ECE 320 - Homework #6

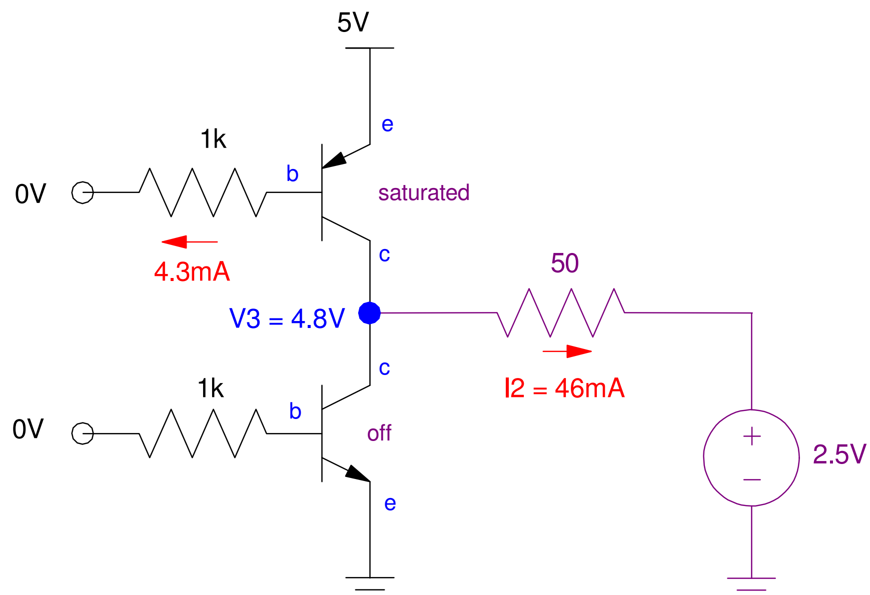
H-Bridge, DC to DC Converters

H-Bridges:

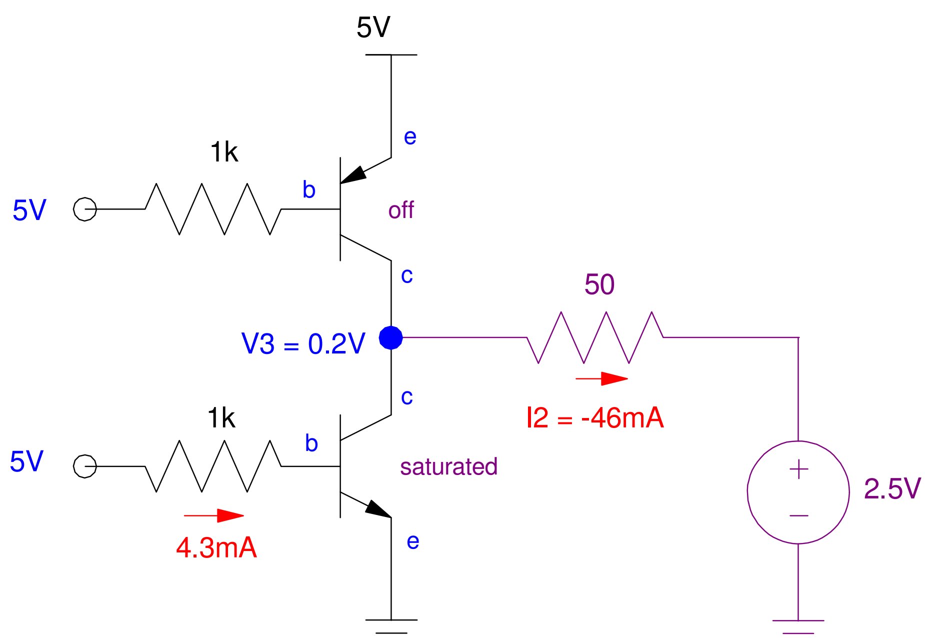
1) Determine the voltages and currents for the following 1/2 H-bridge for

