

Evaluating the **ADP2389/ADP2390**, 18 V, 12 A Step-Down Regulators with Programmable Current Limit

FEATURES

Input voltage: 4.5 V to 18 V
Continuous output current: 12 A
Integrated MOSFET: 17 mΩ/4.5 mΩ
Reference voltage: 0.6 V $\pm$ 0.5%
Programmable switching frequency: 200 kHz to 2.2 MHz
Enhanced transient response
Programmable current-limit with $\pm$ 10% accuracy
Precision enable and power good
External compensation and soft start
PFM mode (ADP2390 only)
Start up into a precharged output
Supported by ADIsimPower™ design tool

GENERAL DESCRIPTION

The **ADP2389/ADP2390** evaluation board is a complete, 12 A, 18 V, step-down regulator solution that allows users to evaluate the performance of the **ADP2389/ADP2390** with a near ideal printed circuit board (PCB) layout.

The programmable current-limit function allows the inductor to be optimized by output current. The peak current-limit threshold is preset to 16.8 A to ensure the 12 A output current capability.

The switching frequency can be programmed between 200 kHz and 2.2 MHz, which provides the possibility for a stackable multiphase power solution.

An enhanced transient response feature improves the load transient performance, which reduces the output capacitance.

The output of the **ADP2389/ADP2390** evaluation board is preset to 1.8 V and the switching frequency is set to 500 kHz. Different output voltage settings can be achieved by changing appropriate passive components. The ambient temperature operating range is -40°C to $+85^{\circ}\text{C}$.

Full details on the **ADP2389/ADP2390** regulators are provided in the **ADP2389/ADP2390** data sheet, available from Analog Devices, Inc., which should be consulted in conjunction with this user guide.

EVALUATION BOARD PHOTOGRAPH

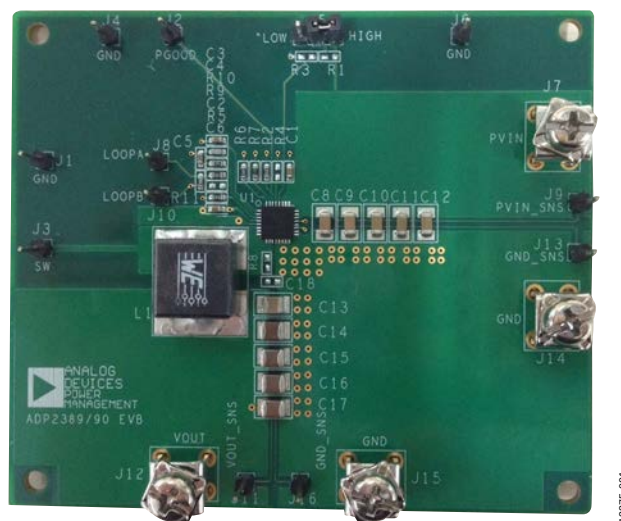


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REVISION HISTORY

9/15—Revision 0: Initial Version

EVALUATION BOARD HARDWARE

POWER SUPPLIES

The ADP2389/ADP2390 evaluation board is provided fully assembled and tested. Before applying power to the evaluation board, follow the procedures in this section.

Jumper J5 (Enable)

Use one of the following methods to enable or to disable the regulator:

- To enable the regulator, short the middle pin of J5, EN, to high.
- To disable the regulator, short the middle pin of J5, EN, to low.

Input Power Source

If the input power source includes a current meter, use that meter to monitor the input current. Connect the positive terminal of the power source to J7 (PVIN) of the evaluation board, and the negative terminal of the power source to J14 (GND) of the evaluation board.

If the power source does not include a current meter, connect a current meter in series with the input source voltage. Connect the positive lead (+) of the power source to the positive (+) ammeter terminal, the negative lead (–) of the power source to J14 (GND), and the negative lead (–) of the ammeter to J7 (PVIN).

Output Load

Prior to connecting the load, ensure that the evaluation board is turned off. Connect an electronic load or resistor to the output of the evaluation board to set the load current.

