

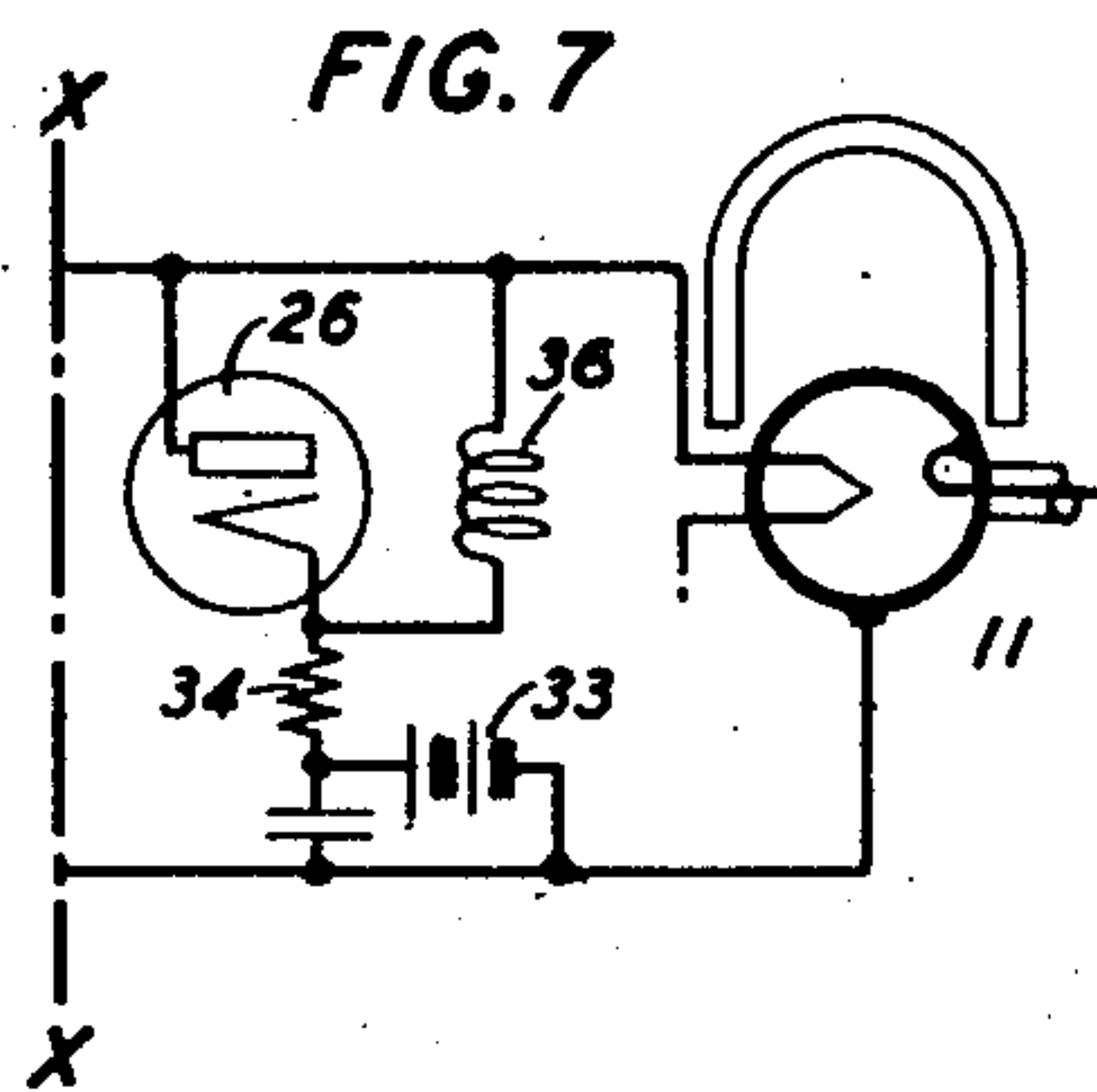
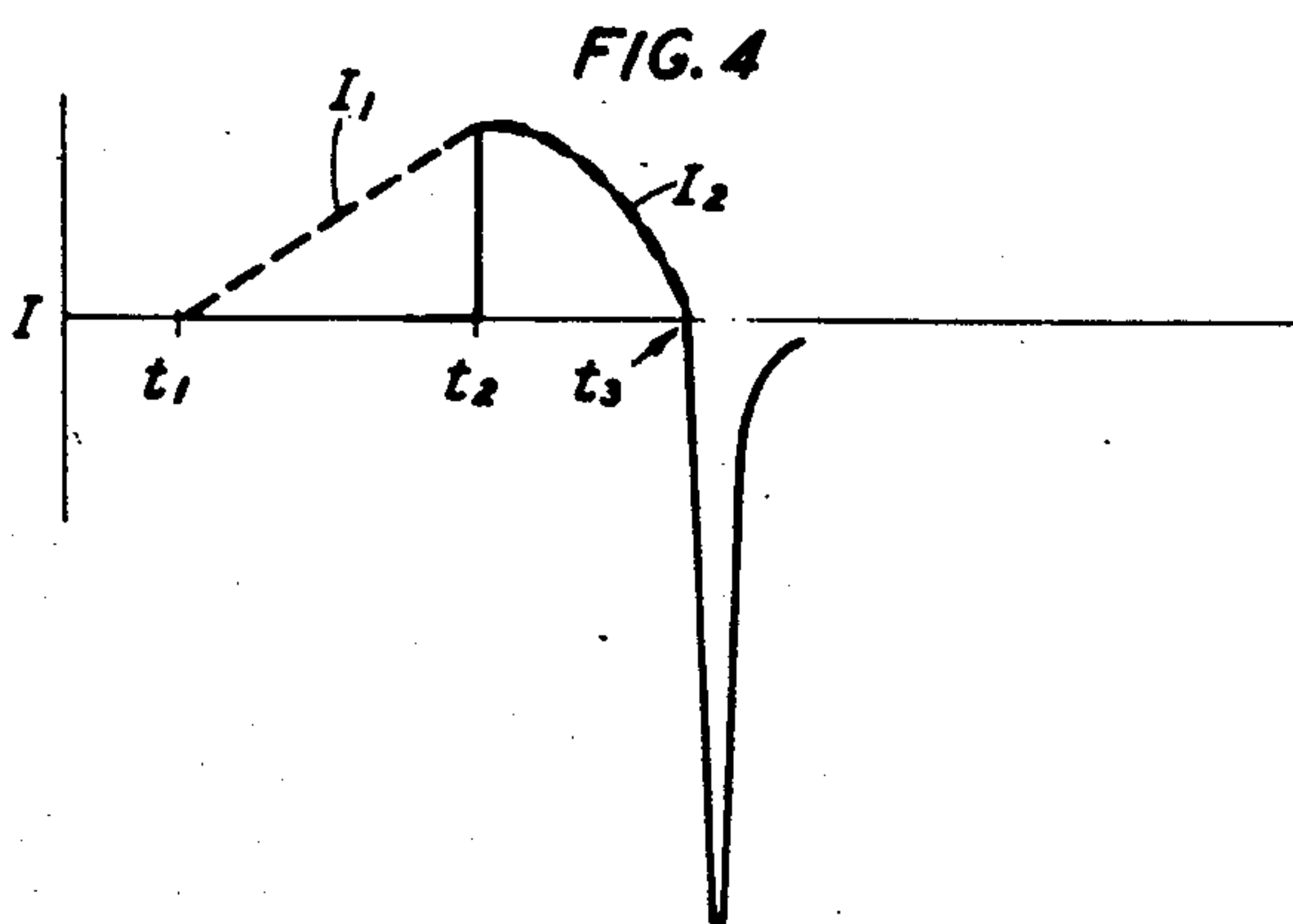
