EVM User's Guide: TPS65224Q1EVM
TPS6522x Evaluation Module

TEXAS INSTRUMENTS

Description

The TPS6522x power management integrated circuit (PMIC) family is extremely flexible providing multiple outputs in a single package helping to optimize space usage in a system. TPS6522x PMIC includes four step-down converters (buck regulators) and three low-dropout (LDO) regulators. Two of these buck regulators can be used in multi-phase mode to provide up to 10 A source. The PMIC also has a built-in analog-to-digital converter (ADC) which can be used to monitor the core temperature or external signals which helps to reduce the required system space further. The TPS6522x evaluation module (EVM) is both an evaluation and development tool. With the EVM both device level and system level configurability is available through an easy to use graphical user interface (GUI) tool.

Get Started

1. Order the EVM here.

2. Download the GUI for configuration and evaluation.
3. Download the supporting documents here.
4. Get additional material in functional safety and design secure resources.

Features

- Input voltage range from 3V to 5.5V
- Evaluation module can be powered with a bench power supply or USB-C
- On-board MSP432 to communicate with PMIC using the GUI via USB-C cable
- Board can be reworked to support other TPS6522x devices

Applications

- Automotive infotainment and digital cluster, navigation systems, telematics, body electronics and lighting
- Advanced driver assistance system (ADAS)
- Industrial control and automation
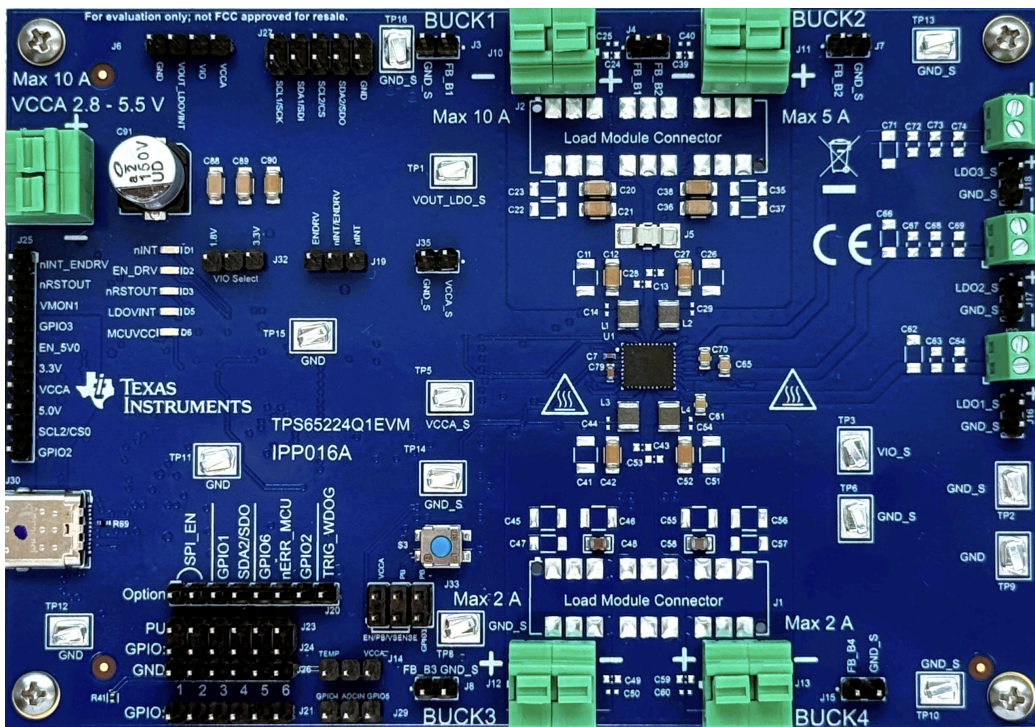
1 Evaluation Module Overview

1.1 Introduction

The TPS65224Q1EVM evaluation module is designed to demonstrate the capabilities of the TPS6522x device family, both automotive and industrial. The EVM can be used to load all the outputs at the maximum current levels and configure different output capacitor combinations for evaluating the performance of the device. The multiple test points in the EVM make measuring voltage levels for all the rails and test the functionality of the device easier. Use this document in conjunction with GUI User's Guide and TPS65224-Q1 Power Management IC (PMIC) with 4 BUCKs and 3 LDOs data sheet.

Multiple jumpers and test points enable a comprehensive evaluation of different functions of TPS6522x devices, both analog and digital. These include voltage monitors, ADC, different enabling options of EN/PB/VSENSE, GPIO functions and communication through I2C or SPI.

Due to the high output power of the TPS6522x devices, the EVM can get hot around the device. These areas are marked with the icon shown below. The maximum output currents of the buck converters are marked next to their connectors.

⚠️🔥	**Caution**	**CAUTION** Hot surface Contact can cause burns. Do not touch!

1.2 Kit Contents

The Following items are included in the EVM box.

1. EVM
2. USB-A male to USB-C male cable
3. Literature, EVM Disclaimer Read Me

1.3 Specification

The EVM is equipped with TPS6522430-Q1 which is designed to provide the power and functionality needed by Texas Instruments AM62P Sitara™ processor. A typical Power Distribution Network (PDN) is shown in Figure 1-1, which utilizes the TPS6522430-Q1 to power the AM62P.

The voltages and current output capabilities of the TPS6522430-Q1 are shown in Table 1-1. These output voltages are enabled when a proper supply is given to the TPS6522430-Q1 and VSENSE is connected to VCCA by a jumper. For all jumper options, please refer to Section 2.2.3.

Table 1-1. TPS6522430-Q1 Rails

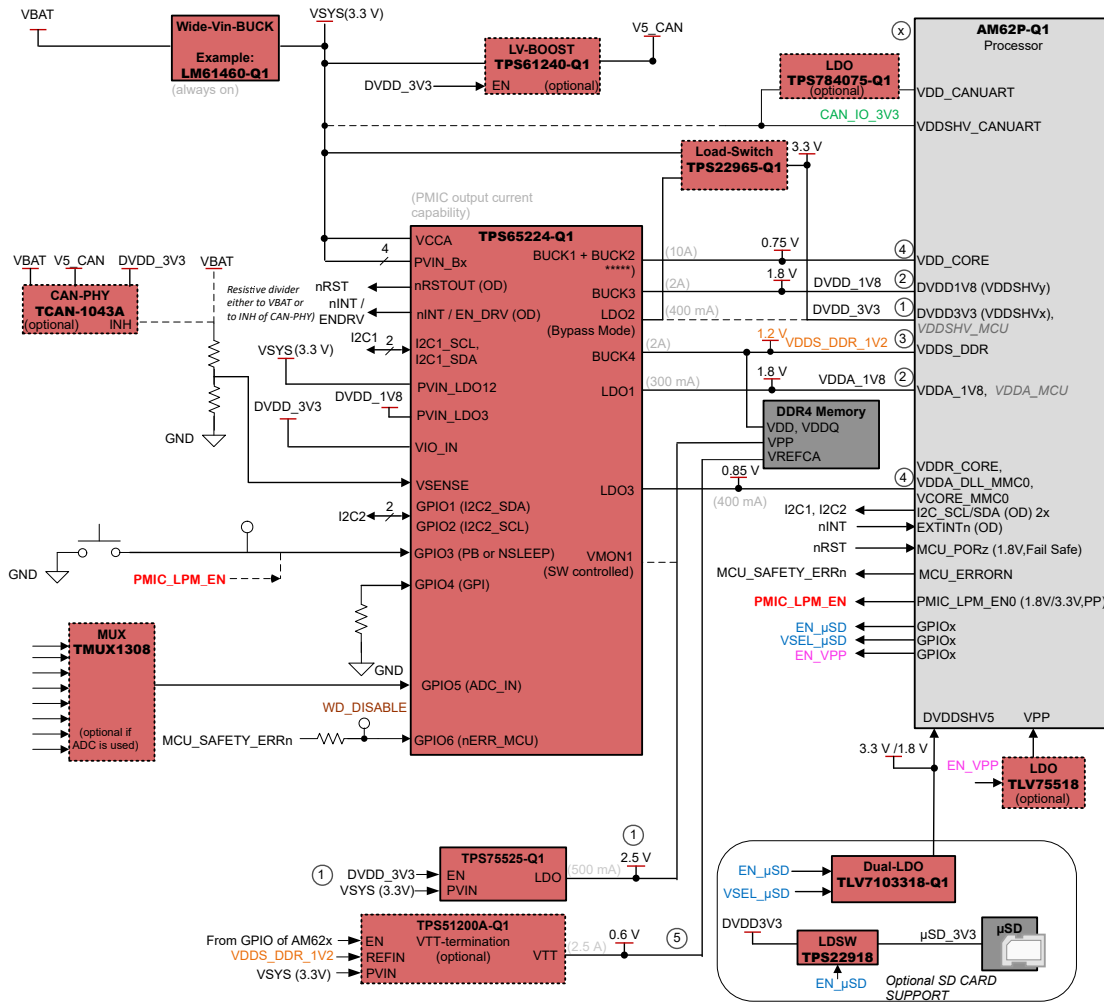| Rail	Voltage	Current capability
VCCA	3.3 V	-
BUCK1+BUCK2	0.75 V	10 A
BUCK3	1.8 V	2 A
BUCK4	1.2 V	2 A
LDO1	1.8 V	300 mA
LDO2	3.3 V	400 mA
LDO3	0.85 V	400 mA
VSENSE	3.3 V	-

Figure 1-1. Typical AM62P PDN Using TPS6522430-Q1

1.4 Device Information

The TPS65224Q1EVM has TPS6522430RAHRQ1 PMIC populated by default with the configuration shown in Section 1.3. The EVM is designed to demonstrate and validate the functionality of this device. The EVM also has MSP432E401Y microcontroller to enable communication with the GUI.

