TPS92661EVM-001 LED Matrix Manager Evaluation Module (EVM) User's Guide

The TPS92661EVM-001 EVM is intended to aid firmware and system designers in designing and communicating with the TPS92661Q lighting matrix manager (LMM). The TPS92661 allows individual shunt-FET dimming control of up to 96 independently-controlled LEDs on a single communications bus. It is intended for use in automotive exterior lighting systems such as adaptive front-lighting systems (AFS).

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1 Introduction

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2 Warnings

Observe the following precautions when using the TPS92410EVM-001.

WARNING

High temperatures

WARNING

Do not stare directly into the LED light source. Intense light sources have a high secondary blinding effect. A temporary reduction in visual acuity and afterimages can occur, leading to irritation, annoyance, visual impairment, and even accidents – depending on the situation. Always consider the use of light filtering and darkening protective eyewear and be fully aware of surrounding laboratory type set-ups when viewing intense light sources to minimize or eliminate such risks in order to avoid accidents related to temporary blindness.

WARNING

Do not stare at the operating LED – (Risk Group 1 (RG1)). See IEC32471-1 ed1.0:2009-08 for risk group definitions.

3 EVM Overview

The features of this EVM are as follows:

- 2x TPS92661 channels (24 LEDs) with independently-controlled buck current sources
- On-board, reprogrammable C2000 Piccolo™ microcontroller with embedded firmware for communicating between a PC and the TPS92661s
- Local power supply generation enables single input voltage testing
- Expandable bus interface to custom hardware
- Ability to interface an external microcontroller to the TPS92661s to allow custom firmware development

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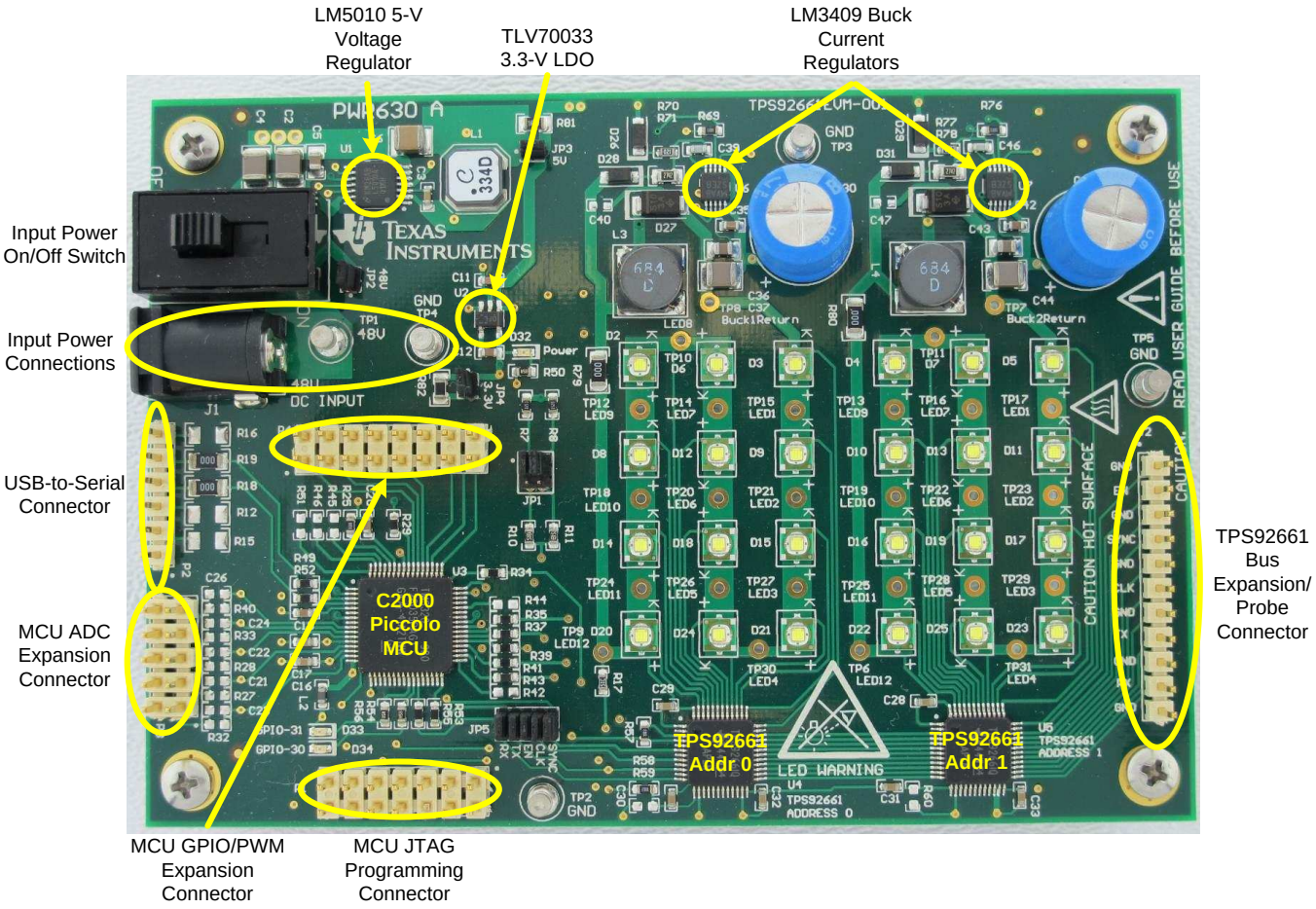


Figure 1. EVM Overview

4 Power Supply Requirements and Connections

4.1 Input Power

The device only requires a single power supply input. The voltage must be greater than 12 × V_f of the LEDs to allow enough overhead for the LM3409 buck converters to regulate the individual string currents. TI recommends that users begin with a 48-V input because that provides enough headroom in all cases. A 2.1-mm ID barrel connector, J1, is provided for use with standard AC/DC wall transformers and test turrets, TP1 and TP4, which can be used with bench supplies. The EVM is intended to primarily assist the designer in understanding how the TPS92661 works and how it is used at the system level. To that end, the string currents through the LEDs are kept small to avoid too much light output which makes it difficult to probe the board or work near it while the user is developing. Each string has a max current rating of approximately 135 mA. So, the worst-case power draw is when all 24 LEDs are at 100% duty cycle (fully on) with the max current through both strings. Calculate that power as in Equation 1.

$$2 \text{ strings} \times 12 \text{ LEDs} \times 3V_f \times .135 \text{ A} = 9.72 \text{ W} \quad (1)$$

To account for other circuitry and any conversion efficiency, TI recommends that the user use >12-W supply, if max light output is desired.

4.2 PC Connection (P2)

The C2000 can communicate with a PC through a FTDI TTL-232R-3V3 USB cable (included) that plugs into P2. Pin 1 is the black wire of the cable and should be oriented to align with the P2 pin 1 dot in the silkscreen of the PCB. The green wire of the cable is nearest the J1 input power barrel connector.

4.3 C2000 JTAG Programming Header (P1)

The C2000 Piccolo microcontroller can be reprogrammed and debugged using Texas Instruments' Code Composer Studio™ software and an appropriate JTAG debugger. One possible solution is Spectrum Digital's XDS100v3, which can be ordered from the product page.

This header is keyed to allow the programmer to plug in only one way. Use of this header/programmer can allow custom firmware development for the C2000 microcontroller.

4.4 TPS92661 Bus Expansion/Probe Header (J2)

All relevant signals to the TPS92661 can be monitored by this header. Additionally, the user can connect this header to their own hardware for testing purposes. The PC interface can be used to send commands to additional TPS92661s that are connected to these posts. Take care if using TPS92661 read commands if the user's hardware has any TPS92661s at the same logical address as the two on-board LMMs. This will likely cause bus contention. However, writes will function normally.

Additionally, the user can remove the five jumpers of JP5 to completely remove the on-board C2000 microcontroller from the board and wire their own microcontroller into the J2 header. This allows custom firmware development on the preferred core without having to design/develop the power electronics/LED load board hardware.

4.5 C2000 I/O Expansion Headers (P3 and P4)

Several microcontroller ADC channels are brought out to the P3 header. These channels could be used for purposes such as monitoring various system voltages or temperatures for either system development or debug and test.

The P4 header breaks out the remaining microcontroller PWM channels, which can be used to generate PWM signals, analog voltages, or as GPIOs for user development.

Several other GPIO pins do not go to a header, but are accessible through an unstuffed resistor pad.

5 Jumper Settings

5.1 JP1 – C2000 Boot Mode Select

The C2000 boot mode select jumpers allow the user to instruct the microcontroller to boot from various peripherals/memory locations. For further details, reference the appropriate C2000 Piccolo literature on www.ti.com.

Table 1. JP1 Jumper Position Settings

Position 1 (GPIO-34)	Position 2 (TDO)	Result
Logic 0: 3 to 5 shorted	Logic 0: 4 to 6 shorted	Parallel I/O
Logic 0: 3 to 5 shorted	Logic 1: 2 to 4 shorted	Wait mode
Logic 1: 1 to 3 shorted	Logic 0: 4 to 6 shorted	SCI boot
Logic 1: 1 to 3 shorted	Logic 1: 2 to 4 shorted	Get mode/flash *(default)*

5.2 JP2 – Input Voltage Current Sense

JP2 is shorted by default, but may be removed to sense input current into the system. A 2-Ω, 1% accurate resistor sits across the JP2 terminals. Measuring the voltage drop across the resistor allows the user to find the input current from $I_{IN} = V_{R83\text{-}DROP} / 2\ \Omega$.

5.3 JP3 – 5-V Voltage Output Current Sense

JP3 is shorted by default, but may be removed to sense output current from the 5-V switching regulator. The 5-V rail supplies the 3.3-V LDO regulator, the TPS92661s, and acts as a reference to the LM3409 off timers when the LED string voltage is below 5 V. A 1.5-Ω, 1% sense resistor sits across the JP3 terminals allowing 5-V current to be sensed as $I_{5V} = V_{R81\text{-}DROP} / 1.5\ \Omega$.

5.4 JP4 – 3.3-V Voltage Output Current Sense

JP4 is shorted by default, but may be removed to sense the output current from the 3.3-V LDO. The 3.3-V rail is the supply for the microcontroller. Because an LDO's output current is equal to its input current, that allows the user to subtract out the microcontroller's contribution from the 5-V rail's current consumption and to gain a better understanding of the power consumed by the TPS92661. A 1-Ω, 1% sense resistor sits across the JP4 terminals allowing 3.3-V current to be sensed as $I_{3V3} = V_{R82\text{-}DROP} / 1\ \Omega$.

