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19-2782; Rev 0; 2/03

MAX5037 Evaluation Kit

General Description

The MAX5037 evaluation (EV) kit is a fully assembled and tested VRM power-supply evaluation kit. The EV kit module can be inserted directly into the VRM daughter board AMP connector (1364125-1 or equivalent) on Pentium® 4 processor motherboards. The input voltage range is either 4.75V to 5.5V or 8V to 13.2V. The EV kit design is optimized for the best performance at 12V input and 1.75V output voltage settings. The output is programmable from 1.1V to 1.85V through VID input in compliance with Intel's VRM 9.0 specification. Up to 52A load current is possible from dual-phase conversion. High-power density and simple assembly is achieved due to a lower component count using the MAX5037.

Warning

The MAX5037 EV kit is designed to operate at high currents, and some of the components operate at high temperatures. Avoid touching the components. **The evaluation board is not provided with a fuse. Use a controlled current source to power up the board.** Under severe fault conditions, this EV kit may dissipate a large amount of power. To avoid possible personal injury, operate this kit with care.

Pentium is a registered trademark of Intel Corp.

Component List

DESIGNATION	QTY	DESCRIPTION
C1, C2	2	47µF ±20%, 16V X5R ceramic capacitors (2220) TDK C5750X5R1C476M
C3–C11	9	22µF ±20%, 16V X5R ceramic capacitors (1812) TDK C4532X5R1C226M
C12–C21	10	270µF, 2V, 15mΩ low-ESR specialty capacitors Panasonic EEFUE0D271R
C22, C23	2	100µF ±10%, 6.3V ceramic capacitors (2220) Murata GRM55FR60J107KA01L
C24–C29	6	10µF ±20%, 6.3V X5R ceramic capacitors (0805) TDK C2012X5R0J106M
C30, C42	2	0Ω resistors (0603)
C31, C35, C37	3	0.01µF ±5%, 50V X7R ceramic capacitors (0603) Murata GRM188R71H103KA01

Features

- ♦ Designed to Meet VRM 9.0 Mechanical and Electrical Specifications
- ♦ Two-Phase Power Conversion
- ♦ 5V or 12V Input Operation (Design Optimized for 12V Input)
- ♦ Output Voltage Programmable from 1.1V to 1.85V in 25mV Step-Through VID Input
- ♦ VRM 9.0-Compliant Integrated 5-Bit DAC
- ♦ 52A Output Current
- ♦ Adaptive Voltage Positioning for Optimized Transient Response
- ♦ Average Current-Mode Control for Superior Current Sharing
- ♦ Current-Sharing Accuracy Within 5% Between Parallel Channels
- ♦ Up to 95% Efficiency
- ♦ 500kHz Effective Switching Frequency (Two Phases)
- ♦ Output Overload Protection
- ♦ Output Overvoltage Crowbar Protection
- ♦ Internal Undervoltage Lockout and Startup Circuit
- ♦ Excellent Line-and-Load Transient Response
- ♦ Phase Failure Detector
- ♦ Multiple-Phase Synchronization Between Parallel Modules
- ♦ VRM 9.0-Compliant EDGE Connector

Ordering Information

PART	TEMP RANGE	IC PACKAGE
MAX5037EVKIT	0°C to +60°C	44 QFN

Component List (continued)

DESIGNATION	QTY	DESCRIPTION
C32, C41	2	0.47µF ±10%, 16V capacitors (0805) TDK C1608X5R1A474K
C33, C36, C38	3	470pF ±5%, 16V COG ceramic capacitors (0603) Murata GRM1885C1H471JAB01
C34	1	4700pF ±5%, 16V X7R ceramic capacitor (0603) Vishay VJ0603Y471JXJ
C39, C44, C45	3	0.1µF ±10%, 16V X7R ceramic capacitors (0603) Murata GRM188R71C104KA01
C40	1	1µF, 10V Y5V ceramic capacitor (0603) Murata GRM188F51A105
C43	1	4.7µF ±10%, 16V X7R ceramic capacitor (0805) Murata GRM40-034X5R475K6.3
CON1	0	Not installed
D1, D2	2	Schottky diodes ON Semi MBRS340T3
D3, D4	2	Schottky diodes ON Semi MBR0520LT1
HS1, HS2	2	Surface-mount flatback heatsinks AAVID NP973541
JP3, JP4	2	3-pin headers Digi-Key S1012-03-ND
JP5	1	2-pin header Digi-Key S1012-02-ND

DESIGNATION	QTY	DESCRIPTION
L1, L2	2	0.6µH ±10% power inductors, 13mm × 13mm Panasonic ETQP1H0R6BFX
Q1, Q2, Q5, Q6	4	MOSFETs PowerPAK SO-8 Vishay-Siliconix Si7860DP
Q3, Q4, Q7, Q8	4	MOSFETs PowerPAK SO-8 Vishay-Siliconix Si7886DP
R1–R4	4	0.0027Ω resistors (2512) Panasonic ERJM1WSF2M7U
R5	1	10Ω ±1% resistor (0603)
R6, R19, R21	3	Not installed
R7, R15	2	3.3Ω ±1% resistors (0805)
R8	1	2.2Ω ±1% resistor (0805)
R9	1	7.5kΩ ±1% resistor (0603)
R10, R18	2	1kΩ ±1% resistors (0603)
R11, R14	2	49.9Ω ±1% resistors (0603)
R12, R20	2	0Ω ±1% resistors (0805)
R13, R16	2	0Ω ±1% resistors (0603)
R17	1	1Ω ±1% resistor (0603)
R22, R23	2	37.4kΩ ±1% resistors (0603)
R24	1	4.99kΩ ±1% resistor (0603)
R25	1	10kΩ ±1% resistor (0603)
SCR1	1	SCR 200V, 12A D-Pack Teccor S2012D
U1	1	MAX5037ETH, dual-phase controller (44-pin QFN)
None	2	Shunts, JP3-2/3, JP4-2/3 Digi-Key SD9000-ND

Component Suppliers

SUPPLIER	PHONE	FAX	WEBSITE
AAVID Thermalloy	603-224-9988	603-223-1790	www.aavidthermalloy.com
Murata	770-436-1300	770-436-3030	www.murata.com
ON Semiconductor	602-244-6600	602-244-3345	www.on-semi.com
Panasonic	714-373-7939	714-373-7183	www.panasonic.com
TDK	847-803-6100	847-390-4405	www.tdk.com
Teccor	972-580-7777	972-550-1309	www.teccor.com
Vishay	402-563-6866	402-563-6296	www.vishay.com

Note: *When contacting these suppliers, please indicate you are using the MAX5037.*

Quick Start

The MAX5037 EV kit is fully assembled and tested. The termination for input, output, and control is provided at the edge connector as per VRM 9.0 specification. The MAX5037 EV kit module fits into AMP connector 1364125-1 or equivalent. Follow these steps to verify board operation. In the quick-start operation, full load performance cannot be verified.

