

## EVM User's Guide: LM5192QEV-400

带 I<sup>2</sup>C 评估模块的 LM5192-Q1 CC-CV 降压转换器

## 说明

LM5192QEV-400 EVM 是一款同步降压稳压器，能够通过 I<sup>2</sup>C 接口进行恒流恒压调节。该 EVM 在 15V 至 70V 的输入电压范围内工作，可在 CC 模式下提供最高 8A 稳定电流，在 CV 模式下提供最高 12V 稳定电压。

## 开始使用

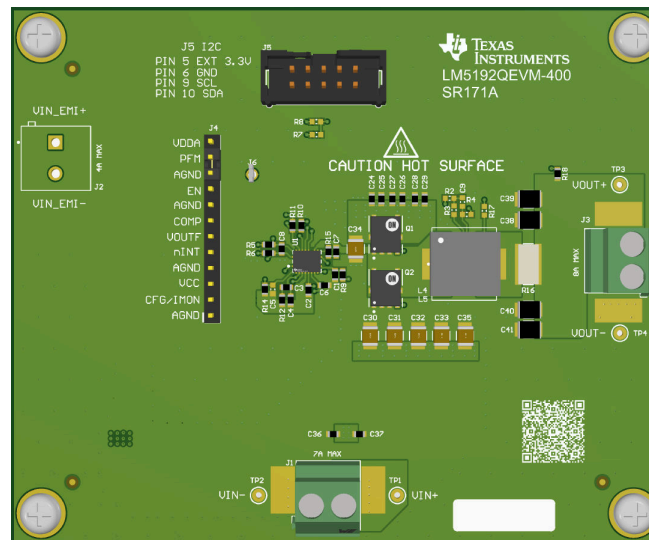
1. 将 EVM 连接到电源和负载。
2. 将 [USB2ANY](#) 适配器连接到 EVM 和 PC。
3. 启动 [产品文件夹](#) 中的配置 GUI。

## 特性

- 输入电压工作范围：15V 至 70V (在 J1 VIN 端子处)
- 可编程输出电压高达 12V，并具有可编程电缆压降补偿 (CDC)
- 可编程平均电流限制高达 8A
- V<sub>SUPPLY</sub> = 48V 时具有 96% 的峰值满载效率
- 采用 6 层 2oz PCB 的高效散热布局

## 应用

- 汽车照明
- 信息娱乐系统与仪表组
- 汽车 USB 充电



LM5192QEV-400

## 1 评估模块概述

### 1.1 简介

LM5192QEVM-400 EVM 是一款具有恒流恒压 (CC-CV) 调节功能和 I<sup>2</sup>C 接口的同步直流/直流降压稳压器。该 EVM 在 15V 至 70V (VIN 端子) 的输入电压范围内工作, 可在 CC 模式下提供 8A (最大) 的稳定电流, 在 CV 模式下提供 12V (最大高) 的稳定电压。平均电感器电流限制和输出电压的调节目标可通过 I<sup>2</sup>C 进行编程。默认情况下, 输出电压预编程为 5V, 平均电感器电流限制预编程为 0.5A, 自由运行频率预编程为 400kHz。

该 EVM 具有电缆压降补偿、展频、可选 FPWM/OVP、有源输出放电、输出压摆率控制、软启动、PFM 以及具有断续模式保护功能的峰值电流限制。EVM 的设计开关频率为 400kHz。

### 1.2 套件内容

- 一个 LM5192QEVM-400 EVM 电路板
- EVM 免责声明自述文件

### 1.3 规格

表 1-1 表列出了评估模块的电气特性。请参阅 [LM5192-Q1 产品文件夹](#), 详细了解器件规格。效率和其他性能指标会根据工作输入电压、负载电流、外部连接的输出电容器和其他参数而变化。运行时建议的空气流量为 200LFM。

表 1-1. 电气性能特性

参数	测试条件	最小值	典型值	最大值	单位
<b>输入特性</b>					
输入工作范围, V <sub>SUPPLY</sub>	VIN+, VIN- 端子	15	48	70	V
输入电流, I <sub>SUPPLY</sub>				8	A
输入电流, 空载	PFM, BIAS_EN = 1, EN = VIN, V <sub>LOAD</sub> = 12V, R11 已删除, 无 I <sup>2</sup> C 通信	V <sub>SUPPLY</sub> = 24V	195		μA
		V <sub>SUPPLY</sub> = 48V	105		
		V <sub>SUPPLY</sub> = 60V	88		
<b>输出特性</b>					
额定输出电压 V <sub>LOAD</sub>	CV 模式		12		V
平均电感器电流, I <sub>LOUT</sub>	CC 模式			8	A
<b>系统特性</b>					
开关频率 f <sub>SW</sub>			400		kHz
满负载效率	I <sub>LOAD</sub> = 8A	V <sub>SUPPLY</sub> = 24V	97.1%		
		V <sub>SUPPLY</sub> = 48V	96.0%		
		V <sub>SUPPLY</sub> = 60V	95.5%		

### 1.4 器件信息

表 1-2. 具有集成 CC-CV 控制和 I<sup>2</sup>C 接口的 LM(2)5192(-Q1) 同步降压控制器系列

直流/直流	最大 VIN	输出量程	汽车级认证
LM5192-Q1	80V	1V - 24V / 3.3V - 48V	AEC-Q100 Grade1
LM25192-Q1	42V	1V - 24V / 3.3V - 24V	AEC-Q100 Grade1
LM5192	80V	1V - 24V / 3.3V - 48V	商用级

## 2 硬件

### 2.1 测试装置和过程

#### 2.1.1 EVM 连接

图 2-1 展示了建议使用的测试设置。在提供 ESD 保护的工作站上工作时，请确保在处理 EVM 之前已连接所有腕带、靴带或垫子以使用户接地。

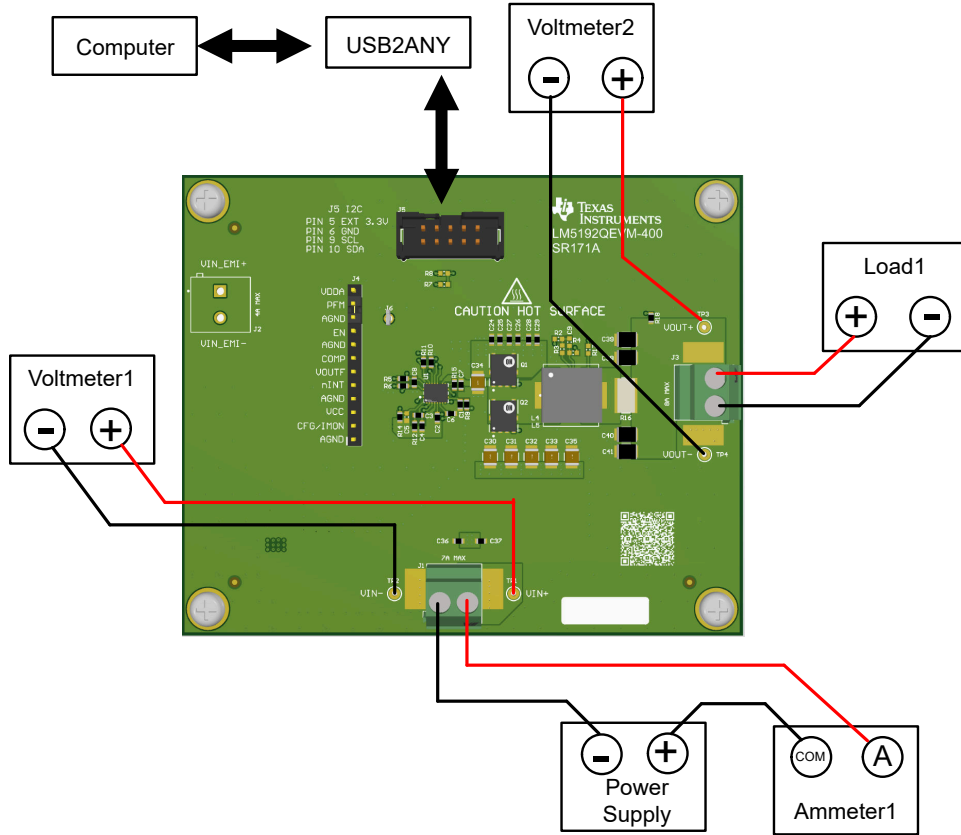


图 2-1. EVM 测试设置

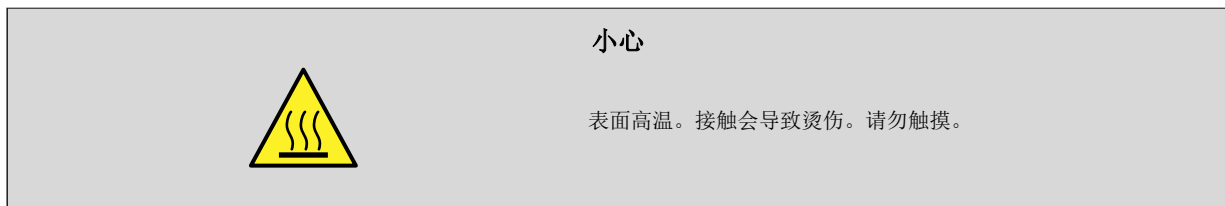


表 2-1. 电源连接

参考位号	标签	说明
J1	VIN+	正输入电压电源连接
J1	VIN-	负输入电压电源连接
J2	VIN_EMI+	用于 EMI 测试的正输入电压电源连接
J2	VIN_EMI -	用于 EMI 测试的负输入电压电源连接
J3	VOUT+	正输出电压电源连接
J3	VOUT -	负输出电压电源连接

