LMS36x5x-Q1 EVM User's Guide

The LMS3655xQEVM is specifically designed for automotive and high-performance industrial applications, providing an output voltage of 5 V, 3.3 V, or an adjustable output at a continuous load of 5.5-A. The LMS3635xQEVM is implemented using the same PCB board and components, but the IC current limit is set for a maximum continuous load of 3.5-A. The LMS3655xQEVM can be used to evaluate both the LMS3655-Q1 IC and the LMS3655 IC.

Figure 1. LMS3635xQEVM and LMS3655xQEVM Evaluation Board – Top View

All aspects of the LMS3635xQEVM and LMS3655xQEVM are optimized for high-performance industrial and automotive markets. An input voltage range to 36 V eases the input surge protection design. Exceptional dropout performance allows for the elimination of a boost stage in many designs for start and stop applications. An open-drain RESET output, with filtering and Power Good delay, provides a true indication of system status. This feature negates the requirement for additional supervisory circuitry, saving cost, and board space. Seamless transition between PWM and PFM operation, along with a low quiescent current, ensures high efficiency at all loads. The Texas Instruments LMS3655xQEVM and LMS3635xQEVM help to evaluate the operation and performance of the LMS3655-Q1, LMS3655, and LMS3635-Q1. The LMS36x5xQEVM is available for order in four variants.

See Table 1 for orderable EVM variants and configurations.

Table 1. Orderable EVM Variants and Configuration for LM53625 and LM53635

EVM VARIANT	EVM ORDERABLE NAME	IC U1	CONTINUOUS LOAD	OUTPUT VOLTAGE	SPREAD SPECTRUM	AVAILABLE
001	LMS3655AQEVM	LMS3655AQRNLRQ1	5.5 A	5 V Adjusted	—	Yes
002	LMS3655MQEVM	LMS3655MQRNLRQ1	5.5 A	5 V Adjusted	Yes	Yes
003	LMS3655NQEVM	LMS3655NQRNLRQ1	5.5 A	3.3 V Fixed	Yes	Yes
004	LMS3635MQEVM	LMS3635MQRNLRQ1	3.5 A	5 V Adjusted	Yes	Yes

Contents

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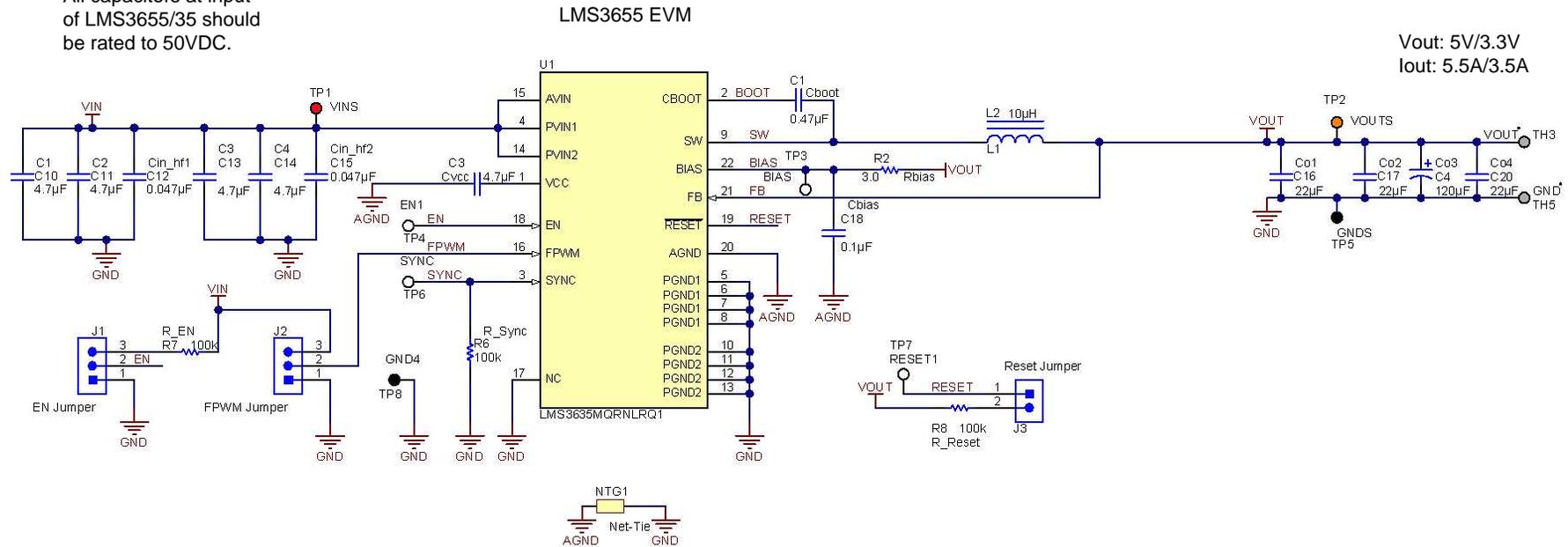
1   Technical Specification EVM Board

Table 2 shows specifications for the LMS3635xQEVM and LMS3655xQEVM board.

Table 2. Technical Specification

| BOARD SIZE			
	4000 × 3000 mil	101 mm × 76 mm	76 cm^2
BOARD LAYER			
	4-Layer FR4 PCB	Top Layer1 and Bottom Layer2 Mid Layer2 and Mid Layer3	2.8-mil, 2-oz. Cu 1.4-mil, 1-oz. Cu
SOLUTION SIZE			
	700 mil × 1700 mil	17.78 mm × 43.18 mm	7.68 cm^2
POWER INPUT			
	VIN1 and GND1 IN+ / IN–	Power Supply Input Power Input for EMI Test	typical 13.5 V (range 3.5 to 36 V) typical 13.5 V (range 3.5 to 36 V)
POWER OUTPUT			
	VOUT and GND	Power Output to Load	typical 3.3 V or 5 V
JUMPERS			
	J1 FPWM pin J2 ENABLE pin J3 RESET pin	Auto Mode or Forced PWM Enable LMS3635x and LMS3655x Open-drain output	Set – Default [AUTO-MODE] Set – Default [EN-VIN] Optional - [RESET-VOUT]
TEST POINTS			
	GNDS, GND2 and GND3 EN VINS VOUTS BIAS RESET SYNC	Sense GND Points Enable Pin Voltage Input Voltage Sense Output Voltage Sense BIAS Voltage Sense RESET output Switch node SYNC input	Sense Ground If J2[EN-VIN], then EN = VIN1 3.5 to 36 V Sense VIN1 3.5 to 36 V Sense VOUT typical 3.3 V or 5 V Sense BIAS typical 3.3 V or 5 V If J3 [RESET-VOUT], then RESET = VOUTS External sync frequency source

2   Schematics

Figure 2. Fixed - Output Voltage Option Schematic

The fixed voltage option has an internal resistor divider, and the FB pin connects directly to the output capacitance.

