Evaluates: MAX16491

MAX16491 Evaluation Kit

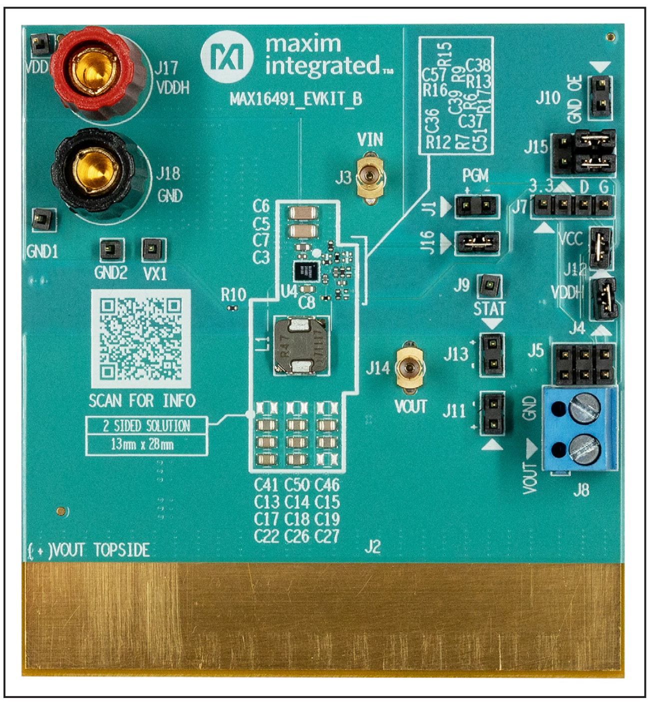
General Description

The MAX16491 evaluation kit (EV kit) serves as a reference platform for evaluating the MAX16491 voltage regulator IC. This single-chip, integrated switching regulator provides an extremely compact, highly efficient, fast, accurate, and reliable power delivery solution for low-output voltage applications. The MAX16491 has different programmability options to enable a wide range of configurations.

The EV kit consists of a full-assembled and tested Printed Circuit Board (PCB) implementation of the MAX16491. Jumpers, test points, and input/output connectors are included for flexibility and ease-of-use. Refer to the IC data sheet for *ordering information* and more details.

***Ordering Information** appears at end of data sheet.*

MAX16491 EV Kit Board Photo



Benefits and Features

- 4.5V to 16V Input Voltage Range
- 0.6V to 5.5V Output Voltage Range
- 9A Maximum Load
- High-Efficiency Solution
  - Up to 96% Peak
  - Up to 95.5% Full Load
  - Up to 94% Light-Load Efficiency at 1A with DCM Enabled
- Flexible Design allows Early PCB Definition
  - Footprint Compatible with VT2491/VT2491A and Related Scalable Products
  - Programmable Switching Frequency up to 1MHz
  - Programmable Soft-Start and STAT Delay Timings
  - Programmable Reference Voltage with External Input Option
  - Programmable Positive and Negative OCP Limit
  - Supports Current Sourcing and Sinking
- Advanced Architecture, Protection, and Reporting Guarantees Reliable Designs
  - Analog Current or Temperature Reporting
  - Differential Remote Sense with Open-Circuit Detection
  - Fast Transient Response with Quick-PWM™ Architecture
  - Percentage-Based Output Power Good and OVP
  - Open-Drain Status Indicator (STAT) Pin
  - Input Undervoltage and Overvoltage Lockout
  - Adaptive Dead-Time Control
- Saves Board Space
  - Integrated Boost Switch
  - 19-Bump WLCSP (2.2mm x 2.8mm) Footprint
  - Operation Using Ceramic Input and Output Capacitors

Quick-PWM is a trademark of Maxim Integrated Products, Inc.

319-100790; Rev 0; 7/21

Quick Start

Required Equipment

- MAX16491 EV kit
- 4.5V to 16V power supply
- Load capable of sinking 9A
- Oscilloscope, probes, and voltmeter

Procedure

The EV kit is fully assembled and tested. Follow the steps to verify board operation.

Caution: Do not turn on the power supply until all connections are completed.

1) Connect a 12V power supply to the banana jacks. Use red for positive and black for ground.
2) Make sure the shunt is installed on:
   - J16 (1-2) to close the sense line.
   - J4 (1-2) to power up the on-board LDO which regulates 1.8V.
   - J12 (1-2) to provide the 1.8V bias supply to the regulator from the on-board LDO.
   - J15 (3-5) to pull up the STAT pin.
   - J15 (4-6) to pull up the OE pin.
3) Connect a voltmeter to J8 (J11, J13, and J14 can be used as well).
4) Turn on the power supply.
5) Verify that the voltmeter reads 3.3V.

Detailed Description of Hardware

The MAX16491 provides compact high-efficiency power delivery for precision outputs that demand fast transient response. The 19 balls (2.2mm x 2.8mm) CSP package minimizes the printed circuit board area. The EV kit is preset for 3.3V output and can provide up to 9A from a 4.5V to 16V input supply.

Bias Supply

The EV kit has an on-board LDO (U2) which can provide the required 1.8V V_{CC} bias voltage to the regulator as well as the pull-up voltage for the Output Enable (OE) input. This allows testing the part using a single external power supply.

To enable the on-board LDO install the shunt on jumper J4. To effectively use the LDO to supply the V_{CC} bias voltage to the regulator also install the shunt on jumper J12.

