Feb. 16, 1960 E. F. MYERS ET AL 2,925,492

VARIABLE WIDTH CONSTANT CURRENT DRIVER

Filed Aug. 31, 1956

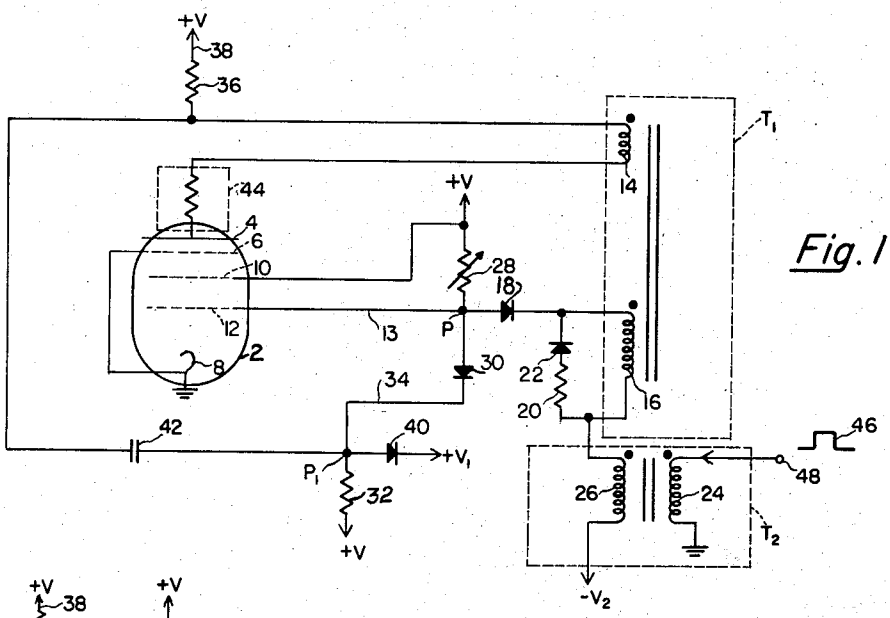


Fig. 1

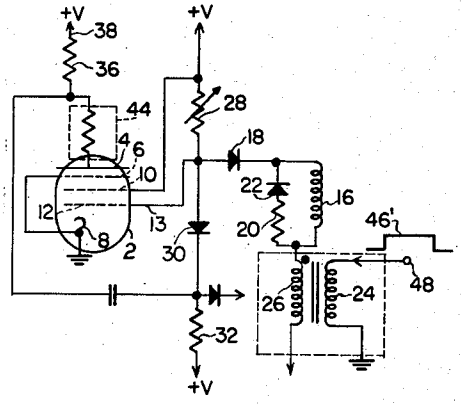


Fig. 2

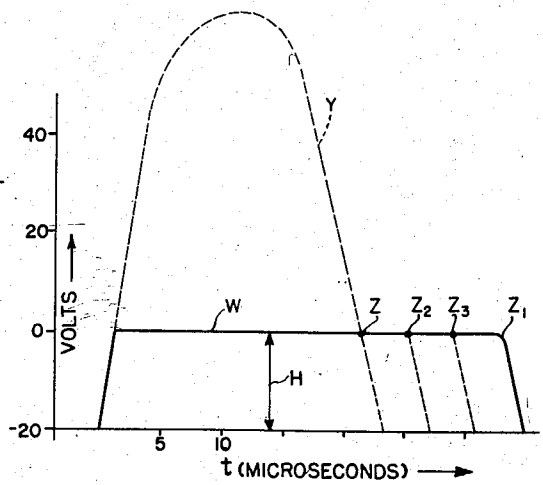


Fig. 4

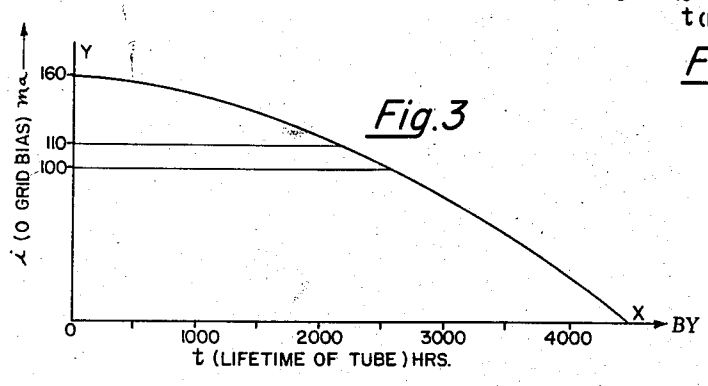


Fig. 3

INVENTORS
EDWARD F. MYERS
PAUL WINSOR III
George Baum
ATTORNEY

United States Patent Office 2,925,492
Patented Feb. 16, 1960

2,925,492

VARIABLE WIDTH CONSTANT CURRENT DRIVER

Edward F. Myers, Yeadon, and Paul Winsor III, Paoli, Pa., assignors to Burroughs Corporation, Detroit, Mich., a corporation of Michigan

Application August 31, 1956, Serial No. 607,372

6 Claims. (Cl. 250—27)

This invention relates to pulse forming circuits in general, but more particularly to pulse generating circuits that are adapted to provide substantially square wave current pulses.

In conventional circuits utilizing power tubes, transistors, and the like, it is often times desirable to obtain not only constant current pulses, but constant current pulses of variable widths. Moreover, a power tube utilized in a pulse generating circuit is subject to deterioration due to age so that whereas a new tube might conduct 160 milliamperes for zero bias on its control grid, the same tube may, after a certain number of hours of tube operation, conduct only 100 milliamperes for zero bias on the control grid. Such change in tube characteristics must be monitored to assure that the pulse generating circuit employing such power tube is capable of maintaining the desired constant current output.

The present invention carries out the dual role of not only attaining constant current pulses of variable widths, but also of automatically maintaining constant current output from the power tube used in the generator circuit, regardless of change in tube characteristics due to aging of the tube. The latter role of stabilizing current output despite change of tube life is accomplished by utilizing a novel degenerative feedback circuit to the control grid circuit of the power tube in a manner hereinafter to be described. The former role of achieving constant current pulses of variable widths is carried out, in one embodiment of the invention, by biasing the control grid of the power tube through a series circuit comprising a secondary of a transformer and a diode such that the power tube is biased to cut-off. When