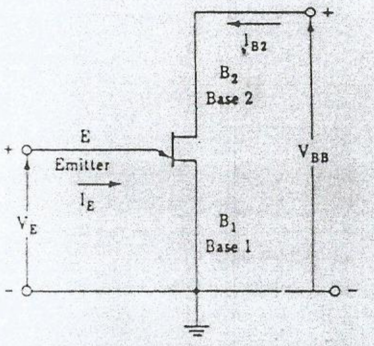


Figure 3.14. Unijunction transistor.

...ce is the interbase resistance (R_{BB}), and at 25°C has values in range from 4.7 kΩ to 9.1 kΩ.

The normal biasing conditions for a typical UJT are indicated in ...ure 3.15. If the emitter voltage, V_E, is less than the emitter peak ...nt voltage, V_p, the emitter will be reverse biased and only a small

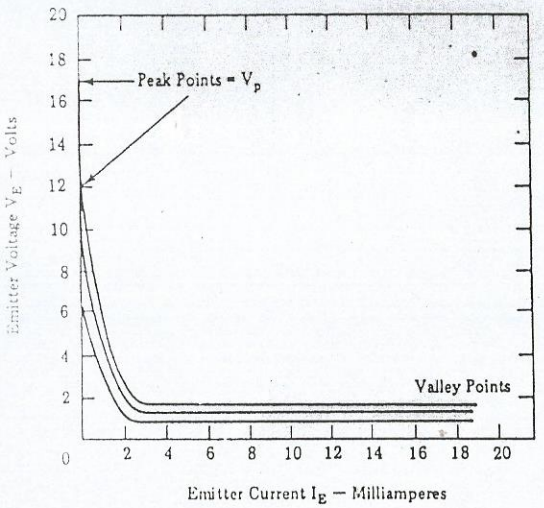


Figure 3.15. UJT biasing conditions.

reverse leakage current, I_{EO}, will flow. When V_E is equal to V_p, and the emitter current, I_E, is greater than the peak point current, I_p, the UJT will turn on. In the on condition, the resistance between the *emitter* and *base-one* is very low and the emitter current will be limited primarily by the series resistance of the emitter to base-one external circuit.

The peak point voltage of the UJT varies in proportion to the interbase voltage, V_{BB}, according to the equation:

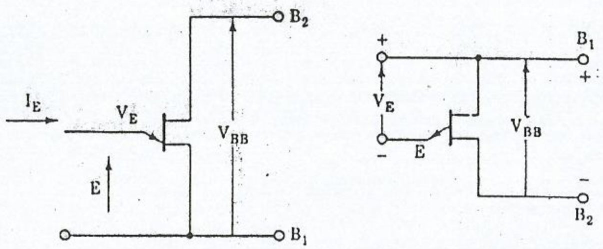
$$V_p = \eta V_{BB} + V_D \tag{3.5}$$

The parameter η is called the intrinsic standoff ratio. The value of η lies between 0.51 and 0.82, and the voltage, V_D, the equivalent emitter diode voltage, is in the order of 0.5 volt at 25°C, depending on the particular type of UJT.

3.10 Complementary Unijunction Transistor (CUJT)

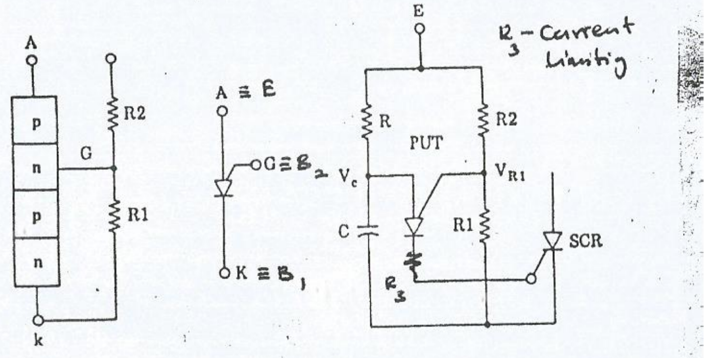
Complementary unijunction transistor is a silicon planar, monolithic integrated circuit. It has unijunction characteristics with superior stability, a much tighter intrinsic-standoff ratio distribution, and lower saturation voltage.