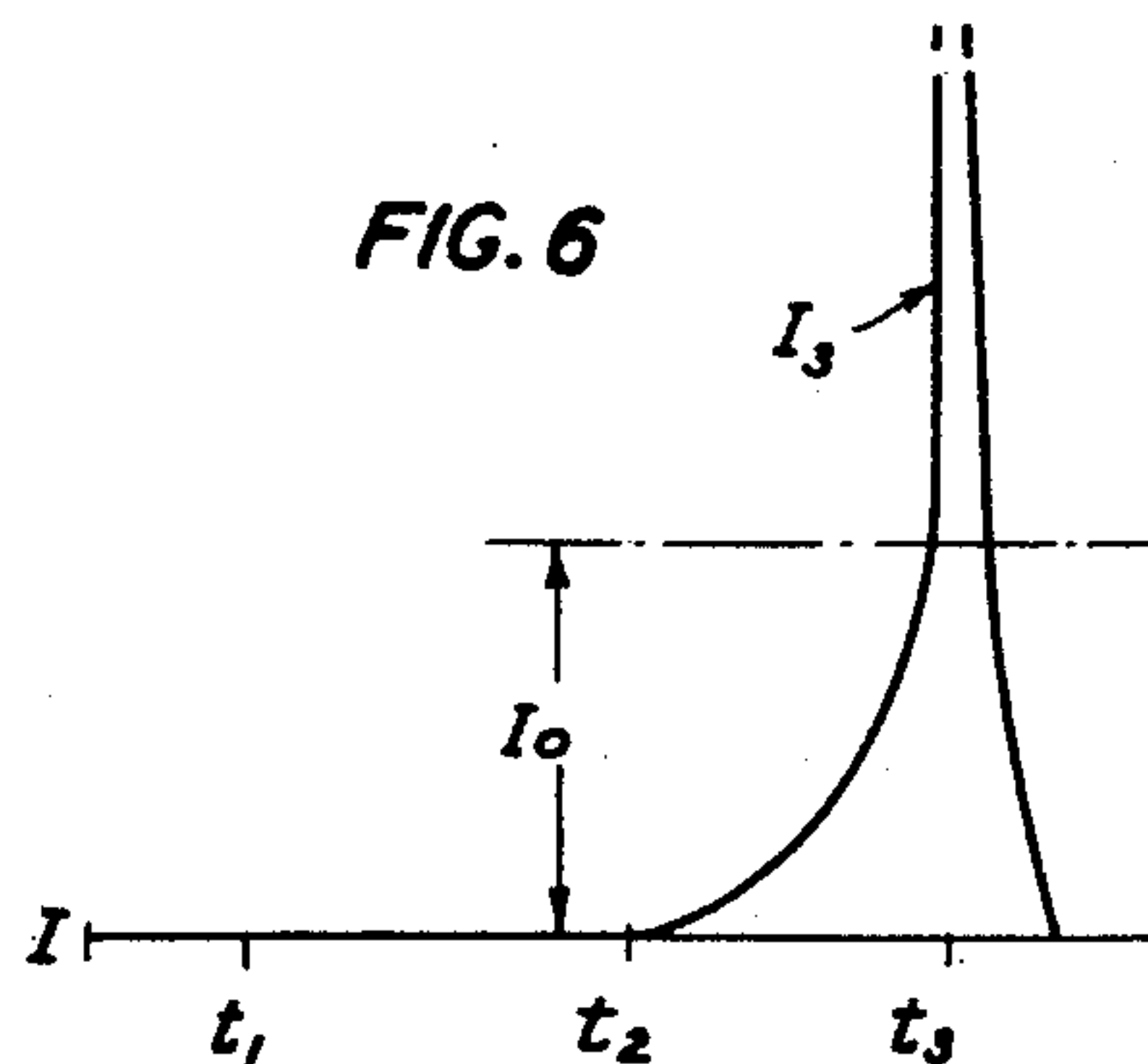
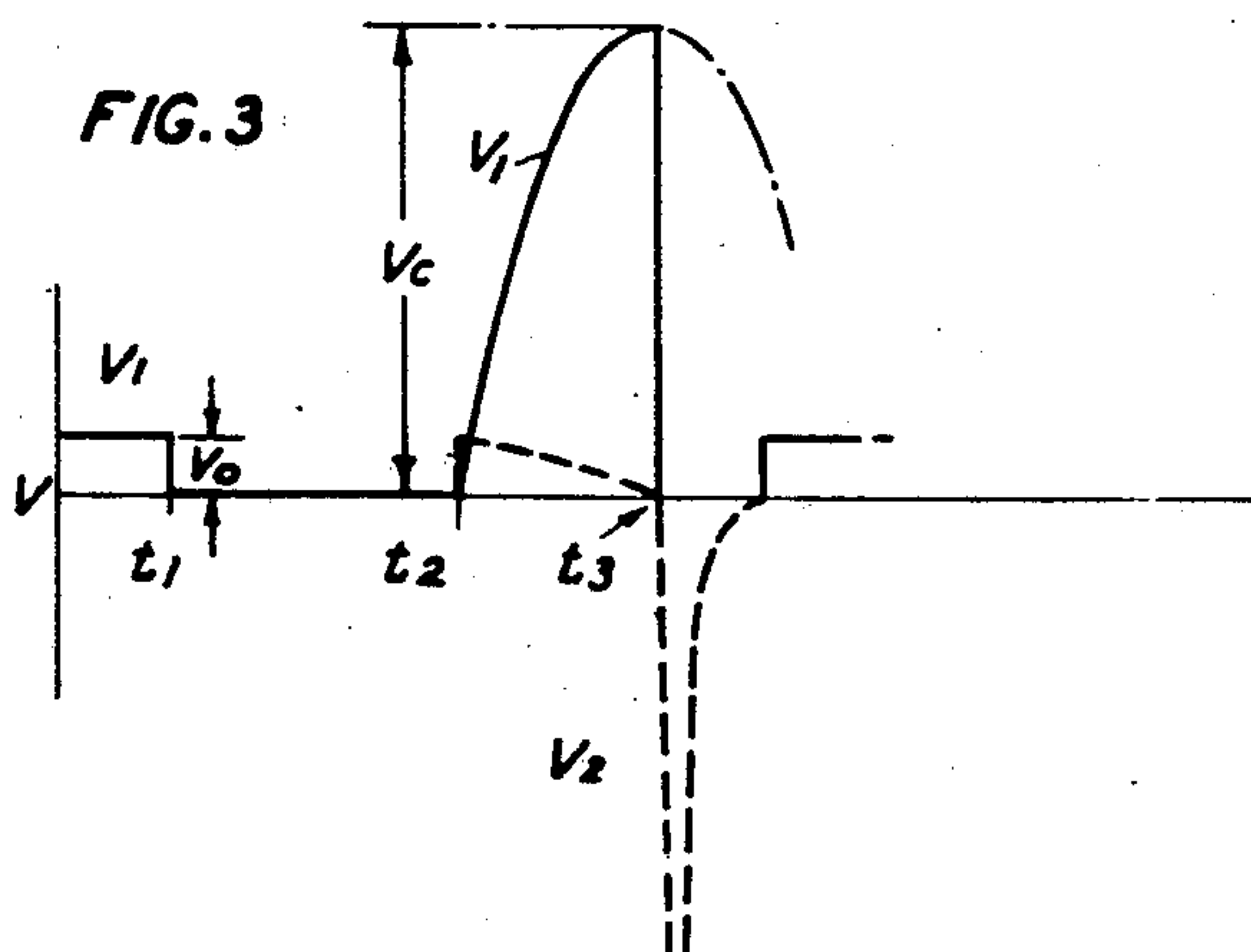