The TPS6522x device family has both automotive and industrial versions available. Automotive version is denoted by "Q1" at the end of the product number as in TPS6522430-Q1. In this document when referring to "TPS6522x" the whole device family is referenced including both industrial and automotive devices. When referencing to a feature or capability of a specific device the full product number is used, for example TPS6522430-Q1.

2 Hardware

2.1 Getting Started

Only a power supply and the EVM are required to evaluate and test the TPS6522x default configuration under load conditions.

1. Connect the proper jumpers. For the default jumper connections see Figure 2-1.
2. Connect power to the EVM.
3. Connect the EVM to the host PC through the USB. If the power is provided by the USB cable, apply the appropriate jumper connection to connect 3.3V with VCCA. Please refer to Table 2-5 for the correct connections.
4. Launch the GUI and evaluate.

Terminal J9, labeled VCCA in Figure 2-1 can accept wire gauges up to 14 AWG. The voltage supplied must be within the input range of the device, 3 V to 5.5 V. The power supply providing the input to VCCA is required to supply 135% of the output power. Once power has been supplied to VCCA, the VCCA can be connected to the EN/PB/VSENSE pin by placing jumper in J33 to power up the rails. Please refer to Table 2-6 for the correct jumper connection.

Note

External Power Supply or Power Accessory Requirements:
- Nominal Output Voltage: 3.3 or 5 VDC
- Maximum Output Current: 10 A
- Efficiency Level V

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, PSE, etc

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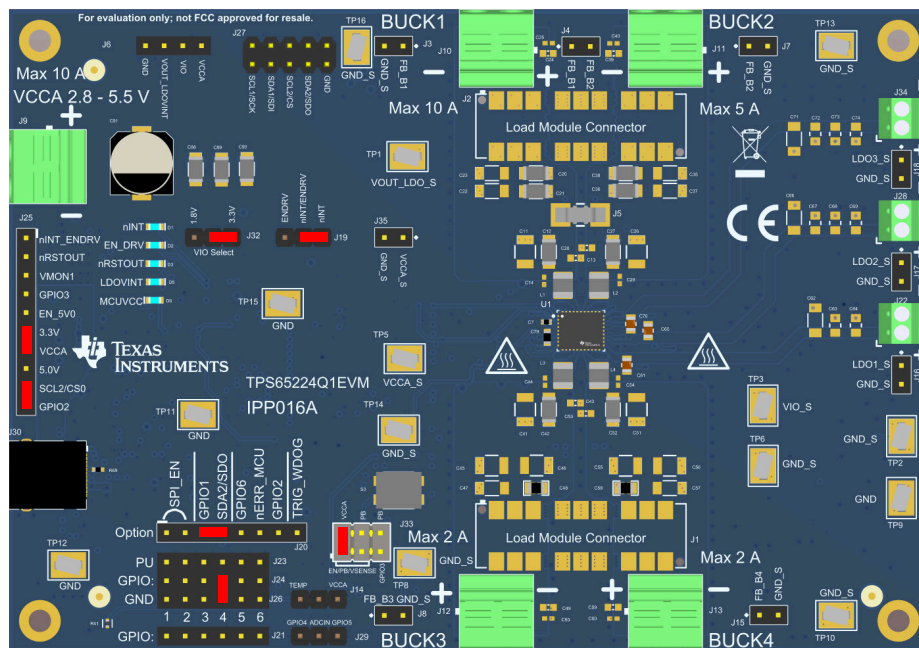
Figure 2-1. EVM with Default Jumper Options Shown in Red (Top View)

Note
To ensure proper functionality of the TPS6522x VCCA must be between 3 V and 5.5 V although the label next to terminal J9 states lowest voltage of 2.8 V.

2.2 EVM Details

The following sections describe the various interfaces for measuring and controlling the configuration.

Note

The configurations are in coordination with the settings of the PMIC. Understand that both the EVM configuration and the settings of the PMIC must match is important. For example, if the GUI is used to change the function of the EN/PB/VSENSE pin, the jumper on J33 needs to be placed accordingly.

2.2.1 Terminal Blocks

The terminal blocks are simple push and release terminals which can accommodate wire sizes up to 14 AWG. Table 2-1 lists the terminal blocks found around the perimeter of the EVM. J9, VCCA, is the input voltage for the regulators. The rest of the terminal blocks are for the BUCK and LDO outputs.

Table 2-1. Terminal Blocks

Terminal	Designator	Description
VCCA	J9	Input for bucks and selected LDOs, 3V to 5.5V Range
BUCK1	J10	Buck 1 Output, 5.5A Capable
BUCK2	J11	Buck 2 Output, 5.5A Capable
BUCK3	J12	Buck 3 Output, 2.4A Capable
BUCK4	J13	Buck 4 Output, 2.4A Capable

Note

The PMIC output current capabilities has been updated to 5.5A for bucks 1 and 2 and to 2.4A for bucks 3 and 4. The silkscreen values can thus be dismissed.


2.2.2 Test Point Descriptions

Numerous test points are provided to access voltages and signals. Test points marked with _S are designed for sensing voltages only and are not designed to carry large DC currents.

Table 2-2. Test Point Descriptions

Test Point	Device Pin	Description
TP1	VOUT_LDO_S	Voltage sense point for the internal LDO.
TP2, TP6, TP8, TP10, TP13, TP14, TP16,	GND_S	Ground sense points routed from various locations.
TP3	VIO_S	VIO voltage sense routed from the VIO pin of the TP65224-Q1
TP5, J35 (Right pin)	VCCA_S	VCCA voltage sense point.
TP9, TP11, TP12, TP15	GND	Solid ground points. Are able to carry larger DC currents.
J3, J7, J8, J15	FB_B1, FB_B2, FB_B3, FB_B4	Buck output voltage sense points. Unused regulator can also be used as voltage monitor for an external rail.
J16, J17, J18	LDO1, LDO2, LDO3	LDO output voltage sense points. Unused regulator can also be used as voltage monitor for an external rail.

2.2.3 Configuration Headers

There are seven headers available to configure the EVM function, some of which are shown in Figure 2-2. Header J20 is used to configure the EVM to match the feature setting written to the TPS6522x configuration registers. J32 is used to select the PMIC IO voltage, either 1.8 V or 3.3 V. J25 allows VCCA to be powered from the USB connection and the configuration of GPIO2 as I2C2 or SPI. Header J33 is used to enable the device and J14 together with J29 are used to configure the ADC input. J19 is used to configure the nINT/EN_DRV pin to the correct LED. Refer to Section 2.2.6 for more information on J19.
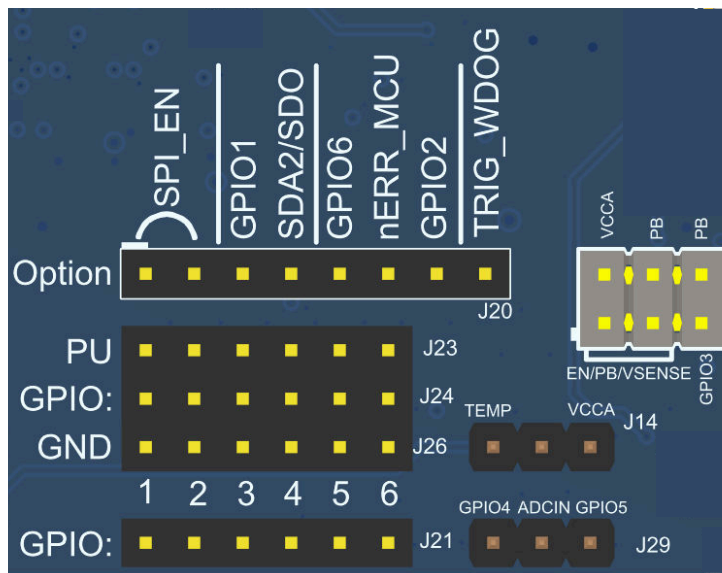
Figure 2-2. J14, J20, J24, J29 and J33 Configuration Headers

