

LM27403EVM DC/DC Buck Regulator Evaluation Module

User's Guide



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LM27403EVM Evaluation Module

The LM27403EVM evaluation module (EVM) is a synchronous buck DC/DC regulator providing a fixed 1.2-V output at currents up to 25 A. The EVM is designed to operate from a single supply rail—no additional bias voltage is required. The regulator uses the LM27403 high performance, synchronous buck controller with voltage-mode PWM control loop, integrated MOSFET gate drivers, inductor DCR current sensing, and remote temperature sense. The EVM's output voltage has better than 1% setpoint accuracy and is adjustable between 0.6 V and 5.5 V simply by changing the lower feedback resistance. The switching frequency is 250 kHz and is synchronizable to a higher frequency if required. Nominal input voltage is 12 V but can vary from 3 V to 20V with suitable adjustment of the programmable UVLO.

The LM27403 PWM controller is available in a 4-mm × 4-mm WQFN-24 PowerPAD™ package to enable high power density and superior thermal performance. Please consult the [LM27403 datasheet](#) for more details. Even though the LM27403 is WEBENCH® Designer enabled, the reader is also encouraged to avail of the [LM27403 Design Tool](#), particularly for quick-start guidance with power train and compensation circuit component selection.

1 Description

The LM27403EVM is designed to use a regulated or non-regulated input bus (3 V–20 V) to produce a tightly regulated output of 1.2 V at up to 25 A of load current. The EVM is intended to demonstrate the LM27403 PWM controller in a typical 12-V bus to low voltage application while providing a number of test points to evaluate the performance of the LM27403.

1.1 Typical Applications

- Point-of-load synchronous buck regulators
- High current density modules
- Communications, cloud, server, storage
- Embedded computing, FPGAs, ASICs, DSPs

1.2 EVM Features and Electrical Performance

- Nominal output voltage of 1.2 V with 1% feedback accuracy
- High efficiency at full load: 91% at 1.2 V, 25 A
- Wide input voltage operating range of 3 V to 20 V
- 250-kHz free-running switching frequency set by resistor
- Overcurrent protection via inductor DCR current sensing with thermal compensation
- Programmable thermal shutdown based on remote-sensed temperature
- Soft-start time of 8 ms
- Monotonic pre-bias output voltage startup
- Programmable input UVLO set to turn on and off at 6.5 V and 5.2 V, respectively
- Voltage-mode PWM control architecture supporting all-ceramic output capacitor design or ceramic/electrolytic implementation
- Output voltage adjustable from 0.6 V to 5.5 V by changing lower feedback resistance

- Remote output voltage sensing for optimal load regulation performance
- Power Good indicator
- Input circuit damping with optional electrolytic capacitor
- Synchronizable to an external clock signal up to 1.2 MHz
- Simple access to IC features including Power Good, enable, remote diode temperature sense, soft-start and error amplifier
- Convenient test points for simple, non-invasive measurements of converter performance

2 Electrical Performance Specifications

Table 1. Electrical Performance Specifications

Parameter	Test Conditions	MIN	TYP	MAX	UNITS
INPUT CHARACTERISTICS					
Input voltage range, V_{IN}		7	12	20	V
Input voltage turn on, $V_{IN(ON)}$	Set by UVLO/EN resistors		6.5		V
Input voltage turn off, $V_{IN(OFF)}$			5.2		V
Input current, full load, $I_{IN(MAX)}$ ⁽¹⁾	$V_{IN} = 7\text{ V}$, $I_{OUT} = 25\text{ A}$		4.71		A
	$V_{IN} = 12\text{ V}$, $I_{OUT} = 25\text{ A}$		2.75		A
Input current, no load, $I_{IN(NL)}$	$V_{IN} = 12\text{ V}$, $I_{OUT} = 0\text{ A}$		20		mA
Input current, disabled, $I_{IN(OFF)}$	$V_{IN} = 12\text{ V}$, $V_{UVLO/EN} = 0\text{ V}$		0.28		mA
OUTPUT CHARACTERISTICS					
Output voltage, V_{OUT} ⁽¹⁾		1.188	1.200	1.212	V
Output current, I_{OUT}		0		25	A
Output voltage regulation, ΔV_{OUT}	Load Regulation: $I_{OUT} = 0\text{ A to }25\text{ A}$		0.2%		
	Line Regulation: $V_{IN} = 7\text{ V to }20\text{ V}$		0.2%		
Output voltage ripple, $V_{OUT(AC)}$	$V_{IN} = 12\text{ V}$, $I_{OUT} = 10\text{ A}$		10		mVpp
Output overcurrent protection, I_{OCP}		26	28	30	A
Soft-start time, t_{SS}			8		ms
SYSTEMS CHARACTERISTICS					
Switching frequency (free running), $F_{SW(NOM)}$ ⁽¹⁾			250		kHz
Switching frequency range (using SYNC)		$F_{SW(NOM)}$		1200	kHz
Peak efficiency, η_{PK}	$V_{IN} = 12\text{ V}$, $I_{OUT} = 10\text{ A}$		93.5%		
Full load efficiency, η_{FULL}	$V_{IN} = 7\text{ V}$, $I_{OUT} = 25\text{ A}$		91%		
	$V_{IN} = 12\text{ V}$, $I_{OUT} = 25\text{ A}$		91%		
	$V_{IN} = 20\text{ V}$, $I_{OUT} = 25\text{ A}$		89%		
Loop bandwidth, f_c	$V_{IN} = 12\text{ V}$, $I_{OUT} = 10\text{ A}$		45		kHz
Phase margin, ϕ_M			55		°
Ambient temperature, T_A			25		°C
System-level thermal shutdown, T_{OTP}			110		°C

⁽¹⁾ The default output voltage and switching frequency are 1.2 V and 250 kHz, respectively. Efficiency and other parameters will change based on chosen output voltage, load current, and frequency.

