ECE 320 - Homework #7

Comparitors and Schmitt Triggers, DC to AC, SCR. Due Monday, October 14th

Comparitors and Schmitt Triggers

Assume a thermistor with a temperature - resistance relationship of

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

1) Design a circuit which outputs

- 5V when the temperature is less than 0C
- 0V when the temperature is more than 0C

Assume the load is 20mA or less (i.e. a LM833 op-amp can drive it directly)

This is a comparitor. At 0C: (273K)

R = 3320 Ohms

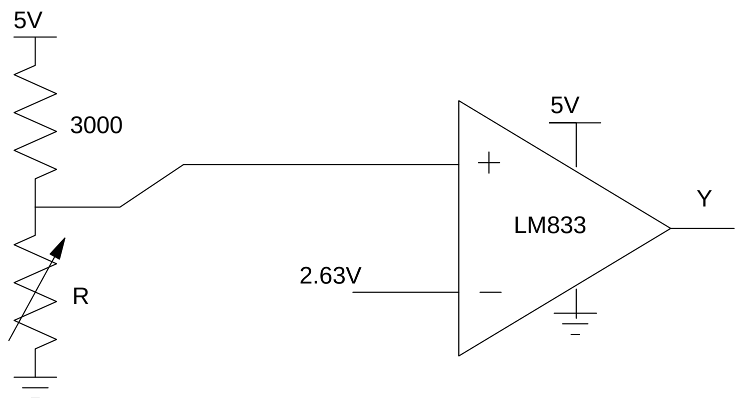
Assume a voltage divider with 3000 Ohms and 5V

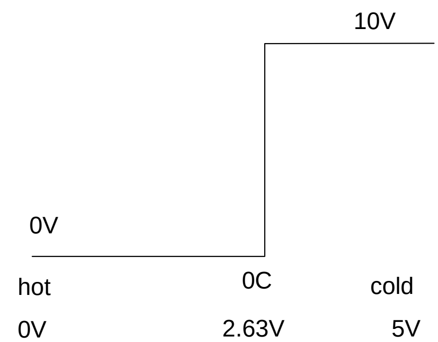
$$V = \left(\frac{3320}{3320+3000}\right)5V = 2.63V$$

Switch at 2.63V. When temperature goes to infinity

- R goes to zero
- V goes to zero
- Vout goes to zero (positive correlation)

Connect to the + input





2) Design a circuit which outputs

- 5V when the temperature is less than 0C
- 0V when the temperature is more than 5C
- No change for 0C < T < 5C

Assume the load is 20mA or less (i.e. a LM833 op-amp can drive it directly)

This is a Schmitt Trigger. Assume a voltage divider with 5V and 3000 Ohms

At 0C: (273K)

- R = 3320 Ohms
- Vin = 2.6266V
- Vout = 5V

At 5C: (278K)

- R = 2567 Ohms
- $V_{in} = \left(\frac{2567\Omega}{2567\Omega+3000\Omega}\right)5V = 2.3055V$
- Vout = 0V

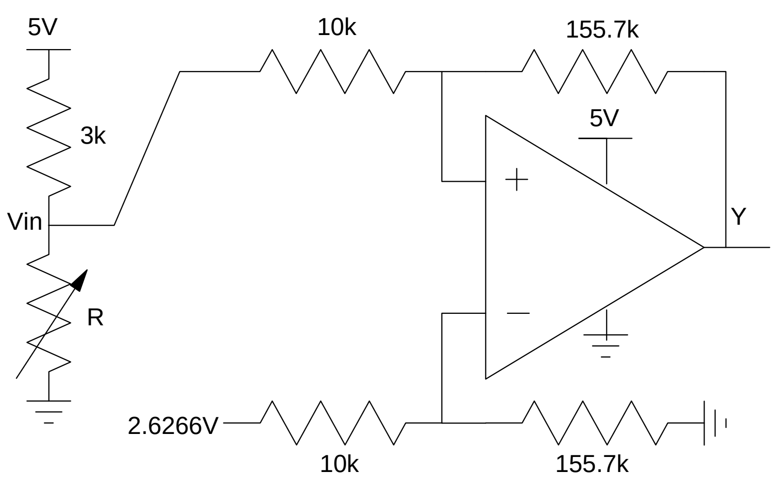
As the input gets smaller, the output gets smaller. Connect to the + input.

