

# XMC1302

32-bit Microcontroller Series for Industrial Applications

## Server Fan Control Reference Design

AP32294

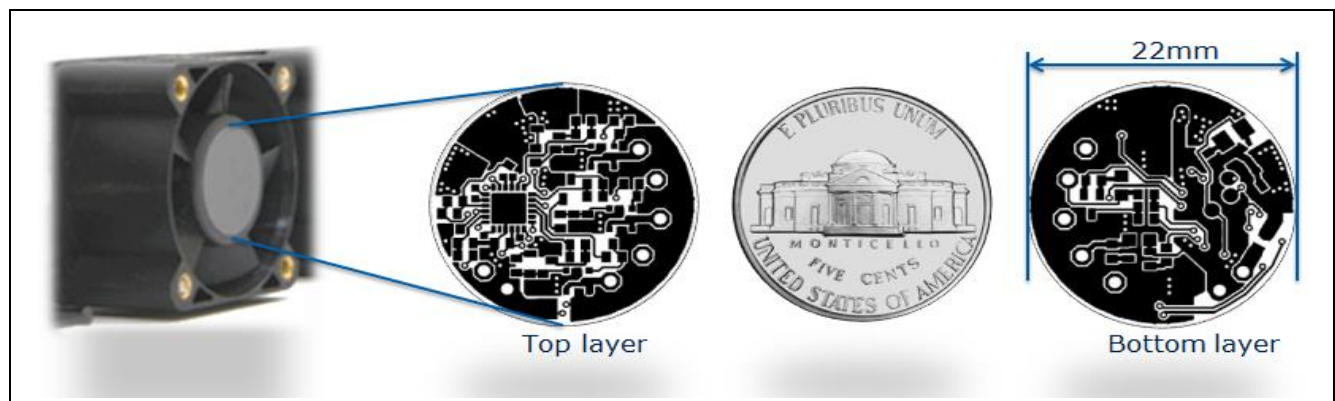
Application Note

### About this document

#### Scope and purpose

The Infineon ‘Server Fan Reference Design’ is a complete solution for a low-voltage fan motor drive application (a BLDC and PMSM server fan motor), with low noise, minimal motor vibration, and a very low external component count. This application is typically used to supply cooling air to electronic equipments. The compact design is based around the Infineon 32-bit ARM® Cortex™ XMC1302 microcontroller with ready-to-use sensorless Field Oriented Control (FOC) firmware to support fast implementation into existing development platforms. The XMC1302 is a low-cost, high-performance microcontroller, and has flexible ADC features, Capture Compare Units (CCU4/8), and a Math Co-processor.

The PCB layout has a unique ‘coin concept’. The spacing on the PCB board is utilized with surface mount components which results in lower BOM costs:



**Figure 1** Server Fan PCB layout ‘coin concept’

#### Intended audience

Server Fan motor manufacturers and design engineers who intend to reduce the system cost, improve efficiency, and shorten the application development cycle.

### Table of Contents

#### Applicable Products

- XMC1302
- BSL308C
- BC848W
- IFX20001MB
- DAVE™

#### References

The User's Manual can be downloaded from <http://www.infineon.com/XMC>

DAVE™ and its resources can be downloaded from <http://www.infineon.com/DAVE>

## Table of Contents

<b>About this document .....</b>	<b>1</b>
<b>Table of Contents .....</b>	<b>2</b>
<b>1 XMC1302 features .....</b>	<b>3</b>
<b>2 Reference Design Target Requirements .....</b>	<b>4</b>
<b>3 System Block Diagram.....</b>	<b>5</b>
<b>4 Motor Drive features .....</b>	<b>6</b>
4.1 Infineon Sensorless FOC algorithm with XMC1302 .....	6
<b>5 Hardware design.....</b>	<b>7</b>
5.1 Form factors .....	7
5.2 Pin mapping .....	7
5.3 Microcontroller Motor Control Ports .....	8
5.4 MOSFET stage.....	9
5.5 Microcontroller Control Interface.....	10
5.6 Power Supply .....	11
<b>6 Software State Machine.....</b>	<b>12</b>
<b>7 Motor Control Test Data .....</b>	<b>13</b>
7.1 Start-up Current Waveform .....	13
7.2 Power Stage Inverter Dead-Time.....	14
7.3 Motor Steady-State Current Waveform .....	16
7.4 Motor High Speed Current Waveform .....	17
7.5 Start-up Lock Detection .....	18
<b>8 Revision History.....</b>	<b>19</b>

# **1 XMC1302 features**

The XMC1302 is a low-cost microcontroller, optimized for motor control applications.

## **Package types**

- TSSOP-16
- VQFN-24
- TSSOP-28
- TSSOP-38
- VQFN-40

## **XMC1302 as a controller for various types of motor**

- Permanent Magnet Synchronous Motors (PMSM)
- Brushless DC Motors
- AC Induction Motors (ACIM)
- Servo Motors
- Brushed DC Motors

## **Key features**

- High performance 32-bit Cortex-M0 CPU
- MATH Co-processor (MATH), consists of a CORDIC unit for trigonometric calculation and a division unit
- On-Chip Memories, 16 kbytes on-chip high-speed SRAM, up to 200 kbytes on-chip Flash program and data memory
- 12 channels 12-bit ADCs with hardware trigger
- Built-in Temperature Sensor
- Capture/Compare Units 4 (CCU4) for use as general purpose timers
- Capture/Compare Units 8 (CCU8) for motor control PWM generation
- Watchdog Timer (WDT) for safety sensitive applications

## **2 Reference Design Target Requirements**

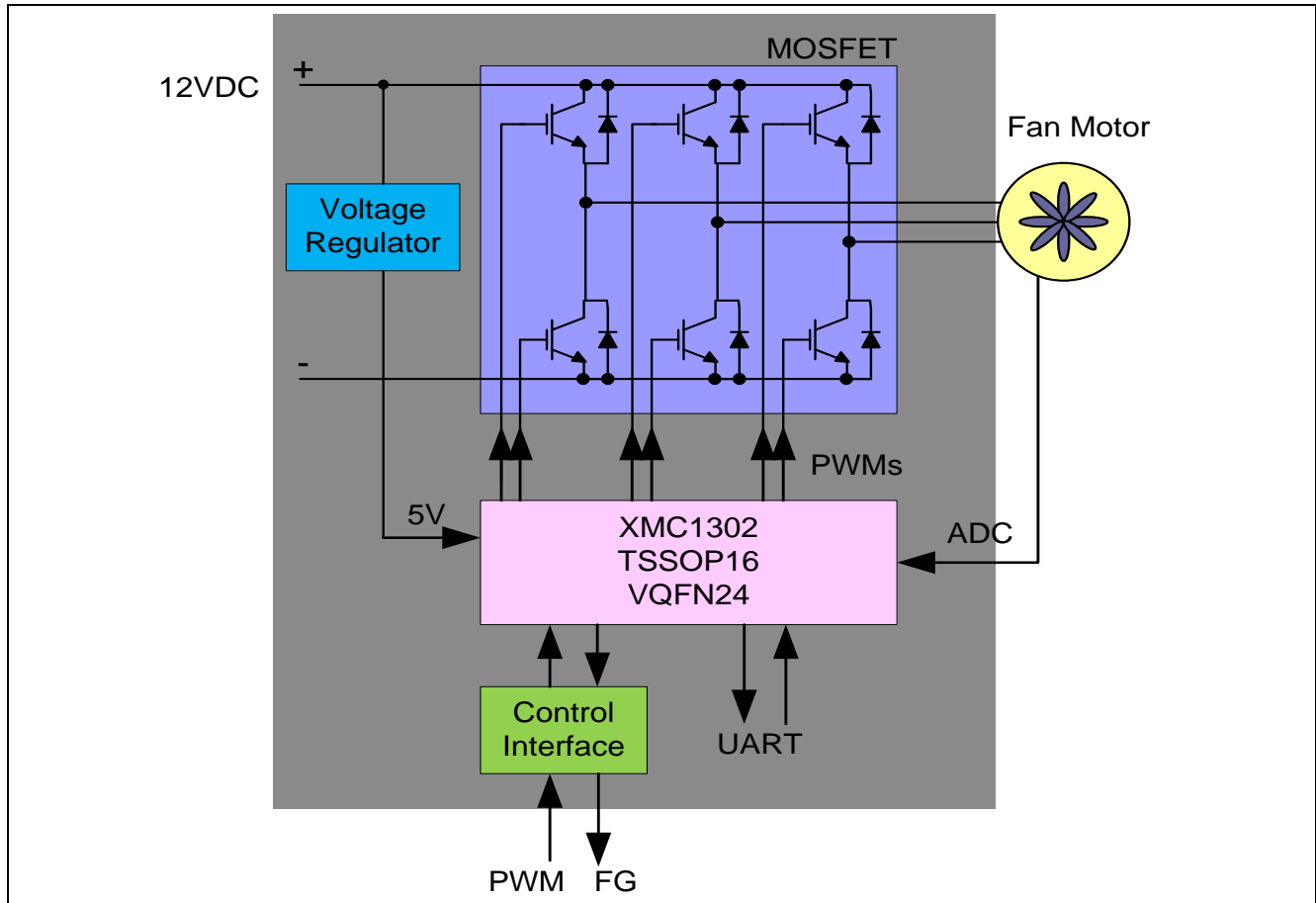
The reference design is intended to meet common server fan application specifications:

**Table 1 Reference Design Requirements**

<b>Item</b>	<b>Requirement</b>
Motor Type	3 Phase PMSM motor
Motor Pole Pair	2 pp
Motor Resistance (per phase)	1.1 ~ 1.2 $\Omega$
Motor Inductance (per phase)	293 ~ 302 $\mu$ H (10 kHz)
PCB Layout Diameter	22 mm
Operating Voltage	12 V
Current Rating	1.00 A
Power Rating	12 W
Speed	0 to 25000 rpm
Fault Detection	Lock, reverse polarity
Over Current	Yes
Control Interface	POT / PWM input / FG Output
Control Algorithm	Field Oriented Control
Microcontroller	XMC1302 TSSOP16/VQFN24

*Note: All test waveforms are captured and shown later in this document.*

### 3 System Block Diagram



**Figure 2 System Block Diagram**

The hardware can be divided into four parts:

- Microcontroller (MCU)
  - The MCU consists of an XMC1302 ARM® Cortex™ with single-shunt Field Oriented Control (FOC) algorithm. It is used to control high-side and low-side transistors with adjustable dead-time.
- MOSFET stage
- Control interface
- Voltage regulator

This reference design uses ADC for current measurement with integrated gain in the XMC1302 microcontroller.

A two-wire SWD or single-wire SPD debugging interface is supported.

## **4 Motor Drive features**

The major requirements of server fan applications are for low audible noise and high efficiency. To boost the efficiency, design engineers need a means to offset the higher cost of a 3-phase fan motor compared to a single or dual-phase fan motor.

Most server fan motors are based on a 3-phase Brushless DC (BLDC) motor and Permanent Magnet Synchronous Motor (PMSM). While BLDC and PMSM motors have always been preferred for performance (efficiency, noise, starting torque), a complex and robust sensorless motor control algorithm is required.

### **4.1 Infineon Sensorless FOC algorithm with XMC1302**

- Fast execution with hardware Math co-processor
- Optimized FOC block, without Inverse Park Transform
- Optimized Space Vector Modulation (SVM) using internal amplifier for single-shunt current sensing
- One single CORDIC calculation for Space Vector Modulation (SVM)
- Smooth and low-power start-up

## 5 Hardware design

This reference design hardware includes single-shunt current measurement. The operating supply voltage of the hardware is 10V to 30V. It supports up to 25 kHz PWM switching frequency.

### 5.1 Form factors

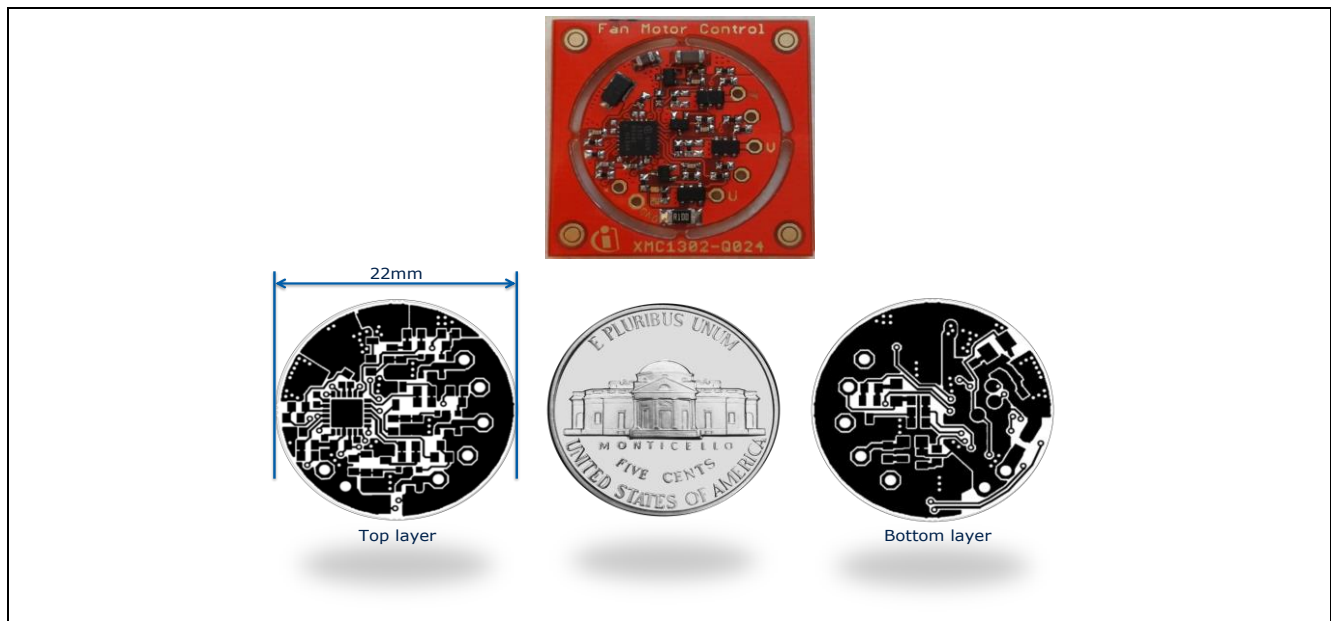


Figure 3 Diameter 22 mm with 2 layer Circular PCB layout

### 5.2 Pin mapping

XMC1302-VQFN24			
S/N	Signal	Description	1-Shunt, CoinInverter
1	HO1	High side drive for Phase U MOSFET	P0.0 (CCU80.OUT00)
2	LO1	Low side drive for Phase U MOSFET	P0.5 (CCU80.OUT01)
3	HO2	High side drive for Phase V MOSFET	P0.7 (CCU80.OUT10)
4	LO2	Low side drive for Phase V MOSFET	P0.6 (CCU80.OUT11)
5	HO3	High side drive for Phase W MOSFET	P0.8 (CCU80.OUT20)
6	LO3	Low side drive for Phase W MOSFET	P0.9 (CCU80.OUT21)
7	IDC+	ADC for DC link current sensing	P2.7 (G1.CH1)
8	DC_LINK_DIV	Voltage of DC link (with voltage divider)	P2.2 (G0.CH7)
9	IN (PWM)	PWM duty cycle for speed adjustment	P1.1 (CCU40.IN1L)
10	OUT (FG/RD)	Voltage of DC link (with voltage divider)	P1.2 (CCU40.OUT2)
11	Debug	SWDIO_0 / SPD_0 / RX	P0.14
12	Debug	SWDCLK_0 / TX	P0.15

