TIOL221 Dual Channel IO-Link Device Evaluation Module

TEXAS INSTRUMENTS

Description

The TIOL221 evaluation module (EVM) is a platform to evaluate the main features and performance of the TIOL221 in both the pin-control and SPI configurations. The EVM contains an industry standard 4-pin M12 connector with a Class A 2-channel configuration implementing one IO-Link communication channel and one digital input or output channel. A screw terminal block for bare wire connections or external loads is also provided.
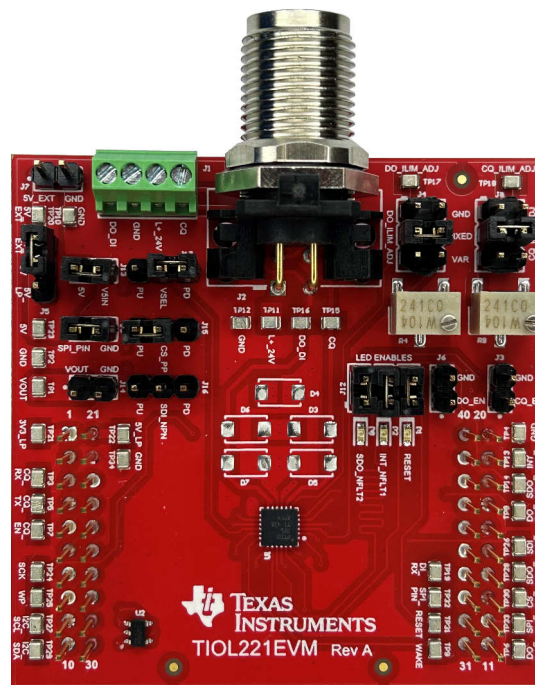
Features

- TIOL221 dual channel IO-link device PHY with integrated LDO and SPI interface
- Industry standard 4-pin M12 connector for a 2-channel configuration (one IO-Link and one DO/DI) as well as a bare-wire screw terminal

- Footprints for TVS diodes or extra filtering components to protect from noise and transient pulses
- Current limits are configurable with potentiometers or a dedicated resistor option selected with a jumper
- Fault conditions visually indicated with LEDs
- Header pins, and test points to facilitate both Pin Mode and SPI Mode operation
- 8KB I2C EEPROM

Applications

- Field transmitters and actuators
- Factory automation
- Process automation
- IO-link PHY in remote IO

TIOL221EVM

1 Evaluation Module Overview

1.1 Introduction

The TIOL221EVM provides the user with the ability to evaluate all features of the TIOL221 device.

The EVM contains an industry standard 4-pin M12 connector with a Class A 2-channel configuration implementing one IO-Link communication channel and one digital input or output channel. A screw terminal block for bare wire connections or external loads is also provided for the L+_24V, GND, CQ, and DO/DI nets.

The low-voltage digital input and output signals are easily accessible for connection to test equipment or a microcontroller through both header pins and test points. The profile of the board also allows the board to be directly connected to a number of TI microcontroller boards for rapid prototyping.

1.2 Kit Contents

- One TIOL221EVM board
- EVM disclaimer Read Me

1.3 Specification

When TIOL221 is connected to an IO-Link controller through a three-wire interface, the controller can initiate communication and exchange data with a remote node with the TIOL221 IO-Link transceiver acting as a complete physical layer for the communication.

The TIOL221EVM can be directly mated with many compatible TI microcontrollers, or connected to any other board through the interface headers. Standalone evaluation of the TIOL221 using standard test equipment is also possible with the TIOL221EVM.

The TIOL221 can operate in two modes: pin-mode or SPI mode. When the SPI/$\overline{\text{PIN}}$ pin is low, the device operates in pin-mode. When the SPI/$\overline{\text{PIN}}$ pin is high, the device operates in SPI mode. Placing a shunt jumper on header J9 connects the SPI/$\overline{\text{PIN}}$ to GND holding the pin low and causing the device to operate in pin-mode. Likewise, not connecting a shunt jumper on header J9 connects the SPI/$\overline{\text{PIN}}$ to VOUT through a pull-up resistor causing the device to operate in SPI mode.
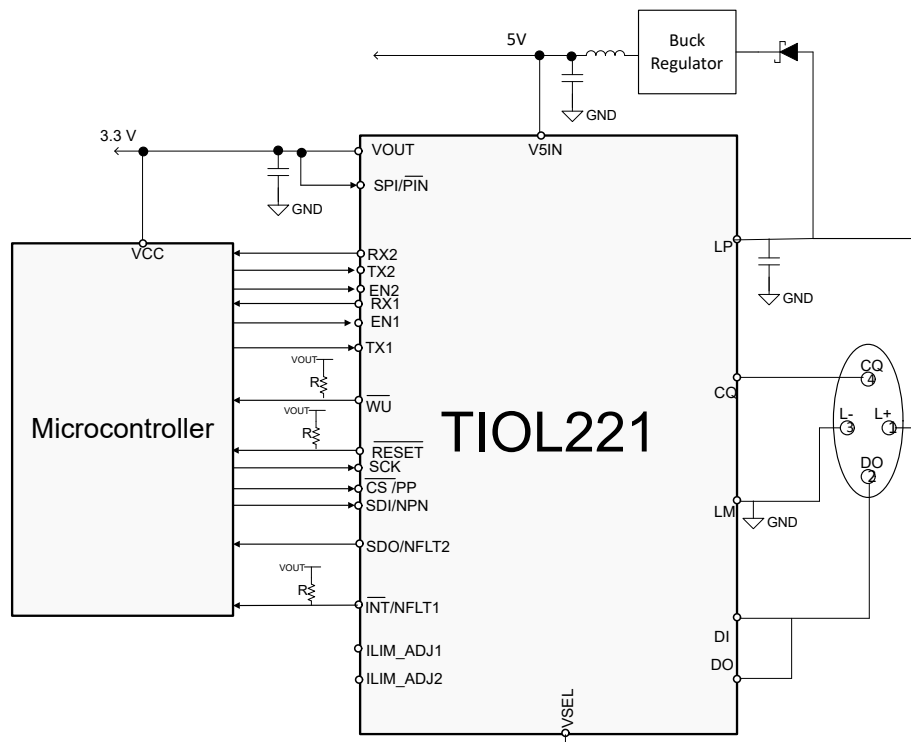

