BLOCKING OSCILLATORS

A Blocking oscillator is often used as a master oscillator in equipment. It is capable of generating pulses of very short duration that can be used to trigger or synchronize other circuits in the equipment. Blocking oscillators come in three basic forms or modes; the Free-running Blocking Oscillator, the Synchronized Blocking Oscillator and the Triggered Blocking Oscillator. Blocking oscillators are Relaxation Oscillators. A relaxation oscillator is one which generates a non-sinusoidal wave by quickly charging and gradually discharging a capacitor or inductor through a resistance.

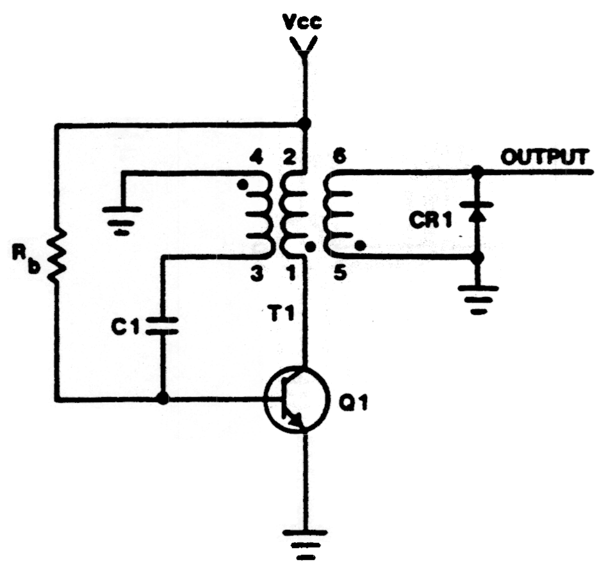


Figure 1

Figure 1 is a basic blocking oscillator. The function of the components shown in figure 1 are as follows: Rb is a biasing resistor used to provide the bias for Q1. Q1 is a transistor that will be used as a switch. Q1 will either be saturated, acting as a closed switch or cutoff acting as an open switch. C1 will function as a coupling capacitor to couple an induced signal from pin 3 of T1 to the base of Q1. C1 will develop a charge when Q1 conducts. The discharge time of C1 will determine the length of time Q1 will remain cutoff. The third winding of T1, pins 5 & 6, is called a Tertiary Winding and will couple the signal developed by the circuit to the output. The term TERTIARY refers to a third coil added to a transformer to supply a third output connection. CR1 is a diode placed across the tertiary winding to prevent any distortion of the output signal.

The charge and discharge paths of C1 are important to the understanding of the circuit operation. Refer to figure 2. When Q1 is conducting a positive potential will be felt at pin 3 of T1. This positive potential will result in C1 charging through the forward biased emitter junction of Q1.

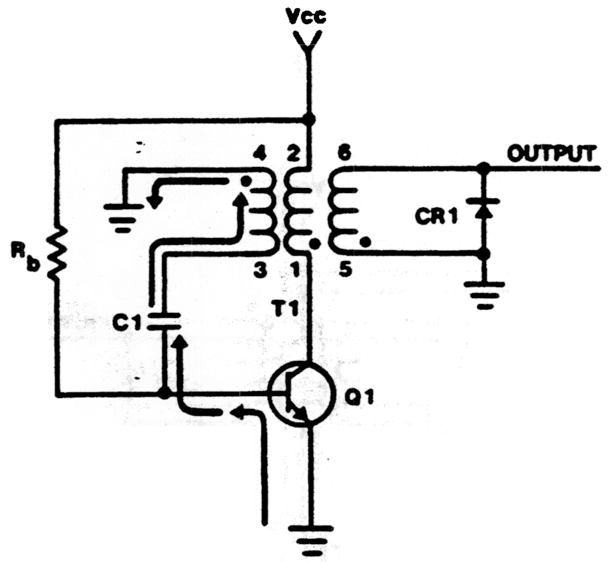


Figure 2.

The discharge path of C1 is shown in figure 3. When Q1 is cutoff C1 will discharge through Rb, through the power supply, from ground to T1 pin 4 to 3, to the top plate of C1.

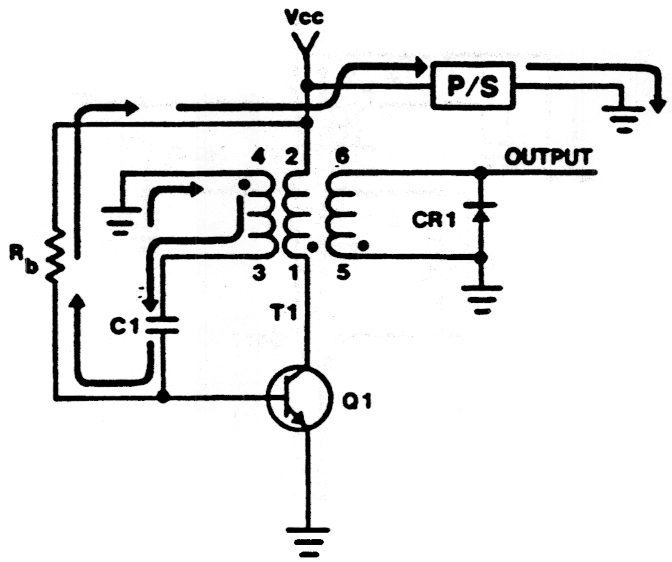


Figure 3

As C1 starts to discharge through Rb it creates a negative to positive drop across Rb. The signal created by the discharge of C1 will turn Q1 off. Q1 will remain off until C1 discharges to the point that it can no longer hold Q1 off. At that time the bias supplied by Rb will allow Q1 to turn on.

