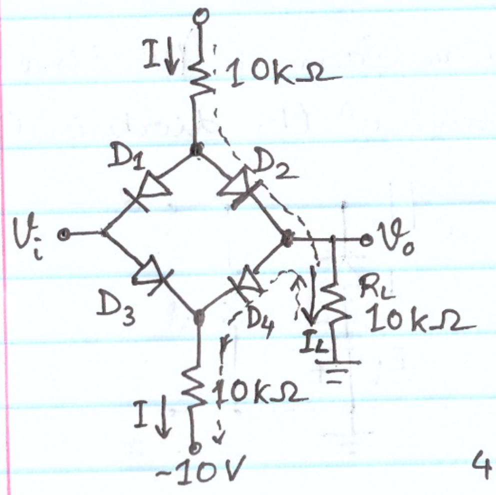
Sol^n:

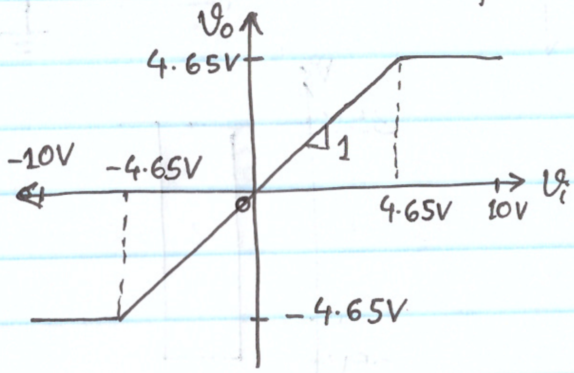


For, $v_i > 0$, D_1 & D_4 are off.

$$I_L \cong I = \frac{10-0.7}{20\times10^3} = 0.465\,mA$$

$$v_o = I_L R_L = 0.465\times10^{-3}\times10\times10^3$$
$$= 4.65V$$

$\therefore$ $v_o = v_i$ for $v_i = \pm 4.65V$

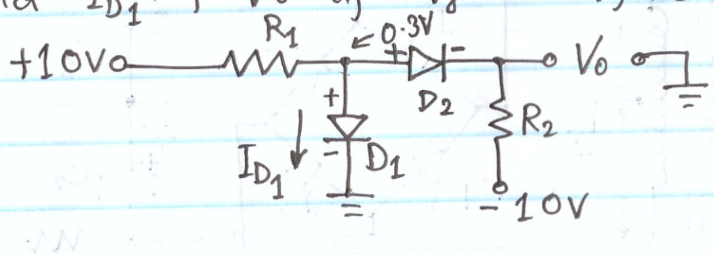


Similarly, while $v_i < 0$, D_2 & D_3 are off.

$$-I_L \cong I = \frac{10-0.7}{20k} = 0.465\,mA$$

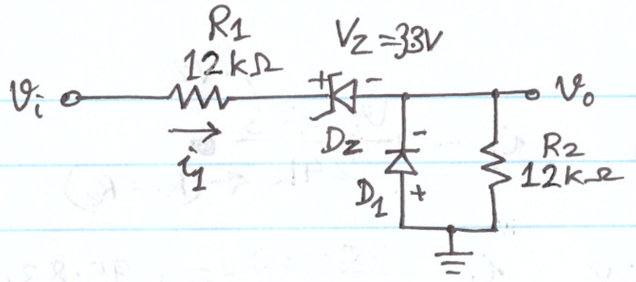
& , $-v_o = -I_L . R_L = -4.65V$

18. Find I_{D_1} & V_o if $V_\gamma = 0.3V$, $R_1 = 6.8k\Omega$ & $R_2 = 12k\Omega$



Sol^n: While, D_1 & D_2 are ON, $V_o = +.3 - .3 = 0V$ (Ans)

Now, $I_{D_1} = \frac{10-0.3}{6.8k} - \frac{0-(-10)}{12k} = 0.593\,mA$ (Ans)

19. 

$V_\gamma = 0$

$v_i = -20V$ to $+20V$

Plot: v_o Vs v_i (&) i_1 Vs v_i

Sol^n. During, $v_i = 0$ to $-20V$, zener & normal D are conducting (FB) $\Rightarrow V_{o(-20V \text{ to } 0V)} = 0$

For, $v_i = 0$ to $+3.3V$, zener is in reverse blocking mode (not in breakdown) $\Rightarrow i_1 = 0$ & $V_{o(0-3.3V)} = 0$

For, $v_i > 3.3V$, Z-diode enters into brk-dwn state.