it is desired to trigger the power tube into conduction, a signal pulse is transmitted through the primary of the transformer so as to induce a potential in the secondary of the transformer of such a polarity as to overcome the cut-off bias being applied to the power tube and start the tube conducting. The tube conducts, yielding in its output circuit a substantially constant amplitude pulse, such pulse normally terminating when the signal pulse that has been applied to the transformer primary terminates. However, as soon as the power tube is about to cease conducting because of the return of the control grid to its cut-off bias, a current path is made to take place through the diode and secondary of the transformer, such current path being such as to maintain the control grid at a potential that will enable the power tube to continue conducting some time after the termination of the trigger pulse, with a consequent increase in pulse width of the output pulse generated. How much longer the tube will remain conductive will depend upon the circuit parameters of the series circuit that includes the aforementioned diode and transformer secondary.

Accordingly it is an object of this invention to provide an improved pulse generator.

It is a further object to provide automatic control of pulse amplitudes and pulse widths during the life of a power tube generating the pulse whose widths and amplitudes are to be controlled.

It is yet another object to provide a simplified system of pulse width control substantially independent of the triggering pulse that fires the tube and without affecting the rise time of the constant amplitude current pulse produced by the generator.

Various other advantages and objects of the invention will become apparent to those skilled in the art from the following description taken together with the accompanying drawing wherein:

Fig. 1 is an electric schematic of an embodiment of the invention;

Fig. 2 is an electric schematic of another embodiment of the invention wherein operation of the invention is carried out without a transformer in the plate and grid circuit of the power tube of Fig. 1;

Fig. 3 is a plot of curent output v. tube life of a typical pentode utilized in this invention; and

Fig. 4 is a voltage-time plot of a pulse generated by this invention in order to enhance the explanation of how pulses are widened by the instant invention.

