# SmartMCD™

## BOARD

USER MANUAL

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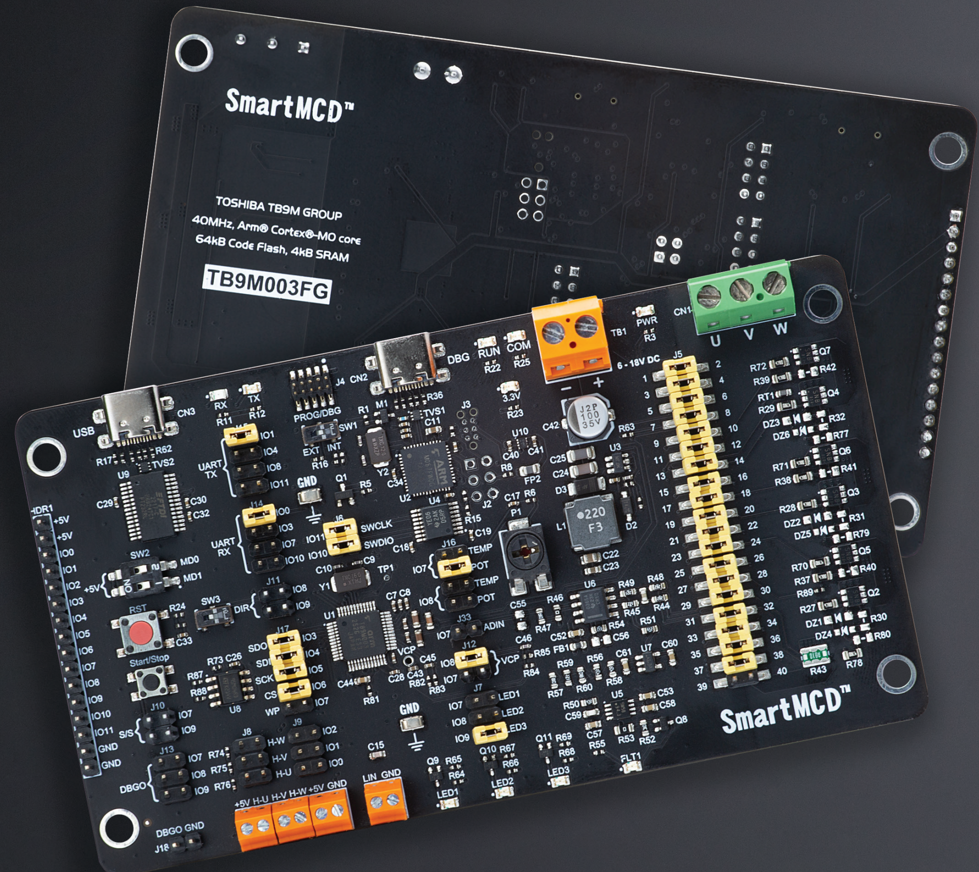


Figure: SmartMCD™ board front and back view

**The SmartMCD™ board** offers an advanced solution for controlling brushless motors in automotive body systems. Central to the SmartMCD™ board is the TB9M003FG (U1), a gate driver IC with a built-in MCU specifically designed for automotive brushless DC (BLDC) motor applications, such as electric pumps and fans, and three-phase motor control.

This IC includes a 32-bit Arm® Cortex®-M0 core with a maximum operating frequency of 40MHz and 64KB of code flash memory. This memory, equipped with ECC SEC/DED, allows customization of control methods and parameters to match specific motor and application needs. Additionally, Toshiba's unique Vector Engine (VE) helps streamline motor vector control calculations, reducing the load on the CPU.

The SmartMCD™ board includes an integrated inverter comprising six small-package, AEC-Q101 qualified MOSFETs (SSM6K809R) for efficient power management. It also supports connection of external inverter versions utilizing various power MOSFETs, such as TK1R4S04PB, XPH2R404PS, TPW1R104PB, and XPN3R804NC, providing flexibility for different power requirements.

The board's compact design, measuring 130mm (x) 73mm, includes all circuits needed for motor control, switches, and potentiometers for operational testing.

# 1. Key microcontroller features

At its core, the SmartMCD™ board uses the **TB9M003FG** MCU.

The TB9M003FG (U1) is Toshiba's implementation of the 32-bit ARM® Cortex®-M0 core, capable of operating at a maximum frequency of 40MHz. It includes 64KB of code flash memory with ECC SEC/DED, allowing the programming of control methods and parameters tailored to specific motor and application requirements. Additionally, this IC incorporates Toshiba's unique Vector Engine (VE), simplifying motor vector control and reducing CPU load.

