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R. PROSKAUER

2,483,431

BLOCKING OSCILLATOR

Filed May 10, 1944

2 Sheets-Sheet 1

FIG. 1

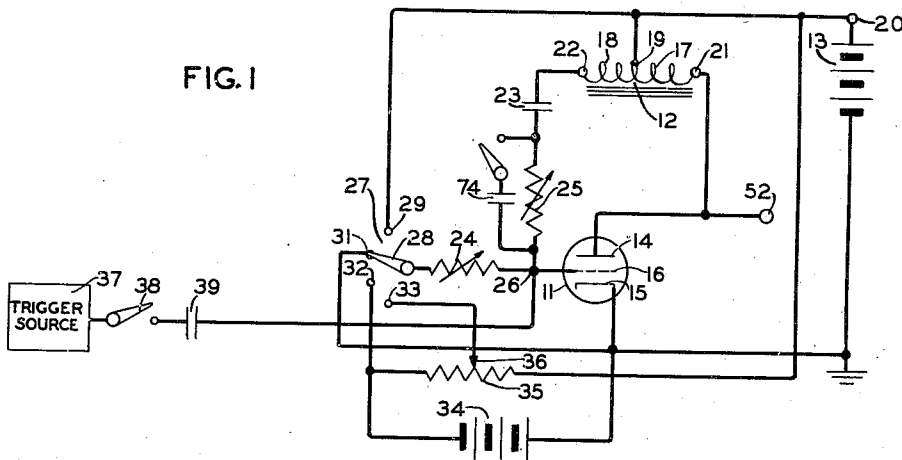
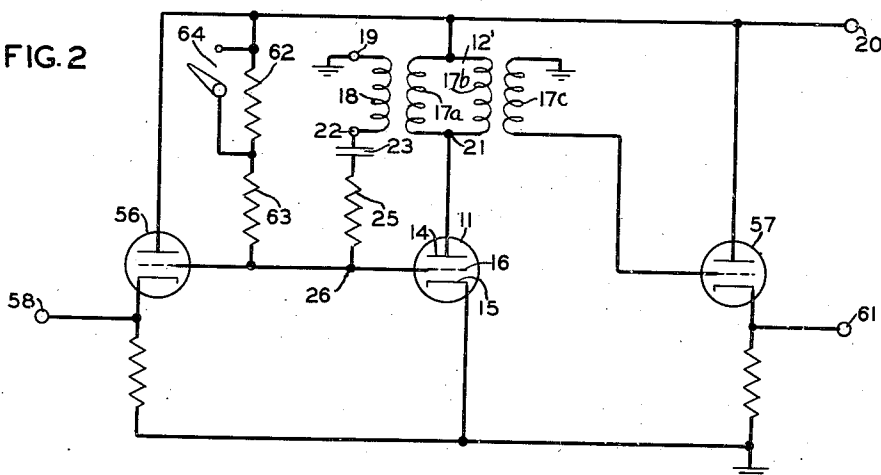