Table 2-3. Header J20 Description

Option Pins	Configuration	Description	
SPI_EN	Open (Default)	I^{2}C Mode. The signal path for I^{2}C communication between the MCU and the PMIC is enabled.	
	Closed	SPI mode. The signal path for SPI communication between the MCU and the PMIC is enabled.	
GPIO1, SDA2/SDO	Open	GPIO mode. GPIO1 from PMIC is connected to PM0 of the MCU through a level translator.	
	Closed (default)	I^{2}C Mode (J20 SPI_EN: Open)	Q&A Watchdog mode. GPIO1 of the PMIC must be in the alternative function to support the Q&A Watchdog and the I^{2}C mode is selected. This setting must also be done on connector J25 by closing GPIO2 to SCL2/CS0 if I2C2 is wanted to be used.
		SPI mode (J20 SPI_EN: Closed)	SPI mode, Chip Select. GPIO1 and GPIO2 of the PMIC must be in the alternative function to support SPI communication. This setting must also be done on connector J25 by closing GPIO2 to SCL2/CS if SPI is wanted to be used.
GPIO6, nERR_MCU	Open (default)	GPIO mode. GPIO6 of the PMIC is connected to PQ1 of the MCU through a level translator.	
	Closed	System error countdown input signal from the MCU. GPIO6 of the PMIC must be in the alternative function to support the system error count down from the MCU.	
GPIO2, TRIG_WDOG	Open (default)	GPIO mode. GPIO2 of the PMIC is connected to PM7 of the MCU through a level translator.	
	Closed	Trigger signal for trigger mode watchdog. GPIO2 of the PMIC must be in the alternative function to support the trigger mode watchdog signal.	

Table 2-4. Header J32 VIO Voltage Select

Configuration	Description
Open	Not Allowed, 1.8 V or 3.3 V must be selected.
VIO Select, 3.3 V: Closed (Default)	VIO is 3.3 V.
VIO Select, 1.8 V: Closed	VIO is 1.8 V.

Table 2-5. Header J25, VCCA, GPIO2/I2C/SPI

Configuration	Description	
3.3V, VCCA: Closed (Default)	3.3 V from TLV733P-Q1 (U11) is connected to VCCA. The input for U11 is the 5 V from the USB connection (VBUS). VBUS is not intended to support heavy load conditions. 2 W must be the maximum power drawn from the USB.	
EN_5V0, 3.3V: Open and VCCA, 5.0V: Open	On board 5 V regulator is disabled and VCCA isolated from other on board supplies. VCCA must be powered from J9.	
EN_5V0, 3.3V: Closed	5 V on board regulator (powered from USB) is enabled. 5 V regulated supply can be used to power VCCA.	
VCCA, 5.0V: Closed	5 V on board regulator (powered from USB) is connected to the TPS6522x VCCA. 5 V on board regulator is not intended for heavy load condition.	
GPIO2, SCL2/CS0: Open	GPIO mode. GPIO2 of the PMIC is connected to PM7 of the MCU.	
GPIO2, SCL2/CS0: Closed (Default)	I^{2}C mode (J20 SPI_EN: Open)	Q&A Watchdog mode. GPIO1 and GPIO2 of the PMIC must be in the alternative function to support the Q&A Watchdog and the I^{2}C mode selected. This setting must also be done on connector J20 by closing GPIO1 to SDA2/SDO if I2C2 is wanted to be used.
	SPI mode (J20 SPI_EN: Closed)	SPI mode, Chip Select. GPIO1 and GPIO2 of the PMIC must be in the alternative function to support SPI communication. This setting must also be done on connector J20 by closing GPIO1 to SDA2/SDO.

Note

The PMIC device can be configured for a power good level of 3.3 V or 5.0 V for the VCCA pin. If VCCA_VMON feature is enabled, then check that the input voltage is correct and use sense connection to compensate IR voltage drop with heavy load currents. Align the VCCA/3.3V/5.0V jumper with the PMIC configuration. The default PMIC configuration is monitoring for 3.3 V VCCA voltage through LDO2 which is configured as load switch. This monitoring is enabled when the rails are enabled.

The TPS6522x has EN/PB/VSENSE pin that is used to enable the PMIC. This pin can be configured to work as enable, push-button or voltage sense input. In TPS6522430-Q1, which is populated by default on the EVM, this pin is configured as VSENSE to sense the battery voltage through a voltage divider as shown in Figure 1-1. The GPIO3 can also be configured as push-button input if EN/PB/VSENSE is not configured as push-button input. The J33 configuration header must be used to match the EVM to the PMIC configuration. Refer to Table 2-6 for all the options of the J33. For more details, please see Section 4.1.

Table 2-6. Header J33 Description

Jumper Option	Description
EN/PB/VSENSE, VCCA	VCCA is connected directly to EN/PB/VSENSE.
EN/PB/VSENSE, PB	EN/PB/VSENSE is connected to push button S3. A resistor pulls the pin high when not pressed. When pressed, EN/PB/VSENSE is connected to ground.
GPIO3, PB	GPIO3 is connected to push button S3. A resistor pulls the pin high when not pressed. When pressed, EN/PB/VSENSE is connected to ground.

Note

Additional configuration for the functionality of the EN/PB/VSENSE pin is available with the DIP switch S2. See Section 2.2.5 for more information.

Some TPS6522x devices, including TPS6522430-Q1, have a built-in 12-bit ADC, which can be used to either monitor the junction temperature of the device or an external DC signal. GPIO4 and GPIO5 can be used as the inputs for the ADC. Configuration headers J14 and J29 can be used to connect different signals to the appropriate GPIO pin. Refer to Table 2-7 for connection options and descriptions. For more details, please see Section 4.1.

Table 2-7. ADC input Options

Configuration Header	Jumper Option	Description
J29	GPIO4, ADCIN	Connects GPIO4 to J14 middle pin.
	GPIO5, ADCIN	Connects GPIO5 to J14 middle pin.
J14	TEMP, middle pin	Connects resistive divider using NTC thermistor to the middle pin (not available in the IPP016E1 version).
	VCCA, middle pin	Connects VCCA through a resistive divider to the middle pin.

2.2.4 Connectors

Two load module connector footprints are provided, J1 and J2. These load module connectors are intended to be used with PMICLOADBOARDEVM which is sold separately. The connector components are not populated and the required connectors are shipped with PMICLOADBOARDEVM.

2.2.5 Dip Switches

There are two DIP switches S1 and S2 on the bottom side of the PCB. These switches allow the user to disconnect the level shifter from the PMIC GPIOs or serial interfaces. The level shifter has pull-up resistors on the MCU side that can cause unwanted high state on the GPIO signals if configured in high impedance state. See Table 2-8 for the descriptions of the switches.

Table 2-8. Dip switches

Switch	Pin	Signal line
S1	1-16	SDA_I2C1/SDI_SPI
	2-15	SCL_I2C1/SCK_SPI
	3-14	SDA_I2C2/SDO_SPI
	4-13	SCL_I2C2/CS_SPI
	5-12	GPIO1
	6-11	GPIO2
	7-10	GPIO3
	8-9	GPIO4
S2	1-16	GPIO5
	2-15	GPIO6
	3-14	nINT
	4-13	VCCA - VCCA_ADC
	5-12	VOUT_LDOVINT - LDOVINT_NTC
	6-11	Pull-up - PB_P
	7-10	Pull-down - EN_PB_VSENSE
	8-9	VIO - SREF

2.2.6 EVM Control and GPIO

The EVM has a built-in USB interface based on the MSP432E401Y (U3) to allow the GUI, from the host computer, to communicate with the PMIC. The supply voltage required by the MSP432E401Y is generated automatically by the TLV73333PQDRVRQ1 (U11) and TLV73318PQDRVRQ1 (U12) LDOs, which provide 3.3 V and 1.8 V from USB power, +VBUS. These voltages are available for supplying VIO for the PMIC (selectable from J32). Two SN74GTL2003 level shifters (U4, U6) are used to support the use case of the PMIC VIO of 1.8 V (the MCU IO is always be 3.3 V). In addition to the level shifters, the TS3A5018RSVR (U8) switch is used to

apply the pullup voltages to the I²C lines when SPI_EN is LOW (I2C is used). Additional TS3A5018RSVR (U9) switch is used for SPI enable/disable. The application of the pullup resistors is for I²C mode only.

