

Introduction

The PE24111 is a compact, low-profile, and ultra-high efficiency step-down DC-DC converter solution capable of delivering 20A output current from an input voltage range from 3.0–3.6V. The output voltage is set between 0.35V and 0.7V with external feedback resistors and can be adjusted by an external AVS DAC.

Based on pSemi advanced two-stage architecture, the PE24111 consists of a two-phase interleaved charge pump followed by an interleaved buck regulator stage. This power system greatly reduces the inductance necessary for high efficiency while maintaining a small solution size for small-footprint and height-constrained applications.

Evaluation kit overview

The EK24111-03, EK24111-04, and EVK24111-05 evaluation kits (EVKs) are hardware platforms that allow you to easily test the PE24111 step-down DC-DC converter. The buck converter operates at a default switching frequency of 800 kHz, but you can change the switching frequency by swapping the resistor between the FSW pin and GND. You can adjust the output voltage using the on-board potentiometer. The kit is available in three configurations that can demonstrate one, two, or three PE24111 devices connected in parallel as power stages allowing output currents of 20A, 40A, or 60A.

EVK user manual overview

This *PE24111 Evaluation Kit (EVK) User Manual* includes information about the hardware required to control and evaluate the functionality of the DC-DC converter. This manual also includes test results, schematic diagrams, printed circuit board (PCB) layouts, and bills of materials (BOMs).

Evaluation kit contents and requirements

Kit contents

The PE24111 EVK includes one of the configurations listed in Table 1, which are required to evaluate the DC-DC converter.

Table 1. EVK configurations

Quantity	Description	Part no.
1	PE24111 DC-DC converter evaluation board assembly with one device	EK24111-03
1	PE24111 DC-DC converter evaluation board assembly with two devices	EK24111-04
1	PE24111 DC-DC converter evaluation board assembly with three devices	EK24111-05

Hardware requirements

To evaluate the performance of the evaluation board, the following equipment is required:

- Bench supply capable of providing 3.0V to 3.6V at 10A per device with sense lines
- Three digital multi-meters for measuring VIN, VOUT, and various test points
- Four-channel oscilloscope with probes
- Active load capable of 20A for a single device configuration, 40A for a dual device configuration, or 60A for a three-device configuration



The PE24111 DC-DC converter EVK contains components that could be damaged by exposure to voltages more than the specified voltage, including voltages produced by electrostatic discharges. Handle the board in accordance with procedures for handling static-sensitive components. Avoid applying excessive voltages to the power supply terminals or signal inputs or outputs. When connecting the EVK to the source power supply, verify that the power supply is off. Connecting the EVK to a live power supply unit could cause failures.

Quick start guide

Quick start overview

pSemi designed the evaluation board to ease your evaluation of the PE24111 DC-DC converter. This section guides you through configuring the hardware and the startup procedures.

Evaluation board overview

The evaluation board contains the following:

- Power input/output terminals
- Enable jumpers
- Feedback mode selection jumpers
- DAC input for VOUT control
- Sense points and PGOOD signal

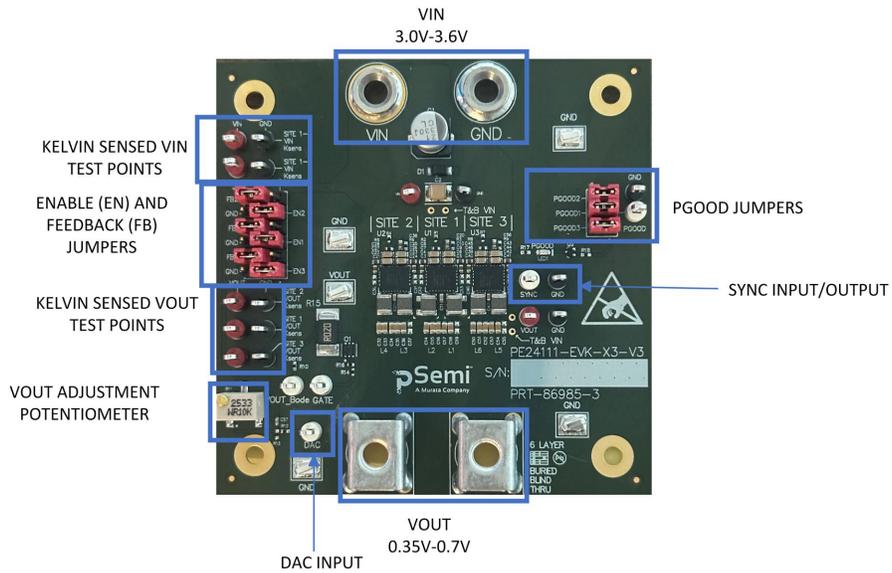


Figure 1. PE24111 evaluation board assembly, x2 configuration

EVK test connections

Connect the EVK and the lab equipment as shown in Figure 2. Connect the power supply sense lines to the VIN kelvin sense test points to ensure minimal supply voltage drop and accurate voltage regulation at the device input. Due to the high currents present—especially in the x2 and x3 configurations—use 14-gauge connection wires for the supply and load.

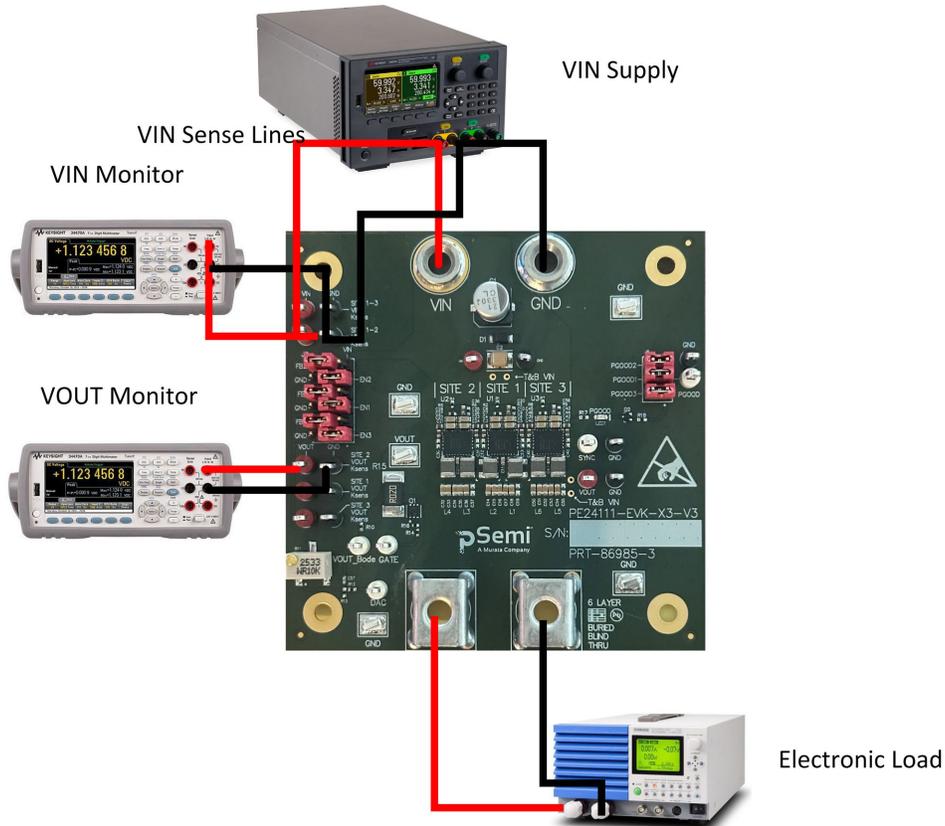


Figure 2. EVK connection example

The PE24111 EVK can have three different parallel configurations, including:

- A single device or x1, up to 20A load current (EK24111-03)
- Two devices in parallel or x2, up to 40A load current (EK24111-04)
- Three devices in parallel or x3, up to 60A load current (EK24111-05)

The provided jumpers connect the enable pins to VIN or GND to enable or disable each device. Normal operation requires the EN jumpers to be in place and connected to VIN for the given board configuration. There are also jumper positions for the feedback (FB) pins of each device, which allow connection to VIN or to the other device's FB pins (common FB). Normal operation requires the common FB pin configuration. Figure 3 shows the x3 board with one jumper in place for the EN pin and FB pin of each device.