For proper measurement of regulator's efficiency, the LDO should not be active. To disable it, both the shunts on J4 and J12 need to be removed. An external 1.8V, 0.1A current limited power supply needs to be connected between J12–2 and the ground. The same signal should be connected to J10 (1-2) to pull up the OE pin.

Regulator Enable

To enable the regulator, the OE pin needs to be pulled HIGH. If the on-board 1.8V LDO is active (the shunt on jumper J4 is in place) its output voltage can be used for the purpose. Installing a shunt on J15 (4-6) pulls the OE signal HIGH to 1.8V through a 20kΩ resistor. To shut down the regulator a shunt needs to be installed on J10. This forces the OE pin LOW.

Status Pin

MAX16491 has an open collector status (STAT) output to report fault or output undervoltage event. Install a shunt on J15 (3–5) to pull up this pin to V_{CC} through a 20kΩ resistor. Since STAT pin is 3.3V tolerant, a shunt on J15 (2-3) can be installed to pull up this pin through a 20kΩ resistor to the 3.3V provided by the on-board regulator U3 (install a shunt on J5 (3-4) to enable the LDO).

Scenario Selection

Several parameters of the MAX16491 can be programmed to allow optimization for specific applications. By selecting the appropriate value of resistor R_SEL (R1) and capacitor C_SEL (C4), the optimum set of parameters (scenario) can be programmed. While R_SEL selects the proper scenario, C_SEL determines the nominal f_{SW}. Table 1 shows the scenario table for the MAX16491.

A combination of R_SEL and C_SEL selects the f_{SW} setting. There are six options available (from #1 to #6), indicating six different nominal switching frequencies, from lowest to highest. Since the actual value of f_{SW} also depends on V_{OUT}, refer to Figure 1 to select the proper f_{SW} setting for a specific application.

By default, this EV kit is configured to have a switching frequency of 860kHz (f_{SW} #6 at V_{OUT} = 3.3V). The soft-start time, another programable parameter, is set to 6ms.

Table 1. MAX16491 Configuration Table

<table>
<tr><th rowspan="3">R_SEL (kΩ)</th><th rowspan="3">V_{REF} (V)</th><th rowspan="3">SOFT-START TIME (t_{SS}) (ms)</th><th rowspan="3">VALLEY OCP INCEPTION (A)</th><th rowspan="3">OPERATION MODES</th><th rowspan="3">REPORTING (CURRENT / TEMP)</th><th rowspan="3">R_{SENSE} (GAIN) (mΩ)</th><th colspan="3">f_{SW} SETTING</th><th rowspan="3">t_{STAT} (µs)</th></tr>
<tr><th colspan="3">C_SEL</th></tr>
<tr><th>0pF</th><th>200pF</th><th>820pF</th></tr>
<tr><td>1.78</td><td rowspan="4">0.95</td><td rowspan="2">6</td><td>6.45</td><td>CCM</td><td rowspan="9">Current</td><td rowspan="10">2.1</td><td rowspan="11">f_{SW} #4</td><td rowspan="11">f_{SW} #5</td><td rowspan="11">f_{SW} #6</td><td rowspan="11">2000</td></tr>
<tr><td>2.67</td><td>8.3</td><td>CCM/DCM</td></tr>
<tr><td>4.02</td><td rowspan="3">3</td><td>6.45</td><td>CCM</td></tr>
<tr><td>6.04</td><td>8.3</td><td>CCM/DCM</td></tr>
<tr><td>9.09</td><td rowspan="2">Ext.</td><td>6.45</td><td>CCM</td></tr>
<tr><td>13.3</td><td>1.5</td><td></td><td></td></tr>
<tr><td>20</td><td rowspan="5">0.6</td><td rowspan="5">6</td><td rowspan="2">10.3</td><td>CCM/DCM</td></tr>
<tr><td>30.9</td><td rowspan="2">CCM</td></tr>
<tr><td>46.4</td><td rowspan="3">6.45</td></tr>
<tr><td>71.5</td><td rowspan="2">CCM/DCM</td><td>Temp</td></tr>
<tr><td>107</td><td>Current</td><td>1.05</td></tr>
<tr><td>162</td><td>Ext.</td><td>1.5</td><td>8.3</td><td>CCM</td><td>Temp</td><td>2.1</td><td>f_{SW} #1</td><td>f_{SW} #2</td><td>f_{SW} #3</td><td>128</td></tr>
</table>

