SECTION 9

BLOCKING AND SHOCK-EXCITED OSCILLATOR CIRCUITS

PART A. ELECTRON-TUBE CIRCUITS

FREE-RUNNING PRF GENERATOR.

APPLICATION.

The free-running prf generator is a basic blocking oscillator. It produces short-time-duration, large-amplitude pulses for use as timing, synchronizing, or trigger pulses in radar modulators and display indicators.

CHARACTERISTICS.

Output pulse is a single cycle of oscillation caused by tube conduction at the beginning of each pulse-repetition period.

Pulse-repetition time is determined primarily by the R-C time constant of the grid circuit. The pulse repetition frequency is generally fixed within the range of 200 to 2000 pulses per second, although the circuit can be arranged to change the R-C time constant and provide for operation at other fixed pulse-repetition frequencies.

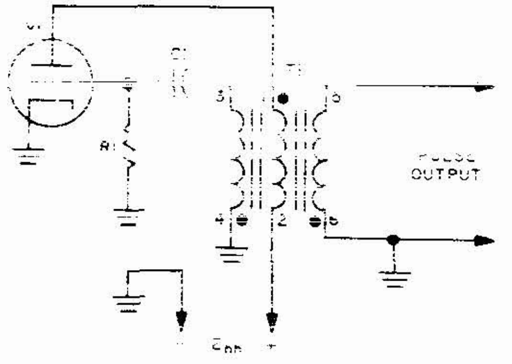
Frequency stability is ±5 percent.

Pulse width and rise time of the output pulse are determined primarily by the transformer characteristics.

Output-pulse polarity is determined by the phasing of the transformer output-tertiary winding. With minor circuit changes, output can also be taken from the cathode circuit.

CIRCUIT ANALYSIS.

General. The free-running blocking oscillator (prf generator) is a special-type oscillator in that the oscillator completes one cycle of operation to produce a pulse and then becomes inactive (blocked) for a considerable period of time, whereupon the cycle of operation to produce a pulse is repeated and the oscillator again becomes inactive. This mode of operation continues, and thus produces a series of output pulses which are of short-time duration, separated by relatively long time intervals.

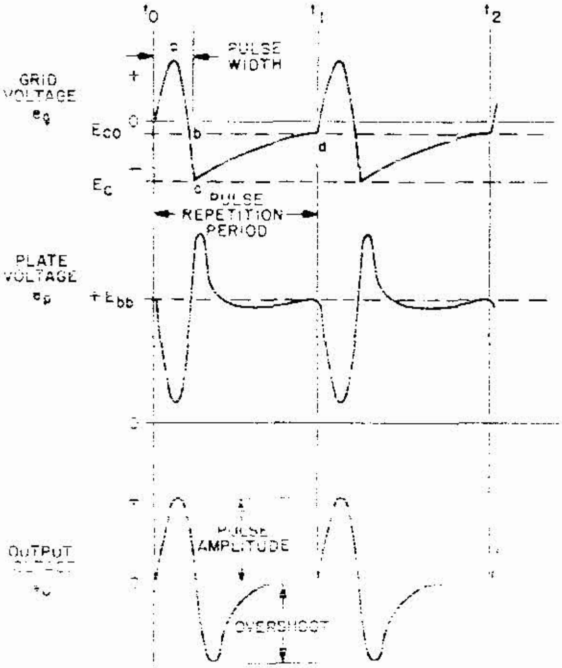


Free-Running PRF Generator

Circuit Operation. The accompanying circuit schematic illustrates a triode electron tube in a basic free-running blocking oscillator circuit. Transformer T1 provides the necessary coupling between the plate and grid of electron tube V1; terminals 1 and 2 of transformer T1 connect to the plate (primary) winding, terminals 3 and 4 connect to the grid (secondary) winding, and terminals 5 and 6 connect to the output (tertiary) winding. Capacitor C1 and resistor R1 form an R-C circuit to determine the discharge time constant in the grid circuit. The output pulse is taken from the tertiary winding (terminals 5 and 6) of transformer T1.

On the circuit schematic, note the placement of small dots near winding terminals 1, 4, and 6 of transformer T1. These dots are used to indicate similar winding polarities. For example, if current flows through the plate winding and terminal 1 is negative, the voltage induced in each of the other windings is such that the dot end is also negative in each winding at the same time; therefore, at this same instant of time, terminals 3 and 5 are positive.

For the discussion of circuit operation which follows, refer to the accompanying illustration of the blocking oscillator grid-signal, plate-signal, and output-voltage waveforms.



Theoretical Grid-, Plate-, and Output-Voltage Waveforms

When plate voltage is first applied to the circuit, the grid of V1 is at zero bias and plate current starts to flow through the plate winding (terminals 1 and 2) of transformer T1. A magnetic field is set up about the plate winding and a voltage is induced (through transformer action) in the grid winding (terminals 3 and 4) of transformer T1. Because of the phasing of the plate and grid windings, the voltage produced across the grid winding is impressed on the grid of the tube through coupling capacitor C1 with such polarity as to drive the grid in a positive direction. This results in an increase in the tube plate current, and the action continues with the grid being driven further in the positive direction. When the grid is driven sufficiently positive, the tube begins to draw grid current and capacitor C1 begins to charge. Grid capacitor C1 is charged through the relatively low internal cathode-to-grid resistance of the tube, causing the plate of capacitor C1, which is attached to the grid of V1, to accumulate a surplus of electrons. At this time, however, the plate current has reached its saturation value and the current through the plate winding of transformer T1 can no longer increase (change); as a result, the voltage induced in the grid winding of the transformer can no longer increase (point **a** on grid-voltage waveform). As a further result, since no induced voltage appears in the grid winding, capacitor C1 starts to discharge through resistor R1 causing the grid potential of V1 to become slightly less positive. This causes the plate current in the plate winding to decrease slightly, accompanied by a decrease in the magnetic field about the plate winding. As the magnetic field begins to collapse, a voltage is induced in the grid winding of a polarity opposite that originally produced; thus, the grid is driven in a negative direction.

As the grid of V1 is driven negative, the plate current continues to decrease and the magnetic field about the plate winding collapses completely. This causes the grid to be driven still further in a negative direction until cutoff is reached (point **b** on waveform) at which time plate current no longer flows through transformer T1.

The highly negative charge existing on capacitor C1 places the grid of V1 below cutoff (point **c** on waveform); then the capacitor slowly discharges through resistor R1 and the grid winding of transformer T1. Since the resistance of the grid winding is low compared to that of the resistor, R1, the resistor is the determining factor in the discharge time of capacitor C1. Furthermore, since the resistance of R1 is large compared to the internal cathode-grid resistance of the tube when the grid of V1 is positive, resistor R1 does not affect the charging of capacitor C1.

After an elapsed period of time, as governed by the time constant of R1 and C1, capacitor C1 discharges through resistor R1 to a point near cutoff (point **d** on waveform), where the grid voltage allows the tube to conduct. As plate current once again starts to flow through the plate winding of transformer T1, the entire cycle of operation is repeated.

The changing magnetic field produced about the plate winding of transformer T1 also induces a changing voltage in the tertiary or output winding (terminals 5 and 6). Thus, an output-voltage waveform is produced across the tertiary winding which is similar to the plate-voltage waveform of the blocking oscillator. The pulse output can be of either polarity (with respect to ground) depending upon which terminal of the tertiary winding is grounded. As shown in the circuit schematic, terminal 6 of T1 is grounded; therefore, the initial output pulse is positive with respect to ground. If desired, limiting or clipping techniques can be applied to the output signal to reduce or eliminate the overshoot (amplitude extreme) in the output waveform. In some instances the desired signal may actually be the overshoot and is used to provide a trigger pulse which is delayed in time by the width of the initial pulse.

The approximate time interval required for the capacitor voltage, E_C, to discharge from maximum to the cutoff value, E_{co} (point **c** to point **d** on the grid-voltage waveform), may be determined by use of the following formula:

$$t \cong 2.30\ RC\ \log \frac{E_C}{E_{CO}}$$

Where: t = time interval to discharge to cutoff (seconds)

E_c = maximum voltage change across capacitor

E_{co} = negative cutoff value for tube

R = resistance of grid resistor (megohms)

C = capacitance of grid-coupling capacitor (μf)

Since the pulse width of the blocking oscillator is usually small compared with the capacitor discharge time, the pulse width may be neglected when approximating the natural operating frequency of the oscillator. The natural operating frequency (cycles), f_o, can be expressed as the reciprocal of capacitor discharge time; thus, the blocking-oscillator frequency may be approximated using the following formula:

$$f_o \cong \frac{1}{t}$$

Where: t = capacitor discharge time (seconds)

The free-running blocking oscillator, with minor circuit changes, may be synchronized to an external trigger signal by choosing values of R1 and C1 so that the natural oscillating frequency of the blocking oscillator is slightly lower than the desired frequency. The synchronizing trigger signal, then, must be slightly above the natural oscillating frequency of the blocking oscillator. Under these conditions, when the tube is held below cutoff, the application of a positive synchronizing pulse will drive the tube into conduction somewhat earlier than the R-C time constant would normally permit. Thus, the oscillator will synchronize its frequency of operation with that of the trigger source and the repetition period of the blocking oscillator will be that of the trigger source.

In a practical blocking-oscillator circuit, resistance R1 is usually made up of two resistors: a fixed resistance and a variable resistance connected in series. The variable resistance is then adjusted to provide operation at the desired pulse-repetition frequency. The operating frequency of the blocking oscillator can be changed by switching values of R, C, or both R and C, to alter the time constant. For example, a blocking oscillator designed to operate at 600 pps can be changed to a lower frequency, such as 300 pps, by switching a larger value of R, C, or both, into the circuit to lower the pulse-repetition frequency. Another method of shifting the operating frequency of the blocking oscillator, over a limited range, is to change the quiescent grid voltage of the tube. This method is unaffected by lead resistance, stray capacitance, etc, and is well adapted to remote-control operation.

Important factors affecting the frequency stability of the blocking oscillator are: the stability of grid resistor R1 and of capacitor C1, the variation or changes in applied filament and plate voltages, and the changes occurring in the electron tube. The circuit is particularly sensitive to changes in filament voltage; a 10 percent decrease in filament voltage may change the oscillator frequency as much as 2 percent, while a 10 percent increase in filament voltage may change the frequency about 1 percent. A change in plate voltage of 10 percent will change the frequency about 1 percent.

FAILURE ANALYSIS.

No Output. In a nonoscillating condition, negative grid voltage will not be developed; the measured plate voltage at the plate of V1 will be below normal because of the steady value of plate current flowing through the plate winding of transformer T1 (assuming the plate winding is not open). Capacitor C1 and resistor R1 directly affect the pulse timing; a shorted capacitor will cause oscillations to cease and prevent development of oscillator grid voltage, and an open resistor will prevent capacitor discharge. Sustained periodic oscillations of the blocking oscillator depend upon feedback obtained from transformer T1 as well as the action of capacitor C1 and resistor R1. Therefore, any defect in the transformer, such as an open plate or grid winding or a number of shorted turns in either of these windings, will prevent the circuit from operating. A shorted output winding or shorted load impedance may also cause the circuit to stop oscillating, since the tertiary winding is coupled to the plate and grid windings of the transformer. In this case, the impedance reflected to the plate and grid windings may cause excessive losses which will prevent sustained oscillations. Note that if the tertiary winding should open, the circuit will continue to operate; however, no output will be obtained from the tertiary winding.

Incorrect Frequency. The value of oscillator R-C components should be within design tolerance in order to produce the desired operating frequency; where an adjustment is provided, a small change in operating frequency can be compensated for by adjustment of the variable resistance in the grid circuit. It is reasonable to assume that any change in the R-C time constant of the blocking-oscillator grid circuit (change in value of resistance or capacitance, leaky capacitor, etc) will be accompanied by a change in operating frequency. Also, changes in applied filament and plate potentials will affect the operating frequency.

Indiscriminate substitution of tubes in the free-running blocking-oscillator circuit can cause a frequency change because of differences in individual tube characteristics.

Incorrect Pulse Width Or Unstable Output. Capacitor C1 affects the pulse width as well as the R-C discharge time; however, transformer T1 is of greatest influence in determining pulse width and the rise time of the output pulse. The rate of rise of the leading edge of the output pulse depends upon the transformer turns ratio between plate and grid windings and also upon the rate at which current may rise in the windings as determined by their inductance. (A transformer with high step-up ratio and low inductance will produce relatively short-duration pulses.) The pulse width normally obtained is approximately equal to the time of one half cycle which would be produced at the natural oscillating frequency if the relatively large grid-blocking capacitor C1 were not used in the circuit. Thus, a defect in the transformer, T1, would be likely to cause a change in pulse width accompanied by unstable or erratic output.

The instantaneous blocking-oscillator grid-to-cathode voltage is the difference between the instantaneous charge voltage on the capacitor and the instantaneous negative voltage produced across the grid winding of transformer T1. A rise in capacitor voltage causes the grid voltage to become less positive faster than if the action depended upon transformer voltage alone; thus, the initial pulse is effectively shortened. If either capacitor C1 or resistor R1 should change value, the effect would be more readily noticed as a change of frequency rather than a change of pulse width.

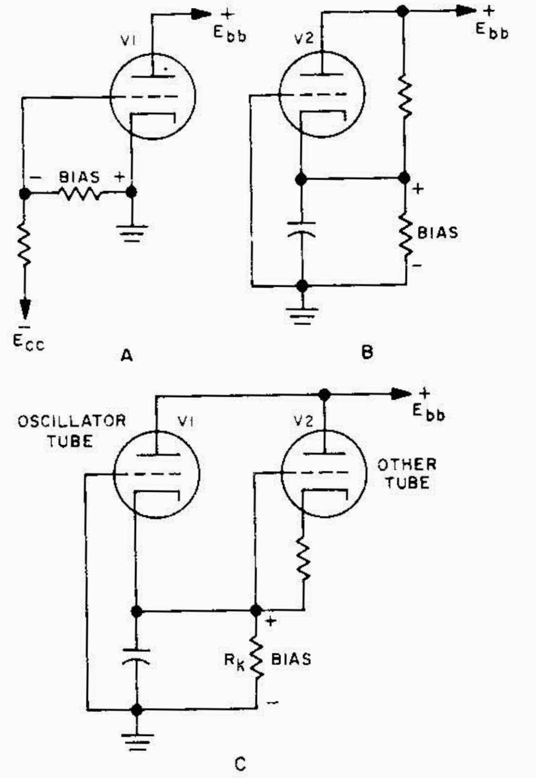
TRIGGERED BLOCKING OSCILLATORS.

Triggered blocking oscillators are used to produce large-amplitude pulses for triggering modulators, indicators, multivibrators, pulse-frequency dividers, or pulse shapers.

Triggered blocking oscillators may have several circuit configurations, which differ mainly in three aspects: the method of biasing, the method of triggering, and the method of output coupling.

Biasing. Triggered blocking oscillators can be provided with grid bias from a negative voltage source utilizing a voltage divider, as shown by the simplified circuit in part A of the accompanying illustration, or with cathode bias obtained from a positive voltage source utilizing a voltage divider, as shown in part B. As an alternative to the cathode-bias circuit shown in part B, the simplified circuit shown in part C uses the cathode current of another tube to obtain bias from a common cathode resistor (R_k); however, this latter arrangement may produce undesirable interaction between the blocking oscillator and the associated circuit.

Triggering. Two methods are used to trigger blocking-oscillator circuits: the parallel trigger method and the series trigger method. The simplified circuit shown in part A of the accompanying illustration shows a common arrangement used to obtain parallel triggering. The trigger is applied in parallel with the plate of the oscillator utilizing the plate winding of the blocking-oscillator transformer as a common impedance for the trigger-amplifier and the blocking-oscillator tubes. The circuit shown in part B is a variation of that given in part A; in this case, a separate (tertiary or third) winding on the blocking-oscillator transformer is used to provide inductive coupling between the trigger-amplifier and the blocking-oscillator tubes. The circuit shown in part C illustrates another arrangement used to obtain parallel triggering; in this case, the trigger pulse is capacitively coupled to the grid of the blocking oscillator.



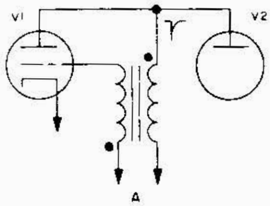
Blocking-Oscillator Biasing Methods

Parallel triggering of a blocking oscillator results in a time delay between the application of the trigger pulse and the start of the blocking-oscillator pulse; however, there is very little reaction of the blocking oscillator upon the trigger source.