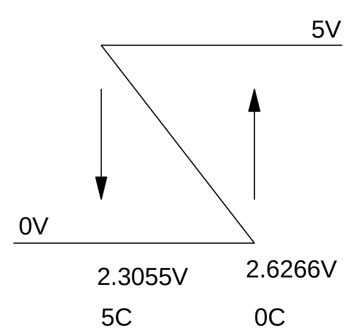
The gain required is

$$gain = \left(\frac{\text{change in output}}{\text{change in input}}\right) = \left(\frac{5V-0V}{2.6266V-2.3055V}\right) = 15.57$$

Let R1 = 10k, R2 = 155.7k

When the output is 0V, you switch at 2.6266V. The offset is 2.6266V





3) Design a circuit which

- Turns on a motor when the temperature is less than 0C
- Turns off a motor when the temperature is more than 5C
- No change for 0C < T < 5C

Assume the motor draws 200mA at 10V.

(hint: use problem #6 along with a transistor switch)

Add a transistor switch. Assume a TIP112 transistor.

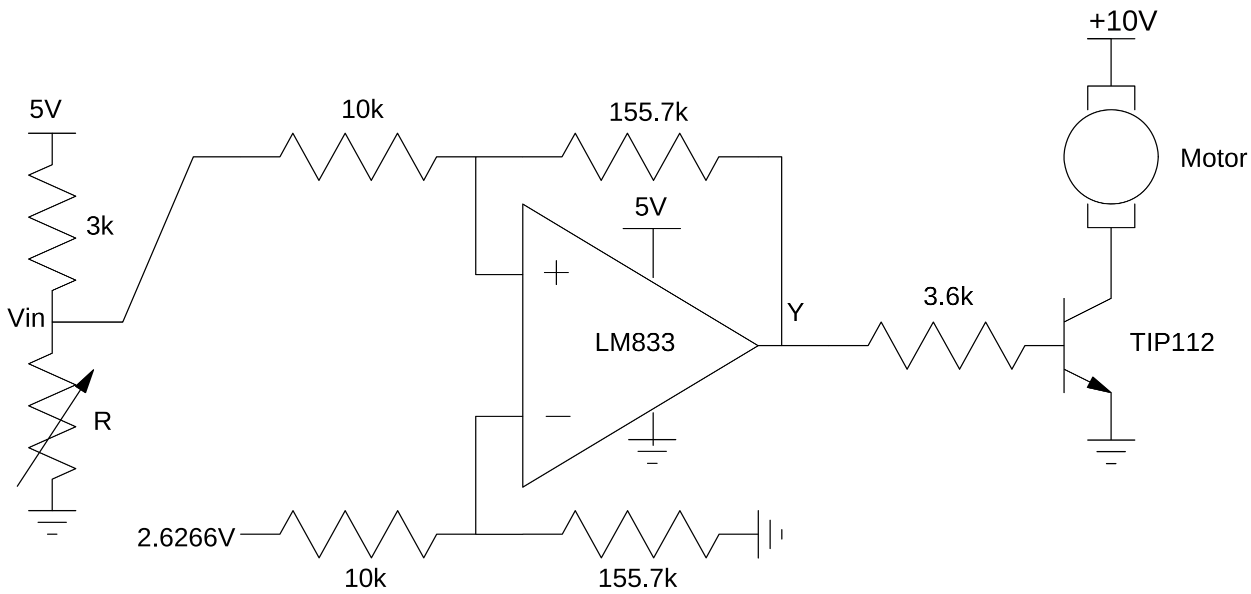
Ic = 200mA

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

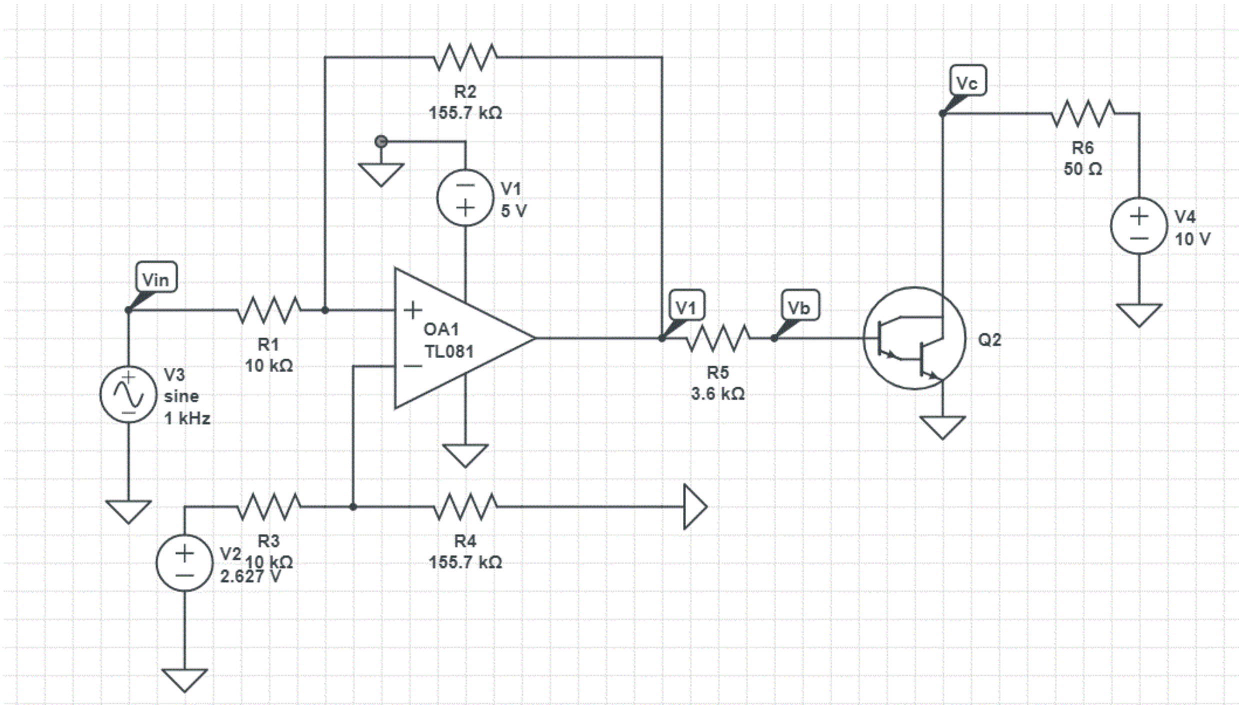
$$I_b > 200\mu A$$

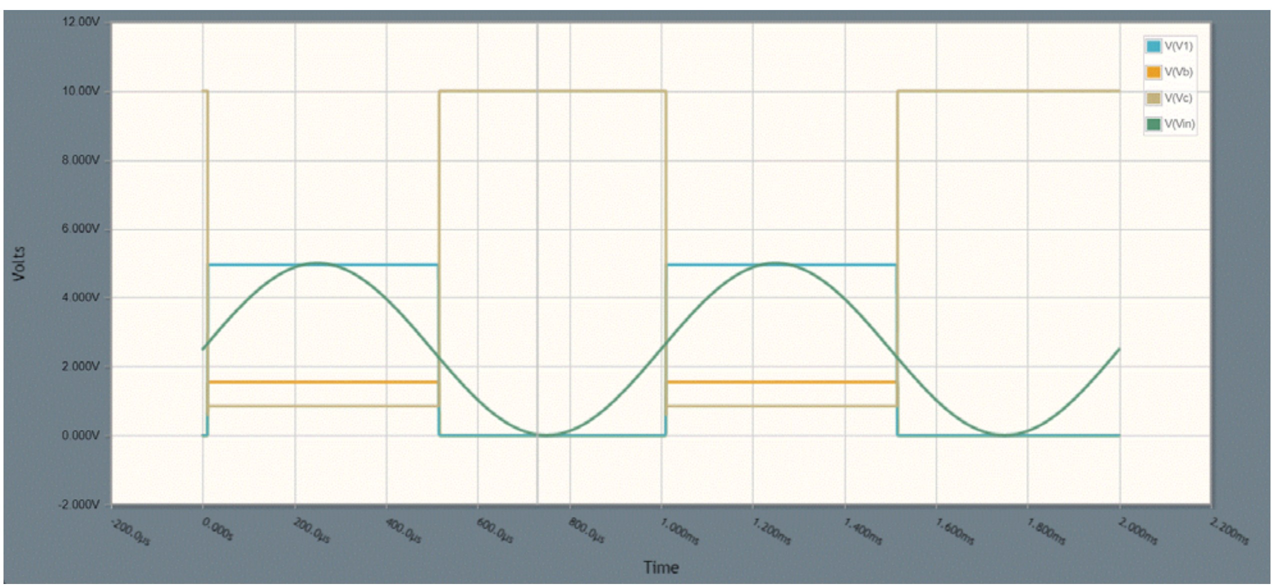
Let Ib = 1mA

$$R_b = \left(\frac{5V - 1.4V}{1mA}\right) = 3.6k\Omega$$



4) Simulate your design for problem #3. (note: PartSim struggles with Schmitt Triggers. CircuitLab doesn't have any problems though...)





