RADIO-ELECTRONIC Engineering SECTION

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RADIO & TELEVISION NEWS

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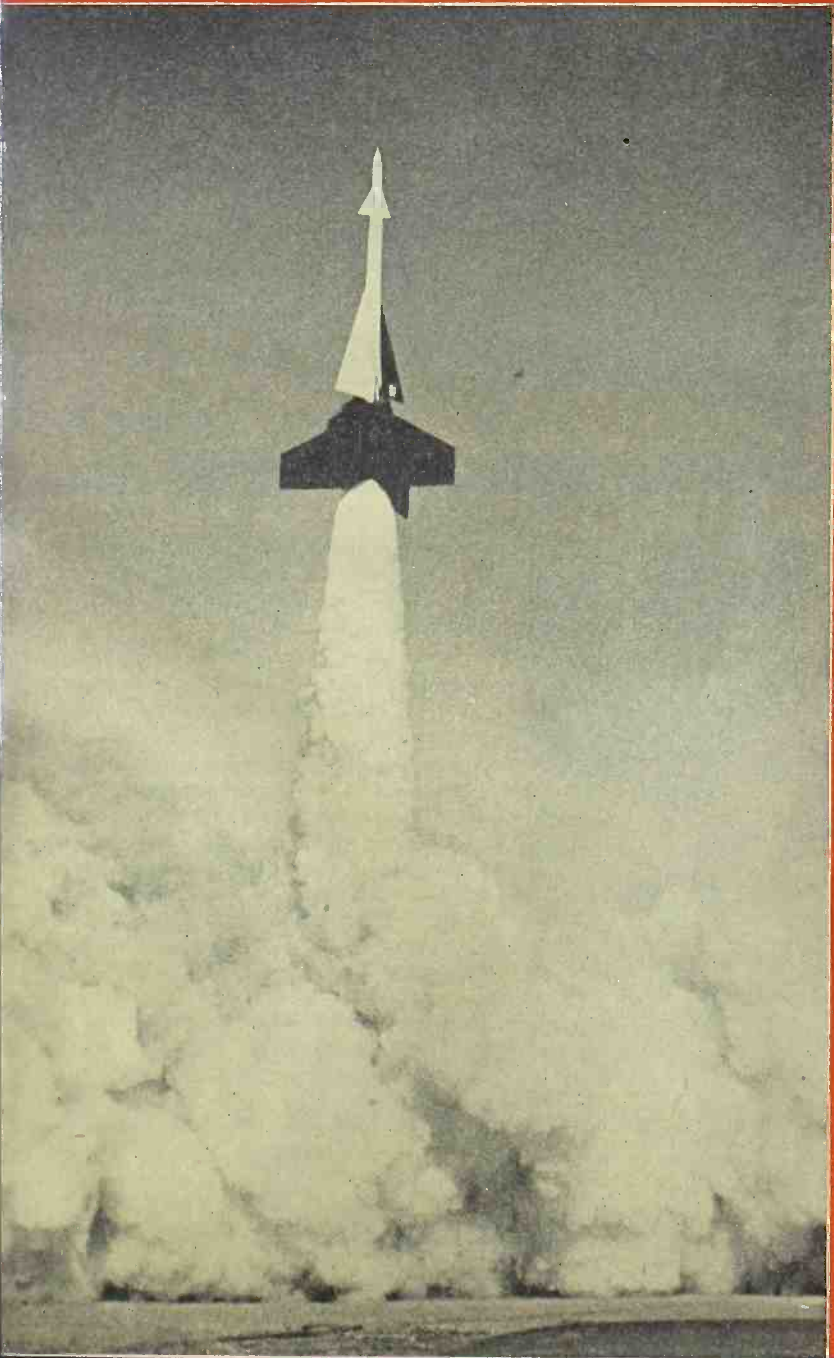


AUGUST, 1951

DEPARTMENTS

RADIO-ELECTRONIC ENGINEERING is published each month as a special edition in a limited number of copies of RADIO & TELEVISION NEWS, by the Ziff-Davis Publishing Company, 185 N. Wabash Avenue, Chicago 1, Illinois.

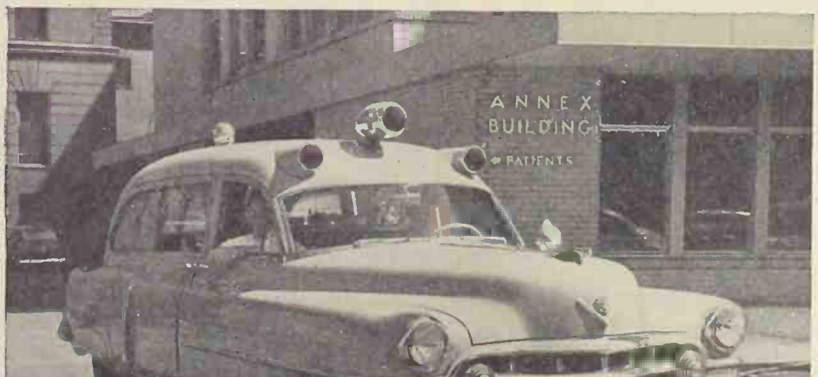
← An accurate electronic control system for guiding pilotless missiles to high-flying enemy aircraft has been developed by Bell Telephone Laboratories. One of these guided missiles, fired and steered by this control system, is shown during a firing test.

WHEN EMERGENCY CALLS FOR *Speed...*

1. In Minneapolis, the police radio network is linked to hospital ambulances by two-way mobile rigs equipped with Sylvania receiving and transmitting tubes. Immediately the Minneapolis Police headquarters hears of an accident, a General Hospital ambulance is alerted by 2-way radio and routed to the scene.

2. Police cars nearby are also instructed to go to the location and lend whatever police help is needed.

Minneapolis calls on Sylvania tubes



In Minneapolis, when seconds count, police and hospital authorities know they can count on the sure performance of Sylvania high-quality tubes.

In scores of other critical assignments, including railroads, airlines, steamships, and taxi cabs, you'll find Sylvania tubes get first call.

Now available in types and sizes for every need . . . from subminiature, low-drain battery types to television receiving and picture tubes. For full information and ratings about the types you need, drop a line to: Sylvania Electric Products Inc., Dept. R-1308, Emporium, Pa. *Sylvania Representatives are also located in all foreign countries.*

3. This quick, efficient coordination between the Minneapolis Hospital and the Police Department has been an important factor in enabling this city to win the *National Safety Council award as the nation's "Safest City" . . . for 2 successive years.*

SYLVANIA ELECTRIC PRODUCTS INC. 1901–1951 50th ANNIVERSARY FIVE DECADES OF PROGRESS

SYLVANIA

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

An Introduction to COMPUTER CONCEPTS

The Consolidated Engineering Corp. Model 30-103 electrical computer for solving up to 12 simultaneous linear equations.

By
JOHN D. GOODELL
The Minnesota Electronics Corp.

Part 1 of this series discusses the basic principles involved, and the future potentialities of computers.

A GREAT deal of material has appeared in the last few years relating to computing machinery. This has been fairly well divided between news stories along the "wonders of science" line and engineering discussions in various technical journals. The former have contained little of real interest to the engineer, and the latter have too often been such highly specialized discussions that those not specifically skilled in the art found them of relatively little interest. A large percentage of computer designs involves the use of electronic circuits. Their broad potential applications and implications in the progress of this civilization make them important to every engineer in the industry. It is the purpose of the first article in this series to discuss the existing status of computing machinery in general, the principles involved, its potentialities for the future and the validity of the "thinking machine" concepts.

For some reason there are two strongly opposed schools of thought on the subject of relating the functions of computing machinery to the processes of human thinking. In some respects this seems a completely unimportant point and one which depends largely on the semantic problem involved in defining the word "think" in its various forms. On the other hand, it is of considerable importance in the future development and application of these devices that such concepts be clearly understood and that the analogies, similarities and essential identities be applied without prejudice.

At least one basic purpose in the design of computers is to provide devices that will relieve human beings of labor. In the same sense that the steam shovel minimizes the need for physical labor, so does the adding machine lower the requirements for mental effort. Whether or not the process of adding a column of figures is called "thinking" is of no consequence. But it is of considerable importance that all the possibilities for reducing more complex mental functions be considered, and without comparison to existing processes of the mind the probability of such developments is appreciably lowered. A fundamental approach to the guidance of research is to observe existing methods and thus conceive computers that *might* be designed in terms of their value in times of peace or in terms of defense.

From a structural standpoint it is the exception rather than the rule when man develops machinery in his own image, or in any framework that conforms with the solutions found in nature. Obvious examples of this appear in the design of aircraft and other means of locomotion. An exception is the microphone which is reasonably analogous to simple mechanisms of the ear. But if there had been no birds or fish to observe and study, the invention of aircraft and submarines might well have been appreciably delayed.

Actual knowledge of mechanisms in the brain is very limited indeed, and even if it were a fruitful form of research the attempt to copy brain structures would be frustrated at this time by the lack of availability of suitable components. Duplication of brain functions is quite another matter. In much the same sense that modern aircraft outstrip the performance of birds, so do existing computing mechanisms run circles around contemporary brains in the rapid handling of masses of statistical data. Certainly comparisons between computers and the human mind are of interest.

There are two basic types of computer systems. One is the analog variety where comparisons between physical quantities, such as distance, are used in analogy to other quantities. The other is the digital type that functions with basic units of information in accordance with an essentially numerical code. The former is typified by the slide rule, the latter by an adding machine. Within the limits of existing knowledge the human brain is essentially a digital computer with regard to the manner in which information is handled. Basic digital computer elements are relays, switches, and tubes performing relay and switching functions. Tubes are also used in computer designs where the various characteristics of electrical energy, such as volt-

	COMPUTERS	CENTRAL HUMAN NERVOUS SYSTEM
Switches	Tubes, Relays etc. Up to 500,000	Neurons, synapses Around 10,000,000
Power Source	Electromechanical generators	Electrochemical actions
Power consumption	Kilowatts	25 watts
Transmission speeds	Up to the speed of light—186,000 mi./sec (approx.)	200 to 300 feet/sec (max)
Pulse repetition rates	Up to megacycles	Normally 30 to 40/sec Kilocycle (max)
Maximum number of parallel circuits for purposes of automatic checking of results	Two or three	100 or more
Effect of environment	Minimal	Determining factor
Emotional factors	None—though designs including them have been suggested	Plenty
Life Expectancy with reasonable upkeep	25 to 50 years	25 to 50 years (deducting the first 15 to 20 years as strictly developmental
Direction	Operator (s)	Self-determined
Purpose	To solve problems	? ? ?

A comparative table of computers and the human nervous system. Functionally similar built-in systems include servomechanisms, sensing devices, and feedback loops.

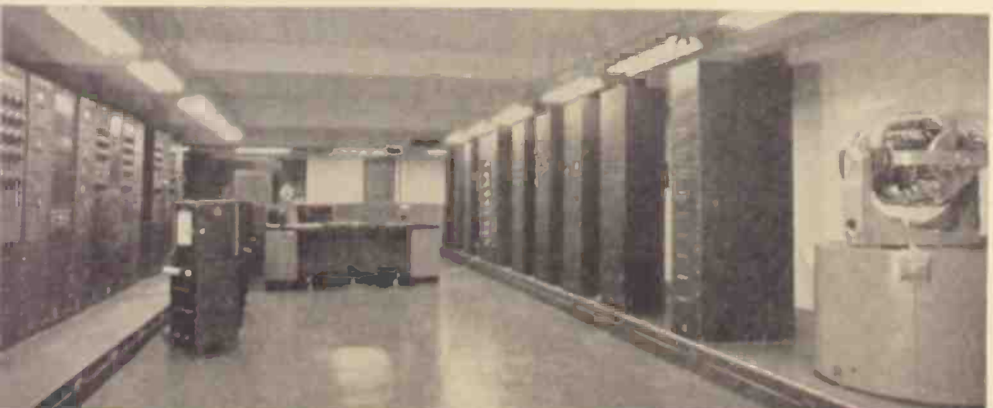
age, current, etc., are representative of problem quantities. Basic human nerve structures are relays and switches performing similar functions.

Computers are composed of components with considerable physical size, but the number of relays, switches and tubes in even the largest existing machines is only in an order of a hundred thousand or so. The human nervous system is made up of components of much smaller physical size. A nerve cell may approximate one or two ten-thousandths of an inch in diameter. The number of neurons in a human structure is in an order of magnitude around ten million.

Power consumption of computers for work performed is relatively high and many of the larger ones consume thousands of watts. The source of power is generally electrical which can be traced back to mechanical and chemical origins. The human brain heats a pint of blood one degree Fahrenheit per minute, corresponding to a power consumption of about 25 watts. The nerve cells are electrically operated and the source of power is in chemical actions.

Computers may be designed with sensing elements capable of observing data in almost any form, including stereophonic vision with suitable television cameras, hearing via microphones, etc. In addition to the perceptions available to the human system with built-in equipment, it is capable of operating a wide variety of supplemental instrumentation such as microscopes, etc. Similar accessories are available for computers, with suitable arrangements for operating them.

Part of Project Cyclone, one of the world's largest analogue computer installations, designed and built by engineers of the Reeves Instrument Corp.



Memory storage devices in existing computers are capable of handling only relatively limited amounts of information, particularly with respect to the storage space required. The human structure is capable of storing information units numbering in an order of ten trillion. This covers storage actually within the system and does not include material recorded and available in the outside world, such as written and photographic material. It is of some interest that this number is larger than the calculated total of neurons and may indicate some form of recording on a molecular level. In computers some systems of storage and recovery, such as electrostatic storage tubes, use scanning mechanisms to investigate and observe continually the stored intelligence. The scanning rate may be varied considerably and extremely high speeds are possible. With high gain amplifiers it is possible to observe the electrical waveform generated in the brain that is believed to represent a similar scanning mechanism. This is the "Alpha" rhythm that is cyclic at the rate of about ten per second with a normal, relaxed and fully conscious person. This "scanning" rate slows to three or four cycles per second in sleep or deep anesthesia. It is measurable as a continuous phenomenon in the brains of most living creatures during life and ends only at death. Many systems used in computers for storing information permit erasure and the insertion of new data. It is widely believed that information recorded in the memory banks of the mind is never erased except through organic damage. It is quite possible that this applies only to certain types of storage and that "temporary" systems are also available.

Almost all computer designs make use of feedback circuits. In some instances regenerative feedback may be used as a memory system. Degenerative feedback is used to reduce distortion, stabilize the system with respect to dynamic loading, accomplish many servomechanism functions, sometimes perform mathematical operations, etc. Human structures contain many feedback loops. Some of these extend through the outside world, others are entirely internal. Certain types of human memory are believed to function by means of damped oscillatory feedback loops. Feedback is continually used to effect suitable adjustments with regard to dynamic loading of muscle elements.

The travel of impulses along the wiring of computers is measured in terms of thousands of miles per second. Computers are capable of handling large amounts of statistical data and obtaining answers at incredibly high speeds.

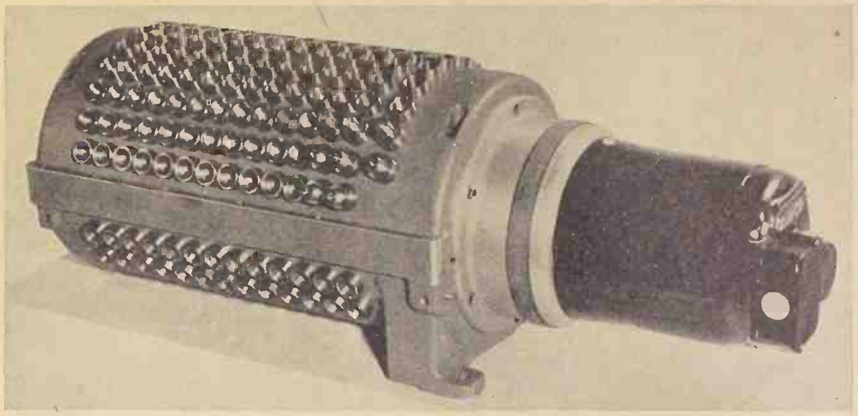
Tube elements may function at pulse repetition rates up to millions per second. The speed of transmission along nerve fibers is in maximum terms of hundreds of feet per second. Relay and switching functions of neurons are limited to maximums of a few hundred pulses per second and actually are rarely activated at rates above 30 or 40 per second. Note that sounds are not transmitted to the brain at audio frequencies but are observed by selective resonance in the inner ear and transmitted along coded nerve fibers.

Some computers perform functions in parallel, using simultaneous circuits that continually compare answers to increase the accuracy of results. In some functions of the human nervous system secondary circuits require agreement from a hundred input signals and the accuracy is of an extremely high order. There are approximately a hundred million photoreceptors in the eye feeding a million or fewer secondary trunk lines that require agreement from appreciably large percentages of the multiple source circuits for transmission of a signal to the visual cortex areas. This produces a high order of accuracy but makes trouble-shooting extremely difficult.

Computers are largely dependent upon exterior control and direction while the human structure is generally believed to be self determined. Computers to date are not self reproducing, self perpetuating nor even self improving. Humans are self reproducing, self perpetuating and self improving. Actually genetics indicates that the basic cell structures contain only the necessary data to build a relatively simple system that in turn constructs a secondary structure capable of building a third, etc., the latter being additionally guided by environmental factors. Computers, in general, are not influenced by environment either during their construction or after they are completed. They are largely static devices with regard to performance and ability to perform. Humans are a function of their genetic blueprint plus their environment. Their performance and ability to perform is continually influenced by their environment.

Computers may be "aware" of their own structures and of their environment via sensing mechanisms. Humans are "aware" of themselves and also "aware of being aware."

It has been suggested, and is doubtless possible, that mechanisms be designed to respond to stimuli in a manner analogous to, if not identical with, emotional concepts in humans. To date computers are not capable of worry, fear, pain, pleasure, etc. Humans are largely governed by emotional rather than rational decisions. Some of these responses appear to be built-in pushbutton arrangements but many, if not all, are in a state of constant dynamic adjustment to the environment.



Housing and motor for Engineering Research Associates, Inc. magnetic storage drum.

Machines are not consciously competitive. Humans are. Computers may be designed for applications requiring logical as well as mathematical processes. There is no theoretical reason why they cannot accomplish all of the processes now commonly handled by human mental effort. Their desirability is not merely a matter of relieving existing burdens but of accomplishing results that represent so large a load that they are impractical of attack by conventional methods of thinking. Their fundamental advantage is speed. This applies not only to handling masses of data simultaneously and computing answers but also to searching out information and data in storage systems. While it has been mentioned that the human mind has greater storage capacity than existing computers, it is noted that computers may be coupled to microfilm libraries with unlimited available information.

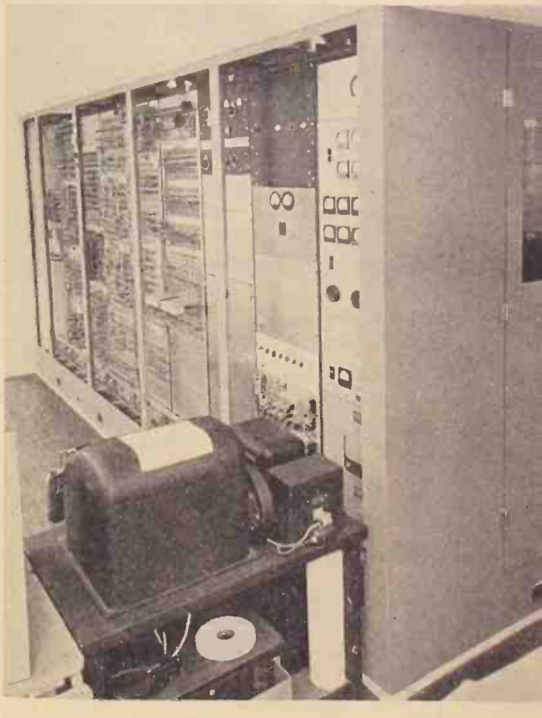
It is important to realize that the term "computer" does not only apply to the complex devices that have been built principally to handle statistical data and solve mathematical problems, but also to devices encountered in the daily activities of every individual. Everyone who drives a car equipped with an automatic transmission is served by a computer mechanism. It should be evident from the foregoing that the computer is a tool for achievement without parallel and that it is certain to affect the future profoundly. It is not appropriate in this article to discuss the economic, sociological and political implications involved, but because they are intimately linked with the future life of every individual it is perhaps proper to make one comment along this line. Machines, of themselves, are neither good nor bad, selfish nor unselfish. It is not envisioned that they should become sentient beings capable of autonomous control. Their application is in the hands of men, and since they are the product of the scientists and engineers who design them, an inherent responsibility is simultaneously undertaken to guide their use in fields that benefit mankind.