- 64KB Code Flash
- 12KB ROM
- 4KB of SRAM
- Operating frequency up to 40 MHz

For the complete list of MCU features, please refer to the **TB9M003FG** ***datasheet.***

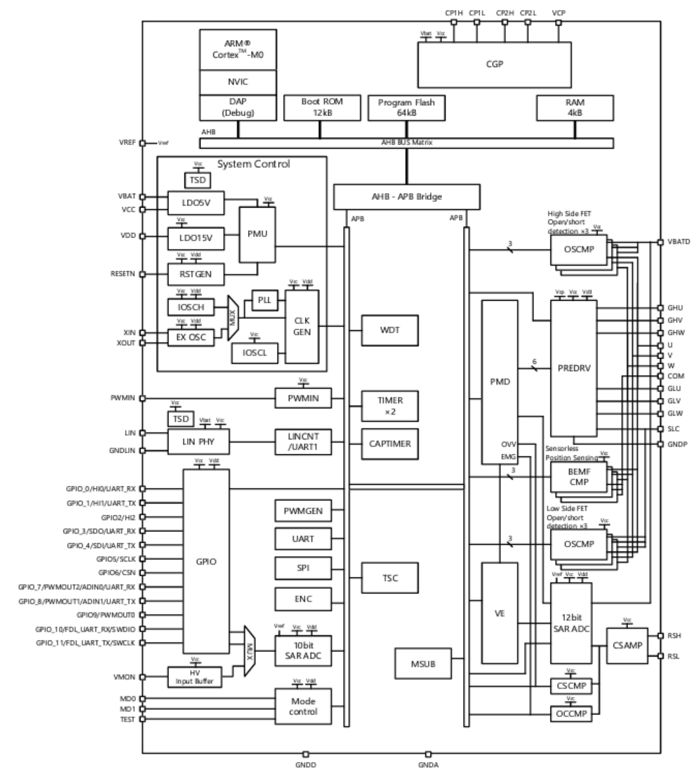


Figure 1: TB9M003FG MCU block diagram

MCU FEATURES

# 2. MOSFET Power Stage

As mentioned, the SmartMCD™ board includes an integrated inverter comprising of six small-package, AEC-Q101 qualified MOSFETs (SSM6K809R - from Q2 to Q7) for efficient power management, connected via populated jumpers on the J5 header **[1]**. These MOSFETs are driven by gate-signal outputs from the TB9M003FG (U1). The inverter produces three-phase outputs labeled U, V, and W, which drive a brushless motor connected to the 3-phase brushless motor terminal (CN1) **[2]**.

Several external inverter board versions can also be connected via the 40-pin J5 header for applications requiring higher currents. These external boards use various Toshiba's power MOSFETs, including the TK1R4S04PB, XPH2R404PS, TPW1R104PB, and XPN3R804NC, providing enhanced current handling capabilities. This flexibility allows for the adaptation of the system to different power requirements, ensuring robust and efficient motor control.

