

Microprocessor Interfacing

ETC 423

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Portable Sensor Bay

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Introduction

This capstone project involves designing and implementing a portable, modular sensor bay using a Raspberry Pi 5 and a 7-inch touchscreen interface. The system is built to support quick sensor interchangeability, allowing users to hot-swap different sensors without constant rewiring or setup changes. This modular approach creates a more efficient testing and diagnostic environment for technicians working in the field.

In modern industrial environments, such as Amazon fulfillment centers, predictive maintenance teams rely on a wide range of tools to monitor machinery health. They often carry thermal readers, ultrasonic sensors, and other specialized devices to identify early signs of equipment failure. The portable sensor bay combines these capabilities into a single, integrated platform. By reducing tool load and including multiple sensing options in one system, this device aims to improve mobility, streamline workflows, and increase maintenance responsiveness.

The objective of this project is to develop a portable and user-friendly sensor workstation that enhances operational efficiency by integrating multiple industrial sensors into one modular system. The device should enable rapid sensor replacement, provide real-time data visualization, and support ongoing expansion for additional sensors and maintenance applications. The project also emphasizes scalability, allowing additional sensors and features to be incorporated as needed for different operational requirements.

Planning

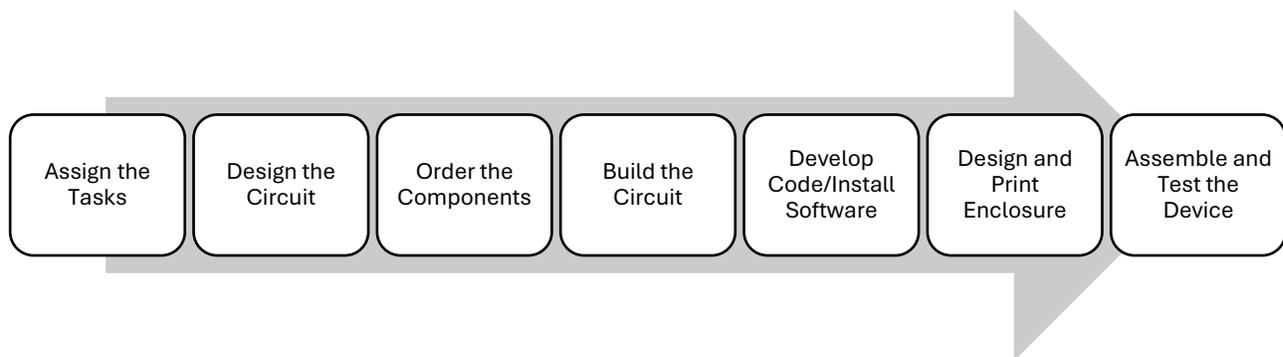


Figure 1: Project Development Workflow

Budget

Item	Qty	Total
Adafruit I2S 3W Class D Amplifier Breakout - MAX98357A	1	\$5.95
Speaker - 40mm Diameter - 4 Ohm 5 Watt (PID: 3968)	1	\$4.95
AMG8833 88 IR Thermal Camera Sensor	1	\$35.59
Mini Keyboard with Touchpad	1	\$22.99
Raspberry Pi 5 - 16 GB RAM (PID: 6125)	1	\$132.00
Official Raspberry Pi 27W PD Power Supply 5.1V 5A with USB C PID: 5814	1	\$14.04
Official Raspberry Pi 5 Active Cooler PID: 5815	1	\$13.50
Pi Foundation Display - 7" Touchscreen Display for Raspberry Pi (PID: 2718)	1	\$79.95
Total	-	\$308.97

Table 1: Project Components and Costs

Process

The system was designed to support a diverse range of sensors that communicate through the I2C protocol. These sensors required only a minimal wiring interface consisting of power, ground, a data line, and a clock line. To streamline usability and reduce repetitive wiring tasks, the project goal is to implement a modular “sensor cartridge” approach.

Each sensor will be mounted on a removable cartridge that interfaced directly with the main unit. To enable automatic sensor identification upon connection, each cartridge incorporated a uniquely valued resistor tied to the power rail. When the cartridge was inserted, the system read the corresponding analog voltage, allowing the Raspberry Pi to determine which sensor was installed.

This approach ensured plug-and-play functionality, supported rapid hot-swapping, and enabled seamless transitions between different sensing modules without manual configuration.