NOTE: Cvcc and Cbias must connect directly to AGND, pin 20.

All capacitors at input of LMS3655/35
should be rated to 50VDC.

V_{OUT} : 3.3V/5V
I_{OUT} : 5.5A/3.5A
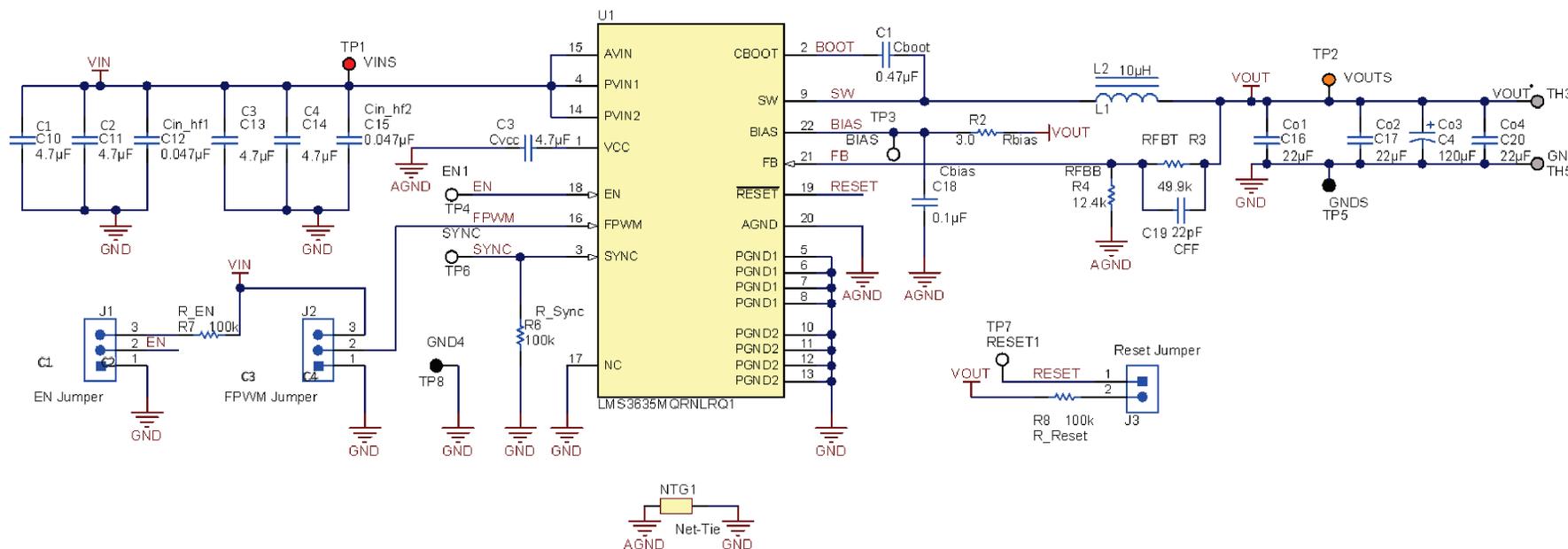
Figure 3. Adjustable - Output Voltage Option Schematic

The adjustable output option uses an external resistor divider to define output voltage. The CFF capacitor can be adjusted to make the feedback loop response faster for load transients. By lowering the total resistance of the feedback divider, the noise immunity can be increased.

NOTE: To minimize noise coupling into the feedback pin, the maximum resistance recommended for the feedback resistor RFBT is 50 kΩ. The feedback resistors RFBB and RFBT must be placed as close to the FB pin as possible, and RFBB must be grounded to the AGND pin.

3 Board Layout

The LMS3655xQEVM uses a four-layer PCB stack-up design. Top Layer 1 and Bottom Layer 4 are implemented using 2-oz. copper for optimized heat transfer and dissipation. Mid Layer 2 and Mid Layer 3 use 1-oz. copper. Total PCB thickness is 61 mil (1.55 mm).
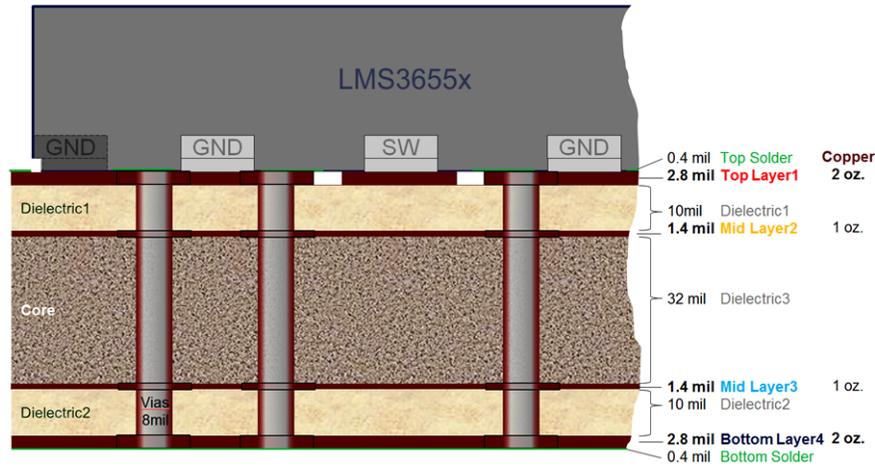

Figure 4. Four-Layer PCB Stack-Up

The overall EVM PCB board size dimension is 4000 mil × 3000 mil (101 mm × 76 mm) with a top surface area of 76 cm^2. All vias on the PCB are constructed using 8-mil drill through-hole with 16-mil pad size.

Figure 5 to Figure 8 shows the PCB Layout for each Cu Layer. Top Layer 1 and Bottom Layer 4 are constructed using large filled Cu areas connected to GND. This is done to improve thermal performance as well as improve overall EMI performance. Mid Layer 2 is constructed using a large GND plane. The purpose is to minimize loop inductance by placing metal directly under the Top Layer 1 traces, which minimizes the cross section of current loops. Mid Layer 3 is mainly used to route non-critical signal traces to the IC.


