

EVM User's Guide: TMAG6180DEVM

TMAG6180D-Q1 Evaluation Model



Description

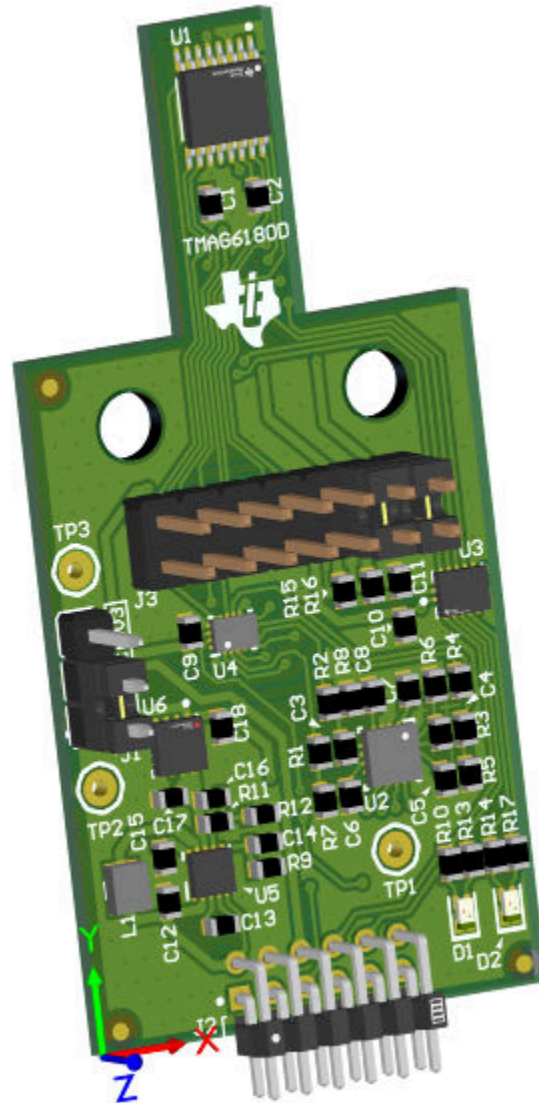
TMAG6180D-Q1 is a dual die device intended to provide redundant sensing commonly required for automotive applications requiring functional safety. TMAG6180D-Q1 has magnetic sensors built on anisotropic magnetoresistive (AMR) sensing technology. Typically, AMR sensors are only able to resolve 180° rotation, but with additional integrated Hall-effect sensing, each sensor produces both sine and cosine differential outputs which are used to measure the absolute angular position of a rotating magnet. Each sensor is capable of detecting a full 360° rotation unlike typical AMR sensors. The TMAG6180D-Q1 provides additional outputs Q0 and Q1 which can be used to determine the quadrant of rotation. Using the information from these outputs, extending the 180° output to a full 360° position calculation is possible.

Features

- Onboard 16-bit analog-to-digital converter
- Differential sine and cosine analog outputs
- Independent access to both sensor outputs
- Compatible with the [Rotate & Push module](#) (sold separately)
- Compatible with TI - Sensor Control Board ([TI-SCB](#), sold separately)

Applications

- [Electric Power Steering](#)
- [Steering Angle Sensor](#)
- [BLDC/PMSM Motor Position Sensing](#)
- E-bikes
- [Wiper modules](#)
- Actuators
- [Servo drive position sensors](#)
- Traction motors



TMAG6180DEVM

1 Overview

This user's guide describes the characteristics, operation, and use of the TMAG6180D-Q1 evaluation module (EVM). This EVM is designed to evaluate the performance of the TMAG6180D-Q1. Throughout this document, the terms evaluation board, evaluation module, and EVM are synonymous with the TMAG6180DEVM. This document includes a schematic, reference printed circuit board (PCB) layouts, and a complete bill of materials (BOM).

TMAG6180D-Q1 is installed on the top side of the EVM.

Table 1-1. TMAG6180 Device Summary

PRODUCT	INPUT RANGE	ANALOG OUTPUTS	DIGITAL OUTPUTS	SUPPLY VOLTAGE RANGE
TMAG6180D-Q1	20mT - 1T	Differential Sine and Cosine	Q0 and Q1 Quadrant	2.7V - 5.5V

1.1 Kit Contents

[Table 1-2](#) lists the contents of the EVM kit. Contact the nearest [Texas Instruments Product Information Center](#) if any component is missing. The [3D-printed Rotate & Push module](#) that can be used for evaluating the EVM is sold separately.

Table 1-2. Kit Contents

ITEM	QUANTITY
TMAG6180DEVM	1

2 Hardware

The EVM is an easy-to-use platform for evaluating the main features and performance of the TMAG6180D-Q1-Q1. The EVM includes a graphical user interface (GUI) used to read and save data sampled by the onboard [ADS8354](#) ADC from the TMAG6180D-Q1 AMR sensors.

The EVM is intended to provide basic functional evaluation of the devices. The layout is not intended to be a model for the target circuit, nor is the model laid out for electromagnetic compatibility (EMC) testing. The EVM is intended to interface with the [TI-SCB](#), but can be used as a standalone device if desired.

2.1 Features

- Onboard 16-bit analog-to-digital converter
- Differential sine and cosine analog outputs
- Independent access to both sensor outputs
- Compatible with the [Rotate & Push module](#) (sold separately)
- Compatible with TI - Sensor Control Board ([TI-SCB](#), sold separately)

3 Operation

The EVM can be operated independently or with the TI-SCB and Push Rotate Module.

