

## Evaluation Board for the **ADP5023/ADP5024/ADP5034/ADP5037** Micro Power Management Unit (PMU)

### FEATURES

- Full-featured evaluation board for the [ADP5023/ADP5024/ADP5034/ADP5037](#)**
- Standalone capability**
- Simple device measurements, including line and load regulation, demonstrable with**
- A single voltage supply**
- A voltmeter**
- An ammeter**
- Load resistors**
- Easy access to external components**
- Cascading options to supply the low dropout (LDO) from either buck**
- Dedicated enable option for each channel**
- Mode option to change bucks from PFM to PWM operation**

### GENERAL DESCRIPTION

This user guide describes the hardware for the evaluation of the [ADP5023/ADP5024/ADP5034/ADP5037](#) and includes detailed schematics and PCB layouts. The [ADP5023/ADP5024/ADP5034/ADP5037](#) are available in a 24-lead 4 mm × 4 mm LFCSP package. The [ADP5023/ADP5024](#) are three-channel devices that share a common PCB evaluation board. The [ADP5034/ADP5037](#) are four-channel devices and share a common evaluation board. The [ADP5023/ADP5024/ADP5034](#) and [ADP5037](#) all operate in the same manner. Note that this user guide covers all of these boards, but refers to the [ADP5034](#) for simplicity.

The [ADP5034](#) LFCSP evaluation board has two step-down regulators with two LDOs that enable evaluation of the [ADP5034](#). The evaluation board is available in an adjustable voltage option.

Full details on the parts are provided in the appropriate product data sheet available from Analog Devices, Inc., which should be consulted in conjunction with this evaluation board user guide.

### DIGITAL PICTURE OF THE [ADP5034](#) EVALUATION BOARD

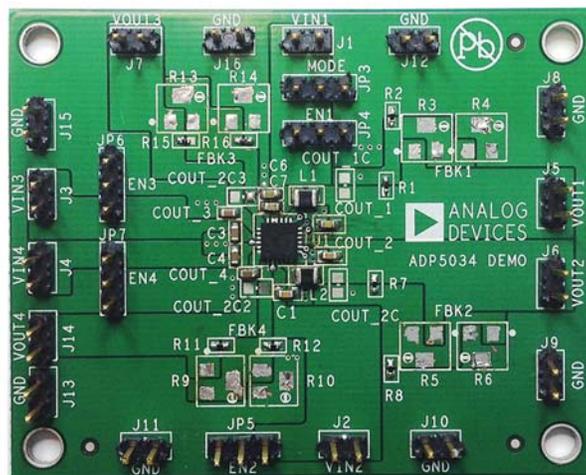


Figure 1.

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## REVISION HISTORY

### 6/14—Rev. A to Rev. B

Changes to Figure 16.....	10
Changes to Figure 20.....	12
Changes to Table 4.....	14

### 7/12—Rev. 0 to Rev. A

Added ADP5023, ADP5024, and ADP5037	
Throughout .....	Universal
Replaced all Figures Throughout .....	Universal
Changes to General Description Section .....	1
Replaced Powering Up the Evaluation Board Section.....	3
Replaced Evaluation Board Schematics and Artwork Section.....	10
Changes to Bill of Materials and added Related Links Section.....	14

### 8/11—Revision 0: Initial Version

## USING THE EVALUATION BOARD

### POWERING UP THE EVALUATION BOARD

The ADP5034 evaluation board is supplied fully assembled and tested. Before applying power to the evaluation board, follow the procedures in this section.

#### Enable

Each channel has its own enable pin, which must be pulled high to enable that channel (see Table 1).

**Table 1. Channels of the Enable Pins**

Channel	Enable Pin	
	ADP5034/ADP5037	ADP5023/ADP5024
1	JP4	JP4
2	JP5	JP5
3	JP6	JP6
4	JP7	N/A

#### Jumper J3 (MODE)

The Jumper JP3 as shown in Figure 1 is used to connect the MODE pin of the device to either ground or VIN1. To force Buck 1 and Buck 2 into forced PWM operation, shunt the center contact of Jumper JP3 (MODE) to the left pin header to pull the MODE pin high to J1 (VIN1). To allow Buck 1 and Buck 2 to operate in automatic PWM/PSM operation, shunt the center contact of JP3 (MODE) to the right pin header to pull the MODE pin low to J12 (GND1).

#### Input Power Source

If the input power source includes a current meter, use that meter to monitor the input current. Connect J1 (VIN1) to J2 (VIN2) with a short wire. Connect the positive terminal of the power source to J1 (VIN1) on the evaluation board and the negative terminal of the power source to J12 (GND).

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 ammeter positive (+) connection, the negative lead (-) of the power source to J12 (GND) on the evaluation board, and the negative lead (-) of the ammeter to J1 (VIN1) on the board. Be aware that the current meters add resistance to the input source, and this voltage reduces with high output currents.

#### Output Load

Connect an electronic load or resistor to set the load current. If the load includes an ammeter, or if the current is not measured, connect the load directly to the evaluation board, with the positive (+) load connected to one of the channels. For example, connect Buck 1, J5 (VOUT1) and the negative (-) load connection to J8 (GND).

If an ammeter is used, connect it in series with the load. Connect the positive (+) ammeter terminal to the evaluation board for Buck 1, J5 (VOUT1), the negative (-) ammeter terminal to the

positive (+) load terminal, and the negative (-) load terminal to the evaluation board at J8 (GND).

#### Input and Output Voltmeters

Measure the input and output voltages with voltmeters. Make sure that the voltmeters are connected to the appropriate evaluation board terminals and not to the load or power sources themselves.

If the voltmeters are not connected directly to the evaluation board, the measured voltages will be incorrect due to the voltage drop across the leads and/or connections between the evaluation board, the power source, and/or the load.

Connect the input voltage measuring voltmeter positive terminal (+) to the evaluation board at J1 (VIN1), and input voltage measuring voltmeter negative (-) terminal to the evaluation board at J12 (GND1).

Connect the output voltage measuring voltmeter positive (+) terminal to the evaluation board at J5 (VOUT1) for measuring the output voltage of Buck 1, and the output voltage measuring voltmeter negative (-) terminal to the evaluation board at J8 (PGND).

#### Turning On the Evaluation Board

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

The power source voltage for the Bucks (VIN1, VIN2) is >2.3 V to <5.5 V. The power source voltage for the LDOs (VIN3, VIN4) is from  $V_{OUT\ LDO} + 0.5\ V$  or 1.7 V (whichever is greater) to 5.5 V.

The desired channel is enabled and monitors the output voltage.

If the load is not enabled, enable the load; check that it is drawing the proper current and that the output voltage maintains voltage regulation.

#### Setting the Output Voltage of the Bucks

The buck output voltage is set through external resistor dividers, shown in Figure 2 for Buck 1. The output voltage can optionally be factory programmed to default values as indicated in the data sheet. In this event, R1 and R2 are not needed, and FB1 can be left unconnected. In all cases, VOUT1 must be connected to the output capacitor. FB1 is 0.5 V.

