User's Guide

SLVU192A–February 2007–Revised March 2008

Using the TPS40077EVM-001 12-V Input, 1.8-V Output, 10-A Synchronous Buck Converter

The TPS40077EVM-001 evaluation module (EVM) is a synchronous buck converter providing a fixed 1.8-V output at up to 10 A from a 12-V input bus. The EVM is designed to start up from a single supply; no additional bias voltage is required for start-up. The TPS40077 Reduced Pin Count Synchronous Buck Controller used in the EVM employs predictive gate drive. This feature provides improved efficiency by eliminating shoot-through switching current,and minimizing the reverse-conduction time of the synchronous rectifier FET.

Contents

List of Figures

List of Tables

1 Introduction

1.1 Description

TPS40077EVM-001 is designed to use a 12-V (8 V-to-16 V) bus to produce a high current, regulated 1.8-V output at up to 10 A of load current. The TPS40077EVM-001 demonstrates the use of the TPS40077 in a typical 12-V bus to low-voltage application, while providing a number of test points to evaluate the performance of the TPS40077. The EVM can be modified to support output voltages from 0.9 V to 3.3 V by changing a single resistor.

1.2 Applications

- Non-isolated, medium-current point-of-load and low-voltage bus converters.
- Networking equipment
- Telecommunications equipment
- DC-power distributed systems

1.3 Features

- 8 V–16 V input range
- 1.8-V fixed output, adjustable with single resistor
- 10-A DC steady-state output current
- 300-kHz switching frequency
- Single main switch N-channel MOSFET and single synchronous rectifier N-channel MOSFET
- Double-sided PCB with all components on top side
- Active converter uses less than 2.4 square inches – 1.0" × 2.4"
- Convenient test points for probing critical waveforms and non-invasive loop response testing

2 TPS40077EVM-001 Electrical Performance Specifications

Table 1. TPS40077EVM-001 Electrical and Performance Specifications

PARAMETER		NOTES AND CONDITIONS	MIN	NOM	MAX	UNITS
INPUT CHARACTERISTICS						
V_{IN}	Input voltage		8	12	16	V
I_{IN}	Input current	V_{IN} = nom, I_{OUT} = max		1.7	1.8	A
	No-load input current	V_{IN} = nom, I_{OUT} = 0A		80	100	mA
V_{IN_UVLO}	Input UVLO	I_{OUT} = min to max	5.4	6	6.6	V
V_{IN_ONV}	Input ONV	I_{OUT} = min to max	6.3	7	7.7	V
OUTPUT CHARACTERISTICS						
V_{OUT}	Output voltage	V_{IN} = nom, I_{OUT} = nom	1.75	1.8	1.85	V
	Line regulation	V_{IN} = min to max, I_{OUT} = nom			0.5%	
	Load regulation	V_{IN} = nom, I_{OUT} = min to max			0.5%	
	Output ripple voltage	V_{OUT}_ripple V_{IN} = nom, I_{OUT} = max			40	mVpp
	Output current	I_{OUT} V_{IN} = min to max	0	5	10	A
	Output overcurrent inception point	I_{OCP} V_{IN} = nom, V_{OUT} = V_{OUT}–5%	12.25	19.4	34	A
	Transient response					
ΔI	Load step	I_{OUT_max} to 0.2 x I_{OUT_max}		8		A
	Load slew rate			1		A/µsec
	Overshoot			300		mV
	Settling time			0.1		msec
SYSTEMS CHARACTERISTICS						
f_{SW}	Switching frequency		240	300	360	kHz
ηpk	Peak efficiency	V_{IN}=nom, I_{OUT} = min to max		90%		
η	Full-load efficiency	V_{IN}=nom, I_{OUT} = max		89%		
Top	Operating temperature range	V_{IN} = min to max, I_{OUT} = min to max	–40	25	85	°C
MECHANICAL CHARACTERISTICS						
W	Dimensions (active area)	Width		1		ins
L		Length		2.4		ins
h		Component height		0.41		ins
NOTE 1: Voltage accuracy effected by resistor tolerance.						