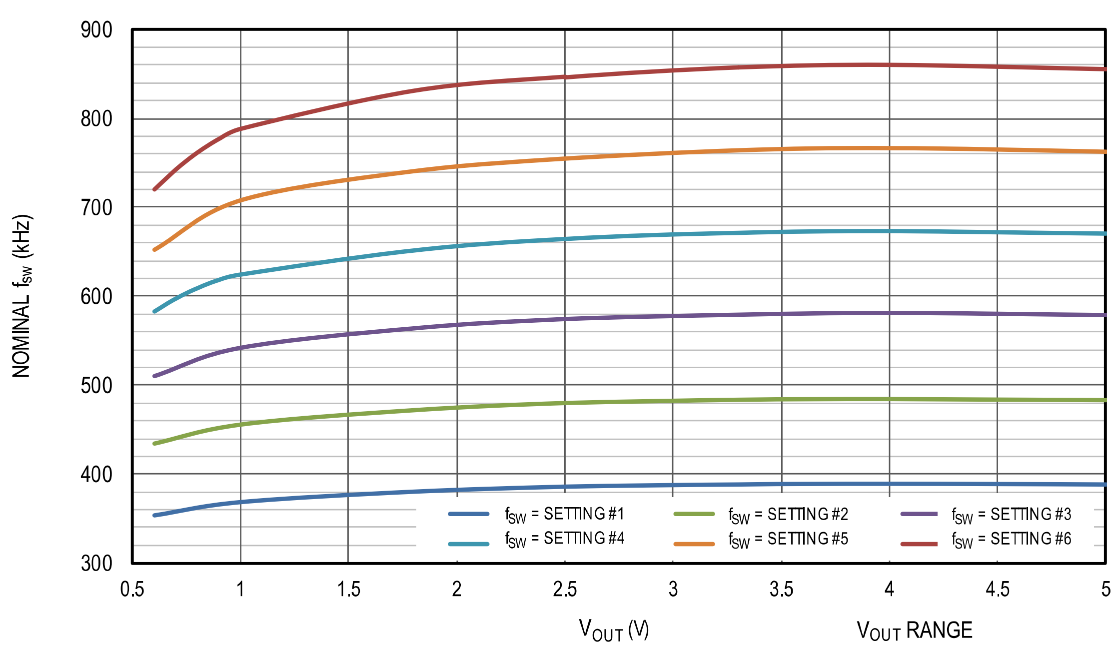


Figure 1. Nominal Switching Frequency vs. V_{OUT} and f_{SW} Settings

Setting the Output Voltage

The output voltage of MAX16491 is set by selecting a reference voltage and using an appropriate resistive voltage-divider, as shown in Equation 1.

Equation 1

$$V_{OUT} = V_{REF} \times \left(1 + \frac{R_{FB1}}{R_{FB2}}\right)$$

The reference voltage is selected using R_SEL (see Table 1) and can be either internal or external (Refer to the MAX16491 datasheet for more details). To improve the DC output-voltage accuracy, use the highest V_{REF} value available and suitable for the application. For instance, use V_{REF} = 0.6V for 0.6V ≤ V_{OUT} < 0.95V and V_{REF} = 0.95V for 0.95V ≤ V_{OUT} < 5.5V.

To optimize the common-mode rejection of the error amplifier, choose the resistive voltage-dividers so that their parallel resistance is as close as possible to 2kΩ (Equation 2).

Equation 2

$$V_{FB1} = V_{OUT} \times \left(\frac{R_{PAR}}{R_{REF}}\right)$$

$$R_{FB2} = R_{FB1} \times \left(\frac{R_{PAR}}{R_{FB1} - R_{PAR}}\right)$$

where:

R_{FB1} = Top divider resistor

R_{FB2} = Bottom divider resistor

R_{PAR} = Desired parallel resistance of R_{FB1} and R_{FB2}

V_{OUT} = Output voltage

V_{REF} = Reference voltage

Operation with External V_{REF}

When using an external reference, adopt the configuration shown in Figure 2. The MAX16491 employs a specialized soft-start sequence. Once OE is asserted, the regulator briefly discharges the SENSE- node and releases it as regulation begins. The resulting soft-start ramp timing is determined by the external low-pass filter time constant. The external filter time constant needs to be lower than t_{SS}/3 to avoid premature assertion of STAT pin while the output voltage is still ramping.

The external reference voltage should be limited between 0.8V and 1.1V and can be applied before enabling the regulator or ramped up right after enable is asserted. In both cases, the low-pass filtered reference voltage at SENSE- pin must reach its final value within t_{SS}.

Typical values for the filter components are:

- R_F = 2.2kΩ
- C_F = 0.22µF

When changing the external reference voltage during normal operation (after the part has powered up, and reached regulation level), the regulator must be able to follow the reference-voltage change fast enough to avoid OVP and PWRGD faults. Reference-voltage change timing from the initial to the final value should not exceed 1/(2 x BW), where BW is the bandwidth of the regulator in Hertz (Hz).

