

# MAXIM

## MAX1813 Evaluation Kit

### General Description

The MAX1813 evaluation kit (EV kit) demonstrates the high-power, dynamically adjustable notebook CPU application circuit. This DC-DC converter steps down high-voltage batteries and/or AC adapters, generating a precision, low-voltage CPU core VCC rail. The MAX1813 EV kit meets the Intel mobile CPU's transient voltage specification (IMVP-II/Coppermine), using voltage positioning to minimize the output-capacitor requirements. The MAX1813 has an internal multiplexer which accepts three unique 5-bit VID DAC codes corresponding to performance, battery, and suspend modes. Precision slew-rate control provides "just-in-time" arrival at the new DAC setting, minimizing surge currents to and from the battery.

This fully assembled and tested circuit board provides a digitally adjustable 0.6V to 2.0V output from a 7V to 24V battery input range. It delivers up to 22A output current. The EV kit operates at 300kHz switching frequency and has superior line- and load-transient response.

### Features

- ◆ High Speed, Accuracy, and Efficiency
- ◆ IMVP-II/Coppermine/AMD Compatible
- ◆ Voltage-Positioned Output
- ◆ Low Output-Capacitor Count (6)
- ◆ Fast-Response Quick-PWM™ Architecture
- ◆ 7V to 24V Input Voltage Range
- ◆ 0.925V to 2.0V Output Voltage Range (Coppermine/AMD, 5-Bit DAC)
- ◆ 0.6V to 1.75V Output Voltage Range (IMVP-II, 5-Bit DAC)
- ◆ 22A Load-Current Capability
- ◆ 300kHz Switching Frequency
- ◆ Power Good (PGOOD) Indicator
- ◆ 28-Pin QSOP Package
- ◆ Low-Profile Components
- ◆ Fully Assembled and Tested

### Ordering Information

PART	TEMP. RANGE	IC PACKAGE
MAX1813EVKIT	0°C to +70°C	28 QSOP

### Component List

DESIGNATION	QTY	DESCRIPTION
C1-C4, C20	5	10µF, 25V ceramic capacitors (1812) Taiyo Yuden TMK432BJ106KM TDK C4532X5R1E106M
C5, C6, C7, C10, C13, C16	6	220µF, 2.5V, 15mΩ low-ESR specialty polymer capacitors Panasonic EEFUE0E221R
C8	1	10µF, 6.3V X5R ceramic capacitor (1210) Taiyo Yuden JMK325BJ106MN TDK C3216X5R0J106M
C9	1	0.1µF ceramic capacitor (0805)
C11, C12	2	0.22µF, 16V X5R ceramic capacitors (0805) Taiyo Yuden EMK212BJ224KG

DESIGNATION	QTY	DESCRIPTION
C14	1	47pF ceramic capacitor (0805)
C15	1	1µF, 10V X5R ceramic capacitor (0805) Taiyo Yuden LMK212BJ105KG TDK C2012X5R105M
C18, C27	2	1000pF ceramic capacitors (0805)
C17, C19, C23, C24, C25	5	4700pF ceramic capacitors (0805)
C21, C22, C26	0	Not installed
D1	1	5A Schottky diode Central Semiconductor CM5H5-40
D2	1	100mA Schottky diode Central Semiconductor CMP5H-3

Evaluates: MAX1813

# MAX1813 Evaluation Kit

## Component List (continued)

DESIGNATION	QTY	DESCRIPTION
D3	1	200mA Switching diode Central Semiconductor CMPD2838
J1	1	Scope probe connector Berg Electronics 33JR135-1
JU1, JU2	2	4-pin headers
JU8	1	3-pin header
JUA0–JUA4, JUB0–JUB4	10	2-pin headers
JU3, JU4, JU5, JU6	0	Not installed
L1	1	0.68μH power inductor Toko EH125C-R60N or Sumida CEP125 #4712-T011 or Sumida CDEP134H-0R6 or Panasonic ETQP6F0R6BFA
N1, N2	2	N-channel MOSFETs (SO-8) International Rectifier IRF7811W International Rectifier IRF7811
N3, N4, N5	3	N-channel MOSFETs (SO-8) International Rectifier IRF7822 Fairchild FDS7764A
R1	1	20Ω ±5% resistor (0805)
R2–R6, R9, R22–R27	13	100kΩ ±5% resistors (0805)
R7	0	Not installed (short PC trace) (0805)
R8, R11	2	100Ω ±5% resistors (0805)
R12	1	0.0015Ω ±5% 1W resistor (2512) Panasonic ERJM1WTJ1M5U
R13, R28	2	10kΩ ±5% resistors (0805)
R14	1	51.1kΩ ±1% resistor (0805)
R15	1	20kΩ ±5% resistor (0805)
R16	1	300kΩ ±5% resistor (0805)
R17	1	200kΩ ±5% resistor (0805)
R18, R19	0	Not installed (0805)
R20	1	150kΩ ±5% resistor (0805)
R29	1	Not installed (2512)
SW1	1	DIP-8 dip switch
U1	1	MAX1813EEI (28-QSOP)

