

User's Guide

LP8864 Evaluation Module



ABSTRACT

The Texas Instruments LP8864EVM evaluation module helps designers to evaluate the operation and performance of the LP8864-Q1 device. This document includes a hardware setup instructions, software instructions, a complete schematic diagram, printed-circuit board (PCB) layout, and bill of materials (BOM) of the LP8864EVM.

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1 Introduction

The LP8864EVM helps designers to evaluate the characteristics, operation, and use of the LP8864-Q1 device, a high-performance LED driver for automotive lighting. The LP8864-Q1 device is a high-efficiency LED driver with boost controller. The four 200-mA high-precision current sinks support phase shifting that is automatically adjusted based on the number of channels in use. LED brightness can be controlled globally through the I2C interface or PWM input.

1.1 Features

The EVM has the following features:

- Up to 48-V V_{OUT} boost controller
- Four high-precision current sinks
- Supports built-in phase-shift PWM dimming, hybrid dimming, current dimming and direct PWM dimming mode
- LED brightness controlled globally through I2C interface or PWM input
- Extensive fault diagnostics

1.2 Applications

Backlight for:

- Automotive infotainment
- Automotive instrument clusters
- Smart mirrors
- Heads-Up Displays (HUD)
- Central Information Displays (CID)
- Audio-Video Navigation (AVN)

2 Test Setup

This section describes how to properly connect and setup the LP8864EVM.

2.1 LP8864EVM Kit

The LP8864EVM kit contains (see [Figure 2-1](#)):

- USB2ANY
 - Ribbon cable
 - USB cable
- LP8864EVM
- LP886X-LEDLOAD-EVM

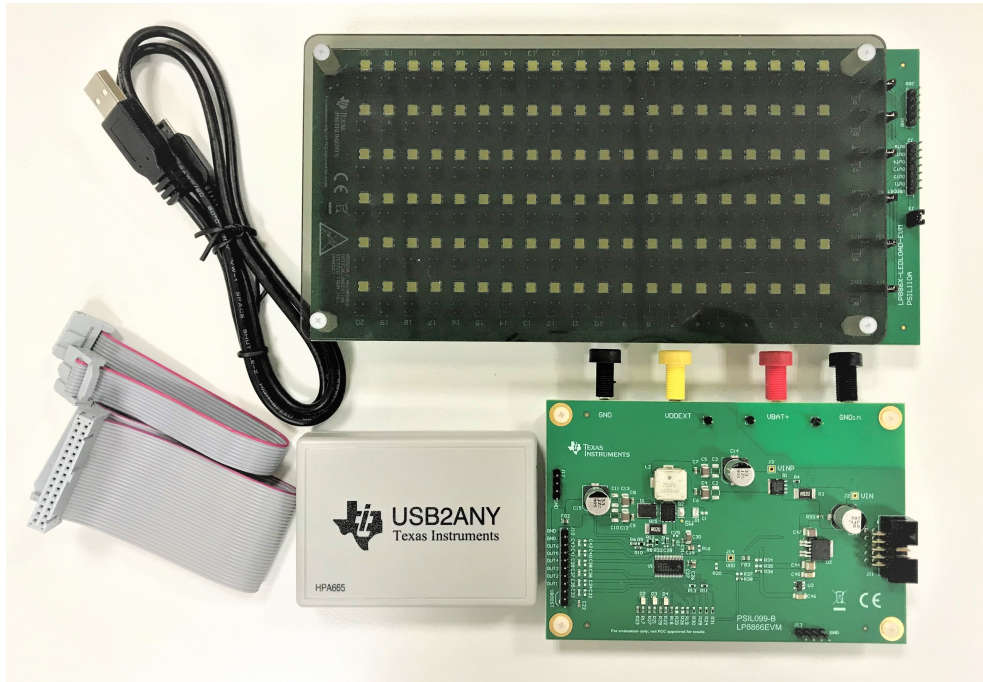


Figure 2-1. LP8864EVM Kit

2.2 System and Equipment Requirements

- DC power supply: 24 V or higher, 6 A or higher
- LED cable: 5-position ribbon cable
- PC to run GUI software
- GUI software

2.3 Hardware Setup

Figure 2-2 shows the hardware setup of the LP8864EVM.

- Connect a 12-V external power supply between the power input terminals VBAT+ and GNDin on the LP8864EVM
- Connect the USB2ANY module to the PC with the USB cable
- Connect the USB2ANY module to the LP8864EVM with the provided ribbon cable
- Connect the LP8864EVM to the LP886X-LEDLOAD-EVM with a 5-position ribbon cable

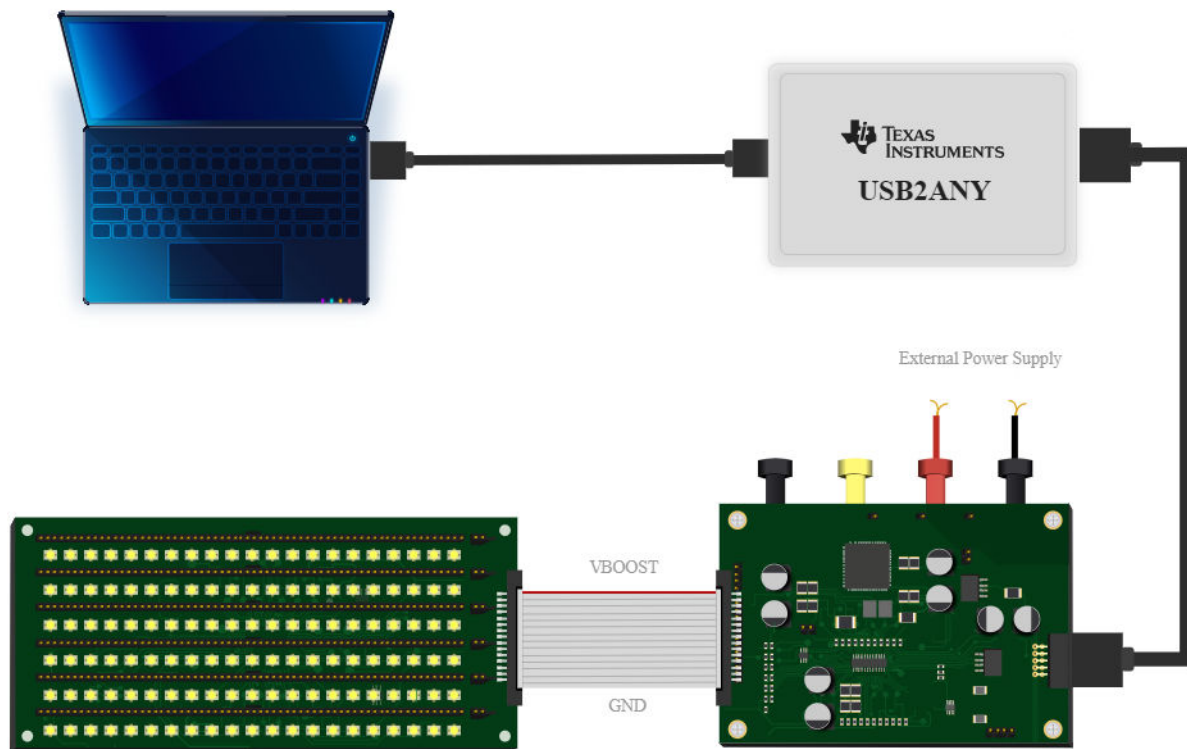


Figure 2-2. LP8864EVM Hardware Setup

2.4 Software Installation

Download the GUI software from the [LP8864EVM tools folder](#). Follow the instructions to finish the GUI installation. Once installed, a shortcut to the GUI is found on the desktop and also in the start-up menu under the Texas Instruments folder.

