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MEASURING AND INDICATING CIRCUITS

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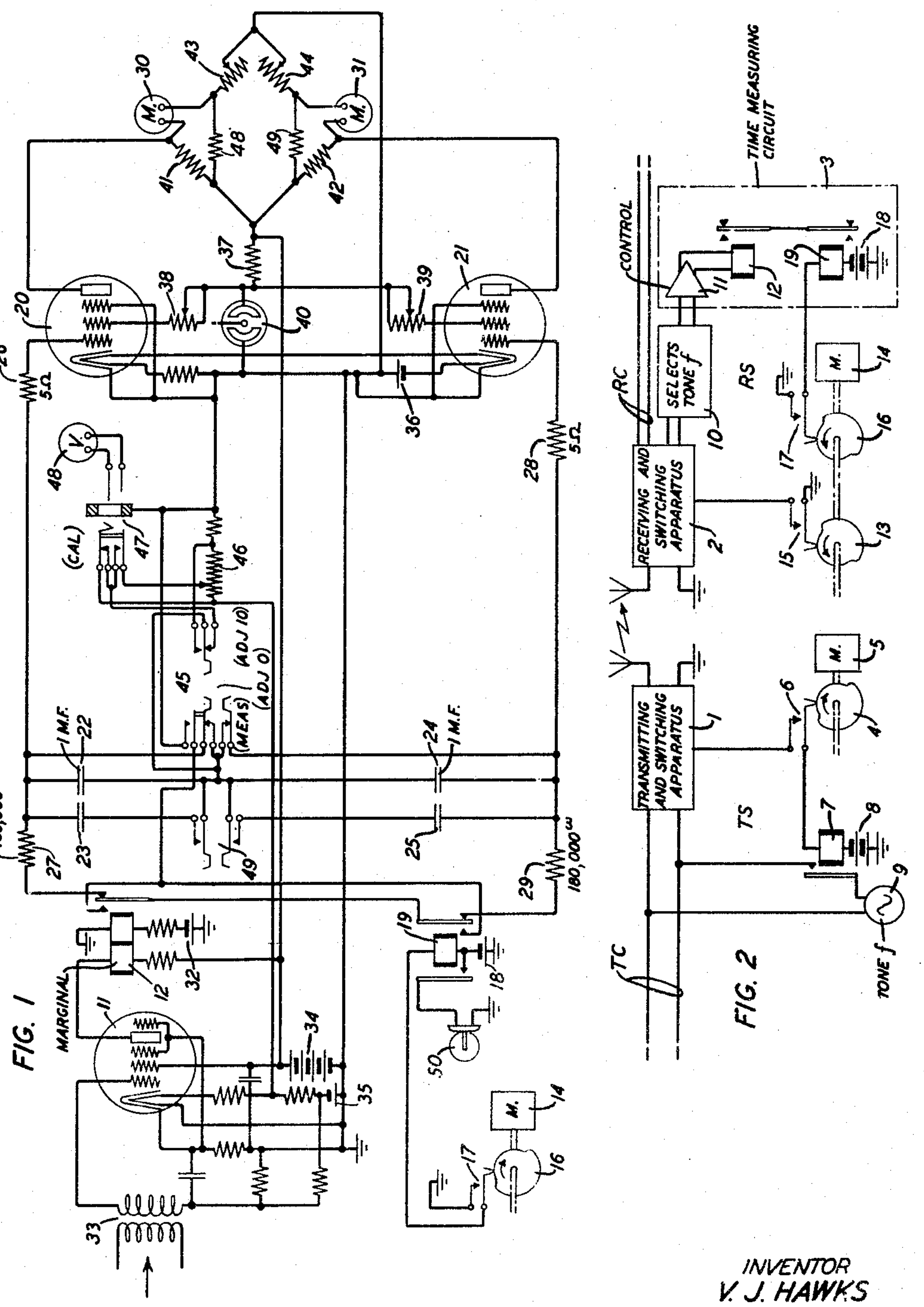

FIG. 1

FIG. 2

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MEASURING AND INDICATING CIRCUITS

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The invention relates to measuring and indicating circuits and particularly to time measuring and indicating circuits.