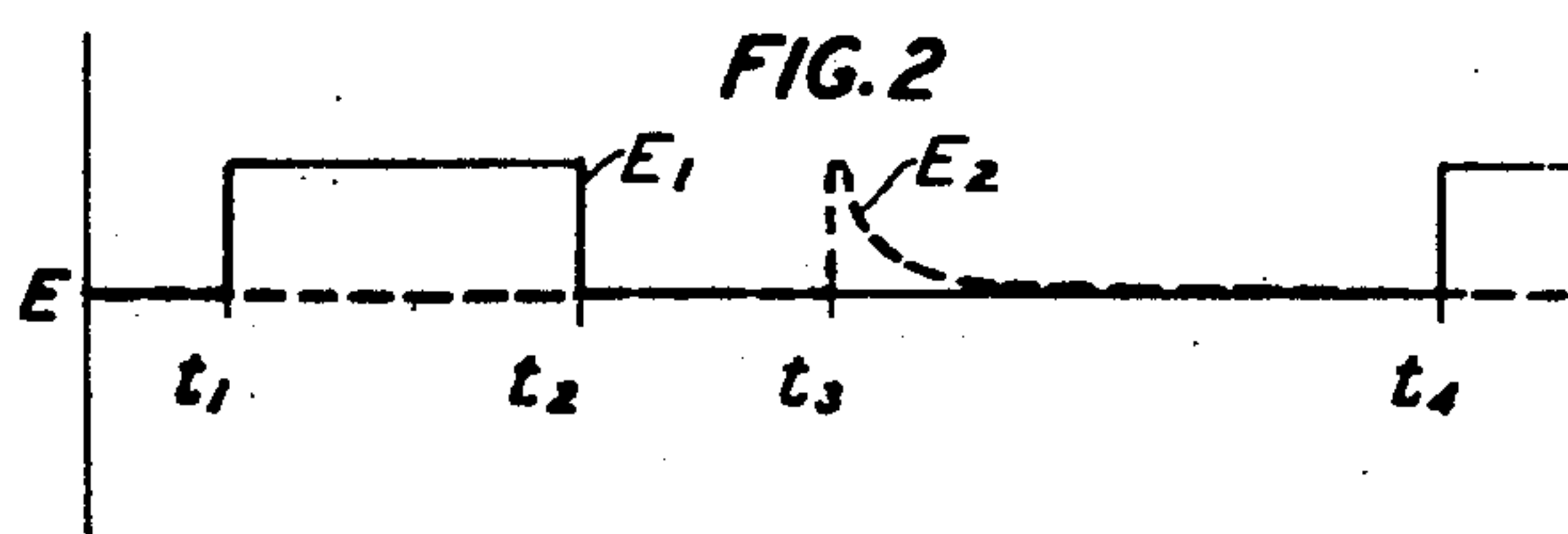
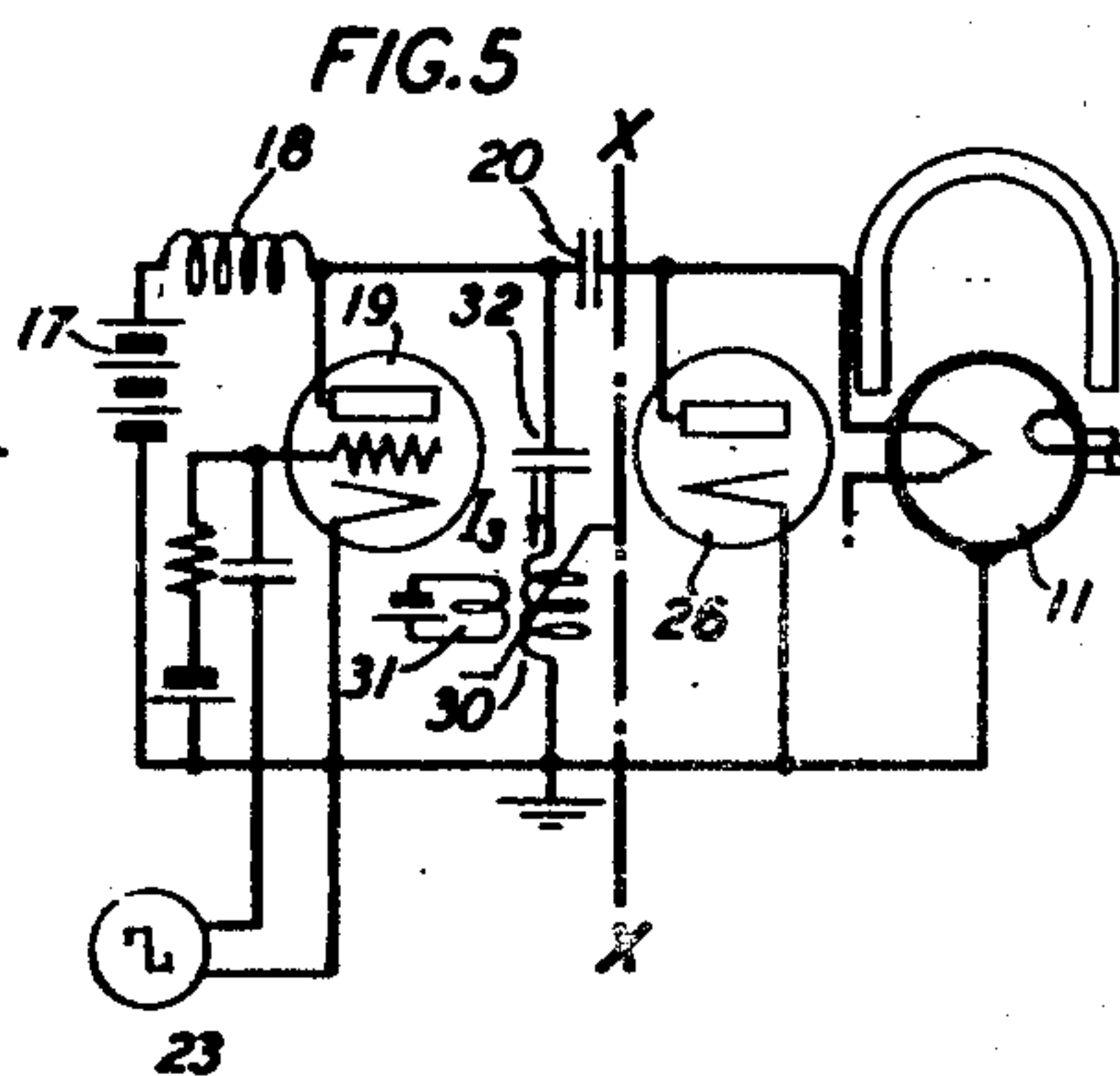
