1 kW engine cooling fan reference design for 12 V application

OptiMOS-6™ 40 V sTOLL MOSFET, TLE9879QXW40 Embedded Power IC

Design Overview

This Reference Design Guide describes a detailed implementation of an automotive engine cooling fan application. The system is controlled by a system on chip microcontroller with integrated MOSFET driver in combination with OptiMOS™-6 leadless MOSFETs.

The design is capable to drive loads up to 1 kW 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

- TLE9879QXW40
- IAUA250N04S6N007

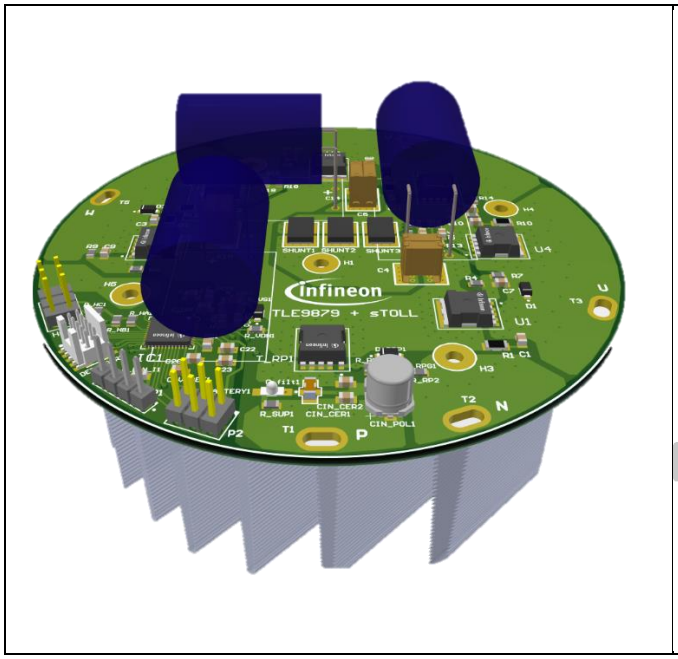
Target Application

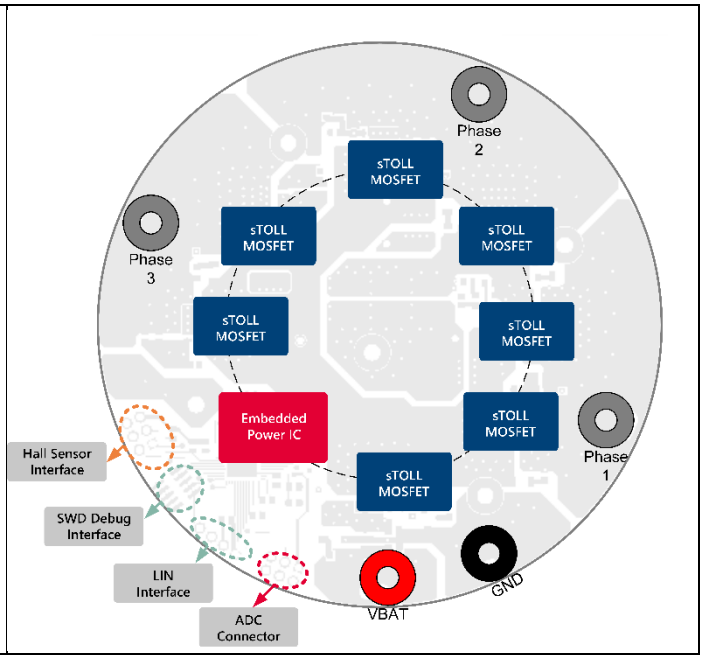
- Engine Cooling Fan
- Radiator Fan
- 1 kW BLDC Motor for 12 V application

Highlighted Design Aspects

1 kW functional | EMC optimized | Thermally optimized

Reference Design and Block Diagram





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1 System Description

The reference design describes a solution for an engine cooling fan with a power capability. This solution can be used for similar applications with smaller or equal power consumption. The circuit contains an integrated 3-phase motor control solution. The SoC microcontroller is a member of the Embedded Power IC family. It combines an Arm® Cortex®-M3 microcontroller with application specific modules like an integrated 3-phase MOSFET driver, power supply and LIN-transceiver. In combination with the OptiMOS™-6 sTOLL MOSFETs the system is optimized for a minimum of PCB size for this power class. The focus of the reference design is to use standard PCB materials and processes.

