Nov. 8, 1960 H. M. ZEIDLER 2,959,731

DRIVE CIRCUIT

Filed July 24, 1959

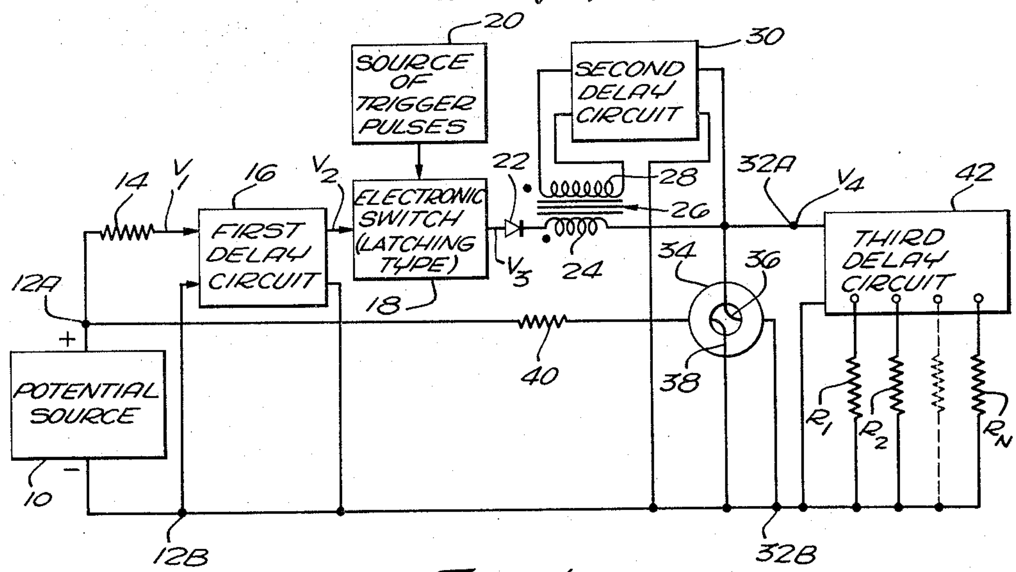

FIG. 1.

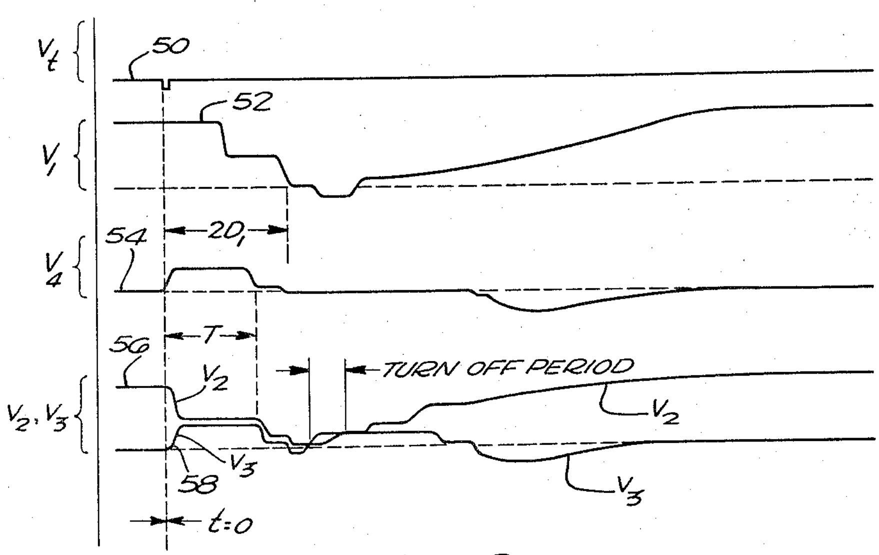

FIG. 2.

INVENTOR.
HOWARD M. ZEIDLER
BY
Lyon & Lyon
ATTORNEYS

United States Patent Office

2,959,731

Patented Nov. 8, 1960

2,959,731

DRIVE CIRCUIT

Howard M. Zeidler, Palo Alto, Calif., assignor to AMP Incorporated, Harrisburg, Pa., a corporation of New Jersey

Filed July 24, 1959, Ser. No. 829,456

5 Claims. (Cl. 323—89)

This invention relates to circuits for providing power for driving electronic apparatus with pulses and, more particularly, to improvements therein.

Electronic apparatus such as a shift register requires the generation of suitable regularly recurring drive pulses which have considerable amounts of pulse power. This is especially the case where it is desired to drive shift registers made of magnetic cores. A magnetic-core shift register is described, for example, in an article by H. D. Crane, entitled "Logic System Using Magnetic Elements and Connecting Wire Only," published in the Proceedings of the I.R.E., volume 47, pages 63 through 73, January 1959.

