PID HOT PLATE

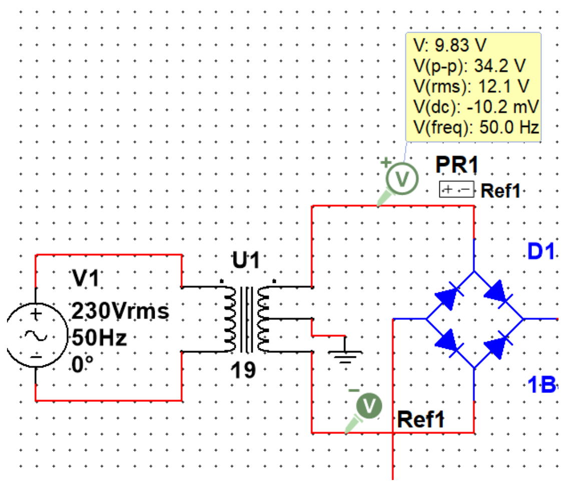
Lab project ll

GROUP 19

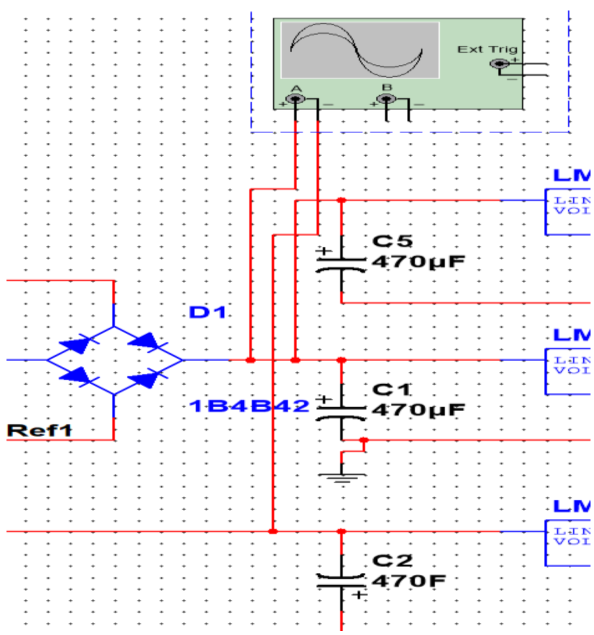
1) POWER SUPPLY UNIT

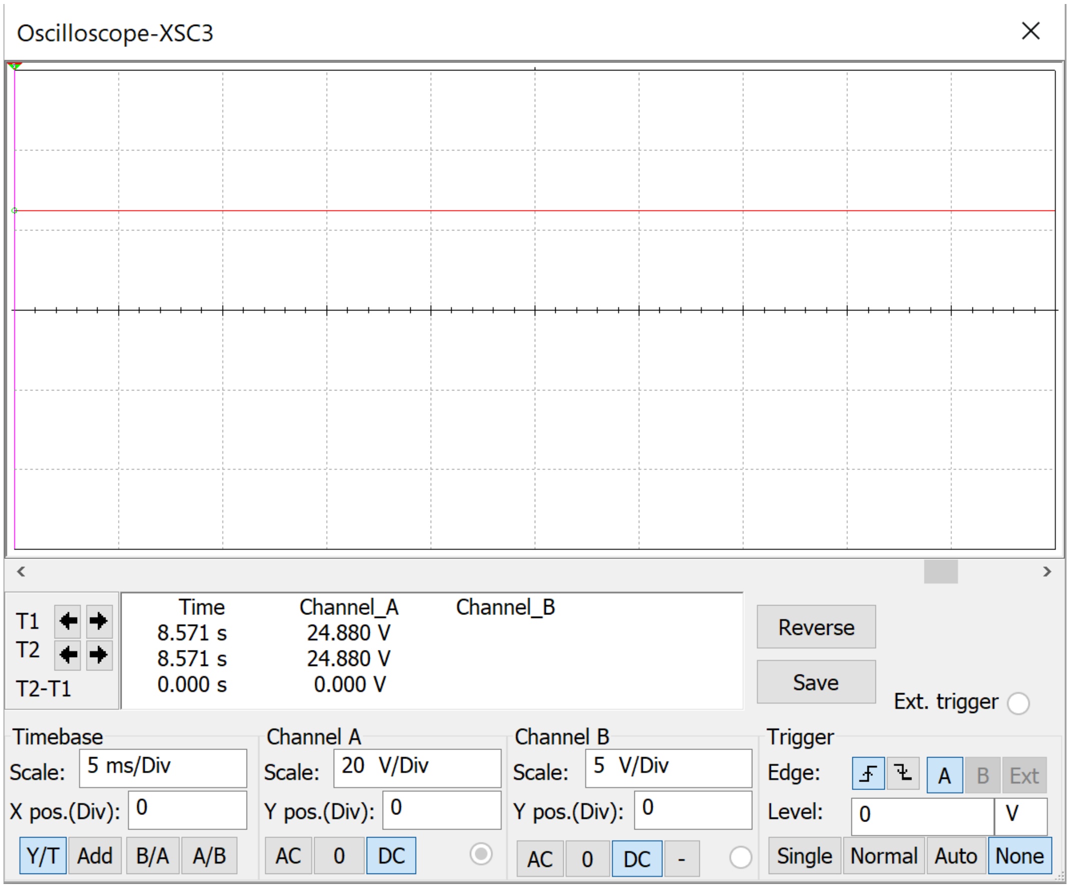
we have to make PID Hot plate using analog electronics. Mainly we have to use four units to complete this project. First one of them is power supply unit. The other three units are used different voltages to get proper functionality of that units. But for all that purpose we have to use usual house voltage(230V,50Hz). But the sensors and op amps are mainly used 12V, -12V and 5V. so we have to convert this AC 230V current to above values. We use bellow items for that reason. Then we can get stable voltages that we need.