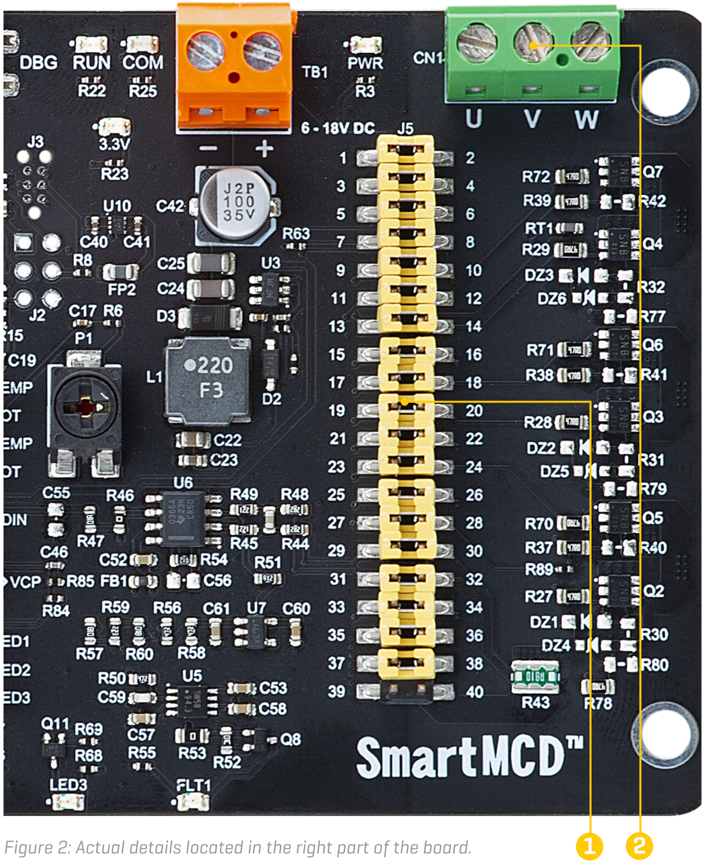


*Figure 2: Actual details located in the right part of the board.*

# 3. Power Supply

The main power supply, which ranges from 6V to 18V (typically 12V), is provided to the TB9M003FG (U1) via the TB1 **(1)** terminal. This power supply also feeds the entire inverter circuit and the step-down DC-DC converter, the MCP16331 (U3). The presence of active external power can be visually confirmed by a green PWR LED **(2)** located near the connector.  Even the TB9M003FG generates its own 5V supply, which can be used for external components up to 100mA, the MCP16331 is responsible for converting the VBAT power supply to 5V, which is then used to power various ICs and components around the TB9M003FG (U1). Additionally, the 5V power supply is further regulated to 3.3V via an LDO regulator, the NCP186 (U10), which primarily supplies the TMPM067FWQG (U2) MCU for programming purposes. Similar to the PWR LED indicating the presence of external power, a green LED labeled 3.3V indicates the successful generation and activation of the 3.3V power supply.

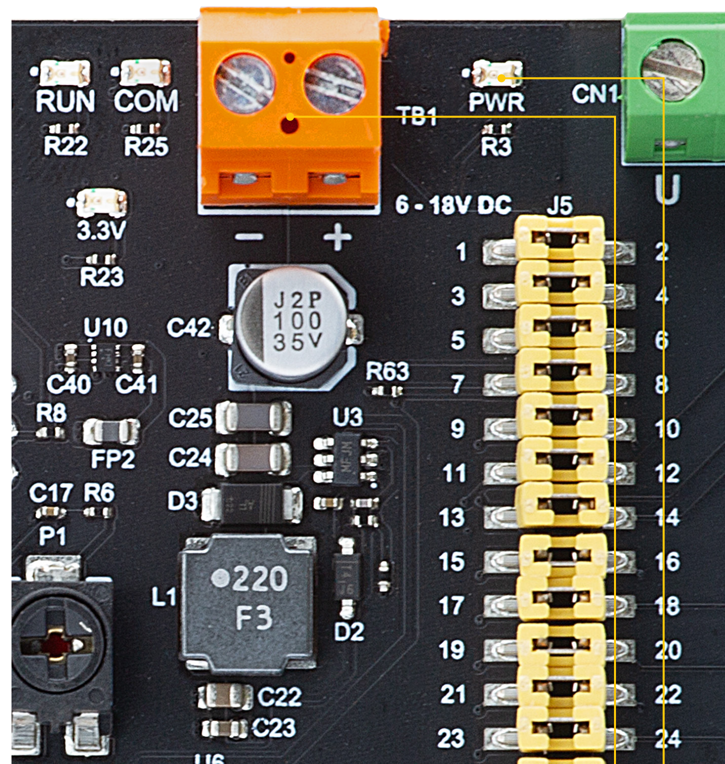


*Figure 3: Actual details located in the upper right corner of the board.*

1 2

# 4. MCU Programming

The program/debug switch (SW1) **(1)** allows you to select the source for programming and debugging the TB9M003FG (U1). When set to the INT position, it enables programming and debugging via the onboard CMSIS-DAP (U2). Alternatively, setting it to the EXT position allows for programming and debugging through the SWD connector (J4). **(2)**

## 4.1 Programming with onboard debug unit

SmartMCD™ board uses Toshiba's TMPM067FWQG (U2) as the on-board Debug Unit. It is compliant with an on-board emulator standard called CMSIS-DAP. The CMSIS-DAP is the interface firmware for a Debug Unit that connects the Debug Port to USB. Debuggers, which execute on a host computer, connect via USB to the Debug Unit and the Device running the application software. The Debug Unit connects via SWD to the target Device. Once the SmartMCD™ board is powered up and the PWR/DBG connector is connected to the PC, the on-board debug unit takes a few seconds to initialize. After initializing the on-board CMSIS-DAP, two LEDs, RUN (LD2) and COM (LD4), blink once.