Every engineer concerned with the design of industrial equipment has an opportunity to use principles developed in computer work. An understanding of the basic concepts and fundamental approach to such problems is of inestimable value. The material that follows is intended to develop a broad understanding of these principles which will be later spelled out in terms of practical circuitry and specific application.

The term "computer" is rapidly broadening in meaning and application.

(Continued on page 30)

A view of the NBS SEAC with the operator's control table in the foreground.



WIDE RANGE LOGARITHMIC AMPLIFIER

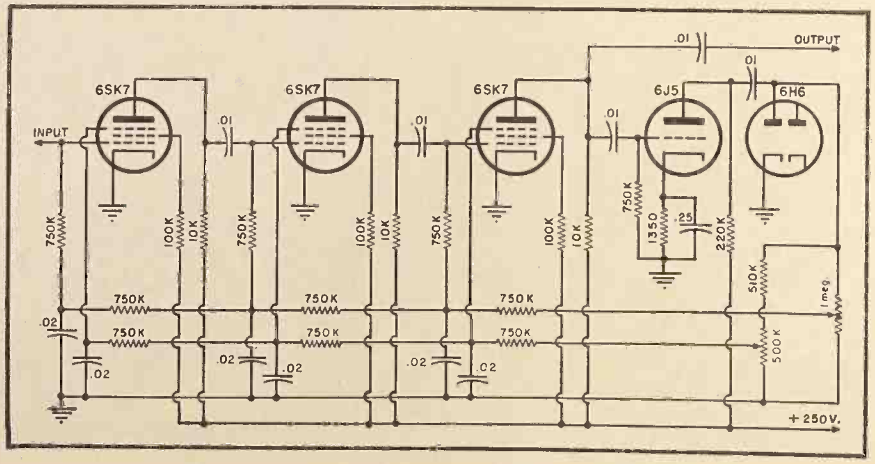
A logarithmic amplifier having an input range of 100 db below the maximum input of 5 volts.

By CLAUDE H. CHILD

THE NEED for a logarithmic a.c. amplifier in the measurement of antenna field patterns, acoustic properties, and other similar applications arises quite frequently. The approach used by Ballantine,[1] Freedman,[2] and others has been to use an a.c. amplifier employing some form of a.v.c. and d.c. instruments to record the magnitude of the a.v.c. voltage or the diode current. In many cases it is desirable to use an alternating voltage to drive a recorder directly, as in the case of the polar recorder built by the *Antenna Research Laboratory*. This recorder and others of similar design operate at a low signal level which makes necessary a rather large attenuator if the signal output is taken from the last stage of most logarithmic amplifiers. A further disadvantage to such an arrangement is that the logarithmic characteristics are dependent to some extent on the characteristics of the linear amplifier and diodes used to produce the a.v.c. voltage and meter current. These conditions are particularly pronounced when the range is extended to values in excess of 40 db.

In view of the above mentioned problems, it was felt that an effort should be made to produce an amplifier whose a.c. output would be a logarithmic function of its input over a range of between 80 and 100 db. Such an amplifier should operate with an input voltage of less than 10 volts and should have a maximum signal output as low as possible consistent with the desired range. The low input is desirable in order to avoid the need of several high gain amplifiers preceding the logarithmic amplifier. As mentioned previously, the low input is desirable in order to reduce the size of the attenuator needed to bring the output to the level necessary for the operation of the recorder.

Fig. 1. Circuit diagram and values of components for the complete amplifier.



Measurements made on several 6SK7 tubes indicated that the suppressor grid-plate transconductance is an exponential function of the suppressor grid voltage. These characteristics should give rise to a ratio of output voltage to input voltage which is an exponential function of the d.c. voltages applied to the control and suppressor grids. This ratio is expressed by:

$$\frac{e_2}{e_1} = A\varepsilon(\exp)\, M\, (AE_{g1} + BE_{g3}) \quad . \quad (1)$$

If the effects of the bias voltage applied to the two grids are combined and considered as a single parameter cE, (1) reduces to:

$$\frac{e_2}{e_1} = A\varepsilon^{ncE} \quad . \ . \ . \ . \ . \ . \ . \ . \ . \quad (2)$$

where n is the number of identical stages, c and A are constants, and E is a linear combination of Eg_1 and Eg_3. Reich[3] shows that if e_2 is constant then:

$$\text{db.} = k + mE \quad . \ . \ . \ . \ . \ . \ . \quad (3)$$

where k and m are constants.

Because e_2 is not entirely constant and because the assumption of an exponential relation between gain and bias is not entirely valid, there is some departure from the linearity expressed in (3). However, this nonlinearity can be used to correct for some of the nonlinearities found in the recorders.

By means of vacuum-tube voltmeters it has been possible to introduce slight non-linearities which compensated for the deviation in the logarithmic characteristic of the amplifier. This procedure has been entirely satisfactory where meters or d.c. recorders have been employed as indicating devices. However, the a.c. output of these amplifiers was not, as a rule, a logarithmic function of the input over an extended range. An inspection of (2) and (3) shows that E is the independent variable. Since the bias voltage is generated by rectification of the signal output, a logarithmic relation should exist between the signal output and input, provided that E is a linear function of the signal output and provided further that the relation between the gain and the bias can be made more nearly exponential over the desired operating range. It was the meeting of this final provision which led to the application of a control voltage to the suppressor grid. Tests indicated that the amplification of the tube could be made to approach quite closely an exponential function of a linear combination of the bias voltages.

These voltages were applied in a ratio of approximately 2:1 with the higher voltage applied to the control grid. The exact ratio should be determined after measurement of the suppressor grid transfer characteristics of the tube employed. It was found that by proper selection, three 6SK7's could be matched to have similar suppressor characteristics which allowed the application of an a.v.c. voltage in the order of 22 volts before the plate current was reduced to less than 1 ma. Since there is no quality control on the suppressor grids of 6SK7's insofar as transfer characteristics are concerned, it is necessary to hand pick the tubes for use in this circuit. Fig. 1 shows the schematic diagram of the amplifier as it was finally fabricated for use in the Aerophysics Laboratory of *North American Aviation, Inc.* A word about the construction of the amplifier might be well at this point. Since the input has a range of 100 db down from 4 volts, it is necessary to employ all of the techniques usually used in a good high gain low level amplifier such as adequate shielding, single point chassis ground, d.c. heater supplies, etc.

Fig. 2 shows the response characteristic of the amplifier with maximum input levels of 5 volts rms and 4 volts rms at 1000 cycles. Fig. 4 shows the response of the amplifier with a maximum input level of 4 volts rms at 100 cycles, 400 cycles, 1 kc. and 10 kc. The over-all frequency response of the amplifier with constant level input is shown in Fig. 3. The rising characteristic at the low frequency end of the curve is probably due to the short time constant employed in the a.v.c. filter network. This situation would allow positive a.c. feedback to the first and third stages at low frequencies. The short time constant employed was dictated by the need for faithful response of the recorder to changes in signal level approaching a step function. The time constant of the a.v.c. filter determines the amount of electrical inertia present in the system and should be adjusted so that this inertia is less than any mechanical inertia in the recorder system. Because this amplifier was intended for use at only one fixed frequency at any one time, this rising characteristic does not cause us any difficulty.

As used at present, the amplifier eliminates the need for a number of high gain amplifiers between it and the detector or other signal source and the need for a large amount of attenuation

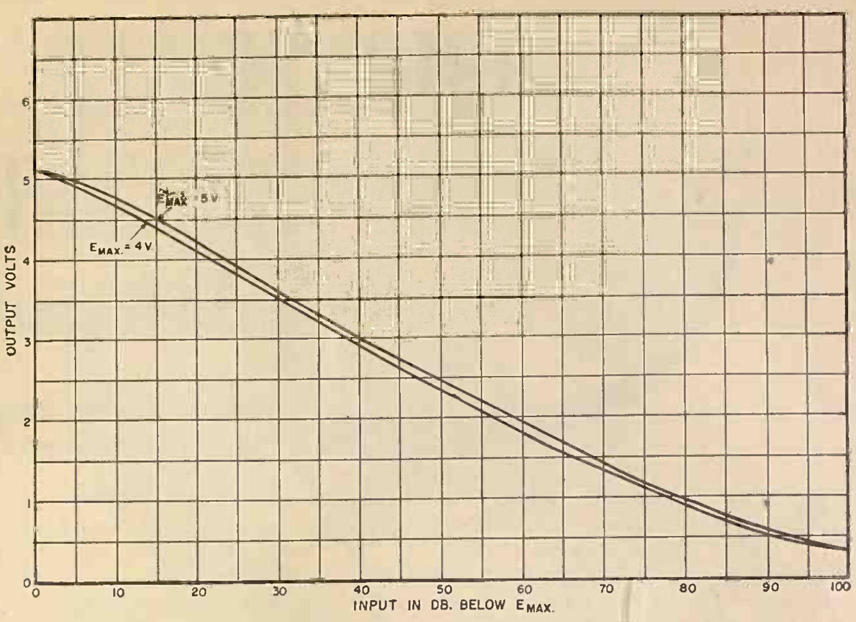


Fig. 2. Response of amplifier at 1000 cycles for maximum inputs of 5 volts and 4 volts rms.

in its output to reduce the signal to the level required by the recorder. Tests have shown that the output of the amplifier is a good reproduction of the input wave shape provided that the maximum level of 5 volts rms is not exceeded.

When used with a linear source the amplifier has a range of 100 db, but if a square law detector is employed the range is reduced by a factor of 2. The resulting 50 db over-all dynamic range has been found to be sufficient for all measurements encountered to date in our antenna work. If used with a suitable compensating network, the amplifier should prove to be a useful tool in the field of microscope and loudspeaker measurements, particularly

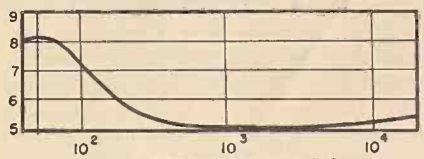


Fig. 3. Over-all frequency response of amplifier with constant input level.

where it is desired to use a direct view oscilloscope with suitable sweep frequency provision.

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2. *Freedman, Samuel, "Automatic Antenna Pattern Recorder"*, RADIO-ELECTRONIC ENGINEERING, *June*, 1950.
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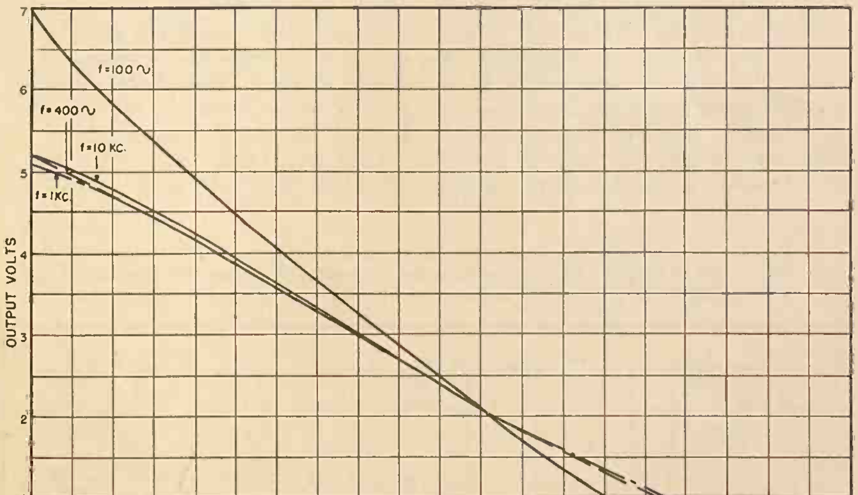
Fig. 4. Response of amplifier at various frequencies with an input of 4 volts rms.



BRIDGED-TEE PHASE MODULATORS

NBS engineers developed these circuits to give a large variable phase shift with a single control.

AN ELECTRICAL network frequently encountered in practice is the lattice, which is often designed to serve as a null network. The equivalent bridged-tee circuit is also widely used for the same purpose. Recently, Dr. M. G. Pawley of the National Bureau of Standards has derived several circuits—very similar in appearance to those commonly used as null networks—which are designed so that the phase of an applied sinusoidal voltage is shifted through a wide range by a variation in but one of the circuit elements and without a change in attenuation. Bridged-tee phase modulators, as the networks are called, have been successfully used in circuits related to radio telemetering, frequency modulation, servomechanisms, and other applications where variable impedance control of phase is required.

Generally, lattice networks which are used for variable-resistance or variable-reactance control of phase require push-pull circuits symmetrical to ground and simultaneous variation in two circuit elements to produce phase modulation. Many of these circuits do not permit grounding one side of the input or one end of the controlling impedance. A serious limitation of some networks is the change in attenuation accompanying phase modulation, corrective measures often taking the form of amplitude limiters which follow the phase modulating network. In addition, many networks cannot be loaded appreciably.

The bridged-tee phase modulators overcome all of these restrictive characteristics of networks. Wide-range phase shift with constant attenuation is achieved by variation in a single control impedance. In one version, the circuit may be adapted for voltage control of phase, thus providing a simple and highly stable phase modulator useful in radio communication. The circuits function with a common ground and have the ability to work into low-resistance loads.

The modulator circuit shown in Fig. 1A is designed to obtain a phase shift by varying either the capacitance, C_2, or the frequency. With the values of the circuit components as shown and an operating frequency of 4170 cycles, the circuit attenuation remains constant at 16 db and the phase shifts 90° as C_2 is varied from zero to 25 $\mu\mu$fd.

With C_2 made equal to zero the bridged-tee network of Fig. 1 functions as a frequency discriminator. As the input frequency is varied from a few cycles per second to approximately 8000 cycles per second the phase shifts nearly 360° while the attenuation remains constant. The phase characteristic is quite linear in the neighborhood of the center frequency.

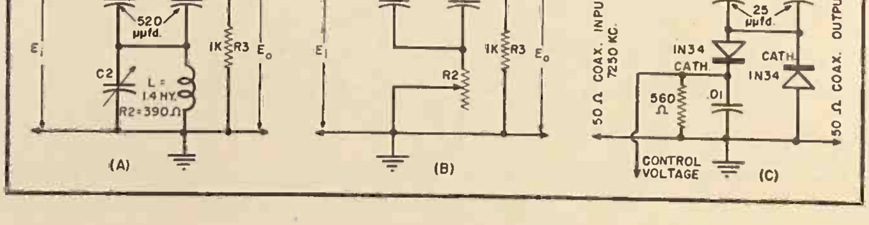
If in Fig. 1A $R_1 = 114$ ohms, $R_2 = 1.75$ ohms, $R_3 = 50$ ohms, $C_1 = 10.5$ $\mu\mu$fd., and $L = 1.44$ μhy., and the circuit is operated at a frequency of 29.1 mc., the phase may be shifted by varying C_2. The attenuation remains constant at 12 db and the phase shifts 135° as C_2 is varied from zero to 5 $\mu\mu$fd. A variation of only 2 $\mu\mu$fd. in C_2 results in a 90-degree phase shift.

Phase shift is produced in the bridged-tee network in Fig. 1B by a variation in the resistance R_2. At a frequency of 4170 cycles, the attenuation of the circuit is constant at 30 db; and when R_2 is varied from zero to 10,000 ohms, the resulting phase shift is about 120°.

In Fig. 1C the variable phase-controlling resistor R_2 of Fig. 1B is replaced by a varistor including two germanium diodes; consequently, a variable input control voltage modulates the phase. Static tests at 7250 kc. indicate excellent linearity of phase versus bias voltage over a 90-degree phase shift. The nonlinear characteristic of the biased varistor compensates for the nonlinear phase characteristics of the bridged-tee network, resulting in a remarkably linear phase response over the 90-degree range. As in the other forms of the network, the modulation is effected with no change in attenuation.

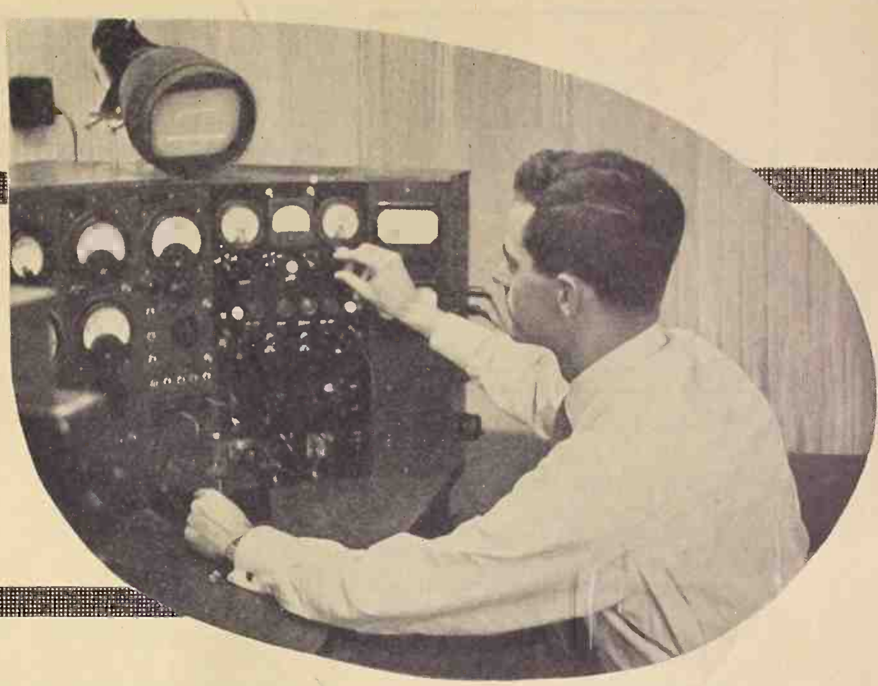
The bridged-tee phase-shifting circuits were developed originally for use with variable-resistance or variable-reactance telemetering pickup devices to produce phase modulation in multiplex time-division telemetering systems, and frequency modulation in multiplex frequency-division telemetering systems. The network using voltage-control of phase (Fig. 1C) has proved successful as a phase-modulating unit inserted in the coaxial coupling between low-level stages of a frequency-modulated high-frequency transmitter. In general, this bridged-tee phase modulator should be used in low-level applications in which the relatively high attenuation does not incur a serious power loss.

Fig. 1. Three circuits for phase modulation without change in attenuation. (A) Phase shift is obtained by varying C_2 or the frequency. (B) Phase shift is obtained by varying R_2. (C) Phase shift is obtained by varying the input control voltage.



By
J. H. KUYKENDALL
Tung-Sol Lamp Works, Inc.

ELECTRON TUBE CURVE TRACER



This device, constructed from standard parts, features a direct reading calibration marker.

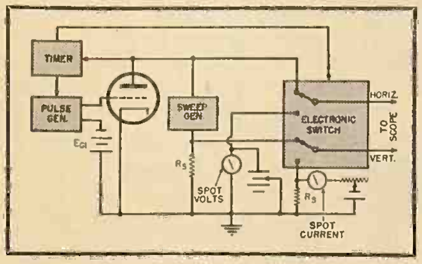
Fig. 1. The author at the controls of the curve tracer, which is incorporated into an existing tube test console.

