Electronics Online Challenge 2020

Disassembling a VEX ARM® Cortex®-based Microcontroller

Team: 8059Z

Contents

Report

We have been using the VEX ARM® Cortex®-based Microcontroller (Cortex) extensively since we joined the 8059 VEX Robotics team and its inner workings have always intrigued us. When we first heard about the TI Challenge, we did not hesitate to use this opportunity to break down and examine the components of the Cortex. After being granted permission to break down the Cortex we got to work, starting by researching basic electronic components and functions. We took photographs of all the individual components while we were disassembling the Cortex.

Despite the simple PCB with no components that pose a significant risk, we still wore safety glasses at all times and took all necessary precautions to ensure our safety including having a fire extinguisher nearby. We also got our selection approved by our teacher-mentor beforehand. To deconstruct the cortex, we unscrewed 4 screws from the outer casing, pulled apart the casing and unscrewed the motherboard from the case. We carefully analysed the motherboard and identified the components in the Cortex. For the parts that were too small, we identified them by using a phone's flashlight and magnifier. Most of the components had the product number on them which allowed us to identify them by searching online for the product numbers. We also researched online of all the functions of each component and how they worked. For example, some chips only had numbers and letters on them and we were only able to identify the chips by searching the product number on the internet. There were 2 components that we identified to be from Texas Instruments. The first is the LM2940CS, a voltage regulator, which maintains a fixed voltage output no matter what the input voltage is, preventing excessive charge from damaging the Cortex. The second is the SN74ACT04PWR, an Inverter Integrated Chip, which also controls the LED Interface of the VEX Cortex. We researched the different components and tracked down their corresponding datasheets and product overviews to get more information about them and their functions.

From this experience, our team was able to gain new insights and perspectives on electronics. We learnt how the different components helped make the Cortex work. Being the brain of the robot, it coordinated all the robot's information and power. We inferred that it plays a very important role in the robot's system as it controls all the functions and movements of the robot. We were perplexed by the complexity and the sheer number of chips and components that were used in the device in order for it to function. Through the process, we identified and discovered how the components worked by using information from websites which contained key information on the various parts. This was extremely useful in aiding with our research and the process of our investigation. Therefore, this was a very enriching experience that enabled us to learn a lot about the Cortex's technology and its parts. We also learnt more about how to disassemble and research electrical components.