- For the x1 configuration: Install the jumpers for EN1, FB1, and PGOOD1.
- For the x2 configuration: Install the jumpers for EN1, EN2, FB1, FB2, PGOOD1, and PGOOD2.

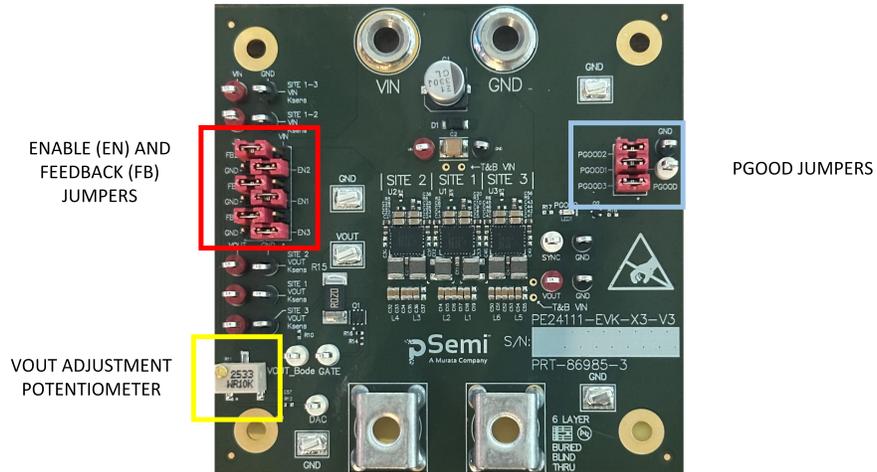


Figure 3. Enable and feedback jumper position and V_{OUT} potentiometer

Changing VOUT

The output voltage is adjustable by varying the potentiometer R11, as shown in [Figure 3](#). Adjusting the potentiometer clockwise decreases VOUT. Although the potentiometer allows for a wider VOUT range, limit the VOUT range from 0.35–0.70V maximum.

Other test points

- PG is the test point for the power good (PGOOD) signal, asserted high when the output is within 10% of the target value.
- SYNC is the internal oscillator signal. The default frequency of 1600 kHz can be monitored using an oscilloscope.
- SYNC can be used to override the internal oscillator by injecting an external clock signal for the DC-DC converter and charge pump. The signal must be a square wave with a 1.75–2.6 MHz frequency—or at least twice the selected switching frequency—with an amplitude of at least 2.1 V_{PP}.

Switching frequency selection

The PE24111 supports user-selectable default switching frequency options for the charge pump and down-stream buck converter. The switching frequency is selected by tying a 1% tolerance resistor between the FSW pin and AGND. The device reads the resistance when VIN is applied and EN is pulled high. The decoded value is then latched until the next time the power is cycled or the EN pin is pulled low. To identify what resistance to tie between FSW and AGND for your preferred switching frequency setting, see Table 2:

- For site 1, change R2.
- For site 2, change R5.
- For site 3, change R8.

The internal clock frequency setting is twice the frequency of the charge pump and buck switching frequency. For a 2-device configuration, verify that both resistor settings are the same to ensure that both devices operate at the same switching frequency.

Table 2. Switching frequency setting vs. resistance between the FSW pin and AGND

R2, R5, and R8 value (Ω)	Charge pump and buck switching frequency (kHz)	Internal clock frequency setting (kHz)
0	800	1600
22.1k	1500	3000
40.2k	1200	2400
84.5k	1000	2000
287k	800	1600
1M	500	1000
Open	800	1600

Verify that the calculated on time is above the minimum on time (typically 145 ns). pSemi recommends some margin between the calculated on time and the minimum on time to account for transient behavior. Limit the switching frequency to 1.2 MHz for VOUT below 0.5V. Calculate the on time using the following equation:

$$TON = \frac{VOUT}{\left(\frac{VIN_MAX}{2}\right) * FSW}$$

Equation 1. ON time calculation

Parallel modes of operation

This EVK allows for up to three PE24111 devices to operate in parallel as power stages, providing output currents of 20A, 40A, or 60A. In parallel operation, connect the FB, SYNC, COMP, PGOOD, and EN pins of all devices. To adjust the output voltage, use a single DAC to externally feed a current through a resistor into the feedback network.

Compensation

Each regulator device has pads for an RC compensation network:

- The compensation components for U1 are R3 and C20.
- The compensation components for U2 are R6 and C38.
- The compensation components for U3 are R9 and C56.

The schematic in [Figure 14](#) shows the standard values. Use 10 nF for the compensation capacitor and 909Ω for the compensation resistor. [Figure 7](#) shows a bode plot for the default configuration.

Default jumper connections

Table 3. Default jumper connections

Jumper	Name	Jumper position	Function
J7	FB2	17-18*	Connects FB for U2 to the common FB node.
		Leave disconnected	Disconnects FB for U2 from the common FB node.
	EN2	13-14*	Enables U2 output.
		14-15	Disables U2 output.
	FB1	11-12*	Connects FB for U2 to the common FB node.
		Leave disconnected	Disconnects FB for U2 from the common FB node.
	EN1	7-8*	Enables U2 output.
		8-9*	Disables U2 output.
	FB3	5-6*	Connects FB for U3 to the common FB node.
		Leave disconnected	Disconnects FB for U3 from the common FB node.
	EN3	1-2*	Enables U3 output.
		2-3*	Disables U3 output.
J8	PGOOD3	1-2*	Connects PGOOD3 to common PGOOD test point.
		Disconnected	Disconnects PGOOD3 from common PGOOD test point.
	PGOOD1	3-4*	Connects PGOOD1 to common PGOOD test point.
		Disconnected	Disconnects PGOOD1 from common PGOOD test point.
	PGOOD2	5-6*	Connects PGOOD2 to common PGOOD test point.
		Disconnected	Disconnects PGOOD2 from common PGOOD test point.

EVK startup

1. With the power off, verify that the jumpers are in the positions shown in [Table 3](#).
2. Connect the power supply and sense lines, electronic load, and DMMs as shown in [Figure 2](#).
3. Apply a voltage between 3.0V and 3.6V between V_{IN} and GND.
4. Adjust R11 to set the output voltage between 0.35V and 0.7V.
5. Monitor V_{OUT} and adjust the load current within the operating range of 0A to 20A per device.

Test results

[Figure 4](#)–[Figure 7](#) show the typical efficiency and V_{OUT} waveforms of the PE24111 evaluation board, x1 configuration, $V_{OUT} = 0.50V$.