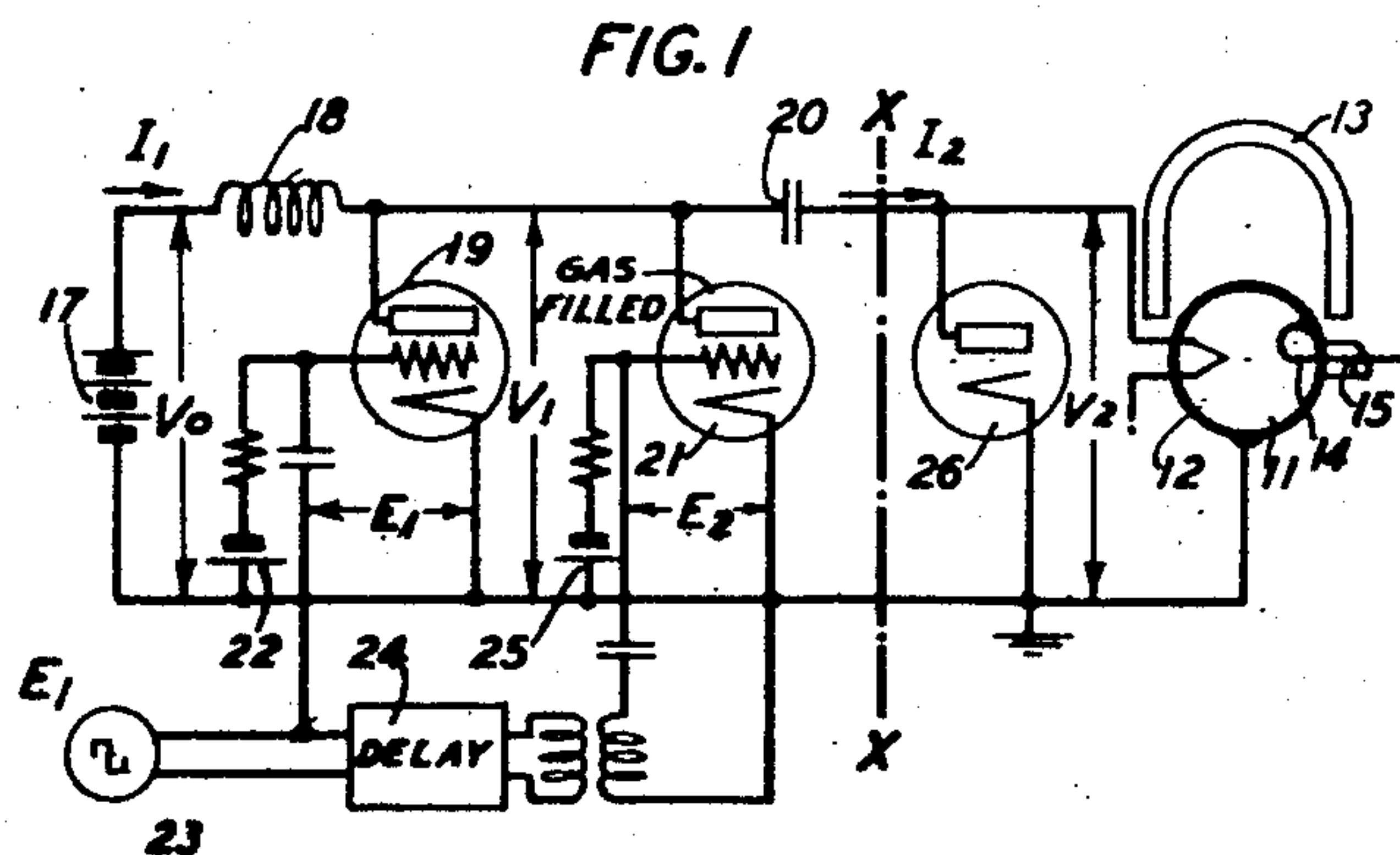
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2,416,718

