User's Guide

Using the UCC14131EVM-070 for Biasing GaN and Gate Driver ICs in Automotive and Industrial Applications

ABSTRACT

This user's guide provides a description and instructions for use of the UCC14131EVM-070 to evaluate the UCC14131-Q1; a high frequency, integrated transformer, DC-DC converter module from Texas Instruments. The EVM comes with UCC14131-Q1 populated by default but can also accommodate UCC14130-Q1. UCC14131-Q1 and UCC14130-Q1 are pin-to-pin compatible and functionally equivalent. All performance data and waveforms shown within this document were obtained testing the UCC14131-Q1 used in HVP070, Rev E1. This EVM allows designers to quickly and efficiently evaluate the UCC14131-Q1 for use in automotive or industrial applications requiring gate driver IC bias power as high as 1.5 W, meeting up to 5 kV_{RMS} isolation.

This user's guide can accompany UCC14131EVM-070, HVP070, Rev E1 and Rev A. Rev E1 and Rev A are identical.

Table of Contents

List of Figures

List of Tables

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1 Introduction

The UCC14131-Q1 is a high efficiency, low-emissions, 5 kV_{RMS} Isolated DC-DC Converter capable of delivering 1.5-W of power. Since the UCC14131-Q1 provides isolated power in an integrated package, this allows systems to reduce cost and size by removing the need for separate isolated power supplies. The UCC14131-Q1 delivers class-leading efficiency in power conversion from the primary to the secondary side while removing the need for bulky external transformers or power modules commonly used in existing designs. This integration allows for minimal printed circuit board (PCB) area as well as decreased height profile.

Note

Please follow the latest UCC14131-Q1 data sheet for each pin function.

1.1 U1 Component Selection

The UCC14131-Q1 is the default IC used in the UCC14131EVM-070 but any of the alternate versions listed in Table 1-1 can be used for evaluation. Each of the component versions listed in Table 1-1 are pin-to-pin compatible, functionally equivalent, drop in replacements with respect to one another.

Table 1-1. UCC1413x-Q1 Version Differences

General Part Number	Orderable Part Number	Isolation/Surge/Working Voltage
UCC14131-Q1	UCC14131QDWNQ1	5 kV_{RMS}/10 kV_{PK}/1 kV_{RMS}
UCC14130-Q1	UCC14130QDWNQ1	3 kV_{RMS}/6.5 kV_{PK}/850 kV_{RMS}

If U1 replacement is required, then TI recommends to always use best practice soldering techniques. Techniques can include taking appropriate ESD precautions and having qualified personnel, skilled at surface mount soldering and board level rework, removing and installing U1. Visually verify the desired UCC1413x-Q1 component version is properly installed in the EVM. If rework on U1 has previously been performed, then visually verify correct orientation of U1 according to Figure 1-1. The pin 1 identifying dot on top of the IC package is oriented at the top left according to Figure 1-1.

1.2 Pin Configuration and Functions

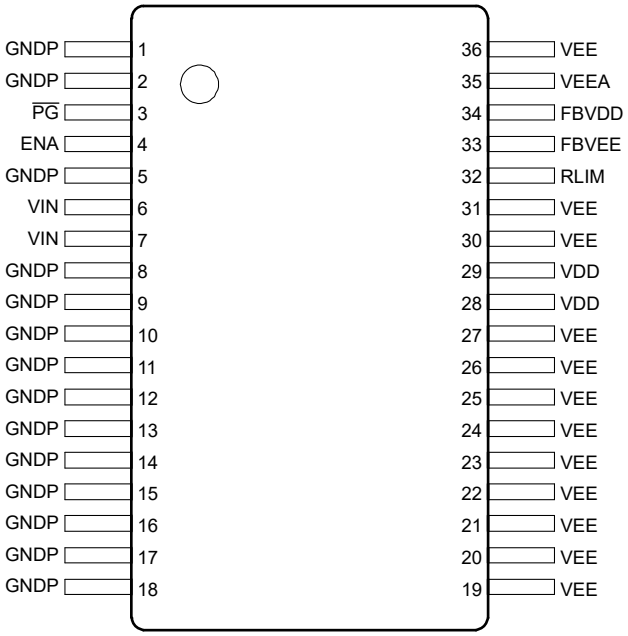


Figure 1-1. DWN Package, 36-Pin SSOP (Top View)

Table 1-2. Pin Functions (refer and follow the data sheet)

PIN		TYPE[1]	DESCRIPTION
NAME	NO.		
GNDP	1, 2, 5, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	G	Primary-side ground connection for VIN. PIN 1,2, and 5 are analog ground. PIN 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, and 18 are power ground. Place several vias to copper pours for thermal relief.
$\overline{PG}$	3	O	Active low power-good open-drain output pin. $\overline{PG}$ remains low when (UVLO ≤ V_{VIN} ≤ OVLO); (UVP1 ≤ (VDD – VEE) ≤ OVP1); $T_{J\_Primary}$ ≤ $TSHUTP_{PRIMARY\_RISE}$; and $T_{J\_secondary}$ ≤ $TSHUT_{SECONDARY\_RISE}$
ENA	4	I	Enable pin. Forcing ENA LOW disables the device. Pull HIGH to enable normal device functionality. 5.5-V recommended maximum.
VIN	6, 7	P	Primary input voltage. PIN 6 is for analog input, and PIN 7 is for power input. For PIN 7, connect two, parallel, 10-µF ceramic capacitors from power VIN PIN 7 to power GNDP PIN 8. Connect a 0.1-µF high-frequency bypass ceramic capacitor close to PIN 7 and PIN 8.
VEE	19, 20, 21, 22, 23, 24, 25,26, 27, 30,31, 36	G	Secondary-side reference connection for VDD. The VEE pins are used for the high current return paths.
VDD	28, 29	P	Secondary-side isolated output voltage from transformer. Connect a 10-µF and a parallel 0.1-µF ceramic capacitor from VDD to VEE. The 0.1-µF ceramic capacitor is the high frequency bypass and must be next to the IC pins.
RLIM	32	P	Secondary-side second isolated output voltage resistor to limit the source current from VDD.
FBVEE	33	I	Feedback output voltage sense pin used to adjust the output voltage.
FBVDD	34	I	Feedback (VDD – VEE) output voltage sense pin and to adjust the output (VDD – VEE) voltage. Connect a resistor divider from VDD to VEE so that the midpoint is connected to FBVDD, and the equivalent FBVDD voltage when regulating is 2.5 V. Add a 330-pF ceramic capacitor for high frequency decoupling in parallel with the low-side feedback resistor. The 330-pF ceramic capacitor for high frequency bypass must be next to the FBVDD and VEEA IC pins on top layer or back layer connected with vias.
VEEA	35	G	Secondary-side analog sense reference connection for the noise sensitive analog feedback inputs, FBVDD and FBVEE. Connect the low-side feedback resistors and high frequency decoupling filter capacitor close to the VEEA pin and respective feedback pin FBVDD or FBVEE. Connect to secondary-side gate drive lowest voltage reference, VEE. Use a single point connection and place the high frequency decoupling ceramic capacitor close to the VEEA pin.

(1) P = power, G = ground, I = input, O = output

2 Description

The UCC14131EVM-070 is intended to allow designers to evaluate the performance characteristics and capabilities of the UCC14131-Q1 quickly and easily for use in automotive, isolated, gate driver bias applications, as well as a variety of isolated industrial bias power applications. The EVM allows users to test functions of the UCC14131-Q1 such as: Enable/Disable (EN) of the device and easily apply variable loads to the outputs. This EVM allows the user to measure efficiency across the input voltage range and varying output loads according to system requirements. Another feature of the EVM is the ease of probing during test. Test points are strategically placed and described according to Table 4-1.

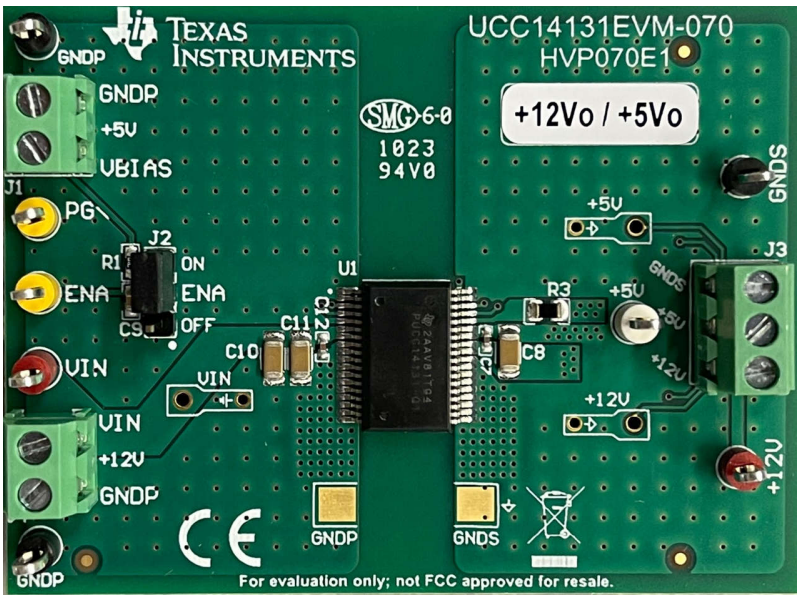


Figure 2-1. UCC14131EVM-070 (Top View)

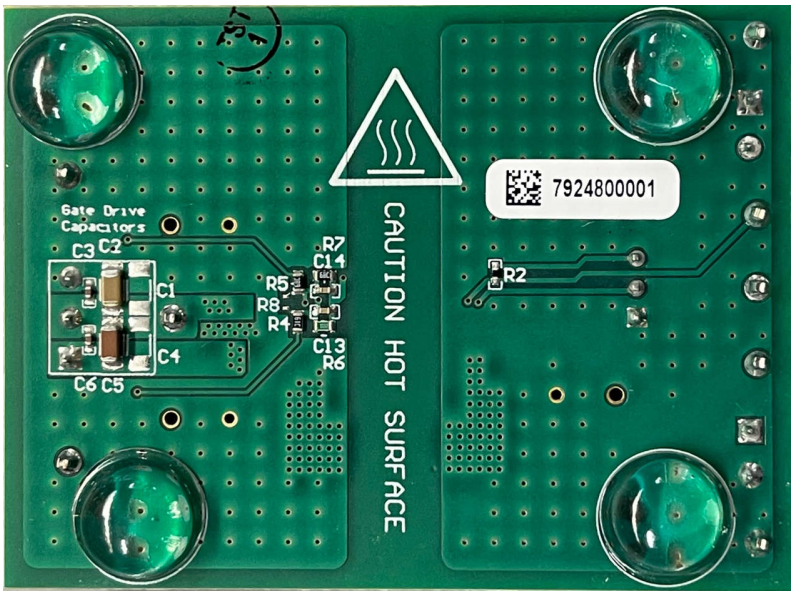


Figure 2-2. UCC14141EVM-070 (Bottom View)

