Electronics Online Challenge 2021
VEX V5 Smart Motor Model No. 276-4840

9181C

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Final Summary Report

The element of curiosity and passion sparks various chains of innovative discoveries.

The decision to participate in this challenge began as an individual passion project for the robotics course at our school. A broken VEX V5 motor became the item of choice for disassembly. During the 2019-20 VRC season, many of our teams experienced numerous Smart Motors ”burning out” on their intake system, making them nonfunctional. This led to many questions about a smart motor’s reliability and faults. Thus, the motor evoked a strong interest in exploration for this challenge.

Research question:
Why is the motor faulty, and is there visible damage?

The disassembly process was initiated by removing the top, middle and bottom housing sections of the motor, which were held together by screws (figure 2.1-2.4). When all the housing pieces were removed, it exposed the inner gearing mechanism, motor cartridge, DC motor, and mainboard (figure 2.5-2.10). With closer inspection of the mainboard, capacitors, inductors and integrated circuit chips could be spotted, as well as the shaft encoder (figure 3.1-3.4). Some chips have logos imprinted on top indicating the manufacturer, but others only had numbers and letters which did not directly reveal the manufacturer. It was later found that Texas Instruments (TI) components are used in the motor. Moreover, the research phase began with reading the motor overview on the VEX website **[1]**. It provided further detail of the motor’s components and their functionality. With the help of forums, TI’s Part Marking Lookup **[2]** and various websites, it solidified a foundation point for research. These sources were used to obtain datasheets and information on the internal components by searching up the markings and part numbers. It was later discovered that the TI components used were mainly to regulate the motor's electrical power. One of which is the **Fault Protected Transceiver**, which is responsible for protection against any overvoltages **[II]**. Interestingly, the motor also has an NXP **microcontroller** that monitors the motor's status (temperature, voltage, etc.) and also utilizes a PID controller to regulate the motor's activity of motion **[VI]**.

Altogether, this challenge generated much interest in the functions and usage of the various electronic components. It also provided an opportunity to familiarize me with the process of identifying them. Furthermore, it sparked an interest in repairing and restoring the motor and other electronic components. With reference back to the research question, it's concluded that the fault is not visible. With more knowledge of the V5 Smart Motor's components, plans were made to find a repair solution. During a separate teardown of a **functional** motor, it was discovered that the motor spins at **full speed** when the shaft encoder fails to detect the encoder disk rotating. Because of the pattern of intake motors breaking, it's theorized that the fault is caused by overvoltage from the input source and strain from the weight of game elements. Therefore, an attempt to repair will most likely occur by targeting the semiconductors that regulate current.

(Word Count of Report: 491)

Preparation

Figure 1.1 *Taking the necessary precautions!*

Figure 1.2 *Tools needed for disassembly*

External View of the

Figure 1.3-1.6 *Top view (Left), side view (Top Centre), front view (Bottom Centre), and bottom view (Right)*