Figure 4 XMC1302 VQFN pin assignment

### 5.3 Microcontroller Motor Control Ports

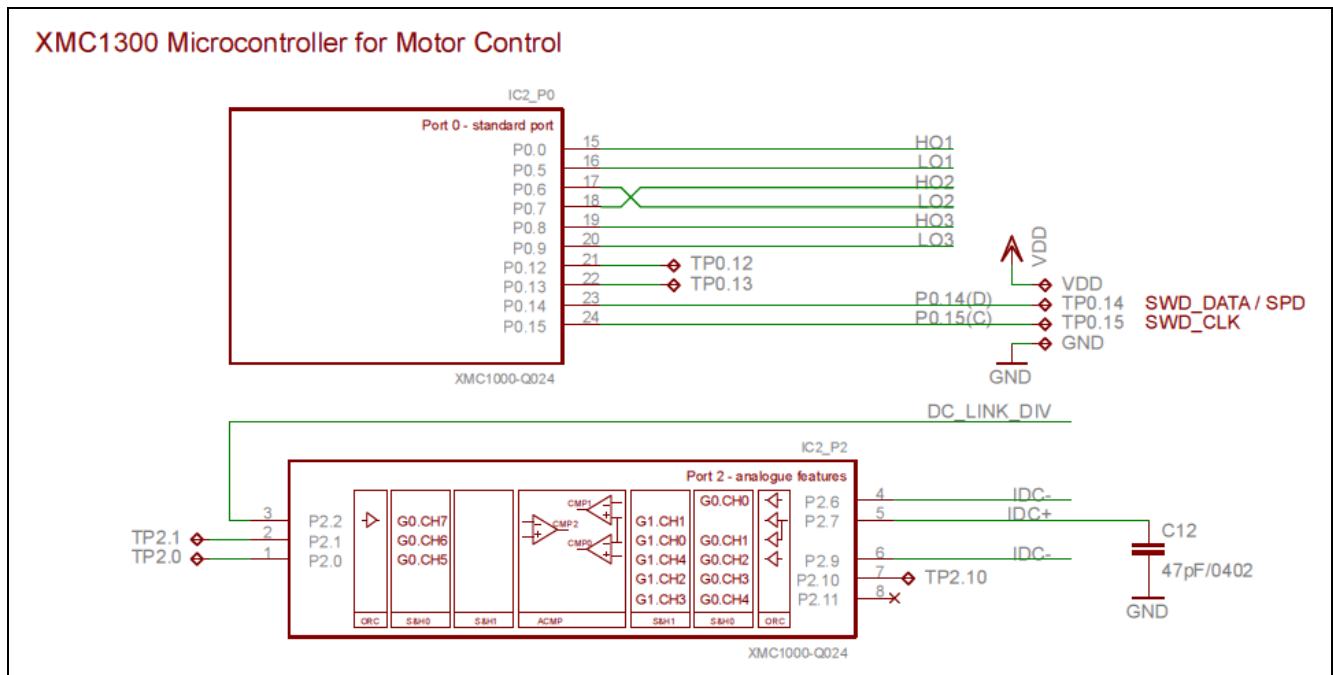


Figure 5 XMC1302 Motor Control Ports

#### Highlights

- XMC1302 ARM® Cortex™ - M0 32-bit microcontroller for motor control.
- Control of High-side and Low-side transistors with dead-time.
- ADC current measurement with adjustable gain.
- Support debug interface which includes two wire SWD or 1 wire SPD.
  - The non-isolated debug interface pins are connected directly to the controller.
- No external crystal or resonator is required. This helps for small size PCB layout.



## 5.4 MOSFET stage

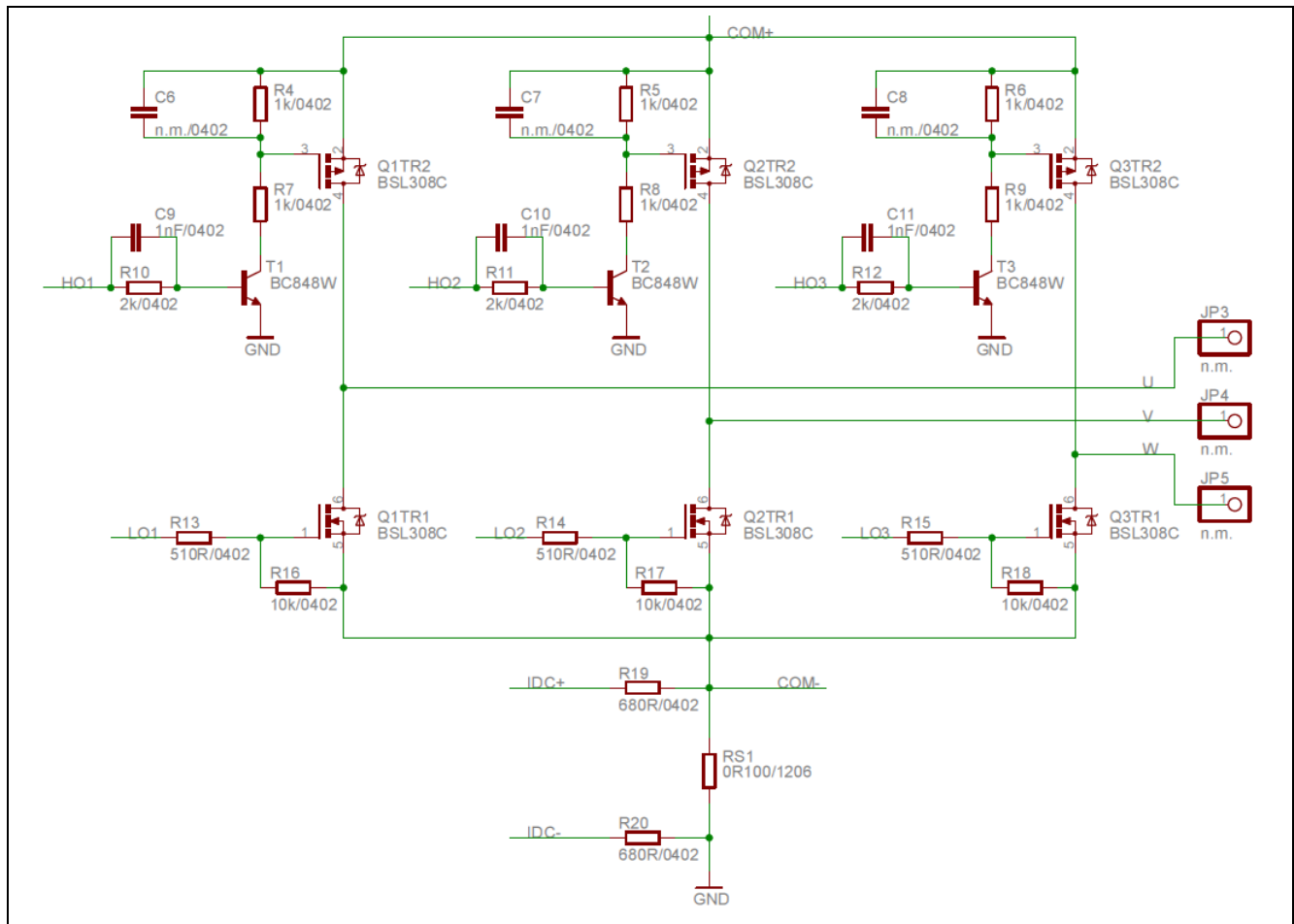


Figure 6 High-side and Low-side MOSFET circuitry

### Highlights

- Dual MOSFET switching with enhanced High-side driver circuitry.
- Direct drive of Low-side MOSFET.
- Single Shunt current sensing measurement.

