参考文献

EVM User's Guide: LM67680-Q1EVM

LM67680-Q1 60V_{IN}、 –12V_{OUT}、-6A 反相降压/升压 DC/DC 稳压器评估模块

说明

LM67680-Q1EVM 评估模块 (EVM) 旨在展示配置为反相降压/升压 (IBB) 实现方案的 LM67680-Q1 DC/DC 转换器。该 EVM 在 3.8V 至 60V 的输入电压范围内工作，可提供 –12V 输出和最高 6A 电流。

开始使用

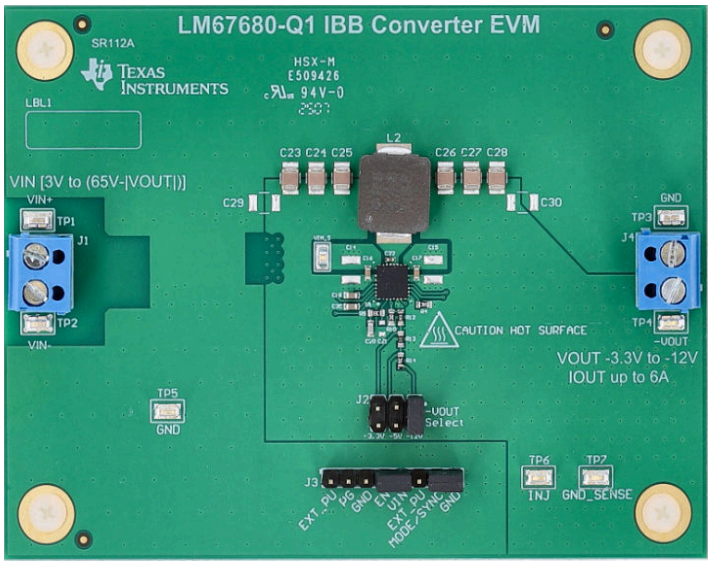
1. 订购 LM67680-Q1EVM。
2. 参见 LM67680-Q1 产品文件夹。
3. 查看 Altium PCB 布局源文件。
4. 使用 LM67680-Q1 快速入门计算器帮助在设计中选择组件。
5. 使用 PSPICE 或 SIMPLIS 对设计进行模拟。

特性

- 在宽负载电流范围内高效运行的 65V 同步 IBB 转换器：48V_{IN}、 –12V_{OUT}、 –6A 时为 93%
- MODE/SYNC、EN 和 PG 上的集成式电平移位器方便轻松连接到系统控制信号
- 开关频率为 400kHz，可与外部时钟信号同步 ±20%
- ZEN 1 开关技术
  - 展频 (DRSS) 和开关转换率控制可降低峰值发射
  - 输入 π 级 EMI 滤波器有助于满足 CISPR 25 5 类和 UNECE Reg 10 EMI 标准
- 集成保护特性造就稳健设计：过流保护 (OCP)；通过 100kΩ 上拉电阻连接至外部电压源的电源正常 (PG) 指示器；内部 5.3ms 软启动 (SS) 计时器
- 经过全面组装、测试和验证的 PCB 布局

应用

- 激光雷达，ADAS，汽车显示屏
- 汽车信息娱乐系统与仪表组
- 混合动力、电动和动力总成系统
- 工业自动化、测试和测量
- 医疗成像系统
- 无线基础设施系统



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1 评估模块概述

1.1 简介

LM67680-Q1EVM 评估模块 (EVM) 采用 LM67680-Q1，该转换器系列具有高转换效率、灵活性、可扩展性和小设计尺寸，因此适用于各种应用。IC 具有高达 (65V – $|V_{OUT}|$) 的输入电压和高达 8A 的电感器电流，从而实现具有高功率密度以及低传导和辐射发射的设计。可用的 EMI 缓解功能选择包括双随机展频 (DRSS) 和压摆率 (SR) 控制，可降低峰值发射。

该 EVM 设计具有 –3.3V、–5V 或 –12V 的可选输出电压和 400kHz 的开关频率。还支持满足应用特定上电和断电要求的远程使能，可用于降低噪声敏感应用中拍频的外部时钟同步、时序控制和输出电压监测的电源正常 (PG) 指示器、自动模式下实现轻负载性能的引脚可选模式控制或在强制脉宽调制 (FPWM) 模式下实现固定开关频率、外部补偿和内部软启动 (SS)。

所选的动力总成无源器件，包括 6.8 µH IBB 电感器、4.7 µF/100V/X7R/1210 陶瓷输入电容器和 22 µF/25V/X7S/1210 陶瓷输出电容器，均可从多个组件供应商处获得。若要优化元件选择并检查线路和负载范围内的预测效率性能，请下载 LM67680-Q1 快速入门计算器。

1.2 套件内容

- LM67680-Q1EVM 电路板
- EVM 免责声明自述文件

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1.3 规格

表 1-1 列出了 EVM 规格。V_{IN} = 48V，V_{OUT} = －12V，I_{OUT} = －6A，F_{SW} = 400kHz，除非另有说明。

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
输入特性						
输入电压范围，V_{IN}	稳定状工作范围		5	48	60	V
空载时的输入电流 I_{IN-NL}	I_{OUT} = 0A，MODE/SYNC 低连接至 SGND	V_{IN} = 12V		420		μA
		V_{IN} = 24V		233		
		V_{IN} = 48V		146		
关断时的输入电流 I_{IN-OFF}	V_{EN} = 0V	V_{IN} = 12V		65		μA
输出特性						
输出电压，V_{OUT} (1)			-12.1	-12	-11.9	V
输出电流 I_{OUT}	V_{IN} = 48V 至 (65V － $\|V_{OUT}\|$)，空气流量 = 100LFM(2)				-6	A
输出电压调节，ΔV_{OUT}	负载调整	I_{OUT} = 0A 至 -6A		0.2%		
	线性调整率，I_{OUT} = 2A	V_{IN} = 9V 至 (65V － $\|V_{OUT}\|$)		0.2%		
输出电压纹波 V_{OUT-AC}				20		mV_{RMS}
软启动时间，t_{SS}	内部软启动			5.3		ms
系统特性						
开关频率，F_{SW}				400		kHz
同步频率范围，F_{SYNC}			320		480	kHz
轻负载效率，自动模式，η_{LIGHT}	I_{OUT} = -1A	V_{OUT} = -12V		90.5		%
		V_{OUT} = -5V(1)		89		%
		V_{OUT} = -3.3V		86		%
半负载效率 η_{HALF}	I_{OUT} = -3A	V_{OUT} = -12V		93.3		%
		V_{OUT} = -5V		91		%
		V_{OUT} = -3.3V		87.5		%
满载效率，η_{FULL}	I_{OUT} = -6A	V_{OUT} = -12V		93		%
		V_{OUT} = -5V		89.5		%
		V_{OUT} = -3.3V		88		%
LM67680-Q1 结温，T_J			-40		150	°C

(1) 此 EVM 的默认输出电压为 -5V。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。
(2) 注意：EVM 上的可接触元件和表面可能会超过 55°C（25°C 环境温度标准化）。高环境温度可能需要强制冷却或其他热管理步骤，以将 IC 结温保持在 150°C 以下。请参见 节 3.1.5。

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1.4 器件信息

此 EVM 设计采用 LM67680-Q1 65V，8A IBB 转换器 IC，该转换器可实现高转换效率并包含以下主要特性：

- 多种同步 IBB 转换器系列
  - 宽输入电压范围，3.8V 至 (65V – $|V_{OUT}|$)
  - 4A、6A 和 8A 电感器电流选项
  - 单片集成式功率 MOSFET 和控制器
    - 优化的近零死区时间开关可更大限度地减少功率损耗和温升
  - 超低关断电流和睡眠静态电流
  - 具有 BIAS 选项的双输入 VCC 子稳压器
  - EN 输入支持应用特定的上电和断电要求
- ZEN 1 开关技术
  - 有助于符合 CISPR 25 5 类标准
  - 增强型 HotRod™ QFN (eQFN) 封装，具有对称引脚排列设计和清除开关波形的最小寄生环路电感
  - 用于降低 EMI 的可选双随机展频 (DRSS) 调制和开关电压压摆率 (SR) 控制
  - AUTO、FPWM 或 SYNC 操作
- 通过优化引脚排列设计和相邻引脚短路测试间隙空间提高可靠性
  - 1.1mm 的 VIN 至 PGND 引脚间隙
  - 物料组 I 绝缘（符合 IEC 60664-1）
  - 蝶形变换 (VIN1、PGND1) 和 (VIN2、PGND2) 引脚排列可改善电流分布

LM67680-Q1 采用 4.5mm× 4.5mm 热增强型 26 引脚 eQFN 封装，采用倒装芯片可布线引线框 (FCRLF) 封装技术。集成式电平转换器可以直接连接到 EN、PG 和 MODE/SYNC 引脚，这些引脚以 IBB 设计中的系统接地 (SGND) 为基准。LM67680-Q1 利用集成功率 MOSFET、EMI 抑制特性以及小设计尺寸，是一种不错的负载点稳压器选择，适用于需要高效设计并具有可用电流、使用寿命可靠性和成本优势的 IBB 应用。