2.5 Quick Start-Up Procedure

1. After the hardware is connected successfully, run the GUI software. Turn on the 12-V external power supply. Select the right device variant of the EVM, which is LP8864, as shown in [Figure 2-3](#).

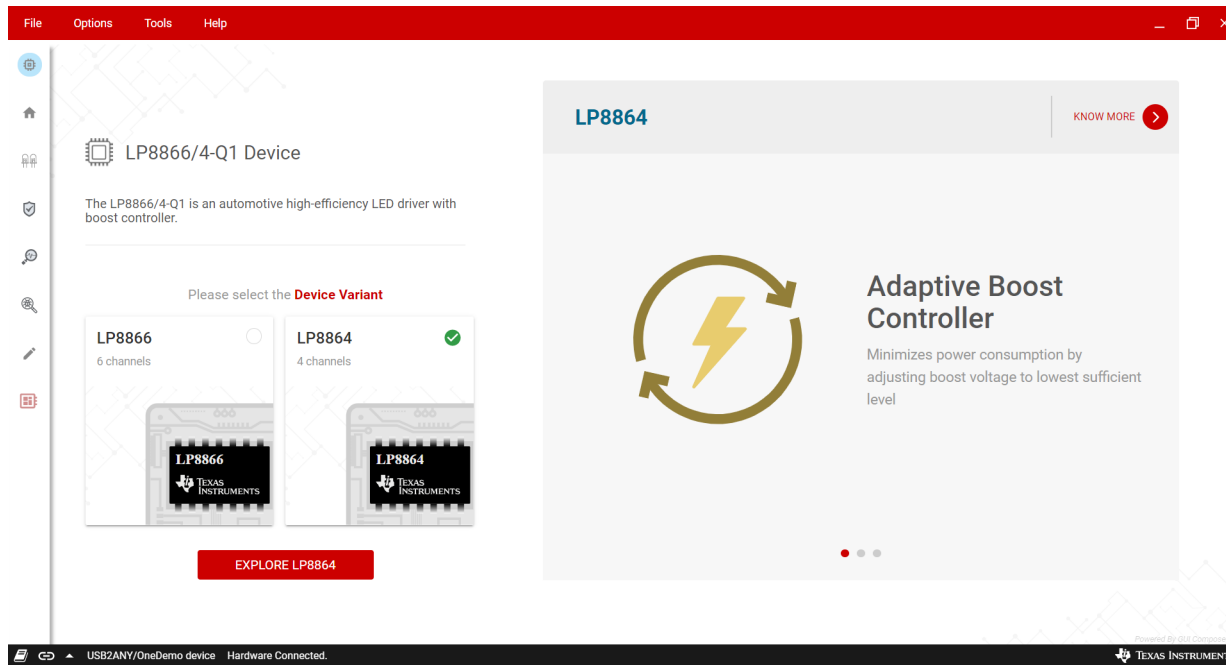


Figure 2-3. LP8866/4 Family GUI Landing Page

2. Check the connection status button on the bottom left corner of the GUI. The button should be like the one shown in [Figure 2-3](#). There should be a *Hardware Connected* message on the status bar next to the button. If it shows *Hardware not Connected*, click the button to manually connect the hardware. This button can be used to connect or disconnect the GUI to the hardware during the evaluation. Besides the connection status button, the device should be enabled to be connected to the GUI. Ensure the *Enable* button on the LED Control Page (see [Figure 2-5](#)) is enabled.

3. Click the *EXPLORE LP8864* button to go to the LP8864EVM GUI home page (see Figure 2-4).

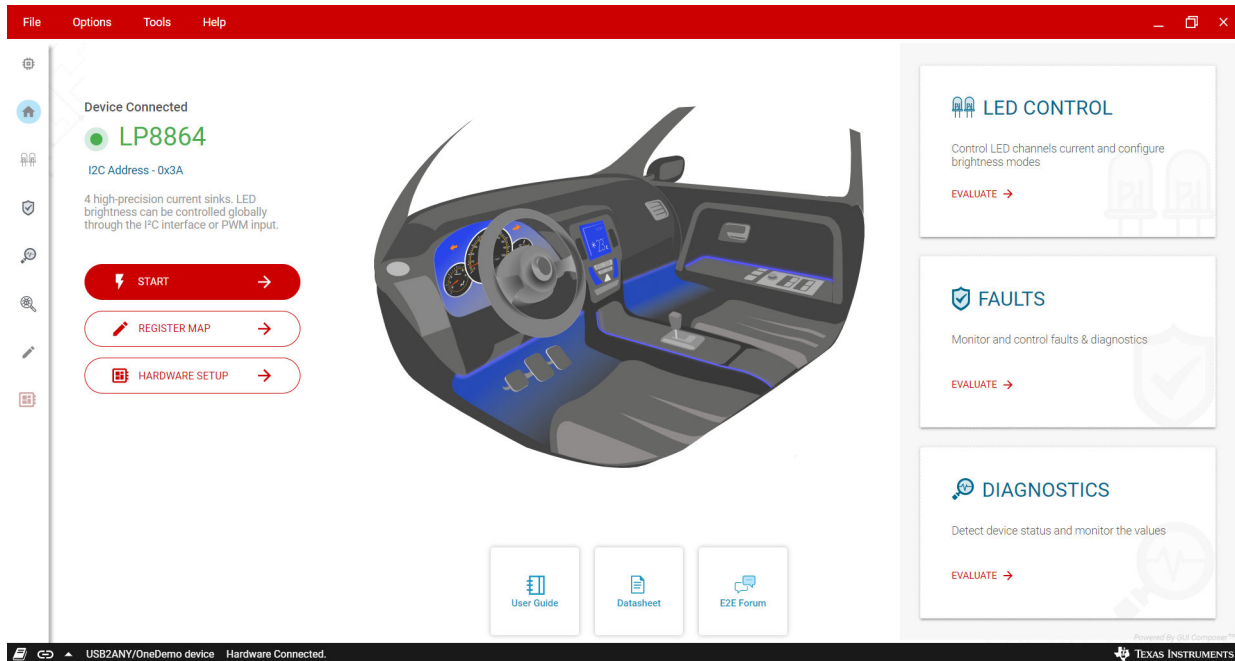


Figure 2-4. LP8864EVM GUI Home Page

4. Click the *START* button to go to the LED Control page (see Figure 2-5). On the LED Control page, the user can control all the register-based control functions of the device, like brightness control, current control, sloper control, dither control, boost synchronization configuration, and spread spectrum configuration.