表 2-2. DVM 连接

参考位号	标签	说明
TP1	VIN+	正输入电压检测
TP2	VIN-	负输入电压检测
TP3	VOUT+	正输出电压检测
TP4	VOUT-	负输出电压检测

表 2-3. J4 跳线

编号	标签	说明
12	VDDA	VDDA 连接
11	PFM	PFM / FPWM 模式选择和同步输入引脚
10	AGND	接地连接
9	EN	使能输入。将该引脚连接至 GND 以禁用该器件
8	AGND	接地连接
7	COMP	外部补偿引脚
6	VOUTF	VOUTF 连接引脚
5	nINT	中断指示器引脚。
4	AGND	接地连接
3	VCC	VCC 连接
4	CFG/IMON	IMON 连接。电流监控引脚。在启动期间将该引脚保持悬空状态。
1	AGND	接地连接

表 2-4. J5 跳线

编号	标签	说明
1、2、3、4、7、8	NC	无连接引脚
5	EXT-3.3V	从 USB2ANY 连接到外部 3.3V
6	GND	接地连接
9	SCL	I <sup>2</sup> C 时钟引脚
10	SDA	I <sup>2</sup> C 数据引脚

### 2.1.2 测试设备

- **电源**：使用能够提供 0V 至 70V 电压和 10A 电流的输入电压源。
- **电压表 1**：测量 VIN+ 至 VIN - 的输入电压。
- **电压表 2**：测量 VOUT+ 至 VOUT - 的输出电压。
- **电流表 1**：测量输入电流。连接到电源和 VIN+。
- **负载 1**：负载必须是能够进行恒压 (CV) 和恒流 (CC) 调节的电子负载。电子负载必须能够在 12V 及更低电压下灌入 10A 电流。

**示波器**：将示波器带宽设置为 20MHz 并采用交流耦合模式，使用示波器探头通常提供的短接地引线直接测量输出电容器两端的输出电压纹波。TI 不建议使用长引线接地，因为这会在接地回路很大时引起额外的噪声。若要测量其他波形，请根据需要调整示波器。在接触任何可能带电或通电的电路时，请务必小心。

### 2.1.3 建议的测试设置

使用位于电源端子块附近的 VIN+/TP1 和 VIN - /TP2 测试点以及 VOUT+/TP3、VOUT - /TP4 测试点作为电压监测点，通过连接电压表来分别测量输入和输出电压。请勿将这些检测端子用作输入电源或输出负载连接点。连接到这些检测端子的 PCB 迹线不能支持高电流。在向 EVM 供电之前，请确保已在合适的位置放置了 J4 跳线。

### 小心

在高输出电流和高输入电压下长时间运行会使元件温度升高到 55°C 以上。为避免烧伤风险，断开电源后不要立即触摸元件，直到元件充分冷却为止。输入电源和输出电气负载的线规需要至少为 9AWG，且长度不得超过 1 英尺。请拧紧输入和输出端子螺钉，以尽量减少接触电阻。

#### 2.1.3.1 输入连接

1. 在连接输入电源之前，将输入电源的电流限值设置为最大 0.1A。确保输入源最初设置为 0V 并连接到 J1 端子，如图 2-1 所示。
2. 在 VIN+ 和 VIN- 测试点上连接电压表 1 以测量输入电压。
3. 连接电流表 1，以测量输入电流。

#### 2.1.3.2 输出接头

1. 将电子负载连接到 J3。在施加输入电压之前，将负载设置为 CV 模式并设为 14V。
2. 在 VOUT+ 和 VOUT- 测试点上连接电压表 2 以测量输出电压。

#### 2.1.3.3 I<sup>2</sup>C 连接

1. 将 10 引脚带状电缆插入 USB2ANY 和 J5。
2. 将 USB mini-B 连接器插入 USB2ANY 和计算机。

#### 2.1.4 测试程序

##### 2.1.4.1 图形用户界面 (GUI)

###### 2.1.4.1.1 快速概览

首先，使用 USB mini-B 连接器将 USB2ANY 适配器连接到计算机，使用 10 引脚带状电缆将 USB2ANY 适配器连接到 EVM，将电源和负载连接到 EVM，为 EVM 上电，然后启动配置 GUI。

GUI 会自动连接到 EVM，但如果未连接，则在 GUI 底部的状态栏中选择 **重新连接** 按钮以连接到 EVM。

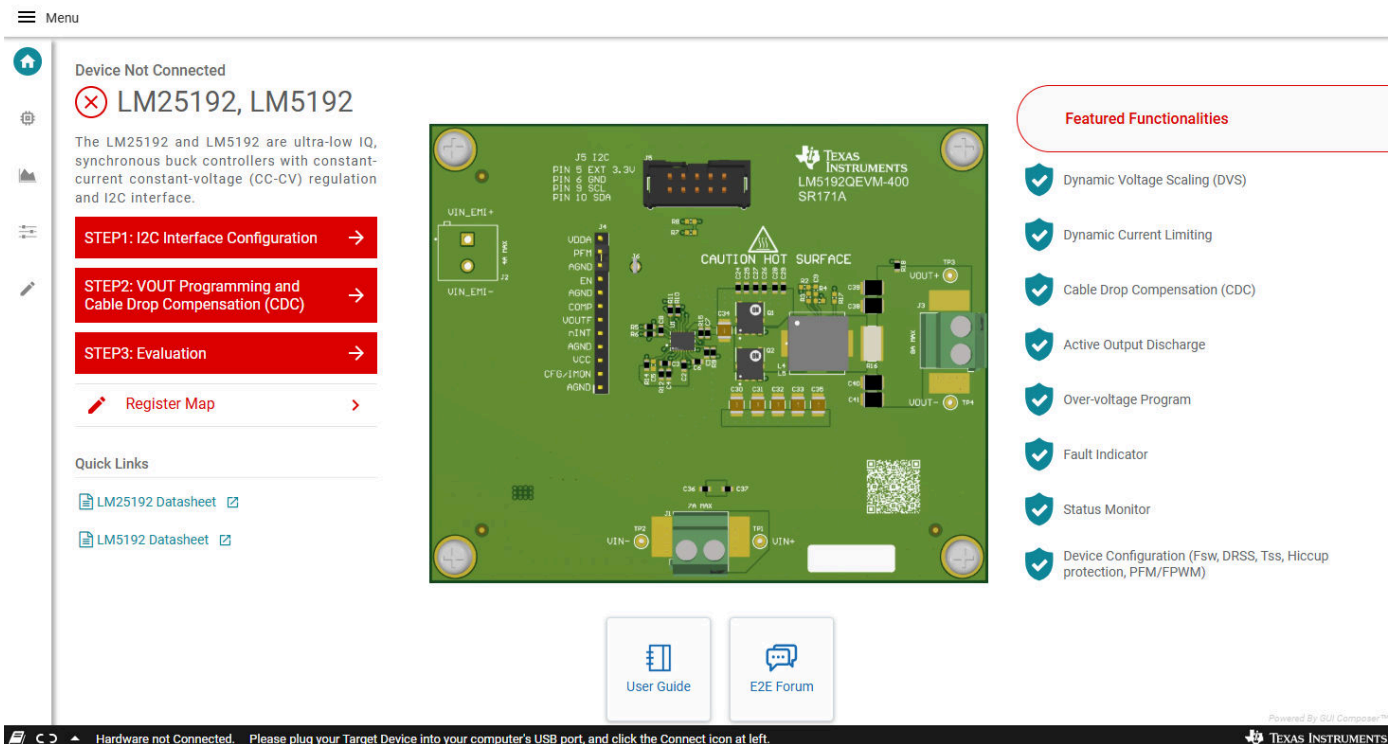


图 2-2. 开始使用

在对器件进行编程之前，完成第 1 步中的 I<sup>2</sup>C 接口配置。选择 *LM5192* 作为 GPN，选择 *5mΩ* 作为检测电阻值。该器件支持标准，快速和快速 + 模式，但 GUI 仅支持标准和快速模式。请选择标准模式作为起点。使能 USB2ANY 适配器内部的上拉电阻，然后选择 **配置 USB2ANY** 按钮。选择 *0x6A* 作为 I<sup>2</sup>C 目标地址，然后选择 **连接到 EVM** 按钮。

