Electronics Online Challenge

Amazon Kindle Paperwhite Disassembly

Team 5327C

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GAEL FORCE ROBOTICS 5327C

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Final Summary Report

Our team decided to disassemble a Kindle Paperwhite because it uses a unique E-Ink display, quite different from the LCD displays commonly found in other electronics. We were curious as to how the E-Ink display works and how a Kindle operates in general.

We began by carefully removing the front and back covers to reveal the motherboard and display. Next, the heat and EMI (Electromagnetic Interference) shields were removed, exposing the integrated chips. Using part numbers and branding on the chips, we were able to locate datasheets for most and determine their functions. The motherboard had a Freescale ARM-Cortex based processor, a Samsung LPDDR2 memory chip, a Maxim power management chip, a SanDisk storage chip, a Micronix flash storage chip and an Atheros wireless communication chip. Unfortunately, we were unable to locate any TI chips on the motherboard. Aside from the chips, there were a variety of other electronic components. Identifying them was extremely challenging due to their minute size and large quantity. Under the lens of a microscope, capacitors, resistors, transistors, inductors, oscillators, crystal oscillators, relays, antennas, and diodes came into clear view. We discovered that our Kindle even implemented zero-ohm resistors in place of jumper wires. We also found some things on the motherboard that weren't really electronic components, but were crucial to the assembly process: fiducial marks, solder heat resistance test sites, and test points. We identified the gold spots at the edges of the motherboard as fiducial marks, which the assembly machines use to align themselves for precision component placement. Test points and solder heat resistance test sites introduced us to the important subjects of electronics quality control and how manufacturers verify the device is working.

After thoroughly inspecting the motherboard, we began to take apart the E-Ink display. Unfortunately, it was secured into place with a strong adhesive, so we were forced to break off a piece. Using the microscope, we observed the E-Ink microcapsules, as well as the electrode grid that generates charges. We learned that the display involves charged ink particles. When an electrode inside the display has a negative charge, the negatively charged white ink will be repelled and rise to the surface; likewise, when the electrode has a positive charge, the positively charged black ink will be repelled and rise to the surface. This is how the Kindle displays black and white.

During this challenge, our team learned about designing and manufacturing electronic devices. We observed how electrical components work together to make a functioning device. We found that the E-Ink display uses the charges of the electrodes and ink to display text. Conducting in-depth research helped us discover components we had never encountered before, like Zero-Ohm Resistors and Fiducial Marks. This challenge helped us appreciate the complexity and elegance of design required for such a compact device. Overall, we gained valuable knowledge about electronic components which has fueled our continued curiosity about the inner workings of electronic devices.

Word Count: 488

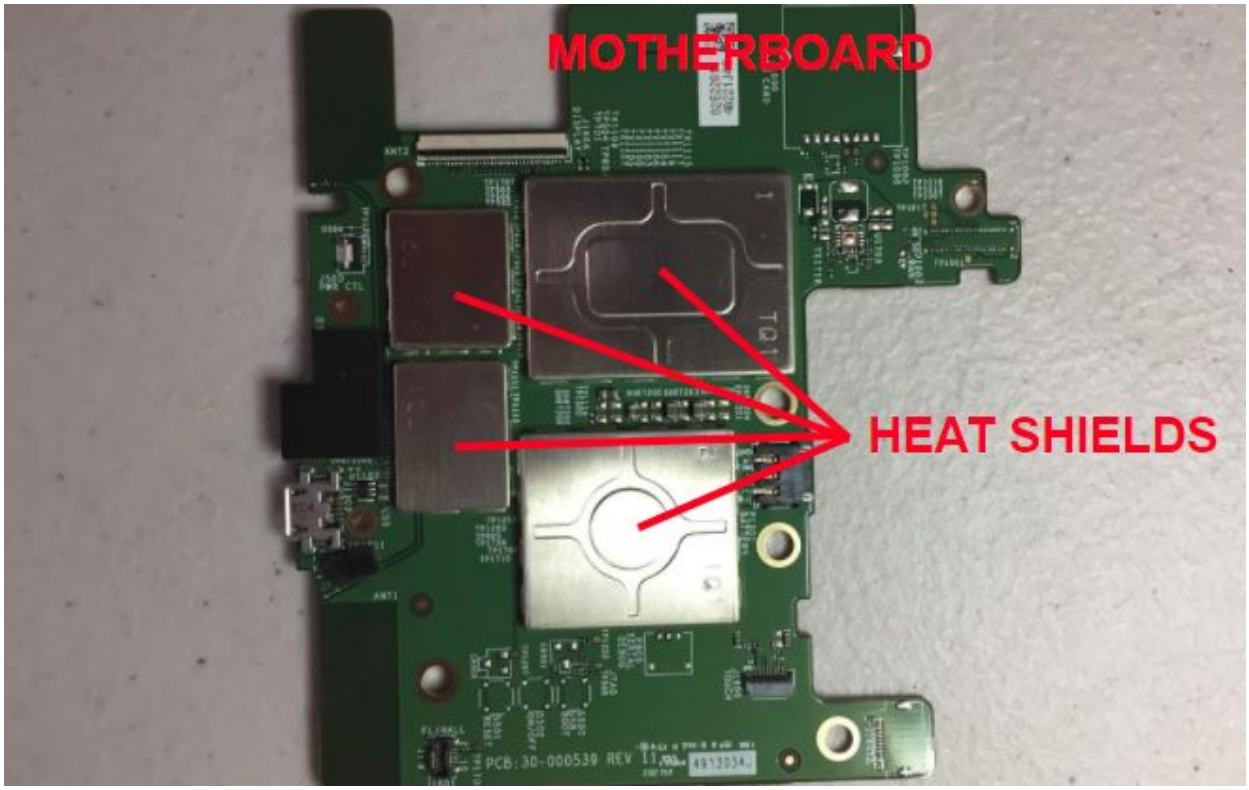
Disassembly Procedure

Step one: Obtain broken Kindle Paperwhite and tools, including but not limited to: tweezers, pliers, gloves, exacto knife, safety goggles, etc.