## 5.5 Microcontroller Control Interface

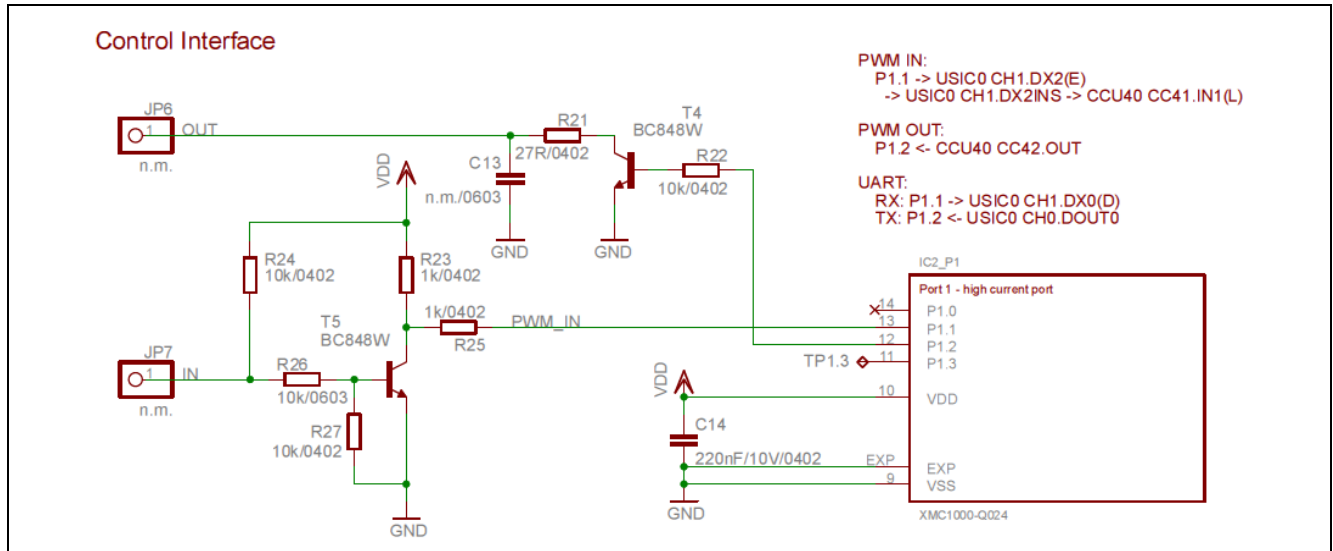
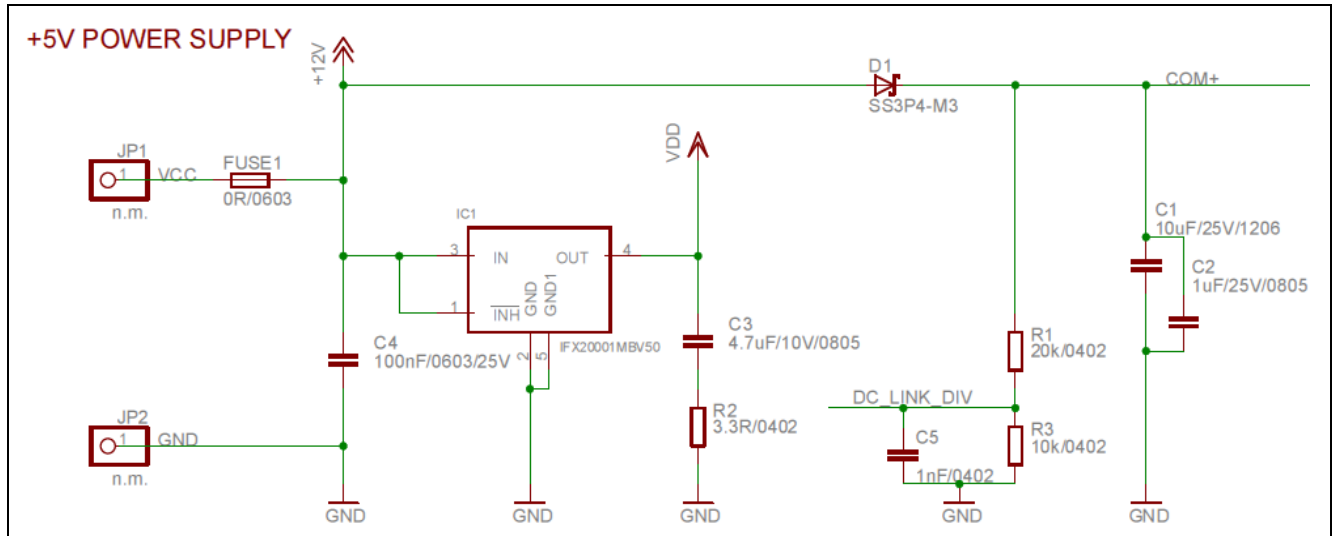


Figure 7 Interface circuitry with XMC1302

### Highlights

- Speed control with PWM input including 12V level shifter.
- FG output with open collector circuitry for use in 12V domain.
- Two independent UART channels (RXD/TXD) with 12V level shifter (optional).

## 5.6 Power Supply



**Figure 8 Low Dropout Power Supply**

### Highlights

- IFX20001MBV5 in small package SCT-595.
- Input voltage range up to 45V.
- Output voltage 5V, output current 30mA.
- Protection functions include over-temperature protection, and reverse polarity protection.
- Wide temperature range  $-40^{\circ}\text{C} \leq T_j \leq 125^{\circ}\text{C}$ .

## 6 Software State Machine

The Infineon Server Fan Control Reference Design software provides the following life-cycle states:

- Brake
  - When the board is powered on, braking is applied for position alignment.
- Start-up
  - The motor will start based on the voltage applied.
- Ramping
  - It performs speed adjustment (ramp-up or ramp-down).
- Transition
  - Maximum Efficiency Tracking (MET) is applied to increase transition from open loop to closed loop stability.
- Stop/Trip Protection
  - If any over-current protection is triggered, the motor will stop or stop-restart the operation.
- FOC PLL Observer
  - Closed loop algorithm to estimate the rotor position based on single shunt current feedback measurement.