2.1 EVM Electrical Performance Specifications

Table 2-1. EVM Electrical Specifications

V_{IN} = 12 V, VDD-VEE = 12 V, [+5V]-VEE = 5 V, T_A = 25°C, (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
INPUT CHARACTERISTICS						
V_{IN}	Input voltage range	$P_{VDD-VEE}$ = 1.5 W	11.2	12	14	V
V_{IN_ON}	Input voltage on		9		10	V
V_{IN_OFF}	Input voltage off			7.2		V
I_{IN_FL}	Input current at full load	V_{IN} = 11.2 V, I_{VDD} = 132.6 mA		290		mA
		V_{IN} = 12 V, I_{VDD} = 128.5 mA		282		
		V_{IN} = 14 V, I_{VDD} = 128.5 mA		274		
I_{IN_NL}	Input current at no load	V_{IN} = 11.2V, I_{VDD} = 0 mA		22		mA
		V_{IN} = 12 V, I_{VDD} = 0 mA		21		
		V_{IN} = 14 V, I_{VDD} = 0 mA		19		
I_{IN_OFF}	Input current at EN LOW	EN LOW, VDD = VEE = 0 V		540		µA
EN to /PG delay		I_{VDD} =I_{VEE} = 0 mA		4.6		ms
OUTPUT CHARACTERISTICS						
VDD-VEE	DC full load set-point	11.2 V < V_{IN} <14 V, I_{VDD} = 130 mA		12		V
I_{VDD}	VDD load current range	11.2 V < V_{IN} < 14 V	0		130	mA
$VDD_{\%LD}$	Load regulation	$\mathrm{VDD_{REG}} = \left[\frac{V_{I(min)} - V_{I(max)}}{V_{I(max)}}\right] \times 100\%$ V_{IN} = 12 V, 0 mA ≤ I_{VDD} ≤ 130 mA		0.7		%
$VDD_{\%LN}$	Line regulation	$\mathrm{VDD_{REG}} = \left[\frac{V_{I(min)} - V_{I(max)}}{V_{I(max)}}\right] \times 100\%$ I_{VDD} = 124 mA, 11.2 V ≤ V_{IN} ≤ 14 V		0.2		%
VDD_{AC}	pk-to-pk AC ripple	I_{VDD} = 130 mA		115		mV
VDD_{SS}	Soft-start	I_{VDD} = $I_{[+5V]}$ = 0 mA		16		ms
P_{MAX}	Maximum output power	I_{VDD} = 130 mA, $I_{[+5V]}$ = 0 mA, 11.2 V < V_{IN} < 14 V		1.5		W
[+5V]	DC full load set-point	11.2 V ≤ V_{IN} ≤ 14 V, $I_{[+5V]}$ = 10 mA		5		V
$I_{[+5V]}$	[+5V] load current range	11.2 V ≤ V_{IN} ≤ 14 V	0	10		mA
$[+5V]_{AC}$	pk-to-pk AC ripple	$I_{[+5V]}$ = 10 mA		155		mV
SYSTEM CHARACTERISTICS						
$\eta_{100\%}$	Full load efficiency	I_{VDD} = 130 mA, VDD = 12 V,		45		%
$\eta_{50\%}$	Half load efficiency	I_{VDD} = 65 mA, VDD = 12 V,		41		%
F_{SW}	Switching frequency (1)	V_{IN} = 11.2 V, 0 mA < I_{VDD} < 130 mA		20.5		MHz
		V_{IN} = 12 V, 0 mA < I_{VDD} < 130 mA		19.1		
		V_{IN} = 14 V, 0 mA < I_{VDD} < 130 mA		16.6		
$VDD_{(OCL)}$	VDD overcurrent limit ($I_{[+5V]}$ = 0 mA)	V_{IN} = 11.2 V, V_{DD} = 12 V		140		mA
		V_{IN} = 12.0 V, V_{DD} = 12 V		155		
		V_{IN} = 14.0 V, V_{DD} = 12 V		170		
$[+5V]_{(OCL)}$	[+5V] overcurrent limit (I_{VDD} = 0 mA)	V_{IN} = 12.0 V, V_{DD} = 12 V		16		mA
T_{MAX}	Maximum temperature rise above ambient	I_{VDD} = 130 mA, $I_{[+5V]}$ = 0 mA, VDD = 12 V		75		°C

(1) Switching frequency is specified as primary-side switching frequency. Secondary-side is 2x primary.

3 Schematic

Figure 3-1 shows the EVM electrical schematic. C2, C4 and R8 are intentionally unpopulated as indicated by a red X on the secondary side, placed directly over the component.

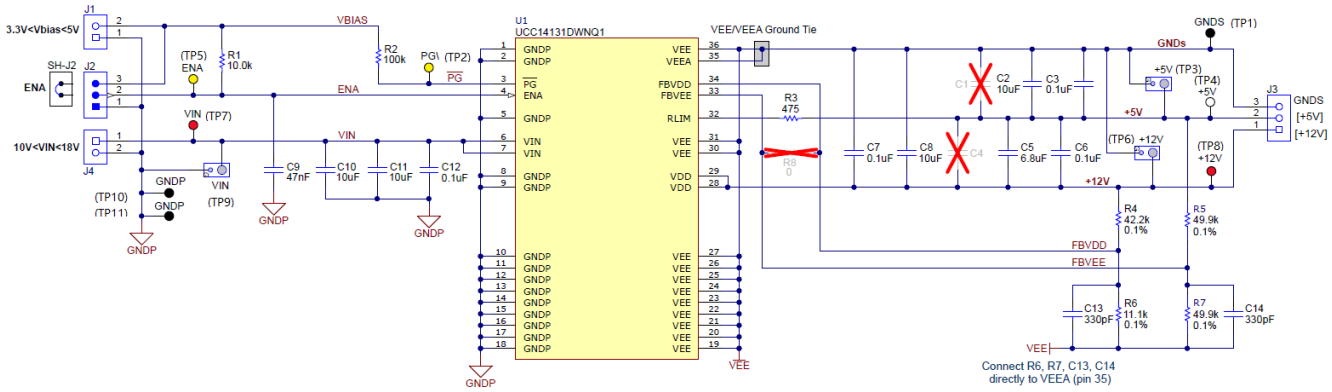


Figure 3-1. UCC14131EVM-070 Schematic Diagram

4 EVM Setup and Operation

4.1 Recommended Test Equipment

- V_{BIAS}: 5-V DC power supply1: 5 V, 0 to 10 mA
- V_{IN}: DC power supply2: 8 to 18 V, 500 mA
- I_{VDD}: Electronic load or fixed resistor: 12 V, 0 to 150 mA
- $I_{[+5V]}$: Electronic load or fixed resistor: 5 V, 10 mA
- (3) DVMs measuring DC voltage < 30 V
- (3) DVMs measuring DC current < 200 mA on I_{VDD} or $I_{[+5V]}$, and < 500 mA on I_{VIN}
- Oscilloscope: 4 channel, 500 MHz or better, voltage probes, current probes
- Minimum wire gauge 20 AWG to 22 AWG or better
- Thermal camera (optional) or thermocouple to measure U1 case temperature

4.2 External Connections for Easy Evaluation

The UCC14131EVM-070 EVM utilizes screw terminals for quickly connecting to VIN, VDD, [+5V] and VEE (refer to Table 4-1). Connecting the appropriate ammeters and voltmeters, as shown in Figure 4-1, allows accurate EVM efficiency measurements to be made.

Connecting Test Equipment

1. Move jumper SH-J1 into the J2:1-2, EN OFF position. This makes sure the EVM cannot start while test equipment is being connected.
2. Connect a 5-V DC bias power supply to J1:1-2 (+3.3 V to +5 V). Set the power supply to 0 V. The 5-V supply at J1 serves as the pullup bias for /PG and ENA. Turn off/disable the 5-V DC Bias power supply.
3. Connect the V_{IN} DC power supply capable of 8 V<V_{IN}<18 V, 300 mA at J4:1-2 (V_{IN}). Adjust the power supply to 12 V, and set the current limit to 350 mA. Set the power supply voltage to 12 V. Turn off/disable the V_{IN} power supply.
4. Connect a variable load between J3:1 (VDD) and J3:3 (VEE). If using an electronic load, set to constant current (CC), 68 mA. Leave the load disabled until the EVM is powered.
5. Connect a second load between J3:2 ([+5V]) and J3:3 (VEE). If using an electronic load, set to constant current (CC), 10 mA. Leave the load disabled until the EVM is powered. Since the required load is small, a through-hole, 250-mW, 400-Ω load resistor can be connected between J3:2-3.
6. Some electronic loads are not be able to regulate/stabilize CC when setting in the low mA range. Monitor the input current and load currents by inserting ammeters, A1-A3, as shown in Figure 4-1. Use a current probe with the oscilloscope to verify the stability of the DC current being regulated by an electronic load.

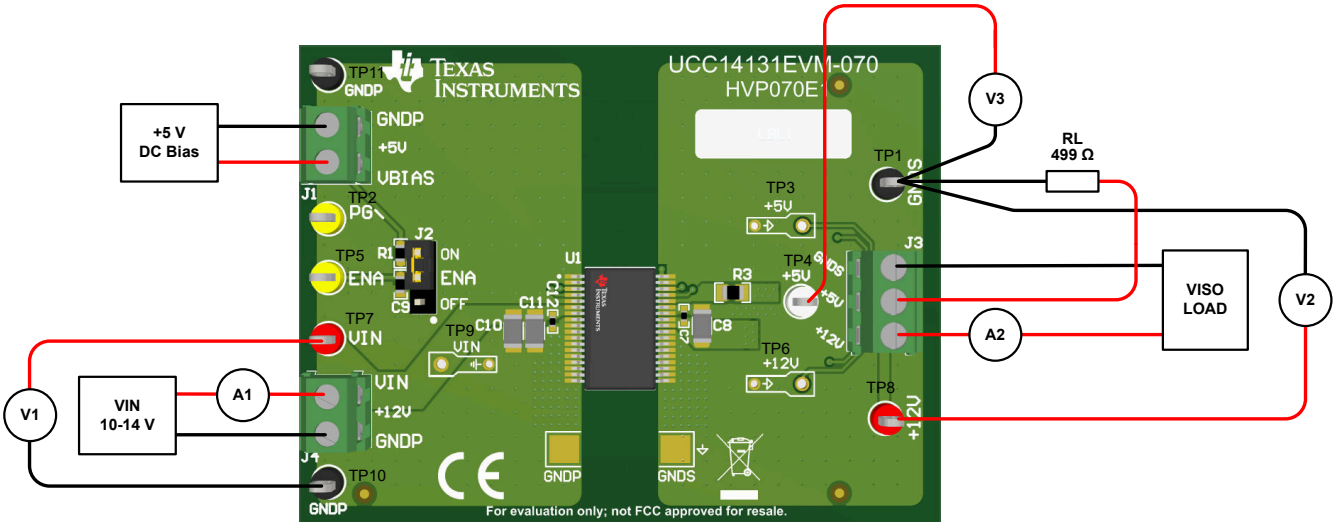


Figure 4-1. Typical Efficiency Measurement Setup

4.3 Powering the EVM

WARNING

- Hot Surface. Contact can cause burns. U1 package surface can reach temperatures of 45°C above ambient. Do not touch!
- Do not test this EVM unless you are trained in the proper safety, handling and testing of power electronics.

4.3.1 Power on for Start-up

1. Verify VIN and 5-V DC bias power supplies are OFF/disabled and no voltage is applied to the UUT
2. Move EN shorting jumper, SH-J1, to the J2:2-3 EN ON position
3. Turn on the V_{IN} DC power supply. Verify 12-V is present at VIN(TP7)-to-GNDP(TP10)
4. Verify the loads on VDD and VEE are disabled
5. Turn on the 5-V DC bias power supply. EVM is now enabled with VDD and +5V in regulation under no load conditions.
6. Verify 12-V is present on VDD-VEE and 5-V is present on [+5V](TP3)-GNDS(TP1)
7. Enable the 100-mA load on VDD-(+5V), enable the 10-mA load on [+5V]-GNDS
8. The UCC14131-Q1 is now regulating VDD and VEE and processing 1.5-W of isolated output power
9. Vary VIN between 11.2 V<V_{IN}<14 V, vary I_{VDD} between 0 mA<I_{VDD}<130 mA, vary I_{VEE} between 0 mA<$I_{[+5V]}$<30 mA.
10. Insert oscilloscope probes into VIN(TP9), [+12V](TP6) and [+5V](TP3) for measuring V_{IN}, [+12V] and [+5V] start-up, steady state and AC ripple voltage

4.3.2 Power off for Shutdown

1. Move EN shorting jumper SH-1 to the J2:1-2, EN OFF position
2. Turn off the 5-V DC bias power supply
3. Disable the I_{VDD} load
4. Disable the $I_{[+5v]}$ load
5. Turn off V_{IN} power supply

4.4 EVM Test Points

Table 4-1 describes the various EVM test points, allowing easy access for connecting oscilloscope probes, DVM test leads and wire connections to lab test equipment as shown in Figure 4-1. Pay attention to maintain separation between the primary side, GNDP and secondary side, VEE (= GNDS). Primary-side test points are not to be referenced to VEE through improper test equipment insertion. Likewise, secondary-side test points are not to be referenced to GNDP through improper test equipment insertion.

