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ELECTRICAL POWER & MACHINE DEPARTMENT

INDUSTRIAL POWER ELECTRONIC LABROTORY

PRACTICAL EXPERIMENTS IN POWER ELECTRONIC

FOR STUDENTS OF THIRD STAGE

EXPERIMENT NO.2

EXPERIMENT NA.UJT CHARACTERISTICS

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EXPERIMENT 2

UJT CHARACTERISTICS

OBJECTIVE

1. Understanding the construction and characteristics of a UJT.
2. Understanding the operation and the two-transistor equivalent of a UJT.
3. Measuring the characteristics of a UJT.
4. Constructing and measuring basic UJT application circuits.

THEORY

The unijunction transistor (UJT) has, like that for the SCR or TRIAC, been increasing at an exponential rate. It was first introduced in 1948 and became commercially available device from 1952. The low cost combined with the excellent characteristics of the device, have warranted its use in a wide variety of applications such as oscillators, trigger circuits, sawtooth generators, phase control, and timing circuits. Generally the UJT is a low-power-absorbing device under normal operating conditions and is a powerful device to promote the efficiency of systems.

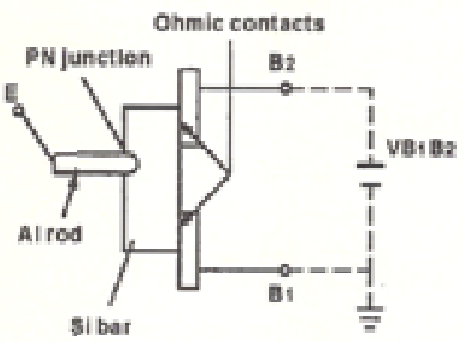

Fig.2-1 UJT construction

The UJT is conveniently considered as a silicon bar to which a p-n junction is made, as illustrated in Fig. 2-1. An n-type silicon bar with high resistivity has two base contacts attached to both ends and an aluminum rod alloyed to the silicon bar. The terminals from the two ends are called base 1 (B1) and base 2 (B2). The p-n junction of the device is formed at the boundary of the aluminum rod and the n-type silicon bar. The single p-n junction accounts for the terminology unijunction. The rectifying contact is called the emitter (E). The UJT was originally called a double base diode due to the presence of two base contacts. Note in Fig. 2-1 that the aluminum rod is alloyed to the silicon bar at a point closer to the B2 contact than the B1 contact. In practice, the B2 terminal is usually made positive with respect to the B1 terminal by the potential of V_{B1B2}. The circuit symbol and basic biasing arrangement for the UJT is shown in Fig. 2-2.

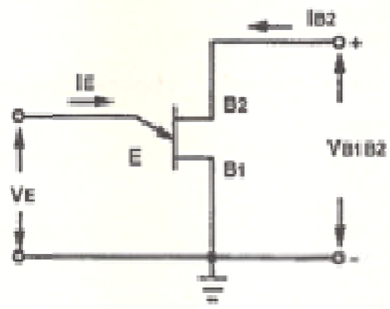

Fig.2-2 Circuit symbol and basic biasing arrangement for UJT

The equivalent circuit of the UJT is shown in Fig. 2-3. The diode represents the p-n junction characteristic between the emitter and the base bar. The interbase resistance R_{BB} is the resistance of the device between terminals B_2 and B_1 when $I_E=0$, and can be considered as consisting of the resistors R_{B1} and R_{B2} in series. In equation form,

$$R_{BB} = R_{B1}+R_{B2}\Big|_{I_E = 0} \qquad \text{(2-1)}$$

The magnitude of R_{BB} is typically from 4 to 10 KΩ. The resistance is fairly distributed between B_1 and B_2 when the emitter is open-circuited ($I_E = 0$). Due to the position of the emitter is closer to the base 2 contact than the base 1 contact, the magnitude of R_{B1} is slightly larger than the R_{B2} value. The resistance R_{B1} is shown as a variable resistor since its magnitude will vary with the emitter current I_E. For example, the R_{B1} values of 2N492 UJT are 4.6 KΩ at $I_E = 0$, 2KΩ at $I_E = 1mA$, 150Ω at $I_E = 10mA$, and 40Ω at $I_E = 50mA$.

