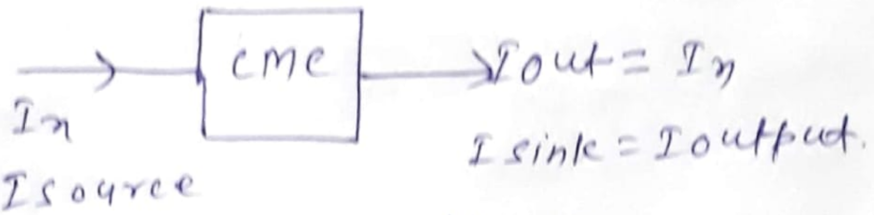
UNIT - IV

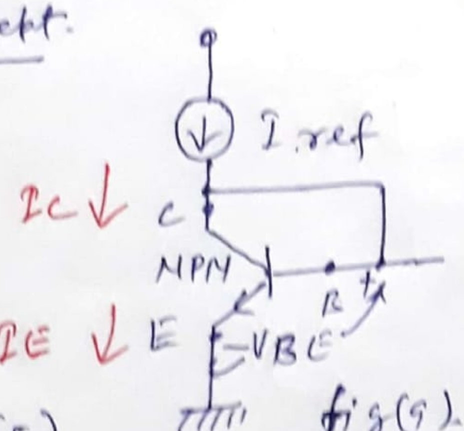
Current mirror circuit

The circuit which is force to output current should be equal to Input current. that is output current is mirror image of input current. This is known current mirror circuit.



Block diagram.

Concept.



fig(9).

$V_{CB} = V_C - V_B$

$V_{CB} = 0$ Volts

V_C & V_B are same so $V_{CB} = 0V$

This figure is known diode connected transistor.

$(I_C = I_E)$,

if β = large = ∞, then

$I_B = 0A$

$I_C = I_E$

Iref → Reference current.

Now, Emitter current (I_E),

$$I_E = I_0 e^{V_{BE_1}/V_T}$$

Where, $V_T \rightarrow \frac{T}{11600}$ → Thermal voltage.

I_0 → Reverse saturation current (R.S.C).

if $I_E = I_C = I_{ref}$, then,

$$I_{ref} = I_0 e^{V_{BE1}/V_T}$$

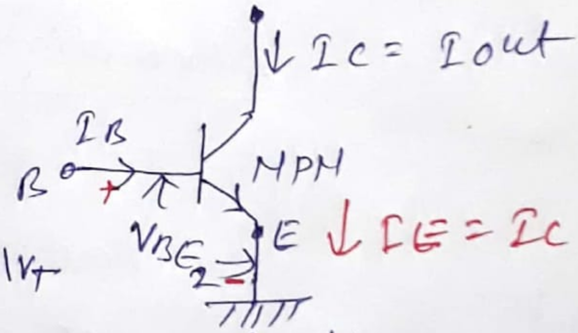
$$\frac{I_{ref}}{I_0} = e^{V_{BE1}/V_T}$$

Taking log of natural both side, then

$$\ln \frac{I_{ref}}{I_0} = \frac{V_{BE1}}{V_T}$$

$$\therefore \boxed{V_{BE} = V_T \ln\left(\frac{I_{ref}}{I_0}\right)} \quad \text{——— (1)}$$

Now, fig(b).



fig(b).

if $I_C = I_E = I_{out}$

$$= I_0 e^{V_{BE2}/V_T}$$

Similer to above eqn.

$$\boxed{V_{BE2} = V_T \ln\left(\frac{I_{out}}{I_0}\right)} \quad \text{——— (2)}$$

if $V_{BE1} = V_{BE2}$, then

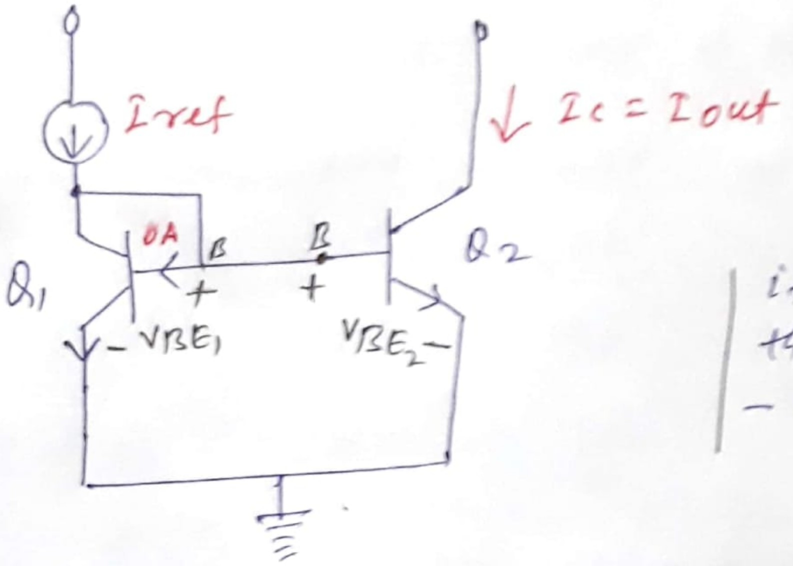
$$V_T \ln \frac{I_{ref}}{I_0} = V_T \ln \frac{I_{out}}{I_0}$$

