ECE 320 - Homework #7

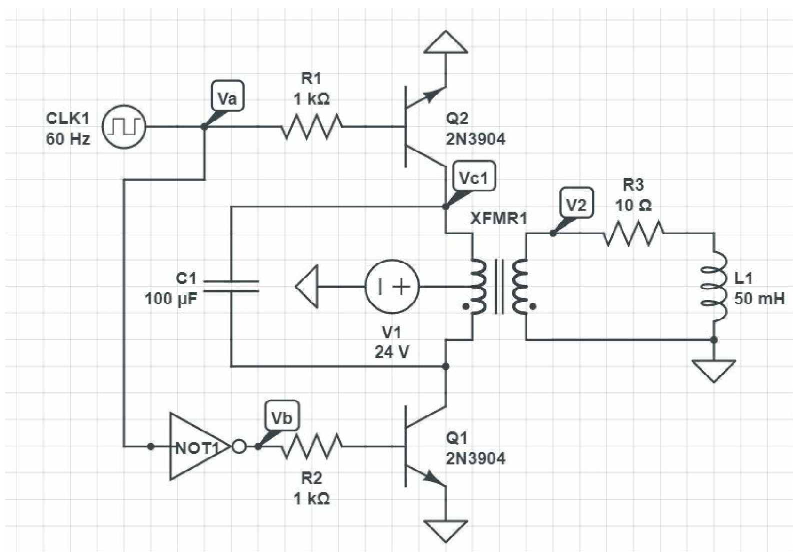
DC to AC, SCR, Boolean Logic. Due Monday, February 27th

DC to AC

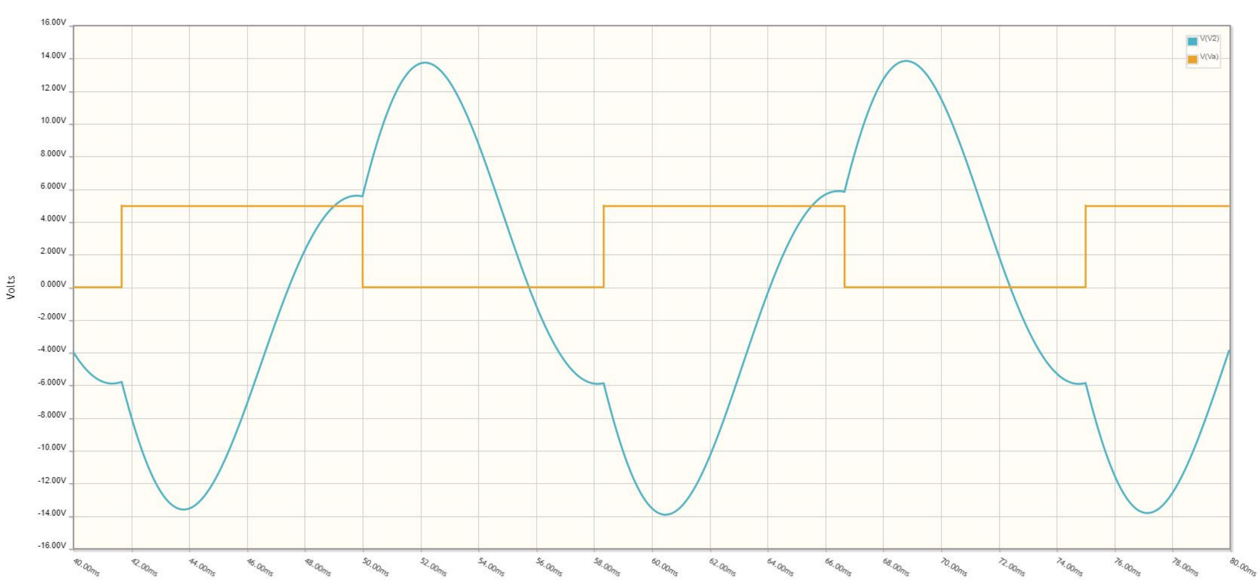
1) Let C1 = 100uF, L1 = 50mH

- Va = 0V / 5V square wave, 60Hz, 0 degree time delay
- Vb = 0V / 5V square wave, 60Hz, 180 degree time delay
- C1 = 10uF