The EVM has 5 LEDs to indicate board power, PMIC power and some pre-defined PMIC GPOs status. The signals are listed in Table 2-9. Since nINT and EN_DRV share the same pin on the TPS6522x there is a configuration jumper J19 to match the EVM and the PMIC configurations. This jumper selects if the nINT/ EN_DRV pin is connected to D1 or D2.

Table 2-9. EVM LED Indicators

LED Designator	Indication
D1	LED is on when nINT is low.
D2	LED is on when EN_DRV is high.
D3	LED is on when nRSTOUT is low.
D5	PMIC power indicator.
D6	EVM power indicator.

2.3 Customization

The EVM, in conjunction with GUI tool, provides various degrees of customization. A couple of examples are provided here which can be generalized to a number of functions. There are spare components assembled on the EVM to help with the customization, namely inductors L5...L8 and capacitors C80...C87.

2.3.1 Changing the Communication Interface

The default settings for communication with the PMIC is I²C. Changing to SPI requires a minor change to the jumper settings. These jumper settings are highlighted in red in Figure 2-3. The first jumper to place is on the SPI_EN option on connector J20. Placing this jumper connects the microcontroller to the SPI bus, which is connected to the PMIC. The other two jumpers that need to be connected are GPIO1 to SDA2/SDO on J20 and GPIO2 to SCL2/CS0 on J25. These jumpers connect the CS and SDO signals from the MCU to the GPIO pins of the TPS6522x through a level shifter.
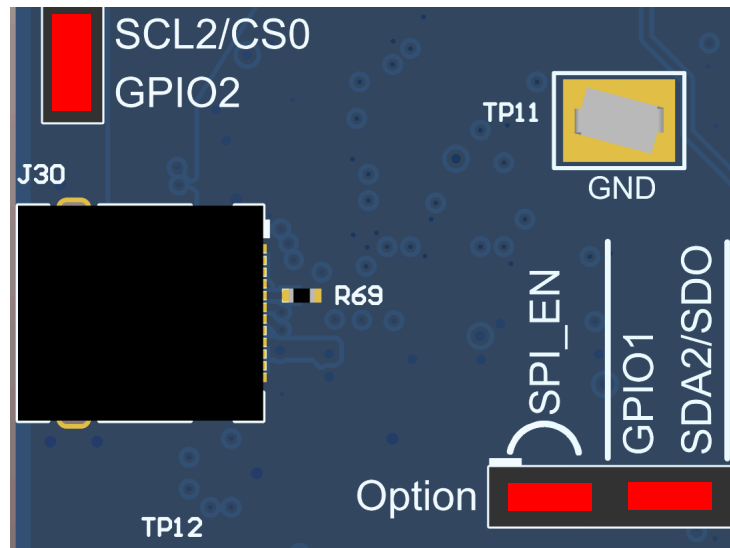
Figure 2-3. Interface Settings for SPI Communication

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2.3.2 Changing the Phase Configuration

There are two possible phase configurations as shown in Table 2-10. The phase configuration of the EVM must match the phase configuration of the PMIC. Jumper J5 is located on the top side of the PCB, whereas the resistors R1-R3 are on the bottom side of the PCB.

Table 2-10. Phase Configurations

Phase Configuration	R1	R2/R3	J5
1(1+1+1+1)	R1	R3	N
2(2+1+1)	R1	R2	Y

This table is also printed on the EVM on the bottom side of the PCB. All the feedback voltages can be measured from J3, J4, J7, J8 and J15 where J4 is a differential feedback.

Note

It is possible to use the unused feedback of the secondary buck for voltage monitoring. 0 ohm resistor R2 connecting the FB pin to GND must be opened in this case.

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3 Software

3.1 GUI Tool

Texas Instruments provides a GUI tool to enable, configure, and evaluate the various features of the TPS6522x with the EVM. Please refer to the GUI User's Guide for a more detailed description of this tool.

The GUI runs on most PC platforms and requires an available USB port. The EVM USB connector is USB Type-C® and a type-A to type-C cable is provided with the EVM to connect to the host computer. The EVM enumerates as two COM ports and one additional port for the device firmware updates. The GUI must use a ACCtrl COM port, which can be found from the device manager of the operating system. The COM port can be changed from the GUI from Options - Device Settings.
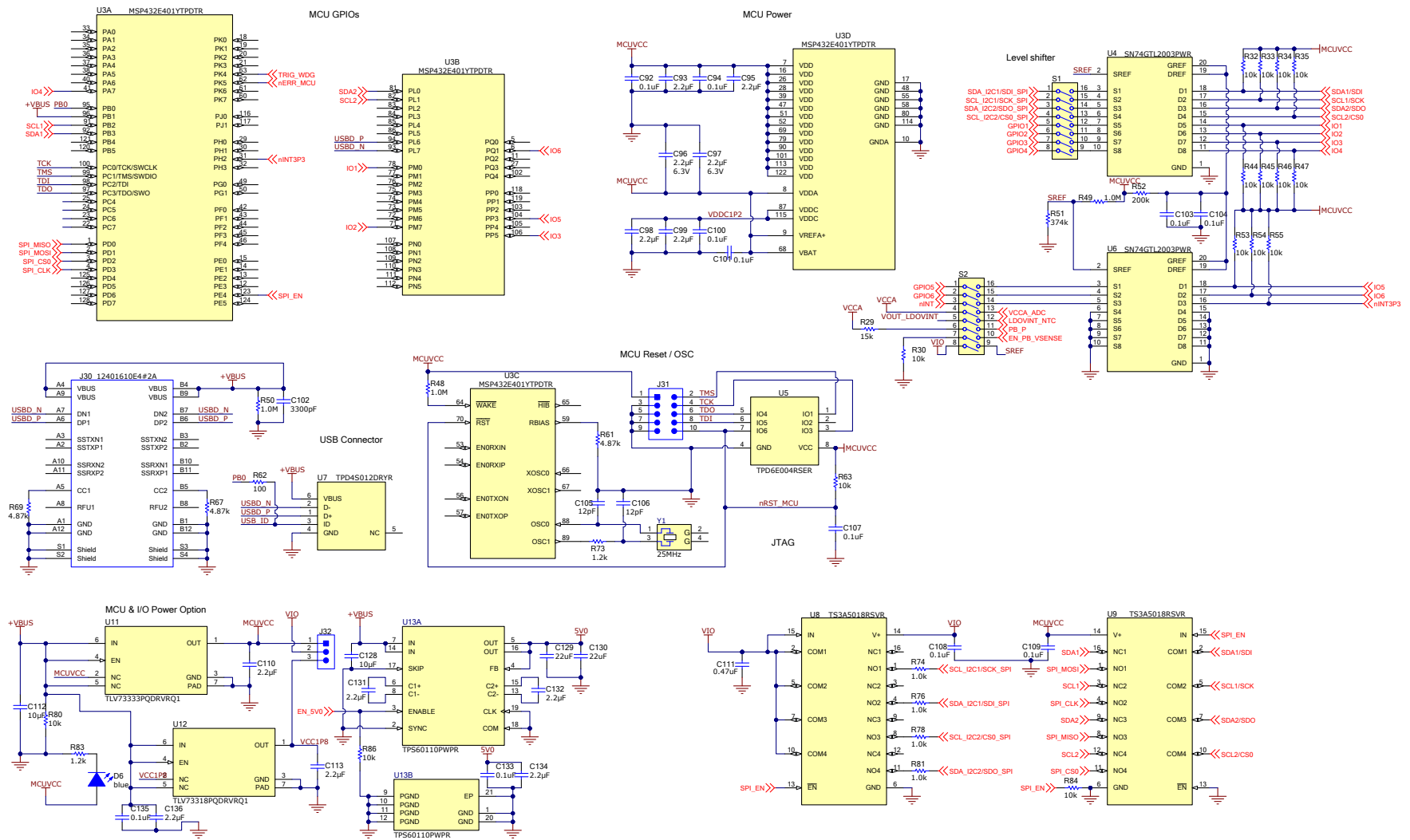
4 Hardware Design Files

