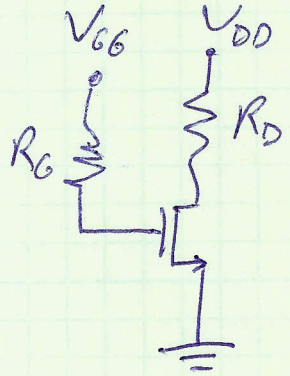
MOSFET fixed bias

- similar to BJT fixed bias
- Not stable



- no current through R_G
  - not necessary, but needed if coupling capacitors are used

$V_{GS} = V_{GG}$

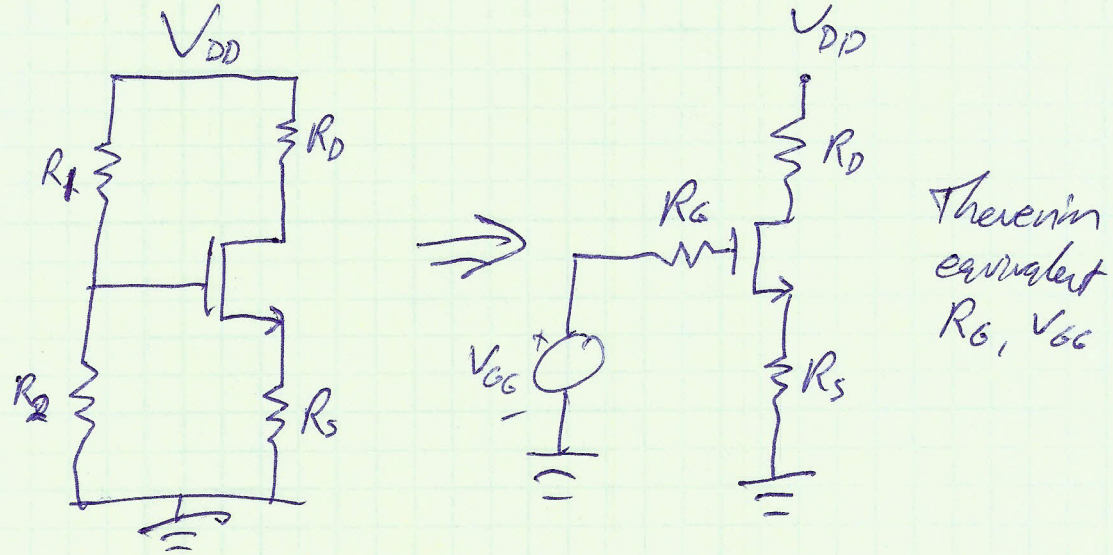
$I_D = \frac{1}{2} k_n' \frac{W}{L} (V_{GS} - V_t)^2 = \frac{1}{2} k_n \frac{W}{L} (V_{GG} - V_T)^2$

DS-KVL: $I_D R_D + V_{DS} = V_{DD}$

$\rightarrow V_{DS} = V_{DD} - \frac{1}{2} k_n' \frac{W}{L} R_D (V_{GG} - V_T)^2$

- Subject to variations in k_n' and V_t which vary with temperature

MOSFET bias with source degeneration



$$V_{GG} = \frac{R_2}{R_1+R_2} V_{DD} \quad , \quad R_G = R_1 \| R_2$$

GS-KVL:

$$V_{GG} = V_{GS} + I_D R_S$$
$$I_D = \frac{1}{2} k_n' \frac{W}{L} (V_{GS} - V_T)^2$$

} can solve for V_{GS} and I_D

DS-KVL:

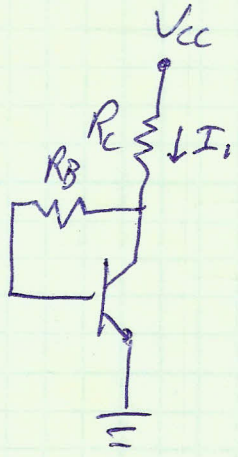
$$V_{DD} = I_D R_D + V_{DS} + I_D R_S$$

← can solve for V_{DS}

Negative feedback: $V_{GS} = V_{GG} - R_S I_D$

- increase in I_D causes decrease in V_{GS} which causes decrease in I_D.
- not constant because of quadratic relationship but variations are much smaller with feedback
- Don't need to worry about $R_B \ll (1+\beta) R_E$ as in BJT because $I_G = 0$, so R_1 and R_2 can be large (MΩ)

Self Bias – uses R_C as feedback resistor



note $V_{CE} = R_B I_B + V_{BE}$

$= R_B I_B + V_{DD} > V_{DD}$

Transistor is always in active mode

$V_{CC} = R_C I_1 + R_B I_B + V_{BE}$, and $I_1 = I_C + I_B$

$= R_C (I_C + I_B) + R_B I_B + V_{DO}$

$= R_C I_C + (R_B + R_C)\frac{I_C}{\beta} + V_{DO}$

$$I_C = \frac{V_{CC} - V_{DO}}{R_C + (R_C + R_B)/\beta} \approx \frac{V_{CC} - V_{DO}}{R_C}$$ If $R_B \ll (\beta - 1) R_C$