DESIGNATION	QTY	DESCRIPTION
None	12	Shunts
None	4	Rubber bumpers 3M SJ-5007, Mouser 517-SJ- 5007BK or equivalent
None	1	MAX1813 PC board
None	1	MAX1813 data sheet
None	1	MAX1813 EV kit data sheet

## Component Suppliers

SUPPLIER	PHONE	FAX
Central Semiconductor	516-435-1110	516-435-1824
Fairchild	408-721-2181	408-721-1635
International Rectifier	310-322-3331	310-322-3332
Panasonic	714-373-7939	714-373-7183
Sumida	708-956-0666	708-956-0702
Taiyo Yuden	408-573-4150	408-573-4159
TDK	847-390-4373	847-390-4428
Toko	408-432-8281	408-943-9790

## Recommended Equipment

- 7V to 24V, >30W power supply, battery, or notebook AC adapter
- DC bias power supply, 5V at 100mA
- Dummy load capable of sinking 22A
- Digital multimeter (DMM)
- 100MHz dual-trace oscilloscope

## Quick Start

- 1) Ensure that the circuit is connected correctly to the supplies and dummy load prior to applying any power.
- 2) Set switches SW1-A ( $\overline{\text{SHDN}}$ ) and SW1-C (ZMODE) to the ON position, and SW1-B (SKIP) to the OFF position. This configures the EV kit for fixed-frequency PWM-mode operation. The DAC code settings (D4–D0) are set for 1.30V output for the impedance-mode configuration through jumpers JUB4, JUB2, and JUB1, and to 1.15V output for the logic mode configuration through installed jumpers JUA4, JUA1, and JUA0 (CODE = 1, JU8 pins 1 and 2).
- 3) Turn on the battery power before turning on the 5V bias power; otherwise, the output UVLO timer will time out, and the FAULT latch will be set, disabling the regulator until 5V power is cycled or shutdown is toggled.

## MAX1813 Evaluation Kit

- 4) Observe the 1.30V output voltage with the DMM and/or oscilloscope. Look at the LX switching-node and MOSFET gate-drive signals while varying the load current.
- 5) Toggle the ZMODE switch, and observe the output voltage transition to the new 1.15V setting.

**Note:** When driving ZMODE with the dip switch, the transition may take longer than expected due to switch bounce.

### Detailed Description

This 22A buck-regulator design is optimized for a 300kHz frequency and output voltage settings around 1.15V to 1.3V. At  $V_{OUT} = 1.3V$ , inductor ripple is approximately 30%.

### Setting the Output Voltage

The MAX1813 has a unique internal multiplexer that can select one of three different VID DAC code settings for different processor states. Depending on the logic level at SUS (SW1-D), the suspend mode multiplexer selects the VID DAC code settings from either the ZMODE multiplexer, or the S0/S1 (JU1, JU2) input decoder. The output voltage can be digitally set from 0.925V to 2.0V (Table 1, CODE = 0, JU8 pins 2 and 3) or from 0.6V to 1.75V (Table 1, CODE = 1, JU8 pins 1 and 2) from the D0–D4 pins, and from 0.6V to 0.975V (Table 2) from S0/S1 pins. There are four different ways of setting the output voltage:

- 1) **Drive the external VID0–VID4 inputs** (no jumpers installed). Set the output voltage by driving the VID0–VID4 with open-drain drivers (pullup resistors are included on the board) or 3V/5V CMOS output logic levels. The internal multiplexer must be in the logic-mode configuration (ZMODE = low, SUS = low)
- 2) **Install jumpers JUA0–JUA4** (logic-mode configuration: SW1-C OFF, ZMODE = low, and SW-D OFF, SUS = low). When JUA0–JUA4 are not installed, the MAX1813's D0–D4 inputs are at logic 1 (connected to VCC). When JUA0–JUA4 are installed, D0–D4 inputs are at logic 0 (connected to GND). In the logic-mode configuration, change the output voltage during operation by installing and removing jumpers JUA0–JUA4. As shipped, the EV kit is configured for operation in the logic mode with jumpers JUA0–JUA4 set for 1.15V output (Table 1).
- 3) **Install jumpers JUB0–JUB4** (impedance-mode configuration: SW1-C ON, ZMODE = high, and SW1-D OFF, SUS = low). When JUB0–JUB4 are not installed, a 100k $\Omega$  resistor is in series with each of the D0–D4 inputs, making it a logic 1. When JUB0–JUB4 are installed, the 100k $\Omega$  resistors are shorted, making D0–D4 logic 0. As shipped, the EV

kit is configured for operation in the impedance mode with jumpers JUB0–JUB4 set for 1.30V output (Table 1).

