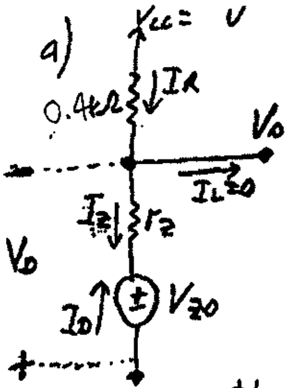
EECE 2412: HW4 Solutions

1 **Prob. 1**

a)



assuming the diode is in the breakdown region

$$I_Z = \frac{V_{cc} - V_{Z0}}{0.4k\Omega + r_Z} = \frac{9V - 6.7V}{0.4k\Omega + 20\Omega} = 5.48mA$$

$I_Z > I_{ZK} = 0.2mA$ → The Zener is in breakdown.

$V_o = I_Z \cdot r_Z + V_{Z0} = (5.48mA)\cdot(20\Omega) + 6.7V$

$\boxed{V_o = 6.8\ V}$

b) Repeating the calculation in part a) with $V_{cc} = 8V$ and $V_{cc} = 10V$:

$V_{o(max)} = 6.86\ V$

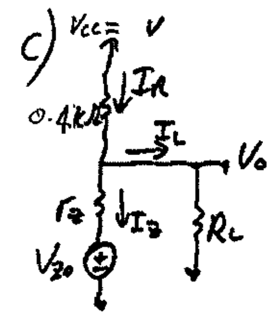
$V_{o(min)} = 6.76\ V$

$\Delta V_{o(max)} = V_{o(max)} - V_o \approx 47.6\ mV$

$\Delta V_{o(min)} = V_{o(min)} - V_o \approx -47.6\ mV$

$\boxed{\Delta V_{cc} \text{ of } \pm 1V \text{ results in } \Delta V_o \text{ of } \pm 47.6\ mV}$

c)



$I_R = \frac{9V - V_o}{k\Omega}$, $I_L = \frac{V_o}{R_L}$, $I_Z = \frac{V_o - V_{Z0}}{r_Z}$

$I_R = I_L + I_Z$

↳ $\frac{9V - V_o}{0.4k\Omega} = \frac{V_o}{2k\Omega} + \frac{V_o - 6.7V}{20\Omega}$

(solving for V_o) → $\boxed{V_o = 6.75\ V}$

$\Delta V_o = 6.75\ V - 6.8\ V = \boxed{-642\ mV = \Delta V_o}$

check: $I_Z = \frac{6.75\ V - 6.7V}{20\Omega} = 2.26mA > I_{ZK}$ → The Zener is in breakdown.

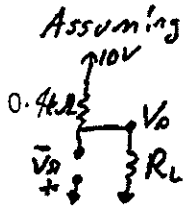
d) Repeating the analysis in c) with $R_L = 0.5k\Omega$ results in:

$V_o = 6.56\ V$

Diode assumption check: $I_Z = \frac{6.56\ V - 6.7V}{20\Omega} = -7.02\ mA < I_{ZK}$

→ does not satisfy the breakdown region condition

Assuming that the diode is reverse-biased ("off"):



$V_o = V\cdot\left(\frac{R_L}{R_L + 0.4k\Omega}\right) = 9V\left(\frac{0.5k\Omega}{0.5k\Omega + 0.4k\Omega}\right) = \boxed{5V = V_o}$

$\Delta V_o = 5V - 6.8\ V$

$\boxed{\Delta V_o = -1.8\ V}$

check: reverse bias requires that $-V_{Z0} = -6.7V < V_D < V_{D0} \approx 0.7V$

↳ Satisfied because $V_D = -V_o =$ V

... Prob. 1 cont.:

e) Using the same diagram as in part c):

$I_{ZK} = 0.2mA$ at the edge of the breakdown region

$$I_{ZK} = 0.2mA = \frac{V_O - V_{Z0}}{r_Z} = \frac{V_O - 6.7V}{20}$$

$$\rightarrow V_O = 6.704V$$

$$I_{ZK} = 0.2mA = I_R - I_L$$

$$0.2mA = \frac{V_{CC} - V_O}{0.4k\Omega} - \frac{V_O}{R_{L(min.)}} = \frac{V_{CC} - 6.704}{400} - \frac{6.704}{R_{L(min.)}}$$