- 230 to 12V center tapped transformer – for get 12 V AC current



- 1B4B42 rectifier – for get 12 V DC current

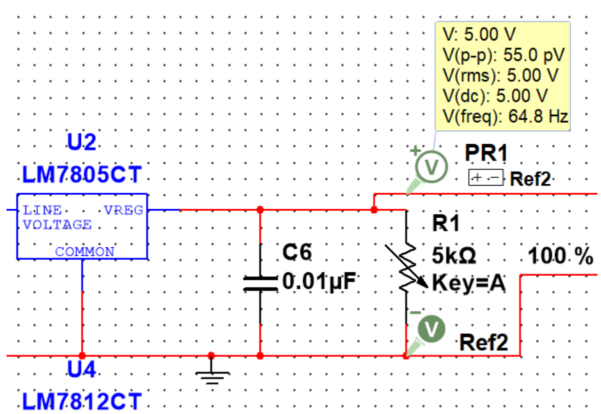




Rectified 24V Current

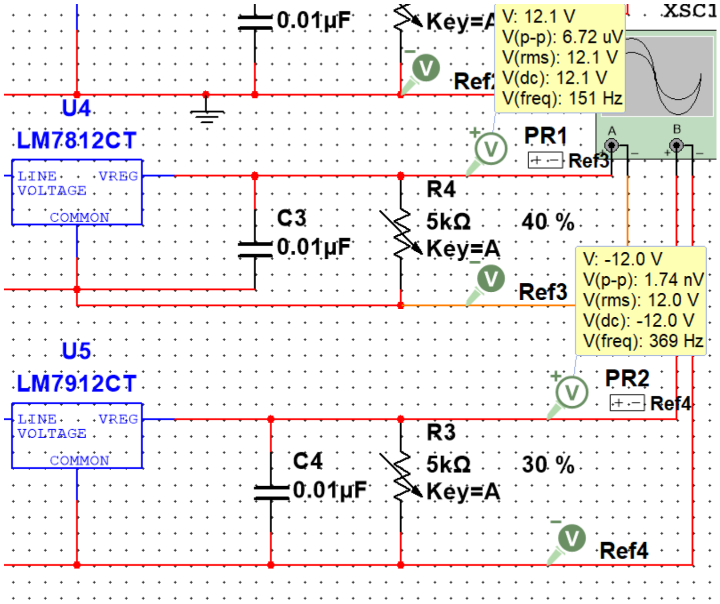
- LM7805 – for get 5V DC voltage

This 5V is used to sensor unit (Op amps)

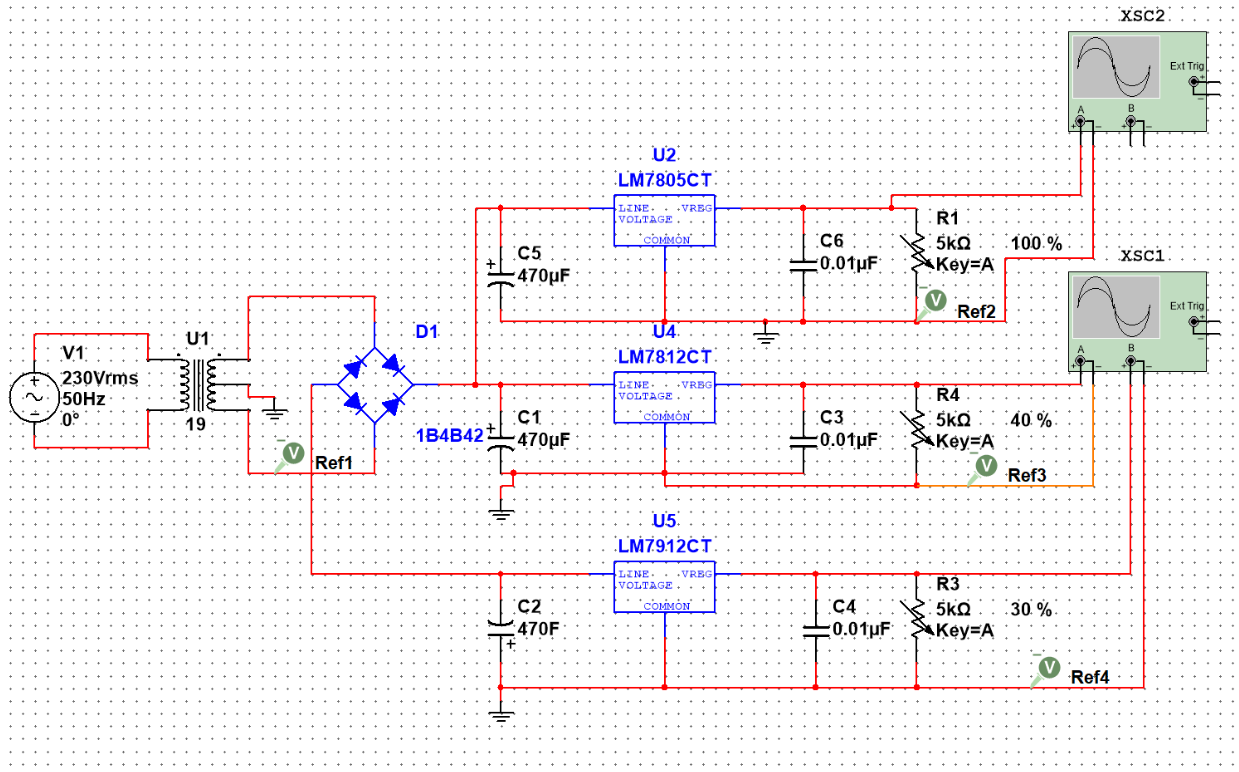


- LM7812 – for get 12V DC voltage
- LM7912 – for get -12V DC voltage

This 12V and -12V are used for PID unit and firing angle unit (op amps).



Further we want to give 230V house normal current for HOT PLATE. But it is not safety for low voltage circuits. So we should isolate all units from that voltage. For this purpose we use optocouplers. Then we can protect other all units from high voltages.



Final circuit

2)PID CONTROLLER UNIT

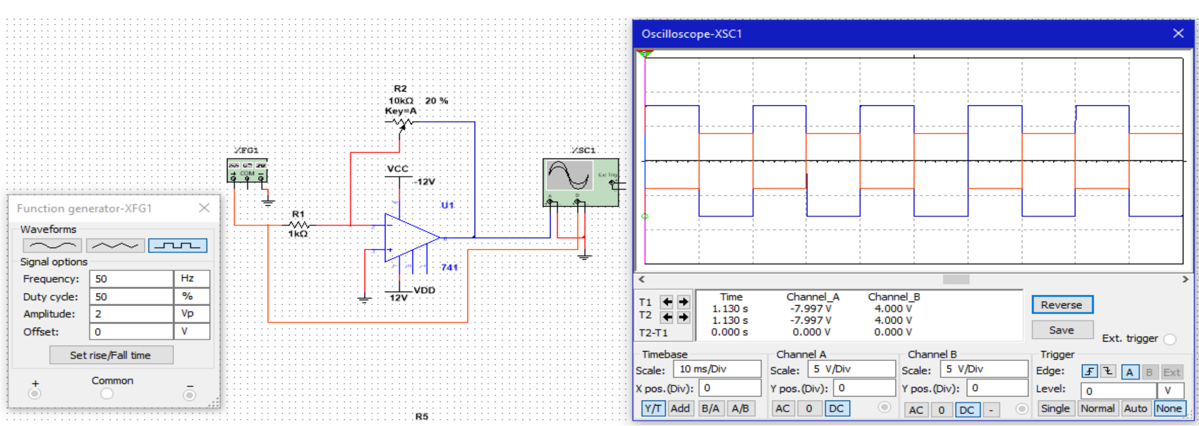
Sub levels of PID circuit

<u>Proportional term</u>

The proportional term produce the output which is proportional to the current error signal with phase shift. This can be adjusted using the proportional co-efficient (proportional gain constant). For this purpose we can use potentiometer as the feedback resistor.