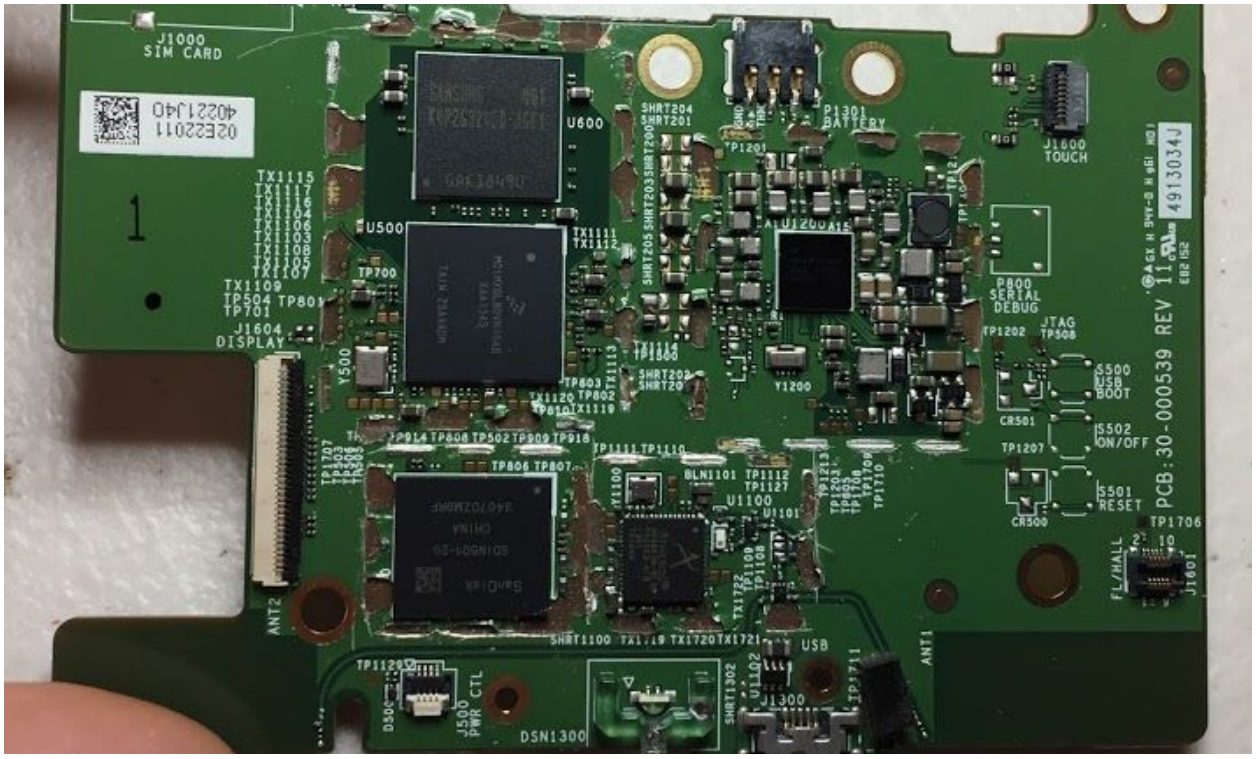
Step two: Remove bezel plate using exacto knife to cut away adhesive.

Step three: Flip over Kindle and remove back cover without damaging anything. This was difficult because it is attached with adhesive that is securely attached.

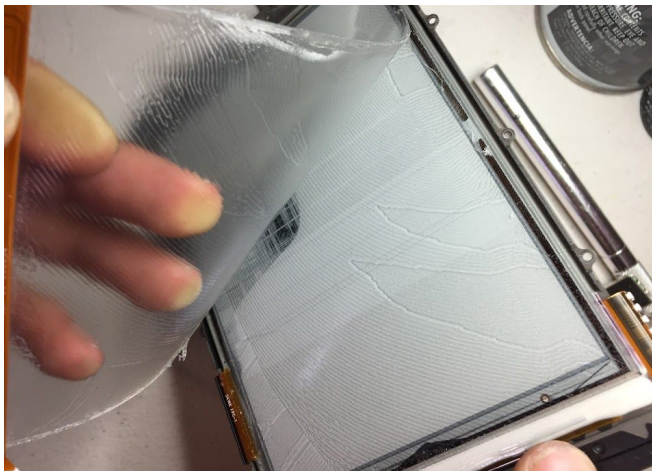
Step four: Remove motherboard from mid frame, disconnecting the battery first.



Step five: Remove heat shields from motherboard, examine motherboard at length.



Step six: Remove screen protector, and then the illumination panel, it was attached with a thick adhesive layer.



 Removing the two layers from the display.

 Separating the two layers from each other.

Step seven: Remove the E-ink display and other screen layers from mid frame. Because it's secured with adhesive, this is impossible to do without cracking the display.

 Our Captain Christy extracting a sample.

 Peeling the E-ink display off the midframe.

Step eight: Examination and research time!

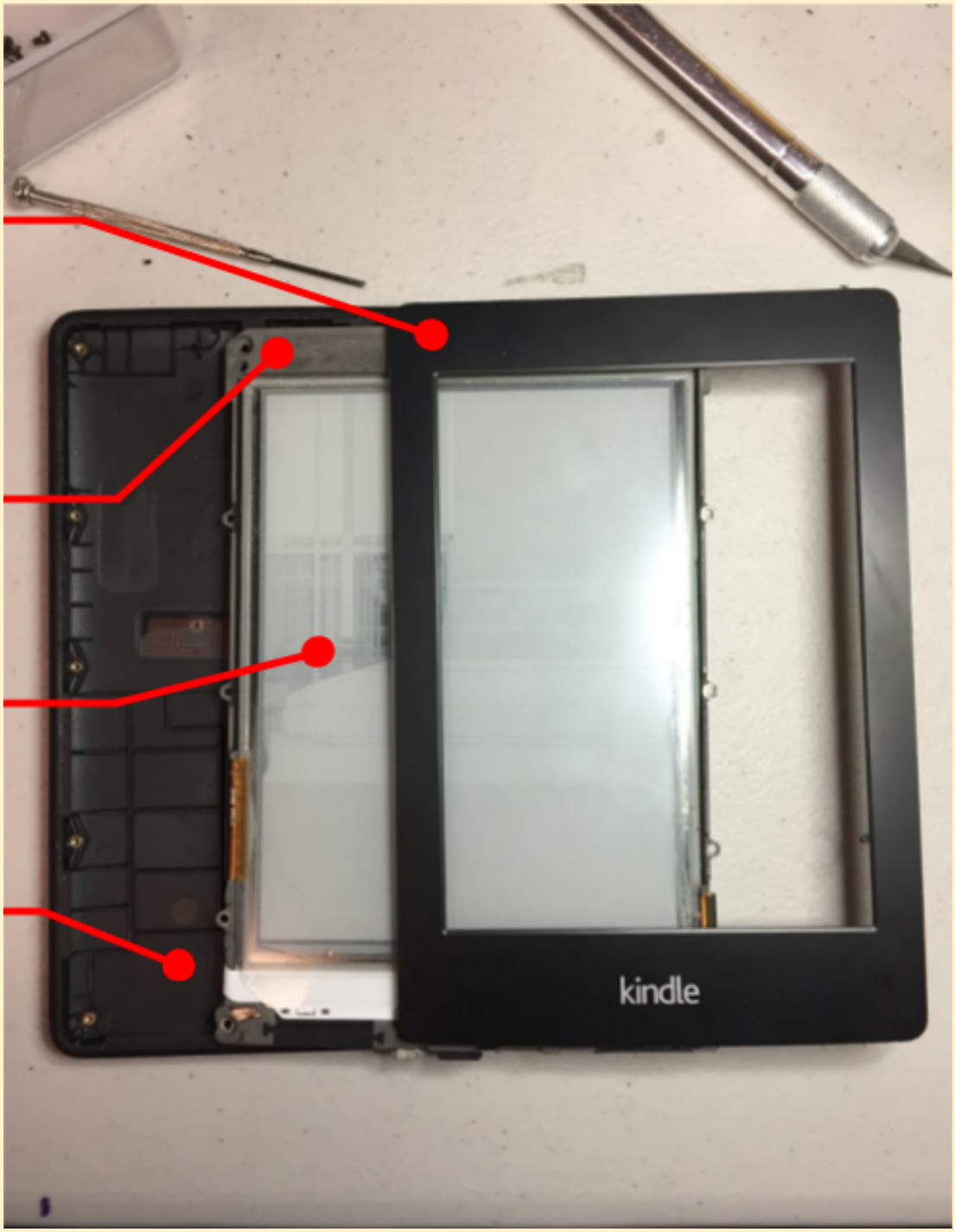
 Noah examining a surface mount resistor using a microscope.

