ECE 320 - Homework #6

H-Bridge, DC to DC Converters, DC to AC Converters. Due Wednesday, February 21st, 2018

H-Bridges

1) Determine the voltages and currents for the follownig H-bridge. Assume 3904/3907 transistors:

- $\beta = 100$
- $V_{ce(sat)} = 0.2V$
- $V_{be} = 0.7V$

Transistors 1 and 4 are off.

Transistor 2:

$$I_b = \left(\frac{12V-0.7V}{20k}\right) = 565\mu A$$

$$\beta I_b = 56.5mA$$ (this transisor allows up to 56.5mA to flow)

Transistor 3:

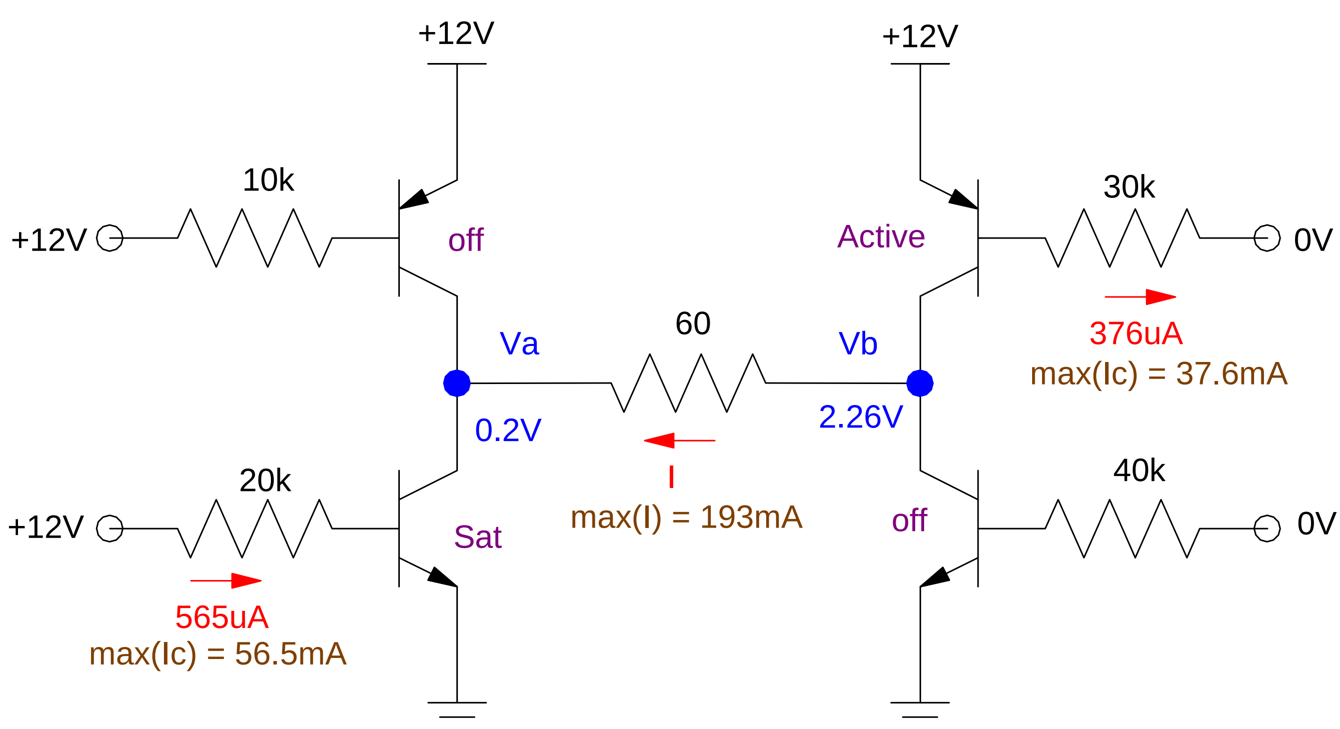
$$I_b = \left(\frac{21V-0.7V}{30k}\right) = 376\mu A$$

$$\beta I_b = 37.6mA$$ (this transistor allows up to 37.6mA to flow)

