Homework Assignment #4

ECE 0257 – Spring 2019

Full Name

Avery Peiffer

Collaborators

Daniel Stumpp

Book Problems

Sedra & Smith 4.80
Sedra & Smith 5.4
Sedra & Smith 5.9
Sedra & Smith 5.10
Sedra & Smith 5.12
Sedra & Smith 5.14

Simulation Problems

DC power supply design

Check-list Before Submission

- ☐ Write within boxes, no boxes are moved
- ☐ Write your full names in designated area
- ☐ Save this file as a PDF before uploading, keep the number of pages (**16**) unchanged
- ☐ Notify "TO BE CONTINUED" accordingly if you used the extra pages (page 14-16)

Sedra & Smith 4.80

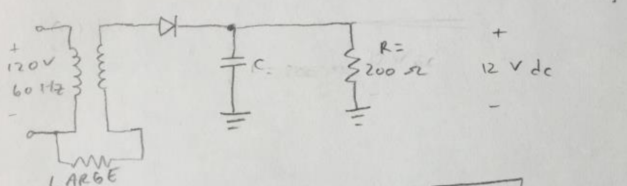
Avery Peiffer
CoE 0257
Homework 4

4.80

DC output voltage of 12 V
± 1 V ripple
Load $= 200\ \Omega$

Line voltage $= 120$ V rms, 60 Hz

Diodes have 0.7 V drop



(a) rms voltage $= \dfrac{12.7 + 1\text{ V ripple}}{\sqrt{2}} = \boxed{9.69\text{ V}}$

(b) Ripple $= 2$ V

$V_R = V_P \dfrac{T}{RC}$ $\quad 2 = 13 \dfrac{1}{60(200)\,C} \Rightarrow \boxed{C = 542\ \mu F}$

(c) $V_s = -V_p = \boxed{13.7\text{ V}}$ = Peak Reverse voltage

PIV $= 1.5$ (Max Reverse) $= \boxed{20.55\text{ V}}$

(d) $i_{D_{av}} = I_L\left(1 + \pi\sqrt{\dfrac{2V_p}{V_R}}\right)$

$= \boxed{721\text{ mA}}$

$V_{o,avg} = -\dfrac{1}{2\pi}\displaystyle\int_{.05515}^{3.086} (12.7\sin\phi - 0.7)\,d\phi = -3.699$ V

$I_{o,avg} = 18.5$ mA

(e) Peak current $= \dfrac{12.7 - 0.7}{200\ \Omega}$

$= \boxed{60\text{ mA}}$

(e) $i_{D_{max}} = I_L\left(1 + 2\pi\sqrt{\dfrac{2V_p}{V_R}}\right)$

$= \boxed{1.38\text{ A}}$

5.4

(a) $2V_{ov} = 2(V_{GS} - V_T)$

$1/2$

$R_{DS} = \dfrac{1}{\mu_n C_{ox} \frac{W}{L}(V_{GS} - V_T)}$

(b) $2W \rightarrow 1/2$

Sedra & Smith 5.4

LARGE

(a) rms voltage = $\frac{12.7 + 1\text{ V ripple}}{\sqrt{2}} = \boxed{9.69\text{ V}}$

(b) Ripple = 2 V

$V_R = V_P \frac{T}{RC}$ $\quad 2 = 13 \frac{1}{60(200)C} \Rightarrow \boxed{C = 542\ \mu F}$

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$V_{o,avg} = \frac{-1}{2\pi}\int_{.05515}^{3.086}(12.7\sin\phi - 0.7)\,d\phi = -3.699\text{ V}$

$I_{o,avg} = 18.5\text{ mA}$

(e) Peak current = $\frac{12.7-0}{200}$

$= \boxed{60\text{ mA}}$

5.4

(a) $2V_{OV} = 2(V_{GS} - V_T)$ $\qquad R_{DS} = \frac{1}{\mu_n C_{ox}\frac{W}{L}(V_{GS}-V_T)}$