↳ note $\frac{R_C + R_B}{\beta} \ll R_C \rightarrow R_C + R_B \ll \beta R_C \rightarrow R_B \ll R_C(\beta - 1)$

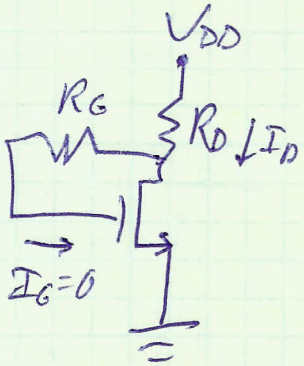
Bias point is stable and independent of β

- Negative feedback illustrated here:

BE-KVL: $$I_B = \frac{V_{CC} - V_{DO} - I_C R_C}{R_B}$$ ($I_C R_C$ ↓)

Increase in I_C will decrease I_B, which decreases I_C

MOSFET self bias



- Transistor always in Saturation $V_{DS} = V_{GS} > V_{GS} - V_T$

$V_{DD} = I_D R_D + V_{GS}$

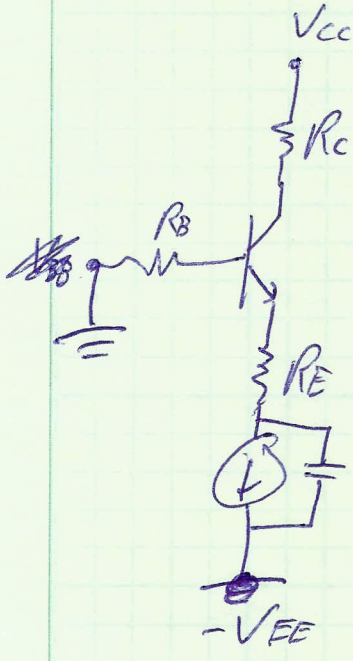
$I_D = \frac{1}{2} k_n' \frac{W}{L} (V_{GS} - V_T)$ } combined I_D and V_{GS}

Note: R_G does not affect bias, but cannot be removed

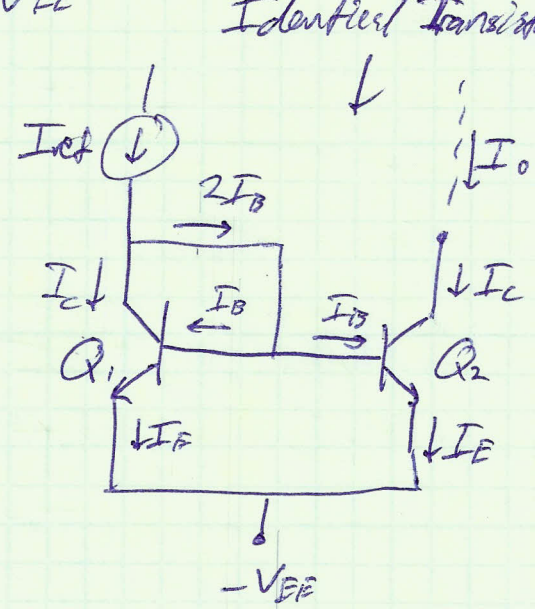
- Removing R_G would mean direct connection from input to output of amp.

Current Mirrors

- Purpose of stable bias circuit is I_C or I_D independent of transistor parameters and temperature variation
- Can also use current bias



Note that capacitor is needed for signal to pass
Otherwise current would be constant, including AC part
Only necessary for ideal current sources
Not needed with the designs we will use



- Q_1 is ON because of I_{ref}
- $V_{CE1} = V_{BE1} = V_{DO}$ → active
- $V_{BE2} = V_{BE1} \rightarrow I_{C2} = I_{C1}$
- If Q_2 also in active state:

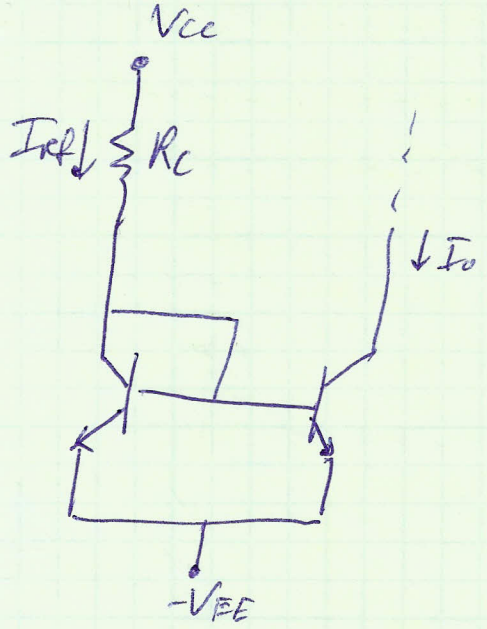
$$I_B = \frac{I_C}{\beta}, \quad I_o = I_C = \beta I_B$$

$$I_{ref} = I_C + 2I_B = (\beta + 2) I_B$$

$$\frac{I_o}{I_{ref}} = \frac{\beta}{\beta + 2} = \frac{1}{1 + 2/\beta} \simeq 1$$