5.5 JP5 – C2000 Disconnects for TPS92661 Bus

By default, all five of these shunts are in place. This connects the C2000 microcontroller to the five signals of the TPS92661 bus (ENABLE, SYNC, CLOCK, TX, and RX). Individual jumpers may be removed to disconnect the C2000 microcontroller from the bus. This may be useful to allow the user to test connections with less than the full contingent of signals. The user may also remove all five jumpers to completely disconnect the C2000 from the bus. An external microcontroller could then be used to control the TPS92661s through J2.

6 Control Interface

6.1 Overview

A UART interface from the PC controls the TPS92661EVM. The UART is set up for 115.2 kbps, 8N1 data formatting. The user may use any terminal program they choose.

In a final system application, the microcontroller is responsible for bridging data from the various automotive sensors/controllers and translating that into mapping for the pixel array. While the microcontroller does attempt to handle many of the low level details and timing, it is also possible to send TPS92661 commands directly from the PC. This allows the user to not only see what the end application might look like, but to work directly with the TPS92661 packet interface to understand how the part works.

6.2 Hardware Setup

The commands are carried across a FTDI USB-to-serial cable. The user should ensure that they have installed the latest FTDI drivers prior to plugging in the USB cable included with the kit. Because the EVM operates on raw byte streams, it is possible to use any supported OS that FTDI provides drivers for. The latest drivers can be downloaded directly from the FTDI website.

After these drivers are installed, the USB-to-serial cable can be plugged in. The user must tell their terminal program what COM port the USB-to-serial cable appears as and set it up for 115.2 kbps, 8N1, no hardware flow control.

6.3 Commands

Each command is a series of bytes that is sent to the C2000 MUC as a packet. The general format of each packet is:

- First byte sent = Number of bytes to follow
- Second byte sent = Command
- ** Additional bytes dependent upon command

Table 2 shows a list of all available commands:

Table 2. Commands

BYTE 0 (N Bytes to Follow)	BYTE 1 (Command)	Command Name	Description	Command Data Format	Response Data Format
1	0x00	GET_FW_VER	Return the major/minor firmware versions		Byte 0 = Major version, Byte 1 = Minor version
2	0x01	SET_LMM_ENABLE	Set ENABLE high or low on the TPS92661 bus	Byte 2 = 0x01 for on, 0x00 for off	
4	0x02	SET_BUCKS	Turn the bucks on/off and adjust output current	Byte 2[0] = Ch0 on/off, Byte 2[1] = Ch1 on/off, Byte 3 = Ch0 ADIM, Byte 4 = Ch1 ADIM	
1	0x03	SEND_COMMS_RST	Send TPS92661 communications reset		
2	0x04	CLOCK_STOP	Remove TPS92661 clock or restart it	Byte 2 = 0x01 for on, 0x00 for off	
1	0x05	GET_SYS_STATE	Get present setting of ENABLEs and ADIMs		Byte 0[0] = TPS92661 enable, Byte 0[1] = CH0 buck enable, Byte 0[2] = CH1 buck enable, Byte 1 = CH0 ADIM, Byte 2 = CH1 ADIM
2	0x06	DEMO_MODE	Can disable the demo mode or turn it back on	Byte 2 = 0x01 for enable, 0x00 for disable	
2	0x07	WATCHDOG_ADJ	Enables or disables the TPS92661 watchdogs	Byte 2[0] = CMWEN on/off, Byte 2[1] = CKWEN on/off	
3	0x08	ADJ_RD_TIME	Adjust how often the MCU reads FAULT (in ms)	Byte 2 = LSByte of 16-bit timer, Byte 3 = MSByte of 16-bit timer	
3	0x09	ADJ_FAULT_LIM	Change how many consecutive faults to accumulate	Byte 2 = LSByte of number, Byte 3 = MSByte of number	
3	0x0A	RD_LMM_REG	Return the value from the requested register	Byte 2 = LMM address, Byte 3 = Register address	Byte 0 = 0xAA for success, 0x00 on failure; Byte 1 = Data for success, 0xFF on failure
1	0x0B	GET_FAULT_SET	Returns the read timer setting and fault accumulation limit		Byte 0 = LSByte read timer, Byte 1 = MSByte read timer, Byte 2 = LSByte fault limit, Byte 3 = MSByte fault limit
5	0x0C	SET_DC_IND	Changes an individual LED duty cycle	Byte 2 = Y-coordinate, Byte 3 = X-coordinate, Byte 4 = LSByte DC, Byte 5 = MSByte DC	
3	0x0D	SET_DC_ALL	Change all LEDs in the array to new duty cycle	Byte 2 = LSByte DC, Byte 3 = MSByte DC	
1	0x0E	SYNC_SHADOW	Force the MCU to go refresh its shadow registers		
2	0x0F	CONST_RFRSH	Turn on and off constant refresh/reads	Byte 2[0] = Constant reads on/off, Byte 2[1] = Constant writes on/off	

Table 2. Commands (continued)

BYTE 0 (N Bytes to Follow)	BYTE 1 (Command)	Command Name	Description	Command Data Format	Response Data Format
1	0x10	HOW_MANY_LMMS	Determine how many TPS92661s were found by MCU		Byte 0 = 0xAA, Byte 1 = Bit-packed LMM addresses found
2	0x11	GET_LMM_ENS	Reads the enable shadow memory from MCU	Byte 2 = LMM address	Byte 0 = LSByte ENON, Byte 1 = MSByte ENON, Byte 2 = LSByte ENOFF, Byte 3 = MSByte ENOFF
2	0x12	GET_LMM_ONS	Read the LEDON shadow memory from MCU	Byte 2 = LMM address	Byte 0 = LSByte LEDON1, Byte 1, = MSByte LEDON1, Byte 2 = LSByte LEDON2, And so forth
2	0x13	GET_LMM_OFFS	Read the LEDOFF shadow memory from MCU	Byte 2 = LMM address	Byte 0 = LSByte LEDOFF1, Byte 1, = MSByte LEDOFF1, Byte 2 = LSByte LEDOFF2, And so forth
7	0x14	SET_LMM_ENS	Set the enable shadow memory in the MCU	Byte 2 = LMM address, Byte 3 = LSByte ENON, Byte 4 = MSByte ENON, Byte 5 = LSByte ENOFF, Byte 6 = MSByte ENOFF, Byte 7[0] = 1 writes it to LMM	
1	0x15	TOGGLE_LED1	Toggle the GUI-controlled signal LED		
2	0x16	CORNERING	Enter cornering mode/fade	Byte 2[0] = 0x01 for on, 0x00 for Off, Byte 3 = Step (0 to 20)	

As an example, if the user wanted to change the duty cycle of a single pixel located at X = 3, Y = 2 to a value of 50% (512 / 1024), they would send the following packet:

- First byte sent = 0x05 (Indicates 5 bytes to follow)
- Second byte sent = 0x0C (Command for changing one pixel)
- Third byte sent = 0x02 (Y coordinate)
- Fourth byte sent = 0x03 (X coordinate)
- Fifth byte sent = 0x00 (LSByte of 512, or 0x200)
- Sixth byte sent = 0x02 (MSByte of 512)

The user should see the pixel at (Y,X) 2,3 change it's on time to 50%.

Additionally, a raw TPS92661 packet can be sent and this is passed along by the microcontroller to the LMM bus. The details of constructing a TPS92661 packet can be found in the TPS92661 data sheet, but an example is included here. To perform a read of the PCKDIV register of TPS92661 at logical address 1, the packet appear as follows:

- First byte sent = 0x04 (Indicates 4 bytes to follow); this is stripped away by the MCU
- Second byte sent = 0xC1 (Command Frame Init Byte = 1 1000 001)
- Third byte sent = 0xC0 (This is the register address to read from, PCKDIV)
- Fourth byte sent = 0x51 (LSByte of the CRC-16 over 0xC1C0)
- Fifth byte sent = 0xC0 (MSByte of the CRC-16 over 0xC1C0)

The user can use the online CRC calculator found at http://www.lammertbies.nl/comm/info/crc-calculation.html to generate the required CRC-16. When using the calculator, set the **Input type** radio button for hex, and then enter the bytes that are being checked into the text box and click the **Calculate CRC** button. The calculated CRCs will change, and the one of interest is 'CRC-16'. As a test, the user should enter the above two data bytes (C1C0) and calculate the CRC. It should return 0xC051, as shown previously.

If the above transaction is sent over the UART interface to the microcontroller, the MCU strips off the first byte and forwards the next 4 bytes to the TPS92661 bus. If a response occurs from the bus, it is forwarded back to the PC by the microcontroller. In this case, assuming that the user has not changed the default EVM programming, the response should return as:

- First byte returned = 0x00 (Response Frame Init Byte = 0 0000 000; 1 data byte to follow)
- Second byte returned = 0x12 (data read from PCKDIV)
- Third byte returned = 0x01 (bit-reversed LSByte of CRC on 0x0012; bit-corrected = 0x80)
- Fourth byte returned = 0xB0 (bit-reversed MSByte of CRC; bit-corrected = 0x0D)

When directly interfacing to the TPS92661s, the microcontroller does *not* cache any of the reads and writes. Therefore, it may lose synchronization with its internal shadow storage that it uses for managing the individual pixels. A command is included to force the microcontroller to go refresh its shadow registers from the TPS92661 hardware registers.

