Generic power evaluation board design for 12 V application - SSO8 and TLE9879QXA40

OptiMOS-6™ 40 V SSO8 MOSFET, MOTIX™ MCU TLE9879QXA40

Design Overview

This documentation describes the Generic Power evaluation board for 12V fit for the implementation of an automotive inverter application for controlling fans or pumps driven by BLDC motors. The system is controlled by a system- on-chip MOTIX™ MCU with integrated MOSFET drivers in combination with OptiMOS™-6 leadless MOSFETs.

The design is capable to drive loads up to 400W supplied by 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

- TLE9879QXA40
- IAUC120N04S6N006
- IAUC120N04S6N010

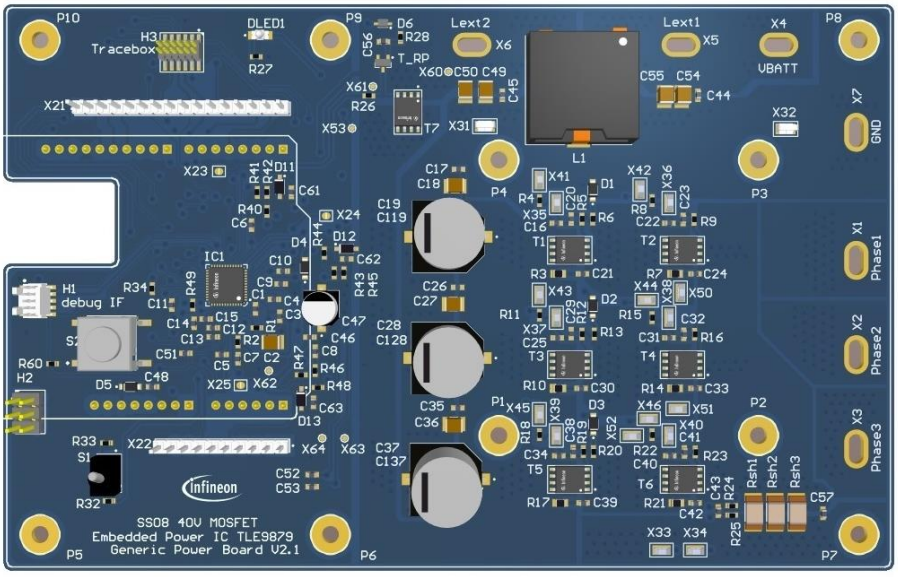
Target Application

- Automotive Fan and Pump
- Radiator fan, Water pump
- 400 W BLDC Motor for 12 V application

