ECE 320 - Homework #6

H-Bridge, DC to AC, SCR. Due Monday, October 5th

1) Design an H-Bridge to drive an 8-Ohms speaker forward and back.

Input:

- 5VDC, capable of driving 3A (i.e. DC power supply on lab bench)
- 0V / 5V TTL signals capable of driving 25mA (i.e. switches on the CADET boards)

Output: 8 Ohm Speaker

Relationship: You should be able to apply +5V, -5V, or 0V across the speaker by adjusting the switches

Note: The transistors in lab are $0.05 each (vs. $1.00 for Zetex)

- 3904: NPN, $\beta > 100$, Icmax = 200mA
- 3906: PNP, $\beta > 100$, Icmax = 200mA

Limit the current to 200mA by adding a 0.5W, 20 Ohm resistor in series with the speaker

Calculations:

NPN

$$I_c = \frac{5V}{25\Omega} = 200mA$$

$$\beta I_b > I_c = 200mA$$

$$I_b > 2mA$$

$$R_b < \frac{5V - 0.7V}{2mA} = 2150\Omega$$

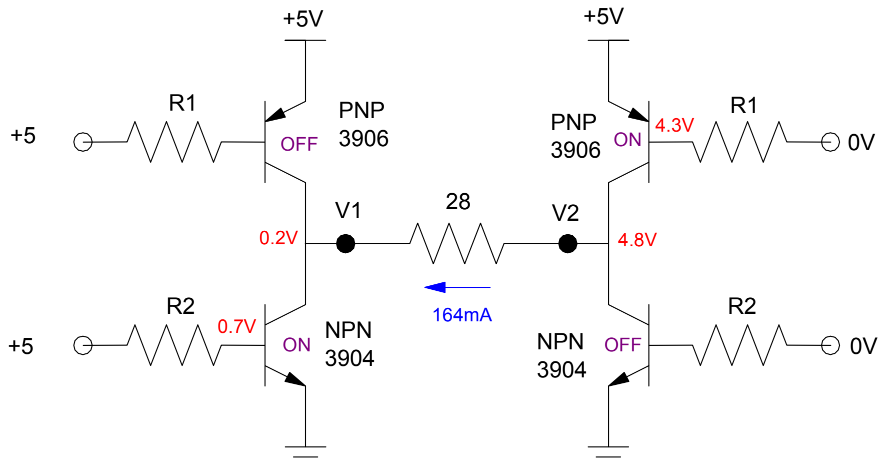
Let Rb = 1k

PNP: (same as above except)

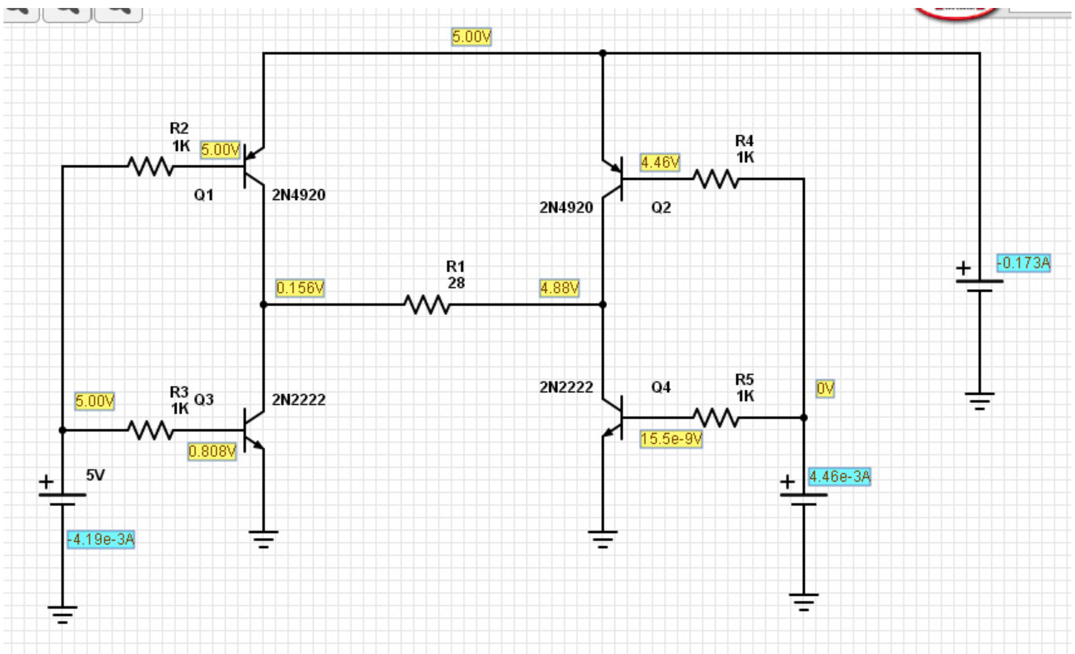
$$R_b < \frac{4.3V - 0V}{2mA} = 2150\Omega$$

