

Nov. 29, 1960

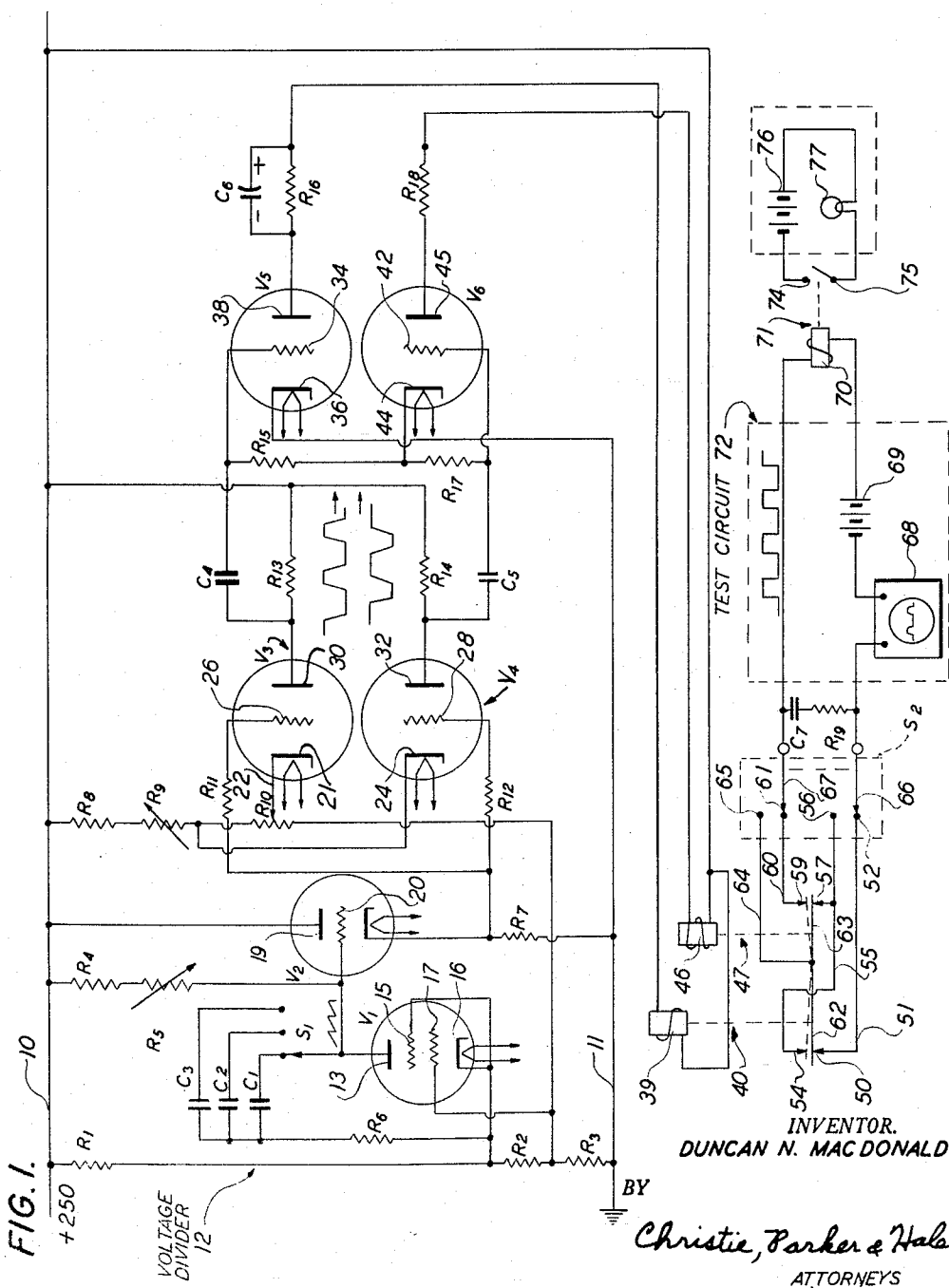
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PULSE GENERATOR

