

ECE 320 - Homework #6

H-Bridge, DC to DC Converters, Fourier Transforms. Due Monday, October 4th

H-Bridges:

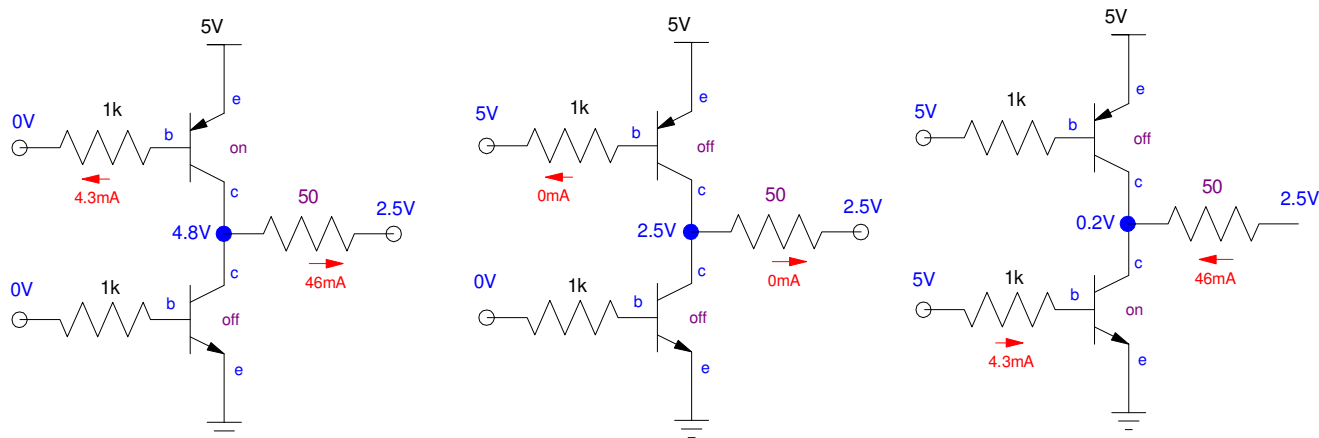
The following circuit is 1/2 of an H-bridge. (the mirror image (minus the 2.5V supply) is repeated to the right for a full H-bridge). Also note: the 50 Ohm & 2.5V source is the Thevenin equivalent of two 100 Ohm resistors (shown to the right). The circuit to the right is easier to build and is equivalent to the part shown in purple.