THE INCREASE in the quantity and variety of electron tube applications in recent years has imposed a measurements problem upon those responsible for obtaining electron tube characteristics. The old method of obtaining data, point by point, is not only too slow for present day needs but is difficult to apply in the positive grid region. The need for a better measurement method has resulted in the development of several characteristic curve tracers which present a curve or family of curves on the face of a cathode-ray tube. The equipment to be described is also of this nature but differs in detail considerably from any similar equipment which has been described in the literature.

A study of the requirements for a characteristic curve tracer indicates that it is desirable to obtain curves in the positive grid region for values of grid voltage up to about 100 volts. For receiving type tubes, grid or plate currents of the order of two amperes may be expected. In addition to providing for such voltages and currents, some provision must be made to present a voltage and current calibration marker on the face of the CRT. With these requirements as a goal, and with particular stress on accuracy of measurement, the equipment pictured in Fig. 1 and shown schematically in Figs. 4 and 5 was designed and constructed in the Chicago laboratory of *Tung-Sol Lamp Works, Inc.*

A general description of the technique employed in this equipment can best be made by reference to the functional diagram in Fig. 2. In this diagram the tube under test is a triode and the system is connected so as to produce a plate characteristic curve on the oscilloscope. In the absence of a grid pulse, the tube is cut off by the bias voltage E_{c1}. The plate voltage is made to sweep from zero to the desired maximum value by the plate sweep generator at a sixty cycle rate. Grid pulses occur at a ten cycle rate and their duration and phase are controlled by the timer. The allowable pulse duration is normally determined by the dissipation rating and peak emission capabilities of the tube under test. If these conditions permit, the grid pulse duration is adjusted to equal the period of the plate sweep voltage which is 1/120 sec. Under these conditions the duty cycle is about 8%. In the extreme case the pulse may be shortened to about 0.5 millisecond which gives a duty cycle of only 0.5%. In this case only a small portion of a curve can be traced, but data over a range of plate voltages can be obtained quite simply by varying the phasing of the grid pulse. Reference to Fig. 2 will make it apparent that if the plate voltage (E_p) and the voltage across R_s are applied to the horizontal and vertical input terminals of an oscilloscope, the pattern on the CRT will be an I_p, E_p curve of the tube under test in addition to a zero current base line which is traced when the tube is cut off. While such an arrangement would give qualitative data, it would not be satisfactory for the purposes of a laboratory measuring device. In order to make measurement of voltage and current both accurate and convenient, an electronic switch is employed to switch the inputs of the oscilloscope to calibrated sources of voltage and current for a short period (about 50 milliseconds) immediately following each grid pulse. With this arrangement a spot is produced on the CRT which can be moved to any desired position to measure voltage and current. The accuracy of the d.c. meters and the resistors used is the only limitation on the accuracy of measurement. Provision is made to check and balance the electronic switch circuit at any point in question.

Fig. 2. Functional diagram of the tracer.



The preceding description has been given with respect to a plate characteristic curve. Provision is also made to obtain transfer curves. In this case the grid pulse is given a sawtooth shape and the voltage and current to be measured are applied to the electronic switch inputs. In this case also, the calibrating spot appears on the CRT.

It will be noted that this equipment is not capable of presenting a family of

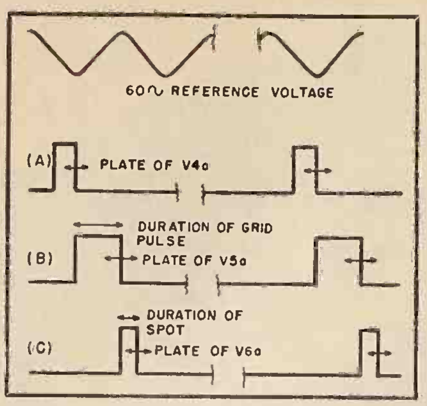


Fig. 3. Timer waveforms.

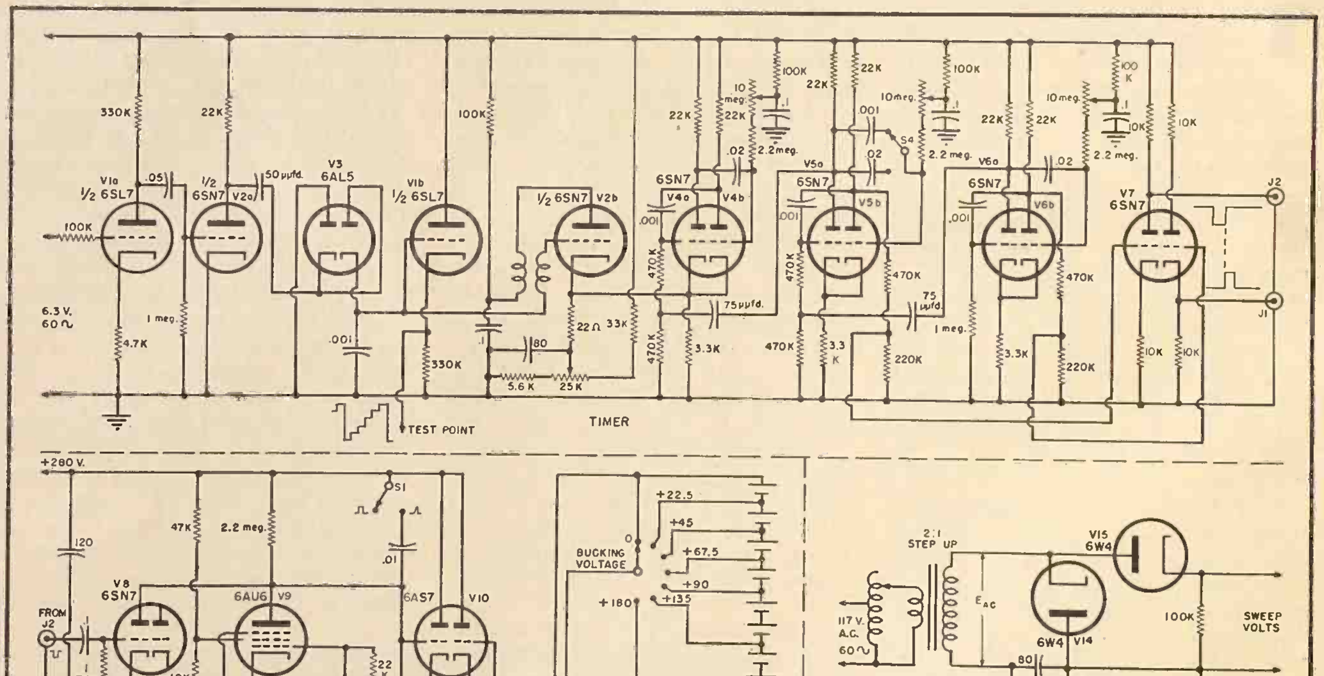
curves and in some cases will present only part of one curve. This compromise results in a relatively simple system which is flexible enough to satisfy changing laboratory requirements; and both accurate and reliable enough to eliminate concern over interpretation of the data obtained.

Circuit Description

The timer is composed of tubes V_1 through V_6 in **Fig. 4.** The 60-cycle heater voltage is amplified and shaped in V_{1a} and V_{2a}. V_3 and V_{2b} form a conventional counter circuit which is adjusted to give one output pulse for each six incoming cycles. This ten cycle pulse is used to key the chain of multivibrators formed by V_4, V_5, V_6 and the associated circuitry. The idealized waveforms at the plates of V_{4a}, V_{5a} and V_{6a} are shown in A, B & C respectively in Fig. 3. These multivibrators are of the one-kick variety and are so arranged that the trailing edge of the output pulse of the first multivibrator is used to key a second multivibrator, etc. The duration of the pulses may be varied by the ten megohm controls in the respective grid circuits. In the case of the multivibrator formed by the V_5 circuit, a switch is used to provide for a very short output pulse. The first multivibrator (V_4) is used only for phase control. The second multivibrator (V_5) provides the keying pulse for the grid pulse generator. The last multivibrator provides the keying pulse for the electronic switch.

The grid pulse generator is probably the most important part of the equipment. It must provide an output pulse from a very low impedance, and with constant amplitude for its duration. In this equipment advantage was taken of the known characteristics of d.c. regulated power supplies. In Fig. 4, it will be noted that if V_8 were removed from the circuit, then V_9, V_{10} and V_{11} would form the regulator circuit in a conventional d.c. regulated supply. V_8 is actually used to key this regulator on and off in response to the keyer impulse from the timer. When V_8 is conducting, its plate is sufficiently negative to maintain the 6AS7G grid at a voltage below cut-off. For the duration of the keyer pulse V_8 is cut off so that V_{10} and V_9 provide a regulated output voltage. This system was found capable of providing flat-topped pulses from an extremely low internal impedance source. V_{12} is a peak rectifier used to measure the output pulse. An accurately calibrated vacuum-tube voltmeter is arranged to measure the sum of this rectified pulse voltage and the bias or bucking voltage (E_{c1}), which is always negative. This provides

Fig. 4. Circuit of the timer, pulse generator and sweep generator portions of the equipment.



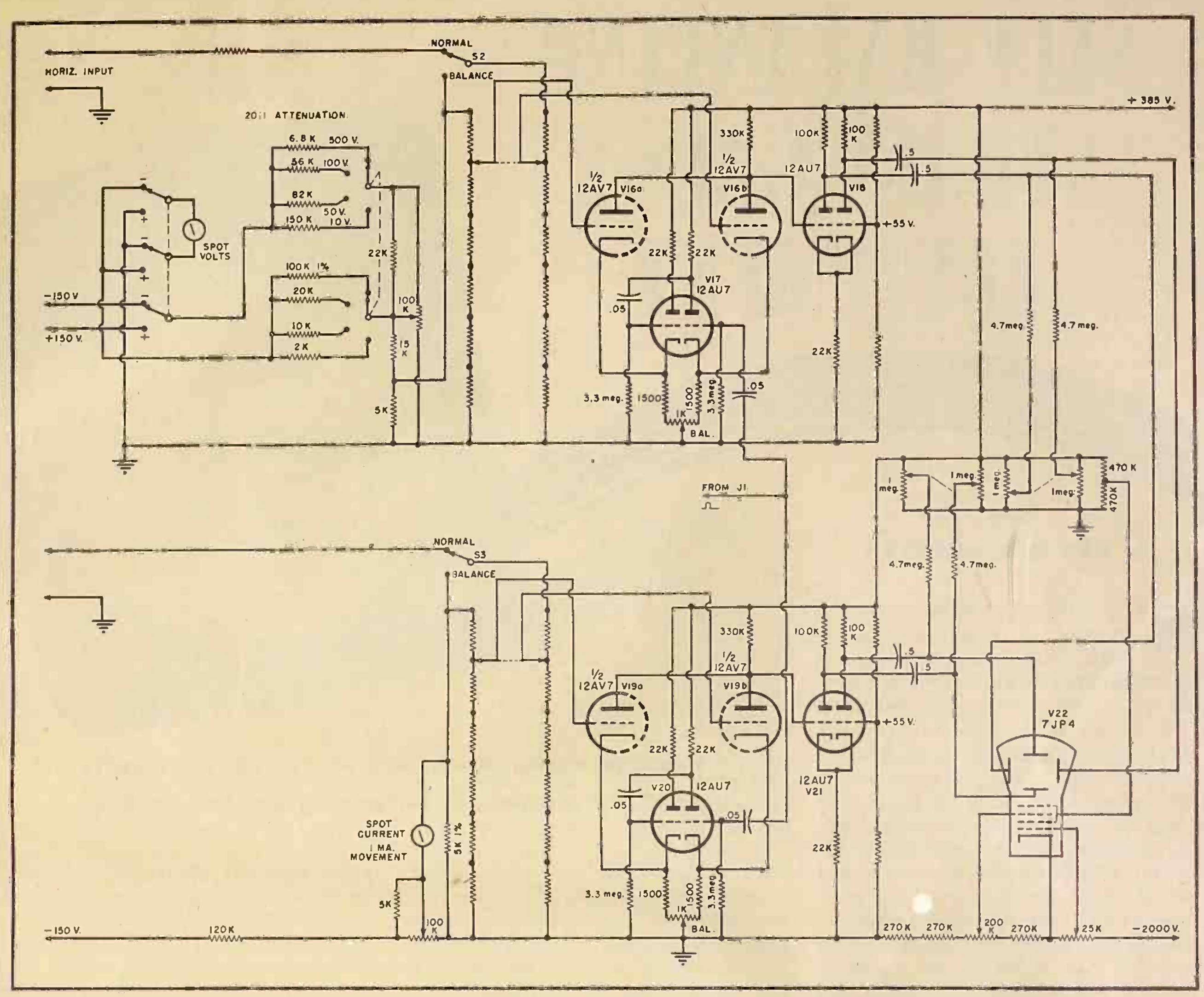


Fig. 5. Circuit diagram of the electronic switch and oscilloscope. This circuit interconnects with Fig. 4.

a meter reading for the value of the grid voltage during the pulse. The output pulse may be varied from 100 to 130 volts and E_{c1} may be changed in 22.5 volt steps. This provides an output pulse with a peak voltage with respect to ground of from -50 to $+130$ volts.

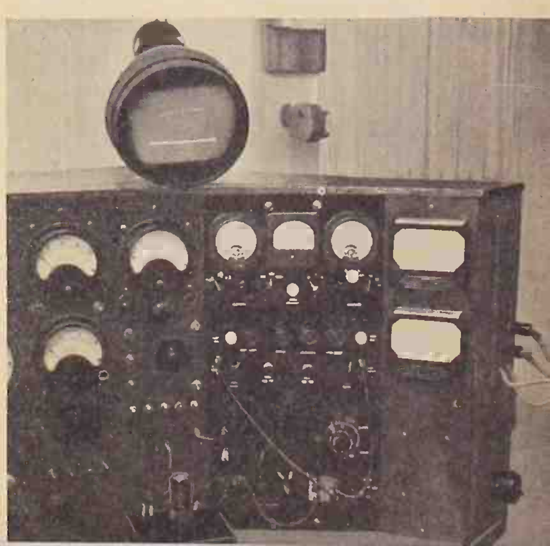
When transfer curves are to be plotted, the same generator is used to provide a sawtooth output pulse. This is done quite simply by switching a capacitor across the plate resistor of the regulator tube V_9. This causes a sawtooth buildup of voltage at the 6AS7G grid. The exact shape of the output pulse is not important nor is perfect regulation required because this voltage is displayed on the CRT where its value at any point can be measured by the calibrating spot. The maximum amplitude is controlled by the keyer pulse duration control and may be adjusted from 5 to 100 volts with a maximum output current of one ampere.

For simplicity, a sixty cycle sine wave is used for the plate sweep voltage. In order to prevent the plate voltage from swinging in the negative region, a d.c. voltage (E_{dc}) equal to the peak a.c. swing is added to the a.c. voltage (E_{ac}). This composite voltage is provided by the transformer, V_{14}, V_{15} and the associated circuitry. V_{14} rectifies the a.c. voltage provided by the transformer and this rectified voltage appears across the 80 μfd. condenser. The voltage appearing across V_{14} is then the sum of E_{ac} and E_{dc}. Under load E_{dc} will be less than E_{ac} resulting in a slight negative excursion. V_{15} is provided to block this negative voltage from appearing at the output terminals.

The electronic switch (Fig. 5) is composed of two identical sections, one each for the vertical and horizontal inputs to the oscilloscope. The switching for the horizontal circuit is performed by V_{16} and V_{17}. The switching action is made possible by the common cathode resistors and by the difference in the cut-off voltages of V_{16} and V_{17}. Conduction of V_{17b} for the duration of the keyer pulse produces a cathode voltage which cuts off V_{16b} to which the horizontal input signal is applied. At the same time V_{17a} is cut off allowing V_{16a} to conduct and amplify the calibrating signal. The push-button switch S_2 and

(Continued on page 29)

Fig. 6. The darker center panel is the control panel for the instrument. A typical curve is seen on the scope screen.



SELF-BALANCING STRAIN GAUGE EQUIPMENT

Typical "writing" recorder. This is similar to the printing recorder but uses a pen instead of a printer.

By
ALVIN B. KAUFMAN

Various techniques, equipment, and circuits used for automatic balancing and recording.

SELF-BALANCING and automatic printing or line recording of strain gauge indicated stresses is a natural step forward from the early manually operated test equipment.

This sort of equipment has but a single recording channel and must be switched sequentially from channel to channel to record correlating data. In commercial equipment the main limiting factor is the speed with which the machine hunts for balance, pauses, and stamps its impression on the paper. For widely divergent strains this can take three to five seconds. Equipment designed for aircraft use in which photographs are taken of a small dial as its pointer comes to rest permits much higher recording speeds, approximately one to two per second. Such equipment is usable only in multi-channel installations where the actual strain changes slowly or not at all between loads. For single channels dynamic information may be recorded, particularly with "line" or "writing" recorders.

Strain gauge equipment may be divided roughly into two groups:

1. (Automatic) Balancing Indicating/Recording Type
2. (Non-Automatic) Unbalance Indicating/Recording Type[2]

Most of the balancing type electronic recorders, which, incidentally, are practically the same design as for measuring thermocouple potentials, employ the same basic circuit and theory of operation, a carrier system with phase sensitive detector.

They are basically a resistance measuring instrument incorporating a Wheatstone bridge, two legs being the strain gauges, the other two the slide wire system. The system operates on the principle of a continuously rebalanced bridge circuit in which the bridge output potential is amplified to operate a motor-driven potentiometer, which restores the system to balance. Since strain or stress as sensed by the strain gauge determines the position of the potentiometer wiper, an indication of psi or strain is provided by an indicator pointer attached to the potentiometer shaft. A mechanical or electrical arrangement causes the pointer to print on the paper after it comes to rest. This is not required where a trace or writing recording is made.

D.c. is applied to the strain gauge bridge. The unbalance output is fed into a synchronous electromechanical chopper which, in conjunction with a center-tapped input transformer, produces an alternating output wave whose frequency is the same as that of the line frequency supplying the chopper. These choppers are produced commercially by *Stevens-Arnold* and *Minneapolis-Honeywell* and may be secured in operating ranges of 50 to 500 cycles. In order for the vibrating element to put out the same frequency as the coil exciting frequency it uses a magnetized reed which is pushed one way for one half of the exciting frequency cycle and then pulled the other way for the other half-cycle. Thus, the current into the input transformer alternates direction, at the same frequency and completely in or out of phase with current flowing on the exciting line, according to the polarity of the input voltage.

The a.c. produced signal can then be treated like a standard a.c. signal, amplified (as in typical schematic, Fig. 1) in three stages of 7F7's and then applied to the four grids of two 7N7 tubes. The grids of these two tubes are connected together and therefore they will all go positive or negative at the same instant. The plates of these triodes are fed a.c. by a stepup transformer from the power line. When the plates of the "A" triodes go positive, the "B" plates go negative and vice-versa with alternation of the line voltage. Thus, if the plates of the "A" triodes go positive at the same instant that the grids go positive, they will pass more current. At that instant, however, the plates of the "B" triodes are negative and will therefore not pass current. At the next instant (a half-cycle later) when the "B" plates are positive, all grids are negative, and therefore current does not flow in the "A" triodes and only a small amount in the "B" triodes. As long as this phase relationship between incoming signal voltage and plate voltage exists, the "A" triodes will pass more current than the "B" triodes. If, however, the phase relationship between the incoming signal voltage is such that when the grids go positive, the plates of the "B" triodes go positive, the reverse condition is true and the "B" triodes pass more current than the "A" triodes.

Inasmuch as the chopper and tubes are both powered by the same 115 volt line, the determining factor as to which pair of triodes is caused to conduct current is the phase relationship between the incoming signal voltage and the plate voltage on these tubes. A reversal of input d.c. potential, as when the bridge goes through the balance, would cause a 180 degree phase shift in the amplified a.c. voltage and its relationship to the plate potentials.

