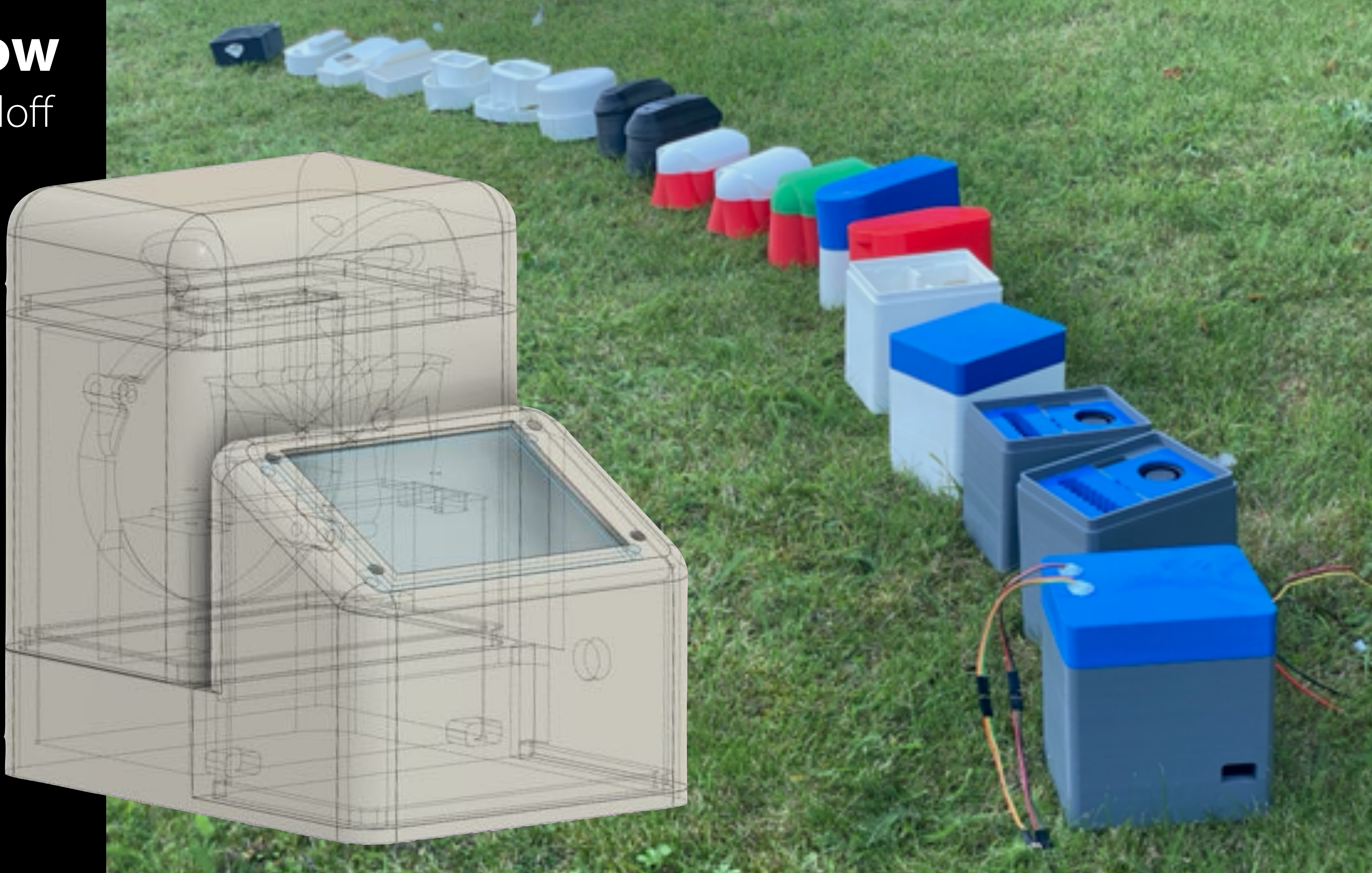
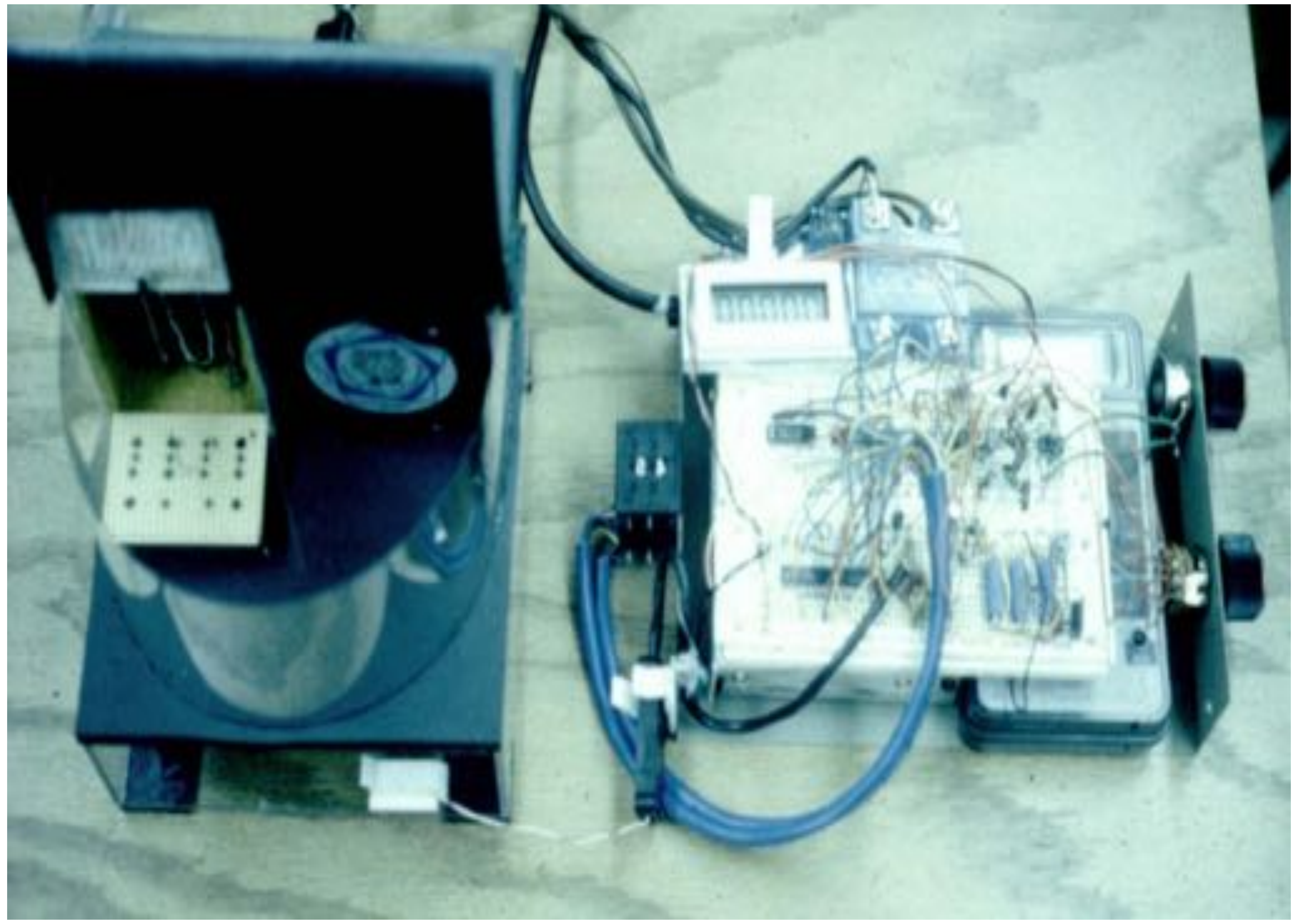
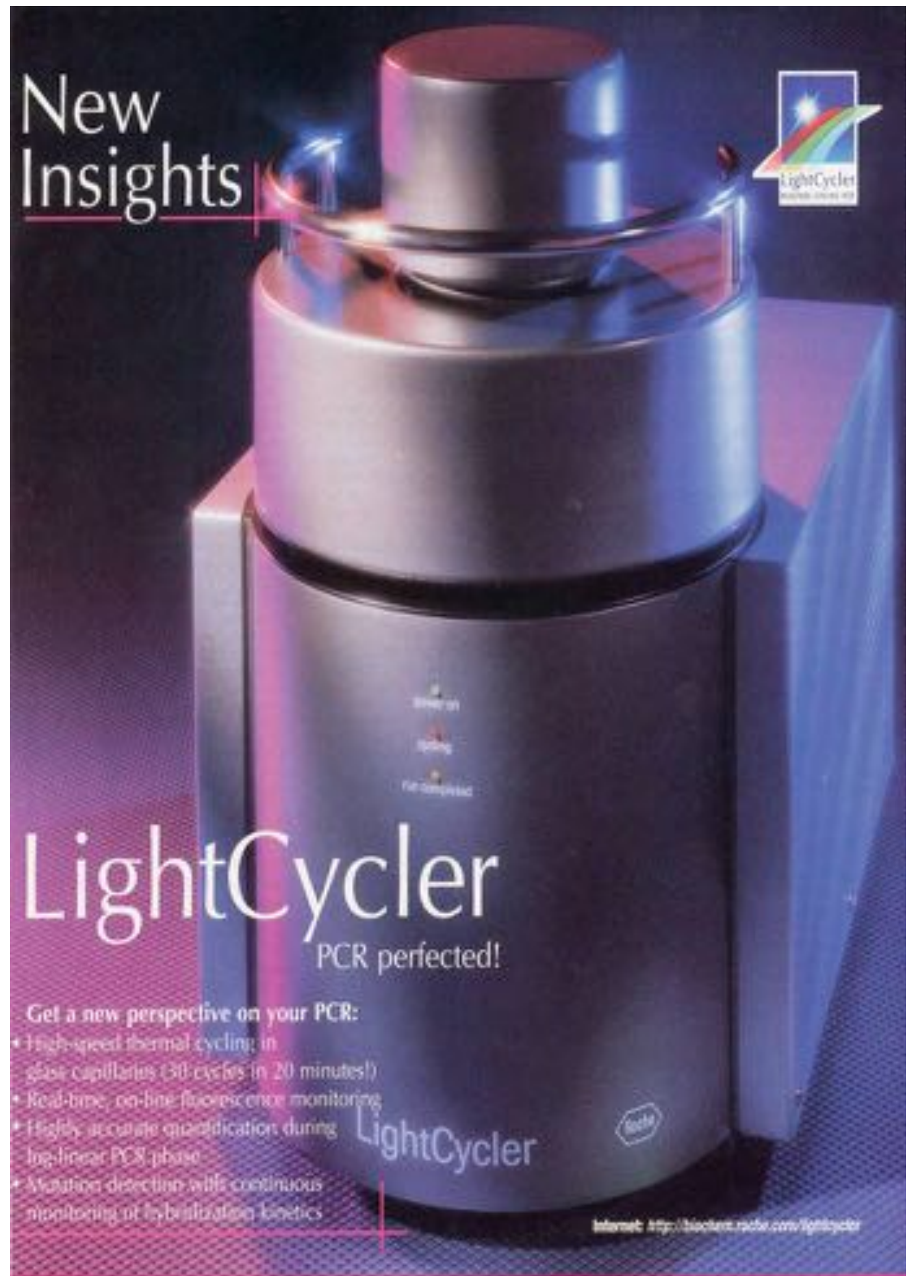
AirFlow