Filed Dec. 27, 1954

2 Sheets-Sheet 1



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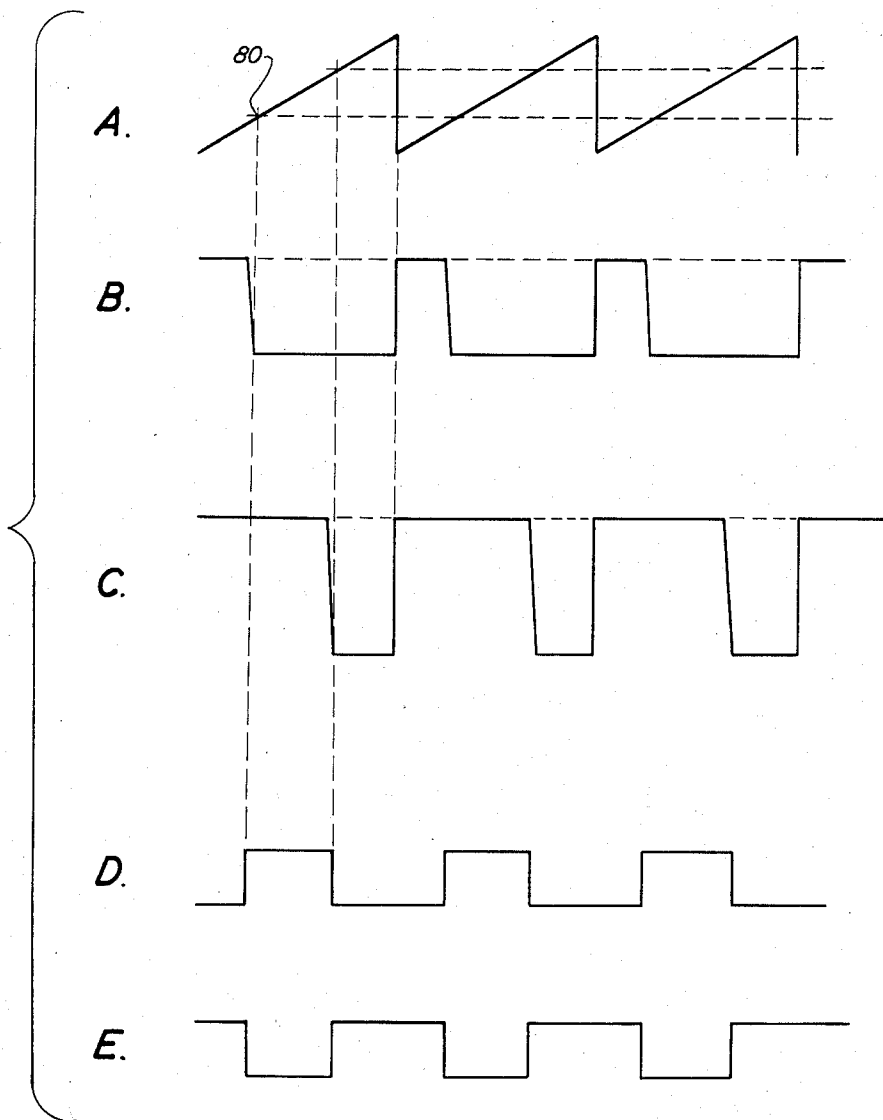
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FIG. 2.



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PULSE GENERATOR

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1 Claim. (Cl. 307—132)

This invention relates to electric pulse generators, and provides a compact, simple source of contact closure pulses, i.e., pulses which are produced by the closing and opening of mechanical contacts.

Contact closure pulses can be made to contain much more power than pulses produced electronically only and are capable of driving low impedance loads. Such pulses are useful for a wide variety of purposes, such as determining performance characteristics of electromagnetically operated equipment such as solenoids, actuators, counters, relays and switches. In the development, application and maintenance of these low impedance electromagnetic devices there is often a need for quantitative information on the timing characteristics for correct operation under various conditions. Generally, the operate and release times of the devices under various conditions provides the necessary information.