Process of Disassembly

Figure 2.1 Unscrewing the top cover of the motor

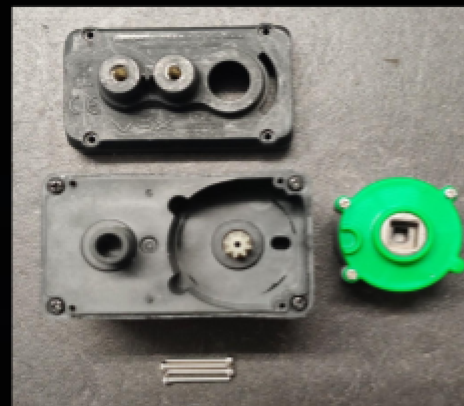


Figure 2.2 Parts found after removing the bottom cover

Figure 2.3 Unscrewing the middle cover of the motor

Figure 2.4 Cover piece removed, exposes the internal components

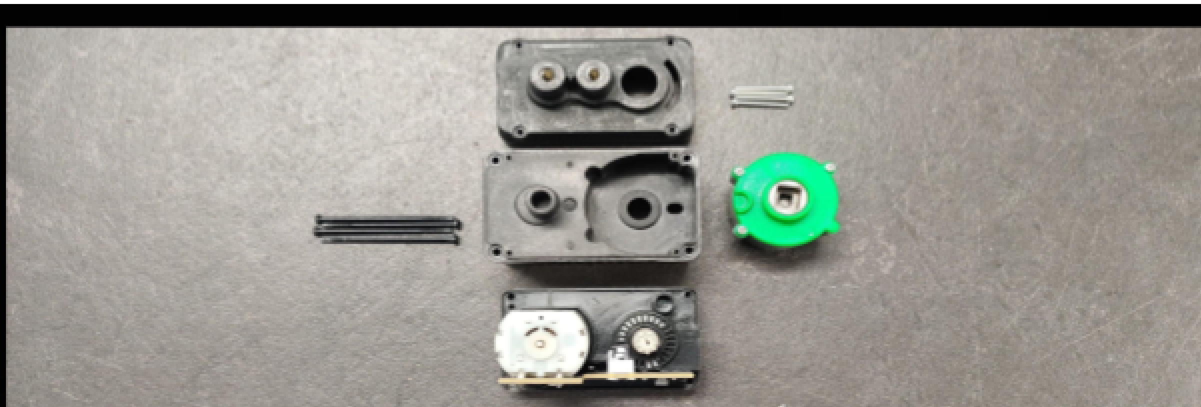


Figure 2.5 Parts found so far | screw count: 8

