REF_18VDC_MTRC: Motor drive inverter for power tools

About this document

Scope and purpose

This document describes Infineon's REF_18VDC_MTRC motor drive inverter reference board intended for implementing Infineon's OptiMOS™ 7 40V motor-drive-optimized power MOSFET in a compact design and support up to 820 W peak power.

It utilizes the MOTIX™ 6EDL7141 gate driver, which is a highly integrated 3-phase gate driver for motor drive applications. The gate driver interacts with the XMC1400 family XMC™ XMC1402-Q040X0032 AA microcontroller and drives the OptiMOS™ 7 motor-drive-optimized MOSFETs in the 5 x 6 SuperSO8 over molded and DSC package (PQFN), offering superior $R_{DS(on)}$, improved immunity, wide safe operating area (SOA), and lower switching losses.

Intended audience

The intended audience for this document are design engineers, technicians, and developers who intend to implement REF_18VDC_MTRC in a system of their design, or wish to test the functionalities and capabilities of the essential components comprising this system.

Key points

- Demonstrates how the reference board integrates power stage, gate driver, and MCU to implement sensored trapezoidal motor control and explains the control schemes, firmware structure, and commutation logic supporting voltage and speed-controlled BLDC operation
- Describes system-level power architecture, thermal behavior, and test conditions relevant for high-power tool design and provides guidance on MOSFET selection, package thermal characteristics, and dual-side-cooling advantages for compact designs

About this product family

Product family

Infineon's OptiMOS™ 7 motor-drives optimized power MOSFETs provide outstanding performance with in lower $R_{DS(on)}$, lower switching losses, wider safe-operating-area, and better immunity.

Target applications

- Cordless power tools

Devices

- OptiMOS™ ISCH57N04NM7VSC
- MOTIX™ 6EDL7141
- XMC™ XMC1402-Q040X0032 AA

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1 System overview

The REF_18VDC_MTRC Reference Board (Figure 1) is a fully operational motor-drive inverter intended for cordless power-tool applications (Figure 2).

The PCB is designed in a compact form factor, measuring 300 mm in length and 100 mm in width.

The REF_18VDC_MTRC Reference Board is optimized for 18 V battery-powered tools, operating with sensor-based block commutation control. OptiMOS™ 7 40 V motor-drive–optimized power MOSFETs ensure reliable operation and excellent thermal performance. Rotor position and speed are derived from three Hall sensors, typically integrated into the PMSM stator.

The power and voltage ratings aim to accommodate a common exchangeable Li-ion battery type for hand-held battery-powered tools.

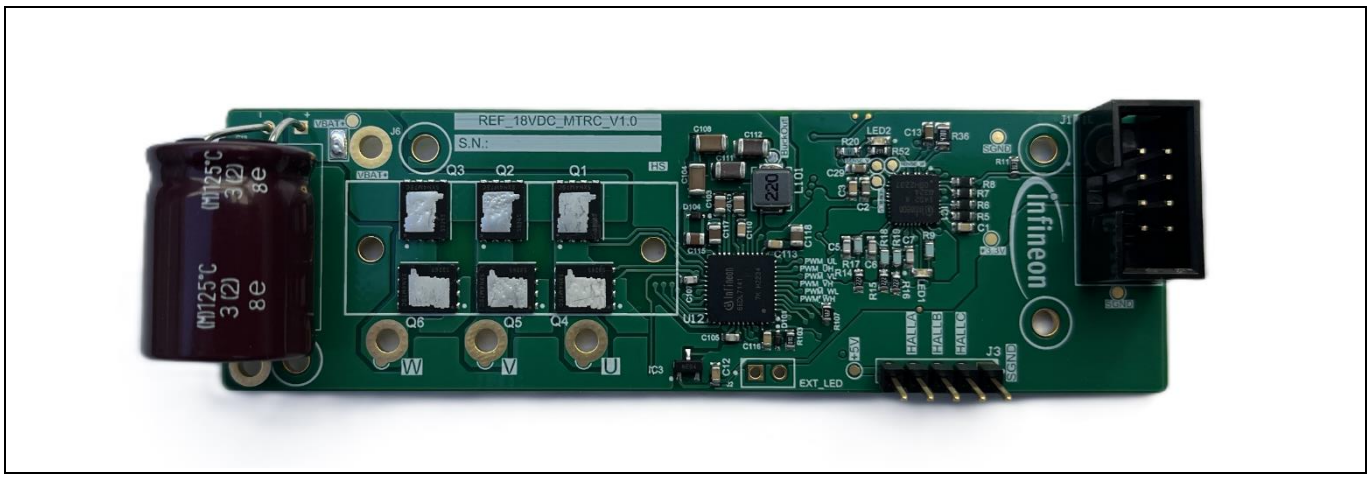


Figure 1 REF_18VDC_MTRC Reference Board (top view without heatsink)



Figure 2 Cordless power drill

1 System overview

1.1 Board description

The REF_18VDC_MTRC reference board integrates the power stage (OptiMOS™ 7 40 V motor-drive-optimized power MOSFETs), the MOTIX™ 6EDL7141 smart gate driver IC with an integrated supply, the XMC1402 microcontroller (MCU), and all required interfaces. These include connectors for the Hall sensors, the XMC™ Link ribbon-cable interface, the DC supply input, and the motor output wiring.

The board is operated via a graphical user interface (GUI); further information is provided in Section 6 of this application note [1].

1.2 Board parameters and technical data

Table 1 REF_18V_MTRC Reference Board parameters

Parameter	Symbol	Conditions	Value	Unit
Supply voltage	V_{DC}	–	14 ~ 22	V
Rating power	P_{rating}	V_{DC} = 18 V, T_a = 25°C, 10 min	500	W
Peak power	P_{peak}	V_{DC} = 18 V, T_a = 25°C, 10 s	820	W
Maximum supply current	$I_{IN(max)}$	V_{DC} = 18 V, T_a = 25°C, 10 min	28	A
Maximum phase current	$I_{OUT(max)}$	V_{DC} = 18 V, T_a = 25°C, 10 s, 2500 rpm	80	A
Maximum allowed operating temperature of power half bridges (MOSFETs and shunts)	$T_{HB(max)}$	Case temperature	120	°C
Maximum allowed operating temperature of aluminum electrolytic capacitors	$T_{cap(max)}$	Case temperature	120	°C
Maximum allowed operating temperature of other components	$T_{Comp.(max)}$	Case temperature	100	°C
PWM switching frequency	f_{PWM}	–	10 ~ 20	kHz
Maximum efficiency	η_{max}	V_{DC} = 18 V, T_a = 25°C, f_{PWM} = 20 kHz, at rating power	96.6	%
Peripheral supply voltage	DVDD	–	3.3	V
Peripheral supply linear regulator overcurrent protection	DVDD_OCP	DVDD = 3.3 V	450	mA

2 Firmware and control description

2.1 Block diagram

The major modules for this example software are shown in Figure 3.

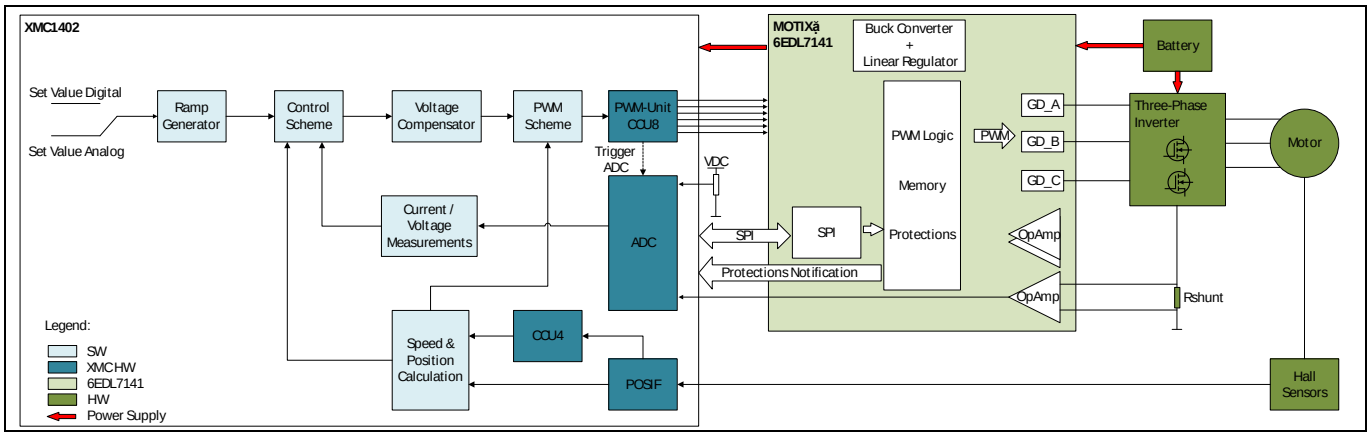


Figure 3 Block diagram

2.2 Trapezoidal control (six-step or block commutation)

Trapezoidal control—also referred to as “six-step” or “block commutation”—is the most straightforward control method for BLDC motors.

