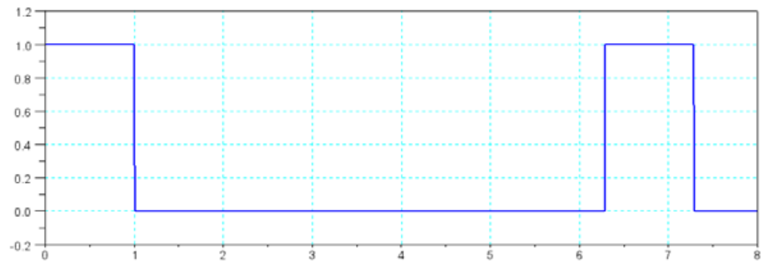
ECE 320 - Quiz #6 - Name ______________________

DC to AC Converters, Semiconductor Relays. October 12, 2017

1) A function which is periodic over the period of 2π is

$$f(t) = \begin{cases} 1 & 0 < t < 1 \\ 0 & 1 < t < 2\pi \end{cases}$$



Determine the DC value of f(t) and the 1st harmonic

DC term average(f(t))	$a_1 = 2 \cdot mean(\sin(t) \cdot f(t))$	$b_1 = 2 \cdot mean(\cos(t) \cdot f(t))$
0.1592	**0.1463**	**0.2678**

$$DC = \frac{1}{2\pi} \int_0^{2\pi} f(t) \cdot dt$$

$$DC = \frac{1}{2\pi} \int_0^{1} 1 \cdot dt$$

$$DC = \frac{1}{2\pi} = 0.1592$$

$$a_1 = \frac{2}{2\pi} \int_0^{2\pi} f(t) \cdot \sin(t) \cdot dt$$

$$a_1 = \frac{1}{\pi} \int_0^{1} \sin(t) \cdot dt$$

$$a_1 = \frac{1}{\pi}(-\cos(t))\Big|_0^1$$

$$a_1 = \left(\frac{1-\cos(1)}{\pi}\right)$$

$$a_1 = 0.1463$$

$$b_1 = \frac{2}{2\pi} \int_0^{2\pi} f(t) \cdot \cos(t) \cdot dt$$

$$b_1 = \frac{1}{\pi} \int_0^{1} \cos(t) \cdot dt$$

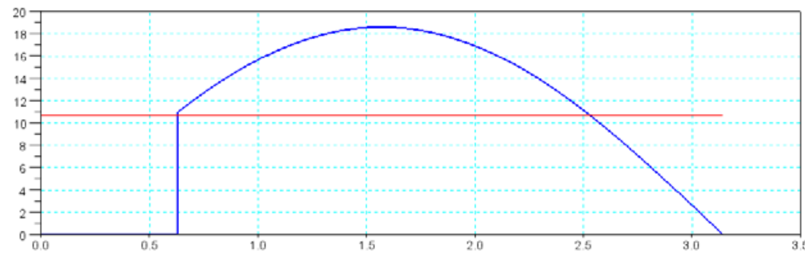
$$b_1 = \frac{1}{\pi}(\sin(t))\Big|_0^1$$