1) Determine the voltages and currents for the following 1/2 H-bridge for

- $V_1 = 0V, V_2 = 0V$
- $V_1 = 5V, V_2 = 5V$
- $V_1 = 5V, V_2 = 0V$

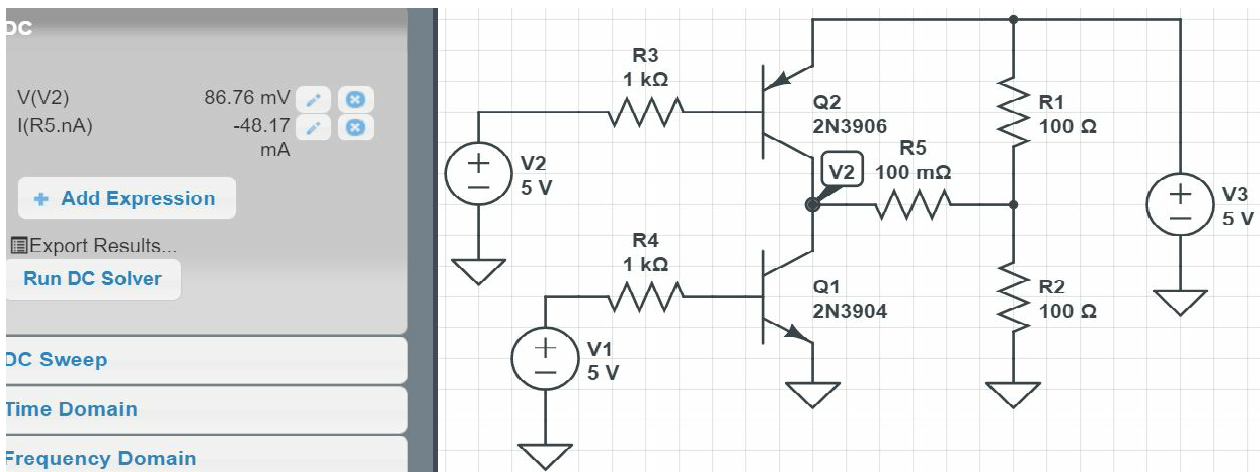
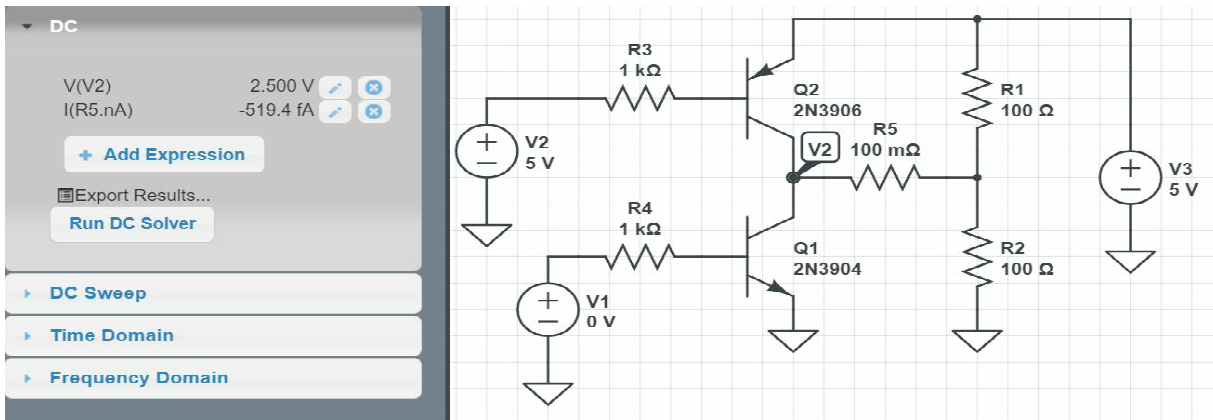
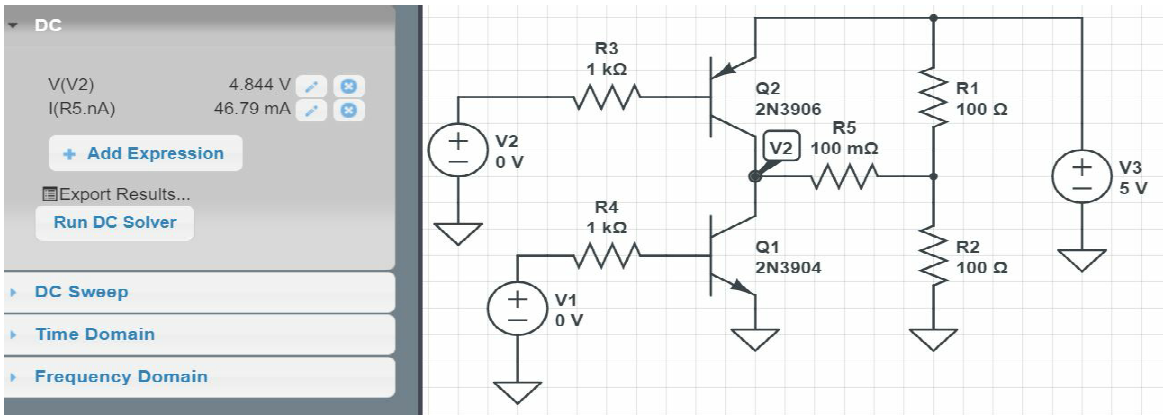
Assume 3904/3906 transistors