6.4 Command Descriptions

6.4.1 Get Firmware Version

- Description: Gets the version of the firmware stored in the MCU flash
- Send String: 0x01 0x00
- Returns: Major version, minor version

6.4.2 Set TPS92661 ENABLE

- Description: Drives the TPS92661 ENABLE pin high or low.
- Drive Enable High Send String: 0x02 0x01 0x01
- Drive Enable Low Send String (reset TPS92661): 0x02 0x01 0x0
- Returns: No return data

6.4.3 Buck Current Regulator Control

- Description: Allows the user to turn on or turn off the LED current sources, or to adjust the amount of current through each individual string.
- Send String: 0x04 0x02 [0x00-0x03] [0x00-0xFF] [0x00-0xFF]
- Returns: No return data

6.4.4 Send TPS92661 Communications Reset

- Description: If the asynchronous communications between the MCU and the TPS92661s get out of synch, this sends a break to reset the TPS92661 communications state machines. Note that this does not affect the internal registers of the TPS92661s.
- Send String: 0x01 0x03
- Returns: No return data

6.4.5 Stop the TPS92661 Clock from Toggling

- Description: Useful to understand how the LMM behaves when the clock is lost in the system. By default, the clock watchdog is enabled in both TPS92661s by the firmware. In the event of a lost clock, the array defaults to its DEFLED settings, which are initialized to the bottom two rows ($0 \le Y \le 1$) by the firmware.
- Stop Clock Send String: 0x02 0x04 0x00
- Resume Clock Send String: 0x02 0x04 0x01
- Returns: No return data

6.4.6 Get System State

- Description: This returns the present system settings of the TPS92661 ENABLE, the current source enables, and the current source output current settings.
- Send String: 0x01 0x05
- Returns: [0x00-0x07] [0x00-0xFF] [0x00-0xFF]

6.4.7 Demonstration Mode Control

- Description: When power is first applied to the EVM, the microcontroller runs a canned demonstration comprises two repeating patterns. The first is a uniform fade up or fade down of all pixels. The second is a snake pattern that alternates rows with a fading tail. This mode pauses whenever a UART string is received from the PC, but resumes if no further commands are received for about 15 s. This mode may be enabled/disabled with this command. TI recommends that the user stop this demo mode prior to sending other commands.
- Cease Demo Send String: 0x02 0x06 0x00
- Begin Demo Send String: 0x02 0x06 0x00
- Returns: No return data

6.4.8 Enable or Disable TPS92661 Watchdogs

- Description: The TPS92661 contains two internal watchdogs. The first is a clock watchdog. If no clock pulse is received for 32 internal oscillator cycles, the TPS92661 defaults the LEDs to the DEFLED register programming. The second is a communications watchdog. If no successful UART transaction is received in 222 input clock toggles, the TPS92661 defaults the LEDs to the DEFLED register programming. At power-up, the MCU on the EVM programs the clock watchdog to 1, but leaves the communications watchdog cleared. With this command, the user may change the setting.
- Send String: 0x02 0x07 [0x00-0x03]
- Returns: No return data

6.4.9 Adjust Fault Read Timings

- Description: As an example of one way to process LED faults that are reported by the TPS92661, the

MCU can be set up to read back the FAULTL/H registers at a periodic rate. The default read timeout is 50 ms, but this command can be used to change it from 1 to 216 ms. The user is cautioned that programming the MCU to read faults to frequently decreases the usable bandwidth on the bus.

- Send String: 0x03 0x08 [0x00-0xFF] [0x00-0xFF]
- Returns: No return data

6.4.10 Adjust Fault Accumulation Limit

- Description: This sets the number of times that the FAULTL/H individual register bits must be read high prior to declaring that an individual LED has failed. By default, this is set to 10, but may be adjusted between 1 to 216. Note that this number × the Fault Read timing number determines how long a fault must exist in the hardware prior to being recorded by the MCU. The default settings of reading every 50 ms × 10 means that it takes about 500 ms for the MCU to declare a pixel “bad”. This is an arbitrary number chosen by the firmware for this EVM platform and is not indicative of any recommended operating point.
- Send String: 0x03 0x09 [0x00-0xFF] [0x00-0xFF]
- Returns: No return data

6.4.11 Read TPS92661 Hardware Register

- Description: This command allows the user to peer into any register in the TPS92661s. If no data is returned, it is likely the bus has gotten out of synchronization in some fashion.
- Send String: 0x03 0x0A [0x00-0x07] [0x00-0xFF]
- Successful return: 0xAA [DATA READ]
- Unsuccessful return: 0x00 0xFF

6.4.12 Read Present MCU Fault Settings

- Description: This command returns the present fault read settings.
- Send String: 0x01 0x0B
- Returns: [LSByte Read Timer] [MSByte Read Timer] [LSByte Limit] [MSByte Limit]

6.4.13 Set Individual LED Duty Cycle (0 – 1023)

- Description: This command instructs the MCU to change the duty cycle setting of any LED in the on-board array.
- Send String: 0x05 0x0C [0x00-0x03] [0x00-0x05] [0x00-0xFF] [0x00-0x03]
- Returns: No return data

6.4.14 Set Array LED Duty Cycle (0 – 1023)

- Description: This command changes all LEDs to the commanded duty cycle.
- Send String: 0x03 0x0D [0x00-0xFF] [0x00-0x03]
- Returns: No return data

6.4.15 Shadow Memory Synchronization

- Description: If the user is issuing raw LMM packets to the TPS92661 bus, the MCU does *not* cache those changes in its local shadow memory of the registers. This may lead to a situation where the MCU and the TPS92661 registers are not synchronized. This command can be used to force the MCU to go reread all of the relevant TPS92661 registers.
- Send String: 0x01 0x0E
- Returns: No return data

6.4.16 Enable/Disable Periodic TPS92661 Writes/Reads

- Description: To understand what the bandwidth limitations of the channel might be, this command

allows the user to turn on periodic reads of the FAULTL/H registers, and/or periodic writes/refreshes of the array. In a typical end application, the MCU is responsible for both updating the pixel array at a reasonable refresh rate based on new/updated sensing and control inputs, and for occasionally checking for faults in the system. This command allows the EVM the ability to mimic this behavior

- Send String: 0x02 0x0F [0x00-0x03]
- Returns: No return data

6.4.17 How Many TPS92661s Were Found

- Description: Upon power-up, the C2000 MCU attempts to write a 1 to the PWR bit in the SYSCFG register located at each TPS92661 logical address. It then attempts to read back from each of those addresses and see if a correct read response occurs. While doing this, it updates a byte-wide variable with the addresses it found. This is a useful diagnostic upon power-up to ensure all bus members are still functional. This command returns the bit-packed byte value that the MCU assembled and may be useful in debugging connections to a user's own LED load board with TPS92661s on it.
- Send String: 0x01 0x10
- Returns: 0xAA [0x00-0xFF] (default for on-board 2 TPS92661s is 0x03)

6.4.18 Get TPS92661 ENON/ENOFF Shadow Values

- Description: This reads back the values presently stored in the ENON and ENOFF shadow memory locations of the MCU. The MCU uses these to manage the LED duty cycles. **Note that this is shadow memory in the MCU, not the TPS92661 register value.** However, they should match unless the user has issued raw TPS92661 commands to change these registers without the MCU's assistance.
- Send String: 0x02 0x11 [0x00-0x01]
- Returns: [LSB ENON] [MSB ENON] [LSB ENOFF] [MSB ENON]

6.4.19 Get TPS92661 LEDON Shadow Values

- Description: This reads back the values presently stored in the LEDON shadow memory locations of the MCU. The MCU uses these to manage the LED duty cycles. **Note that this is shadow memory in the MCU, not the TPS92661 register value.** However, they should match unless the user has issued raw TPS92661 commands to change these registers without the MCU's assistance.
- Send String: 0x02 0x12 [0x00-0x01]
- Returns: [LSB LEDON1] [MSB LEDON1] [LSB LEDON2] [MSB LEDON2]… x24

6.4.20 Get TPS92661 LEDOFF Shadow Values

- Description: This reads back the values presently stored in the LEDOFF shadow memory locations of the MCU. The MCU uses these to manage the LED duty cycles. **Note that this is shadow memory in the MCU, not the TPS92661 register value.** However, they should match unless the user has issued raw TPS92661 commands to change these registers without the MCU's assistance.
- Send String: 0x02 0x13 [0x00-0x01]
- Returns: [LSB LEDOFF1] [MSB LEDOFF1] [LSB LEDOFF2] [MSB LEDOFF2]… x24

6.4.21 Set TPS92661 ENON/ENOFF Shadow Values

- Description: This allows the user to set/clear individual bits in the ENON/ENOFF shadow memory of the MCU, and to synchronize it to the TPS92661 hardware registers, if desired.
- Send String: 0x07 0x14 [0x00-0x01] [LSB ENON] [MSB ENON] [LSB ENOFF] [MSB ENOFF] [0x00-0x01]
- Returns: No return data

6.4.22 Toggle MCU LED1 (GPIO31)

- Description: There is a signal-level red LED attached to GPIO31 of the C2000 MCU that may be toggled by sending this command. This gives a simple check to ensure that communications are still good between the MCU and the PC, and that the MCU is still functional.

- Send String: 0x01 0x15
- Returns: No return data

6.4.23 Enter Cornering Fade Mode

- Description: One of the possible uses for a LMM system is in cornering beam applications. This command places the EVM in a mode that shows how the cornering beam might be implemented across the array. Because each pixel is controllable with the TPS92661, this command can implement a log-20 fade across the 24 on-board LEDs. In this case, the MCU assigns 20 virtual columns across the array and calculates the fade based on how far from the commanded step, or center point, of the command.
- Send String: 0x02 0x16 [0x00-0x14]
- Returns: No return data

7 Getting Started

7.1 Overview

This section is intended to guide the user in unboxing the EVM, getting the required tools set-up, and making some initial measurements.

7.2 Equipment

The following equipment is required:

- 48-V power supply
- FTDI TTL-232R-3V3 cable (included)
- USB drivers: http://www.ftdichip.com/Drivers/VCP.htm

TI recommends to use an oscilloscope.

To modify or debug the source firmware, the user needs the JTAG programmer.

7.3 Initial Setup

1. Go to FTDI and download the most recent driver package. Install it on the test PC prior to plugging in the USB cable to the PC.
2. Remove the EVM from the ESD packaging and place it on an ESD-safe bench. Ensure that the power switch is set to *off* (slid so that it is nearest the edge of the PCB).
3. Plug the 48-V supply into J1 or use a bench supply and feed it into test turrets TP1 (+48 V) and TP4 (GND).
4. Attach the USB-to-serial cable. Pin 1 of P2 should be connected to the black wire of the cable SIP connector, as shown in Figure 2.

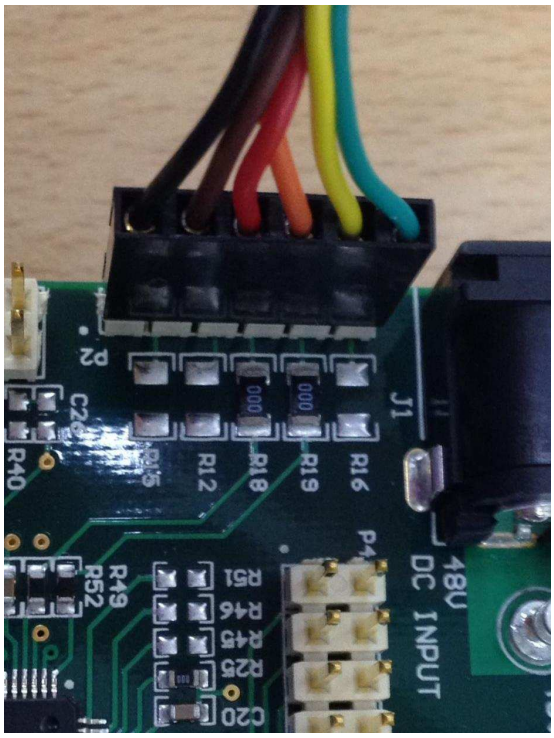


Figure 2. Cable Connections

5. Slide the S1 power switch to *on*.
6. The EVM should power up, run through the initial configuration, and begin the demonstration mode. If the user does not see light output from the LED array, reference *Section 8*.