In a three-phase machine, each commutation interval establishes a current path through two motor phases, while the third phase is left floating. The Hall sensor signals indicate rotor position as logic high/low states, depending on which rotor magnetic pole is closest to each sensor. As the rotor turns and a north–south pole boundary passes a Hall sensor, the corresponding output changes state. The controller then advances commutation by applying the DC bus voltage to the next phase pair (denoted below as phase “A”, “B”, or “C”). The XMC1400 family microcontroller provides adequate performance to implement this algorithm.

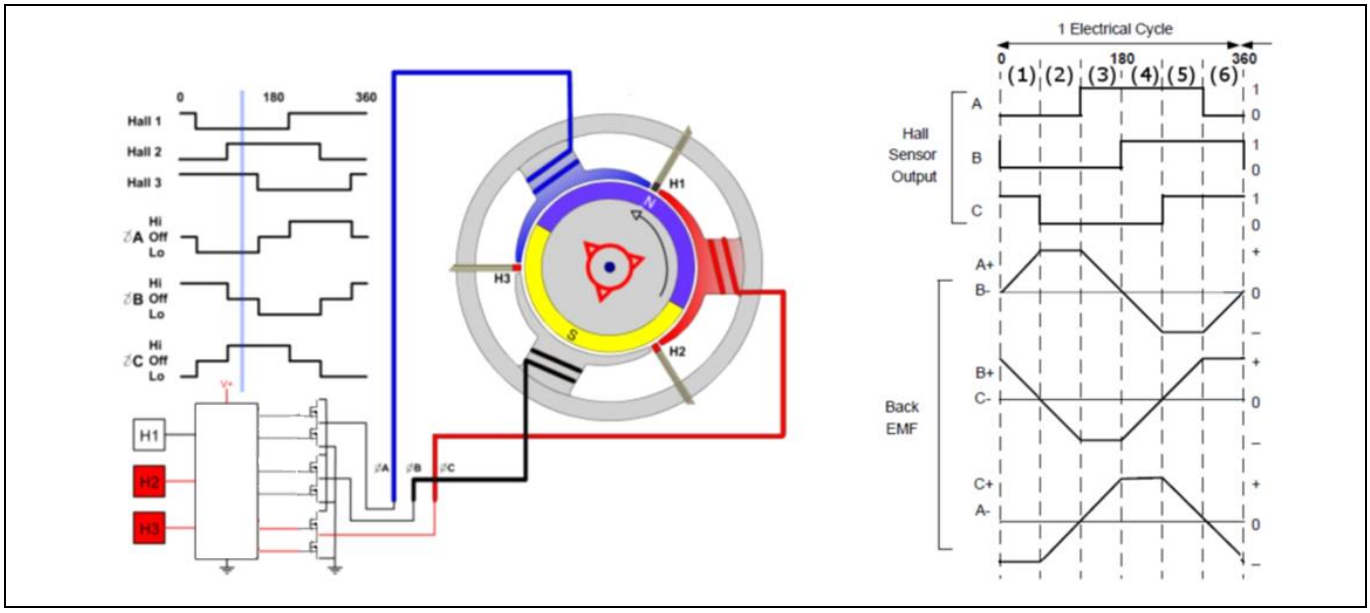


Figure 4 Control of a BLDC motor with Hall sensors

2 Firmware and control description

With six-step commutation, the phase voltage is applied in a rectangular waveform, which leads to trapezoidal phase current and back-EMF waveforms in the motor. For each commutation step, one winding conducts current into the phase, a second winding conducts current out of the phase, and the remaining winding is unpowered (open circuit). Torque is generated by the interaction between the stator magnetic field and the rotor permanent magnets. In an ideal case, maximum torque is obtained when the two fields are orthogonal (90°), and it decreases as the alignment between the fields increases.

The block diagram of a typical BLDC trapezoidal control block commutation system with Hall sensors is shown below:

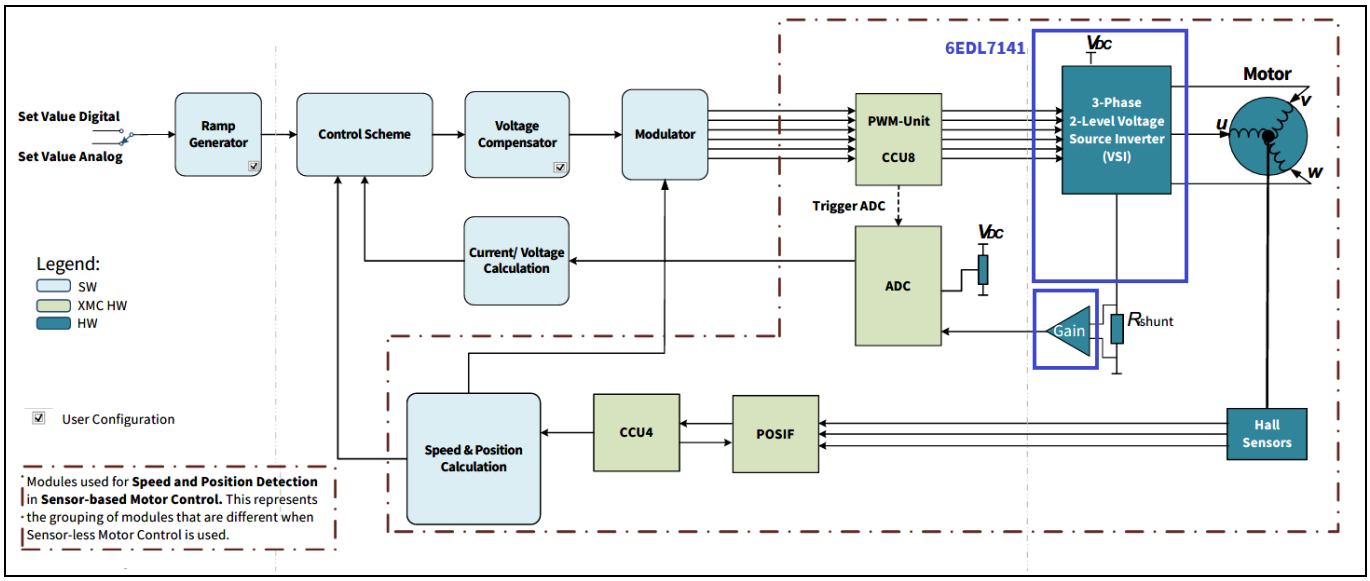


Figure 5 Block diagram of trapezoidal/block commutation algorithm

2.3 Control schemes

The firmware supports two operating modes for three-phase BLDC motor control: voltage control and speed control. The desired mode can be selected through the GUI.

2.3.1 Voltage control

Voltage control provides motor behavior similar to that of a brushed DC motor. While the Hall sensors keep the stator field commutated in synchronism with the rotor, the resulting speed and torque depend on the specific motor characteristics and the applied mechanical load. The voltage reference is taken either from the ramp generator (when enabled) or from a user-defined value/analog input, depending on the configuration.