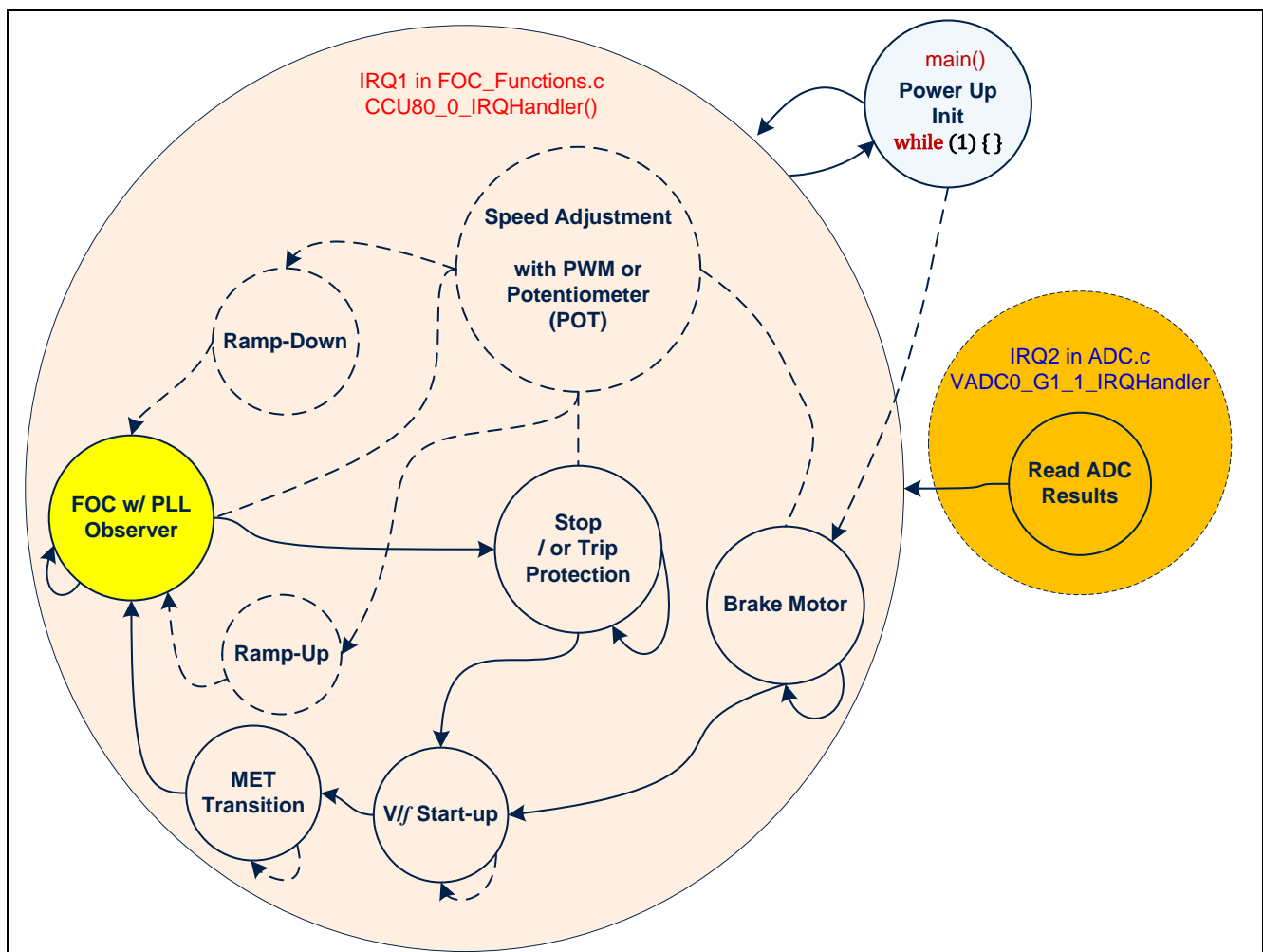


Figure 9 Software State Machine

## 7 Motor Control Test Data

### 7.1 Start-up Current Waveform

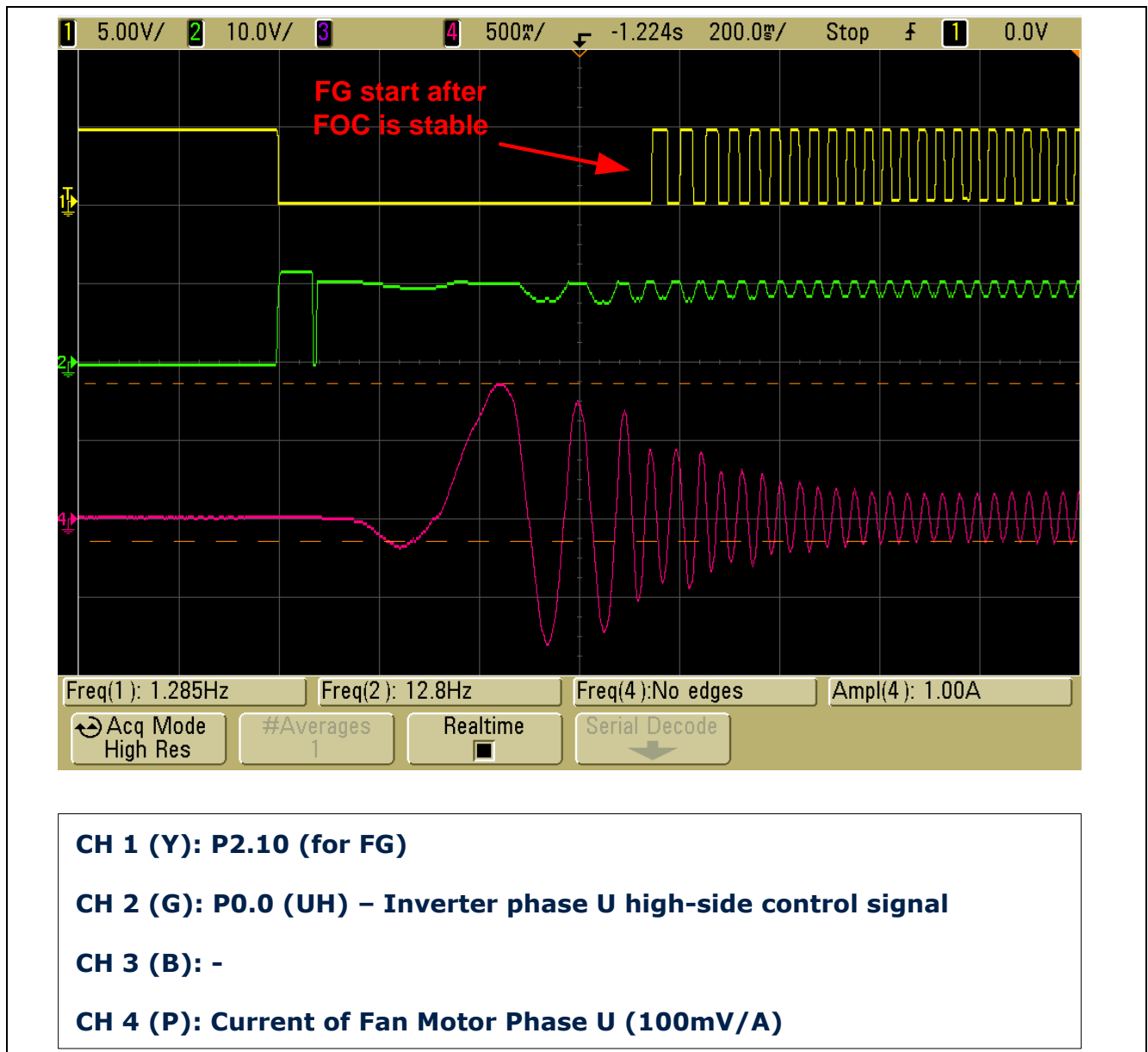


Figure 10 Direct FOC Start-up

When the fan motor is at a standstill, it is impossible to sense positional information from motor back-EMF. The Infineon Server Fan Reference Design provides FOC direct start-up control to achieve better efficiency.

## 7.2 Power Stage Inverter Dead-Time

To minimize the unwanted ripple in torque that may affect motor motion smoothness, the XMC1302 Capture Compare Unit (CCU4/8) provides flexible dead-time generation. This is used to generate a blanking time period (high-side and low-side transistor in off-state simultaneously). Both transistors are switched off for a short period of time to prevent the transistors conducting simultaneously and causing a short circuit from DC link voltage to ground. The CCU8 supports assymetric dead-time which is required in this application for efficient switching.

