EE 434

Lecture 28

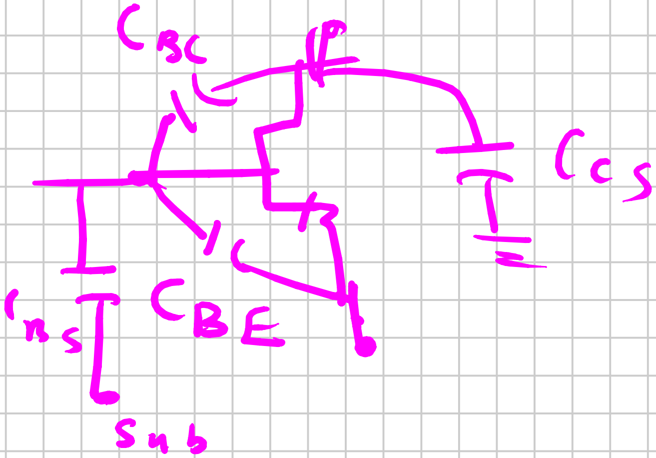
- BJT Models for Computer Simulation
- Basic Linear Applications

Review from last time

Model on junction capacitance

$$C_j = \begin{cases} \dfrac{C_{j0} A}{\left(1 - \dfrac{V_{FB}}{\phi_B}\right)^n} & V_{FB} < \dfrac{\phi_B}{2} \\ 2^n C_{j0} A \left[\dfrac{2 n V_{FB}}{\phi_B} + (1-n) \right] & V_{FB} > \dfrac{\phi_B}{2} \end{cases}$$

Review from Last Time



$$C_{BE} = C_{BEJ} + \tau_F g_m$$

$$C_{AC} = \tau_F \frac{I_{CQ}}{kT/q}$$

Model of BJT for computer simulations

MOS

- Process Description
- Geometric Parameter Description

BJT

- Model for a reference device
  - often for several reference devices
- Device scale factor (A_E / A_{ER})

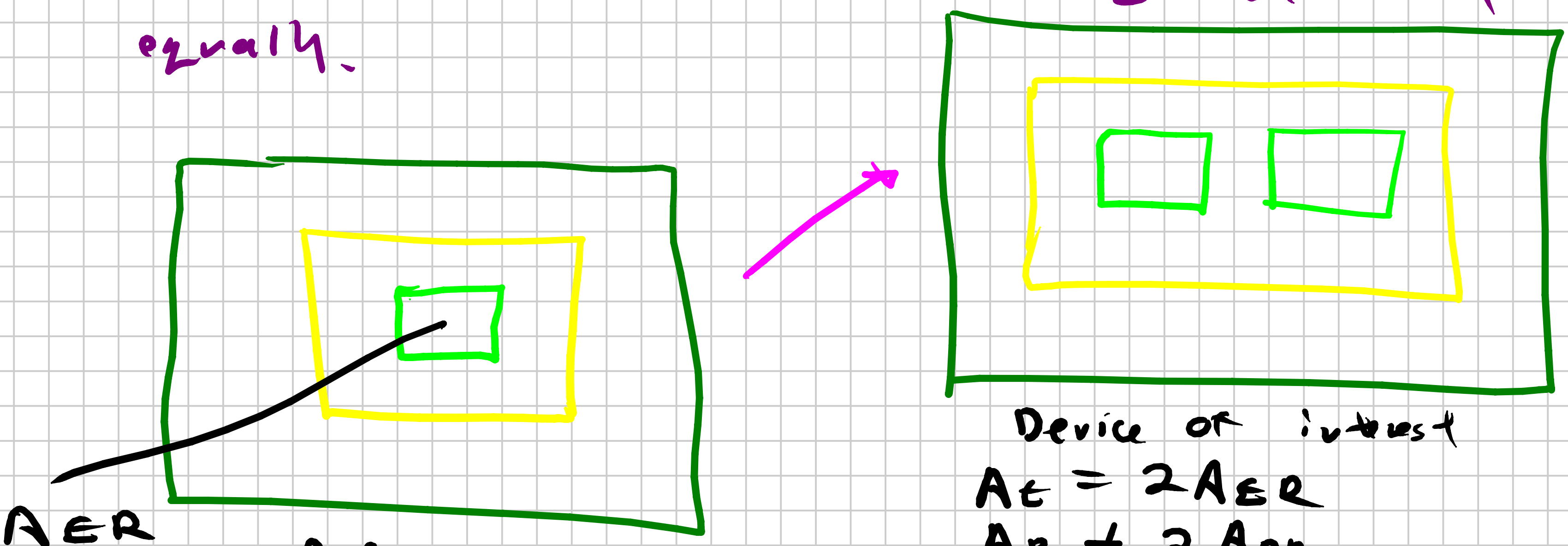
$$I_{CR} \cong J_S A_{ER} e^{V_{BE}/V_t}$$

$$I_C = J_S \times A_{ER} e^{V_{BE}/V_t}$$

Issues with this approach:

- all caps are assumed to be part of the model of the reference device

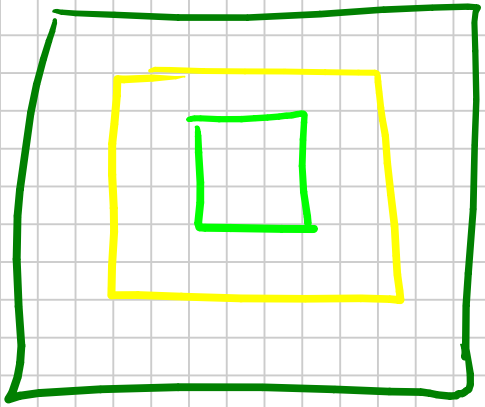
- Base area and collector Area may not scale equally.

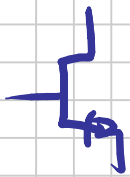


Reference Device

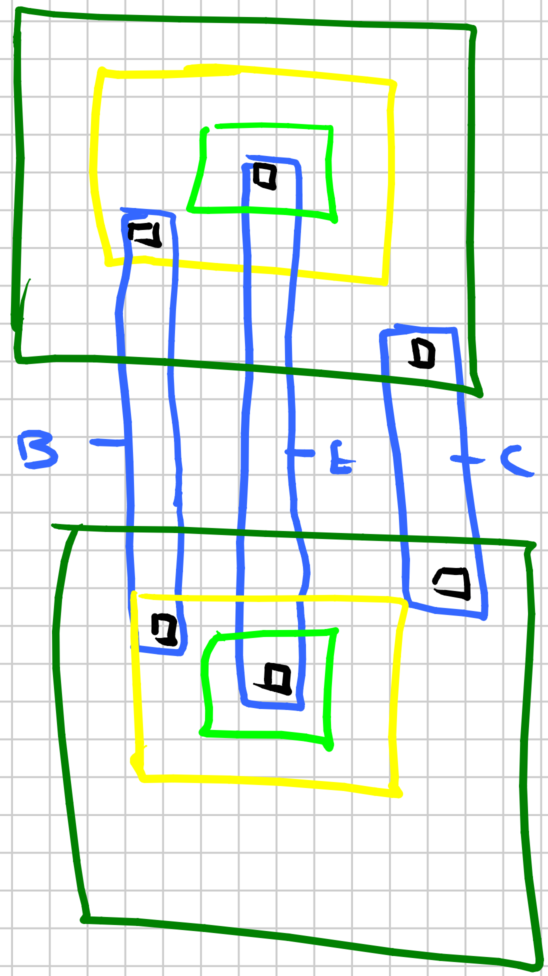
Device of interest

$$A_E = 2A_{ER}$$
$$A_B \neq 2A_{BR}$$
$$A_C \neq 2A_{CR}$$





A_{ER}

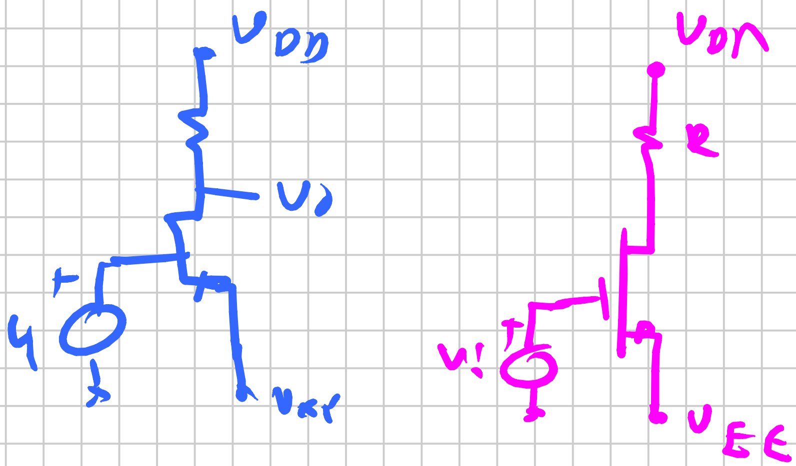


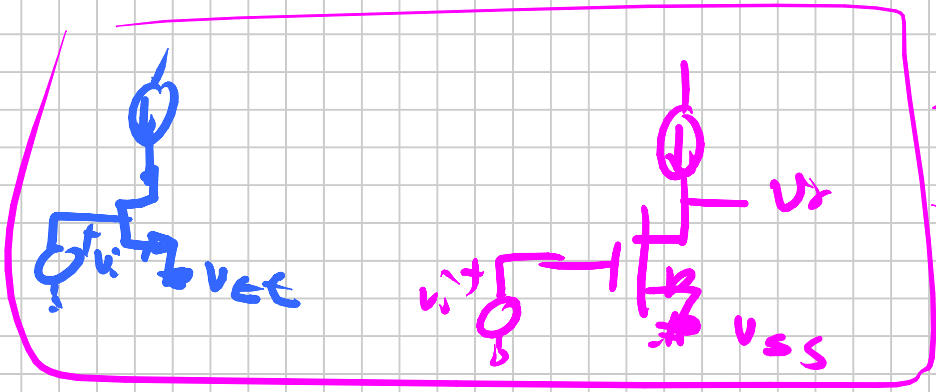
$A_E = 2A_{E}$

This scaling is not necessarily attractive because area may be considerably larger than that required to simply change A_E and then make modest changes in A_B, A_C

