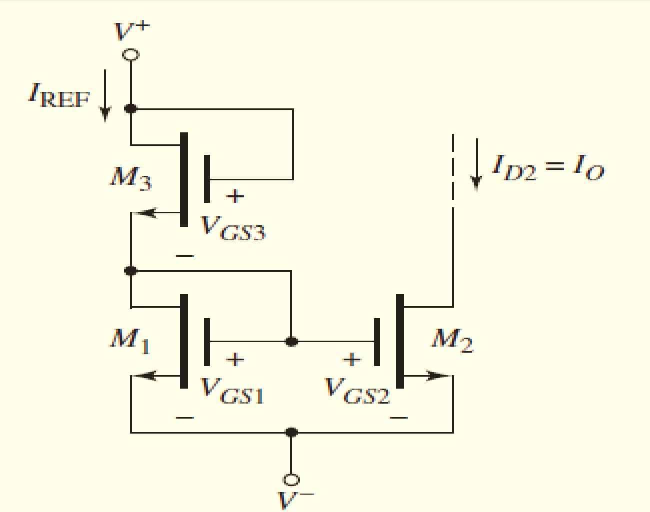
Numerical

Design a MOSFET current source circuit to meet a set of specifications.



The bias voltages are $V+ = 2.5$ V and $V- = 0$. Transistors are available with parameters $k'_n = 100\ \mu A/V^2$, $V_{TN} = 0.4$ V, and $\lambda = 0$. Design the circuit such that $I_{REF} = 100 \mu A$, $I_O = 60 \mu A$, and $V_{DS2(sat)} = 0.4$ V

We have $V_{DS2}(\text{sat}) = 0.4 = V_{GS2} - 0.4$, so that $V_{GS2} = V_{GS1} = 0.8$ V

Then for transistor M_2,

$$\left(\frac{W}{L}\right)_2 = \frac{I_0}{\left(\frac{k_n'}{2}\right)(V_{GS2} - V_{TN})^2} = \frac{60}{\left(\frac{100}{2}\right)(0.8 - 0.4)^2} = 7.5$$

For transistor M_1,

$$\left(\frac{W}{L}\right)_1 = \frac{I_{\text{REF}}}{\left(\frac{k_n'}{2}\right)(V_{GS1} - V_{TN})^2} = \frac{100}{\left(\frac{100}{2}\right)(0.8 - 0.4)^2} = 12.5$$

WKT

From the circuit, we see that

$$V_{GS1} + V_{GS3} = V^{+} - V^{-}$$

The value of V_{GS3} is found as

$$V_{GS3} = (V^{+} - V^{-}) - V_{GS1} = 2.5 - 0.8 = 1.7\ \text{V}$$

Then for transistor M_3 we find

$$\left(\frac{W}{L}\right)_3 = \frac{I_{\text{REF}}}{\left(\frac{k'_n}{2}\right)(V_{GS3} - V_{TN})^2} = \frac{100}{\left(\frac{100}{2}\right)(1.7 - 0.4)^2} = 1.18$$

Problem Statement

Consider the MOSFET current-source circuit in Figure with $V^+ = +2.5$ V and $R = 15$ kΩ. The transistor parameters are $V_{TN} = 0.5$ V, $k_n' = 80\ \mu\text{A/V}^2$, $W/L = 6$, and $\lambda = 0$. Determine I_{REF}, I_O, and $V_{DS2}(\text{sat})$.

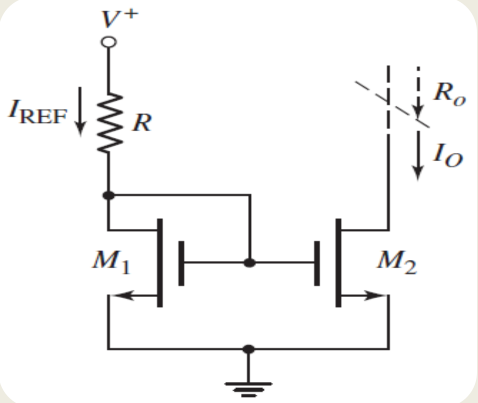
$$I_{REF} = \frac{2.5 - V_{GS}}{15} = \left(\frac{0.08}{2}\right)(6)(V_{GS} - 0.5)^2$$