3 Application Circuit Diagram

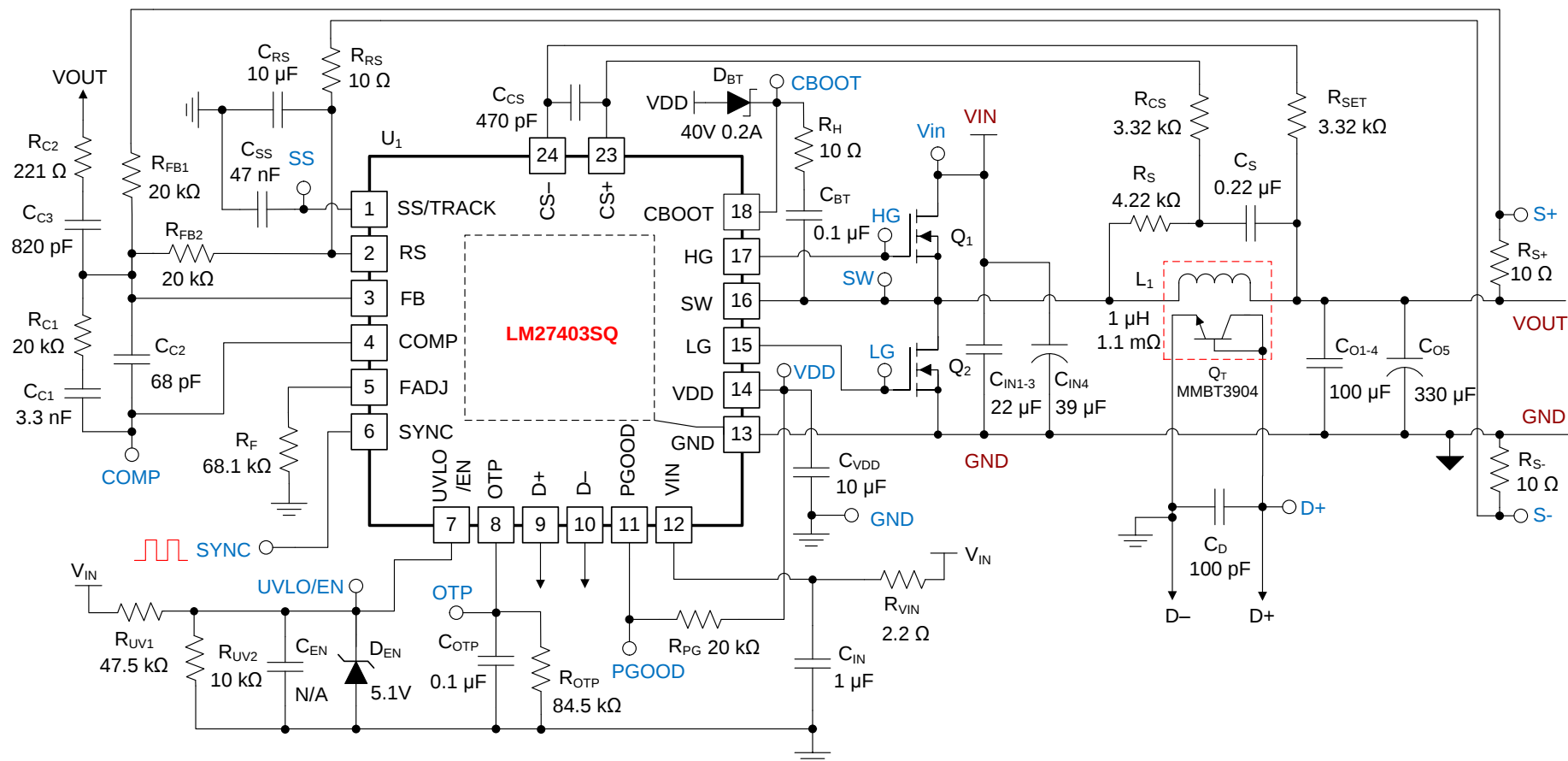


Figure 1. Circuit Diagram

4 EVM Photo

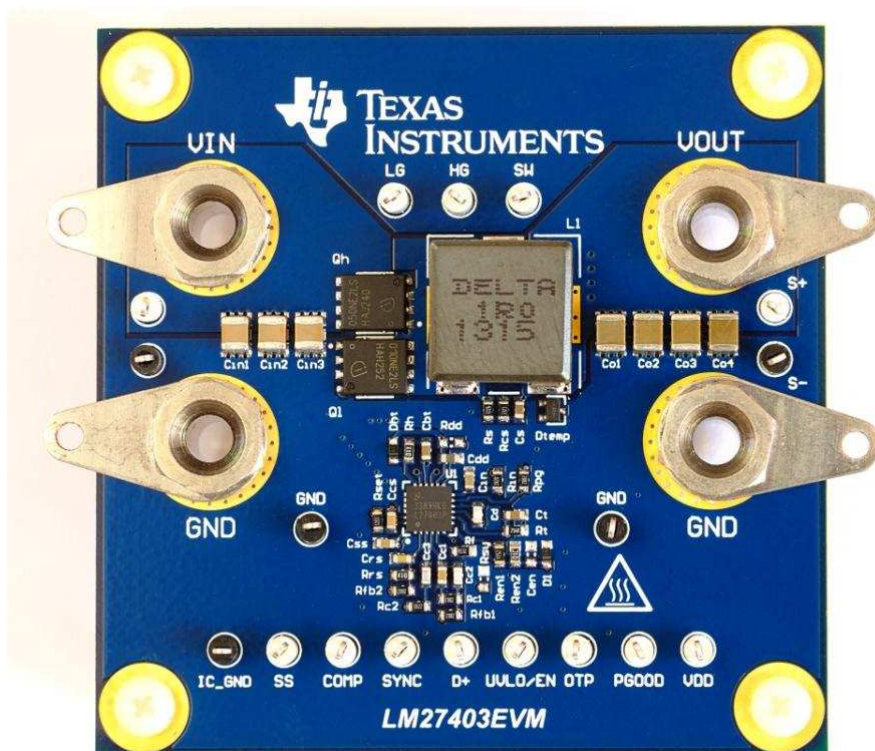


Figure 2. Photo of EVM

5 Signal Connections and Test Point Descriptions

5.1 Test Point Descriptions

Table 2. Test Point Descriptions

LABEL	DESCRIPTION
VIN	Input voltage
GND	GND reference for V_{IN}
S+	Output voltage positive sense connection
S-	Output voltage negative sense connection
IC_GND	LM27403 GND
SS	Soft-start pin, tracking input
COMP	Error amplifier output
SYNC	SYNC input
D+	Temperature sense NPN BJT collector/base
UVLO/EN	UVLO/Enable input, tie to GND to disable converter
OTP	Overtemperature set pin
PGOOD	Power good
VDD	Bias supply sub-regulator output
GND	GND reference
HG	High-side MOSFET gate driver output
SW	Switch node
LG	Low-side MOSFET gate driver output

5.2 Signal Connections

5.2.1 Input Voltage Monitoring

The LM27403EVM provides two test points for measuring the input voltage. This allows the user to measure the actual input voltage without losses from input cables and connectors. All input voltage measurements should be made between VIN and GND test points.

5.2.2 Output Voltage Monitoring

The LM27403EVM provides two test points for measuring the output voltage. This allows the user to measure the actual output voltage without losses from output cables and connectors. Output voltage measurements should be made between S+ and S- test points, or alternatively at the output voltage banana connections.

5.2.3 Power Good Voltage Output

The LM27403EVM provides a test point for measuring the power good output voltage. A 20-k Ω resistor pull-up to VDD is included to allow the Power Good signal to be monitored without requiring an external pullup. For true open-drain operation with no pullup, remove Rpg. With Rpg removed, PGOOD can be connected to UVLO/EN of another LM27403EVM to provide sequential startup of the two LM27403-based regulators.

5.2.4 Soft-Start Voltage Monitoring / Track Input

The LM27403EVM provides a test point for measuring the Soft-Start voltage and for applying a tracking voltage source. An external voltage from SS/TRACK to GND of 0 V to 0.6V can be used to adjust the output voltage. Of course, where multiple regulators are used (e.g. in a distributed power architecture application), the output voltage of one regulator can be applied to the SS/TRACK input of another regulator using a resistor divider to provide appropriate scaling. Coincident or ratiometric startup behaviors are thus possible.

5.2.5 UVLO / Enable Voltage Input

The LM27403EVM provides a test point for measuring the UVLO/EN voltage. Shorting this test point to GND disables the regulator. The UVLO/EN voltage should not exceed the input voltage.

5.2.6 SYNC Input

The LM27403EVM provides a test point for applying a synchronization (SYNC) input signal. The free-running switching frequency is set at 250 kHz by resistor Rf. However, the regulator can align in frequency and phase with that of the applied SYNC signal up to 1.2 MHz. The applied SYNC voltage should not exceed 5.5 V.

CAUTION

Some parameters can be configured, such as control loop compensation, to values that can result in unexpected behavior of this EVM. Please refer to the LM27403 [datasheet](#), LM27403 [design tool](#), or WEBENCH® Power Designer for guidance related to component selection.

6 Test Setup and Procedure

Figure 3 shows the recommended test setup to evaluate the LM27403 EVM. Working at an ESD workstation, make sure that any wrist straps, boot straps or mats are connected referencing the user to earth ground before power is applied to the EVM.

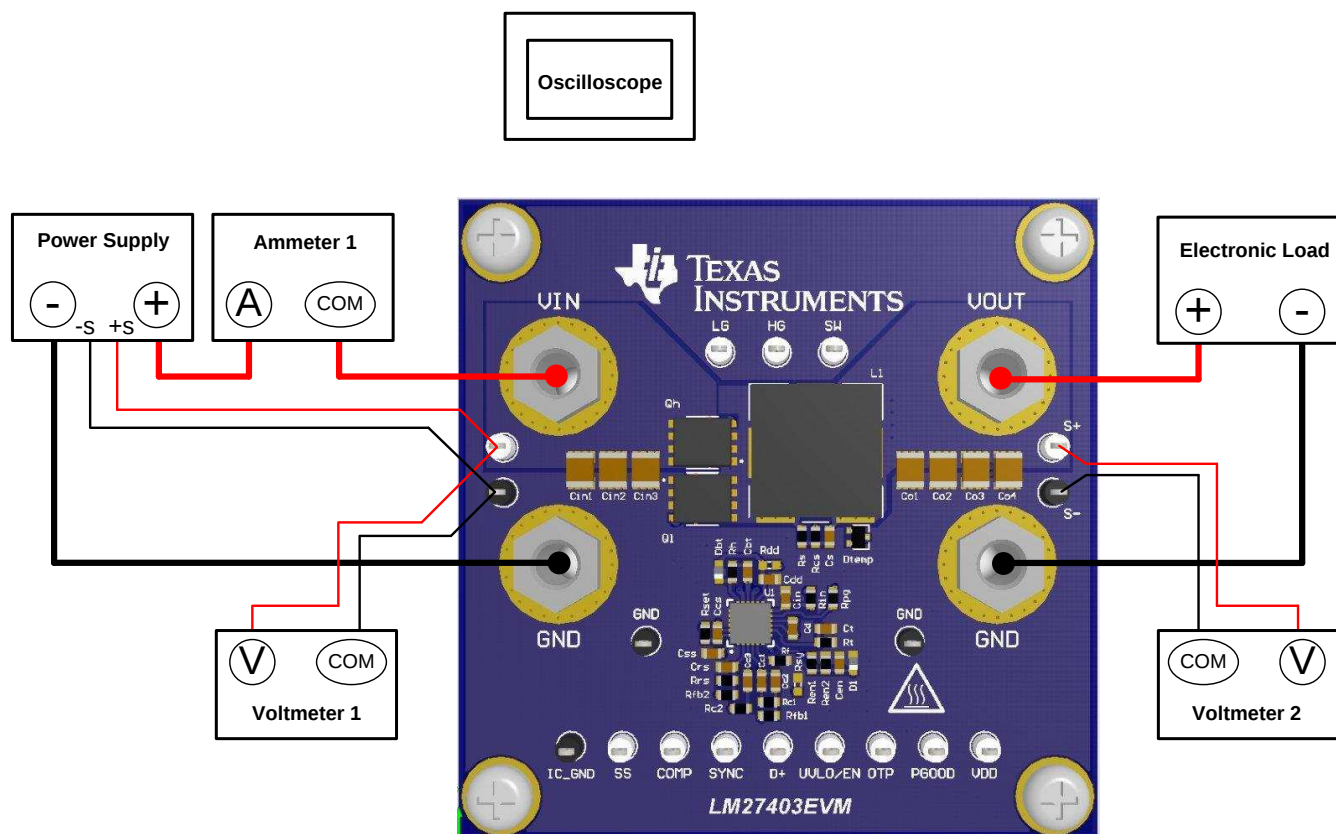


Figure 3. Connection Diagram

6.1 Test Equipment

Voltage Source: The input voltage source VIN should be a 0–20-V variable dc source capable of supplying 10 A.

Multimeters:

- **Voltmeter 1:** Input voltage at VIN to GND
- **Voltmeter 2:** Output voltage at S+ to S– (or using the output connector lugs if remote sense is used)
- **Ammeter 1:** Input current (or use the power supply readout if its accuracy is deemed acceptable)

Electronic Load: The output load should be an electronic constant-resistance or constant-current mode load capable of 0 Adc to 30 Adc at 1.2 V.

Oscilloscope: A digital or analog oscilloscope can be used to measure pertinent converter waveforms. With the scope set to 20-MHz bandwidth and AC coupling, the output voltage ripple can be measured directly across an output capacitor with a short ground lead normally provided with the scope probe. Place the oscilloscope probe tip on the positive terminal of the output capacitor, holding the probe's ground barrel through the ground lead to the capacitor's negative terminal. It is not recommended to use a long leaded ground connection because this may induce additional noise given a large ground loop. To measure other waveforms, adjust the oscilloscope as needed.

Fan: Some of this EVM's components may approach temperatures of 50°C during operation. Although not mandatory, a small fan capable of 200–400 LFM can be used to reduce component temperatures while the EVM is operating. Exercise care when touching the EVM while the fan is not running. Always exercise caution when touching any circuits that may be live or energized.

Recommended Wire Gauge:

- **Input Source to VIN and GND:** The recommended wire size is 1 × AWG #14 per input connection, with the total length of wire less than 4 feet (2 feet input, 2 feet return).
- **VOUT to LOAD:** The minimum recommended wire size is 2 × AWG #14, with the total length of wire less than 4 feet (2 feet input, 2 feet return).

6.2 Recommended Test Setup

6.2.1 Input Connections

- Prior to connecting the DC input source, it is advisable to limit the source current to 10 A maximum. Make sure the input source is initially set to 0 V and connected to VIN and GND banana connections as shown in [Figure 3](#). While the on-board OSCON electrolytic capacitor provides input circuit damping, an additional high-ESR input capacitor may be required if long input lines are used.
- Connect voltmeter 1 at VIN and GND test points to measure the input voltage.
- Connect ammeter 1 to measure the input current.

6.2.2 Output Connections

- Connect an electronic load to VOUT and GND connections. Set the load to constant-resistance mode or constant-current mode at 0 Adc before input voltage is applied. Use short load lines to minimize voltage drop to the load.
- Connect voltmeter 2 at S+ and S– (or output connectors' solder lugs) to measure the output voltage.
- The output current level can be taken from the electronic load readout (if its accuracy is deemed acceptable).

6.3 Test Procedure

6.3.1 Line, Load Regulation and Efficiency

- Set up the EVM as described above.
- Set load to constant resistance or constant current mode and to sink 0 Adc.
- Increase input source from 0 V to 12 V, using voltmeter 1 to measure input voltage.
- Use voltmeter 2 to measure output voltage, V_{OUT} .
- Vary load from 0 to 25 Adc, V_{OUT} should remain within load regulation specification.
- Vary input source voltage from 7 V to 20 V, V_{OUT} should remain within line regulation specification.
- Decrease load to 0 A. Decrease input source voltage to 0 V.

