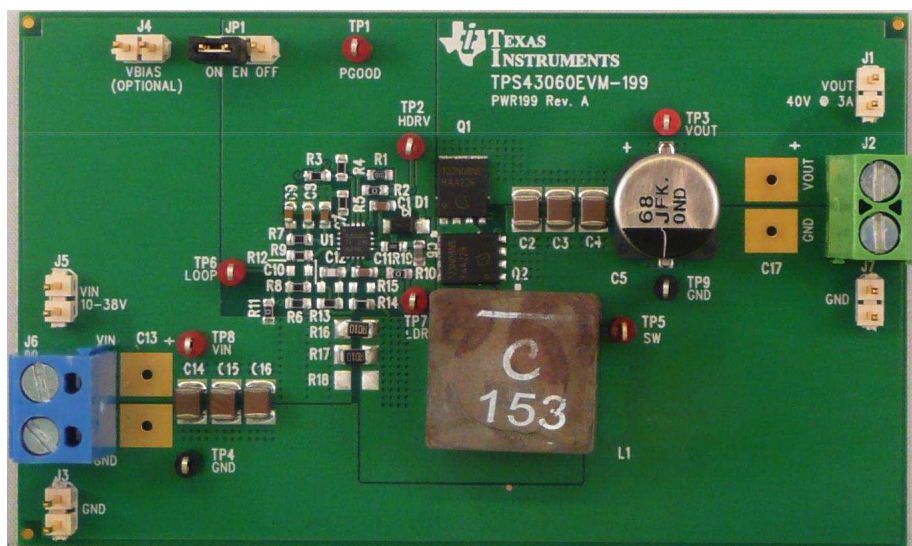


## Using the TPS43060 Boost Evaluation Module (EVM)



This user's guide contains information for the TPS43060EVM-199 evaluation module (PWR199) including the performance specifications, schematic, and the bill of materials.

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## 1 Introduction

This user's guide contains background information for the TPS43060 as well as support documentation for the TPS43060EVM-199 evaluation module (PWR199). Also included are the performance specifications, schematic, and the bill of materials for the EVM.

### 1.1 Background

The TPS43060 is a DC-DC synchronous boost controller designed for a maximum output voltage of 58 V from an input voltage source of 4.5 V to 38 V. It has a 7.5-V gate-drive supply optimized for use with standard threshold MOSFETs. Rated input voltage and output current range for the evaluation module are given in [Table 1](#). This evaluation module is designed to demonstrate the high efficiency and high power possible when designing with the TPS43060 controller. The switching frequency is externally set at a nominal 300 kHz. The gate-drive circuitry for the external high-side and low-side FET is incorporated inside the TPS43060 package. PWR199 uses the Infineon BSC123N08NS3G for both the high-side and low-side MOSFETs. External inductor DCR or resistor current sensing allows for an adjustable cycle-by-cycle current limit. The compensation components are external to the integrated circuit (IC), and an external resistor divider allows for an adjustable output voltage. Additionally, the TPS43060 provides an adjustable undervoltage lockout with hysteresis through an external resistor divider, adjustable slow-start time with an external capacitor and a power good output voltage indicator. The absolute maximum input voltage for the PWR199 is 38 V.

**Table 1. Input Voltage and Output Current Summary**

| EVM             | Input Voltage Range                   | Output Current Range                 |
|-----------------|---------------------------------------|--------------------------------------|
| TPS43060EVM-199 | $V_{IN} = 10\text{ V to }38\text{ V}$ | $I_{OUT} = 0\text{ A to }3\text{ A}$ |

## 1.2 Performance Specification Summary

A summary of the EVM performance specifications is provided in [Table 2](#). Specifications are given for an input voltage of  $V_{IN} = 24\text{ V}$  and an output voltage of  $40\text{ V}$ , unless otherwise specified. This EVM is designed and tested for  $V_{IN} = 10\text{ V}$  to  $38\text{ V}$ . The ambient temperature is  $25^{\circ}\text{C}$  for all measurements, unless otherwise noted.

**Table 2. TPS43060EVM-199 Performance Specification Summary**

| Specification            | Test Conditions                                                  | MIN            | TYP         | MAX  | Unit |
|--------------------------|------------------------------------------------------------------|----------------|-------------|------|------|
| $V_{IN}$ voltage range   |                                                                  | 10             | 24          | 38   | V    |
| Output voltage set point |                                                                  |                | 40          |      | V    |
| Output current range     | $V_{IN} = 15\text{ V}$ to $38\text{ V}$                          | 0              |             | 3    | A    |
| Output current range     | $V_{IN} = 10\text{ V}$                                           | 0              |             | 2    | A    |
| Line regulation          | $V_{IN} = 10\text{ V}$ to $35\text{ V}$ , $I_{OUT} = 2\text{ A}$ |                | $\pm 0.1\%$ |      |      |
| Load regulation          | $I_{OUT} = 0.001\text{ A}$ to $3\text{ A}$                       |                | $\pm 0.1\%$ |      |      |
| Load transient response  | $I_{OUT} = 0.75\text{ A}$ to $2.25\text{ A}$                     | Voltage change |             | -700 | mV   |
|                          |                                                                  | Recovery time  |             | 1    | ms   |
|                          | $I_{OUT} = 2.25\text{ A}$ to $0.75\text{ A}$                     | Voltage change |             | 600  | mV   |
|                          |                                                                  | Recovery time  |             | 1    | ms   |
| Loop bandwidth           | $I_{OUT} = 3\text{ A}$                                           |                | 4.7         |      | kHz  |
| Phase margin             | $I_{OUT} = 3\text{ A}$                                           |                | 64          |      | °    |
| Input voltage ripple     | $I_{OUT} = 3\text{ A}$                                           |                | 100         |      | mVpp |
| Output voltage ripple    | $I_{OUT} = 3\text{ A}$                                           |                | 350         |      | mVpp |
| Output rise time         |                                                                  |                | 25          |      | ms   |
| Operating frequency      |                                                                  |                | 300         |      | kHz  |
| Peak efficiency          | $I_{OUT} = 3\text{ A}$                                           |                | 97.7%       |      |      |
| DCM threshold            |                                                                  |                | 660         |      | mA   |
| Pulse skipping threshold |                                                                  |                | 3.5         |      | mA   |
| No load input current    |                                                                  |                | 1.3         |      | mA   |
| UVLO start threshold     |                                                                  |                | 9.66        |      | V    |
| UVLO stop threshold      |                                                                  |                | 7.92        |      | V    |

Figure 1 is the schematic for the EVM.