In wave transmission systems employing at different points therein wave-responsive devices which for proper operation of the system are required to function at the same time or within definite intervals of time, it is desirable to have some automatic means for giving at an observation point an indication or measure of the relative time of operation of these devices. For example, such automatic measuring circuits are of utility in a radio or wire telephone system employing switching mechanism at the transmitting and receiving stations to insert complementary types of distortion in the transmitted and received signal waves to provide secrecy, in order to give a measure of the amount and direction of asynchronism between the operation of the switching apparatus at the two terminals, to facilitate the proper adjustment of that apparatus.

It is an object of the present invention to obtain automatically an indication and measure of the relative time of operation of several wave-responsive devices in a system.

This object is attained in accordance with one modification of the invention by a time indicating and measuring circuit in which the operation of the several wave-responsive devices respectively control the charge and discharge of condensers in the control grid circuits of vacuum tubes in such manner that the amount of plate current flow in the plate circuits of the tubes as indicated by meters therein gives a measurement of the time interval between the operation of the devices and an indication of which has operated first.

Various features and objects of the invention will be understood from the following detailed description thereof when read in connection with the accompanying drawing in which:

Fig. 1 shows schematically a time measuring circuit embodying one modification of the invention; and

Fig. 2 shows diagrammatically a radio signal wave transmission system to which the time measuring circuit of the invention may be applied, and the manner of application.

The invention will be described as applied to a radio signaling system having in addition to the usual transmission apparatus at each terminal station, auxiliary switching apparatus the operation of which requires synchronization at the two terminal stations. This switching apparatus may be mechanisms in a so-called privacy or secrecy system requiring synchronization at the two terminal stations, such as mechanisms for controlling timing cams to shift from one secret signal combination to another at a transmitting station and for performing the reverse operation at a receiving station to reproduce the original signals, as disclosed in the Chesnut et al. Patent No. 1,829,783 or the patent application of A. C. Dickieson Serial No. 149,815, filed June 23, 1937, which issued as Patent No. 2,132,205, on Oct. 4, 1938.

Referring to the radio transmission system of Fig. 2, the signal transmitting and the switching apparatus at the transmitting station TS and the signal receiving and the switching apparatus at the receiving station RS are represented by the boxes 1 and 2 in the signal transmitting circuit TC and in the signal receiving circuit RC at the respective stations, so labeled. The time indicating and measuring circuit of the invention is represented by the dot-dash box 3 at the receiving station RS. The operation of the circuit 3 to measure the direction and amount of asynchronism between switching apparatus at stations TS and RS requires the transmission of an impulse of control current or tone of suitable frequency f which may be inside or outside the transmitted signal frequency band, from the transmitting station TS to the receiving station RS over the intermediate transmission medium each time the switching apparatus at the station TS is operated. The beginning of a pulse represents the start of operation of the switching apparatus and the length of the pulse the duration of that operation. This pulse may be transmitted in any suitable manner. The apparatus at station TS illustrates diagrammatically one method of accomplishing this.

At the transmitting station TS in Fig. 2, the cam 4 driven at constant speed by the motor 5 may be designed to close the switch 6 to initiate operation of the switching apparatus in the box 1 at the proper instant and to open the switch 6 at the time desired for the cessation of that operation or for shifting the switching apparatus to another type of operation. The closing of the switch 6 also closes an energizing circuit for the winding of relay 7 from the battery 8, causing operation of that relay to close its armature and contact to connect the source 9 of the control tone f to the transmission circuit TC supplying signals to the radio transmission apparatus within the box 1. The deenergization of the winding of relay 7 on the opening of the switch 6 an instant later under control of the cam 4, breaks the relay armature and contact disconnecting the source 9 from the circuit TC. This operation results in the radiation of a pulse of control current of the frequency f from the transmitting station TS to the receiving station RS during the period of operation of the switching apparatus at the transmitting station TS.

