Infineon Mobile Robot (IMR) motor control

Using DEMO_IMR_MTRCTRL_V1 and DEMO_ANGLE_SENS_V1

About this document

Scope and purpose

This document describes the functions and usage of the DEMO_IMR_MTRCTRL_V1 board together with the DEMO_ANGLE_SENS_V1 board. DEMO_IMR_MTRCTRL_V1 board is capable of driving a brushless DC (BLDC) motor using Hall or encoder-based sensors and completely sensor less. This proposed design is intended to be used for mobile robotic applications like automated guided vehicles (AGV) or autonomous mobile robots (AMR) in the low speed regime focusing on a modular design approach. Selected communication interface is CAN where speed and direction commands are received. The board utilizes the MOTIX™ IMD701A fully programmable motor controller combining microcontroller and gate driver IC in combination with OptiMOS™ 6 ISZ053N08NM6 power MOSFETs. The IMD701A integrates a fully programmable XMC1404 Arm® Cortex®-M0 microcontroller from Infineon XMC1400 family with 6EDL7141, a 60 V three-phase smart gate driver with integrated power supply. Both devices integrated allow an ultra-compact design for drives applications up to 60 V including not only the microcontroller and a flexible three-phase gate driver, but also the complete power supply required in the system (synchronous buck converter and LDO), three current sense amplifiers (CSAs), protections, and a set of configurations to adjust to specific needs. Additionally, the used angle sensor solution is described.

Intended audience

The document is addressed to design engineers, technicians, and developers in the field of robotics and battery-powered motor drives who strive for highly integrated and efficient solutions.

Infineon components featured

- OptiMOS™ 6 ISZ053N08NM6 80 V/5.3 mΩ PG-TSDSON-8 FL
- MOTIX™ IMD701A-Q064X128AA fully programmable motor controller combining microcontroller and gate driver IC
- TLE9351VSJ high speed CAN FD transceiver
- XENSIV™ TLI5012B E1000 angle sensor

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Note: *Please note the following warnings regarding the hazards associated with development systems.*

Table 1   **Safety precautions**

⚠	**Warning:** *The DC link potential of this board is up to 1000 VDC. When measuring voltage waveforms by oscilloscope, high-voltage differential probes must be used. Failure to do so may result in personal injury or death.*
⚠	**Warning**: *The evaluation or reference board contains DC bus capacitors, which take time to discharge after removal of the main supply. Before working on the drive system, wait 5 minutes for capacitors to discharge to safe voltage levels. Failure to do so may result in personal injury or death. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.*
⚠	**Warning:** *The evaluation or reference board is connected to the grid input during testing. Hence, high-voltage differential probes must be used when measuring voltage waveforms by an oscilloscope. Failure to do so may result in personal injury or death. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.*
⚠	**Warning:** *Remove or disconnect power from the drive before you disconnect or reconnect wires, or perform maintenance work. Wait five minutes after removing power to discharge the bus capacitors. Do not attempt to service the drive until the bus capacitors have discharged to zero. Failure to do so may result in personal injury or death.*
⚠	**Caution:** *The heat sink and device surfaces of the evaluation or reference board may become hot during testing. Hence, necessary precautions are required while handling the board. Failure to comply may cause injury.*
⚠	**Caution:** *Only personnel familiar with the drive, power electronics and associated machinery should plan, install, commission and subsequently service the system. Failure to comply may result in personal injury and/or equipment damage.*
⚠	**Caution:** *The evaluation or reference board contains parts and assemblies sensitive to electrostatic discharge (ESD). Electrostatic control precautions are required when installing, testing, servicing or repairing the assembly. Component damage may result if ESD control procedures are not followed. If you are not familiar with electrostatic control procedures, refer to the applicable ESD protection handbooks and guidelines.*
⚠	**Caution:** *A drive that is incorrectly applied or installed can lead to component damage or reduction in product lifetime. Wiring or application errors such as undersizing the motor, supplying an incorrect or inadequate AC supply, or excessive ambient temperatures may result in system malfunction.*
⚠	**Caution:** *The evaluation or reference board is shipped with packing materials that need to be removed prior to installation. Failure to remove all packing materials that are unnecessary for system installation may result in overheating or abnormal operating conditions.*

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1 Introduction

1.1 Mobile robot general description

Mobile robots have become a firmly established part of day-to-day operations. It is in logistic and warehouse centers, production sites but also hospitals, restaurants, schools, or as last-mile delivery vehicles of packages and goods.

Many types of mobile robots exist, but on a high-level the two main types are:

- **Automated guided vehicles (AGVs):** AGVs are fixed, they follow predefined paths using lasers, barcodes, radio waves, vision sensors, or magnetic tape for navigation.
- **Autonomous mobile robots (AMRs):** AMRs are not fixed and do not need external paths as they utilize autonomous mapping, localization, navigation, and obstacle avoidance by using sensors.

Both types have in common that the operating speed of the robot is low and therefore have similar requirements in terms of motor control and drive. Usually, the robots are battery-powered whereas the voltage level depends on the size and weight characteristics.

1.2 Infineon Mobile Robot (IMR)

The board described in this document is primarily targeted to be used in combination with the Infineon Mobile Robot (IMR). The IMR is a comprehensive robotic platform intended to be used with a wide variety of different boards (sensors, motor controls, wireless communication, battery management, etc.).
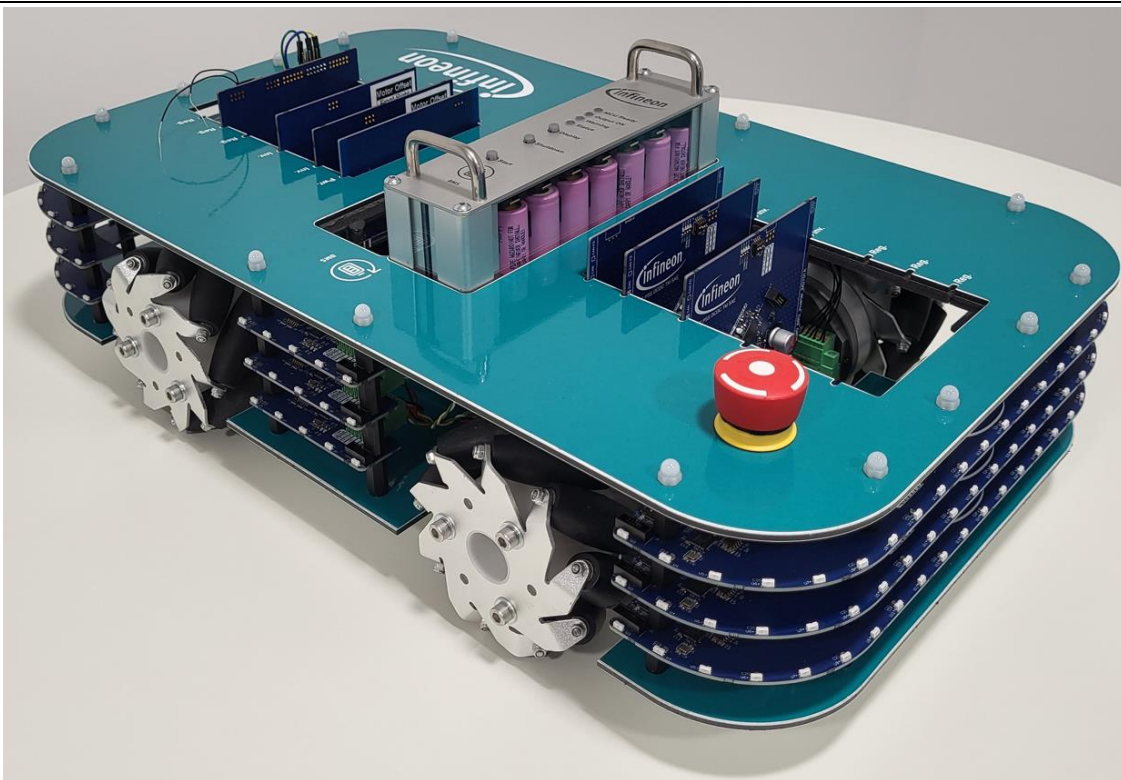

Figure 1   **Isometric view of the IMR**

The overall target of the IMR is to provide a demonstration platform for autonomous service robot functionalities applying Infineon components. This document describes the DEMO_IMR_MTRCTRL_V1 board to directly drive the BLDC motor in the IMR and DEMO_ANGLE_SENS_V1 board to provide the angular position of the rotor in the motor in such a way to provide a more accurate motor control especially for a very low speed.
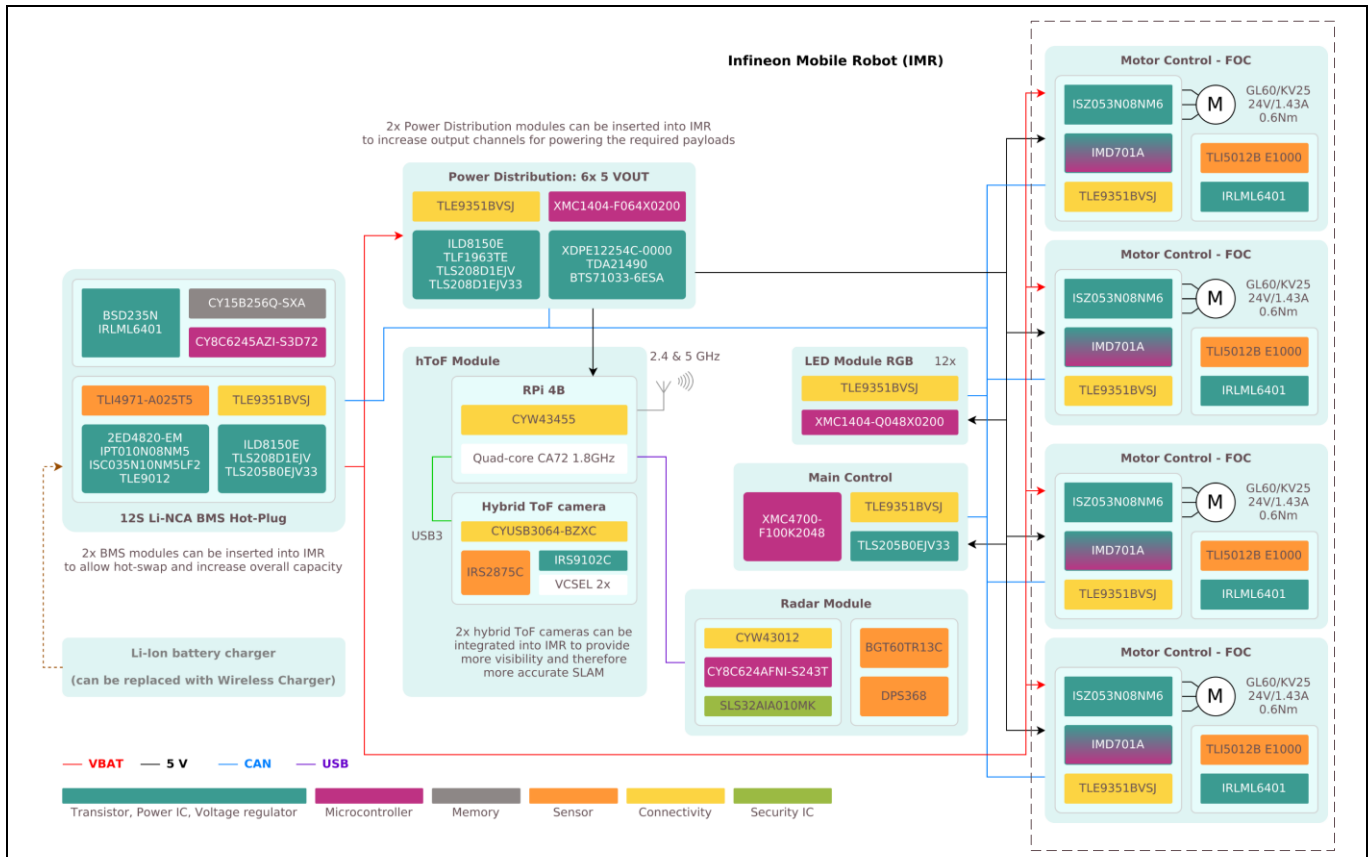

Figure 2   **Overview of the IMR**

The board described in this document is motor control – FOC (highlighted) as shown in Figure 2. Four motor control boards are installed in IMR to drive the four wheels of IMR.