While in the impedance mode, changing jumpers JUB0–JUB4 does not immediately change the output voltage setting. SHDN, ZMODE, SUS, or VBIAS must be cycled to sample the new jumper settings. Refer to the MAX1813 data sheet for more information.

- 4) **Install jumpers JU1 and JU2** (suspend-mode configuration: SW1-D ON, SUS = high). As shipped, the EV kit is configured for operation in the suspend mode with jumpers JU1 and JU2 set for 0.85V output (Table 2). In the suspend mode, change the output voltage during operation by installing and removing jumpers JU1 and JU2. Refer to the MAX1813 data sheet for more information.

### Dynamic Output Voltage Transition Experiment

Observe the output voltage transition between:

- 1) 0.85V and 1.15V by setting SW1-C OFF (ZMODE = low) and toggling SW1-D (SUS) position between ON and OFF.
- 2) 1.15V and 1.30V by toggling the SW1-C (ZMODE) position between ON and OFF (SW1-D OFF, SUS = low).
- 3) 0.85V and 1.30V by setting SW1-C ON (ZMODE = high) and toggling SW1-D (SUS) position between ON and OFF. This is the worst-case transition and should complete within 100 $\mu$ s.

This EV kit is set to transition the output voltage at 8.8mV/ $\mu$ s. Alter the speed of the transition by changing resistor R14 (51.1k $\Omega$ ). Longer-than-expected transitions maybe observed due to switch bounce (SW1). To eliminate switch bounce, set SW1-D (SUS) to the OFF position, and drive the SUS pin (TP2) with a function generator.

During the voltage transition, watch the inductor current by looking across R12 with a differential scope probe or by inserting a current probe in series with the inductor. Observe the low, well-controlled inductor current that accompanies the voltage transition. The same slew rate and controlled inductor current are used during shutdown and start up, resulting in well-controlled currents into and out of the battery (input source).

# MAX1813 Evaluation Kit

Evaluates: MAX1813

**Table 1. MAX1813 Output Voltage Adjustment Settings**

D4 JUA4 JUB4	D3 JUA3 JUB3	D2 JUA2 JUB2	D1 JUA1 JUB1	D0 JUA0 JUB0	OUTPUT VOLTAGE CODE = 0 (JU8 PINS 2 AND 3)	OUTPUT VOLTAGE CODE = 1 (JU8 PINS 1 AND 2)
0	0	0	0	0	2.000V	1.750V
0	0	0	0	1	1.950V	1.700V
0	0	0	1	0	1.900V	1.650V
0	0	0	1	1	1.850V	1.600V
0	0	1	0	0	1.800V	1.550V
0	0	1	0	1	1.750V	1.500V
0	0	1	1	0	1.700V	1.450V
0	0	1	1	1	1.650V	1.400V
0	1	0	0	0	1.600V	1.350V
0	1	0	0	1	1.550V	1.300V
0	1	0	1	0	1.500V	1.250V
0	1	0	1	1	1.450V	1.200V
0	1	1	0	0	1.400V	1.150V
0	1	1	0	1	1.350V	1.100V
0	1	1	1	0	1.300V	1.050V
0	1	1	1	1	NO CPU*	1.000V
1	0	0	0	0	1.275V	0.975V
1	0	0	0	1	1.250V	0.950V
1	0	0	1	0	1.225V	0.925V
1	0	0	1	1	1.200V	0.900V
1	0	1	0	0	1.175V	0.875V
1	0	1	0	1	1.150V	0.850V
1	0	1	1	0	1.125V	0.825V
1	0	1	1	1	1.100V	0.800V
1	1	0	0	0	1.075V	0.775V
1	1	0	0	1	1.050V	0.750V
1	1	0	1	0	1.025V	0.725V
1	1	0	1	1	1.000V	0.700V
1	1	1	0	0	0.975V	0.675V
1	1	1	0	1	0.950V	0.650V
1	1	1	1	0	0.925V	0.625V
1	1	1	1	1	NO CPU*	0.600V

\*In the no-CPU state, DH and DL are held low and the slew-rate controller is set for 0.425V.

# MAX1813 Evaluation Kit

Evaluates: MAX1813

There are two other methods to create an output voltage transition. Select D0–D4 logic mode by setting the ZMODE switch to the OFF position (SW1-C). Then either manually change the JUA0–JUA4 jumpers to a new VID code setting (Table 1), or remove all jumpers and drive the VID0–VID4 PC board test points externally to the desired code settings.