For example, in the case of a simple solenoid or relay, operate and release times can be obtained by applying to the relay a train of electric pulses of known repetition rate. The pulse width may be increased until the relay first operates and just follows the pulses. The pulse width then equals the operate time. The release time may be obtained by applying to the relay a relatively wide pulse, i.e., one which is sufficiently wide that the time intervals between pulses is insufficient to allow the relay to release. If the pulses are gradually decreased in width until the relay first releases and just follows the pulse, the interval between pulses then equals the release time.

Briefly, the invention contemplates a pulse generator circuit which comprises a pair of switches connected in series and adapted to be connected to a source of electrical power. Each of the switches is provided with actuating means responsive to an electrical signal to operate the respective switch. There is also provided means for generating an electric signal and applying it to each of the switch actuating means. Each switch actuating means is arranged to operate responsive to the electric signal at different times so that the switches are not actuated simultaneously, thus producing a circuit which may be either open or closed for the interval between the actuation of the switches.

In a preferred form, a series of signal pulses are generated electronically and applied to each of the actuating means of the switches. Means are provided for shifting the phase of operation of one switch with respect to the other so that pulse output from the switches is equal to the difference in phase of the operation of the two switches. In this manner a pulse train is generated in which the repetition rate and duty cycle of the pulses can be varied infinitely and independently of each other even though the switches which generate the pulse have finite operate and release times.

These and other aspects of the invention will be more clearly understood from the accompanying drawings in which:

Fig. 1 is a schematic circuit diagram of one form of the

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invention illustrating how it may be used to obtain operate and release times of a test relay;

Figs. 2A through 2E represent typical wave forms produced at various points in the circuit of Fig. 1.

Referring to Fig. 1, a positive lead 10 and a negative lead 11 are arranged to be connected to a source of D.C. potential (not shown). Resistors R_1 , R_2 , and R_3 are connected in series across the positive and negative leads to form a voltage divider 12. Plate 13 of a tube V_1 which is a thyatron serving as a saw-tooth relaxation oscillator is connected serially with a resistor R_4 and a variable resistor R_5 to the positive lead. The plate 13 is also arranged to be connected through a 3-pole selector switch S_1 through either one of capacitors C_1 , C_2 or C_3 in series with a resistor R_6 to the voltage divider between resistors R_1 and R_2 . The thyatron screen 15 and cathode 16 are connected to the voltage divider between R_1 and R_2 . The thyatron control grid 17 is connected to the voltage divider between resistors R_2 and R_3 .

Plate 19 of a vacuum tube V_2 serving as a cathode follower is connected to the positive lead 10 and the cathode is connected in series with a cathode resistor R_7 to the negative lead. The cathode follower buffers or isolates the oscillator from the remainder of the circuit. The output of the oscillator plate is connected to the cathode follower grid 20. A resistor R_8 , a variable resistor R_9 , and a potentiometer R_{10} are connected serially between the positive lead and a point between resistors R_2 and R_3 .

A cathode 21 of a vacuum tube V_3 , arranged to serve as a first slicer, is connected to movable tap 22 of potentiometer R_{10} and the cathode 24 of a vacuum tube V_4 which serves as a second slicer is connected between resistor R_9 and potentiometer R_{10} . For the purpose of this invention the term "slicer" is used to mean an electron discharge device such as a vacuum tube or transistor which controls the flow of electrons in response to an electric signal applied to a control electrode, such as a control grid in a vacuum tube. The output of the cathode follower is connected in series with a resistor R_{11} to grid 26 of the first slicer and in series with a resistor R_{12} to grid 28 of the second slicer. Plate 30 of the first slicer is connected in series with a plate load resistor R_{13} to the positive lead, and plate 32 of the second slicer is connected in series with a plate load resistor R_{14} to the positive lead. The plate output of the first slicer is connected in series with a capacitor C_4 to grid 34 of a vacuum tube V_5 which serves as a first power amplifier. The grid of the first power amplifier is connected through a grid leak resistor R_{15} to cathode 36 of the first power amplifier which is connected to the negative lead. The plate 38 of the first power amplifier is connected in series with a resistor R_{16} and the winding 39 of a first double-pole, single-throw relay switch, indicated generally at 40, to the positive lead 10. A by-pass condenser C_6 is connected across the resistor R_{16} .

