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EN2160: Electronic Design Realization

Reverse Engineering Report of Leadshine CL57C Driver

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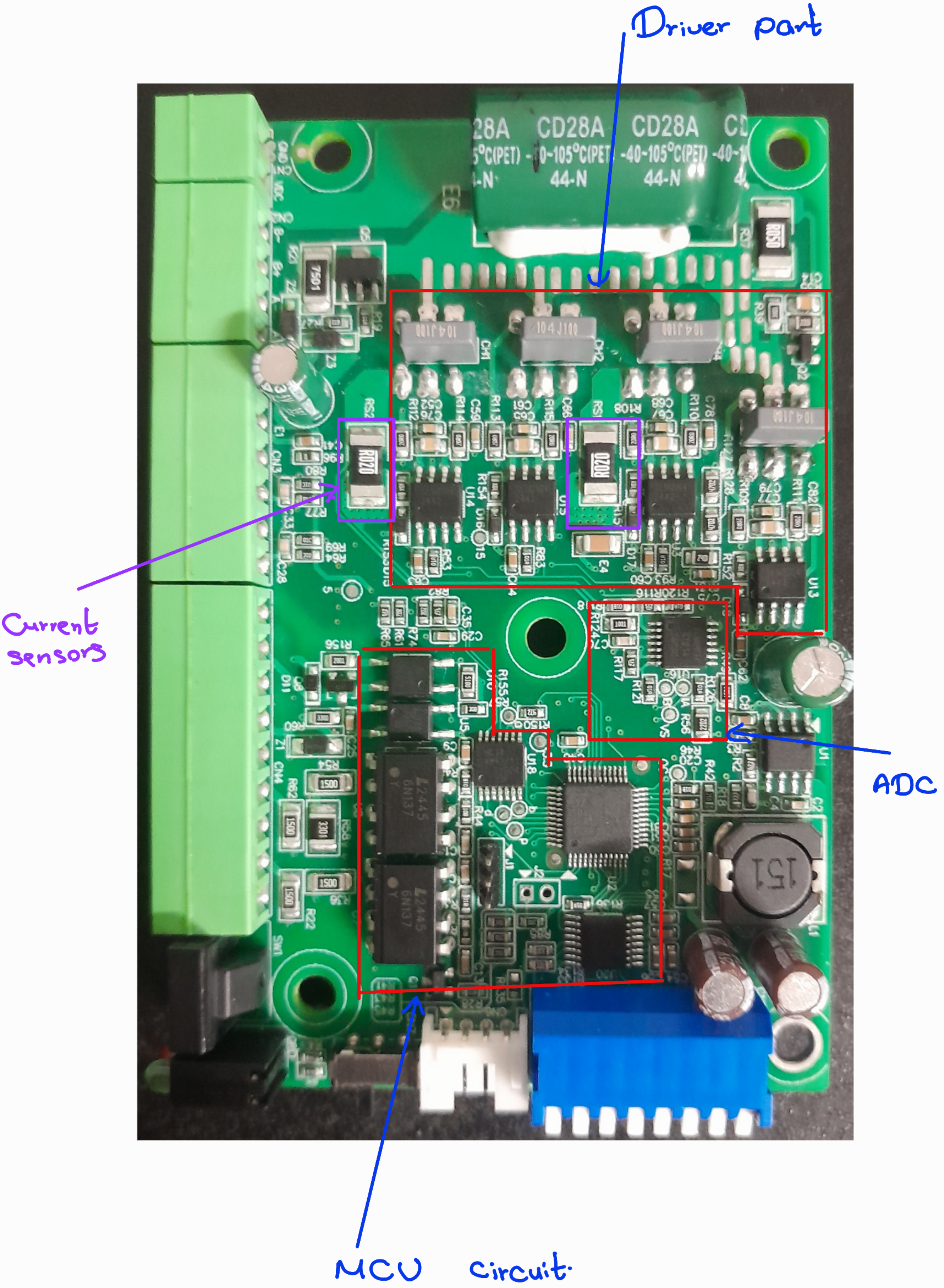
Driver part
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ADC
