POCKET PCR

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Contents

1 Introduction

1.1 Specifications

Parameters	Typical Values
Electrical block size	122x70x40mm
Thermal block size	50x50x50mm
Weight	
Thermal Control	PID Control
Ramp Rate	$> 1°C/s$
Power	9V, 2A USB C PD
No. of wells	5
Sample Size	0.2 mL

Table 1: PocketPCR specifications

1.2 Our Product

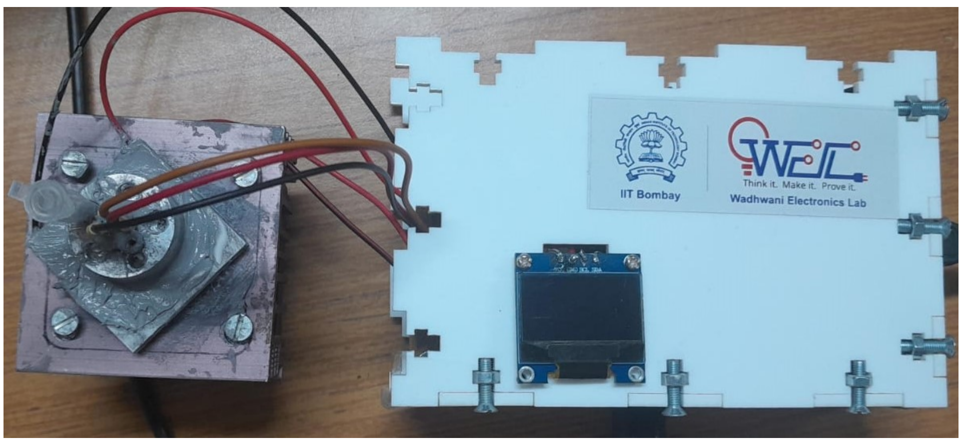

Figure 1: POCKET PCR - Final Product

The electrical block is the pcb side and the thermal block is the combination of heatsink, fan, peltier and the aluminium block and both the blocks can be carried separately.

1.3 PCR-GUI

The following is the thermal cycle obtained in this project with overshoot of $1°C$ in the beginning of the stages of the PCR cycle. The GUI takes inputs from the user like no. of cycles to run and the no. of samples given and shows the progress of the PCR.

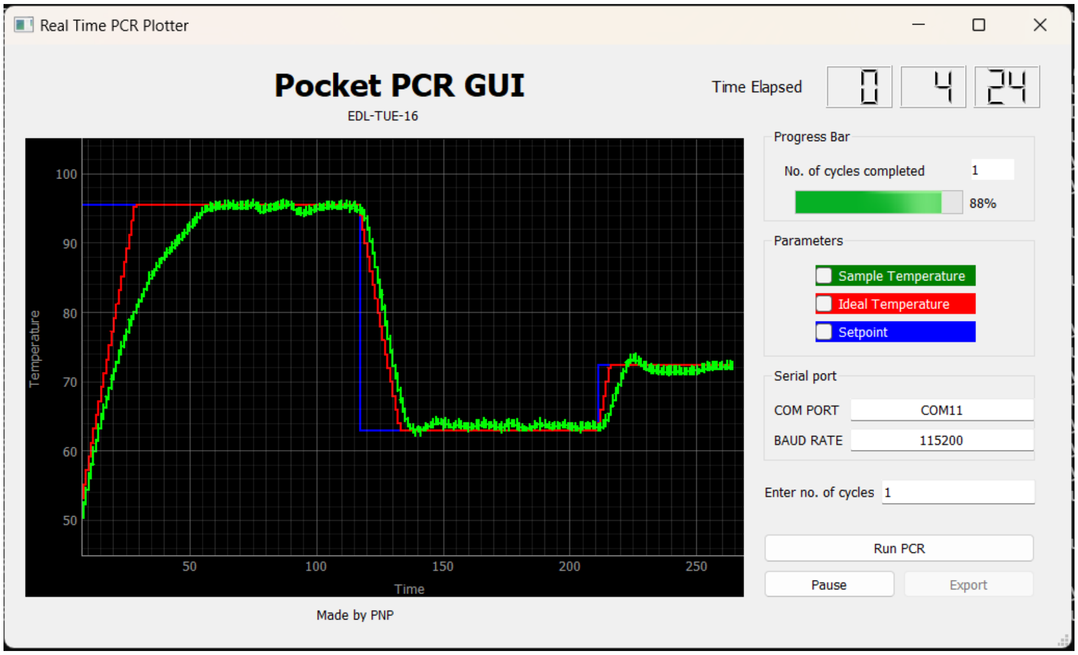

Figure 2: Real Time Plotter

The GUI plotter works on serial communication between computer and the microcontroller. This is developed using Qt Designer which is an easy to design GUI platform and python QSerial for communication and PyQtGraph for real time plotting