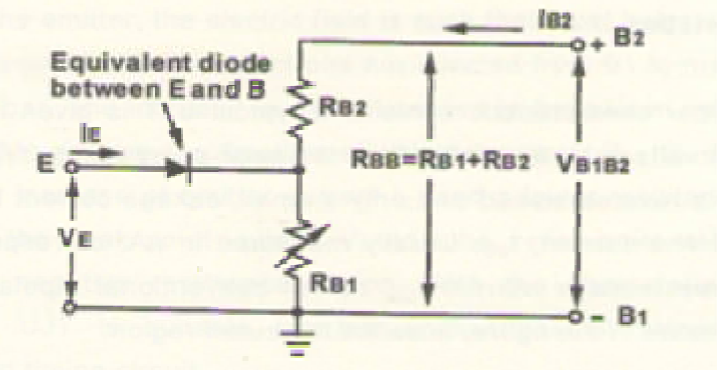

Fig.2-3 Equivalent circuit of UJT

The interbase resistance R_{BB} is dependent of temperature but the temperature coefficient is small, approximately 0.5 to 1%/°C.

With $I_E = 0$, the voltage drop on the resistor R_{B1} is determined by the voltage-divider rule:

$$V_{RB1} = \frac{R_{B1}}{R_{B1}+R_{B2}} \times V_{B1B2} \Big|_{I_E=0} = \eta \times V_{B1B2} \Big|_{I_E=0} \quad \text{..................(2-2)}$$

The intrinsic standoff ratio of the UJT, η, is typically within the range of 0.5 to 0.85. For example, the 2N4870 UJT has η values between 0.56 and 0.75, and 0.65 typical. The 2N4871 UJT has η values between 0.7 and 0.85, and 0.75 typical.

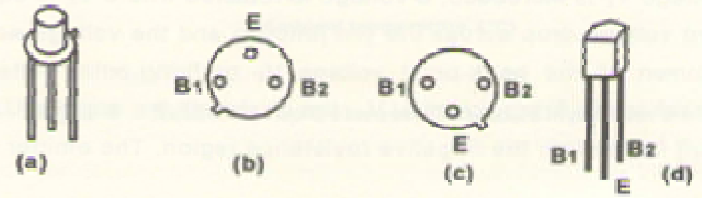

Fig.2-4 (a) UJT appearance, (b) Leads for 2SH20 and 2SH22, (c) Leads for SS537 and 2N2420, (d) Leads for 2N4870 and 2N4871

Fig. 2-4 shows the appearances and lead identifications of the commonly used UJTs.

UJT Characteristics

The static emitter characteristic curve of a typical UJT is given in Fig. 2-5. When applied emitter voltage V_E is smaller than the peak-point voltage V_P, the p-n junction at the emitter is reverse-biased and only a small leakage current I_{EO} normally flows in the emitter. The current, I_{EO}, usually measured in μA, corresponds very closely with the reverse leakage current I_{CO} of the conventional bipolar transistor. This region, as indicated in the figure, is called the cutoff region.

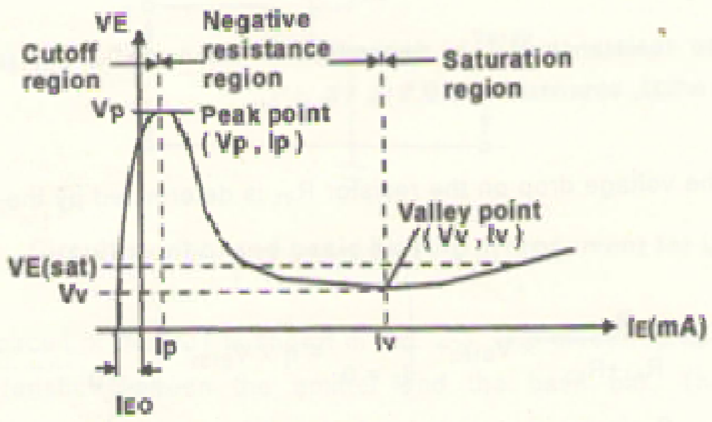

Fig.2-5 UJT static emitter characteristic

When the voltage V_E is increased, a voltage is reached where V_E is equal to the sum of the forward voltage drop across the p-n junction and the voltage across R_{B1}. This voltage is known as the peak-point voltage V_P or firing-point voltage. When the applied V_E reaches the firing potential V_P, the diode will fire and the UJT will conduct from the cutoff region into the negative resistance region. The emitter firing potential is given by

$$V_P = \eta V_{B1B2} + V_D \qquad (2\text{-}3)$$

where the forward voltage drop across the diode V_D is typically 0.7V.