Connect the positive terminal of the load to J12 (VOUT) of the evaluation board and connect the negative terminal of the load to J15 (GND).

Input and Output Voltmeters

Measure the input and output voltages using voltmeters. Ensure that the voltmeters are connected to the appropriate terminals of the evaluation board and not to the load or power source. If the voltmeters are not connected directly to the evaluation board, it produces incorrect measured voltages because the voltage drops across the leads or connections between the evaluation board, the power source, and the load.

To measure the input voltage, connect the positive terminal of the voltmeter to J9 (PVIN_SNS) and the negative terminal to J13 (GND_SNS). Likewise, to measure the output voltage, connect the positive terminal of the voltmeter to J11 (VOUT_SNS) and the negative terminal to J16 (GND_SNS).

Turning On the Evaluation Board

When the power source and load are connected to the evaluation board, it can be powered for operation.

Perform the following steps to turn on the board:

1. Ensure that the power source voltage is >4.5 V and <18 V.
2. Ensure that EN is high and monitor the output voltage.
3. Turn on the load, check that it is drawing the proper load current, and verify that the output voltage maintains its regulation.

MEASURING EVALUATION BOARD PERFORMANCE

Measuring the Switching Waveform

To observe the switching waveform with an oscilloscope, place the oscilloscope probe tip at Test Point J3 (SW) with the probe ground at J1 (GND). Set the scope to dc with the appropriate voltage and time divisions. Alternate the switching waveform limits between ~0 V and the input voltage.

Measuring Load Regulation

Measure the load regulation by observing the change in the output voltage while increasing the output load current. To minimize the voltage drop, use short, low resistance wires.

Measuring Line Regulation

Measure the line regulation by varying the input voltage and examining the change in the output voltage with a fixed output current.

Line Transient Response

To test the line transient response, generate a step input voltage change and observe the behavior of the output voltage using an oscilloscope.

Load Transient Response

To test the load transient response, generate a load current transient at the output and observe the output voltage response using an oscilloscope. Attach the current probe to the wire between the output and the load to capture the current transient waveform.

Measuring Efficiency

The efficiency, η , is measured by comparing the input power with the output power.

$$\eta = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times I_{IN}}$$

Measure the input and output voltages as close as possible to the input and output capacitors to reduce the effect of voltage drop.

Measuring Inductor Current

To measure the inductor current, remove one end of the inductor from its pad and connect a current loop in series with the inductor end and its pad (a current probe can be connected onto this wire).

Measuring Output Voltage Ripple

To observe the output voltage ripple, place the oscilloscope probe across the output capacitor with the probe ground lead connected to the negative (–) capacitor terminal and the probe tip placed at the positive (+) capacitor terminal. Set the oscilloscope to ac, 10 mV/division, 2 μs/division time base, and 20 MHz bandwidth.

A standard oscilloscope probe has a long wire ground clip. For high frequency measurements, this ground clip picks up high frequency noise and injects it into the measured output ripple. Figure 2 shows an easy way to measure the output ripple properly. It requires removing the oscilloscope probe sheath and wrapping an unshielded wire around the oscilloscope probe. By keeping the ground length of the oscilloscope probe as short as possible, the true ripple can be measured.

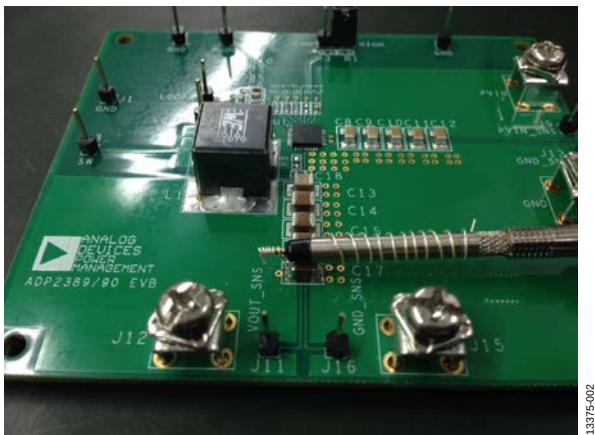


Figure 2. Measuring Output Voltage Ripple

MODIFYING THE BOARD

To modify the ADP2389/ADP2390 evaluation board configuration, unsolder and/or replace or remove the appropriate passive components or jumpers on the board.