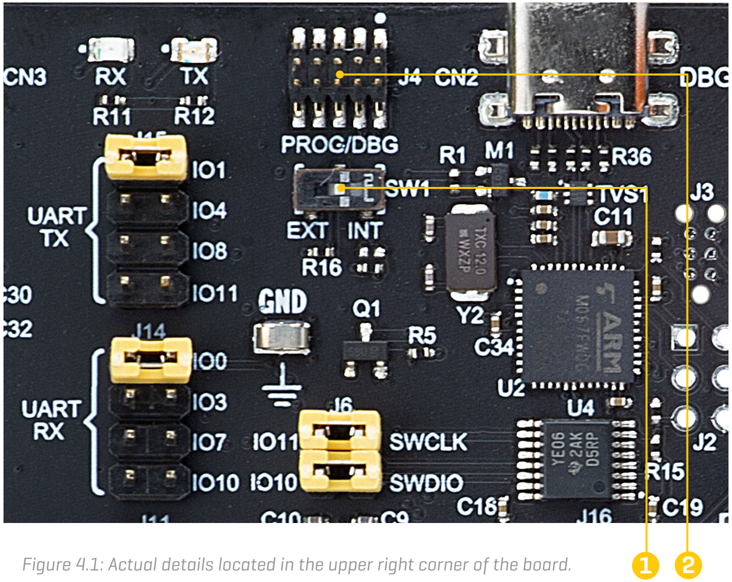


*Figure 4.1: Actual details located in the upper right corner of the board.*

# 4.2 Programming with an external programmer

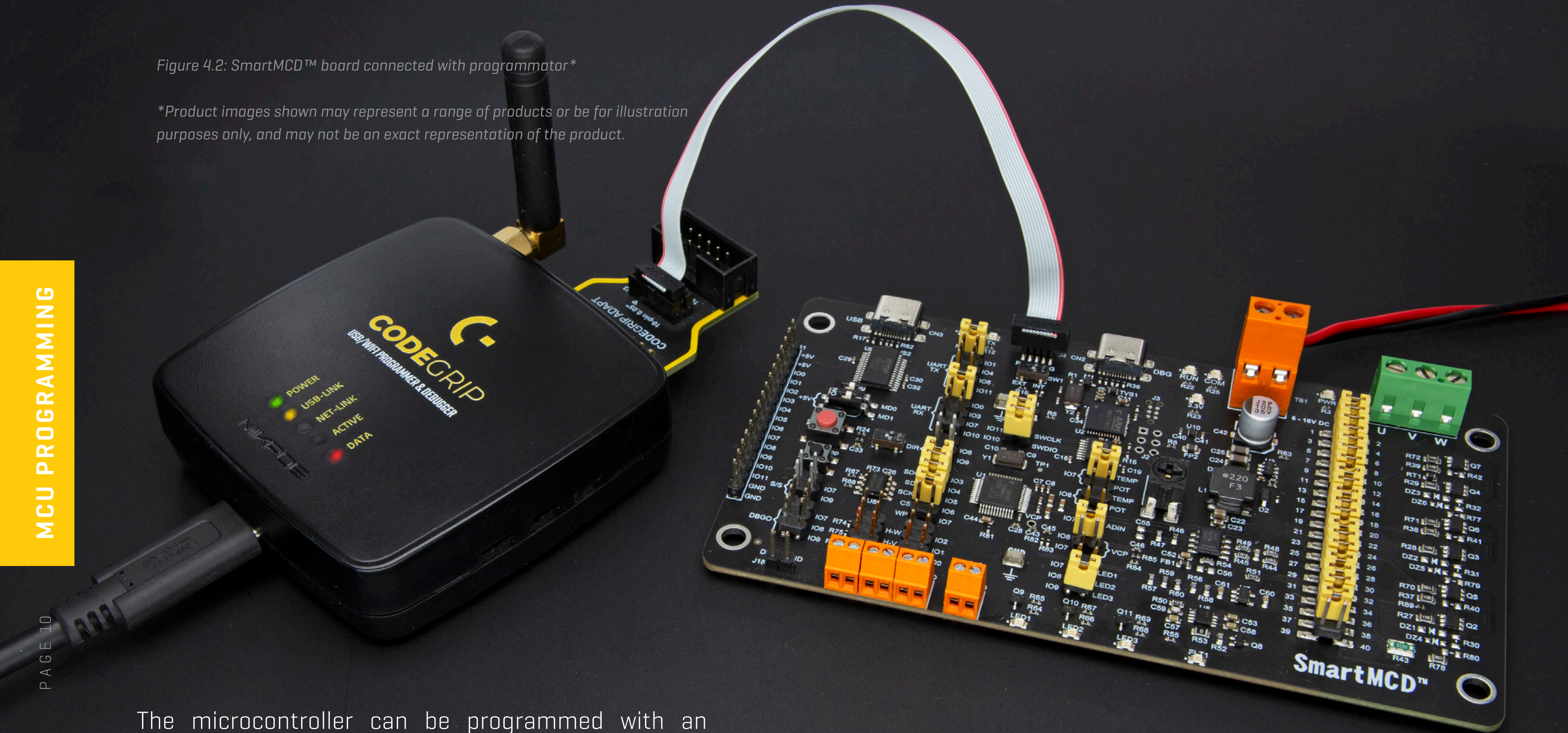


*Figure 4.2: SmartMCD™ board connected with programmator**

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The microcontroller can be programmed with an external programmer and supported software. The external programmer is connected to the development board via a 2x5 PROG/DBG connector soldered on the J4 connector pads.

**NOTE**

*Please check if the programmer pinout and the 2x5 pin header pinout are compatible before usage. A corresponding adapter might be needed based on the programmer/debugger tool pinout.*

# 5. Connectivity

Serial communication with the TB9M003FG (U1) can be achieved through an external USB hosting device connected to the USB Type-C **[1]** connector located in the upper left corner (CN3). The USB signals (USB-D_P, USB-D_N) are converted to UART serial data signals (UART-TX, UART-RX) by the USB-UART controller , the FT232RL (U9), enabling serial communication with the TB9M003FG (U1). To protect the USB signals (USB-D_P, USB-D_N) from electrostatic discharge, an ESD protection diode (TVS2) is used.