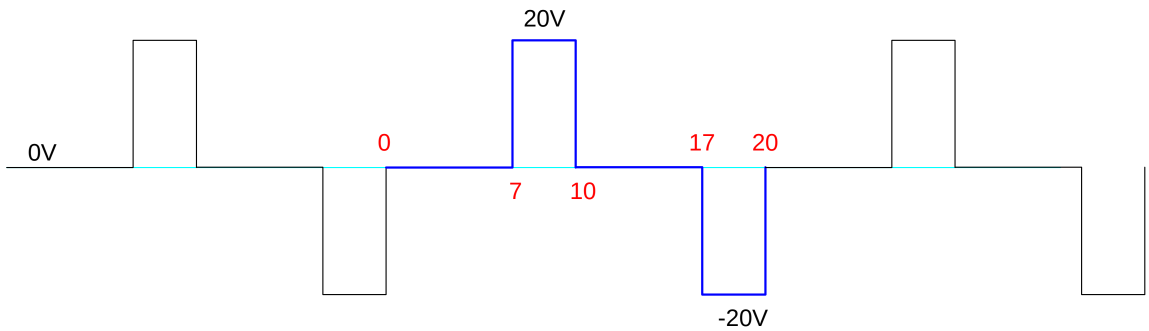
5) (Lab): Build your circuit in lab and verify it works

- Check the temperature (i.e. resistance or voltage) where the motor turns on
- Check the temperature (i.e. resistance or voltage) where the motor turns off
- Check that the transistor is saturated when on

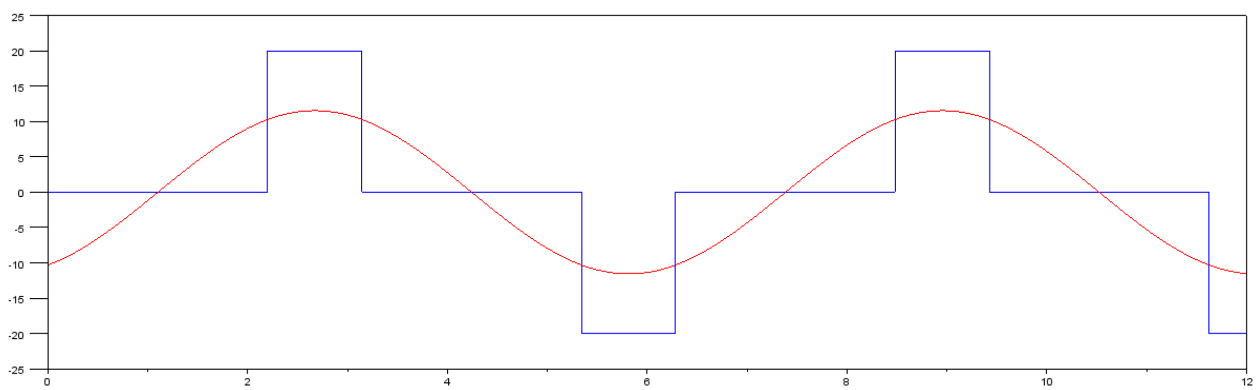
	Calculated	Simulated	Measured
On Voltage (Vin)	2.6266 V	2.679 V	
Vb(on)	1.40 V	1.537 V	
Vc(on)	0.90 V	0.845 V	
Off Voltage (Vin)	2.3055 V	2.233 V	
Vb(off)	0.0 V	0.0 V	
Vc(off)	10.0 V	10.0 V	