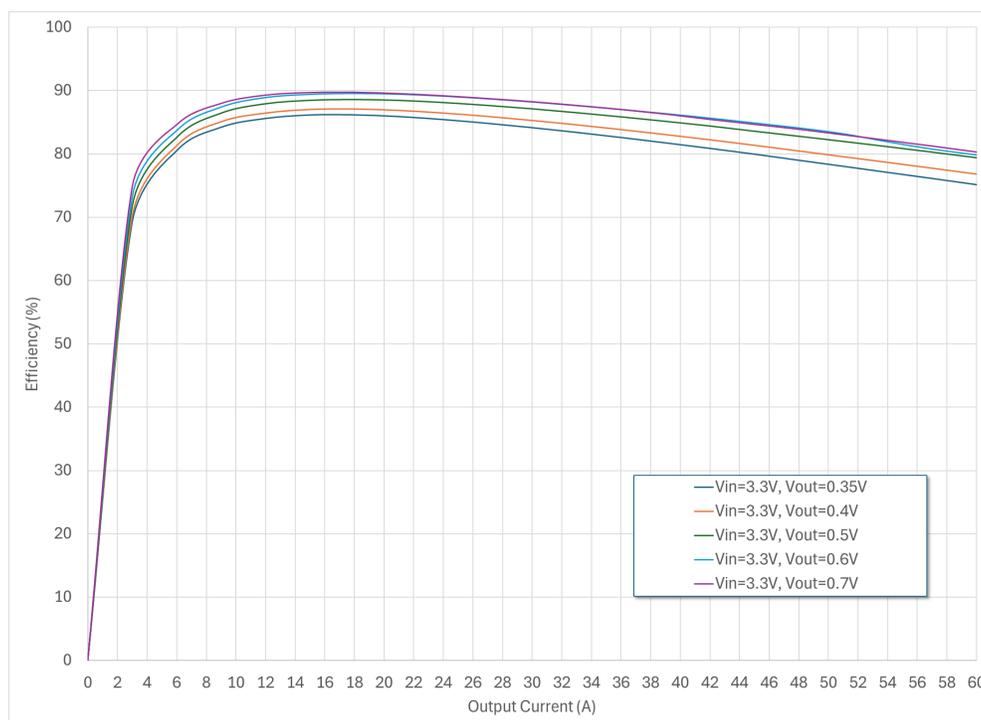


Figure 4. Efficiency vs. output current, x3 configuration

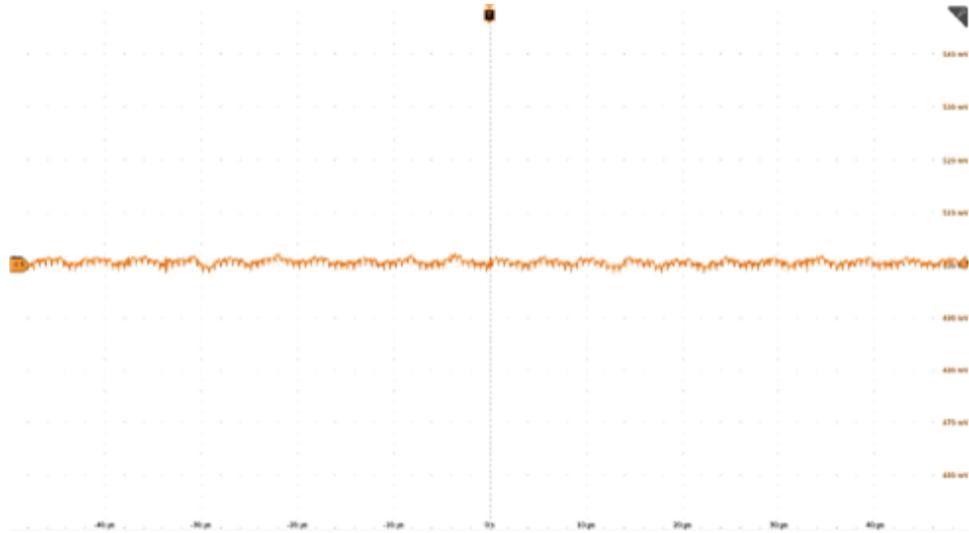


Figure 5. Output ripple ($V_{IN} = 3.3V$, $V_{OUT} = 0.5V$, $I_{OUT} = 10A$), x1 configuration

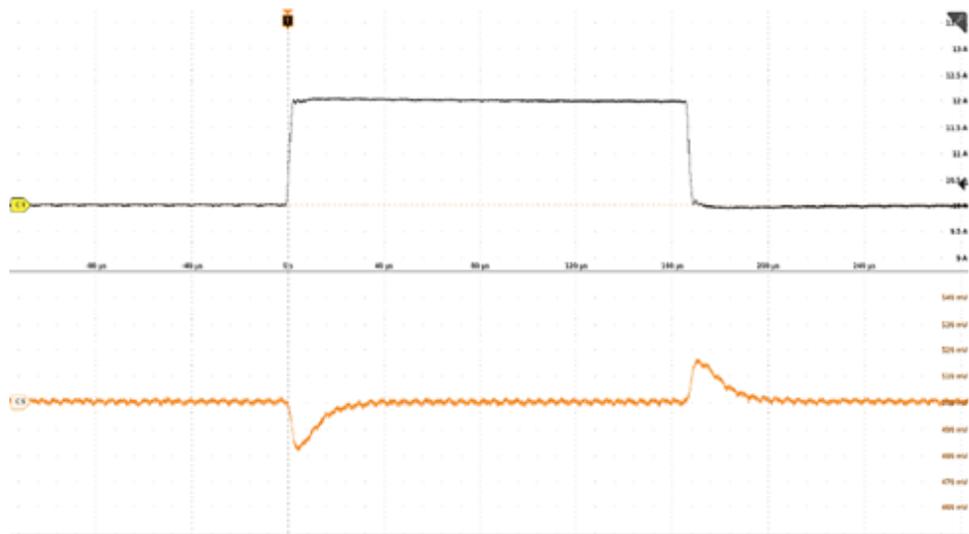


Figure 6. Load transient response ($V_{IN} = 3.3V$, $V_{OUT} = 0.5V$, 10 – 12A load step, $1A/\mu s$), x1 configuration

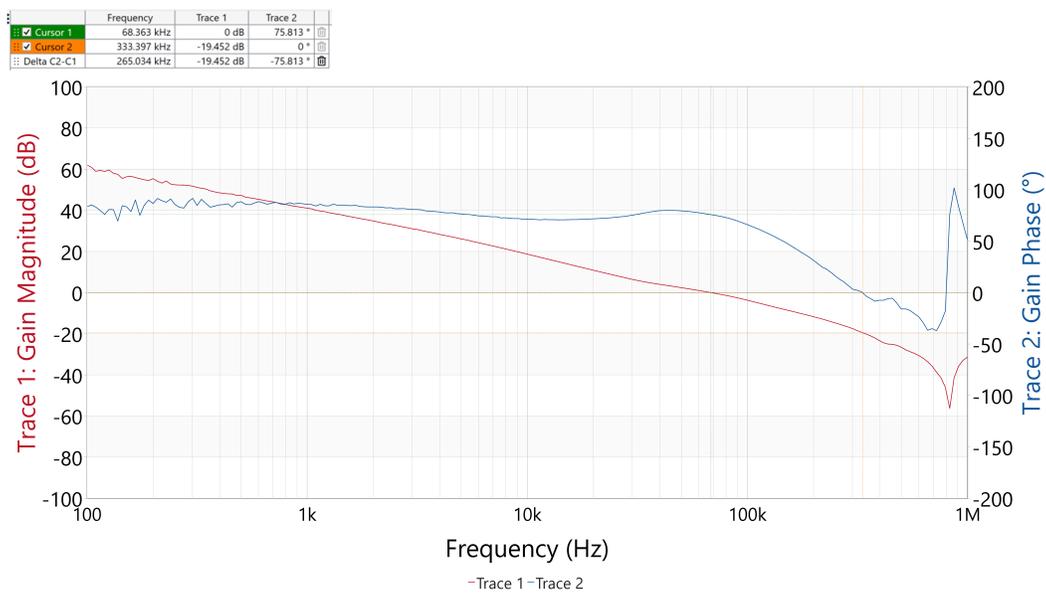


Figure 7. Bode plot example ($V_{IN} = 3.3V$, $V_{OUT} = 0.5V$, $30A$), x3 configuration