1.3   DEMO_IMR_MTRCTRL_V1

This document provides a detailed description of the DEMO_IMR_MTRCTRL_V1 board for mobile robot applications. The board is designed to drive either one BLDC or stepper motor, with multiple angle sensor options including encoder and Hall-based. See the simplified system block diagram in Figure 4. The intended voltage supply is battery-powered using a 12-cell lithium ion configuration but operation with a reduced count is also possible. However, the power level will be reduced.

The board can be interfaced via CAN and receive the speed information. Latter can be used as a reference input for the speed loop control. Several boards can be used on the same bus with identical firmware as the CAN address can be changed via a dual in-line package (DIP) switch.

Several different BLDC and stepper motors can be used with this board. In this document, the GL60 out-running gimbal motor is used as an example. The GL60 motor consists of 14 pole pairs, making low speed rotation without a gear box feasible. In addition to a BLDC motor, an external J-Link debugger is needed to flash the firmware (FW) into the microcontroller.

The form-factor of the board is selected due to the modular concept used in the IMR. The card edge connector is used to interface with the motherboard of the IMR.
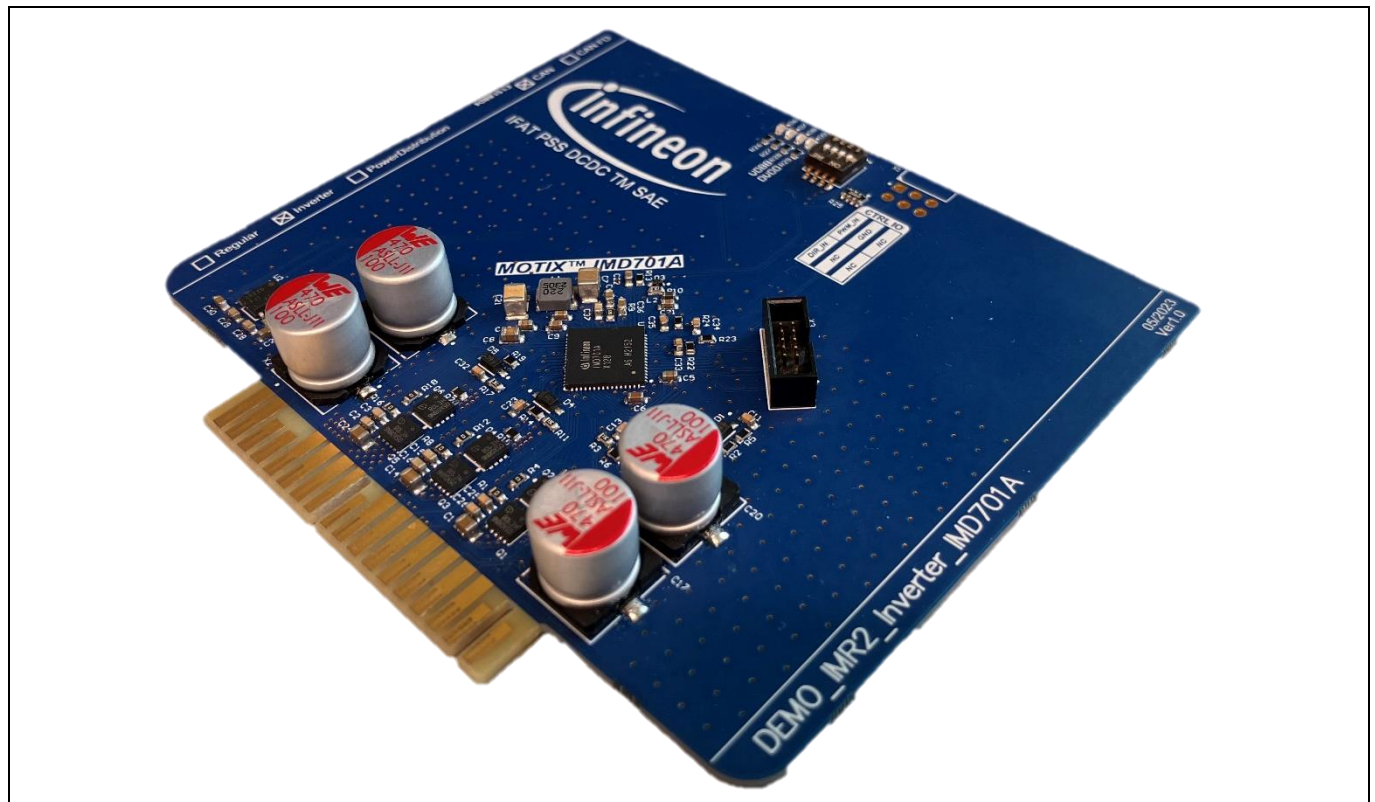

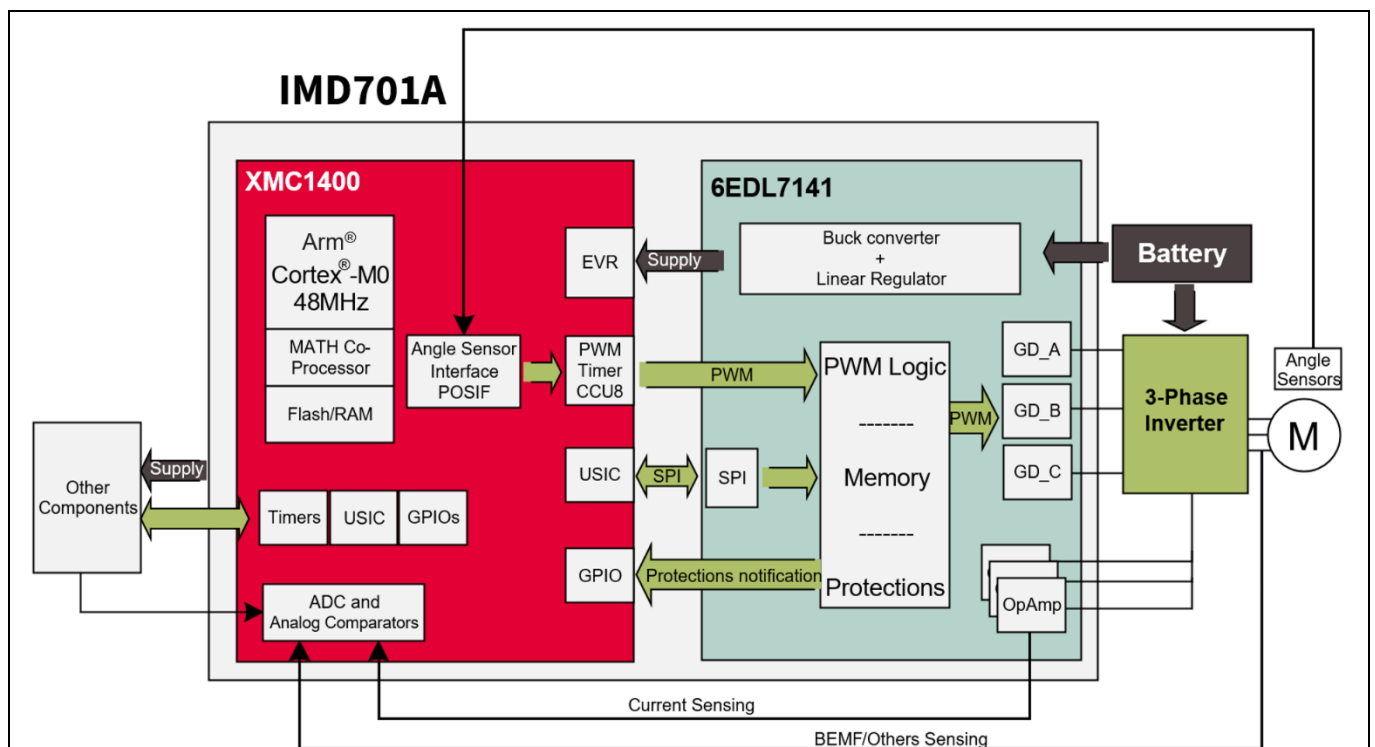**Figure 3   DEMO_IMR_MTRCTRL_V1 board**

Figure 4   Simplified system block diagram

2 Specifications

Input and output at normal operation

- DC input voltage 18 to 60 V, nominal 48 V
- Maximum input current 10 A
- Output voltage three-phase FOC
- Maximum output current per phase 5 A_{RMS}
- Maximum output continuous power 150 W

Control scheme

- Sensored/sensorless FOC with speed control (the document focus is encoder-based)
- Switching frequency 20 kHz
- Three current shunts

Protection features

- Overcurrent protections (OCP)
  - DVDD linear regulator
  - Buck converter
  - Motor leg shunt OCP
- Undervoltage lockout (UVLO) protection
  - Gate driver supply voltage both high side and low side drivers
  - Supply voltage PVDD
  - DVDD linear regulator output voltage
  - Buck converter output voltage
- DVDD linear regulator overvoltage lockout (OVLO) protection
- Overtemperature shutdown (OTS) and warning (OTW)

Maximum component temperature

In an ambient temperature of 30°C, the maximum allowed component temperatures are as follows:

- Resistors less than 100°C
- Ceramic capacitors, film capacitors, and electrolytic capacitors less than 100°C
- MOSFET transistors and diodes less than 100°C
- ICs less than 100°C

Dimensions of the evaluation board

Width 100 mm, length 88.09 mm, and height 12.25 mm.

