SAM L. ACKERMAN**

Air Force Missile Test Center
Patrick Air Force Base

THOSE in nearly every craft or profession have at one time or another had the occasion to record data. In the fields of electricity and electronics, perhaps the furthest advances have been made in precision data indicating and recording of scientific phenomena. The recording oscillographs, utilizing galvanometer elements, provide an ideal means for observing and recording static and dynamic data, and will be the main subject of this article. Auxiliary or accessory equipment recently developed to provide flexibility and standardization of installation and operating techniques at one of the advanced missile radio telemetry stations at the Air Force Missile Test Center, Patrick Air Force Base, Florida, will be discussed in detail.

The Recording Oscillograph

For those not familiar with this type of recorder, it may be well to describe in some detail the fundamental aspects of this instrument. No doubt the oscillograph which would normally come first to mind would be a conventional electronic unit with a scope tube on the front, similar to the common TV set, and with a camera focused on the oscilloscope tube. However, as mentioned before, the equipment to be discussed uses a galvanometer as the active indicating element. The recording oscillograph is really quite simple —it is composed of a light source, a mirror moved by a sensitive meter movement to reflect the light, and a photosensitive medium to record the reflected light beam.

A review of the recording galvanometer oscillograph manufacturers listed in business guides indicates that this is a multi-million dollar enterprise. However, only a few of the available manufacturers produce recorders satisfactory for extensive use, and for precise measurements in the field of missile or aircraft testing. Most of the reasons for this will become self-evident, and a survey will show that some of the mechanical and electrical characteristics of a few far surpass the others.

The Galvanometer

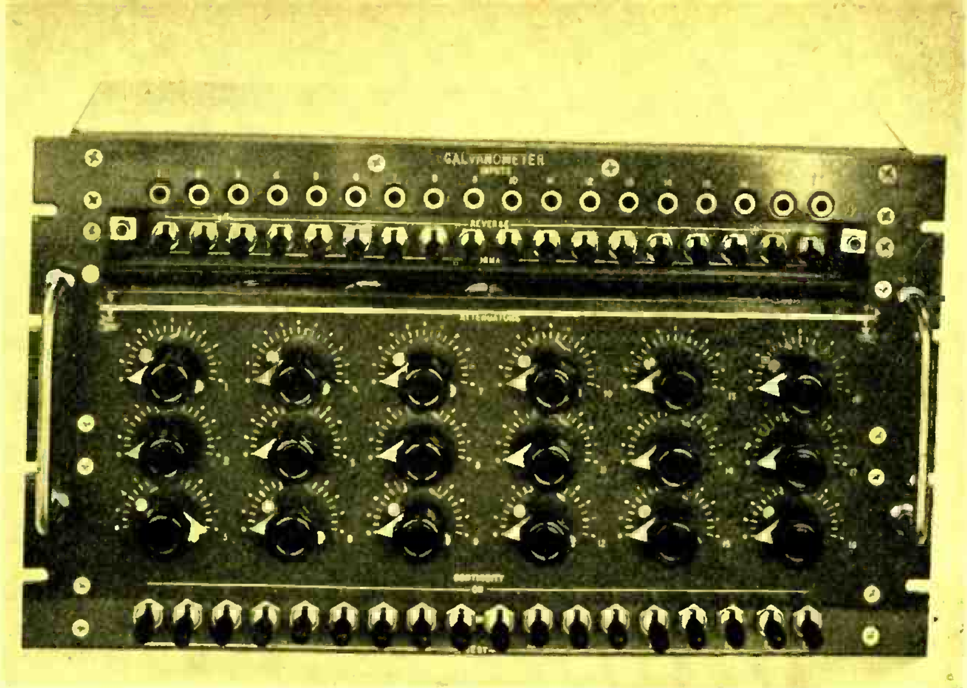
The galvanometer element, which on occasion may have been presented too mysteriously, is in reality a d'Arsonval meter movement without any pointer; a small mirror replaces the pointer. The movement of a current-carrying wire in a magnetic field is one of the basic concepts of electromagnetic theory and this principle is utilized in converting the electrical energy into mechanical energy in the galvanometer. Degree of force or motion produced is mostly dependent upon the flow of electrons, the number of turns of the conductor, and the strength of the magnetic field. Thus, with the present design, a compact element exists which very conveniently converts the flow of electrons to the proportional movement of a mirror. The moving beam of light reflected from the mirror is then projected on a ground glass screen for viewing, calibration and setup purposes, and is simultaneously projected onto photographic material to preserve the data permanently.

Main components required to make up the galvanometer are: a coil of wire, a suspension for positioning the coil of wire, a mirror, and a case or shell. Of course, the galvanometer must be positioned in a magnetic field for operation, but this magnet is separate and external for operational reasons. A photo-optical system is used in conjunction with the mirror since it provides the means for producing a record without extracting any appreciable energy from the galvanometer. Characteristics of the galvanometers in general use conform to the following:

1. Small size (approximate dimensions: ⅛" to 3/16" by 2" to 2½")

*Chief, Telemetry Section, Technical Systems Lab.
**Major, USAF; Chief, Internal Electronic Engineering Branch, Technical Systems Lab.

A technician is adjusting the position of a galvanometer in the oscillograph.



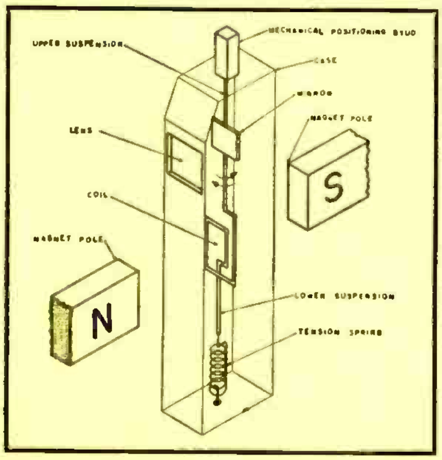
Front view of galvanometer panel, showing function controls as well as polarity switches which are recessed and normally protected by the hinged cover plate.

2. Good sensitivity (low frequency, 0.033 ma./in.; high frequency, 40 ma./in.)
3. Wide frequency response (0-2000 cps)
4. Rugged construction (suitable for field, mobile or airborne installations)
5. Accuracy (1%)
6. Replaceability (electrically and mechanically interchangeable)
7. Cost ($100 to $150 each)

Damping

The suspension of the galvanometer is a free moving element, so that its action under forced vibration follows all the theory and formulas pertaining to such motion. Of primary concern to the user is the motion of the element when a signal is applied. The mass of the movement and its inertia will distort the motion of the recorded output in relation to the input if rapid changes occur. Thus, the damping characteristics of the element as associated with its circuitry should be understood.

Pictorial cutaway illustration of a typical D'Arsonval galvanometer element.



Basically, two fundamental damping mediums are used: (1) fluid damping, i.e., the suspension rotates within a viscous fluid, and (2) electromagnetic damping, which utilizes the back emf generated by the coil moving in a magnetic field. Actually, any galvanometer has additional damping effects produced by both mediums since the air in which an electromagnetically damped galvanometer moves produces some of the fluid damping effects, and the source impedance of a fluid damped galvanometer furnishes electromagnetic damping. The total damping is the arithmetical sum of all the per-unit dampings of the particular system.

Damping is used mainly to control the frequency response but it also introduces a phase shift (very slight), protects the galvanometer from violent overswings, and controls the time required to respond to sudden changes in current.

Normally, 0.64 per-unit damping or 64% of critical damping is used since it produces maximum frequency range with minimum inherent error. Unfortunately, many users procure galvanometers and standard shunts without realizing that circuitry associated with the galvanometer may at times seriously alter the damping characteristics.

Frequency Response

Whether electromagnetic or fluid damping should be used is mainly determined by the frequency response required and the driving current available. The electromagnetic type is generally more desirable since it normally has higher sensitivity and a far lower temperature coefficient. With the present manufacturing techniques, it can be shown by the following basic formula that the limiting factor for electromagnetic galvanometers is the frequency response:

$$R = K/F$$

where R is the shunt resistance in ohms, K a constant of construction and installation, and F the frequency.

From the above, it is easy to understand how the shunt resistance R becomes lower in value as the frequency F is increased. Table 1 has been prepared from values in one of the instruction manuals furnished with a commercial recording oscillograph. Actually, the shunt resistance will never become zero but its value will become less than the internal resistance of the galvanometer and its low sensitivity will render it useless, fluid damping then being necessary.

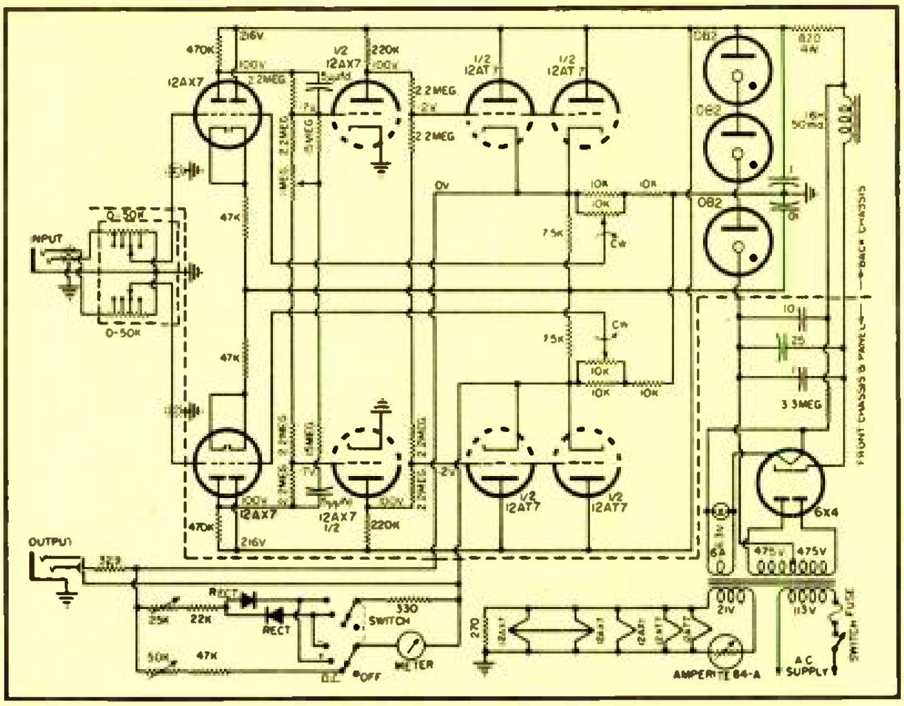
The present oscillographs utilize a magnetic block to provide proper flux density for all the galvanometers in the instrument. Thirty-six galvanometer element installations are common in blocks of about four or five inches long. The frequency response range, linear ± 5% at 64% of critical damping, of commercially available galvanometers is from 0-2000 cps. Greater sensitivity is obtainable by selecting elements—whenever possible—that have a flat re-

Table 1. Relationship between response, the shunt resistance, and sensitivity.

Frequency Response (cps)	Shunt Resistance (ohms)	Sensitivity (ma/in.)
0- 60	350	0.033
0-100	180	0.035
0-180	83	0.040

sponse range limited to the intelligence frequency to be investigated. By considering the theory of galvanometer operation, it is easy to realize that since the flux density is a constant, more force will be produced by a constant current if the number of turns is increased. Unfortunately, more turns increase the mass, so the natural frequency is low. Conversely then, reducing the number of turns will increase the natural frequency but reduce the force or degree of rotation of the mirror.

Data received at telemetry stations is generally stored on magnetic tape, which is played back after the test has been completed, and is recorded directly on a recorder which produces a visual and permanent record. In the oscillograph recorder, the photosensitive paper travels at a constant speed while an accurate time base is recorded, and the information is presented as a trace deflection proportional to the intelligence data. The usefulness of the record is threefold—an experienced engineer can view a record after a flight and, reading it as a graph, estimate performance; he can read data accurately by tabulating each period of time required; or if the data are to be fed from magnetic storage into electronic computers, he can determine which portions are worth while tabulating or printing and at what rate it should be accomplished.



Circuit diagram and parts values for the galvanometer amplifier.

Applications

Utilization of recording oscillographs to record data in telemetry installations at the guided missile test ranges has become a necessity. Merely to place them on benches or tables is most inefficient and not in keeping with the present "state of the art." If varying work loads exist whereby "setup conditions" have to be changed occasionally, the work becomes very difficult and discouraging. In fact, where lack of standardization is apparent, so much individualism creeps in that set procedures cannot be adhered to. The result is eventually disastrous. Sooner or later, while under pressure or while training new personnel on the job, the time will come when the signals supposedly connected to the instrument will be missing from the record.

The early oscillographs were developed to enable seismograph recordings to be made in geophysical exploration, and they still find wide application in that field. In these early models, small pickups would indicate amplitude and the recorder itself would apply a time base so that small exploding charges could be set off to indicate terrain configuration.

Radio telemetry is one of the prime users of oscillographs today, and has fostered or made practical many of the improvements on oscillographs which have been adapted in the past few years. Recording oscillographs are in use in the majority of telemetry systems as one of the means of recording data, and they will be found on most of the missile test ranges. Some of the ranges employ 20 to 40 such instruments.

The recording oscillograph, when used by itself, can be operated on a laboratory bench or table. While the instrument is only 12-14" high, 10-12" wide and 18-24" deep, it requires a considerable amount of free space for cabling, galvanometer adjustment, changing drive speed, magazine loading and operational viewing. In fact, every side must be accessible except the bottom and the back. Unfortunately, to provide accessibility, many instrumentation installations merely space them wide apart in rows on tables. Thus, all the engineering planning of the installation is lost somewhere in a maze of cabling that resembles a conglomeration of short-circuited one-armed bandits. The small oscillograph now requires a floor area of about nine square feet.

Oscillograph Racks

Because of experiences gained from the other missile test ranges, the engineers in the AFMTC's Technical Systems Laboratory felt that it was necessary to develop and fabricate oscillograph recording racks for installations of elaborate telemetry facilities, and furthermore, that centralized recording techniques should be employed. The final AFMTC design provided for all information from as many as three 16-channel or six 8-channel FM/FM telemetry systems to be available for "set up" at each oscillograph.

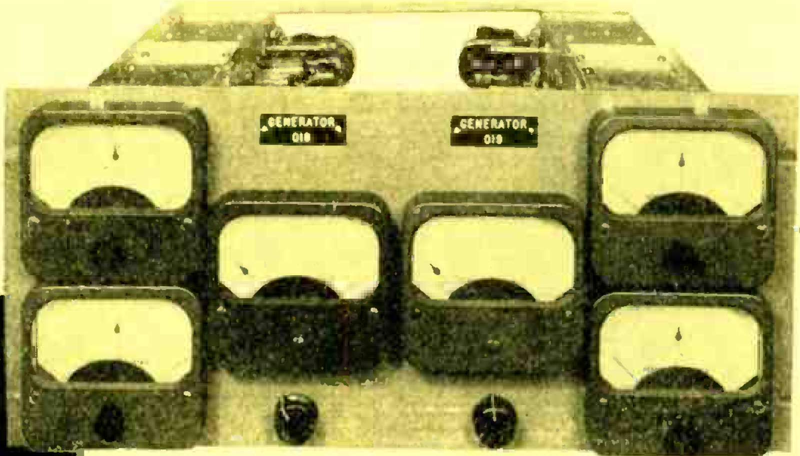
Each oscillograph rack is complete in itself. Separate panels are provided for each group of data outputs from the telemetry stations. This permits easy expansion or adaptability to other types of instrumentation for standardization. The basic design parameters were to provide proper installation and

(*Continued on page* 28)

Typical oscillograph record with trace lines and timing markers identified.

A THERMOCOUPLE A.F. WATTMETER*

By
J. D. RYDER
and
M. S. McVAY
University of Illinois



Instrumentation for an analog computer. Central instruments are electronic voltmeters and outer vertical pairs are wattmeters.

By using electronic amplification, many disadvantages of the thermocouple for measuring power are overcome.

AUDIO-FREQUENCY power measurements have usually been made by dissipation of the power in a known resistive load, since few audio-frequency wattmeters have been available. Numerous proposals appear in the literature covering low-burden electronic instruments which usually employ some form of square-law circuit, as in Fig. 1, but practical forms of the instrument have rarely appeared.

Usual Theory

It can be seen that the input to diode (or triode) V_1 in Fig. 1 is:

$$e_1 = e - iR_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

and the input to diode V_2 is:

$$e_2 = e + iR_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where e is the instantaneous value of voltage applied to the load, and i is the instantaneous value of current flowing to the load. Resistors R_2 are assumed small and equal.