Changing the Output Voltages

The output voltage setpoints of the ADP2389/ADP2390 can be changed by replacing the R9 and R5 resistors with the resistor values shown in Table 1.

Table 1. Resistive Divider for Various Output Voltages

V _{OUT} (V)	R9, ±1% (kΩ)	R5, ±1% (kΩ)
1.0	10	15
1.2	10	10
1.5	15	10
1.8	20	10
2.5	47.5	15
3.3	10	2.21
5.0	22	3

To limit output voltage accuracy degradation due to the FB pin bias current (0.1 μA maximum) to less than 0.5% (maximum), ensure that the bottom divider string resistor, R5, is less than 30 kΩ.

The top resistor, R9, value is calculated using the following equation:

$$R9 = R5 \times \left(\frac{V_{OUT} - 0.6 \text{ V}}{0.6 \text{ V}} \right)$$

When the output voltage is changed, the values of the inductor (L1), the output capacitors (C13, C14, C15, C16, and C17), and the compensation components (R10, C5, and C4) must be recalculated and changed to ensure stable operation (see the ADP2389/ADP2390 data sheet for details on external component selection).

Changing the Switching Frequency

The switching frequency (f_{sw}) setpoint can be changed by replacing the R6 resistor with a different value, as shown in the following equation:

$$f_{sw} \text{ (kHz)} = 67,000 / (R6 \text{ (k}\Omega) + 12)$$

A 210 kΩ resistor sets the frequency to 300 kHz, and a 100 kΩ resistor sets the frequency to 600 kHz.

When the switching frequency is changed, the values of the inductor (L1), the output capacitors (C13, C14, C15, C16, and C17), and the compensation networks (R10, C5, and C4) must be recalculated and changed for stable operation (see the ADP2389/ADP2390 data sheet for details on external component selection).

Changing the Soft Start Time

The soft start time of the ADP2389/ADP2390 on the evaluation board is programmed to 4 ms.

To change the soft start time, t_{ss} , replace the C3 capacitor value using the following equation:

$$C3 \text{ (nF)} = 5.67 \times t_{ss} \text{ (ms)}$$

Changing the Peak Current-Limit Threshold

The peak current-limit threshold of ADP2389/ADP2390 can be changed by replacing the R7 resistor with a different value, as shown in the following equation:

$$I_{OCP} \text{ (A)} = 1000 / (R7 \text{ (k}\Omega) + 0.5)$$

A 54.9 kΩ resistor sets the current-limit threshold to 18 A, an 82.5 kΩ resistor sets the current-limit threshold to 12 A, and a 110 kΩ resistor sets the current-limit threshold to 9 A.

By programming the peak current-limit threshold at different levels, the value and size of the inductor (L1) can be optimized based on actual applications.

