# ADP5091-1-EVALZ/ADP5092-1-EVALZ User Guide
UG-967

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## Evaluation Board for the ADP5091/ADP5092 Ultralow Power Energy Harvesting PMU

### GENERAL DESCRIPTION

The ADP5091/ADP5092 is a 2-channel ultralow power energy harvesting PMU in a compact 4 mm × 4 mm LFCSP package. The ADP5091-1-EVALZ and ADP5092-1-EVALZ run from input voltages of 0.38 V to 3.3 V and require minimal external components to provide a high efficiency solution with integrated power switches, synchronous rectifier, battery management, and hybrid controlled and regulated output.

The ADP5091-1-EVALZ and ADP5092-1-EVALZ evaluation boards provide an easy way to evaluate the device. This user guide describes how to quickly set up the evaluation board and deliver up to 3.5 V maximum voltage to the SYS output using an external resistor divide. The internal switches turn on as long as the storage element voltage at BAT pin is above the externally programmed SETSD of 2.4 V. The PGOOD indicator toggles high when SYS ramps up to 3 V. The REG_OUT is set to 2.5 V as the default output voltage. Complete information about the ADP5091/ADP5092 is available in the ADP5091/ADP5092 data sheet. Consult the data sheet in conjunction with this user guide when using the evaluation boards.

### ADP5091/ADP5092 EVALUATION BOARDS


14443-001

*Figure 1. ADP5091-1-EVALZ*


14443-002

*Figure 2. ADP5092-1-EVALZ*

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## REVISION HISTORY

**5/2016—Revision 0: Initial Version**

# SETTING UP THE EVALUATION BOARD

## POWERING UP THE EVALUATION BOARD

The ADP5091-1-EVALZ and ADP5092-1-EVALZ evaluation boards are fully assembled and tested. Before applying power to the evaluation board, follow the setup procedures in this section.

### *Jumper Settings*

Table 1 describes the jumper settings.

**Table 1. Jumper Settings.**

| Jumper | State or Connection | Function |
|---|---|---|
| J1 (DIS_SW) | SYS | Disables the main boost |
| | GND | Enables the main boost |
| J2 (VID) | Floating | Set REG_OUT as 2.5 V |
| | RES | Set output voltage by an external resistor through VID to ground |
| | GND | Set output voltage by external resistor divide at REG_FB pin |
| J3 (REG_D1) | SYS | Enable LDO mode of the REG_OUT |
| | GND | Disable LDO mode of the REG_OUT |
| J4 (PGOOD) | | Pull high when the SYS voltage ramps up to preset the SETPG rising threshold |
| J5 (REG_D0) | SYS | Enable boost mode of the REG_OUT |
| | GND | Disable boost mode of the REG_OUT |
| J12 (RDIV) | MPPT | With MPPT sensing function |
| | Floating | Without MPPT dynamic sensing function, provide an external voltage at CBP pin as MPPT voltage |
| J13 (FIX MPPT) | Floating | Dynamic MPPT sensing mode |
| | Connected | MPPT fixed mode |

### *Input Power Source Connection*

Energy harvesting power sources are high impedance sources. Figure 3 shows that a source meter configured as a current source with a voltage limit set to the open circuit voltage of the harvester is the best way to simulate the harvester. For low output impedance power supply (voltage source), it is necessary to simulate the impedance of the harvester with a physical external resistor (R) between the supply and the VIN pin. If the input current source includes a voltage meter, use the meter to monitor the input voltage as follows:

1. Connect the positive terminal (+) of the power source to the VIN terminal (J11) on the evaluation board.
2. Connect the negative terminal (−) of the power source to the GND terminal (J11) on the evaluation board.

If the input power supply does not include a current meter, connect a current meter in series with the input power supply as follows:

1. Connect the external series resistor of the power source to the positive terminal (+) of the current meter.
2. Connect the negative terminal (−) of the power source to the GND terminal (J10) on the evaluation board.
3. Connect the negative terminal (−) of the current meter to the VIN terminal (J11) on the evaluation board.

### *SYS Load Connection*

Before connecting the load to the ADP5091-1-EVALZ and ADP5092-1-EVALZ evaluation boards, ensure that the SYS voltage is higher than 2 V, or that the power-good signal is high. If the load includes a current meter, or if the current is not measured, connect the load directly to the evaluation board as follows:

1. Connect the positive load connection (+) to the SYS terminal (J9) on the evaluation board.
2. Connect the negative load connection (−) to the GND terminal (J9) on the evaluation board.