The transmit serial data (UART-TX) from the USB-UART controller , the FT232RL (U9), can be routed to IO1, IO4, IO8, or IO11 of the TB9M003FG (U1) by placing the appropriate jumper on the J15 header **[2]**. When serial data is transmitted, the TX LED **[4]** illuminates. Similarly, the receive serial data (UART-RX) from the USB-UART controller , the FT232RL (U9), can be connected to IO0, IO3, IO7, or IO10 of the TB9M003FG (U1) by placing the corresponding jumper on the J14 **[3]** header. The RX LED **[4]** lights up when serial data is received.

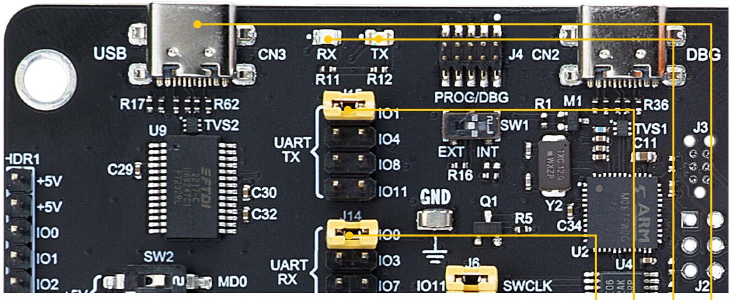


*Figure 5.1: Actual details located in the upper left corner of the board.*

LIN (Local Interconnect Network) communication is possible through the LIN connector **[5]** (TB2). To ensure reliable communication and minimize interference, a bypass capacitor (C15) **[6]** is included in the circuit. This capacitor helps to reduce the amount of noise generated during LIN communication, enhancing signal integrity and overall performance.


*Figure 5.2: Actual details located in the lower left corner of the board.*

# 6. Onboard Settings

## 6.1 Switches

The start mode selection switch (SW2) **(1)** is used to choose the activation mode of the TB9M003FG (U1). Upon resetting, the mode is determined based on the settings of the MD0 and MD1 switches. The available modes are Normal, Flash Download, and Debug. When both MD0 and MD1 switches are OFF, the IC operates in Normal mode. The IC enters Flash Download mode if MD1 is ON and MD0 is OFF. Conversely, the IC switches to Debug mode when MD1 is OFF and MD0 is ON.

| MD0 | MD1 | IC |
|---|---|---|
| OFF | OFF | Normal |
| OFF | ON | Flash Download |
| ON | OFF | Debug Mode |

*Figure 6.1: Activation modes of TB9M003FG(U1)*

The slide switch (SW3) **(2)** can be connected to either IO8 or IO9 of the TB9M003FG (U1) by placing the appropriate jumper on the J11 header **(3)**. The software uses this switch to change the motor rotation direction and perform additional functions.

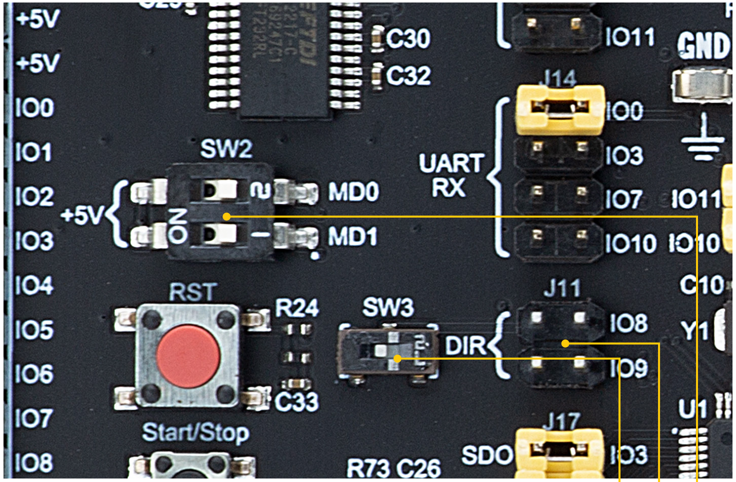


*Figure 6.2: Actual details located in the center left corner of the board.*

# 6.2 Headers, Jumpers and Connectors

Some of the pins on the TB9M003FG (U1) are multiplexed, with their assignments determined by the software configuration after startup. The DBGO signal output connector (J18) **(1)** is used to externally monitor the debug output signal (DBGO) of the TB9M003FG (U1). This signal can be connected to IO7, IO8, or IO9 of the TB9M003FG (U1) via the DBGO (J13) **(2)** header connector.