PE24111 EVK PCB layout

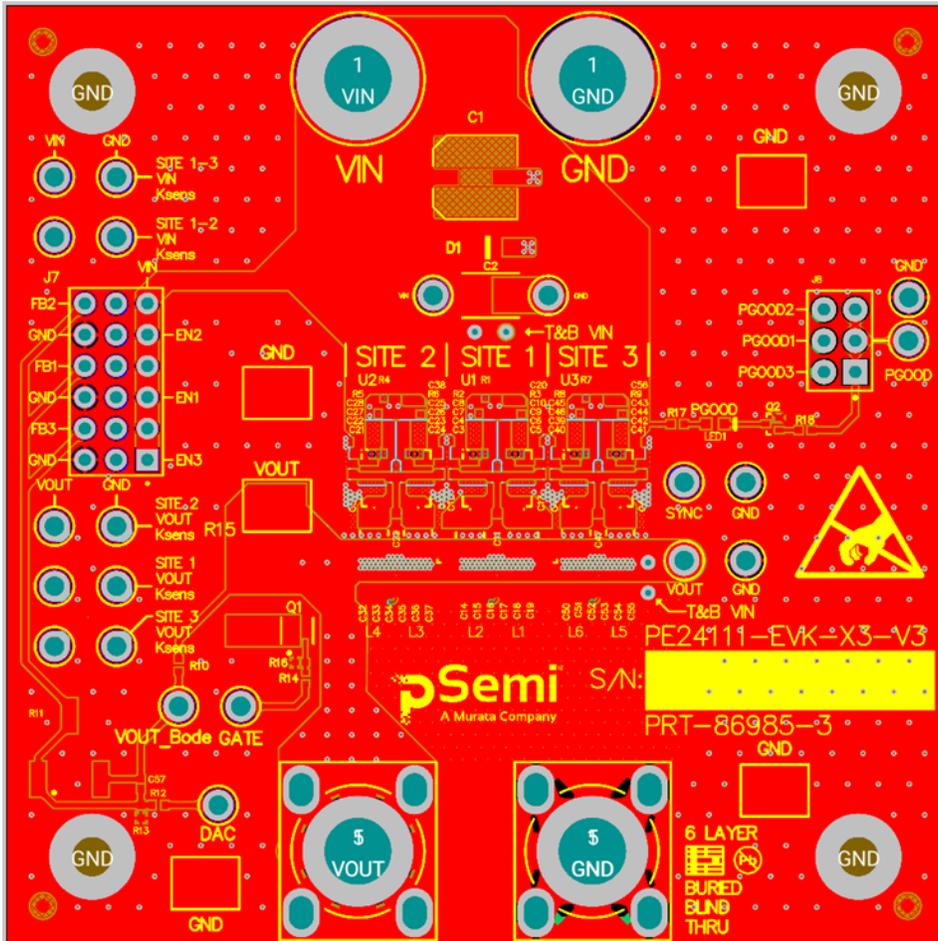


Figure 8. Evaluation board layout, top layer

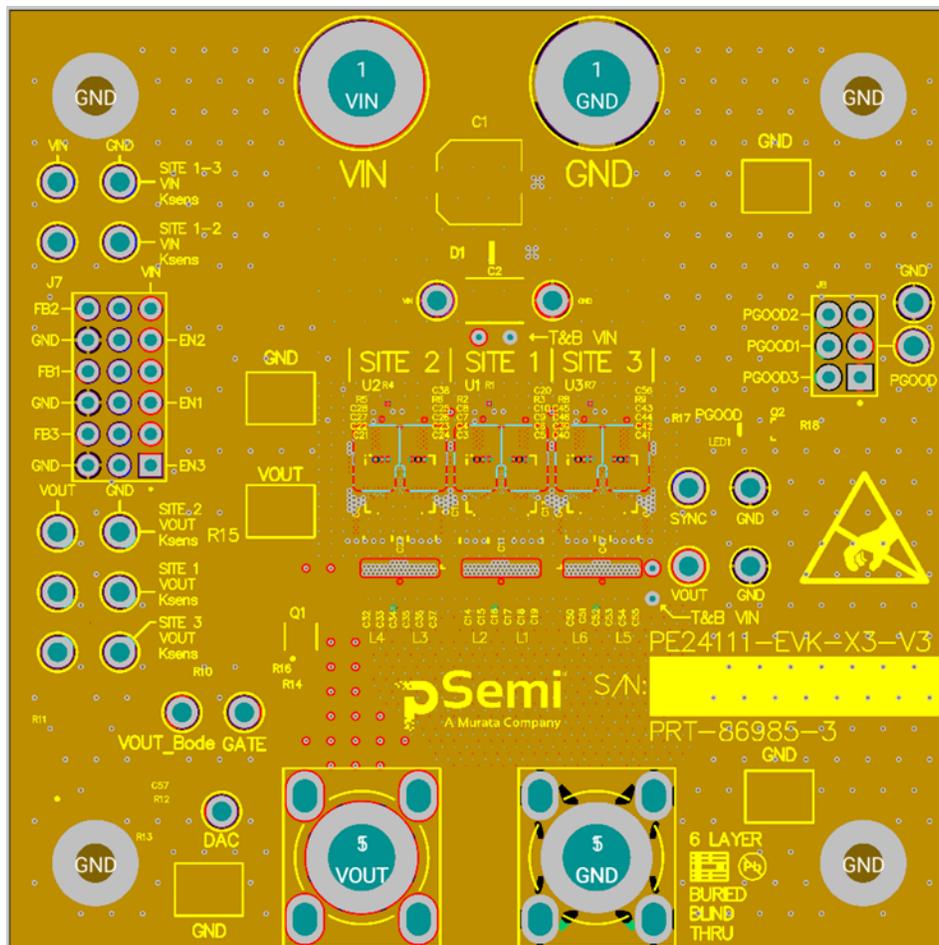


Figure 9. Evaluation board layout, layer 2

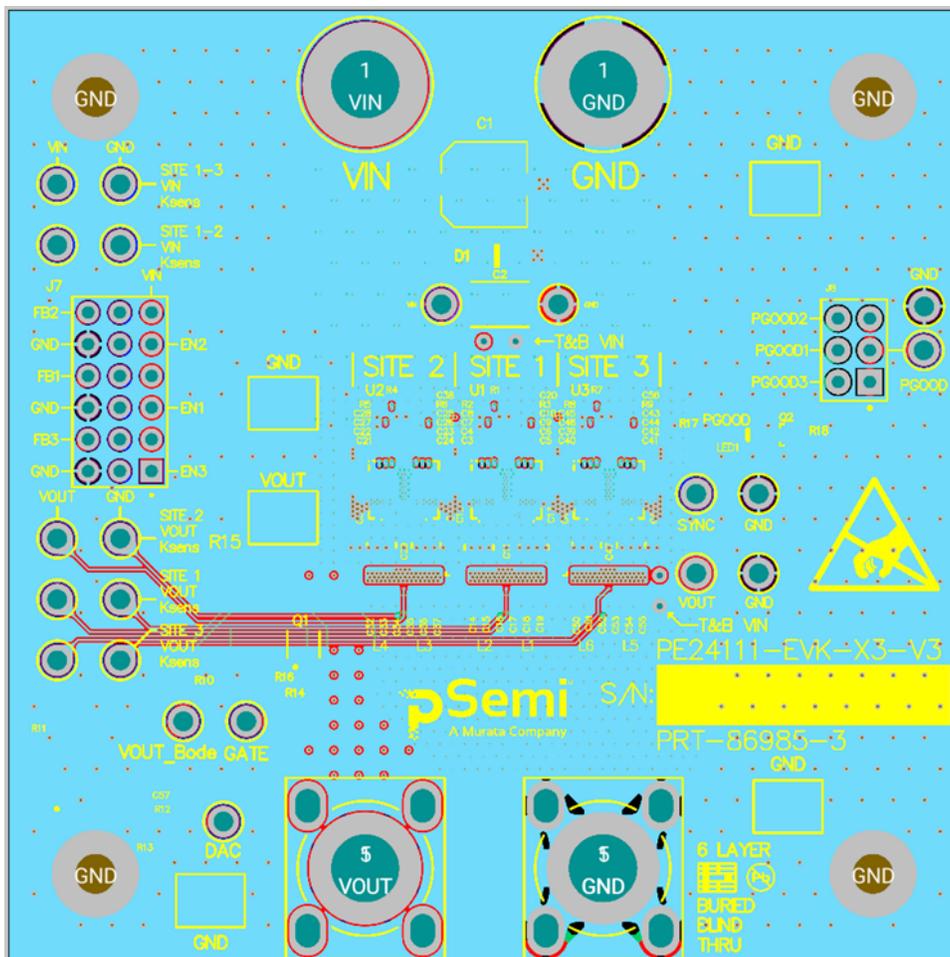


Figure 10. Evaluation board layout, layer 3

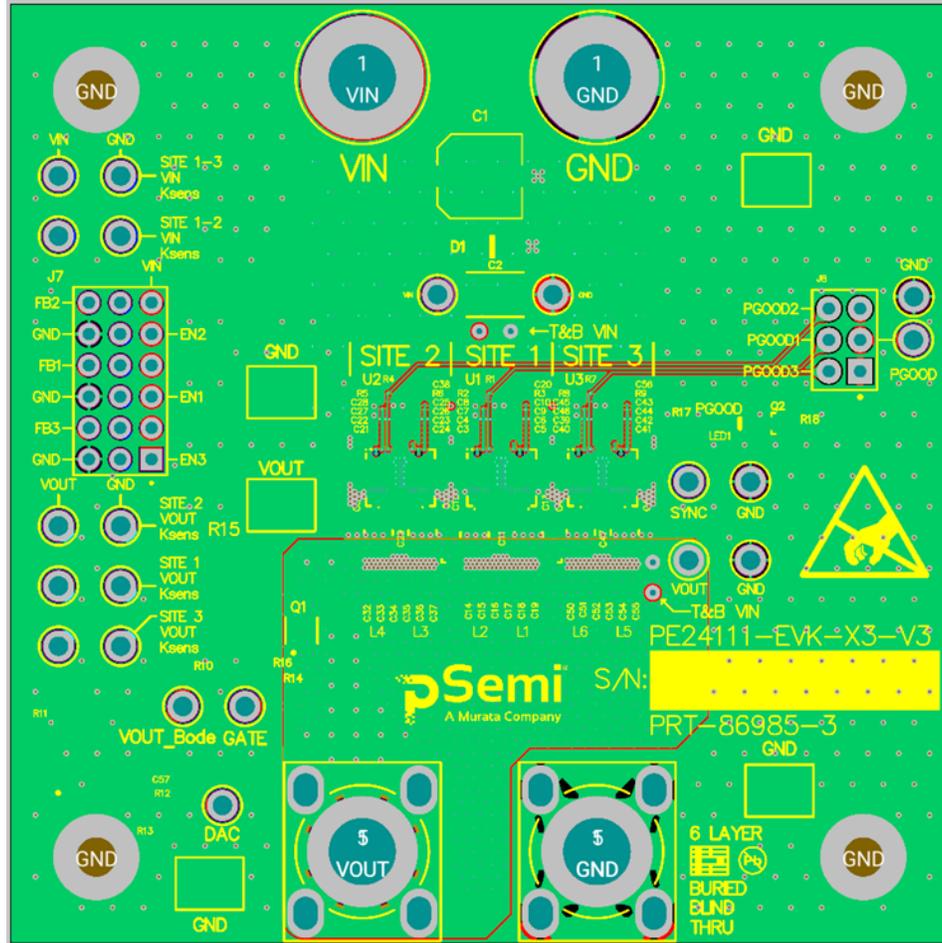


Figure 11. Evaluation board layout, layer 4

