Oct. 14, 1947.

A. M. SKELLETT

2,428,819

SECONDARY ELECTRON EMISSION TYPE OF PULSE GENERATOR

Filed Dec. 15, 1942

FIG. 1

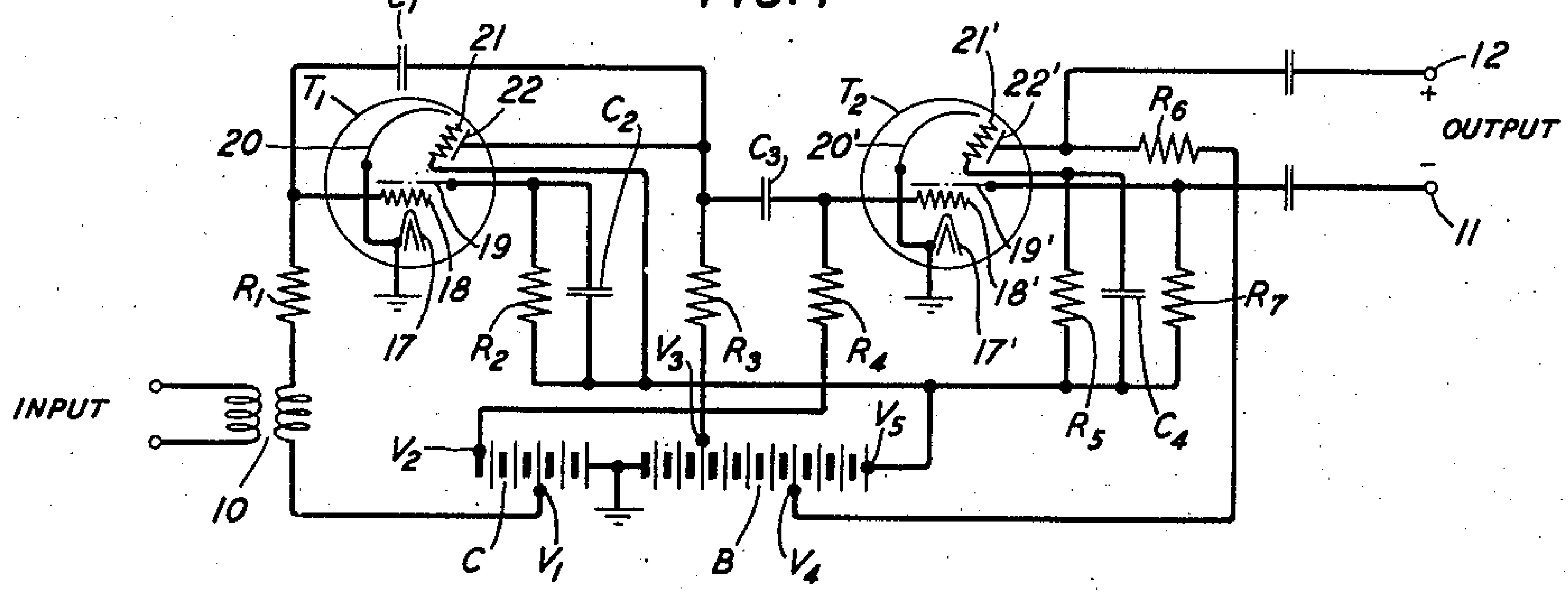


