Unijunction Transistor (UJT)
&
Programmable Unijunction Transistor(PUT)

Unijunction Transistor (UJT)

- Although first introduced in 1948, the device did not become commercially available until 1952.
- The *low cost per unit* combined with the *excellent characteristics* of the device have warranted its use in a wide variety of applications, including “oscillators, trigger circuits, sawtooth generators, phase control, timing circuits, bistable networks, and voltage- or current-regulated supplies”.
- The fact that this device is, in general, a **low-power-absorbing** device under normal operating conditions is a tremendous aid in the continual effort to design relatively efficient systems.

Programmable Unijunction Transistor(PUT)

- The programmable unijunction transistor (PUT) is actually a type of thyristor and not like the UJT at all in terms of structure.
- The only similarity to a UJT is that the PUT can be used in some oscillator applications to **replace the UJT**.
- The PUT is similar to an SCR except that **its anode-to-gate** voltage can be used to both turn on and turn off the device.

Unijunction Transistor (UJT)

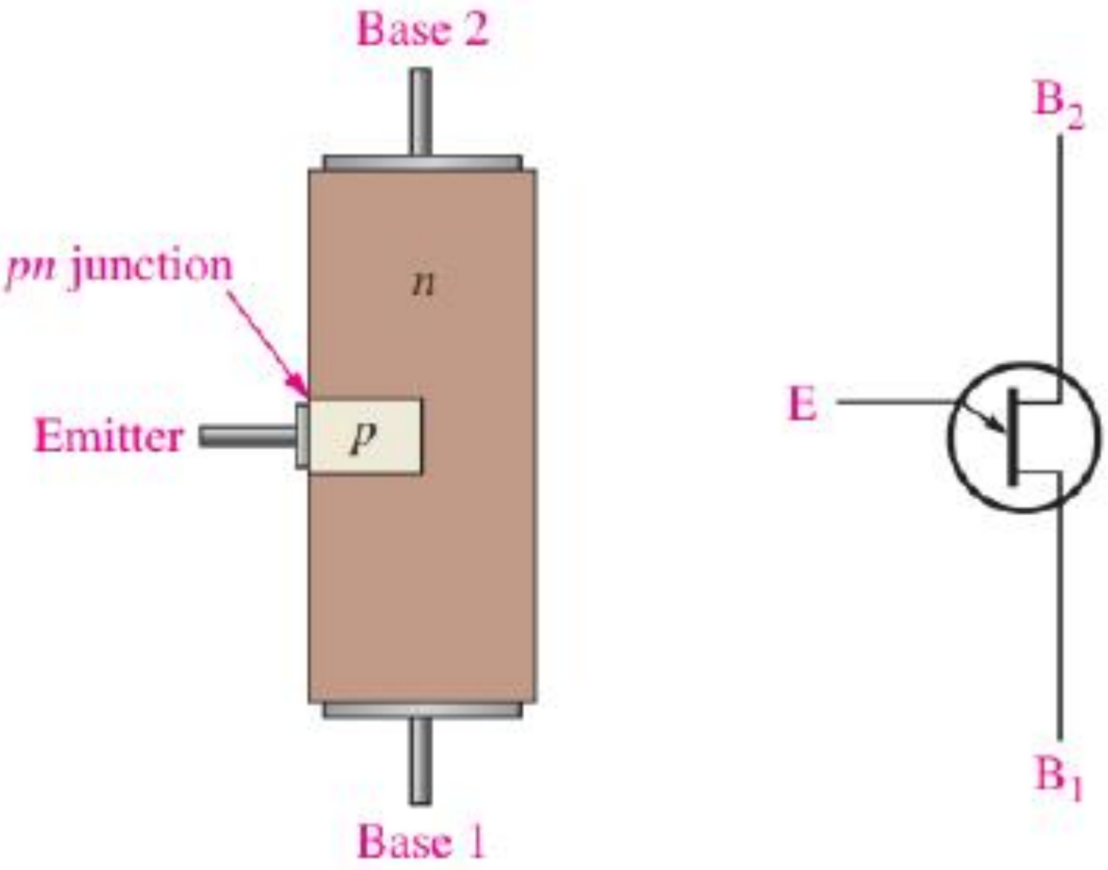
UNIJUNCTION TRANSISTOR (UJT)

- The unijunction transistor **does not belong** to the thyristor family because it **does not have a four-layer** type of construction.
- The term “unijunction” refers to the fact that the UJT has a **single pn junction**.
- The UJT is useful in certain oscillator applications and as a triggering device in thyristor circuits.
- It is a three-terminal device whose basic construction is shown in Figure 2–1(a). The schematic symbol appears in Figure 2–1(b).

UNIJUNCTION TRANSISTOR (UJT)

▶ FIGURE 2-1

The unijunction transistor (UJT).