As the emitter-base1 voltage greater than V_P the p-n junction is forward-biased so that holes are injected from the emitter into the silicon bar. Since the B1 is negative with respect to the emitter, the electric field is such that most holes move toward the B1 terminal. An equal number of electrons are injected from B1 to maintain electrical neutrality in the bar. The increase in current carried in the silicon bar decreases the value of R_{B1}. This causes the fraction of voltage across R_{B1} to decrease, which causes a further increase of emitter current I_E, and a lower resistance for R_{B1}. This region between the peak point voltage V_P and the valley-point voltage V_V on the curve is called negative resistance region. With the characteristic of negative resistance, the UJT is suitable for the applications of relaxation oscillator, multivibrator, and timing circuit.

From Eq. (2-3), the peak-point voltage V_P is proportional to the magnitude of the interbase voltage V_{B1B2} and is inversely proportional to the operating temperature. The peak-point current I_P, measured in μA or nA, is the minimum emitter current required to fire the UJT. The I_P is inversely proportional to the V_{B1B2}. Fig. 2-6 shows the relationship between I_P and temperature with V_{B1B2} = 20V. When the temperature exceeds 25℃, the I_P will decrease with the temperature increased.

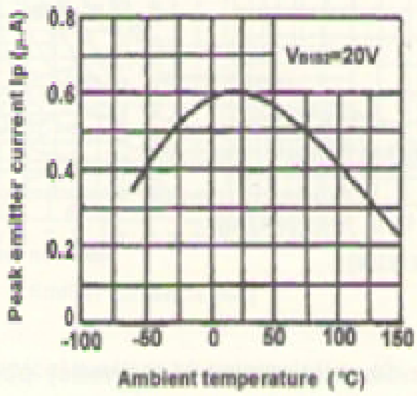

Fig.2-6 Relatonship between IP and temperature

The lowest point on the curve is called the valley point. As shown in Fig. 2-7, when the magnitude of V_{B1B2} increases, the valley-point voltage V_V increases. If the junction temperature increases, the valley-point voltage will decrease. With a constant V_{B1B2}, the valley-point voltage is inversely proportional to the magnitude of the resistor R2 externally connected to B2, while it is directly proportional to the resistor R1 connected to B1. The emitter current at the valley point is called the valley-point current. As the V_{B1B2} increases, the valley current increases. If the junction temperature increases, the valley current will decrease. The characteristics of the valley current are shown in Fig. 2-8. In addition, an increase in R1 or R2 will cause a decrease in the valley-point current.