表 1-2. 可订购器件型号

通用器件型号	可订购器件型号	输入电压范围	额定电流	TI 功能安全分类(2)	用于 IBB 的电平转换器
LM67680-Q1	LM67680RZYRQ1	3.8V 至 65V	8A	功能安全型	是
LM67660-Q1(1)	LM67660RZYRQ1		6A		
LM67640-Q1	LM67640RZYRQ1		4A		
LM65680-Q1	LM65680RZYRQ1	3.5V 至 65V（70V 瞬态电压）	8A	功能安全型	否
LM65660-Q1(1)	LM65660RZYRQ1		6A		
LM65640-Q1(1)	LM65640RZYRQ1		4A		
LM68680-Q1(1)	LM68680FRZYRQ1	3.5V 至 65V	8A	符合 ASIL C 功能安全标准	否
LM68660-Q1(1)	LM68660FRZYRQ1		6A		
LM68640-Q1(1)	LM68640FRZYRQ1		4A		
LM68580-Q1(1)	LM68580FRZYRQ1	3.5V 至 42V	8A		
LM68580-Q1(1)	LM68560FRZYRQ1		6A		

(1) 预发布信息（非量产数据）。如需更多信息，请联系 TI。
(2) 请参阅 功能安全主页，了解 TI 的功能安全分类（在开发流程、分析报告和诊断说明方面）。

1.4.1 应用电路图

图 1-1 显示了 LM67680-Q1 IBB 转换器的原理图，其中输出电压由指定为 R_{FB1} 和 R_{FB2} 的反馈电阻器设置。II 型补偿网络由组件 R_{COMP}、C_{COMP} 和 C_{HF} 定义，设置电压环路交叉频率和相位裕度，以满足目标负载瞬态响应规格。

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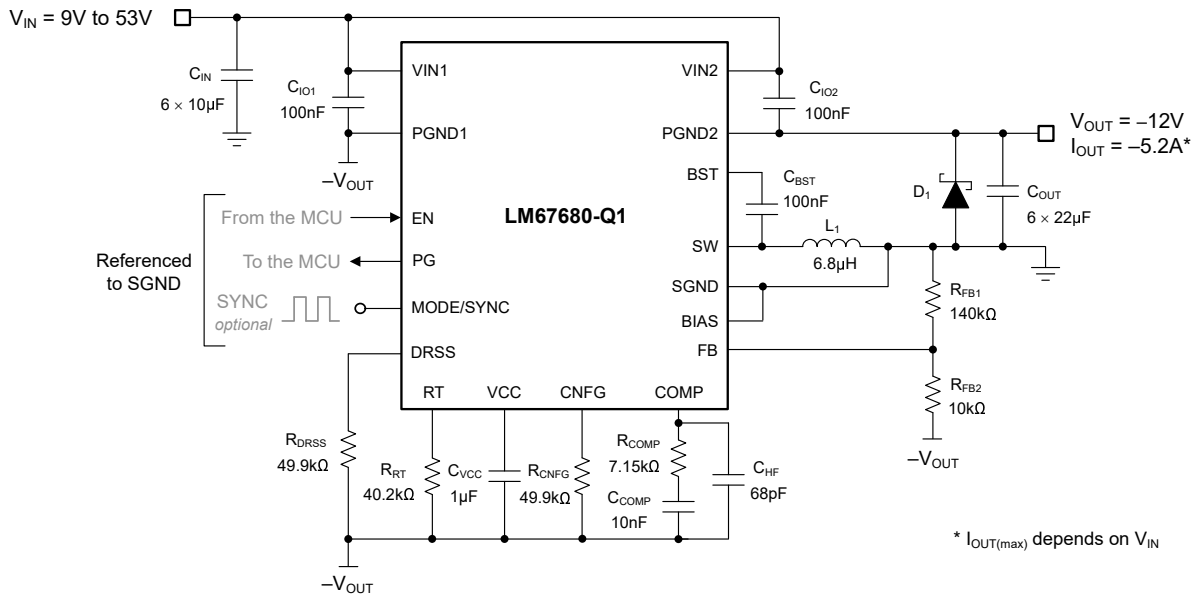


图 1-1. 典型电路原理图

偏置输入从输出（在电压高于 4V 切换阈值时）获取电流，特别是用于实现更低的 IC 功率损耗，并提高轻负载时的效率。图 1-1 中未显示的是输入端的 EMI 滤波器级。

1.4.2 IBB 最大输出电流

与升压或反激式拓扑类似，IBB 转换器中的电感器在每个周期的 PWM 导通时间（或 D 间隔）期间存储能量，并仅在关断时间（或 1 – D 间隔）期间将能量传输到输出。因此，方程式 1 给出了采用 IBB 设计时可实现的输出电流

$$I_{OUT(max)} = I_{L,DC(max)} \times (1 - D) \quad (1)$$

其中 LM67680-Q1 的 $I_{L,DC(max)}$ 为 8A 的额定电流，D 为由计算得出的 IBB 占空比

$$D = \frac{|V_{OUT}|}{|V_{OUT}| + V_{IN}} \quad (2)$$

图 1-2 绘制了在 –3.3V、–5V 和 –12V 的输出电压下，LM67680-Q1 的最大输出电流能力与输入电压之间的关系。在最小输入电压下，可用的输出电流最低。

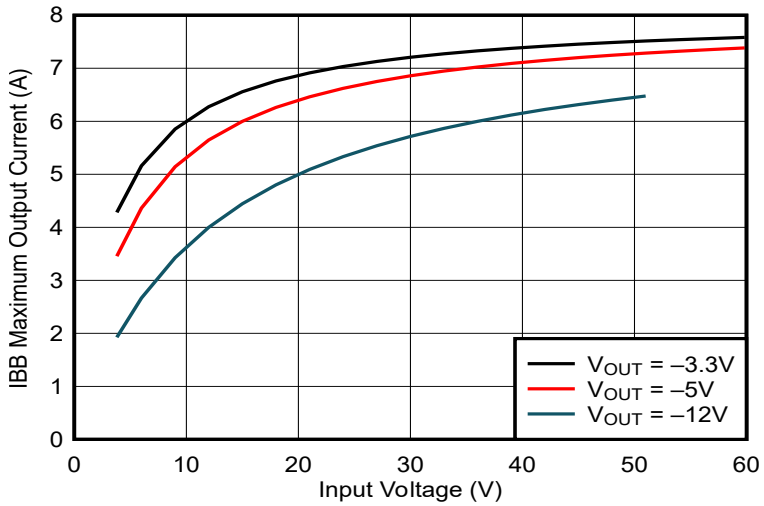


图 1-2. IBB 最大输出电流

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2 硬件

2.1 测试装置和过程

2.1.1 EVM 连接

参考表 2-1 中描述的 EVM 接头，使用图 2-1 中推荐的测试装置评估 LM67680-Q1。在提供 ESD 保护的工作站上工作时，请确保在处理 EVM 并向其供电之前已连接所有腕带、靴带或垫子以使用户接地。

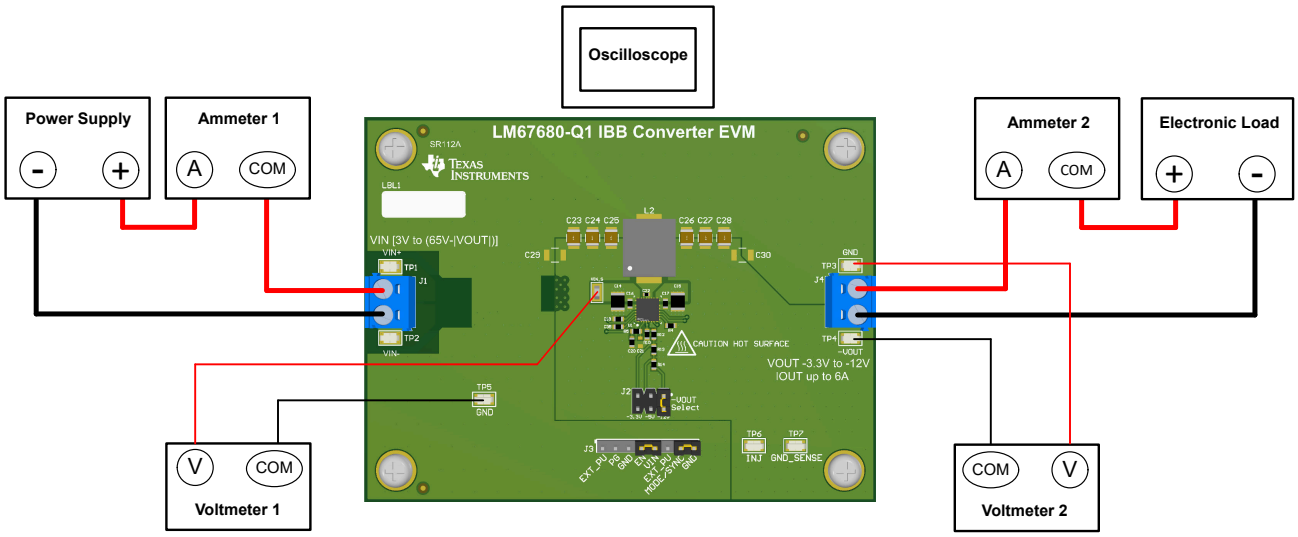


图 2-1. EVM 测试设置

备注

有关元件选型和转换器操作的其他指导，请参阅 *LM67680/60/40-Q1 采用 ZEN 1 低 EMI 开关技术的 65V、8A/6A/4A 汽车级反相降压/升压转换器系列数据表*和 WEBENCH® Power Designer。