FIG. 2



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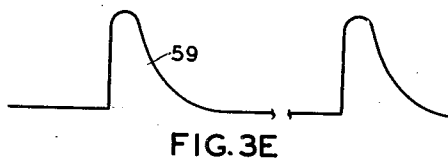
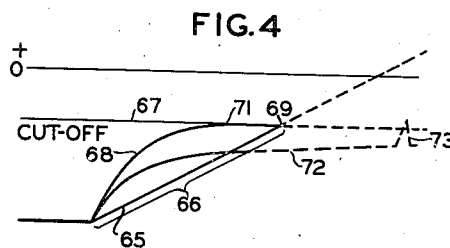
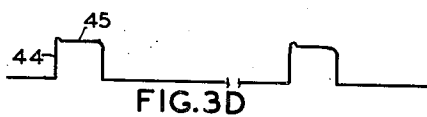
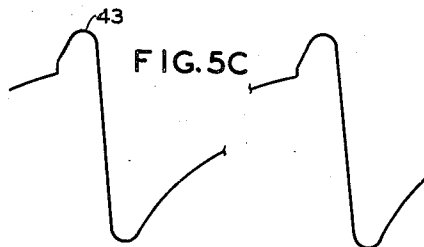
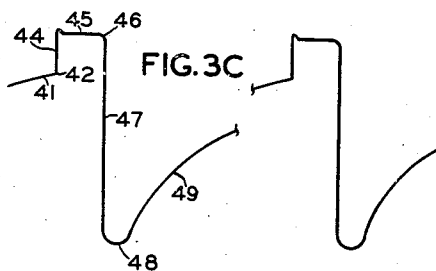
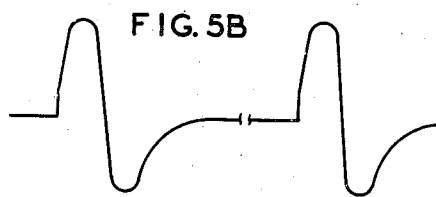
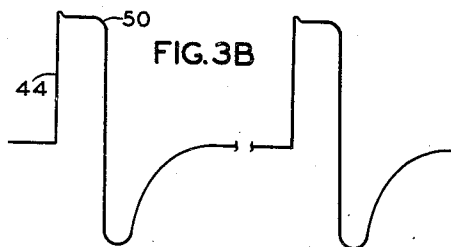
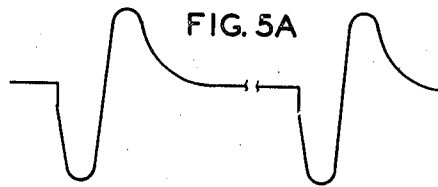
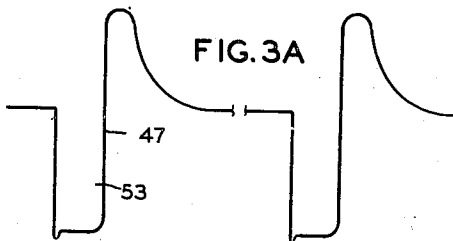
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BLOCKING OSCILLATOR

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5 Claims. (Cl. 250—36)

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My invention relates to circuits for electric discharge devices, and concerns, particularly, oscillator circuits and pulse-producing circuits.

It is an object of my invention to provide an improved pulse generator and an improved oscillator of the type which is timed by means of resistance-capacity circuits.

A further object of the invention is to provide a vacuum-tube pulse generator in which the leading and trailing edges of conduction-period pulses are steep.

Another object is to provide constancy and predictability of conduction-period pulse duration, as well as steepness and great amplitude of overshoot, having polarity opposite to the conduction-period pulse, immediately following the conduction period.

More particularly an object of the invention is to provide an oscillator having an extremely low temperature coefficient of frequency.

A further object of the invention is to provide an oscillator which may be adjusted to have a frequency which is substantially independent of variations in supply voltage and relatively unaffected by aging and other variations in vacuum tube characteristics.

A further object of the invention is to provide a pulse generator having both readily adjustable repetition rate and readily adjustable pulse duration, or ratio of conduction period to non-conducting period.

Still another object of the invention is to reduce absorption of power by a grid circuit from the electromagnetic field of a pulse transformer and so to improve the sharpness and steepness of the produced pulse.

A further object of the invention is to provide an arrangement in which a relatively small, light and inexpensive pulse transformer may be employed to produce a good wave form in a blocking oscillator.

Another object is to square the pulse produced by a blocking oscillator.

Still another object of the invention is to limit peak tube current and so prolong the tube life in a blocking oscillator.

Still another object of the invention is to provide an oscillator having a highly stabilized frequency or pulse repetition rate.

An additional object of the invention is to provide a delay device or synchronizer in which two trigger pulses may be produced with a fixed time delay between them, and, when desired, with complete isolation between the devices triggered by the two trigger pulses.

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A further object of the invention is to provide a blocking oscillator which produces steep, sharp waves whether operated as a self-oscillator, a synchronized oscillator or a triggered oscillator.

Still another object of the invention is to provide pulsing apparatus which may be synchronized at a subharmonic of the input frequency such as a seventh harmonic, for example, and which is capable of choosing harmonics as high as the twenty-fifth.

