VEX VRC 2022-2023

Reverse Engineering Challenge

Disassembly and Summary Report of an Epson Stylus Photo 785EPX Printer

Gael Force Robotics

Team 5327Swag

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Introduction

Our Team

5327S was founded in 2018 for the Turning Point game and was revived in 2021 and 2022 by Elizabeth Koh and Jeia So. As the game changes, so do certain policies and rules, especially in light of the pandemic. With almost everything becoming virtual, one significant change we've made is the transition from a physical to an online digital notebook. We found that although this was initially more efficient and accessible for our team, it became a problem when a competition accepted physical notebooks only. With the amount of papers that we had to print (almost 200!), we were inspired to take apart a printer to understand the mechanisms behind the device we use daily.

Figure 1.1 and Figure 1.2: 5327S proudly shows off their robot.

Preliminary Planning and Research

Action Plan

As a team, we needed to establish the steps necessary to complete the project in order to better organize our disassembly and analysis process.

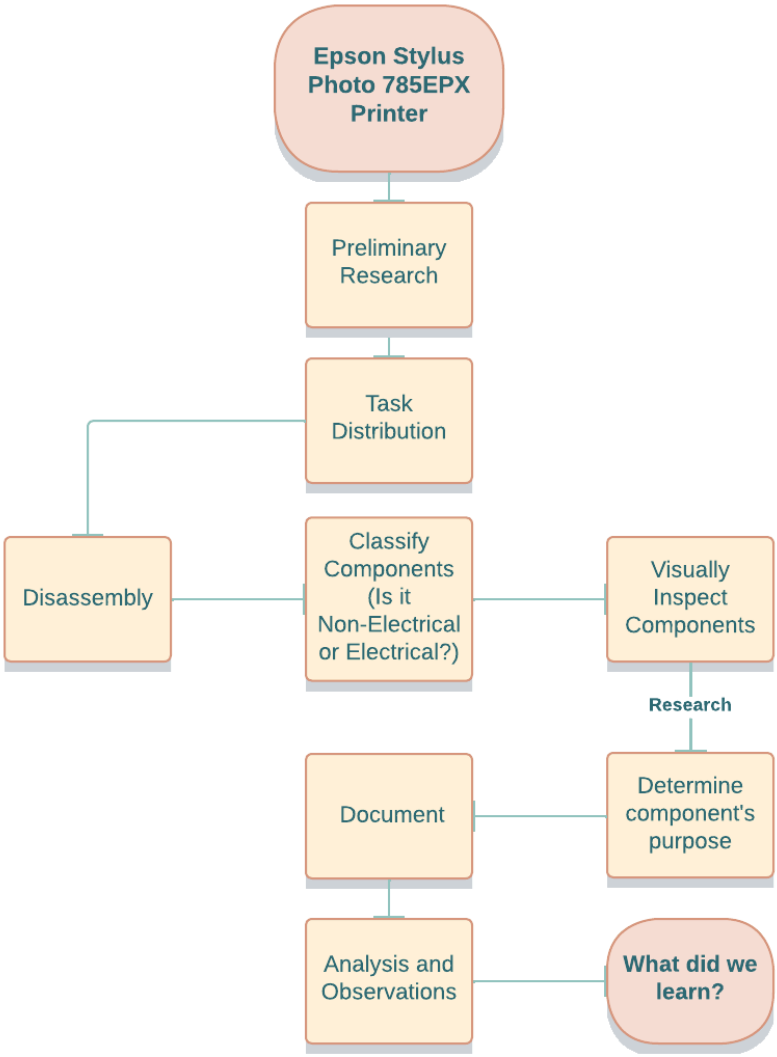


Figure 1 - 5327S flowchart plan to disassemble and analyze the Epson Printer.

Parts Schematic Diagram

Prior to disassembly, we researched more information on the printer to gain a better understanding of its internal parts and structure. This schematic would help us in the disassembly stage as it illustrates each component within the printer, allowing us to stay organized when breaking it down.

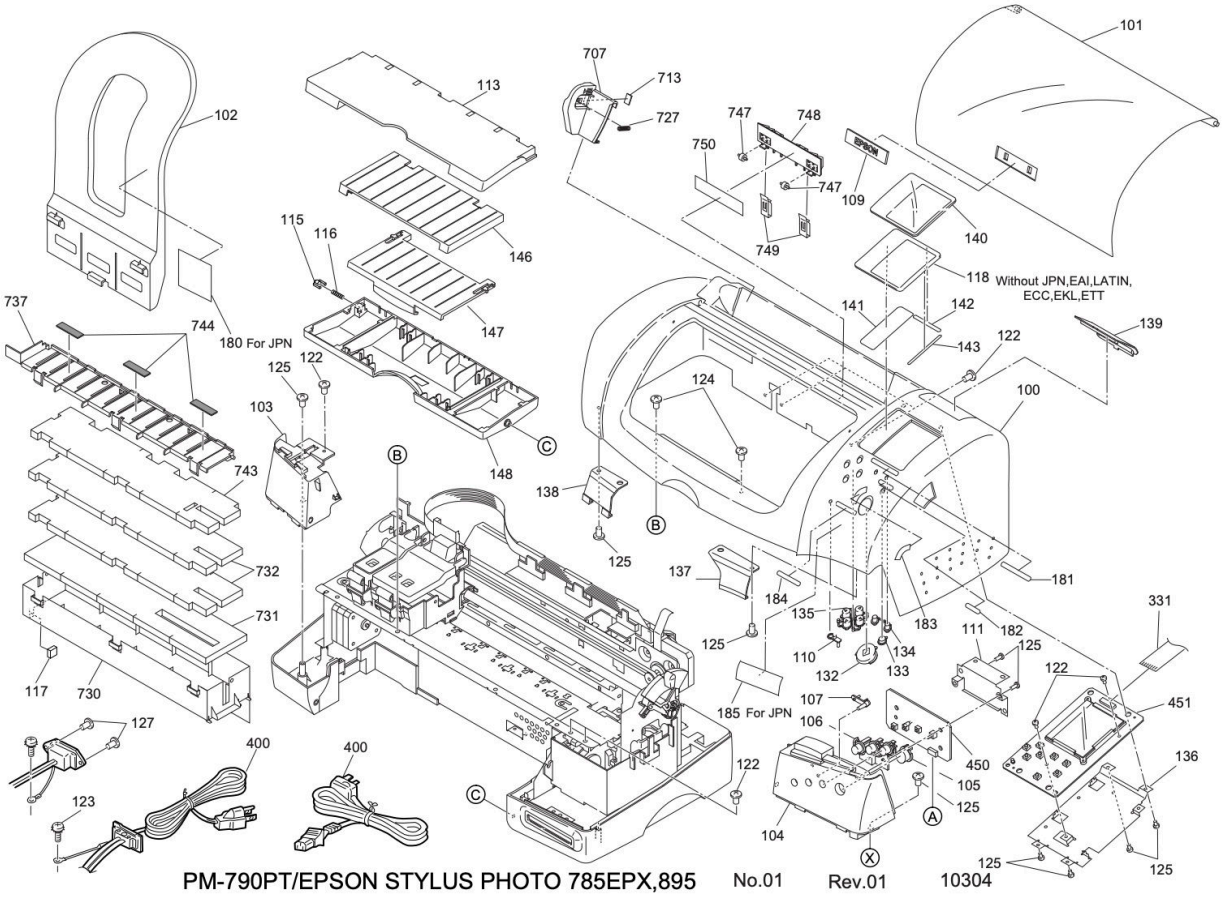


Figure 2 - Epson Stylus Photo 785EPX Parts Schematic.

Printer Components

After completing our planning and preliminary research, we disassembled the printer and analyzed its internal components.

Tools

- ➔ Phillips screwdriver
- ➔ Pliers
- ➔ Tweezers
- ➔ Nut Driver

Safety Precautions

- ➔ Gloves
- ➔ Protective Goggles
- ➔ Tarp/Trash Bag
- ➔ Mask

Disassembly Process

Step 1:

Acquire all safety equipment including gloves, goggles, a tarp, and masks, as well as the tools.

Step 2:

Remove the outer housing of the printer to reveal the internal mechanisms.

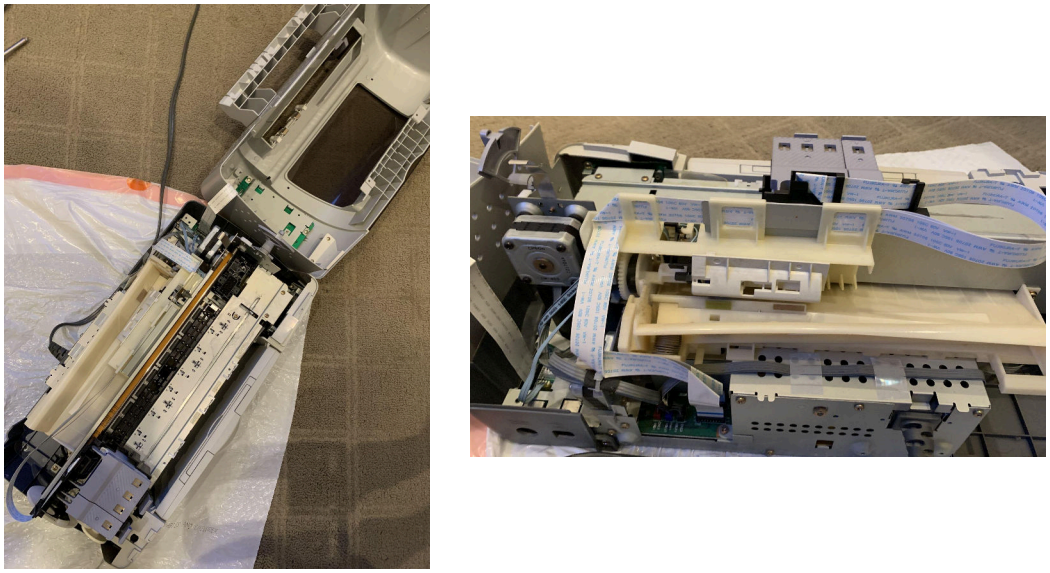


Figure 3.1: The internal mechanisms of the printer.

Step 3:

Locate and remove the panel circuit boards from the housing.

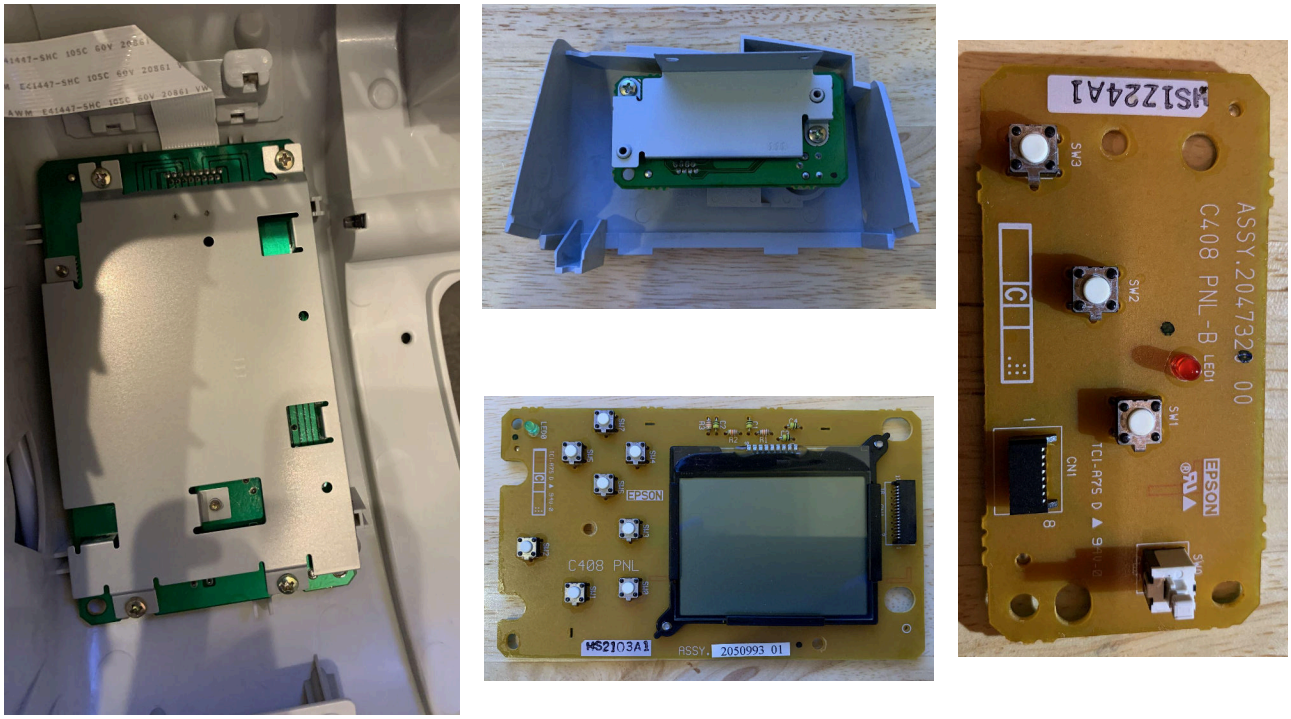


Figure 3.2: The printer's circuit boards.