2 Overview of Methodology

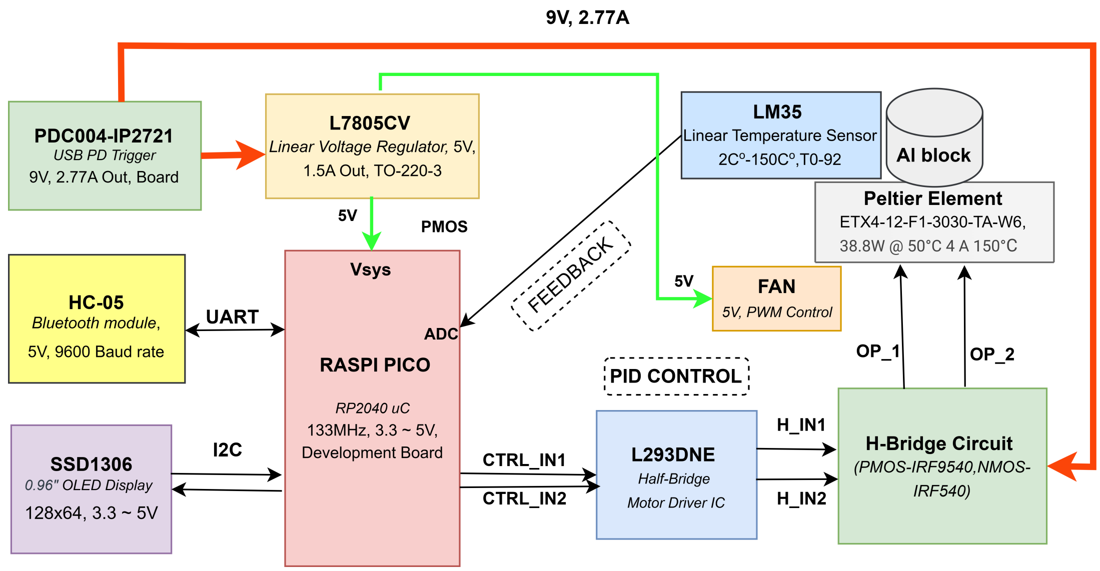

Figure 3: Overall block diagram

3 Component Selection

The critical components in this project are peltier module, H-bridge circuit, temperature sensor and power supply. Peltier module chosen should give high ramp rate and the operting temperature should be above 120°C.

- **Peltier Module**
  Model Selected : ETX4-12-F1-3030-TA-W6 38.8W @ 50°C 4 A 150°C
  The following calculation was done to decide the peltier module selection based on the maximum power transferred on the hot side of the peltier at the operating temperature. We have critically observed the I-V graphs of the Peltier module as this is the critical component in this project to obtain a high ramp rate.