Jim Haseloff



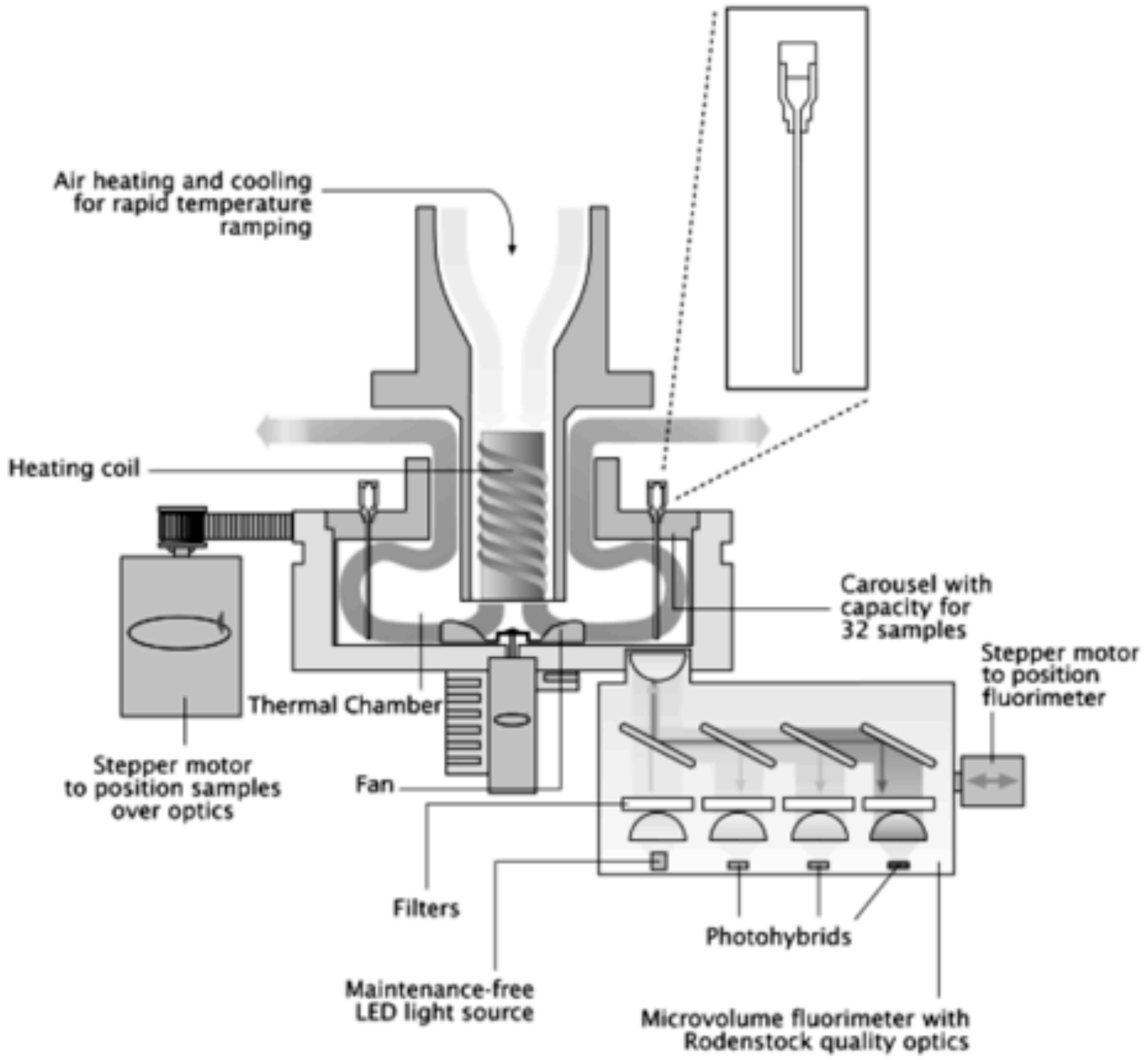
Early thermal cycler designs: used heated air and venting - subsequently overtaken by solid-state devices





Heating with a Hair Dryer (1995)
"For a real-time system, the light bulb in the thermal cycler had to be replaced with another source of heat. We went back to the hair dryer concept. The dryer and vacuum cleaner were connected to the center drum by vacuum hose tubings. This contraption was so loud! It was remarkable that it worked as a thermal cycler."

Carl Wittwer Lab, University of Utah
https://arup.utah.edu/media/rapid_pcr/rapid_pcr_slides.pdf



High temperature (>100ºC) resistant plastics

new materials for 3D printing

plastic fibre optics

Polylactic acid (PLA)

Thermal

Property	Value
Glass transition temperature	60.0 °C
Heat deflection temperature	60.0 °C
Melting point	175.0 °C

Extrudr GreenTEC Pro

Thermal

Property	Value
Melting point	190 - 210 °C
Vicat softening temperature	160 °C

https://matmatch.com

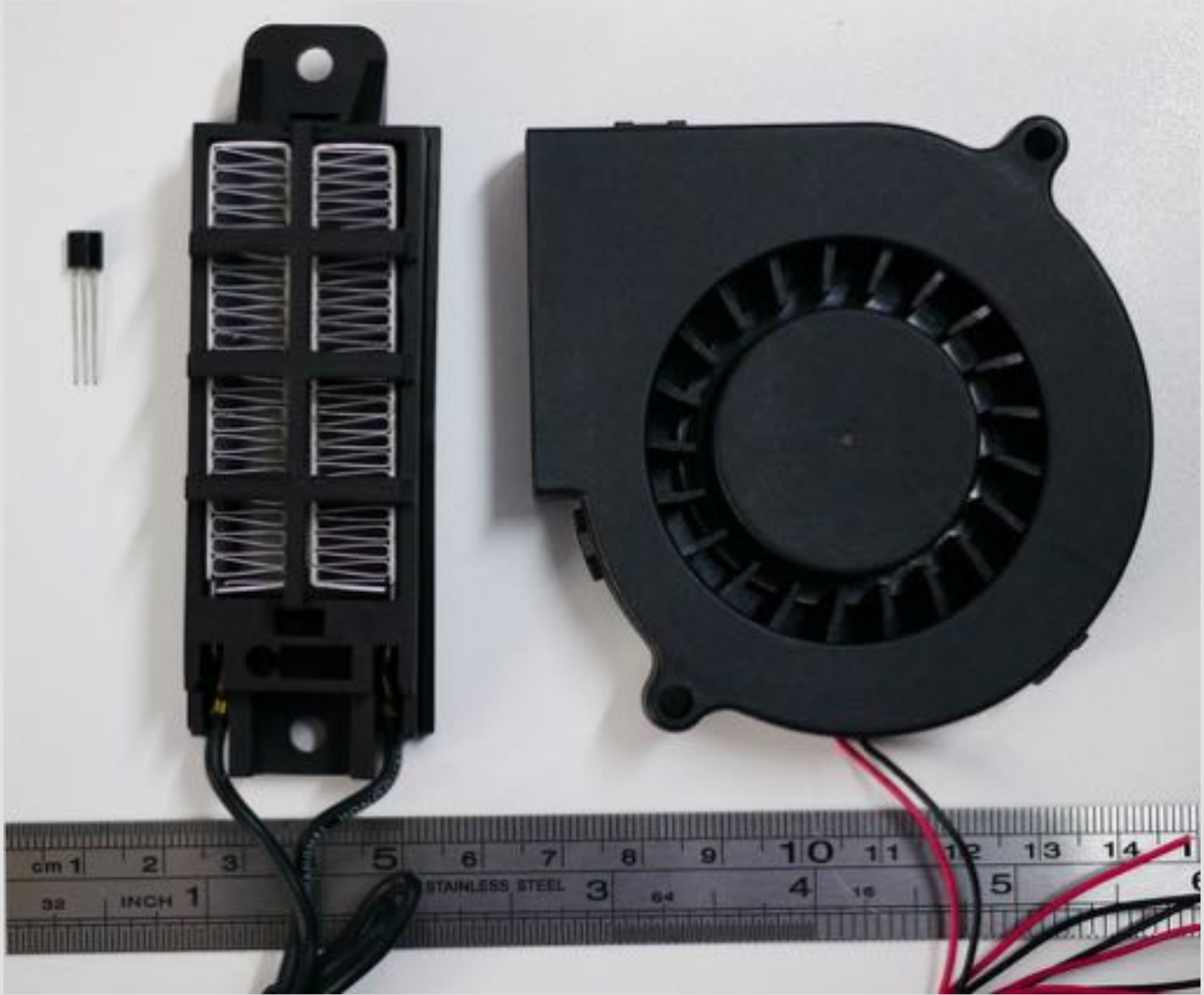
Plastic fiber optic KHTE-C01-2,2-2,0-K118

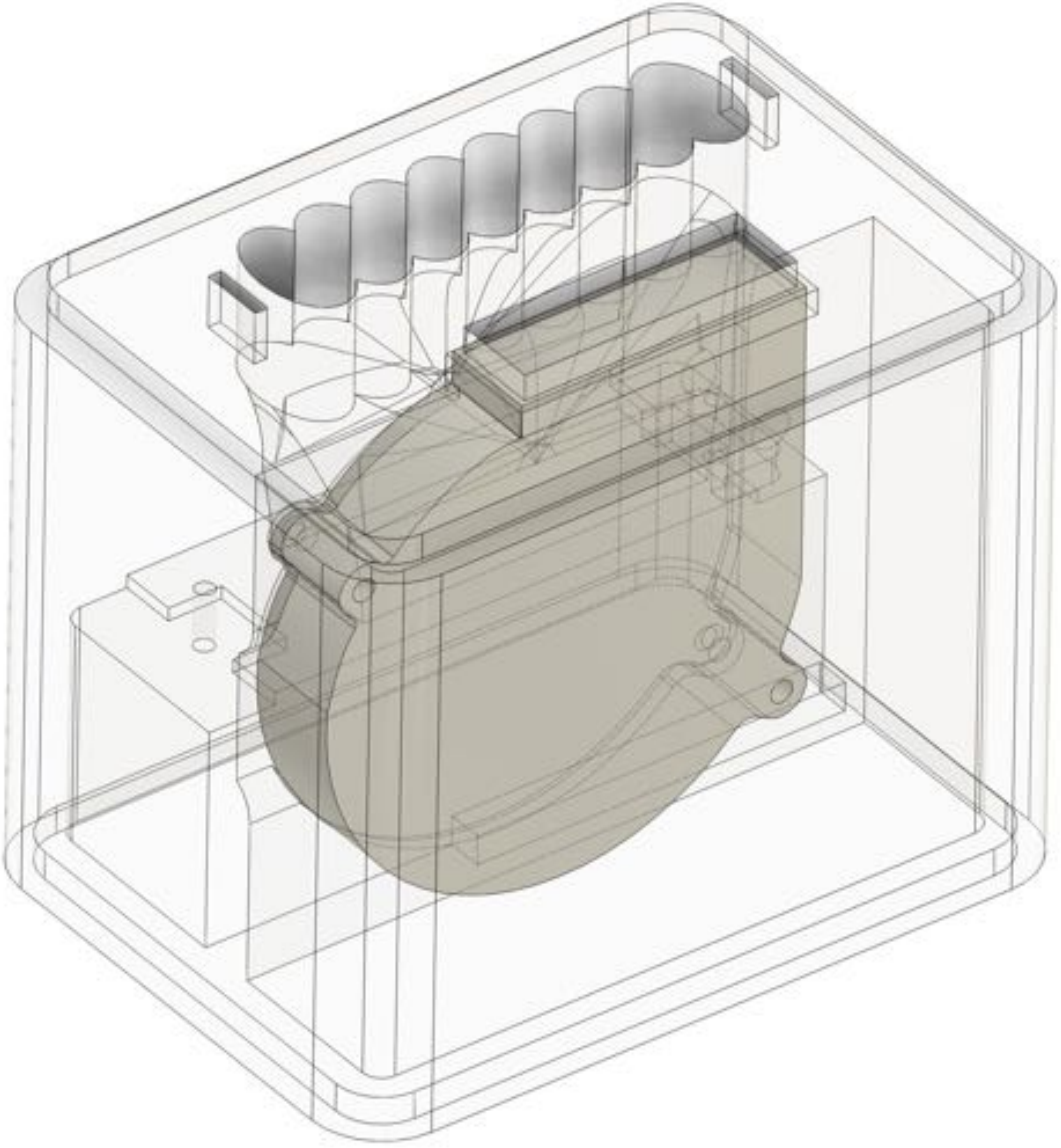
Technical data		
General specifications		
Detection range		SU18: 115 mm SU18/35: 800 mm SU19: 115 mm
Fiber optic length	l	2000 mm , adjustable
Fiber optic diameter	d	2.2 mm
Adapter form		00
End piece		Side view / Periscope
Bending radius		min. 25 mm
Fiber configuration	Fv	see dimensions
Angle of divergence		67 °
Accessories provided		Cutter for plastic fiber optics
Ambient conditions		
Ambient temperature		-55 ... 115 °C (-67 ... 239 °F)
Mechanical specifications		
Material		
Optical face		plastic
Sheathing		PVC
Core		plastic
End piece		Stainless steel 1.4305 / AISI 303
General information		
Scope of delivery		Fiber optic cables packaged in pairs