Word Count : 495

Complete Deconstruction and Research Process

Deconstructing the Cortex using a screwdriver

Figure 1: Deconstructing the Cortex by unscrewing the Outer Casing

Removing the outer casing to remove the internal circuit board

Figure 2: Removing to outer casing to get access to the internal circuit board

Completely Deconstructed Cortex

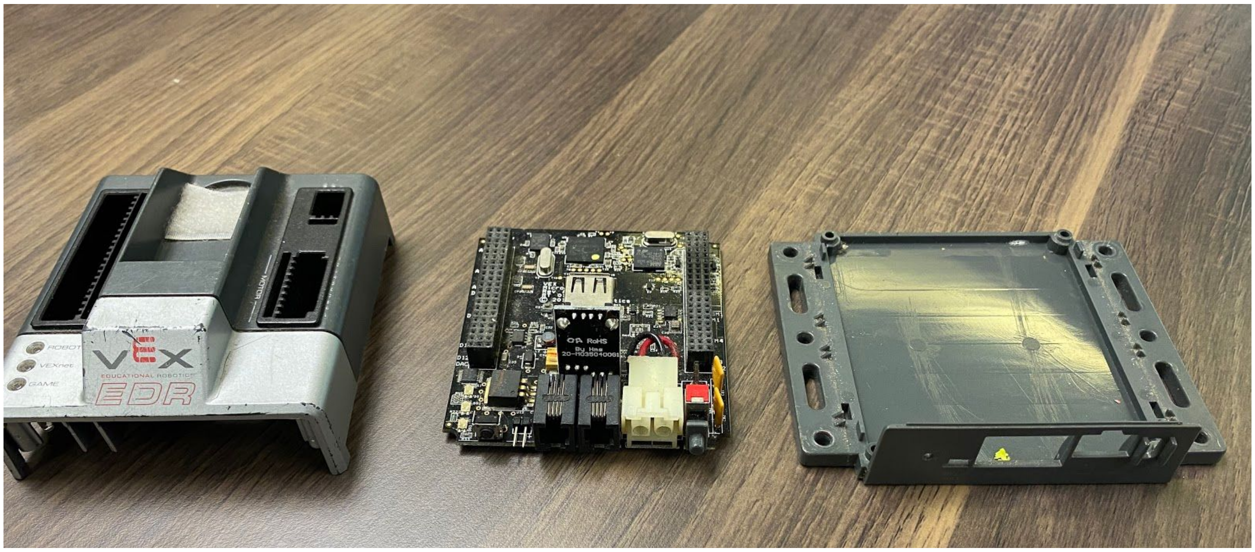


Figure 3: Completely deconstructed Cortex

Identifying the different components

Figure 4: Identifying the different components using a phone camera magnifier

Researching on the different components online using datasheets forums, blogs and product overviews

Figure 5: Researching on the different components online to get more information about the different components and their functions

Labelled images of circuit board (Top and bottom view)