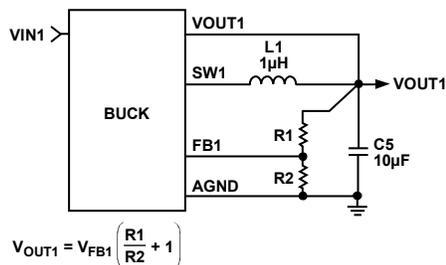


Figure 2. Buck 1 External Output Voltage Setting

**Setting the Output Voltage of the LDOs**

Each LDO output voltage is set through external resistor dividers as well as shown in Figure 3 for LDO1. The output voltage can optionally be factory programmed to default values as indicated in the data sheet. In this event, FB3 must be connected to the top of the capacitor on VOUT3 by placing a 0 Ω resistor on R<sub>TOP</sub>, and leaving R<sub>BOT</sub> unpopulated. Refer to Table 2 for the corresponding 0 Ω resistor placements on R<sub>TOP</sub> per channel.

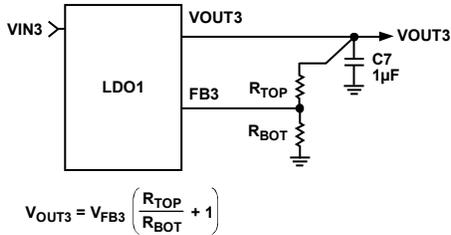


Figure 3. LDO1 External Output Voltage Setting

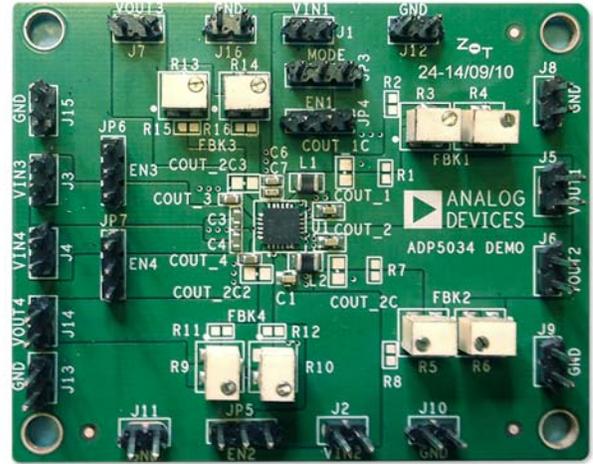


Figure 4. Demo Board with Trimmer Resistors

**External Resistor Divider Setting for Bucks and LDOs**

The ADP5023/ADP5024/ADP5034/ADP5037 demo boards are supplied with fixed resistors with values chosen for a target output voltage. Varying the resistor values of the resistor divider networks varies the output voltage accordingly.

**Table 2. External Resistor Dividers (Fixed)**

Resistor Divider	Buck 1	Buck 2	LDO1	LDO2
R <sub>TOP</sub>	R1	R7	R15	R11
R <sub>BOT</sub>	R2	R8	R16	R12

Aside from the fixed resistors shown in Table 2, the demo boards also have footprints for trimmer resistors as listed in Table 3. The trimmer resistors make for easier adjustments of the output voltage by turning the adjustment slots on top of the resistors as shown in Figure 4.

Turning the adjustment slot clockwise increases the resistance and vice versa; adjust accordingly to get the desired output voltage. The footprints are designed for 3214W-1-204E parts, which are 200 kΩ trimmer resistors. The trimmers are for quick evaluation purposes and are not recommended for final application; this is because of the possible mechanical issues and complex impedance. Once the desired output voltage is found, replace the trimmers with fixed value resistors.

**Table 3. External Resistor Dividers (Trimmer Resistors)**

Resistor Divider	Buck 1	Buck 2	LDO1	LDO2
R <sub>TOP</sub>	R3	R5	R13	R9
R <sub>BOT</sub>	R4	R6	R14	R10

**MEASURING EVALUATION BOARD PERFORMANCE**

**Measuring Output Voltage Ripple of the Buck Regulator**

To observe the output voltage ripple of Buck 1, place an oscilloscope probe across the output capacitor (COUT\_1) with the probe ground lead at the negative (-) capacitor terminal and the probe tip at the positive (+) capacitor terminal.

Set the oscilloscope to ac, 10 mV/division, and 2 µs/division time base, with BW set to 20 MHz to avoid noise to interfere with the measurements. It is recommended to shorten the ground loop of the oscilloscope probe to minimize coupling. A good way of measuring the output voltage ripple is to solder a wire to the negative (-) capacitor terminal and wrap it around the barrel of the probe, while the tip directly connects to the positive (+) capacitor terminal as shown in Figure 5.

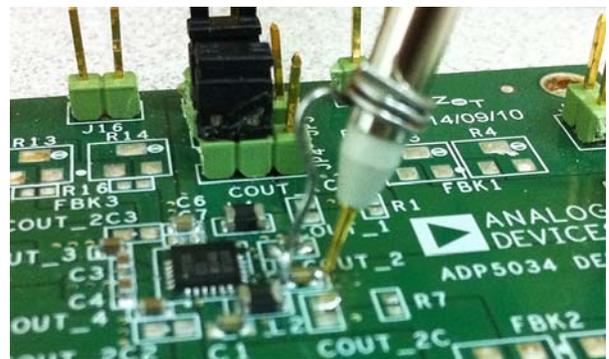


Figure 5. Measuring Output Voltage Ripple

### Measuring the Switching Waveform of Buck

To observe the switching waveform with an oscilloscope, place the oscilloscope probe tip at the end of the inductor with the probe ground at GND. Set the oscilloscope to dc, 2 V/division, and 200 ns/division time base.

When the MODE pin is set to high, the buck regulators operate in forced PWM mode. When the MODE pin is set to low, the buck regulators operate in PWM mode when the load is above a predefined threshold. When the load current falls below a predefined threshold, the regulator operates in power save mode (PSM), improving the light load efficiency. Typical PWM and PSM switching waveforms are shown in Figure 6 and Figure 7.