Note: *To operate the board, configure the firmware correctly for the specific motor being driven. This requires motor parameters such as phase-winding inductance and resistance to be entered into depending on either the motor control GUI or the firmware before flashing the firmware to the target board.*

Attention: ***The board must be tested only by qualified engineers and technicians.***

3 Schematics

The main component on the board is the IMD701A-Q064X128-AA, see Figure 5, which is a highly integrated chip consisting of a:

- Fully programmable drives optimized Arm® Cortex®-M0 microcontroller (XMC1404 at 48 MHz main clock) with additional MATH co-processor (96 MHz)
- Three-phase smart gate driver: 1.5 A sink/ 1.5 A source peak gate driver currents
- Three current sense amplifiers with integrated gain and offset generation
- Integrated synchronous buck converter controller and LDO for complete BLDC system supply

This allows for a compact design with highly reduced BoM and complexity. There is only a minimum of external components necessary which include several buffer capacitors as well as one external inductor for the internal synchronous buck converter.
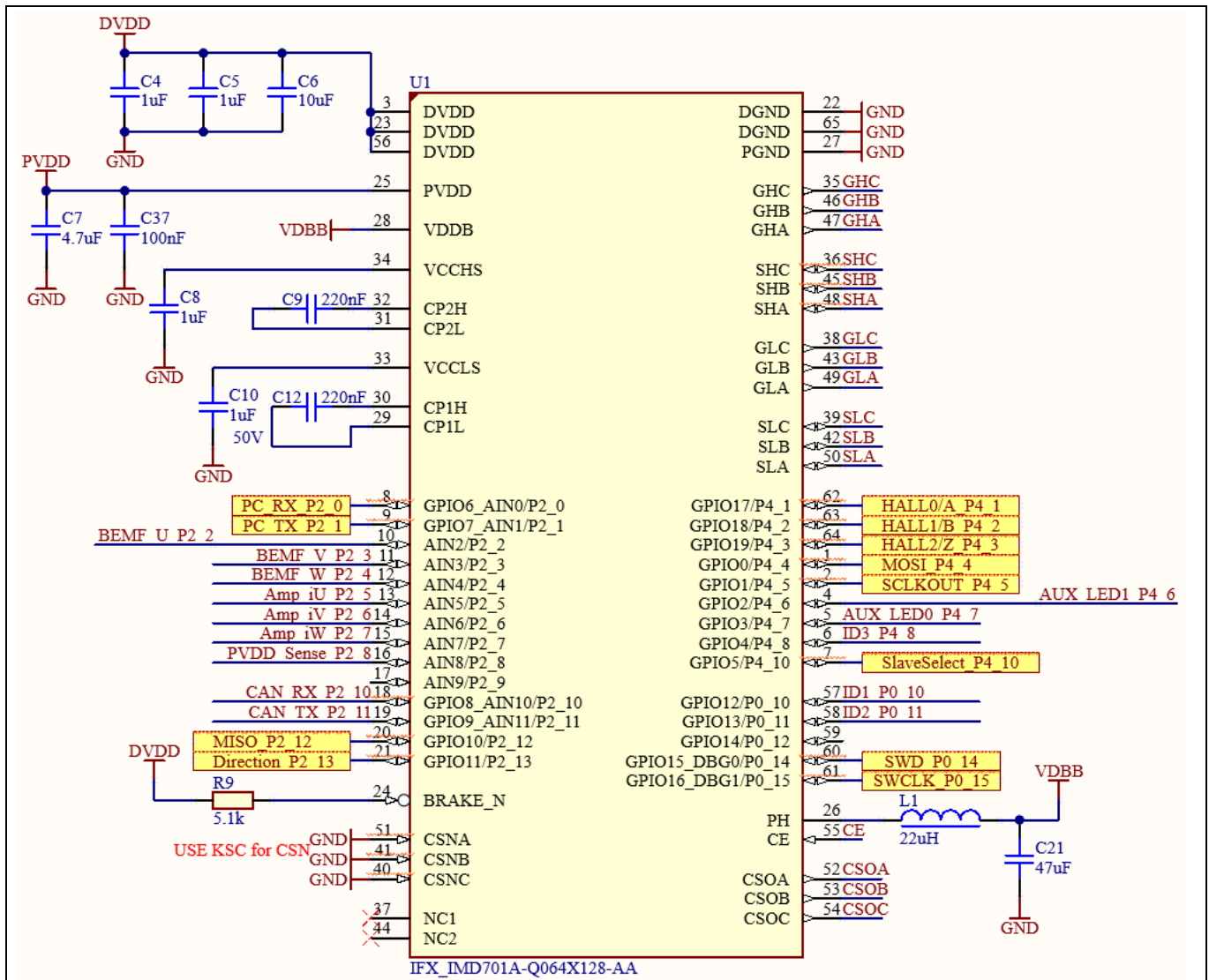

Figure 5 **Schematic around the IMD701A motor controller**

Schematics

The board can be controlled via a CAN interface. The CAN transceiver used is the TLE9351VSJ, which is a high speed CAN transceiver used for automotive and industrial applications. It can be supplied on in- and output with different voltage levels. This allows the IMD701A motor controller to be used directly with TLE9351VSJ CAN transceiver without any level shifter. As the board is used with other boards on the same CAN bus, there is the option to change the CAN address via the mounted DIP switch (S1). This allows the same firmware to be flashed onto multiple boards situated on the same bus. Note that in the firmware only ID1 and ID2 are in use.
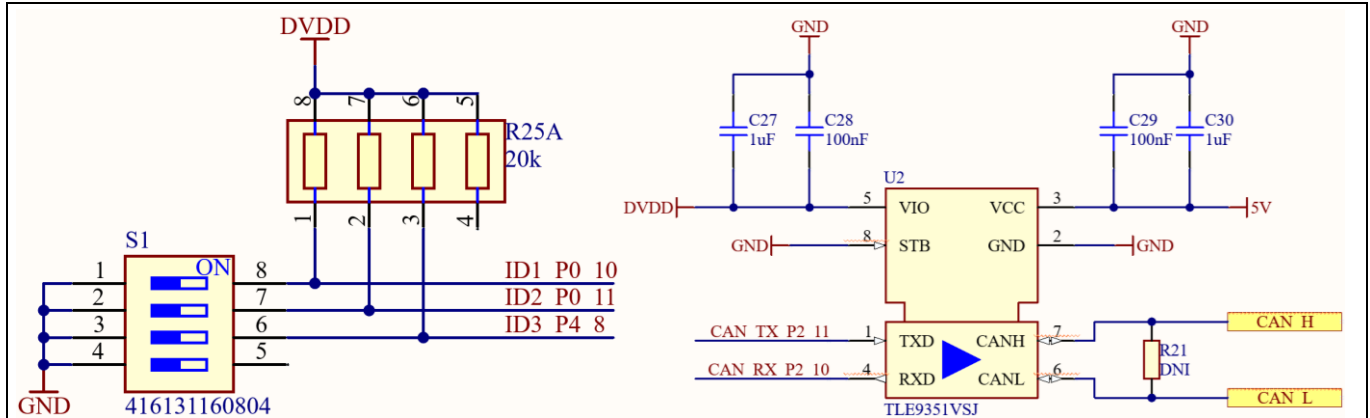

Figure 6   **DIP switch for CAN address setting and TLE9351VSJ CAN transceiver**

The three phase inverter itself consists out of six OptiMOS™ 6 ISZ053N08NM6 80 V/5.3 mΩ switches in a compact PG-TSDSON-8 FL package. Each phase output is connected to the card edge connector to be fed to the motor as well as to a voltage divider if back EMF information is required. Furthermore, each half-bridge possesses their own buffer capacitors as close as possible to the switches. All gates are connected via 0 Ω resistors to the IMD701A which are only used for debugging and measurement purposes. The gate charge current itself can be programmed onto the IMD701A making the use of external gate resistors abundant.
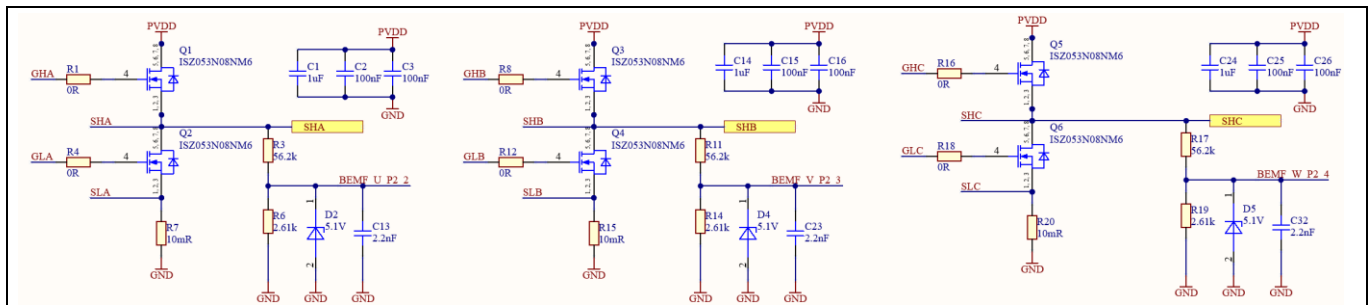

Figure 7   **Three phase inverter utilizing the OptiMOS™ 6 ISZ053N08NM6 80 V/5.3 mΩ PG-TSDSON-8 FL package**

The connection to the board can happen via two interfaces, the 10-pin debugging interface for programming and the card edge header. Latter is used for supplying the board with the battery voltage (nominal 48 V) and carrying the phase output voltages, angle sensor pins, and CAN interface. This header layout is standardized so that the board can be interchanged if another inverter solution is chosen.

The card edge header on the PCB should be designed based on the receptacle connector EBC18DCWN-S371 from Sullins Connector Solutions.