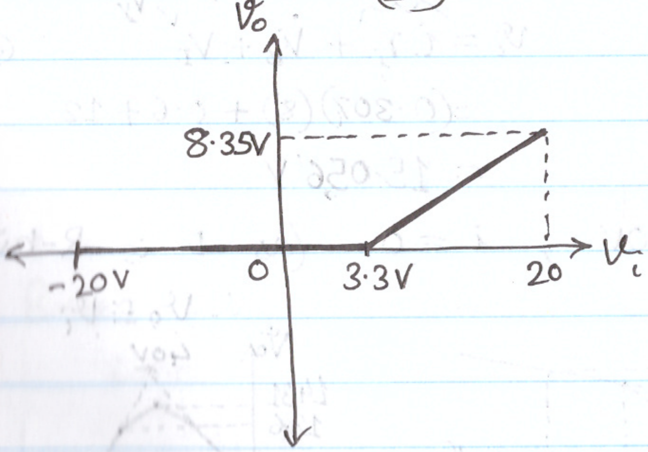
$$i_1 = \frac{v_i - 3.3}{12k + 12k} \text{ A}$$

&, $$V_{o(3.3 \text{ to } 20V)} = \left[\frac{v_i - 3.3}{12k + 12k}\right](\underset{R_2}{12k}) = \frac{v_i - 3.3}{2}$$

At, $v_i = +20V$,

$$i_1 = \frac{20 - 3.3}{24k} = 695.83\ \mu A$$

$$V_{o(20V)} = 8.35V$$

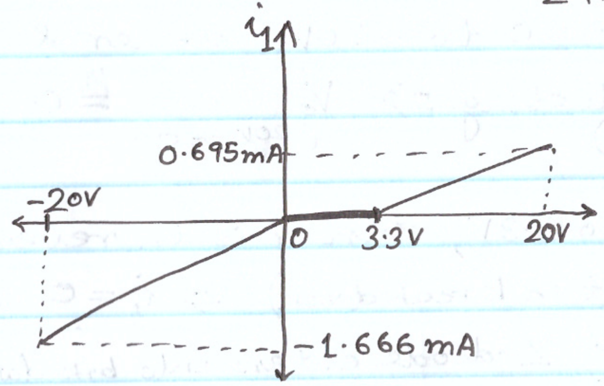


For, $v_i < 0$, $V_o = 0V$ & $-i_1 = \frac{0 - v_i}{\underset{R_1}{12k}} = \frac{0-(-20)}{12k}$

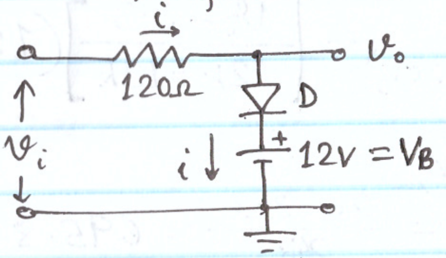
$i_1 = -1.666$ mA

For, $v_i > 3.3V$, $\quad i_1 = \dfrac{v_i - \overset{\swarrow V_Z}{3.3}}{24k \leftarrow (R_1+R_2)}$

At, $v_i = +20V$, $\quad i_1 = \dfrac{20-3.3}{24k} = 695.83\mu A$



20. If $V_\gamma = 0.6V$, $r_f = 8\Omega$, $v_i = \pm 40V$, plot v_o Vs. v_i



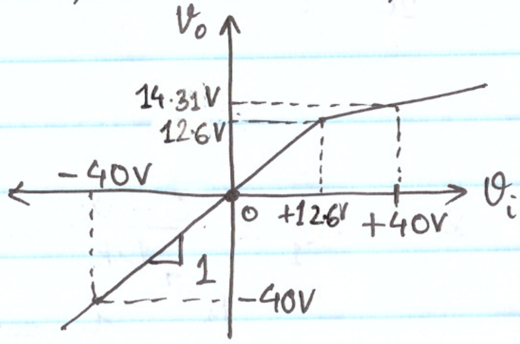
Draw v_o if v_i is a triangular wave of ±40V.

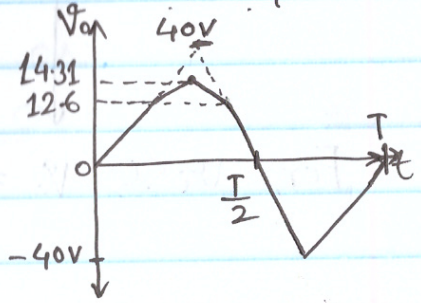
Sol^n. For, $v_i = +40V$, $\quad i = \dfrac{40-0.6-12}{120+8} = \underline{214.06}$ mA

$$v_o = i.r_f + V_B + \overset{\swarrow V_\gamma}{V_D} \qquad @ D_1 \text{ is FB}$$
$$= (0.214)(8) + 0.6 + 12$$
$$= 14.31V$$

For, $v_i = -40V$, $\quad i = 0$ (as D is R-biased)