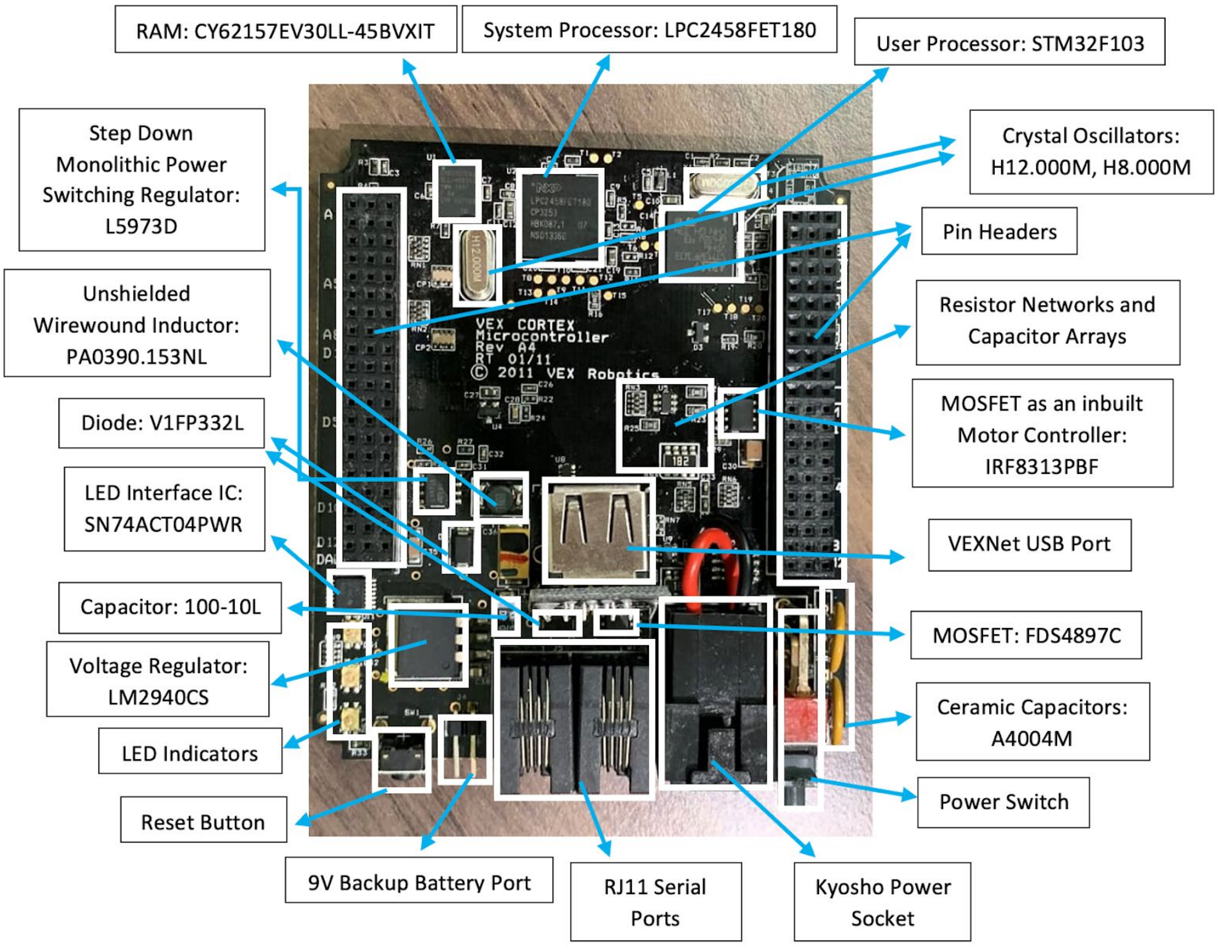


Figure 6: Top view of labelled image

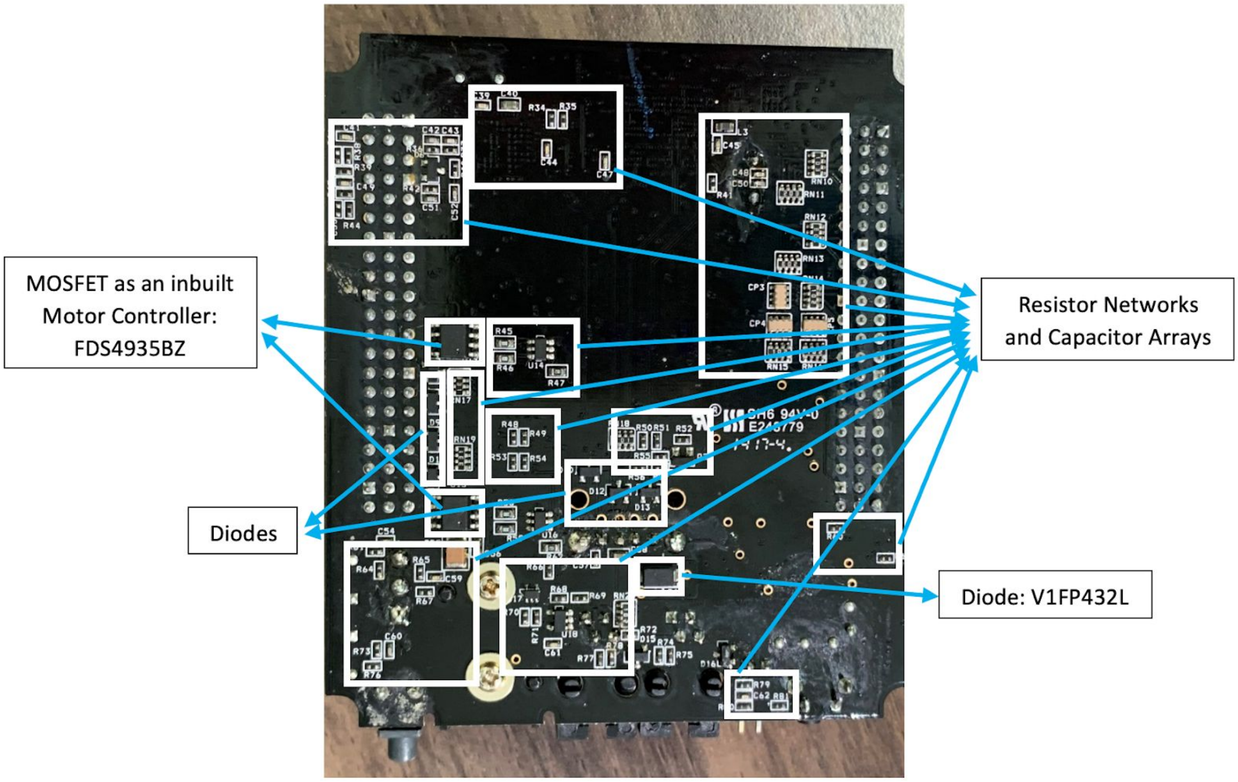
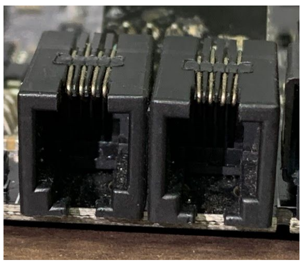
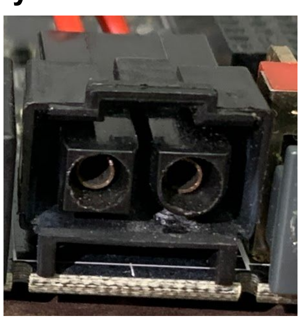
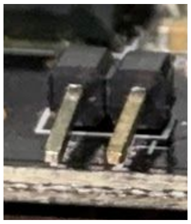
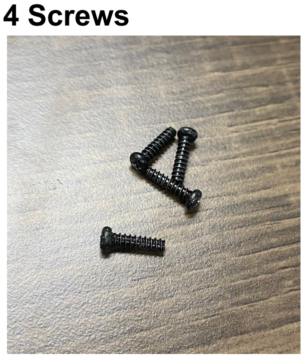