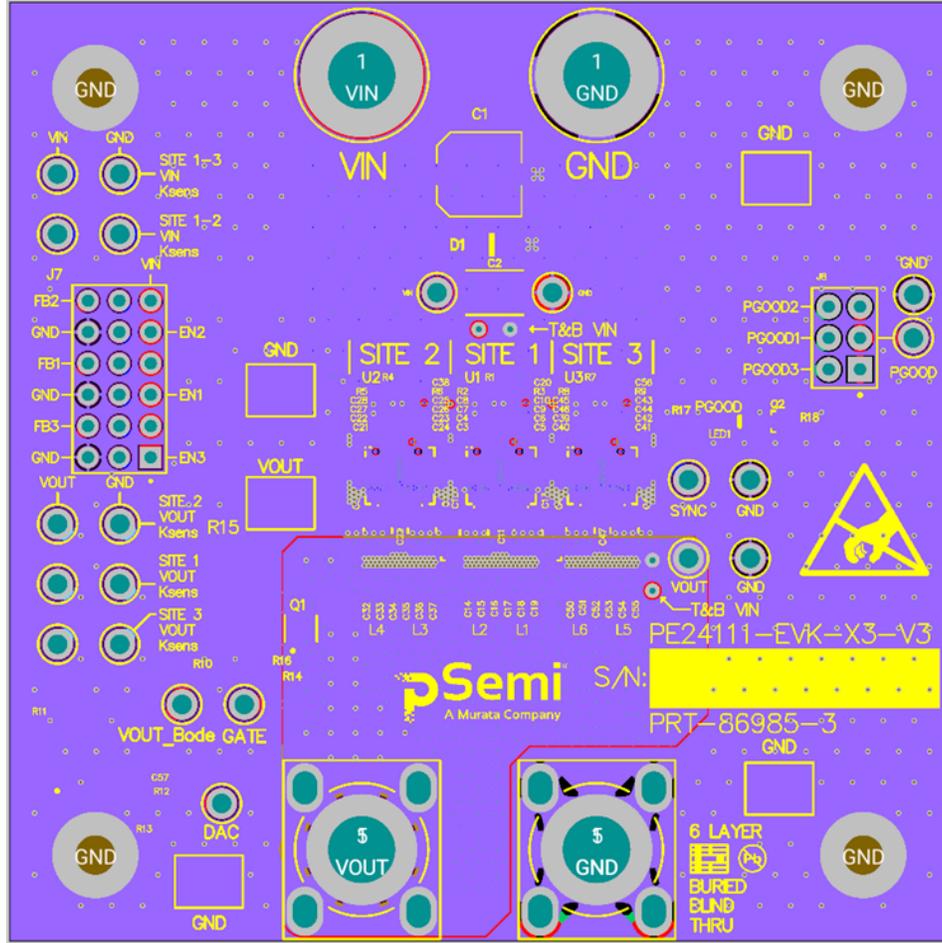


Figure 12. Evaluation board layout, layer 5

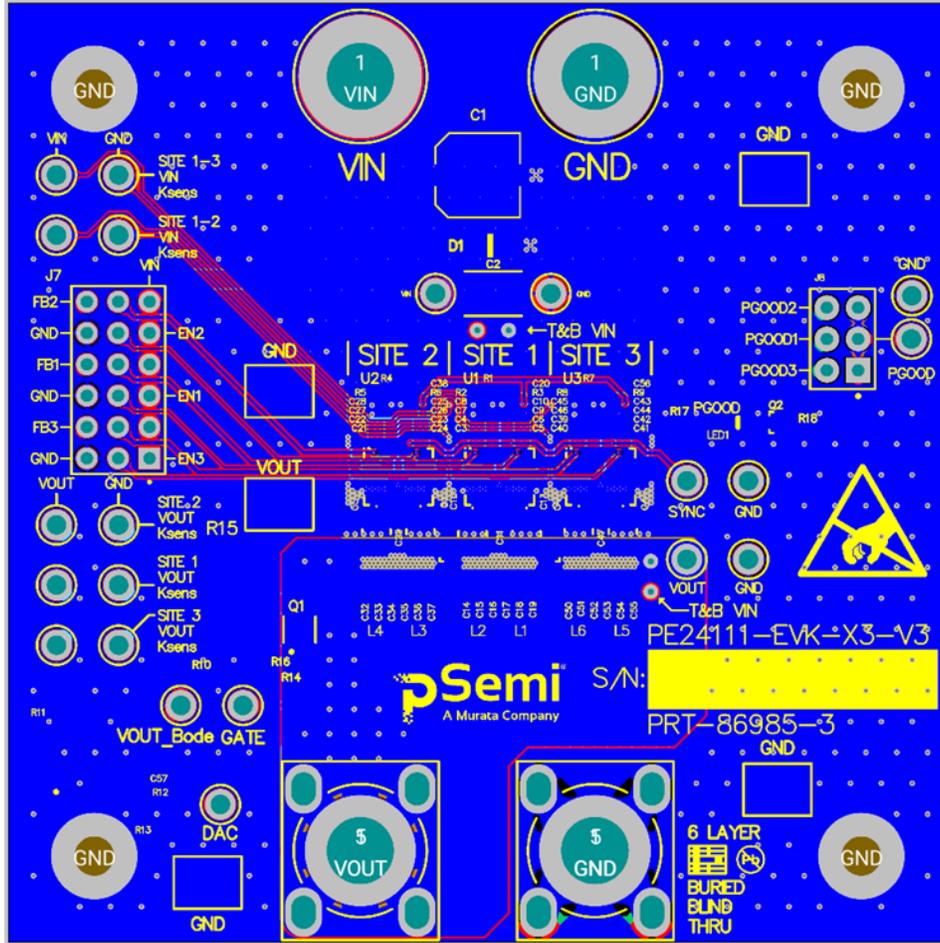


Figure 13. Evaluation board layout, layer 6

PE24111 EVK PCB schematic

Figure 14 shows the full x3 board schematic. For other versions with x1 or x2 devices populated, start with position 1 for x1, and the successive pages for the other versions (x2 includes position 2, and so on).