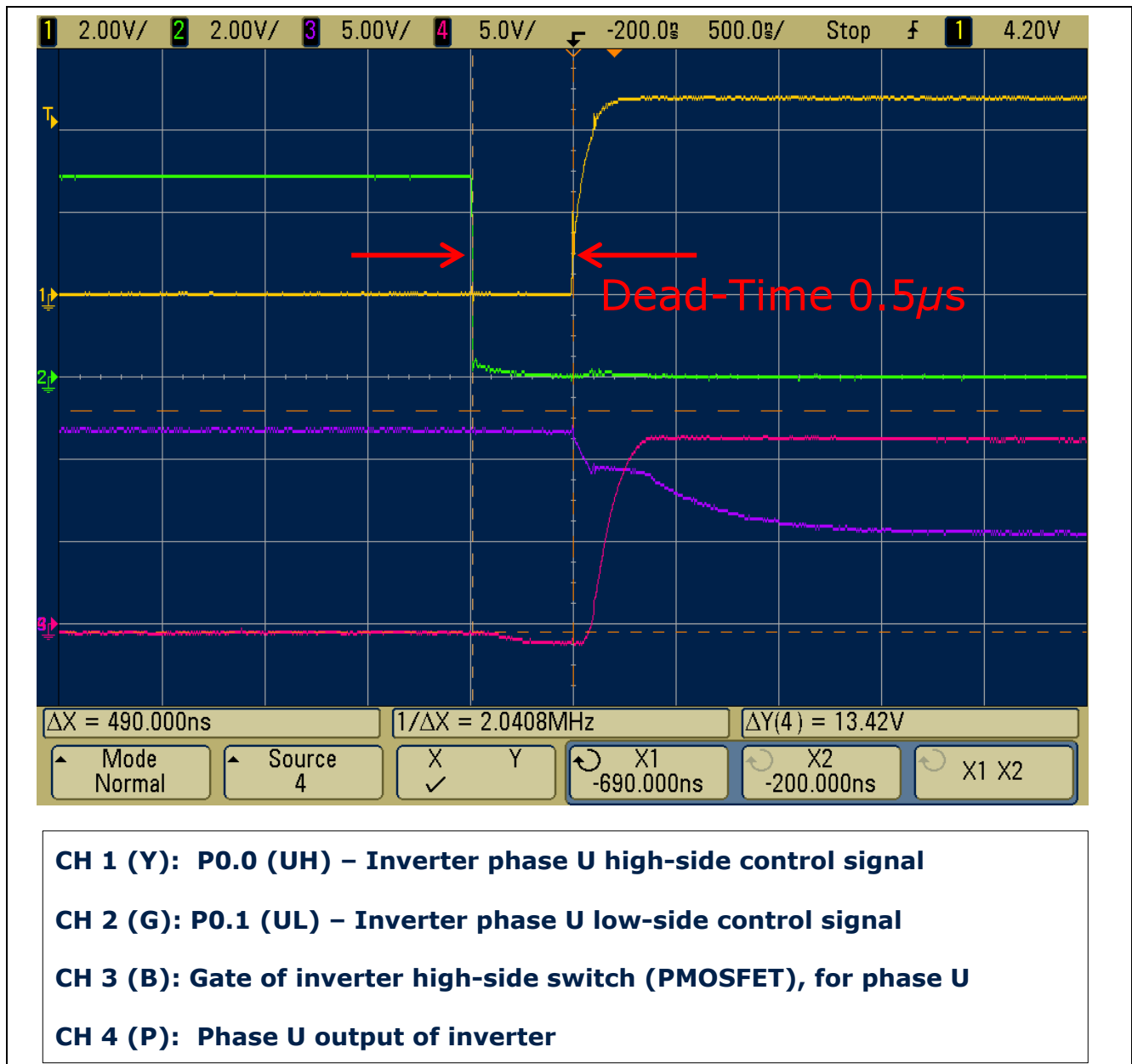


Figure 11 Phase U Rising Edge Output

Motor Control Test Data

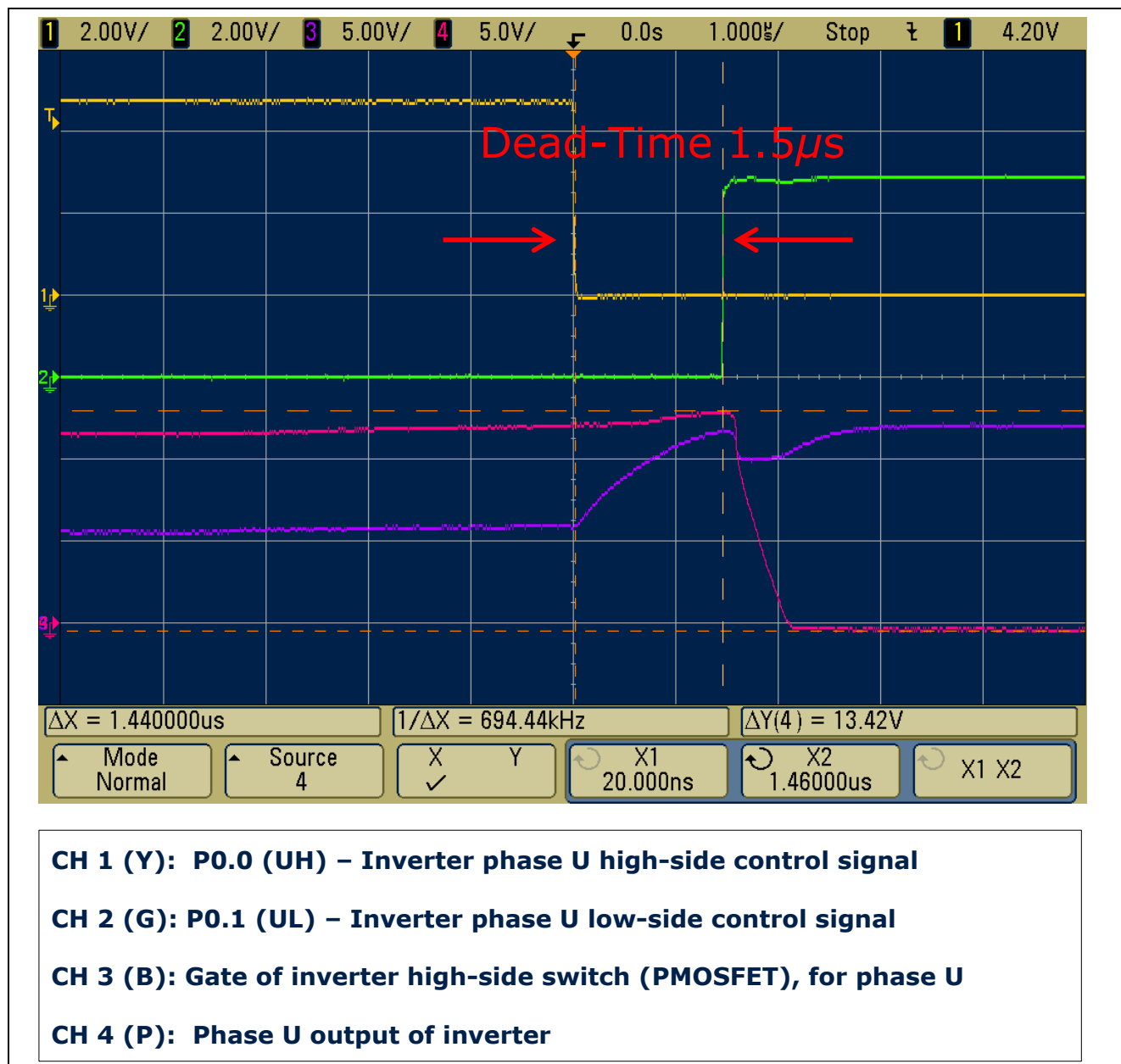
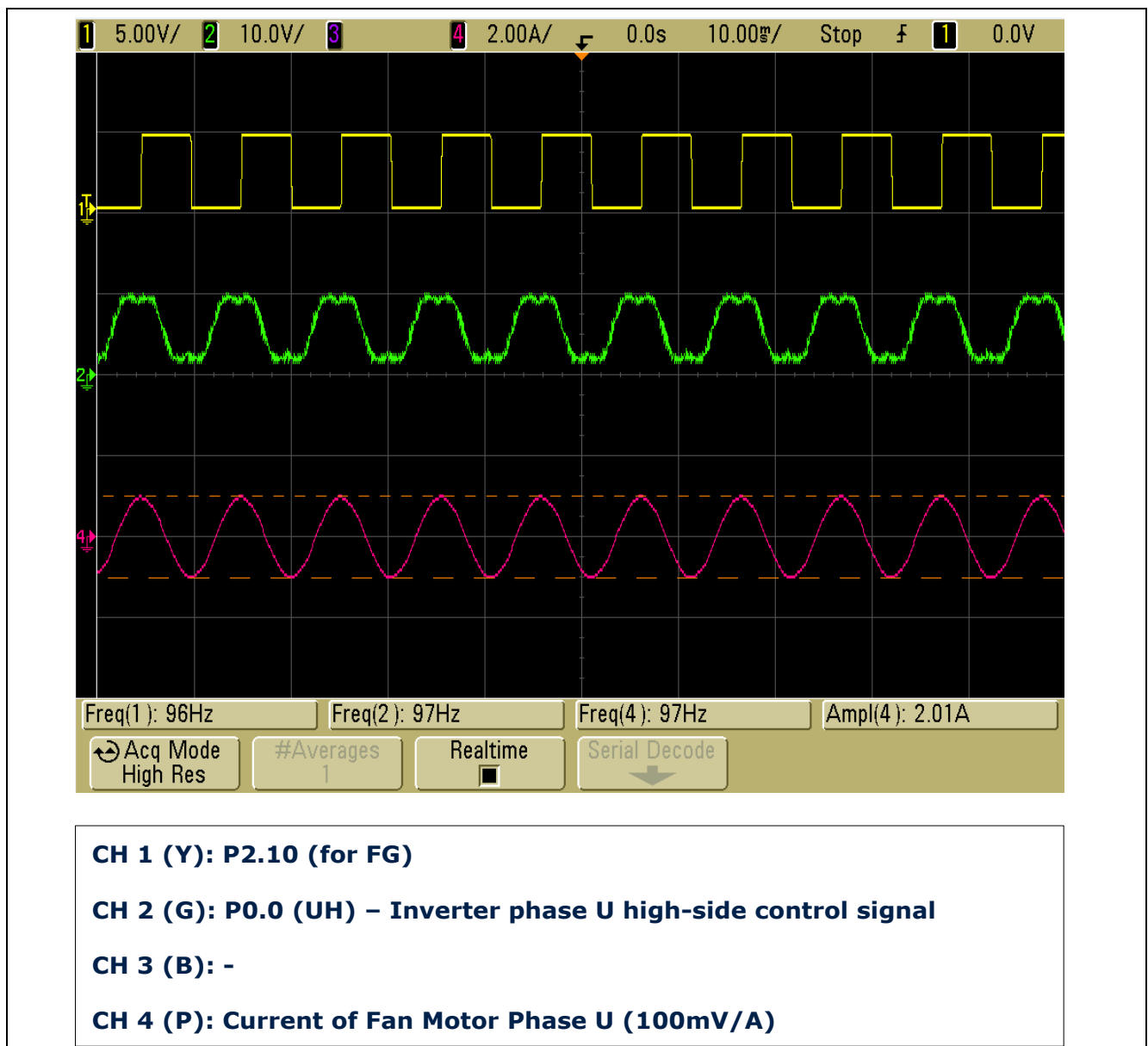