Let Rb = 1k

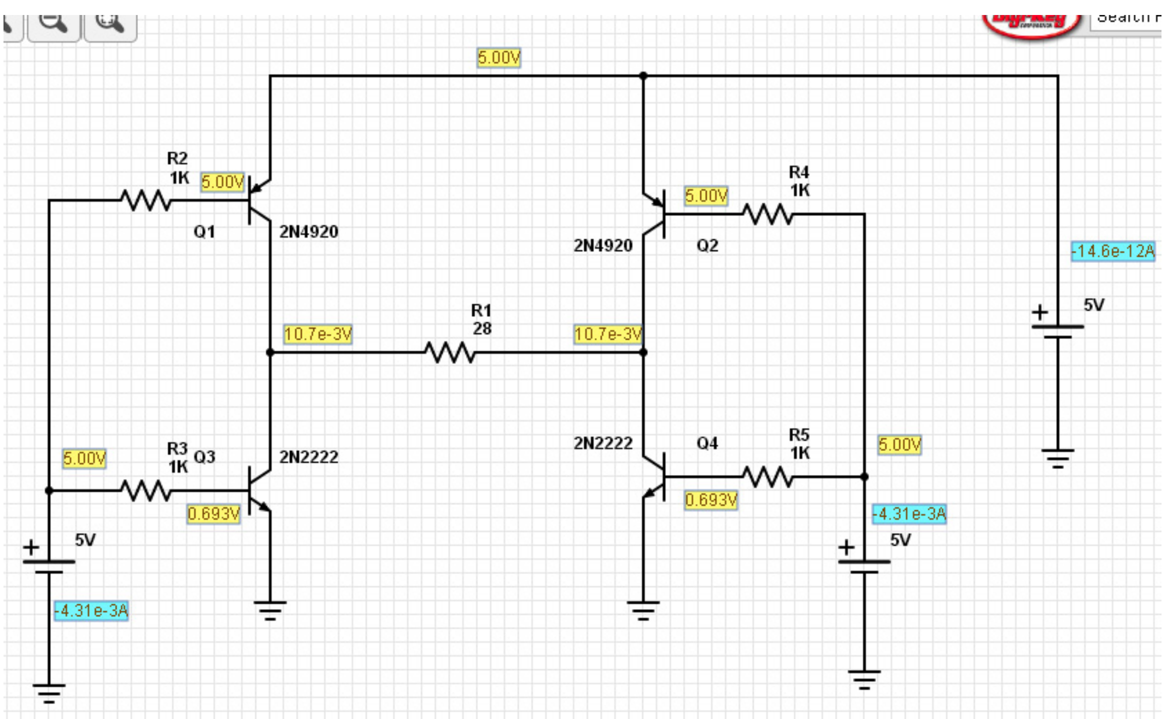
The voltages and currents expected are then as follows:


+5V
+5V
R1
PNP
3906
+5
OFF
PNP
3906
ON
4.3V
R1
0V
V1
28
V2
0.2V
4.8V
164mA
R2
0.7V
+5
ON
NPN
3904
NPN
3904
OFF
R2
0V

2) Check youd design in PartSim (three tests: 0V, 5V, -5V)



Simulated Votlages for +5 (flip left for -5V)

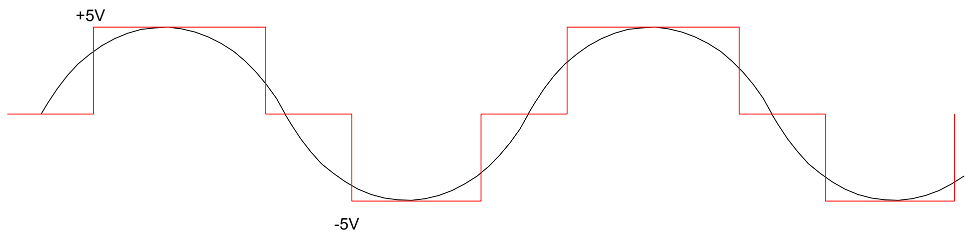


Simulated 0V across speaker

3) Assume the H-bridge is to be used to drive an AC motor (BLDC, AC Synchronous, AC Induction motor).