Often see a large number of specific bipolar transistors with various layouts and with various A_E. Designers simply use parallel combinations of these devices rather than simply scaling A_E

Basic Linear Applications
(MOS & Bipolar Devices)

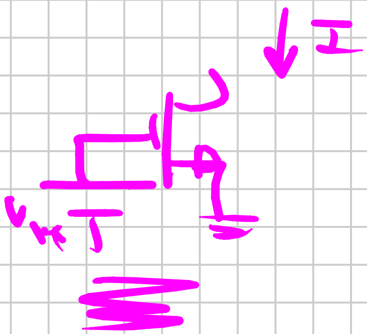




- Large gains
- $A_{vMOS} << A_{vBJT}$
- Current source was used for biasing

- Whereas in discrete design, current sources are expensive with limited use, in linear integrated design current sources are very inexpensive and widely used.

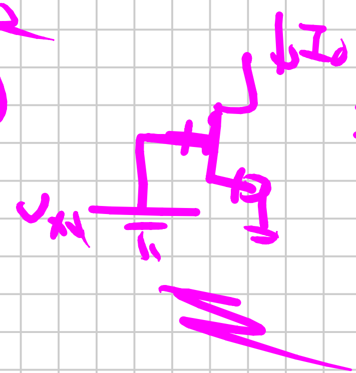
Current Source Design



If $\lambda = 0$

$$I \approx \frac{\mu C_{ox} W}{2L} \underbrace{(V_{xx} - V_T)^2}_{S}$$

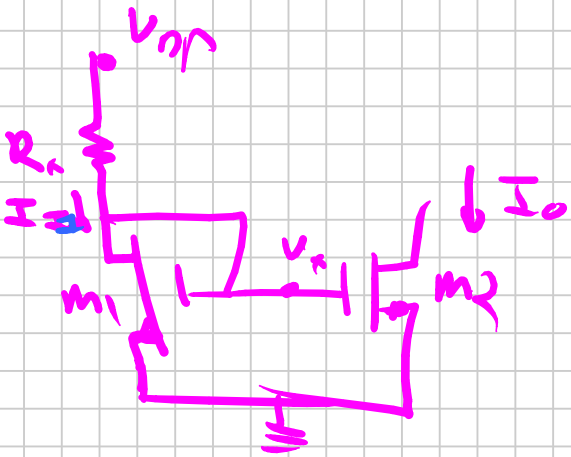
- I is nearly constant
- This simple 1-transistor circuit behaves as a current source



