Development Of A Temperature Monitoring And Control System Using Temperature Sensor

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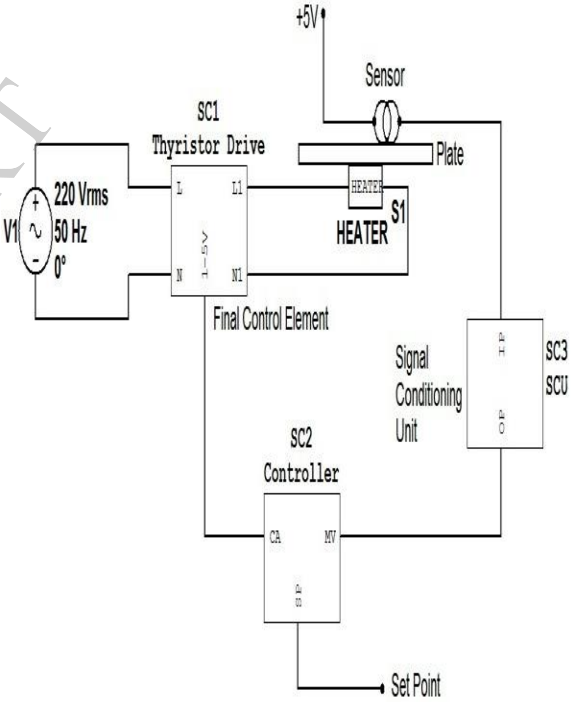
i) Abstract: This project aims at controlling the temperature of an aluminum plate which is being heated by a 50 watt heating element. For controlling the temperature of the metal plate the current through the heating element is controlled. The thermal energy produced by the heater is directly proportional to the square of the current passing through the heater coil. Hence, by controlling the current through the heater coil ,the heat produced by the heater is controlled. The target is to control the temperature of the plate between room temperature and 100 °C with the optimal control range being from 44°C to 63°C. Following this significance of temperature control in processes, a temperature sensor and control system using the AD590 IC as the temperature sensor is designed.

Keywords— Temperature sensors, AD-590 sensor, Heater, Thyristor, Signal conditioning unit, PID controller.

*ii) **Proposed design:***



fig(1) Block diagram

The main scheme of the project is to control the temperature of the plate via a feedback control loop. The system consists of a plate heated by an electrical heater, temperature sensor IC – AD590, a signal conditioning unit, a controller and a final control element.

The function of each of the following blocks is briefly explained below:

Heater:

The heater used was a 50 watt heating element. This was used to heat an aluminum plate whose temperature was in turn measured and controlled.

Temperature sensor:

The function of the temperature sensor is to produce an electrical signal whose magnitude would be proportional to the temperature of the plate. Here, the temperature sensor used is an IC temperature sensor named AD590. This device produces an electrical current directly proportional to the absolute temperature. The output of this sensor is fed to the signal conditioning unit.

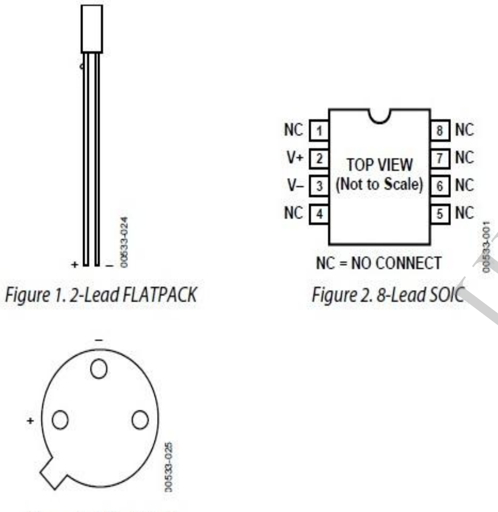


Figure 1. 2-Lead FLATPACK

Figure 2. 8-Lead SOIC

Figure 3. 3-Pin TO-52

fig(2) AD590 PIN out

Parameter	Rating
Forward Voltage (E+ or E–)	44 V
Reverse Voltage (E+ to E–)	–20 V
Breakdown Voltage (Case E+ or E–)	±200 V
Rated Performance Temperature Range[1]	–55°C to +150°C
Storage Temperature Range[1]	–65°C to +155°C
Lead Temperature (Soldering, 10 sec)	300°C