Note

Refer to Figure 4-1 to locate test point location on the board for TP1, TP2, etc.

Table 4-1. Input, Output, Test Point (I/O/TP) Description

PIN	Name	I/O/TP	COLOR	DESCRIPTION	MIN	TYP	MAX	UNIT
J1	5-V	I	Green	VBIAS, EN and /PG bias	3	V_{BIAS}	5	V
J2:1-2	EN	I	Green	EN, off		0		V
J2:2-3	EN	I	Black	EN, on		V_{BIAS}		V
J3:1-3	VDD, [+12V]	O	Green	Secondary, +12V Output, [+12V]-to-VEE, or VDD-VEE		12		V
J3:2-3	[+5V]	O	Green	Secondary, +5V Output, [+5V]-to-VEE, or [+5V]-VEE		5		V
J4	V_{IN}	I	Green	V_{IN}, primary input voltage	8	12	18	V
TP1	GNDS	TP	Black	VEE and GNDS, secondary side reference		0		V
TP2	/PG	TP	Yellow	/PG, power good test point		V_{BIAS}		V
TP3	+5V	TP	PCB	[+5V]-VEE, secondary COM scope probe point	0		5	V
TP4	+5V	TP	White	[+5V]-VEE, secondary +5V output	0		5	V
TP5	EN, ENA	TP	Yellow	EN, enable test point		V_{BIAS}		V
TP6	VDD, [+12V]	TP	PCB	[+12V]-to-VEE, or VDD-VEE, secondary VDD scope probe point		12		V
TP7	VIN	TP	Red	V_{IN}, positive probe point	8	12	18	V
TP8	VDD, [+12V]	TP	Red	[+12V], secondary VDD test point		12		V
TP9	VIN	TP	PCB	V_{IN}-to-GNDP scope probe point	8	12	18	V
TP10	GNDP	TP	Black	GNDP, shared primary GND test point		0		V
TP11	GNDP	TP	Black	GNDP, shared primary GND test point		0		V

4.5 Probing the EVM

Using TP3 ([+5V]), TP6 ([+12V]) and TP9 (VIN) oscilloscope probe PCB test points (see Figure 4-1 and Figure 4-2), the UCC14131-Q1 is a high frequency DC-DC module that requires careful measurement for accurately capturing transient events and measuring high frequency, AC ripple voltage. Remove the *witch hat* probe tip cover and ground lead from the scope probe. If scope probe ground springs are not available, wrap a piece of 22 AWG bare wire around the scope probe ground ring or use a fitted ground spring and insert the probe tip and ground into the EVM as shown in Figure 4-2.

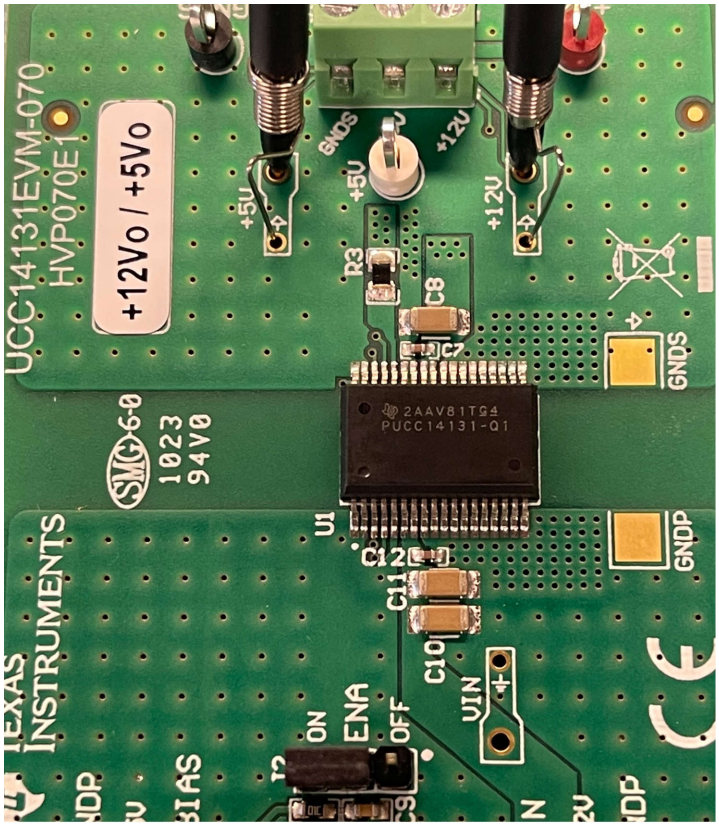


Figure 4-2. UCC14131EVM-070, PCB Scope Probe Test Points

The EVM output nomenclature (VDD, VEE) corresponds to what is commonly used when referring to isolated gate driver ICs for [+12V] and GNDS of this evaluation board. As shown in Figure 4-2, [+5V](TP4) is the [+5V] output (ref Table 4-1). When the UCC14131-Q1 is used to bias a gate driver IC, [+12V] (VDD to VEE) and [+5V] (capacitor-middle to VEE) are referred to with respect to VEE (= GNDS). When testing the EVM as a stand-alone bias power supply, oscilloscope probing of the secondary-side outputs are limited to [+5V](TP3) and [+12V](TP6), which are referenced to VEE or GNDS.

5 Performance Data

Unless otherwise specified, all performance data and waveforms collected using electronic load set to constant current.

5.1 Efficiency Data

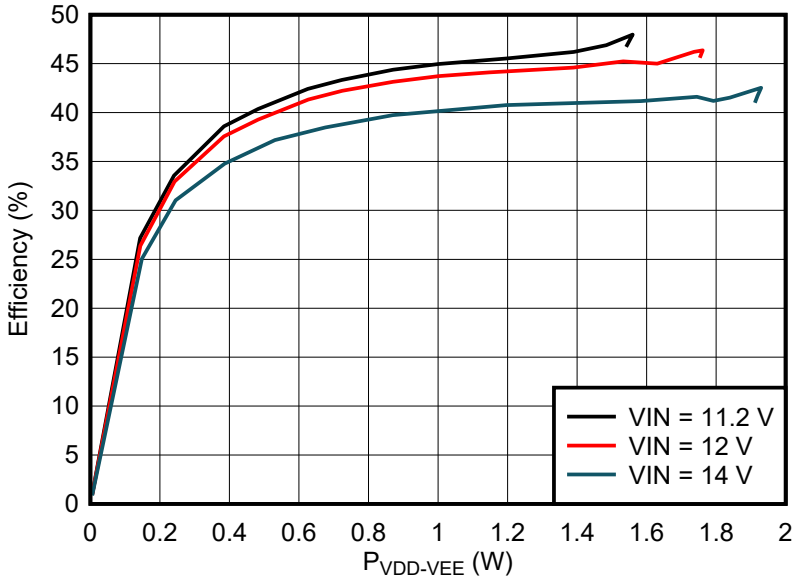


Figure 5-1. Measured Efficiency, VDD-VEE = 12-V Loading Only

Table 5-1. Efficiency Test Data (VIN = 11.2 V)

VIN (V)	IIN (mA)	VDD-VEE (V)	$I_{VDD-VEE}$ (mA)	[+5V]-VEE (V)	PIN (W)	$P_{VDD-VEE}$ (W)	Eff (%)
11.21	22.20	12.023	0.00	5.02	0.25	0.00	0.00
11.21	47.00	12.013	11.91	5.02	0.53	0.14	27.17
11.21	63.90	12.015	20.00	5.02	0.72	0.24	33.56
11.21	88.87	12.008	32.00	5.01	1.00	0.38	38.58
11.21	106.59	12.002	40.17	5.01	1.19	0.48	40.36
11.21	131.62	11.991	52.17	5.01	1.47	0.63	42.41
11.21	148.95	11.989	60.33	5.01	1.67	0.72	43.33
11.21	175.11	11.983	72.66	5.01	1.96	0.87	44.37
11.21	198.67	11.976	83.58	5.01	2.23	1.00	44.96
11.21	234.50	11.966	99.96	5.01	2.63	1.20	45.52
11.21	268.62	11.953	116.31	5.01	3.01	1.39	46.19
11.21	282.53	11.931	124.40	5.00	3.17	1.48	46.88
11.21	**290.25**	**11.766**	**132.58**	**5.00**	**3.25**	***1.56***	**47.96**
11.21	294.42	11.269	136.78	5.00	3.30	1.54	46.72

Note

VDD, VEE, and [+5V], etc., refer to Table 4-1 and Figure 4-1.

Table 5-2. Efficiency Test Data (VIN = 12 V)

VIN (V)	IIN (mA)	VDD-VEE (V)	$I_{VDD-VEE}$ (mA)	[+5V]-VEE (V)	PIN (W)	$P_{VDD-VEE}$ (W)	Eff (%)
12.02	21.39	12.036	0.00	5.02	0.26	0.00	0.00
12.02	45.30	12.030	11.93	5.02	0.54	0.14	26.38
12.02	61.20	12.020	20.14	5.02	0.73	0.24	32.95
12.02	85.20	12.013	31.98	5.02	1.02	0.38	37.56
12.02	102.33	12.007	40.19	5.02	1.23	0.48	39.28
12.02	126.36	12.001	52.24	5.02	1.52	0.63	41.32
12.02	142.91	11.992	60.41	5.02	1.72	0.72	42.22
12.02	168.05	11.987	72.62	5.02	2.02	0.87	43.14
12.02	190.87	11.981	83.63	5.01	2.29	1.00	43.72
12.01	216.78	11.975	95.84	5.01	2.60	1.15	44.10
12.01	259.45	11.962	116.13	5.01	3.11	1.39	44.60
12.01	**282.30**	**11.954**	**128.24**	**5.01**	**3.39**	***1.53***	**45.23**
12.01	301.86	11.947	136.48	5.01	3.62	1.63	44.99
12.01	313.04	11.913	145.76	5.01	3.76	1.74	46.20
12.01	316.52	11.744	149.99	5.01	3.80	1.76	46.35
12.01	320.33	11.380	154.06	5.01	3.85	1.75	45.59

Note

VDD, VEE, and [+5V], etc., refer to Table 4-1 and Figure 4-1.

Table 5-3. Efficiency Test Data (VIN = 14 V)

VIN (V)	IIN (mA)	VDD-VEE (V)	$I_{VDD-VEE}$ (mA)	[+5V]-VEE (V)	PIN (W)	$P_{VDD-VEE}$ (W)	Eff (%)
14.01	19.35	12.043	0.00	5.02	0.27	0.00	0.00
14.01	42.17	12.036	12.29	5.02	0.59	0.15	25.05
14.01	56.40	12.027	20.38	5.02	0.79	0.25	31.03
14.01	79.31	12.019	32.14	5.02	1.11	0.39	34.78
14.01	101.91	12.011	44.18	5.03	1.43	0.53	37.18
14.01	125.44	12.004	56.30	5.02	1.76	0.68	38.47
14.01	156.40	11.990	72.59	5.02	2.19	0.87	39.74
14.01	209.63	11.978	99.92	5.02	2.94	1.20	40.77
14.01	233.87	11.971	111.96	5.02	3.28	1.34	40.92
14.01	**274.64**	**11.956**	**132.45**	**5.01**	**3.85**	***1.58***	**41.17**
14.01	299.44	11.950	145.98	5.01	4.19	1.74	41.60
14.01	310.70	11.945	150.04	5.00	4.35	1.79	41.19
14.01	316.27	11.933	154.19	5.00	4.43	1.84	41.53
14.01	323.90	11.889	162.29	5.00	4.54	1.93	42.53
14.01	328.53	11.527	166.50	5.00	4.60	1.92	41.71
14.01	332.90	11.213	170.46	5.00	4.66	1.91	41.00

Note

VDD, VEE, and [+5V], etc., refer to Table 4-1 and Figure 4-1.