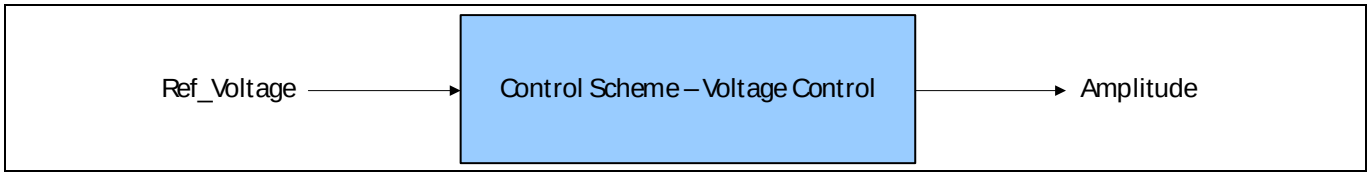


Figure 6 Control scheme – voltage control

2.3.2 Speed control

Speed control is a closed-loop mode that regulates motor voltage to track a commanded speed. When the load changes dynamically, the controller automatically adjusts the applied voltage to maintain a nearly constant speed. The measured speed is derived from the Hall sensor signals and/or phase voltage. The speed reference is provided either by the ramp generator (when enabled) or by a user-defined value/analog input, based on the configuration.

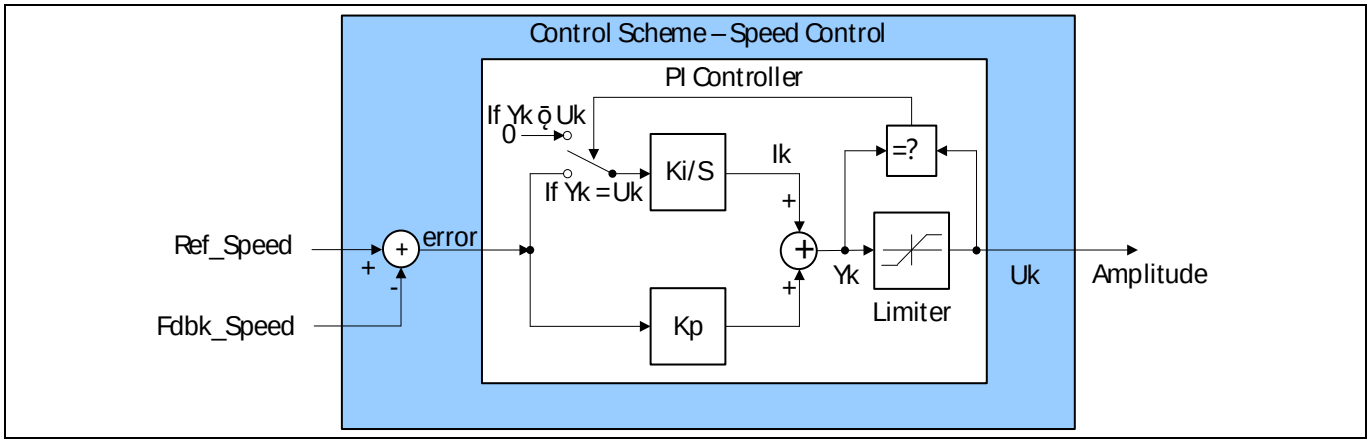


Figure 7 Control scheme – speed control

More details of the control scheme can be found in [2].

3 Power stage description

3.1 System power architecture

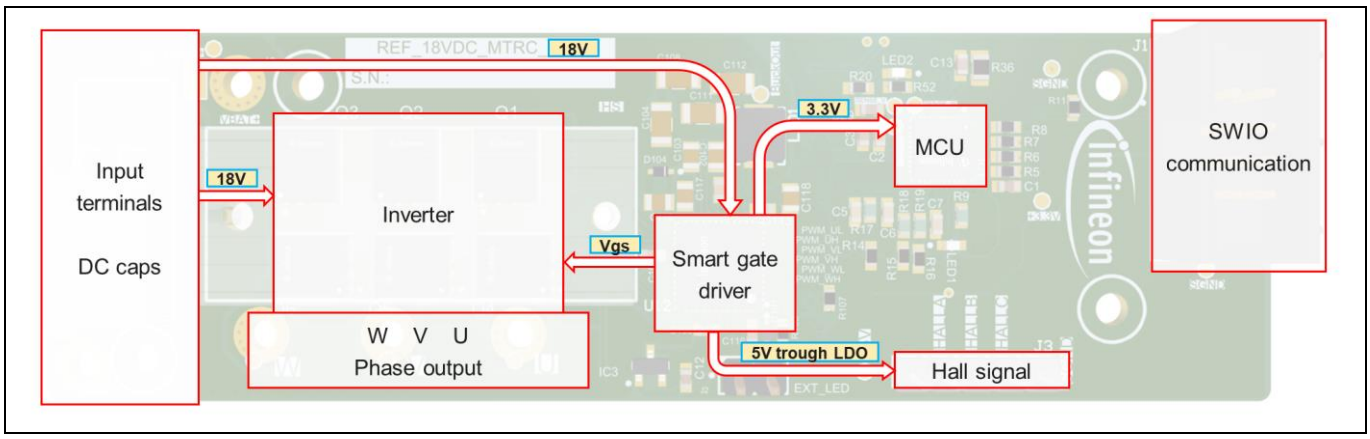


Figure 8 System power architecture

The board is powered from an 18 V (nominal) DC input source. The smart gate driver integrates buck converters and charge pumps to supply the MCU, the MOSFET gate drive, and the LDO.

3.2 Power MOSFET

The design uses the ISCH57N04NM7VSC, an OptiMOS™ 7 motor-drive-optimized MOSFET in a SuperSO8 5 × 6 dual-side-cooled (PG-WSON-8) package.

3.2.1 OptiMOS™ 7 motor drive optimized MOSFET

Infineon's OptiMOS™ 7 motor-drive-optimized MOSFET family [3] (Figure 9) is well suited for power tool and gardening tool applications. Key improvements include:

- Superior $R_{DS(on)}$
- Enhanced immunity
- Wide safe operating area
- Lower switching losses

The 40 V motor-drive-optimized portfolio provides these benefits in common package options such as SuperSO8 5 × 6 (PG-TDSON), PQFN 3.3 × 3.3 (PG-TSDSON), and SuperSO8 5 × 6 dual-side-cooled (PG-WSON-8).

All the devices of the OptiMOS™ 7 motor-drive-optimized MOSFET portfolio except ISZ015N04NM7V (Figure 9) can be placed on the board for evaluation.

3 Power stage description

Product Name	R_{Dson} max. @10V [mΩ]	Package
ISCH54N04NM7V	0.54	SuperSO8 5x6
ISCH69N04NM7V	0.69	SuperSO8 5x6
ISCH99N04NM7V	0.9	SuperSO8 5x6
ISC011N04NM7V	1.1	SuperSO8 5x6
ISC012N04NM7V	1.2	SuperSO8 5x6
ISC016N04NM7V	1.6	SuperSO8 5x6
ISZ015N04NM7V	1.5	PQFN 3.3x3.3

Packages



SuperSO8 5x6



PQFN 3.3x3.3

Product Name	R_{Dson} max. @10V [mΩ]	Package
ISCH57N04NM7VSC	0.57	SuperSO8 5x6 DSC
ISCH75N04NM7VSC	0.75	SuperSO8 5x6 DSC
ISCH92N04NM7VSC	0.92	SuperSO8 5x6 DSC

Packages



SuperSO8 5x6 DSC

Figure 9 OptiMOS™ 7 motor-drive-optimized MOSFET portfolio

3.2.2 Dual-side cooling

Within the OptiMOS™ 7 motor-drive-optimized family, dual-side-cooled (DSC) variants are available. Using DSC MOSFETs (ISCH57N04NM7VSD) together with an appropriate heatsink enables outstanding power capability to the board.

Equation 1 summarizes typical datasheet thermal values for three package technologies and provides the method for calculating the effective thermal resistance of a DSC package. As indicated by the equation, the low junction-to-top thermal resistance of DSC devices offers a clear thermal advantage.

$$R_{th} = \frac{(R_{thJC(top)}+R_{thTA})*(R_{thJC(bot)}+R_{thBA})}{(R_{thJC(top)}+R_{thTA})+(R_{thJC(bot)}+R_{thBA})}$$

Equation 1 Combined thermal resistance of the DSC package

Table 1 Comparison of thermal resistances for different packaging technologies

Package	$R_{thJC(top)}$-typ [K/W]	$R_{thJC(bot)}$-typ [K/W]	Definition
SO8	15	15	
SuperSO8 5x6	15	1	Bottom-side-cooled
SuperSO8 dual-side-cooled 5x6	0.7	1	Dual-side-cooled

More details about Infineon's OptiMOS™ 7 motor-drive-optimized MOSFETs can be found in the application note [4].