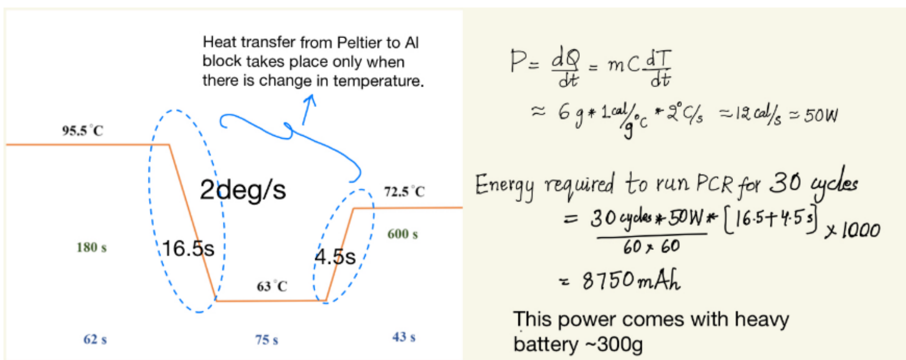

Figure 4: Power required came to be $50W$

- **Power Supply** So based on the power requirement in the above figure, we need a power supply of 50 W to achieve the ramp rate. Available options are battery, switch mode power supply (SMPS), and USB/DC power. High wattage rechargeable lithium polymer battery comes at heavy weight of around 300g and is not reliable to stay for 3 hrs of 30 PCR cycles. SMPS is bulky and risk of getting shocks while operating.
  USB power using C port requires configuration of CC pins to draw high power. We opted for USB power delivery with 12V and 3A as a power supply. While testing we used 9V, 2.77A USB C Samsung Charger using a USB PD Trigger in the final prototype.

- **H-Bridge IC** DRV8870DDA is chosen based on the voltage and current ranges at input and output.

- **Temperature Sensor** PTS1206 smd thermistor is chosen due to the linear temperature vs resistance characteristics.

4 PCB

4.1 Schematics

The schematics are gone through multiple revisions due to change in the components. The figure 5 is the final schematic used in the project.