1.1 Design Specifications

The design specifications are related to the used components and design considerations. They shouldn't 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_{IN}	-0.3	12	40	V	P_1.1.1 (TLE9879QXW40)
Functional input voltage	V_{IN}	7	12	18	V	Specified for Design
Output current peak	I_{OUT}	-	-	100	A	Peak current (<10 s), air cooling attached (>1.3 m/s)
Output current continous	I_{OUT}	-	40	80	A	Specified for Design
Hall Sensor Inputs	V_{HALL}	-0.3	5	5.5	V	Specification related to GPIO Port 0,1
LIN interface	V_{LIN}	-28	12	40	V	P_1.1.7 (TLE9879QXW40)
ADC Inputs	V_{ADC}	-0.3	5	5.5	V	Specification related to GPIO Port 2
Phase 1,2,3	V_{SH}	-8.0	12	48	V	P_1.1.11 (TLE9879QXW40)
Thermal						
Operating temperature	T_A	-40	25	105	°C	Specified for Design

Electromagnetic Compatibility		
Conducted emissions	Class 3	CISPR25, 150 kHz -108 MHz

Mechanical Specification	
Dimensions	100 mm x 100 mm x 58 mm (W x D x H)
PCB	62 mil 6-layer 2 oz high temperature FR4 Ø100 mm

1.2 Overview

Figure 1 shows the 3D CAD view of the system. The board has seven sTOLL MOSFETs, one 3-phase gate driver, and 3 shunt resistors in parallel. Each circle in the figure is color-coded, in order to make it easy to locate. All active components, including the seven MOSFETs and one driver IC, are carefully located on the board to distribute the heat over the whole area of the PCB. As passive components, the shunt resistors are additional heat sources. Those are collecting all return current from three legs of the bridge. The board is designed to dissipate the heat of the shunts effectively through the thermal pad and also through the center bolt. As the PCB does not have any surface-mounted components, it is possible to attach a simple flat heatsink at the bottom of the board. Only the lead of the through-hole electrolytic capacitors are sticking out on the bottom surface and can be accommodated with minimum amount of heatsink machining.