60 Ohm Load: If both transistors are saturated, the 60 Ohm load limits the current to

$$\max(I_c) = \left(\frac{12-0.2-0.2}{60}\right) = 193mA$$

The actual current is the smallest of these three: 37.6mA



2) Modify this circuit so that I = 200mA (approx)

Actually, limit the current to 193mA (the 60 Ohm load). This means both transistors have to be saturated:

Transistor 2:

$$\beta I_b > 193mA$$

$$I_b > 1.93mA$$

Let Ib = 4mA

$$R_b = \left(\frac{12V - 0.7V}{4mA}\right) = 2825\Omega$$

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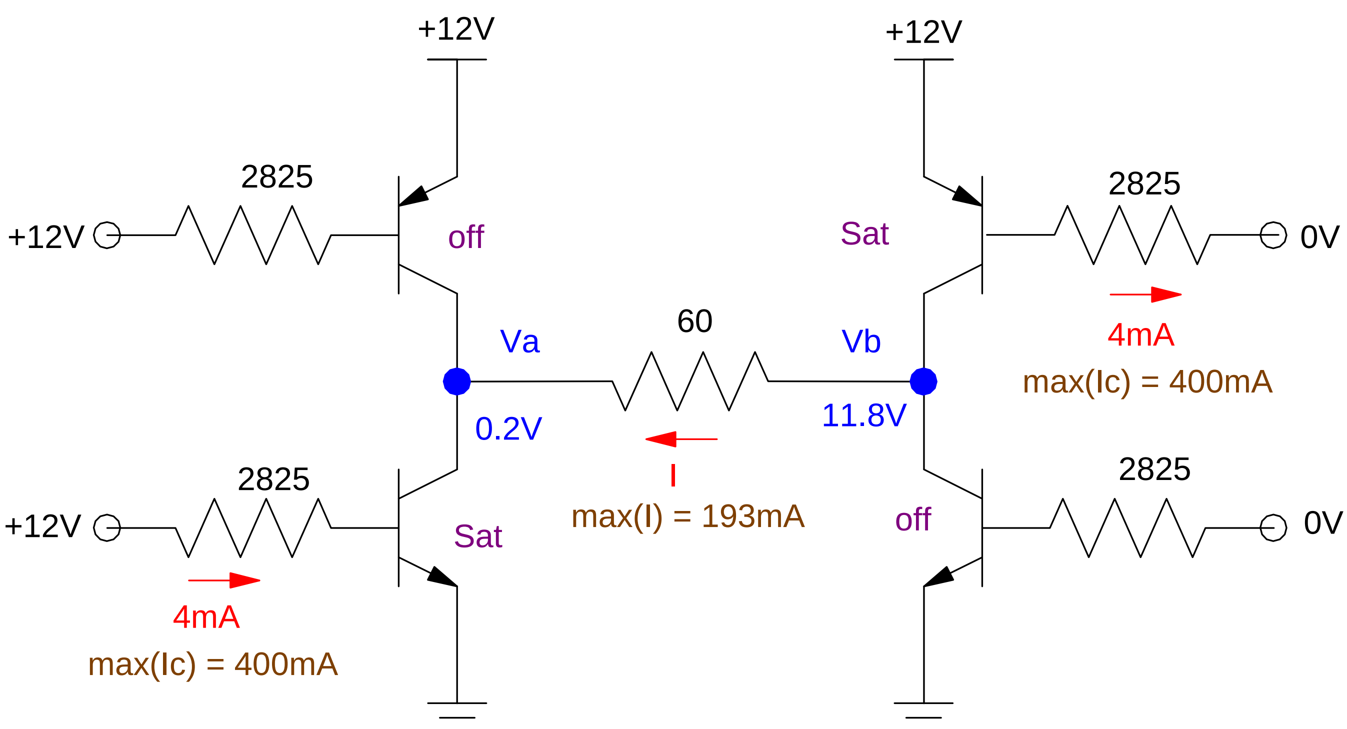
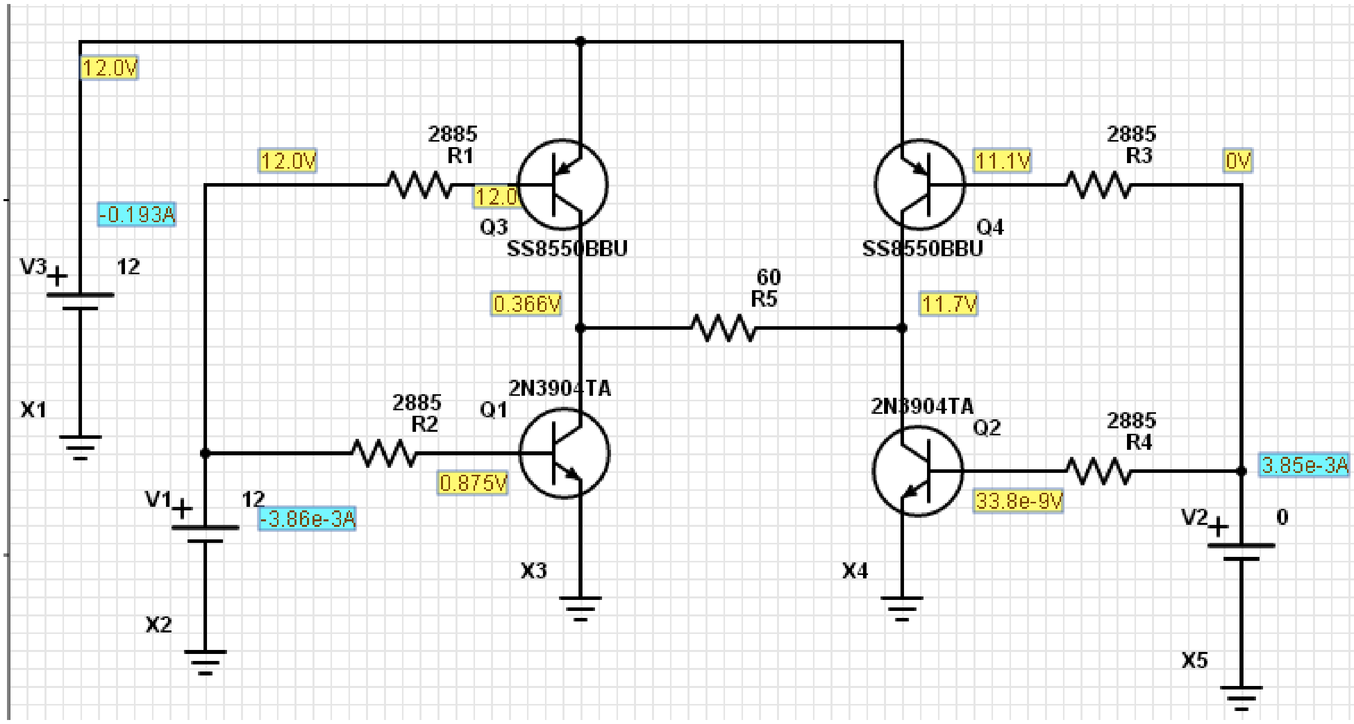