FIG. 2

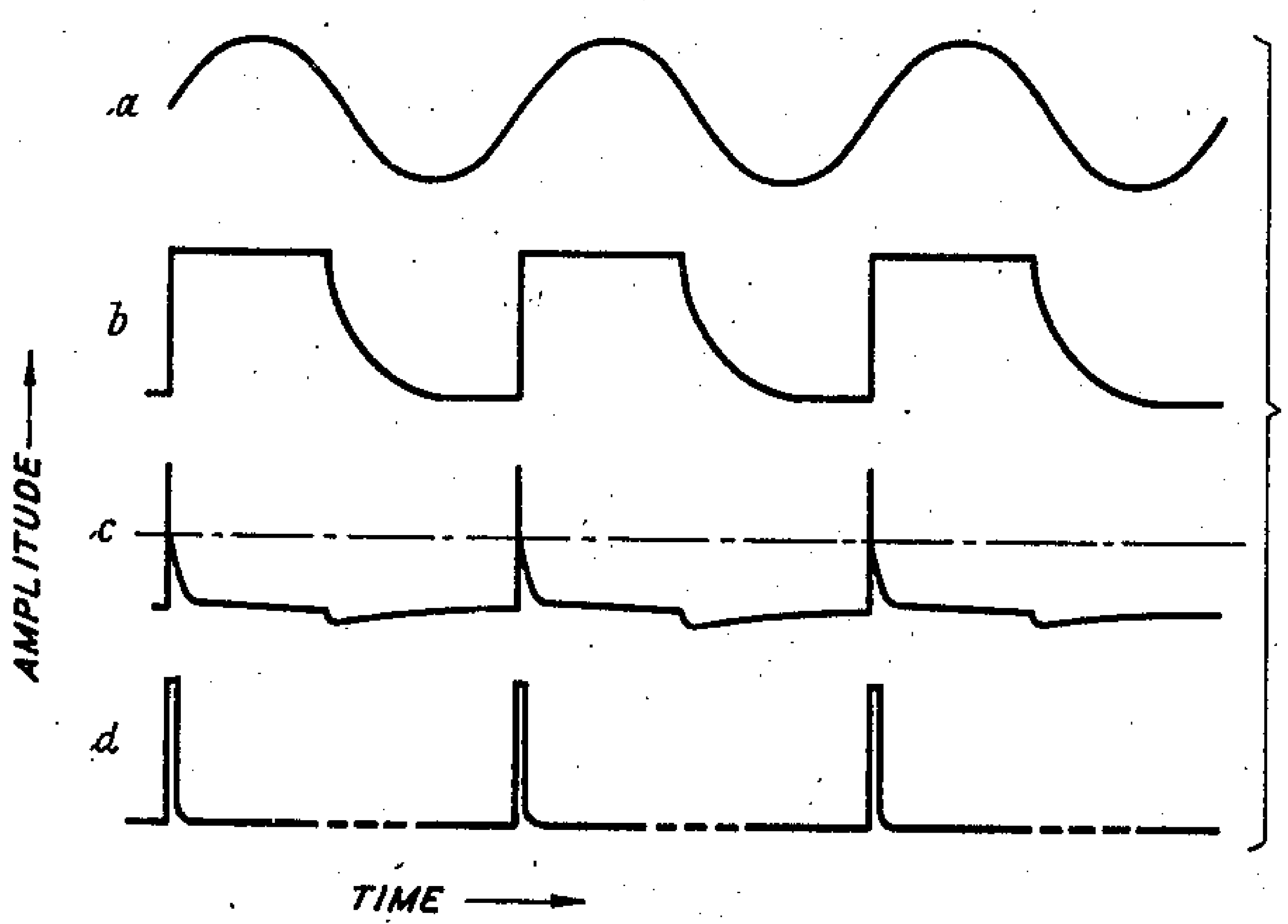
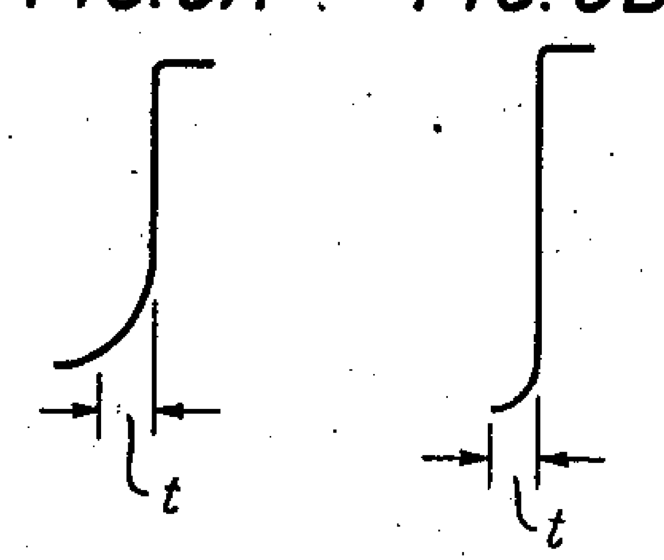
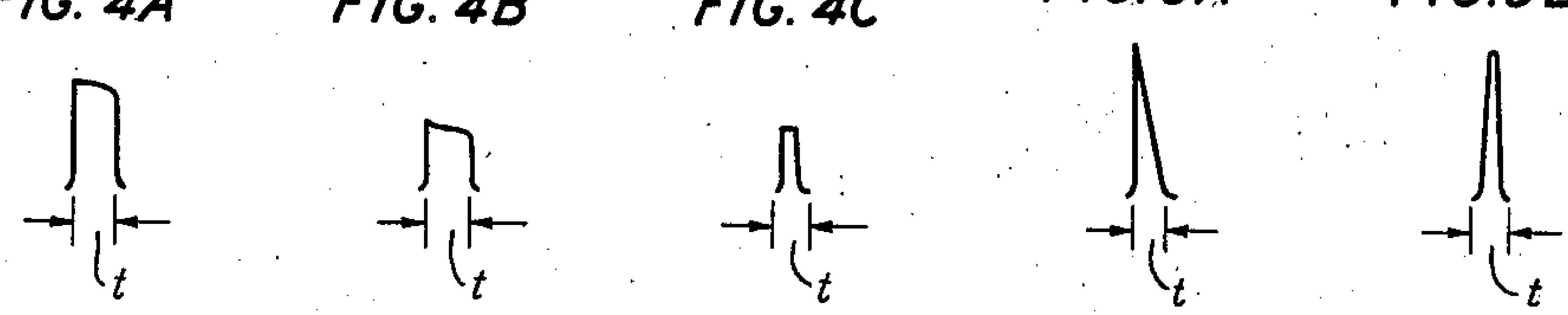