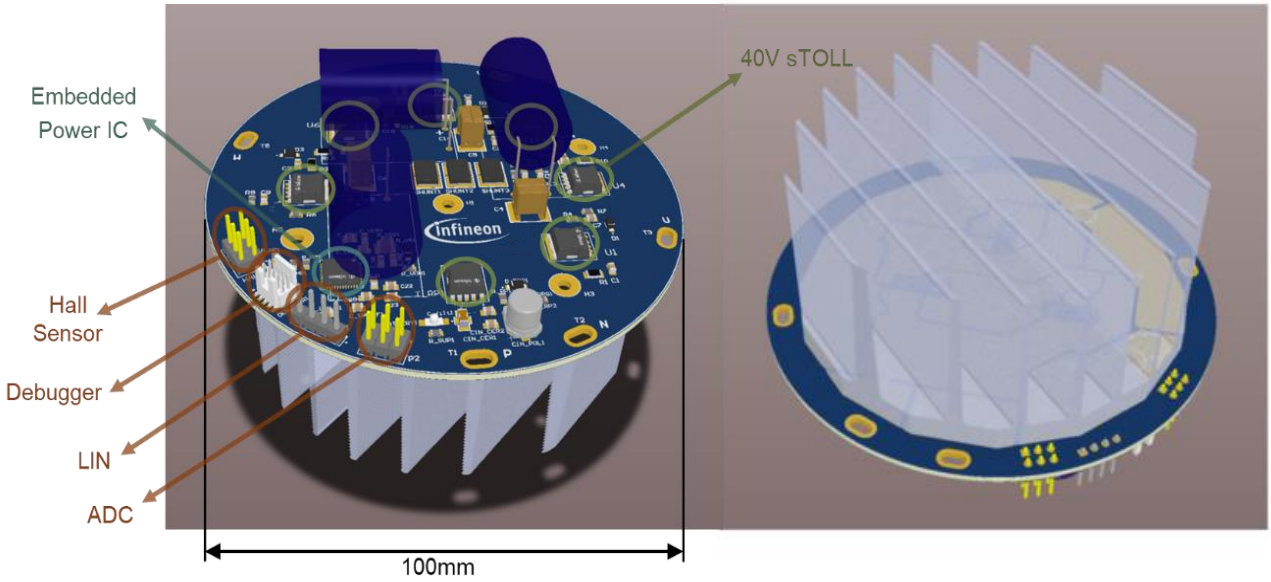

Figure 1 External view of the reference design from top and bottom

1.3 Highlighted Products

1.3.1 OptiMOS-6™ 40 V sTOLL(HSOF-5) MOSFET

The sTOLL package offers high current capability of 250 A, more than standard D²PAK (180 A), with a footprint of 56 mm² that is even smaller than DPAK (65 mm²). In combination with Infineon's leading OptiMOS-6™ 40 V and OptiMOS-5™ 40 V power MOS technology, sTOLL offers best in class power density and power efficiency at Infineon's well known quality level for robust automotive packages. For more information about the product, please visit the Infineon web-page linked below.

- www.infineon.com/cms/en/product/promopages/power-mosfet-package-stoll/

Table 2 Automotive sTOLL MOSFET with 40 V OptiMOS-6™ and OptiMOS-5™

Package	Silicon Technology	Product	Max $R_{DS(on)}$ [mΩ]	ID [A]
sTOLL (HSOF-5)	OptiMOS™-6	IAUA250N04S6N006	0.64	250
		IAUA250N04S6N007	0.70	250
	OptiMOS™-5	IAUA200N04S5N010	1.00	200
		IAUA180N04S5N012	1.20	180
		IAUA120N04S5N014	1.40	120

1.3.2 3-Phase Bridge Driver IC with Integrated Arm® Cortex®-M3

The TLE987x family addresses a wide range of smart 3-phase brushless DC motor control applications such as auxiliary pumps and fans. It provides an unmatched level of integration and system cost to optimize the target application segments. 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 Infineon web-page linked below.

- www.infineon.com/tle987x

Table 3 Product Family of 3-Phase Bridge Driver IC with Integrated Arm® Cortex®-M3

Grade	Product	Flash	RAM	Frequency	Interface	Tjmax
Grade-0	TLE9873QXW40	48 kByte	3 kByte	40 MHz	PWM + LIN	175 °C
	TLE9877QXW40	64 kByte	6 kByte	40 MHz	PWM + LIN	175 °C
	TLE9879QXW40	128 kByte	6 kByte	40 MHz	PWM + LIN	175 °C
Grade-1	TLE9871QXA20	36 kByte	3 kByte	24 MHz	PWM	150 °C
	TLE9877QXA20	64 kByte	6 kByte	24 MHz	PWM + LIN	150 °C
	TLE9877QXA40	64 kByte	6 kByte	40 MHz	PWM + LIN	150 °C
	TLE9879-2QXA40	128 kByte	6 kByte	40 MHz	PWM + LIN	150 °C
	TLE9879QXA40	128 kByte	6 kByte	40 MHz	PWM + LIN	150 °C

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2 Getting Started

2.1 Toolchain Installation

In order to get the board ready and running, the software shown in Table 4 shall be installed.