(a) Basic construction (b) Symbol

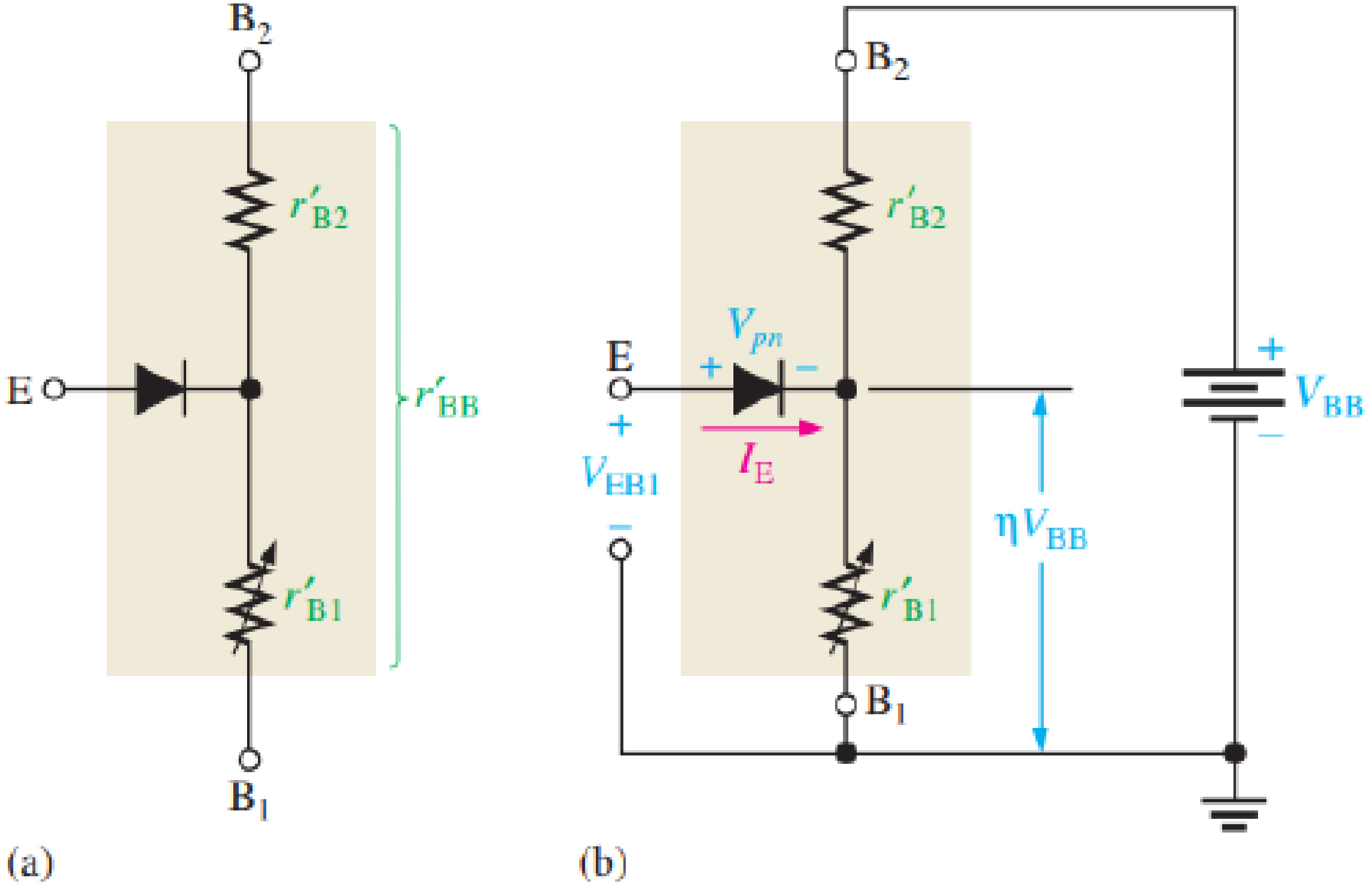
UNIJUNCTION TRANSISTOR (UJT)

- Notice the terminals are labelled Emitter (E), Base 1 (B1), and Base 2 (B2).
- Do not confuse this symbol with that of a JFET; the difference is that the arrow is at an angle for the UJT.
- The UJT has only one pn junction, and therefore, the characteristics of this device are different from those of either the BJT or the FET.

Equivalent Circuit

▶ FIGURE 2-2

UJT equivalent circuit.



Equivalent Circuit

- The equivalent circuit for the UJT, shown in Figure 2–2(a), will aid in understanding the basic operation.
- The **diode** shown in the figure represents the pn junction r’B1, represents the internal dynamic resistance of the silicon bar between the emitter and base 1, and r’B2 represents the dynamic resistance between the emitter and base 2.
- The total resistance between the base terminals is the sum of r’B1 and r’B2 and is called the interbase resistance, r’BB.

$$r'_{BB} = r'_{B1} + r'_{B2}$$

Equivalent Circuit

- The value of *r′*B1 varies inversely with emitter current *I*E, and therefore, it is shown as a variable resistor.
- Depending on *I*E, the value of *r′*B1 can vary from several thousand ohms down to tens of ohms.
- The internal resistances *r′*B1 and *r′*B2 form a voltage divider when the device is biased, as shown in Figure 2–2(b).
- The voltage across the resistance *r′*B1 can be expressed as

$$V_{r'_{B1}} = \left(\frac{r'_{B1}}{r'_{BB}}\right) V_{BB}$$

Standoff Ratio (η)

- The ratio $\frac{r'_{B1}}{r'_{BB}}$ is a UJT characteristic called the intrinsic standoff ratio and is designated by "**η**".

$$\eta = \frac{r'_{B1}}{r'_{BB}}$$

- As long as the applied emitter voltage ***V*EB1 is less than $Vr'B1$+Vpn** there is no emitter current because the *pn* junction is not forward-biased (Vpn is the barrier potential of the *pn* junction).
- The value of emitter voltage that causes the pn junction to become forward-biased is called **peak-point voltage** and is expressed as

$$V_P = \eta V_{BB} + V_{pn}$$

- When VEB1 reaches VP, the pn junction becomes forward-biased and IE begins.
- Holes are injected into the n-type bar from the p-type emitter.
- This increase in holes causes an increase in free electrons, thus increasing the conductivity between emitter and B1 (decreasing r’B1).
- After turn-on, the UJT operates in a negative resistance region up to a certain value of as shown by the characteristic curve in Figure 2–3.