1/2

(b) 2W → 1/2

(c) Uncharged → 1

(d) Thickness halved - Cox doubled → W and L cancel each other

1/2

5.9

$k_n = 4\ \frac{mA}{V^2}$ $\quad V_t = 0.5\text{ V}$ $\quad V_{GS} = 1.0\text{ V}$

Saturation Region: $V_{DS} \geq V_{OV}$

$\ldots 0.5\text{ V}) = \boxed{0.5\text{ V}}$

Sedra & Smith 5.9

$I_{o,avg} = 18.5\ mA$

(e) Peak current $= \frac{12.7-}{200-}$

$= \boxed{60\ mA}$

5.4

(a) $2V_{ov} = 2(V_{GS} - V_T)$ $\qquad R_{DS} = \frac{1}{\mu_n C_{ox} \frac{W}{L}(V_{GS}-V_T)}$

1/2

(b) 2W → 1/2

(c) Unchanged → 1

(d) Thickness halved - C_{ox} doubled → W and L cancel each other

1/2

5.9

$k_n = 4\ \frac{mA}{V^2}$ $\quad V_t = 0.5\ V$ $\quad V_{GS} = 1.0\ V$

Saturation Region: $V_{DS} \geq V_{ov}$

$$V_{DS} \geq (1.0\ V - 0.5\ V) = \boxed{0.5\ V}$$

$$I_D = \frac{1}{2} k_n'\left(\frac{W}{L}\right) V_{ov}^2$$

$$= \frac{1}{2} k_n V_{ov}^2 = \frac{1}{2}\left(4\ \frac{mA}{V^2}\right)(0.5\ V)^2 = \boxed{0.5\ mA}$$

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5.10

$L_{min} = 0.25\,\mu m$

$t_{ox} = 6\,nm$

$\mu_n = 460\ \frac{cm^2}{V \cdot s}$

$V_t = 0.5\ V$

(a) $C_{ox} = \frac{3.9\varepsilon_0}{t_{ox}} = \frac{3.9(8.85\times10^{-12}\frac{F}{m})}{6\times10^{-9}\,m} = .0057525\ \frac{F}{m^2}$

$K'_n = \mu_n C_{ox} = (.045\ \frac{m^2}{V \cdot s})(.0057525\ \frac{F}{m^2}) = \boxed{2.59\times10^{-4}\ \frac{F}{V \cdot s}}$

$\mu_n = 450\frac{cm^2}{V \cdot s} = .045\ \frac{m^2}{V \cdot s}$

(b) $\frac{W}{L} = \frac{20\,\mu m}{0.25\,\mu m}$

$I_D = 0.5\ mA$

V_{ov}

V_{GS}

$V_{DS_{min}}$

Saturation Region: $0.5\,mA = \frac{1}{2}(2.59\times10^{-4}\frac{F}{V \cdot s})(\frac{20}{0.25})V_{ov}^2$

$\boxed{V_{ov} = 0.2197\ V}$

$V_{GS} = V_{ov} + V_T = \boxed{0.7197\ V}$

$\boxed{V_{DS_{min}} = V_{ov} = .2197\ V}$

(c) Operate as $100\,\Omega$ resistor for very small V_{DS}

$V_{ov},\ V_{GS}$

$\frac{1}{100\,\Omega} = \mu_n C_{ox} \frac{W}{L}(V_{GS} - V_T)$

$\frac{1}{100\,\Omega} = (2.59\times10^{-4}\frac{F}{V \cdot s})(\frac{20}{.25})(V_{GS} - 0.5\,V)$