Figure 7: Bottom view of labelled image of circuit board

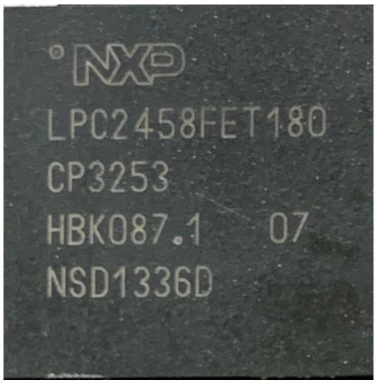
List of components

External Components

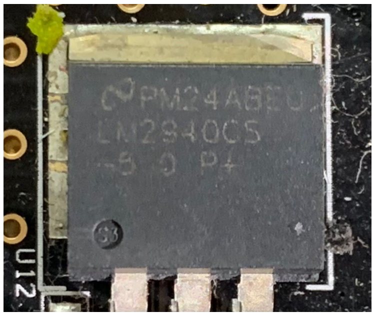
Components (Name, Picture*) *Insert picture below name	Part Type	Part Description (Function/Comments)
RJ11 Serial Ports 	Serial Ports	Reprogram firmware
Reset Button 	Button	Forcibly clears the RAM and initiates the boot up procedure
Kyosho Power Socket 	Socket	An interface to allow the flow of power from lithium ion battery to the board components

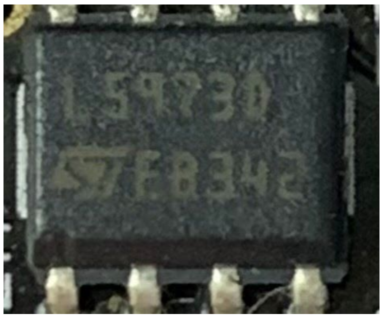
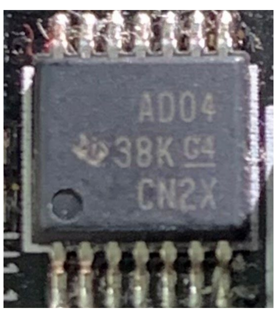
Backup battery port 	Port	An interface to allow a 9V battery to provide power to the board in the event the lithium ion cell fails or runs out of power.
Power switch 	Switch	To toggle the flow of power from the battery to the board components
Outer Casing 	Plastic Casing	Protects the fragile PCB from damage during use
4 Screws 	Screw	Prevents the case from coming loose during use

