Exam 2 Proposed Problems
ECE2204 CRN:82929

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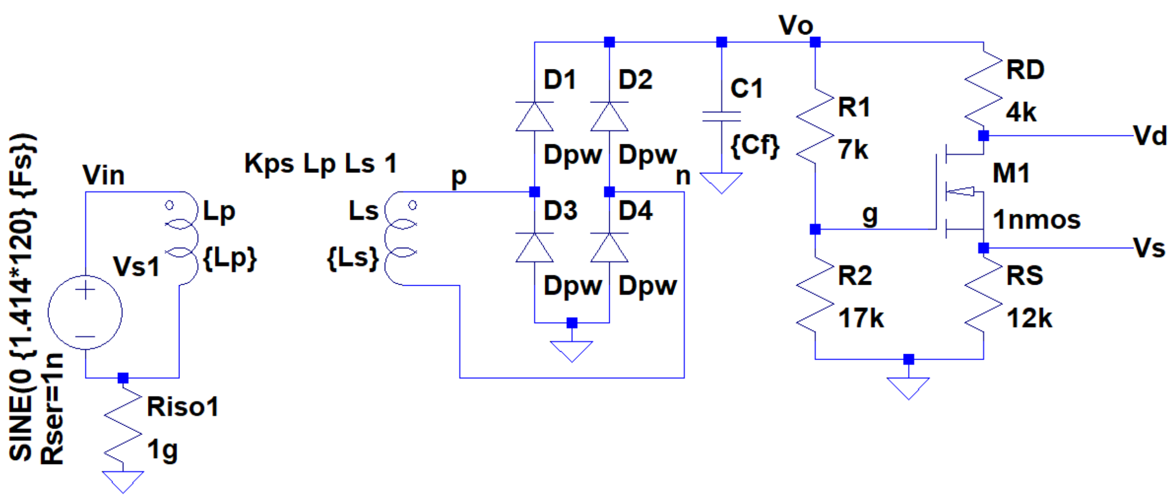
Problem 1:

Design

Design the circuit below such that the rectifier has a ripple voltage of $V_r \leq 0.05V$ and output voltage of $V_o = 12V$. Then calculate the max and min rectifier output voltages V_o^+ and V_o^-. At the max and min rectifier output voltages, determine the mode and calculate the drain voltage V_d, the source voltage V_s, and the drain current I_d.

Assume the input voltage is $V_{in} = 120V(\text{rms})60Hz\text{AC}$, and the diode has a forward voltage $V_\gamma = 1.2V$. Assume the eNMOS transistor has a threshold voltage $V_T = 0.65V$, a Width-Length ratio of $\frac{W}{L} = 2$, and a transistor constant $K_n' = 0.25mA/V^2$. Assume the resistor values are $R_1 = 7k\Omega$, $R_2 = 17k\Omega$, $R_S = 4k\Omega$, and $R_D = 12k\Omega$.



$$V_{Step} = \frac{V_{in}}{10} = 12V(\text{rms})60Hz\text{AC}$$
$$V_S max = |V_{step}(max)| + 2V_\gamma = |12V| + 2 \times 1.2V = 14.4V$$
$$V_{Srms} = \frac{14.4V}{2\sqrt{2}} = 10.18V$$
$$Tr = \frac{120V}{10.18V} = 11.79$$
$$R_{Th} = \frac{(R1 + R2)(RS + RD)}{R1 + R2 + RS + RD} = \frac{(7k\Omega + 17k\Omega)(4k\Omega + 12k\Omega)}{7k\Omega + 17k\Omega + 4k\Omega + 12k\Omega} = 9.6k\Omega$$
$$Cf = \frac{V_M}{2fRV_r} = \frac{12V}{2(60Hz)(9.6k\Omega)(0.05V)} = 0.208mF$$
$$V_o^+ = V_M = 12V$$
$$V_o^- = V_M - V_r = 12V - 0.05V = 11.95V$$