If a current meter is used, connect it in series with the load as follows:

1. Connect the positive terminal (+) of the current meter to the SYS terminal (J9) on the evaluation board.
2. Connect the negative terminal (−) of the current meter to the positive terminal (+) of the load.
3. Connect the negative terminal (−) of the load to the GND terminal (J9) on the evaluation board.

### *Storage Elements Connection*

The ADP5091-1-EVALZ and ADP5092-1-EVALZ evaluation boards can charge some types of energy storage elements, such as: rechargeable batteries, super capacitors, and conventional capacitors. In general, the storage elements maintain constant power or peak power of the system that cannot directly come from the input source. It is necessary to consider the significant leakage current of batteries and super capacitors. For the application information, refer to the ADP5091/ADP5092 data sheets.

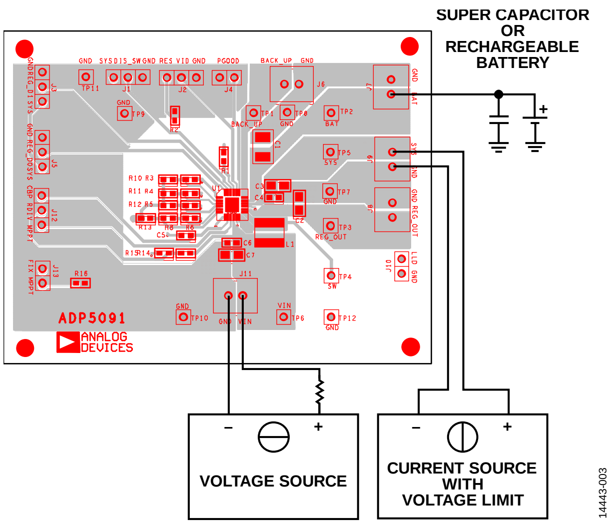


*Figure 3. Setup for the ADP5091-1-EVALZ and ADP5092-1-EVALZ*

### *Input and SYS Voltmeter Connections*

Measure the input and SYS voltages with voltmeters. Ensure that the voltmeters connect to the appropriate test points on the board. If the voltmeters are not connected to the correct test points, the measured voltages may be incorrect due to the voltage drop across the leads, or due to the connections between the board, the power source, and/or the load.

1. Connect the positive terminal (+) of the input voltage measuring voltmeter to Test Point TP6 on the evaluation board.
2. Connect the negative terminal (−) of the input voltage measuring voltmeter to Test Point TP10 on the board.
3. Connect the positive terminal (+) of the output voltage measuring voltmeter to Test Point TP5 on the board.
4. Connect the negative terminal (−) of the output voltage measuring voltmeter to Test Point TP7 on the board.

### *REG_OUT Load Connection*

REG_OUT is a regulated output that can be set via the VID pin. REG_D0 and REG_D1 control the operation mode of the REG_OUT. See the detailed configuration in Table 1. If the load includes a current meter, or if the current is not measured, connect the load directly to the evaluation board as follows:

1. Connect the positive load connection (+) to the REG_OUT terminal (J8) on the evaluation board.
2. Connect the negative load connection (−) to the GND terminal (J8) on the evaluation board.

If a current meter is used, connect it in series with the load as follows:

1. Connect the positive terminal (+) of the current meter to the REG_OUT terminal (J8) on the evaluation board.
2. Connect the negative terminal (−) of the current meter to the positive terminal (+) of the load.
3. Connect the negative terminal (−) of the load to the GND terminal (J8) on the evaluation board.

### *Powering On the Evaluation Board*

As long as the input current source open circuit voltage is above a minimum input voltage of cold start (0.38 V), and the input power is above a minimum input power of cold start (6 µW), the ADP5091-1-EVALZ and ADP5092-1-EVALZ enter cold start, if the SYS voltage is lower than end of the cold start-up threshold (1.93 V). Otherwise, the evaluation board enables the main boost instead of the cold start.

When the MPPT sampling circuit is active, the harvester open circuit voltage is detectable because there is no input current to create a drop across the impedance. The main boost runs and draws current until the VIN voltage drops to the sampled MPPT voltage stored at CBP pin.

