Retrofitting an iMac G3 & Mouse for Use in the 21st Century

ECE 445 Final Report
Team 23

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1 Introduction

Purpose:

Disposal of outdated technology contributes to approximately 50 million tons of e-waste annually, leading to environmental concerns. Our project aims to demonstrate a sustainable approach to repurposing technology from the past, diverting it from landfills and back into the consumers' hands. Specifically, by modernizing old devices, like updating the original iMac G3 to modern computing standards, as well as its original peripherals, such as the mouse included with the device, we not only extend the lifespan of these devices but also preserve their original creative style and design intent. This initiative will align vintage technology with modern computing needs, ultimately fostering a more eco-friendly and innovative technological landscape. Our project aims to replace legacy hardware within the 1998 iMac G3 by utilizing the internal components of a newer Mac Mini computer. The new components will be mounted inside the original iMac shell to give new life to this outdated machine. The original CRT screen will be replaced with a newer LCD screen. The original speakers and disc drive of the iMac will be re-utilized as well, and the ports will be upgraded to the relevant modern port types. We also aim to update the original Apple USB mouse included with the device by using modern optical sensors and Bluetooth to replace the legacy hardware. A modern switch of higher quality and durability will replace the original switch used for the mouse button and rather than physical rollers interacting with a rubberized ball on the bottom of the mouse, we will use an optical sensor to detect mouse movement. The user can customize the sensitivity of the mouse, a feature unavailable on the original hardware. The USB connection will be replaced with Bluetooth to communicate with a computer. Due to its wireless nature, the mouse will be battery powered. The mouse can detect when it is not being used and automatically shut off as a battery saving measure, similar to modern Bluetooth mice.

Our project was born out of a recognition of the enduring value and iconic design of the iMac G3, a revolutionary computer introduced by Apple in 1998. However, as technology rapidly advances, these vintage machines face obsolescence due to compatibility issues with modern software and peripherals. Our goal was to preserve the aesthetic and functionality of the iMac G3 while making it relevant and usable in today's digital landscape. Our solution involves retrofitting the iMac G3 with updated hardware and software components to enhance its compatibility and usability without compromising its original design ethos. The key components of our design include upgrading the internal hardware to improve performance, integrating modern connectivity options such as Wi-Fi and USB-C, and refurbishing the original mouse to ensure seamless interaction with contemporary interfaces.

Visual Aid:

Figure 1: Visual aid showing the mouse connected to the iMac through Bluetooth.

High Level Requirements:

1. The mouse must connect to modern computers using Bluetooth and allow movement of the cursor as well as clicking.
2. The iMac must connect to WiFi, have Bluetooth capability, and run at least two applications simultaneously, as well as perform actions within these applications.
3. The mouse must have a latency of no more than 20 milliseconds

Functionality:

These high-level requirements outline the basis of our project and what we want to accomplish. The first and third requirements relate to the mouse. In order for the mouse to be useful in today's world it must be Bluetooth-enabled and allow for easy movement and clicking. The latency is also a critical factor because the mouse needs to be at par with today's advanced Bluetooth mice. The second high-level requirement identifies three important standards the iMac must reach in order to be considered a "modern" computer. Wifi connection, Bluetooth capability for the mouse and any other peripherals desired to be used, as well as the ability to run applications are all necessary for a modern computer. These requirements guided our project scope and development and ultimately ensured we would have a successful outcome upon project completion.

Block Diagram:

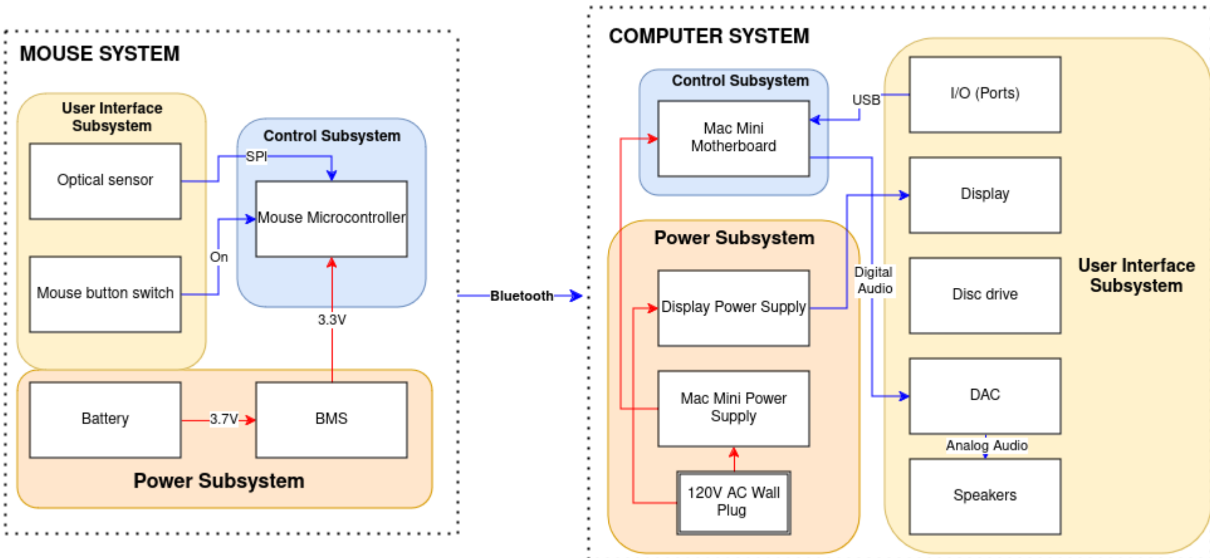

Figure 2: Block diagram with all subsystems. Note that blue indicates data and red indicates power.

Subsystem Overview:

Mouse System - User Interface Subsystem:

The mouse button switch allows the user to click the mouse button. The switch must activate every time the mouse button is pressed and release only when the button is released (no bouncing). The optical sensor will allow the mouse to function as a normal, modern Bluetooth mouse. This sensor will replace the ball originally within the mouse. The sensor will control the movement of the mouse and track it more efficiently. Moving the mouse to the x or y-axis should move the cursor in the corresponding direction.

Mouse System - Control Subsystem:

The mouse control system will be the main hub for mouse functionality and is the most important part of the mouse. This subsystem will connect the mouse to the computer using Bluetooth[5]. The control subsystem will communicate to the computer to move the cursor and click with a latency of 20ms or less as outlined by our high-level requirement.

Mouse System - Power Subsystem:

The power subsystem of the mouse will consist of a lithium-ion battery as well as a battery management system (BMS). This subsystem powers the different components of the mouse such as the microcontroller, optical sensor, and the button switch.

Computer System - Power Subsystem:

The power subsystem of the computer will consist of both the display power supply and the Mac Mini power supply, which will both be powered by a 120V AC plug. These power supplies are the manufacturer-supplied power supplies for the respective products and will not be modified.

Computer System - Control Subsystem:

The control subsystem of the computer will consist of the Mac Mini motherboard, which will be housed in the iMac G3. The new motherboard will allow for the upgraded features of a new computer within the G3 outer shell. This motherboard will be the core of the computer and allow the high-level requirements we have previously outlined to be fulfilled.

Computer System - User Interface Subsystem:

The User Interface subsystem will include the LCD display, as well as the I/O ports of the Mac Mini. The updated LCD display will allow for heightened clarity and picture quality at the correct aspect ratio. The ports of the Mac Mini will also be accessible and functional.

2 Design

Design Procedure:

Mouse System - User Interface Subsystem:

An optical sensor[4] was chosen over the traditional mouse ball design to provide smooth, precise cursor tracking without the friction and maintenance issues of the ball system. The PMW-3389 optical sensor IC was selected for its proven performance.

For the microcontroller, the ESP32 mini variant[3] was used instead of the normal ESP32 due to the compact size constraints of the circular PCB and the goal of fitting every component within the original mouse housing. The mini's smaller form factor allowed it to be incorporated onto the PCB design, which was integral to the mouse's core function of being used a pointing device.

Mouse System - Control Subsystem:

The ESP32 mini was chosen to serve as the main microcontroller, leveraging its integrated Bluetooth for wireless connectivity to the computer and low-power capabilities for battery operation.

Mouse System - Power Subsystem:

For the battery, lithium-ion was chosen over alkaline for its high energy density and rechargeable capabilities. This battery type was also chosen due to size constraints, again due to the small form factor of the mouse housing.

Computer System - User Interface Subsystem:

An LCD panel was used to replace the original CRT display, as it provided a much easier installation process and better video interface compatibility with the newer Mac Mini internal hardware. The LCD also offered improved resolution and aspect ratio compared to the CRT.

Computer System - Control Subsystem:

To modernize the internal computing capabilities, a 2014 Mac Mini was selected to replace the iMac's original internal components. The Mac Mini provided an all-in-one motherboard/CPU/RAM solution with ample processing power to run modern operating systems and applications. Its compact size also allowed it to be integrated within the retrofitted iMac housing.