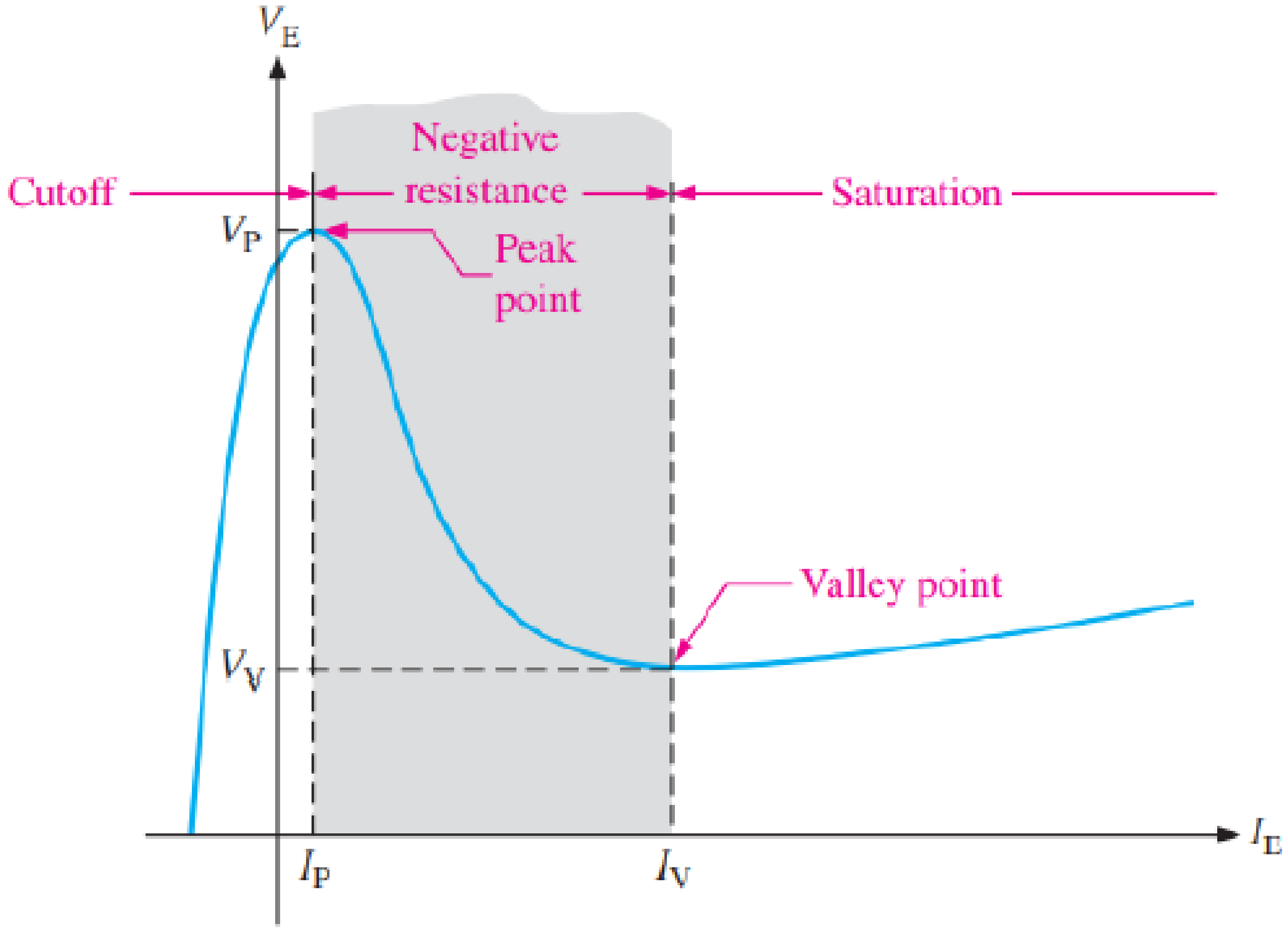


FIGURE 2-3

UJT characteristic curve for a fixed value of V_{BB}.

- As you can see, after the peak point ($VE = VP$ and $IE = IP$), VE decreases as IE continues to increase, thus producing the negative resistance characteristic.
- Beyond the valley point ($VE = VV$ and $IE = IV$), the device is in saturation, and VE increases very little with an increasing IE.

UJT Application

- The UJT can be used as a trigger device for SCRs and triacs.
- Other applications include nonsinusoidal oscillators, sawtooth generators, phase control, and timing circuits.
- Figure 2–4 shows a UJT relaxation oscillator as an example of one application.