Figure 1-1. Typical Application

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1.4 Device Information

The TIOL221 has an IO-Link compatible channel (CQ), a digital output driver (DO) and a digital input (DI) interface. The drivers at CQ and DO can be used in either push-pull, high-side driver (PNP), or low-side driver (NPN) configuration using the $\overline{CS}$/PP and SDI/NPN pins in the pin-mode or via the serial peripheral interface (SPI). The internal receiver on the CQ line converts the 24V signal to standard logic levels on the receiver data output pin, RX1. Similarly, the internal receiver on the DI line converts the 24V signal to standard logic levels on the receiver data output pin, RX2. A simple parallel interface is used to receive/transmit data and status information between the device and the local controller.

The device can be configured by using the pins via pin-mode (when SPI/$\overline{PIN}$ is tied low) or using the SPI (when SPI/$\overline{PIN}$ is tied high). By using the SPI, the microcontroller can read additional diagnostics and status information as well as configure the device.

The device has integrated IEC 61000-4-4/5 EFT and surge protection. In addition, tolerance to ±70V transients enables flexibility to choose from a wider range of TVS diodes if an application requires higher levels of protection. These integrated robustness features simplify the system level design by reducing external protection circuitry.

TIOL221 transceiver implements protection features for overcurrent, overvoltage and over-temperature conditions. The device also provides a current-limit setting on the driver output current using an external resistor.

The device derives the low-voltage supply from the IO-Link LP voltage (24V nominal) via an internal linear regulator to provide power to the local controller and sensor circuitry.
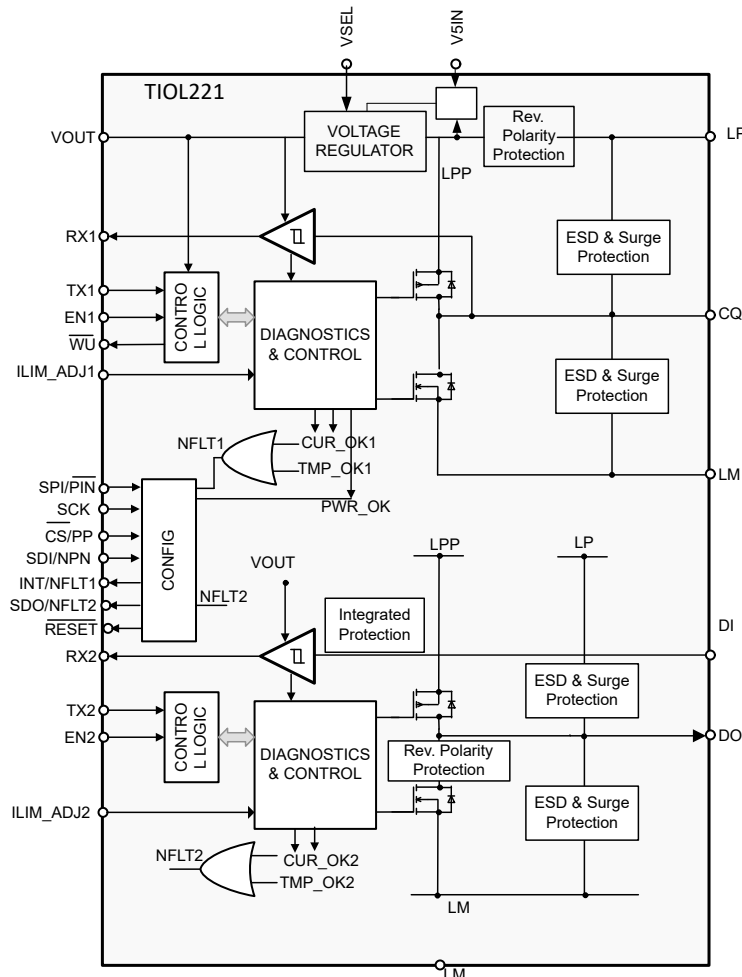

Figure 1-2. TIOL221 Functional Block Diagram

2 Hardware
2.1 Power Requirements

L+_24V is the primary supply voltage for the board and must be applied to pin 1 (L+_24V) and pin 3 (GND) of the M12 connector (J2), pin 2 (L+_24V) and pin 3 (GND) of the wire terminal (J1), or test points TP11 (L+_24V) and TP12 (GND).

External Power Supply or Power Accessory Requirements:

• Nom output voltage: 24VDC
• Max output current: 1A
• Efficiency level: V

Note

TI recommends using an external power supply or power accessory which complies with applicable regional safety standards such as (by example) UL, CSA, VDE, CCC, PE, and so on.

The TIOL221 has an integrated linear voltage regulator (LDO) which can supply power to external components with up to 20mA of current. The LDO can use either the L+_24V as the input voltage or an external 5V supply voltage can be applied to the V5IN pin to reduce the power dissipation in the device.