EVALUATION BOARD SCHEMATIC AND ARTWORK

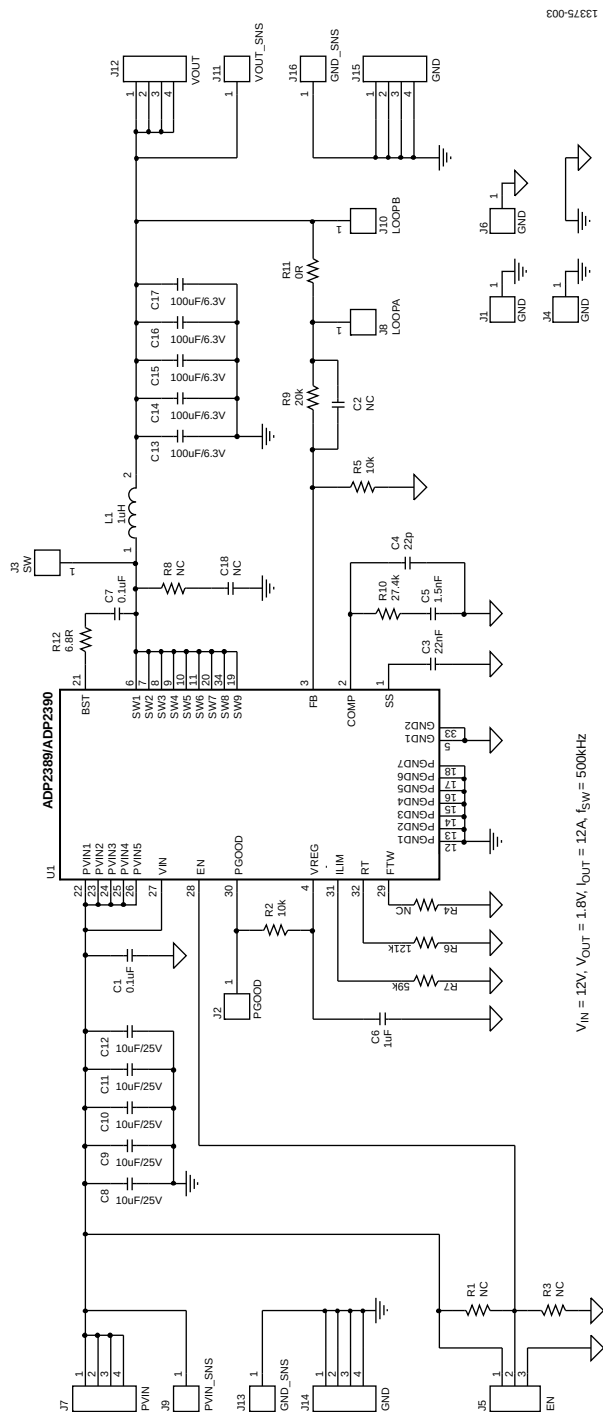


Figure 3. Evaluation Board Schematic for ADP2389/ADP2390

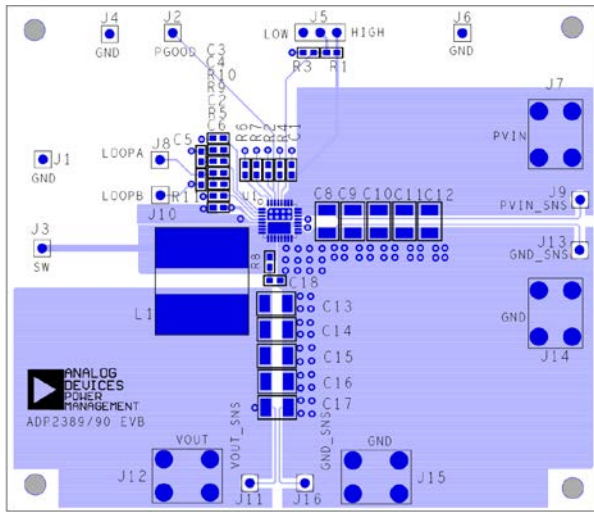


Figure 4. Layer 1, Component Side

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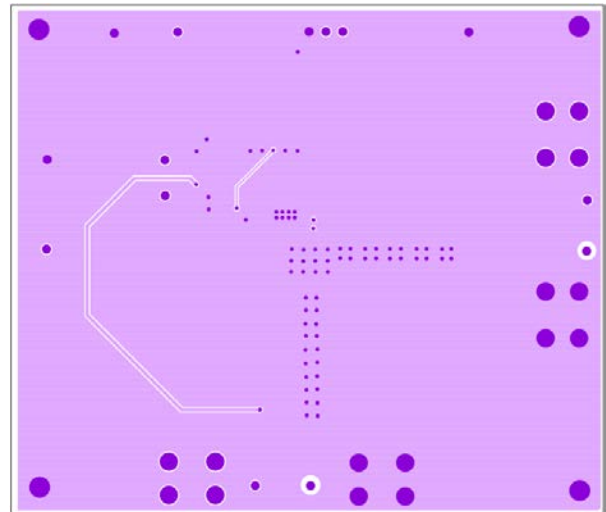


