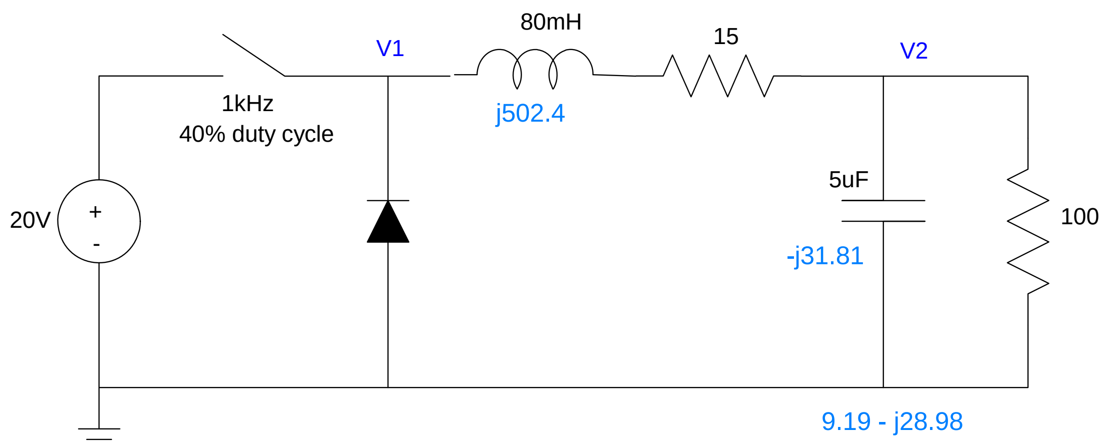
ECE 320 - Homework #6

DC to DC Converters, Schmitt Triggers, Fourier Transforms. Due Monday, February 24th

DC to DC Converters

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



V1

(DC) $V_1 = 0.4 \cdot 20V + 0.6 \cdot (-0.7V) = 7.58V$

(AC) $V_1 = 20.7V_{pp}$

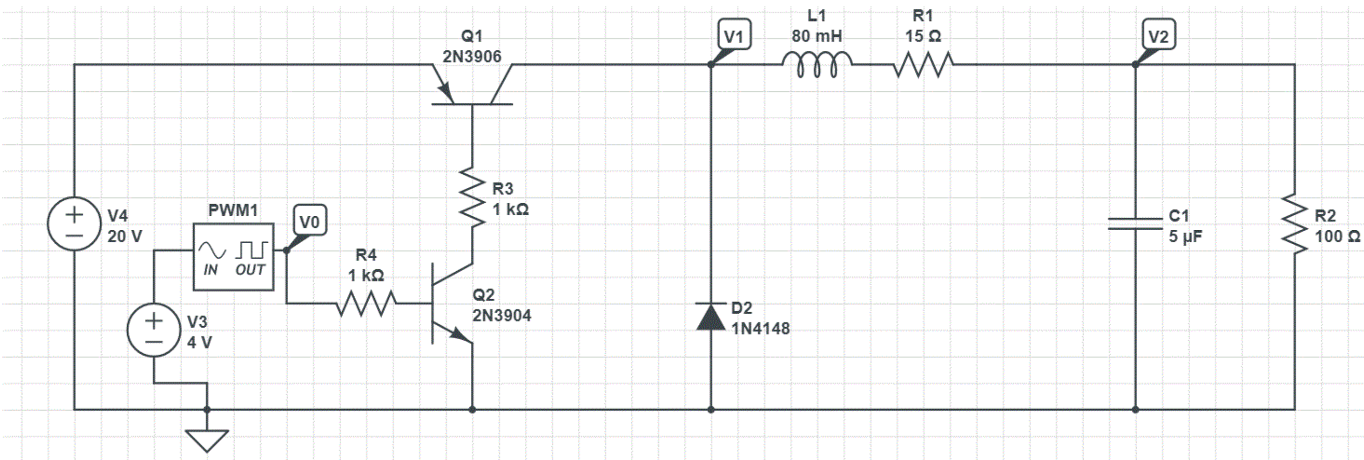
V2:

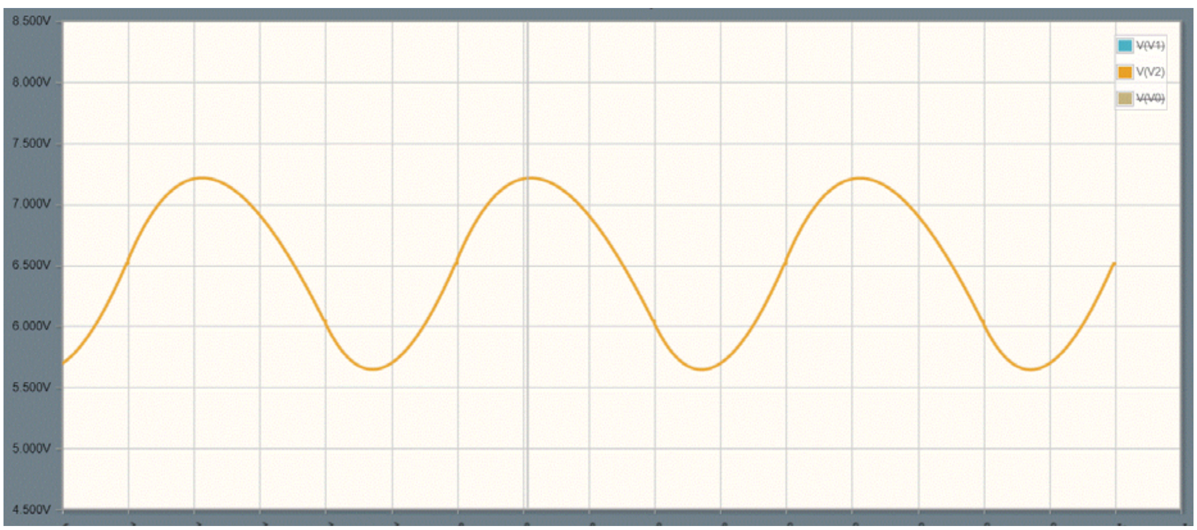
(DC) $V_2 = \left(\frac{100}{100+15}\right) 7.58V = 6.59V$

(AC) $V_2 = \left(\frac{9.19-j28.98}{(9.19-j28.98)+(15+j502.4)}\right) \cdot 20.7V_{pp}$

$V_2 = 1.32V_{pp}$

2) Simulate this circuit in CircuitLab and determine the voltages at V1 and V2 (both DC and AC)





	V1		V2	
	DC	AC	DC	AC
Calculated	7.58V	20.7Vpp	6.59 V	1.32 Vpp
Simluated	9.65V	20.7Vpp	6.285 V	1.569 Vpp

3) Change the duty cycle and C so that

- The DC voltage at V2 = 5.00V
- The ripple at V2 is 100mVpp

The voltage at V1 should be

$$V_2 = 5.00V = \left(\frac{100}{100+15}\right) V_1$$

$$V_1 = 5.75V$$

The duty cycle should then be

$$\alpha = \left(\frac{5.75+0.7}{20+0.7}\right) = 0.31159$$

Make the duty cycle 31.16%

For a 100mVpp ripple

Without C2, the ripple is

$$V_2 = \left(\frac{100}{100+(15+j502.4)}\right) \cdot 20.7V_{pp}$$

$$V_2 = 4.016V_{pp}$$

For a ripple of 100mVpp,

The ripple needs to be 40.16x smaller

Zc = 40.16 times smaller than 100 Ohms

$$\left|\frac{1}{j\omega C_2}\right| = \left(\frac{1}{40.16}\right) 100\Omega = 2.49\Omega$$

$$C_2 = 63.94\mu F$$

Schmitt Triggers

4) A thermistor has the following resistance vs. temperature relationship

$$R = 1000 \cdot \exp\left(\frac{3905}{T} - \frac{3905}{298}\right)\ \Omega$$

where T is the temperature in degrees Kelvin (Celsius + 273). Design a circuit which outputs

- +10V when T > 5C
- 0V when T < 0C
- No change for 0C < T < 5C

Assume a 2k resistor for a voltage divider.