12V Input Operation

1) Connect a wire from edge-connector pin 57 to COM. This sets the VID code to 01111 and output voltage of 1.475V.
2) Place a jumper between pins 2 and 3 of JP4 for 250kHz switching frequency operation.
3) Connect a voltage source (15V/20A, min) at the input (across C1 or C2). Use heavy-gauge wire, and keep the connecting wires between the EV kit and voltage source short. Use 2200µF/16V at the input if the wires running from the voltage source to the EV kit are thin and long. Connect voltmeters across +VIN to COM and +VOUT to COM.
4) Connect the load between +VOUT (edge-connector pins 49, 50) to COM (edge-connector pins 40, 42), with ammeter in series; set the load to 1Ω. Connect the voltmeter between SENSE+ (edge-connector pin 52) and SENSE- (edge-connector pin 11) to monitor the output voltage.
5) Gradually increase the input voltage to 12V while monitoring the output voltage and input current.

5V Input Operation

1) Short the JMPR-5VIN pins with wire on the bottom layer of the EV kit PC board. This connects IN (MAX5037 pin 28) and VCC (MAX5037 pin 27) (Figure 18).
2) Connect a wire from edge-connector pin 57 to COM. This sets the VID code to 01111 and output voltage of 1.475V.
3) Place a shunt between pins 2 and 3 of jumper JP4 for 250kHz switching frequency operation. For 500kHz operation, move the shunt to pins 1 and 2 of jumper JP4.
4) Connect a voltage source (range up to 15V/20A) at the input (across C1 or C2). Use heavy-gauge wire, and keep the connecting wires between the EV kit and voltage source short. Use 2200µF/16V at the input if the wires running from the source to the EV kit are thin and long. Connect voltmeters across +VIN to COM and +VOUT to COM.
5) Connect the load between +VOUT (edge-connector pins 49, 50) to COM (edge-connector pins 40, 42), with ammeter in series; set the load to 1Ω.
6) Connect the voltmeter between SENSE+ (edge-connector pin 52) and SENSE- (edge-connector pin 11) to monitor the output voltage.
7) Gradually increase the input voltage to 5V while monitoring the output voltage and input current.

Caution

1) Do not cover the gold plating of the edge connector with solder if you want to evaluate the full load operation using the AMP connector.
2) In case of 5VIN operation, keep the input voltage below 6V (Refer to the *Absolute Maximum Ratings* of the MAX5037 data sheet).

Specifications

V_{IN} = 5V or 12V (±10%)

V_{OUT} = 1.1V to 1.85V through VID inputs (see Table 1)

I_{OUT} = 52A

Efficiency = 90%

Adaptive Voltage Positioning = 120mV at 52A

Step Load = 9A to 52A

Step Load Slew Rate = 50A/µs

Dynamic Load Regulation = -189mV$_{MAX}$ (for VID setting of 1.75V$_{OUT}$)

Termination = 62-pin edge connector (AMP136125-1 or equivalent)

Pin Details = As per VRM 9.0 specifications

Operating Temperature = 0°C to +60°C (with 400LFM airflow)

Table 1. Output Voltage vs. DAC Codes

VID INPUTS (0 = Connected to SGND, 1 = Open Circuit)					**OUTPUT VOLTAGE (V)**
VID4	**VID3**	**VID2**	**VID1**	**VID0**	**V_{OUT}**
1	1	1	1	1	Output off
1	1	1	1	0	1.100
1	1	1	0	1	1.125
1	1	1	0	0	1.150
1	1	0	1	1	1.175
1	1	0	1	0	1.200
1	1	0	0	1	1.225
1	1	0	0	0	1.250
1	0	1	1	1	1.275
1	0	1	1	0	1.300
1	0	1	0	1	1.325
1	0	1	0	0	1.350
1	0	0	1	1	1.375
1	0	0	1	0	1.400
1	0	0	0	1	1.425
1	0	0	0	0	1.450
0	1	1	1	1	1.475
0	1	1	1	0	1.500
0	1	1	0	1	1.525
0	1	1	0	0	1.550
0	1	0	1	1	1.575
0	1	0	1	0	1.600
0	1	0	0	1	1.625
0	1	0	0	0	1.650
0	0	1	1	1	1.675
0	0	1	1	0	1.700
0	0	1	0	1	1.725
0	0	1	0	0	1.750
0	0	0	1	1	1.775
0	0	0	1	0	1.800
0	0	0	0	1	1.825
0	0	0	0	0	1.850

