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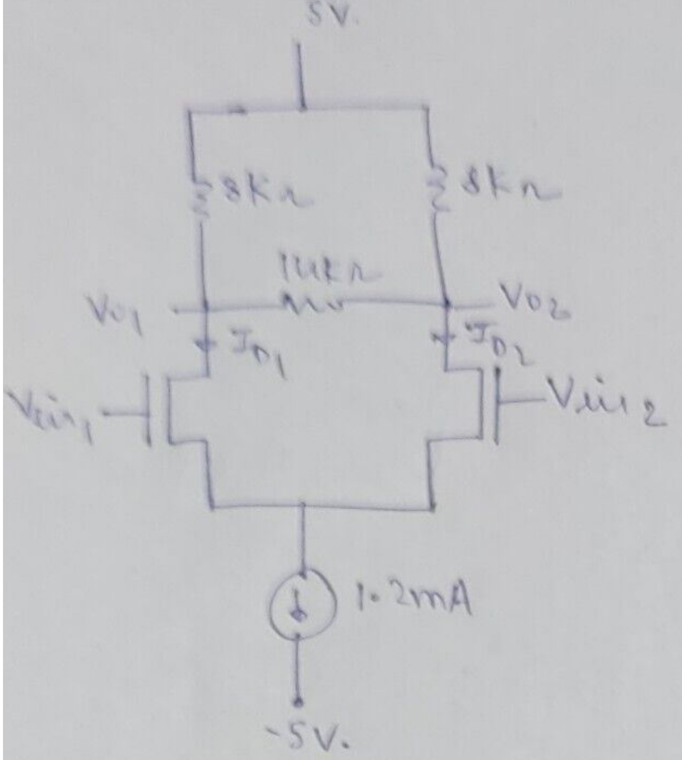


(i) Common-mode Analysis:-

- $V_{in_1} = V_{in_2} = V_c$
- $I_{D_1} = I_{D_2} = 0.6\text{mA} = \left(\frac{I_{SS}}{2}\right)$
- $I_{D_1} = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)(V_{gs}-V_{th})^2$

$\Rightarrow (0.6\times10^{-3}) = \frac{1}{2}\times\frac{(5\times10^{-5})}{2}(V_{gs}-V_{th})^2$

$\Rightarrow V_{gs}-V_{th} = \sqrt{48} = 4\sqrt{3}$

$\Rightarrow \boxed{V_{gs} = (4\sqrt{3}+1)} = 7.928\text{ V}.$

For saturation of MOS:- $V_{ds} \geq V_{gs} - V_{th}$

$V_d \geq (V_g - V_{th})$

$\Rightarrow 5 - \frac{(1.2\times10^{-3})}{2}\times(14\times10^{3}) \geq (V_g - 1)$

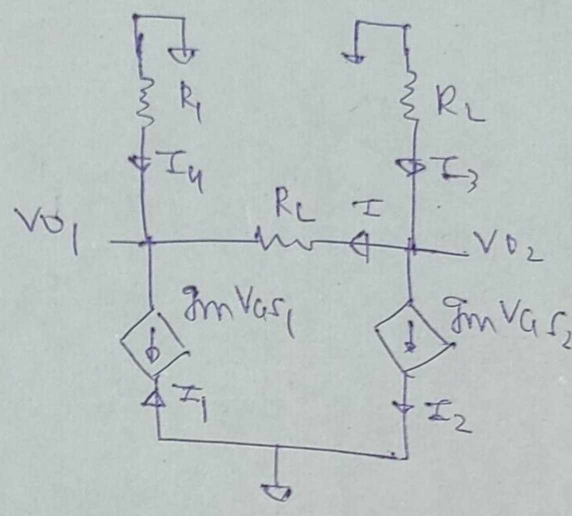
$\Rightarrow \boxed{V_g \leq -2.4V}$

The value of V_g at which $V_{gs} = 7.928$ volt is:

$V_c = V_{g_1} = V_{g_2} = -2.4$ volt.

Differential mode analysis:-

Small signal circuit:-



- As V_{in_1} and V_{in_2} are out of phase, $\boxed{V_{GS_1} = -V_{GS_2}}$
- Hence, $I_1 = I_2 = g_m V_d$
- By KCL, $\left.\begin{array}{l} I_1 + I_4 + I = 0 \quad (1) \\ I_3 = I + I_2 \end{array}\right\}$ As $I_1 = I_2 \Rightarrow \boxed{I_3 = -I_4}$
- Now $V_{O_2} - V_{O_1} =$ voltage across $R_L = V_O$
- Let $V_{in_2} - V_{in_1} = V_i = 2V_d$
- By KVL, $-I_4 R_1 + I R_L + I_3 R_2 = 0$
- We have, $R_1 = R_2 = R$ and also $I_3 = -I_4$.

$$\boxed{I_4 = \frac{I R_L}{2R}}$$

From eqn. (1): $I + I_1 + I_4 = 0$

$$\frac{V_O}{R_L} + g_m V_d + \frac{V_O}{2R} = 0$$

$$\Rightarrow \boxed{\frac{V_O}{V_i} = \frac{-g_m}{\left(\frac{2}{R_L} + \frac{1}{R}\right)}}$$

$\Rightarrow$ differential voltage gain.