$$2.5 - V_{GS} = 3.6\left(V_{GS}^2 - V_{GS} + 0.25\right)$$

$$3.6V_{GS}^2 - 2.6V_{GS} - 1.6 = 0$$

$$V_{GS} = \frac{2.6 \pm \sqrt{6.76 + 23.04}}{2(3.6)}$$

$$V_{GS} = 1.12\ \text{V}\,(1.1193)$$



$$I_{REF} = \frac{2.5 - 1.1193}{15} \Rightarrow I_{REF} = 92.0\ \mu\text{A}\ (92.05)$$

$$I_o = 92.0\ \mu\text{A}$$

$$V_{DS2}(\text{sat}) = V_{GS} - V_{TN} = 1.1193 - 0.5$$

$$V_{DS2}(\text{sat}) = 0.619\ \text{V}$$

$MOSFET\ Current\ source\ circuit$

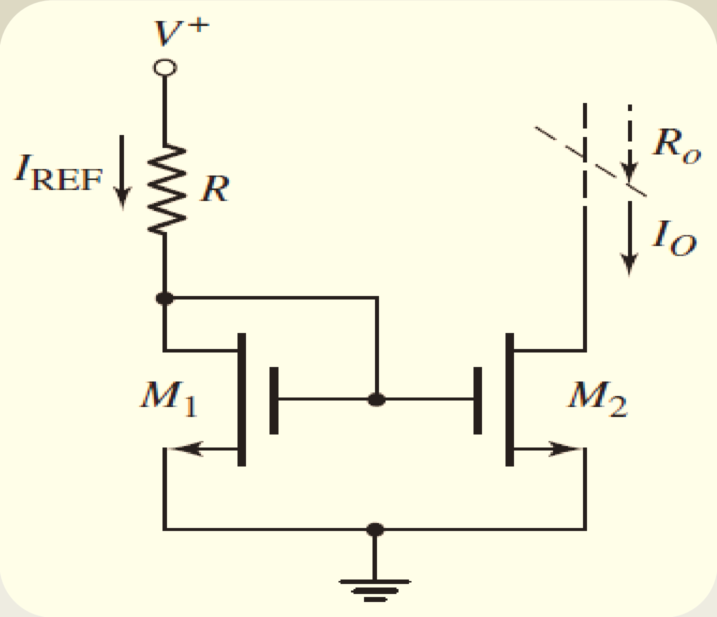
$V^{+} = 2V$

$Parameters$ are $\mathrm{V_{TN}} = 0.5V\ K_n = 80\mu A/V^2, V_{DS2}(sat) = 0.25V\ and\ \lambda = 0.015V^{-1}$

$(a) Design\ the$ circuit such that $\mathrm{I_{REF}} = 50\mu A$ and normal bias current $\mathrm{I_0} = 100\mu A$

$(b) Find\ the\ output\ resis\tan ce(R_o)$

$(c) Deter\min e\ the$ percentatge change in $\mathrm{I_0}$ for a change in drian to source voltage $\Delta V_{DS2} = 1V$



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$$I_{REF} = 50 = \left(\frac{80}{2}\right)\left(\frac{W}{L}\right)_1 (V_{GS} - 0.5)^2$$

$$I_{REF} = 0.050 = \frac{2.0 - V_{GS}}{R}$$

Design such that $V_{DS2}(\text{sat}) = 0.25 = V_{GS} - 0.5$

$$V_{GS} = 0.75 \text{ V}$$

$$0.050 = \frac{2 - 0.75}{R} \Rightarrow \underline{R = 25 \text{ K}}$$

$$50 = \left(\frac{80}{2}\right)\left(\frac{W}{L}\right)_1 (0.75 - 0.5)^2 \Rightarrow \underline{\left(\frac{W}{L}\right)_1 = 20}$$

$$\frac{\left(\frac{W}{L}\right)_1}{\left(\frac{W}{L}\right)_2} = \frac{I_{REF}}{I_O} \Rightarrow \frac{20}{\left(\frac{W}{L}\right)_2} = \frac{50}{100} \Rightarrow \underline{\left(\frac{W}{L}\right)_2 = 40}$$