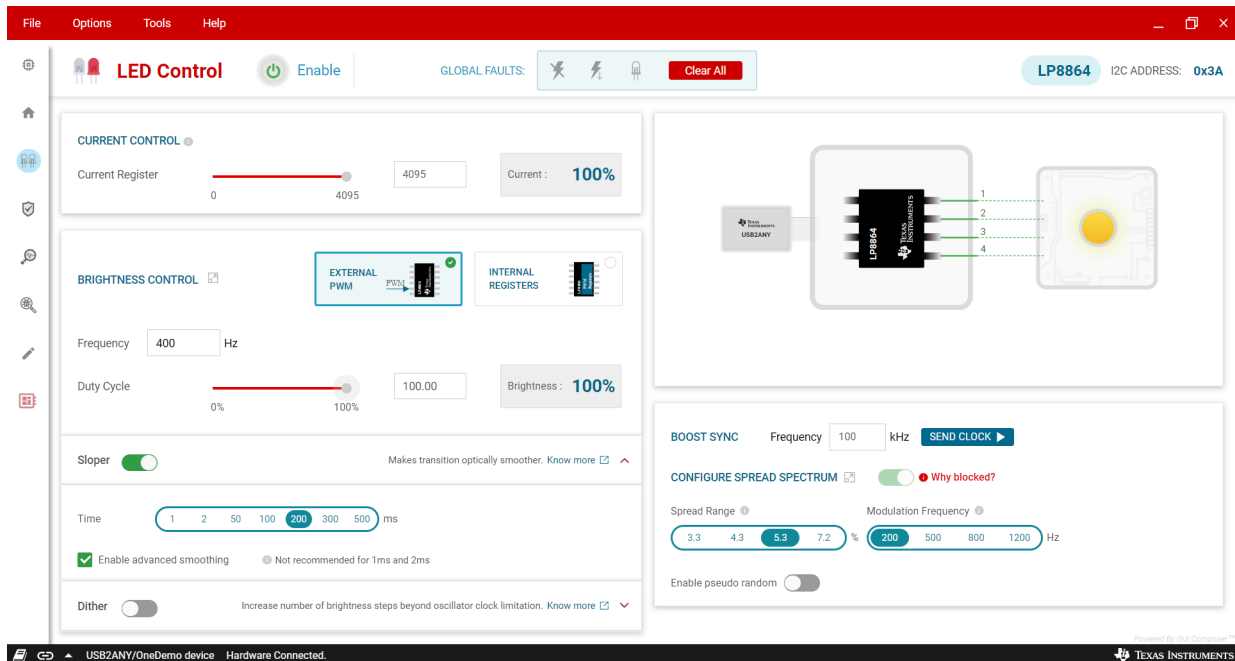


Figure 2-5. LP8864EVM LED Control Page

2.6 Additional GUI Functions

In the selection tab on the left-hand side, the user can switch between LED Control, Monitor Faults, Diagnostics and Register Map tabs. This section introduces GUI functions provided in the Monitor Faults, Diagnostics, and Register Map tabs.

2.6.1 Monitor Faults Page

From the Monitor Faults page (see [Figure 2-6](#)), the user has access to LP8864-Q1 fault status bits. Faults can be cleared by software by clicking the *Clear All* button. Fault interrupt can be enabled or disabled globally by toggling the *Interrupt All* button. Besides that, each fault interrupt and each fault status can be controlled individually.

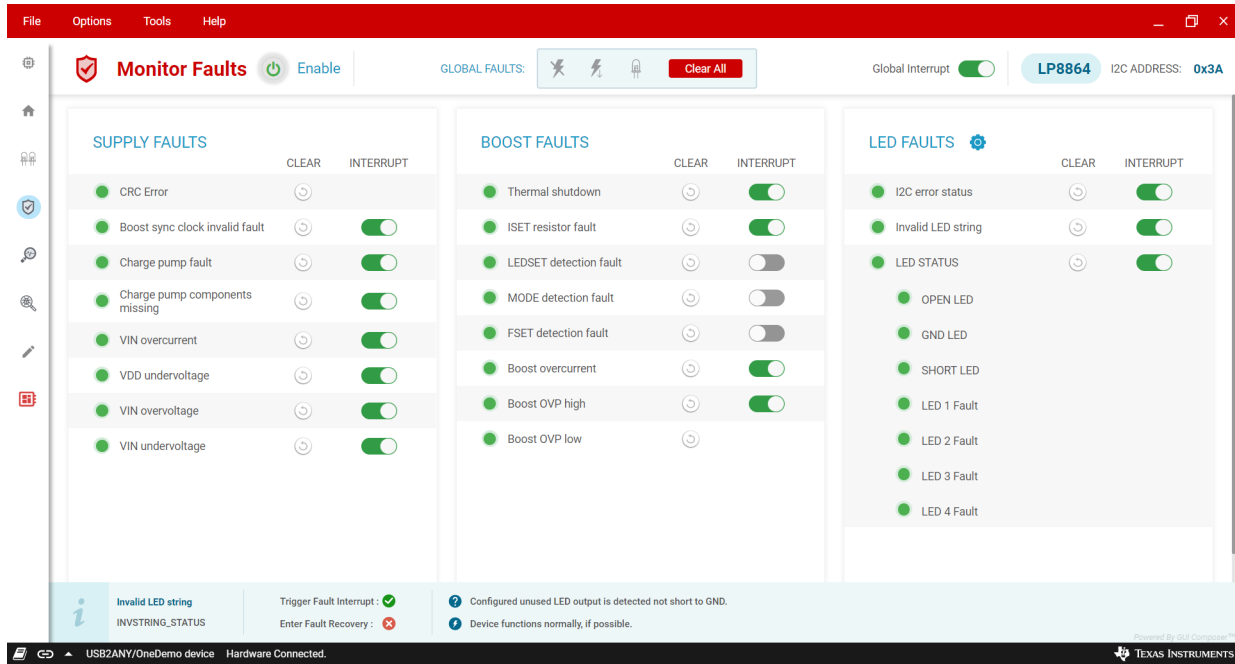


Figure 2-6. LP8864EVM Monitor Faults Page

2.6.2 Diagnostics Page

From the Diagnostics page (see [Figure 2-7](#)), the user can read back the following diagnostics register values and corresponding device status.