$$
\begin{aligned}
V_G^+ &= \frac{R_2}{R_1+R_2}(V_o^+) = \frac{17k\Omega}{7k\Omega+17k\Omega}(12V) = 8.5V \\
V_{GS}^+ &= V_G^+ - I_D^+ R_S = 8.5V - 12k\Omega I_D^+ \\
I_D &= \frac{K_n'}{2}\frac{W}{L}(V_{GS}^+ - V_T)^2 = 0.25mA/V^2(8.5V - 12k\Omega I_D - 0.65V)^2 \\
&= 532.54\mu A OR 803.57\mu A \\
V_o^+ &= V_D^+ + V_{DS}^+ + V_S^+ = V_{DS}^+ + I_D^+ R_S + I_D^+ R_D = V_{DS}^+ + I_D^+(R_S + R_D) \\
V_{DS}^+(sat) &= V_{GS}^+ - V_T \\
&= 8.5V - 12k\Omega(532.54\mu A) - 0.65V = 1.5V \\
&= 8.5V - 12k\Omega(803.57\mu A) - 0.65V = -1.8V \\
V_{DS}^+ &= V_o^+ - I_D^+(R_S + R_D) \\
&= 12V - (532.54\mu A)(4k\Omega + 12k\Omega) = 3.479V \\
&= 12V - (803.57\mu A)(4k\Omega + 12k\Omega) = -0.857V
\end{aligned}
$$

$3.479V > 1.5V$ and therefore the transistor is in saturation mode for V_o^+.

$$
\begin{aligned}
I_D^+ &= 532.54\mu A \\
V_S^+ &= I_D^+ R_S = (532.54\mu A)(12k\Omega) = 6.39V \\
V_D^+ &= V_S^+ + V_{DS}^+ = 6.39V + 3.479V = 9.869V
\end{aligned}
$$

$$
\begin{aligned}
V_G^- &= \frac{R_2}{R_1+R_2}(V_o^+) = \frac{17k\Omega}{7k\Omega+17k\Omega}(11.95V) = 8.46V \\
V_{GS}^- &= V_G^- - I_D R_S = 8.46V - 12k\Omega I_D \\
I_D &= \frac{K_n'}{2}\frac{W}{L}(V_{GS}^- - V_T)^2 = 0.25mA/V^2(8.46V - 12k\Omega I_D - 0.65V)^2 \\
&= 529.55\mu A OR 799.89\mu A \\
V_{DS}^-(sat) &= V_{GS}^- - V_T \\
&= 8.46V - 12k\Omega(529.55\mu A) - 0.65V = 1.46V \\
V_{DS}^- &= V_o^- - I_D^-(R_S + R_D) \\
&= 12V - (529.55\mu A)(4k\Omega + 12k\Omega) = 3.527V
\end{aligned}
$$

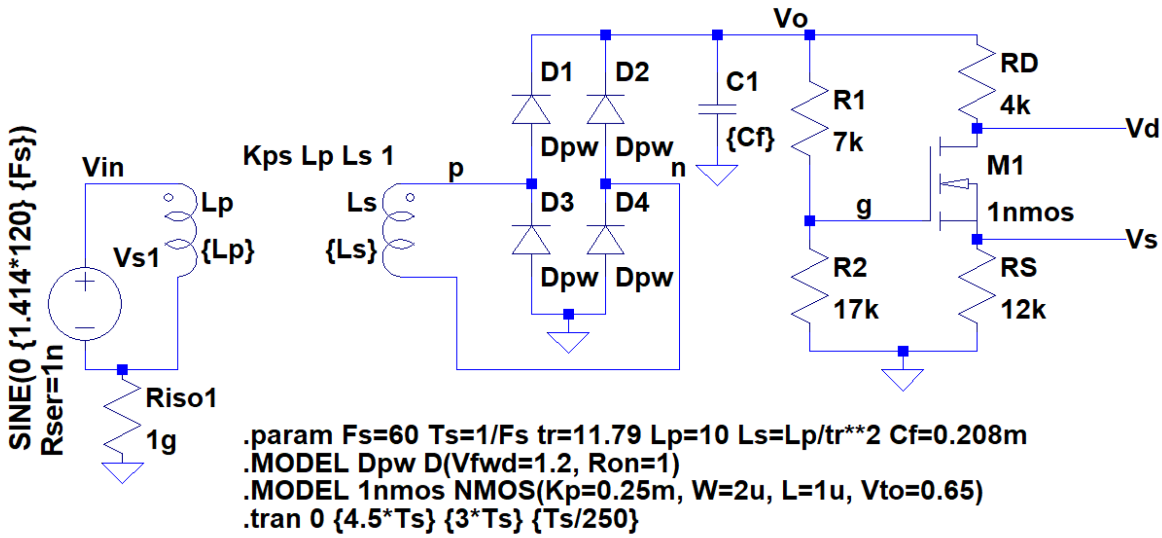
$3.527V > 1.46V$ and therefore the transistor is in saturation mode for V_o^-.