### *Optional BACK_UP Setup*

An optional primary battery connected to the BACK_UP pin can accelerate the cold start or maintain the system load. When $V_{BAT} < V_{BACK\_UP}$ and $V_{BAT} < V_{SET\_BK}$, the ADP5091-1-EVALZ and ADP5092-1-EVALZ turn on the internal power switches between the BACK_UP pin and the SYS pin. When $V_{BAT} > V_{BACK\_UP}$ and $V_{BAT} > V_{SET\_BK}$, the internal power switches turn off.

## MEASURING EVALUATION BOARD PERFORMANCE

### *Measuring the Switching Waveform*

To observe the switching waveform with an oscilloscope, place the oscilloscope probe tip at Test Point TP4 with the probe ground connected to the Test Point TP12 GND Set the oscilloscope to a dc coupling, 2 V/division, 10 µs/division time base. The switching waveform alternates between 0 V and the approximate SYS voltage.

### *Measuring Efficiency*

Measure the efficiency (η) by comparing the input power with the output power. Figure 4 shows the test setup. Float the RDIV jumper (J12) and provide an external voltage at CBP pin as MPPT voltage so that the input voltage is regulated to this voltage. With a voltage source meter, which can sink current to connect to SYS pin, the output voltage and output current can be obtained.

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

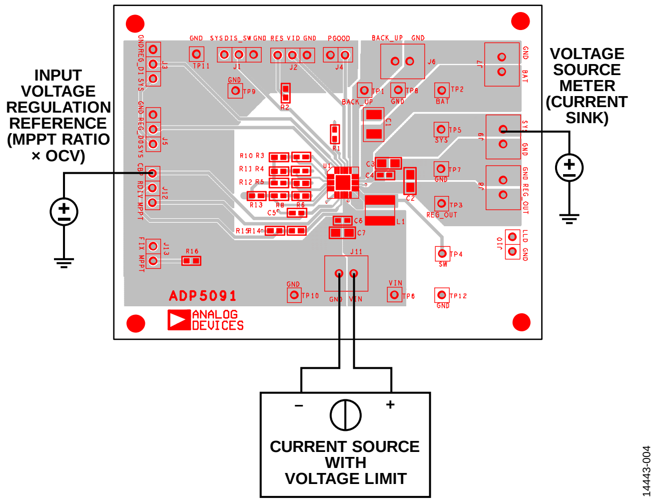


Figure 4. Setup for Measuring Efficiency

### Measuring the Inductor Current

Measure the inductor current by removing one end of the inductor from the pad on the board and using a wire connected between the pad and the inductor. Then, use a current probe to measure the inductor current.

### Measuring the Output Voltage Ripple

To observe the output voltage ripple, place an oscilloscope probe across output Capacitors C2 and C3 with the probe ground lead placed at the negative capacitor terminal (−) and the probe tip placed at the positive capacitor terminal (+). Set the oscilloscope to an ac coupling, 50 mV/division, 1 seconds/division time base and a 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.

To eliminate the noise injection, it requires removing the oscilloscope probe sheath and wrapping a nonshielded wire around the oscilloscope probe. By keeping the ground lengths of the oscilloscope probe as short as possible, true ripple can be measured.

### BAT Voltage Change

The ADP5091-1-EVALZ and ADP5092-1-EVALZ output voltages are preset to 3.5 V. However, the output voltage can be adjusted using the following equation:

$$V_{SYS} = \frac{3}{2} V_{REF}\left(1 + \frac{R5}{R12}\right)$$

To prevent deeply discharging storage elements at BAT, the voltage threshold can be programmed using the following equation:

$$V_{SETSD} = V_{REF}\left(1 + \frac{R3}{R10}\right)$$

where the typical $V_{REF}$ value is 1.0 V.

### REG_OUT Voltage Change

The regulated output voltage of the ADP5091-1-EVALZ and ADP5092-1-EVALZ can be set via VID jumper (J2). The detailed configuration is shown in Table 1. For more information on the VID resistors configuration, see the ADP5091/ADP5092 data sheetsPtent. The output voltage can also be programmable via the external feedback resistor divide using the following equation:

$$V_{REG\_OUT} = V_{REF}\left(1 + \frac{R7}{R9}\right)$$

where the typical $V_{REF}$ value is 1.0 V.