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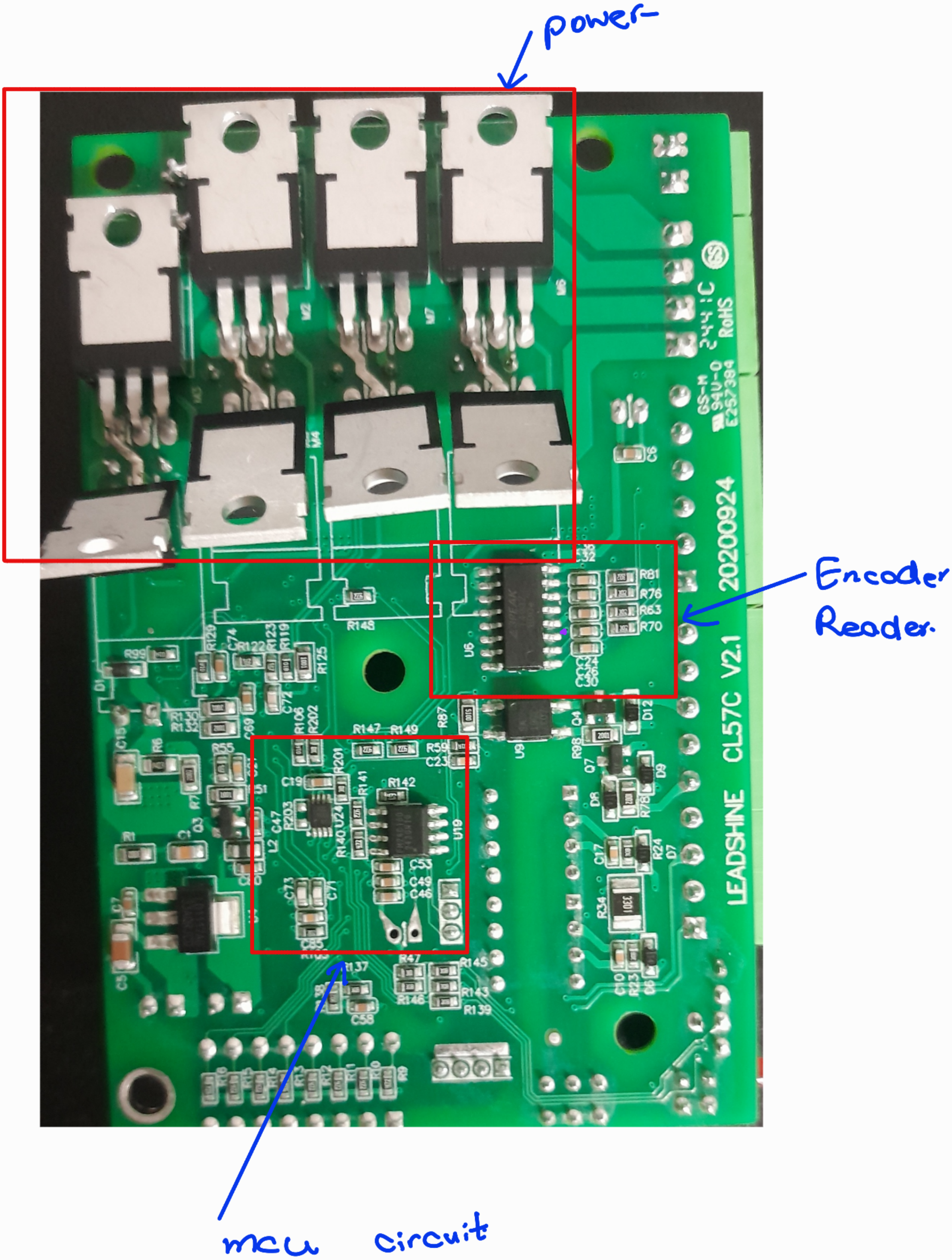
power
Encoder Reader
mcu circuit
LEADSHINE CL57C V2.1
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From the above pictures the main parts of the circuit identified are:

- MCU circuit
- Driver circuit
- Current sensing circuit
- Power circuit

1 Block Diagram of the Circuit

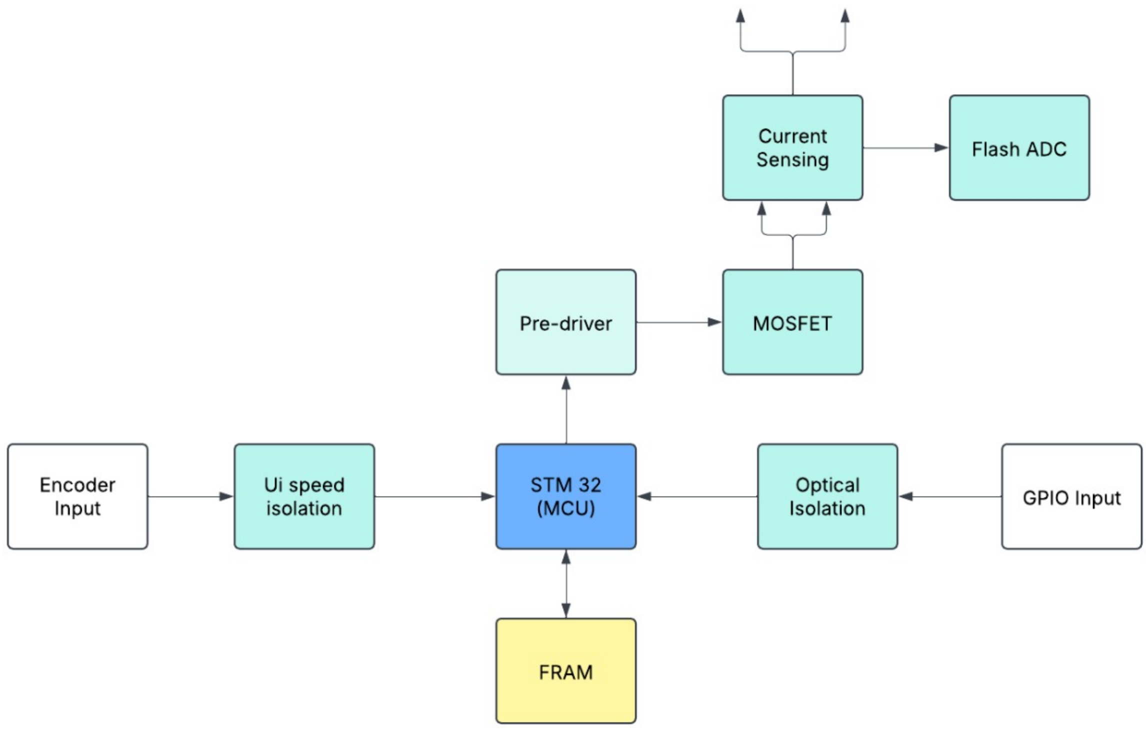

Figure 1: Block Diagram

2 MCU Circuit

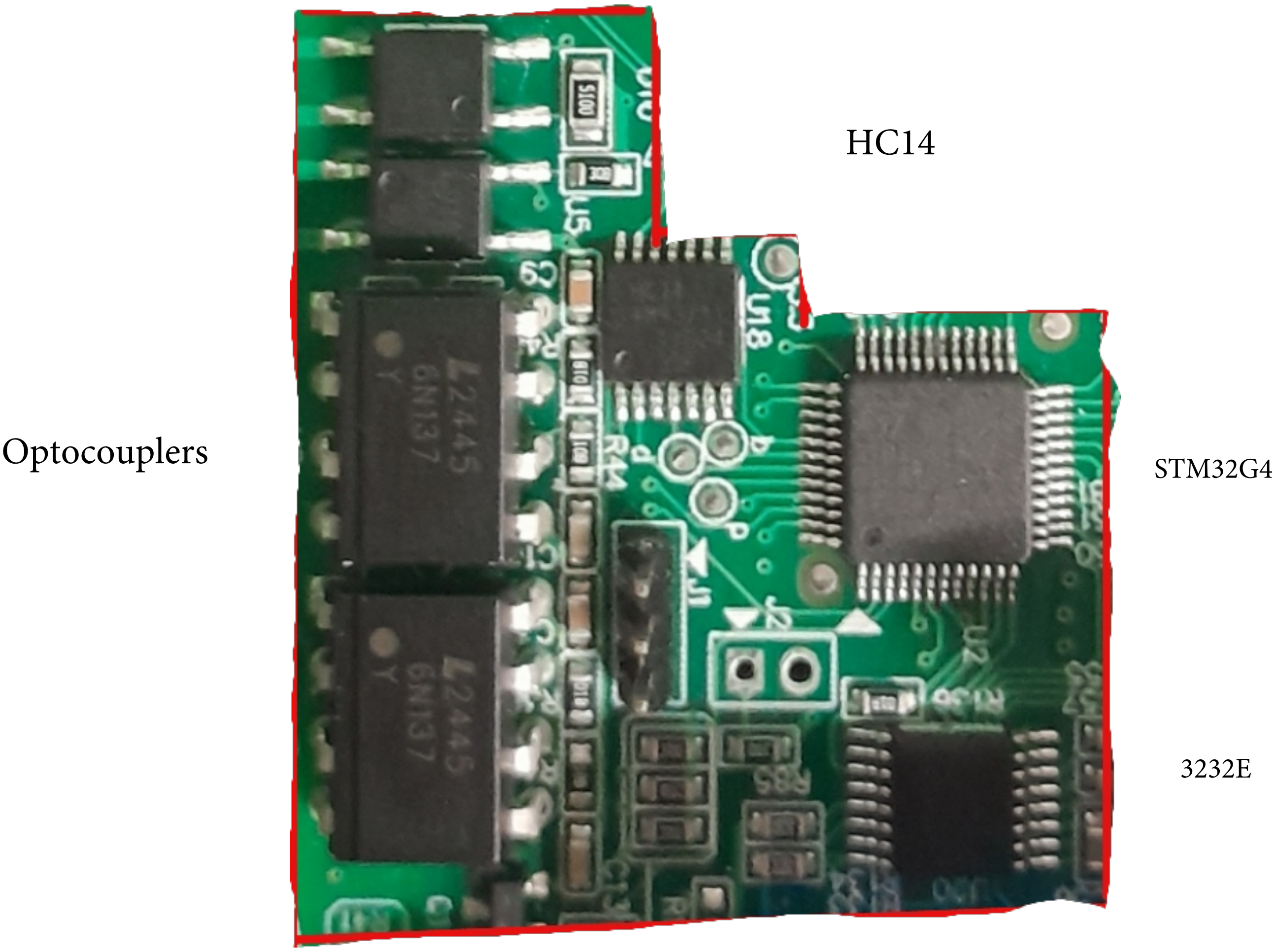

Figure 2: MCU circuit consisting of optocouplers

Main components used:

- **L2445 Optocouplers** – Provide electrical isolation between the MCU and high-voltage sections of the motor driver. They protect the MCU by transmitting control or feedback signals optically across an isolation barrier.
- **HC14 (SN74HC14)** – A hex inverter with Schmitt-trigger inputs used for signal conditioning. It cleans up noisy encoder signals or switch inputs, ensuring the MCU receives stable digital inputs for precise feedback control.
- **TPT3232E (likely MAX3232E or equivalent)** – A dual RS-232 transceiver used to interface the MCU with serial communication lines (e.g., to a PC or external controller). It converts between TTL logic levels and RS-232 voltage levels.
- **FM24C16D** – A 16-kbit I2C FRAM (Ferroelectric RAM) chip used to store parameters such as calibration data, motor profiles, or error logs. Unlike EEPROM, it offers fast writes and virtually unlimited endurance.

- **T4032 BDOe** – Likely refers to the TPT4032, a quad RS-422 differential receiver. It is possibly used to receive differential encoder signals from the stepper motor over long distances. The IC converts the high-speed RS-422 differential signals into standard TTL/CMOS logic levels readable by the MCU. Its strong ESD protection and wide input voltage tolerance ensure reliable communication in noisy industrial motor control environments.