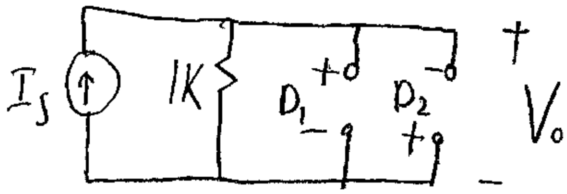
with $V_{CC} = 10V \rightarrow R_{L(min.)} = 833.8\ \Omega$

with $V_{CC} = 8V \rightarrow R_{L(min.)} = 2.2\ k\Omega$

$\boxed{R_{L(min.)} = 2.2\ k\Omega}$ ensures $I_Z > 0.2mA = I_{ZK}$ (over the complete range of V_{CC})

③ $\boxed{\text{Prob. 2}}$

for $-0.7mA < I_s < 0.7mA$



KVL:

$V_o = I_s * 1K$

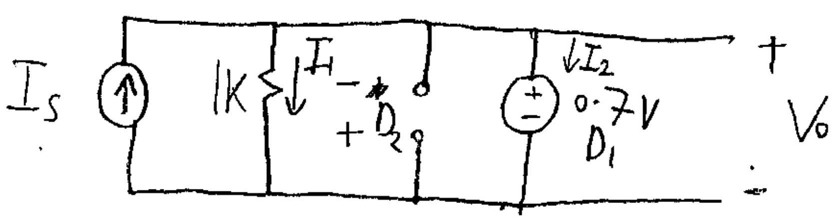
$V_{D1} = V_o \rightarrow -0.7 < V_o < 0.7 \rightarrow -0.7 < V_{D1} < 0.7$

$\therefore D_1$ is off

$V_{D2} = -V_o \longrightarrow \therefore -0.7 < V_{D2} < 0.7$

$\therefore D_2$ is off

for $I_s > 0.7mA$

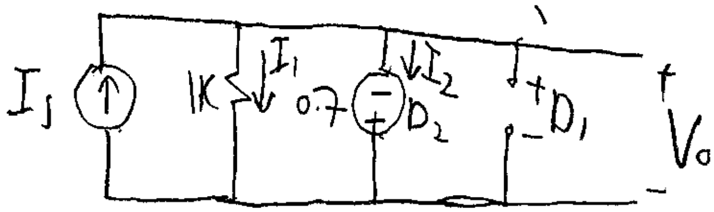


$V_o = 0.7V = V_{D1}$

$I_1 = \frac{V_o}{1k} = 0.7mA, \; I_2 = I_s - I_1 = I_s - 0.7mA > 0 \rightarrow D_1$ is on