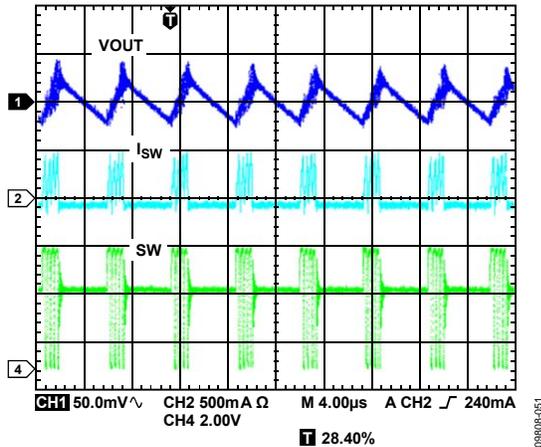


Figure 6. Typical Waveforms,  $V_{out1} = 3.3\text{ V}$ ,  $I_{out1} = 30\text{ mA}$ , PSM Mode

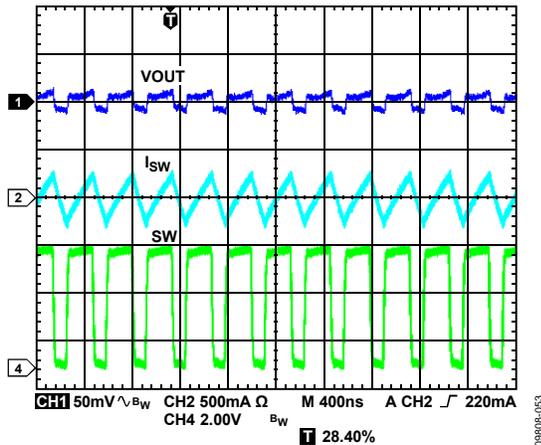


Figure 7. Typical Waveforms,  $V_{out1} = 3.3\text{ V}$ ,  $I_{out1} = 30\text{ mA}$ , PWM Mode

### Measuring Load Regulation of Buck

Test the load regulation by increasing the load at the output and looking at the change in output voltage. The input voltage must be held constant during this measurement. To minimize voltage drop, use short low resistance wires, especially for loads approaching maximum current.

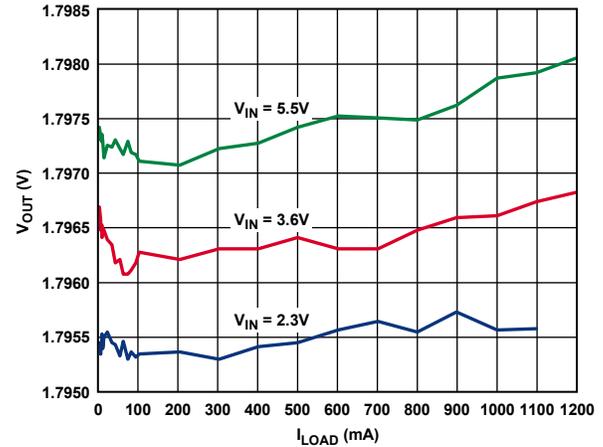


Figure 8. Buck Load Regulation

### Measuring Line Regulation

Vary the input voltage and examine the change in the output voltage.

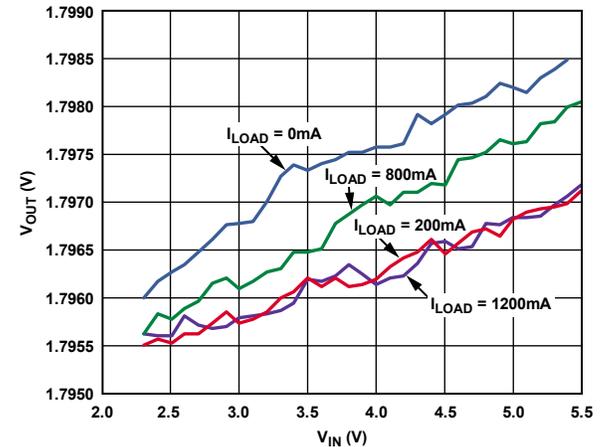


Figure 9. Buck Line Regulation

**Measuring Efficiency of Buck**

Measure the efficiency,  $\eta$ , 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 IR drops.

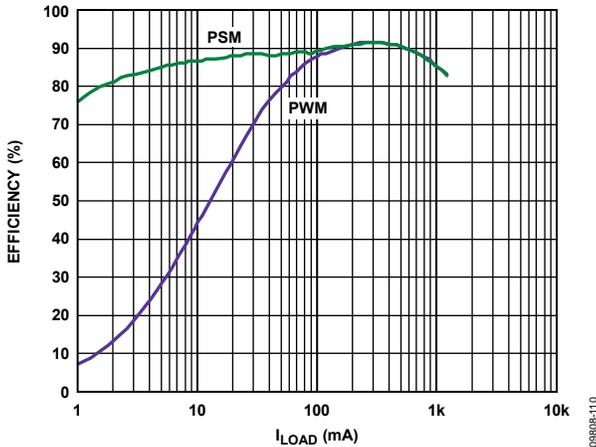


Figure 10. Buck Efficiency,  $V_{IN} = 3.6\text{ V}$ ,  $V_{OUT} = 1.8\text{ V}$

**Measuring Inductor Current**

Measure the inductor current by removing one end of the inductor from its pad and connecting a current loop in series. A current probe can be connected to this wire.

**Measuring Line Regulation of LDOs**

For line regulation measurements, the output of the regulator is monitored while its input is varied. For good line regulation, the output must change as little as possible with varying input levels. To ensure that the device is not in dropout mode during this measurement,  $V_{IN}$  must be varied between  $V_{OUT}$  nominal + 0.5 V (or 2.3 V, whichever is greater) and  $V_{IN}$  maximum. For example, a fixed 3.3 V output needs  $V_{IN}$  to be varied between 3.8 V and 5.5 V. This measurement can be repeated under different load conditions. Figure 11 shows the typical line regulation performance of the LDO with a fixed 3.3 V output.

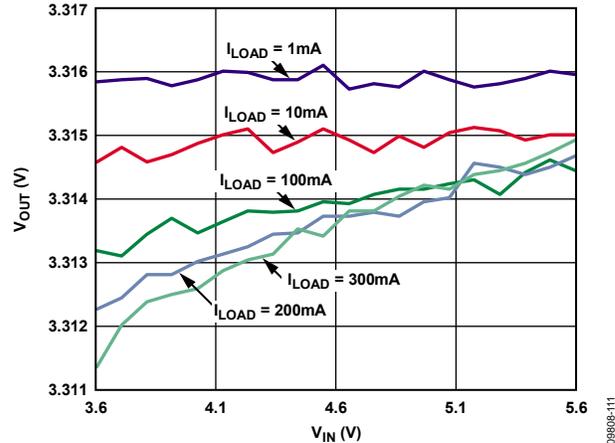


Figure 11. LDO Line Regulation

**Measuring Load Regulation of LDO**

For load regulation measurements, the regulator output is monitored while the load is varied. For good load regulation, the output must change as little as possible with varying loads. The input voltage must be held constant during this measurement. The load current can be varied from 0 mA to 300 mA. Figure 12 shows the typical load regulation performance of the LDO with a 3.3 V output for different input voltages.