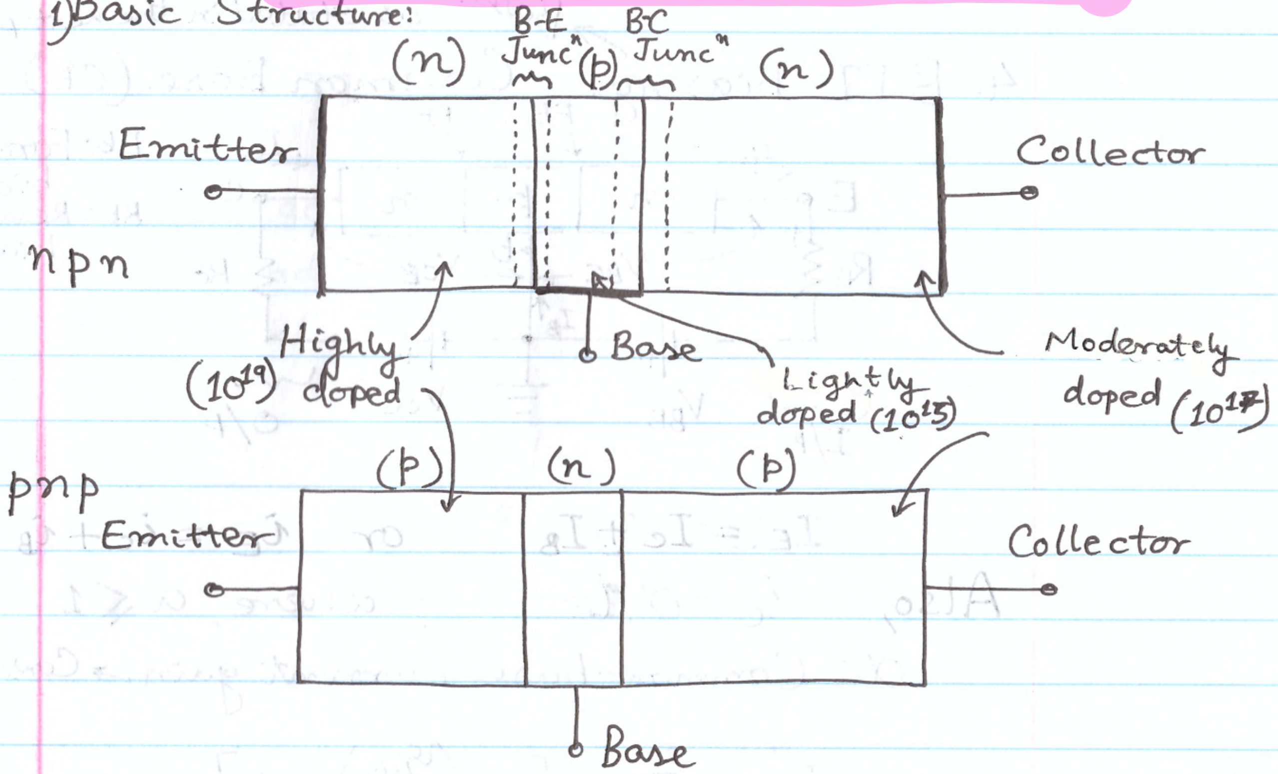
$\therefore V_o \cong V_i$



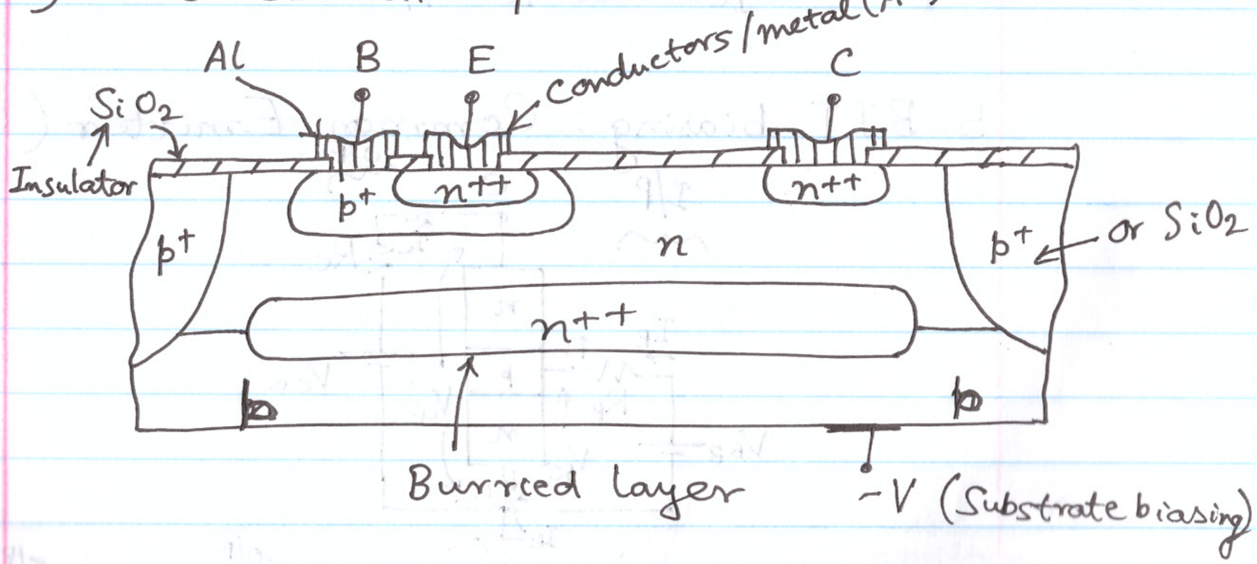


BJT
(Bipolar Junction Transistors)

1) Basic Structure:



2) Cross-section: npn BJT



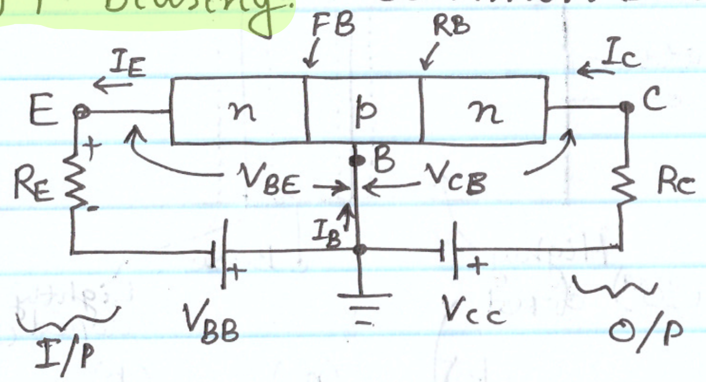
3) Types of BJTs:

1) n-p-n
2) p-n-p

- BE juncth is Fwd. biased.
- BC juncth is reverse biased.

Active Region → Based on modes of operation, as stated in the next page.

4. BJT biasing: Common Base (CB)



FB: Forward biased
RB: Reverse biased

$$I_C = \alpha . I_E$$

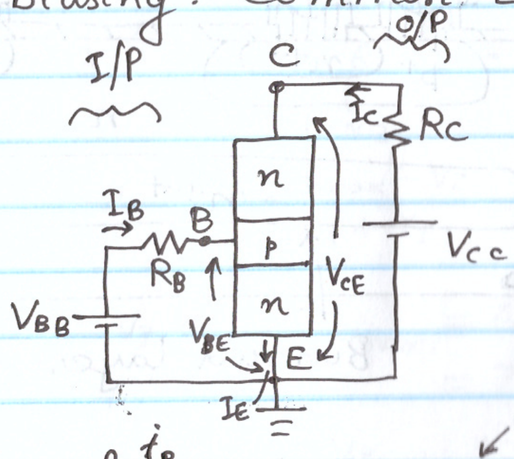
$$i_C = \alpha . i_E \qquad ; \text{ where, } \alpha \leqslant 1$$

α: Common-base current gain → Constant no.

$$i_E = I_{EO} . \left[e^{\left(\frac{v_{BE}}{V_T}\right)} - 1 \right]$$

I_{EO}: 10^{-12} to 10^{-15} A

5. BJT biasing: Common Emitter (CE)



$$i_E = \underbrace{i_C}_{\beta . i_B} + i_B \quad ; \quad i_C = \beta . I_B \;\leftarrow \text{O/P},\ \text{I/P}$$

$$\Rightarrow i_E = (1+\beta)\, i_B \qquad \beta \gg 1$$

β: Common emitter current gain.

$$\&, \; i_C = \left(\frac{\beta}{1+\beta}\right) i_E$$

Current Relationships

If we treat the bipolar transistor as a single node, then, by Kirchhoff's current law, we have

$$i_E = i_C + i_B \tag{5.7}$$

If the transistor is biased in the forward-active mode, then

$$i_C = \beta i_B \tag{5.8}$$

Substituting Equation (5.8) into (5.7), we obtain the following relationship between the emitter and base currents:

$$i_E = (1 + \beta) i_B \tag{5.9}$$

Solving for i_B in Equation (5.8) and substituting into Equation (5.9), we obtain a relationship between the collector and emitter currents, as follows:

$$i_C = \left(\frac{\beta}{1 + \beta}\right) i_E \tag{5.10}$$

We can write $i_C = \alpha i_E$ so

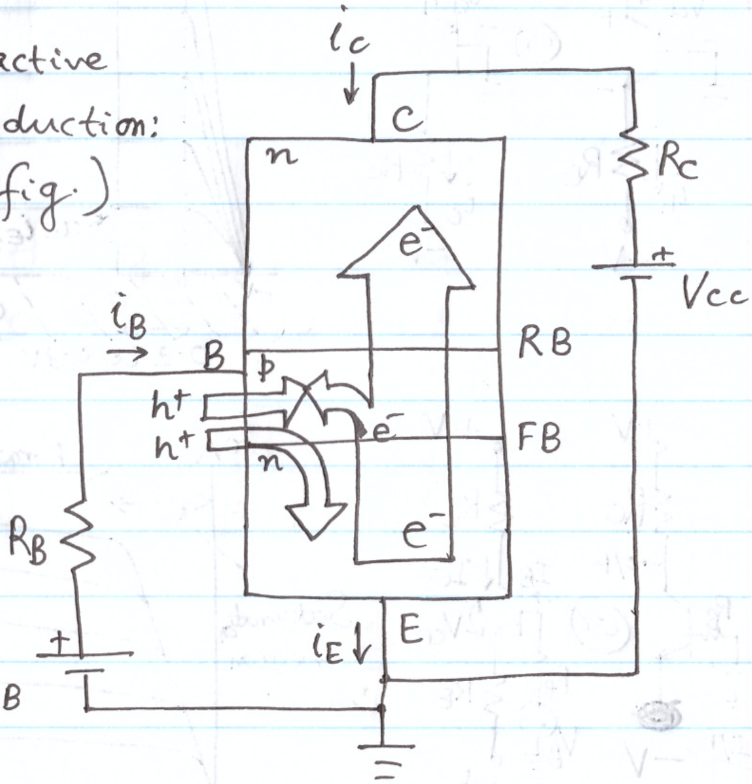
$$\alpha = \frac{\beta}{1 + \beta} \tag{5.11}$$

The parameter α is called the common-base current gain and is always slightly less than 1. We may note that if $\beta = 100$, then $\alpha = 0.99$, so α is indeed close to 1. From Equation (5.11), we can state the common-emitter current gain in terms of the common-base current gain:

$$\beta = \frac{\alpha}{1 - \alpha} \tag{5.12}$$

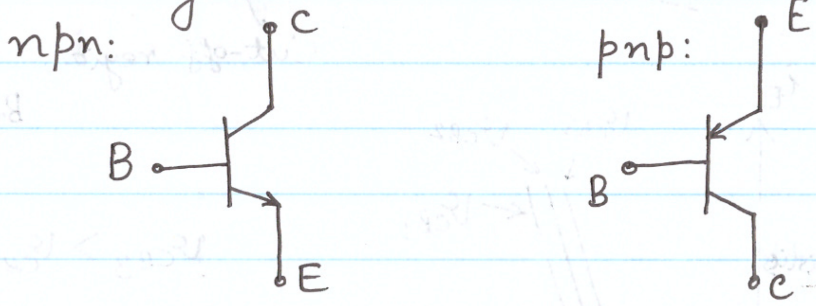
$$\alpha = \frac{\beta}{1+\beta} \qquad (\&) \qquad \beta = \frac{\alpha}{1-\alpha}$$

5. Forward active mode conduction: (CE config.)



$V_{CC} > V_{BB}$

6. BJT symbols:



7. a. Transistor (BJT) modes of operation:
1) Common base (CB)
2) Common emitter (CE)
3) Common collector (CC)

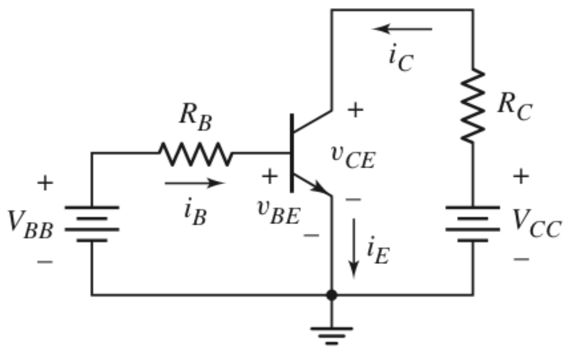
b. Transistor (BJT) regions of operation:

1) Cut-off (OFF switch)
2) Saturation (resistor-like)
3) Active → Forward / Reverse (ON switch with resistance) (special resistor)
4) Breakdown (causes permanent damage)

CB

The C–B voltage can be varied by changing the V^+ voltage (Figure 5.11(a)) or the V^- voltage (Figure 5.11(b)). When the collector–base junction becomes forward biased in the range of 0.2 and 0.3 V, the collector current i_C is still essentially equal to the emitter current i_E. In this case, the transistor is still basically biased in the forward-active mode. However, as the forward-bias C–B voltage increases, the linear relationship between the collector and emitter currents is no longer valid, and the collector current very quickly drops to zero.