5.2 Regulation Data

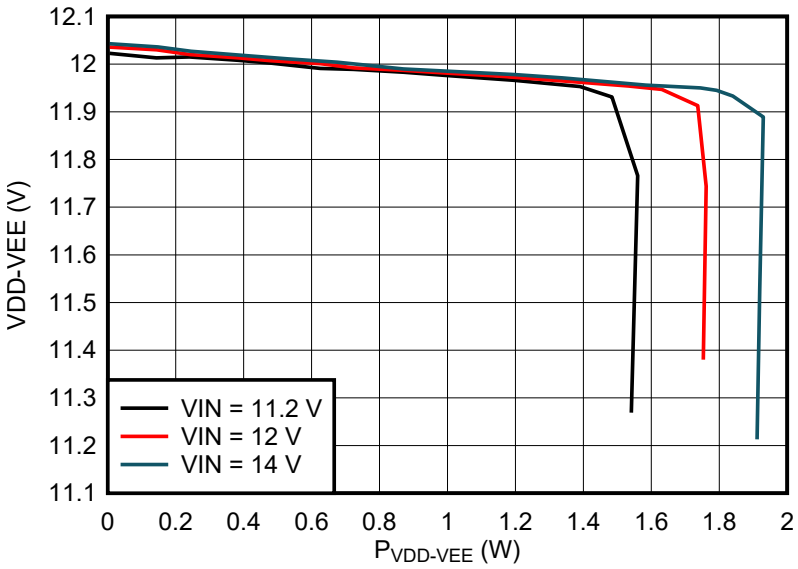


Figure 5-2. Regulation vs Power, VDD-VEE Loading Only

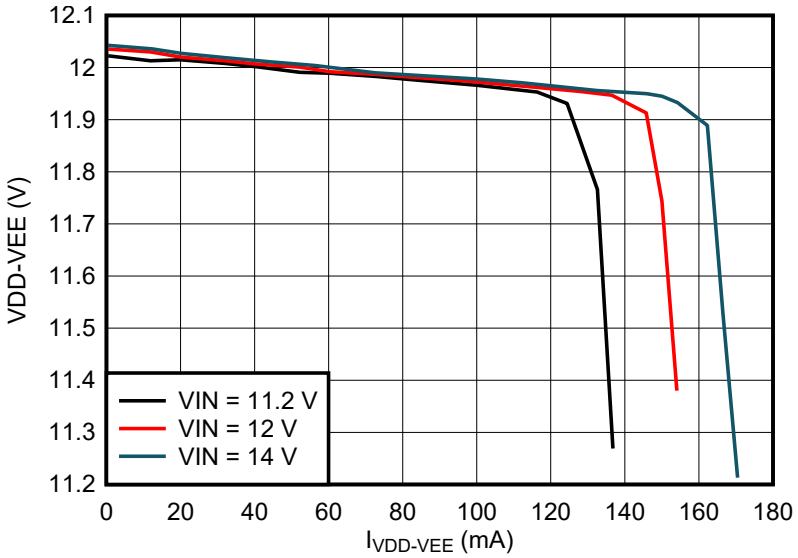


Figure 5-3. Regulation vs Current, VDD-VEE Loading Only

5.3 Steady State Input Current

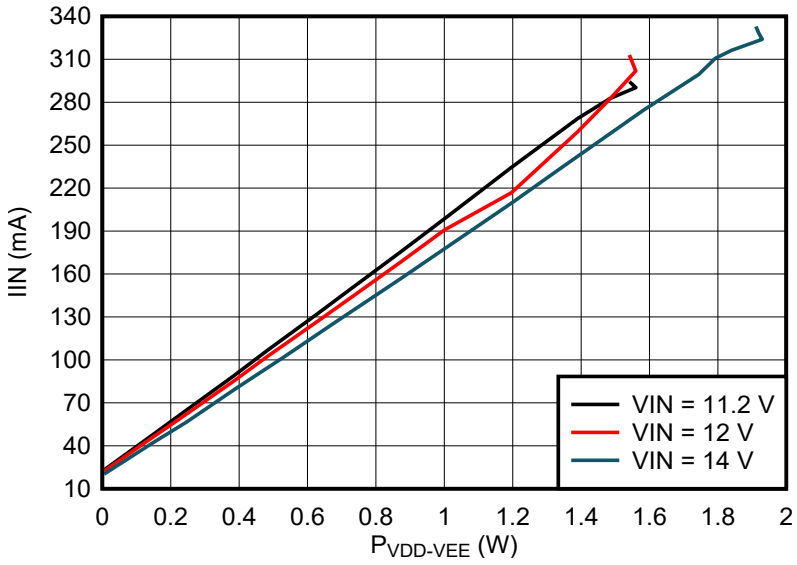
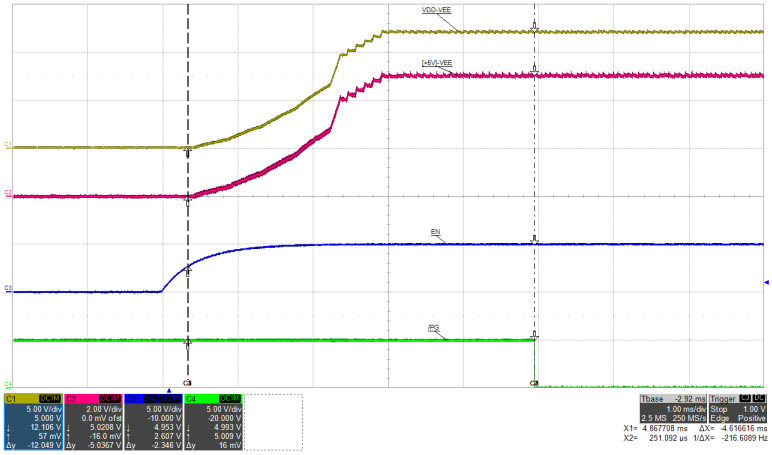


Figure 5-4. Input Current vs Power, VDD-VEE Loading Only

5.4 Start-Up Waveforms

Note

VDD, VEE, and [+5V], etc., refer to Table 4-1 and Figure 4-1.

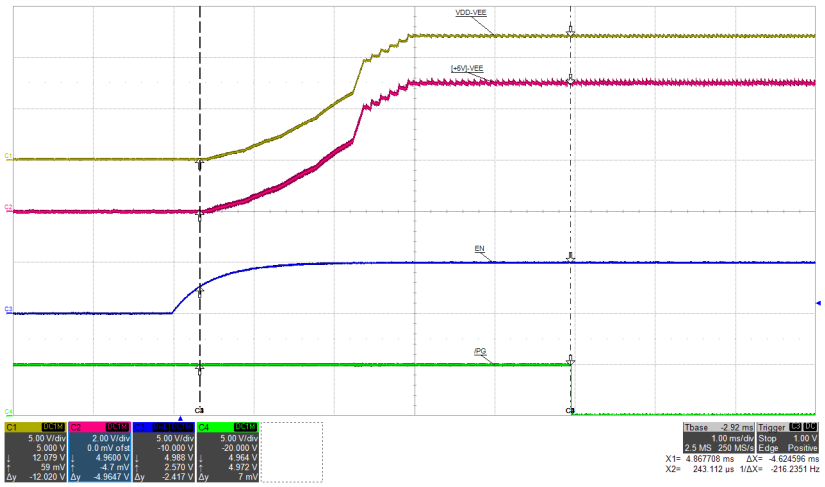


top: VDD-VEE, 5 V/div,	bot: /PG, 5 V/div,
mid-1: [+5 V]-VEE, 2 V/div,	time = 1 ms/div
mid-2: EN, 5 V/div,	

Figure 5-5. Start-up 1: VIN = 12 V, I_{VDD} = 0 mA, $I_{[+5V]}$ = 0 mA

Note

VDD, VEE, and [+5V], etc., refer to Table 4-1 and Figure 4-1.

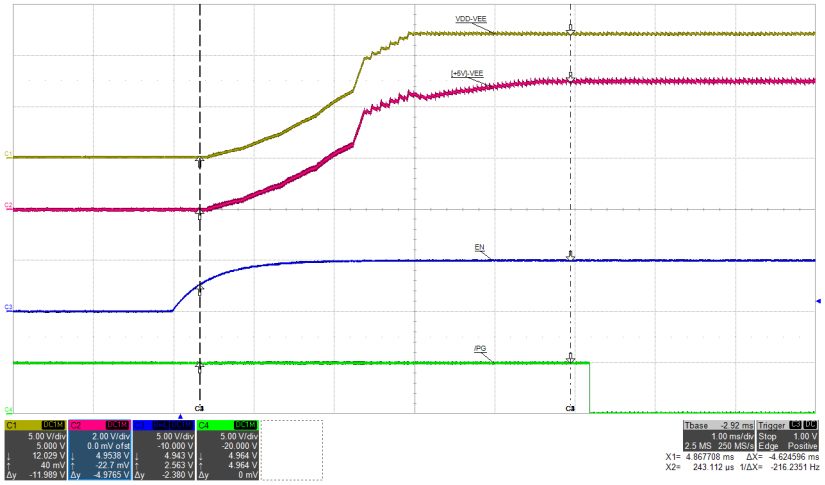


top: VDD-VEE, 5 V/div,	bot: /PG, 5 V/div,
mid-1: [+5 V]-VEE, 2 V/div,	time = 1 ms/div
mid-2: EN, 5 V/div,	

Figure 5-6. Start-up 2: VIN = 12 V, I_{VDD} = 130 mA, $I_{[+5V]}$ = 0 mA

Note

VDD, VEE, and [+5V], etc., refer to Table 4-1 and Figure 4-1.

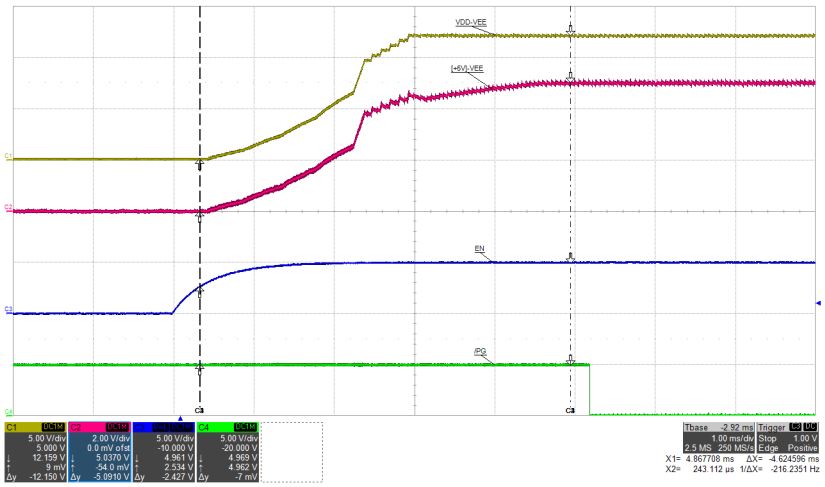


top: VDD-VEE, 5 V/div,	bot: /PG, 5 V/div,
mid-1: [+5 V]-VEE, 2 V/div,	time = 1 ms/div
mid-2: EN, 5 V/div,	

Figure 5-7. Start-up 3: VIN = 12 V, I_{VDD} = 0 mA, $I_{[+5V]}$ = 10 mA

Note

VDD, VEE, and [+5V], etc., refer to Table 4-1 and Figure 4-1.