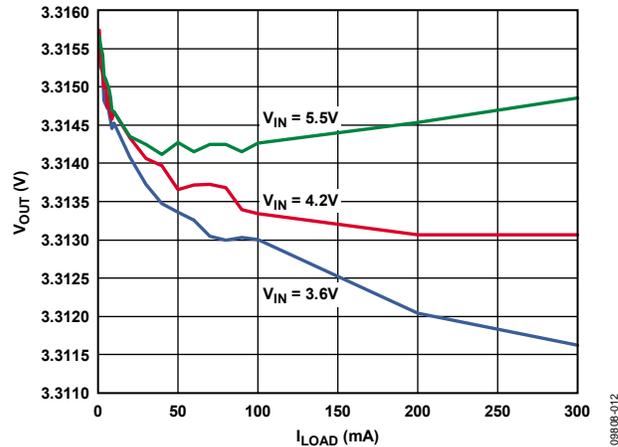


Figure 12. LDO Load Regulation

### Measuring Dropout Voltage of LDO

Dropout voltage is defined as the input-to-output voltage differential when the input voltage is set to the nominal output voltage. One way to measure dropout voltage is to get the output voltage ( $V_{OUT}$  nominal) with  $V_{IN}$  initially set to  $V_{OUT}$  nominal + 0.5 V; output load can be set to 100  $\mu$ A. Then, force the input voltage equal to  $V_{OUT}$  nominal, and measure the output voltage accordingly ( $V_{OUT}$  dropout). Dropout voltage is then calculated as  $V_{OUT}$  nominal –  $V_{OUT}$  dropout. This applies only for output voltages greater than 1.7 V. Dropout voltage increases with larger loads. For more accurate measurements, a second voltmeter can be used to monitor the input voltage across the input capacitor. The input supply voltage may need to be adjusted to account for IR drops, especially if large load currents are used.

### Measuring Ground Current Consumption of LDO

Ground current measurements can determine how much current the internal circuits of the regulator consume while the circuits

perform the regulation function. To be efficient, the regulator needs to consume as little current as possible. Typically, the regulator uses the maximum current when supplying its largest load level (300 mA). When the device is disabled, the ground current drops to less than 1  $\mu$ A. Refer to Figure 14 for a detailed instruction on how to perform ground current measurements.

### Cascading an LDO from the Buck Regulator

For certain applications such as analog circuit supplies, the LDOs are preferred over the bucks because of better noise performance. Where not all the buck outputs are being used, the input supply of the LDO can be taken from these outputs. An example demo board connection is shown in Figure 13 wherein  $V_{OUT1}$  is tied to  $V_{IN3}$ , which is the supply of LDO1. In this configuration, the output voltage of the buck regulator should have enough headroom with the desired output voltage of the LDO to guarantee the LDO to operate within specifications.

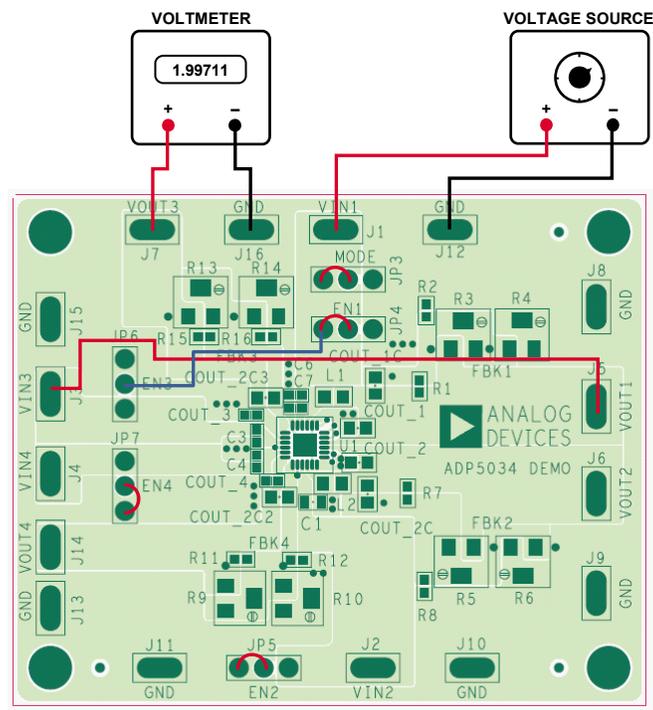


Figure 13. Cascading LDO from Buck

## MEASURING OUTPUT VOLTAGE

Figure 14 shows how the evaluation board can be connected to a voltage source and a voltmeter for basic output voltage accuracy measurements.

Figure 14 shows a voltage source connected to VIN1 and a voltmeter connected to VOUT1, which is the output of Buck 1. EN1 is connected to VIN1 via a shunt, which enables Buck 1, and EN2, EN3, EN4 are connected to ground, disabling the other channels. When measuring the voltages on VOUT2, VOUT3, and

VOUT4, make sure that the respective channels are enabled, and the voltmeters are connected to the respective outputs.

A resistor can be used as the load for the regulator. Ensure that the resistor has a power rating adequate to handle the power expected to be dissipated across it. An electronic load can also be used as an alternative. Ensure that the voltage source can supply enough current for the expected load levels.

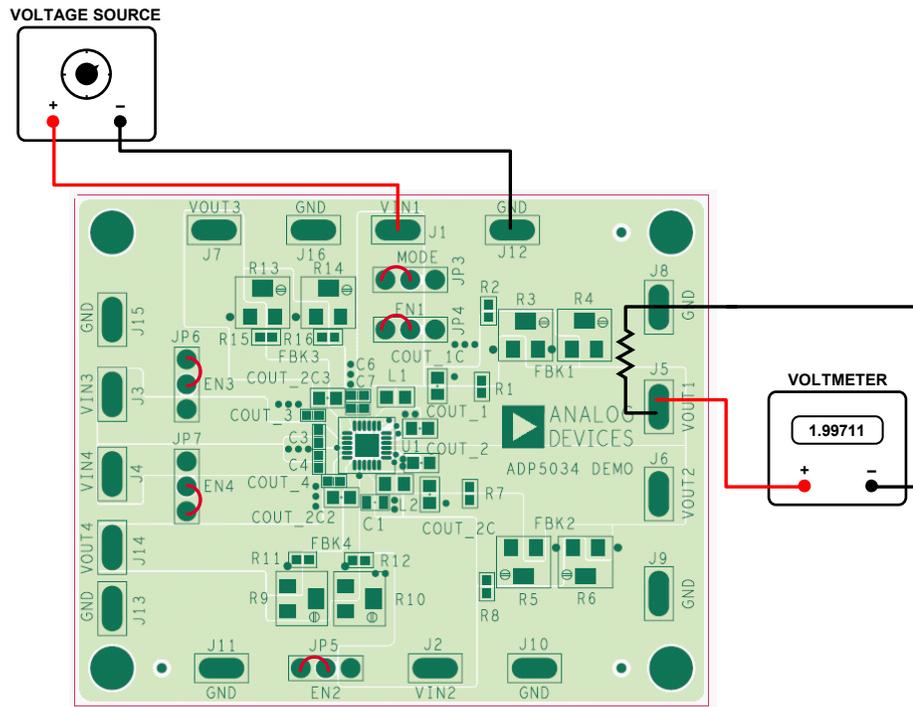


Figure 14. Ground Current Measurement

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## MEASURING GROUND CURRENT

Figure 15 shows the evaluation board connected to a voltage source and an ammeter for ground current measurements. A resistor can be used as the load for the regulator. Ensure that the resistor has a power rating that is adequate to handle the power expected to

be dissipated across it. An electronic load can be used as an alternative. Ensure that the voltage source used can supply enough current for the expected load levels.