Step 4:

Locate and remove the ink cartridges from the printhead, then remove the printhead.

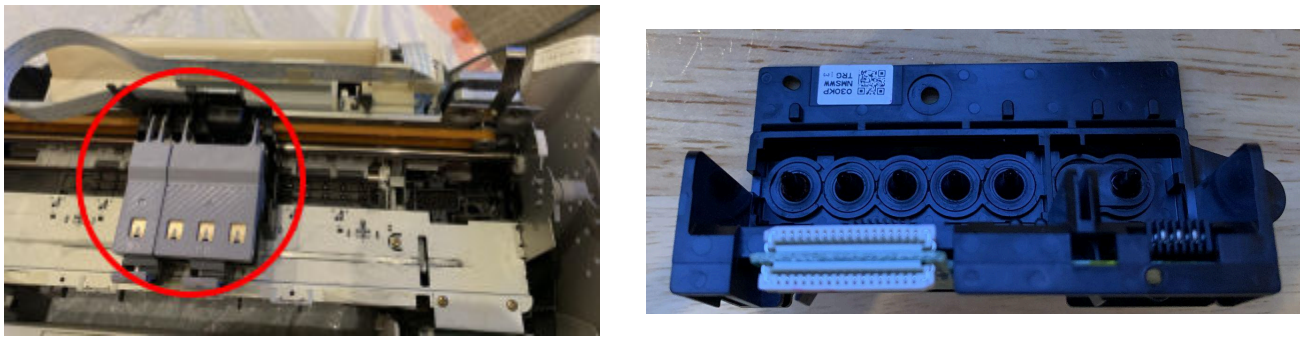


Figure 3.3: Removing the printhead from the printer.

Step 5:

Remove the Waste Ink Reservoir and Foam Pads.

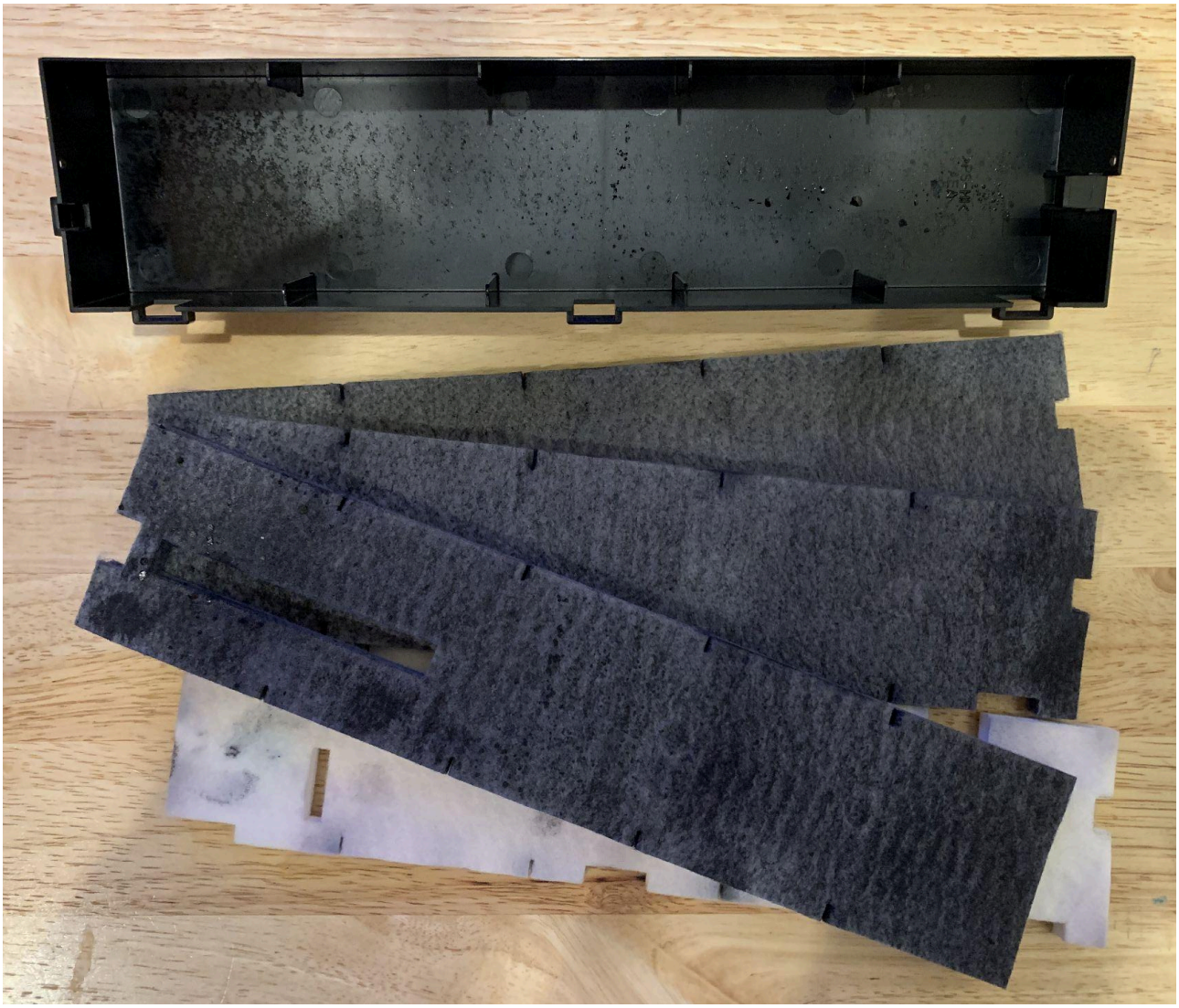


Figure 3.3: Waste Ink Reservoir and Foam Pads.

Step 6:

Remove metal housings over MAIN circuit board and C408 PSB circuit board, then remove each respectively.

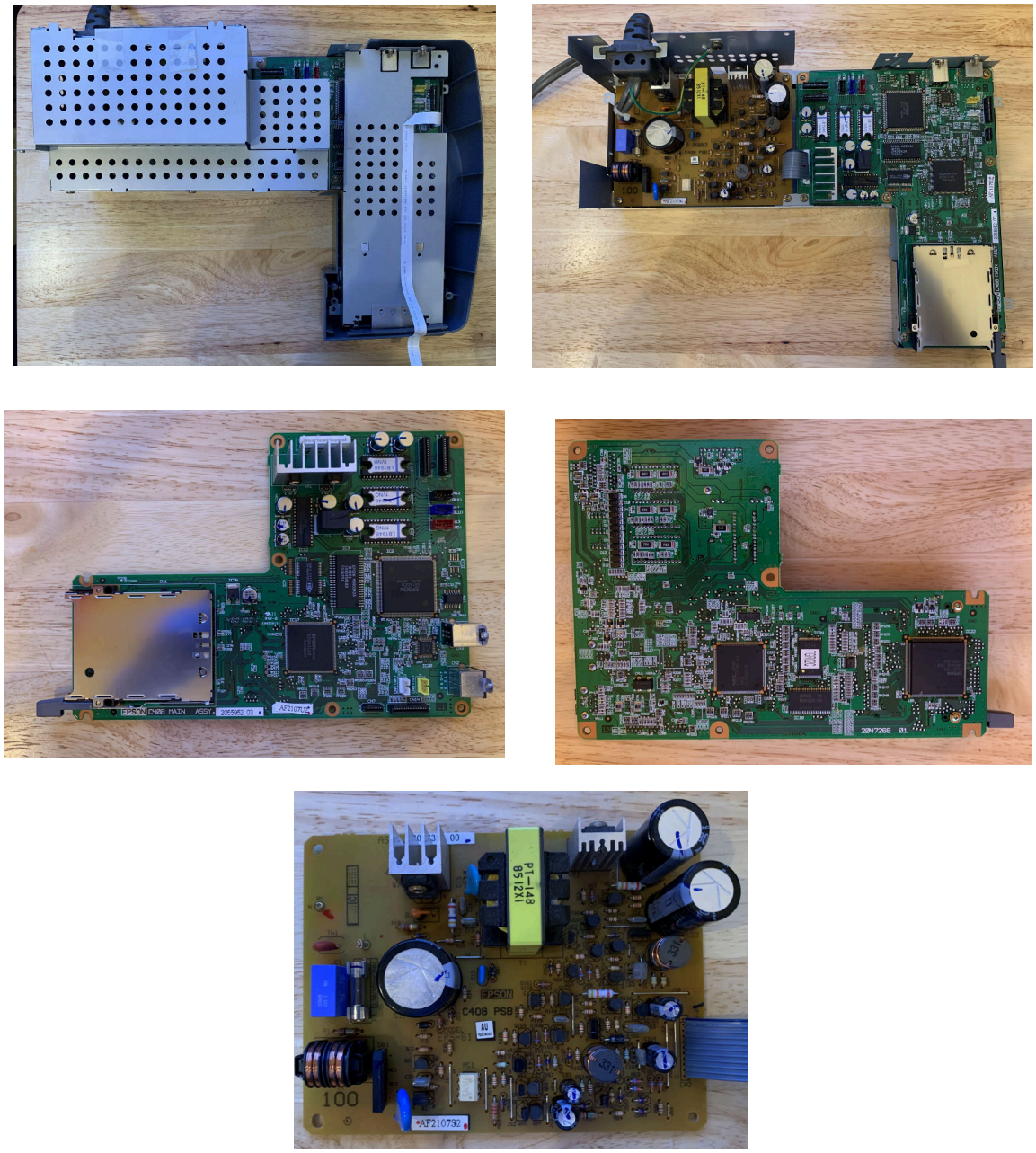
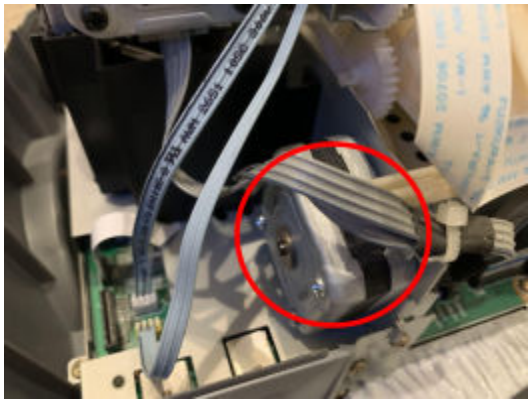
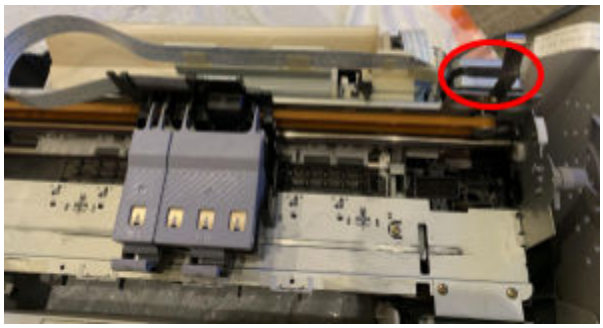
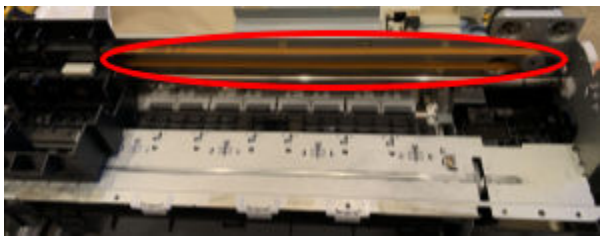
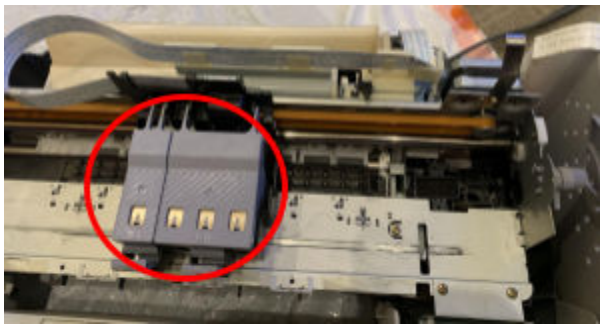
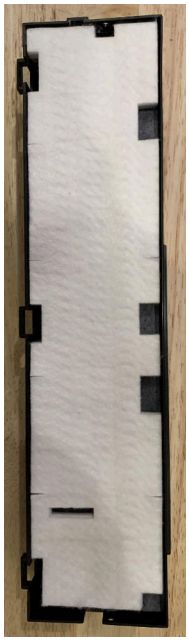
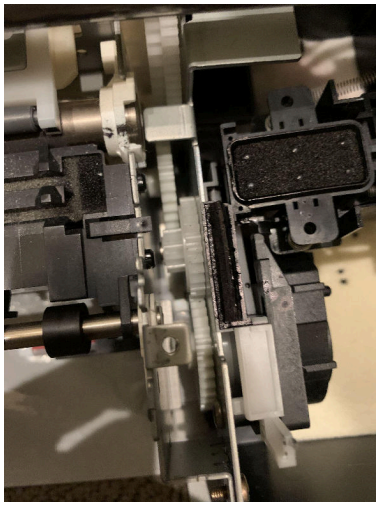
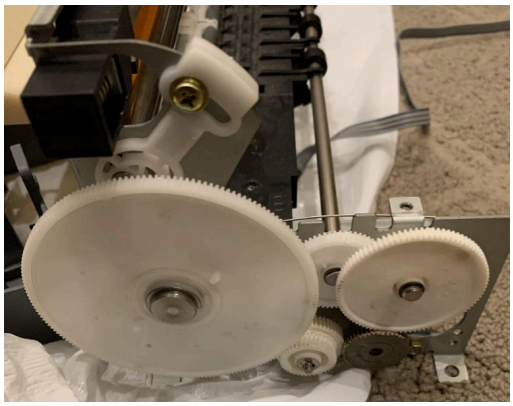