3) Simulate your circuit for problem #2 in PartSim. Check that the voltages and currents you compute are correct.



	Transistor 2				Transistor 3			
	Vb	Vc	Ib	Ic	Vb	Vc	Ib	Ic
Calculated	0.7V	0.2V	4mA	193mA	11.3V	11.8V	4mA	193mA
Simulated	0.875V	0.366V	3.86mA	189mA	11.1V	11.7V	3.85mA	189mA

4) Lab: A dual H-brigde is a L1110 ($0.91 ea - shown right). Connect

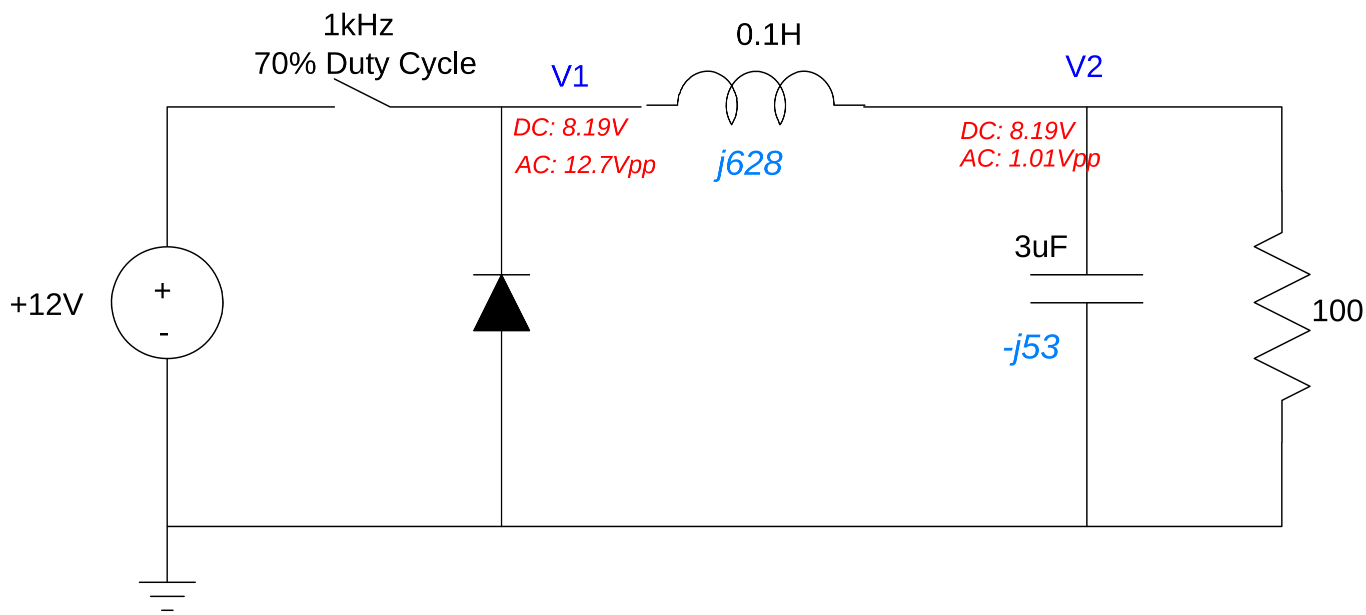
- Vcc = +12V
- gnd = 0V
- A-1A and A-1B are the control inputs (0V / 5V).
- MOTOR-A: DC motor

Measure the voltage across the motor for the following inputs:

Forward		Stop		Reverse	
A-1A	A-1B	A-1A	A-1B	A-1A	A-1B
0V	5V	0V	0V	5V	0V
+11.22V		**0.00V**		**-11.22V**	

DC to DC Converters (Buck converters)

5) Find the voltage (DC and AC) for V1 and V2



V1: DC

$$V_1 = 0.7 \cdot 12V + 0.3 \cdot (-0.7V)$$

$$V_1 = 8.19V$$

V1: AC

$$V_1 = 12.7V_{pp}$$

V2: DC

same as V1(DC): 8.19V

V2:AC

$$-j53 || 100 = 21.9 - j41.4$$

$$V_2 = \left(\frac{(21.9-j41.4)}{(21.9-j41.4)+(j628)}\right) \cdot 12.7V_{pp}$$

$$|V_2| = 1.013V_{pp}$$

6) Modify this circuit so that

- The voltage at V2 is 8VDC
- With a ripple of 2Vpp when C = 0, and
- With a ripple of 0.5Vpp with C > 0.