$\boxed{2}$

$$R_o = \frac{1}{\lambda I_o} = \frac{1}{(0.015)(0.1)} \Rightarrow R_o = 667 \text{ K}$$

$$\Delta I_o = \frac{\Delta V}{R_o} = \frac{1}{666} \Rightarrow 1.5\ \mu\text{A}$$

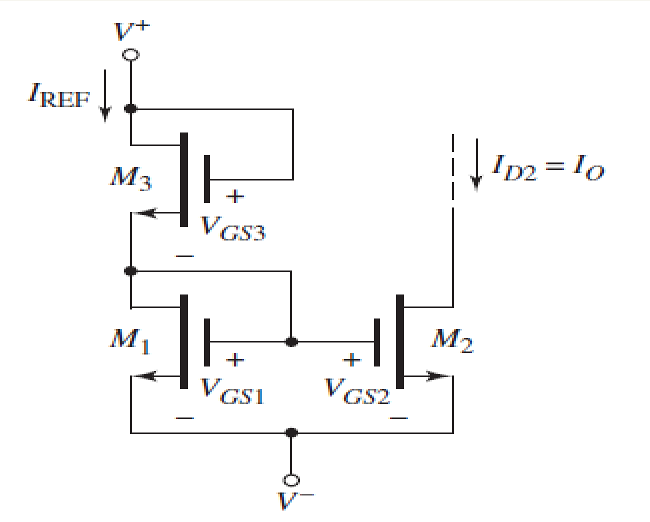
$\boxed{3}$

$$\Delta I_o = \frac{\Delta V}{R_o} = \frac{1}{666} \Rightarrow 1.5\ \mu\text{A}$$

$$\frac{\Delta I_o}{I_o} \times 100\% = \left(\frac{1.5}{100}\right) \times 100\% \Rightarrow \underline{1.5\%}$$

A:1

Design a MOSFET current source circuit to meet a set of specifications.



The bias voltages are $V+ = 5$ V and $V- = 0$. Transistors are available with parameters $k'n = 20$ $\mu A/V^2$, $VTN = 1$ V, and $\lambda = 0$. Design the circuit such that $I_{REF} = 0.25$mA, $I_O = 0.1$mA, and $V_{DS2(sat)} = 0.85$ V

Calculate the dc characteristics of a MOSFET diffamp

Consider the diff $-$ *amp shown in Figure* 11.20. *The transistor parameters are*

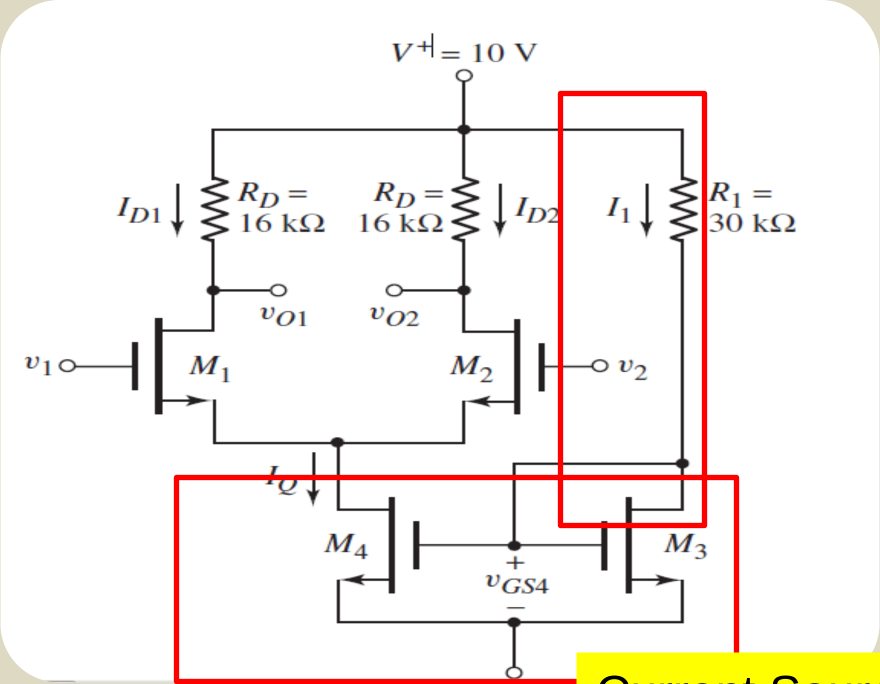
$K_{n1} = K_{n2} = 0.1\, mA/V^2$, $Kn_3 = Kn_4 = 0.3\, mA/V^2$,