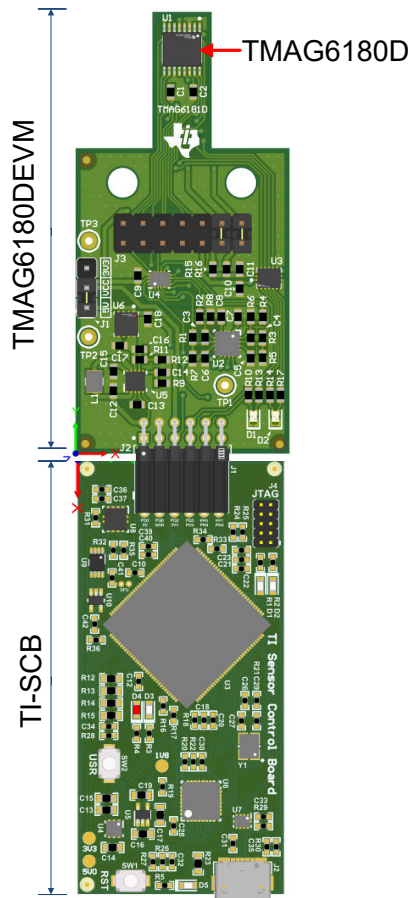


Figure 3-1. TMAG6180DEVM Connected to TI-SCB

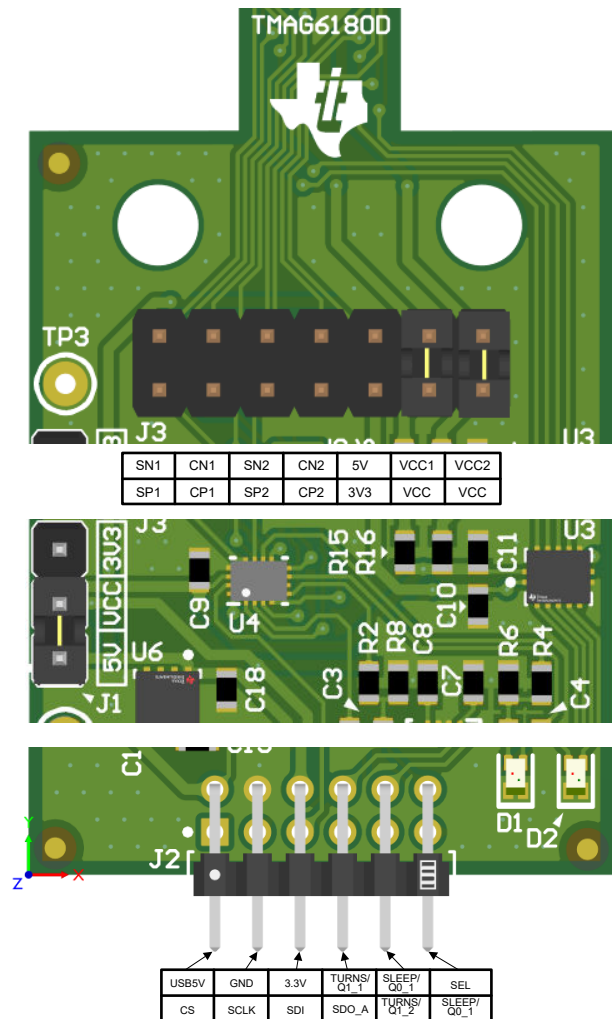


Figure 3-2. Connections for TMAG6180DEVM when Operated Independently

3.1 Quick Start Setup

3.1.1 TMAG6180DEVM With TI-SCB and Push Rotate Module

- Download and install the PAMB Windows® USB driver: <http://www.ti.com/lit/zip/sbac253>.
- Attach the EVM to the Sensor Control Board (TI-SCB).
 - TI-SCB is not included with EVM and must be purchased separately.
- Apply a magnetic field to the sensor by doing one of the following:
 - Mount the EVM with the sensors aligned to the axis of rotation of a rotating magnet.
 - If the Rotate & Push module was purchased, connect the module to the EVM (see [Figure 3-7](#)).
- Connect the EVM to a PC using a USB cable.
 - Insert the micro USB cable into the TI-SCB Controller onboard USB receptacle J2.
 - Plug the other end of the USB cable into a PC.
- Access the GUI from the following link in either a Firefox™ or Google Chrome™ browser:
 - TMAG6180DEVM GUI: <https://dev.ti.com/gallery/search/TMAG6180-6181>.
- Select a device to test

- a. Click plots icon to advance to main device interface.
 - b. EVM GUI defaults to TMAG6180D-Q1 die 1.
7. Click *Collect Data*
 8. Observe the outputs in the GUI. See [Section 3.2.1.3](#) for more information on GUI setup and operation.

3.1.2 Standalone TMAG6180DEVM Operation

The TMAG6180D-Q1 can be evaluated independent of the TI-SCB with multiple discrete instruments or a multifunction instrument. Required supporting instruments include a power supply, oscilloscope with differential probes, protocol analyzer, logic analyzer, and pattern generator. The EVM has signal chain composed of the TMAG6180D-Q1, a multiplexer, an ADC, and a level translator. The user has the option to probe directly at the TMAG6180D-Q1 or at the ADC and level translator output.

3.1.3 Measure at Device

1. While instruments are disabled, connect the power supply to the following pins. Refer to [Figure 3-2](#) for guidance. Power can be applied at header J2 or J3. For visual feedback through the LED indicators for Q0 and Q1 outputs, apply power through the J2 Header.

Power from J3 Header

- a. Remove jumpers from pin pairs 11, 12 and 13, 14 of header J3.
- b. Apply stable voltages between 2.7V to 5.5V to VCC1 (pin 12) and VCC2 (pin 14) of header J3.