7.4 Initial Measurements

Using an oscilloscope, probe the following locations with the EVM in demonstration mode (see Table 3).

Table 3. Jumper Descriptions

Jumper	Pin	Description
J2	4	This is the SYNC pin of the TPS92661 bus. Its period is equivalent to the PWM duty cycle of the LED array. In the base configuration of the EVM, this should measure 293 Hz. The signal is driven by TPS92661 address 0 by default.
	6	This is the clock pin of the TPS92661 bus. It is driven by one of the MCU's PWM peripherals, but could be driven just as easily by a local oscillator. The firmware in the MCU drives this at 7.2 MHz by default, which gives a UART bitrate of 7.2 MHz / 16 or 450 kbps.
	8	This is the TPS92661 Tx bus signal. The Tx is with respect to the TPS92661. This pin connects to the MCU's UART Rx pin. This pin should idle in the high position when unused, and should have TTL UART traffic on it whenever the MCU performs a read from the TPS92661s.
	10	This is the TPS92661 Rx bus signal. It connects to the MCU's UART Tx pin. While in demonstration mode, there should be fairly regular communications traffic on this pin while the MCU updates the duty cycle registers.
TP6 or TP9		This is the buck current regulator output, and the top of the LED stack. Measuring the voltage here shows how the TPS92661 shunt dimming works. At any instant of time, the voltage measured here is representative of the number of LEDs that are presently on. In the fade up/fade down pattern, notice how the stack voltage moves between about 0 V (all LEDs off) and about 36 V (all LEDs on).

7.5 Leaving Demonstration Mode and Verifying Communications With the PC

Using your selected terminal program, send the following commands:

1. 0x01 0x00: This should return the firmware version and means the MCU is able to communicate in both directions successfully with the PC. The EVM leaves demo mode momentarily. If no additional commands are sent, then a timeout occurs and demo mode is entered again.

NOTE: If the firmware does not respond to the previous command, send 0x01 0x15. This should toggle the user-controlled signal LED, D33. If this command is functional, then there is a problem with the signaling from MCU-to-PC, but the PC-to-MCU channel is working. If this command has no effect, there may be a problem with the communications to the PC or the EVM itself. Check *Section 8*.

2. 0x02 0x06 0x00: This takes the EVM out of demo mode permanently.

7.6 Changing the Duty Cycle Within the Array

The EVM has all 24 LEDs at 10% duty cycle when initially leaving demonstration mode. The user is encouraged to observe the stack voltage waveform at TP6 or TP9. Due to the programmed phase shifting of the LEDON times, only a single LED toggles at any one time. This decreases the overall dynamic range that the power converters have to handle, and makes the input current less irregular.

While observing the voltage waveform on TP9, send the following command: 0x05 0x0C 0x00 0x00 0xFF 0x01. The user should see the LED pixel at 0,0 increase from 10% brightness to 50% brightness, and see a corresponding change in the waveform. Try programming several different duty cycles to the LEDs to see how it changes the voltage (and thereby power) waveforms.

7.7 Fault Handling

The TPS92661 actively detects, corrects, and reports faulty LED conditions. Open LEDs are immediately detected and corrected by the TPS92661, and both short and open conditions are reported by the FAULTL/H registers. The firmware is set-up to monitor the fault registers and eventually disable the turning on of the LED. This is not mandatory behavior, and the TPS92661 always actively protects against faults. However, it is shown in this guide to demonstrate one possible solution to the faulty LED problem.

By default, periodic reads are disabled. They can be enabled by sending: 0x02 0x0F 0x01. If the user probes the TPS92661 bus Rx pin, they should see a periodic read every 50 ms after issuing this command. Note that this timeout can be changed if desired.

After fault reads are running, use a wire or metal object to short across one of the LEDs. Notice how fault conditions do not affect the other LEDs and how the LED returns to normal operation after the short is removed. This is how the TPS92661 is designed to operate. It tests the open/short LED condition on every PWM cycle and handles it appropriately. The MCU is programmed to read the FAULTL/H registers every 50 ms and accumulate 10 total faults before declaring a LED bad. Hold the short in place for ≥500 ms and notice how the LED eventually just stays off. A fault message should be reported by the UART when this occurs. An end system should perform some kind of similar process where it low-pass filters faults, eliminating known false fault conditions, and eventually declares a LED as bad and reports that upstream.

8 Troubleshooting

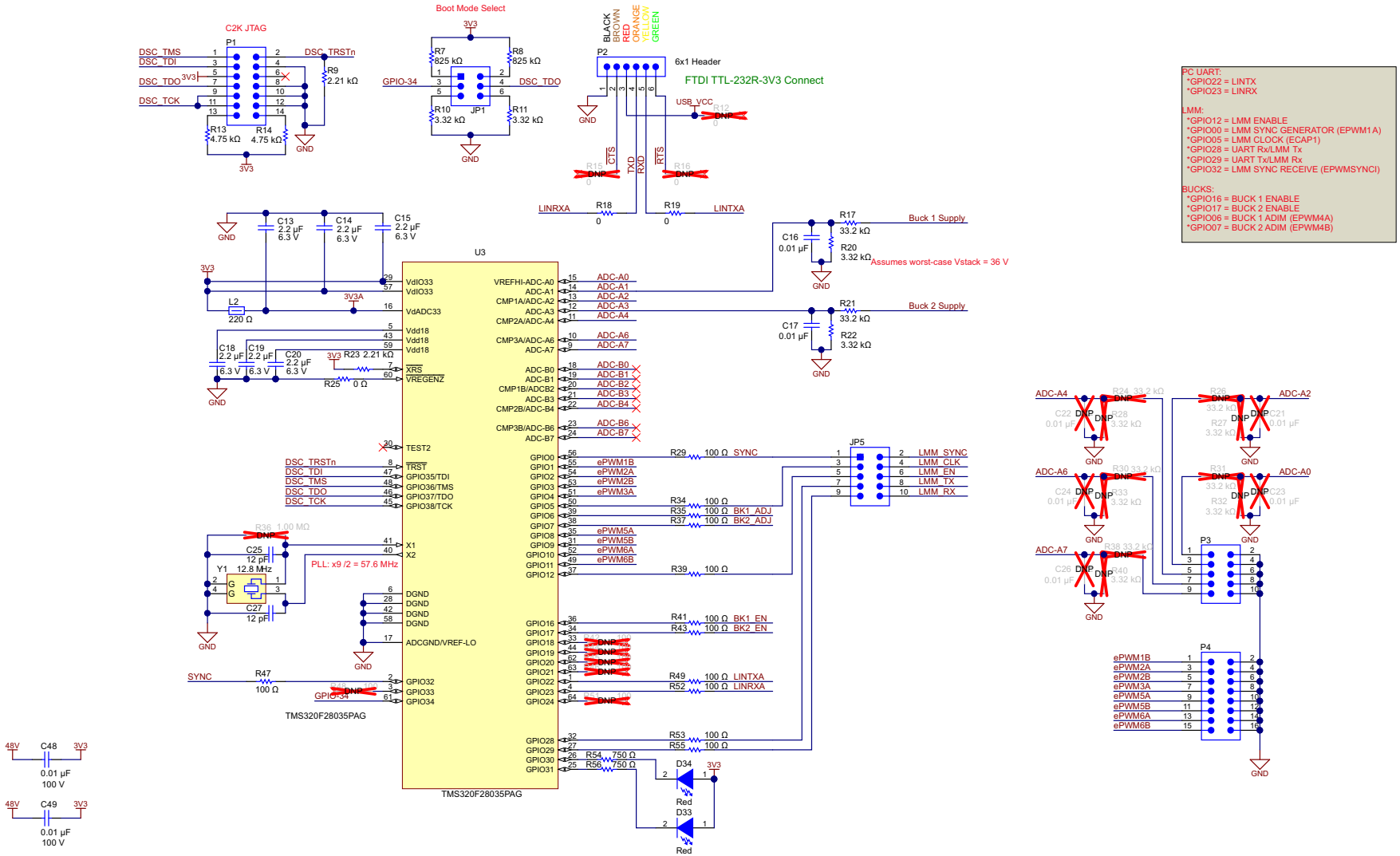
8.1 Problem: Demonstration Mode Does Not Occur Upon Initial Power Up

