

# Reference Design Guide

## Auxiliary Water Pump 100W

### Design overview

This Infineon Reference Design Guide describes a detailed implementation of an automotive auxiliary water pump using the 3-phase motor driver TLE9879 of the Embedded Power ICs family as BLDC motor controller. The three half-bridge MOSFET in a SSO8 package are used to control an auxiliary water pump with sensor less FOC.

The design is capable to drive loads up to 100W 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.

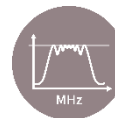
### Highlighted Components

- TLE9879QXW40
- IAUC60N04S6N031H
- IPZ40N04S5-3R1

### Applications

- Auxiliary water pump
- Oil pump
- 100W BLDC Motor for 12 V applications

### Highlighted Design Aspects



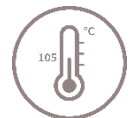
EMC  
optimized



Cost  
optimized

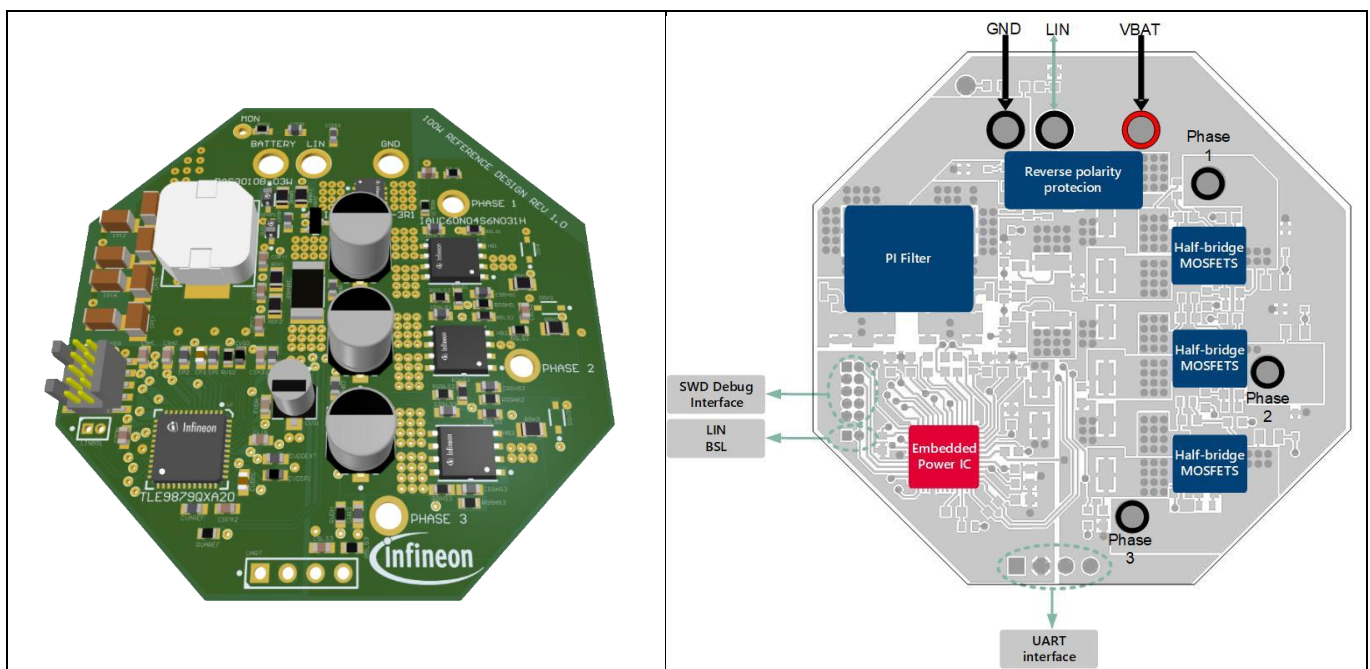


Space  
optimized



Thermally  
optimized

### Reference Design and Block Diagram



## Table of contents

<b>Table of contents</b> .....	<b>2</b>
<b>Important notice</b> .....	<b>3</b>
<b>1 System description</b> .....	<b>4</b>
1.1 Design specifications.....	4
1.2 Overview .....	6
1.3 Highlighted products .....	6
1.3.1 OptiMOS-6™ 40 V SSO8 (PG-TDSON-8) MOSFET .....	6
1.3.2 3-Phase bridge driver IC with integrated arm® Cortex®-M3.....	7
1.3.3 OptiMOS-5™ 40 V S308 (PG-TDSON-8) MOSFET .....	7
<b>2 Toolchain installation</b> .....	<b>8</b>
2.1.1 Configuration .....	8
<b>3 Electrical design and components</b> .....	<b>9</b>
3.1 DC-link electrolytic capacitor .....	9
3.2 Shunt resistor .....	9
3.3 Snubber .....	10
3.4 EMI input Pi-filter.....	10
3.5 Reverse polarity protection .....	10
<b>4 Hardware design</b> .....	<b>11</b>
4.1 Current flow.....	11
4.2 Thermal coupling .....	13
<b>5 System performance</b> .....	<b>14</b>
5.1 System test setup.....	14
5.1.1 FOC setup .....	15
5.1.2 Gate-drive setup.....	15
5.1.3 CCU6 setup .....	17
5.2 Electrical test result.....	18
5.2.1 Switching characteristics.....	18
5.3 Thermal behavior .....	20
5.3.1 Water cycles in thermal management.....	21
5.3.2 Thermal testing test setup.....	22
5.3.3 Self heating of active components.....	22
5.4 EMC .....	25
5.4.1 EMC test setup.....	25
5.4.2 Conducted emission with motor in off-state.....	25
5.4.3 Conducted emission with motor in on-state .....	26
5.4.4 Note for radiated emission measurement .....	28
<b>6 Project collaterals</b> .....	<b>30</b>
6.1 Schematics .....	30
6.2 Bill of material .....	34
6.3 Layout .....	37
<b>7 Abbreviations and definitions</b> .....	<b>40</b>
<b>8 Reference documents</b> .....	<b>41</b>
<b>Revision history</b> .....	<b>42</b>

