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INDUSTRIAL POWER ELECTRONIC LABROTORY

PRACTICAL EXPERIMENTS IN POWER ELECTRONIC

FOR STUDENTS OF THIRD STAGE

EXPERIMENT NO . 3

EXPERIMENT NA . UJT OSCILLATOR & TIMER CIRCUITS .

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EXPERIMENT 3

UJT OSCILLATOR &TIMER CIRCUITS .

OBJECTIVE

1. Understanding the operation of UJT relaxation oscillator circuit.
2. Understanding the operation of UJT timer circuit.

THEORY

UJT Relaxation Oscillator

Most triggering circuits for SCR and TRIAC triggering use the basic relaxation oscillator as a pulse generator. Any semiconductor device whose V-I characteristics include a negative resistance region may be used. The devices usually used include the UJT, PUT, SCS, DIAC, and Shockley diode.

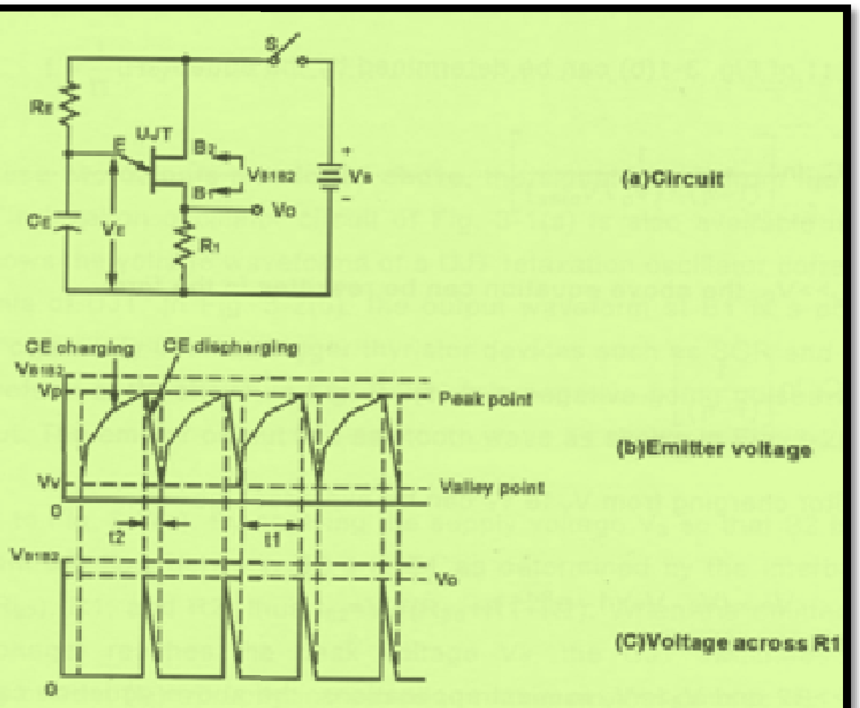


Fig.3-1 Basic UJT relaxation oscillator

Fig. 3-1 shows the circuit and voltage waveforms of the basic UJT relaxation oscillator. When the switch S is closed, the capacitor C_E charges toward V_B by current flow through R_E. The UJT will turn on at the point where the capacitor voltage V_E reaches the peak-point voltage V_P. The capacitor will then discharge through the E-to-B_1 junction of the UJT generating a voltage pulse output across R_1. The amplitude of the output pulse is given by

$$V_0 = I_E \times R1 \quad \text{......(3-1)}$$

When the emitter current decays to the level of the UJT valley-point current, I_V, the UJT turns off and the capacitor begins to charge again. The cycle repeats as long as the switch S remains closed. The period of oscillation is quite small and typically a few µs.

In Fig. 3-1(b), the voltage waveform of V_E is basically an exponential curve. In normal operation, the time constant of discharging is equal to $((R_{B1}+R1) \times C_E)$ and the time constant of charging is $(R_E \times C_E)$. Since $R_E >> (R_{B1}+R1)$ in actual circuits, therefore $(R_E \times C_E) >> ((R_{B1}+R1) \times C_E)$.

The period t1 of Fig. 3-1(b) can be determined by the equation

$$t1 = R_E C_E \ln\left[\frac{1}{(1-\eta)-(V_D/V_{B1B2})}\right] \quad \text{......(3-2)}$$

Since $V_{B1B2} >> V_D$, the above equation can be rewritten in the form

$$t1 = R_E C_E \ln\left[\frac{1}{(1-\eta)}\right] \quad \text{......(3-3)}$$

The capacitor charging from V_V to V_P can be expressed as

$$V_P = (V_B - V_V)(1-e^{\frac{-t1}{R_E C_E}})$$

Since $R_{BB} >> R2$ and $V_B >> V_V$ in most applications, the above equation can be written as

$$V_P = V_B(1-e^{\frac{-t1}{R_E C_E}})$$

Therefore the charging period t1 can be determined by

$$t1 = R_E C_E \ln\left[\frac{V_B}{V_B - V_P}\right] \quad \text{......(3-4)}$$

From Fig. 3-1(c), the frequency of output pulse can be calculated by

$$f = \frac{1}{t1 + t2}\ (\text{Hz}) \quad \text{......(3-5)}$$

where t1 is the charging period and t2 the discharging period. The period of time to complete one cycle is usually defined by T, that is, T=t1+t2. The capacitor discharges through the emitter of UJT, R_{B1} and R1. Since R_{B1} is small enough to neglect and R_E>>R1, the discharging period t2 therefore is quite small compared with t1. In practice, the frequency of output pulse can be calculated by the simplified equation:

$$f = \frac{1}{t1}\ (\text{Hz}) \quad \text{......(3-6)}$$

Besides these two outputs mentioned above, the signal output from the terminal B2 in the UJT relaxation oscillator circuit of Fig. 3-1(a) is also available if necessary. Fig. 4-2 shows the voltage waveforms of a UJT relaxation oscillator corresponding to the terminals of UJT. In Fig. 3-2(b), the output waveform at B1 is a positive-going pulse train commonly used to trigger thyristor devices such as SCR and TRIAC. The output waveform at B2 shown in Fig. 3-2(b) is a negative-going pulse train opposite to B1 output. The emitter output is a sawtooth wave as shown in Fig. 3-2(d).

Now revert to Fig. 3-2(a). By applying the supply voltage V_B so that B2 is positive, a small current will flow between B2 and B1 as determined by the interbase resistor ($R_{BB}=R_{B1}+R_{B2}$), R1, and R2, thus $I_{B2}=V_B/(R_{BB}+R1+R2)$. When the emitter voltage V_E (the C_E voltage) reaches the peak voltage V_P, the UJT switches on. The C_E discharging current (I_E) abruptly increases to maximum that causes R_{B1} to decrease and I_{B2} to increase. The result is a decrease in B2 voltage caused by an increase in voltage drop across R2, that is, $V_{B2}=V_B-I_{B2}R2$. At the end of discharging period, the UJT switches OFF so that the B2 output returns to initial potential. Thus the output waveform at terminal B2 is a negative pulse as shown in Fig. 3-2(b).

The resistor R2 is used for the temperature compensation and will be discussed later.

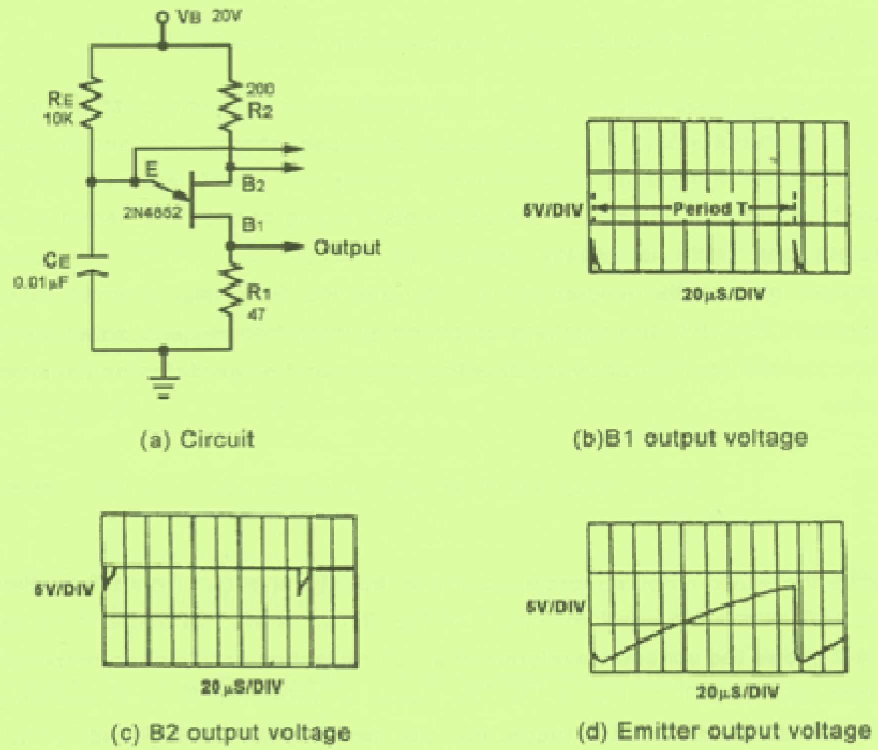


Fig.3-2 UJT relaxation oscillator

Up to now, we have discussed the characteristics of the UJT and the operating principle of UJT relaxation oscillator. For the following discussion, we summarize the typical values of UJT important parameters as follows.