Pin 21 of the TB9M003FG (U1), labeled VCP, provides the voltage output of the charge pump circuit. This output voltage is divided using resistors (R84, R85) and can be connected to IO7 or IO8 of the TB9M003FG (U1), which can be used as analog inputs, by placing the appropriate jumper on the header (J12) **(3)**. This configuration allows the software to monitor the charge pump voltage. The HDR1 1x16 pin header **(4)** provides additional connections and can be used to connect from IO0 to IO11 pins of the TB9M003FG (U1), as well as to the 5V power supply and GND for testing purposes.

The potentiometer (P1) **(5)** can be connected to IO7 or IO8 of the TB9M003FG (U1) by placing the corresponding jumper on the TEMP-POT header (J16). The voltage output level of this potentiometer can be adjusted between 0V and 5V, depending on its rotational position (counterclockwise rotation). This adjustment is used by the software to change the motor rotational speed, among other functions .

# 6.3 Buttons

The RST button **[6]** generates a reset signal for the TB9M003FG(U1). The Start/Stop button (T2) **[7]** is a push switch that connects the switch's output to GND when pressed. It is possible to route this signal to the TB9M003FG (U1) through the jumper pin connector (J10) **[8]** by placing a jumper on either the IO7 or IO9 position. These jumper pins are used to connect the push-switch (T2) output (S/S) to IO7 or IO9 of the TB9M003FG (U1). The software uses this switch to start and stop the motor, as well as for other functions.

# 6.4 LED Indicators

LED1, LED2 and LED3 **[9]** can be controlled by the software. When the LED signal (LED1, LED2, LED3) for any LED becomes HIGH, the corresponding SSM3K15AFU MOSFETs (Q9, Q10 and Q11) operating as a low-side switch are activated, and the LED lights up. These LEDs can also be connected to IO7, IO8 or IO9 of the TB9M003FG (U1) by placing the corresponding jumpers on the header (J7) **[10]**. Additionally, the red FLT1 LED **[11]** lights up when the bus current of the inverter circuit (on-board or external inverter) detects an overcurrent, providing a visual indication of this condition.