NOTE: The PCB layout is not fully optimized to use for final applications, but gives a good starting point. The layout can be simplified and optimized by eliminating features included for evaluation purposes such as measurement sense lines, jumper connections, and features unused in a particular application such as the feedback resistor divider for fixed voltage options.
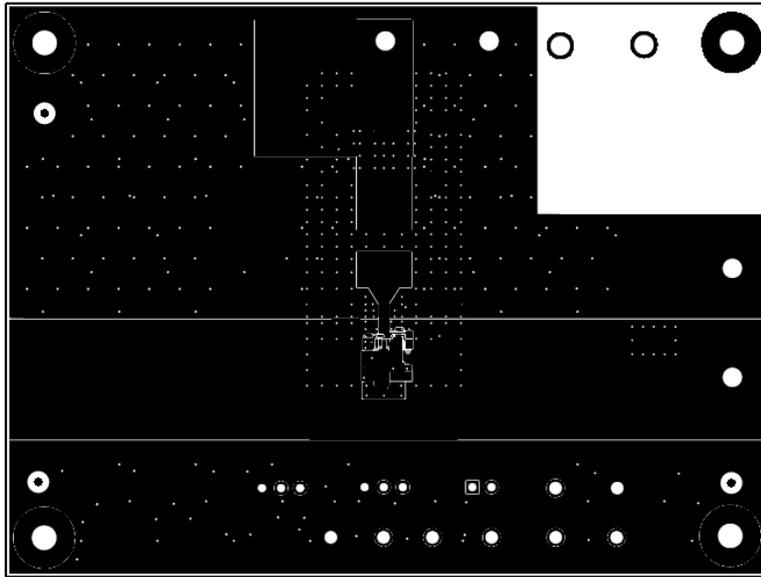
Figure 5. PCB Layout Top Layer 1 – Top View
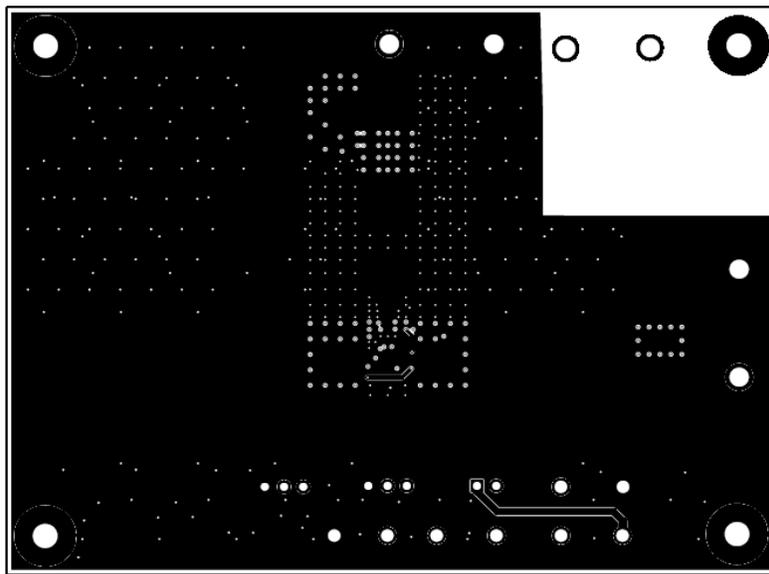
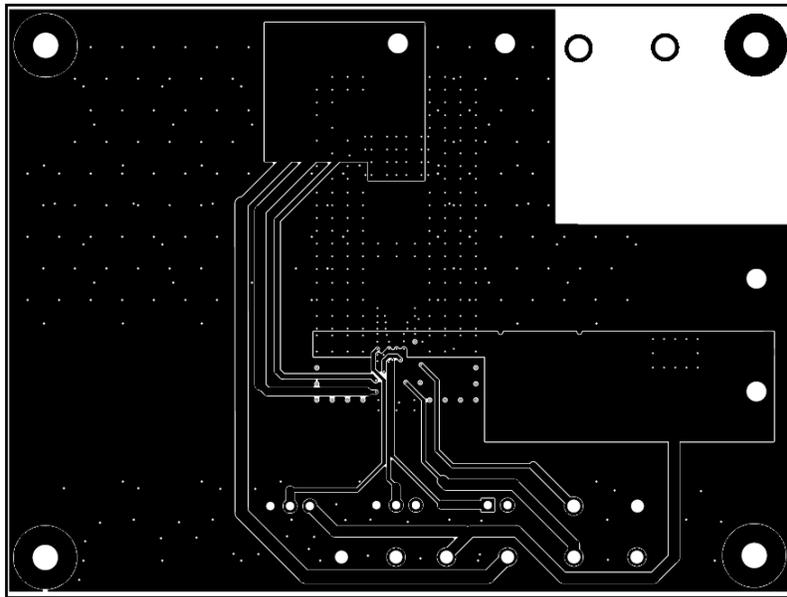**Figure 6. PCB Layout Mid Layer 2 GND Plane – Top View**

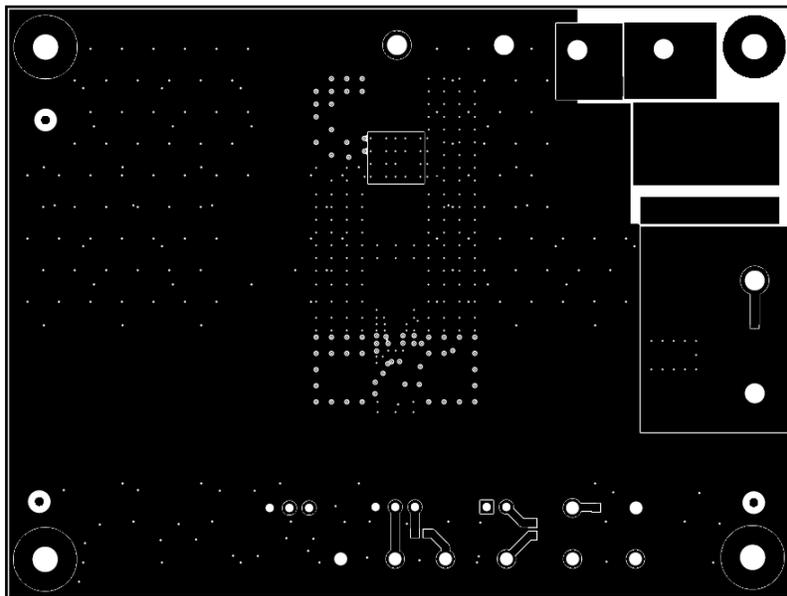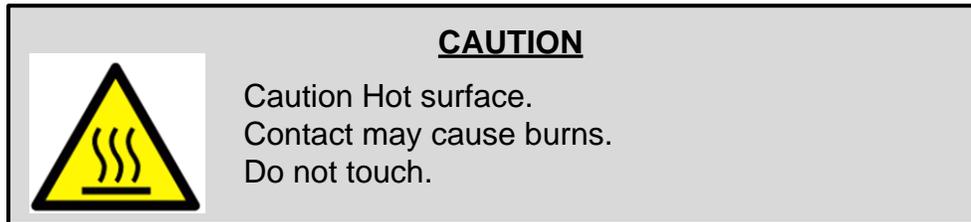**Figure 7. PCB Layer Mid Layer 3 – Top View**