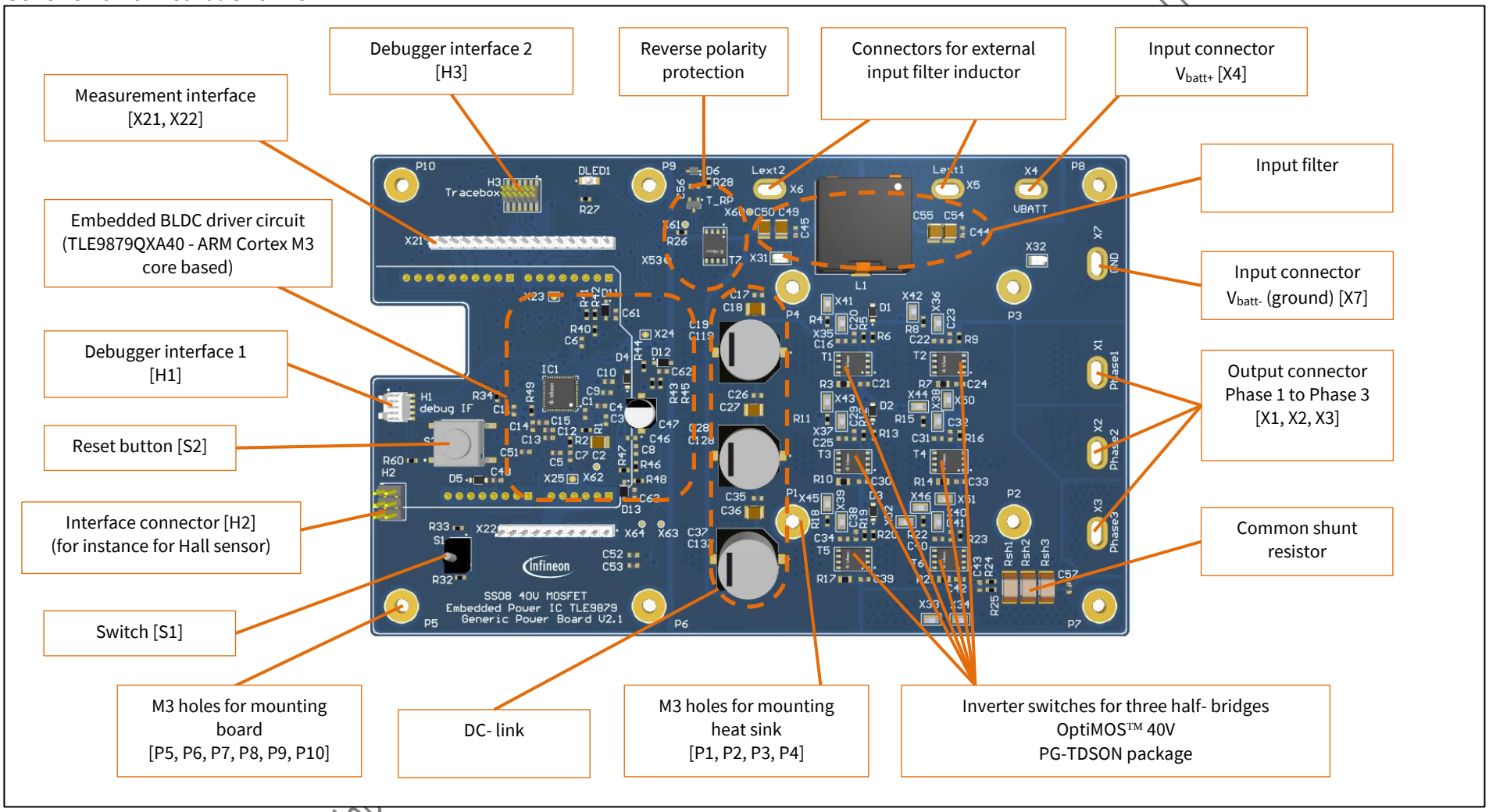
Highlighted Design Aspects

400 W functional | EMC optimized | Thermally optimized

Generic Power Board: Top View



Generic Power Board: Overview



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1 System Description

The inverter design describes a solution for an engine cooling fan with a power capability up to 400W output power. This solution can be used for similar applications with smaller or equal output power. The circuit contains an integrated 3-phase motor control solution. The SoC microcontroller is a member of the MOTIX™ MCU 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 40V MOSFETs in PG-TDSON-8 package (SSO8) the board system is optimized for a minimum of PCB size for this power class. The focus of the demonstrator 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 (TLE9879QXA40)
Functional input voltage	V_{IN}	7	12	18	V	Specified for Design
Output current peak	I_{OUT}	-	-	44	A	Peak current (<10 s), air cooling attached (>1.3 m/s)
Output current continuous	I_{OUT}	-	20	35	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 (TLE9879QXA40)
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 (TLE9879QXA40)
Thermal						
Operating temperature	T_A	-40	25	105	°C	Specified for Design

Electromagnetic Compatibility		
Conducted emissions	Class 2	CISPR25, 150 kHz -108 MHz

Mechanical Specification	
Dimensions	168 mm x 107 mm x 15 mm (L x W x H) [1]
PCB	6-layer, top/bottom layer 2 oz, inner layers 1 oz, standard FR4, 168mm x 107 mm (L x W), thickness 1.6 mm

[1] A possibly mounted heatsink is not considered. The overall high is given by using C19, C28 and C37 in circuit DC link.