Figure 3.2: Removing circuit board metal housing.

Physical (Non-Electrical) Components Overview

Component and Description	Image
ASF (Auto Sheet Feed) Motor This motor is used to load paper into the printer from the rear, and guides it into the PF rollers.	
PF (Paper Feed) Motor This motor is a part of the paper feeding mechanism within the printer, taking the paper from the ASF and feeding it into the printer.	
CR (Carriage) Motor This motor controls the carriage unit to move it back and forth. It is connected to the carriage unit with the CR Timing belt.	

CR Timing Belt This belt rotates parallel to the printing surface in order to move the printhead along the sheet of paper.	
Printhead This component stores ink cartridges (black and color) and dispenses the ink.	
Waste Ink Reservoir This reservoir along with the porous foam pads inside collect any excess ink that may leak during the printing process.	 

Right Mounted Geartrain Works in conjunction with the ASF Motor.	
Left Mounted Geartrain Works in conjunction with the PF Motor.	
Rubberized Rollers These rollers are used in conjunction with the PF and ASF motors to guide the paper.	

Electrical Components Overview

Within the Epson Stylus Photo 785EPX, there are a total of 4 circuit boards that allow the printer to function. We inspected and analyzed each of these circuit boards to understand their role in the entire system.

C408 Main Control Circuit Board:

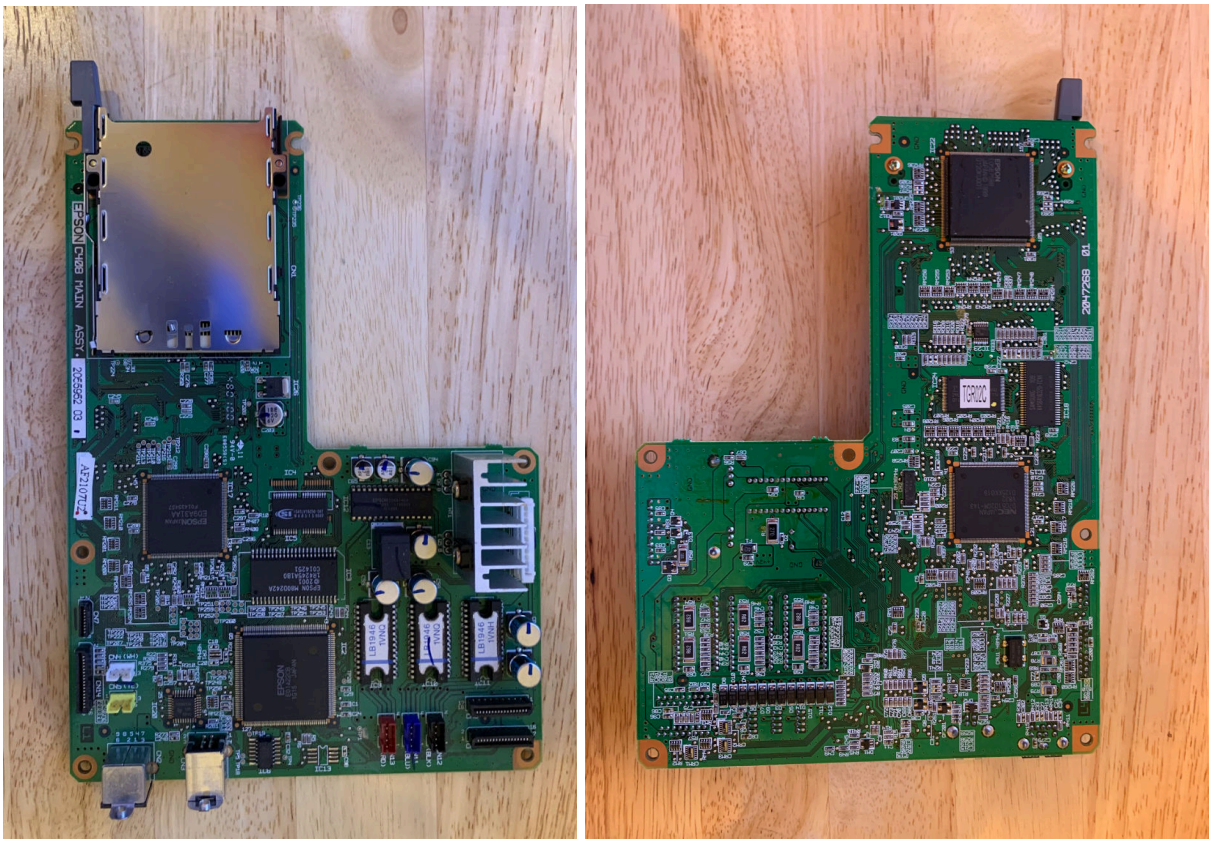
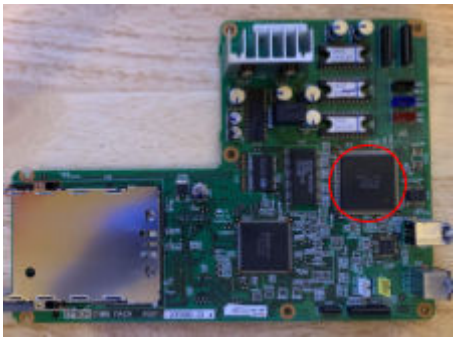
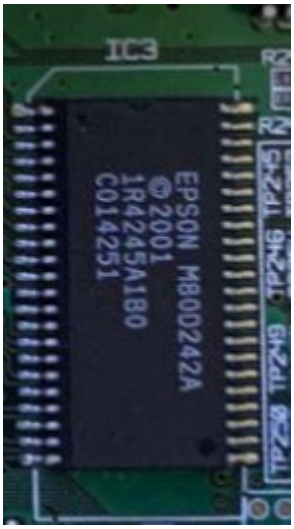
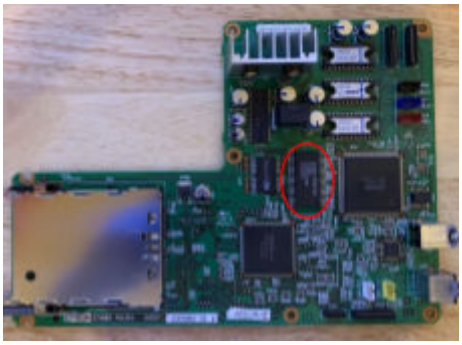
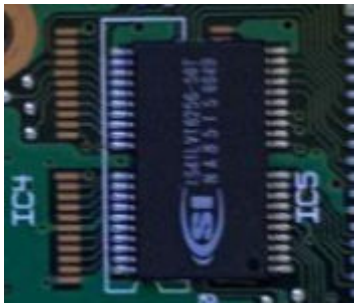
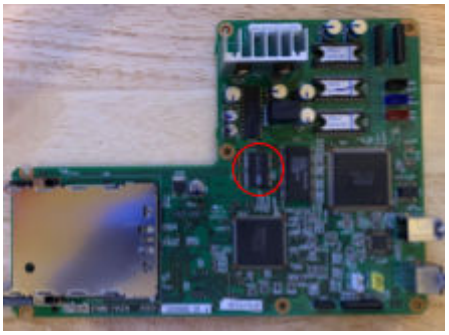
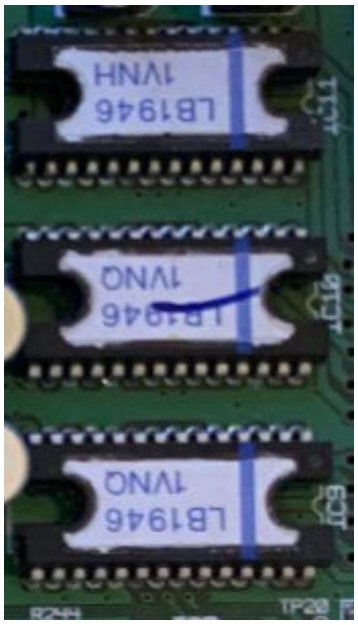
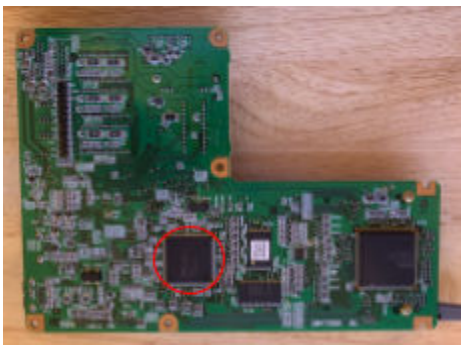
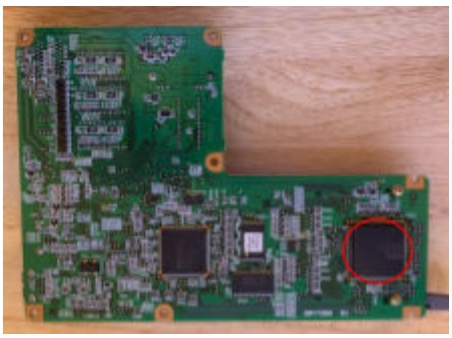
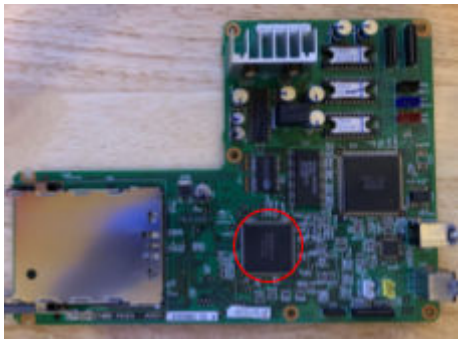
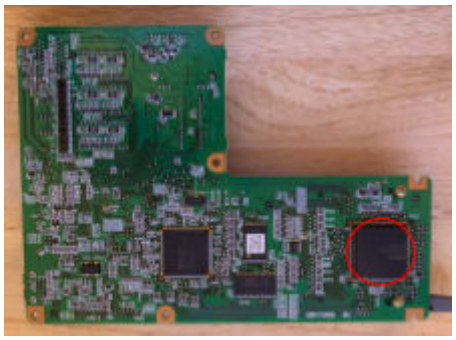
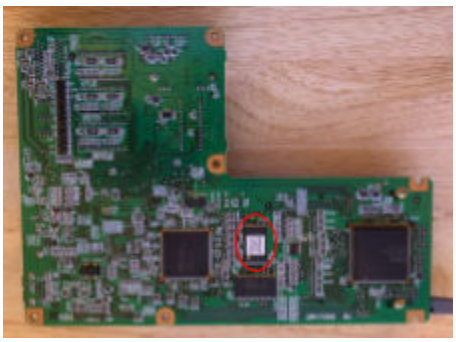
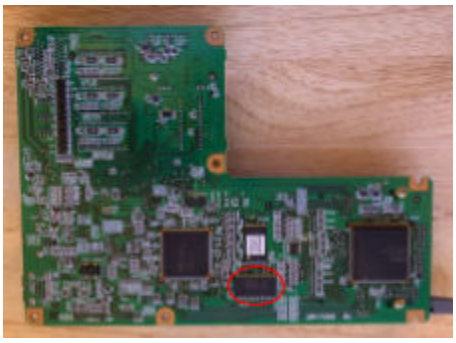
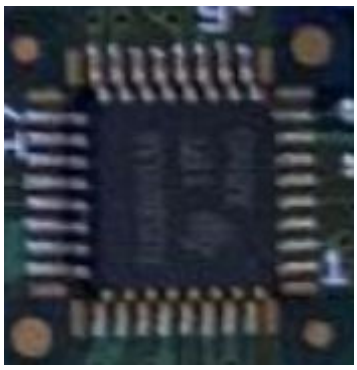


Figure 4.1.1: Front and back images of C408 Main Control Circuit Board.