4 Test results

4.1 Test setup

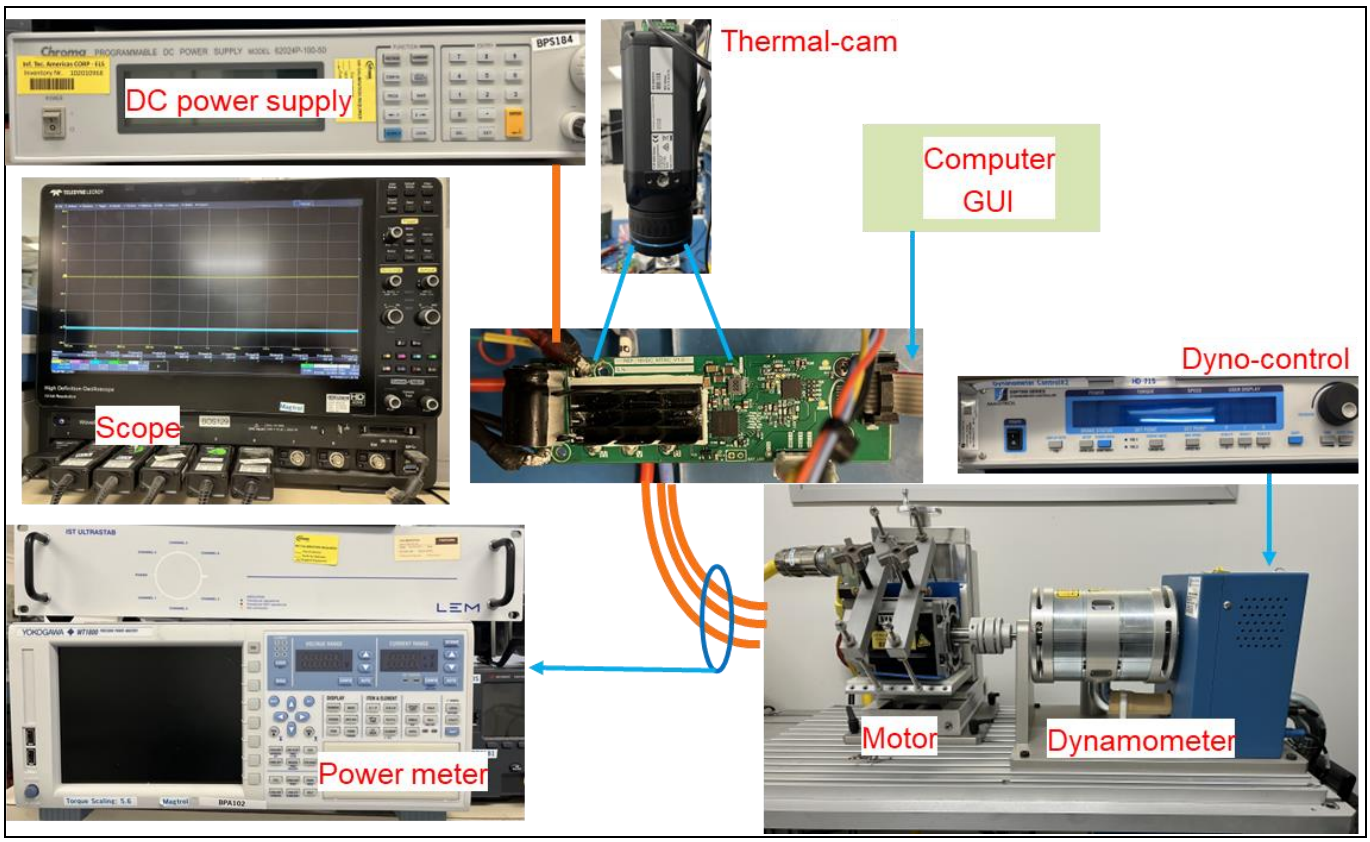


Figure 10 Test setup

The reference board was evaluated using a motor–dynamometer test bench (Figure 10). Testing was performed with an 18/36 V, 1.4/1.6 kW BLDC motor (Parker Hannifin, CMP1152X1E-202412) mechanically coupled to a Magtrol dynamometer (HD-715-5C1-010H).

The board is operated via the GUI, while the dynamometer is managed through the Magtrol controller. An 8-channel oscilloscope, a power meter, and a thermal camera were used to capture electrical and thermal measurement data.

4.2 Rating power

The designed rating power of the board is 500W, with a 10-minute operating duration limited by thermal constraints.

Temperature data was obtained using both the thermal camera and the onboard temperature sensor located near the phase W output terminal. The temperatures are recorded after 10 minutes operating at rating power, with 18 VDC bus voltage, 20 kHz switching frequency, and 2400 RPM motor speed (Figure 11).

4 Test results

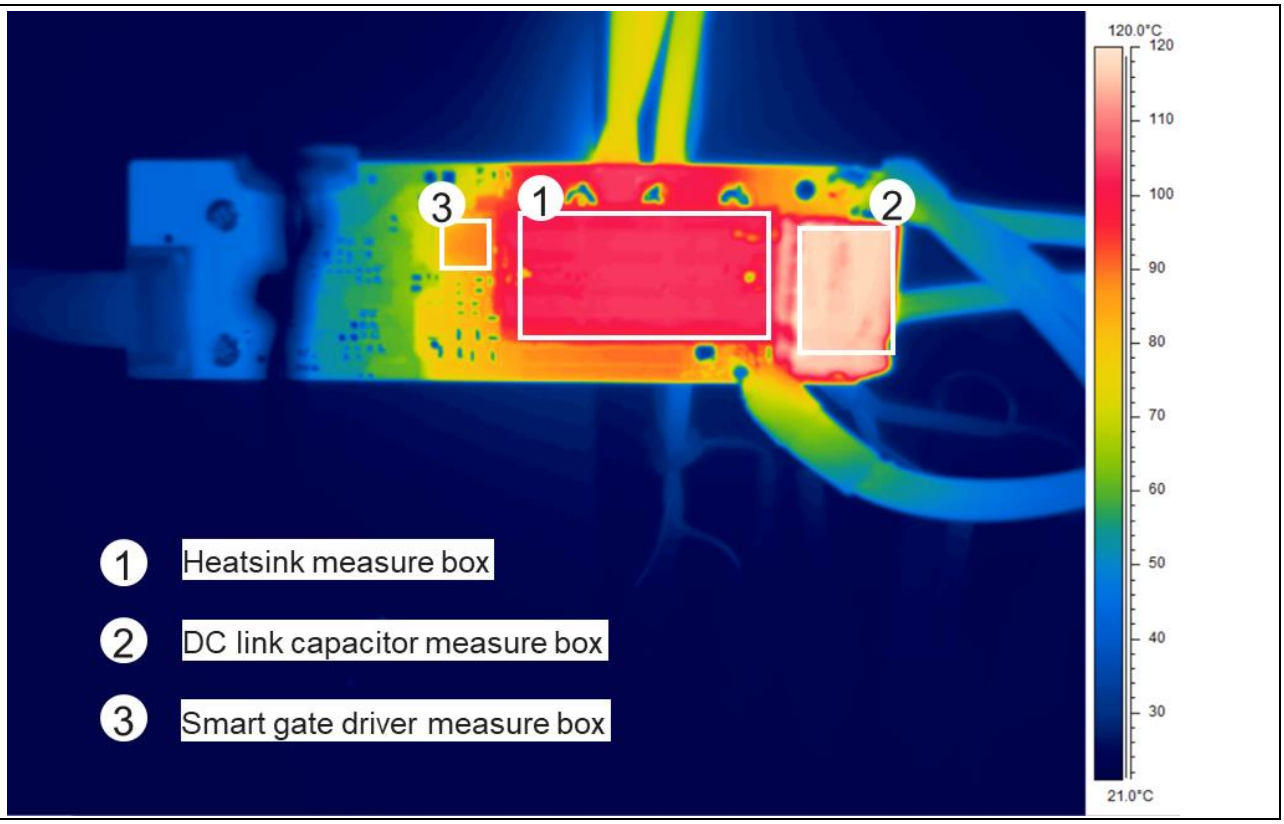


Figure 11 Test results – temperature at rating power

The test results:

- Heatsink: 104.8ºC
- DC link cap: 118.6ºC
- Smart gate driver (case): 90.4ºC
- Temperature at the board temperature sensor: 93ºC

The power stage area is as small as 315 mm^2 (22.5 mm x 14 mm, MOSFET area).