Power from J2 Header

- a. **USB5V:** Apply a USB-compliant voltage (4.4V to 5.5V, $\leq 900\text{mA}$) to USB5V pin found on the J2 header at the bottom edge of the board. Place the J1 jumper on 5V and VCC.
 - b. **3V3:** Apply 3.3V to pins found on either the J2 header at the bottom edge of the board or at header J3 found in the middle of the board.
 - c. **GND:** Apply ground connection to GND found on J2 or header or to TP3.
2. Connect one set of differential oscilloscope probes to SN_x and SP_x and the other set to CN_x and CP_x from header J3. x corresponds to 1 or 2 and refers to the outputs seen from either TMAG6180D-Q1 die 1 or die 2.
 3. Enable power supplies.
 4. Apply a magnetic field to the sensor by doing one of the following:
 - a. Mount the EVM with the sensors aligned to the axis of rotation of a rotating magnet.
 - b. If the Rotate & Push module was purchased, connect the module to the EVM (see [Figure 3-7](#)).

3.1.4 Measure at ADC and Level Translator

1. While instruments are disabled, connect the power supply to the following pins. See [Figure 3-2](#).
 - a. **USB5V:** Apply a USB-compliant voltage to USB5V (4.4V to 5.5V, $\leq 900\text{mA}$) pin found on the J2 header at the bottom edge of the board. Place the J1 jumper on 5V and VCC.
 - b. **3V3:** Apply 3.3V to pins found on either the J2 header at the bottom edge of the board or at header J3 found in the middle of the board.
 - c. **GND:** Apply ground connection to GND found on J2 or header or to TP3.
2. Enable supplies
3. Connect the SPI protocol analyzer to pins CS, SCLK, SDI, SDO_A, and GND.
4. Connect a pattern generator to the SEL pin found on J2 to toggle between die 1 or die 2 of the TMAG6180D-Q1.
5. Apply a magnetic field to the sensor by doing one of the following:
 - a. Mount the EVM with the sensors aligned to the axis of rotation of a rotating magnet.
 - b. If the Rotate & Push module was purchased, connect the module the EVM (see [Figure 3-7](#)).
6. Program the ADC configuration register (CFR) to transmit both ADC channels through SDO_A. The first 16 SDI bits of any 32-bit frame write can be used to write to the CFR. Recommended write value for programming CFR is 0x21A0.
7. Collect data from the ADC by reading the last 16 bits of the 32-bit SDO frame.

3.2 EVM Operation

To use the EVM, TI recommends interfacing with the device through a TI-SCB and computer. The TI-SCB is an accessory EVM that supports multiple TI position sensing and current sensing EVMs and is sold separately. When the EVM is connected through the TI-SCB, various measurement settings can be configured through TI's EVM cloud platform. If the TI-SCB is not purchased, the user can still evaluate the device as discussed in [Section 3.1.2](#).

[Figure 3-3](#) outlines the supporting signal chain on the EVM intended to streamline evaluation with the TI-SCB. The primary signal chain comprises the TMAG6180D-Q1 for [magnetic position sensing](#), the TMUX1574 to [multiplex](#) between TMAG6180D-Q1 die1 and die2 outputs, the ADS8354 [ADC](#) to quantize the TMAG6180D-Q1 measurement and transmit serially off the board through SPI. Input to the [ADS8354](#) is controlled using pin 12 (SEL) of J2. The SEL signal sets the output of multiplexer U4. Access to the SPI I/O pins of the [ADS8354](#) are available on pins 1, 3, 5, and 7 of J2 as shown in [Figure 4-8](#). The auxiliary signal chain includes the TXS0104EBQA to level translate the TMAG6180D-Q1 Q0 and Q1 outputs for LED indicators.

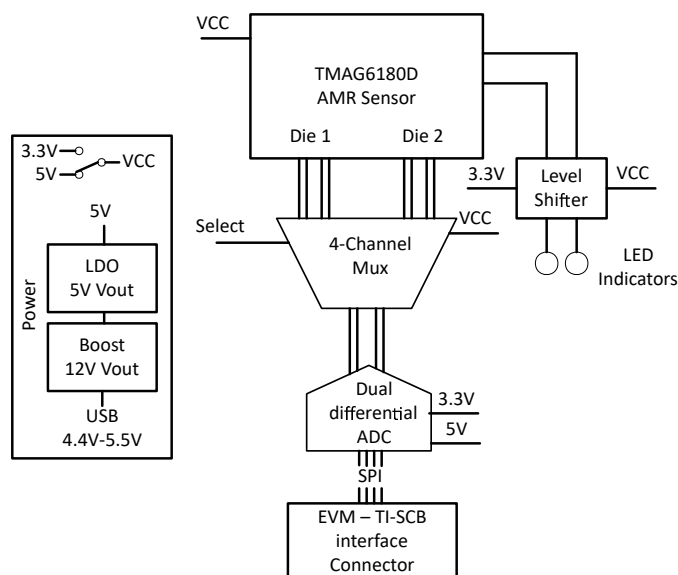


Figure 3-3. TMAG6180DEVM Block Diagram

Access to 5V, GND, and 3.3V are respectively available on pins 2, 4, and 6 of J3. The 5V input from TI-SCB is provided over USB and is not used to directly power TMAG6180D-Q1. U9 and U10 on TMAG6180D-Q1 accept this input and provide a low noise 5V AVDD voltage for the [ADS8354](#) (U4) and sensors.

Full details of the hardware schematic are available in [Section 4.1](#).

3.2.1 Software Setup

3.2.1.1 Driver Installation

Download and install the PAMB Windows USB driver: <http://www.ti.com/lit/zip/sbac253>. This is a one-time step per computer. Unzip the folder and run the .exe file with administrator privileges.

3.2.1.2 Firmware

The GUI can load firmware onto the TI-SCB as described in [Section 3.2.1](#). Firmware updates are pushed through the GUI (requires driver installation). Downloaded offline GUIs can check for GUI/Firmware updates depending on the version.