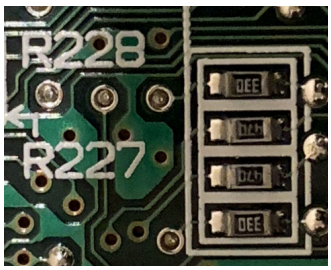
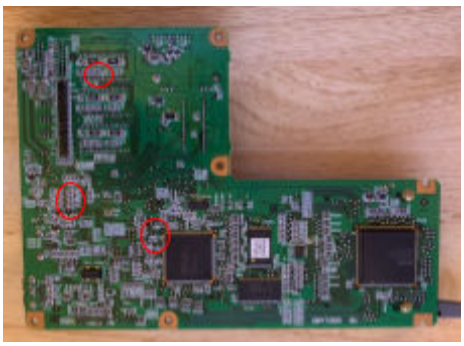
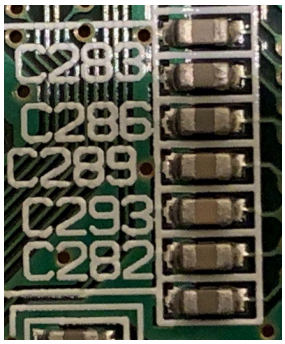
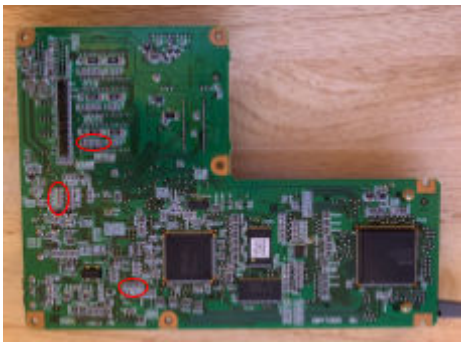
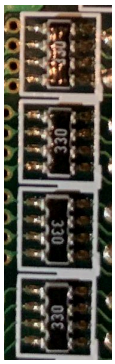
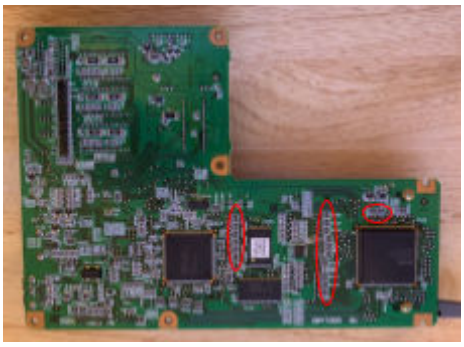
Component and Description	Image	Location
CPU-ASIC 2in1 (IC2) - E01A22CA A 16-bit CPU that controls the printer, located on main board side 1. Data Sheet Not Available		
PROM (IC3) Memory which stores permanent data after the manufacturing process, located on main board side 1.		
DRAM (IC4, IC5) Software necessary for the printer to function is stored in DRAM, accessed by the CPU. Located on main board side 1.		

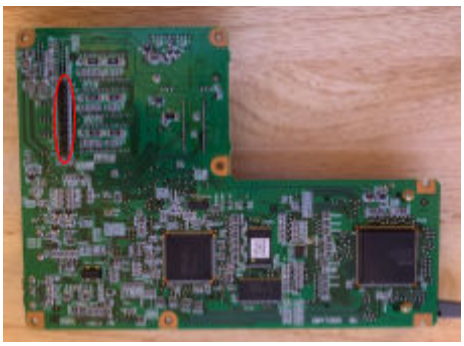
RTC (IC6) - RTC9822 Generates clock pulses that are required by the CPU and other ICs. Located on main board side 1. Data Sheet Not Available		
PWM Current Control Stepping Motor Driver (IC9, IC10, IC11) - LB1946 Sends pulses to stepper motors (Carriage Motor, Paper Feeding Motor, Auto Sheet Feeding Motor) to dictate the speed and direction of the motor. Located on main board side 1. Data Sheet		
CPU V832 (IC15) - UPD705102GM-143-8ED Controls storage for USB and image processing. Located on main board side 2. Data Sheet		

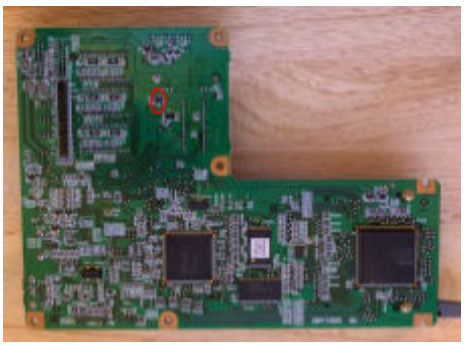
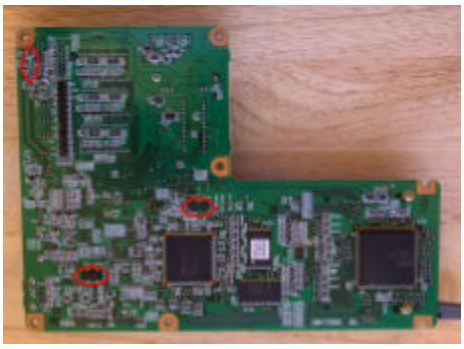
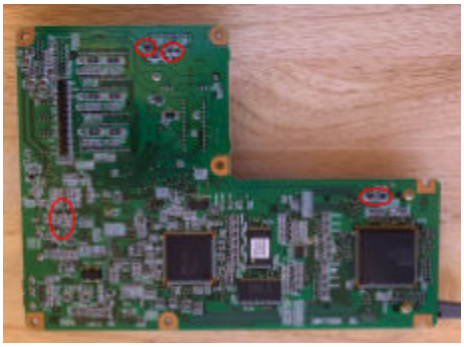
ASIC1 (IC22) - E05B75B* Custom silicon IC for use in an inkjet printer. Located on main board side 2. No Data Sheet Available		
ASIC2 (IC17) - E09A27A* Custom silicon IC for use in an inkjet printer. Located on main board side 1. No Data Sheet Available		
PCMCIA Socket Power Controller (IC23) - MAX1602 AD (Analog to Digital) convertor. Located on main board side 2. Data Sheet		

Flash ROM (IC24) - MBM29LV160TC/BC Non-volatile storage that can be electrically erased and reprogrammed. Located on main board side 2. Data Sheet		
SDRAM (IC18) - K4S641632D Synchronized Dynamic RAM is a type of DRAM which is synced with system clock and is faster than regular DRAM. Located on main board side 2. Data Sheet		
USB HUB IC (IC20) - TUSB2036VF USB 2.0 compliant device with integrated transmitter and receiver (transceiver) for upstream and downstream ports. Located on main board side 1. Data Sheet		

Common Driver (IC12) - E09A14RA An IC which controls the print head. Located on main board side 1. Data Sheet Not Available		
Linear Voltage Regulator (IC26) - BA25BC0FP An IC which regulates voltage providing 2.5V DC and 1 AMP of Current. Located on main board side 1. Data Sheet		

SMD Resistors Common type of resistor used to limit current and as a voltage divider. Quantity: 186 *Too small/many to determine all locations*		
SMD Capacitors Used to filter the output voltage in a power supply by storing an electrical charge, has a lower capacitance. Quantity: 155 *Too small/many to determine all locations*		
SMD Chip Resistor Array Array of resistors used to limit current and as a voltage divider. Quantity: 50 *Too small/many to determine all locations*		

SMD Diode - EC10QS06 Restricts current to only flow in one direction. Quantity: 15 Data Sheet *Too small/many to determine all locations*		
SMD Electrolytic Capacitor Used to filter the output voltage in a power supply by storing an electrical charge, has a higher capacitance. Quantity: 9		
Mosfet - A2037 1G Typically used to either increase or decrease the flow of energy; can control the conductivity of the circuit. Quantity: 2 No Data Sheet Available		

SMD Fuse - CCP2E40TE Ensures that electricity is cut off when an excessive current passes through Quantity: 1 Data Sheet		
Crystals Used to resonate at a specific frequency; crystals are typically used to keep track of time within a circuit. Quantity: 5		
Transistors - DTC143X Transistors are used to control an electric current to fit the circuit's needs. Quantity: 12 Data Sheet		

Purpose:

Being the main control board within the printer, this circuit board's main purpose is essentially to control the printer's processes. If a signal to print is detected by the main control board, it will instruct the subsystems in the printer— paper loading and feeding mechanisms, homing the carriage unit (carriage mechanism), what state the printhead should be in, etc— and ultimately will direct the printer to complete its given task.

Component Distribution of the C408 Main Control Circuit Board:

Component	Quantity
Resistors	236
Capacitors	164
NPN Transistors	10
Diodes	15
Mosfet Transistors	2
Crystals	5
Fuse	1
Connectors	13

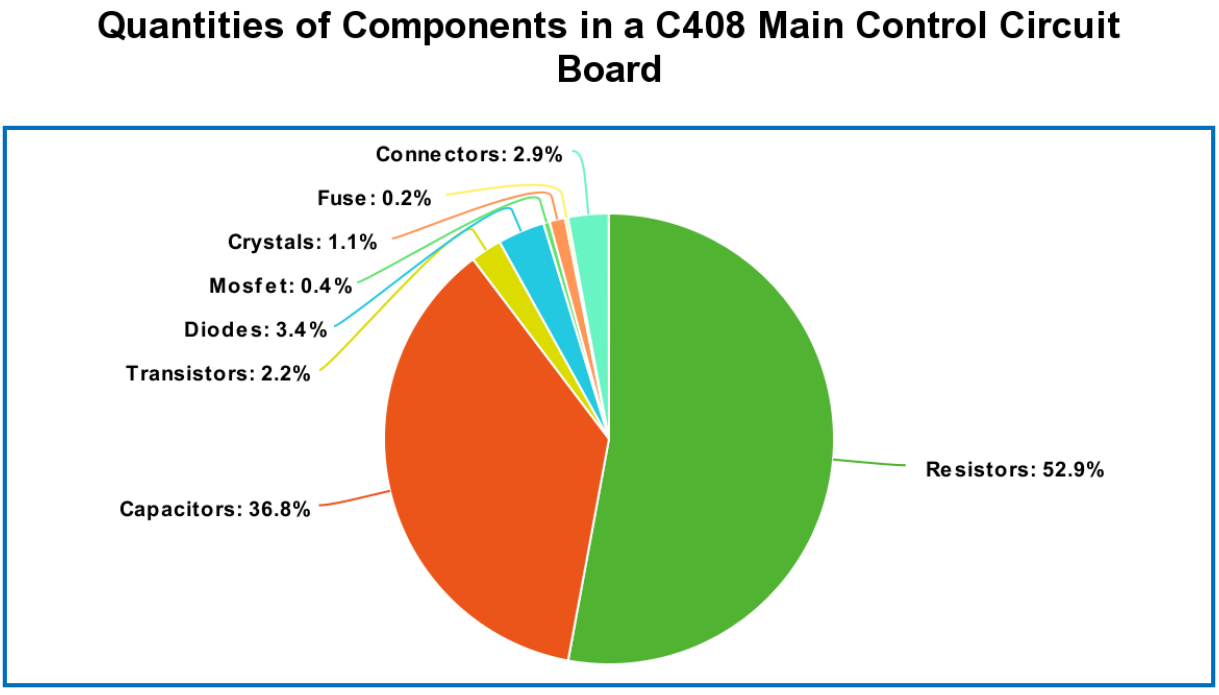


Figure 4.1.2: Pie chart of component quantities in the C408 Main Control Circuit Board.