- $|V_{be}| = 0.7V$
- current gain = 100
- $V_{ce(sat)} = 0.2V$



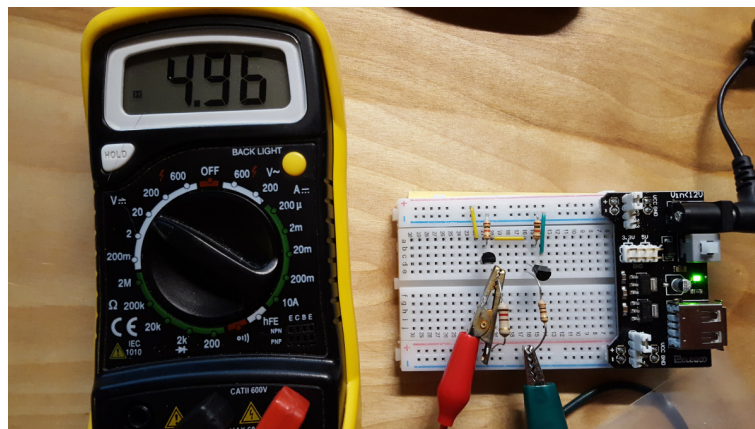
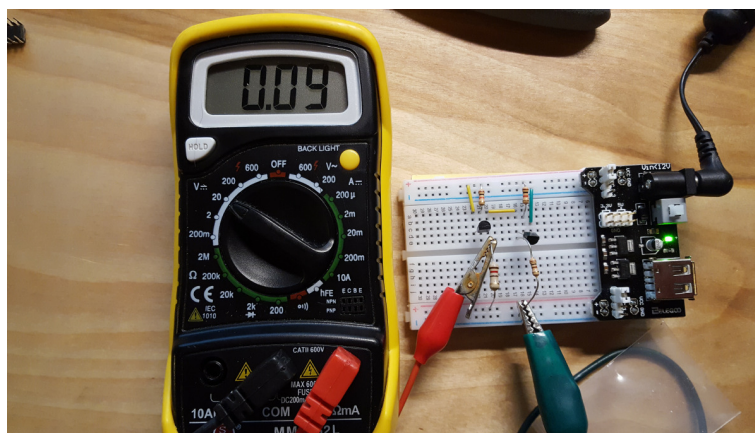
2) Check your results (votlages and currents) in CircuitLab

- The results match (save the saturation voltage isn't exactly 0.200V)



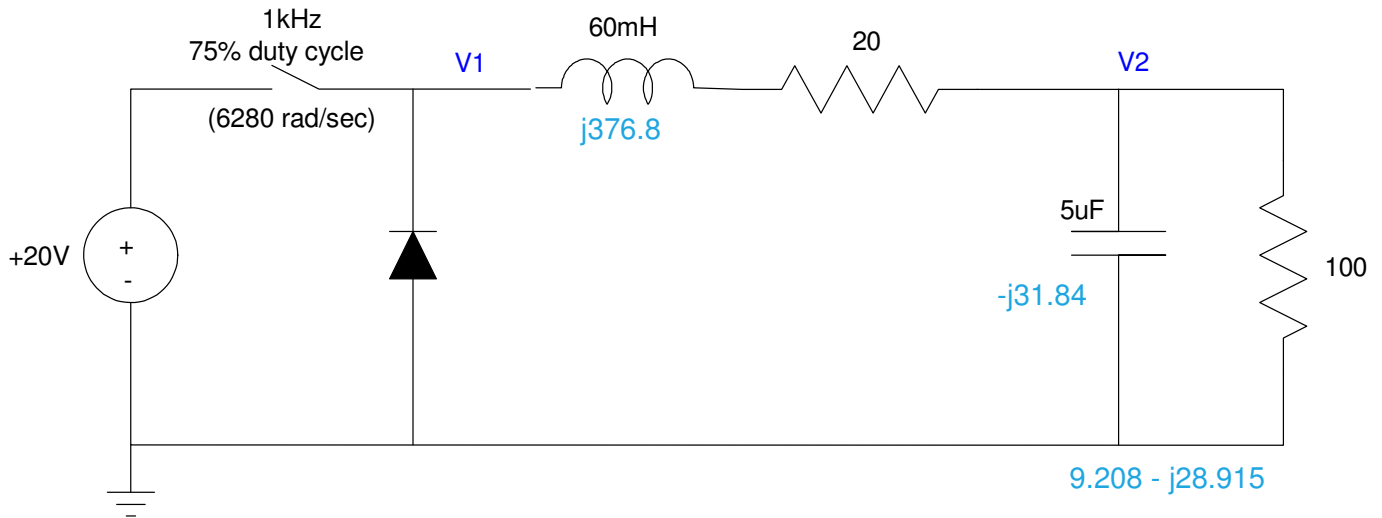
3) Lab: Build this circuit and measure the voltages and currents. (note: it's OK to compute the currents from the measured voltages).

		Calculated	Simulated	Measured
V1 = 5V V2 = 5V	V3	0.20V	86.89mV	0.09V
	I2	-46.0mA	-48.26mA	-48mA
V1 = 0V V2 = 0V	V3	4.80V	4.884V	4.96V
	I2	+46.0mA	+46.87mA	+49mA
V1 = 5V V2 = 0V	V3	2.50V	2.500V	2.46V
	I2	0.0mA	0.0mA	-1mA



DC to DC Converters

4) Determine the voltages (both DC and AC) for V1 and V2.