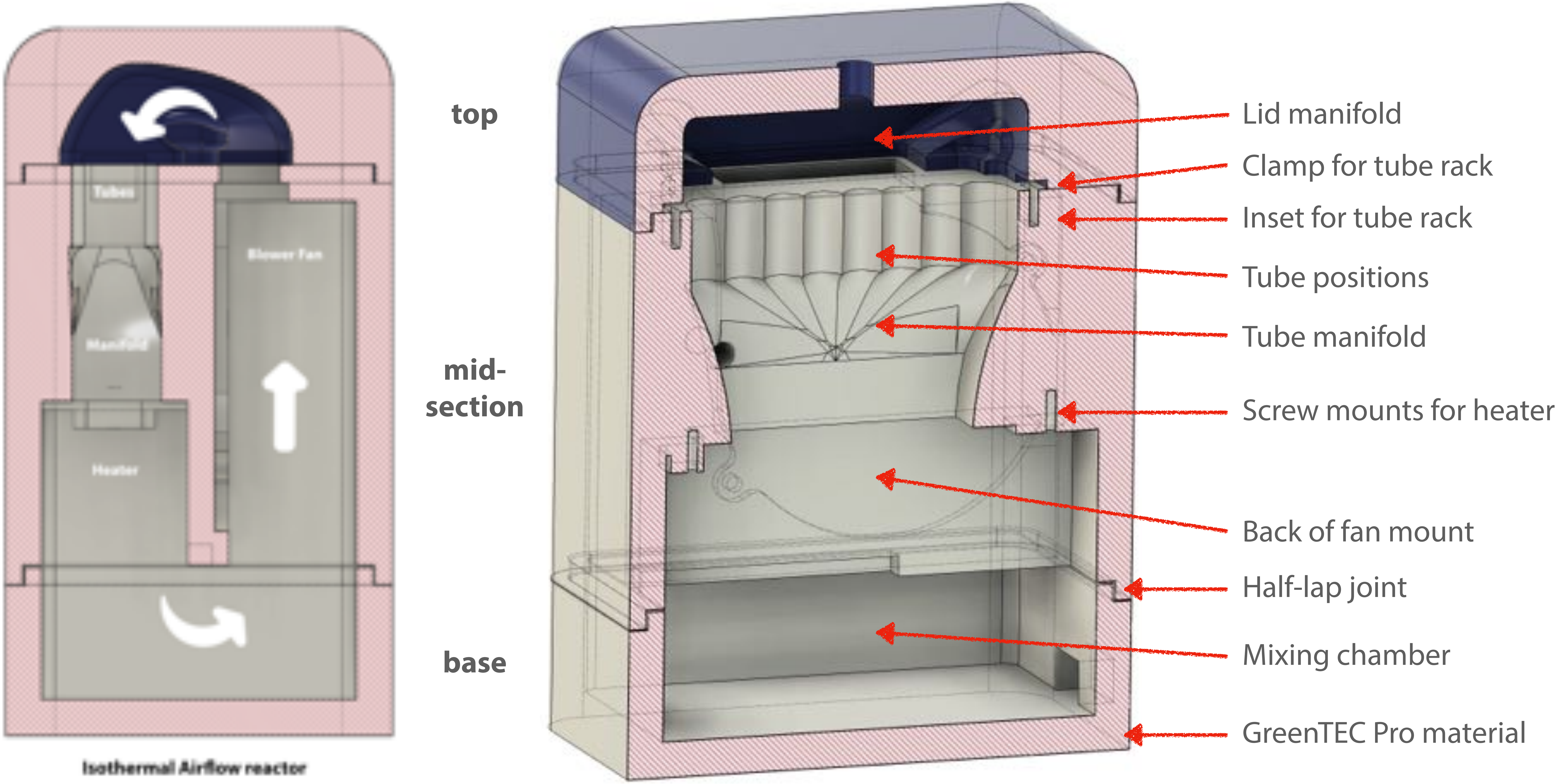
Temperature regulated microreactor

Device specifications:

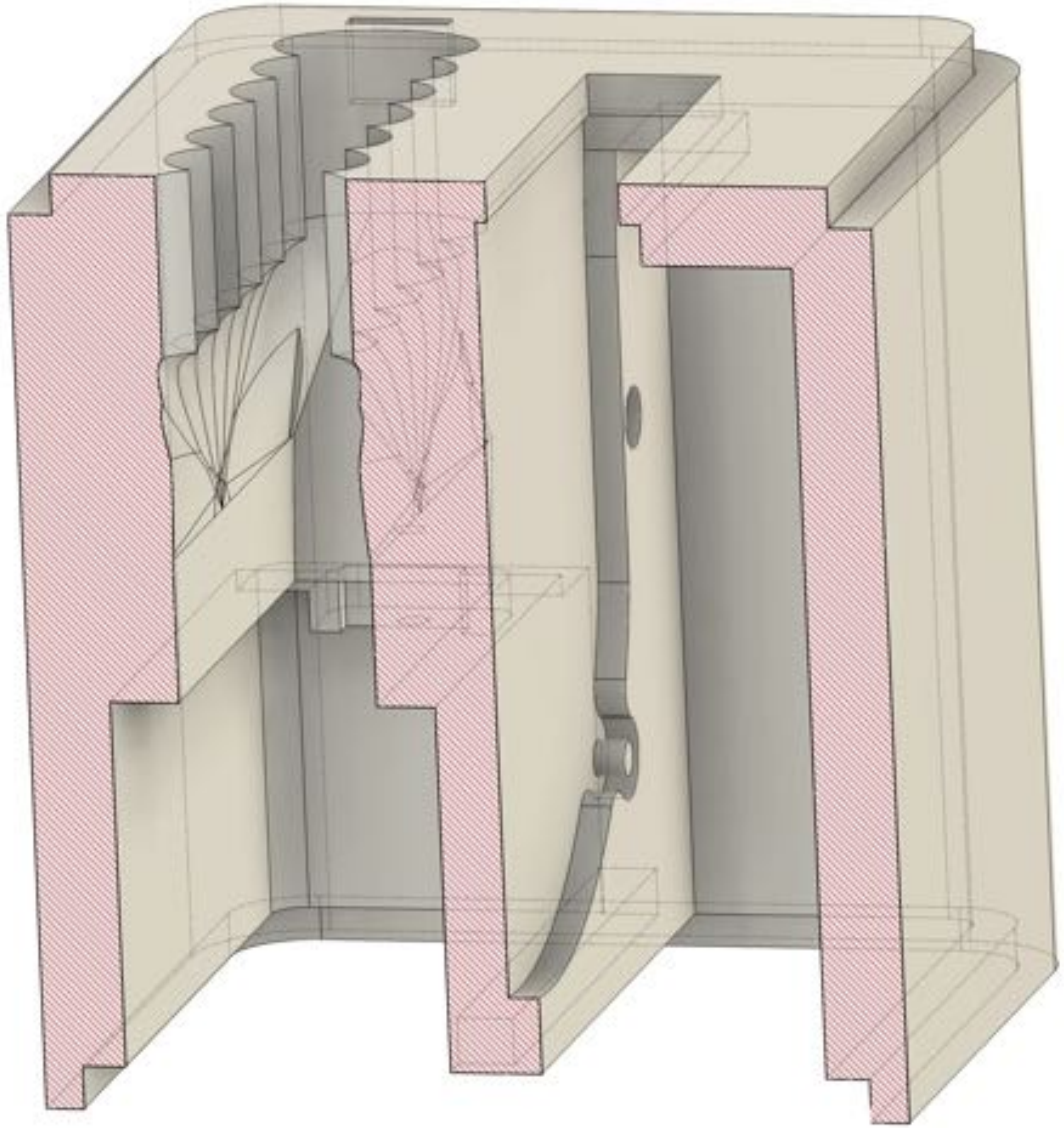
- **Heating**: an off-the-shelf PTC resistive element as heat source.
- **Air flow**: unidirectional fan-forced air flow through the device, using a low-cost computer blower fan.
- **Sample holder**: space for at least one 8-microtube strip that takes up a volume of approximately 80x30x10mm - with allowance for possible future integration of optical sensors or cheap plastic fibre optics.
- **Control**: an accurate thermal control system using low-cost Arduino electronics and sensors.
- **Interface**: touchscreen microcontroller interface that allowed easy use of the programmable device.
- **Size**: minimal volume of air for recirculation, to improve response to heating (or cooling).
- **Accessible**: minimise costs of construction and use components that are globally accessible.
- **Sharing**: use open source documentation of 3D printing, no-code programming, commodity electronics to promote free sharing and modifications of the design.