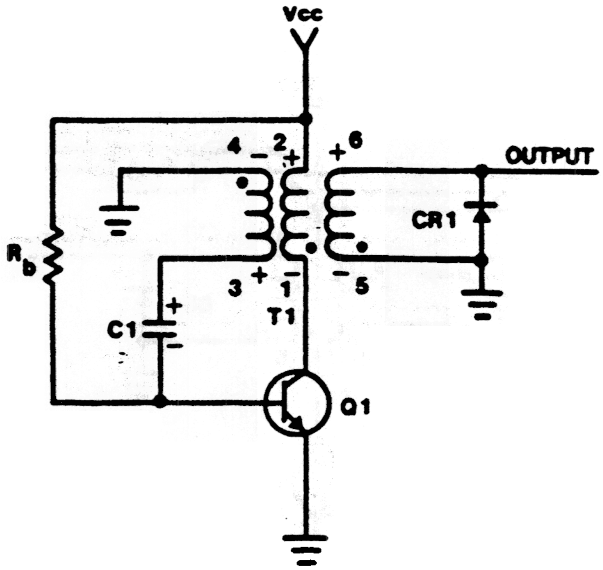
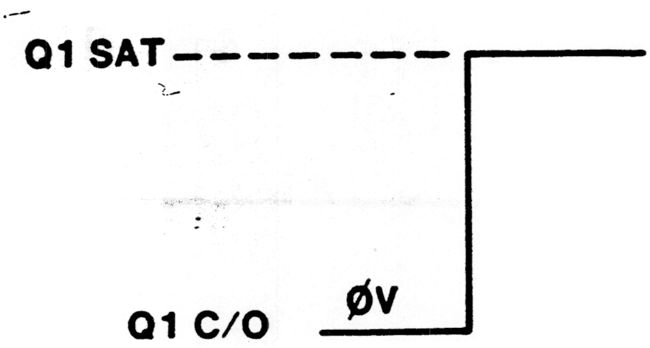


Figure 4

Refer to figure 4. We will now cover one cycle of operation of the blocking oscillator. When power is first applied, a positive potential will be felt by Q1's base through Rb. Q1 will start to conduct passing current through T1's primary, pin 1 to 2. As current flows through T1's primary, it develops a negative to positive voltage drop across the primary. This current also results in magnetic lines being built around the primary which induce a voltage into the secondary winding. The secondary is wound so that the induced voltage is 180 degrees out of phase. This results in a positive voltage being developed at pin 3. This positive potential is coupled through C1 and felt on the base of Q1, driving Q1 into saturation. At this time C1 will start to charge from ground through the emitter/base junction. Due to the low resistance of the charge path, C1 will charge very rapidly and maintain this charge until it is allowed to discharge. Before Q1 started conducting no voltage was being induced into the tertiary winding of T1. The voltage at pin 6 was 0V. As Q1 conducts a voltage is induced into the tertiary winding and the voltage at pin 6 now increases. The feedback from pin 3 to Q1's base drives it into saturation immediately. This results in an instantaneous change at pin 6 from 0V to some positive voltage. See figure 5.



TERTIARY WINDING OUTPUT SIGNAL

Figure 5

As Q1 becomes saturated, current flow through it ceases to increase and the magnetic field built around T1 primary ceases to expand. At this point the voltage induced in the secondary winding (pin 3 & 4) and the tertiary winding (pin 5 & 6) will return to zero. This produced a positive pulse on pin 6 of the tertiary (output) winding. When pin 3 of the secondary returned to zero C1 starts discharging through Rb. C1 will discharge through Rb, the power supply and T1's secondary. The resistance of these components will determine how long it takes C1 to discharge. When Q1 cutsoff the field around the primary collapses and will induce a negative signal at pin 6 of the tertiary winding (refer to figure 6A). This would be the output without CR1. With CR1 across the tertiary winding the negative pulse at pin 6 will forward bias CR1 placing a short across the winding and removing the negative pulse (refer to figure 6B).

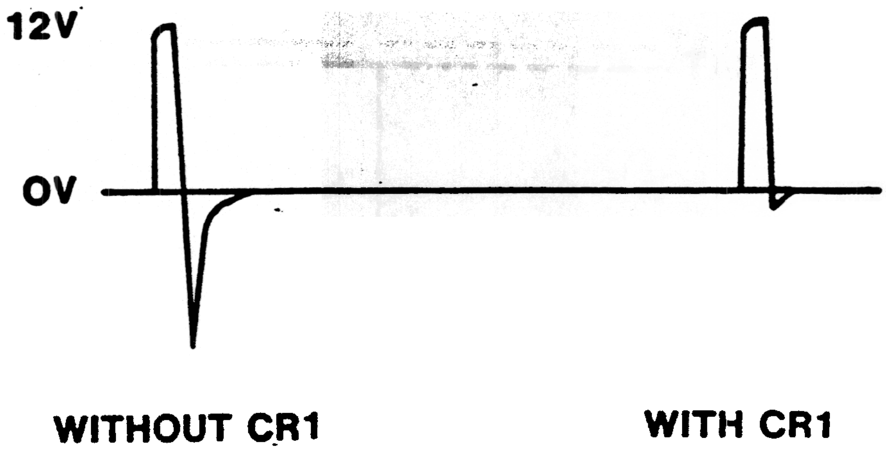


Figure 6

As C1 slowly discharges it will eventually reach a point where it can no longer hold Q1 cutoff. The forward bias supplied by Rb will then allow Q1 to turn on and the cycle will repeat itself. Figure 7 illustrates the signals developed in the circuit.