Design Details:

Present the detailed design, with diagrams and component values. Show how the design equations were applied. Give equations and diagrams with specific design values and data. Place large data tables in an appendix. Circuit diagrams that are too large to be readable on a single page should be broken into pieces for presentation. The full diagram may be included in an appendix. Use photographs only as necessary and treat them, along with all other graphics except tables, as figures.

Design Alternatives:

An inertial measurement unit (IMU) was considered to track mouse movement, but deemed not viable for this project. While an IMU could provide motion tracking, it would require the mouse to be periodically recalibrated by placing it on a flat surface. Additionally, it would be significantly more difficult to measure lift off distance and determine whether the mouse was being moved in mid air or on a surface. This would have introduced too much complexity and when compared to the simplicity and reliability of using a dedicated optical sensor designed specifically for mouse tracking, it seemed obvious to utilize an optical sensor instead for this purpose.

Design Description and Justification:

The overall design aims to integrate modern technology into the mouse and computer housing, while still preserving the iconic original aesthetics.

An optical sensor provides a robust, low-friction cursor tracking solution that improves upon the traditional ball and vertical and horizontal rollers design. Paired with the compact ESP32-Mini running code to maintain Bluetooth connectivity and transmits data from the optical sensor, it enables responsive, reliable wireless mouse operation.

Within the computer subsystem, the action of replacing the CRT with an LCD display was necessary in order to work more cohesively with the newer Mac Mini video output. The LCD also provides a crisper image thanks to its higher resolution capabilities.

For the mouse PCB, modifying the plastic housing slightly was necessary in order to allow for our finalized PCB that no longer included a hole through the middle of it, as the original PCB did. By modifying the mouse housing to reduce the size of the plastic piece that originally integrated with the board, we were able to remove the PCB hole, maximize the available area of the redesigned PCB, and include overall better component organization and an optimized circuit system.

While an IMU could theoretically track mouse motion, the optical sensor approach was favored for its intuitive operation without needing to periodically recalibrate on a flat surface. This idea upholds the goal of providing a seamless, modernized mouse experience.

For the computer control subsystem, using a modern Mac Mini provided an easy way to completely update the internal computing hardware and capabilities. Its small size allowed it to fit inside the retrofitted iMac body, while providing superior performance for running current operating systems, applications, and connecting modern peripherals like the wireless mouse. Utilizing the Mac Mini modernized the core computing experience significantly compared to the iMac's original hardware.

Overall, our design leverages modern components and techniques where it makes sense, while still preserving the essence of the original devices through their iconic aesthetic housing designs. It balances achieving modern performance with maintaining the nostalgic appeal that makes these retro devices special.

Subsystem Diagrams and Schematics:

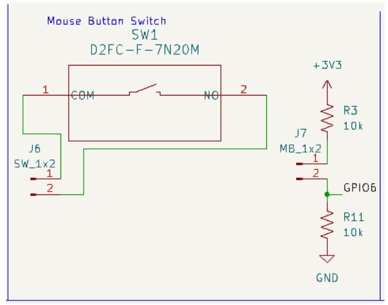

Figure 3: Schematic for the mouse button (part of mouse user interface subsystem)

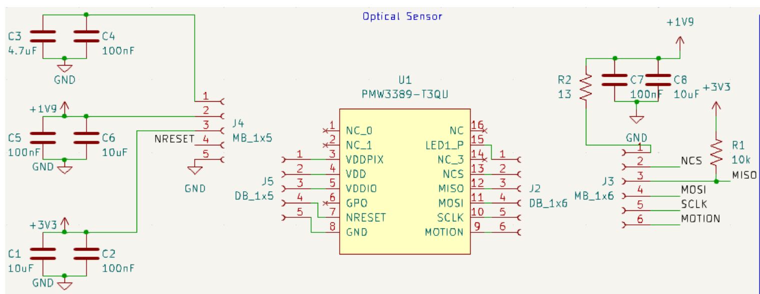

Figure 4: Schematic for the optical sensor (part of mouse user interface subsystem)

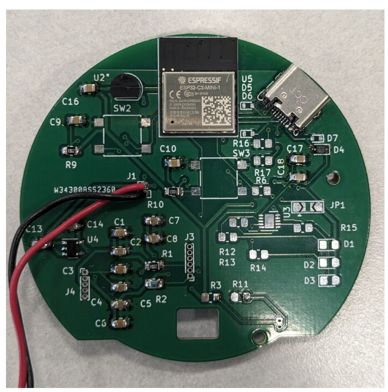

Figure 5: Partially assembled PCB with power and control subsystems

3 Cost and Schedule

Table 1: Detailed Cost Analysis

Part Description	Quantity	Price ($)
ESP32 MCU	1	1.85
D2LS-21 Switch	1	2.00
PMW-3389 Optical Sensor	1	15.00
Battery	1	˜7.00
Voltage regulator	2	˜3.00
Resistors	˜10	˜1.00
Capacitors	˜5	˜0.50
Misc. SMD Components	˜10-15	˜5.00
DB15-HDMI adapter	1	˜25.00
DAC	1	˜20.00
iMac G3 Mouse	1	20.00
iMac G3	1	40.00
Mac Mini	1	120.00