At 5C (on)

- R = 2567 Ohms
- Va = 5.62V

At 0C (off)

- R = 3320 Ohms
- Va = 6.24V

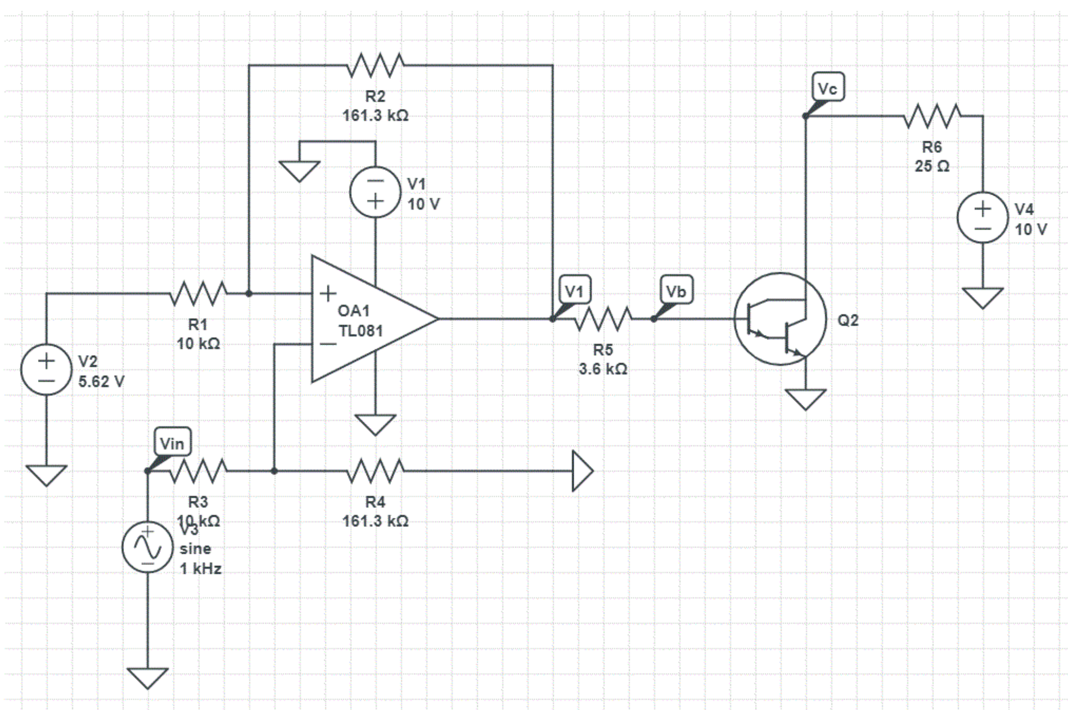
The output increases as Va decreases. Connect to the minus input.

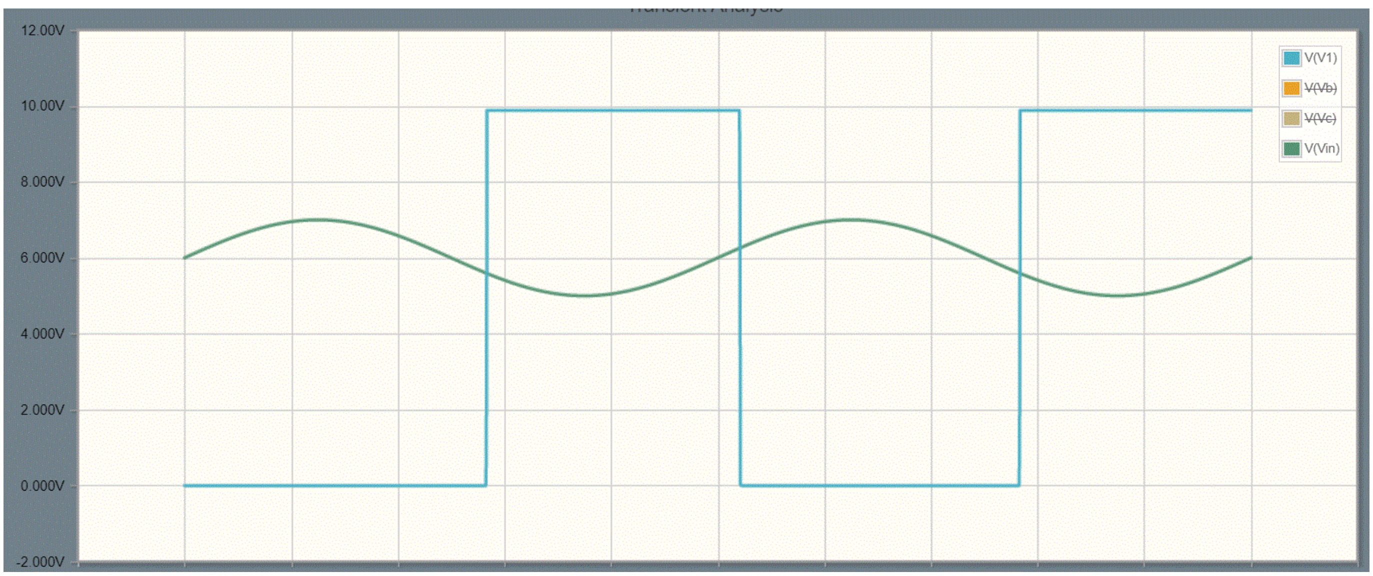
When the output is 0V, you switch at 5.62V. Make the offset 5.62V.