Figure 8. PCB Layer Bottom Layer 4 – Flipped View (as Seen From Bottom of Board)

Figure 9. PCB Layer Composite Top

Figure 10. PCB Layer Composite Bottom

4   Operation and Test Setup

<table>
<tr><td rowspan="2">[hot surface warning icon]</td><td style="text-align:center"><u>CAUTION</u></td></tr>
<tr><td>Caution Hot surface.
Contact may cause burns.
Do not touch.</td></tr>
</table>

4.1   Efficiency Measurement

1. Connect power supply to posts VIN1 and GND1, and verify that the power supply provides sufficient current.

    NOTE: There is no reverse polarity protection or fuse on the evaluation board.

2. Connect electronic load to posts VOUT and GND. For all power wires, it is preferable to use twisted lab wires to reduce inductive parasitic of lab cables. If the power supply wires are very long > 50 cm, solder additional 470-µF, 50-V bulk capacitor to posts VIN1 and GND1. Always use sufficient power wires and separate measurement sense wires.

    NOTE: These sense lines are not designed to carry power.

3. To accurately sense input and output voltage use the test points VINS, VOUTS, and GNDS. Alternatively, sense wires can be soldered directly over input capacitors C1, C2, C3, or C4 and the output capacitors Co1, Co2, Co3, and Co4.

4. Make sure the IC is enabled by having jumper J2 set to [EN-VIN] and check test point EN is driven high. While measuring I_{Q_VIN} (unloaded input current), remove all the input and output voltage probes that are most likely causing additional current draw.

    NOTE: If the jumper J1 is set to [MODE-FPWM], the part will have a lower efficiency at light loads by maintaining the 400-kHz switch frequency. To measure the highest light load efficiency place the Jumper J1 in [AUTO-MODE].

4.2 *Measure Load Transient*

1. Connect power supply to posts VIN1 and GND1, and make sure the power supply can provide sufficient peak current.

   NOTE: There is no reverse polarity protection or fuse on the evaluation board.

2. Connect transient load to posts VOUT and GND. For all power wires, it is preferable to use twisted lab wires to reduce inductive parasitic of lab cables. If the power supply wires are very long > 50 cm, solder additional 470-µF, 50-V bulk capacitor to posts VIN1 and GND1. Use sufficient power wires to avoid voltage drops and use short sense probe connection for the measurement.

3. To accurately sense the output voltage, the scope probe must be placed directly over the output capacitors Co1, Co2, Co3, and Co4. Make sure to connect the scope probe GND ring directly to the output capacitor GND pad for minimal ground loop. Ground loops can introduce ringing in observed waveforms which is an artifact; not present on the PCB. Alternatively use a differential probe over the output capacitors. Do not use wires as a differential probe and always probe directly with shortest possible pins.

   Make sure the IC is enabled by having jumper J2 set to [EN-VIN] and check test point EN is driven high and not drooping during the load transient.

4.3 *Measure EMI*

1. Connect power supply cable from LISN to posts IN+ and IN–, and make sure the board is placed 5 cm above the table.

   NOTE: The length of the LISN cable to VIN+/VIN– must be between 20 cm to 40 cm for conducted EMI CISPR 25.

2. Connect resistive load directly to posts VOUT and GND. Use extremely short leads.

   NOTE: To accurately measure EMI, make sure the table has a good ground connection to the chamber; connect the battery GND cable to the table without touching the EVM, especially the region near the switch node. The board has a very effective 3-stage EMI filter where the common-mode choke is not assembled by default. If the common-mode choke is added, remove the bypass resistors R1 and R2.
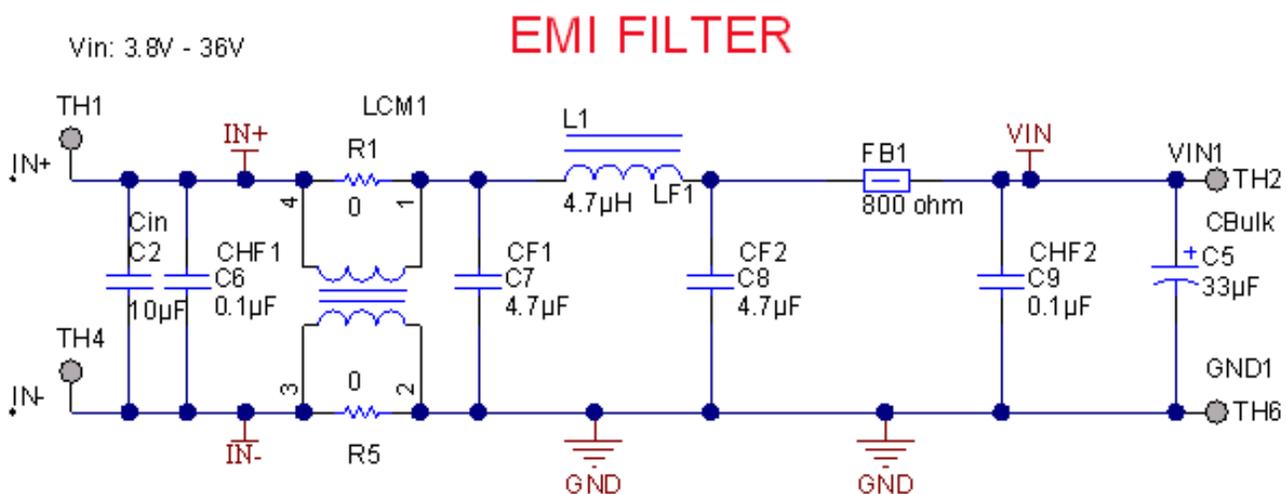
Figure 11. 3-Stage EMI Filter Schematic

5   Posts, Probes, and Jumpers

5.1   VIN1 and GND1 Posts

The VIN1 and GND1 posts are standard input posts for connecting a power supply. The maximum input voltage is 36 V with 42-V absolute maximum transient.