Referring to Fig. 1, there is shown a pentode **2** having a plate or anode **4**, a suppressor grid **6** attached to grounded cathode **8** so as to maintain the suppressor grid at substantially the same potential as the cathode, a screen grid **10**, and a control grid **12**. A transformer T_1 is in the plate-control grid circuit of pentode tube **2** and includes a primary winding **14** in a circuit that includes plate **4** and a secondary winding **16** in a circuit that includes control grid **12**. Interposed between grid **12** and secondary winding **16** is a diode **18** having its anode joined to the control grid **12** and its cathode joined to a terminal of secondary winding **16**. A resistor **20** and diode **22** are provided to damp out any undesired oscillations that may arise in the circuit that includes the secondary winding **16**.

Another transformer T_2 comprises a primary winding **24** and a secondary winding **26**, such secondary winding **26** having one of its terminals connected to the secondary winding **16** of transformer T_1 and its other terminal connected to a source of negative potential $-V_2$ so that control grid **12** is biased to cut-off through winding **26**, winding **16**, and diode **18**.

A circuit path that is parallel to the current path between plate **4** and cathode **8** of tube **2** includes a variable resistor **28**, diode **30**, and resistor **32**, the latter three elements being joined in a series circuit by conductor **34**, and both terminals of such conductor **34** being maintained at the same positive potential. Point P is the junction of the control grid lead **13**, the low voltage terminal of variable resistor **28**, and the anodes of diodes **18** and **30**. A voltage dropping resistor **36** connects the positive terminal of a power supply, not shown, to the anode **4** through primary winding **14**, supplying a positive potential $+V$ to the lead **38** of the resistor **36**. Point P_1 represents the junction of the cathode of diode **30**, the low potential terminal of resistor **32**, the anode of diode **40**, and one plate of capacitor **42**. A positive potential $+V_1$ is applied to the cathode of diode **40** to clamp the point P_1 at the $+V_1$ potential.

The operation of the variable width constant current pulse generator will now be described with particular reference being made to Fig. 1 of the drawing. Power tube **2**, in its quiescent state, has a negative bias $-V_2$ applied to its grid **12** through winding **26**, winding **16**, and diode **18**. Such negative bias $-V_2$ is chosen, in accordance with the operating characteristics of tube **2**, to supply cut-off bias to the tube **2**. A potential of $+V$ volts is applied to various elements of the tube **2** as shown, so that while the tube **2** is cut-off, steady state

current will flow from the +V terminal of the available power supply, most of such steady state current finding a path through variable resistor 28, diode 18, and to the negative terminal of the $-V_2$ source of potential, since the positive $+V_1$ bias on the cathode of diode 30 disables diode 30 and prevents current flow from variable resistor 28 through diode 30. Another quiescent current path can be traced from the +V side of a source of power, through resistor 32, diode 40, to the $+V_1$ terminal of a source of biasing voltage so as to maintain point P_1 at a fixed clamping voltage.