The gain is

$$gain = \left(\frac{\text{change in output}}{\text{change in input}}\right) = \left(\frac{10V - 0V}{6.24V - 5.62V}\right) = 16.13$$

Pick the resistors to be in a 16.13 : 1 ratio





Checking in simulation, V1 turns on and off at

	Calculated	Simulated
On Voltage	5.62V	5.597 V
Off Voltage	6.24V	6.246 V

5) Design a circuit which turns on and off a DC motor based upon temperature

- The motor turns on when T > 5C
- The motor turns off when T < 0C
- No change for 0C < T < 5C

Assume the motor draws 400mA @ 10V when on.

Use the previous circuit and add a transistor as a switch. To make sure the transistor saturates

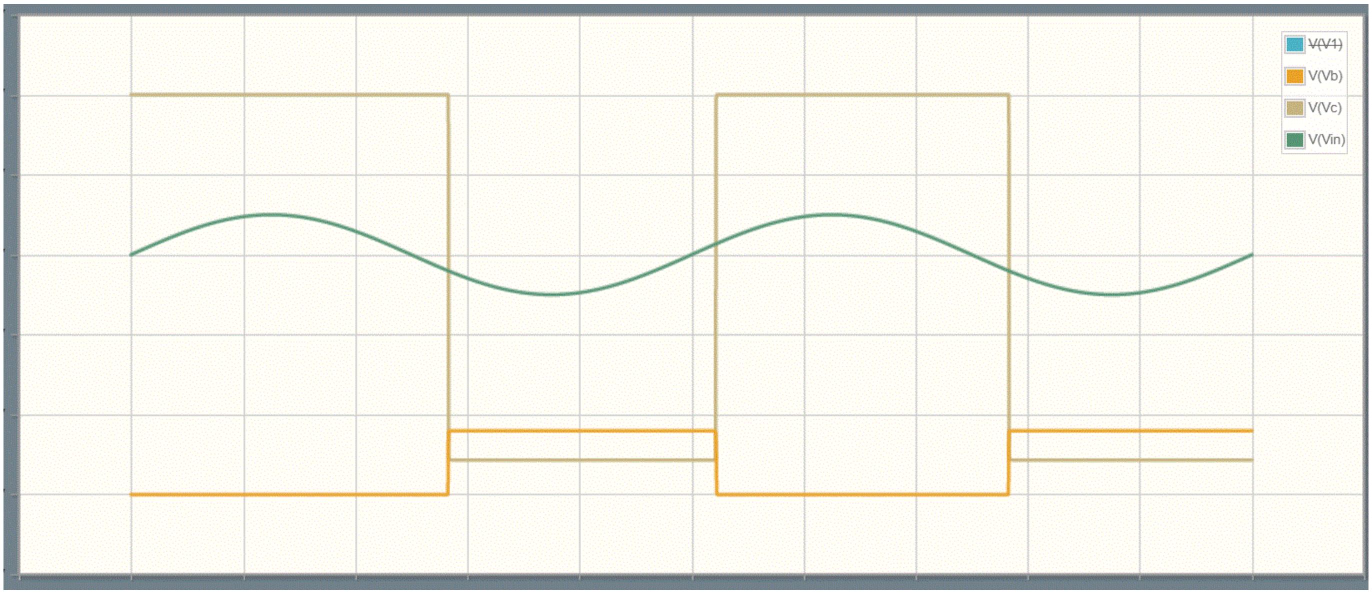
$$\beta I_b > I_c$$

$$I_b > \frac{I_c}{\beta} = \frac{400mA}{1000} = 400\mu A$$

Let Ib = 1mA

$$R_b = \left(\frac{10V - 1.4V}{1mA}\right) = 8.6k\Omega$$

6) (Lab): Build the circuit you designed for problem #5.