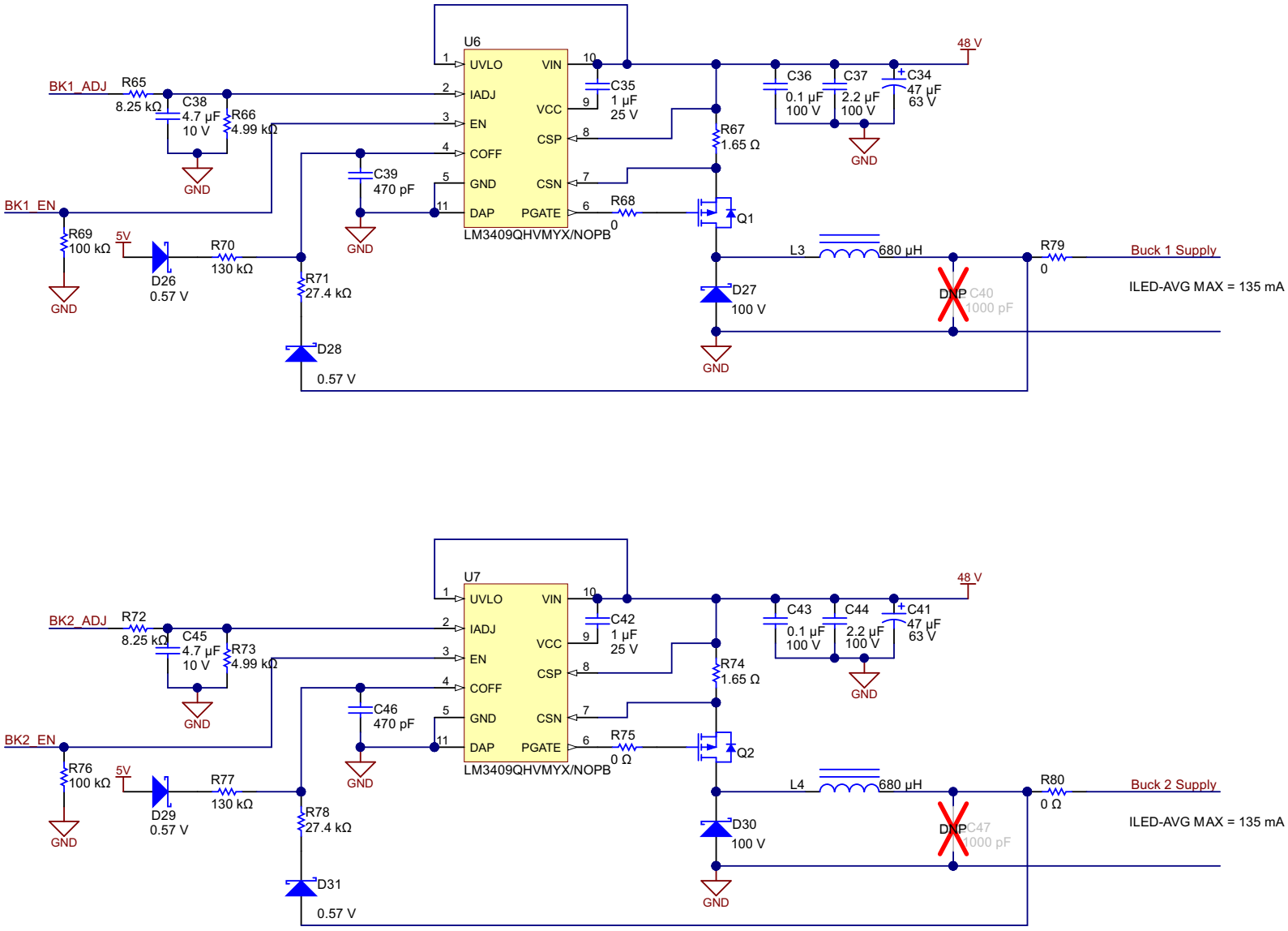
1. Verify that the +48-V input voltage is present at the input to the system by removing JP2 and measuring for the voltage on either pin
   (a) Input voltage is present? Proceed to next step.
   (b) Input voltage is not present. Check power supply is functional and S1 is *on*.
2. Verify that +5 V is correctly generated on the EVM by removing JP3 and measuring for the voltage on either pin.
   (a) +5 V is present? Proceed to next step.
   (b) +5 V is not present. There may be a problem with U1. Look for about 400-kHz switching at pin 2 of U1. An easy place to measure is the via between the '**S**' of Texas Instruments' silkscreen and L1. If there is no switching there, it is likely that U1 is damaged. If there is switching, there may be a short downstream from the +5-V output.
3. Verify that +3.3 V is being correctly generated by removing JP4 and measuring for the voltage on either pin.
   (a) +3.3 V is present? Proceed to next step.
   (b) +3.3 V is not present. There may be a problem with U2.
4. Is red signal LED D34 toggling at 1 Hz?
   (a) Yes: Check that all jumpers of JP5 are in place and shorted 1 to 2, 3 to 4, and so forth. After checking the jumpers, look for the CLK and SYNC signals to be present at J2.
   (b) No: There may be a problem with the MCU or its programming. Ensure that JP1 is set to its default settings.

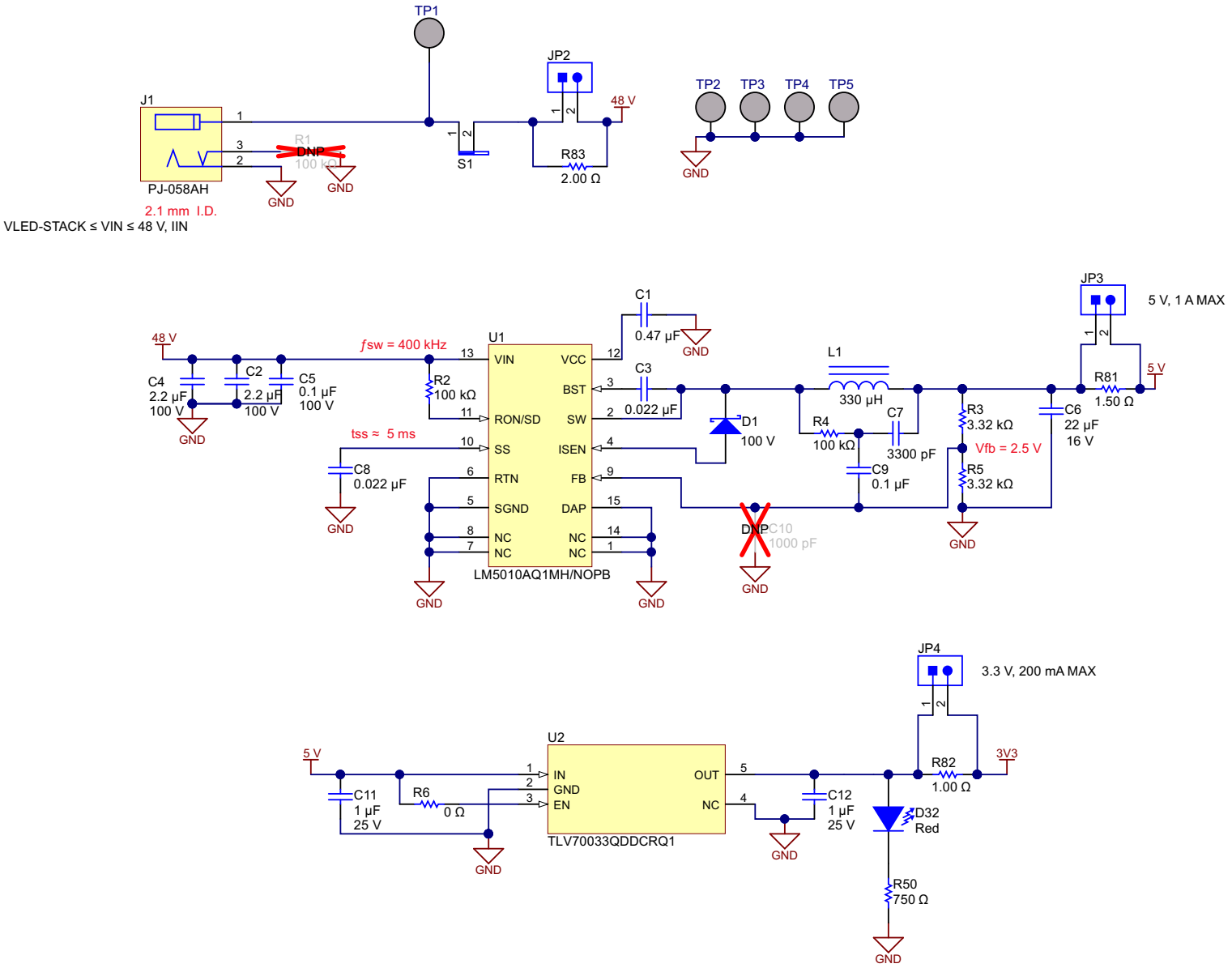
8.2 Problem: PC is Unable to Communicate With the EVM

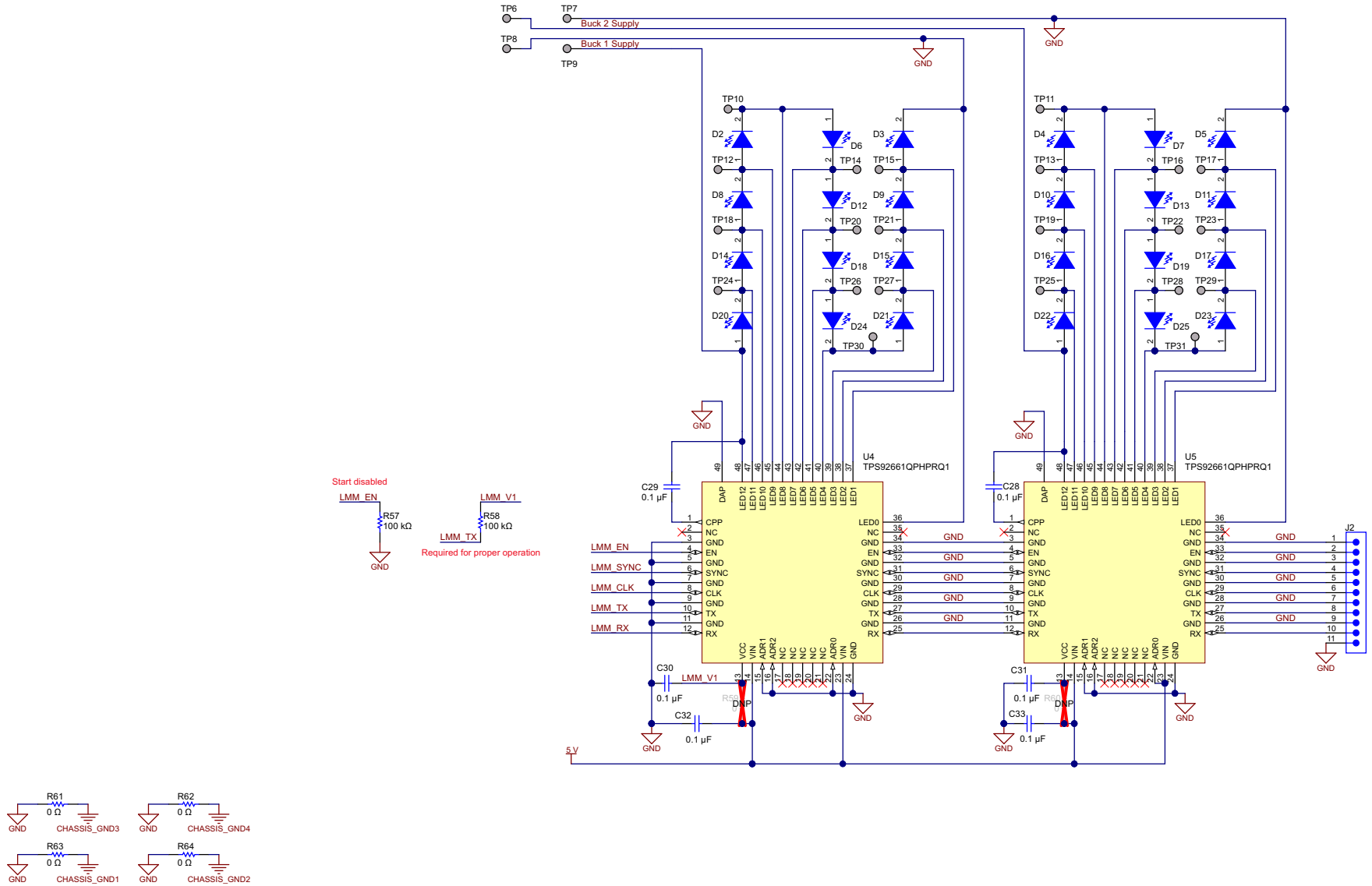
1. Ensure that the USB-to-serial cable is plugged in correctly as per Figure 2.
2. Check that the terminal program has been set up appropriately with the correct baudrate, that the byte format is set to 8N1, and that flow control is disabled.
3. Use an oscilloscope to look for UART traffic at R18 when sending commands from the terminal program. If there is no traffic at R18, then the commands are not making it to the MCU from the PC.
4. If there is UART traffic at R18, verify that a read command such as Get Firmware Version, results in a UART response at R18. If there is no transaction present when sending the Get Firmware Version Command, MCU responses are not making it to the PC.