Determine using CircuitLab the voltage V2 (i.e. the votlage across a DC motor, modeled as a 10 Ohm & 100mH load)

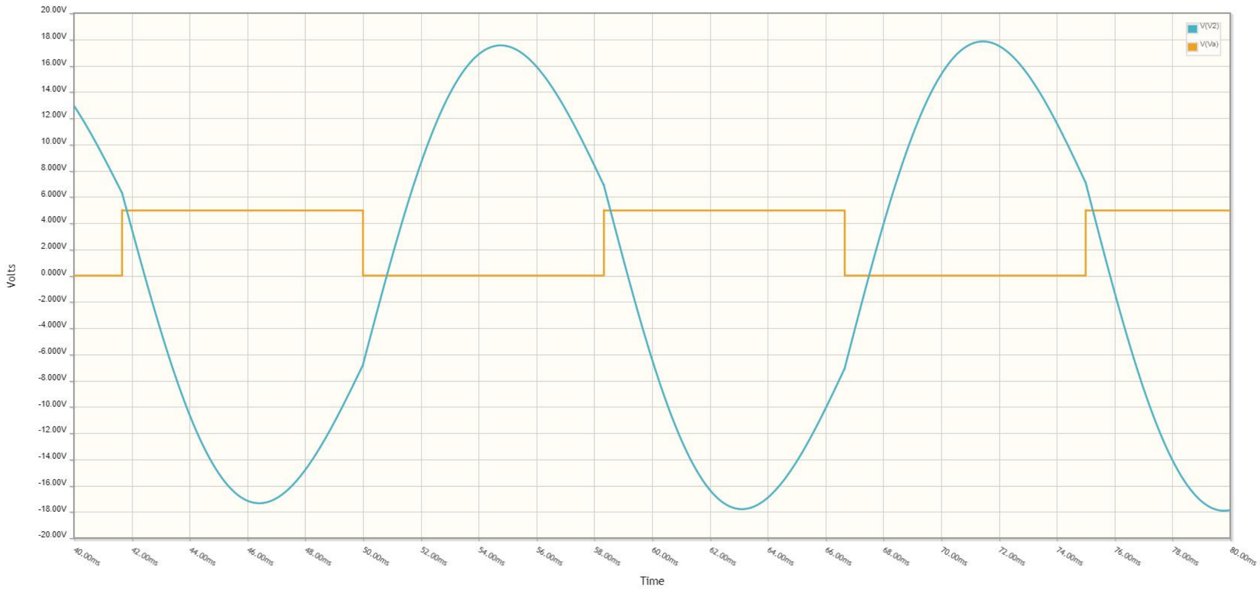


DC to AC Converter (problem 1 & 2)



2) Adjust C1 so that V2 looks closer to a sine wave

Increase C1 to 200uF



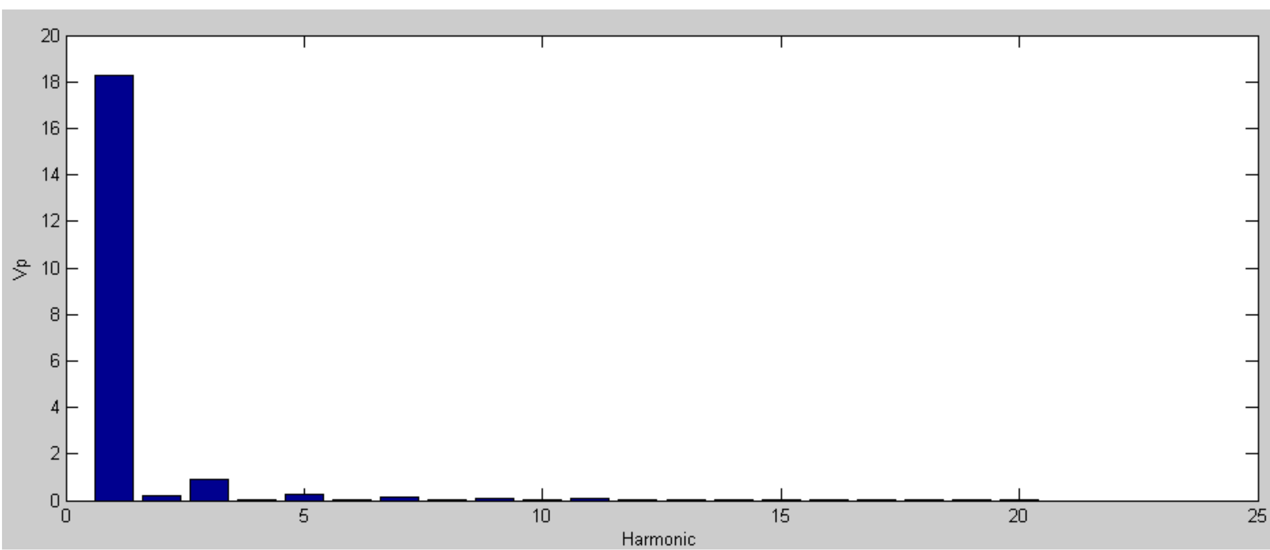
3) With the adjusted C1, determine the frequency content of V2 out to 300Hz