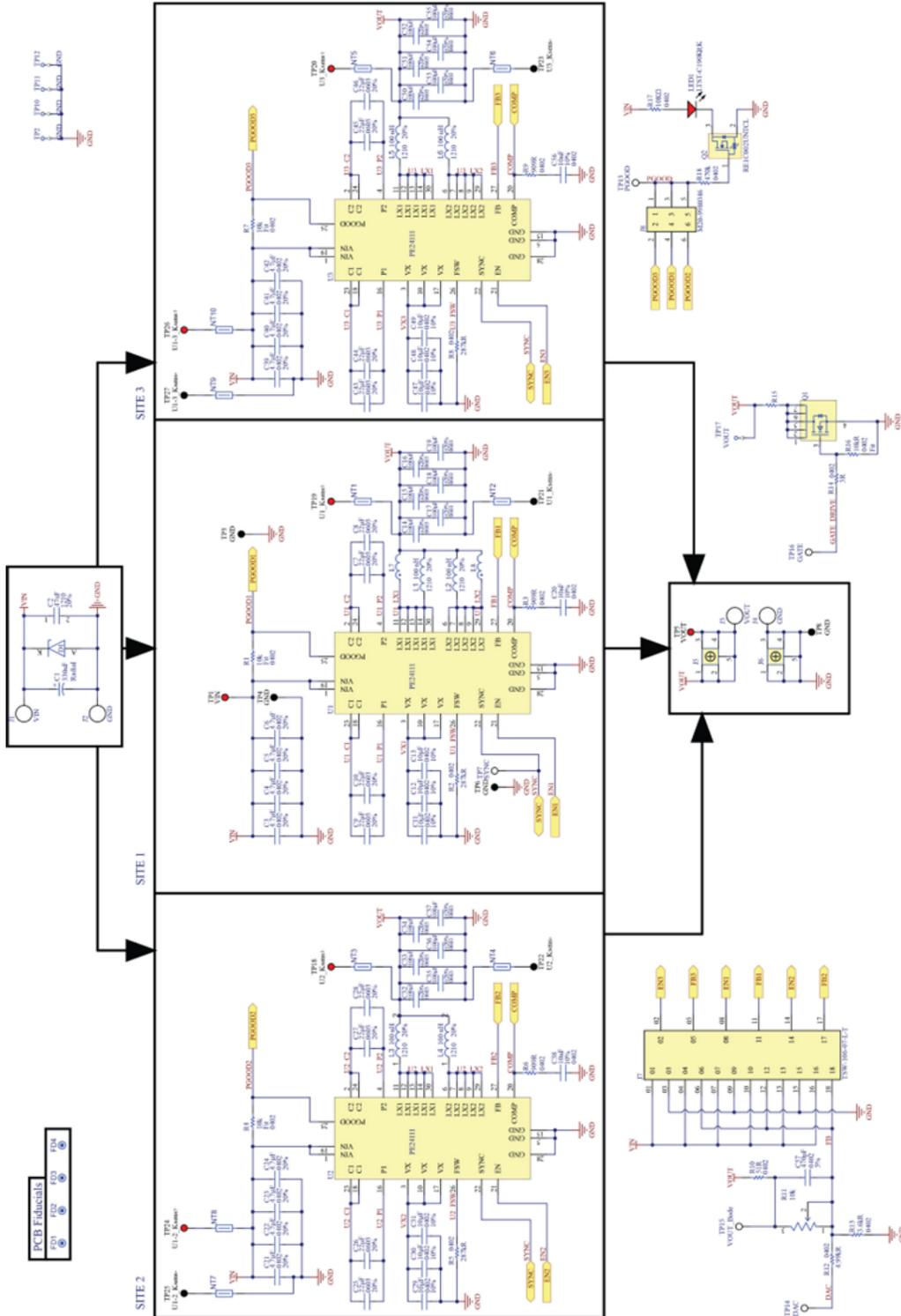


Figure 14. Evaluation board schematic

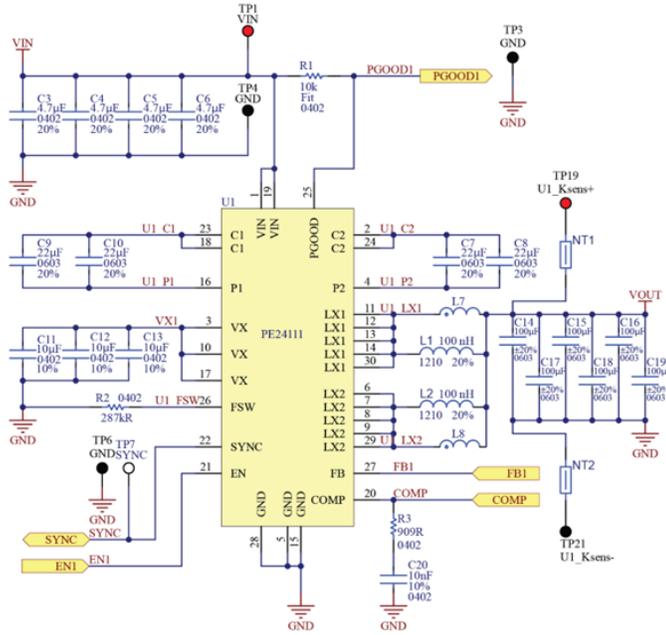


Figure 15. Evaluation board schematic, U1 circuit

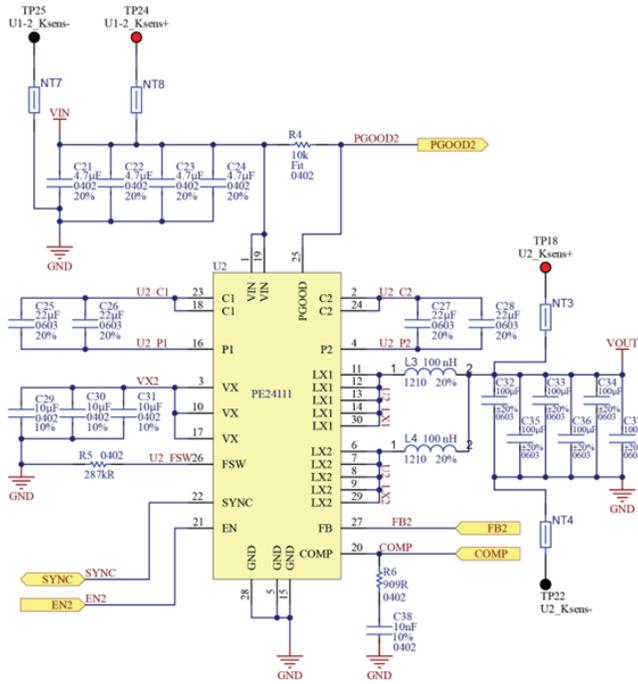


Figure 16. Evaluation board schematic, U2 circuit

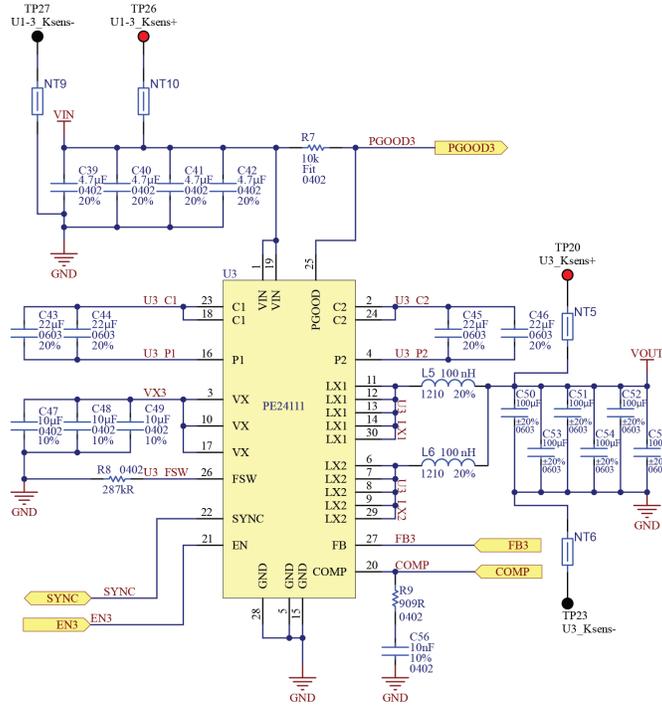


Figure 17. Evaluation board schematic, U3 circuit

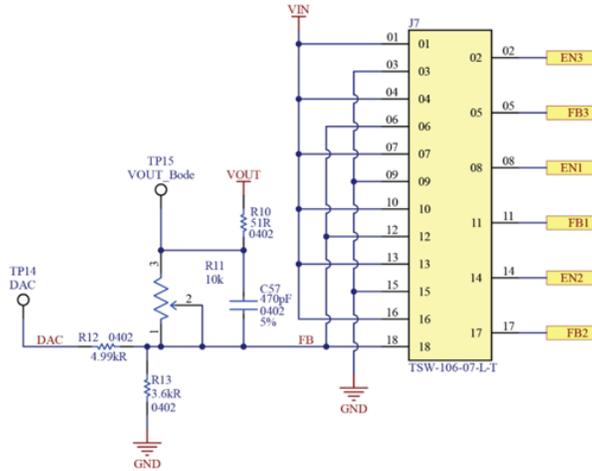


Figure 18. Evaluation board schematic, jumpers

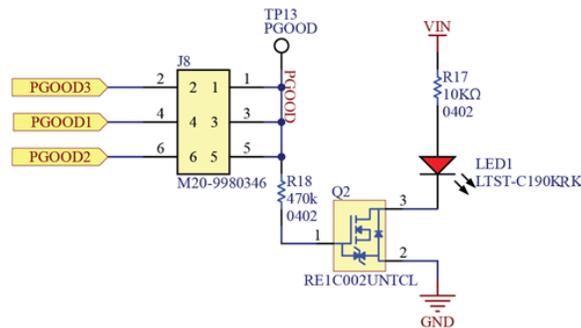


Figure 19. Evaluation board schematic, PGOOD circuit

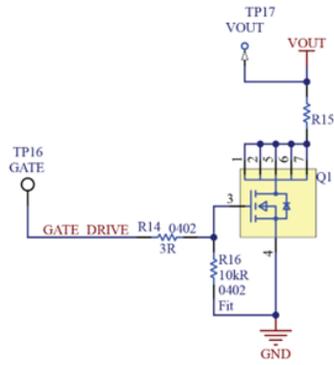


Figure 20. Evaluation board schematic, load transient circuit

PE24111 EVK BOM list, x3 configuration

Table 4. x3 EVK BOM list

Reference	Value	Description	Manufacturer	Part number
<i>Required components</i>				
C3, C4, C5, C6, C21, C22, C23, C24, C39, C40, C41, C42	4.7 μ F	0402; \pm 20%; 6.3V; X7T	Murata	GRM155D70J475ME15D
C7, C8, C9, C10, C25, C26, C27, C28, C43, C44, C45, C46	22 μ F	0603; \pm 20%; 6.3V; X7T	Murata	GRM188D70J226ME01D
C11, C29, C47	10 μ F	0402; \pm 20%; 4V; X7T	Murata	GRM155D70G106ME18D
C14, C15, C16, C17, C18, C32, C33, C34, C35, C36, C50, C51, C52, C53, C54	100 μ F	0603; \pm 20%; 2.5V; X6S	Murata	GRM188C80E107ME01
C20, C38, C56	10 nF	0402; \pm 10%; 50V; X7R	Murata	GCM155R71H103KA55D
C57	470 pF	0402; \pm 5%; 50V; C0G	Murata	GRM1555C1H471JA01D
L1, L2, L3, L4, L5, L6	100 nH	1210; 8A; 8m Ω max DCR	TDK	TFM322512ALMAR10MTAA
R1, R4, R7	10 k Ω	0402; \pm 1%; 1/10W	Panasonic	ERJ-2RKF1002X
R2, R5, R8	287 k Ω	0402; \pm 1%; 1/10W	Panasonic	ERJ-2RKF2873X
R3, R6, R9	909 Ω	0402; \pm 1%; 1/16W	Yageo	RC0402FR-07909RL