A further object is to provide apparatus which may be either self-oscillating or triggered.

Still another object of the invention is to provide arrangements for utilizing both forward and back pulses from a pulse transformer in a blocking oscillator.

Still another object of the invention is to provide a pulse former in which the output pulse is delayed by a time interval which is independent of the duration and amplitude of the trigger pulse.

Other and further objects and advantages will become apparent as the description proceeds.

In carrying out the invention in its preferred form I employ an improvement upon a conventional blocking oscillator tube circuit in which a pulse transformer is employed for providing the requisite voltage inversion in order to obtain regeneration for sustaining oscillation. However, I provide a "throttling" resistor in a circuit including the grid winding of the pulse transformer and a grid condenser coupling the pulse transformer to the vacuum tube grid. This is done for the purpose of limiting grid current during positive voltage pulses in the grid winding of the pulse transformer in order to prevent absorption by the grid circuit of magnetic energy stored in the magnetic field of the pulse transformer, and in order thereby to have this energy available for producing high amplitude pulses with steep leading and trailing edges for the conduction period of the pulse.

A better understanding of the invention will be afforded by the following detailed description considered in conjunction with the accompanying drawings, and those features of the invention which are believed to be novel and patentable will be pointed out in the appended claims.

In the drawings,

Fig. 1 is a circuit diagram of an embodiment of the invention including adjustments for obtaining various types of operation;

Fig. 2 is a circuit diagram of a synchronizer or delay device forming an embodiment of my in-

vention including a squared pulse or blocking oscillator such as illustrated in Fig. 1;

Figs. 3A, 3B, 3C, 3D and 3E, are graphs illustrating the wave forms obtainable at various points in the apparatus of Figs. 1 and 2;

Fig. 4 is a graph illustrating the principle of operation of the apparatus adjusted for operating with a highly stabilized repetition rate and also illustrating adjustments for synchronized and triggered operation; and

Figs. 5A, 5B and 5C are graphs illustrating wave forms which may be obtained without using the improvement described in the application.

The apparatus of Fig. 1 comprises an electric discharge device 11 with a pulse transformer 12 for producing regeneration and a power supply represented for convenience as a battery 13. The electric discharge device 11 may be of the triode vacuum tube type, for example, having an anode 14, a cathode 15 represented as indirectly heated, and a control electrode or grid 16. It will be understood, however, that the invention is not limited to the use of a triode vacuum tube.

The pulse transformer 12 may be either an auto transformer, as shown in Fig. 1, or a multiple winding transformer according to the desired connections and the manner in which the blocking oscillator is to be employed. As illustrated in Fig. 1, the transformer 12 has a primary or anode circuit winding 17 and a secondary or grid circuit winding 18 with a common terminal 19 connected to the positive terminal 20 of the power supply 13 and with end terminals 21 and 22 of opposite polarity which are respectively connected to the anode 14 and coupled to the grid 16 of the discharge device 11. The invention is not, however, limited to the use of a common terminal for the primary and secondary transformer windings as will be apparent from consideration of Fig. 2 to be described hereinafter.

A coupling condenser 23 is interposed between the terminal 22 of transformer winding 18 and the grid 16. For biasing the grid 16 to a predetermined voltage, a conventional grid-leak resistor 24 is provided.

In order to prevent the grid 16 from loading the grid winding 18 and in order to enable steep front pulses to be produced, I interpose a resistor 25 which I call a "throttling" resistor in series with the coupling condenser 23. As shown in the drawing, the throttling resistor 25 is connected between the coupling condenser 23 and the grid 16. Nevertheless, my invention is not limited to this particular location of the throttling resistor 25, as it may also be connected between the terminal 22 and the condenser 23, for example, or between the grid 16 and a terminal 26 which is shown as common to the circuits respectively including the grid-leak resistor 24 and the coupling condenser 23. However, I consider it important to place the throttling resistor 25 between the high potential or ungrounded terminal 22 of the pulse transformer grid winding 18 and the grid 16 rather than between the terminal 19 of the grid winding 18 and the rest of the circuit. In case a pulse transformer is employed having isolated primary and secondary windings 17a and 18 as in Fig. 2, for example, it is preferable that the throttling resistor 25 be connected between the terminal 22 and the grid 16 rather than in series with the conductor from the terminal 19, which is usually connected to a fixed potential terminal such as one of the terminals of the power supply 13 or to a point with respect

to which the grid potential varies such as the anode or cathode of the tube 11.