Figure 12 Phase U Failing Edge Output

### 7.3 Motor Steady-State Current Waveform



**Figure 13 At steady state stage (FOC Closed Loop)**

The Frequency Generator (FG) output is an important feature because it provides feedback for the system to monitor the speed behavior of the Server Fan. For example, if the FG output is at 96Hz:

$$\omega = \frac{60 \times FG_{freq}}{n} = \frac{60 \times 96 \text{ Hz}}{2}$$

$$\omega = 2880$$

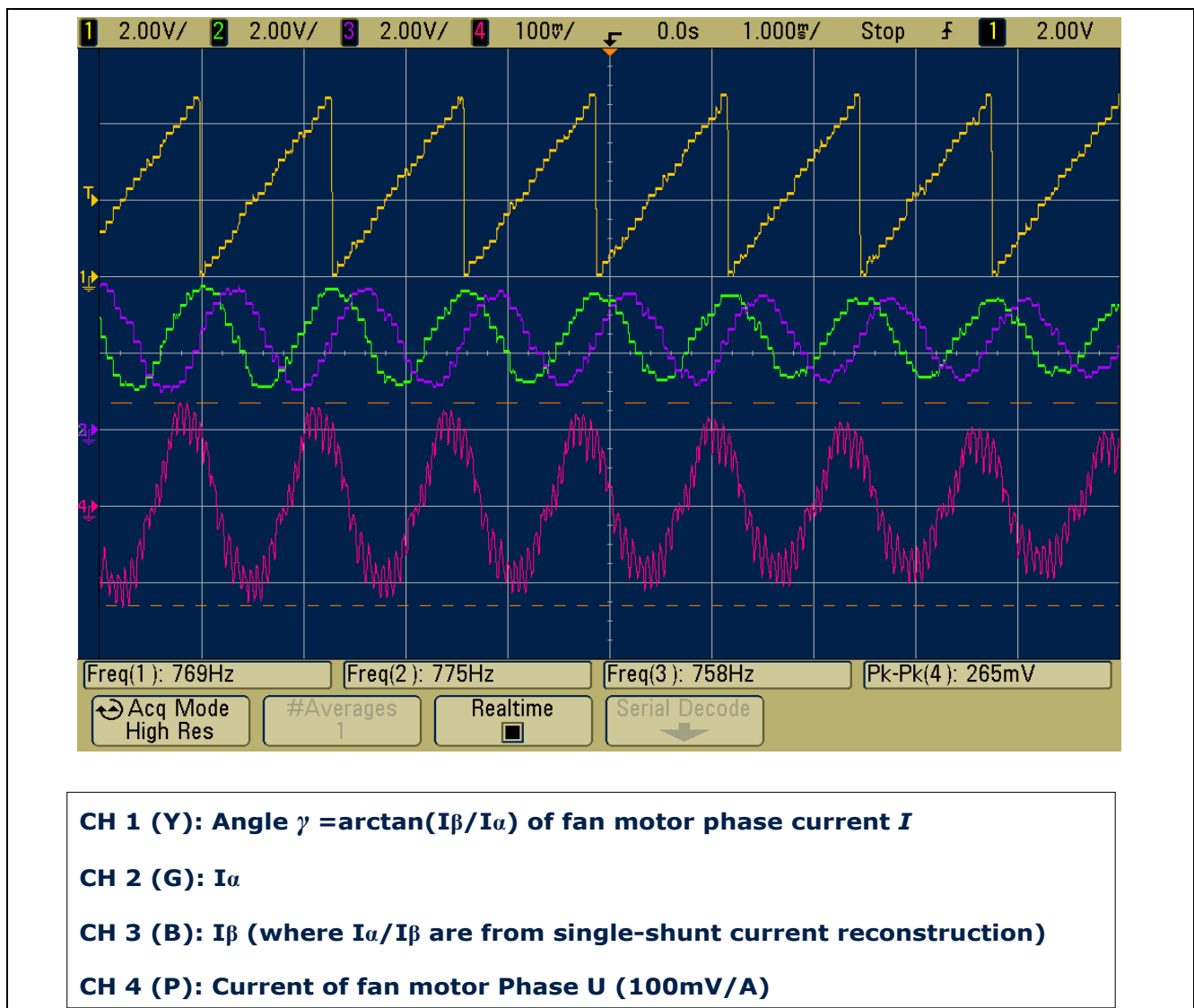
Where:

$\omega$  = Motor Speed (in rpm)

$n$  = Number of pole pairs



## 7.4 Motor High Speed Current Waveform



**Figure 14 Motor Phase Current with constant high speed**

The motor phase current waveform has a harmonic PWM frequency of 15 kHz. The harmonic distortion is mainly due to the small phase inductance of the fan motor. By increasing the PWM frequency, the harmonic distortion could be reduced.

