ECE 320 - Homework #7

DC to AC Converters, Semiconductor Relays, Op-Amps. Due Monday, October 9th, 2017

DC to AC Converter

Assume an H-bridge outputs the following voltatge to an AC motor:

- +10V for 3/8th of the time
- -10V to 3/8th of the time
- 0V inbetween

1) Determine the Fourier transform for this waveform out to the 3rd harmonic

First, input y(t)

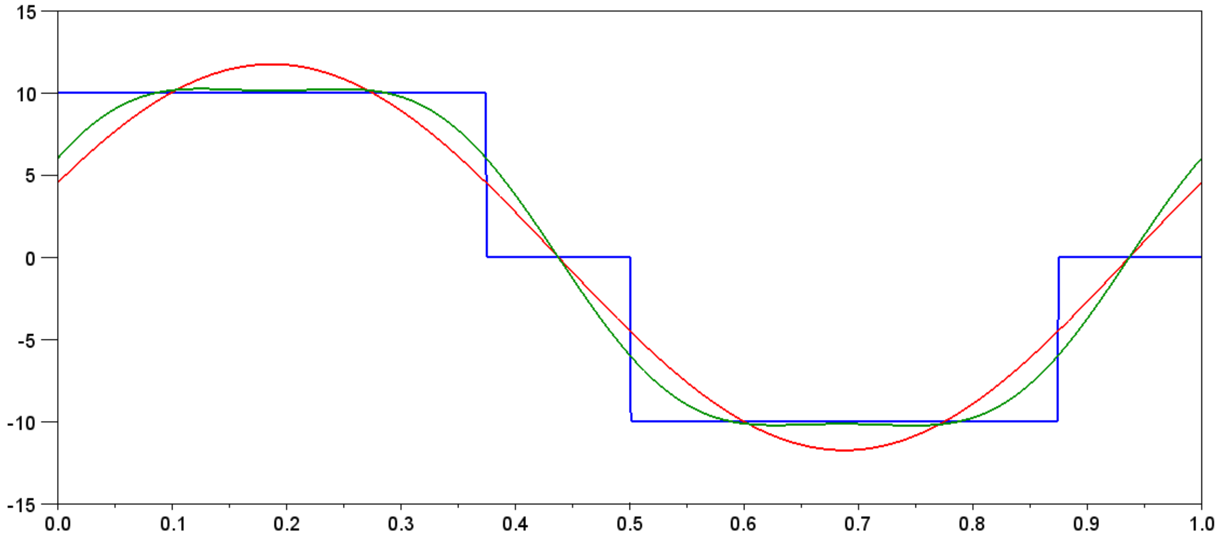
```
-->t = [0:0.001:1]';
-->y = 10*(t<3/8)  - 10*(t>4/8).*(t<7/8);
-->plot(t,y)
```

Next, compute the Fourier coefficients:

```
-->a1 = 2*mean(y .* sin(2*%pi*t))

    10.842759

-->a2 = 2*mean(y .* sin(2*2*%pi*t))

  - 7.240D-16

-->a3 = 2*mean(y .* sin(3*2*%pi*t))

    0.6067714

-->b1 = 2*mean(y .* cos(2*%pi*t))

    4.5111977

-->b2 = 2*mean(y .* cos(2*2*%pi*t))

    0.0199800

-->b3 = 2*mean(y .* cos(3*2*%pi*t))

    1.4848558
```

Now check if the Fourier series matches y(t)

```
-->y1 = a1*sin(2*%pi*t) + b1*cos(2*%pi*t);
-->y2 = y1+ a2*sin(2*2*%pi*t) + b2*cos(2*2*%pi*t);
-->y3 = y2+ a3*sin(3*2*%pi*t) + b3*cos(3*2*%pi*t);
-->plot(t,y,t,y1,t,y2,t,y3)
```



y(t) (blue) and its Fourier Series approximation taken out to 1 harmonic (red) and 3 harmonics (green)

2) Determine the efficiency of this DC to AC converter

```
-->mean(y.^2)

    74.825175

-->mean(y1.^2)

    68.909601

-->mean(y1.^2) / mean(y .^ 2)

    0.9209414
```

This A/D converter is 92% efficient

Semiconductor Relay

3) Determine the voltages at V1 and V2 (DC and AC) assuming a firing angle of 20 degrees

V1 DC:

$$V_{1dc} = 18.6 \cdot \frac{1}{\pi} \int_{\pi/9}^{\pi} \sin(t)dt$$

$$V_{1dc} = 18.6 \cdot \left(\frac{1+\cos\left(\frac{\pi}{9}\right)}{\pi} \right) = 11.484V$$