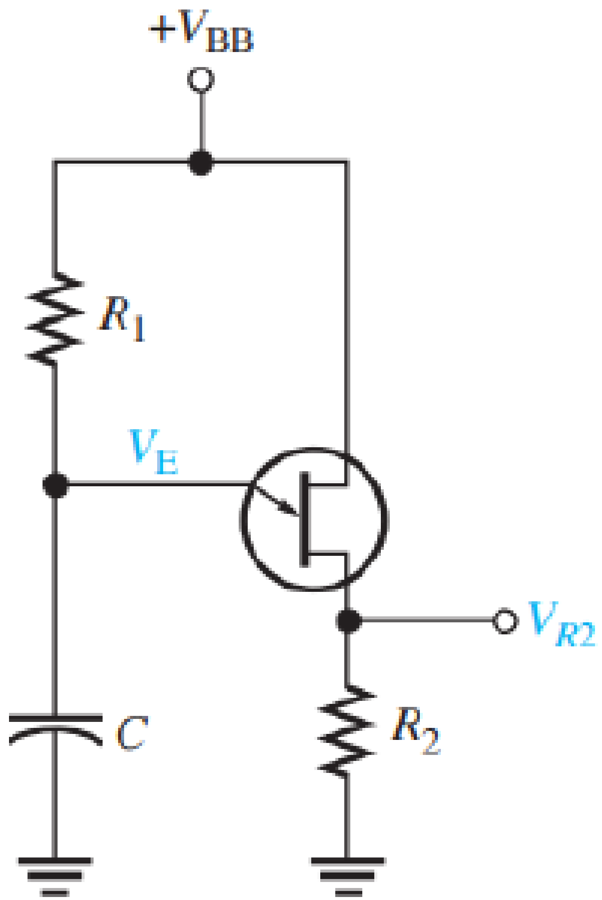


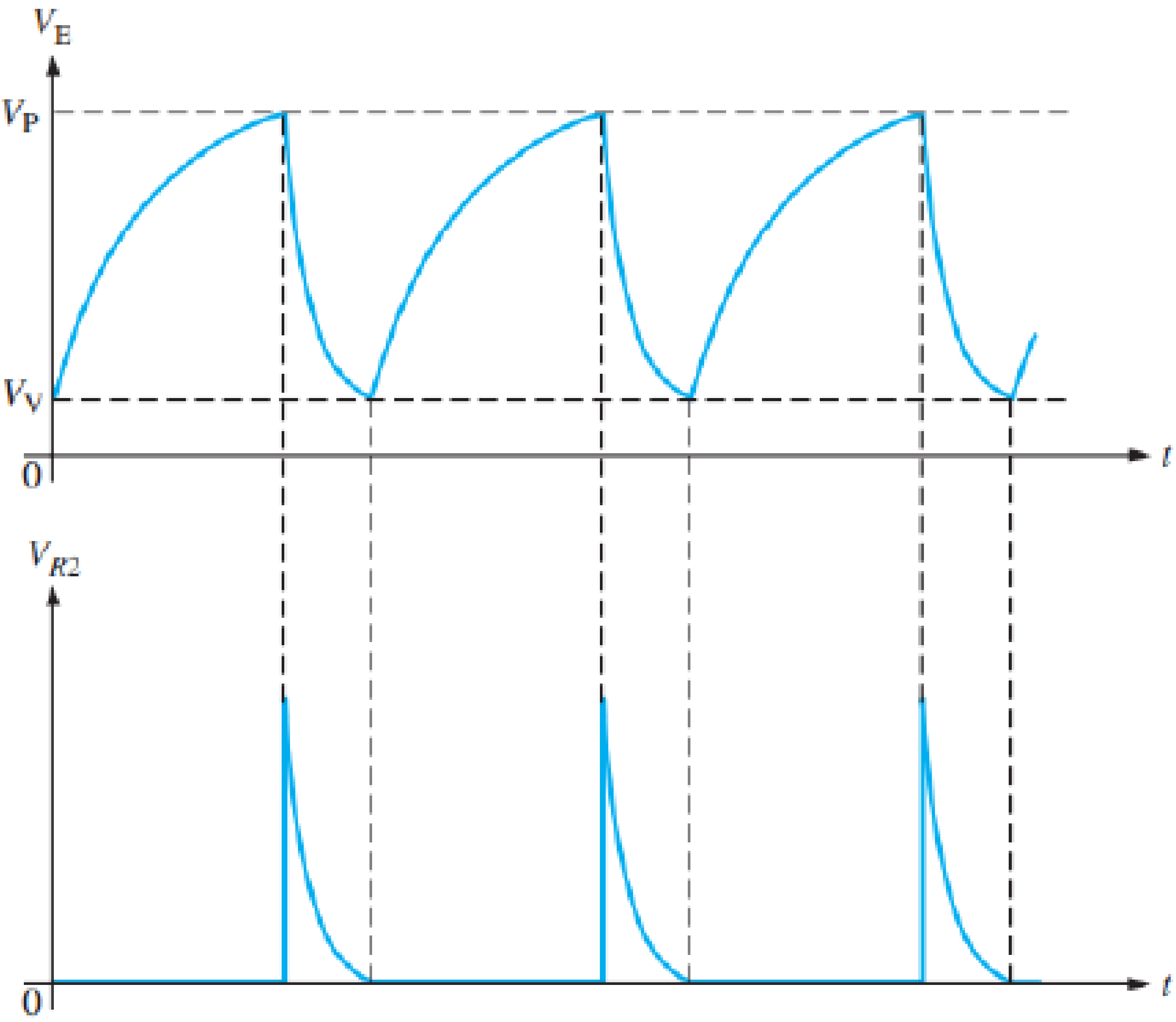
FIGURE 2-4

Relaxation oscillator.

Relaxation Oscillator

- When dc power is applied, the capacitor C charges exponentially through R1 until it reaches the peak-point voltage VP.
- At this point, the pn junction becomes forward-biased, and the emitter characteristic goes into the negative resistance region (VE decreases and IE increases).
- The capacitor then quickly discharges through the forward-biased junction, r'B, and R2.
- When the capacitor voltage decreases to the valley-point voltage Vv, the UJT turns off, the capacitor begins to charge again, and the cycle is repeated, as shown in the emitter voltage waveform in Figure 2–4 (top).
- During the discharge time of the capacitor, the UJT is conducting. Therefore, a voltage is developed across R2, as shown in the waveform diagram in Figure 2–4 (bottom).
- When a UJT is used as a relaxation oscillator, the **time required** for the capacitor to reach **Vp** is

$$T = R_1 C \ln\left(\frac{1}{1-\eta}\right)$$



▲FIGURE 2-5

Waveforms for UJT relaxation oscillator.