We have to control the output of this circuit, because if the gain is too high system can become unstable. The small gain results small output response to a large input error.

Circuit simulation for square wave



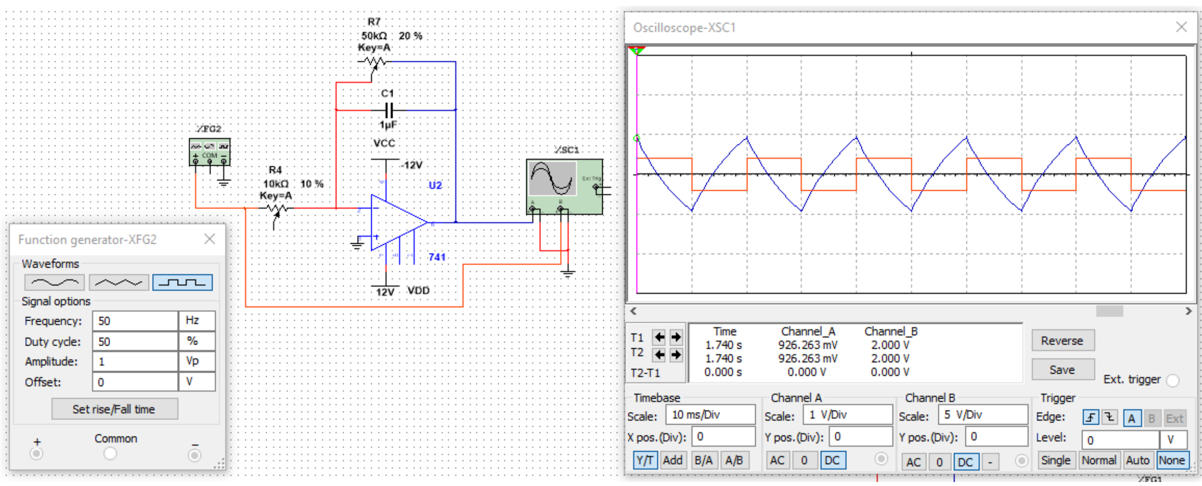
We can increase or decrease the gain of this circuit using the potentiometer.

Integral term

The integral term produce sum of the instantaneous error over time. This term can be adjusted using integral co-efficient (integral gain). Also for this purpose we can use potentiometer.

In the integral circuit we have to put a large value resistor parallel to the feedback capacitor to limit gain of the output signal.

Circuit simulation for square wave



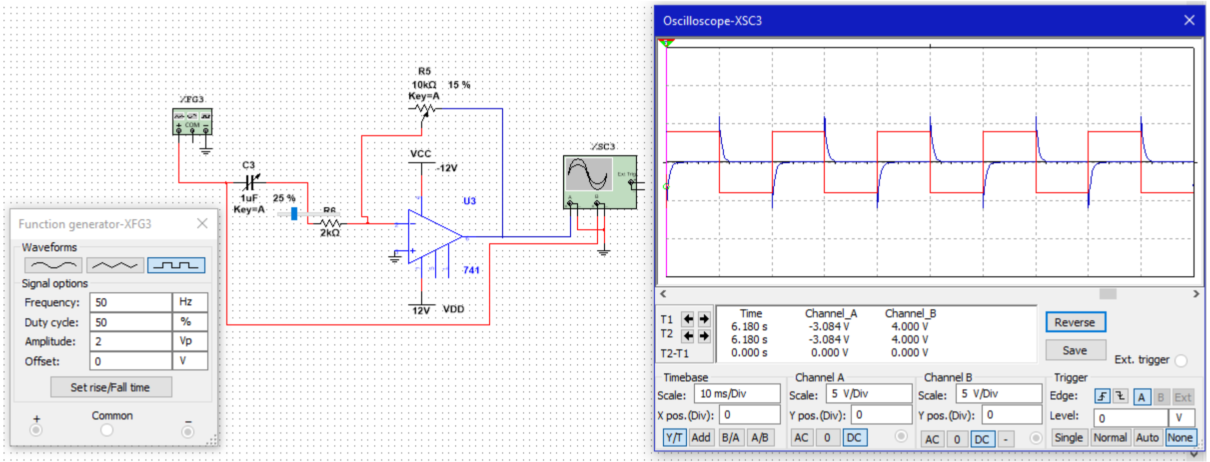
Using above potentiometers we can adjust the output signal as we wish

Derivative term

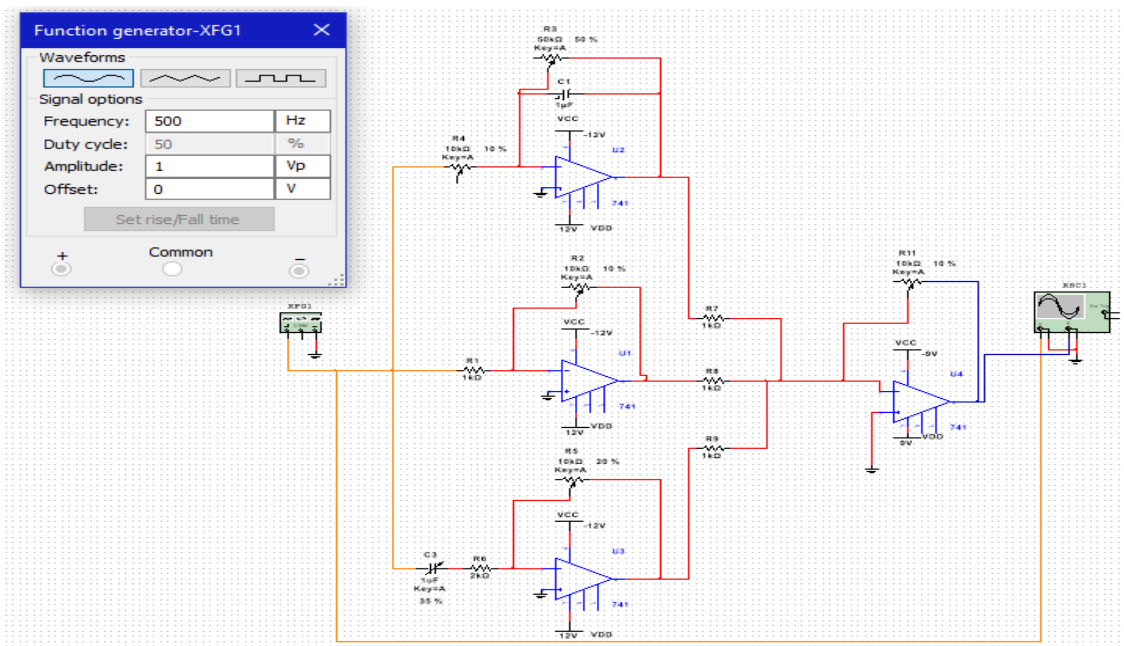
This term counteracts the proportional gain and the integral gain when the output changes quickly. This helps to reduce the overshoot and ringing. This term has no effect on final error.