- FSM_LIVE_STATUS: current status of the functional state machine
- PWM_INPUT_STATUS: 16-bit value for detected duty cycle of PWM input signal
- PWM_OUTPUT_STATUS: 16-bit value for configured duty cycle of PWM output signal
- LED_CURRENT_STATUS: 12-bit current DAC code that brightness path is driving to OUT1-4 output
- VBOOST_STATUS: 11-bit boost voltage code that adaptive voltage control loop sending to analog boost block
- AUTO_PWM_FREQ_SEL: LED PWM frequency value from PWM_SEL resistor detection
- AUTO_LED_STRING_CFG: LED string configuration from LED_SET resistor detection
- AUTO_BOOST_FREQ_SEL: boost switching frequency value from PWM_FSET resistor detection
- MODE_SEL: LED dimming mode value from MODE resistor detection

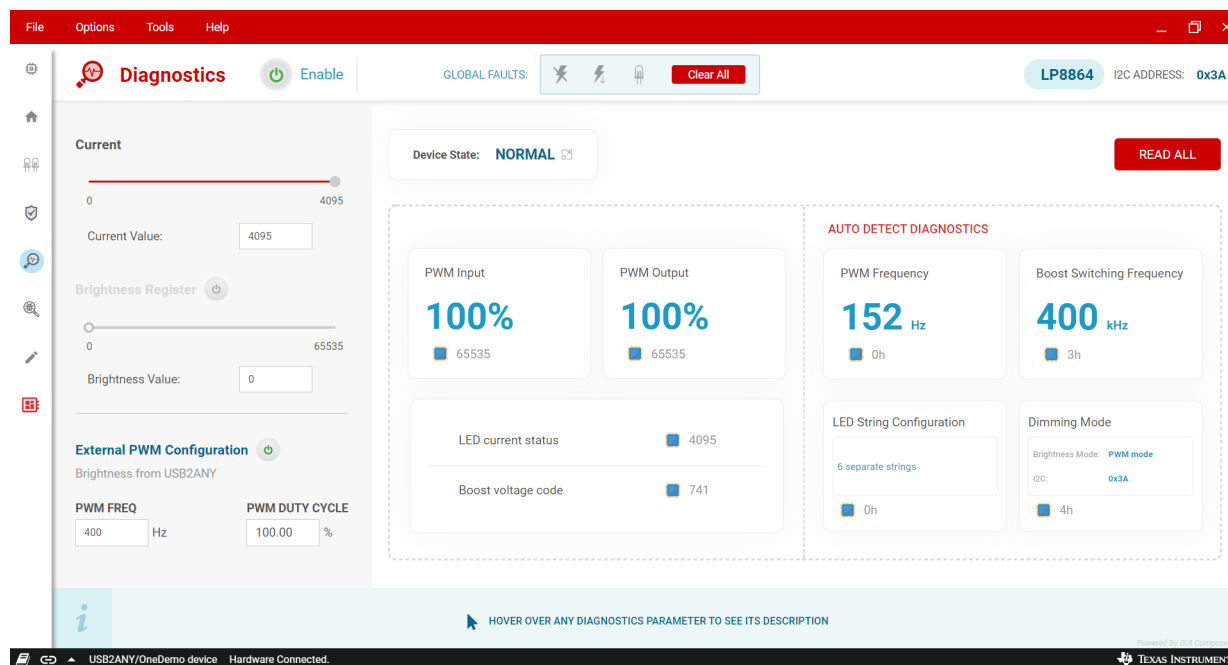


Figure 2-7. LP8864VM Diagnostics Page

2.6.3 Register Map Page

Figure 2-8 shows the registers map page. All the registers are available on this page. When *Auto Read* is set to other than "Off", all the registers will be read automatically and periodically according to the interval time the user selects. Otherwise, the user needs to click the *READ REGISTER* button to read the selected register or click the *READ ALL REGISTERS* button to read all of the registers.

Clicking on the row of a register automatically updates the corresponding field view on the right side of the page. The register value can be updated by modifying the hexadecimal value in the *Value* column or by double-clicking the corresponding bit in the *Bits* column. The modified value is effective immediately if "Immediate Write" is selected in the drop-down menu. When "Deferred Write" is selected, the modified value will not take effect until the user clicks the *WRITE REGISTER* button. The value of all the registers can be updated together by clicking the *WRITE ALL REGISTERS* button.

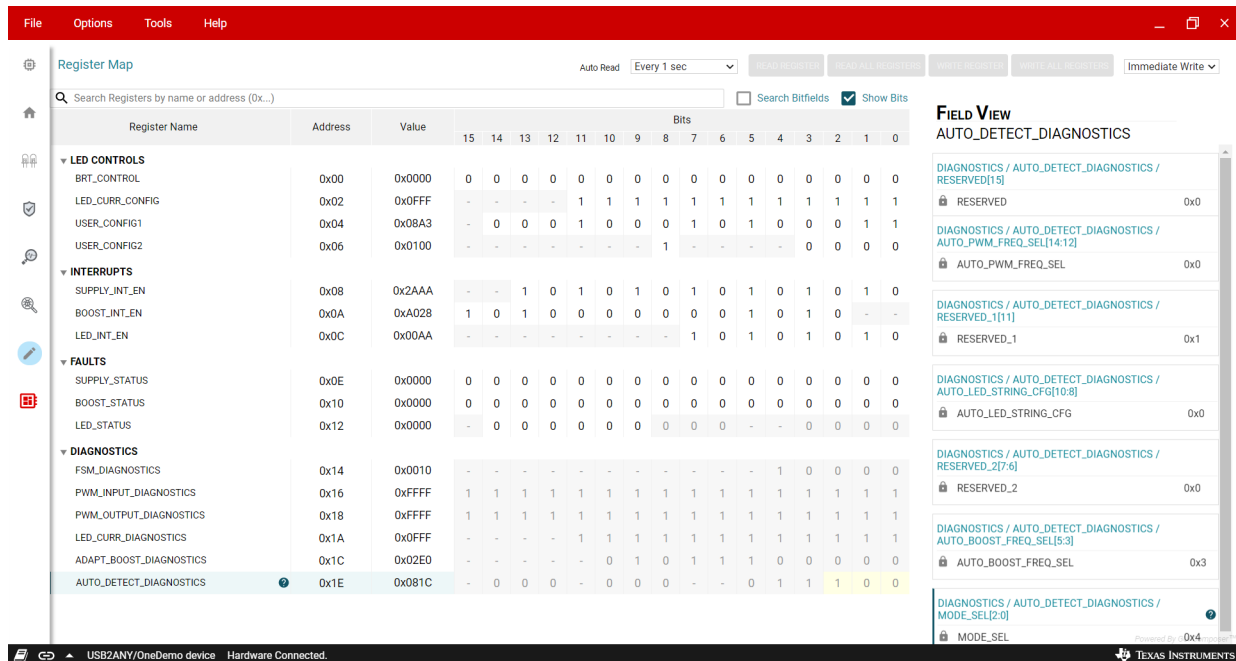


Figure 2-8. LP8864EVM Register Map Page

2.7 Instructions for Standalone Evaluation

The LP8864EVM can be used for standalone evaluation (without GUI software and PC connection). To support standalone mode, it must be modified from its default settings as described in the following list:

1. Mount R20 to pull up EN input.
2. Change pullup and pulldown resistors to select spread spectrum enable (R18) or disable (R25) option.
3. Mount R19 to pull up PWM input for 100% brightness. If brightness needs to be changed from 100%, connect external PWM source at PWM pin.

The minimum procedures for turning on the LEDs after the previously-listed modifications are as follows:

1. Connect a 12-V external power supply between the power input terminals VBAT+ and GNDin on the LP8864EVM.
2. Connect the LP886X-LEDLAOD-EVM board (4 strings, 8 LEDs per string) to J10 on the LP8864EVM.
3. Turn on the external power supply.

3 LP8864EVM Board Layout

Figure 3-1 and Figure 3-2 illustrate the EVM board layout.