### Load-Transient Experiment

One interesting experiment is to subject the output to large, fast-load transients and observe the output with an oscilloscope. This necessitates careful instrumentation of the output, using the supplied scope-probe jack. Accurate measurement of output ripple and load-transient response invariably requires that ground clip leads be completely avoided and that the probe be removed to expose the GND shield, so the probe can be plugged directly into the jack. Otherwise, EMI and noise pickup will corrupt the waveforms.

Most benchtop electronic loads intended for power-supply testing lack the ability to subject the DC-DC converter to ultra-fast load transients. Emulating the supply current di/dt at the CPU VCORE pins requires at least 10A/μs load transients. One easy method for generating such an abusive load transient is to solder a power MOSFET directly across the scope-probe jack. Then drive its gate with a strong pulse generator at a low duty cycle (10% or less) to minimize heat stress in the MOSFET. Vary the high-level output voltage of the pulse generator to vary the load current.

To determine the load current, one might expect to insert a meter in the load path, but this method is prohibited here by the need for low resistance and inductance in the path of the dummy load MOSFET. There are two easy alternative methods of determining how much load current a particular pulse-generator amplitude is causing. The first and best is to observe the inductor current with a calibrated AC current probe,

**Table 2. Output Voltage Adjustment Settings, Suspend Mode**

SHUNT LOCATION JU2	SHUNT LOCATION JU1	S1 PIN	S0 PIN	OUTPUT VOLTAGE
1, 2	1, 2	GND	GND	0.975V
1, 2	1, 3	GND	REF	0.950V
1, 2	Not installed	GND	OPEN	0.925V
1, 2	1, 4	GND	VCC	0.900V
1, 3	1, 2	REF	GND	0.875V
1, 3	1, 3	REF	REF	0.850V
1, 3	Not installed	REF	OPEN	0.825V
1, 3	1, 4	REF	VCC	0.800V
Not installed	1, 2	OPEN	GND	0.775V
Not installed	1, 3	OPEN	REF	0.750V
Not installed	Not installed	OPEN	OPEN	0.725V
Not installed	1, 4	OPEN	VCC	0.700V
1, 4	1, 2	VCC	GND	0.675V
1, 4	1, 3	VCC	REF	0.650V
1, 4	Not installed	VCC	OPEN	0.625V
1, 4	1, 4	VCC	VCC	0.600V

such as a Tektronix AM503 or by looking across R12 with a differential probe. In the buck topology, the load current is equal to the average value of the inductor current. The second method is to put on a static dummy load and measure the battery current. Then connect the MOSFET dummy load at 100% duty momentarily and adjust the gate-drive signal until the battery current rises to the appropriate level (the MOSFET load must be well heat-sinked for this to work without causing smoke and flames).

**Table 3. Switch SW1-A/SW1-B Functions ( $\overline{\text{SHDN}}$ , SKIP)**

SW1-A	SW1-B	CONNECTION	EFFECT
OFF	X	SKIP, $\overline{\text{SHDN}}$ connected to GND through R15 and R17	Shutdown mode, $V_{\text{OUT}} = 0\text{V}$
ON	ON	SKIP, $\overline{\text{SHDN}}$ connected to VCC through R15	Output enabled. SKIP mode operation. Allows automatic PWM/PFM switchover for pulse skipping at light-load for highest efficiency. Refer to the Forced PWM Mode section in the MAX1813 data sheet for more information.
ON	OFF	SKIP, $\overline{\text{SHDN}}$ connected to +2V through R15 and divider R16/R17	Output enabled. Low-noise mode. Forced fixed-frequency PWM operation. Recommended for output voltage transitions.

## MAX1813 Evaluation Kit

**Table 4. Switch SW1-C/SW1-D Functions (ZMODE, SUS for IMVP II, Code = 1)**

SW1-C	SW1-D	CONNECTION	INTERNAL MULTIPLEXER
ON	OFF	ZMODE connected to VCC, SUS connected to GND	Impedance Mode
OFF	OFF	ZMODE connected to GND, SUS connected to GND	Logic Mode
X	ON	SUS connected to VCC	Suspend Mode

**Table 5. Jumpers JU3/JU4/JU5 Functions (Switching-Frequency Selection)**

SHUNT LOCATION			TON PIN	FREQUENCY (kHz)
JU3	JU4	JU5		
Installed	Not Installed	Not Installed	Connected to VCC	200
Not Installed	Installed	Not Installed	Connected to REF	550
Not Installed	Not Installed	Installed	Connected to GND	1000
Not Installed	Not Installed	Not Installed	Floating	300 (as shipped)

**IMPORTANT:** Don't change the operating frequency without first recalculating component values. The frequency has a significant effect on the inductor peak current, MOSFET heating, preferred inductor value, PFM/PWM switchover point, output noise, efficiency, and other critical parameters.

