

April 6, 1948.

R. M. WALKER

2,439,324

ELECTRICAL CIRCUIT

Filed Aug. 1, 1945

FIG. 1

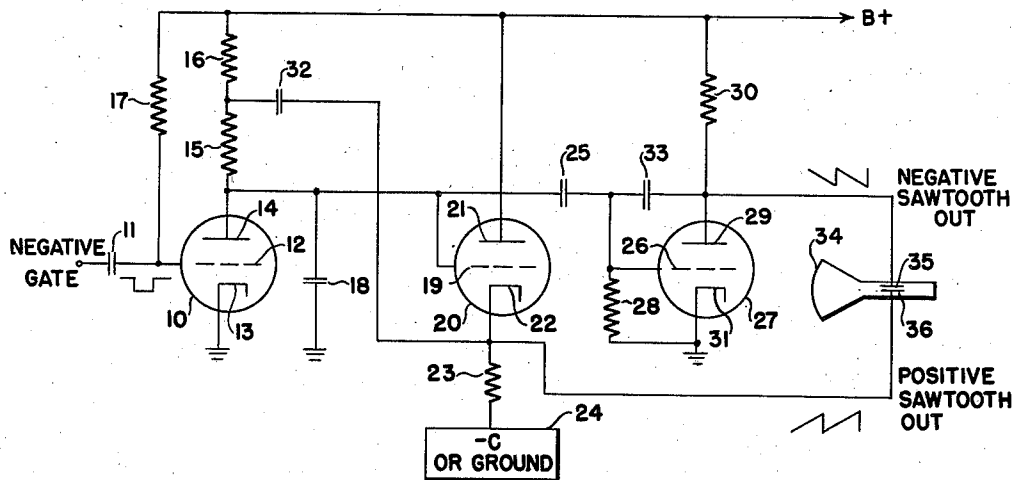
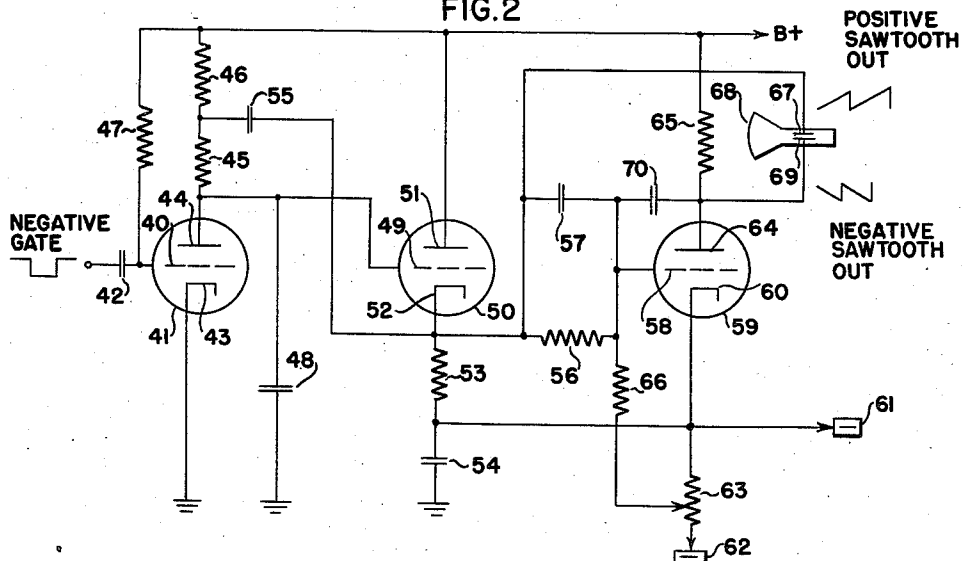


FIG. 2



INVENTOR

ROBERT M. WALKER

BY

William D. Lee

ATTORNEY

UNITED STATES PATENT OFFICE

2,439,324

ELECTRICAL CIRCUIT

Robert M. Walker, Belmont, Mass., assignor, by
mesne assignments, to the United States of
America as represented by the Secretary of War

Application August 1, 1945, Serial No. 608,304

6 Claims. (Cl. 315—26)

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This invention relates in general to electrical circuits and more particularly to circuits for generating the sawtooth sweep voltages to be used with a cathode ray tube.