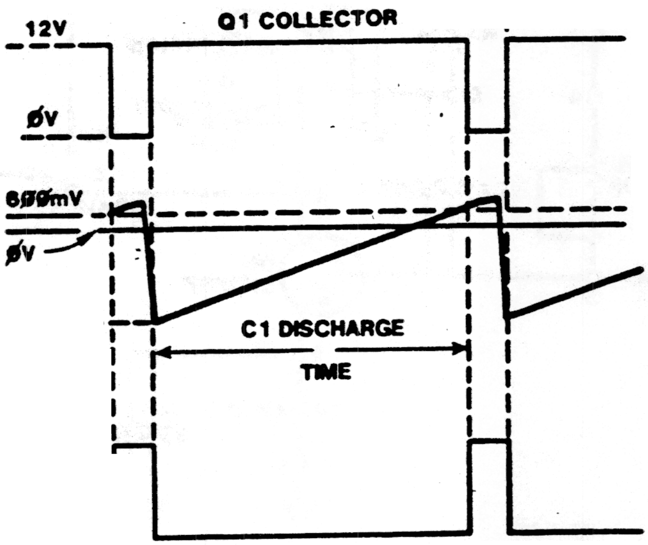
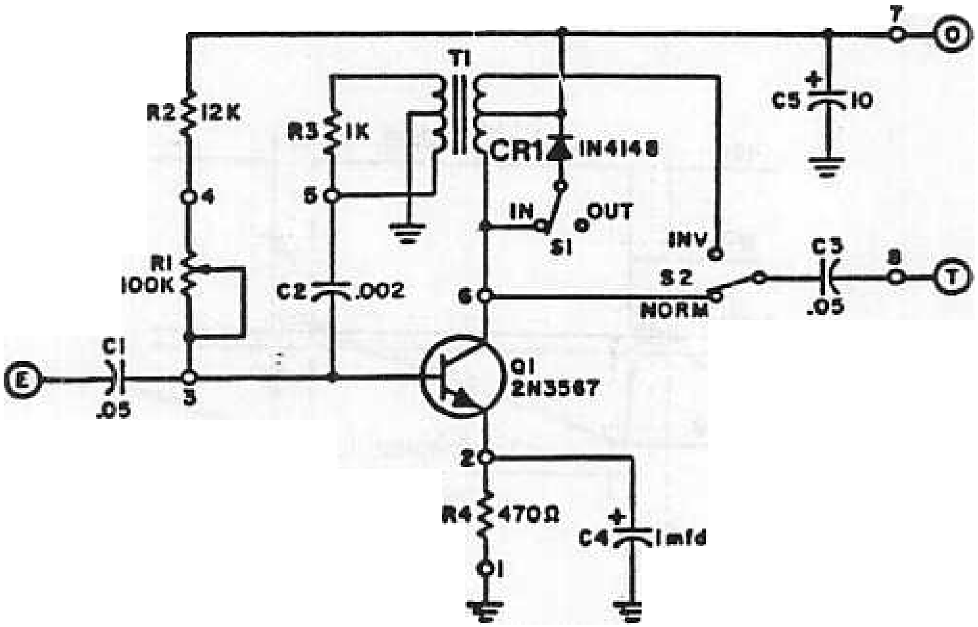


Figure 7

PC 42

The blocking oscillator shown in figure 8 performs the same function as the one previously discussed. The output will be a series or train of pulses. The circuit operates the same as the one just covered but can operate as a free-running, synchronizes or triggered blocking oscillator. These three modes of operation will be discussed individually.



BLOCKING OSCILLATOR PC 42

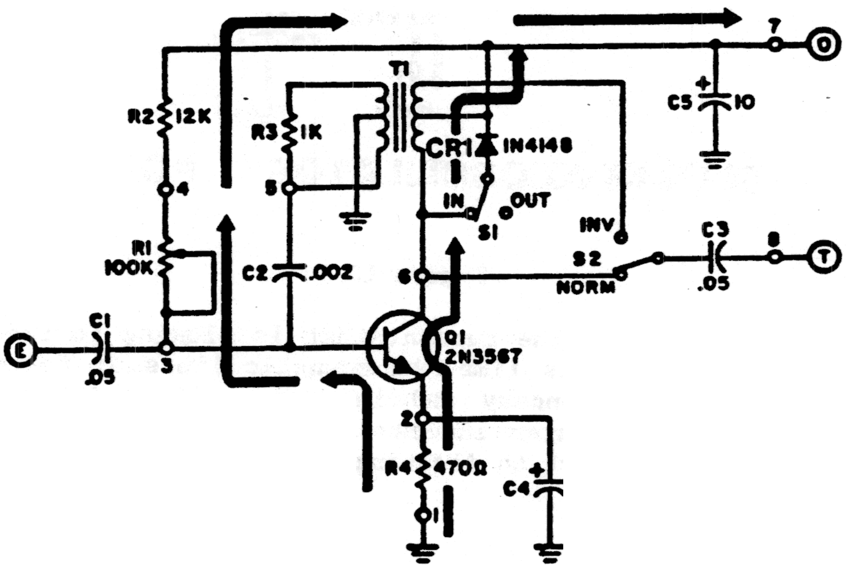
Figure 8

CIRCUIT COMPONENTS

C1 will allow a signal from an external source to be coupled into the circuit. C1 will be used in the synchronized or triggered mode of operation. R4 is an emitter resistor which will help limit the current through the transistor as well as aid in the development of emitter-base bias. C4 is an emitter bypass capacitor used to prevent circuit degeneration. R1 and R2 will be used to provide base bias for Q1. R3 is placed in the circuit to prevent ringing of the secondary. They also provide a discharge path for C2. By varying R1 the resistance in the discharge path of C2 can be increased or decreased. This will vary the amount of time it takes C2 to discharge. C2 will be used to feed back a portion of the signal from Q1's collector that is the result of Q1 switching on and off. C2 will charge to the potential felt at the bottom of T1's secondary and C2's discharge time will control how long Q1 will be cutoff. Q1 is an NPN transistor that will be used as a switch. Q1 will continuously switch between cutoff and saturation. T1 provides the load for Q1. It will also provide a feedback voltage that will be coupled to the base of Q1 to drive it into saturation. CR1 is in the circuit to prevent ringing of the primary of T1. S2 allows the output to be taken from either the collector or the top of T1's primary. The two signals are nearly identical but are 180 degrees out of phase. C3 will couple the signal out of the circuit. C5 acts as a filter capacitor to prevent any signal developed by the circuit from being coupled back to the power supply.