3a) Explain how you convert a DC power supply into an AC voltage

```
Use an H-Bridge as in problem #1.  Switch between +5V and -5V to create an
approximate sine wave
```



3b) Explain how you adjust the speed of the AC motor

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Vary the frequency of the sine wave.  Frequency = speed
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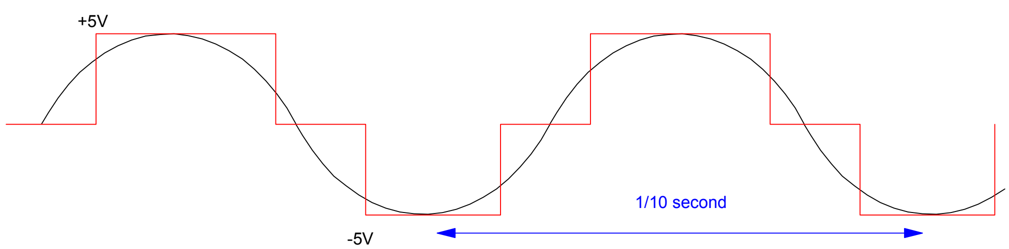
3c) Specify the AC waveform you would send to the motor at 10Hz



3d) Calculate the efficiency of your DC to AC converter (MATLAB helps here)

First, input the square wave, Y(t)

```
-->t = [0:0.001:1]';
-->Y = 5*(t>1/6).*(t<3/6) -5*(t>4/6);
-->plot(t,Y)
```

The DC term is zero:

```
-->DC = mean(Y)

  - 0.0049950
```

Compute the 1st harmonic

```
-->w0 = 2*%pi;

-->a1 = sum(sin(w0*t) .* Y) / sum( (sin(w0*t)).^2 )

    4.7775263

-->b1 = sum(cos(w0*t) .* Y) / sum( (cos(w0*t)).^2 )

  - 2.7494819
```

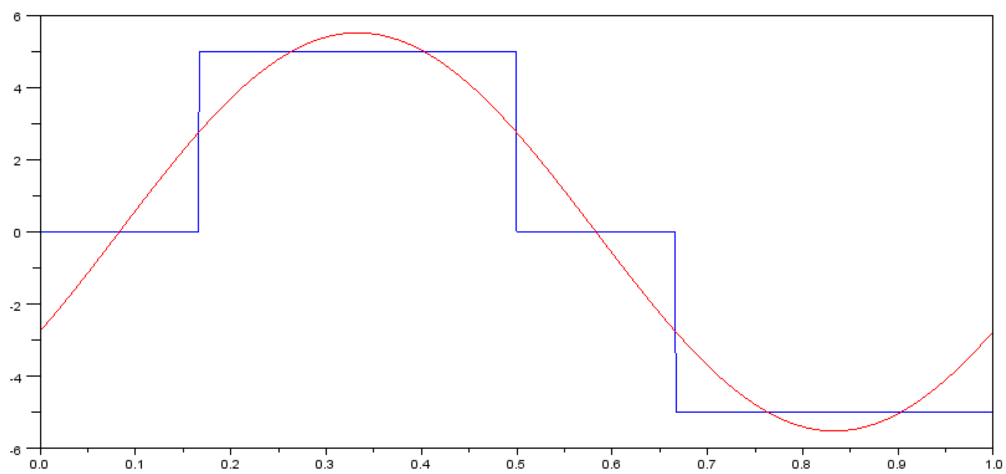
meaning

$$y(t) = 0 + 4.777\sin(\omega_0 t) - 2.749\cos(\omega_0 t) + \ldots$$

The energy in the total signal vs. the 1st harmonic is:

```
-->y1 = a1*sin(w0*t) + b1*cos(w0*t);
-->plot(t,y1,'r')

-->Pin = mean(Y.^2)

    16.658342

-->Pout = mean(y1 .^ 2)

    15.184579

-->eff = Pout / Pin

    0.9115301
```