CE



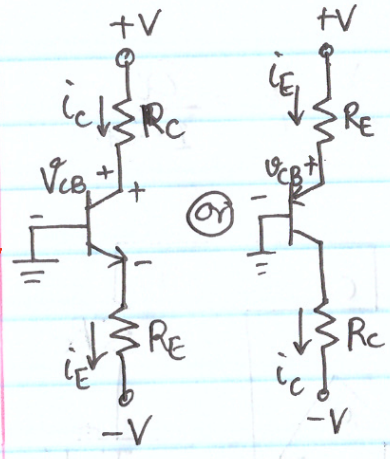
[redacted]. In this circuit, the V_{BB} source forward biases the B–E junction and controls the base current i_B. The C–E voltage can be varied by changing V_{CC}.

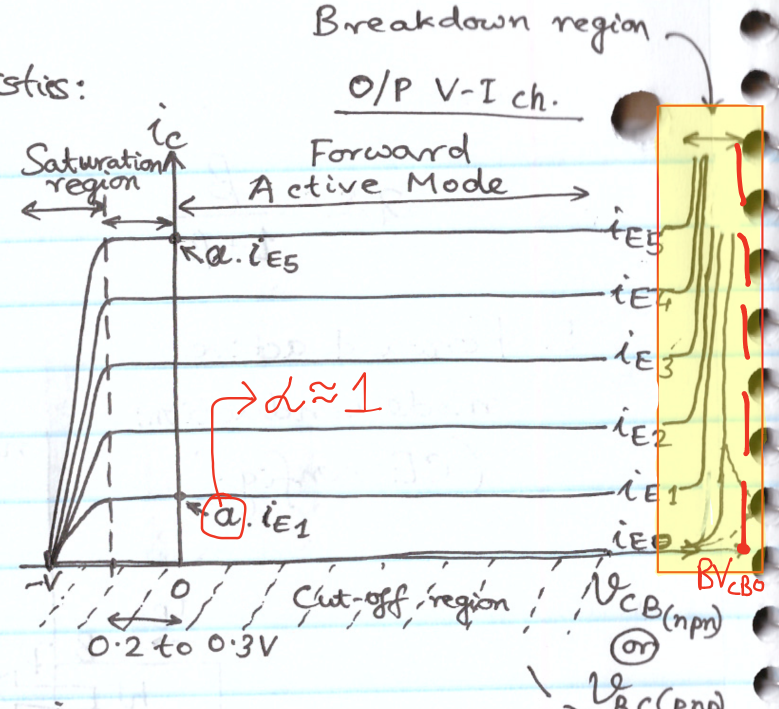
In the npn device, in order for the transistor to be biased in the forward-active mode, the B–C junction must be zero or reverse biased, which means that V_{CE} must be greater than approximately $V_{BE}(\text{on})$.[5] For $V_{CE} > V_{BE}(\text{on})$, there is a finite slope to the curves. If, however, $V_{CE} < V_{BE}(\text{on})$, the B–C junction becomes forward biased, the transistor is no longer in the forward-active mode, and the collector current very quickly drops to zero.

7c. V-I characteristics:

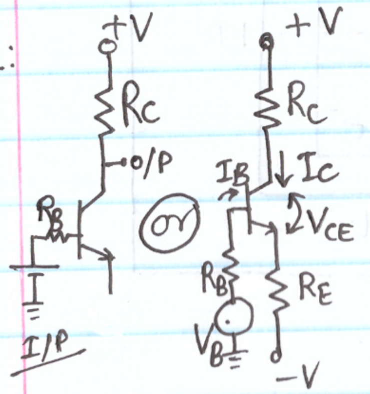
CB:

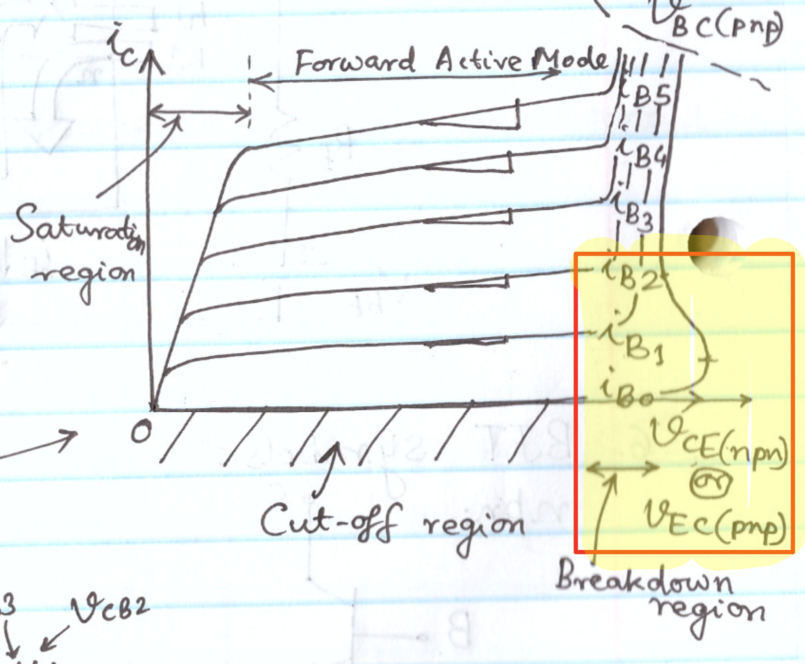
Can be treated as a const. I source.



