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1232A

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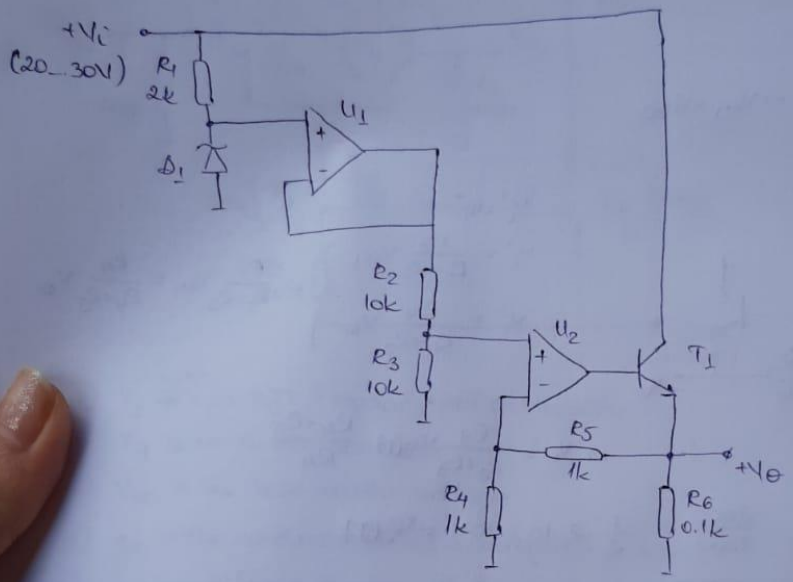
AIC

= FINAL EXAM =

S1 U_1, U_2 - op amp. T_1 has $V_{BE} = 0.6V$, $V_{CE_{sat}} = 0.2V$, $\kappa_{CE} = \infty$.

D_1 is a diode with $V_{Z0} = 10V$ at $T = 300K$, $I_{Z_{min}} = 5mA$, $I_{Z_{max}} = 50mA$, $r_z = 10\Omega$

$\alpha = 1mV/K$



a) D_1 is a Zener diode

b) R_1 converts V_i into current, polarizing the diode ⇒ it acts as a voltage reference for U_1.

c) U_1 receives the voltage from D_1 (Zener voltage) and passes it through a voltage divider.

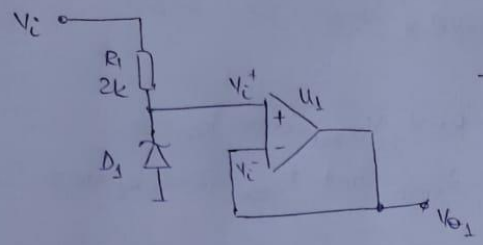
d) U_2 acts as a source of current at the input of T_1. (is a voltage buffer)

e) T_1 provides the output current for the circuit

f) R_2-R_3 is a voltage divider

g) R_6 is a pull down resistor

h) $V_\theta = ?$ (at $T = 300K$)



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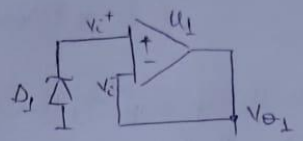
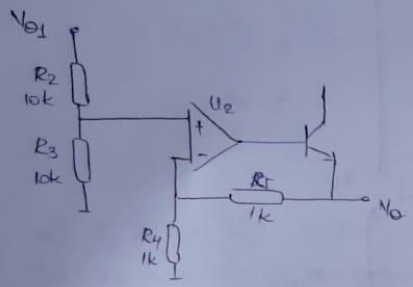


$V_i^+ = V_i^-$

$V_{Z0} = V_i^+$

$V_i^- = V_{\theta 1}$

$\Rightarrow V_{\theta 1} = V_{Z0}$



$V_i^+ = V_i^-$

$V_i^+ = \frac{R_3}{R_2+R_3} V_{\theta 1}$

$V_i^- = \frac{R_4}{R_4+R_5} V_\theta$

$\Rightarrow \frac{R_3}{R_2+R_3} V_{\theta 1} = \frac{R_4}{R_4+R_5} V_\theta$

$\Rightarrow V_\theta = \frac{R_3}{R_2+R_3} V_{Z(T)} \cdot \frac{R_4+R_5}{R_4}$

$V_\theta = \frac{10 \cdot 10^3}{20 \cdot 10^3} \cdot 10 \cdot \frac{2000}{1000} = \frac{1}{2} \cdot 2 \cdot 10 = 10V$