DC:

$$V_1(DC) = (0.75)(20V) + (0.25)(-0.7V) = 14.825V$$

$$V_2(DC) = \left(\frac{100}{100+20} \right) V_1(DC) = 12.354V$$

AC:

$$V_1(AC) = 20.7V_{pp} \quad \text{max} = 20V, \text{ min} = -0.7V$$

$$V_2(AC) = \left(\frac{(9.208-j28.915)}{(9.208-j28.915)+(20+j376.8)} \right) \cdot 20.7V_{pp}$$

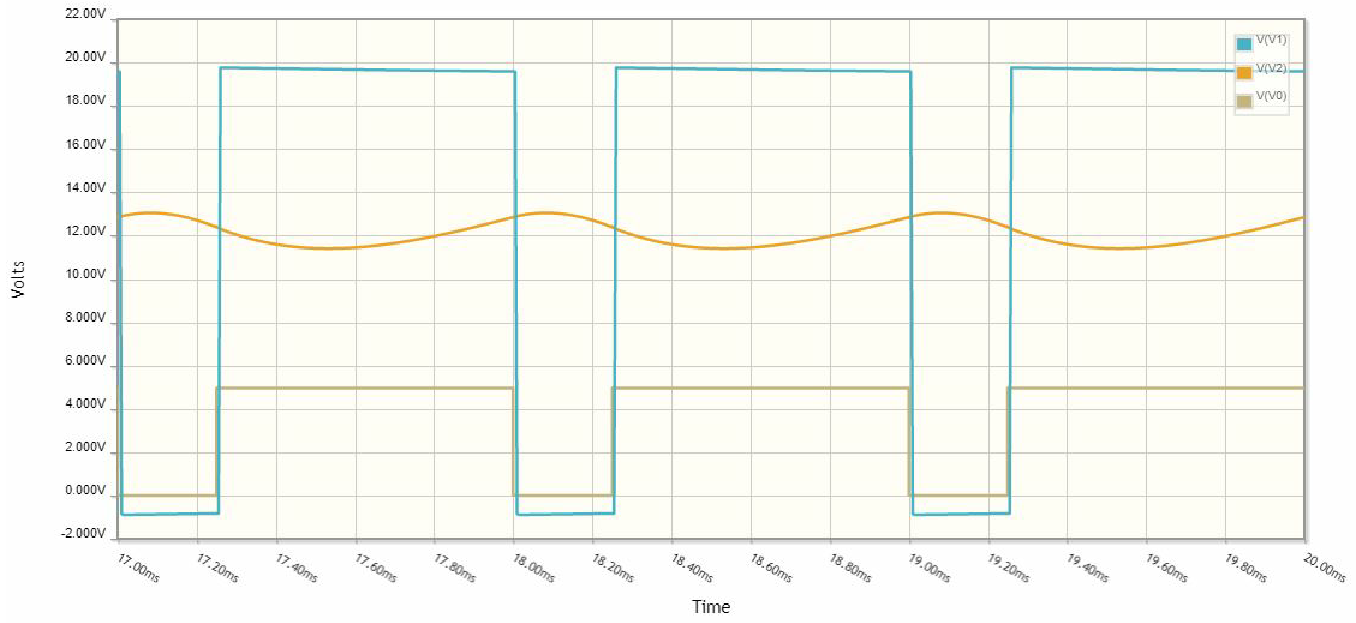
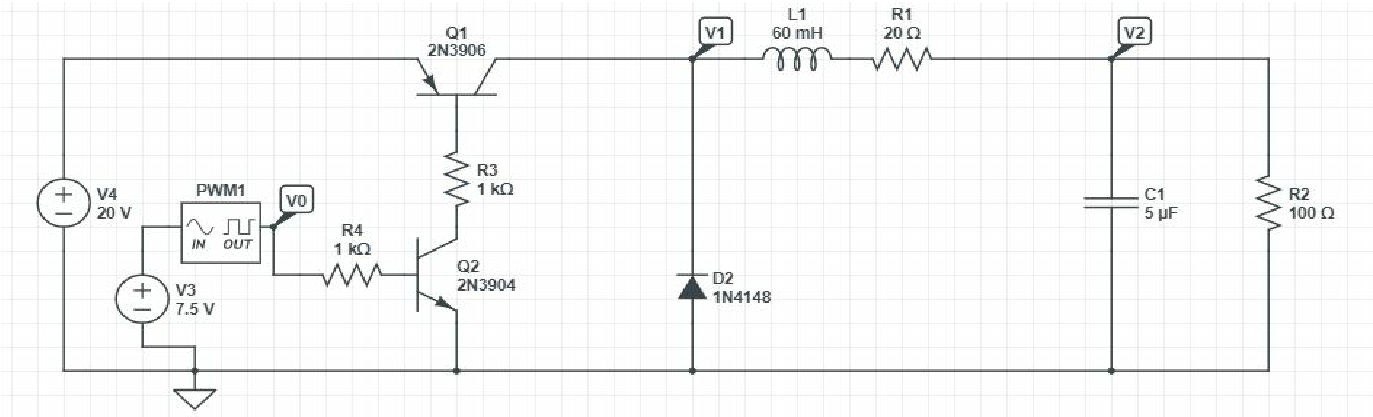
$$V_2(AC) = 1.799V_{pp} \quad \text{take the magnitude (phase doesn't matter)}$$