To implement this system, the supporting hardware and enclosure were carefully designed. The electrical circuit connected all components to their corresponding pins to ensure reliable I2C communication and accurate analog identification of each sensor cartridge. Additionally, all compatible sensors were pre-programmed into the device firmware so that the system could automatically recognize, initialize, and display data from any module inserted into the bay.

A custom enclosure was also developed and 3D-printed to house the Raspberry Pi, touchscreen display, power components, and hot-swap connection interface. This enclosure provided durability, safe cable management, and user-friendly access to the

sensor port, allowing fast and secure replacement of sensor cartridges in the field. The system was also designed with scalability in mind, allowing new or alternative sensors to be integrated at any time by adding the appropriate software drivers or code updates to ensure full device compatibility.

3D Models

For the 3D models used in this project, we found one model on Thingiverse that encapsulates the screen, and we designed the secondary part ourselves using AutoCAD.

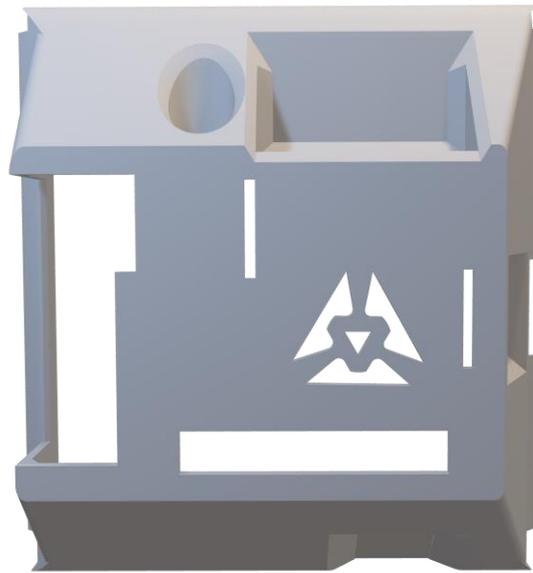


Figure 2: 3D model found on thingiverse

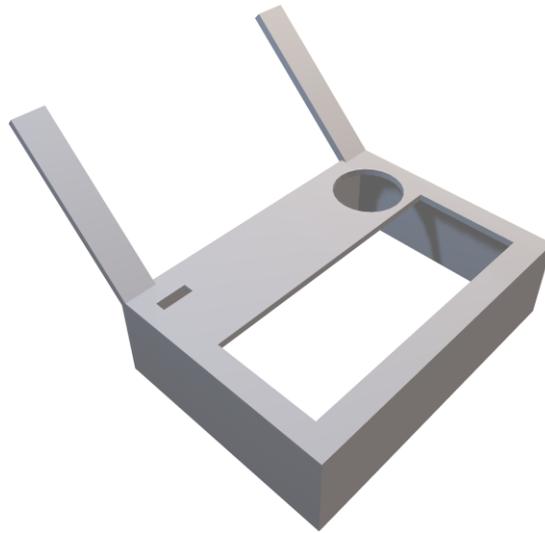


Figure 3: 3D model created by Rob

Schematic Diagrams

Pinout

Max98357 (I2S)	Connect To
V _{IN}	5V
GND	Ground
D _{IN}	I2S Data
BCLK	I2S Bit Clock
LRC	I2S Left/Right Clock
SPK+	Speaker +
SPK-	Speaker -
GAIN	Optional Gain Select Wiring
SD	Optional Mode/Shutdown Control

Table 2: MAX98357 I2S Amplifier Pin Connections

Sensor Pin	Connect To
V _{DD}	3.3v or 5v
SDA	MCU SDA pin
GND	Ground

SCL	MCU SCL pin
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Table 3: Sensor Pin Connections