When it is desired to trigger tube 2 into conduction, a pulse 46 of suitable amplitude and polarity is applied to input terminal 48 of primary winding 24 of transformer T_2. The dot notation at the terminals of each winding indicates diagrammatically that when current enters a first winding at its dotted terminal, a positive potential is induced at the dotted terminal of the winding that is transformer-coupled to said first winding. Consequently the current pulse 46 will induce a potential in winding 26 such that the dotted terminal of winding 26 assumes a positive potential that exceeds the negative bias $-V_2$, such positive potential effectively disconnecting diode 18 and driving tube 2 into conduction. As tube 2 begins to draw current from its power supply so that the current enters primary winding 14 of transformer T_1, there is transformer coupling between primary winding 14 and secondary winding 16 such that the dotted terminal of winding 16 assumes a positive potential while current is building up in tube 2. Such induced positive potential is fed back to the grid 12 so as to maintain tube 2 in its conducting state. It is noted that the static current that was flowing through resistor 28, diode 18, winding 16, and winding 26 when the negative bias $-V_2$ was effectively applied to control grid 12 now flows through diode 30, capacitor 42, primary winding 14, load 44, tube 2 and to ground when diode 18 becomes disconnected due to a positive potential, in excess of the $-V_2$ potential, appearing at the dotted terminal of winding 16. Such diversion of the static current from transformer winding 16 through the capacitor circuit lasts only so long as the diode 18 is cut off, or as long as the pulse flowing through tube 2. The positive voltage induced at the dotted terminal of winding 16, and shown as dotted curve Y of Fig. 4, will build up in direct proportion to the rate of change of plate current flowing through the winding 14. As the plate current reaches saturation, the field of the plate winding 14 is no longer increasing and, therefore, the voltage induced in the winding 16 falls off rapidly and is depicted by the substantially sharp drop of the dashed line Y of Fig. 4. As the potential appearing at the dotted terminal of winding 16 falls, the diode 18 will commence conducting and there will be current flow from the +V source across the resistor 28, through the diode 18, through the winding 16, and winding 26 to the $-V_2$ potential source. To this instantly applied D.-C. potential, the inductance 16 represents an impedance and the voltage appearing across the inductance 16 is equal to $L\,di/dt$. Assuming that the inductance 16 has a fixed L value, it becomes clear that the voltage appearing thereacross is proportional to di/dt. Depending on the setting of the variable resistance 28, the change of current flowing through the inductance 16 can be made greater or smaller. So long as the rate of change of current remains substantially constant, the potential appearing at the dotted terminal of 16 will be sufficiently positive to cause the tube 2 to remain in the state of conduction. When the rate of change of current (di/dt) reaches a small enough value so that the developed potential drop when measured from the $-V_2$ reference is below the cutoff value of the tube 2, the tube will no longer conduct. As a generality this time is reached when there is a steady state current passing through the inductance 16. At such time when steady state current is reached, there is no lonoger any positive potential appearing at the dotted terminal of winding 16 so that the cut-off potential $-V_2$ is reapplied to the control grid 12, and the generated pulse terminates.

Fig. 4 represents the waveform of the pulse generated by this invention. The waveform W is the general configuration of the pulse produced at the control grid 12 of tube 2. Dotted waveform Y represents the build up of positive potential at the dotted terminal of secondary winding 16. Initially the tube 2 is biased to cut-off by the application of a $-V_2$ bias to its control grid 12. Such $-V_2$ voltage is chosen, for purposes of illustration, as −20 volts. The triggering pulse 46 and the action of the regenerative coupling of windings 14 and 16 raise the potential of control grid 12 towards zero potential. However clamping diode 30 prevents the grid 12 potential from rising above a certain predetermined potential, namely, near ground, and the tube 2 conducts at a constant amplitude H. The amplitude of waveform W would normally drop to −20 volts at point Z upon cessation of the regenerative coupling of windings 14 and 16. However, as was explained hereinabove, a substantially constant rate of change of current di/dt takes place through diode 18 and winding 16 as soon as the potential at the dotted terminal of winding 16 goes below point P. Since the inductance L of winding 16 is constant, a substantially constant voltage

$$e=L\frac{di}{dt}$$

is produced across winding 16 until the steady $-V_2$ bias is seen at point P. This constant voltage continues to maintain grid 12 above the cut-off potential of tube 2 so that the output pulse W is widened by the amount $Z-Z_1$. The current available for flow through winding 16 is limited by the value of the resistance chosen for resistor 28. Z_2 and Z_3 represent different widths of generated pulses for different settings of variable resistor 28.

Fig. 2 is similar to Fig. 1 save that the winding 14 and transformer coupling associated with T_1 are removed. However, in removing the advantages of the regenerative effects provided by the blocking oscillator operation attained in Fig. 1, it is necessary to apply a wider triggering pulse 46' at the input terminal 48 than was applied at the terminal 48 of Fig. 1 in order to maintain tube 2 conductive for the required number of microseconds. The operation of the pulse widening circuit comprising variable resistor 28, diode 18, winding 16, its parallel damping circuit of resistor 20 and diode 22, and secondary winding 26 still remains the same, namely, that of maintaining control grid 12 above cut-off potential so that tube 2 conducts even after the triggering pulse 46 has terminated.