### Figure 1. TPS43060EVM-199 Schematic

### 1.4.2 Current Sensing

The default configuration of the EVM is for resistor current sensing. R13 and R14 are populated with R15 open. When adjusting the input voltage, output voltage or desired maximum output voltage, the current sense resistors R16 and R17 may need to be adjusted. The peak inductor current should first be calculated with Equation 2. Equation 3 is then used to calculate the required current sense resistor where  $V_{CS\text{typ}}$  is the current sense threshold.  $V_{CS\text{typ}}$  should be determined from the TPS43060 data sheet with the maximum duty cycle in the application. Ensure the current sense resistor is rated for the expected power dissipation. For inductor DCR current sensing, R14 should be left open while R15, R16, R17 and R18 are shorted.

$$I_{L\text{peak}} = \frac{I_{OUT}}{1 - \frac{V_{OUT} - V_{IN\text{min}}}{V_{OUT}}} + \frac{V_{IN\text{min}} \times \frac{V_{OUT} - V_{IN\text{min}}}{V_{OUT}}}{2 \times L \times f_{SW}} \quad (2)$$

$$R_{CS} = \frac{V_{CS\text{typ}}}{1.2 \times I_{L\text{peak}}} \quad (3)$$

### 1.4.3 Slow-Start Time

Adjust the slow-start time by changing the value of C7. Equation 4 can be used to calculate the required capacitance based on a desired slow-start time,  $t_{SS}$ .  $I_{SS}$  is the charging current of 5- $\mu\text{A}$  typical and  $V_{REF}$  is the internal reference voltage of 1.22 V. The EVM is set for a slow-start time of 25 ms using  $C7 = 0.1 \mu\text{F}$ .

$$C_{SS} = \frac{t_{SS} \times I_{SS}}{V_{REF}} \quad (4)$$

### 1.4.4 Adjustable UVLO

The undervoltage lockout (UVLO) can be adjusted externally using R3 and R4. The EVM is set for a start voltage of 9.66 V and stop voltage of 7.92 V, using  $R3 = 357 \text{ k}\Omega$  and  $R4 = 47.5 \text{ k}\Omega$ . Use Equation 5 and Equation 6 to calculate the required resistor values for R3 and R4, respectively, for different start and stop voltages. The typical values of the constants in the two equations are as follows:  $V_{EN\_DIS} = 1.14 \text{ V}$ ,  $V_{EN\_ON} = 1.21 \text{ V}$ ,  $I_{EN\_pup} = 1.8 \mu\text{A}$ , and  $I_{EN\_hys} = 3.2 \mu\text{A}$ .

$$R_{UVLO\_H} = \frac{V_{START} \times \left( \frac{V_{EN\_DIS}}{V_{EN\_ON}} \right) - V_{STOP}}{I_{EN\_pup} \times \left( 1 - \frac{V_{EN\_DIS}}{V_{EN\_ON}} \right) + I_{EN\_hys}} \quad (5)$$

$$R_{UVLO\_L} = \frac{R_{UVLO\_H} \times V_{EN\_DIS}}{V_{STOP} - V_{EN\_DIS} + R_{UVLO\_H} \times (I_{EN\_pup} + I_{EN\_hys})} \quad (6)$$

### 1.4.5 Input Voltage Rails

The EVM is designed to accommodate different input voltage levels for the power stage and control logic. In the default configuration, the VIN inputs connected with R11 populated with a 0- $\Omega$  resistor. The input voltage is supplied to J6. If desired, the two input voltage rails may be separated by unpopulating R11. The control logic input voltage can be supplied to J4 and the power stage input voltage to J6.

### 1.4.6 Further Modification

Changing the input and output of conditions of the EVM will impact the design. It may also be necessary to modify the inductor, output capacitor and compensation components for the desired performance in the application. Please see the data sheet or the excel design spreadsheet located in the product folder for details.

## 2 Test Setup and Results

This section describes how to properly connect, set up, and use the EVM. The section also includes test results typical for the EVM covering efficiency, output voltage regulation, load transients, loop response, output ripple, input ripple, start up and shutdown.

### 2.1 Input/Output Connections

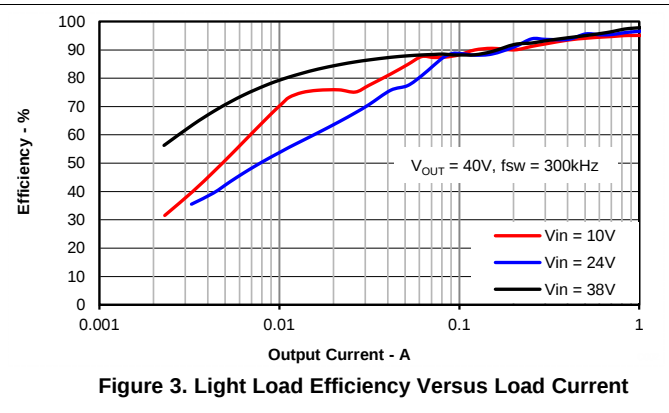
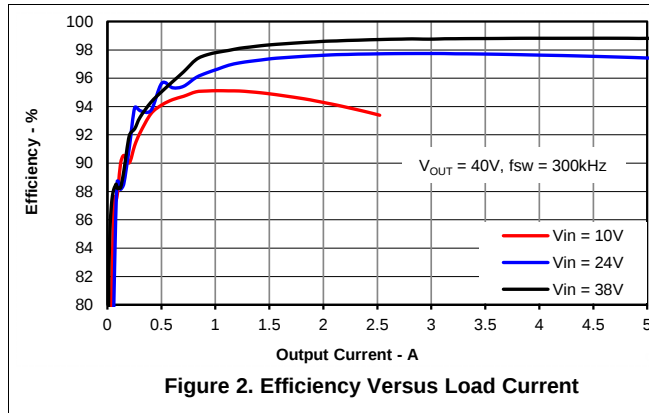
This EVM includes I/O connectors and test points as shown in [Table 3](#). A power supply capable of supplying at least 12 A must be connected to J6 through a pair of 20-AWG wires. The load must be connected to J2 through a pair of 20-AWG wires. The maximum load-current capability must be 3 A. Wire lengths must be minimized to reduce losses in the wires. If any modification is done to the EVM design, an input supply and load rated for the new design are required. Test point TP8 provides a connection to monitor the  $V_{IN}$  input voltages with TP9 providing a convenient ground reference. TP3 is used to monitor the output voltage with TP4 as the ground reference.

**Table 3. EVM Connectors and Test points**

| Reference Designator | Function                                                                                            |
|----------------------|-----------------------------------------------------------------------------------------------------|
| J1                   | 2-pin header for $V_{OUT}$ voltage connections                                                      |
| J2                   | $V_{OUT}$ , 40 V at 3-A maximum                                                                     |
| J3                   | 2-pin header for GND connections                                                                    |
| J4                   | 2-pin header for optional $V_{BIAS}$ input voltage connections (see <a href="#">Section 1.4.5</a> ) |
| J5                   | 2-pin header for $V_{IN}$ input voltage connections                                                 |
| J6                   | $V_{IN}$ (see <a href="#">Table 1</a> for $V_{IN}$ range)                                           |
| J7                   | 2-pin header for GND connections                                                                    |
| JP1                  | 3-pin header for EN jumper. Install jumper from pins 1-2 to enable or pins 2-3 to disable.          |
| TP1                  | PGOOD test point for power good output voltage indicator                                            |
| TP2                  | HDRV test point for high-side gate-drive voltage                                                    |
| TP3                  | $V_{OUT}$ test point at $V_{OUT}$ connector                                                         |
| TP4                  | GND test point at $V_{OUT}$ connector                                                               |
| TP5                  | SW test point for switch node voltage                                                               |
| TP6                  | Test point between voltage divider network and output used for loop response measurements           |
| TP7                  | LDRV test point for low-side gate-drive voltage                                                     |
| TP8                  | $V_{IN}$ test point at $V_{IN}$ connector                                                           |
| TP9                  | GND test point at $V_{IN}$ connector                                                                |