# EVALUATION BOARD SCHEMATICS

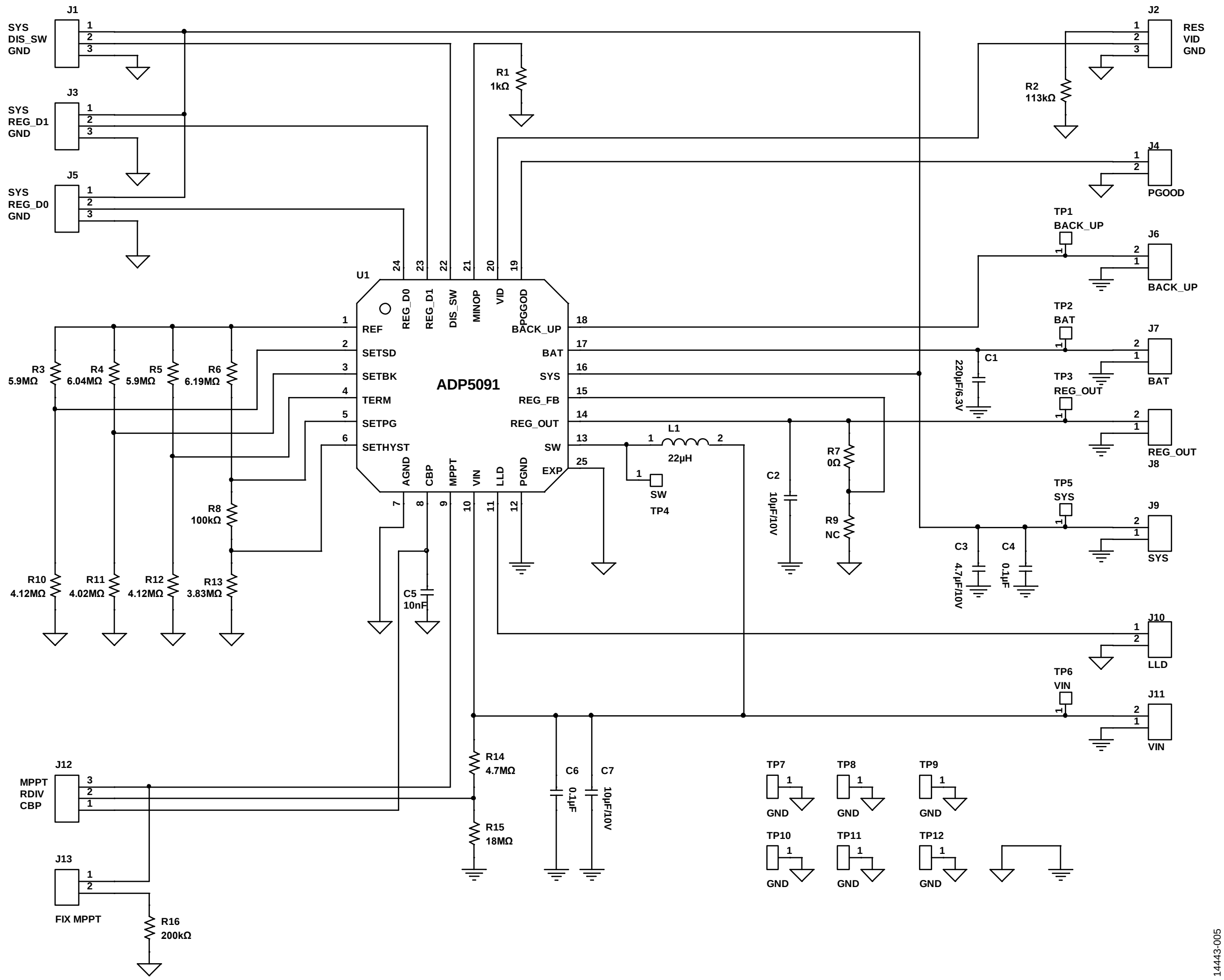


*Figure 5. Schematic of the ADP5091-1-EVALZ Evaluation Board*

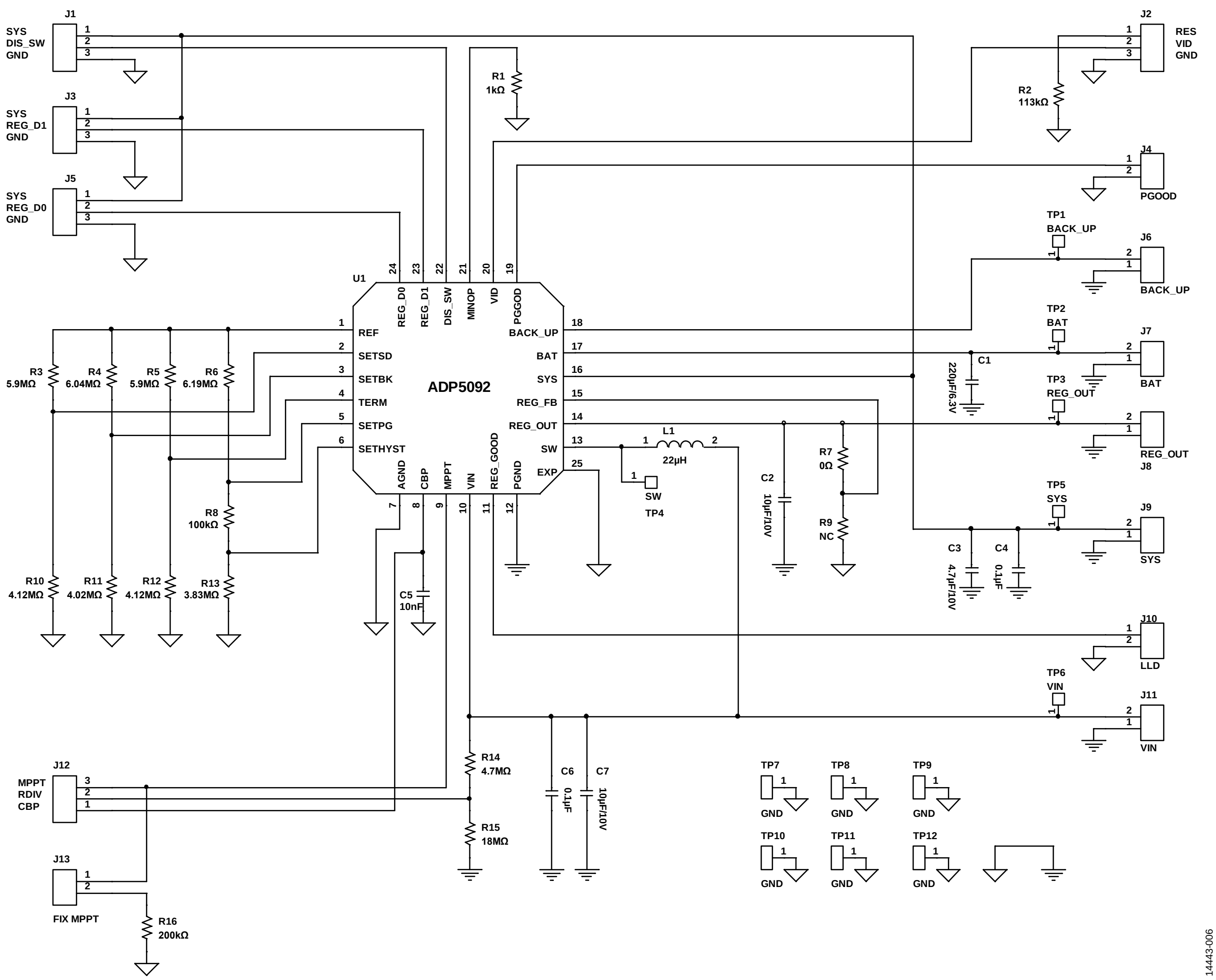


*Figure 6. Schematic of the ADP5092-1-EVALZ Evaluation Board)*

# EVALUATION BOARD LAYOUT

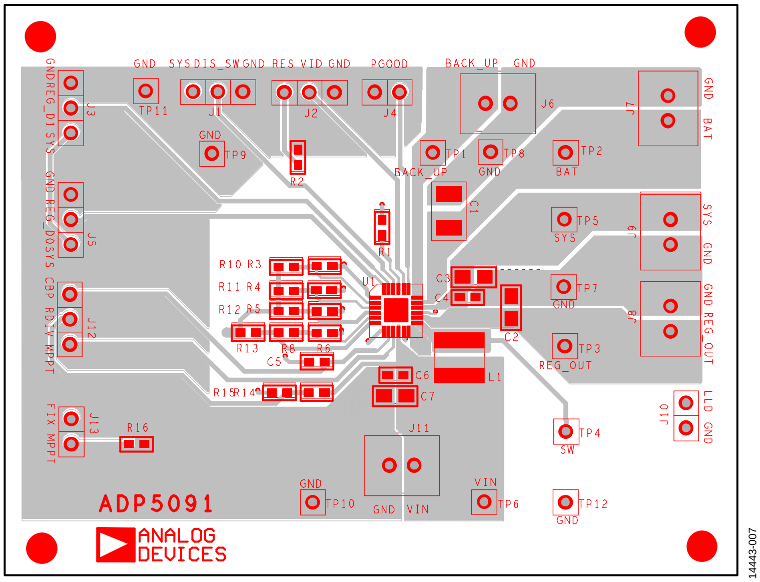


Figure 7. ADP5091-1-EVALZ Top Layer

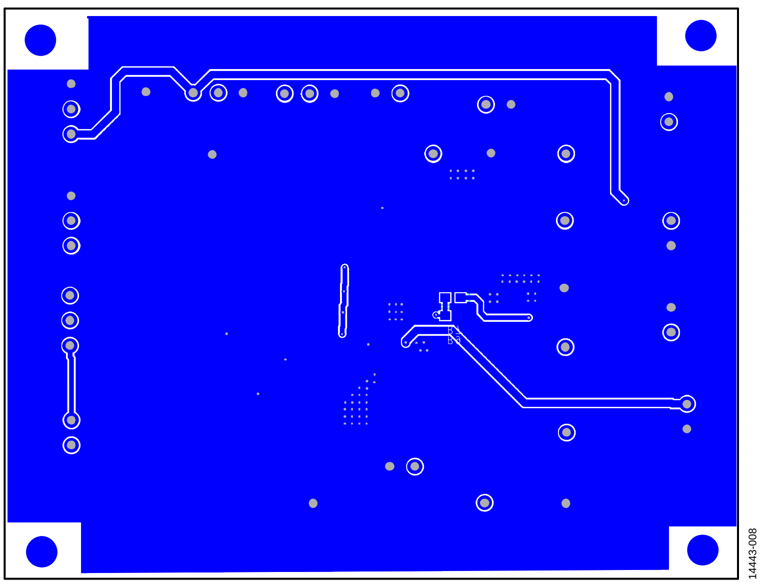


Figure 8. ADP5091-1-EVALZ Bottom Layer

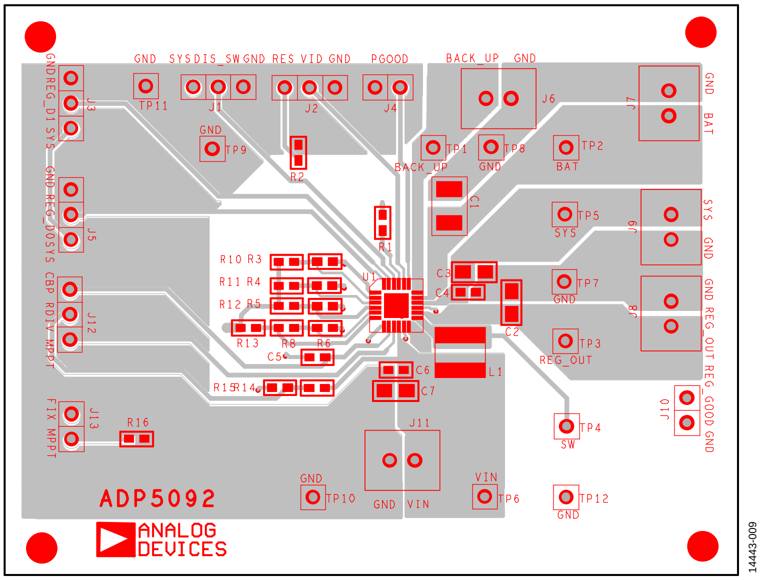

Figure 9. ADP5092-1-EVALZ Top Layer

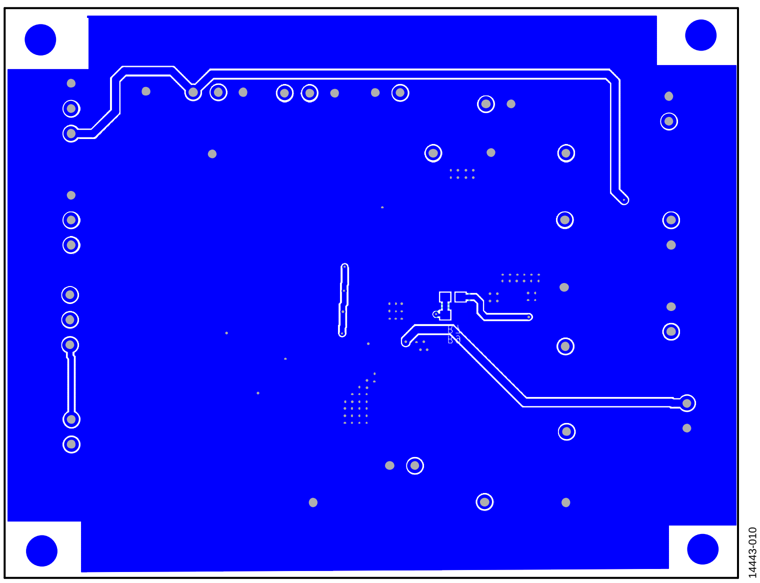

Figure 10. ADP5092-1-EVALZ Bottom Layer

# ORDERING INFORMATION

## BILL OF MATERIALS

Table 2. ADP5091-1-EVALZ Evaluation Board Bill of Materials

| Quantity | Reference Designator | Description | Part Number | PCB Footprint | Vendor |