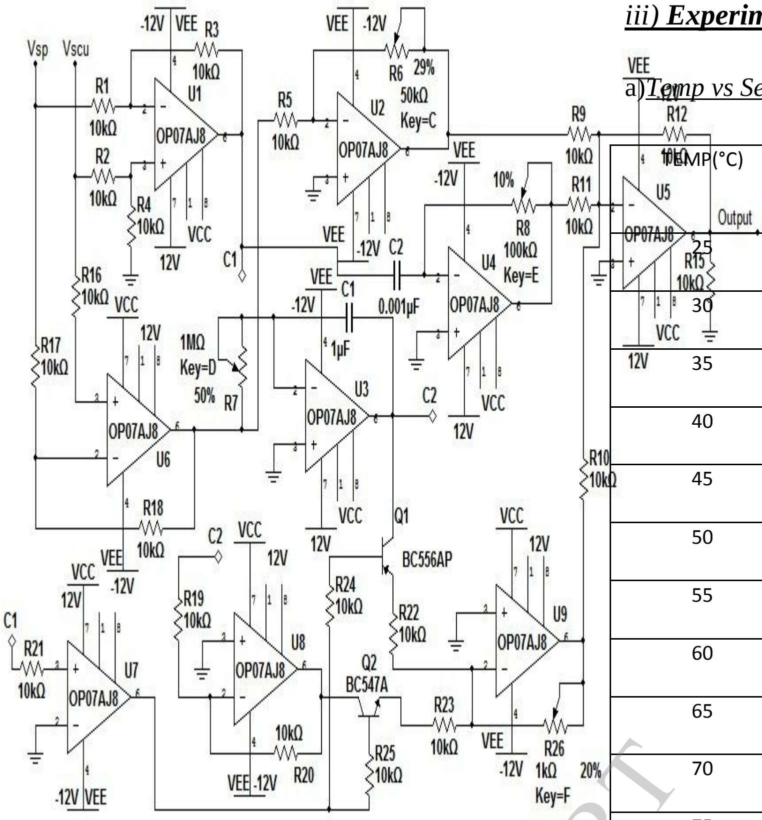
fig(2.1) Absolute maximum ratings for AD-590

Signal Conditioning Unit:

The signal is so named because it takes its input from the sensor and produces an electrical signal that is usable by the controller circuitry. This is necessary since the electrical output of the sensor is of very low magnitude. It is necessary to amplify these signals before they can be processed by the controller. Typically, the output of sensors is in the order of mill volts. The signal conditioning unit performs this necessary amplification with the help of small signal amplifiers. Mostly op amps and instrumentation amplifiers are used for this purpose.

Controller:

The controller performs the function of controlling the process output by changing the manipulated variable. In this case the manipulated variable is the current through the heating element which cannot be directly controlled by the controller. Hence. It controls the manipulated variable with the help of the final control element. There are two inputs to the controller namely, the measured value and the set point. The measured value is the sensor output processed by the signal conditioning unit. The set point input is used to set the temperature at which we are to control the plate temperature. A controller can be of discontinuous type or continuous type. Here a continuous type controller was used. The controller was used both in the PD mode and in the PID mode and the results were observed. When used in the PD mode, the process featured a constant steady state offset error. The PID mode featured a near to set point process output with a maximum variation of 0.75°C. The controller circuit was primarily constructed and simulated using NI Multisim 11 simulation software. After successful simulation it was interfaced to the process namely, the signal conditioning unit and the final control element through a DAS card. The same circuit was constructed in the form of the original controller.