		Calculated	Simulated
Motor On	Vb	1.40 V	1.5940 V
	Vc	0.90 V	0.8637 V
Motor Off	Vb	0V	432uV
	Vc	10V	10.00 V

Fourier Transforms

The voltage V1 in problem #1 is a 40% duty cycle square wave

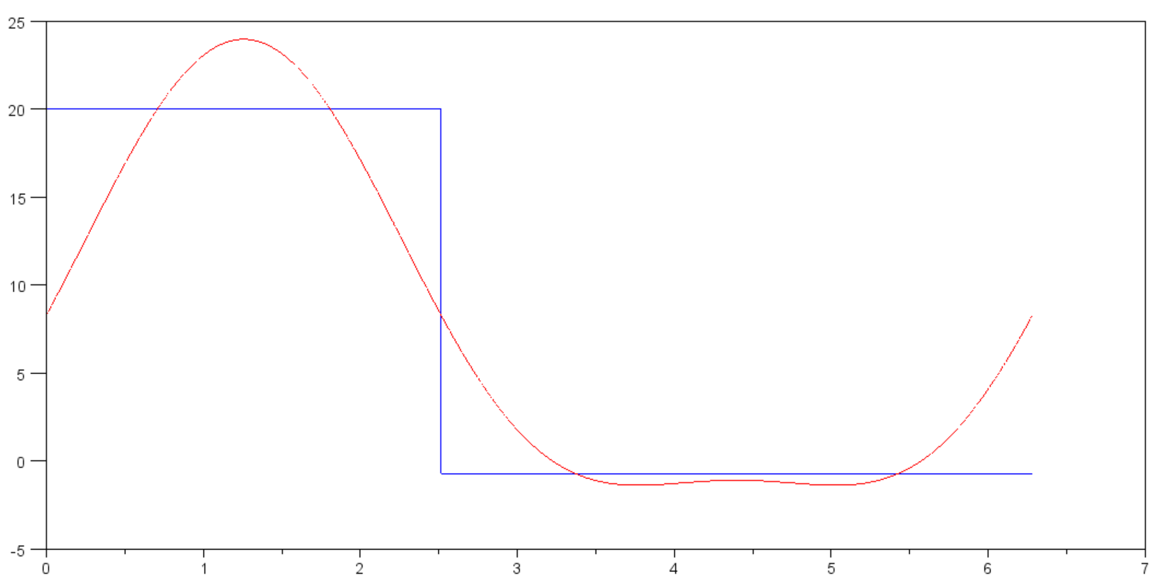
$$V_1(t) = V_1(t + 1ms)$$ *V1 is periodic in 1ms - i.e. it's a 1kHz square wave*

$$V_1(t) = \begin{cases} +20V & 0 < t < 400\mu s \\ -0.7V & 400\mu s < t < 1000\mu s \end{cases}$$

7) Determine the first five terms for the Fourier transform for V1(t)

$$V_1(t) = a_0 + a_1\cos(\omega_0 t) + b_1\sin(\omega_0 t) + a_2\cos(2\omega_0 t) + b_2\sin(2\omega_0 t)$$

```
t = [0:0.0001:1]';
V1 = 20*(t<0.4) - 0.7*(t>=0.4);
t = t * 2*pi;

a0 = mean(V1)

 a0  =  7.5791721

a1 = 2*mean(V1 .* exp(-j*t))

 a1  =    3.8761426 - 11.917231i

a2 = 2*mean(V1 .* exp(-j*2*t))

 a2  = -3.1316587 - 2.2781891i

plot(t,V1,'b',t,real(a0 + a1*exp(j*t) + a2*exp(j*2*t)),'r');
```