$\boxed{V_{GS} = 0.983\ V \quad V_{ov} = 0.483\ V}$

5.12

$\mu_p = 0.4\mu_n$

Equal channel lengths

Equal drain currents and overdrive voltages

Equal

Sedra & Smith 5.12

(b) $\frac{W}{L} = \frac{20\ \mu m}{0.25\ \mu m}$

$I_D = 0.5\ mA$

V_{ov}

V_{GS}

$V_{DS_{min}}$

Saturation Region: $0.5\ mA = \frac{1}{2}(2.59 \times 10^{-4} \frac{F}{V \cdot s})(\frac{20}{0.25})V_{ov}^2$

$\boxed{V_{ov} = 0.2197\ V}$

$V_{GS} = V_{ov} + V_T = \boxed{0.7197\ V}$

$\boxed{V_{DS_{min}} = V_{ov} = .2197\ V}$

(c) Operate as 100Ω resistor for very small V_{DS}

V_{ov}, V_{GS}

$$\frac{1}{100\ \Omega} = \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_T)$$

$$\frac{1}{100\ \Omega} = (2.59 \times 10^{-4} \frac{F}{V \cdot s})(\frac{20}{.25})(V_{GS} - 0.5\ V)$$

$\boxed{V_{GS} = 0.983\ V \quad V_{ov} = 0.483\ V}$

5.12

$\mu_p = 0.4\mu_n$

Equal channel lengths

Equal drain currents and overdrive voltages

Relative widths $(\frac{W_P}{W_N})$

$\frac{1}{0.4} = \boxed{2.5 \text{ times wider}}$

Sedra & Smith 5.14

5.14

$t_{ox} = 6\,nm$

$\mu_n = 460 \frac{cm^2}{V \cdot s} = .046 \frac{m^2}{V \cdot s}$

$V_t = 0.5\ V$

$\frac{W}{L} = 10$

Find I_D

(a) $V_{GS} = 2.5\ V$ and $V_{DS} = 1\ V$

Triode Region:

$$I_D = k_n' \left(\frac{W}{L}\right)\left(V_{ov} - \frac{1}{2} V_{DS}\right) V_{DS}$$

$$C_{ox} = \frac{3.9\,\varepsilon_0}{t_{ox}} = \frac{3.9(8.85 \times 10^{-12})}{6 \times 10^{-9}} = .0057525$$

$$I_D = \left(.046 \frac{m^2}{V \cdot s}\right)(.0057525)(10)\left(2 - \frac{1}{2}\right)(1)$$

$$\boxed{I_D = 3.9\ mA}$$

(b) $V_{GS} = 2\ V$ and $V_{DS} = 1.5\ V$

Saturation Region

$$I_D = \frac{1}{2} k_n' \frac{W}{L} V_{ov}^2 = \frac{1}{2}\left(.046 \frac{m^2}{V \cdot s}\right)(.0057525)(10)(2V - 0.5V)^2$$

$k_n' = \mu_n C_{ox}$ $\quad I_D = \boxed{2.98\ mA}$

(c) $V_{GS} = 2.5\ V$ and $V_{DS} = 0.2\ V$

Linear Region

$$I_D = \left(.046 \frac{m^2}{V \cdot s}\right)(.0057525)(10)(2.5 - 0.5)\,0.2 = \boxed{1.06\ mA}$$

(d) $V_{GS} = V_{DS} = 2.5\ V$

$$I_D = \frac{1}{2}\left(.046 \frac{m^2}{V \cdot s}\right)(.0057525)(10)(2.5V - 0.5V)^2 = \boxed{5.29\ mA}$$

DC power supply design 1(a)