## Important notice

The Evaluation Boards and Reference Boards and the information in this document are solely intended to support designers of applications to evaluate the use of products of Infineon Technologies in the intended application.

Environmental conditions have been considered in the design of the Evaluation Boards and Reference Boards provided by Infineon Technologies. The design of the Evaluation Boards and Reference Boards is **tested by** Infineon Technologies only as described in this document. The design is not qualified in terms of safety requirements, manufacturing and operation over the entire operating temperature range or lifetime.

The Evaluation Boards and Reference Boards provided by Infineon Technologies are **subject to functional testing only under typical load conditions**. Evaluation Boards and Reference Boards are not subject to the same procedures as regular products regarding returned material analysis (RMA), process change notification (PCN) and product discontinuation (PD).

Evaluation Boards and Reference Boards are not commercialized products and are **solely intended to be used for evaluation and testing purposes**. They shall in particular not be used for reliability testing or production. Hence, the Evaluation Boards and Reference Boards may not comply with CE or similar standards (including but not limited to the EMC Directive 2004/EC/108 and the EMC Act) and may not fulfill other requirements of the country in which they are operated by the customer. The customer shall ensure that each Evaluation Boards and Reference Board will be handled in a way which is compliant with all relevant requirements and standards in the country in which they are operated.

The Evaluation Boards and Reference Boards and any information in this document are addressed **only to qualified and skilled technical staff, for laboratory usage**, and shall be used and managed according to the terms and conditions set forth in this document and in any other related documentation provided with the respective Evaluation Boards or Reference Board.

It is the **responsibility of customer's technical departments to evaluate the suitability** of the Evaluation Boards and Reference Boards for the intended application and the completeness and correctness of the information provided in this document with respect to such application.

The customer accepts that the Evaluation Boards and Reference Boards are not intended to be used for life-endangering applications such as medical, nuclear, military, life-critical or other applications, where failure of the Evaluation Boards and Reference Boards or any results from the use thereof can reasonably be expected to result in personal injury.