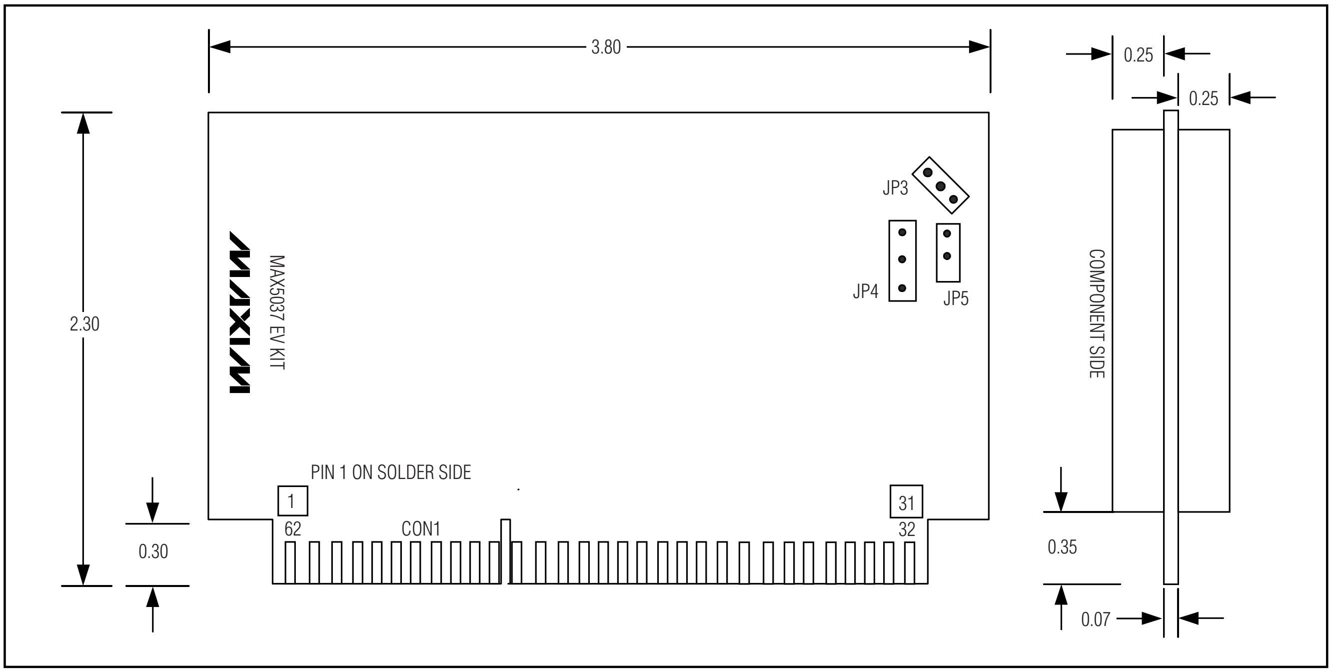

Figure 1. Outline Drawing of MAX5037 EV Kit

Table 2. Edge-Connector Pin Configuration

PIN	FUNCTION	PIN	FUNCTION	PIN	FUNCTION	PIN	FUNCTION
1	VIN+	16	VO+	31	VO-	47	VO+
2	VIN+	17	VO-	32	VO-	48	VO-
3	VIN+	18	VO+	33	VO+	49	VO+
4	VIN+	19	VO-	34	VO-	50	VO+
5	Rsvd	20	VO+	35	VO+	51	Rsvd
6	Key	21	VO-	36	VO-	52	SENSE+
7	VID3	22	VO+	37	VO+	53	EN
8	VID1	23	VO-	38	VO-	54	NC
9	Rsvd	24	VO+	39	VO+	55	VID0
10	PGOOD	25	VO-	40	VO-	56	VID2
11	SENSE-	26	VO+	41	VO+	57	VID4
12	Rsvd	27	VO-	42	VO-	58	VRM-pres
13	VO-	28	VO+	43	VO+	59	VIN-
14	VO+	29	VO-	44	VO-	60	VIN-
15	VO-	30	VO+	45	VO+	61	VIN-
				46	VO-	62	VIN-

Detailed Description

The MAX5037 EV kit is a voltage-regulating module that provides 1.1V to 1.85V at 52A current from either a 5V or 12V input. The input voltage range can be 4.75V to 5.5V for 5V input and 8V to 13.2V for 12V input conditions. Use 2200µF/16V across the input if the wires running from the source to the EV kit are thin and long. The output voltage is set from 5-bit VID input according to the Intel VRM 9.0 specification (see Table 1). The form factor and input/output terminations are also as per the Intel VRM 9.0 specification. See Table 2 for pinouts of edge connectors compatible with AMP1364125-1. CLKIN is accessible through a 3-pin header (JP3), and a shunt is provided for setting the switching frequency to either 250kHz or 500kHz. The phase-shifted clock output (CLKOUT) is available at the 2-pin header (JP5) and can be used to synchronize other MAX5037 EV kits. Use JP3 to set the phase shift of 60°, 90°, or 120°.

The MAX5037 EV kit is designed to achieve optimum electrical performance at a 12V input. High efficiency is achieved with careful component selection (Figure 18). The switching MOSFETs, inductors, and sense resistors are the major power-dissipating components. Two MOSFETs are used at the upper and lower sides of each phase to distribute the dissipated power in two different packages. The product of the gate charge and on-resistance of the MOSFET is a figure of merit, with a lower number signifying better performance. The MOSFETs chosen are optimized for a high-frequency switching application. The upper MOSFETs have a low gate charge and moderate on-resistance, and the lower MOSFETs have very low on-resistance and a moderate gate charge. The inductor is a low-profile, high-current type with low DC resistance. The sense resistors have very low inductance. Plenty of copper is provided around these power components to dissipate heat effectively. The input capacitors are high-ripple-current capacity, very low ESR, ceramic type. The output capacitors have to support large output current during the load transient. Both polymer and ceramic-type capacitors are used to achieve high output capacitance and low ESR at high frequency.

5V Input Operation

The EV kit is designed for the best efficiency, transient load performance at 12V input. The 5V input operation can also be verified without significant component change. Short the JMPR-5VIN pins with wire on the bottom layer of the EV kit PC Board. This connects IN (pin 28) and V_{CC} (pin 27) of the MAX5037. For 5V input operation, the switching frequency can be increased to 500kHz without significantly increasing the power losses. To change the switching frequency to 500kHz, move the shunt to pins 1 and 2 of JP4. For optimum transient load performance, replace the existing 0.6µH inductors with 0.3µH inductors.

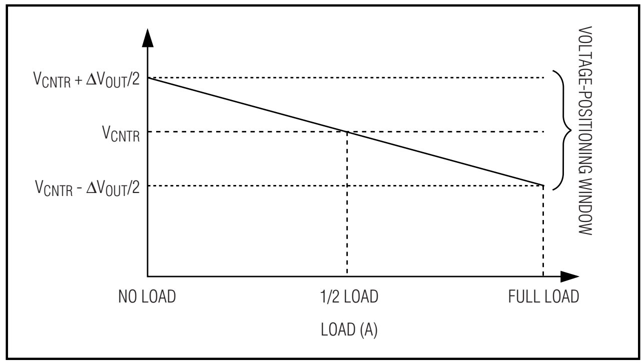

Figure 2. VRM Loadline with V_{CNTR} = VID at Half Load

Output Voltage

The output voltage set through the VID code has ±0.8% accuracy. The voltage positioning and the ability to operate with multiple reference voltages might require the output to regulate away from a center value. Define the center value as the voltage when the output voltage equals the VID reference at exactly one-half the maximum output current.