表 2-1. EVM 电源接头

标签	说明
VIN+	正输入电源连接
VIN-	负输入电源连接
GND	正输出电源连接
–VOUT	负输出电源连接

表 2-2. EVM 信号接头

标签	说明
EXT_PU	PG 外部上拉电压
PG	电源正常状态指示器
GND	GND 连接
EN	使能输入 – 连接到 GND，以禁用该器件
VIN	输入电压
EXT_PU	MODE/SYNC 的外部上拉电压
MODE/SYNC	FPWM/AUTO 模式选择和同步输入。在 AUTO 模式下，将 MODE/SYNC 连接到 GND，或在 FPWM 模式下连接到 EXT_PU。将外部时钟信号（320kHz 至 480kHz）连接到 MODE/SYNC 以同步器件并在 FPWM 模式下运行。
GND	GND 连接

表 2-3. EVM 输出电压（–VOUT）选择选项

标签	说明
-12V	J2 上引脚 1 至引脚 2 之间的跳线将输出电压设置为 –12V

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表 2-3. EVM 输出电压 (–VOUT) 选择选项 （续）

标签	说明
-5V	J2 上引脚 3 至引脚 4 之间的跳线将输出电压设置为 –5V
-3.3V	J2 上引脚 5 至引脚 6 之间的跳线将输出电压设置为 –3.3V

表 2-4. EVM 测试点连接

标签	说明
VIN_S	输入电源电压监测点
GND_SENSE	–VOUT 和 INJ 的 GND_SENSE 电压监测点
INJ	环路响应的 50Ω 注入点

2.1.2 测试设备

电压源：输入电压源 V_{IN} 必须是能够提供 8A 的 80V 可变直流电源。

万用表：

- **电压表 1：**测量 VIN_S 至 GND 测试点 (TP3) 的输入电压。
- **电压表 2：**测量 GND (TP3) 至 –VOUT (TP4) 的输出电压。
- **电流表 1：**测量输入电流。
- **电流表 2：**测量输出电流。

电子负载：负载必须是电子恒阻 (CR) 或恒流 (CC) 模式，能够支持 0A 至 6A 电流。对于空载输入电流测量，请断开电子负载，因为它会消耗少量剩余电流。

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。将示波器探头尖端放在输出电容器的正极端子上，通过接地引线将探头的接地筒形连接器固定到电容器的负极端子。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。

安全性：在接触任何可能带电或通电的电路时，请务必小心。始终做好 ESD 保护。

2.1.3 建议的测试设置

2.1.3.1 输入连接

- 在连接直流输入源之前，将输入源的电流限值设置为 0.1A。确认输入源最初设置为 0V 并连接到 VIN+ 和 VIN– 连接点，如图 2-1 所示。
- 在 VIN_S 和 GND (TP3) 连接点上连接电压表 1 以测量输入电压。
- 连接电流表 1，以测量输入电流。

2.1.3.2 输出接头

- 将电子负载连接到 GND 和 –VOUT 连接，如 图 2-1 所示。在施加输入电压之前，将负载设置为恒阻模式或恒流模式，电流为 0A。
- 在 GND_SENSE (TP7) 和 –VOUT (TP4) 检测点上连接电压表 2，以测量输出电压。
- 连接电流表 2，以测量输出电流。

2.1.4 测试程序

2.1.4.1 线路与负载调节和效率

- 按照 *EVM 连接* 中的描述设置 EVM。
- 在 J2 (–VOUT 选择) 上放置一根跳线，以将输出电压设置为 –12V。
- 将负载设置为恒阻或恒流模式以具有 0A 的灌电流。
- 将输入源电压从 0V 增加到 65V – $|V_{OUT}|$；使用电压表 1 测量输入电压。
- 将输入电源的电流限值增加到 8A。
- 使用电压表 2 测量输出电压。在 48V 输入电压下，将负载电流从 0A 更改为 6A。V_{OUT} 必须保持在负载调整规范内。
- 将负载电流设置为 2A 并将输入电压源从 12V 更改为 (65V – $|V_{OUT}|$)。V_{OUT} 必须保持在线路调整规范内。

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- 将负载电流设置为 3.8A、5.2A 和 6A 并分别测量典型输入电压（12V、24V 和 48V）下的效率。
- 将负载降至 0A。将输入电压源降至 0V。

警告

在高输出电流下长时间运行会使元件和 EVM 电路板温度升高到 55°C 以上。为避免烧伤风险，在断开电源后，不要立即触摸元件和 EVM 电路板，直到充分冷却为止。

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3 实现结果

3.1 性能数据和结果

图 3-1 至 图 3-11 展示了 EVM 的典型性能曲线。实际性能数据可能会受到测量技术和环境变量的影响，因此这些曲线仅供参考，并可能与实际现场测量结果有所不同。