3 Schematic

For Reference Only, See Table 3: Bill of Materials for Specific Values

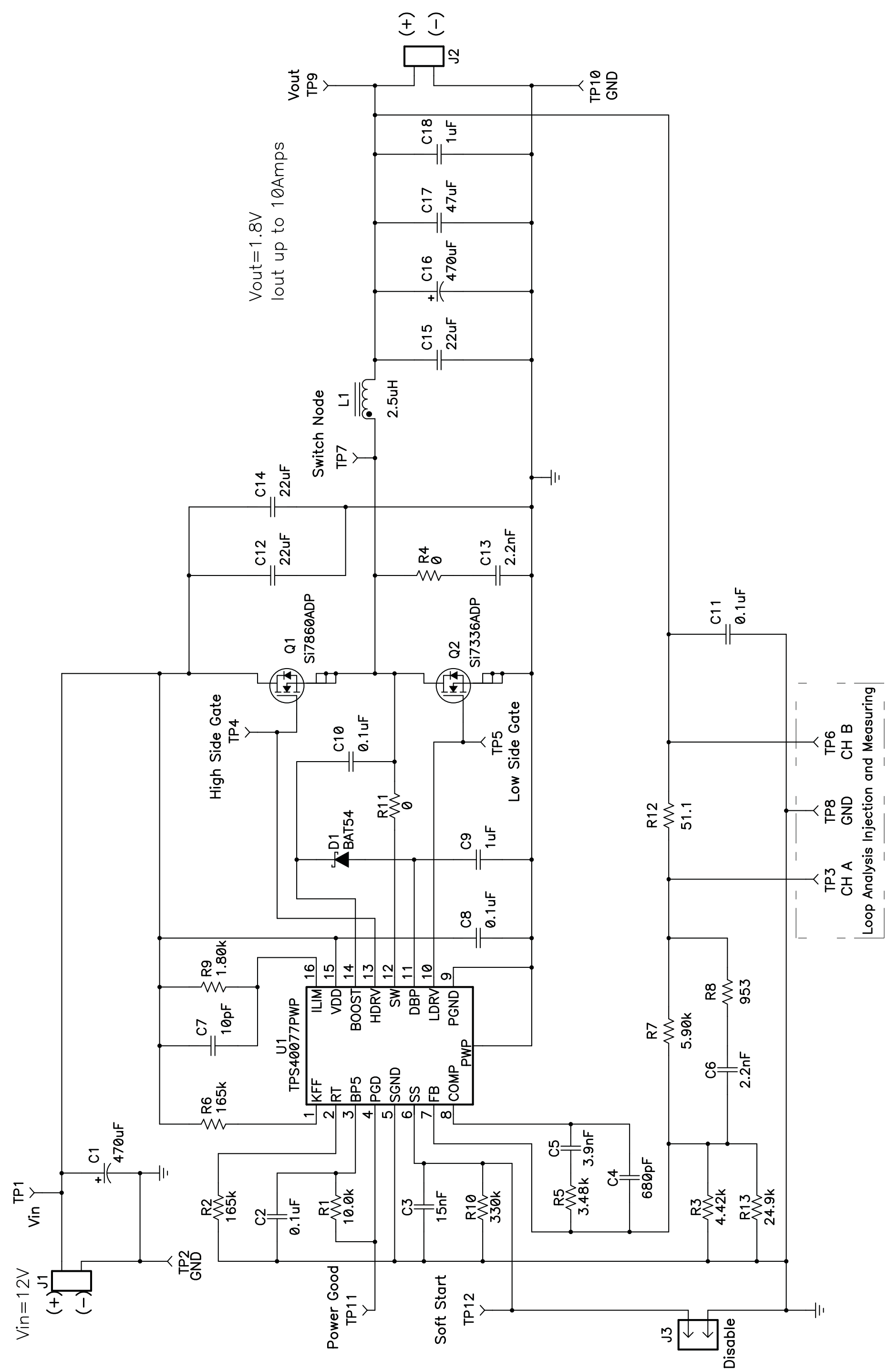

Figure 1. TPS40077EVM-001 Schematic

3.1 Adjusting Output Voltage (R3 & R13)

The regulated output voltage can be adjusted within a limited range by changing the ground resistors in the feedback resistor-divider (R3, R13).

Table 2 contains common values for R3 and R13 to generate popular output voltages. TPS40077EVM-001 is stable through these output voltages but the efficiency may suffer as the power stage is optimized for the 1.8 V output.

Table 2. Adjusting V_{OUT} With R3

V_{OUT}	R3	R13
1.2 V	9.53 kΩ	62.0 kΩ
1.5 V	5.36 kΩ	140 kΩ
1.8 V	4.42 kΩ	24.9 kΩ
2.5 V	2.37 kΩ	71.5 kΩ
3.3 V	1.60 kΩ	220 kΩ

3.2 Disable (J3)

The TPS40077EVM-001 provides a Disable input (J3) that allows the user to evaluate the TPS40077's Enable/Disable Function. When a short is applied across the pins of J3 the TPS40077 controller is disabled and the EVM shuts down. When the TPS40077 is disabled, both FET Drivers are off.

3.3 Test Set Up

3.3.1 Equipment

3.3.1.1 Voltage Source

V_{12V_IN}
The input voltage source (V_{12V_IN}) should be a 0–16 V variable-DC source capable of 5 A DC. Connect V_{12V_IN} to J1 as shown in Figure 3.

3.3.1.2 Meters

- A1: 0-5 A DC, ammeter
- V1: V_{12V_IN}, 0-16 V voltmeter
- V2: V_{1V5_OUT} 0-5 V voltmeter

3.3.1.3 Loads

LOAD1
The Output Load (LOAD1) should be a constant-current mode electronic load capable of 0-15 A DC at 1.8 V.

3.3.1.4 Oscilloscope

A digital or analog oscilloscope can be used to measure the ripple voltage on V_{OUT}. The oscilloscope should be set for 1-MΩ impedance, 20-MHz bandwidth, AC coupling, 1-µs/division horizontal resolution, 20-mV/division vertical resolution for measuring output ripple. TP9 and TP10 can be used to measure the output ripple voltage by placing the oscilloscope probe tip through TP9 and holding the ground barrel to TP10 as shown in Figure 2. For a hands free approach, the loop in TP10 can be cut and opened to cradle the probe barrel. Using a leaded ground connection should be avoided because it induces additional noise due to its large ground-loop area.