Table 2-1. Power Supply Specifications

PARAMETER	TEST CONDITIONS		MIN	NOM	MAX	UNIT
$V_{(LP)}$	24V Input supply voltage		7	24	36	V
$V_{(V5IN)}$	5V Input supply voltage		4.5	5	5.5	V
$V_{(VOUT)}$	Voltage regulator output	VOUT set to 5V	4.75	5	5.25	V
		VOUT set to 3.3V	3.13	3.3	3.46	V
$I_{(VOUT)}$	LDO output current				20	mA
$V_{(I)}$	Logic level input voltage at TX1, TX2, EN1, EN2,$\overline{CS}$/PP, SDI/NPN, SCK, SPI/$\overline{PIN}$	3.3V configuration	3	3.3	3.6	V
		5V configuration	4.5	5	5.25	V

The LDO output level is configurable via the VSEL pin. When VSEL is connected to GND, VOUT is configured to provide a 3.3V output with L+_24V as the input supply. When VSEL is left floating, VOUT provides a 3.3V output, with V5IN as the supply input to reduce the power dissipation in the device. When the VSEL is connected to VOUT, VOUT is set to 5V. The VSEL pin status is detected at power-up and the VOUT output level is determined and latched until the next power-up cycle.

Table 2-2. LDO Voltage Selection

VSEL Pin Connection on J17	VOUT
Connected to GND through Pull Down (PD) resistor	3.3V (supplied from L+_24V)
Floating	3.3V (supplied from V5IN)
Connected to VOUT through Pull Up (PU) resistor	5V

An external 5V supply voltage can be applied to TIOL221 V5IN pin by placing a jumper shunt on J13 to connect the device V5IN pin to the boards 5V rail. The 5V net can be supplied by either an external 5V power supply, or from the 5V_LP source when the EVM is mated to a TI Microcontroller board.

An external 5V supply can be connected through either the 5V_EXT and GND pins J7, or TP20 and TP10. A jumper shunt needs to be connected between the 5V_EXT and 5V pins of J5 to connect the 5V_EXT supply the 5V net of the board.

The 5V_LP supply from a TI Microcontroller board is available on pin 21 of J10, or TP22. A jumper shunt needs to be connected between the 5V_LP and 5V pins of J5 to connect the 5V_LP supply to the 5V net of the board.

Test point TP23 can be used to monitor the board 5V net.

2.2 Current Limit Configuration

The output current limit for the CQ and DO pins can be configured independently.

In pin-mode, the current limit of CQ and DO can be configured through a resistance (R_{SET}) on the ILIM_ADJ1 and ILIM_ADJ2 pins. The highest current limit setting with an external resistor of 10kΩ provides a minimum of 300mA over the operating temperature and voltage range.

Output disable, due to current fault and current fault auto recovery features, can be disabled by floating ILIM_ADJ1/2 pins. However, the current fault indication is still active in this configuration and this feature is useful when driving large capacitances.

When ILIM_ADJ1/2 pins are shorted to GND, the CQ and DO drivers can be configured to be in the IO-Link controller mode. In this mode, the drivers can source or sink a minimum of 500mA to generate a wake-up request. In addition, this enables a small current sink of 5mA (minimum) at the driver output pins. The current fault indication, output disable, and auto recovery features are disabled in this mode.

Table 2-3. Current Limit Configuration in Pin-mode

ILIM_ADJ1/2 Pin Condition	CQ/DO Current Limit (Min.)	NFLT1/2 Indication Due to Current Fault	Current Fault Blanking Time (t_{SC})	Output Disable and Auto Recovery
R_{SET} resistor to L- (10kΩ to 110kΩ)	Variable (35mA to 300mA)	Yes	200µs (typ)	Yes
Connected to L- (R_{SET} 0 to 5kΩ)	500mA	No	N/A	No
OPEN	260mA	Yes	None (immediate fault indication)	No

In the SPI mode, CQ and DO driver current limits can be configured via SPI. The CQ driver current limit can be configured via the CQ_CURLIM[7:5] register. Similarly, the DO driver current limit can be configured via the DO_CURLIM[7:5] register.

2.3 Setup

> **WARNING**
> External Connections: all external connections to the hardware must stay within the recommended operating conditions and intended usage for all hardware and components connected in the system.