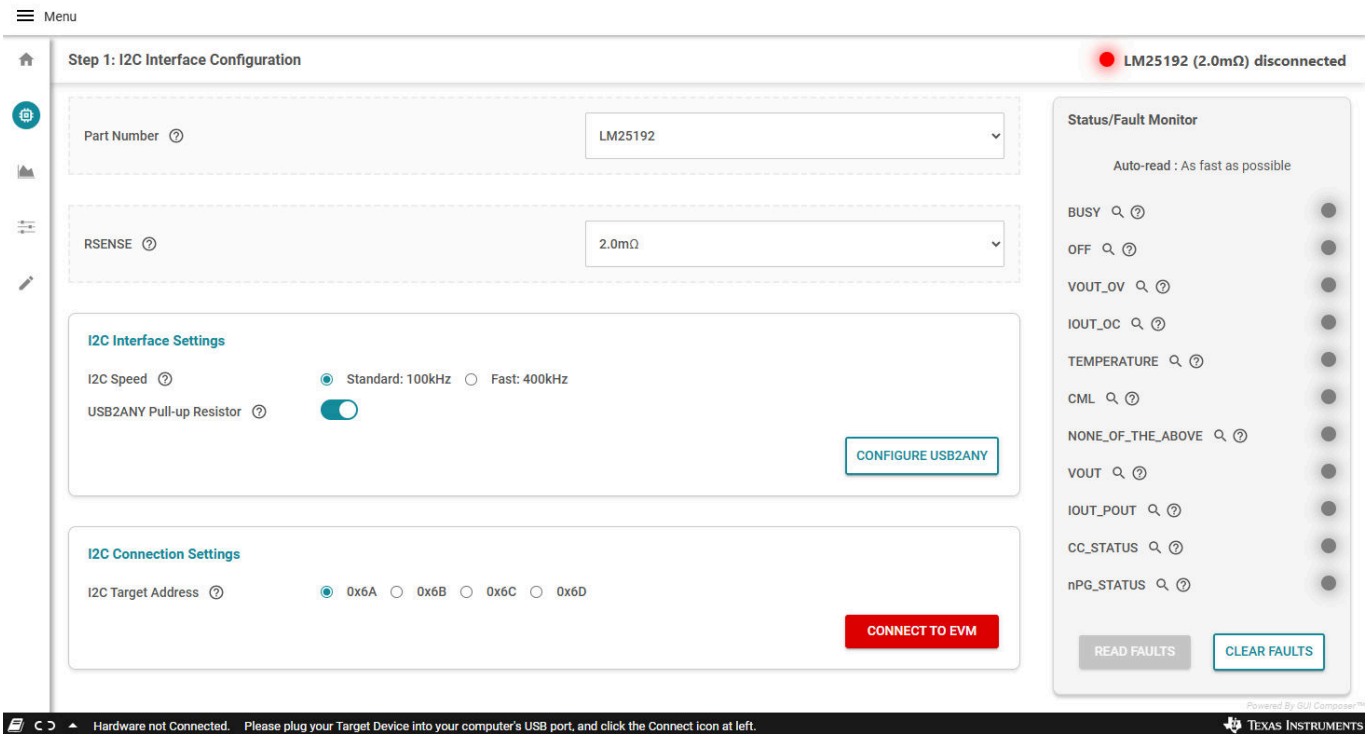


图 2-3. 第 1 步 : I<sup>2</sup>C 接口配置

在第 2 步中，将 VOUT 调节目标编程为将 12V 作为起点，并根据需要对电缆补偿增益进行编程。

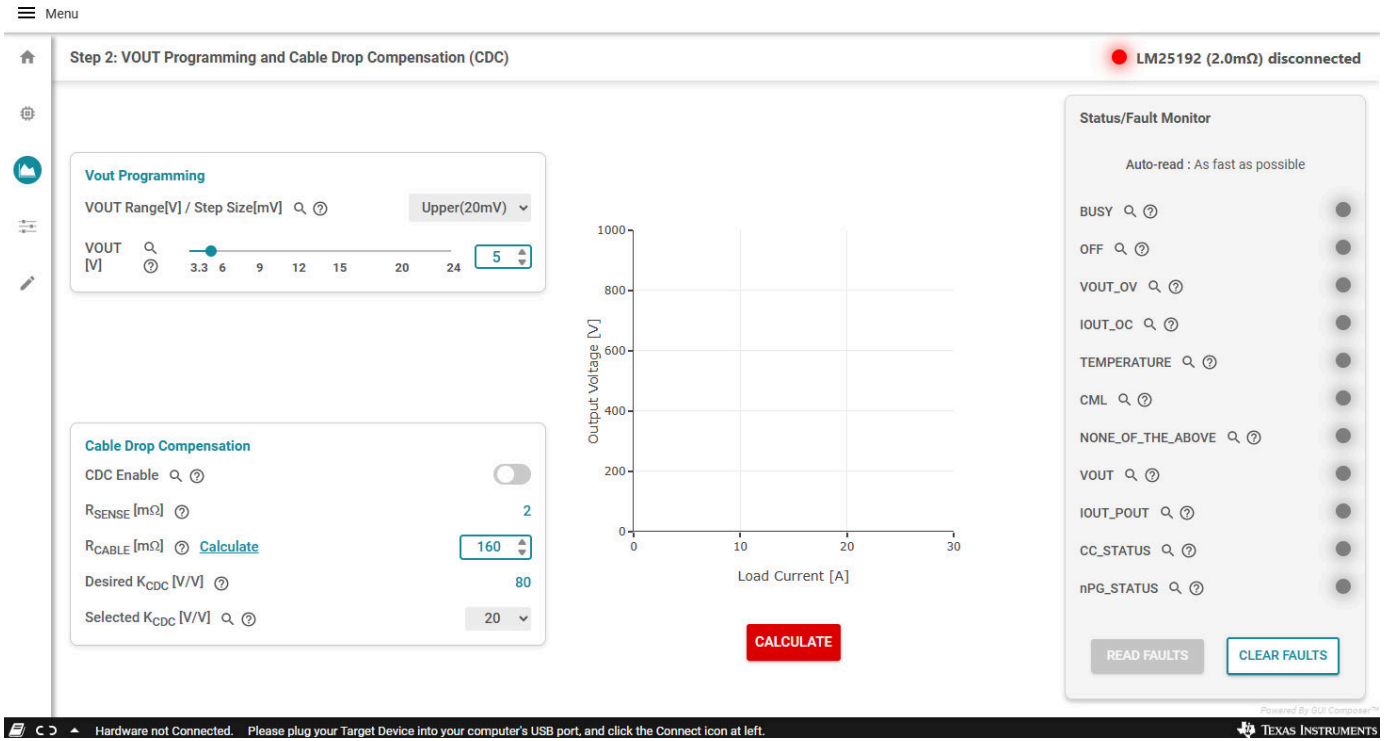


图 2-4. 第 2 步 : VOUT 编程和 CDC

在第 3 步中对其余参数进行编程，包括开关频率、展频、CC 模式调节目标、OVP、PGOOD、DVS 和 VOUT 放电。将 CC 模式调节目标编程为 8A，并将开关频率编程为将 400kHz 作为起点。器件编程完成后，可以通过切换使能转换器的切换按钮来使能转换器。