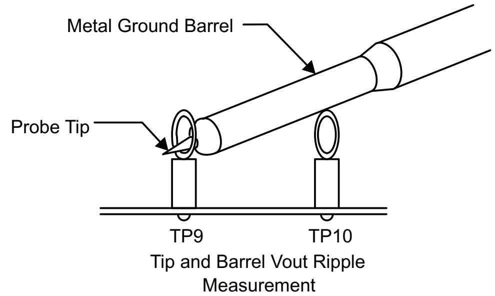

Figure 2. Output Ripple Measurement – Tip and Barrel Using TP9 and TP10

3.3.1.5 Recommended Wire Gauge

V_{12V_IN} to J1

The connection between the source voltage, V_{12V_IN} and J1 can carry as much as 3 A DC. The minimum recommended wire size is AWG #16 with the total length of wire less than 4 feet (2 feet input, 2 feet return).

J2 to LOAD1 (Power)

The power connection between J2 and LOAD1 can carry as much as 15 A DC. The minimum recommended wire size is 2 × AWG #16, with the total length of wire less than 4 feet (2 feet output, 2 feet return).

3.4 Equipment Setup

Shown in Figure 3 is the basic test set up recommended to evaluate the TPS40077EVM-001. Note that although the return for J1 and J2 are the same, the connections should remain separate as shown in Figure 2.

3.4.1 Procedure

1. Working at an ESD workstation, make sure that any wrist straps, bootstraps or mats are connected referencing the user to earth ground before power is applied to the EVM. Electrostatic smock and safety glasses should also be worn.
2. Prior to connecting the DC input source, V_{12V_IN}, it is advisable to limit the source current from V_{12V_IN} to 5.0 A maximum. Make sure V_{12V_IN} is initially set to 0 V and connected as shown in Figure 3.
3. Connect an Ammeter A1 as shown in Figure 3.
4. Connect Voltmeter V1 to TP1 and TP2 as shown in Figure 3.
5. Connect LOAD1 to J2 as shown in Figure 3. Set LOAD1 to constant current mode to sink 0 A DC before V_{12V_IN} is applied.
6. Connect Voltmeter V2 to Output J2 as shown in Figure 3.
7. Connect Oscilloscope probe to TP9 and TP10 as shown in Figure 2.

