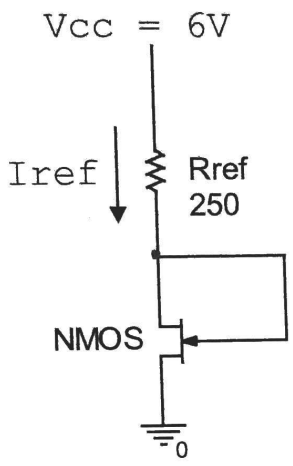
Homework 11

Reading: 7.1, 7.2-5 (FET discussion)

Problem 1) Current mirrors



$V_{CC} = V_R + V_{DS}$

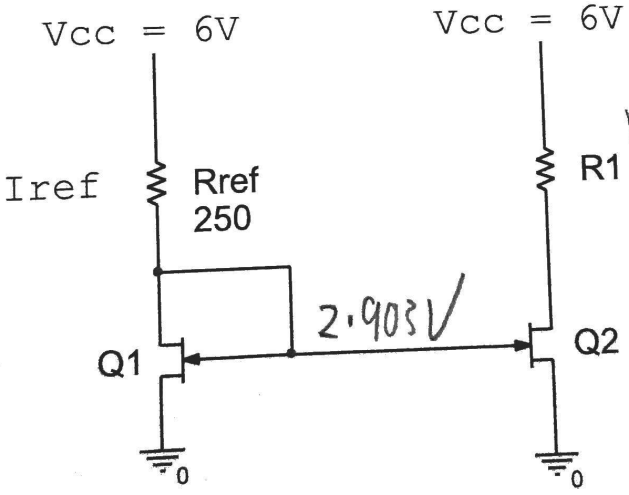
$\delta = \frac{1}{2} k_n (V_{GS} - V_{Tn})^2 R + V_{GS}$

$V_{GS} = 2.9$ or ~~1.3~~

Thus $I_{ref} = 12.4$ mA

For the above circuit, VTN = 2.2V and Kn = 50mA/V^2.

a) Determine the reference current through Rref.



$V_{ds} > V_{GS} - V_{Tn}$

$V_{CC} - V_R > V_{GS} - V_{Tn}$

$6 - V_R > 0.7$

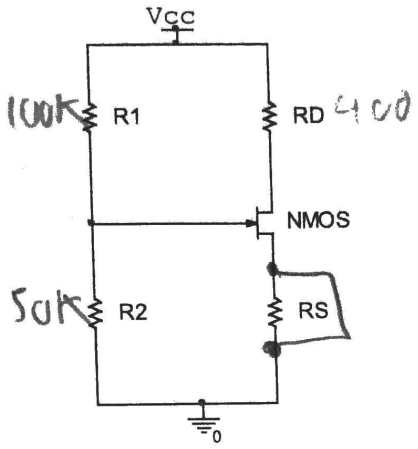
$5.3 > R \cdot I_{Ref}$

$427.42 > R$

b) Both FETs are identical and have the same specifications as above. Determine the range of R1 such that the current through R1 is the mirror of Iref ($I_{R1} = I_{ref}$).

$R_1 < 427.42\ \Omega$

Problem 2) Circuit sensitivity



The NMOSFET in the above circuit has characteristics, VTN = 2.2V and Kn = 40mA/V^2

a) For Vcc = 9V, R1 = 100k, R2 = 50k, RD = 400Ω and RS = 0Ω (a short circuit), determine the DC bias characteristics, ID, VGS and VDS.
b) If the transistor threshold voltage changed to 2.1V, determine the same DC bias characteristics.
c) For a change of ~5% of the threshold voltage, what percentage change did you observe in the drain current, ID?

A: Assume sat: $V_{GS} = \frac{9V(50k)}{100+50k} = 3V$ $I_D = \frac{1}{2}(0.04)(3-2.2)^2 = 12.8mA$

$V_{CC} = V_{RD} + V_{DS}$ $9 = (.0128)(400) + V_{DS}$ $V_{DS} = 3.88 > 3-2.2$

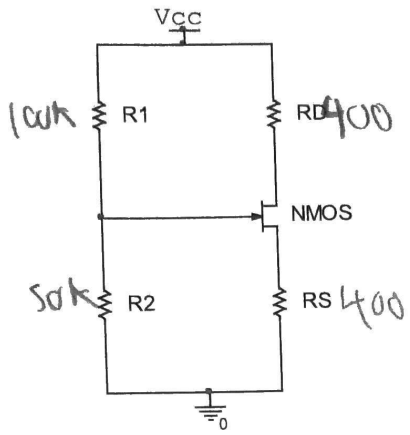
Saturation is checked $V_{GS} = 3V$ $V_{DS} = 3.88$ $I_D = 12.8mA$