**Table 6. Jumper JU6 Functions (Fixed/Adjustable Current-Limit Selection)**

SHUNT POSITION	ILIM PIN	CURRENT-LIMIT THRESHOLD
ON	Connected to VCC	50mV (default)
OFF	Connected to an external resistor divider, R18/R19. Refer to the <i>Pin Description ILIM</i> section in the MAX1813 data sheet for more information.	Adjustable between 50mV to 200mV.

# MAX1813 Evaluation Kit

Evaluates: MAX1813

**Table 7. Troubleshooting Guide**

SYMPTOM	POSSIBLE PROBLEM	SOLUTION
Circuit won't start when power is applied.	Power-supply sequencing: 5V bias supply was applied before battery voltage.	Cycle SW1-A $\overline{\text{SHDN}}$ .
Circuit won't start when +5V bias supply cycled.	Output overvoltage due to shorted high-side MOSFET	Replace the MOSFET.
	Output overvoltage due to load recovery overshoot	Reduce the inductor value, raise the switching frequency, or add more output capacitance.
	Output overload condition	Remove excessive load.
	Broken connection, bad MOSFET, or other catastrophic problem	Troubleshoot the power stage. Are the DH and DL gate-drive signals present? Is the 2V $V_{\text{REF}}$ present?
On-time pulses are erratic or have unexpected changes in period.	VBATT power source has poor impedance characteristic.	Add a bulk electrolytic bypass capacitor across the benchtop power supply, or substitute a real battery.
Excessive EMI, poor efficiency at high input voltages.	Gate-drain capacitance of N3/N4/N5 is causing shoot-through cross-conduction.	Observe the gate-source voltage of N3/N4/N5 during the low-to-high LX node transition (this requires careful instrumentation). Is the gate voltage being pulled above 1.5V, causing N3/N4/N5 to turn on? Use a smaller low-side MOSFET or add a BST resistor (R7).
Poor efficiency at high input voltages, N1/N2 get hot.	N1/N2 has excessive gate capacitance.	Use a smaller/faster high-side MOSFET or add more heatsinking.