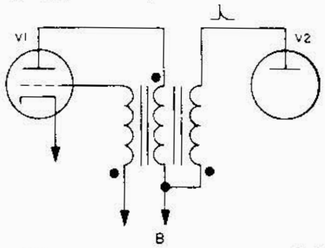
The simplified circuit shown in part D illustrates a common arrangement used to obtain series triggering of a blocking oscillator. The cathode follower supplies the trigger to the grid-return circuit of the blocking oscillator (effectively in series with the grid-signal source). A variation of this circuit is given in part E, where the plate circuit of a trigger-amplifier tube is capacitively coupled to the grid-return resistance of the blocking-oscillator tube.

Series triggering of a blocking oscillator minimizes the time delay between the application of the trigger and the start of the blocking-oscillator pulse; however, the heavy grid-current flow during operation of the blocking oscillator generally reacts upon the trigger source.

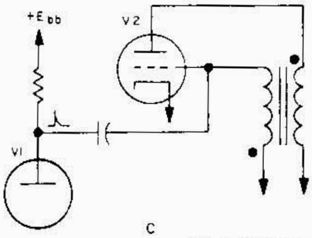
Output Coupling. Several methods are used to obtain the output pulse from the blocking oscillator. The simplified circuit shown in part A of the accompanying illustration uses a third (or tertiary) winding on the blocking-oscillator transformer to supply the output. This method, which is perhaps the most commonly used, offers the advantage that either polarity of the initial pulse may be obtained



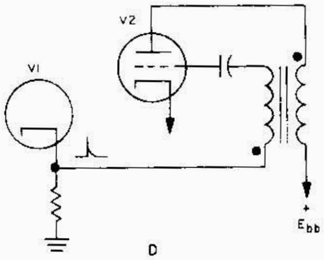
PARALLEL TRIGGER, COMMON PLATE WINDING



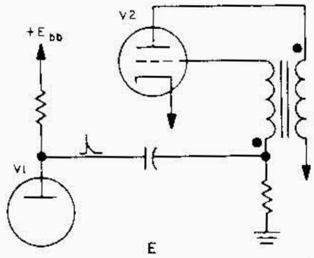
PARALLEL TRIGGER, INDUCTIVE COUPLING



PARALLEL TRIGGER, CAPACITIVE COUPLING



SERIES TRIGGER, CATHODE FOLLOWER



SERIES TRIGGER, CAPACITIVE COUPLING

Blocking-Oscillator Triggering Methods

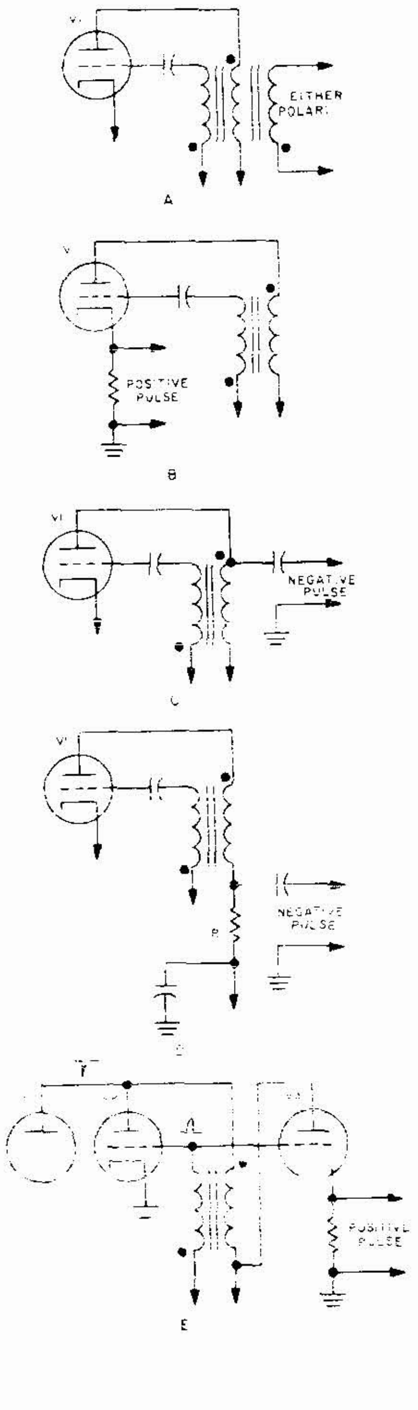
from the transformer, depending upon which terminal of the tertiary winding is grounded. Furthermore, the pulse-output circuit can be isolated from ground for special applications requiring such isolation. This circuit configuration normally produces an overshoot (or amplitude extreme) of opposite polarity immediately following the desired initial pulse. The overshoot results from the collapse of the magnetic field about the transformer windings at the end of the initial pulse and after the tube is at cutoff; it can be almost completely eliminated, if desired, through the use of a damping-diode circuit.

The circuit shown in part B produces a positive output pulse in the cathode circuit. When the cathode resistor has a low value, which is usually the case, this output-coupling method provides a relatively low output impedance.

The circuit shown in part C produces a negative output pulse. The output impedance of this circuit is relatively high.

The circuit shown in part D also produces a negative output pulse, across the series dropping resistor (R) in the plate circuit. Except for polarity, this pulse is similar to the cathode output pulse for the circuit in part B; however, the output impedance of the circuit in part D is much higher than that of the circuit in part B.

The circuit shown in part E produces a positive output pulse in the cathode circuit of a cathode follower. A negative voltage (bias) is applied to the grids of the blocking oscillator and the directly-coupled cathode follower. The advantages of this output circuit are a low-impedance output, negative peak clipping by the action of the cutoff cathode-follower stage, and practically no loading effect upon the blocking oscillator.



Output Coupling Methods

PARALLEL-TRIGGERED BLOCKING OSCILLATOR.

APPLICATION.

The parallel-triggered blocking oscillator is used to produce short-time duration, large-amplitude pulses for use as synchronizing or trigger pulses in radar modulators and display indicators.

CHARACTERISTICS.

Output pulse is a single cycle of oscillation caused by trigger-amplifier tube conduction which is, in turn, synchronized by a trigger pulse at the beginning of each pulse-repetition period. Some delay is introduced between the time of trigger application to the trigger amplifier and the development of the leading edge of the output pulse.

Pulse-repetition time is determined by an external positive-trigger source in conjunction with the RC time constant of the grid circuit. The pulse-repetition frequency is generally fixed within the range of 200 to 2000 pulses per second.

Trigger amplifier provides isolation and prevents blocking oscillator from reacting on trigger source; also, amplification of trigger pulse sharpens pulse somewhat.

Pulse width and rise time of the output pulse are determined primarily by the transformer characteristics.

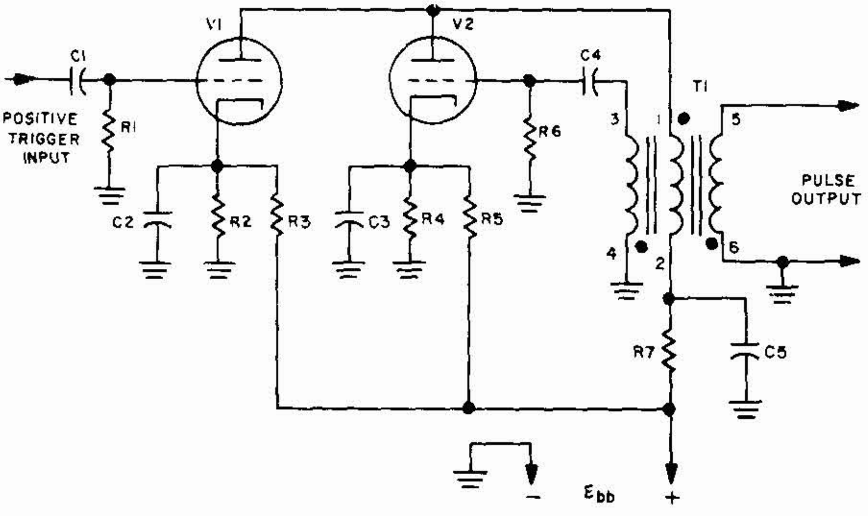
Output-pulse polarity is determined by the phasing of the transformer output tertiary winding. If the circuit changes, the output can also be taken from the cathode circuit (positive pulse) or from the plate circuit (negative pulse).

CIRCUIT ANALYSIS.

General. The parallel-triggered blocking oscillator is similar to the free-running prf generator except that its pulse-repetition frequency is determined by a positive synchronizing trigger pulse which is applied to a trigger amplifier. The plates of the trigger-amplifier tube and the blocking-oscillator tube are in parallel and share a common plate winding of the blocking-oscillator transformer. When the trigger amplifier receives a pulse from an external source, it amplifies the pulse and causes current to flow in the plate winding of the transformer; thus, a cycle of oscillation is initiated. Upon completion of the pulse cycle, the circuit becomes inactive until the amplifier receives another trigger pulse. Normal operation of the parallel-triggered blocking oscillator results in the generation of an output pulse each time a trigger pulse is applied to the trigger amplifier.

Circuit Operation. The accompanying circuit schematic illustrates two triode electron tubes in a parallel-triggered blocking-oscillator circuit; one electron tube is the blocking oscillator and the other is the trigger amplifier. Although the schematic illustrates two separate triodes, V1 and V2, a twin-triode is frequently used in this circuit.

Transformer T1 provides the necessary coupling (inductive feedback) between plate and grid of electron tube V2; terminals 1 and 2 connect to the plate (primary) winding, which is common to both V1 and V2, terminals 3 and 4 connect to the grid (secondary) winding, and terminals 5 and 6 connect to the output (tertiary) winding. Capacitor C1 couples the input trigger pulse to the grid of V1; resistor R1 is the grid-return resistor for V1. Resistors R2 and R3 form a voltage divider to provide cathode bias for the trigger-amplifier tube, V1; similarly, resistors R4 and R5 provide cathode bias for the blocking-oscillator tube, V2. Capacitors C2 and C3 are the cathode bypass capacitors for V1 and V2, respectively. Capacitor C4 and resistor R6 form an R-C circuit to determine the discharge time constant in the grid circuit of V2. Resistor R7 and capacitor C5 form a plate decoupling network.



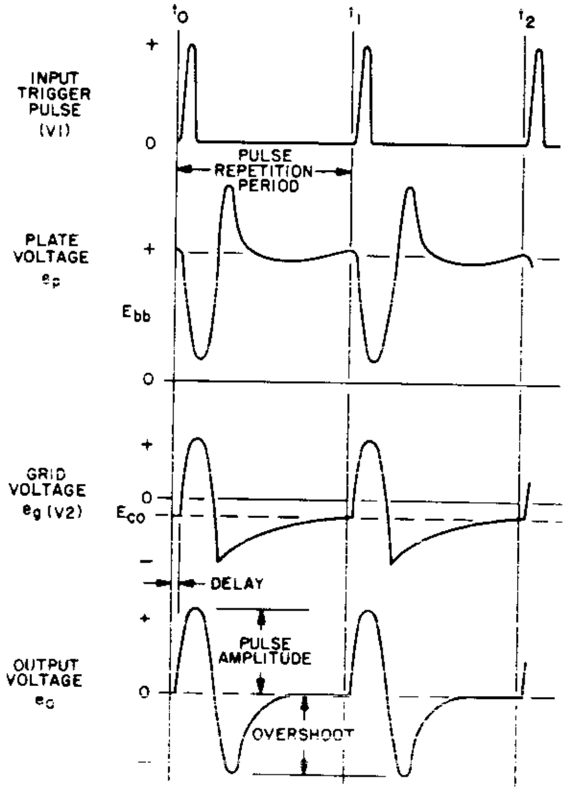
Parallel-Triggered Blocking Oscillator

The output pulse from the blocking oscillator is taken from the tertiary winding (terminals 5 and 6) of transformer T1.

For the following discussion of circuit operation, refer to the accompanying illustration which shows the input trigger and blocking-oscillator plate-signal, grid-signal, and output-voltage waveforms. Bias voltage for the trigger amplifier, V1, is developed by cathode resistor R2 as a result of the d-c current through the series resistance of R2 and R3, connected as a voltage divider between the supply voltage and ground; also, bias is developed for the blocking oscillator, V2, by cathode resistor R4, which is in series with resistor R5 to form a similar voltage divider. The amount of bias developed by resistor R2 is sufficient to hold the grid of V1 near cutoff, whereas the bias developed by resistor R4 places the grid of V2 below cutoff.

To start a single cycle of operation, a positive trigger pulse is applied to the input of trigger amplifier V1 across coupling capacitor C1 and grid-return resistor R1. The trigger pulse developed across resistor R1 is applied to the grid of V1 and amplified by the trigger amplifier. As a result of the positive-going pulse on the grid of V1, the tube conducts and plate current flows through the plate winding (terminals 1 and 2) of the pulse transformer, T1. The voltage at the plates of V1 and V2 starts to drop as the current of the trigger amplifier increases in the plate winding; the increasing current through the plate winding sets up a magnetic field about the winding, and a voltage is induced (through transformer action) in the grid winding (terminals 3 and 4) of transformer T1. Since the trigger pulse is of short duration, the trigger amplifier returns to its initial condition at the end of the trigger pulse, and V1 ceases to conduct because of the cathode bias developed by resistor R2. The blocking-oscillator action which follows is similar to that which occurs during one cycle of operation for the free-running (prf generator) blocking oscillator.

When trigger-amplifier plate current flows through the plate winding, a grid-signal voltage is produced across the grid winding and is impressed on the grid of V2 through coupling capacitor C4 to drive the grid of V2 in a positive direction. (See grid-voltage waveform.) This causes the blocking-oscillator tube to start to conduct when the positive grid voltage exceeds the value of cathode bias; the regenerative action (feedback) which occurs to complete the cycle of operation is essentially the same as the action previously described for the free-running (prf generator) blocking oscillator. Near the end of the cycle of operation and after the trigger-amplifier tube returns to cutoff, the grid of the blocking oscillator is driven below cutoff as the result of the highly negative charge existing on capacitor C4. (See grid-voltage waveform.) Capacitor C4 slowly discharges through resistor R6 and the grid winding of T1. The time constant of R6 and C4 is chosen so that the grid is held below cutoff for a considerable period of time; thus, the grid gradually approaches the initial value of bias, at which time the circuit is ready to be triggered to initiate another cycle of operation. (The initial value of bias developed across R4 is sufficient to keep the blocking-oscillator tube at or below cutoff.) Under the conditions of operation described above, the blocking oscillator produces an output pulse each time a trigger pulse is applied to the input of the trigger amplifier, V1. The output pulse is delayed slightly, but has the same repetition frequency as the synchronizing trigger pulse.



Theoretical Trigger-, Plate-, Grid-, and Output-Voltage Waveforms

With minor modification to change the time constant of R6C4, the parallel-triggered blocking oscillator circuit may be used as a pulse-frequency divider to produce output pulses at a submultiple of the trigger-pulse frequency.

The output pulse is taken from the tertiary winding (terminals 5 and 6) of transformer T1 in the same manner as that previously described for the free-running (prf generator) blocking-oscillator circuit.

The parallel-triggered blocking oscillator is relatively insensitive to changes in filament and plate supply voltages. A change in plate voltage of 10 percent may reflect a change as great as 7 percent in pulse amplitude; however, there is little change in pulse width or rise time.

FAILURE ANALYSIS.

No Output. It is important to establish that the cathode bias voltage developed by each voltage divider (R2, R3, and R4, R5) is correct for the trigger-amplifier and blocking-oscillator tubes, V1 and V2. Since the trigger-amplifier and blocking-oscillator tubes are normally biased at or below cutoff, it is also important to establish that a trigger pulse of correct polarity and amplitude is being supplied to the circuit. When the circuit is in a nonoscillating condition, assuming that the bias voltage is correct for both tubes, the voltage measured at the plates of V1 and V2 will approach the value of the supply voltage, provided that the plate winding of T1 and the decoupling filter (R7 and C5) are not defective. Any defect in the plate or grid windings of transformer T1 is likely to prevent the proper regenerative feedback from occurring; as a result, the circuit will not provide the proper output pulse or may not oscillate at all.

If the tertiary winding of transformer T1 should open, the circuit may still operate but no output will be obtained from the tertiary winding.

Unstable Output. Whenever the output-pulse repetition rate of the blocking oscillator becomes unstable or erratic, the trigger pulse should first be checked to determine whether the fault lies within the trigger-generator circuit. Since the stability of the blocking oscillator is dependent upon the repetition-frequency and pulse-amplitude stability of the trigger source, it is entirely possible that an unstable trigger applied to the trigger amplifier will cause the blocking oscillator to produce output pulses which are synchronized to the faulty trigger. The time constant of R6 and C4 must allow the grid of V2 to return to the initial value of bias before the blocking oscillator is triggered; otherwise, the blocking oscillator may not respond reliably to the amplified trigger pulse. Random pulsing of the blocking oscillator can also result if the cathode bias (derived from resistors R4 and R5) is reduced and approaches zero bias. In this case, although the trigger pulse will frequently initiate an operating cycle, the oscillator may attempt to become free-running because of the lack of correct bias. Leakage in capacitor C4 will cause a change in the R-C time constant of the blocking oscillator, and will result in an unstable output which is usually accompanied by a decrease in pulse amplitude.