DC to AC

6) Determine the efficiency of the following DC to AC converter (i.e. how much of the energy is in the 1st harmonic?). (15% high, 35% off, 15% low, 35% off, repeat)




```
t = [0:0.001:20]';
V = 20*(t>7).*(t<10)  - 20*(t>17);

t = t*2*pi/20;

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

  - 10.299034 - 5.2466008i

Pout = 1/2* abs(V1)^2

    66.798457

Pin = mean(V .^ 2)

    119.974

eff = Pout / Pin

    0.5567744
```



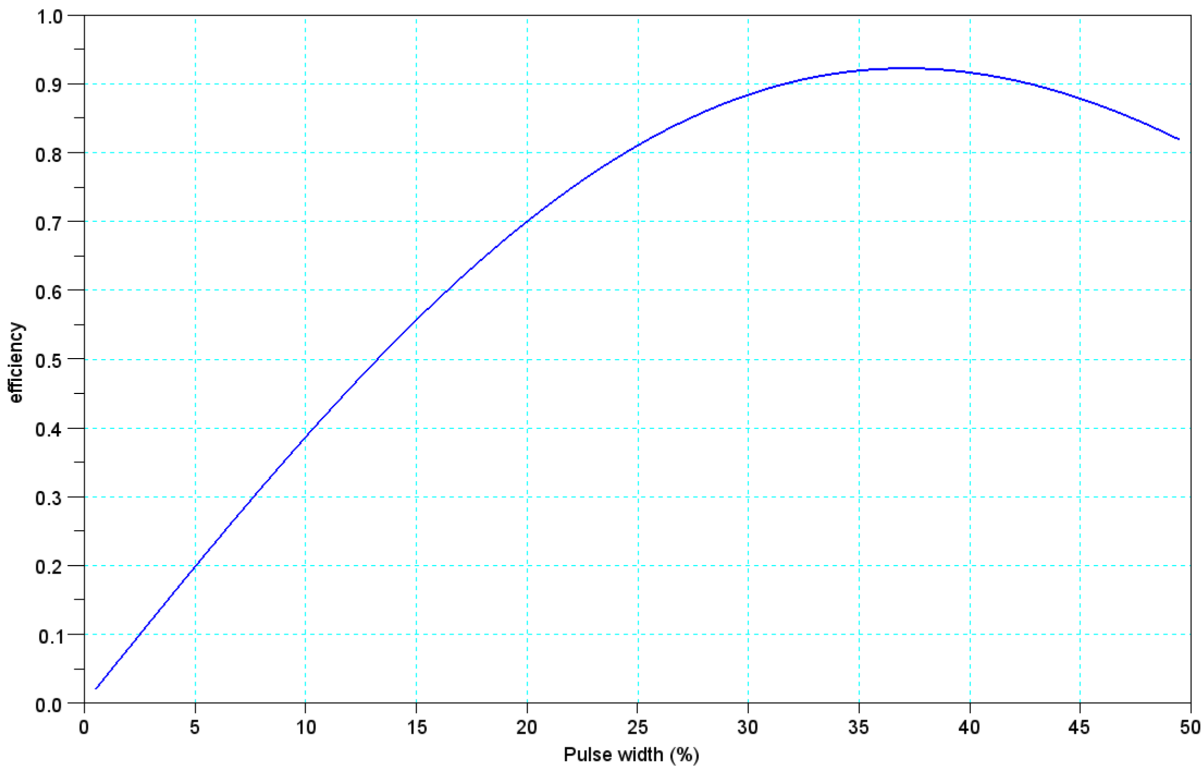
Waveform and it's 1st harmonic. 55.677% of the energy is in the 1st harmonic.

7) If you change the off times (when the signal is 0V), you can improve the efficiency. What is the maximum efficiency you can get with this type of DC to AC converter?