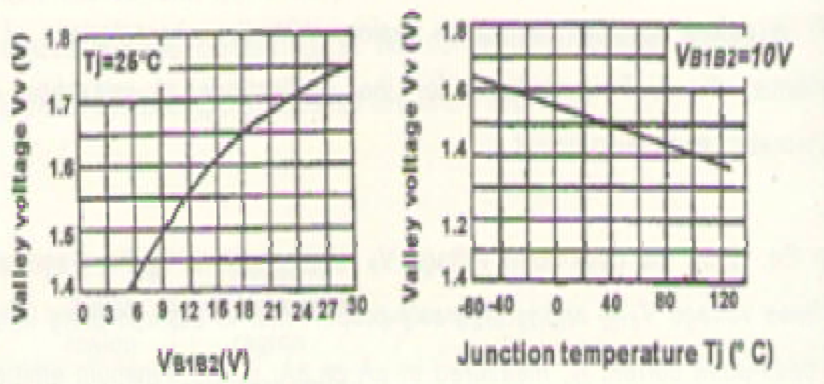

Fig.2-7 Characteristics of the valley-point voltage

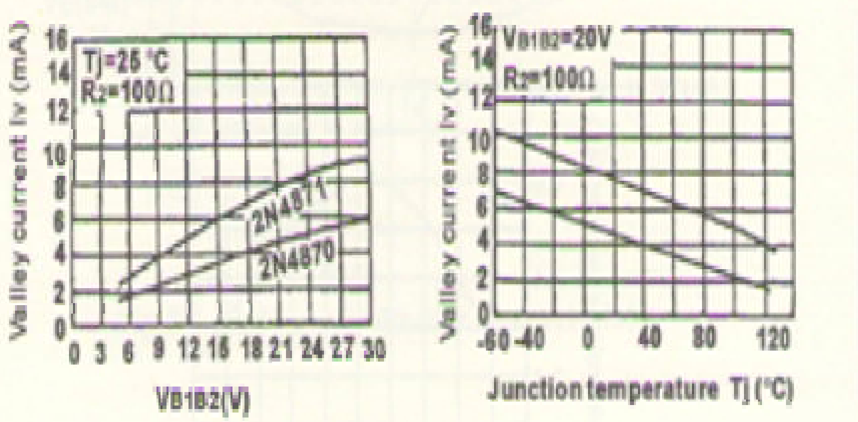

Fig.2-8 Characteristics of the valley-point current

At the valley-point voltage and higher voltages the density of charge carriers is so high that the lifetime of the carriers is decreased which counteracts the effect of new carriers being generated, and the emitter voltage V_E increases gradually at currents above I_V and then reaches a nearly constant value $V_{E(sat)}$. This voltage is called saturation voltage. The region to the right of the valley point is known as the saturation region, where the dynamic resistance is determined by the slope of I-V curve and is given between 10 and 20Ω.

If the emitter voltage returns to zero, the UJT operating in saturation will be cut off. The emitter resistance of UJT ranges from several hundred ohms to several mega ohms. In cutoff region, the emitter resistance is typically several hundred thousand ohms or several mega ohms. In negative resistance region, the emitter resistance is typically several thousand ohms and is about several hundred ohms in saturation region.

From Eq. (2-3), the magnitude of V_P will vary as V_{BB} for the fixed values of V_D and η. A typical set of static emitter characteristic curves is provided in Fig. 2-9.

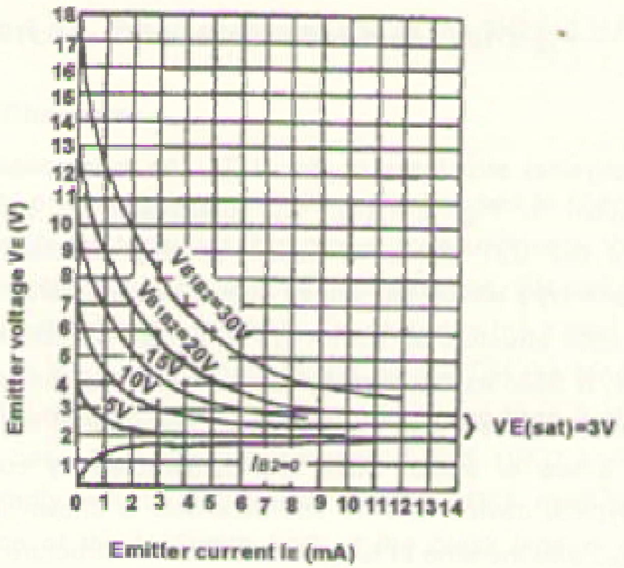

Fig.2-9 Typical emitter characteristic curves of a UJT

One of the important characteristics of UJT is the interbase characteristic shown in Fig. 2-10. The interbase characteristic, similar to the collector characteristic of a conventional transistor, shows that the resistance of the interbase is linear only when the emitter current is zero. In designing a UJT circuit, a load line is plotted on the curves to determine the amplitude of output signal.