Set the voltage-positioning window (ΔV_{OUT}) using the resistive feedback of the voltage-error amplifier. Use the following equation to determine the values of R_F (R23) and R_{IN} (R24) required for setting the voltage-positioning window:

$$\Delta V_{OUT} = (R24 \times I_{OUT}) / (2 \times R23 \times G_C)$$

The voltage at CNTR (pin 18) regulates to 1.2V (Figure 18). The inverting input to the voltage-error amplifier (VEA) mirrors the current set by the resistor at CNTR, centering the output voltage-positioning window around the VID programmed output voltage. Set the center of the output voltage with a resistor from CNTR to SGND as:

$$R21 = \frac{1.2 \times R24}{I_{OUT}\left(\frac{R24}{2 \times R23 \times G_C}\right) + (V_{OUT} - VID)}$$

$$G_C = \frac{0.05}{R_S}$$

$$R_S = \frac{R1 \times R2}{R1 + R2} = \frac{R3 \times R4}{R3 + R4}$$

where R24 and R23 are the input and feedback resistors of the voltage-error amplifier, GC is current-loop gain, and RS is the current-sense resistor. See Figure 4 and Figure 5 for the output voltage vs. the R_{CNTR} (R21).

Applying the voltage-positioning window at different VRM voltage settings requires an additional element proportional to the VID setting. The resistor from REG (pin 15) to SGND provides a current proportional to the VID setting (Figure 18). Calculate the resistor from REG to SGND as:

$$R22 = R23$$

where R23 is the feedback resistor of the voltage-error amplifier. The voltage on REG is internally regulated to the programmed VID output voltage.

Note that in the case of VID voltage setting equal to $V_{COREMAX}$ at I_{OUT} = 0 (no load), R21 is calculated from the above equation as infinity. Because the VID setting has an output voltage set-point accuracy specification of 0.8%, the output voltage may exceed the V_{CCMAX} limit. For systems requiring V_{CCMAX} as an absolute maximum voltage at I_{OUT} = 0 (no load), R_{REG} can be recalculated using the following equation:

$$R22 = \frac{R24 \times R23}{R24 + R23 \times \left(1 - \frac{V_{COREMAX}}{VID}\right)}$$

The voltage positioning of 120mV at 52A load is set in the MAX5037 EV kit. See Figure 6 for the VRM output load line for voltage positioning at a different ratio of R_F (R23) and R_{IN} (R24).

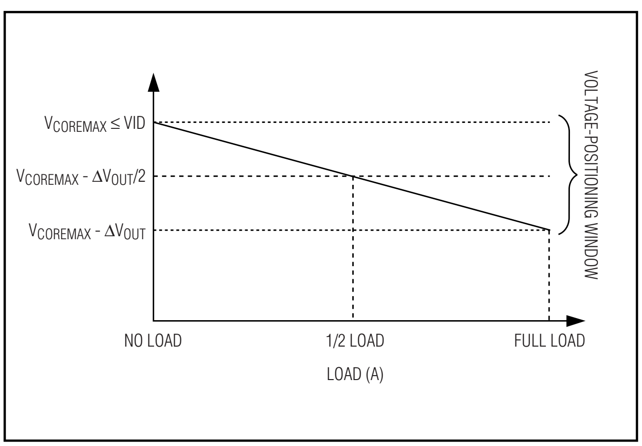

Figure 3. VRM Loadline with $V_{COREMAX}$ = VID at No Load

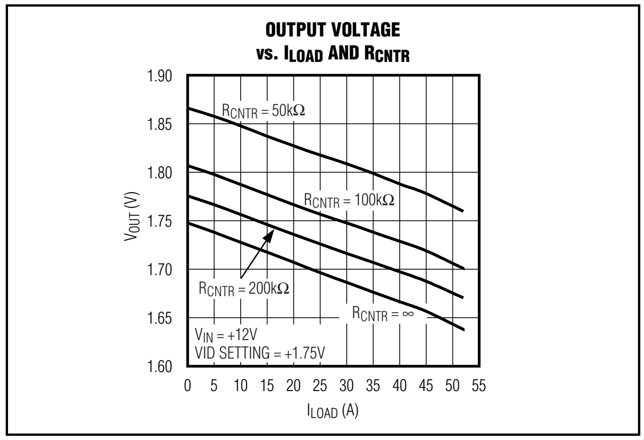

Figure 4. Output Voltage vs. I_{LOAD} and R_{CNTR}

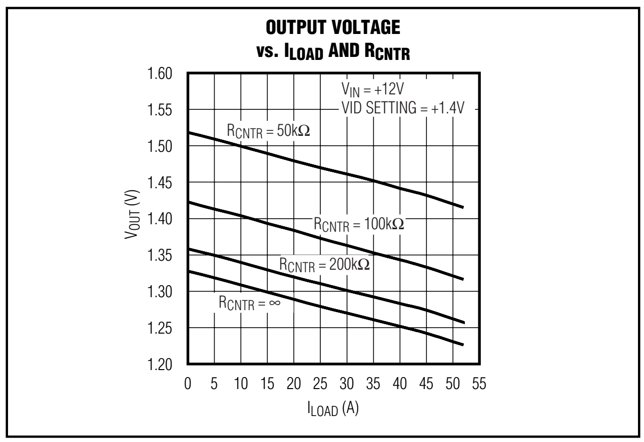

Figure 5. Output Voltage vs. I_{LOAD} and R_{CNTR}

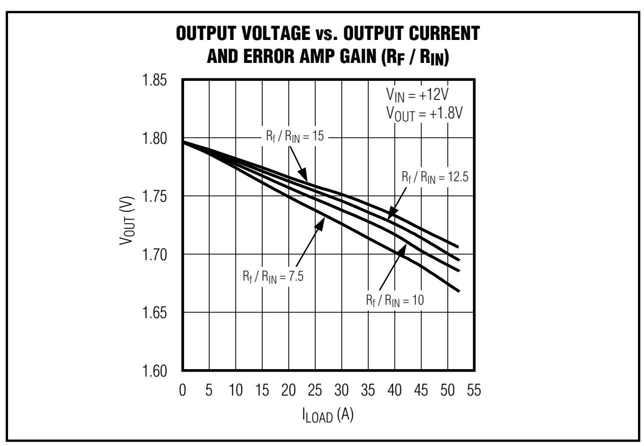

Figure 6. Output Voltage vs. Output Current and Error AMP GAIN (R_F/R_{IN})