Low Output. Reduced plate-supply voltage will affect the amplitude (and perhaps the pulse width and rise time) of the output pulse. Also, if shorted turns should develop in the tertiary winding of T1 or if a decrease in load impedance should occur, the pulse-output amplitude will be reduced not only because of the change in load impedance but also because of the impedance reflected into the plate and grid windings of transformer T1. If the load impedance should fall considerably below the normal value for the circuit, an increase in time delay will occur between the trigger pulse and the start of the output pulse; also, the rise time of the output pulse will increase and will be accompanied by a decrease in pulse amplitude.

SERIES-TRIGGERED BLOCKING OSCILLATOR.

APPLICATION.

The series-triggered blocking oscillator is used to produce short-time-duration, large-amplitude pulses for use as synchronizing or trigger pulses in radar modulators and display indicators.

CHARACTERISTICS.

Output pulse is a single cycle of oscillation caused by tube conduction which is initiated by a synchronizing trigger pulse at the beginning of each pulse-repetition period.

Pulse-repetition time is determined by an external positive-trigger source in conjunction with the R-C time constant of the grid circuit. The pulse-repetition frequency is generally fixed within the range of 200 to 2000 pulses per second, although the circuit can be arranged to change the R-C time constant and provide for operation at a submultiple of the trigger-pulse frequency; in this case, the triggered blocking oscillator operates as a pulse-frequency divider.

Requires a low-impedance trigger source; there is considerable reaction on the trigger source even if a cathode follower is used for triggering the circuit.

Pulse width and rise time of the output pulse are determined primarily by the transformer characteristics.

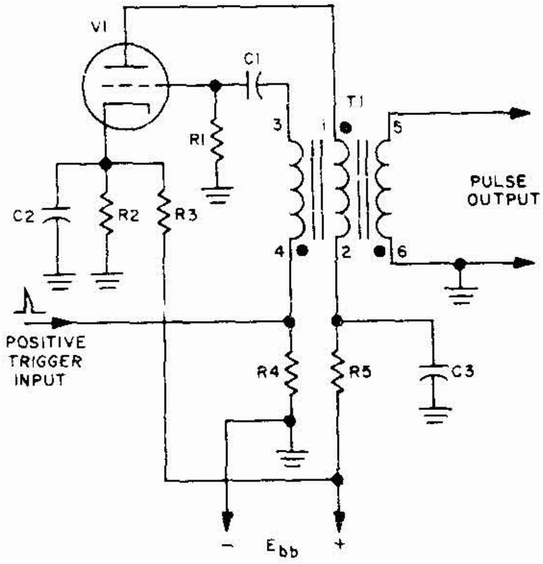
Output-pulse polarity is determined by the phasing of the transformer output-tertiary winding. With minor circuit changes, the output can also be taken from the cathode circuit.

CIRCUIT ANALYSIS.

General. The series-triggered blocking oscillator is similar to the free-running prf generator except that its pulse-repetition frequency is determined by a positive synchronizing trigger pulse. When the oscillator is triggered by a pulse from an external source, it completes one cycle of operation to produce an output pulse and then becomes inactive; the cycle of operation is repeated upon application of another trigger pulse. Normal operation of the series-triggered blocking oscillator results in the generation of an output pulse each time a trigger pulse is applied to the circuit.

Circuit Operation. The accompanying circuit schematic illustrates a triode electron tube in a series-triggered blocking-oscillator circuit. Transformer T1 provides the necessary coupling (inductive feedback) between the plate and grid of electron tube V1; terminals 1 and 2 connect to the plate (primary) winding, terminals 3 and 4 connect to the grid (secondary) winding, and terminals 5 and 6 connect to the output (tertiary) winding. Capacitor C1 and resistor R1, in conjunction with R4, form an R-C circuit to determine the discharge time constant in the grid circuit. Resistors R2 and R3 form a voltage divider to provide cathode bias for the tube; the voltage developed across R2 is sufficient to bias the tube at or below cutoff. Capacitor C2 is a cathode bypass capacitor. The synchronizing trigger pulse is applied across resistor R4, which is effectively in series with the grid signal. The value of resistor R4 is generally low; however as indicated previously, this resistance is a part of the total resistance which determines the R-C time constant of the circuit. Resistor R5 and capacitor C3 form a plate decoupling network.

The output pulse from the blocking oscillator is taken from the tertiary winding (terminals 5 and 6 of transformer T1.

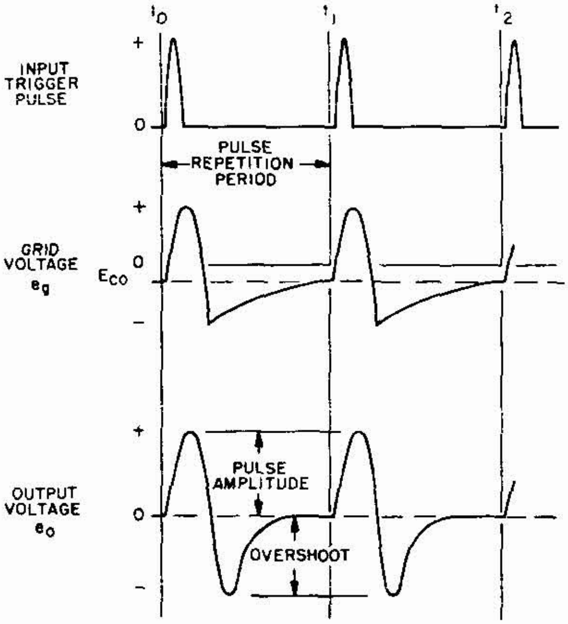


Series-Triggered Blocking Oscillator

For the brief discussion of circuit operation which follows, refer to the accompanying illustration which shows the blocking-oscillator-trigger, grid-signal, and output-voltage waveforms.

When voltage is first applied to the circuit, bias voltage for the tube is developed by cathode resistor R2 as a result of the d-c current through the series resistance of R2 and R3 connected between the supply voltage and ground. The amount of bias developed is sufficient to hold the grid at or slightly below cutoff; thus, plate current does not flow at this time.

To start a single cycle of operation, a positive trigger pulse is applied across resistor R4. This pulse is applied through the grid winding of transformer T1 and capacitor C1 to the grid of V1, and raises the grid voltage above cutoff. (The positive-going trigger pulse must be of sufficient amplitude to drive the grid out of the cutoff region to initiate the cycle.) At this time the tube starts to conduct, and the regenerative action which occurs during the cycle of operation is essentially the same as the action previously described for the free-running (prf generator) blocking oscillator. Near the end of the cycle, when the grid is driven below cutoff and plate current no longer flows through the plate winding of T1, the highly negative charge existing on capacitor C1 slowly discharges through resistors R1 and R4 and the grid winding of transformer T1. Since the resistance of the grid winding is low in comparison with the combined resistance of R1 and R4, it has little effect on the discharge time of capacitor C1. Furthermore, the resistance of R4 is low compared to that of R1, therefore, R1 has the predominant effect on the discharge time of capacitor C1.



Theoretical Trigger, Grid-Voltage, and Output-Voltage Waveforms

After an elapsed period of time, as governed by the time constant of R1, R4, and C1, capacitor C1 discharges and allows the grid potential to reach a point near cutoff. When a positive trigger pulse is again applied across resistor R4, another cycle of operation is initiated.

If it were not for the periodic application of the positive trigger pulse to resistor R4, the blocking oscillator would remain cut off because of the value of cathode bias developed across cathode resistor R2. Under these conditions, each time a trigger pulse is applied to the circuit, a complete cycle of the blocking oscillator produces an output pulse which is in synchronism with the trigger pulse and has the same repetition frequency. For synchronization to occur, the values of R and C must be chosen so that the natural oscillating frequency of the blocking oscillator, in the absence of cathode bias, is slightly lower than the repetition frequency of the synchronizing trigger pulse.

The operating frequency of the triggered blocking oscillator can be conveniently changed to a submultiple of the trigger frequency by switching R-C values to alter the time constant. For example, an additional resistance could be switched into the circuit in series with resistor R1 to increase the R-C time constant. In this case, if the time constant were at least doubled, the oscillator would respond to every other trigger pulse and, therefore, the blocking-oscillator repetition frequency would be one-half that of the trigger source.

The output pulse is taken from the tertiary winding (terminals 5 and 6) of transformer T1 in the same manner as previously described for the free-running (prf generator) blocking-oscillator circuit.

In a practical series-triggered blocking-oscillator circuit, resistor R4 may actually be the cathode resistor for a cathode-follower circuit. In this case, the trigger is applied to the grid of the cathode-follower electron tube, and resistor R4, across which the trigger pulse is developed, represents a low-impedance trigger source to the blocking-oscillator circuit.

The series-triggered blocking oscillator is relatively insensitive to changes in filament and plate-supply voltages, although a change in plate voltage of 10 percent may produce a change as great as 10 percent in pulse amplitude and may be accompanied by some change in pulse width. However, this effect is reduced to some extent by the change in the bias voltage developed across resistor R2 whenever the plate-supply voltage changes.

FAILURE ANALYSIS.

No Output. Since the oscillator is normally biased to cutoff, it is important that a trigger pulse of the correct polarity and amplitude be supplied to the oscillator circuit. When the circuit is in a nonoscillating condition, assuming that the developed cathode bias is normal, the voltage measured at the plate of V1 will approach the value of the supply voltage, provided that the plate winding of T1 and the decoupling filter (R5 and C3) are not defective. Any defect in the plate or grid windings of transformer T1 is likely to prevent the proper regenerative feedback from occurring; as a result, the circuit will not provide the proper output pulse or may not oscillate at all. If the tertiary winding of transformer T1 should open, the circuit may still operate but no output will be obtained from the tertiary winding.

Unstable Output. Whenever the output-pulse repetition rate of the blocking oscillator becomes unstable or erratic, the trigger pulse should first be checked to determine whether the fault lies within the trigger-generator circuit. Since the stability of the blocking oscillator is dependent upon the repetition-frequency and pulse-amplitude stability of the trigger source, it is entirely possible that an unstable trigger applied to the oscillator will cause the blocking oscillator to produce output pulses which are synchronized to the random triggering. Random pulsing of the blocking oscillator can also result if the fixed bias (derived from resistors R2 and R3) should be reduced and approach zero bias. In this case, although the trigger pulse will frequently initiate an operating cycle, the oscillator may attempt to become free-running because of the lack of correct bias. Leakage in capacitor C1 will cause a change in the R-C time constant of the blocking oscillator, and will result in an unstable output which is usually accompanied by a decrease in pulse amplitude.

Low Output. Reduced plate-supply voltage will affect the amplitude (and perhaps pulse width) of the output pulse. Also, if shorted turns should develop in the tertiary winding or if a decrease in load impedance should occur, the output will be reduced not only because of the change in load impedance but also because of the impedance reflected into the plate and grid windings of transformer T1.

FAST-RECOVERY BLOCKING OSCILLATOR.

APPLICATION.

The fast-recovery blocking oscillator produces short-time-duration, large-amplitude pulses for use as timing, synchronizing, or trigger pulses in radar modulators and display indicators.

CHARACTERISTICS.

Output is a single pulse caused by tube conduction and initiated by a trigger pulse at the beginning of each pulse repetition period.

Pulse repetition frequency is determined by an external trigger source.

Pulse repetition period is much shorter in the fast-recovery blocking oscillator than in other types of blocking oscillators.

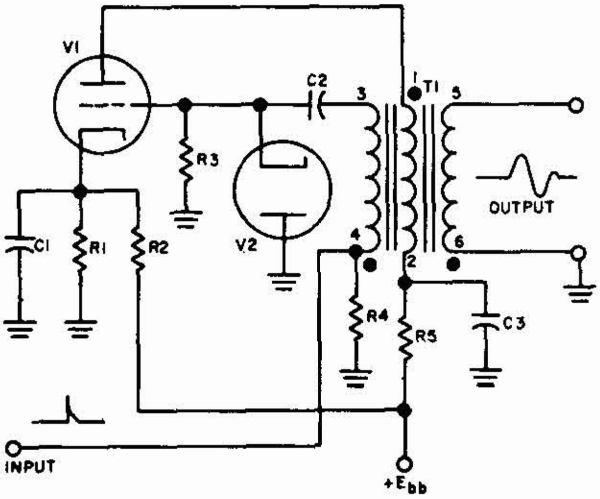
Pulse width and rise time are determined primarily by the transformer characteristics.

Output pulse polarity is determined by the phasing of the transformer output (tertiary) winding.

CIRCUIT ANALYSIS.

General. The fast-recovery blocking oscillator is similar to other types of triggered blocking oscillators in that, when triggered, it supplies one output pulse and then becomes inactive. In the normal triggered blocking oscillator, the grid voltage must be allowed to return to a point near cutoff before the circuit is triggered again. This period of time, called **recovery time,** is normally much longer than the pulse width and limits the pulse repetition frequency. The fast-recovery blocking oscillator uses a number of methods to overcome the difficulty of long recovery time.

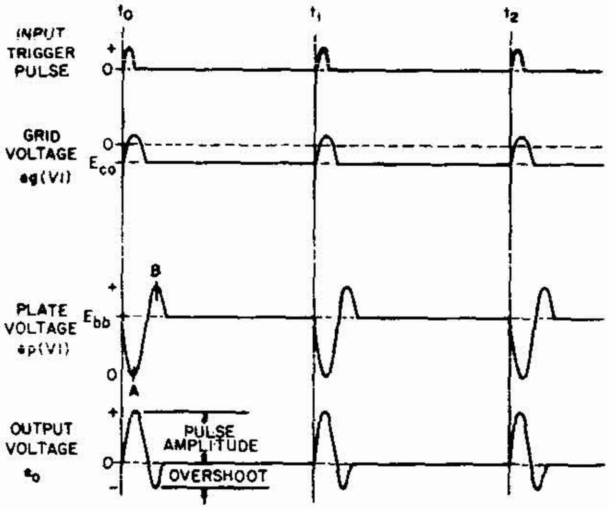
Circuit Operation. The accompanying circuit schematic illustrates one type of fast-recovery blocking oscillator. With the exception of diode V2, it is identical to the SERIES-TRIGGERED BLOCKING OSCILLATOR discussed previously in this section of the Handbook.



Fast-Recovery Blocking Oscillator

Transformer T1 provides the necessary coupling (inductive feedback) between plate and grid of electron tube V1. Terminals 1 and 2 connect to the plate (primary) winding, terminals 3 and 4 connect to the grid (secondary) winding, and terminals 5 and 6 connect to the output (tertiary) winding. Resistors R1 and R2 form a voltage divider which provides cathode bias for triode V1. The voltage developed across cathode resistor R1 biases triode V1 to plate current cutoff. Capacitor C1 is the cathode bypass capacitor for triode V1, and resistor R3 is the grid return resistor. The positive trigger pulse is applied across resistor R4, which has a relatively low value of resistance. Grid capacitor C2 and resistors R3 and R4 normally determine the time constant of the grid circuit. However, when capacitor C2 discharges, diode V2 conducts, shunting grid resistor R3, and the discharge time for the circuit is greatly reduced. Resistor R5 and capacitor C3 form a conventional plate decoupling network. The output from the blocking oscillator is taken from the tertiary winding (terminals 5 and 6) of transformer T1.

The following illustration shows the trigger-, grid-, plate-, and output-voltage waveforms in their proper time relationship.



Trigger-, Grid-, Plate-, and Output-Voltage Waveforms

When voltage is first applied to the circuit, d-c current flows through voltage divider consisting of resistors R1 and R2. This current flow develops a bias voltage on the cathode of triode V1 which is sufficient to keep the tube biased to plate-current cutoff. Hence, no current flows in the plate circuit.

When a positive trigger pulse is applied to resistor R4, it passes through the grid winding of transformer T1 and is applied to grid capacitor C2. The positive potential on the transformer side of capacitor C2 causes an electron flow from ground through grid resistor R3 to the grid side of the capacitor. This current flow, which eventually charges the capacitor, develops a positive voltage across grid resistor R3 sufficient to raise the bias of triode V1 above cutoff and cause V1 to conduct. As plate current increases and flows through the plate winding terminals 1 and 2) of transformer T1, it produces a magnetic field around the winding. This increasing magnetic field induces a voltage into the grid winding of the transformer. The transformer phasing is such that the induced positive voltage increases the voltage across C2, causes more current to flow through grid resistor R3, increases the charge on grid capacitor C2, and drives the grid of V1 further positive. The increase in positive grid voltage, due to feedback, causes the plate current to increase still further. This **regenerative action** continues. That is a continual increase in grid voltage causes a continual increase in plate current which, in turn, causes a further increase in the grid (feedback) voltage. Meanwhile, as the plate current rapidly increases toward plate-current saturation, the grid voltage becomes more positive until it reaches zero bias, and grid current flows, charging grid capacitor C2 to its maximum value.