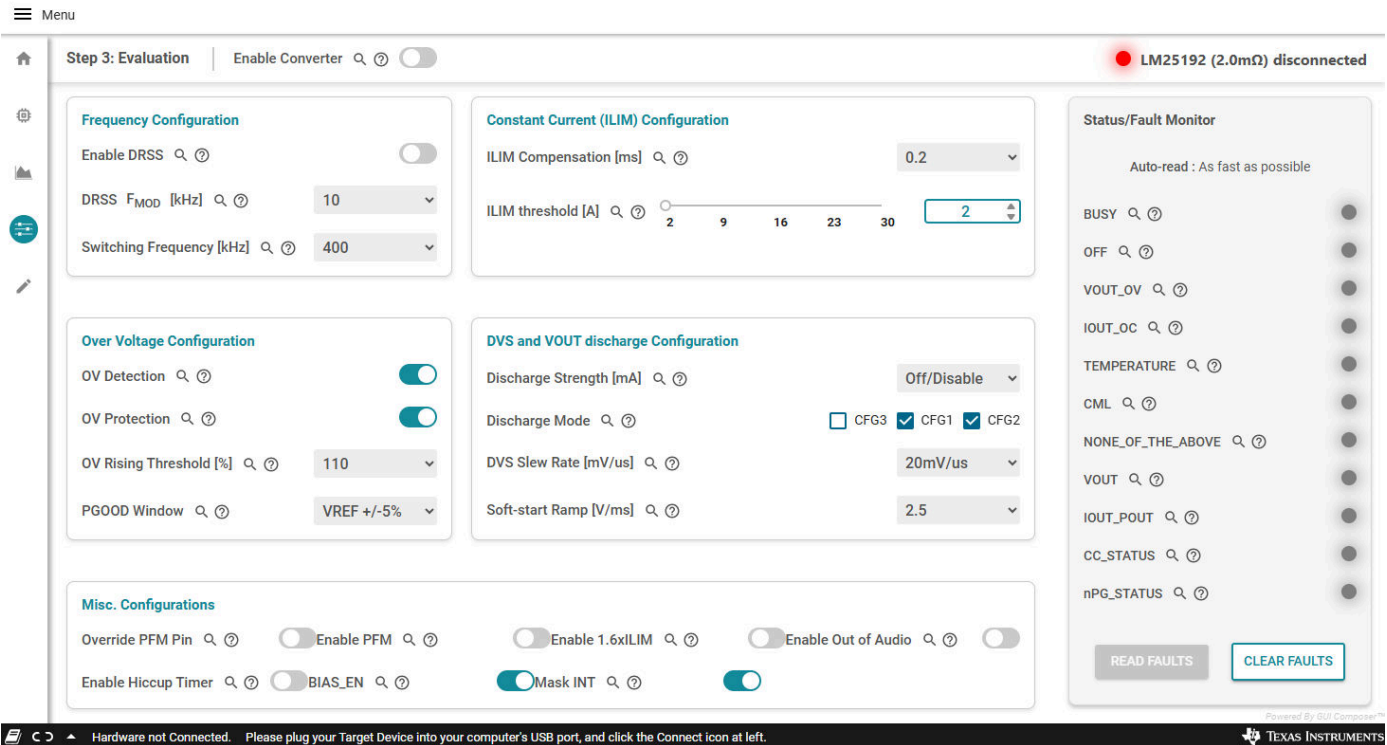
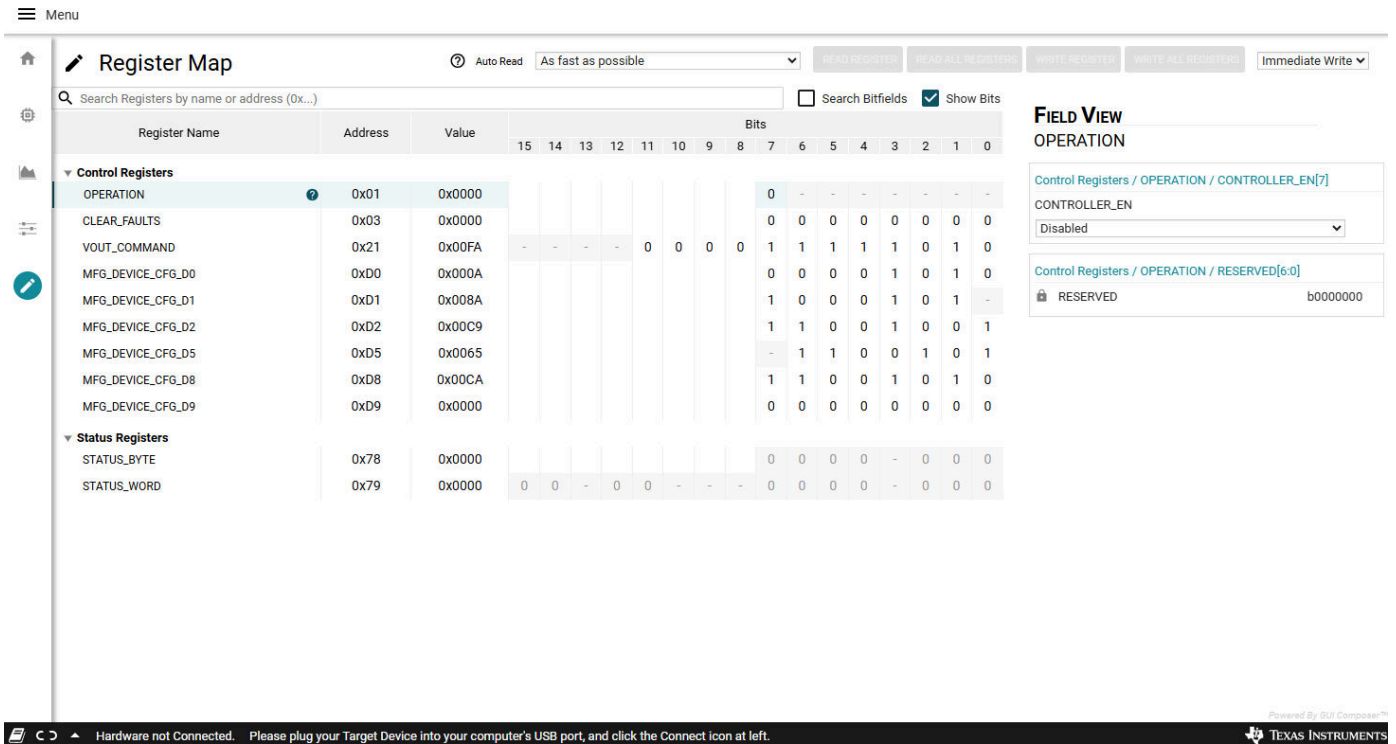


图 2-5. 第 3 步 : 评估

每个 I<sup>2</sup>C 寄存器和位都可以在寄存器映射中进行监控或编程。如果熟悉器件操作和 I<sup>2</sup>C 接口，请直接对 I<sup>2</sup>C 寄存器映射进行编程。



**Register Map** Auto Read As fast as possible READ REGISTER READ ALL REGISTERS WRITE REGISTER WRITE ALL REGISTERS Immediate Write

Search Registers by name or address (0x...) Search Bitfields Show Bits

Register Name	Address	Value	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<b>Control Registers</b>																		
OPERATION	0x01	0x0000									0	-	-	-	-	-	-	-
CLEAR_FAULTS	0x03	0x0000									0	0	0	0	0	0	0	0
VOUT_COMMAND	0x21	0x00FA	-	-	-	-	0	0	0	0	1	1	1	1	1	0	1	0
MFG_DEVICE_CFG_D0	0xD0	0x000A									0	0	0	0	1	0	1	0
MFG_DEVICE_CFG_D1	0xD1	0x008A									1	0	0	0	1	0	1	-
MFG_DEVICE_CFG_D2	0xD2	0x00C9									1	1	0	0	1	0	0	1
MFG_DEVICE_CFG_D5	0xD5	0x0065									-	1	1	0	0	1	0	1
MFG_DEVICE_CFG_D8	0xD8	0x00CA									1	1	0	0	1	0	1	0
MFG_DEVICE_CFG_D9	0xD9	0x0000									0	0	0	0	0	0	0	0
<b>Status Registers</b>																		
STATUS_BYTE	0x78	0x0000									0	0	0	0	-	0	0	0
STATUS_WORD	0x79	0x0000	0	0	-	0	0	-	-	-	0	0	0	0	-	0	0	0

**FIELD VIEW**  
OPERATION

Control Registers / OPERATION / CONTROLLER\_EN[7]  
CONTROLLER\_EN  
Disabled

Control Registers / OPERATION / RESERVED[6:0]  
RESERVED b0000000

Hardware not Connected. Please plug your Target Device into your computer's USB port, and click the Connect icon at left.

图 2-6. 寄存器映射

#### 2.1.4.2 基本测试过程

1. 如前文所述设置 EVM、USB2ANY、电源、电子负载、电流表、DVM 和配置 GUI。请勿使能转换器。
2. 将负载设置为恒压 (CV) 模式并设置为 14V。
3. 将输入电源的电流限值设置为最大 0.1A。
4. 将输入源设置为 48V 并打开。
5. 通过 I<sup>2</sup>C 对转换器进行编程并启用转换器。将输出电压编程为 12V，并将 ILIM 阈值编程为 8A。
6. 将输入电源的电流限值设置为最大 10A。
7. 将负载电压设置为 11V。负载电流必须处于 8A 调节目标范围内。
8. 将负载电压设置为 14V。负载电压必须处于 12V 调节目标范围内，负载电流必须为 0A。
9. 通过 I<sup>2</sup>C 禁用转换器。
10. 关闭输入电源。

