IX. MISCELLANEOUS PROBLEMS

A. ELECTRONIC DIFFERENTIAL ANALYZER

The present objectives of this project are (1) to improve existing and develop new computing elements for use in the electronic differential analyzer, and (2) to use the analyzer to solve differential equations of interest.

1. Computing Elements

During the past three months, two integrators and one adder have been added to the operating differential analyzer. This permits the solution of differential equations of orders through the sixth. The new units do not differ materially from those previously built and no particular difficulties have been encountered in the solution of the higher-order equations.

A considerable amount of time is being spent investigating the limitations of the crossed-fields multiplier (Quarterly Progress Report, January 15, 1948). The emphasis here is upon those factors which limit the dynamic range of the multiplier.

A dual-purpose unit to be used for either multiplication or function generation is being developed. A first model of this unit has been built, and it was used as a function generator in the solution of Equations (5) and (6) described below.

A detailed study has been made of the 60-cps gate generator used with the differential analyzer. The results of this study will permit the design of an improved gate generator.

2. Differential Equations

The equation

$$\frac{d^2y}{dt^2} + a_1\frac{dy}{dt} + a_0y = K \sin \omega t \qquad (1)$$

and the simultaneous equations

$$\frac{d^2y}{dt^2} + a_1\frac{dy}{dt} + a_0y - k\frac{d^2x}{dt^2} = K \sin \omega t \qquad (2)$$

and

$$\frac{d^2x}{dt^2} + b_1\frac{dx}{dt} + b_0x - k\frac{d^2y}{dt^2} = 0 \qquad (3)$$

have been solved to illustrate the use of the electronic differential analyzer as a teaching tool. Solutions of Equation (1) and Equations (2) and (3) give the response of single-and double-(or stagger-) tuned circuits to a sinusoidal pulse. It is particularly easy with the analyzer to investigate the response of these circuits for pulse frequencies other than the bandcenter frequency.

Three other equations which have been solved during the past quarter are

$$\frac{d^2y}{dt^2} + \epsilon \cos(\omega_m t + \Theta)\frac{dy}{dt} + \omega_o^2 y = 0, \tag{4}$$

$$\frac{d^2y}{dt^2} + k\left(\frac{dy}{dt}\right)^3 + \omega_o^2 y = 0, \tag{5}$$

and

$$\frac{d\Theta}{dt} - K e^{-\alpha t}\sin\Theta = C. \tag{6}$$

Equation (6) was derived by Mr. E.E.David in connection with the study of the starting phenomena of a microwave magnetron. Its solution on the analyzer required the simultaneous use of a multiplier and a function generator. Figure IX-1 is a triple-exposure photograph of three typical solutions of this equation observed on the differential analyzer.

A report on the electronic differential analyzer is being written.
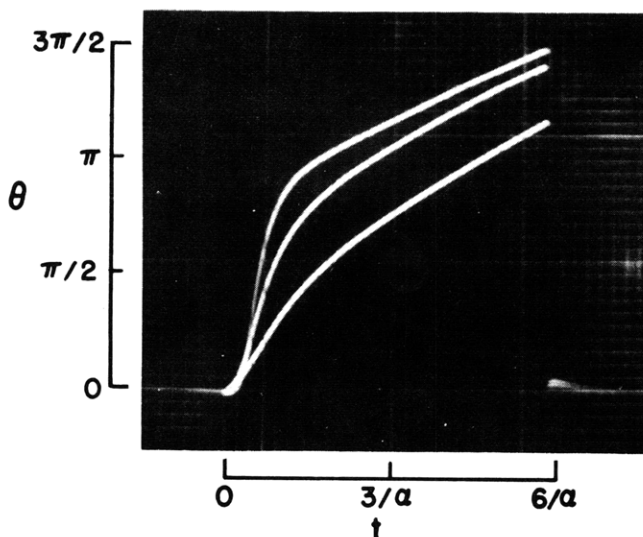
Prof. H.Wallman, Dr. A.B.Macnee, R.Maartmann-Moe

Fig. IX-1. Triple-exposure photograph of three solutions of equation

$$d\Theta/dt - K e^{-\alpha t}\sin\Theta = C$$

for $\Theta_o = 0$, C = .4306 and $K/\alpha = 2.5$, 6.3 and 12.5.