The advantages of my improved circuit are obtained whether the blocking oscillator is operated as a self-oscillator, as a synchronized oscillator or as a triggered oscillator. In order to illustrate the manner of changing the bias of grid 16 in order to obtain any one of the various types of operation of which a blocking oscillator is capable, a change-over switch 27 is shown having a movable arm or blade 28 connected to one end of the grid-leak resistor 24, and having a plurality of stationary terminals 29, 31, 32 and 33 connected to various fixed potential points. The terminal 29 is connected to the positive terminal 20 of the power supply 13 or to a point strongly positive with respect to the cathode 15 for use if it is desired to have a highly stabilized or constant repetition rate for a fixed power supply voltage. The switch terminal 31 is connected to the cathode 15 or to a point somewhere between cathode potential and a potential less negative than cut-off potential for use when synchronized operation of the blocking oscillator is desired; that is, self-oscillation which may readily be modified in frequency and phase to conform to the rate of input synchronizing pulses. The terminal 32, on the other hand, is connected to the negative terminal of a "C" battery 34 which has a voltage greater than the cut-off voltage of the tube 11 for use when triggered operation of the blocking oscillator is desired, that is, when it is desired that the blocking oscillator shall not produce a pulse except when it is triggered by an input pulse. When so connected the circuit may also be called a "blocked oscillator," but for convenience I have retained the designation "blocking oscillator" for all three connections.

When there is any possibility that the power supply 13 may fluctuate in voltage and it is desired that the frequency or repetition rate of the oscillator shall be substantially unaffected by changes in power supply voltage as well as being relatively unaffected by aging or variations in tube characteristics, I may provide a potentiometer 35 having an adjustable tap 36 thereon connected to the transfer switch terminal 33. The potentiometer 35 is connected across the voltage supplies 13 and 34 in series or across any other suitable source of direct voltage which will enable the tap 36 to be adjusted to a potential which stabilizes the oscillator frequency with respect to variations in power supply voltage.

For use when synchronized or triggered operation is desired, a synchronizing or triggering pulse generator or source 37 may be provided having an output selectively coupled to the grid 16 through a switch 38 and a coupling condenser 39.

The circuit of Fig. 1 produces an output pulse with a steep leading edge and a steep trailing edge during the conduction period regardless of which setting of the transfer switch 27 is used. Accordingly, the operation need be described for only one setting of the switch. It is assumed that switch 27 is set with the blade 28 connected to the terminal 29 or the terminal 31 so that self-oscillation is produced because the grid 16 is biased to a potential at which the tube 11 tends to conduct current. Accordingly assuming that the potential of the grid 16 has been driven negative beyond cut-off it will tend to rise to cut-off potential along the portion 41 of the voltage curve representing discharge of the condenser 23, as shown in Fig. 3C. When it reaches cut-off potential at the point 42, the tube 11 suddenly be-

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comes conducting and a pulse of current is drawn through the primary winding 17 of the pulse transformer 12. This pulse of current induces a positive voltage at the terminal 22 of the grid winding 13 which further raises the potential of the grid 16 and causes further increase in the tube current; and a cumulative effect of the regeneration or feed-back is to cause a further increasing current in the tube 11 and a further increasing voltage in the winding 18. This action tends to take place so rapidly that a very steep front high amplitude voltage would be induced in the winding 18 were it not for the fact that the grid 16 tends to draw a current as soon as it becomes positive with respect to the cathode 15 and thus tends to load the grid winding 18. If the throttling resistor 25 were not employed, the grid voltage would tend to be rounded off following the portion 43 of the curve, shown in Fig. 5C. However, the presence of the throttling resistor 25 limits the grid current to a fraction of the plate current and permits the pulse transformer 12 to continue storing an increasingly large amount of energy in its magnetic field and allows the potential of the terminal 22 to rise very steeply along the portion 44 of the curve shown in Fig. 3C. Owing to the voltage drop in the resistor 25, the grid voltage is limited or squared off so as to follow the flat portion 45 of the curve.