One field winding of the two-phase balancing motor is continually excited from the line, and the other, the direction sensing winding, is excited by the amplifier from which the other half of the driving power is obtained. From examination of the schematic it can be seen that if no signal is applied to the grids of the "phase sensitive power tubes," the zero signal current flowing through the output tubes will be of equal magnitude and will lead or lag the line-excited field winding current. Therefore, the motor averages out the small bidirectional rotational signals and no motor rotation occurs. If, however, a voltage signal is applied to the grids which is in phase with the plate voltage of either tubes "A" or "B", the output current thus developed is impressed through the amplifier-excited field winding of the motor. It can be seen that the current in this field winding, with "A" triodes conducting, will be 180 degrees out of phase with that when "B" triodes are conducting. The condenser in the lead to the line-excited field winding has been so chosen that the current in the amplifier-excited field winding either leads or lags the current in the line-excited field winding by approximately 90 degrees, causing motor rotation. Direction of motor rotation is determined by whether current in the amplifier winding leads or lags the current in the field winding. Therefore, the phase relationship between the incoming signal voltage from the bridge and the plate voltage of the phasing tubes in the amplifier determines the direction which is pre-selected so that the motor rotation operates the slide wire returning the bridge to a balanced condition.

The sensitivity or full-scale strain change which this system will indicate is arranged by proper selection of resistor *X*, or by changing values of the *YY* pair. As shown on the schematic, a balancing arrangement must be included to compensate for manufacturing tolerances in the gauge resistance values and to allow the potentiometer to be balanced to zero strain indication. A calibration resistor is also supplied, with switch, allowing a simulated stress to be produced at any time so that the accuracy of the instrument may be checked.

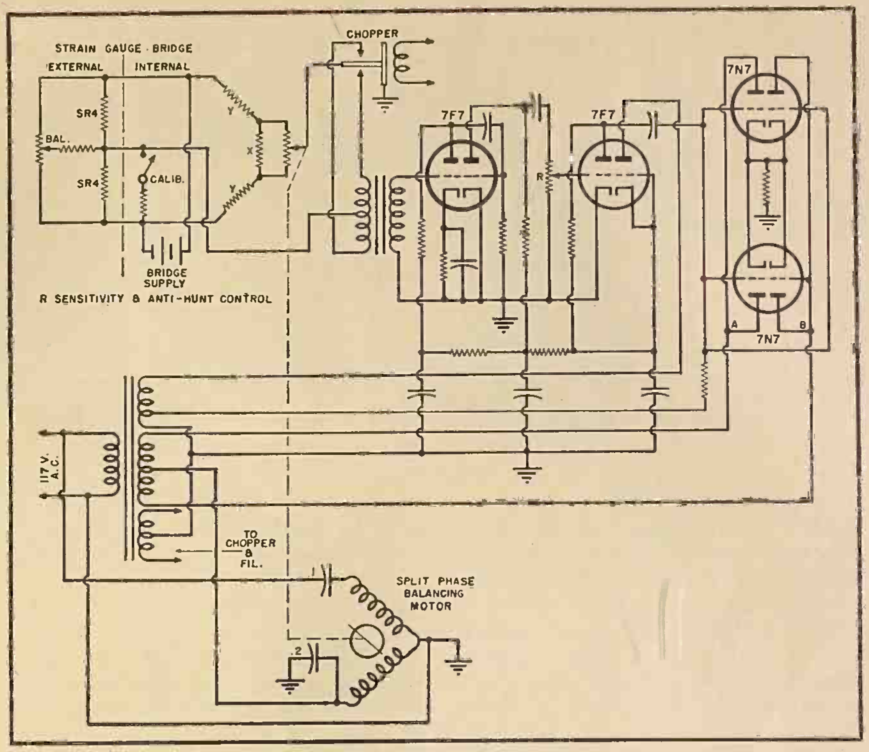


Fig. 1. Circuit diagram of a self-balancing strain gauge potentiometer.

The diagram illustrated is essentially a modified *Brown* recording thermocouple amplifier. Variations have been made of this circuit to allow indication of fuel quantity (via capacity variation of tank capacitor) and for the control of d.c. and a.c. currents through relays or motor manipulation, but these applications are all beyond the scope of this article.

The design of the amplifier must be such as to maintain a negligible phase shift in the a.c. amplifier section of the unit to insure that the signal applied to the power tubes' grids is exactly in or out of phase with the tubes' a.c. plate potential. If this is not accomplished, poor efficiency and operation will occur.

With the high gain used in these typical automatic balancing amplifiers, input lead resistance variations up to

Low level d.c. synchronous chopper. Amplifier input leads enter through top to minimize a.c. pickup.

A commercial synchronous chopper such as might be used in strain gauge and thermocouple recorders.

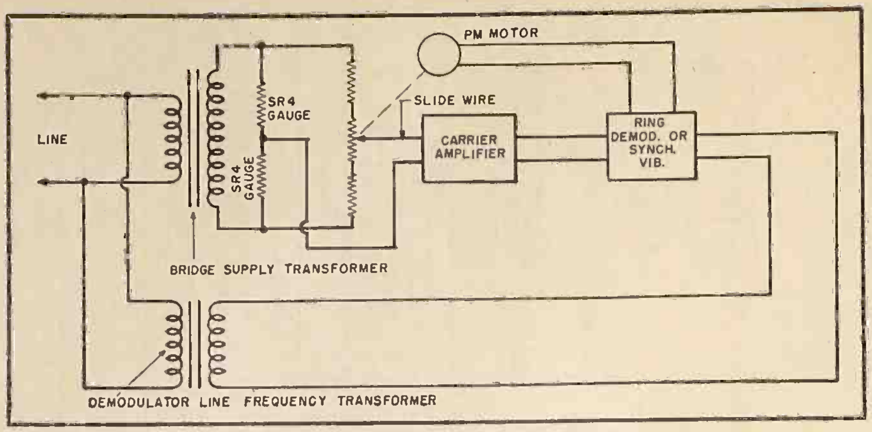
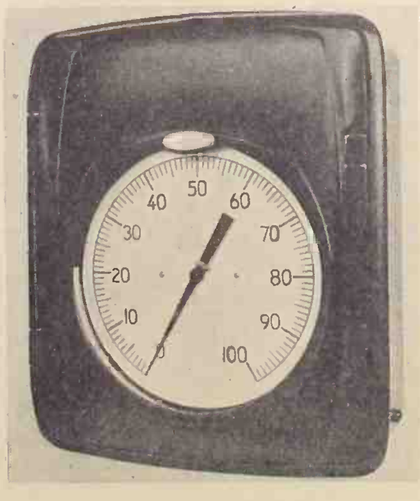


Fig. 2. Basic block diagram of an experimental self-balancing bridge.

several thousand ohms is acceptable and will not cause any error in indication. Gain variation in the amplifier is likewise no problem, both of these variations causing little or no indication. The reason for this is apparent when it is remembered that the unbalance signal is balanced out to zero signal current and voltage, and that the amplifier has so much gain it is normally saturated or overloaded in the signal amplification section of the unit. As long as sufficient signal exists to cause the amplifier to operate the balancing motor, then accurate indication will result. Where the signal level is too low, there will be insufficient output from the amplifier and the motor will not operate.

An interesting query may occur to some readers. If the d.c. signal is turned into an a.c. signal, why not eliminate the chopper and supply line frequency a.c. directly to the bridge. Any voltage variation in this supply would not matter as the circuit is of the null balancing type. As a matter of fact, this can be done successfully, if certain limiting factors are kept in mind. With a.c. on the bridge, capacitive balance as well as resistive is required if a true null is to be reached. As the amplifier output is phase conscious, normally the capacitive signal being of the wrong phase would cause no motor operation and could be ignored. Unfortunately, the amplifier cannot handle large capacitive signals and the resistive signal at the same time without overloading and causing an erroneous indication. Where the capacitive signal is small, by proper selection of shielded cables, or possibly where a signal channel is to be recorded, then capacity balance need not be employed. Experience, however, for multichannel installation has shown that the d.c. system is preferable, requiring neither capacitive balancing or shielded wires (which have a tendency to load down the a.c. power supply excessively).

Typical dial face for a non-recording type of strain indicator.



A possible variation in self-balancing automatic equipment is the use of a phase sensitive circuit employing a ring demodulator and permanent magnet motor (with brake) as the follow-up for balancing the bridge. Basically the design is similar to that employed in the previously discussed circuit, with one major exception. The amplified a.c. signal is fed into a copper oxide ring demodulator or mechanical synchronous vibrator which acts as a phase sensing and rectification device which delivers a d.c. output current whose amplitude and polarity depends upon the phase of the input signal to the amplifier. The mechanical synchronous rectifier can be used in place of the ring demodulator only where the carrier frequency (or bridge supply) is within the range of frequency operation of commercially available units, manufactured to operate synchronously with line frequency. As with the previously discussed unit, a.c. line frequency (or from an oscillator) may be applied to the bridge directly, taking into account the same capacity balancing limitations. Some amplifiers have been built to handle both the capacitive and resistive bridge signals without overloading and these will work successfully with this phase sensitive output design. The d.c. output is supplied to a small high speed geared down motor, which with its permanent magnetic field (or armature) will rotate in a direction depending upon the polarity of the applied d.c. potential. A built-in brake on the high-speed shaft locks to prevent hunting or overshoot as the bridge passes through balance and the drive signal drops to zero.

With all such automatic equipment, the balancing motor operates at high rpm (1800-3600) and is geared down to a shaft speed of 50 to 95 rpm which is further reduced by gears or cables and pulleys to turn the recording disc or move the slide-wire from one end to the other in approximately five seconds. Where paper recording is used, the paper drive speed is coordinated with the printing speed to allow the highest possible desired recording speed.

Modification of the designs presented have been made to allow manual or automatic extension of the recording range, as required. Resistor X (Fig. 1) or YY may be changed in value by a selector switch or stepping switch to allow expansion of the strain scale. It is imperative to maintain low switch contact resistances or the scale indication will be in error. For this reason hermetically sealed *Western Electric* capsule switches are used in many designs. These capsule single-pole switches are actuated through an external coil and its resultant magnetic field.

For automatic operation, microswitches are placed at the low and high end of the scale. When the strain is such that the scale pointer goes off scale on the high end it strikes a microswitch which operates a latching relay which switches in the required scale control resistor, and the pointer comes down scale to an indication. One of the latching relay contacts turns on a warning light to indicate that the instrument is on the high scale. When the input signal drops below the value of the low end of the high scale, the pointer moving off scale on the low end actuates the microswitch at that end, unlatching the relay and returning the unit to its normal scale, then the pointer goes upscale to the proper indication.

A similar circuit to this has been used on thermocouple recording instruments, and has been found to be highly satisfactory in both of these applications.

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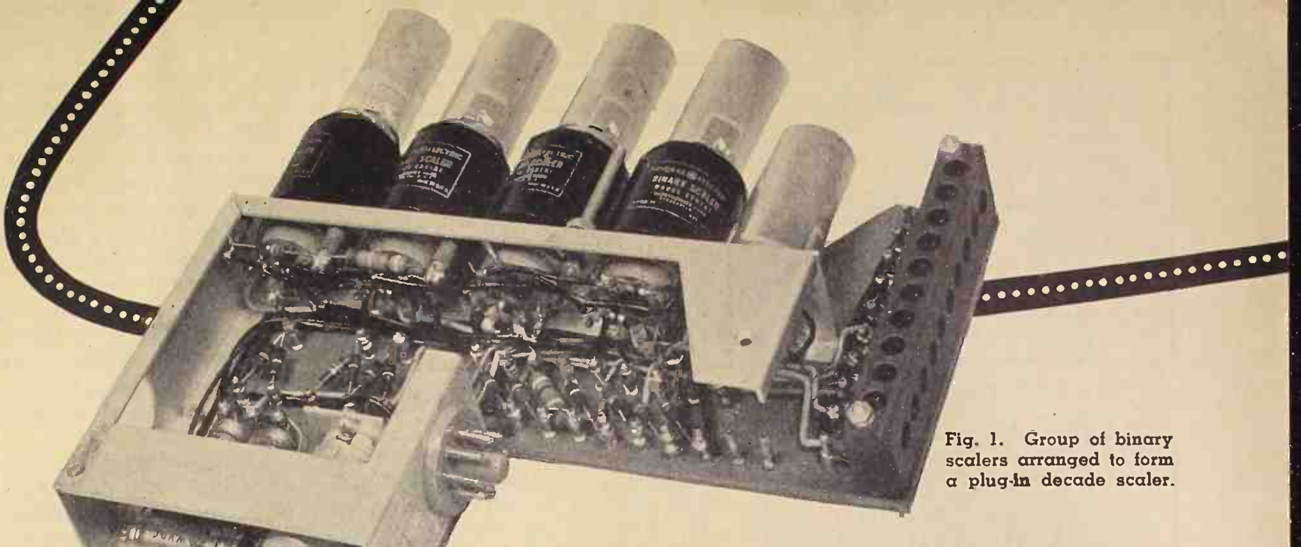

Fig. 1. Group of binary scalers arranged to form a plug-in decade scaler.

The Versatile BINARY SCALER

By
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Design considerations, indication, and scale-of-ten operation of the binary scaler, a basic scaling unit.

THE International Auto-Alarm Signal is composed of twelve dashes transmitted in one minute. Each dash is four seconds long and the interval between dashes is one second. It is the prelude to a distress message, following within two minutes. All radio stations of the maritime mobile service are required to be alert for this signal on 500 kc., twice every hour for three minutes, beginning 15 and 45 minutes after the hour. Happily, traffic is slow on this wavelength but when it comes the radio operator must receive it.

No doubt an electronic device is required enabling a radio operator to handle traffic on other frequencies, while being informed whenever the International Auto-Alarm is heard. With the ringing of a signal, he would monitor the distress wave, 500 kc., and note the actual message. A binary scaler has been successfully used to keep this faithful vigil.

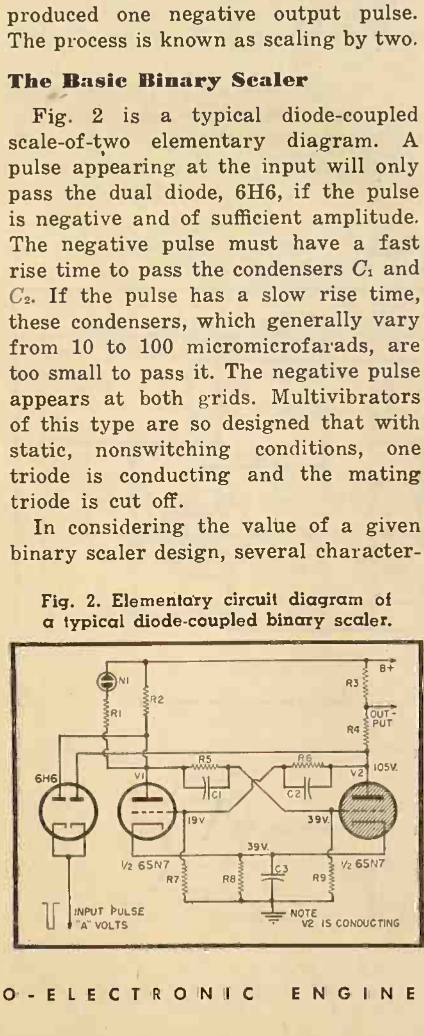
A binary scaler generally involves a pair of triodes or pentodes plus the necessary components to make an oscillator with feedback from each plate to the other grid. The binary scaler, or bistable multivibrator, as the name implies, may be triggered into two entirely stable positions. This property is such that if a proper trigger is applied to the binary scaler the first stable position is obtained. A second trigger creates the second unique stable position, completing one cycle of binary operation. Thus for two input pulses the bistable multivibrator has gone through only one cycle. Differentiating through an *RC* network will produce a negative and a positive pulse. If the bistable multivibrator is so designed, it will trigger only with negative pulses. For two negative input pulses we have produced one negative output pulse. The process is known as scaling by two.

The Basic Binary Scaler

Fig. 2 is a typical diode-coupled scale-of-two elementary diagram. A pulse appearing at the input will only pass the dual diode, 6H6, if the pulse is negative and of sufficient amplitude. The negative pulse must have a fast rise time to pass the condensers C_1 and C_2. If the pulse has a slow rise time, these condensers, which generally vary from 10 to 100 micromicrofarads, are too small to pass it. The negative pulse appears at both grids. Multivibrators of this type are so designed that with static, nonswitching conditions, one triode is conducting and the mating triode is cut off.

In considering the value of a given binary scaler design, several characteristics are desirable. In order to achieve them, some essential compromises present themselves.

Fig. 2. Elementary circuit diagram of a typical diode-coupled binary scaler.



Ideally, a binary scaler should tally every count received. However, in the process of storing extremely rapidly occurring pulses, other pulses may be lost.

It has been felt in the art that a speed of 200,000 cycles per second will handle 90% of the possible applications without losing a significant per-cent. The time required to swing from one tube conducting to the mating tube conducting depends on the rise time of the pulse appearing at the grid of the cut-off tube. Once the tubes have reversed their states, the recovery time of the cut-off grid, which is about 90 volts beyond cut-off in Fig. 2, becomes a limitation. Fast switching is accomplished by choosing (1) sharp driving pulses, (2) high g_m tubes, (3) large plate currents with small plate resistors, (4) reducing plate-to-grid, plate-to-ground and grid-to-ground capacities, and (5) limiting grid and plate excursions.

Secondly, output characteristics are important. The ability to drive succeeding binary scaler stages without intermediate amplifiers is very desirable. The driving impedance, output rise time and output amplitude must be selected. A 50 volt output pulse with two microsecond rise time is adequate to drive the succeeding stages shown in Fig. 2.

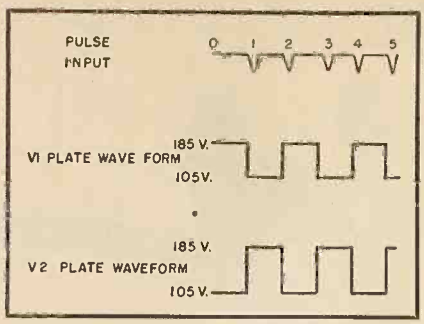


Fig. 3. Binary scaler waveforms.

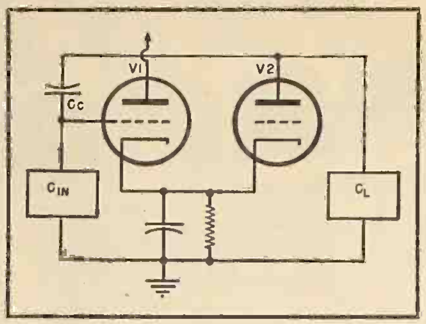


Fig. 4. Effect of distributed capacity.

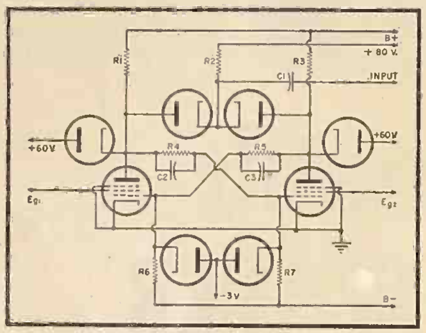


Fig. 5. High speed scale-of-two counter.

An output characteristic, rarely mentioned in the literature, is the amount of plate-to-ground capacity necessary to upset the binary scaler's positive feedback. In order to swing from one tube conducting to the mating tube conducting, sufficient voltage must be present at the cut-off grid to begin the switch. Additional load capacity, C_L, Fig. 4, in parallel with the rising plate potential serves to reduce the effective signal appearing across C_{IN}, the input capacity of V_1 grid. The greater the load capacity, C_L, the less signal voltage is available to perform switching.

The limiting load capacity is that amount which just keeps the binary scaler from operating. Using a cathode-ray oscilloscope without decoupling the pickup lead may exceed the critical load capacity. Some schemes of feedback present the body capacity to ground of the feedback components which can approach the critical load capacity.