**The Evaluation Boards and Reference Boards and any information in this document is provided "as is" and Infineon Technologies disclaims any and all warranties, express or implied, including but not limited to warranties of non-infringement of third party rights and implied warranties of fitness for any purpose, or for merchantability.**

**Infineon Technologies shall not be responsible for any damages resulting from the use of the Evaluation Boards and Reference Boards and/or from any information provided in this document. The customer is obliged to defend, indemnify and hold harmless Infineon Technologies from and against any claims or damages arising out of or resulting from any use thereof.**

Infineon Technologies reserves the right to change this document and/or any information provided herein at any time without further notice.

## 1 System description

The reference design describes a solution for an auxiliary water pump. 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 (TLE9879QXW40) 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 SSO8 half-bridge 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.

Parameter	Symbol	Values			Unit	Comment
		Min.	Typ.	Max.		
<b>System Parameters</b>						
Input voltage	$V_{IN}$	-0.3	12	40	V	P_1.1.1 (TLE9879QXW40)
Functional input voltage	$V_{IN}$	7	12	18	V	Specified according to water-pump specification
Peak input current	$I_{IN}$	-	-	13.5	A	Peak current (<10 s)
Nominal input current	$I_{IN}$	-	5	10	A	Specified for design
LIN interface	$V_{LIN}$	-28	12	40	V	P_1.1.7 (TLE9879QXW40)
Phase 1,2,3	$V_{SH}$	-8	12	48	V	P_1.1.11 (TLE9879QXW40)
<b>Thermal</b>						
Operating temperature	$T_A$	-40	25	120	°C	Specified for Design
<b>Electromagnetic Compatibility</b>						
Conducted emissions				Class 5		CISPR25, 150 kHz -108 MHz
<b>Mechanical Specification</b>						
Dimensions PCB	55 mm x 55 mm x 10 mm (W x D x H)					
PCB + pump	118 mm x 74 mm x 140 mm (W x D x H)					



Figure 1 PCB in pump housing

## 1.2 Overview

0 shows the 3D CAD view of the system. The FR4 4 layer board has three SS08 half-bridge MOSFETs, one TSDSON-8 MOSFET for active reverse polarity protection, one 3-phase gate driver, and one shunt resistor. All active components, including the 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 resistor is an additional heat source. It collects all return current from three legs of the bridge. As the PCB does only have surface-mounted components, it is possible to be directly connected to the pumps housing for optimized cooling.