The following figure provides an overview of the TIOL221EVM features.
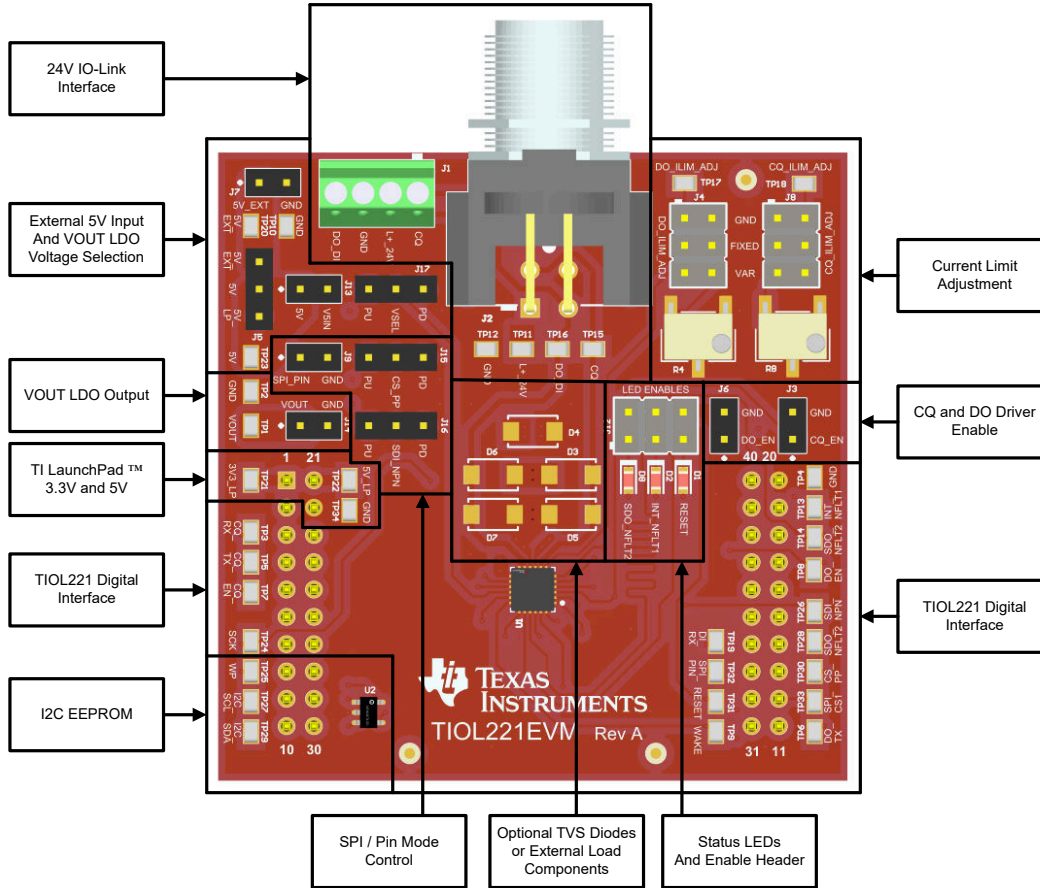

Figure 2-1. TIOL221EVM Feature Overview

2.4 Header Information

All Digital IO signals are available on headers J10 and J11 and the assignments are compatible with TI LaunchPad™ 40-pin microcontroller boards.

Some TIOL221 device pins have a different purpose between SPI and pin-mode operation and can have an additional LED or header that allows for static configuration with shunt jumpers. When operating the device in SPI mode, make sure the shunt jumpers are removed from headers J3, J6, J9, J12, J15, and J16.

Header J7 can be used to connect and external 5V power supply. Header J14 can be used to connect external circuits to the TIOL221 LDO VOUT pin. Shunt jumpers must not be placed on either header J7 or J14.

2.5 Jumper Information

Header J17:

- VSEL-PD: VOUT = 3.3V with L+_24V as the LDO input supply.
- VSEL-PU: VOUT = 5V with L+_24V as the LDO input supply.
- No shunt jumper: VOUT = 3.3V with V5IN as the LDO input supply.

Header J13:

- V5IN-5V: connects the board's 5V rail to the TIOL221 V5IN pin.
- No shunt jumper: isolates the TIOL221 V5IN pin.

Header J5:

- 5V-5V_EXT: connects the 5V rail of the board to the external 5V supply header J7 and TP20.
- 5V-5V_LP: connects the 5V rail of the board to the 5V_LP rail of the board if connected to a TI LaunchPad.

Header J9:

- SPI_PIN-GND: configures the TIOL221 to operate in pin-mode.
- No shunt jumper: configures the TIOL221 to operate in SPI mode.

Header J15:

- CS_PP-PD: The CQ and DO driver operates in either PNP or NPN mode if SPI/$\overline{\text{PIN}}$ is low.
- CS_PP-PU: The CQ and DO driver operate in Push-Pull mode if SPI/$\overline{\text{PIN}}$ is low.
- No shunt jumper and SPI/$\overline{\text{PIN}}$ is High: The $\overline{\text{CS}}$/PP pin operates as the SPI chip select and CQ and DO driver modes selected via SPI.

Header J16:

- SDI_NPN-PD: the CQ and DO driver operates in PNP mode if SPI/$\overline{\text{PIN}}$ is low and $\overline{\text{CS}}$/PP is low.
- SDI_NPN-PU: the CQ and DO driver operates in NPN mode if SPI/$\overline{\text{PIN}}$ is low and $\overline{\text{CS}}$/PP is high.
- No shunt jumper and SPI/$\overline{\text{PIN}}$ is high; the SDI/NPN pin operates as the SPI serial data input and CQ and DO driver modes selected via SPI.

Table 2-4. CQ and DO Driver Modes

SPI/$\overline{\text{PIN}}$	$\overline{\text{CS}}$/PP	SDI/NPN	CQ and DO Driver Mode
L	L	L	PNP
L	L	H	NPN
L	H	X	Push-Pull
H	X	X	CQ & DO driver mode selected via SPI

Header J3:

- CQ_EN-GND: the CQ driver is disabled if SPI/$\overline{\text{PIN}}$ is Low.
- No shunt jumper and SPI/$\overline{\text{PIN}}$ is low; the CQ driver is enabled to transmit data supplied to the CQ_TX pin of the board.

Header J6:

- DO_EN-GND: the DO driver is disabled if SPI/$\overline{\text{PIN}}$ is low.
- No shunt jumper and SPI/$\overline{\text{PIN}}$ is low; the DO driver is enabled to transmit data supplied to the DO_TX pin of the board.

Header J12:

- Shunt jumper on pins 1 and 2 next to LED D8: connects LED D8 to the SDO/NFLT2 pin when the device is used in pin-mode and SPI/$\overline{\text{PIN}}$ is low to indicate faults with the DO channel.
- No shunt jumper on pins 1 and 2 and SPI/$\overline{\text{PIN}}$ is high: the SDO/NFLT2 pin operates as the SPI Serial Data Output.
- Shunt jumper on pins 3 and 4 next to LED D2: connects LED D2 to the $\overline{\text{INT}}$/NFLT1 pin when the device is used in pin-mode and SPI/$\overline{\text{PIN}}$ is low to indicate faults with the CQ channel.
- No shunt jumper on pins 3 and 4 and SPI/$\overline{\text{PIN}}$ is high: the $\overline{\text{INT}}$/NFLT1 pin operates as the interrupt output.
- Shunt jumper on pins 5 and 6 next to LED D1: connects LED D1 to the $\overline{\text{RESET}}$ pin to indicate UV or VOUT.
- No shunt jumper on pins 5 and 6: LED D1 is isolated from the $\overline{\text{RESET}}$ pin.

