Feb. 6, 1951 F. C. WILLIAMS 2,540,923

ELECTRON-DISCHARGE TUBE CIRCUIT ARRANGEMENT

Filed July 21, 1947 2 Sheets-Sheet 1

FIG. 1.

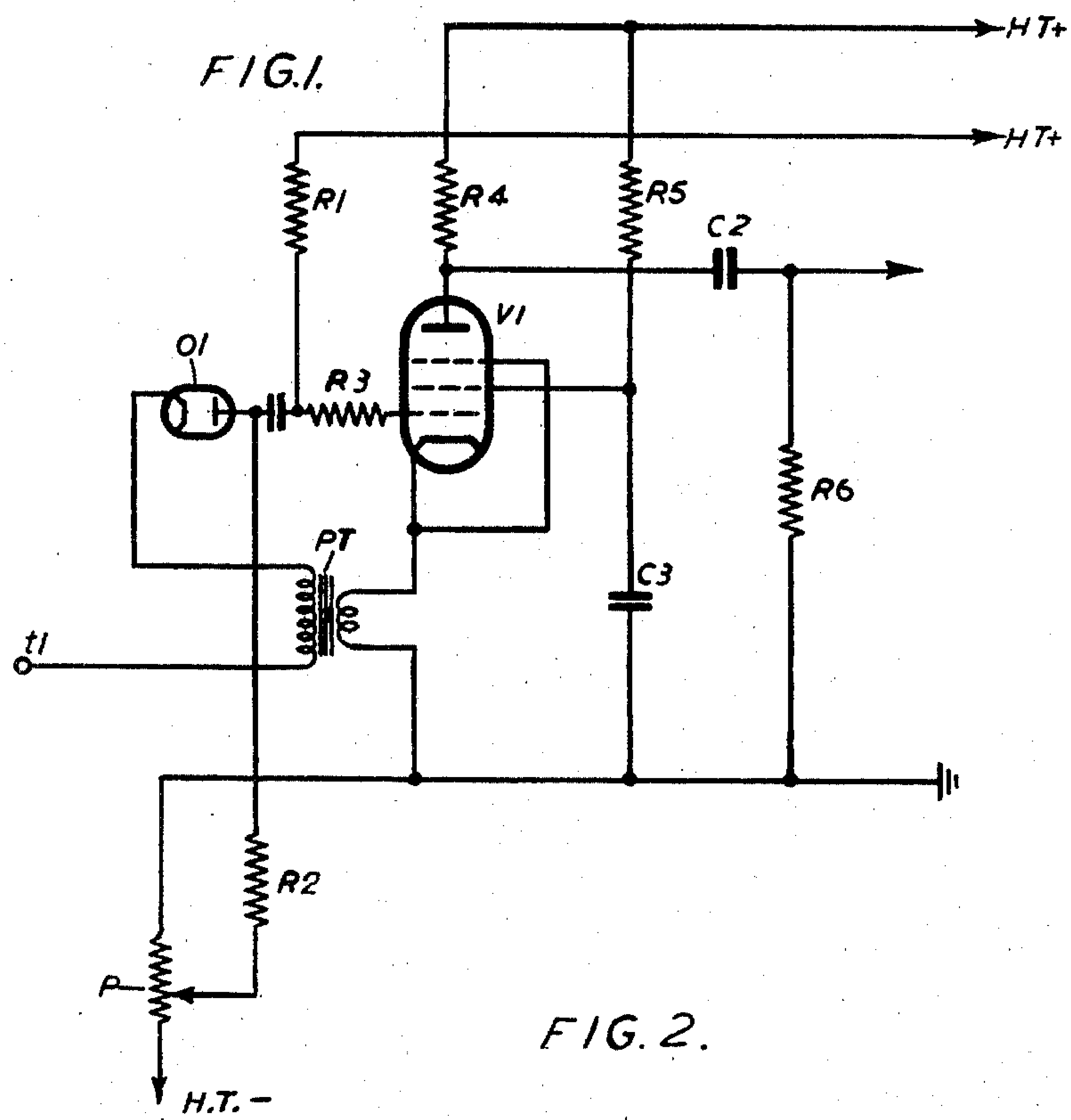
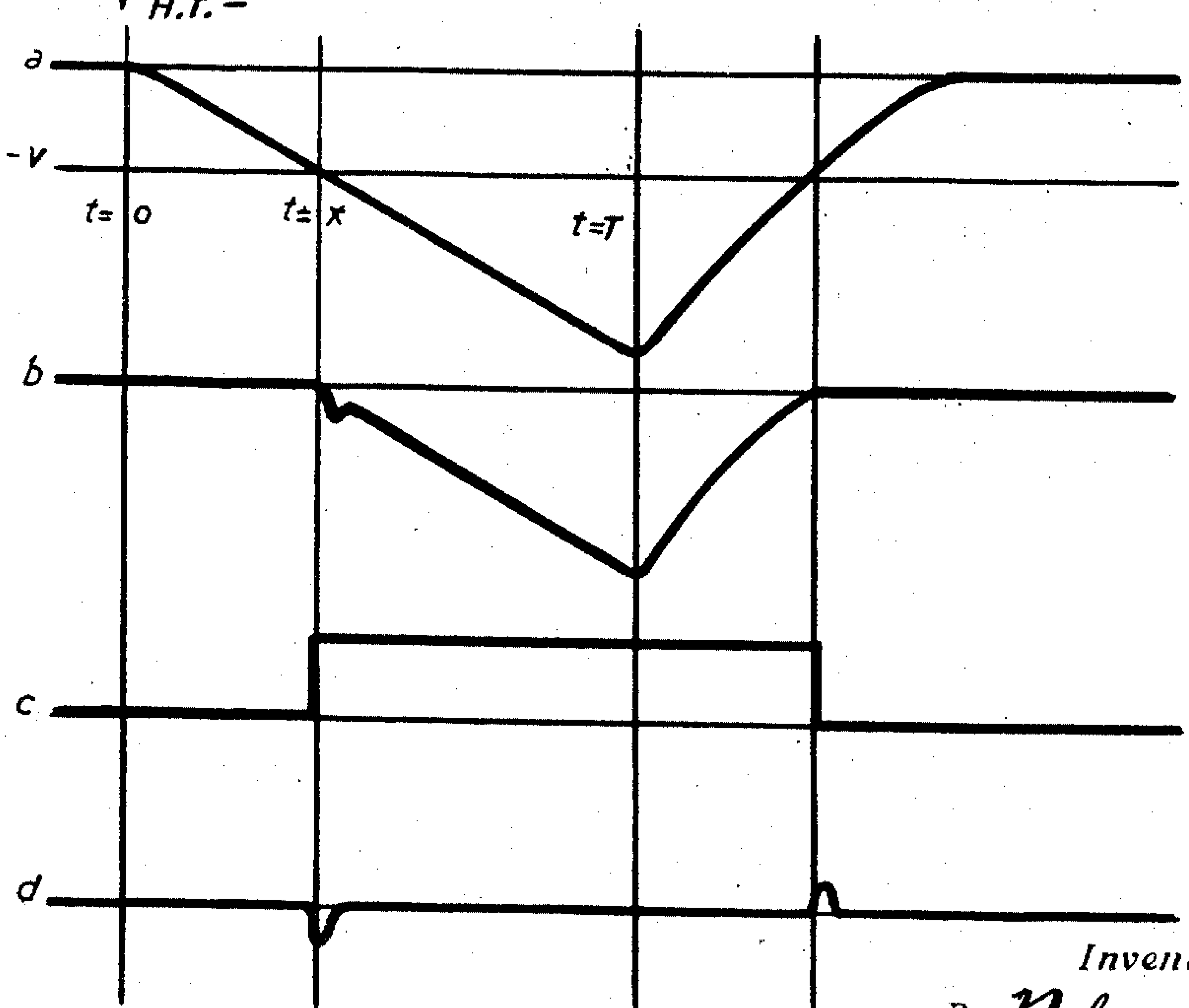


FIG. 2.



Inventor F. C. WILLIAMS.