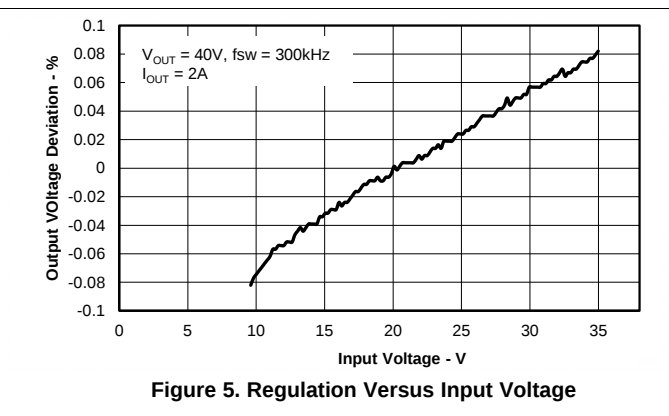
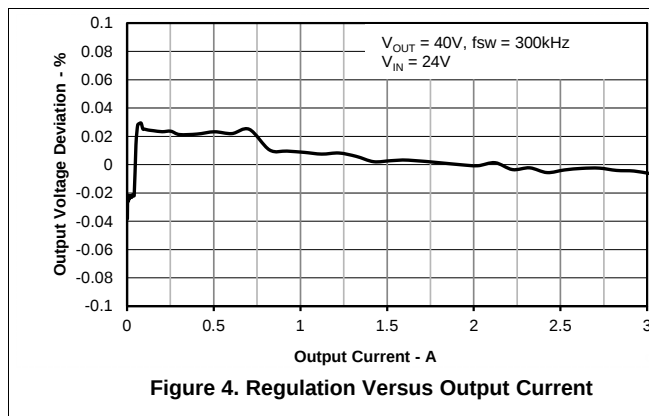
## 2.2 Efficiency

With the nominal  $V_{IN}$  of 24 V, the efficiency of this EVM peaks at a load current of about 3 A, and then decreases as the load current increases towards maximum load. Figure 2 shows the efficiency for the EVM up to current limit with 1-V input and up to a 5-A load with 24-V and 38-V input. Figure 3 shows the light load efficiency using a semi-log scale. Measurements are taken at ambient temperature of 25°C. The efficiency may be lower at higher ambient temperatures due to temperature variation in the drain-to-source resistance of the selected external MOSFETs.



## 2.3 Output Voltage Regulation

The load regulation for the EVM is shown in Figure 4. The line regulation for the EVM is shown in Figure 5. Measurements are given for an ambient temperature of 25°C.



## 2.4 Load Transients and Loop Response

The EVM response to load transients is shown in Figure 6. The current step is from 25% to 75% of maximum rated load at nominal 24-V input. Total peak-to-peak voltage variation is as shown, including ripple and noise on the output. The EVM loop-response characteristics are shown in Figure 7. Gain and phase plots are shown for nominal  $V_{IN}$  voltage of 24 V. Load current for the measurement is 3 A.

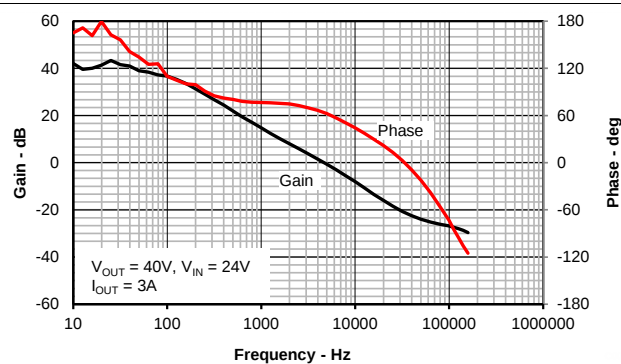
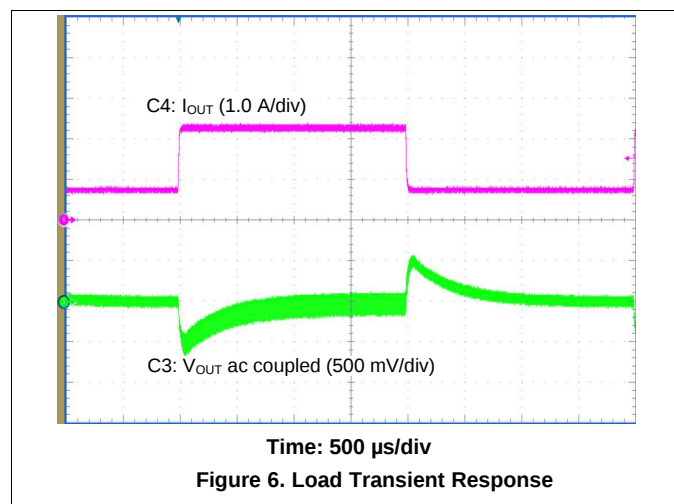


Figure 7. Loop Response

## 2.5 Output Voltage Ripple

The EVM continuous conduction mode (CCM) output voltage ripple is shown in Figure 8. The output current is the rated full load of 3 A and nominal  $V_{IN}$  of 24 V. The voltage ripple is measured directly across the output capacitors with a short ground lead. The discontinuous conduction mode (DCM) output voltage ripple is shown in Figure 9. The output current is 0.3 A and nominal  $V_{IN}$  of 24 V. The pulse skip mode output voltage ripple is shown in Figure 10. There is no external load on the output and nominal  $V_{IN}$  of 24 V.

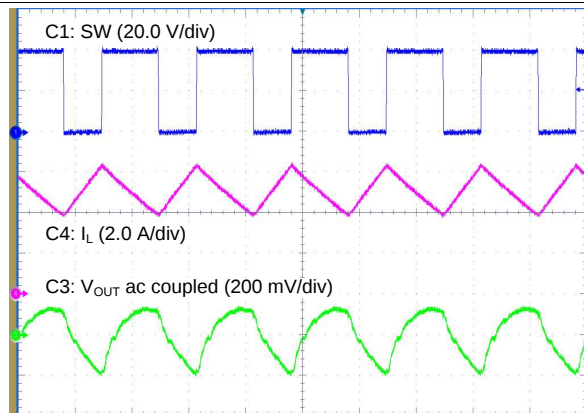

Time: 2.0  $\mu$ s/div

Figure 8. Output Voltage Ripple CCM

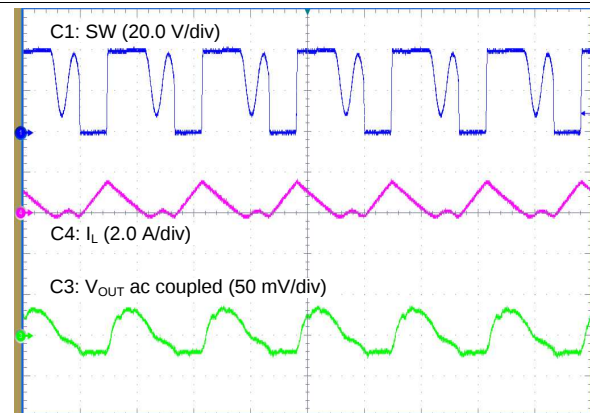
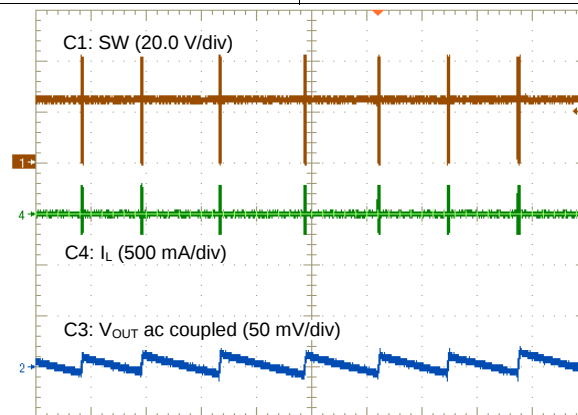