Conditions for Turn-On and Turn-Off

- In the relaxation oscillator of Figure 2–4, certain conditions must be met for the UJT to reliably turn on and turn off.
- First, to ensure turn-on, **R1 must not limit IE at the peak point to less than IP**.
- To ensure this, the voltage drop across R1 at the peak point should be greater than IPR1 Thus, the condition for turn-on is

$$V_{BB} - V_P > I_P R_1$$

or

$$R_1 < \frac{V_{BB} - V_P}{I_P}$$

- To ensure turn-off of the UJT at the valley point, *R1* must be large enough that *IE* (at the valley point) can decrease below the specified value of *IV*.
- This means that the voltage across *R1* at the valley point must be less than *IVR1*. Thus, the condition for turn-off is

$$V_{BB} - V_V < I_V R_1$$

or

$$R_1 > \frac{V_{BB} - V_V}{I_V}$$

- Therefore, for a proper turn-on and turn-off, *R* must be in the range

$$\frac{V_{BB} - V_P}{I_P} > R_1 > \frac{V_{BB} - V_V}{I_V}$$

Programmable Unijunction Transistor(PUT)

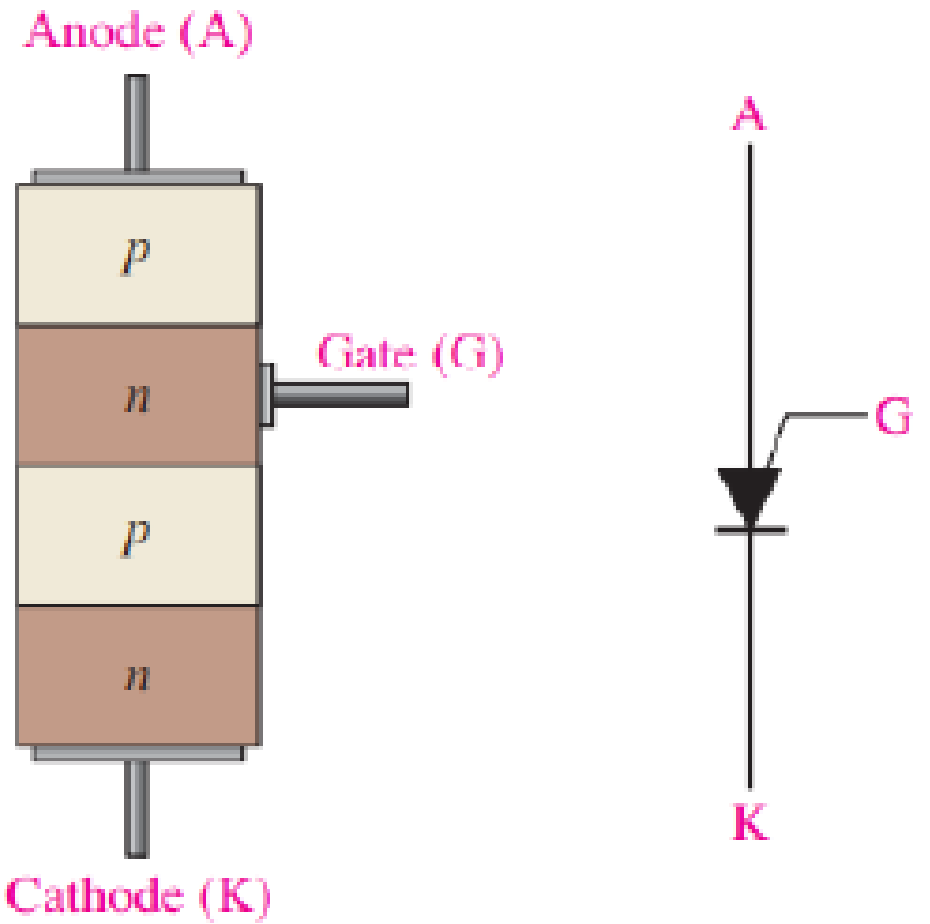
Programmable Unijunction Transistor(PUT)

- Programmable unijunction transistor or PUT is a close relative of the thyristor family.
- Its has a four layered construction just like the thyristors and have three terminals named anode(A), cathode(K) and gate(G) again like the thyristors.
- Some call it a programmable UJT just because its characteristics and parameters have much *similarity* to that of the *unijunction transistor*.
- It is called programmable because the parameters like intrinsic **standoff ratio** (η), **peak voltage**(Vp), etc. can be programmed with the help of two external resistors.
- The main application of programmable UJT are relaxation oscillators , thyristor firing, pulse circuits and timing circuits.

Programmable Unijunction Transistor(PUT)

FIGURE 2-6

The programmable unijunction transistor (PUT).