3.1.1 转换效率

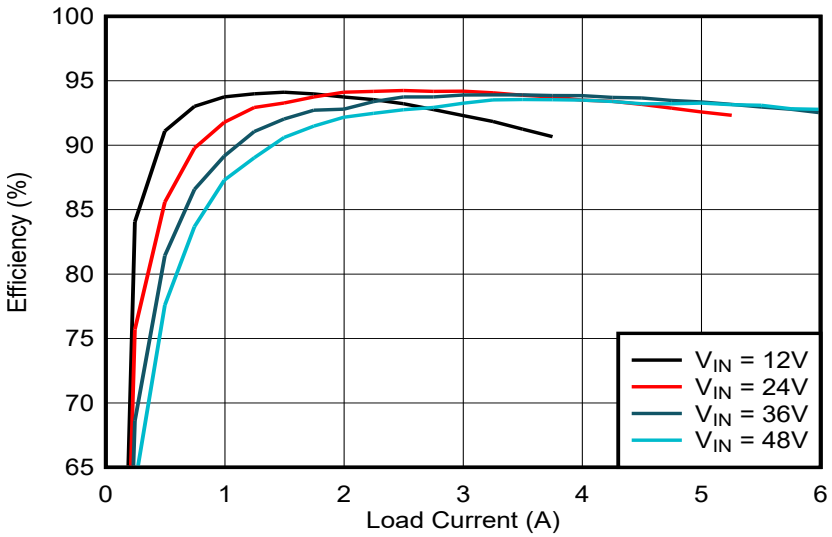


图 3-1. 效率，V_{OUT} = -12V，FPWM 模式

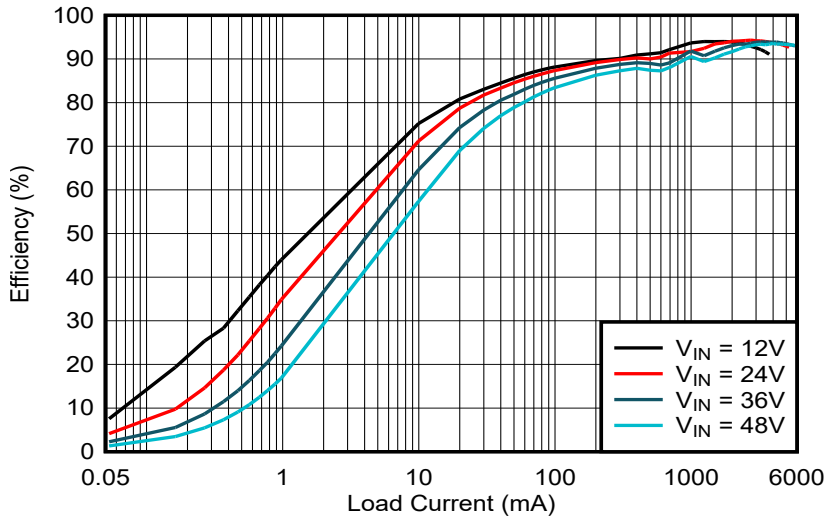


图 3-2. 效率，V_{OUT} = -12V，AUTO 模式

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3.1.2 工作波形

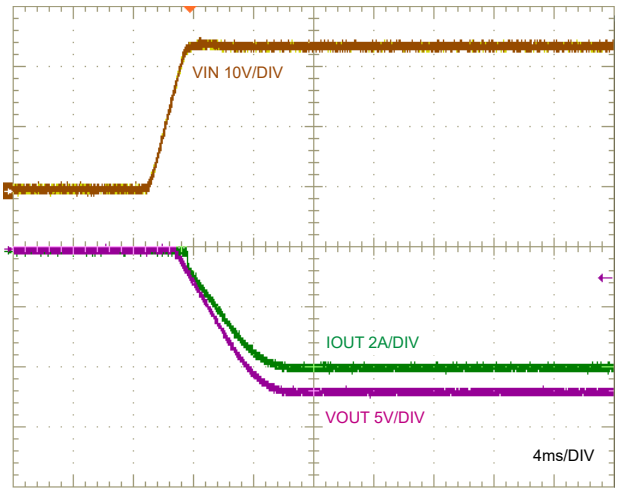


图 3-3. 启动特性，V_{IN} = 48V，V_{OUT} = -12V，3Ω 电阻负载

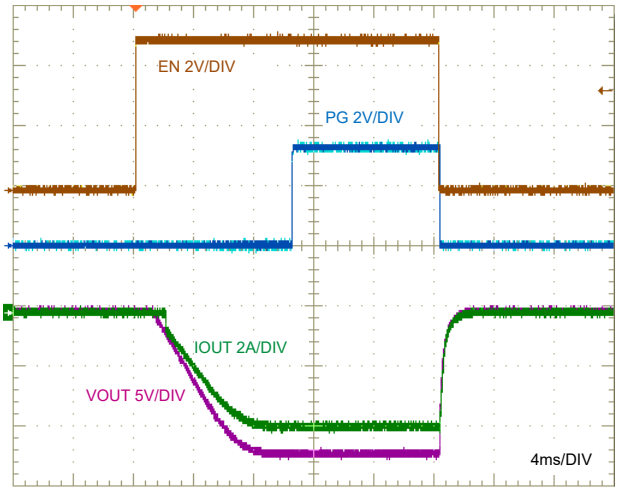


图 3-4. 启用开/关特性，V_{IN} = 48V，I_{OUT} = 12V，3Ω 电阻负载

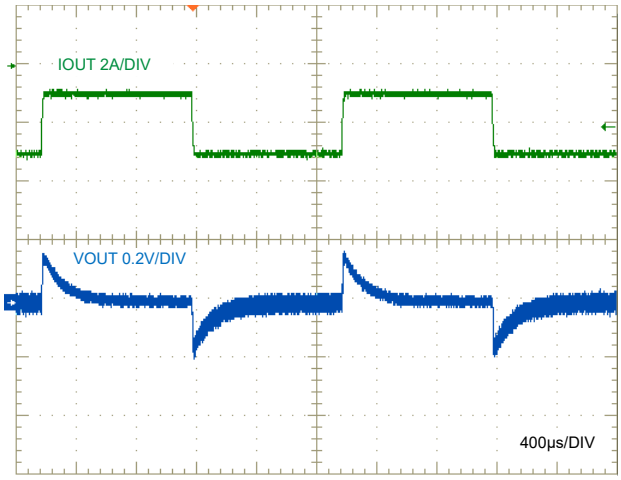


图 3-5. 负载瞬态响应，V_{IN} = 48V，V_{OUT} = -12V，I_{OUT} = –1A 至 –3A，FPWM

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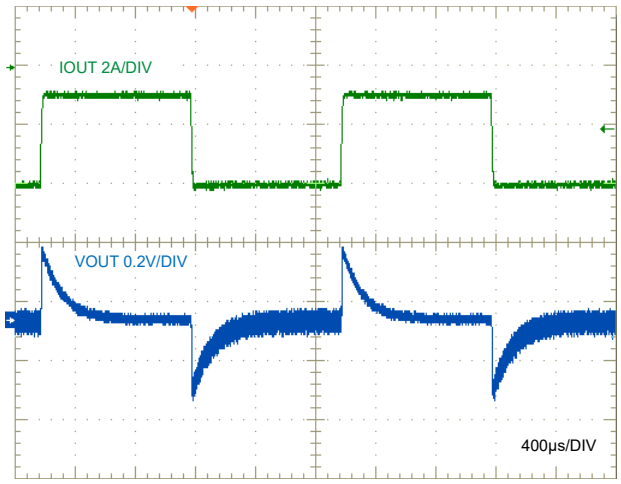


图 3-6. 负载瞬态响应，V_{IN} = 48V，V_{OUT} = -12V，I_{OUT} = －1A 至 －4A，FPWM

3.1.3 波特图

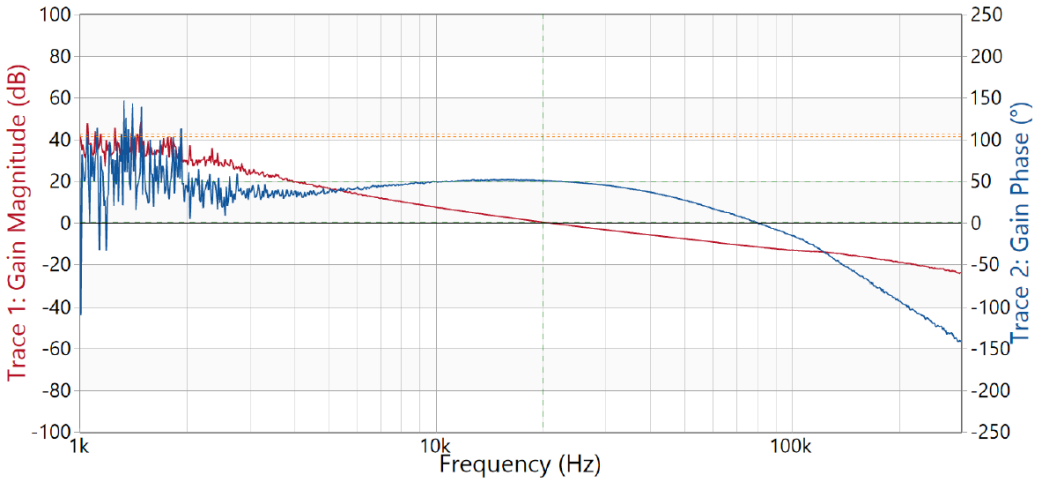


图 3-7. 波特图，V_{IN} = 24V，V_{OUT} = -12V，I_{OUT} = 5.2A 电阻负载，f_C = 20kHz，PM = 50°

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3.1.4 CISPR 25 EMI 性能

图 3-8 和 图 3-9 显示了 LM67680-Q1 EVM 在 24V 输入（启用 DRSS）时的辐射和传导发射性能。根据 CISPR 25 规范使用 5μH LISN，在 150kHz 至 108MHz 的频率范围内对传导发射进行测量。CISPR 25 5 级峰值和平均限值线以红色表示。分别使用峰值检测法和平均值检测器来测量紫色和绿色光谱。辐射发射在 30MHz 至 6GHz 的频率范围内测得。CISPR 25 5 级峰值和平均限值线分别以橙色和绿色表示。分别使用峰值检测法和平均值检测器来测量橙色和绿色光谱

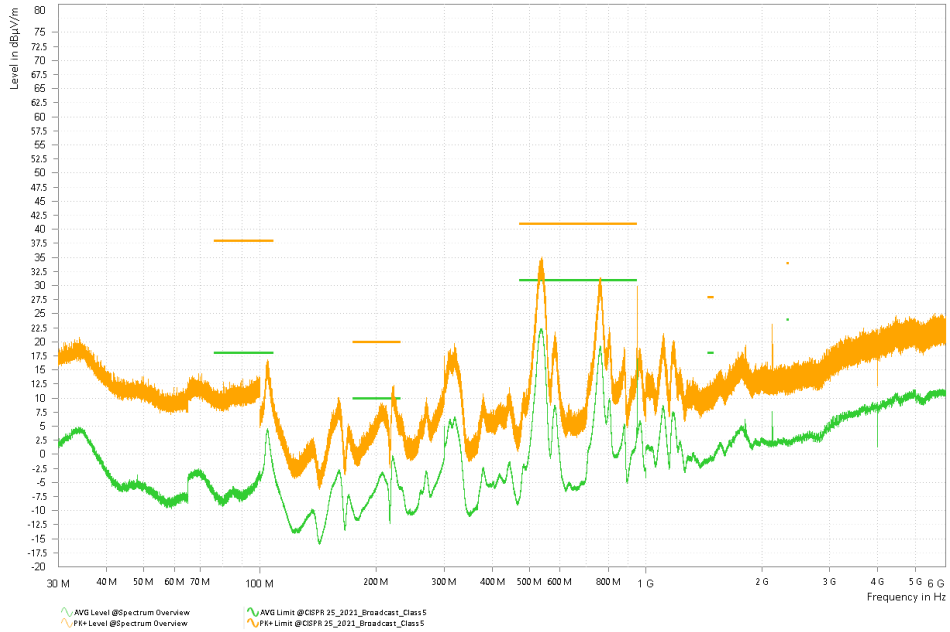


图 3-8. 典型 CISPR 25 5 级辐射发射，30MHz 至 6GHz，DRSS 开，V_{IN} = 24V，V_{OUT} = -12V，I_{OUT} = -4A 电阻负载，F_{SW} = 400kHz

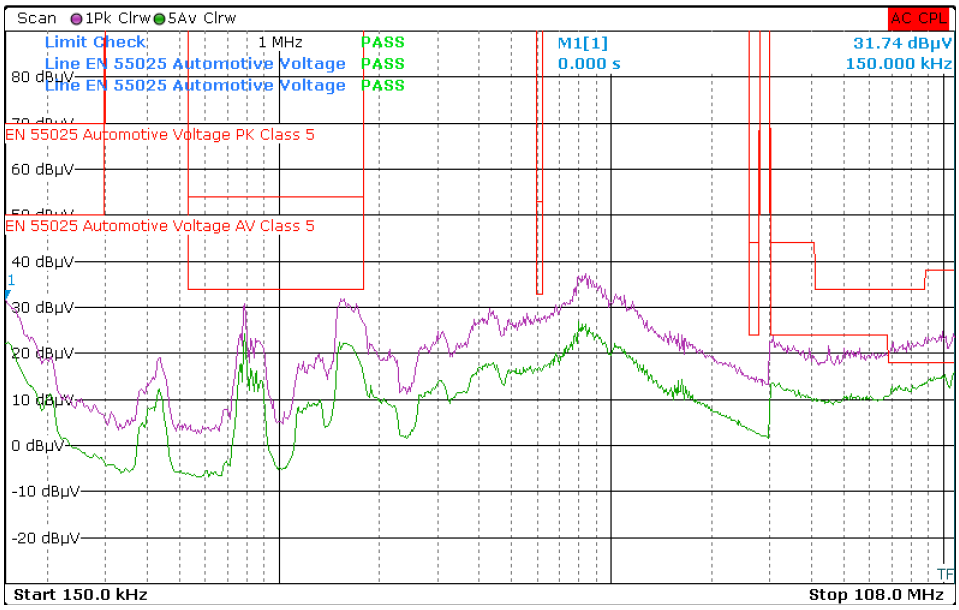


图 3-9. CISPR 25 5 级传导发射图，150kHz 至 108MHz，DRSS 开，V_{IN} = 24V，V_{OUT} = -12V，I_{OUT} = -4A 电阻负载，F_{SW} = 400kHz