The efficiency DC to AC conversion is 91%



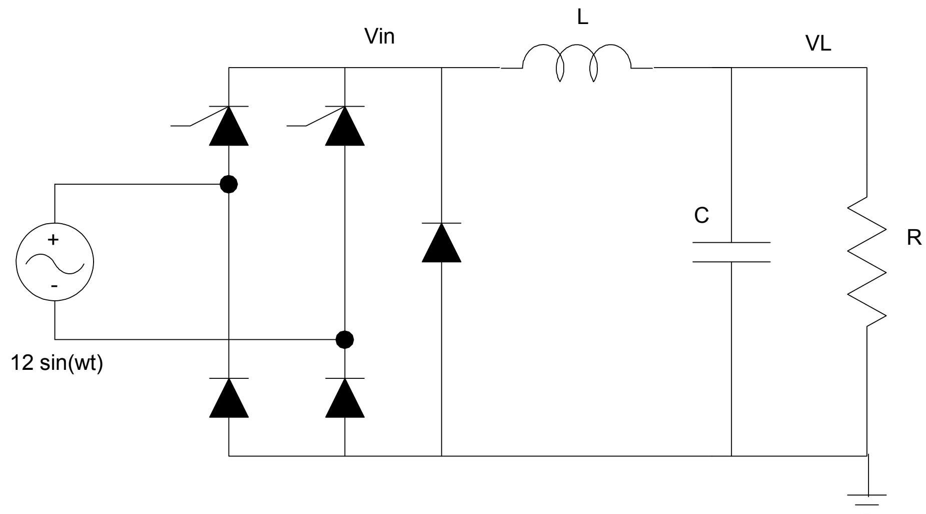
Waveform of the signal produced by the H-bridge (blue) and the first term of its Fourier transform

4) Design a full-wave AC to DC converter using diodes and SCRs.

Input: 12V peak, 60Hz, AC signal capable of driving 1A

Output: 4.9V .. 5.1V DC signal, capable of driving 100mA

Tolerance: Output ripple < 200mV @ 100mA



Assume the turn-on time is 'a'. If the AC signal is 10.6V peak and the average is to be 5V, then