5) Simulate the circuit in CircuitLab and determine V2 (DC and AC)

- $\max(V2) = 13.05V$
- $\min(V2) = 11.41V$

DC = $(\max + \min) / 2 = 12.23V$ (vs. 12.35V computed)

AC = $(\max - \min) = 1.64V_{pp}$ (vs. 1.799V_{pp} computed)



6) Change the duty cycle and C so that

- The DC voltage at V2 = 5.00V
- The ripple at V2 is 1Vpp

For 5V

$$V_2 = \left(\frac{100}{100+20} \right) V_1 = 5.00V$$

$$V_1 = 6.00V$$

$$6V = 20V \cdot \alpha + (-0.7V) \cdot (1 - \alpha)$$

$$\alpha = \left(\frac{6.7}{20.7} \right) = 32.4\%$$

For C:

- 5uF resulted in 1.64Vpp ripple
- Larger C results in less ripple

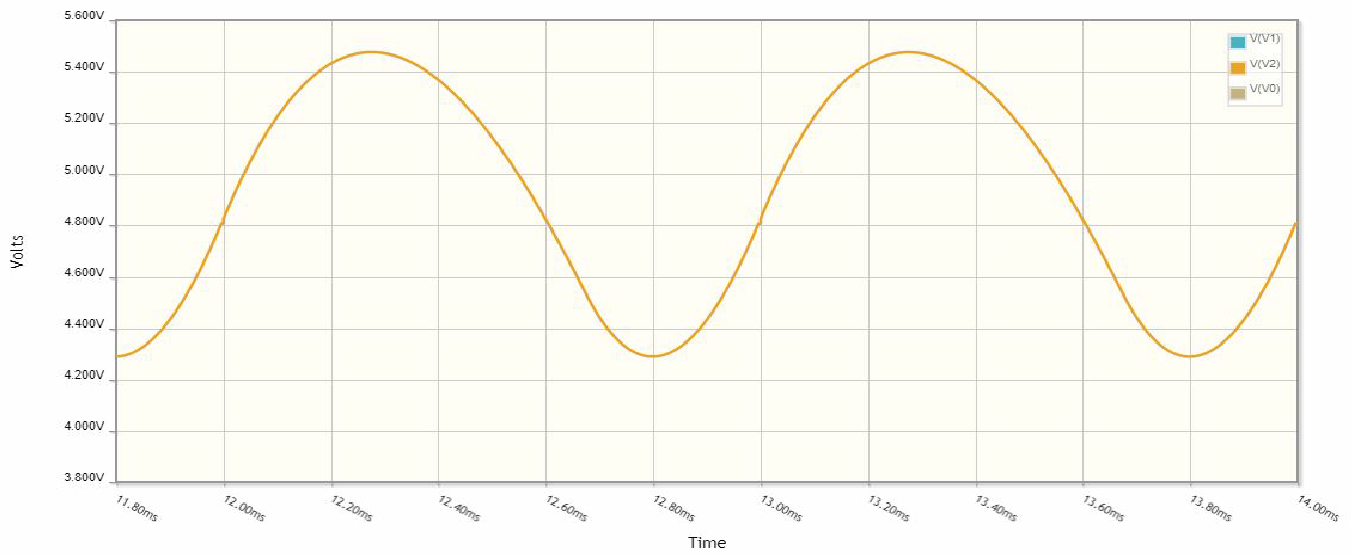
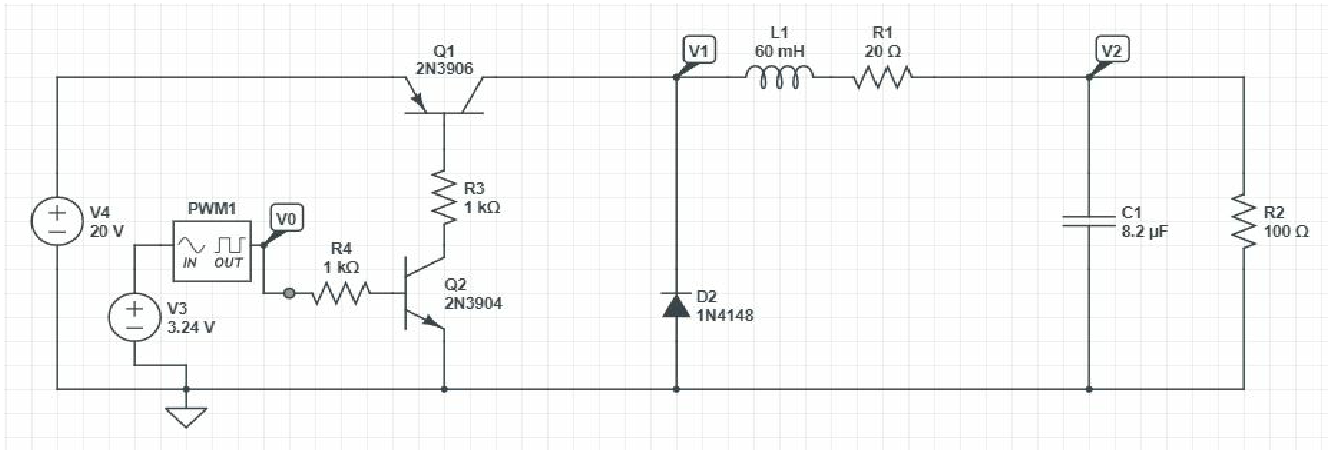
$$C \approx \left(\frac{1.64V_{pp}}{1V_{pp}} \right) 5\mu F = 8.2\mu F$$

