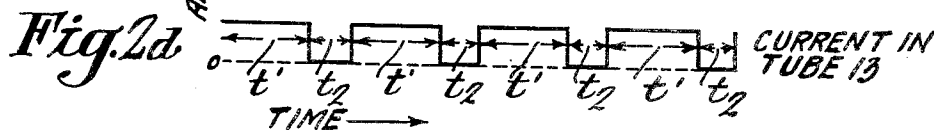
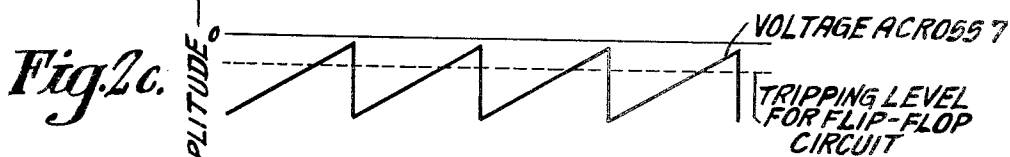
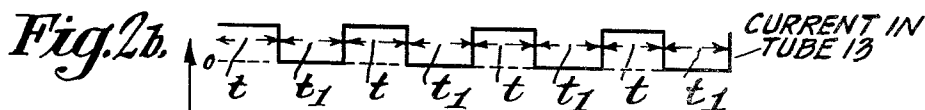
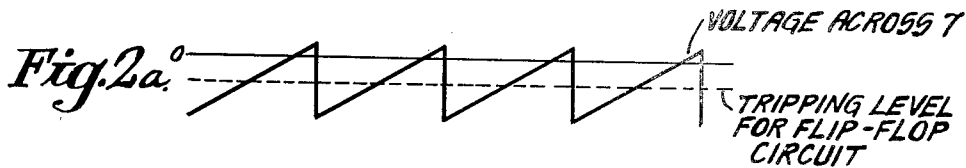
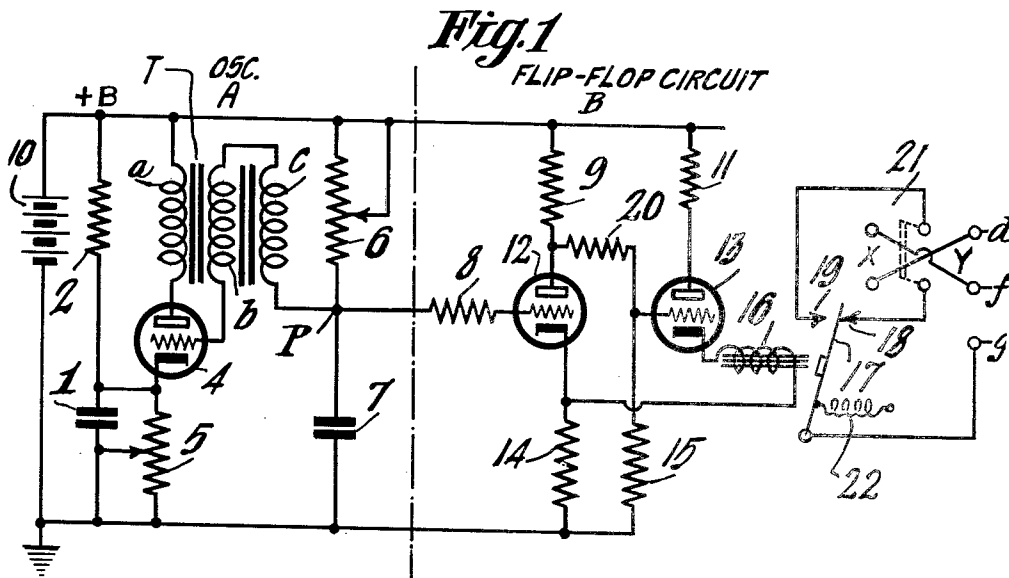


March 11, 1952

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ELECTRONIC TIMING DEVICE

2,589,085

Filed Oct. 1, 1947



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2,589,085

ELECTRONIC TIMING DEVICE

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Application October 1, 1947, Serial No. 777,251

3 Claims. (Cl. 250—27)

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This invention relates broadly to electric control circuits, and more specifically to an electronic timing device, sometimes referred to as an interval timer.

The present invention provides a method of and electronic apparatus for automatically opening and closing a circuit at any desired frequency ranging from less than 1 cycle per minute to over 120 cycles per minute. A feature of the invention comprises an arrangement which enables the ratio of closing to opening times to be continuously adjusted over any desired range up to 60% of the cyclic time interval.