CUJT characteristics are like those of a standard UJT except that the currents and voltages applied to it are of opposite polarity. The opposite polarity has been chosen so that standard npn planar passivated transistor processing techniques can be used. CUJTs can be used in most applications that use standard UJTs. Their unique stability and uniform properties make them ideal for stable oscillators, timers, and frequency dividers.



(a) Standard Unijunction (b) Complementary Unijunction

Figure 3.16 (a) Standard unijunction. (b) Complementary unijunction.



(a) pnpn structure; (b) symbol; (c) typical firing circuit.

Figure 3.17. Programmable unijunction transistor: (a) pnpn structure; (b) symbol; (c) typical firing circuit.

3.11 Programmable Unijunction Transistor (PUT)

The PUT (Figure 3.17) is a three-terminal planar passivated pnpn device in the standard plastic low-cost TO-98 package. The terminals are designated as anode, anode gate, and cathode.

The programmable unijunction transistor offers many advantages over conventional unijunction transistors. The designer can select R1 and R2 to program unijunction characteristics such as η, R_{BB}, I_p, and I_v to meet his particular needs.

The operation of the circuit is as follows: A definite voltage is applied to the gate of the PUT through the voltage divider action of R2 and R1. The voltage is given by

$$V_{R1} = \frac{E}{R2 + R1} \cdot R1$$

The capacitor is charged to voltage V_c from voltage E through R and C. When the anode voltage V_c exceeds the gate voltage V_{R1}, the PUT starts conducting and triggers the SCR.

3.12 Unijunction Transistor Trigger Circuits

Because of its unique combination of economy, simplicity, compactness, low-power consumption, and high effective power gain, the UJT

UJT as a relaxation oscillator

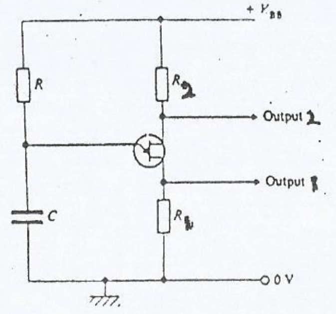


Fig. 6.2 UJT relaxation oscillator circuit.

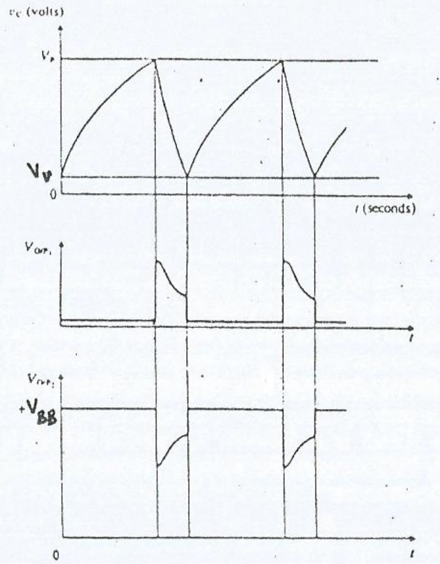


Fig. 6.3 Waveforms occurring in the relaxation oscillator.

$$T \approx RC \ln\left(\frac{V_{BB}-V_V}{V_{BB}-V_P}\right) \simeq RC \ln\left(\frac{V_{BB}}{V_{BB}-\eta V_{BB}}\right)$$

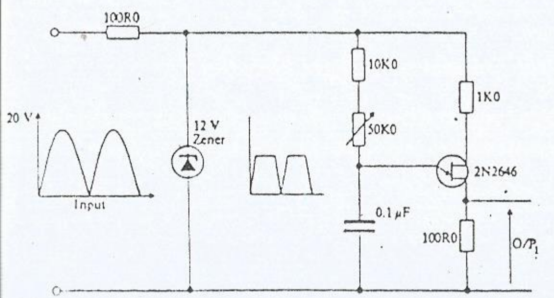


Fig. 6.6 UJT relaxation oscillator supplied from clipped rectified a.c.