PULSE GENERATOR

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PULSE GENERATOR

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1

This invention relates to pulse generators and transmitters, and particularly to generators for keying or modulating ultrahigh frequency radio transmitters for the transmission of recurrent, short pulses of high power.

Various systems, for example, distance measuring and object locating systems employ high power recurrent pulses of ultra-high frequency radio waves. Such pulses may be of very short duration compared to the interval between pulses, for example, the pulse recurrence rate may be of the order of 1000 to 4000 per second while the pulse length is of the order of one micro-second. Consequently, the average power output and accordingly the average power demand on the prime power source is quite low even for high peak power outputs. On the other hand, the system must be capable of meeting the high instantaneous power demands during the pulse interval.

An object of the invention is to improve the economy of apparatus and operation of pulse generators.

Another object of the invention is to obtain recurrent, short, high energy pulses without a comparable instantaneous demand on the power supply.

A further object of the invention is to energize an ultra-high radio frequency oscillation generator with recurrent, short pulses of high voltage direct current from a low voltage direct current source.

In accordance with a feature of the present invention recurrent high voltage, high energy pulses for impulsing an ultra-high radio frequency oscillation are developed from a lower voltage direct current source by storing energy from the source electromagnetically and electrostatically during the interval between pulses. In more detail, current from the source flowing through an inductor is interrupted to build up a high voltage charge in a capacitor which charge is released to excite the oscillator during the required pulse period.

These and other objects, features and aspects of the invention may be more readily understood by reference to the following detailed description in connection with the drawing in which:

Figure 1 is a schematic diagram of one embodiment of the invention;

Figs. 2, 3 and 4 are graphs illustrating voltage and current relations in the circuit of Fig. 1;

Fig. 5 is a schematic circuit diagram of a modification of the circuit of Fig. 1;

2

Fig. 6 is a graph of the current in one branch of the circuit of Fig. 5; and

Fig. 7 is a schematic diagram of an alternative circuit arrangement which may be substituted for the portions of the circuits of Fig. 1 or 5 to the right of the dash-dot lines X—X.

In the system of Fig. 1 the invention is employed for producing recurrent short pulses of high power ultra-high frequency radio waves. The ultra-high frequency oscillations are produced in a multicavity magnetron 11 which may be of the type of United States Patent 2,063,342 to Samuel, December 8, 1936, for example. In this type of ultra-high frequency generator the anode 12 forms the external sheath or enclosure which it is desirable to maintain at ground potential. When the tube is subjected to a magnetic field supplied by the magnet 13 and a high direct current voltage is impressed between the anode and cathode there are produced high power oscillations of frequency determined by the internal structure of the device as described in more detail in the Samuel patent referred to. These oscillations may be picked up by a loop 14 and transmitted through a coaxial line 15 to an antenna or other suitable utilization circuit (not shown).

As set forth in the introductory portion of the specification, one aspect of the present invention relates to the problem of energizing such a generator for the production of recurrent high power pulses of short duration. Because of the relation of the working portion of such a cycle of operation to the idle portion thereof such a device can be utilized to operate at peak powers far above a safe rating for continuous operation. This, of course, requires high instantaneous power input and in the interests of economy of both operation and apparatus it is desirable that such inputs be produced from a prime source of power of comparably lower continuous rating and without such peak loads on the prime source.