6.3.2 Control Loop Gain and Phase

The 10-Ω positive sense resistor of the LM27403EVM is a convenient injection point for loop response analysis.

- Reconfigure resistor Rc2 so that the compensator's RC lead network connects not to VOUT but to S+ (Rc2 is typically connected to VOUT to mitigate noise injection into FB when long sense lines are used).
- Set up EVM as described previously.
- Connect isolation transformer secondary across Rs+.
- Connect input signal amplitude measurement (REF) probe to S+ and output signal amplitude measurement probe (TEST) to VOUT.
- Connect ground leads to the GND test point as required.

- Apply 10 mV or less AC signal to the isolation transformer primary. Adjust amplitude as necessary.
- Sweep the frequency over the frequency range of interest (e.g. 100 Hz to 1 MHz) with 10 Hz or lower post filter.
- Measure the control loop gain and phase characteristic. Record the crossover frequency and phase margin.
- Disconnect isolation transformer before making other measurements (signal injection into the loop may interfere with the integrity of other measurements).

7 Test Data and Performance Curves

Figure 4 through Figure 24 present typical performance curves for the LM27403 EVM. Since actual performance data can be affected by measurement techniques and environmental variables, these curves are presented for reference and may differ from actual field measurements.

7.1 Efficiency

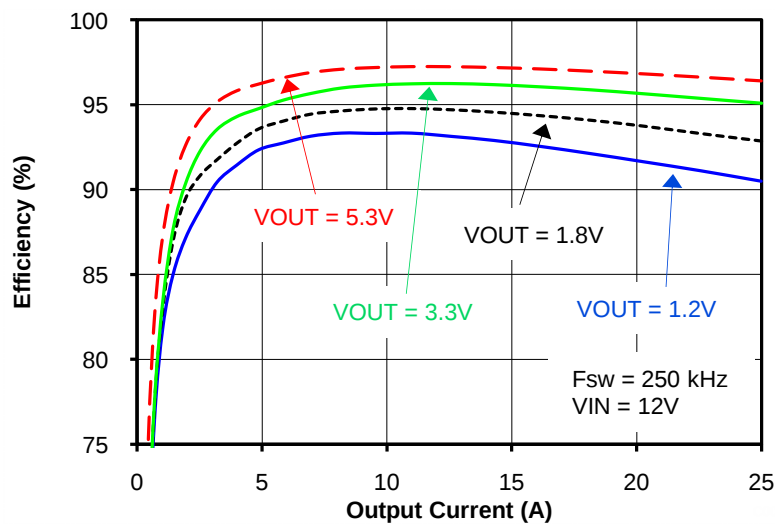


Figure 4. Efficiency Plot 1

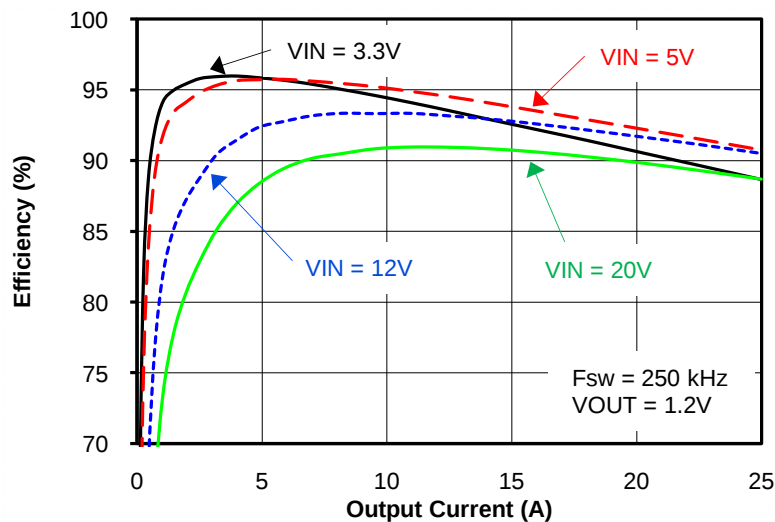


Figure 5. Efficiency Plot 2

7.2 Load Regulation

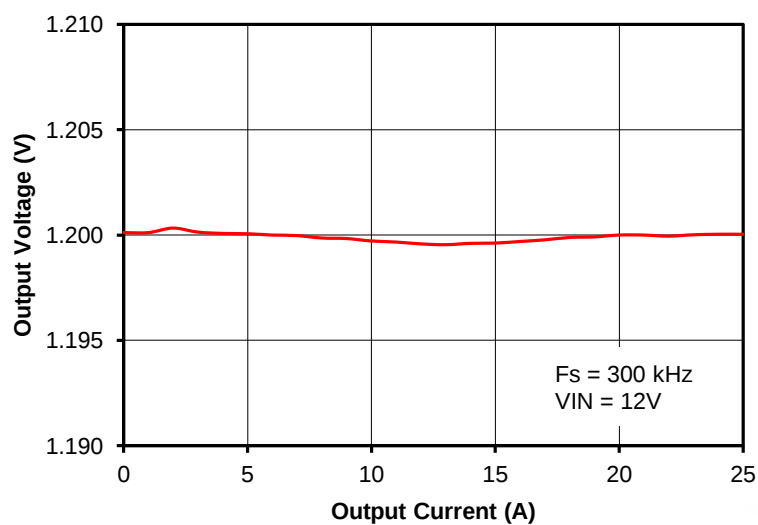


Figure 6. Load Regulation

7.3 Line Regulation

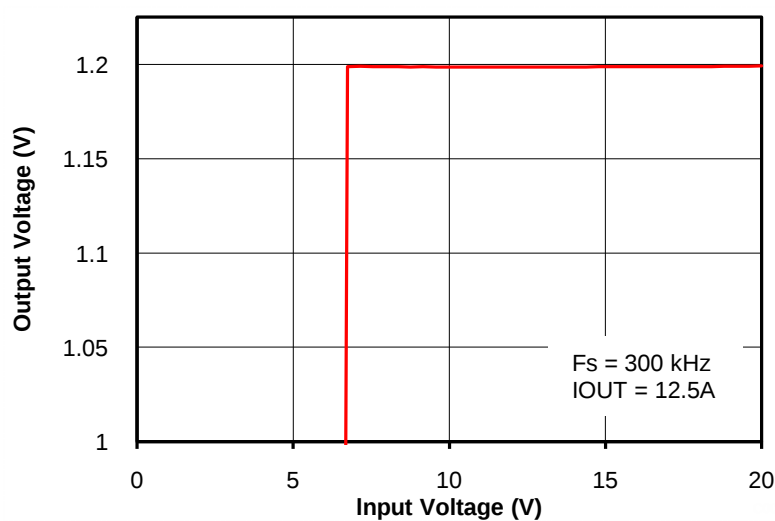


Figure 7. Line Regulation

7.4 Current Limit Inception

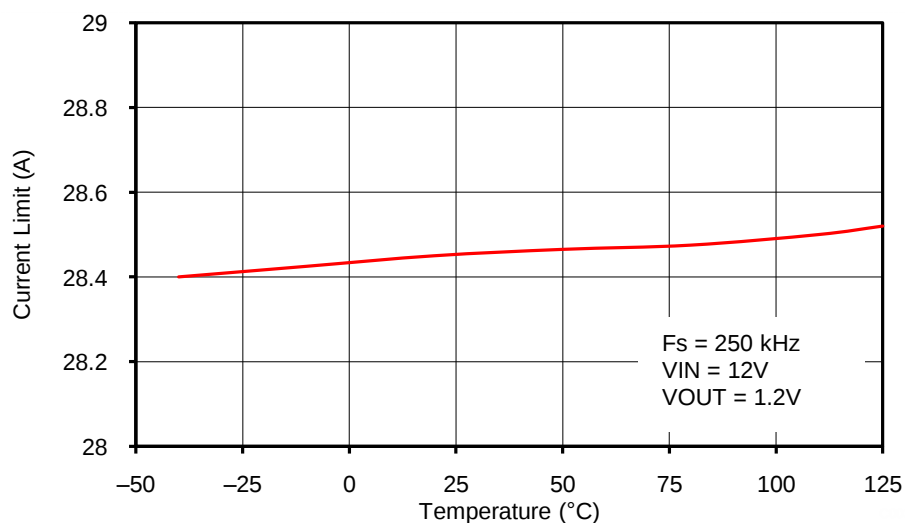


Figure 8. Current Limit Inception vs Temperature

7.5 Current Limit Hiccup Mode

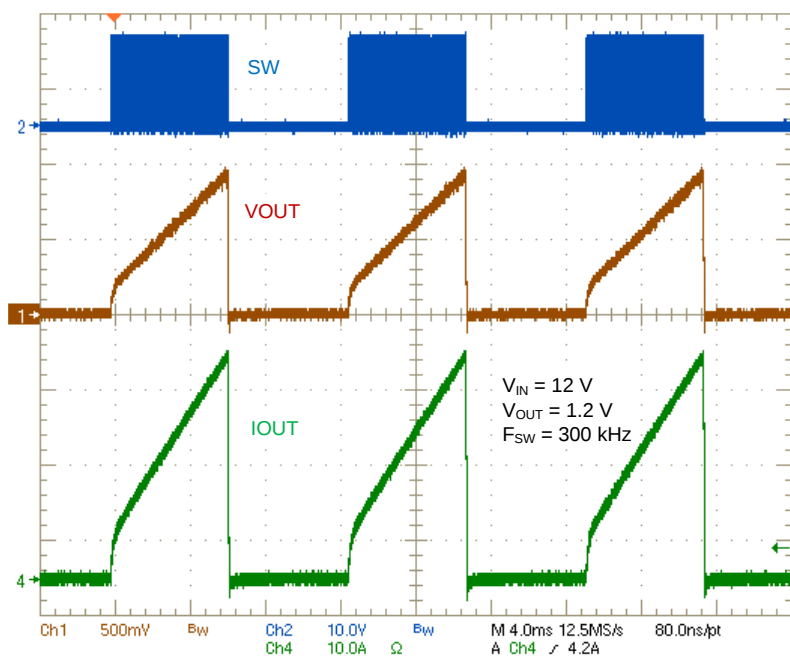


Figure 9. Current Limit Hiccup Mode

7.6 Load Transient Response

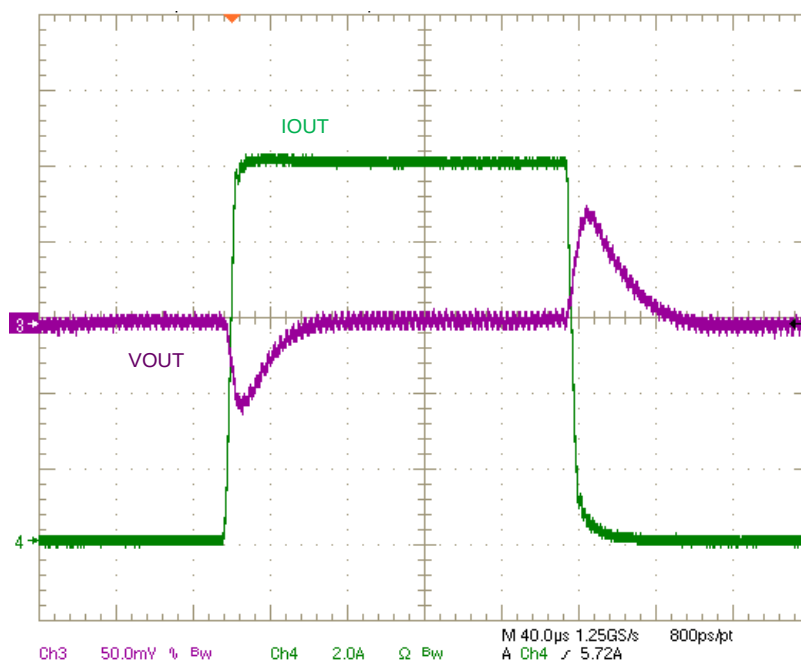


Figure 10. Load Transient Response; $V_{IN} = 12\text{ V}$, $V_{OUT} = 1.2\text{ V}$, 0 A to 10 A at 2 A/ μs