### 3 实现结果

#### 3.1 测试数据和性能曲线

除非另有说明，否则  $V_{\text{SUPPLY}} = 48\text{V}$  且  $f_{\text{SW}} = 400\text{kHz}$

##### 3.1.1 效率

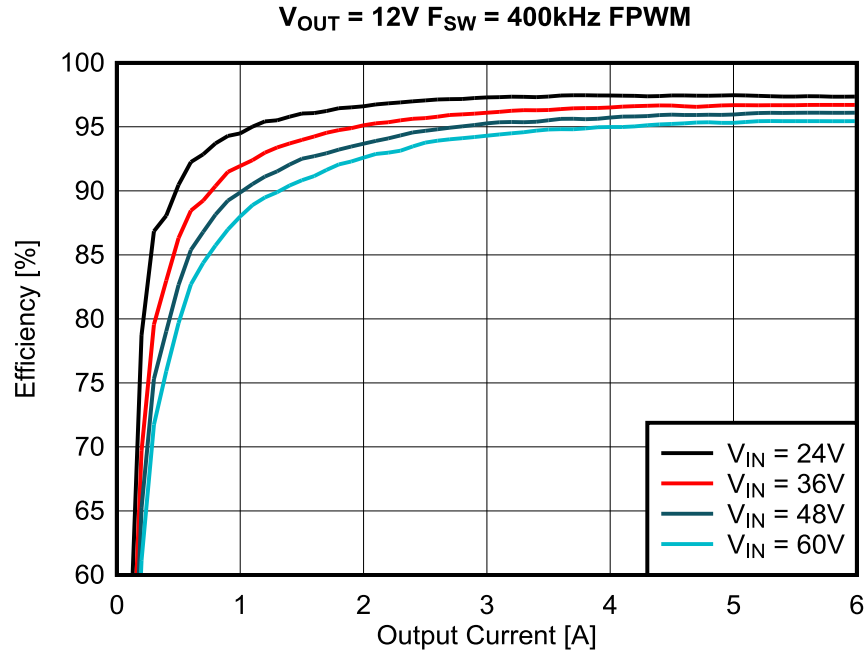


图 3-1. FPWM 模式，线性标度

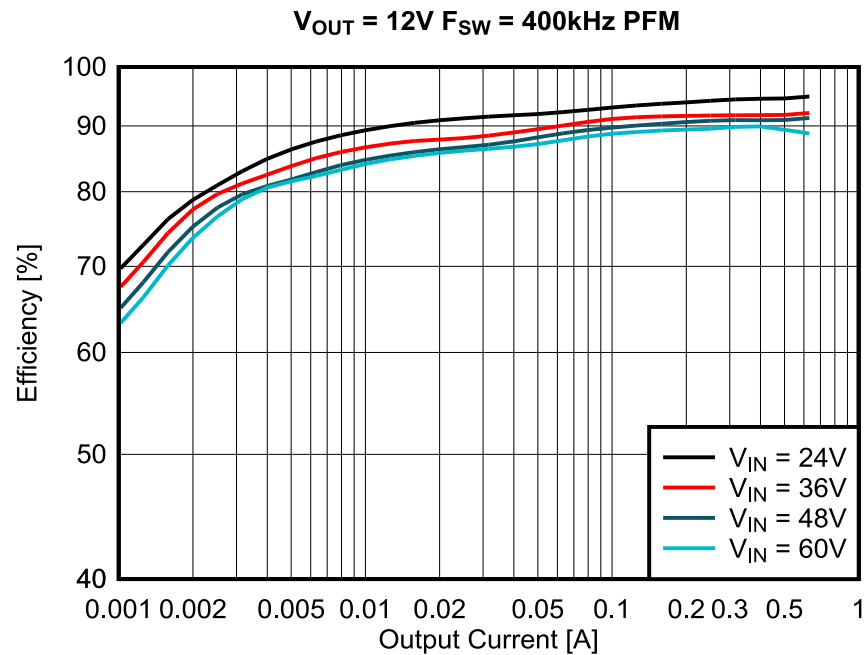


图 3-2. PFM 模式，对数标度

### 3.1.2 工作波形

#### 3.1.2.1 启动和关断

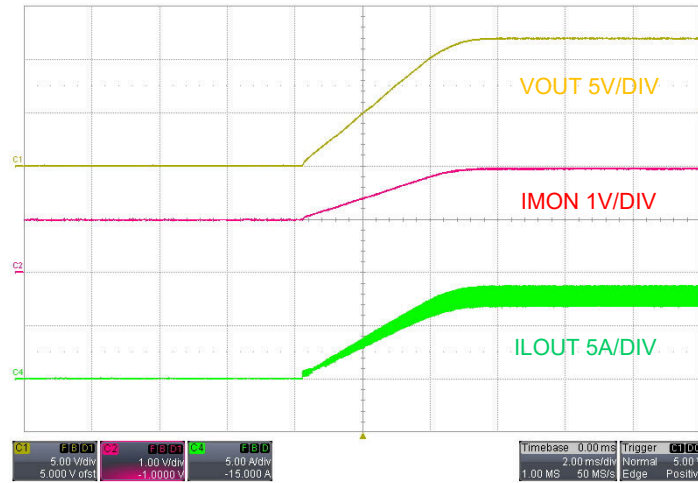


图 3-3.  $V_{\text{SUPPLY}} = 48\text{V}$  ,  $I_{\text{LOAD}} = 8\text{A}$  电阻负载

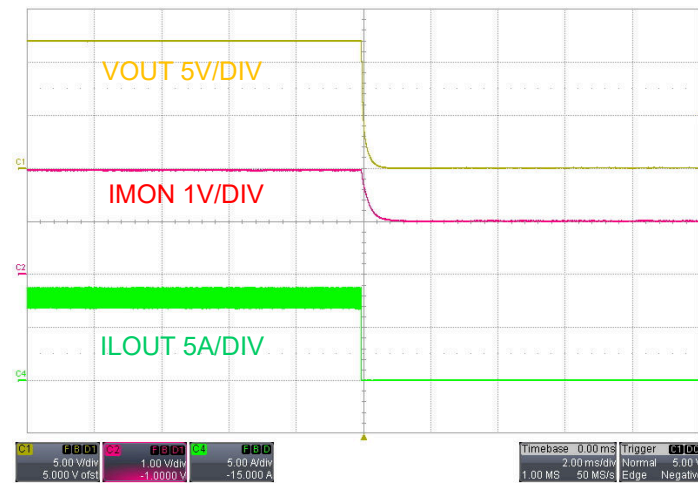


图 3-4.  $V_{\text{SUPPLY}} = 48\text{V}$  ,  $I_{\text{LOAD}} = 8\text{A}$  电阻负载

#### 3.1.2.2 开关

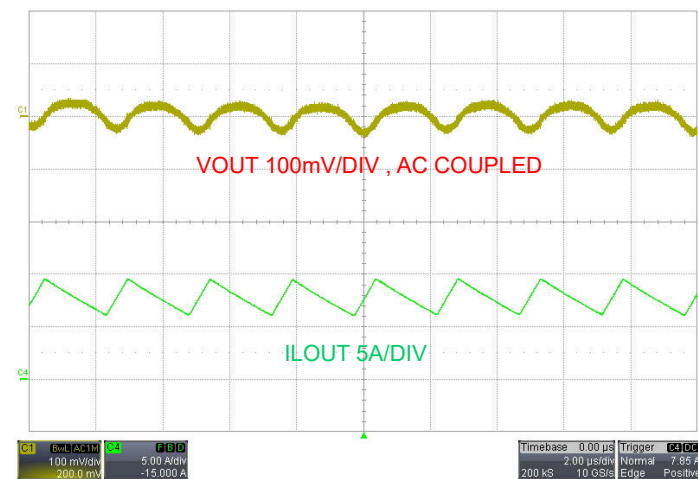


图 3-5. 输出纹波 ,  $V_{\text{SUPPLY}} = 48\text{V}$  ,  $I_{\text{LOAD}} = 8\text{A}$

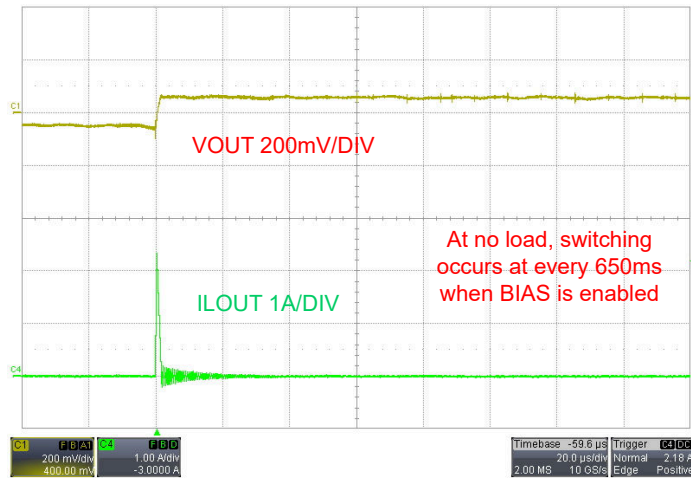


图 3-6. PFM 模式、 $V_{\text{SUPPLY}} = 48\text{V}$ 、 $I_{\text{LOAD}} = 0\text{A}$  条件下的空载运行