3.2.1.2.1 Firmware Debug

If the firmware becomes corrupted or requires manual reinstallation for any reason, follow these steps to restore the firmware. This is demonstrated in the [TMAG5170 EVM Quick Start Video](#):

1. Configure the MCU on the TI-SCB Controller to Device Firmware Update (DFU) Mode.
 - a. The MCU entering DFU mode is possible. If so, then the GUI sends a notification and tries to update the firmware to the latest version after the GUI is connected to the PC.
 - b. DFU mode can be entered manually through one of the following methods while the TI-SCB Controller is powered on:
 - Through software:
 - Send the command 'bsl' on the TI-SCB's USB Serial (COM) port.
 - Through the hardware:
 - Make sure TI-SCB is connected to the PC through a USB
 - Short the two test points near PK1 and PK2 of the header pins (see [Figure 3-4](#)) with a pair of tweezers (or wire) while pressing the RESET button.

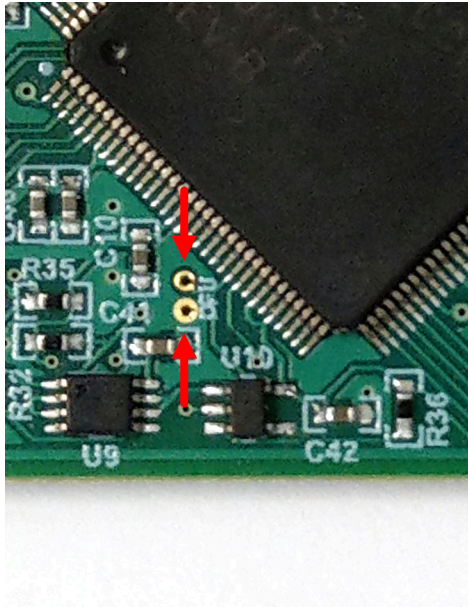


Figure 3-4. Test Points Used to Enter DFU Mode Manually

- c. LEDs D1 and D2 are off if successful.
2. With the MCU in DFU mode, upload the firmware through the GUI:
 - Open the *File* menu and select *Program Device*.
 - The firmware update initiates.
 - After the GUI re-initializes, the TI-SCB automatically connects.

If the firmware programming was unsuccessful, then TI recommends to repeat the above steps with a different USB port connection on the machine.

3.2.1.3 GUI Setup and Usage

Access the GUI from the following link in either a Firefox or Google Chrome browser:

- TMAG6180DEVM GUI: <https://dev.ti.com/gallery/search/TMAG6180-6181>

3.2.1.3.1 Initial Setup

To set up the GUI the first time, follow these steps:

1. Make sure that the above mentioned driver was installed successfully to verify that everything works properly and that the GUI can update the EVM firmware, if necessary.
2. With the EVM/TI-SCB Controller unit plugged to the PC, go to the GUI link: <https://dev.ti.com/gallery/search/TMAG6180-6181>.
3. To launch the GUI from the web browser, click the *GUI Composer* application to open the *GUI Composer* window (see [Figure 3-5](#)).

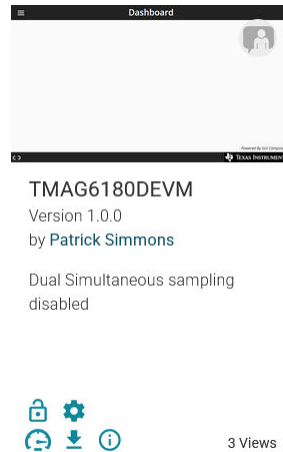


Figure 3-5. GUI Composer Application Window

- a. For first-time GUI Composer setup, follow the prompts to download the *TI Cloud Agent* and browser extension (see [Figure 3-6](#)). These prompts appear after you close the README.md dialog.


TI Cloud Agent Installation

Hardware interaction requires additional one time set up. Please perform the actions listed below and try your operation again.(What's this?)

- Step 1: **INSTALL** browser extension
- Step 2: **DOWNLOAD** and install the TI Cloud Agent Application
- Help. I already did this

FINISH

Figure 3-6. TI Cloud Agent

4. Optionally, click the  icon in the *GUI Composer* window to download the GUI for offline use (see [Figure 3-5](#)).

3.2.1.3.2 GUI Operation

To operate the GUI, follow these steps:

1. Connect the EVM to TI-SCB. If Rotate & Push Module purchased, mount onto the EVM as indicated in [Figure 3-7](#). Otherwise rotate a diametric magnet centered over the TMAG6180D.

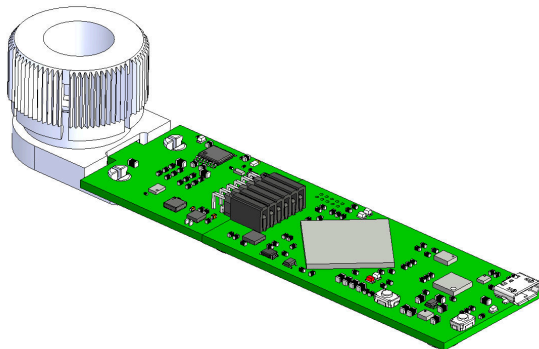


Figure 3-7. TMAG6180DEVM with Magnet Knob Attachment

2. Connect to and launch the GUI as described in [Section 3.2.1.3.1](#).
3. With the EVM connected to the GUI, close the README.md file page. The text near the bottom-left hand corner of the GUI reads *Hardware Connected* (see [Figure 3-8](#)).

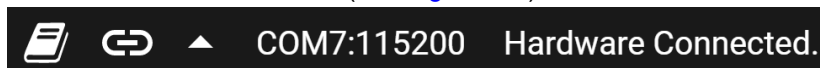


Figure 3-8. Hardware Connected Indicator

- a. If *Hardware Connected* does not show in the bottom-left hand corner of the GUI, check different hardware COM ports under *Options* → *Serial Port* (see [Figure 3-9](#)).