As the tube current increases it finally reaches the value at which the voltage drop in the primary winding 17 is so great that the potential of the anode 14 falls to the point at which no further increase in tube current takes place. Consequently, the voltage induced in the secondary winding 18 disappears and no further current flows through the throttling resistor 25. The current which has flowed through the throttling resistor 25, however, has charged the condenser 23 to a negative voltage which is a substantial fraction of the peak positive voltage induced in the winding 18; and upon disappearance of the induced voltage in the winding 18, the strong negative bias voltage stored upon the condenser 23 drives the grid 16 sharply below cut off, abruptly cutting off the flow of current through the tube 11. The sudden collapse of the magnetic field of the pulse transformer 12 further reduces the potential of the grid 16 so that the grid potential falls very abruptly at the point 46 with a considerable voltage drop as represented by the portion 47 of the grid voltage curve of Fig. 3C. This action is assisted also by the fact that the entire stored energy of the magnetic field, which has been allowed to increase to a maximum at point 46, is abruptly released.

Inasmuch as the grid 16 is biased to a potential more positive than the very low potential at the point 48 to which it has been driven, the grid potential gradually drifts upward along the curve 49 which becomes exponential due to the discharging of the condenser 23 through the high resistance grid-leak resistor 24 (in series with lower-resistance circuit elements). When, as is frequently the case, the time interval between conduction-period pulses is adjusted to be greater than the duration of the conduction-period pulses by a relatively large factor, such as approximately 100 or more, the adjustment of the interval determines the repetition rate. The time interval between pulses may be adjusted by varying the magnitude of the grid-leak resistor 24, which is shown as adjustable to illustrate the repetition rate adjustment; and the duration of

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the conduction period of the pulse, that is, the length of the flat wave 45, may be adjusted by varying the magnitude of the throttling resistor 25, which is also shown as adjustable to illustrate the adjustment of the pulse duration. Although variation of the resistance of the throttling resistor 25 has a slight effect on the repetition rate, this circumstance will not impede rapid setting of desired pulse duration and repetition rate if the pulse duration adjustment is made first. It will be understood, of course, that various values of the capacity of the coupling condenser 23 may also be employed for varying the frequency and pulse duration. Variations in the bias of the grid may, also, be employed for varying the pulse repetition rate.

Although the grid winding 18 of the pulse transformer 12 is shown connected to the anode side of the anode-cathode circuit in Fig. 1, the invention is not limited to this arrangement and the low potential terminal 19 of the grid winding 18 may also be connected to the cathode side of the anode-cathode circuit or to any other suitable point of relatively fixed potential. For example, as illustrated in Fig. 2, a four-winding transformer may be employed having two primary windings 17a and 17b connected in parallel, and two secondary windings 18 and 17c so wound as to have a very high coefficient of coupling and low leakage with respect to the primary windings 17a and 17b, respectively. In this case the grid winding 18 has its low potential terminal 19 grounded and its high potential terminal 22 connected in the same manner as in the arrangement of Fig. 1. Owing to the fact that such transformers necessarily have some mutual capacity between windings, the connection of the throttling resistor between the high potential terminal 22 of the grid winding 18 and the grid 16 is preferable to connecting the throttling resistor 25 between the low potential terminal 19 and the ground connection. The windings have a certain distributed capacity to ground. This distributed capacity to ground would tend to by-pass a throttling resistor if it were connected between the terminal 19 and ground. This problem would arise also if the throttling resistor were connected between the terminal 19 and the anode 14. I have found, in fact, that when such a connection is employed the advantages of the throttling resistor are not obtained and the blocking oscillator has an output wave form with a rounded off positive portion as shown by 43 in Fig. 5C, and with a much weaker and less steep trailing edge than that illustrated in Fig. 3C.