Here, Vsp = set point voltage, Vscu = voltage input from SCU i.e. the measured value

fig(3) Practical circuit for controller

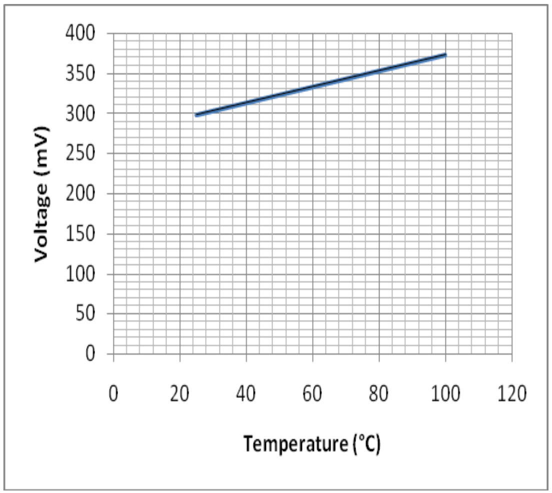
Final Control Element:

The final control element does the job of receiving the control signal (1V to 5V) from the controller and accordingly changing the manipulated variable. This is necessary since the controller alone does not have the ability to handle such high AC loads. The final control element used here is a thyristor drive. The response of the thyristor drive was observed to be linear in the range of 3V to 5V of the control voltage. The thyristor drive output voltage is directly proportional to the