In the derivative circuit we have to use resistor series to the input capacitor. Because this circuit is a high pass filter. It may amplify unwanted noises. To reduce this effect this we use this resistor. Also we put the capacitor parallel to the feedback capacitor. This capacitor helps to reduce the high frequency gain in the output signal. Adding these elements improve the stability of the circuit.

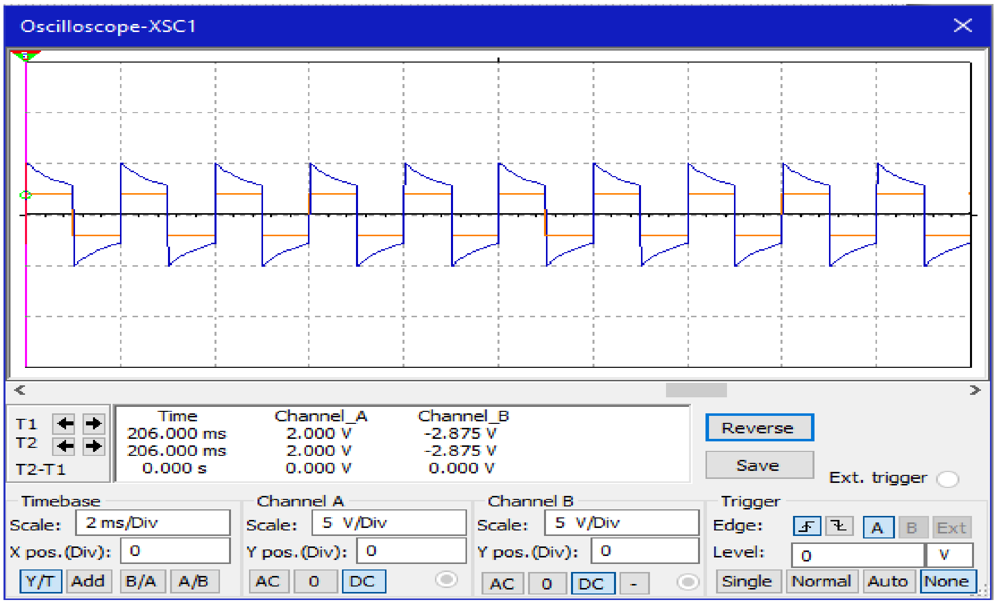
Circuit simulation for square wave



After simulating separately, we can combine these three circuits into one circuit.

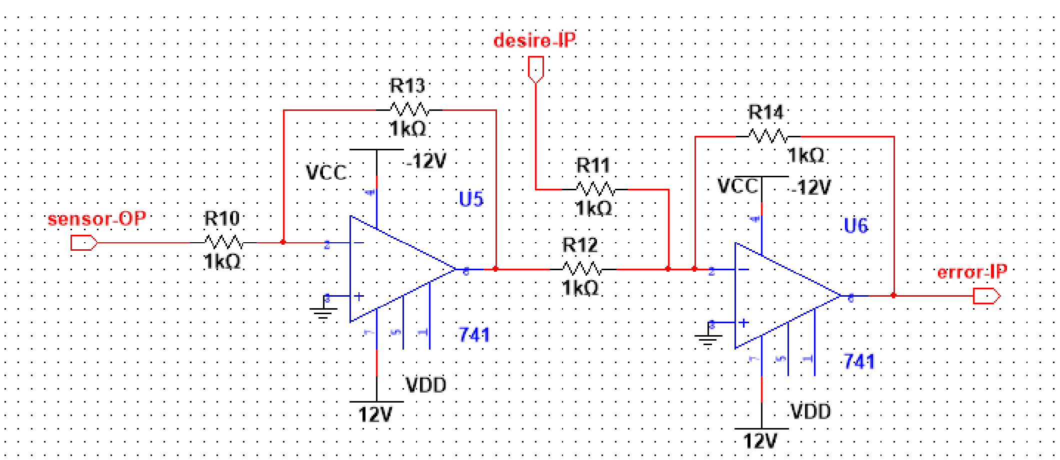


Combined circuit simulation for square wave signal



To control the system correctly we have to input the error signal to PID unit. To get the error signal first we can invert the sensor output signal using op-amp. Then we can add the inverted signal and desire input signal using another op-amp. The resultant output is the difference between sensor signal and desire input signal. This error signal is the input for the PID control circuit.

Error signal generation



3) SENSOR INTERFACE UNIT

The resistance variation of the RTD Pt100 with temperature is approximately linear. The variation of resistance is approximated as follows,

$RTD(T) \approx RTD_0 (1 + T \times \alpha)$

Where: RTD(T) = the RTD element's resistance at T (Ω)

RTD0 = the RTD element's resistance at 0°C (Ω) (100 Ω for Pt100)

T = the RTD element's temperature (°C)

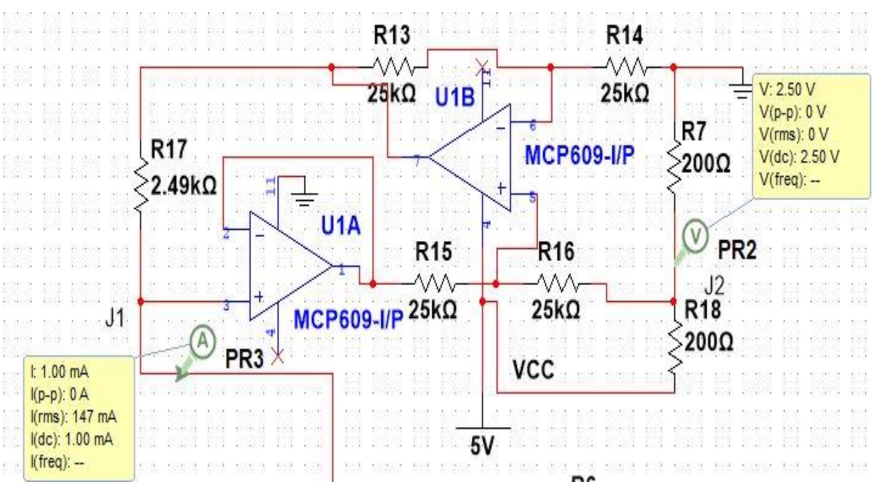
α = 0.00385 Ω/Ω/°C (Temperature coefficient of RTD element)

As per actual readings obtained for temperature range 0-200°C the resistance varies in the range 100 – 175.86 Ω.