According to the type of wave form desired and the polarity desired, an output wave may be taken from any one of several different suitable points. For example, if a wave form, such as illustrated in Fig. 3C, is desired, it may be taken from the terminal 26. A higher positive-amplitude wave 50 may be taken from the transformer terminal 22 as illustrated in Fig. 3B. If an inverted wave form is desired it may be taken from a terminal 52 connected to the anode 14 or it may be taken from a secondary winding such as the winding 17c of Fig. 2. Such an inverted wave form as illustrated in Fig. 3A corresponds to the wave form 50 of Fig. 3B.

It will be observed that the wave forms of Fig. 3A, Fig. 3B and Fig. 3C each provide two very abrupt or steep voltage variations spaced by a fixed time duration determined by the constants of the circuit. Thus, if a positive wave front fol-

lowed by a negative wave front is desired, the wave form of Fig. 3B or Fig. 3C may be employed, utilizing the steep portions 44 and 47. On the other hand, if a negative variation followed by a positive variation is desired, the wave form of Fig. 3A may be employed. Likewise, two spaced negative voltage variations or two spaced positive voltage variations may be obtained by utilizing the leading edge of one of the two wave forms and the trailing edge of the other. The steepness of the trailing edge of the pulse makes the apparatus well suited for cascading whereby the trailing edge of the pulse of one oscillator trips the pulse of a second oscillator.

In Fig. 2 there is illustrated a more detailed arrangement for eliminating the negative portions of the wave and obtaining only a squared positive wave followed after a fixed time duration by a sharp positive peak.

As illustrated in Fig. 2, a cathode follower 56 is provided which is driven from the terminal 26 to produce an undelayed trigger, and a second cathode follower 57 is provided which is driven from the secondary output winding 17c to produce a delayed trigger. Since the cathode followers 56 and 57 are so biased as not to reproduce negative voltages, only positive portions of the waves in Figs. 3A and 3B are reproduced. Thus, the portion 45 of Fig. 3C appears as shown in Fig. 3D, at the output or cathode terminal 58 of the cathode follower 56, and a positive peak 59, corresponding to the trailing edge 47 of the wave of Fig. 3C appears at the terminal 61 of the cathode follower 57 as illustrated in Fig. 3E.

Without the throttling resistor 25, the wave forms would be very irregular. For example, the wave forms at the terminals 52, 22 and 23 might be such as illustrated in Figs. 5A, 5B and 5C, respectively, or even worse depending upon conditions.

In the arrangement of Fig. 2, a grid-leak resistor is employed consisting of two series elements 62 and 63, one of which, for example the element 62, may be short-circuited by means of a switch 64 when it is desired to reduce the repetition rate. Theoretically any type of variable resistor or rheostat of high resistance might be employed or a plurality of resistors selectively connectible in shunt might be employed for varying the effective resistance of the grid-leak resistor. In practice, however, I have found, particularly where the apparatus is to be employed on shipboard or for other reasons subjected to salt spray or the like, it is preferable to use the arrangement of Fig. 2 with a plurality of series elements, one or more of which may be short-circuited to vary the total resistance, since in such an arrangement the resistance varies less as a result of exposure and consequently a higher degree of stability of frequency is obtained.

I have found that the blocking oscillator circuits of Figs. 1 and 2 produce a high degree of frequency stability. With regard to temperature stability, for example, it will be found that any variation in the resistance of the grid-leak 24 with a variation in temperature tends to be overcome by a corresponding variation in resistance of the throttling resistor 25 with temperature. Increasing the resistance of the grid-leak tends to decrease the frequency of the oscillator, whereas increasing the resistance of the throttling resistor tends to increase its frequency. Since both resistances will ordinarily have a positive

temperature coefficient of variation, temperature variations may be compensated by properly relating the total resistances and temperature coefficients.

It has been found that, when the power supply voltage of a blocking oscillator varies, increasing the voltage tends to increase the frequency, if the grid leak is returned to a high potential, but tends to decrease the frequency if the grid leak is returned to a lower potential. Accordingly, when there is any possibility that the power supply voltage may fluctuate, the change-over switch 27 (Fig. 1) is moved to the position making contact with the terminal 33 and the tap 36 is moved to a neutral position which may be found by experiment to be such a potential that the frequency neither increases nor decreases with variation in voltage of the source 13. The same adjustment will serve, in the event that the oscillator is synchronized from an external source, to cause the oscillator to fire in a uniform phase relationship with respect to the synchronizing signal independently of minor variations in the power supply voltage.