Use Matlab to determine the efficiency for pulse width from 0% to 50%

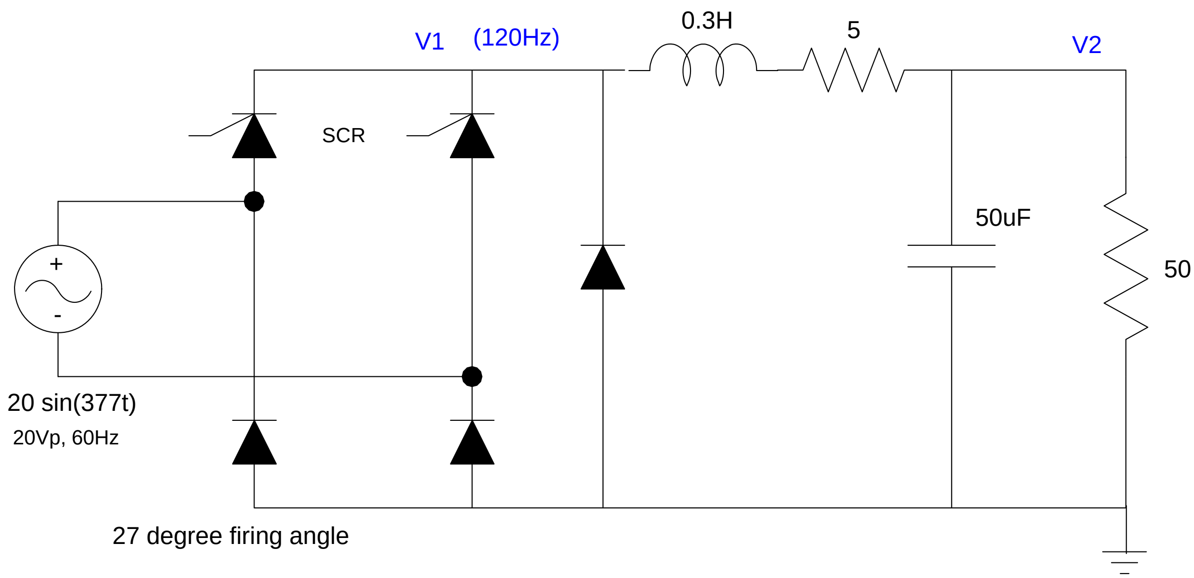
```
y = [];

for i=1:100

    a = i/10;

    t = [0:0.001:20]';
    V = 20*(t>a).*(t<10)  - 20*(t>a+10);

    t = t*2*pi/20;

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

    Pout = 1/2* abs(V1)^2;
    Pin = mean(V .^ 2);

    eff = Pout / Pin;

    y = [y; eff];

    end


plot(y)

max(y) = 0.9225497
```

Maximum effficiency = 92.25%



SCR

8) Assume a firing angle of 27 degrees. Determine the voltage at V1 and V2 (both DC and AC).



DC:

$$V_1 = \frac{V_p}{\pi}(1+\cos\theta)$$

$$V_1 = \frac{18.6V}{\pi}(1+\cos(27^0))$$

$$V_1 = 11.19V$$

$$V_2 = \left(\frac{50}{50+5}\right)11.19$$

$$V_2 = 10.178V$$

AC:

$$V_{1pp} = 18.6V-(-0.7V)$$

$$V_{1pp} = 19.3V_{pp}$$

$$V_2 = \left(\frac{10.98-j20.70}{(10.98-j20.70)+(5+j226.19)}\right)\cdot 19.3V_{pp}$$

$$V_2 = 2.19V_{pp}$$

9) Change this circuit so that

- The voltge at V2 is 10.0V (DC)
- With a ripple of 0.5Vpp

The DC voltage at V1 is

$$V_1 = \left(\frac{50+5}{50}\right) 10.0V$$

$$V_1 = 11V$$

To compensate for the -0.7V when the rectifier is turned off, shift everything up 0.7V (so it's at 0V at a minimum). This also shifts

- Vmax = 19.3V (18.6 + 0.7)
- V1(DC) = 11.7V (11.0 + 0.7)

The firing angle is then

$$11.7V = \frac{19.3V}{\pi}(1 + \cos(\theta))$$

$$\theta = 25.24^0$$

$$\theta = 31.1^0$$ if you don't account for V1 being -0.7V when the rectifier is off....

With C = 50uF, the ripple is 2.19Vpp (from problem #8).

To make the ripple 0.5V, scale C

$$C = \left(\frac{2.19V_{pp}}{0.5V_{pp}}\right) 50\mu F$$

$$C = 219.4\mu F$$

Check: With C = 219.4uF

$$Z_c = -j6.0447\Omega$$

$$-j6.0447 \,||\, 50 = 0.72 - j5.95$$

$$V_2 = \left(\frac{(0.72-j5.95)}{(0.72-j5.95)+(5+j226)}\right) \cdot 19.3V_{pp}$$

$$V_2 = 0.5262V_{pp}$$