For most purposes the time base of an electrically-deflected cathode ray beam is a linearly increasing voltage with a fast return to a rest value. This requires that the voltage wave take the form of a sawtooth or serrated wave, its action being to move the spot formed by the impingement of the cathode ray beam on the face of a tube at a constant speed in one direction thereacross. An increase in linearity of the motion of this trace over that resulting from the use of a single sawtooth wave may be accomplished by using a push-pull sweep-generating circuit; i. e., one that applies sawtooth waveforms to both cathode ray tube deflection plates of one set, these waveforms being inverted with respect to each other.

Among the objects of this invention, therefore, are:

1. To provide a circuit for generating sawtooth voltage waveforms;
2. To provide such a circuit in which the sawtooth wave is substantially linear; and
3. To provide such a circuit having a push-pull output.

In accordance with the present invention there are provided two embodiments of a push-pull sawtooth wave sweep circuit. In the first embodiment a normally-conducting switch tube has an effective capacitance connected between the plate of the tube and ground. A negative square pulse applied to the grid turns off the tube at the start of the development of the sawtooth wave. The voltage on the plate of this tube is coupled to a buffer tube and is then fed back through the cathode of this buffer to the plate load circuit of the switch tube. The output of the switch tube is also connected to an inverter tube through a capacitance voltage divider, the output of the inverter tube being one sawtooth wave of the push-pull output of the circuit. The other sawtooth wave of the push-pull output is taken from the cathode of the buffer tube.

In the second embodiment of the circuit a normally-conducting switch tube has a condenser connected between the plate and ground. A negative square pulse applied to the grid turns off the tube at the start of the development of the sawtooth wave. This plate is connected to the grid of a buffer tube, the cathode of which is connected back to a load resistor of the switch

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tube for feedback purposes. The cathode of the buffer tube is also connected through a capacity voltage divider to the grid of an inverter tube. One part of the push-pull sawtooth wave output is taken from the plate of the inverter tube, and the other part is taken from the cathode of the buffer tube.

This invention will best be understood by reference to the drawings, in which:

Fig. 1 shows one embodiment of my invention; and

Fig. 2 shows another embodiment of my invention.

Referring now to a description of the first embodiment of the circuit and to Fig. 1, it is seen that the input pulse is coupled to the grid 12 of switch tube 10 through coupling condenser 11. The cathode 13 of tube 10 is grounded. Connecting the plate 14 of tube 10 to the source of plate voltage, B+, are two load resistors 15 and 16. The grid 12 of switch tube 10 is returned to B+ through grid-leak resistor 17. A condenser 18 is placed between the plate 14 of tube 10 and ground.

The plate 14 of switch tube 10 is coupled to the grid 19 of buffer tube 20. The plate 21 of tube 20 is connected directly to B+, and the cathode 22 of this tube is connected through a load resistor 23 to a source of negative voltage (-C) or to ground 24. The cathode 22 of tube 20 is connected back to the lower end of load resistor 16 through coupling condenser 32. One part of the push-pull output of the circuit, the so-called positive sawtooth wave, is taken from the cathode 22 of the buffer tube 20.

The plate 14 of switch tube 10 is also coupled through condenser 25 to the grid 26 of inverter tube 27. Grid leak resistor 28 connects the grid 26 of this tube to ground. The plate 29 of tube 27 is connected through load resistor 30 to B+, and the cathode 31 of this tube is grounded. Feedback condenser 33 connects the plate 29 of tube 27 to the grid 26 of this tube. The other part of the push-pull output of the circuit, the so-called negative sawtooth wave, is taken from the plate of inverter tube 27.

The negative sawtooth wave is coupled to one deflection plate 35 of cathode ray tube 34, while the positive sawtooth wave is coupled to the other deflection plate 36 of this tube.

Referring now to a description of the second embodiment of the sweep circuit and to Fig. 2, it is seen that the input pulse is fed to grid 40 of switch tube 41 through coupling condenser 42. The cathode 43 of tube 41 is grounded, and the

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plate 44 is connected to a source of positive voltage, B+, through load resistors 45 and 46. The grid 49 of tube 41 is returned to B+ through grid-leak resistor 47. A sweep condenser 48 is connected from the plate 44 to ground.