|---|---|---|---|---|---|
| 1 | C1 | 220 µF/6.3 V | GRM32ER60J107ME20 | C1210 | Murata |
| 2 | C2, C7 | 10 µF/10 V | GRM21BR71A106KE51 | C0805 | Murata |
| 1 | C3 | 4.7 µF/10 V | GRM21BR61A475KA73 | C0805 | Murata |
| 2 | C4, C6 | 0.1 µF | GRM188R71H104KA93 | C0603 | Murata |
| 1 | C5 | 10 nF | GRM188R71H103KA01 | C0603 | Murata |
| 1 | J1 | DIS_SW | M20-9990246 | SIP3 | Harwin |
| 1 | J2 | VID | M20-9990246 | SIP3 | Harwin |
| 1 | J3 | REG_D1 | M20-9990246 | SIP3 | Harwin |
| 1 | J4 | PGOOD | M20-9990245 | SIP2 | Harwin |
| 1 | J5 | REG_D0 | M20-9990246 | SIP3 | Harwin |
| 1 | J6 | BACK_UP | 61900211121 | SIP2 | Würth |
| 1 | J7 | BAT | 61900211121? | SIP2 | Harwin |
| 1 | J8 | REG_OUT | 61900211121? | SIP2 | Harwin |
| 1 | J9 | SYS | 61900211121? | SIP2 | Harwin |