Header J4:

- DO_ILIM_ADJ-GND: connects the ILIM_ADJ2 pin directly to GND (R_{SET} = 0Ω).
- DO_ILIM_ADJ-FIXED: connects the ILIM_ADJ2 pin to GND through a fixed resistor R3 (R_{SET} = 25kΩ).
- DO_ILIM_ADJ-VAR: connects the ILIM_ADJ2 pin to GND through a variable resistance potentiometer R4 (R_{SET} = 0Ω to 100kΩ).
- No shunt jumper: isolates the ILIM_ADJ2 pin (R_{SET} = OPEN).

Header J8:

- CQ_ILIM_ADJ-GND: connects the ILIM_ADJ1 pin directly to GND (R_{SET} = 0Ω).
- CQ_ILIM_ADJ-FIXED: connects the ILIM_ADJ1 pin to GND through a fixed resistor R7 (R_{SET} = 25kΩ).
- CQ_ILIM_ADJ-VAR: connects the ILIM_ADJ1 pin to GND through a variable resistance potentiometer R8 (R_{SET} = 0Ω to 100kΩ).
- No shunt jumper: isolates the ILIM_ADJ1 pin (R_{SET} = OPEN).

2.6 IO-Link Interface

The EVM contains an industry standard 4-pin M12 connector (J2) with a Class A 2-channel configuration implementing one IO-Link communication channel and one digital input or output channel as well as a screw terminal block (J1) for bare wire connections or external loads.

The TIOL221 power supply input (24V typical) pin "LP" has been labeled "L+_24V" on the board to help clarify that this is the +24V Power Supply.

Likewise the TIOL221 ground pin "LM" has been labeled "GND" on the board to help clarify that this is the Ground pin of the Power Supply.

The TIOL221 has separate digital output "DO" and digital input (DI) pins, but only one mode can be used at a time. Therefore, the DO and DI pins are connected together to allow either mode configuration to be used with the same hardware configuration and cabling.

2.7 Test Points

Test points are included on digital interface pins and are placed adjacent to the digital interface header pins. Test points for the power supply rails are also provided in close proximity to the connectors and headers.

2.8 I2C EEPROM

The TIOL221EVM contains an 8Kb EEPROM device with an I2C interface that can be used for local storage of device parameters accessible when the EVM is used with a microcontroller. This device is not directly connected to the TIOL221 device and is provided solely for the convenience of the user and is not required to evaluate any features of the TIOL221.

Note

The CAT24C08TDI-GT3 EEPROM device has Device Address of 0x50 and a Write Protect pin (WP) that must be pulled low to allow write access to the protected memory.

For example, the following parameters store the byte values of 0x12 in the EEPROM memory address 0x00 when following standard I2C protocol.
- Device Address = 0x50
- Read/Write bit = 0
- Memory Address = 0x00
- Data Byte = 0x12
- WP = Low

Likewise, the following parameters return the values stored in the EEPROM memory address 0x00 when following standard I2C protocol for a selective read.
- Device Address = 0x50
- Read/Write bit = 1
- Memory Address = 0x00

3 Software

The TIOL221EVM does not store or require any programmable code to operate and the EVM is provided as a hardware interface.

If the TIOL221 is to be used in SPI mode, then refer to the *SPI Programming and TIOL221 Register* sections of the TIOL221 Dual Channel IO-Link Device PHY with Integrated LDO and SPI Interface data sheet for detailed information.