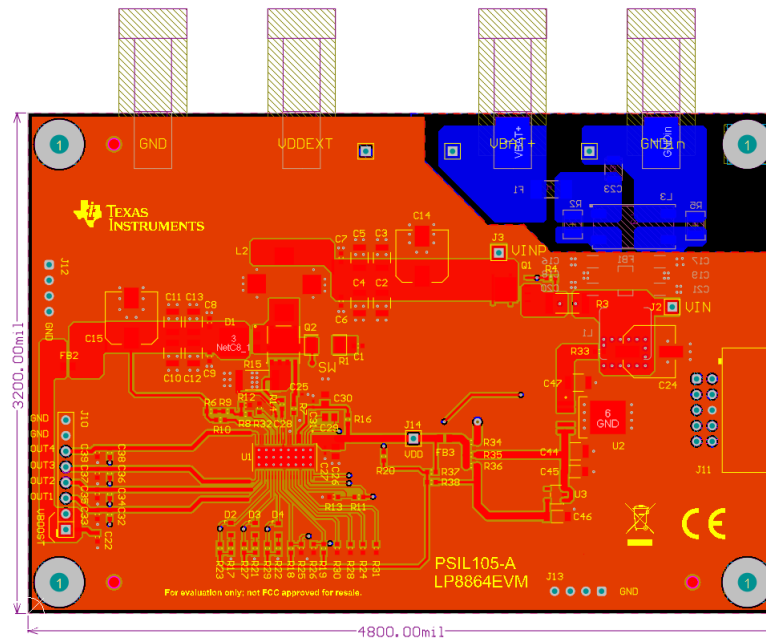


Figure 3-1. LP8864EVM Layout - Top

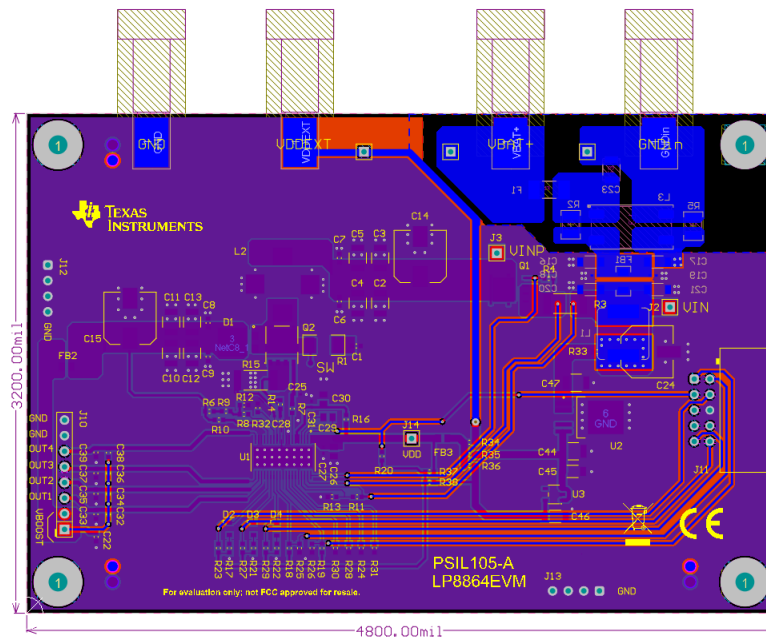


Figure 3-2. LP8864EVM Layout - Bottom

4 LP8864EVM Schematic

Figure 4-1 shows the LP8864EVM schematic.

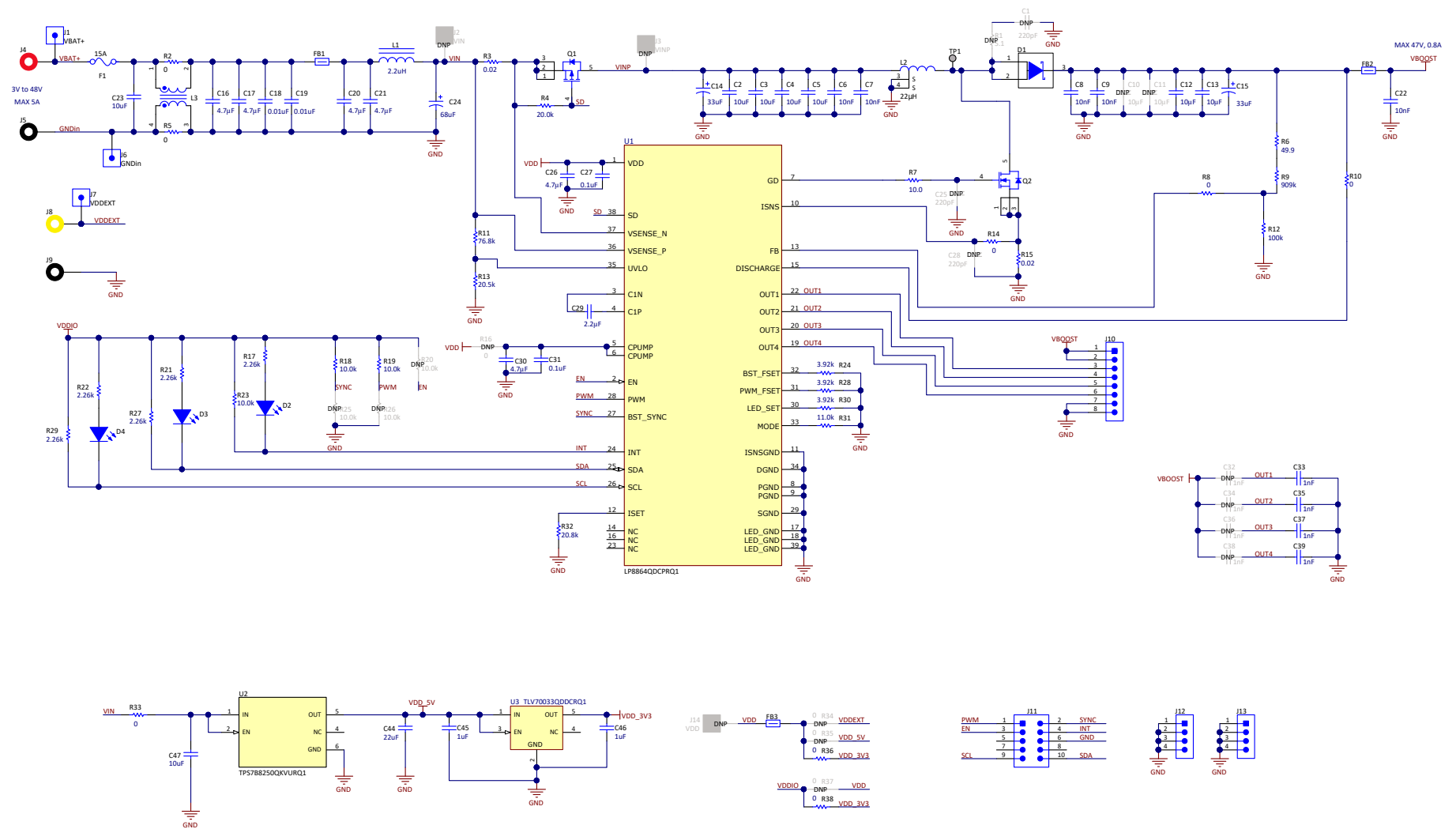


Figure 4-1. LP8864EVM Schematic

5 LP8864EVM Bill of Materials

Table 5-1 lists the bill of materials for the LP8864EVM.