DC Voltage = 8V

$$\alpha \cdot 12V + (1-\alpha)\cdot(-0.7V) = 8V$$

$$\alpha = \left(\frac{8.7}{12.7}\right) = 0.685$$

Ripple is 2V with C = 0

The ripple drops by a factor of 6.35

$$\left(\frac{12.7V_{pp}}{2V_{pp}}\right) = 6.35$$

wL should be 6.35 times larger than R

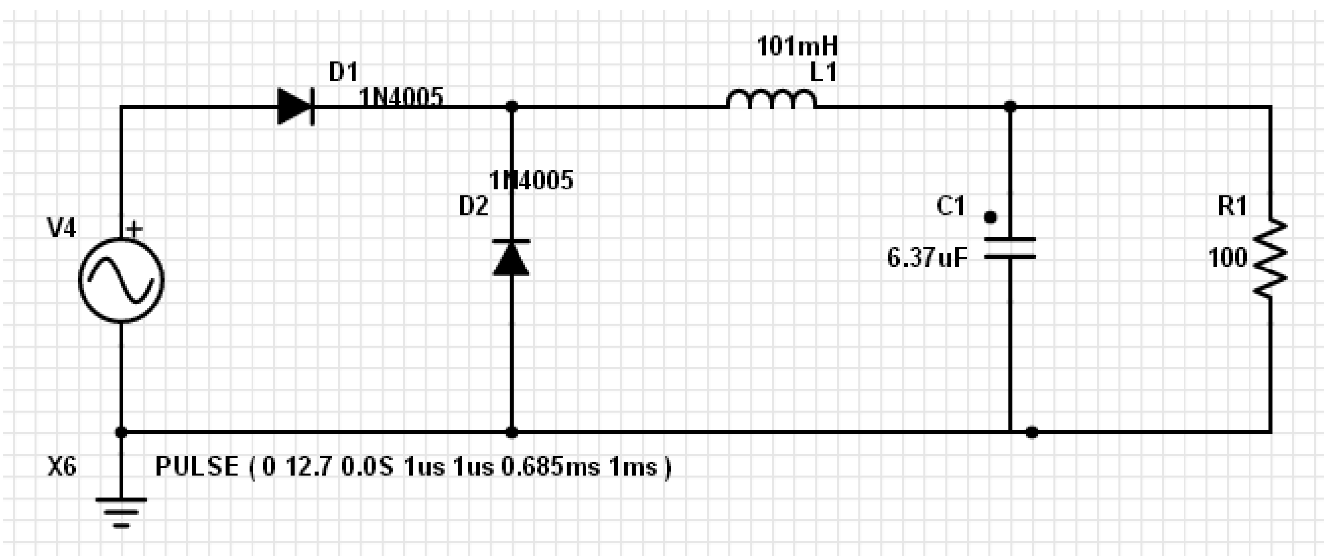
$$\omega L = 6.35 \cdot R$$

$$L = \left(\frac{635}{6280}\right) = 0.101H$$

C then reduces the ripply by another factor of 4x

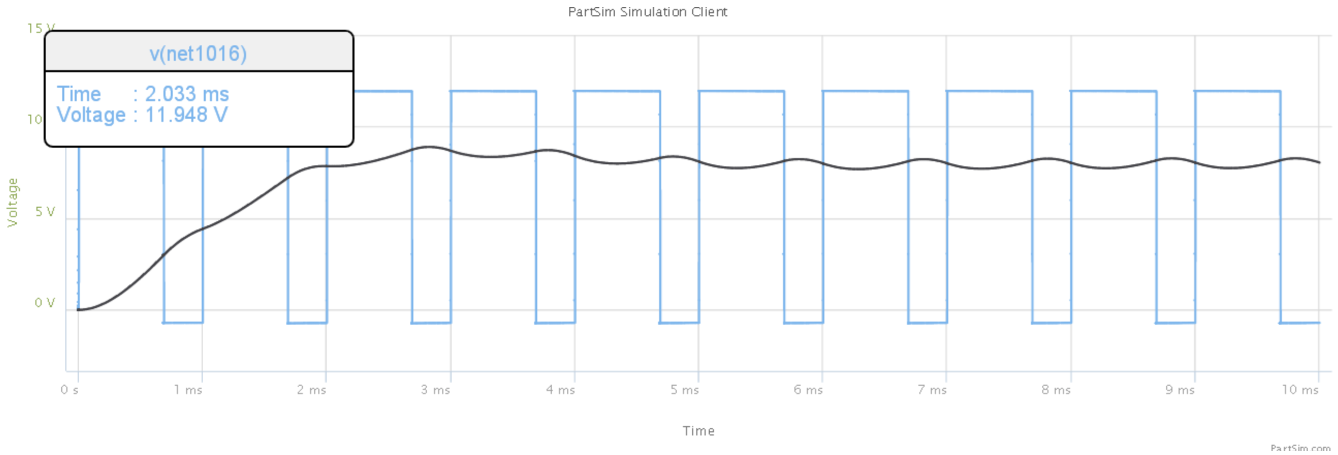
$$\left(\frac{1}{\omega C}\right) = \frac{1}{4}\cdot 100\Omega$$