By Nelson Moore

Attorney

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ELECTRON-DISCHARGE TUBE CIRCUIT ARRANGEMENT

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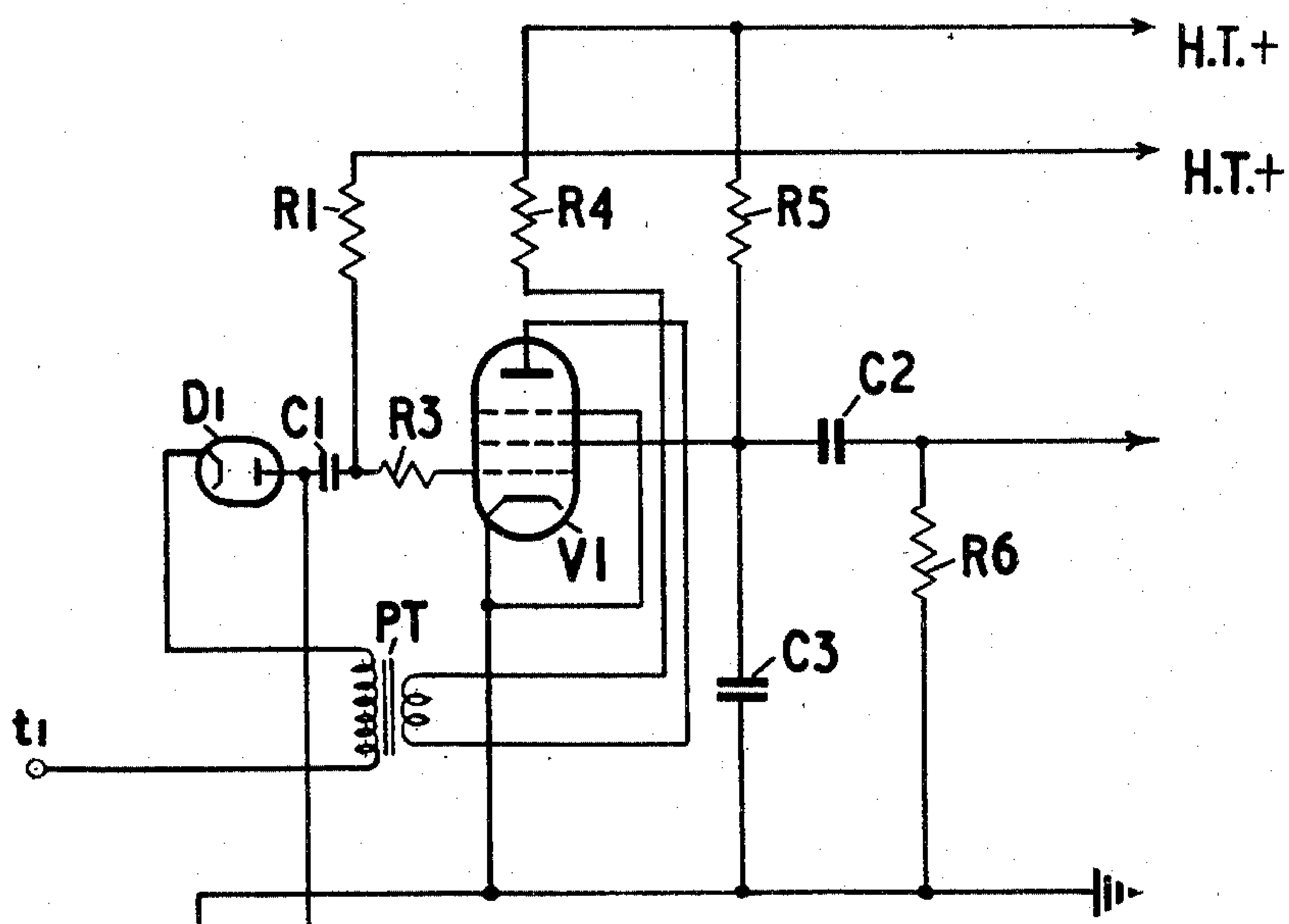