PC 42 CIRCUIT OPERATION

When the voltage is applied to pin O, it will be felt on the collector of Q1 and a portion of this voltage will be felt on the base of Q1. This bias voltage will forward bias Q1 and it will start to conduct. When Q1 conducts, current will flow from ground, through the emitter/base junction, through R1 and R2 to the power source. Once base current has been established collector current will start to flow. Collector current will flow through the primary winding of T1, out the center-tap and to the power source. In this case we will call the right hand winding of T1 the primary winding. As collector current flows from the collector through T1 primary it will cause a negative to positive voltage drop across the primary. See figure 9.



BLOCKING OSCILLATOR PC42

Figure 9

Due to the way the transformer is wound, as the collector current flows through the primary, the expanding magnetic fields will induce a voltage into the secondary which will be 180 degrees out of phase with the primary. The voltage developed at the bottom of the secondary will be positive in respect to the top. This positive voltage, felt at TP5, will be coupled through C2 and be felt at the base of Q1. This positive potential will cause Q1 to conduct harder and eventually go into saturation. The positive potential felt at TP5 will cause C2 to charge. C2 will charge as shown in figure 10. As long as Q1 is increasing its conduction C2 will continue to increase its charge.

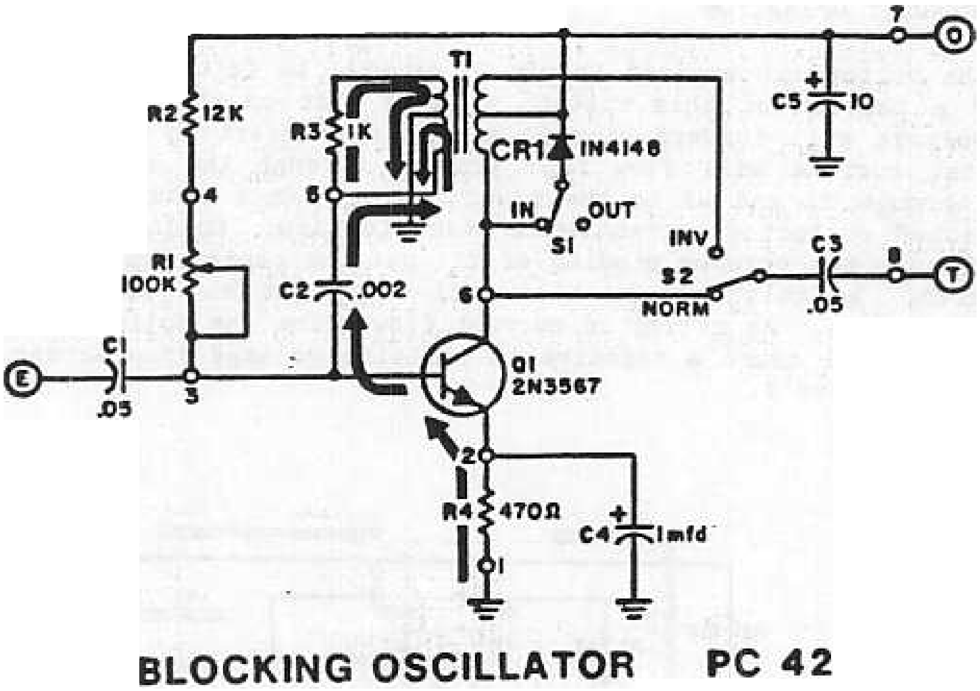
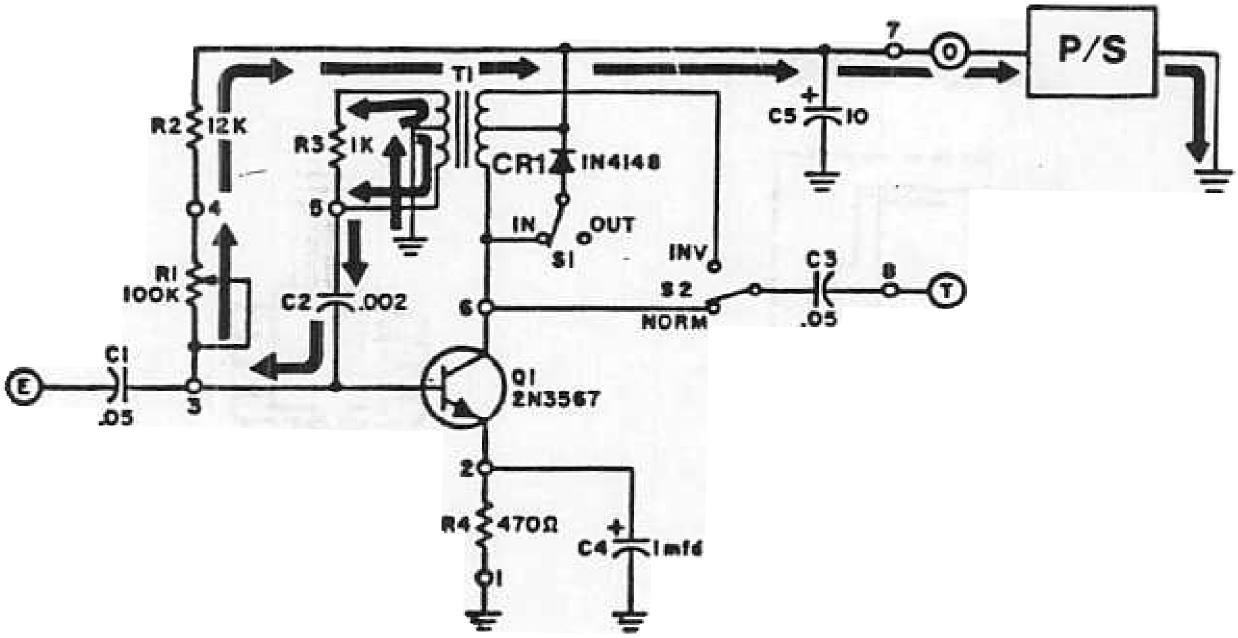


Figure 10

Once Q1 reaches saturation, the current that is flowing in the primary of T1 becomes constant. At this time the magnetic lines of force that have been moving across the secondary and inducing voltage into it will now become stationary and no longer induce a voltage. With no voltage being felt at TP5, C2 will now start to discharge. See figure 11.