B. AN AUTOMATIC IMPEDANCE-FUNCTION ANALYZER

During the past three months, work has continued on the construction of a device for solving experimentally the approximation problem in filter design. As described in previous progress reports, the device consists of a conducting plane of Teledeltos paper into which currents are introduced to represent poles and zeros of an impedance function. The voltage along the imaginary axis in the plane is proportional to the logarithm of the magnitude of the impedance function. It is sampled by a set of probes along the axis and displayed on the face of a cathode-ray tube. The device may be used to find a set of poles and zeros which will give a desired form to the impedance function.

Progress has been made recently in the following three directions:
(a) An analysis of the errors in the method;
(b) The construction of a "double" commutator;
(c) Partial construction of the Mk. 4 machine.

1. Analysis of the Errors in the Method

A theoretical analysis has been carried out to determine the extent of the errors caused by a finite size of plane. It has been found that the plane must extend about four decades beyond the region in which the poles and zeros are located if the errors are to be less than one per cent in the worst possible case. This size is not feasible in the ordinary Z plane, but it can be achieved fairly easily in the logarithmic strip which is obtained from the original plane by the transformation

$$W = \log_e Z.$$

The general nature and some of the inherent advantages of this transformation have been discussed in a previous progress report.

2. Commutator Construction

The original mechanical commutator was capable of switching 100 lines at a repetition rate of 20 cycles per second. This device has been modified in two ways. The speed has been doubled in order to facilitate the display on the cathode-ray tube. In addition, a second set of contacts has been added. These modifications will make it possible to obtain the phase as well as the logarithm of the magnitude of the impedance function (see below).

3. Construction of the Mk. 4 Machine

Construction of the Mk. 4 machine is proceeding at the present time. The logarithmic strip of Teledeltos paper will be 16.7 inches wide and about 50 inches long. This is the equivalent of 8 decades in the impedance plane. Two rows of 300 probes, spaced 0.1 inch apart, are being constructed to pick up the voltage along the imaginary axis. The sum of voltages from successive pairs of probes in the two rows is proportional to the logarithm of the magnitude of the impedance function, and the difference of the voltages on successive pairs of probes is proportional to the rate of change of phase. The actual phase will be obtained by integration.

Since the actual commutator has only two sets of 100 contacts, it will be necessary to use switches to view the whole range of the probes along the axis.   Prof. E.A.Guillemin, R.E.Scott

C. PROTON-VELOCITY METER

The signal generator and phase-measuring equipment are completed. Work has been discontinued until the Van de Graaff generator is installed.
                                                        L.D.Smullin, P.Lally

D. ELECTRONIC-POTENTIAL MAPPING

Since the last Progress Report, a considerable number of moving pictures have been taken of the heart patterns of subjects. A program will shortly be set up to get a catalogue of patterns of typical normal and abnormal patterns as a first step in using the area display as an aid in the diagnosis of heart disease.

Skull patterns of many different subjects have been observed and motion pictures of six of them have been recorded. This has been done without the aid of the tuning units mentioned in the previous progress report, since only four of these units have so far been completed. The observed displays were thus the instantaneous patterns. Direct observation showed interesting and characteristic individual patterns and movements, including a good deal of activity which was probably due to muscular movements in the presumably relaxed head. Probably the most interesting part of the activity, however, was the apparent presence of scanning or, at least, traveling waves. Motion pictures of the skull activity when projected in slow motion by a factor of 4 to 1 (64 frames per second projected at a rate of 16 frames per second)

accentuated and clarified this traveling-wave activity. The principal frequency was around ten per second and it thus appears that these traveling waves may be identified with the alpha rhythm observed in electro-encephalograms. This view is strengthened by the fact that the envelope of intensity of the traveling waves rises and falls at about the rate observed for the alpha rhythm. Although detailed observations of these waves are made difficult by artifacts, it appears that they arise in the occipital area. These waves will, of course, be studied in more detail as soon as possible.

A much slower type of phenomenon was also of interest in the direct observation of one subject. This phenomenon was almost certainly of muscular origin. It showed a very slowly traveling electrical activity across the skull, which was originated by the subject speaking a few words. The activity, however, did not commence until several seconds after the speech was finished. About twenty minutes later, when the subject was more relaxed, the subject was asked to speak the same words, but the slow traveling activity could no longer be observed, although it had been observed every time in many previous trials at the beginning of the test when the subject was more tense. It was tentatively concluded that the originally observed pattern was due to the unnecessary involvement of distant head muscles by the subject's speaking when he was not thoroughly relaxed. This subject was perfectly normal.