4.1 Schematics

Figure 4-1. Schematic Page 1
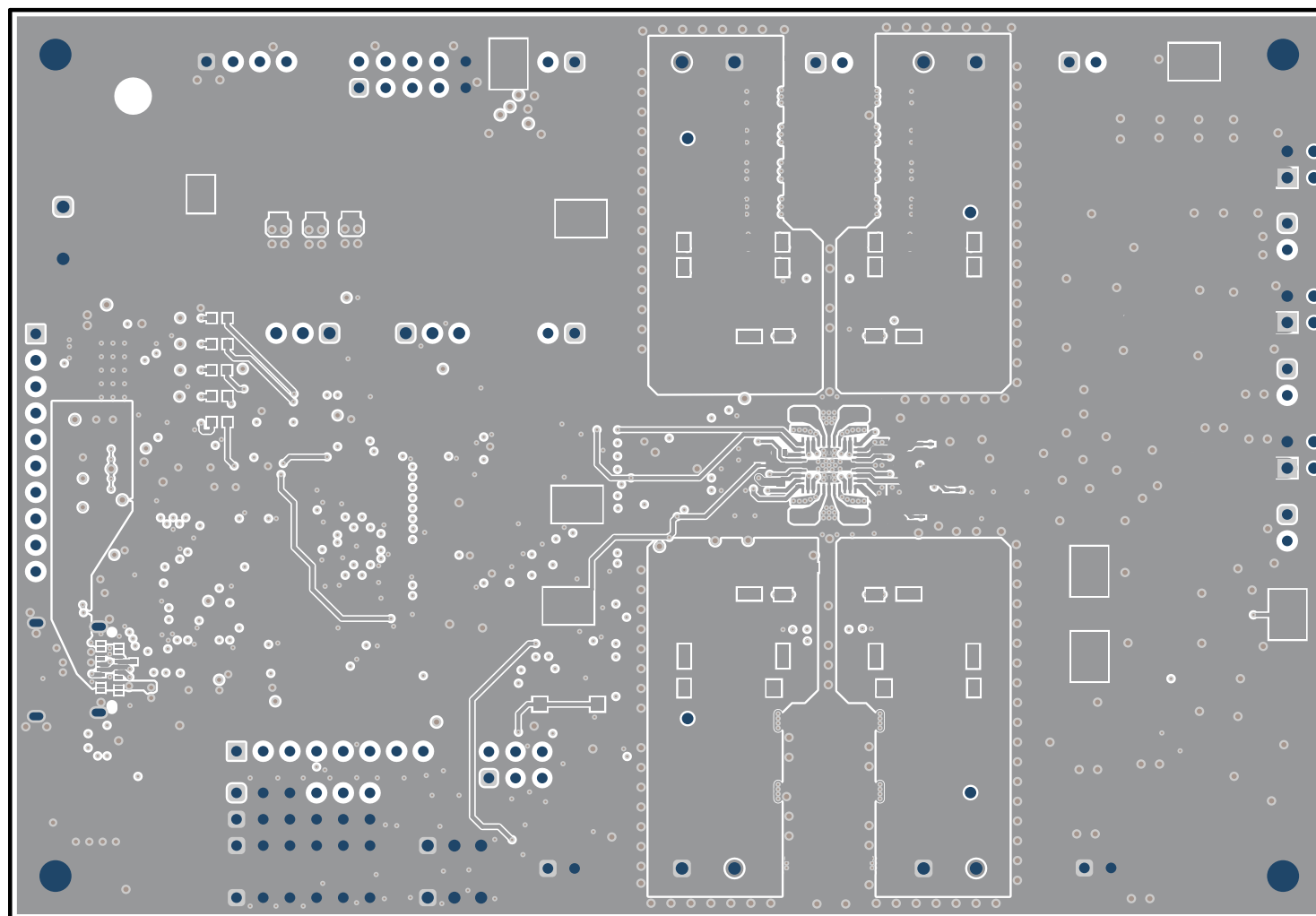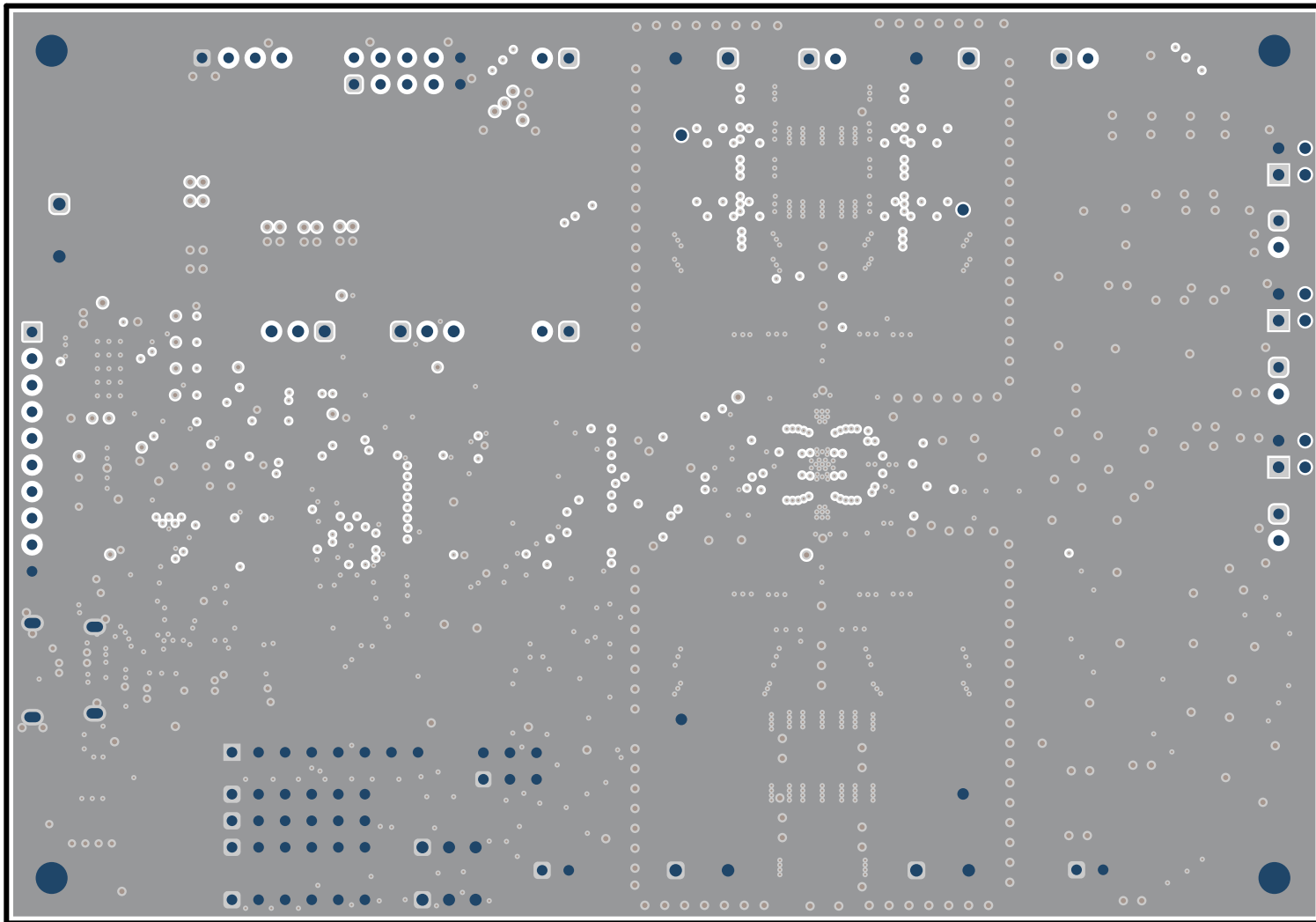
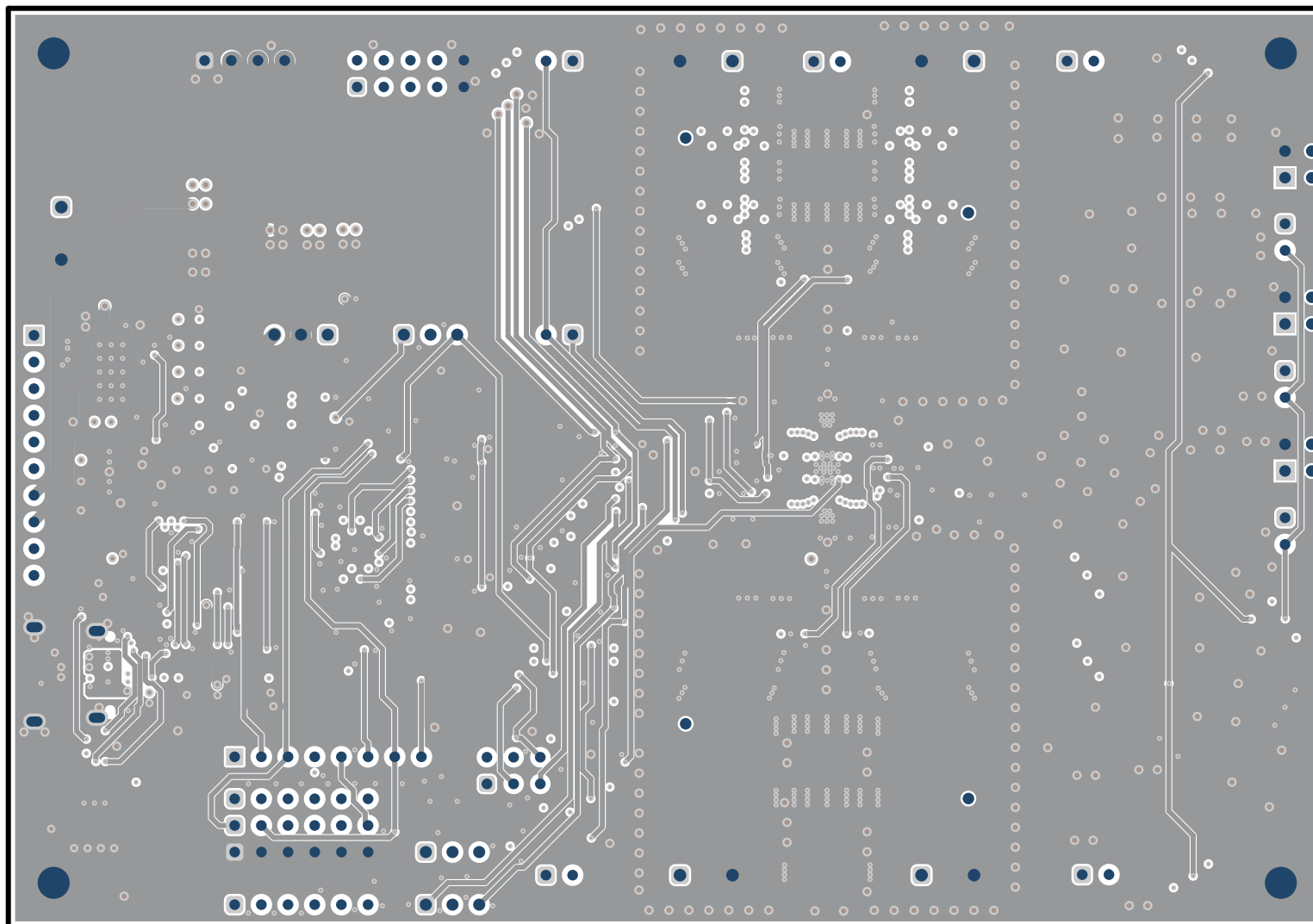**Figure 4-2. Schematic Page 2**