1.2 Overview

Figure 1 shows the 3D CAD view of the system. The board has seven MOSFETs equipped in a PG-TDSON-8 package (SSO8), one microcontroller with LIN and integrated 3-phase BLDC MOSFET gate driver. The board allows the configuration of the common low-side shunt-resistor of the B6- bridge by three resistors connected in parallel. All active components, including the seven MOSFETs and one driver IC, are large-area arranged 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 the three legs of the bridge. The board is designed to dissipate the heat of the shunts effectively through the thermal pads. As the power circuitry part of the PCB does not have any surface-mounted components on its bottom side, it is possible to attach a simple flat heatsink at the bottom of the board. Only controller side has through-hole connectors and a switch.

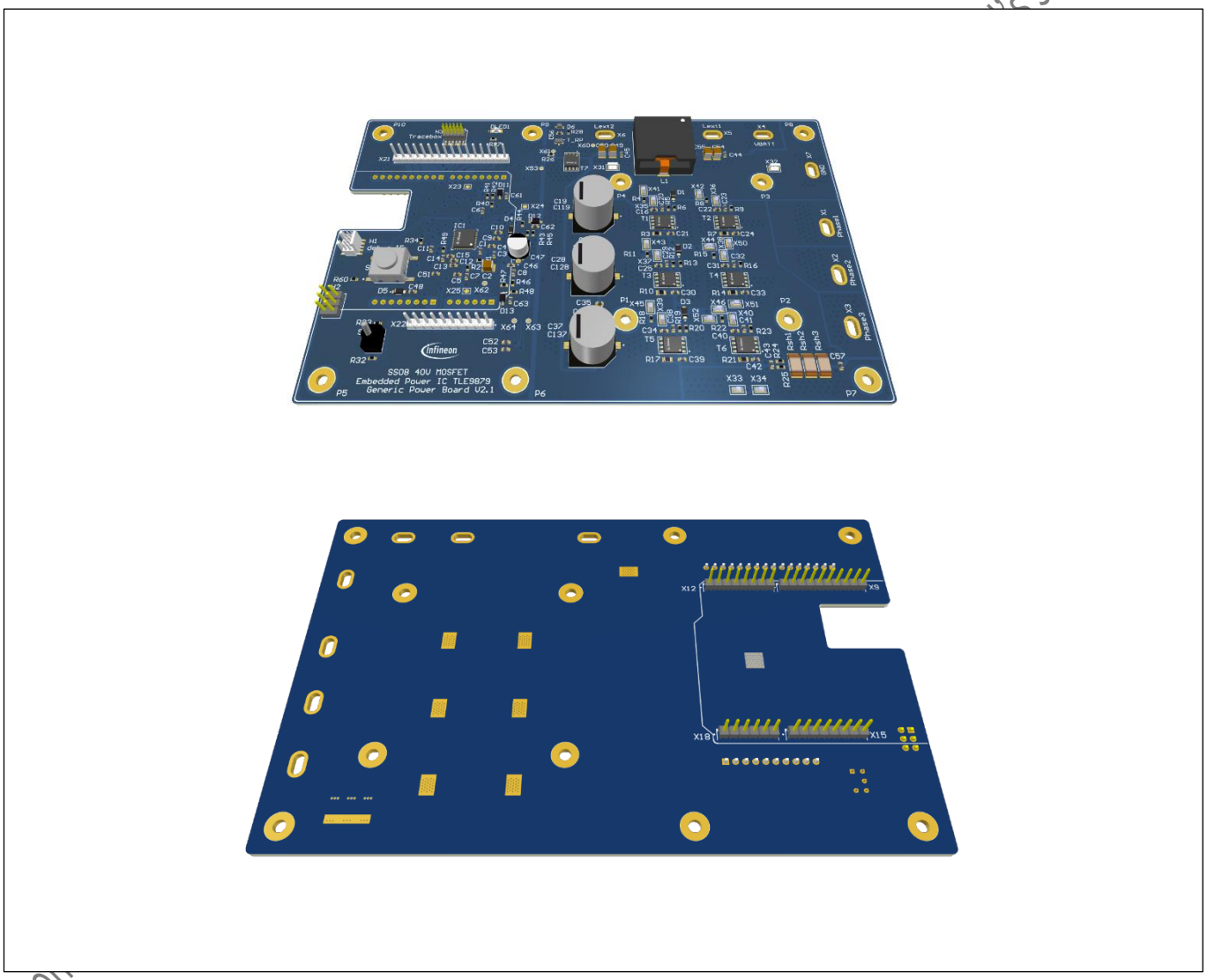

Figure 1 View to the evaluation Generic Power Board (top and bottom view)

1.3 Highlighted Products

Components highlighted with a grey background are used on the Generic Power Board.