| 1 | J10 | LLD | M20-9990245 | SIP2 | Harwin |
| 1 | J11 | VIN | 61900211121? | SIP | Harwin |
| 1 | J12 | RDIV | M20-9990246 | SIP3 | Harwin |
| 1 | J13 | FIX MPPT | M20-9990245 | SIP2 | Harwin |
| 1 | L1 | 22 µH | LPS4018-223MLB | 4 mm × 4 mm | Coilcraft |
| 1 | L1 | 22 µH | 74437324220 | 4 mm × 4 mm | Würth |
| 1 | R1 | 1 kΩ | CRCW06031K00FKEA | R0603 | Vishay Dale |
| 1 | R2 | 113 kΩ | CRCW0603113KFKEA | R0603 | Vishay Dale |
| 2 | R3, R5 | 5.9 MΩ | CRCW06035M90FKEA | R0603 | Vishay Dale |
| 1 | R4 | 6.04 MΩ | CRCW06036M04FKEA | R0603 | Vishay Dale |
| 1 | R6 | 6.19 MΩ | CRCW06036M19FKEA | R0603 | Vishay Dale |
| 1 | R7 | 0 Ω | CRCW06030000FKEA | R0603 | Vishay Dale |
| 1 | R8 | 100 kΩ | CRCW0603100K0FKEA | R0603 | Vishay Dale |
| 1 | R9 | NC | N/A | R0603 | Vishay Dale |