$L_1 =$ 2 H $L_2 = 27.2$ mH

Calculations: $N_1/N_2 = V_1/V_2$

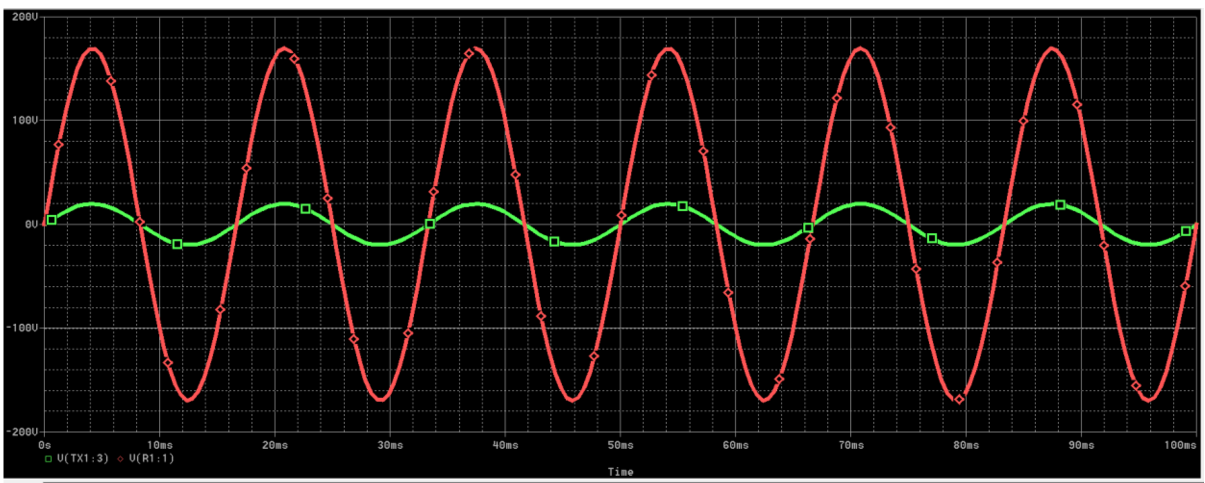
$N_1/N_2 = 120\ V/14\ V$

$N_1/N_2 = 60$ winds/7 winds

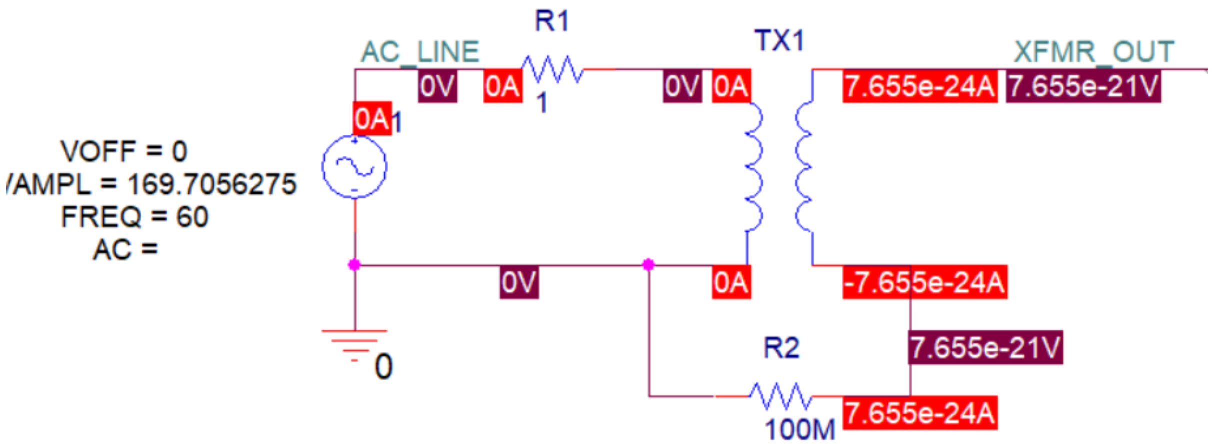
$N_1/N_2 = \mathrm{sqrt}(L_1/L_2)$ $60/7 = \mathrm{sqrt}(L_1/L_2)$