3.4.2 Diagram

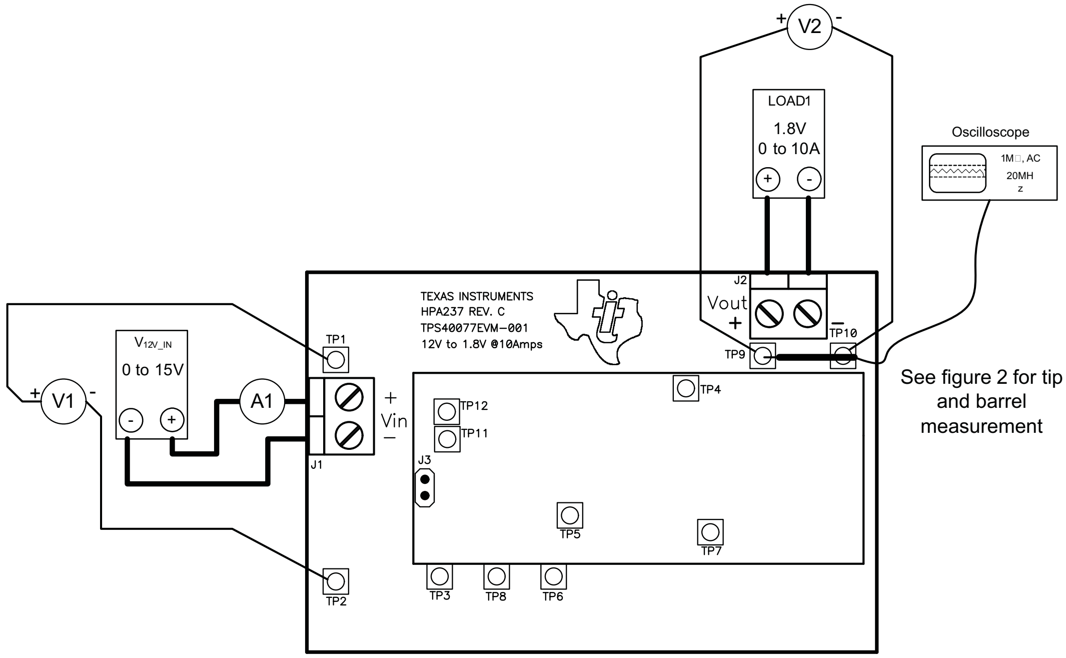

Figure 3. TPS40077EVM-001 Recommended Test Set-Up

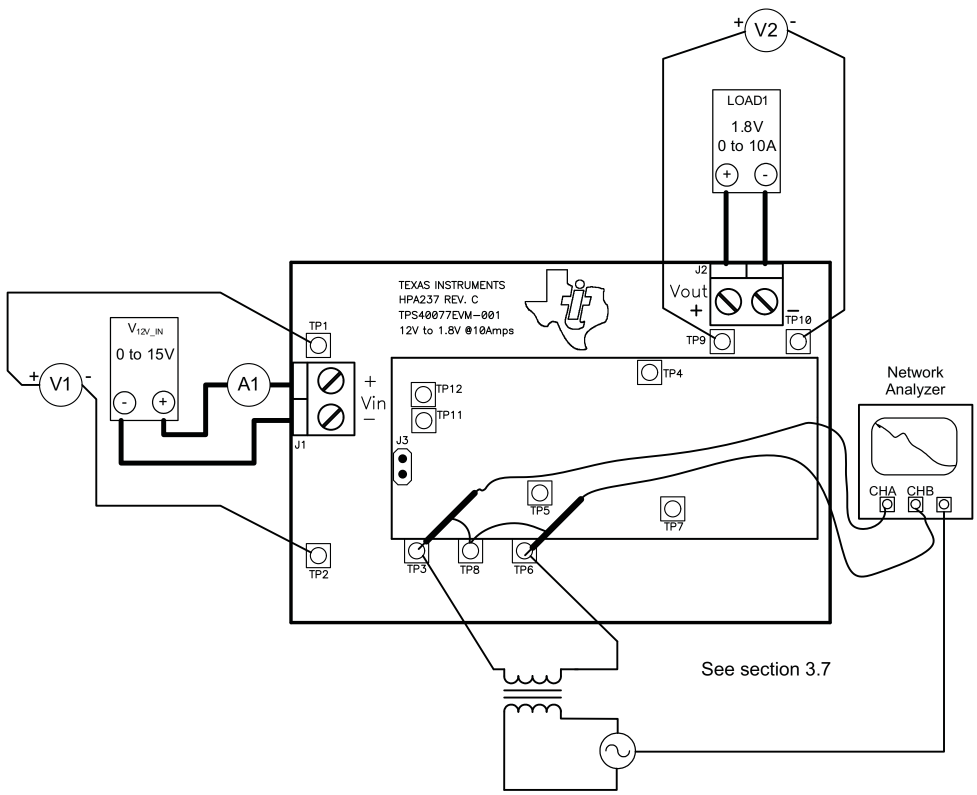

Figure 4. Control Loop Measurement Setup

3.5 Start Up / Shut Down Procedure

1. Increase V_{12V_IN} from 0 V to 12 V DC.
2. Vary LOAD1 from 0–10 A DC
3. Vary V_{12V_IN} from 8 V DC to 16 V DC
4. Decrease LOAD1 to 0 A.

3.6 Control Loop Gain and Phase Measurement Procedure

1. Connect 1 kHz–1 MHz isolation transformer to TP3 and TP6 as shown in Figure 4
2. Connect input-signal amplitude-measurement probe (channel A) to TP3 as shown in Figure 4
3. Connect output-signal amplitude measurement probe (channel B) to TP6 as shown in Figure 4
4. Connect ground lead of channel A and channel B to TP8 as shown in Figure 4
5. Inject 25 mV or less signal across TP3 and TP6 through an isolation transformer
6. Sweep frequency from 1 kHz to 1 MHz with 10 Hz or lower post filter
7. Control-loop gain can be measured by $20 \times \text{LOG}\left(\frac{\text{ChannelB}}{\text{ChannelA}}\right)$
8. Control-loop phase is measured by the phase difference between channel A and channel B
9. Disconnect isolation transformer from TP3 and TP6 before making other measurements (Signal injection into feedback may interfere with accuracy of other measurements)

3.7 Equipment Shutdown

1. Shut Down Oscilloscope
2. Shut down LOAD1
3. Shut down V_{12V_IN}

4 TPS40077EVM Typical Performance Data and Characteristic Curves

Figure 5 through Figure 10 present typical performance curves for the TPS40077EVM-001. 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.