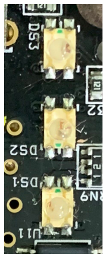
Internal Components

Components (Name, Picture*) **Insert picture below name*	Part Type	Part Description (Function/Comments)
LPC2458FET180 	System Processor	The LPC2458FET180 microcontroller is for multi-purpose communication applications. It interacts with the external gpio pins to control movement of motors or receive and process data from sensors. NXP Semiconductors designed the LPC2458 microcontroller around a 16-bit/32-bit ARM7TDMI-S CPU core with real-time debug interfaces that include both JTAG and embedded trace. The LPC2458 has 512 kB of on-chip high-speed flash memory. This flash memory includes a special 128-bit wide memory interface and accelerator architecture that enables the CPU to execute sequential instructions from flash memory at the maximum 72 MHz system clock rate. This feature is available only on the LPC2000 ARM microcontroller family of products. The LPC2458 can execute both 32-bit ARM and 16-bit Thumb instructions. Support for the two instruction sets means engineers can choose to optimize their application for either performance or code size at the sub-routine level. When the core executes instructions in Thumb state it can reduce code size by more than 30 % with only a small loss in performance while executing instructions in ARM state maximizes core performance.

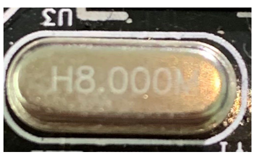
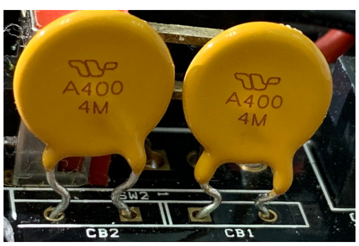
STM32F103  	User Processor	It is the main computing unit (MCU) which interprets the code and relays information to the other components. The STM32F103xx medium-density performance line family incorporates the high performance ARM® Cortex®-M3 32-bit RISC core operating at a 72 MHz frequency, high speed embedded memories (Flash memory up to 128 Kbytes and SRAM up to 20 Kbytes), and an extensive range of enhanced I/Os and peripherals connected to two APB buses. All devices offer two 12-bit ADCs, three general purpose 16-bit timers plus one PWM timer, as well as standard and advanced communication interfaces: up to two I2Cs and SPIs, three USARTs, an USB and a CAN
CY62157EV30LL-45BVXIT 	Memory	Serves as RAM that temporarily stores information or data from the motors, sensors and code for later use in executing functions . SRAM - Asynchronous Memory IC 8Mb (512K x 16) Parallel 45ns 48-VFBGA (6x8)

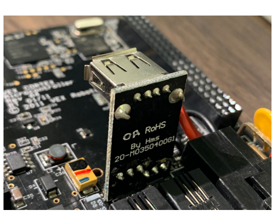
LM2940CS 	Low Dropout Voltage Regulator	Part by **Texas Instruments** A voltage regulator is a device designed to maintain a fixed voltage level automatically. The LM2940CS regulator is a low dropout voltage regulator which is a DC linear voltage regulator that can regulate the output voltage even when the supply voltage is very close to the output voltage. The difference between a low dropout regulator and other DC to DC regulators is that a low dropout regulator does not have switching and is simpler and smaller by design, reducing cost. The disadvantage is that in order to regulate voltage a low dropout regulator must dissipate power in the form of heat, which may cause damage. This is useful in the VEX Cortex as the voltage of the power supply is usually close to the required voltage of the Cortex. Hence, a low dropout regulator can be used instead of a normal DC to DC regulator, reducing cost and resources.. The LM2940CS regulator features the ability to source 1A of output current with a dropout voltage of typically 0.5V and a maximum of 1V over the entire temperature range. Furthermore, a quiescent current reduction circuit has been included which reduces the ground current when the differential between the input voltage and the output voltage exceeds approximately 3V. The quiescent current with 1A of