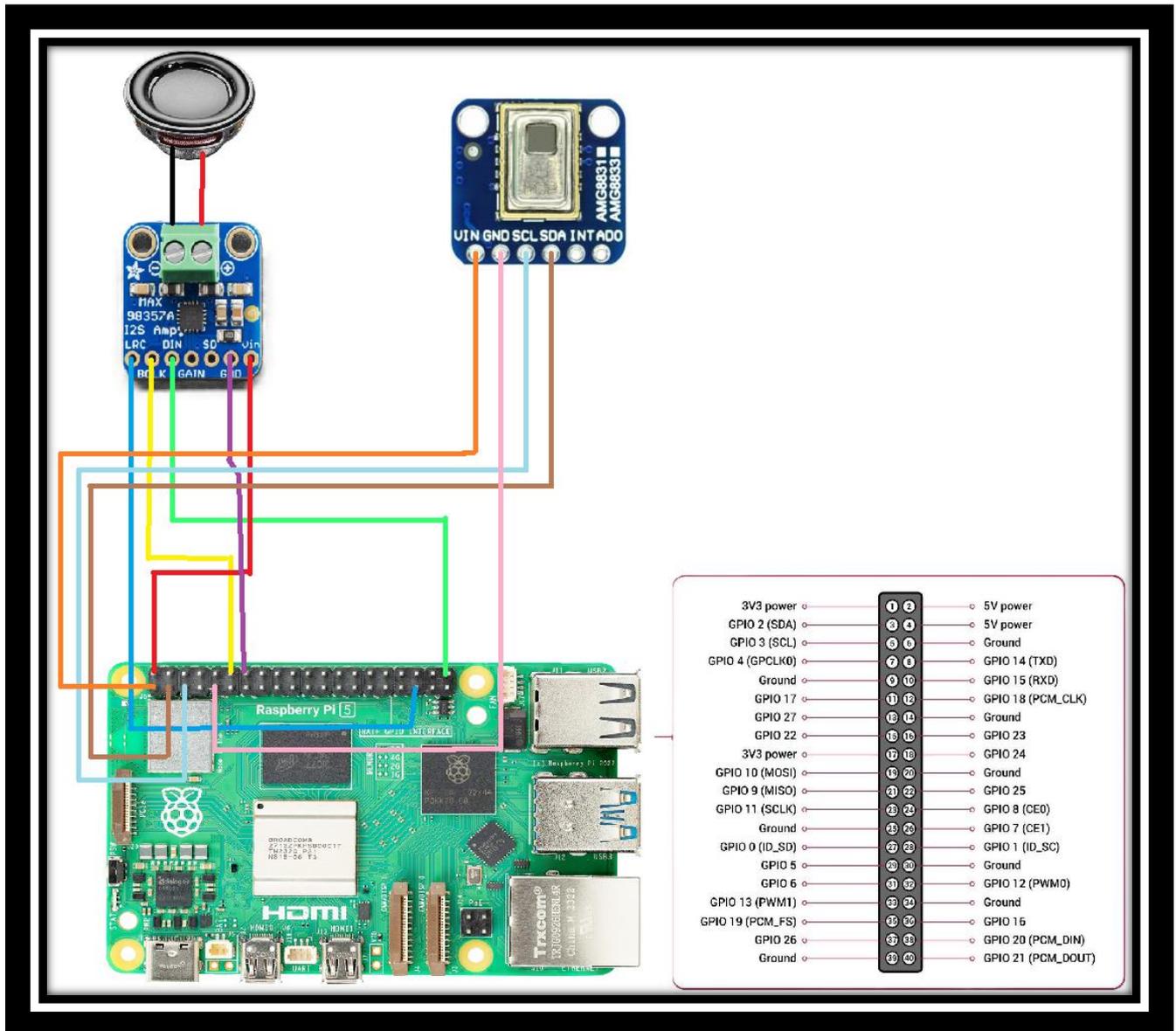


Figure 4: Wiring Diagram

Code

The Raspberry Pi runs its own operating system where you can use the command prompt to build and run python scripts. It also includes Chromium where you can browse the internet and watch YouTube.