$$\ln \frac{I_{ref}}{I_0} = \ln \frac{I_{out}}{I_0}$$

$$\therefore \boxed{I_{ref} = I_{out}}$$

⇓

(1) If both transistors voltage ($V_{BE_1} = V_{BE_2}$) Then;



If Apply KVL then,

$-V_{BE_1} + V_{BE} = 0$

fig (1). Basic current mirror ckt.

If suppose $\beta \neq \infty$, then

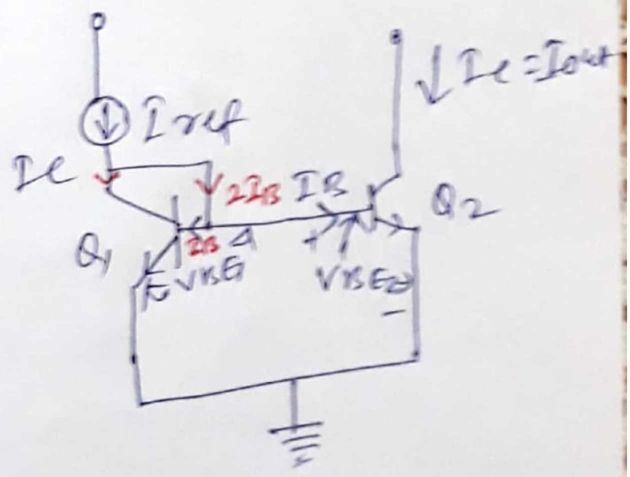
$I_B \neq 0A$

so,

$I_{ref} = I_C + 2I_B$

$= I_C + 2\left(\frac{I_C}{\beta}\right)$

$$\boxed{I_{ref} = I_C\left[\frac{\beta+2}{\beta}\right]}$$



$I_{ref} = I_{out}\left[\frac{\beta+2}{\beta}\right]$

$$\therefore \boxed{I_{out} = I_{ref}\left[\frac{\beta}{\beta+2}\right]}$$

(2). Requirement for current mirror circuits:-

(Both transistor are identical & same.)

1. ~~BAE~~ $V_{BE1} = V_{BE2} = V_{BE}$
2. $I_{C1} = I_{C2} = I_C$
3. $I_{B1} = I_{B2} = I_B$
4. $\beta_1 = \beta_2 = \beta$ (large)

(3) Junction Area:- (AE). ~~(Idea~~

$$\boxed{AE_1 = AE_2}$$ ✓

✗

$$\boxed{AE \propto I_0}$$ ✓

AE → junction Area.

⇒ if let, $AE_2 = 2AE_1$

$I_{02} = I_{01}$

$$V_{BE2} = V_T \ln \frac{I_{out}}{I_{02}}$$

$$V_{BE1} = V_T \ln \frac{I_{out}}{I_{01}}$$

V.V.I. ∴ $\boxed{I_{out} = 2 I_{ref}}$ ✗

$$\frac{I_{out}}{I_{02}} = \frac{I_{ref}}{I_{01}}$$

$$\frac{I_{out}}{2I_{01}} = \frac{I_{ref}}{I_{01}}$$

$$\boxed{I_{out} = 2 I_{ref}}$$

① * →

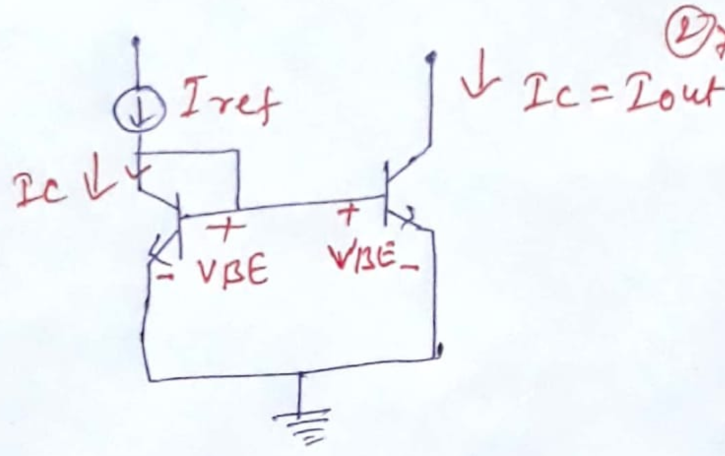


fig (a).