$V_{D2} = -0.7V < 0.7V \rightarrow \therefore D_2$ is off

④ for $I_s < -0.7mA$

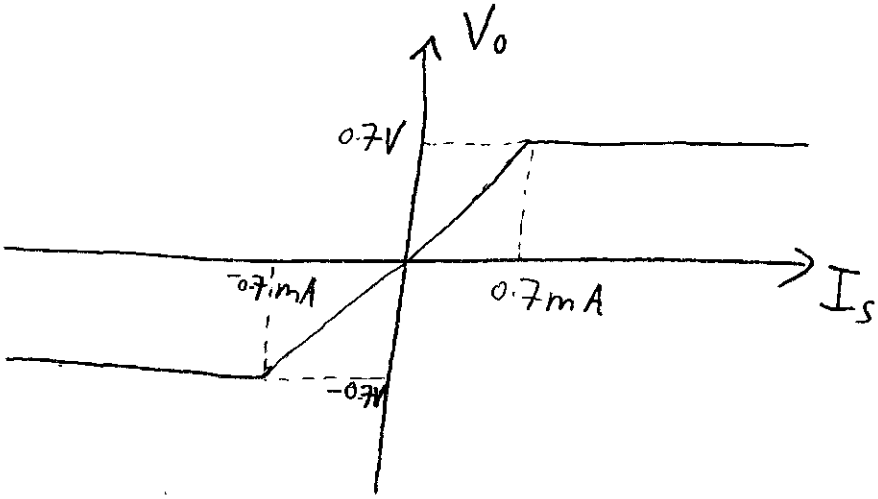


$V_o = -0.7V = -V_{D2}$

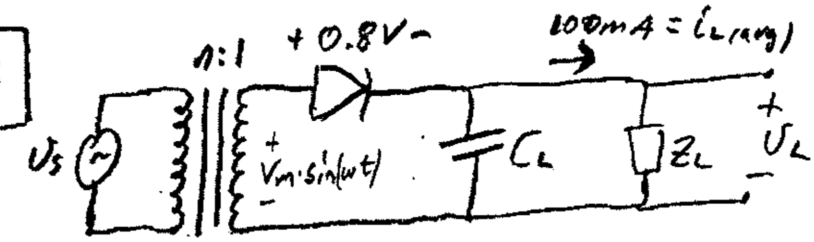
$I_1 = \dfrac{V_o}{1K} = -0.7mA$

$I_2 = I_s - I_1 = I_s + 0.7mA < 0 \rightarrow D_2$ is on

$V_{D1} = V_o = -0.7V < 0.7V \rightarrow \therefore D_1$ is off



(5) $\boxed{\text{Prob. 3}}$



1.) $V_{L(avg)} = 9V \pm 1V$ ripple
(2 V peak-peak) $\longrightarrow$ $\boxed{V_{L(min)} = 8V}$

$\boxed{V_{L(max)} = 10V}$

2.) KVL:
$V_{L(peak)} = -0.8V + V_m = 10V \rightarrow \boxed{V_m = 10.8V}$

3.) $V_{s(peak)} = V_{s(RMS)} \cdot \sqrt{2} = 110V \cdot \sqrt{2} = 155.563V$

$$n = \frac{V_{s(peak)}}{V_m} = \frac{155.563V}{10.8V} = \boxed{14.4 = n}$$

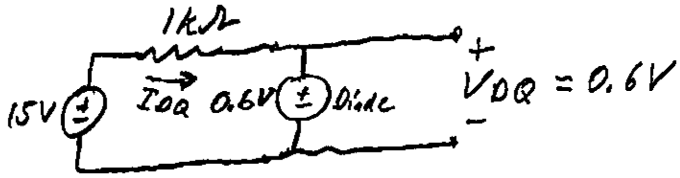
4.) Using equation 3.4 in the book:

$$C = \frac{i_{L(avg)} \cdot T}{V_r} = \frac{(100mA) \cdot (\frac{1}{60Hz})}{2V}$$

$$\boxed{C = 833.3 \mu F}$$

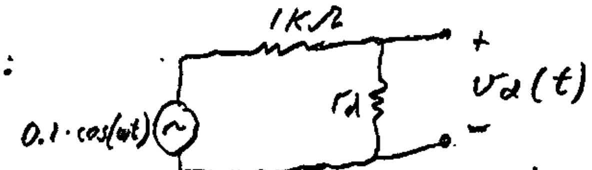
Problem 4:

a) DC equivalent circuit:



$I_{DQ} = \frac{15V - 0.6V}{1k\Omega} = 14.4mA$

AC equivalent circuit:



$r_d = \frac{n \cdot V_T}{I_{DQ}} = \frac{1 \cdot 26mV}{14.4mA}$

$r_d = 1.806\,\Omega$

$v_d(t) = 0.1 \cdot \cos(\omega t) \times \left(\frac{r_d}{r_d + 1k\Omega}\right) = 0.18 \times 10^{-3} V \cdot \cos(\omega t)$

total output voltage: $\boxed{v_D(t) = V_{DQ} + v_d(t) = 0.6V + 0.18 \times 10^{-3} V \cdot \cos(\omega t)}$

b) Source regulation $= \frac{\Delta V_o}{\Delta V_{ss}} \times 100\%$

In part a), the change of the source voltage is $\Delta V_{ss} = 0.1V\cos(\omega t)$,

while $\Delta V_o = v_d(t) = 0.18 \times 10^{-3} V \cdot \cos(\omega t)$.

Thus, source regulation $= \frac{0.18 \times 10^{-3} V \cdot \cos(\omega t)}{0.1 V \cdot \cos(\omega t)} \times 100\% = \boxed{0.18\%}$