Output

Script for the Thermal Sensor

```
import time
import board
import busio
import numpy as np
import tkinter as tk
from PIL import Image, ImageTk, ImageDraw
import adafruit_amg88xx

# Initialize I2C + Sensor
i2c = busio.I2C(board.SCL, board.SDA)
sensor = adafruit_amg88xx.AMG88XX(i2c)

# Color map (ironbow-style)
def temp_to_color(t, tmin, tmax):
    x = (t - tmin) / (tmax - tmin + 1e-6)
    x = max(0, min(1, x))

    r = int(255 * x)
    g = int(255 * (1 - abs(x - 0.5) * 2))
    b = int(255 * (1 - x))

    return (r, g, b)

# Build UI Window
root = tk.Tk()
root.title("Thermal Camera")
canvas_size = 300 # UI resolution
thermal_img_label = tk.Label(root)
thermal_img_label.pack()

# Update loop
def update_frame():
    pixels = np.array(sensor.pixels)
    tmin = np.min(pixels)
    tmax = np.max(pixels)

    img = Image.new("RGB", (8, 8))
    draw = ImageDraw.Draw(img)

    for y in range(8):
        for x in range(8):
            color = temp_to_color(pixels[y][x], tmin, tmax)
            draw.point((x, y), fill=color)

    # Upscale to window size
    img_big = img.resize((canvas_size, canvas_size), Image.NEAREST)
    tk_img = ImageTk.PhotoImage(img_big)

    thermal_img_label.imgtk = tk_img
    thermal_img_label.config(image=tk_img)

# Re-run this function ASAP (~10-15 FPS)
root.after(50, update_frame)

# Kick off loop
update_frame()
root.mainloop()
```

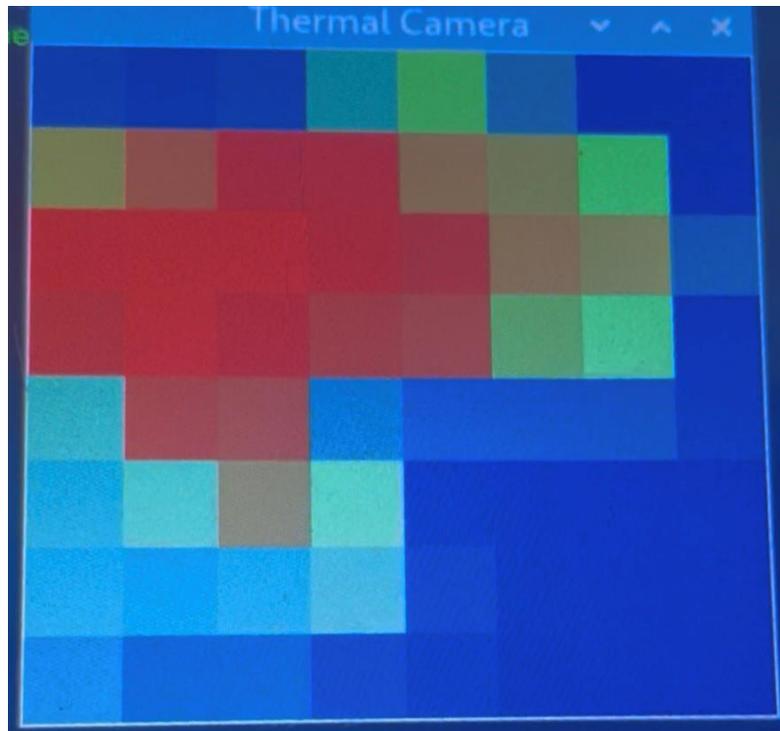


Figure 5: The thermal map from the sensor visualized from the heat measurements

Conclusion

The development of the portable sensor bay was successful. The system performed as intended, providing a reliable, hot-swappable interface for a wide range of sensors while ensuring accurate real-time data monitoring. With integrated Bluetooth and Wi-Fi connectivity, the device can be deployed in numerous environments and job roles, from engineering labs to maintenance operations, making data collection both efficient and highly mobile.

Minor refinements were required during the build process, including adjustments to the enclosure design to accommodate the addition of a heat sink. Future iterations will also transition the enclosure to a TPU 3D-printed design. TPU's flexible, rubber-like properties will significantly improve durability, shock resistance, and field reliability compared to rigid materials. We would also like to modify the 3D models to be more ergonomic as well as watertight.

Additionally, the overall cost of the system could be reduced by purchasing components in bulk or by selecting more economical alternatives without compromising performance.

Due to time constraints, we used Dupont connectors for the quick swapping of the sensors. Ideally, we would swap them for something more robust like Deutch connectors that are

watertight and do not run the risk of unplugging. Overall cable management will need to be addressed in the future work.

Ultimately, the project resulted in a versatile, all-in-one diagnostic tool that can benefit engineers, IT technicians, and field personnel alike. Its modular design, wireless communication capabilities, and expandability ensure long-term usability and adaptability as new sensing needs emerge.

References

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- Screen Enclosure 3D Model - <https://www.thingiverse.com/thing:2756684>