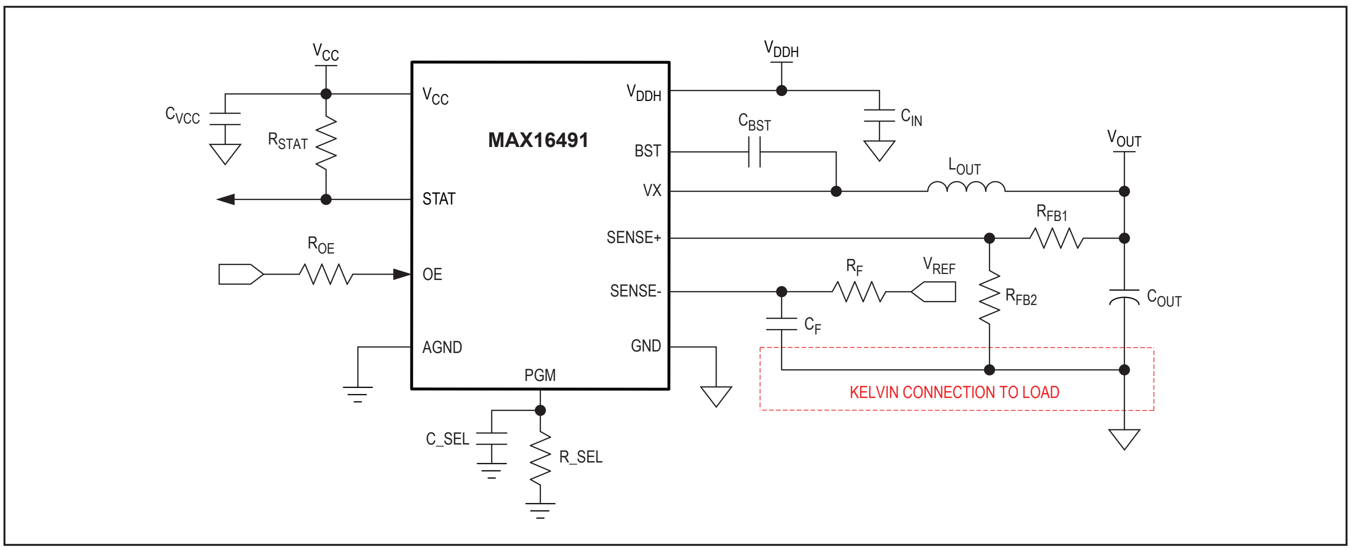


Figure 2. Electrical Connections to use the External Voltage Reference Feature

Status Monitoring

The regulator status (STAT) signal provides an open-drain output (4V ABS MAX) that indicates whether the MAX16491 is functioning properly. J9 can be used to monitor the STAT signal.

Whenever the part is actively regulating, and the output voltage is within the Power Good (PWRGD) window, the STAT pin is HIGH. In all other conditions, including enabled but in a fault state, the STAT pin is pulled LOW. Refer to the MAX16491 IC data sheet for more details.

Input Voltage Monitoring

V_{DD1} and GND1 sense points as well as J3 can be used to monitor the input supply.

Output Voltage Monitoring

J11 and J13 monitor the output voltage. These test points should not be used for loading. Use scopejack J14 to monitor the output voltage ripple on an oscilloscope.

Efficiency Measurement

The following steps describe how to measure the regulator efficiency:

1) Connect a 12V power supply to the banana jacks. Use red for positive and black for ground. To avoid the input voltage dropping at high load due to power losses on connection cables connect the sense lines of the power supply to V_{DD1} and GND1 headers.
2) Connect an external 1.8V, 0.1A current limited power supply between J12–2 and ground.
3) Connect the same power supply to J10–1 to enable the regulator.
4) Connect a load to the edge strip for better results. J8 can also be used for low currents.
5) Make sure the shunt is installed on J16 (1-2) to close the sense line.
6) Remove all the other jumpers.
7) Connect a voltmeter to J11 or J13.
8) Turn on the power supply.
9) Measure V_{IN}, I_{IN}, V_{OUT}, I_{OUT}, V_{BIAS}, and I_{BIAS}.
10) Calculate the efficiency using Equation 3.

Equation 3

$$\eta = V_{OUT} \times \frac{I_{OUT}}{(V_{IN} + I_{IN}) + (V_{BIAS} \times I_{BIAS})}$$

Ordering Information

PART	TYPE
MAX16491EVKIT#	EV Kit

#Denotes RoHS compliance.

MAX16491 EV Kit Bill of Materials

SL NO.	REF_ DES	DNI/ DNP	QTY	MFG PART #	MANUFACTURER	VALUE	DESCRIPTION
1	C1, C2	—	2	TPSD107K020R0085	AVX	100UF	CAP; SMT (7343); 100UF; 10%; 20V; TANTALUM
2	C3	—	1	GRM155R71E104KE14; C1005X7R1E104K050BB; TMK105B7104KVH; CGJ2B3X7R1E104K050BB	MURATA; TDK; TAIYO YUDEN; TDK	0.1UF	CAP; SMT (0402); 0.1UF; 10%; 25V; X7R; CERAMIC
3	C4	—	1	C0402C821K5RAC; GRM155R71H821KA01	KEMET; MURATA	820PF	CAP; SMT (0402); 820PF; 10%; 50V; X7R; CERAMIC
4	C5, C6, C10, C11	—	4	GRM31CR71E106KA12; CL31B106KAHNNN	MURATA; SAMSUNG ELECTRONICS	10UF	CAP; SMT (1206); 10UF; 10%; 25V; X7R; CERAMIC
5	C7, C21, C54	—	3	TMK107B7105KA; 06033C105KAT2A; C1608X7R1E105K080AE	MURATA; TAIYO YUDEN; AVX; TAIYO YUDEN	1UF	CAP; SMT (0603); 1UF; 10%; 25V; X7R; CERAMIC
6	C8	—	1	GRM188R71E474KA12	MURATA	0.47UF	CAP; SMT (0603); 0.47UF; 10%; 25V; X7R; CERAMIC
7	C9, C55	—	2	GRM155R60J475ME87; GRM153R60J475ME15; GRM155R60J475ME47	MURATA; MURATA; MURATA	4.7UF	CAP; SMT (0402); 4.7UF; 20%; 6.3V; X5R; CERAMIC
8	C12-C20, C22, C26, C33	—	12	C2012X6S0J226M125AB; GRM21BC80J	TDK; MURATA	22UF	CAP; SMT (0805); 22UF; 20%; 6.3V; X6S; CERAMIC
9	C24	—	1	C0402C103K5RAC; GRM155R71H103KA88; C1005X7R1H103K050BE; CL05B103KB5NNN; UMK105B7103KV	KEMET; MURATA; TDK; SAMSUNG ELECTRONIC; TAIYO YUDEN	0.01UF	CAP; SMT (0402); 0.01UF; 10%; 50V; X7R; CERAMIC
10	C36	—	1	C0402C105K8PAC; CC0402KRX5R6BB105	KEMET; YAGEO	1UF	CAP; SMT (0402); 1UF; 10%; 10V; X5R; CERAMIC
11	C37	—	1	C0402C223K3RAC; GRM155R71E223KA61; GCM155R71E223KA55; TMK105B7223KV; CL05B223KA5NNN	KEMET; MURATA; MURATA; TAIYO YUDEN; SAMSUNG	0.022UF	CAP; SMT (0402); 0.022UF; 10%; 25V; X7R; CERAMIC
12	C39	—	1	TMK105BJ472KV-F	TAIYO YUDEN	4700PF	CAP; SMT (0402); 4700PF; 10%; 25V; X5R; CERAMIC
13	D1	—	1	MBRS540T3G	ON SEMICONDUCTOR	MBRS540T3	DIODE; SCH; SURFACE MOUNT SCHOTTKY POWER RECTIFIER; SMC; PIV=40V; IF = 5A