Schematics

Table 1   Pin out of inverter board slot on IMR motherboard with thick row lines marking polarizing key positions

| Pin	Function	Pin	Function
A1	CAN_L	B1	5 V
A2	CAN_H	B2	GND
A3	Reserved for CAN_FD_L	B3	Reserved for CAN_FD_L
A4	Reserved for CAN_FD_H	B4	Reserved for CAN_FD_H
A5	GND	B5	GND
A6	GND	B6	GND
A7	Battery voltage	B7	Battery voltage
A8	Battery voltage	B8	Battery voltage
A9	Reserved for Stepper B-	B9	Reserved for Stepper B-
A10	W/Stepper B+	B10	W/Stepper B+
A11	V/Stepper A-	B11	V/Stepper A-
A12	U/Stepper A+	B12	U/Stepper A+
A13	A/TTL U	B13	B/TTL V
A14	C(Z)/TTL W	B14	MOSI
A15	MISO	B15	CS
A16	CLK	B16	No connection
A17	Reserved for GND	B17	Reserved for GND
A18	Reserved for 5 V	B18	Reserved for 5 V
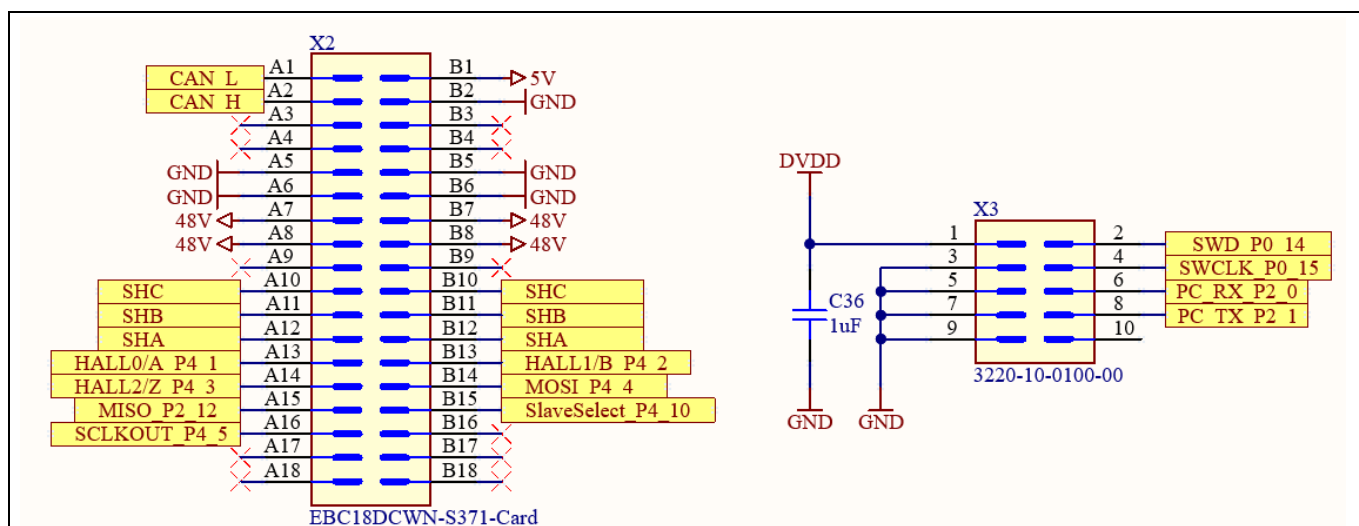
Figure 8   Card edge header and 10-pin debug connector

The IMD701A motor controller has three internal amplifiers for phase current sensing. The gain can be adjusted in the firmware by following values: 4, 8, 12, 16, 20, 24, 32, and 64 and an external filter network is populated on the board. For more details, see the IMD70xA datasheet [1]. Furthermore, the input voltage to the three phase inverter is measured and can be used to tune the modulation index in the SVPWM.
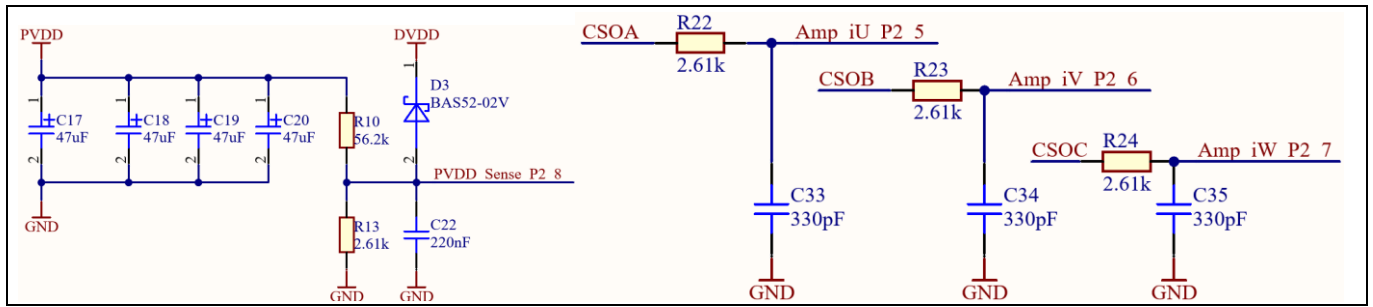
Figure 9   PVDD and phase current sensing filters

Furthermore, on the board several signal LEDs are populated where D8 signals for the presence of the gate drive voltage and D9 the voltage of the internal voltage regulator. D6 and D7 are controlled via the firmware, where D6 indicates a received CAN message and D7 has no function till now.

Additionally, needed on the board is to set the chip enable of the IMD701A which gets high as soon as the battery voltage is supplied.
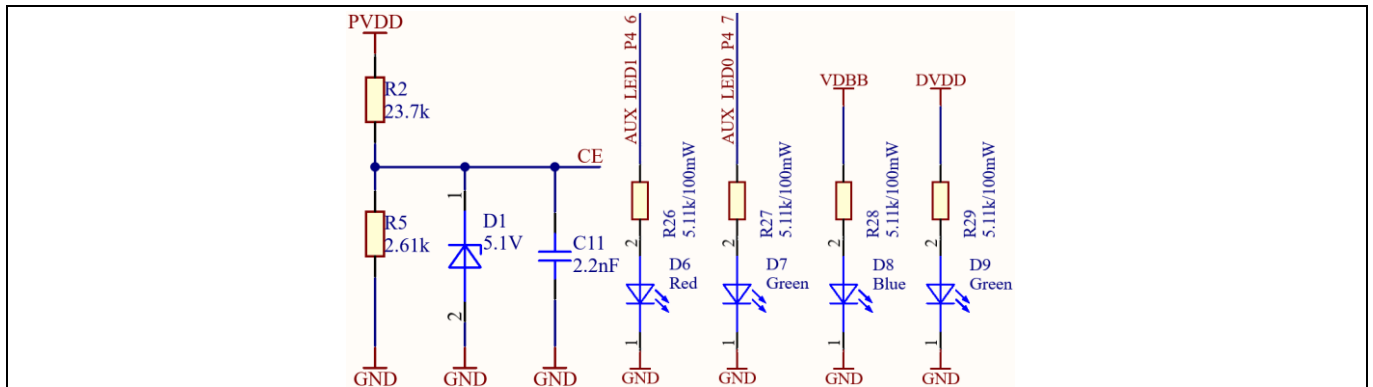

Figure 10   Chip enable and signal LEDs

Figure 11 shows all areas with their respective functions on the board. The board itself is a four-layer board with a size of 100 mm times 88.09 mm. The shape and size of the board is standardized so that it can be easily replaced by a board with same functionality. This enables a wide testing and showcase environment to compare and demonstrate various solution options.
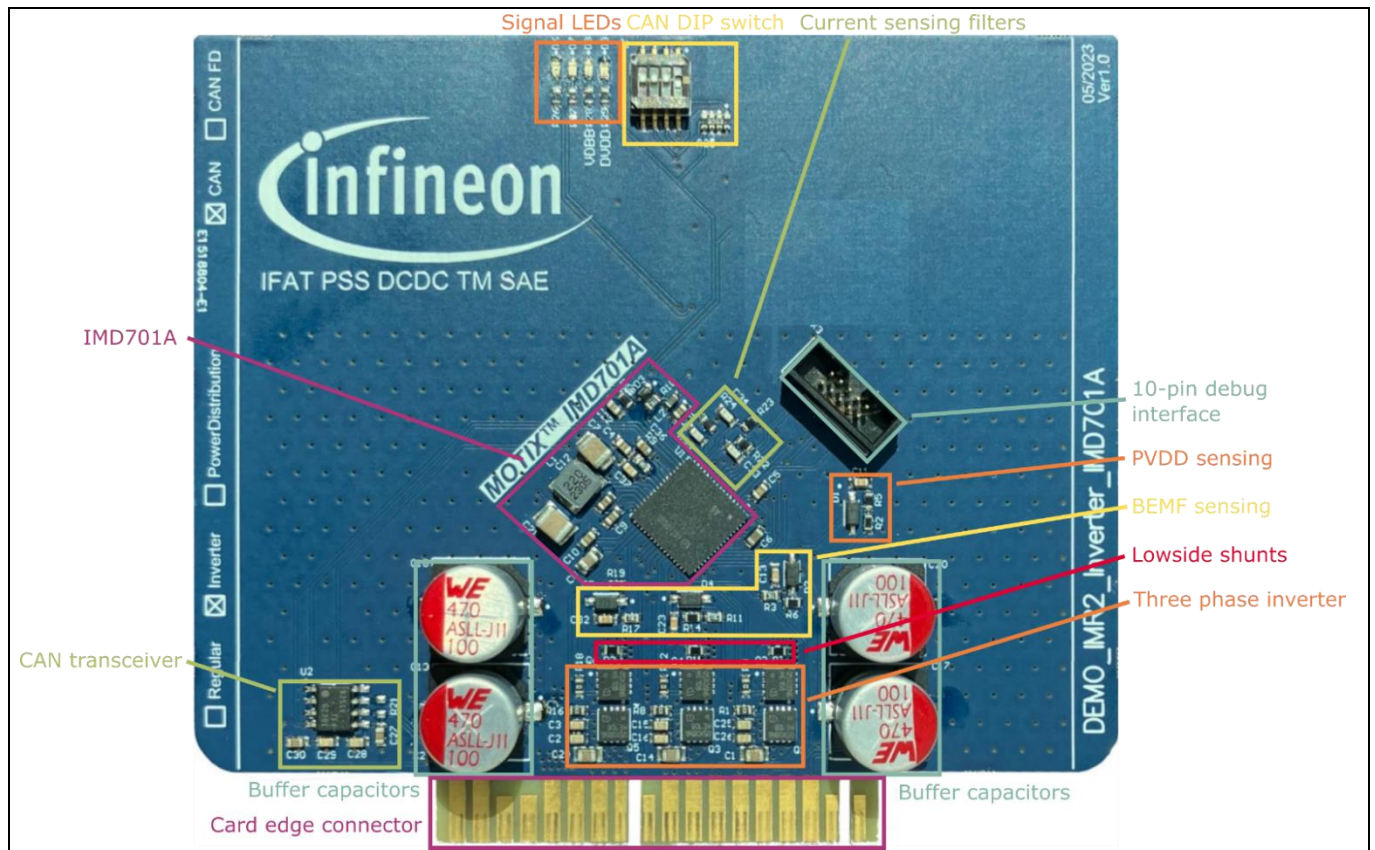
Figure 11   **DEMO_IMR_MTRCTRL_V1 with all function blocks**

4 Motor

As the motor control board is used in an AGV/AMR application, the requirements on the drive train are usually focused on a low form-factor with low weight and low rotational speeds. Generally, the low rotational speeds are reached via a high ratio gear box, however, this adds additional weight, size, and cost to the robot. Therefore, for this application, a motor with a high pole pair count is chosen which is usually used in gimbal systems specifically design for cogging free motion at very low speeds. The motor in use is the GL60. It is an out-running motor with 14 pole-pairs and a rated voltage of 24 V. However, the manufacturer advised that an operation at 48 V is possible. The diameter of the motor is 69 mm with a thickness of 22.3 mm. The phase to phase inductance is at 2.72 mH and the phase to phase resistance at 5.5 Ω.