V1 AC:

max = 18.6V

min = -0.7V

$$V_{1ac} = 19.3V_{pp}$$

V2 DC

same as V1

$$V_{2dc} = 11.484V$$

V2 AC:

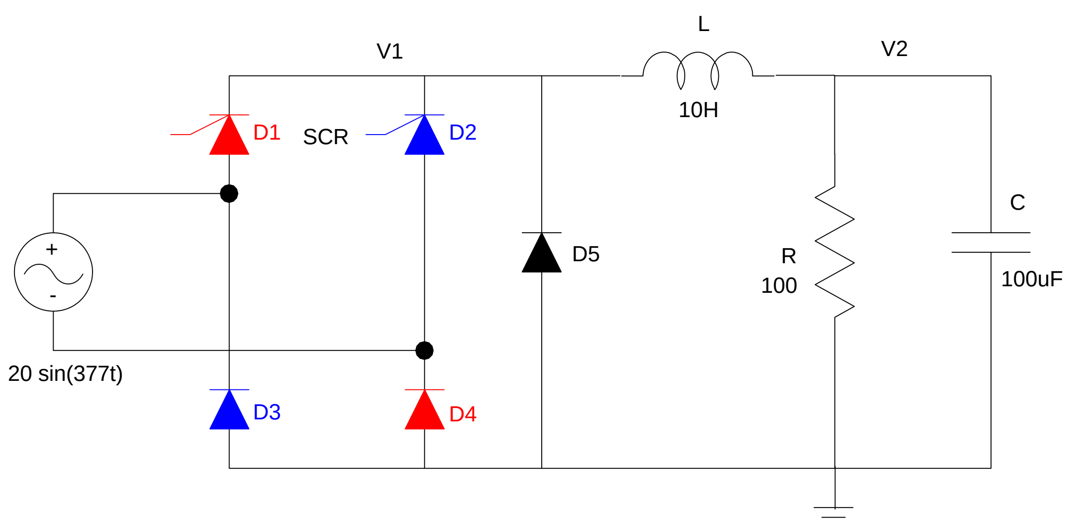
The frequency at V1 is 120Hz, so

$$Z_L = j\omega L = j6280$$

$$Z_c = \frac{1}{j\omega C} = -j1.59\Omega$$

The ripple at V2 is then

$$V_{2pp} = \left(\frac{-j1.59 || 100}{-j1.59 || 100 + j6280} \right) \cdot 12.9V_{pp} = 0.0033V_{pp}$$



4) Determine the firing angle, L, and C so that

- The DC voltage at V2 is 5V
- The ripple at V2 is 200mVpp

Firing Angle:

$$\frac{1}{\pi}\int_{\theta}^{\pi} 18.6\sin(t)dt = 5V$$

$$\frac{18.6}{\pi}(1+\cos(\theta)) = 5$$

$$\theta = 98.9^{0}$$

The ripple at V1 is 19.07V

V1pp = 18.37V + 0.7V = 19.07Vpp

Let L reduce the ripple by 10x

$$\omega L = 10R = 1000$$

$$L = \frac{1000}{754} = 1.32H$$

This makes the ripple at V2 1.907Vpp. To reduce this to 200mVpp

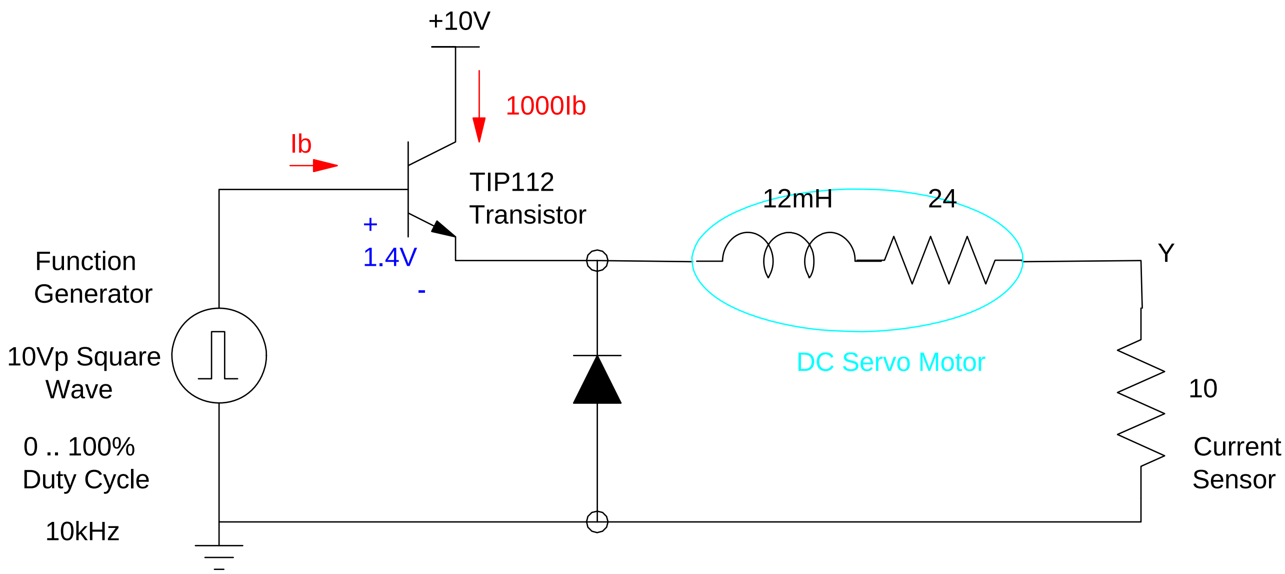
$$\frac{1}{\omega C} = \frac{0.2V_{pp}}{1.907V_{pp}}R = 0.1049R = 10.49\Omega$$