Table 5-1. LP8864EVM Bill of Materials

| Designator | QTY | Value | Part Number | Manufacturer | Description | Package Reference |
|---------------------|-----|-----------|----------------------|-----------------------------|--|------------------------------|
| !PCB1 | 1 | | PSIL105 | Any | Printed Circuit Board | |
| C4, C5, C23, C47 | 4 | 10uF | UMK325AB7106KMHT | Taiyo Yuden | CAP, CERM, 10 uF, 50 V, ±10%, X7R, AEC-Q200 Grade 1, 1210 | 1210 |
| C6, C7, C8, C9, C22 | 5 | 0.01uF | GCM188R72A103KA37J | MuRata | CAP, CERM, 0.01 µF, 100 V, ±10%, X7R, AEC-Q200 Grade 1, 0603 | 0603 |
| C12, C13 | 2 | 10uF | CGA6P1X7R1N106M250AC | TDK | CAP, CERM, 10 µF, 75 V, ±20%, X7R, AEC-Q200 Grade 1, 1210 | 1210 |
| C14, C15 | 2 | 33uF | EEH-ZC1J330P | Panasonic | CAP, Polymer Hybrid, 33 uF, 63 V, ±20%, 40 ohm, 8x10 SMD | 8x10 |
| C16, C17, C20, C21 | 4 | 4.7uF | CGA5L3X7R1H475K160AE | TDK | CAP, CERM, 4.7 µF, 50 V, ±10%, X7R, AEC-Q200 Grade 1, 1206 | 1206 |
| C18, C19 | 2 | 0.01uF | GCM155R71H103KA55D | MuRata | CAP, CERM, 0.01 uF, 50 V, ±10%, C0G/NP0, 0402 | 0402 |
| C24 | 1 | 68uF | EEE-FK1J680UP | Panasonic | CAP, AL, 68 uF, 63 V, ±20%, 0.65 ohm, AEC-Q200 Grade 2, SMD | SMT Radial F |
| C26, C30 | 2 | 4.7uF | GCM21BR71C475KA73L | MuRata | CAP, CERM, 4.7 uF, 16 V, ±10%, X7R, AEC-Q200 Grade 1, 0805 | 0805 |
| C27, C31 | 2 | 0.1uF | C0402C104K4RACAUTO | Kemet | CAP, CERM, 0.1 uF, 16 V, ±10%, X7R, AEC-Q200 Grade 1, 0402 | 0402 |
| C29 | 1 | 2.2uF | CGA4J3X7R1H225K125AB | TDK | CAP, CERM, 2.2 uF, 50 V, ±10%, X7R, AEC-Q200 Grade 1, 0805 | 0805 |
| C33, C35, C37, C39 | 4 | 1000pF | CGA3E2X7R2A102K080AA | TDK | CAP, CERM, 1000 pF, 100 V, ±10%, X7R, AEC-Q200 Grade 1, 0603 | 0603 |
| C44 | 1 | 22uF | CGA6P1X7R1C226M250AC | TDK | CAP, CERM, 22 uF, 16 V, ±20%, X7R, AEC-Q200 Grade 1, 1210 | 1210 |
| C45, C46 | 2 | 1uF | CGA5L2X7R1E105M160AA | TDK | CAP, CERM, 1 uF, 25 V, ±20%, X7R, AEC-Q200 Grade 1, 1206_190 | 1206_190 |
| D1 | 1 | 100V | FSV10100V | Fairchild Semiconductor | Diode, Schottky, 100 V, 10 A, AEC-Q101, TO-277A | TO-277A |
| D2, D3, D4 | 3 | Super Red | VLMS20J2L1-GS08 | Vishay-Semiconductor | LED, Super Red, SMD | 2.2x1.3x1.4mm |
| F1 | 1 | | 0679L9150-01 | Bel Fuse | FUSE BRD MNT 15A 125VAC/VDC | 2410 |
| FB1 | 1 | 50 ohm | BLM31SN500SZ1L | MuRata | Ferrite Bead, 50 ohm @ 100 MHz, 12 A, 1206 | 1206 |
| FB2, FB3 | 2 | 560 ohm | 782853561 | Würth Elektronik | Ferrite Bead, 560 ohm @ 100 MHz, 1.5 A, 0805 | 0805 |
| H1, H2, H3, H4 | 4 | | NY PMS 440 0025 PH | B&F Fastener Supply | Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead | Screw |
| H5, H6, H7, H8 | 4 | | 1902C | Keystone | | Standoff |
| H9 | 1 | | PSIL110 | | PSIL110, LP886X-LEDLOAD-EVM, CDDS#: 6631820 | |
| H10 | 1 | | USB2ANY | | USB2ANY, CDDS#: 6542513 | |
| J1, J6, J7 | 3 | | TSW-101-07-G-S | Samtec | Header, 100mil, 1pos, Gold, TH | Testpoint |
| J4 | 1 | | 6091 | Keystone | Standard Banana Jack, Insulated, Red | 6091 |
| J5, J9 | 2 | | 6092 | Keystone | Standard Banana Jack, Insulated, Black | 6092 |
| J8 | 1 | | 108-0907-001 | Cinch Connectivity | BANANA JACK, 15A, Insulated, Nylon, Yellow | 940x438x438mil |
| J10 | 1 | | TSW-108-07-G-S | Samtec | Header, 100mil, 8x1, Gold, TH | 8x1 Header |
| J11 | 1 | | SBH11-PBPC-D05-RA-BK | Sullins Connector Solutions | Header(shrouded), 2.54mm, 5x2, Gold, R/A, TH | Header, 2.54mm, 5x2, R/A, TH |
| J12, J13 | 2 | | TSW-104-07-G-S | Samtec | Header, 100mil, 4x1, Gold, TH | 4x1 Header |
| L1 | 1 | 2.2uH | IHLP3232DZER2R2M01 | Vishay-Dale | Inductor, Shielded, Powdered Iron, 2.2 uH, 10.5 A, 0.0137 ohm, SMD | 322x158x322mil |
| L2 | 1 | 22uH | IHLE4040DDER220M5A | Vishay-Dale | Inductor, Shielded, 22 µH, 4.1 A, 0.07544 ohm, AEC-Q200 Grade 0, SMD | Shielded Inductor |