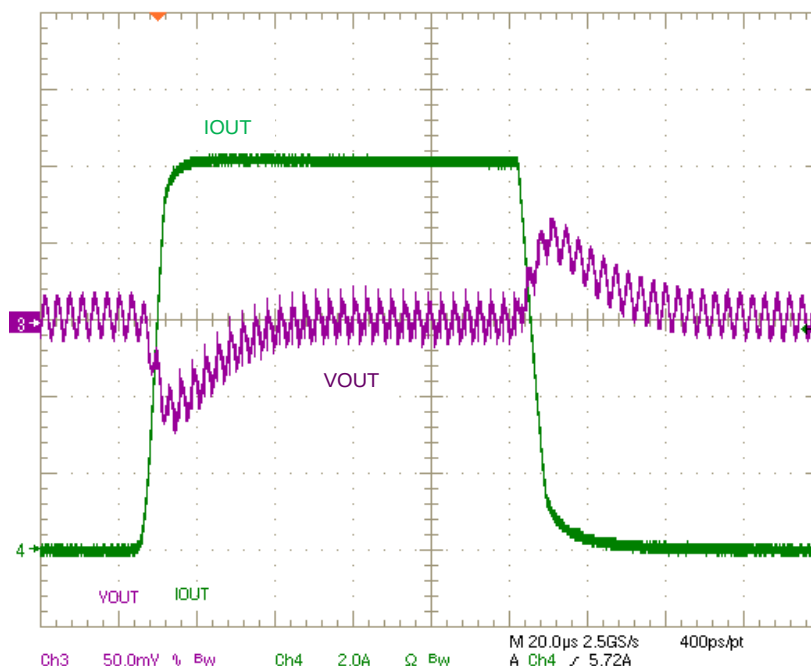


Figure 11. Load Transient Response; $V_{IN} = 12\text{ V}$, $V_{OUT} = 5.5\text{ V}$, 0 A to 10 A at 2 A/ μs

7.7 Output Ripple

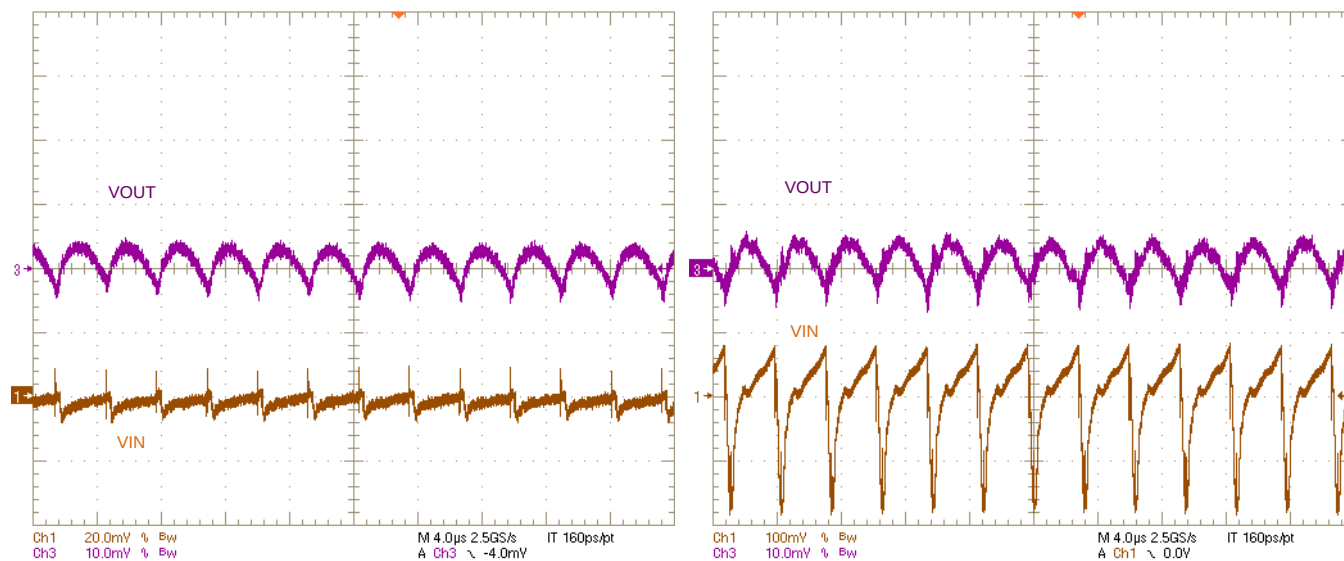


Figure 12. Input and Output Voltage Ripple; $V_{IN} = 12\text{ V}$, $V_{OUT} = 1.2\text{ V}$, $I_{OUT} = 0\text{ A}$ and 25 A

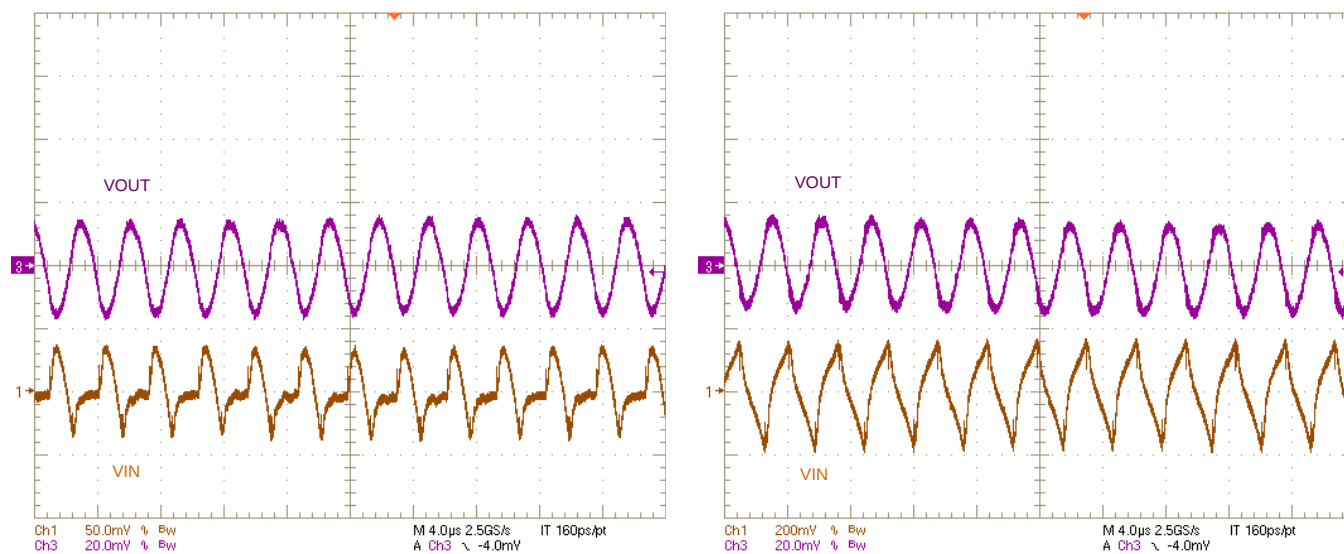


Figure 13. Input and Output Voltage Ripple; $V_{IN} = 12\text{ V}$, $V_{OUT} = 5.5\text{ V}$, $I_{OUT} = 0\text{ A}$ and 15 A

7.8 Startup and Shutdown - VIN

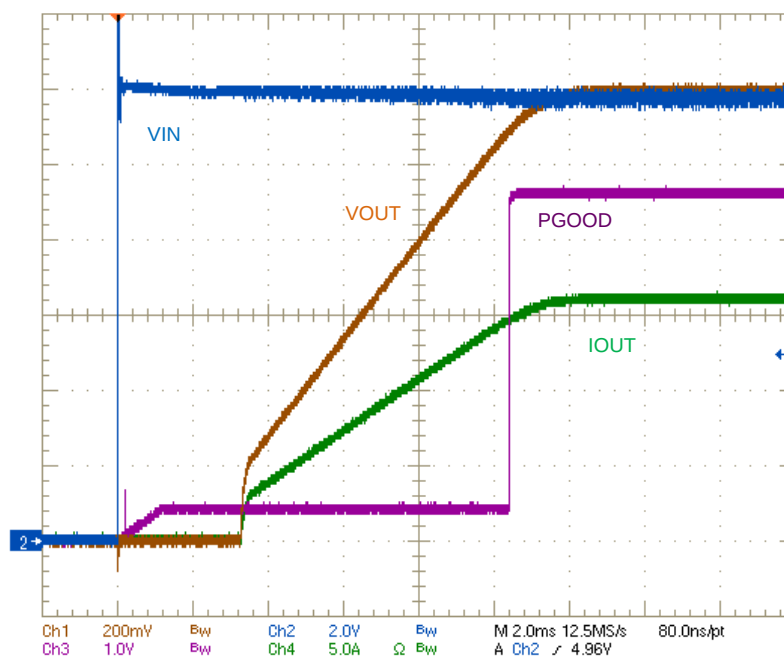


Figure 14. Startup with VIN Stepped to 12 V; $V_{OUT} = 1.2$ V, 70-mΩ Load

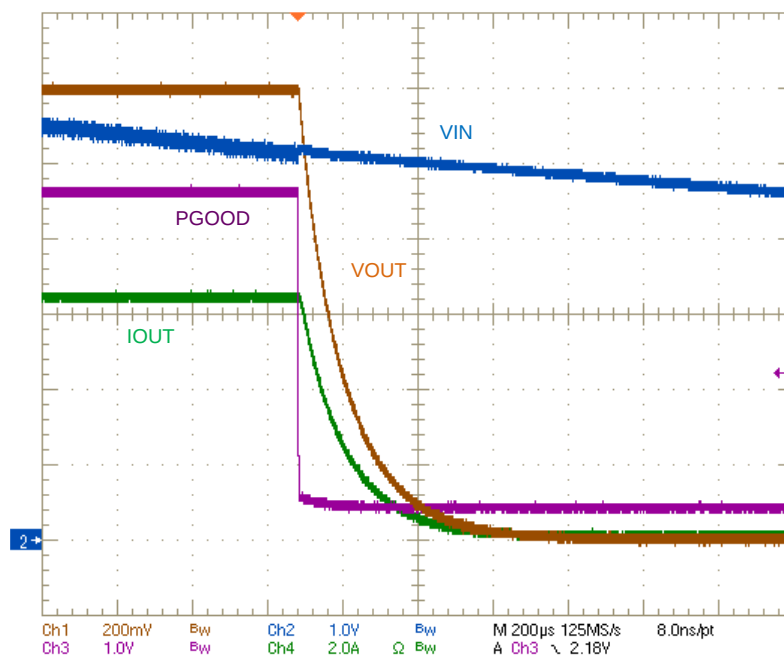


Figure 15. Shutdown After VIN Disconnected; $V_{IN} = 12$ V, $V_{OUT} = 1.2$ V, 200-mΩ Load