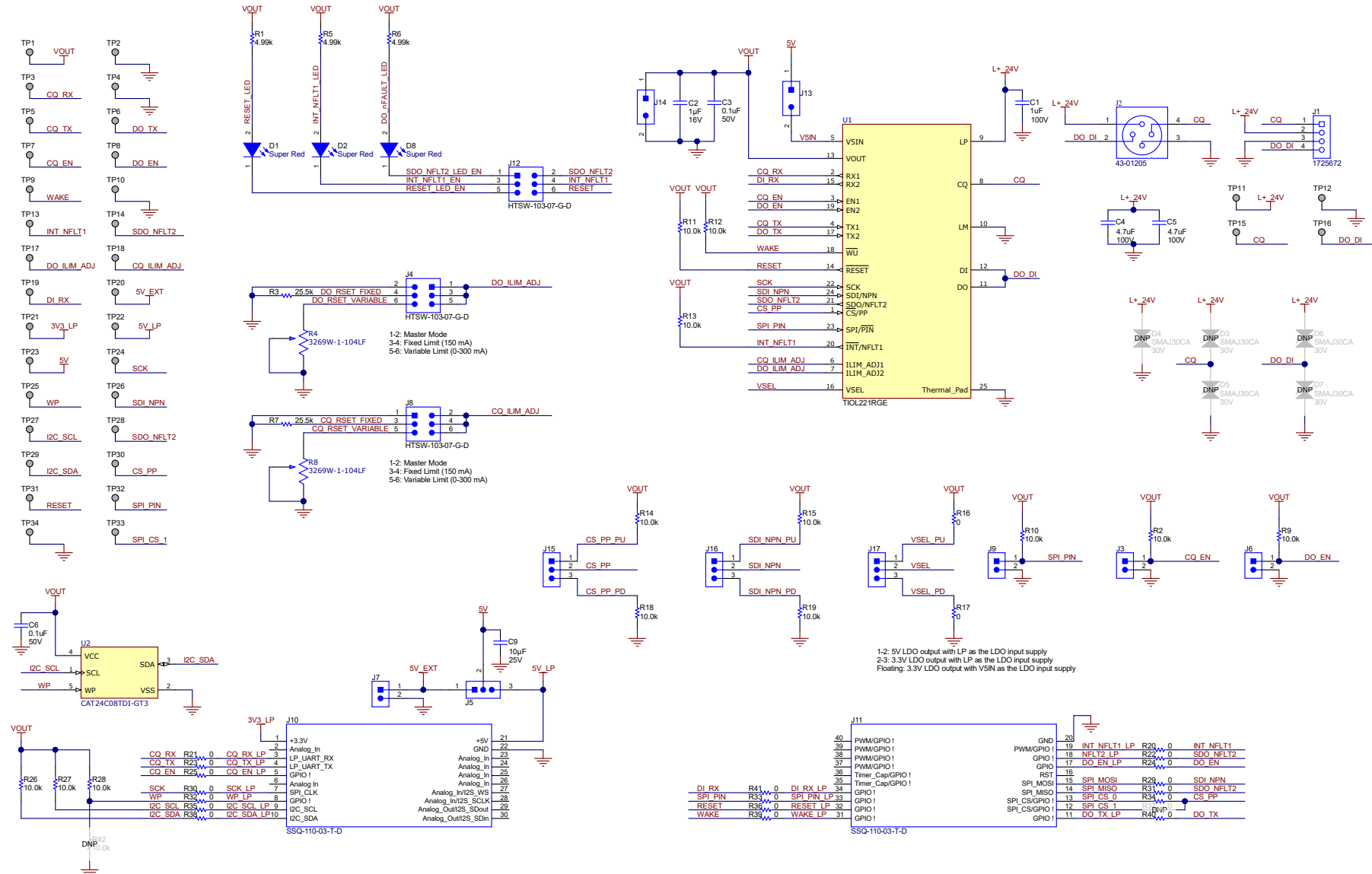# 4 Hardware Design Files

4.1 Schematics
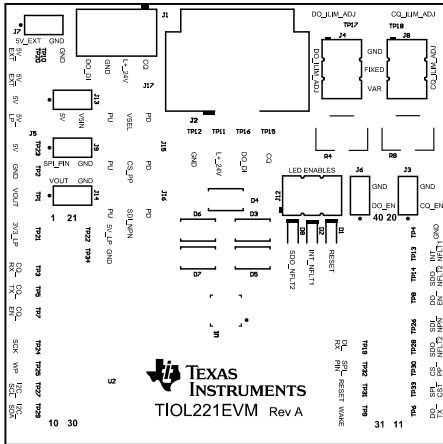

Figure 4-1. Schematic
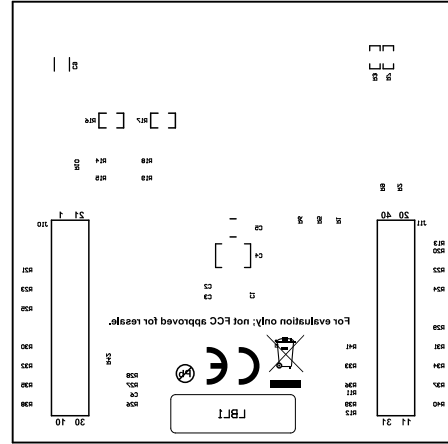
4.2 PCB Layouts

Figure 4-2. Top Overlay

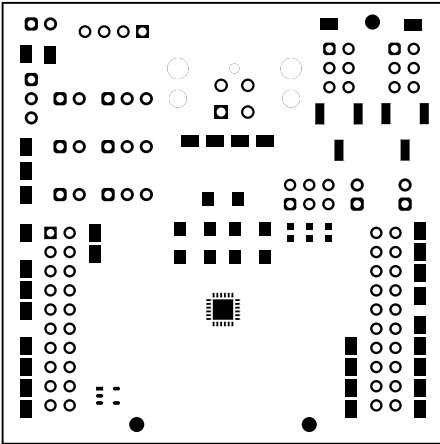**Figure 4-3. Bottom Overlay**
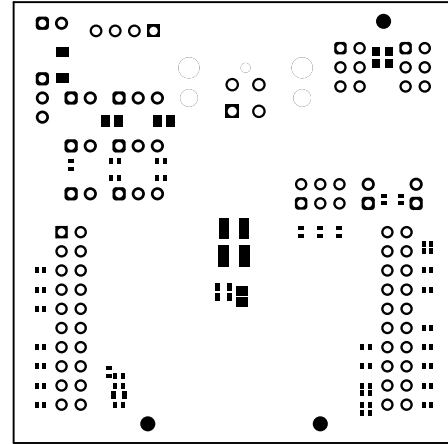