In the usual manner, if the diodes have identical volt-ampere curves given by:

$$i = a_0 + a_1e + a_2e^2 \quad . \quad . \quad . \quad . \quad (3)$$

then the anode current of V_1 is:

$$i_1 = a_0 + a_1e - a_1iR_2 + a_2e^2 - 2a_2eiR_2 + a_2i^2R_2^2 \quad . \quad . \quad . \quad . \quad (4)$$

The anode current i_2 of V_2 differs only in that the two negative signs become positive.

The output or load circuit is acted upon by the difference of currents i_1 and i_2, and it is apparent that all positive terms appearing in both equations will cancel, leaving only a result equal to twice that of the negative terms in (4). Thus:

$$i_{out} = i_2 - i_1 = 2a_1iR_2 + 4a_2eiR_2 \quad . \quad (5)$$

If the applied electromotive force is sinusoidal, or $e = E_1 \sin \omega t$ and $i = I \sin (\omega t + \theta)$, where θ is the power factor angle of the load, then the output current is:

$$i_{out} = 2a_1IR_2 \sin (\omega t + \theta) + 4a_2E_1IR_2 \sin (\omega t) \sin (\omega t + \theta) \, . \, (6)$$

If $IR_2 = E_2$, the above becomes by expansion:

$$i_{out} = 2a_1 IR_2 (\cos \theta \sin \omega t + \sin\theta \cos \omega t) + 2a_2E_1IR_2(\sin \theta \sin 2\omega t - \cos \theta \cos 2\omega t) + 2a_2E_1IR_2 \cos \theta \quad . \quad . \quad . \quad . \quad . \, (7)$$

If this difference current is applied to a d.c. or average reading instrument M, only the last term of (7) will deflect the meter, since the first two terms represent a.c. currents. These may be bypassed around M by a suitable capacitor.

If $IR_2 = E_2$, then the instrument M is deflected by a d.c. current of value:

$$i_M = 2a_2E_1E_2 \cos \theta \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

which is proportional to the average load power, angle θ being the load power factor angle. Thus meter M becomes an indicator of average load power.

Reasons for Dissatisfaction

Certain assumptions have been made in reaching the above results, and these are:

(a) The two tubes have identical volt-ampere curves, or pass identical currents for all values of applied voltage.

(b) The matching of (a) exists throughout the life of the tubes, and for all values of heater voltage.

(c) The tube volt-ampere curve is accurately expressed by (3), and no higher power terms are present.

In practice, it has been impossible to find or to maintain tubes or crystals meeting these assumptions, such that power measurement accuracies of better than 5% can be achieved without severely restricting the load current or voltage to a very small range. Two tubes or two crystals may be matched to equal quiescent currents or values of a_0, by adjustment of the tap on R_3, but balanced currents will probably not be obtained at other applied voltages. This action, of course, indicates unequal values of a_1 and a_2.

Fig. 1. Basic form of the square-law circuit used for power measurement.

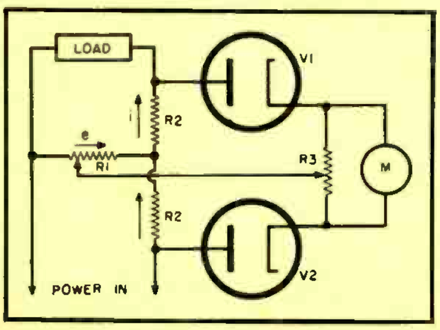
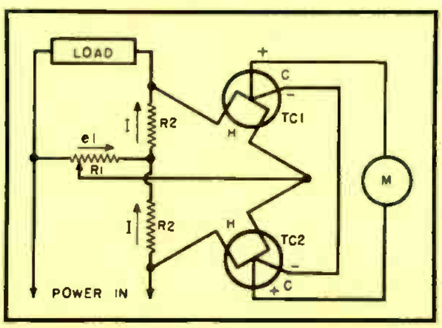


Fig. 2. Schematic diagram showing basic principles of thermal converter.



*This article is based on a paper presented in Chicago at the 1952 National Electronics Conference, held Sept. 29, 30 and Oct. 1.

Controls may be added for additional individual adjustment, usually taking the form of resistors in the circuit. However, it should be noted that coefficient a_2 of (3) appears in the results of (7) and (8). Any additional resistance added to the circuit for adjustment purposes has the effect of linearizing the circuit, reducing the value of a_2, and thus lowering the sensitivity of the circuit when used as a wattmeter.

Since three coefficients appear in the series (3), three independent adjustments are theoretically needed. These additional adjustments may be obtained by use of triodes or pentodes with grid bias controls, but the over-all result is not changed—to achieve and *maintain* a match of volt-ampere characteristics over an applied voltage range of possibly 50 to 1 is not a practical matter with commercial tubes.

Use of Thermocouples

It should be noted that the important property required of this circuit is its ability to square, or cross-multiply, the input voltages, since it is only the squared term of (3) which leads to the result of (7) or (8). Another electrical device that inherently employs this squaring property is the thermocouple, as its output is obtained from heat or i^2R input to its heater.

Actually, the thermocouple has been employed for many years as a squaring device in a wattmeter, sometimes used in the electric utility industry. When so used, the device is known as a Lincoln "thermal converter" wherein a d.c. electromotive force is generated proportional to load watts, this d.c. electromotive force then being telemetered or transmitted over telephone lines to a distant point where the power is indicated or recorded.

The desired squaring property is present in the thermocouple together with certain disadvantages, such as limited overload capacity, slowness of response, low heater resistances, and thus rather large current inputs. By using electronic amplifiers and techniques in the thermal converter circuit, it is possible to overcome all of these disadvantages except the slowness of response. This can be controlled to some extent by the selection of very small thermocouples of low heat capacity, and an anticipating electrical circuit can be added if needed.

Thermal Converter

The principle of the thermal converter is illustrated in Fig. 2, from which it can be seen that this unit is fundamentally the same as the electronic unit of Fig. 1. Thermocouples are employed to square the respective sum and difference input voltages, and to subtract the outputs, leaving a net current through the microammeter M which is proportional to power in the load circuit. In Fig. 2, H indicates heater connections, C the couple connections; vacuum-mounted thermocouples are preferred.

There is one objection to the use of the simple circuit of Fig. 2. Theory indicates that the circuit has maximum power sensitivity when voltages E_1 and E_2 of (8) are equal. Since it is not usually desirable to make the series voltage drop of IR_2 equal to the line voltage E_1 because of excessive losses, some form of amplification of voltage $E_2 = IR_2$ is desirable. In order to reduce the loading effect of the wattmeter on the circuit to a minimum, an electronic amplifier is indicated. It should be pointed out, however, that the amplifier will only be required to be linear, all squaring or nonlinearity of characteristics being a function assigned to the thermocouples.

The Wattmeter Circuit

The circuit of the amplifier incorporated between the shunts and the two thermocouples is shown in Fig. 5. A 50:1 step-up transformer is used across the shunts, as this seemed an easy way to obtain isolation and a voltage increase. Shunt values are chosen to produce 20 millivolts at full-load current, and the line voltage is taken off the shunted potentiometer at a point providing one volt maximum. It is realized that the use of good transformers is necessary at this point if wide frequency response is to be obtained. However, if a poor transformer is used, its performance can be considerably improved by shunting the secondary with a loading resistor.

The first amplifier stage is conventional. The second stage employs two

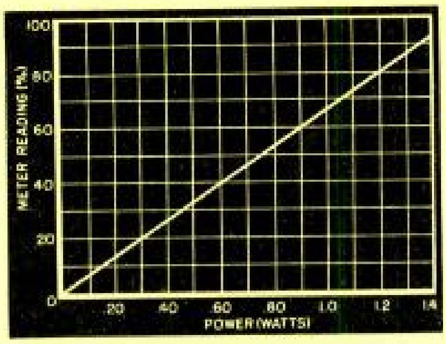


Fig. 3. Typical calibration curve.

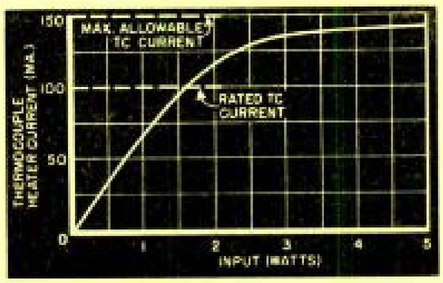


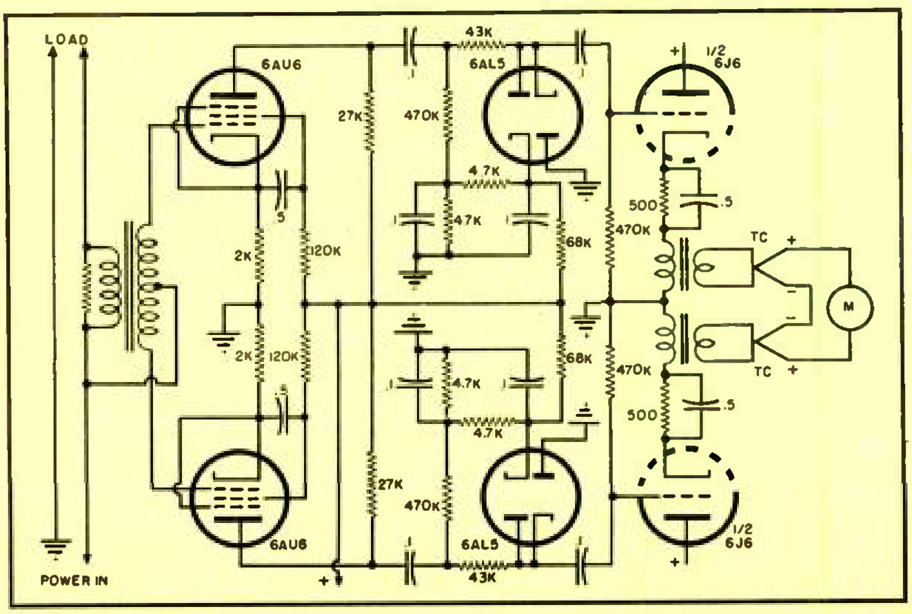
Fig. 4. Performance of vacuum tube limiters in preventing the thermocouples from burning out.

6J6 tubes, with halves paralleled, and with cathode-follower output. This form of output provides much wider frequency response from a given transformer than if the more usual plate output were used. In this case, the transformers are needed for matching the relatively low-resistance thermocouple heaters (2 ohms, 100 ma.) to the 6J6 tubes, and low-cost tube-to-voice coil transformers were found to be satisfactory.

It should be noted that this is not a push-pull amplifier since the two side channels are amplifying different signals ($e - iR_2$ and $e + iR_2$), and no cou-

(*Continued on page* 20)

Fig. 5. Schematic diagram and parts values for the complete instrument.



ULTRASONIC MICROSCOPE*

Translated by
GILBERT B. DEVEY
Office of Naval Research

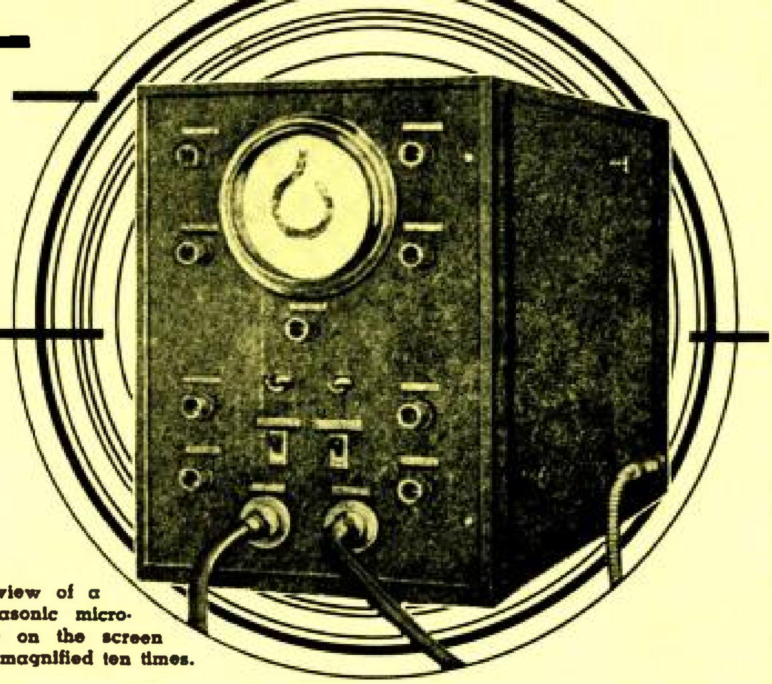


Fig. 1. Over-all view of a developmental ultrasonic microscope. The picture on the screen shows a wire loop magnified ten times.

Ultrasonic waves have been successfully used as the source of illumination in a microscope.

THE successful development of ultra-acoustics and the obtaining of very short ultrasonic waves, of the order of the wavelength of visible light, has led to the development of an ultrasonic microscope with which it is possible to view the picture of an object in magnified scale. Inasmuch as nearly all bodies in nature are transparent to ultrasonic waves, the ultrasonic microscope is expected to have a very wide field of application. Its principle of operation may be found in the proposal of S. Y. Sokolov in 1936 (U. S. patent 2,164,125, issued June 27, 1939).

Operation of the ultrasonic microscope may be described as follows. A narrow beam of ultrasound is bunched (Fig. 2), and radiated by a piezoelectric quartz plate (1) to illuminate the object under examination (2). Reflections of the ultrasonic beam from the object fall on an acoustical collector lens (3), the focus of which is set for reception at (4), consisting of a piezoelectric (e.g., quartz) plate.

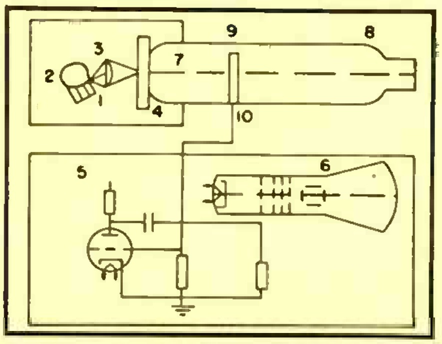
The reception plate is located at the base of the tube (8). The narrow beam of the cathode rays (7), inside the cathode ray tube, falls on the inner surface of the narrow plate and dislodges secondary electrons, which are then collected by the anode (9).

Under the action of the charge, the image on the inner surface of the narrow plate comes from the region of the ultrasound, and secondary electrons are emitted when the surface of the plate is made to undergo a change. This change of secondary emission results in greater current acting on the anode (9), the magnitude being increased by special amplifiers and passed to the modulator arrangement of the cathode of the tube (6). Then the intensification of the cathode beam in the tube (6) causes a fluctuation which conforms to the variation of secondary emission from the surface (4). This is accomplished by the television method of synchronism of motion by lines and frames of the cathode beams of the tubes (6) and (8). The screen of the cathode tube (6) then shows the semblance of a picture as distributed by the electrical charge on the receiver plate (4).

Piezoelectric charges appear on the surface of the quartz plate at the same points where deformation has taken place. Therefore, a picture is distributed on the surface of the quartz plate in exact conformance to the ultrasonic field in the focal plane of the lens (3).

Inasmuch as the configuration of the ultrasonic field in the focal plane in its line of conformance portrays the object, this object is immediately seen on the screen of the tube (6). Transposition of the object understandingly gives the appearance of transference of its image to the screen.

Fig. 2. Diagram illustrating the principle of operation of the microscope.



Magnification of the image, given in the description of the system, is determined by the ratio of the linear dimensions of the cathode tubes (6) and (8). Calculations show that in the ultrasonic microscope magnification approaches the order of tens of thousands of times. The resolving capacity depends on the cross-sectional area of the cathode beam in the tube (8), parameters of the piezoelectric plate, and length of the ultrasonic waves.

Experiment shows that a frequency of 10^9 cycles can be obtained without particular difficulty and that there is a good possibility of obtaining a frequency of 10^{10} cycles. In water, the length of ultrasonic waves at a frequency of 3×10^9 cycles is equal to 5×10^{-5} cm., i.e., the wavelength of visible light. At that frequency, the resolving power of the ultrasonic microscope may reach an extreme, close to the resolving power of the optical microscope.