| 2 | R10, R12 | 4.12 MΩ | CRCW06034M12FKEA | R0603 | Vishay Dale |
| 1 | R11 | 4.02 MΩ | CRCW06034M02FKEA | R0603 | Vishay Dale |
| 1 | R13 | 3.83 MΩ | CRCW06033M83FKEA | R0603 | Vishay Dale |
| 1 | R14 | 4.7 MΩ | CRCW06034M70FKEA | R0603 | Vishay Dale |
| 1 | R15 | 18 MΩ | RK73B1JTTD186J | R0603 | KOA |
| 1 | R16 | 200 kΩ | CRCW0603200KFKEA | R0603 | Vishay Dale |
| 1 | TP1 | BACK_UP | M20-9990245 | SIP1 | Harwin |
| 1 | TP2 | BAT | M20-9990245 | SIP1 | Harwin |
| 1 | TP3 | REG_OUT | M20-9990245 | SIP1 | Harwin |
| 1 | TP4 | SW | M20-9990245 | SIP1 | Harwin |
| 1 | TP5 | SYS | M20-9990245 | SIP1 | Harwin |
| 1 | TP6 | VIN | M20-9990245 | SIP1 | Harwin |
| 6 | TP7, TP8, TP9, TP10, TP11, TP12 | GND | M20-9990245 | SIP1 | Harwin |
| 1 | U1 | ADP5091 | ADP5091-ACZP-1-R7 | 24-lead LFCSP | Analog Devices, Inc. |