9 Schematics and Layout









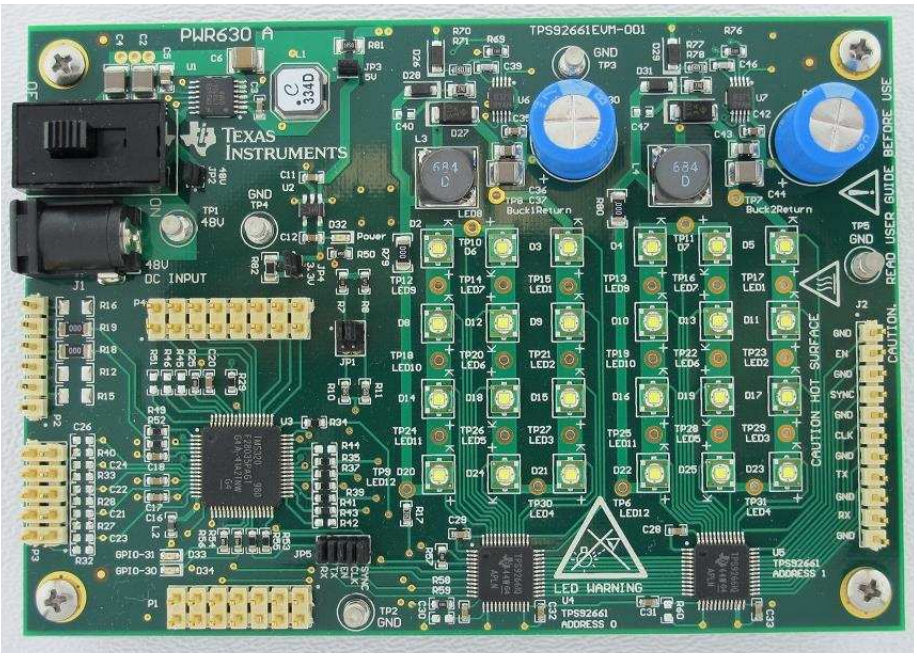


Figure 3. Top View

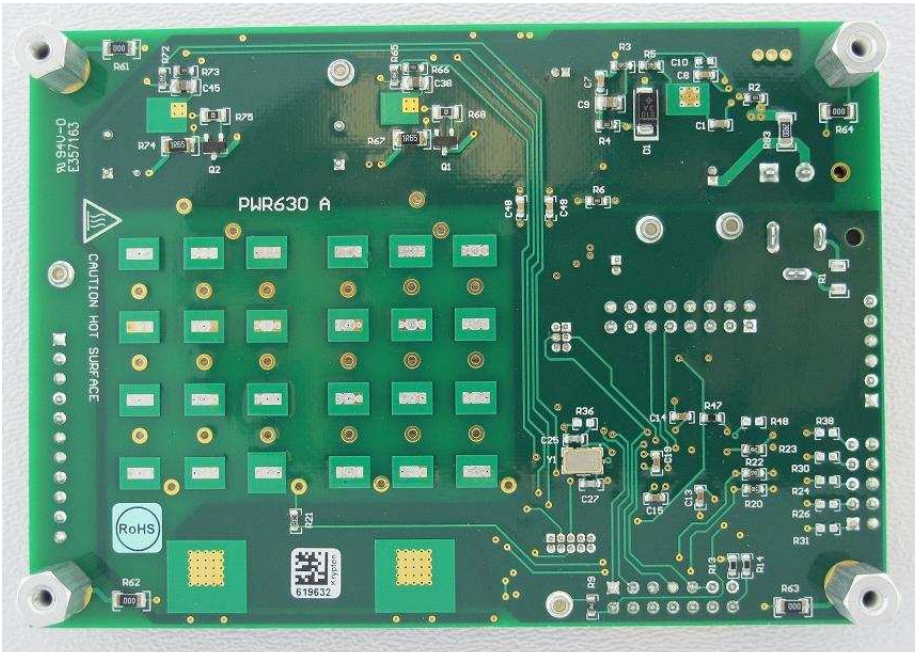


Figure 4. Bottom View

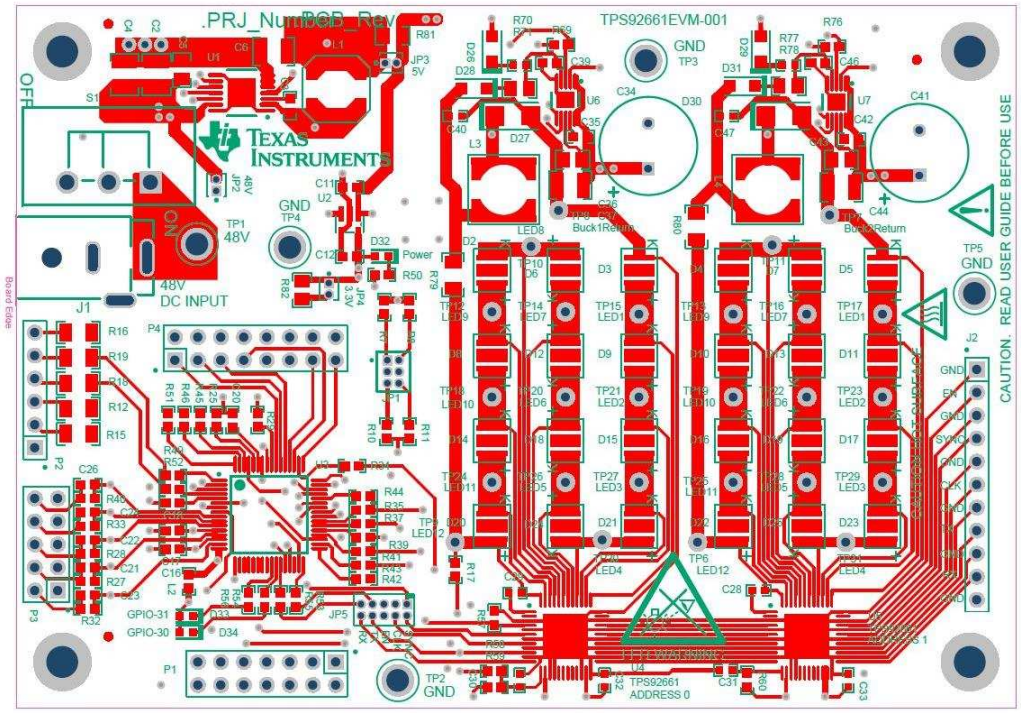


Figure 5. Top Layer

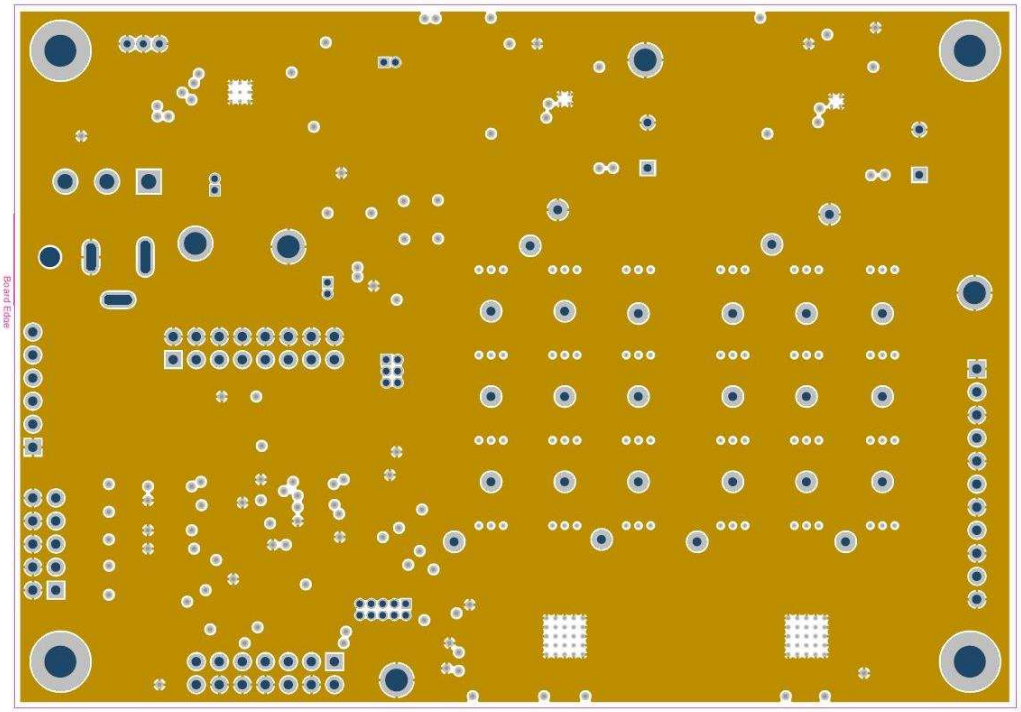


Figure 6. Ground Layer

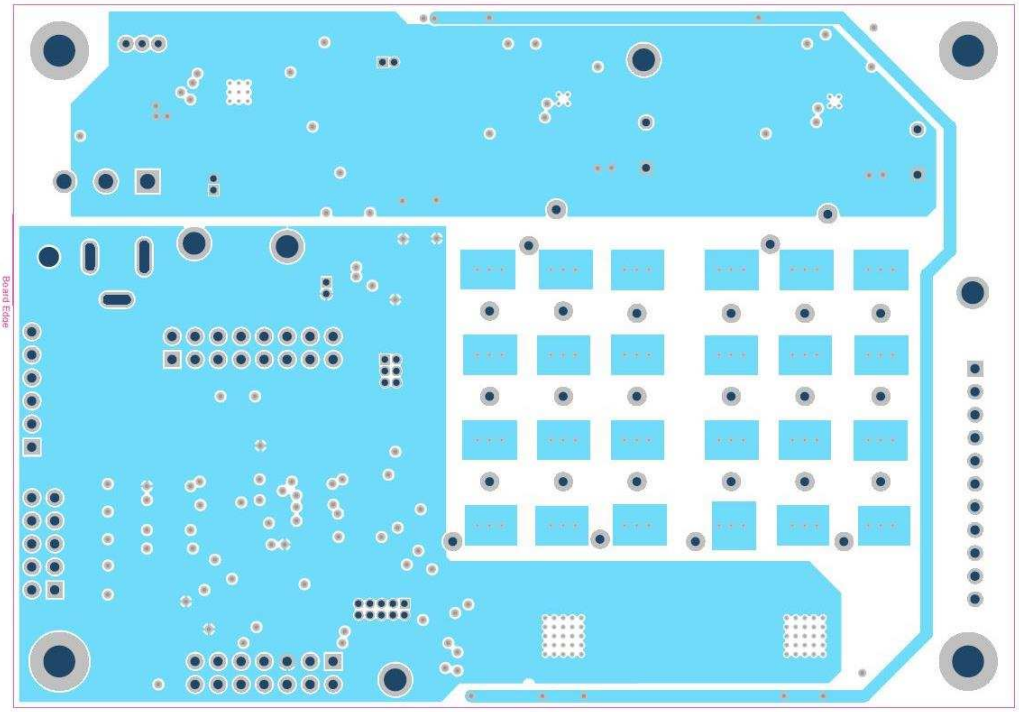


Figure 7. Power Layer

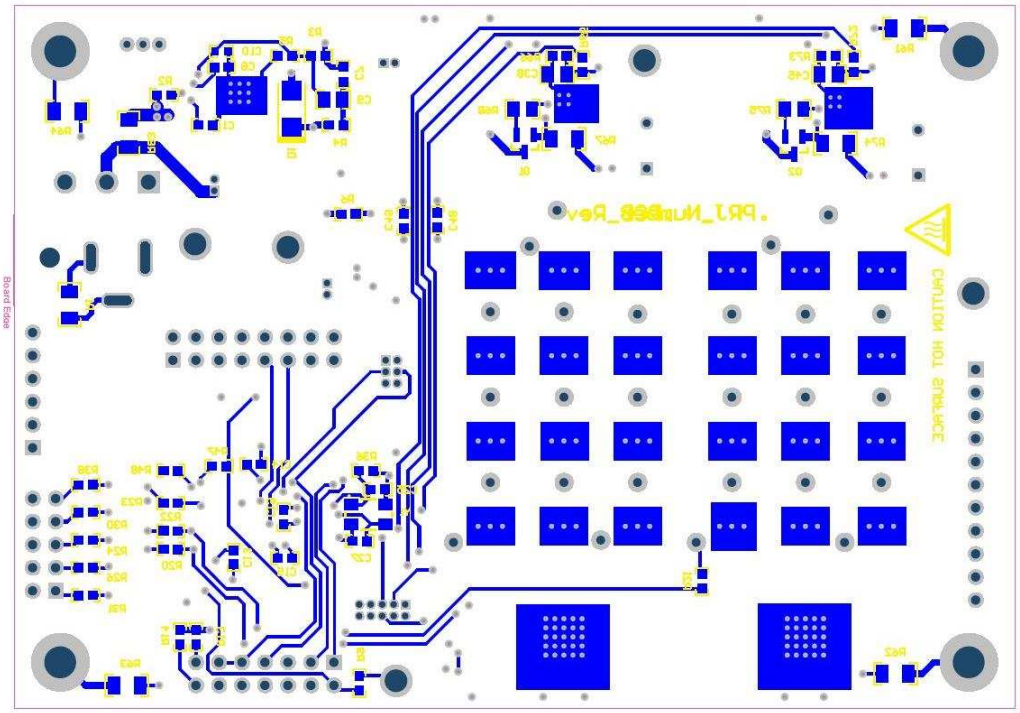


Figure 8. Bottom Layer

10 Bill of Materials

Designator	Qty	Value	Description	Package Reference	Part Number[1]	Manufacturer	Alternate Part Number and Manufacturer
!PCB	1		Printed circuit board		PWR630	Any	—
C1	1	0.47uF	CAP, CERM, 0.47uF, 25V, +/-10%, X7R, 0603	0603	GRM188R71E474KA12D	MuRata	
C2, C4	2	2.2uF	CAP, CERM, 2.2uF, 100V, +/-10%, X7R, 1210	1210	HMK325B7225KN-T	Taiyo Yuden	
C3, C8	2	0.022uF	CAP, CERM, 0.022uF, 50V, +/-10%, X7R, 0603	0603	GRM188R71H223KA01D	MuRata	
C5, C9, C36, C43	4	0.1uF	CAP, CERM, 0.1uF, 100V, +/-10%, X7R, 0805	0805	HMK212B7104KG-T	Taiyo Yuden	
C6	1	22uF	CAP, CERM, 22uF, 16V, +/-10%, X7R, 1210	1210	GRM32ER71C226KE18L	MuRata	
C7	1	3300pF	CAP, CERM, 3300pF, 100V, +/-10%, X7R, 0603	0603	GRM188R72A332KA01D	MuRata	
C11, C12, C35, C42	4	1uF	CAP, CERM, 1uF, 25V, +/-10%, X7R, 0603	0603	GRM188R71E105KA12D	MuRata	
C13, C14, C15, C18, C19, C20	6	2.2uF	CAP, CERM, 2.2uF, 6.3V, +/-10%, X7S, 0603	0603	GRM188C70J225KE20D	MuRata	
C16, C17	2	0.01uF	CAP, CERM, 0.01uF, 50V, +/-10%, X7R, 0603	0603	GRM188R71H103KA01D	MuRata	
C25, C27	2	12pF	CAP, CERM, 12pF, 50V, +/-5%, C0G/NP0, 0603	0603	GRM1885C1H120JA01D	MuRata	
C28, C29, C30, C31, C32, C33	6	0.1uF	CAP, CERM, 0.1uF, 25V, +/-10%, X7R, 0603	0603	GRM188R71E104KA01D	MuRata	—
C34, C41	2	47uF	CAP, AL, 47uF, 63V, +/-20%, 0.59 ohm, SMD	Cap, 10x12.5mm	UBT1J470MPD1TD	Nichicon	
C37, C44	2	2.2uF	CAP, CERM, 2.2uF, 100V, +/-10%, X7R, 1210	1210	GRM32ER72A225KA35L	MuRata	
C38, C45	2	4.7uF	CAP, CERM, 4.7uF, 10V, +/-10%, X7R, 0805	0805	GRM21BR71A475KA73L	MuRata	
C39, C46	2	470pF	CAP, CERM, 470pF, 50V, +/-5%, C0G/NP0, 0603	0603	GRM1885C1H471JA01D	MuRata	—
C48, C49	2	0.01uF	CAP, CERM, 0.01uF, 100V, +/-10%, X7R, 0603	0603	GRM188R72A103KA01D	MuRata	
D1, D27, D30	3	100V	Diode, Schottky, 100V, 1A, SMA	SMA	SS1H10-E3/61T	Vishay-Semiconductor	
D2, D3, D4, D5, D6, D7, D8, D9, D10, D11, D12, D13, D14, D15, D16, D17, D18, D19, D20, D21, D22, D23, D24, D25	24	Cool White	LED, Cool White, SMD	XLamp XP-E	XPEWHT-L1-R250-00D01	Cree	
D26, D28, D29, D31	4	0.57V	Diode, Schottky, 60V, 1A, SOD-123F	SOD-123F	PMEG6010CEH,115	NXP Semiconductor	Equivalent, any
D32, D33, D34	3	Red	LED, Red, SMD	Red LED, 1.6x0.8x0.8 mm	LTST-C190CKT	Lite-On	