4.1 Efficiency

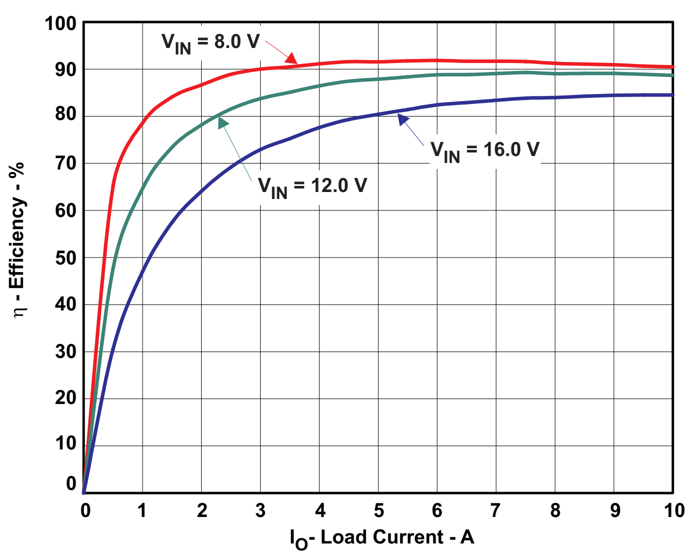

Figure 5. TPS40077EVM-001 Efficiency

4.2 Line and Load Regulation

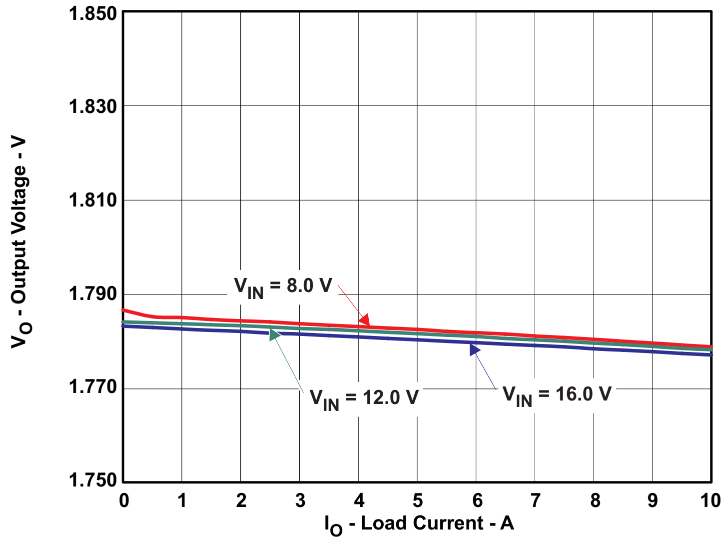

Figure 6. TPS40077EVM-001 Line and Load Regulation

4.3 Output Ripple

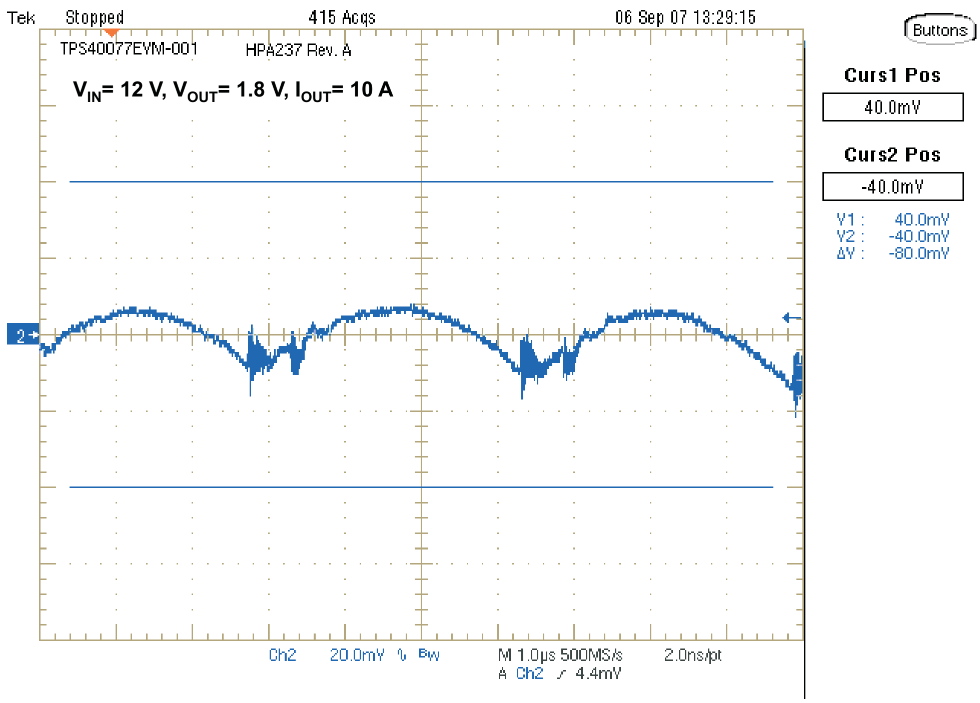

Figure 7. TPS40077EVM-001 Typical Output Ripple

4.4 Transient Response

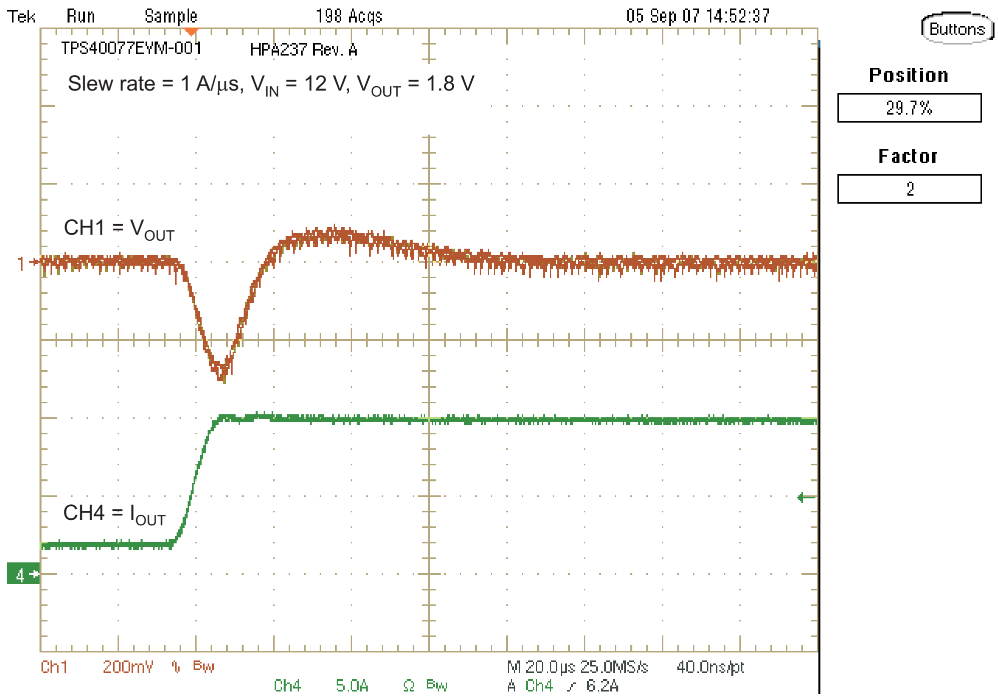

Figure 8. Load Transient, 2 A to 10 A

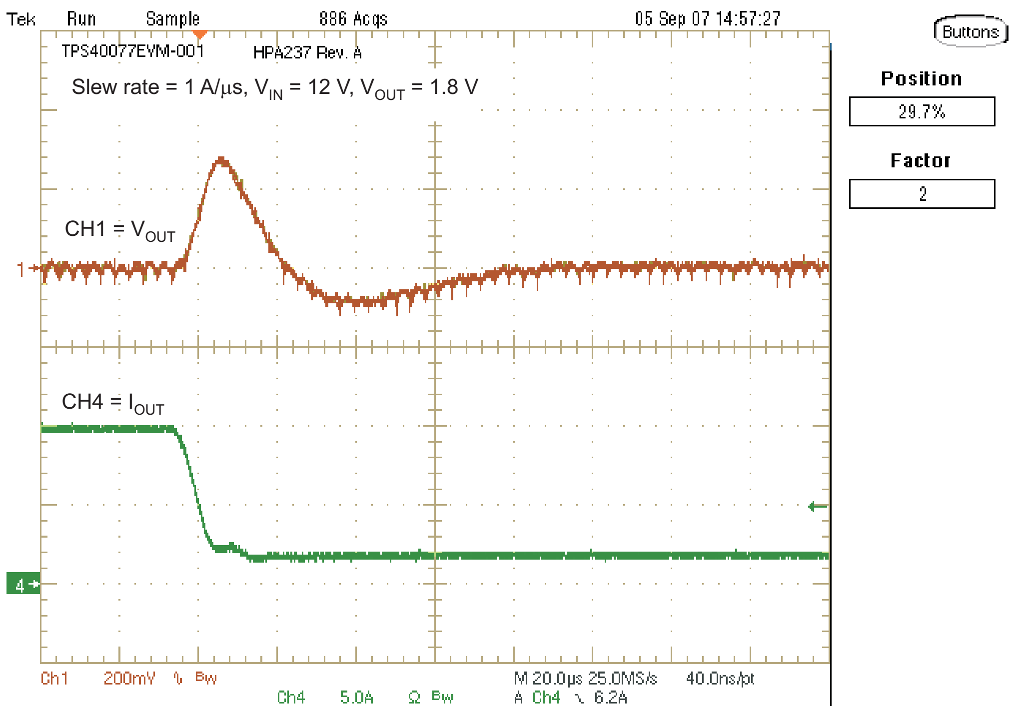

Figure 9. Load Transient, 10 A to 2 A

4.5 Bode Plot

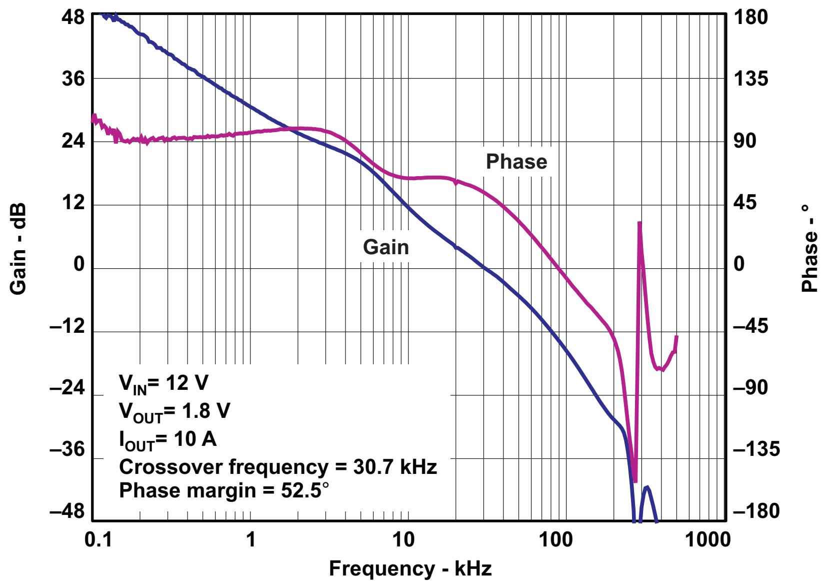

Figure 10. Typical Bode Plot

5 EVM Assembly Drawings and Layout

The following figures (Figure 11 through Figure 13) show the design of the TPS40077EVM-001 printed circuit board. The EVM has been designed using a double-sided, 2-oz copper-clad circuit board, with all components on the top side to allow the user to easily view, probe and evaluate the TPS40077 in a practical application. Moving components to both sides of the PCB or using additional internal layers can offer additional size reduction for space-constrained systems.