A more detailed description of the invention follows in conjunction with a drawing, wherein:

Fig. 1 illustrates schematically the electrical circuit embodiment of the invention, and

Figs. 2a to 2d are curves given in explanation of the operation of the circuit of Fig. 1.

Referring to Fig. 1, the system of the invention comprises a pulse or blocking type of feedback oscillator A which drives or controls a self-restoring flip-flop type of circuit B. This flip-flop circuit, is, in effect, an Eccles-Jordan type of self-restoring trigger circuit having a pair of vacuum tube electrode structures in which only one electrode structure at a time passes anode current.

Pulse oscillator A includes a triode vacuum tube 4 whose anode is connected through one winding *a* of a three-winding transformer T to the positive terminal +B of a source of unidirectional current 10. In circuit with the cathode of tube 4 and connected between the cathode and ground is the parallel combination of a potentiometer 5 and a by-pass condenser 1. A bleeder resistor 2 is connected between the cathode of tube 4 and the positive +B terminal. The grid of tube 4 is connected through the other two windings *b* and *c* (in series) of the transformer T to one end P of variable resistor 6. Windings *b* and *c* of transformer T are so connected that the voltage developed between point P and the grid of tube 4 is greater than the voltage developed across winding *a*. Resistor 6 is connected between positive terminal +B and ground through a serially arranged condenser 7.

The flip-flop or trigger circuit B comprises a pair of triode vacuum tube electrode structures 12 and 13, which although shown within separate evacuated envelopes may be contained within a single evacuated envelope. Only one tube at a time is conductive in this trigger circuit. In the stable state, tube 12 is nonconductive and tube 13 conductive. In the active or tripped

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state, tube 12 is conductive and tube 13 nonconductive. The anodes of tubes 12 and 13 are separately connected to the +B terminal of battery 10 through resistors 9 and 11, respectively.

The anode of tube 12 is connected to the grid of tube 13 through resistor 20. The grid of tube 13 is connected to ground through resistor 15. In effect, resistors 20 and 15 may be considered a voltage divider. The cathode of tube 13 is connected through the operating winding of a load relay 16 to the cathode of tube 12. A common cathode resistor 14 is provided between ground and the cathode of tube 12. A resistor 8 is connected between the grid of tube 12 and the junction point P of resistor 6 and condenser 7 in the pulse or blocking type oscillator A.

Relay 16 in the cathode circuit of tube 13 of the flip-flop circuit B is provided with an armature 17 which is adapted to engage either of two oppositely disposed contacts 18 and 19. In the unenergized condition of this relay, the armature 17 engages contact 18 by virtue of the pressure exerted by a return spring 22.

As mentioned above, the flip-flop circuit B is so arranged that normally tube 12 is cut-off (that is, biased to the anode current cut-off condition), and tube 13 conducts, in which normal condition relay 16 will be energized and armature 17 will engage contact 19.

A detailed description of the operation of the electronic device of the invention will now be given:

The frequency of the pulse oscillator A is adjusted by means of potentiometer 6 whose adjusted value determines the rate of build-up of voltage across condenser 7. When the voltage across condenser 7 rises above the bias potential on tube 4, the bias potential being determined by the adjustment of variable resistor 5 in the cathode circuit, current starts to flow through the anode winding *a* of transformer T. This flow of current in winding *a* results in a voltage being developed across windings *b* and *c*. Windings *a*, *b* and *c* of transformer T are so poled that when the current in winding *a* increases, a positive voltage (positive with respect to the junction point P of condenser 7 and resistors 6 and 8) is applied to the grid of tube 4. This positive voltage further increases the anode current in tube 4 which flows through winding *a* and in turn further increases the positive voltage applied to the grid. This action continues until the voltage developed across condenser 7 approaches the voltage across the grid windings. At this time the rate of change of

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anode current in tube 4 starts to decrease, as a result of which there is a decrease in grid voltage across the grid windings which, in turn, further decreases the anode current. This action continues until current through tube 4 ceases completely (that is, tube 4 is cut-off). When tube 4 cuts-off, a negative voltage, approximately equal in magnitude to the voltage pulse developed across the grid windings *b* and *c* of transformer T, is present across condenser 7. This voltage starts to rise, the rate of rise being determined by the time constant of resistor 6 and condenser 7. By varying the tap on variable resistor 6, the rate of voltage rise across condenser 7 is varied and hence the repetition rate or frequency of the pulses produced by pulse oscillator A is varied. Stated in other words, during the time when the grid of tube 4 is positive, electron current flows from the grid of tube 4, through windings *b* and *c* of transformer T, and into condenser 7, resulting in a charge being stored there-in. During the time interval when tube 4 is cut-off, this charge starts to leak off through resistor 6, resulting in a sawtooth wave being developed across condenser 7 as shown in Figs. 2a and 2c. The rate at which this charge leaks off is a function of the values of resistor 6 and condenser 7. When the charge leaks off to a value such that the voltage at point P is slightly less than the bias applied to the cathode of tube 4, (that is equal to the bias applied to tube 4 less the cut-off potential of the tube used), it again starts to conduct causing condenser 7 to be recharged, thus starting a new cycle of operations.