Total parts cost: $260.35
Estimated labor costs:
$40/hr x 2.5 x 60 hours = $6,000 per partner
$6,000 x 3 = $18,000
Total cost:
$260.35 (parts) + $18,000 (labor) = $18,260.35

02/19

- Everyone
  - Complete Design Document

02/26

- Everyone
  - Construct initial parts list
- Saif
  - Begin initial design of PCB, laying out component schematics and connections
- Savannah
  - Conduct research into Kicad footprints/schematics
- Sebastian
  - Conduct research into ESP32 schematic

03/04

- Everyone
  - Make changes to design document for resubmission
- Saif
  - Continue to edit PCB design for week 2 review
- Savannah
  - Help with PCB design and ESP32 research
- Sebastian
  - Begin initial research into ESP32 coding of microcontroller and optical sensor

03/11

- Saif
  - Continue to edit PCB design for week 2 review
- Sebastian
  - Continue to research ESP32 microcontroller code

03/18

- Saif

- Finalize PCB design for submission

- Savannah
  - Assist in coding of microcontroller
- Sebastian
  - Begin Arduino project and compile code to begin testing with dev board

03/25

- Everyone
  - Begin testing ESP32 Dev board with Mac Mini
  - Complete individual progress reports
- Saif
  - Continue PCB revision for next round of orders
- Savannah
  - Revise PCB to new shape without hole in order to make overall PCB design and component organization easier
- Sebastian
  - Implement optical sensor code with existing Bluetooth mouse code

04/01

- Everyone
  - Compile new round of inventory to submit for ordering
  - Finish latest PCB design
  - Finish code for optical sensor and begin to test with ESP32 dev board

04/08

- Everyone
  - Finalize official last PCB for round 5 ordering
  - Complete team contract

04/15

- Everyone
  - Prepare for mock demo
- Saif
  - Begin soldering PCB

- Savannah, Sebastian
  - Plan construction of iMac and buy necessary components
  - Construct iMac for final demo

04/22

- Everyone
  - Complete miscellaneous tasks related to final demo
- Saif
  - Complete soldering for final demo
- Savannah, Sebastian
  - Construct iMac for final demo

04/29

- Everyone
  - Complete slide show for Final presentation
  - Complete final paper

4 Requirements and Verification

Subsystem	Requirement	Verification
Mouse: User Interface Subsystem	1) The mouse button switch is clickable 2) The optical sensor allows the cursor to move	1) The switch must activate every time the mouse button is pressed and release only when the button is released (no bouncing) 2) While the mouse is initially at rest, move it along both x and y axes. Verify that the cursor moves only in the direction the mouse moves, and stops once movement ceases.
Mouse: Control Subsystem	1) The microcontroller will connect to the computer using Bluetooth	1) The microcontroller will communicate to the computer to move the cursor and click with a latency of 20ms or less
Mouse: Power Subsystem	1) The battery will be connected to the BMS which will provide 3.3V(+/-3V) DC 2) The battery will provide the optical sensor 1.9V(+/-3V)	1) Use a multimeter to probe the microcontroller to ensure it is receiving the correct voltage 2) Use a multimeter to probe the optical sensor to ensure it is receiving the correct voltage.
Computer: Power Subsystem	1) The power system of the computer will consist of the original display power supply and the Mac Mini power supply	1) Both the display and the Mac Mini will be powered by a 120V AC plug
Computer: User Interface Subsystem	1) The screen should be able to display with the correct aspect ratio 2) The iMac Mini ports will be accessible and fully functional	1) Boot up the computer. Verify that the display actively shows the computer's output with no aspect ratio issues. 2) Verify any input into the port of the iMac allows for full functionality such as a mouse or keyboard.
Computer: Control Subsystem	1) The Mac Mini is fully functioning and can display correctly as well as run multiple applications	1) With iMac powered on, open web browser and google apple.com. Open photos at the same time to verify applications open and run smoothly.