Time: 2.0  $\mu$ s/div

Figure 9. Output Voltage Ripple DCM

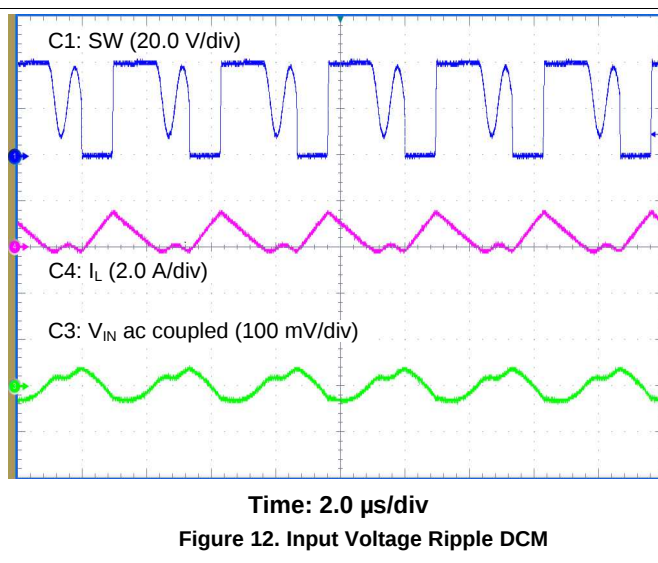
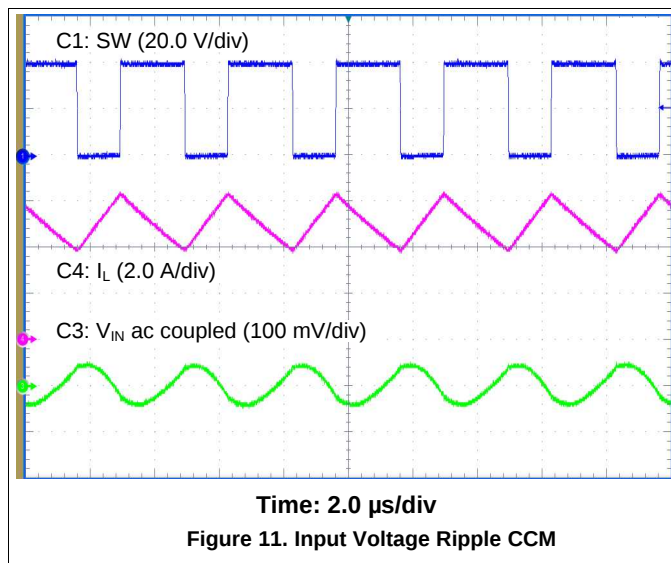


Time: 10.0 ms/div

Figure 10. Output Voltage Ripple Pulse Skip Mode

## 2.6 Input Voltage Ripple

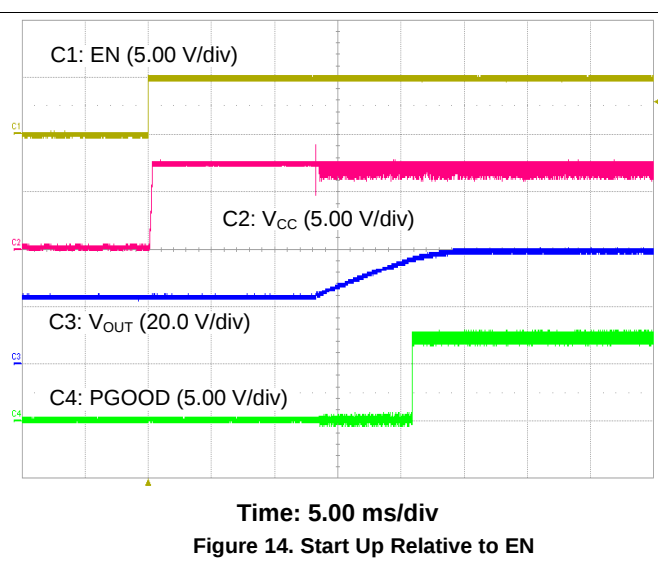
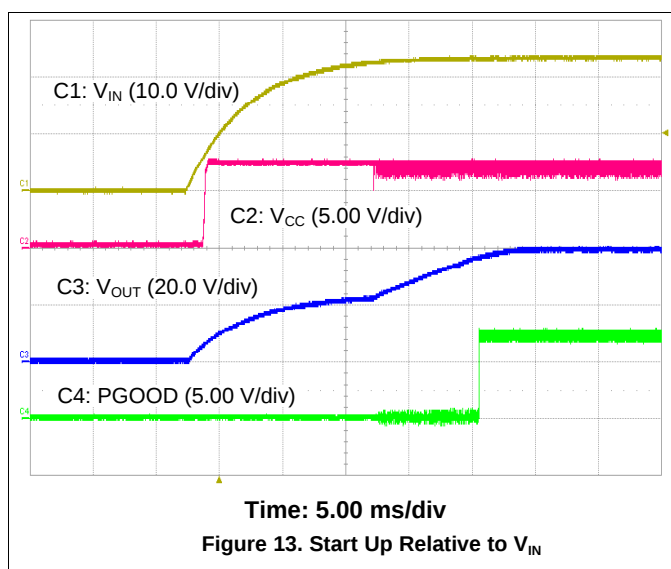
The EVM CCM input voltage ripple is shown in Figure 11. The output current is the rated full load of 3 A and nominal  $V_{IN}$  of 24 V. The voltage ripple is measured directly across the input capacitors. The DCM input voltage ripple is shown in Figure 12. The output current is 0.3 A and nominal  $V_{IN}$  of 24 V.



## 2.7 Start Up

The start up waveforms are shown in Figure 13 and Figure 14. The input voltage for these plots is the nominal 24 V and the output has a 2.5-A resistive load. In Figure 13 the input voltage supply is turned on and  $V_{IN}$  begins rising. Both the  $V_{CC}$  and  $V_{OUT}$  rail initially rise with  $V_{IN}$ . When the input reaches the undervoltage lockout threshold set by the external resistor divider, the device can begin switching and the output ramps up to the set value of 40 V with the slow-start voltage. PGOOD goes high when  $V_{OUT}$  is in regulation.