Design Considerations

Multivibrators are divisible into two groups, (a) the standard multivibrators operating to about 0.5 megacycle, and (b) those that operate to 10 megacycles.

Both groups require circuits that are readily analyzed by the figure of merit for sharp waveforms, $g_m^2/C_1 C_2$. C_1 and C_2 are input and output capacities of the stage respectively, g_m being the transconductance of the tube being considered at the actual operating point. It is obvious that a pentode generally has a greater g_m and the input capacity is less due to the absence of Miller effect. Miniature tubes are preferred to the standard series due to smaller distributed capacities. For these reasons, a miniature pentode is a better performer than a triode. However, other considerations are present, as will be shown later.

A small plate resistor will reduce switching time due to the smaller value of the time constant involved. The coupling condensers, C_1 and C_2 of Fig. 2, should be as small as possible for the same reason.

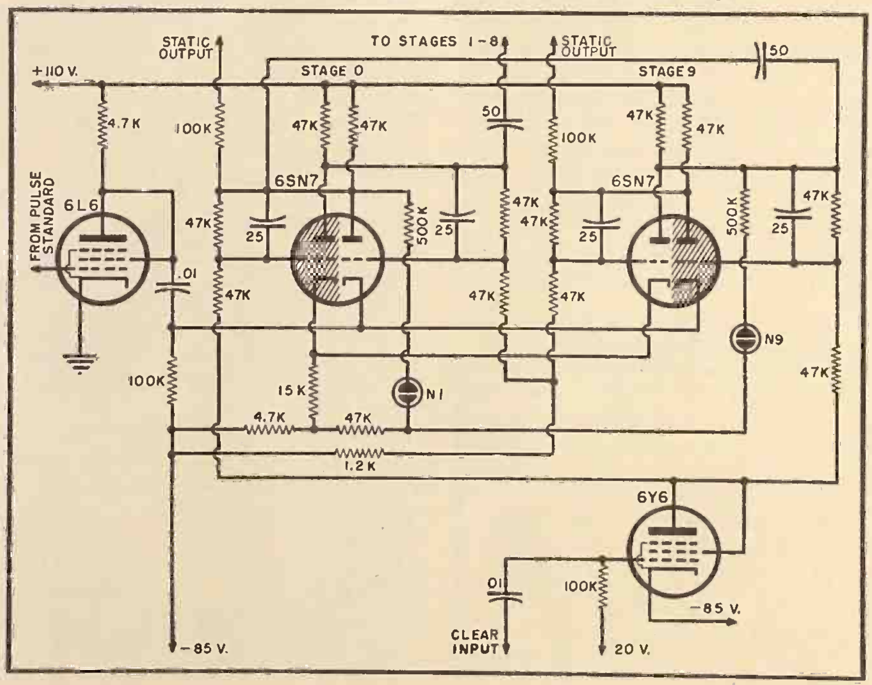
The most significant improvement in high speed operation is to limit both plate and grid swing. The cut-off grid is about 90 volts beyond cut-off for the circuit of Fig. 2. By having the grid returned to —3v. as shown in Fig. 5, the maximum negative grid value is —3 while the maximum positive is 0. The plate swing is limited to +80 and +60 volts. Pentodes are used to insure high g_m and low distributed capacity. C_2 and C_3 are extremely small to keep $R_5 C_3$ and $R_4 C_2$ small.

It was indicated that the figure of merit for fast waveform generation marks the pentode as a very desirable scaler tube. Factors which may outweigh this desirability in a particular design are smaller plate current requirements of triodes and a factor of two saving in envelopes. One pentode binary scaler requires two envelopes, while a triode binary scaler requires one twin triode envelope.

Several miniature twin triodes finding wide scaler utilization are listed in Table I. The 2C51 is a long life tube having very small input and output capacities. It can be operated at a higher frequency than any of the other tubes and has a life expectancy of about 15,000 hours. The 12AT7 is a high transconductance tube with excellent performance characteristics. The amplification factor of 55 with E_p 250 volts and I_b 10 milliamperes is the best in Table I. The 12AU7 and its older prototype 6SN7 are found in perhaps more scaler circuits than any other tube. The 12BH7 is a newly introduced tube that has been successfully used in computer multivibrator circuits and computer blocking oscillator applications, thereby reducing tube types required for computer maintenance. The maximum peak positive pulse plate potential, 1500 volts, is unusual. Considering the fairly high transconductance in addition, the 12BH7 should find general multivibrator acceptance.

Both the 5670 and 5814 are ruggedized tubes developed under the *Aeronautical Radio, Inc.* program. These are 2C51 and 12AU7 prototypes redesigned with additional supports, thicker

Fig. 6. Decade ring counter. Shading indicates conduction. Stages 1-8 identical to stage 0, but right triode conducting as in stage 9.



top mica and revised heater structure. Each tube undergoes a 50 hour break-in period and passes strict quality control to assure dependable performance aboard aircraft, where a tube failure in blind landing or radio is a serious failure. The result has been a 10 to 1 reduction in commercial airline tube failures.

The 5963 has been designed as a computer type tube. It is essentially a selected 12AU7 guaranteed to pass no more than 20 microamperes with a plate voltage of 150 and grid bias at -15 volts. A premium pure tungsten heater is added to give a markedly longer life than the usual receiving tubes. The cathode is described as passive. It is claimed that with a passive cathode the 5963 will maintain its emission capabilities after one side is cut off for extremely long periods. A phenomenon known among equipment designers as "sleeping sickness" has been mainfested by no plate current flow after driving the grid definitely to a conducting region after cut-off periods. The passive cathode has been suggested as a method of solving "sleeping sickness."

Given an extremely compact binary scaler as shown in Fig. 7, the problems of insuring reproducible results, freedom from effects of shock and hermetic sealing become acute. Upon operating on an average summer's day with humidity at about 80%, considerable "breathing" (drawing in of moisture) will occur after shutting off the binary scaler. The binary scaler has a shortened life. Vibration and changes in over-all performance result due to proximity of the leads. Sealing in an appropriate dielectric is the most desirable solution.

Most attractive of the available dielectrics are certain polymers. These molecules like styrene, methyl methacrylate (Lucite, Plexiglass), polyester resins and EPON resins are capable of forming long chain molecules by hooking onto each other or to some intermediate molecule which is added just as potting is begun. There are many practical catalysts and accelerators which are added to the various embedding materials and cause the hardening and subsequent curing within a few days at, or close to, room temperature.

Using *Emerson and Cuming Co.* resin 40 in an assembly the size of the binary scaler shown in Fig. 7 requires six hours at 60°C which is entirely harmless to the electronic components involved. Most applications have different potting procedures since polymerization depends on the size of unit being cast, speed of pouring and permissible curing cycles.

In the interest of dependable performance over long periods of time and wide temperature ranges, the JAN or RMA specifications are best followed. Good quality composition resistors conservatively used are satisfactory for the exacting requirements of a multivibrator, without depending on the larger wire-wound resistors. Some designers of large quantity binary scalers require matched pairs of resistors in mating symmetrical circuits, (*i.e.*, R_5 and R_6 in Fig. 2) accurate within 2½%, to assure reliable operation. On the other hand, circuits operating from −20°C to +70°C over a 115 to 270 volt d.c. supply range have been built in large quantities using 5% resistors.

Physically small components reduce high frequency loss due to stray capacity to ground. A potted circuit similar to Fig. 7 employed two 15 μμfd. ceramic condensers with an input sensitivity of 20 volts. The ceramic condenser was insulated by a steatite sleeve and moisture sealed by a wax. An improvement of 20% was realized by using the same value ceramic condenser, but employing a condenser design which depended on only wax coating for insulation in lieu of the large steatite sleeve construction. The difference in projected area was about 20%.

Sealing and Indication

Scales of Ten

The binary scaler connected in series without additional circuitry will divide input pulses by 2. For n binary scalers this is a scaling factor of 2 x 2 x 2 . . . ., n times or 2^n. The resultant scaling factors are not based on the decimal but on the binary system and are definitely awkward to read, especially for inexperienced and nontechnical personnel. The most obvious modification of a series of binary scalers is to make it a scale of ten or a decade scaler. Scales of other than 10 and 2^n are possible and have been used.

Three basic methods of altering the count are by feedback, ring counting, and diode gating.

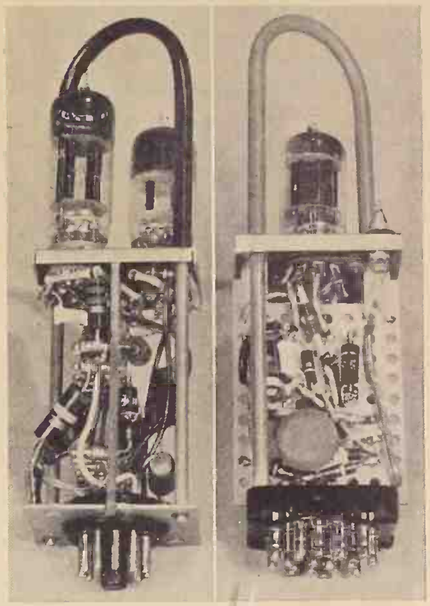


Fig. 7. Binary scalers—computer type. Left one has cathode follower, right one has Ne-2 neon indicator.

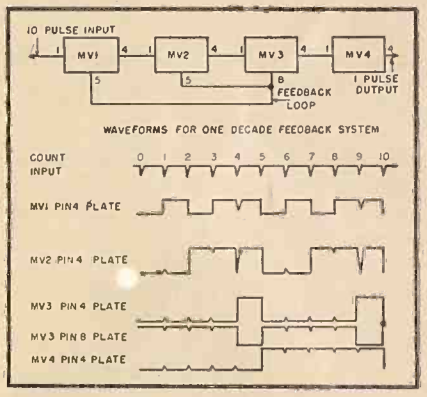


Fig. 8. One feedback system which may be used for scale-of-ten operation.

1. *Decade feedback.* This method consists of scaling the output of four successive binary scalers by two. The scaling factor is 2 x 2 x 2 x 2 = 16. By taking six counts from the third binary

Table 1. Miniature twin triodes for binary scaler service—as of Jan. 1, 1951.

Tube Type	JAN Approval	Amplification	Transconductance	I_b (E_p=90v.) (E_c= 2v.)	E_{co} (E_p=210v.)	Passive Cathode	A.R. Inc. Type	Historical Prototype
2C51	Yes	35 (E_b=150v., I_b=8.2 ma.)	5500	0.5	−6.5	No	No	7F8
12AT7	Yes	55 (E_b=250v., I_b=10)	5500	0.5	−3.5	No	No	
12AU7	Yes	17 (E_b=250v., I_b=10.5)	2200	7.5	−16	No	No	6SN7
12BH7	No	17 (E_b=250v., I_b=11.5)	3100	16	−13	No	No	
5670	No	35 (E_b=150v., I_b=8.2)	5500	0.5	−6.5	No	Yes	2C51
5814	No	17 (E_b=250v., I_b=10.5)	2200	7.5	−16	No	Yes	12AU7
5963	No	22 (E_b=67v., I_b=7)	2800	5	−17	Yes	No	12AU7

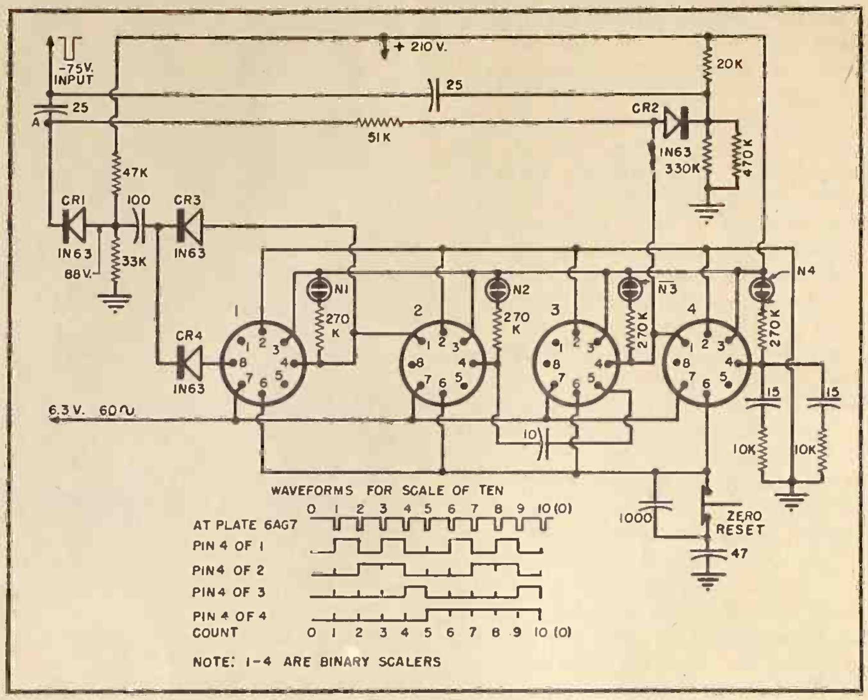


Fig. 9. A diode-gated decade for scale-of-ten operation.

scaler and feeding them back to the first and second binary scalers, the net total out is ten.

Fig. 8 illustrates one feedback system for a scale of ten. Triggering, as has been described, from MV_1 to MV_2 is dependent on the reception of a negative trigger. MV_3 and MV_4, in similar manner, depend on a negative trigger from the immediately preceding stage.

The scaling-counting sequence is entirely on a binary scaling basis for counts 0, 1, 2, and 3 with all pulses coming from the input for MV_1 and from the preceding binary scaler for MV_2. Fig. 8 is identical with Fig. 3 for these counts.

At the count of 4, MV_1 actually begins to flip as is shown by the negative spike in plate waveform for MV_1, count 4. This triggers MV_2 and MV_2, in turn, triggers MV_3. The waveform at pin 8 of MV_3 shows a negative swing, which is differentiated by the feedback loop. The resultant pulses cut off MV_1 and MV_2, arresting the process which was beginning in those binary scalers. As shown, the plate waveforms for count 4 effectively introduce one count at MV_1 and three counts at MV_2 due to the pulse fed back from MV_3. This occurs a second time at the count of nine. Six false, internal counts are thereby introduced for ten true input counts. The four binary scalers are still a scale of sixteen but require only ten true input counts per one output count.

2. *Decade Ring Counter.* An entirely different decade scaler, known as a decade ring counter, was used in ENIAC. This ring counter requires twelve tubes to the four required by the decade feedback system. Other features are present in this ring counter; the preceding decade feedback system is not as versatile.

Fig. 6, the ring counter, contains ten twin triodes, one for each decimal digit. The right hand halves of stage 1 to stage 9 are initially conducting with the left hand half of stage 0 conducting. Initial zeroing is effected by a negative pulse to the "Clear Input" 6Y6. The composite plate resistor of this tube consists of the ten grid resistors. With the tube cut off these grids go positive, making the desired halves conducting. The 6L6 serves as a buffer amplifier and phase inverter that cathode triggers the right-hand halves of each 6SN7. The negative cathode pulse drops all cathodes with respect to their grids. All right-hand tubes are conducting but stage 0. The right-hand side of this stage begins to conduct. The 25 μμfd. plate-to-grid condenser shuts off the left-hand side of stage 0 with a consequent rise in plate potential. This rise is coupled by the 25 μμfd. "between stage" condenser to make the left-hand side of stage 1 conduct. The plate potential drop at the left-hand side of stage 1 shuts off the right-hand side of stage 1. In this manner one count has been added. Switching of the ninth stage would register the completion of ten input pulses.

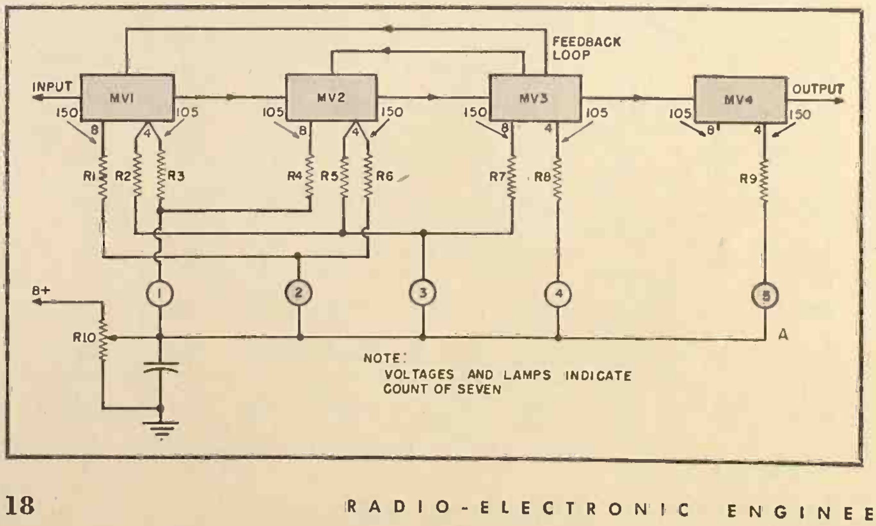
3. *Diode Gating Decade.* The "decade feedback" system is limited to a lower speed of operation than a straight binary circuit. This scale of ten depends on a pulse being passed through three binary scalers and then fed back to the first two binary scalers in the chain. A considerable delay is caused by the switching of three binary scalers followed by an additional delay through the feedback circuit. Temperature variations have an effect on pulse rise time and amplitude. MV_3 of Fig. 8 is especially sensitive to distributed capacity.

The diode gated decade circuit of Fig. 9 does not depend on a pulse race at the count of 4 and 9 for operation. The circuit shown has operated from 120 to 270 volts plate supply emphasizing the freedom from exacting operational conditions. The maximum speed of a diode gated decade is, ideally, the speed of a binary scaler. This is true since no input binary scaler is dependent on additional binary scaler switching time or feedback time. Due to the increased capacity of the gating circuit, actual decade speed is not the same as for one binary scaler.

The diode-gated decade, Fig. 9, depends on two principles: (1) The binary scaler will give one negative pulse at the following grid for every two to the input, and (2) The binary

(Continued on page 30)

Fig. 10. Elementary circuit diagram of the bi-quinary system.



VARIABLE-FREQUENCY CLOCK-PULSE GENERATOR

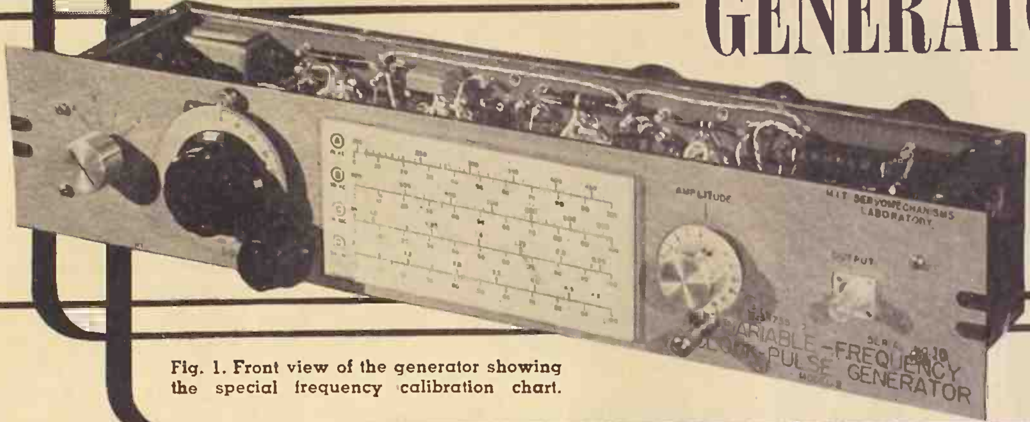


Fig. 1. Front view of the generator showing the special frequency calibration chart.

By ROBERT R. RATHBONE
Massachusetts Institute of Technology

A highly stable oscillator for providing 0.1 microsecond pulses at a PRF of 0.2 to 4.9 mc.