***Figure 2.6** Unscrewing the bottom cover of the motor*

***Figure 2.7** Cover removed, exposes the internal gearing setup (17:23:5 gear ratio)*

***Figure 2.8** Unscrewing the DC motor from the frame*

***Figure 2.9** Top frame separated*

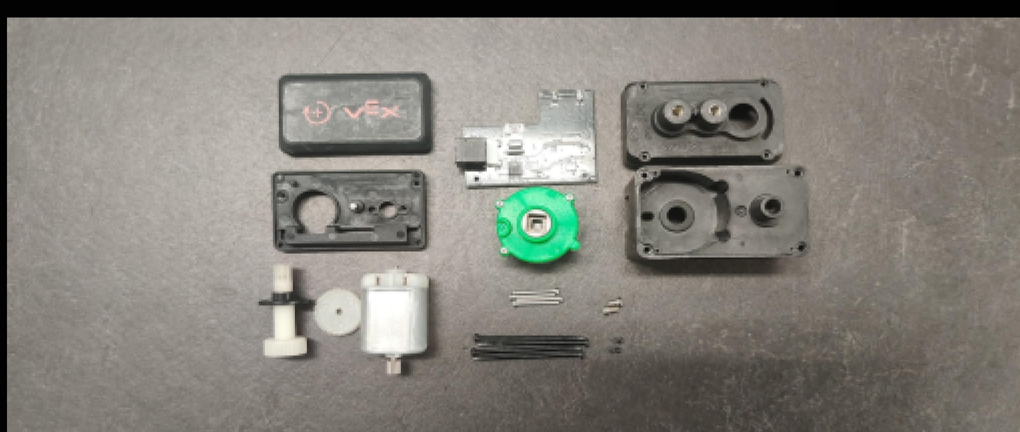


***Figure 2.10** Motor fully disassembled | screw count: 12*

Identified Integrated Circuits on the Mainboard

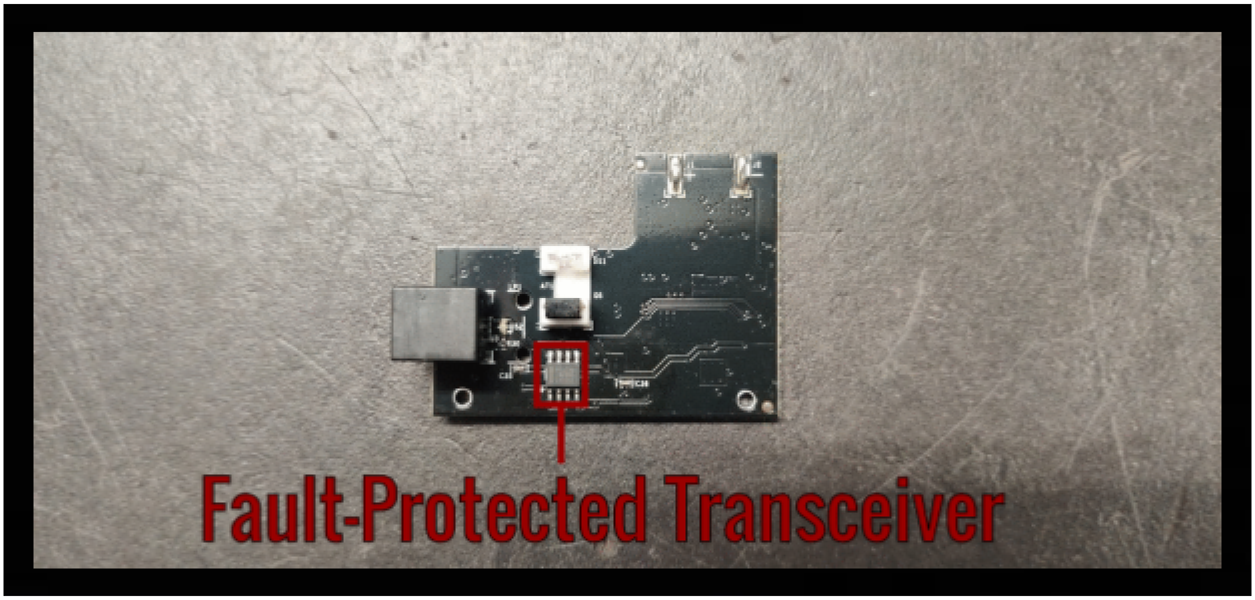


Figure 3.1 Front side of the mainboard