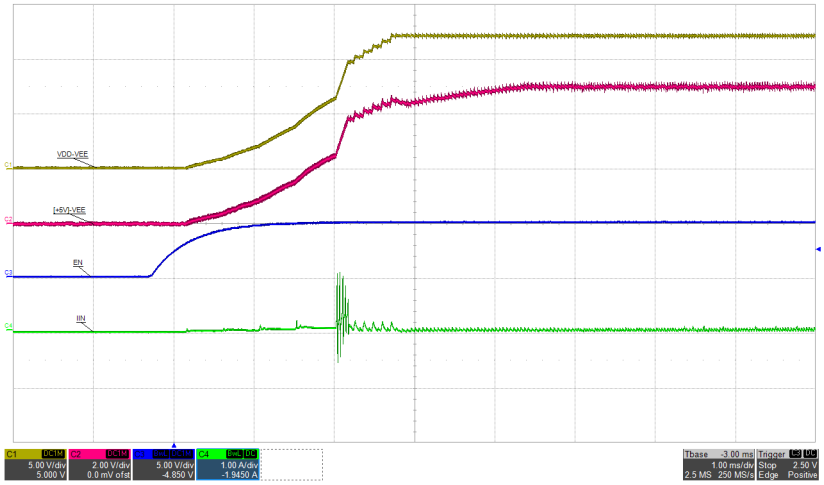


top: VDD-VEE, 5 V/div,	bot: /PG, 5 V/div,
mid-1: [+5 V]-VEE, 2 V/div,	time = 1 ms/div
mid-2: EN, 5 V/div,	

Figure 5-8. Start-up 4: VIN = 12 V, I_{VDD} = 130 mA, $I_{[+5V]}$ = 10 mA

5.5 Inrush Current

Inrush current measurement made with VIN applied and toggle EN pin. This makes sure the input capacitors are pre-biased to VIN and make negligible contribution to the measure inrush current. Inrush current is measured by connecting a current probe to the positive connecting cable between the input supply voltage and the EVM, J4 terminal block.

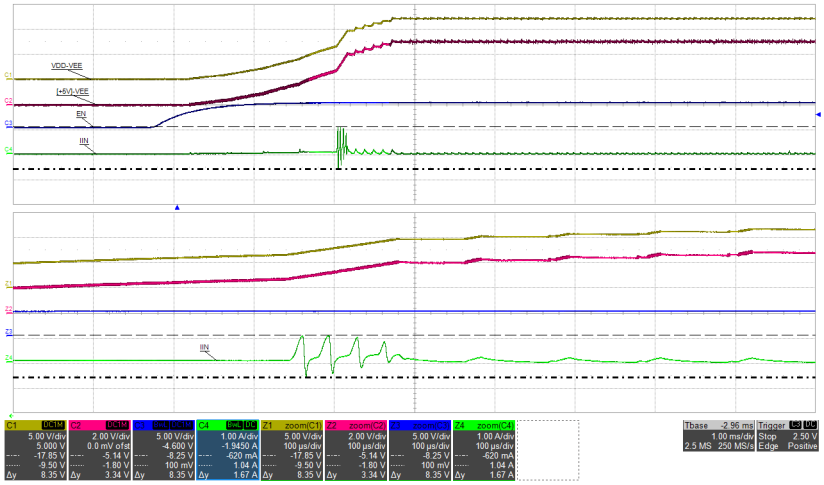


top: VDD-VEE, 5 V/div,	bot: IIN, 1 A/div,
mid-1: [+5 V]-VEE, 2 V/div,	time = 1 ms/div,
mid-2: EN, 5 V/div,	

Figure 5-9. Inrush Current: VIN = 12 V, I_{VDD} = 130 mA, $I_{[+5V]}$ = 10 mA

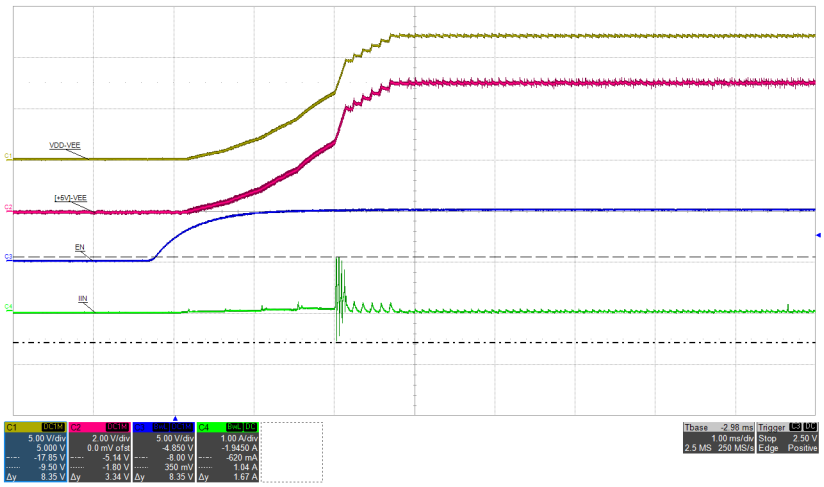
Note

VDD, VEE, and [+5V], etc., refer to Table 4-1 and Figure 4-1.



top: VDD-VEE, 5 V/div,	bot: IIN, 1 A/div,
mid-1: [+5 V]-VEE, 2 V/div,	time = 1 ms/div,
mid-2: EN, 5 V/div,	time_zoom = 100 µs/div

Figure 5-10. Inrush Current: VIN = 12 V, I_{VDD} = 130 mA, $I_{[+5V]}$ = 10 mA

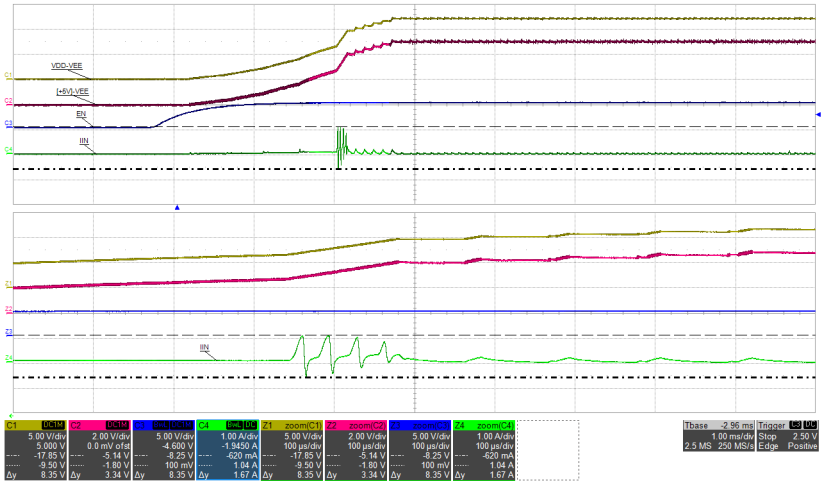


top: VDD-VEE, 5 V/div	bot: IIN, 1 A/div
mid-1: [+5V]-VEE, 2 V/div	time = 1 ms/div
mid-2: EN, 5 V/div,	

Figure 5-11. Inrush Current: VIN = 12 V, I_{VDD} = 0 mA, $I_{[+5V]}$ = 0 mA

Note

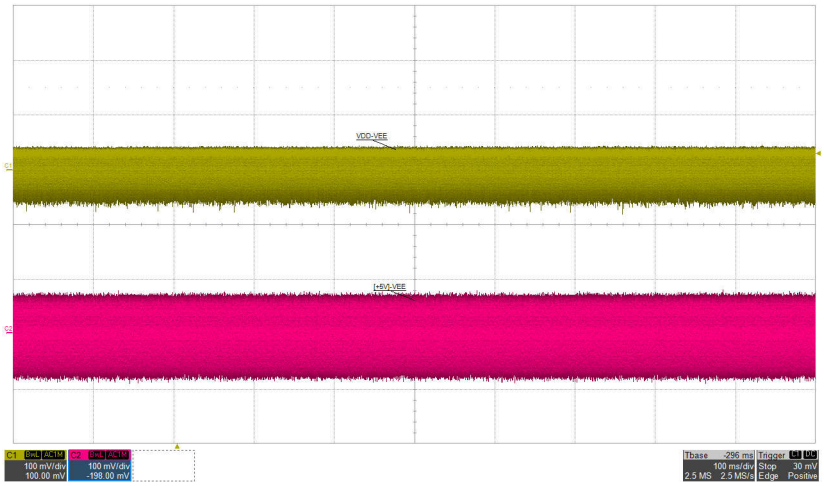
VDD, VEE, and [+5V], etc., refer to Table 4-1 and Figure 4-1.



top: VDD-VEE, 5 V/div,	bot: IIN, 1 A/div,
mid-1: [+5 V]-VEE, 2 V/div,	time = 1 ms/div,
mid-2: EN, 5 V/div,	time_zoom = 100 µs/div

Figure 5-12. Inrush Current: VIN = 12 V, I_{VDD} = 0 mA, $I_{[+5V]}$ = 0 mA

5.6 AC Ripple Voltage

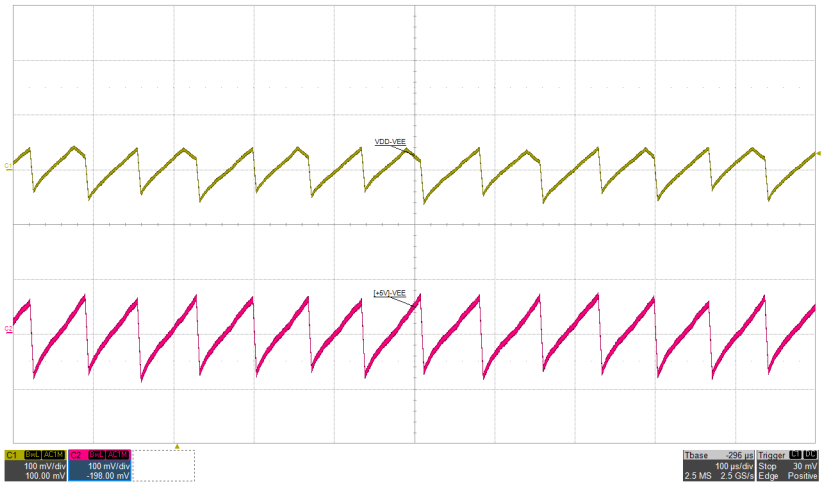


top: VDD-VEE, 100 mV/div,	pk-to-pk = 157 mV),
pk-to-pk = 113 mV,	time = 100 ms/div
bot: [+5 V]-VEE, 100 mV/div,	

Figure 5-13. AC Ripple: VIN = 12 V, I_{VDD} = 130 mA, $I_{[+5V]}$ = 10 mA

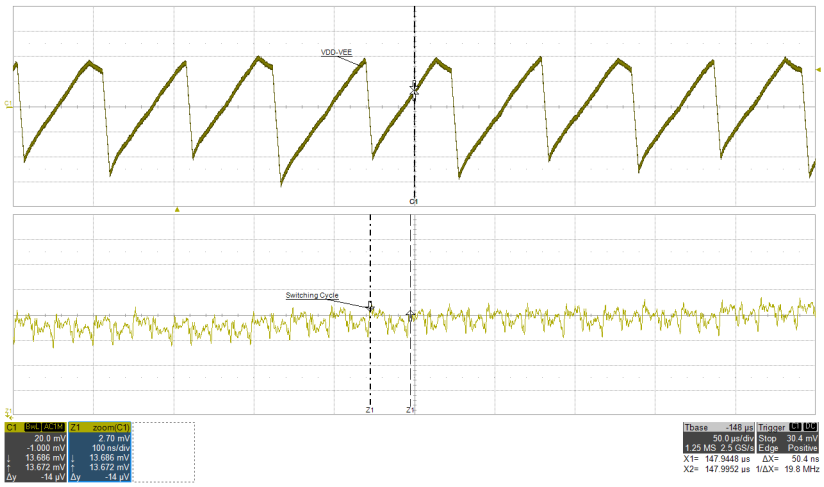
Note

VDD, VEE, and [+5V], etc., refer to Table 4-1 and Figure 4-1.