THE usual method of transmitting intelligence in a large-scale system of pulsed circuits is to supply a signal pulse on a particular line at a specified time. To test such a system, external equipment is needed which will generate, route, delay, gate, store, shape, and measure pulses. The Electronic Computer Division of Servomechanisms Laboratory, Massachusetts Institute of Technology, under the sponsorship of the Office of Naval Research, has developed a new line of test units for all these operations.

This equipment is designed to operate with positive, 0.1-microsecond, half-sine-wave pulses and a minimum pulse period of 0.5 microsecond. Most of the units have a pulse-shaping circuit to insure that output pulses are uniform. Each contains an average of 6 vacuum tubes, may be mounted on a 19-inch relay rack, and performs some basic function of a pulsed circuit. A standard input and output impedance of 93 ohms permits interconnecting the units as basic building blocks for a large variety of pulsed systems.

Clock-Pulse Generator

The variable-frequency clock-pulse generator is a primary pulse source for test setups of gate tubes, flip-flops, matrices, bus drivers, line drivers, and other components of pulsed circuits. It is also a basic building block for complete systems and special tests. Model 2, shown in Fig. 1, was designed to provide a simple, compact clock-pulse generator for general laboratory use.

The generator provides output pulses 0.1 μsec. long at a 93-ohm impedance level, with pulse-repetition frequencies variable from 0.2 to 4.9 megacycles. Frequency stability is 20 parts in 1,000,000. The amplitude of the output pulse also can be varied from 0 to 40 volts at low frequencies and from 0 to 35 volts at high frequencies. The output control is linear.

The unit is constructed on a panel and chassis for standard 19-inch rack mounting. All controls are located on the front panel (Fig. 1). From left to right these controls are: frequency band switch, prf control, and amplitude control. The chassis measures 3 x 4½ x 17 inches and is completely shielded. All tubes are mounted on the rear; their positions are shown in Fig. 2.

Power for the unit is obtained from a central laboratory power supply and connects into the chassis through a *Jones* 400-series 6-pin plug (Fig. 2). The voltages and currents used are +250 v. d.c., 130 ma., −150 v. d.c., 1.3 ma., 6.3 v. a.c. 3.05 amp.

Editor's Note: This article is the first in a series describing the special pulsed-circuit test equipment recently developed at the Servomechanisms Laboratory, M.I.T., under the sponsorship of the Office of Naval Research. The equipment was built for the purpose of testing an electronic digital computer, but the units are sufficiently flexible in design to be valuable laboratory tools for general pulsed-circuit testing.

A calibration chart is located in the center of the front panel for calibrating the four frequency bands. These frequency bands, designated "A", "B", "C", and "D", are overlapping and range as follows:

Band A—200 to 450 kc.
Band B—420 to 980 kc.
Band C—0.8 to 2.25 mc.
Band D—2.2 to 4.9 mc.

The circuit of the variable-frequency clock-pulse generator employs a cathode-coupled oscillator, an inverter, an *R-L-C* peaker, and a buffer amplifier.

As noted in Fig. 4, the oscillator uses a 6SN7 double triode in a cathode-coupled circuit. One half of the tube is connected as a cathode follower which drives the second half as a grounded-grid amplifier. The output of this stage is fed back to the tuned circuit.

Each coil which controls oscillation within a given frequency band has only two connections. Use of the cathode-coupled oscillator permits standard commercial coils to be utilized.

The variable-frequency sine waves from the oscillator are fed to the *R-L-C* peaker through a 6AG7 inverter V_2 (Fig. 4). The control gird of this tube is biased negatively by the clamping action of grid resistor R_4. All but the tops of the excitation waves are cut off, and current flows in the plate circuit only during that part of the cycle when the tops of the sine waves are applied to the grid. The portion of the sine wave between the maximum positive amplitude and cut-off bias is inverted.

When the 1200-ohm resistor R_6 is conducting, the plate voltage drops approx-

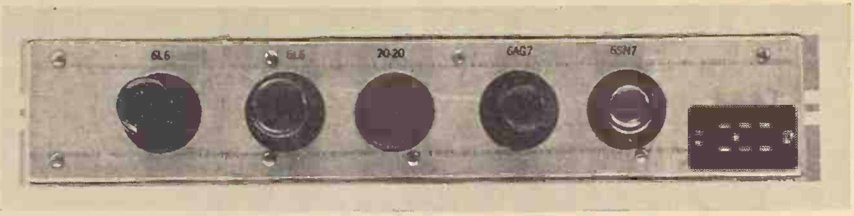


Fig. 2. Rear view showing tubes and power plug.

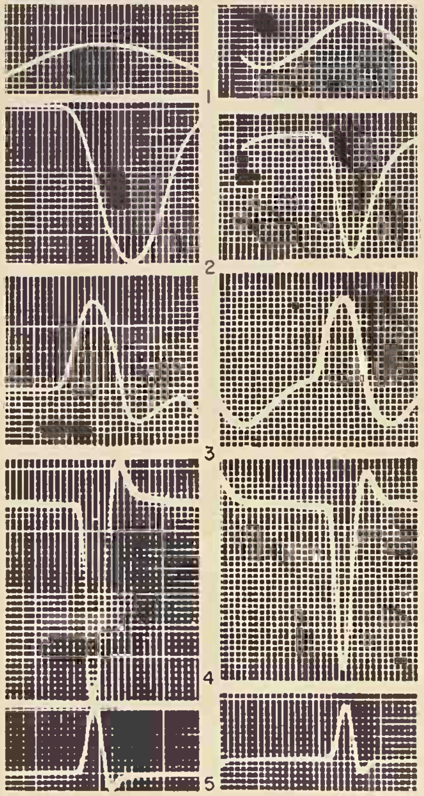


Fig. 3. Waveforms at various test points. Pulse repetition frequency in the left column, 1 mc.; right column, 2 mc. (1) Grid of inverter. (2) Plate of inverter. (3) Plate of peaker. (4) Plate of buffer. (5) Output. 10 horizontal spaces=0.2 microsec., 10 vertical spaces=45 volts.

imately 30 volts. When conduction ceases, the tendency of the plate voltage to ring is checked by the crystal CR_1. This damping enables the plate voltage to be kept at near normal potential.

Two advantages of the inverter are:

1. It provides a slow rise time on the positive-going edge, which tends to minimize extraneous ringing at the *R-L-C* peaker.
2. It supplies a favorable duty factor for the *R-L-C* peaker, thus giving more time for recovery between pulses.

The 6L6 *R-L-C* peaker V_3 is normally on. The arrival of the negative peaks from the inverter cuts the tube off. As cut-off occurs rapidly, the plate current charges the capacity of the peaker, which in turn discharges into the inductance and sets up oscillation with a natural period dependent on the values of L and C.

As we are interested only in the first positive half-cycle of the oscillations, the crystal rectifiers CR_2 and CR_3 are so arranged that as soon as the plate voltage drops below B+ the crystals conduct and further oscillation is damped out. No more oscillations can be generated until the peaker plate current is turned on by the inverter.

Test point 3 of Fig. 3 shows the output of the peaker. Notice that both pulses have approximately the same amplitude and length.

The buffer amplifier is used in the output stage mainly as a power amplifier to enable the output pulse to be used with a 93-ohm terminated cable.

The 0.1-megohm potentiometer R_{11} used to control the tube bias acts as the amplitude control of the output pulses.

The output transformer T_1 inverts the pulse from the plate, terminal 4 going to ground and providing positive pulses at J_1. *This transformer must see a 93-ohm output impedance, either as a resistor or a terminated coaxial cable.*

Test point 4 in Fig. 3 gives the waveform at the plate of the buffer; test point 5, the positive output pulse. The scope pictures were taken with the amplitude control fully on for both frequencies.

As there are only three panel controls for the unit, operation is simple. The first step after power is supplied to the unit is to select the desired frequency band with the band switch on the left-hand side of the front panel. The prf vernier dial is turned to the scale division indicated by the calibration chart for the selected frequency. The amplitude of the output is then controlled by turning the amplitude control knob.

It should be noted that this last control is not calibrated and must be adjusted to the desired voltage with a peak voltmeter or by means of visual indication. If the latter method is used, it is necessary to divide the clock-pulse frequency to one that is low enough to trigger the sweep of a synchroscope. For this purpose, a device like the scope synchronizer, another newly developed piece of test equipment, should be used.

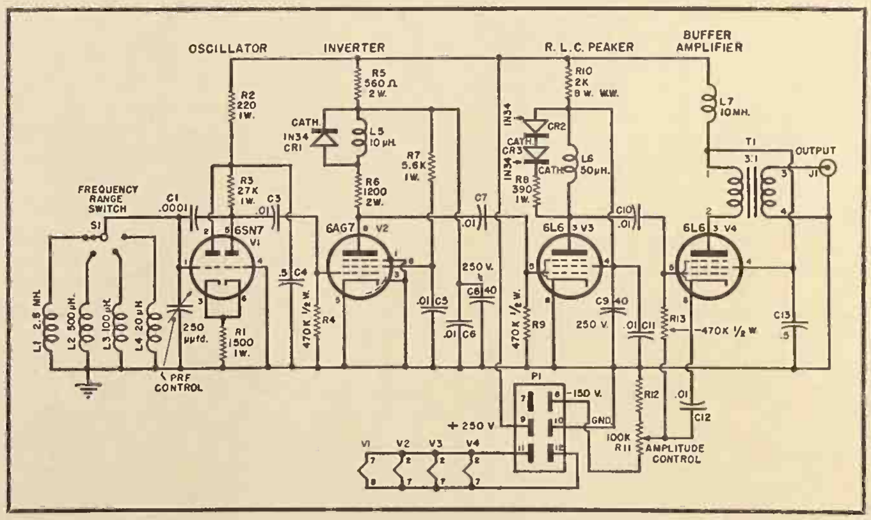
One limitation of this model is that the output voltage is noticeably less at high frequencies than at low frequencies. This difference in amplitude can be traced as a gradual decrease when the operator tunes from low to high frequencies at full amplitude. With the amplitude control half-way on, the output will alternately rise and fall as the frequency is increased. The waveforms at test points 4 and 5 of Fig. 3 illustrate the difference in pulse amplitude at 1 and 2 megacycles. All pictures were taken with the amplitude control fully on.

At low amplitude there is slightly less pulse length than there is at full amplitude. This difference is caused by the bias control in the buffer amplifier cutting the output pulse at different levels.

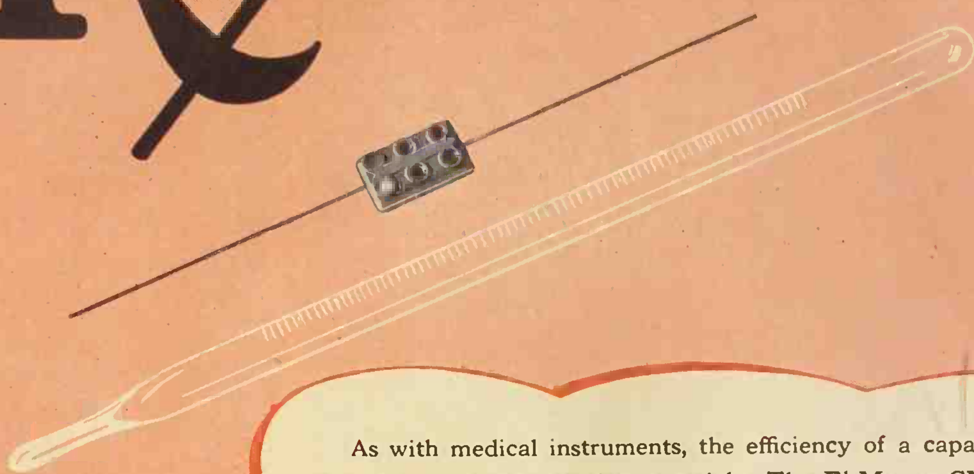
A basic device needed to test pulsed circuits is one which will continuously supply uniform pulses. The variable-frequency clock-pulse generator is designed for this job. It provides positive 0.1-μsec. half-sine-wave pulses at a 93-ohm impedance level, with the pulse-repetition frequency continuously variable from 200 kilocycles to 4.9 megacycles.

★

Fig. 4 Circuit diagram of the variable-frequency clock-pulse generator.



R̸ FOR PERFORMANCE



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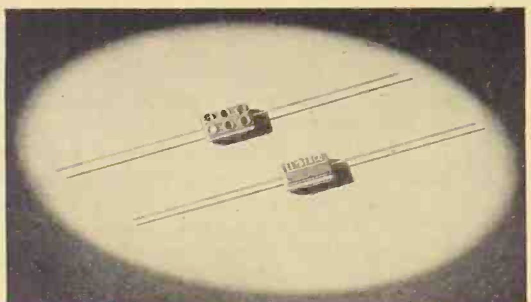

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NEW TUBES

LIGHTHOUSE TUBE

General Electric Tube Divisions now have in production another in the series

of lighthouse tubes used so widely in radar during World War II.

The GL-2C39A is a high-mu triode which can operate at full rating up to frequencies as high as 2500 megacycles. The maximum d.c. plate voltage is 1000 volts and the dissipation is 100 watts.

This tube can also be used in radio communications and other military equipments. Its non-military applications include aircraft traffic and location controls, broadcast relay equipment, microwave test apparatus, and utility telemetering and communications systems.

Further information on the GL-2C39A may be obtained direct from the *GE* Tube Divisions, Schenectady, New York.

POWER TRIODE

A 25 kw. power triode for use in high-powered TV and FM broadcast-

ing, cyclotron or synchroton oscillators, and industrial h.f. heating equipment has been developed by *Federal Telephone and Radio Corporation*, Clifton, New Jersey.

Designated as the F-5512, the tube operates in the 88 to 108 megacycle range. The anode is fabricated from oxygen-free, high-conductivity, heavy-wall copper to allow uniform heat distribution and high dissipation. A water flow of 7 GPM is necessary to cool the anode, and low-pressure air is required on the filament stem to limit maximum glass temperature to 150°C. The F-5512 is supplied with an integral water jacket for quick replacement of tube.

Maximum ratings of the new tube are: d.c. plate voltage 9000 volts, d.c. plate current 10 amperes, and plate dissipation 25 kilowatts. The filament current is 435 amperes at 6.2 volts.

RCA TUBES

Picture Tube

The 17BP4-A announced by the Tube Department of the *Radio Corporation of America*, Harrison, New Jersey, is a short, directly viewed rectangular picture tube having a picture area 14⅜" x 11 1/16".

The design of this tube incorporates

a high-efficiency, white fluorescent screen on a face made of Filterglass; employs magnetic focus and magnetic deflection; has a built-in capacitor formed by the internal and external conductive coatings to serve as a supplementary filter capacitor for the high-voltage supply; and utilizes an ion-trap gun requiring only a single-field external magnet.

The 17BP4-A has a diagonal deflection angle of 70° and a horizonal deflection angle of 65°.

Converter

The *RCA* 6X8 is a 9-pin miniature type containing a medium-mu triode and a sharp-cutoff pentode designed especially for use as a combined oscillator and mixer tube in television receivers utilizing an intermediate frequency in the order of 40 megacycles per second.

In such service, a single 6X8 is reported to give converter performance comparable to that obtainable with a 6AG5 as mixer and one unit of a 6J6 as oscillator. The pentode unit may be

used in the AM section as a pentode mixer to provide high gain, and in the FM section either as a pentode mixer or as a triode-connected mixer depending on signal-to-noise considerations.

The triode unit of the 6X8 can be used as an oscillator for either the AM section or the FM section.

Rectangular Kinescope

The first metal-shell rectangular picture tube to be made commercially available is the 17CP4 announced by *RCA*. It is a 17-inch picture tube for TV receivers and has a picture area 14-⅝" x 11".

Employing magnetic focus and magnetic deflection, the 17CP4 features an improved design of funnel-to-neck section which facilitates centering of the yoke on the neck. The diagonal deflection angle is 70° and the horizontal deflection angle is 66°. Other features include short over-all length and an ion-trap gun which requires only a single-field, external magnet.

Cathode-Ray Tube

Another of the tubes recently announced by *RCA* is a five-inch cathode-

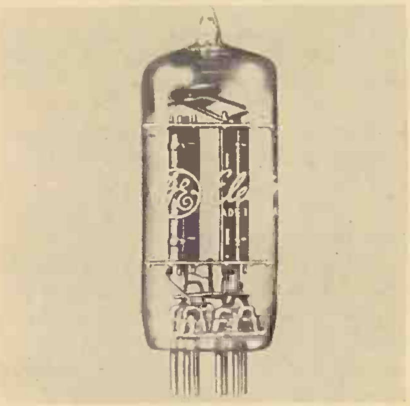
ray tube for use as the flying-spot scanner in a high-quality, video-signal generator.

Superseding the 5WP15, the new 5ZP16 features a metal-backed phosphor to provide a good signal-to-noise ratio and a stable decay characteristic. Other features include a high-resolution gun of the electrostatic-focus type.

An external conductive coating on the neck, when grounded, prevents corona between yoke and neck. A built-in capacitance between interior and exterior neck coatings serves as a supplementary filter capacitor for the high-voltage power supply; and an external insulating coating on the bulb cone minimizes sparking over the surface of the glass bulb under conditions of high humidity.

COMPUTER TUBE

Designed for use in moderately high-speed digital computers, the GL-5844 announced by the *General Electric* Tube



Divisions of Schenectady, N. Y., directly replaces the type 6J6 and requires one-third less heater power.

This twin triode is expected to be widely used in "flip-flop" service in binary-system calculators. Plate output at zero-bias conditions exceeds that of the 6J6 because of higher perveance. Of particular interest is the fact that the cut-off voltage between triodes balances within one-volt limit. The GL-5844 requires only 300 milliamperes heater current.

TRIODE

Federal Telephone and Radio Corporation, Clifton, N. J., has designed a 200 kw. triode suitable for use as a radio-frequency amplifier, oscillator, or Class B modulator.

This three-electrode tube, the F-5918, is water-cooled and capable of dissipating 60 kilowatts in continuous commercial service and weighs approximately 25 pounds. Kovar glass-to-metal seals are used throughout and the specially treated grid is capable of high heat dissipation.

Incorporating a multi-strand filament of thoriated tungsten, it is reported that this feature permits hairpins to expand individually and tends to eliminate stresses that might cause filament warping.

NEW PRODUCTS

POWER SUPPLY

Pedersen Electronics, Lafayette, California, has announced a Model 300 regu-

lated power supply featuring unusually close voltage regulation.

Four outputs are provided with this model. Output #1 supplies 250 to 320 volts at 0 to 300 ma., with regulation better than .07% with load, .02% with line. Outputs #2 and #3 supply either 105 or 150 volts, 0 to 30 ma., VR tube regulated. Output #4 supplies 6.3 volts a.c., center-tapped, at 0 to 6 amps. Input is 105 to 125 volts, 60 cycles, 500 watts. Source impedance on output #1 is less than 1 ohm d.c. to 40 kc., rising to 3 ohms at 100 kc., and can work into any load without loss of stability.

The unit is supplied with a 0-350 voltmeter and a 0-300 milliammeter, and is available in either standard relay-rack mounting or fully cased for bench use.

VARIABLE INDUCTOR

C. G. S. Laboratories has announced the "Increductor" which is the trademark of a new type of variable inductor that has no moving parts whatever and is electrically controlled. It is variable over an inductive range of 100 to 1, 200

to 1 or even more in some applications, maintains high *Q* even at megacycles, is controlled with minimal power, and is compact and light in weight. A.c. or d.c. variations through the low power control winding produce corresponding variations in the inductance of the Increductor signal winding.

Patents have been applied for by *C. G. S. Laboratories, Inc.*, 391 Ludlow St., Stamford, Conn.

TIMER

A synchronous-motor timer for accurate control of a wide variety of timed operations has been designed by the *General Control Company*, Boston 34, Mass.