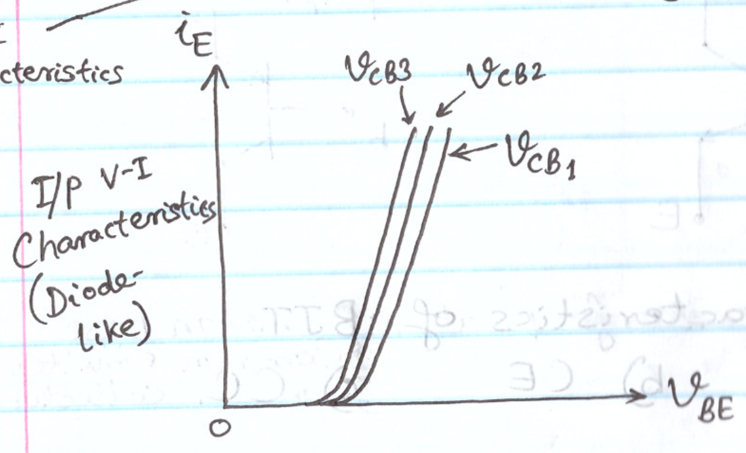


CE:

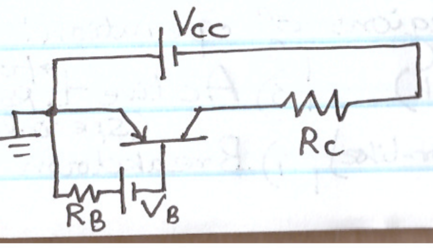




O/P V-I Characteristics



$v_{CB3} > v_{CB2} > v_{CB1}$



CE config for pnp

Breakdown Voltage: Common-Emitter Characteristics

Figure 5.18 shows the i_C versus v_{CE} characteristics of an npn transistor, for various constant base currents, and an ideal breakdown voltage of BV_{CEO}. The value of BV_{CEO} is less than the value of BV_{CBO} because BV_{CEO} includes the effects of the transistor action, while BV_{CBO} does not. This same effect was observed in the I_{CEO} leakage current.