and for all transistors $\lambda = 0$ *and* $V_{TN} = 1\, V$

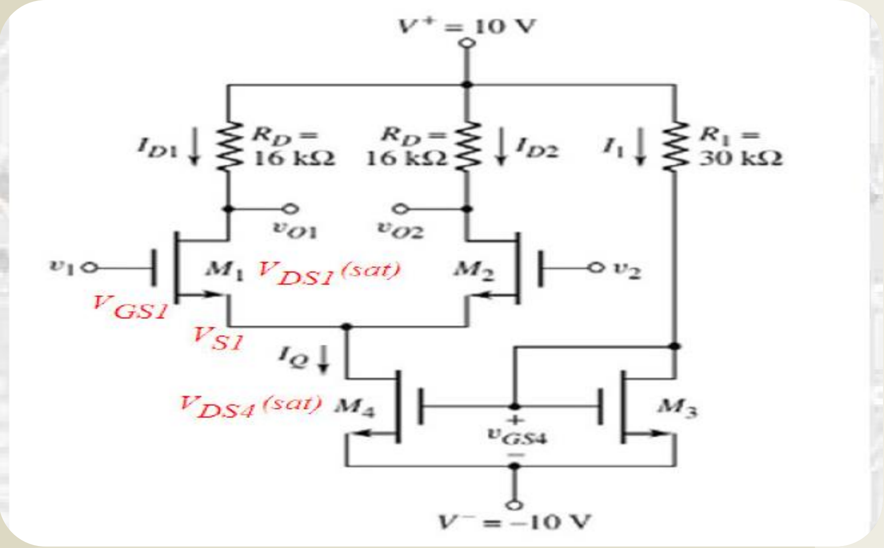
Determine the maximum range of common $-$ *mode input voltage, i.e.*

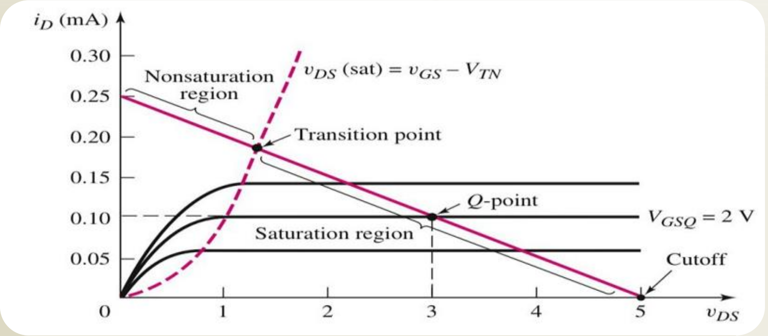
find $v_{CM\ (max)}$ *and* $v_{CM\ (min)}$