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

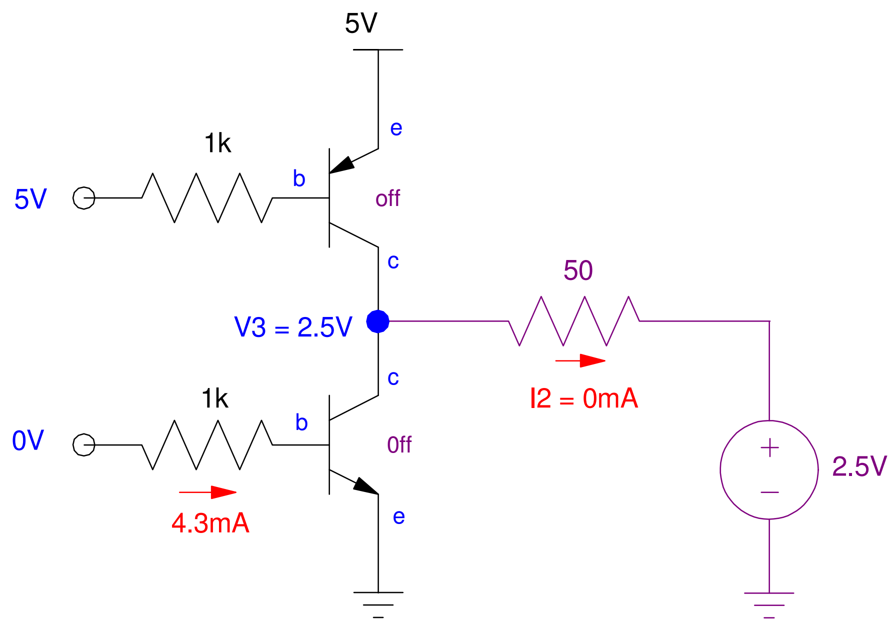
Assume 3904/3906 transistors



0V : 0V results in V2 = 4.8V

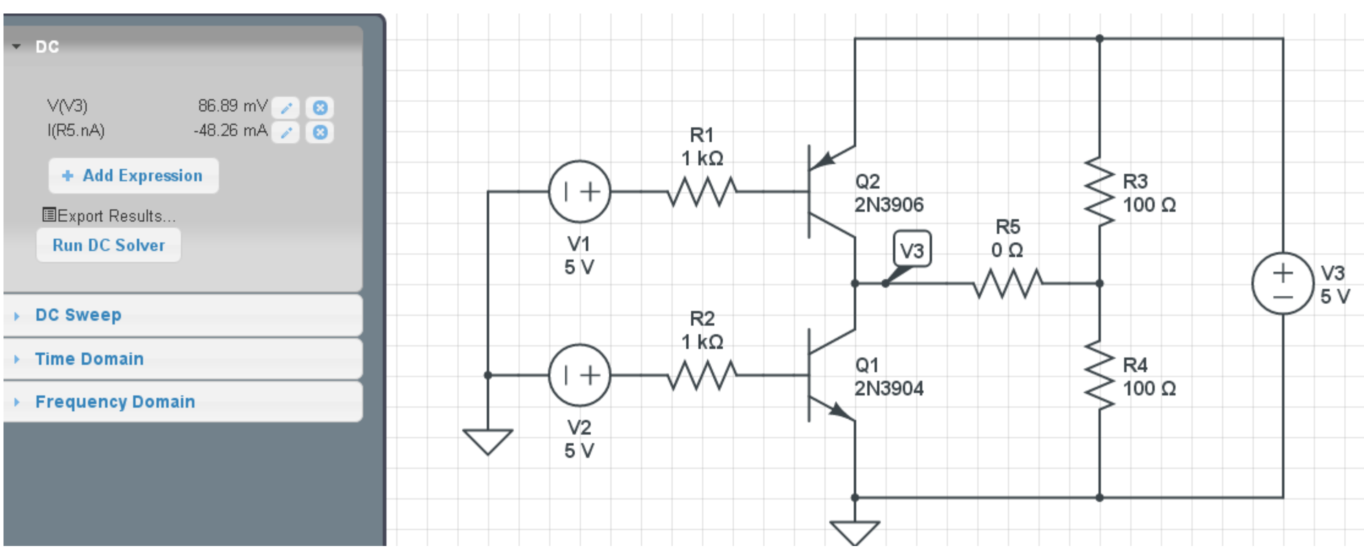


5V : 5V results in 0.2V



Voltages for 5V : 0V input

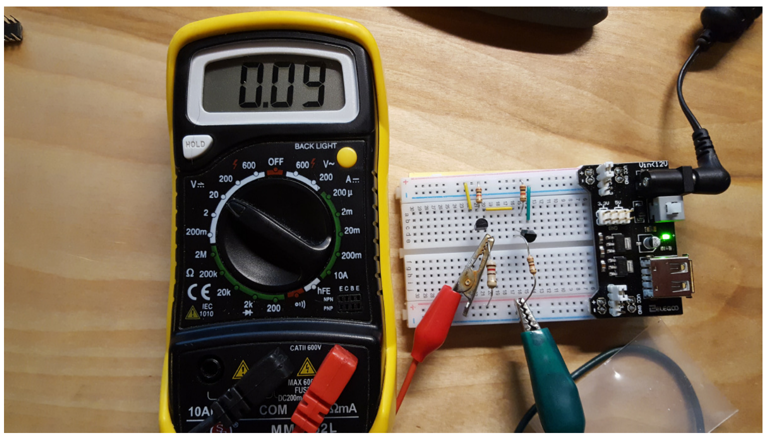