This type SY "Promatic" Timer can be used for all time periods between ½ second and 24 hours. It actuates

five s.p.d.t. load contacts independent of the timer-control circuits. There are two separate solenoids—one operates the clutch and timing mechanism, the other actuates the load contacts. The timer automatically resets for each new cycle.

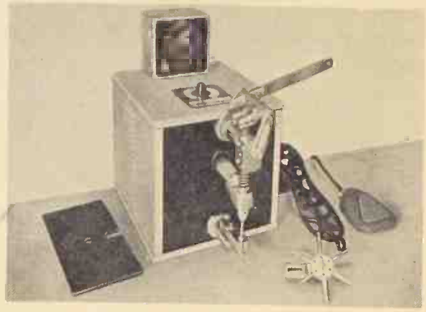
The pre-set interval and the elapsed time are both clearly visible on the 3⅜" diameter dial, and the unit is available for either 115 or 230 volts a.c.

SPOT WELDING & SOLDERING MACHINE

Joyal Products, Inc., 56 Belmont Ave., Newark 3, N. J., has announced its new resistance spot welding & soldering machine (Model 1000 WV, or 2000 WV—a.c. only), equipped with timer. This machine silver solders, soft solders and spot welds precious and dissimilar metals. It spot welds steel parts up to 3/32 of an inch in thickness, brass up to ⅛ of an inch, as well as sterling silver and other precious metals.

A Bakelite worktable can be furnished with all vertical electrode machines at extra cost. Collars determine control pressure to protect parts soldered from excessive heat that would cause marking. Special engineering assistance is available if required.

An automatic cut-off timer regulates soldering time. Heat control with eleven adjustments determines correct heat. When dials are set, uniform sol-



dering time, heat, and holding pressure on the electrodes are maintained, regardless of how long the footswitch is held down.

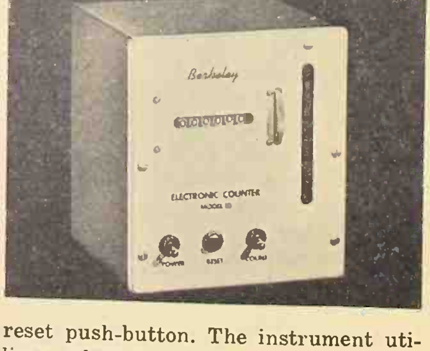
For additional information and catalog write direct to the company.

ELECTRONIC COUNTER

Berkeley Scientific Corp., 2200 Wright Ave., Richmond, California has announced its new Model 10 electronic counter which has been developed to satisfy the need for a rugged, industrial type electronic counter.

A source of potential is available on the rear of the instrument to be used with closing contacts, and may be used to operate a variety of standard photocells. Whenever the grid terminal of the counter has a positive potential of 2 volts or greater applied to it, the decimal counting unit will register one count. The acceptance of the pulse is not dependent upon the rate of rise of the applied potential. A slowly varying voltage will trigger the unit just as readily as a voltage pulse of one microsecond duration.

The front panel controls consist of a power switch, a count switch, and a



reset push-button. The instrument utilizes selenium rectifiers in the power supply and all wiring is moisture and fungus proofed to insure reliability and long operating life. All circuits are developed around one tube type, the 12AU7, in order to facilitate replacement. Model 10 is not affected by normal variations in the 117 volt line potential and all counters are tested to insure proper operation over a line voltage range of 105 to 130 volts. Power consumption is approximately 25 watts.

MINIATURE BALL BEARING

Manufactured by *Miniature Precision Bearings, Inc.*, Keene, N. H., this miniature pivot ball bearing has an outside diameter of 1.5 millimeters. Diameter tolerance is held to plus zero and minus two ten-thousandths of an inch. The pivot shaft holds the balls in place and the raceway wall is designed so that its mass occurs at points of greatest strain. This permits relatively heavy loads under severe conditions of shock and vibration.

Uses for these ball bearings include various precision instruments, textile rollers, servomechanisms, gyros, transits, etc. The illustration shows the size compared to a magnified portion of a common pin.

THERMOCOUPLE GAUGE

Distillation Products Industries, Rochester 3, N. Y., a division of *Eastman Kodak Company*, is announcing an inexpensive vacuum gauge in multistation form for coaters, dehydrators, vacuum furnaces, and other industrial high vacuum equipment.

Known as the Thermocouple Gauge, Type TG-09, it is available with two, three, four, five, or six stations, all reading on a single meter. Range covered is from a few microns to one millimeter Hg. More than half the range of the indicating needle is devoted to the region below 60 microns. The smallest meter division represents 5 microns; 1000 microns is the highest numerical value indicated.

The multi-station gauge and the previously available single-station Thermocouple Gauge, Type TG-02, operate from 115 v. 60 cycle lighting circuits. Also available is a single-station Thermocouple Gauge, Type TG-08, which operates from two flashlight dry cells.

TV MONOSCOPE

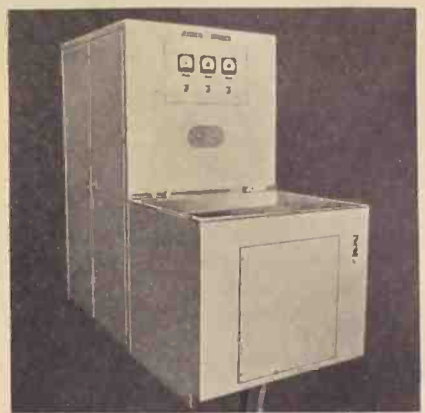
A new television monoscope, Type PH-3-A, has been announced by the *General Electric* Commercial Equipment Division. It features low current drain, composite output, and both horizontal and vertical feedback sweeps. Possible damage to the tube in event of sweep failure is prevented by an automatic sweep protection circuit.

The rack mounted unit incorporates a separate input for any test signal and an adjustable sweep yoke for obtaining a rectangular raster. Video response of the new unit is within plus or minus one-half db to 7 megacycles, and 3 db down at 9 megacycles. Signal-to-noise ratio is approximately 35 db. Further information is available from Dept. N-3, *GE* Advertising Division at Electronics Park, Syracuse, N. Y.

INDUCTION HEATER

An electronic type 20 kw. induction heater, featuring a nonventilated, dust-proof, NEMA Type 12 enclosure, has been announced by *General Electric's* Industrial Heating Divisions.

The heater is designed for use in high-speed annealing, brazing, hardening, and soldering. The totally-enclosed steel cabinet is equipped with felt-gasketed and bolted doors to protect the components from dirt, grit, or oily vapors, and is certified to meet FCC regulations. In addition to water cooling, blowers recirculate air within the enclosure to cool seals of the oscillator



tube and bases of the rectifier tubes. Oscillator, control, and other components are located within the cabinet for easy maintenance and accessibility.

The heater may be used for long or short-run production and is available in two models. The Type HM-20L1 heater is recommended for short-run production. This model has variable

(Continued on page 29)

NEWS BRIEFS

ALFRED NOBLE PRIZE AWARD

Ralph J. Kochenburger, (right) assistant professor of electrical engineering, University of Connecticut, Storrs,

Conn., is shown receiving the Alfred Noble Prize of the American Institute of Electrical Engineers. The presentation is being made by E. E. Howard, consulting engineer, N. Y.

This annual award of approximately $350 and a certificate is made to the member of the four national civil, mining, mechanical or electrical engineering societies who, in the opinion of the awards committee, has presented a technical paper of particular merit and accepted for publication by one of the societies. The recipient must be under thirty-one years of age.

EXPERIMENTAL SAMPLES

Philips Laboratories, Inc., Irvington-on-Hudson, New York, now has available to electron tube manufacturers experimental samples of its new high emission density L-Cathode.

The L-Cathode originated in the *Philips Research Laboratories* in Holland and was further developed by *Philips Laboratories* here. Two types of the L-Cathode are being offered as experimental samples: the cylindrical, especially adaptable to magnetrons, and the planar type, applicable to high frequency disc seal triodes, klystrons, iconoscopes, cathode-ray and other tubes.

Hundreds of samples have already been supplied to a number of leading electronic research laboratories. On the basis of use in klystrons, disc seal triodes, iconoscopes, magnetrons, special cathode-ray tubes and other types, they have reported outstanding results and a high degree of reliability. Production types will be announced as soon as adequate manufacturing facilities have been established.

CURTISS-WRIGHT TO PURCHASE PLANT

Negotiations are underway for the sale of the *Columbia Protektosite Company* plant in Carlstadt, New Jersey, to *Curtiss-Wright Corporation's* Electronics Division.

Curtiss-Wright plans to purchase the land, buildings, trade names, and other assets of the plastic products manufacturer and plans to continue present plastics manufacturing operations and utilize presently available space and possible additional construction to house the recently created Electronics Division now located at Caldwell, New Jersey. J. P. Brunetti, President of *Columbia Protektosite,* will assist in the continued plastics operation.

IMPROVED TECHNIQUE

An improved technique for semi-automatic production of intercommunication amplifiers for aircraft use was the subject of a paper authored by W. H. Hannahs and Walter Serniuk of the Physics Laboratories, *Sylvania Electric Products Inc.*, Bayside, N. Y., which was delivered to a National Conference on Airborne Electronics.

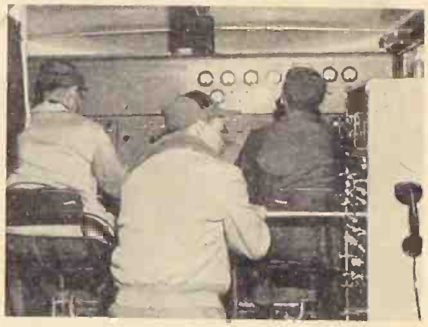
The authors reported that the new technique, which was developed under sponsorship of the Air Materiel Com-

mand, reduces the equipment bulk 70 per-cent and weighs 60 per-cent less than standard design with the same performance. The new unit employs a flexible sheet or "blanket" of a rubber-type plastic in which wiring is imbedded. The sheet is wrapped around an indexed assembly of the components. The complete assembly has a circular cross section with terminals distributed radially along the circumference. The terminals may be soldered or welded.

Mr. Hannahs is engineer in charge of electronic miniaturization and Serniuk is head of the Contracts Section at the *Sylvania* Physics Laboratories.

ANTIAIRCRAFT GUIDED MISSILES

The launching and flight of one of the nation's newest antiaircraft guided missiles, which travels at supersonic



speeds, are controlled from a master panel. Complex electronic devices developed by *Bell Telephone Laboratories* determine where the powerful missile should meet high-flying enemy aircraft, guide it to that point, and then explode it. The project is part of a contract between the *Western Electric Company,* manufacturing and supply unit of the *Bell System,* and the Army Ordnance Corps. Aerodynamics of the project and design of the missile itself are being handled by the *Douglas Aircraft Co., Inc.*, as a subcontractor.

LABORATORY EXPANSION

The *General Electric Company*, Electronics Park, Syracuse, N. Y. announces expansion of its electronic laboratory. The size of the laboratory building, situated at the Company's 190-acre, campus-like electronics headquarters, will be increased from 33,000 to 101,000 sq. ft. by the addition of two wings. Each wing will be a two-story brick structure with architectural design following the present building.

The laboratory now employs 162 people. An additional 173 employees will be hired when the wings are completed. The Electronics Laboratory is under the direction of Dr. Lloyd T. DeVore.

FOUNDATION PROMOTIONS

Dr. H. A. Leedy, Foundation director announces the promotion of two scientists to head new divisions at *Armour Research Foundation* of Illinois Institute of Technology.

Dr. LeVan Griffis, chairman of applied mechanics, was named manager of a new engineering mechanics division. He will head three new departments: structural research, mechanism and propulsion research, and heat-power research.

Dr. E. H. Schulz was appointed manager of a new physics and electrical engineering division to include two existing departments. He had been chairman of electrical engineering and acting chairman of the physics department.

HIGH-SPEED ELECTRONIC COMPUTER

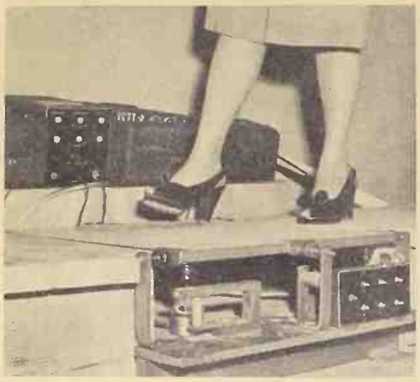
Since its dedication in June, 1950, the National Bureau of Standards Eastern Automatic Computer, SEAC, has solved a large number of problems and has demonstrated a reliability in operation. SEAC was developed and constructed by the NBS staff under the sponsorship of the Department of the Air Force to provide a high-speed computing service for Air Force Project SCOOP (Scientific Computation of Optimum Programs), a pioneer effort in the application of mathematical techniques to large-scale problems of military procurement and administration. SEAC was the first postwar, automatically-sequenced, super-speed computer to be put into productive operation.

The illustration shows R. J. Slutz inspecting the input medium, a perforated paper tape, while S. N. Alexander examines a problem solution being printed by the machine's output unit.

ELECTRONIC STEPMETER

To obtain basic quantitative data on some of the factors involved in the slipperiness of walkways and to aid in the elimination of such hazards, the National Bureau of Standards has devised an electronic stepmeter which measures the three components of force produced between the foot and the floor in normal walking.

Under the direction of Perry A. Sigler of the Bureau's Building Technology Division, the project has involved several phases of investigations.

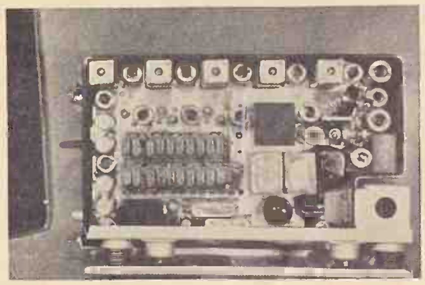


These include study of published pictures of persons at various stages of locomotion; the production and study of slow-motion pictures of people walking; an investigation of the contour of the rear portion of worn shoe heels; and the quantitative determination of vertical and horizontal components of the force exerted by the leg on a walkway surface during progression using the electromechanical force plate.

The electronic stepmeter, developed by W. E. Williams of the NBS staff, consists primarily of a 2-foot square platform mounted on ball bearings attached to four J-shaped springs. Electromechanical pickups, an adaptation of the mutual-inductance electronic micrometer previously developed by M. L. Greenough at NBS, are mounted adjacent to the appropriate springs. Deflections of the springs due to forces exerted against them produce output voltages which are amplified and are recorded with respect to time by an oscillograph.

GLIDE SLOPE RECEIVER

The AN/ARN-18 Glide Slope Receiver was displayed by *Emerson Radio and Phonograph Corporation*, 111 Eighth Ave., New York 11, N. Y. at the Armed Forces Day exhibit held at Mitchel Field, Hempstead, L. I. *Emerson* is co-designer of the Glide Slope Receiver and has started production



(Continued on page 28)

Personals

JOHN WARD DAWSON, formerly in charge of equipment engineering for the Stanford Research Institute, has been appointed chief engineer for the Electronics Division of *Sylvania Electric Products Inc.* A member of the AIEE and the IRE, Mr. Dawson received degrees from Iowa State College and the University of Pittsburgh. Formerly associated with *Westinghouse Electric* and *Raytheon Manufacturing*, Mr. Dawson holds some eighty patents.

U. CLARKE S. DILKS has joined the Research Division of *Burroughs Adding Machine Company* as a Research Engineer. Mr. Dilks was formerly associated with the *Philadelphia Electric Co.*, the Bartol Research Foundation, the Franklin Institute, and the Moore School of Electrical Engineering. A member of the IRE, Mr. Dilks was awarded the Naval Ordnance Development Award for his special work during the war.

JAMES V. McGOODWIN has been appointed director of the Institute of Inventive Research at San Antonio, Texas. Mr. McGoodwin resigned as vice president and general manager of the San Antonio Chamber of Commerce to take his new post. A graduate of the University of Texas, Mr. McGoodwin was a former executive with the *Hughes Tool Company* and was associated with Paul G. Hoffman on the Committee for Economic Development.

E. W. RITTER, manager of the new Electronic Tube Division at *Westinghouse Electric Corporation,* has been named a vice-president. Mr. Ritter was formerly associated with *RCA* and *Corning Glass Works* and joined *Westinghouse* a year ago as a consultant on electronic tube design and development. A graduate of Purdue University with a degree in electrical engineering, Mr. Ritter will head a division of three new plants now under completion.

B. V. RONCO, designer of experimental buses and other test projects for twelve years and chief inspector for *Mack* trucks for thirteen years, has been appointed chief engineer of *Morrison Steel Products, Inc.*, Buffalo, New York. Mr. Ronco is a graduate of Lafayette College, where he received the degree of Mechanical Engineer. He is a registered professional engineer in the state of Pennsylvania and a member of the Society of Automotive Engineers.

GEORGE O. SMITH has been appointed Manager of Components Engineering at *Emerson Radio and Phonograph Corporation.* During World War II, Mr. Smith was connected with The National Defense Research Council and authored instruction manual projects in the technical use of sonar, radar, etc. His new duties will cover the design, procurement, and production use of all materials prior to manufacture of civilian and military electronic equipment.

News Briefs

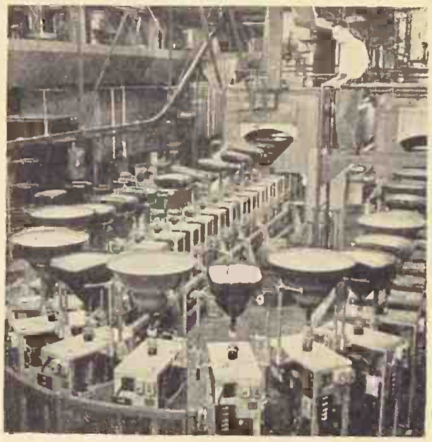
(Continued from page 27)

operations on this unit for the Air Materiel Command.

The *Emerson* model was displayed in conjunction with a demonstration of "Navigational Aids for Instrument Landing" staged by the Airways and Air Communications Service. A miniature diorama model of the complete landing field, with glide slope and other equipment including mock-up of the pilot control panel, provided a realistic background to demonstrate the use of electronic equipment for landing planes under adverse weather conditions.

EXHAUST MACHINES

One of the largest in-line exhaust machines in the world is located at *General Electric's* television picture tube plant, Electronics Park, Syracuse, N. Y. The machine is capable of taking both round and rectangular tubes up to 24-in. in size. Each "buggy" has an oil diffusion pump which creates a vacuum.



As the tubes move through the "tunnel" they go through a bake-out process which consists of heating each tube to a temperature of 400 degrees Centigrade at which time the pump draws out the gases and other impurities. When the tube emerges from the tunnel, an operator seals them off with an oxygen torch.

AUTOMATIC PILOT

An electrical "co-pilot" has been developed that will guide America's newest all-weather jet fighter plane through loops, rolls and other combat maneuvers with split-second accuracy. Scientists and engineers of the *Westinghouse Electric Corporation* teamed up with flight engineers of the Air Materiel Command's Armament Laboratory, Control Equipment Branch, to develop the autopilot.

The midget device will be installed in the F94C fighter plane being built for the U. S. Air Force by the *Lockheed*

Aircraft Corporation. The heart of the new instrument is three spinning gyroscopes. The gyroscopes, rotating at 12,000 rpm, are "locked" to the plane and follow it during all maneuvers without any possibility of tumbling.

Development of the new instrument for fighter plane use began more than a year ago at the Wright-Patterson Air Force Base in Dayton, Ohio. Mounted in an F-82 "Twin Mustang" fighter plane, the autopilot was put through more than 60,000 miles of banked turns, rolls, loops, and level flight while the human pilot and *Westinghouse* engineers observed, improved upon, and tested it. The autopilot is also suitable for large and small commercial planes. Radio controlled, it can also serve to direct the flight of guided missiles and pilotless aircraft.