# MAX1813 Evaluation Kit

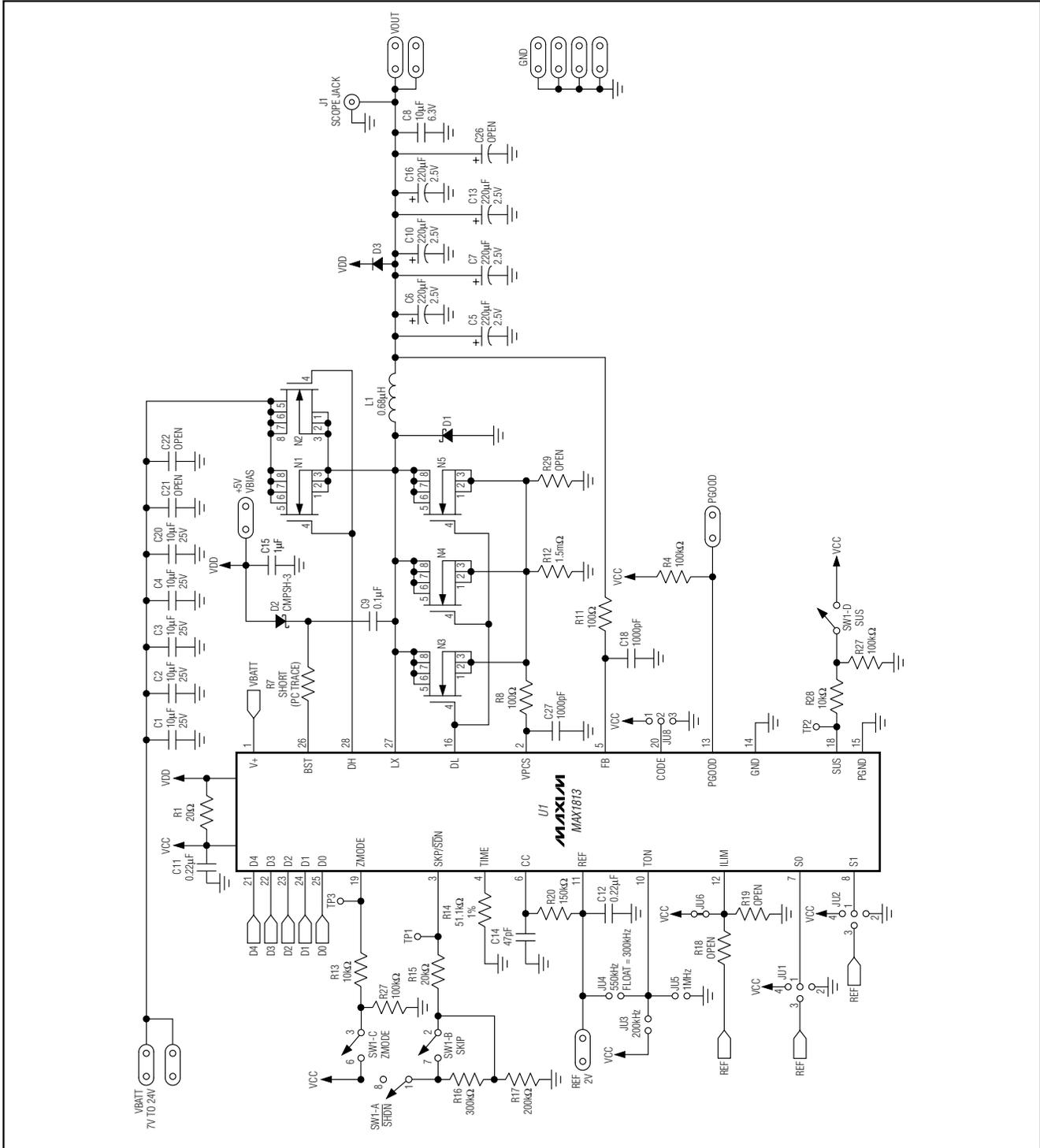


Figure 1. MAX1813 EV Kit Schematic

# MAX1813 Evaluation Kit

Evaluates: MAX1813

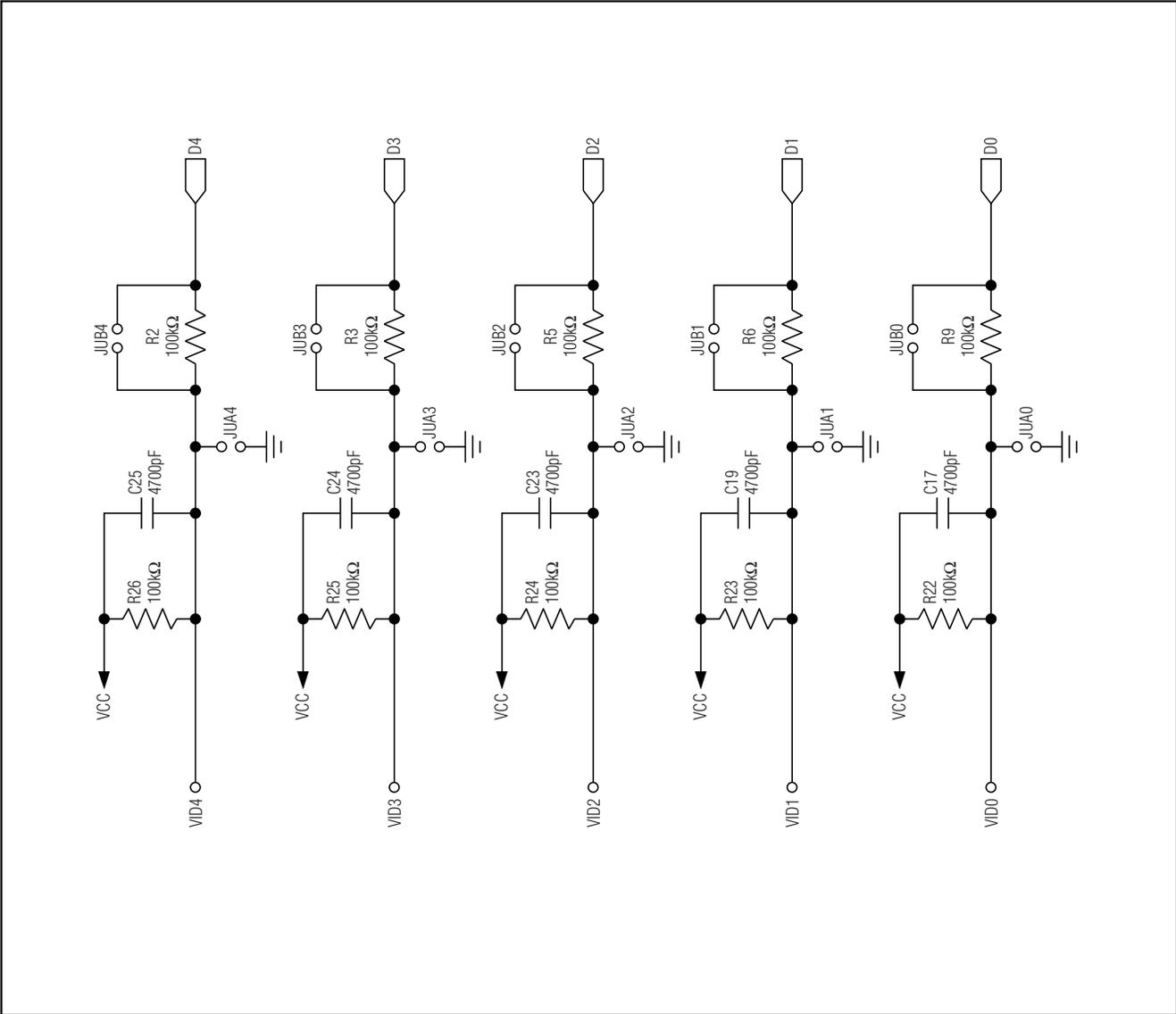


Figure 1. MAX1813 EV Kit Schematic (continued)