### 3.1.2.3 负载瞬态 (CV)，模式转换 (CV 至 CC)

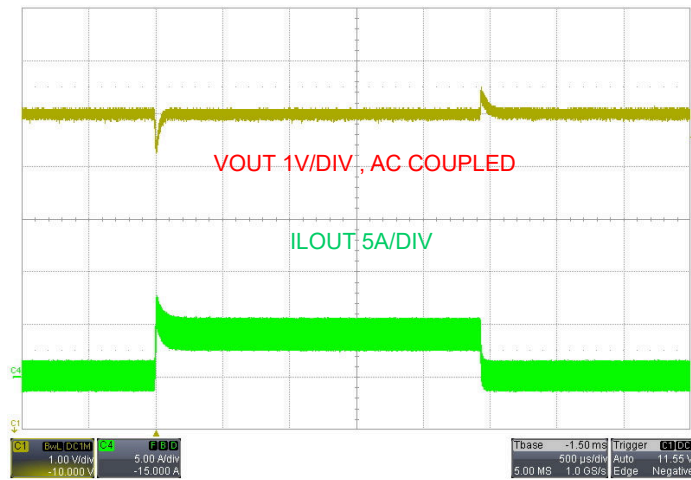


图 3-7.  $V_{\text{SUPPLY}} = 48\text{V}$ 、FPWM、从 0A 变为 4A 时的负载瞬态响应

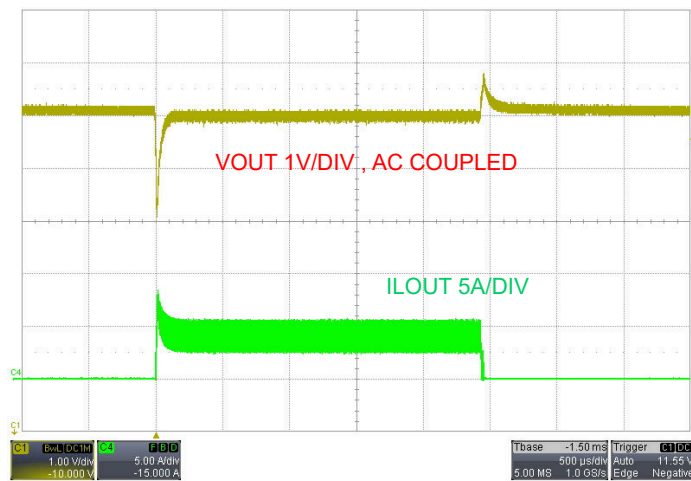


图 3-8.  $V_{\text{SUPPLY}} = 48\text{V}$ 、PFM、从 0A 变为 4A 时的负载瞬态响应

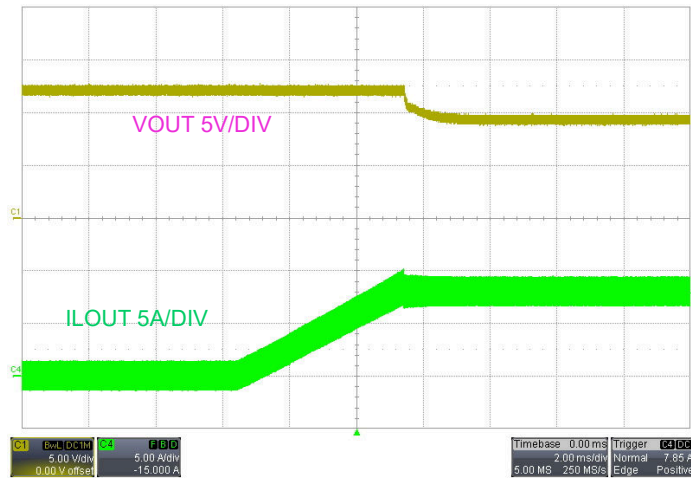


图 3-9. CV 至 CC 模式转换， $V_{\text{SUPPLY}} = 48\text{V}$ ， $V_{\text{LOAD}} = 12\text{V}$  至  $9\text{V}$

### 3.1.3 热性能

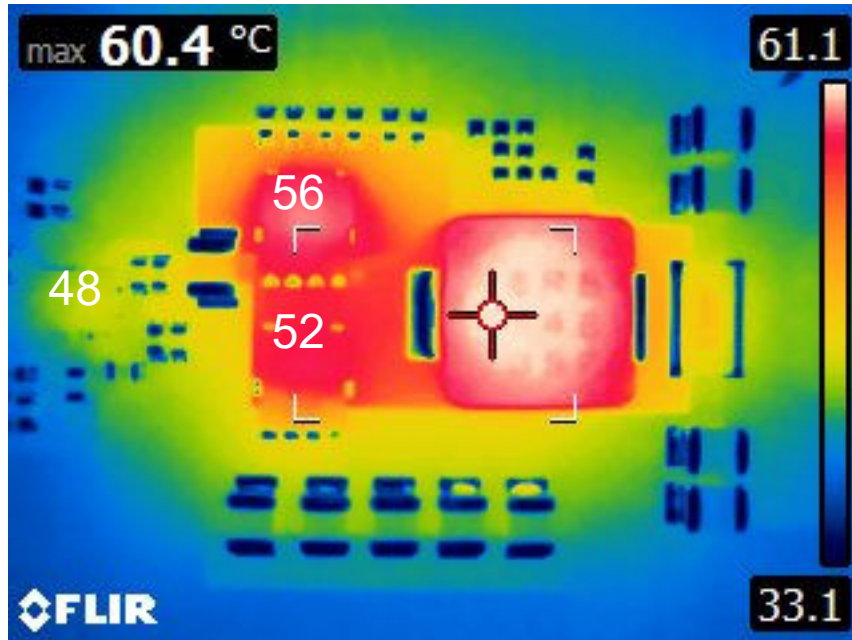


图 3-10. 热性能， $V_{\text{SUPPLY}} = 48\text{V}$ ， $V_{\text{LOAD}} = 12\text{V}$ ， $I_{\text{LOAD}} = 8\text{A}$ ， $T_{\text{A}} = 25^{\circ}\text{C}$ ，无气流

### 3.1.4 EMI 性能

EMI 测试期间组装的 EMI 滤波器元件 ( L1 : XGL4040-222MEC、L2 : CM7060P701R-10、C11 : 20uF ) 。

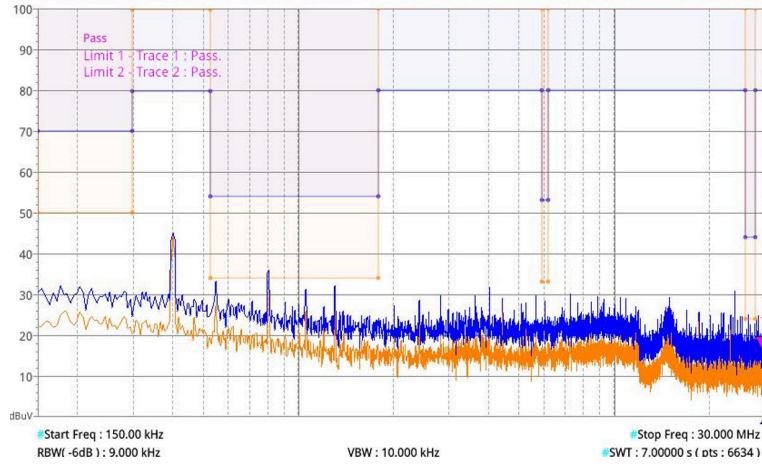


图 3-11. 150kHz 至 30MHz ,  $V_{\text{SUPPLY}} = 48\text{V}$  ,  $V_{\text{LOAD}} = 12\text{V}$  ,  $R_{\text{LOAD}} = 2\ \Omega$