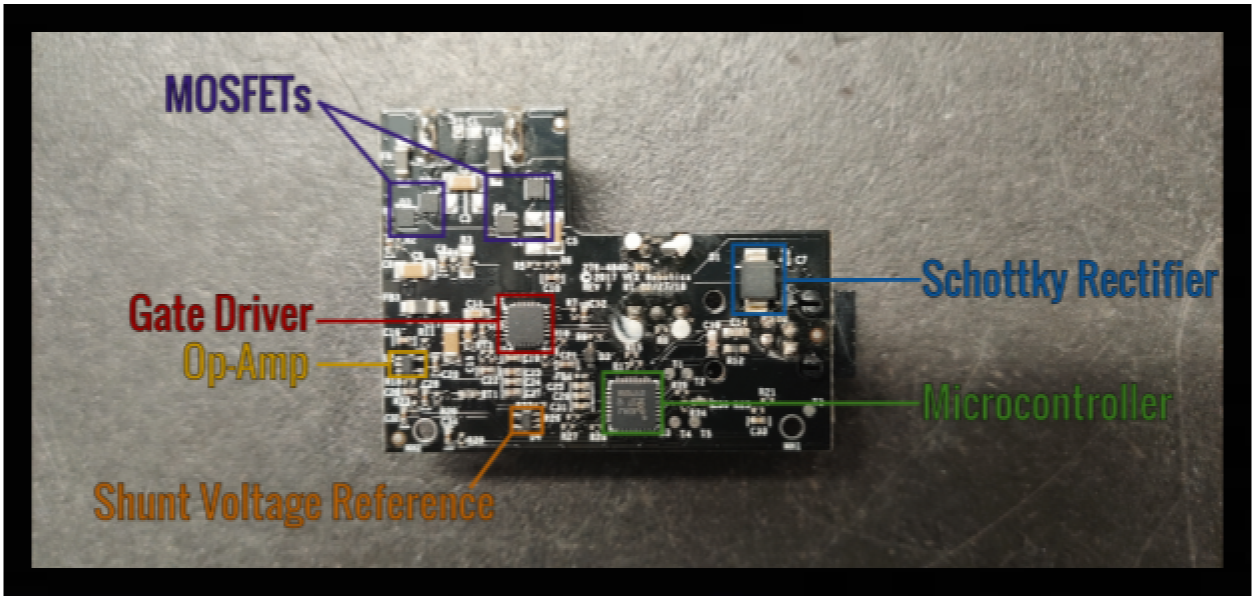


Figure 3.2 Back side of the mainboard

Other Components on the Mainboard

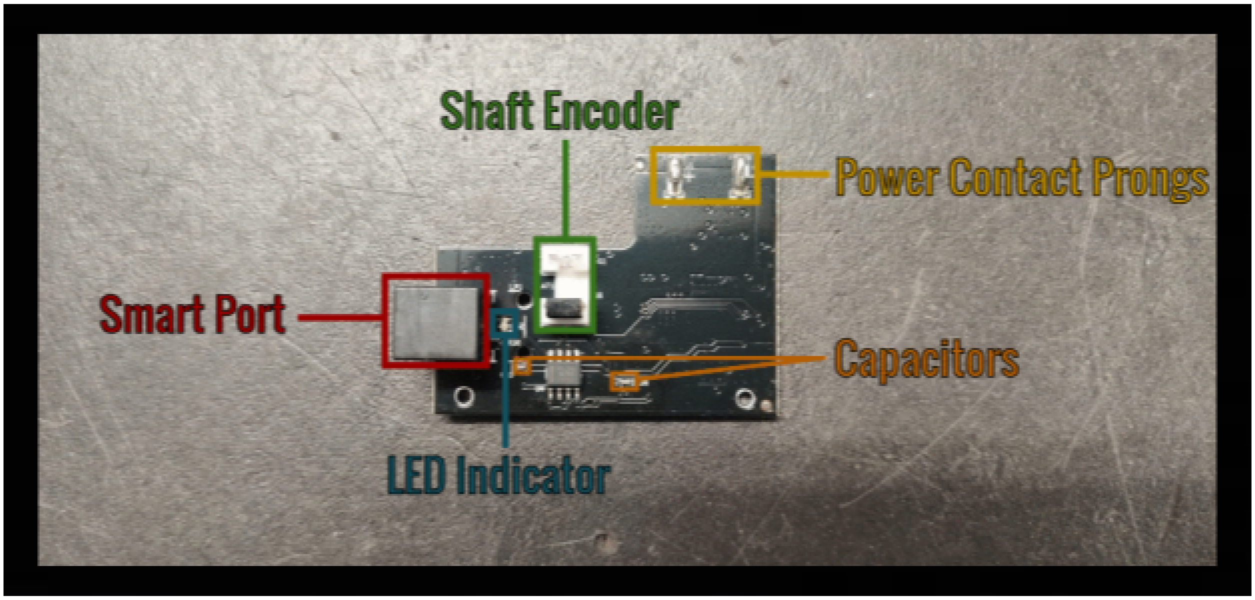


Figure 3.3 Components on the front side of the mainboard

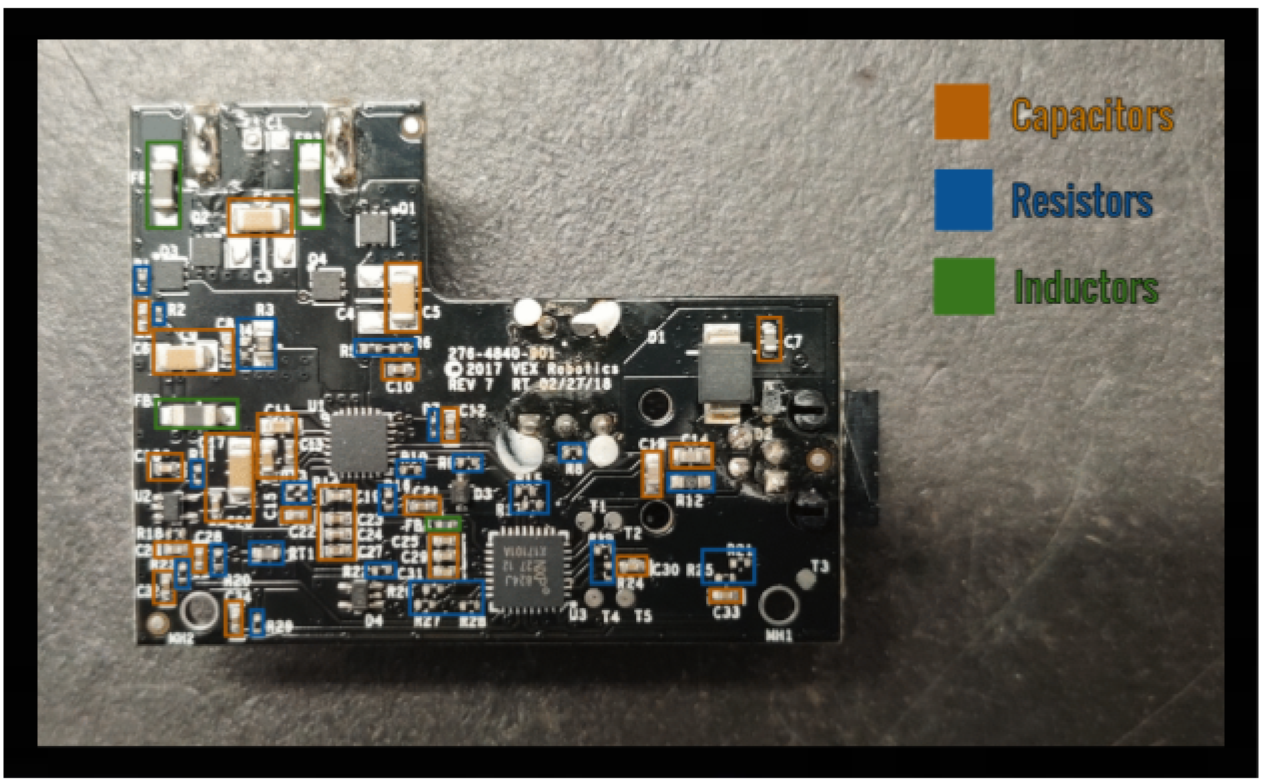
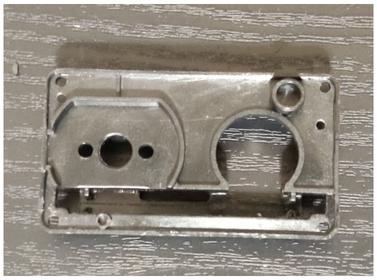
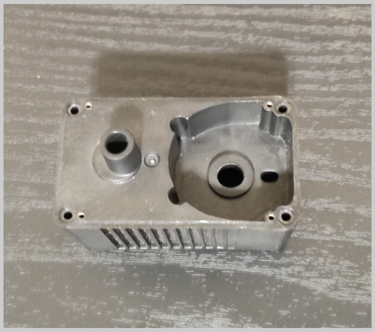


Figure 3.4 Components on the back side of the mainboard

Table 1.1: External Components

External Components	Function/Usage
Top Cover 	Covers the gear system and other internal components from the outside of the motor.
Top Frame 	Used to screw in the DC motor place to keep the mainboard situated. The frame is also responsible for mounting the gear system.
Middle Cover 	Covers the internal components of the motor by combining it with the bottom frame. Holds the interchangeable motor cartridge in place.