 Roshni using a multimeter to identify components based on resistance.

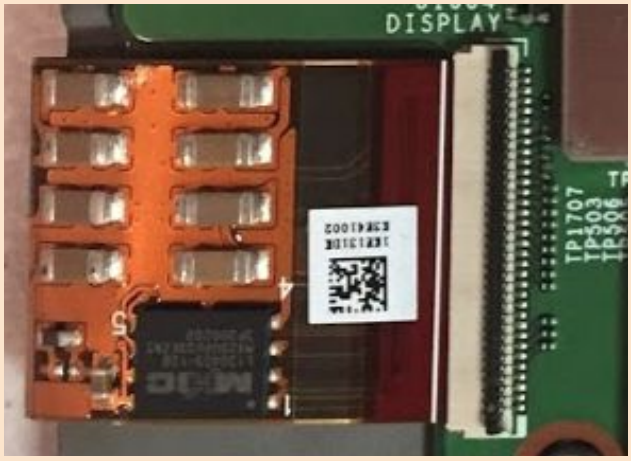
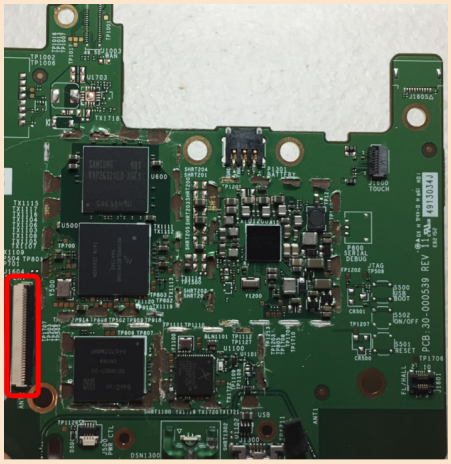
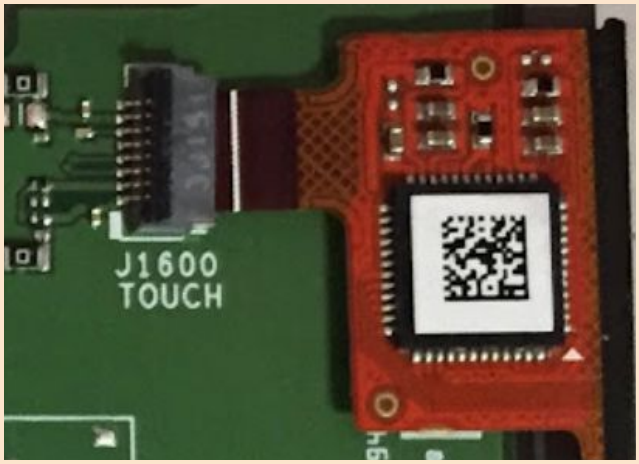
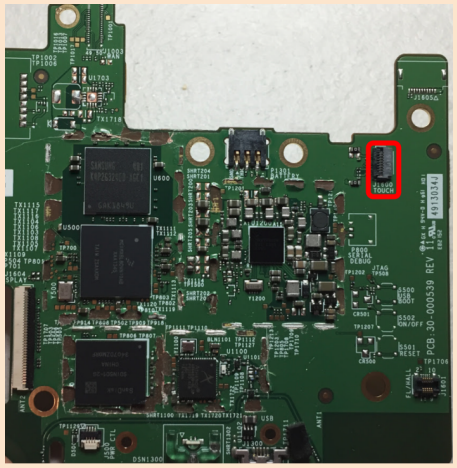
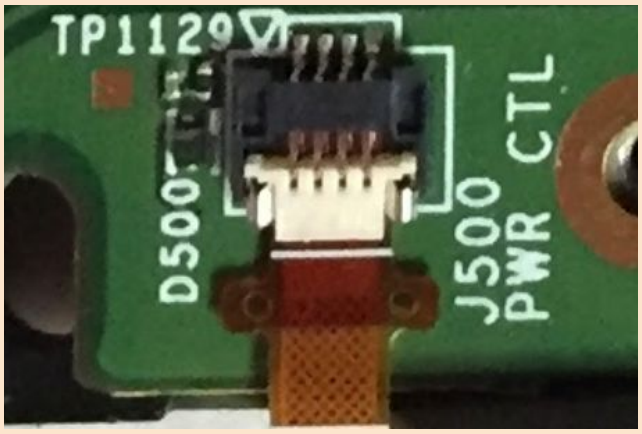
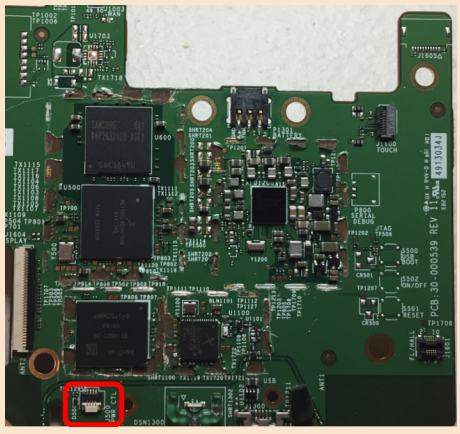
Note: We can only identify components using a multimeter if one end is leading to a disconnected port, because otherwise the current from the multimeter could be taking another path through the motherboard, and we wouldn't be reading the resistance of the component.