The plate 44 is coupled directly to the grid 49 of buffer tube 50. The plate 51 of tube 50 is connected directly to B+, and the cathode 52 of tube 50 is connected through a load resistor 53 to a source of negative voltage 61. The lower end of resistor 53 is connected to ground by condenser 54. The cathode 52 of tube 50 is connected back to the lower end of load resistor 46 through coupling condenser 55.

The cathode 52 of tube 50 is also connected through a parallel network of resistor 56 and condenser 57 to the grid 58 of inverter tube 59. The cathode 60 of tube 59 is connected to a source of negative potential 61, which in turn is connected to another source of negative potential 62 through potentiometer 63. The plate 64 of tube 59 is connected to B+ through plate resistor 65. The grid 58 is connected to the center arm of potentiometer 63 through resistor 66. Feedback condenser 70 connects the plate 64 to the grid 58 of this tube.

The positive sawtooth output, which is coupled to one plate 67 of cathode ray tube 68, comes from the cathode 52 of buffer tube 50, while the negative sawtooth output, which is coupled to the other plate 69 of the cathode ray tube 68, comes from the plate 64 of inverter tube 59.

Referring now to the operation of the first embodiment of the circuit and to Fig. 1, it is seen that, due to the positive grid return of switch tube 10, this tube will be normally highly conducting, and its plate potential will be low. A negative rectangular pulse is applied to the grid of this tube, cutting it off. Immediately two parallel capacitances begin charging one being condenser 18, and the other being the series capacitance of condenser 25 and the input capacitance of tube 27. This latter value is made quite large due to the condenser 33 from plate 29 to grid 26. Thus, neglecting the effect of the feedback through condenser 32, the plate voltage of tube 10 would rise exponentially as soon as the switch tube stops conducting. Due to the feedback connection from the cathode of tube 20 to the lower end of resistor 16, this latter point rises in potential at a rate comparable with the voltage rise at the plate of tube 10. The effect of this feedback is to cause a substantially constant charging current to flow into the abovementioned parallel capacitances, and so to cause a linear rise in voltage at the plate of tube 10. This will also cause a linear positive sawtooth to appear at the cathode of tube 20. This waveform is applied to one deflection plate 36 of the cathode ray tube 34.

The positive sawtooth wave on the plate of tube 10 is applied to the grid of tube 27 through a capacity voltage divider of condenser 25 and the input capacitance of tube 27. This input capacitance is purposely increased by making use of the Miller effect. Thus, the capacitance from the grid of tube 27 to ground is equal to the plate-to-grid capacitance, which is effectively equal to the capacitance of condenser 33, multiplied by the factor $(G+1)$, where G is the gain of tube 27. Thus if E_0 is the instantaneous output plate voltage of tube 10, E_1 is the instantaneous input grid voltage of tube 27, and the capacitance 33 is equal to the capacitance 25,

$$E_1 = \frac{E_0}{G+2}$$

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and the instantaneous voltage E_2 appearing at the plate of tube 27 will be

$$E_2 = E_1 \frac{G}{G+2}$$

As can be seen from Equation 5-3, pg. 221, in the book "Ultra-High-Frequency Techniques" by Brainerd et al., of the load resistor in a cathode follower stage is large as compared to the plate resistance of the tube, the amplification A of a cathode follower is

$$A = \frac{\mu}{\mu+1}$$

where μ is the amplification factor of the tube. Since tube 20 is acting as a cathode follower, the instantaneous voltage at cathode 22, which is the instantaneous positive sawtooth voltage, will be $\mu/(\mu+1)$ times the voltage at the plate of tube 10. The negative sawtooth is taken from the plate of tube 27, and the voltage at this point at any instant is $G/(G+2)$ times the voltage on the plate of tube 10. Thus it can be seen that the positive and negative sawtooth voltages are approximately equal.