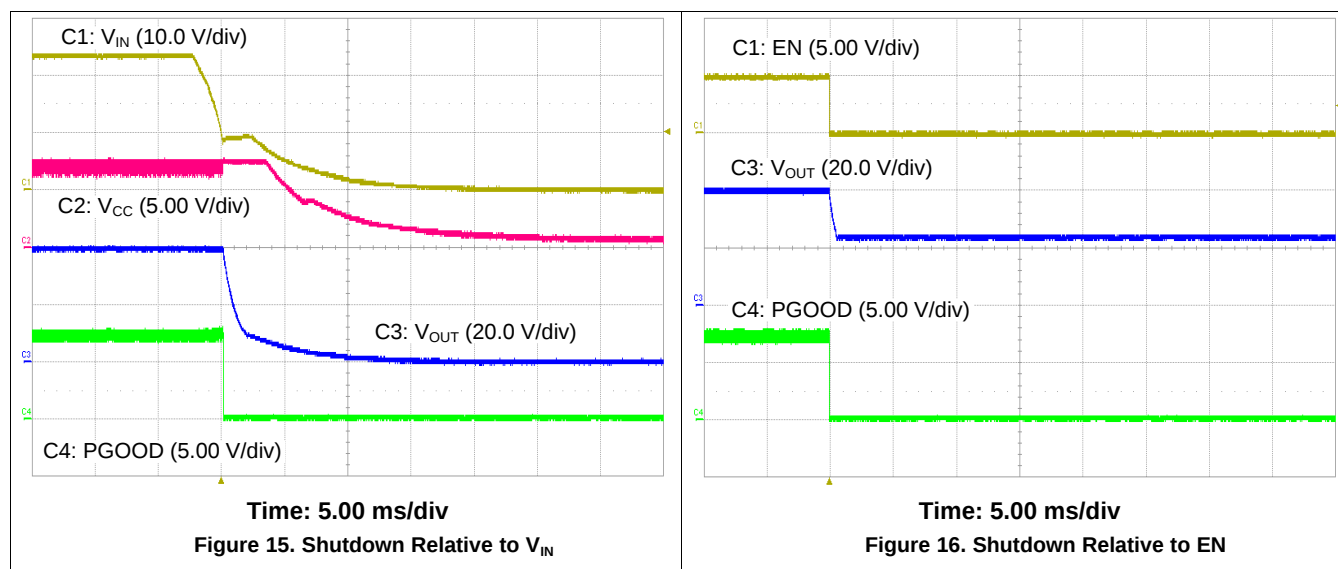
In Figure 14 the input voltage is applied with EN held low. The output voltage is a diode drop below the input voltage and  $V_{CC}$  is disabled. When EN is released, the start up sequence begins with  $V_{CC}$  coming into regulation and the output ramps up to the set value of 40 V. PGOOD goes high when  $V_{OUT}$  is in regulation.



## 2.8 Shutdown

The shutdown waveforms are shown in Figure 15 and Figure 16. In Figure 15 the input voltage is removed, and when the input falls below the undervoltage lockout threshold set by the EN resistor divider, the TPS43060 shuts down, PGOOD is pulled low and the output falls to ground. The output has a 2.5-A resistive load.

In Figure 16 the input voltage is held at 24 V with no load and EN is shorted to ground. When EN is grounded, the TPS43060 is disabled, PGOOD is pulled low and the output voltage discharges to  $V_{IN}$ .



## 2.9 Gate-Drive Signals

In Figure 17 the gate-drive signals for the high-side and low-side FETs can be seen with the switching node. The input voltage is 24 V and the output has a 3-A load.

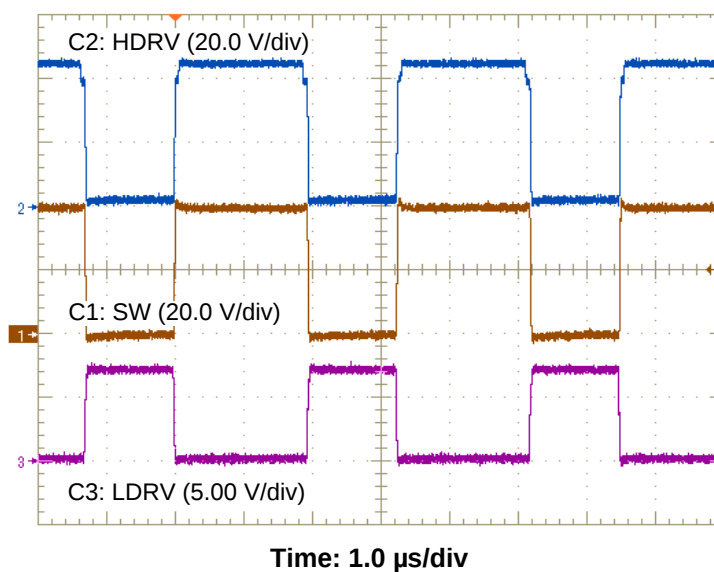


Figure 17. Gate-Drive Signals

### 3 Bill of Materials

Table 4 presents the bill of materials for the EVM.

**Table 4. TPS43060EVM-199 Bill of Materials**

| COUNT                                                                         | RefDes      | Value         | Description                                            | Size               | Part Number                    | MFR                 |
|-------------------------------------------------------------------------------|-------------|---------------|--------------------------------------------------------|--------------------|--------------------------------|---------------------|
| 1                                                                             | C5          | 68μF          | Capacitor, Aluminum, 63V, 20%                          | 0.406 x 0.406 inch | EEVFK1J680P                    | Panasonic           |
| 1                                                                             | C6          | 4.7μF         | Capacitor, Ceramic, 16V, X5R, 10%                      | 0603               | STD                            | STD                 |
| 1                                                                             | C8          | 1200pF        | Capacitor, Ceramic, 10V, X5R, 10%                      | 0603               | STD                            | STD                 |
| 1                                                                             | C9          | 0.022μF       | Capacitor, Ceramic, 10V, X5R, 10%                      | 0603               | STD                            | STD                 |
| 0                                                                             | C10         | Open          | Capacitor, Ceramic, 10V, X7R, 10%                      | 0603               | STD                            | STD                 |
| 1                                                                             | C12         | 100pF         | Capacitor, Ceramic, 50V, X7R, 20%                      | 0603               | STD                            | STD                 |
| 3                                                                             | C1 C7 C11   | 0.1μF         | Capacitor, Ceramic, 50V, X7R, 10%                      | 0603               | STD                            | STD                 |
| 5                                                                             | C2-4 C14-16 | 10μF          | Capacitor, Ceramic, 50V, X7R, 10%                      | 1210               | STD                            | STD                 |
| 0                                                                             | C13 C17     | Open          | Capacitor                                              | Multi sizes        | Engineering Only               | STD                 |
| 1                                                                             | D1          | MBR1H100SFT3G | Diode, Schottky Power Rectifier, 1A, 100V              | SOD-123LF          | MBR1H100SFT3G                  | On Semi             |
| 5                                                                             | J1 J3-5 J7  | PEC02SAAN     | Header, Male 2-pin, 100mil spacing                     | 0.100 inch x 2     | PEC02SAAN                      | Sullins             |
| 2                                                                             | J2 J6       | ED120/2DS     | Terminal Block, 2-pin, 15-A, 5.1mm                     | 0.40 x 0.35 inch   | ED120/2DS                      | OST                 |
| 1                                                                             | JP1         | PEC03SAAN     | Header, Male 3-pin, 100mil spacing                     | 0.100 inch x 3     | PEC03SAAN                      | Sullins             |
| 1                                                                             | L1          | 15μH          | Inductor, Shielded Power, 14A, 9mΩ                     | 15.2x16.2 mm       | XAL1510-153<br>alt:74435571500 | Coilcraft<br>alt:WE |
| 2                                                                             | Q1 Q2       | BSC123N08NS3G | MOSFET, Nch, 80V, 55A, 12.3mΩ                          | TDSON-8            | BSC123N08NS3G                  | Infineon            |
| 1                                                                             | R1          | 100k          | Resistor, Chip, 1/16W, 1%                              | 0603               | STD                            | STD                 |
| 1                                                                             | R3          | 357k          | Resistor, Chip, 1/16W, 1%                              | 0603               | STD                            | STD                 |
| 1                                                                             | R4          | 47.5k         | Resistor, Chip, 1/16W, 1%                              | 0603               | STD                            | STD                 |
| 1                                                                             | R5          | 191k          | Resistor, Chip, 1/16W, 1%                              | 0603               | STD                            | STD                 |
| 1                                                                             | R6          | 49.9          | Resistor, Chip, 1/16W, 1%                              | 0603               | STD                            | STD                 |
| 1                                                                             | R7          | 15.4k         | Resistor, Chip, 1/16W, 1%                              | 0603               | STD                            | STD                 |
| 1                                                                             | R8          | 348k          | Resistor, Chip, 1/16W, 1%                              | 0603               | STD                            | STD                 |
| 1                                                                             | R9          | 11.0k         | Resistor, Chip, 1/16W, 1%                              | 0603               | STD                            | STD                 |
| 0                                                                             | R18         | Open          | Resistor, Chip, 1W, 1%                                 | 1206               | STD                            | STD                 |
| 0                                                                             | R12 R15     | Open          | Resistor, Chip, 1/16W, 1%                              | 0603               | STD                            | STD                 |
| 2                                                                             | R13-14      | 10            | Resistor, Chip, 1/16W, 1%                              | 0603               | STD                            | STD                 |
| 2                                                                             | R16-17      | 10m           | Resistor, Chip, 1W, 1%                                 | 1206               | STD                            | STD                 |
| 3                                                                             | R2 R10-11   | 0             | Resistor, Chip, 1/16W, 1%                              | 0603               | STD                            | STD                 |
| 1                                                                             | SH1         |               | Short jumper, 100mil                                   | 0.100 inch         | 929950-00                      | 3M                  |
| 2                                                                             | TP4 TP9     | 5001          | Test Point, Black, Thru Hole Color Keyed               | 0.100 x 0.100 inch | 5001                           | Keystone            |
| 7                                                                             | TP1-3 TP5-8 | 5000          | Test Point, Red, Thru Hole Color Keyed                 | 0.100 x 0.100 inch | 5000                           | Keystone            |
| 1                                                                             | U1          | TPS43060RTE   | IC, Wide VIN Current Mode Synchronous Boost Controller | VQFN               | TPS43060RTE                    | TI                  |
| 1                                                                             | --          |               | PCB, 3.5 in x 2.1 in x 0.062 in                        |                    | PWR199                         | Any                 |
| Notes:                                                                        |             |               |                                                        |                    |                                |                     |
| 1. These assemblies are ESD sensitive, ESD precautions shall be observed.     |             |               |                                                        |                    |                                |                     |
| 2. These assemblies must be clean and free from flux and all contaminants.    |             |               |                                                        |                    |                                |                     |
| Use of no clean flux is not acceptable.                                       |             |               |                                                        |                    |                                |                     |
| 3. These assemblies must comply with workmanship standards IPC-A-610 Class 2. |             |               |                                                        |                    |                                |                     |
| 4. Ref designators marked with an asterisk (**) cannot be substituted.        |             |               |                                                        |                    |                                |                     |
| All other components can be substituted with equivalent MFG's components.     |             |               |                                                        |                    |                                |                     |