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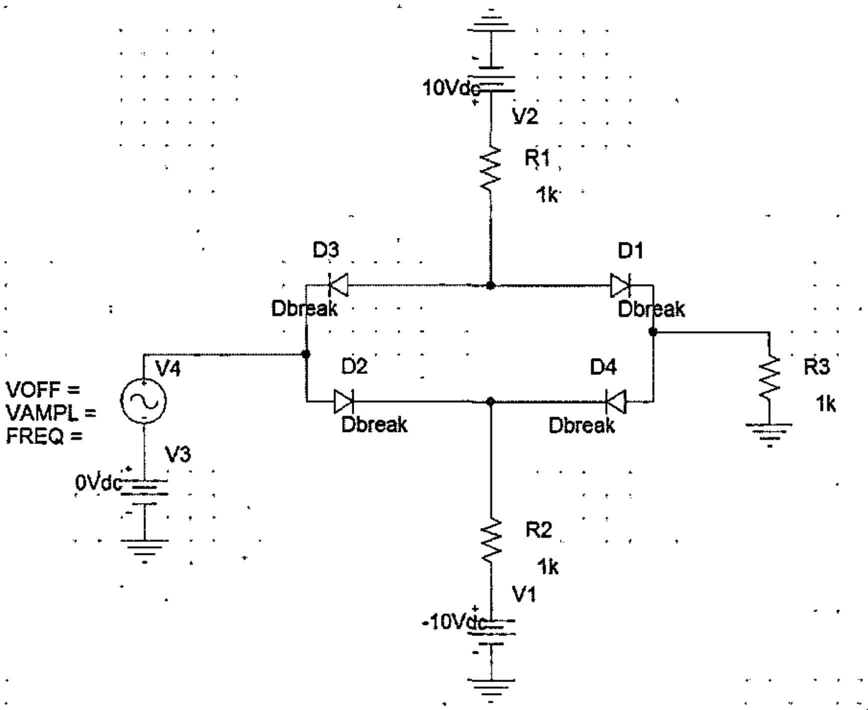
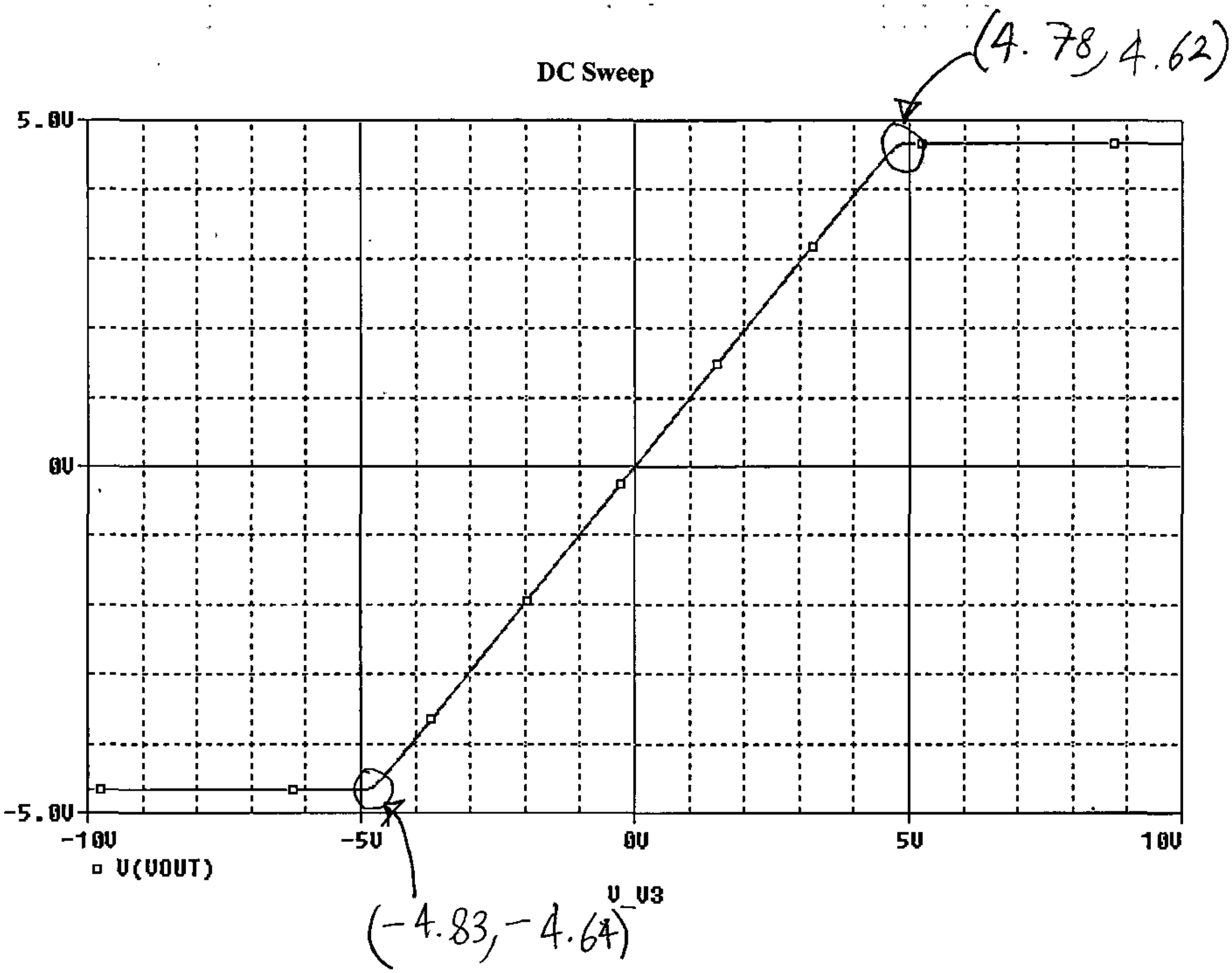
Problem 5