Table 3. ADP5092-1-EVALZ Evaluation Board Bill of Materials

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|---|---|---|---|---|---|
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| 1 | C3 | 4.7 µF/10 V | GRM21BR61A475KA73 | C0805 | Murata |
| 2 | C4, C6 | 0.1 µF | GRM188R71H104KA93 | C0603 | Murata |
| 1 | C5 | 10 nF | GRM188R71H103KA01 | C0603 | Murata |
| 1 | J1 | DIS_SW | M20-9990246 | SIP3 | Harwin |
| 1 | J2 | VID | M20-9990246 | SIP3 | Harwin |
| 1 | J3 | REG_D1 | M20-9990246 | SIP3 | Harwin |
| 1 | J4 | PGOOD | M20-9990245 | SIP2 | Harwin |
| 1 | J5 | REG_D0 | M20-9990246 | SIP3 | Harwin |
| 1 | J6 | BACK_UP | 601900211121 | SIP2 | Würth |
| 1 | J7 | BAT | 601900211121 | SIP2 | Harwin |
| 1 | J8 | REG_OUT | 601900211121 | SIP2 | Harwin |
| 1 | J9 | SYS | 601900211121 | SIP2 | Harwin |
| 1 | J10 | REG_OUT | M20-9990245 | SIP2 | Harwin |
| 1 | J11 | VIN | 601900211121 | SIP2 | Harwin |
| 1 | J12 | RDIV | M20-9990246 | SIP3 | Harwin |
| 1 | J13 | FIX MPPT | M20-9990245 | SIP2 | Harwin |
| 1 | L1 | 22 µH | LPS4018-223MLB | 4 mm × 4 mm | Coilcraft |
| 1 | L1 | 22 µH | 74437324220 | 4 mm × 4 mm | Würth |
| 1 | R1 | 1 kΩ | CRCW06031K00FKEA | R0603 | Vishay Dale |
| 1 | R2 | 113 kΩ | CRCW0603113KFKEA | R0603 | Vishay Dale |
| 2 | R3, R5 | 5.9 MΩ | CRCW06035M90FKEA | R0603 | Vishay Dale |
| 1 | R4 | 6.04 MΩ | CRCW06036M04FKEA | R0603 | Vishay Dale |
| 1 | R6 | 6.19 MΩ | CRCW06036M19FKEA | R0603 | Vishay Dale |
| 1 | R7 | 0 Ω | CRCW06030000FKEA | R0603 | Vishay Dale |
| 1 | R8 | 100 kΩ | CRCW0603100K0FKEA | R0603 | Vishay Dale |
| 1 | R9 | NC | N/A | R0603 | Vishay Dale |
| 2 | R10, R12 | 4.12 MΩ | CRCW06034M12FKEA | R0603 | Vishay Dale |
| 1 | R11 | 4.02 MΩ | CRCW06034M02FKEA | R0603 | Vishay Dale |
| 1 | R13 | 3.83 MΩ | CRCW06033M83FKEA | R0603 | Vishay Dale |
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| 1 | R15 | 18 MΩ | RK73B1JTTD186J | R0603 | KOA |
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| 1 | TP3 | REG_OUT | M20-9990245 | SIP1 | Harwin |
| 1 | TP4 | SW | M20-9990245 | SIP1 | Harwin |
| 1 | TP5 | SYS | M20-9990245 | SIP1 | Harwin |
| 1 | TP6 | VIN | M20-9990245 | SIP1 | Harwin |
| 6 | TP7, TP8, TP9, TP10, TP11, TP12 | GND | M20-9990245 | SIP1 | Harwin |
| 1 | U1 | ADP5092 | ADP5092-ACPZ-1-R7 | 24-lead LFCSP | Analog Devices, Inc. |

## NOTES

**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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**UG14443-0-5/16(0)**

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