FIG. 3A . FIG. 3B



t = 1 MICROSECOND

FIG. 4A FIG. 4B FIG. 4C FIG. 5A FIG. 5B



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SECONDARY ELECTRON EMISSION TYPE OF PULSE GENERATOR

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4 Claims. (Cl. 250—27)

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This invention relates to pulse generators.

An object of the invention is to generate high power, short duration pulses of electric energy at a desired time interval or frequency.

A feature of the invention comprises a pulse generation circuit arrangement embodying secondary emission electronic devices.

A further feature comprises utilizing a secondary electron trigger type vacuum tube or device to generate a square-topped output wave in response to a control signal or voltage, and a second such device to generate a pulse of the desired magnitude and duration in response to the steep front only of the square-topped wave.

In the practice of the invention, electronic devices of the type described in my Patent 2,293,177, issued August 18, 1942, may be employed. The device of the aforenoted patent is a secondary electron emission, trigger type vacuum tube. In general, it comprises a triode or primary electron section and a secondary electron section. The triode section comprises a primary electron source or cathode, an input control grid, and a primary anode the latter is provided with an aperture or slot for the escape of a preassigned percentage of the primary electrons arriving at the anode from the cathode. The secondary electron section comprises a secondary anode having a surface treated for emission of electrons in ratio greater than unity when bombarded with escaped primary electrons, and a secondary electron collector electrode or grid, the secondary grid and anode being positioned out of the direct path of the escaped primary electrons so that the secondary electron emitting surface will not be contaminated by cathode particles. The escaped primary electrons are directed onto the secondary anode by a deflector electrode positioned in the path of the escaped electrons, and which may be maintained at cathode potential. As explained in greater detail in Patent 2,293,177, if the input grid is initially biased beyond primary anode current cut-off and the secondary anode and the input grid are interconnected and the collector grid is maintained at a potential more positive than the secondary anode, a positive pulse of small order of magnitude applied to the cathode-input grid circuit to initiate primary electron flow in the triode section, will cause the secondary anode to rise quickly to a high and stable floating potential which, applied to the input grid through the interconnection between the input grid and secondary anode, drives the input grid more positive with respect to the cathode and accelerates

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establishment of a high magnitude of primary electron flow between the cathode and primary anode. In the absence of an interconnection between the input grid and the secondary anode, the establishment of primary electron flow between the cathode and primary anode and the bombardment of the secondary anode with escaped primary electrons will cause the secondary anode to rise to a high and stable floating potential at which it will remain so long as primary electron flow and the appropriate collector grid potential are maintained.

In accordance with the invention, two such electronic devices are arranged in a circuit such that one of the devices produces or generates a square-topped output wave of the same frequency as and in response to an input signal thereto, and the second produces a single pulse at the time of the steep front of the square-topped wave. The output of the second device is independent, over wide limits, of the amplitude and wave shape of the input signal or control voltage.