5 Conclusion

Accomplishments:

Accomplishments of our final project include a fully functioning updated iMac G3 and also fulfilling our high-level requirements for the computer subsystems. The updated iMac includes a new LCD display (in place of the original CRT) connected to the Mac Mini motherboard. This connection allows for WiFi connectivity, Bluetooth connection, and the ability to run a number of computer applications simultaneously.

Our mouse subsystems were partly successful. While we were unable to fully combine the subsystems we outlined, we were however able to complete each subsystem individually. The completed subsystems included a fully functioning optical sensor that was tested with the ESP32 development board. We were able to successfully flash the ESP32 with the Bluetooth mouse code and connect to a laptop to successfully move the computer cursor with the optical sensor. The power subsystem was also able to successfully supply the correct voltages to our PCB for both the microcontroller and the optical sensor.

Figure 6: The final updated iMac G3

Uncertainties:

Our uncertainties mainly stem from our mouse subsystem. The main issue was being unable to flash the ESP32 microcontroller soldered to our PCB and subsequently have it function. We were able to upload a sketch to the board but we were unable to receive a response back. We believe this issue could have arisen due to a soldering issue or underlying software issue that was not prevalent at the time.

Another uncertainty arose in the form of designing the PCB, mainly due to the odd shape of the circuit board (circular) and subsequently fitting all of the necessary components on the board in a manner that made sense. The shape of the board created unforeseen constraints on component organization. We had to create a number of PCB design iterations as a result in order to ensure the PCB not only fit within the plastic mouse housing, but was also able to hold all of the necessary components without compromising the overall mouse function. This issue led to difficulties in the design process and multiple orders of PCBs and rounds of testing. Ultimately, we did not receive a stencil with our Round 4 board, which proved to be an obstacle when soldering components. We also placed an order for our Round 5 board, but did not receive the board at all after being told the order had been placed, which was frustrating because this iteration of the board had fixed a critical issue with our Round 4 board, that of which being connecting the button for power. This incident put a lot of stress on our timeline and ultimately we could not fully complete the mouse due to not having access to our Round 5 board. We did, however, do our best to work with the Round 4 board and create a working solution, though unfortunately our efforts did not produce a viable final mouse.

Future Work:

Future work concerning our project efforts could include redesigning the iMac to utilize the original CRT screen display. Utilizing the CRT was the early-stage initial plan, however after research into this possibility, it proved to be a much larger task than anticipated. This realization led us to use a LCD display instead for feasibility. With more time and resources, using the original iMac CRT would certainly be an exciting project, as it would allow for use of almost all of the original technology with only minor added modifications.

The overall hope upon the completion of this project is that it leads to others re-purposing their old technology and potentially fitting or adding to these devices so they can be used in our current modern computing world and given a new purpose. This passion for revitalizing historical technology was the main driving force behind our project, and it was extremely inspiring and insightful to witness firsthand what we were able to accomplish and give new life to older technology that can now be used today.

Ethics:

The ethical issues that are relevant to our project that may arise during development relate to violations of patents. Within the ACM Code of Ethics[1], section 1.5 details the protection of a creator's work and ideas. Our project involves upgrading an existing computer and mouse created by Apple, therefore we must credit the creator during our development process. Throughout our project, we aimed to maintain the design, structure, and many of the original components of the original computer and mouse. In order to uphold these ethics, we do not take credit for the original designs that were used throughout this project. We will follow the IEEE Code of Ethics[2], which in part states that engineers must uphold the highest standards of integrity. Within this code of ethics, it is outlined that one must properly credit the contributions of others. The goal of this project was to not pass any original designs used off as our own, but instead to showcase the great innovation of the original iMac and mouse.

6 References

[1] Association for Computing Machinery. *ACM Code of Ethics and Professional Conduct.* `https://www.acm.org/code-of-ethics`. Accessed: Jun. 22, 2018. June 2018.

[2] Ian R. Dutton. "Engineering code of ethics". In: *IEEE Potentials* 9.4 (1990), pp. 30–31. DOI: `10.1109/45.65865`.

[3] Expressif Systems. *Smallsized WiFi and Bluetooth module*. Version 1.3. ESP32-C3-MINI-N1, 2022.

[4] mrjohnk. *mrjohnk/PMW3389DM*. GitHub repository. Apr. 2024. URL: `https://github.com/mrjohnk/PMW3389DM` (visited on 05/02/2024).

[5] T-vK. *ESP32-ble-mouse: Bluetooth LE Mouse Library for the ESP32 (Arduino IDE compatible)*. GitHub repository. 2024. URL: `https://github.com/T-vK/ESP32-BLE-Mouse/tree/master` (visited on 03/25/2024).