For capillary waves, the speed of diffusion is considerably less; and the wavelength accordingly is much smaller than the wavelength of visible light. Consequently, if the radiation type of capillary waves can be obtained at higher frequencies in the future, there will be an opportunity to increase the resolution capacity of the ultrasonic microscope by one or two orders to compare with the best optical microscope.

The objects under examination can be illuminated with a continuous ultrasonic beam as well as with single im-

*Translated from an article entitled "The Ultrasonic Microscope" by S. Y. Sokolov which appeared in the Russian Journal "Progress in Physical Science," Vol. XL, Jan., 1950.

pulses. For amplification of the secondary emission, it is expedient for the inner surface of the receiving plate to be covered by a special layer which possesses great secondary emission.

The method of obtaining a visible picture may be altered, as shown in Fig. 3(A). Here, the piezoelectric quartz plate (1) serves as the base of the vacuum triode (2). An ultrasonic beam falls on the outer surface of the piezoelectric plate (1), the inner surface of which is covered by a photosensitive layer. Under the action of the ultraviolet beam (3), uniformly illuminating the inner surface of the plate, photoelectrons are emitted which—accelerated by the application of an electrical field—pass through the system of magnetic and electrical lenses (4) and fall on the fluorescent screen (5). On the screen, as in the usual electron microscope, only the image of the source of electrons may be seen—in this case, the image of the distribution of photoelectric emission from the surface of the piezoelectric plate (1). Distribution of photoemission on the surface of the plate is in precise conformance to the distribution of the piezoelectric charge, which reproduces the configuration of the ultrasonic field. On the screen (5), the image of the ultrasonic field can be seen; this is a repetition of the image of the object, established by the ultrasonic field, in conformance with the magnified scale.

The resolution capability in this case is dependent on the length of the ultrasonic wave, on the thickness and dielectric property used in the piezoelectric plate, and on the construction of the lens system. Ultraviolet radiation, illuminating the quartz plate, can be replaced by a homogeneous electron cluster.

Another version of the ultrasonic microscope is illustrated by Fig. 3(B). This, as in the preceding version, depicts the object received in magnified scale on the screen (5). However, in this scheme, the screen (5) consists of a thin plate on which a photosensitive mosaic layer is drawn, causing secondary electrons under the action of falling electrons to be collected on the annular anode (6). Electrons in the beam (7) fall on the screen (5) and, as in the usual television tube, move line and frame, equalizing in such a manner on the screen (5) as to form an image of the object by electrical potential. The change in secondary-electron emission is amplified and passed to the second tube, in which the cathode beam movement is synchronized with the cathode beam (7). In this case, the image of the object is received on the screen of the second tube.

It should be noted that the capabilities have to be determined not only from the facts mentioned above but also by additional factors of another kind, primarily by the complexity of the vibrations of the quartz plate which is excited by different types of ultrasonic beams; the action of these beams induce not merely longitudinal waves but also transverse and surface waves, which will distort the image. Use of the quartz plate is accomplished by special cuts and choice of the proper method of strengthening (border conditions), which may be diametrical, and the surface waves in the quartz plate are greatly attenuated to increase the clearness of the picture. Applications for the ultrasonic microscope evidently are diversified enough and have sufficient possibilities to warrant rapid growth in this field.

Now to the description of the experimental performance of the ultrasonic microscope in scientific laboratories:

In Fig. 4, a metallic object is shown immersed in an opaque liquid (magnified ten times).

Figure 5 illustrates a glass rod and glass tube of equal dimensions. In the rod, the clear space shows ultrasonic waves partially suppressed. The tube displays uniform illumination, as the ultrasonic ray does not pass across the tube. Therefore, the shape, with the help of the ultrasonic microscope, may be distinguished by the presence of a capillary.

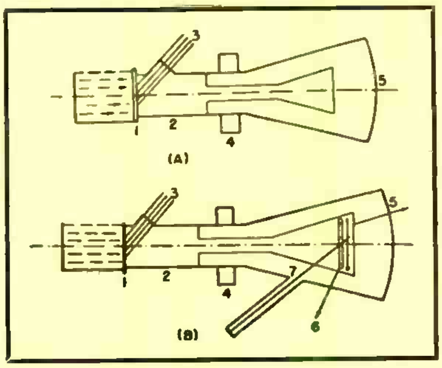


Fig. 3. Two alternate versions of the ultrasonic microscope. (A) Image is formed by acceleration of secondary electrons from treated surface of quartz plate 1. (B) Image is formed by electron beam 7 which scans element 6.

In Fig. 6, the rod and tube are again shown, illuminated by a different type of ultrasonic ray. This discriminates between particles illuminated with different intensities and therefore depicts alterations.

With the ultrasonic microscope, especially good observations may be made of structures. It must be determined which structure of the ultrasonic wave will give exactness of transmission without a type of deformation. When the radiating quartz plate oscillates in the fundamental mode, and no object is being examined, a light even spot is obtained. For oscillations above the fundamental, a nonuniform illumination results.

In the ultrasonic microscope, the object conforms to the tube, bound with the ultrasonic wave, and the image conforms to the transmission tube, on the screen of which the object is seen. One form of an ultrasonic microscope is shown in Fig. 1.

Fig. 4 Ultrasonic microscope image of metallic loop immersed in opaque liquid.

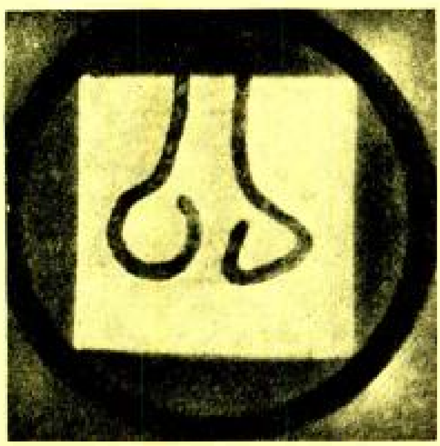


Fig. 5. Image of glass rod (left) and tube (right) in a homogeneous field.

Fig. 6. Glass rod (left) and tube (right) in a nonhomogeneous ultrasonic field.

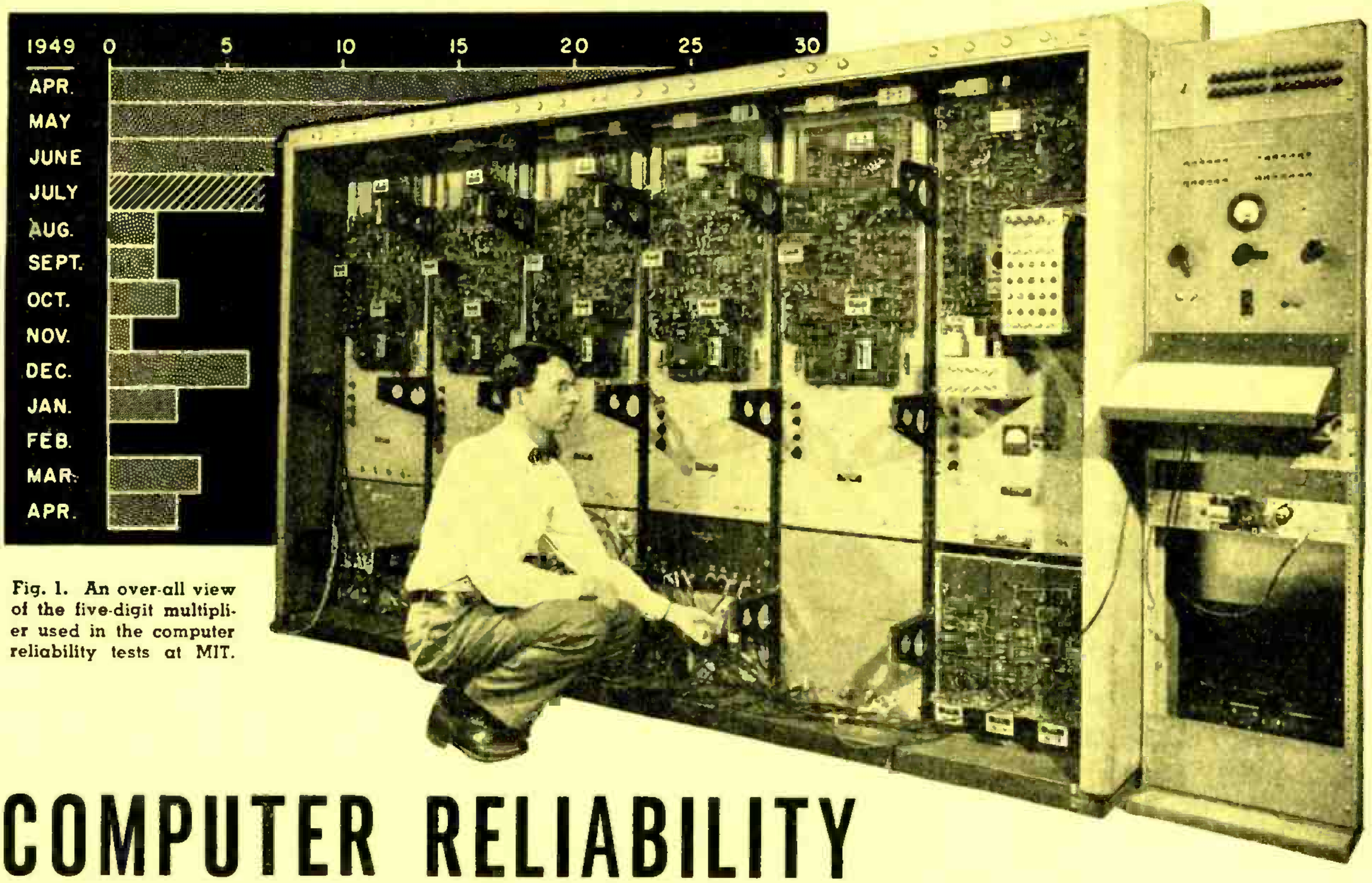


Fig. 1. An over-all view of the five-digit multiplier used in the computer reliability tests at MIT.

COMPUTER RELIABILITY

By

EDWIN S. RICH and ROBERT R. RATHBONE

Digital Computer Lab., Massachusetts Institute of Technology

Performance criteria of electronic digital computers based on results of an extended 27-month life test.

MAINTAINING system reliability in a large digital computer is a far different problem from that encountered in the operation of radar, television, and other communication systems. A stray pulse or an intermittent failure of any one of thousands of electrical components, for example, may cause a circuit to function improperly and thereby invalidate all subsequent calculations. The engineer who enters the field of electronic computation must therefore adopt an entirely new concept of system reliability, based on the elimination of single errors. Unfortunately, he cannot find the criteria for implementing this concept in any textbook; he must learn them gradually from the experience of others and through his own cut-and-try methods.

The purpose of this article is to place on record the results of a 20,000-hour reliability run of a prototype digital computer, in which the goal was error-free operation for extended periods. Although this life test does not offer a specific answer to every question it raises, the findings may give the reader a point of departure for developing his own philosophy on the subject.

Five-Digit Multiplier

Before the construction of the MIT Whirlwind I electronic computer* could be completed, it was essential that pertinent data be obtained on the reliability of basic circuits and the life expectancy of vacuum tubes and other components. Since no information on the extended operation of a system such as the Whirlwind could be found in the literature, a five-digit multiplier (Fig. 1) was built as the proving ground for the new pulsed circuits and components.

A short description of the multiplier will aid the reader in understanding the discussion of the life test which follows. The logical design of this prototype computer is shown in Fig. 2. The arithmetic element uses 275 vacuum tubes, 350 crystal rectifiers, 800 resistors, 675 capacitors, 100 pulse transformers, and 80 r.f. chokes. Design was limited to one arithmetic process because the circuits and techniques are similar for each process; multiplication was chosen because of the strict circuit requirements it imposes. Storage and input-output elements were not stressed and appear in the simplest forms: toggle switches, push buttons, and indicator lights. The control was built from special pulse-control test equipment developed at MIT* and contains approximately 100 vacuum tubes and 950 other components.

When two numbers are to be multiplied, they are inserted manually into the registers of toggle-switch (T-S) storage. The numbers are read into the arithmetic registers and multiplication is executed by 0.1-microsecond pulses. A control switch provides for either automatic (2-mc.) or step-by-step (push-button) operation. Results are displayed in binary notation by flip-flop indicator lights.

A preventive-maintenance scheme, called "marginal checking," was built into the system in order to detect deteriorating components before they could cause errors in computations. (The rack at the extreme right in Fig. 1 holds these circuits.) The function of marginal checking is to vary certain

*A high speed digital computer sponsored by the Office of Naval Research.

*Described in the Aug., 1951, through February, 1952, issues of RADIO-ELECTRONIC ENGINEERING.

voltages, generally screen voltages, in selected circuits of the multiplier so that the components operate under great stress. Any component with a low operating margin will effectively lose this margin during the check and the circuit will not operate. When a test problem is run, the operator can then isolate the weak component and replace it.

Power for the multiplier is supplied from three motor-generator sets whose d.c. outputs are -100, $+150$, and $+250$ volts. Power for marginal checking is obtained from a *G-E* amplidyne whose d.c. output can be manually varied from -100 to $+100$ volts. During marginal checking this generator is switched in series with the d.c. supply to the circuits which are to be checked.

Extended Reliability Run

On April 1, 1949, the multiplier started a reliability run which extended for 27 months. During this time, the machine continuously multiplied two five-binary-digit numbers and checked for a correct result at the end of each multiplication. The multiplications required about 8 microseconds each and were repeated at the rate of 15,000 times a second. When errors occurred, they were recorded by electromechanical counters and an *Esterline-Angus* inking recorder. Three counters were used as a "two-out-of-three" check; twice a day they were tested carefully to be sure they would respond to a single-error pulse.

Performance requirements were rigorous. All errors of undetermined origin and those from failures of defective, deteriorating, or accidentally damaged components were counted. Those resulting from failures of power supplies were also charged against the system. The only exceptions were errors caused directly by two failures in city power, two power line failures, and a transient introduced into the power line by a local thunderstorm.

For the first 18 months, about half an hour of each working day was spent in preventive maintenance. During the last nine months, as performance improved, this checking was reduced to twice a week. In addition, troubleshooting for intermittent failures, not isolated by marginal checking, was necessary—especially for the first six months.

A log was kept during the entire run, with entries stating when errors occurred and what remedial action was taken. An operation chart was drawn daily from the information in the log to provide an over-all picture of the multiplier's reliability. The longest error-free run extended for 143 days, or nearly five months. It was interrupted when, for some unknown reason, a power supply fuse burned out.

The test was terminated June 30, 1951, because operating experience on the Whirlwind I computer had reached a point where little benefit could be obtained from further studies of the five-digit multiplier.

Error Periods

Figure 4 summarizes the number of error periods that occurred during each of the 27 months. An "error period" is defined as the discrete period during which any number of errors occur without interruption. This number may range from one to several thousand, but since single errors, as well as multiple errors, can invalidate results and require the attention of an operator, each error period is considered as having the same weight regardless of the number of errors recorded. The total number of error periods over the 27 months was 142, or an average of one every 136 hours.

Work During Shutdown

Over half of the error periods (78) occurred during the first 96 days (April 1 through July 5, 1949). Considerable dependence had been placed on the marginal-checking facilities as a means of obtaining and keeping a high level of system performance, but this large number of error periods indicated that the new maintenance technique alone was not sufficient.