New Products

(Continued from page 25)

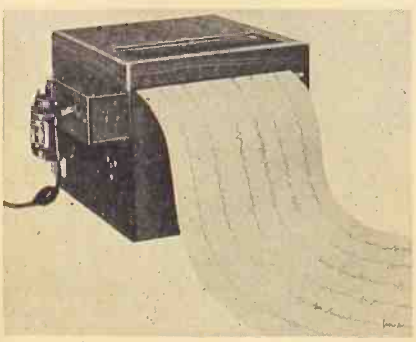
power adjustment from 0 to 100 percent by means of a rheostat. For long-run, higher-production applications which do not have rapid cycling, the Type HM-20L2 heater, without variable power adjustment is recommended by *GE* engineers. Either of the two models weigh approximately 3600 pounds. Units are available for operation on 230, 460, or 550 volt, three-phase, 60-cycle power supply.

Booklet GEA-5594 is available by writing directly to *General Electric Co.*, Schenectady 5, N. Y.

OSCILLOGRAPH

Offner Electronics Inc., 5320 North Kedzie Avenue, Chicago, Illinois, is now offering to the industry a direct writing, high speed oscillograph with microvolt d.c. sensitivity.

Known as the Dynograph, this instrument features a pen deflection linearity of 1% with pen response of 1/120th of



a second; sensitivity of 150 microvolts d.c. per centimeter of pen deflection; and stability and drift free operation through a special chopper type amplifier. No extra equipment is needed with the reluctance type pickups and true differential input is obtained through special transformer coupling.

Curve Tracer

(Continued from page 11)

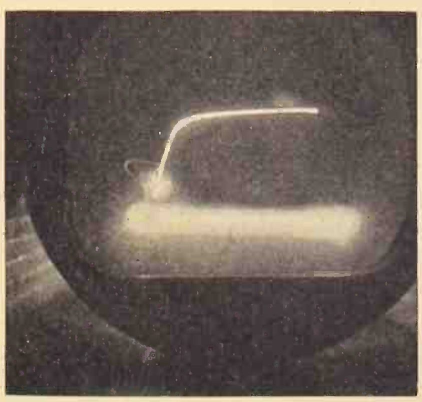
the balance control are provided as front panel adjustments so that the calibrating voltage may be applied to both inputs and balance obtained at any point in question. In practice, this adjustment is not often necessary if some care is exercised in the choice of the 12AV7 used.

Due to the simplicity and relatively small size of this equipment it was possible to incorporate it as an addition to an existing tube test console. This made possible the use of existing heater, bias, and B supplies for the tube under test. The front panel controls and terminals were arranged for the greatest flexibility to permit the equipment to be used to plot a curve of voltage for any electrode versus the current of the same or any other electrode in the tube.

In investigating cases of irregular tube behavior, or in searching for optimum design parameters for a given tube circuit, this equipment quickly proves its worth. A few examples of its use which have led to the solution of problems will best demonstrate the need for flexibility. In one case it was necessary to determine the effect of negative suppressor grid voltage on the plate current of an r.f. type pentode. In another problem, the curve of signal grid current versus voltage in the positive grid region, for a type 6BE6 converter tube was required for a series of conditions of oscillator grid and screen grid voltage.

Definite compromises have been made in this equipment. However, they are of the type which restrict the amount of qualitative information which can be presented at one time; but do not limit its capability to obtain accurate data over the desired range of voltages and currents. The resulting equipment is thereby made relatively simple and inexpensive and may be constructed of standard laboratory parts.

Fig. 7. Close-up of the scope, showing a typical curve.



TECHNICAL BOOKS

"ADVANCES IN ELECTRONICS" Volume III, Edited by L. Marton, National Bureau of Standards. Published by *Academic Press Inc.*, 125 East 23rd St., New York 10, N. Y. 357 pages. $7.50.

Volume III of this popular series presents an up-to-date review of outstanding developments in the rapidly expanding field of electronics both in the United States and abroad. Each of the nine chapters summarizes important progress in theory, techniques, and devices made during the past year.

Contributors to Volume III include: F. Ashworth, *Metropolitan-Vickers Electrical Co.*, England; F. Bloch, Stanford University; L. Brillouin, *International Business Machines Corp.;* M. Chodorow, Stanford University; E. L. Ginzton, Stanford University; P. R. Guénard, Compagnie Générale de T.S.F., Paris, France; E. A. Guillemin, MIT; Meyer Leifer, *Sylvania Electric Products Inc.;* H. F. Mayer, School of Electrical Engineering, Cornell University; William F. Schreiber, *Sylvania Electric Products Inc.;* Gustave Shapiro, National Bureau of Standards; R. R. Warnecke, Compagnie Générale de T.S.F., Paris, France; and John E. White, National Bureau of Standards.

Papers contributed cover such pertinent subjects as microscopy, tube design, and miniaturization.

"TIME BASES" by O. S. Puckle. Published by *John Wiley & Sons, Inc.*, 440 Fourth Avenue, New York 16, N. Y. 387 pages. $5.00.

The second edition of this authoritative book on the construction, testing and uses of time bases has been completely revised and expanded by more than 150 pages. All the more important electronic devices which are available for producing the time axis in television receivers, cathode-ray oscillographs, engine indicators, and similar apparatus involving precise timing have been thoroughly covered.

The most significant war-time developments in the time base field have been the great improvements in linearity and the greatly increased trace velocities which have resulted from the development of the Miller-capacitance and other negative feedback types of circuits. A completely new chapter dealing with Miller-capacitance time bases has been added to the text.

Eight appendices are now included and eighteen useful tables of data are spaced throughout the book.

Computer Concepts

(*Continued from page* 5)

The dictionary says: "A calculating machine," and under "calculate" is included: "To ascertain or determine by mathematical processes . . . to plan with forethought . . . to forecast consequences, etc." Increasingly there is included in current usage not only the components that accomplish the calculation but associated devices that carry out functions determined and guided by the computing elements. A very general and inclusive definition would be: "Any device that is capable of generating a signal as a function of two or more other signals."

In the processes of human thought various languages are used as representations of the material being handled. Language is a code. Computers may use various types of codes, all of which involve representations as a function of change. The simplest form of change is defined by a concept that recognizes only two significant states. This is the form represented by "go—no go," "on—off," "conducting—nonconducting" devices. It is the form of binary arithmetical notation that uses only the numbers one and zero. With such a code it is possible to represent any kind of information provided a sufficient quantity of such binary signals is available. The counting circuits of most recently designed high speed computers and the nerve cells of most living organisms function in accordance with this notation. It is worthwhile to note here, and to remember for future reference, that no mechanism exists that is binary in fact as well as concept for there is always a transition stage. No perfect square wave change is possible. This means that all such devices have a time constant limitation defined by their ability to approach instantaneous change from one state to the other. This does not appear to be a limitation of consequence since existing machines are capable of five thousand or more additions per second, and equipment now in the design stage will increase this by a factor of 20 or more. The choice of binary notation is not in imitation of nervous system function nor is it entirely a matter of maximum simplification. It has been considerably influenced by the lack of an entirely satisfactory device that is capable of representing more than two states.

Many engineers who work with electron tubes still think of them as relatively undependable devices with seriously limited life expectancy. Actually when they are operated under ideal conditions and the demand on them is within the limits of really conservative design, tubes are extremely reliable and compare favorably with any type of switching device known. Such is their application in computing circuits.

These are the basic concepts of computer design. Information of any kind can be reduced to a code suitable for electrical circuits and other devices to manipulate in such a manner as to generate any function of the information desired. Such machinery can then be made to perform all of the operations ordinarily considered as "thinking" processes. Coupled with suitable input and output arrangements, supplied with memory devices and designed to produce results in accordance with natural laws, computers may be designed to take over the drudgery of most mental processes. With the relatively slow and inaccurate thought processes of human minds, the last century has produced scientific advances that appear in many ways miraculous. Given suitable computers to accomplish the thinking at enormously increased speeds, future progress should be greatly accelerated.

Binary Scaler

(*Continued from page* 18)

scaler can be shut off by a crystal rectifier gating provided suitable voltage limits are chosen.

Given a simple scaling factor as ten, the means of indication of the number of counts stored within an electronic register or counter should easily be read by indicators.

(1) By connecting a lamp as shown in Fig. 2, a four-lamp decade indicating system may be devised. Whenever the right-hand side of Fig. 2 is cut off, the lamp is lighted. Dependent on which decade system is used, two complete systems of lamp indication are possible for each digit. The reading of these systems is definitely difficult, and the following systems are more attractive.

CALENDAR of Coming Events

AUG. 20-23—Pacific General Meeting of AIEE, Portland, Oregon.

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

SEPT. 10-13 — NEDA Second Annual Electronic Parts Distributor Show, Cleveland, Ohio.

OCT. 8-10 — Fall Meeting of U.S.A. National Committee of URSI and IRE Professional Group on Antennas and Propagation, Ithaca, N.Y.

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

OCT. 22-26 — Fall General Meeting, AIEE, Cleveland, Ohio.

OCT. 29-31—Radio Fall Meeting, King Edward Hotel, Toronto, Ont., Canada.

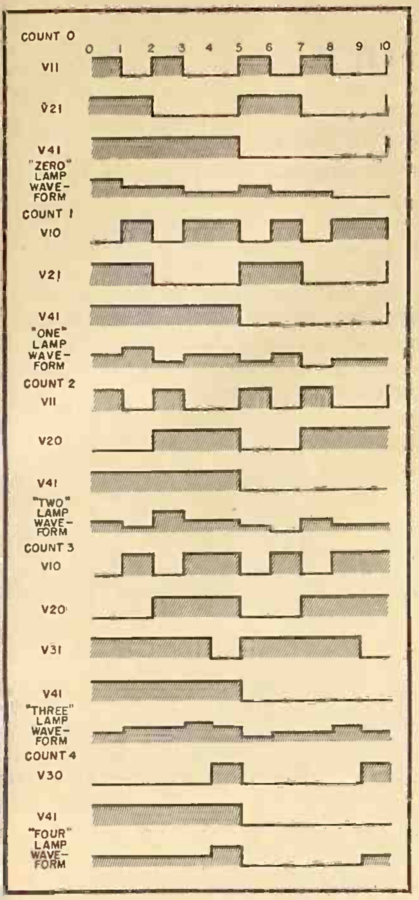


Fig. 11. Synthesizing a ten-lamp indicator system.

The circuit of Fig. 6 has ten twin triodes as well as ten neon indicating lamps. It is also possible to use four twin triodes with ten neon indicating lamps to give a "decimal" indication (*i.e.*, ten lamp indication).

By employing the known ten count waveforms of Fig. 8, in addition to the inverse waveforms for mating plates, not shown, a decimal indicating system may be developed.

Fig. 11 illustrates the method. Half the counts are shown, the remainder, count 5 to count 9, is obtained by using the output of V_{40} in place of V_{41}.

The waveforms of each plate are combined by resistor networks. With all plates connected to a given neon lamp, at cut-off, full voltage is across the neon lamp, igniting it. When one or more tubes associated with a lamp conduct, that lamp cannot ignite because insufficient voltage is present at the neon anode.

The greater the difference between cut-off and conducting plate voltages, the more reliable is the indication. The system has several variations in practice to assure definite indication over a broad plate supply range.

Ten lamp systems require elaborate circuitry and tubes over the basic scaling components. This is to insure neon lamp firing over a large range of input and plate supply voltages. A compromise between the electronically elaborate, easy reading, ten lamp system and the electronically simple, difficult-to-read binary system is the *bi-quinary* lamp system of Fig. 10. The same system as in "Decade Feedback" is understood. The ten count plate waveforms are identical. These waveforms are combined by means of resistors to light and extinguish the lamps in the sequence 1, 2, 3, 4 and 5, as those pulses are introduced. With counts 6, 7, 8 and 9, the 5 lamp remains lighted while 1, 2, 3 and 4 lamps come on and off as appropriate. A 0 lamp may be connected to MV_4, pin 8, if desired.

Neon lamp firing, without igniting incorrect neon lamps, can be done by introducing the output of a 6.3 volt filament transformer to the neon lamp cathode bus at A. This additional 60 cycles, 17 volts peak-to-peak swing is desirable where neon lamp breakdown voltages vary considerably. The swing also serves to de-ionize lamp 3 at counts 4 and 9 where the 15 volt drop may not be sufficient to shut off that lamp.

Matching-stub

(*Continued from page* 32)

where $\theta_1 = \tanh R/Z_0$ and $\theta_2 = 0$. Separating the real and imaginary parts and solving for l_1 and l_2 gives:

$$l_1 = \frac{\lambda}{2\pi} \tan^{-1} \sqrt{\frac{R}{Z_0}} \quad . \quad . \quad . \quad (4)$$

$$l_2 = \frac{\lambda}{2\pi} \tan^{-1} \sqrt{\frac{Z_0 R}{R - Z_0}} \quad . \quad . \quad (5)$$

$$l_1' = \frac{\lambda}{2\pi} \tan^{-1} \left(- \sqrt{\frac{R}{Z_0}} \right) \quad . \quad . \quad (6)$$

$$l_2' = \frac{\lambda}{2\pi} \tan^{-1} \frac{\sqrt{Z_0 R}}{Z_0 - R} \quad . \quad . \quad . \quad (7)$$

When R is larger than Z_0, we can use (4) and (5) giving:

$\lambda/8 < l_1 < \lambda/4,\ 0 < l_2 < \lambda/4$ . . (8)

or, using (6) and (7):

$\lambda/4 < l_1' < 3\lambda/8,\ \lambda/4 < l'_2 < \lambda/2$. (9)

When R is smaller than Z_0, using (4) and (5) gives:

$0 < l_1 < \lambda/8,\ \lambda/4 < l_2 < \lambda/2$ . . (10)

or, using (6) and (7):

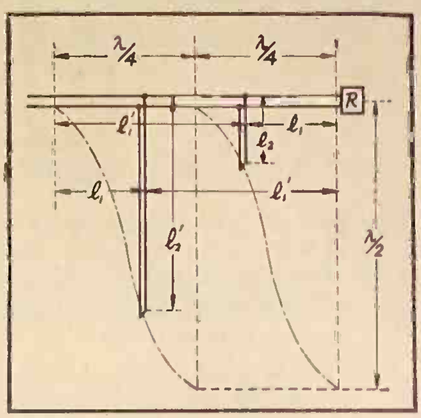


Fig. 2.

$3\lambda/8 < l_1' < \lambda/2,\ 0 < l_2' < \lambda/4$. (11)

Those relations are shown in Fig. 2.

The following relations are also true:

$$\left. \begin{aligned} l_1 + l_1' &= \lambda/2 \\ l_2 + l_2' &= \lambda/2 \end{aligned} \right\} \quad . \quad . \quad . \quad . \quad . \quad (12)$$

For convenience, let us assume that l_2 is smaller than $\lambda/4$. Therefore when R is larger than Z_0, we determine the dimensions l_1 and l_2; when R is smaller than Z_0, we use l_1' and l_2'.

For an example, assume that the load resistance R is 300 ohms, the characteristic impedance Z_0 of the feeder is 200 ohms and the frequency is 150 mc. We determine l_1 and l_2, since R is smaller than Z_0. The chart then gives $l_1 = 11.1''$, $l_2 = 14.8''$.

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MATCHING-STUB CALCULATIONS

By SEIZO YAMASITA

A nomograph for determining the position and length of matching stubs on Lecher wire lines.

IF the attenuation constant of a transmission line is negligible, the input impedance Z_{ab} of a resistive loaded line of characteristic impedance Z_o, length l, and phase constant $j\beta$ is:

$$Z_{ab} = Z_o \tanh (j\beta l + \theta) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

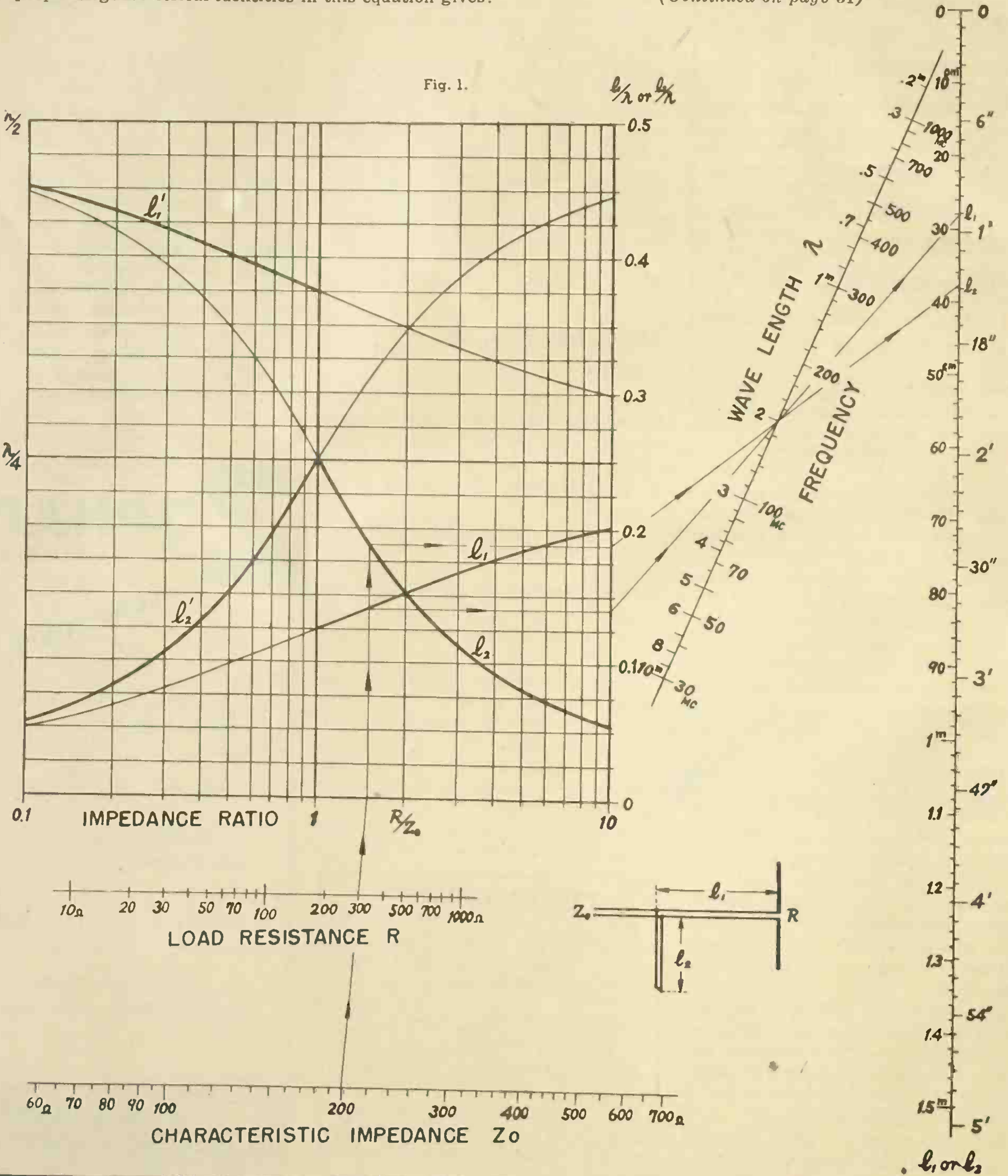
where $\beta = 2\pi/\lambda$, and $\theta = \tan R/Z_o$. Substitution of the proper trigonometrical identities in this equation gives:

$$Z_{ab} = \frac{Z_o\,(R + j\,Z \tan \beta\, l)}{Z_o + j\,R \tan \beta\, l} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

The Lecher wire line shown at the bottom right of Fig. 1 has a matching stub shorted at the bottom end. When the feeder is matched to a resistive load of R ohms:

$$\coth\,(j\,\beta\, l_1 + \theta_1) + \coth\,(j\,\beta\, l_2 + \theta_2) = 1 \quad . \quad . \quad (3)$$

(Continued on page 31)



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