With a small heatsink (L x W x H: 35 mm x 14 mm x 12mm), the board can work at 500 W below the temperature limit, indicating the low conduction/switching losses of ISCH57N04NM7VSD and strong heat extraction via the dual-side cooling package.

4.3 Peak power

In the peak power test, the input power gradually increases from 100 W to 820 W and hold at 820 W for 10 seconds, with 18 VDC bus voltage, 20 kHz switching frequency, and 2500 RPM motor speed, then decreases from 820 W to 0 W (stop).

The temperatures are recorded for the whole operation (Figure 12). All the components work at a safe temperature level.

4 Test results

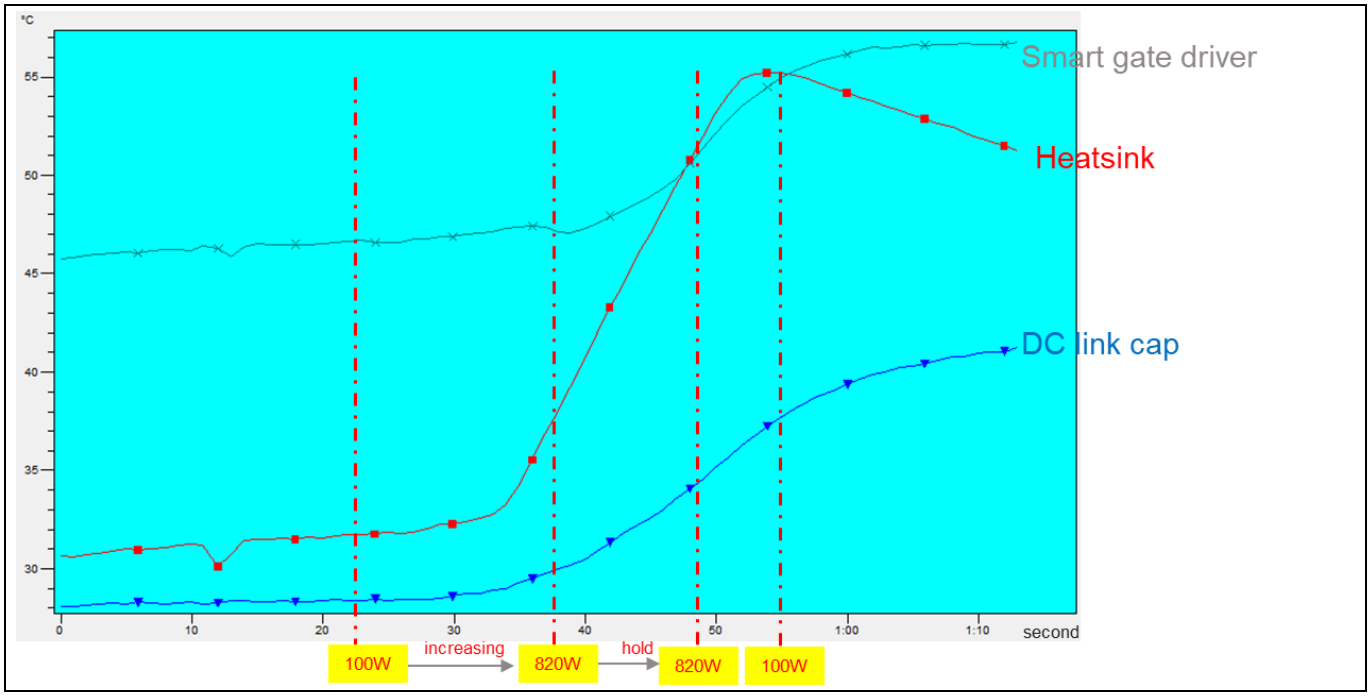


Figure 12 Test results – temperature curve with peak power operation for 10 s

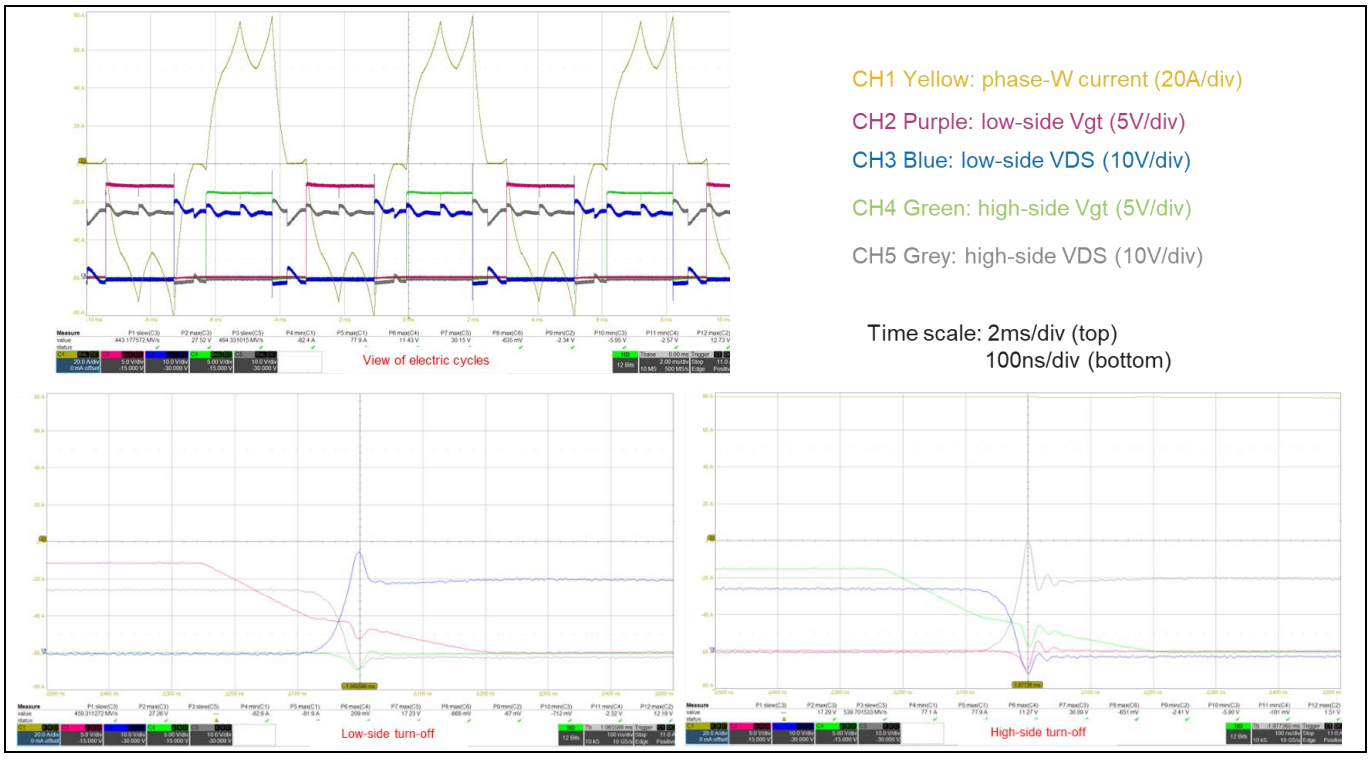


Figure 13 Test results – waveforms at peak power

The waveforms are recorded while the board is working at 820 W, with 18 VDC BUS voltage, 12 V gate voltage, and 2500 RPM motor speed (Figure 13). The PWM duty cycle is 100% at the peak power condition. The gate current is programmable.