input control voltage. Hence, by varying the control voltage to the thyristor drive, the voltage applied to the heater can be varied.

*iii) **Experimental Results:***

a) *Temp vs Sensor output voltage*

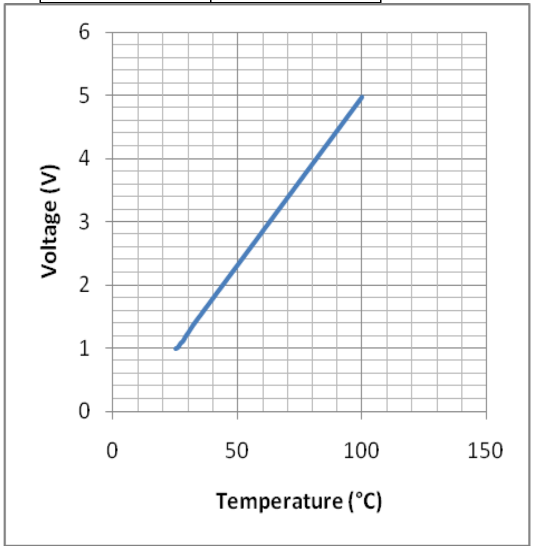
TEMP(°C)	SENSOR OUTPUT (mV)
25	298
30	303
35	308
40	313
45	318
50	323
55	328
60	333
65	338
70	343
75	348
80	353
85	358
90	363
95	368
100	373



fig(4) *Temperature vs sensor output voltage.*

b)*Temp vs Signal conditioning unit O/P*

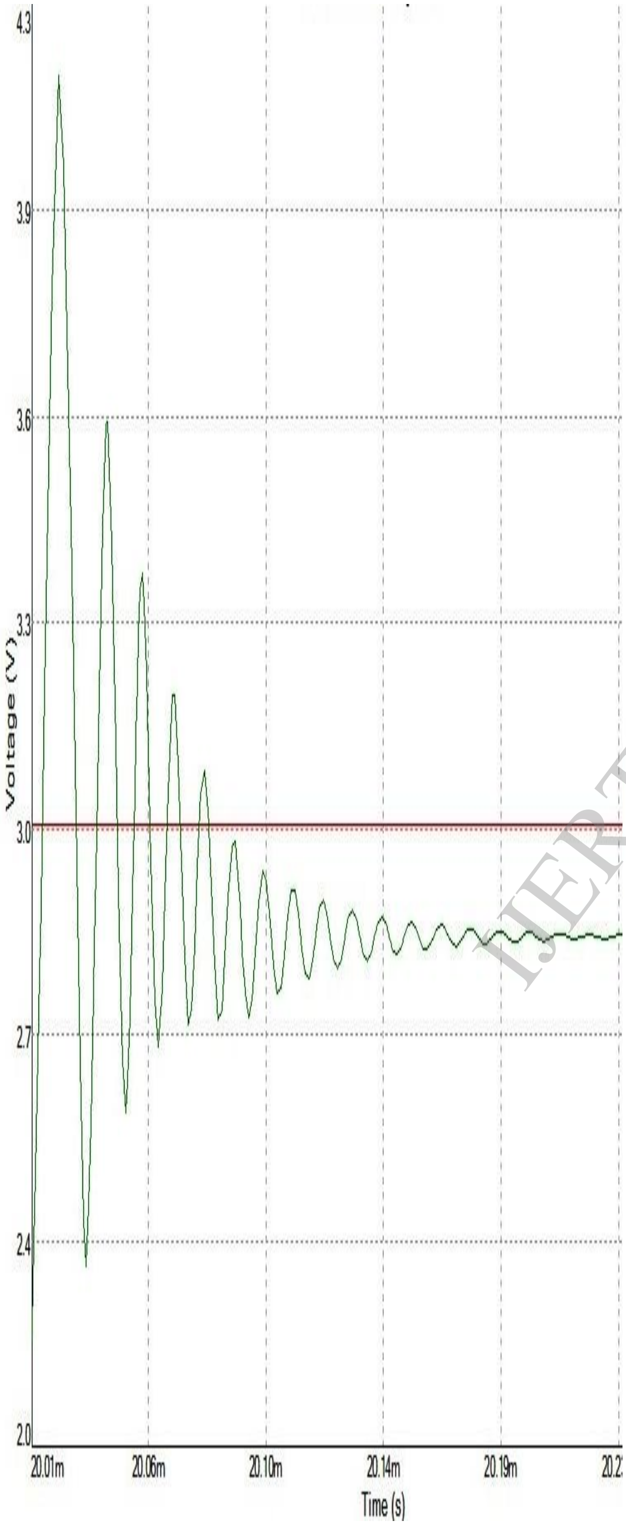
TEMP(°C)	SCU Output (V)
25	1.007
30	1.248
35	1.53
40	1.795
45	2.06
50	2.325
55	2.59
60	2.855
65	3.12
70	3.385
75	3.65
80	3.915
85	4.18
90	4.445
95	4.71
100	4.975