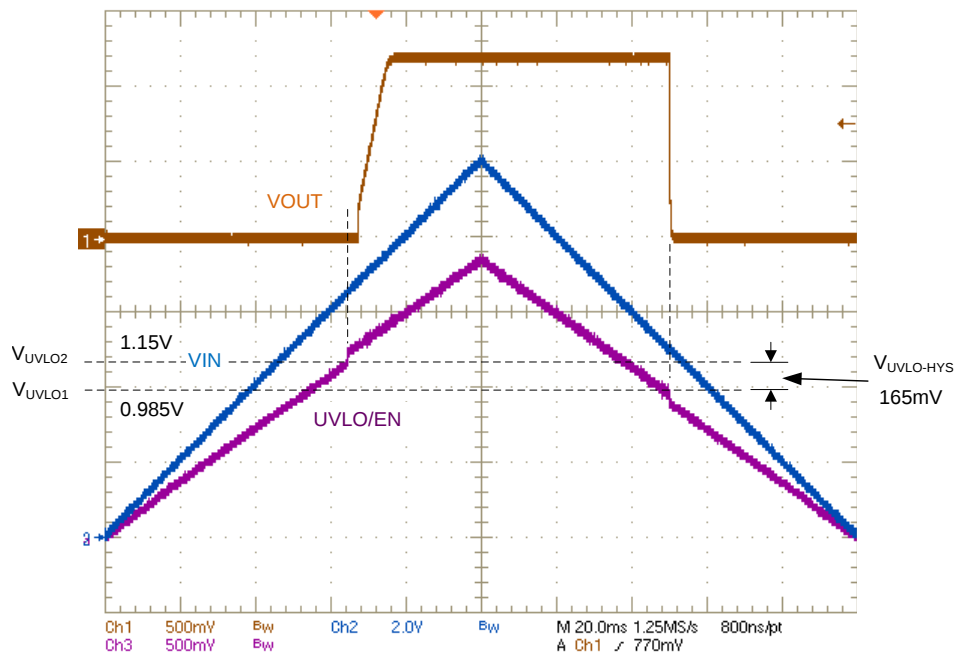


Figure 16. Startup with V_{IN} Ramping Slowly 0 V – 8 V – 0 V; V_{OUT} = 1.2 V, 200-mΩ Load

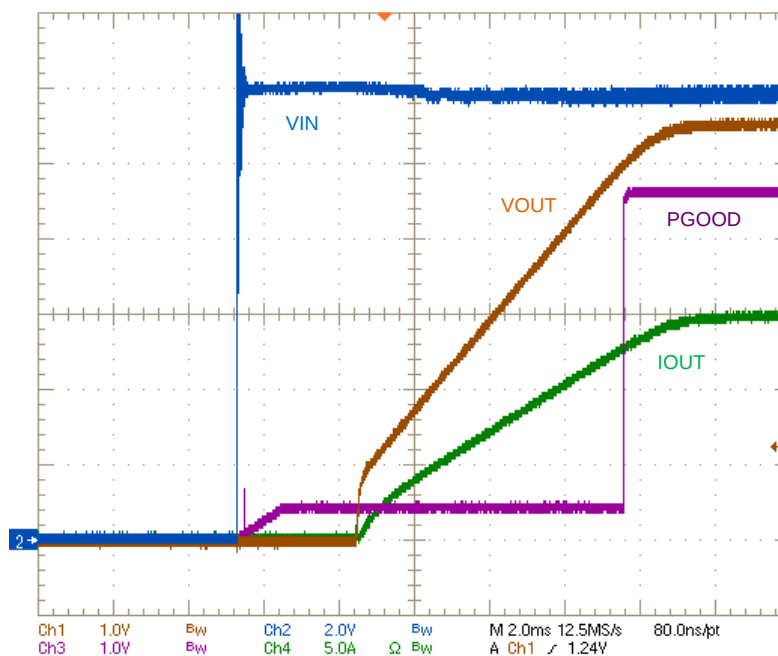


Figure 17. Startup with V_{IN} Stepped to 12 V; V_{OUT} = 5.5 V, 340-mΩ Load

7.9 Startup and Shutdown - Enable

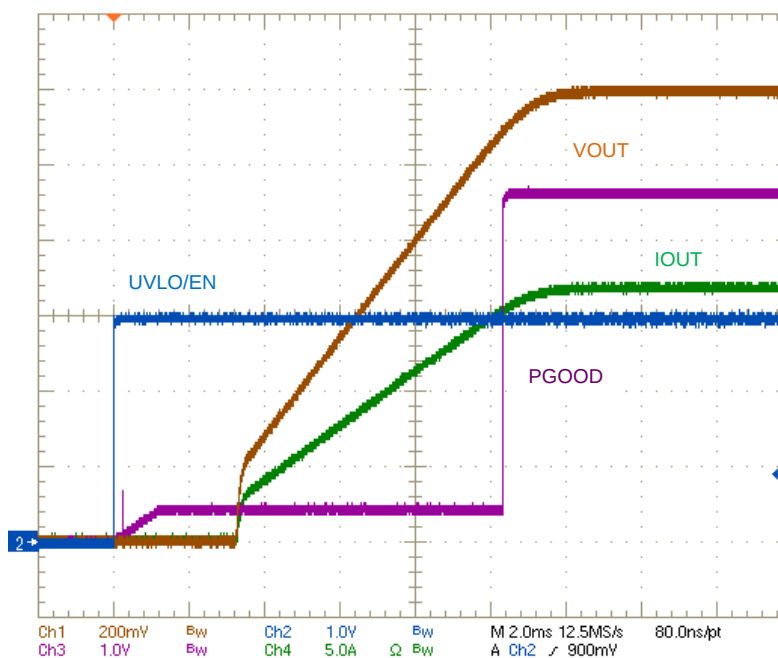


Figure 18. Startup with UVLO/EN Stepped to 3 V; $V_{IN} = 12\text{ V}$, $V_{OUT} = 1.2\text{ V}$, 70-m Ω Load

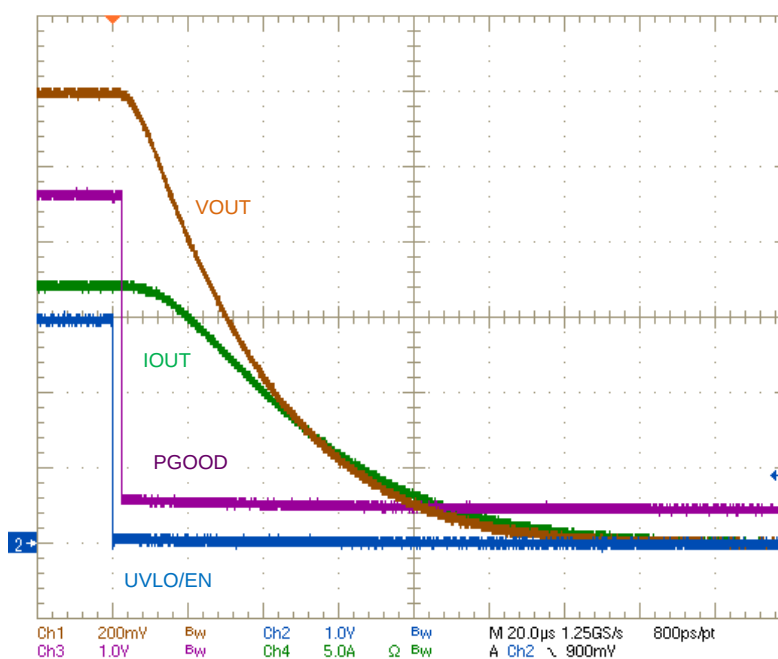


Figure 19. Shutdown with UVLO/EN Pulled To GND; $V_{IN} = 12\text{ V}$, $V_{OUT} = 1.2\text{ V}$, 70-m Ω Load