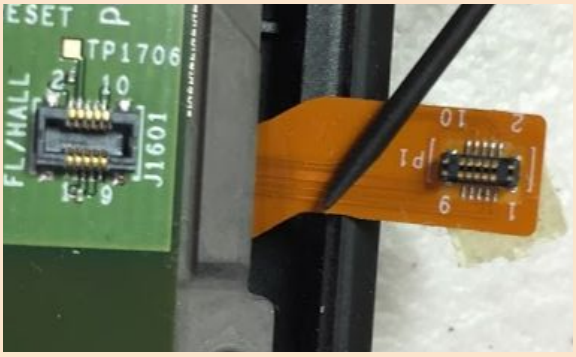
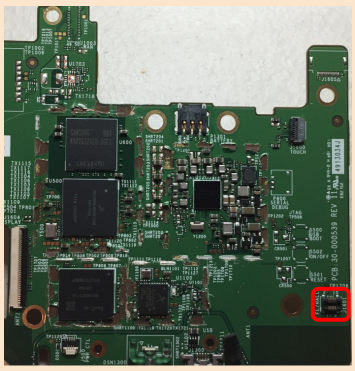
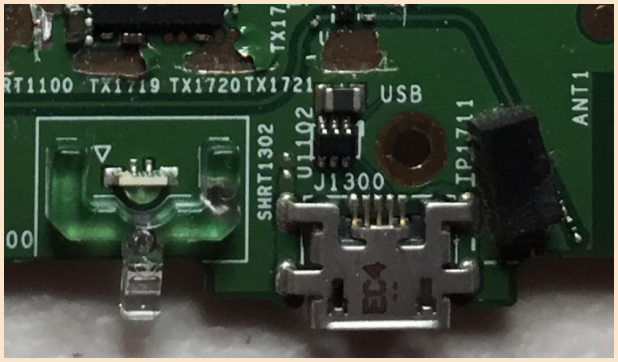
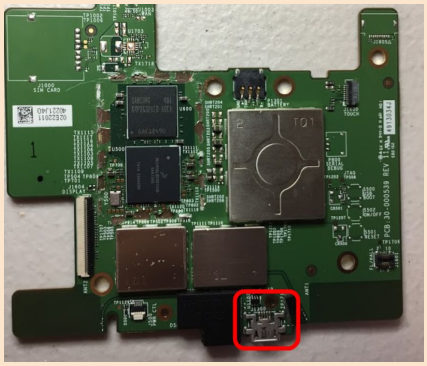
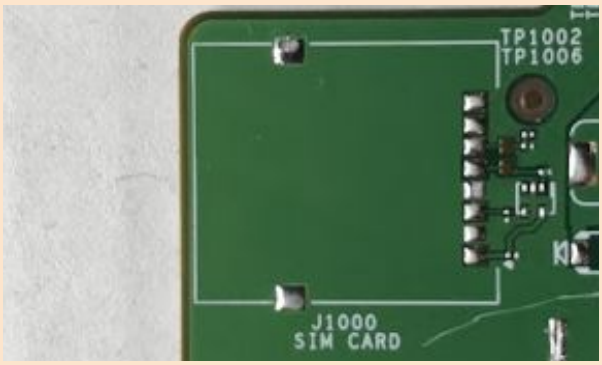
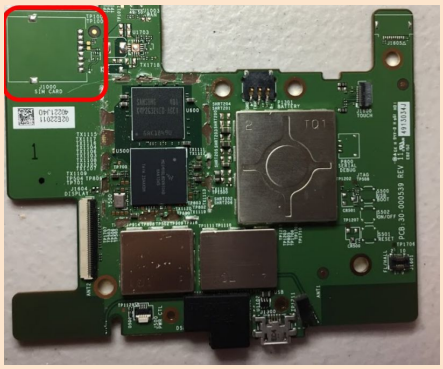
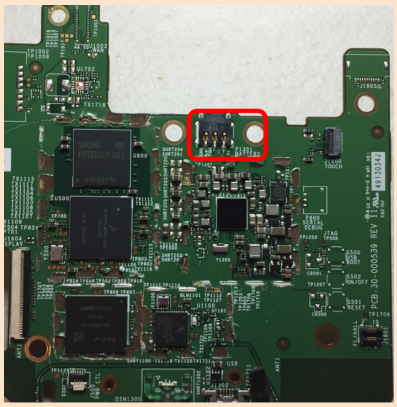
Component Identification and Analysis

A. Structure

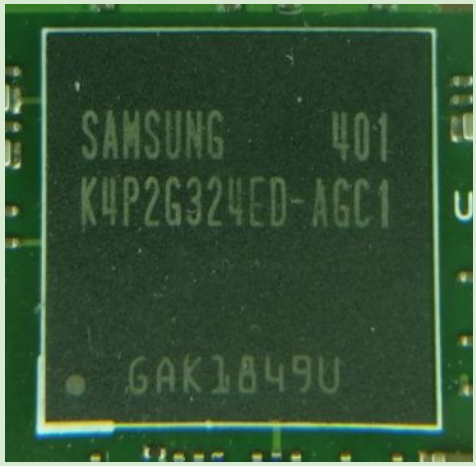
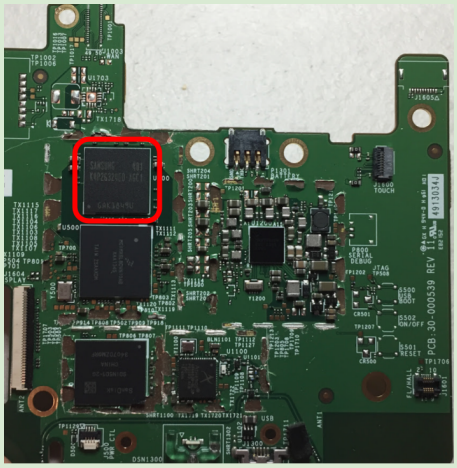
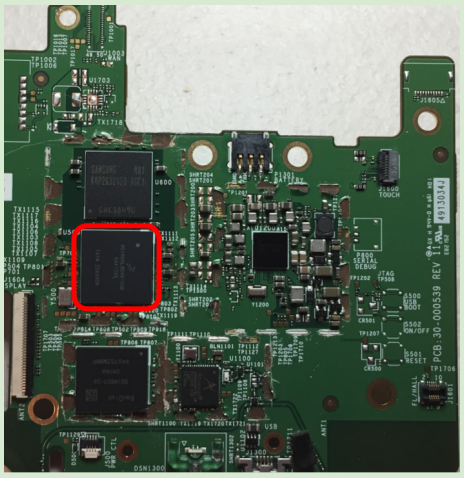
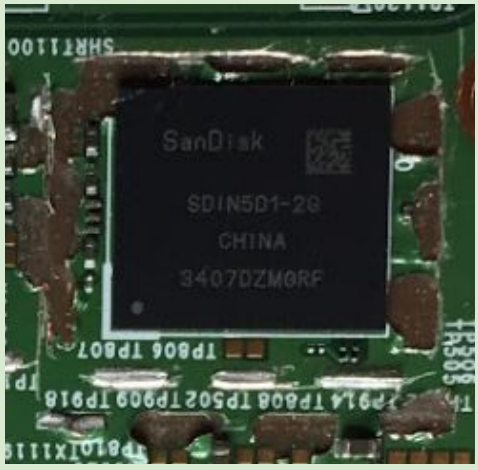
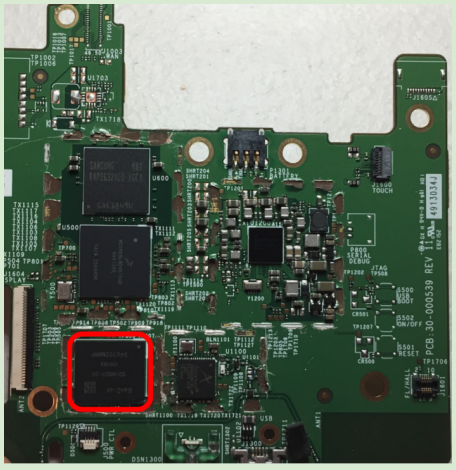