Circuit Source: Donald A. Neamen



Current Source





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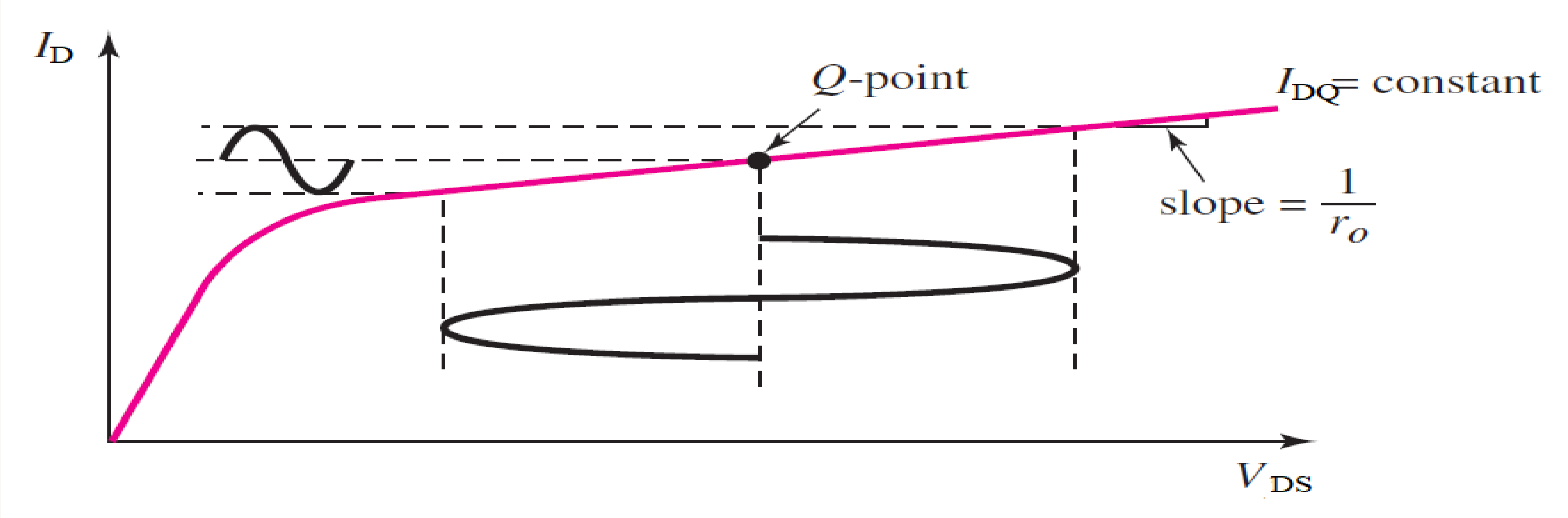


I_D
Q-point
I_{DQ}= constant
slope = $\frac{1}{r_o}$
V_{DS}

The reference current can be determined from:

$$I_1 = \frac{V^+ - V^- - V_{GS4}}{R_1} = \frac{20 - V_{GS4}}{R_1}$$ Eq.1

$$I_1 = K_{n3}(V_{GS4} - V_{TN})^2$$ Eq.2

Comparing equation 1 and 2

$$\frac{20 - V_{GS4}}{30} = (0.3)(V_{GS4} - 1)^2$$

$$20 - V_{GS4} = 9(V_{GS4} + 1 - 2V_{GS4})$$

$$20 - V_{GS4} = 9V_{GS4}{}^2 + 9 - 18V_{GS4}$$

$$9V_{GS4}{}^2 - 17V_{GS4} - 11 = 0$$

$$V_{GS4} = 2.40\ V$$

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Substitute $V_{GS4} = 2.40$ V from Eq.1