7.10 Pre-Bias Startup

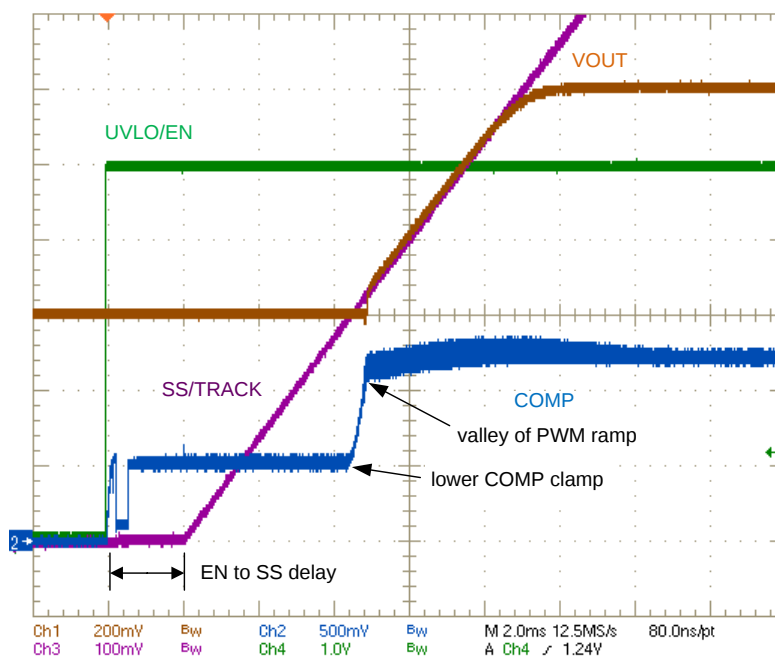


Figure 20. Pre-bias Startup; $V_{IN} = 12\text{ V}$, No Load, 0.6-V Pre-bias

7.11 Switch Node and SYNC

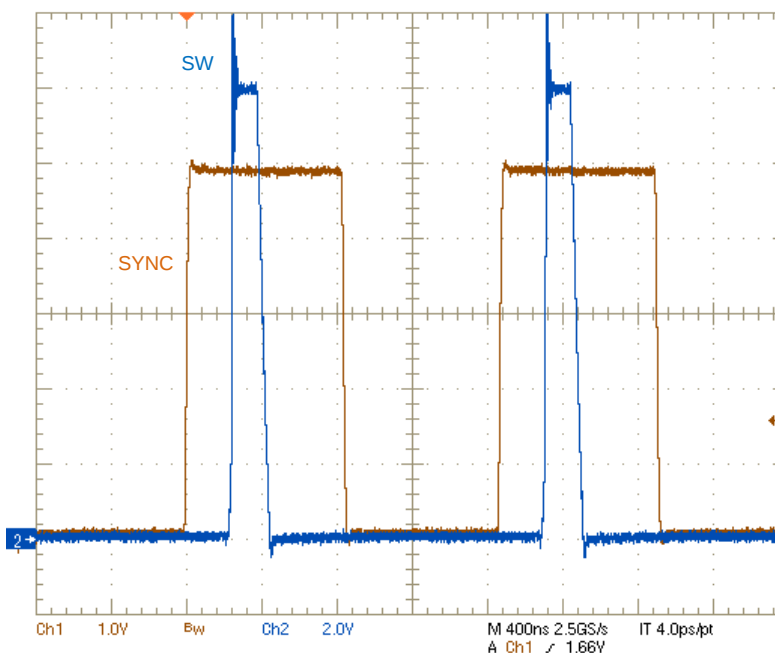


Figure 21. Switch Node and External SYNC Voltages; $V_{IN} = 12\text{ V}$, $V_{OUT} = 1.2\text{ V}$, $F_{SYNC} = 600\text{ kHz}$

7.12 Deadtimes

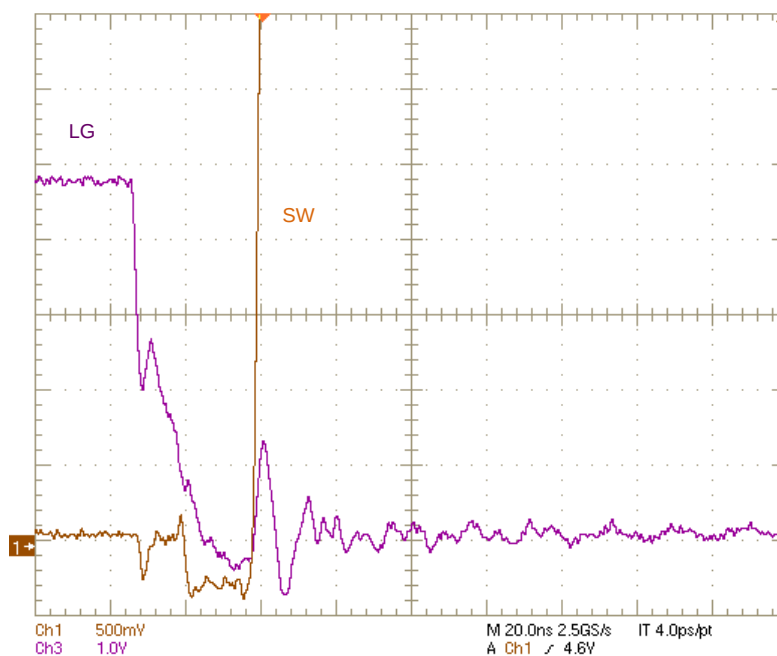


Figure 22. Deadtime Prior To High-side MOSFET Turn-on; $V_{IN} = 12\text{ V}$, $V_{OUT} = 1.2\text{ V}$, 120-m Ω Load

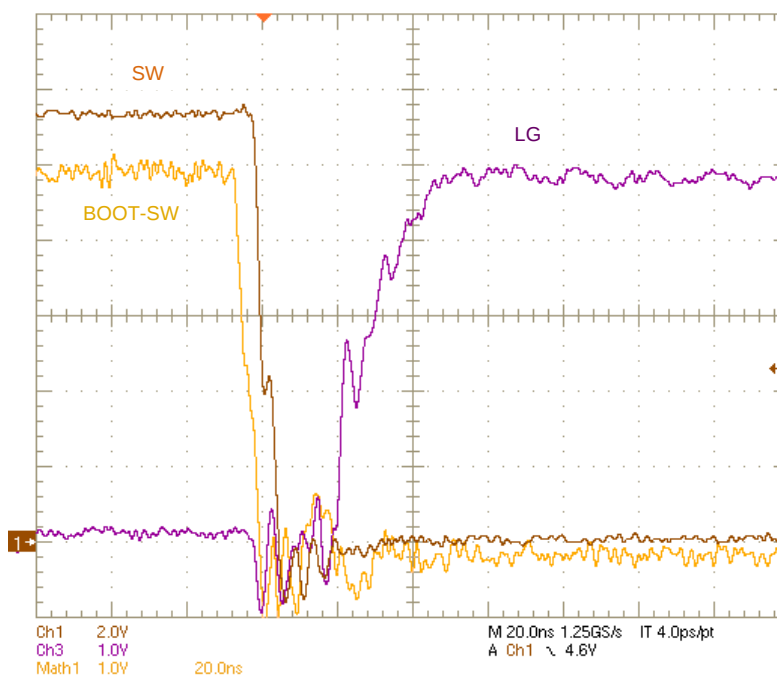


Figure 23. Deadtime Prior To High-side MOSFET Turn-off; $V_{IN} = 12\text{ V}$, $V_{OUT} = 1.2\text{ V}$, 120-m Ω Load

7.13 Remote Temperature Sense

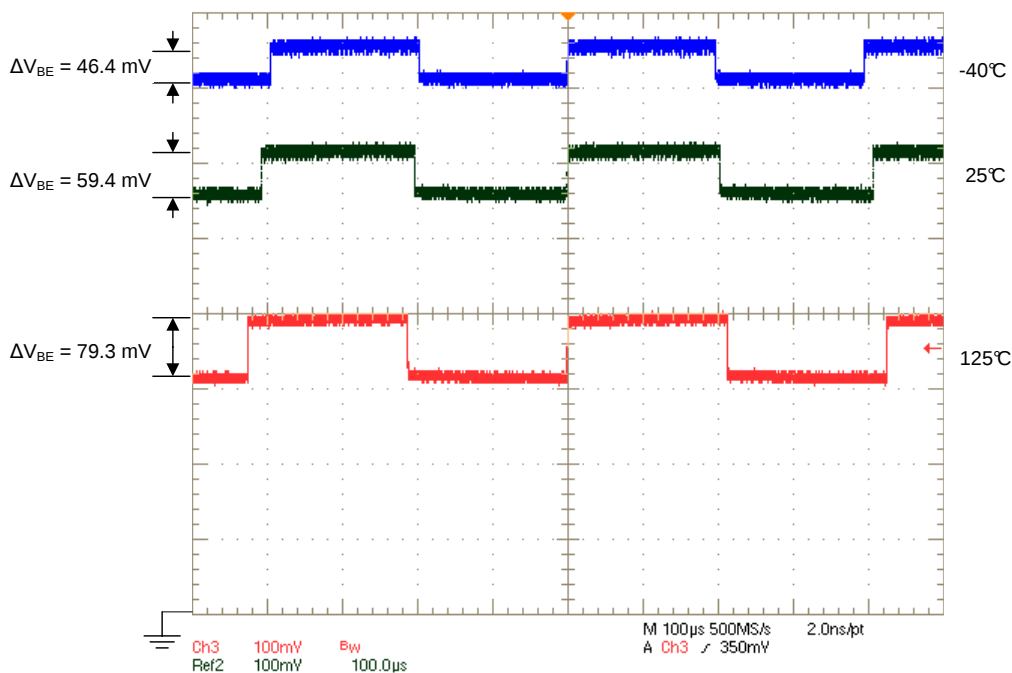


Figure 24. D+ Voltage (ΔV_{BE}) at -40°C, 25°C, 125°C Operating Temperatures

8 EVM Documentation

8.1 Schematic

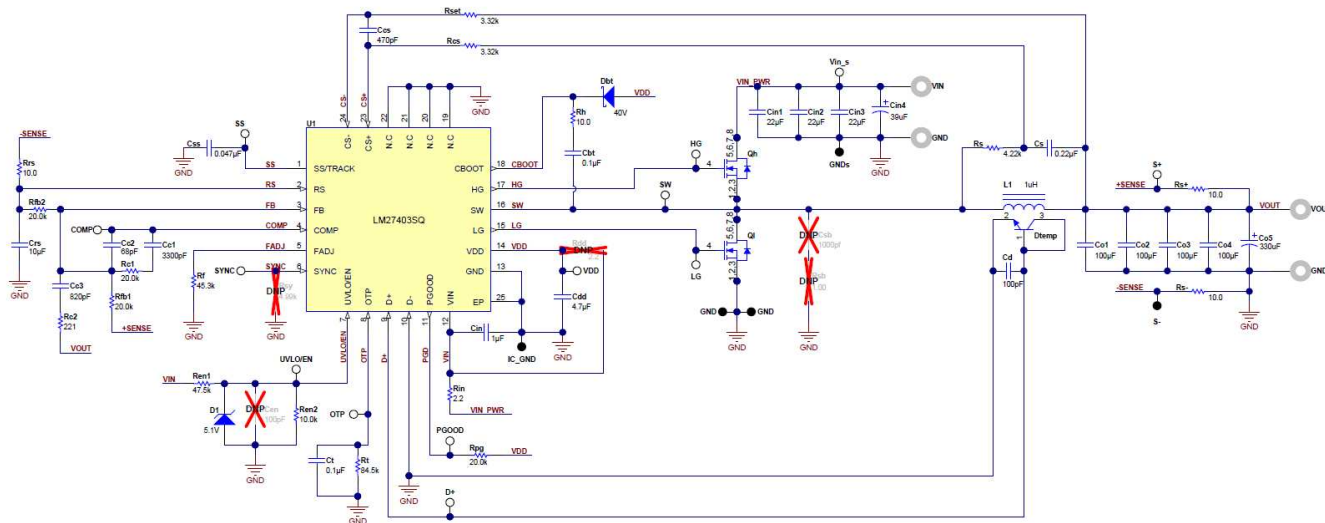


Figure 25. Schematic

8.2 PCB Layout

Figure 26 through Figure 33 show the design of the LM27403 6-layer PCB (2-oz copper). The EVM is largely a single-sided design, except for input and output bulk capacitors and a few signal components.