It may be observed that when the apparatus of Fig. 2 is employed for providing a delayed trigger and an undelayed trigger, it is unnecessary to employ a delay line. Delay lines for such a purpose are relatively expensive, bulky and require the use of materials often difficult to obtain promptly. Furthermore, such a delay circuit as illustrated in Fig. 2 provides two trigger pulses to two different pieces of apparatus which remain completely isolated from each other. Alternatively, the two trigger pulses may be supplied to the same terminal by connecting together the cathodes of cathode-follower tubes 57 and 58.

Owing to the use of the throttling resistor 25 to limit grid current, the apparatus not only produces greatly improved wave form, but also greatly prolongs the tube life by limiting the maximum current drawn by the tube. For example, in a specific instance, when a peak value of 0.5 ampere of space current was obtained without the throttling resistor, the addition of the throttling resistor reduced peak space current to 60 milliamperes.

The manner in which repetition rate is stabilized when the transfer switch 27 is connected to the strongly positive biasing terminal 29 will become apparent from the consideration of the grid voltage curves shown in Fig. 4. When the grid 16 is biased to a point far above cut off, and far above the potential which it can ever be expected to reach in the operation of the circuit, so that it would tend to follow the curve 55 if the condenser 23 were permitted to continue charging through the resistor 25 until the grid 16 had reached the potential of the positive terminal of the supply 13, the first portion of the curve, designated 66, is relatively straight and intersects the cut-off voltage line 67 at a relatively large angle. Consequently, slight changes in voltage effects or the introduction of ripple voltages from an external source have relatively little effect on the instant of time when the curve 55 crosses the cut-off line 67.

On the other hand, if the time constant of the circuit represented by the condenser 23 and the resistor 24 is decreased and the bias voltage is lowered to substantially the cut-off voltage in order to produce a discharge curve 68, which normally reaches the cut-off line 67 at the same time as the curve 55, at the point 69, slight ex-

traneously introduced ripple voltages may cause the grid voltage to reach the cut-off line 67 at an earlier or later instant of time, for example, at an instant represented by the point 71. Consequently, considerable variations in time duration of the charging curve and therefore the repetition rate of the oscillator may occur when the grid 16 is biased to a point near cut-off or even biased to cathode potential, as represented by the setting of the change-over switch 27 to the terminal 31.

This connection, however, is useful when the oscillator is to be operated synchronously with pulses supplied by the synchronizing generator 37. In this case the normal frequency of the oscillator is made somewhat lower than the frequency of the synchronizer 37 so that the tube 11 is always fired by the synchronizing source 37, but for safety purposes oscillation continues even though the source 37 should fail. On the other hand, if it is desired that the tube 11 should produce a pulse only when triggered through the coupling condenser 39, this result is accomplished when the transfer switch 27 is set to make connection with the low potential terminal 32 so that the grid 16 follows the discharge curve 72 of Fig. 4, never reaching the cut-off potential 67 until the triggering pulse 73 from the source 37 is applied.

The duration of the conduction period pulse for a given voltage of the power supply 13 may be adjusted by adjusting the resistance of the throttling resistor 25. Where the power supply 13 is subject to variation in output voltage, the pulse duration may be stabilized by the choice of a suitable resistance for the throttling resistor 25. With relatively small throttling resistance, the pulse duration tends to increase with increasing power supply voltage, and with relatively large resistance, the pulse duration tends to decrease with increasing power supply voltage. A suitable intermediate value for stabilizing pulse duration may be found by experiment.