4.2 PCB Layouts

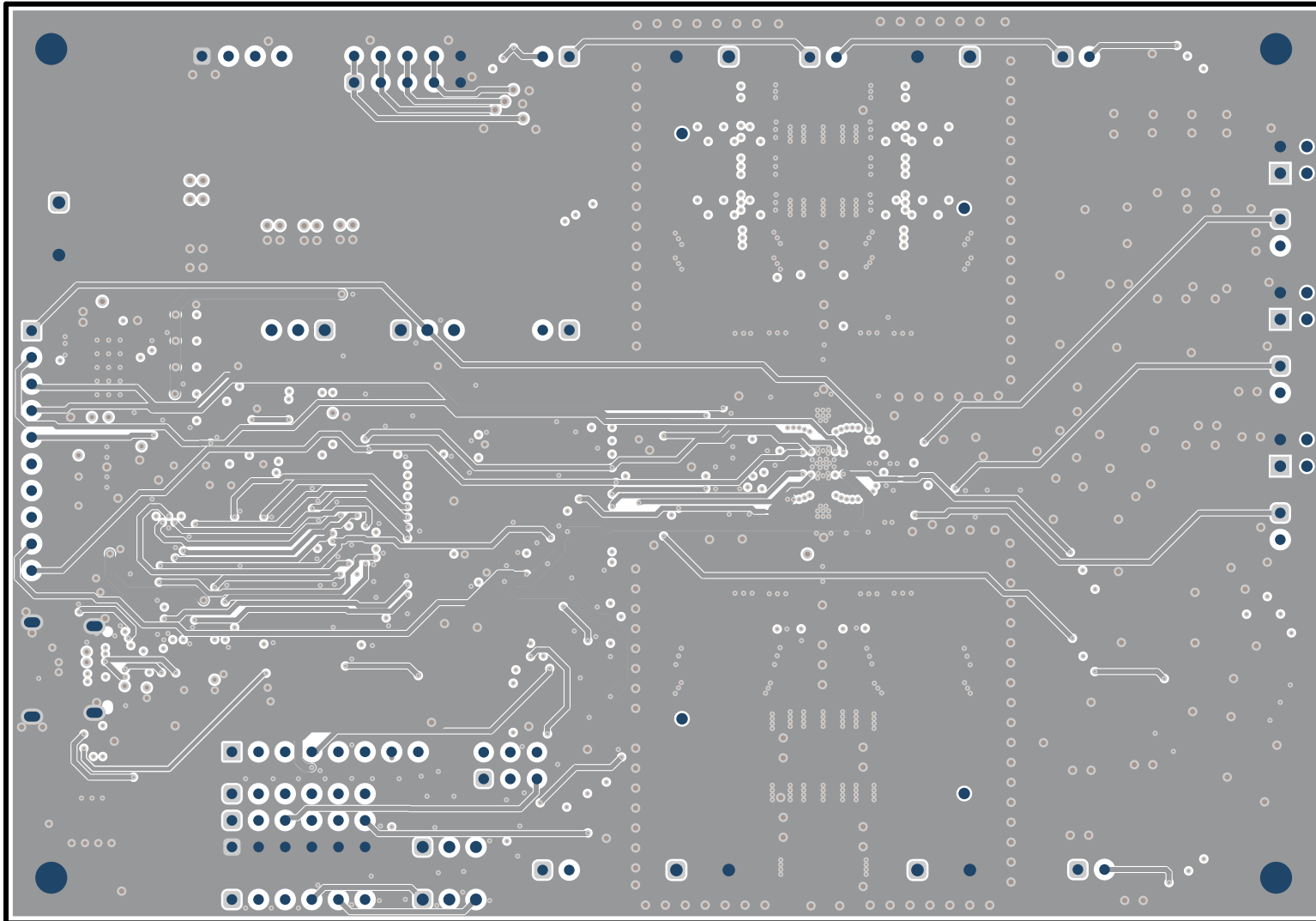**Figure 4-3. Layout Top, Layer 1**
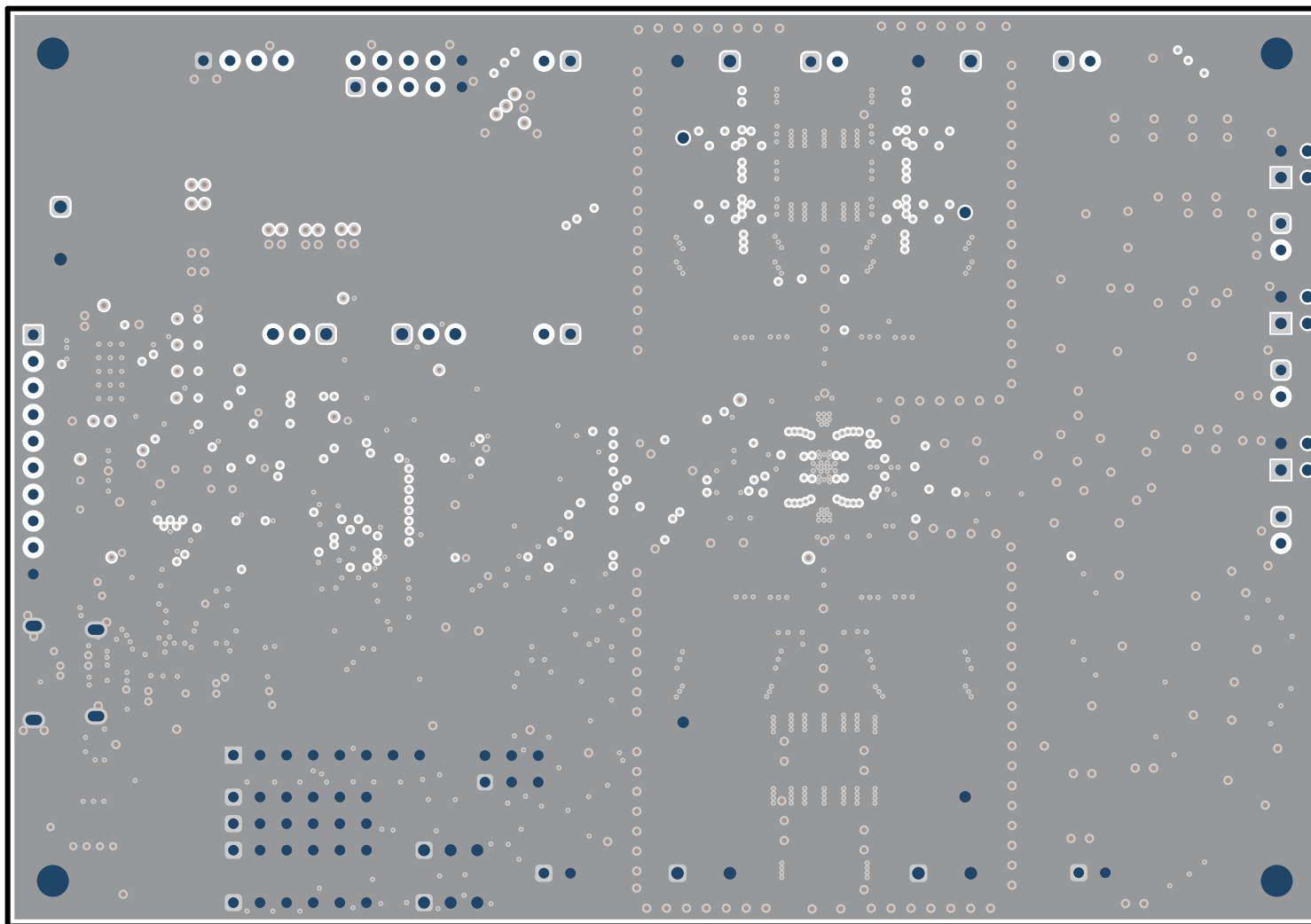
Figure 4-4. Layout Ground, Layer 2
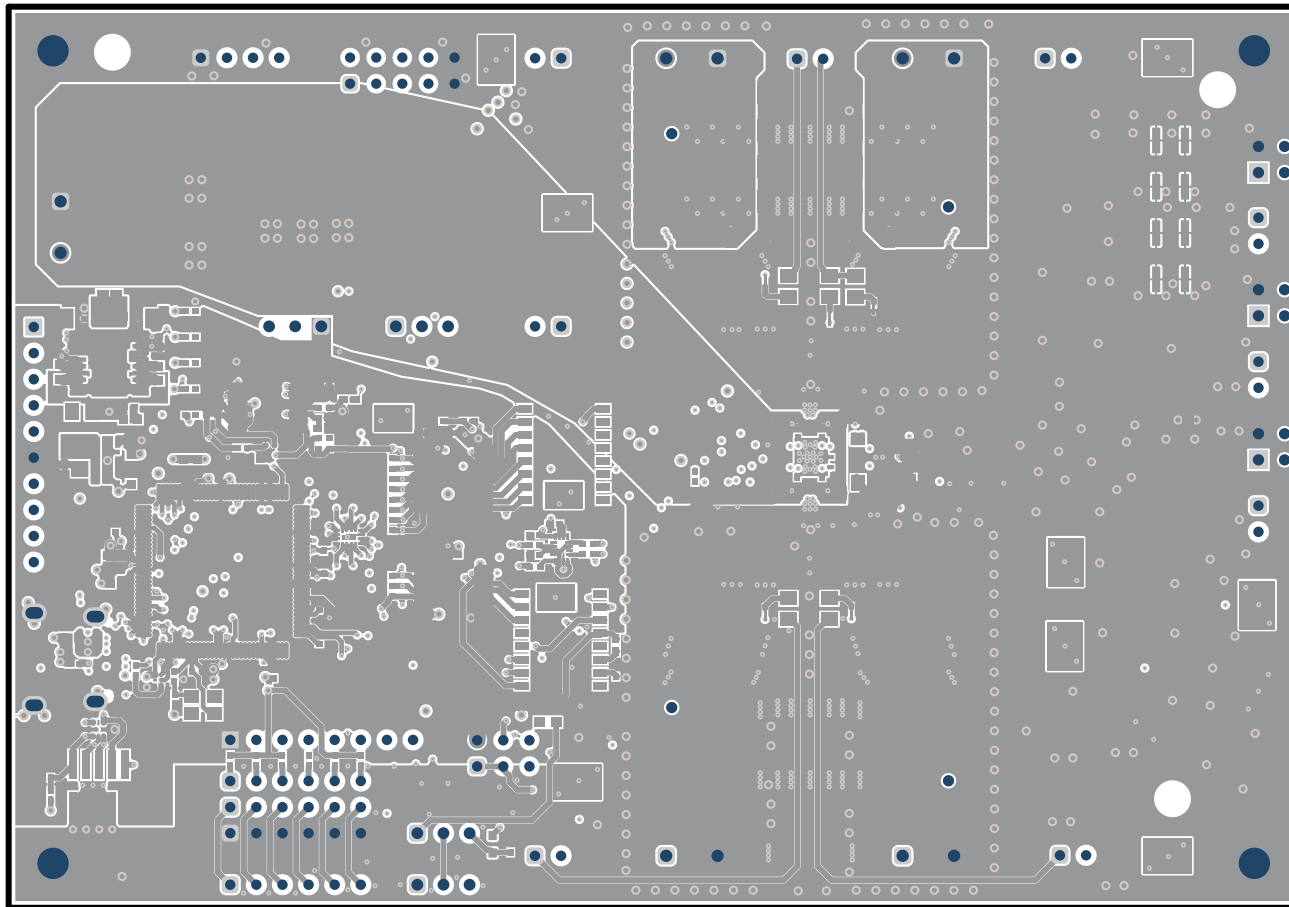
Figure 4-5. Layout Signal, Layer 3