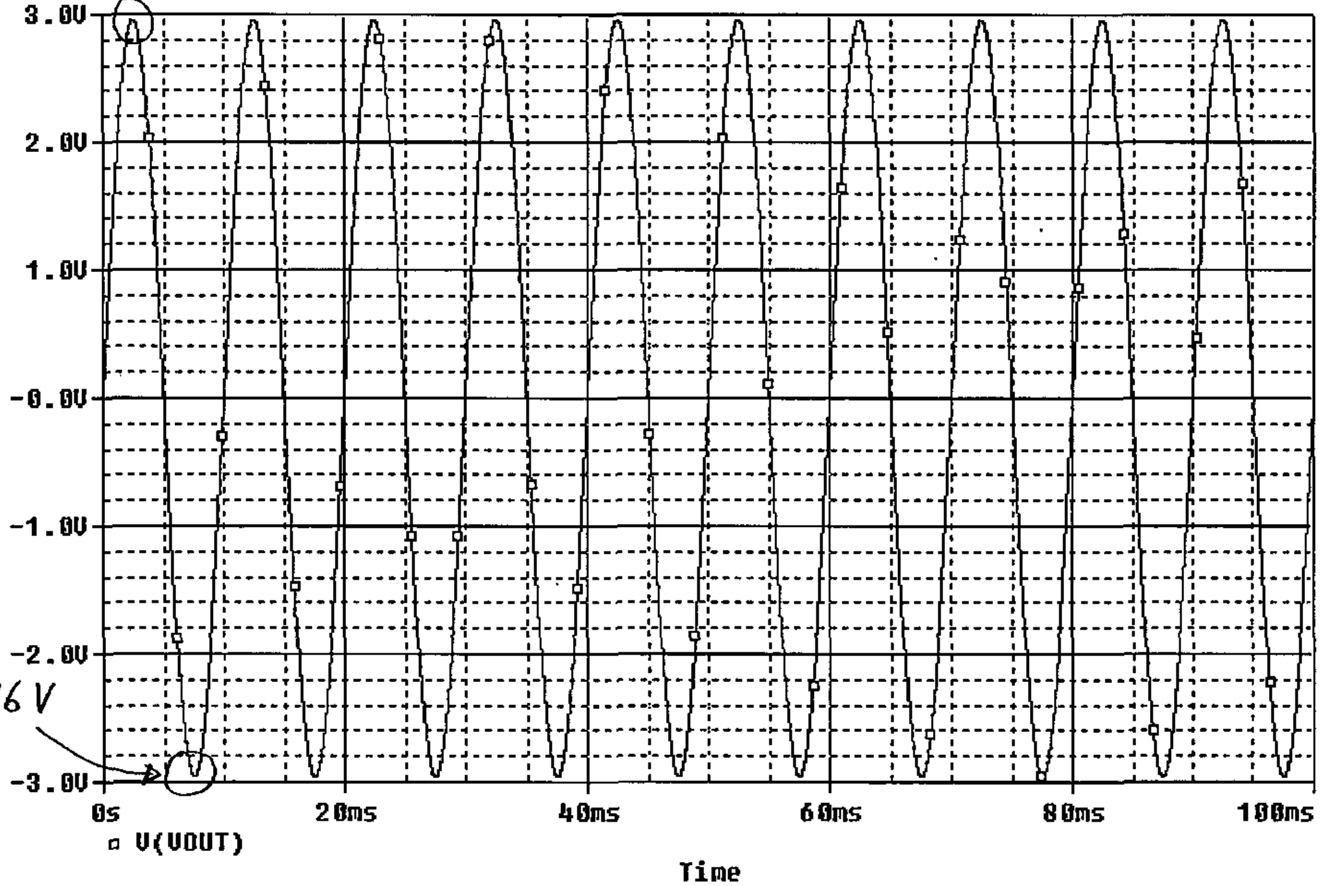


DC Sweep



2.96V (8)