7) Check your results for problem #6 in CircuitLab

- $\max(V2) = 5.476V$
- $\min(V2) = 4.289V$

$$DC = (\max + \min) / 2 = 4.883V$$

$$AC = \max - \min = 1.187V_{pp}$$

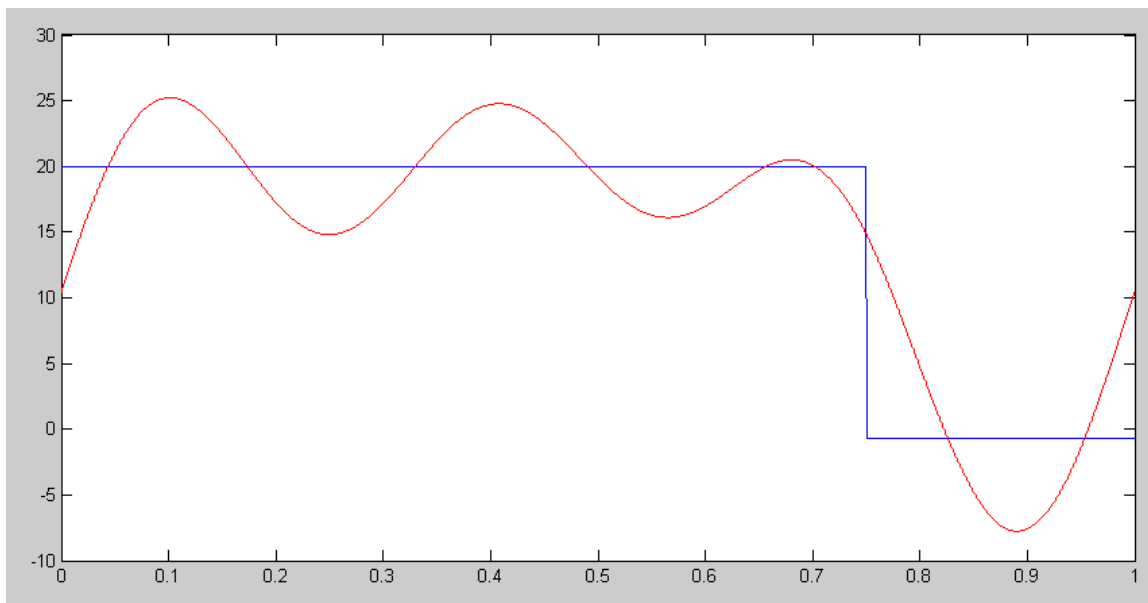


DC to DC Converter (problems 4 - 6)