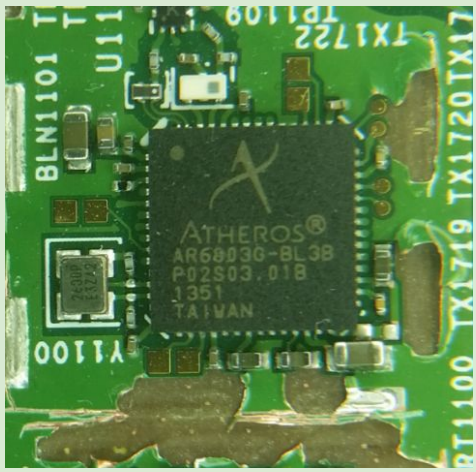
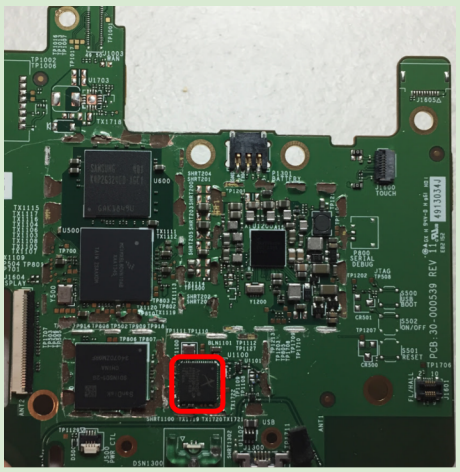
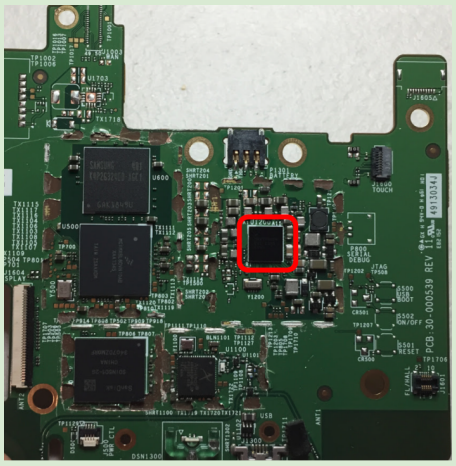
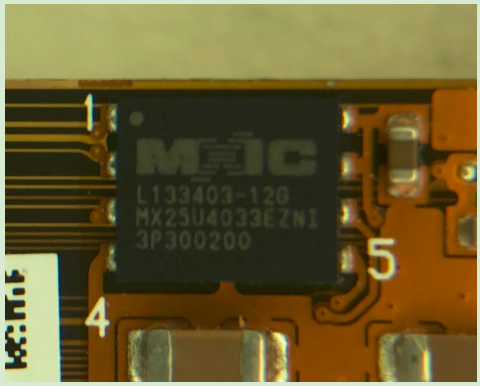
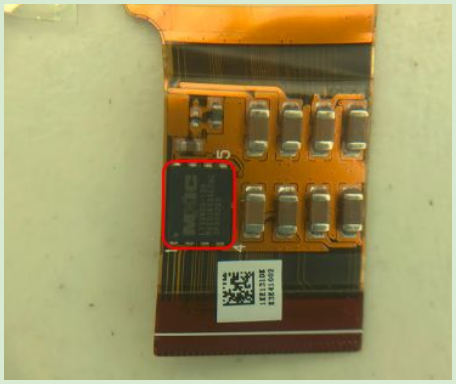
B. Ports & Connectors

Port and Description	Picture	Location on Motherboard
Display --- The largest connection to the motherboard, transfers all the inputs required to the E Ink display for the desired image to appear.		
Touch --- Sends receives input from the Kindle's touch screen, which is a thin layer on top of the E Ink display. *(We tried scanning the QR code and identifying the chip but we found nothing.)*		
Power Button --- Gets a signal from the power button when pressed and sends it to the processor to start up the Kindle.		

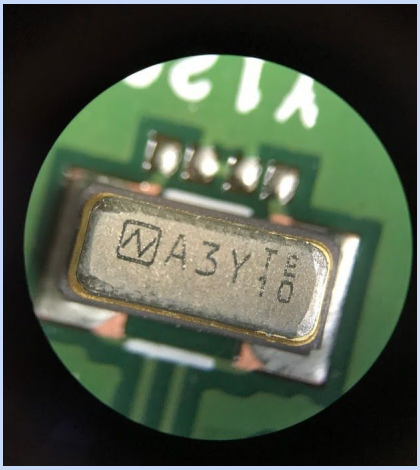
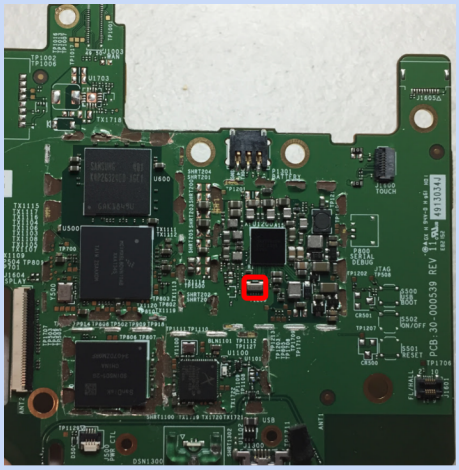
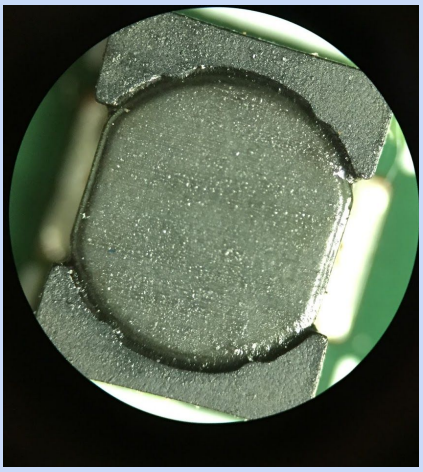
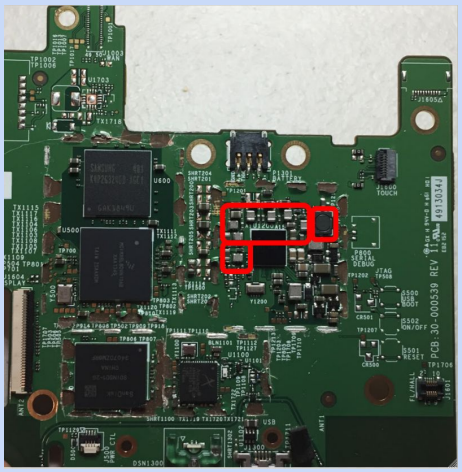
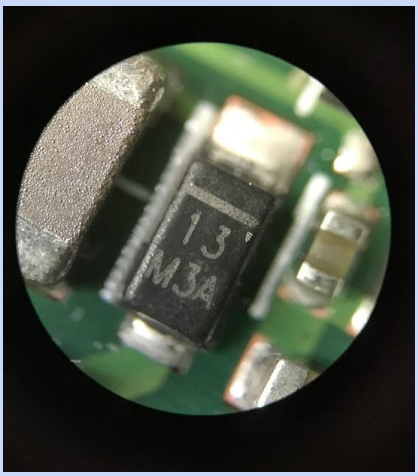
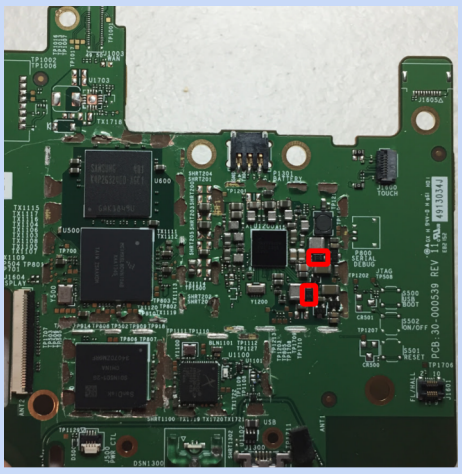
Light Pad --- Outputs power to the four LEDs in the light pad which illuminate the Kindle's screen.		
Micro USB --- An externally accessible port that serves to charge the Kindle's battery and allows for direct communication with other devices.		
SIM Card Mounting (Unused) --- The PCB was manufactured to be able to house a SIM card which would allow for 3g, but in our Kindle it was left out.		
Battery Connector --- The battery connector allows for easy installation of the battery in the manufacturing process and allows the consumer to replace or remove the battery.		