5.2   VOUT and GND Posts

The VOUT and GND posts are standard output posts for loading the EVM. Use sufficient lab cables and preferably twisted wires to reduce inductive parasitic of lab cables. The typical output voltage is 5 V or 3.3 V.

5.3   IN+ and IN– Posts

Use IN+ and IN- for EMI measurements. When using IN+ and IN– posts, the IC is operated with an input EMI filter. By default there is a 2-stage filter assembled with a wire wound Inductor PI-Filter for low frequency filtering followed by a ferrite bead for high-frequency filtering. If one wishes to measure a setup with a common-mode choke, add the choke by removing bypass resistors R1 and R2.

5.4   EN and GND2 Probe

EN and GND2 probe can be used to measure the enable voltage or drive it from external source. If an external source is used, make sure to remove jumper J2. By default J2 jumper connects EN to VIN.

5.5   VINS, VOUTS, and GNDS Probe

VINS and VOUTS are sense points for input and output voltage.

> **NOTE:** Do not use for power supply or load.

These probe points are intended for use as kelvin sense points for static measurements including efficiency, line regulation, and load regulation. For dynamic measurements please measure directly over the input capacitors C1, C2, C3, and C4, and directly over the output capacitors Co1, Co2, Co3, and Co4.

5.6   BIAS and GNDS Probe

The BIAS probe senses the bias voltage to the IC. Bias voltage is provided from the output voltage of the IC over Rbias = 3-Ω resistor. An external bias supply voltage can be provided by removing Rbias to disconnect IC output voltage as the source for bias.

5.7 $\overline{RESET}$ and GND3 Probe

$\overline{RESET}$ provides an accurate Power Good signal with release delay. By default jumper J3 is set to VOUT and pulls the $\overline{RESET}$ pin to VOUT through a 100-kΩ resistor. Since $\overline{RESET}$ is an open-drain output, it can also be pulled to other external voltage levels by removing jumper J3.

5.8   SYNC and GND3 Probe

By default the IC is running with internal oscillator at 400 kHz. Over the SYNC pin, an external function generator can be connected to take control of the LMS3635 and LMS3655's clock, changing the switching frequency. SYNC function can be used for custom frequency modulation techniques. Spread spectrum will always be disabled when a SYNC signal is present.

5.9 Jumper J1

Jumper J1 sets light load operation mode of the IC. If set to [AUTO-MODE] when lightly loaded the IC goes automatically into PFM operation with fewer switching pulses and higher efficiency. The IC can be set into forced PWM mode (jumper position is marked *FPWM*) to operate with a constant switching frequency over the entire load range. This forced FPWM mode of operation will have improved load transient behavior because there is no operation mode change during load transient steps.

5.10 Jumper J2

Jumper J2 enables the IC. By default it is set to [EN-VIN] and pulls the enable pin through a 100-kΩ resistor to Vin. If an external source drives the EN pin, then remove jumper J2 and use probe points EN and GND2 or use a 3-pin wire connector directly plugged over J2.

5.11 Jumper J3

Jumper J3 pulls the open-drain $\overline{\text{RESET}}$ output to VOUT through a 100-kΩ resistor. If another $\overline{\text{RESET}}$ output level is needed, use probe point $\overline{\text{RESET}}$ and pullup resistor to external reference voltage and remove jumper J3.
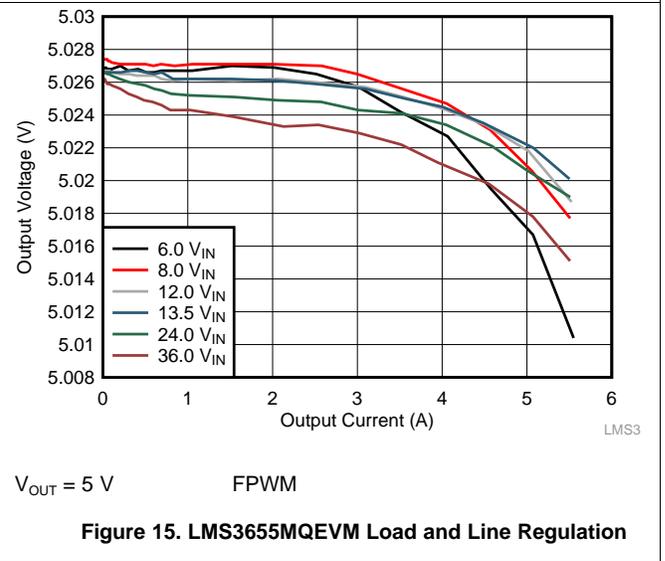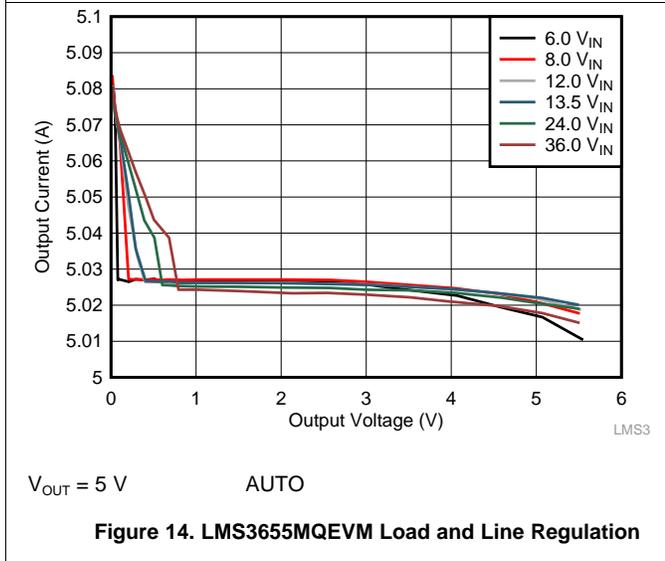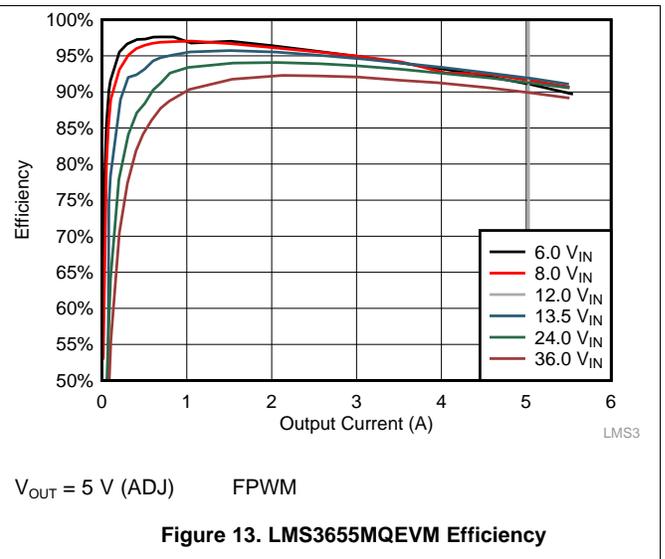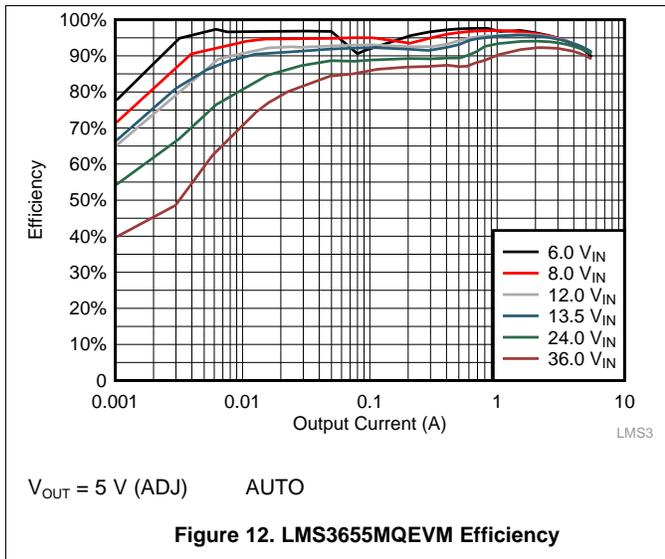
6 Bill of Materials