The plate output of the second slicer is connected in series with a capacitor C_5 to grid 42 of a vacuum tube V_6 which serves as a second power amplifier. The grid of the second power amplifier is connected in series with a grid leak resistor R_{17} to the cathode 44 of the second power amplifier. The plate 45 of the second power amplifier is connected in series with a resistor R_{18} and the winding 46 of a second double-pole, single-throw relay switch, indicated generally at 47, to the positive lead. Preferably the first and second relays are high speed power relays such as mercury relays.

The first relay 40 has a first contact 50 connected by a first lead 51 to a first contact 52 of a double-pole, double-throw switch S_2 . The first relay has a second contact 54 connected by a second lead 55 to a second contact 56 of the switch S_2 . The second relay has a first contact 57 connected to the second lead 55, the second

pole 56 of the switch S_2 , and to the second contact 54 of the first relay. The second relay has a second contact 59 connected by a third lead 60 to the third contact 61 of the switch S_2 . The removable armatures 62, 63 of the first and second relays, respectively are connected by a fourth lead 64 to the fourth contact 65 of the switch S_2 . The movable contacts 66, 67 of the switch S_2 are connected in series with an oscilloscope 68, a source of D.C. potential 69, and the winding 70 of a relay 71 which is under test to form a test circuit 72.

A capacitor C_7 and a resistor R_{19} are connected in series across the movable contacts of switch S_2 to reduce arcing of the contacts of the first and second relays as switch S_2 is operated. The contacts 74, 75 of the relay under test are connected in series with a source of D.C. potential 76 and with an element for indicating a completed circuit, e.g., an incandescent lamp 77, to form an indicator circuit.

For simplicity, the various conventional cathode heater circuits for the above circuit are omitted.

A fuller understanding of the above circuit may be had from reference to the following table which gives as typical but not limiting the values of components used in an actual circuit:

Resistors, ohms

R_1 —20K	R_{11} —1M
R_2 —200	R_{12} —1M
R_3 —25K	R_{13} —125K
R_4 —200K	R_{14} —125K
R_5 —750K	R_{15} —1M
R_6 —100	R_{16} —2K
R_7 —25K	R_{17} —1M
R_8 —5K	R_{18} —2K
R_9 —10K	R_{19} —100
R_{10} —10K	

Capacitors, mfd.

C_1 —1.5	C_5 —1
C_2 —.4	C_6 —10
C_3 —.1	C_7 —.02
C_4 —1	

Vacuum tubes

V_1 —2D21	V_4 — $\frac{1}{2}$ 12AX7
V_2 — $\frac{1}{2}$ 12AU7	V_5 — $\frac{1}{2}$ 12AU7
V_3 — $\frac{1}{2}$ 12AX7	V_6 — $\frac{1}{2}$ 12AU7

The operation of the circuit to determine the operate time of the test relay is as follows: The oscillator produces at its plate a series of saw-tooth signal pulses having the wave form illustrated in Fig. 2A. Both slicers (vacuum tubes V_3 and V_4) are biased to cut-off, the cathode of the first slicer being at a most negative value than the cathode of the second slicer by the amount determined by the potentiometer R_{10} , thus the first slicer will become conductive before the second slicer as the voltage applied to the grids of the slicers is increased in a positive direction. Before the voltage from the oscillator reaches the value indicated at 80 in Fig. 2A, both slicers are cut-off and current is drawn through both power amplifiers so that both the first and second relays are energized to hold their respective armatures up in the dotted line position shown in Fig. 1.

Assuming the switch S_2 to be in the lower position shown in Fig. 1, power pulses are supplied to the test circuit as follows: As the voltage from the oscillator, which is fed through the cathode follower to the grids of each of the slicers, reaches the value indicated at 80 in Fig. 2A, the first slicer begins to conduct and produces a negative actuating pulse as shown in Fig. 2B. This negative pulse is applied to the grid 34 of the first power amplifier and causes the first power amplifier to stop conducting, thus de-energizing the first relay 40 allow-

ing its armature 62 to move down from the second contact 54 to the first contact 50. This completes the test circuit through the third lead 60, the armature 63 of the second relay 47, the armature 62 of the first relay 40 and the first lead 51. At a slightly higher voltage in the cycle of the oscillator output the second slicer begins to conduct and produces a negative actuating pulse as shown in Fig. 2C which is applied to the grid 42 of the power amplifier causing the second power amplifier to stop conducting and thus de-energizing the second relay 47. This interrupts the test circuit which was previously completed when the first relay 40 was de-energized.