Figure 4-6. Layout Signal, Layer 4

Figure 4-7. Layout Ground, Layer 5

Figure 4-8. Layout Bottom

4.3 Bill of Materials

Table 4-1. Bill Of Materials

Designator	Quantity	Value	Description	PartNumber	Manufacturer
!PCB1	1		Printed Circuit Board	IPP016	Any
C1, C2, C3, C4, C128	5	10uF	CAP, CERM, 10 uF, 10 V, +/- 10%, X7R, 0805	GCM21BR71A106KE22L	MuRata
C7	1	0.47uF	CAP, CERM, 0.47 uF, 10 V,+/- 10%, X7S, 0402	GCM155C71A474KE36D	MuRata
C8, C61, C70	3	2.2µF	Ceramic Capacitor for Automotive 2.2uF ±10% 16VDC X7R 0805 Embossed T/R	GCM21BR71C225KA64L	Murata
C9, C48, C58	3	4.7uF	CAP, CERM, 4.7 uF, 10 V, +/- 10%, X7S, AEC-Q200 Grade 1, 0805	GCM21BC71A475KA73L	MuRata
C12, C20, C21, C27, C36, C38, C42, C52, C84, C85, C86, C87, C88, C89, C90, C129, C130	17	22uF	CAP, CERM, 22 uF, 10 V, +/- 10%, X7R, AEC-Q200 Grade 1, 1206	GCM31CR71A226KE02L	MuRata
C65	1		Ceramic Capacitor for Automotive 2.2uF ±10% 16VDC X7R 0805 Embossed T/R	GCM21BR71C225KA64L	Murata
C75, C76, C77, C78, C92, C94, C133, C135	8	0.1uF	CAP, CERM, 0.1 uF, 16 V, +/- 10%, X7R, 0402	GCM155R71C104KA55D	MuRata
C79, C93, C95, C96, C97, C110, C131, C132, C134, C136	10	2.2uF	CAP, CERM, 2.2 uF, 6.3 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	GCM188R70J225KE22D	MuRata
C80, C81, C82, C83	4	47uF	CAP, CERM, 47 uF, 6.3 V, +/- 20%, X7R, 1210	GCM32ER70J476ME19L	MuRata
C91	1	150uF	CAP, AL, 150 uF, 35 V, +/- 20%, 0.17 ohm, SMD	UUD1V151MNL1GS	Nichicon
D1, D2, D3, D5, D6	5	Blue	LED, Blue, SMD	LB Q39G-L2N2-35-1	OSRAM
D4	1		Diode Schottky 40 V 500mA (DC) Surface Mount SOD-923	NSR05T40P2T5G	onsemi
H1, H2, H3, H4	4			FC2058-440-A	Fascomp
H5, H6, H7, H8	4		MACHINE SCREW PAN PHILLIPS 4-40	9900	Keystone
J3, J4, J7, J8, J15, J16, J17, J18, J35	9		Header, 100mil, 2x1, Gold, TH	TSW-102-07-G-S	Samtec
J5	1		JUMPER TIN SMD	S1911-46R	Harwin
J6	1		Header, 100mil, 4x1, Gold, TH	TSW-104-07-G-S	Samtec

Table 4-1. Bill Of Materials (continued)

