

TLE9893-150W Reference Design Guide Preview

Coolant pump 150W

Design overview

This Infineon reference design guide describes a detailed implementation of an automotive coolant pump using the 3-phase motor driver TLE9893 of the MOTIX™ MCU embedded power IC family as BLDC motor controller. The three half-bridge MOSFETs in a SSO8 package are used to control a coolant pump with sensor-less FOC.

The design is capable of driving loads up to 150 W at a battery voltage of 12 V.

This design guide contains a description of the design, schematics, and measurement reports.

EMC is tested according to the CISPR25 standard. Thermal performance information is given and discussed.

Highlighted components

- TLE9893-2QKW62s
- IAUCN04S7N020D
- IPZ40N04S5-3R1

Applications

- Coolant pumps
- Oil pumps
- 150 W BLDC motor for 12 V applications

Highlighted design aspects



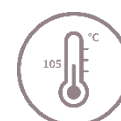
EMC
optimized



Cost
optimized

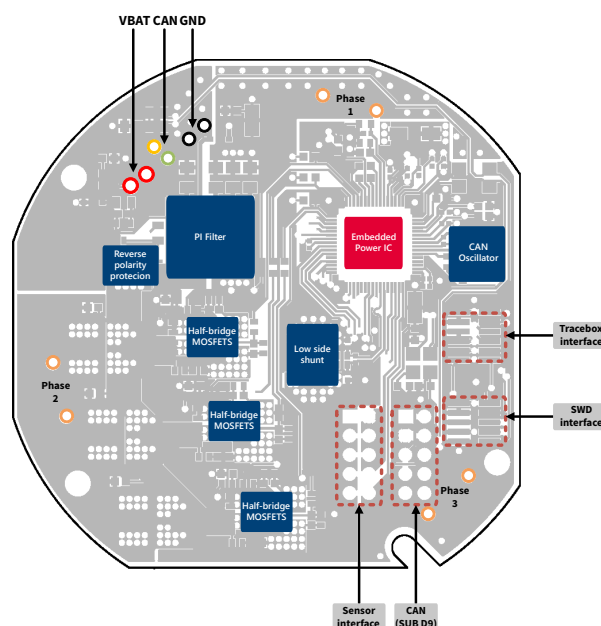
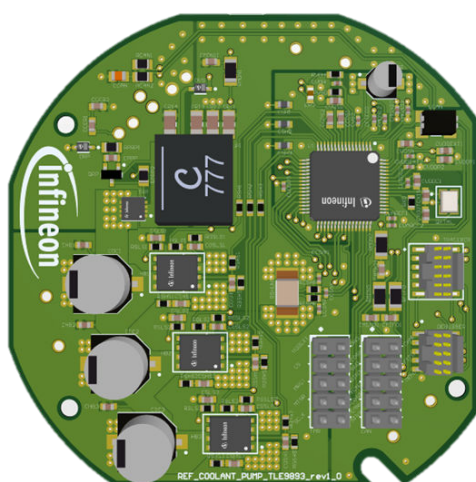


Space
optimized



Thermally
optimized

Reference design and diagram



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1 Design specifications

1 Design specifications

The design specifications are related to the used components and design considerations. They should not differ from the product datasheet values. In case of misalignment, the datasheet values of the products are valid.

Table 1 Design specifications

Parameter	Symbol	Values			Unit	Comment
		Min.	Typ.	Max.		
System parameters						
Input voltage	V_{s_max}	-0.3	–	30	V	Specified by design
Functional input voltage	V_{IN}	7	13.5	18	V	Specified according to coolant pump specification
Peak input current	I_{IN}	–	–	15	A	Peak current (<10 s)
Nominal input current	I_{IN}	–	9	–	A	Specified by design (7000 rpm)
CAN interface	V_{CAN}	-27	–	40	V	P_GEN_03_01 (TLE989x/8x datasheet)
Phase 1,2,3	V_{SH}	-8	-	48	V	P_GEN_02_05 (TLE989x/8x datasheet)
Thermal						
Operating temperature	T_A	-40	25	120	°C	Specified by design
Electromagnetic compatibility						
Conducted emissions	Class 5	CISPR25, 150 kHz -108 MHz				
Mechanical specification						
Dimensions PCB	66 mm × 66 mm × 12 mm (W × D × H)					

2 Overview

Figure 1 shows the 3D CAD view of the system. The FR4 4-layer board has, among other components, three SSO8 half-bridge MOSFETs, one TSDSON-8 MOSFET for active reverse polarity protection, one integrated 3-phase gate driver and one shunt resistor. All active components are carefully placed on the board to distribute the heat over the whole area of the PCB. The shunt resistor is an additional heat source, as it collects all return current from three legs of the bridge. Since the PCB does have surface-mounted components mounted only on the top side, it is possible to directly connect the board to the pump housing for an optimized cooling.