BLOCKING OSCILLATOR PC 42

Figure 11

The discharge path for C2 is from the negative, or bottom, plate of C2 through R1, R2, the power supply to ground, to the ground of the secondary of T1, through both sides of the secondary of T1 and R3.

The frequency determining device (FDD) consists of R1, R2, R3, secondary of T1, resistance of the power supply and C2. R3 was placed across the secondary of T1 to act as a swamping resistor to prevent ringing in the secondary winding. Due to the fact that some discharge current will flow through R3 it becomes part of the FDD. When the capacitor (C2) starts to discharge, no current is flowing in the secondary windings of T1 because no voltage is now being induced from the primary. As C2 starts to discharge the secondary windings will offer a high reactance (X_L) to current flow. If the path for current flow is from ground on the center-tap of the transformer, current will see a parallel path. See figure 12.

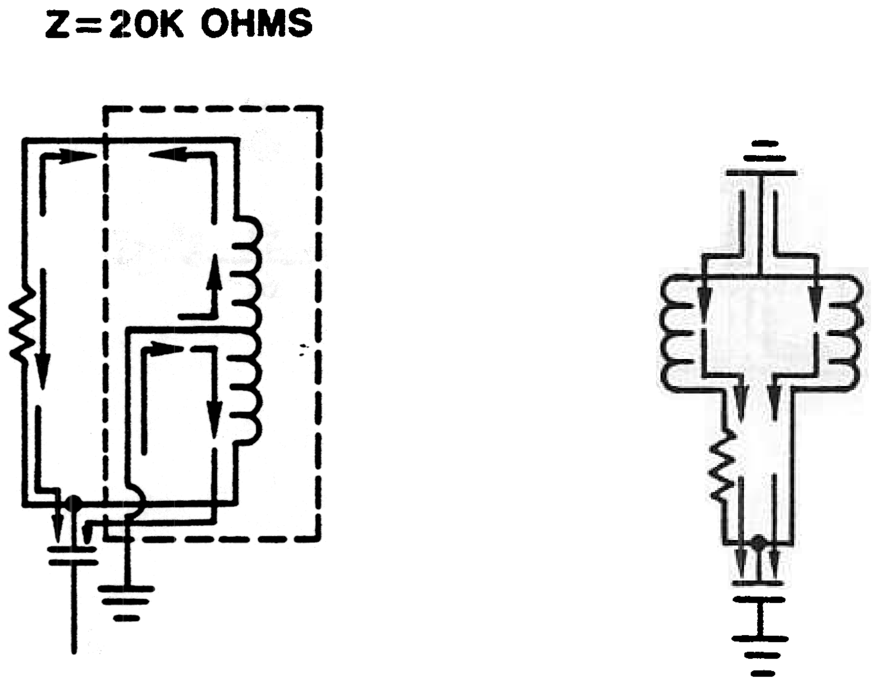


Figure 12

If, for example, the opposition of the transformer windings was 20K ohms, then each half of the windings would offer 10K ohms of opposition in parallel and R3 would make very little difference to the discharge current, however, it will have some effect. If the value of R3 is changed it will effect the discharge time of C2 which will change the frequency slightly. R3 was placed in the circuit primarily to prevent ringing, not as a frequency determining component. Ringing in a transformer can be compared to the current in a tank circuit. The current will flow in one direction, then reverse directions. If nothing is placed in the circuit to oppose the current flow, the current will continue to switch directions until all voltage potential has been depleted. Figure 13 is a drawing of the waveform that would be produced by ringing.

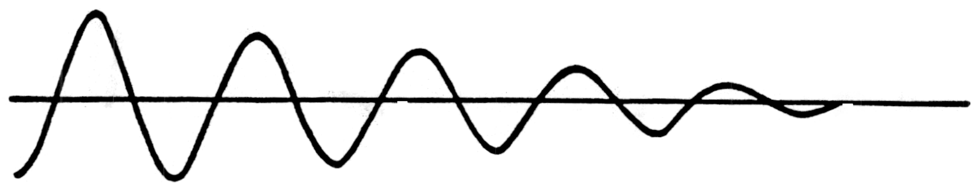


Figure 13

When C2 starts to discharge electrons will leave the bottom plate and flow up through R1. This results in a negative voltage being developed at TP3. This negative voltage will be felt on the base of Q1 and turn Q1 off. As C2 slowly discharges the negative potential felt at TP3 will slowly decrease toward zero. Eventually the negative voltage at TP3 will decrease to a point that it can no longer hold Q1 off. At this point the biasing network will forward bias Q1 and Q1 will start to conduct. The blocking oscillator has now completed one cycle of operation. Figure 14 is a drawing of the signal that will be developed at TP3 as a result of the charge and discharge of C2. R1 is adjustable, so the discharge time of C2 can be increased or decreased by varying the resistance of R1. This will allow the free-running frequency to be varied.

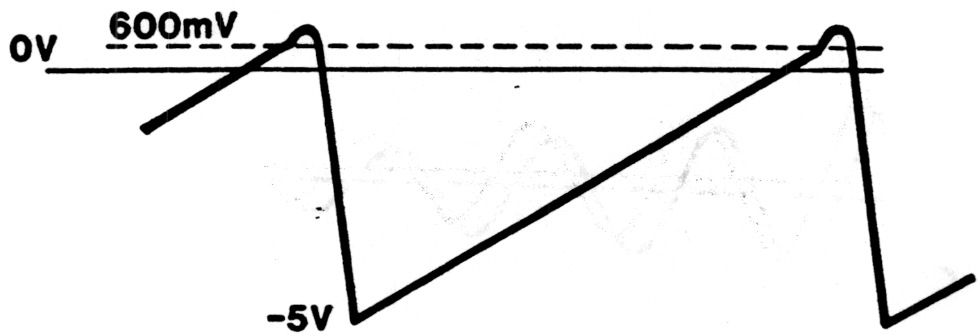


Figure 14

The output signal is taken from the collector of Q1 (TP6) when S2 is in the NORM position. The output is the signal created by Q1 switching from cutoff and back to saturation. Figure 15 is a comparison of the signal present at the base and collector.