2) Check your results (votlages and currents) in CircuitLab

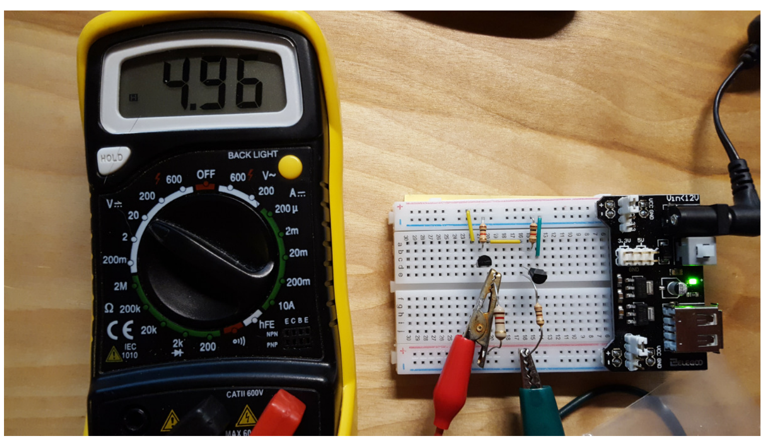


		Calculated	Simulated	Measured
V1 = 5V V2 = 5V	V3	0.20V	86.89mV	
	I3	-46.0mA	-48.26mA	
V1 = 0V V2 = 0V	V3	4.80V	4.884V	
	I3	+46.0mA	+46.87mA	
V1 = 5V V2 = 0V	V3	2.50V	2.500V	
	I3	0.0mA	0.0mA	