1.3.1 OptiMOS™-6 40 V SSO8 (TDSON-8) MOSFET

The SSO8 package offers compact 33mm² footprint size with drain to source on-state resistance $R_{DS(on)}$ ranging from typically 0.54 ~4.4 [mΩ]. Its current rating is up to 3 times bigger than the S3O8 (TSDSON-8) package. In combination with Infineon's OptiMOS™-6 40 V power MOS technology, the TDSON package offers a compact yet powerful solution for automotive 3-phase motor drive up to 400W at Infineon's well known quality level for robust automotive packages.

Table 2 Automotive SSO8 MOSFET with 40 V OptiMOS™-6

Package	Silicon Technology	Product	Max $R_{DS(on)}$ [mΩ]
SSO8 (TDSON-8)	OptiMOS™-6	IAUC120N04S6L005	0.55
		IAUC120N04S6N006	0.6
		IAUC120N04S6N008	0.8
		IAUC120N04S6L008	0.8
		IAUC120N04S6N009	0.9
		IAUC120N04S6L009	0.9
		IAUC120N04S6N010	1.0
		IAUC120N04S6L012	1.2
		IAUC120N04S6N013	1.3
		IAUC100N04S6L014	1.4
		IAUC100N04S6N015	1.5
		IAUC100N04S6L020	2.0
		IAUC100N04S6N022	2.2
		IAUC100N04S6L025	2.5
		IAUC100N04S6N028	2.8
		IAUC80N04S6L032	3.2
		IAUC80N04S6N036	3.6
		IAUC60N04S6L039	3.9
		IAUC60N04S6N044	4.4

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 a high level of integration and low 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's webpage 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
	TLE9872QXA40	256 kByte	8 kByte	40 MHz	PWM + LIN	150 °C
	TLE9872-2QXA40	256 kByte	8 kByte	40 MHz	PWM + LIN	150 °C
	TLE9877QXA20	64 kByte	6 kByte	24 MHz	PWM + LIN	150 °C
	TLE9877QXA40	64 kByte	6 kByte	40 MHz	PWM + LIN	150 °C
	TLE9879QXA20	128 kByte	6 kByte	24 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

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 Developer Center. If you don't have this Infineon toolbox yet, please go to **Infineon Developer Center Launcher** and enjoy the release management for updates.
STEP3 Download and Install **Segger J-Link Driver**	XMC™ Link based on SEGGER J-Link technology	• XMC™ Link is a debug probe for all XMC microcontrollers • The debug probe is based on Segger J-Link debug firmware, which enables use with DAVE and all major third-party compiler/IDEs known from the wide ARM® ecosystem
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.