fig(5) Temperature vs signal conditioning unit output voltage

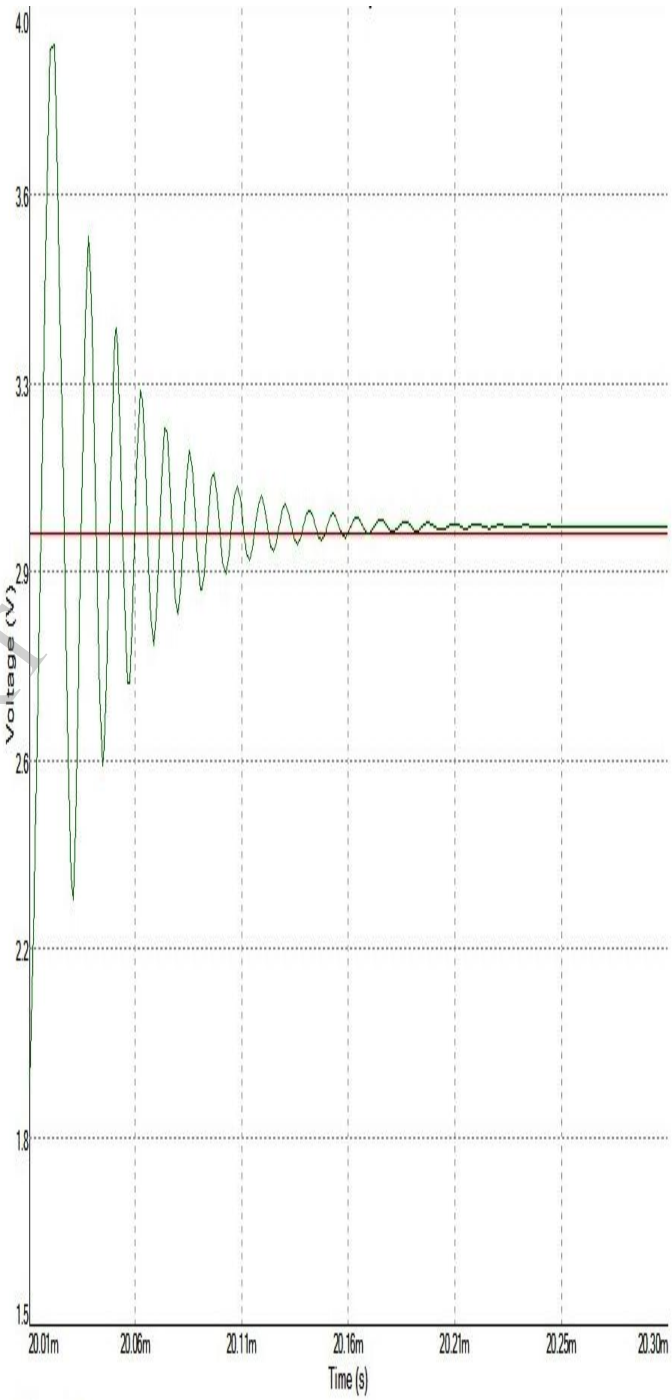
b)*Temp vs DPM output*

TEMP(°C)	SENSOR OUTPUT(mV)	DPM DISPLAY VALUE
25	298	25.1
30	303	30.2
35	308	35.0
40	313	40.0
45	318	45.0
50	323	50.0
55	328	55.0
60	333	60.1
65	338	65.0
70	343	70.0
75	348	75.0
80	353	80.0
85	358	85.0
90	363	90.0
95	368	95.0
100	373	100.0



RED=set point voltage & GREEN=controller response

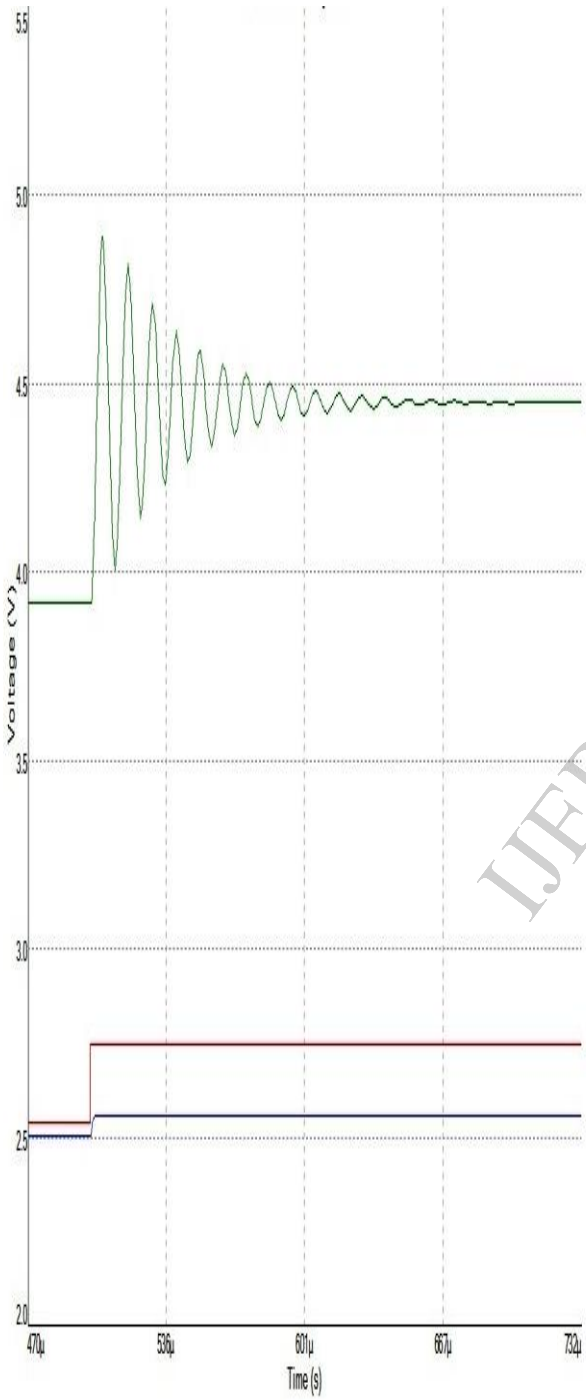
fig(6)Controller response in PD mode.