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

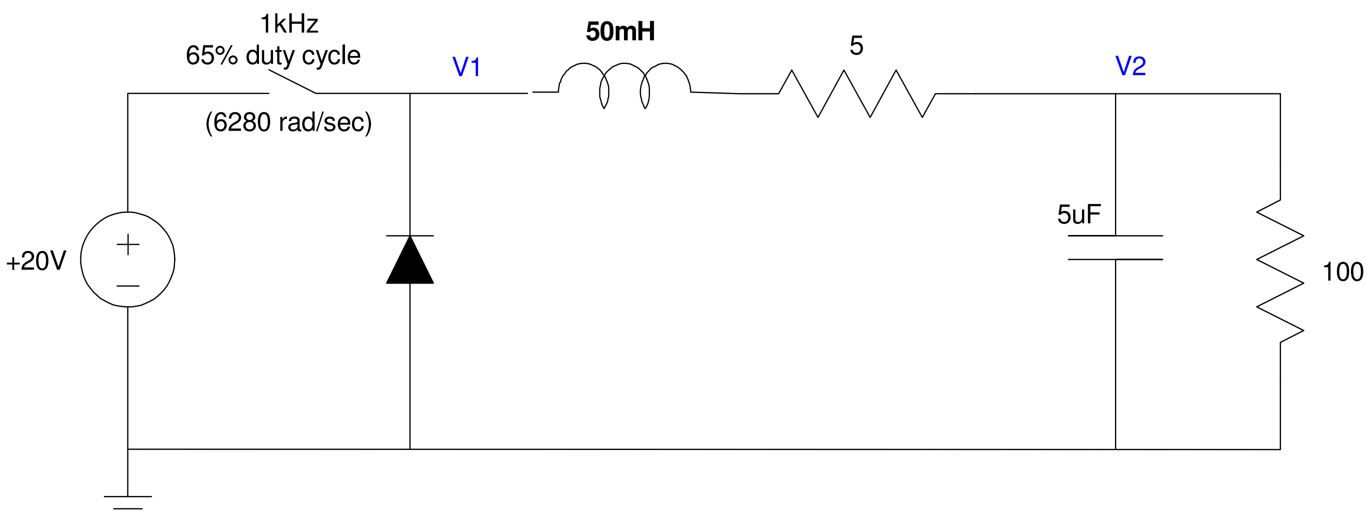
		Calculated	Simulated	Measured
V1 = 5V V2 = 5V	V3	0.20V	86.89mV	0.09V
	I2	-46.0mA	-48.26mA	-48mA
V1 = 0V V2 = 0V	V3	4.80V	4.884V	4.96V
	I2	+46.0mA	+46.87mA	+49mA
V1 = 5V V2 = 0V	V3	2.50V	2.500V	2.46V
	I2	0.0mA	0.0mA	-1mA





DC to DC Converters

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



DC:

$$V_1(DC) = 0.65 \cdot 20V + 0.35 \cdot (-0.7V)$$

$$V_1(DC) = 12.755V$$

$$V_2(DC) = \left(\frac{100}{100+5}\right) 12.755V$$

$$V_2(DC) = 12.148V$$

AC:

$$V_1(AC) \approx 20.7V_{pp}$$

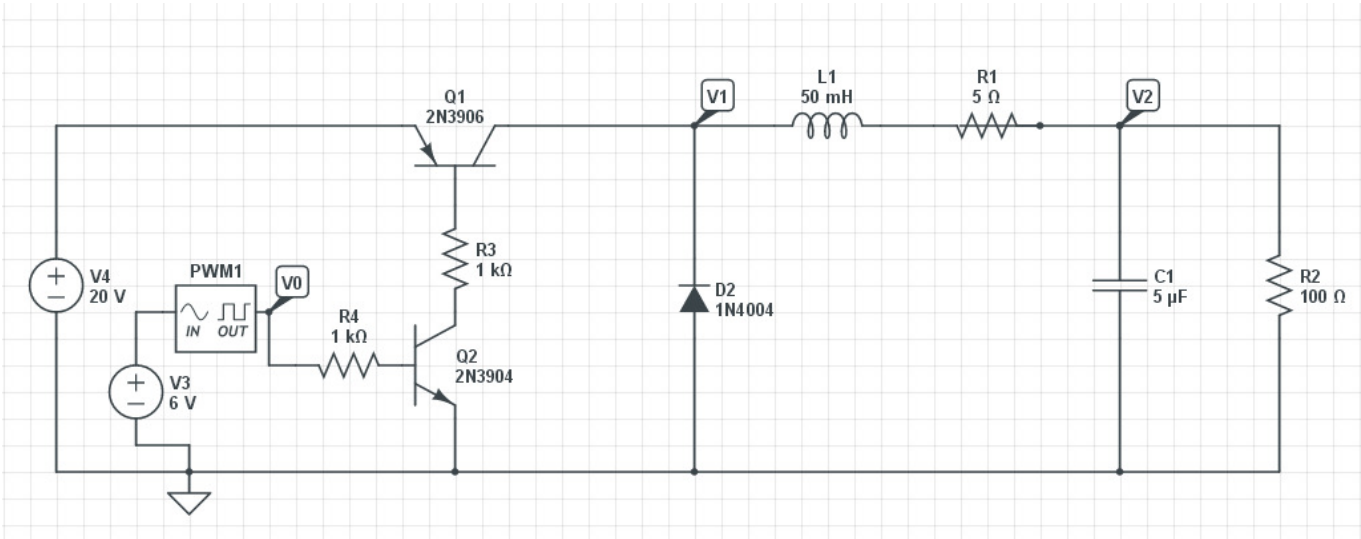
$$V_2(AC) \approx \left(\frac{(9.2084 - j29.9145)}{(9.2084 - j29.9145) + (5 + j314)}\right) 20.7V_{pp}$$