(a) Basic construction (b) Symbol

PUT characteristics

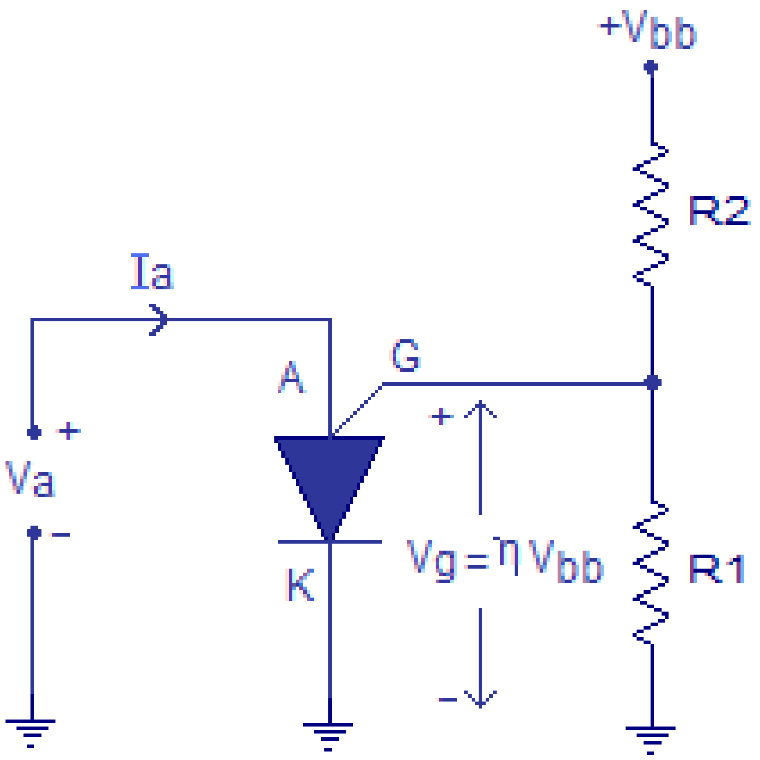


Fig 3: PUT biasing circuit

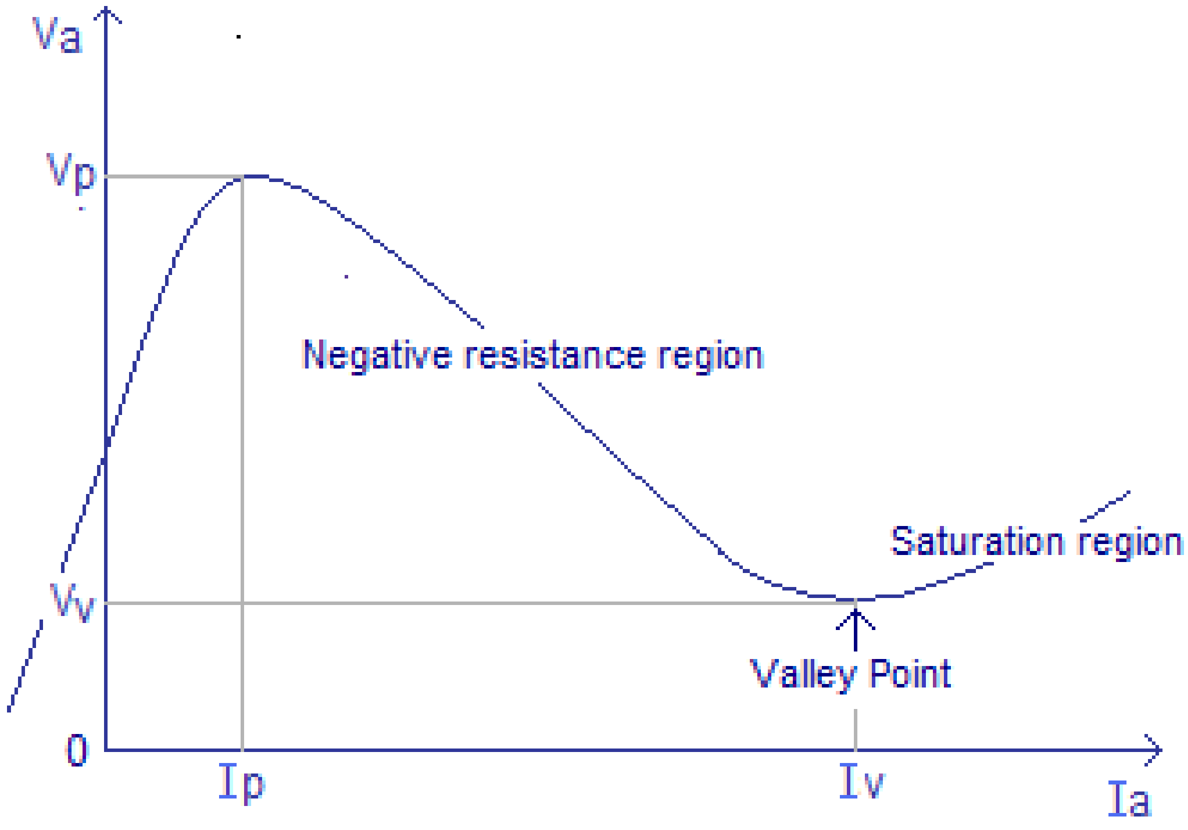


Fig 4: PUT characteristics

PUT Operation

- Typically the anode of the PUT is connected to a positive voltage and the cathode is connected to the ground.
- The gate is connected to the junction of the two external resistor R1 and R2 which forms a voltage divider network. It is the value of these two resistors that determines the intrinsic standoff ratio(η) and peak voltage (Vp) of the PUT.
- When the anode to cathode voltage (Va)is increased the anode current will also get increased and the junction behaves like a typical P-N junction. But the Va cannot be increased beyond a particular point.
- At this point sufficient number of charges are injected and the junction starts to saturate. Beyond this point the anode current (Ia) increases and the anode voltage (Va) decreases.

PUT Operation

- This is equal to a negative resistance scenario and this negative resistance region in the PUT characteristic is used in relaxation oscillators.
- When the anode voltage (Va) is reduced to a particular level called “Valley Point”, the device becomes fully saturated and no more decrease in Va is possible. There after the device behaves like a fully saturated P-N junction.

Peak Voltage (Vp)

- It is the anode to cathode voltage after which the PUT jumps into the negative resistance region.
- The peak voltage Vp will be usually one diode drop (0.7V) plus the gate to cathode voltage (Vg).
- Peak voltage can be expressed using the equation:

$$\mathrm{V_P} = \mathbf{0.7\ V + V_G = 0.7\ V + V_{R1} = 0.7\ V + \eta V_{BB}}$$

Programmable Unijunction Transistor(PUT)

- Notice that the gate is connected to the **n region** adjacent to the anode.
- This pn junction controls the on and off states of the device.
- The gate is always biased positive with respect to the cathode.
- When the anode voltage exceeds the gate voltage by approximately 0.7 V, the pn junction is forward-biased and the PUT turns on.
- The PUT stays on until the anode voltage falls back below this level, then the PUT turns off.