cm
INCH
STAINLESS STEEL



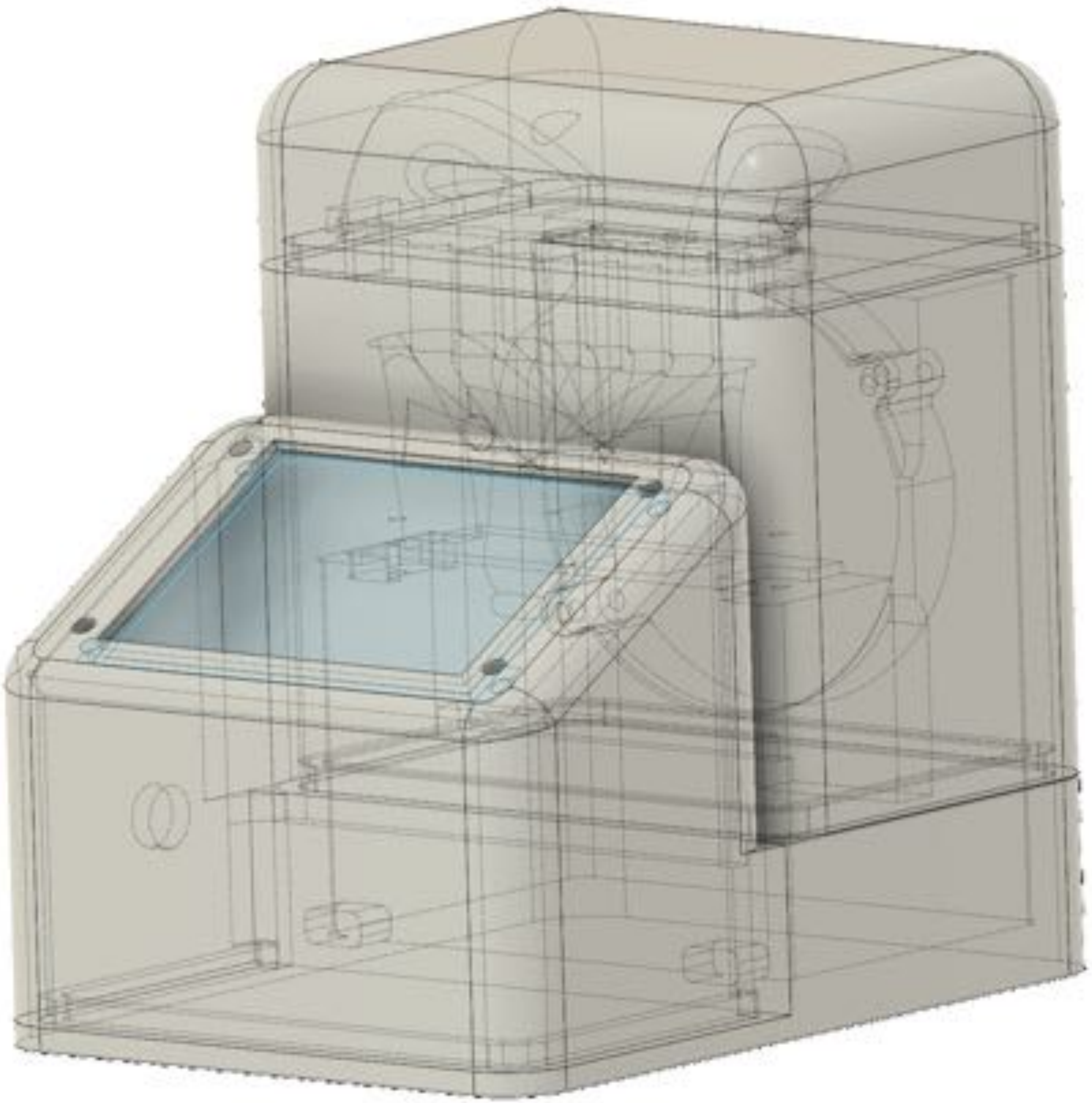


Isothermal Airflow reactor



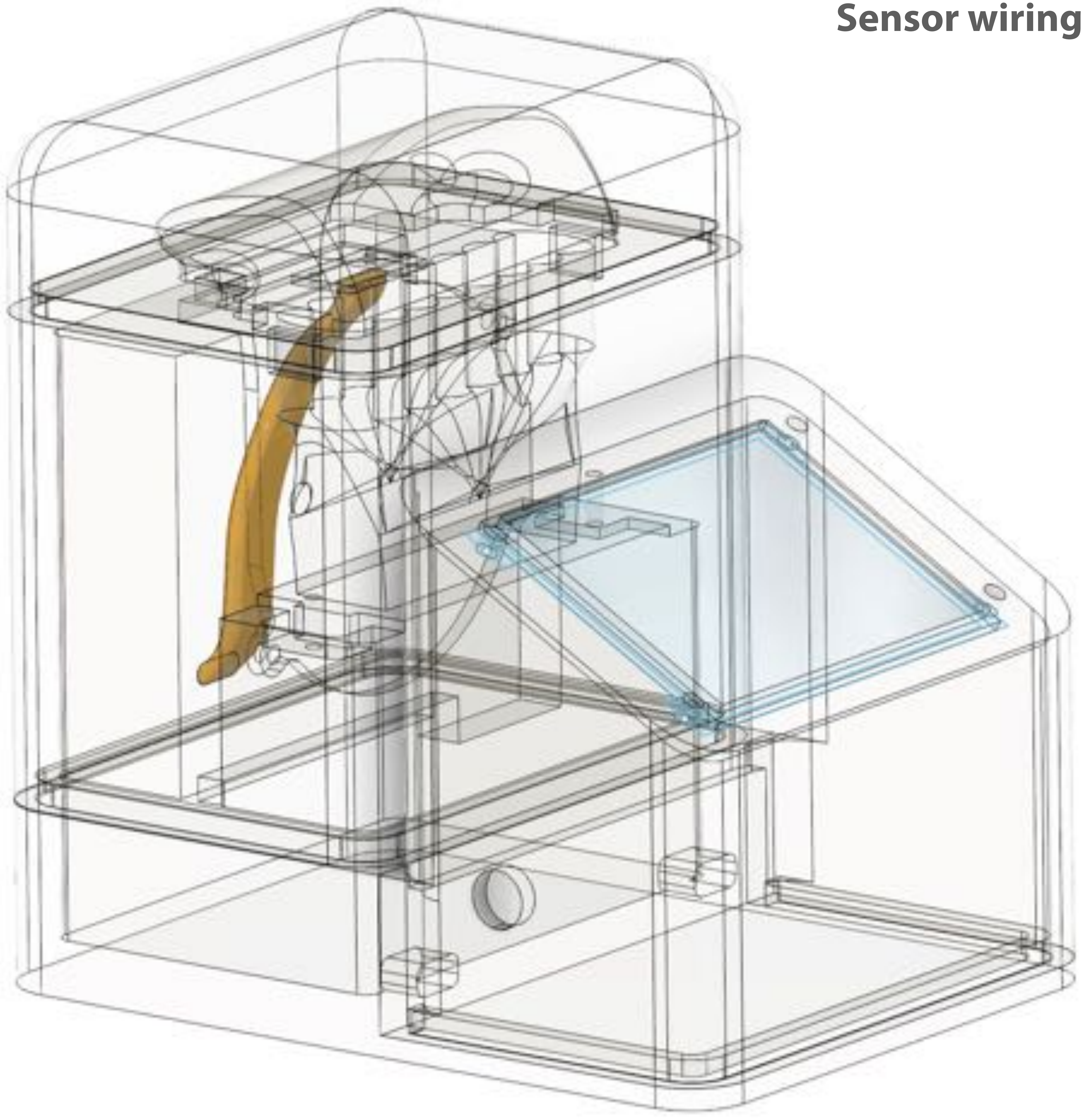
Vessels printed in sections: to fit components and include inbuilt manifold for air flow

Addition of console section

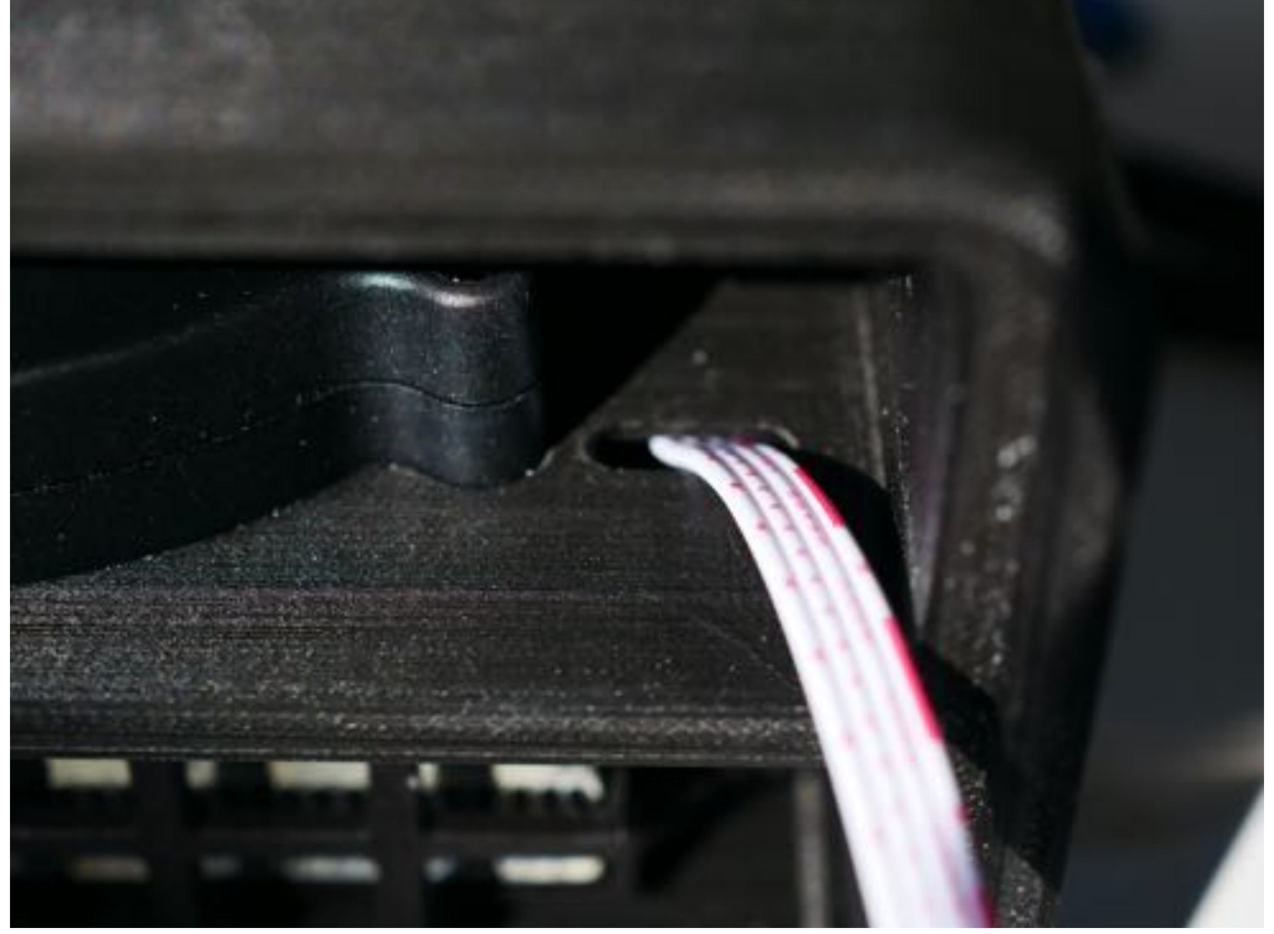


3D printed with Extrudr GreenTEC Pro filament

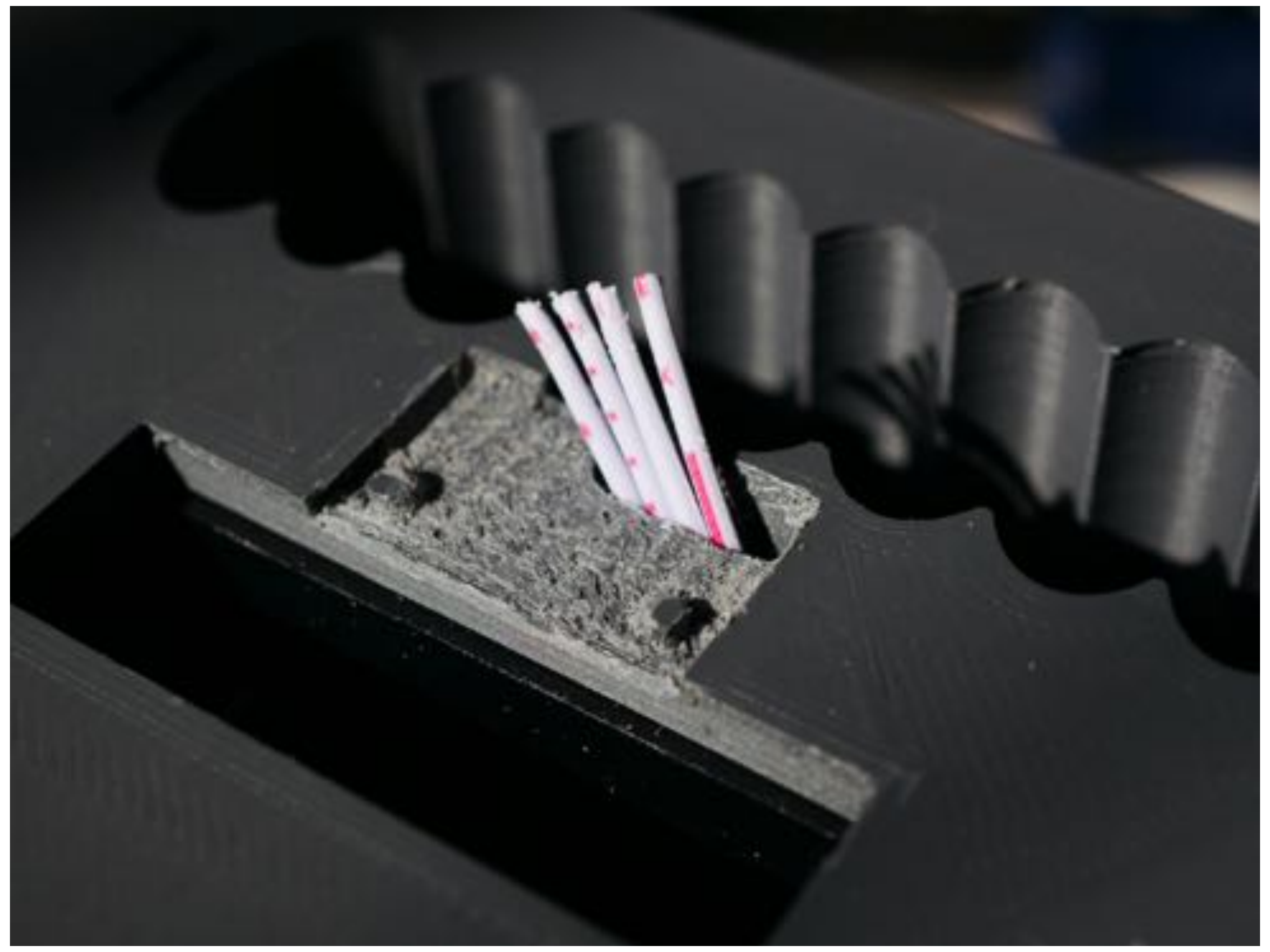
Sensor wiring



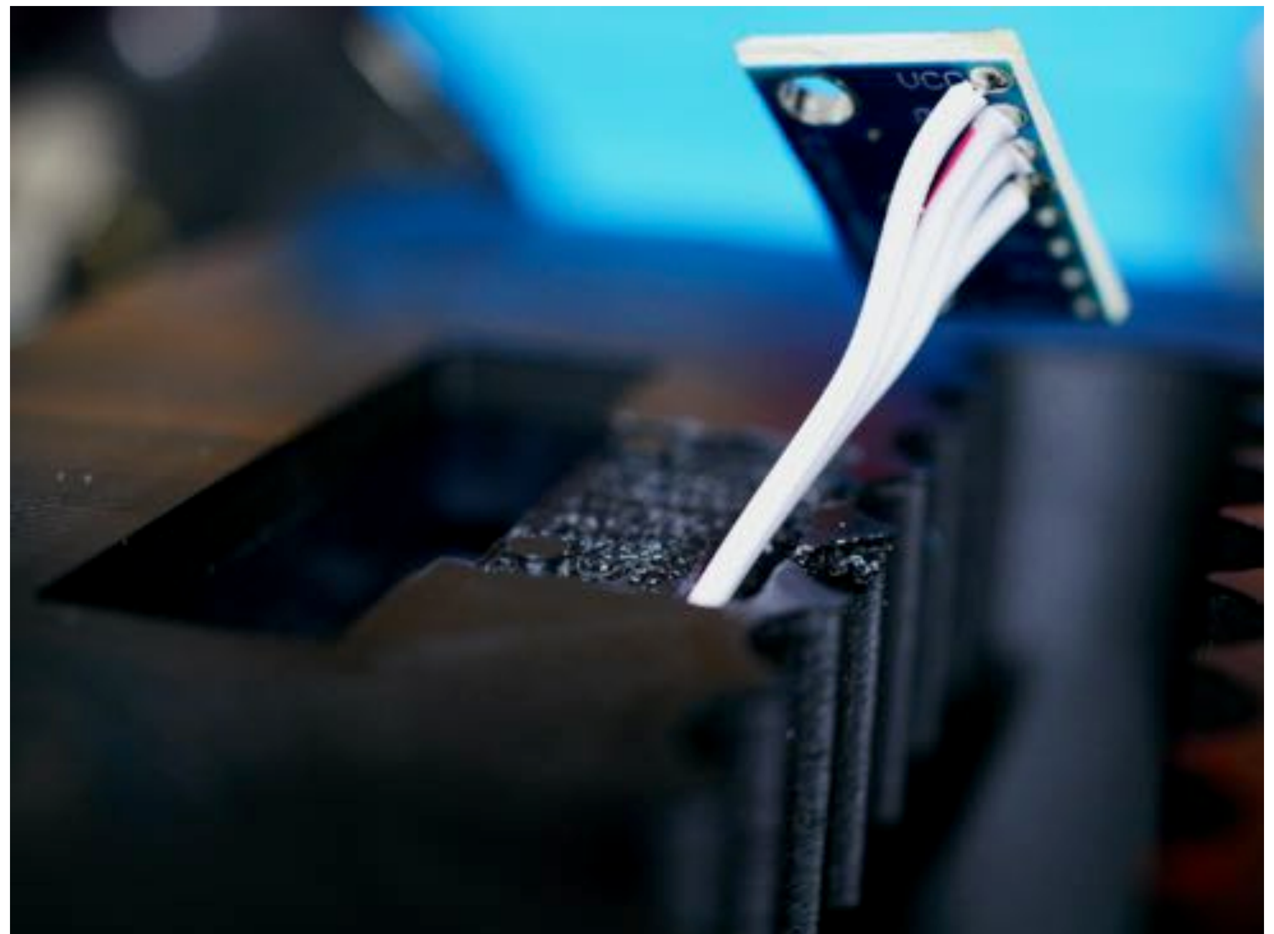
Cable routing for MCP9808 temperature sensor (+/- 0.25ºC)