$L_1/L_2 = 73.469$, Let $L_1 = 2$ H then $L_2 = 27.2$ mH

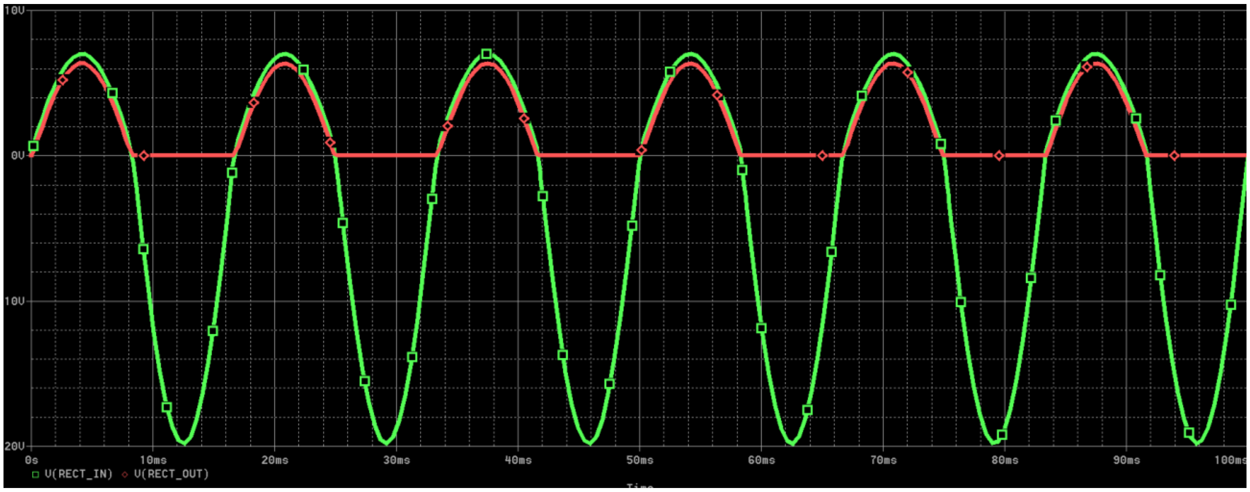
DC power supply design 1(b)



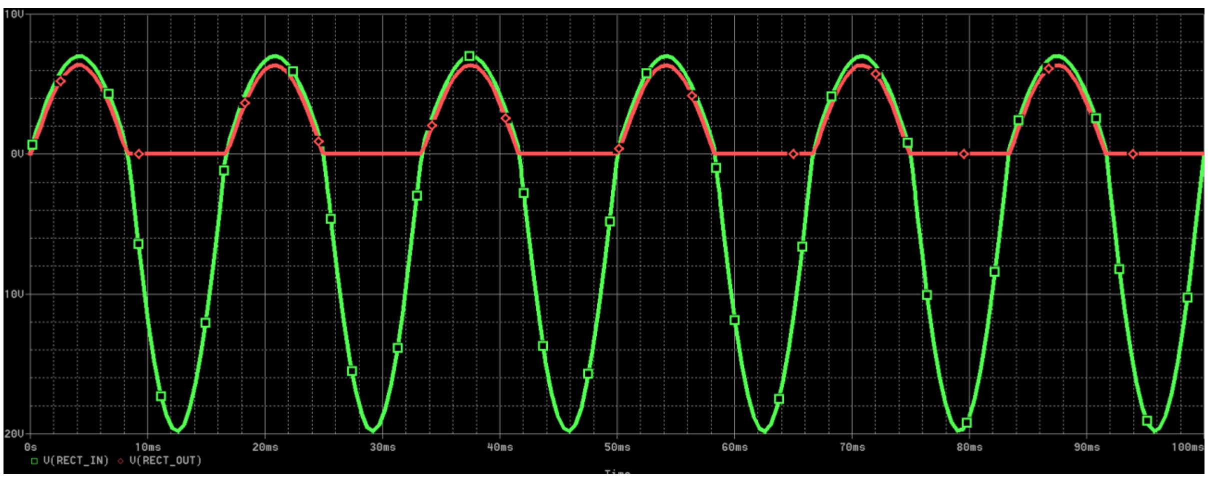
DC power supply design 1(c)