## 4 Board Layout

This section provides a description of the EVM, board layout, and layer illustrations.

### 4.1 Layout

The board layout for the EVM is shown in Figure 18 through Figure 22. This design has 4 layers of 2-oz copper.

The top layer contains the main power traces for  $V_{IN}$ ,  $V_{OUT}$ , and SW. Also on the top layer are all other components to allow the user to easily view, probe, and evaluate the TPS43060 control IC. The remaining area is filled with ground. The remaining three layers have additional copper for VIN, VOUT, AGND, and PGND connected with multiple vias. Additional copper is also connected to the sense resistor to aid with thermal dissipation. The second internal layer and bottom layer contain signal routes. Four vias directly under the TPS43060 device provide a thermal path from the top-side ground plane to the bottom-side and internal AGND plane. Lastly, the layout guidelines should be followed for Q1 and Q2. Vias are placed near both FETs to aid with thermal dissipation.

All noise-sensitive analog circuitry are placed as close as possible to the IC. The voltage divider network ties to the output voltage at the point of regulation on the bottom layer, near the output capacitors. Q1 and Q2 are placed as close as possible to the IC to keep the gate-drive traces as short as possible. The output capacitors are placed next to Q1 and Q2 to limit the length of the high frequency switching current path. The SW copper is kept as small as possible to limit radiated noise from the high-frequency switching voltage node. The power pad is connected to the AGND pin and all noise-sensitive circuitry must use this as the ground return path. The ground return for the power components are connected to the PGND pin. The AGND and PGND are connected at one point near the PGND pin. The bypass capacitors for VIN and VCC are placed next to their respective pins. The filter capacitor between ISNS+ and ISNS– is located next to the pins to help filter out switching noise. An additional input bulk capacitor may be required (C13) depending on the connection to the EVM from the input supply. See the product datasheet for all layout recommendations.