Figure 12   GL60 motor, an out-running PMSM used for gimbal systems

The motor offers three solder pads for the phase connection. The mounting can be done with screws and cables can be fed through the motor if needed. In this case, the center is occupied due to the usage of a magnet for a rotary sensor.

A cross-section through an exemplary buildup of the motor wheel system is shown in Figure 13. On the motor itself, the mounting bracket is screwed on the stator and the coupling to the wheel is screwed on the rotor. The coupling is then connected with long screws to the mecanum wheel. This wheel type is chosen to ease the robot control as instantaneous movement in all directions is needed. Furthermore, a smooth rolling of the wheels is highly beneficial for the use with time of flight (ToF) or radar sensors, therefore, mecanum wheels are chosen over omni wheels. The complete motor assembly is 100 mm x 100 mm x 125 mm (L × W × H) in size.

Inside the coupling, a magnet is glued which allows the rotary sensor PCB on top to sense the mechanical rotation angle of the motor itself. As the magnetization orientation of the magnet differs depending on the actual rotation of the magnet to the motor when it is glued, it is required to calibrate the motor-offset position in the firmware. The calibration also needs to be done in case the coupling is demounted from the motor and mounted again.
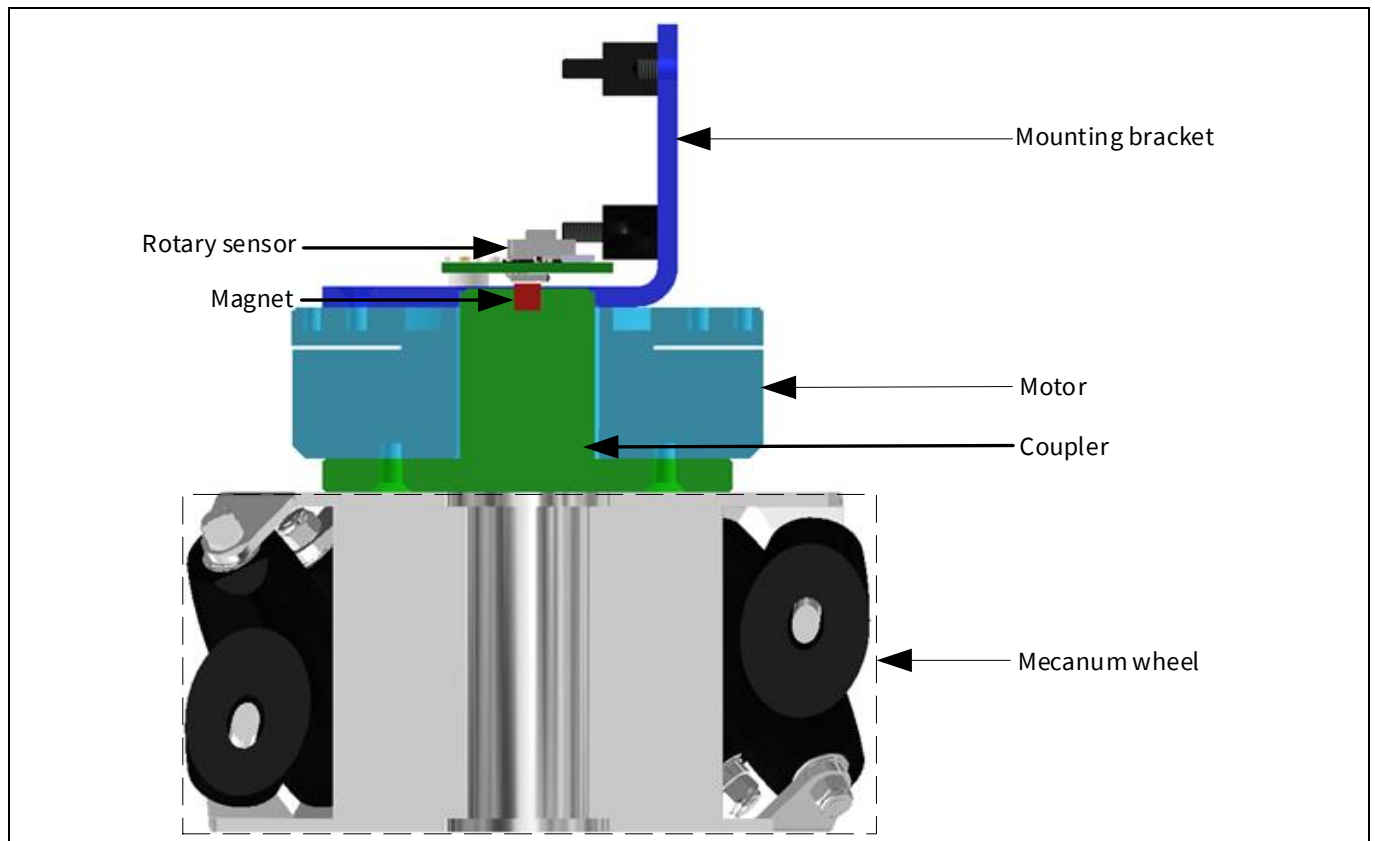
Figure 13   Cross-section through a wheel as used in the IMR demonstrator

5   DEMO_IMR_ANGLE_SENSE_V1 board

As the applications require low speeds and torque from standstill, a sensorless approach would lead to poor performance, requiring the rotational angle information of each motor. Therefore, an angle sensor PCB is designed with the TLI5012B E1000.

The TLI5012B E1000 is a 360° angle sensor that detects the orientation of a magnetic field. This is achieved by measuring sine and cosine angle components with monolithic integrated giant magneto resistance (iGMR) elements. These raw signals (sine and cosine) are digitally processed internally to calculate the angle orientation of the magnetic field (magnet). The TLI5012B E1000 is a pre-calibrated sensor. The calibration parameters are stored in laser fuses. At startup, the values of the fuses are written into flip-flops, where these values can be changed by the application-specific parameters. Further, the precision of the angle measurement over a wide temperature range and a long lifetime are improved with the internal autocalibration algorithm. Data communications are accomplished with a bidirectional synchronous serial communication (SSC) that is SPI-compatible. The sensor configuration is stored in registers, which are accessible by the SSC interface. Additionally, four other interfaces are available with the TLI5012B sensor: pulse-width-modulation (PWM) protocol, short-PWM-code (SPC) protocol, Hall switch mode (HSM), and incremental interface (IIF). These interfaces can be used in parallel with SSC or alone. Pre-configured sensor derivates with different interface settings are available. The one used is the IIF-type: E1000.

5.1   Incremental interface (IIF)

The incremental interface (IIF) emulates the operation of an optical quadrature encoder with a 50% duty cycle. It transmits a square pulse per angle step, where the width of the steps can be configured from 9 bit (512 steps per full rotation) to 12 bit (4096 steps per full rotation) within the register MOD_4 (IFAB_RES)1). The rotation direction is given either by the phase shift between the two channels IFA and IFB (A/B mode) or by the level of the IFB channel (Step/Direction mode). The incremental interface can be configured for A/B mode or Step/Direction mode in the MOD_1 (IIF_MOD) register. Using the IIF requires an up/down counter on the microcontroller, which counts the pulses, keeps track of the absolute position. The counter can be synchronized periodically by using the SSC interface in parallel. The angle value (AVAL register) read out by the SSC interface can be compared to the stored counter value. In case of a non-synchronization, the microcontroller adds the difference to the actual counter value to synchronize the TLI5012B sensor with the microcontroller.

The TLI5012B-E1000 sensor is preconfigured for IIF and fast angle update period (42.7 µs). It is most suitable for BLDC motor commutation.

- Autocalibration mode 1 enabled.
- Prediction enabled.
- Hysteresis is set to 0.703.
- 12-bit mode, one count per 0.088° angle step.
- IIF A/B mode.

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DEMO_IMR_ANGLE_SENSE_V1 schematic and PCB

6　　　　DEMO_IMR_ANGLE_SENSE_V1 schematic and PCB

There are two interface options available on the PCB: IIF and SPI, where the latter is not used in this application. When using only IIF, the initial angle detection is more difficult as after startup, the IIF transmits a number of pulses which correspond to the actual absolute angle value. Therefore, the microcontroller gets the information about the absolute position. The index signal that indicates the zero crossing is available on the IFC pin, this requires that the sensor is started after the POSIF interface of the microcontroller is active. This is achieved by Q1 which can be enabled by the inverter card and can be powered up and down at will.

The PCB has two elongated holes which allow for a flexible positioning to be used also in other applications.
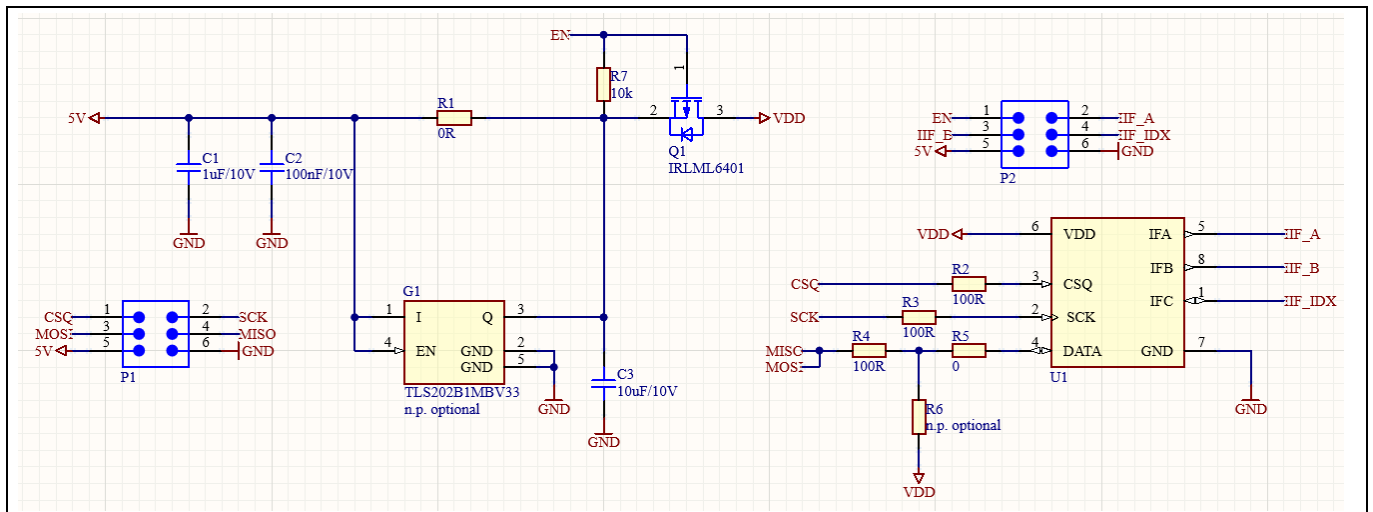