DC power supply design 2(a)



DC power supply design 2(b)

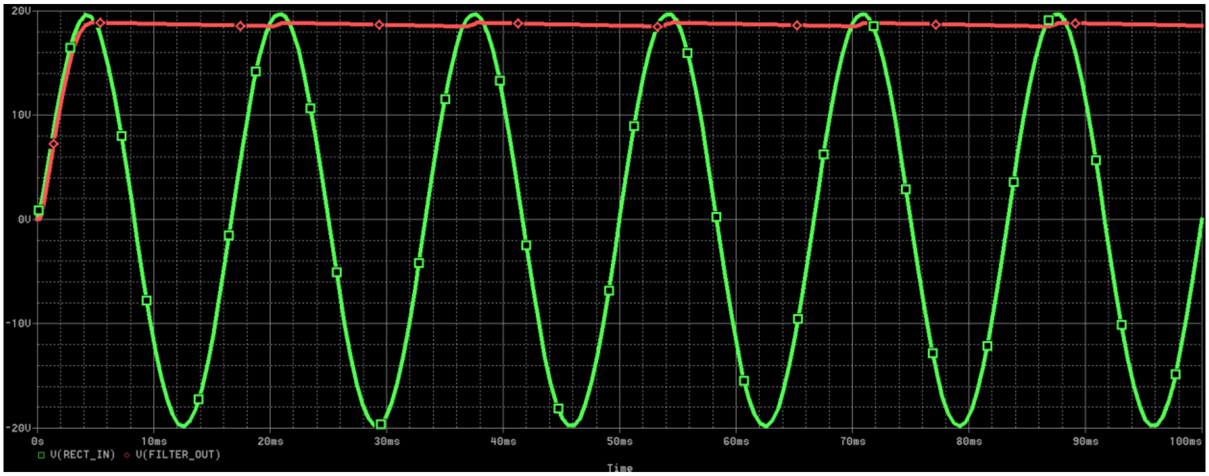


Cursor Calculations: Left Click on V(RECT_IN) at peak, Right Click on V(RECT_OUT) immediately below