(https://www.tnpinstruments.com/sitebuildercontent/sitebuilderfiles/pt100_385c_table.pdf)

Current excitation

A RTD requires a 1mA or less constant current for best linearity. The following circuit is used to generate this constant current.



U1B and R13 through R16 serves as a difference amplifier with a gain=1 since all resistors are equal in value. A 2.5V voltage is supplied at J2. U1A outputs the voltage at J1 as reference for U1B. The output of A1 is given by,

$V_{OUT\_U1B} = 2.5 * G_{A1} + V_{OUT\_U1A}$ $(G_{A1}=1)$

As per the general operation of OpAmps, $V_{OUT\_U1A} = V_{J1}$.

The voltage across R17 = $V_{OUT\_U1B} - V_{J1}$

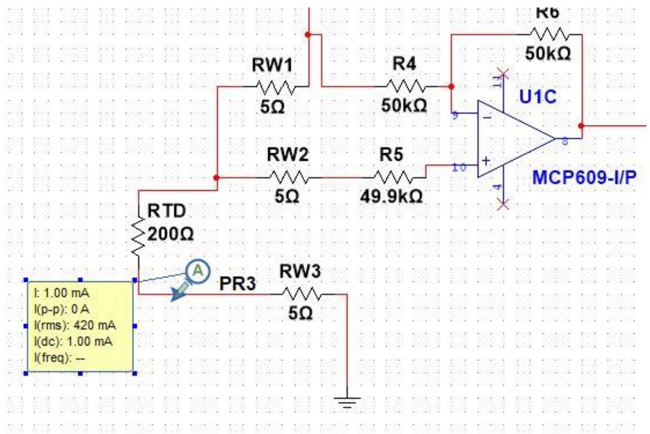
= 2.5V.

Therefore the current supplied will be 2.5V / R17.

Different connections

A RTD can be connected using 2 wires, 3 wires or 4 wires. The most accurate ways are 3- wire and 4-wire connections as they compensate for the resistances of lead wires.

Here a 3-wire connection is used. R_{W1} through R_{W3} represents the resistances in the three wires.



U1C, R4, R6 rectifies the error readings due to R_{W1} and R_{W3}. A current in the range of pA passes through R_{W2} (negligible) due to the OpAmp and the higher resistance of R5. The values of R4 through R6 are selected to ensure no leakage (minimal as possible) currents, which will cause errors to the RTD reading.

The output of U1C is as follows,

$$V_{OUT\_U1C} = (V_{IN} - VW1)(1+R6/ R5) + V_{IN} (R6/ R5)$$

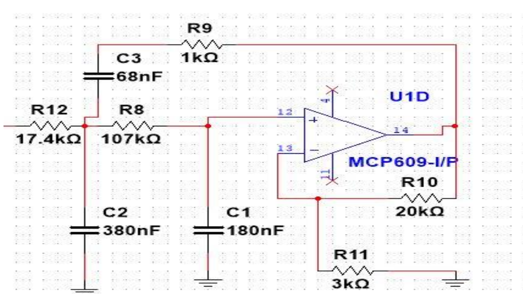
$$V_{IN} = V_{W1}+V_{RTD}+V_{W3}$$

Since $R_6=R_4$ and $R_{W1}= R_{W3}$,

$$V_{OUT\_U1C}=V_{RTD}$$

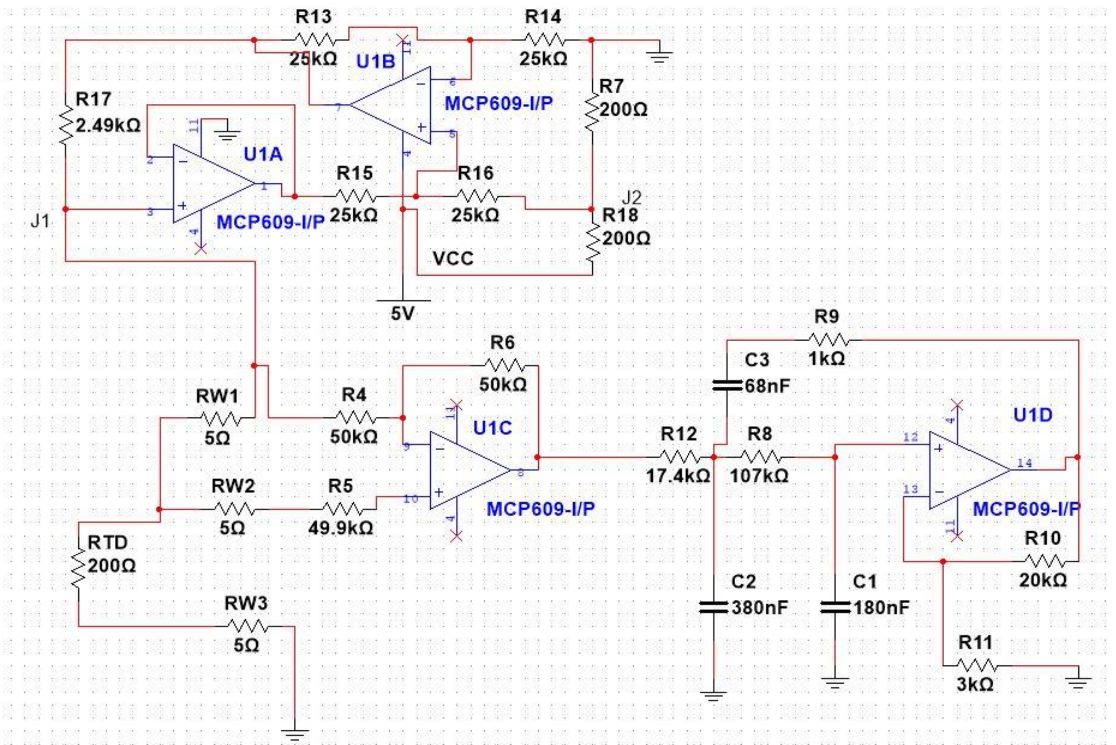
Reading Amplification

V_{RTD}= RTD resistance* 1mA(or <1mA). This reading is too small and it can be amplified as preferred. Output of U1C is first filtered using a second order low pass filter of 10Hz bandwidth comprised of R8 R12, C1, C2. R9 isolates the output of U1D from the capacitive loads. In U1D R10 and R11 sets a gain of (1+ R10/R11).