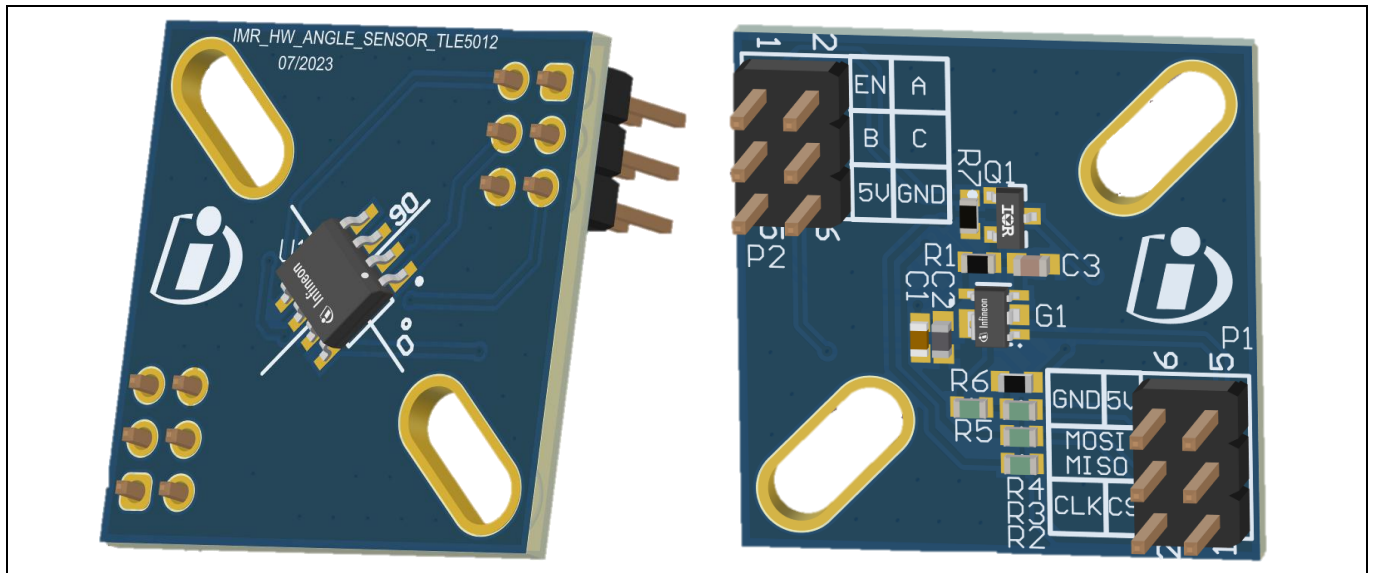**Figure 14**　　　**Schematic of the DEMO_IMR_ANGLE_SENSE_V1 board**

Figure 15　　　**3D view of the DEMO_IMR_ANGLE_SENSE_V1 board**
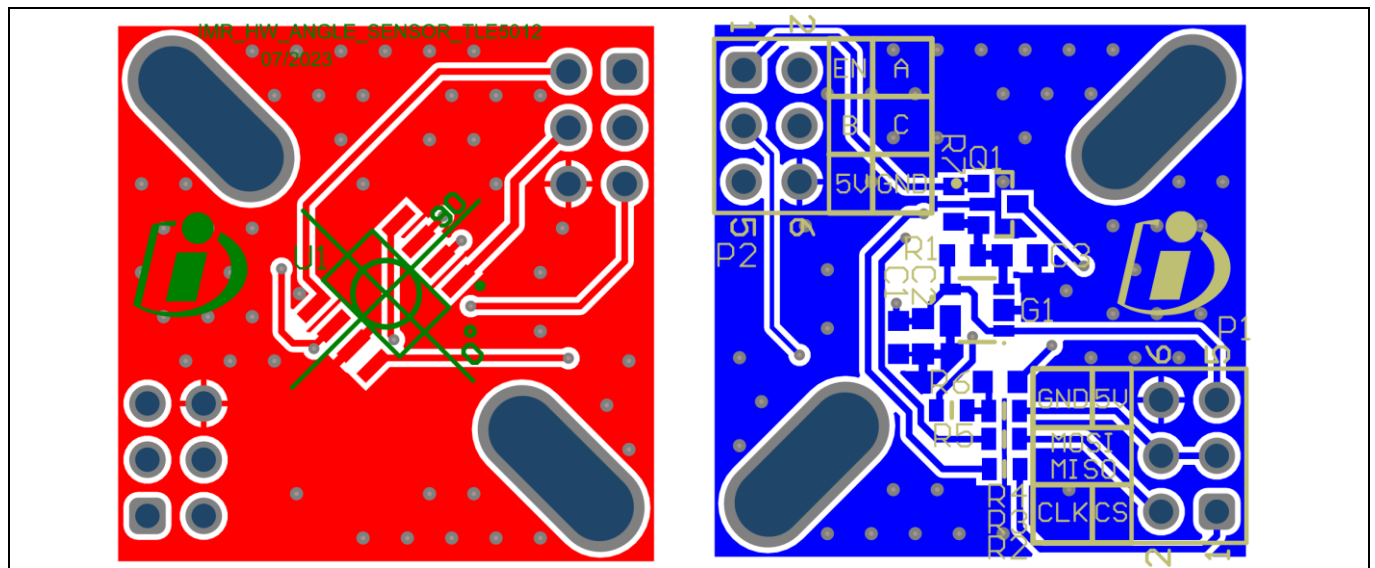
Figure 16   Top – top overlay layer and bottom – bottom overlay layer

7 DEMO_IMR_ANGLE_SENSE_V1 bill of materials (BOM)

Table 2 **DEMO_IMR_ANGLE_SENSE_V1 BOM**

Reference	Qty	Type	Value/rating	Manufacturer	Part number
C1	1	Capacitor	1 uF, 10 V, 0603, X7S	Würth Elektronik	885012206026
C2	1	Capacitor	100 nF, 10 V, 0603, X7R	Würth Elektronik	885012206020
C3	1	Capacitor	10 uF, 10 V, 0603, X7R	Murata	GRM188R61A106ME69D
G1	1	IC	Voltage regulator 3.3 V	Infineon	TLS202B1MBV33
P1, P2	2	Connector	Header vertical 3 x 2	Würth Elektronik	61300621121
Q1	1	PMOS	-12 V P-channel power MOSFET	Infineon	IRLML6401
R1, R5	2	Resistor	0R, 0603	Bourns	CR0603AJ/-000EAS
R2, R3, R4	3	Resistor	100R, 0603	Yageo	RC0603FR-07100RL
R6	1	Resistor	n.p., optional	–	–
R7	1	Resistor	10k R, 0603	Yageo	RC0603JR-0710KL
U1	1	IC	Magnetic angle sensor	Infineon	TLI5012B E1000