1. R_{BB}=4~10K

2. η=0.6, R_{B1} = 0.6R_{BB}, R_{B2} = 0.4R_{BB}

3. I_P=0.5~50μA

4. I_V=1~10mA

5. V_V=1~3V

6. R_{sat}=5~25Ω

(1) Linearity Improvement

From Figs. 3-1(b) and 3-2(d), we can see that the emitter voltage waveform is not a true sawtooth wave because the charging current is an exponential form. To obtain a linear charging voltage across the capacitor, it is a good solution by using a constant-current source to provide a constant-current charging.

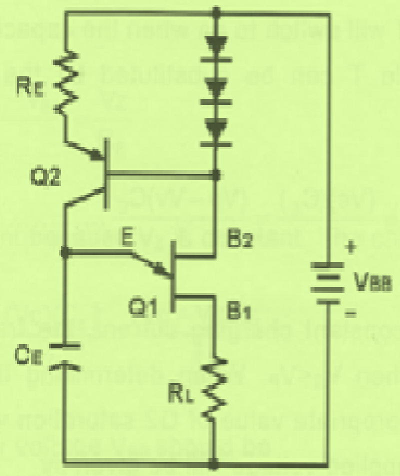


Fig.3-3 UJT relaxation oscillator with constant-current charging

Referring to Fig. 3-3, the constant-current source is formed by the PNP transistor Q2, resistor R_E, and three forward-biased diodes. Assume that the forward voltage drop across each diode is exactly equal to the forward V_{BE} of transistor Q2. The emitter current of Q2 can be calculated by the following equation:

$$I = \frac{0.6N - 0.6}{R_E} = \frac{(N-1)(0.6)}{R_E} \quad \text{.......................................(3-7)}$$

where the number of diodes, N are three in this circuit. Therefore the emitter current of transistor Q2, I_E=1.2V/R_E, is constant and determined by the resistor R_E. Since I_C ≈ I_E, the capacitor C_E charges in a constant current as long as the R_E value is set.

By the definition of the capacitance of a capacitor, the capacitor voltage can be written in equation form as

$$Vc = \frac{Q}{C_E} \text{..............................} (3\text{-}8)$$

The actual charge Q in the capacitor depends upon the average rate at which charge is moving into it, multiplied by the time it takes to move it in. That is

$$Q = It \text{..............................} (3\text{-}9)$$

As mentioned earlier, the capacitor charges from the valley voltage V_V toward the peak voltage V_P, the UJT will switch to on when the capacitor voltage V_C reaches V_P. The period of one cycle T can be substituted by the charging time t1 and is expressed by

$$t1 = T = \frac{Q}{I} = \frac{(Vc)(C_E)}{I} = \frac{(Vp - Vv)C_E}{I} \text{..............................} (3\text{-}10)$$

In order to maintain a constant charging current, the transistor Q2 should be not operate in saturation when V_E<V_P. When determining the applied voltage to the circuit of Fig. 3-3, an appropriate value of Q2 saturation voltage must be accounted into. If $V_{CE2(sat)}$=1V, the applied voltage will be given by

$$V_{BB} \geq Vp + 1 + (N - 1) \times 0.6 \text{..............................} (3\text{-}11)$$

Fig. 3-4 shows a practical constant-current source for the UJT oscillator circuit. The series voltage divider network consisting of a zener diode, bias diode, and resistor R_2 provide a constant forward bias to the base of transistor Q2. The bias diode having the same V-I characteristic as the E-B junction of transistor is selected for the use of temperature compensation.

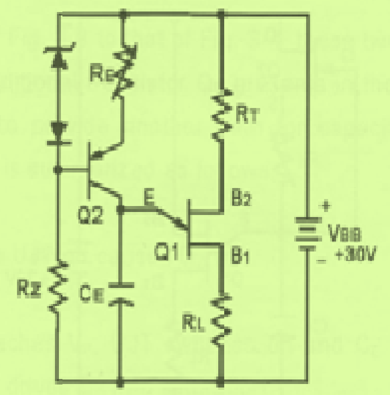


Fig.3-4 UJT oscillator with zener constant-current source

The emitter current of Q2 is determined by the zener voltage V_Z and the resistor R_E. That is

$$I_E = \frac{V_Z + V_D - V_{BE}}{R_E} = \frac{V_Z}{R_E}$$

Thus I_E should be constant because V_Z is constant. The charging time t1 is equal to

$$t1 = T = \frac{Q}{I} = \frac{(V_C)(C_E)}{I} = \frac{(V_P - V_V)C_E}{I} \quad \text{.......................................(3-12)}$$

In such a case, the power voltage V_{BB} should be

$$V_{BB} \geq V_P + 1 + V_Z \quad \text{..(3-13)}$$

The last constant-current source circuit here is shown in Fig. 3-5. The JFET Q2 connected in common-drain (CD) configuration provides a constant charging current to charge the capacitor. From I_D-V_{GS} characteristic of FET, the charging current is determined by

$$I = \frac{V_{GS}}{R_E}$$

The period of oscillation varies with the change in the resistance of R_E.

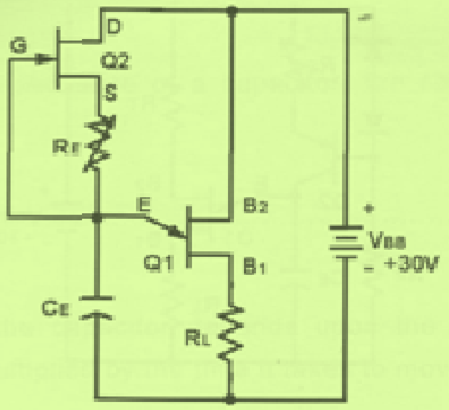


Fig.3-5 UJT oscillator with JFET constant-current source

(2) V_V Elimination

The amplitude of the emitter voltage output in a UJT relaxation oscillator is in the range from V_V to V_P. For expanding the range of output voltages, one method is to increase V_P and the other is to decrease V_V. Recalling the equation $V_P = V_B(1-e^{\frac{-t1}{R_EC_E}})$, the peak voltage V_P can be easily increased by increasing the applied voltage V_B. To minimize or eliminate the valley voltage V_V, the technique used in the circuit of Fig. 3-6 is useful.

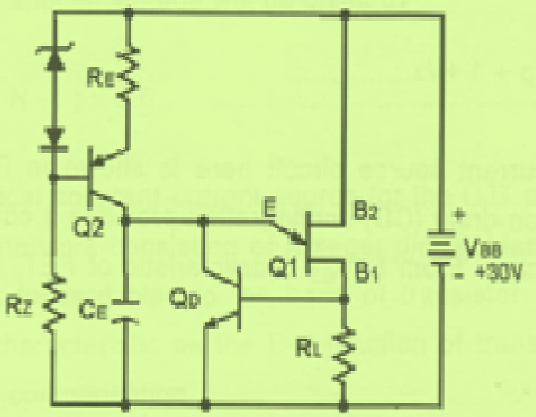


Fig.3-6 Additional transistor for V_V elimination

Comparing the circuit of Fig. 3-6 to that of Fig. 3-4, these two circuits are exactly the same except that an additional transistor Q_D presents in the circuit of Fig. 3-6. The additional Q_D is used to provide another path for capacitor discharging. A brief description of operation is summarized as follows.

1. While C_E charges, the UJT off causes Q_D off.

2. When C_E voltage reaches V_P, UJT switches on and C_E discharges through R1. The pulse across R1 drives Q_D into saturation.

3. Since Q_D operates in saturation, the $V_{CE(sat)}$ is very close to zero (typically 0.1V). However, this value is quite smaller than the V_V (typically 1~3V) without Q_D added.

4. The Q_D decreases the discharging time.

If a negative pulse output with the amplitude from 0V to V_{BB} is desired, the circuit of Fig. 3-7(a) may satisfy this requirement. The transistor Q_P is connected in CE amplifier configuration, which acts as an inverter. When the UJT oscillator operates normally, the positive pulse at terminal B1 will drive the transistor Q_P conducting in saturation. A negative pulse with narrow duration of 5 to 12μs appears at the collector output as shown in Fig.3-7(b).