3 Current Sensing Circuit

Main components used:

- **20 mΩ Current Sense Resistors** – Used to measure the current flowing to the stepper motor. The small voltage drop across these low-value resistors is sensed by the op-amps or ADCs in the MCU to monitor motor current in real-time and enable closed-loop control.
- **SGM8634 Quad OpAmp** – This is a quad low-noise CMOS operational amplifier. It can be used to implement a simple **Flash ADC** (Analog-to-Digital Converter) when paired with a **resistor voltage divider** network (ladder) and a set of **comparators**.

  Flash ADC Concept with Op-Amps and Resistors:

  - A **resistor ladder** creates a set of evenly spaced reference voltages across a range (e.g., 0V to 3.3V).
  - Each of the four op-amps in the SGM8634 can be configured as a **comparator**, comparing the analog input signal to one of the reference voltages.
  - The output of each comparator (op-amp) goes high or low depending on whether the input signal is above or below the reference threshold.
  - The digital outputs of the comparators form a **thermometer code**, which can be decoded into a binary output by the MCU or a logic circuit.

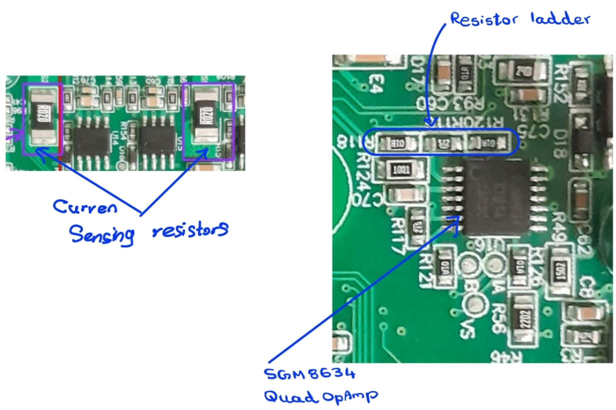

Figure 3: Current sense components and flash ADC implementation

4 Driver Circuit

Main components used:

- **SLM2004S** – This is a smart gate driver IC designed for driving MOSFETs in full H-bridge or half-bridge configurations. Each SLM2004S typically contains two high-side and two low-side gate drivers, allowing it to control a full H-bridge. It provides integrated dead-time control and other motor controls which are essential for robust and efficient motor control.

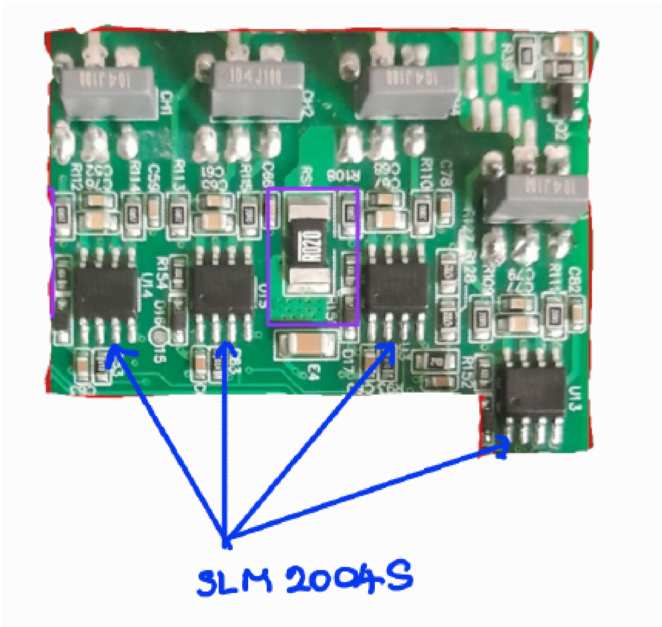

Figure 4: Components of driver circuit

- **8 MOSFETs** – These are power transistors used to switch current to the motor phases. In an H-bridge configuration, four MOSFETs are used per phase (two per leg), enabling precise control over current direction and amplitude for each winding of the stepper motor.