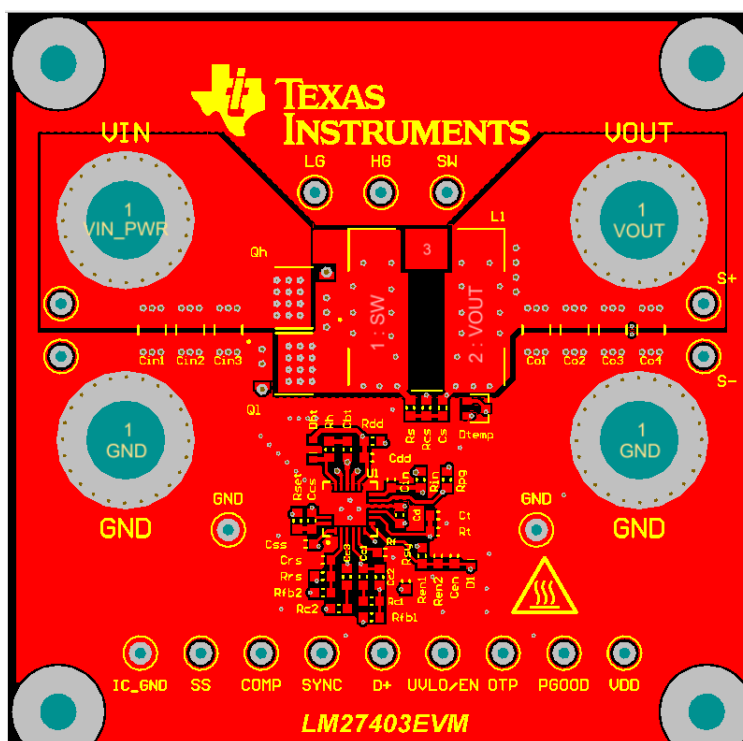


Figure 26. Top Copper (Top view)

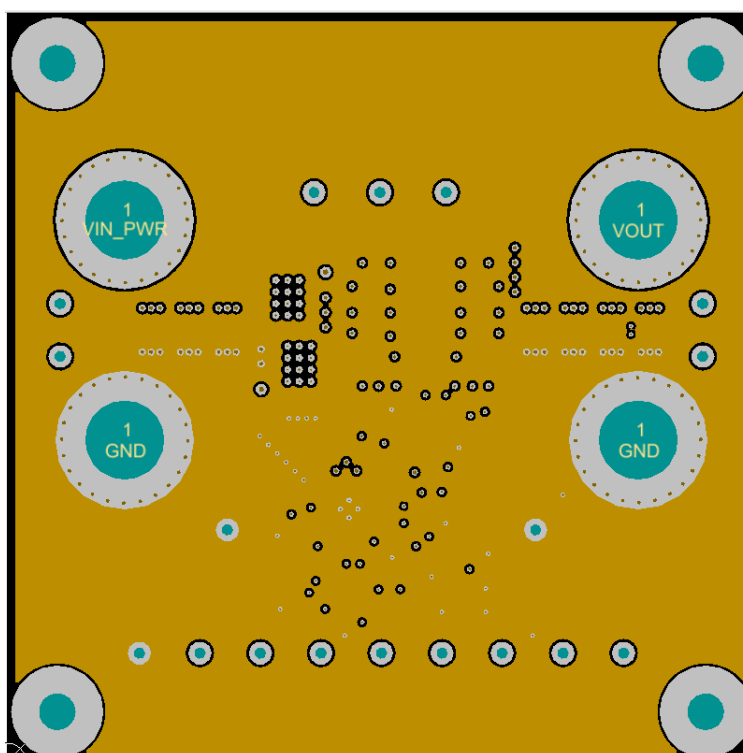


Figure 27. Internal Layer 2 (Top view)

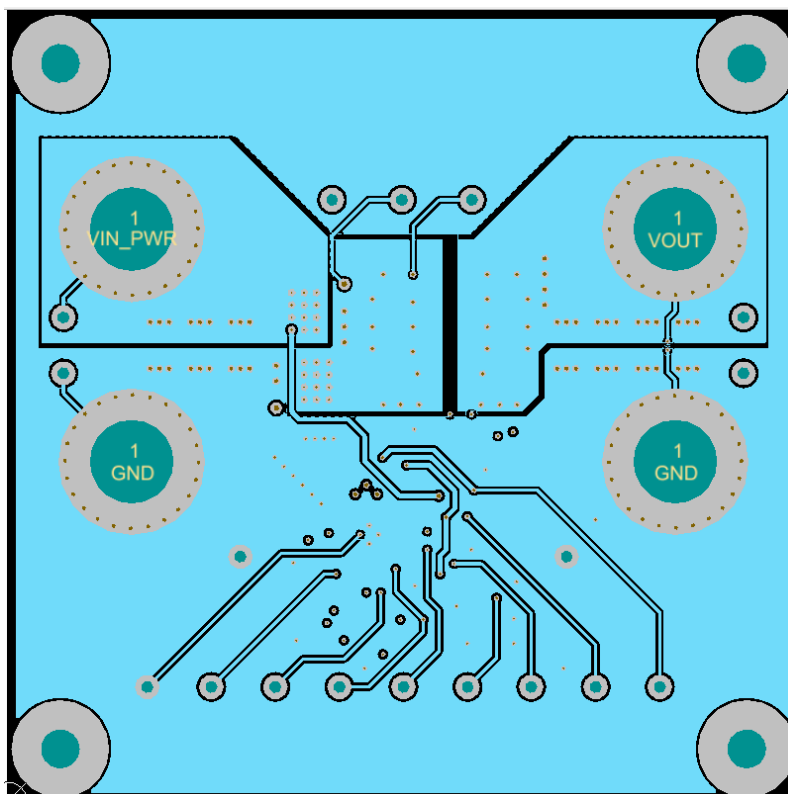


Figure 28. Internal Layer 3 (Top view)

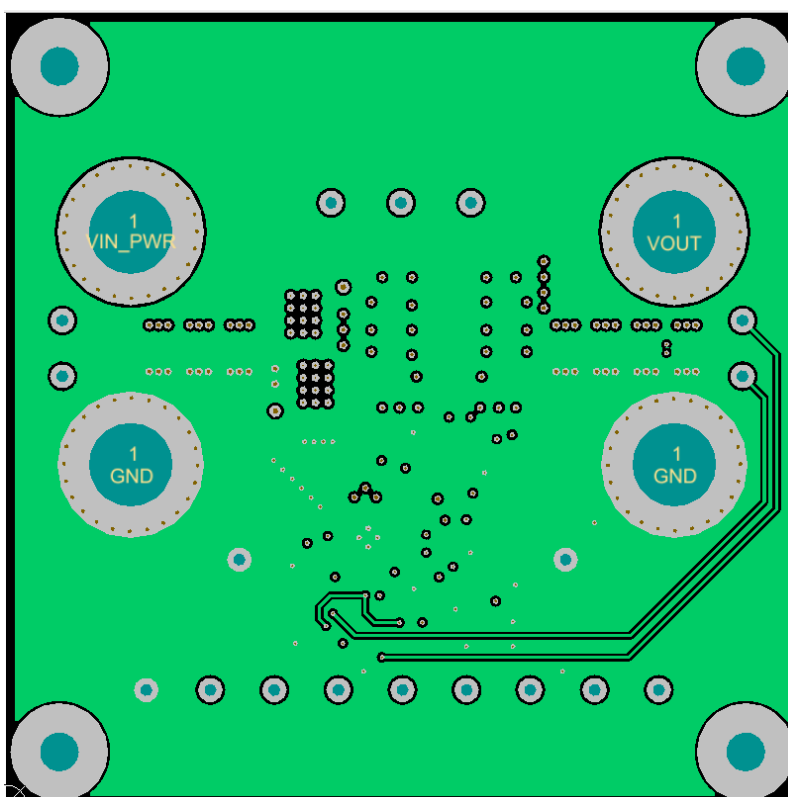


Figure 29. Internal Layer 4 (Top view)

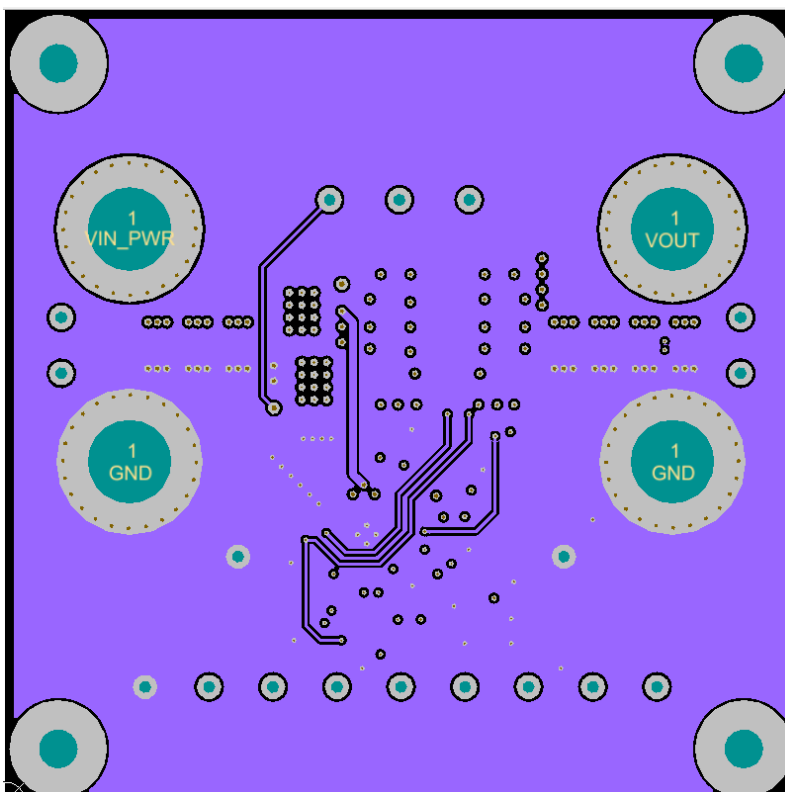


Figure 30. Internal Layer 5 (Top view)