Figure 6. Layer 3, Power Plane

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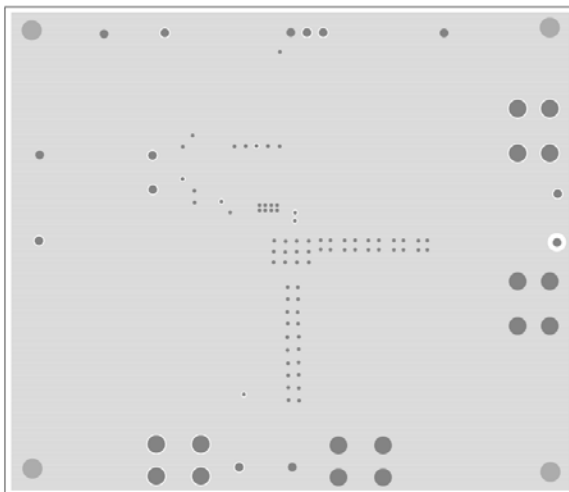


Figure 5. Layer 2, Ground Plane

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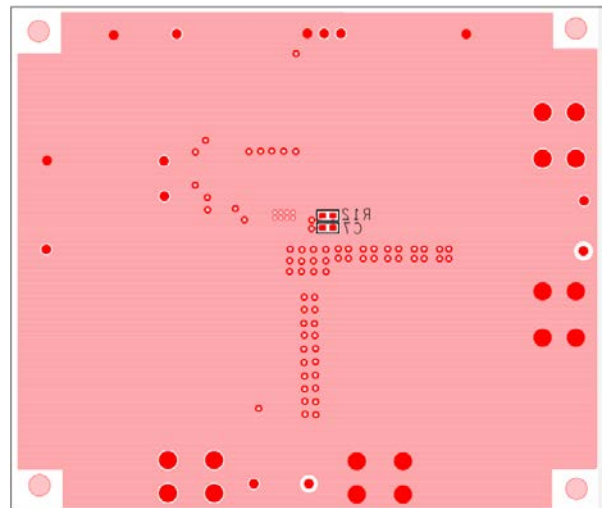


Figure 7. Layer 4, Bottom Side

13375-007

ORDERING INFORMATION

BILL OF MATERIALS

Table 2. [ADP2389](#) Bill of Materials

Qty.	Reference Designator	Description	Part Number/Vendor
2	C1, C7	0.1 μ F, 16 V, capacitor, 0603	GRM188R71C104KA01D/Murata
2	C2, C18	Optional, capacitor, 0603	Optional/Murata
1	C3	22 nF, 16 V, capacitor, 0603	GRM188R71C223KA01D/Murata
1	C4	22 pF, 50 V, capacitor, 0603	GRM1885C1H220JA01D/Murata
1	C5	1.5 nF, 25 V, capacitor, 0603	GRM188R71E152KA01D/Murata
1	C6	1 μ F, 16 V, capacitor, 0603	GRM188R61C105KA93D/Murata
5	C8, C9, C10, C11, C12	10 μ F, 25 V, capacitor, 1206	GRM31CR61E106MA12L/Murata
5	C13, C14, C15, C16, C17	100 μ F, 6.3 V, capacitor, 1210	GRM32ER60J107ME20L/Murata
1	L1	Inductor, 7443320100, L = 1 μ H, I_{SAT} = 32 A, DCR = 1.17 m Ω	7443320100/Würth Elektronik
4	R1, R3, R4, R8	Optional, resistor, 0603	Optional/Vishay Dale
2	R2, R5	10 k Ω , 1%, resistor, 0603	CRCW060310K0FKEA/Vishay Dale
1	R6	121 k Ω , 1%, resistor, 0603	CRCW0603121KFKEA/Vishay Dale
1	R7	59 k Ω , 1%, resistor, 0603	CRCW060359K0FKEA /Vishay Dale
1	R9	20 k Ω , 1%, resistor, 0603	CRCW060320K0FKEA/Vishay Dale
1	R10	27.4 k Ω , 1%, resistor, 0603	CRCW060327K4FKEA/Vishay Dale
1	R11	0 Ω , 0.1 W, resistor, 0603	CRCW06030000Z0EA/Vishay Dale
1	R12	6.8 Ω , 1%, resistor, 0603	CRCW06036R80FKEA/Vishay Dale
1	U1	18 V, 12 A, synchronous, step-down regulator, 32-lead, LFCSP_VQ, with exposed paddles	ADP2389 /Analog Devices, Inc.
11	J1, J2, J3, J4, J6, J8, J9, J10, J11, J13, J16	Test point, 2.54 mm pitch SIL vertical PC tail pin header, 6.1 mm mating pin height, tin, SIP1	M20-9990245/Harwin
1	J5	Jumper, 0.1-inch header, three-way, SIP3	M20-9990346/Harwin
4	J7, J12, J14, J15	Terminal screw vertical PC mount	8191/Keystone Electronics