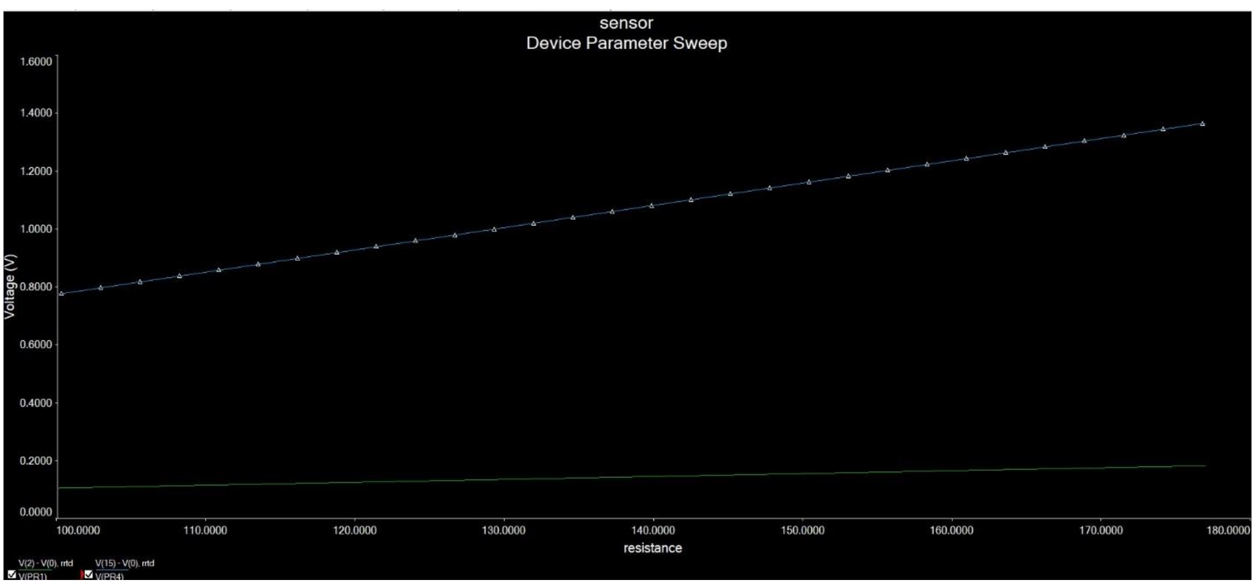


The final output is obtained at the output of U1D.

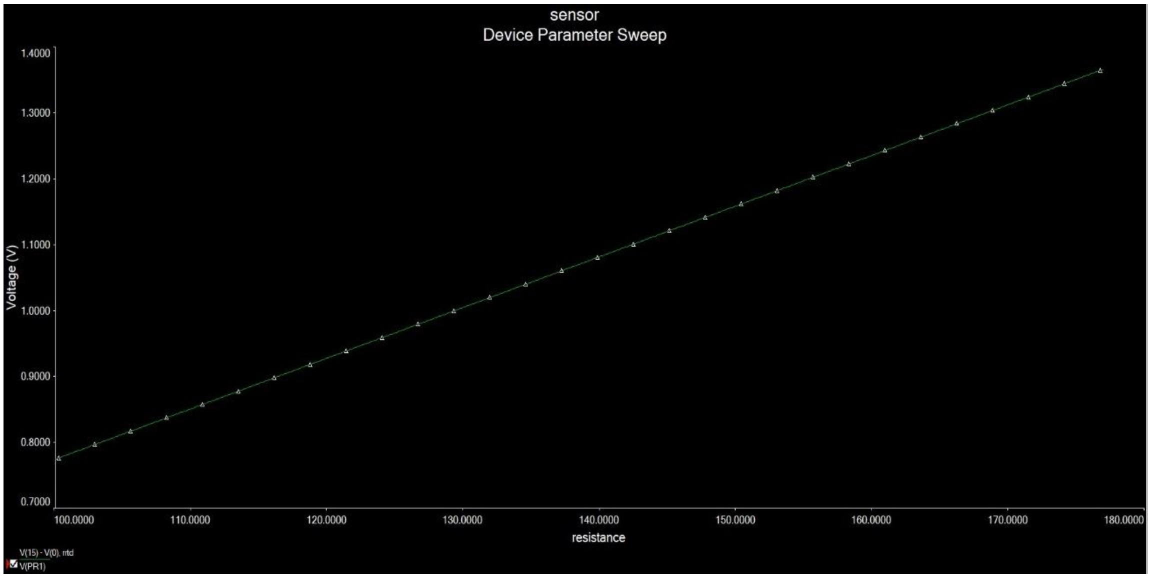
Full circuit:



Final voltage reading (Blue), Original V_{RTD} reading(Green) vs resistance of RTD graph