One technique for obtaining pulses with a considerable amount of power is to discharge, or "trigger," the energy stored in a delay line into the load. Such delay-line discharge technique is well-known; however, where magnetic-core circuits constitute the load, it is preferred that the voltage-time product of the pulses being applied thereto should be controlled so that the value required to drive the cores is provided regardless of factors, such as temperature variations, which can alter these requirements.

One of the methods used to insure that the voltage-time product of the pulses is proper at all times is to control such voltage-time product by a magnetic element which has the same characteristics as those of the cores in the load to be driven. Under these circumstances, it becomes necessary to control the flux reversal of the magnetic element upon the termination of a drive pulse; otherwise, faulty operation is experienced. Thus, a condition of operation imposed upon the equipment required to turn off an electronic device utilized in the triggering of the energy from the source delay line into the load is that it must delay flux reversal of the magnetic element used to control the voltage-time product until the effects produced thereby can be dissipated, without such delay slowing the operation of the drive circuit.

An object of this invention is to provide a novel "turn-off circuit" for a pulse-generation circuit having a magnetic element for controlling the voltage-time product of the pulses.

Another object of this invention is the provision of a novel arrangement for enabling the rapid turnoff of a latching-type electronic switch in a pulse-generation circuit, wherein the voltage-time product of pulses is controlled by a magnetic element.

Yet another object of the present invention is the provision of a novel and useful pulse-generation circuit for driving loads having a variable voltage-time product requirement.

These and other objects of the invention are achieved in an arrangement wherein a latching type of an electronic switch is employed to enable the discharge of the energy stored in the delay line into a load. By a latching type of electronic switch is meant an electronic switch which, when triggered by a pulse into its "closed" or conductive condition, remains conductive despite the re-

moval of the trigger pulse. The magnetic core having the same characteristics as the magnetic cores employed in the load is connected across the load terminals. Thereby, since this magnetic core is placed in the same environment as those in the load, it modifies the energy being applied to the load in order to maintain the voltage-time product at a proper value. Means are provided to drive this magnetic core by the pulse which is simultaneously being applied to the load. Means are also provided to reset this magnetic core to the original condition from which it is driven upon the termination of the driving pulse. In accordance with this invention, a circuit is provided whereby energy is derived from the driving pulse which is applied to the magnetic core to prevent it from being reset until such time as the electronic latching-type switch is open. Such opening is achieved by deriving energy from the pulse which was applied to the load and applying it to the electronic switch with a polarity which causes it to open.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention itself, both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawings, in which:

Figure 1 is a block diagram showing an embodiment of the invention; and

Figure 2 shows waveforms obtained at various points in Figure 1 which assist in an understanding of this invention.

Reference is now made to Figure 1, which is a block schematic diagram of an embodiment of the invention. A potential source **10** provides a constant voltage to a pair of input terminals **12A**, **12B**. The terminal **12A** is connected to a series impedance **14**, which is here represented as a resistor. The first delay circuit **16** has its input connected to resistor **14** and to the terminal **12B**. The resistance value of resistor **14** is high, when compared to the characteristic impedance of the delay line. This first delay circuit is the pulse-source delay line, which is permitted to discharge into the load.

The output of the first delay circuit **16** is applied to a switch **18**, which is here designated as an electronic switch (latching type). A source of trigger pulses **20** provides the signal required for closing the latching-type of electronic switch **18**. The latching-type switch **18** can be any of various well-known electronic switches, such as, for example, a thyratron, a thyristor, or a four-layer diode. The characteristics of this type of latching type of electronic switch are well known. Only a very small current can flow therethrough until a pulse or trigger signal is applied to the control electrode. Thereafter, current flows readily through the switch, until the potential thereacross is reduced below some relatively low value, depending upon the type of switch employed.

The eletronic switch **18** is connected through a diode **22** to the primary winding of a transformer **24**. The secondary winding **28** of the transformer **26** is connected to the input of a second delay circuit **30**. The output of the second delay circuit **30** is connected to a pair of load terminals **32A**, **32B**. The winding **24** is connected to the load terminal **32A**. A magnetic core **34** has a control winding **36** connected across the load terminals **32A**, **32B**. A reset winding **38** is connected through a resistor **40** to the input terminals **12A**, **12B**. The load is here represented for purposes of generality by a multiplicity of resistors R1, R2 . . . RN, which receive pulse energy in timed sequence from a third delay circuit **42**. The third delay circuit is connected to the load terminals **32A**, **32B** and the loads R1, R2 to RN are connected to the third delay circuit **42**.