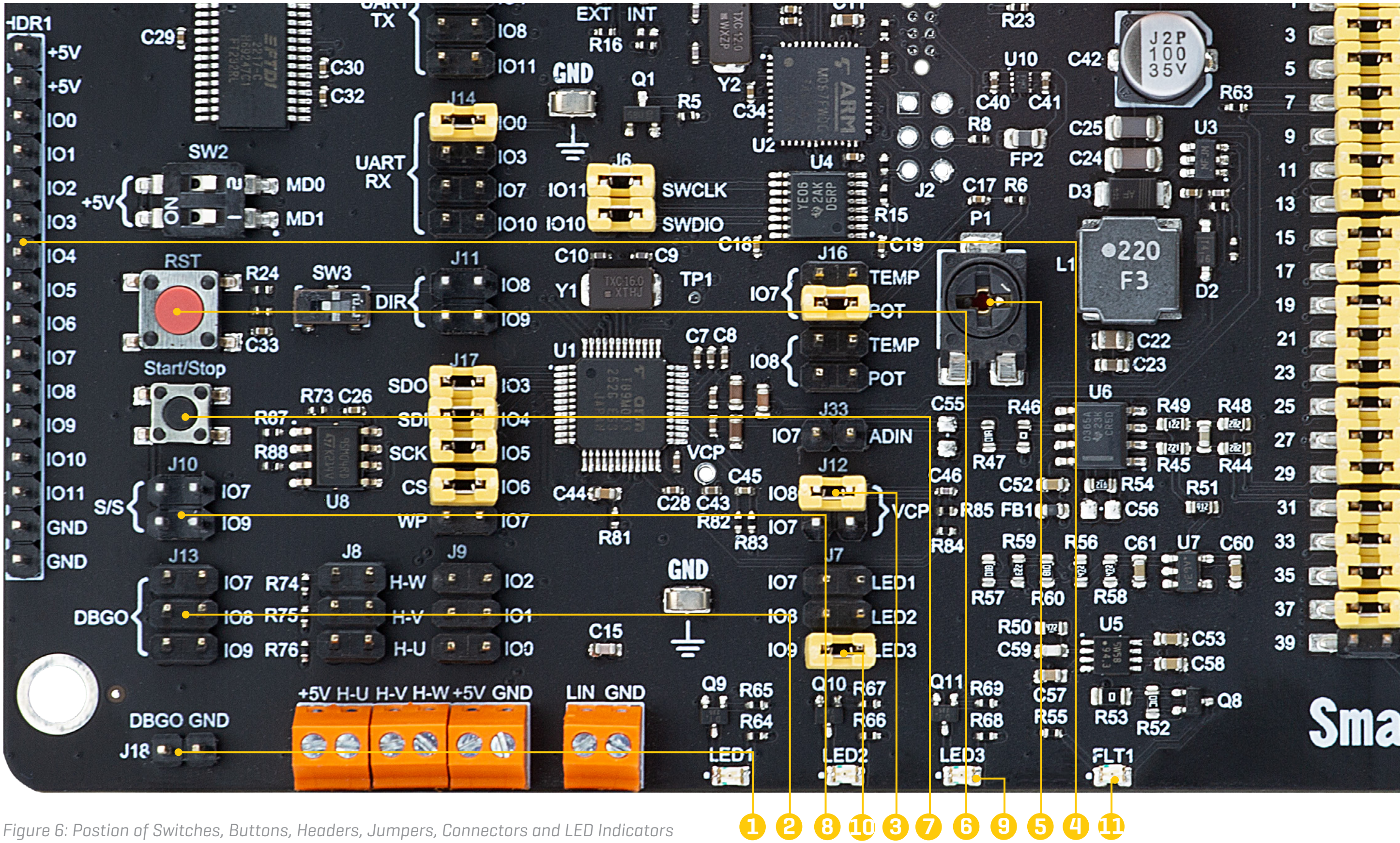


*Figure 6: Postion of Switches, Buttons, Headers, Jumpers, Connectors and LED Indicators*

# 7. SmartMCD™ board Peripherals



The external EEPROM memory (U8) can be connected to the TB9M003FG (U1) via the header (J17) **(1)**. By placing jumpers on J17, the EEPROM's SDO, SDI, SCK, CS, and WP pins can be connected to IO3, IO4, IO5, IO6, and IO7 of the TB9M003FG (U1), respectively.

The external hall sensor signals (HALL-U, HALL-V, HALL-W) **(2)** can be connected to the TB9M003FG (U1) by placing the corresponding jumpers on the header (J9). Additionally, header (J8) can be used to externally pull up the hall sensors (HALL-U, HALL-V, HALL-W) to 5V. These signals can then be connected to the appropriate terminals labeled with HALL designations.

The NTC thermistor (RT1), located near the inverter part of the board, is connected in a voltage divider configuration with the resistor (R63). The output signal (TEMP) from this voltage divider can be connected to IO7 or IO8 of the TB9M003FG (U1) by placing the corresponding jumper on the TEMP-POT header (J16) **(3)**. This TEMP signal can be used by the software to monitor the temperature and detect abnormal heat generation.

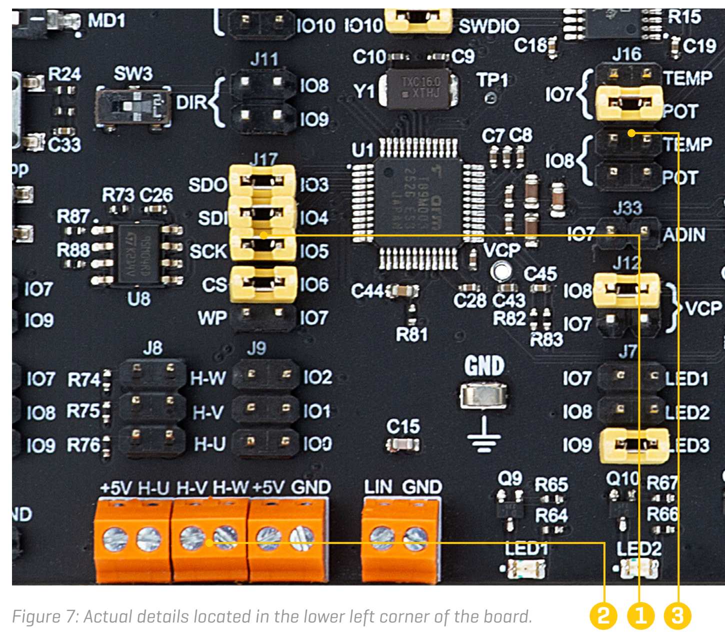


*Figure 7: Actual details located in the lower left corner of the board.*

# 8. Current Monitoring

Both sides of the inverter shunt resistor (R43) **(1)** are connected to the RSH pin (pin 27) and RSL pin (pin 28) of the TB9M003FG (U1). The voltage generated by the shunt resistor is amplified by the current-sensing amplifier built into the TB9M003FG (U1), and then output to the Overcurrent Detection Comparator (OCCMP) and Current Clamp Comparator (CLCMP). Overcurrent is detected by monitoring the inverter bus current flowing through a 10m◦ shunt resistor (R43). The maximum is about 6A, using a gain factor of x40 for the internal current sensing amplifier. The threasholds should be set to about 4.000V.