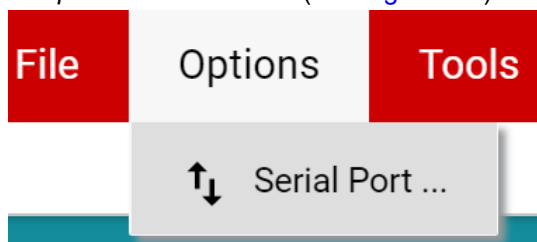


Figure 3-9. Change Serial Port

- b. If the hardware still does not connect, make sure you are using the correct GUI/EVM combination.
4. Click the Plots icon to setup the EVM for measurements.



Plots

Plots for device outputs

Figure 3-10. Plots Page Icon

5. Select the sensor to test using the drop-down menu shown below:

Results to collect/show

Angle θ

TMAG6180 dev 1 Outputs

TMAG6180 dev 2 Outputs

TMAG6180_1 v

Figure 3-11. Device Select Drop-Down

6. Click *Collect Data* to initiate data capture.

COLLECT DATA #Samples Only

Delay between samples:

ms Auto Delay

SAVE ALL PLOTS CLEAR ALL PLOTS

#Samples:

(Changing #Samples clears all plots)

Figure 3-12. Data Collection Settings

- a. *Delay between samples* sets the sample rate.
 - b. *#Samples* sets the plot record length.
 - c. *#Samples Only* stops collecting after the specified samples are captured, and disabling this checkbox causes data to stream continuously.
7. Observe the status indicators relative to the device being tested:
 - a. TMAG6180-Q1: Q0 and Q1 indicates the quadrant of rotation for the magnetic source. The quadrant of rotation is also indicated by LEDs mounted on the EVM.

Q1: ● Q0: ●

SAVE PLOT

CLEAR PLOT

Manual Scale

Max:

Min:

Figure 3-13. TMAG6180 Quadrature Output Indicators

- Click *Stop Collect* to stop data capture.

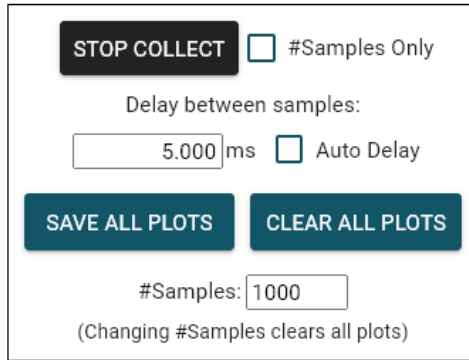


Figure 3-14. Stop Data Collection

- Click *Save Plot* or *Save all Plots* to store captured data locally.



Figure 3-15. Save Button

4 Schematics, PCB Layout, and Bill of Materials

4.1 Schematics

TMAG618xD - AMR Sensors

VCC can be anywhere from 3.3 to 5V

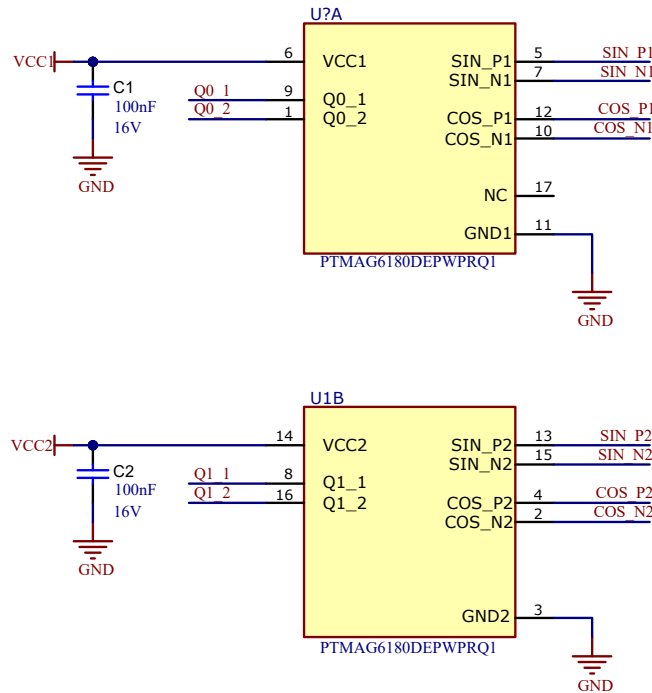
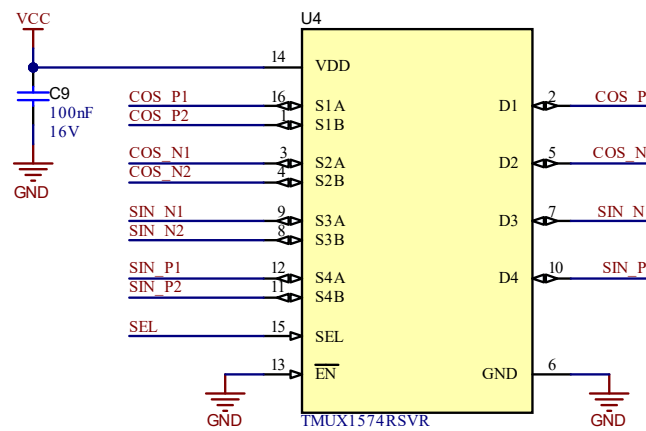


Figure 4-1. TMAG6180D-Q1 Schematic

Sensor Multiplexing to ADC



SEL = 0 enables A channels (Die 1)
SEL = 1 enables B channels (Die 2)

Figure 4-2. Multiplexor Schematic

Dual Channel Differential ADC (ADS8354)