$$C = 6.37\mu F$$

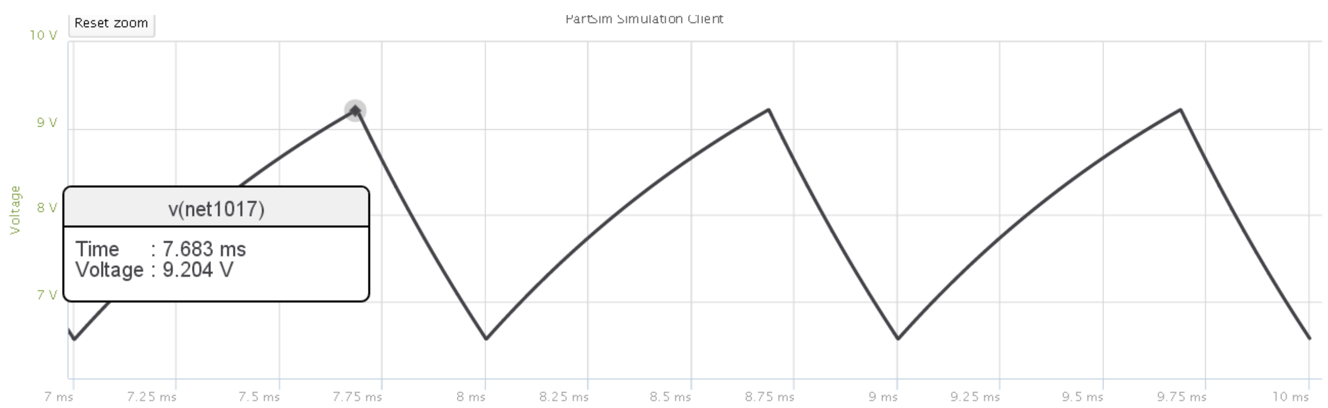


7) Check your analysis in PartSim (or similar program)

