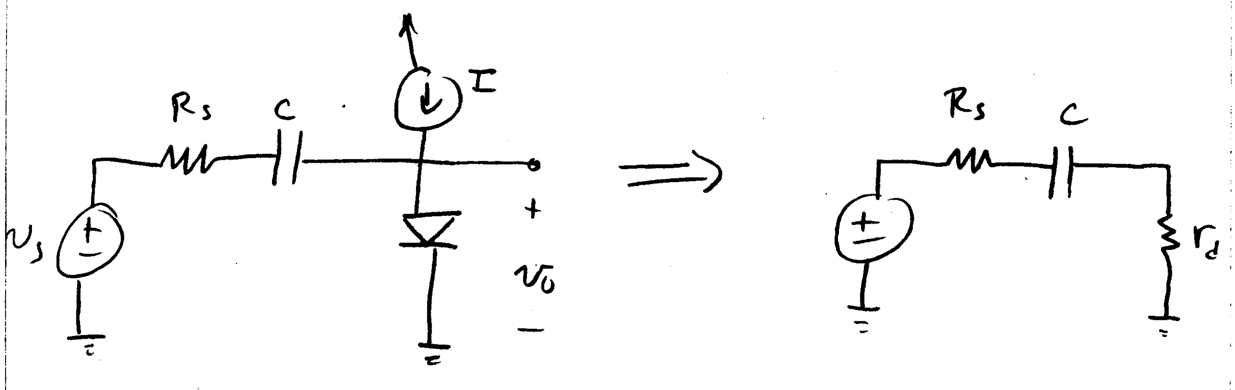
EE 321

Fall 2002

Homework #6

Solutions

3.71



$$V_o(s)/V_s(s) = \frac{r_d}{r_d + \frac{1}{Cs} + R_s} = \frac{r_d Cs}{1 + (r_d + R_s)Cs}$$

$$r_d = \frac{nV_T}{I}$$

$$V_o(s)/V_s(s) = \frac{\frac{nV_T}{I} Cs}{1 + \left(\frac{nV_T}{I} + R_s\right)Cs}$$

3 dB freq: $\omega_{3dB} = \dfrac{1}{\left(\frac{nV_T}{I} + R_s\right)C}$ $\quad f_{3dB} = \dfrac{\omega_{3dB}}{2\pi} = \dfrac{1}{2\pi\left(\frac{nV_T}{I} + R_s\right)C}$

Let $n = 2$, $V_T = 25\,mV$, $R_s = 1\,k\Omega$, $f_{3dB} = 100\,Hz$

$$C = \frac{1}{2\pi\left(\frac{nV_T}{I} + R_s\right) f_{3dB}}$$

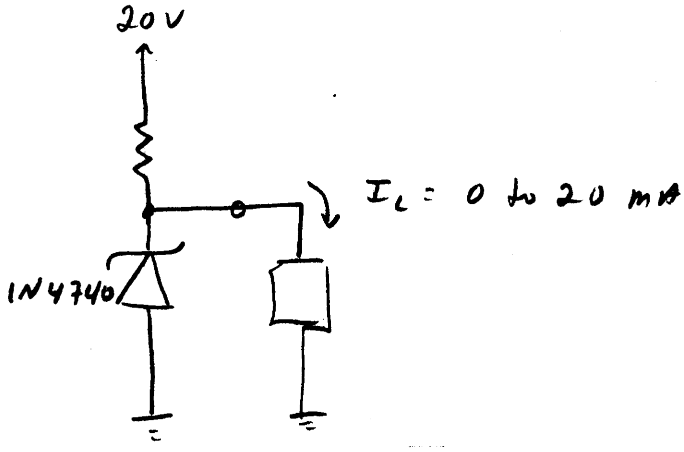
I	C
10 μA	0.26 μF
1 mA	1.5 μF

Need $C \geq 1.5\,\mu F$

For $C = 1.5\,\mu F$, $f_{3dB} = 17\,Hz$ @ $I = 10\,\mu A$

$f_{3dB} = 100\,Hz$ @ $I = 1\,mA$

3.80



(a) $V_{Z0} = V_Z - r_Z I_{ZT} = 10V - (7\Omega)(25mA) = 9.825V$

(b) $V_S = 20V \pm 25\% \Rightarrow$ V_S between 25V & 15V $\Rightarrow V_{S\,min} = 15V$