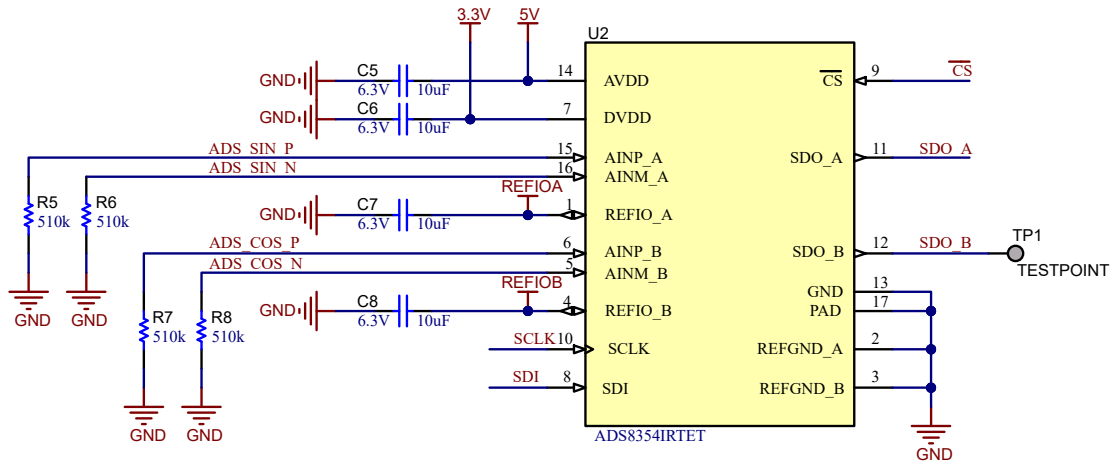


Figure 4-3. ADC Block

Sensor Level Shifter

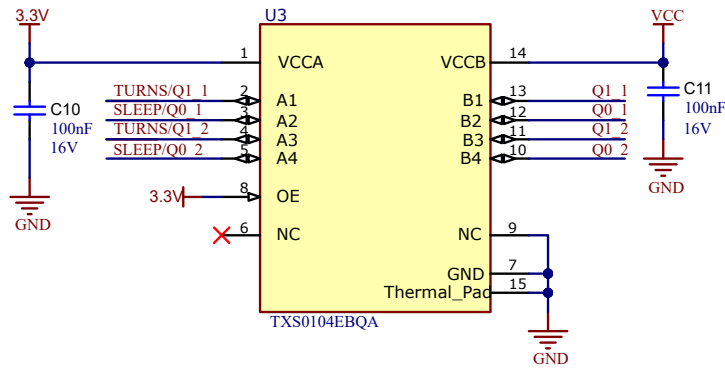


Figure 4-4. Level Shifter

Low Noise 5V Supply

TI-SCB 5V is powered via USB and is less ideal for use as an ADC supply. This block steps up to 12V and then drives 5V using an LDO for lower noise

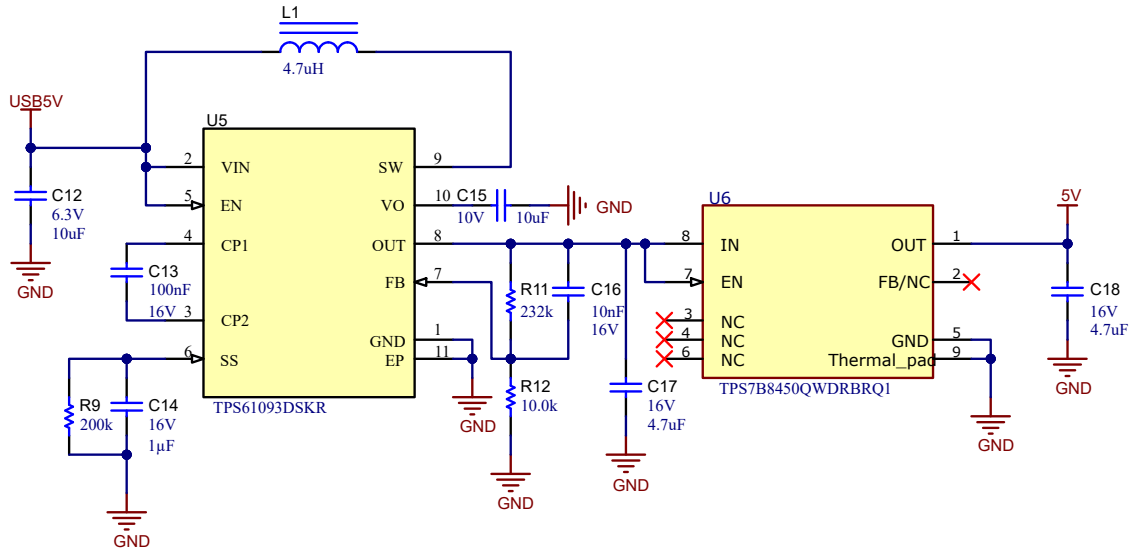


Figure 4-5. Power Block

Anti-aliasing Filter

This passive stage follows the recommended examples provided for ADS8354 to provide anti-alias filtering for precision measurements