$$5 = \frac{1}{\pi}\int_a^\pi 10.6\sin(t)dt$$

$$0.4717 = \frac{1}{\pi}\int_a^\pi \sin(t)dt$$

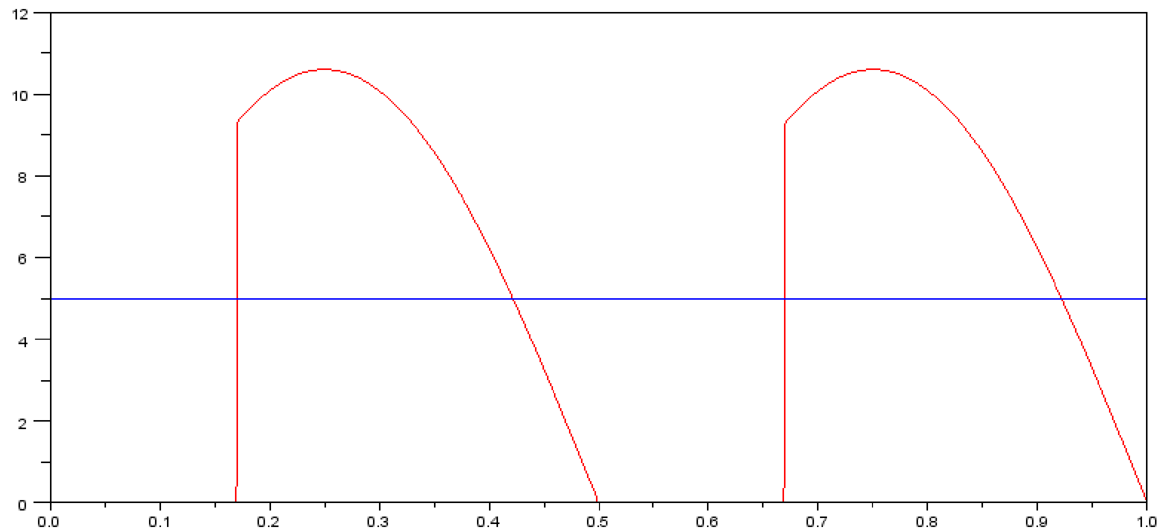
$$1.4819 = -\cos(t)|_a^\pi$$

$$1.4819 = 1 + \cos(a)$$

$$a = 61.19^0$$

Checking in MATLAB:

```
-->t = [0:0.001:1]';
-->w0 = 2*%pi;
-->y = abs(10.6*sin(w0*t));

-->y1 = y;
-->y1(1:170) = 0;
-->y1(500:670) = 0;
-->mean(y1)

    4.994485

-->plot(t,y1);
```



Finding R:

For 100mA at the load

$$R = \frac{5V}{100mA} = 50\Omega$$

To keep the ripple less than 200mVpp

$$V_{in} \approx 5 + 10.6V_{pp}\sin(2\omega_0 t)$$

The DC term goes to the load unchanged (L and C have no effect at DC)

The AC term has an input of 10.6Vpp @ 120Hz

The output by voltage division is

$$V_o = \left(\frac{R||\frac{1}{j\omega C}}{R||\frac{1}{j\omega C}+j\omega L}\right)10.6V_{pp}$$

If C = 0

$$0.2V_{pp} = \left(\frac{50\Omega}{50\Omega+j\omega L}\right)10.6V_{pp}$$

$$L = 3.51H$$

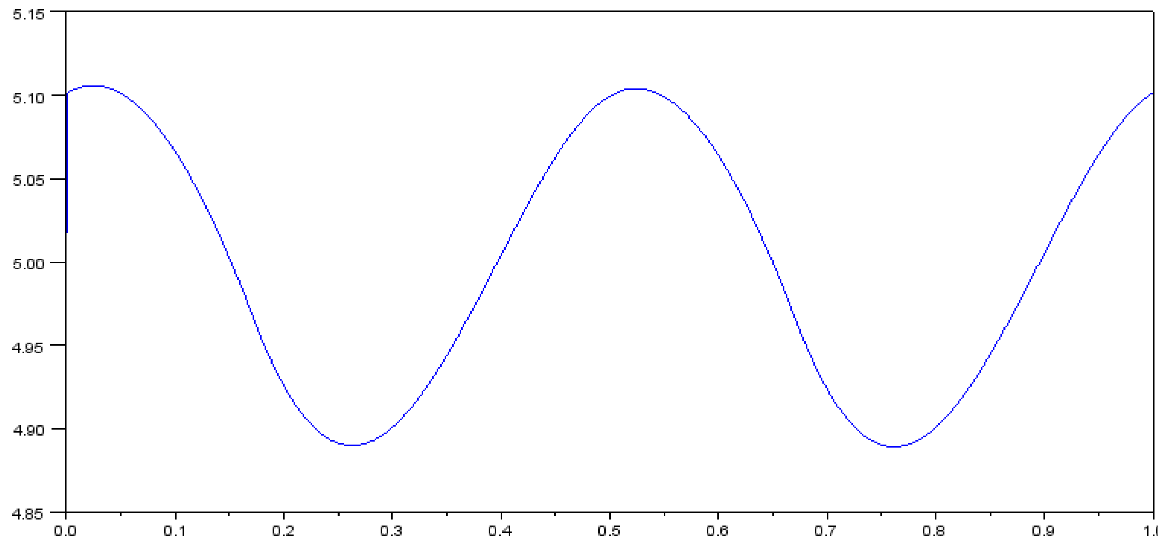
If L = 1H

C = 93uF

Checking: In MATLAB, using the code from before for Vin:

```
IL = 0.1;
Vc = 5;
```

```
L = 1;
C = 93e-6;
R = 50;

dt = 1/60 / 1000;


for n=1:1000

Vc = Vo(1000);

for i=1:1000

   dIL = (Vin(i) - Vc) / L;
   dVc = (IL - Vc/R) / C;

   IL = IL + dIL*dt;
   Vc = Vc + dVc*dt;

   Vo(i+1) = Vc;

   end

end

plot(t,Vo);
```



Computed Value of VL with Ideal Diodes after 166 Seconds. L = 1H, C = 93uF

Lab:

5) Build the H-bridge and verify your computations for problem 1.