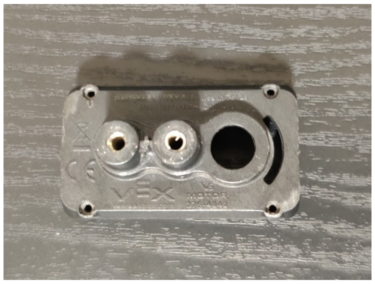
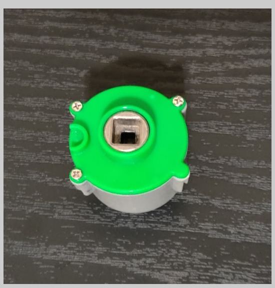
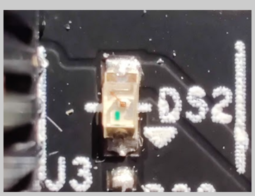
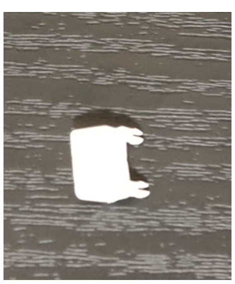
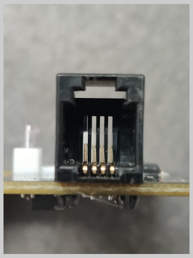
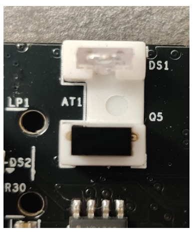
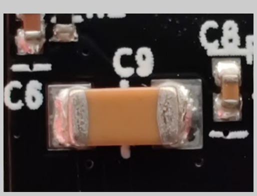
Bottom Cover 	Goes on the middle cover and secures the motor cartridge. Responsible for mounting the motor onto surfaces with its threaded points with screws.

Table 1.2: Internal Components

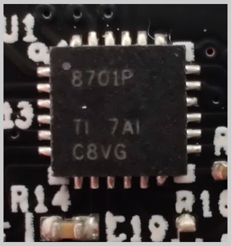
Internal Components	Quantity	Function/Usage
[3]**Motor Cartridge** 	1	Adjusts the motor's torque and speed potential. (Standard 200 RPM 18:1 shown in photo)
[4]**Brushed DC Motor (10 Tooth)** 	1	Winding coils inside the motor are used to convert electrical energy into mechanical energy.

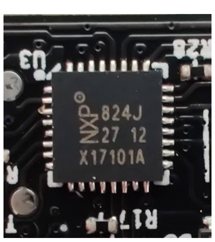
Plastic Gear (46 Tooth) 	1	Responsible for gearing up the DC motor to the encoder shaft in the internal gearing system.
[5]**Encoder Shaft (34 Tooth)** 	1	The shaft is driven by the DC motor. Has an encoder disk to function with the shaft encoder when rotating.
LED Indicator 	1	Indicates the power state of the motor. Turns on when the motor receives power from the V5 Brain.
LED Light Cover 	1	Covers the LED so that its light could be directed towards the transparent Smart plug in the port to indicate the state of power.

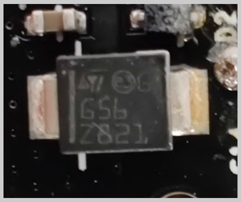
Smart Port (4-pin) 	1	Port where a Smart Cable is inserted for communication and power transfer between the V5 Brain and the Smart Motor.
[5]**Infrared Shaft Encoder** 	1	Integrated shaft encoder on the mainboard. Keeps track of the angular position and motion of the shaft.
Power Contact Prongs 	1	The connection point between the DC motor and the mainboard. Powers the core to generate mechanical energy.
[6]**Surface Mount Resistor** 	32	Provides an amount of resistance to an electrical circuit by opposing the flow of current.
[7]**Surface Mount Capacitor** 	33	Stores energy passively in the circuit and can create a fluctuation in voltage.