A more complete understanding of the invention will be obtained from the description that follows, taken in conjunction with the appended drawing, wherein:

Fig. 1 illustrates a circuit arrangement embodying the invention;

Fig. 2 illustrates the electric wave shapes present during operation of the circuit of Fig. 1, Fig. 2*d* having an expanded time axis so as to show in better detail the shape of the output pulse;

Figs. 3A to 5B show cathode ray oscillograph tracings illustrative of pulse shapes obtainable with the pulse generator of the invention.

The circuit comprises a pair of secondary electron trigger type vacuum tubes or devices T1, T2, such as described more fully in my Patent 2,293,177. Tube T1 comprises a cathode 17, an input control electrode or grid 18, a primary anode 19 containing an aperture for the egress or escape of some of the primary electrons that may arrive at the anode from the cathode, an electron deflector electrode 20 in the path of escaped electrons, and that may be connected to the cathode and maintained at cathode potential, a secondary electron collector electrode or grid 21, and a secondary anode 22, the latter having a surface treated to emit secondary electrons in ratio greater than unity when bombarded with escaped primary electrons directed onto it by the deflector electrode. With the collector grid of such a tube maintained at a potential more positive than the secondary anode, the latter has the characteristic, when bombarded by escaped primary electrons, of rising rapidly to a stable potential somewhat less than the collector grid potential. Tube T2 comprises similar electrodes to which the same designations primed are applied.

The input grid and secondary anode of tube T1 are interconnected through capacitor C_1, so that, for such operation of the tube T1 as causes the anode 22 to rise in potential, the grid 18 will be caused simultaneously to become more positive with respect to the cathode. The latter and the deflector electrode may be maintained at ground or reference potential. The grid 18 is biased negatively to beyond primary anode current cut-off, the bias being provided by the source C of biasing potential through the secondary winding of the input transformer 10 and resistor R_1. The latter is of a magnitude sufficient to prevent the grid 18 from assuming too positive a potential at large input voltages. Collector grid 21 is connected directly to the high potential terminal of source B of collector grid and anode potential, and anode 22 is connected through a resistor R_3 to a point of lower potential on source B. The resistance-condenser network R_2—C_2 between the primary anode and high potential terminal of source B may be found desirable when high primary anode potentials are involved. In a specific arrangement, it was included when the potential (V_5) exceeded about 250 volts. The time constant of the network should be such that the secondary anode may rise to its high stable potential before the potential of the primary anode drops appreciably from the magnitude present with no primary anode current flow. The signaling wave or control voltage input to tube T1 may be through the transformer 10.

The input grid 18′ of tube T2 is coupled to the secondary anode of tube T1 through a capacitor C_3 of a capacity that offers high impedance to all but the very high frequencies present in the steep front of a square-topped wave. Grid 18′ is also biased by source C through resistor R_4 to a potential beyond primary anode current cut-off. Primary anode 19′ may be connected directly to the high potential terminal of source B, or, as shown in the drawing, a resistor R_7 may be interposed thereby enabling the derivation of a negative pulse in the output of the circuit at terminal 11. The collector grid 21′ is also connected to the high potential terminal of source B with a resistance-condenser network R_5—C_4 interposed. The constants chosen for the latter network will determine the duration of the positive pulses. The higher the value of the resistance R_5, the shorter the pulse, the time constant of the network (that is, $R_5 \times C_4$) being held constant. The secondary anode 22′ is connected to positive pulse terminal 12 and through a resistor R_6 to a point on source B of lower potential than that of the collector grid.

The operating features of the circuit will now be described. The input signal or control voltage is applied to the cathode-input grid circuit of tube T1 through the transformer 10. The input signal might be an alternating current of sine wave character such as is illustrated by curve *a* of Fig. 2. The grid 18 will swing in instantaneous potential above and below cut-off. On its excursion above cut-off, primary electrons emitted from the cathode have access to the primary anode and, through the aperture in the primary anode, to the secondary anode of tube T1. As described in detail in my Patent 2,293,177, the anode 22 will rise to a stable potential determined by the magnitude of resistor R_3 and the potential on the collector grid, and will remain in such high potential state until the primary electron flow is interrupted as a result of the excursion of the grid 18 sufficiently negative with respect to the cathode. Cessation of primary electron bombardment of the anode 22 restores the latter to the potential determined by its connection to the source B.