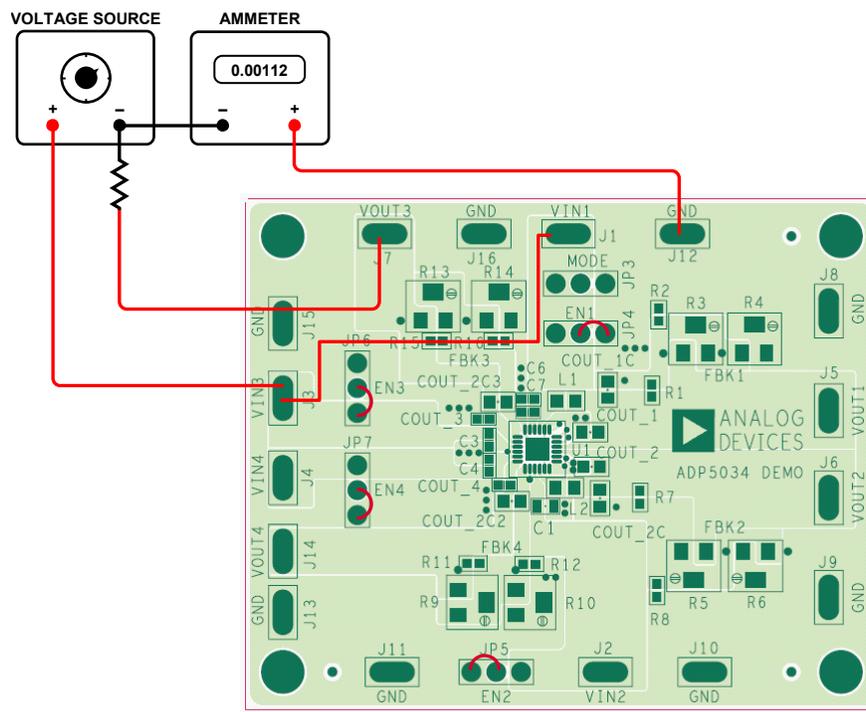


Figure 15. Ground Current Measurement

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EVALUATION BOARD SCHEMATICS AND ARTWORK