Table 5-1. LP8864EVM Bill of Materials (continued)

| Designator | QTY | Value | Part Number | Manufacturer | Description | Package Reference |
|------------------------------------|-----|--------|----------------------|---------------------------|--|-------------------|
| L3 | 1 | 9uH | PLT10HH501100PNL | MuRata | Coupled inductor, 9 uH, 10A, 0.0036 ohm, SMD | 12.9x6.6mm |
| Q1 | 1 | -60V | SQJ459EP-T1_GE3 | Vishay-Semiconductor | MOSFET, P-CH, -60 V, -52 A, AEC-Q101, PowerPAK_SO-8L | PowerPAK_SO-8L |
| Q2 | 1 | 60V | NVMFSSC673NLWFAFT1G | ON Semiconductor | MOSFET, N-CH, 60 V, 50 A, SO-8FL | SO-8FL |
| R2, R5 | 2 | 0 | CRCW1210000Z0EAHP | Vishay-Dale | RES, 0, 1%, 0.75 W, AEC-Q200 Grade 0, 1210 | 1210 |
| R3, R15 | 2 | 0.02 | CRA2512-FZ-R020ELF | Bourns | RES, 0.02, 1%, 3 W, 2512 | 2512 |
| R4 | 1 | 20.0k | ERJ-3EKF2002V | Panasonic | RES, 20.0 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603 | 0603 |
| R6 | 1 | 49.9 | CRCW060349R9FKEA | Vishay-Dale | RES, 49.9, 1%, 0.1 W, AEC-Q200 Grade 0, 0603 | 0603 |
| R7 | 1 | 10.0 | CRCW060310R0FKEA | Vishay-Dale | RES, 10.0, 1%, 0.1 W, AEC-Q200 Grade 0, 0603 | 0603 |
| R8, R10, R14, R33, R36, R38 | 6 | 0 | RMCF0603ZT0R00 | Stackpole Electronics Inc | RES, 0, 1%, 0.1 W, AEC-Q200 Grade 0, 0603 | 0603 |
| R9 | 1 | 909k | CRCW0603909KFKEA | Vishay-Dale | RES, 909 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603 | 0603 |
| R11 | 1 | 76.8k | CRCW060376K8FKEA | Vishay-Dale | RES, 76.8 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603 | 0603 |
| R12 | 1 | 100k | CRCW0603100KFKEA | Vishay-Dale | RES, 100 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603 | 0603 |
| R13 | 1 | 20.5k | CRCW060320K5FKEA | Vishay-Dale | RES, 20.5 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603 | 0603 |
| R17, R21, R22, R27, R29 | 5 | 2.26k | CRCW06032K26FKEA | Vishay-Dale | RES, 2.26 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603 | 0603 |
| R18, R19, R23 | 3 | 10.0k | RMCF0603FT10K0 | Stackpole Electronics Inc | RES, 10.0 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603 | 0603 |
| R24, R28, R30 | 3 | 3.92k | CRCW06033K92FKEA | Vishay-Dale | RES, 3.92 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603 | 0603 |
| R31 | 1 | 11.0k | RMCF0603FT11K0 | Stackpole Electronics Inc | RES, 11.0 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603 | 0603 |
| R32 | 1 | 20.8k | RT0603BRD0720K8L | Yageo America | RES, 20.8 k, 0.1%, 0.1 W, 0603 | 0603 |
| U1 | 1 | | LP8864QDCPRQ1 | Texas Instruments | Automotive display LED-backlight with Four 200-mA channels | HTSSOP38 |
| U2 | 1 | | TPS7B8250QKVURQ1 | Texas Instruments | Automotive 300-mA high-voltage ultra-low-Iq low-dropout (LDO) regulator, KVVU0005A (TO-252-5) | KVVU0005A |
| U3 | 1 | | TLV70033QDDCRQ1 | Texas Instruments | Single Output Automotive LDO, 200 mA, Fixed 3.3 V Output, 2 to 5.5 V Input, with Low IQ, 5-pin SOT (DDC), -40 to 125 degC, Green (RoHS & no Sb/Br) | DDC0005A |
| C1 | 0 | 220pF | GRM188R72A221KA01D | MuRata | CAP, CERM, 220 pF, 100 V, ±10%, X7R, 0603 | 0603 |
| C2, C3 | 0 | 10uF | UMK325AB7106KMHT | Taiyo Yuden | CAP, CERM, 10 uF, 50 V, ±10%, X7R, AEC-Q200 Grade 1, 1210 | 1210 |
| C10, C11 | 0 | 10uF | CGA6P1X7R1N106M250AC | TDK | CAP, CERM, 10 uF, 75 V, ±20%, X7R, AEC-Q200 Grade 1, 1210 | 1210 |
| C25, C28 | 0 | 220pF | CGA2B2X7R1H221K050BA | TDK | CAP, CERM, 220 pF, 50 V, ±10%, X7R, AEC-Q200 Grade 1, 0402 | 0402 |
| C32, C34, C36, C38 | 0 | 1000pF | CGA3E2X7R2A102K080AA | TDK | CAP, CERM, 1000 pF, 100 V, ±10%, X7R, AEC-Q200 Grade 1, 0603 | 0603 |
| FID1, FID2, FID3, FID4, FID5, FID6 | 0 | | N/A | N/A | Fiducial mark. There is nothing to buy or mount. | N/A |
| J2, J3, J14 | 0 | | TSW-101-07-G-S | Samtec | Header, 100mil, 1pos, Gold, TH | Testpoint |
| R1 | 0 | 5.1 | CRCW20105R10JNEF | Vishay-Dale | RES, 5.1, 5%, 0.75 W, AEC-Q200 Grade 0, 2010 | 2010 |
| R16, R34, R35, R37 | 0 | 0 | RMCF0603ZT0R00 | Stackpole Electronics Inc | RES, 0, 1%, 0.1 W, AEC-Q200 Grade 0, 0603 | 0603 |
| R20, R25, R26 | 0 | 10.0k | RMCF0603FT10K0 | Stackpole Electronics Inc | RES, 10.0 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603 | 0603 |

6 LED Load Board

An LED load board LP886X-LEDLOAD-EVM is included in the EVM kit. The LED board is intended to be used as the load for LED driver and can be configured for up to 6 strings and up to 20 LEDs in the string (Number of LEDs in use is defined by jumpers). The initial setting on the board is 8 LEDs in series per string. Cree XLamp ML-C LEDs with maximum current of 350 mA (for parallel use) and maximum forward voltage of 3.4 V at 100 mA (3.2-V typical) are used on the board.