Ripple and Noise

The worst-case peak-to-peak output-ripple voltage depends on the inductor ripple current, capacitance, and ESR of the output capacitors. In multiphase converter design, the ripple currents from individual phases cancel each other, and the resultant ripple current is lower. The degree of ripple cancellation depends on the operating duty cycle and number of phases. Note that ripple cancellation is maximum when the N_{PH} = K/D condition is met, where N_{PH} is the number of phases, D is the operating duty cycle, and K = 1, 2, or 3. See Figure 7 for the output ripple waveforms of the EV kit at full load.

Transient Load Response

The EV kit is designed to handle high slew-rate-current step without exceeding the dynamic load regulation limit of the output voltage. Figure 8 depicts the dynamic load performance with 50A/µs slew rate of the current step.

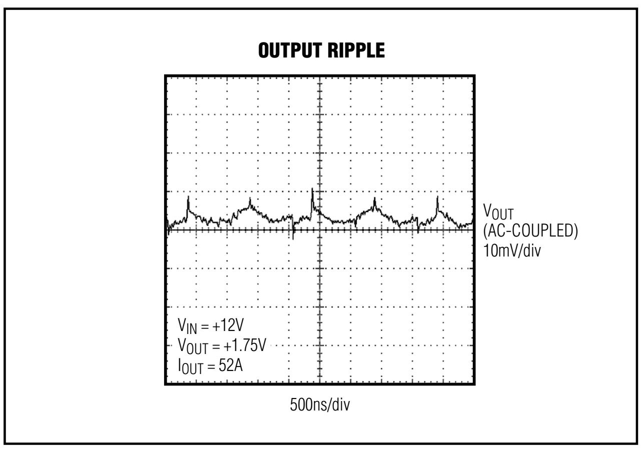

Figure 7. Output Ripple

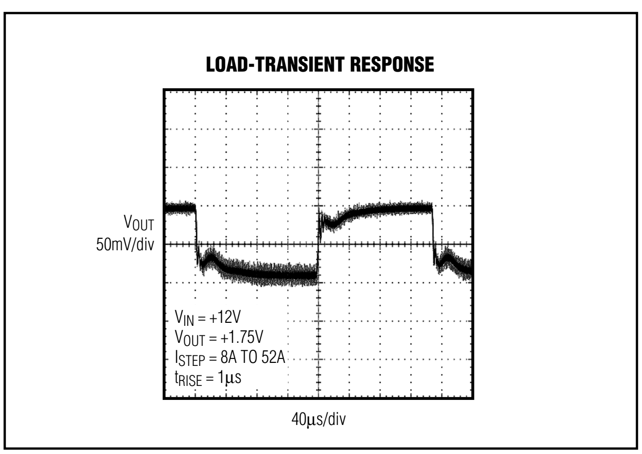

Figure 8. MAX5037 EV Kit Transient Response

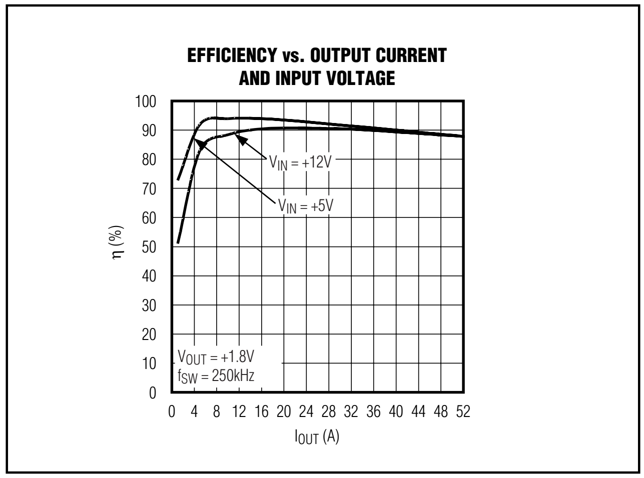

Figure 9. Efficiency vs. Output Current and Input Voltage

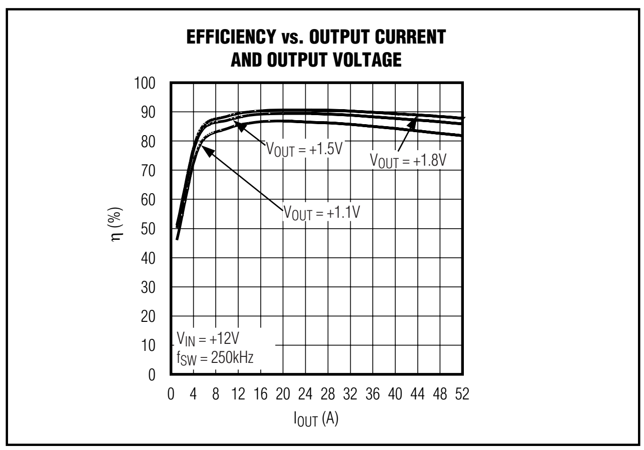

Figure 10. Efficiency vs. Output Current and Output Voltage

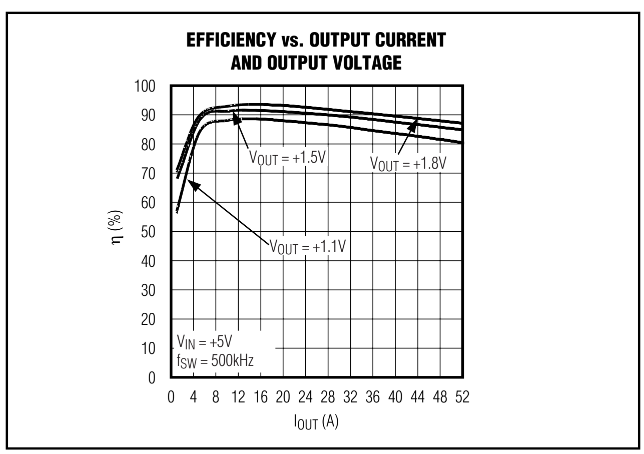

Figure 11. Efficiency vs. Output Current and Output Voltage

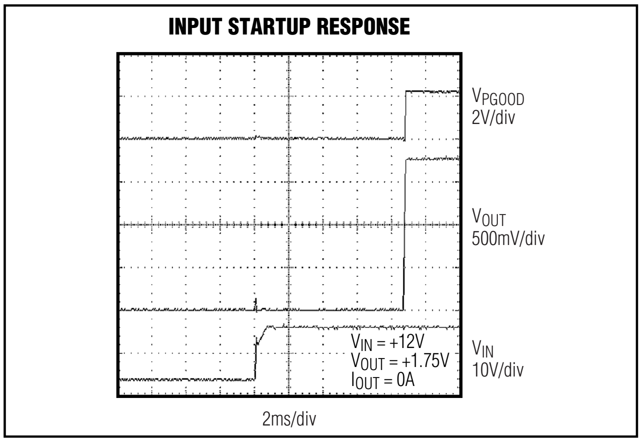

Figure 12. Input Startup Response

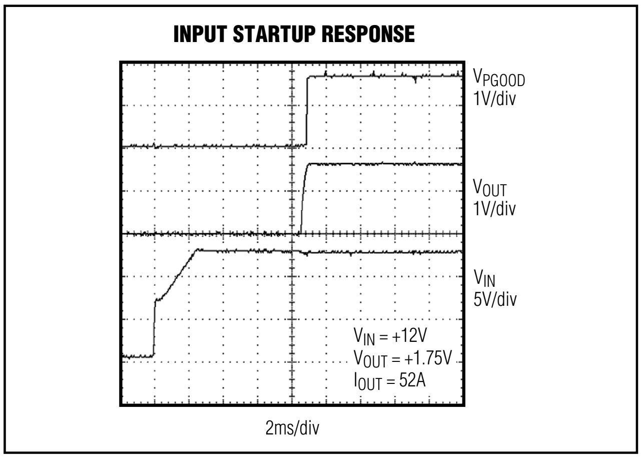

Figure 13. Input Startup Response

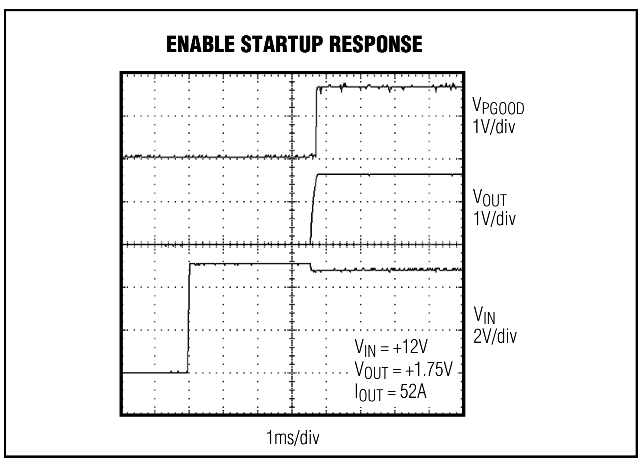

Figure 14. Enable Startup Response

Turn On