FIG. 3

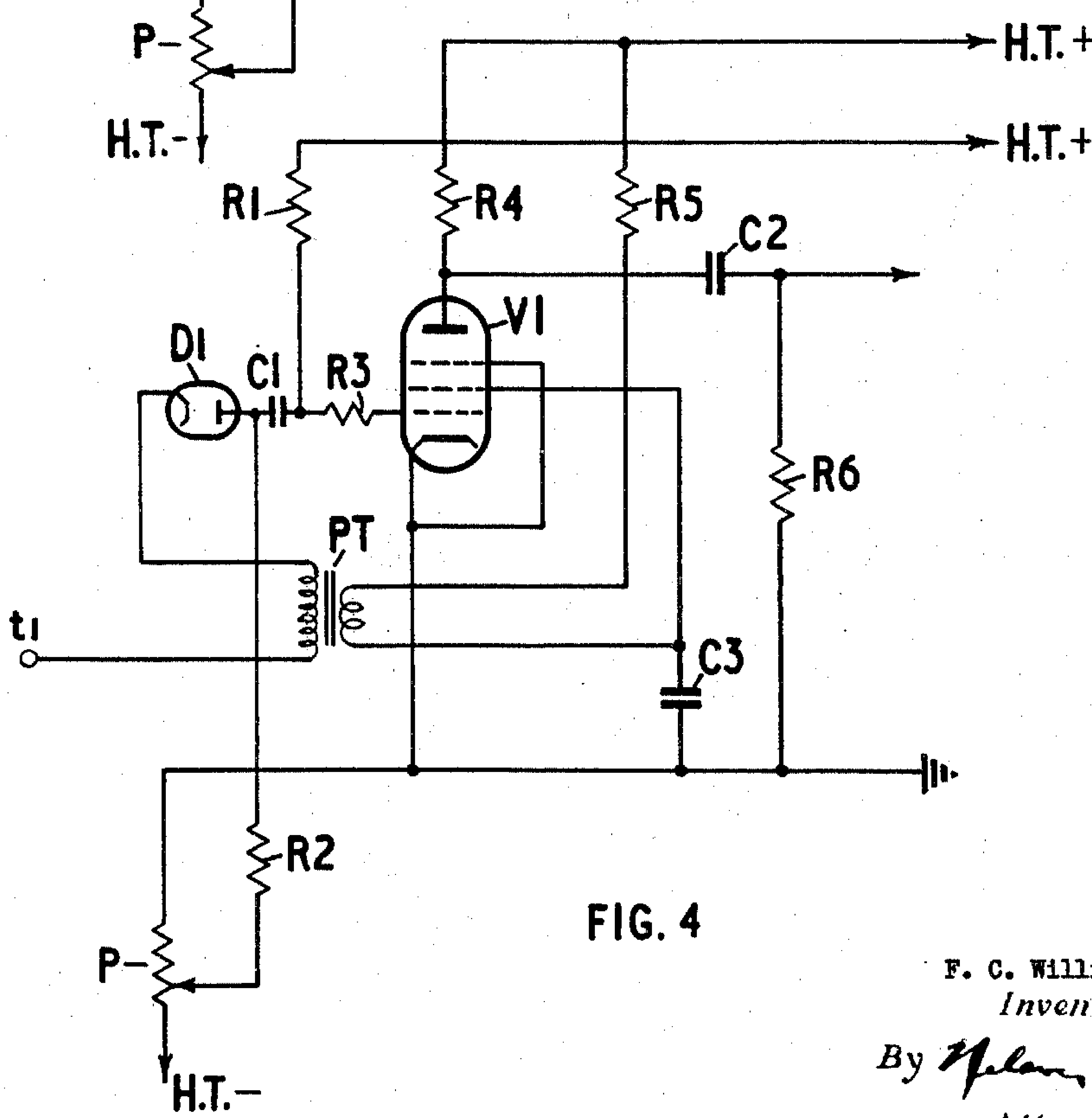

FIG. 4

F. C. Williams
Inventor

By [signature]
Attorney

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ELECTRON-DISCHARGE TUBE CIRCUIT ARRANGEMENT

Frederic Calland Williams, Timperley, England

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Section 1, Public Law 690, August 8, 1946
Patent expires October 2, 1964

12 Claims. (Cl. 250—27)

This invention relates to electron-discharge tube circuit arrangements for use in producing waveforms showing desired characteristics and the object of the invention is to provide a circuit arrangement for producing a sharp wavefront at a predetermined instant.