- $I_o = I_{ref}$, no matter what is attached to Q_2
- For Q_2 in active state, V_{CE2} must be $\geq V_{DO}$

Current can be set with simple resistor

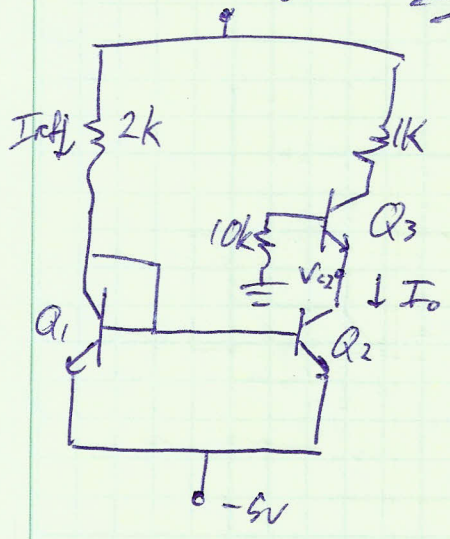


$V_{cc} = I_{ref} R_c + V_{BE1} - V_{EE}$

$I_{ref} = \dfrac{V_{cc} + V_{EE} - V_{D0}}{R_c} = \underline{\text{constant}}$

Example

$\beta = 100$



BE1-KVL: $5 = 2k\, I_{ref} + V_{BE1} - 5$

$I_{ref} = 4.65\,mA$

$I_{E3} \cong I_o \cong 4.65\,mA$

$I_{B3} = \dfrac{I_{E3}}{1+\beta} = 46\,\mu A$

$I_{C3} = I_{E3} - I_{B3} = 4.6\,mA$

BE3-KVL: $0 = 10k \cdot I_{B3} + V_{BE3} + V_{C2}$

$\rightarrow V_{C2} = -1.16\,V$

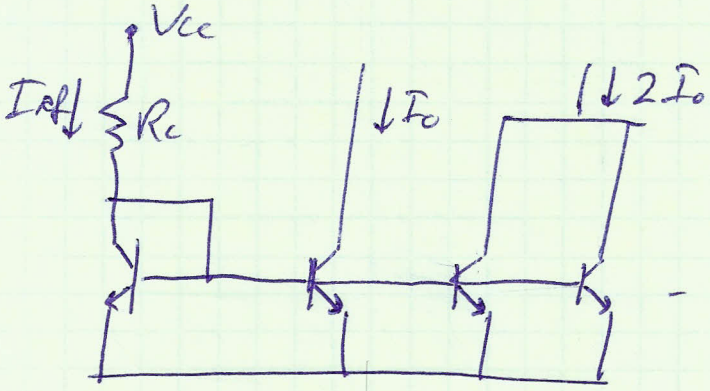
Q_2 is active: $V_{CE2} = V_{C2} - (-5) = 3.84\,V > V_{D0}$

CE3-KVL: $5 = 1k \cdot I_{C3} + V_{CE3} + V_{C2}$

$\rightarrow V_{CE3} = 1.56\,V > V_{D0}$

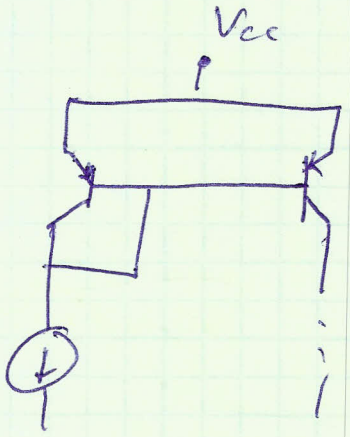
Q_3 is active

Other current mirrors

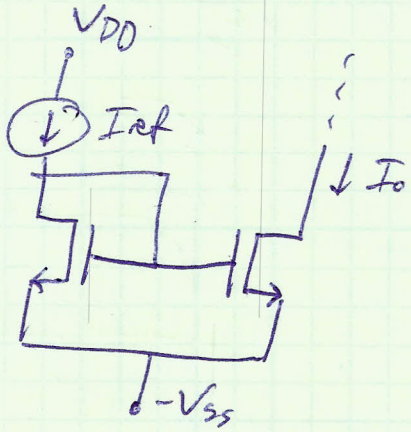


multiple outputs

can also sum currents



PNP version



FET version