Because daily checking ensured that all circuits basically had wide operating margins, it was concluded that the frequent errors were caused by transient disturbances rather than by slow drifts in circuit tolerances. Intermittent connections were suspected first, and for lack of more refined methods, the search for such connections was made by painstakingly tapping panels and components. Within a short time sufficient weaknesses were found to indicate that a shutdown for overhaul was necessary. Nearly all of the faults discovered were ones which caused momentary rather than permanent failure. Furthermore, they would have been overlooked if evaluated by the usual criteria of performance; they were shown up in this case by the extreme sensitivity of the multiplier acting as a detecting instrument. The defects found were (1) insufficient spring pressure in cartridge-type fuse holders, (2) inadequate contact pressure in power distribution relays, (3) momentary shorts or leakage between elements within vacuum tubes, (4) poor connections in adapters which had been provided to permit use of lock-in-base tubes in circuits built for octal-base tubes, (5) loose screws on power-wiring terminal strips, and (6) unsoldered or cold-soldered component connections. The shutdown was utilized to correct all of the faults that had been discovered and to guarantee reliability further by eliminating all unnecessary contacts (such as relays and manual switches) and by replacing all fuse holders and tube adapters with

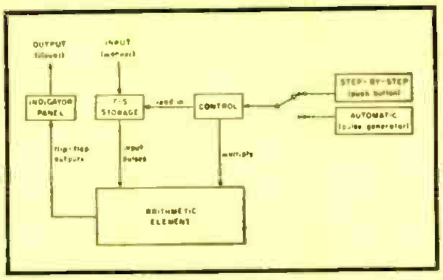
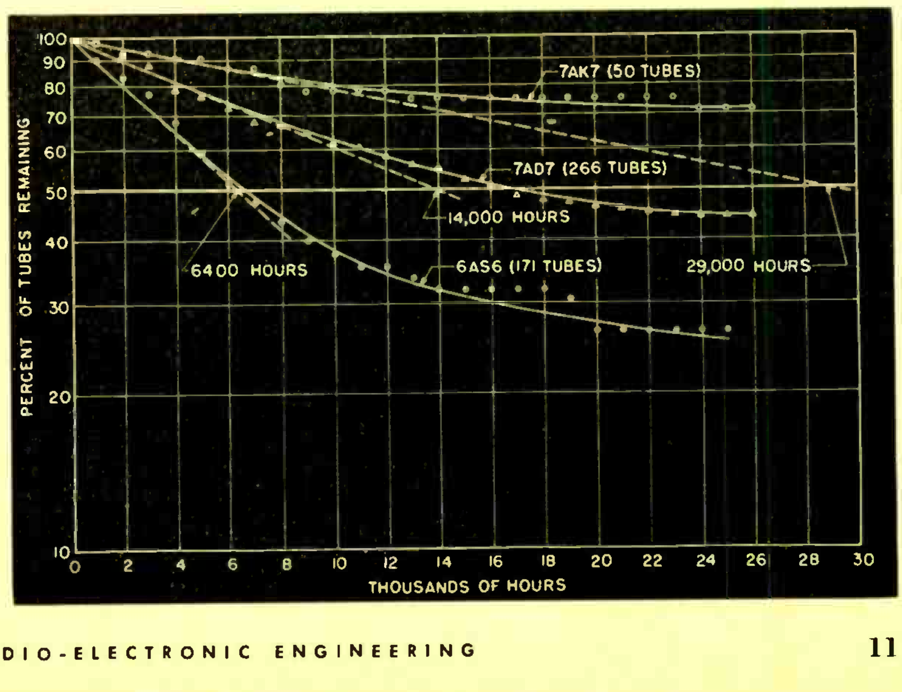


Fig. 2. Block diagram showing logical design of the five-digit multiplier.

Fig. 3. Graphs of vacuum tube life in the five-digit multiplier.



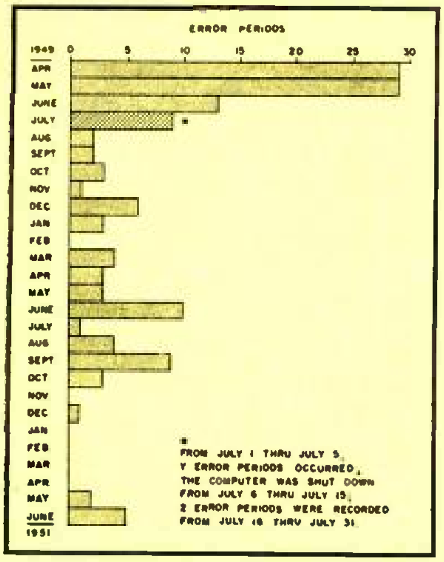


Fig. 4. Performance of the five-digit multiplier during the reliability run.

more rugged units. It is not known that all of these weaknesses would have caused operational failures if they had remained, but as a conservative measure they were regarded as potential faults and were therefore corrected.

During the 96 days following shutdown, the number of error periods decreased to seven. The error rate for the remainder of the 27-month run was an average of one every 286 hours.

Vacuum Tube Life

Significant information on vacuum tube life has been obtained from records on tubes used in the five-digit multiplier. The multiplier contains about 375 tubes (sockets) of which approximately half are types extensively used in the Whirlwind computer (40% of type 7AD7 and 10% of type 7AK7). About 18 per cent of the tube complement is type 6AS6, while small numbers of other types comprise the remainder.

Figure 3 shows the life characteristics of (1) the 7AK7, a dual-control-grid pentode which was manufactured under pilot plant conditions, (2) the 7AD7, a video amplifier pentode purchased from commercial production, and (3) the 6AS6, a miniature dual-control-grid tube also from commercial production. The plot is percentage survival vs. length of service for original and replacement tubes. The criterion for the end-of-life of a tube is the tube's failure to perform satisfactorily in the circuit to which it is assigned. Life of the 6AS6 tubes is apparently much shorter than that of the other two types, because the 6AS6's are used in circuits that have smaller operating margins and the effective life of tubes in a given piece of equipment is closely related to circuit design. If it had been possible to build circuits in which changes in tube characteristics had no effect on circuit performance, then the percentage of survival would have been much higher than these curves show.

A question sometimes raised in discussions of tube life is whether tubes tend to have a definite period of usefulness and therefore should be replaced as a group after a certain length of time or whether the failures occur at a fixed rate so that nothing would be gained by wholesale tube replacement. Experience with the multiplier seems to point to the latter type of behavior and certainly indicates that wholesale replacement is not warranted within the period of time shown on these curves. In Fig. 3, the data are shown on a semi-log plot with smooth curves (the solid lines) drawn through the points so that the slope of a curve is a measure of the rate of tube failure. For all three types the rate of failure decreases for increasing length of service, as indicated by the flattening out of the curves. However, the samples are probably too small for this fact to be considered significant. To get a conservative measure of tube life in this equipment, points have been determined where 50 per cent of the tubes would have remained if failures had continued at their initial rates, as shown by the broken lines. These figures are 6400 hours for the 6AS6, 14,000 hours for the 7AD7, and 29,000 hours for the 7AK7.

Other Components

No capacitors or r.f. chokes failed during the test and only two pulse transformers had to be replaced. On the other hand, it was necessary to replace 29 of the 120 carbon resistors selected to less than 1% tolerance for use in flip-flop circuits. Crystal clamps were also troublesome in flip-flop circuits, where a back resistance of at least 0.5 megohm is essential. One hundred clamps of a special high-back-resistance type similar to the 1N38 were used in these circuits, and a total of 78 replacements was necessary because of the small tolerances. By comparison, 386 crystals (type 1N34 or equivalent) used in other less critical circuits required only 32 replacements.

Because a guarantee of maximum reliability was the intended goal, this sensitive clamp circuit should have been redesigned. However, rather than interrupt the test, a simple marginal-checking routine was applied periodically to the clamp circuits and the deteriorating crystals were quickly located. In this case, then, the desired reliability was ensured at the expense of additional preventive maintenance.

The importance of extensive operating experience in discovering unpredictable factors that influence reliability was emphasized on several occasions. Two examples are of interest. As originally designed, the multiplier had pilot lights to indicate the presence of the +150-volt and +250-volt power inputs to each panel. These lights were 110-volt lamps fed from the respective supply points through appropriate dropping resistors. During the reliability run, it was discovered that occasionally an error count was caused by the burning out of one of these lamps. A search revealed that the dropping resistors were mounted near the filter circuits at the bottom of the panel and that the leads at the top of the panel were cabled for some distance with several wires which distributed power to the circuits on the panel. Under these conditions, interruption of current to a lamp caused a sudden jump in voltage on the wire to that lamp. This voltage jump, capacitively coupled into the power distribution circuits, was responsible for the errors observed. Relocating the dropping resistors at the lamps rather than at the filters eliminated the trouble.

The second example of unpredictable factors which can affect reliability was discovered accidentally. A metal coat tree in the multiplier room was habitually used by a few employees who worked in that portion of the building. One employee observed that a static discharge from hanging his new plastic raincoat on the coat tree caused multiplier errors. The exact way in which these were introduced was not determined. Previously, qualitative tests had been made to discover whether the system was sensitive to radiated signals and negative results were obtained. A commercial r.f. bomber was used for these tests and no attempt was made to cover the complete r.f. spectrum.

Noise Measurements

One of the aims of the multiplier reliability test was to examine the adequacy of maintenance techniques and, if possible, to discover new techniques which might be applicable to the Whirlwind I computer. Toward this end, some experiments were carried out to determine the sensitivity of the system to noise signals.

In the majority of electronic circuit applications outside the computer field, an occasional transient disturbance whose amplitude is comparable to that of the wanted signal is of little or no consequence. Interpretation of signals within these systems, whether by human beings or electrical equipment, involves an averaging or filtering process which effectively discriminates against noise. In a digital computer, however, interpretation of signals is done by memory

(Continued on page 31)

FUNDAMENTAL CHARACTERISTICS OF DIGITAL AND ANALOG UNITS*

By **JOHN M. SALZER**
Hughes Research & Development Labs.

The terms "digital" and "analog" by themselves are not adequate to describe a computer fully.

THOSE who are familiar with various complex present-day computers will have no difficulty in classifying a specific one as being either "analog" or "digital." This classification into analog or digital computation is apt to be considered both exclusive and exhaustive. It is not difficult to put such two-valued faith to task. This faith may have been strained (though not broken) for the first time, perhaps, when the digital differential analyzer appeared on the scene. Some described it as a digital computer programmed in an analog fashion. Future computers may require, not a single, but a repeated employment of both of these words.

However, no revolutionary developments in the computer field are necessary to cause hopeless entanglement with this limited vocabulary. Suppose a novice were to ask humbly for an explanation of the difference between digital and analog. It would be natural to try to clear up this difference once and for all with a few simple examples. Take the speedometer of a car. The speed indication is by means of a shaft whose angular position is the analog of the speed of the car. This is a fine example of an analog unit, although an innocent reference of the novice to the numerical calibration of the dial might leave an uneasy doubt in the mind. The mileage indicator, on the other hand, is an excellent example of a digital unit: the leftmost wheel counts one for each 10,000 miles, the next wheel for each 1000 miles, and so on down the line. Unfortunately, the purity of this example is rudely shattered by the rightmost wheel; this black wheel of the family turns in a continuous fashion as any decent analog shaft would and seems to carry those large numerals only for the sheer purpose of confusion.

By this time there would probably be a distressed expression on the beginner's face, and, in search of a better example, the electric clock on the wall might be considered. Both hands of such a clock are mounted on continuously rotating shafts whose positions are the analog of time. When about to call the clock an analog unit, however, the beginner might suddenly announce that the two hands of the clock seem to be related to each other in a manner very similar to the wheels of the mileage indicator. In fact, are not the hands of the clock like digits, one showing finer details of the measured quantity than the other?

At this juncture, it might seem like a good idea to execute a strategic retreat and call the clock a unit consisting of analog elements combined digitally. Indeed, it could even be said that this description would fit all clocks and watches. But then the pupil might point out that his watch says "tick-tock" and really measures time by counting the ticks and the tocks, that somebody had told him counting was an action characterizing a digital unit, and that this would make at least the second hand of his watch digital rather than analog! If this is not obvious, it is certainly clear that a stop watch moves in discrete jerks. To add to this burden of proof, it is only necessary to recall the big clock in any high school corridor, which jumps at one minute intervals.

After such an unhappy encounter with a novice, it would certainly be appropriate to re-examine the situation and it would not take very long to find that "digital" and "analog" are about as fortunate classifications for physical units as straw hats and round hats would be for men's headgear. Just as almost every hat is round in some respects, so is any measuring device or computer the analog of something in some respects. The analog of temperature, for example, could be a voltage in an analog unit or a number in a digital unit—in both cases within a certain accuracy. If an analog computer is the analog of a differential equation, a digital computer is the analog of a difference equation.

Whereas the analog class seems to be basically unrestricted, the digital class has more definite boundaries, as will be pointed out below. The real difficulty with the use of these words is caused by an endeavor to make them describe too much at once. Properties which are more fundamental should be reverted to and the equipment classified in terms of these properties. The writer has proposed[1] the following three features as a basis:

1. Positional notation
2. Quantization
3. Sampling

A purebred digital computer would incorporate all of these features, a thoroughly analog one none. But now examine each quality separately.

Positional Notation

Positional notation is a feature that is fundamentally digital. In the number 888, there are three identical digits; however, they carry different weights according to their relative positions. The high precision attainable in a digital unit is closely tied in with this positional notation. It is only necessary to use more digits of the same kind to increase the accuracy.

There are two ways in which the relative positions of the digits of a number can be recognized: in space or in time. A parallel machine handles all digits simultaneously and requires identical equipment (arranged in space) for each digit. On the other hand, a serial machine recognizes the weight of a digit by the relative time of its appearance at a particular point.

If it is agreed that "digital" means that which consists of digits—and how could it not be so?—, then it is clear that positional notation is a cardinal property of a digital unit. A binary relay register, for instance, is surely a digital

This article is based on a paper presented at the National Electronics Conference which was held in Chicago, Sept. 29, 30 and Oct. 1, 1952.

$\omega_0 t$ in Degrees		$y(t) = \sin \omega_0 t$
From:	To:	
.	.	.
.	.	.
.	.	.
44.72	44.81	0.704
44.82	44.86	0.705
44.87	44.95	0.706
44.96	45.03	0.707
45.04	45.11	0.708
45.12	45.19	0.709
45.20	45.27	0.710
.	.	.
.	.	.
.	.	.

Table 1. Indication of how an unsampled quantity can be represented digitally.

unit; each relay is twice as significant as one of its neighbors, although it is physically identical. Or take the time clock at the entrance of a factory; the hour wheel has a much greater effect on the weekly pay check than the physically identical minute wheel.

Now consider a gas meter. One type of gas meter in existence shows about five small dials, like small clocks. Each dial is calibrated from 0 to 9 and boasts one hand only. The gasman reads the total consumption as a five-digit number. Although the five indicators are identical, they have different influence on the gas bill. So far, everything that has been said about the meter would class it a digital unit. Only when the individual digits are examined will any doubt arise, for each hand moves in a continuous fashion. As the gas flows, so moves each hand; therefore, each hand (with its own scale factor) is the analog of the gas consumed. Were the movements of the hands rigged with some escape mechanisms so that they would go through a revolution in ten distinct and equal jumps, the gas meter would be called digital without a doubt.

Quantization

This difference in the mechanism of an individual digit belongs in the discussion of the second basic feature, *quantization*. Assume an n-digit binary relay register; then for any finite n greater than one, it will certainly be a digital unit. Even when n goes to one, the single-relay register is still likely to be considered digital because it can occupy only two possible states, i.e., it gives a quantized measure of whatever it represents. Had a decimal register been assumed, the individual digit would again be considered a digital unit because it is capable of assuming only ten different states.

As the number of possible states increases, the quantized nature of a unit becomes obscure and it is finally called analog. Indeed, some people say an analog unit is that which is quantized into an infinite number of states. Actually no shaft, however well machined, can stop at any of an infinite number of possible angles. The voltage on a condenser is generally considered a good example of an analog; yet it cannot change in smaller steps than the voltage due to a charge of a single electron.

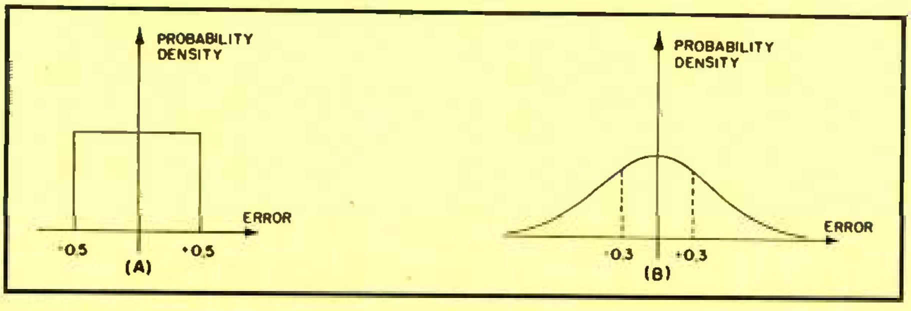
To have faith in quantum theory, the fact that everything is quantized must be accepted in the final analysis. If so, how many possible states must a single-digit unit be capable of occupying—a hundred, a thousand, or a million—before it should be called analog? A direct answer to this question could only be arbitrary. The important factor is that quantization introduces an uncertainty into a physical quantity.