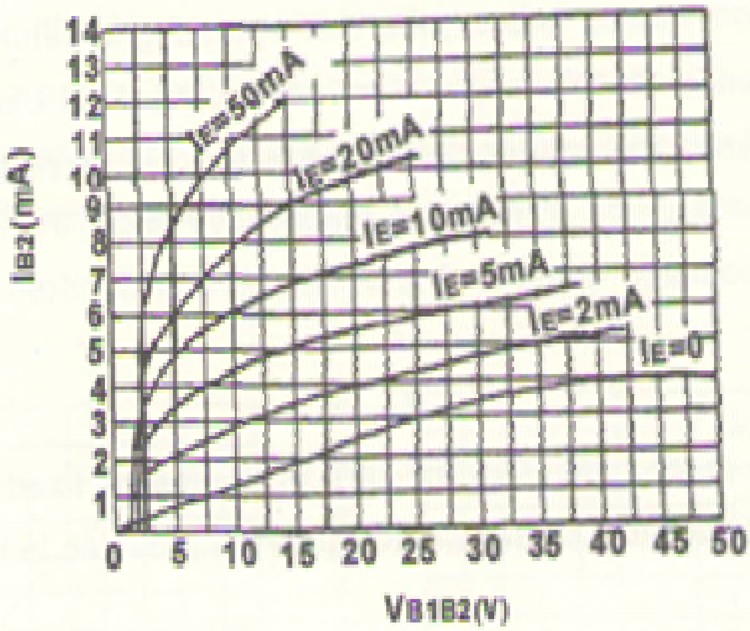

Fig.2-10 Interbase characteristic of UJT

There are two physical structures of the UJT. The most popular one is the bar structure as shown in Fig. 2-11(a). The discussion of the construction and characteristics of the UJT above is based on this structure. The base bar is constructed by an n-type silicon bar whose size is approximately 8 × 10 × 60 mils.

The other is the cube structure as shown in Fig. 2-1(b). A cubic n-type silicon, about 13 × 17 × 17 mils, is used as the base bar and a metal rod (B1) of 2 mils in diameter is brought into ohmic contact with the base bar. The lead of B2 is connected to the substrate. Only a few of actual UJTs are constructed by cube structure. Type 2N2646 is the typical device and its characteristic is shown in Fig. 2-12. It has smaller V_P, $V_{CE(sat)}$, and the time of turn on than the bar structure. In addition, a large pulse can be obtained from B1 lead so that it is suitable for the use of trigger pulse generators.