In the system of Fig. 1 the prime source is a battery 17, though, of course, it may be a rectifier, generator or other direct current source. An inductor or choke coil 18 is connected to the positive terminal of the battery 17. During the idle or non-working portion of the operating cycle current is caused to flow from the battery 17 through the coil 18 by way of the space path of the vacuum tube 19. When this current has reached a value sufficiently high to have stored the required energy in the magnetic field of the coil the flow of current from the battery is interrupted by blocking the space path of the tube

3

19. The current, however, will tend to continue to flow in the same direction so that the capacitor or condenser 20 will be charged, the energy stored in the magnetic field of the coil 18 being transferred to the electrostatic field of the condenser 20.

In the absence of other control features the current would then reverse and the energy returned to the coil, the cycle of operations continuing in the well-known manner of an oscillatory circuit until the energy was dissipated by the resistance of the circuit.

However, in the system of this invention a circuit is established at substantially the instant of complete transfer of energy to the condenser 20 by triggering off the gas discharge tube 21. This establishes a path whereby the energy stored in the condenser is supplied to the space path of the magnetron oscillator 11. When the condenser 20 has completely discharged through the magnetron, there will no longer be any voltage present on the anode of the gas tube 21 so that its discharge will be extinguished.

The action of the tubes 19 and 21 is controlled by a timing impulse supplied by a suitable source 23 shown in the drawing as a square wave generator. The output of the source 23 is applied to the grid of the tube 19 so that the blocking bias supplied by the battery 22 will be overcome as will be explained in more detail in the paragraph immediately following. Similarly, the output from source 23 is supplied through the delay circuit 24 to the grid of the tube 21, which is normally blocked by the grid bias voltage from the battery 25.

The detailed operation of the system may be best understood by reference to the explanatory diagrams of Figs. 2, 3 and 4 in which various voltages and currents in the circuit are plotted against time. Thus, just prior to the instant t_1 the voltage E_1 from the source 23 is zero and the tube 19 is blocked. Similarly, the voltage E_2 applied to the grid of the tube 21 is zero and that tube is also blocked. Accordingly, the voltage V_1 indicated in Fig. 1 between the right-hand terminal of the coil 18 and ground is equal to the voltage V_0 of the battery 17 as shown in Fig. 3. At this instant the current I_1 is zero as shown in Fig. 4. At the instant t_1 , the voltage E_1 applied to the grid of tube 19 becomes positive unblocking the tube and permitting space current to flow. The voltage V_1 then drops substantially to ground or zero potential because of the negligible resistance of the space path of tube 19. Current I_1 then begins to flow through the coil 18 as shown in Fig. 4, the current gradually increasing with time as is the well recognized condition in an inductive circuit. At the instant t_2 the voltage E_1 applied to the grid of tube 19 drops to zero cutting off the flow of current through the space path of the tube 19. However, due to the induction effect of the coil 18 the current tends to flow in the same direction through the capacitor 20 and diode 26 charging the condenser 20. This continues until the energy stored in the magnetic field of the coil 18 is transferred to the dielectric field of the condenser 20. At the same time the voltage V_1 on the condenser is built up.

The energy W stored in the magnetic field is represented by the equation

$$W = \frac{1}{2} LI^2$$

where L equals the inductance of the coil 20 and I the current flowing therethrough. Similarly,

4

the energy in the electrostatic field is expressed by the equation

$$W = \frac{1}{2} CV_c^2$$

where C is the capacity of the condenser and V_c the voltage across the condenser. Neglecting dissipation, all of the energy stored in the magnetic field is transferred to the electrostatic field,

$$\frac{1}{2} LI^2 = \frac{1}{2} CV_c^2 \text{ or } V_c = I \sqrt{\frac{L}{C}}$$

Consequently, it is readily evident that by the proper choice of circuit constants the voltage on the condenser can be built up to a high value many times the voltage V_0 of the battery 17.

At the instant t_3 the voltage E_2 applied to the grid of tube 21 becomes positive triggering off the discharge of that tube so that the resistance of its space path drops to substantially zero with the result that the voltage V_1 drops to zero or ground potential and the condenser 20 is discharged through the magnetron 11, the resultant voltage V_2 across the magnetron being represented by the curve of Fig. 3 and the current through the magnetron by the negative pulse of the current I_2 in Fig. 4. As soon as the condenser 20 is discharged the gas tube 21 will become blocked due to the lack of a positive anode voltage. The circuit then is restored to its inactive condition indicated at the beginning of the description of the operation in which state it will remain until the voltage E_1 again becomes positive at the instant t_4 when the active portion of the operation cycle will be repeated.

It will be observed that the instant of triggering off the discharge of the gas tube 21 is quite critical to the efficient operation of the system. Thus, if the discharge is triggered off prior to the instant t_3 the voltage of the condenser 20 will not have reached its full value as the complete transfer of energy thereto will not have been completed. Similarly, in the absence of any control operation, the condenser 20 after being fully charged by the energy from the coil 18 will discharge back into the coil following the well-known pattern of an oscillatory circuit. Consequently, if the discharge of tube 21 is not triggered off until after the instant t_3 the condenser voltage will have fallen below its maximum value due to this return of the energy. The triggering off of the gas tube is, therefore, controlled by the same voltage source 23 which sets up the cycle of operation. The required interval between the cutting off of the current supply to the coil 18 from the battery 17 and the triggering off of the tube 21 is determined by the delay circuit 24.

In Fig. 5 there is shown a modification of the system of the invention in which the discharge of the condenser may be considered as self-timed. Except for the substitution of the saturable or non-linear inductor 30 for the gas tube, this circuit is identical to that of Fig. 1 and corresponding elements have been given the same reference numerals.

As is recognized in the art an inductor of this type having a magnetic core that is readily saturable while having a high μ at very low flux densities has an action very analogous to that of a switch. Thus, it has a high impedance for low values of current while at some definite low current value the core saturates and the impedance suddenly drops to a very low value, the action in so far as its effect in the associated circuit is

concerned may be considered analogous to the closing of a previously opened switch.

