Student Name: ID Number:

ECE 2EI4 Lab Test (Section 1)

Use the following formulae in your solutions

NMOS Transistor Mathematical Model

Cut off region $i_{DS}=0$ for $v_{GS} < V_{TN}$

Linear region $i_{DS} = K_n(v_{GS} - V_{TN} - 0.5 v_{DS}) v_{DS}$ for $v_{GS}-V_{TN} \geq v_{DS} \geq 0$

Saturation region $i_{DS} = \frac{K_n}{2}(v_{GS} - V_{TN})^2(1+\lambda v_{DS})$ for $v_{DS} \geq v_{GS}-V_{TN} \geq 0$

PMOS Transistor Mathematical Model

Cut off region $i_{SD}=0$ for $v_{SG} < -V_{TP}$

Linear region $i_{SD} = K_p(v_{SG} + V_{TP} - 0.5 v_{SD}) v_{SD}$ for $v_{SG}+V_{TP} \geq v_{SD} \geq 0$

Saturation region $i_{SD} = \frac{K_p}{2}(v_{SG} + V_{TP})^2(1+\lambda v_{SD})$ for $v_{SD} \geq v_{SG}+V_{TP} \geq 0$

Small signal Model Parameter of NMOS Transistors

$$g_m = \sqrt{2 K_n I_{DS} (1+\lambda V_{DS})}$$

$$r_o = \frac{\frac{1}{\lambda} + V_{DS}}{I_{DS}}$$

Propagation delays for reference CMOS inverter with V_{DD}=5V, V_{TN}=1V and V_{TP}=-1V

$$\tau_{PHL} = 0.322 \frac{C}{K_n}$$

$$\tau_{PLH} = 0.322 \frac{C}{K_p}$$

Student Name: ID Number:

Mathematical Model of the pn junction

$$I = I_s(\exp(V_D / V_T) - 1)$$

Full Transport Model of npn transistors

$$i_C = I_s\left[\exp(\frac{v_{BE}}{V_T}) - \exp(\frac{v_{BC}}{V_T})\right] - \frac{I_s}{\beta_R}\left[\exp(\frac{v_{BC}}{V_T}) - 1\right]$$

$$i_E = I_s\left[\exp(\frac{v_{BE}}{V_T}) - \exp(\frac{v_{BC}}{V_T})\right] + \frac{I_s}{\beta_F}\left[\exp(\frac{v_{BE}}{V_T}) - 1\right]$$

$$i_B = \frac{I_s}{\beta_F}\left[\exp(\frac{v_{BE}}{V_T}) - 1\right] + \frac{I_s}{\beta_R}\left[\exp(\frac{v_{BC}}{V_T}) - 1\right]$$

Simplifications of the Transport Model of npn Transistors

Forward active region: $i_C = I_s \exp(\frac{v_{BE}}{V_T})$, $i_B = \frac{i_C}{\beta_F}$ and $i_E = \frac{i_C}{\alpha_F}$

Saturation Region: v_{CESAT}=0.2 V

Cut-off region: $i_B = i_C = i_E = 0$

Full Transport Model of pnp transistors

$$i_C = I_s\left[\exp(\frac{v_{EB}}{V_T}) - \exp(\frac{v_{CB}}{V_T})\right] - \frac{I_s}{\beta_R}\left[\exp(\frac{v_{CB}}{V_T}) - 1\right]$$

$$i_E = I_s\left[\exp(\frac{v_{EB}}{V_T}) - \exp(\frac{v_{CB}}{V_T})\right] + \frac{I_s}{\beta_F}\left[\exp(\frac{v_{EB}}{V_T}) - 1\right]$$

$$i_B = \frac{I_s}{\beta_F}\left[\exp(\frac{v_{EB}}{V_T}) - 1\right] + \frac{I_s}{\beta_R}\left[\exp(\frac{v_{CB}}{V_T}) - 1\right]$$

Simplifications of the Transport Model of pnp Transistors

Forward active region: $i_C = I_s \exp(\frac{v_{EB}}{V_T})$, $i_B = \frac{i_C}{\beta_F}$ and $i_E = \frac{i_C}{\alpha_F}$