- From, CircuitLab, run a time-domain simulation
- Download the voltage at V2 to a CVS file (Export Plot CVS)
- Copy the data in to Matlab and determine the Fourier transform of V2 out to the 5th harmonic (300Hz)

What percentage of the energy is in the 1st harmonic (60Hz)?

```
>> t = DATA(:,1);
>> V = DATA(:,2);
>> plot(t,V)
>> size(t)

ans =        2035           1

>> X = V(1605:2035);
>> C = zeros(20,1);
>> for n=1:20
   C(n) = 2*mean(X .* exp(-j*n*t));
   end
>> bar(abs(C))
>> C2 = abs(C) .^ 2;
>> C2(1) / sum(C2)

ans =    0.9971
```

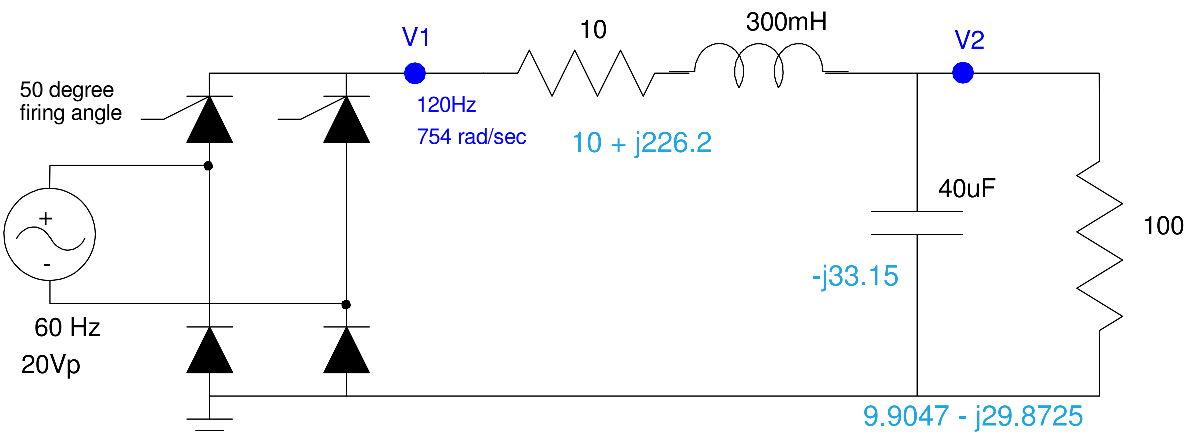
99.71% of the energy in this signal is in the 1st harmonic



SCR

4) Assume a firing angle of 50 degrees. Determine the voltage at V1 and V2 (both DC and AC).

- Assume V1 has two terms: a DC term and an AC (120Hz) term
- The DC term matches the actual DC voltage at V1
- The AC term matches the peak-to-peak voltage at V1.