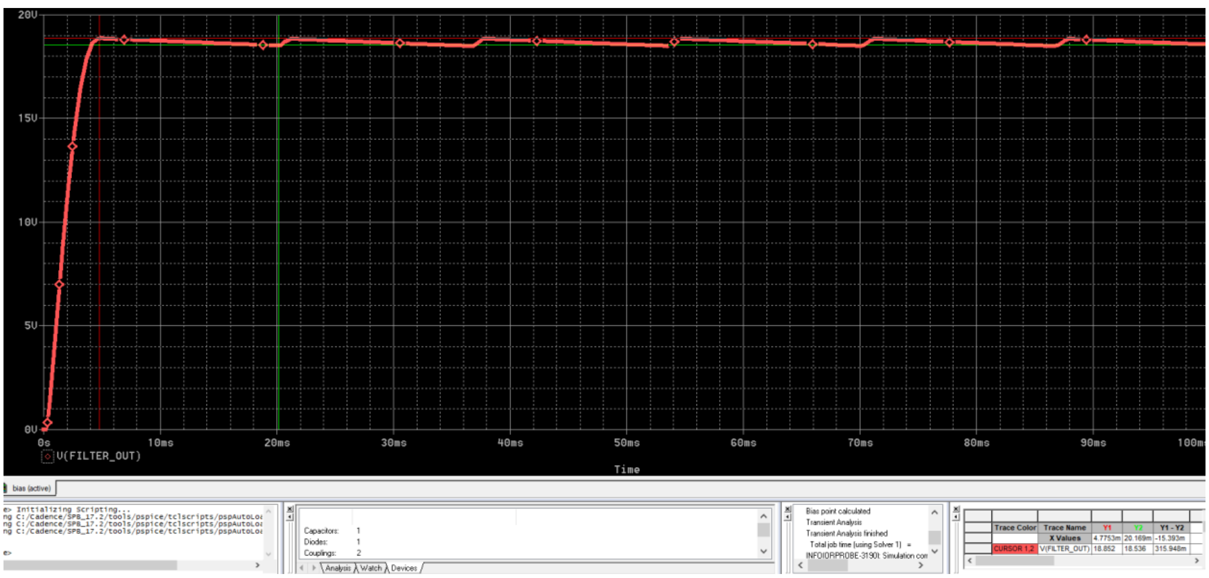
V(RECT_IN) = 7.0032 V

V(RECT_OUT) = 6.3538 V **V_d = .6494 V**

DC power supply design 3(a)



DC power supply design 3(b)



Voltage Ripple = 18.848 V – 18.529 V = .319 V

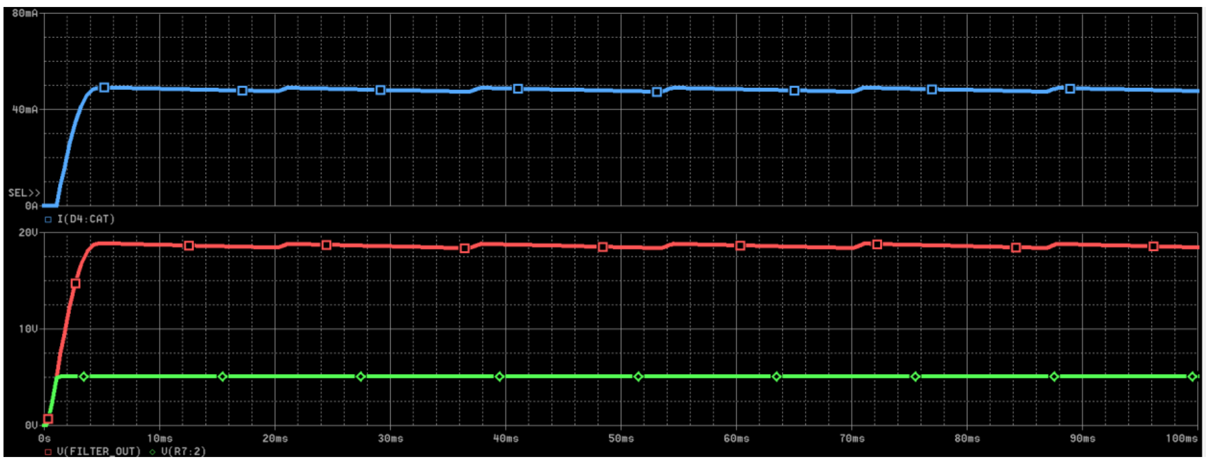
DC power supply design 4(a)

Zener voltage = 5.1 V at 49 mA.