Fourier Transforms

8) Going back to problem #4, determine the Fourier Transform for V1 out to the 3rd harmonic (3kHz)

```
>> t = [0:0.0001:1]';  
>> V1 = 20*(t<0.75) - 0.7*(t>0.75);  
>> DC = mean(V1)  
  
DC =  
  
    14.8235  
  
>> c1 = 2*mean(V1 .* exp(-j*2*pi*t))  
  
c1 =  
  
   -6.5864 - 6.5903i  
  
>> c2 = 2*mean(V1 .* exp(-j*2*pi*t * 2))  
  
c2 =  
  
    0.0039 - 6.5884i  
  
>> c3 = 2*mean(V1 .* exp(-j*2*pi*t * 3))  
  
c3 =  
  
    2.1980 - 2.1942i  
  
>> Yf = DC + real(c1)*cos(2*pi*t) - imag(c1)*sin(2*pi*t);  
>> Yf = Yf + real(c2)*cos(2*pi*t*2) - imag(c2)*sin(2*pi*t*2);  
>> Yf = Yf + real(c3)*cos(2*pi*t*3) - imag(c2)*sin(2*pi*t*3);  
>> plot(t,V1,'b',t,Yf,'r');  
>>
```



9) Using the Fourier Transform approximation for V1, determine V2 out to the 3rd harmonic (3kHz)

```
>> % DC
>> w = 0;
>> V2_0 = 100 / (100+20) * DC

V2_0 =

    12.3529

>> % 1st harmonic
>> w = 2*pi*1000;
>> C = 1/(j*w*5e-6);
>> L = j*0.06*w;
>> R1 = 1 / (1/100 + 1/C);
>> R2 = 20 + L;
>> V2_1 = (R1 / (R1 + R2))*c1

V2_1 =