The pulse of frequency f will be impressed on the receiving apparatus 2 in the circuit RC at the receiving station RS and will be picked off therefrom in any suitable manner, for example, by selective circuit 10, and will cause operation of the control device 11 forming part of the time measuring circuit 3 of the invention, to cause operation of the relay 12 in that circuit for a period determined by the duration of the controlling pulse which in turn will depend on the duration of the switching operation at the transmitting station TS.

At the receiving station RS, a cam 13 of identical design with the cam 4 at the station TS, driven at constant speed by the motor 14, is desired to close and open a switch 15 to initiate and stop operation of the receiving switching apparatus within the box 2 in synchronism with the transmitting switching apparatus within the box 1 at the station TS. Another cam 16 on the same shaft as cam 13 and of identical construction, is driven synchronously with cam 13 by motor 14, and causes the opening and closing of a switch 17 in synchronism with the switch 15 driven by cam 13. The switch 17 is closed by operation of the cam 16 at the instant the switching apparatus in box 2 operates, to close an energizing circuit from battery 18 for the winding of the synchronizing relay 19 causing the operation of that relay. The switch 17 opens at the end of the operation of the switching apparatus to break the energizing circuit for relay 19 from battery 18 and causing that relay to release. The difference in the time of operation of the two relays 12 and 19 in the time measuring circuit 3 will indicate the amount by which the switching apparatus at station RS is out of synchronism with the switching apparatus at station TS, and the manner in which this time interval is measured by the time measuring circuit 3 of the invention will be explained by reference to Fig. 1 showing in detail that circuit.

The main elements of the time measuring circuit of the invention in Fig. 1, in addition to the control device 11 and the relays 12 and 19 illustrated within the box 3 in Fig. 2, are the two pentode vacuum tubes 20 and 21; the condensers 22, 23 adapted to be connected in the control grid-cathode circuit of tube 20, and the condensers 24, 25 adapted to be connected in the control grid-cathode circuit of tube 21; the series resistances 26 and 27 associated with the control grid of tube 20, and the series resistances 28 and 29 associated with the control grid of tube 21; and the current meters 30, 31 respectively connected in the anode-cathode circuits of tubes 20 and 21.

The relay 12 is a marginal relay having a biasing winding supplied with biasing current from the battery 32 through a series resistance in such direction that the relay is adapted to be operated quickly on application of energizing current to the operating winding of the relay. The control device 11 comprises a single pentode vacuum tube, similar to the tubes 20 and 21, the control grid-cathode circuit of that tube being connected to the selective circuit 10 in receiving apparatus 2 in the system of Fig. 2 by input transformer 33, and the operating winding of relay 12 is connected in the anode-cathode circuit of the tube 11 so as to be energized by a flow of plate current therein, when a tone impulse is impressed upon the control grid-cathode circuit.

Space current is supplied to the plate of the tubes 11, 20 and 21 from the common plate battery 34, as indicated. Heating current is supplied to the heater of the heater type cathode of tube 11 from battery 35, and to the heaters of the heater type cathodes of tubes 20 and 21 from battery 36. Suitable negative biasing potentials for the control grids of tubes 11, 20 and 21 are obtained from the filament circuit for tube 11, as indicated.

The screen grid of tube 11 is positively biased with respect to the plate and cathode of the tube by a direct connection from the positive terminal of the plate battery 34, and the screen grids of the tubes 20 and 21 are brought to a positive potential less than that of the plates of these tubes by a connection from the positive terminal of plate battery 34 through the resistance 37 and rheostat 38 or 39, as indicated. The rheostats or variable resistances 38 and 39 in the screen grid circuits for tubes 20 and 21 are provided to permit by their adjustment the upper end of the scale of the meters 30 and 31 in the anode-cathode circuits of these tubes to be adjusted to some assigned value (say 10 milliamperes).