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3.1.5 热性能

图 3-10 和 图 3-11 分别展示了输出为 –12V 和 –5V 时的热性能。

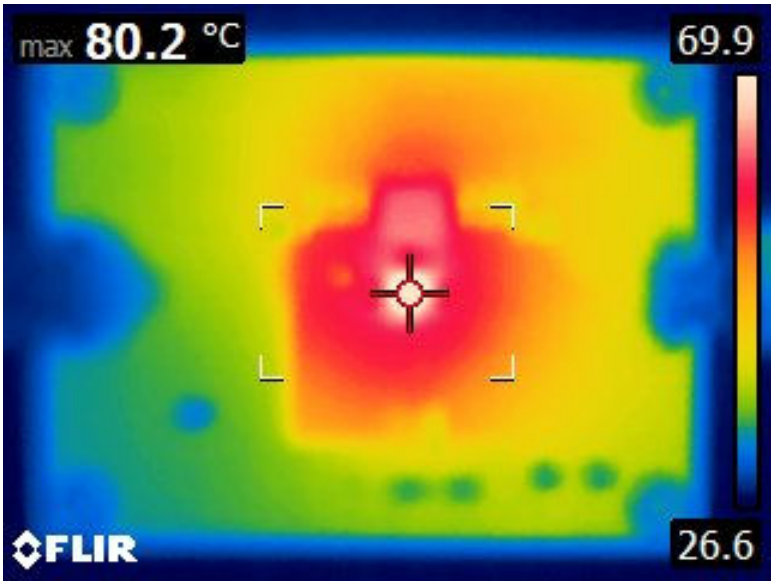


图 3-10. 热性能，V_{IN} = 24V，V_{OUT} = -12V，I_{OUT} = -4A，T_A = 25°C，无气流

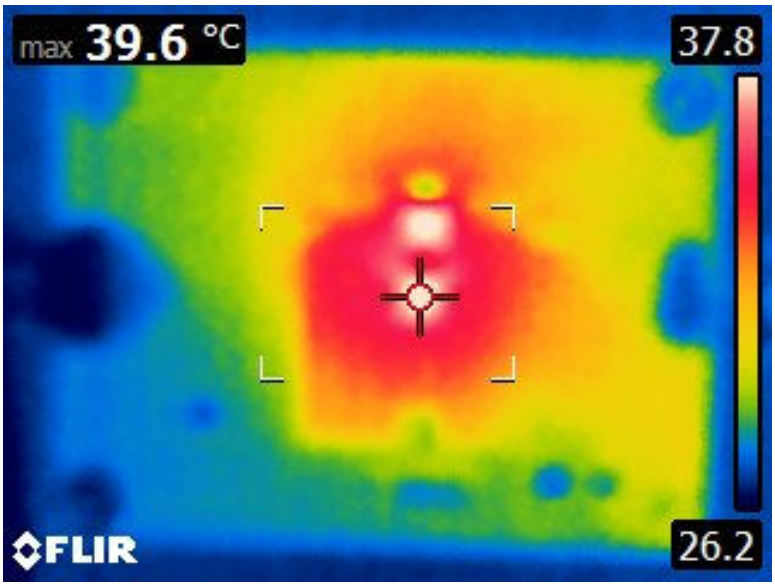


图 3-11. 热性能，V_{IN} = 12V，V_{OUT} = -5V，I_{OUT} = -2.7A，T_A = 25°C，无气流

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4 硬件设计文件

4.1 原理图

图 4-1 提供了 EVM 原理图。

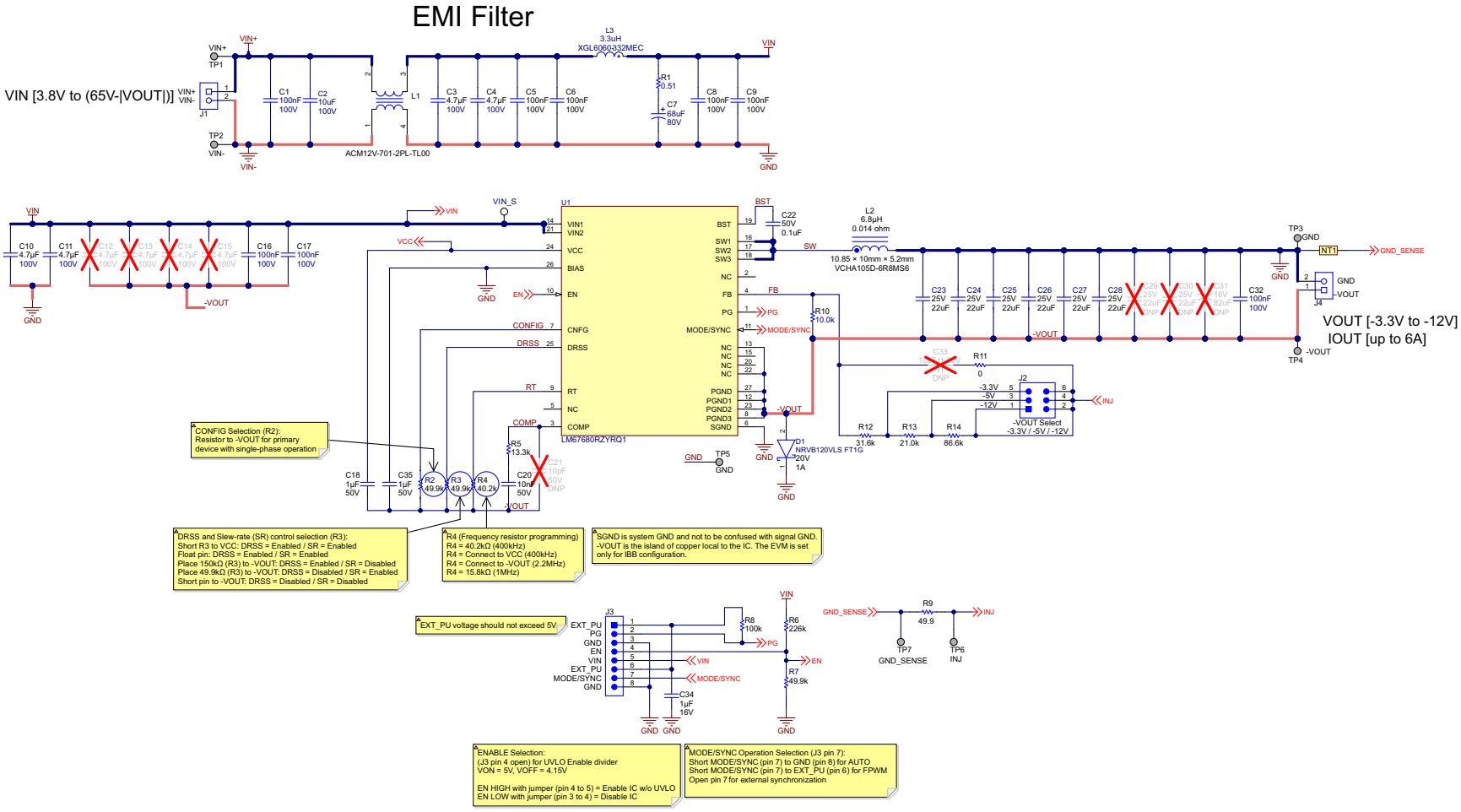


图 4-1. EVM 原理图