The effect of the non-linear inductor 30 may be observed from Fig. 6 in which current is plotted against time, the instants t_1 , t_2 and t_3 corresponding to the time intervals established for circuit operations as indicated in Figs. 2 and 3. As the voltage on the condenser 20 builds up during the interval from t_2 to t_3 a low value of current flows through the inductor 30, the value of the current I_3 in the coil being kept very low due to its high inductance in this unsaturated region (the current scale in Fig. 6 is greatly expanded as compared to that of Fig. 4). When the saturation value of the current (I_0) is reached the inductance and consequently the impedance of coil 30 drops very suddenly to a very low value permitting the condenser 20 to discharge through the coil 30 and magnetron 11, the current rising to a high peak value as indicated. For the efficient operation of the system it is required that this saturation value of current is reached at the instant (t_3) when the voltage of condenser 20 reaches a maximum. In order to facilitate this critical adjustment, the use of a biasing winding 31 on the core of coil 30 is found advantageous.

The blocking condenser 32 prevents the establishment of a steady flow of direct current through the coil 30.

Fig. 7 shows a modification of the circuit to the right of the dash-dot line X—X of Fig. 1 or 5. In some applications of the invention the circuit modification shown in Fig. 7 has been found advantageous particularly with respect to pulse shaping. In this modification a retard coil 36 is connected between the anode and cathode of the diode 26. Also the cathode of the magnetron is given a small positive bias by means of the resistor 34 and battery 33.

The retard coil 36 provides a leakage path to prevent static charges from remaining on the cathode of the magnetron 11.

In a circuit of this type the diode 26 performs a function in addition to that of providing a path for the charging current to the capacitor 20. This may be called a pulse forming or clipping action. One analysis of this action is based on the fact that it is a characteristic of a magnetron oscillator of the type of the magnetron 11 that its output decreases and its effective anode-cathode impedance increases quite abruptly for low anode voltages (below about 50–60 per cent of the optimum value). This results in a residual remaining in the circuit after the useful part of the transmitting pulse. This voltage if uncontrolled would begin a train of damped oscillations among the reactances represented by the coil 36, capacitor 20 and the stray capacities throughout the circuit. Actually such an oscillation is begun but is effectively damped out in the first reversal of polarity by the diode 26. Since that polarity is not effective in exciting the magnetron 11 it causes no harmful effect. The bias provided by the battery 33 prevents the magnetron from being excited by any residual energy which may remain during the next half cycle of the damped oscillations.

While this description has reference to particular forms of the invention it will be obvious that various other forms and modifications may be resorted to without departing from the scope of the invention.

What is claimed is:

1. A pulse generator comprising a source of direct current, an inductor, a capacitor, a load circuit having an asymmetrical conduction char-

acteristic, a charging circuit having an asymmetrical conduction characteristic and so connected in shunt to said load circuit as to provide a path for current in the direction opposite to that provided by said load circuit, means for periodically causing a current to flow from said source through said inductor to store energy therein and interrupting said flow of current whereby said energy is transferred to said capacitor through said charging circuit, and means for discharging the energy thus stored in said capacitor through said load circuit.

2. A pulse generator comprising a source of current, an inductor, a capacitor, and a load circuit connected in series with each other, switching means for first establishing a path for the flow of current from said source through said inductor and next interrupting said circuit to cause said capacitor to be charged to a high voltage by the energy stored in said inductor, and current operated switching means for closing a path for the discharge of said capacitor through said load circuit.

3. A pulse generator for supplying pulses to a unilateral conducting load circuit, comprising a source of direct current, an inductor, a capacitor connected in series with each other and with said load circuit, switching means for periodically establishing a path for the flow of direct current from said source through said inductor and periodically interrupting said flow of direct current, a unilateral conducting device connected in shunt to said load circuit to provide a path for the flow of current from said inductor to said capacitor upon said interruption of said flow of direct current, and switching means for causing the discharge of said condenser through said load circuit at the instant of substantially complete transfer of the energy from said inductor to said capacitor.

4. A system for producing recurrent pulses of ultra-high frequency oscillations comprising, an oscillation generator having a cathode and a grounded anode, a capacitor having one side connected to said cathode, an inductor having one terminal connected to the other side of said capacitor, a source of direct current voltage having its positive terminal connected to the other terminal of said inductor and its negative terminal grounded, a charging circuit connected in shunt to the space path of said oscillation generator to permit the flow of current in the direction opposite to that permitted by said space path, switching means connected between ground and the point of connection of said capacitor and inductor, and means for cyclically operating said switching means, first to close the circuit between said point and ground to permit the flow of current from said source through said inductor, second to open said circuit to interrupt the flow of current from said source and to cause said capacitor to be charged by the electromagnetic energy of said inductor, and third to close said circuit to cause the discharge of said capacitor through the space path of said oscillation generator.

5. In a system for producing recurrent pulses of ultra-high frequency oscillations employing an oscillation generator having a cathode and an anode, a circuit for producing recurrent pulses of direct current through the cathode-anode path of said generator to cause the production of ultra-high frequency oscillations comprising, a direct current source, an inductor, an electric discharge

7

device having a space path, a control electrode therefor and so connected that current from said source may flow through said space path to said inductor, means for periodically varying the voltage of said control electrode to alternately cause said space path to be conductive whereby energy from said source is stored in the magnetic field of said inductor and to block said space path, a capacitor connected in circuit with said inductor whereby the energy stored in the magnetic field of said inductor is transferred to the electrostatic field of said capacitor when said space path is blocked, and switching means for discharging the energy stored in the dielectric field of said capacitor through the anode-cathode path of said generator, said switching means comprising a gas-discharge device having a control electrode normally biased to block the space path thereof and means controlled in definite time relation to the blocking of the space path of said electric discharge device for impressing a positive voltage on said control electrode to trigger off said gas-discharge device.