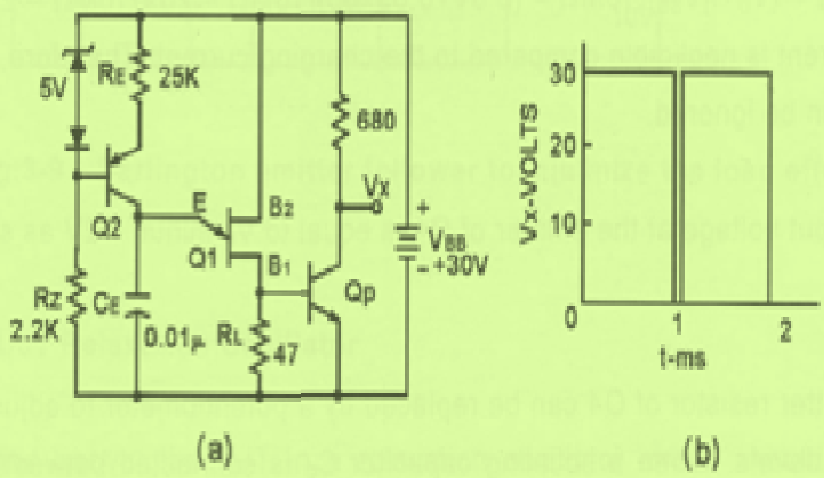


Fig.3-7 **Negative pulse output with wide amplitude range and narrow duration**

(3) Minimizing Load Effect

Fig. 3-8 shows a load resistor R_D shunted with the capacitor of a basic UJT relaxation oscillator. The R_D and R_E form a voltage divider. If the resistance of R_D is too small to get a voltage drop greater than V_P, the oscillator will never oscillate because the UJT can not switch on. In addition, the oscillating frequency will be varied by the change of UJT input impedance due to the R_D added. This effect is known as load effect. To avoid the occurrence of load effect, a load with extremely high input resistance and quite low output resistance is required. As shown in Fig. 3-9(a), the Darlington-pair (Q3-Q4) emitter follower acts as an active impedance-matching circuit. The operation of this circuit is summarized as follows.

1. Assume that each transistor has a dc current gain β of 100. The total dc current gain of the Darlington pair is 10000 (β^2).

2. Since R_E=1KΩ, the input resistance of the Darlington emitter follower is 10MΩ (1KΩ×10000). The 10MΩ resistance is connected to the capacitor in parallel.

3. The charging current to the capacitor C_E is 200μA (V_Z/R_E=5V/25K).
   In the worst case, the maximum shunt current in the input resistance of 10MΩ occurs at V_E = V_P and is calculated by
   V_P/10MΩ = (V_D+ηV_{BB})/10MΩ = (0.5V+0.65×30)/10MΩ = 20V/10MΩ = 2μA.
   This current is negligible compared to the charging current. Therefore, the load effect can be ignored.

4. The output voltage at the emitter of Q4 is equal to V_E minus 1.2V as shown in Fig. 3-9(b).

5. The emitter resistor of Q4 can be replaced by a potentiometer to adjust the output voltage levels. When a coupling capacitor C_C is connected between the emitter resistor and the load, the average dc level is blocked by C_C and thus the range of output voltage is from −10 to +10V as shown in Fig. 3-9(b).

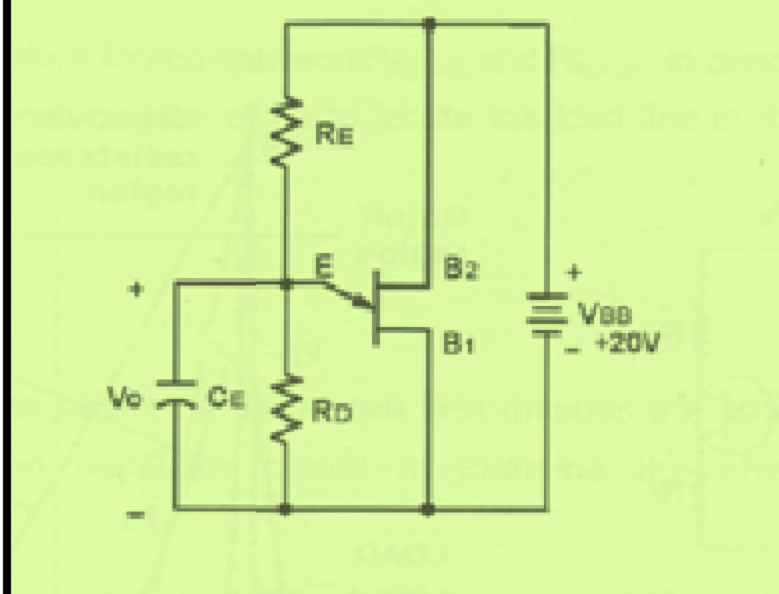


Fig.3-8 Illustration for Load effect

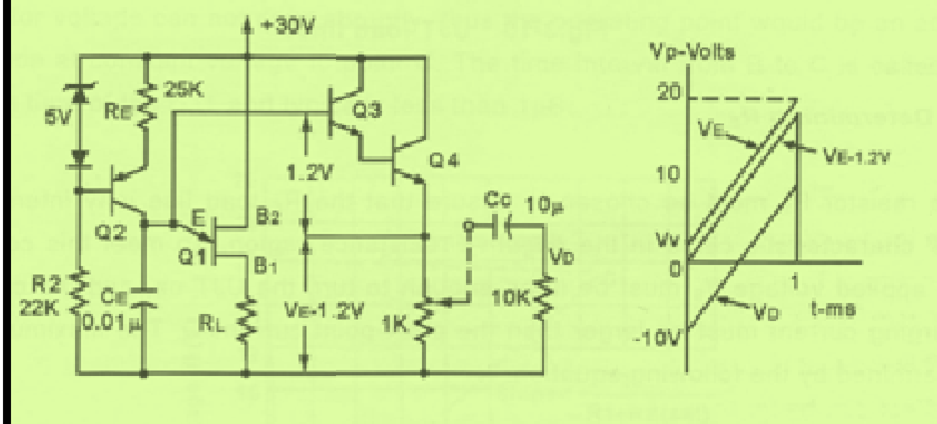


Fig.3-9 Darlington emitter follower to minimize the load effect

Design of UJT Relaxation Oscillator

As mentioned above, the UJT in a relaxation oscillator circuit should operate in negative resistance region. When designing a UJT relaxation oscillator, the load line must be designed to pass through the static V_E-I_E curve in the negative resistance region as shown the load line 3 in Fig. 3-10. The design procedure steps are listed below.

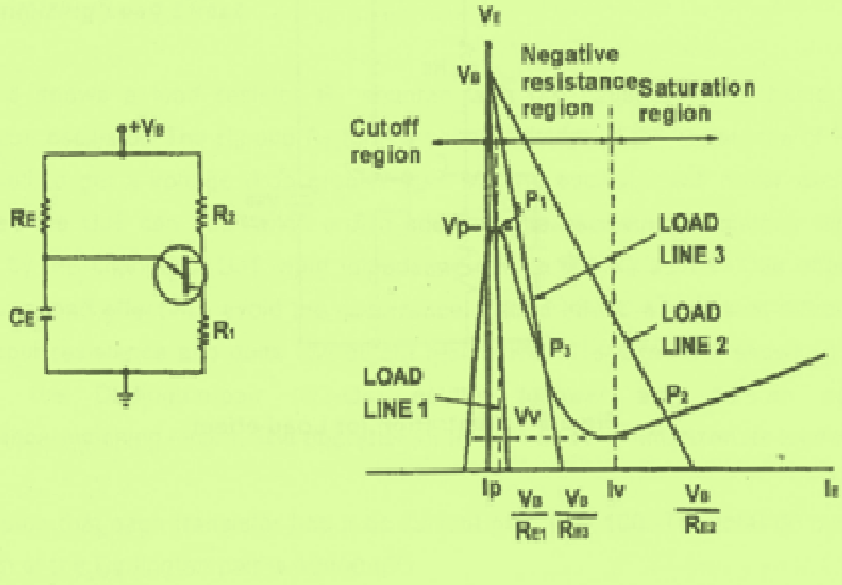


Fig.3-10 UJT load lines

(1) Determining R_E

The resistor R_E must be chosen to ensure that the R_E load line may intersect the UJT characteristic curve in the negative resistance region. To meet this condition, the applied voltage V_B must be large enough to turn the UJT on, and the capacitor charging current must be larger than the peak-point current I_P. The maximum R_E is determined by the following equation.

$$R_E < \frac{V_B - Vp}{Ip} = R_E(max) \qquad (3\text{-}14)$$

The $R_{E(max)}$ load line is the load line 1 shown in Fig. 3-10. The actual value of RE should be chosen smaller than $R_{E(max)}$. If R_E is too small to ensure the discharging current smaller than the valley current I_V, the UJT will operate in the saturation region (load line 2) and can not be turned off. To ensure turning off, the minimum R_E should be

$$R_E > \frac{V_B - Vv}{Iv} = R_E(min) \qquad (3\text{-}15)$$

The range of R_E is therefore limited between $R_{E(max)}$ and $R_{E(min)}$. In general, the value of 2 or 3 times $R_{E(min)}$ is a reasonable value of R_E to locate the load line in the negative resistance region.