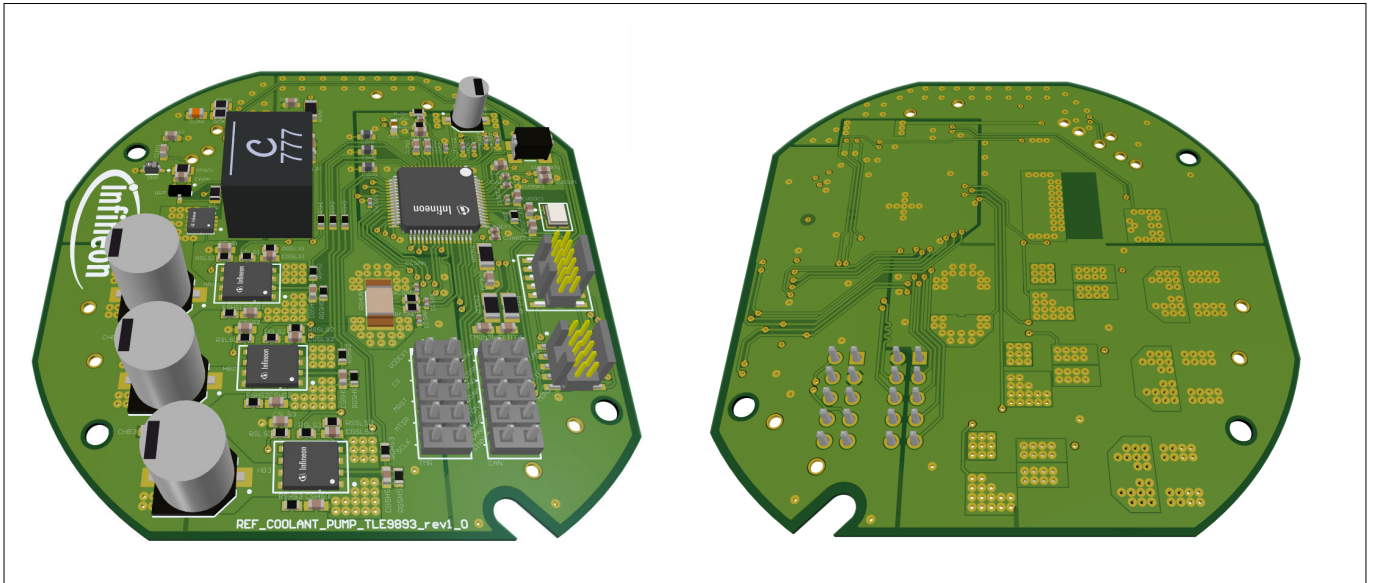


Figure 1 View of the reference design from top and bottom

Note: The delivered reference design has pin 3 of the SWD debugger connector clipped.

3 Highlighted products

3 Highlighted products

3.1 OptiMOS-7™ 40 V SS08 (PG-TDSON-8-60) MOSFET

The dual SS08 package offers high current capability of 60A with a footprint of $5 \times 6 \text{ mm}^2$. In combination with Infineon leading OptiMOS-7™ 40 V power MOS technology, they are optimized to meet and exceed the energy efficiency and power density requirements of automotive BLDC and H-bridge applications. Thanks to Infineon's robust SS08 package technology, it enables very small and efficient systems designs with minimal $R_{DS(on)}$ down to 1.9 mΩ. For more information about the product, please visit the Infineon webpage: <http://www.infineon.com/optimos7>.

Table 2 Automotive SS08 MOSFET with 40 V OptiMOS-7™

Product	Max. $R_{DS(on)}$ [mΩ]	ID (DC) [A]	ID (limitation) [A]	Q_G typ. [nC]
IAUCN04S7N020D	1.9	60	210	36
IAUCN04S7N030D	2.5	60	130	24
IAUCN04S7N045D	4.2	60	80	14
IAUCN04S7N055D	5.5	60	60	14
IAUCN04S7N060D	5.8	60	60	10

3.2 3-phase bridge driver IC with integrated arm® Cortex®-M3

The TLE989x family addresses a wide range of smart 3-phase brushless DC motor control applications such as coolant pumps, fans and general BLDC motor applications that require space-constraint solutions and CAN-FD communication. It provides an unmatched level of integration and system cost to optimize the target application. In addition, it offers scalability in terms of flash memory sizes and MCU system clock frequency, supporting a wide range of motor control algorithms, either sensor-based or sensor-less. For more information about the product, please visit the Infineon webpage: <http://www.infineon.com/tle989x>.