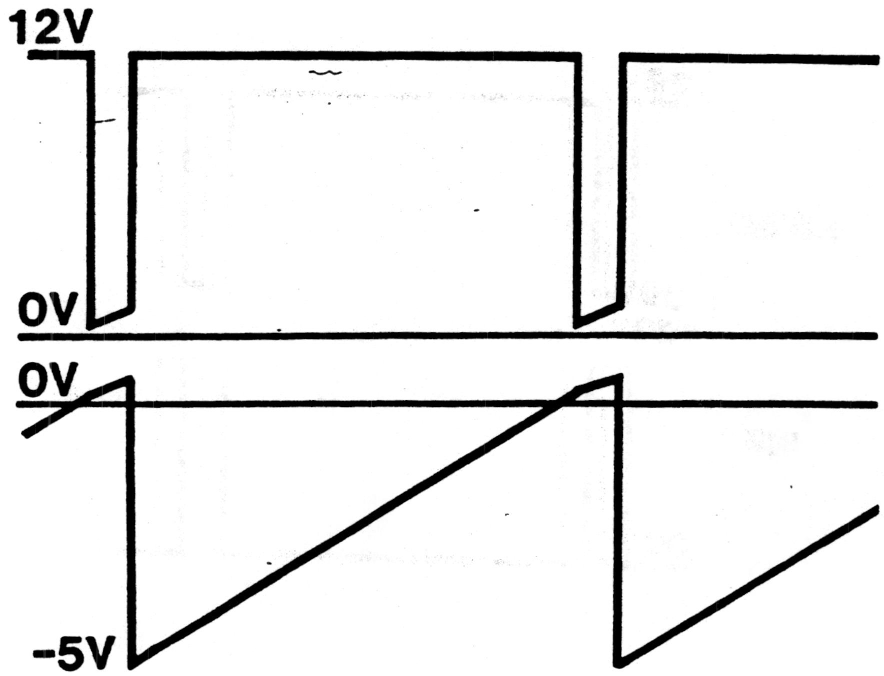


Figure 15

If S2 is placed in the INV (inverted) position the output signal can be taken from the top end of T1. Keep in mind that the signals present at opposite ends of a transformer are 180 degrees out of phase. Figure 16 is a comparison of the outputs with S2 in the NORM and INV positions.

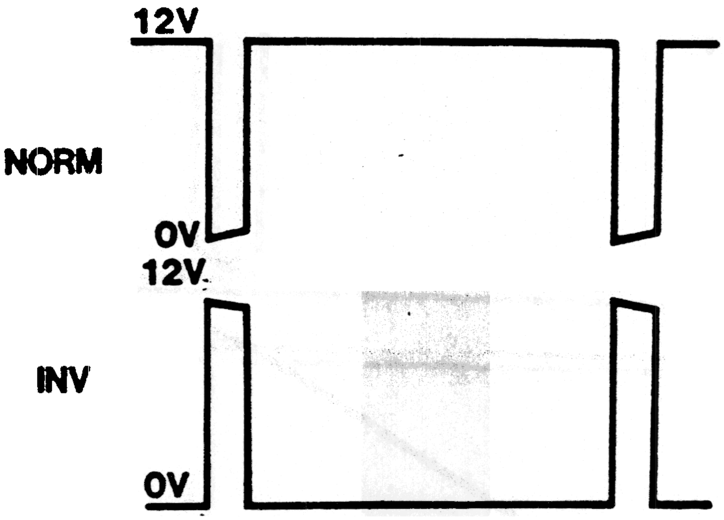


Figure 16

CR1 is placed across the primary windings of T1 to prevent ringing of the primary. C5 is a decoupling capacitor. It provides another filter for the power supply by removing any portion of the input signal that might be felt at the top of R2 and by keeping the output DC voltage level constant. C4 is a bypass capacitor for the emitter of Q1. C1 is a coupling capacitor that will be used in the synchronized and triggered modes.

SYNCHRONIZED BLOCKING OSCILLATOR

Since R1 can vary the frequency of the blocking oscillator, it can be used to synchronize the blocking oscillator to input triggers. To synchronize means to lock one element of a system into step with another. Input triggers will be applied through C1 from an external circuit. R1 can be adjusted so that the blocking oscillator will be triggered by any preselected number of input pulses. The free-running frequency of the blocking oscillator must be slightly lower than that of the incoming triggers. Refer to figure 17. The triggers are all 1 milli second apart.

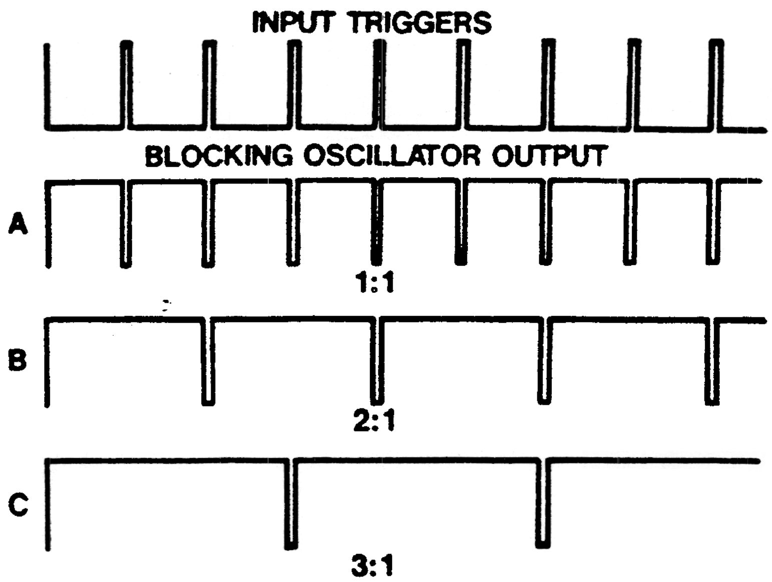


Figure 17

In view A, the blocking oscillator has been adjusted so that each input trigger will cause it to go through one cycle of operation. In view B the blocking oscillator has been readjusted to trigger on every other input trigger. View C indicates the blocking oscillator is triggering on every third input trigger.