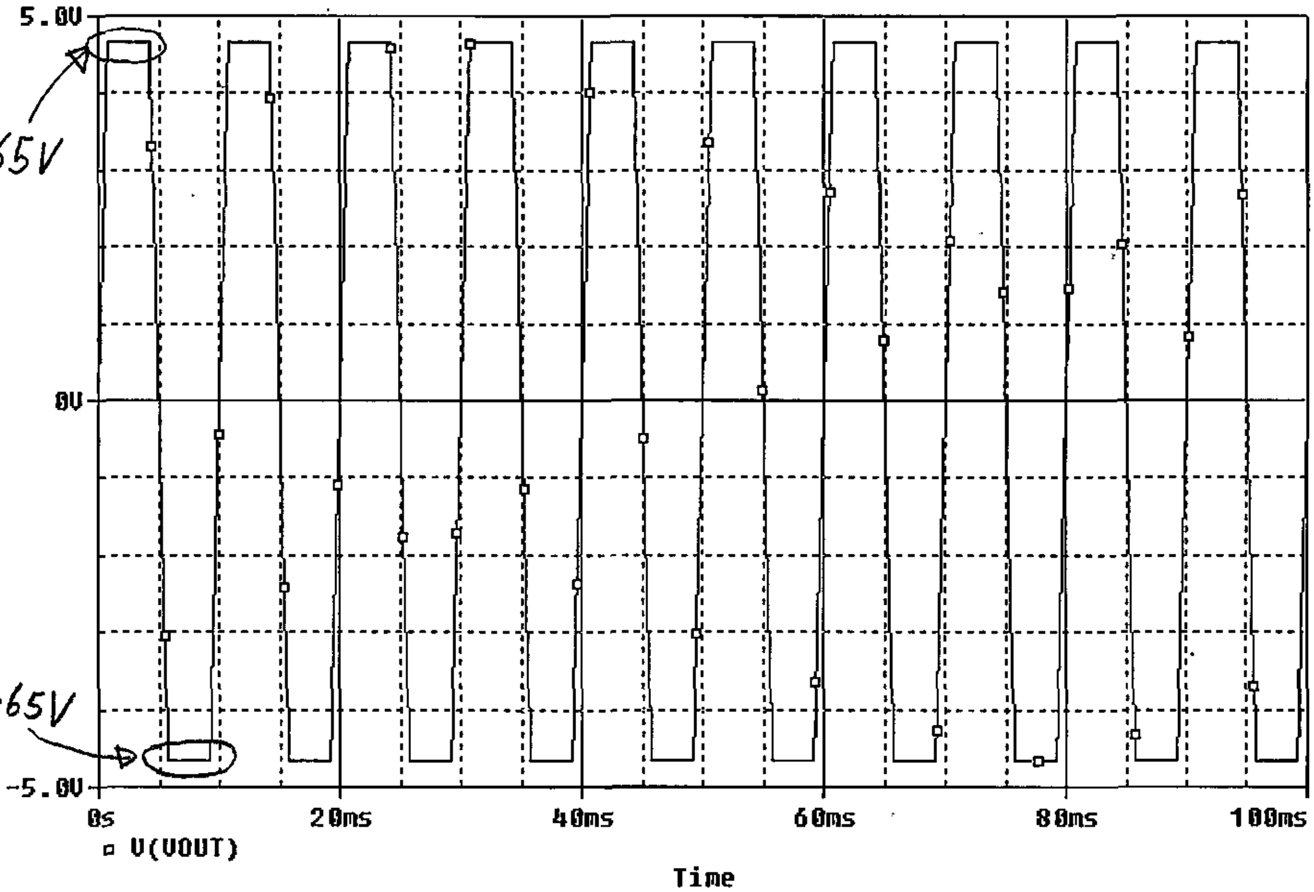
Transient analysis at amplitude = 3V.



-2.96 V

Transient analysis at amplitude = 10V.

4.65V



-4.65V