When a three-digit decimal counter reads 115, it may indicate that the value of the represented physical quantity is between 114.5 and 115.5. Therefore, the quantized representation is accurate within a tolerance. However, so is a nonquantized representation. If the indicator of a voltmeter stops at the 115-volt mark, it may only be known that the voltage is, for example, 115 ± 0.3.

Thus, an error is associated with both quantized and continuous indications. In what respect do these errors differ? They differ in their statistical distributions. Figure 1 shows possible distributions of errors in the examples used above. A quantized representation of 115 volts may mean anything between 114.5 and 115.5 with equal probability. If so, the error is uniformly distributed, as illustrated in Fig. 1(A). On the other hand, the nonquantized representation generally has a less definite error distribution, which is often assumed to be normal. The tolerance limits may then correspond to the probable error, and such a distribution corresponding to the above example is shown in Fig. 1(B).

Just as statistical methods have recently been applied to noise analysis in communication engineering, they have long been applied to quantization errors or roundoff errors[2]. The use of the same methods in both cases is not accidental; rather it underscores the fundamental connection between uncertainties due to varied causes.

Fig. 1. Possible distributions of errors in the examples given. (A) Uniformly distributed error. (B) Nonquantized representation of error distribution.



Sampling

The third aspect that is bound to enter a discussion of this kind is the process of *sampling*. Sampling can be defined as the act of taking specimens of a dependent quantity at particular values of the independent quantity. If time is the independent quantity, sampling implies that data are measured, defined, or examined only at particular instants of time.

Thus, sampling is basically related to the time and manner of observing data, rather than the type of unit involved. It is true that most kinds of digital units, such as digital data transmission equipment and conventional digital computers, require the sampling of data; nevertheless, digital units can be built that operate in a continuous fashion. It is further true that information approaching or leaving an analog unit is usually continuous; however, for technical convenience, sampled data are sometimes employed in analog systems. The only generality that can be stated is that when equipment is time-shared or when the observation of data takes a discrete length of time, the data involved must be sampled.

The process of sampling is illustrated in Fig. 2. Part (A) shows a continuous function of time, which may be displayed on an oscilloscope. The height of the luminous line above the base line is the analog of $y(t)$. If the grid of the cathode-ray tube is pulsed on periodically, the sampled display of part (B) results. In part (C), the same sampled function is expressed digitally.

This simple illustration may raise two questions. First, although analog sampling is possible, why would it be used? Second, how can sampling be avoided in the digital case?

Consider pulse communication. It is well known that if it is desired to transmit a band of B cps, it will be necessary to use a pulse repetition rate of at least $2B$. The pulsed transmission of data has the advantage that the same channel may be used for several sets of information by time-multiplexing. The amplitude, the width, or the time of the pulse may be the analog of the function transmitted. On the other hand, in pulse code modulation the samples of the transmitted function are represented digitally.

Besides the time-sharing of equipment, another reason for sampling data is that an observation or a measurement may take a specific length of time to make. In radar, the time needed to receive an echo at maximum range defines the highest permissible pulse rate. The measured range is represented by an analog distance on the face of the oscilloscope. A motion picture is another example of sampled analog representation. Each frame is a sample of the object's illumination in terms of a chemical analog. The limitation of bandwidth due to sampling is vividly illustrated in movies when the wheel of the stage coach seems to rotate backward.

In order to indicate how an unsampled quantity can be represented digitally, Table I has been prepared. A portion of the sine wave is described in a continuous fashion within an accuracy of three decimal digits. This is done by indicating the degrees (or times) at which the function changes by a quantizing unit. No sampling is involved because the function is defined at all values of the independent variable.

One can build digital units or even digital computers to operate in a continuous manner, but time-sharing of equipment is precluded. This means that a separate element is needed for each digit (parallel unit) and for each operation. A dozen additions would call for a dozen parallel static adders. Such designs are possible and may be practical. A complex diode matrix may be designed to give the binary sum of two binary inputs, which energize the matrix. An experimental tube, the computron[3], has been partly developed to perform static arithmetic operations. At a recent computer symposium in Pittsburgh, a paper was presented on a special-purpose continuously operating digital computer[4].

Elaboration on the difference and the relation between quantizing and sampling may be in order. Both processes introduce discontinuities, but while quantization produces a discontinuity in the value of a quantity, sampling produces a discontinuity in the times at which a quantity is specified. Figure 3 shows a portion of a sine curve quantized but not sampled in part (A) and sampled but not quantized in part (B). The step-discontinuities of quantization depend on the magnitude of the dependent variable, while the impulse-discontinuities of sampling depend on the independent variable.

Although quantization and sampling are fundamentally different effects, they are interrelated. For example, it would be foolish to tabulate (sample) a sine wave at every millionth of a degree if it is defined only to three decimal places. Similarly, if sampling is done at every ten degrees, there is little advantage in a quantizing accuracy of ten decimal places. In numerical analysis, quantizing errors are called roundoff errors, while the errors arising from sampling are called truncation errors. In an efficient numerical procedure, these two types of errors are balanced.

The analogous situation has been commonplace in conventional analog equipment design. The counterparts of quantizing noise and sampling delay are respectively noise and response lag. Resulting errors (called respectively static and dynamic) should be of the same order in a well-designed analog unit.

Conclusion

It has been indicated that the division of units into digital and analog classes is often obscure and sometimes confusing. Three features have been proposed—positional notation, quantization, and sampling—as more fundamental in characterizing the nature of particular equipment.

Understanding these basic characteristics is not just of academic interest; it can also help in orienting engineers in new avenues of endeavor. By combining these basic properties in various degrees, new ideas and equipment may be more easily created than by thinking in terms of what is conventionally meant by digital and analog. Consider the future problems and solutions which may be ahead of us.

An interesting problem is the balancing of errors due to sampling and errors due to random noise. In serial digital computers, adjustable word lengths may be thought of as a means of changing the quantizing error and the real-time sampling rate simultaneously. Halving the word length could almost double the machine speed and would increase the quantizing error while decreasing the sampling error. The corresponding design change in an analog case makes the unit less accurate but also less sluggish at the same time.

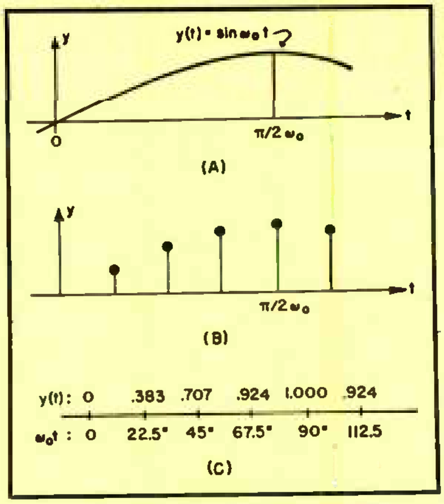


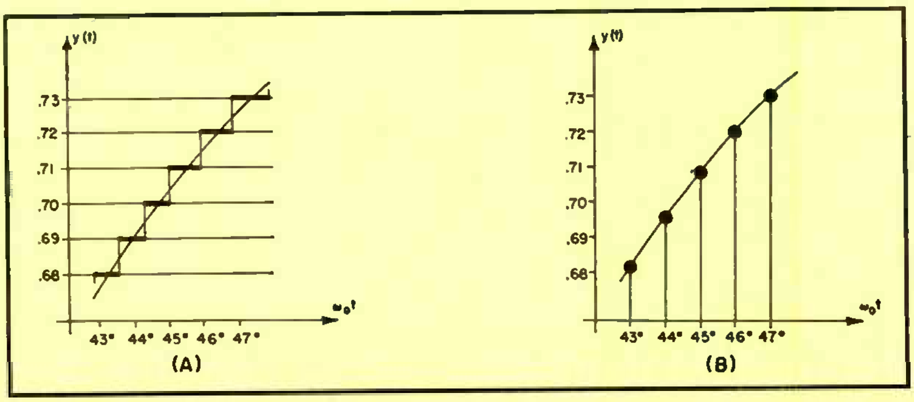
Fig. 2. The process of sampling. (A) A continuous function of time. (B) Result of periodic pulsing. (C) Sampled function displayed digitally.

A fascinating possibility is the use of units consisting of analog (nonquantized) elements combined in a digital manner, just as in the examples of the electric clock and the gas meter. For the transmission of data, such representation is not new. The coarse and fine dials with corresponding selsyns have been used in numerous cases. Could some kind of a computation be done on data so represented?

As techniques in designing compact digital equipment improve, the use of digital schemes for special purposes will become more and more popular. For fixed programs, the magnetic drum may prove a much more efficient and rapid storage element than for general purposes. Digital computations with nonsampled data may also be expected. In addition to the examples already cited, new developments, such as the perfection of ferroelectric techniques, might make such static computers generally practical. These computers will have

(*Continued on page* 30)

Fig. 3. (A) Portion of a sine curve quantized but not sampled. and (B) portion of a sine curve sampled but not quantized.



NEW PRODUCTS

ULTRA-LOW FREQUENCY OSCILLATOR

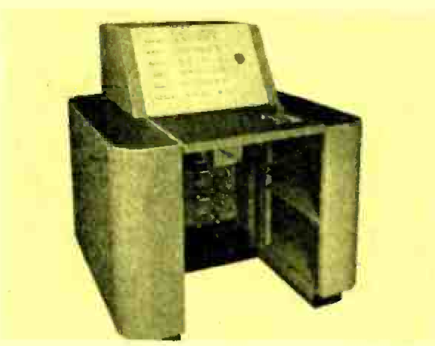
An ultra-low frequency oscillator with standard rack panel construction has been announced by the *Krohn-Hite Instrument Company.* Model 400-C simultaneously provides both sine- and square-wave voltages at any frequency

between 0.009 and 1100 cps. The sine-wave output may be used either balanced or single-ended. Maximum output is 30 volts peak-to-peak across a 1000-ohm load.

Special circuitry to eliminate tuning and bandswitching transients has been incorporated in this *RC* bridge oscillator. Descriptive pamphlet is available on request from the *Krohn-Hite Instrument Co.*, 580 Massachusetts Avenue, Cambridge 39, Mass.

TV MASTER SWITCHBOARD

Increased operating control and flexibility are made possible by the television master switchboard recently developed by *Federal Telecommunication Laboratories, Inc.*, Nutley, N. J. Completely self-contained, the unit permits the channeling of six separate inputs to six destinations by means of indirect relay

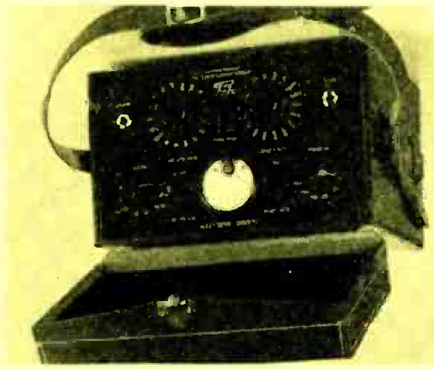


switching. These relays may be located in the console or at a remote rack.

Automatic clearing, termination and holding features have been incorporated in the switchboard, as well as adjustment of the gap or lap switching interval. The built-in fader employs a two-channel video amplifier through which any two incoming signals may be routed; the output signal may then be reinserted as an additional signal source. Tally lights and internally illuminated push buttons aid in operating effectiveness.

NOISE ANALYZER

Hermon Hosmer Scott, Inc., has announced a versatile sound analyzer which separates noise, sound and vibration signals into their component frequency bands. The high- and low-pass filters can be independently adjusted in steps of ½ octave, and a simple interlock permits the passband width to be fixed in any multiple of ½ octave. The



position of this passband can then be adjusted throughout the audible range by a single control.

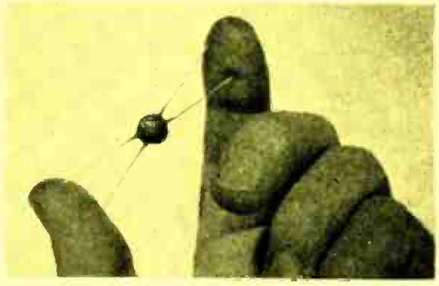
Housed in a saddle-leather case with a shoulder strap for portable use, Type 420-A includes a calibrated attenuator, an indicating meter meeting ASA standards, and an output jack for general purpose filter applications.

Inquiries should be sent to V. H. Pomper, *Hermon Hosmer Scott, Inc.*, 385 Putnam Avenue, Cambridge 39, Mass. Bulletin is available on request.

MINIATURE PULSE TRANSFORMER

The smallest pulse transformer now commercially available was recently developed by *P C A Electronics, Inc.* Weighing less than .03 ounces, the MPT 101-0.1 is slightly smaller than a pea, making it specially suited to miniature assemblies; it will, however, operate equally well in conventional circuits. New design techniques and a special iron core make possible 0.1-microsecond pulse widths and rise times of less than .005 millimicroseconds when used in recommended *P C A* circuits.

MPT 101-0.1 meets MIL-T27 test specifications. It can operate indefinitely



at temperatures ranging from —70°C to +125°C., and will operate normally for a short time at +150°C. Although it is designed for pulse forming, it can also be used for pulse coupling. For further information, write to *P C A Electronics, Inc.*, 6368 De Longpre Avenue, Hollywood 28, Calif.

WAVE ANALYZER

Analysis of the frequencies and amplitudes of signal components in a complex waveform is accomplished in a simple and direct way with the new *Sierra* Model 121 wave analyzer. Signal components are read directly on a 4" indicating instrument calibrated in decibels. Voltage is calibrated with an internal 100-kc. injection oscillator, and a listening jack is provided for monitoring the signal being measured.

Just introduced by the *Sierra Electronic Corporation*, 813 Brittan Avenue, San Carlos, Calif., this 15 to 500 kc. wave analyzer incorporates a novel two-attenuator design which permits a wide range of measuring amplitudes without the introduction of instrument

distortion. It has an input level range of from +42 dbm to —70 dbm at a 600-ohm impedance level; input impedance is 10,000 ohms in the passband.

SCINTILLATION DETECTOR

A new scintillation detector, Model DS-1, has been announced by *Nuclear Instrument & Chemical Corporation*, 229 West Erie Street, Chicago 10, Ill. Designed for efficient gamma-ray counting in clinical and laboratory applications, the detector is provided with a

(*Continued on page* 30)

12 Reasons why Electronics Engineers should specify

SYLVANIA PICTURE TUBES

To definitely establish the superiority of Sylvania Picture Tubes, in comparison with other brands, Sylvania called an outside research organization . . . the United States Testing Company.

Eight picture tubes of nine different manufacturers were selected and submitted to identical electrical and mechanical tests.

Shown above is Sylvania's outstanding record. The test results showed that Sylvania Picture Tubes outlasted and outperformed all others tested. For the detailed report of these significant tests, write to: Sylvania Electric Products Inc., Dept. 3R-3502, 1740 Broadway, New York 19, N. Y.

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NEW TUBES

RCA TUBES

The Tube Department of *Radio Corporation of America*, Harrison, N. J. has released three new tubes: a beam power amplifier, a medium-mu twin triode, and a "premium" twin diode.

Intended primarily for use in the output amplifier of automobile radio receivers operating from a 12-volt storage battery, the 12V6-GT is a beam power tube of the heater-cathode type. A single 12V6-GT operated with a plate and



screen voltage of 250 volts can deliver a maximum-signal output of 4.5 watts.

The 6BQ7-A is a medium-mu twin triode of the miniature type designed for use as the first r.f. amplifier tube in a v.h.f. television-receiver tuner or as a low-noise i.f. preamplifier tube in a u.h.f. television receiver employing a crystal mixer. It supersedes the 6BQ7.

Especially useful as a detector in circuits utilizing wide-band amplifiers, the 5726 is a high-perveance, miniature twin diode. Constructed to give dependable performance under shock and vibration, this is a "premium" version of the 6AL5W.

HYTRON TUBES

Hytron Type 27EP4 is a 27" rectangular, 90°, all-glass, magnetically focused picture tube which provides an effective area of over 400 square inches. Features include an aluminized screen, single ion-trap gun design, and a neutral-density, spherical face plate.

Type 1N64 is a germanium diode designed to meet the requirements for a video detector in television applications. It is application-tested at both the low and high intermediate frequencies.

Both of these tubes are manufactured by the *Hytron Radio & Electronics Co.*, Salem, Mass.

TV PENTODE AND TWO DIODES

A new television pentode, the 12BY7, and two diodes for use in television horizontal frequency damper circuits have been announced by the Radio Tube Division of *Sylvania Electric Products Inc.*, at Emporium, Pa.