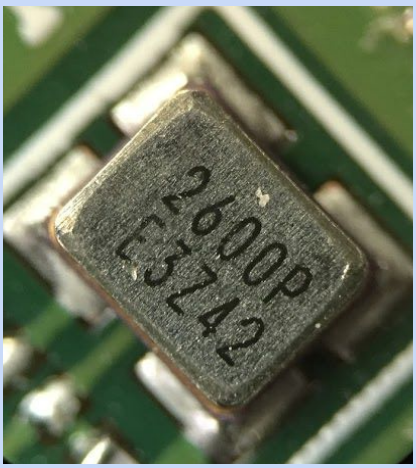
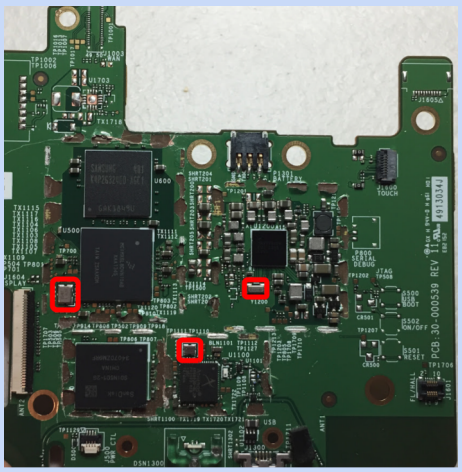
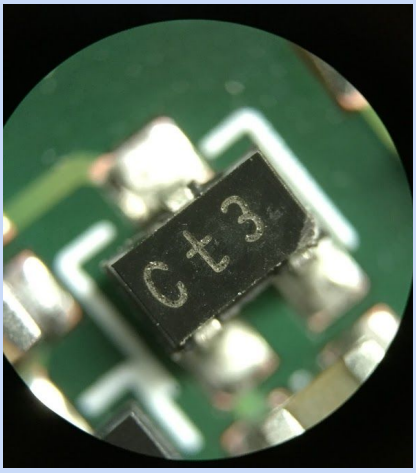
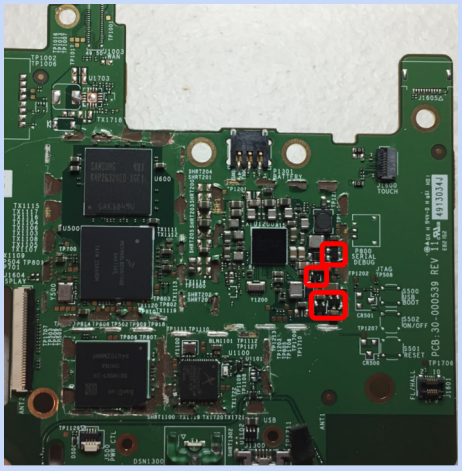
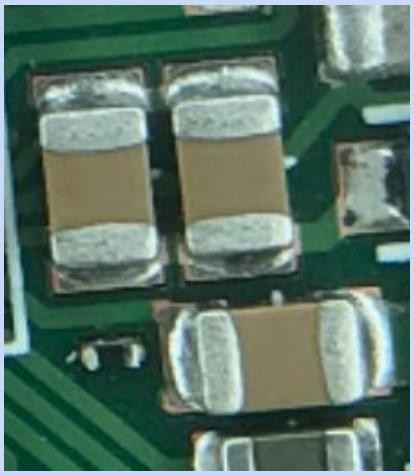
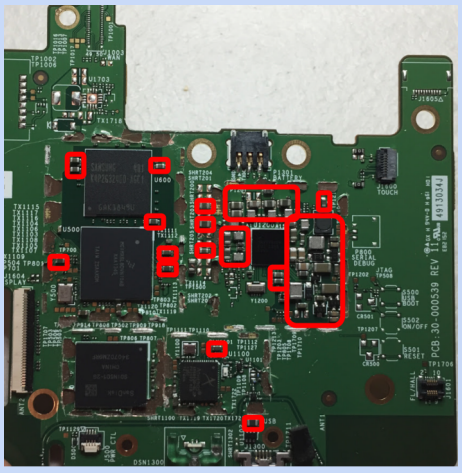
C. Integrated Chips

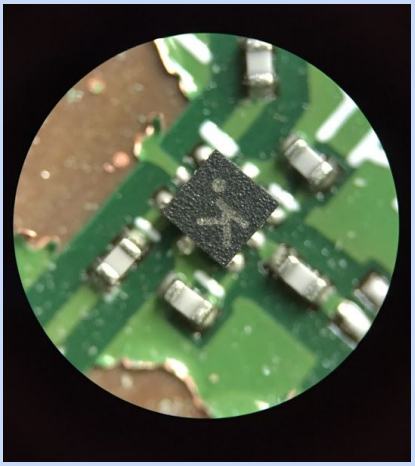
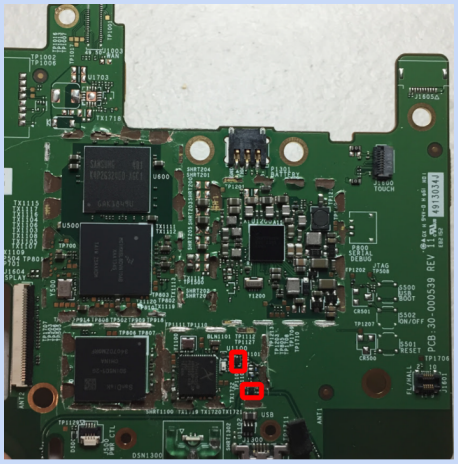
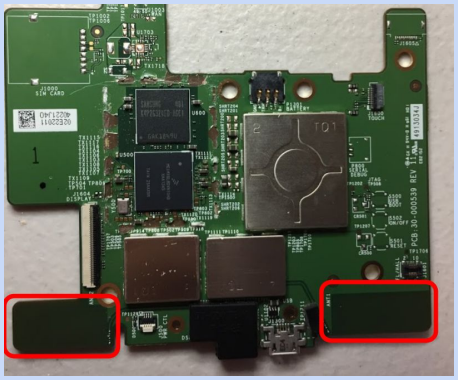
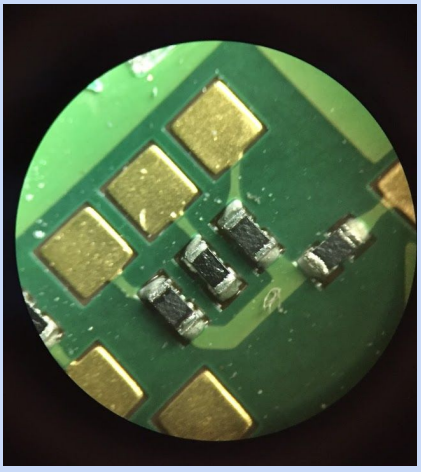
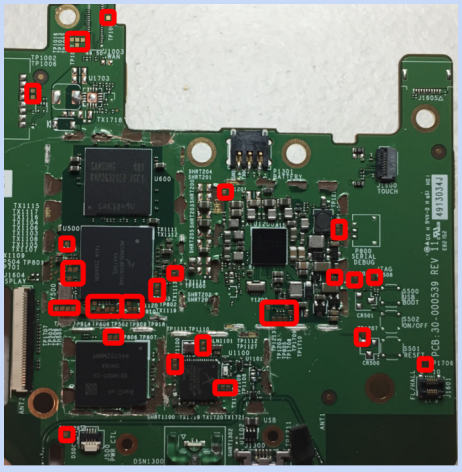
Chip and Description	Picture	Location on Motherboard
Memory - Samsung K4P2G324ED-AGC1 --- Memory is used to retain data for quick access only when powered. This SDRAM is low powered and has a synced clock with the processor.		
Processor - NXP/Freescale MCIMX6L8DVN10AB --- Essentially a ton of transistors crammed together, the processor does all the actual computing like arithmetic and logic operations and “thinking” for the kindle. Data Sheet: https://goo.gl/gqRKN5		
Storage (Flash memory) - SanDisk SDIN5D1-2G --- Storage is used to store the operating system and data. Flash memory is more compact and resistant to drops compared to hard drives. Data Sheet: https://goo.gl/xEV4KG		