$$C = \frac{1}{754\cdot 10.49\Omega} = 126\mu F$$

Final Design:

- Firing Angle = 98.9 degrees
- L = 1.32H
- C = 126uF

Buck Converter:



The DC servo motors in the lab have the following characterisics

- Ra = 24 Ohms
- La = 12mH

5) Determine the DC voltage at Y and the peak-to-peak voltage at Y (which is also the current through the DC motor) for a duty cycle of

- 25%
- 50%
- 75%

DC Voltage at V1

$$V_{25\%} = 0.25 \cdot 8.6V + 0.75 \cdot (-0.7V) = 1.625V$$

$$V_{50\%} = 0.5 \cdot 8.6V + 0.5 \cdot (-0.7V) = 3.95V$$

$$V_{75\%} = 0.75 \cdot 8.6V + 0.25 \cdot (-0.7V) = 6.275V$$

DC Votlage at V2:

$$V_2 = \left(\frac{10}{10+24}\right) V_1 = 0.29 V_1$$

25%: 478mV

50% 1.16V

75%: 1.84V

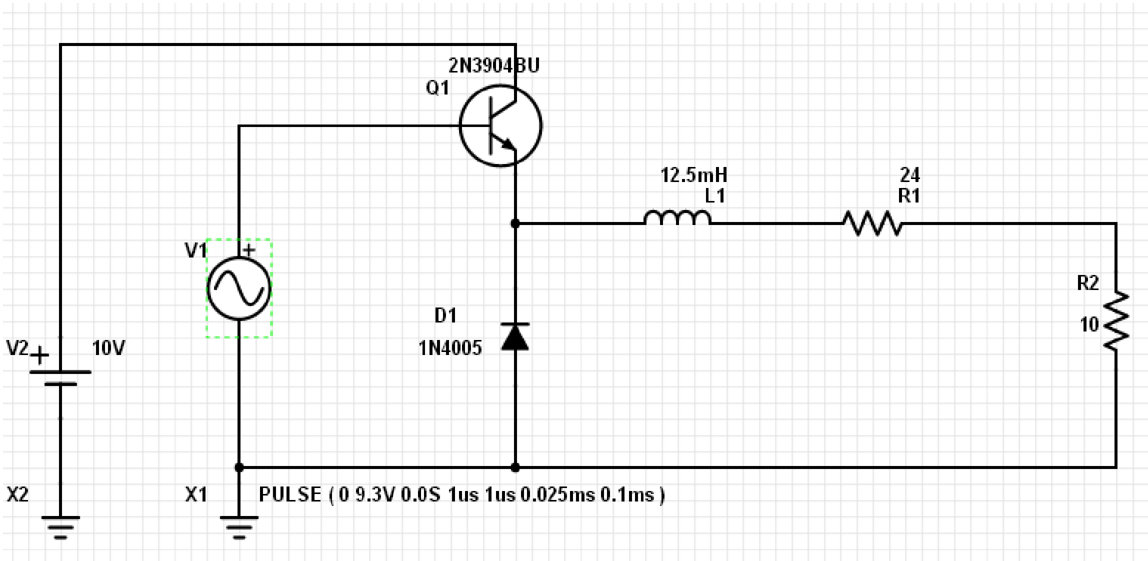
AC Voltage: Won't change

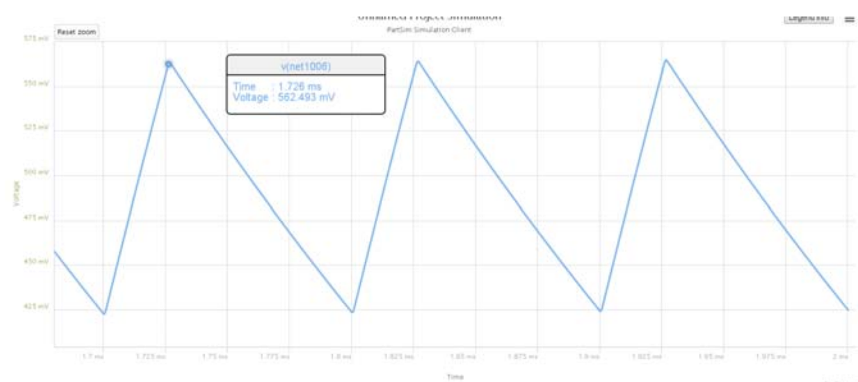
$$V_y = \left(\frac{10}{10+24+j\omega L}\right) 9.3V_{pp}$$

$$V_y = \left(\frac{10}{34+j753.6}\right) 9.3V_{pp}$$

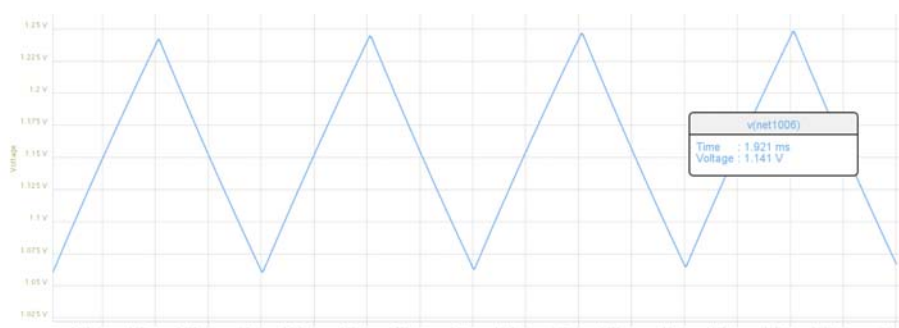
$$V_y = 0.123V_{pp}$$

6) Check your calculatins in PartSim. Compare the results to your comutations.

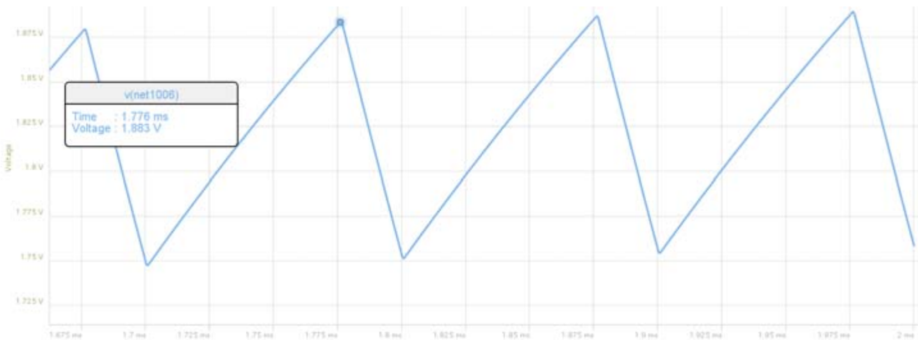




25% Duty Cycle: Y = 492mV (avg), 141mVpp



50% Duty Cycle: 1.15V (avg), 183mVpp



75% Duty Cycle: 1.796V (avg), 96mVpp

Comparing to analysis results:

	25% Duty Cycle		50% Duty Cycle		75% Duty Cycle	
	Vdc	Vac	Vdc	Vac	Vdc	Vac
Calculated	0.478V	123mVpp	1.16V	123mVpp	1.84V	123mVpp
Simulated	0.492V	141mVpp	1.15V	183mVpp	1.796V	96mVpp

7) (Lab): Build the above circuit in lab and measure the voltage at Y (DC and AC) with the motor stalled (hold the motor so it doesn't spin) with a duty cycle of 25% / 50% / 75%. Compare the results to your computations and simulation results.

8) (just for fun): Let the motor spin freely and measure the voltage at Y (DC and AC). Note: This won't match up with your computations or simulations due to the back emf of the motor.

Term Project

Propose a project for your term project. It must include at least two different circuits we cover in ECE 320.

9a) Overall Requirements: Specify the

- Inputs
- Outputs
- How they relate

9b) Project Breakdown. Show how you can split this overall design into 2 or more sections with each section being a circtuit we cover in ECE 320.