[8], [9]**Ferrite Bead Inductor** 	4	Can passively store energy and resist any changes of current in a circuit.

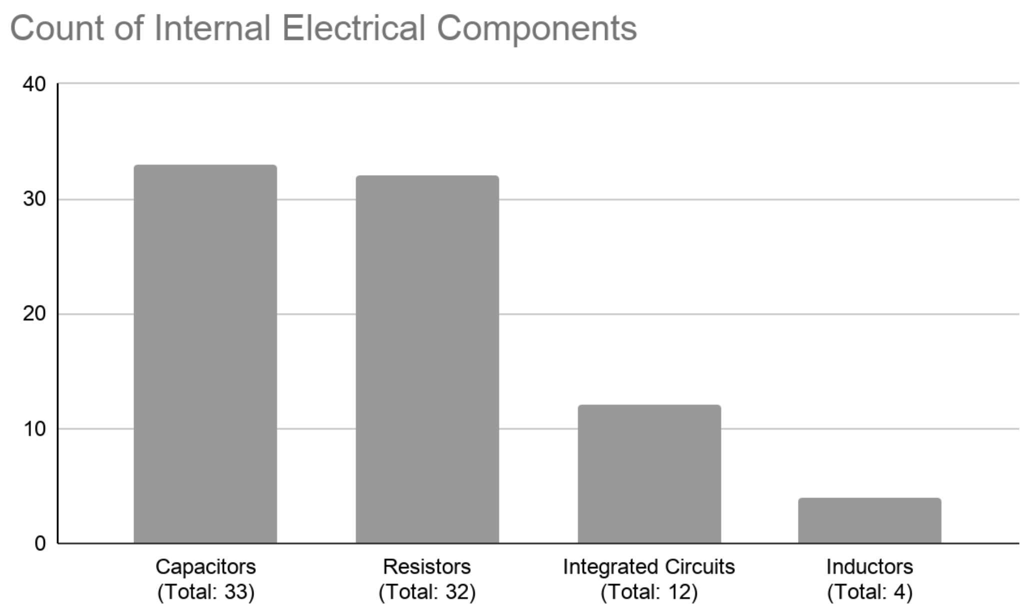
Table 1.3: Integrated Circuits

Manufacturer/Part Number	Quantity	Function/Comments	Package | Pins	Information Source
[I] **Texas Instruments** DRV8701 	1	**Motor gate driver** - Works as a power amplifier to drive the bidirectional motor. Regulates the winding current of the circuit.	RGE | 24	Datasheet
[II] **Texas Instruments** SN65HVD1782 	1	**Fault-Protected Transceiver** - Used to survive overvoltage faults caused by the input voltage. Cuts off the supply if the input exceeds the standard value.	D | 8	Datasheet