8 DEMO_IMR_ANGLE_SENSE_V1 PCB layout

The DEMO_IMR_MTRCTRL_V1 board utilizes a four-layer PCB with 1 oz. copper on the top and bottom layers and 1 oz. copper on the internal layers. Components are mounted on the top and bottom sides. The width is 100 mm and the length is 88.09 mm.
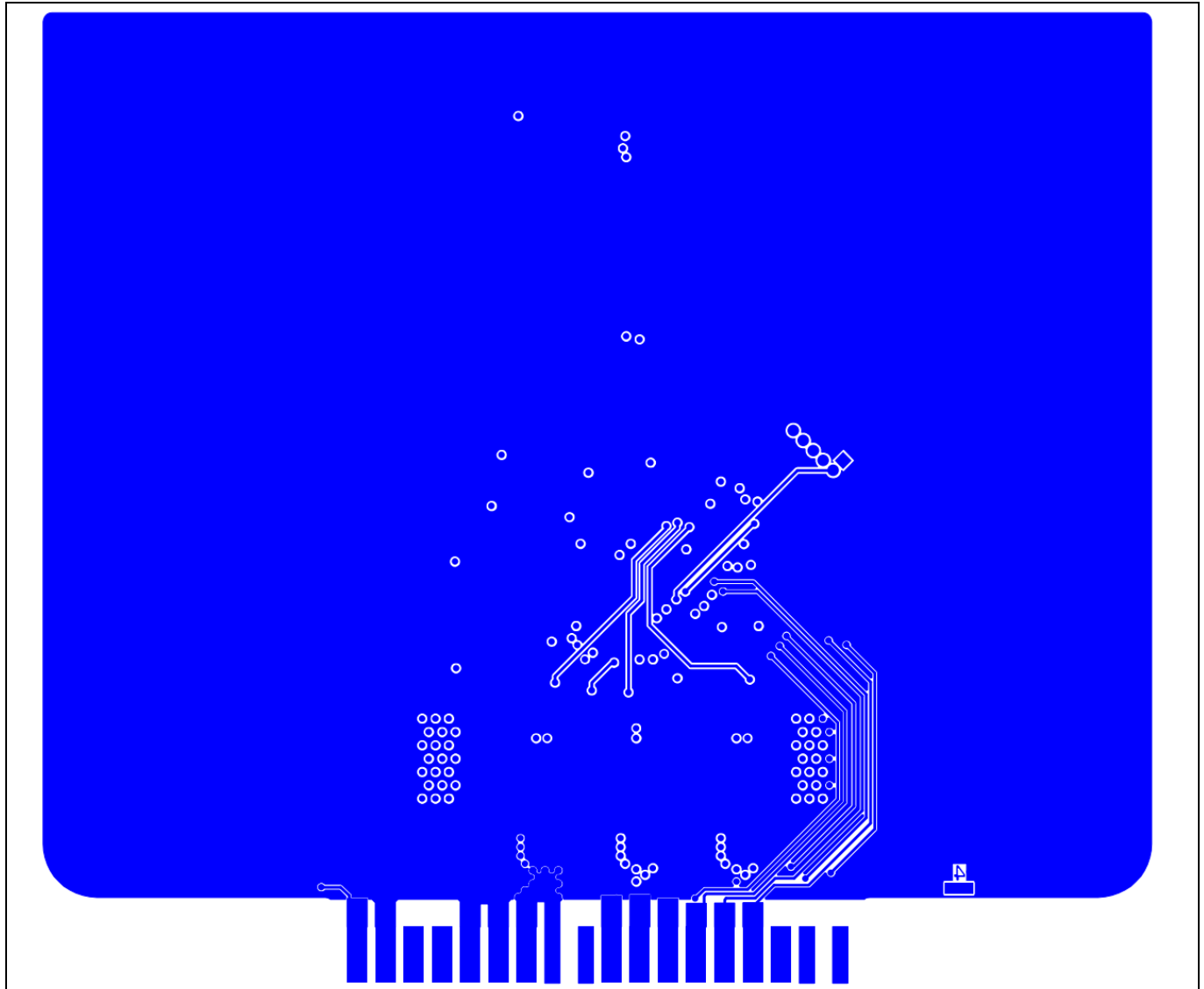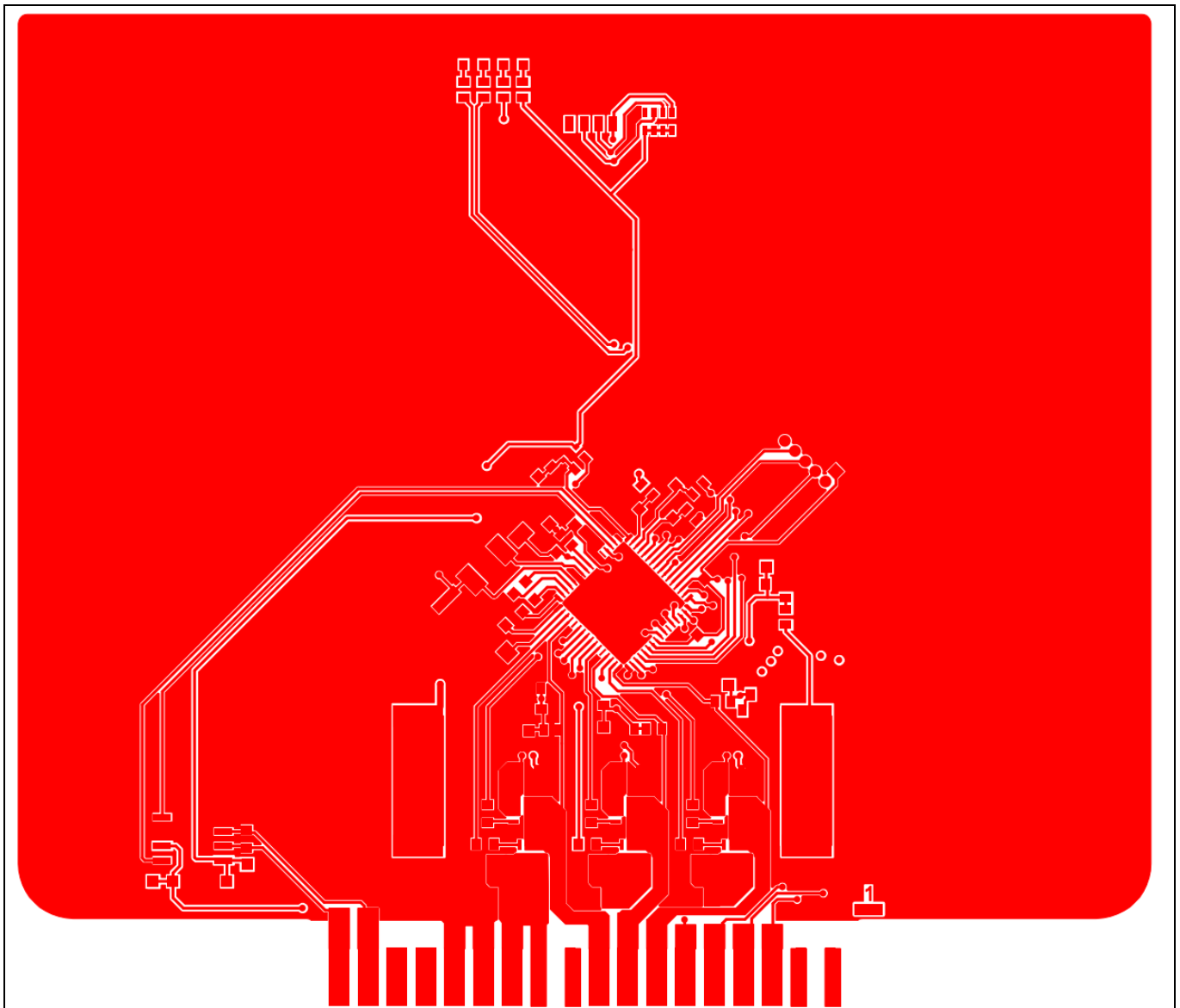

Figure 17 **DEMO_IMR_MTRCTRL_V1 PCB bottom layer**

Figure 18   **DEMO_IMR_MTRCTRL_V1 PCB top layer**
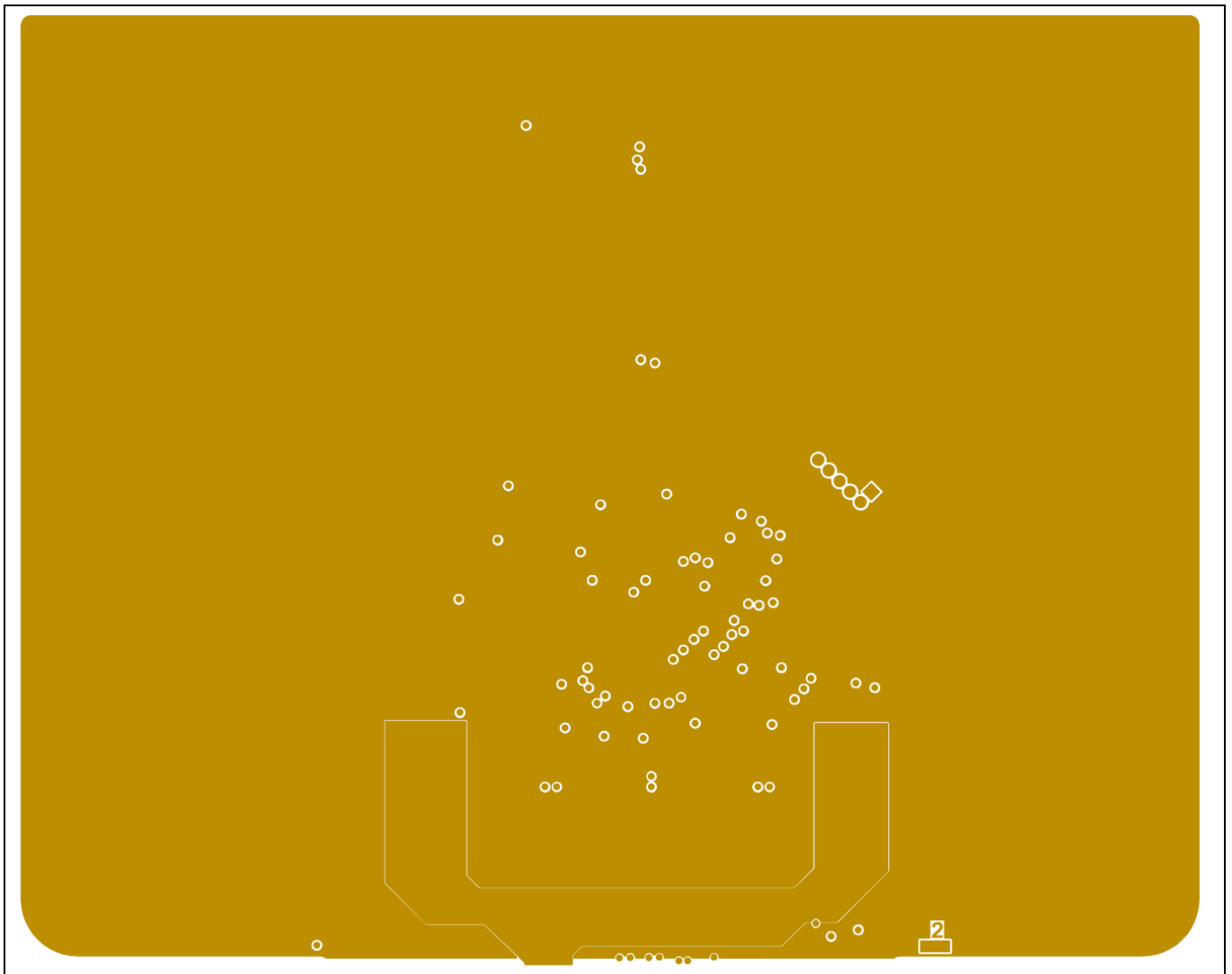
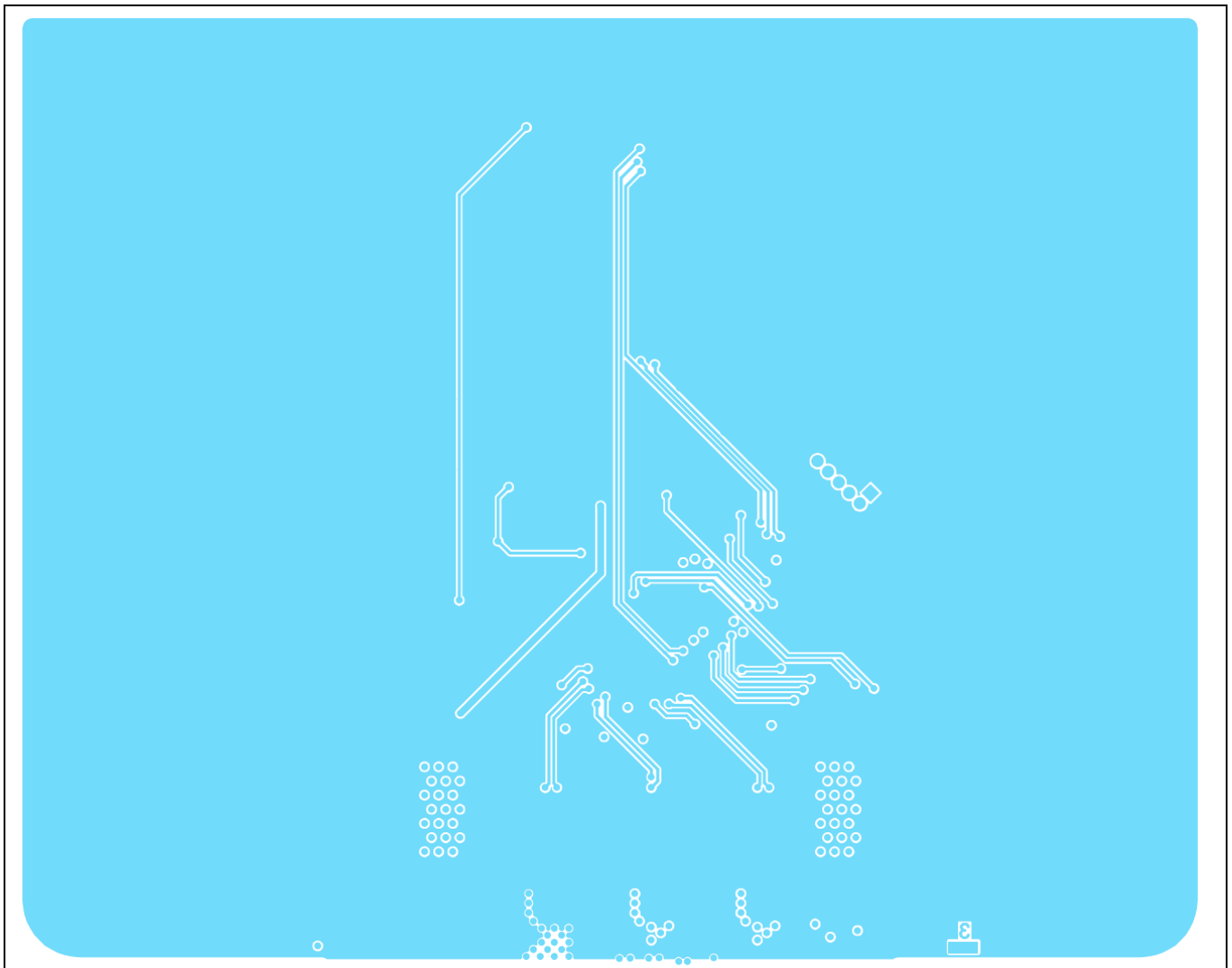**Figure 19   DEMO_IMR_MTRCTRL_V1 PCB mid layer 1**