RED=set point voltage & GREEN=controller response

fig(7)Controller response in PID mode

c)*Performance characteristics of PID controller*



RED=set point voltage, GREEN=PID controller response, BLUE=measured value

fig(8)PID controller output vs step change from 2.5v to 2.75v

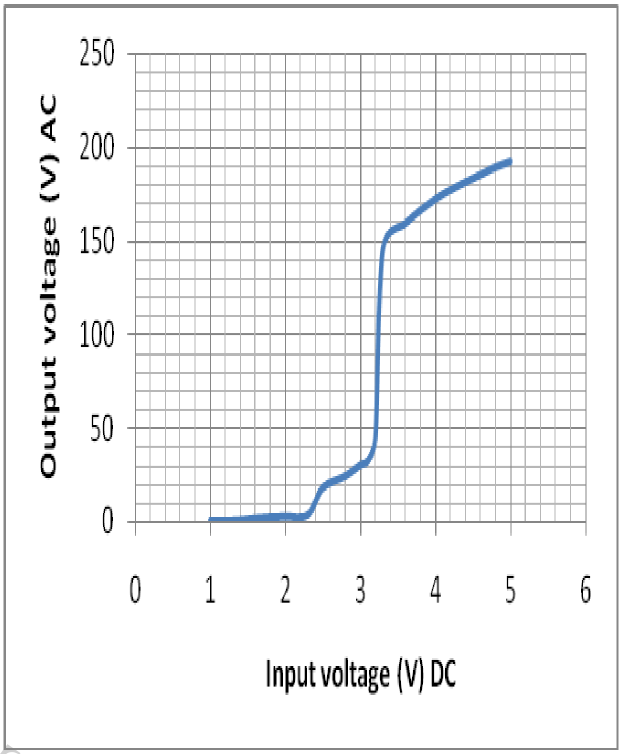
d)*Performance characteristics of final control element:*

Table for Input volt vs output volt(increasing)

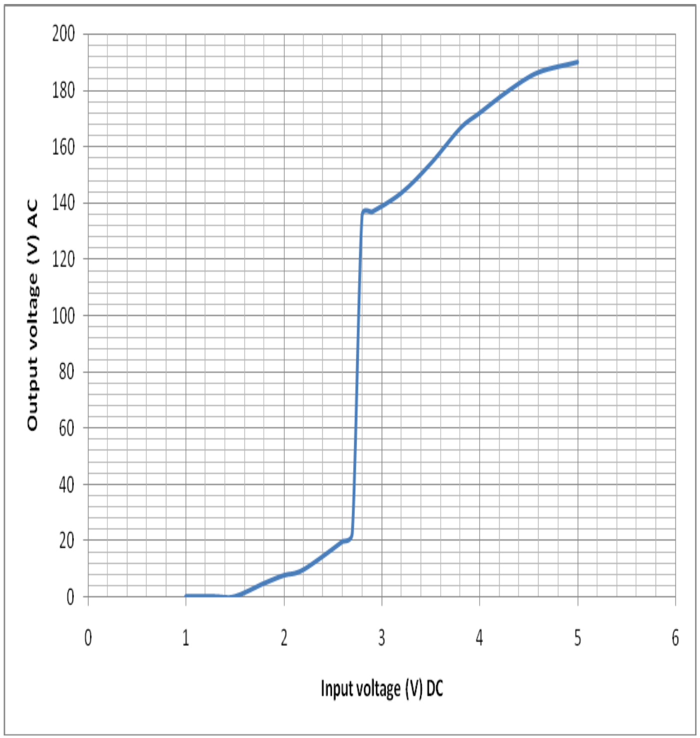
Input DC voltage (V)	Output AC voltage (V)
1.0	0.16
1.3	0.16
1.7	1.9
2.0	2.5
2.3	3.4
2.5	17.8
2.8	24
3.0	30
3.1	32.25
3.2	44
3.3	145
3.6	159
4.0	172
4.3	179
4.6	185
4.8	189
5.0	192

Table for Input volt vs output volt(decreasing)

Input DC voltage (V)	Output AC voltage (V)
5.0	190
4.6	186.4
4.3	180
4.0	172
3.8	166.5
3.5	154
3.2	143.6
2.9	136.9
2.8	135.7
2.7	23
2.6	20
2.2	10
2.0	8
1.8	5.2
1.5	0.16
1.3	0.16
1.0	0.16



fig(9)input control voltage versus output voltage of final control element(increasing)



fig(9)input control voltage versus output voltage of final control element(decreasing)

iv)Reference:

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