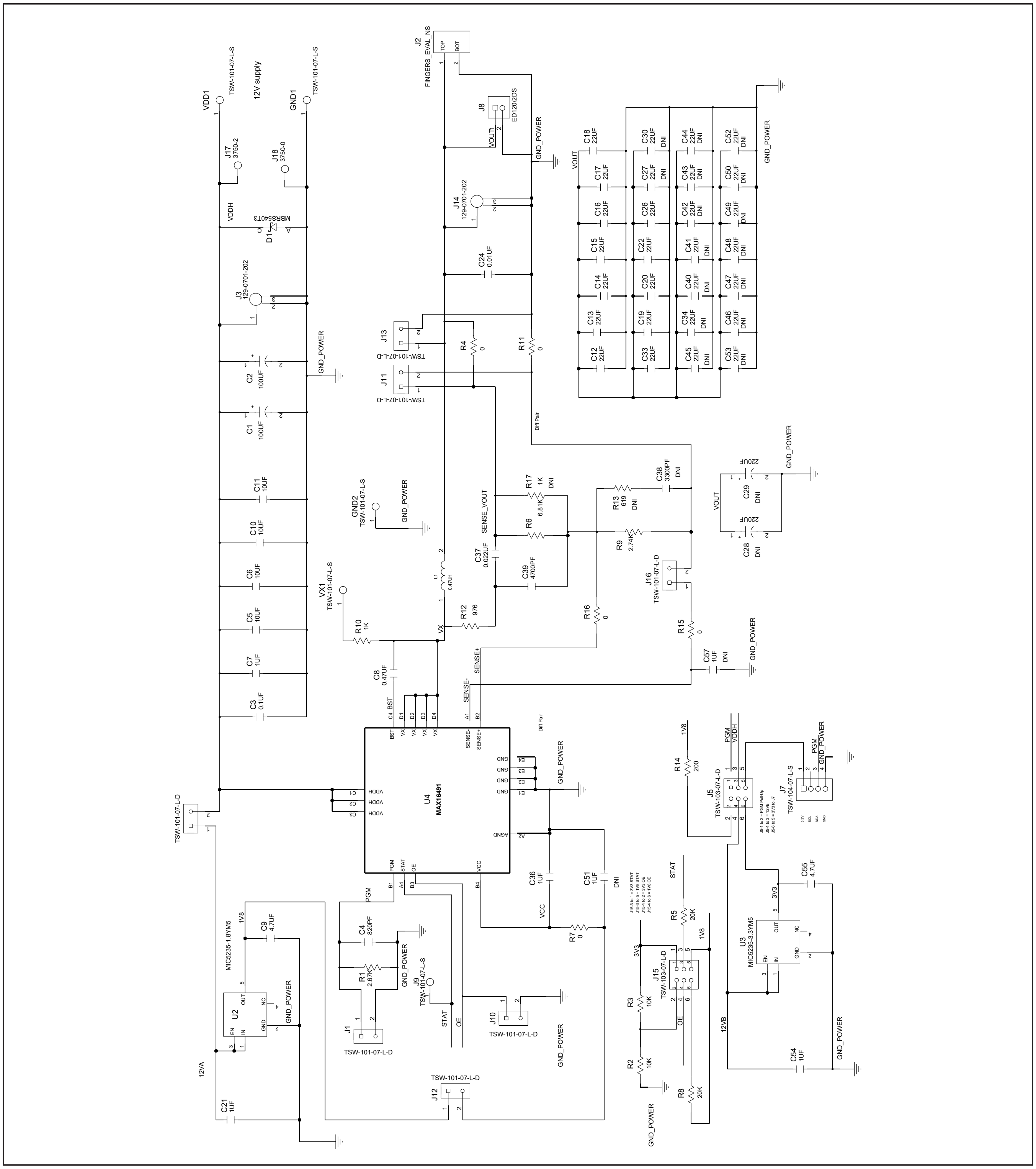
MAX16491 EV Kit Bill of Materials (continued)