H1, H2, H3, H4	4		Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	Used in PnP output	NY PMS 440 0025 PH	B&F Fastener Supply	—
H5, H6, H7, H8	4		Standoff, Hex, 0.5"L #4-40 Nylon	Standoff	1902C	Keystone	—

(1) Unless otherwise noted in the Alternate Part Number and/or Alternate Manufacturer column, all parts may be substituted with equivalents.

Designator	Qty	Value	Description	Package Reference	Part Number[1]	Manufacturer	Alternate Part Number and Manufacturer
H9, H10, H11, H12, H13, H14, H15, H16, H17, H18	10	Shunt	CONN SHUNT 1.27MM BLACK W/HANDLE	50mill shunt	M50-2000005	Harwin Inc	—
H19, H20	2		CABLE USB EMBD UART 3.3V .1"HDR	Used in PnP output	TTL-232R-3V3	FTDI, Future Technology Devices International Ltd	—
J1	1		Connector, DC Jack 2.5 mm Center Pin, TH	15.2x11x9mm	PJ-058AH	CUI Inc.	
J2	1		Header, 100mil, 11x1, Gold, TH	11x1 Header	TSW-111-07-G-S	Samtec	
JP1	1		Header, 3x2, 1.27mm, TH	Header, 3x2, 1.27mm, TH	GRPB032VWVN-RC	Sullins Connector Solutions	
JP2, JP3, JP4	3		Header male, 2x1, 50mil, TH	2x1 Header	GRPB021VWVN-RC	Sullins Connector Solutions	
JP5	1		Header, 50mil, 5x2, TH	Header, 5x2, 50mil	GRPB052VWVN-RC	Sullins Connector Solutions	
L1	1	330uH	Inductor, Shielded Drum Core, Ferrite, 330uH, 0.28A, 2 ohm, SMD	LPS6225	LPS6225-334MLB	Coilcraft	
L2	1	220 ohm	2.5A Ferrite Bead, 220 ohm @ 100MHz, SMD	0603	BLM18SG221TN1D	MuRata	
L3, L4	2	668uH	Inductor, Shielded Drum Core, Ferrite, 220uH, 1.6A, 0.32 ohm, SMD	MSS7341T	MSS7341T-684KLB	Coilcraft	Equivalent, any
P1	1		Header, TH, 100mil, 7x2, Gold plated, 230 mil above insulator	7x2 Header	TSW-107-07-G-D	Samtec	
P2	1		Header, TH, 100mil, 6x1, Gold plated, 230 mil above insulator	6x1 Header	TSW-106-07-G-S	Samtec	
P3	1		Header, TH, 100mil, 5x2, Gold plated, 230 mil above insulator	5x2 Header	TSW-105-07-G-D	Samtec	
P4	1		Header, TH, 100mil, 8x2, Gold plated, 230 mil above insulator	8x2 Header	TSW-108-07-G-D	Samtec	
Q1, Q2	2	-60V	MOSFET, P-CH, -60V, -0.9A, SOT-23	SOT-23	ZXMP6A13FTA	Diodes Inc.	None
R2, R4, R57, R58, R69, R76	6	100k	RES, 100k ohm, 1%, 0.1W, 0603	0603	CRCW0603100KFKEA	Vishay-Dale	
R3, R5, R10, R11, R20, R22	6	3.32k	RES, 3.32k ohm, 1%, 0.1W, 0603	0603	CRCW06033K32FKEA	Vishay-Dale	
R6, R25	2	0	RES, 0 ohm, 5%, 0.1W, 0603	0603	CRCW06030000Z0EA	Vishay-Dale	
R7, R8	2	825k	RES, 825k ohm, 1%, 0.1W, 0603	0603	CRCW0603825KFKEA	Vishay-Dale	
R9, R23	2	2.21k	RES, 2.21k ohm, 1%, 0.1W, 0603	0603	CRCW06032K21FKEA	Vishay-Dale	
R13, R14	2	4.75k	RES, 4.75k ohm, 1%, 0.1W, 0603	0603	CRCW06034K75FKEA	Vishay-Dale	
R17, R21	2	33.2k	RES, 33.2k ohm, 1%, 0.1W, 0603	0603	CRCW060333K2FKEA	Vishay-Dale	
R18, R19, R61, R62, R63, R64, R79, R80	8	0	RES, 0 ohm, 5%, 0.25W, 1206	1206	CRCW12060000Z0EA	Vishay-Dale	Equivalent, any