$\boxed{V_\theta = V_{Z0} = 10V}$

$V_Z(T) = V_{Z0} + a(T - T_0)$

$\Rightarrow V_\theta = V_Z(T) = V_{Z0} + a(T - T_0)$

$T_0 = 300K$, $T = 300$ $\Rightarrow a(T - T_0) = 0$ $\Rightarrow$

$\Rightarrow V_\theta = V_{Z0}$

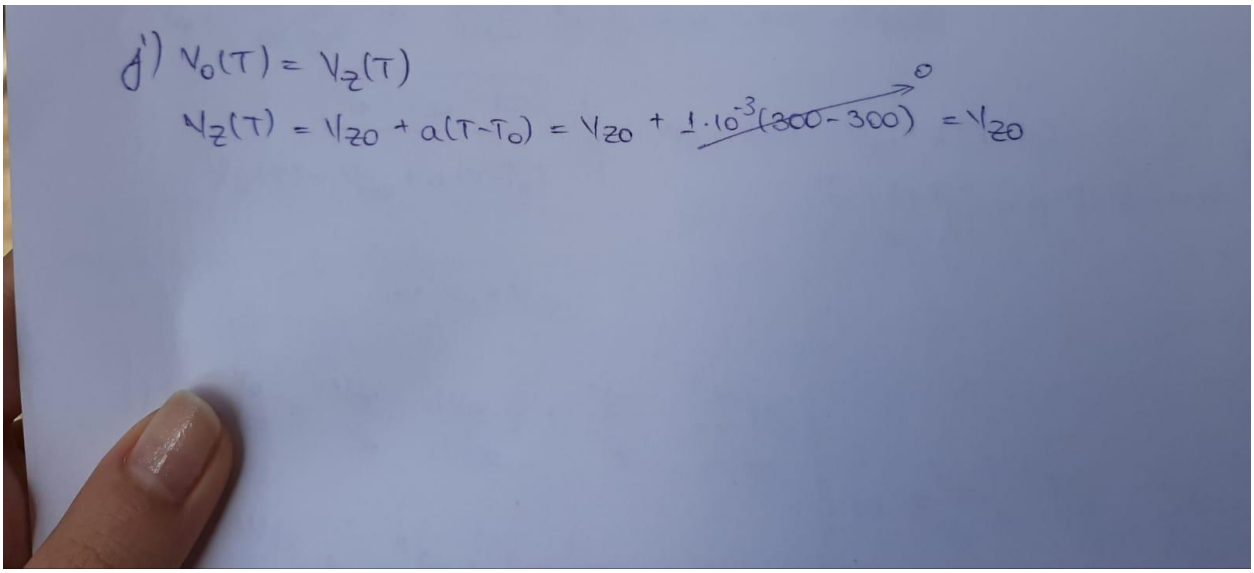
i) $S_{V_{cc}}^{V_\theta} = \frac{V_{cc}}{V_\theta} \cdot \frac{dV_\theta}{dV_{cc}} = \frac{V_{cc}}{V_\theta} \cdot \frac{dV_{Z0}}{dV_{cc}}$

$\frac{dV_{Z0}}{dV_{cc}} = \frac{r_Z}{R_1} \cdot \frac{1}{1 + \frac{r_Z}{R_1}}$

$\Rightarrow S_{V_{cc}}^{V_\theta} = \frac{V_{cc}}{V_{Z0}} \cdot \frac{r_Z}{R_1} \cdot \frac{1}{1 + \frac{r_Z}{R_1}}$

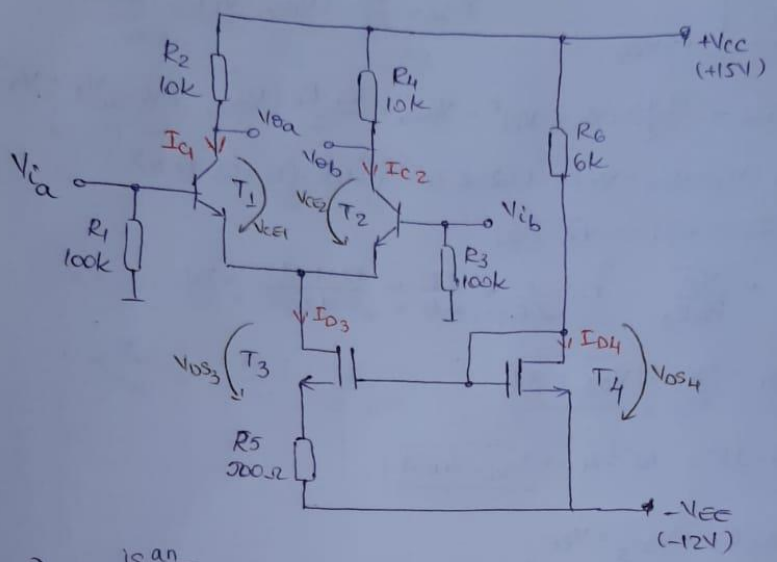
KVL: $V_{cc} = V_{CE} + V_\theta = 0.2 + 10 = 10.2V$

$S_{V_{cc}}^{V_\theta} = \frac{10.2}{10} \cdot \frac{10}{2 \cdot 10^{3/2}} \cdot \frac{1}{1 + \frac{10}{2 \cdot 10^{3/2}}} = \frac{10.2}{2 \cdot 10^3} \cdot \frac{200}{201} = \frac{20,2}{20 \cdot 201} = 5 \cdot 10^{-3}$


d') $V_0(T) = V_Z(T)$
$V_Z(T) = V_{Z0} + a(T-T_0) = V_{Z0} + 1 \cdot 10^{-3}(300-300) = V_{Z0}$
0