Given: $R_1 = R_2 = (8\times10^3)\,\Omega$; $R_L = (14\times10^3)\,\Omega$

$\cdot\ I_1 = I_2 = (0.6\times10^{-3})\,A = (6\times10^{-4})\,A$

$$g_m = \sqrt{2 I_d \cdot \mu_n C_{ox}\left(\frac{W}{L}\right)} = \sqrt{\frac{2\times(6\times10^{-4})\times(5\times10^{-5})}{2}}$$

$$\# \ g_m = \sqrt{3}\times10^{-4}$$

A_v = differential voltage gain $= \dfrac{-g_m}{\left(\dfrac{2}{R_L}+\dfrac{1}{R}\right)}$

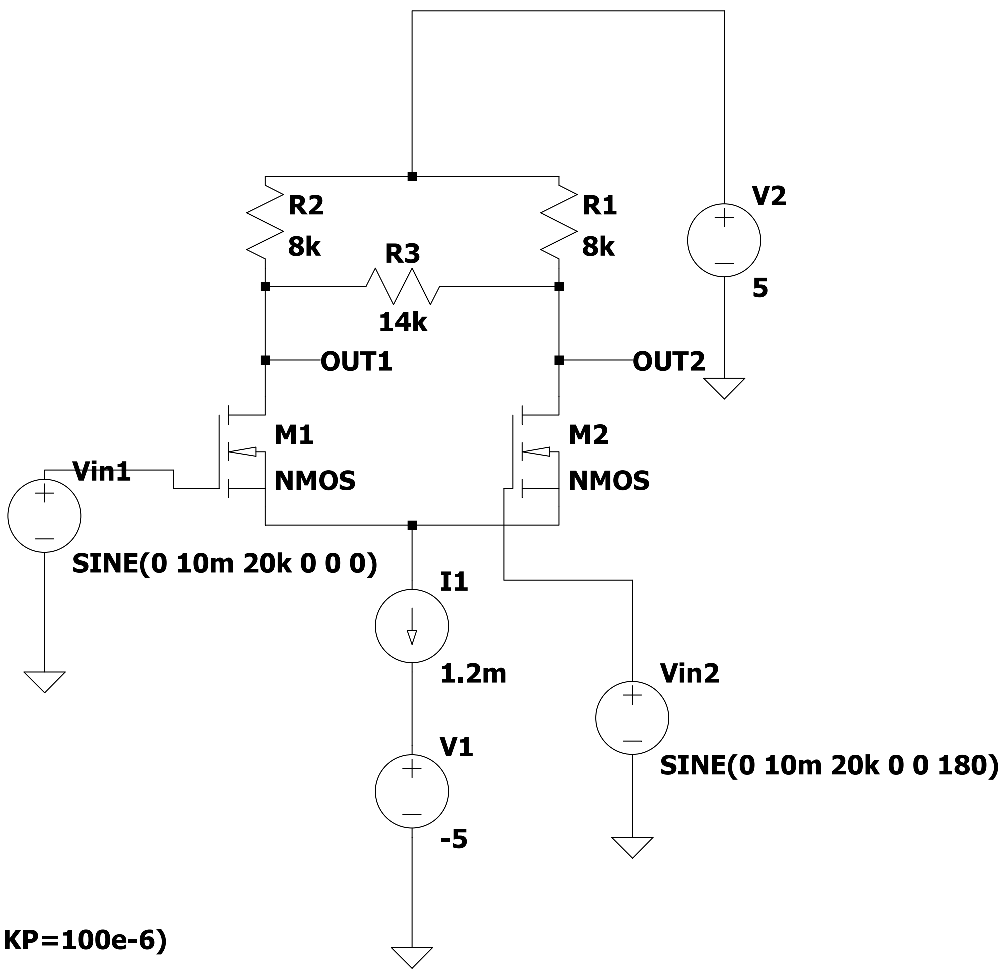
$$= \frac{-\sqrt{3}\times10^{-4}}{\left(\frac{2}{14}+\frac{1}{8}\right)\times10^{-3}}$$