(2) Determining C_E

Before determining the capacitor value, we first discuss the path of operation of the UJT in the relaxation oscillator circuit to examine the effect of the charging capacitor.

Fig. 3-11 shows the static V_E-I_E characteristic of the UJT discussed previously and the dynamic path of operation. When the capacitor voltage reaches V_P (point B), the UJT goes on and intends to operate at the point of intersection of the corresponding load line with the device characteristic in the negative resistance region. Since the capacitor voltage can not drop abruptly, thus the operating point would be an abrupt transition at constant voltage to point C. The time interval from B to C is called the turn-on time of the UJT and typically less than 1 μS.

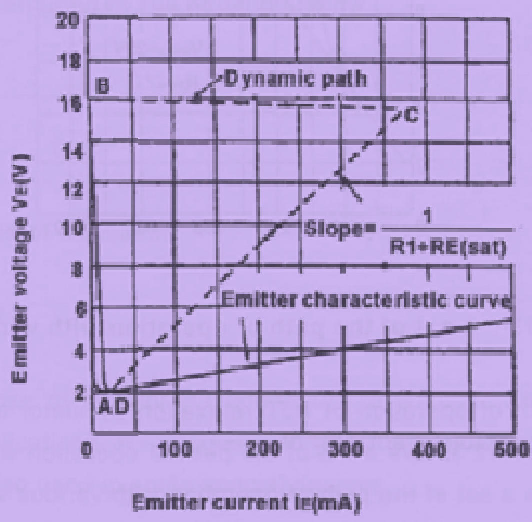


Fig.3-11 Dynamic and static characteristics of UJT

At point C, the capacitor discharges abruptly so that the operating point from point C shifts to point D along with a straight line whose slope is determined by R1 and $R_{E(sat)}$. Point D is near the valley point. The emitter current would not maintain the operating point to stay at point D. At this moment, if the capacitor C_E is absent in the circuit, the operating point will shift from D to the point of intersection of static load line with the characteristic in negative resistance region. Actually C_E presents and the operating point shifts from point D to point A. At this point the capacitor begins to charge for next cycle. Therefore, the period of oscillation is determined by $R_E C_E$ time constant, and the characteristics of turn-on time and turn-off time of the UJT.

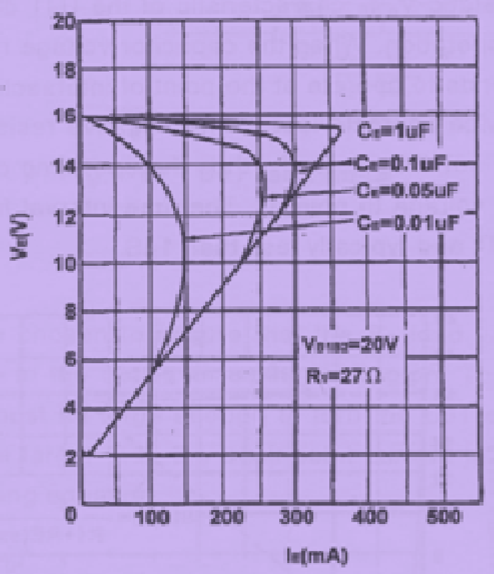


Fig.3-12 A set of the path of operation with various C_E

In practice, the path of operation of UJT relaxation oscillator is determined by C_E, V_{B1B2}, and R1. Fig. 3-12 shows a set of the path of operation with various values of C_E. Fig. 3-13 shows a set of the path of operation with various values of V_{B1B2} and a fixed C_E. From these two figures, we observe that an increase in either C_E or V_{B1B2} causes an increase in I_E and a longer path of operation. The increase in I_E will increase the output amplitude across R1, and the longer path of operation will lower the oscillation frequency.

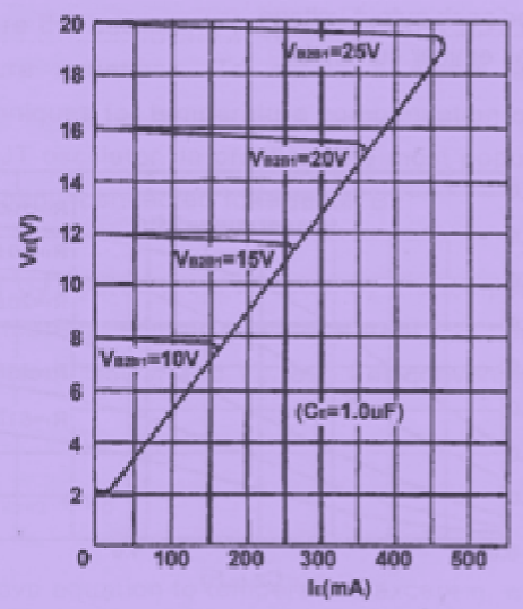


Fig.3-13 A set of the path of operation with various V_{B2B1}

As discussed above, the frequency of oscillation depends on the amount of C_E. The C_E value can be determined by the equation below.

$$C_E \approx \frac{T}{R_E \times \ln\frac{1}{1-\eta}} \quad \text{(3-16)}$$

where T is the period of oscillation.

(3) Determining R1

The principal purpose of resistor R1 connected to B1 is to determine the voltage output. In most applications, R1 is chosen to less than 100Ω; however, R1 value as high as 2~3KΩ is also used in some special designs.

Generally the required output voltage across R1 depends upon the need of the load. For example, a UJT relaxation oscillator is used to trigger a SCR, which needs a minimum trigger voltage of 3V. In such a case, the output voltage across R1 should be larger than 3V. The value of R1 can be calculated by

$$R1 = \frac{\text{Desired peak output voltage}}{\text{Peak emitter current } I_E} \quad \text{(3-17)}$$

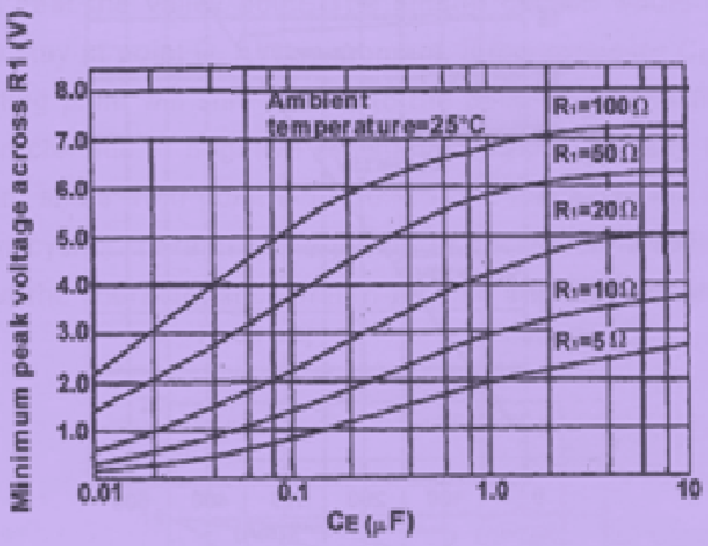


Fig.3-14 R1 output voltage vs C_E with R1 as parameter

For example, if a peak voltage of 3V is desired and peak I_E is 300mA, a 10Ω resistor should be chosen for R1. Moreover the peak I_E is the function of the voltage V_{B1B2}. Fig. 3-14 shows the relationship between the output voltage across R1 and C_E capacitance with supply voltage V_B at 20V. If a V_B over 20V is used, some adjustment should be made by the following:

$$\text{Error factor} = \frac{V_B - 6}{14} \quad \text{(3-18)}$$

For Fig. 3-14 example, when V_B=20V, C_E=1μF, and R1=10Ω, the minimum voltage across R1 is 3V. If now V_B=25V, we first calculate the error factor as (25-6)/14=1.358, and then the output peak voltage is 1.358 × 3 = 4V.

(4) Determining R2

The UJT, like most semiconductor devices, is sensitive to temperature variations. The resistor R2 in B2 lead provides thermal stability for the oscillator. From Eq. (2-3), we observe that the peak voltage V_P varies as V_{B1B2}, η, and V_D vary with temperature. Therefore the oscillating frequency of the UJT relaxation oscillator will vary with temperature variations. To obtain a stable and precise oscillating frequency, some techniques for temperature compensation or thermal stability must be considered in a UJT oscillator. In practice, the most popular technique is that an appropriate resistor simply connected to terminal B2.