C408 PSB (Power Supply Board) Circuit Board:

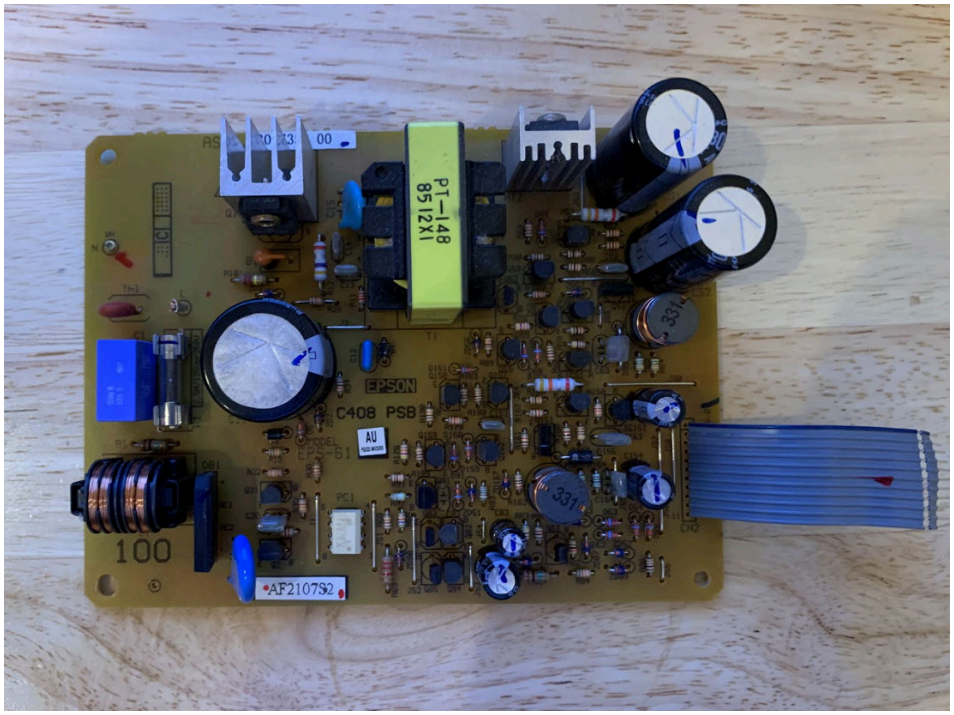
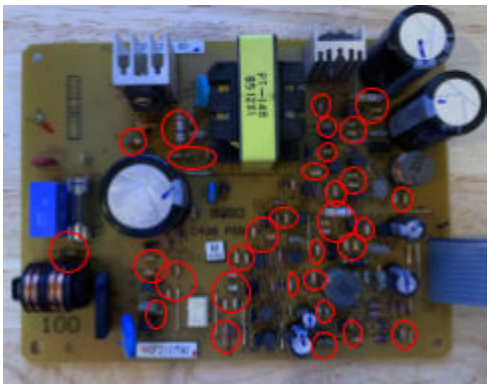
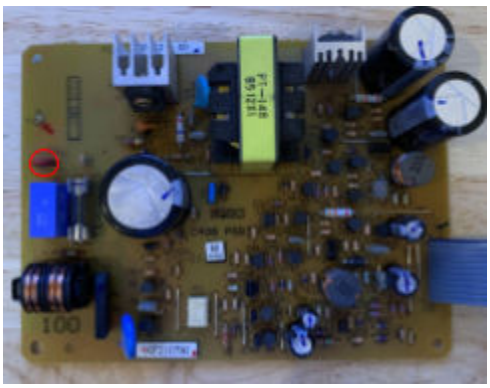
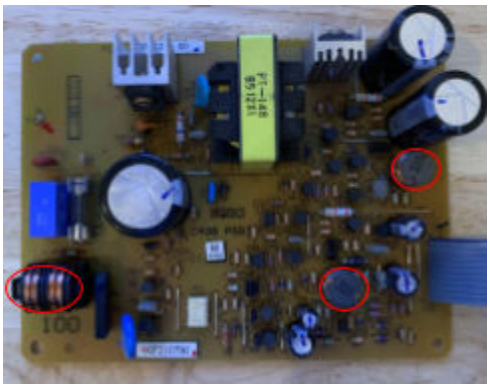
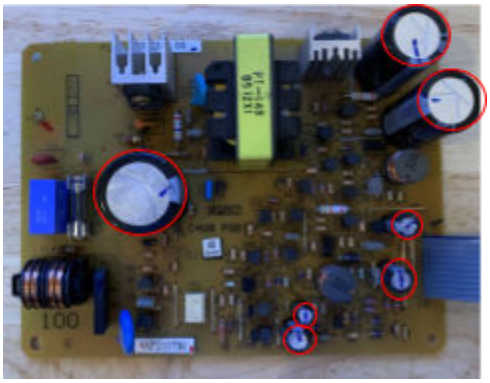
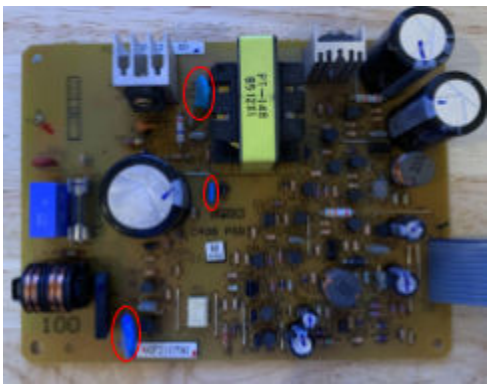
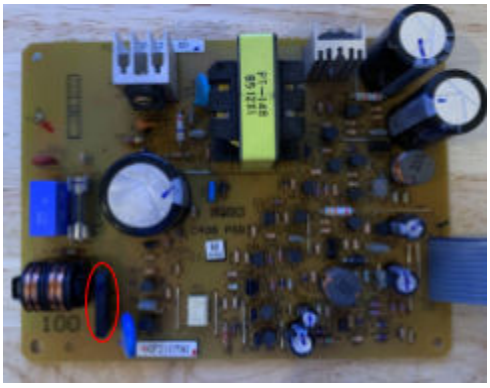
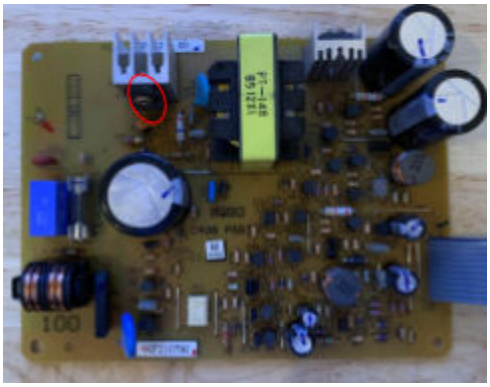
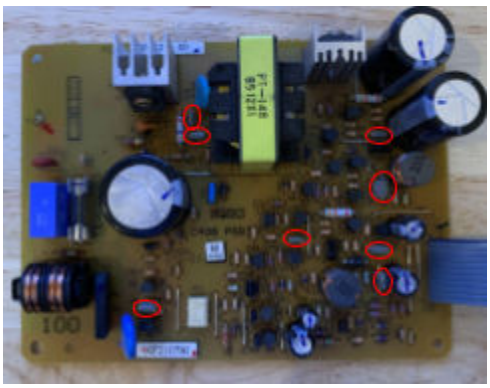
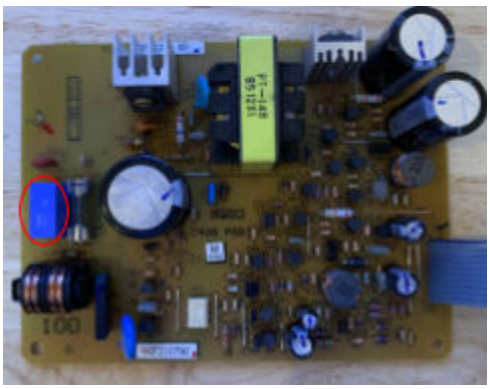
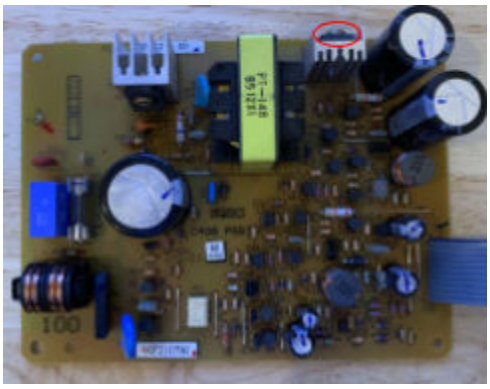


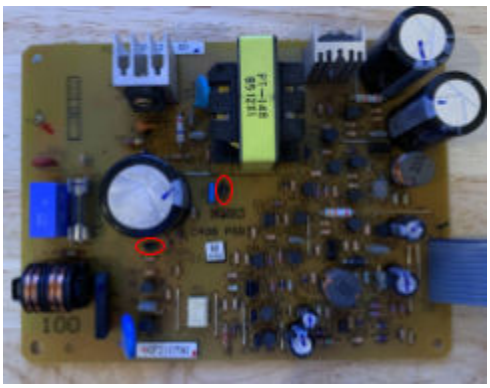
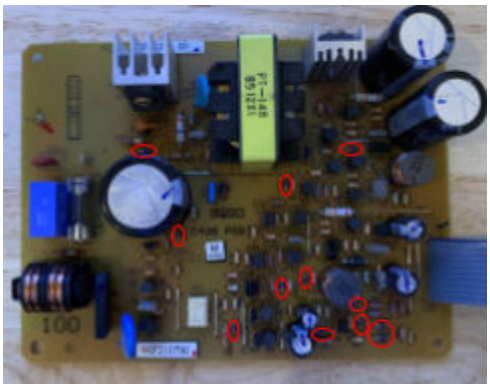
Figure 4.2.1: Front view of C408 PSB Circuit Board.

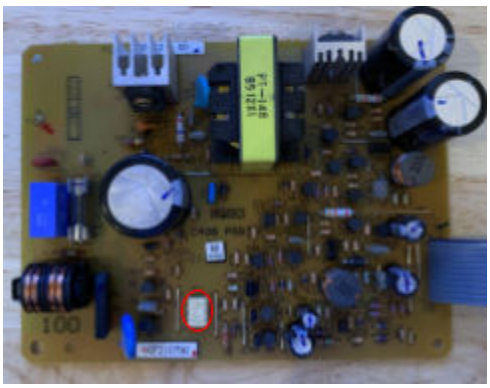
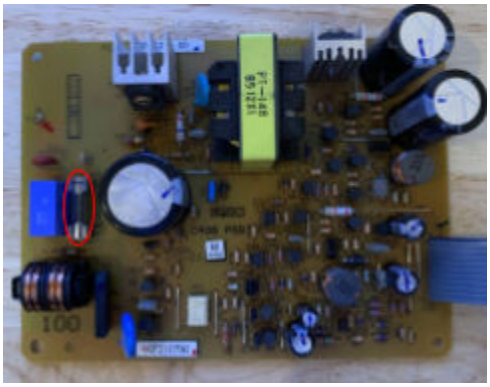
Component and Description	Image	Location
Carbon Film Resistors Common type of resistor used to limit current and as a voltage divider. Quantity: 53 Data Sheet		