The load resistors R1, R2 through RN may represent, for example, the four windings employed in operating a magnetic-core shift register. These windings, as exemplified in the shift register shown and described in the previously noted article by H. D. Crane, includes a first winding which advances digital data from the even-numbered cores employed in the shift register to the odd-numbered cores in the shift register. A second winding, known as the clear-even-core winding, resets or clears all the even-numbered cores in the register. The third winding is used to advance the data stored in the odd-numbered cores to the even-numbered cores. The fourth winding is employed for clearing all the odd-numbered cores to their reset condition.

The core **34** serves the function of establishing the voltage-time product of the pulses being applied to the load at the value required for the load. This result is obtained by using a core having the same characteristics as the cores employed in the load and exposing it to the same environment as the cores employed in the load.

Reference will be made to Figure 2 in explaining the operation of the block diagram, including an embodiment of the invention shown in Figure 1. Figure 2 shows the significant waveforms which are encountered in operating the circuit shown in Figure 1. The initiating trigger pulse provided by the source of trigger pulses **20** occurs at time $T=0$. This is represented by the wave shape **50**. This initiating trigger pulse turns on the latching-type electronic switch **18**. The first delay circuit **16**, which has been charged up from the potential source **10** through the resistor **14**, can now deliver its stored energy to the load over a period equal to twice the actual inherent delay of the first delay circuit **16**. This is represented by the wave shape **52**, which diminishes from a voltage value V_1 down to zero over an interval designated as 2D1. This interval commences at time $T=0$. The voltage appearing at the input to the first delay circuit is designated as V_1. The voltage appearing at the output of the first delay circuit is designated as V_2.

If a simple resistive load were presented to the output of the first delay circuit **16**, the voltage developed thereacross would be merely a rectangular voltage pulse of duration 2D1. However, in view of the presence of the core **34** and the connection of its control winding **36** across the load terminals **32A**, **32B**, current flows through the control winding to cause this core to be driven to magnetic saturation after the occurence of the desired number of volt microseconds. At this point, essentially a short circuit is provided to the output of the first delay circuit, thereby drastically decreasing the voltage V_4, which exists across the two load terminals **32A**, **32B**. The duration of the pulse voltage V_4 is represented at τ, and the voltage V_4 is represented by the wave shape **54**. It will be appreciated that the required volt microseconds for driving the cores in the load to their states of magnetic remanence will equal the product of τ and V_4.

The current which continues to be supplied by the first delay line continues to keep the magnetic core **34** in its saturated state. Such current continues to be supplied through the now-latched electronic switch **18**. At the end of the interval 2D1, however, the energy previously stored in the first delay circuit is expended, and at this time the magnetic core **34** would tend to become reset by the reset current being supplied to the reset winding **38** from the input terminals **12A**, **12B**. However, if allowed to become reset immediately, a voltage would be induced in the control winding which would tend to keep the latching electronic switch in its closed, or conducting, state. Consequently, the resetting of this core must be controlled in order to enable the first delay circuit to be rapidly charged up again for the next operation.

The resetting control of the magnetic core **34**, as well as the turnoff of the electronic switch **18**, is achieved by deriving energy from the pulse being applied to the load terminals and thereafter applying it to maintain the core **34** in its driven condition until the latching-type electronic switch can be opened. When the pulse which drives the load occurs, energy is derived for the turnoff circuit, including the transformer **26** and second delay circuit **30**, in two different directions. First, some pulse energy is injected without appreciable delay through the transformer **26** to the second delay circuit **30**. The delay of the second delay circuit should be such that the delayed pulse energy arrives at the control winding **36** of the core **34** just prior to the desired turnoff period for the electronic switch **18**. This energy is of the appropriate polarity to keep the core **34** in its set, or driven, state. It can thus operate to prevent the resetting of the core **34** during the critical turnoff period.

Concurrently with the injection of energy into the second delay circuit through the transformer **26**, additional energy from the original pulse is injected into the second delay circuit **30** in the reverse direction. This energy subsequently is applied to the transformer, where it is injected in series with the electronic switch circuit during the critical turnoff period. The polarity of this injected voltage V_3 is that required to enable turnoff of the latching-type electronic switch.

Referring to Figure 2, the voltage across the electronic switch **18** is the difference between voltages V_2 and V_3. This difference voltage is the significant voltage which determines whether or not the electronic switch **18** continues to conduct or is turned off. It will be noted from the wave shapes **56**, **58**, respectively representing the voltages V_2 and V_3, that the polarity of the difference voltage reverses, or goes negative, during the critical interval labeled as the turnoff period in Figure 2.