There are a variety of UJT parameters affected by the temperature variation such as the interbase resistance R_{BB}, emitter reverse current I_{EO}, peak voltage and current, valley voltage and current, and η and V_D, etc. For convenience, we write Eq. (2-3) again.

$$V_P = \eta V_{B1B2} + V_D$$

Differentiating the above equation to temperature except η, we obtain

$$\frac{dV_P}{dT} = \eta \frac{dV_{B1B2}}{dT} + \frac{dV_D}{dT}$$

For a silicon diode, the value of dV_D/dT is negative. In other words, an increase of temperature will cause V_D to decrease. If making $\eta dV_{B1B2}/dT = dV_D/dT$, the frequency variation will be minimized by the use of proper R2.

A precise formulation of the R_2 value to be used is quite complex due to the number of UJT parameters involved. Motorola's engineers report that an empirically derived formula

$$R2 \approx 0.015\, V_B\, \eta\, R_{BB} \quad \text{(3-19)}$$

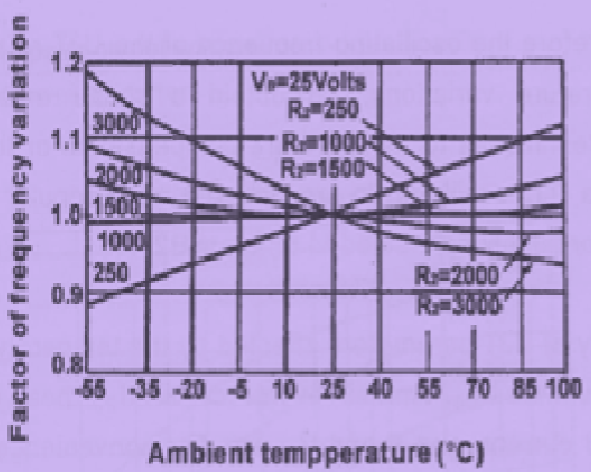


Fig.3-15 Temperature vs frequency variation with R2 as parameter

Fig. 3-15 shows the relationship between the oscillating frequency and temperature variation with various R2. As the figure shown, if R2 is chosen to 1.5 KΩ, the frequency of oscillation will be very stable within the temperature range between -5°C to 80°C.

Let us look at the design example of the UJT relaxation oscillator of Fig. 3-2(a).

Example 3-1 Given the UJT relaxation oscillator of Fig. 3-2(a). For the UJT, $V_V = 2V$, I_V = 6mA, η= 0.8, and R_{BB} = 8KΩ. With power supply V_B =20V, If the desired minimum output peak voltage at B1 is 1.5V and the desired frequency of oscillation is 5.6KHz, determine the values of R_E, C_E, R1, and R2.

From Eq. (3-15), the value of $R_{E(min)}$ is

$$R_E(min) = \frac{V_B - Vv}{Iv} = \frac{20-2}{6 \times 10^{-3}} = 3K\Omega$$

Choose $R_E = 3R_{E(min)} = 9K\Omega$. In such a case, we can use a fixed resistor of 10KΩ or a 25-KΩ potentiometer to adjust a precise frequency of oscillation.

The desired frequency of oscillation is 5.6KHz so that the period of oscillation is calculated by T =1/5.6KHz = 175μS. From Eq. (3-16), the capacitance of C_E would be

$$C_E = \frac{T}{R_E \times \ln\frac{1}{1-\eta}} = \frac{175 \times 10^{-6}}{10 \times 10^{3} \ln\frac{1}{1-0.8}} = 0.01\mu F$$

From Fig. 3-14, we use R1=50Ω for the conditions of C_E = 0.01μF and the desired minimum peak voltage of 1.5V.

The value of R_2 can be determined from Eq. (3-19). That is

$$
\begin{aligned}
R2 &= 0.015\, V_B\, \eta\, R_{BB} \\
&= 0.015 \times 20 \times 0.8 \times 8 \times 10^3 \\
&= 1920\Omega
\end{aligned}
$$

In most applications, the value of R2 is designed between 200Ω and 3KΩ. We use 2KΩ.

Designing the Triggering Circuits for Thyristors Using UJT Oscillator

Most triggering circuits for SCR and TRIAC switching use the basic UJT relaxation oscillator as a pulse generator. As shown in Fig. 3-16(a), the pulse voltage across R1 is used to trigger the gate of SCR.

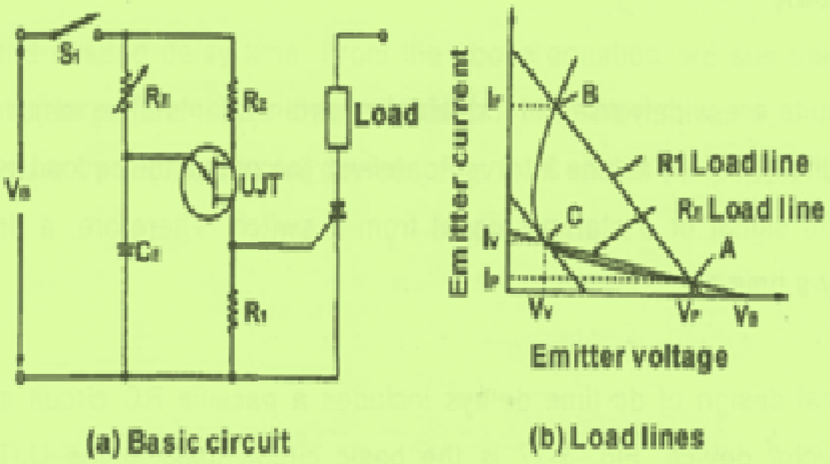


Fig.3-16 Basic UJT relaxation oscillator

There are some conditions that must be met in the design of the UJT relaxation oscillator as a triggering circuit. Besides the conditions for designing the relaxation oscillator as discussed above, some characteristics of thyristor should be concerned. In order to avoid premature triggering, R1 should be chosen so that:

$$V_{GT}(max) > \frac{R1 V_{B2}}{R_{BB} + R1} \quad (3\text{-}20)$$

$$(I_F - I_V)\, R1 > V_{GT}(min) \quad (3\text{-}21)$$

where $V_{GT(max)}$ is the maximum gate voltage that will not trigger the SCR or TRIAC and $V_{GT(min)}$ is the minimum gate voltage that will trigger the device. V_{B2} represents the voltage at the B_2 terminal. The capacitor discharge time constant should be greater than the turn-on time of the UJT so that saturation resistance will not affect the R1 load line. If we make $C_E \times R1$ at least 10 times t_{on}, then

$$C_E > \frac{10\, ton}{R1} \quad (3\text{-}22)$$

Fig. 3-16(b) shows the load lines and the static characteristic curve. The point B is the point of intersection of R1 load line with the characteristic . The emitter current at B, I_F, represents the peak gate current required for the thryristor.

Timer Circuit

Timer circuits are widely used in industrial control systems. The major function of a timer circuit is to delay a time interval to deliver the power to the load after receiving a command signal or a starting signal from a switch. Therefore, a timer circuit is essentially a time delay circuit.

The general design of dc time delays includes a passive RC circuit and an active semiconductor device. Fig. 3-17 is the basic circuit used in the UJT time delay. Notice that the circuit is the relaxation oscillator as discussed above.

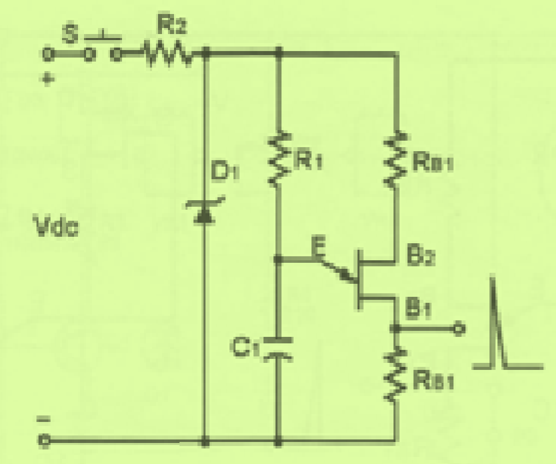


Fig.3-17 Basic UJT time delay circuit

When switch S is closed, the dc supply voltage provides the voltage for operation of the UJT relaxation oscillator through the zener regulation circuit consisting of R_2 and D_1. Current flow through resistor R_1 charges C_1 toward the zener voltage of D_1. When the voltage of C_1 reaches the peak point voltage V_P of the UJT, the UJT conducts so that the output pulse at B_1 can be used to trigger power control elements.

The design of the time delay circuit is the same as the UJT relaxation oscillator. The delay time is determined by the R1C1 time constant and R1 value is limited by the conditions of oscillation. The general equation for determined R1 is the following:

$$C > \frac{T}{R1} \qquad (3\text{-}28)$$

where T is the desired delay time. From the above equation, we see that long time delays require large and expensive capacitors. The alternative is to replace the charging resistor by semiconductor devices. Fig. 3-18 shows the popular circuits.