Since the plate current at any grid voltage for a pentode tube is largely determined by the screen voltage, a cold-cathode tube 40 is connected between the biasing circuit for the screen grids of the tubes 20 and 21 and a common point in the cathode circuits for these tubes to reduce to a small amount the variations in the screen voltages due to variation in the plate battery 34.

The current meters 30 and 31 in the plate-cathode circuits of the tubes 20 and 21 are connected in a bridge circuit with the fixed resistances 41, 42, 48 and 49, and the variable resistances or rheostats 43 and 44 as indicated, to provide a means for adjusting the anode-cathode circuits of the tubes 20 and 21 to make the meters 30 and 31 more sensitive to changes in plate current, and also to minimize to some extent the effects of slight changes in plate current due to plate voltage variations.

In the unoperated condition of the time measuring circuit as indicated in Fig. 1 with no tone being received and with the energizing circuit for relay 19 broken at switch 17, the relays 12 and 19 are released, and their armatures are held on the back contacts of the respective relays. This connects the control grids of tubes 20 and 21 together through the two 180,000-ohm resistances 27 and 29 and the two 5-megohm resistances 26 and 28 in series. To condition the time measuring circuit to measure the time difference between the operation of the two relays 12 and 19, the key 45 must be thrown to the left (MEAS) position to remove the normal short circuits across the condensers 22 and 24 in the control grid-cathode circuits of the tubes 20 and 21. The key 49 is provided for connecting the additional condensers 23 and 25 of suitable values in parallel with condensers 22 and 24, respectively, to increase the charging capacity by the necessary amount, if the time interval to be measured is greater than a certain value.

The potentiometer 46, the (CAL) jack 47 and the voltmeter 48 associated with the center (ADJ 0) position of the switch 45 are provided for making a zero adjustment of the meters 30 and 31, and to permit a calibration (plate current versus time) to be made of the time measuring circuit without involving the use of auxiliary time measuring equipment.

The various steps in adjusting, calibrating and using the time-measuring circuit of Fig. 1 may be described briefly as follows:

(1) The rheostats 43 and 44 in the bridge circuit in the output of tubes 20 and 21 are adjusted for zero current in the meters 30 and 31;

(2) The key 45 is thrown to the (ADJ 10) position, and the rheostats 38 and 39 in the screen grid circuits of tubes 20 and 21 are adjusted to set the upper ends of the scales of the meters 26 and 27 to the assigned value, say 10 milliamperes;

(3) Return key 45 to the normal (ADJ 0) position and check the zero current adjustment in the meters 30 and 31;

(4) Insert voltmeter 48 into the (CAL) jack 47 and note the reading of biasing voltage, and note the readings of meters 30 and 31 for various adjustments of the variable resistance 46;

(5) The time-voltage characteristic for the charging circuit may be computed from the expression

$$v=E\left(l-\epsilon^{-\frac{t}{RC}}\right)$$

where R is the value of resistance 27 or 28 (180,000 ohms), C is the capacity of condenser 22 or 24 (1 MF), and E is the voltage measured by voltmeter 48 in (4) (It is better to plot both the calibration characteristic obtained in (4) and the computed time characteristic in terms of steps of adjustment of the variable calibrating resistance 46 since this automatically takes care of the differences in the normal bias voltage due to ballast lamp, tube and applied voltage variations in the circuit);

(6) Check the zero adjustment on meters 30 and 31;

(7) Have tone *f* sent from the transmitting terminal TS for synchronization purposes;

(8) With the synchronizing relay 19 deenergized, as indicated by the dark condition of the (TIME) lamp 50 controlled thereby, the key 45 should be thrown to the (MEAS) position;

(9) Note readings on meter 30 or 31, after relays 12 and 19 operate, and before lamp 50 goes out, and return key 45 to normal; and

(10) Read time on calibration chart corresponding to the meter reading.