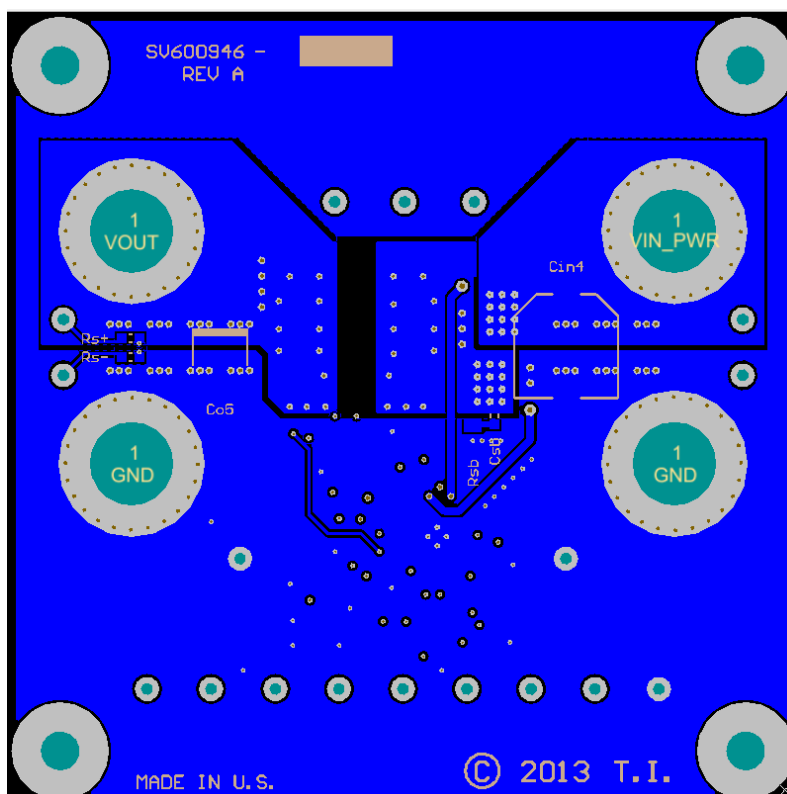


Figure 31. Bottom Copper (Bottom view)



8.3 Bill of Materials

Table 3. Bill of Materials

Count	RefDes	Description	Part Number	MFR
2	Cbt, Ct	Capacitor, Ceramic, 0.1 μ F, 50V, X7R, 10%, 0603	Std	Std
1	Cc1	Capacitor, Ceramic, 3300pF, 50V, X7R, 10%, 0603	Std	Std
1	Cc2	Capacitor, Ceramic, 68pF, 50V, C0G/NPO, 5%, 0603	Std	Std
1	Cc3	Capacitor, Ceramic, 820pF, 50V, C0G/NPO, 5%, 0603	Std	Std
1	Ccs	Capacitor, Ceramic, 470pF, 50V, X7R, 10%, 0603	Std	Std
1	Cd	Capacitor, Ceramic, 100pF, 50V, X7R, 10%, 0603	Std	Std
1	Cdd	Capacitor, Ceramic, 4.7 μ F, 10V, X5R, 10%, 0603	C0603C475K8PACTU	Kemet
1	Cin	Capacitor, Ceramic, 1 μ F, 25V, X5R, 10%, 0603	Std	Std
3	Cin1, Cin2, Cin3	Capacitor, Ceramic, 22 μ F, 25V, X5R, 10%, 1210	12103D226KAT2A	AVX
1	Cin4	Capacitor, OSCON, 39 μ F, 35V, 30m Ω	35SVPF39M	Sanyo
4	Co1, Co2, Co3, Co4	Capacitor, Ceramic, 100 μ F, 6.3V, X5R, 20%, 1210	C1210C107M9PACTU	Kemet
1	Co5	Capacitor, POSCAP, 330 μ F, 6.3V, 9m Ω	6TPF330M9L	Sanyo
1	Crs	Capacitor, Ceramic, 10 μ F, 6.3V, X5R, 20%, 0603	Std	Std
1	Cs	Capacitor, Ceramic, 0.22 μ F, 25V, X7R, 10%, 0603	Std	Std
1	Css	Capacitor, Ceramic, 47nF, 25V, X7R, 10%, 0603	Std	Std
1	D1	Diode Zener, 5.1V, 300mW, SOD523	BZX585-B5V1	NXP
1	Dbt	Diode Schottky, 30V, 200mA, SOD523	1PS79SB30	NXP
1	Dtemp	Transistor, NPN, 40V, 0.2A, SOT-323	MMBT3904WT1G	On Semi
1	Lout	Inductor, 1 μ H, 1.1m Ω DCR, 30A Isat	HMP1360-1R0-63	Delta
1	Qh	MOSFET, N-Channel, 25V, TDSON-8	BSC032NE2LS	Infineon
1	Ql	MOSFET, N-Channel, 25V, TDSON-8	BSC010NE2LS	Infineon
4	Rc1, Rfb1, Rfb2, Rpg	Resistor, Chip, 20k Ω , 1/10W, 1%, 0603	Std	Std
1	Rc2	Resistor, Chip, 221 Ω , 1/10W, 1%, 0603	Std	Std
2	Rcs, Rset	Resistor, Chip, 3.32k Ω , 1/10W, 1%, 0603	Std	Std
1	Ren1	Resistor, Chip, 47.5k Ω , 1/10W, 1%, 0603	Std	Std
1	Ren2	Resistor, Chip, 10k Ω , 1/10W, 1%, 0603	Std	Std
1	Rf	Resistor, Chip, 68.1k Ω , 1/10W, 1%, 0603	Std	Std
4	Rh, Rrs, Rs+, Rs-	Resistor, Chip, 10 Ω , 1/10W, 1%	Std	Std
1	Rin	Resistor, Chip, 2.2 Ω , 1/10W, 5%, 0603	Std	Std
1	Rs	Resistor, Chip, 4.22k Ω , 1/10W, 1%, 0603	Std	Std
1	Rt	Resistor, Chip, 84.5k Ω , 1/10W, 1%, 0603	Std	Std
1	U1	IC, Synchronous Buck Controller with DCR Current Sensing and Thermal Compensation, 4-mm x 4-mm WQFN-24 PowerPAD™ package	LM27403SQ	TI
1	PCB	PCB, FR4, 6 layer, 2" x 2" x 0.062"	PCB1	Any
4	VIN, VOUT, GND, GND	Banana Jack Power Terminal	108-0740-001	Emerson
4	H1, H2, H3, H4	Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	NY PMS 440 0025 PH	B&F Fastener Supply
4	H5, H6, H7, H8	Standoff, Hex, 0.5"L #4-40 Nylon	1902C	Keystone

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Texas Instruments (TI) provides the enclosed Evaluation Board/Kit/Module (EVM) under the following conditions:

The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user indemnifies TI from all claims arising from the handling or use of the goods.

Should this evaluation board/kit not meet the specifications indicated in the User's Guide, the board/kit may be returned within 30 days from the date of delivery for a full refund. THE FOREGOING LIMITED WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE. EXCEPT TO THE EXTENT OF THE INDEMNITY SET FORTH ABOVE, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

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REGULATORY COMPLIANCE INFORMATION

As noted in the EVM User's Guide and/or EVM itself, this EVM and/or accompanying hardware may or may not be subject to the Federal Communications Commission (FCC) and Industry Canada (IC) rules.

For EVMs **not** subject to the above rules, this evaluation board/kit/module is intended for use for ENGINEERING DEVELOPMENT, DEMONSTRATION OR EVALUATION PURPOSES ONLY and is not considered by TI to be a finished end product fit for general consumer use. It generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to part 15 of FCC or ICES-003 rules, which are designed to provide reasonable protection against radio frequency interference. Operation of the equipment may cause interference with radio communications, in which case the user at his own expense will be required to take whatever measures may be required to correct this interference.

General Statement for EVMs including a radio

User Power/Frequency Use Obligations: This radio is intended for development/professional use only in legally allocated frequency and power limits. Any use of radio frequencies and/or power availability of this EVM and its development application(s) must comply with local laws governing radio spectrum allocation and power limits for this evaluation module. It is the user's sole responsibility to only operate this radio in legally acceptable frequency space and within legally mandated power limitations. Any exceptions to this are strictly prohibited and unauthorized by Texas Instruments unless user has obtained appropriate experimental/development licenses from local regulatory authorities, which is responsibility of user including its acceptable authorization.

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

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

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.

For EVMs annotated as IC – INDUSTRY CANADA Compliant

This Class A or B digital apparatus complies with Canadian ICES-003.

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

Concerning EVMs including radio transmitters

This device complies with Industry Canada licence-exempt RSS standard(s). 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.

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.

Cet appareil numérique de la classe A ou B est conforme à la norme NMB-003 du Canada.

Les changements ou les modifications pas expressément approuvés par la partie responsable de la conformité ont pu vider l'autorité de l'utilisateur pour actionner l'équipement.

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.

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.

【Important Notice for Users of EVMs for RF Products in Japan】

This development kit is NOT certified as Confirming to Technical Regulations of Radio Law of Japan

If you use this product in Japan, you are required by Radio Law of Japan to follow the instructions below with respect to this product:

1. Use this product 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 this product only after you obtained the license of Test Radio Station as provided in Radio Law of Japan with respect to this product, or
3. Use of this product only after you obtained the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to this product. Also, please do not transfer this product, unless you give the same notice above to the transferee. Please note that if you could not follow the instructions above, you will be subject to penalties of Radio Law of Japan.

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EVALUATION BOARD/KIT/MODULE (EVM) WARNINGS, RESTRICTIONS AND DISCLAIMERS

For Feasibility Evaluation Only, in Laboratory/Development Environments. Unless otherwise indicated, this EVM is not a finished electrical equipment and not intended for consumer use. It is intended solely for use for preliminary feasibility evaluation in laboratory/development environments by technically qualified electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems and subsystems. It should not be used as all or part of a finished end product.

Your Sole Responsibility and Risk. You acknowledge, represent and agree that:

1. You have unique knowledge concerning Federal, State and local regulatory requirements (including but not limited to Food and Drug Administration regulations, if applicable) which relate to your products and which relate to your use (and/or that of your employees, affiliates, contractors or designees) of the EVM for evaluation, testing and other purposes.
2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates, contractors or designees, using the EVM. Further, you are responsible to assure 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.
3. Since the EVM is not a completed product, it may not meet all applicable regulatory and safety compliance standards (such as UL, CSA, VDE, CE, RoHS and WEEE) which may normally be associated with similar items. You assume full responsibility to determine and/or assure compliance with any such standards and related certifications as may be applicable. You will employ reasonable safeguards to ensure that your use of the EVM will not result in any property damage, injury or death, even if the EVM should fail to perform as described or expected.
4. You will take care of proper disposal and recycling of the EVM's electronic components and packing materials.

Certain Instructions. It is important to operate this EVM within TI's recommended specifications and environmental considerations per the user guidelines. Exceeding the specified EVM ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings please 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 result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM User's 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, some circuit components may have case temperatures greater than 60°C as long as the input and output are maintained at a normal ambient operating temperature. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during normal operation, please be aware that these devices may be very warm to the touch. As with all electronic evaluation tools, only qualified personnel knowledgeable in electronic measurement and diagnostics normally found in development environments should use these EVMs.

Agreement to Defend, Indemnify and Hold Harmless. You agree to 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 use of the EVM that is not in accordance with the terms of the agreement. This obligation shall apply whether Claims arise under law of tort or contract or any other legal theory, and even if the EVM fails to perform as described or expected.

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TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

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