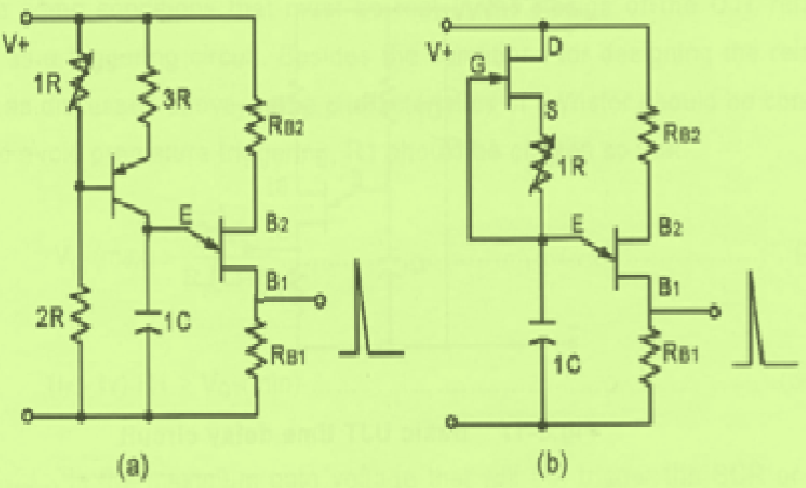


Fig.3-18 Time delay circuits

In Fig. 3-18(a), the charging resistor is replaced by a junction transistor. The charging current is controlled by the biasing resistors 1R, 2R, and 3R. A constant current source of higher impedance is achieved by using an FET in place of the charging resistor as in the circuit of Fig. 3-18(b). The amount of charge current is controlled by the choice of source resistor 1R.

Description of Experiment Circuit

Fig. 3-19 shows the experiment circuit on Module KL-53001. It consists of the UJT relaxation oscillator and UJT timer cirucits.

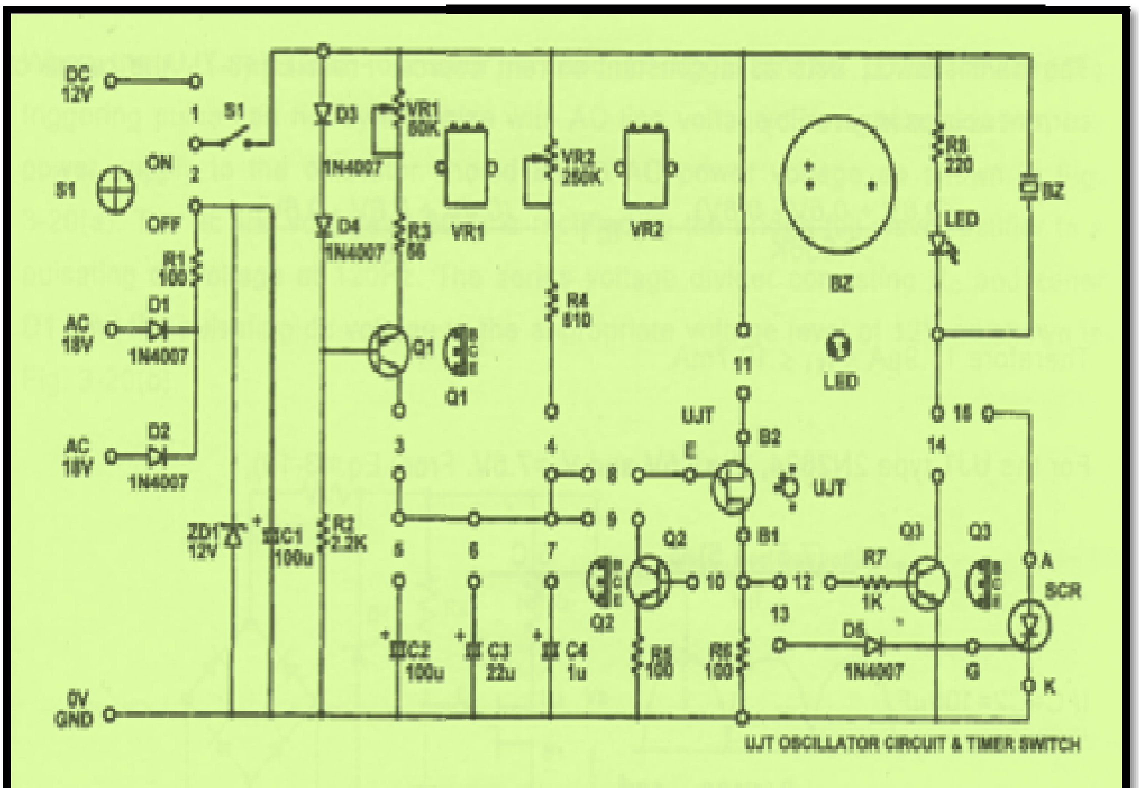


Fig.3-19 Experiment circuit

(1) UJT Oscillator Circuit

The power supply for the UJT oscillator circuit is 12Vdc voltage. When the power is applied, the charging current flows through charging resistors VR2 and R4 to charge C. From the capacitor charging formula, the charging time can be calculated as the following:

VR2=minimum, T1 = R4xC = 510 × C

VR2=maximum, T2 = (R4 + VR2)C = (510 + 250 × 10^3) × C

If C=C2=100μF, then T1=0.051 seconds, and f1 = 19.6 Hz

T2=25.051 seconds, and f2 = 0.0399 Hz

If C=C3=22μF, then T1=0.011 seconds, and f1 = 90.9 Hz

T2=5.51 seconds, and f2 = 0.181Hz

If C=C4=1μF, then T1=0.00051 seconds, and f1 = 1960.8Hz

T2=0.25 seconds, and f2 = 4 Hz

We can get a sawtooth wave at the emitter and a positive-going pulse at B1. Various frequencies can be obtained by adjusting VR2.

The transistor Q1 acts as a constant-current source. From Eq.(3-7), the range of current source is given by

$$\frac{(0.6V + 0.6V - 0.6V)}{50.056K} \le IE1 \le \frac{(0.6V + 0.6V - 0.6V)}{56\Omega}$$

Therefore $11.9\mu A \le I_{E1} \le 10.7mA$.

For the UJT type 2N2624, V_V=1.5V and V_P=7.5V. From Eq. (3-10),

$$T = \frac{(7.5 - 1.5)\,C}{I_{E1}} = \frac{6\,C}{I_{E1}}$$

If C=C2=100μF,

$$T1 = \frac{6 \times 100 \times 10^{-6}}{11.9 \times 10^{-6}} = 50.42\ s$$

$$f1 = 0.0198\ Hz$$

$$T2 = \frac{6 \times 100 \times 10^{-6}}{10.7 \times 10^{-3}} = 0.056\ s$$

$$f2 = 17.85\ Hz$$

If C = C3=22μF,

T1=11.09 Sec

f1=0.09 Hz

T2=0.012 Sec

f2 =83.33 Hz

If C=C4=1μF,

T1 = 0.5 Sec

f1 = 2 Hz

T2 = 0.00056 Sec

f2 = 1785.7 Hz

As mentioned above, the constant-current source provides good linearity for the sawtooth wave at the emitter.

When the UJT relaxation oscillator is used to trigger an AC power device, the triggering pulse can not synchronize with AC line voltage. For synchronization, the power supply to the oscillator should be an AC power voltage as shown in Fig. 3-20(a). The ac line voltage at 60Hz is rectified by the bridge full-wave rectifier to a pulsating dc voltage at 120Hz. The series voltage divider consisting R_D and zener D1 limit the pulsating dc voltage to the appropriate voltage level of 12V as shown in Fig. 3-20(b).

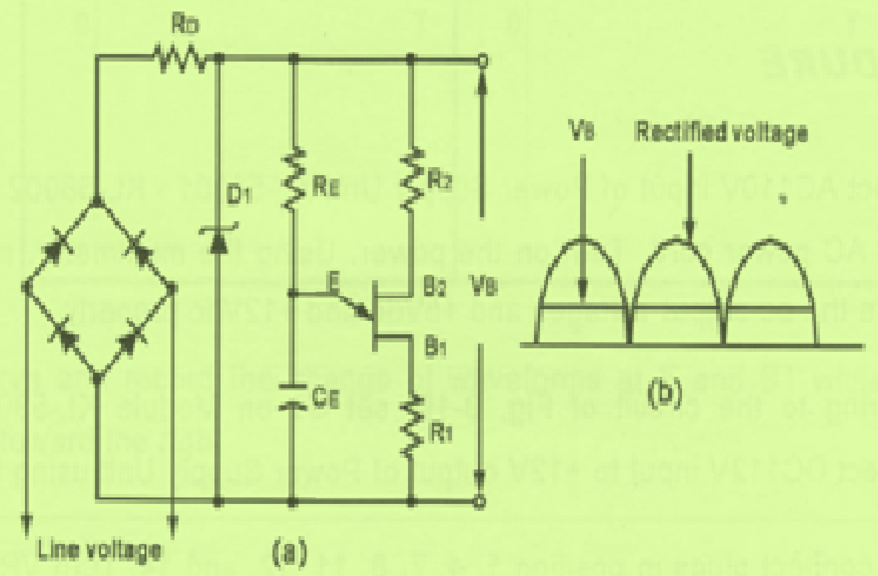


Fig.3-20 Triggering pulse synchronize with line voltage

Transistor Q2 is used to shorten the discharging time. The amount of V_V is determined by R5.