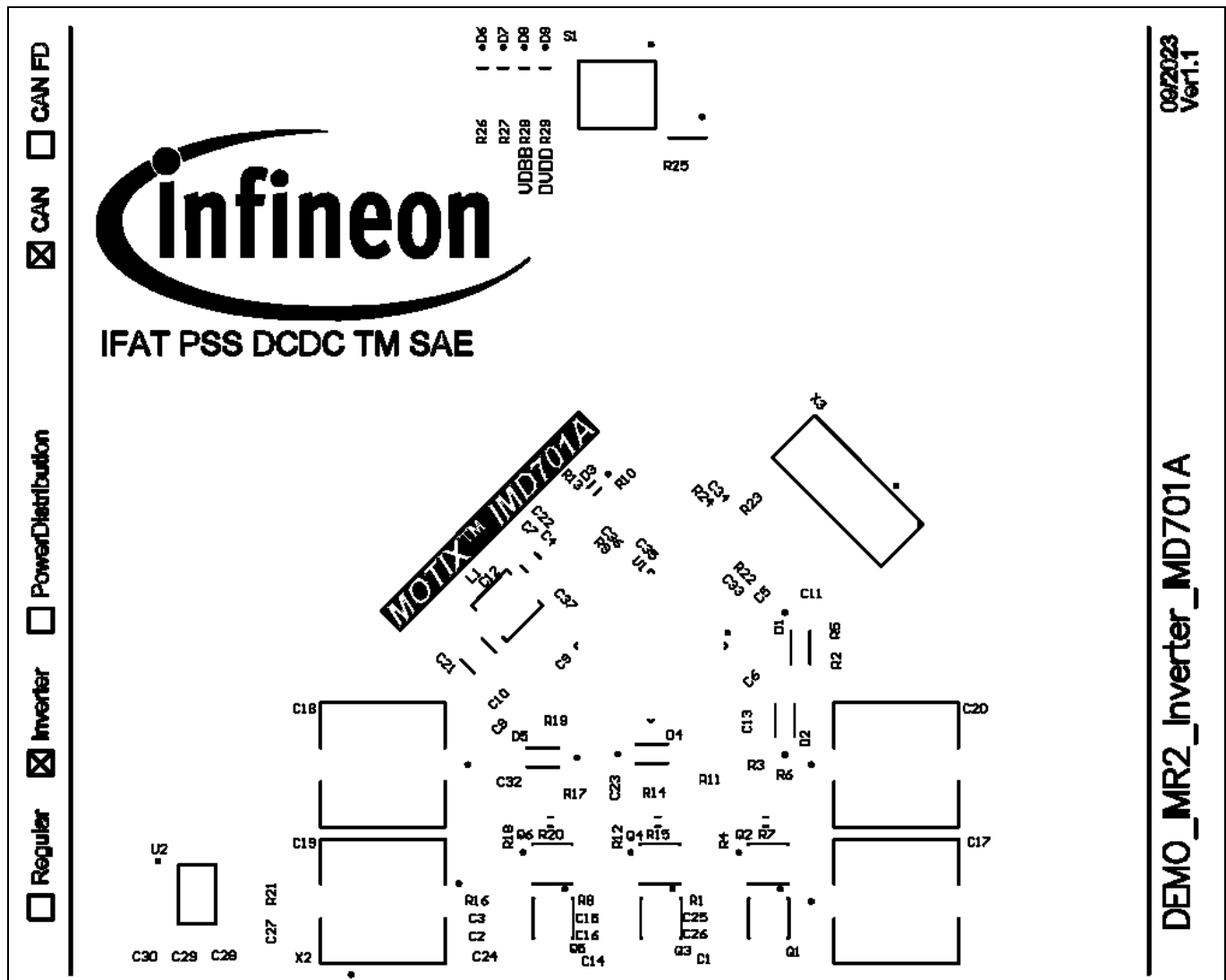**Figure 20**   **DEMO_IMR_MTRCTRL_V1 PCB mid layer 2**

Figure 21   DEMO_IMR_MTRCTRL_V1 PCB top silkscreen layer

The PCB layout is optimized to minimize parasitics. This is done by keeping the loops carrying the switching currents as small as possible. The top layer and the first inner layer are used for the 48 V supply to the inverter. The remaining area of the first inner layer is completely occupied by ground potential. The second inner layer and bottom layer are used for signal routing. Special care has been laid on the parallel routing of the current measurement traces which are shielded by the ground layers. The components are all placed on the top layer to allow for easier measurement access due to the evaluation nature of the board.

9 DEMO_IMR_MTRCTRL_V1 bill of materials

Table 3 **DEMO_IMR_MTRCTRL_V1 BOM**

Reference	Qty	Type	Value/rating	Manufacturer	Part number
C1, C8, C14, C24	4	Capacitor	1 uF, 100 V, 0805, X7S	Murata	GRJ21BC72A105KE11L
C2, C3, C15, C16, C25, C26, C37	7	Capacitor	100 nF, 100 V, 0603, X7R	Würth Elektronik	885012206120
C4, C5, C27, C30, C36	5	Capacitor	1 uF, 25V, 0603, X7R	Würth Elektronik	885012206076
C6	1	Capacitor	10 uF, 16V, 0603, X5R	Murata	GRM188R61C106KAAL
C7	1	Capacitor	4.7 uF, 100 V, 1206, X7S	MuRata	GRM31CC72A475KE11L
C9, C12, C22	3	Capacitor	220 nF, 25 V, 0603, X7S	Würth Elektronik	885012206073
C10	1	Capacitor	1 uF, 50 V, 0603, X5R	Murata	GRM188R61H105MAAL
C11, C13, C23, C32	4	Capacitor	2.2 nF, 25 V, 0603, X7R	Murata	GRM188R71E222JA01
C17, C18, C19, C20	4	Capacitor	47 uF, 100 V, Aluminium electrolytic capacitor	Würth Elektronik	865060857005
C21	1	Capacitor	47 uF, 16 V, 1210, X5R	Murata	GRM32ER61C476KE15
C28, C29	2	Capacitor	100 nF, 25 V, 0603, X7R	Würth Elektronik	885012206071
C33, C34, C35	3	Capacitor	330 pF, 50 V, 0603, X7R	Würth Elektronik	885012206080
D1, D2, D4, D5	4	Diode	Zener, 5.1 V, 500 mW, SOD-123	Onsemi	MMSZ4689T1G
D3	1	Diode	Schottky, 45 V, 200 mA, SC79	Infineon	BAS52-02V
D6	1	Diode	LED, Red	Würth Elektronik	150060RS55040
D7, D9	2	Diode	LED, Green	Würth Elektronik	150060VS75000
D8	1	Diode	LED, Blue	Würth Elektronik	150060BS75000
L1	1	Inductor	22 uH, 1 A	Würth Elektronik	74437324220
Q1, Q2, Q3, Q4, Q5, Q6	6	MOSFET	N-channel, 80 V, 90 A, 5.3 mΩ, PG-TSDSON-8 FL package	Infineon	ISZ053N08NM6
R1, R4, R8, R12, R16, R18	6	Resistor	0 R, Jumper, 0603	Yageo	RC0603JR-070RL
R2	1	Resistor	23.7 kΩ, 0.1 W, 1%, 0603	Vishay	CRCW060323K7FK

Reference	Qty	Type	Value/rating	Manufacturer	Part number
R3, R10, R11, R17	4	Resistor	56.2 kΩ, 0.1 W, 1%, 0603	Vishay	CRCW060356K2FK
R5, R6, R13, R14, R19, R22, R23, R24	8	Resistor	2.61 kΩ, 0.1 W, 1%, 0603	Vishay	CRCW06032K61FK
R7, R15, R20	3	Resistor	10 mΩ, 0.33 W, 1%, 0603	Würth Elektronik	580060716002
R9	1	Resistor	5.1 kΩ, 0.1 W, 1%, 0603	Vishay	CRCW06035K10FK
R21	1	Resistor	120 Ω, 0.1 W, 1%, 0603	Yageo	RC0603FR-07120RL
R25	1	Resistor	20 kΩ, Array, 0.063 W, 1%, 1206	Bourns	CAT16A-2002F4LF
R26, R27, R28, R29	4	Resistor	5.11 kΩ, 0.1 W, 1%, 0603	Vishay	CRCW06035K11FK
S1	1	Switch	DIP switch, 25 mA, 24 V	Würth Elektronik	416131160804
U1	1	IC	Gate driver, three phase, motor drive, PGVQFN-64-8 package	Infineon	IMD701A-Q064X128-AA
U2	1	IC	High speed CAN transceiver	Infineon	TLE9351VSJ
X2	1	Header	Card edge header	N/A	N/A
X3	1	Connector	Male box header, 5 x 2, through-hole, 1.27 mm pitch	Würth Elektronik	62701021621

References

[1]   Infineon Technologies AG: *MOTIX™ IMD701A datasheet*; Available online

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[3]   Infineon Technologies AG: *XMC1404 Arm® Cortex®-M0 datasheet*; Available online

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[5]   Infineon Technologies AG: XENSIV™ TLI5012B E1000 *datasheet*; Available online

[6]   *GL60 24V Gimbal System Motor-KV55*; Available online

[7]   Infineon Technologies AG: *AP0803620 - XC866 Optimized Space Vector Modulation and Over-modulation with the XC866*; Available online

Revision history

Document revision	Date	Description of changes
1.0	2024-04-08	Initial release

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