Table 3. Bill of Materials

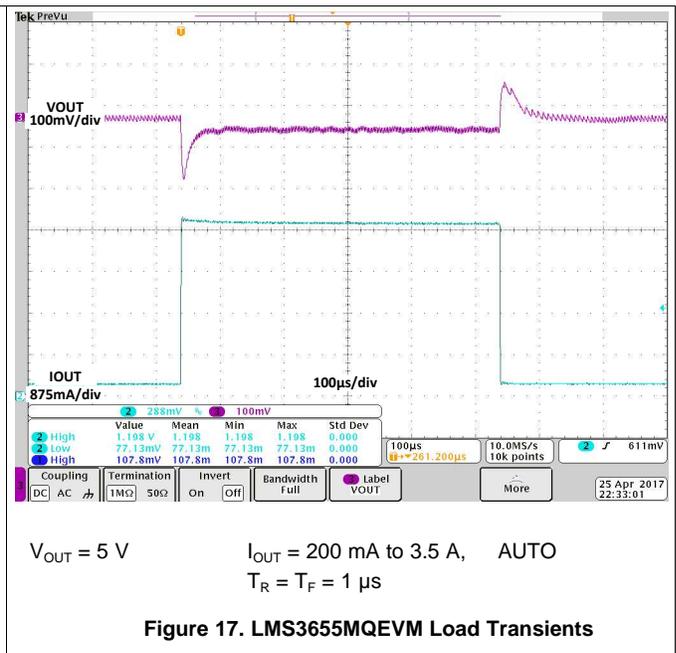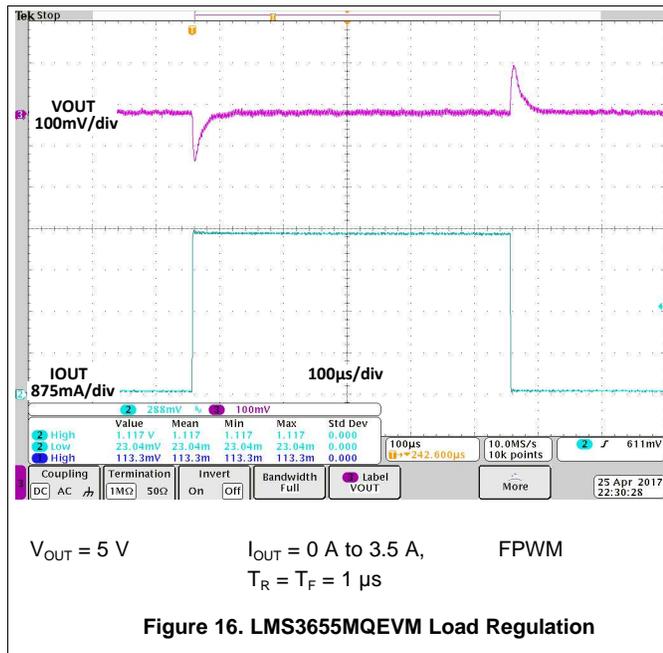| DESIGNATOR	QTY	VALUE	DESCRIPTION	PART NUMBER
C1	1	0.47 µF	CAP, CERM, 0.47 µF, 25 V, ±10%, X7R, 0603	GRM188R71E474KA12D
C2	1	10 µF	CAP, CERM, 10 µF, 50 V, ±10%, X7R, 1210	UMK325AB7106KM-T
C3	1	4.7 µF	CAP, CERM, 4.7 µF, 16 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0805	GCM21BR71C475KA73L
C4	1	120 µF	CAP, AL, 120 µF, 16 V, +/- 20%, 0.024 ohm, SMD	APXE160ARA121MH70G
C5	1	33 µF	CAP, Aluminum Polymer, 33 µF, 50 V, +/- 20%, 0.04 ohm, AEC-Q200 Grade 1, D6.3xL7.7mm SMD	HHXA500ARA330MF80G
C6, C9	2	0.1 µF	CAP, CERM, 0.1 µF, 50 V, ±10%, X7R, AEC-Q200 Grade 1, 0603	06035C104KAT2A
C7, C8, C10, C11	4	4.7 µF	CAP, CERM, 4.7 µF, 50 V, ±20%, X7R, AEC-Q200 Grade 1, 1210	CGA6P3X7R1H475M250AB
C12, C15	2	0.047 µF	CAP, CERM, 0.047 µF, 50 V, +/- 10%, X7R, 0603	GRM188R71H473KA61D
C18	1	0.1 µF	CAP, CERM, 0.1 µF, 16 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	GCM188R71C104KA37J
FB1	1	800 Ω	Ferrite Bead, 800 Ω at 100 MHz, 8A, 1206	HR2220V801R-10
H1, H2, H3, H4	4		Machine Screw, Round, #4-40 × 1/4, Nylon, Philips panhead	NY PMS 440 0025 PH
H5, H6, H7, H8	4		Standoff, Hex, 0.5"L #4-40 Nylon	1902C
J1, J2	2		Header, 100 mil, 3×1, Gold, TH	HTSW-103-07-G-S
J3	1		Header, 100 mil, 2×1, Gold, TH	HTSW-102-07-G-S
L1	1	4.7 µH	Inductor, Wirewound, Ferrite, 4.7 µH, 7.5 A, 0.0135 ohm, SMD	7443340470
L2	1	10 µH	Inductor, Shielded Drum Core, WE-Superflux200, 10 µH, 7.5 A, 0.0163 ohm, SMD	7443251000
LBL1	1		Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll	THT-14-423-10
LCM	1		Coupled inductor, 5 A, 0.01 Ω, SMD	ACM9070-701-2PL-TL01
R1, R2	2	0 Ω	RES, 0Ω, 5% 0.25 W, 1206	CRCW12060000Z0EA
R2	1	3 Ω	RES, 3 Ω, 5%, 0.063 W, 0402	CRCW04023R00JNED
R6, R7, R8	3	100 k	RES, 100 K, 5%, 0.1 W, 0603	CRCW0603100KJNEA
SH-J1, SH-J2, SH-J3	3	1×2	Shunt, 100 mil, Gold plated, Black	969102-0000-DA
TP1	1		Test Point, Miniature, Red, TH	5010
TP2	1		Test Point, Miniature, Orange, TH	5013
TP3, TP4, TP6, TP7	4		Test Point, Multipurpose, White, TH	5012
TP5, TP8	2		Test Point, Miniature, Black, TH	5011