The foregoing observations suggest that the area display may be useful in studies of fatigues and in studies of spastic diseases.

<div align="right">Dr. S.Goldman, W.F.Santelmann,Jr., W.E.Vivian</div>

E. TUBE LABORATORY

1. Resistance Thermometer for Temperature Control

A simple device is described for controlling high-temperature ovens and furnaces. Use is made of a resistance-thermometer element consisting essentially of a platinum wire wound on a ceramic form. This is connected into a conventional a-c bridge circuit. (Fig.IX-2) which comprises a single small thyratron tube, a relay and a means to set the temperature desired.

The resistance-thermometer element is constructed as shown in Fig.IX-3. Small-size platinum wire (.004-inch) is wound on a fluted steatite form, one end of which is cemented into a nickel or stainless steel tube of appropriate length. This element has been operated satisfactorily at temperatures slightly higher than $1000^{\circ}C$. Connection is made by means of an

DETAIL OF
LAVA FORM
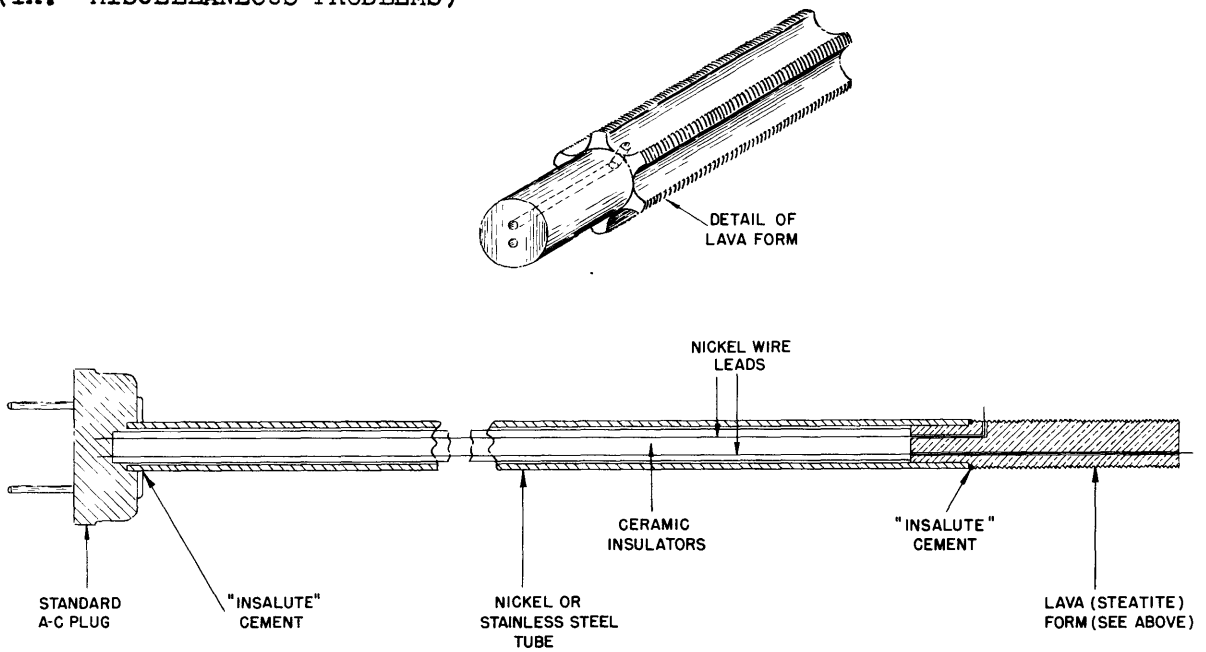
NICKEL WIRE
LEADS

CERAMIC
INSULATORS

"INSALUTE"
CEMENT

STANDARD
A-C PLUG

"INSALUTE"
CEMENT

NICKEL OR
STAINLESS STEEL
TUBE

LAVA (STEATITE)
FORM (SEE ABOVE)

Fig. IX-2. Resistance thermometer.