The resulting electric wave that appears across the resistor R_3 is illustrated by curve *b* of Fig. 2. The steepness of the front of this wave and its amplitude are substantially independent of the input voltage and frequency, being dependent on the parameters of the tube and the time constants of the circuit, particularly of the potential of grid 21 and the R_2—C_2 network. Figs. 3A and 3B show cathode ray oscillograph tracings of this steep front for two sets of conditions with a circuit such as is shown in Fig. 1. For Fig. 3A, V_5 was equal to 250 volts and the R_2—C_2 network was omitted. For Fig. 3B, V_5 was equal to 400 volts, R_2 was 50,000 ohms and C_2 was .00002 microfarad. As already indicated, resistor R_1 prevents the grid 18 from going too far positive for large input voltages. The capacitor C_1 feeds back to the grid 18 the upward surge of the secondary anode potential so as to accelerate the potential rise of the secondary anode by causing the input grid to become more positive and to permit an increased flow of primary electrons to the primary and secondary anodes. This regenerative action shifts control of the input grid to the secondary anode, and assists in making the steepness of the generated wave front independent of the input signal; the latter is thus used only to trigger on the electron current.

The capacitor C_3 is of small capacity so that only the higher frequencies are transferred to the grid 18′, and since these high frequencies have appreciable magnitude only at the steep front of the square-topped wave, grid 18′ receives a sharp input pulse at that time, the input wave to the cathode-input grid circuit of tube T2 being as illustrated by curve *c* of Fig. 2; the dotted line shows the relative potential of primary anode current cut-off for tube T2, the primary electrons being allowed to flow in the second tube for a very short interval, for example, a microsecond or less. By choice of constants for capacitor C_3 and resistor R_4, the pulse duration may be varied; change in the bias on grid 18′ will alter the pulse width.

The action of the secondary anode 22′ is similar to that of anode 22 of tube T1 except that no feedback to the input grid is provided as the positive swing of the grid 18′ will be sufficiently rapid. If the network R_5—C_4 were not present, that is, if the collector grid 21′ were connected directly to the high potential terminal of the source B, the tube T2 would produce a square-topped wave such as is illustrated by curve *d* of Fig. 2, detectable at terminal 12, the symmetry of the sides of the wave being effected by selection of a suitable value of V_4 so that at the top of the pulse the potential of the anode 22′ will be in the positive resistance portion of its characteristic. Since the potential to which the secondary anode rises is determined primarily by the potential of the collector grid 21′ and the magnitude of resistor R_6, the height of the pulse may be varied by changing V_4 without altering the width of the base of the pulse.

In a pulse generator constructed in accordance with Fig. 1 for the generation of positive pulses, the circuit components had the following values:

R_1=1 megohm
R_2=50,000 ohms
R_3=2 megohms
R_4=200,000 ohms
R_6=10,000 ohms
C_1=2.5 micromicrofarads
C_2=.00025 microfarad
C_3=.00001 microfarad
C_4=.00002 microfarad

Figs. 4A, 4B and 4C illustrate cathode ray oscilloscope tracings of the output pulse of tube T2 for three different potential conditions of the tubes. That of Fig. 4A was obtained for potential settings on sources B and C of $V_1=-35$ volts, $V_2=-55$ volts, $V_3=55$ volts, $V_4=295$ volts and $V_5=400$ volts. To give Fig. 4B, $V_1=-35$ volts, $V_2=-25$ volts, $V_3=50$ volts, $V_4=180$ volts and $V_5=250$ volts. To give Fig. 4C, $V_1=-35$ volts, $V_2=-55$ volts, $V_3=50$ volts, $V_4=350$ volts and $V_5=400$ volts, and resistor R_4 was changed to 20,000 ohms. The amplitude of the pulse for these respective conditions was 65, 40 and 30 volts. In each case the collector grid 21′ and the primary anode 19′ were connected directly to the high potential (V_5) terminal of source B, resistors R_5 and R_7, condenser C_4 and the negative pulse terminal being omitted.

An output pulse from tube T2 shaped more or less like a right triangle is obtainable by selecting a lower value for V_4 than in the previous cases. Figs. 5A and 5B illustrate cathode ray oscilloscope tracings for the following conditions. Fig. 5A: $V_1=-35$ volts, $V_2=-55$ volts, $V_3=65$ volts, $V_4=140$ volts, $V_5=250$ volts. Fig. 5B: $V_1=-35$ volts, $V_2=-25$ volts, $V_3=65$ volts, $V_4=165$ volts and $V_5=400$ volts. To obtain the more symmetrical Fig. 5B tracing, the R_5—C_4 network was included in the collector grid lead from the source B with the values R_5=1 megohm and C_4=20 micromicrofarads. In each case, the pulse amplitude was of the order of 142 volts.