R11	10 k Ω	10k Ω potentiometer; \pm 10%; 0.25W	Bourns	84WR10KLFTR
R13	3.6 k Ω	0402; \pm 1%; 1/16W	Vishay	CRCW04023K60FKED
U1, U2, U3	N/A	3V, 20A, two-stage buck regulator	pSemi	PE24111A
<i>Optional components for evaluation purposes</i>				
C1	330 μ F	Electrolytic; \pm 20%; 6.3V; 105C	Nichicon	UCL0J331MCL1GS
C2	47 μ F	1210; \pm 20%; 10V; X7R	Murata	GRM32ER70J476KE20L
C12, C13, C30, C31, C48, C49	DNI	DNI (10 μ F)	0402; \pm 20%; 4V; X7T	Murata
C19, C37, C55	DNI	DNI (100 μ F)	0603; \pm 20%; 2.5V; X6S	Murata
L7, L8	DNI	N/A	N/A	
D1	N/A	5V Surface Mount TVS Diode	Vishay	SMF5V0A-E3-08
J1, J2, J3, J4	N/A	Banana Connectors	Keystone Electronics	575-4

Reference	Value	Description	Manufacturer	Part number
J3, J4 (DNI)	N/A	Banana Connectors	Keystone Electronics	575-4
J5, J6	N/A	M5, 80A PCB Screw Terminal	Blockmaster	OT-017F-M4
J7	N/A	18 pin header	Samtec	TSW-106-07-L-T
J8	N/A	6 pin header	Harwin	M20-9980346
LED1	N/A	62.5mW 2-pin SMD Red LED	Lite-on	LTST-C190KRKT
Q1	N/A	25V; 4-pin PQFN; N-Channel MOSFET	Infineon	ISK024NE2LM5AULA1
Q2	N/A	20V; 0.2A; N-Channel MOSFET	ROHM	RE1C002UNTCL
R10	51Ω	0402; ±1%; 1/16W	Yageo Group	AC0402FR-0751RL
R12	4.99 kΩ	0402; ±1%; 1/10W	Panasonic	ERJ-2RKF4991X
R14	3Ω	0402; ±5%; 1/16W	ROHM	MCR01MZPJ3R0
R15	0.02Ω	2512; ±1%; 3W	Bourns	CRA2512-FZ-R020ELF
R16, R17	10 kΩ	0402; ±5%; 1/5W	Vishay	CRCW040210K0FKEDHP
R18	470 kΩ	0402; ±1%; 1/10W	Vishay	CRCW0402499KFKED
TP1, TP5, TP18, TP19, TP20, TP24, TP26	N/A	Test point	Keystone	5010
TP7, TP13, TP14, TP15, TP16	N/A	Test point	Keystone	5012
TP3, TP4, TP6, TP8, TP21, TP22, TP23, TP25, TP27	N/A	Test point	Keystone	5011
TP2, TP10, TP11, TP12, TP17	N/A	Test point	Keystone	5016