Table 3. Bill of Materials (continued)

DESIGNATOR	QTY	VALUE	DESCRIPTION	PART NUMBER
Variant 001			**LMS3655AQEVM Adjustable 5-V, 5.5-A Without Spread Spectrum**	
U1	1		3.5/5.5-A Synchronous Buck Regulator for Automotive Applications, RNL0022A	LMS3655AQRNLRQ1
R4	1	12.4 k	RES, 12.4 k, 1%, 0.063 W, 0402	CRCW040212K4FKED
R3	1	49.9 k	RES, 49.9 k, 1%, 0.063 W, 0402	CRCW040249K9FKED
C16, C17	2	10 µF	CAP, CERM, 10 µF, 25 V, +/- 20%, X7R, 1210	C3225X7R1E106M250AC
C19	1	22 pF	CAP, CERM, 22 pF, 50 V, ±5%, C0G/NP0, AEC-Q200 Grade 1, 0402	CGA2B2NP01H220J050BA
Variant 002			**LMS3655MQEVM Adjustable 5-V, 5.5-A With Spread Spectrum**	
U1	1		3.5/5.5-A Synchronous Buck Regulator for Automotive Applications, RNL0022A	LMS3655MQRNLRQ1
R4	1	12.4 k	RES, 12.4 k, 1%, 0.063 W, 0402	CRCW040212K4FKED
R3	1	49.9 k	RES, 49.9 k, 1%, 0.063 W, 0402	CRCW040249K9FKED
C16, C17	2	10 µF	CAP, CERM, 10 µF, 25 V, +/- 20%, X7R, 1210	C3225X7R1E106M250AC
C19	1	22 pF	CAP, CERM, 22 pF, 50 V, ±5%, C0G/NP0, AEC-Q200 Grade 1, 0402	CGA2B2NP01H220J050BA
Variant 003			**LMS3655NQEVM Fixed 3.3-V, 5.5-A With Spread Spectrum**	
U1	1		3.5/5.5-A Synchronous Buck Regulator for Automotive Applications, RNL0022A	LMS3655NQRNLRQ1
R4	0	DNP		
R3	1	0 Ω	RES, 0 Ω, 5%, 0.063 W, 0402	CRCW04020000Z0ED
C16	1	22 µF	CAP, CERM, 22 µF, 16 V, +/- 20%, X7R, AEC-Q200 Grade 1, 1210	CGA6P1X7R1C226M250AC
C17, C20	2	22 µF	CAP, CERM, 22 µF, 16 V, +/- 10%, X7R, 1210	GCM32ER71C226KE19L
C19	0	DNP		
Variant 004			**LMS3635MQEVM Adjustable 5-V, 3.5-A With Spread Spectrum**	
U1	1		3.5/5.5-A Synchronous Buck Regulator for Automotive Applications, RNL0022A	LMS3635MQRNLRQ1
R4	1	12.4 k	RES, 12.4 k, 1%, 0.063 W, 0402	CRCW040212K4FKED
R3	1	49.9 k	RES, 49.9 k, 1%, 0.063 W, 0402	CRCW040249K9FKED
C16, C17	2	4.7 µF	CAP, CERM, 4.7 µF, 50 V, +/- 20%, X7R, AEC-Q200 Grade 1, 1210	CGA6P3X7R1H475M250AB
C19	1	22 pF	CAP, CERM, 22 pF, 50 V, ±5%, C0G/NP0, AEC-Q200 Grade 1, 0402	CGA2B2NP01H220J050BA

7 Efficiency and Line and Load Regulation

The LMS3655MQEVM variant is used for all measurements and curves in Figure 12 to Figure 20.