Table 3 Product family of 3-phase bridge driver IC with integrated Arm® Cortex®-M3

Grade	Product	Flash	RAM	Security	Interface	SDADC	FuSa
Grade-0	TLE9893-2QKW62S	248 kByte	31 kByte	Yes	CAN-FD	Yes	ASIL-B
	TLE9893QKW62S	248 kByte	31 kByte	Yes	CAN-FD	No	ASIL-B
	TLE9893-2QTW62S	248 kByte	31 kByte	Yes	CAN-FD	Yes	ASIL-B
	TLE9891-2QTW61	120 kByte	16 kByte	No	CAN-2.0	Yes	ASIL-B
	TLE9891-2QTW60	120 kByte	16 kByte	No	CAN-2.0	Yes	QM
Grade-1	TLE9893-2QTA62S	248 kByte	31 kByte	Yes	CAN-FD	Yes	ASIL-B
	TLE9893-2QTA62	248 kByte	31 kByte	No	CAN-FD	Yes	ASIL-B
	TLE9891QTA61	120 kByte	16 kByte	No	CAN-2.0	No	ASIL-B

3 Highlighted products

3.3 OptiMOS-5™ 40 V SS08 (PG-TDSON-8-33) MOSFET

The SS08 package offers high current capability of 40 A with a footprint of $3.3 \times 3.3 \text{ mm}^2$. In combination with Infineon's leading OptiMOS-5™ 40 V power MOS technology, it is optimized to meet and exceed the energy efficiency and power density requirements of automotive BLDC and H-bridge applications. Thanks to Infineon's robust S308 leadless package technology, it enables very small and efficient systems designs with minimal $R_{DS(on)}$ down to 2.8 mΩ. For more information about the product, please visit the Infineon webpage: www.infineon.com/optimos5-40v60v.

Table 4 Automotive S308 MOSFET with 40 V OptiMOS-5™

Package	Silicon technology	Product	Max. $R_{DS(on)}$ [mΩ]	ID [A]
S308 (PG-TDSON-8)	OptiMOS-5™	IPZ40N04S5L-2R8	2.8	40
		IPZ40N04S5-3R1	3.1	40
		IPZ40N04S5L-4R8	4.8	40
		IPZ40N04S5-5R4	5.4	40
		IPZ40N04S5L-7R4	7.4	40
		IPZ40N04S5-8R4	8.4	40

4 Switching characteristics

4 Switching characteristics

The switching waveforms of HB3 (low-side MOSFET) were measured during the tests.

5 Self-heating of components

Active components are the main source of power dissipation on the reference design. The biggest sources are the TLE9893 and the half-bridge MOSFETs, whose losses are described as follows:

- TLE9893:
 - Charge pump
 - Gate drivers
 - Internal (CPU, PMU)
- IAUC60N04S7N020D
 - Switching losses
 - Conduction losses

6 Conducted emissions

6.1 Conducted emissions with motor in off-state

In this condition, the reference design is supplied with 13.5 V and the microcontroller of the TLE9893-2QW62S is executing the code, without controlling the motor. Peak (PK) and average (AV) micro only shows the conducted emissions while the MOSFET bridge driver and charge pump are disabled.

6.2 Conducted emissions with motor in on-state

During this test, the reference design is powered and the microcontroller of the TLE9893-2QW62S is executing the code and the spread spectrum features are enabled. The motor is spinning with 2000 rpm, 5000 rpm, 7000 rpm and 8000 rpm. The MOSFET bridge driver is enabled.

7 Abbreviations and definitions

Table 5 Abbreviations

Abbreviation	Definition
CAN	Controller Area Network
FOC	Field Oriented Control
MI	Modulation Index
RPP	Reverse Polarity Protection
PSI	Pound per Square Inch
ECU	Electronic Control Unit
PWM	Pulse Width Modulation
PCB	Printed Circuit Board
EMC	Electromagnetic Compatibility
IC	Integrated Circuit
DC	Direct Current
ESR	Equivalent Series Resistance
DUT	Device under test

8 Reference documents

This document should be read in conjunction with the following documents:

- 1.** TLE989x/8x Datasheet, Infineon Technologies AG, Rev 1.1
- 2.** TLE989x/8x User Manual, Infineon Technologies AG, Rev 1.0
- 3.** TLE989x/8x Hardware Design Guideline, Infineon Technologies AG, Rev 1.0
- 4.** MOTIX™ TLE989x Motor Control FOC Demo, Infineon Technologies AG, Rev 1.0
- 5.** Reverse Polarity Protection for Embedded Power ICs, Infineon Technologies AG, Rev 1.0
- 6.** IPZ40N04S5L-3R1 Datasheet, Infineon Technologies AG, Rev 1.01
- 7.** IAUCN04S7N020D, Preliminary Datasheet (myICP), Infineon Technologies AG
- 8.** Analytical calculation of the RMS current stress on the DC-link capacitor of voltage-PWM converter systems, 2006-07, IEE Proc.-Electr. Power Appl., Vol. 153, No.4.
- 9.** IPC-2152, 2003-05, Institute for Interconnecting and Packaging Electronic Circuits
- 10.** IEC 60664-1, 2007-04, International Electrotechnical Commission

Revision history

Revision history

Document version	Date of release	Description of changes
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