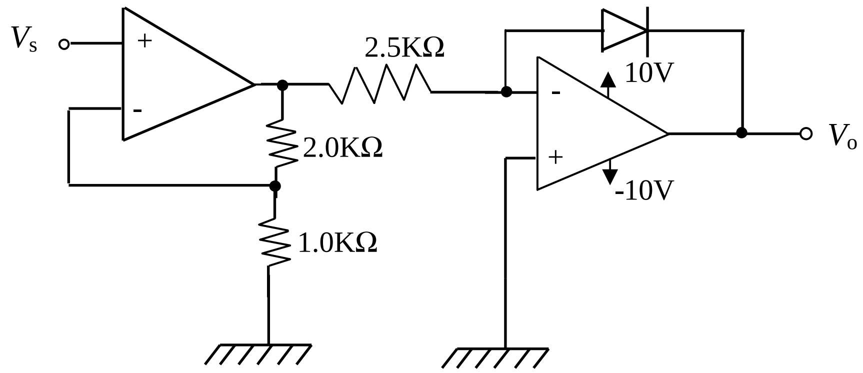
Saturation Region: v_{ECSAT}=0.2 V

Cut-off region: $i_B = i_C = i_E = 0$

Student Name: ID Number:

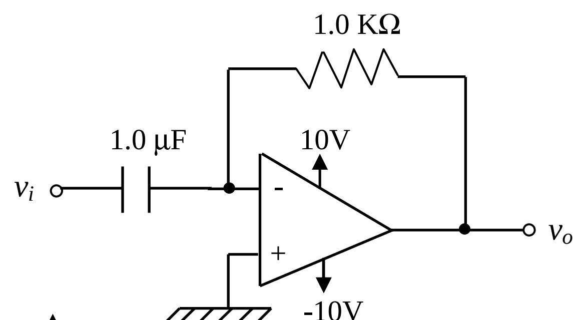
1) For the shown circuit the diode reverse saturation current is $I_s = 10^{-15}$ A. If $V_s = 1.0$ V, V_o is

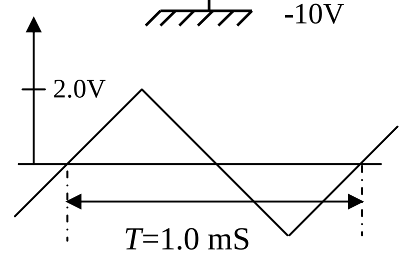
a) 0.6852 V
b) -0.6852 V
c) 0.755 V
d) -0.755V
e) -10V



2) The input to the shown circuit is a triangular waveform with amplitude of 2.0 V. The output v_o as observed on the scope is

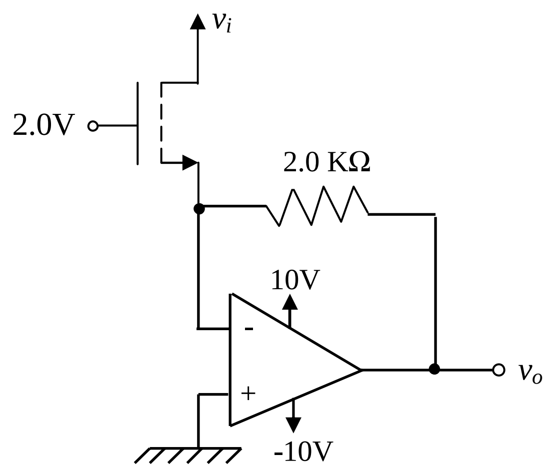
a) a triangular waveform with amplitude 10V and frequency 1.0 KHz.
b) a square waveform with amplitude 10 V and frequency 1.0 KHz.
c) a square waveform with amplitude 8 V and frequency 1.0 KHz.
d) a triangular waveform with amplitude 8V and frequency 1.0 KHz.
e) a square waveform with amplitude 8 V and frequency 2.0 KHz.





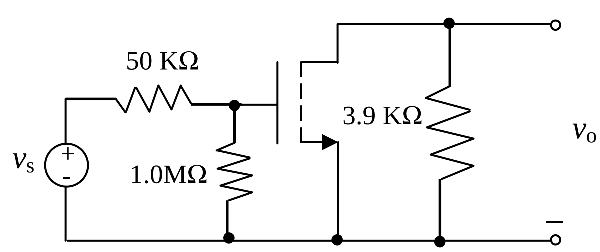
Student Name: ID Number:

3) The enhancement NMOS transistor in the shown circuit has K_n=1.0 mA/V^2, V_{TN} = 1.0 V and λ = 0 V^{-1}. If the voltage v_i changes from 1.0 V to 2.0 V, which one of the following statements will be correct?



a) The output voltage changes from -1.0 V to -2.0 V.
b) The output voltage changes from -2.0 V to -4.0 V.
c) The transistor changes state from saturation region to linear region.
d) The transistor is in the cut-off region.
e) The output voltage does not change.