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4.2 PCB 布局

图 4-2 至 图 4-9 展示了使用 62mils 标准厚度和 2oz 铜的四层 PCB 的 LM67680-Q1 EVM 设计。

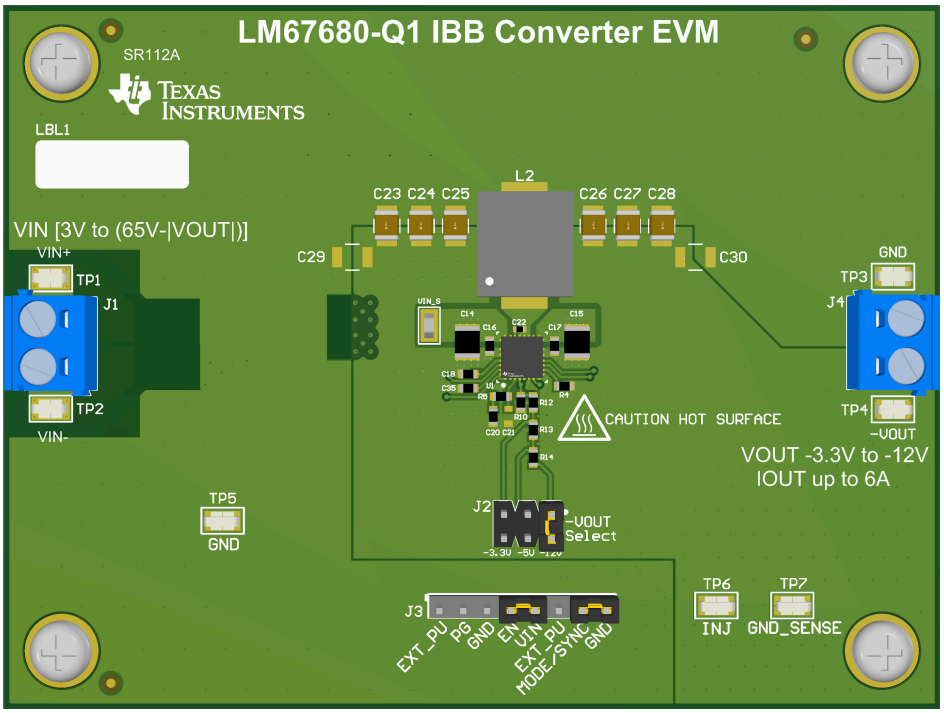


图 4-2. 3D 顶视图

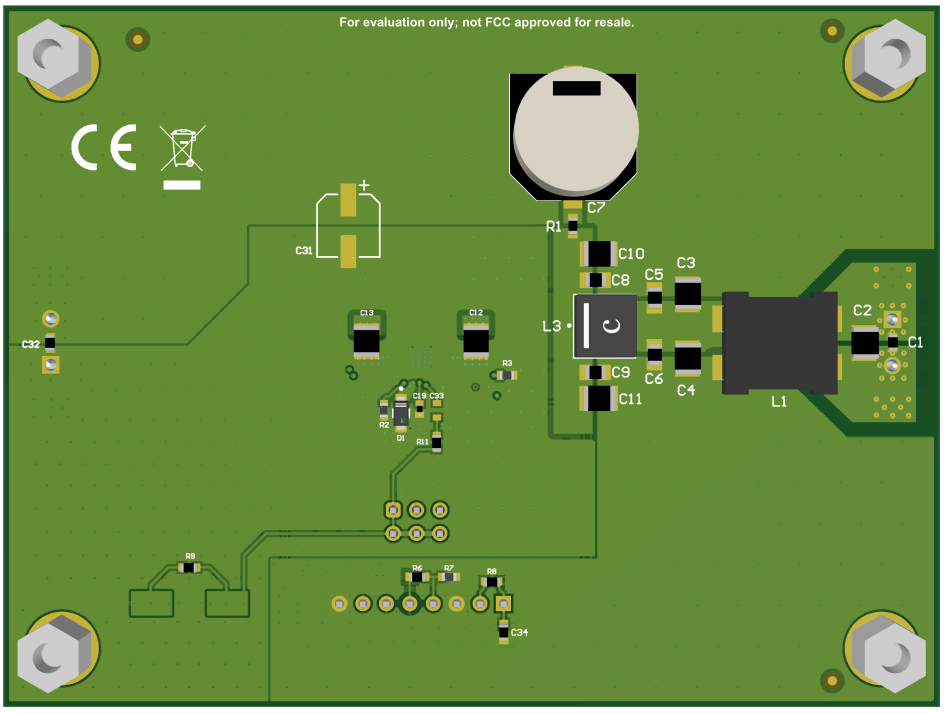


图 4-3. 3D 底视图（仰视图）

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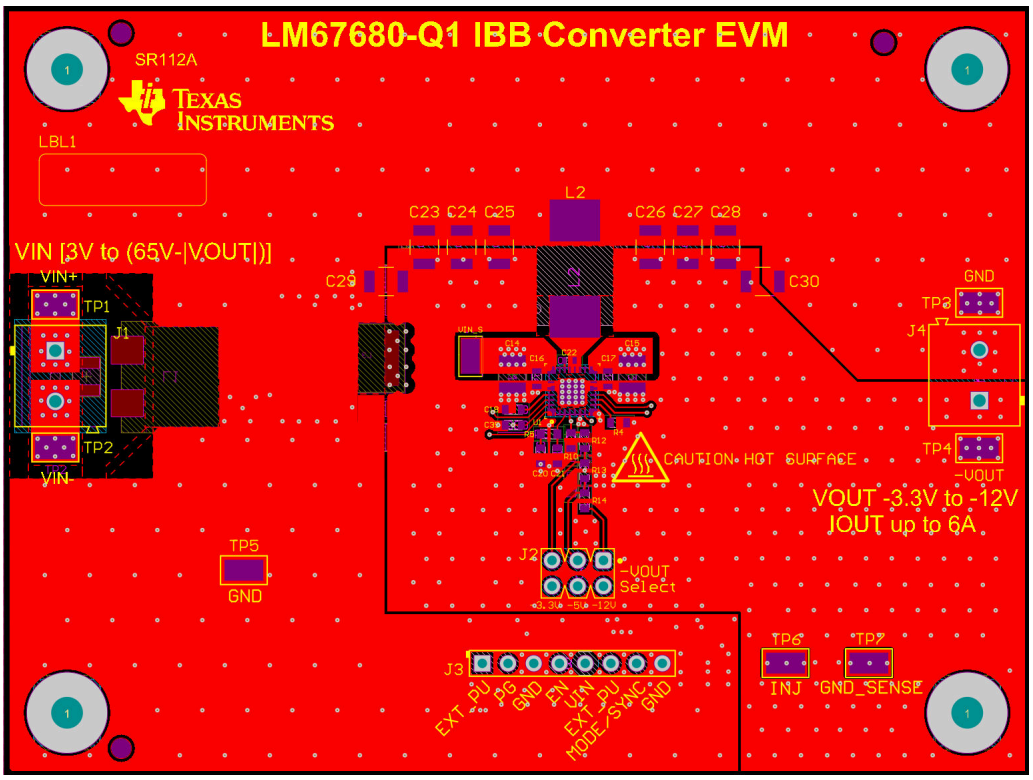


图 4-4. 顶层覆铜（顶视图）

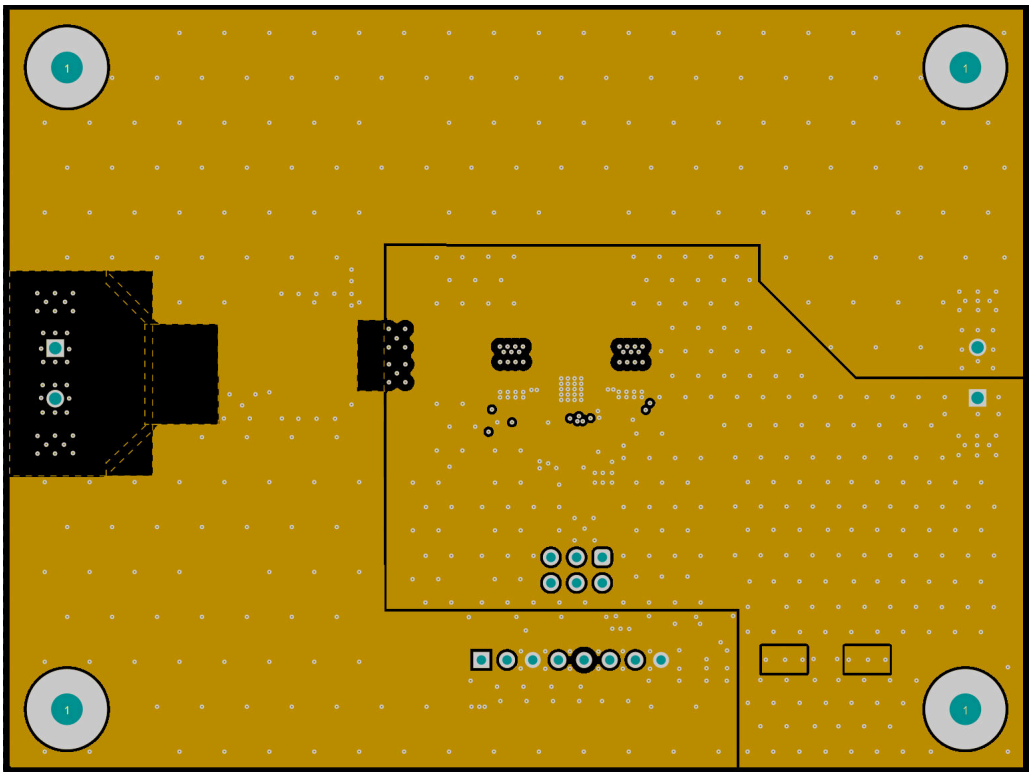


图 4-5. 第 2 层覆铜（顶视图）

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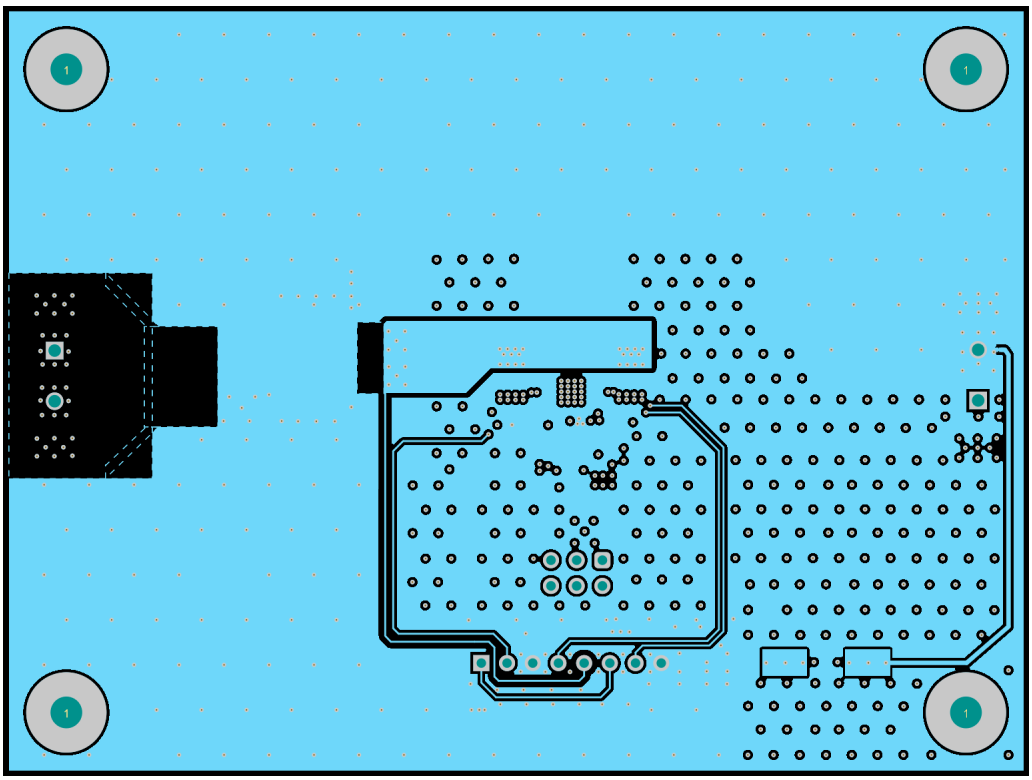