Isolation of the trigger circuit

In many cases thyristors are used in circuits with a.c. mains voltages supplied. The low voltage trigger circuits need to be isolated from these mains voltages. Two methods of achieving this isolation are considered below:

1. *By current transformer*, as shown in Fig. 7.4(*a*).
2. *By optical isolator*, as shown in Fig. 7.4(*b*). The input is fed into a light-emitting diode (LED) and the light emitted is sensed by a photo transistor. This turns the transistor on and the resulting current pulse generates a voltage across an external resistor which is connected to the thyristor gate/cathode circuit. Isolation between the LED and the photo diode can be up to 2.5 kV.

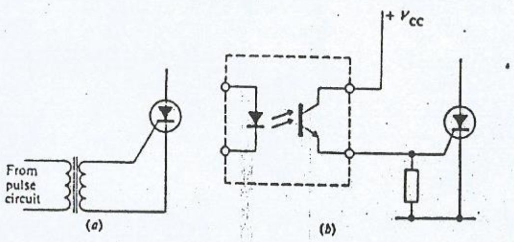


Fig. 7.4 Isolation of trigger circuit. (*a*) Circuit transformer; (*b*) optical isolator.

Phase control of the thyristor in a.c. circuits

Here, the thyristor is used as a switch to control the current flowing in an a.c. load. The thyristor is switched on by the first suitable pulse during a positive half-cycle and remains on for the rest of that half-cycle. As the supply voltage falls to zero the current is reduced below the holding current level and the thyristor switches off. It remains off during the negative half-cycle. The sequence repeats itself during each cycle, and the waveforms are shown in Fig. 7.5.

The trigger signals can be obtained from a unijunction relaxation oscillator circuit as previously described, and if operated from a full-wave rectified circuit, will be *synchronized* to the a.c. supply of the thyristor so that for a given setting of *CR* the thyristor will always receive its trigger pulse at the same angle. The angle may be varied by changing the value of *CR*. In practice, this is achieved by making *R* a variable resistor.

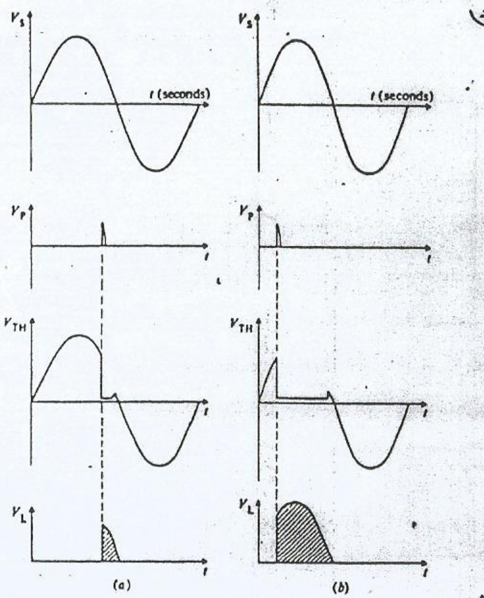


Fig. 7.5 Waveforms with phase control. (*a*) Late firing angle; (*b*) early firing angle.

This method of control is used in speed and light control circuits, in power supply control replacing rectifiers and many other applications. The main disadvantage is that one half-cycle is lost. The second half-cycle can be used if two thyristors are connected back-to-back in parallel, i.e., *inverse-parallel connection* and fired on alternate half-cycles.

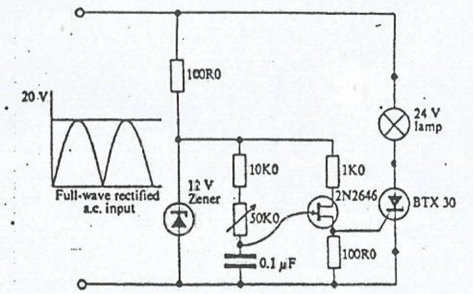


Fig. 7.8 Lamp dimming circuit.

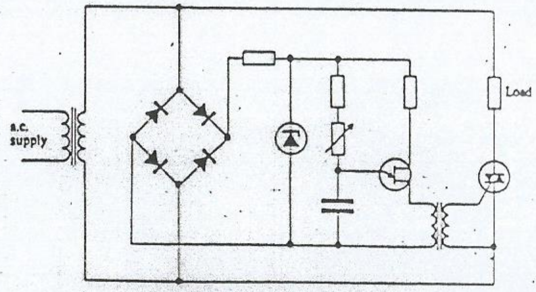


Fig. 7.10 Full-wave (UJT trigger circuit) triac control.