Final voltage reading vs resistance of RTD graph



Reading at 200°C (176Ω) = 1.36V

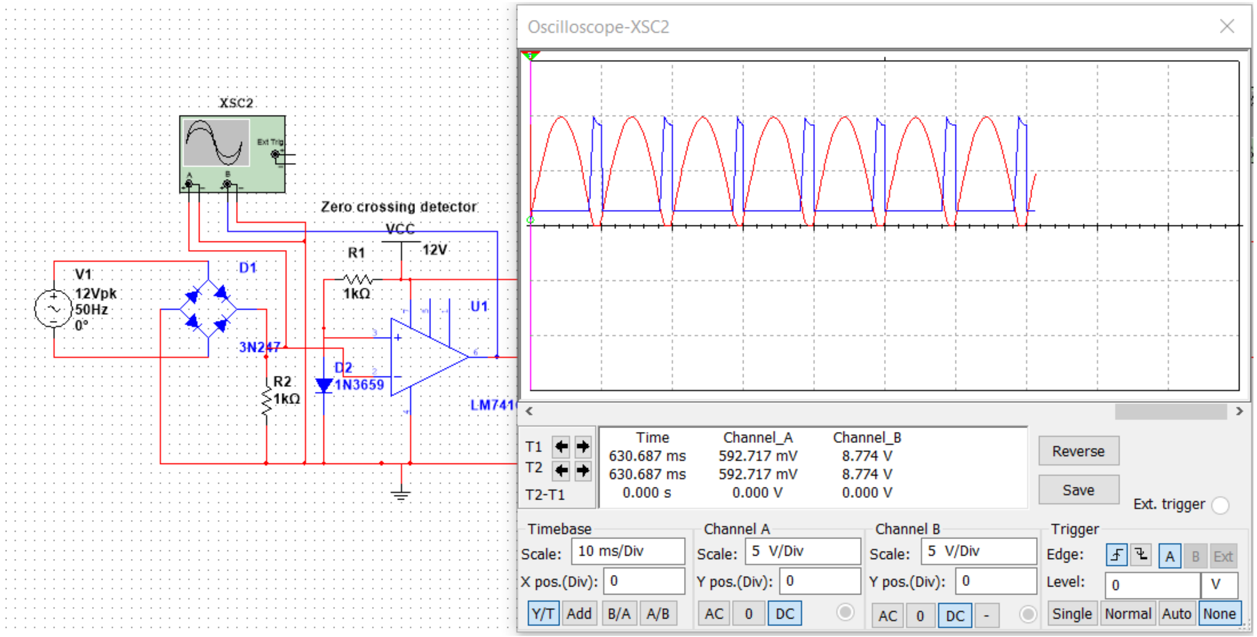
The above simulation results were obtained after setting the amplification of U1D = (1+ 20k/3k) = 7.67.

4) FIRING ANGLE CONTROL UNIT

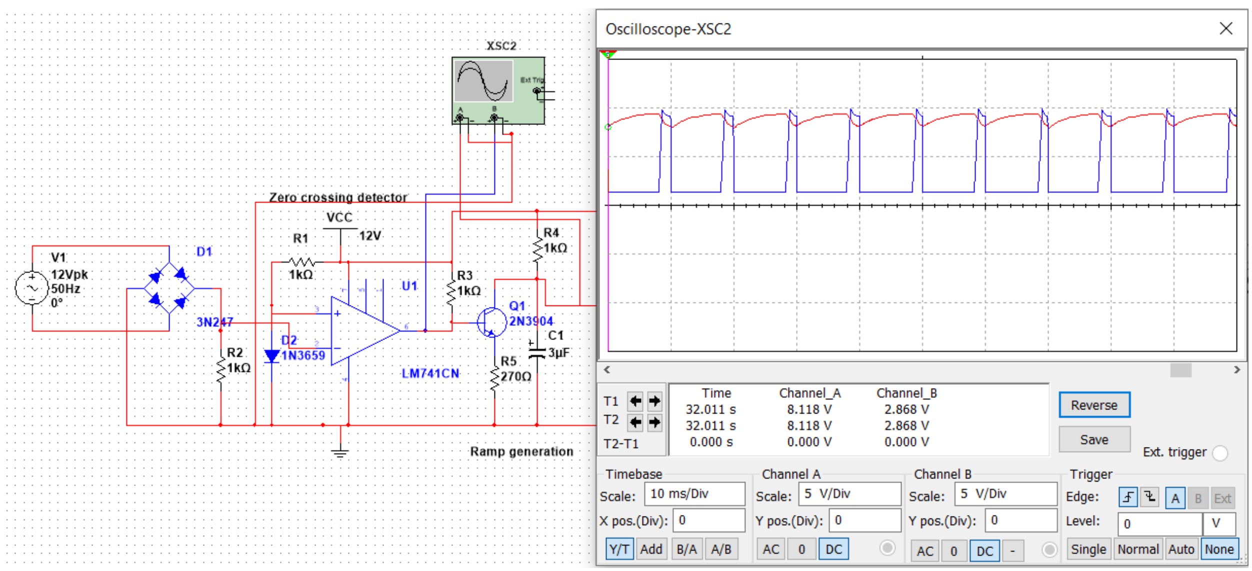
We have the PID output signal. But that signal is cannot be used directly to control the power that provides to the hot-plate. To do that we are using a firing angle control system. In this system we are creating a PWM signal which changes the width of the pulse according to the PID output. the main steps are simulated and described as follows.

Zero crossing detection

When we are controlling the power of the outer circuit, we need to control every half cycle of the AC wave form in the same way. If not, it is difficult to increase or decrease power. This process is to generate pulses for each half cycles of the original AC wave form. Then we can provide a pulse for each half cycle to control it equally. When the inverting voltage is higher than the non-inverting it give 12 V as a output. otherwise is give 0V output.