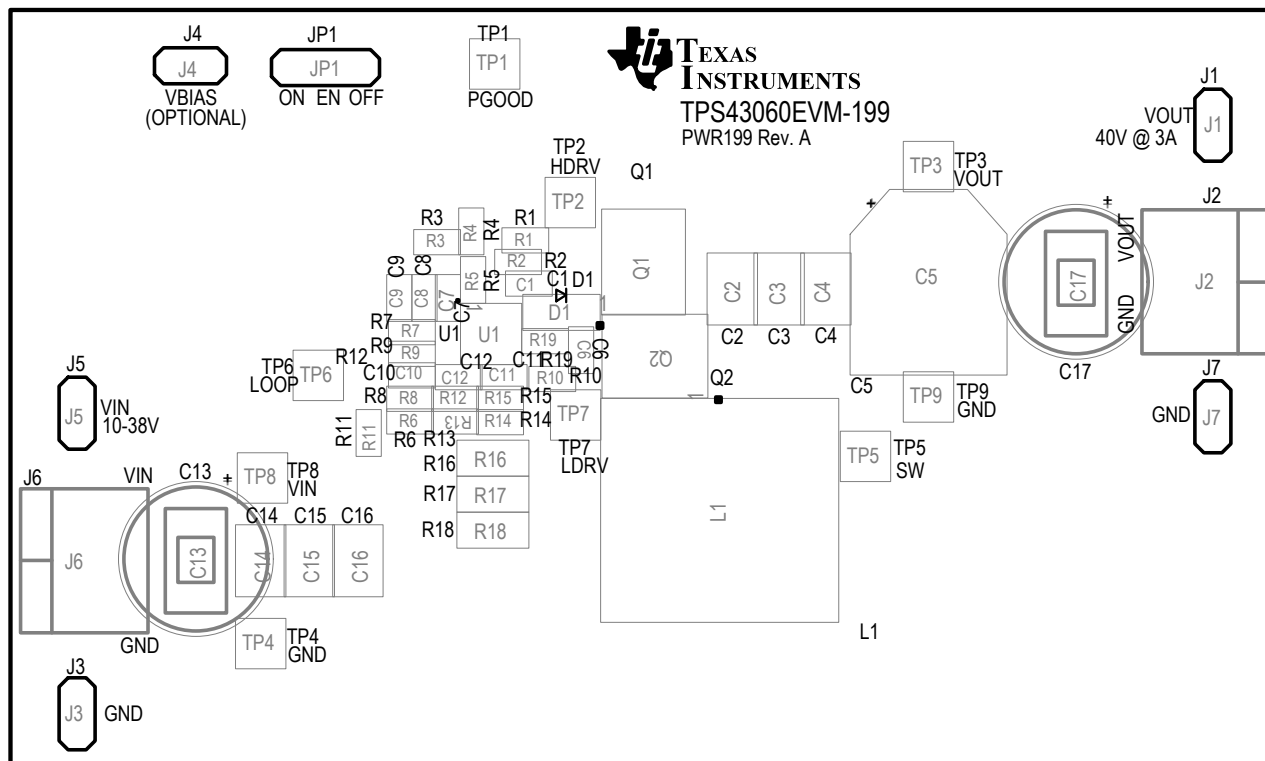


Figure 18. TPS43060EVM-199 Top Assembly and Silkscreen

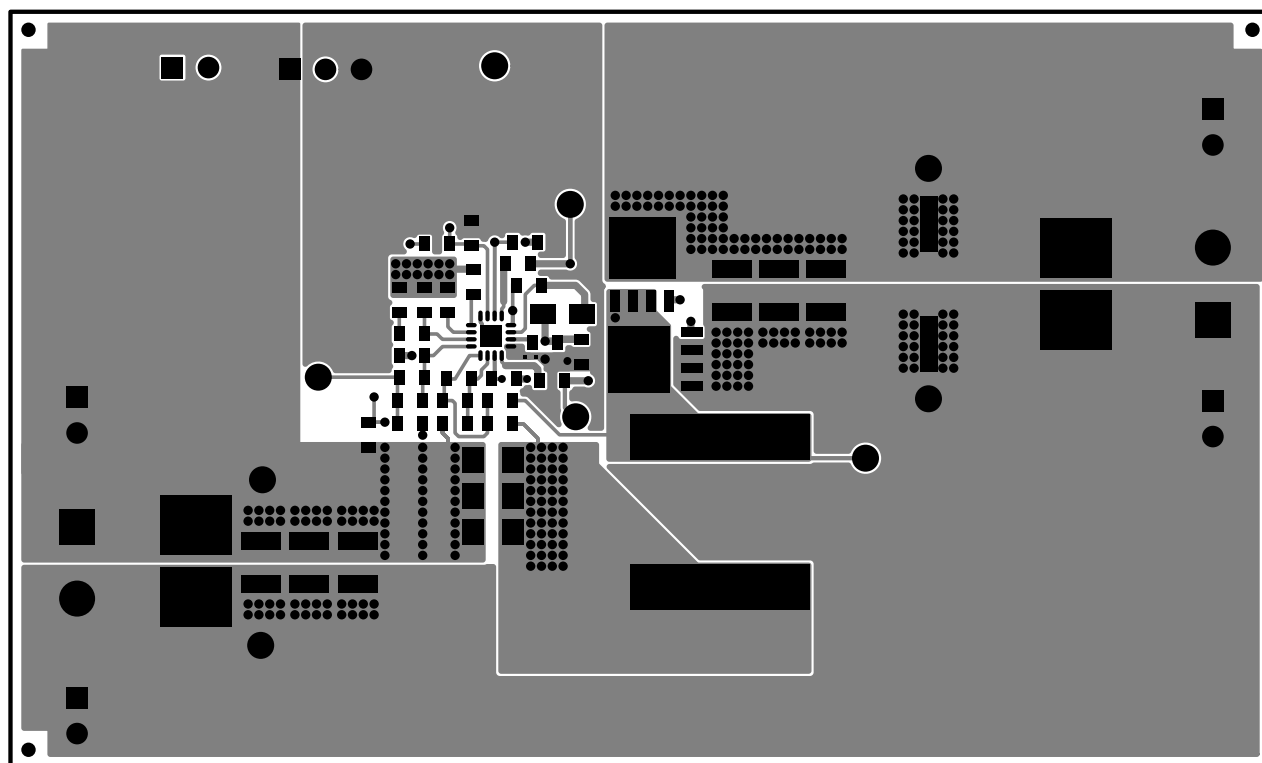


Figure 19. TPS43060EVM-199 Top-Side Layout

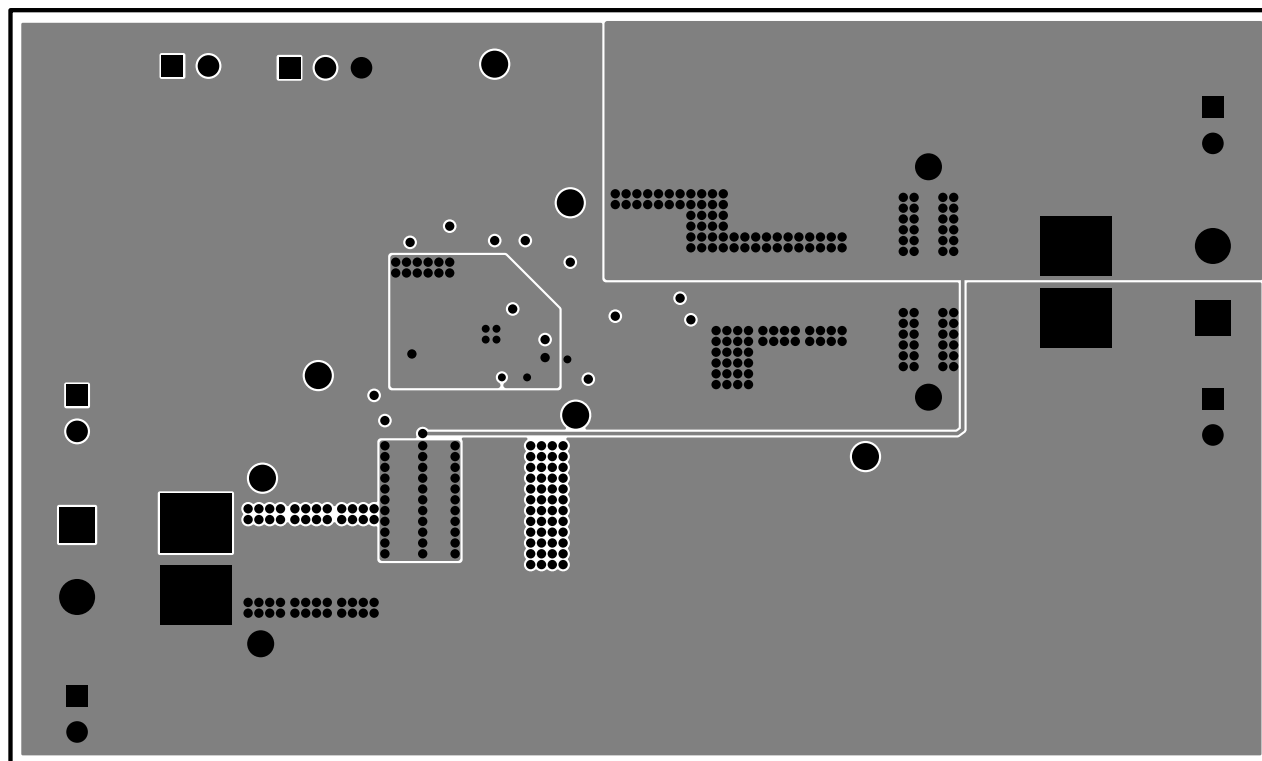


Figure 20. TPS43060EVM-199 Layer 2 Layout

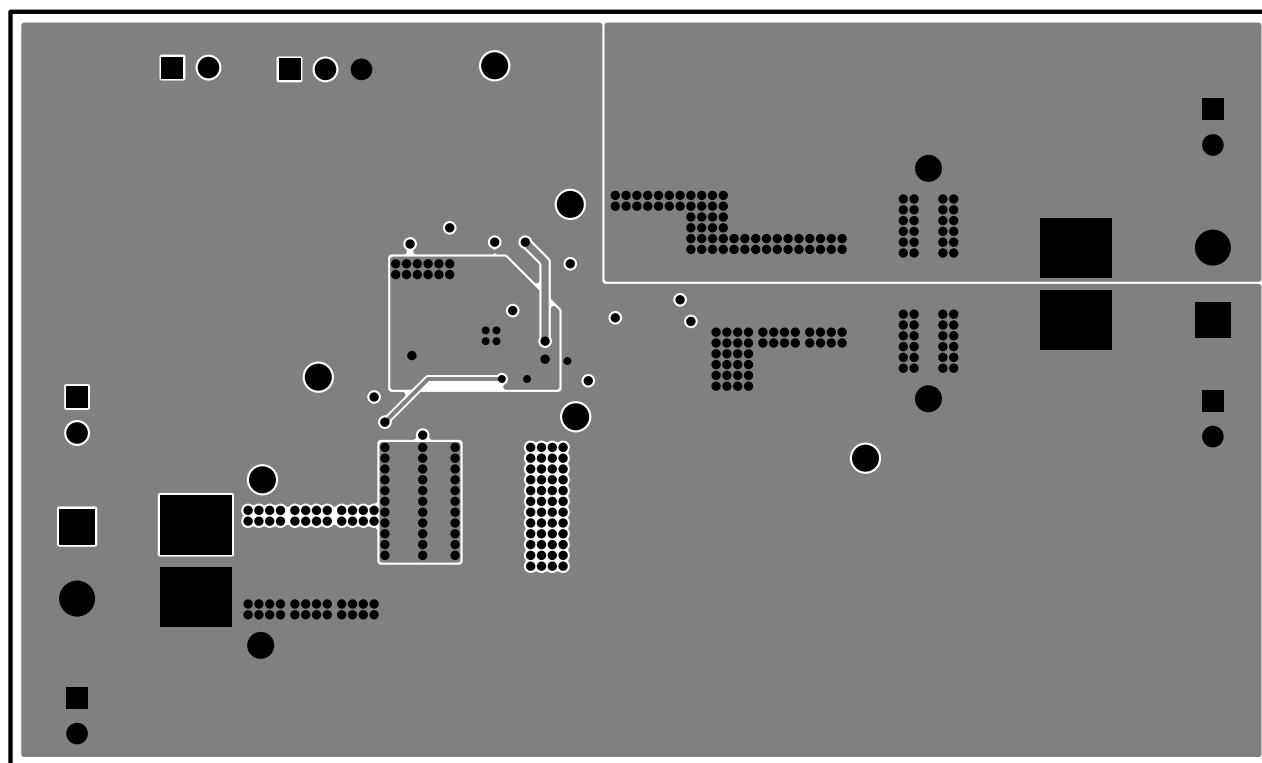


Figure 21. TPS43060EVM-199 Layer 3 Layout

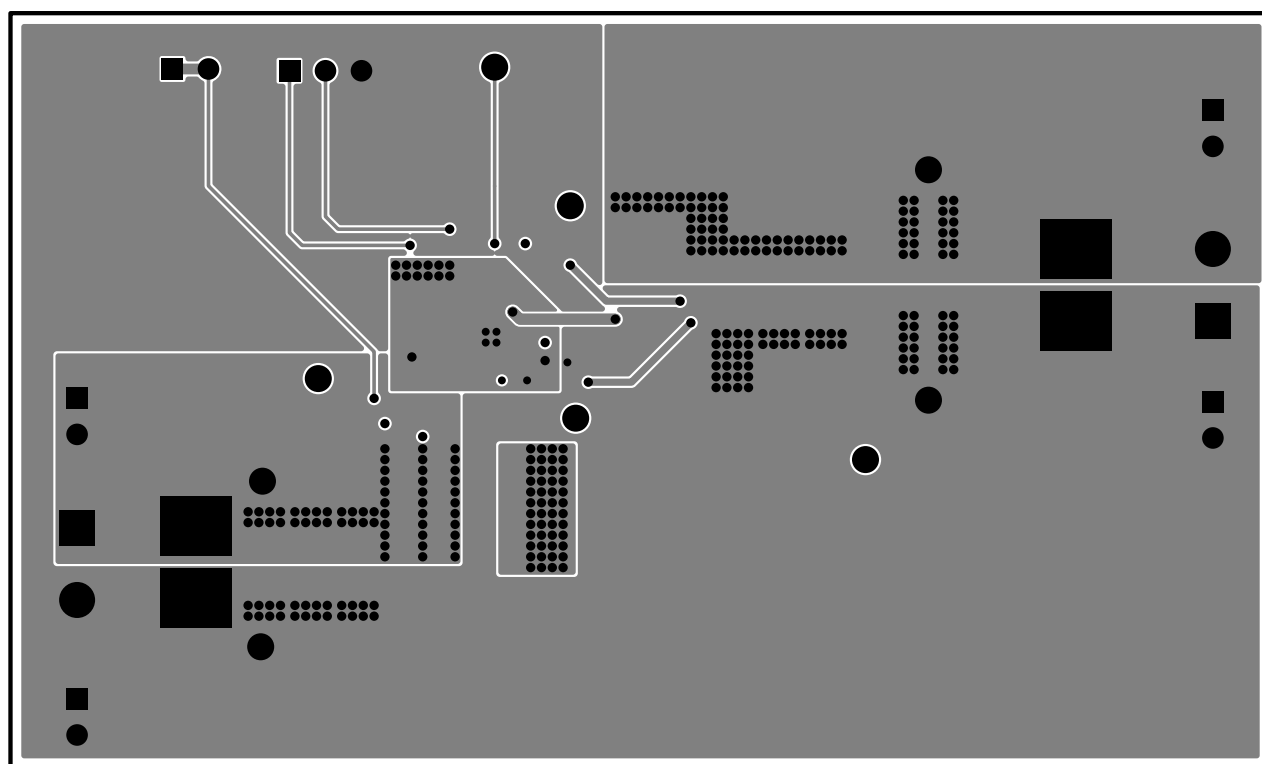


Figure 22. TPS43060EVM-199 Bottom-Side Layout

## 4.2 Estimated Circuit Area

The estimated printed-circuit-board area by outlining the components and the routing between them is 1.86 in<sup>2</sup> (1202 mm<sup>2</sup>). This area does not include test points or connectors. Also note, this design uses 0603 components for easy modifications and places all components on one layer so the area can be reduced.

## Revision History

| Changes from Original (January 2013) to A Revision                                        | Page               |
|-------------------------------------------------------------------------------------------|--------------------|
| • Changed <a href="#">Table 4</a> , L1 Part Number From: XAL1510-103 To: XAL1510-153..... | <a href="#">13</a> |

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

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- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

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Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

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This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

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2. Use EVMs only after user obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after user obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless user gives the same notice above to the transferee. Please note that if user does not follow the instructions above, user will be subject to penalties of Radio Law of Japan.

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