SCR: Problem 4 - 6

DC Voltage:

$$V_1(DC) \approx \frac{2}{\pi} V_p \cos\theta - 1.4$$

$$V_1(DC) = \frac{2}{\pi} \cdot 20V \cdot \cos(50^0) - 1.4$$

$$V_1(DC) = 6.7842V$$

$$V_2(DC) = \left(\frac{100}{100+10}\right) V_1(DC) = 6.1675V$$

AC Voltage

$$V_1(AC) = 20V \cdot (1 + \sin(50^0))$$

$$V_1(AC) = 35.3209 V_{pp}$$

$$V_2(AC) = \left(\frac{(9.9047 - j29.8725)}{(9.9047 - j29.8725) + (10 + j226.2)}\right) \cdot 35.3209 V_{pp}$$

$$|V_2(AC)| = 5.6331 V_{pp}$$

5) Repeat problem #4 using Fourier transforms (more accurate analysis of V1 and V2)

- Find the DC and 1st-harmonic (60Hz) terms for V1 using Fourier transforms
- Determine V2 based upon these two terms

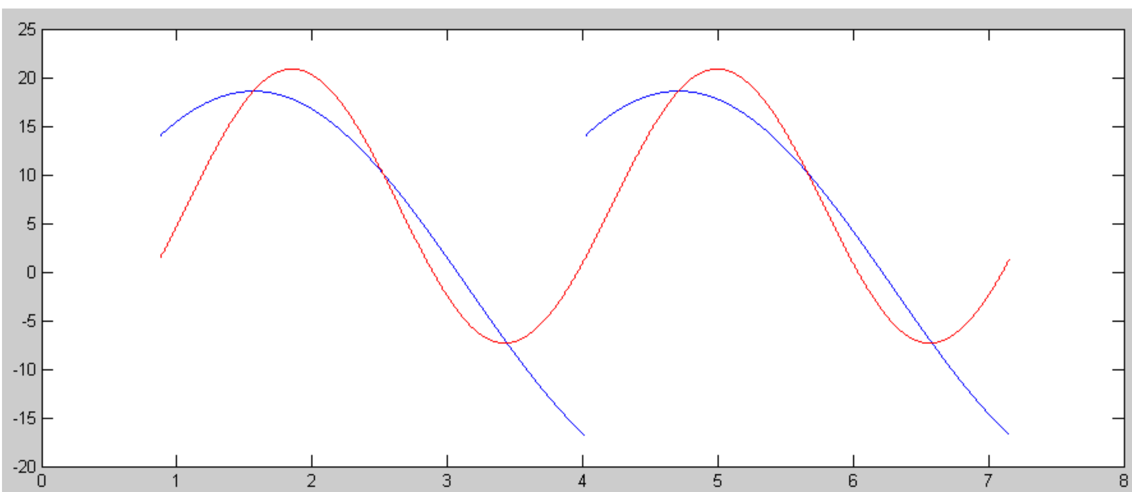
DC Term:

```
>> t = [0:0.0001:1]' * pi  +  (50/180)*pi;
>> V1 = 20*sin(t) - 1.4;
>> DC = mean(V1)

DC =    6.7834

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

AC = -11.8585 + 7.6310i

>> 2*abs(AC)

ans =   28.2033
```

The 1st harmonic is actually 28.2Vpp (vs. 35.32Vpp). A better estimate of the AC votlage at V2 would be

$$V_2(AC) = \left(\frac{(9.9047 - j29.8725)}{(9.9047 - j29.8725) + (10 + j226.2)}\right) \cdot 28.2033 V_{pp}$$