top: VDD-VEE, 100 mV/div,	time = 100 µs/div	bot: [+5V]-VEE, 100 mV/div)

Figure 5-14. AC Ripple: VIN = 12 V, I_{VDD} = 130 mA, $I_{[+5V]}$ = 10 mA

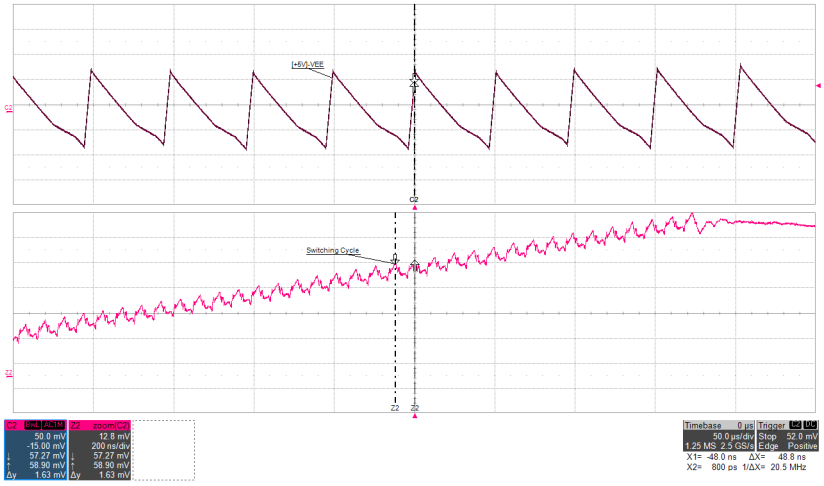


VDD-VEE, 20 mV/div,	time = 50 µs/div,
zoom VDD-VEE, 2.7 mV/div),	time_zoom = 100 ns/div

Figure 5-15. AC Ripple: VIN = 12 V, I_{VDD} =0 mA, $I_{[+5V]}$ = 0 mA

Note

VDD, VEE, and [+5V], etc., refer to Table 4-1 and Figure 4-1.



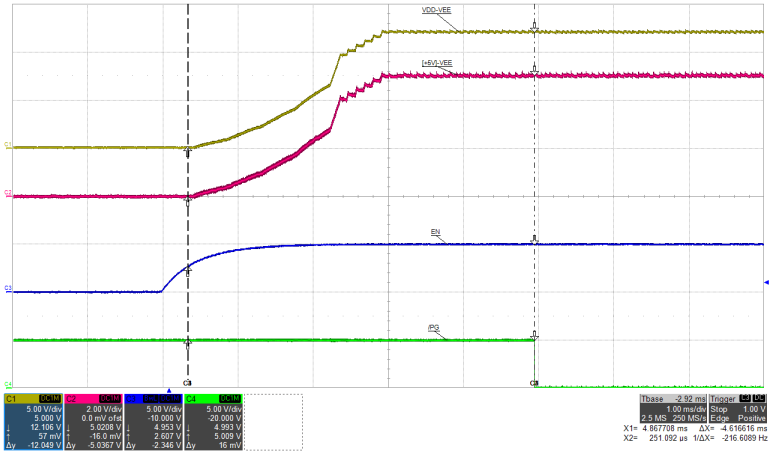
[+5V]-VEE, 50 mV/div,	time = 5 µs/div,
Zoom: [+5V]-VEE, 12.8 mV/div,	time_zoom = 200 ns/div

Figure 5-16. AC Ripple: VIN = 12 V, I_{VDD} = 130 mA, $I_{[+5V]}$ = 10 mA

5.7 EN and Timing

Note

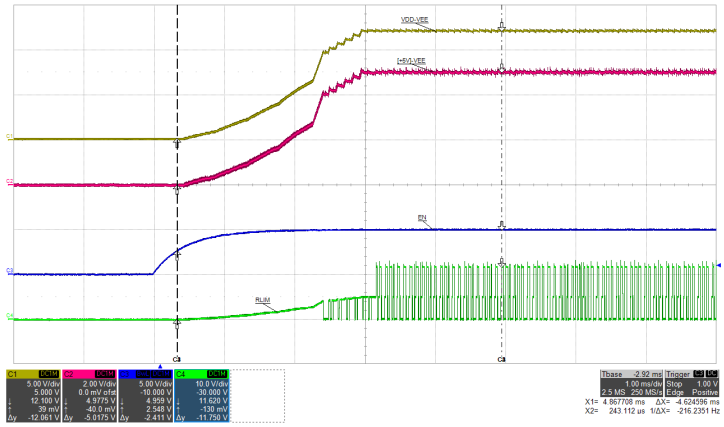
VDD, VEE, and [+5V], etc., refer to Table 4-1 and Figure 4-1



top: VDD-VEE, 5 V/div,	bot: /PG, 5 V/div,
mid-1: [+5 V]-VEE, 2 V/div,	time = 1 ms/div
mid-2: EN, 5 V/div,	

Figure 5-17. EN to /PG Delay, 4.62 ms, I_{VDD} = 0 mA, $I_{[+5V]}$ = 0 mA

5.8 RLIM

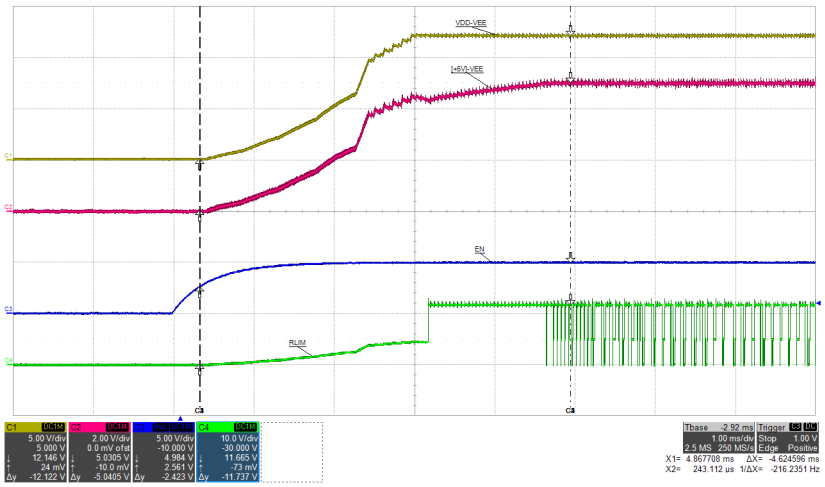


top: VDD-VEE, 5 V/div,	bot: RLIM, 10 V/div,
mid-1: [+5V]-VEE, 2 V/div,	time = 1 ms/div
mid-2: EN, 5 V/div,	

Figure 5-18. RLIM: VIN = 12 V, I_{VDD} = 0 mA, $I_{[+5V]}$ = 0 mA

Note

VDD, VEE, and [+5V], etc., refer to Table 4-1 and Figure 4-1.

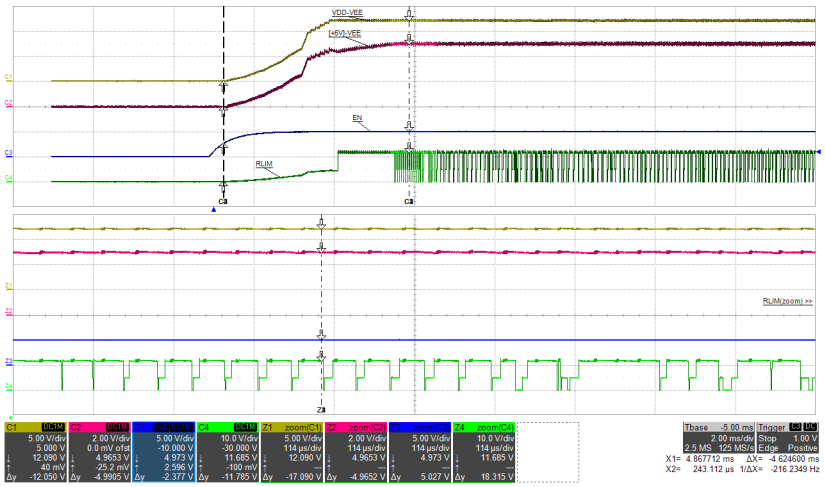


top: VDD-VEE, 5 V/div,	bot: RLIM, 10 V/div,
mid-1: [+5V]-VEE, 2 V/div,	time = 1 ms/div
mid-2: EN, 5 V/div,	

Figure 5-19. RLIM: VIN = 12 V, I_{VDD} = 130 mA, $I_{[+5V]}$ = 10 mA

Note

VDD, VEE, and [+5V], etc., refer to Table 4-1 and Figure 4-1.



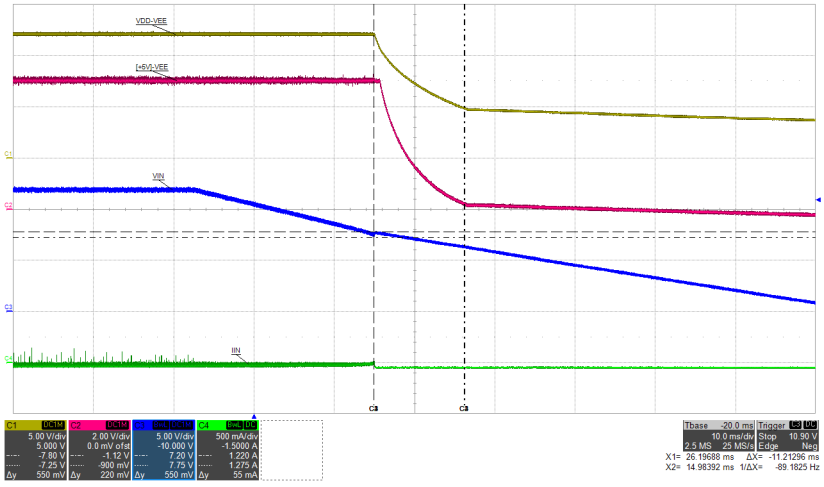
top: VDD-VEE, 5 V/div,	bot: RLIM, 10 V/div,
mid-1: [+5V]-VEE, 2 V/div,	time = 2 ms/div,
mid-2: EN, 5 V/div,	time_zoom = 50 µs/div

Figure 5-20. RLIM: VIN = 12 V, I_{VDD} = 130 mA, $I_{[+5V]}$ = 10 mA

5.9 Shutdown

Note

VDD, VEE, and [+5V], etc., refer to Table 4-1 and Figure 4-1.

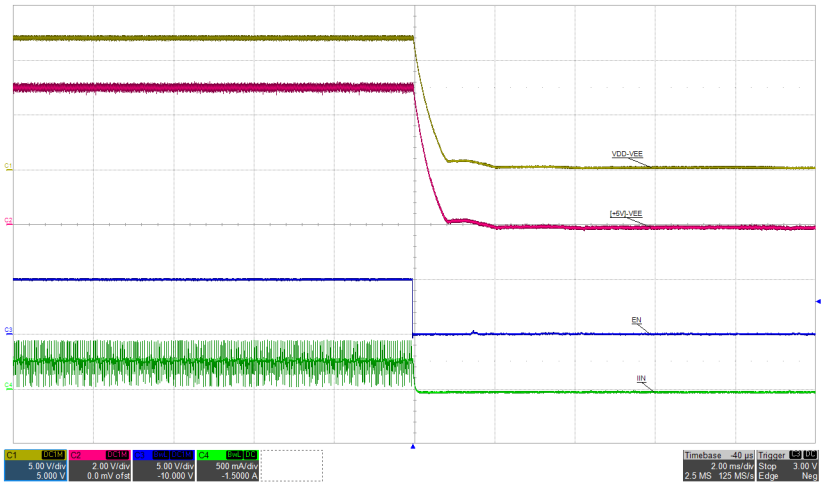


top: VDD-VEE, 5 V/div,	bot: IIN, 1 A/div,
mid-1: [+5V]-VEE, 2 V/div,	time = 10 ms/div
mid-2: VIN, 5 V/div,	

Figure 5-21. Shutdown by VIN Removal: VIN_{OFF} = 7.2 V, I_{VDD} = 0 mA, $I_{[+5V]}$ = 0 mA

Note

VDD, VEE, and [+5V], etc., refer to Table 4-1 and Figure 4-1.