Working Together in a Closed-Loop Stepper Motor Driver:

To drive a 2-phase bipolar stepper motor in a closed-loop system:

- **4 SLM2004S** ICs are used. Since each phase of the motor requires an H-bridge for bidirectional current control, two SLM2004S ICs can control one phase.
- With **4 SLM2004S ICs** and **8 MOSFETs**, you can construct **two full H-bridges** – one for each motor phase.
- The stepper motor phases are driven with current controlled via the MOSFETs, under the supervision of the SLM2004S drivers.
- In a closed-loop system, feedback from a position or current sensor (e.g., via op-amp/comparator circuits) is processed by the MCU, which adjusts the gate drive signals sent to the SLM2004S ICs to maintain precise motor positioning and torque.

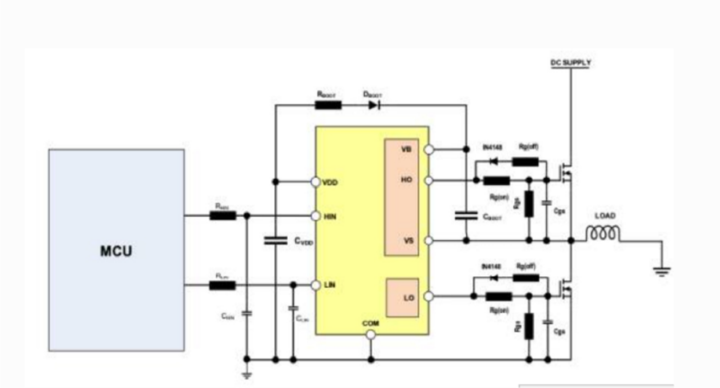

Figure 5: Working of driver

5 Power Circuit

Main components used:

- **150 μH Inductor** – This is likely part of a buck (step-down) converter circuit. In buck regulators, the inductor stores and transfers energy to step down the voltage efficiently from a higher supply voltage (e.g., 24V) to a lower voltage level.
- **LD117AG** – This is a low dropout (LDO) linear voltage regulator. It is used to provide a stable and precise output voltage (typically 3.3V) from a higher input voltage. The "G" variant generally refers to specific package or thermal characteristics

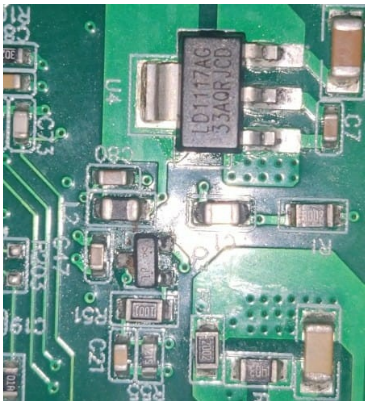

Figure 6: LD117AG

Some components on the PCB could not be identified as they are either unmarked or are custom ICs, likely proprietary to the manufacturer.

Possible working scenario: Based on the circuitry observed, it is likely that the 24V input supply is first stepped down using a buck converter, and the resulting intermediate voltage is then further regulated by the LD117AG LDO to provide a clean and stable 3.3V supply for powering the MCU and other sensitive logic components.

6 Comparison

Table 1: Comparison: Leadshine Closed-loop Driver vs Custom Driver

Feature / Component	Leadshine Closed Loop Driver	Custom Driver
Microcontroller (MCU)	**STM32G4** – ARM Cortex-M4 with motor control peripherals	**TI C2000** (TMS320 series) – Real-time control MCU
Motor Driver IC	Pre-driver + External MOSFETs	**Toshiba TB67H400** – Integrated MOSFETs in single chip
Signal Isolation	Uses **optocouplers** – For isolation and accurate signal transmission between control and power domains	**No optocouplers** – Direct interfacing between MCU and driver IC
Current Sensing	External 20 mΩ shunt resistors + Likely op-amp based **Flash ADC**	External 62 mΩ shunt resistors + **SAR ADC**
Encoder Feedback Interface	RS-422 receiver (e.g., **TPT4032**) to handle encoder feedback	Uses differential line receiver, level shifter & QEP module of MCU to receive feedback
Voltage Regulation	Buck stage followed by **LD117AG LDO** to 3.3V for powering MCU	Buck stage followed by two LDO's to convert to 3.3V & 5.5V