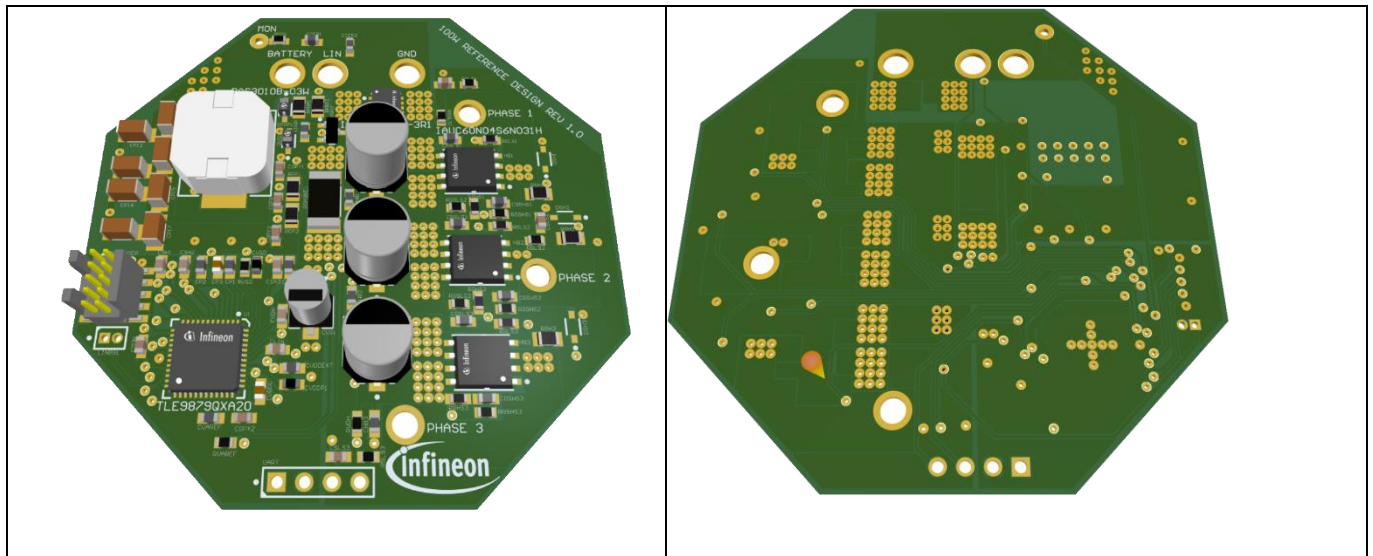


Figure 2 View of the reference design from top and bottom

## 1.3 Highlighted products

### 1.3.1 OptiMOS-6™ 40 V SS08 (PG-TDSON-8) MOSFET

The SS08 package offers high current capability of 60 A with a footprint of 5x6 mm<sup>2</sup>. In combination with Infineon’s leading OptiMOS-6™ 40 V power MOS technology, SS08 offers optimized layout for B6 applications and cost 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/IAUC60N04S6N31H](http://www.infineon.com/IAUC60N04S6N31H)

Table 1 Automotive SS08 MOSFET with 40 V OptiMOS-6™

Package	Silicon Technology	Product	Max R <sub>DS(on)</sub> [mΩ]	ID [A]	QG [nC]
SS08 (TDSON-8)	OptiMOS™-6	IAUC60N04S6L030H	3.0	60	27
		IAUC60N04S6N031H	3.1	60	23
		IAUC60N04S6L045H	4.5	60	14
		IAUC60N04S6N050H	5.0	60	13
		IAUC45N04S6L063H	6.3	45	10
		IAUC45N04S6N070H	7.0	45	9

### 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](http://www.infineon.com/tle987x)

**Table 2 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
	TLE9879QX40W	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

### 1.3.3 OptiMOS-5™ 40 V S308 (PG-TDSON-8) MOSFET

The S308 package offers high current capability of 40 A with a footprint of 3.3x3.3 mm<sup>2</sup>. In combination with Infineon's leading OptiMOS-5™ 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. In combination with Infineon's robust S308 leadless package technology, it enables very small and efficient systems designs with minimal RDS(on) down to 2.8 mΩ. For more information about the product, please visit the Infineon web-page linked below.

- [www.infineon.com//optimos5-40v60v](http://www.infineon.com//optimos5-40v60v)

**Table 3 Automotive S308 MOSFET with 40 V OptiMOS-5™**

Package	Silicon Technology	Product	Max R <sub>DS(on)</sub> [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

## 2 Toolchain installation

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

The  $\mu$ Vision software is a development tool provided by arm® Keil®. With code length limitation, the shareware version of the  $\mu$ Vision 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  $\mu$ Vision 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  $\mu$ Vision.

**Table 4 Software Toolchain Installation Guide**

Steps	Company	Description
<b>STEP1</b> Download and Install <a href="#">Keil® <math>\mu</math>Vision5</a>	Arm® Keil®	<ul style="list-style-type: none"> <li>Arm® Keil® <math>\mu</math>Vision is an integrated development environment which consists of code editor, compiler and debugger.</li> <li>To learn how to use arm® Keil® <math>\mu</math>Vision 5, check out our video "<a href="#">Get your motor spinning</a>".</li> </ul>
<b>STEP2</b> Download Config Wizard	Infineon Technologies	<ul style="list-style-type: none"> <li>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.</li> <li>Config Wizard can be installed via the Infineon Toolbox. If you don't have the Infineon Toolbox yet, please go to <a href="#">Infineon Toolbox</a> and enjoy the release management for updates.</li> </ul>
<b>STEP3</b> Download and Install <a href="#">Segger J-Link Driver</a>	SEGGER	<ul style="list-style-type: none"> <li>SEGGER J-Link is a widely used driver for "on-board" or "stand-alone" debugger.</li> </ul>
<b>STEP4</b> Download the SDK via $\mu$ Vision5 Pack Installer	Infineon Technologies	<ul style="list-style-type: none"> <li>The Embedded Power Software Development Kit (SDK) is a low level driver library which can be downloaded within Keil® <math>\mu</math>Vision via the "Pack Installer"</li> </ul>

For the toolchain installation and free motor drive software, please check below link.