6. In a system for producing recurrent pulses of ultra-high frequency oscillations employing an oscillation generator having a cathode and an anode, a circuit for producing recurrent pulses of direct current through the anode-cathode path of said generator comprising a unilateral conducting device so connected in shunt to the anode-cathode path of said generator as to provide a path for current in the direction opposite to that provided by said anode-cathode path, a source of direct current, an inductor, and a capacitor connected in series with each other and the parallel circuit formed by said unilateral conducting device and said anode-cathode path, an electric discharge device having a control electrode and a space path connected to form a path for direct current from said source to said inductor, means for normally biasing said control electrode to block said space path, a source of timing pulses, means for impressing timing pulses from said source on said control electrode to periodically render said space path conductive whereby energy from said direct current source is stored in said inductor during said timing pulses and the energy stored in said inductor is transferred to said capacitor through said unilateral conducting device during the period between said timing pulses, a gas discharge device having a control electrode and a space path connected to provide a conducting path for discharging said capacitor through said anode-cathode path of said generator, means for normally biasing said control electrode of said gas discharge device to block the space path thereof, and means controlled by said timing pulses for triggering off said gas discharge device at substantially the instant of the complete transfer of the energy from said inductor to said capacitor.

7. In combination a magnetron oscillator having an anode and a cathode and adapted when energized by said anode being made positive with respect to said cathode to produce ultra-high frequency oscillations, a diode connected in shunt to the anode-cathode path of said magnetron to conduct current of opposite polarity, a capacitor, a gas discharge device having an anode, a cathode and a discharge control element and being connected in series with said capacitor and the anode-cathode path of said magnetron to form a path for applying a charge on said condenser to said magnetron for causing its operation, means for normally biasing said discharge control element

8

to block the anode-cathode path of said gaseous discharge device, an inductor connected to form a series circuit with said capacitor and said diode, a source of current, an electric discharge device having an anode, a cathode and a control electrode and connected so that the anode-cathode path forms a series circuit with said inductor and said source of current, means including said control electrode for rendering the anode-cathode path of said electric discharge device conductive to cause the flow of current from said source through said inductor, means for blocking said anode-cathode path to interrupt said flow of current and cause said capacitor to be charged by the energy stored in the magnetic field of said inductor, and means for impulsing the discharge control element of said gaseous discharge device to discharge said condenser through said magnetron.

8. In a system for transmitting pulses of ultra-high frequency oscillations, an oscillator having an anode and a cathode, a circuit for producing recurrent short pulses of direct current for energizing said oscillator for generating the ultra-high frequency oscillations, and a unilateral conducting device connected in shunt to the anode-cathode path of said oscillator to provide a conduction path in the direction opposite to that provided by said anode-cathode path.

9. In a system for producing pulses of ultra-high frequency oscillations, a magnetron oscillator having an anode and a cathode, a source of short pulses of direct current for energizing said oscillator, and a unilateral conducting device so connected in shunt to the anode-cathode path of said oscillator as to provide a conduction path in the direction opposite to that provided by said anode-cathode path.

10. A recurrent pulse generator comprising a load circuit, a source of direct current, an inductor, a blocking capacitor, means for alternately establishing a flow of direct current from said source through said inductor and for interrupting said flow, a storage capacitor connected to be charged by the surge developed by the interruption of said flow, an inductor having a core of magnetic material of high permeability at low flux densities and readily saturable at higher flux densities, and means connecting said last-mentioned inductor, said blocking capacitor, said storage capacitor and said load circuit in series so that said surge causes the current through said last-mentioned inductor to so vary as to saturate said core and provide a low impedance path for the discharge of said storage capacitor to said load circuit.

11. A recurrent pulse generator comprising a load circuit, a direct current source, an inductor, a capacitor, circuit connections including said load circuit, said direct current source, said inductor and said capacitor in series with each other, switching means for alternately establishing a flow of current from said source to said inductor and interrupting said flow of current whereby said capacitor becomes charged to a high voltage by the surge produced upon the interruption of said flow of current, and an inductor having a core of magnetic material of high permeability at low flux densities and readily saturable at higher flux densities and a winding thereon connected effectively in shunt to said switching means whereby said core becomes saturated by the current produced through said winding by said surge, providing a low impedance path for the discharge of said capacitor to said load circuit.

12. In a system for producing recurrent pulses of ultra-high frequency oscillations employing an oscillation generator having a cathode and an anode, a circuit for producing recurrent pulses of direct current through the anode-cathode path of said generator comprising, a unilateral conducting device so connected in shunt to the anode-cathode path of said generator as to provide a path for current in the direction opposite to that provided by said anode-cathode path, a source of direct current, an inductor, a capacitor, circuit connections including said source of direct current, said inductor, said capacitor and the parallel circuit formed by said unilateral conducting device and said anode-cathode path in series with each other, an electric discharge device having a space path connected to form a path for direct current from said source through said inductor and a control electrode, a source of recurrent timing impulses, means for impressing timing impulses from said source on said control electrode to render said space path alternately conducting and non-conducting whereby energy from said direct current source is stored in said inductor during the conductive periods and transferred to said capacitor through said unilateral conducting device during the non-con-

ducting periods, an inductor having a core of magnetic material of high permeability at low flux densities and readily saturable at higher flux densities, and means connecting the last-mentioned inductor effectively in shunt to the space path of said electric discharge device and in series with said capacitor and said oscillation generator so that the current variation produced in said last-mentioned inductor by the surge developed during said non-conducting periods carries the core through the non-saturated region to the saturation region.

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Disclaimer

2,416,718.—*William Shockley*, Madison, N. J. PULSE GENERATOR. Patent dated Mar. 4, 1947. Disclaimer filed Mar. 30, 1950, by the assignee, *Bell Telephone Laboratories, Incorporated*.

Hereby enters this disclaimer to claim 1 of said patent.
[*Official Gazette May 2, 1950.*]

Disclaimer

2,416,718.—*William Shockley*, Madison, N. J. PULSE GENERATOR. Patent dated Mar. 4, 1947. Disclaimer filed Sept. 1, 1950, by the assignee, *Bell Telephone Laboratories, Incorporated*.

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