Designator	Qty	Value	Description	Package Reference	Part Number[1]	Manufacturer	Alternate Part Number and Manufacturer
R29, R34, R35, R37, R39, R41, R43, R47, R49, R52, R53, R55	12	100	RES, 100 ohm, 1%, 0.1W, 0603	0603	CRCW0603100RFKEA	Vishay-Dale	
R50, R54, R56	3	750	RES, 750 ohm, 1%, 0.1W, 0603	0603	CRCW0603750RFKEA	Vishay-Dale	
R65, R72	2	8.25k	RES, 8.25k ohm, 1%, 0.1W, 0603	0603	CRCW06038K25FKEA	Vishay-Dale	
R66, R73	2	4.99k	RES, 4.99k ohm, 1%, 0.1W, 0603	0603	CRCW06034K99FKEA	Vishay-Dale	
R67, R74	2	1.65	RES, 1.65 ohm, 1%, 0.25W, 1206	1206	CRCW12061R65FKEA	Vishay-Dale	
R68, R75	2	0	RES, 0 ohm, 5%, 0.125W, 0805	0805	CRCW08050000Z0EA	Vishay-Dale	—
R70, R77	2	130k	RES, 130k ohm, 1%, 0.1W, 0603	0603	CRCW0603130KFKEA	Vishay-Dale	Equivalent, any
R71, R78	2	27.4k	RES, 27.4k ohm, 1%, 0.125W, 0805	0805	CRCW080527K4FKEA	Vishay-Dale	
R81	1	1.50	RES, 1.50 ohm, 1%, 0.125W, 0805	0805	CRCW08051R50FKEA	Vishay-Dale	
R82	1	1.00	RES, 1.00 ohm, 1%, 0.125W, 0805	0805	CRCW08051R00FKEA	Vishay-Dale	
R83	1	2.00	RES, 2.00 ohm, 1%, 0.25W, 1206	1206	CRCW12062R00FKEA	Vishay-Dale	
S1	1		SWITCH SLIDE SPST 4A PCB, TH	Slide Switch, TH, SPST	L101011MS02Q	C&K Components	
TP1, TP2, TP3, TP4, TP5	5	Double	Terminal, Turret, TH, Double		1502-2	Keystone Electronics	
U1	1		High Voltage 1A Step Down Switching Regulator, 14-pin TSSOP-EP, Pb-Free	MXA14A	LM5010AQ1MH/NOPB	National Semiconductor	
U2	1		200IC REG LDO 3.3V 0.2A SOT5	SOT-23-5 Thin, TSOT-23-5	TLV70033QDDCRQ1	Texas Instruments	None
U3	1		Piccolo(TM) Microcontrollers, PAG0064A	PAG0064A	TMS320F28035PAG	Texas Instruments	None
U4, U5	2		High-Brightness LED Matrix Manager for Automotive Headlight Systems, PHP0048D	PHP0048D	TPS92661QPHPRQ1	Texas Instruments	None
U6, U7	2		PFET Buck Controller for High Power LED Drives, 10-pin eMSOP, Pb-Free	MUC10A	LM3409QHVMYX/NOPB	National Semiconductor	
Y1	1		Crystal,12.8MHz, 10pF, SMD	Crystal 3.2x1x5mm	405C11A12M80000	CTS Electrocomponents	
C10, C40, C47	0	1000pF	CAP, CERM, 1000pF, 50V, +/-10%, X7R, 0603	0603	GRM188R71H102KA01D	MuRata	
C21, C22, C23, C24, C26	0	0.01uF	CAP, CERM, 0.01uF, 50V, +/-10%, X7R, 0603	0603	GRM188R71H103KA01D	MuRata	
FID1, FID2, FID3	0		Fiducial mark. There is nothing to buy or mount.	Fiducial	N/A	N/A	
R1	0	100k	RES, 100k ohm, 1%, 0.25W, 1206	1206	CRCW1206100KFKEA	Vishay-Dale	
R12, R15, R16	0	0	RES, 0 ohm, 5%, 0.25W, 1206	1206	CRCW12060000Z0EA	Vishay-Dale	
R24, R26, R30, R31, R38	0	33.2k	RES, 33.2k ohm, 1%, 0.1W, 0603	0603	CRCW060333K2FKEA	Vishay-Dale	

Designator	Qty	Value	Description	Package Reference	Part Number[1]	Manufacturer	Alternate Part Number and Manufacturer
R27, R28, R32, R33, R40	0	3.32k	RES, 3.32k ohm, 1%, 0.1W, 0603	0603	CRCW06033K32FKEA	Vishay-Dale	
R36	0	1.00Meg	RES, 1.00Meg ohm, 1%, 0.1W, 0603	0603	CRCW06031M00FKEA	Vishay-Dale	
R42, R44, R45, R46, R48, R51	0	100	RES, 100 ohm, 1%, 0.1W, 0603	0603	CRCW0603100RFKEA	Vishay-Dale	
R59, R60	0	0	RES, 0 ohm, 5%, 0.1W, 0603	0603	CRCW06030000Z0EA	Vishay-Dale	

Appendix A

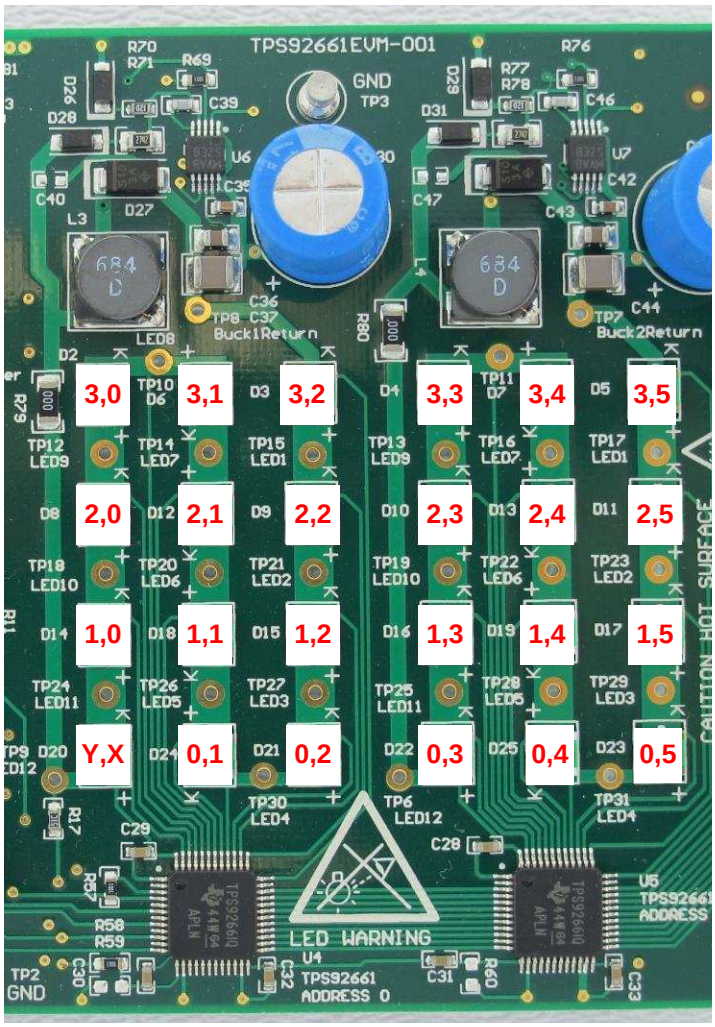


Figure 9. X-Y Coordinates

Revision History

Changes from Original (September 2014) to A Revision	Page
• Added new schematics	16

STANDARD TERMS AND CONDITIONS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, or documentation (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms and conditions set forth herein. Acceptance of the EVM is expressly subject to the following terms and conditions.

   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 and conditions 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 and conditions 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 any defects that are 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. Moreover, TI shall not be liable for any defects that result from User's design, specifications or instructions for such EVMs. Testing and other quality control techniques are used to the extent TI deems necessary or as mandated by government requirements. TI does not test all parameters of each EVM.

   2.3 If any EVM fails to conform to the warranty set forth above, TI's sole liability shall be at its option to repair or replace such EVM, 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.

3 *Regulatory Notices:*

   3.1 *United States*

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

      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*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSS standard(s). 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。
http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

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

If User uses EVMs in Japan, User is required by Radio Law of Japan to follow the instructions below with respect to EVMs:

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】

本開発キットは技術基準適合証明を受けておりません。

本製品のご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

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

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

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

日本テキサス・インスツルメンツ株式会社

東京都新宿区西新宿６丁目２４番１号

西新宿三井ビル

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

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

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 WRITTEN DESIGN MATERIALS PROVIDED WITH THE EVM (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 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 AND CONDITIONS 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 MADE, CONCEIVED OR ACQUIRED PRIOR TO OR AFTER DELIVERY OF THE EVM.

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 AND CONDITIONS. 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 ANDCONDITIONS OR THE USE OF THE EVMS PROVIDED HEREUNDER, 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 ONE YEAR AFTER THE RELATED CAUSE OF ACTION HAS OCCURRED.

   8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY WARRANTY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS AND CONDITIONS, OR ANY USE OF ANY TI EVM PROVIDED HEREUNDER, EXCEED THE TOTAL AMOUNT PAID TO TI FOR THE PARTICULAR UNITS SOLD UNDER THESE TERMS AND CONDITIONS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM AGAINST THE PARTICULAR UNITS SOLD TO USER UNDER THESE TERMS AND CONDITIONS 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.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265

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In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

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