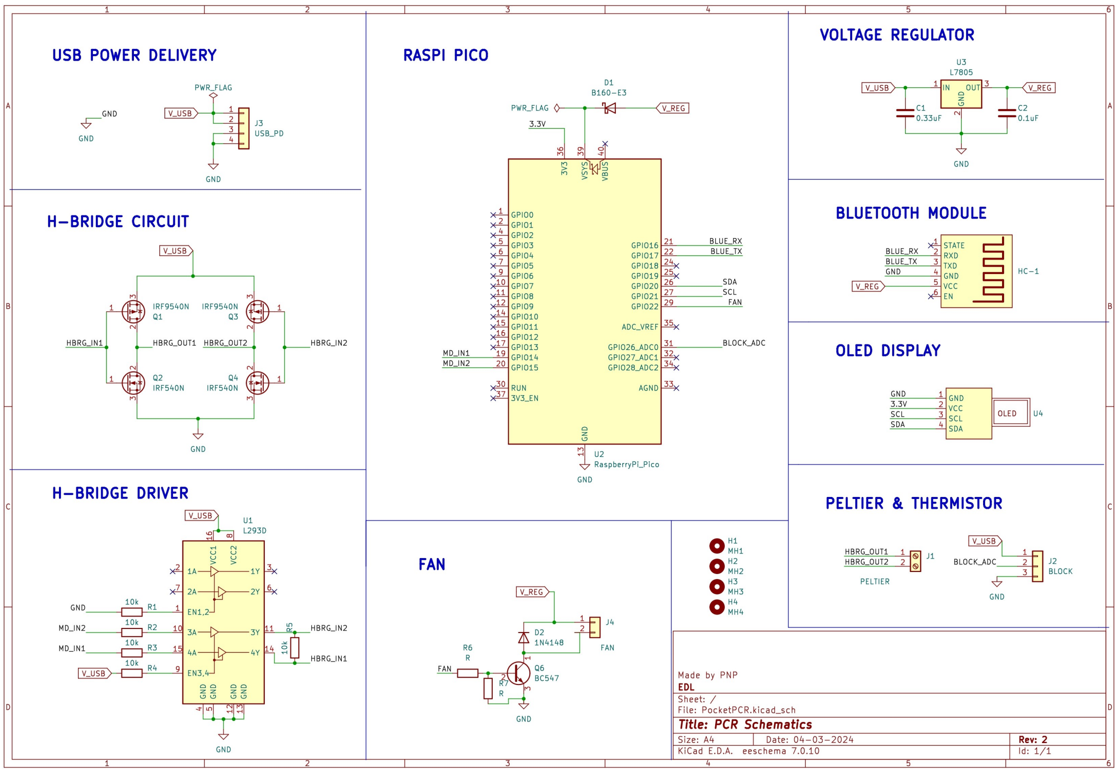

Figure 5: Final Schematics

4.2 Layout

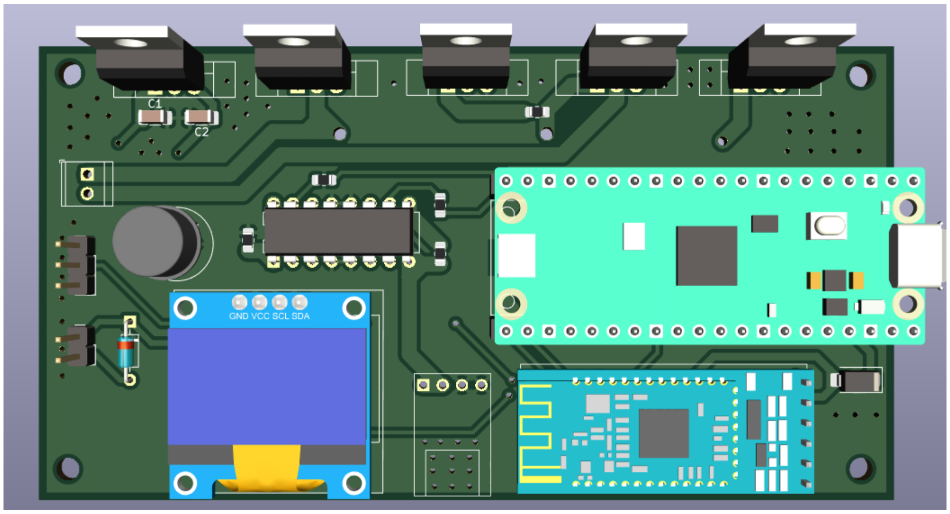

Figure 6: 3D view of the PCB

5 CAD Model

The following of the CAD model are taken from the github of Gaudi PCR.

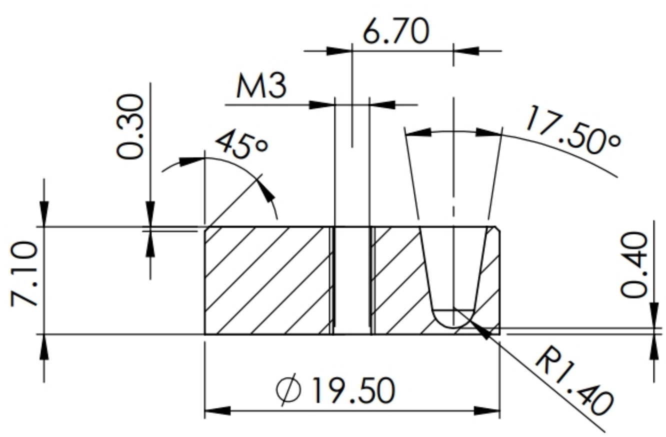

Figure 7: Aluminium block dimensions

Key factors The temperature sensors must fit in contact with the aluminium throughout the PCR Cycle. So the slot for the temperature sensor must be designed carefully while taking into the consideration of mass. Adding extra mass on the aluminium block decreases the ramp rate.

6 PID Tuning

PCR cycle has 3 stages: Denaturation ($@95.5°C\ for\ 62s$), Annealing($@63°C\ for\ 75s$) and Extension($@72.5°C\ for\ 43s$). PID tuning is only used in the beginning of these stages and rest everywhere the duty cycle is set either high or low to achieve the maximum ramp rate. PID constants vary with the change in mass, sample and material. PID constats are tuned separately for the 3 of the stages.

Principle PID constants are intialized at zero and Kp is increased until the error oscillates. Then Ki is increased to minimise the error and Kd to slow down the response. Factors into consideration: high Kp leads to exponential increase in the steady state error and high Kd adds the constant steady state error. The major concern is the overshoot in the beginning of the stage.