# MAX1813 Evaluation Kit

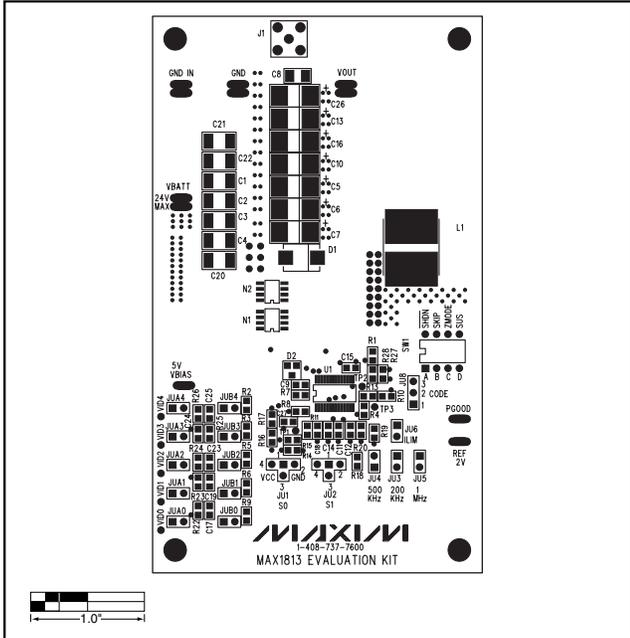


Figure 2. MAX1813 EV Kit Component Placement Guide—Top Silkscreen

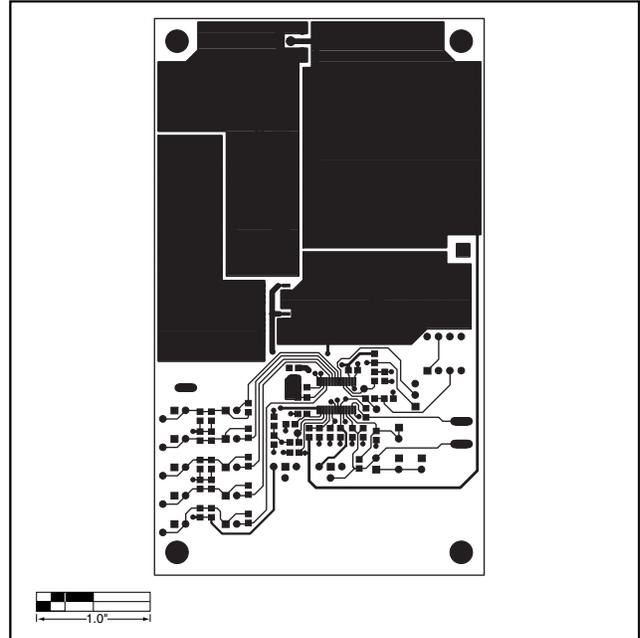


Figure 3. MAX1813 EV Kit PC Board Layout—Component Side

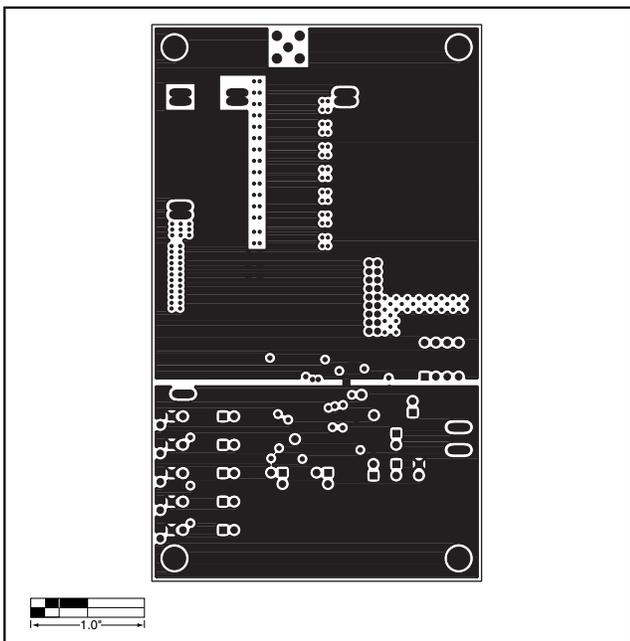


Figure 4. MAX1813 EV Kit PC Board Layout—Ground Layer 2

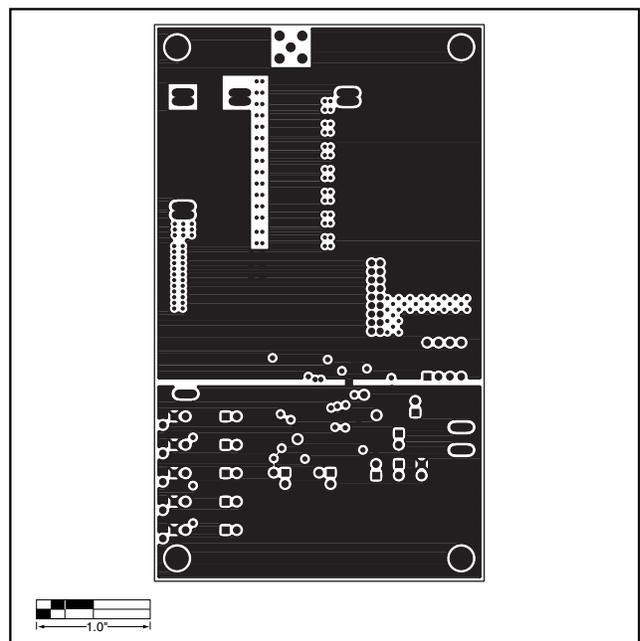