With C = 6.37uF

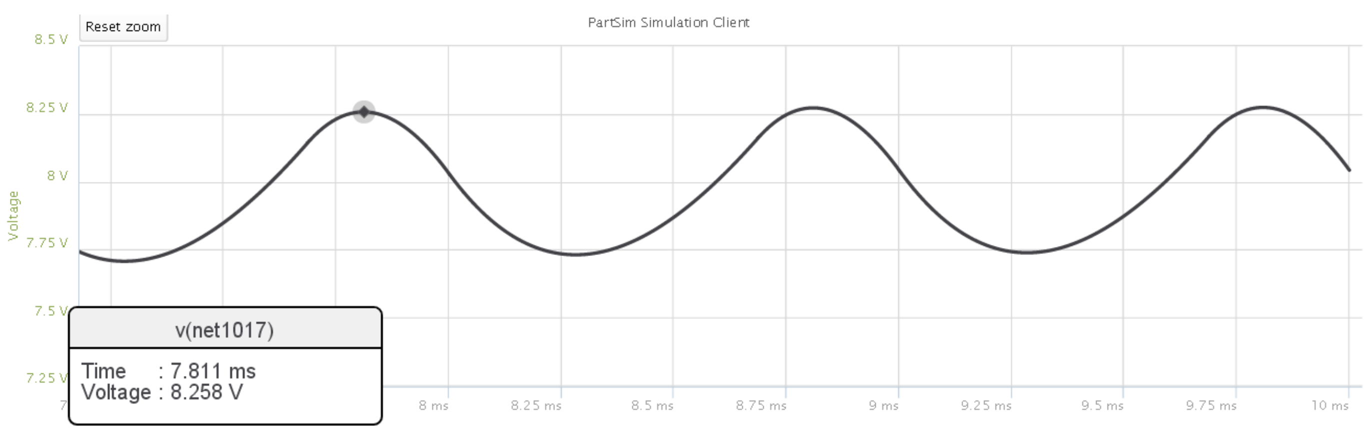


Zooming in: C = 0



C=0: 6.568V < V2 < 9.206V.   DC = 7.887 (approx), AC = 2.638Vpp

Zooming In: C = 6.37uF



7.738V < V2 < 8.272V (DC = 8.005V, AC = 0.534Vpp)

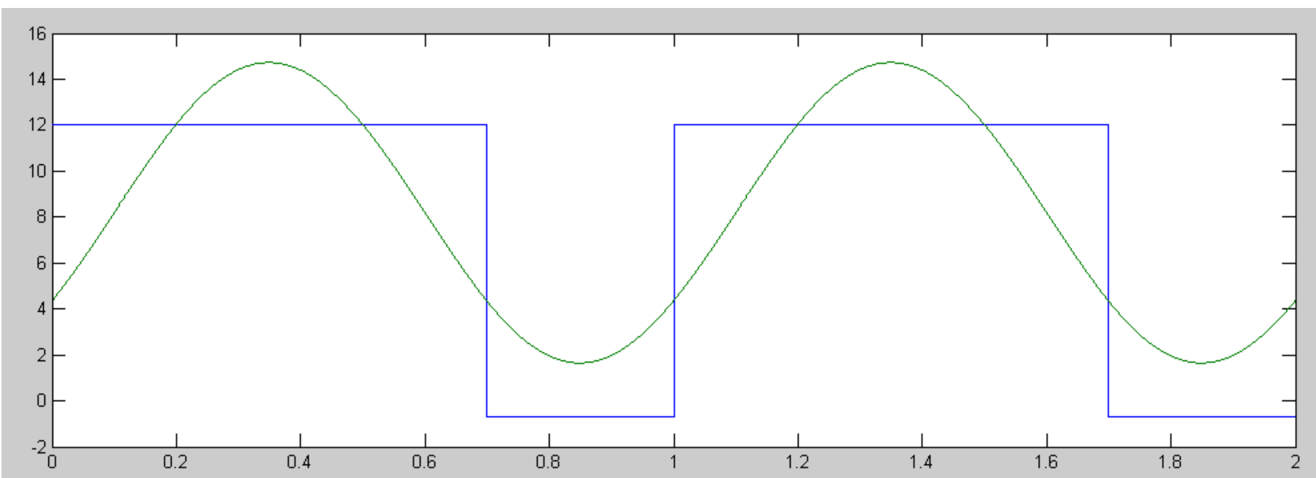
DC to AC Converters

8a) Determine the first two terms of the Fourier series for the following waveform