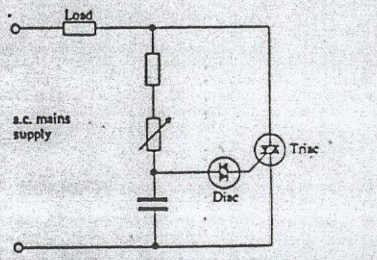


Fig. 7.12 Phase control of triac – using diac triggering.

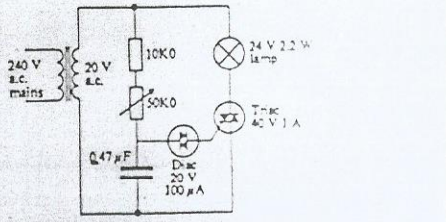


Fig. 7.13 Triac lamp dimming circuit, using diac trigger circuit.

…equency interference

…use of the fast switching action of SCRs and triacs when they …n to conduct into resistive loads, the circuit current rises to its …l value very rapidly. The sudden transient generates harmonics …ch could be a source of interference to other equipments. …use the amplitude of the harmonics generated decreases with …uency the problem is most acute at the lower end of the r.f. …trum. The interference may be radiated or carried via power …s to the affected equipment which has the same power source for …pply voltage. The effect of the line induced interference can be …mised by placing a choke in series with the SCR or triac load. …use the choke, in opposing current flow, slows down the rise of …t when the device switches the effect of harmonic interference …duced. However, to be effective the choke must be very large …a suitable alternative is to use an *LC* filter. A possible …gement is shown in Fig. 9.23.

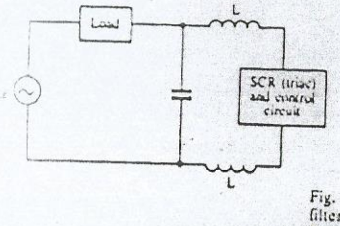


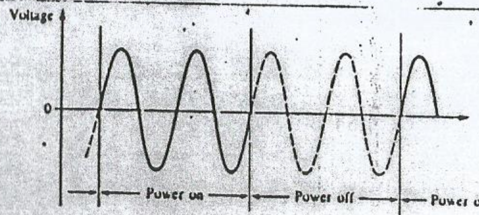
Fig. 9.23 Use of an LC filter to minimise radio frequency interference.

…st firing

…se of *LC* filters to suppress radio frequency interference (RFI) …t economically viable for very large load currents. An …native approach to switching the load voltage at some firing …e 0 when the voltage, and hence the current, may be large is to …urst firing. In this arrangement the SCR or triac is switched as …voltage source crosses the zero voltage point and current is …ed to flow for an integral number of cycles before the device is …hed off. The device is also switched off as the voltage source …s the zero voltage point. The waveform for a switched triac …t is shown in Fig. 9.24.

…e power delivered into a resistive load depends on the ratio of …umber of cycles when the device is on to the total number of

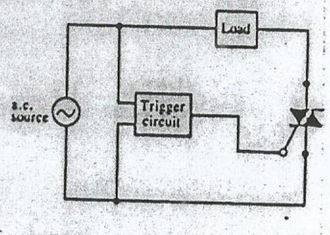
Fig. 9.24 Voltage waveform illustrating the concept of burst firing.



cycles in a switching cycle. From Fig. 9.24 the switching cycle is four cycles of which only two supply power to the load. Hence the average applied power to the load in this case is 2/4 × 100% or 50%.

A circuit for utilising the zero-crossing technique is shown in Fig. 9.25. A suitable trigger circuit for this circuit is available in monolithic i.c. form. The RCA-CA3058/CA3059/CA3079 are zero-voltage switches operating from an a.c. source voltage of 24, 120 or 230 V at 50, 60 or 400 Hz. The CA3059/CA3079 are 14 in DIL (dual in line) packs with plastic encapsulation while the CA3058 is a 14 pin ceramic DIL package.