3 System Design

3.1 Electrical Design and Components

3.1.1 Input Filter

3.1.2 Reverse Polarity Protection

3.1.3 DC-link Electrolytic Capacitor

3.1.4 Shunt Resistor

3.1.5 Snubber

3.1.6 Gate Driver

3.1.7 Gate driver circuit

3.1.8 Heatsink

3.2 Switching Performance

3.3 EMC performance

3.3.1 Measurement configuration

3.3.2 Measurement results

3.4 Thermal performance

I

4 Project Collaterals

4.1 Schematics

4.2 Bill of Material

4.3 Layout

4.3.1 PCB Stack

4.3.2 Layout Printing

5 Abbreviations and definitions

Table 5 Abbreviations

Abbreviation	Definition
AC	Alternating Current
ARM	Advanced RISK Machine
ADC	Analogue-to-Digital Conversion
BDRV	Bridge Driver Module of Embedded Power IC
BLDC	Brushless Direct Current
BOM	Bill of material
CISPR	Comité International Spécial des Perturbations Radioélectriques
DC	Direct Current
DIL	Dual-In-Line
DUT	Device Under Test
ECU	Electrical Control Unit
ECF	Engine Cooling Fan
EMC	Electromagnetic Compatibility
ESR	Equivalent Series Resistant
FOC	Field Oriented Control
GPIO	General Purpose Input/Output
IC	Integrated Circuit
LIN	Local Interconnect Network
LISN	Line Impedance Stabilization Network
MCU	Microcontroller Unit
MI	Modulation Index
MLCC	Multi-Layer-Ceramic Capacitor
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
PCB	Printed Circuit Board
PG-TDSON	Plastic Green- Thin Dual Small-Outline Non-leaded
PWM	Pulse Width Modulation
RAM	Random Access Memory
RBP	Reverse Battery Protection
RC	Resistor-Capacitor
RISC	Reduced Instruction Set Computer
RMS	Root-Mean-Square value
S3O8	Shrink Super Small-Outline 8 pin
SDK	Software Development Kit
SMD	Surface-Mounted Device
SMT	Surface-Mounted Technology

SoC	System On a Chip
SOA	Safe Operating Area
SSO8	Super Small-Outline 8 pin
TIM	Thermal Interface Material
TH	Through Hole

6 Reference documents

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

[1] TLE9879QXA40 data sheet, Infineon Technologies AG, https://www.infineon.com/dgdl/Infineon-TLE9879QXA40-DataSheet-v02_00-EN.pdf?fileId=8ac78c8c81ae03fc0181d840096a3c2f

[2] XMC Link user's manual, Infineon Technologies AG, https://www.infineon.com/dgdl/Infineon-XMC_Link_Board_Users_Manual.pdf-UserManual-v01_00-EN.pdf?fileId=5546d462518ffd850152451695e45edc

[3] TLE986x_TLE987x Bridge Driver Application Note, 2022-05-02, Infineon Technologies AG, Rev 1.03 https://www.infineon.com/dgdl/Infineon-AppNote-TLE986x-TLE987x-FAQ-ApplicationHints_3-ApplicationNotes-v01_03-EN.pdf?fileId=5546d4625b62cd8a015ba9870bd91373

[4] IAUC120N04S6N010 datasheet, Infineon Technologies AG, https://www.infineon.com/dgdl/Infineon-IAUC120N04S6N010-DataSheet-v01_00-EN.pdf?fileId=5546d4626c1f3dc3016c4c43cb2e1748

[5] IAUC120N04S6N006 datasheet, Infineon Technologies AG, https://www.infineon.com/dgdl/Infineon-IAUC120N04S6N006-DataSheet-v01_00-EN.pdf?fileId=5546d46275b79adb0175e120b4b310b3

[6] 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.

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

[8] ERU chokes datasheet, TDK, https://www.tdk-electronics.tdk.com/inf/30/ds/B82559B_A019.pdf

[9] Heat sink profile, RS-Online, https://de.rs-online.com/web/p/kuhlkorper/1686330

[10] Thermal interface material TIM, DOWSIL™ TC-4060 Thermal Gel, https://www.dow.com/en-us/pdp.dowsil-tc-4060-thermal-gel.512275z.html?productCatalogFlag=1&#tech-content

[11] Motor load, Nanotc DB42S02, https://en.nanotec.com/products/635-db42s02

[12] Current controlled hysteresis break, Mobac HB-50-2DS, https://www.mobac.de/fileadmin/user_upload/Mobac/PDF/strom/strom-stand-bs.pdf

[13] User Manual TLE987x Microcontroller with LIN and BLDC MOSFET driver for automotive applications https://www.infineon.com/dgdl/Infineon-TLE987x_UM-UserManual-v01_08-EN.pdf?fileId=8ac78c8c81ae03fc0181d38669525fab

[14] Reverse Polarity Protection for Embedded Power ICs Application Note, https://www.infineon.com/dgdl/Infineon-Reverse_Polarity_Protection-AN-v01_00-EN.pdf?fileId=5546d46267c74c9a01684be08bf45dfb

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