$I_{out} = \left(\frac{\beta}{\beta+2}\right) I_{ref}$ ✓

$I_{out} = I_{ref}\ (\beta = \infty)$ ✓

② * →

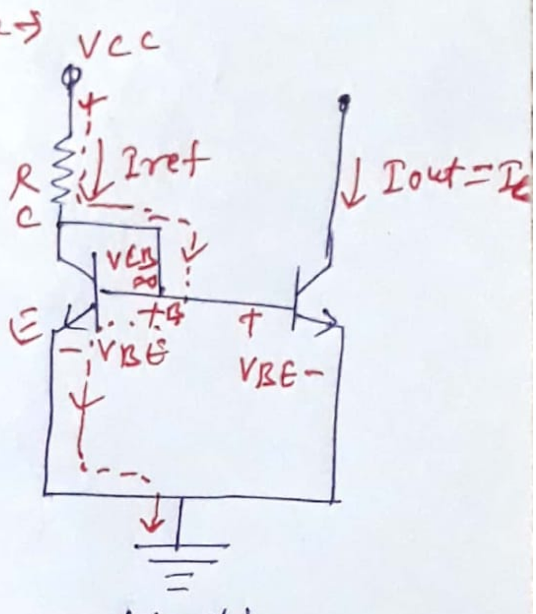


fig (b).

$I_{out} = \left(\frac{\beta}{\beta+2}\right) \cdot I_{ref}$ ✓

$I_{out} = I_{ref}\ (\beta = \infty)$. ✓

Now Apply KVL, then.

$V_{CC} = I_{ref} \cdot R + 0 + V_{CE}$ (VCB ≈ 0)

$\therefore \boxed{I_{ref} = \frac{V_{CC} - V_{CE}}{R}}$ ✓

③ * →

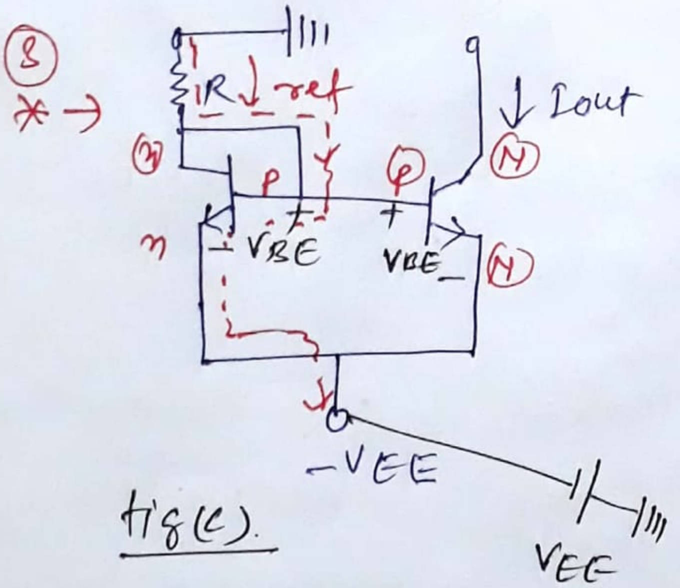


fig (c).

$I_{out} = \left(\frac{\beta}{\beta+2}\right) I_{ref}$ ✓

$I_{out} = I_{ref}\ (\beta \neq \infty)$ ✓

Apply KVL,

$0 + I_{ref} \cdot R + 0 + V_{BE} - V_{EE}$ (VCB ≈ 0) (−ve supply)

$\therefore \boxed{I_{ref} = \frac{V_{BE} - V_{EE}}{R}}$ ✓

④

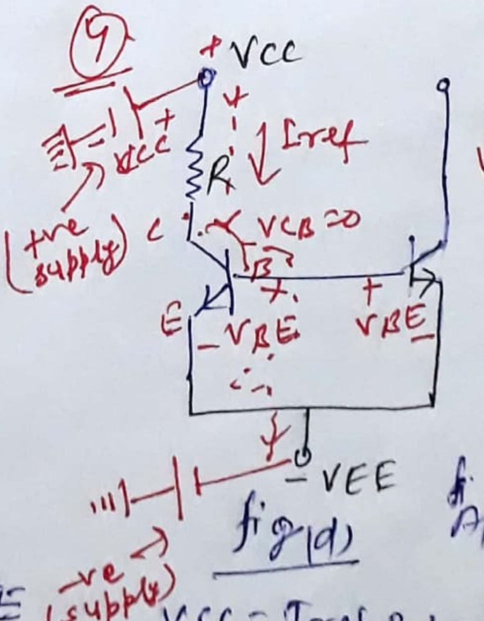


fig (d)