$$b_1 = \left(\frac{\sin(1)-\sin(0)}{\pi}\right)$$

$$b_1 = 0.2678$$

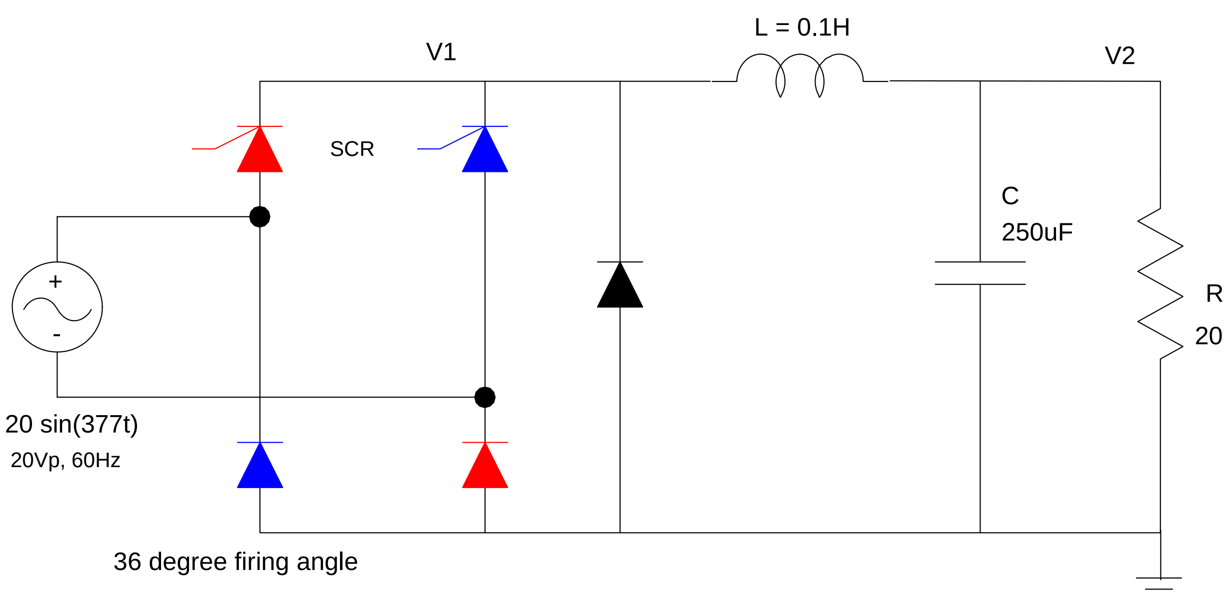
2) A 20Vp 60Hz sine wave goes through the following circuit. Assume a firing angle of 36 degrees. Determine the DC and AC signal at V1.

$$V_1(t) = \begin{cases} 0 & 0 < t < \frac{\pi}{5} \\ 18.6\sin(t) & \frac{\pi}{5} < t < \pi \end{cases}$$



DC value of V1 mean(V1)	AC value of V1 V1pp

10.71 V	**18.6 Vpp**
	`according to V1(t) given above`
	19.3 Vpp
	`if you include the -0.7V`



DC:

$$DC = \frac{1}{T}\int_0^T f(t)\cdot dt$$

$$DC = \frac{1}{\pi}\int_{\pi/5}^{\pi} 18.6\sin(t)\cdot dt$$

$$DC = \frac{18.6}{\pi}\cdot(-\cos(t))_{\pi/5}^{\pi}$$

$$DC = \left(\frac{18.6}{\pi}\right)\left(1+\cos\left(\frac{\pi}{5}\right)\right)$$

$$DC = 10.71V$$

AC:

max(V1) = 18.3V

min(V1) = 0V

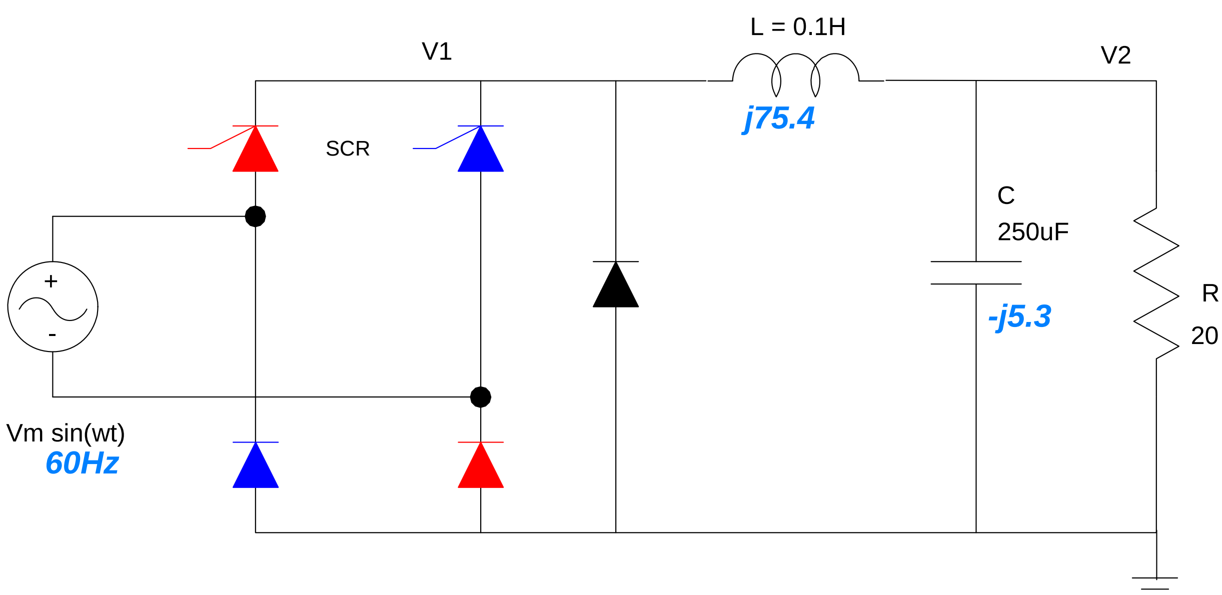
V1pp = 18.6V

3) Assume that V1 has the following parameters:

- DC value of V1 = 15.0 Volts
- AC value of V1 = 20.0Vpp

Determine the voltage at V2 (DC and AC)

V1 (DC) mean(V1)	V1 (AC)	V2 (DC) mean(V2)	V2 (AC)
15.0V	**20.0Vpp**	**15.0V** same as V1	**1.454 Vpp**



AC:

$$\omega = 2\pi f = 2\pi \cdot 120Hz = 754$$

$$j\omega L = j75.4\Omega$$

$$\frac{1}{j\omega C} = -j5.3\Omega$$

$$20 || -j5.3 = 5.12\angle -75^0$$

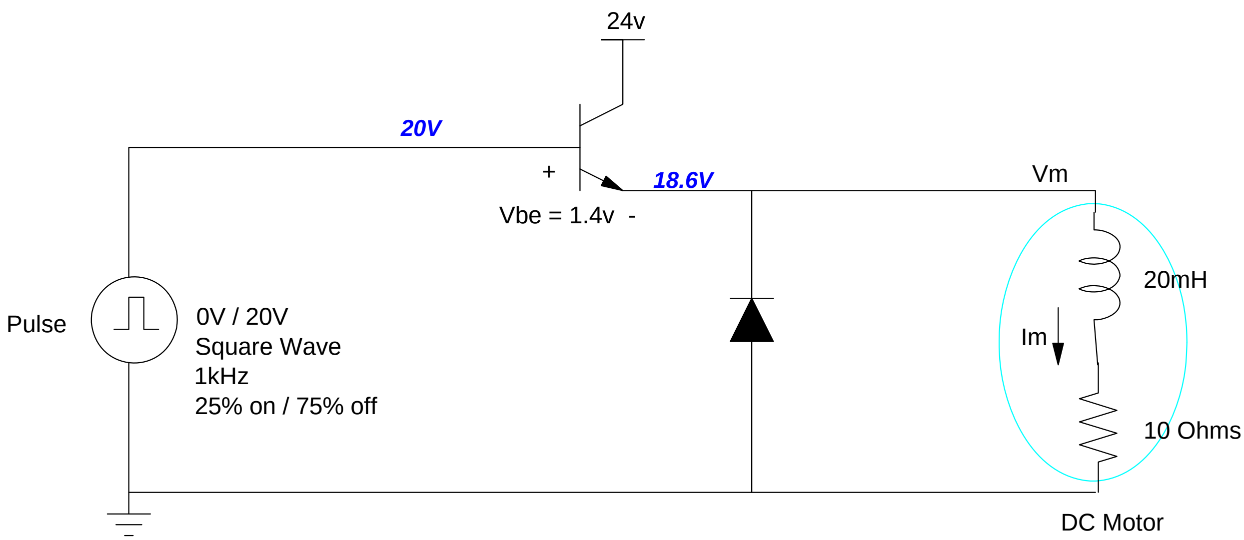
$$V_2 = \left(\frac{5.12\angle -75^0}{5.12\angle -75^0 + j75.4}\right) V_1$$

$$V_2 = (0..0727\angle -164^0) \cdot 20V_{pp}$$

$$V_2 = 1.454\angle -164^0 V_{pp}$$

4) Buck Converter. A 1kHz, 20V square wave with a duty cycle of 25% drives a stalled DC motor (figure below). Determine the DC and AC values of the voltage across the motor (Vm) and the current through the motor (Im)

Vm		Im	
DC	AC	DC	AC
4.125V	**19.3 Vpp**	**412.5mA**	**153mApp**



Vm:

$$DC = 0.25 \cdot 18.6V + 0.75 \cdot (-0.7V)$$

$$DC = 4.125V$$

AC:

max(Vm) = 18.6V

min(Vm) = -0.7V

Vm = 19.3Vpp

Im:

$$I_{DC} = \left(\frac{4.125V}{10+j0}\right)$$

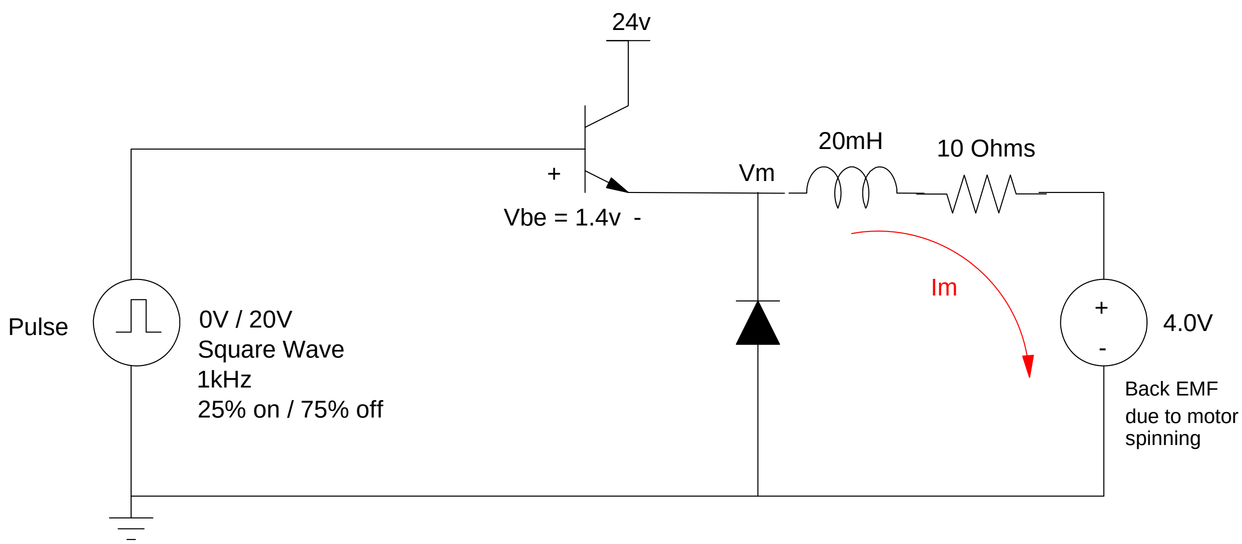
$$I_{DC} = 0.4125A$$

$$I_{AC} = \left(\frac{19.3V_{pp}}{10+j125.6}\right)$$

$$I_{AC} = (0.153\angle -85^0)A_{pp}$$

5) Buck Converter. A 1kHz, 20V square wave with a duty cycle of 25% drives a spinning DC motor (figure below). Assume the motor is generating 4.0V due to its rotation. Determine the DC and AC values of the voltage across the motor (Vm) and the current through the motor (Im))

Vm		Im	
DC	AC	DC	AC
4.125V `same as problem 4`	**19.3 Vpp** `same as problem 4`	**12.5mA**	**153mApp** `same as problem 4`



The 4V back EMF is a DC term - it only affects the DC current

$$I_{DC} = \left(\frac{4.125V - 4.00V}{10 + j0}\right) = 0.0125A$$

Bonus! According to Wikipedia, in 2014 the U.S. used 3.9 trillion kWh of electricity

$$E = 3.9 \cdot 10^{12} \text{ kWh}$$

How many 2MW wind turbines would you need to power the entire U.S. with wind energy, making our power grid carbon-free?

Assuming a 2MW wind turbine runs 75% of the time (typical in North Dakota), the energy it produces in one year is

$$E = 0.75 \cdot 2MW \cdot \left(\frac{\text{24h}}{\text{day}}\right) \cdot \left(\frac{\text{365 days}}{\text{year}}\right) = 13.14 \cdot 10^{9}\ Wh = 13.14MWh \quad \text{per wind turbine}$$

The number of wind turbines you would need is then

$$N = \left(\frac{3.9\cdot10^{12}\ kWh}{13.14MWh/turbine}\right) = 296,800 \text{ wind turbines}$$

The cost to build this many wind turbines (typical $1 / kW)

Cost = $593 billion

To put this in perspective, the Department of Defense budget in 2018 is $639 billion.

- For less than the cost of running the Department of Defense, we could build enough wind turbines to make the United States power grid completely carbon free.
- If the Department of Defense would use 10% of its budget to build wind turbines, it would take less than 10 years to completely replace every coal, oil, and nuclear power plant with wind turbines. Less if you take into account the wind turbines already being installed by public utilities.
- If you took the $80 billion increase in the DoD budget that congress approved and instead spent it elsewhere, you would have $1.1 trillion over 14 years. This is enough to
  - Build 300,000 wind turbines ($600 billion), and
  - Make college free for all public colleges and universities in the United Sates ($500 billion)

It's a matter or priorities: which is more important.