$$V_2(AC) \approx 2.2006V_{pp}$$

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

Use a PNP transistor as an electronic switch.

- Turn it on 65% of the time with PWM



The voltages at V1 and V2 are:

- V2(max) = 13.28V
- V2(min) = 10.83V

	V1		V2	
	Max	Min	DC	AC
Calculated	20V ignores the 0.2V drop across the transistor	-0.7V	12.148V	2.200Vpp
Simulated	19.84V	-0.7898V	12.055V	2.450Vpp

6) Change the duty cycle and C so that

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

DC Analysis:

$$V_2 = 5.00V = \left(\frac{100}{100+5}\right) V_1$$

$$V_1 = 5.25V$$

Duty Cycle

$$5.25V = 20V \cdot \alpha + (1-\alpha)(-0.7V)$$

$$\alpha = \left(\frac{5.25V+0.7V}{20V+0.7V}\right) = 28.74\%$$

AC Analysis: (Method #1)

5uF produced 2.588Vpp ripple, so

$$C = \left(\frac{2.588V_{pp}}{1V_{pp}}\right) 5\mu F = 12.94\mu F$$

AC Analysis (Method #2)

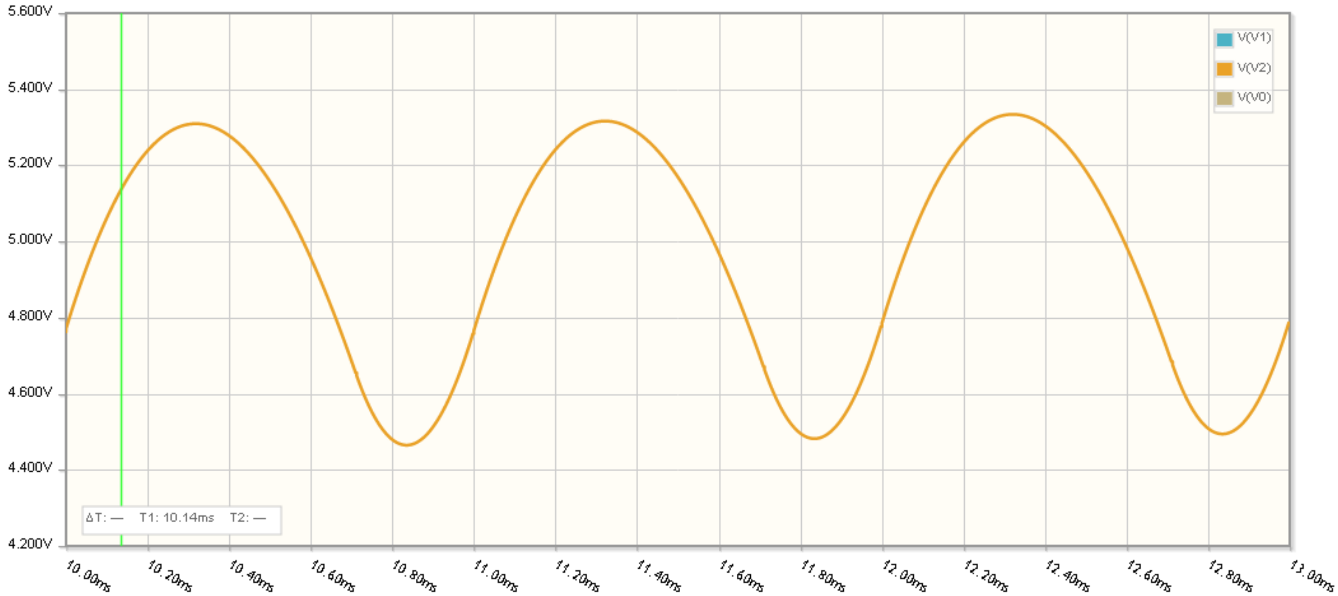
$$V_2 = 1V_{pp} = \left(\frac{R||\frac{1}{j\omega C}}{R||\frac{1}{j\omega C}+(5+j314))}\right) 20.7V_{pp}$$