B: $I_d = \frac{1}{2}(0.04)(3-2.1)^2 = 0.0162$ $9 = (0.0162)(400) + V_{ds}$

saturation is checked $V_{GS} = 3V$ $I_d = 16.2mA$ $V_{ds} = 2.52 > 3-2.1$

C: $\frac{16.2-12.8}{12.8} = .26 \times 100 = 26.6\%$

Problem 3) Four resistor biasing and circuit sensitivity



The NMOSFET in the above circuit has characteristics, VTN = 2.2V and Kn = 40mA/V^2

a) For Vcc = 9V, R1 = 100k, R2 = 50k, RD = 400Ω and RS = 400Ω, determine the DC bias characteristics, ID, VGS and VDS.

b) If the transistor threshold voltage changed to 2.1V, determine the same DC bias characteristics.

c) For a change of ~5% of the threshold voltage, what percentage change did you observe in the drain current, ID?

d) For the original FET parameters and part a component values (except RD), determine the range of RD such that the FET is in saturation.

e) For the original FET parameters and part a component values (except R2), determine the range of R2 such that the FET is in saturation.

A: $V_g = \frac{9(50k)}{150k} = 3V$ assume saturation $3V = V_{GS} + \frac{1}{2}(0.04)(V_{GS} - 2.2)^2 400$

$V_{GS} = 2.46$ or ~~1.1~~ $I_D = 1.35mA$

$9 - (1.35\times10^{-3})400 - (1.35\times10^{-3})400 = V_{DS} = 7.918$ saturation is valid.

$V_{GS} = 2.46V$, $I_d = 1.35mA$, $V_{DS} = 7.92V$

B: $3V = V_{GS} + \frac{1}{2}(0.04)(V_{GS} - 2.1)^2 400$ $V_{GS} = 2.38$ $I_D = 1.57mA$

$9 - (400 \cdot 1.57mA) - (400 \cdot 1.57mA) = V_{DS} = 7.75V$ sat is valid

$V_{GS} = 2.38V$, $I_d = 1.57mA$, $V_{DS} = 7.75V$ next page →

C: $\frac{1.57mA - 1.35mA}{1.35mA} = .16 \times 100 = 16.30\%$

P: $V_{CC} - V_{RD} > 2.46 - 2.2$

$9 - .26 - (1.35mA)4k\Omega > V_{RD}$

$8.2 > V_{RD}$

$6074 > R_D$

$R_D < 6074$

E: $V_{CC} - V_{RD} - V_{RS} > V_{GS} - V_{TN}$

$V_{CC} - I_D R_D - I_D R_S > V_{GS} - 2.2$

$11.2 - 4kI_D - V_{RS} > V_g - V_{RS}$

$11.2 - 4kI_D > V_g$

$11.2 - 4kI_D > V_G$ Transistor must be On.

$V_g - V_{RS} > 2.2$

$V_g - 4kI_D > 2.2$

$R_2 > 33,000\ \Omega$

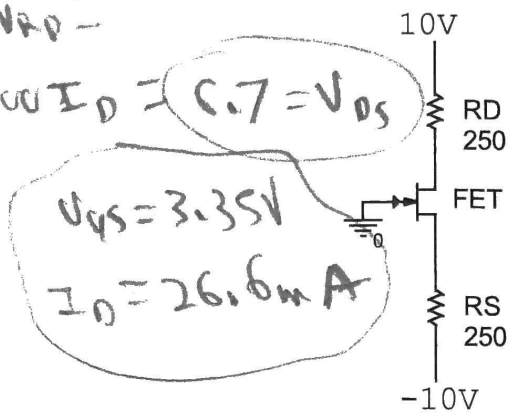
Problem 4) More biasing

$V_{DS} = 20 - 2V_{RD}$

$20 - 500 I_D = 0.7 = V_{DS}$

$V_{GS} = 3.35V$

$I_D = 26.6mA$



$V_{GS} + V_{D-S} = 0$

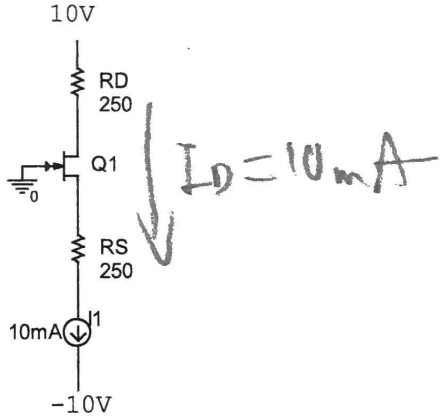
$V_{GS} + 2(0.5(0.04)(V_{GS} - 2.2)^2) = 10$

$V_{GS} = 3.35$ or ~~8.8~~

thus $I_D = 26.59mA$

The NMOSFET in the above circuit has characteristics, VTN = 2.2V, and Kn = 40mA/V^2

a) Determine the bias characteristics, VGS, VDS, and ID, of the above FET circuit.



$I_D = 10mA$

The NMOSFET in the above circuit has characteristics, VTN = 2.2V, and Kn = 40mA/V^2

b) Determine the bias characteristics, VGS, VDS, and ID, of the above FET circuit.

$V_{GS} = 10 - 250 \cdot 0.01 = 7.5V = V_{GS}$

$V_{DS} = 20 - 500 I_D = 15V = V_{DS}$

$10mA = I_D$