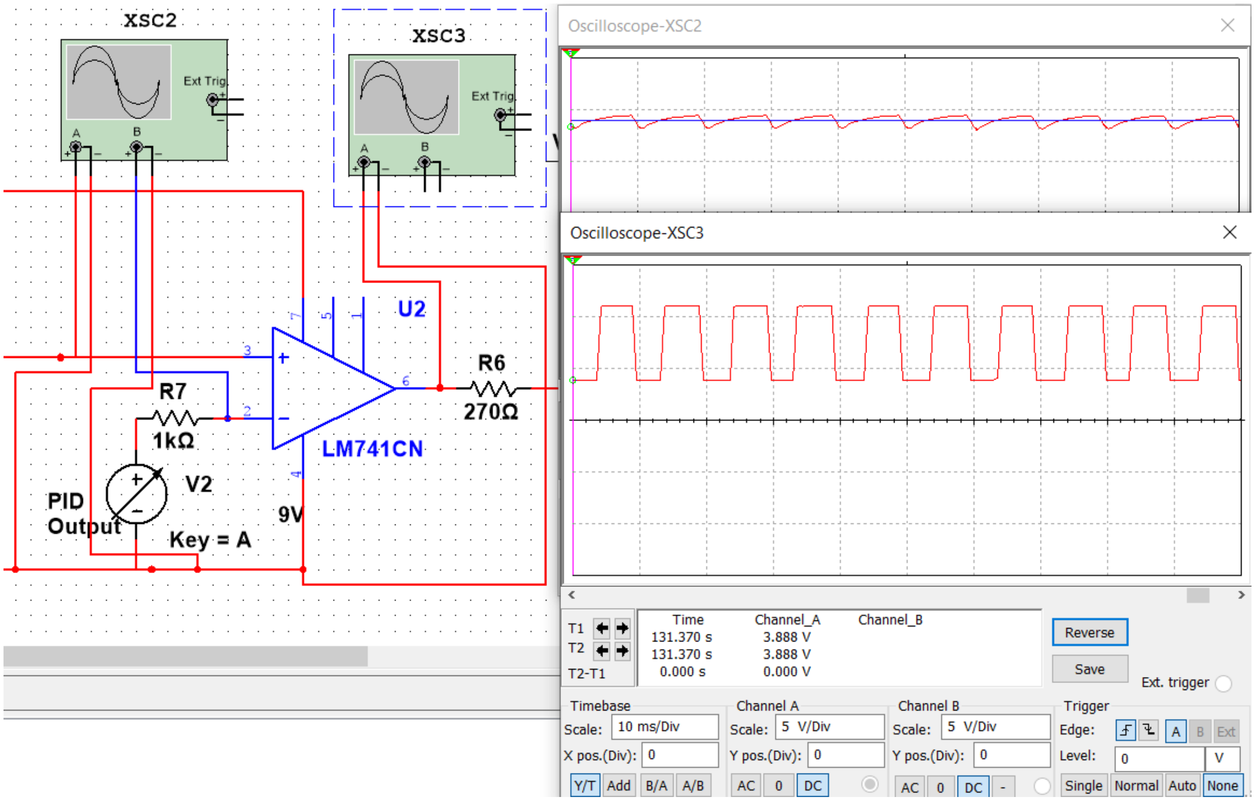
Ramp generation



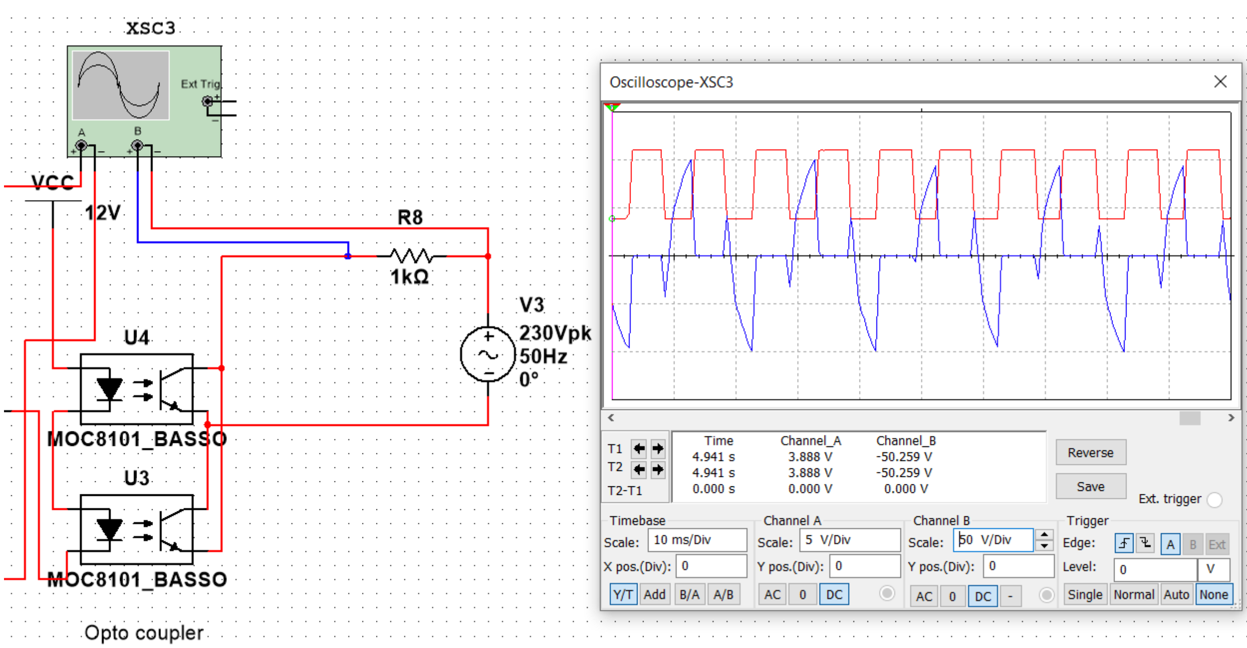
This ramp is used as threshold which decides whether the outer circuit is open or not. This ramp is created using a capacitor. When the output of the zero-crossing detector circuit is zero the transistor is in the cut off region (act as a open circuit) and capacitor charges. when there is a pulse In the output the transistor is in the saturation region (act as a closed circuit) and the capacitor dissipates through the transistor.

PWM signal generation

In this step the op amp creates a PWM signal. When the ramp voltage is higher than the PID output voltage the output is 12V. otherwise, the output is 0V.

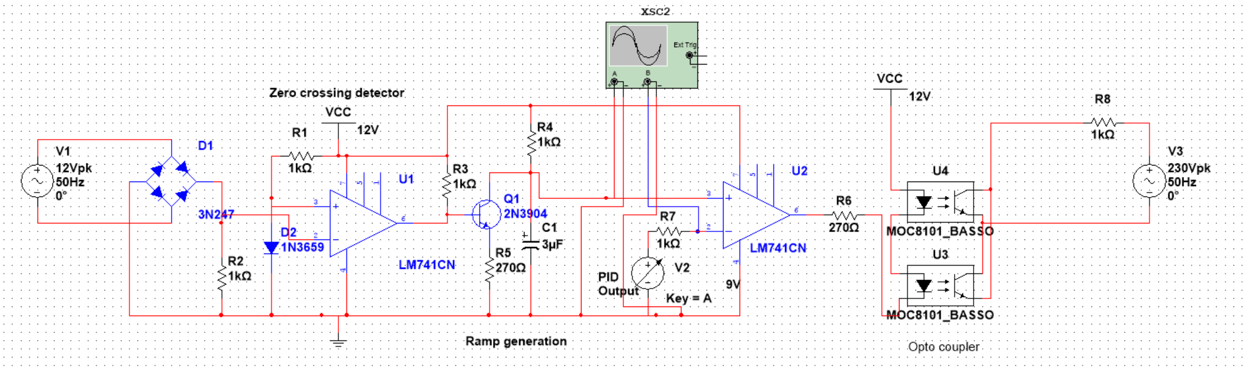


Controlling the power using opto-isolators



This is the final step which controls the outer circuit. In this step we have use opto-couplers to isolate the low power controlling circuit from the high-power outer circuit. This also works as a switch to the outer circuit. When the PWM signal has a low voltage it act as a closed switch. Otherwise it act as a open switch.

The complete circuit



Work allocation

Index	Name	work
180544U	Ravinhansa W.A.V	PID controller
180715V	Wijethunga U. I. D	Firing angle controlling system
180604F	Silva P. H. D. S	Sensors
180379R	Maheekumara K. A. G. D	Power supply