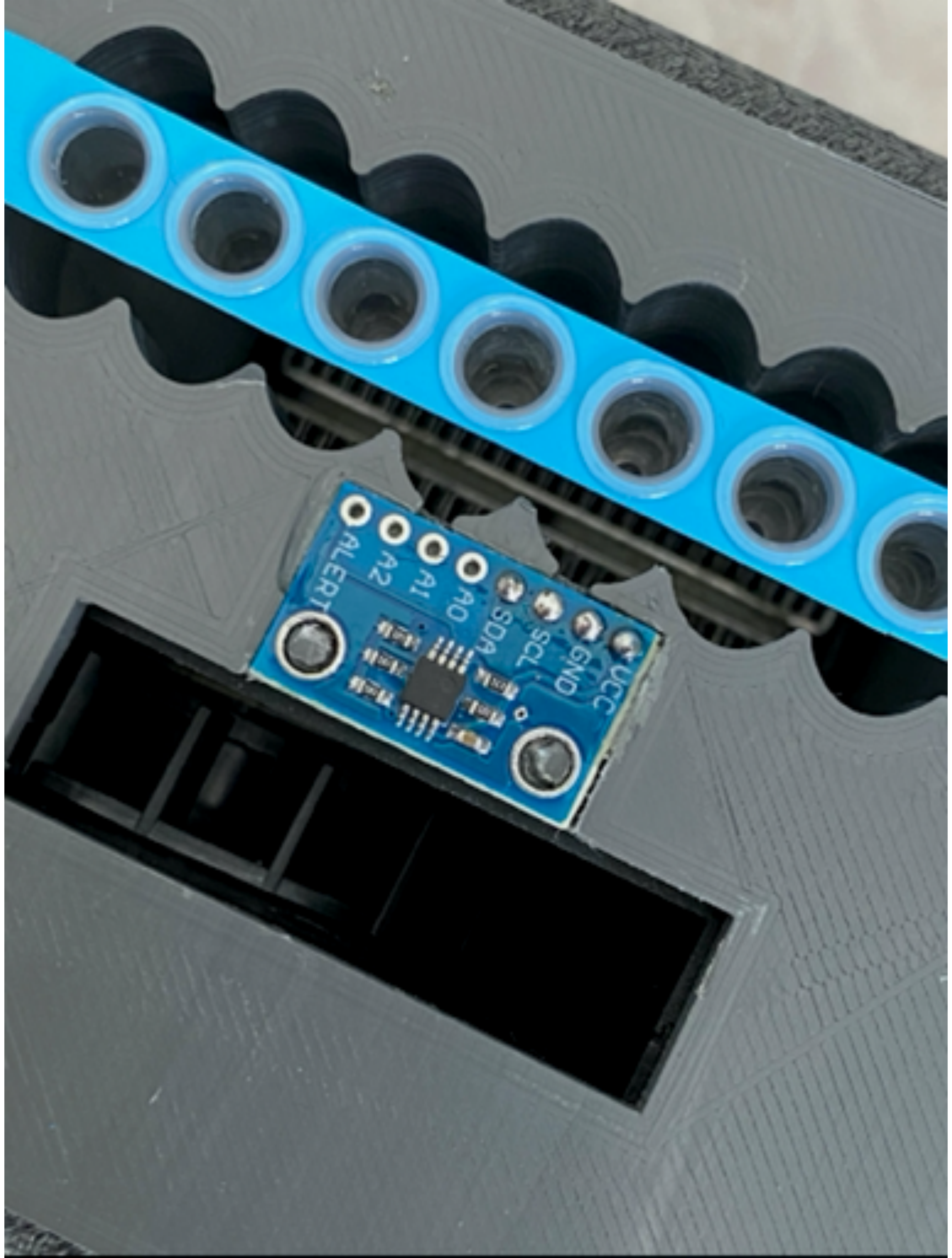
In



Out



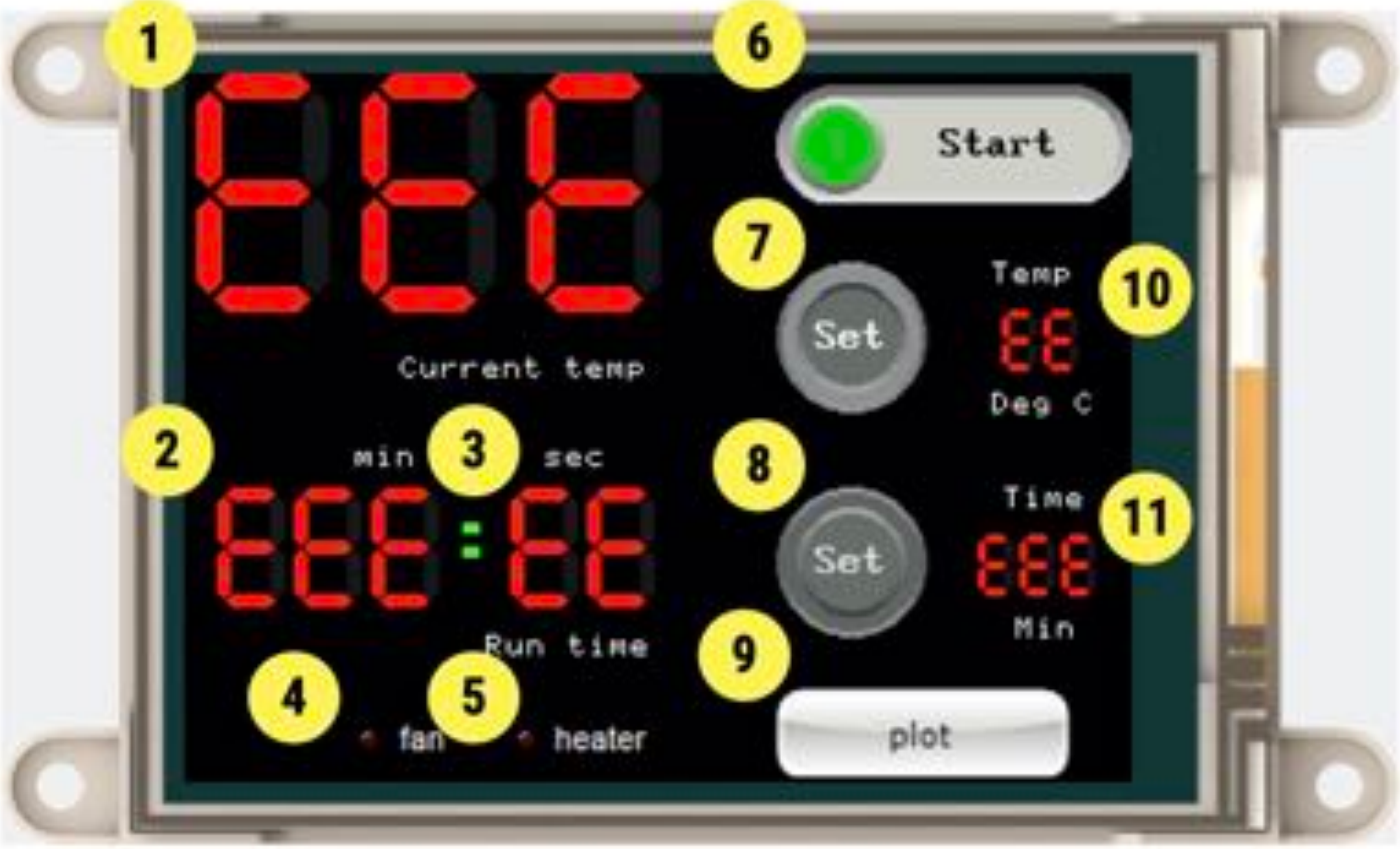
Fix



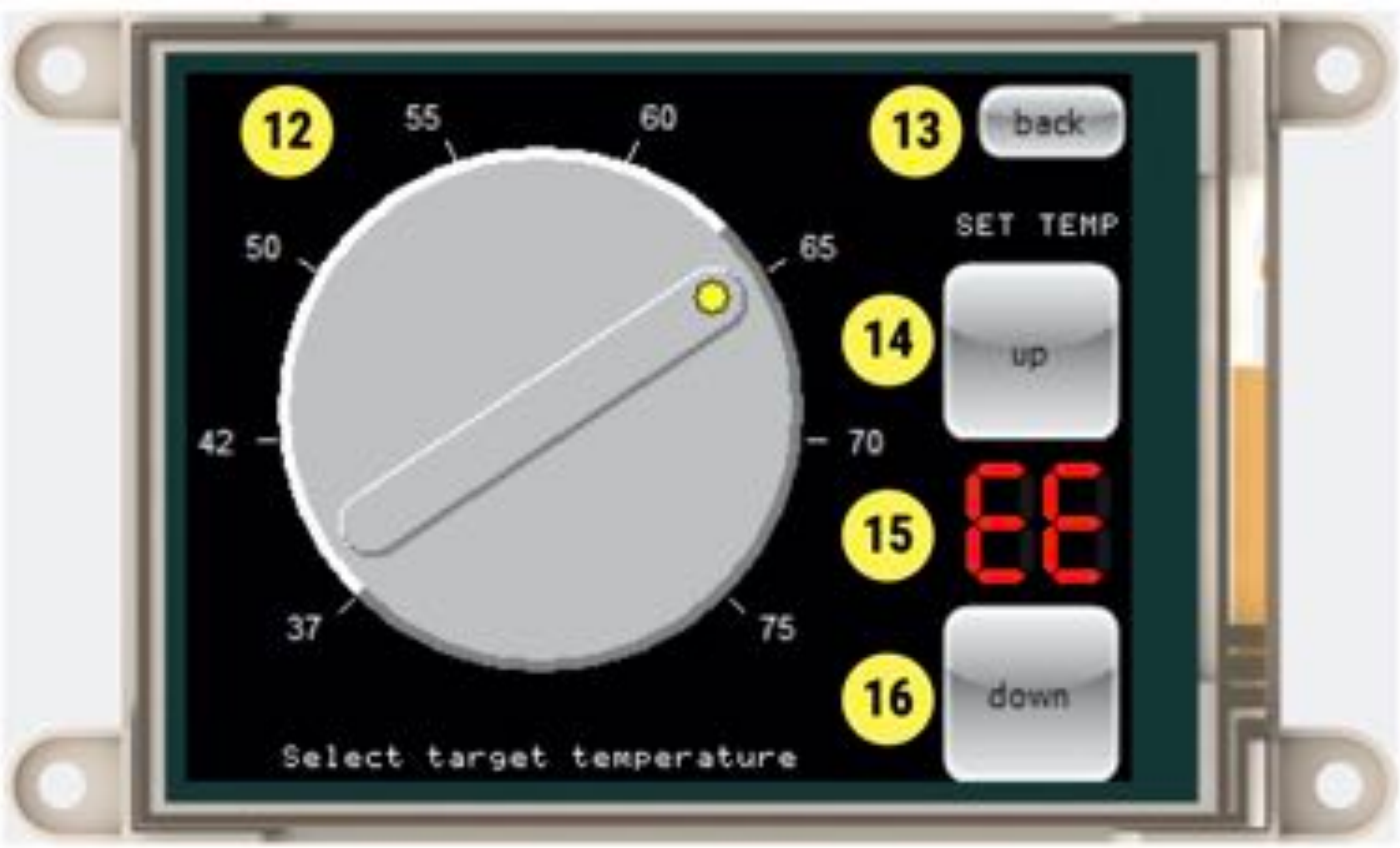

Circuit board location area

Control electronics

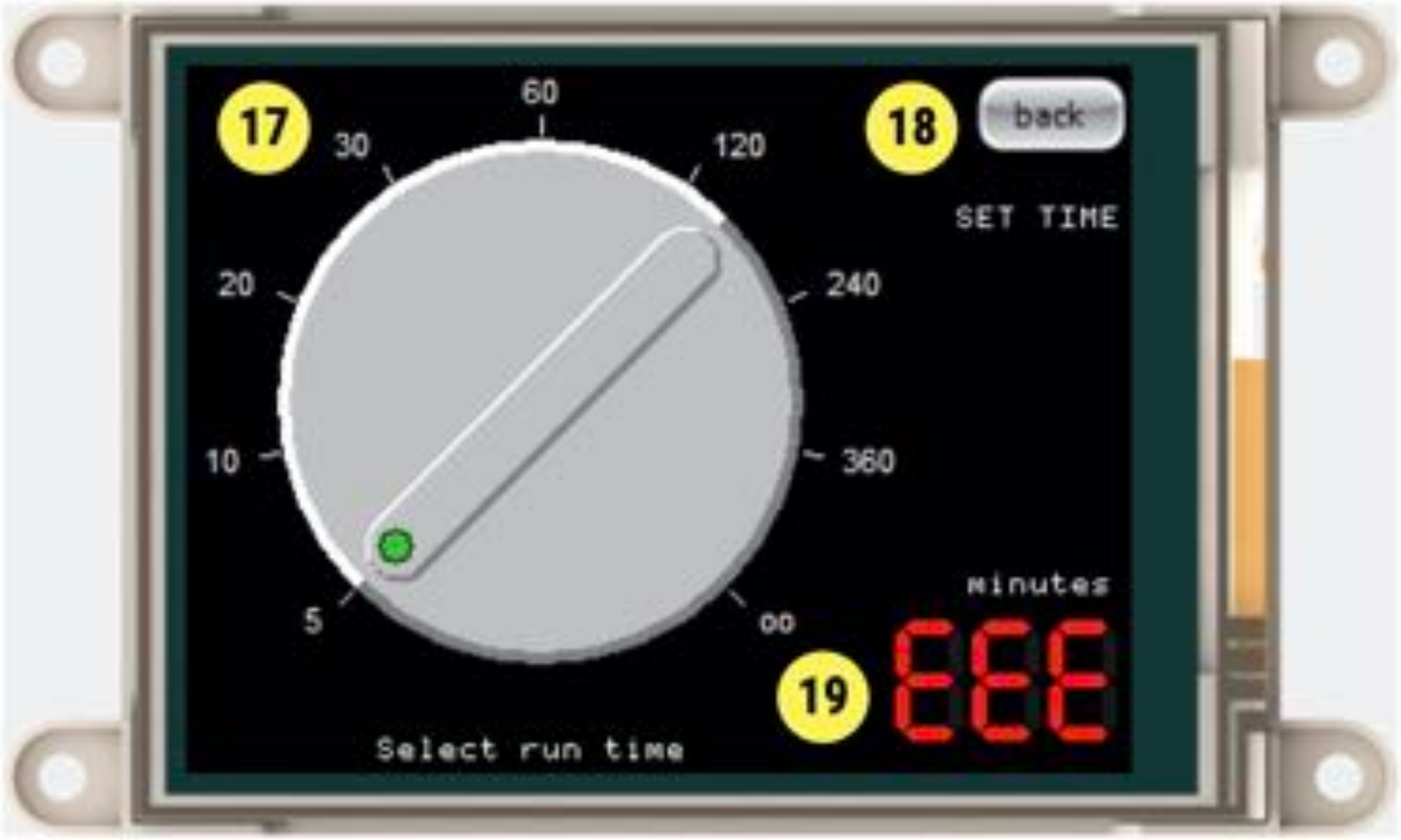
No-code programming of touchscreen interfaces using 4D Systems Workshop4