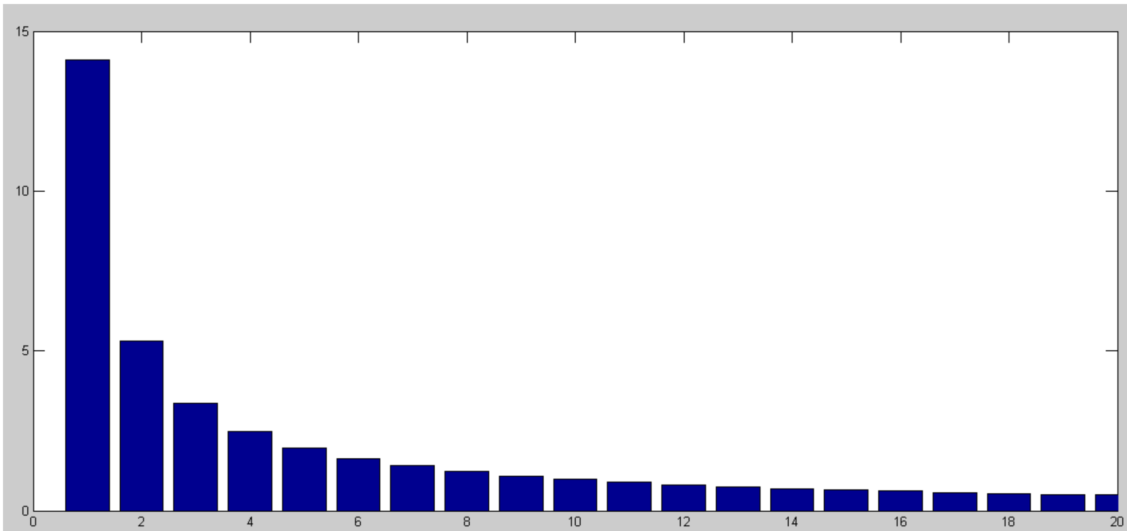
$$V_2(AC) = 4.4980 V_{pp}$$



Signal at V1 (blue) and it's Fourier approximation inluding the DC and 120Hz term (only)

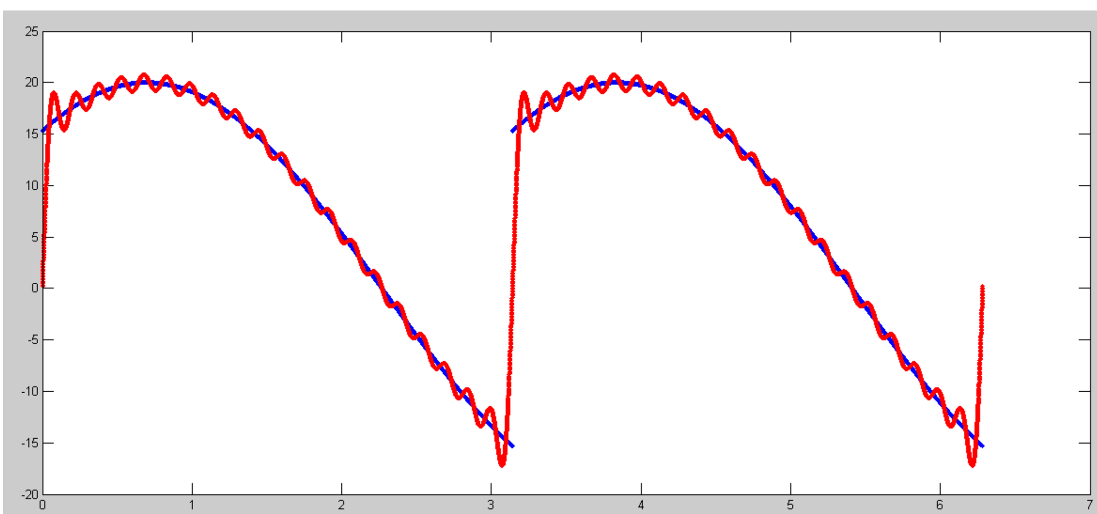
Just for fun, go out to the 20th harmonic (not asked for)

```
>> C = zeros(20,1);
>> for n=1:20
   C(n) = 2*mean(V1 .* exp(-j*2*n*t));
   end
>> bar(abs(C))
>> DC = mean(V1)
```



Magnitude of Each Harmonics (n = 1..20)

```
>> y = DC;
>> for n=1:20
y = y + real(C(n))*cos(2*n*t) - imag(C(n))*sin(2*n*t);
end
plot(t,V1,t,y)
```