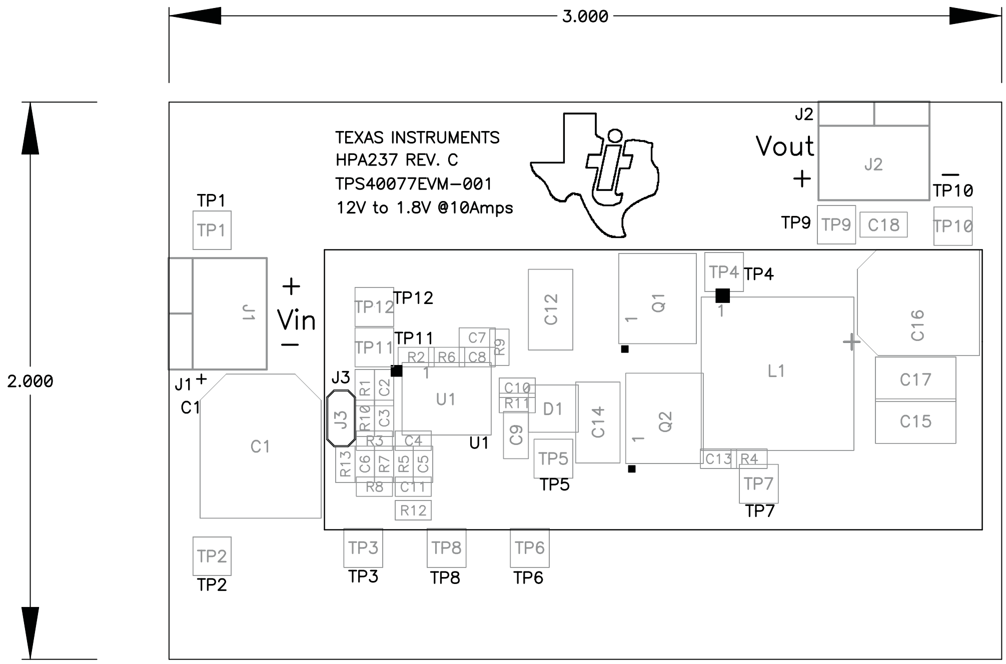

Figure 11. TPS40077EVM-001 Component Placement (Viewed from Top)

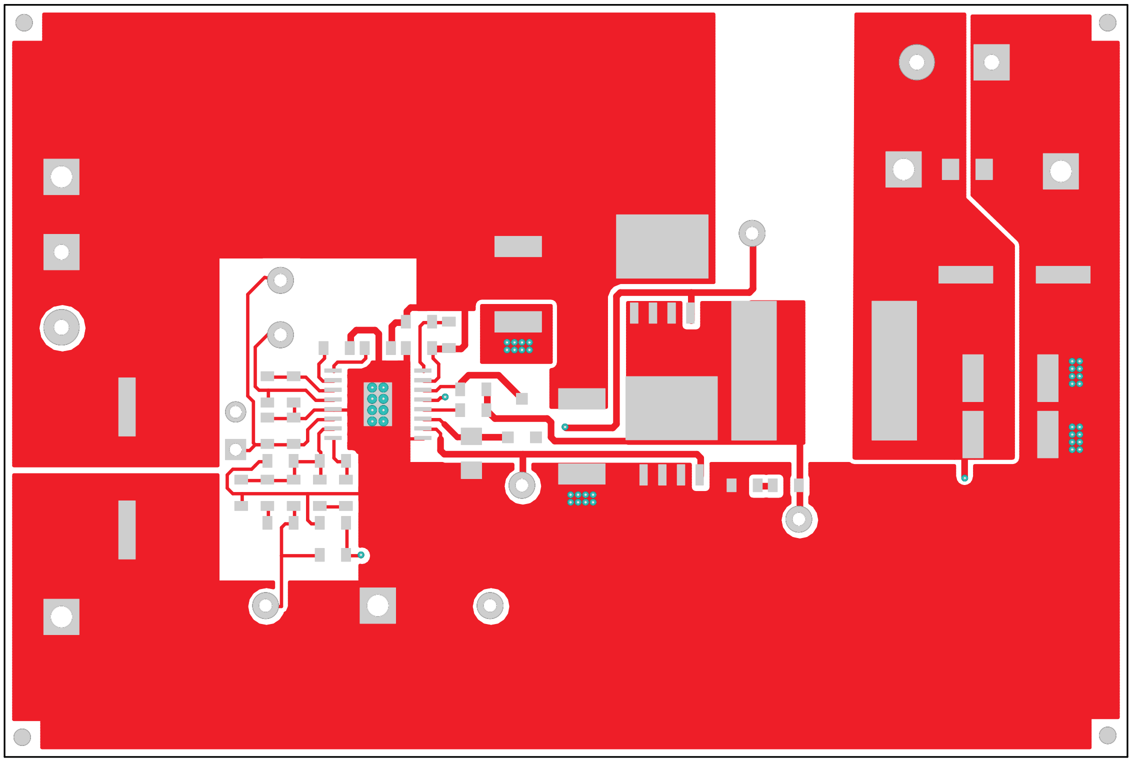

Figure 12. TPS40077EVM-001 Top Copper (Viewed from Top)