$$I_1 = \frac{20 - 2.40}{30} = 0.587A$$

Since M3 and M4 are identical, we also find

$I_Q = 0.587$ mA

The quiescent drain currents in Ml and M2 are

$I_{D1} = I_{D2} = I_Q/2$

Circuit Source: Donald A. Neamen

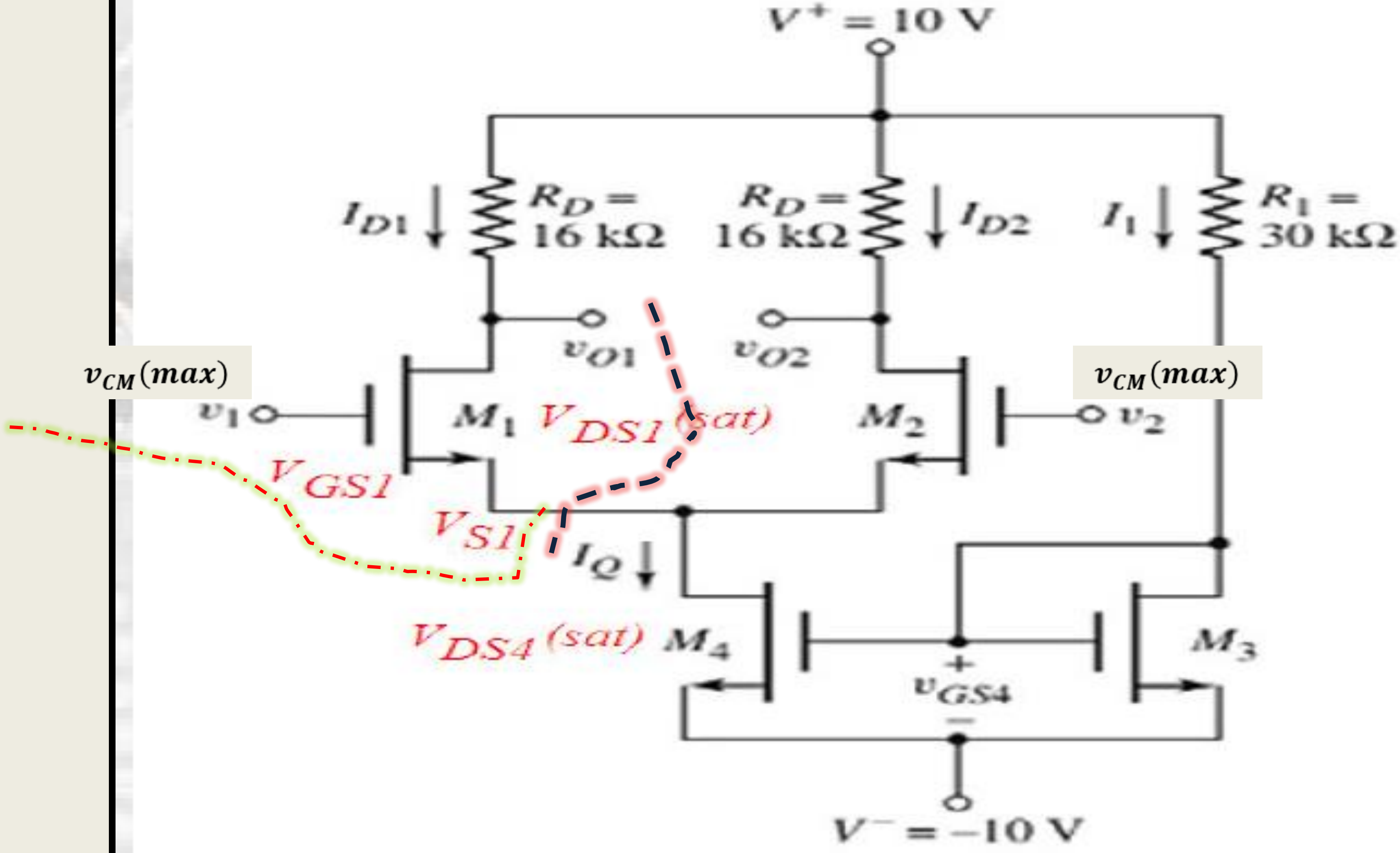
The gate-to-source voltages are then

$$V_{GS1} = V_{GS2} = \sqrt{\frac{I_{D1}}{K_{n1}}} + V_{TN} = \sqrt{\frac{0.293}{0.1}} + 1 = 2.71\text{V}$$

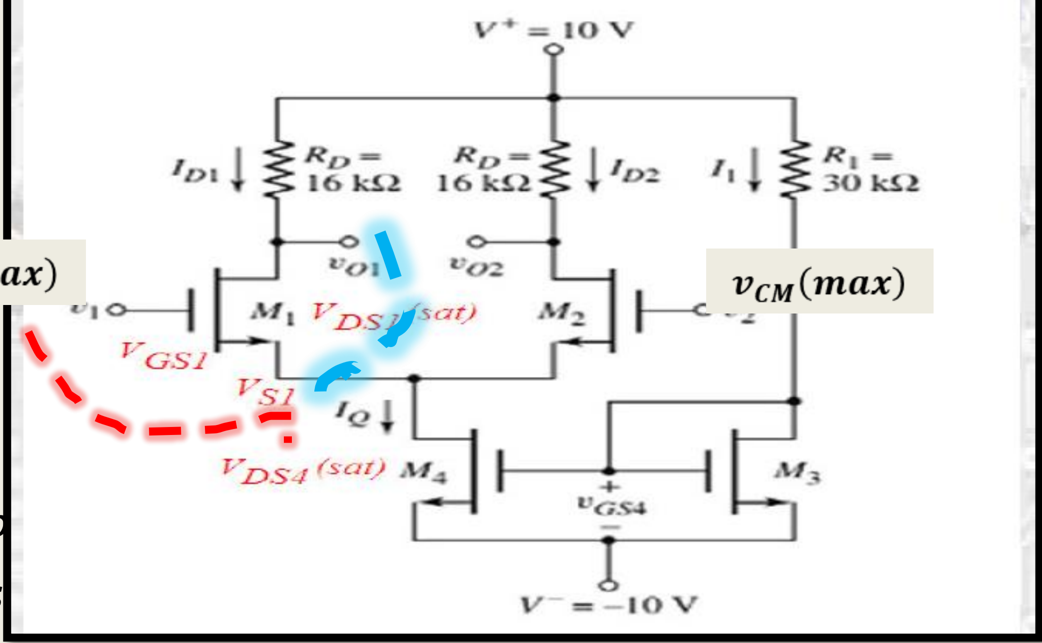
The quiescent values of v_{O1} and v_{O2} are