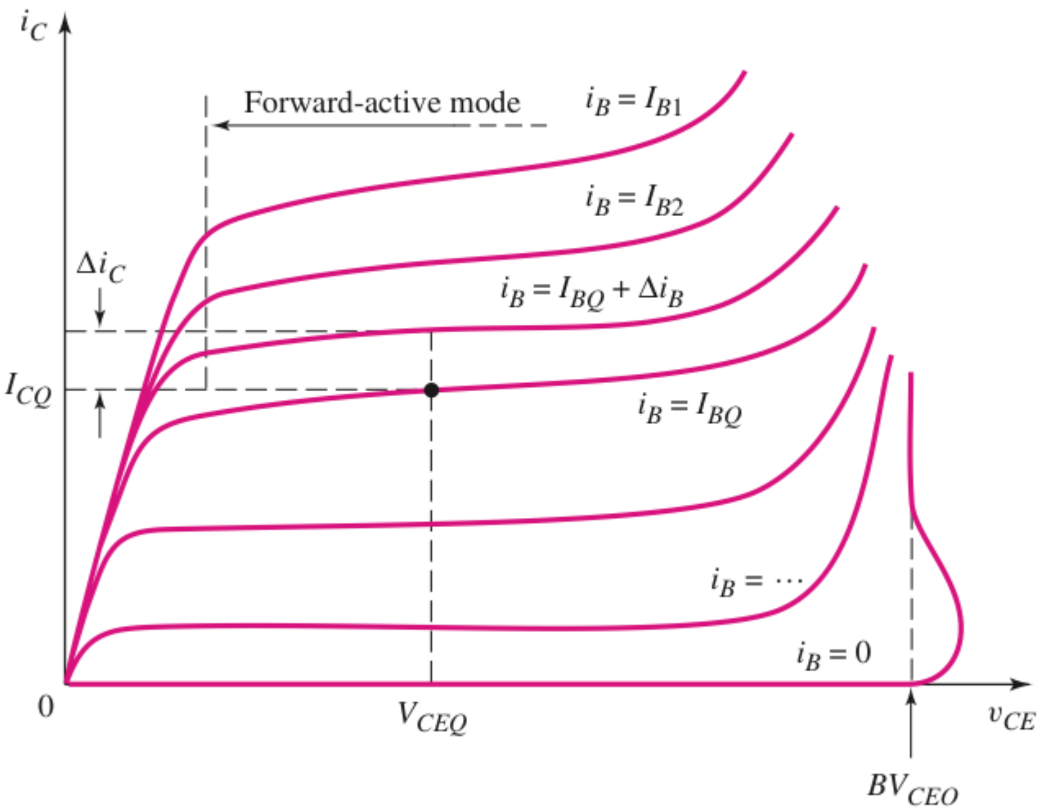


Figure 5.18 Common-emitter characteristics showing breakdown effects

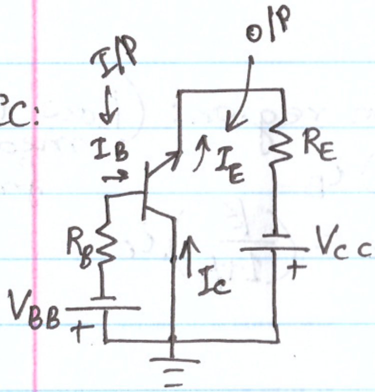
The breakdown voltage characteristics for the two configurations are also different. The breakdown voltage for the open-base case is given by

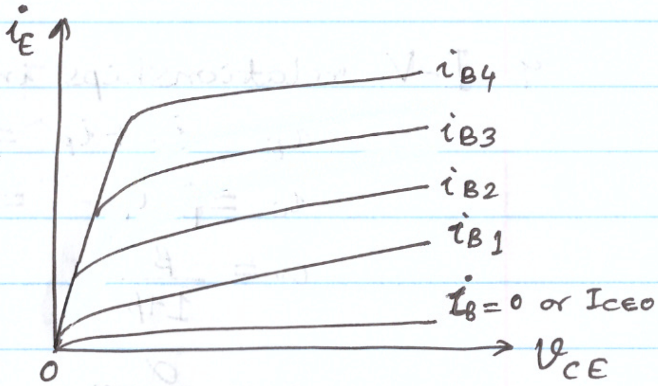
$$\boxed{BV_{CEO} = \frac{BV_{CBO}}{\sqrt[n]{\beta}}} \tag{5.22}$$

where n is an empirical constant usually in the range of 3 to 6.

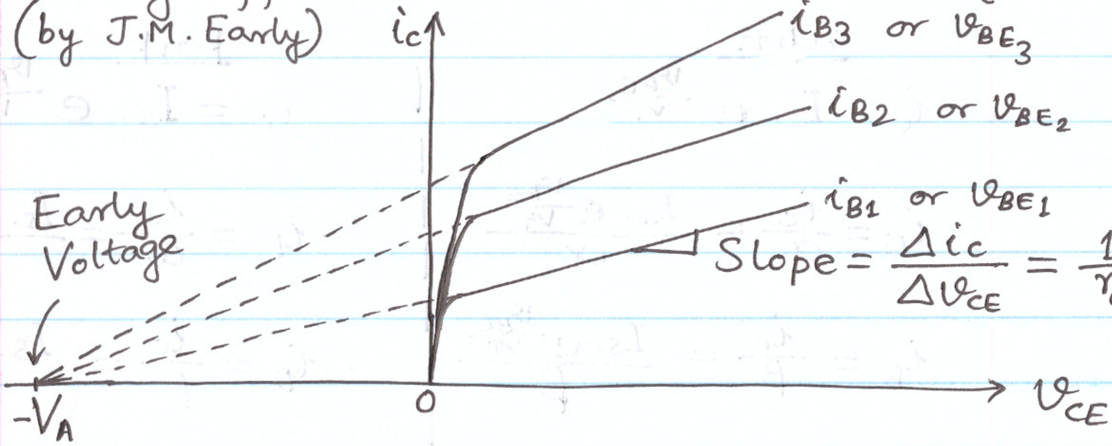
BJT (cont.)

CC:





8. Early effect & base width modulation (CE):
(by J.M. Early)



$$\text{Slope} = \frac{\Delta i_C}{\Delta v_{CE}} = \frac{1}{r_o}$$

r_o: O/P resistance

$$r_o \cong \frac{V_A}{I_C}$$

$$\boxed{i_C = I_S \cdot e^{\left(\frac{v_{BE}}{V_T}\right)} \cdot \left(1 + \frac{v_{CE}}{V_A}\right)}$$ While early effect is considered.

$|V_A|$: 50 to 300V (typically)

Base width modulation: $v_{BE}\uparrow$ $i_B\uparrow$ Junc^n width (CB) $\downarrow$

Width of base region $\uparrow$ $i_C\uparrow$

[redacted]. The slope in these characteristics is due to an effect called base-width modulation that was first analyzed by J. M. Early. The phenomenon is generally called the *Early effect*. When the curves are extrapolated to zero current, they meet at a point on the negative voltage axis, at $v_{CE} = -V_A$. The voltage V_A is a positive quantity called the **Early voltage.** [redacted]