Setting the Trigger Voltage

- The gate can be biased to a desired voltage with an external voltage divider, as shown in Figure 2–7(a), so that when the anode voltage exceeds this “programmed” level, the PUT turns on

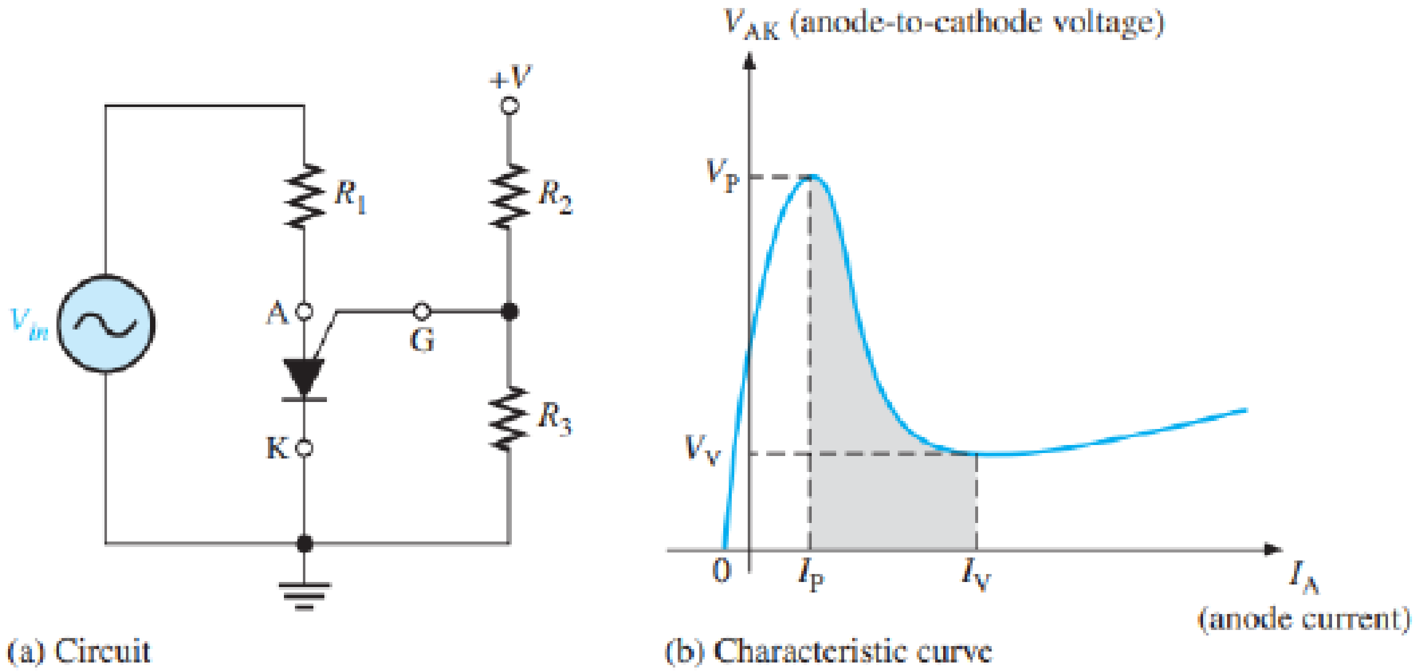


FIGURE 2-7

PUT biasing.

Application of PUT

- A plot of the anode-to-cathode voltage, VAK, versus anode current, IA, in Figure 2–7 (b) reveals a characteristic curve similar to that of the UJT. Therefore, the PUT replaces the UJT in many applications. One such application is the relaxation oscillator in Figure 2–8 (a).

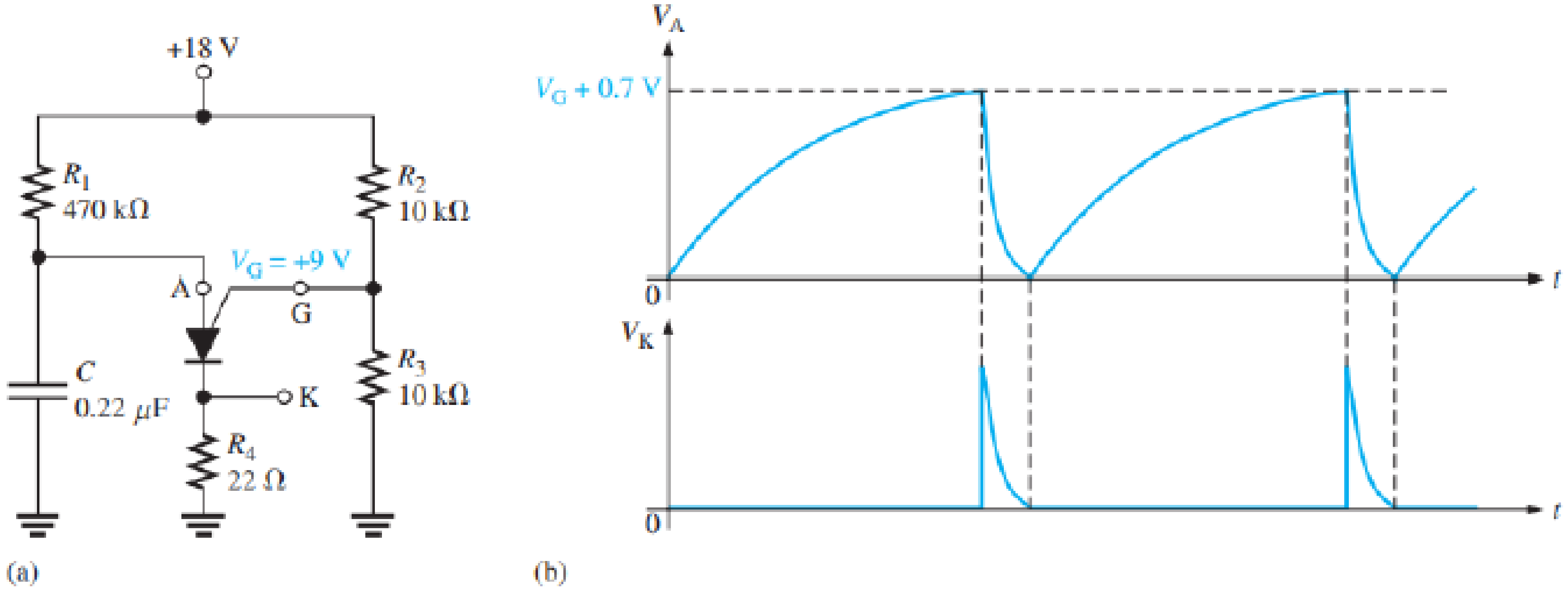


FIGURE 2-8

PUT relaxation oscillator.