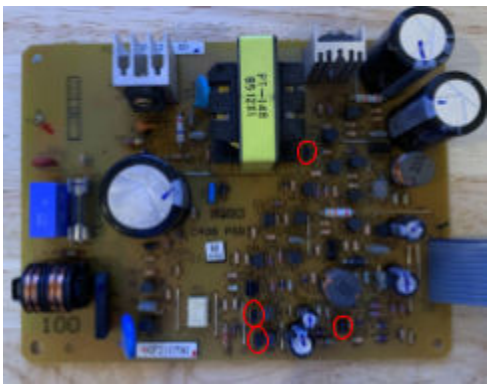
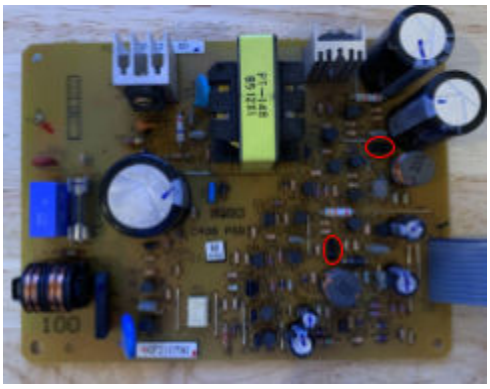
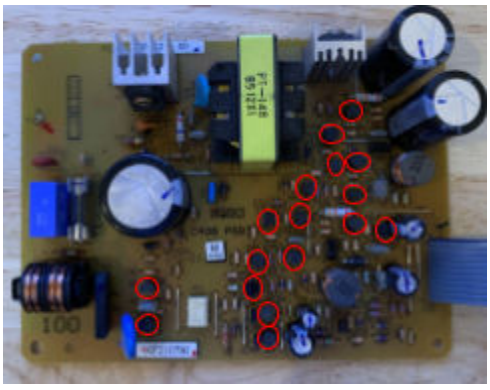
Polyfuse Used as a safety precaution against overcurrent, expands polymer when excess current is passed through and returns to original shape under normal circumstances. Quantity: 1 Similar Data Sheet		
Inductor Used to filter and regulate current in Switched-Mode Power Supply (SMPS). Quantity: 3		
Electrolytic Capacitor Used to filter the output voltage in a power supply by storing an electrical charge, has a higher capacitance. Quantity: 7		

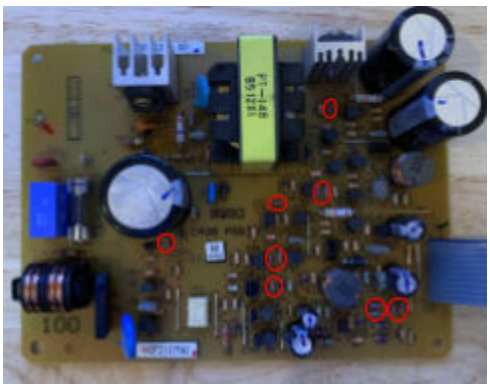
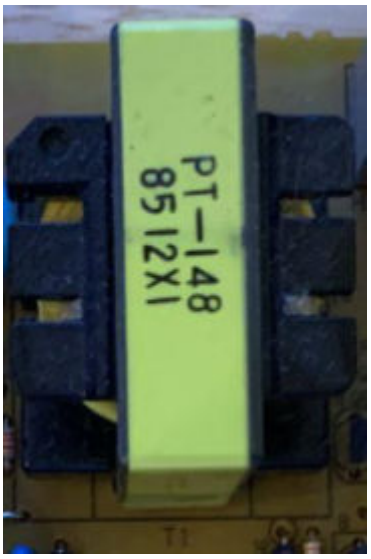
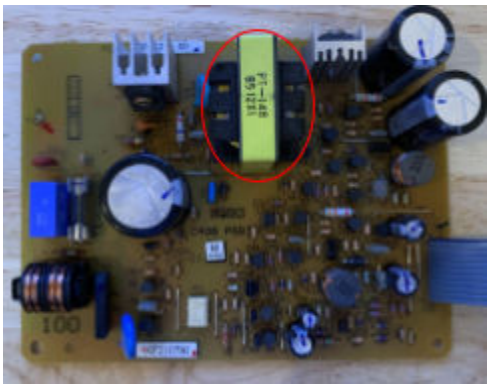
Ceramic Capacitor Used to filter the output voltage in a power supply by storing an electrical charge– has a lower capacitance. Quantity: 3		
Bridge Rectifier - D2SBA60-4001 A set of 4 diodes arranged in a bridge circuit to convert from AC to DC in a power supply. Quantity: 1 Data Sheet		
Mosfet - H5N5006FM Used to control and determine the conductivity of the circuit. Quantity: 1 Data Sheet		

Polyethylene Propylene Film Capacitor Used to filter the output voltage in a power supply by storing an electrical charge– has a lower capacitance. Quantity: 8		
Film Box Capacitor - X2 Used to filter the output voltage in a power supply by storing an electrical charge– has a higher capacitance, Quantity: 1 No Data Sheet Available		
Schottky Diode - FSH04A10 A diode used for significantly fast switching speeds. Quantity: 1 Data Sheet		

Diode - EAB83 Restricts current to only flow in one direction. Quantity: 2 Data Sheet Not Available		
Zener Diode - HZS7A-1 Allows current to flow once it reaches the Zener voltage, and is always connected reverse-biased. Quantity: 12 Data Sheet		

Opto-Coupler - TLP621-2 Isolates high tension from low tension circuits in a power supply. Quantity: 1		
Fuse 2.5A 125 or 250V Provides a safety measure against an overflow of current within a circuit as it cuts off the flow of energy by melting. Quantity: 1		

Bias Resistor built-in Transistor - DTA113Z To reduce the number of components, specifically resistors, on a circuit board, a BRT is a bipolar transistor containing bias resistors. Quantity: 4 Data Sheet		
Silicon PNP Transistor - A1707 A transistor with a high current capacity and switching speed. Quantity: 2 Data Sheet		
Silicon NPN Transistor - 2SC4408 A transistor with high current capacity, amplifying, and fast switching applications. Quantity: 17 Data Sheet		

Germanium Diode - GMAO 1U A diode made with germanium, allowing energy to flow in only one direction, but has a lower temperature stability. Quantity: 12		
Potential Transformer - PT-148 8512X1 A component that typically measures alternating voltage within a circuit, and can convert high voltages to lower voltages. Quantity: 1		

Purpose:

Shown below is a side by side of the actual circuit and the block diagram of the PSB/PSE. The power supply boards of Stylus Photo 925 use a RCC (Ringing Chalk Converter) circuit, which generates +42VDC for the drive line and +5VDC, +3.3VDC for the logic line to drive the printer, according to the data sheet. It amplifies and transmits between the printer's terminals and serves as an interface between logic lines. This is very important for providing the necessary voltage certain parts of the printer require to function.

There are multiple control circuits on the PSB/PSE to pause the voltage output if a malfunction occurs in the printer to prevent any further damage to the system. In this circuit, the main component is where 42V, 3.3 V, and 5 V DC power is generated for different parts of the printer to use. This process is managed by multiple protection circuits that help ensure that there is no power overload while constant voltage is being generated. There is also a control circuit and a power saving mode based on specific printer functions to time the voltage.

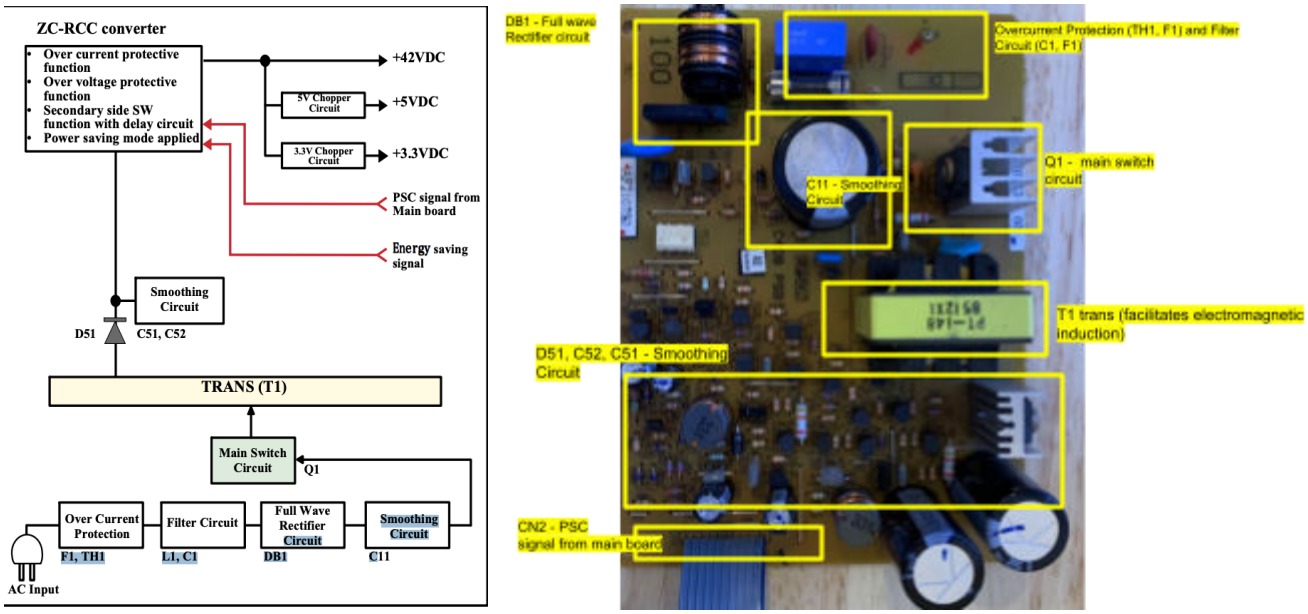


Figure 4.2.2: Side by side image of the C408 PSB Circuit

Component Distribution of the C408 PSB Circuit Board:

Component	Quantity
Resistors	57
Capacitors	19
Inductors	3
Diodes	27

NPN Transistors	23
Mosfet	1
Bridge Rectifier	1
Opto-Coupler	1
Transformer	1
Fuse	2

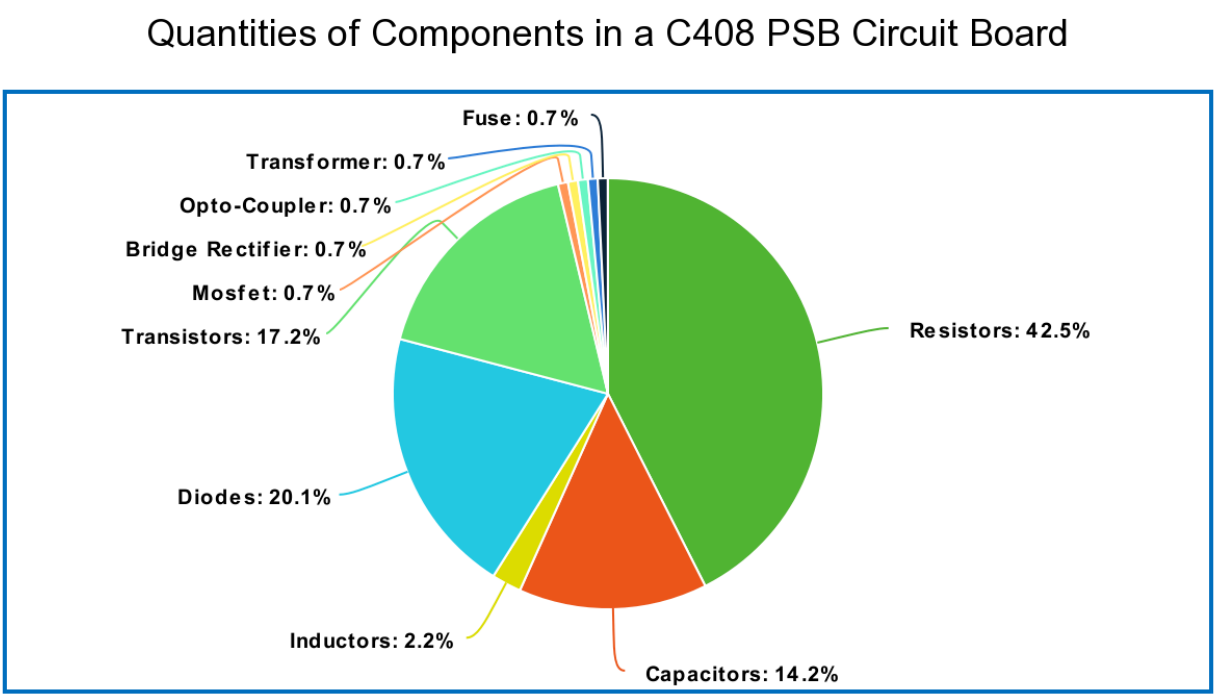


Figure 4.2.3: Pie chart of component quantities in the C408 PSB Circuit Board.