(2) Timer Circuit

The UJT relaxation oscillator is also used as a timer or time delay circuit. The frequency of output pulse is controlled by VR1 or VR2. The output pulse is available to drive a relay, lamp, SCR, or buzzer to achieve the control of ON-delay or OFF-delay.

In Fig. 4-19, the pulse voltage across R6 provides the base drive of transistor Q3 so that Q3 conducts and drives the LED and buzzer ON. When the delay time is over, the pulse voltage disappears and Q3 OFF. Both LED and buzzer are OFF.

EQUIPMENT REQUIRED

1 – Power Supply Unit KL-51001、KL-58002

1 – Isolation Transformer KL-58002

1 – Module KL-53001

1 - Oscilloscope

1 - Multimeter

PROCEDURE

1. Connect AC110V input of Power Supply Unit KL-51001、KL-58002 to AC outlet using AC power cord. Turn on the power. Using the multimeter, measure and ensure the ac output voltages and +5Vdc and +12Vdc properly.

2. Referring to the circuit of Fig. 3-19, set S1 on Module KL-53001 to OFF. Connect DC112V input to +12V output of Power Supply Unit using test leads.

3. Insert connect plugs in position 1, 4, 7, 8, 11, 12, and 14. Turn VR2 fully CCW to get the minimum value.

4. Switch S1 to ON position. Using the oscilloscope, measure and record the output pulse at B1 in Table 3-1. Measure and record the period of oscillation. T= ______________________________

   (Note: If no oscillation occurs, slowly turn VR2 to the right until a visible waveform is present.)

5. Using the oscilloscope, measure and record the voltage waveform at the emitter of the UJT in Table 3-1. Measure and record the period of oscillation. T=______________________________

   Do these two results of T agree? ____________________________________

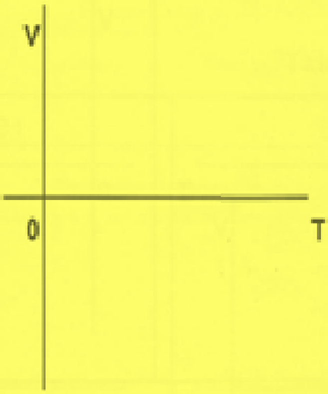
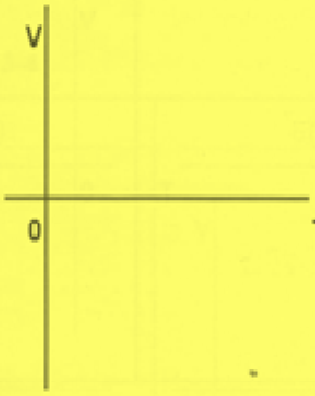
6. Turn VR2 fully CW. Observe and record the states of LED and buzzer. LED __________________________; Buzzer _____________________________

   Using a stopwatch, count and record the OFF time of LED.

   T=____

   (If circuit can't oscillate,turn VR2 CCW slowly.)

Table 3-1

B1	E
	

7. Observe and record the change of waveforms at E and B1 while turning the VR2 toward the right.

8. Turn VR2 fully CW. Calculate the period.

   T = (VR2 + R4) × C4 =______________________________

   (If circuit can't oscillate,turn VR2 CCW slowly.)

9. Using the oscilloscope, measure and record the waveform at B1 in Table 3-2. Measure and record the period of oscillation.

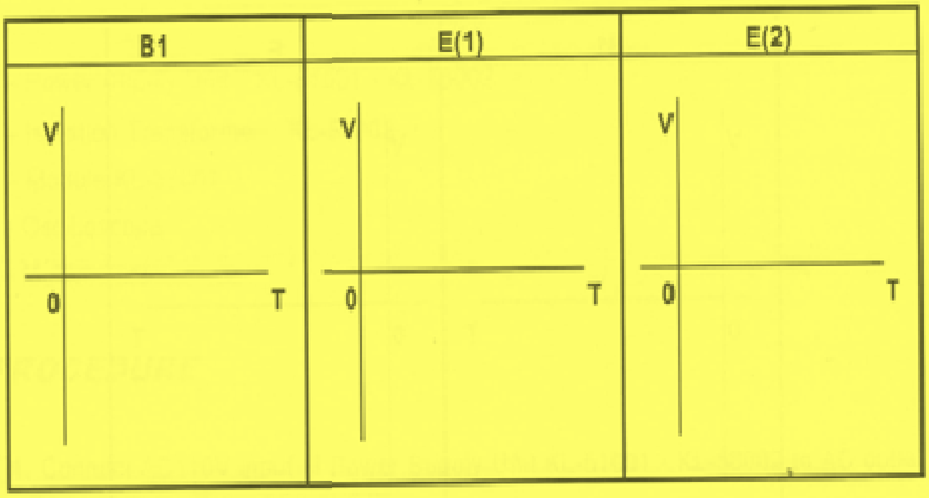
   T=____________________

10. Do these two results in steps 8 and 9 nearly agree?

11. Measure and record the waveform at E in Table 3-2. Measure and record the period of oscillation. T= ______________________

    Does this T agree with the T of step 9?

Table 3-2



12. From the voltage waveform at E, determine the parameters of UJT.

    V_V=____________________V; V_P=____________________V.

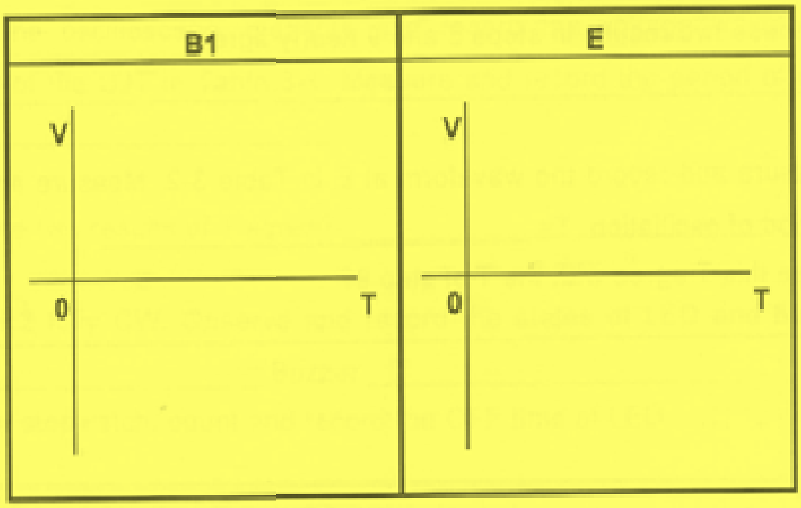
13. Remove connect plugs from positions 12 and 14 and then insert them in positions 13 and 15, respectively. Measure the time from S1 ON to LED and buzzer ON. T =__________________________

    Measure and record the volatge waveform at E in Table 3-2.

14. Remove the connect plug from position 7 and insert it in position 6. Turn VR2 fully CCW. Repeat steps 4 through 7 and record the results in Table 3-3.

    (If circuit can't oscillate,turn VR2 CW slowly.)

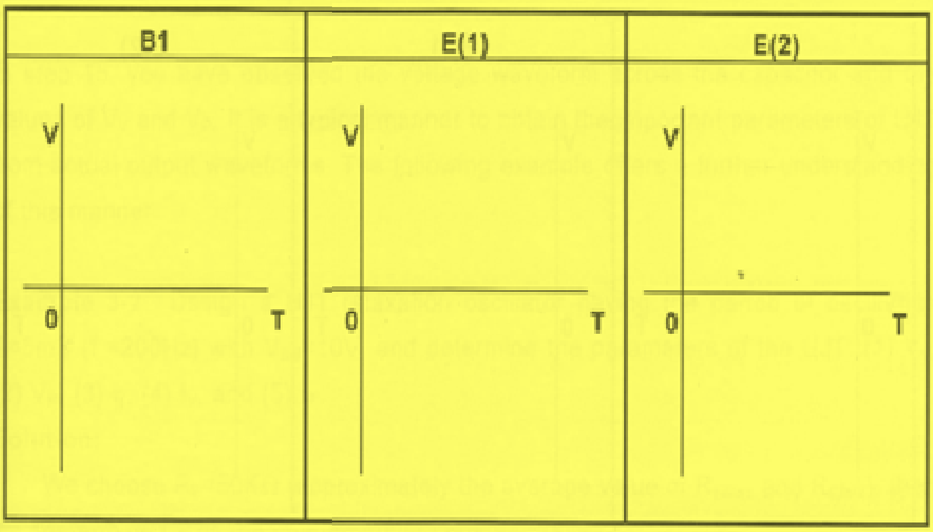
Table 3-3



15. Turn VR2 fully CW. Repeat steps 8 through 11 and record the results in Table 3-4.

(If circuit can't oscillate,turn VR2 CCW slowly.)