Figure 5. MAX1813 EV Kit PC Board Layout—Ground Layer 3

# MAX1813 Evaluation Kit

Evaluates: MAX1813

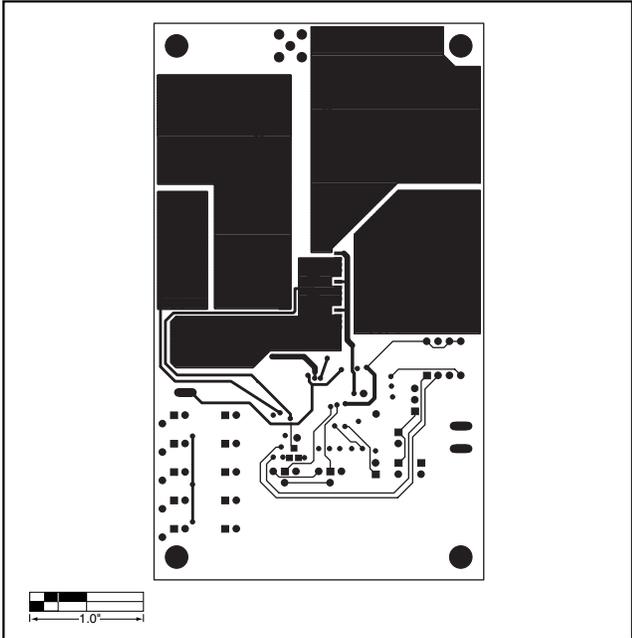


Figure 6. MAX1813 EV Kit PC Board Layout—Solder Side

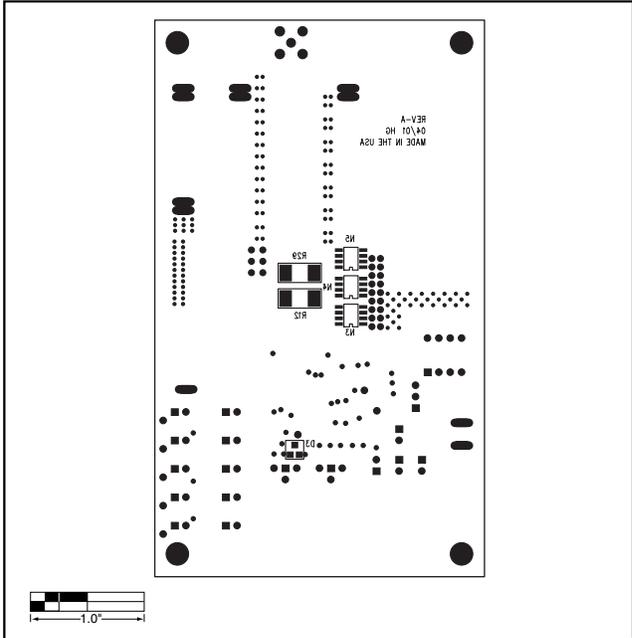


Figure 7. MAX1813 EV Kit Component Placement Guide — Bottom Silkscreen

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