    0.3100 + 0.7473i

>> % 2nd harmonic
>> w = 2*pi*1000 * 2;
>> C = 1/(j*w*5e-6);
>> L = j*0.06*w;
>> R1 = 1 / (1/100 + 1/C);
>> R2 = 20 + L;
>> V2_2 = (R1 / (R1 + R2))*c2

V2_2 =

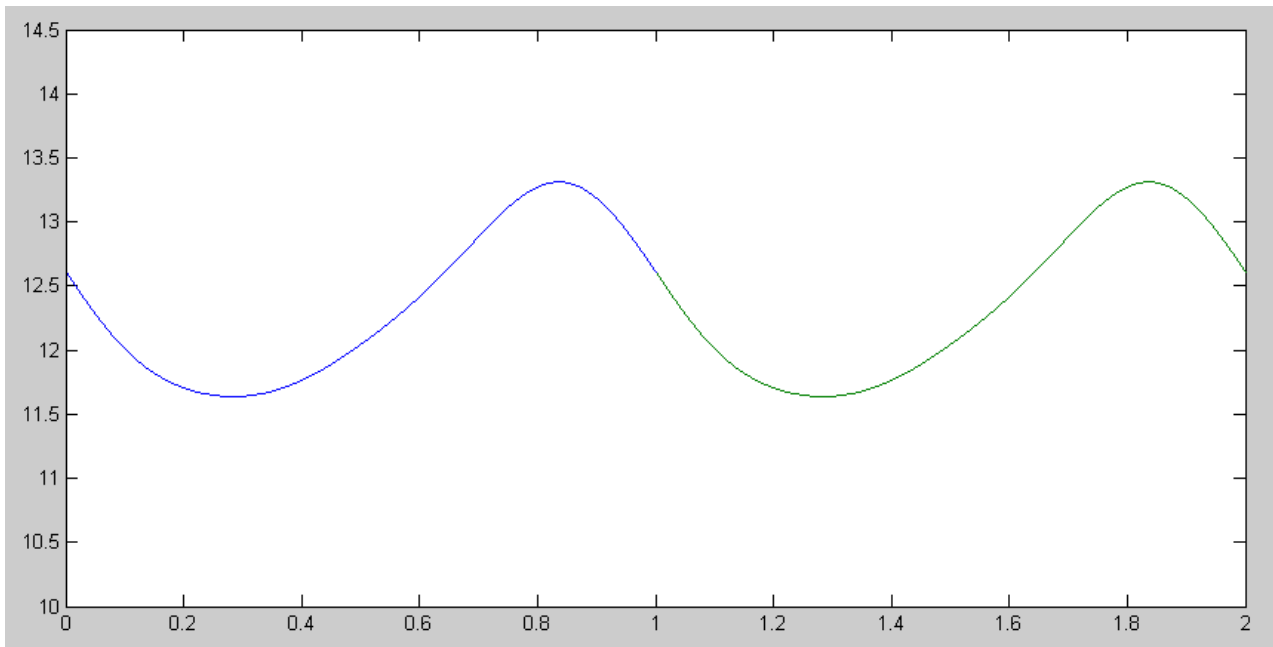
   -0.0263 + 0.1377i

>> % 3rd harmonic
>> w = 2*pi*1000 * 3;
>> C = 1/(j*w*5e-6);
>> L = j*0.06*w;
>> R1 = 1 / (1/100 + 1/C);
>> R2 = 20 + L;
>> V2_3 = (R1 / (R1 + R2))*c3

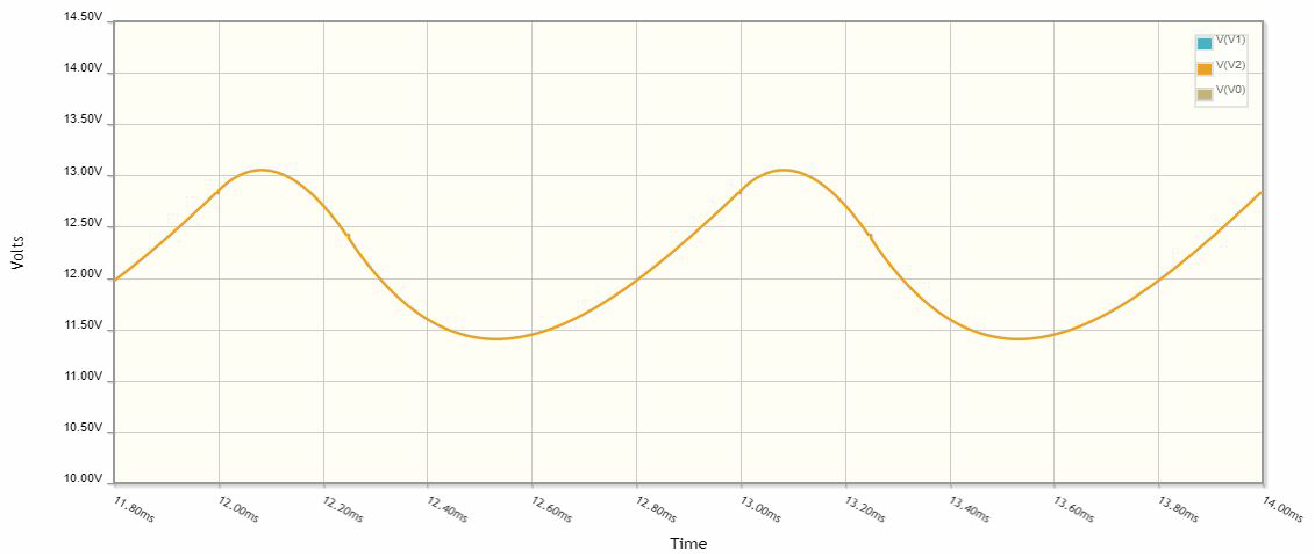
V2_3 =

   -0.0231 + 0.0179i

>>
>> V2 = 0*t + V2_0;
>> w0 = 2*pi;
>> V2 = V2 + real(V2_1)*cos(w0*t) - imag(V2_1)*sin(w0*t);
>> V2 = V2 + real(V2_2)*cos(2*w0*t) - imag(V2_2)*sin(2*w0*t);
>> V2 = V2 + real(V2_3)*cos(3*w0*t) - imag(V2_3)*sin(3*w0*t);
>> plot(t,V2)
>> xlabel('Time (ms)');
```



Matlab Result for V2 (problem #4) using 3 terms from the Fourier Transform



CircuitLab Simulation for V2 (problem #4)

```
>> mean(V2)
ans = 12.3530

>> max(V2) - min(V2)
ans = 1.6727
```

These match the CircuitLab simulations

- $DC = (max + min) / 2 = 12.23V$
- $AC = (max - min) = 1.64V_{pp}$