Recall that the conduction of Q1 is controlled by the signal on the base. In the free-running version of the blocking oscillator, the transistor was held off by the decreasing negative voltage applied to the base by the discharge of C2. If positive pulses are coupled through C1 they will ride on the base signal. See figure 18.

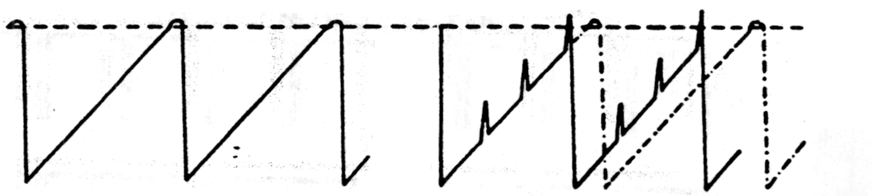


Figure 18

The transistor will be held cutoff only so long as the base voltage is negative enough to do so. As C2 discharges the voltage on the base will change in a positive direction. In figure 19 the transistor would turn on as soon as the base signal reaches 600mV (view A). If a positive pulse is applied to the base circuit before the base voltage would normally allow the transistor to turn on, and is of sufficient amplitude to raise the base voltage above cutoff, the transistor will start conducting at an earlier time (view B).

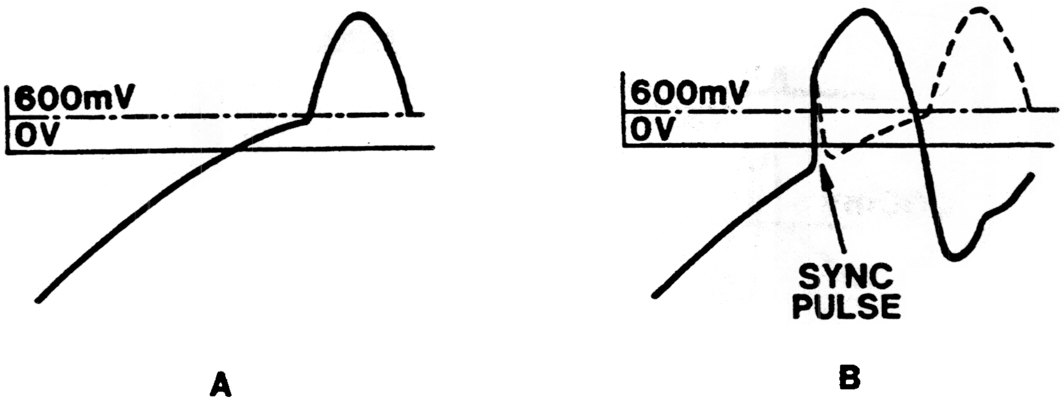


Figure 19

When the sync pulse frequency is slightly higher than the free-running frequency, each sync pulse will raise the base to a level sufficient to forward bias the transistor and allow it to conduct. See figure 20.

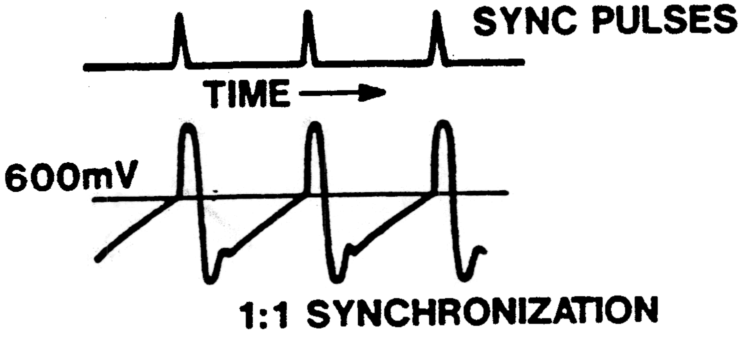


Figure 20

There is one blocking oscillator output pulse for each sync pulse applied to the base. The blocking oscillator frequency is equal to the sync frequency.

Figure 21 illustrates the synchronization of a blocking oscillator to one third and one half the sync pulse frequency.

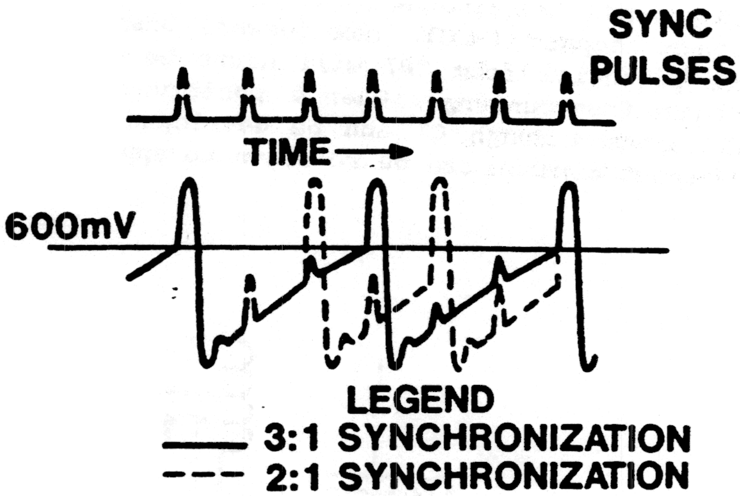


Figure 21

The first two pulses do not increase the base voltage above the cutoff valve. Therefore, these two pulses do not make the transistor conduct. The third pulse, however, does raise the base above cutoff and start the oscillator cycle. There is one blocking oscillator cycle of operation for each three sync pulses. If the sync pulse frequency is 210KHz, the oscillator frequency is 210KHz divided by 3 or 70KHz. This is 3:1 synchronization.