Load 44, shown in dotted block form, represents any suitable load to be driven by the generated pulse. The pulses generated by the instant invention have particular utility in driving an array of magnetic cores, wherein such cores are of the type that have substantially square hysteresis loop characteristics. The cores are bistable elements that present relatively large loading when each is in the other stable state. For proper switching of such cores it is necessary to apply constant current pulses to switching windings associated with the cores so that the variable load presented by such cores can be driven without diminution of power to any of the cores in the array. A constant current driver, of which the instant invention is an improvement, has been filed by John Paul Jones on May 24, 1954, and was given the Serial No. 431,678. The Jones' application is assigned to the assignee of the instant application.

The amplitude control of the generated pulse is obtained by the network that includes resistor 36, capacitor 42, resistor 32 and diodes 30 and 40. It will be assumed that the tube 2 selected in the novel pulse generator has

a maximum output of 160 milliamperes when the control grid is maintained at zero volts grid bias and a potential of 250 volts is placed across the anode and cathode of the tube. Fig. 3 is a plot of current output in milliamperes v. tube life in hours. In the instant case, it is desired to control the amplitude of the generated variable width pulse between a range of 100–110 ma. for zero volts bias on the control grid 12. A positive reference voltage $+V_1$ is placed at the cathode of diode 40 so that point P_1 is maintained at this $+V_1$ potential. When the tube 2 is new, the resistor 36 is chosen so that the amount of voltage drop for 100 ma. current flowing through the tube 2 will be substantially that of the potential $+V_1$ but opposite in polarity. When current through tube 2 exceeds 100 ma., the potential at P_1 becomes increasingly negative due to the increased potential drop across resistor 36. Such increased potential drop can, by proper selection of resistor 36, be sufficient to overcome the $+V_1$ potential being applied to diode 30 through diode 40 and render the cathode of diode 30 negative. Diode 30 now conducts so that the static current which flowed through resistor 28 and diode 18 will now flow through resistor 28, diode 30, capacitor 42 and through tube 2 to ground. Such current pulse lowers the potential of point P as well as control grid 12 so that plate current diminishes. The automatic amplitude control is maintained throughout the life of the tube, and the stability and range of such control depends on the initial selection of the value of resistor 36 and the original setting of the potential $+V_1$. The current output of the power tube 2 will be between 100–110 ma. as shown in Fig. 3.

A typical, though nowise limiting set of values, for a 6197 or 6LC6 tube is:

$+V=250$ volts	Winding 14=15 Turns
$+V_1=10$–20 volts	Winding 16=735 Turns
$-V=-20$ volts	Winding 24=50 Turns
$R_{36}=100$	Winding 26=500 Turns
$R_{32}=270{,}000$	$C_1=0.1\mu$ farads
$R_{20}=27{,}000$	

The aforedescribed invention is capable of attaining variable width and constant amplitude pulses without reliance upon active elements such as tubes. Since the passive elements comprising the instant invention can be manufactured to retain their electrical characteristics for a relatively long time for the range in which the current driver will operate, the present circuit is rugged, reliable, and economical.

What is claimed is:

1. A variable-width current driver comprising: an amplifier tube having input and output electrodes; a variable resistance; an inductance; means connecting the lower end of said resistance to the upper end of said inductance, thereby to connect said resistance and inductance in series forming an RL voltage divider circuit; a direct-current potential source connected across said series-connected resistance and inductance with the high-potential side of said source connected to the upper end of said resistance; said resistor and inductance respectively having characteristic values to render the steady-state potential at the lower end of said resistance relatively negative; means for connecting said lower end of said resistance to an input electrode of said tube to apply said relatively negative potential thereto to bias said tube beyond cutoff; transformer means having primary and secondary windings, said secondary winding coupled to said inductance, said primary winding coupled to receive an input current pulse to produce in response thereto a voltage at said upper end of said inductance of a polarity and of a magnitude to override said bias, thereby to drive said tube into conduction for a period of time equal to the period during which the flux resulting from said input current pulse is changing at a rate sufficiently fast to produce a voltage of overriding magnitude, and for an additional period of time after said flux ceases to change at such rate, and as a result of current from said direct-current potential source being driven through said inductance, said additional period of time having a duration which is determined by the values of said resistance and inductance; and means in the output circuit of said tube for deriving an output pulse whose duration is a function of the period of conduction of said tube as controlled by the setting of said variable resistance.