If $V_{AF} = \infty$

$$I_o = J_s A_E e^{\frac{V_{xx}}{V_T}}$$

Assume M_2 in saturation, neglect λ effects



$$I_o = \frac{\cancel{\mu C_{ox}} W_2}{2L_2}(V_x - V_T)^2$$

$$I_1 = \frac{\mu C_{ox} W_1}{2L_1}(V_x - V_T)^2$$

$$\therefore \quad \frac{I_o}{I_1} = \frac{W_2 L_1}{W_1 L_2}$$

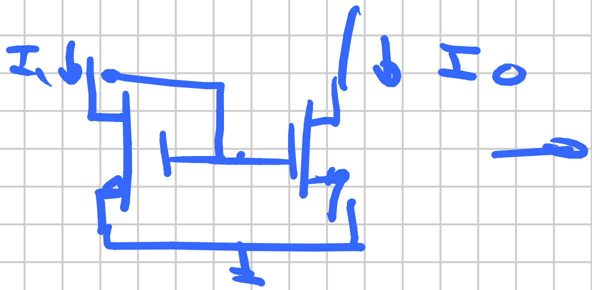
or $\quad I_o = \left[\frac{W_2 L_1}{W_1 L_2}\right] I_1$

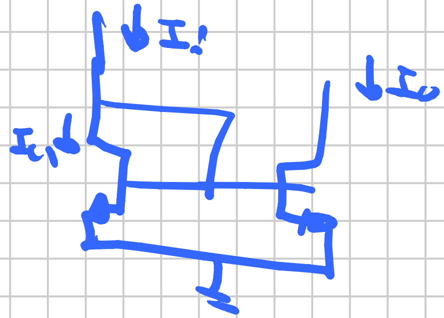
- It behaves as a current amplifier with gain $\frac{W_2 L_1}{W_1 L_2}$
- If I_1 is a constant, this behaves as a current source!

• since $\frac{W_1}{W_2}, \frac{L_2}{L_1}$ can be accurately controlled,

the gain of the current amplifier is quite accurate

(i.e. does not change much with process variations or temp).





If β is very large

$V_{AF} = \infty$

$I_{c1} \simeq I_{in}$

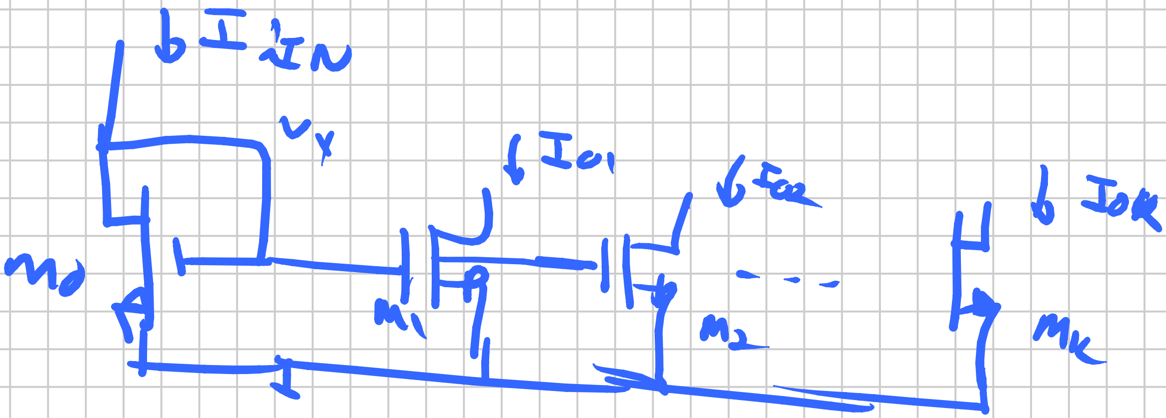
$I_{c1} = J_s A_{E1} e^{\frac{V_{BE}}{V_T}}$