7 Perfboard Testing

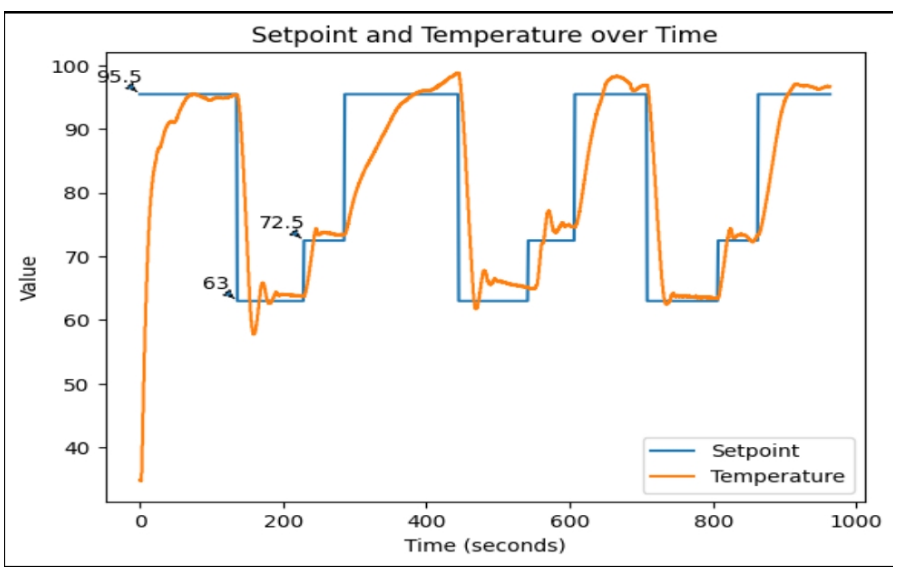

Figure 8: Ramp rate of $1.67°C/s$

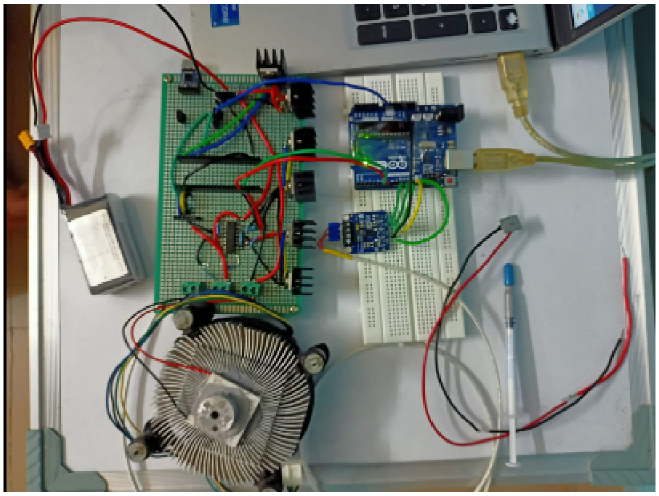

Figure 9: Perfboard testing setup

8 Challenges Faced

8.1 H-Bridge IC

- **Problem Faced :** The H bridge motor driver IC is meant to drive inductive loads only. Therefore it could not drive the peltier module which is a capacitative load. As can be seen in Figure 10 that in the datasheet mentioned inductive load

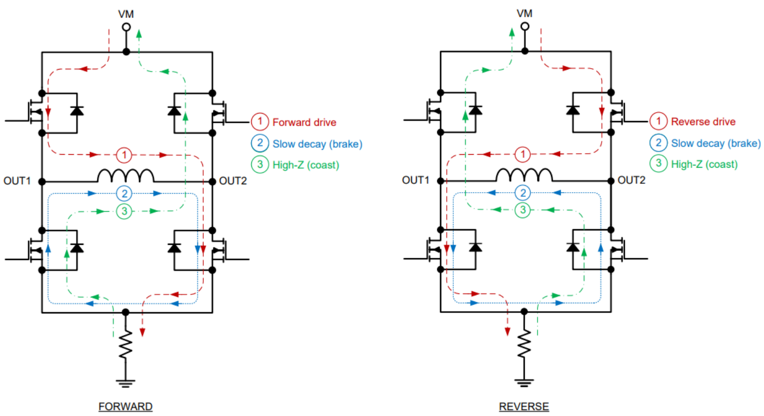

Figure 10: Datasheet of DRV8870 showing the load connected at the output terminals of the H-Bridge

- **Solution:** Instead of using H bridge motor driver IC we used PMOS(IRF9540) and NMOS(IRF540) in H bridge configuration driven by L293DNE motor driver as seen in Figure 11.