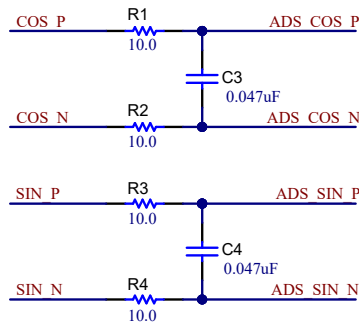


Figure 4-6. Filter

6180D Header

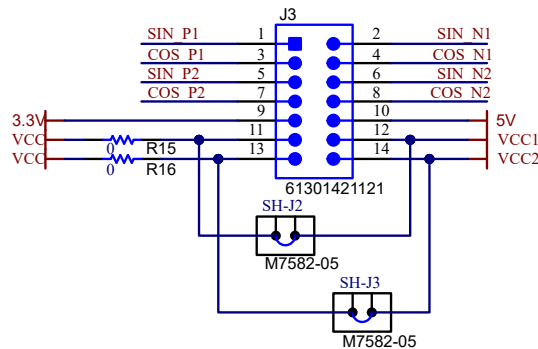


Figure 4-7. 6180D Header

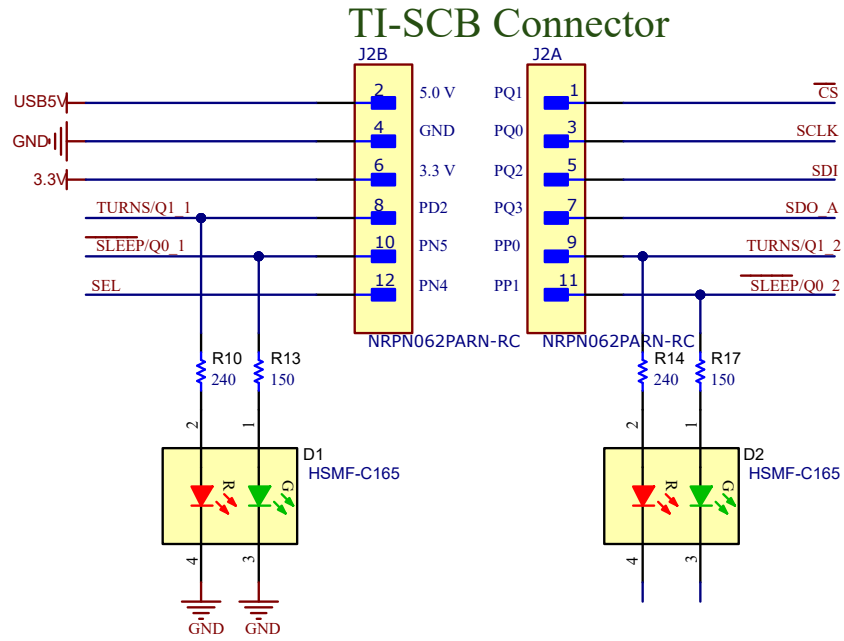


Figure 4-8. SCB Connector

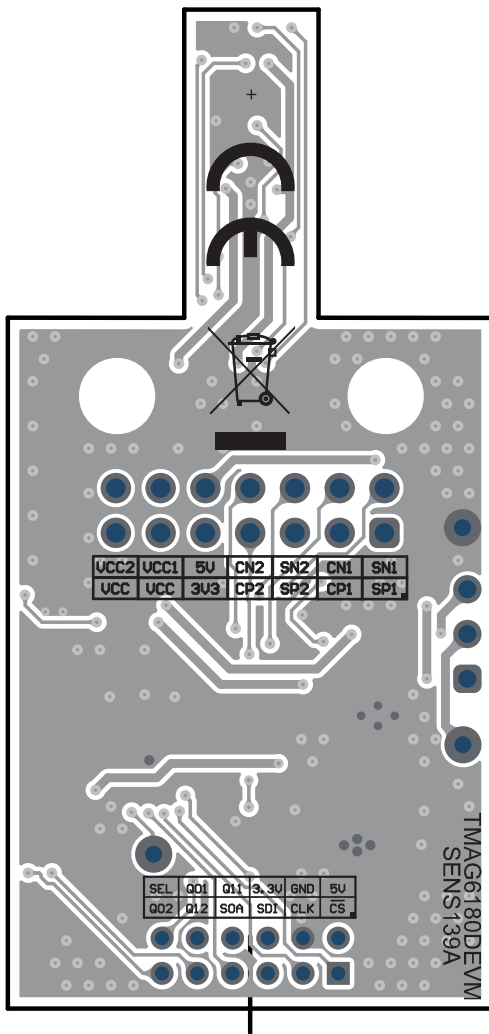


Figure 4-11. Bottom View

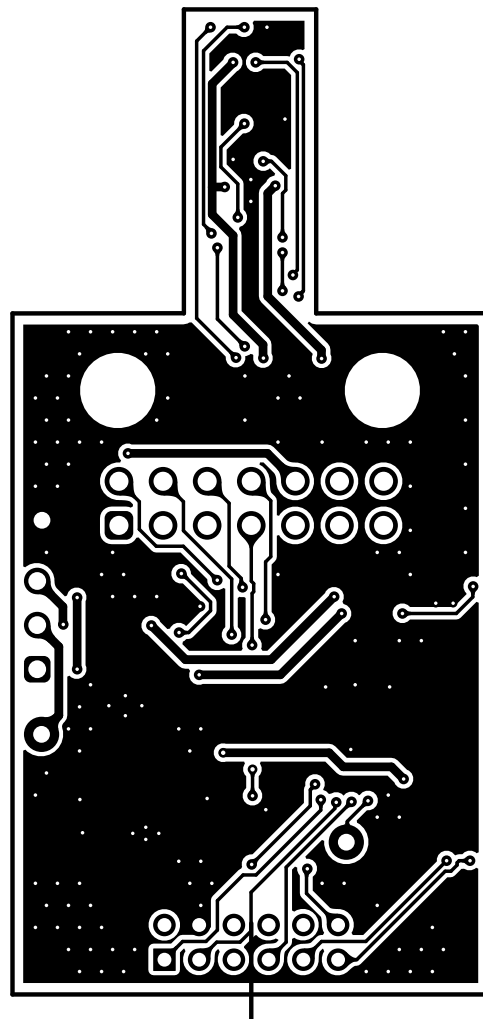


Figure 4-12. Bottom Layer

4.3 Bill of Materials

The following table provides the parts list for the EVM.