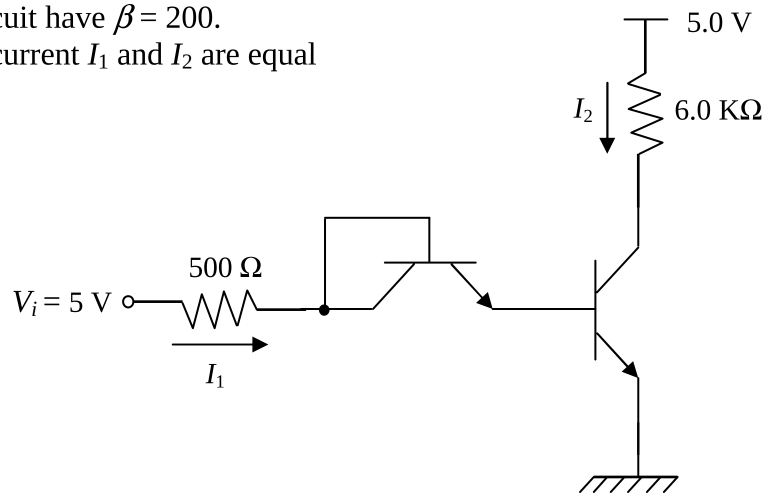
4) The figure to the right shows the ac equivalent circuit of an NMOS amplifier with K_n=1.0 mA/V^2, V_{TN}=1.0 V and λ=0 V^{-1}. The operating point is (I_{DS}, V_{DS})=(2.0 mA ,7.5 V). If the ac source is v_s=0.1 sin(2π×10^3t)V, the maximum and minimum values of the total drain-to-source voltage v_{DS} are approximately



a) 8.24 V, 6.76 V
b) 0.74 V, -0.74 V
c) 8.24 V, 7.76 V
d) 7.76 V, 6.76 V
e) None of the above

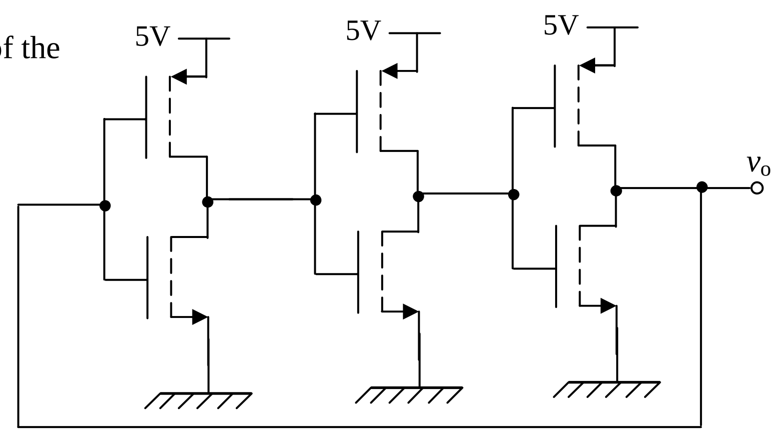
Student Name: ID Number:

5) Both transistors in the shown circuit have $\beta = 200$.
For an input voltage $V_i = 5.0$ V, the current I_1 and I_2 are equal to, respectively,



a) 7.2 mA, 0.8 mA
b) 7.2 mA, 1.44 A
c) 8.6 mA, 0.8 mA
d) 8.6 mA, 1.72 A
e) None of the above

6) The propagation delay in each one of the inverter stages in the shown circuit is t_p=2.0 nSec. The frequency of this ring oscillator is