The MAX5037 offers inherent soft-start at turn-on through its current-error amplifier compensation capacitors. The output rises monotonically without overshoot. The output voltage reaches its specified range within 10ms of the input power reaching its operating voltage range at full load. See Figures 12, 13, and 14.

Current Limiting

The average current-mode control technique of the MAX5037 limits the maximum output current per phase accurately. The MAX5037 senses and limits the peak inductor current (I_{L-PK}) across the sense resistor. Two channels limit the current. The regular channel terminates the ON cycle when the current-sense voltage reaches 48mV (typ). The faster channel, with only 260ns delay, terminates the ON cycle when the voltage across the sense resistor reaches 112mV during output short-circuit and inductor saturation. Use the following equation to calculate the current limit:

$$I_{OUT} = \left(\frac{0.05}{R1 // R2}\right) \times N$$

For the EV kit, current limit occurs at 63A typically with R_{SENSE} equal to 1.6mΩ. In case of a short circuit at the output, the average output current is maintained at its current-limit value.

External Synchronization with CLKIN and CLKOUT

Multiple MAX5037 EV kits can be paralleled to increase output current capacity. The EV kit is provided with the CLKIN input (JP4) and CLKOUT (JP5) output for easy paralleling. The CLKOUT is phase delayed from CLKIN or DH1 by an amount set by PHASE (JP3). A jumper between pins 1 and 2 set the phase delay to 60°, a jumper between pins 2 and 3 set the delay to 120°, and the OPEN jumper sets the phase delay to 90°. Figures 15, 16, and 17 show the CLKOUT position with respect to CLKIN and DH1 for 60°, 90°, and 120°, respectively.