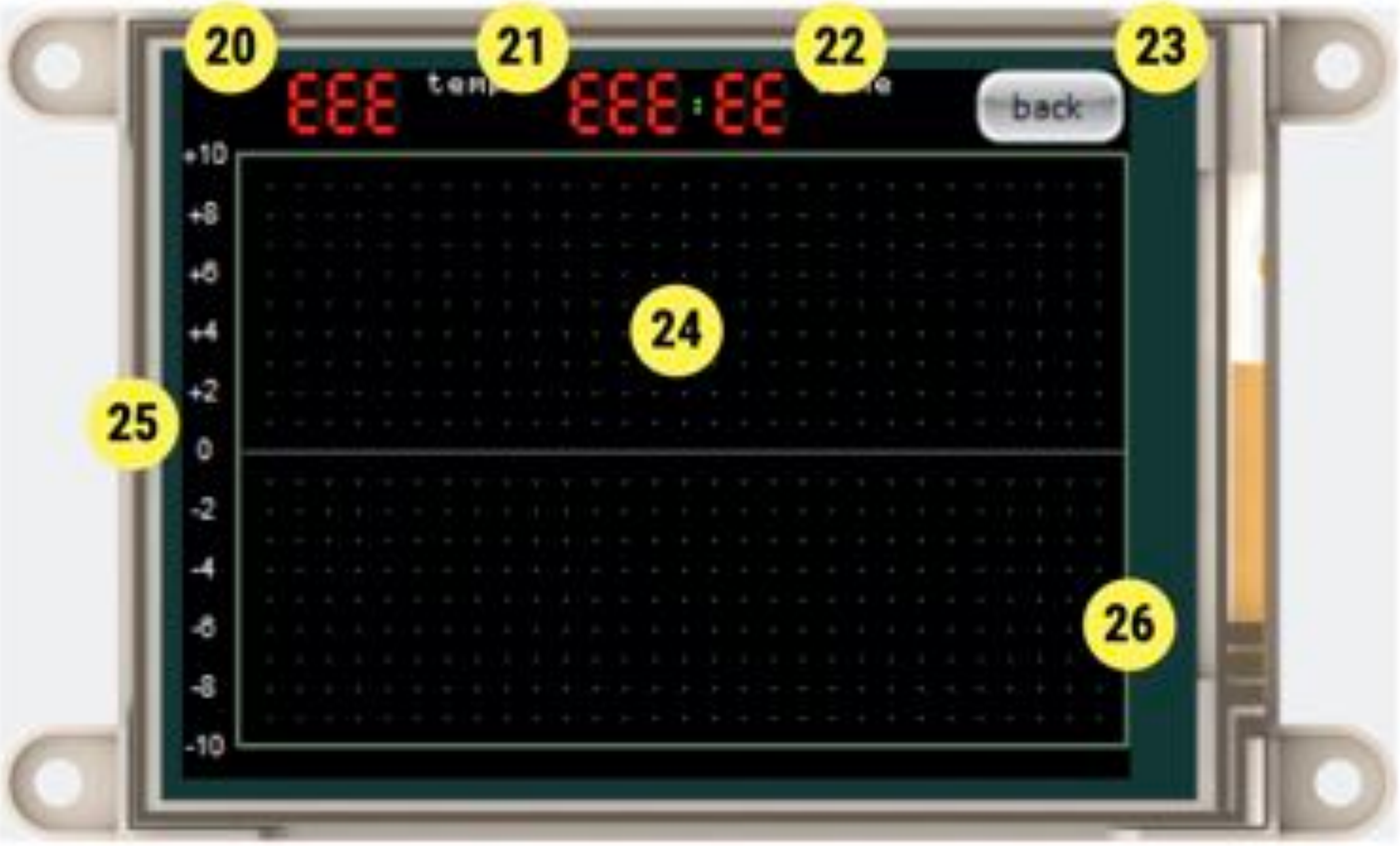
1. ILedDigits0
2. ILedDigits3
3. ILedDigits2
4. LED0
5. LED1
6. ISwitch0
7. IButtonD0
8. IButton D3
9. Winbutton3
10. ILedDigits1
11. ILedDigits5



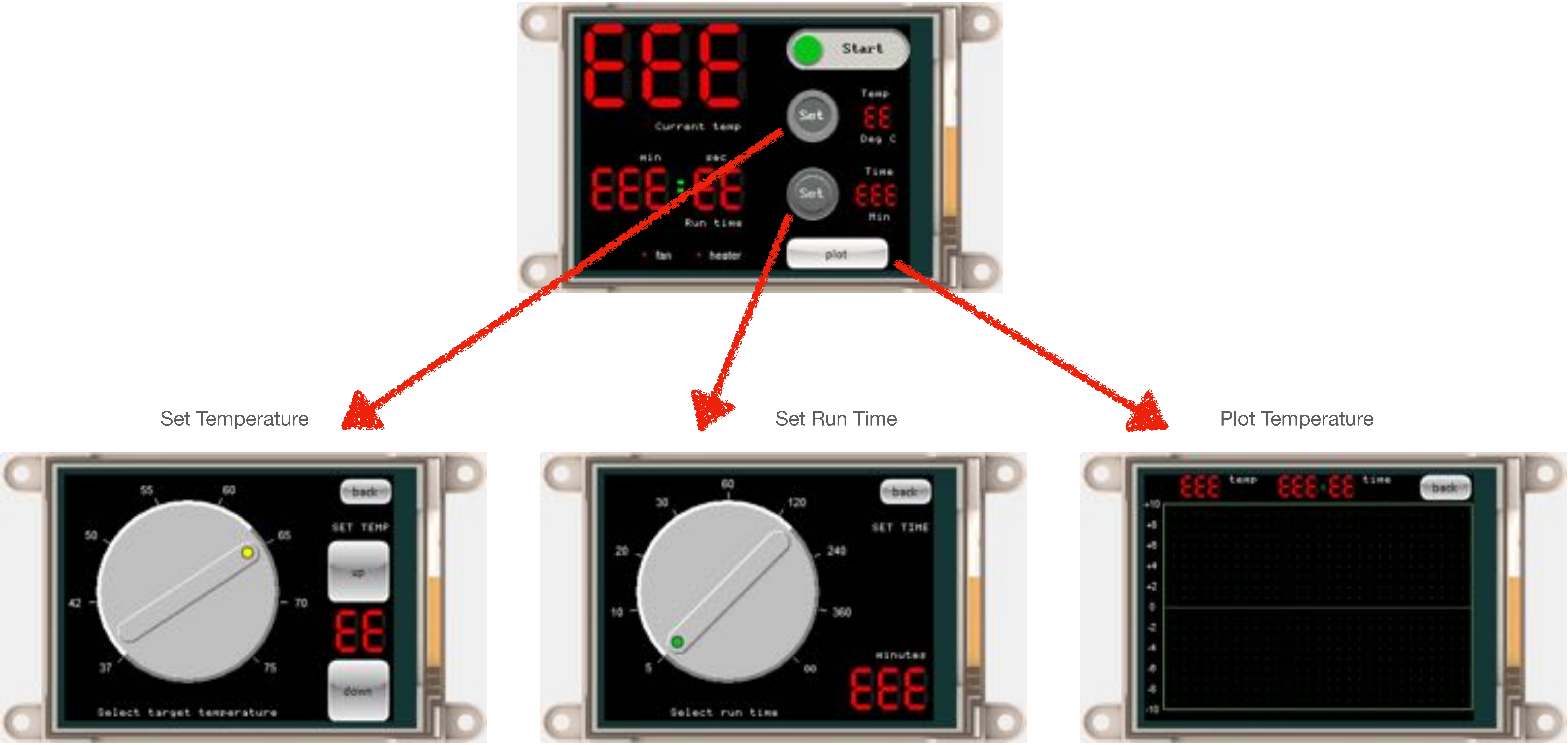
12. Rotaryswitch1
13. Winbutton0
14. Winbutton2
15. ILedDigits4
16. Winbutton4