The µVision software is a development tool provided by Arm® Keil®. With code length limitation, the shareware version of the µVision is still able to edit, compile and debug. The Infineon Config Wizard is a tool for configuring peripherals of the Embedded Power IC. The tool can be called from the pull-down menu of the µVision and helps users changing parameters from its user interface and then generates the software code accordingly. Infineon provides standard motor drive software codes for the Embedded Power IC. It can be downloaded from the Pack Installer within the µVision.

Table 4 Software Toolchain Installation Guide

Steps	Company	Description
STEP1 Download and Install **Keil® µVision5**	Arm® Keil®	• Arm® Keil® µVision is an integrated development environment which consists of code editor, compiler and debugger. • To learn how to use Arm® Keil® µVision 5, check out our video "**Get your motor spinning**".
STEP2 Download Config Wizard	Infineon Technologies	• Infineon provides the Config Wizard free of charge, which is designed for configuration of chip modules. Config Wizard supports easy configuring of Embedded Power IC peripherals. • Config Wizard can be installed via the Infineon Toolbox. If you don´t have the Infineon Toolbox yet, please go to **Infineon Toolbox** and enjoy the release management for updates.
STEP3 Download and Install **Segger J-Link Driver**	SEGGER	• SEGGER J-Link is a widely used driver for "on-board" or "stand-alone" debugger.
STEP4 Download the SDK via µVision5 Pack Installer	Infineon Technologies	• The Embedded Power Software Development Kit (SDK) is a low level driver library which can be downloaded within Keil® µVision via the "Pack Installer"

For the toolchain installation and free motor drive software, please check below link.
www.infineon.com/embedded-power
For more information about the tool chain installation steps, watch our video.
Toolchain Installation for Embedded Power ICs / TLE98xx

2.1.1 Configuration

Open a motor drive code project in µVision5 and go to “Tools” and open “Config Wizard”. From there, setup the parameters of motor, speed/current controller and the peripherals of TLE987x. As the Embedded Power IC has a current-source gate driving scheme, the switching speed is not controlled by gate resistors, but by the “Gate Charge/Discharge” parameters in the BDRV tap of the peripherals. For more details about the configuration, please visit the Infineon website of Embedded Power ICs.

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6 Abbreviations and definitions

Table 7 Abbreviations

Abbreviation	Definition
ECF	Engine Cooling Fan
LIN	Local Interconnect Network
FOC	Field Oriented Control
MI	Modulation Index
RBP	Reverse Battery Protection
PSI	Pound Force per Square Inch
ECU	Electrical 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
LISN	Line Impedance Stabilisation Network
BDRV	Bridge Driver Module of Embedded Power IC

7 Reference documents

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

[1] TLE9879QXA40 datasheet, Infineon Technologies AG, https://www.infineon.com/dgdl/Infineon-TLE9879QXW40-DS-v01_01-EN.pdf?fileId=5546d4625b10283a015b248fc7622e4b

[2] TLE986x_TLE987x Bridge Driver Application Note, 2018-12, Infineon Technologies AG, Rev 1.02 https://www.infineon.com/dgdl/Infineon-TLE987x_TLE986x-BDRV-ApplicationNotes-v01_02-EN.pdf?fileId=5546d46267c74c9a0167cbe1686a191d

[3] IAUA250N04S6N007 datasheet, Infineon Technologies AG, https://www.infineon.com/dgdl/Infineon-IAUA250N04S6N007-DataSheet-v01_00-EN.pdf?fileId=5546d462712ef9b701717821bea511a7

[4] 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.

[5] Snubber Capacitors Application Guide, 2018-01, Cornell Dubilier

[6] IPC-2152, 2003-05, Institute for Interconnecting and Packaging Electronic Circuits

[7] IEC 60664-1, 2007-04, International Electrotechnical Commission

Revision history

Major changes since the last revision

Date	Version	Description
2020-06-18	V1.0	Initial version

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