SL NO.	REF_ DES	DNI/ DNP	QTY	MFG PART #	MANUFACTURER	VALUE	DESCRIPTION
14	GND1, GND2, J9, VDD1, VX1	—	5	TSW-101-07-L-S	SAMTEC	TSW-101-07-L-S	CONNECTOR; MALE; THROUGH HOLE; TSW SERIES; STRAIGHT; 1PIN
15	J1, J4, J10-J13, J16	—	7	TSW-101-07-L-D	SAMTEC	TSW-101-07-L-D	CONNECTOR; MALE; THROUGH HOLE; TSW SERIES; DOUBLE ROW; STRAIGHT; 2PINS
16	J3, J14	—	2	129-0701-202	JOHNSON COMPONENTS	129-0701-202	CONNECTOR; FEMALE; THROUGH HOLE; SHIELDED TEST VERTICAL JACK ; STRAIGHT; 3PINS
17	J5, J15	—	2	TSW-103-07-L-D	SAMTEC	TSW-103-07-L-D	CONNECTOR; MALE; THROUGH HOLE; THROUGH HOLE 0.025 POST HEADER; STRAIGHT; 6PINS
18	J7	—	1	TSW-104-07-L-S	SAMTEC	TSW-104-07-L-S	CONNECTOR; MALE; THROUGH HOLE; TSW SERIES; SINGLE ROW; STRAIGHT; 4PINS
19	J8	—	1	ED120/2DS	ON-SHORE TECHNOLOGY INC.	ED120/2DS	CONNECTOR; FEMALE; THROUGH HOLE; BLUE TERMINAL BLOCK; STRAIGHT; 2PINS
20	J17	—	1	3750-2	POMONA ELECTRONICS	3750-2	CONNECTOR; FEMALE; SMT; COLOR RED; STANDARD BINDING POST; STRAIGHT; 1PIN
21	J18	—	1	3750-0	POMONA ELECTRONICS	3750-0	CONNECTOR; FEMALE; SMT; COLOR BLACK; STANDARD BINDING POST; STRAIGHT; 1PIN
22	L1	—	1	SPM6530T-R47M-HZ	TDK	0.47UH	INDUCTOR; SMT; FERRITE; 0.47UH; 20%; 20.5A
23	R1	—	1	ERJ-2RKF2671	PANASONIC	2.67K	RES; SMT (0402); 2.67K; 1%; +/-100PPM/DEGC; 0.1000W
24	R2, R3	—	2	ERJ-2RKF1002	PANASONIC	10K	RES; SMT (0402); 10K; 1%; +/-100PPM/DEGC; 0.1000W
25	R4, R7, R11, R15, R16	—	5	ERJ-2GE0R00	PANASONIC	0	RES; SMT (0402); 0; JUMPER; JUMPER; 0.1000W
26	R5, R8	—	2	ERJ-2GEJ203	PANASONIC	20K	RES; SMT (0402); 20K; 5%; +/-200PPM/DEGC; 0.1000W
27	R6	—	1	ERJ-2RKF6811	PANASONIC	6.81K	RES; SMT (0402); 6.81K; 1%; +/-100PPM/DEGC; 0.1000W
28	R9	—	1	CRCW04022K74FK	VISHAY DALE	2.74K	RES; SMT (0402); 2.74K; 1%; +/-100PPM/DEGC; 0.0630W

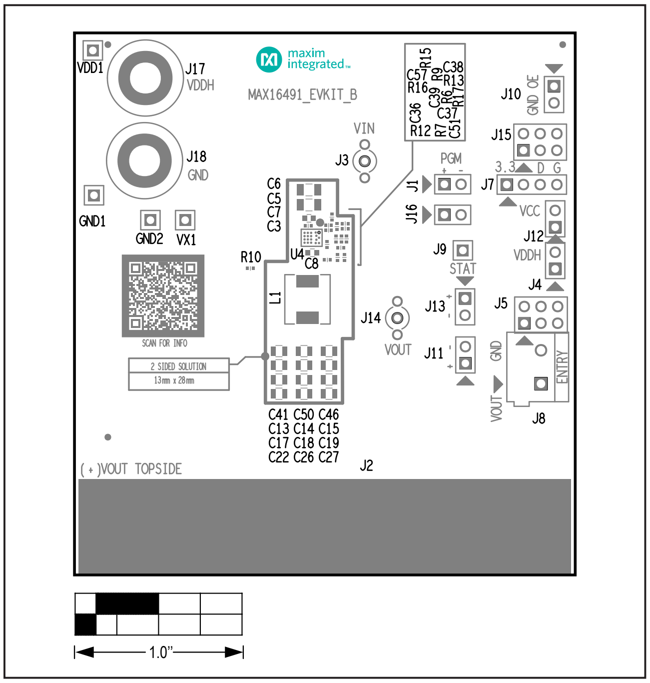
MAX16491 EV Kit Bill of Materials (continued)