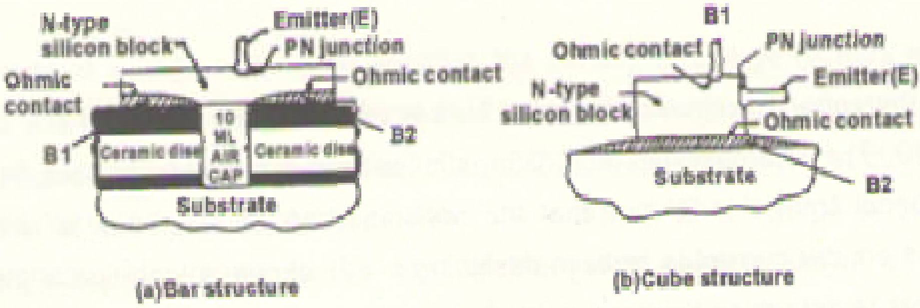

Fig.2-11 UJT structures

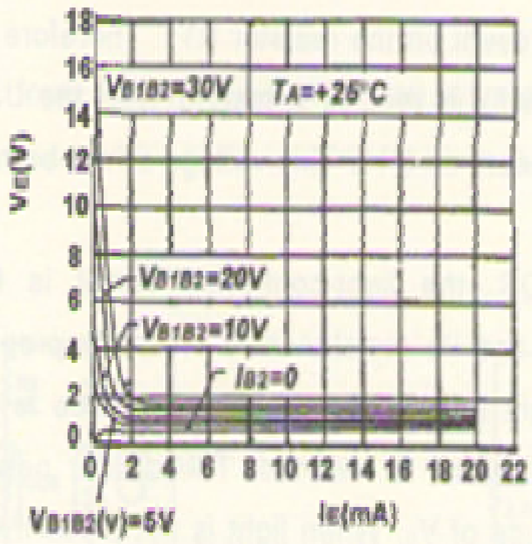

Fig.2-12 Static characteristic of the 2N2646 UJT

Testing UJT with Ohmmeter

An ohmmeter, found on the analog multimeter, can be used to check the condition of the UJT and to identify the terminals. For proper measurements, the internal battery polarity of the ohmmeter should be verified before testing. We use an ohmmeter that the negative of internal battery is internally connected to the + lead (normally the red) and the positive is to the – lead (normally the black). Set the range selector of the multimeter to R×1KΩ range. Connect the red lead to the base 2 of the UJT and the black lead to the base 1. A reading between 4 and 10KΩ should be obtained. Reversing the polarity will be the same reading. This reading represents the interbase resistance of the UJT with I_E=0. If the black lead is connected to the emitter and the red lead to the base 1 or base 2, the p-n junction is forward-biased by the internal battery and the meter should indicate a low resistance. Thus the emitter terminal is located. The resistance of E-B1 is greater than the resistance of E-B2. Thus these three terminals of the UJT are identified.

Description of Experiment Circuit

Fig. 2-13 shows the experiment circuit on the KL-53001 module. Transistors Q1 and Q2 form a two-transistor equivalent circuit of the UJT. It is used to simulate the operation of an actual UJT. The transistor Q3 acts as an LED driver and its base drive comes from the trigger signal across R11. The UJT and associated components are used for the characteristic measurements. AC voltage source and the series divider network R4, VR1, and R5 determine the emitter voltage V_E of the UJT. If VR1 is very small, the UJT will operate in cutoff state due to $V_E<V_P$ and thus no output voltage is present on the resistor R11. Therefore Q3 and LED are OFF. If the condition $V_E>V_P$ +0.5V is met by adjusting VR1, the UJT will be turned on and the output voltage appears on R11. This voltage drives both Q3 and LED ON.

Replacing R4 by CDS, the light-controlled circuit is formed. The CDS is a light-sensitive device and its resistance is inversely proportional to light level. In other words, when light is not present, the resistance is increased. When light is present, the CDS resistance is reduced. The divider network CDS, VR1, and R5 determine the magnitude of V_E. When light is not present, the resistance of CDS is quite large so that $V_E<V_P$ and the UJT is cutoff. If the CDS's resistance is reduced by the high light level, the V_E will increase to a sufficient voltage to fire the UJT and thus the LED is ON. In this case, the potentiometer VR1 is used as a sensitivity adjustment. This circuit is a basic control circuit of streetlight.

When replacing R4 by the thermistor RTH, the circuit can be used as a fire alarm circuit. The RTH is a negative temperature coefficient (NTC) thermistor. The resistance of an NTC is inversely proportional to the ambient temperature. In other words, a temperature increase causes the resistance of an NTC thermistor to decrease; a temperature decrease causes the resistance of an NTC thermistor to increase. The operating principle of this circuit is similar to the CDS light-controlled circuit discussed above.

EQUIPMENT REQUIRED

1 — Power Supply Unit KL-51001
1 — Isolation Transformer KL-58002
1 — Module KL-53001
1 — Analog Multimeter
1 — Dual-Trace Oscilloscope