Table 4-1. TMAG6180DEVM Bill of Materials

REFERENCE DESIGNATOR	QUANTITY	VALUE	DESCRIPTION	PACKAGE REFERENCE	PART NUMBER	MANUFACTURER
!PCB1	1		Printed Circuit Board		SENS139	Any
C1, C2, C9, C10, C11, C13	6	0.1uF	CAP, CERM, 0.1 uF, 16 V, +/- 5%, X7R, 0603	0603	C0603C104J4RAC7867	Kemet
C3, C4	2	0.047uF	CAP, CERM, 0.047 uF, 50 V, +/- 10%, X5R, 0603	0603	C1608X5R1H473K080AA	TDK
C5, C6, C7, C8, C12	5	10uF	CAP, CERM, 10 uF, 10 V, +/- 20%, X7R, 0603	0603	GRM188Z71A106MA73D	MuRata
C14	1	1uF	CAP, CERM, 1 uF, 16 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	0603	CL10B105K08VPNC	Samsung Electro-Mechanics
C15	1	10uF	CAP, CERM, 10 uF, 10 V, +/- 20%, X6S, 0603	0603	GRM188C81A106MA73D	MuRata
C16	1	0.01uF	CAP, CERM, 0.01 uF, 16 V, +/- 10%, X7R, 0603	0603	885012206040	Würth Elektronik
C17, C18	2	4.7uF	CAP, CERM, 4.7 uF, 16 V, +/- 10%, X6S, 0603	0603	C1608X6S1C475K080AC	TDK
D1, D2	2	Rg	LED, Rg, SMD	1.6x0.8mm	HSMF-C165	Avago
J1	1		Header, 2.54mm, 3x1, Tin, TH	Header, 2.54mm, 3x1, Tin, TH	22284030	Molex
J2	1			HDR12	NRPN062PARN-RC	Sullins Connector Solutions
J3	1		Header, 2.54mm, 7x2, Gold, TH	Header, 2.54mm, 7x2, TH	61301421121	Würth Elektronik
L1	1	4.7uH	Inductor, Film, 4.7 uH, 1.6 A, 0.2 ohm, AEC-Q200 Grade 0, SMD	2.5x2mm	TFM252012ALMA4R7MTAA	TDK
R1, R2, R3, R4	4	10	RES, 10.0, 1%, 0.1 W, 0603	0603	RC0603FR-0710RL	Yageo
R5, R6, R7, R8	4	510k	RES, 510 k, 1%, 0.1 W, 0603	0603	RC0603FR-07510KL	Yageo
R9	1	200k	RES, 200 k, 1%, 0.1 W, 0603	0603	RC0603FR-07200KL	Yageo
R10, R14	2	240	RES, 240, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603240RJNEA	Vishay-Dale
R11	1	232k	RES, 232 k, 1%, 0.1 W, 0603	0603	RC0603FR-07232KL	Yageo
R12	1	10.0k	RES, 10.0 k, 1%, 0.1 W, 0603	0603	ERJ-3EKF1002V	Panasonic
R13, R17	2	150	RES, 150, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603150RJNEA	Vishay-Dale
R15, R16	2	0	RES, 0, 0%, 0.25 W, AEC-Q200 Grade 0, 0603	0603	PMR03EZPJ000	Rohm

Table 4-1. TMAG6180DEVM Bill of Materials (continued)

REFERENCE DESIGNATOR	QUANTITY	VALUE	DESCRIPTION	PACKAGE REFERENCE	PART NUMBER	MANUFACTURER
SH-J1, SH-J2, SH-J3	3		Single Operation 2.54mm Pitch Open Top Jumper Socket	Single Operation 2.54mm Pitch Open Top Jumper Socket	M7582-05	Harwin
U1	1		High-Precision Analog AMR Angle Sensor With Integrated Turns Counter	TSSOP16	PTMAG6180DEPWPRQ1	Texas Instruments
U2	1		SAR ADC, Dual, 700 kSPS, 16 Bit, Simultaneous Sampling, RTE0016D (WQFN-16)	RTE0016D	ADS8354IRTET	Texas Instruments
U3	1		4-Bit Bidirectional Voltage-Level Translator for Open-Drain and Push-Pull Applications	WQFN14	TXS0104EBQA	Texas Instruments
U4	1		Low-capacitance, 2:1 (SPDT) 4-channel, powered-off protection switch with 1.8 V logic, RSV0016A (UQFN-16)	RSV0016A	TMUX1574RSVR	Texas Instruments
U5	1		Low Input, 20V/1.1A Step-Up DC/DC Converter with Integrated Power Diode and Input/Output Isolation, DSK0010A (WSON-10)	DSK0010A	TPS61093DSKR	Texas Instruments
U6	1		Linear Voltage Regulator IC Positive Fixed 1 Output 150mA 8-SON (3x3)	VSON8	TPS7B8450QWDRBRQ1	Texas Instruments

5 Additional Information

5.1 Trademarks

Firefox™ is a trademark of Mozilla Foundation.

Google Chrome™ is a trademark of Google LLC.

Windows® is a registered trademark of Microsoft Corporation.

All trademarks are the property of their respective owners.

6 Related Documentation

For related documentation, see the following:

- Texas Instruments, [TMAG6181-Q1 High-Precision Analog AMR Angle Sensor With Integrated Turns Counter data sheet](#)
- Texas Instruments, [TI Sensor Control Board user's guide](#)
- Texas Instruments, [ROTATEPUSH-MAG-ACC user's guide](#)

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 semiconductor 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 DEGRADATION 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/llds/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 2 4 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/llds/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.

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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.
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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, INDEMNITY 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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