According to the present invention a circuit arrangement for generating a voltage waveform having a sharp wavefront at a desired instant during the run-down of an applied negative-going voltage comprising an electron discharge tube, switch means such as a diode through which said voltage may be applied to the control grid of the tube at the desired instant as determined by the instantaneous value of said voltage and a regenerative feedback circuit closed by the switch means, the arrangement being such that if the negative-going voltage is applied when the tube is conducting then at the desired instant both the applied waveform and the feedback become effective in turning the tube off on its control grid thereby generating the sharp wavefront in an output circuit of the tube.

Also according to the present invention, a circuit arrangement for producing a voltage waveform of desired timing and of sharp wavefront includes an electron-discharge tube the control grid of which normally takes current and a regenerative feedback circuit for controlling the potential of the control grid of the tube in such a manner that the application to the grid of a negative-going voltage cuts off the grid current at an instant determined by an initial negative potential effective in the feed-back circuit. The feedback circuit may be connected between the control grid and another electrode of the tube and the initial potential referred to may be that applied to an electrode of a unilaterally conducting device such as the anode of a diode in the feedback circuit, to the cathode of which the negative-going voltage is applied, the anode of the diode being coupled to the control grid of the electron discharge tube.

In a particular circuit arrangement embodying the invention the feedback circuit is constituted by a transformer coupling between the cathode of the tube and the control grid, the transformer coupling being completed through a unilaterally conducting device such as a diode and through a coupling condenser, and the operation of the circuit is such that regeneration does not occur until the potentials applied to the unilaterally conducting device cause the feedback circuit to become effective.

In order that the invention may be more clearly understood, and readily carried into effect, one circuit arranged to operate in accordance therewith will now be described by way of example with reference to the accompanying drawing in which:

Fig. 1 shows such a circuit,

Fig. 2 shows voltage wave forms associated with certain electrodes of the valves shown in Fig. 1, and

Figures 3 and 4 show modifications of the circuit shown in Figure 1.

The circuit of Figure 1 is intended to produce a wave form having an extremely sharp wavefront or leading edge which is timed to occur at any controlled instant during the period of a sawtooth wave form. It may be assumed that there is available at the input of the circuit shown in Fig. 1 a sawtooth voltage waveform as shown at *a* in Fig. 2 and that it is desired to produce a sharp wavefront at the instant *x* in the sawtooth cycle. The linear part of the sawtooth occurs during the period from $t=0$ to $t=T$ and it will be assumed that *x* may have any value such that 0 is less than *x* which in turn is less than T.

Referring to Fig. 1, the initial quiescent state of the circuit is such that the control grid of a pentode valve V1 is taking current, the anode current of the valve being at saturation level such that its voltage is at the lowest level. The sawtooth voltage waveform *a*, the D. C. component of which is restored to ground level, is applied from terminal *t1* through the secondary winding of a pulse transformer PT to the cathode of a diode valve D1. The potential of the anode of this diode is adjusted to a value $-V$ by a tapping on a potentiometer resistance P connected to a source of 200 volts negative, a resistance R2 being connected in the lead to the anode of the diode.

If now the slope of the sawtooth is *v* volts per microsecond, that is to say the waveform goes increasingly negative at the rate of *v* volts per microsecond, the cathode potential of the diode will become equal to the anode potential after a period represented by *x* microseconds where