The detailed operation of the time measuring circuit of Fig. 1 is as follows:

For the case where the switching apparatus at the two terminal stations are out of synchronism and the operation at the receiving station RS is behind that at the transmitting station TS, the tone impulse *f* from the station TS impressed on the input of control tube 11 by transformer 33 will cause operation of that tube to operatively energize relay 12 while relay 19 is still in the deenergized condition. Relay 12 as biased is a fast relay and is capable of following the operation of the relays in the switching circuit at the distant terminal quite closely (say, within 0.005 second). Relay 12 will operate to shift its armature from the back to the front contact breaking the connection of the control grids of the tubes 20 and 21 through the resistances 26, 27, 28 and 29 and the back contacts of the two relays 19 and 12, and causing the condenser 24 to begin to be charged from battery 35 through the closed contacts of the two relays and resistance 29 by virtue of ground being connected to resistance 29 and a potential of approximately −15 volts which is normally connected to one side of condenser 24. The normal short circuits around condenser 24 and condenser 22 had previously been removed by throwing the key 45 to the left (MEAS) position.

The charging of condenser 24 will gradually make the voltage on the control grid of the tube 21 less and less negative and result in a corresponding increase in the plate current of tube 21 which will be indicated by the reading of the meter 31 in its plate circuit.

When the relay 19 operates in response to the later operation of the switching apparatus 2 at station RS, to shift its armature from the back to the front contact, the connection of ground to resistance 29 through the former contact is removed and the charging of the condenser 24 is stopped. The operation of the relay 19 is indicated to the observer by the lighting up of lamp 50 and its release by the lamp 50 going out.

The reading of the meter 31 must be taken during the known time interval of the pulse received from station TS, that is, before relay 12 releases, and before the synchronizing relay 19 releases, that is, while the lamp 50 is still lighted. This reading of meter 31 will be proportional to the maximum charge on the condenser 24 and will give a measure of time interval between the operation of the relays 12 and 19, which is the time interval by which the switching mechanism at the two stations are out of synchronism, when reduced to time units by reference to the calibration chart of the time measuring circuit. Of course, this time interval may be read directly if a time scale obtained by calibration is placed on the meter.

After the time measurement for this switching operation has been taken, the key 45 should be returned to the normal condition indicated in Fig. 1, in which the normal short circuits are placed across the condensers 24 and 22 so that a zero adjustment of the circuit may be made. The key 45 may then be again thrown to the (MEAS) position so that the circuit will be in condition for measuring the asynchronism for a succeeding switching operation when another synchronizing pulse is transmitted from the transmitting station TS in the manner previously described.

In case the switching mechanism at station RS is ahead of that at station TS, relay 19 will be operated first by the first switching mechanism which will be indicated by the lighting of lamp 50. The shifting of the right-hand armature of relay 19 from the back to the front contact will break the normal connection of the control grids of tubes 20 and 21 to each other through the former contact, and will cause condenser 22 to begin to be charged from battery 35 through the closed contacts of relays 19 and 12 and resistance 27 by virtue of ground being connected to resistance 27 and a potential of approximately −15 volts to one side of condenser 22. The charging of condenser 22 will make the voltage on the control grid of tube 20 less and less negative and proportionately increases the plate current in the plate circuit of tube 20, which is measured by meter 30. When relay 12 operates at a later instant in response to the pulse of control energy of frequency *f* transmitted from station TS under control of the switching mechanism at that station, to break its armature and front contact the ground connection to resistance 27 is broken and the charging of condenser 22 is stopped. The maximum reading of meter 30 during the switching operation and before the two relays 12 and 19 have released will give a measure of the time interval between the operation of the two relays and thus of the amount of asynchronism of the switching apparatus at the transmitting and receiving stations.