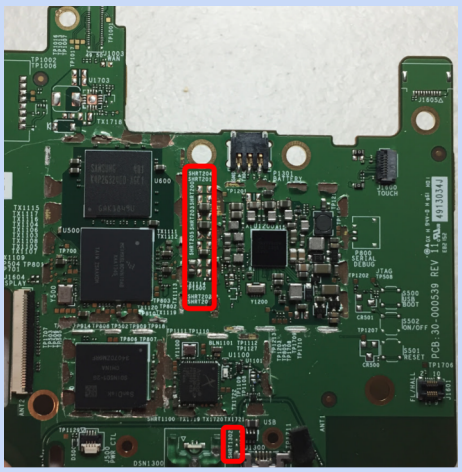
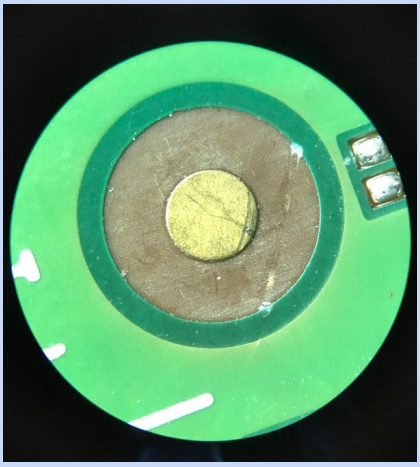
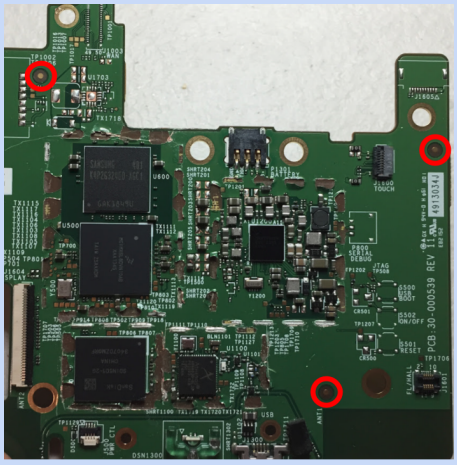
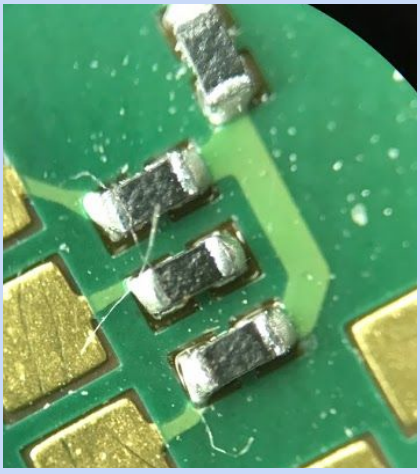
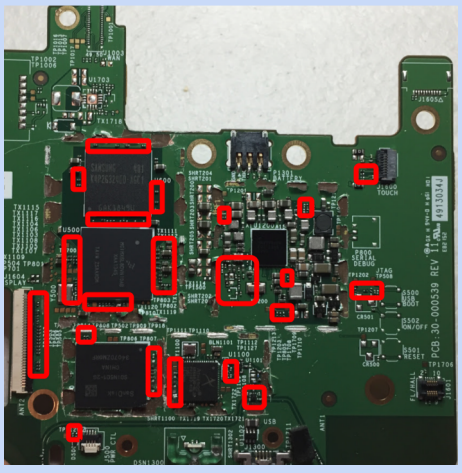
Wireless Communication Chip - Atheros AR6803G-BL38 --- Wireless Communication Chip for WiFi and Cellular Network connectivity. Wireless communication allows the kindle to get OS updates and the user to download books.		
Power Management - Maxim MAX77696A --- Power Management chip manages the battery charging and power distribution. Data Sheet: https://goo.gl/zBxDfU		
Flash Memory - Macronix MX25U4033E --- Separate flash memory on the ribbon cable of the display. Probably used to aid the display computing, like a GPU. Data Sheet: https://goo.gl/sYnfNk		

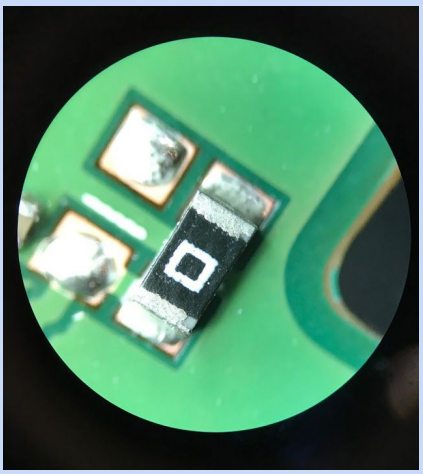
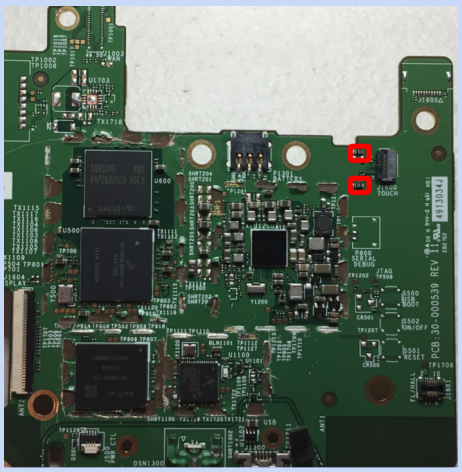
D. Electronic Components and PCB Details

Component and Description	Picture	Location on Motherboard
Crystal Oscillator (Y) --- A crystal oscillator is an oscillator that utilizes a vibrating crystal to create an oscillating electric current. Commonly called a “clock” **Count: 1**		
Inductor (L) --- An inductor stores energy with the magnetic field generated by the coil. Inductors are often used as filters for wireless signals and power. **Count: 11**		
Diode (D) --- A diode only allows electric current to flow in only one direction. Diodes were located near the Power IC and the Wireless IC. **Count: 7**		

Oscillator (Y) **----------** Oscillators produce sine or square waves for the clock signal for processors/ICs. We found oscillators near the processor, wireless chip and power management chip. **Count: 3**		
Transistor (Q) **----------** Transistors are signal-controlled switches control current flow. They can also amplify AC and DC power. These were mostly near the Power IC. **Count: 4**		
SMD Capacitors (C) **----------** Capacitors store energy in an electrostatic field and release it to the circuit. They also stabilize the flow of electricity in a circuit. **Count: ~ 182**		