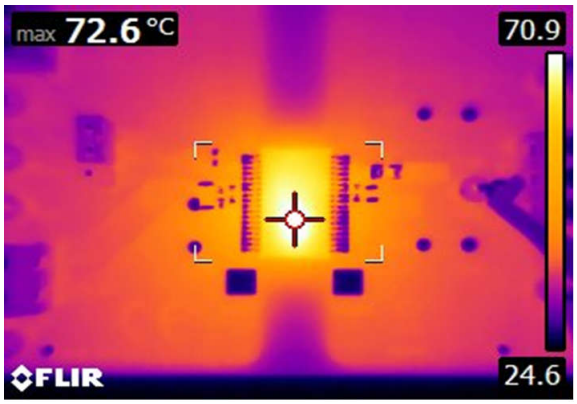


top: VDD-VEE, 5 V/div,	bot: IIN 0.5A/div,
mid-1: [+5V]-VEE, 2 V/div,	time = 2 ms/div
mid-2: EN, 5 V/div,	

Figure 5-22. Shutdown by EN Low: VIN = 12 V, I_{VDD} = 130 mA, $I_{[+5V]}$ = 10 mA

5.10 Thermal Performance

As shown in Figure 5-23 , full load EVM operation can result in very hot U1 package temperature. Use caution not to touch the U1 case when probing or handling the EVM during full load operation.



V_{IN} = 12 V V_{DD} = 12 V I_{VDD} = 128.5 mA
V_{+5V} = 5.01 V I_{+5V} = 0 mA P_{OUT} = 1.54 W
T_{RISE} = 48°C (see Equation 1)

Figure 5-23. VIN=12 V, I_{VDD} = 128.5 mA, 1.54 W

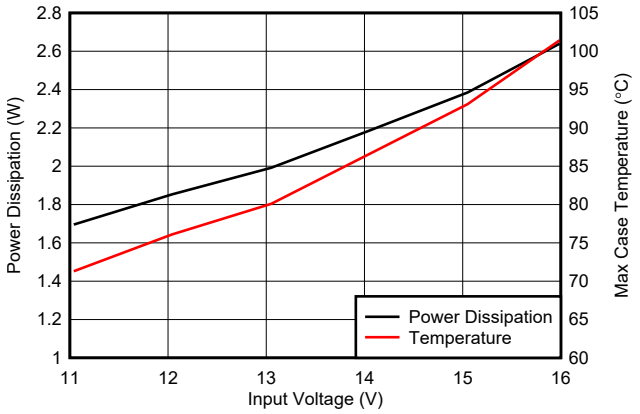
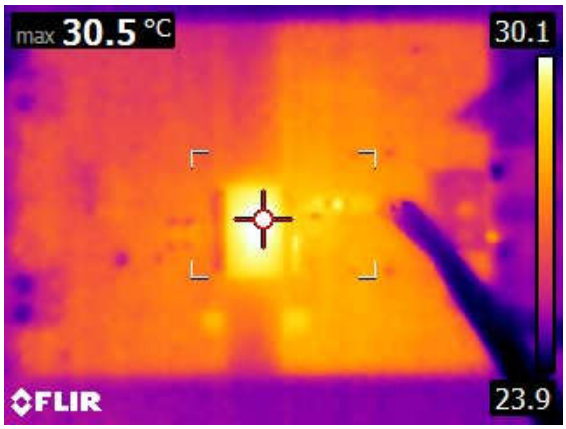


Figure 5-24. Power Dissipation and Case Temperature vs Input Voltage, T_A=24.6°C, 1.54 W

$$T_{RISE} = 72.6°C - 24.6°C = 48°C \quad (1)$$



V_{IN} = 12 V V_{DD} = 12 V I_{VDD} = 0 mA
V_{+5V} = 5.01 V I_{+5V} = 0 mA P_{OUT} = 0 W
T_{RISE} = 6.6 °C (see Equation 2)

Figure 5-25. VIN=12 V, I_{VDD} =0 mA, POUT=0 W

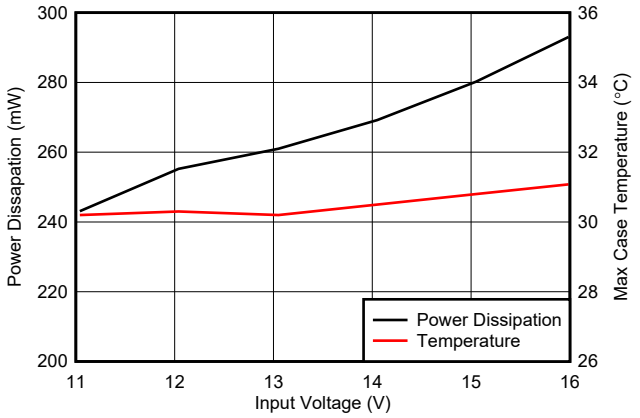


Figure 5-26. Power Dissipation and Case Temperature vs Input Voltage, T_A=23.9°C, 0 W

$$T_{RISE} = 30.5°C - 23.9°C = 6.6°C \quad (2)$$

6 Assembly and Printed Circuit Board (PCB) Layers

The UCC14131EVM-070 is designed using a four-layer, FR4, PCB, fabricated with 2-ounce copper on all four layers. The EVM, PCB demonstrates the important use of ground planes and tented stitching vias for shielding and improving EMI performance. For higher density PCBs such as automotive traction inverters, the PCB can include several additional signal layers but similar design methodology can be applied as best as possible.