The presence of the throttling resistor 25 serves to produce the squareness of the wave form appearing at the grid terminal 26. Excessively large or excessively small values of resistance for the throttling resistor 25 tend to interfere with the steepness of the pulses 44 and 47 of the waves shown in Figs. 3A to 3C. However, I have found that the desired square wave form remains unimpaired for large variations in resistance of the throttling resistor. Variations over a range from 1,000 to 4,000 ohms for example, in a specific case have no injurious effect. In fact, the maximum value of the resistance seems to be limited only by the integrating effect of the inherent grid-cathode capacity of the tube 11. So long as the resistance of the throttling resistor 25 does not exceed a value comparable with the impedance of the grid-cathode capacity at frequencies upon which pulse-steepness depends, steepness of wave form is retained. In the event that it is desired to use a higher resistance for the throttling resistor 25, it is desirable to overcome the integrating effect of the grid-cathode capacity by shunting the throttling resistor 25 with a small condenser 74 having a capacity ratio to the grid-cathode capacity comparable with the ratio between the resistance of the throttling resistor 25 and the grid-cathode resistance when the grid becomes positive. In this manner the requisite voltage division is maintained, without sacrificing steepness of the leading edge of the pulse delivered to the grid 16.

I have herein shown and particularly described certain embodiments of my invention and certain methods of operation embraced therein for the purpose of explaining its principle of operation and showing its application, but it will be obvious to those skilled in the art that many modifications and variations are possible, and I aim, therefore, to cover all such modifications and variations as fall within the scope of my invention which is defined in the appended claims.

What is claimed is:

1. A blocking oscillator comprising an electric discharge device having an anode, a cathode and a control electrode, a pulse transformer having primary and secondary windings, a grid-leak resistor, a coupling condenser and a throttling resistor, the primary winding of said transformer being connected in series with the anode and the secondary winding being connected to the control electrode by a series network comprising said coupling condenser and said throttling resistor, the grid-leak resistor being connected directly between the control electrode and a fixed potential point.

2. In combination, a resistance capacitance timed oscillator, comprising an electric discharge device having an anode and a control electrode with a pulse-sharpening throttling resistor interposed in circuit therewith, a first cathode follower stage coupled to said control electrode, and a second cathode follower stage coupled to said anode by a phase-inverting coupling means.

3. Apparatus for producing a first trigger pulse and a second, delayed trigger pulse comprising; a blocking oscillator having an electron tube with input and output electrodes, a variable pulse-sharpening resistor connected in circuit with said input electrode for producing on said input electrode a first voltage variation and on said output electrode a second voltage variation, which latter voltage variation is phase reversed with respect to said first voltage variation, a cathode follower connected to said input electrode for producing said first trigger pulse from a leading edge of said first voltage variation, a cathode follower connected to said output electrode for producing said second delayed trigger pulse from the trailing edge of said second voltage variation, and means for varying the pulse-sharpening resistor to vary the delay interval between said first and second trigger pulses.

4. Apparatus for producing a pair of trigger pulses of the same polarity with a predetermined delay interval therebetween, comprising a blocking oscillator, having input and output circuits, for respectively generating two voltage variations, one variation having a leading edge with a slope of one polarity and a trailing edge with a slope of the opposite polarity, and the other variation being in reverse with respect to said one variation, a first cathode follower circuit coupled to the input circuit of said blocking oscillator for producing one of said pair of trigger pulses from the leading edge of said one voltage variation, and the second cathode follower circuit coupled to the output circuit of said blocking oscillator for producing the other of said pair of trigger pulses from the trailing edge of the other of said voltage variations.

5. Apparatus according to claim 4 further comprising means for varying the time period between the instance of occurrence of the leading and trailing edges of each of the said two voltage

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variations and hence the delay interval between the said pair of trigger pulses.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,085,409	Bedford	June 29, 1937
2,118,626	Smith	May 24, 1938

12

Number	Name	Date
2,140,004	Falloon	Dec. 13, 1938
2,165,770	Tolson	July 11, 1939
2,215,776	Barnard	Sept. 24, 1940
2,226,459	Bingley	Dec. 24, 1940
2,246,631	Knick	June 24, 1941
2,250,706	Geiger	July 29, 1941
2,292,835	Hepp	Aug. 11, 1942
2,358,297	Bedford	Sept. 19, 1944
2,360,697	Lyman	Oct. 17, 1944
2,405,238	Seeley	Aug. 6, 1946