When the plate-current saturation point is reached (point A on the plate-voltage waveform), current flow in the plate winding of transformer T1 no longer increases. Since there is no longer a changing magnetic field around the plate winding of the transformer, no further voltage is induced into the grid winding. Grid capacitor C2 is now fully charged, and since there is no longer a voltage across the grid winding of transformer T1 to sustain this charge, the capacitor begins to discharge. Normally, the capacitor would discharge through grid resistor R3, resistor R4, and the grid winding of the transformer. However, the negatively charged side of grid capacitor C2 is connected to the cathode of diode V2. This negative potential on the cathode of the diode makes it conduct, shunting grid resistor R3. Capacitor C2 now discharges through diode V2, resistor R4, and the grid winding of transformer T1. Since the high resistance of grid resistor R3 is shunted by diode V2 and effectively removed from the circuit, resistor R4 alone determines the discharge time constant of the circuit. Since the value of R4 is low, the time constant is short, and capacitor C2 discharges very quickly. When capacitor C2 discharges, the grid voltage level drops until it reaches the fixed cathode bias (determined by resistors R1 and R2) which keeps the triode biased to cutoff, and plate current ceases.

As plate current stops flowing in the plate winding of transformer T1, the magnetic field around the winding collapses. The collapsing field induces into the plate winding a voltage of a polarity which tends to keep current flowing in the same direction. (That is, the polarity of the induced voltage is series-aiding with that of the plate-supply voltage.) The result of adding these voltages is a momentary increase in plate voltage over and above the plate-supply voltage, called **overshoot** (point B on the plate-voltage waveform). As the magnetic field around transformer T1 decreases in intensity, the induced voltage (overshoot) decreases accordingly, and the plate voltage quickly returns to the normal quiescent value.

Any changes of current in the primary winding of transformer T1 also induce a changing voltage into the tertiary, or output, winding (terminals 5 and 6). The polarity of the output pulse from this winding is determined by which terminal is connected to ground. As shown in the circuit schematic, terminal 6 is grounded. Therefore, in this case, a positive output pulse results (for a negative output it would be necessary to ground terminal 5 instead).

The fast-recovery blocking oscillator provides one output pulse each time a positive trigger pulse is applied. It is ready again almost immediately to receive another trigger pulse and produce another output pulse. Therefore, it is preferred for circuits operating at fast repetition rates.

FAILURE ANALYSIS.

No output. Since the oscillator depends on a positive trigger pulse to initiate operation, it is important to determine whether the input pulse is of the proper polarity and of sufficient amplitude to drive the grid of V1 above cutoff. Use an oscilloscope to observe the input waveform.

If the proper trigger pulses are present at the input, use the oscilloscope to observe the signal at the plate of V1. If pulses similar to those shown in the illustration of the plate-voltage waveform are observed, but still no output is obtained, the output (tertiary) winding of transformer T1 is either open or shorted. Use an ohmmeter to check the continuity of this winding; also check for a short to ground (indication of less than 0.1 ohm). If no pulses are observed at the plate of V1, either no plate voltage is present or there is a defective feedback circuit or a defective cathode-bias circuit. Measure the voltage on the plate of V1 with a high-resistance voltmeter. If no voltage is measured at this point, a number of other possibilities exist: either an open in the plate winding of transformer T1, an open plate resistor R5, or a shorted bypass capacitor C3. Use an ohmmeter to check these components and isolate the trouble. If the proper voltage is measured at the plate of V1 but no plate pulses are seen on the oscilloscope, the trouble is in either the feedback or bias circuits. Use an ohmmeter to check for an open grid capacitor, C2, or for an open grid winding of transformer T1 to clear the feedback circuits. Then check for proper resistance values of resistors R1, R2, R3, and R4 to clear the bias circuits. If these checks fail to locate the trouble, the tube is probably at fault; replace triode V1 with a tube known to be good.

Unstable Ouput. Since the output stability of the oscillator is dependent upon the input trigger pulse, it is important to be certain that the input trigger is of the proper amplitude and frequency. Use an oscilloscope to observe the input waveform. If the proper input waveform is observed, the bias circuit or feedback circuit may be faulty. Use an ohmmeter to check capcitor C1 for an open or a short, and to check bias resistors R1 and R2 for proper resistance values. If these checks show that the bias circuit is not defective, check the feedback circuit with an ohmmeter. First check grid capacitor C2 for a short, and then check resistors R3 and R4 for the proper resistance values. Also use the ohmmeter to check transformer T1 for continuity of the grid and plate windings, for shorts between the windings, and for shorts to ground (less than 1 ohm). If these checks fail to locate the trouble, replace triode V1 and diode V2 with tubes known to be good.

Low Output. Low output may be caused by weak emission in the triode, low plate-supply voltage, or excessive circuit loading. If substituting a good tube for triode V1 does not remedy the trouble, use a high-resistance voltmeter to measure the plate-supply voltage. If this voltage is low, the trouble is in the power supply. If the plate-supply voltage is normal, the transformer is probably defective; replace it with one known to be good.

PULSE-FREQUENCY DIVIDER.

APPLICATION.

The pulse-frequency divider is used to produce high-amplitude pulses at a submultiple of the input trigger pulse frequency for use as timing or synchronizing pulses in radar and communications equipment.

CHARACTERISTICS.

Output pulse frequency is a submultiple of the input pulse frequency.

Frequency-division ratio can be adjusted within a small range.

Requires a high-impedance trigger source which produces positive trigger pulses.

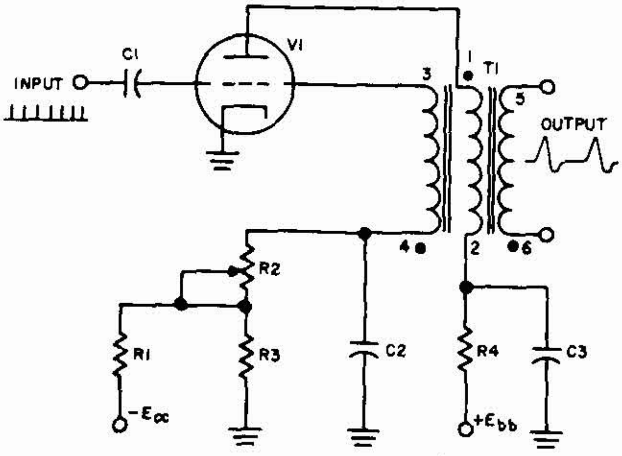
Output pulse width and rise time are determined primarily by the transformer characteristics.

Output pulse polarity is determined by the phasing of the transformer output (tertiary) winding.

CIRCUIT ANALYSIS.

General. The operation of the pulse-frequency divider is similar to that of other types of triggered blocking oscillators. However, the pulse-frequency divider is designed so that, instead of producing out-put pulses at the same frequency, as the input pulse frequency, it produces output pulses at a frequency which is only a fraction of the input pulse frequency. In other words, the circuit divides the input pulse frequency down to a lower frequency. The ratio of the input pulse frequency to the output pulse frequency is called the **division ratio.** Although pulse-frequency divider circuits have been designed with division ratios as high as 100:1, a low division ratio (less than 6:1) gives the best stability. Consequently, most pulse-frequency dividers are designed to operate at low division ratios.

Circuit Operation. The accompanying circuit schematic illustrates a pulse-frequency divider with a division ratio that can be adjusted between 2:1 and 5:1.

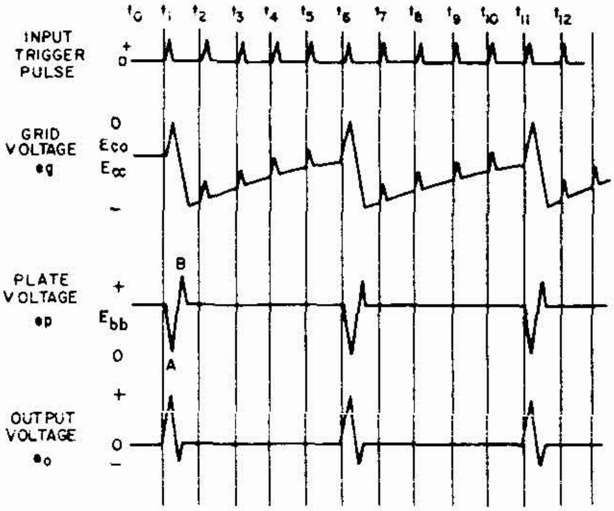


Pulse-Frequency Divider

Transformer T1 provides the coupling (inductive feed-back) between the plate and the grid of triode V1. Terminals 1 and 2 connect to the plate (primary) winding, terminals 3 and 4 connect to the grid (secondary) winding, and terminals 5 and 6 connect to the output (tertiary) winding.

The positive trigger pulses are applied through coupling capacitor C1 to the grid of triode V1. Capacitor C2 and resistors R2 and R3 make up the grid R-C circuit. Resistor R2 is variable and allows the time constant of this R-C circuit to be adjusted for the desired division ratio. Resistors R1 and R3 form a voltage-divider network which supplies fixed grid bias voltage for triode V1. Resistor R4 and capacitor C3 form a conventional plate decoupling network.

The following illustration shows the trigger-, grid-, plate-, and output-voltage waveforms in their proper time relationship.



Trigger-, Grid-, Plate-, and Output-Voltage Waveforms

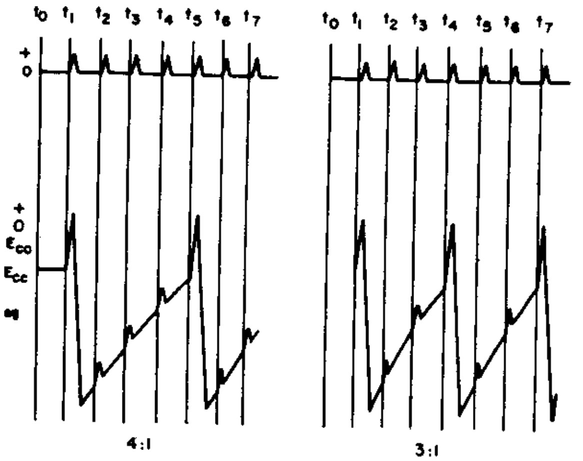
In the quiescent condition (with no trigger pulse applied), V1 is held at plate-current cutoff by the fixed negative bias taken from the voltage divider made up of resistors R1 and R3, and applied through grid resistor R2 and the grid winding of transformer T1 to the grid of V1 (time t_0 on the waveform illustration).

When the first positive trigger pulse is applied to the grid of triode V1 through coupling capacitor C1, it drives the grid above cutoff and causes the tube to conduct (time t_1 on the waveform illustration). The increasing plate current flowing through the plate winding (terminals 1 and 2) of transformer T1 produces a magnetic field in the transformer. The changing magnetic field induces a feedback voltage into the grid winding of transformer T1. The transformer phasing and polarity are such that the induced feedback voltage drives the grid of triode V1 more positive, and the plate of capacitor C2 which is connected to the negative end of the grid winding more negative. Thus, the induced feedback voltage causes two things to occur simultaneously: the capacitor charges to a higher potential, and the tube is biased more positive. The increased positive bias causes the plate current of triode V1 to increase further. The increasing plate-current flow through the plate winding of transformer T1 causes the magnetic field in the transformer to increase accordingly, and induces a still larger voltage into the grid winding of transformer T1. This continuous increase in feedback voltage, grid voltage, and plate current produces a **regenerative-feedback** action which quickly drives the tube toward plate-current saturation. As the grid of triode V1 is driven more and more positive, grid current eventually begins to flow. The flow of grid current through the grid winding of transformer T1 to capacitor C2 causes the capacitor to quickly charge to its maximum negative value.

When plate-current saturation is reached (point A on the plate-voltage waveform), the plate current can no longer increase. Consequently, the magnetic field in transformer T1 no longer increases, and no feedback voltage is now induced into the grid winding. The grid of triode V1 is therefore driven negative by the large negative charge on capacitor C2. This negative grid voltage causes the triode plate current to decrease. As the plate current through the plate winding of transformer T1 decreases, the magnetic field in the transformer decreases accordingly, inducing a feedback voltage of opposite polarity into the grid winding of the transformer. This induced feedback voltage drives the grid of triode V1 further negative, increasing the negative grid bias, and causing plate-current flow through the plate winding of transformer T1 to decrease still further. As previously explained. the regenerative feedback from the plate to the grid of triode V1 produces a continuous cycle which causes the grid to be driven far below cutoff. As plate-current occurs, the plate current ceases to flow, and the magnetic field in the transformer collapses. The collapsing magnetic field induces into the plate winding of transformer T1 a voltage of such polarity that it tends to keep current flowing in the same direction as the original plate-current flow (that is, the induced voltage is series-aiding with the plate-supply voltage). The result of adding these voltages is a momentary increase in plate voltage over and above the plate-supply voltage, called **overshoot** (point B on the plate-voltage waveform). As the magnetic field decreases to zero, the induced voltage (overshoot) decreases accordingly, and the plate voltage returns to the normal, quiescent value.

When plate current ceases, the charge on capacitor C2 is no longer sustained, and the capacitor discharges through resistors R2 and R3 towards the negative fixed-bias value. Since the time constant of this R-C circuit is very large, capacitor C2 discharges very slowly, and its potential decreases only a small amount by the time the plate pulse and overshoot are completed. The discharge time of the circuit is, in fact, many times longer than the input pulse repetition period. Consequently, the next input trigger pulse (time t_2 on the waveform illustration) occurs while capacitor C2 is still discharging and reducing the bias towards the fixed cutoff bias value. This positive trigger pulse (number 2), when combined with the negative grid voltage remaining on capacitor C2, is not of sufficient amplitude to raise the grid of triode V1 above cutoff. Therefore, trigger pulse number 2 has no effect on the operation of the circuit, and triode V1 remains cut off with capacitor C2 still discharging. The same result occurs during the next three input trigger pulses (times t_3, t_4, and t_5 on the waveform illustration). However, when the next input trigger pulse (time t_6 on the waveform illustration) occurs, capacitor C2 is now discharged to nearly the fixed negative bias voltage across resistor R3 (cutoff bias). Therefore, when trigger pulse number 6 is combined with the negative grid voltage remaining on capacitor C2, the resulting pulse is of sufficient amplitude to again drive the grid of triode V1 above cutoff and cause the tube to conduct. Thus, the sixth trigger pulse causes the circuit to begin another cycle of operation. The pulse-frequency divider produces an output pulse as previously explained, and then remains inactive for the next four input trigger pulses. It produces an output pulse for every fifth input pulse. Therefore, the circuit is said to have a division ratio of 5:1.

The division ratio of the pulse-frequency divider is entirely dependent upon the discharge time of capacitor C2, which is determined by the time constant of the grid R-C circuit. Resistor R2 is made variable so that the time constant of the R-C circuit can be adjusted for the desired output frequency. If the value of resistor R2 is decreased, the time constant of the R-C circuit decreases and capacitor C2 discharges more quickly. Thus by proper adjustment of resistor R2, the circuit will operate on every fourth input trigger pulse, giving a division ratio of 4:1. As the value of resistor R2 is decreased still further, the division ratio decreases accordingly. The accompanying illustration shows the trigger- and grid- voltage waveforms for two different settings of resistor R2, and consequently for two different frequency-division ratios.



Trigger- and Grid-Voltage Waveforms for Two Settings of Resistor R2

FAILURE ANALYSIS.

General. Since the output signal of the pulse-frequency divider is dependent upon the input signal, it is important to be certain that the proper trigger pulses are applied. If the proper input trigger pulses are not applied, the output from the circuit, if present at all, will be unstable or of the wrong frequency. Therefore, the first step in troubleshooting this circuit is to use an oscilloscope to observe the input waveform, and compare it with the waveform shown in the equipment instruction book to be certain that it is of the proper polarity, amplitude, and frequency.