$$v_{O1} = v_{O2} = 10 - I_D R_D = 10 - (0.293)(16) = 5.31\text{V}$$

Circuit Source: Donald A. Neamen



V+ = 10 V
ID1
RD = 16 kΩ
RD = 16 kΩ
ID2
I1
R1 = 30 kΩ
vO1
vO2
vCM(max)
vCM(max)
v1
v2
M1
M2
VDS1(sat)
VGS1
VS1
IQ
VDS4(sat)
M4
M3
+
vGS4
−
V− = −10 V



Circuit Source: Donald A. Neamen

The maximum common – mode inp

when M1 and M2 reach the trans

$$V_{DS1} = V_{DS2} = V_{DS1\,(sat)} = V_{GS1} - V_{TN}$$

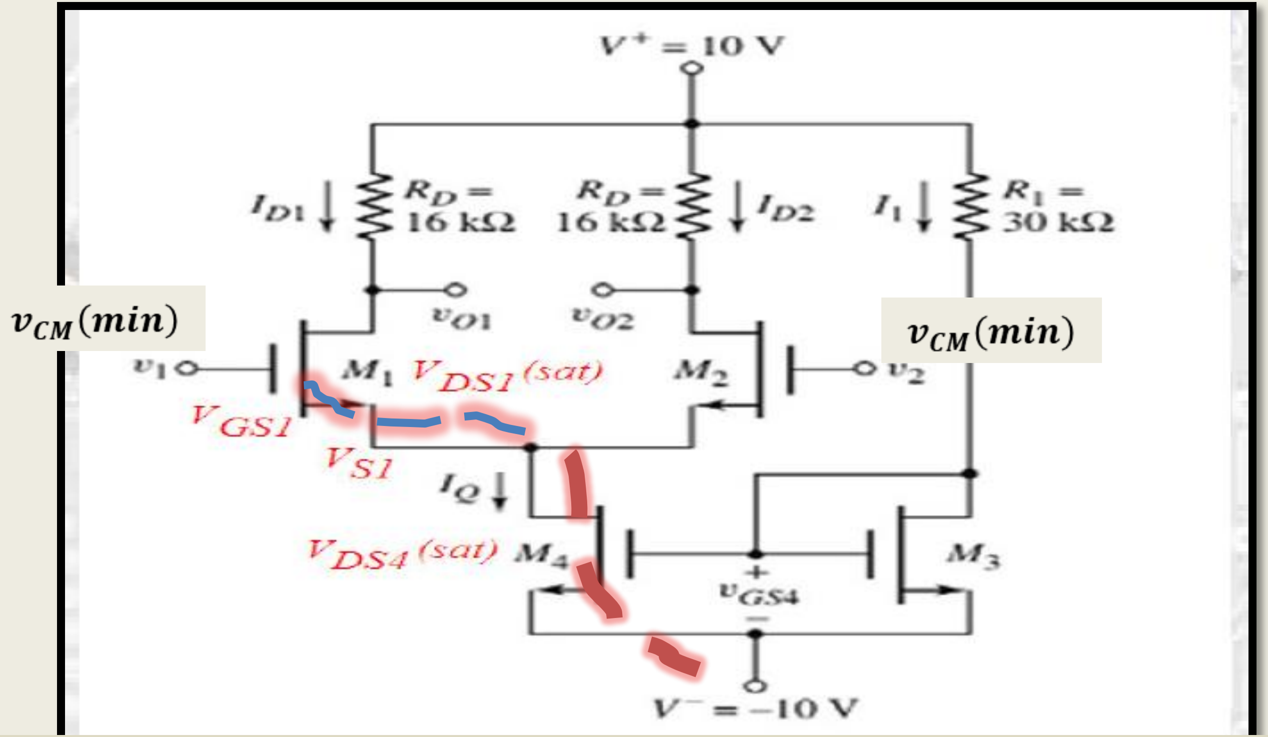
$$V_{DS1} = 2.71 - 1 = 1.71\,V$$

$$v_{CM\ (max)} = V_{S1\,(max)} + V_{GS1}$$

Therefore,

$$v_{CM\ (max)} = v_{O1} - V_{DS1\,(sat)} + V_{GS1}$$

$$= 5.31 - 1.71 + 2.71 = 6.31\,V$$



The minimum common – mode input voltage is the value when M4 reaches the transition point,