J9, J10, J11, J12, J13	5		Terminal Block, 5mm, 2x1, R/A, TH	1792863	Phoenix Contact
J14, J19, J29, J32	4		Header, 2.54 mm, 3x1, Gold, TH	61300311121	Wurth Elektronik
J20	1		Header, 100mil, 8x1, Gold, TH	TSW-108-07-G-S	Samtec
J21, J23, J24, J26	4		Header, 100mil, 6x1, Gold, TH	TSW-106-07-G-S	Samtec
J22, J28, J34	3		Terminal Block, 100mil, 2x1, 6A, 63V, TH	1725656	Phoenix Contact
J25	1		Header, 100mil, 10x1, Gold, TH	TSW-110-07-G-S	Samtec
J27	1		Header, 2.54mm, 5x2, Gold, TH	PRPC005DAAN-RC	Sullins Connector Solutions
J30	1		Receptacle, 0.5mm, USB TYPE C, R/A, SMT	12401610E4#2A	Amphenol Canada
J33	1		Header, 2.54mm, 3x2, Gold, TH	HTSW-103-07-G-D	Samtec
L1, L2, L3, L4	4	220nH	Inductor, Thin Film, 220 nH, 7.6 A, 0.01 ohm, AEC-Q200 Grade 0, SMD	TFM322512ALMAR22MTAA	TDK
L5, L6, L7, L8	4	470nH	Inductor, Thin Film, 470 nH, 5.3 A, 0.021 ohm, AEC-Q200 Grade 0, SMD	TFM322512ALMAR47MTAA	TDK
R1, R2, R4, R7	4	0	RES, 0, 5%, 0.125 W, AEC-Q200 Grade 0, 0805	CRCW08050000Z0EA	Vishay-Dale
R8, R28	2	20k	RES, 20 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW040220K0JNED	Vishay-Dale
R9, R16, R17, R22, R23, R24, R25, R26, R27, R30, R32, R33, R34, R35, R42, R44, R45, R46, R47, R53, R54, R55, R63, R80, R84, R86	26	10k	RES, 10 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW040210K0JNED	Vishay-Dale
R10, R12, R14, R18, R20, R36	6	0	RES, 0, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW04020000Z0ED	Vishay-Dale
R11, R13, R15, R73, R83	5	1.2k	RES, 1.2 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW04021K20JNED	Vishay-Dale
R29	1	15k	RES, 15 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW040215K0JNED	Vishay-Dale
R39	1	3.92Meg	RES, 3.92 M, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW06033M92FKEA	Vishay-Dale
R40	1	50k	High Precision-High Stability Chip Resistor Thin Film 0603 50kOhm 0.1% Paper T/R	RT0603BRD0750KL	Yageo

Table 4-1. Bill Of Materials (continued)

R41	1	100k	Thermistor NTC 100kOhm ±0.5% 0402 2-Pin SMD Paper T/R	NCU15WF104D6SRC	Murata
R48, R50	2	1.0Meg	RES, 1.0 M, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW04021M00JNED	Vishay-Dale
R51	1	374k	RES, 374 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW0402374KFKED	Vishay-Dale
R52	1	200k	RES, 200 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW0402200KJNED	Vishay-Dale
R61, R67, R69	3	4.87k	RES, 4.87 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW04024K87FKED	Vishay-Dale
R62	1	100	RES, 100, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW0402100RJNED	Vishay-Dale
R74, R76, R78, R81	4	1.0k	RES, 1.0 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW04021K00JNED	Vishay-Dale
S1, S2	2		Switch, SPST, 8 Pos, 25mA, 24VDC, SMD	218-8LPST	CTS Electrocomponents
S3	1		Switch, Tactile, SPST-NO, 0.1A, 16V, SMT	7914G-1-000E	Bourns
SH-J1, SH-J2, SH-J3, SH-J4, SH-J5, SH-J6, SH-J7, SH-J8, SH-J9, SH-J10, SH-J11, SH-J12	12		Shunt, 100mil, Gold plated, Black	881545-2	TE Connectivity
TP1, TP2, TP3, TP5, TP6, TP8, TP9, TP10, TP11, TP12, TP13, TP14, TP15, TP16	14		Test Point, Compact, SMT	5016	Keystone Electronics
U1	1		Power Management IC (PMIC) with 4 BUCKs and 3 LDOs for SafetyRelevant Automotive Applications	TPS6522430RAHRQ1	Texas Instruments
U2	1		AEC-Q100 Quad Comparator, PW0014A (TSSOP-14)	LM2901AVQPWRQ1	Texas Instruments
U3	1		MSP432E401YTPDT, PDT0128A (TQFP-128)	MSP432E401YTPDTR	Texas Instruments
U4, U6	2		8-BIT BIDIRECTIONAL LOW-VOLTAGE TRANSLATOR, PW0020A (TSSOP-20)	SN74GTL2003PWR	Texas Instruments
U5	1		Low-Capacitance 6-Channel +/-15 kV ESD Protection Array for High-Speed Data Interfaces, RSE0008A (UQFN-8)	TPD6E004RSER	Texas Instruments

Table 4-1. Bill Of Materials (continued)

U7	1		4-Channel USB ESD Solution with Power Clamp, DRY0006A (USON-6)	TPD4S012DRYR	Texas Instruments
U8, U9	2		10-Ohm Quad SPDT Analog Switch, RSV0016A (UQFN-16)	TS3A5018RSVR	Texas Instruments
U11	1		Capacitor-Free, 300-mA, Low-Dropout Regulator for Automotive, DRV0006A (WSON-6)	TLV73333PQDRVRQ1	Texas Instruments
U12	1		Capacitor-Free, 300-mA, Low-Dropout Regulator for Automotive, DRV0006A (WSON-6)	TLV73318PQDRVRQ1	Texas Instruments
U13	1		5 V, Boost Charge Pump, 300 mA, 2.7 to 5.4 V Input with Synchonrization pin, -40 to 85 degC, 20-pin SOP (PWP20), Green (RoHS & no Sb/Br)	TPS60110PWPR	Texas Instruments
Y1	1		CRYSTAL 25.0000MHZ 8PF SMD	NX3225SA-25.000M-STD-CRS-2	NDK
C10, C111	0	0.47uF	CAP, CERM, 0.47 uF, 10 V,+/-10%, X7S, 0402	GCM155C71A474KE36D	MuRata
C11, C16, C17, C18, C19, C26, C31, C32, C33, C34, C41, C45, C46, C51, C55, C56	0	47uF	CAP, CERM, 47 uF, 6.3 V, +/-20%, X7R, 1210	GCM32ER70J476ME19L	MuRata
C13, C24, C28, C39, C43, C49, C53, C59, C98, C99, C113	0	2.2uF	CAP, CERM, 2.2 uF, 6.3 V, +/-10%, X7R, AEC-Q200 Grade 1, 0603	GCM188R70J225KE22D	MuRata
C14, C25, C29, C40, C44, C50, C54, C60, C100, C101, C103, C104, C107, C108, C109	0	0.1uF	CAP, CERM, 0.1 uF, 16 V, +/-10%, X7R, 0402	GCM155R71C104KA55D	MuRata
C15, C30	0	220µF	220 µF ±20% 2.5V Ceramic Capacitor X7T 1210 (3225 Metric)	GCM32ED70E227ME36L	Murata
C22, C23, C35, C37, C47, C57, C62, C66, C71	0	22uF	CAP, CERM, 22 uF, 10 V, +/-10%, X7R, AEC-Q200 Grade 1, 1206	GCM31CR71A226KE02L	MuRata
C63, C64, C67, C68, C69, C72, C73, C74, C112	0	10uF	CAP, CERM, 10 uF, 10 V, +/-10%, X7R, 0805	GCM21BR71A106KE22L	MuRata
C102	0	3300pF	CAP, CERM, 3300 pF, 50 V, +/- 10%, X7R, 0603	C0603C332K5RACTU	Kemet

Table 4-1. Bill Of Materials (continued)

C105, C106	0	12pF	CAP, CERM, 12 pF, 50 V,+/- 5%, C0G/NP0, AEC-Q200 Grade 1, 0402	GCM1555C1H120JA16J	MuRata
H9	0		USB A MALE TO USB C Male	3021090-01M	Qualtek
J1, J2	0		Receptacle, 2.5mm, 3x2, Gold, SMT	6651712-1	TE Connectivity
J31	0		Header (Shrouded), 1.27mm, 5x2, Gold, SMT	FTSH-105-01-F-DV-K	Samtec
R3	0	0	RES, 0, 5%, 0.125 W, AEC-Q200 Grade 0, 0805	CRCW08050000Z0EA	Vishay-Dale
R5	0	10k	RES, 10 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW040210K0JNED	Vishay-Dale
R6, R19, R21	0	0	RES, 0, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW04020000Z0ED	Vishay-Dale
R31	0	1.2k	RES, 1.2 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW04021K20JNED	Vishay-Dale
R49	0	1.0Meg	RES, 1.0 M, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW04021M00JNED	Vishay-Dale

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5 Additional Information

Trademarks

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6 Related Documentation

- Scalable PMIC's GUI User's Guide
- TPS65224-Q1 Power Management IC (PMIC) with 4 BUCKs and 3 LDOs data sheet

7 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

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

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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.

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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.

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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.

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