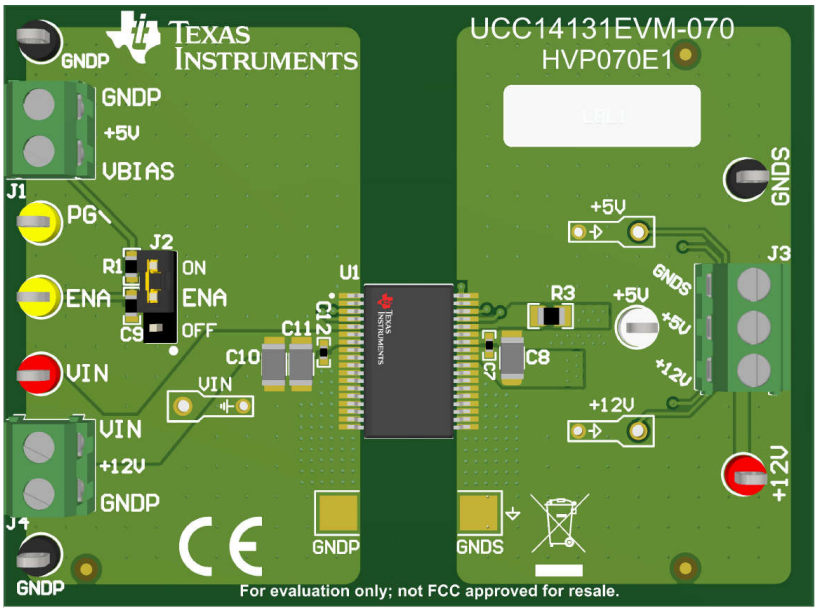


Figure 6-1. UCC14131EVM-070, Fully Assembled 3D Top View

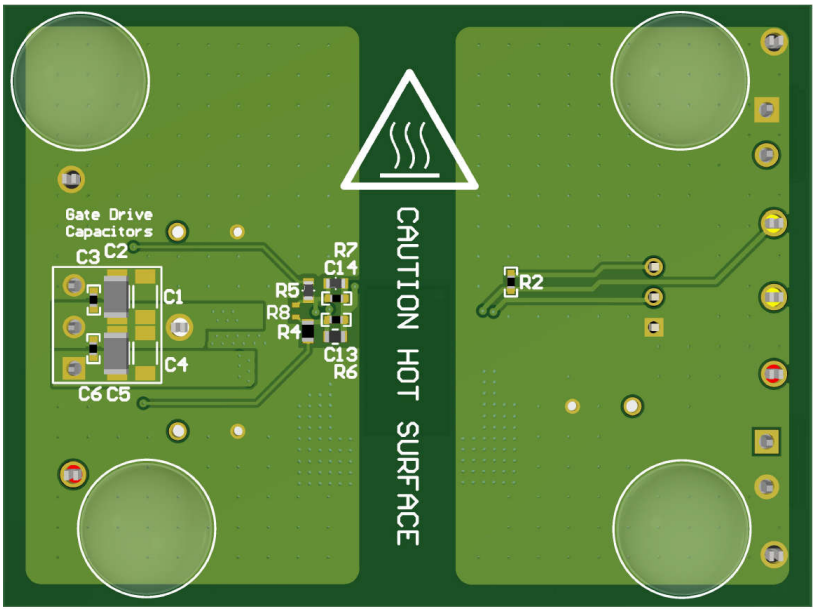


Figure 6-2. UCC14131EVM-070, Fully Assembled 3D Bottom View

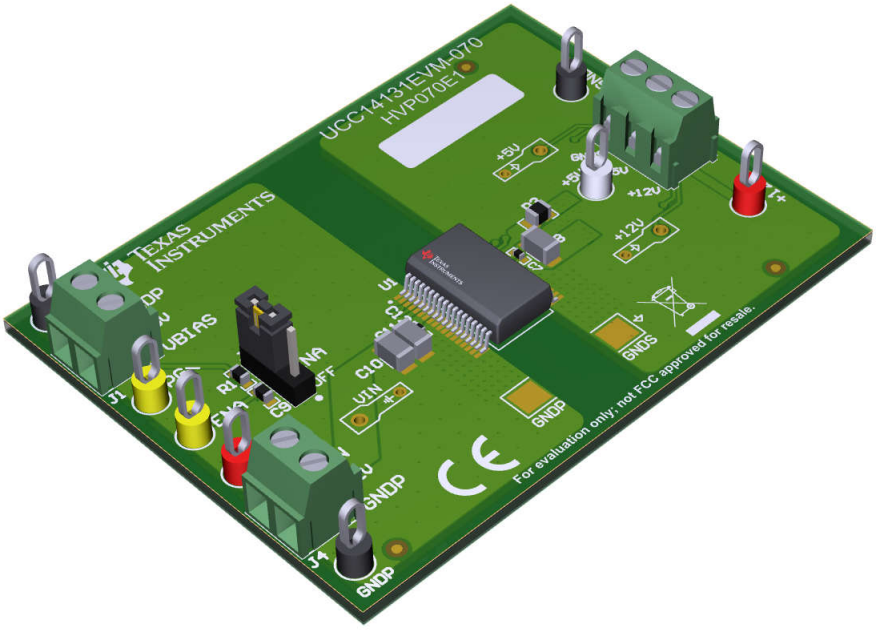


Figure 6-3. UCC14131EVM-070, 3D Angle View

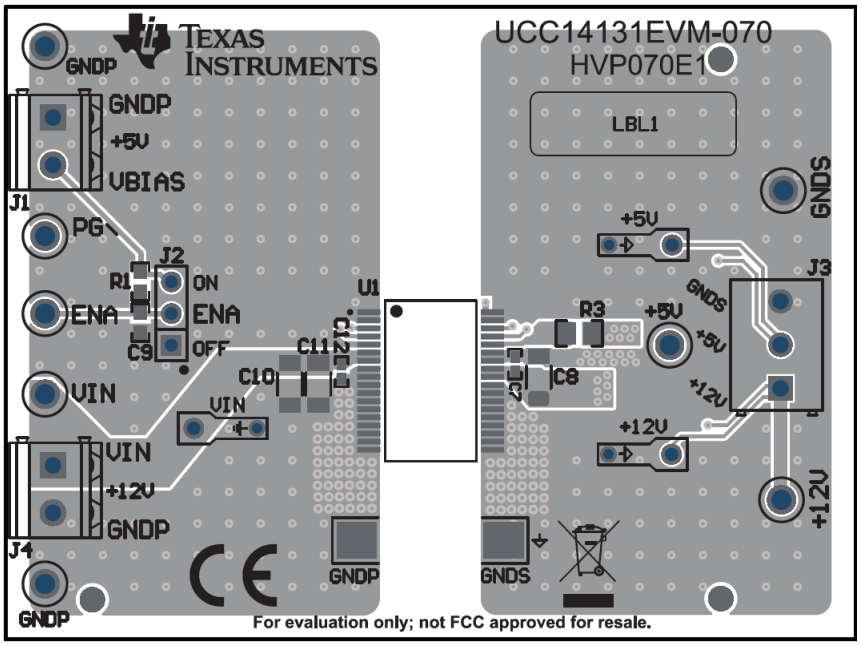


Figure 6-4. UCC14131EVM-070, PCB Top Layer, Assembly

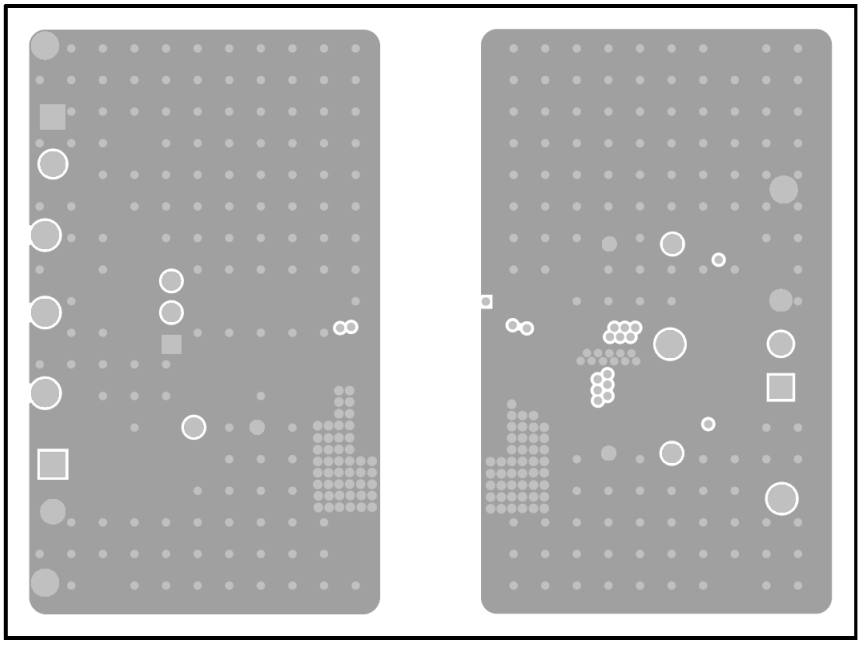


Figure 6-5. UCC14131EVM-070, GND Layer 2 (same as layer 3)

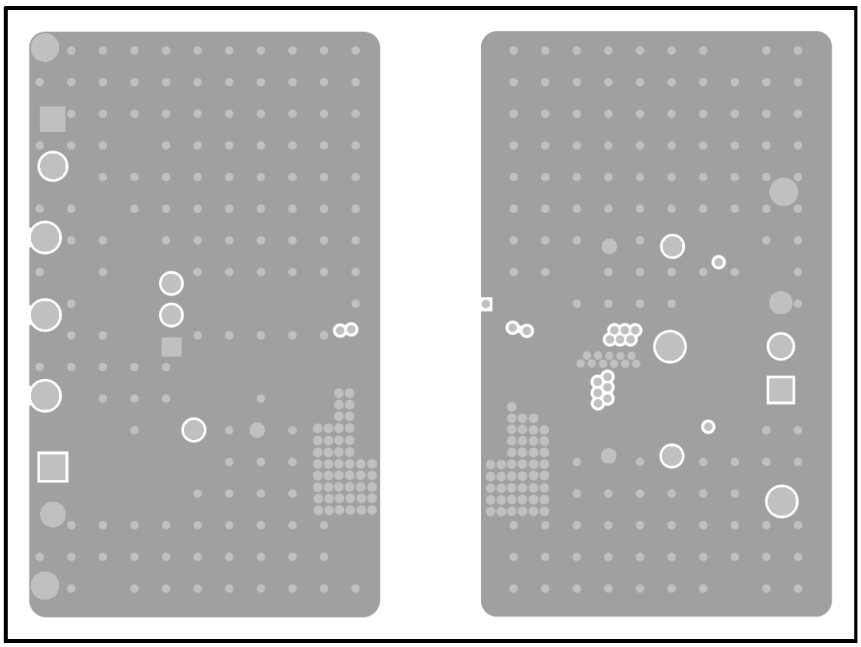


Figure 6-6. UCC14131EVM-070, GND Layer 3 (same as layer 2)

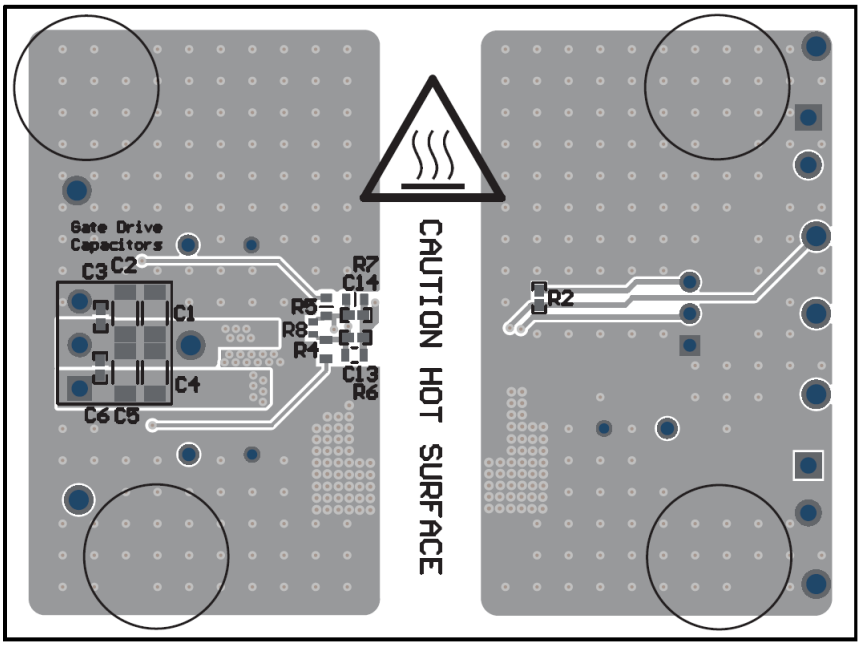


Figure 6-7. UCC14131EVM-070, PCB Bottom Layer, Assembly (mirrored view)

7 Bill of Materials (BOM)

Table 7-1. UCC14131EVM-070 BOM

Designator	Qty	Description	Part Number	Manufacturer
PCB1	1	Printed Circuit Board	HVP070E1	Any
C1	0	CAP, CERM, 10 µF, 35 V, +/- 10%, X7R, AEC-Q200 Grade 1, 1206_190	CGA5L1X7R1V106K160AC	TDK
C2, C8, C10, C11	4	CAP, CERM, 10 µF, 35 V, +/- 10%, X7R, AEC-Q200 Grade 1, 1206_190	CGA5L1X7R1V106K160AC	TDK
C3,C6, C7, C12	4	CAP, CERM, 0.1 µF, 50 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0402	GCM155R71H104KE02D	MuRata
C4	0	CAP, CERM, 6.8 µF, 35 V, +/- 10%, X7R, AEC-Q200 Grade 1, 1206_190	CGA5L1X7R1V685K160AC	TDK
C5	1	CAP, CERM, 6.8 µF, 35 V, +/- 10%, X7R, AEC-Q200 Grade 1, 1206_190	CGA5L1X7R1V685K160AC	TDK
C9	1	CAP, CERM, 0.047 µF, 16 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	AC0603KRX7R7BB473	Yageo
C13, C14	2	CAP, CERM, 330 pF, 50 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0402	CGA2B2X7R1H331K050BA	TDK
H1, H2, H3, H4	4	Bumpon, Hemisphere, 0.44 X 0.20, Clear, Adhesive	SJ-5303 (CLEAR)	3M
J1, J4	2	Terminal Block, 2x1, 3.81mm, 24-16 AWG, 10 A, 300 VAC, TH	691214310002	Wurth Elektronik
J2	1	Header, 100mil, 3x1, TH	PEC03SAAN	Sullins
J3		Terminal Block, 3.5mm, 3x1, TH	691214110003	Wurth Elektronik
R1	1	RES, 10.0 kΩ, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060310K0FKEA	Vishay-Dale
R2	1	RES, 100 kΩ, 5%, 0.1 W, AEC-Q200 Grade 0, 0402	ERJ-2GEJ104X	Panasonic
R3	1	RES, 475 Ω, 1%, 0.125 W, AEC-Q200 Grade 0, 0805	CRCW0805475RFKEA	Vishay-Dale
R4	1	RES, 42.2 kΩ, 0.1%, 0.1 W, 0603	RT0603BRD0742K2L	Yageo
R5, R7	2	RES, 49.9 kΩ, 0.1%, 0.1 W, 0603	ERA-3AEB4992V	Panasonic
R6	1	RES, 11.1 kΩ, 0.1%, 0.1 W, AEC-Q200 Grade 0, 0603	TNPW060311K1BEEN	Vishay-Dale
R8	0	RES, 0 Ω, 5%, 0.1 W, AEC-Q200 Grade 0, 0402	ERJ-2GE0R00X	Panasonic
SH-J1	1	Shunt, 100mil, Gold plated, Black	SNT-100-BK-G	Samtec
TP1, TP10, TP11	3	Test Point, Multipurpose, Black, TH	5011	Keystone
TP2, TP5	2	Test Point, Multipurpose, Yellow, TH	5014	Keystone
TP4	1	Test Point, Multipurpose, White, TH	5012	Keystone
TP7, TP8	2	Test Point, Multipurpose, Red, TH	5010	Keystone
U1	1	1.5W, 12V-Vin, 12V-Vout, High-Density, 5 kVRMS Isolated DC-DC Module	UCC14131DWNQ1	Texas Instruments
U1-alternate	0	1.5W, 12V-Vin, 12V-Vout, High-Density, 3 kVRMS Isolated DC-DC Module	UCC14130DWNQ1	Texas Instruments

8 Revision History

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

Changes from Revision * (March 2023) to Revision A (September 2023)	Page
• Changed *Abstract* to include UCC14130-Q1 and UCC14131-Q1	1
• Added *U1 Component Selection* section	3
• Changed capacitor recommendation on row *VIN, Pin 6, 7* in Table 1-2	3
• Added 1x, U1-alternate part numbers to include UCC14130-Q1	30

STANDARD TERMS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.

   1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM (“Software”) shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software

   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 *Limited Warranty and Related Remedies/Disclaimers*:

   2.1 These terms do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.

   2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

WARNING

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

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

NOTE:

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

3 *Regulatory Notices:*

3.1 *United States*

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

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

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

CAUTION

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

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

FCC Interference Statement for Class A EVM devices

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

FCC Interference Statement for Class B EVM devices

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

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

3.2 *Canada*

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

Concerning EVMs Including Radio Transmitters:

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

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

Concernant les EVMs avec appareils radio:

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

Concerning EVMs Including Detachable Antennas:

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

Concernant les EVMs avec antennes détachables

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

3.3 *Japan*

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

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

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

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

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

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

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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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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.

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