17. Rotaryswitch0
18. Winbutton17
19. ILedDigits11

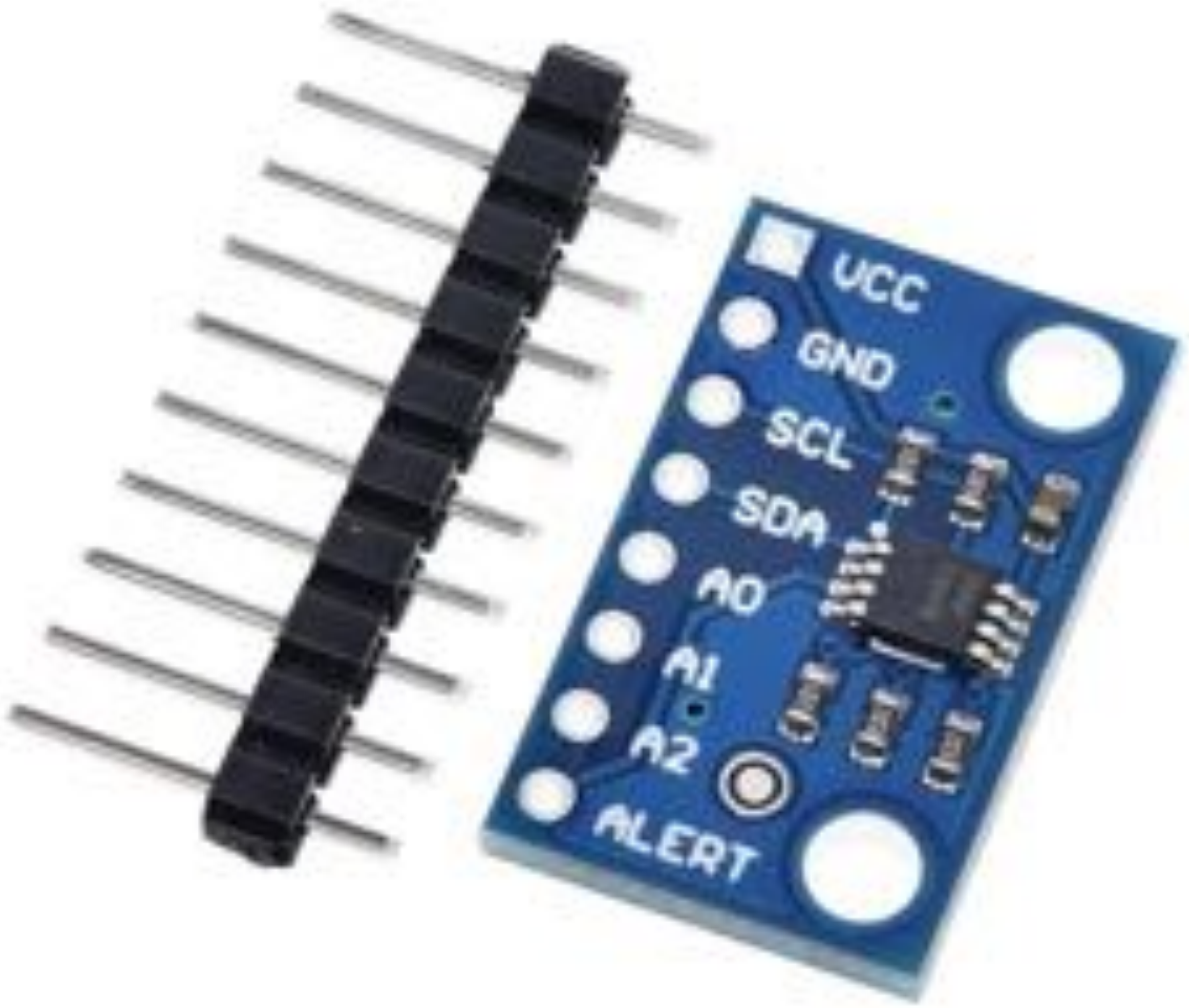


20. ILedDigits7
21. ILedDigits8
22. ILedDigits9
23. Winbutton1
24. Scope0
25. Scale0
26. Border0


Start
Set
Temp
Deg C
Current temp
min
sec
Run time
Set
Time
Min
fan
heater
plot
Set Temperature
Set Run Time
Plot Temperature
back
SET TEMP
up
down
Select target temperature
back
SET TIME
minutes
Select run time
temp
time
back