49 mA = (18.848 V – 5.1 V) / R

-> R = 280.51 ohms

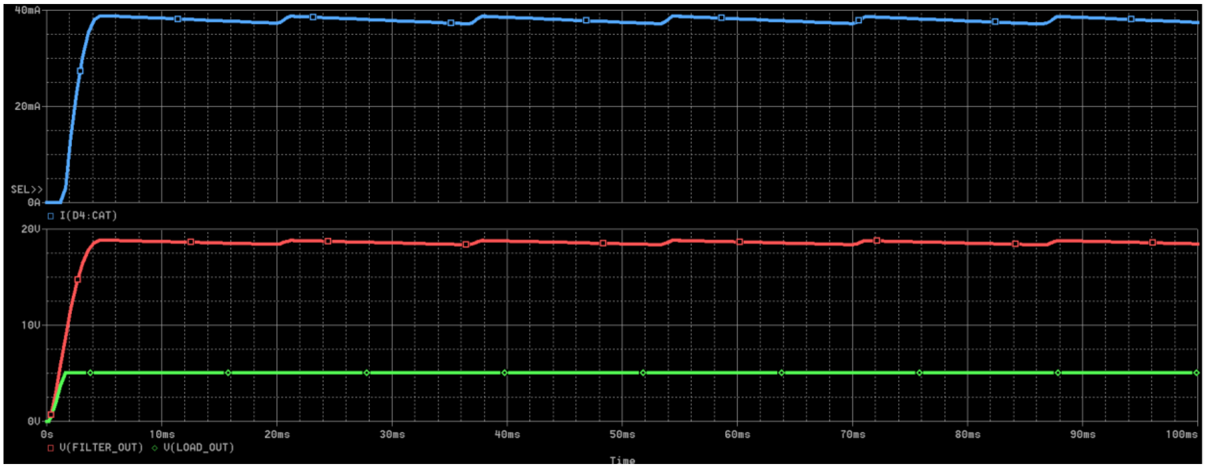
DC power supply design 4(b)



V(REG_IN) = .319 V V(REG_OUT) = 5.1002 V – 5.0997 V = .0005 V

Line Regulation = .0005 V/.319 V = 1.57 mV/V

DC power supply design 5(a)



DC power supply design 5(b)

Ripple 1 = 18.852 V – 18.431 V = .421 V

Ripple 2 = 5.0966 V – 50960 V = .0006 V

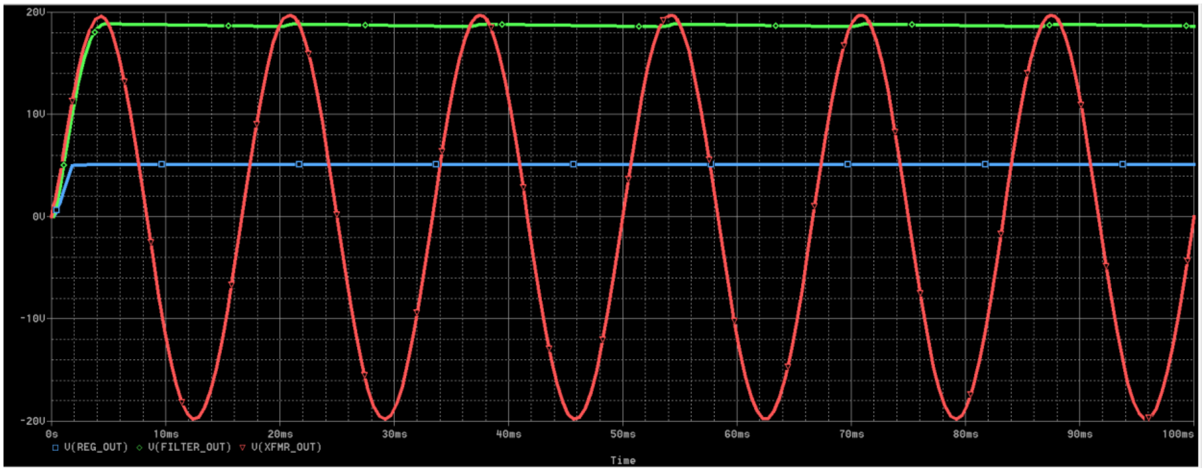
Line Regulation = .0006 V / .421 V = 1.43 mV/V

The ripple voltages increase for both measured values because the current through the Zener diode decreases, meaning it is not as far in the breakdown region.

DC power supply design 5(c)

I changed the resistor in the regulator circuit from 280.51 ohms to 500 ohms. This resulted in a ripple voltage of .206 V in and .0004 V out, for a line regulation of 1.94 mV/V. This is an improvement because the ripple voltage is below the maximum allowed threshold of .319 V as determined earlier.

DC power supply design 5(d)



EXTRA PAGES

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