The variable resistor 5 located in the cathode circuit of tube 4 determines the potential with respect to ground at which tube 4 will start to conduct current. The bleeder resistor 2 increases the voltage drop across resistor 5. In some cases this resistor may be eliminated. Condenser 1 is a bypass capacitor which maintains the voltage across resistor 5 constant by bypassing the *a-c* components of cathode current.

It will thus be appreciated that the amplitude of voltage change across condenser 7 is a function of the characteristics of transformer T and tube 4 and the size of condenser 7. When resistor 5 is adjusted, this only changes the potential across condenser 7 with respect to ground at which tube 4 starts to conduct; and hence changes the maximum negative and positive potential which is developed across condenser 7, providing the potential developed across resistor 5 is small compared with the anode potential. That is, the peak-to-peak amplitude of the sawtooth voltage developed across 7 does not appreciably change when resistor 5 is adjusted, whereas the D. C. voltage across 7 changes by an amount proportional to the voltage change across 5.

The waveforms of the voltage across condenser 7 for two conditions are shown in the curves of Figs. 2a and 2c. It should be noted that these waveforms are sawtooth in character. In Fig. 2a the bias developed across resistor 5 is such that the potential across condenser 7 rises to a slightly positive value with respect to ground before tube 4 conducts, and in Fig. 2c the tap on the cathode bias resistor is raised toward the cathode of tube 4 and the voltage across condenser 7 rises to a value slightly less than zero before the tube 4 conducts.

Tube 12 of the flip-flop circuit B is normally

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non-conductive (cut-off) due to the bias developed across resistor 14 by the cathode current flowing in normally conductive tube 13. The normal cathode current of tube 13 is sufficient to operate relay 16 and close contacts 17 and 19. When the voltage on the grid of tube 12 rises to a point where tube 12 starts to conduct (due to the application of the sawtooth waveform from the pulse oscillator A), the anode voltage of tube 12 starts to drop. As a result, the positive voltage applied to the grid of tube 13 starts to decrease, thereby causing the current in tube 13 to decrease. The decrease in current in tube 13 causes the biasing voltage developed across resistor 14 to decrease, which in turn allows tube 12 to carry more current and hence reduce its anode potential to a still lower value. This action continues until tube 13 is completely cut-off and tube 12 is carrying full current.

Tube 12 remains in a conducting condition and causes tube 13 to remain non-conducting for the remainder of the applied sawtooth wave. The result is that the relay 16 remains in its de-energized state for this period and contacts 17 and 18 are engaged. In this condition the bias developed across resistor 14 by the current in tube 12 is sufficient to maintain tube 13 beyond cut-off.

At the end of the sawtooth wave (when the pulse oscillator becomes operative and discharges 7), the grid of tube 12 is suddenly reduced to a value which causes tube 12 to cease conducting and hence the bias voltage developed across resistor 14 by tube 12 is removed and also the positive voltage applied to the grid of tube 13 increases. Thus tube 13 again establishes a bias across resistor 14 which causes tube 12 to be non-conductive.

Resistor 8 in series with the grid of tube 12 limits the maximum grid-to-cathode potential of tube 12 to zero and prevents the grid circuit of tube 12 from appreciably loading condenser 7. The value of resistor 9 is so chosen that a sufficient amount of anode current flows when tube 12 is conducting so as to maintain tube 13 cut-off.

Since a predetermined potential with respect to ground must be reached before tube 12 conducts, then by varying resistor 5 it is possible to make tube 12 conduct over a variable portion of the sawtooth voltage developed across condenser 7. In this way a change in bias on the pulse oscillator will produce a change in the time of control of the flip-flop trigger circuit with only a negligible change in the frequency of the pulse oscillator.

In Figs. 2a and 2c, the dashed line indicates the tripping level of the flip-flop circuit B. It should be noted that the tripping potential is negative with respect to zero by the same amount in Figs. 2a and 2c. In the case of Fig. 2a, the flip-flop circuit B trips at a lower amplitude on the sawtooth waveform than in the case of Fig. 2c due to the sawtooth rising to a higher value in Fig. 2a than in Fig. 2c.