PROCEDURE

1. Connect AC 12V from Power Supply Unit KL-51001 · KL-58002 to Module KL-53001.

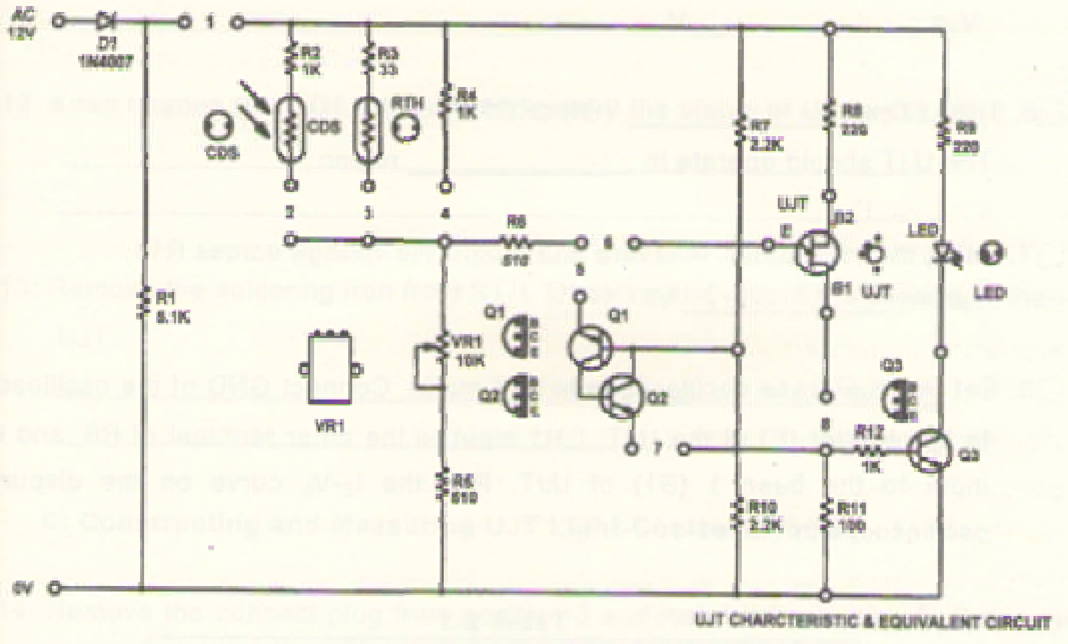

Fig. 2-13 Experiment circuits

A. UJT Characteristic Measurement

2. Insert connect plugs in 1, 4, 6, and 8 positions. Adjust VR1 fully CCW to obtain a minimum resistance.

3. Turn on the power. Observe and record the state of LED. ____________
   The UJT is operating in ____________ region. Using the multimeter, measure and record the voltage across R11. ______________ V.

4. Measure and record the emitter voltage of the UJT with the multimeter (the red lead to E, the black lead to GND).
   V_E= ______________ V

5. Slowly turning the VR1 to the right (CW), observe the change of V_E until the voltage reading reaches a peak value and abruptly reduces to a valley value. Record the peak and valley values. The peak value represents the peak-point voltage of the UJT and the valley value is the valley-point voltage.

V_P= ______________ V

V_V= ______________ V

6. The LED is ______________ (ON or OFF).

The UJT should operate in ______________ region.

7. Using the multimeter, measure and record the voltage across R11.

V_{R11}= ______________ V.

8. Set the dual-trace oscilloscope to X-Y mode. Connect GND of the oscilloscope to the emitter (E) of the UJT, CH1 input to the other terminal of R6, and CH2 input to the base 1 (B1) of UJT. Plot the I_E-V_E curve on the display of oscilloscope in Table2-1.

Table 2-1

9. Adjusting VR1, observe and record the change of I_E-V_E curve.

10. Turn off the power.

B. Contructing and Measuring UJT Temperature-Control Circuit

11. Remove the connect plug from position 4 and insert it in position 3. Turn the power. Approach a hot soldering iron to the thermistor RTH. Measure a record the change of V_E. *(Properly adjust VR1)*
12. *Keep heating the RTH. Observe and record the states of UJT and LED.*
13. Remove the soldering iron from RTH. Observe and record the change of the UJT.

C. Constructing and Measuring UJT Light-Control Circuit

14. Remove the connect plug from position 3 and insert it in position 2. Cover the CDS window with your hand. Observe and record the states of UJT and LED. (Properly adjust VR1)
15. Remove your hand from the CDS window to increase sensed light level. Observe and record the states of UJT and LED.

D. Measuring the Characteristics of Two-Transistor UJT

16. Insert connect plugs in 1, 4, 5, and 7 positions. Set the dual-trace oscilloscope to X-Y mode. Connect GND of the oscilloscope to the emitter of Q1, CH1 input to the other terminal of R6, and CH2 input to the emitter of Q2. Plot the I_E-V_E curve on the display of oscilloscope in Table 2-2.

Table 2-2

SUMMERY

In procedure step 5, the measured V_P and V_V should be about 2.5V and 0.9V, respectively. By the equation $V_P=\eta V_{B1B2} + V_D$, the η value of the UJT can be obtained.

A resistance increase of VR1 causes the emitter voltage V_E to increase. When V_E reaches the value of V_P+0.5V, the UJT is turned on and the voltage drop on the resistor R11 should be about 0.5V. This voltage drives transistor Q3 into conducting so that the LED should be ON.

QUATIONS