Fouier Series Approximation taken out to 20 terms

6) Change this circuit so that

- The voltge at V2 is 9.00V (DC)
- With a ripple of 1.00Vpp

For the DC votlage to be 9.00V

$$V_2(DC) = \left(\frac{100}{100+10}\right) V_1(DC)$$

$$V_1(DC) = 9.90V$$

$$9.90V = \frac{2}{\pi} \cdot 20V \cdot \cos(\theta) - 1.4$$

$$\theta = 27.4392^0$$

AC:

$$V_1(AC) \approx 20V \cdot (1 + \sin(\theta)) = 29.2162V_{pp}$$

More accurate - use the Fourier series:

```
>> t = [0:0.0001:1]' * pi  +  (27.4392/180)*pi;
>> V1 = 20*sin(t) - 1.4;
>> DC = mean(V1)

DC =    9.8989

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

AC = -10.7317 + 1.6612i

>> V1pp = 2*abs(AC)

V1pp =   21.7191
```

Now find C2. Assuming C = 02, the ripple at V2 will be

$$V_2 = \left(\frac{100}{100+(10+j226.2)}\right) \cdot 21.719V_{pp}$$

$$|V_2| = 8.6348V_{pp}$$

Pick C2 to be 1/8.63 x 100 Ohms

$$\left|\frac{1}{j\omega C_2}\right| = \left(\frac{1V_{pp}}{8.6348V_{pp}}\right) 100\Omega = 11.581\Omega$$

$$C_2 = 114.5\mu F$$

Boolean Logic:

7) Design a circuit to implement Y using NAND gates

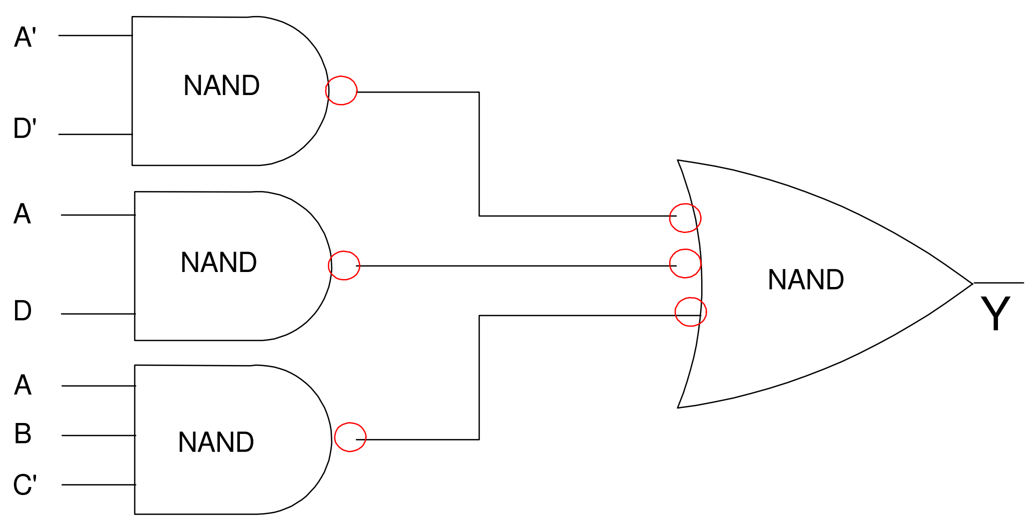
NAND gates: Circle the ones

Y(A,B,C,D)	CD: 00	01	11	10
AB: 00	1	0	0	x
01	1	0	x	1
11	1	x	1	0
10	0	1	x	0

$$Y = \overline{A}\overline{D} + AD + AB\overline{C}$$

Implement this with an/or gates

Add double negatives to make these NAND gates



8) Design a circuit to implement Y using NOR gates

- Circle the zeros

Y(A,B,C,D)

AB \ CD	00	01	11	10
00	1	0	0	x
01	1	0	x	1
11	1	x	1	0
10	0	1	x	0

$$\overline{Y} = \overline{A}D + AC\overline{D} + A\overline{B}\,\overline{D}$$

Use DeMorgan's law

$$Y = \left(A + \overline{D}\right)\left(\overline{A} + \overline{C} + D\right)\left(\overline{A} + B + D\right)$$

Implement using AND/OR gates. Add double negatives to make these NOR gates