$I_{c2} = \cancel{J_s} A_{E2} \cancel{e^{\frac{V_{BE}}{V_T}}}$

$\therefore \quad \frac{I_{c2}}{I_{c1}} = \frac{A_{E2}}{A_{E1}}$

- serves as a current amplifier
- A_{E2}/A_{E1} is precisely controllable

Many current sources are often required for blocks in ICs



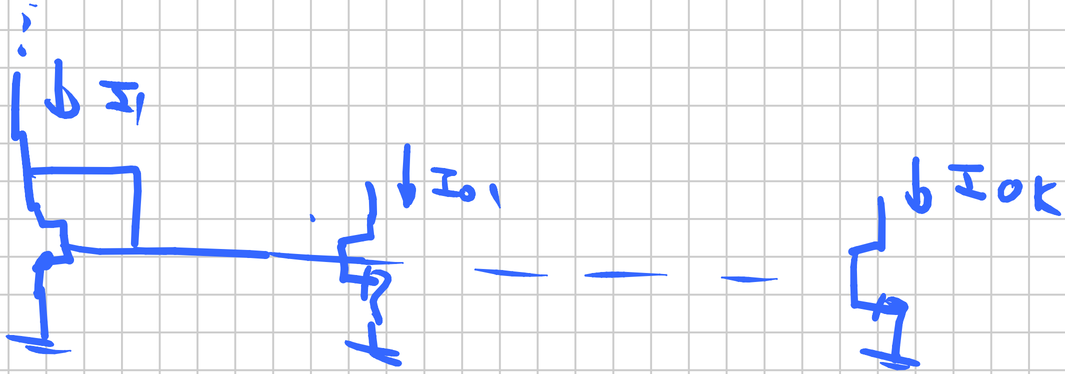
$$I_{IN} = \frac{\mu C_{ox} W}{2L}(V_X - V_T)^2$$

$$I_{ok} = \frac{\mu C_{ox} W_k}{2L_k}(V_X - V_T)^2$$

$$I_{ok} \approx I_{IN}\left(\frac{W_k}{W_1}\right)\left(\frac{L_1}{L_k}\right)$$

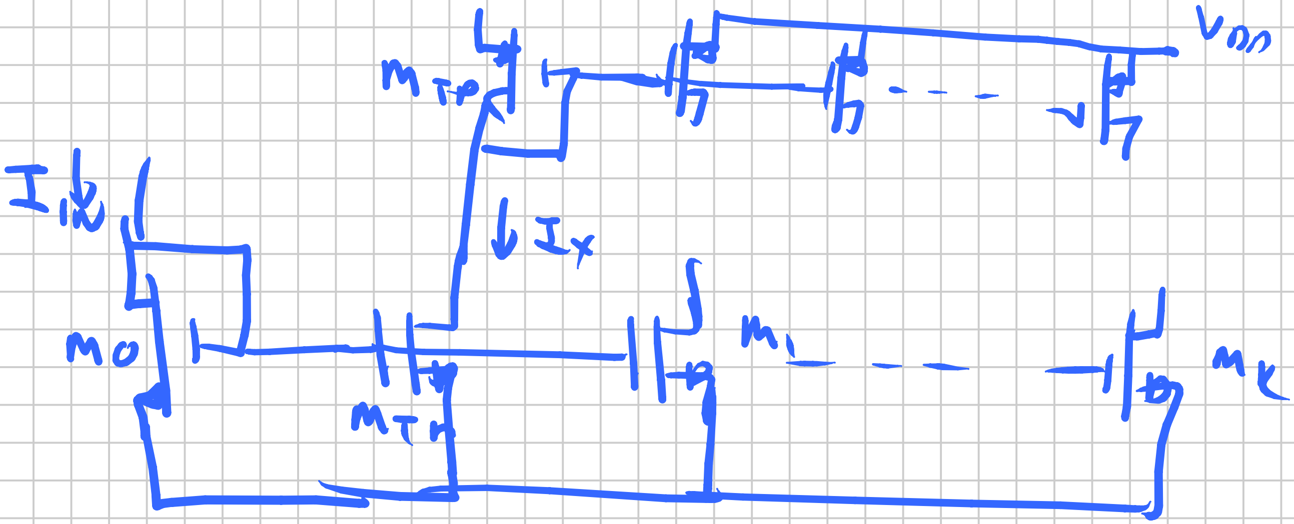
If I_{IN} is a dc current, multiple output currents proportional to I_{IN} can be obtained readily!

Bipolar Current Sources



$$I_{oj} = \frac{A_{Ej}}{A_{E0}} I_1$$

Examples all produced sinking currents



$$I_x = \frac{A_{ET}}{A_{E0}} I_1$$

$$I_{OTk} = \frac{A_{ET}}{A_{E0}} \frac{A_{Ek}}{A_{ETP}} I_1$$

∴ - this circuit provides both sourcing and sinking current outputs

- require one additional transistor for each additional output