MAX5037 Evaluation Kit

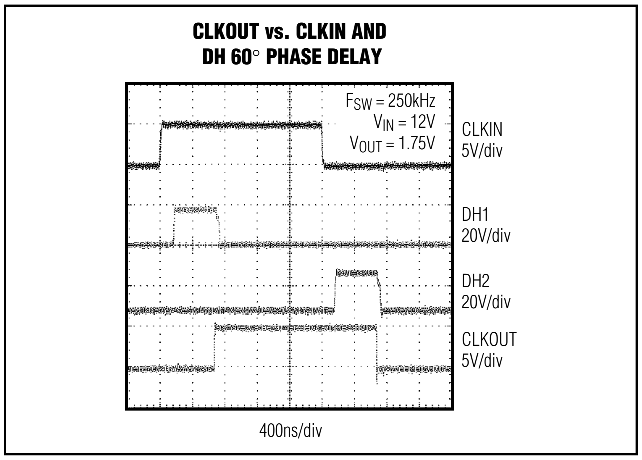

Figure 15. CLKOUT vs. CLKIN and DH 60° Phase Delay

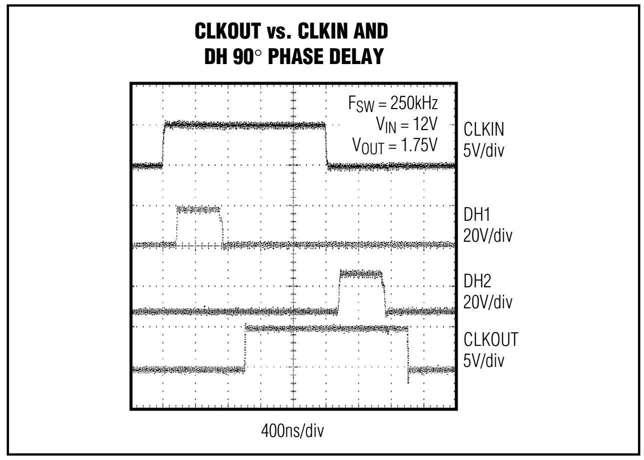

Figure 16. CLKOUT vs. CLKIN and DH 90° Phase Delay

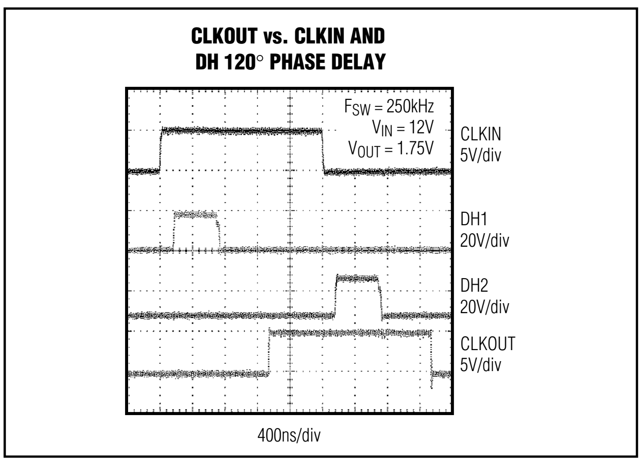

Figure 17. CLKOUT vs. CLKIN and DH 120° Phase Delay

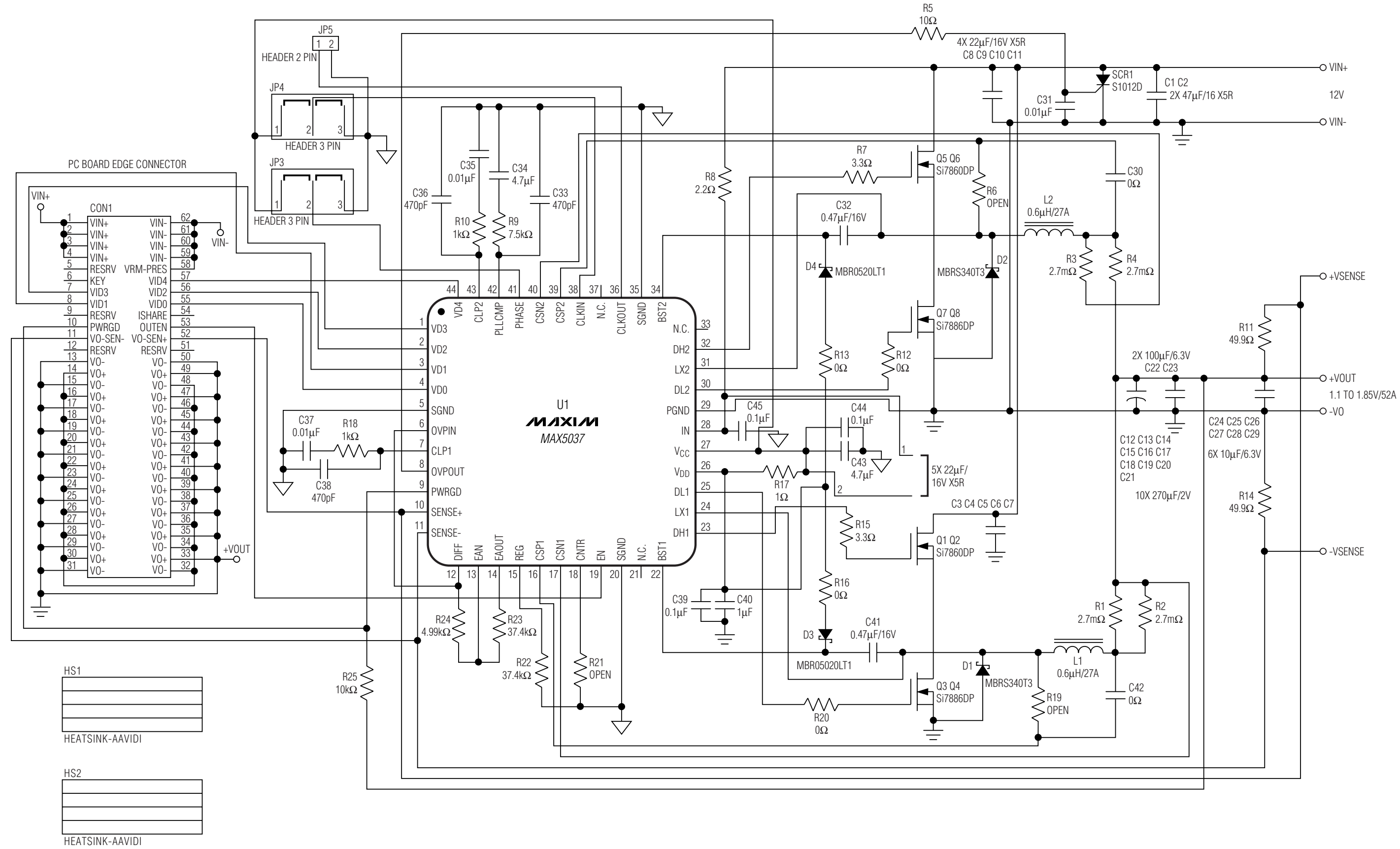

Figure 18. MAX5037 EV Kit Schematic

EV Kit Layout

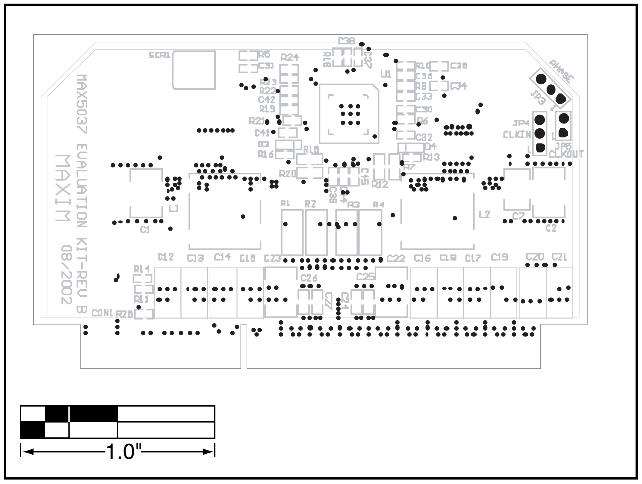

Figure 19. MAX5037 EV Kit Component Placement Guide—Component Side