$$= \frac{-0.1732}{(15/56)}$$

$$= -0.6466 \ \underline{Ans}$$

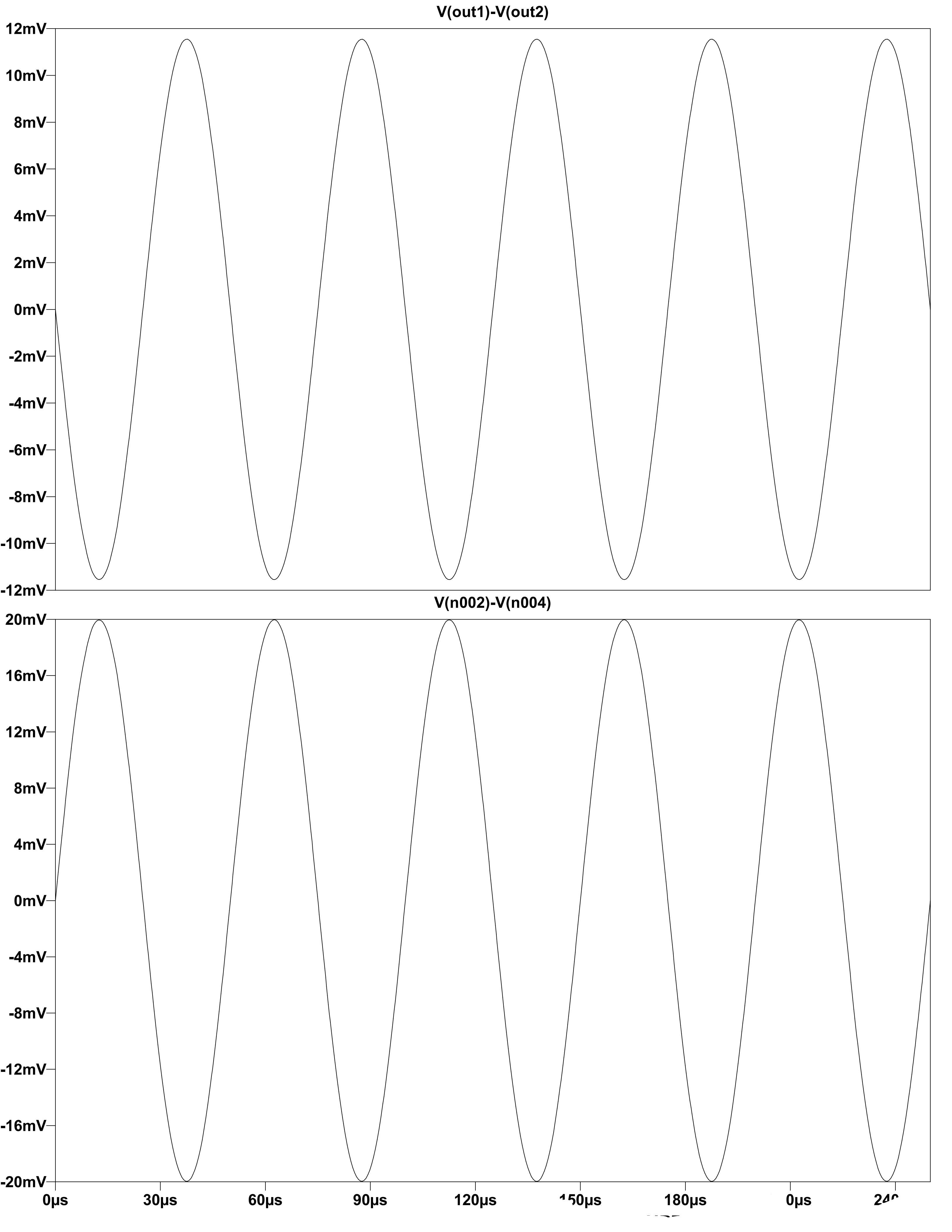
LTspice result:

$\left|\dfrac{V_{o_2}-V_{o_1}}{V_{in_1}-V_{in_2}}\right| = \dfrac{-11.5}{20} = -0.575$ Ans



.tran 0.25ms

.model mos nmos (Vto=1V KP=100e-6)



V(out1)-V(out2)
12mV
10mV
8mV
6mV
4mV
2mV
0mV
-2mV
-4mV
-6mV
-8mV
-10mV
-12mV
V(n002)-V(n004)
20mV
16mV
12mV
8mV
4mV
0mV
-4mV
-8mV
-12mV
-16mV
-20mV
0µs
30µs
60µs
90µs
120µs
150µs
180µs
0µs