ECE 320 - Homework #6

H-Bridge, DC to DC Converters, Fourier Transforms. Due Wednesday, February 23rd

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

- V1 = 0V, V2 = 0V
- V1 = 5V, V2 = 5V
- V1 = 5V, V2 = 0V

Assume 3904/3906 transistors

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



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







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

		Calculated	Simulated	Measured
V1 = 5V V2 = 5V	V3	0.20V	86.89mV	0.09V
	12	-46.0mA	-48.26mA	-48mA
V1 = 0V V2 = 0V	V3	4.80V	4.884V	4.96V
	12	+46.0mA	+46.87mA	+49mA
V1 = 5V V2 = 0V	V3	2.50V	2.500V	2.46V
	12	0.0mA	0.0mA	-1mA





DC to DC Converters

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





 $V_1(DC) = 0.55 \cdot 20V + 0.45 \cdot (-0.7V)$ $V_1(DC) = 10.685V$

$$V_2(DC) = \left(\frac{75}{75+10}\right) \cdot 10.685V$$

 $V_2(DC) = 9.428V$

AC Voltage

$$V_1(AC) = 20.7V_{pp}$$
$$V_2(AC) = \left(\frac{(8.346 - j23.586)}{(8.346 - j23.586) + (10 + j314)}\right) \cdot 20.7V_{pp}$$

$$V_2(AC) = 1.780V_{pp}$$

(note: take the magnitude of V2(AC). Phase doesn't matter)

- 5) Simulate the circuit in CircuitLab and determine V2 (DC and AC)
 - max(V2) = 10.38V
 - min(V2) = 8.206V
 - V2(DC) = (max + min)/2 = 9.293V
 - V2(AC) = (max min) = 2.174Vpp

	V1		V2	
	DC	AC	DC	AC
calculated	10.658V	20.7Vpp	9.428V	1.780Vpp
simulated	-	-	9.293V	2.174Vpp





6) Change the duty cycle and C so that

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

$$V_2 = \left(\frac{75}{75+10}\right) V_1$$
$$V_1 = \left(\frac{85}{75}\right) V_2 = 5.667V$$

Duty cycle

$$\alpha = \left(\frac{5.667V + 0.7V}{19.8V + 0.7V}\right) = 31.1\%$$

note: I'm using 19.8V in the denominator to account for the 0.2V drop across the PNP transistor when saturated

To bring the ripple down to 1Vpp

6uF results in 2.174Vpp ripple

$$C = \left(\frac{2.174V_{pp}}{1V_{pp}}\right) 6\mu F = 13.04\mu F$$

7) Check your results for problem #6 in CircuitLab

- max(V2) = 5.435v
- $\min(V2) = 4.558V$
- V2(DC) = 4.997V
- V2(AC) = 0.877Vpp



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 = 19.8 * (t<0.55) - 0.7*(t >= 0.55);
>> X0 = mean(V1)
X0 = 10.5739
>> X1 = 2*mean(V1 .* exp(-j*2*pi*t))
X1 = -2.0124 -12.7307i
>> X2 = 2*mean(V1 .* exp(-j*4*pi*t))
X2 = 1.9178 - 0.6218i
>> X3 = 2*mean(V1 .* exp(-j*6*pi*t))
X3 = -1.7564 - 3.4549i
```

$$V_{1}(t) \approx 10.5739$$

-2.01 cos ($\omega_{0}t$) + 12.73 sin ($\omega_{0}t$)
+1.92 cos ($2\omega_{0}t$) + 0.62 sin ($2\omega_{0}t$)
-1.75 cos ($3\omega_{0}t$) + 3.45 sin ($3\omega_{0}t$)

 $\omega_0 = 6280 \frac{rad}{sec}$



V1(t) (blue) and its Fourer approximation taken out to the 20th harmonic (red)

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

```
>> % DC
>> X0 = mean(V1);
>> G0 = 75 / 85;
>> Y0 = G0 * X0;
Y0 =
        9.3299
>> % 1st harmonic
>> X1 = 2*mean(V1 .* exp(-j*2*pi*t));
>> w = 6280;
>> L = j*w*0.05;
>> C = 1/(j*w*6e-6);
>> R2 = 1/(1/75 + 1/C);
>> L = 0.05;
>> C = 6e-6;
>> R2 = 1/(1/75 + j*w*C);
>> R1 = 10 + j*w*L;
>> Y1 = (R2 / (R1 + R2))*X1
```

```
Y1 = -0.2703 + 1.0747i
```

```
>> Y1pp = 2*abs(Y1)
```

```
Y1pp = 2.2163
```

```
>> % 2nd harmonic
```

```
>> X2 = 2*mean(V1 .* exp(-j*4*pi*t));
>> w = 6280 * 2;
>> R2 = 1/( 1/75 + j*w*C );
>> R1 = 10 + j*w*L;
>> Y2 = (R2 / (R1 + R2))*X2
```

```
Y2 = -0.0425 + 0.0051i
```

```
>> % 3rd harmonic
```

```
>> X3 = 2*mean(V1 .* exp(-j*6*pi*t));
>> w = 6280 * 3;
>> R2 = 1/( 1/75 + j*w*C );
>> R1 = 10 + j*w*L;
>> Y3 = (R2 / (R1 + R2))*X3
```

```
Y3 = 0.0122 + 0.0344i
```

```
V_2(t) \approx 9.3299
-0.270 cos (\omega_0 t) - 1.075 sin (\omega_0 t)
-0.043 cos (2\omega_0 t) - 0.005 sin (2\omega_0 t)
+0.012 cos (3\omega_0 t) - 0.034 sin (3\omega_0 t)
```

Note:

- In CircuitLab, V2(AC) = 2.174Vpp, which closely matches the 1st-harmonic Y1pp.
- The harmonics past the 1st harmonic are almost zero. Ignoring them doesn't change the results that much.