Relay (K) --- Relays are electromagnetic switches that can be used to turn things on and off or to amplify power. Relays were connected to the antenna on the kindle. **Count: 2**		
Antenna (ANT) --- An antenna is a transducer that can change AC to radio frequency or vice versa. The Antenna on this kindle is used to send and receive information via WiFi. **Count: 2**		
Test Pads (TP) --- Test pads are for quality control checks that occur during manufacturing. A machine can send input and see if the output is within regulation. **Count: 119 including back side**		

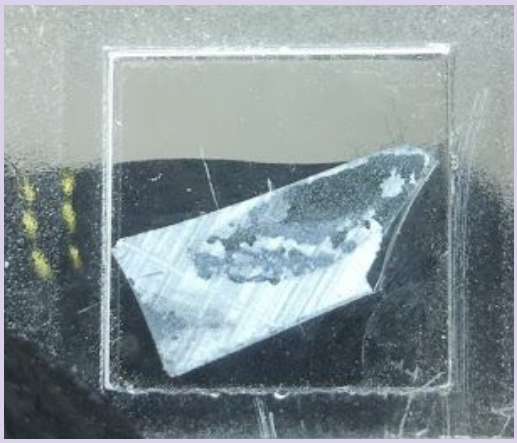
Solder Heat Resistance Test (SHRT) --- SHRT could stand for Solder Heat Resistance Test. We believe that SHRT indicates a testing of the PCB's ability to handle thermal stress by doing test soldering. **Count: 9**		
Fiducial Marks --- Fiducial Marks are marks to align the machines to solder SMD (surface mount devices) components. There were 3 in the corner of the PCB. **Count: 3**		
SMD Resistors (R) --- Resistors regulate the amount of current that flows in the circuit. SMD Resistors are smaller than traditional resistors, making the device more compact. **Count: 53**		

Zero Ohm Resistors --- Zero Ohm resistors are used in place of jumper wires. This eliminates the need to use a different machine for installing jumper wires. **Count: 2**		
Battery (B or BT) --- The Kindle uses a Lithium Ion Polymer battery. Lithium ions in the electrolyte move from the negative to the positive electrode to provide electron flow. **Count: 1**		
LED lighting system --- Paperwhite features backlighting for dark reading environments. Light from 4 LEDs at the base of the display reflects through a light guide beneath the display. **Count: 1**		
Note: Letters inside parenthesis () indicate PCB Reference Designator		

E. E-Ink Display

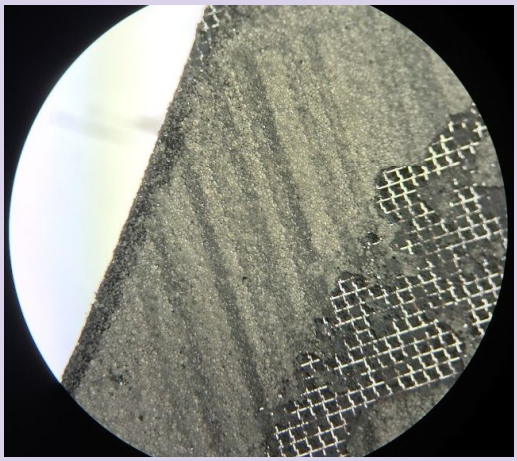
E-Ink Display Shard Macro View

We took a shard from the Kindle's E-ink display. Notice the black lines and areas where the ink seems to be scraped off.



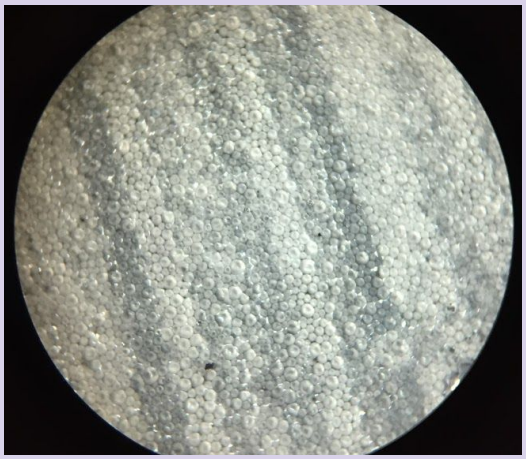
Microscope 40x View - Electrode Grid and E-Ink

In this picture you can see the E-ink microcapsules that form the lines, and where they are scraped off you can see the electrodes that repel or attract the charged ink.



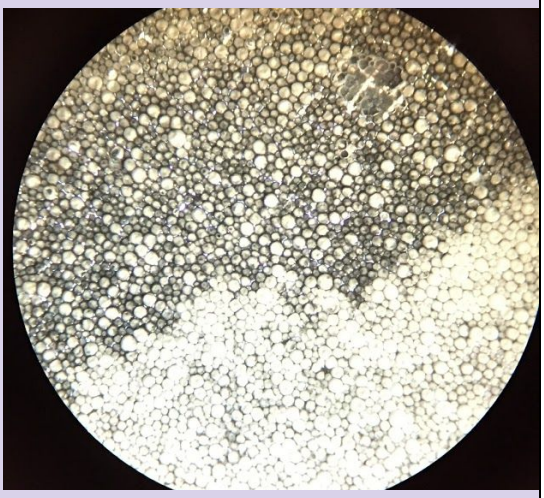
Microscope 100x View - Black Stripes

Increased magnification, lines are still visible.



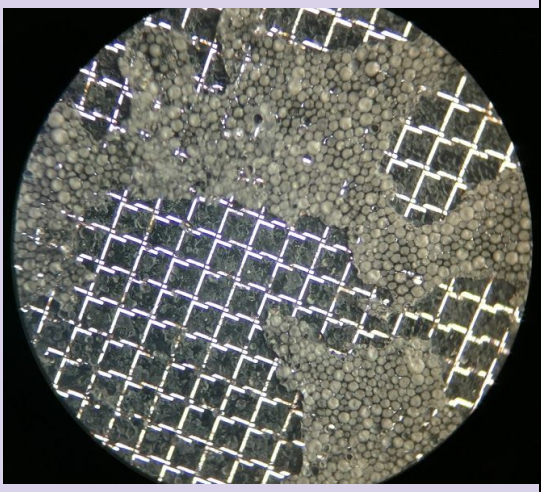
Microscope 100x View - Black & White

Here some of the individual ink capsules are clearly seen.



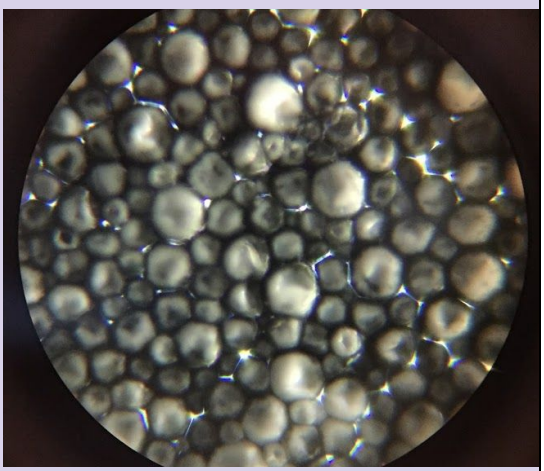
Microscope 100x View - Electrode Grid and E-Ink

Here a lot of capsules were scratched off and the electrode grid below is clearly visible.



Microscope 400x View - E-Ink Microcapsules

High magnification shot of the microcapsules containing the black and white E-Ink.



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