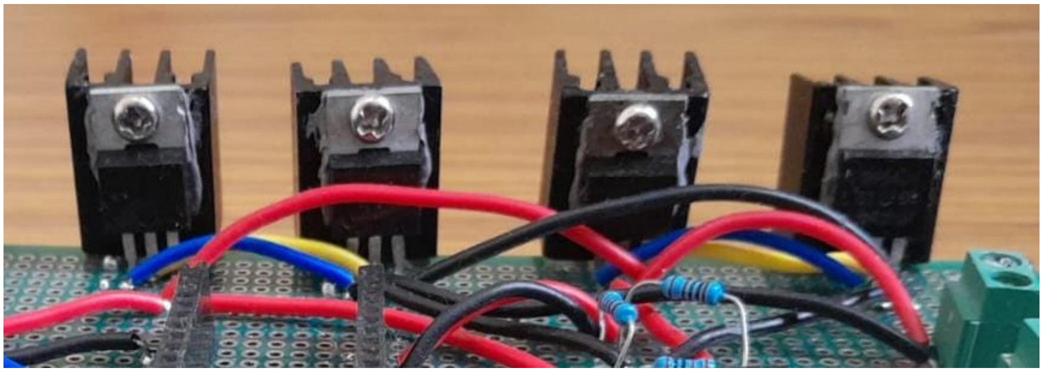

Figure 11: H-bridge configuration using PMOS and NMOS

- **Concern** MOSFETs and heatsinks takes more space increases the form factor of the PCR. In future, a h-bridge driver which is capable of running a peltier has to be used.

8.2 SMD Thermistor

- **Problem Faced** - Initially we choose PTS1206 15 for reading temperature value because it has linear characteristics. Later we realised it gave unreliable readings as shown in Figure 12 and could not be used directly
- **Mitigation** - Because of the noise in the temperature readings, we have used an instrumentation amplifier for low noise readings. Our circuit runs on single supply, so INA1218 is chosen to read the voltage values of thermistor in wheatstone bridge configuration. This also did not work because RTD sensors require constant current source to give accurate readings ($V = I * R$) so even if we had used instrumentation amplifier it would not have worked unless and until constant current source was provided

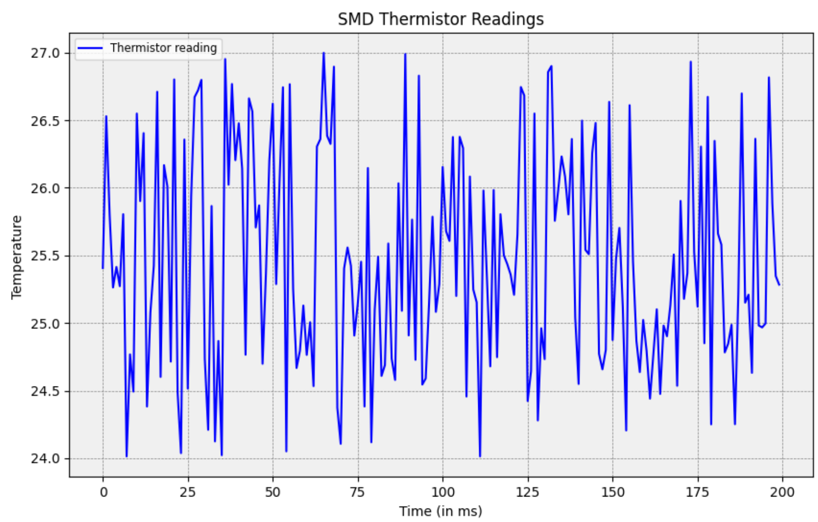

Figure 12: Temperature readings using PTS1206 (SMD Thermistor) in Voltage Divider configuration on Raspi pico ADC

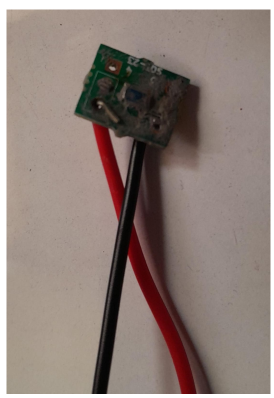

Figure 13: SMD Thermistor

8.3 THT Sensor Issues

- **Problem Faced** - After facing issue with the SMD thermistor we switched to LM35 precison thermistor at the last moment. It gave reliable readings but due to it's peculiar shape it was difficult to keep it in contact with the aluminium block

- **Solution** - We made a new aluminium block with a slot for the LM35 sensor as shown