图 4-6. 第 3 层覆铜（顶视图）

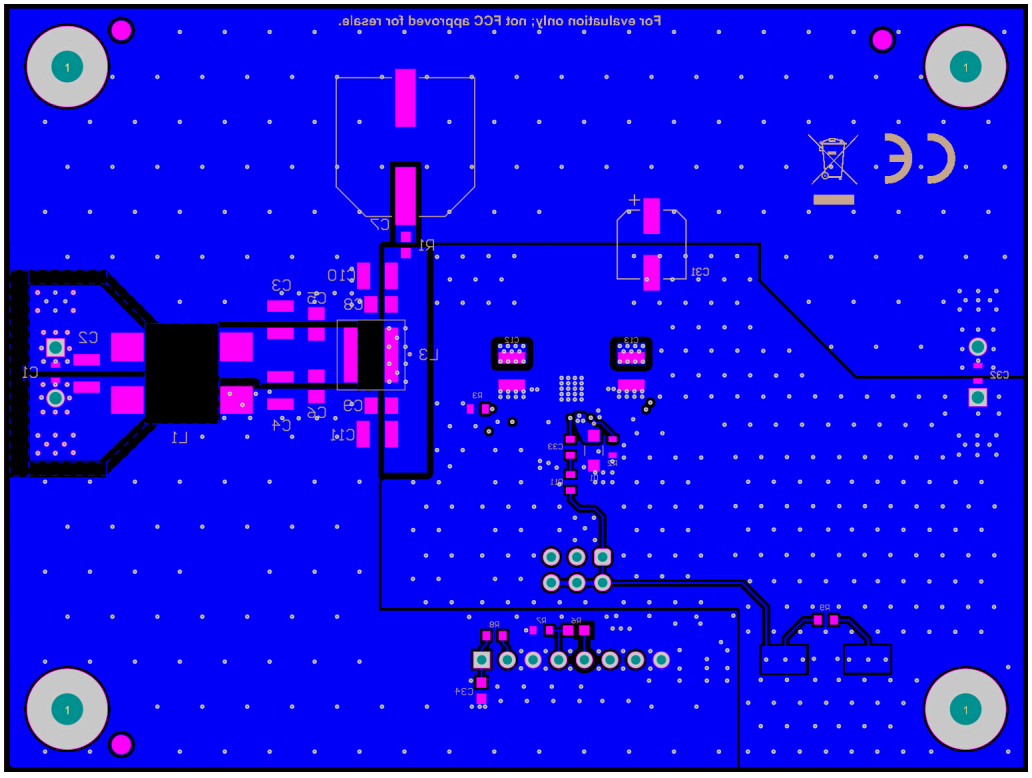


图 4-7. 底部铜层（顶视图）

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4.2.1 元件图

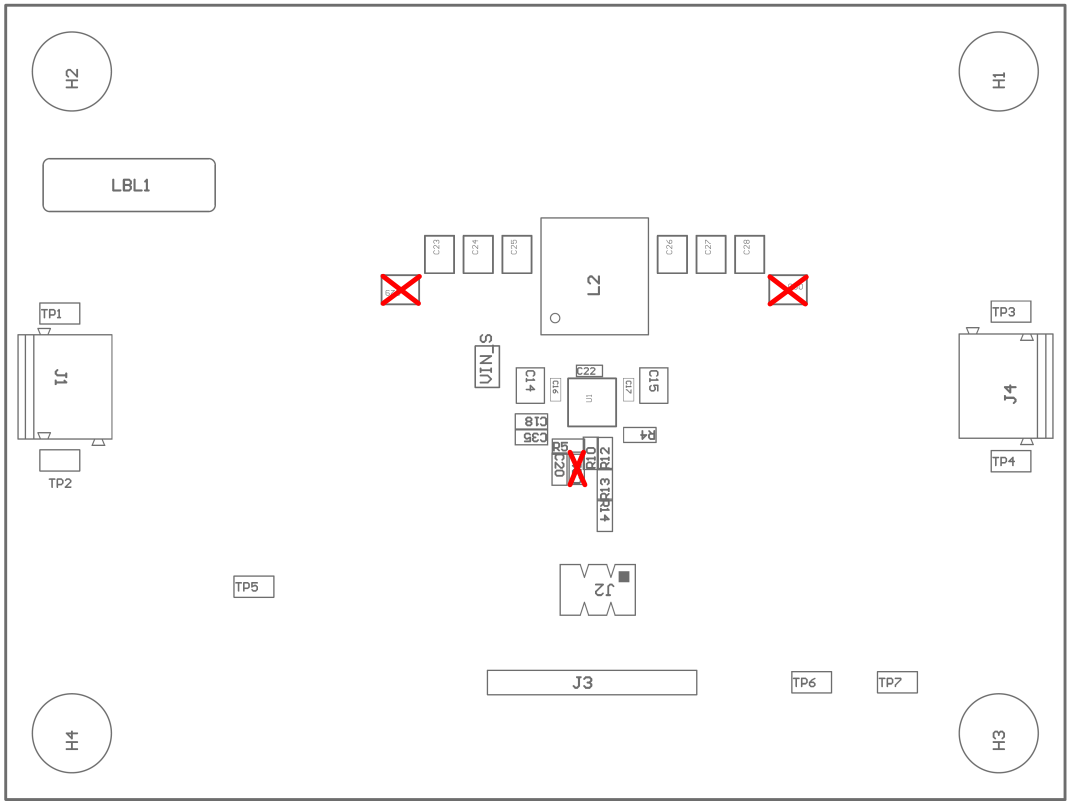


图 4-8. 顶层元件图

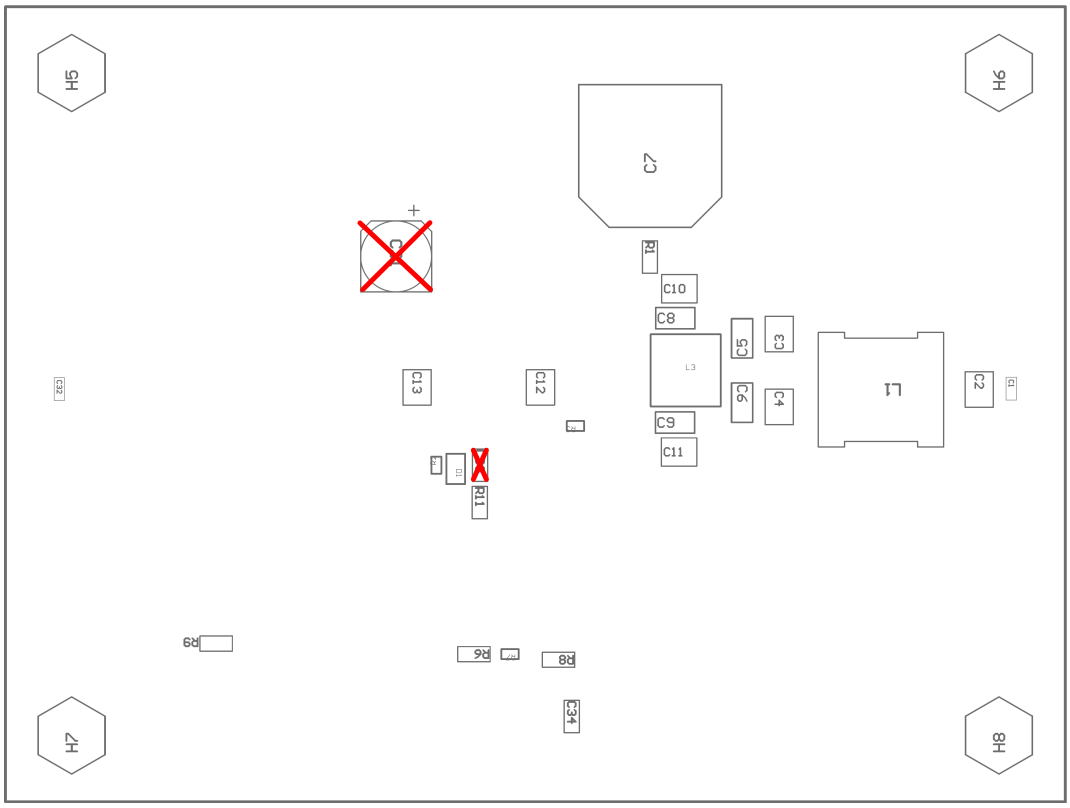


图 4-9. 底层元件图

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4.2.2 多层叠

#	Name	Material	Type	Weight	Thickness	Dk	Df
	Top Overlay		Overlay				
	Top Solder	Solder Resist	Solder Mask		0.4mil	3.5	
1	Top Layer		Signal	2oz	2.8mil		
	Dielectric1	FR-4 High Tg	Core		5mil	4.2	
2	Signal Layer 1		Signal	2oz	2.8mil		
	Dielectric 2	FR-4 High Tg	Prepreg		40mil	4.2	
3	Signal Layer 2		Signal	2oz	2.8mil		
	Dielectric 3	FR-4 High Tg	Core		5mil	4.2	
4	Bottom Layer		Signal	2oz	2.8mil		
	Bottom Solder	Solder Resist	Solder Mask		0.4mil	3.5	
	Bottom Overlay		Overlay				