$$\omega = \frac{60 \times \gamma}{n} = \frac{60 \times 769 \text{ Hz}}{2}$$

$$\omega = 23,070$$

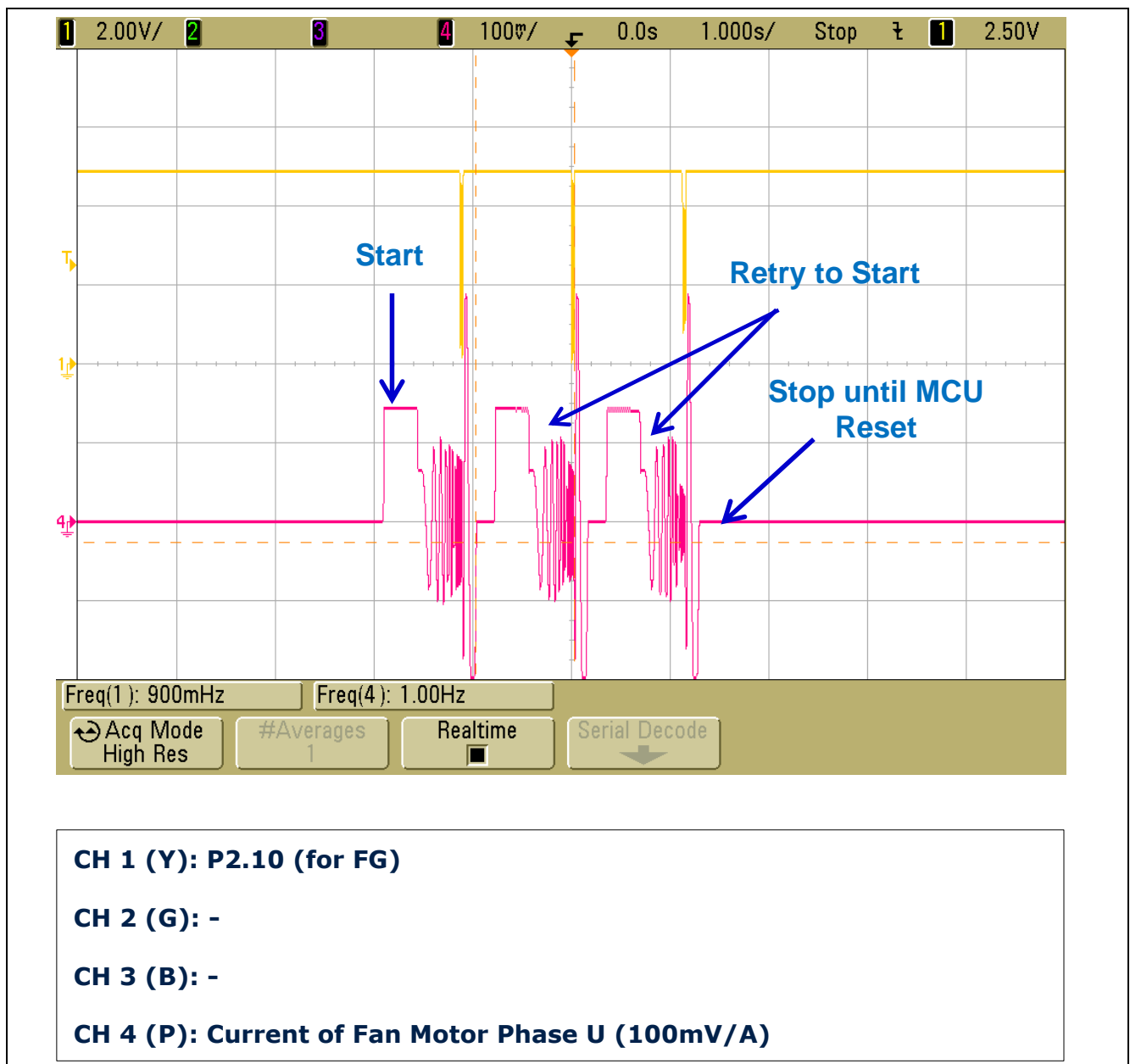
Where:

$\omega$  = Motor Speed (in rpm)

$n$  = Number of pole pairs

$\gamma$  = Angle (in Hz)

## 7.5 Start-up Lock Detection



**Figure 15 Phase Current Waveform during Start-up**

The FG pin outputs a PWM waveform under normal operating conditions. During the start-up lock protection, FG output remains high until the motor restarts. The retry process will only be stopped when the microcontroller power is reset.

## 8 Revision History

Current Version is V1.0, 2015-04

Page or Reference	Description of change
V1.0, 2015-03	
	Initial Version

#### Trademarks of Infineon Technologies AG

AURIX™, C166™, CanPAK™, CIPOST™, CIPURSE™, CoolGaN™, CoolMOS™, CoolSET™, CoolSiC™, CORECONTROL™, CROSSAVE™, DAVE™, DI-POL™, DrBLADE™, EasyPIM™, EconoBRIDGE™, EconoDUAL™, EconoPACK™, EconoPIM™, EiceDRIVER™, eupec™, FCOS™, HITFET™, HybridPACK™, ISOFACE™, IsoPACK™, i-Wafer™, MIPAQ™, ModSTACK™, my-d™, NovalithIC™, OmniTune™, OPTIGA™, OptiMOS™, ORIGA™, POWERCODE™, PRIMARION™, PrimePACK™, PrimeSTACK™, PROFET™, PRO-SIL™, RASIC™, REAL3™, ReverSave™, SatRIC™, SIEGET™, SIPMOS™, SmartLEWIS™, SOLID FLASH™, SPOC™, TEMPFET™, thinQ!™, TRENCHSTOP™, TriCore™.

#### Other Trademarks

Advance Design System™ (ADS) of Agilent Technologies, AMBA™, ARM™, MULTI-ICE™, KEIL™, PRIMECELL™, REALVIEW™, THUMB™, μVision™ of ARM Limited, UK. ANSI™ of American National Standards Institute. AUTOSAR™ of AUTOSAR development partnership. Bluetooth™ of Bluetooth SIG Inc. CAT-iq™ of DECT Forum. COLOSSUS™, FirstGPS™ of Trimble Navigation Ltd. EMV™ of EMVCo, LLC (Visa Holdings Inc.). EPCOS™ of Epcos AG. FLEXGO™ of Microsoft Corporation. HYPERTERMINAL™ of Hilgraeve Incorporated. MCS™ of Intel Corp. IEC™ of Commission Electrotechnique Internationale. IrDA™ of Infrared Data Association Corporation. ISO™ of INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. MATLAB™ of MathWorks, Inc. MAXIM™ of Maxim Integrated Products, Inc. MICROTEC™, NUCLEUS™ of Mentor Graphics Corporation. MIPI™ of MIPI Alliance, Inc. MIPS™ of MIPS Technologies, Inc., USA. muRata™ of MURATA MANUFACTURING CO., MICROWAVE OFFICE™ (MWO) of Applied Wave Research Inc., OmniVision™ of OmniVision Technologies, Inc. Openwave™ of Openwave Systems Inc. RED HAT™ of Red Hat, Inc. RFMD™ of RF Micro Devices, Inc. SIRIUS™ of Sirius Satellite Radio Inc. SOLARIS™ of Sun Microsystems, Inc. SPANSION™ of Spansion LLC Ltd. Symbian™ of Symbian Software Limited. TAIYO YUDEN™ of Taiyo Yuden Co. TEAKLITE™ of CEVA, Inc. TEKTRONIX™ of Tektronix Inc. TOKO™ of TOKO KABUSHIKI KAISHA TA. UNIX™ of X/Open Company Limited. VERILOG™, PALLADIUM™ of Cadence Design Systems, Inc. VLYNQ™ of Texas Instruments Incorporated. VXWORKS™, WIND RIVER™ of WIND RIVER SYSTEMS, INC. ZETEX™ of Diodes Zetex Limited.

Last Trademarks Update 2014-07-17

[www.infineon.com](http://www.infineon.com)

**Edition 2015-04**

**Published by**

**Infineon Technologies AG**

**81726 Munich, Germany**

**© 2015 Infineon Technologies AG.**

**All Rights Reserved.**

**Do you have a question about any aspect of this document?**

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

**Document reference**

AP32294

#### Legal Disclaimer

THE INFORMATION GIVEN IN THIS APPLICATION NOTE (INCLUDING BUT NOT LIMITED TO CONTENTS OF REFERENCED WEBSITES) IS GIVEN AS A HINT FOR THE IMPLEMENTATION OF THE INFINEON TECHNOLOGIES COMPONENT ONLY AND SHALL NOT BE REGARDED AS ANY DESCRIPTION OR WARRANTY OF A CERTAIN FUNCTIONALITY, CONDITION OR QUALITY OF THE INFINEON TECHNOLOGIES COMPONENT. THE RECIPIENT OF THIS APPLICATION NOTE MUST VERIFY ANY FUNCTION DESCRIBED HEREIN IN THE REAL APPLICATION. INFINEON TECHNOLOGIES HEREBY DISCLAIMS ANY AND ALL WARRANTIES AND LIABILITIES OF ANY KIND (INCLUDING WITHOUT LIMITATION WARRANTIES OF NON-INFRINGEMENT OF INTELLECTUAL PROPERTY RIGHTS OF ANY THIRD PARTY) WITH RESPECT TO ANY AND ALL INFORMATION GIVEN IN THIS APPLICATION NOTE.

#### Information

For further information on technology, delivery terms and conditions and prices, please contact the nearest Infineon Technologies Office ([www.infineon.com](http://www.infineon.com)).

#### Warnings

Due to technical requirements, components may contain dangerous substances. For information on the types in question, please contact the nearest Infineon Technologies Office. Infineon Technologies components may be used in life-support devices or systems only with the express written approval of Infineon Technologies, if a failure of such components can reasonably be expected to cause the failure of that life-support device or system or to affect the safety or effectiveness of that device or system. Life support devices or systems are intended to be implanted in the human body or to support and/or maintain and sustain and/or protect human life. If they fail, it is reasonable to assume that the health of the user or other persons may be endangered.