Referring now to the operation of the circuit of Fig. 2, it is seen that normally-conducting switch tube 41 is switched off by the negative rectangular pulse applied to the grid, at which time condenser 48 begins charging. As in the circuit of Fig. 1, this sawtooth waveform is made to be quite linear by coupling the plate of tube 41 to the grid of buffer tube 50, and then feeding the voltage on the cathode of tube 50 back to the load circuit of tube 41.

The sawtooth on the cathode of buffer tube 50 is fed to the grid of inverter tube 59 through a compensated voltage divider. The time constant of the resistance of resistor 56 multiplied by the capacitance of condenser 57 is made substantially equal to the time constant of the resistance of resistor 66 multiplied by the input capacitance of tube 59, which is the capacitance of condenser 70 times $(G+1)$ where G is the gain of tube 59. With the two time constants being equal, the ratio of the voltage divider is made insensitive to frequency changes. In addition, the condenser 70 introduces negative feedback for tube 59 and so increases the linearity and speed of starting of the sawtooth wave. The positive sawtooth is taken from the cathode of buffer tube 50, while the negative sawtooth is taken from the plate of inverter tube 59.

It will be observed that there is a $d-c$ path from the cathode of tube 50 to one deflection plate 67 of the cathode ray tube. If desired, sweep centering may be obtained by adjusting the potential of the cathode of tube 41 which will control the potential on the cathode of tube 50. An increase in the potential of the cathode of tube 41 will decrease the average potential on the upper deflection plate 67 and increase the average potential on the lower deflection plate 69 and the position of the sweep on the screen will be lowered.

While there has been described what is at present considered the preferred embodiment of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

I claim:

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1. A circuit for generating push-pull sawtooth sweep voltages for a cathode ray tube comprising a switch tube having a load circuit, capacitance means connected between the plate of said switch tube and a point of reference potential, means for applying pulses from a source external to said circuit onto said switch tube, whereby said switch tube is made impervious to current flow therethrough and a positive sawtooth wave of voltage is generated at the plate thereof, a buffer stage comprising a cathode follower circuit, means coupling said positive sawtooth wave to the grid of said cathode follower circuit, first condenser means coupling the cathode of said cathode follower circuit back to the load circuit of said switch tube, whereby the linearity of said positive sawtooth wave is increased over the linearity of an exponential wave, means coupling said positive sawtooth wave at the cathode of said buffer tube to a first deflection means of said cathode ray tube, an inverter tube, voltage divider means applying said positive sawtooth wave to the grid of said inverter tube, whereby a negative sawtooth wave is present on the plate of said inverter tube, and means applying said negative sawtooth wave to a second deflection means of said cathode ray tube.

2. A circuit for generating push-pull sawtooth sweep voltages for a cathode ray tube comprising a switch tube having a resistive load circuit, a capacitance means connected between the plate of said switch tube and a point of reference potential, means for applying negative pulses from a source external to said circuit onto the grid of said switch tube, whereby said switch tube is made impervious to current flow therethrough and a positive sawtooth wave of voltage is generated at the plate thereof, a buffer cathode follower tube, means direct-coupling the plate of said switch tube to the grid of said buffer tube, a first condenser coupling the cathode of said cathode follower tube back to an intermediate point on the resistive load circuit of said switch tube, whereby the linearity of said positive sawtooth wave is increased over the linearity of the exponential wave which would occur at the plate of said switch tube in the absence of the use of said first condenser, an inverter tube, a portion of said capacitance means coupling the plate of said switch tube to the grid of said inverter tube, a second condenser connecting the plate of said inverter tube to the grid of said inverter tube, whereby the input capacitance of said inverter tube is used with said portion of said coupling capacitance as a voltage divider, means coupling the plate of said inverter tube to a first deflection means of said cathode ray tube, and means coupling the cathode of said buffer tube to a second deflection means of said cathode ray tube, whereby push-pull sawtooth voltage waves are generated at the cathode of said buffer tube and at the plate of said inverter tube.