4 Test results

The pre-charge source current is 500 mA and last for 60 ns. After pre-charge, high-side source current is 300 mA and low-side source current is 500 mA, and the charging period lasts for 80 ns. Both high-side and low-side sink currents at the first step is 175 mA and last for 180 ns, then the sink current increases to 500 mA and lasts for 200 ns.

- The low-side V_{DS} peak during the low-side turn-off transient is 27.3 V with –82 A phase current
- The high-side V_{DS} peak during the high-side turn-off transient is 30.1 V with 77 A phase current

Due to the excellent performance of the OptiMOS™ 7 motor-drive-optimized MOSFET, with maximum current (around 80 A), the V_{DS} overshoot is about 10 V lower than the breakdown voltage ($V_{(BR)DSS}$).

5 Schematics

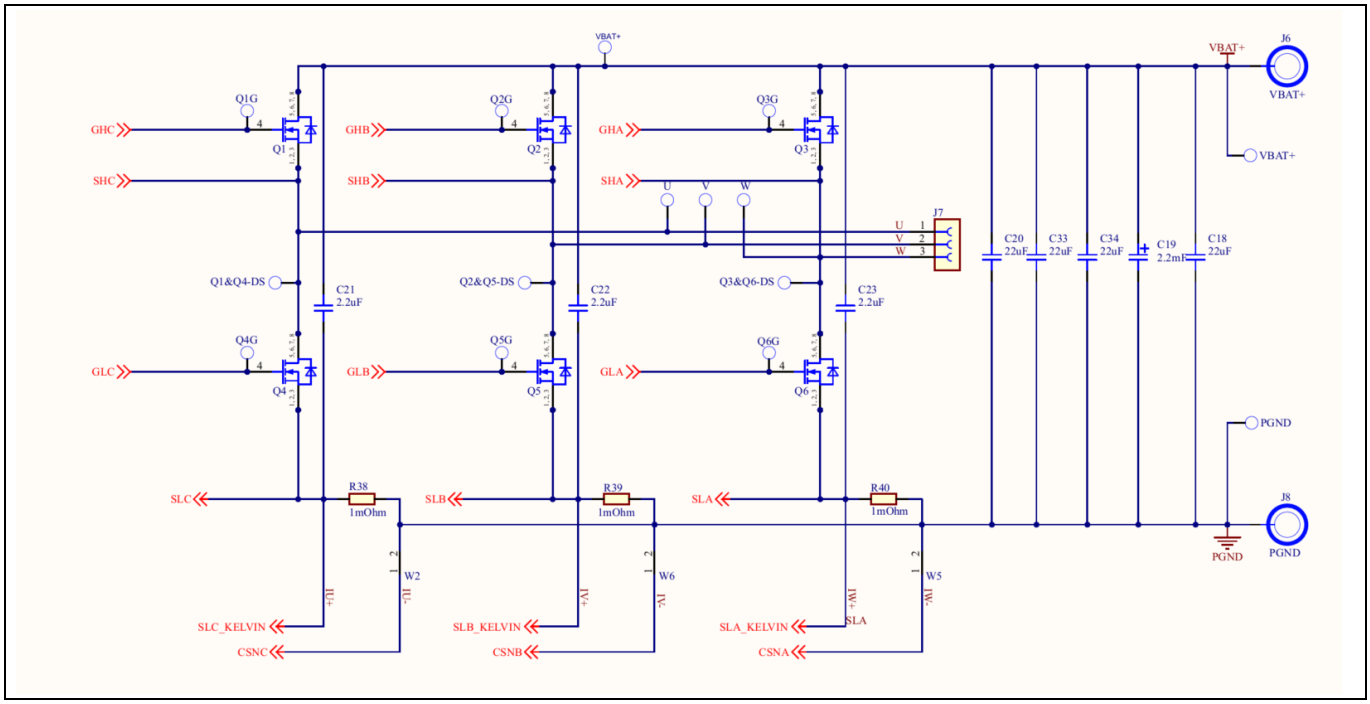


Figure 14 REF_18VDC_MTRC – Power – 3-phase power inverter stage schematic

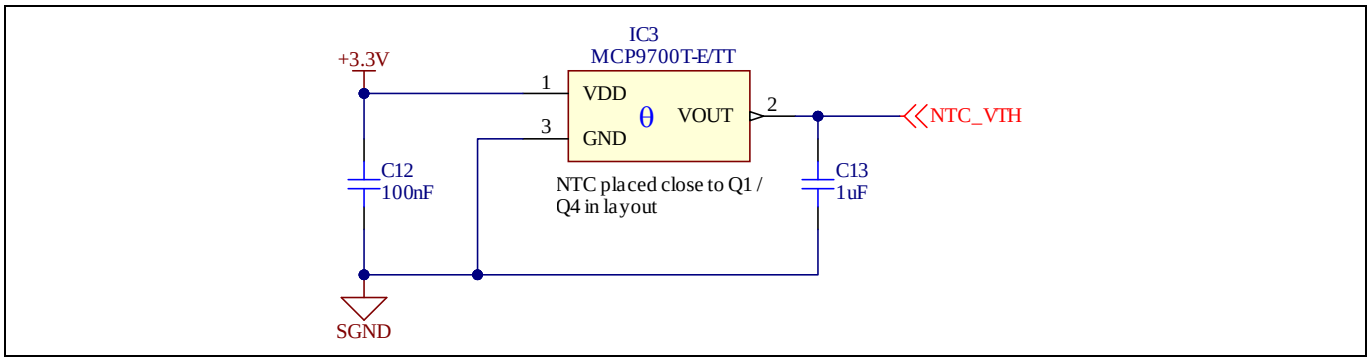


Figure 15 REF_18VDC_MTRC – Power – half-bridge temperature sensor schematic

5 Schematics

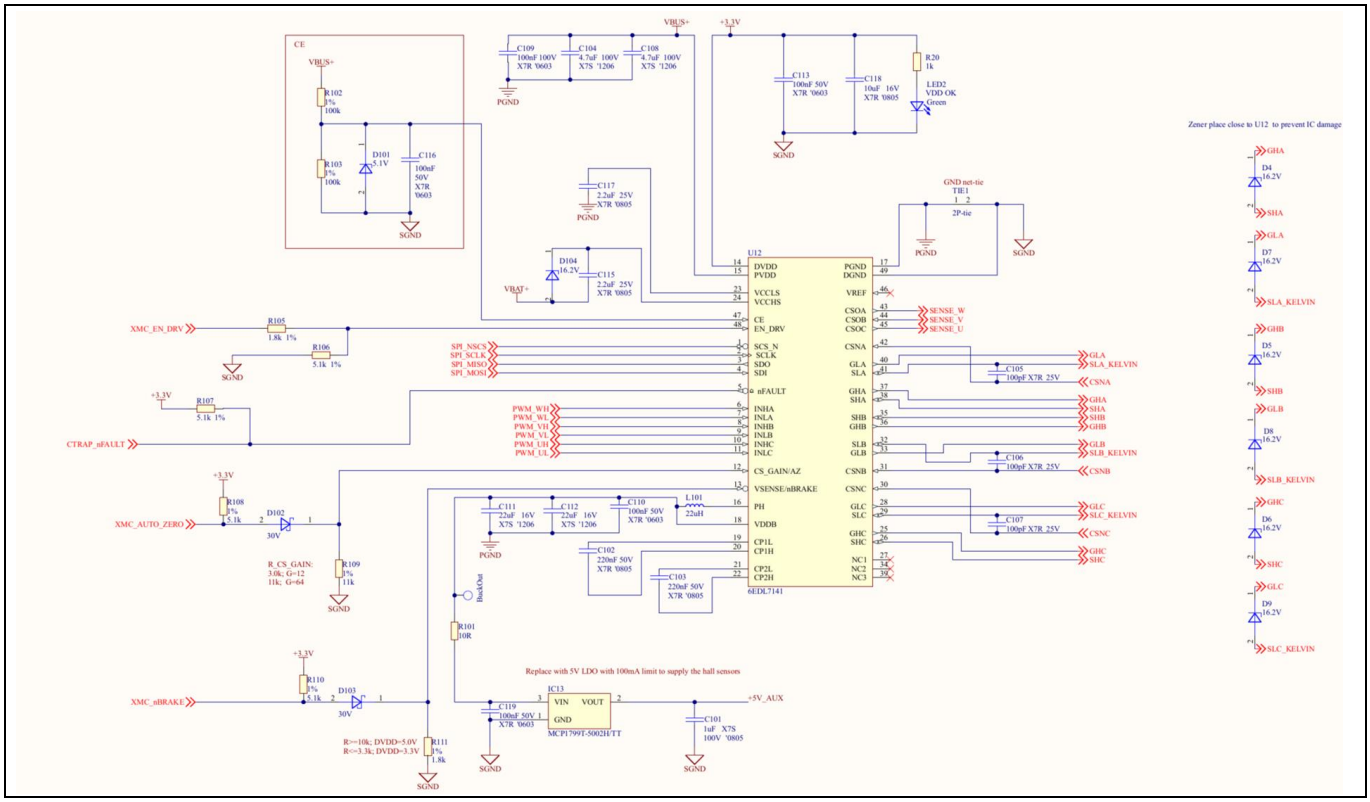


Figure 16 REF_18VDC_MTRC – 6EDL7141 gate driver section schematic

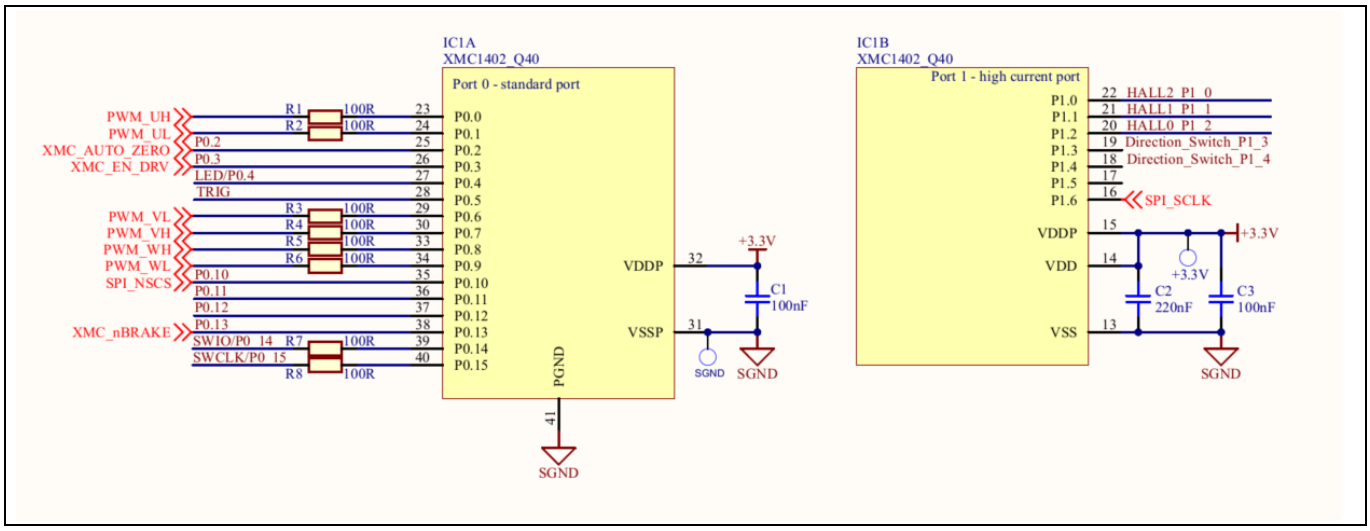


Figure 17 REF_18VDC_MTRC – XMC™ – XMC1402 microcontroller digital and supply section schematic

5 Schematics

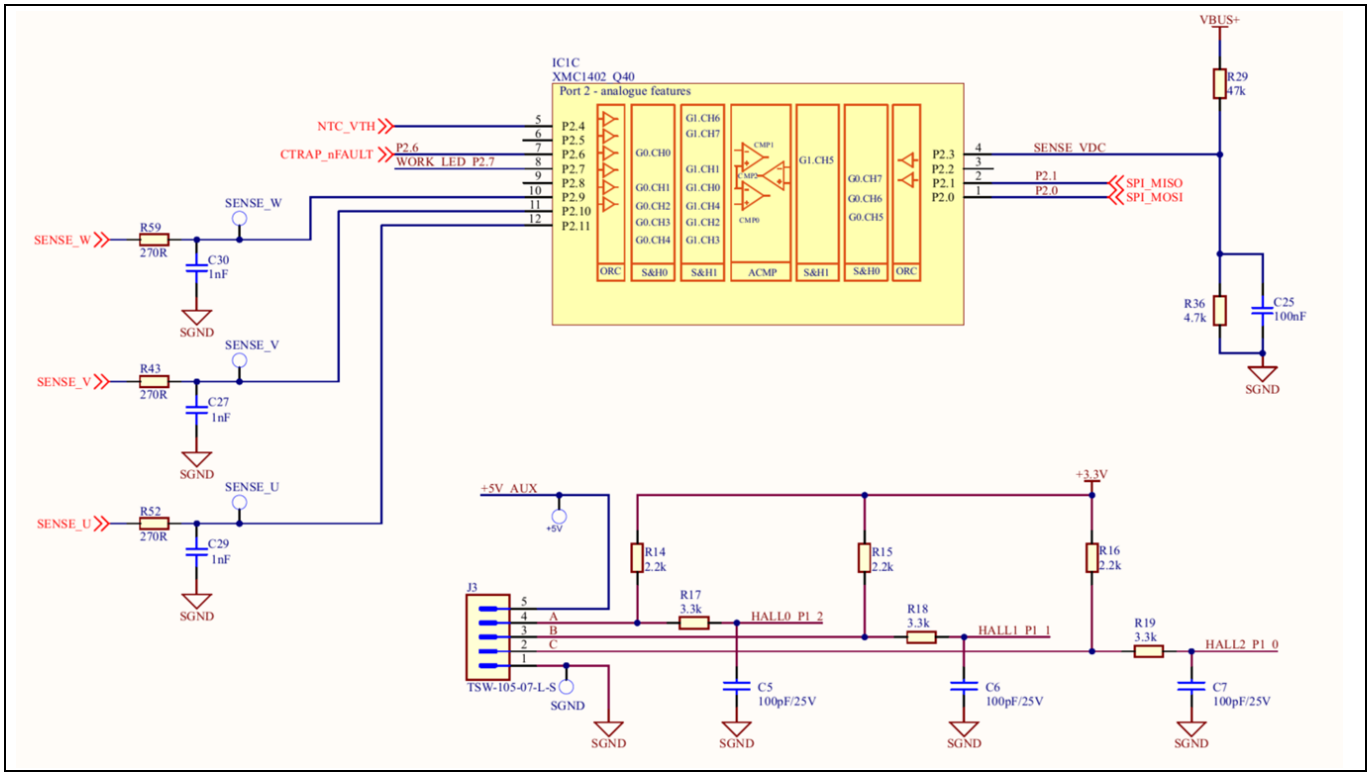


Figure 18 REF_18VDC_MTRC – XMC™ – XMC1402 microcontroller analog input, Hall sensor input, and filtering schematic