$I_{Z\,min} = 5\,mA$, $r_Z = 7\Omega$, $I_{L\,max} = 20\,mA$

$$R \le \frac{V_{S\,min} - V_{Z0} - r_Z I_{Z\,min}}{I_{Z\,min} + I_{L\,max}} = 205\,\Omega$$

(c) $\text{Line Reg} = \frac{\Delta V_O}{\Delta V_S} = \frac{r_Z}{R + r_Z} = \frac{7}{205+7} = 33\,mV/V = \underline{3.3\%}$

For ±25% change in V_S (±5V) $\Delta V_O = (33mV/V)(10V) = 330mV$

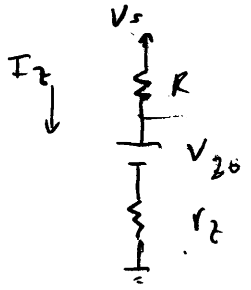
% change = 330 mV / 10V = 3.3%

(d) $\text{Load Reg} = -(r_Z // R) = -\frac{(7)(205)}{7 + 205} = \underline{6.8\,mV/mA}$

For 20mA change, $\Delta V_O = (6.8mV/mA)(20mA) = 135mV$

$\% \text{ change} = \frac{135mV}{10V} \times 100 = \underline{1.35\%}$

(e) Maximum current is when $I_L = 0$ and $V_S = 25V$



$$I_{Z\,max} = \frac{V_S - V_{Z0}}{R + r_Z} = \frac{25 - 9.825}{205 + 7} = 72\,mA$$

$$V_{Z\,max} = V_{Z0} + r_Z I_{Z\,max} = 10.3\,V$$

$$P_{max} = I_{Z\,max} V_{Z\,max} = 744\,mW$$

3.87

120 V RMS ⇒ $120\sqrt{2} = 170$ V peak

10 : 1 step down ⇒ peak v_s is 17 V

$v_s = 17 \sin(120\pi t)$

By KVL, $v_s = v_R + 2 \times V_{diode\ drop}$

$v_{R_{peak}} = 17 - 2(0.7) = 15.6$ V

v_s must reach 1.4 V before the diodes turn on

Diodes will conduct when $17 \sin(120\pi t) > 1.4$

$120\pi t = \sin^{-1}\left(\frac{1.4}{17}\right) = 0.082$

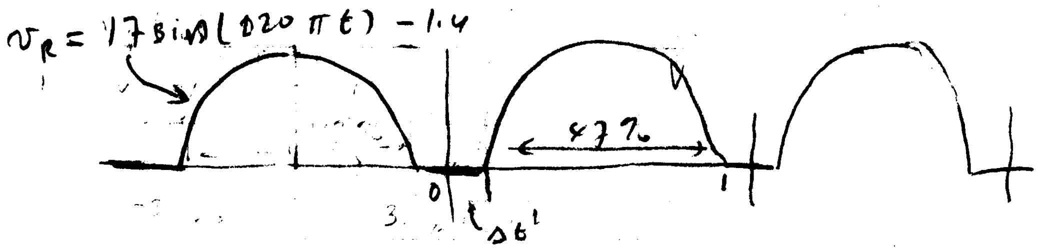
$t = \frac{0.082}{120\pi} = 0.22$ ms

Diodes are off for 4 times this long each cycle

Off for 0.88 ms out of $\frac{1}{60\,Hz} = 16.7$ ms

On for $16.7 - 0.88 = 15.8$ ms

% time on: $\frac{15.8\,ms}{16.7\,ms} \approx 95\%$ of the time

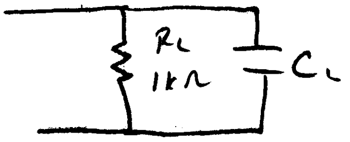


$$v_{R_{avg}} = \frac{1}{T/2} \int_{\Delta t}^{T/2 - \Delta t} (17\sin(120\pi t) - 1.4)\, dt$$

$$= 120 \left[\frac{-17}{120\pi} \cos(120\pi t) - 1.4t \right]_{0.22\,ms}^{\frac{1}{120} - 0.22\,ms} = 9.5\,V$$