Figure 4-4. Top Solder Mask

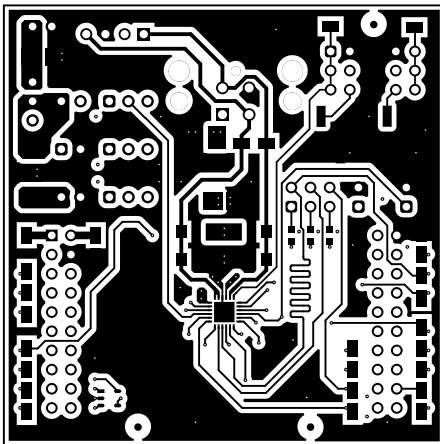**Figure 4-5. Bottom Solder Mask**

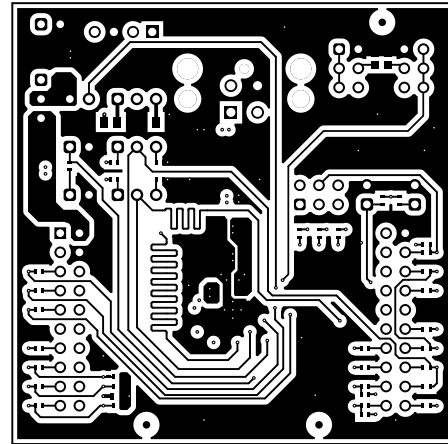**Figure 4-6. Top Layer**

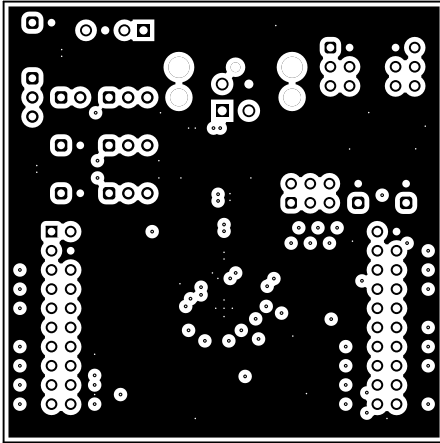**Figure 4-7. Bottom Layer**

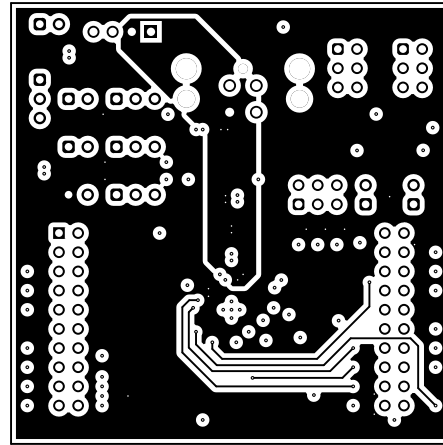**Figure 4-8. Layer 2 GND**
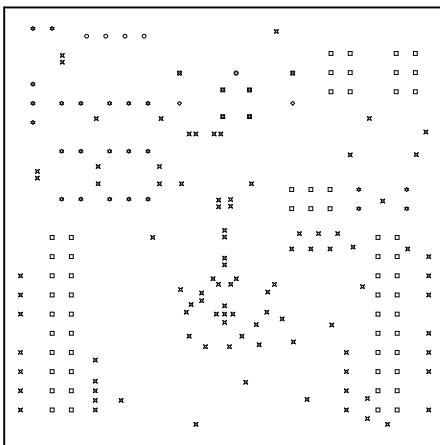

Figure 4-9. Layer 3 PWR
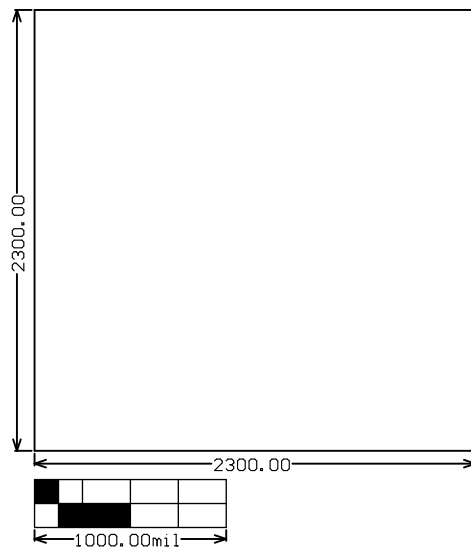

Figure 4-10. Drill Drawing

Figure 4-11. Board Dimensions

4.3 Bill of Materials (BOM)

Table 4-1. Bill of Materials

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
C1	1	1uF	CAP, CERM, 1uF, 100V, +/- 10%, X7S, AEC-Q200 Grade 1, 0805	0805	CGA4J3X7S2A105K125AB	TDK
C2	1	1uF	CAP, CERM, 1uF, 16V, +/- 10%, X7R, 0603	0603	885012206052	Wurth Elektronik
C3, C6	2	0.1uF	CAP, CERM, 0.1uF, 50V, +/- 10%, X7R, 0603	0603	06035C104KAT2A	AVX
C4, C5	2	4.7uF	CAP, CERM, 4.7uF, 100V, +/- 10%, X7S, AEC-Q200 Grade 1, 1210	1210	CGA6M3X7S2A475K200AB	TDK
C9	1	10uF	CAP, CERM, 10μF, 25V,+/- 10%, X7R, 1206	1206	C3216X7R1E106K160AB	TDK
D1, D2, D8	3	Super Red	LED, Super Red, SMD	LED_0603	150060SS75000	Wurth Elektronik
J1	1		Terminal Block, 4x1, 2.54mm, Green, TH	Terminal Block, 4x1, 2.54mm, TH	1725672	Phoenix Contact
J2	1		M12 Socket, Backmounting, 4Pos, Gold, R/A, TH	M12 Socket, Backmounting, 4Pos, R/A, TH	43-01205	Conec
J3, J6, J7, J9, J13, J14	6		Header, 100mil, 2x1, Gold, TH	2x1 Header	TSW-102-07-G-S	Samtec
J4, J8, J12	3		Header, 2.54mm, 3x2, Gold, TH	Header, 2.54mm, 3x2, Gold, TH	HTSW-103-07-G-D	Samtec
J5, J15, J16, J17	4		Header, 100mil, 3x1, Gold, TH	3x1 Header	TSW-103-07-G-S	Samtec
J10, J11	2		Receptacle, 2.54mm, 10x2, Tin, TH	10x2 Receptacle	SSQ-110-03-T-D	Samtec
LBL1	1		Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll	PCB Label 0.650 x 0.200 inch	THT-14-423-10	Brady
R1, R5, R6	3	4.99k	RES, 4.99 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0402	0402	ERJ-2RKF4991X	Panasonic
R2, R9, R10, R11, R12, R13, R14, R15, R18, R19, R26, R27, R28	13	10.0k	RES, 10.0 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040210K0FKED	Vishay-Dale
R3, R7	2	25.5k	RES, 25.5 k, 1%, 0.1 W, 0603	0603	RC0603FR-0725K5L	Yageo
R4, R8	2		100 kOhms 0.25W, 1/4W Gull Wing Surface Mount Trimmer Potentiometer Cermet 12 Turn Top Adjustment	SMD	3269W-1-104LF	Bourns
R16, R17	2	0	RES, 0, 1%, 0.5 W, 0805	0805	5106	Keystone
R20, R21, R22, R23, R24, R25, R29, R30, R31, R32, R33, R34, R35, R36, R38, R39, R40, R41	18	0	RES, 0, 5%, 0.063 W, 0402	0402	RC0402JR-070RL	Yageo America

