CURRENT MIRRORS AS ACTIVE LOADS:

Let's re-cap a common-emitter amplifier with passive loads.

![Circuit Diagram]

**Fig - 32.1**

- \( V_B, R_B \) and \( R_C \) are used to bias the amplifier to its desired operating point.

- \( C_e \) is used to short the emitter to ground for AC frequencies so that it is more of a common-emitter configuration.

- \( R_C \) is used both for setting DC operating point and the gain of the amplifier.

- The small-signal gain can be shown to be

\[
A_v = -g_m \times R_C = - \frac{I_{CQ} \times R_C}{V_T}
\]
Drawbacks of the method for IC Design:

- Resistors are area consuming and in some cases prohibitive.
- As seen from the small-signal gain expression, Ic×Re is limited by the power supply and hence the maximum achievable gain.

**Common-Emitter Amplifier with Active Load**

![Common-Emitter Amplifier Circuit Diagram]

\[ I_{out} = I_{c1} \]
\[ V_{out} = V_{ce1} \]

*Let's study the circuit using large-signal analysis.*
(a) $I_{c1}$ vs $V_{ce}$ Characteristic
Figure: 32.3

Since $I_{c1} = I_{c2} = I_{on}$, we can now combine both the graphs

(b) $I_{c2}$ vs $V_{ce2}$

(a) I-V characteristics with load characteristics superimposed
Figure: 32.4

* Fig 32.4(a) is the superimposed I-V characteristics of $Q1$ and $Q2$.

* Since $I_{c1} = I_{c2}$, Fig 32.4(a) shows the graphical solution of $I_{on}$ vs. $V_{out}$ for given $V_i$. 
As shown there are 4 distinct regions of operation marked by (1), (2), (3) & (4) on the graph.

1. This is when Q1 is cut-off and Q2 is in deep saturation region.

2. Q1 is in saturation and Q2 is on the transition from saturation to active.

3. Q1 and Q2 are in forward-active region. This is the intended region of operation for an amplifier.

4. Q1 is in deep saturation and Q2 is in forward-active region.

Fig 32.4(b) shows the DC transfer function Vout vs. Vin derived from 32.4(a).

As shown in Fig 32.4(b), the gain of the amplifier is non-linear i.e. dependent on the input.

The output is pegged to VCC from (1) to (2) and then you get the high gain region & then it's pegged to VCE(sat).
Gain Analysis

Analyzing gain using large-signal equation is not only tedious, it doesn't give you insight into the working of the amplifier.

Instead, we will do a small-signal analysis. And remember, it's only valid about that operating point.

Let's do a small-signal analysis in the region where both the transistors are in forward-active region.

Since the current source is constant, the circuit can be simplified to

![Circuit Diagram]

Figure: 82.5
Since \( V_2 = 0 \), the small-signal model:

\[
\begin{align*}
V_{out} &= -g_m \cdot V_i \times \left( \frac{R_0}{R_{o2}} \right) \\
\text{or} & \quad A_v = -g_m \left( \frac{R_0}{R_{o2}} \right)
\end{align*}
\]

On substituting:

\[
R_0 = \frac{V_A}{I_{co}} \approx \frac{V_A}{I_{ca}} \quad \text{and} \quad g_m = \frac{I_{ca}}{V_T}
\]

\[
A_v = -\frac{I_{ca}/V_T}{\frac{I_{ca}}{V_{A1}} + \frac{I_{ca}}{V_{A2}}}
\]

\[
\text{or,} \quad A_v = -\frac{1}{\frac{V_T}{V_{A1}} + \frac{V_T}{V_{A2}}}
\]

* \( A_v \) is independent of the bias current \( I_{ca} \).
* It's because \( g_m \) varies proportional to \( I_{ca} \) & \( R_0 \) varies inversely and therefore cancels.
Example:

Let \( v_{A1} = v_{A2} = 100 \text{ V} \)

& we know \( v_T = 26 \text{ mV @ 300}^\circ \text{K} \)

\[
A_v = -\frac{100}{2 \times 26 \text{ mV}} = 1928
\]