SL NO.	REF_ DES	DNI/ DNP	QTY	MFG PART #	MANUFACTURER	VALUE	DESCRIPTION
29	R10	—	1	ERJ-2GEJ102	PANASONIC	1K	RES; SMT (0402); 1K; 5%; +/-200PPM/DEGC; 0.1000W
30	R12	—	1	CRCW0402976RFK	VISHAY	976	RES; SMT (0402); 976; 1%; +/-100PPM/DEGC; 0.0630W
31	R14	—	1	ERJ-2RKF2000	PANASONIC	200	RES; SMT (0402); 200; 1%; +/-100PPM/DEGC; 0.1000W
32	SU1-SU5	—	5	S1100-B; SX1100-B; STC02SYAN	KYCON; KYCON; SULLINS ELECTRONICS CORP.	SX1100-B	TEST POINT; JUMPER; STR; TOTAL LENGTH = 0.24IN; BLACK; INSULATION = PBT; PHOSPHOR BRONZE CONTACT=GOLD PLATED
33	U2	—	1	MIC5235-1.8YM5	MICROCHIP	MIC5235-1.8YM5	IC; VREG; ULTRA-LOW QUIESCENT CURRENT; 150MA MICROCAP LDO REGULATOR; SOT23-5
34	U3	—	1	MIC5235-3.3YM5	MICROCHIP	MIC5235-3.3YM5	IC; VREG; ULTRA-LOW QUIESCENT CURRENT; 150MA MICROCAP LDO REGULATOR; SOT23-5
35	U4	—	1	MAX16491	MAXIM	MAX16491	EVKIT PART -IC; INTEGRATED STEP-DOWN SWITCHING REGULATOR WITH SELECTABLE APPLICATIONS CONFIGURATIONS; PACKAGE OUTLINE DRAWING: 21-0915; PACKAGE LAND PATTERN: 90-0544; PACKAGE CODE: C192B2+1; WLCSP19
36	PCB	—	1	MAX16491	MAXIM	PCB	PCB:MAX16491
37	C27, C30, C34, C40-C50, C52, C53	DNP	0	C2012X6S0J226M125AB; GRM21BC80J	TDK;MURATA	22UF	CAP; SMT (0805); 22UF; 20%; 6.3V; X6S; CERAMIC
38	C28, C29	DNP	0	T494D227M010AT	KEMET	220UF	CAP; SMT (7343); 220UF; 20%; 10V; TANTALUM ; NOTE:PURCHASE DIRECT FROM THE MANUFACTURER
39	C38	DNP	0	GRM155R71H332KA01	MURATA	3300PF	CAP; SMT (0402); 3300PF; 10%; 50V; X7R; CERAMIC
40	C51, C57	DNP	0	C0402C105K8PAC; CC0402KRX5R6BB105	KEMET;YAGEO	1UF	CAP; SMT (0402); 1UF; 10%; 10V; X5R; CERAMIC
41	R13	DNP	0	CR0402-16W-6190FT; CRCW0402619RFK	VENKEL LTD.; VISHAY DALE	619	RES; SMT (0402); 619; 1%; +/-100PPM/DEGC; 0.0630W
42	R17	DNP	0	ERJ-2RKF1001	PANASONIC	1K	RES; SMT (0402); 1K; 1%; +/-100PPM/DEGC; 0.1000W
TOTAL			76				