C408 PNL Circuit Board:

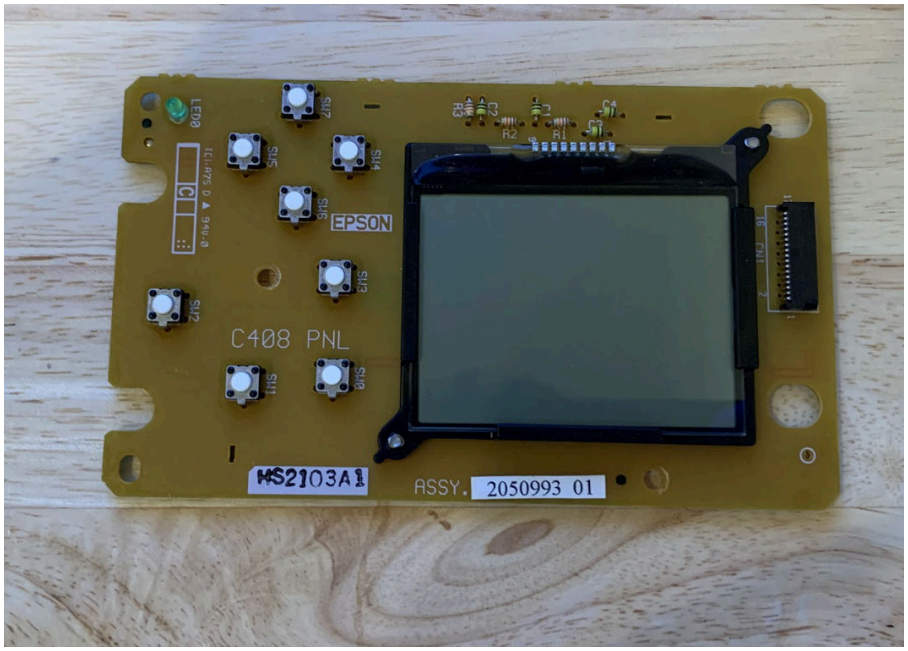
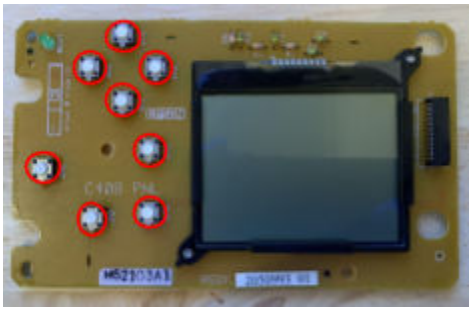
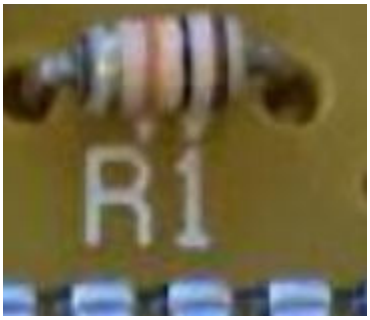
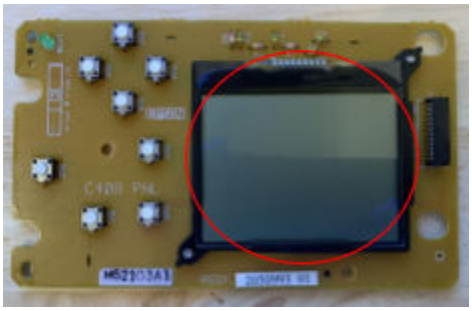


Figure 4.3.1: Front view of C408 PNL Circuit Board.

Component and Description	Image	Location
Push Button Switch (SPDT) Used to manually control the circuit; can switch on or off. Quantity: 8		

Carbon Film Resistors Common type of resistor used to limit current and as a voltage divider. Quantity: 3 Data Sheet		
Carbon Film Capacitor Used to filter the output voltage in a power supply by storing an electrical charge, has a lower capacitance. Quantity: 4		
LED (Light Emitting Diode) Used to signal when an action is successfully performed during the printing process. Quantity: 1		
Monochrome Panel - RCM1738R-A A small display used to show messages from the printer. Quantity: 1		

Purpose:

This controls the main user interface for the primary functions of the printer. Once the printer is turned on (PNL-B) a digital menu will be displayed on the monochrome panel. Each Push Button Switch is used for various inputs such as: Photo selection, brightness, print, arrow keys, and cancel.

Component Distribution of the C408 PNL Circuit Board:

Component	Quantity
Monochrome Panel	1
Push Button Switch	8
Resistors	3
Capacitors	4
Connector	1

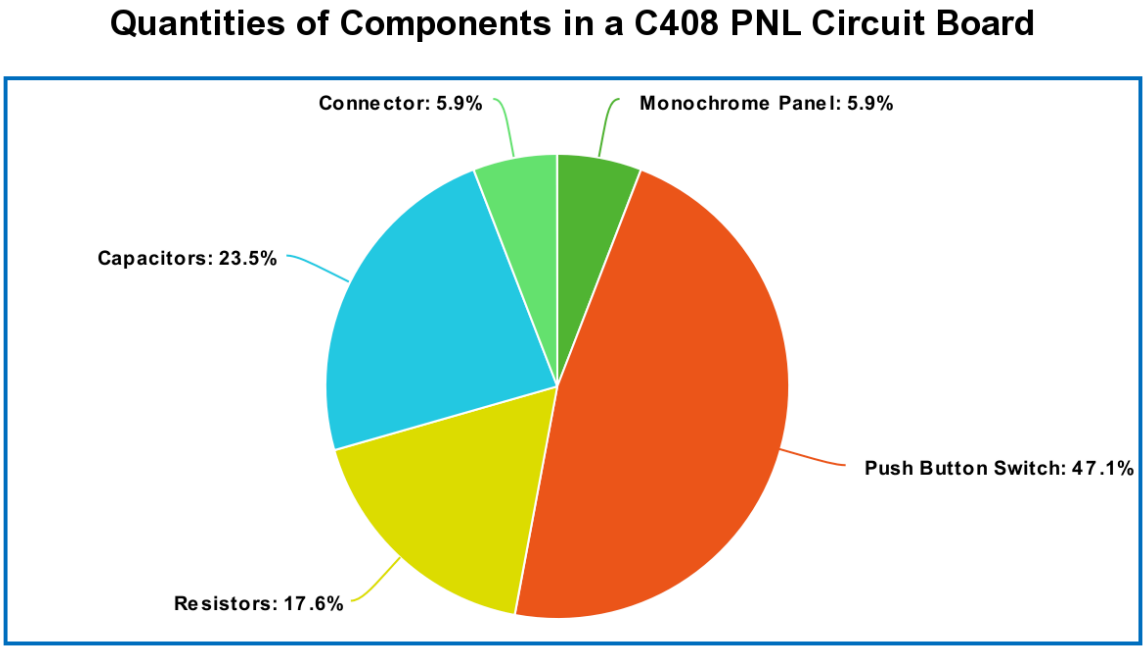


Figure 4.3.2: Pie chart of component quantities in the C408 PNL Circuit Board.

C408PNL-B Circuit Board:

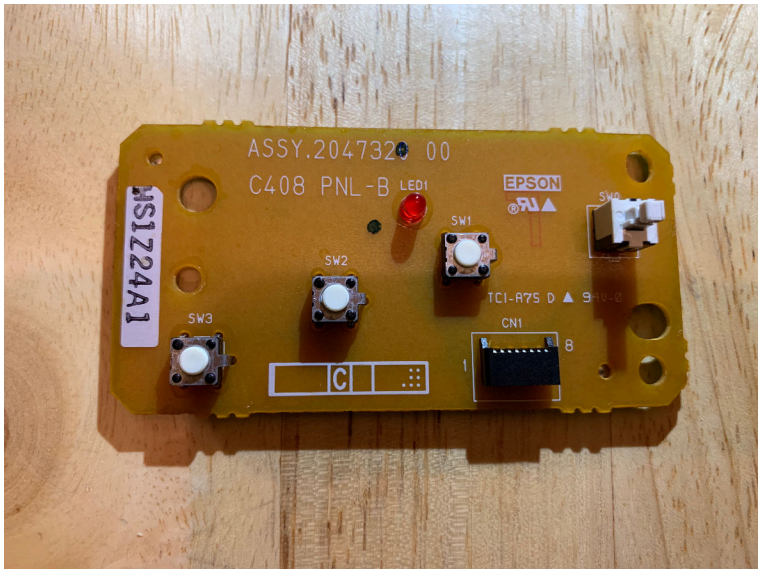
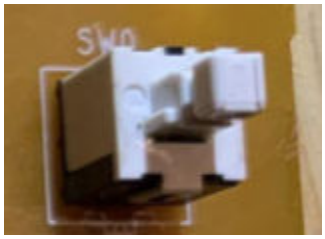
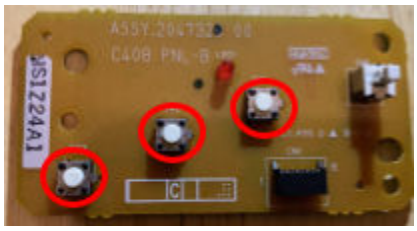
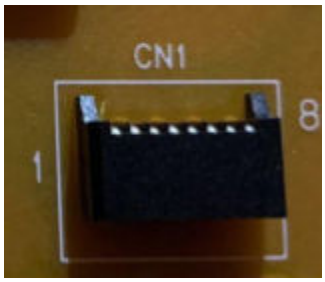


Figure 4.4.1: Front view of C408PNL-B Circuit Board.

Component and Description	Image	Location
Push Lock Switch A switch that can be pressed to manually open or close an electrical circuit. This button causes the printer to power on. Quantity: 1		
Push Button Switch A switch that can be used to manually control an electrical circuit, turning a process on or off. Quantity: 3		

LED (Light Emitting Diode) This LED is used within the printer to signal an error. Quantity: 1		
Connector Electrically connects parts of the circuit together. Quantity: 1		

Purpose:

This is the secondary user interface used to turn on the printer (Push Lock Switch) and perform maintenance when necessary. The three Push Button Switches are used to Reset the printer, eject/insert paper, or replace the ink cartridges. An LED also indicates if there is an error during the printing process.

Component Distribution of the C408PNL-B Circuit Board:

Component	Quantity
Switches	4
Connector	1
LED	1

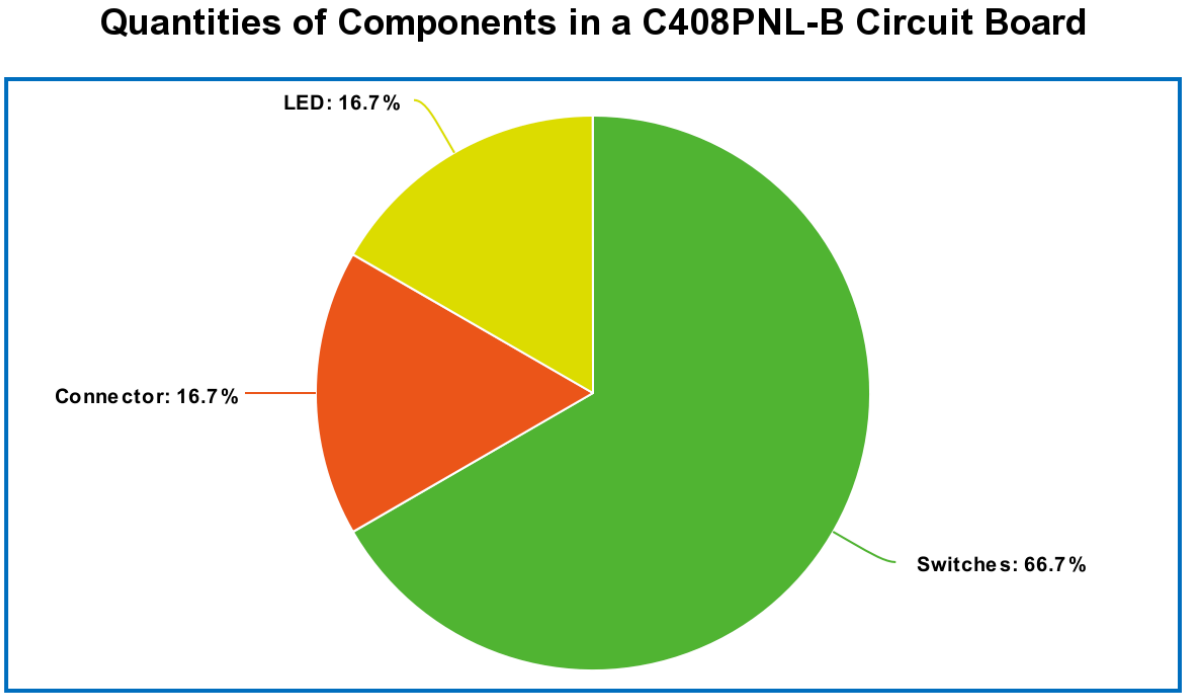


Figure 4.4.2: Pie chart of component quantities in the C408 PNL-B Circuit Board.