The frequency of synchronization can also depend on the amplitude of the sync pulses. If the amplitude of the sync pulses were increased so that the second pulse raised the base voltage above cutoff, the blocking oscillator would be one-half the frequency of the sync pulses. If the amplitude of the sync pulses were increases further the blocking oscillator could be made equal to the sync frequency.

Because of the ability of the blocking oscillator to trigger on different sync pulses it can be used as a frequency divider. If the input sync pulses are lost, the blocking oscillator will revert to it free-running frequency.

The action or operation of the circuit is identical in both the free-running modes. The main difference is the fact that in the free-running mode the discharge of C2 alone controls the output frequency of the oscillator. In the synchronized mode the frequency and/or amplitude of the sync pulses in addition to the discharge time of C2 control the oscillator frequency.

TRIGGERED BLOCKING OSCILLATOR

Notice in figure 23 that PC42 has had a switch added that, when closed, will connect TP4 to ground. By closing S7 a ground is placed at TP4 which will present the power supply (VCC) from forward biasing Q1. With TP4 grounded a positive potential from TP7 will never be felt at TP3. This will prevent PC42 from free-running. When a positive trigger is applied to Pin E, it will couple through C1 and be developed by R1. Figure 22 illustrates how the input circuit can be re-drawn to appear more familiar.

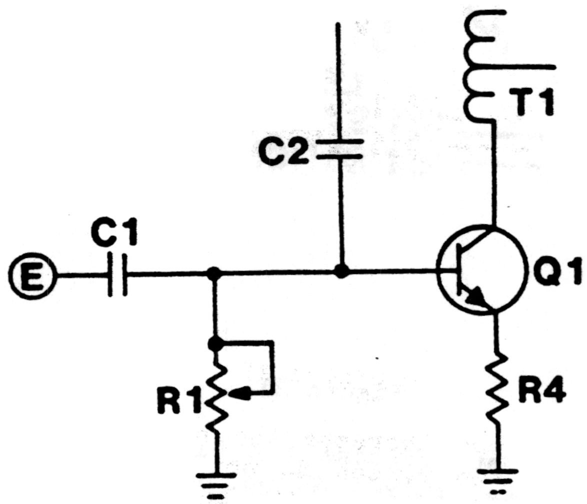
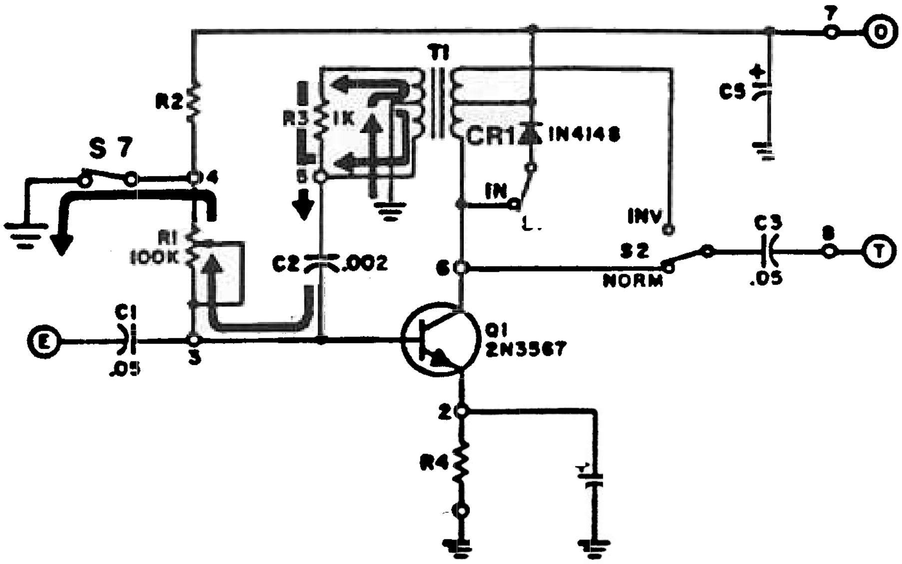


Figure 22

The positive trigger applied to the base of Q1 will be of sufficient amplitude to forward bias Q1. At this point the operation of the oscillator will be the same as the synchronized mode. There is one difference and that is the discharge path of C2. See figure 23.



BLOCKING OSCILLATOR PC 42

Figure 23

With TP4 grounded, C2 will discharge through R1, to ground through S7 to the center-tap of T1's secondary to the top plate of C1. Notice that R1 is still in the discharge path of C2 so the discharge time of C2 can still be controlled. The blocking oscillator can be synchronized to trigger on different selected input triggers. The main difference between the synchronized and triggered modes is that when the input triggers are removed from the synchronized mode the blocking oscillator will revert to its free-running frequency. If the input triggers are removed from the triggered mode of operation the blocking oscillator will shut off completely and develop no output.

TROUBLESHOOTING PC42

The oscilloscope will be used to determine whether or not the oscillator is operating. If troubleshooting the free-running mode you only need to check the output. If troubleshooting either the synchronized or triggered mode the input must also be checked. Once it is determined that the oscillator is not working, DC voltage readings must be taken and compared to the normal readings. By comparing voltage readings is should be possible to identify the malfunctioning component. Resistance checks can be used to verify your selection. One thing that should be remembered is that the negative voltage reading on the base is normal. It is the result of the voltmeter measuring the average voltage of the signal on the base.

SUMMARY: A blocking oscillator is an oscillator that normally does not produce a symmetrical output. It's normal output is a series of narrow pulses. The blocking oscillator can operate free-running or be synchronized to an input signal. If synchronized the output frequency can equal the input frequency or be a multiple of it. Operation in the triggered mode is basically the same as the synchronized mode, if the input is lost the oscillator will revert to its free-running frequency. In the triggered mode if the input is lost the oscillator will shut off.

(The material covered in this presentation is UNCLASSIFIED)