Fig. 9.25 Basic circuit for burst firing control utilising a zero-crossing switch for the trigger circuit.



The devices are multistage circuits employing a diode limiter, a zero-crossing (threshold) detector, a differential comparator and an output driver stage. The d.c. operating voltages for the stages are provided by an internal power supply of sufficient current capability to drive external circuits such as other i.c.'s. The output trigger pulses can be applied directly to the gate of an SCR or triac. The CA3058/CA3059 also feature an interlock circuit that prevents the gating pulse to the SCR should an external sensor be inadvertently shorted or opened. An external inhibit connection is available so that an external signal can inhibit the output drive. Apart from this feature which is not present on the CA3079 the three devices are electrically identical. The block diagram of the zero-voltage switch as the trigger element in a triac controlled switching circuit is shown in Fig. 9.26.

From Fig. 9.26 it can be seen that the zero-voltage switch incorporates four functional blocks. Details of the blocks are as follows:

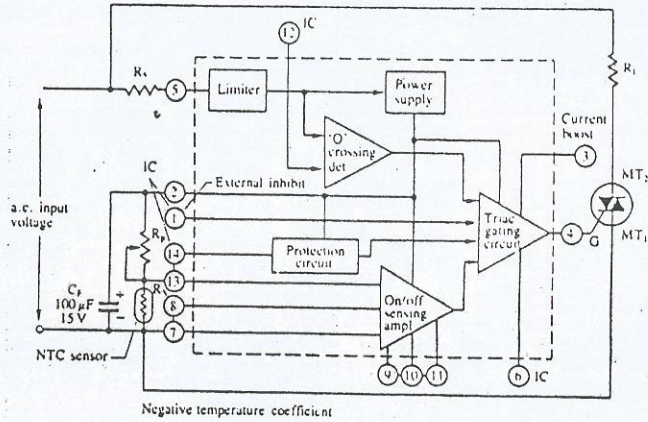


Fig. 9.26 CA3058 series zero voltage switch functional block diagram.

(1) Limiter-power supply. Allows operation directly from an a.c… supply.
(2) Differential on/off sensing amplifier. Tests the condition of external sensors or command signals. Hysteresis or proportional control capability may be implemented in this section.
(3) Zero-crossing detector. Synchronises the output pulses of th… circuit at a time when the a.c. cycle is at a zero-voltage point, t… eliminating RFI when used with resistive loads.
(4) Triac gating circuit. Provides high-current pulses to the gate… the power-controlling thyristor device.

Additionally the CA3058/CA3059 provide the following auxili… functions:

(1) a built in protection circuit that may be activated to remove drive from the triac if the sensor opens or shorts.
(2) thyristor firing may be inhibited through the action of an internal diode gate connected to terminal 1.
(3) high power d.c. comparator action is provided by overriding action of the zero-crossing detector. This may be achieved by connecting terminals 7 and 12 together. Gate current to the thyr… is continuous when terminal 13 is positive with respect to termin…

Miscellaneous thyristor devices

The major components of the thyristor family, namely the SCR and the triac, together with the diac have been covered in earlier sections. However, there are a variety of switching devices, mainly used in the trigger circuits for the SCR or triac, that are related to the thyristor family. Some of these devices will be discussed briefly in this section.

The Shockley diode

Sometimes called a reverse-blocking diode thyristor, this is a four layer device, as shown in Fig. 9.27(a), with an anode and cathode connection but no gate connection. Just as for the SCR, analysis of the Shockley diode could be made in terms of two interconnected transistors, i.e. a p_1-n_1-p_2 and n_1-p_2-n_2 device. Device symbol and voltage-current characteristic is shown in Fig. 9.27(b) and (c) respectively. When a forward voltage is applied (i.e. anode positive with respect to cathode) only the n_1-p_2 junction is reverse biased and at a breakover voltage the junction avalanches to give device conduction. In the reverse bias condition two junctions are reverse biased and could avalanche if the breakover voltage is exceeded in a similar manner to the SCR. Application of the device is for SCR triggering and in timing circuits but to a great extent its application has been superseded by alternative components. It may still be found, however, in older existing equipments.