Table 3. ADP2390 Bill of Materials

Qty.	Reference Designator	Description	Part Number/Vendor
2	C1, C7	0.1 μ F, 16 V, capacitor, 0603	GRM188R71C104KA01D/Murata
2	C2, C18	Optional, capacitor, 0603	Optional/Murata
1	C3	22 nF, 16 V, capacitor, 0603	GRM188R71C223KA01D/Murata
1	C4	22 pF, 50 V, capacitor, 0603	GRM1885C1H220JA01D/Murata
1	C5	1.5 nF, 25 V, capacitor, 0603	GRM188R71E152KA01D/Murata
1	C6	1 μ F, 16 V, capacitor, 0603	GRM188R61C105KA93D/Murata
5	C8, C9, C10, C11, C12	10 μ F, 25 V, capacitor, 1206	GRM31CR61E106MA12L/Murata
5	C13, C14, C15, C16, C17	100 μ F, 6.3 V, capacitor, 1210	GRM32ER60J107ME20L/Murata
1	L1	Inductor, 7443320100, L = 1 μ H, I _{SAT} = 32 A, DCR = 1.17 m Ω	7443320100/Würth Elektronik
4	R1, R3, R4, R8	Optional, resistor, 0603	Optional/Vishay Dale
2	R2, R5	10 k Ω , 1%, resistor, 0603	CRCW060310K0FKEA/Vishay Dale
1	R6	121 k Ω , 1%, resistor, 0603	CRCW0603121KFKEA/Vishay Dale
1	R7	59 k Ω , 1%, resistor, 0603	CRCW060359K0FKEA /Vishay Dale
1	R9	20 k Ω , 1%, resistor, 0603	CRCW060320K0FKEA/Vishay Dale
1	R10	27.4 k Ω , 1%, resistor, 0603	CRCW060327K4FKEA/Vishay Dale
1	R11	0 Ω , 0.1 W, resistor, 0603	CRCW0603000Z0EA/Vishay Dale
1	R12	6.8 Ω , 1%, resistor, 0603	CRCW06036R80FKEA/Vishay Dale
1	U1	18 V, 12 A, synchronous, step-down regulator, 32-lead, LFCSP_VQ, with exposed paddles	ADP2390/Analog Devices, Inc.
11	J1, J2, J3, J4, J6, J8, J9, J10, J11, J13, J16	Test point, 2.54 mm pitch SIL vertical PC tail pin header, 6.1 mm mating pin height, tin, SIP1	M20-9990245/Harwin
1	J5	Jumper, 0.1-inch header, 3-way, SIP3	M20-9990346/Harwin
4	J7, J12, J14, J15	Terminal screw vertical PC mount	8191/Keystone Electronics

**ESD Caution**

ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

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