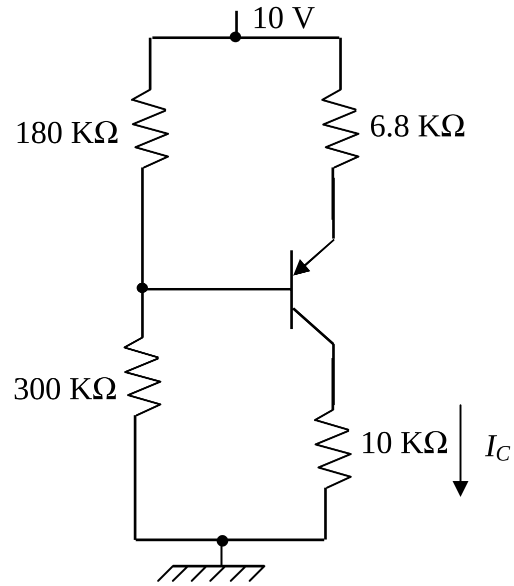


a) 375 MHz
b) 166 MHz
c) 250 MHz
d) 83 MHz
e) None of the above

Student Name: ID Number:

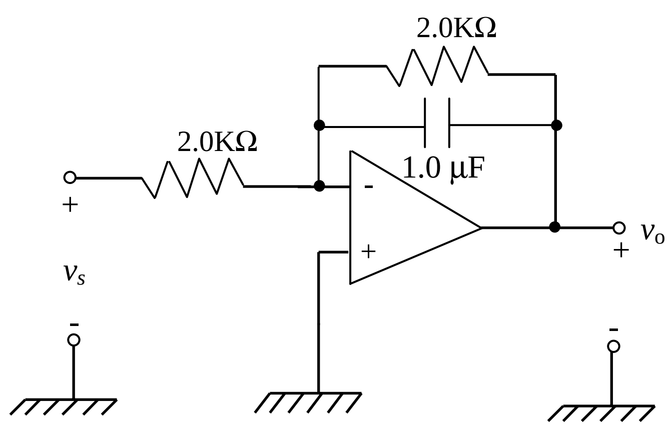
7) The pnp transistor in the shown circuit has $\beta = 100$.
The operating point (V_{EC}, I_C) is

a) -3.5649 V, 0.3816 mA
b) 3.2152 V, 0.527 mA
c) 3.5649 V, 0.3816 mA
d) 4.2354 V, -0.4321 mA
e) None of the above



8) If the input to the shown circuit is $v_s = 2.0 \sin(500t)$, the output v_o is

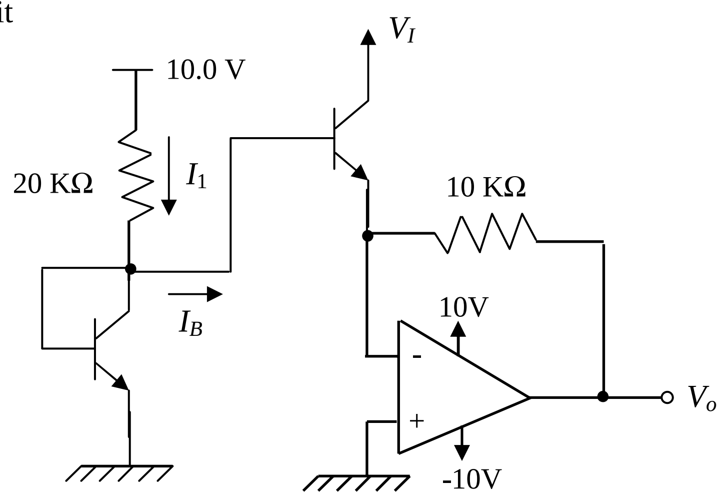
a) $\sqrt{2}\sin(500t - 0.75\pi)$
b) $2.0\sin(500t + 0.75\pi)$
c) $-2.0\sin(500t + 0.75\pi)$
d) $\sqrt{2}\sin(500t + 0.75\pi)$
e) $2.0\sin(500t - 0.75\pi)$



Student Name: ID Number:

9) The two npn transistors in the shown circuit are matched with $\beta = 100$. The currents I_1 and I_B are, respectively,

a) 0.490 mA, 4.8 μA
b) 0.465 mA, 4.55 μA
c) 0.50 mA, 4.9 μA
d) 0.465 mA, 10.0 μA
e) 0.490 mA, 10 μA



10) In problem (9), if $V_I = 5.0$ V, V_o is
a) -4.7 V
b) -4.89 V
c) -3.65 V
d) -5.0 V
e) -4.59 V