The anode current waveforms for tube 13 in the two cases of Figs. 2a and 2c are shown in Figs. 2b and 2d, respectively. Since the flow of current in tube 13 causes the relay 16 to operate, it will be seen that the waveforms of Figs. 2b and 2d also correspond to the operating times of relay 16. Time intervals *t* and *t'* of Figs. 2b and 2d thus represent the time intervals during which

relay 16 is operated and contacts 17 and 19 closed,

while time intervals t_1 and t_2 represent the time intervals during which relay 16 is unenergized and contacts 17 and 18 closed.

Contacts 17, 18 and 19 of relay 16 are connected to a suitable utilization circuit.

The system of the invention provides a means for energizing and de-energizing a relay coil which is used to close utilization circuits at the frequency of the pulse oscillator A. The ratio between energized time and de-energized time may be made continuously adjustable over ranges up to 60% of the cyclic period. A switch 21 is used to extend the range of this unit as follows: In normal operation the relay 16 may be made to be de-energized for periods of time up to 60% of the cyclic period. In other words, contacts 17 and 18 may be engaged for periods of time ranging from 0 to 60% of the period of the pulse oscillator. With switch 21 in position X, terminal d is connected to terminal g through contacts 17 and 18 when the relay 16 is de-energized. Thus it is obvious that terminal d may be connected to g via contacts 17 and 18 for periods of time ranging from 0 to 60% of the period of pulse oscillator A. If it is desired to have these terminals connected together for longer periods of time, from 40% to 100% of the period, then switch 21 may be thrown to position Y and terminal d will be connected to terminal g via contacts 17 and 19 of relay 20.

This system may be used to control other electronic circuits by removing coil 16 and using the positive pulse developed across resistor 11 to drive such electronic circuits. It will be noted that a positive pulse of variable width and at a frequency determined by the design of pulse oscillator A is developed across resistor 11.

What is claimed is:

1. An electronic timing system comprising a vacuum tube pulse oscillator circuit producing a repetitive sawtooth voltage, means for varying the cut-off bias on said vacuum tube, a flip-flop circuit having a predetermined tripping level and coupled to and under control of said pulse oscillator, said flip-flop circuit having a normally non-conductive electrode structure and a normally conductive electrode structure interconnected regeneratively, a connection from said normally nonconductive electrode structure to said pulse oscillator circuit, whereby the variation of the cut-off bias on said vacuum tube varies the time at which said tripping level is reached by said sawtooth voltage, and a utilization circuit coupled to said normally conductive electrode structure.

2. An interval timing system comprising a sawtooth voltage generator comprising a vacuum tube having anode, grid and cathode electrodes, a transformer having separate windings connected to said anode and grid, a variable bias resistor in the cathode circuit of said tube, a condenser in said generator across which the sawtooth voltage is produced, a flip-flop circuit having a predetermined tripping level and under control of

said sawtooth voltage generator, said flip-flop circuit including first and second electrode structures each including a grid, an anode and a cathode, means for supplying polarizing potentials to the anodes of said structures, a connection including a current limiting resistor between the grid of said first structure and said condenser of the sawtooth voltage generator, whereby the variation of said bias resistor varies the time at which said tripping level is reached by said sawtooth voltage, a resistor between the anode of said first structure and the grid of said second structure, a common resistor for the cathodes of said first and second structures, and a utilization circuit coupled to and controlled by the current flow in said second electrode structure.

3. An interval timing system comprising a sawtooth voltage generator comprising a vacuum tube having anode, grid and cathode electrodes, a source of unidirectional potential, a transformer having a winding between the positive terminal of said source and said anode, a variable bias resistor connected between said cathode and the negative terminal of said source, a condenser in series with a variable resistor connected across said source, a pair of series connected windings of said transformer connected between said grid and the junction of said condenser and its serially arranged resistor, a flip-flop circuit under control of and tripped by said sawtooth voltage generator, said flip-flop circuit including a first normally non-conductive and a second normally conductive electrode structure each including a grid, an anode and a cathode, connections from the anodes of said structures to the positive terminal of said source, a connection including a current limiting resistor between the grid of said first structure and said junction, whereby the variation of said bias resistor affects the time of tripping of said flip-flop circuit, a resistor between the anode of said first structure and the grid of said second structure, a common resistor connecting the cathodes of said first and second structures to the negative terminal of said source, and a utilization circuit coupled to the cathode of said second structure and controlled by the current flow in such structure.

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