The 12BY7 is a high-transconductance sharp-cutoff video pentode de-



signed for service in television receivers. It features miniature T-6½ construction, and will furnish large output voltages across low values of load resistance and supply voltage.

Types 6AX4-GT and 12AX4-GT are half-wave, indirectly heated diodes contained in T-9 envelopes. They are designed to withstand the extremely high voltage pulses of line frequency between cathode and both heater and plate elements normally encountered in direct drive circuits. The 6AX4-GT and the 12AX4-GT are identical except for heater characteristics: the 6AX4-GT requires 6.3 volts at 1.2 amperes, while the heater of the 12AX4-GT requires 12.6 volts at 600 ma.

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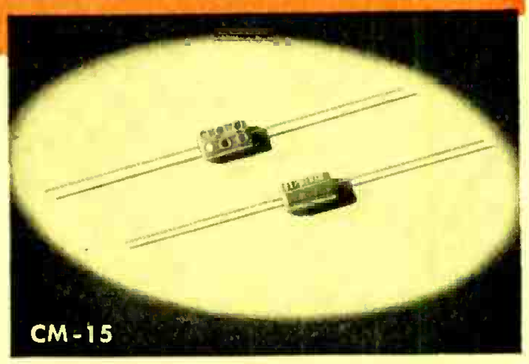
He seems to think you ought to like him for his shell, in spite of the fact that it looks no different from a million other oyster shells. If he's got a pearl inside, why doesn't he say so.



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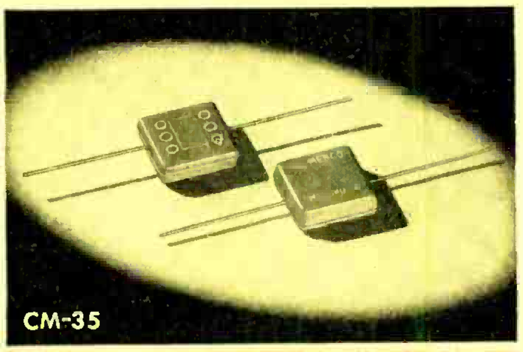

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Personals

DR. ROBERT ADLER, who joined *Zenith Radio Corporation*, Chicago, Ill., in 1941 as a member of its research division, has just been appointed associate director of research. During the intervening years, Dr. Adler has made numerous contributions to the advancement of the electronics industry and to the improvement of communications equipment used by the armed services. He was awarded a Fellowship by the Institute of Radio Engineers in 1951.

F. CLARK CAHILL is now chief engineer of the Engineering and Production Division of *Airborne Instruments Laboratory, Inc.*, Mineola, L. I., N. Y.; he formerly served in the *Laboratory's* Research and Engineering Division as supervisor of the Radar Section. During World War II, Mr. Cahill was associated with the Radio Research Laboratory at Harvard University as head of a war research work division. He has been with *Airborne* since 1945.

EDWARD L. COCHRANE, Vice Admiral, U.S.N., (Ret.), and Dean of the School of Engineering at Massachusetts Institute of Technology, has again been elected a director of *Raytheon Manufacturing Company*, Waltham, Mass. Admiral Cochrane first served in this capacity for *Raytheon* from 1948 until 1950, at which time he took a leave of absence from M.I.T. to direct the maritime administration in Washington as chairman of the Federal Maritime Board.

L. F. HICKERNELL, chief engineer of *Anaconda Wire & Cable Co.*, Hastings-On-Hudson, N. Y., was recently elected a member of the board of directors of the American Institute of Electrical Engineers. Mr. Hickernell served as the chairman of the Detroit-Ann Arbor Section from 1929 to 1930; since then he has worked on many AIEE committees, both general and technical. His term as director will extend from January, 1953, through July, 1954.

DR. URNER LIDDEL has joined *Bendix Aviation Corporation* to direct product development in applied physics and atomic energy. Prior to his most recent position as chief of the physics branch of the U. S. Atomic Energy Commission, Dr. Liddel served as a civilian in the Office of Naval Research where he was director of the Division of Physical Sciences. He is a Fellow of the American Physical Society and the New York Academy of Sciences.

WILLIAM C. LUPFER has been appointed director of contract relations for *Avion Instrument Company*, Paramus, N. J., where he will be responsible for technical representation of all products. In 1943, Mr. Lupfer became associated with *Sylvania Electric Products Inc.*, as contract and facilities supervisor for the Central Engineering Division, and more recently he was with *Allen B. Du Mont Laboratories, Inc.*, as government contracts administrator.

A.F. Wattmeter

(*Continued from page 7*)

pling is employed between the two output transformers. The difference of the outputs is taken by reversing the connections of one thermocouple.

Protection against thermocouple overload and burn out is provided by the double-diode 6AL5 clippers interposed between the two amplifiers. These are adjusted to clip or cut off the output at a voltage value just below the point at which the thermocouple heater currents reach 125% of rated value. Since the couples are rated to stand 150% current, a small safety factor is included here.

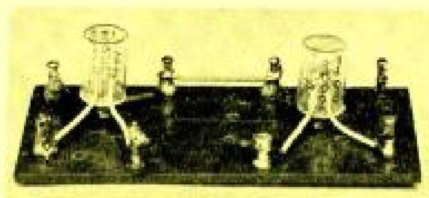
A calibration curve of meter reading vs. input power to resistive or reactive loads is shown in Fig. 3. For a given power input, change of load power factor over a wide range of capacitive or inductive angles makes no change in the reading. For all values of load voltage between zero and 150% of rated value, and with the load current circuit open, the meter stays at zero power.

The particular couples chosen for speed of response have heater ratings of 100 ma., 2 ohms, and couple ratings of 25 millivolts, 7 ohms. The indicating instrument used has a range of 50 microamperes and a coil resistance of 160 ohms. Full scale readings with a load power of 1.5 watts can be obtained.

Speed of response is not as slow as might be expected, full scale being reached from zero in slightly less than one second. For small change from a median reading, the response is even more rapid. Because of the protection given by the diode clippers, there is no fear of burn out or damage due to overload, and the instrument becomes as foolproof as a vacuum tube voltmeter.

Frequency range depends on the selection of the input step-up transformer and coupling capacitors, and to a very limited extent on the choice of the output transformer. The range of 50 to 15,000 cycles can be easily covered with conventional design, and this can be extended through the selection and loading of the input transformer. For extreme frequency ranges, the input transformer can be eliminated and input taken directly from the shunt. Additional voltage gain of about 50 can then be provided with another amplifier stage of conventional design.

Assembly of vacuum thermocouple pair.



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MILITARY

Military types CR15, CR16, CR18, CR19, CR23, CR24, CR27, CR32, CR36, CR47 are representative of current production by Bliley. Complete range of types and cross reference index is given in Bulletin 43.

SHIP-TO-SHORE

Types MC7, SR5 and SR8 are suggested for shipboard dependability. Price and details given in Bulletin 44.

BROADCAST

Types BC46T, MO3B, TC92 are first choice for automatic temperature control in AM, FM and TV transmitters. Consult Bulletin 43 for basic details.

SPECIAL PURPOSE

Types SR10 and MC9 provide wide range frequency choice for TV service, diathermy and citizens band. Request Bulletin 44 for price and description.

COMMUNICATIONS

Type BH6A is the predominant choice for land mobile and airborne applications. Consult Bulletin 43 for basic information.

STANDARD

Types KV3, MC9, SMC100 and MS-433 cover reference frequencies from 100 kc through 10.7 mc. Price and "stock tolerances" given in Bulletin 44.

AMATEUR

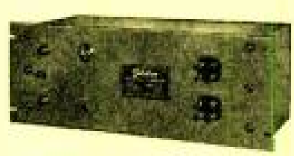
Types AX2 and AX3 together with Bliley packaged oscillator Model CCO-2A were designed to bring precision and price together in the Ham Bands. Price and details are given in Bulletin 44.

ULTRASONIC DELAY LINES

Custom built fused quartz delay lines provide high stability and precision time intervals for manipulation of pulsed or pulse modulated signals. Consult Bulletin 45 for technical information.

FREQUENCY STANDARDS

Model BCS-1A is a high stability instrument for precision reference at 100 kc. Ideal choice for research and development laboratories. Descriptive information given in Bulletin 43.



Bliley CRYSTALS

BLILEY ELECTRIC COMPANY
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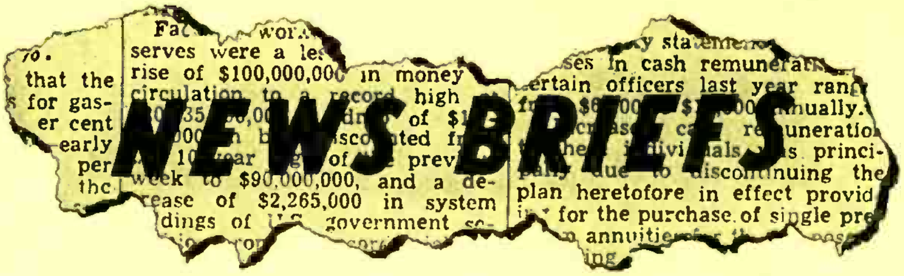
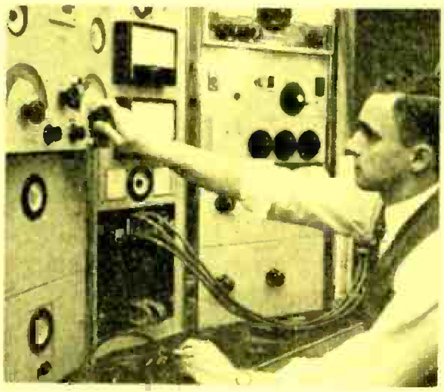


COAXIAL CABLE SYSTEM

A revolutionary coaxial cable system, with triple the telephone circuit capacity of those now in use, has been de-



veloped by *Bell Telephone Laboratories* and is undergoing exhaustive field trials prior to its installation in the *Bell System*. It is expected to go into actual service on circuits between New York and Philadelphia early in 1953.

Known as "L-3" carrier, the new system will enable one pair of coaxial pipes (pencil-size tubes of copper within the cable itself) to handle simultaneously more than 1800 telephone conversations or 600 telephone conversations plus one television program in each direction. It will be the first carrier system on which both television signals and regular telephone conversations can be sent over the same pair of coaxial pipes at the same time. (Photograph shows a *Bell* engineer testing transmission characteristics.)

IEC STANDARDS

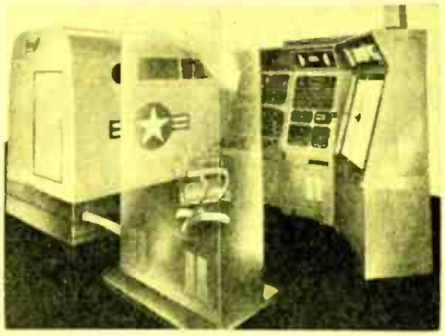
Nineteen countries were represented by 418 delegates at a series of meetings of the International Electrotechnical Commission at Scheveningen, Holland, last September, to discuss international agreement on electrical standards. The United States participated in almost all of the technical meetings.

Among the important actions taken was the authorization of a new technical committee to develop standards for electronic tubes. A number of standards were completed for submission to the national committees, including safety rules for amplifiers and loudspeakers, several standards for radio components, and a revision of standards for power capacitors.

Arrangements were made for extending cooperative action on standards of joint interest to IEC and the International Commission on Rules for the Approval of Electrical Equipment (CEE).

TWIN-ENGINE FLIGHT TRAINER

U. S. Navy airmen will now "fly the beam"—including the new omni-range—in twin-engine ground trainers as the



new ERCO Flightronic trainer takes its place in the fleet's All Weather Flying School at Corpus Christi. Designed by the *Engineering and Research Corporation*, Riverdale, Md., under contract to the Special Devices Center, Office of Naval Research, this instrument trainer features generalized twin-engine type cockpit and performance, the new Navy color- and shape-coded control knobs, and the Special Devices Center's new standard radio aids simulator and flight plotting board.

GIANT TV ANTENNA

Resembling "Big Bertha" herself, this 86-foot television transmitting antenna is undergoing preshipment tests at *General Electric Company's* Syracuse, N. Y., plant. Only half of the antenna is pictured, the other half being behind the test building.

This 8500-pound giant soon will boost by 12 times the transmitter power of

Station WCPO-TV in Cincinnati, Ohio. The preshipment tests are made to insure that the antenna will efficiently accept and radiate TV signals from the station's Channel 9 transmitter.

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RADIO CORPORATION of AMERICA

NEW LITERATURE

TRANSISTOR PROGRESS

The November, 1952, issue of the Proceedings of the Institute of Radio Engineers was completely devoted to the multitude of advances which have been made in transistor research and development. The 528-page journal, containing 51 individual articles, covered all phases of transistor progress. Many of the articles described new applications of transistors in amplifiers, oscillators, rectifiers, electronic computers, and switching circuits.

Copies of this transistor issue are available from the Institute of Radio Engineers, 1 East 79th Street, New York 21, N. Y., at $3.00 each.

TV EQUIPMENT COMPLEMENTS

All equipment used in a television station is arranged into a few functional groups in the bulletin entitled "Television Equipment Complements for Station Planning" which has been published by the Television Transmitter Division of *Allen B. du Mont Laboratories, Inc.* 1500 Main Avenue, Clifton, N. J.

The detailed complement of each group is listed with prices and each complement is given a number for easy reference. A short description of the function of the complement is also included in each case so that the station planner using this bulletin can select equipment for any size station, large or small, and arrive at the approximate total cost of his equipment.

TWO-WAY RADIO

Use of two-way radio for better coordination of men, materials and machines is discussed in an eight-page illustrated booklet published by the *General Electric Company.* Entitled "Instant Communication," the booklet is slanted to those who use materials handling and emergency service equipment, and others who have plant protection problems.

Also contained in this publication is a list of 27 *G-E* offices throughout the United States from which advisory service is now available on communication problems. Copies are free on request to the Advertising Inquiry Section, *General Electric Company,* Electronics Park, Syracuse, N. Y.

RADIOTELEPHONES

Eight radiotelephone models, two radio direction finder models, and various accessory units are described in a new eight-page catalog. Identified as Form 852, it is available from *Applied Electronics Company, Inc.,* 1236P Folsom Street, San Francisco, Calif.

Besides a description of the basic design features of these instruments, the catalog includes a full tabulation of models showing number and types of channels, frequency ranges, receiver sensitivities, transmitter power outputs ranging from 40 to 500 watts peak, tube complements, power requirements, dimensions, and weights.

ELECTRONIC INSTRUMENTATION

In a 32-page booklet, the *Berkeley Scientific Division of Beckman Instruments, Inc.,* 2200 Wright Avenue, Richmond, Calif., briefly describes electronic instruments which provide direct reading digital presentation of information together with their principal industrial applications. "Electronic Instrumentation" covers high-speed counting; counting plus control; precise interval timing; and measurement of rpm, pressure, temperature, flow, viscosity, velocity, frequency, distance, etc.

EMBEDDED SELENIUM RECTIFIERS

The Rectifier Division of *Sarkes Tarzian, Inc.,* located at 415 North College Avenue, Bloomington, Ind., announces publication of a new four-page folder dealing with embedded selenium rectifiers. Designated as Catalog B1, this folder gives detailed information on the various types of embedments made by *Sarkes Tarzian, Inc.* A copy will be mailed free upon request to the manufacturer.

"VIBRATRON"

Model 652 "Vibratron" is a portable instrument for vibration analysis and dynamic balancing. It can be used for balancing practically any rotating part, of any size, without removing the part from its installation, in the range from 500 to 40,000 rpm.

A four-page bulletin describing this device in detail is available from the *International Research and Development Corp.,* Columbus, Ohio.

THERMOPLASTICS

"Custom Extrusions in Thermoplastics" is a new service folder prepared by the *Anchor Plastics Company* which contains comprehensive information on the characteristics of thermoplastics. Forms and shapes of extruded plastics are discussed, and a general summary of how thermoplastics may be used by industry is given.

This folder may be obtained by writing to *Anchor Plastics Company,* 36-36 36th Street, Long Island City, N. Y.