No Output. In addition to an improper input signal, a no-output condition may be caused by a lack of plate-supply voltage, a fault in the grid circuit, a fault in the plate circuit, a defective tube, or an open output winding of transformer T1. After checking the input signal with an oscilloscope (as explained in the previous paragraph), use the oscilloscope to observe the waveform at the grid of triode V1. If no signal appears at this point, capacitor C1 is open and must be replaced. If the proper grid-voltage waveform is observed, use the oscilloscope to observe the waveform on the plate of triode V1. A proper plate-voltage waveform indicates that the output winding of transformer T1 is defective. If no signal is observed on the plate of triode V1, voltage and resistance checks must be made to isolate the defective component. Use a high-resistance voltmeter to measure the plate-supply voltage and determine whether the power supply is at fault. Next, use the voltmeter to measure the voltage on the plate of triode V1. If no plate voltage is present, plate circuit components T1 (primery winding), C3, or R4 are either open or shorted. Use an ohmmeter to check continuity and resistance, and isolate the defective component. If the proper plate voltage is present, either the tube is defective, transformer T1 (secondary winding) is open, resistors R1, R2, or R3 are open, or capcitors C1 or C2 are shorted. Use an ohmmeter to isolate the defective component. If these checks fail to locate a defective component, the tube is probably at fault and should be replaced with one known to be good.

Improper Division Ratio or Unstable Output. An improper input signal, an improper bias-supply voltage, a defective tube, an open or shorted grid circuit, or a defective transformer, T1, may cause either an improper division ratio or an unstable output. After checking the input signal with an oscilloscope (as explained previously), use a high-resistance voltmeter to measure the bias-supply voltage. If the bias-supply voltage is correct, the trouble is in the divider circuit and not in the power supply. Use an ohmmeter to check the grid circuit of the divider for open or shorted components (C1, C2, R1, R2, R3). Triode V1 may also be at fault. Replace the tube with one known to be good, and if this still does not correct the trouble, transformer T1 is probable shorted. Replace it with a good transformer.

Low Output. A low output may be caused by three conditions : low plate voltage, low tube emission, or excessive circuit loading. Use a high-resistance voltmeter to measure the plate-supply voltage and eliminate the possibility of a faulty power supply. Since defects in capacitor C3 or resistor R4 may also cause low plate voltage, use an ohmmeter to check these components. The low output may also be caused by low emission in triode V1. If replacing the tube with a good one does not correct the trouble, the low output may be caused by excessive circuit loading. Such a condition may be caused by shorted turns in transformer T1. Consequently, it should be replaced by a good transformer.

DISTANCE-MARK DIVIDER.

APPLICATION.

The distance-mark divider is used to produce short time duration pulses at a submultiple of the input trigger frequency for use as distance marks in radar display indicators.

CHARACTERISTICS.

Produces output pulses at a submultiple of the input trigger pulse frequency.

Requires a low-impedance trigger source which produces positive trigger pulses.

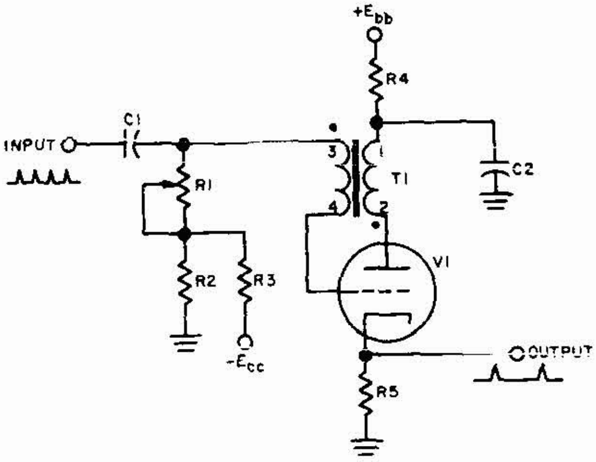
Output consists of positive pulses taken from the cathode of the tube.

Output pulse width and rise time are determined primarily by the transformer characteristics.

CIRCUIT ANALYSIS.

General. The distance-mark divider is a specific application of the pulse-frequency divider discussed earlier in this section of the Handbook. Like the pulse-frequency divider, the distance-mark divider produces output pulses at a submultiple of the input pulse frequency. That is, it divides the input pulse frequency down to a lower frequency. The ratio of input pulse frequency to output pulse frequency is called the **division ratio** of the circuit. While the division ratio of many pulse-frequency divider circuits is adjustable within a small range, the division ratio of the distance-mark divider is normally fixed (usually 2:1 or 3:1). In this way, the circuit can be designed to give the desired characteristics in the output pulse. Moreover, taking the output from the cathode of the tube also helps to produce the desired output pulse shape and eliminates the overshoot present in other types of blocking oscillators.

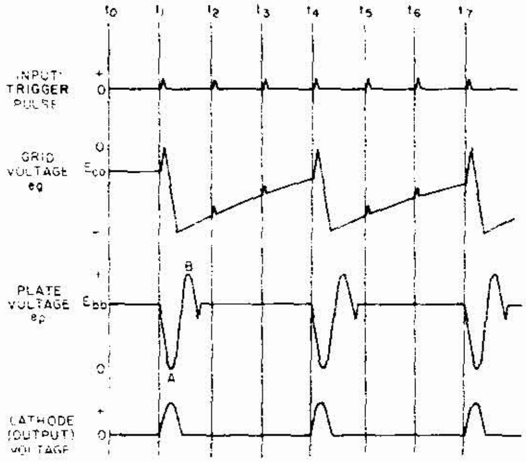
Circuit Operation. The accompanying circuit schematic illustrates a distance-mark divider with a division ratio of 3:1.



Distance-Mark Divider

Transformer T1 provides the coupling (inductive feedback) between the plate and the grid of triode V1. Terminals 1 and 2 connect to the plate (primary) winding, and terminals 3 and 4 connect to the grid (secondary) winding. The input trigger pulses are applied through grid capacitor C1 and the grid winding of transformer T1 to the grid of triode V1. The division ratio of the distance-mark divider is determined by the R-C circuit made up of capacitor C1 and resistors R1 and R2. Resistor R1 is variable and allows the circuit to be adjusted to compensate for variations in component values, supply voltages, and input trigger pulse amplitude. Resistors R2 and R3 form a voltage divider which provides fixed negative grid bias for triode V1. Resistor R4 and capacitor C2 form a conventional plate decoupling network. The output is taken across resistor R5, which is the cathode resistor for triode V1.

The following illustration shows trigger-, grid-, plate-, and cathode-voltage waveforms in their proper time relationship.



Trigger-, Grid-, Plate-, and Cathode-Voltage Waveforms

In the quiescent condition (with no trigger pulse applied), triode V1 is held at plate-current cutoff by the fixed negative bias taken from the voltage divider made up of resistors R2 and R3, and applied through grid resistor R1 and the grid winding of transformer T1 to the grid of V1 (time t_0 on the waveform illustration).

When the first positive trigger pulse is applied through grid capacitor C1 and the grid winding of transformer T1 to the grid of triode V1, it drives the grid above cutoff and causes the tube to conduct (time t_1 on the waveform illustration). The increasing current flowing through the plate winding of transformer T1 produces a magnetic field in the transformer. The changing magnetic field induces a feedback voltage into the grid winding of transformer T1. The transformer phasing and polarity are such that the induced feedback voltage drives the grid of triode V1 more positive and the plate of capacitor C1 which is connected to the negative end of the grid winding more negative. Thus, the induced feedback voltage causes two things to occur simultaneously: the capacitor charges to a higher potential, and the tube is biased more positive. The increased positive bias causes the plate current of triode V1 to increase further. The increasing plate current flow through the plate winding of transformer T1 causes the magnetic field in the transformer to increase accordingly, and induce a still larger voltage into the grid winding. This continuous increase in feedback voltage, grid voltage, and plate current produces a **regenerative feedback** action which quickly drives the tube toward plate current saturation. As the grid of triode V1 is driven more and more positive, grid current eventually begins to flow. The flow of grid current through the grid winding of transformer T1 to capacitor C1 causes the capacitor to quickly charge to its maximum negative value.

When plate-current saturation is reached (point A on the plate-voltage waveform), the plate current can no longer increase. Consequently, the magnetic field in transformer T1 no longer increases, and no feedback voltage is now induced into the grid winding. The grid of triode V1 is therefore driven negative by the large negative charge on capacitor C1. This negative grid voltage, and the positive cathode voltage caused by current flow through cathode resistor R5, cause the triode plate current to decrease. As the plate current through the plate winding of transformer T1 decreases, the magnetic field in the transformer decreases accordingly, inducing a feedback voltage of opposite polarity into the grid winding of the transformer. This induced feedback voltage drives the grid of triode V1 further negative, increasing the negative gride bias, and causing plate-current flow through the plate winding of transformer T1 to decrease still further. As previously explained, the regenerative feedback from the plate to the grid of triode V1 produces a continuous cycle of operation which causes the grid to be driven far below cutoff. As plate-current cutoff occurs, the plate current ceases to flow and the magnetic field in the transformer collapses. The collapsing field induces a momentary surge of voltage, called **overshoot,** into the plate winding of transformer T1 (point B on the plate-voltage waveform). However, since triode V1 is cut off, no current can flow through cathode resistor R5, and the overshoot is not present in the output.

When plate current ceases to flow, the charge on capacitor C1 is no longer sustained, and the capacitor discharges through resistors R1 and R2 toward the fixed negative bias value. The time constant of this R-C circuit is very large, and the discharge time of capacitor C1 is many times longer than the input trigger pulse repetition period. Consequently, the next input trigger pulse (time t2 on the waveform illustration) occurs while capacitor C1 is still discharging and reducing the bias toward the fixed cutoff bias value. This positive trigger pulse (number 2), when combined with the negative grid voltage remaining on capacitor C1, is not of sufficient amplitude to raise the grid voltage of triode V1 above cutoff. Therefore, trigger pulse number 2 has no effect on the operation of the circuit, and triode V1 remains cut off with capacitor C1 still discharging. The same result occurs during the next input trigger pulse (time t_3 on the waveform illustration). However, when the next input trigger pulse (time t_4 on the waveform illustration) occurs, capacitor C1 is discharged to nearly the fixed negative bias voltage across resistor R2 (cutoff bias). Therefore, when trigger pulse number 4 is combined with the negative grid voltage remaining on capacitor C1, the resulting pulse is of sufficient amplitude to again drive the grid of triode V1 above cutoff and cause the tube to conduct. Thus, the fourth trigger pulse causes the circuit to begin another cycle of operation. The distance-mark divider produces an output pulse as previously explained, and then remains inactive for the next two input trigger pulses. It produces an output pulse for every third input pulse. Therefore, the circuit is said to have a division ratio of 3:1.

The division ratio of the distance-mark divider is entirely dependent upon the discharge time of capacitor C1, which is determined by the time constant of the grid R-C circuit. Thus, the distance-mark divider can be made to produce different division ratios by using various component values in the grid R-C circuit. Although resistor R1 is variable, and will change the time constant of the circuit somewhat, this range is not normally broad enough to change the division ratio. Normally, resistor R1 is used only to adjust the circuit to compensate for variations in trigger pulse amplitude and supply voltages.

FAILURE ANALYSIS.

No Output. A no-output condition may be caused by an improper input signal, a lack of plate-supply voltage, a fault in the grid circuit, a fault in the plate circuit, a fault in the cathode circuit, or a defective tube. After checking the input signal with an oscilloscope to be certain that the proper input is applied, use the oscilloscope to observe the waveform at the grid of triode V1. If no signal appears at this point, either capacitor C1 or the grid winding of transformer T1 is open. Use an ohmmeter to make resistance checks and isolate the defective component. If the proper grid-voltage waveform is observed, further voltage and resistance checks must be made to isolate the defective component. Use a high-resistance voltmeter to measure the plate-supply voltage and determine whether the power supply is at fault. Next, measure the voltage on the plate of triode V1. If no plate voltage is present, plate components T1 (primary winding), R4, or C2 are either open or shorted. Use an ohmmeter to check continuity and resistance, and isolate the defective component. If the proper plate voltage is present, either the tube is defective, transformer T1 (secondary winding) is open, or resistors R1, R2, R3, or R5 are open or shorted. Use an ohmmeter to isolate the defective component. If these checks fail to locate a defective component, the tube is probably at fault and should be replaced with one known to be good.

Improper Division Ratio or Unstable Output. An improper input signal, an improper bias-supply voltage, a defective tube, an open or shorted grid circuit, or a defective transformer may cause either an improper division ratio or an unstable output. After checking the input signal with an oscilloscope to be certain that it is of the proper amplitude and frequency, use a high-resistance voltmeter to measure the bias-supply voltage. If the bias-supply voltage is correct, the trouble is in the divider circuit and not in the power supply. Use an ohmmeter to check the grid circuit of the divider for open or shorted components (C1, R1, R2, R3). Triode V1 may also be at fault. Replace the tube with one known to be good. If this still does not correct the trouble, transformer T1 is probably shorted and should be replaced with a good transformer.

Low Output. A low output is usually caused either by low plate voltage or by low tube emission. Use a high-resistance voltmeter to measure the plate-supply voltage and eliminate the possibility of a faulty power supply. Since defects in capacitor C2 or resistor R4 may also cause low plate voltage, use an ohmmeter to check these components. If these checks fail to locate the trouble, the low output is probably caused by low emission in triode V1. The tube should be replaced by one known to be good.

242

SHOCK-EXCITED RINGING OSCILLATOR.

APPLICATION.

The shock-excited ringing oscillator produces a short series of r-f oscillations each time an input gate is applied. The r-f oscillations are normally used as distance marks in radar indicators.

CHARACTERISTICS.

Requires a high-impedance, negative input gate.

Produces an output only when gated.

R-F output pulse duration is equal to that of the input gate.

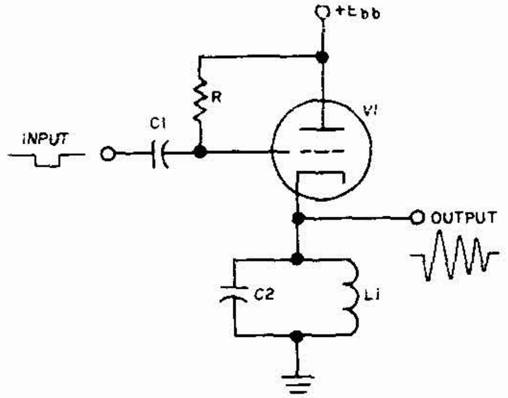
Uses a high-Q resonant tank circuit to produce an r-f output.

Output frequency is determined by the tank-circuit inductance and capacitance values.

CIRCUIT ANALYSIS.

General. The shock-excited ringing oscillator uses a parallel-resonant L-C (tank) circuit to produce an r-f output. An electron tube is used as a switch to control (gate) the r-f oscillations. While the basic circuit discussed below serves to illustrate the principles of operation of the shock-excited ringing oscillator, it is not suitable for use in practical circuits. A typical practical circuit is discussed after the basic circuit operation is established.

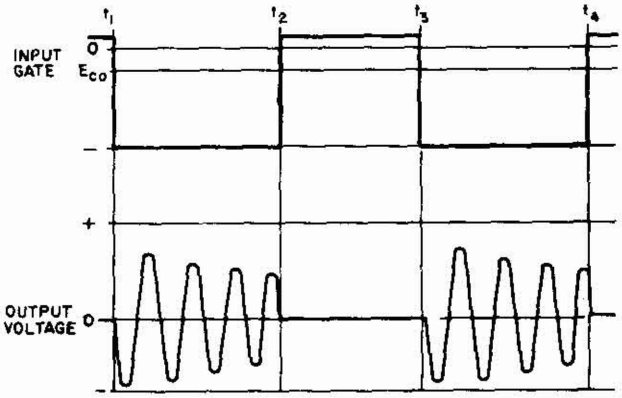
Circuit Operation. The accompanying circuit schematic illustrates a basic shock-excited ringing oscillator.



Basic Shock-Excited Ringing Oscillator

In the quiescent state (with no negative gate applied), positive grid bias is applied from the plate supply through grid resistor R1 to the grid of triode V1, and causes the tube to conduct heavily near plate-current saturation. Electron flow is from ground, through inductor L1 and the tube to the plate supply, building up a magnetic field around the inductor. So long as a negative gate is not applied, the circuit remains in this quiescent state (triode V1 conducting heavily and no r-f output).