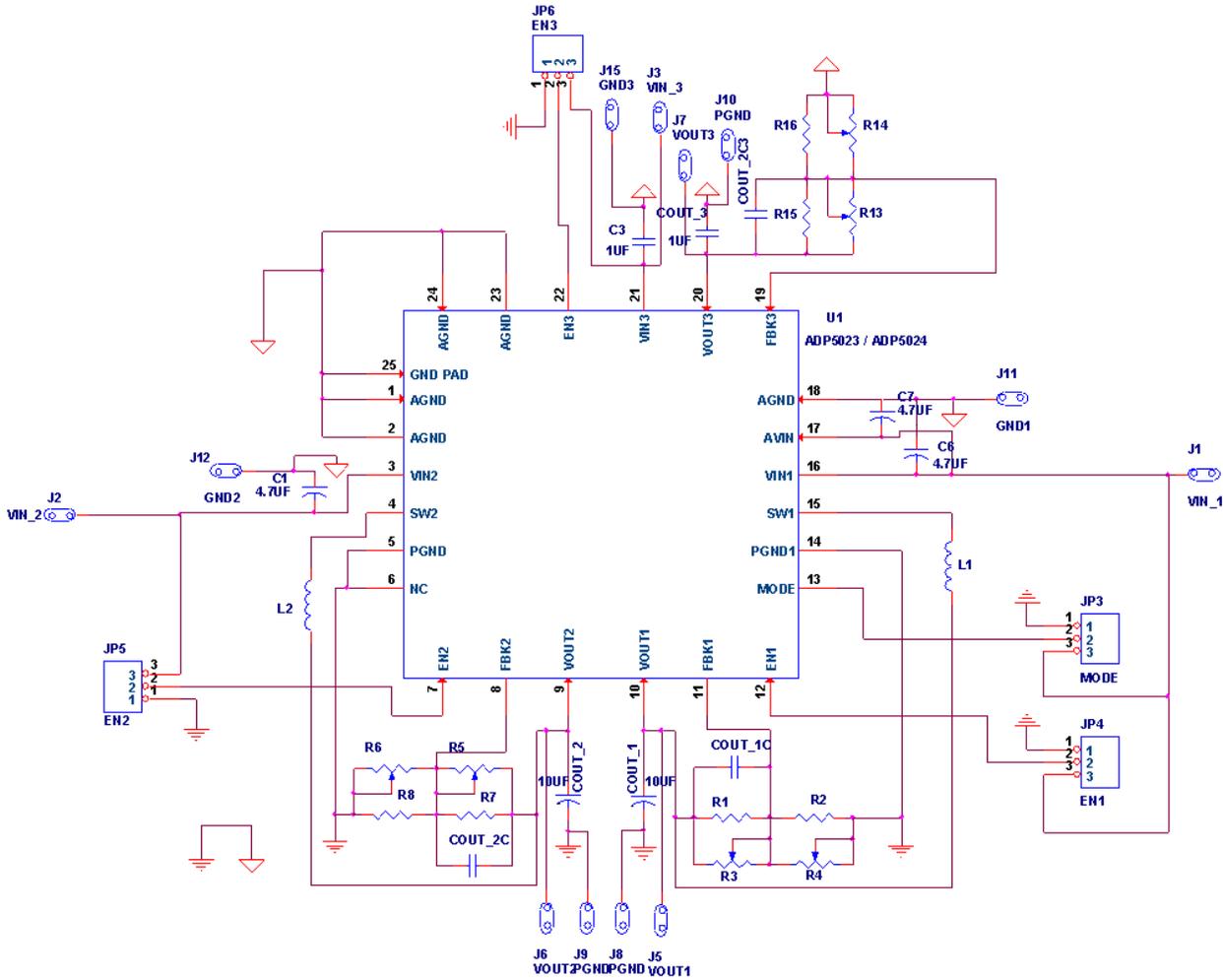


Figure 16. Evaluation Board Schematic of the ADP5023/ADP5024

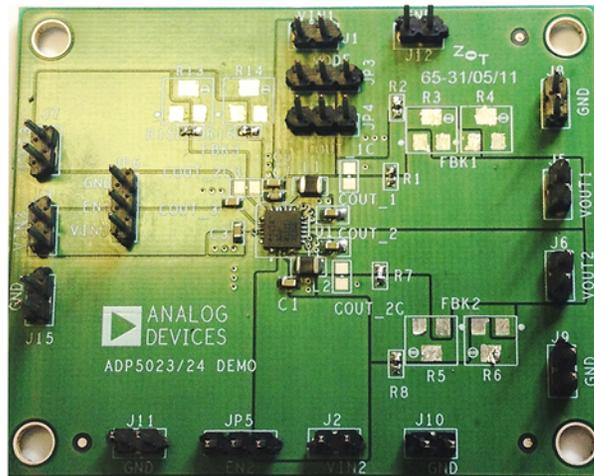
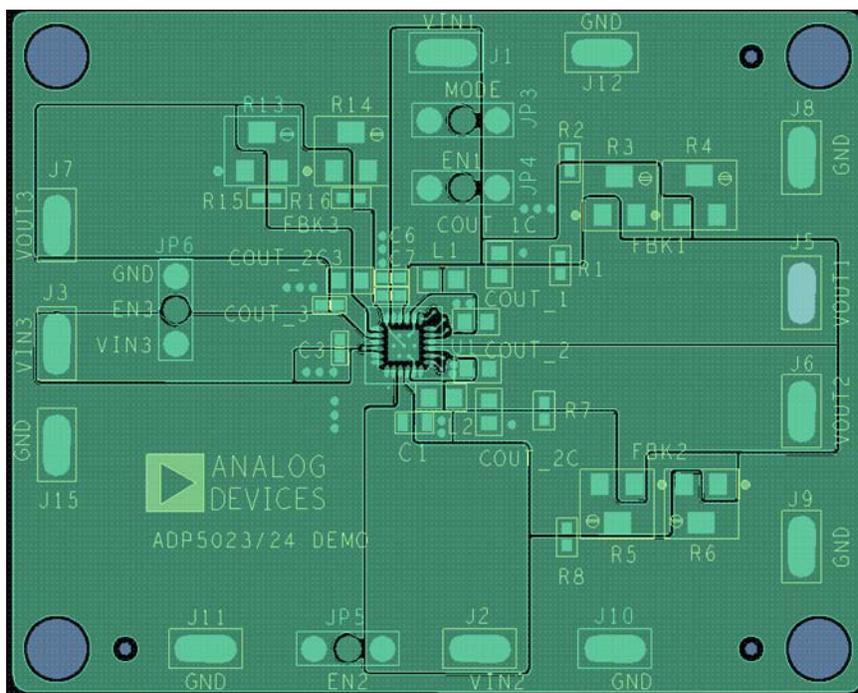
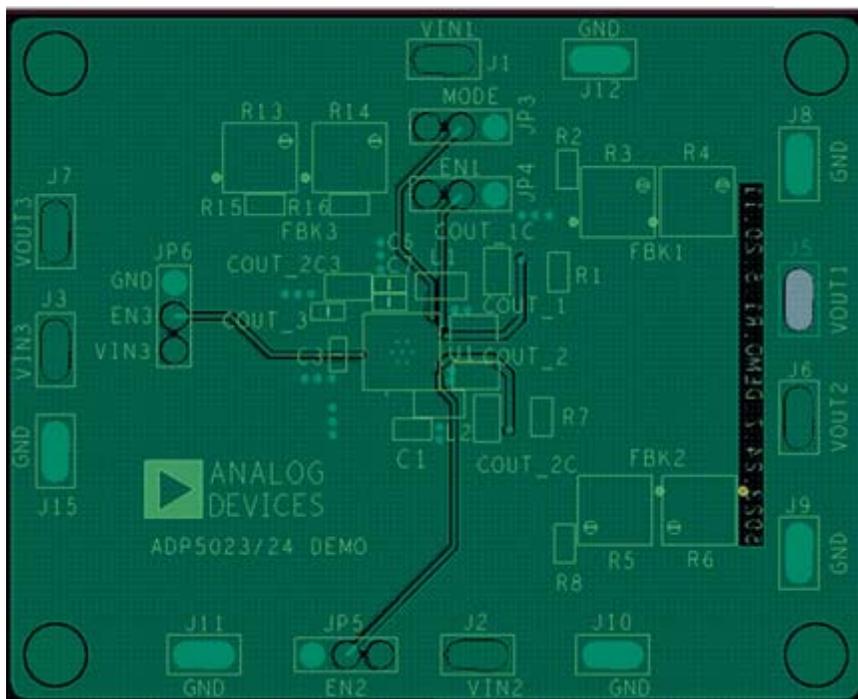


Figure 17. Evaluation Board Schematic of the ADP5023/ADP5024



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Figure 18. Top Layer, Recommended Layout for ADP5023/ADP5024