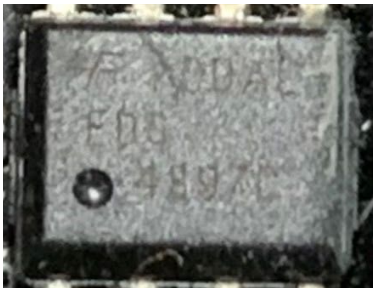
		output current and an input-output differential of 5V is therefore only 30mA. Higher quiescent currents only exist when the regulator is in the dropout mode (VIN − VOUT ≤ 3V)
L5973D 	Step Down Monolithic Power Switching Regulator	The L5973D is a step down monolithic power switching regulator with a minimum switch current limit of 2.5 A so it is able to deliver more than 2 A DC current to the load depending on the application conditions. The output voltage can be set from 1.235 V to 35 V. The device uses an internal P-channel D-MOS transistor (with a typical Rdson of 250 mΩ) as switching element to minimize the size of the external components. An internal oscillator fixes the switching frequency at 250 kHz.
SN74ACT04PWR 	Inverter IC 6 Channel 14-TSSOP	Part by **Texas Instruments** It is the LED Interface IC. It controls the three different LEDs (Light Emitting Diodes). In digital logic, an inverter or NOT gate is a logic gate which implements logical negation.An inverter circuit outputs a voltage representing the opposite logic-level to its input. Its main function is to invert the input signal applied. If the applied input is low then the output becomes high and vice versa. Inverters can be constructed using a single NMOS transistor or a single PMOS transistor coupled with a resistor. Since this 'resistive-drain' approach uses only a single type of transistor, it can be fabricated at a low cost.

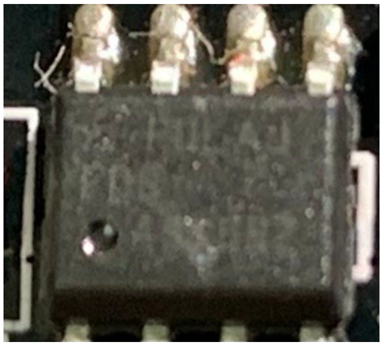
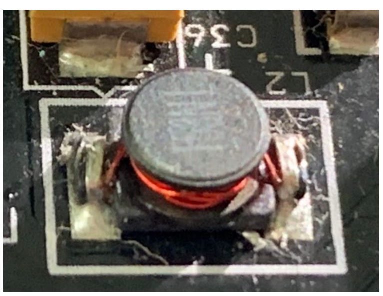
<table>
<tr><td>Light Emitting Diodes (LEDs)

</td><td>LEDs</td><td>Diodes that convert electrical energy into light energy</td></tr>
<tr><td>H12.000M

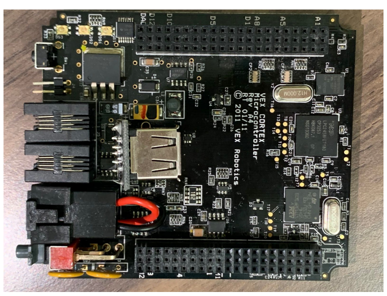
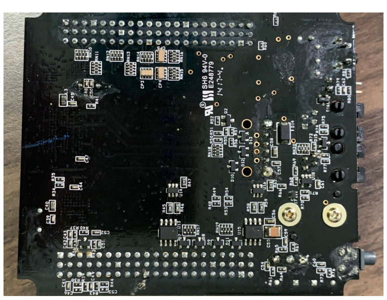
</td><td>Crystal Oscillator</td><td rowspan="2">A crystal oscillator is an electronic oscillator circuit that generates an electrical signal with a constant frequency using the mechanical resonance of a vibrating crystal of piezoelectric material to keep time.