By providing a negative voltage, the latching-type electronic switch is turned off in an extremely short interval, after which the magnetic core **34** may be reset and charging of the first delay circuit can commence again. For optimum turnoff of the electronic switch, the diode **22** should have a hole storage period greater than that of the electronic switch itself, should a solid-state latching-type electronic switch be employed.

It should be appreciated from the above description that the interval between driving pulses, which may be derived from the pulse-generation circuit, in accordance with this invention, is reduced while enabling the utilization of a magnetic element for controlling the volt seconds of energy being applied to the load. Further, by actually applying a reverse voltage to the latching-type electronic switch, its turnoff time is rapidly effected, in spite of the current flowing from the potential source **10** (through resistor **14** and first delay circuit **16**), which is in a direction opposing the turnoff. Where relatively high-pulse repetition rates are involved, the resistor **14** must be of relatively low resistance, and the currents correspondingly large—specifically, larger than the holding current of the electronic switch **18**.

There has accordingly been shown and described herein a novel and useful circuit for enabling an increase in the drive-pulse frequency derived from a pulse-generation circuit with a magnetically controlled voltage-timed product pulse.

I claim:

1. In a pulse-generator unit of the type including a pulse source connected to apply pulses to a load through a latching type of electronic switch, and wherein a saturable magnetic core has a reset winding, and a drive winding connected across said load for volt-second regulation, an improved turnoff circuit for said unit comprising means for deriving from a pulse being applied to said load a turnoff voltage for turning off said latching device, means for applying said turnoff voltage to said latching device after said pulse is applied to said load from said pulse source, means for deriving from said pulse being applied to said load a saturation-maintaining voltage, and

means for applying said saturation-maintaining voltage to said drive winding while said turnoff voltage is being applied to said latching device.

2. In a pulse-generator unit of the type including a pulse source connected to a load through a latching type of switch and wherein a saturable magnetic core has a reset winding, and a drive winding connected across said load for volt-second regulation, an improved turnoff circuit for said unit comprising a delay-circuit having an input and an output and a delay interval on the order of the interval after the application of a pulse from said source to said load at which it is desired to open said latching-type switch, means for applying to said delay-circuit input a pulse from said pulse source also being applied to said load and to said drive winding, means for applying output from said delay-circuit output to maintain said magnetic core saturated in the state to which it is driven by the pulse from said pulse source, means for applying a pulse to said delay-circuit output also being applied to said load and to said drive winding, and means for applying the resulting output at said delay-circuit input to said latching-type of switch to turn it off.

3. In a pulse-generation unit of the type including a pulse source connected to a load through a latching type of electronic switch and wherein a saturable magnetic core has a reset winding, and a drive winding connected across said load for volt-second regulation, an improved turnoff circuit for said unit comprising a delay-circuit having an input and output and having a delay which approaches that of the interval after the application of a pulse to said load at which it is desired to open said latching type of electronic switch, means for coupling said delay-circuit output terminals across said magnetic-core drive winding, a transformer having a primary winding and a secondary winding, means connecting said delay-circuit input to said transformer secondary winding, and means connecting said transformer primary winding between said load and said latching-type electronic switch.

4. A pulse-generating unit comprising a pair of input terminals, an impedance having one end connected to one of said pair of input terminals, a first delay circuit having an input and output, means connecting said first delay-circuit input to the other end of said impedance to said other of said pair of input terminals, a pair of load terminals, a latching type of electronic switch, means connecting said latching type of electronic switch between said first delay-circuit output and said load terminals, means for operating said latching type of electronic switch, a magnetic core having two states of magnetic remanence, a drive winding inductively coupled to said core, means connecting said drive winding to said pair of load terminals, a reset winding inductively coupled to said core, means connecting said reset winding to said pair of input terminals, a second delay-circuit having an input and output and a delay interval exceeding that of said first delay-circuit, means connecting said second delay-circuit output to said pair of load terminals, and means coupling said second delay-circuit input into said means connecting said latching type of electronic switch between said first delay-circuit output and said load terminals.

5. A pulse-generating unit as recited in claim 4 wherein said means coupling said second delay-circuit input into said means connecting said latching type of electronic switch between said first delay-circuit output and said load terminals includes a transformer having a primary and secondary winding, means connecting said secondary winding to said second delay-circuit input, and means connecting said primary winding between said latching type of electronic switch and said load terminals.

No references cited.