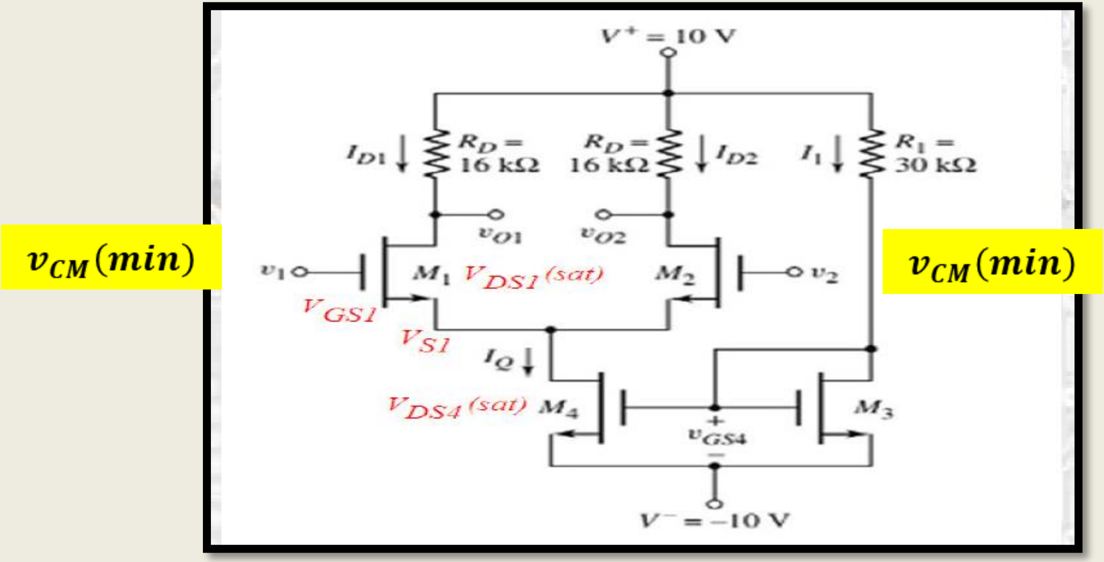
$$V_{DS4} = V_{DS4\,(sat)} = V_{GS4} - V_{TN} = 2.4 - 1 = 1.4\ V$$

Therefore,

$$v_{CM\ (min)} = \mathrm{Vs} + V_{GS1}$$

$$v_{CM\ (min)} = V^{--} + V_{DS4\ (sat)} + V_{GS1} = (-10) + 1.4 + 2.71 = -5.89\ V$$

For this circuit the maximum range for the common-mode input voltage is -5.89 < v_{CM} < 6.31 V.



A:2

For the differential amplifier in Figure , the parameters are: $V+ = 5$ V, $V- = -5$ V, $R1 =$ 80 kΩ, and $RD = 40$ kΩ.
The transistor parameters are $\lambda = 0$ and $VT\,N = 0.8$ V for all transistors, and $Kn3 = Kn4 = 100$ μA/V2 and $Kn1 = Kn2 = 50$ μA/V2. Determine the range of the common-mode input voltage.
a