0980B-014

Figure 19. Bottom Layer, Recommended Layout for ADP5023/ADP5024

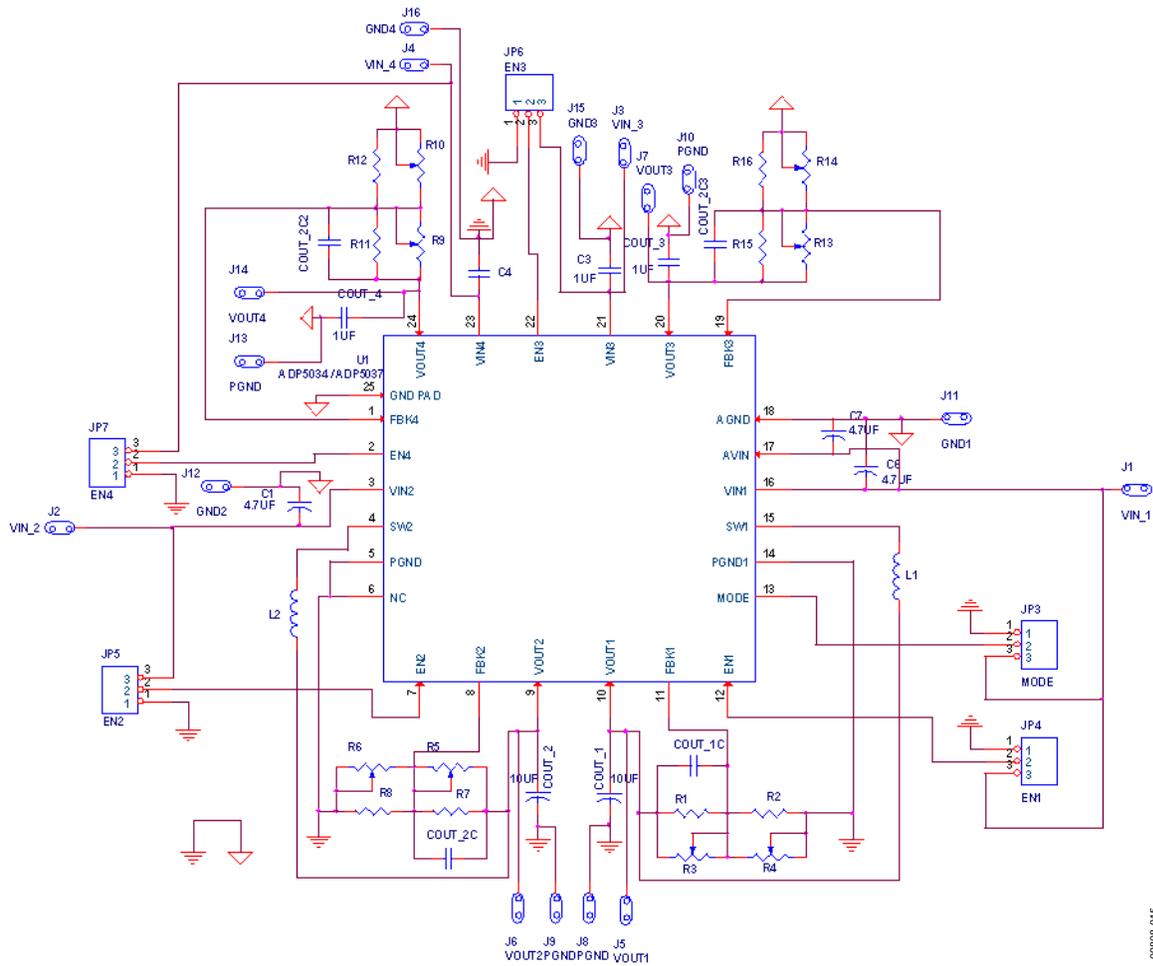


Figure 20. Evaluation Board Schematic of the ADP5034/ADP5037

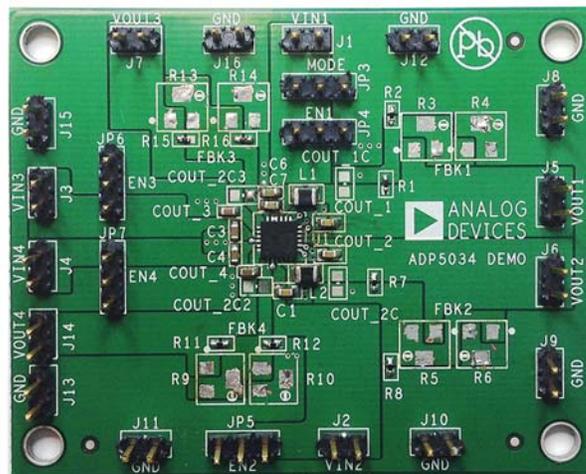


Figure 21. Evaluation Board Schematic of the ADP5034/ADP5037

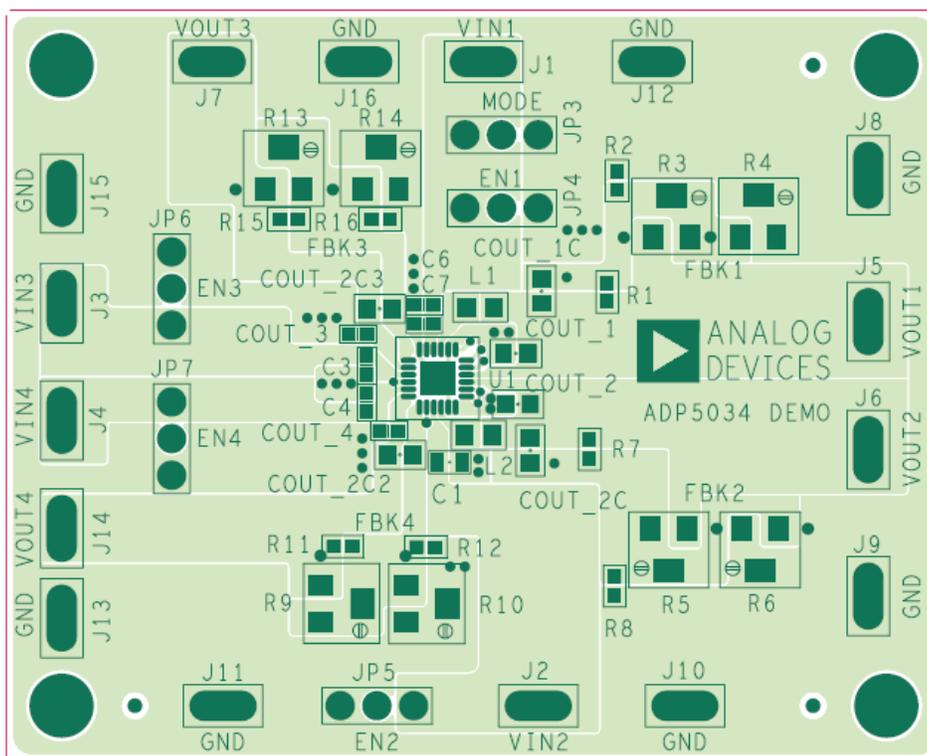


Figure 22. Top Layer, Recommended Layout for ADP5034/ADP5037

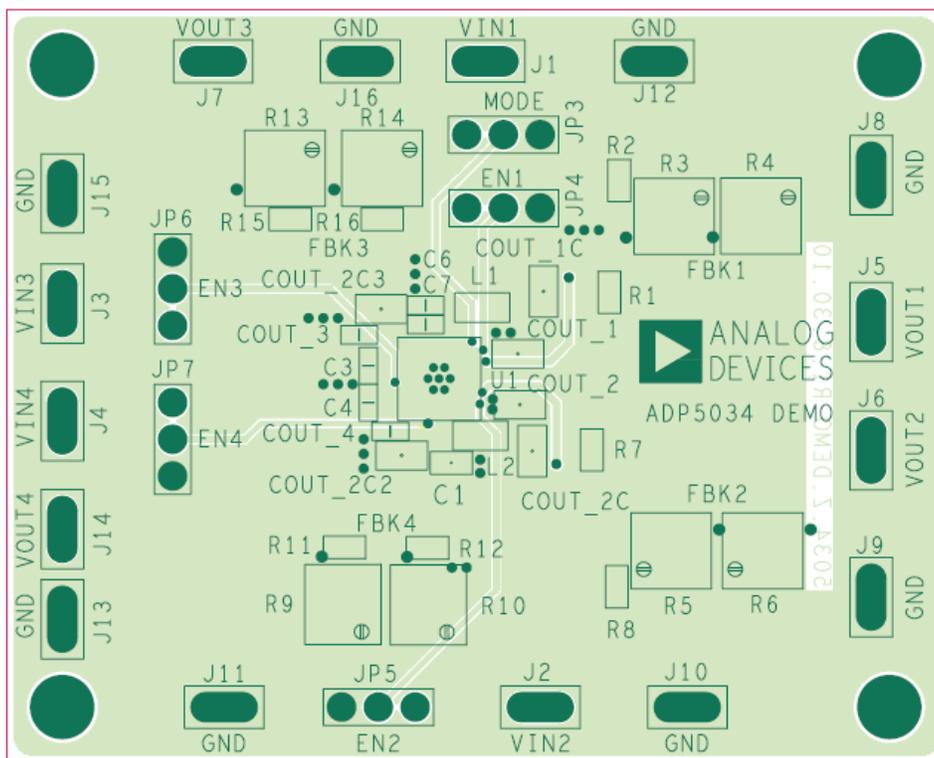


Figure 23. Bottom Layer, Recommended Layout for ADP5034/ADP5037

## ORDERING INFORMATION

### BILL OF MATERIALS

Table 4.