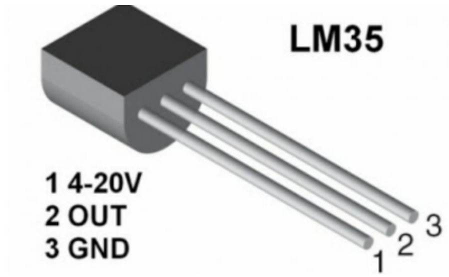

Figure 14: LM35 centigrade sensor

Figure 15: LM35 centigrade sensor

8.4 Aluminium Block

- **Problem Faced** We tried to replace the old model of aluminium block with a new block with a slot for the temperature sensor as shown in 17. But as the mass of the AL block increased the ramp rate decreased to almost less than 1 C/sec
- **Solution** - We tried to reduce the mass of new Al block by chipping off excess metal as much as possible but still there was the issue of low ramp rate hence we switched back to old Al well. Moreover, even in the old Al well it was difficult to maintain the contact of the LM35 sensor hence we tried a lot of ways to improve the contact like adding a 2mm nut bolt or adding copper wires which showed varied temperature profile for the same Kp,Ki and Kd constants as shown in the Figure **??** and **??**

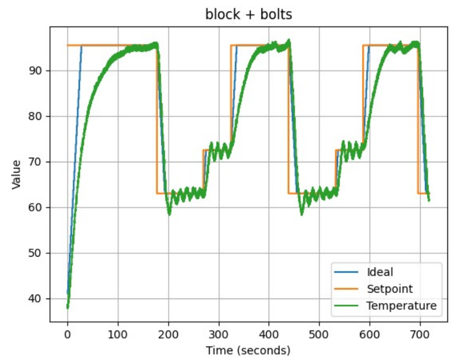

Figure 16: Thermal profile after adding a 2mm bolt to the slot

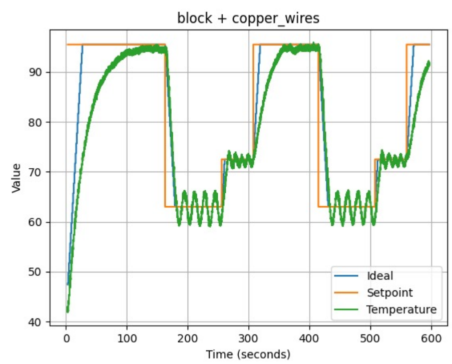

Figure 17: Thermal profile after adding Copper wires to the slot

9 Lessons Learnt

- It is essential to have a resonance among the team members for successful completion of the project. Work ethics play a crucial role in overcoming the challenges.
- We have tested the SMD thermistor in the early stages and mitigate the issue using the instrumentation amplifier.

10 Conclusion

In conclusion we were able to achieve a thermal profile but challenges with the thermal contact of temperature but engineering practices helped to overcome to some extent. We are happy with the engineering aspects of the projects but couldn't get the satisfaction of DNA amplification.

11 Future Work

In future following aspects can be improved upon :

- **PID Tuning for different samples** As the PID constants vary with the thermal load added, PID constants have to be tuned for different no of samples added on the aluminium block. An option to select the no. of samples in the user interface as well.
- **Temperature Sensor -** PT100 is a good temperature sensor with precise readings. We didn't use it in our final product due to size constraint, but in future smaller RTD probes can be used for better performmance
- **Aluminium block -** Special attention must be paid while making the aluminium block. Better to choose a temperature sensor which has easy to drill slot. High power laser cut or hydralic cut can be used to have precise slot for the temperature sensor such that its always in contact with the block
- **Power -** Instead of 9V power adapter we can use 12V power adapter for better ramp rate
- **Mechanical Assembly -** Instead of having T-slots in the acrylic enclosure, having door hinge would be better in case it needs to be opened for maintenance etc. Morevover having an appropriate enclosure for the peltier module and heat sink
- **App development -** Reference can be taken from the miniPCR app available commercially and something of similar sort can be built with MIT App inventor and interfacing Bluetooth module

12 Acknowledgements

- We would like to thank our Prof. Siddharth Tallur for his guidance , critical inputs and words of encouragement
- We thank Maheshwar Sir and Ankur Sir in patiently helping us in debugging and troubleshooting of our circuit
- Our sincerest gratitude to our friend Yashodhan Tingne, for CNC related brainstorming and our fellow classmate Yash Udayan Paritkar for helping us with technical doubts

References

[1] ETX4-12-F1-3030-TA-W6, Peltier module,https://www.digikey.in/en/products /detail/laird-thermal-systems-inc/387004911/13148932

[2] https://github.com/WEL-Projects/WELPCR/