When a negative input-gate is applied through coupling capacitor C1 to the grid of triode V1, it instantaneously drives the grid below plate-current cutoff, and holds it at cutoff for the duration of the input gate. Plate-current flow through inductor L1 abruptly ceases, and the magnetic field around the inductor collapses. The collapsing magnetic field induces into the inductance a voltage of such polarity that it tends to keep current flowing in the same direction. That is, the induced voltage causes a current to flow from ground toward the cathode of triode V1. The triode, however, is biased below cutoff by the negative gate; therefore, no current will flow through the tube. Consequently, the induced current flows around the tank circuit and charges capacitor C2 negative with respect to ground. When the magnetic field has completely collapsed, no further voltage is induced into inductor L1, and the induced current ceases to flow in the tank circuit. Since there is no longer any induced voltage sustain the charge on capacitor C2, the capacitor discharges back through inductor L1. The capacitor discharge current flowing through inductor L1 builds up a magnetic field around the inductor which is of opposite polarity from the original magnetic field. When capacitor C2 is full discharged, current flow around the tank circuit again ceases, and the magnetic field around inductor L1 again collapses and induces into the inductance a voltage which tends to keep current flowing in the same direction. This induced voltage causes current to flow around the tank circuit and charges capacitor C2 positive with respect to ground. After the magnetic field completely collapses, the charge on the tank capacitor is no longer sustained, and the capacitor again discharges through inductor L1, once again building up a magnetic field around the inductor in the original direction. This cycle of charge and discharge continues to repeat, producing a **ringing** effect in the tank circuit. That is, the capacitor and inductor charge and discharge alternately, causing the tank circuit to oscillate at a radio-frequency rate. Since the tank circuit has a very high Q (low loss), the r-f oscillations continue for many cycles. Because of the loss in the tank circuit produced by the d-c resistance of the inductor, successive oscillations gradually decrease in amplitude as the energy in the tank circuit is dissipated by this resistance. The resulting output waveform across the tank circuit is a series of damped oscillations, as shown in the following illustration.

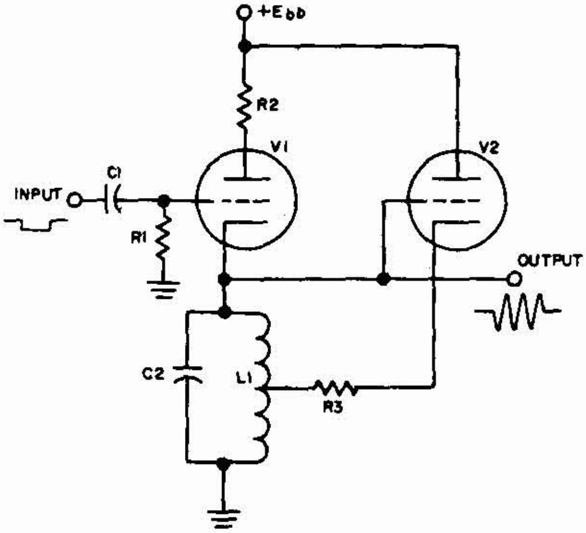


Input Gate and Output-Voltage Waveforms

The damped oscillations continue until the end of the input gate. When the negative input-gate ends, the positive bias supplied by grid resistor R1 resumes control and causes triode V1 to again conduct heavily near plate-current saturation. When the tube conducts, the heavy plate-current flow through inductor L1 produces a magnetic field around the inductor in one unchanging direction, which effectively shunts the tank circuit and decreases the circuit Q. Consequently, the r-f oscillations are effectively damped out very quickly. The heavy plate current flowing through inductor L1 once again builds up a steady magnetic field around the inductor which effectively prevents any possibility of r-f oscillation, and the circuit remains in the quiescent (no-output) state until the next input gate is applied.

Since triode V1 is cut off while output oscillations are being produced, the frequency of the output oscillations is not affected by the tube. Thus, the output frequency is determined solely by the values of inductance and capacitance in the tank circuit. The duration of the train of r-f output oscillations is determined solely by the length of time triode V1 remains cut off, and is therefore controlled by the duration of the input gate.

The basic shock-excited ringing oscillator just discussed always produces damped oscillations when an input gate is applied. Since these oscillations decrease in amplitude, they are not suitable for many applications, particularly for producing distance marks. The accompanying circuit schematic illustrates a practical type of shock-excited ringing oscillator which produces r-f oscillations of a constant amplitude when the input gate is applied.



Typical Shock-Excited Ringing Oscillator

The two-tube shock-excited ringing oscillator shown in the illustration is actually a switched Hartley oscillator (see Section 7 of this Handbook for a detailed discussion of Hartley circuit operation). The circuit consisting of triode V2, capacitor C2, inductor L1, and Resistor R3 is a conventional series-fed Hartley oscillator, and the circuit consisting of triode V1, capacitor C1, and resistors R1 and R2 is a switching circuit which controls the operation of the Hartley oscillator.

In the quiescent state (with no negative gate applied), no bias is applied to the grid of triode V1 and the tube conducts heavily near plate-current saturation. The electron flow is from ground, through inductor L1, triode V1, and resistor R2 to the plate supply, building up a magnetic field around inductor L1. When triode V1 is conducting, the heavy plate-current flow through inductor L1 produces a steady magnetic field around the tank inductor, which effectively shunts the tank circuit and prevents the oscillator from functioning. Consequently, no r-f output oscillations are produced and the circuit remains in this state.

When a negative input-gate is applied to the grid of triode V1 through coupling capacitor C1, it drives the grid far below cutoff. As plate current ceases to flow through tank inductor L1, the magnetic field around it collapses, inducing a voltage into the inductor which tends to keep current flowing in the same direction as the original plate-current flow (that is, from ground thru the inductor to the cathode of triode V1). As in the basic circuit discussed previously, the induced current cannot flow through triode V1 (which is cut off); consequently, it flows around the tank circuit, charging capacitor C2 and initiating a ringing effect. In this practical circuit, however, any potential across the tank is also applied to the grid of oscillator tube V2, and the oscillator section of the circuit functions as a normal Hartley oscillator, producing oscillations of a constant amplitude in the tank circuit. The oscillator portion of this circuit replaces the energy dissipated in the tank coil resistance so that the resulting oscillations are always of constant amplitude. Thus, as long as the negative gate is applied, triode V1 remains cut off, and the oscillator portion of the circuit operates, producing constant-amplitude r-f oscillations.

The oscillator operates until the end of the negative input gate. When the negative gate ends, the grid bias on triode V1 returns to zero, and the triode again begins to conduct heavily near plate-current saturation. When the tube conducts, the heavy current flow through inductor L1 produces a steady magnetic field around the tank inductor, effectively damping out the r-f oscillations very quickly. Thus the circuit is once again operating in the quiescent state, with triode V1 conducting heavily near saturation, and no r-f output.

The practical shock-excited ringing oscillator produces r-f oscillations of constant amplitude when a negative input gate is applied. As in the basic shock-excited ringing oscillator, the output frequency is determined by the values of inductance and capacitance in the tank circuit, and the duration of the r-f output is determined by the length of the input gate. The output waveform is the same as that shown for the basic circuit, except that all the oscillations are of constant amplitude.

FAILURE ANALYSIS.

No Output. Failure of the shock-excited ringing oscillator to produce an output when the gate is applied may be caused by a defective switching circuit, by a defective oscillator circuit, or by a lack of plate-supply voltage. To isolate the trouble to one portion of the circuit, temporarily remove triode V1. If continuous output oscillations are now produced, the trouble is in the switching section of the circuit. Use an ohmmeter to check capacitor C1 for a shorted condition, and resistors R1 and R2 for continuity and proper value. If none of these parts are defective, triode V1 is probably shorted and should be replaced with a tube known to be good. If continuous output oscillations are not produced when triode V1 is temporarily removed, the fault is either in the oscillator section of the circuit or due to a lack of plate-supply voltage. Use a high-resistance voltmeter to check the supply voltage and the plate voltage of triode V2. Proper values of these voltages indicate that the trouble is in the oscillator section of the circuit and not in the power supply. Use an ohmmeter to check capacitor C2 and inductor L1 for a shorted condition, and to check resistor R3 for continuity and proper value. If the trouble still persits, triode V2 is probably at fault and should be replaced with a tube known to be good.

Continuous R-F Output. Defects in the switching portion of the shock-excited ringing oscillator may cause the circuit to produce output oscillations whether or not the input gate is present. Use an ohmmeter to check capacitor C1 and resistors R1 and R2 for a shorted or open condition. If none of these parts are defective, triode V1 is probably at fault. Replace it with a tube known to be good.

Low Output. Defects in the oscillator portion of the circuit or a low plate-supply voltage may cause either low-amplitude output oscillations or damped (decreasing) output oscillations. First measure the plate-supply voltage with a high-resistance voltmeter to eliminate the possibility of low-supply voltage. If the plate-supply voltage is normal, the trouble is in the oscillator section of the circuit and not in the power supply. (If the output oscillations are damped, triode V2 is probably inoperative and should be replaced with a tube known to be good.) Use an ohmmeter to check inductor L1, capacitor C1, and resistor R3 for continuity of shorts. If no defective parts are found, triode V2 is probably defective and should be replaced with a tube known to be good.

SHOCK-EXCITED PEAKING OSCILLATOR.

APPLICATION.

The shock-excited peaking oscillator is used to produce very narrow positive pulses at the beginning of each input gate for use as trigger or synchronizing pulses in radar modulators, display indicators, and other electronic devices.

CHARACTERISTICS.

Requires a high-impedance, negative input gate.

Produces one very sharp positive pulse at the beginning of each negative input gate.

Produces one relatively broad negative pulse at the end of each negative input gate.

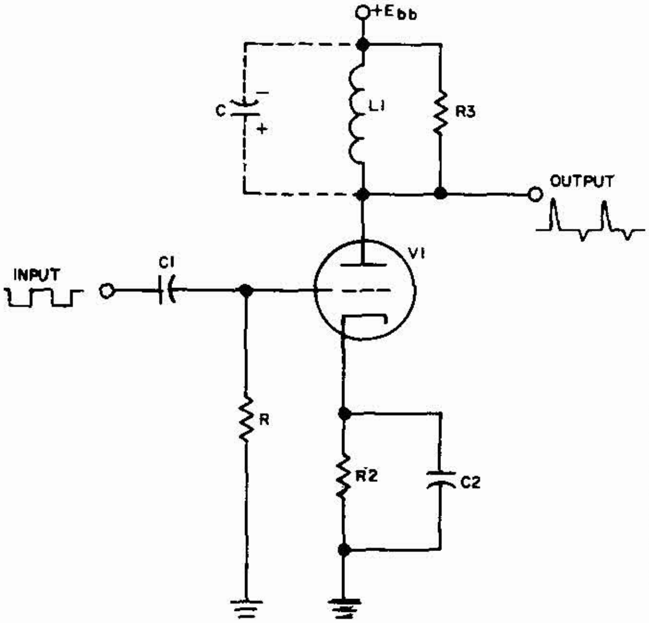
Uses a critically damped tank circuit to produce an output.

Shape of positive output pulse is determined by tank inductance and capacitance valves.

CIRCUIT ANALYSIS.

General. The shock-excited peaking oscillator uses a critically damped resonant L-C (tank) circuit to produce a peaked output. An electron tube is used as a switch to control (gate) the tank circuit.

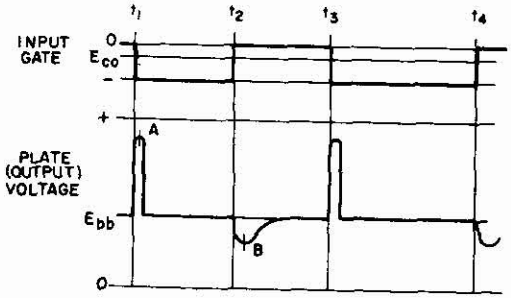
Circuit Operation. The accompanying circuit schematic illustrates a typical shock-excited peaking oscillator.



Shock-Excited Peaking Oscillator

Capacitor C1 and resistor R1 form a conventional R-C input circuit for triode V1, and capacitor C2 and resistor R2 form a conventional cathode bias circuit for the tube. Inductor L1 and its distributed capacitance, C, form a parallel-resonant tank circuit. Since the distributor capacitance is small, the resonant frequency of the tank circuit is very high (approximately 2 mc). This r-f tank is critically damped by shunt resistor R3. That is, the value of resistor R3 is such that it allows the tank circuit to oscillate for only a half cycle after oscillation is started.

The following illustration shows the input-gate and plate-voltage (output) waveforms in their proper time relationship.



Input-Gate and Plate-Voltage Waveforms

In the quiescent state (with no negative input-gate applied), no bias is applied to the grid of triode V1, and the tube conducts heavily near plate-current saturation. The plate current is held constant by the cathode bias developed across cathode resistor R2. This constant plate current flowing through inductor L1 builds up a steady magnetic field around the inductance. So long as a negative gate is not applied, the circuit remains in this quiescent state.

When a negative gate is applied through coupling capacitor C1 to the grid of triode V1 (time t_1 on the waveform illustration), it instantaneously drives the grid far below cutoff, and holds it below cutoff for the duration of the input gate. Plate-current flow through inductor L1 abruptly ceases, and the magnetic field around the inductor collapses. The collapsing magnetic field induces into the inductance a voltage of such polarity that it tends to keep current flowing in the same direction as the original plate-current flow. This induced current flowing in the inductor charges the distributed (tank) capacitance, C, negative on the plate-supply side of the capacitance and positive on the triode side of the capacitance (polarity as shown on schematic). Since the charge time of the capacitance is determined by the resonant frequency of the tank circuit, and the resonant frequency is very high, the capacitance charges very quickly to its maximum value. The potential across the charged capacitance is series-aiding with the plate-supply voltage, and the resultant voltage on the plate of triode V1 momentarily rises above the plate-supply voltage (point A on the plate-voltage waveform). When the magnetic field around the inductor completely collapses, there is no longer any induced voltage to sustain the charge on the distributed (tank) capacitance, the capacitance and begins to discharge. Since the d-c resistance or resistor R3 is much lower than the impedance of inductor L1 at the resonant frequency, the distributed capacitance discharges very quickly through the resistor, and the triode plate voltage quickly returns to the plate-supply value. Thus, the shock-excited peaking oscillator produces one very sharp positive pulse at the beginning of the negative input gate.

Triode V1 remains cut off, and no further output is produced until the end of the negative input gate. When the input gate ends (time t_2 on the waveform illustration), the grid bias on triode V1 returns to zero, and the triode again begins to conduct heavily near plate-current saturation. As plate current flows through inductor L1, a magnetic field builds up around the inductor. The increasing magnetic field induces into the inductance a voltage of such polarity that it tends to oppose the plate current flowing through the inductor. This induced voltage is series-opposing with the plate-supply voltage, and the resulting voltage on the plate of triode V1 momentarily drops below the plate-supply voltage (point B on the plate-voltage waveform). As the magnetic field around the inductance builds up to its maximum value and ceases to increase, the opposing induced voltage decreases to zero, and the triode plate voltage returns to the plate-supply value. Thus at the end of the negative input gate the shock-excited peaking oscillator produces a negative-going pulse and then returns to the quiescent state, with triode V1 conducting heavily near saturation and a steady unchanging magnetic field built up around inductor L1.

The output from the shock-excited peaking oscillator is a series of alternate positive- and negative-going pulses occurring respectively at the beginning and the end of the negative input gate. Since the positive output pulses are much sharper, and of greater amplitude, than the negative-going output pulses, the positive pulses are normally the desired portion of the output. The negative-going output pulses are usually eliminated with a clipping or limiting circuit which passes only the desired positive output pulses.

FAILURE ANALYSIS.

No Output. Failure of the shock-excited peaking oscillator to produce an output when the proper negative input gate is applied may be caused by a defective circuit component, a defective tube, or a lack of plate-supply voltage. After measuring the plate-supply voltage with a high-resistance voltmeter to be certain that the power supply is operating properly, use the voltmeter to measure the voltage on the cathode of triode V1. A lack of cathode voltage indicates that either resistor R2 or capacitor C2 is shorted, or the triode is faulty. If checking resistor R2 and capacitor C2 with an ohmmeter does not reveal a shorted component, triode V1 is probably at fault and should be replaced with a tube known to be good. If the proper voltage is measured on the cathode of triode V1, inductor L1 may be open or shorted, capacitor C1 may be open, or resistor R1 or R3 may be open or shorted. Use an ohmmeter to check these components for continuity, shorts, and proper resistance values. If these checks fail to locate a defective component, triode V1 is probably defective and should be replaced with a tube known to be good.

253/254

Low Output. Output pulses of low amplitude may be caused by low plate-supply voltage, low tube emission, or a defective cathode bias circuit. First, measure the plate-supply voltage with a high-resistance voltmeter to eliminate the possibility of a faulty power supply. If the proper plate-supply voltage is present, use an in-circuit capacitor checker to check cathode capacitor C2 for an open. If this capacitor is open, degenerative action in the cathode bias circuit will cause a low output (see paragraph 2.2.1. in Section 2 of this Handbook). If both the plate-supply voltage and capacitor C2 are normal, low emission in triode V1 is probably the cause of the low-output condition. Replace triode V1 with a tube known to be good.

Distorted Output. Defects in the plate circuit of triode V1 may cause a distorted output. Use an ohmmeter to check shunt resistor R3 for continuity and the proper resistance value. If resistor R3 is not defective, inductor L1 is probably at fault and should be replaced.

PART B. SEMICONDUCTOR CIRCUITS

FREE-RUNNING PRF GENERATOR.

APPLICATION.

The free-running (prf generator) blocking oscillator is a basic blocking oscillator. It produces short-time-duration, large-amplitide pulses for use as timing, synchronizing, or trigger pulses.