No-code programming of control systems using XOD

https://xod.io

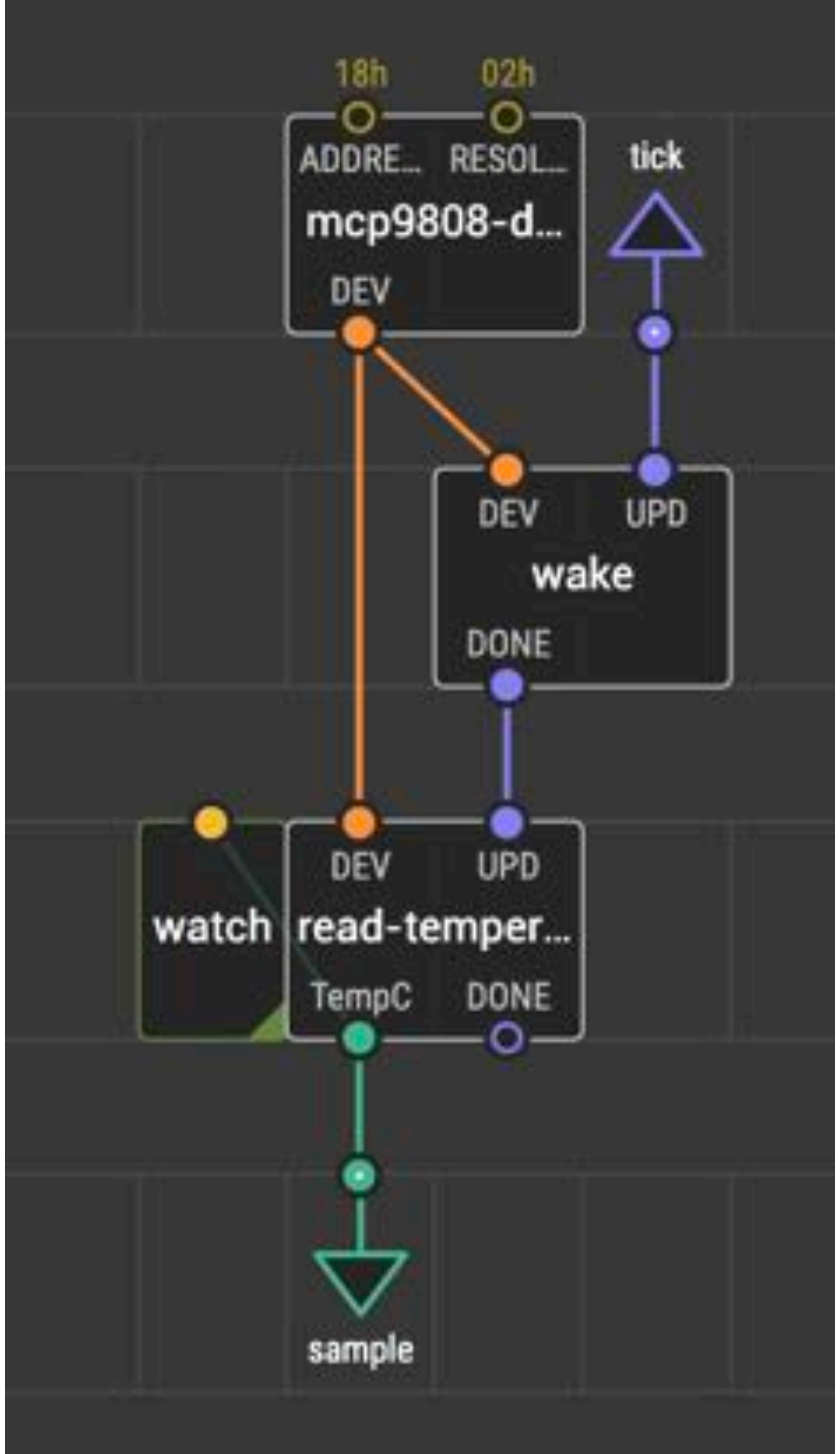


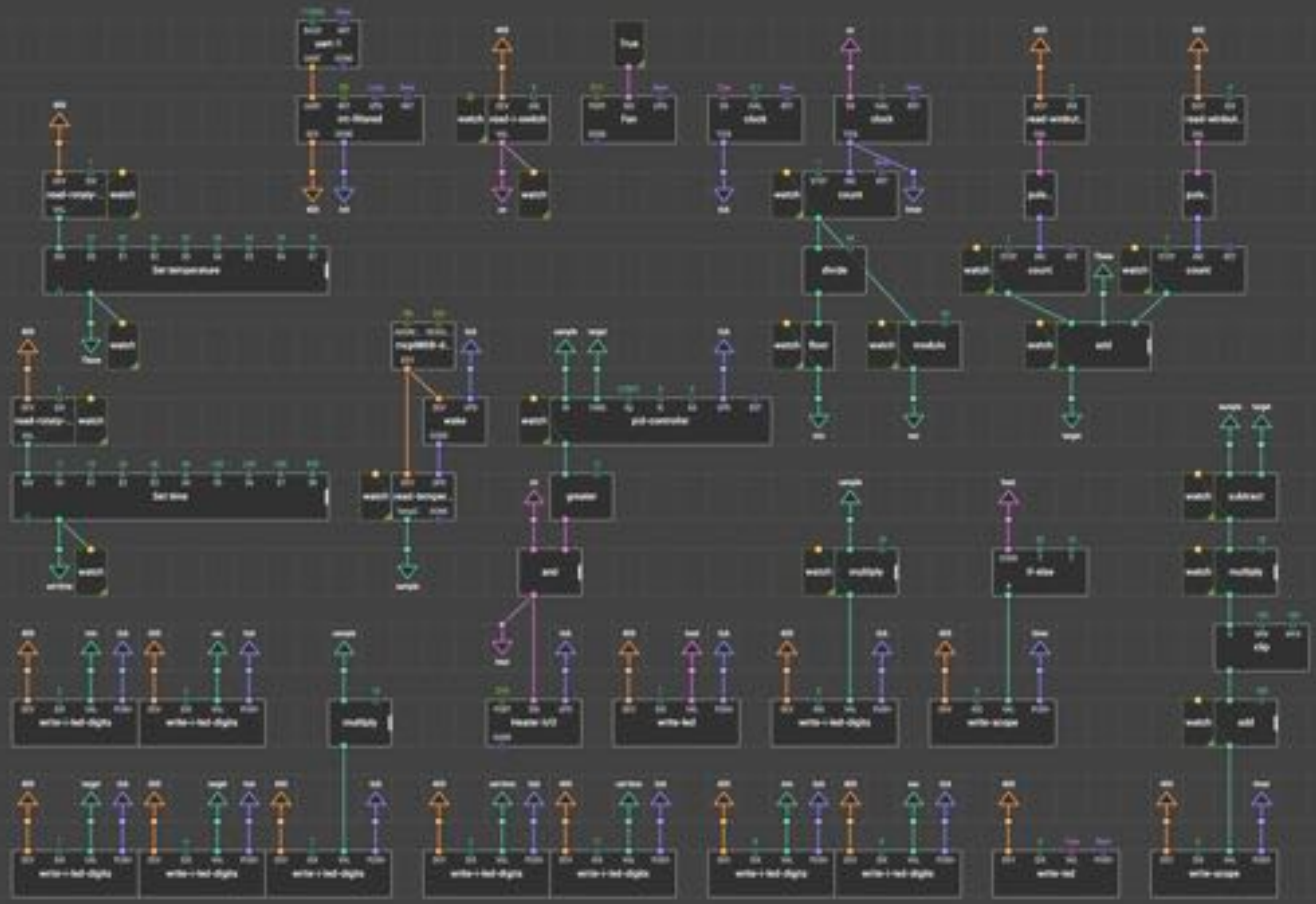
wayland/mcp9808-thermometer@0.0.2

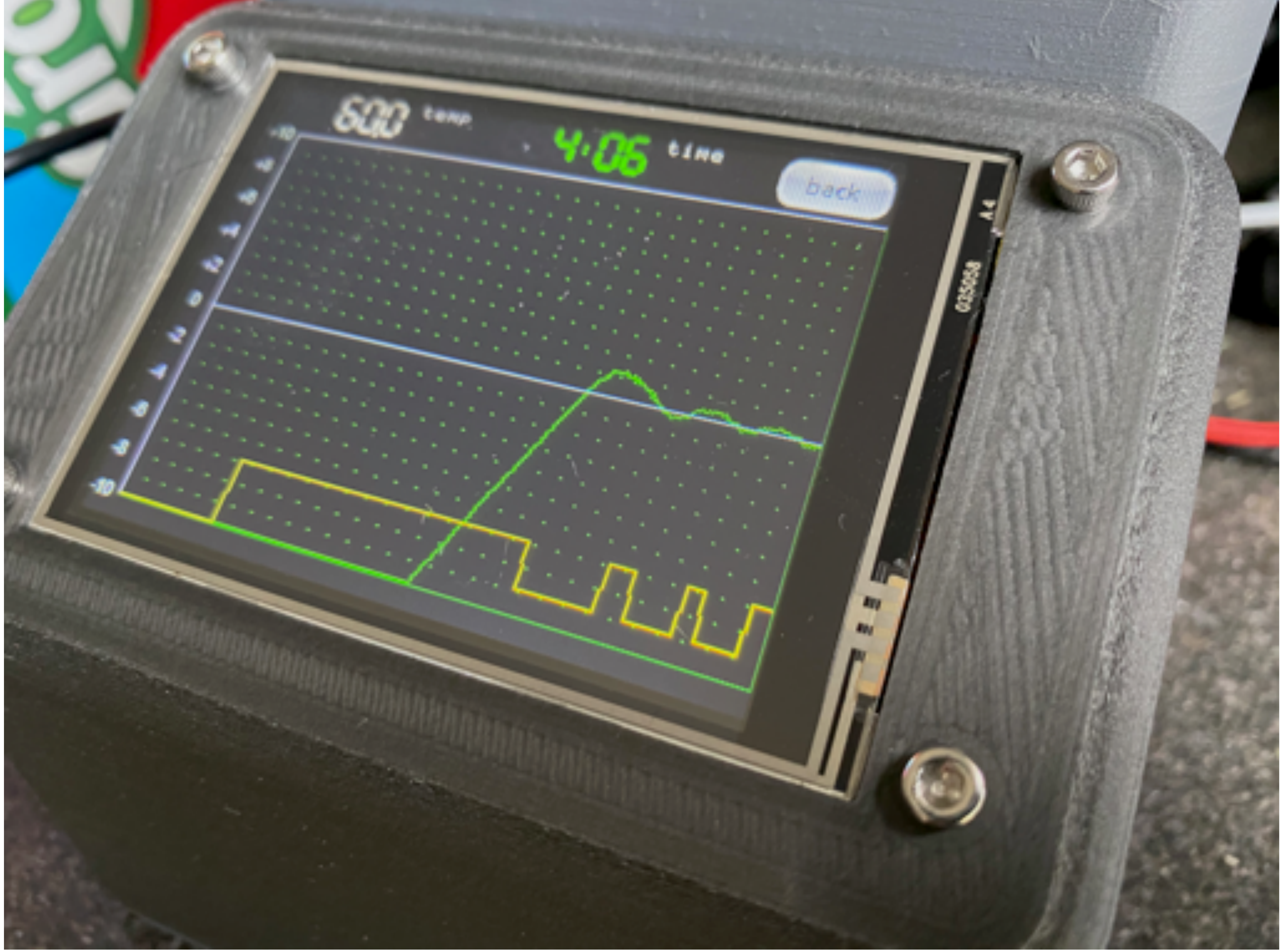
License: BSD 3-Clause

Precision I²C temperature sensor. Arduino library for the MCP9808 sensor (https://learn.adafruit.com/adafruit-mcp9808-precision-i2c-temperature-sensor-guide). Wraps https://github.com/adafruit/Adafruit_MCP9808_Library. Device datasheet: https://cdn-shop.adafruit.com/datasheets/MCP9808.pdf

Node	Description
celsius-to-fahrenheit	Convert from Celsius to Fahrenheit.
get-resolution	Get resolution mode of device. MCP9808 has four resolution modes (resolution and sample time in parentheses): 00h (0.5°C , 30 ms); 01h (0.25°C, 65 ms); 02h (0.125°C, 130 ms); 03h (0.0625°C, 250 ms).
mcp9808-device	Create mcp9808 device.
read-temperature	Read temperature in degrees Celsius. Temperature can be converted to Fahrenheit scale using celsius-to-fahrenheit node.
set-resolution	Set resolution mode of MCP9808 device. Four modes are available (resolution and sample time in parentheses): 00h (0.5°C , 30 ms); 01h (0.25°C, 65 ms); 02h (0.125°C, 130 ms); 03h (0.0625°C, 250 ms).
shutdown	Shutdown MCP9808 device. Stops temperature sampling and reduces power consumption of MCP9808 device to ~0.1 microampere.
wake	Wake up MCP9808 and start temperature sampling. Power consumption when sampling is ~200 microampere.
example-change-resolution	Demonstration of how to change the resolution mode of the MCP9808. Here the resolution mode is changed from 03h (0.0625°C) to 01h (0.5°C). Run this patch in the debugger.
example-output-lcd	Patch to demonstrate sending temperature reading to a text LCD.
example-max-sample-rate	Patch to demonstrate how to maximize sampling rate for a given resolution, by not switching off MCP9808 between reads. Run this patch in debugger.
thermometer	Combines low level nodes to create a simple to use thermometer. Outputs temperature in °C (can be converted to °F using celsius-to-fahrenheit node). To conserve energy the MCP9808 is put into sleep mode between temperature readings. You can maximize sampling rate by not switching off MCP9808 between reads (see example-max-sample-rate).
example-test-thermometer	Patch to test thermometer. Run this patch in debugger.

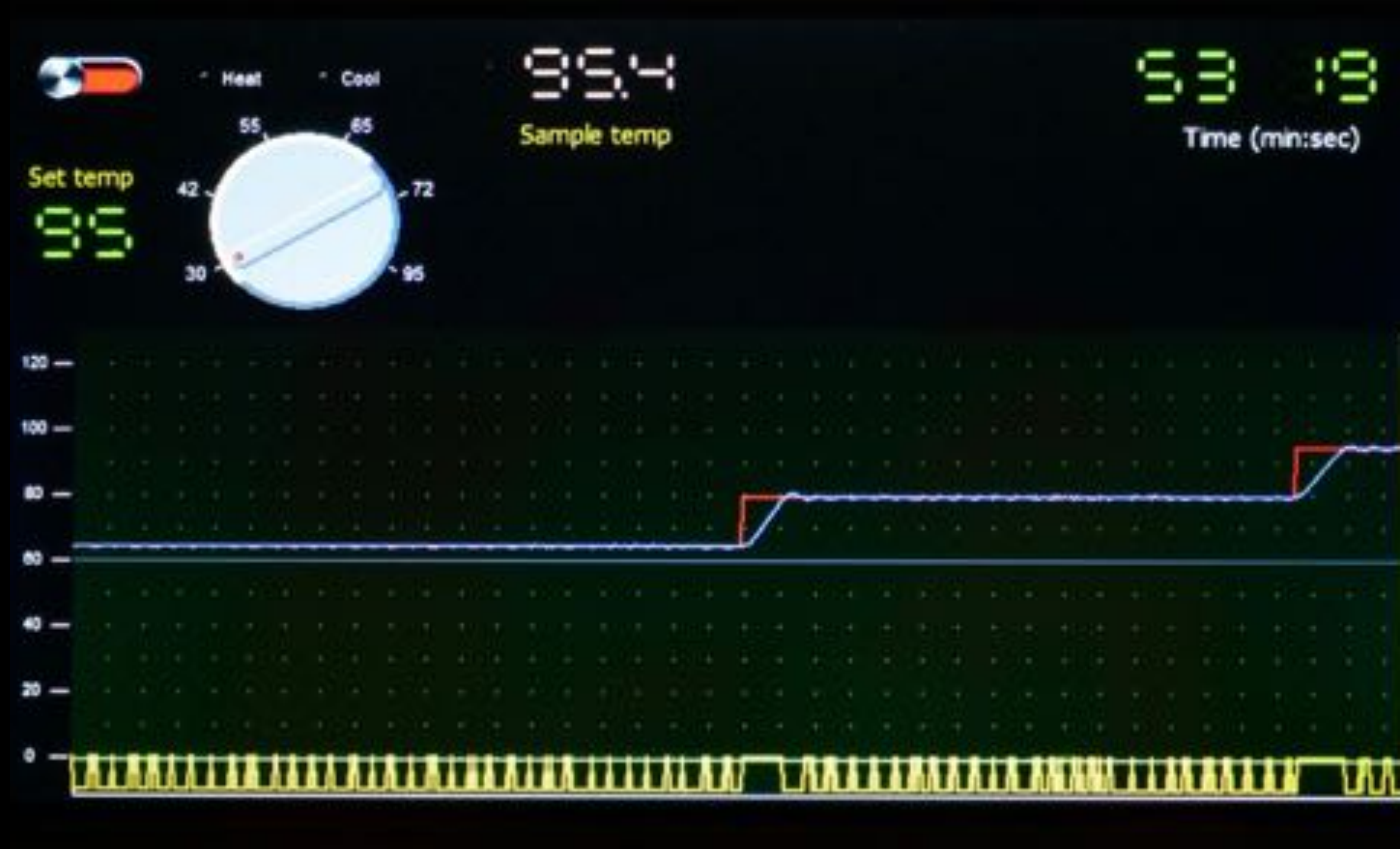



Set temperature
Set time
pid-controller
greater
and
divide
floor
modulo
add
subtract
multiply
if-else
clip
clock
count
Fan
True
Heater I/O
write-led
write-scope
watch



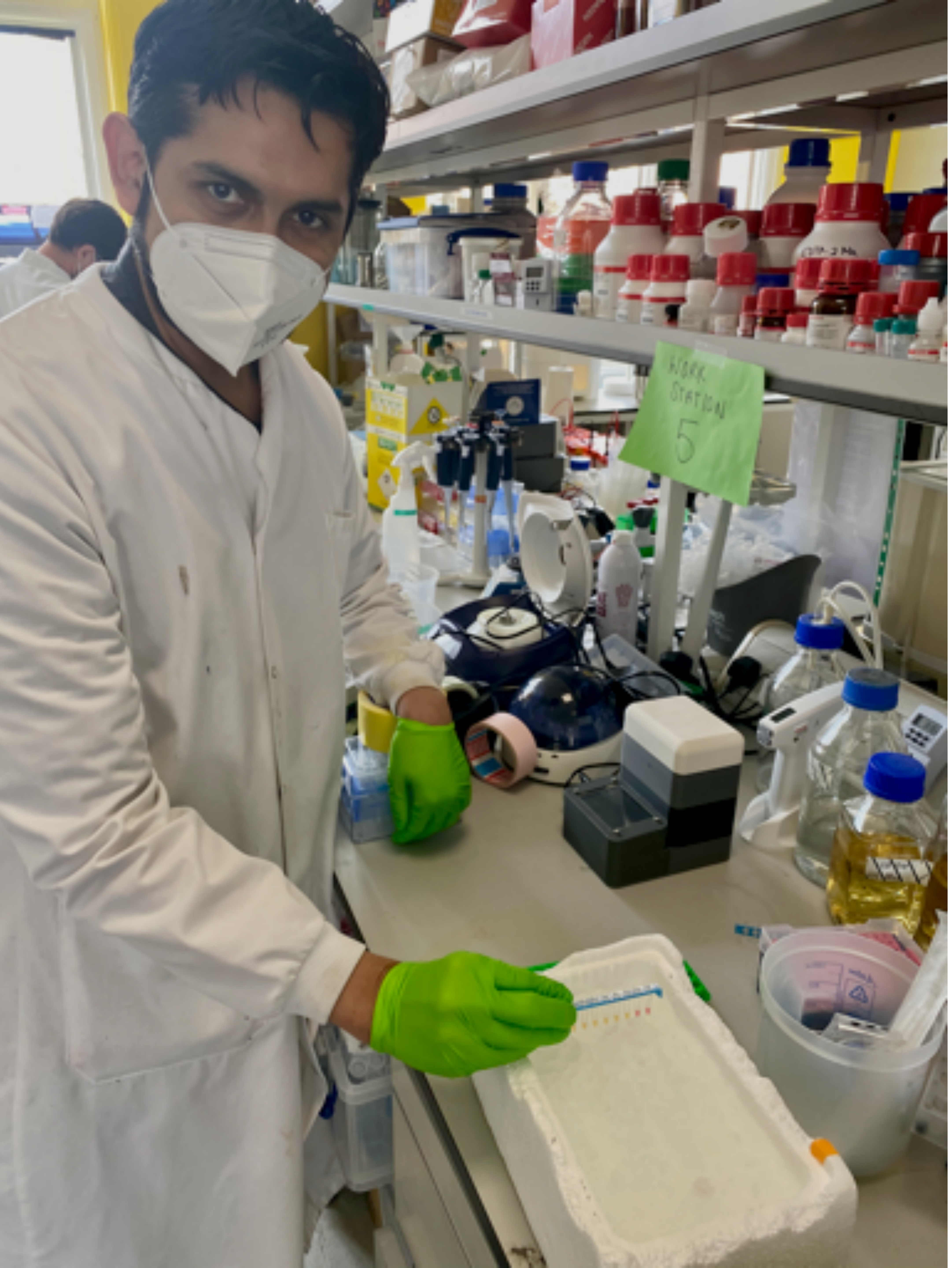
Testing the AirFlow microreactor

Testing the AirFlow microreactor



37ºC 40ºC 50ºC 65ºC 80ºC 95ºC


65.0
65
60
9:28



Testing with colorimetric LAMP assays
(kind donation from New England Biolabs)

Fernando Guzman Chavez

Ideas to take away:

1. Heat-resistant plastics allow 3D printing (and flexible design) of LAMP/PCR reactor vessels.
2. Low-cost power and sensor systems can be built with off-the-shelf commodity parts.
3. XOD allows non-programmers to create and modify Arduino-based control systems.
4. No-code touchscreen displays allow one to build relatively sophisticated user interfaces.

Future challenges

- Continue refining the design of the vessel to reduce cost of materials and increase speed of printing. Investigate designs suitable for injection moulding.
- Explore different display options to reduce cost.
- Test different venting options to allow thermal cycling.
- Introduce optics in the manifold to allow integration of quantitative imaging and analysis.
- Add wireless communications and web-based data collection.

More information about XOD and Arduino experiments at www.biomaker.org

AirFlow project details at https://www.hackster.io/jim-haseloff/airflow-microreactor-657300