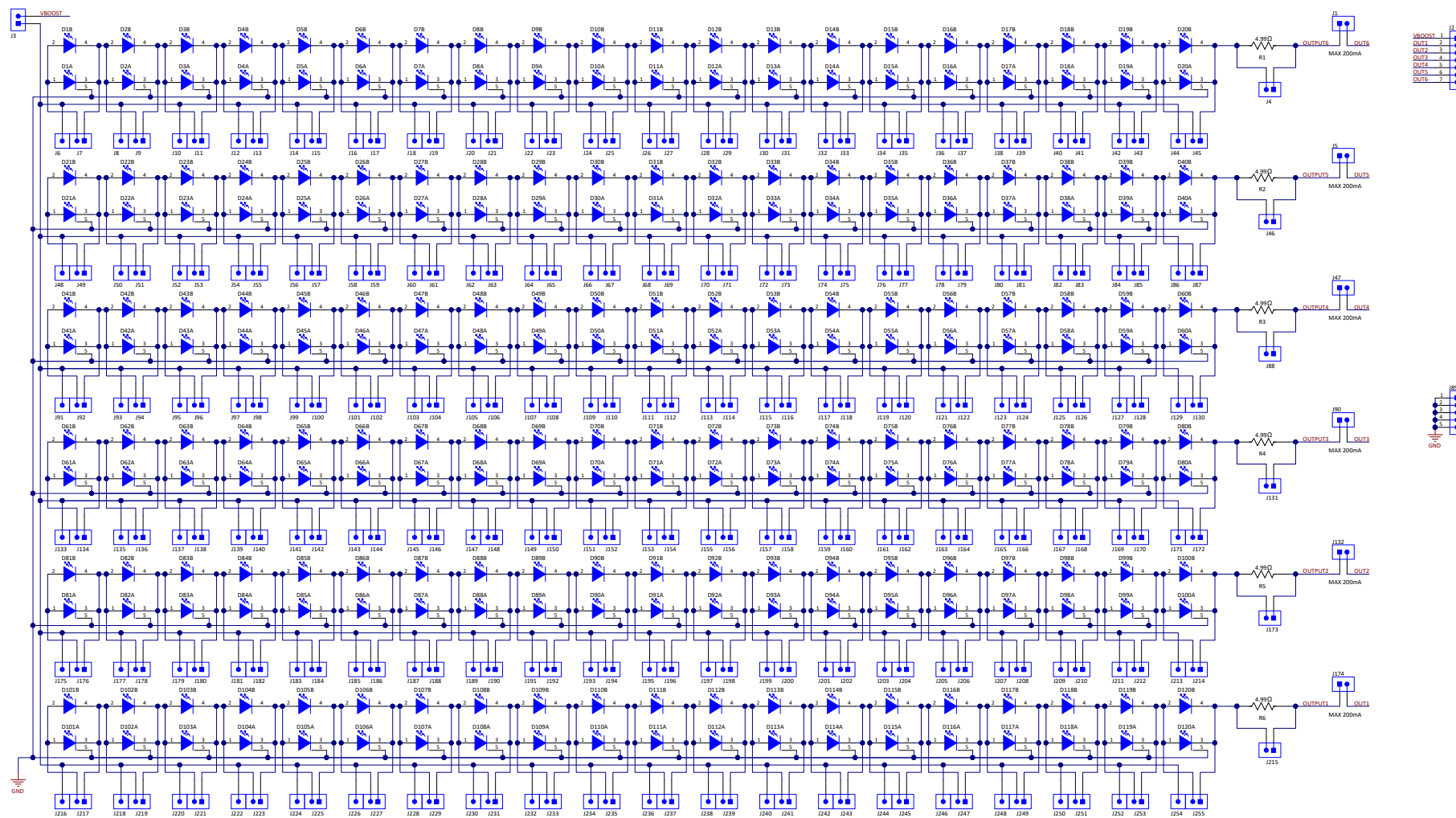


Figure 6-1. LP886X-LEDLOAD-EVM Schematic

Table 6-1. LP886X-LEDLOAD-EVM Bill of Materials

| Designator | QTY | Part Number | Manufacturer | Description | Package Reference |
|--|-----|-----------------------|-----------------------------|---|-------------------------|
| !PCB1 | 1 | PSIL110 | | Printed Circuit Board | |
| D1...D120 | 120 | MLCAWT-A1-0000-000XE1 | Cree Inc. | LED XLAMP COOL WHITE 6500K 4SMD | SMD4 |
| H1, H2, H3, H4 | 4 | NY PMS 440 0038 PH | B&F Fastener Supply | | |
| H5, H6, H7, H8 | 4 | 1902C | Keystone | | Standoff |
| H9, H10, H11, H12 | 4 | 4802 | Keystone | | |
| H13 | 1 | MCH050 | | Gray smoked plexiglass, 0.125" THK. Must comply with REACH directive. Must meet or exceed UL94-V0 | 7.53" X 4" X 0.125" |
| J7, J9...J43, J45; J49, J51...J85, J87; J92, J94...J128, J130; J134, J136...J170, J172; J176, J178...J212, J214; J217, J219...J253, J255; J1, J3, J4, J5, J46, J47, J88, J90, J131, J132, J173, J174, J215 | 133 | TSW-102-07-G-S | Samtec | Header, 100mil, 2x1, Gold, TH | 2x1 Header |
| J2 | 1 | TSW-107-07-G-S | Samtec | Header, 100mil, 7x1, Gold, TH | 7x1 Header |
| J6, J8...J42, J44; J48, J50...J84, J86; J91, J93...J127, J129; J133, J135...J169, J171; J175, J177...J211, J213; J216, J218...J252, J254 | 120 | TSW-101-07-G-S | Samtec | Header, 100mil, 1pos, Gold, TH | Testpoint |
| J89 | 1 | TSW-105-07-G-S | Samtec | Header, 100mil, 5x1, Gold, TH | 5x1 Header |
| R1, R2, R3, R4, R5, R6 | 6 | CRCW12064R99FKEAHP | Vishay Dale | Res Thick Film 1206 4.99 Ohm 1% 0.75W(3/4W) ±100ppm/C Pad SMD Automotive T/R | 1206 |
| SH-J1...SH-J19 | 19 | SPC02SYAN | Sullins Connector Solutions | Shunt, 100mil, Flash Gold, Black | Closed Top 100mil Shunt |
| FID1, FID2, FID3 | 0 | N/A | N/A | Fiducial mark. There is nothing to buy or mount. | N/A |

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 DEGRADATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

3 Regulatory Notices:

3.1 United States

3.1.1 Notice applicable to EVMs not FCC-Approved:

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

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

CAUTION

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

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

FCC Interference Statement for Class A EVM devices

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

FCC Interference Statement for Class B EVM devices

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

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

3.2 Canada

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

Concerning EVMs Including Radio Transmitters:

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

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

Concernant les EVMs avec appareils radio:

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

Concerning EVMs Including Detachable Antennas:

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

Concernant les EVMs avec antennes détachables

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

3.3 Japan

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lstds/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/lstds/ti_ja/general/eStore/notice_01.page

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.

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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。

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http://www.tij.co.jp/lstds/ti_ja/general/eStore/notice_02.page

3.4 European Union

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

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

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- 4 *EVM Use Restrictions and Warnings:*
 - 4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.
 - 4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.
 - 4.3 *Safety-Related Warnings and Restrictions:*
 - 4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.
 - 4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.
 - 4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.
 5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.
 6. *Disclaimers:*
 - 6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.
 - 6.2 EXCEPT FOR THE LIMITED RIGHT TO USE THE EVM SET FORTH HEREIN, NOTHING IN THESE TERMS SHALL BE CONSTRUED AS GRANTING OR CONFERRING ANY RIGHTS BY LICENSE, PATENT, OR ANY OTHER INDUSTRIAL OR INTELLECTUAL PROPERTY RIGHT OF TI, ITS SUPPLIERS/LICENSORS OR ANY OTHER THIRD PARTY, TO USE THE EVM IN ANY FINISHED END-USER OR READY-TO-USE FINAL PRODUCT, OR FOR ANY INVENTION, DISCOVERY OR IMPROVEMENT, REGARDLESS OF WHEN MADE, CONCEIVED OR ACQUIRED.
 7. *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS LICENSORS AND THEIR REPRESENTATIVES HARMLESS FROM AND AGAINST ANY AND ALL CLAIMS, DAMAGES, LOSSES, EXPENSES, COSTS AND LIABILITIES (COLLECTIVELY, "CLAIMS") ARISING OUT OF OR IN CONNECTION WITH ANY HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.
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8. *Limitations on Damages and Liability:*

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

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

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

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

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