The basic operation of the PUT is as follows:

- The gate is biased at +9 V by the voltage divider consisting of resistors R2 and R3.
- When dc power is applied, the PUT is off and the capacitor charges toward +18 V through R1.
- When the capacitor reaches *VG* + 0.7 V, the PUT turns on and the capacitor rapidly discharges through the low on resistance of the PUT and R4.
- A voltage spike is developed across R4 during the discharge.
- As soon as the capacitor discharges, the PUT turns off and the charging cycle starts over, as shown by the waveforms in Figure 2–8(b).

Sample Problems

Problem #1

- The datasheet of a certain UJT gives η = 0.6. Determine the peak-point emitter voltage VP if VBB = 20 V.

Ans.

$$V_P = 12.7 \text{ V}$$

Problem #2

- Determine a value of R1 in Figure 2-9 that will ensure proper turn-on and turn-off of the UJT. The characteristic of the UJT exhibits the following values: η = 0.5, VV = 1 IV = 10mA, IP = 20 µA, and VP = 14 V.

Ans.

$$800\ \text{k}\Omega > \text{R}_1 > 2.9\ \text{k}\Omega$$

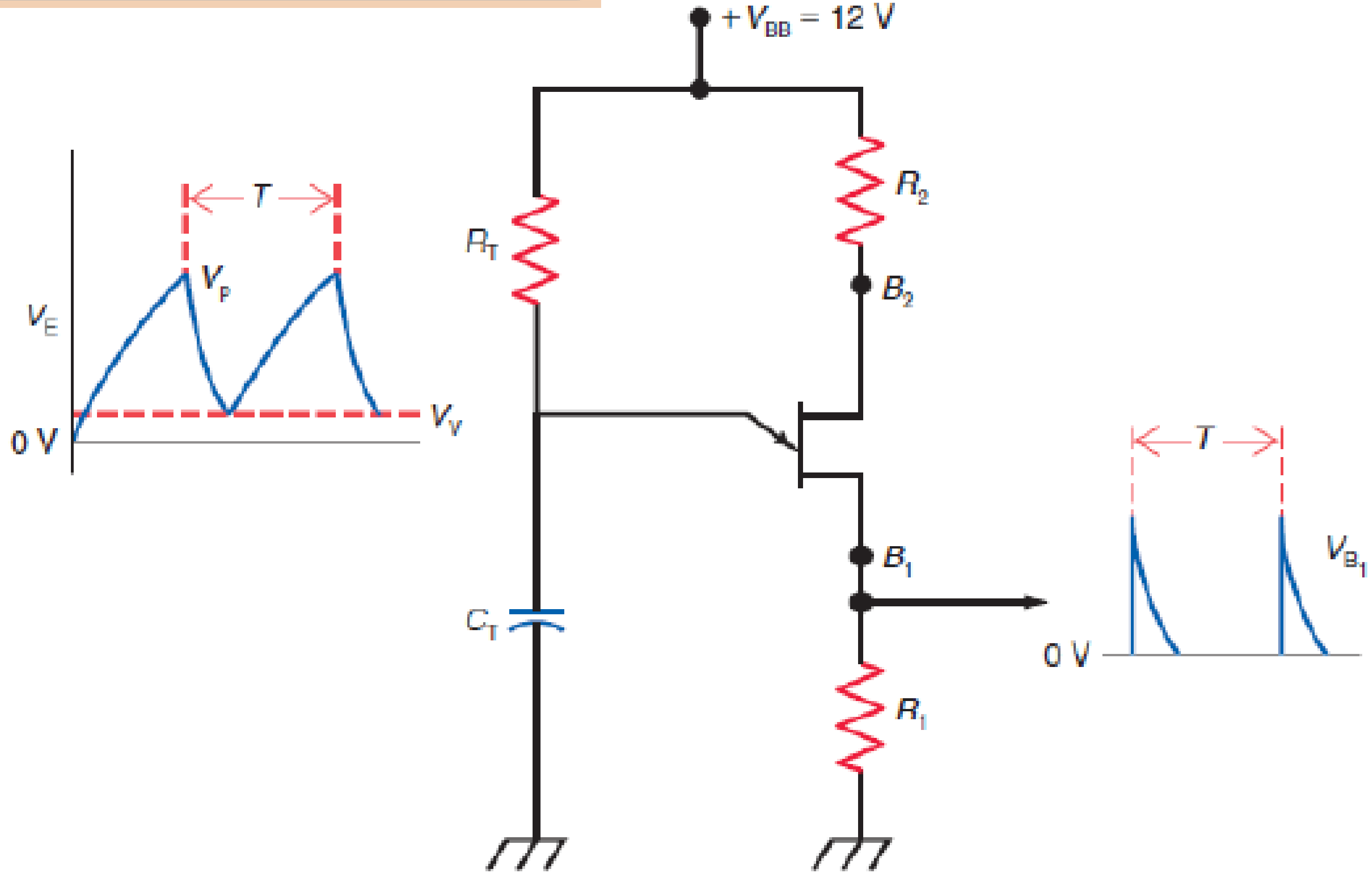
Problem #3

In Figure 2-9, CT = 0.1 µF and RT = 220 kΩ.

- Calculate the frequency of the emitter voltage waveform.

Assume η = 0.6.

FIGURE 2-9



Ans.

$$f = 49.6 \text{ Hz}$$