[www.infineon.com/embedded-power](http://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  $\mu$ Vision5 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.



## 7 Abbreviations and definitions

**Table 11** Abbreviations

Abbreviation	Definition
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

## 8 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](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](https://www.infineon.com/dgdl/Infineon-TLE987x_TLE986x-BDRV-ApplicationNotes-v01_02-EN.pdf?fileId=5546d46267c74c9a0167cbe1686a191d)
- [3] IPZ40N04S5L-2R8 datasheet, Infineon Technologies AG, [https://www.infineon.com/dgdl/Infineon-IPZ40N04S5L-2R8-DS-v01\\_01-EN.pdf?fileId=5546d4624cb7f111014d6601139b4890](https://www.infineon.com/dgdl/Infineon-IPZ40N04S5L-2R8-DS-v01_01-EN.pdf?fileId=5546d4624cb7f111014d6601139b4890)
- [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] Reverse Polarity Protection for Embedded Power ICs, 2018-12, Infineon Technologies AG, Rev 1.0 [https://www.infineon.com/dgdl/Infineon-Reverse\\_Polarity\\_Protection-AN-v01\\_00-EN.pdf?fileId=5546d46267c74c9a01684be08bf45dfb](https://www.infineon.com/dgdl/Infineon-Reverse_Polarity_Protection-AN-v01_00-EN.pdf?fileId=5546d46267c74c9a01684be08bf45dfb)
- [6] IPC-2152, 2003-05, Institute for Interconnecting and Packaging Electronic Circuits
- [7] IEC 60664-1, 2007-04, International Electrotechnical Commission



Reference documents

## Document Preview

### Revision history

#### Major changes since the last revision

Date	Version	Description
29.09.2020	V1.0	Initial version

#### Trademarks

All referenced product or service names and trademarks are the property of their respective owners.

**Edition 2020-03-11**

**Published by**

**Infineon Technologies AG**

**81726 Munich, Germany**

**©2020} Infineon Technologies AG.**

**All Rights Reserved.**

**Do you have a question about this document?**

**Email: [erratum@infineon.com](mailto:erratum@infineon.com)**

**Document reference**

#### IMPORTANT NOTICE

THE INFORMATION AND DATA GIVEN IN THIS DOCUMENT IS PROVIDED BY INFINEON TECHNOLOGIES FOR THE SOLE PURPOSE OF SUPPORTING DESIGNERS OF SYSTEMS TO EVALUATE THE USE OF INFINEON PRODUCTS IN THE INTENDED APPLICATION.

INFINEON TECHNOLOGIES HEREBY DISCLAIMS ALL WARRANTIES AND LIABILITIES OF ANY KIND WITH RESPECT TO ANY INFORMATION AND DATA GIVEN IN THIS DOCUMENT, INCLUDING WITHOUT LIMITATION WARRANTIES OF NON-INFRINGEMENT OF INTELLECTUAL PROPERTY RIGHTS OF ANY THIRD PARTY OR FITNESS FOR A PARTICULAR PURPOSE.

THE INFORMATION AND DATA CONTAINED IN THIS DOCUMENT IS EXCLUSIVELY INTENDED FOR TECHNICALLY SKILLED STAFF. IT IS THE DESIGNER'S RESPONSIBILITY TO EVALUATE THE SUITABILITY OF THE INFINEON PRODUCTS FOR THE INTENDED APPLICATION AND THE CORRECTNESS AND COMPLETENESS OF THE INFORMATION AND DATA GIVEN IN THIS DOCUMENT WITH RESPECT TO SUCH APPLICATION.

WITH REGARD TO THE TECHNICAL SPECIFICATIONS OF PRODUCTS OF INFINEON TECHNOLOGIES, WE KINDLY ASK YOU TO REFER TO THE RELEVANT PRODUCT DATA SHEETS PROVIDED BY US.

WE RESERVE THE RIGHT TO CHANGE THIS DOCUMENT AND/OR ANY INFORMATION AND DATA GIVEN HEREIN AT ANY TIME WITHOUT FURTHER NOTICE.

单击下面可查看定价，库存，交付和生命周期等信息

[>>Infineon\(英飞凌\)](#)