3. A circuit for generating push-pull sawtooth sweep voltage waves for a cathode ray tube comprising a switch tube having a resistive load with a tap at some intermediate point on said load, a first condenser connected from the plate of said switch tube to a first point of reference potential, means for applying negative pulses to the grid of said switch tube, whereby said switch tube is made impervious to current flow therethrough and a positive sawtooth wave of voltage is generated at the plate thereof, a buffer cathode follower tube, means coupling the plate of said switch tube to the grid of said buffer tube, a

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second condenser coupling the cathode of said buffer tube back to said tap on the resistive load circuit of said switch tube, whereby the linearity of said positive sawtooth wave is increased over the linearity of the exponential wave which would appear at the plate of said switch tube in the absence of said second condenser, an inverter tube, a first resistance means connecting the cathode of said buffer tube to the grid of said inverter tube, a third condenser means in parallel with said first resistance means, a second resistance means connecting the grid of said inverter tube to a second reference potential, a fourth condenser means coupling the plate of said inverter tube to the grid of said inverter tube, whereby a voltage divider is formed comprising said first resistance means, said third condenser means, said second resistance means, and the input capacitance to said inverter tube, means coupling the cathode of said buffer tube to a first deflection means of said cathode ray tube, and means coupling the plate of said inverter tube to a second deflection means of said cathode ray tube, whereby push-pull sawtooth voltage waves are generated at the cathode of said buffer tube and at the plate of said inverter tube.

4. A circuit for generating push-pull sawtooth sweep voltages for a cathode ray tube comprising a switch tube having a resistive load circuit, a first condenser connected between the plate of said switch tube and a point of reference potential, means for applying pulses to said switch tube, whereby said switch tube is made impervious to current flow therethrough and a positive sawtooth wave of voltage is generated at the plate thereof, a buffer cathode follower tube, means coupling the plate of said switch tube to the grid of said buffer tube, a second condenser coupling the cathode of said cathode follower tube back to the load circuit of said switch tube, whereby the linearity of said positive sawtooth wave is increased over the linearity of the exponential wave which would appear at the plate of said switch tube in the absence of said second condenser, an inverter tube, means coupling the cathode of said buffer tube to the grid of said inverter tube, means coupling the cathode of said buffer tube to a first deflection means of said cathode ray tube, and means coupling the plate of said inverter tube to a second deflection means of said cathode ray tube, whereby push-pull sawtooth voltage waves are generated at the cathode of said buffer tube and at the plate of said inverter tube.

5. A circuit for generating push-pull sawtooth sweep voltages for a cathode ray tube comprising a switch tube having a load circuit, capacitance means connected between the plate of said switch tube and a point of reference potential, means for applying pulses from a source external to said circuit onto said switch tube, whereby said switch tube is made impervious to current flow therethrough and a positive sawtooth wave of voltage is generated at the plate thereof, a buffer and inverter stage comprising a cathode follower buffer circuit and a plate inverter circuit, means coupling said positive sawtooth wave to control the current in said cathode follower buffer circuit and said plate inverter circuit, condenser means coupling the cathode of said cathode follower circuit back to the load circuit of said switch tube, whereby the linearity of said positive sawtooth wave is increased over the linearity of an exponential wave, means coupling the positive sawtooth wave at the cathode of said buffer cir-

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cult to a first deflection means of said cathode ray tube, and means coupling the inverted sawtooth wave at the plate of said inverter circuit to a second deflection means of said cathode ray tube.

6. A circuit for generating push-pull sawtooth sweep voltages for a cathode ray tube comprising a switch tube having a resistive load circuit, a first condenser connected between the plate of said switch tube and a point of reference potential, means for applying pulses to said switch tube, whereby said switch tube is made impervious to current flow therethrough and a positive sawtooth wave of voltage is generated at the plate thereof, buffer and inverter tube means including a cathode follower buffer circuit and a plate inverter circuit, means coupling the plate of said switch tube to control the current in said circuits, a second condenser coupling the cathode of said cathode follower circuit back to the load circuit of said switch tube, whereby the linearity

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of said positive sawtooth wave is increased over the linearity of the exponential wave which would appear at the plate of said switch tube in the absence of said second condenser, means coupling the positive sawtooth wave at the cathode of said buffer circuit to a first deflection means of said cathode ray tube, and means coupling the inverted sawtooth wave at the plate of said inverter circuit to a second deflection means of said cathode ray tube.

ROBERT M. WALKER.

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