Table 4-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
SH-J1, SH-J2, SH-J3, SH-J4, SH-J5, SH-J6, SH-J7, SH-J8, SH-J9, SH-J10, SH-J11, SH-J12, SH-J13	13		Shunt, 2.54mm, Gold, Black	Shunt, 2.54mm, Black	60900213421	Wurth Elektronik
TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12, TP13, TP14, TP15, TP16, TP17, TP18, TP19, TP20, TP21, TP22, TP23, TP24, TP25, TP26, TP27, TP28, TP29, TP30, TP31, TP32, TP33, TP34	34		Test Point, SMT	Test Point, SMT	S2751-46R	Harwin
U1	1		Dual Channel IO-Link Device PHY with Integrated LDO and SPI Interface	VQFN24	TIOL221RGE	Texas Instruments
U2	1		8KB I2C SER EEPROM TSOT 23	TSOT-23-5	CAT24C08TDI-GT3	ON Semiconductor
D3, D4, D5, D6, D7	0	30V	Diode, TVS, Bi, 30V, 48.4 Vc, 400W, 8.3A, SMA (non-polarized)	SMA (non-polarized)	SMAJ30CA	Littelfuse
FID1, FID2, FID3, FID4, FID5, FID6	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
R37	0	0	RES, 0, 5%, 0.063 W, 0402	0402	RC0402JR-070RL	Yageo America
R42	0	10.0k	RES, 10.0 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040210K0FKED	Vishay-Dale

5 Additional Information

5.1 Trademarks

LaunchPad™ is a trademark of Texas Instruments.

All trademarks are the property of their respective owners.

STANDARD TERMS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an "EVM" or "EVMs") to the User ("User") in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.

   1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM ("Software") shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software

   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2. *Limited Warranty and Related Remedies/Disclaimers*:

   2.1 These terms do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.

   2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

WARNING

Evaluation Kits are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems.

User shall operate the Evaluation Kit within TI's recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI's recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI's instructions for electrical ratings of interface circuits such as input, output and electrical loads.

NOTE:
EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGREDATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

3   *Regulatory Notices:*

3.1   *United States*

3.1.1   *Notice applicable to EVMs not FCC-Approved:*

FCC NOTICE: This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

3.1.2   *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

CAUTION

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

FCC Interference Statement for Class A EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2   *Canada*

3.2.1   *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。

https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,

2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or

3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けて

いないものがあります。 技術適合証明を受けていないもののご使用に際しては、電波法遵守のため、以下のいずれかの

措置を取っていただく必要がありますのでご注意ください。

1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。 日本テキサス・イ

ンスツルメンツ株式会社

東京都新宿区西新宿６丁目２４番１号

西新宿三井ビル

3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-for-power-line-communication.html

3.4 *European Union*

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive):*

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4   *EVM Use Restrictions and Warnings:*

4.1   EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2   User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3   *Safety-Related Warnings and Restrictions:*

4.3.1   User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2   EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4   User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5.   *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

6.   *Disclaimers:*

6.1   EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.

6.2   EXCEPT FOR THE LIMITED RIGHT TO USE THE EVM SET FORTH HEREIN, NOTHING IN THESE TERMS SHALL BE CONSTRUED AS GRANTING OR CONFERRING ANY RIGHTS BY LICENSE, PATENT, OR ANY OTHER INDUSTRIAL OR INTELLECTUAL PROPERTY RIGHT OF TI, ITS SUPPLIERS/LICENSORS OR ANY OTHER THIRD PARTY, TO USE THE EVM IN ANY FINISHED END-USER OR READY-TO-USE FINAL PRODUCT, OR FOR ANY INVENTION, DISCOVERY OR IMPROVEMENT, REGARDLESS OF WHEN MADE, CONCEIVED OR ACQUIRED.

7.   *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS LICENSORS AND THEIR REPRESENTATIVES HARMLESS FROM AND AGAINST ANY AND ALL CLAIMS, DAMAGES, LOSSES, EXPENSES, COSTS AND LIABILITIES (COLLECTIVELY, "CLAIMS") ARISING OUT OF OR IN CONNECTION WITH ANY HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.

8. *Limitations on Damages and Liability:*

    8.1 *General Limitations*. IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS OR THE USE OF THE EVMS , REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

    8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

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