PE24111 EVK BOM list, x2 configuration

Table 5. x2 EVK BOM List

Reference	Value	Description	Manufacturer	Part number
<i>Required components</i>				
C3, C4, C5, C6, C21, C22, C23, C24	4.7 μ F	0402; \pm 20%; 6.3V; X7T	Murata	GRM155D70J475ME15D
C7, C8, C9, C10, C25, C26, C27, C28	22 μ F	0603; \pm 20%; 6.3V; X7T	Murata	GRM188D70J226ME01D
C11, C29	10 μ F	0402; \pm 20%; 4V; X7T	Murata	GRM155D70G106ME18D
C14, C15, C16, C17, C18, C32, C33, C34, C35, C36	100 μ F	0603; \pm 20%; 2.5V; X6S	Murata	GRM188C80E107ME01
C20, C38	10 nF	0402; \pm 10%; 50V; X7R	Murata	GCM155R71H103KA55D
C57	470 pF	0402; \pm 5%; 50V; C0G	Murata	GRM1555C1H471JA01D
L1, L2, L3, L4	100 nH	1210; 8A; 8m Ω max DCR	TDK	TFM322512ALMAR10MTAA
R1, R4	10 k Ω	0402; \pm 1%; 1/10W	Panasonic	ERJ-2RKF1002X
R2, R5	287 k Ω	0402; \pm 1%; 1/10W	Panasonic	ERJ-2RKF2873X
R3, R6	909 Ω	0402; \pm 1%; 1/16W	Yageo	RC0402FR-07909RL
R11	10 k Ω	10k Ω Potentiometer; \pm 10%; 0.25W	Bourns	84WR10KLFTR
R13	3.6 k Ω	0402; \pm 1%; 1/16W	Vishay	CRCW04023K60FKED
U1, U2	N/A	3V, 20A, Two-Stage Buck Regulator	pSemi Corporation	PE24111A
<i>Optional components for evaluation purposes</i>				
C1	330 μ F	Electrolytic; \pm 20%; 6.3V; 105C	Nichicon	UCL0J331MCL1GS
C2	47 μ F	1210; \pm 20%; 10V; X7R	Murata	GRM32ER70J476KE20L
C12, C13, C30, C31, C48, C49	DNI	DNI (10 μ F)	0402; \pm 20%; 4V; X7T	Murata
C19, C37, C55	DNI	DNI (100 μ F)	0603; \pm 20%; 2.5V; X6S	Murata
L7, L8	DNI	N/A	N/A	–
D1	N/A	5V Surface Mount TVS Diode	Vishay	SMF5V0A-E3-08
J1, J2, J3, J4	N/A	Banana Connectors	Keystone Electronics	575-4
J3, J4 (DNI)	N/A	Banana Connectors	Keystone Electronics	575-4

Reference	Value	Description	Manufacturer	Part number
J5, J6	N/A	M5, 80A PCB Screw Terminal	Blockmaster	OT-017F-M4
J7	N/A	18 pin header	Samtec	TSW-106-07-L-T
J8	N/A	6 pin header	Harwin	M20-9980346
LED1	N/A	62.5mW 2-pin SMD Red LED	Lite-on	LTST-C190KRKT
Q1	N/A	25V; 4-pin PQFN; N-Channel MOSFET	Infineon	ISK024NE2LM5AULA1
Q2	N/A	20V; 0.2A; N-Channel MOSFET	ROHM	RE1C002UNTCL
R10	51Ω	0402; ±1%; 1/16W	Yageo Group	AC0402FR-0751RL
R12	4.99 kΩ	0402; ±1%; 1/10W	Panasonic	ERJ-2RKF4991X
R14	3Ω	0402; ±5%; 1/16W	ROHM	MCR01MZPJ3R0
R15	0.02Ω	2512; ±1%; 3W	Bourns	CRA2512-FZ-R020ELF
R16, R17	10 kΩ	0402; ±5%; 1/5W	Vishay	CRCW040210K0FKEDHP
R18	470 kΩ	0402; ±1%; 1/10W	Vishay	CRCW0402499KFKED
TP1, TP5, TP18, TP19, TP20, TP24, TP26	N/A	Test point	Keystone	5010
TP7, TP13, TP14, TP15, TP16	N/A	Test point	Keystone	5012
TP3, TP4, TP6, TP8, TP21, TP22, TP23, TP25, TP27	N/A	Test point	Keystone	5011
TP2, TP10, TP11, TP12, TP17	N/A	Test point	Keystone	5016

PE24111 EVK BOM list, x1 configuration

Table 6. x1 EVK BOM list

Reference	Value	Description	Manufacturer	Part number
<i>Required components</i>				
C3, C4, C5, C6	4.7 μ F	0402; \pm 20%; 6.3V; X7T	Murata	GRM155D70J475ME15D
C7, C8, C9, C10	22 μ F	0603; \pm 20%; 6.3V; X7T	Murata	GRM188D70J226ME01D
C11	10 μ F	0402; \pm 20%; 4V; X7T	Murata	GRM155D70G106ME18D
C14, C15, C16, C17, C18	100 μ F	0603; \pm 20%; 2.5V; X6S	Murata	GRM188C80E107ME01
C20	10 nF	0402; \pm 10%; 50V; X7R	Murata	GCM155R71H103KA55D
C57	470 pF	0402; \pm 5%; 50V; C0G	Murata	GRM1555C1H471JA01D
L1, L2	100 nH	1210; 8A; 8m Ω max DCR	TDK	TFM322512ALMAR10MTAA
R1	10 k Ω	0402; \pm 1%; 1/10W	Panasonic	ERJ-2RKF1002X
R2	287 k Ω	0402; \pm 1%; 1/10W	Panasonic	ERJ-2RKF2873X
R3	909 Ω	0402; \pm 1%; 1/16W	Yageo	RC0402FR-07909RL
R11	10 k Ω	10k Ω Potentiometer; \pm 10%; 0.25W	Bourns	84WR10KLFTR
R13	3.6 k Ω	0402; \pm 1%; 1/16W	Vishay	CRCW04023K60FKED
U1	N/A	3V, 20A, Two-Stage Buck Regulator	pSemi Corporation	PE24111A
<i>Optional components for evaluation purposes</i>				
C1	330 μ F	Electrolytic; \pm 20%; 6.3V; 105C	Nichicon	UCL0J331MCL1GS
C2	47 μ F	1210; \pm 20%; 10V; X7R	Murata	GRM32ER70J476KE20L
C12, C13, C30, C31, C48, C49	DNI	DNI (10 μ F)	0402; \pm 20%; 4V; X7T	Murata
C19, C37, C55	DNI	DNI (100 μ F)	0603; \pm 20%; 2.5V; X6S	Murata
L7, L8	DNI	N/A	N/A	–
D1	N/A	5V Surface Mount TVS Diode	Vishay	SMF5V0A-E3-08
J1, J2, J3, J4	N/A	Banana Connectors	Keystone Electronics	575-4
J3, J4 (DNI)	N/A	Banana Connectors	Keystone Electronics	575-4
J5, J6	N/A	M5, 80A PCB Screw Terminal	Blockmaster	OT-017F-M4
J7	N/A	18 pin header	Samtec	TSW-106-07-L-T

Reference	Value	Description	Manufacturer	Part number
J8	N/A	6 pin header	Harwin	M20-9980346
LED1	N/A	62.5mW 2-pin SMD Red LED	Lite-on	LTST-C190KRKT
Q1	N/A	25V; 4-pin PQFN; N-Channel MOSFET	Infineon	ISK024NE2LM5AULA1
Q2	N/A	20V; 0.2A; N-Channel MOSFET	ROHM	RE1C002UNTCL
R10	51Ω	0402; ±1%; 1/16W	Yageo Group	AC0402FR-0751RL
R12	4.99 kΩ	0402; ±1%; 1/10W	Panasonic	ERJ-2RKF4991X
R14	3Ω	0402; ±5%; 1/16W	ROHM	MCR01MZPJ3R0
R15	0.02Ω	2512; ±1%; 3W	Bourns	CRA2512-FZ-R020ELF
R16, R17	10 kΩ	0402; ±5%; 1/5W	Vishay	CRCW040210K0FKEDHP
R18	470 kΩ	0402; ±1%; 1/10W	Vishay	CRCW0402499KFKED
TP1, TP5, TP18, TP19, TP20, TP24, TP26	N/A	Test point	Keystone	5010
TP7, TP13, TP14, TP15, TP16	N/A	Test point	Keystone	5012
TP3, TP4, TP6, TP8, TP21, TP22, TP23, TP25, TP27	N/A	Test point	Keystone	5011
TP2, TP10, TP11, TP12, TP17	N/A	Test point	Keystone	5016

Technical resources

Additional technical resources are available for download in the Products section at <http://www.psemi.com>. These include the product specification data sheet, S-parameters, zip file, evaluation kit schematic, bill of materials, material declaration form, and PC-compatible software file.

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