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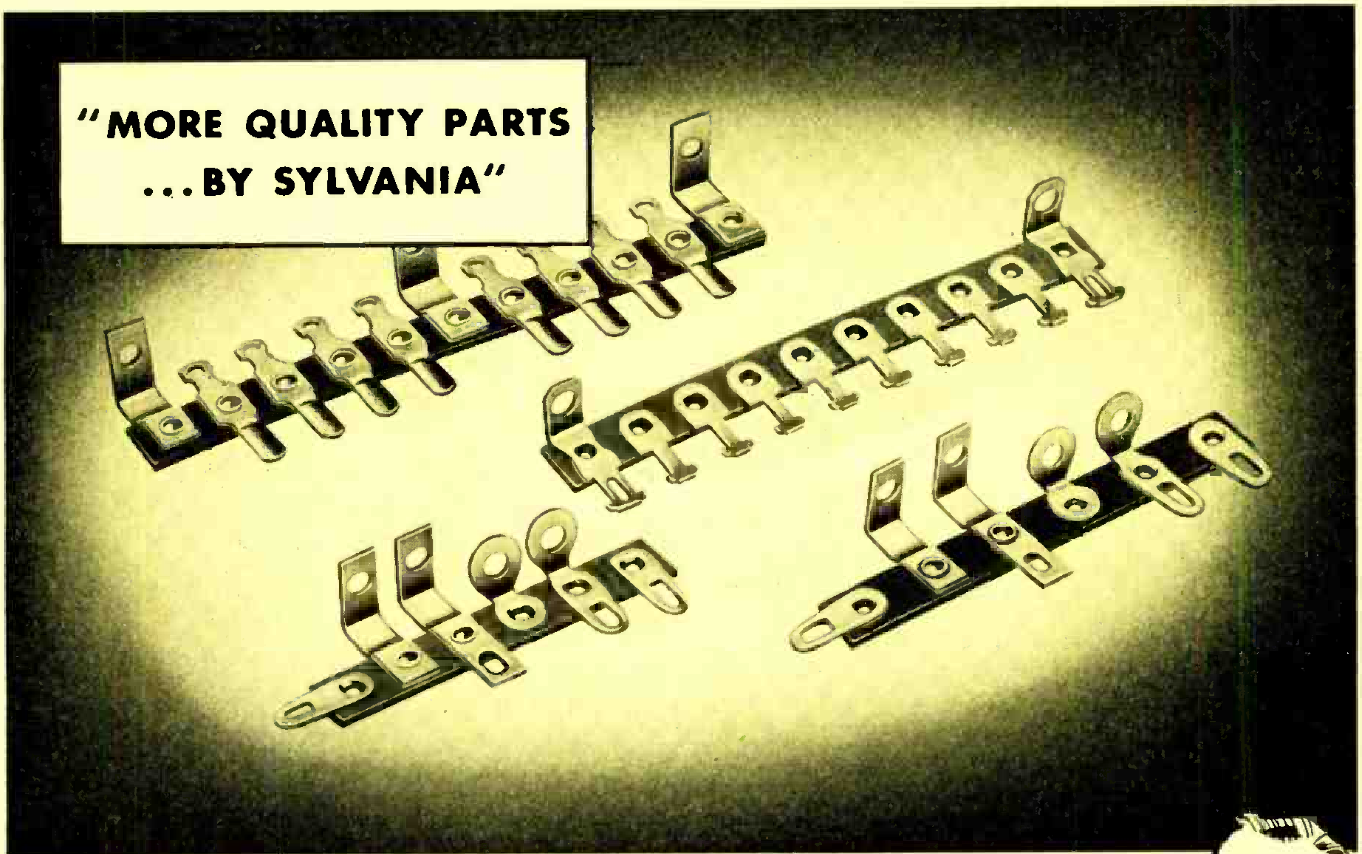

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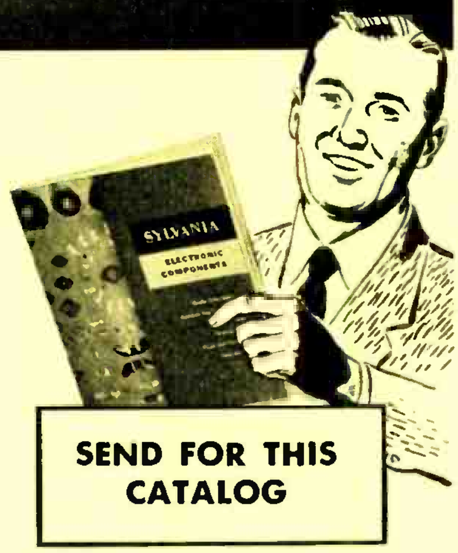


SYLVANIA

RADIO TUBES; TELEVISION PICTURE TUBES; ELECTRONIC PRODUCTS; ELECTRONIC TEST EQUIPMENT; FLUORESCENT TUBES, FIXTURES, SIGN TUBING, WIRING DEVICES; LIGHT BULBS; PHOTOLAMPS; TELEVISION SETS

LOOKING at TUBES

By WILFRID B. WHALLEY

Adjunct Professor of Electrical Engineering
Brooklyn Polytechnic Institute

The development of the image orthicon.

LAST month's article dealt with the development of the *orthicon*. This pickup tube provided quite stable operation, due to the use of low velocity electron beam scanning. It also had higher sensitivity than the *iconoscope*.

Still higher sensitivities were necessary, so that studios could operate with lower light levels, and so that outdoor scenes could be satisfactorily transmitted on cloudy days. Even with the improved characteristics of the orthicon, more lighting was required for good studio pickup than was comfortable for the performers. Further, the coming field of color television would require higher pickup tube sensitivity because of the fundamental loss of light through color filters or dichroic mirrors.

Another important requirement was that of smaller volume, particularly a reduction in the area of the light target so that lenses of sizes similar to those used in moving picture cameras might be employed. Then, too, for a lens of a given *f* number, greater depth of focus could be obtained with a smaller mosaic area; this, despite the fact that a smaller mosaic area reduces the photosensitivity. Also, to increase the depth of picture focus, it was important that the mosaic or light sensitive surface be close to the end of the tube, and therefore adjacent to the lens.

Increasing Sensitivity

Starting with the orthicon, which had a sensitivity already higher than that of the iconoscope, consider what additional methods might be employed to increase the light-to-signal sensitivity further.

First, secondary-emission multiplication of the photoelectrons emitted by the light target might be used. This could follow techniques used in the image-iconoscope and infrared viewing tubes where the mosaic is placed some distance away from and parallel to the semitransparent photoelectron emitting surface (called a photocathode). By operating the photo surface at a negative d.c. potential with respect to the mosaic, and enclosing the device within an axial d.c. magnetic focusing field, the photoelectrons arrive at the mosaic with sufficient velocity to release several secondary electrons for each photoelectron, hence increasing the signal output current from the mosaic.

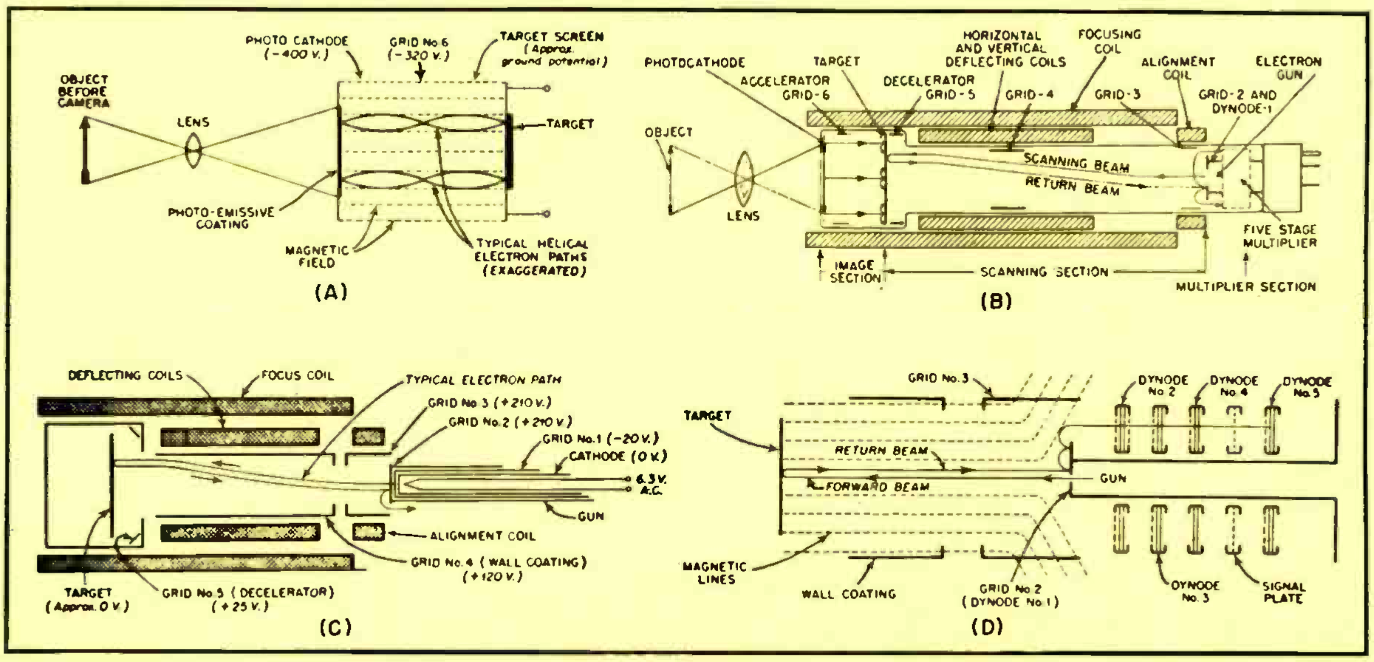
The iconoscope, image-iconoscope and orthicon used video preamplifiers with conventional pentode tubes. Such pentode tube amplifiers had been brought to a high level of efficiency by 1940. The product of voltage gain times mc. bandwidth reached a value of 180. Yet, for very small input signals and bandwidths of 4 mc. or more, these amplifiers gave relatively high noise factors, and were also critical with regard to microphonism and 60-cycle leakage currents. The basic limitation on sensitivity, common to all radio and radar systems, was the fluctuation noise component of plate current in the first-stage tube, combined with the thermal noise current of the input circuit.

Multistage secondary-emission multiplier tubes had noise levels several orders below those of conventional receiving tubes. For example, the input dark "target" current of a good nine-stage electron multiplier type phototube was less than 10^5 electrons per second (less than 10^{-11} ma.). This is approximately 10,000 times lower than the equivalent input noise current of a conventional video tube amplifier. However, to make use of secondary-emission multiplication, the primary signal electrons must be inserted into the evacuated envelope containing the secondary multiplication surfaces.

Secondary Electron Amplification

With iconoscopes and orthicons, the electron flow produced by the sequential discharging of the mosaic elements (with the scanning electron beam) went to a terminal in the glass wall. Hence, it was impossible with these pickup tubes to insert the primary electrons into a secondary-emission amplifier.

Fig. 1. Operation of image orthicon. (A) Image multiplier; (B) complete tube; (C) scanning section; (D) electron multiplier.



However, further examination of the orthicon operation suggested the possibility of using the electron scanning beam. As was discussed in last month's article, when the electron beam approached the surface of the mosaic, electrons were collected in proportion to the potential of each part of the surface (as determined by the degree of illumination). The uncollected electrons in the scanning beam were turned back. Therefore, this returning beam had a density varying, in time, with the degree of darkness of the surface being scanned. Also the noncollected electrons moved through the magnetic deflection region over a path almost identical to that of the forward scanning beam.

If the horizontal scanning were controlled by electromagnetic fields instead of electrostatic as in the orthicon, and this would be practicable if the tube were smaller, then the returning electrons could arrive at a point close to the aperture of the electron gun. Further, it might be possible to have a suitable secondary-emitting surface at the point of arrival so a secondary-emission multiplier could be used.

The *image orthicon* is such a device making full use of secondary-emission multiplication, both at the image and at the signal output.

The Image Orthicon

As may be seen from Fig. 1 (from "Practical Television Engineering" by Scott Helt), the image orthicon contains image multiplication, scanning and secondary-electron multiplier sections. The tube is also physically smaller than the orthicon. The conducting shield, grid No. 6, in combination with the very fine mesh screen adjacent to the mosaic, maintains a uniform electric field in the image multiplier region. Hence, the photoelectrons from the photocathode are accelerated toward the mosaic or target, and kept in focus by the axial magnetic field. The two-sided target or mosaic is a unique development and consists of an extremely thin piece of special glass having a conductivity sufficient to allow electron charges to be neutralized in the time of one picture frame (one-thirtieth of a second). Glass thickness is between 5 and 10 wavelengths of visible light. The target is about two-thousandths of an inch distant from the very fine mesh screen. Because of the close spacing and thin structures, both the target and the screen must be mounted under tension.

In addition to stabilizing the field in the image region, the fine screen also collects any secondary electrons which are emitted from the target, and therefore avoids possible random distribution of electrons over the target surface. The decelerating ring, grid No. 5, together with the conducting wall coating, grid No. 4, between the target and the gun, reduces the arrival velocity of the electrons in the scanning beam to a suitably low value.

The five-stage electron multiplier is built around the electron gun. Each section consists of a disc of many vanes, each vane being inclined at 45° to the axis of the gun, and treated to give high secondary-electron emission. As the returning electrons strike the surface of grid No. 2, (which is effectively also dynode No. 1), secondary electrons are emitted and these are collected by the first ring, dynode No. 2. The secondary electrons produced on the surfaces of dynode No. 2 are accelerated to dynode No. 3, and similarly through the following stages to the collector (or signal plate) to which the video preamplifier is connected. In order to prevent retrace "smear" of the signal, negative blanking pulses are applied to the target.

The image orthicon is now the most used tube for television studio and outdoor cameras. When carefully adjusted, it has a sensitivity approximately 100 times as great as that of the orthicon. Due to its high complexity, however, great care is required in setting the various electrode voltages and the currents for the d.c. magnetic focusing and alignment fields.

Guided Missile Data

(Continued from page 5)

circuit flexibility for recording oscillographs or similar instruments and in no way limit their construction features to telemetry alone.

Communication facilities and remote control are provided for the supervisor of oscillograph recording as well as duplicate control points directly tied in at the telemetry stations. Panels providing for information to be patched into the oscillographs enable recordings to be made of the following data:

1. FM/FM telemetry discriminator outputs
2. FM/FM telemetry decommutator outputs
3. PW/FM telemetry decommutator outputs
4. Land line telemetry (from the missile launcher, such as first motion, squid firing, etc.)
5. Timing signals

The oscillograph rack and all its component units were furnished under a development and fabrication contract (AF-33(038)24908) between the Air Force Missile Test Center at Patrick Air Force Base and *Spar Engineering and Development, Inc.*, Jenkintown, Pennsylvania. Specifications, drawings, and technical exhibits of the contract established the design and layout of the panels and units.

Each panel or unit is separate, removable and essentially complete in itself. The panels provide for patching by means of recessed *Western Electric* type female jacks. An aluminum channel frame is formed to extend in a deep "U" from the front panel to a depth of about 14 inches. Across the outside of the aluminum extrusion in the rear, a Jones strip is mounted which terminates all the jacks mounted on the front panel. Thus, a panel may be easily removed by loosening all the screws on the Jones strip so that the barrier strip securing all the rack cable harness falls free when the front panel screws are removed. This type of construction places all the rear terminals and cable harnesses at a convenient depth in the rack and, since none of the terminal strips are mounted on the front panel, it can be of minimum size. All panels are of standard height or multiples of 1¾", and 19" wide.