Qty.	Reference Designator	Description	Manufacturer	Part Number
1	U1	Micro PMU	Analog Devices	<a href="#">ADP5034</a> or <a href="#">ADP5037</a> or <a href="#">ADP5023</a> or <a href="#">ADP5024</a>
2	C1, C6, C7	Capacitor, MLCC, 4.7 $\mu$ F	Murata	GRM188R60J475ME19D
5	C4 <sup>1</sup> , C3, COUT_3, COUT_4 <sup>1</sup>	Capacitor, MLCC, 1.0 $\mu$ F	Murata	GRM188R60J105KA01B
2	COUT_2, COUT_1	Capacitor, MLCC, 10.0 $\mu$ F	Murata	GRM188R60J106ME47D
2	L1, L2	Inductor, 1.0 $\mu$ H	Murata	LQM2HPN1R0MJ0L
8	R3, R4, R5, R6, R9 <sup>1</sup> , R10 <sup>1</sup> , R13, R14	Trimmer resistors, 200 k $\Omega$	Bournes, Inc.	3214W-1-204E
8	R8, R7, R1, R2, R15, R16, R11 <sup>1</sup> , R12 <sup>1</sup>	Resistor, 0402, 49.9 K <sup>2</sup>	Vishay Draloric	CRCW040249K9FKED
4	COUT_1C, COUT_2C, COUT2C2 <sup>1</sup> , COUT_2C3	Not fitted	Not fitted	Not fitted

<sup>1</sup> With [ADP5034/ADP5037](#) only.<sup>2</sup> Subject to change depending on the output voltage chosen.

### RELATED LINKS

Resource	Description
<a href="#">ADP5023</a>	Dual 3 MHz, 800 mA Buck Regulator with One 300 mA LDO
<a href="#">ADP5024</a>	Dual 3 MHz, 1200 mA Buck Regulators with One 300 mA LDO
<a href="#">ADP5034</a>	Dual 3 MHz, 1200 mA Buck Regulator with Two 300 mA LDOs
<a href="#">ADP5037</a>	Dual 3 MHz, 800 mA Buck Regulators with Two 300 mA LDOs

## NOTES

## 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.

**Legal Terms and Conditions**

By using the evaluation board discussed herein (together with any tools, components documentation or support materials, the "Evaluation Board"), you are agreeing to be bound by the terms and conditions set forth below ("Agreement") unless you have purchased the Evaluation Board, in which case the Analog Devices Standard Terms and Conditions of Sale shall govern. Do not use the Evaluation Board until you have read and agreed to the Agreement. Your use of the Evaluation Board shall signify your acceptance of the Agreement. This Agreement is made by and between you ("Customer") and Analog Devices, Inc. ("ADI"), with its principal place of business at One Technology Way, Norwood, MA 02062, USA. Subject to the terms and conditions of the Agreement, ADI hereby grants to Customer a free, limited, personal, temporary, non-exclusive, non-sublicensable, non-transferable license to use the Evaluation Board FOR EVALUATION PURPOSES ONLY. Customer understands and agrees that the Evaluation Board is provided for the sole and exclusive purpose referenced above, and agrees not to use the Evaluation Board for any other purpose. Furthermore, the license granted is expressly made subject to the following additional limitations: Customer shall not (i) rent, lease, display, sell, transfer, assign, sublicense, or distribute the Evaluation Board; and (ii) permit any Third Party to access the Evaluation Board. As used herein, the term "Third Party" includes any entity other than ADI, Customer, their employees, affiliates and in-house consultants. The Evaluation Board is NOT sold to Customer; all rights not expressly granted herein, including ownership of the Evaluation Board, are reserved by ADI. CONFIDENTIALITY. This Agreement and the Evaluation Board shall all be considered the confidential and proprietary information of ADI. Customer may not disclose or transfer any portion of the Evaluation Board to any other party for any reason. Upon discontinuation of use of the Evaluation Board or termination of this Agreement, Customer agrees to promptly return the Evaluation Board to ADI. ADDITIONAL RESTRICTIONS. Customer may not disassemble, decompile or reverse engineer chips on the Evaluation Board. Customer shall inform ADI of any occurred damages or any modifications or alterations it makes to the Evaluation Board, including but not limited to soldering or any other activity that affects the material content of the Evaluation Board. Modifications to the Evaluation Board must comply with applicable law, including but not limited to the RoHS Directive. TERMINATION. ADI may terminate this Agreement at any time upon giving written notice to Customer. Customer agrees to return to ADI the Evaluation Board at that time. LIMITATION OF LIABILITY. THE EVALUATION BOARD PROVIDED HEREUNDER IS PROVIDED "AS IS" AND ADI MAKES NO WARRANTIES OR REPRESENTATIONS OF ANY KIND WITH RESPECT TO IT. ADI SPECIFICALLY DISCLAIMS ANY REPRESENTATIONS, ENDORSEMENTS, GUARANTEES, OR WARRANTIES, EXPRESS OR IMPLIED, RELATED TO THE EVALUATION BOARD INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTY OF MERCHANTABILITY, TITLE, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF INTELLECTUAL PROPERTY RIGHTS. IN NO EVENT WILL ADI AND ITS LICENSORS BE LIABLE FOR ANY INCIDENTAL, SPECIAL, INDIRECT, OR CONSEQUENTIAL DAMAGES RESULTING FROM CUSTOMER'S POSSESSION OR USE OF THE EVALUATION BOARD, INCLUDING BUT NOT LIMITED TO LOST PROFITS, DELAY COSTS, LABOR COSTS OR LOSS OF GOODWILL. ADI'S TOTAL LIABILITY FROM ANY AND ALL CAUSES SHALL BE LIMITED TO THE AMOUNT OF ONE HUNDRED US DOLLARS (\$100.00). EXPORT. Customer agrees that it will not directly or indirectly export the Evaluation Board to another country, and that it will comply with all applicable United States federal laws and regulations relating to exports. GOVERNING LAW. This Agreement shall be governed by and construed in accordance with the substantive laws of the Commonwealth of Massachusetts (excluding conflict of law rules). Any legal action regarding this Agreement will be heard in the state or federal courts having jurisdiction in Suffolk County, Massachusetts, and Customer hereby submits to the personal jurisdiction and venue of such courts. The United Nations Convention on Contracts for the International Sale of Goods shall not apply to this Agreement and is expressly disclaimed.