图 4-10. 层堆叠

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4.3 物料清单

表 4-1. 元件 BOM

参考位号	数量	说明	器件型号	供应商
C1、C16、C17、C32	4	电容器，陶瓷，0.1µF，100V，X7R，0603	GCJ188R72A104K	MuRata
C2、C3、C4、C10、C11、C12、C13、C14、C15	9	电容器，陶瓷，4.7µF，100V，X7S，1210	GCM32DC72A475K	MuRata
			CGA6M3X7S2A475K	TDK
C5、C6、C8、C9	4	电容器，陶瓷，0.1µF，100V，X7R，0805	CGA4J2X7R2A104K	TDK
C7	1	电容器，铝，68µF，80V，0.32Ω，SMD	EEV-FK1K680Q	Panasonic
C18、C35	2	电容器，陶瓷，1µF，50V，X7R，0603	CGA3E3X7R1H105M	TDK
C20	1	电容器，陶瓷，0.01µF，50V，C0G/NP0，0603	CGA3E2C0G1H103J	TDK
C22	1	电容器，陶瓷，0.1µF，50V，X7R，0402	CGA2B3X7R1H104K	TDK
C23、C24、C25、C26、C27、C28	6	电容器，陶瓷，22µF，25V，X7R，1210	CGA6P3X7R1E226M	TDK
		电容器，陶瓷，22µF，25V，X7S，1210	GCM32EC71A476K	Murata
C34	1	电容器，陶瓷，1µF，16V，X7R，0603	GCM188R71C105M	MuRata
D1	1	二极管，肖特基，20V，1A，SOD-123FL	NRVB120VLSFT1G	onsemi
H1、H2、H3、H4	4	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
H5、H6、H7、H8	4	六角螺柱，0.5"L #4-40，尼龙	1902C	Keystone
J1、J4	2	端子块，5mm，2 x 1，锡，TH	691 101 710 002	Würth Elektronik
J2	1	接头，100mil，3 x 2，锡，TH	5-146254-3	TE Connectivity
J3	1	接头，100mil，8 x 1，锡，TH	5-146278-8	TE Connectivity
L1	1	共模扼流圈，7.6µH，700Ω，12mm × 11mm	ACM12V-701-2PL-TL00	TDK
L2	1	电感器，6.8µH，7.1mΩ，20A，11.3mm × 10mm × 6mm	744393665068	Würth Elektronik
		电感器，6.8µH，14mΩ，10.8A，10.85mm × 10mm × 5.2mm	VCHA105D-6R8MS6	Cyntec
L3	1	电感器，3.3µH，6mΩ，15.6A，6.6mm × 6.4mm × 6.1mm	744393465033	Würth Elektronik
		电感器，3.3µH，6.5mΩ，16.6A，6.7mm × 6.5mm × 6.1mm	XGL6060-332MEC	Coilcraft
		电感器，3.3µH，6.3mΩ，16A，6.6mm × 6.4mm × 6mm	XFHCL6060HC-3R3M	XFMRS
LBL1	1	热转印打印标签，0.65" 宽 x 0.2" 高	THT-14-423-10	Brady
R1、R11	2	电阻，0，0.1W，0603	RMCF0603ZT0R00	Stackpole
R2、R3、R7	3	电阻，49.9kΩ，1%，0.1W，0603	CRCW060349K9FKEA	Vishay
R4	1	电阻，40.2kΩ，1%，0.1W，0603	CRCW060340K2FKEA	Vishay
R5	1	电阻，13.3kΩ，1%，0.1W，0603	CRCW060313K3FKEA	Vishay
R6	1	电阻，226kΩ，1%，0.1W，0603	CRCW0603226KFKEA	Vishay
R8	1	电阻，100kΩ，1%，0.1W，0603	CRCW0603100KFKEA	Vishay
R9	1	电阻，49.9Ω，1%，0.1W，0603	CRCW060349R9FKEA	Vishay
R10	1	电阻，10kΩ，1%，0.1W，0603	CRCW060310KFKEA	Vishay
R12	1	电阻，31.6kΩ，1%，0.1W，0603	CRCW060331K6FKEA	Vishay
R13	1	电阻，21kΩ，1%，0.1W，0603	CRCW060321K0FKEA	Vishay
R14	1	电阻，86.6kΩ，1%，0.1W，0603	CRCW060386K6FKEA	Vishay
SH-J1、SH-J2、SH-J3	3	分流器，100mil，镀金，黑色	SNT-100-BK-G	Samtec
TP1、TP2、TP3、TP4、TP5、TP6、TP7	7	测试点，微型，SMT	5019	Keystone
VIN_S	1	测试点，微型，SMT	5015	Keystone

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表 4-1. 元件 BOM（续）

参考位号	数量	说明	器件型号	供应商
U1	1	LM67680-Q1 65V、8A 同步 IBB 转换器	LM67680RZYRQ1	德州仪器 (TI)
PCB1	1	PCB，FR4，4 层，2oz	PCB	-
C21、C33	0	电容器，陶瓷，10pF，50V，C0G/NP0，0603	GRM1885C1H100JA01D	MuRata
C29、C30	0	电容器，陶瓷，22µF，25V，X7R，1210	CGA6P3X7R1E226M	TDK
C31	0	电容器，铝聚合物，82µF，16V，0.03Ω	875105344009	Würth Elektronik

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5 合规信息

5.1 合规性和认证

LM67680-Q1EVM 欧盟关于限制有害物质 (RoHS) 使用的符合性声明 (DoC) 证书

6 其他信息

6.1 商标

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7 相关文档

欲查看相关文件，请参阅以下内容：

- 德州仪器 (TI)，*LM67680-Q1、LM67660-Q1 和 LM67640-Q1 采用 ZEN 1 低 EMI 开关技术的 65V、8A/6A/4A 汽车级反相降压/升压转换器系列* 数据表
- 德州仪器 (TI)，*LM65680-Q1 65V_{IN}、5V_{OUT}、8A 同步降压 DC/DC 稳压器评估模块* 用户指南

7.1 补充内容

7.1.1 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。
- LM67680-Q1 直流/直流转换器快速入门计算器。

7.1.2 IBB 设计资源

- 德州仪器 (TI)，*降压/升压和 SEPIC* 登录页面
- 德州仪器 (TI)，*如何将降压转换器修改为反相降压/升压拓扑* 技术文章
- 德州仪器 (TI)，*在反相降压/升压拓扑中使用降压转换器* 模拟设计期刊
- 德州仪器 (TI)，*使用反相降压/升压转换器* 应用手册
- 德州仪器 (TI)，*采用 TPSM53602/3/4 实现负输出反相降压/升压应用* 应用报告

7.1.3 PCB 布局资源

- LM65680-Q1 降压稳压器 EVM *Altium 布局* 源文件
- LM67680-Q1 IBB 稳压器 EVM *Altium 布局* 源文件
- 德州仪器 (TI)，*布置反相降压/升压转换器以助力成功* 应用手册
- 德州仪器 (TI)，*通过优化的功率级布局免费提升高电流 DC/DC 稳压器 EMI 性能* 应用简报
- 德州仪器 (TI)，*构建电源之布局注意事项* 研讨会

7.1.4 热设计资源

- 德州仪器 (TI)，*使用热增强型封装提高高环境温度下的热性能* 白皮书
- 应用手册：
  - 德州仪器 (TI)，*热设计：学会洞察先机，不做事后诸葛*
  - 德州仪器 (TI)，*外露焊盘封装实现理想热阻的电路板布局布线指南*
  - 德州仪器 (TI)，*半导体和 IC 封装热指标*
  - 德州仪器 (TI)，*PowerPAD™ 热增强型封装*
  - 德州仪器 (TI)，使用新的热指标
- 德州仪器 (TI)，*PowerPAD™ 速成* 应用简报

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WARNING

Evaluation Kits are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems.

User shall operate the Evaluation Kit within TI’s recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI’s recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI’s instructions for electrical ratings of interface circuits such as input, output and electrical loads.

NOTE:

EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGREDATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

3 *Regulatory Notices:*

3.1 *United States*

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

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

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

CAUTION

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

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

FCC Interference Statement for Class A EVM devices

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

FCC Interference Statement for Class B EVM devices

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

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

3.2 *Canada*

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

Concerning EVMs Including Radio Transmitters:

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

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

Concernant les EVMs avec appareils radio:

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

Concerning EVMs Including Detachable Antennas:

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

Concernant les EVMs avec antennes détachables

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

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。

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

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

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

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

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

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

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

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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/lsds/ti_ja/general/eStore/notice_02.page

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

3.4 *European Union*

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

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

4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

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.

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, INDEMITY 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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