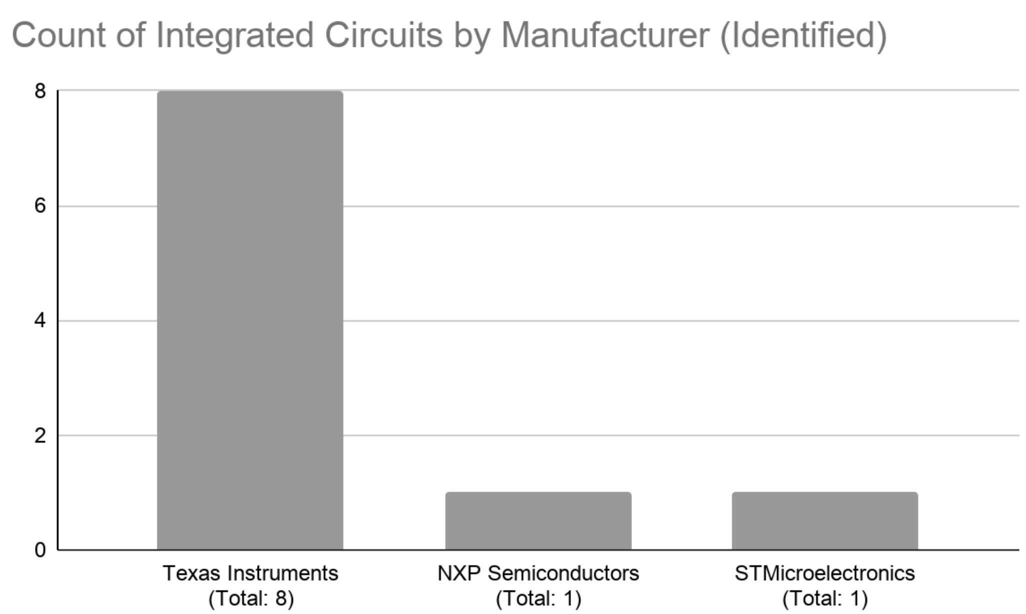
[10],[III] **Texas Instruments** CSD17571 	4	**N-Channel MOSFET** - A transistor used for amplifying and/or converting power.	DQK | 6	[Datasheet]()
[11], [IV] **Texas Instruments** OPA377 	1	**Operational Amplifier** - Component which takes various inputs of voltage and converts it into a single-ended output.	DCK | 5	[Datasheet]()
[12],[V] **Texas Instruments** LM4040 	1	**Shunt Voltage Reference** - Creates a low-resistance path for current to flow through. Used as a voltage regulator in the circuit.	DCK | 5	[Datasheet]()
[1], [VI] **NXP Semiconductors** LPC82X 	1	**Microcontroller** - Regulates the motor's functions and state. Utilizes a PID controller for precise motion.	HVQFN | 33	[Datasheet]()

[VII] **STMicroelectronics** STPS5L60 	1	**Schottky rectifier -** Regulates the flow of current to only travel one way in the circuit. Carries out a rapid DC to DC switching action.	SMB	Datasheet
Unidentified IC 	2	No marking to be spotted on the ICs. Originally coated with a layer of clear adhesive.	N/A	N/A

Graph 1.1: Final Count of Internal Electrical Components Found



Graph 1.2: Count of Integrated Circuits by Manufacturer



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https://www.allaboutcircuits.com/textbook/semiconductors/chpt-8/introduction-operational-amplifiers/

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Datasheets

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[II] Texas Instruments SN65HVD178x-Q1 Fault-Protected RS-485 Transceivers https://www.ti.com/lit/ds/symlink/sn65hvd1780-q1.pdf?ts=1605477594173&ref_url=https%253A%252F%252Fwww.google.com%252F

[III] Texas Instruments CSD17571Q2 30V N-Channel NexFET™ Power MOSFETs https://www.ti.com/lit/ds/symlink/csd17571q2.pdf?ts=1607219264633&ref_url=https%253A%252F%252Fwww.ti.com%252Fproduct%252FCSD17571Q2

[IV] 5MHz, Low-Noise, Single, Dual, Quad CMOS Operational Amplifiers https://www.ti.com/lit/ds/symlink/opa377.pdf?ts=1607219096459&ref_url=https%253A%252F%252Fwww.ti.com%252Fproduct%252FOPA377

[V] LM4040 Precision Micropower Shunt Voltage Reference https://www.ti.com/lit/ds/symlink/lm4040.pdf?ts=1607219208972&ref_url=https%253A%252F%252Fwww.ti.com%252Fproduct%252FLM4040

[VI] 32-bit ARM® Cortex®-M0+ microcontroller; up to 32 kB flash and 8 kB SRAM; 12-bit ADC; comparator https://www.nxp.com/docs/en/data-sheet/LPC82X.pdf

[VII] STMicroelectronics 5 A - 60 V power Schottky rectifier https://www.st.com/resource/en/datasheet/stps5l60.pdf