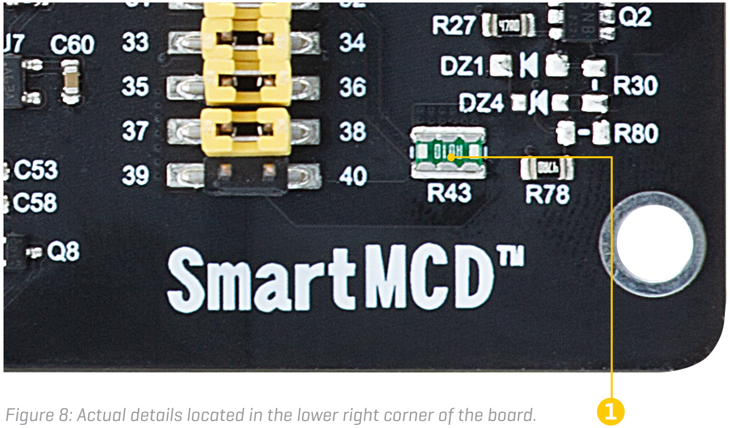


*Figure 8: Actual details located in the lower right corner of the board.*

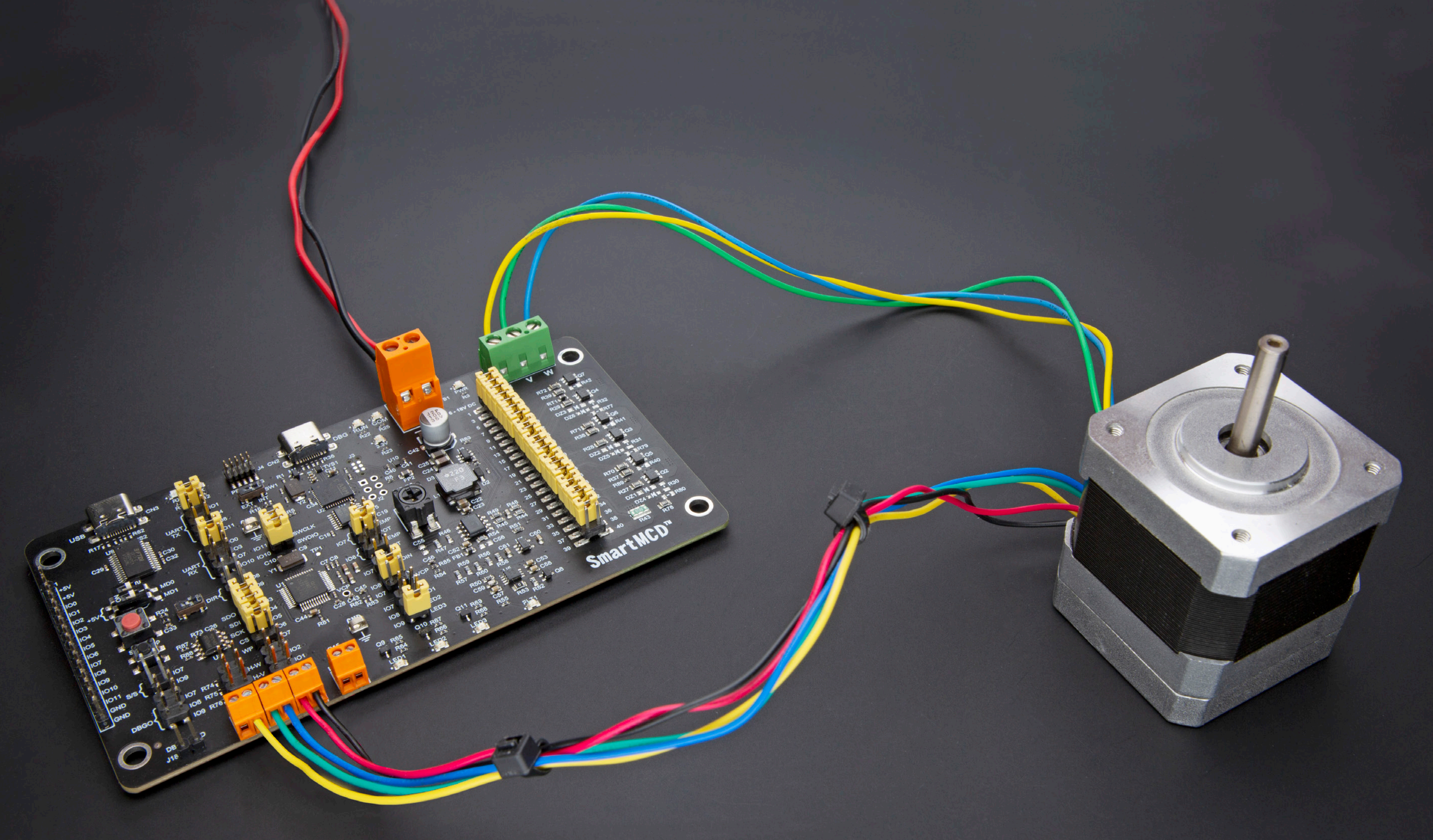


*Figure 9: Brushless Motor with Hall Sensor connected on SmartMCD™ Board*

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