$i_{R_{avg}} = v_{R_{avg}} / R = 19.5$ mA

3.94



$f = 60\ Hz$

$V_p = V_s - 2V_{Do} = 17 - 1.4 = 15.6V$

$V_{r_1} = 0.1\, V_p = 1.56\, V$

$V_{r_2} = 0.01 V_p = 0.156 V$

(i) $C_1 = \dfrac{V_p}{2f V_{r_1} R} = \dfrac{15.6}{2(60)(1.56)(1k)} = 83\mu F$

(ii) $C_2 = \dfrac{V_p}{2f V_{r_2} R} = 830\mu F$

(a) $V_o = V_p - \frac{1}{2} V_r$ (i) $V_{o_1} = 15.4 - 1.5V = 14.8v$

(ii) $V_{o_2} = 15.4 - 0.15V = 15.5V$

(b) $\Delta t = \dfrac{1}{\omega}\sqrt{\dfrac{2V_r}{V_p}} = \dfrac{1}{2\pi f}\sqrt{\dfrac{2V_r}{V_p}} = \dfrac{T}{2\pi}\sqrt{\dfrac{2V_r}{V_p}}$ (eq 3.72)

Diode conducts for Δt out of each half cycle $T/2$
so fraction of time diode is on is $\Delta t / T/2 = \dfrac{2\Delta t}{T}$

(i) $DC_1 = \dfrac{2\Delta t}{T} = \dfrac{1}{\pi}\sqrt{\dfrac{2V_{r_1}}{V_p}} = 14\ \%$

(b) $DC_2 = \dfrac{2\Delta t_2}{T} = \dfrac{1}{\pi}\sqrt{\dfrac{2V_{r_2}}{V_p}} = 4.5\%$

(c) $i_{D_{av}} = I_L(1 + \pi\sqrt{V_p/2V_r})$ $I_L = \dfrac{V_o}{R}$ (eq 3.76)

(i) $i_{D_{av_1}} = \dfrac{V_{o_1}}{R}\left(1 + \pi\sqrt{V_p/2V_{r_1}}\right) = 120\, mA$

(ii) $i_{D_{av_2}} = 368\ mA$

(d) $i_{D_{peak}} = I_L(1 + 2\pi\sqrt{V_p/2V_{r_1}})$ (eq 3.77)

(i) $i_{D_{peak_1}} = 230\ mA$

$i_{D_{peak_2}} = 705\, mA$

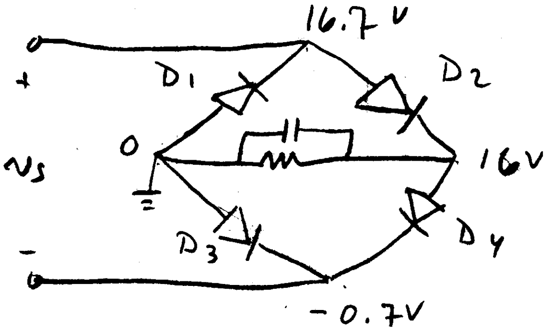
3.97 $V_0 = 15V$, $V_p = 18V$ $v_r = 2V$ $R = 150\Omega$

(a) Need $V_p = 16V$, so $V_s = V_p + 2 \times$ diode drop $= 17.4V$

$v_s\,(RMS) = \frac{V_s}{\sqrt{2}} = 12.3\,V$

(b) $C = \frac{V_p}{2 f V_r R} = \frac{16}{2(60)(2)(150)} = 444\mu F \rightarrow 500\mu F$

(c)



Voltages when $v_s = 17.4\,V$

D_2 and D_3 conduct

Reverse bias on $D_1 + D_4$ is 16.7V

PIV > 16.7 V

(d) $i_{Dave} = I_L\left(1 + \pi\sqrt{V_p/2V_r}\right)$ (eq 3.76)

$= \frac{V_o}{R}\left(1 + \pi\sqrt{V_p/2V_r}\right)$

$= \frac{15V}{150\Omega}\left(1 + \pi\sqrt{16/(2.2)}\right) = 730\,mA$

(e) $i_{Dmax} = I_L\left(1 + 2\pi\sqrt{V_p/2V_r}\right)$ (eq 3.77)

$= 1.36\,A$