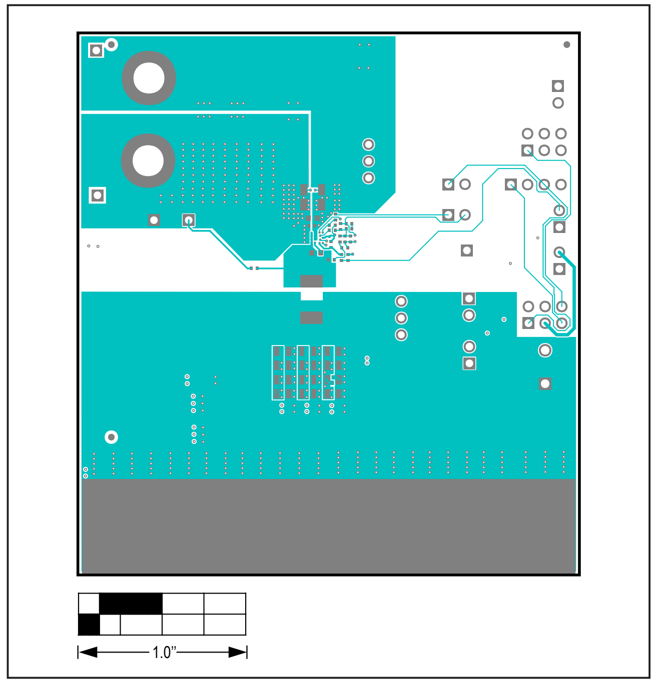
MAX16491 EV Kit Schematic Diagram



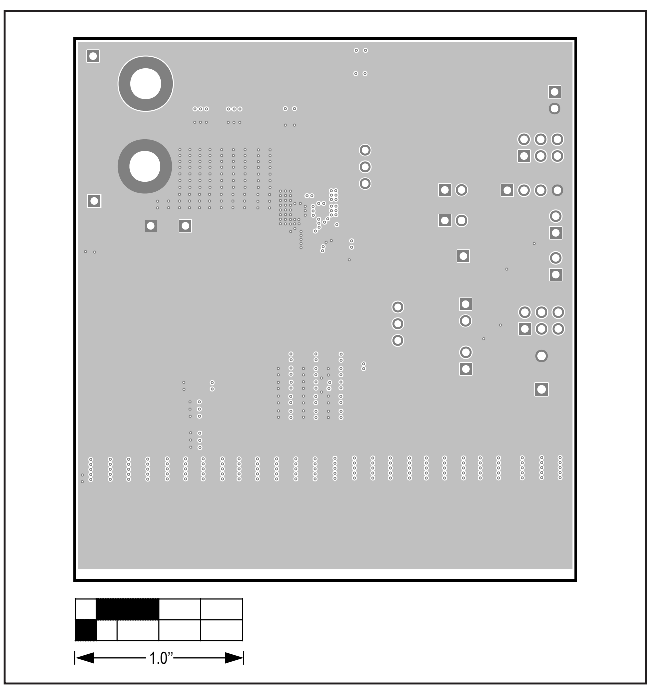
MAX16491 EV Kit PCB Layout Diagrams



MAX16491 EV kit Component Placement Guide—Top Silkscreen

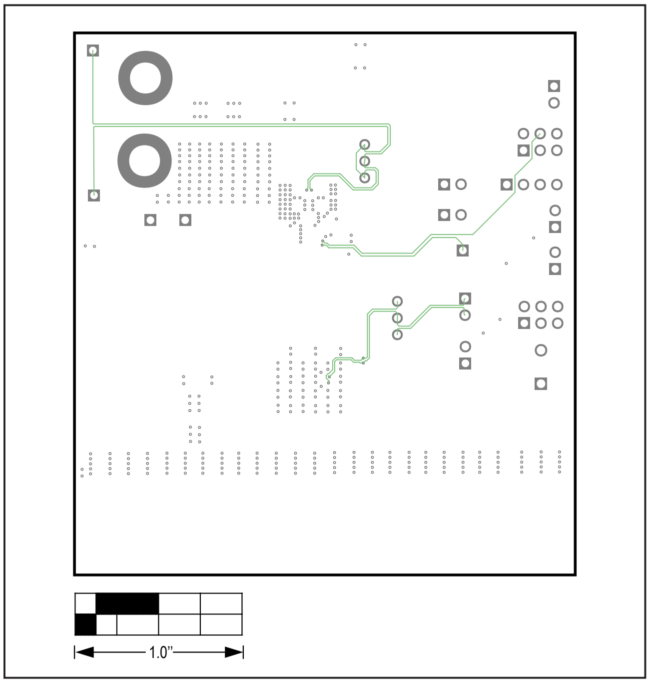


MAX16491 EV kit PCB Layout Diagram—Top View

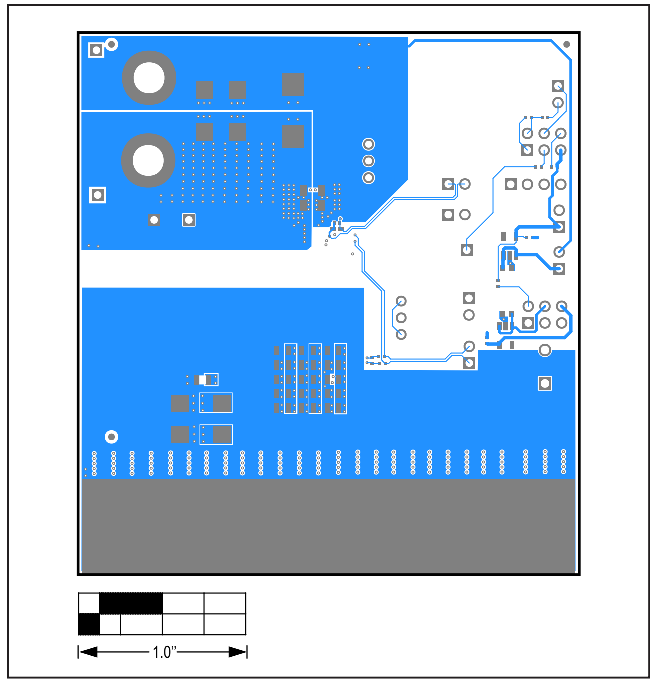


MAX16491 EV kit PCB Layout Diagram—Layer 2

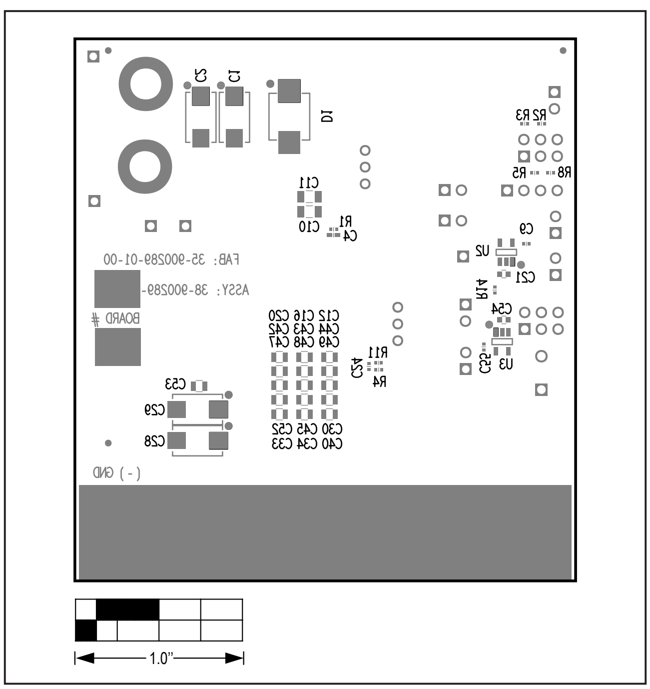
MAX16491 EV Kit PCB Layout Diagrams (continued)



MAX16491 EV kit PCB Layout Diagram—Layer 3



MAX16491 EV kit PCB Layout Diagram—Bottom View



MAX16491 EV kit PCB Layout Diagram—Bottom Silkscreen