$I_{out} = \left(\frac{\beta}{\beta+2}\right) I_{ref}$ ✓

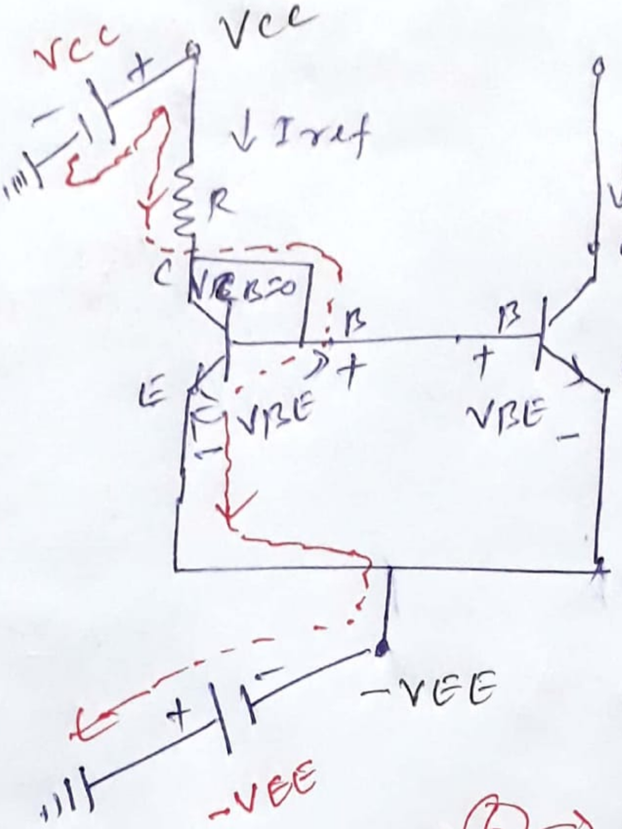
$I_{out} = I_{ref}\ (\beta = \infty)$ ✓

Apply KVL,

$V_{CC} = I_{ref} \cdot R + 0 + V_{BE} - V_{EE}$

$\therefore \boxed{I_{ref} = \frac{V_{CC} + V_{BE} + V_{EE}}{R}}$ ✓

(5)



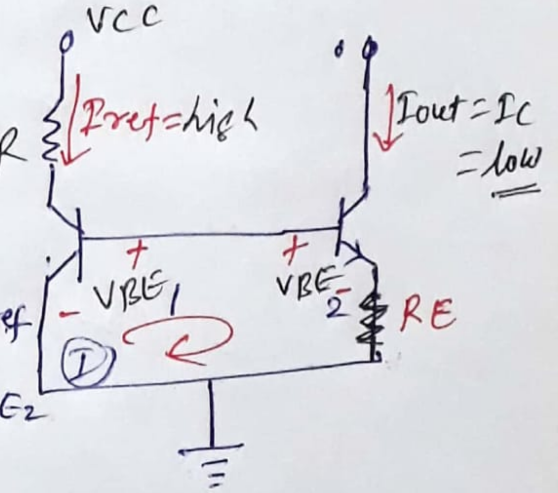
According to ohm's law:

$-V_{CC} + I_{ref} \cdot R + V_{BE} - V_{EE} = 0$

$\therefore I_{ref} = \dfrac{V_{CC} - V_{BE} + V_{EE}}{R}$

ln → log Natural

(6) ⇒



✱ ⇒ Iout = Iref

Iout small = Iref small

Iref = small

R → large

chip Area ∝ R

chip Area → large

$I_{out} \neq I_{ref}$

$V_{BE_1} \neq V_{BE_2}$

According to widlar ckt:→ Widlar current mirror ckt (Widlar cmc).

$I_{out} \neq I_{ref}$ ✓

Iout = low ✓

Iref = high ✓ (The Widlar cmc is used to input current high & output current Low)

$V_{BE_1} = V_T \ln \dfrac{I_{ref}}{I_o}$

$V_{BE_2} = V_T \ln \dfrac{I_{out}}{I_o}$

Now, Apply KVL in (I)

$-V_{BE_1} + V_{BE_2} + I_{out} R_E = 0$

$\therefore I_{out} R_E = V_{BE_1} - V_{BE_2}$

$I_{out} R_E = V_{BE_1} - V_{BE_2}$

$I_{out} R_E = V_T \ln \dfrac{I_{ref}}{I_o} - V_T \ln \dfrac{I_{out}}{I_o}$

$I_{out} R_E = V_T \ln \left[\dfrac{I_{ref}}{I_{out}}\right]$ ($\log x - \log y = \log \dfrac{x}{y}$)

$\therefore R_E = \dfrac{V_T}{I_{out}} \ln [I_{ref} / I_{out}]$