Table 3-4

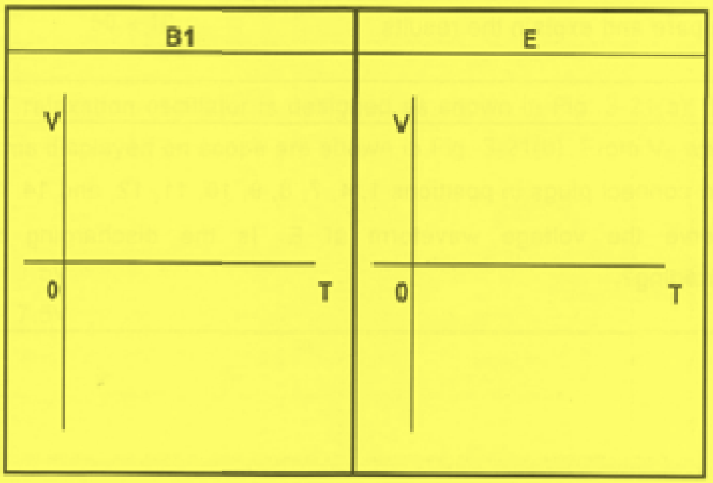


16. Repeat step 13 and record the result in Table 3-4.

17. Remove the connect plug from position 6 and insert it in position 5. Turn VR2 fully CCW. Repeat steps 4 through 7 and record the results in Table 3-5.

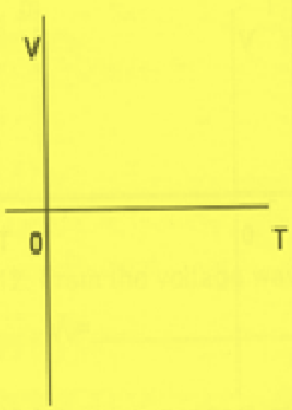
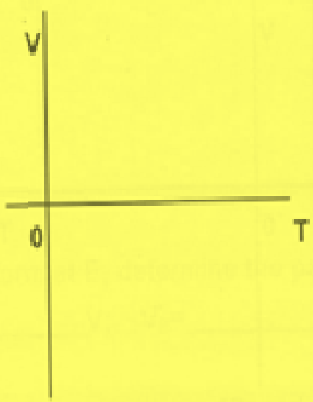
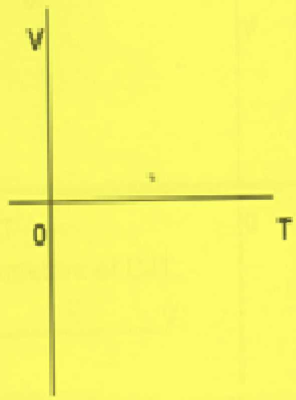
(If circuit can't oscillate,turn VR2 CW slowly.)

Table 3-5



18. Turn VR2 fully CW. Repeat steps 8 through 11 and record the results in Table 3-6.
(If circuit can't oscillate,turn VR2 CW slowly.)

Table 3-6

B1	E(1)	E(2)
		

19. Repeat step 13 and record the result in Table 3-6.
Remove all connect plugs.

20. Connect AC18V-0V-18V inputs to the outputs of Power Supply Unit. Insert connect plugs in positions 2, 4, 7, 8, 11, 12, and 14. Measure and the rectifier output voltage. ______________________________
Repeat the above steps for the measurements of UJT relaxation oscillator. Compare and explain the results.

21. Insert connect plugs in positions 1, 4, 7, 8, 9, 10, 11, 12, and 14. Measure and observe the voltage waveform at E. Is the discharging time rapidly shortening?

SUMMERY

The operation of UJT relaxation oscillator and timer circuits was examined. You have seen the slight difference between the calculated T and the measured T values. This is caused by the electrolytic capacitors that exist inherent error of capacitance.

In step 15, you have observed the voltage waveform across the capacitor and the values of V_V and V_P. It is a typical manner to obtain the important parameters of UJT from actual output waveforms. The following example offers a further understanding of this manner.

Example 3-2 Design a UJT relaxation oscillator having the period of oscillation T=5mS (f =200Hz) with V_{BB}=10V, and determine the parameters of the UJT: (1) V_V, (2) V_P, (3) η, (4) I_V, and (5) I_P.

Solution:

We choose R_E=50KΩ (approximately the average value of R_{Emax} and R_{Emin}), then determine C_E by the charging time-constant formula

$$T = C_E \times R_E$$

Taking T and R_E values into the equation

$$5mS = C_E \times 50K\Omega$$

$$C_E = \frac{5 \times 10^{-3}}{50 \times 10} = 0.01\mu F$$

The UJT relaxation oscillator is designed as shown in Fig. 3-21(a). The voltage waveforms displayed on scope are shown in Fig. 3-21(b). From V_E waveform, we obtain

(1) V_V = 1.5V

(2) V_P = 7.5V

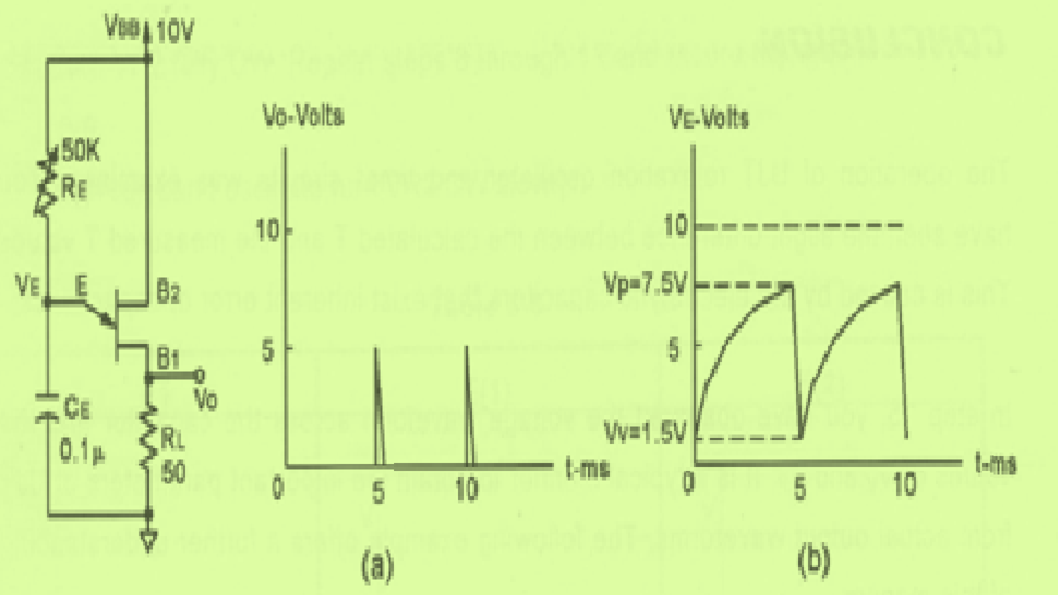


Fig.3-21 UJT relaxation oscillator and voltage waveforms

Slowly increase R_E(50KΩ) until the oscillation stops. Measure the value of R_E as R_{Emax}. Assume that R_{Emax}=3MΩ.

Inversely decrease R_E slowly until the oscillation stops. Measure the value of R_E as R_{Emin}. Assume that R_{Emin}=2KΩ.

From the known V_P=7.5V, V_V=1.5V, R_{Emax}=3MΩ, and R_{Emin}=2KΩ, we obtain

(3) $V_P = V_D + \eta V_{BB}, \therefore \eta = \dfrac{V_P - V_D}{V_{BB}} = \dfrac{(7.5 - 0.5)V}{10V} = 0.7$

(4) $R_{Emin} = \dfrac{V_{BB} - V_V}{I_V}, \therefore I_V = \dfrac{V_{BB} - V_V}{R_{Emin}} = \dfrac{(10-1.5)V}{2K\Omega} = 4.2mA$

(5) $R_{Emax} = \dfrac{V_{BB} - V_P}{I_P}, \therefore I_P = \dfrac{V_{BB} - V_P}{R_{Emax}} = \dfrac{(10-7.5)V}{3M\Omega} = 0.8\mu A$