## 4 硬件设计文件

### 4.1 原理图

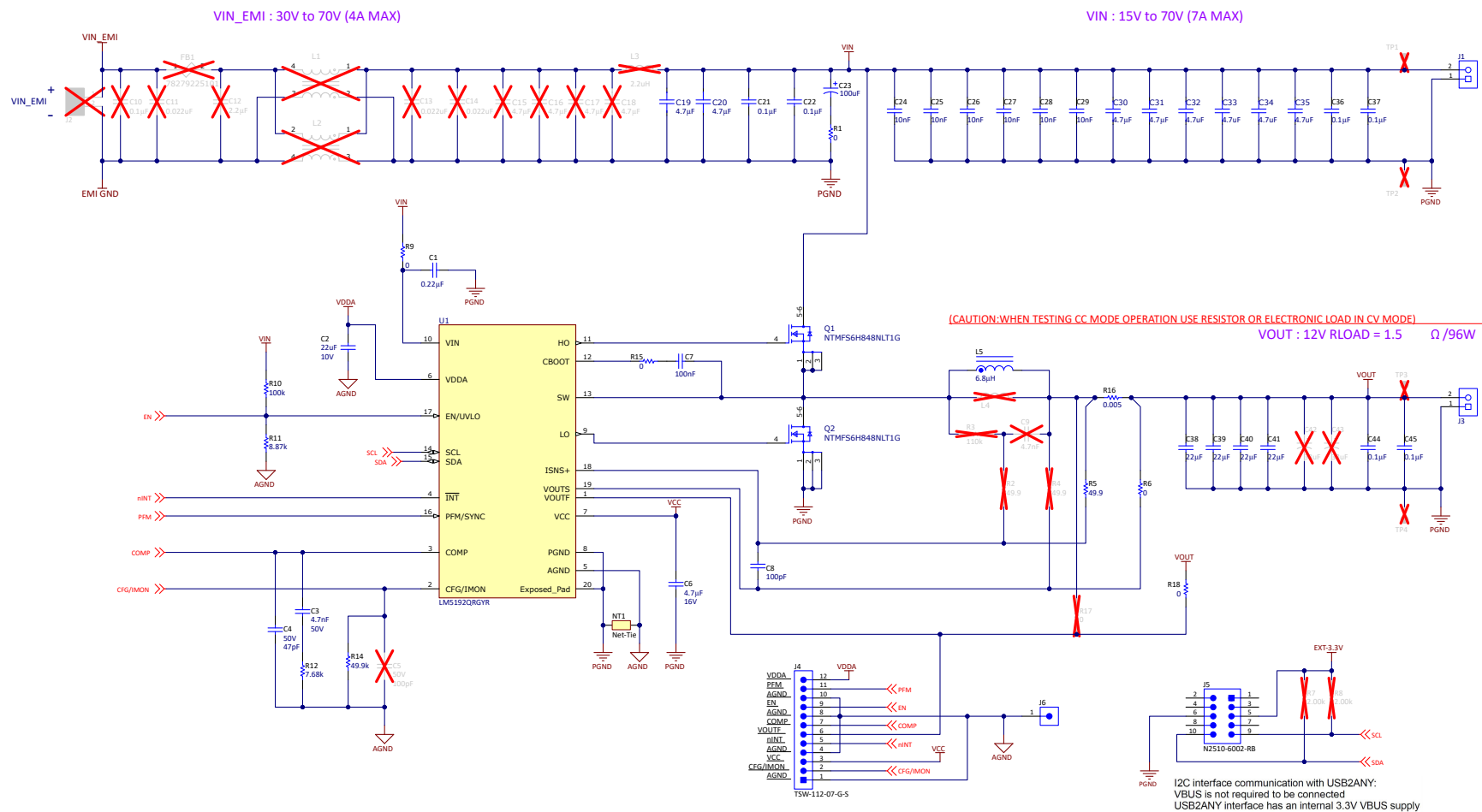


图 4-1. EVM 原理图



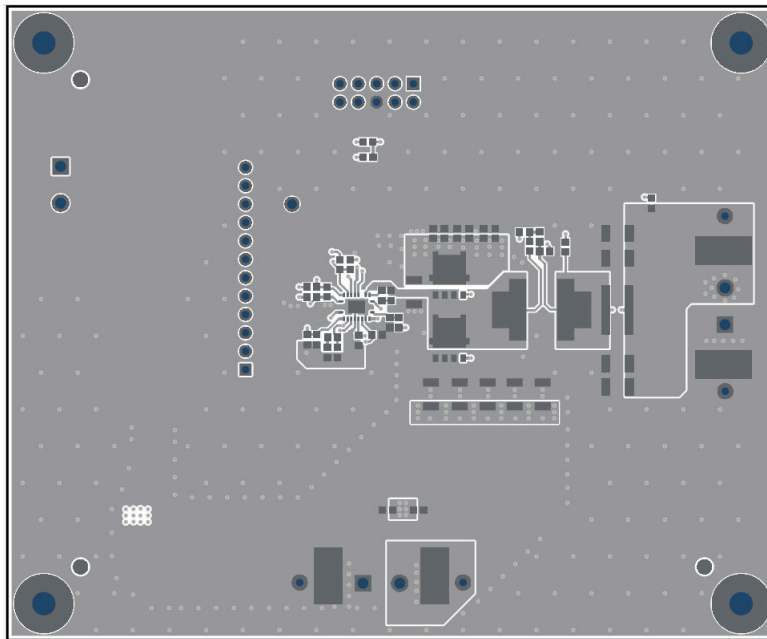


图 4-4. 顶层覆铜 ( 顶视图 )

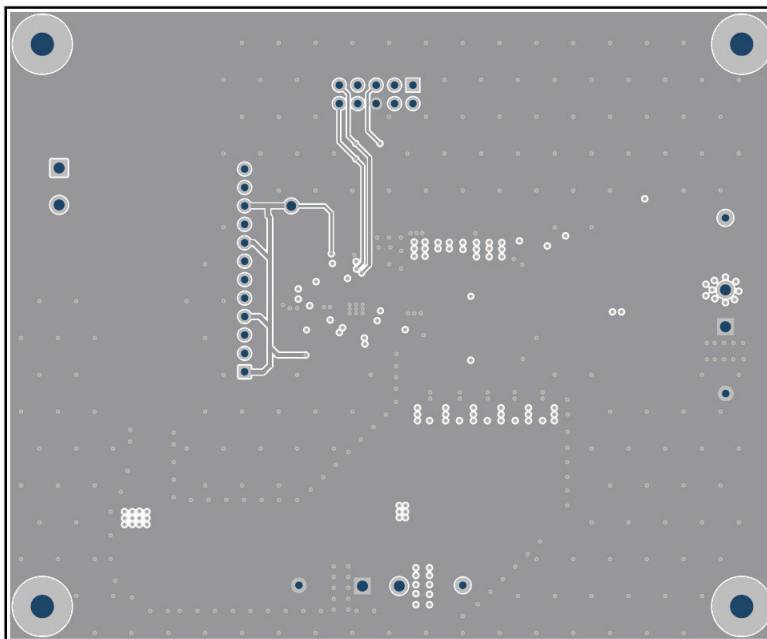


图 4-5. 第 2 层覆铜 ( 顶视图 )

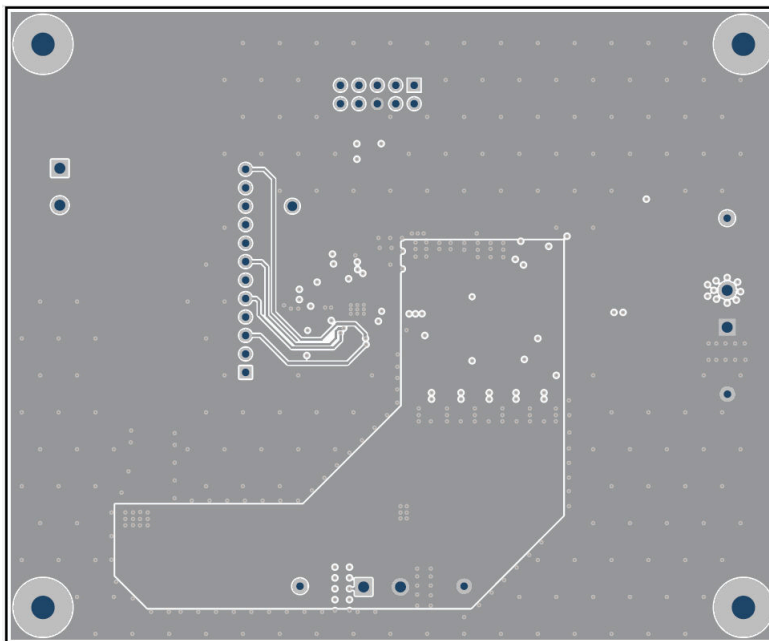


图 4-6. 第 3 层覆铜 (顶视图)

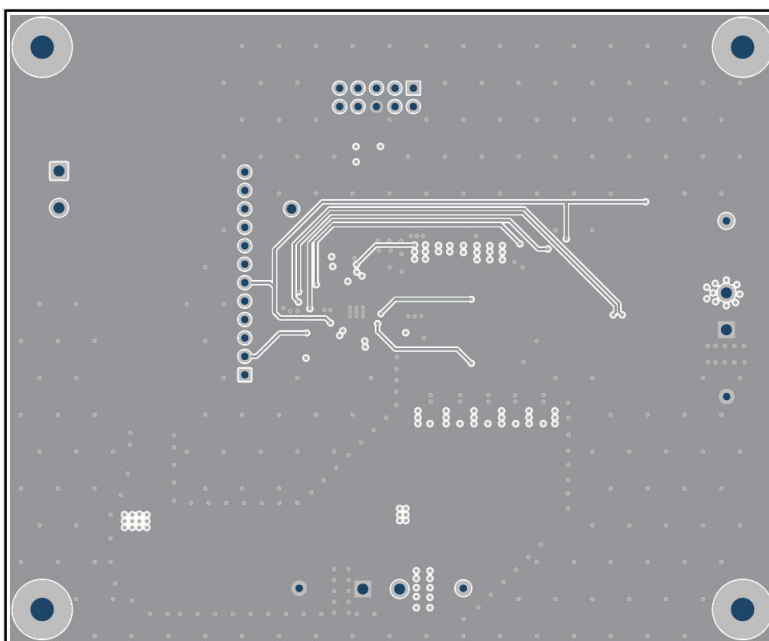


图 4-7. 第 4 层覆铜 (顶视图)

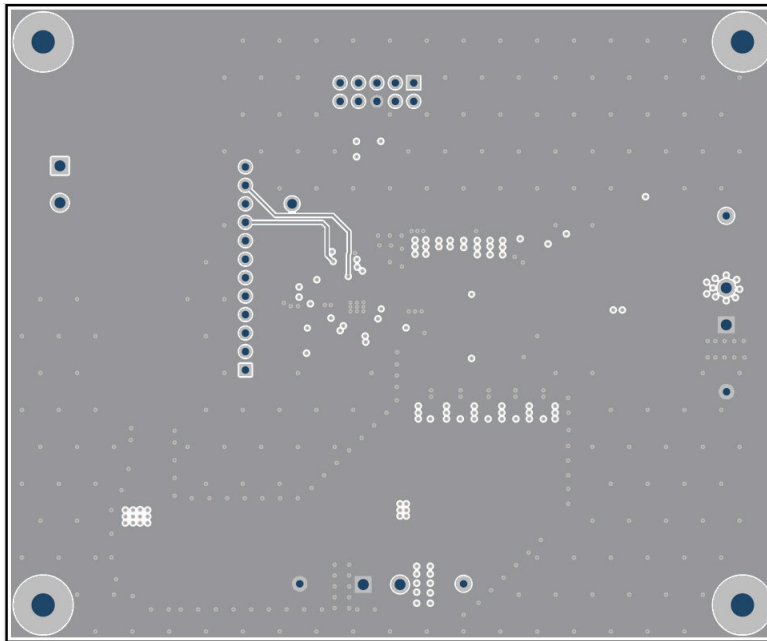


图 4-8. 第 5 层覆铜 (顶视图)