H12.000M: 12MHz
H8.000M: 8MHz</td></tr>
<tr><td>H8.000M
</td><td>Crystal Oscillator</td></tr>
<tr><td>A4004M

</td><td>Ceramic Capacitor</td><td>A ceramic capacitor is a fixed-value capacitor where the ceramic material serves as the dielectric. It is made of two or more ceramic alternating layers and a metal layer serving as the electrodes. The electrical behavior and thus the applications are defined by the composition of the ceramic material.</td></tr>
<tr><td>V1FP332L

</td><td>Diode</td><td>V1FP332L is a semiconductor device that operates essentially as a one-way current switch. It lets current flow freely in one direction, but severely prevents current to flow in the opposite direction.</td></tr>
<tr><td>20-M0350400GI
</td><td>USB Port</td><td>An interface to allow the VEXNET usb to connect to the cortex to allow for the controller to control the robot.
USB 2.0</td></tr>
</table>

FDS4897C  	MOSFET	A MOSFET, or metal oxide semiconductor field effect transistor is an electrical switch that can toggle a circuit on and off. It can function as a logic gate. These dual N- and P-Channel enhancement mode power field effect transistors are produced using Fairchild Semiconductor's advanced PowerTrench process that has been especially tailored to minimize on-state resistance and yet maintain superior switching performance.
IRF8313PbF  	MOSFET	A MOSFET, or metal oxide semiconductor field effect transistor is an electrical switch that can toggle a circuit on and off. It can function as a logic gate. MOSFET that works with **FDS4935BZ (below)** to form a H-Bridge for motor control. The IRF8313PbF incorporates the latest HEXFET Power MOSFET Silicon Technology into the industry standard SO-8 package. The IRF8313PbF has been optimized for parameters that are critical in synchronous buck operation including Rds(on) and gate charge to reduce both conduction and switching losses. The reduced total losses make this product ideal for high efficiency DC-DC converters that power the latest generation of processors for notebook and Netcom applications.
FDS4935BZ	MOSFET	A MOSFET, or metal oxide semiconductor field effect transistor is an electrical switch that can toggle a circuit on and off.

		It can function as a logic gate. MOSFET that works with **IRF8313PbF (above)** to form a H-Bridge for motor control This P-Channel MOSFET has been designed specifically to improve the overall efficiency of DC/DC converters using either synchronous or conventional switching PWM controllers, and battery chargers. These MOSFETs feature faster switching and lower gate charge than other MOSFETs with comparable RDS(ON) specifications. The result is a MOSFET that is easy and safer to drive (even at very high frequencies), and DC/DC power supply designs with higher overall efficiency.
PA0390.153NL 	Unshielded Wirewound Inductor	Wire wound surface mount inductors are passive circuit components, meaning they require an external power source. They have a core made of a magnetic metal like iron with wire wound around it. Energy is stored in a magnetic field when an electrical current flows through the coiled wire which has thick insulation to make the inductors suitable for use with larger currents. They can block or filter radio frequencies. Power Inductor maintains a steady current in an electrical circuit with a different current.

100-10L 	Tantalum Capacitor	It is a device which in an electric field stores electrical energy. Comprising two terminals, it is a passive electronic component. Tantalum electrolytic capacitors are the preferred choice in applications where volumetric efficiency, stable electrical parameters, high reliability, and long service life are primary considerations. The stability and resistance to elevated temperatures of the tantalum / tantalum oxide / manganese dioxide system make solid tantalum capacitors an appropriate choice for today's surface mount assembly technology.
PCB **Front**  **Back** 	Printed Circuit Board	A printed circuit board mechanically supports and electrically connects electrical or electronic components using conductive tracks, pads and other features etched from one or more sheet layers of copper laminated onto and/or between sheet layers of a non-conductive substrate.

Unidentified Chip 		We were unable to find any datasheets on this chip

Note: All images were original from 8059Z.