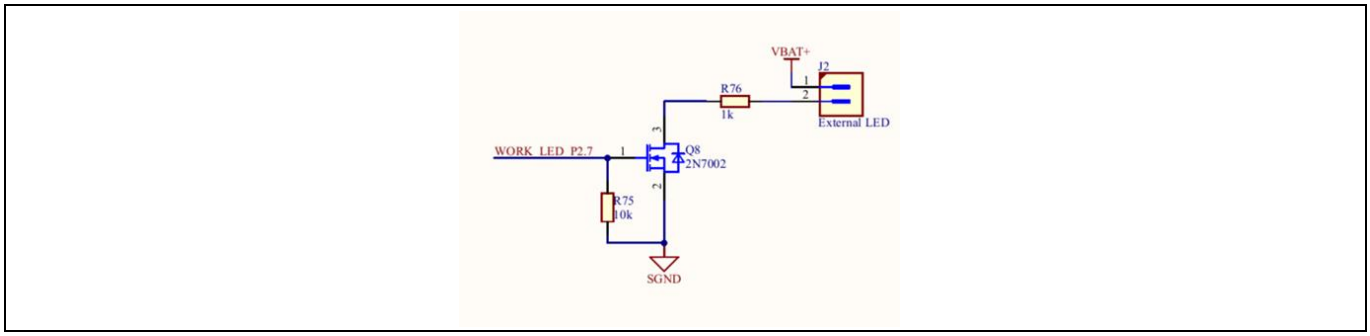


Figure 19 REF_18VDC_MTRC – other – external LED connector schematic

6 Bill of materials

Table 2 Bill of materials

Reference	Qty	Value/rating	Manufacturer	Part number
D102, D103	**2**	**DIODE SCHOTTKY 30V 500MA PGSC792**	**Infineon Technologies**	**BAS3005A02VH6 327XTSA1**
IC1	**1**	**MCU, 32BIT, 32KB FLASH, 40-VQFN**	**Infineon Technologies**	**XMC1402Q040X0 032AAXUMA1**
Q1, Q2, Q3, Q4, Q5, Q6	**6**	**N-CH, 40V, 1.8mΩ, TDSON-8 FL**	**Infineon Technologies**	**ISCH57N04NM7V SC**
U12	**1**	**IC GATE DRVR HALF-BRIDGE 48VFQFN**	**Infineon Technologies**	**6EDL7141XUMA1**
C1, C3, C12	3	CAP CER 0.1UF 25V X8R 0603	TDK Corporation	CGA3E2X8R1E10 4K080AA
C2	1	CAP CER 0.22UF 25V X7R 0603	Würth Elektronik	885012206073
C5, C6, C7	3	CAP CER 0.01UF 50V X7R 0604	KEMET	C0603C103J5REC 7411
C13	1	CAP CER 1UF 25V X7R 0603	Murata Electronics	GCM188R71E105 KA64J
C18, C20	2	CAP CER 2.2UF 50V X7R 1210	KEMET	C1210C225K5RA C
C19	1	CAP ALUM 2200UF 20% 35V RADIAL	Nichicon	UBY1V222MHL6T N
C21, C22, C23, C33, C34	5	CAP CER 22UF 35V X5R 1206	TDK Corporation	810-C3216X5R1V226 M
C25	1	CAP CER 0.1UF 50V X7R 0805	KYOCERA AVX	08055C104K4T2A
C27, C29, C30	3	CAP CER 1000PF 25V X7R 0603	Murata Electronics	GCJ188R71E102K A01D
C101	1	CAP CER 1UF 100V X7S 0805	Murata Electronics	GCM21BC72A105 KE36L
C102, C103	2	C0805C224K5RACAUTO	KEMET	C0805C224K5RA CAUTO
C104, C108	2	CAP CER 4.7UF 100V X7S 1206	Murata Electronics	GRM31CC72A475 KE11L
C105, C106, C107	3	CAP CER 100PF 25V C0G/NP0 0603	KEMET	C0603C101K3GA C7867
C109	1	CAP CER 0.1UF 100V X7R 0603	Samsung Electro-Mechanics	CL10B104KC8NN NC
C110, C113, C116, C119	4	CAP CER 0.1UF 50V X7R 0603	KYOCERA AVX	KAM15AR71H104 KM
C111, C112	2	CAP CER 22UF 16V X7S 1206	Murata Electronics	GCM31CC71C226 ME36L
C115, C117	2	CAP CER 2.2UF 25V X7R 0805	TDK Corporation	C2012X7R1E225K 085AB
C118	1	CAP CER 10UF 16V X7R 0805	Taiyo Yuden	EMK212BB7106K G-T
D4, D5, D6, D7, D8, D9, D104	7	DIODE ZENER 16V 500MW SOD523	On Semiconductor	SZMM5Z16VT1G
D101	1	DIODE ZENER 5.1V 500MW SOD523	On Semiconductor	MM5Z5V1T1G
HS	1	14mm X 35mm HEATSINK	Alpha Novatech, INC.	
IC3	1	SENSOR ANALOG -40C-125C SOT23-3	Microchip Technology	MCP9700T-E/TT

6 Bill of materials

Reference	Qty	Value/rating	Manufacturer	Part number
IC13	1	IC REG LINEAR 5V 80MA SOT23-3	Microchip Technology	MCP1799T-5002H/TT
J1	1	CONN HEADER VERT 8POS 2.54MM	Würth Elektronik	61200821621
J2	1	CONN HEADER VERT 2POS 2.54MM	Würth Elektronik	61300211121
J3	1	CONN HEADER VERT 5POS 2.54MM	Samtec Inc.	TSW-105-07-L-S
L101	1	FIXED IND 22UH 1.2A 500 MOHM SMD	Bourns Inc.	SRP4020TA-220M
LED1, LED2	2	LED GREEN CLEAR 0603 SMD	Würth Elektronik	150060GS75000
Q8	1	MOSFET SOT23 N 60V 5OHM 150C	2N7002	2N7002
R1, R2, R3, R4, R5, R6, R7, R8	8	RES SMD 100 OHM 1% 1/8W 0603	Vishay Dale	CRCW0603100RFKEA
R9	1	RES 1.5K OHM 1% 1/10W 0603	Vishay	MCT06030C1501FP500
R11, R12	2	RES SMD 91K OHM 1% 1/10W 0603	Panasonic Electronic Components	ERJ-3EKF9102V
R14, R15, R16	3	RES SMD 2.2K OHM 1% 1/10W 0603	YAGEO	RT0603FRD072K2L
R17, R18, R19	3	RES 3.3K OHM 1% 1/10W 0603	Vishay	MCT06030C3301FP500
R20, R76	2	RES 1K OHM 1% 1/8W 0603	KOA Speer Electronics, Inc.	RK73H1JTTD1001F
R29	1	RES 47K OHM 1% 1/8W 0805	YAGEO	RC0805FR-1347KL
R36	1	RES 4.7K OHM 1% 1/8W 0805	YAGEO	RC0805FR-074K7P
R38, R39, R40	3	RES 0.001 OHM 1% 1W 2512	Vishay Dale	WSL25121L000FEA
R43, R52, R59	3	RES 270 OHM 1% 1/10W 0603	YAGEO	RC0603FR-07270RL
R75	1	RES 10K OHM 1% 1/10W 0603	YAGEO	RC0603FR-0710KL
R101	1	RES SMD 10 OHM 1% 1/4W 1206	Vishay Dale	CRCW120610R0FKEA
R102, R103	2	RES 100K OHM 1% 1/10W 0603	Stackpole Electronics Inc	RMCF0603FT100KCT-ND
R105, R111	2	RES 1.8K OHM 1% 1/10W 0603	Vishay Dale	CRCW06031K80FKEAC
R106, R107, R108, R110	4	RES 5.1K OHM 1% 1/10W 0603	YAGEO	RC0603FR-075K1L
R109	1	RES 11K OHM 1% 1/10W 0603	YAGEO	RC0603FR-0711KL

7 Summary

This document presents Infineon's REF_18VDC_MTRC motor-drive inverter reference board, designed to implement the OptiMOS™ 7 40 V motor-drive–optimized power MOSFET in a compact form factor and support up to 820 W peak power for high-performance power tools and gardening tools.

By using Infineon's OptiMOS™ 7 ISCH57N04NM7VSC motor-drive-optimized MOSFET, which features very low $R_{DS(on)}$, improved immunity, wide safe operating area, low switching losses, and excellent Rth, the board can work at 820 W peak power for 10 seconds and 500 W rating power for 10 minutes.

The other MOSFETs of OptiMOS™ 7 motor-drive-optimized family are also great candidates for motor drive applications.

References

[1] Infineon Technologies AG: AN_2104 EVAL_6EDL7141_TRAP_1SH 18 V brushless DC motor drive board; Available online

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[3] Infineon Technologies AG: OptiMOS™ 7 motor-drives optimized; Available online

[4] Infineon Technologies AG: AN215719 OptiMOS™ 7 motor-drive optimized N-channel MOSFET 40 V; Available online

Revision history

Document revision	Date	Description of changes
1.00	2026-01-20	Initial release

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