$$x=\frac{V}{v}$$

In the present instance, for example, $v=4$. When the instant *x* is reached the diode functions as a switch means and the sawtooth voltage is applied to the control grid of the valve V1 through the diode, the condenser C1 and the resistance R3. The anode voltage of the diode now follows the curve shown at *b* in Fig. 2 and the control grid potential is thus progressively decreased. The cathode current of the valve V1 is decreased and a negative-going wavefront is developed across the primary winding of the transformer PT, the primary winding of which consists of 135 turns of number 38 S. W. G. wire wound in one layer next to a core of radiometal. The secondary winding consists of 200 turns of similar wire wound on top of the primary winding and suitably insulated. The sudden variation in the primary winding is stepped up by the secondary winding and applied to the cathode of the diode D1 and thence through the coupling condenser C1 and resistance R3 to the control grid of the valve V1. This regenerative action results in the valve V1 being cut off due to feedback almost instantaneously thereby producing at the anode a positive-going voltage waveform with a sharp edge as shown by waveform *c*, Fig. 2, and a negative pip in the potential of its cathode as shown in waveform *d* in Fig. 2.

At the completion of a cycle of the sawtooth voltage waveform, the electrodes of the diode D1 and valve V1 return to their initial operating values and the circuit returns to its quiescent state. If the return time of the sawtooth waveform is short, and the condenser/resistance combination C1/R3 does not transfer the whole of the waveform to the control grid, the back edge of the square waveform *c* may not coincide with the return to quiescence of the waveform *b*.

In the particular circuit described the anode of the valve V1 is connected through its resistance R4 to a high tension source of 330 volts positive and the control grid is connected through resistances R3 and R1 to a source of 200 volts positive.

The resistances and condensers shown have the following values:

Resistances (k=1000)—
R1=10 megohms
R2=270 ohms
R3=470 ohms
R4=56k ohms
R5=33k ohms
R6=1.5k ohms

Condensers—
C1=1000 micro-micro farads
C2=0.1 micro-farad
C3=0.1 micro-farad

A suitable type of diode D1 for the circuit described is the Mullard type EA50 and the valve V1 may be a Mullard type EF50. Clearly, other types of valves with appropriate characteristics may be employed.

It will be understood that variation of the initial negative voltage applied to the anode of the diode D1 and choice of a sawtooth waveform of appropriate slope enables selection to be effected of the instant x at which a sharp voltage wavefront may be developed at the anode of the valve V1 and taken off from the condenser C2.

Again, since A. C. coupling to the control grid of the valve V1 is used, it will be seen that the applied sawtooth waveform may commence at a positive voltage if desired, the anode potential of the diode D1 being adjusted to a smaller positive voltage.

A desired modified anode waveform may be obtained by applying a modulation waveform of the suppressor grid of the pentode valve V1. Thus, for example, if before the time $t=0$ in Fig. 2 a potential is applied to the suppressor grid such that anode current is cut-off and then between the times $t=0$ and $t=T$ the applied potential is raised to cause anode current to flow, the

waveform *c* of Fig. 2 will be a negative square wave commencing at $t=0$ and ending at $t=x$. It will be appreciated that the sharp wavefront occurs at $t=x$ and is the back edge of the negative wave.

Instead of connecting the primary winding of the transformer in the cathode lead of the valve V1 as described, it may be connected in the anode lead. The square waveform output is in this case taken from the screen grid of the valve V1, the remaining circuit connections and performance being similar to the cathode feedback case described. This modification is illustrated in Figure 3. Alternatively, the feedback connection may be taken from the screen grid of the valve V1, the output being taken from the anode as in Fig. 1. This modification is illustrated in Figure 4.

I claim:

1. A circuit arrangement for generating a voltage waveform having a sharp wave front at a desired instant during the run-down of an applied voltage comprising a diode to which said voltage is applied, biasing means for said diode for preventing conduction through said diode until a predetermined time after the beginning of the run-down of said applied voltage, an electron discharge tube, means for applying a pulse to an electrode of said electron discharge tube on the conduction of said diode to cause a change in the condition of said electron discharge tube, and regenerative feedback circuit including an amplifying device between another of the electrodes of said electron discharge tube and the input of said diode, said feed-back circuit being completed on the conduction of said diode whereby a sharp wave front is produced in the output circuit of said electron discharge tube.

2. A circuit arrangement as claimed in claim 1 wherein said regenerative feedback circuit comprises a step-up transformer the primary winding of which is connected in circuit with said electrode while the secondary winding is connected in series with the input circuit to said diode.