CHARACTERISTICS.

Output pulse is a single cycle of oscillation caused by transistor (collector element) conduction at the beginning of each pulse-repetition period.

Pulse-repetition time is determined primarily by the R-C time constant in the base-emitter circuit. The pulse-repetition frequency is generally fixed within the range of 200 to 2000 pulses per second.

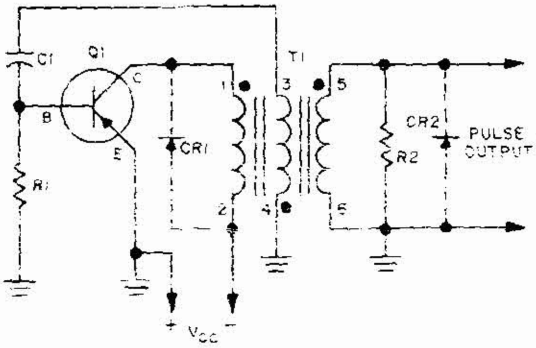
Pulse width and rise time of the output pulse are determined primarily by the transformer characteristics.

Output-pulse polarity is determined by the phasing of the transformer output-tertiary winding.

CIRCUIT ANALYSIS.

General. The free-running blocking oscillator (prf generator) is a special-type oscillator in that the transistor conducts for a short period to produce a pulse and then becomes cut off (blocked) for a much longer period of time; then the cycle of operation to produce an output pulse is repeated and the oscillator again becomes inactive. This mode of operation continues and thus produces a series of output pulses which are of short-time duration, separated by relatively long time intervals.

Circuit Operation. The accompanying circuit schematic illustrates a PNP transistor in a basic free-running blocking oscillator circuit. (Note the similarity between the blocking oscillator circuit given here and the L-C tickler-coil oscillator circuit given in Section 7, Oscillator Circuits.)



Free-Running PRF Generator Using PNP Transistor

Transformer T1 provides the necessary regenerative feedback coupling from the collector to the base of transistor Q1; terminals 1 and 2 of transformer T1 connect to the collector (primary) winding, terminals 3 and 4 connect to the base (secondary) winding, and terminals 5 and 6 connect to the output (tertiary) winding. Capacitor C1 and resistor R1 form the R-C circuit which determines the time constant in the base-emitter circuit.

The output pulse is taken from the tertiary winding (terminals 5 and 6) of transformer T1. Damping resistor R2 is connected across the tertiary winding to reduce the amplitude of the back voltage resulting from the collapse of the magnetic field about the transformer after the occurrence of the initial output pulse.

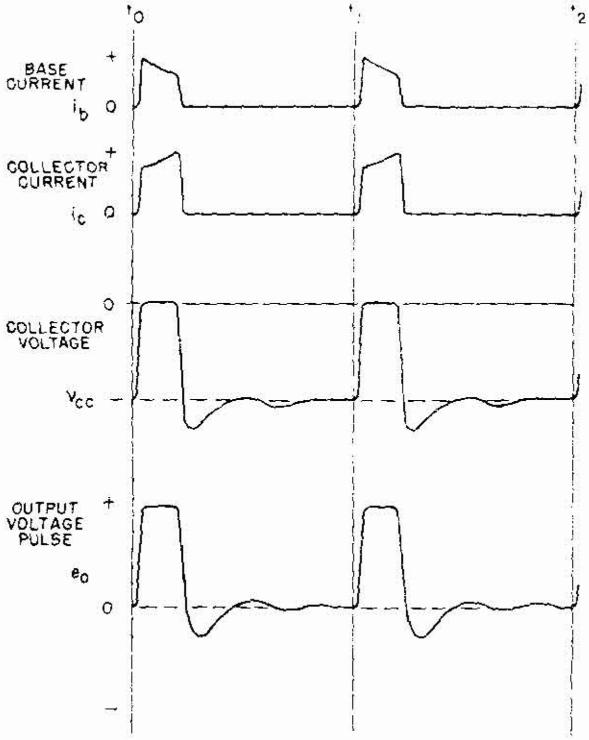
On the circuit schematic, note the placement of small dots near winding terminals 1, 4, and 5 of transformer T1. These dots are used to indicate similar winding polarities. For example, if current flows through the collector winding and terminal 1 is positive, the voltage induced in each of the other windings is such that the dot end is also positive in each winding at the same time; therefore, at this same instant of time, terminals 3 and 6 are negative.

Bias and stabilization techniques employed for a transistor oscillator are essentially the same as those employed for a transistor amplifier. The common-emitter circuit configuration illustrated utilizes a single-battery power source; this source directly produces the required reverse bias voltage in the collector-base circuit. Forward bias for the PNP transistor requires the base to be negative with respect to the emitter. Since the collector is at a negative potential and the emitter is at a positive potential, the two PN junctions within the transistor act as a voltage divider. The junction between collector and base represents a relatively high resistance and develops a large portion of the voltage drop. The junction between emitter and base represents a low resistance and develops a lower voltage drop. The base of the transistor is structurally between the collector and the emitter and assumes a potential which is between the two voltage extremes; therefore, the base can be considered to be less positive than the emitter, or negative with respect to the emitter. Thus, the correct polarity is established to produce a forward bias between the emitter and the base.

The blocking oscillator can be compared to an amplifier with feedback of the proper phase and amplitude to provide regeneration. In the accompanying circuit schematic a common-emitter configuration is shown using a PNP transistor; the regenerative feedback signal must undergo a polarity reversal in passing from the collector to the base. If an NPN transistor is used, the polarity of the supply voltage must be opposite to that given on the schematic in order to maintain forward bias in the base-emitter circuit and reverse bias in the collector-base circuit; however, for either type of transistor the transformer must provide a polarity reversal when feedback [illegible] from collector to base.

For the discussion of circuit operation which follows, refer to the accompanying illustration of the blocking oscillator waveforms.

When d-c power is first applied to the circuit, a small amount of collector current, I_c, will start to flow through the collector winding (terminals 1 and 2) of transformer T1. The current flow in the collector winding induces a voltage in the base winding (terminals 3 and 4) which is negative with respect to ground. The induced voltage causes capacitor C1 to charge through the relatively low forward resistance of the base-emitter junction, and the induced voltage



Theoretical Waveforms for Blocking Oscillator

appears across the forward resistance to increase the forward bias. The increase in forward bias, in turn, increases the collector current, and regeneration continues rapidly until the transistor becomes saturated. During the essentially flat-top portion of the collector voltage waveform, the collector current, i_c, increases at a slower rate, as determined by the amount of magnetizing current necessary to maintain the voltage drop across the collector winding of transformer T1. Also during this period of time, the base current, i_b, gradually falls off from its peak value as a result of the inability of the transistor to maintain the same rate of increase in magnetizing current as the transistor approaches saturation; further, at this same time a charge is accumulating on capacitor C1 which subtracts from the voltage supplied by the base winding of transformer T1. At saturation, the collector current, i_c, can no longer continue to increase, and thus becomes a constant value; therefore, there is no longer a voltage induced in the base winding, terminals 3 and 4. As a result, the magnetic field begins to collapse and induces a voltage across the winding which is of opposite polarity to the original voltage. At the same time, capacitor C1 starts to discharge through resistor R1 and the base winding (terminals 3 and 4). The discharge current of capacitor C1 produces a voltage drop across resistor R1 which is of positive polarity at the base of the transistor, thereby driving the base in a positive direction to reduce the forward bias of the base-emitter junction. The reduction in forward bias causes the collector current, i_c, to decay rapidly, which further accelerates the process; thus reverse bias is rapidly achieved at the base-emitter junction. At this time the base and collector currents drop to zero.

Because of the reverse bias, the transistor remains held at cutoff until capacitor C1 discharges through resistor R1 (and transformer T1) to a point where the transistor returns to a forward-biased condition. When the forward-biased condition is reached, conduction begins and another cycle of operation is initiated.

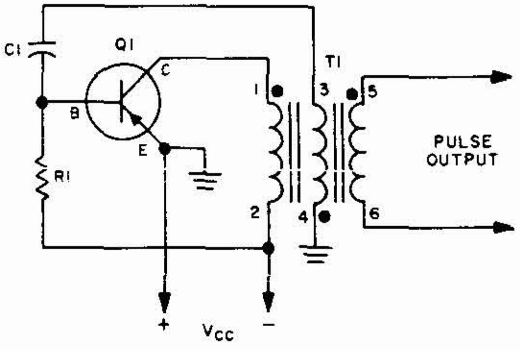
The output pulse width depends principally on the inductance of the transformer, T1. The smaller the the inductance, the more rapidly the collector current must increase to maintain magnetizing current, and the faster the collector current will reach saturation. Normally, capacitor C1 has relatively little effect on the pulse width; however, if it is made small enough that it approaches a value where the capacitor charge can change appreciably during the pulse time, there will be a noticeable decrease in pulse duration (width). As the capacitor is made still smaller, the effect will be more pronounced and the pulse duration will be further reduced.

The repetition rate of the free-running blocking oscillator is determined by the time constant of resistor R1 and capacitor C1. Although the resistance of the base winding (terminals 3 and 4) of the pulse transformer also has an effect upon the discharge time constant, the resistance of the winding is low compared to that of resistor R1.

The output pulse is taken from the tertiary winding (terminals 5 and 6) of transformer T1. Damping resistor R2 is connected across the tertiary winding of the transformer to reduce the amplitude of the back voltage (or overshoot) which results from the collapse of the magnetic field about the transformer at the termination of the desired output pulse. If it were not for the damping resistor, the amplitude of the back-voltage pulse could exceed the breakdown voltage of the transistor and cause damage to the transistor. Several modifications can be made to the basic circuit to further reduce the amplitude or to eliminate the undesirable back voltage. One such modification is to connect a clamping diode across the collector winding (terminals 1 and 2) of the transformer as shown on the circuit schematic by the dotted lines connecting diode CR1. Similarly, a clamping diode can be connected across the output winding (terminals 5 and 6) as shown on the circuit schematic by the dotted lines connecting diode CR2, to accomplish the same purpose. In either case, the diode (CR1 or CR2) is connected in the circuit to conduct whenever the back-voltage pulse occurs and to effectively place a short circuit across the associated transformer winding for the duration of the induced back-voltage pulse; thus it prevents the application of an excessive voltage between the collector and emitter.

The accompanying circuit schematic illustrates a variation of the basic free-running prf generator. In this circuit resistor R1 is returned to the negative terminal of the supply voltage, V_{cc}. Resistor R1 not only limits the base current and establishes the initial condition of forward bias, but also operates in conjunction with capacitor C1 to determine the operating frequency of the blocking oscillator.

The circuit operation is essentially the same as that previously described.



Variation of Basic Free-Running PRF Generator

FAILURE ANALYSIS.

No Output. Voltage measurements should be made with an electronic voltmeter to determine whether the input voltage is present and whether the correct bias voltages are applied to the collector and base of the transistor. It is possible that the base-emitter junction may change resistance and thereby change the forward bias on the base; such a condition may cause thermal runaway with subsequent damage to the transistor.

Any defect in transformer T1, such as an open collector or base winding or shorted turns in any of the windings, will prevent the circuit from operating properly, since oscillations depend upon regenerative feedback from the transformer. A shorted load impedance, reflected to the collector and base windings, may cause excessive losses which will prevent sustained oscillations. Note that if the output winding should open, the circuit will continue to operate; however, no output will be obtained from the winding. Furthermore, if damping resistor R2 should open, the induced back-voltage could exceed the voltage breakdown of the collector-emitter junctions and result in damage to the transistor.

A *shorted or open capacitor* C1 will prevent oscillations, since the regenerative action of the circuit depends upon the charge and discharge of C1. Also, if resistor R1 should open, the base-emitter current path will be broken and thereby prevent transistor operation.

Where the basic oscillator circuit illustrated has been modified to include a clamping diode (CR1 or CR2) across either the collector winding or the output winding, a defective diode with a low front-to-back ratio may cause circuit losses and prevent oscillation. Furthermore, if damping resistor R2 should decrease in value or if the load impedance should drop to an extremely low value, oscillations may not occur because of induced circuit losses.

Reduced Output. The input supply voltage should be measured with an electronic voltmeter to determine whether the input voltage is the correct value. Voltages at the collector and the base of the transistor should also be measured to determine whether they are within tolerances. Where the basic oscillator circuit illustrated has been modified to include a clamping diode across either the collector winding or the output winding, or across each winding, a defective diode with low front-to-back ratio can cause circuit losses which can reduce the output. Moreover, if either clamping resistor R2 or the load impedance should decrease in value, the output amplitude will decrease. Note that if the circuit losses are excessive, the circuit may not oscillate at all.

Incorrect Frequency. The pulse-repetition frequency of the free-running blocking oscillator is determined by the R-C time constant of resistor R1 and capacitor C1; any change in the values of these components will cause a change in operating frequency. Also, any change in the supply voltage will probably affect the pulse-repetition frequency and may affect the amplitude of the output pulse.

TRIGGER BLOCKING OSCILLATORS.

Semiconductor triggered blocking oscillators are externally controlled blocking oscillators which produce output pulses that are synchronized by the input trigger (control) pulses. That is, the triggered blocking oscillator is not free to oscillate like the simple free-running prf generator, but instead, produces an output pulse only when an input (trigger) pulse is applied.

The major difference between the triggered blocking oscillator and the free-running blocking oscillator (described earlier in this section of the Handbook) is the bias arrangement for the transistor. In the free-running blocking oscillator, the base of the transistor is **forward-biased**, and the circuit produces output pulses at a rate determined by the values of resistance and capacitance (R-C time constant) in the base circuit. In the triggered blocking oscillator, however, the base of the transistor is **reverse-biased**, and the circuit remains inactive until a trigger pulse initiates operation. When a trigger pulse is applied, the circuit produces an output pulse in much the same manner as the free-running blocking oscillator, and then returns to the inactive (quiescent) state.

Triggered blocking oscillators may use the common-base, common-emitter, or common-collector configuration, with either a PNP or an NPN type of transistor. However, a PNP transistor using the common-emitter configuration represents the most common usage because it combines appreciable gain with easily matched values of input and output impedance.

Two types of semiconductor triggered blocking oscillator circuits are presently in general use: the Basic Blocking Oscillator and the Nonsaturating, Diode-Clamped Blocking Oscillator. The basic circuit may be used in some applications where high-frequency operation is not required, and where the pulse shape is not critical. However, the nonsaturating, diode-clamped circuit is preferable for most applications because of its higher operating frequency and its better pulse shape. Each of these circuits is discussed in following paragraphs in this section of the Handbook.

BASIC BLOCKING OSCILLATOR.

APPLICATION.

The basic triggered blocking oscillator is used to produce synchronized, large-amplitude pulses for use as timing, trigger, or control pulses in radar equipment, television sets, and similar electronic switching devices.

CHARACTERISTICS.

Requires a negative input trigger pulse.

Output pulse is a single cycle of oscillation (positive and negative alternations).

Output-pulse-repetition frequency is determined by the input trigger frequency.

Output-pulse width and rise time are determined primarily by the transformer inductance, capacitance, and resistance characteristics.

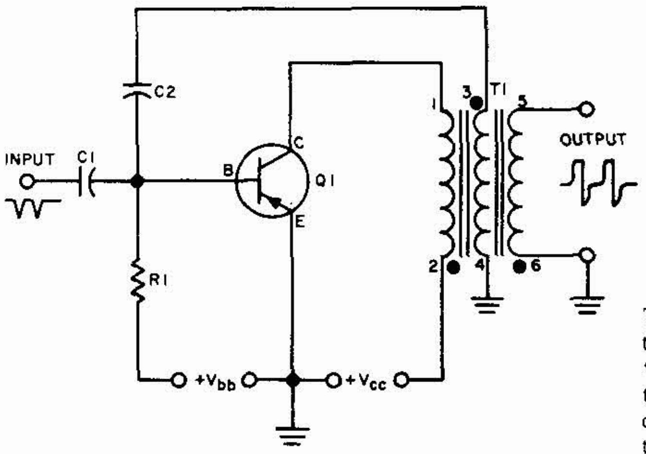
Output-pulse polarity is determined by the transformer output (tertiary) winding phasing.

Fixed, Class B (cutoff) bias is employed.

CIRCUIT ANALYSIS.

General. The basic blocking oscillator produces an output pulse each time an input pulse is applied to activate the circuit. Between trigger pulses, the transistor remains cut off (non-conducting), and no output is produced until an input trigger pulse of sufficient amplitude to produce conduction is again applied. The circuit produces one output pulse and then returns to the inactive (quiescent) state, awaiting the next trigger.

Circuit Operation. The accompanying circuit schematic illustrates a basic triggered blocking oscillator using a PNP transistor connected in the common-emitter configuration.