TO RESISTANCE
THERMOMETER
ELEMENT

TEMPERATURE
SETTING RES.

COUPLING
TRANSF.

580 V CT.

6.3 V CT.

POWER
TRANSF.

115 V
A-C

10 SEC
TIME DELAY

2D21

115 V
A-C RELAY

CONTACTS TO
LOAD CIRCUIT
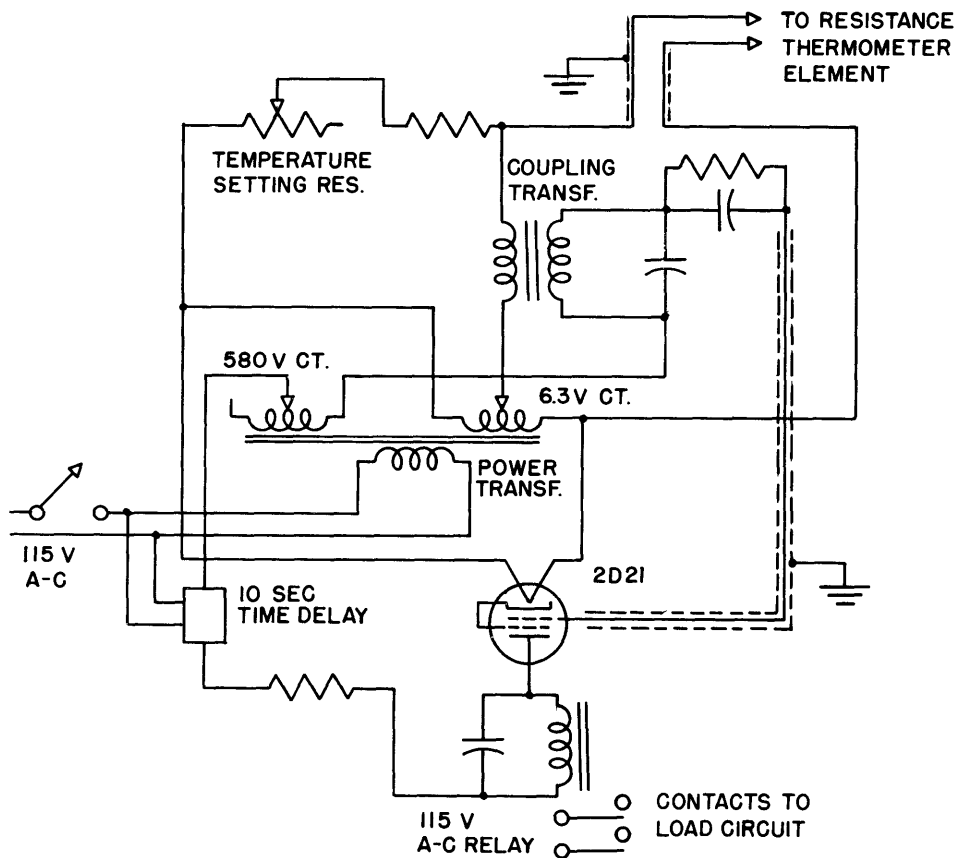
Fig. IX-3. Circuit for resistance thermometer.

ordinary a-c plug which is cemented to the other end of the metal tube. The leads are nickel wires spot-welded to the platinum wire and brought through two-hole ceramic sleeves. A cable with a female a-c plug connects the thermometer to the circuit.   F.Rosebury

F.   TUBE LABORATORY - (Chemical Section)

1.   Aluminum Bonds to Glass, Quartz and Steatite

The preparation of sprayed aluminum-to-glass bonds, although not a new technique, has not been widely used. William Hope of Philco (Philadelphia) has done some work in the sprayed aluminum-glass bond.

The procedure consists of heating the glass to several hundred degrees and spraying on aluminum with a commercial metal spray gun while the glass is hot. The heating of the glass is essential to securing a good bond. Metal sprayed on a cold surface may be easily scraped off, but a sprayed coating prepared in the manner outlined produces a tenacious bond. We have used the same technique in preparing aluminum coatings on both quartz and steatite.

The aluminum surface may be sprayed with copper for soft soldering or it may be plated for purposes of soldering. We have also successfully soldered the aluminum surfaces directly by means of commercial aluminum solders. This technique produces excellent seals for vacuum work.

                                                        C.S.Pearsall