8) Determine V2(t) at each frequency

- DC
- 1kHz
- 2kHz

```
C = 5e-6;
L = 0.08;

w = 0;
Zrc = 1/(j*w*C + 1/100)

 Zrc  =  100.

y0 = Zrc / (Zrc + 15 + j*w*L) * a0
```

y0 = 6.5905844

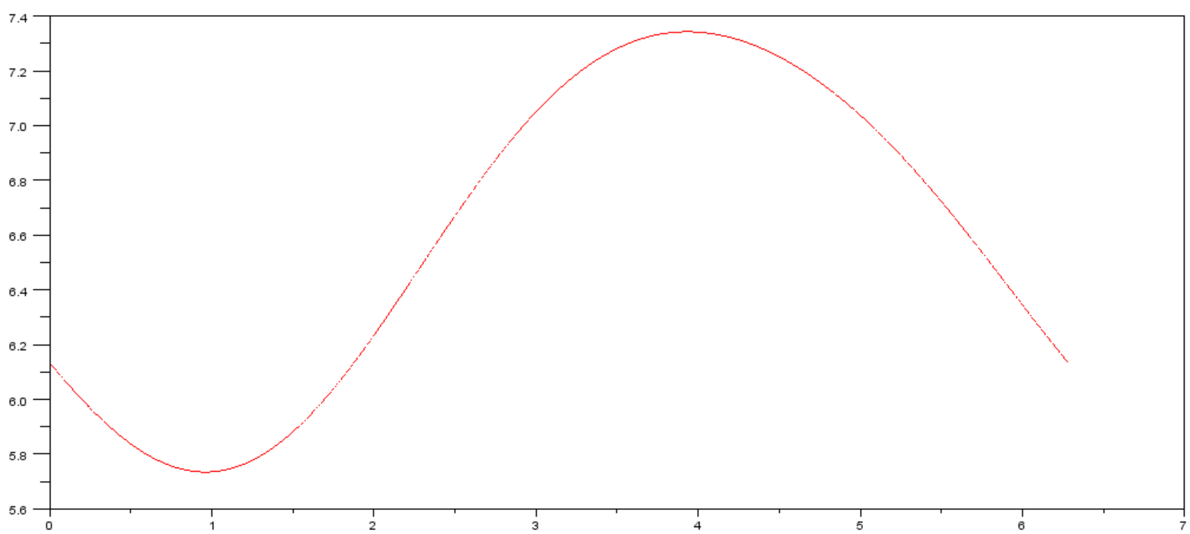
```
w = 2*pi*1000;
Zrc = 1/(j*w*C + 1/100)

 Zrc  =  9.1999668 - 28.902548i

y1 = Zrc / (Zrc + 15 + j*w*L) * a1
```

y1 =-0.4998887 + 0.6262359i

```
w = 2*pi*2000;
Zrc = 1/(j*w*C + 1/100)

 Zrc  = 2.4704523 - 15.52231i

y2 = Zrc / (Zrc + 15 + j*w*L) * a2
```

y2 = 0.0426440 + 0.0442968i

```
plot(t,real(y0 + y1*exp(j*t) + y2*exp(j*2*t)),'r');
```



9) How do your answers for problem #1 and problem #8 compare?

	Problem #1 calcualted	Problem #2 simulated	Problem #8
V2(DC)	6.59 V	6.428 V	6.590 V
V2 1kHz term	1.32 Vpp	1.569 V	1.602 Vpp
V2 2kHz term	0 Vpp		0.123 Vpp

note: The 1kHz term is V1pp for problem #1. This is related to problem #8 as

$$2|a_1 - jb_1| = V_{pp} \qquad \text{at 1kHz}$$

The 2kHz term is V1pp for problem #1 is 0Vpp (we ignored it). This is related to problem #8 as

$$2|a_2 - jb_2| = V_{pp} \qquad \text{at 2kHz}$$

```
V2 = real(y0 + y1*exp(j*t) + y2*exp(j*2*t));

mean(V2)
 ans  =    6.5905387

max(V2) - min(V2)
 ans  =   1.6079241
```