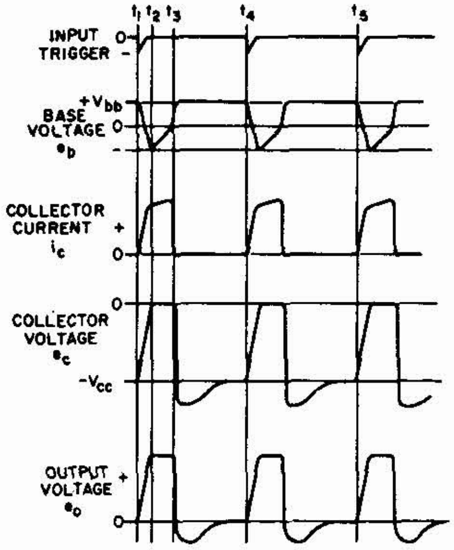


Basic Blocking Oscillator

Transformer T1 provides the regenerative feedback necessary between the collector and the base of transistor Q1 to obtain oscillation. The primary winding (terminals 1 and 2) is connected in series with collector supply Vcc and the collector of transistor Q1. The secondary winding (terminals 3 and 4) supplies the feedback voltage, which is applied to the base of transistor Q1 through capacitor C2. Capacitor C2 is also a d-c blocking capacitor used to isolate the base from the d-c shunting effect of the secondary winding of transformer T1, preventing it from shorting to ground the fixed cutoff bias applied to transistor Q1 through base resistor R1. The negative input trigger is applied through coupling capacitor C1 to the base of transistor Q1, and the output pulse is taken from the tertiary winding (terminals 5 and 6) of transformer T1.

The collector of transistor Q1 is reverse-biased by the negative collector supply, Vcc; the positive base bias supply, VBB, furnishes fixed reverse bias to the base of transistor Q1 through base resistor R1. Thus, in the quiescent state with no input trigger applied, transistor Q1 is completely reverse-biased and cannot conduct. Hence, no output is produced.

When a negative trigger pulse, such as that shown at time t_1 on the accompanying waveform illustration, is applied through coupling capacitor C1 to the base of transistor Q1, it forward-biases the transistor, causing collector current to flow.



Theoretical Waveforms for Basic Blocking Oscillator

The collector current, flowing from the collector supply through the collector (primary) winding of transformer T1 to the transistor, causes a magnetic field to be built up around the collector (primary) winding of the transformer. This increasing magnetic field induces into the base winding of the transformer a voltage of such polarity that the potential on terminals 3 of the winding is negative with respect to ground (terminal 4). This negative potential is applied to the base of transistor Q1 (through capacitor C2), and increases the forward bias on the transistor, causing the collector current to increase further. As the collector current flowing through the collector winding of transformer T1 increases, the magnetic field around the winding increases accordingly, inducing a larger voltage into the base winding of the transformer. The increasing induced voltage is fed back to the base of transistor Q1, causing the forward bias on the transistor, and hence the collector current, to increase still further. Thus, this **regenerative feedback** from the collector to the base of transistor Q1 causes the collector current to continue to increase until the transistor reaches saturation. When transistor Q1 reaches collector-current saturation (time t_2 on the waveform illustration), the collector current flowing through the collector winding of transformer T1 can no longer increase. Therefore, the magnetic field around the collector winding no longer increases; consequently, no feedback voltage is induced into the secondary (base) winding of the transformer. As a result, the voltage across the base winding of transformer T1 decays at a rate determined by the inductance, capacitance, and resistance values of the transformer, causing the negative voltage on the base of transistor Q1 to decrease accordingly. At the same time, the decreasing voltage across the base winding of transformer T1 also induces into the collector winding a voltage of such polarity that it aids (adds to) the collector-supply voltage, effectively increasing the value of the collector-supply voltage. The effectively increased collector-supply voltage raises the saturation point of the transistor; consequently, the collector current increases slightly above the previous saturation value. When the voltage across the base winding of transformer T1 decays to zero (time t_3 on the waveform illustration), no further forward bias is applied through capacitor C2 to the base of transistor Q1, and the transistor ceases to conduct. Since no further forward bias is supplied, the base bias supply resumes control and applied a positive bias voltage through resistor R1 to the base of transistor Q1, reverse-biasing the transistor and holding it below cutoff until the next trigger pulse is applied. Meanwhile, as the transistor decreases in conduction from saturation to cutoff (at time t_3) the collector current flowing through the collector winding of transformer T1 decreases to zero, and the magnetic field around the winding collapses. This collapsing field induces into the collector winding a voltage of such polarity that it tends to keep current flowing in the same direction as the original current flow (that is, the induced voltage aids the collector-supply voltage). The result of adding these voltages is that the voltage on the collector of transistor Q1 momentarily becomes much more negative than the negative collector-supply value. This large negative voltage pulse is called **overshoot** (point A on the collector-voltage waveform). As the magnetic field around the collector winding of transformer T1 collapses completely, the induced voltage (overshoot) also decreases to zero, and the collector voltage returns to the quiescent value.

Any change of current in the collector winding of transformer T1 also induces a changing voltage into the tertiary, or output, winding of the transformer. The polarity of the output pulse is determined by which terminal of the output winding is grounded. As shown in the circuit schematic, terminal 6 is grounded, and a positive output pulse results (a negative output pulse would be obtained if terminal 5 were grounded instead).

FAILURE ANALYSIS.

General. When making voltage checks, use a vacuum-tube voltmeter to avoid the low values of multiplier resistance employed on the low-voltage ranges of the standard 20,000-ohms-per-volt meter. Be careful also to observe proper polarity when checking continuity with an ohmmeter, since a forward bias applied through any of the transistor junctions will cause a false low-resistance reading.

No Output. A no-output condition may be caused by an improper input trigger, a lack of supply voltage, or a defective circuit component. First, use an oscilloscope to observe the input trigger voltage waveform. Compare the observed waveform with one shown in the equipment instruction book to be certain that the proper input trigger is applied. Next, use a vacuum-tube voltmeter to measure the supply voltage and eliminate the possibility of a defective power supply. If the correct input trigger is applied and the normal supply voltage is present, further checks must be made to locate the defective component. Use an in-circuit capacitor checker to check capacitors C1 and C2 for opens and leakage, and an ohmmeter to check resistor R1 and transformer T1 for continuity and proper resistance value. If these checks fail to locate a defective component, transistor Q1 is probably at fault. Replace it with a transistor known to be good.

Low or Distorted Output. Low supply voltage, a defective transistor (Q1), or a defective transformer (T1) may cause either low-amplitude or distorted output pulses. Measure the supply voltage with a vacuum-tube voltmeter. If the normal value of voltage is measured, the trouble is in the blocking oscillator and not in the power supply. Transistor Q1 and transformer T1 are both best checked by the substitution of parts known to be good. If first replacing transistor Q1 does not remedy the trouble, transformer T1 is probably defective and should be replaced.

NONSATURATING, DIODE-CLAMPED BLOCKING OSCILLATOR.

APPLICATION.

The nonsaturating, diode-clamped blocking oscillator is used to produce synchronized, large-amplitude pulses for use as timing or synchronizing pulses in radar, communications, and data processing equipment.

CHARACTERISTICS.

Requires a negative input trigger pulse. Output is a single square pulse caused by transistor conduction.

Output-pulse repetition frequency is determined by the input trigger frequency.

Output-pulse width and rise time are determined primarily by the transformer inductance, capacitance, and resistance characteristics.

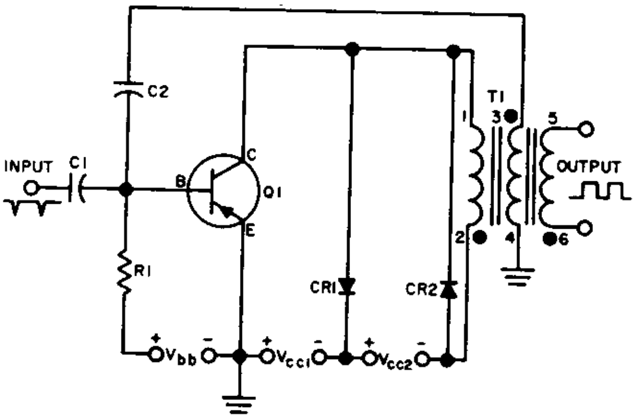
Output-pulse polarity is determined by the transformer output (tertiary) winding phasing.

Fixed, class B (cutoff) bias is employed.

CIRCUIT ANALYSIS.

General. The nonsaturating, diode-clamped blocking oscillator produces one output pulse each time a trigger pulse is applied to activate the circuit. Between trigger pulses the circuit remains in the inactive (quiescent) state, and no output is produced. The operation of the nonsaturating, diode-clamped blocking oscillator is similar to that of other types of blocking oscillators except that in this circuit, diode clamping is employed to prevent transistor saturation and to eliminate the normal overshoot which is present in the output of other types of blocking oscillators.

Circuit Operation. The accompanying circuit schematic illustrates a nonsaturating, diode-clamped blocking oscillator using a PNP transistor connected in the common-emitter configuration.

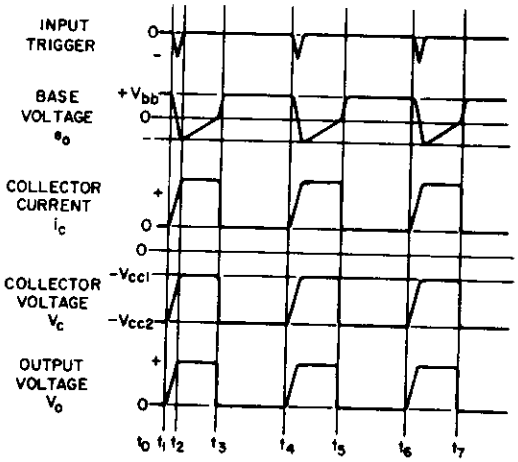


Nonsaturating, Diode-Clamped Blocking Oscillator

Transformer T1 provides the regenerative feedback necessary between the collector and the base of transistor Q1 to obtain oscillation. The primary winding (terminals 1 and 2) is connected in series with the collector supply (made up of V_{CC_1} and V_{CC_2}) and the collector of transistor Q1. The secondary winding (terminals 3 and 4) is connected from ground to the base of transistor Q1 through d-c blocking capacitor C2. This capacitor prevents the base (secondary) winding of the transformer from acting as a d-c shunt to ground for the fixed cutoff bias applied to transistor Q1 through base resistor R1. Clamping diodes CR1 and CR2 limit the collector voltage swing, and prevent transistor saturation and overshoot in the output pulse. The negative input trigger is applied through coupling capacitor C1 to the base of transistor Q1, and the output pulse is taken from the tertiary or output winding (terminals 5 and 6) of transformer T1.

The collector of transistor Q1 is reverse-biased by the combined negative voltage of V_{CC_1} and V_{CC_2}. The base of transistor Q1 is reverse-biased by the positive voltage applied from the bias supply (V_{BB}) through base resistor R1. Thus, in the quiescent state with no input applied transistor Q1 is completely reverse-biased and cannot conduct. Diode CR1 is reverse-biased by V_{CC_2}, which is connected across the diode through the collector (primary) winding of transformer T1, diode CR2 has no bias applied because there is no current flow through the collector winding of transformer T1, and hence no voltage drop occurs it to bias diode CR2. Consequently, neither diode conducts while the circuit is in the quiescent state.

When a negative trigger pulse (such as that shown at time t_1 on the accompanying waveform illustration) is applied through coupling capacitor C1 to the base of transistor Q1, it forward-biases the transistor, causing collector current to begin to flow.



Theoretical Waveforms for Nonsaturating, Diode-Clamped Blocking Oscillator

The collector current flowing from V_{CC_2} through the collector winding of transformer T1 to the transistor causes a magnetic field to be built up around the collector winding. The increasing magnetic field induces into the base winding of the transformer a voltage of such polarity that the potential on terminal 3 of the winding is negative with respect to ground (terminal 4). This negative potential is applied through capacitor C2 to the base of transistor Q1; it increases the forward bias on the transistor and causes the collector current to further increase. As the collector current flowing through the primary (collector) winding of transformer T1 increases, the magnetic field around the winding increases accordingly and induces a larger voltage into the base winding of the transformer. This increasing induced voltage is fed back to the base of transistor Q1, increasing the forward bias and causing the collector current to increase still further. Thus, the **regenerative feedback** from the collector to the base of transistor Q1 causes the collector current to continue to increase once the input trigger pulse starts current flowing. As the collector current increases the voltage on the collector of transistor Q1 decreases from the negative (cutoff) value of V_{CC_2} to the less negative value of V_{CC_1} (time t_2 on the waveform illustration). When the collector voltage becomes less negative than the value of V_{CC_1} diode CR1 becomes forward-biased and conducts. Since the forward-biased (conducting) diode has a very low resistance, the voltage drop across it is negligible and the voltage on the collector of transistor Q1 is held equal to the negative value of V_{CC_1}. Thus, diode CR1 **clamps** the collector voltage to the negative value of V_{CC_1}; in other words, it prevents the collector voltage from becoming less negative (more positive) than V_{CC_1}. Consequently, the collector current flowing through the collector winding of transformer T1, increases, as a result of the regenerative feedback, until the collector voltage drops to the value of V_{CC_1}. At this time, diode CR1 begins to conduct and shunts any additional collector current flow around the collector winding of the transformer. Since there is no longer an increasing current flow in the collector winding of transformer T1, the magnetic field around the winding ceases to increase and no further voltage is induced into the base winding. Since no further induced voltage is present, the voltage across the base winding of transformer T1 decays at a rate determined by the inductance, capacitance, and resistance values of the transformer. When the voltage across the base winding of the transformer decays to zero (time t_3 on the waveform illustration), no further forward bias is applied to the base of transistor Q1 and the transistor ceases to conduct. The base bias supply (V_{BB}) again furnishes reverse bias to the base of transistor Q1 to hold the transistor orbelow cutoff until the next input trigger is applied. Meanwhile, as the collector current flow through the collector winding of transformer T1 decreases to zero, the magnetic field around the winding collapses; this induces into the collector winding a voltage of such polarity that it tends to keep current flowing in the direction of the original collector current flow. The induced voltage forward-biases diode CR2, and the diode conducts, allowing the induced current to flow through it. Thus, diode CR2 effectively shorts out the voltage induced into the collector winding of transformer T1, and prevents it from having any effect on the remainder of the circuit. Consequently, as the collector current decreases from maximum to zero, the collector voltage increases in the negative direction from the negative value of V_{CC_1} to the more negative value of V_{CC_2}, and the circuit returns to the quiescent state.

357/260

Any change in current in the collector winding of transformer T1 also induces a changing voltage into the tertiary, or output, winding of the transformer. The polarity of this output voltage is determined by grounding the proper terminal of the output winding. As shown in the circuit schematic, terminal 6 is grounded. Therefore, in this case, a positive output pulse results (for a negative output pulse, terminal 5 is grounded instead).

FAILURE ANALYSIS.

General. When making voltage checks, use a vacuum-tube voltmeter to avoid the low values of multiplier resistance employed on the low-voltage ranges of the standard 20,000-ohms-per-volt meter. Be careful to observe proper polarity when checking continuity with an ohmmeter, since a forward bias through any of the transistor junctions will cause a false low-resistance reading.

No Output. A no-output condition may be caused by an improper input trigger, a lack of supply voltage, or a defective circuit component. First, use an oscilloscope to observe the input trigger voltage waveform, and compare it with the one shown in the equipment instruction book to determine whether the proper input trigger is applied. Next, use a vacuum-tube voltmeter to measure the supply voltage and eliminate the possibility of a defective power supply. If the proper input trigger is applied and the normal supply voltage is present, further checks must be made to locate the defective circuit component. Use an in-circuit capacitor checker to check capacitors C1 and C2 for open circuits and leakage. Use an ohmmeter to check resistor R1 and transformer T1 for continuity and proper resistance value. Also use the ohmmeter as a diode tester, to check the forward and reverse resistance of diodes CR1 and CR2. If these checks fail to locate a defective component, transistor Q1 is probably at fault and should be replaced with a transistor known to be good.

Low or Distorted Output. Low supply voltage, a defective diode (CR1 or CR2), a defective transistor (Q1) or a faulty transformer (T1) may cause either low-amplitude or distorted output pulses. Measure the supply voltage with a vacuum-tube voltmeter to be certain that the power supply is not at fault. If the normal supply voltage is present, use an ohmmeter or diode tester to check diodes CR1 and CR2 for an adequate front-to-back ratio. If neither diode is defective, the fault is probably in either transistor Q1 or transformer T1. Both the transistor and the transformer are best checked by substitution with parts known to be good. If first replacing transistor Q1 does not remedy the trouble, transformer T1 is probably defective and should be replaced.