(32) T_1, T_2 : $\{V_{BE} = 0.6\,V,\ V_{CE\,sat} = 0.2\,V,\ r_{CE} = 100k\Omega,\ h_{fe} = \beta_F = 100\}$

T_3, T_4 : $\{K' = 25\mu A/V^2,\ \left(\frac{W}{L}\right)_3 = \frac{160}{1},\ \left(\frac{W}{L}\right)_4 = \frac{80}{1},\ V_T = 1V,\ \lambda = 3\cdot10^{-3}V^{-1}\}$



a) T_1 is an npn BJT (bipolar junction transistor)

b) T_4 is an N-mos transistor

c) V_{BE} is the base-emitter voltage

d) g_m is the conductance of a component. $[g_m] = S$ (siemens)

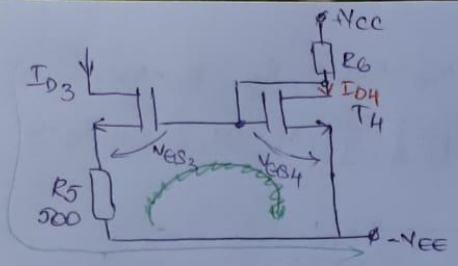
e) β = amplifying factor. It has no measuring unit.

f) The amplifier is formed by 2 blocks :
- the first block (T_1, T_2) is a differential amplifier
- the second block (T_3, T_4) is a current mirror

$K_3 = K' \cdot \left(\frac{W}{L}\right)_3 = 25\cdot10^{-6}\cdot 160 = 4\cdot10^{-3} = 4mA/V^2$

$K_4 = K' \cdot \left(\frac{W}{L}\right)_4 = 25\cdot10^{-6}\cdot 80 = 2\cdot10^{-3} = 2mA/V^2$

$V_{CC} + V_{EE} = R_6 I_{D4} + V_{DS4} + V_{R5}$



$V_{GS4} = V_{DS4}$

$V_{CC} + V_{EE} = I_{D4} \cdot R_G + V_{DS4} = I_{D4} R_G + V_{GS4}$ $\Rightarrow$

$I_{D4} = \frac{K_4}{2} (V_{GS4} - V_T)^2$

$\Rightarrow V_{CC} + V_{EE} = V_{GS4} + \frac{R_G K_4}{2} (V_{GS4} - V_T)^2 = V_{GS4} + \frac{K_4 \cdot R_G}{2} (V_{GS4}^2 - 2V_{GS4}V_T - V_T^2)$

$\Delta = 1 + 2K_4 R_G (V_{CC} + V_{EE} - V_T) = 1 + 2 \cdot 2 \cdot 10^3 \cdot 6 \cdot 10^3 \cdot (15 + 12 - 1) \Rightarrow$

$\Rightarrow \Delta = 1 + 24 \cdot 26 = 625 \Rightarrow \sqrt{\Delta} = 25$

$V_{GS4} = V_T - \frac{1}{K_4 R_G} + \frac{\sqrt{\Delta}}{K_4 R_G} = \overset{12}{1} - \frac{1}{2 \cdot 6} + \frac{25}{2 \cdot 6} = \frac{12 - 1 + 25}{12} = 3V$

$\Rightarrow V_{GS4} = 3V \Rightarrow \boxed{V_{DS4} = 3V}$

$I_{D4} = \frac{2 \cdot 10^{-3}}{2} (3 - 1)^2 = 10^{-3} \cdot 4 \Rightarrow \boxed{I_{D4} = 4mA}$

$I_{D3} R_5 + V_{DS3} = V_{EE}$

$V_{GS3} = V_{DS3}$

$I_{D3} = \frac{K_3}{2} (V_{GS3} - V_T)^2$

$\Rightarrow V_{EE} = V_{GS3} + \frac{K_3 \cdot R_5}{2} (V_{GS3} - V_T)^2$

$\Delta = 1 + 2K_3 R_5 (V_{EE} - V_T) = 1 + 2 \cdot 4 \cdot 10^3 \cdot 0,5 \cdot 10^3 (12 - 1) =$

$= 1 + 4 \cdot 11 = 45 \Rightarrow 3\sqrt{5} = \sqrt{\Delta}$

$V_{GS3} = V_T - \frac{1}{K_3 R_5} + \frac{\sqrt{\Delta}}{K_3 R_5} = \overset{2}{1} - \frac{1}{4 \cdot 0,5} + \frac{3\sqrt{5}}{4 \cdot 0,5} = \frac{2 - 1 + 3\sqrt{5}}{2} =$

$= \frac{1 + 3\sqrt{5}}{2} \approx 3.85 V \Rightarrow \boxed{V_{DS3} = 3.85V}$

$\boxed{I_{D3}} = \frac{\overset{2}{4} \cdot 10^{-3}}{\cancel{2}_1} \left(\frac{1 + 3\sqrt{5}}{2} - \overset{2}{1} \right)^2 = 2 \cdot 10^{-3} \cdot \frac{-1 + 3\sqrt{5}}{2} \approx 10^{-3} \cdot 5,70 \approx \boxed{5.7 mA}$