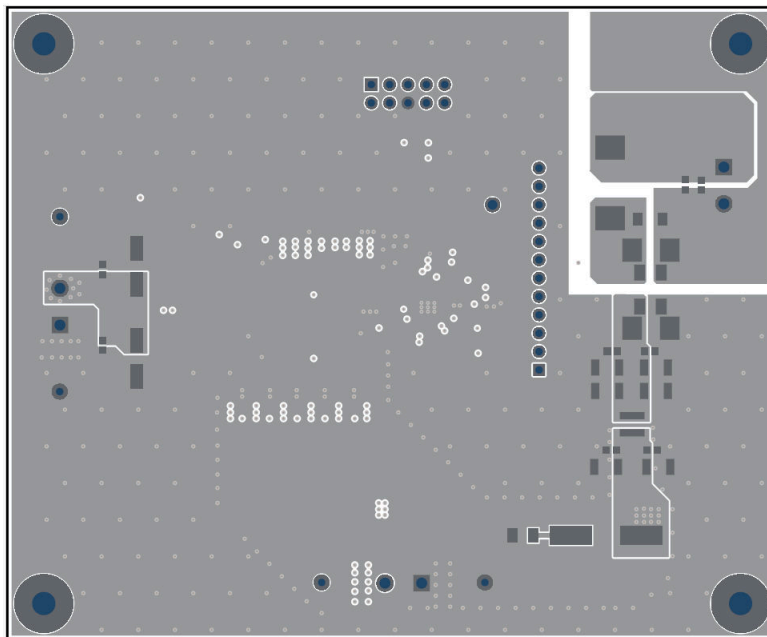


图 4-9. 底层覆铜 (底视图)

## 4.3 物料清单

表 4-1. 物料清单

数量	参考位号	说明	器件型号	制造商
1	C1	电容, 陶瓷, 0.22 $\mu$ F, 100V, +/-20%, X7S, AEC-Q200 1 级, 0603	HMK107C7224MAHTE	Taiyo Yuden
1	C2	电容, 陶瓷, 22 $\mu$ F, 10V, +/-20%, X5R, 0603	C1608X5R1A226M080AC	TDK
1	C3	电容, 陶瓷, 4700pF, 50V, +/-5%, X7R, 0603	C0603C472J5RACTU	Kemet
1	C4	电容, 陶瓷, 47pF, 50V, +/-5%, C0G/NP0, 0603	GRM1885C1H470JA01D	MuRata
1	C6	电容, 陶瓷, 4.7 $\mu$ F, 16V, +/-10%, X7R, 0603	GRM188Z71C475KE21D	MuRata
7	C7、C21、C22、C36、C37、C44、C45	电容, 陶瓷, 0.1 $\mu$ F, VAC/100VDC, +/-20%, X7R, AEC-Q200 1 级, 0603	HMK107B7104MAHT	Taiyo Yuden
1	C8	电容, 陶瓷, 100pF, 100V, +/-5%, C0G/NP0, 0603	GRM1885C2A101JA01D	MuRata
8	C19、C20、C30、C31、C32、C33、C34、C35	4.7 $\mu$ F $\pm$ 10% 100V 陶瓷电容器 X7R 1210 ( 公制 3225 )	CNC6P1X7R2A475K250AE	TDK
1	C23	电容, 铝, 100 $\mu$ F, 100V, +/-20%, 0.33 $\Omega$ , SMD	EMVY101ATR101MKE0S	Chemi-Con
6	C24、C25、C26、C27、C28、C29	电容, 陶瓷, 0.01 $\mu$ F, 100V, +/- 10%, X7R, 0603	885012206114	Würth Elektronik
4	C38、C39、C40、C41	电容, 陶瓷, 22 $\mu$ F, 25V, +/-10%, X7R, 1210	C1210C226K3RAC7800	Kemet
4	H1、H2、H3、H4	机械螺钉, 圆头, #4-40 x 1/4, 尼龙, 飞利浦盘形头	NY PMS 440 0025 PH	B&F Fastener Supply
4	H5、H6、H7、H8	六角螺柱, 1"L #4-40, 尼龙	1902E	Keystone
2	J1、J3	5.08mm 端子块, 水平	691253510002	Würth Electronics
1	J4	接头, 100mil, 12x1, 金, TH	TSW-112-07G-S	Samtec
1	J5	接头 ( 有罩 ), 100mil, 5x2, 高温, 镀金, TH	N2510-6002-RB	3M
1	J6	测试点开槽	1040	Keystone
1	L5	电感器, 鼓芯, 铁粉, 6.8 $\mu$ H, 10.8A, 0.014 $\Omega$ , AEC-Q200 0 级, SMD	VCHA105D-6R8MS6	Cyntec
1	LBL1	热转印打印标签, 0.650" ( 宽 ) x 0.200" ( 高 ) - 10,000/卷	THT-14-423-10	Brady
2	Q1、Q2	N 沟道 80V 13A (Ta)、59A (Tc) 3.7W (Ta)、73W (Tc) 表面贴装 5-DFN (5x6) (8-SOFL)	NTMFS6H848NLT1G	onsemi
1	R1	电阻, 0, 5%, 0.25W, AEC-Q200 0 级, 1206	RCA12060000ZSEA	Vishay-Dale
1	R5	电阻, 49.9, 1%, 0.1W, AEC-Q200 0 级, 0603	ERJ-3EKF49R9V	Panasonic
4	R6、R9、R15、R18	电阻, 0, 5%, 0.1W, 0603	RC0603JR-070RL	Yageo
1	R10	电阻, 100k, 1%, 0.1W, 0603	RC0603FR-07100KL	Yageo
1	R11	电阻, 8.87k, 1%, 0.1W, AEC-Q200 0 级, 0603	CRCW06038K87FKEA	Vishay-Dale
1	R12	电阻, 7.68k, 1%, 0.1W, AEC-Q200 0 级, 0603	CRCW06037K68FKEA	Vishay-Dale
1	R14	电阻, 49.9k, 1%, 0.1W, 0603	RC0603FR-0749K9L	Yageo
1	R16	电阻, 0.005, 1%, 2W, 2512 宽	FCSL64R005FER	Ohmite
1	SH-J4	单操作 2.54mm 间距开顶跳线插座	M7582-05	Harwin
1	U1	带 I2C 的 80V 汽车级高效率 CC-CV 降压控制器	LM5192QRGYR	德州仪器 (TI)

## 5 其他信息

### 5.1 商标

PowerPAD™ is a trademark of Texas Instruments.

WEBENCH® and SIMPLE SWITCHER® are registered trademarks of Texas Instruments.

所有商标均为其各自所有者的财产。

## 6 器件和文档支持

### 6.1 器件支持

#### 6.1.1 开发支持

相关开发支持，请参阅以下文档：

- 有关 TI 的参考设计库，请访问 [TI 参考设计](#)。
- 有关 TI 的 WEBENCH® 设计环境，请访问 [WEBENCH® 设计中心](#)。

### 6.2 文档支持

#### 6.2.1 相关文档

如要查看相关文件，请参阅以下内容：

- 德州仪器 (TI)，[通过优化的功率级布局免费提高大电流直流/直流稳压器性能](#) 应用简报
- 德州仪器 (TI)，[通过更大程度降低电感寄生来降低降压转换器 EMI 和电压应力](#) 模拟应用期刊
- 德州仪器 (TI)，[AN-2162：轻松解决直流/直流转换器的传导 EMI 问题](#) 应用手册
- 白皮书：
  - 德州仪器 (TI)，[评估适用于成本驱动型严苛应用的宽  \$V\_{IN}\$ 、低 EMI 同步降压电路](#)
  - 德州仪器 (TI)，[电源的传导 EMI 规格概述](#)
  - 德州仪器 (TI)，[电源的辐射 EMI 规格概述](#)

#### 6.2.1.1 PCB 布局资源

- 德州仪器 (TI)，[AN-1149 开关电源布局指南](#) 应用手册
- 德州仪器 (TI)，[AN-1229 SIMPLE SWITCHER® PCB 布局指南](#) 应用手册
- 德州仪器 (TI)，[构建电源 - 布局注意事项](#) 电源设计研讨会
- 德州仪器 (TI)，[使用 LM4360x 与 LM4600x 简化低辐射 EMI 布局](#) 应用手册

#### 6.2.1.2 热设计资源

- 德州仪器 (TI)，[AN-2020 热设计：学会洞察先机，不做事后诸葛](#) 应用手册
- 德州仪器 (TI)，[AN-1520 外露焊盘封装实现最佳热阻性的电路板布局布线指南](#) 应用手册。
- 德州仪器 (TI)，[半导体和 IC 封装热指标](#) 应用手册
- 德州仪器 (TI)，[通过 LM43603 和 LM43602 简化热设计](#) 应用手册
- 德州仪器 (TI)，[PowerPAD™ 热增强型封装](#) 应用手册
- 德州仪器 (TI)，[PowerPAD™ 速成](#) 应用简报
- 德州仪器 (TI)，[使用新的热指标](#) 应用手册

## 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](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。

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

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

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

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けていないものがあります。技術適合証明を受けていないものご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

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

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

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東京都新宿区西新宿 6 丁目 2 4 番 1 号  
西新宿三井ビル

3.3.3 *Notice for EVMs for Power Line Communication:* Please see [http://www.tij.co.jp/lstds/ti\\_ja/general/eStore/notice\\_02.page](http://www.tij.co.jp/lstds/ti_ja/general/eStore/notice_02.page)

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

#### 3.4 European Union

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

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

- 
4. *EVM Use Restrictions and Warnings:*
    - 4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.
    - 4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.
    - 4.3 *Safety-Related Warnings and Restrictions:*
      - 4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.
      - 4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.
    - 4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.
  5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.
  6. *Disclaimers:*
    - 6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.
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