$$1V_{pp} \approx \left(\frac{\frac{1}{j\omega C}}{j314}\right) 20.7V_{pp}$$

$$\frac{1}{\omega C} \approx 15.17\Omega$$

$$C \approx 10.50\mu F$$

7) Check your results for problem #6 in CircuitLab



	V2(DC)	V2(AC)
Calculated	5V	1Vpp
Simualted	4.891V	0.8500Vpp

Fourier Transforms

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

- 65% duty cycle square wave
- Going from -0.7V to +19.8V

Using the complex Fourier Transform

```
>> t = [0:0.0001:1]';
>> V0 = 19.8*(t<0.65) - 0.7*(t>=0.65);
>> c0 = mean(V0)

c0 =   12.6257

>> c1 = 2*mean(V0 .* exp(-j*2*pi*t))

c1 =  -5.2779 -10.3582i

>> c2 = 2*mean(V0 .* exp(-j*2*pi*t * 2))

c2 =   3.1040 - 4.2724i

>> c3 = 2*mean(V0 .* exp(-j*2*pi*t * 3))

c3 =  -0.6682 - 0.1058i
```

Translation: V1(t) is approximately

$$
\begin{aligned}
V_1(t) \approx \quad & 12.6357 \\
& -5.2779\cos(\omega_0 t) + 10.3582\sin(\omega_0 t) \\
& +3.1040\cos(2\omega_0 t) + 4.2724\sin(2\omega_0 t) \\
& -0.6682\cos(3\omega_0 t) + 0.1058\sin(3\omega_0 t)
\end{aligned}
$$

where ω_0 is 1000Hz (2000 pi)

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

```
% DC
>> R2 = 100;
>> R1 = 5;
>> Y0 = R2 / (R1+R2)*c0

Y0 =   12.0245

>> % 1kHz
>> w = 2*pi*1000;
>> Zc = 1/(j*w*5e-6);
>> R2 = 1/(1/Zc + 1/100);
>> R1 = 5 + j*w*0.05;
>> Y1 = (R2)/(R2+R1)*c1

Y1 =   0.1396 + 1.2267i

>> % 2kHz
>> w = 2*pi*2000;
>> Zc = 1/(j*w*5e-6);
>> R2 = 1/(1/Zc + 1/100);
>> R1 = 5 + j*w*0.05;
>> Y2 = (R2)/(R2+R1)*c2

Y2 =  -0.0970 + 0.0945i

>> % 3kHz
>> w = 2*pi*3000;
>> Zc = 1/(j*w*5e-6);
>> R2 = 1/(1/Zc + 1/100);
>> R1 = 5 + j*w*0.05;
>> Y3 = (R2)/(R2+R1)*c2

Y3 =  -0.0403 + 0.0441i
```

Pretty much, all that matters is the 1st harmonic (1kHz), resulting in the peak-to-peak voltage at V1 being

```
>> V1pp = 2*abs(Y1)

V1pp = 2.4692  vs. 2.4500Vpp from Circuitlab
```

>>>>>>>

Note: A better way to estimate the signal at V2 is to take the Fourier Transform of V1

DC term

- Tells you the DC term for V1

1st Harmonic

- Tells you the AC term for V1

The other harmonics have a minimal effect and can be ignored.