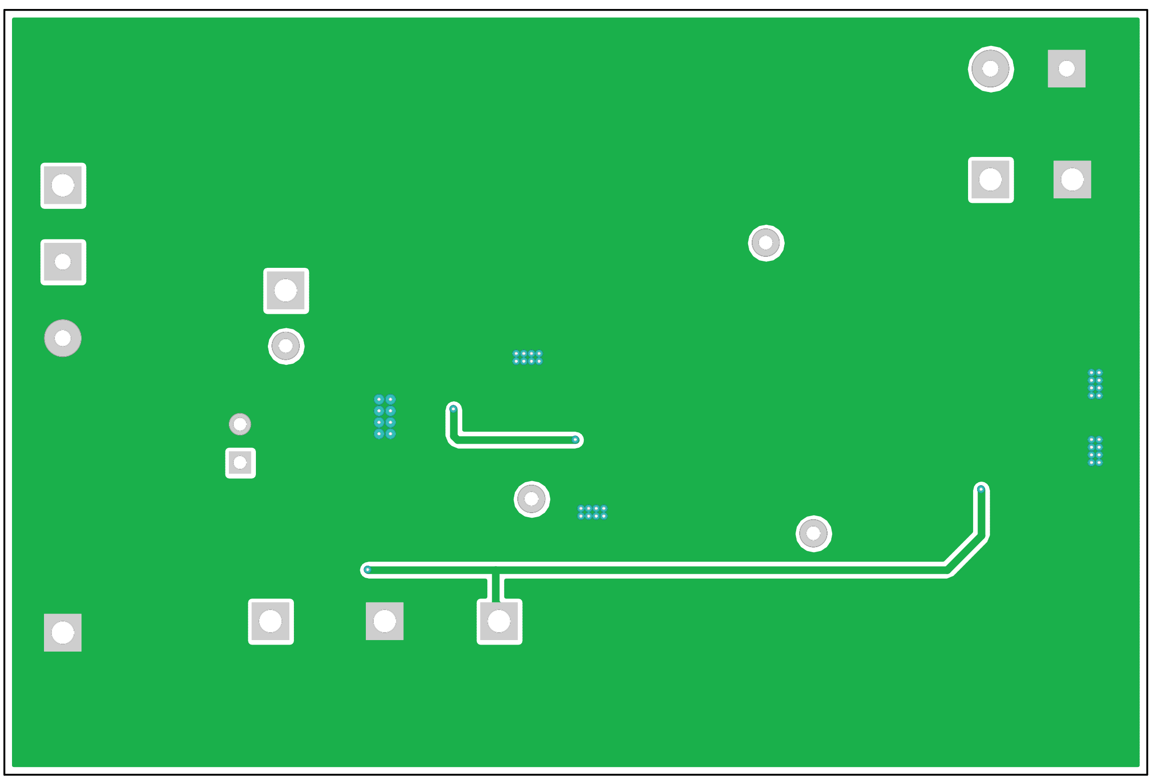

Figure 13. TPS40077EVM-001 Bottom Copper (X-Ray View from Top)

6 List of Materials

Table 3 lists the EVM components as configured according to the schematic shown in Figure 1.

Table 3. Bill of Materials

COUNT	RefDes	Value	Description	Size	Part Number	MFR
1	C1	470 µF	Capacitor, Aluminum, 470-µF, 25-V, 20%	0.457 x 0.406	EEVFK1E471P	Panasonic
3	C12, C14, C15	22 µF	Capacitor, Ceramic, 22µF, 16V, X5R, 20%	1812	C4532X5R1C226 MT	TDK
2	C6, C13	2.2 nF	Capacitor, Ceramic, 25V, X7R 20%	0603	Std	Vishay
1	C16	470 µF	Capacitor, Aluminum, SM, 6.3V, 300mΩ (FK series)	8x10mm	FK-Series	Panasonic
1	C17	47 µF	Capacitor, Ceramic, 47-µF, 6.3-V, X5R, 20%	1812	C4532X5R0J476 MT	TDK
2	C2, C10	0.1 µF	Capacitor, Ceramic, 25V, X7R, 20%	0603	Std	Vishay
1	C3	15 nF	Capacitor, Ceramic, 25V, X7R, 20%	0603	Std	Vishay
1	C4	680 pF	Capacitor, Ceramic, 25V, X7R, 20%	0603	Std	Vishay
1	C5	3900 pF	Capacitor, Ceramic, 25V, X7R 20%	0603	Std	Vishay
1	C7	10 pF	Capacitor, Ceramic, 25V, COG 20%	0603	Std	Vishay
2	C8, C11	0.1 µF	Capacitor, Ceramic, 25V, X7R, 20%	0603	Std	Vishay
1	C9, C18	1 µF	Capacitor, Ceramic, 25V, X7R, 20%	0805	Std	Vishay
1	D1		Diode, Schottky, 200-mA, 30-V	SOT23	BAT54	Vishay
1	L1	2.5 µH	Inductor, SMT, 2.5µH, 16.5 A, 3.4 mΩ	0.515 × 0.516	MLC1550-252ML	Coiltronics
1	Q1		MOSFET, NChannel, 30V, 18A, 8.0 mΩ	PWRPAK S0-8	Si7860DP	Vishay
1	Q2		MOSFET, NChannel, 30V, 18A, 40 mΩ	PWRPAK S0-8	Si7886ADP	Vishay
1	R1	10 kΩ	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R10	330 kΩ	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R12	51 Ω	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R13	24.9 kΩ	Resistor, Chip, 1/16W, 1%	0603	Std	Std
2	R2, R6	165 kΩ	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R3	4.42 kΩ	Resistor, Chip, 1/16W, 1%	0603	Std	Std
2	R4, R11	0 Ω	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R5	3.48 kΩ	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R7	5.90 kΩ	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R8	953 Ω	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R9	1.80 kΩ	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	U1		IC	PWP16	TPS40077PWP	Texas Instruments