Amplifiers are also available to drive galvanometers properly from equipment having low signal outputs, or to provide sufficient levels for high frequency elements, and to provide isolation and sensitivity controls for incoming land line functions. The "amplifier panel" specifications are as follows:

Input impedance—100,000 ohms p.p.
Input level for rated output—5, 10, 50, and 100 volts
Input connector—*Western Electric* jack type 246A
Frequency response—0-10,000 cps
Output impedance—330 ohms balanced
Ouput current—maximum ±10 ma.
Output connector—*Western Electric* jack type
Front panel indicators—meter to show relative output, amplifier balance and jeweled power lamp
Front panel controls—input attenuator, amplifier balance, meter selector switch, power switch and fuse
Power input—110-120 v., 60 cps

The "galvanometer panel," as the name suggests, provides a means of applying signals to the galvanometer elements. It is mounted directly above the oscillograph for operational ease. Since this "galvanometer panel" has been designed to work in conjunction with an 18-element oscillograph, it provides circuitry for the full 18 galvanometers. Information to be fed to a galvanometer is patched in its respectively numbered jack. But, current flowing to any galvanometer must pass through its polarity reversing switch, attenuator, and continuity switch. This arrangement permits the recording technician to present several conditions to the oscillograph and, with the continuity switch open, to keep any or all of the galvanometer circuits open. To check operation, he can flip the switch to "momentary" position. For recording the flight, the desired continuity switches would be set in "continuous" position. The attenuators permit the setting of desired sensitivities directly at the recorder while viewing its limits of deflection. It is true that most of the telemetry equipment provides for level adjustment at the telemetry station itself, but it is not practical to adjust the levels remotely without excessive adjustment time and additional personnel. Polarity reversing switches are required to provide proper direction of deflection in order to permit closer correlation with similar events and easier data reading by deflecting the traces in parallel movement and reducing the times when traces cross, or adjusting channels so that the crossing angle will be great. These switches are recessed and are under a cover plate to maintain a neat appearance and to prevent accidental switching. The "galvanometer panel" specifications are as follows:

Input impedance—330 ohms constant
Input connector—*Western Electric* jack type 246A
Output impedance—330 ohms constant
Front panel controls—polarity reversing switches, attenuators and continuity switches

The feature of this rack assembly

which permits oscillographs to be operated in a minimum of space is the slide rack chassis unit. This type of support for the oscillograph makes it possible for the instrument to be contained within the rack. For operational ease, it can be extended six inches and locked securely for adjustment, calibration or servicing. Continuous operation is achieved in any position. The galvanometer and power leads are twisted pair shielded cables.

An oscillograph phone unit was designed so that voice communications via hand phone or line amplifier would be available between the telemetering stations and missile checkout or launching areas. It also provides remote control facilities for operating the oscillographs, and an operations "hold fire" switch and indicator. The remote control circuits of the oscillograph permit a technician to supervise the operation of a bay of oscillograph racks, or permit it to be remotely operated and monitored at the telemetry receiving station. Control indicators show the standby condition of each oscillograph and any malfunction which may occur during an operation. Since the oscillograph racks are under the surveillance of one supervisor, only one oscillograph rack in a bay requires a phone unit.

The "hold fire" circuit is peculiar only to the missile test ranges. The usual techniques of firing a missile or projectile in any test program involve considerable instrumentation, coordination and safety precautions, and the only way every group involved or affected may be ready is to count down in seconds for the last interval before firing. In a development and test program, it is essential that all instrumentation be operating correctly at the time of launch. Yet, if the inevitable malfunction occurs a short time before firing, it must be reported immediately so that steps may be taken to prevent useless firing and loss of the missile as well as operation of equipment that requires considerable time to adjust or reload. For this purpose a switch, with safety cover, is located on the phone panel to indicate remotely and locally that a malfunction which the supervisor considers of a serious nature has occurred. A buzzer is also energized locally on the panel so that in the event the visual indication from a jeweled lamp is overlooked, the aural indication will alert everyone. Each indication of the "hold fire" system is on a separate electrical circuit.

The hand phones used with the units are Signal Corps Type EE-8. Again, this is equipment common to the majority of missile test ranges in the country today; it is a very fine handset for land line communications. Audio bridging amplifiers are provided so that the messages may be monitored without holding a handset all the time or requiring another man as a "talker." The amplifier has an input for balanced or single-ended lines with an impedance of 50,000 ohms from either side to ground. Output power is 4 watts across a 500-ohm line with 0-db input.

In conclusion, it should be stated that the equipment and design provide professional reliable operation of oscillograph recording equipment. It has been pointed out that each unit, or group of functions which are separate from the others, is fabricated complete in itself. This permits standardization of techniques and layout.

In some applications, several oscillographs are required to operate simultaneously from the same information. This occurs when instruments must be operated in tandem, as in cases where the instruments must be alternately reloaded with magazines for long or fast records. This follows the present planning since an oscillograph rack as described can be supplemented by racks on either side containing two or three oscillographs, each mounted on the oscillograph slide rack chassis assembly. Galvanometer panels may be associated with each oscillograph, or when the same data are on similar galvanometers, they may be controlled from the same panel if the elements are driven in series or parallel.

Proper damping is maintained on all elements at all times with the use of the galvanometer panel. The "T" pad attenuators feed the galvanometers with a constant 330-ohm resistive input, and all galvanometer shunts are made up to provide 64% damping when operating across the 330-ohm load.

Proper isolation and drive for galvanometers, when required for recording data from circuitry or equipment not suitable for direct connection to the elements, are provided by stable d.c. amplifiers. In addition to furnishing a means of setting up proper deflections, the limiting characteristics of the vacuum tube circuits prevent damage to many galvanometers by accidental hookup errors.

While this is not the first time an oscillograph has been assembled for rack mounting, it is one of the first installations to provide packaged components throughout. Although the described assemblies center about a particular application, many of the panels may merely require different labeling or the units may be rearranged to provide a wide variety of applications. All of the equipment described has been developed and fabricated, and is now commercially available. Installations of the described system have been made at the Air Force Missile Test Center, Patrick Air Force Base, Fla.

TECHNICAL BOOKS

"ELECTRON TUBES IN INDUSTRY" edited by Keith Henney, Editorial Director, and James D. Fahnestock, Associate Editor, of Electronics. Published by *McGraw-Hill Book Company, Inc.*, 330 West 42nd Street, New York 36, N. Y. 353 pages. $6.00.

The purpose of this book is to provide industrial personnel — engineers and technicians—with enough fundamentals to permit them to talk intelligently about electronics, to know what can be expected of electronic devices and what their limitations are, and to help them visualize new applications. In presenting these fundamentals, practical tried and tested circuits are used as examples. Many of these circuits have already found successful application in industry.

In this third edition, the book has been almost completely rewritten, bringing it up to date, eliminating unnecessary material, and emphasizing all practical aspects. Complicated theoretical aspects of electron tube technology have been held to a minimum.

Digital and Analog Units

(*Continued from page* 15)

features reminiscent of analog computers: they will have as many separate elements as there are operations to perform, and they will have, not a fixed delay of computation, but an exponential lag characteristic. It might be possible to interleave such digital units with analog ones quite efficiently, because of the continuity of data.

In general, the mixed use of digital and nondigital units in a computer has possibilities which call for constant reexamination as the art progresses. Even the controversy between proponents of digital and analog computers may one day be past history.

Some of the material presented here arose in connection with a doctorate dissertation[1]. The guidance and stimulation given to the author by Professor William K. Linvill has been instrumental in formulating many of these ideas.

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1. *Salzer, J. M., "Treatment of Digital Control Systems and Numerical Processes in the Frequency Domain," thesis for Sc.D. degree, Massachusetts Institute of Technology*, 1951.
2. *Schlesinger, F., "On the Errors in the Sum of a Number of Tabular Quantities." Astronomical Journal*, Vol. 30, pp. 183-190, 1917.
3. *Rajchman, Jan, Snyder, R. L., and Rudnick, P., "Final Report on Computron," RCA Laboratories Report, N.D.R.C. of O.S.R.D., March*, 1943.
4. *Gordon, M. M., and Nicola, R. N., "Special Purpose Digital Data Processing Computers," paper presented at the meeting of A.C.M., at the Mellon Institute, Pittsburgh, May*, 1952.

New Products

(*Continued from page* 16)

thallium-activated sodium iodide crystal and has a plateau length of approximately 200 volts. With the external directional shield in place, efficiencies of 33% or greater are obtainable using cobalt 60, 40% or greater using iodine 131.

Model DS-1 is equipped with a removable directional shield, and has a built-in preamplifier which provides an output pulse in excess of one-quarter volt, making possible its use at the G-M input of any scaler or count-rate meter. It is available as a separate, complete unit, or with a special lead shield for sample counting.

RADIO CUE SYSTEM

Primarily for directing technical personnel and cue actors in a TV studio, the Model AB radio cue system can also be used in factories where the noise level is too high to permit direct communication. It was developed by the *Polarad Electronics Corporation*, 100 Metropolitan Avenue, Brooklyn 11, N. Y.

The transmitter operates on a low r.f. frequency into a loop antenna, which restricts the transmitted information to a closely confined area. Several r.f. channels are available if simultaneous transmission for separate activities is desired. Pocket receivers are small and lightweight.

CALENDAR *of Coming Events*

JANUARY 26-30—IAS-IRE-RTCA-ION Symposium on Electronics in Aviation, New York, N. Y.

JANUARY 26-27 — Seventh Regional IRE Conference, University of New Mexico, Albuquerque, N. M.

FEBRUARY 4-6 — Western Computer Conference, Hotel Statler, Los Angeles, Calif.

FEBRUARY 5-7—IRE Southwestern Conference and Electronics Show, Plaza Hotel, San Antonio, Texas

MARCH 23-26—IRE National Convention, Waldorf-Astoria Hotel and Grand Central Palace, New York, N. Y.

APRIL 11—New England Radio Engineering Meeting, University of Connecticut, Storrs, Conn.

APRIL 18—Spring Technical Conference of the Cincinnati Section, IRE, Engineering Societies Bldg., Cincinnati, Ohio

APRIL 29-MAY 1—Electronic Components Symposium, sponsored by the AIEE, IRE, RTMA and WCEMA, Shakespeare Club, Pasadena, Calif.

MAY 11-13—National Conference on Airborne Electronics, Hotel Biltmore, Dayton, Ohio

Computer Reliability

(*Continued from page* 12)

circuits which cannot distinguish between wanted signals and noise. For correct operation of these circuits, there can be no noise which equals the minimum amplitude of the wanted signal; and in practice, the peak noise should be considerably less than the minimum signal to ensure a margin of safe operation.

Two types of noise measurements were made, one in which asynchronous pulses of variable amplitude were inserted into various signal channels to simulate unwanted information pulses, and the other in which small voltage steps were introduced on different plate and screen lines to simulate power supply transients. The first of the tests uncovered a missing ground connection in one circuit and the second suggested a change in power supply filtering. Although it is felt that tests of this nature should supplement other maintenance procedures, no way has been found in which they can be readily mechanized for application to a large scale computer because of the variation in circuit impedance and in signal characteristics that would be encountered.

Experience gained during the conduct of the multiplier reliability test indicates that three significant conclusions may be drawn regarding the problem of obtaining error-free operation of an electronic computer:

First, errors resulting from gradual deterioration of tubes, crystal rectifiers, and other components can be practically eliminated if marginal-checking methods are used to locate weak circuits before they have caused operation failures. Until marginal checking was built into the multiplier, it was almost impossible to go through a day without computational errors and consequent shutdowns. During the life test, no errors could be attributed to deteriorating components—at least within existing ability to determine causes for failures. A total of 154 vacuum tubes and 83 crystal rectifiers were replaced because of low margins.

Second, lack of attention to the details of construction which ensure permanently good electrical connections throughout the system can result in potential sources of error which may go undetected for a long time. If such conditions exist, long trial runs with satisfactory operation do not establish the fact that the system is a reliable one. An example, taken from the log, will serve to illustrate this point. About halfway through the run, the multiplier started to make errors intermittently. The cause, determined only after tapping each component, was an unsoldered connection which had gone undetected for almost three years.

Third, failures that interfered with the useful operation of the multiplier fell into two general classifications: (1) sudden total failures of components and (2) intermittent circuit failures. At the outset, it was accepted that sudden failures, such as open or short-circuited components or connections, could be expected without warning and would cause errors in operation. Results of the test, however, showed that intermittent failures were far more serious because they were difficult to locate and correct. Of the 142 total error periods, 124 resulted from intermittent failures. Although the sources of some of these were undoubtedly detected and remedied, it was impossible to make direct correlations between errors recorded and defects corrected.

The principal value of the extended reliability test was the proof that circuits of the type used in the Whirlwind I computer could be constructed of presently available components and made to operate in a large system with relatively little time lost in unscheduled trouble-shooting and repair. Test data from the multiplier run could not be used to forecast the reliability of the whole Whirlwind computer since this system contained substantial numbers of components and circuits not present in the multiplier. The performance of the Whirlwind arithmetic element, however, indicates that a linear extrapolation of the multiplier experience to a larger system based on the number of tube cathodes is probably valid if similar circuits are involved. With this criterion, a system of five thousand tubes should average not more than one error period in each 20 hours of operation. For most mathematical, industrial, and scientific applications, this performance would be quite adequate. On the other hand, present-day thinking implies that much larger electronic systems are desirable for controlling actual physical situations where even a low error frequency is objectionable, and one must conclude that continued improvement in components, circuits, and system construction will be needed to obtain satisfactory reliability.

PHOTO CREDITS

PAGE	CREDIT
3, 4, 5	United States Air Force
6, 7, 20	University of Illinois
10	Mass. Inst. of Technology

IRE CONVENTION PROGRAM

Tentative list of papers to be presented at the IRE Convention in New York, March 23-26.

AIRBORNE ELECTRONICS

Some Systems Considerations in Flight Control Servomechanism Design. R. J. Bibbero and R. Grandgent, Republic Aviation Corp.

Faired-In ADF Antennas. L. E. Raburn, Electronics Research Inc.

Magnetic Amplifiers for Airborne Applications. J. K. McKendry, General Precision Labs.

Aircraft Electrical Power. J. C. Dieffenderfer and G. W. Sherman, Wright Air Dev. Ctr.

The Effects of Electronic Equipment Standardization on Aircraft Performance. G. C. Sumner, Consolidated Vultee Co.

The Technique of Monopulse Radar. W. Hausz, G-E.

Reducing Sky Wave Errors in CW Tracking Systems. M. S. Friedland, Patrick AF Base, and N. Marchand, Electronics Lab.

An Application of Integrator Type Signal Enhancer to Direction Finding Equipment. C. A. Strom and J. A. Fantoni, Rome Air Dev. Ctr.

A Theory of Target Glint or Angular Scintillation in Radar Tracking. R. H. Delano, Hughes Aircraft Co.

Automatic Dead Reckoning Navigation Computers for Aircraft. J. L. Dennis, Wright Air Dev. Ctr.

ANTENNAS

The Measurement of Highly Directive Antenna Patterns and Over-All Sensitivity of a Receiving System by Solar and Cosmic Noise. J. Aarons, Air Force Cambridge Research Ctr.

Radiation Patterns for Aperture Antennas with Non-Linear Phase Distributions. C. Allen, G-E.

Factors Affecting Radiation Patterns of Corrugated Surface Antennas. M. Ehrlich and L. Newkirk, Hughes Aircraft Co.

A Microwave Anechoic Chamber for Antenna Pattern Measurements. J. Simmons, Naval Research Lab.

Wide-Frequency-Range Tuned Circuits and Antennas. A. G. Kandoian and W. Sichak, Fed. Telecommunication Labs.

Arrays of Flush Mounted Traveling Wave Antennas. J. N. Hines, V. H. Rumsey and T. E. Tice, Ohio State U.

Transient Build-Up of the Antenna Pattern in End-Fed Linear Arrays. H. Enenstein, Hughes Aircraft Co.

A New Microwave Reflector. K. S. Kelleher, Naval Research Lab.

Crosstalk in Radio Relay Systems Caused by Foreground Reflections. H. W. Evans, Bell Telephone Labs.

Low Side Lobes in Pencil-Beam Antennas. E.M.T. Jones, Stanford Research Inst.

Notes on Propagation. L. A. Byam, Jr., Western Union Telegraph Co.

Tropospheric Propagation in Horizontally Stratified Media Over Rough Terrain. H. M. Swarm, R. N. Ghose and G. H. Keitel, Washington U.

Radio Wave Scattering in Tropospheric Propagation. J. W. Herbstreit, K. A. Norton, P. L. Rice and G. E. Schafer, Nat. Bureau of Standards.

Extended-Range Radio Transmission by Oblique Reflection from Meteoric Ionization. O. G. Villard, Jr., A. M. Peterson, L. A. Manning and V. R. Eshleman, Stanford U.

An Interpretation of Vertical Incidence Equivalent Height vs. Time Recordings on 150 KC. R. Lindquist, Pa. State College.

AUDIO AND ACOUSTICS

Sound Reinforcement System, General Assembly, United Nations. L. Beranek, MIT; C. W. Goyder, UN.

A Variable Time Delay. K. Goff, MIT.

A Flux Sensitive Head for Magnetic Recording Play Back. D. E. Wiegand, Armour Research Foundation.

Uniaxial Microphone. H. F. Olson, J. Preston and J. C. Bleazey, RCA Labs.

Sound Pressure Measurement between 50 and 220 DB. J. K. Hilliard, Altec Lansing Corp.

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