The pulses referred to hereinabove are the positive pulses that appear across the resistor R_6. If negative pulses are also desired, instead of connecting the primary anode 19′ directly to the high potential terminal of source B, anode 19′ is connected to negative pulse terminal 11, and through a resistor R_7 to source B as shown in Fig. 1. The shape of the negative pulses will be the same as those impressed on the grid 18′ since anode 19′ does not have the negative resistance characteristic of anode 22′. The triode structure comprising cathode 17′, grid 18′ and anode 19′ functioning as an amplifier will produce amplified negative pulses. Because of the different magnitudes of the electron currents in the primary and secondary electron sections of the tube T2, the magnitudes of resistors R_6 and R_7 should be different if it is desired to have the positive and negative pulses of the same order of magnitude.

The circuit arrangement described has been found to operate at input voltages as low as one or two volts and over a wide band of frequencies. The amplitude and shape of the output pulses are substantially independent of the frequency, amplitude and wave shape of the input to the circuit. Although the circuit arrangement of Fig. 1 is of utility wherever a single high power, short duration pulse of either sign per cycle of the signal wave or control voltage is desired, it is apparent that it may be employed as a direct reading frequency meter in that a current meter may be inserted in place of the resistor R_7, to provide a current reading linear with frequency from zero to the megacycle range.

Although disclosed with reference to a single embodiment, it is obvious that the invention is not limited thereto but that modifications and other applications will occur to those skilled in the art without departing from the inventive concept.

What is claimed is:

1. An electronic device circuit comprising a pair of electronic devices, each of which comprises a primary electron section and a secondary electron section, means including a regenerative connection between the primary and secondary electron sections of one of said devices for converting signal wave input to the primary electron section of said one device into a square-topped electric wave in the secondary electron section of said one device, means for deriving the higher frequency content from said square-topped wave and for applying it to the primary electron section of the second device to establish a high power, short duration pulse of electric energy in the secondary electron section of the second device.

2. A pulse generator comprising a pair of vacuum electronic devices, each device comprising a cathode, an anode, a control grid containing an aperture for the escape of some of the primary electrons originating in said cathode, a control grid between said cathode and anode, a second anode for emitting secondary electrons when bombarded by escaped primary electrons, and a collector electrode for collecting the electrons emitted by said second anode, a signal wave input circuit connected to the grid and cathode of one of said devices, a reactive coupling between the second anode and the grid of said one device, means connecting the second anode-collector electrode circuit of said one device to the grid and cathode of the second device, and a utilization circuit connected to the second anode and collector electrode of said second device.

3. A pulse generator comprising a pair of vacuum electronic devices, each device comprising a cathode, an anode containing an aperture for the escape of some of the primary electrons originating in said cathode, a control grid between said cathode and anode, a second anode for emitting secondary electrons in ratio greater than unity when bombarded by escaped primary electrons, and a collector electrode for collecting the electrons emitted by said second anode, an input circuit for each device comprising the cathode and grid of the respective device, an output circuit for each device comprising the second anode and collector electrode of the respective device, means for applying a signal wave to the input circuit of one of said devices, a regenerative coupling between the input and output circuits of said one device, and means for connecting the output circuit of said one device to the input circuit of the second of said devices.

4. An electronic device circuit comprising a pair of electronic devices, each of which comprises a primary electron section and a secondary electron section, the primary section comprising a cathode, a primary anode and a control grid between the cathode and anode, the secondary section comprising a second anode adapted to emit secondary electrons in ratio greater than unity when bombarded with electrons from said pri-

mary section and a grid for collecting said secondary electrons, means including a regenerative connection between the control grid and the second anode of said devices for converting a sinusoidal electric wave applied to the control grid-cathode circuit of said one device into a square-topped electric wave in the collector grid-second anode circuit of said one device, means for deriving the higher frequency content only from said square-topped wave and for applying it to the control grid-cathode circuit of the second of said devices to establish, independent of any connection between the second anode and control grid of the second device, a high power, short duration pulse of electric energy in the col-

lector grid-second anode circuit of said second device.

ALBERT M. SKELLETT.

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