As the output of the oscillator reaches its peak value and drops back to its minimum value, both slicers stop conducting and both power amplifiers begin to draw current again. The by-pass capacitor C_6 across the resistor R_{16} in the plate circuit of the first power amplifier insures that the first relay operates before the second relay, thus preventing an unwanted remaking of the test circuit. The above cycle is repeated so that a series of pulses as shown in Fig. 2D are generated in the test circuit.

Assuming that at first the width of the test pulses are less than the operate time of the test relay 71, the indicator circuit will not be closed and the incandescent lamp 77 will fail to light. By making the cathode 21 of the first slicer more negative by adjustment of potentiometer R_{10} thus allowing the first slicer to conduct earlier, the pulse width can be increased until it just equals the operate time of the test relay 71. This will be apparent in the indicator circuit when the incandescent lamp 77 first lights. The pulse width may then be measured either from the oscilloscope 68 in the test circuit or computed from an electronic counter.

The duty cycle of the pulse generator is equal to the width of the pulse output of the oscillator and the percent of the duty cycle used to keep the test circuit closed can be varied from 0 to 100% by using the switch S_2 to reverse the polarity of the test circuit. For example, assume that the percent of the duty cycle illustrated in Fig. 2D required to operate the test relay is considerably less than half of the total duty cycle. Once the operate time has been determined, the switch S_2 is moved up from the position shown in Fig. 1. The train of pulses now generated in the test circuit are as illustrated in Fig. 2E since, when both relays are energized, the test circuit is completed through the second lead, the armature of the first relay and the fourth lead. When the first relay 40 is de-energized, the test circuit is broken, but when the second relay 47 is de-energized the test circuit again completed through the second lead 55, the armature 63 of the second relay 47 and the fourth lead 64. When the two relays 40, 47 are energized, e.g., when the oscillator output drops from maximum to minimum value, the armature 62 of the first relay 40 operates first to complete the test circuit through the second lead 55, the armature 62 of the first relay 40 and the fourth lead 64 before the armature 63 of the second relay 47 operates to interrupt the previously completed test circuit. Thus a relatively wide pulse is obtained as shown in Fig. 2E. Assuming pulses are so wide that the intervals between the pulses are insufficient to allow the test relay to release, the interval can gradually be increased by decreasing the pulse width with the potentiometer R_{10} until the incandescent lamp 77 first goes out. At this instant the interval between the pulses represents the release time of the test relay.

The frequency output of the oscillator can be varied by selecting various capacitors C_1 , C_2 , C_3 through switch S_1 and by adjusting the value of the charging condenser, and the width of the output pulse can be adjusted with the potentiometer at R_{10} . Thus the invention provides a pulse generating circuit capable of driving low impedance loads and yet still infinitely variable in repetition rate and cycle duty. One advantage of these features is that electromagnetic devices can be operated repeatedly at

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various frequencies and "on-off" times to determine their dynamic operating characteristics, and thus provide information to permit an accurate prediction to be made of how a particular device will perform under given operating conditions.

I claim:

Low impedance switching apparatus for periodically making and breaking a circuit between a power source and a load at a controllable duty cycle, said apparatus comprising first and second relays each including a double-pole single-throw switch, a double-pole double-throw switch arranged to selectively connect the relay-operated switches in series circuit and in parallel circuit between the source and load, a saw-tooth wave generator having a variable repetition rate, means for actuating the first and second relays successively in response to the output of the saw-tooth wave generator including first and second bias-controlled conductive means connected to the saw-tooth wave generator and means for selectively vary-

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ing independently the bias level of the first of said conductive means to control the relative time of actuating the relays, and energy storage means connected to one of the relays for holding the one relay until the other is actuated, whereby the first relay to close during the rising portion of the saw-tooth wave is also the first relay to open during the following portion of the saw-tooth wave.

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