Component Analysis Summary

Through utilizing schematic diagrams, visual inspection, and research online, we are able to identify the components in each circuit board and their purpose within the printer. We then created an estimated summary below of the number of each electrical component type amongst all of the circuit boards we analyzed.

Final Quantity of Electrical Components

Component	Quantity
Resistors	296
Capacitors	187
Transistors	23
Diodes	42
Inductors	3
Mosfet Transistors	3
Fuse	3
Connectors	15
Crystals	5
Bridge Rectifier	1
Opto-Coupler	1
Transformer	1
B1	1
Push Button Switch	8
Monochrome Panel	1

LED	1
Switches	4

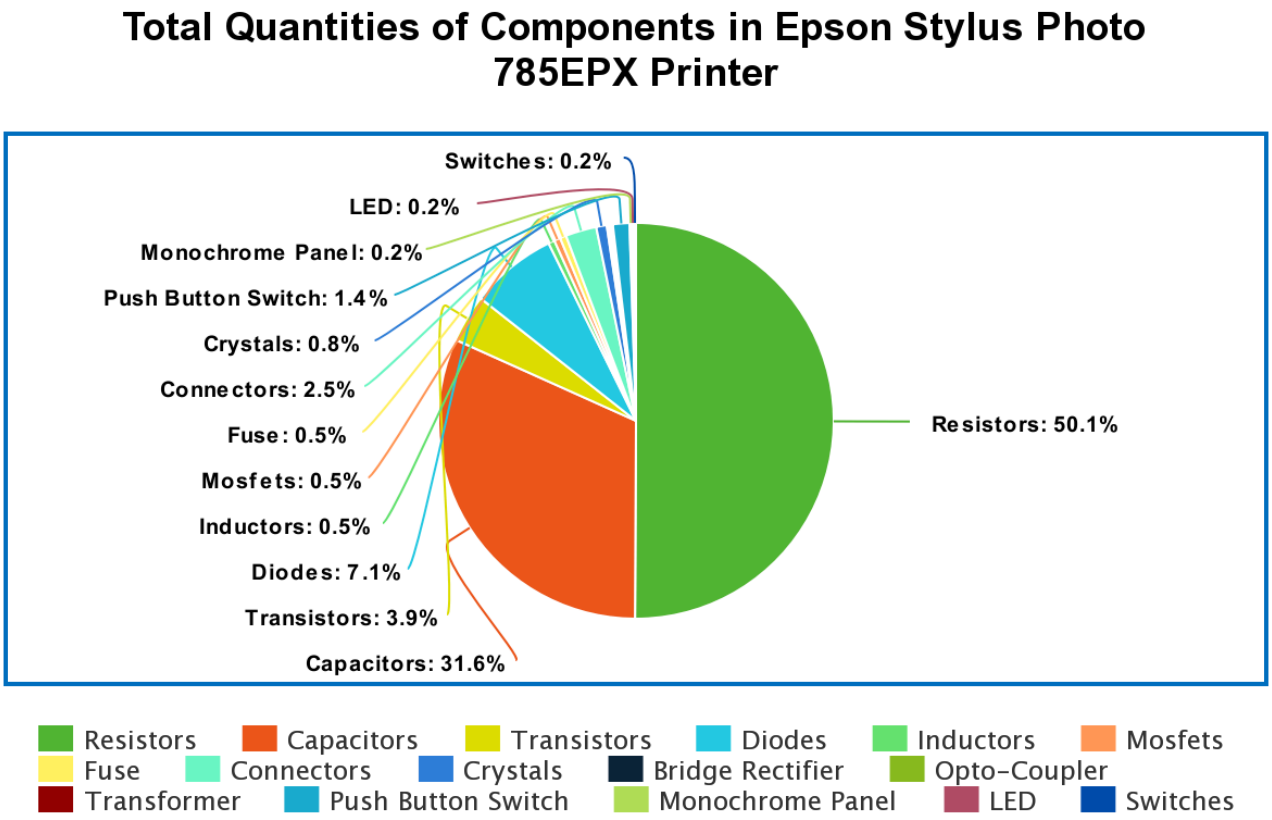


Figure 5: Final pie chart of all components and their quantities in the printer.

System Observations

After inspecting and determining the functions of each of the printer's circuit boards, we were able to see the process the entire device runs through to complete certain tasks, as seen in the control flow chart below.

Control Flow Chart:

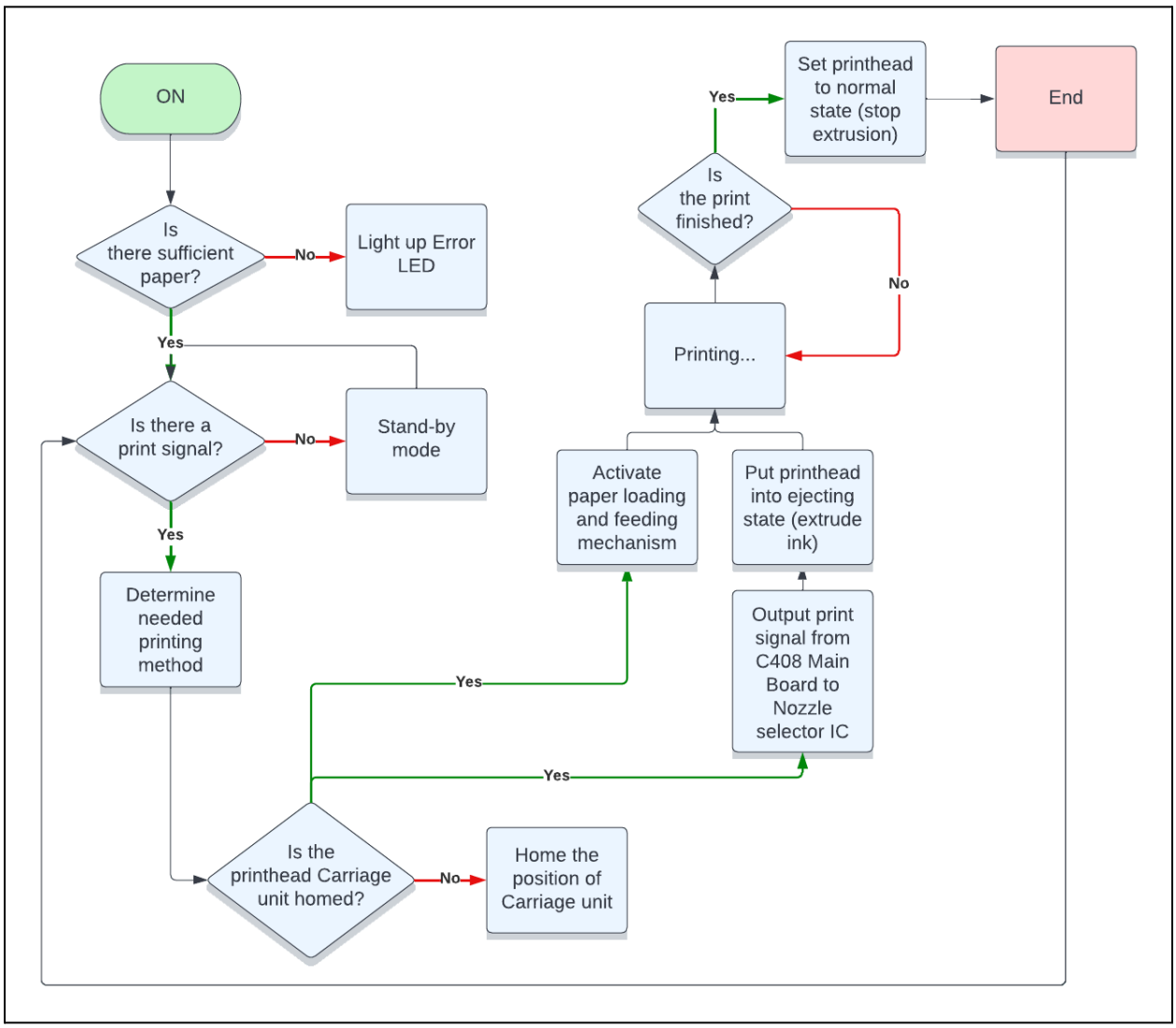


Figure 6: Control flow chart of the printing process.

Conclusion – What did we learn?

There were a total of 4 circuit boards that we analyzed and compiled, all of which were necessary for the mechanical and electronic subsystems to function properly. In order to accurately identify both the mechanical and electrical components, we consulted the service manual, learned about electrical circuits from thorough online research, and bounced thoughts and questions off each other to improve our collective understanding.

The main mechanical systems we found were the Paper Feeding Mechanism (PF Motor, Left Mounted Geartrain), the Auto Sheet Feeder (ASF Motor, Right Mounted Geartrain), Carriage Mechanism (CR Motor, Printhead, CR Timing Belt), and the Waste Ink Reservoir (Felt Pads). Both the Paper Feeding Mechanism and the Auto Sheet Feeder used rubberized rollers to grip and guide the paper.

The electronic systems were on the MAIN Control, the PSB (Power Supply Board), and the PNL/PNL-B, circuit boards. The Main board was a double sided PCB which contained all 16 of the ICs. Side 1 had a CPU, memory (DRAM, PROM), power management, real time clock (RTC), and the printhead & motor drivers. Side 2 had another CPU, memory (Flash ROM, SDRAM), and a socket power (PCMCIA). We concluded that the CPU on side 2 was used for image processing as it was 32-bit compared to the lesser 16-bit CPU on side 1. The most abundant components on the Power Supply Board were resistors, followed by diodes and capacitors. We researched and found that all of these components were crucial to regulate current and voltage throughout a circuit board. Due to the various voltage and current requirements for the many ICs on the main board, we hypothisized that this majority was a consequence of those requirements. The main board had a similar composition. The panel boards

consisted of several buttons, LEDs, and a monochrome display, making up the user interface.

From this process, we learned a lot about teamwork and cooperation; when deconstructing the different systems, we found that we had to be very coordinated with each other to work efficiently, and that we had to focus more than usual because we were dealing with parts that were smaller and more fragile than VEX parts. Additionally, we sped up the process a lot faster by distributing the tasks to different teams. Doing so helped more of us learn about the mechanisms because not only did we take it apart ourselves, but we also repeatedly explained what we did to each other to further our understanding. This process also taught us how valuable it is to have members with diverse perspectives. Often, newer members had questions about parts that could be answered by more experienced members, and through this process members of all experience levels learned new things about everyday mechanisms.

Word Count - 451

Resources

Other resources such as data sheets are linked with its corresponding component within the document

- ➔ https://www.cuidevices.com/blog/push-button-switches-101
- ➔ https://en.wikipedia.org/wiki/Schottky_diode
- ➔ https://www.elprocus.com/mosfet-as-a-switch-circuit-diagram-free-circuits/
- ➔ https://www.tutorialspoint.com/what-is-potential-transformer-p-t-and-how-it-works#:~:text=A%20potential%20transformer%20(P.T.)%20is,voltage%20in%20a%20power%20system.
- ➔ https://www.differencebetween.com/what-is-the-difference-between-silicon-diode-and-germanium-diode/
- ➔ https://byjus.com/physics/working-principle-of-an-electrical-fuse/#:~:text=An%20electrical%20fuse%20is%20a,excess%20current%20flows%20through%20it.
- ➔ https://en.wikipedia.org/wiki/Crystal_oscillator
- ➔ https://www.metrofuser.com/post/printer-parts-glossary
- ➔ https://www.ablcircuits.co.uk/pcb-components/
- ➔ https://www.ourpcb.com/pcb-components.html
- ➔ https://www.seeedstudio.com/blog/2019/06/12/12-commonly-used-components-on-pcbs-for-beginners/
- ➔ https://www.apogeeweb.net/electron/what-is-a-thermal-fuse.html
- ➔ https://www.power-and-beyond.com/understanding-the-role-of-inductors-in-power-electronics-a-dc947f2aa88d7ac3009791f798478d1c/
- ➔ https://toshiba.semicon-storage.com/us/semiconductor/knowledge/faq/diode/for-what-purposes-are-zener-diodes-used.html
- ➔ https://data2.manualslib.com/pdf3/70/6985/698460-epson/stylus_photo_895.pdf?6a5ca50391dbc5cf10bc159e478a9dfa