In the case where the switching apparatus at the two stations are in synchronism and a synchronizing pulse is sent out from the transmitting station TS, the relays 12 and 19 will be operated at the same time and will respectively operate to prevent a charge being placed on the condensers 24 and 22 so that the meters 30 and 31 in the plate circuits of tubes 20 and 21 will not register a reading indicating this synchronism.

It is to be understood that the particular values specified for the elements in the time measuring circuit of the invention as described above and illustrated in the drawing are to be taken by way of example only and not as limiting the invention. Various modifications of the circuits illustrated in the drawing and described above which are within the spirit and scope of the invention will occur to persons skilled in the art.

What is claimed is:

1. A circuit for measuring the time interval elapsing between the operation of different switching devices comprising two electron discharge devices, each having an input circuit and an output circuit, a different electrical storage means in the input circuit of each discharge device, means responsive to the operation of each switching device to cause a different one of said storage means to be charged at the same uniform rate, means responsive to the operation of the switching device which is last to operate to stop the charging of said one storage means by operation of the other switching device, and metering means in the output circuit of each discharge device for indicating the variation in output current during the time interval in which the storage means in the input circuit of that device is being charged as a measure of that time interval and as an indication of which switching device has operated first.

2. A circuit for measuring the time interval elapsing between the operation of different switching devices comprising two electromagnetic relays adapted to be operated respectively in response to operation of a different one of said devices, a source of direct current, two electron discharge devices each having a control electrode, a cathode and an anode, and circuits therefor, a different electrical storage means in the control grid-cathode circuit of each discharge device, means responsive to the operation of each relay to connect said direct current source across a respectively different one of said storage means so that it will be charged from said source, and responsive to the release of that relay to disconnect said source from the storage means, means also responsive to the operation of each relay to prevent subsequent charging of the other storage means under control of the other relay, and a meter in the cathode-anode circuit of each discharge device for indicating the variation of plate current flow therein during a charging time interval as a measure of that time interval.

3. A system for indicating the amount and direction of asynchronism between the operation of identical switching apparatus at two stations of a transmission system comprising at one station means for causing a pulse of control energy to be transmitted to the other station each time the switching apparatus at said one station operates, the length of the pulse being proportional to the duration of the controlling switching operation, and at the other station, means for selecting the received control pulses, a first relay operatively responsive to each selected pulse, a second relay operatively responsive to each corresponding operation of the switching apparatus at said other station, two equivalent electrical storage means, means responsive to the operation of said first relay to cause one of said storage means to be charged at a uniform rate, and to prevent subsequent charging of the other storage means, means responsive to operation of said second relay to cause said other storage means to be charged at the same uniform rate, and to prevent subsequent charging of said one storage means, and separate means for indicating the charge on each electrical storage means during the charging time interval as a measure of that time interval and as an indication of the station at which the switching apparatus has operated first.

4. The system of claim 3, in which said indicating means comprising two electron discharge devices each having a control grid circuit including a different one of the electrical storage means, and a plate circuit including a different current meter for indicating the maximum amplitude of plate current flowing in the plate circuit during the charging interval.

5. The system of claim 3 in which said indicating means comprises two electron discharge devices each having a control grid circuit and a plate circuit, a different one of said storage means being connected in each control grid circuit so that its charge determines the amount of current flowing in the plate circuit, a meter in each plate circuit for indicating the current flow thereon, a bridge circuit including the two meters in corresponding arms and means for balancing said bridge circuit to compensate for differences in the plate circuit impedances.

6. The system of claim 3, in which said indicating means comprises two equivalent electron discharge tubes each having a control grid, a cathode and an anode, and circuits therefor, a different one of said electrical storage means being connected in the control grid-cathode circuit of each tube so that the charge thereon controls the bias on the control grid and thus the amount of plate current flow in the cathode-anode circuit of the tube, a current meter in the cathode-anode circuit of each tube and means for calibrating the meters so that the reading of the meter in the cathode-anode circuit of each tube indicates the time required to bring the electrical storage means in the control grid-cathode circuit of that tube to its maximum value during the time the controlling relay is operated.

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