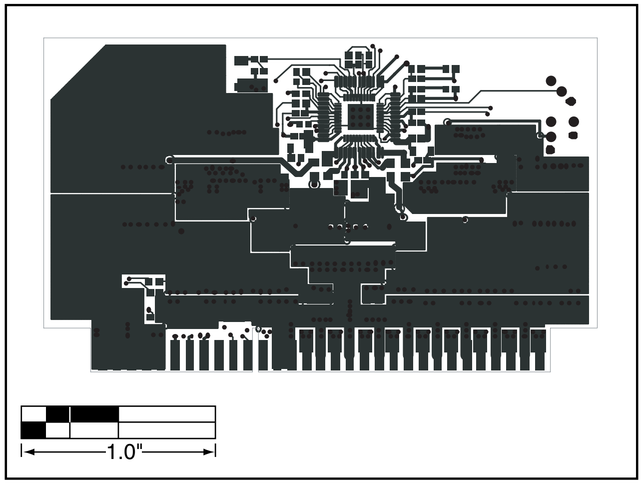

Figure 20. MAX5037 EV Kit PC Board Layout—Component Side

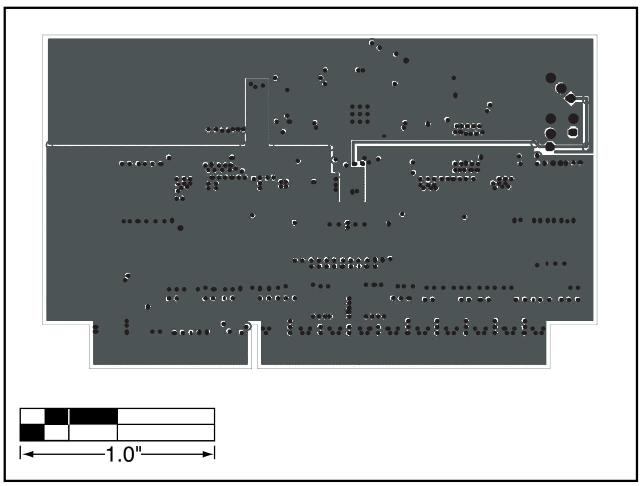

Figure 21. MAX5037 EV Kit PC Board Layout—Inner Layer 2

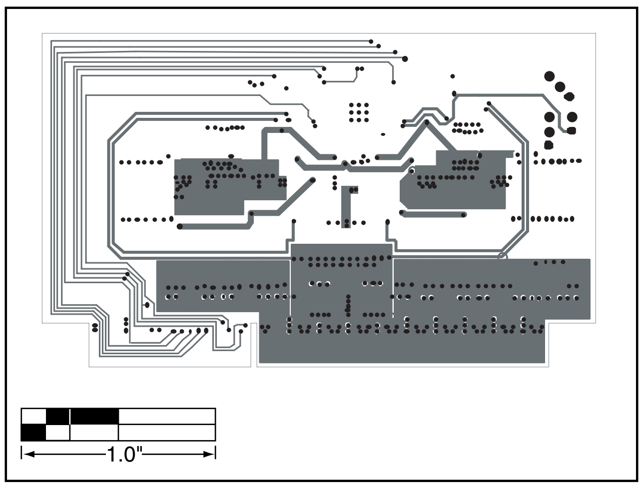

Figure 22. MAX5037 EV Kit PC Board Layout—Inner Layer 3

EV Kit Layout (continued)

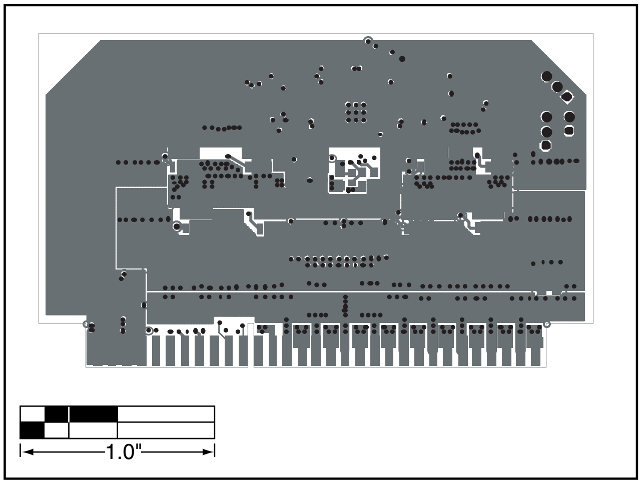

Figure 23. MAX5037 EV Kit PC Board Layout—Solder Side

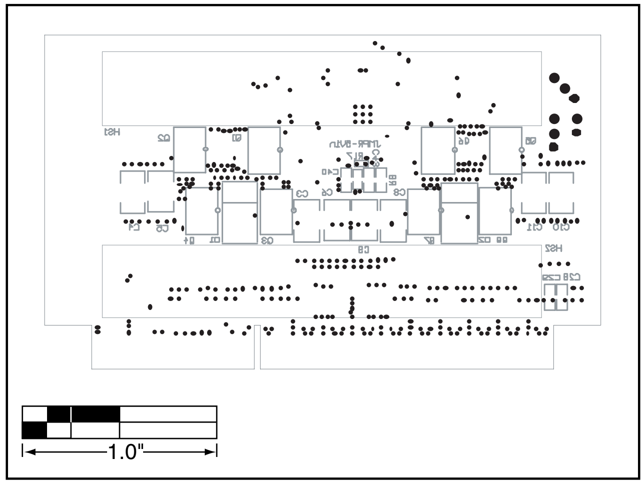

Figure 24. MAX5037 EV Kit Component Placement Guide—Solder Side