3. A circuit arrangement as claimed in claim 2 wherein said primary winding is connected in circuit with the cathode of said electron discharge tube.

4. A circuit arrangement for generating a voltage waveform having a sharp wave front at a desired instant during the run-down of a negative-going voltage comprising a diode having an anode, said diode having a cathode to which is applied said negative-going voltage, variable biassing means for applying a negative bias to the anode of said diode to prevent conduction of said diode until a predetermined time after the beginning of the run-down of said negative-going voltage, an electron discharge tube having an anode and a cathode as well as a control grid, a power circuit for applying a direct current potential between said anode and said cathode with the latter negative, means for applying a positive bias to the control grid of said tube to cause the tube to conduct, an alternating current coupling circuit having a short time constant between the anode of said diode and said control grid whereby on the conduction of said diode a negative-going pulse is applied to said control grid to initiate the cutting off of said tube, and a regenerative feedback circuit including a step-up transformer having its primary winding in series with said power circuit and its secondary winding in series with the cathode of said diode, said feedback circuit being energized on the conduction of said diode

whereby said tube is sharply cut off and a sharp wave front is thus produced in the output circuit of said electron discharge tube.

5. A circuit arrangement as claimed in claim 4 wherein said regenerative feedback circuit is taken from the cathode and the output is taken from the anode of said electron discharge tube.

6. A circuit arrangement as claimed in claim 4 wherein said regenerative feedback circuit is taken from the anode and the output is taken from the screen electrode of said electron discharge tube.

7. A circuit arrangement as claimed in claim 4 wherein said regenerative feedback circuit is taken from the screen electrode and the output is taken from the anode of said electron discharge tube.

8. In a circuit for producing a wave having a sharp wave front, generator means for producing a linearly varying potential, said generator means including an output circuit, an electron discharge device having an anode as well as a cathode with a control grid between the anode and the cathode, a source of direct current potential having its positive side connected to said anode and its negative side connected to said cathode, means connecting the negative side of said output circuit to said grid and the positive side of said output circuit to said cathode, means in said output circuit for blocking passage of current therethrough to said grid when said first-named potential is below a predetermined value and for permitting passage of current to said grid in said output circuit when said first-named potential is above said predetermined value, and means connected in series with said source of direct current potential for increasing the potential of said output circuit in response to a decrease in current flow from said source.

9. In a circuit for producing a wave having a sharp wave front, generator means for producing a linearly increasing potential, said generator means including an output circuit, a half wave rectifier having its negative pole connected to the negative side of the output circuit, an electron discharge device having a cathode and an anode, said device also having a control grid, a feeder connection between said grid and the positive pole of said rectifier, a direct current power supply, a circuit including electrical connections respectively connecting the positive side of said supply to said anode and the negative side of said supply to said cathode, a step-up transformer having a primary winding in series with the last-named circuit and a secondary winding in series with said output circuit, an electrical connection between the positive side of the output circuit and said cathode, and means for applying a potential between the positive pole of the rectifier and the positive pole of the output circuit with the positive side of the last-named potential being applied to the rectifier, the last-named potential having a value greater than the potential of the generator means at the beginning of variation of the latter potential and less than the potential of the generator means at the end of the linear variation of the latter potential.

10. The system defined in claim 9 in which the feeder connection comprises in series, a condenser and a resistor, said condenser and resistor having such values of capacity and resistance respectively that the time constant of the circuit including them is short as compared with the time period elapsing between the beginning and the end of a single linear increase of potential of the generator means.

11. The system defined in claim 10 in which a first side of the condenser is connected to said rectifier and a first side of the resistor is connected to said grid, and a source of direct current having a positive side connected to the second sides of said condenser and resistor and a negative side connected to said cathode, said last-named source applying sufficient potential to said grid to effect saturation of the electron discharge device in absence of current flow through said rectifier.

12. The system defined in claim 9 including in addition means to bias said grid positively to a sufficient degree to effect saturation of the electron discharge device in the absence of bias potential applied through said rectifier.

FREDERIC CALLAND WILLIAMS.

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