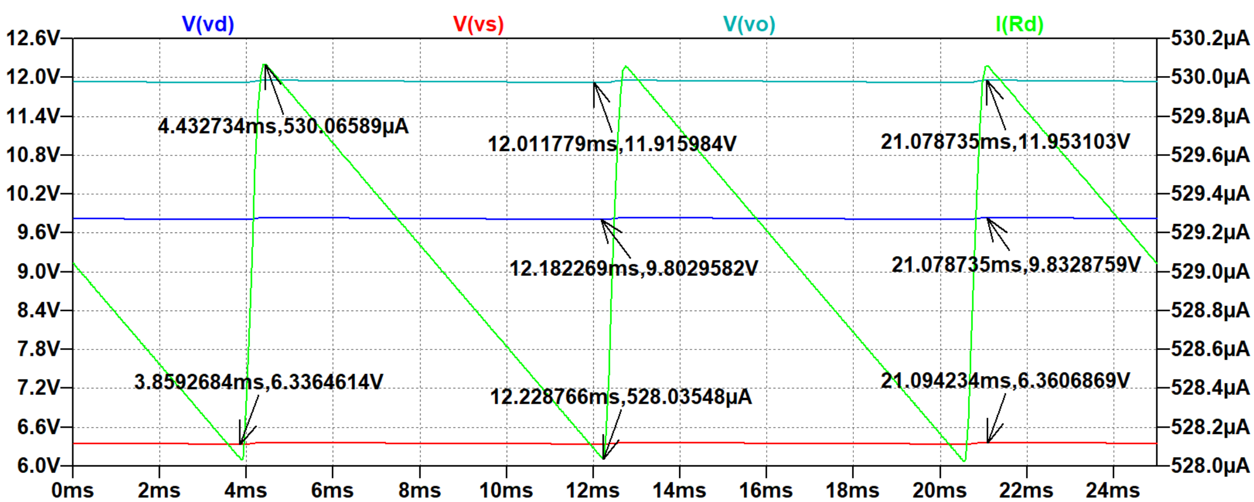
$$
\begin{aligned}
I_D^- &= 529.55\mu A \\
V_S^- &= I_D^- R_S = (529.55\mu A)(12k\Omega) = 6.355V \\
V_D^+ &= V_S^- + V_{DS}^- = 6.355V + 3.527V = 9.882V
\end{aligned}
$$

The final circuit has a transformer ratio of $tr = 11.79$, a capacitor with $C = 208\mu F$, $V_o^+ = 12V$, $I_D^+ = 532.54\mu A$, $V_S^+ = 6.39V$, $V_D^+ = 9.869V$, $V_o^- = 11.95V$, $I_D^- = 529.55\mu A$, $V_S^- = 6.355V$, and $V_D^+ = 9.882V$.

Validation

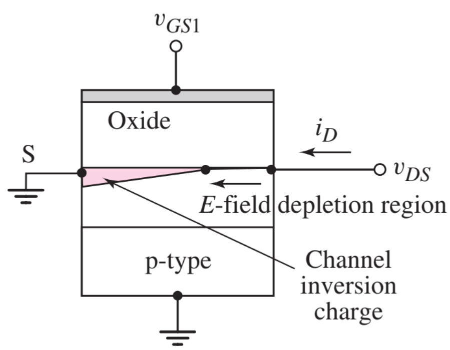
LTSpice Implementation





Problem 2:

Determine the mode of the eNMOS transistor from the cross section shown below with a brief justification.



The transistor is in saturation mode as the channel inversion charge's path is pinched and therefore the current will be restricted and will not be able to linearly increase with the voltage.