2. Apparatus as claimed in claim 1 characterized in that said means connecting the lower end of said resistance and the upper end of said inductance includes a diode poled to be reversed biased by the overriding voltage produced at the upper end of said inductance by said input current pulse, thereby to disconnect said inductance from said resistance.

3. Apparatus as claimed in claim 2 further characterized in that a second resistance is connected between the lower end of said variable resistance and the high potential terminal of said direct-current source in parallel with said variable resistance, and further characterized in that diode clamping means are provided for preventing said input electrode of said tube from rising above a preselected value of potential.

4. Apparatus as claimed in claim 1 characterized in that an inductance is included in the ouput circuit of said tube regeneratively coupled to said first-mentioned inductance for maintaining the potential at said lower end of said resistance at said overriding magnitude for a time period beyond the termination of said input pulse.

5. A variable width current pulse generating circuit comprising an electron transmitting device having an input element, an output element and at least a first control element, a variable impedance means having first and second end terminals, an inductance means having first and second end terminals with said first end terminal connected to said impedance means second end terminal to form a variable voltage divider circuit, a direct current potential source having a high potential output and a low potential output, first circuitry means connecting said impedance means first end terminal to said direct current potential source high potential output, second circuity means connecting said direct current potential source low potential output to said inductance means second end terminal, said impedance means and said inductance means having characteristic values which provide at the second end terminal of said impedance means a potential whose value is relatively negative, third circuitry means connecting said impedance means second end terminal to said control element to apply said relatively negative potential thereto to bias said electron transmitting device into a state of non-conduction, a source of positive input signals coupled to said inductance means second end terminal to be applied thereto thereby biasing said electron transmitting device to conduct, said electron transmitting device remaining in a state of conduction for an initial period of time equal to the time period of a positive input signal applied and in addition for a continuing period of time after said input signal terminates which is as long as the potential, developed by the changing current flowing through said inductance in response to said direct current potential applied and appearing at said inductance first end terminal, biases said electron transmitting device for conduction, and output means coupled to said electron transmitting device output element to provide an output signal in accordance with said electron transmitting device conduction period.

6. A variable width constant current signal generator comprising an electron transmitting device having an input element, an output element, and at least a first control element, a variable impedance means having first and second end terminals, a first inductance means having first and second end terminals with said first end terminal

connected to said impedance means second end terminal to form a variable voltage divider circuit, a direct current potential source having a high potential output and a low potential output, first circuitry means connecting said impedance means first end terminal to said direct current potential source high potential output, transformer means having primary and secondary windings, said secondary winding coupled between said first inductance second end terminal and said direct current potential source low potential output, said impedance means and said first inductance means having characteristic values which provide at the second end terminal of said impedance means a potential whose value is relatively negative, second circuitry means connecting said impedance means second end terminal to said control element to apply said relatively negative potential thereto to bias said electron transmitting device into a state of non-conduction, a source of positive input signals, said primary winding coupled to said source to receive input signals and thereby produce in response a relatively positive voltage at said first inductance means first end terminal, said relatively positive voltage being sufficiently positive to bias said control element to cause said electron transmitting device to conduct, a second inductance means connected to the output element of said discharge device and inductively

coupled to said first inductance means, said electronic discharge device remaining in a state of conduction for an initial period of time equal to a time period of a positive input signal induced on said secondary winding, for a continuous second period of time so long as said second inductance means induces a positive potential on said first inductance means and for a continuous third period of time after said input signal terminates which is as long as the potential, developed by the changing current flowing in response to said direct current potential source through said first inductance and appearing at said first inductance first end terminal, biases said electron transmitting device for conduction, and output means coupled to said electron transmitting device output element to provide an output signal in accordance with said electron transmitting device conduction period.

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