$$y(t) \approx a + b \cdot \cos(\omega t + \phi)$$

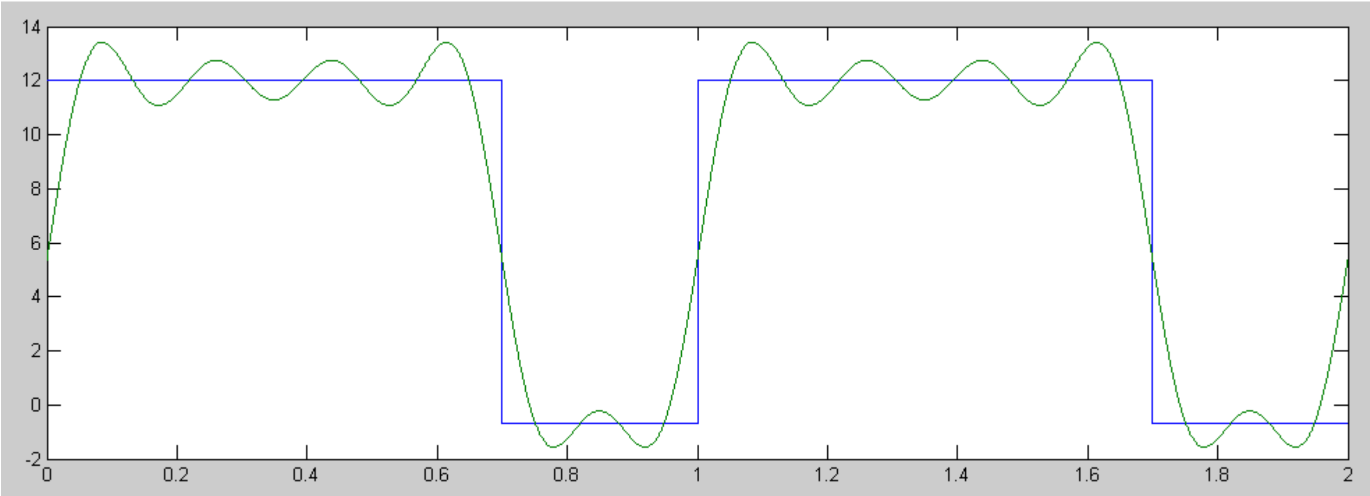
```
>> t = [0:0.0001:1]';
>> y = 12*(t < 0.7) - 0.7*(t>=0.7);
>> DC = mean(y)

DC =

    8.1891

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

    5.2924

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

   -3.8428

>> yf = DC + a1*sin(2*pi*t) + b1*cos(2*pi*t);
>> plot(t,y,t,yf)
```

$$y(t) \approx 8.1891 + 5.29\sin(6280t) - 3.8428\cos(6280t)$$



Sidelight: If you go out to the 5th harmonic:

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

     3.6554

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

     1.1901

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

     0.2566

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

     0.7921

>> a4 = 2*mean(y .* sin(4*2*pi*t))

     0.6995

>> b4 = 2*mean(y .* cos(4*2*pi*t))

    -0.9603

>> a5 = 2*mean(y .* sin(5*2*pi*t))

     1.6169

>> b5 = 2*mean(y .* cos(5*2*pi*t))

     0.0024

>> yf = yf + a2*sin(2*2*pi*t) + b2*cos(2*2*pi*t);
>> yf = yf + a3*sin(3*2*pi*t) + b3*cos(3*2*pi*t);
>> yf = yf + a4*sin(4*2*pi*t) + b4*cos(4*2*pi*t);
>> yf = yf + a5*sin(5*2*pi*t) + b5*cos(5*2*pi*t);
>> plot([t;t+1],[y;y],[t;t+1],[yf;yf]);
>>
```



It really does converge if you add more and more harmonics...

8b) How much of the total energy is contained in these two terms?

```
>> Total = mean(y.^2)

Total =

  100.9370

>> yf = DC + a1*sin(2*pi*t) + b1*cos(2*pi*t);
>>
>> H01 = mean(yf .^ 2)

H01 =

   88.4429

>> H01 / Total

ans =

    0.8762

>>
```

87.62% of the total energy is in the DC term and the 1st harmonic.

After filtering the signal with L and C, this goes up significantly.

Harmonic	w (rad/sec)	| V1 | Volts (peak)	| gain | $\left(\frac{\left(\frac{1}{j\omega C} \| \| R\right)}{\left(\frac{1}{j\omega C} \| \| R\right) + (j\omega L)} \right)$	| V2 |
0 (DC)	0	8.1891	1.000	8.1981
1	6,280	7.071	0.0799	0.565
2	12,560	3.844	0.0208	0.080
3	18,840	0.833	0.0093	0.008
4	25,120	1.188	0.0053	0.006
5	31,400	1.617	0.0034	0.005