V_{OUT} = 5 V (ADJ)   AUTO

Figure 12. LMS3655MQEVM Efficiency

V_{OUT} = 5 V (ADJ)   FPWM

Figure 13. LMS3655MQEVM Efficiency

V_{OUT} = 5 V   AUTO

Figure 14. LMS3655MQEVM Load and Line Regulation

V_{OUT} = 5 V   FPWM

Figure 15. LMS3655MQEVM Load and Line Regulation

7.1 Load Transients

| V_{OUT} = 5 V | I_{OUT} = 0 A to 3.5 A, | FPWM |

V_{OUT} = 5 V I_{OUT} = 0 A to 3.5 A,   FPWM
$T_R = T_F$ = 1 µs

Figure 16. LMS3655MQEVM Load Regulation

V_{OUT} = 5 V I_{OUT} = 200 mA to 3.5 A,   AUTO
$T_R = T_F$ = 1 µs

Figure 17. LMS3655MQEVM Load Transients

NOTE: The output capacitance for all four variants is designed for stable operation across all load transients and optimized performance with a maximum load transient of 0 to 3.5 A. For applications which require superior load transient performance beyond this range, TI recommends increasing the output capacitance. The best starting point for an optimized design is the Texas Instruments WEBENCH Design Tool.

7.2 Conducted EMI
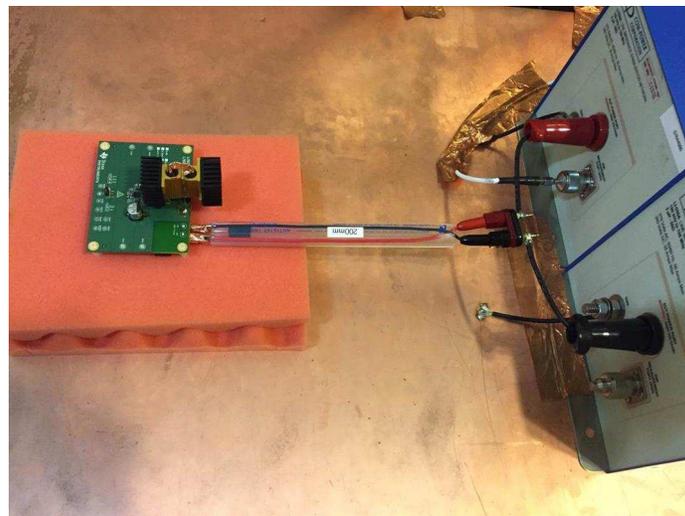
Figure 18. Conducted EMI Setup

Figure 19. LMS3655MQEVM Low Frequency Conducted EMI Results for 5 Vout With Spread Spectrum. Blue-Average and Yellow-Peak

Figure 20. LMS3655MQEVM High Frequency Conducted EMI Results for 5 Vout With Spread Spectrum. Blue-Average and Yellow-Peak
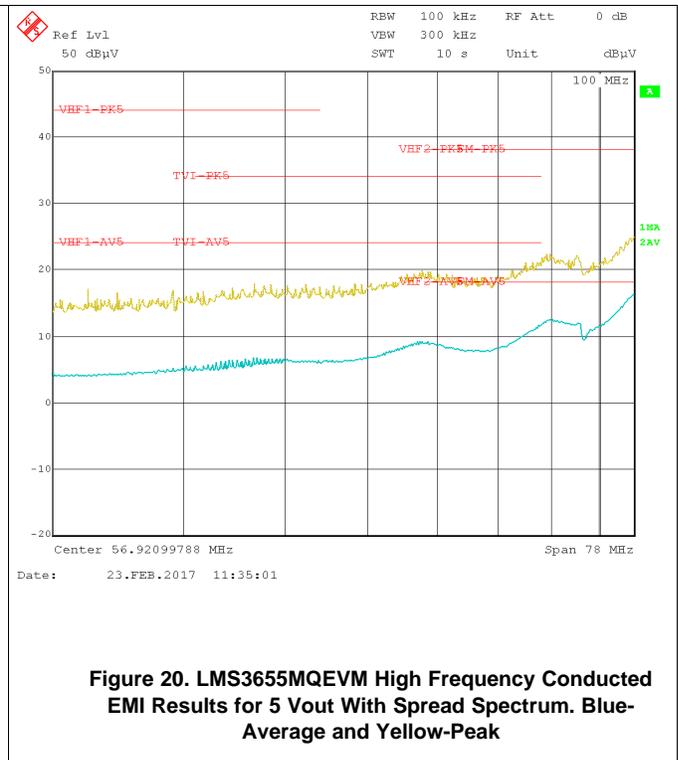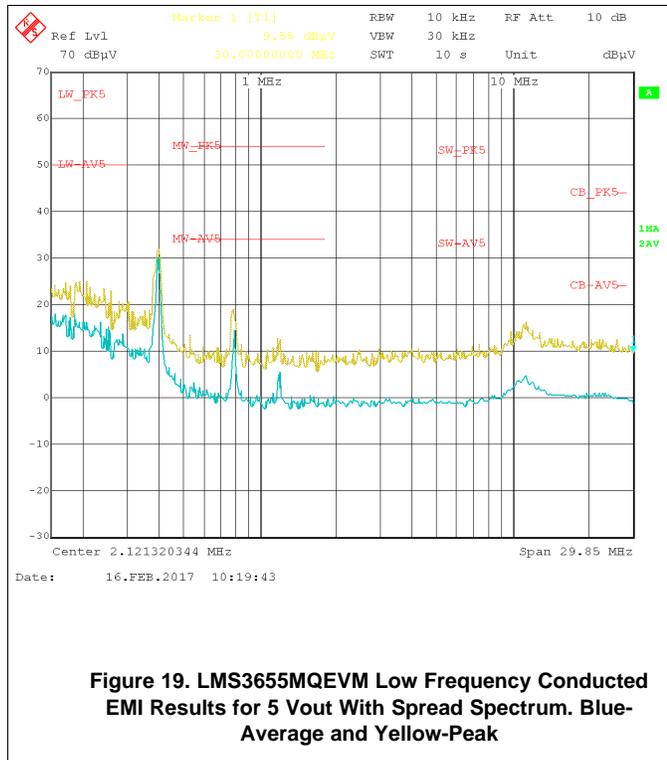
Revision History

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

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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.

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。
 http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

 3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan 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。
　　　　上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。 日本テキサス・イ
ンスツルメンツ株式会社
東京都新宿区西新宿６丁目２４番１号
西新宿三井ビル

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

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, INDEMNITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

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

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