

Using the TPS549A20: DCAP3 Mode, 15-A Synchronous Step-Down SWIFT™ Converter with PMBus PMBus™

User's Guide



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1 Introduction

The TPS549A20EVM-737 evaluation module (EVM) uses the TPS549A20 device. The TPS549A20 device is a D-CAP3™ mode, 15-A synchronous buck-converter with integrated MOSFETs. The device provides a fixed 1.2-V output at up to 15 A from a 12-V input bus.

2 Description

The TPS549A20EVM-737 is designed for a regulated 12-V bus to produce a regulated 1.2-V output at up to 15 A of load current. The TPS549A20EVM-737 is designed to demonstrate the TPS549A20 device in a typical low-voltage application while providing a number of test points to evaluate the performance of the TPS549A20 device.

2.1 Typical Applications

- Servers and storage
- Workstations and desktops
- Telecommunication infrastructure

2.2 Features

The TPS549A20EVM-737 features include the following:

- 15-A DC steady-state output current
- Support for a prebias-output voltage at startup
- Jumper, J2, for enable function
- Jumper, J5, for auto-skip and forced-continuous-conduction-mode (FCCM) selection
- Jumper, J7, for extra 5-V input for further power saving purpose
- Convenient test points for probing critical waveforms

3 Electrical Performance Specifications

Table 1. TPS549A20EVM-737 Electrical Performance Specifications⁽¹⁾

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNITS |
|--------------------------------|--|---|-----|-----|-------|
| INPUT CHARACTERISTICS | | | | | |
| V_{IN} | Voltage range | 5 | 12 | 18 | V |
| $I_{IN(min)}$ | Maximum input current | $V_{IN} = 5\text{ V}$, $I_{OUT} = 8\text{ A}$ | 2.5 | | A |
| $I_{IN(noload)}$ | No load input current | $V_{IN} = 12\text{ V}$, $I_O = 0\text{ A}$ with auto-skip mode | 1 | | mA |
| OUTPUT CHARACTERISTICS | | | | | |
| V_{OUT} | Output voltage | 1.2 | | | V |
| | Line regulation ($5\text{ V} < V_{IN} < 14\text{ V}$ with FCCM) | 0.2 | | | % |
| | Load regulation ($V_{IN} = 12\text{ V}$, $0\text{ A} < I_{OUT} < 8\text{ A}$ with FCCM) | 0.5 | | | % |
| V_{RIPPLE} | Output voltage ripple $V_{IN} = 12\text{ V}$, $I_{OUT} = 8\text{ A}$ with FCCM | 10 | | | mVpp |
| | Output load current | 0 | 15 | | A |
| | Output over current | 15 | | | A |
| t_{SS} | Soft-start time | 1 | | | ms |
| SYSTEMS CHARACTERISTICS | | | | | |
| f_{SW} | Switching frequency | 1000 | | | kHz |
| | Peak efficiency | 91.0 | | | % |
| | Full load efficiency | 90.3 | | | % |
| T_A | Ambient temperature | 25 | | | °C |

⁽¹⁾ Jumpers set to default locations, See [Section 6](#).

4 Schematic

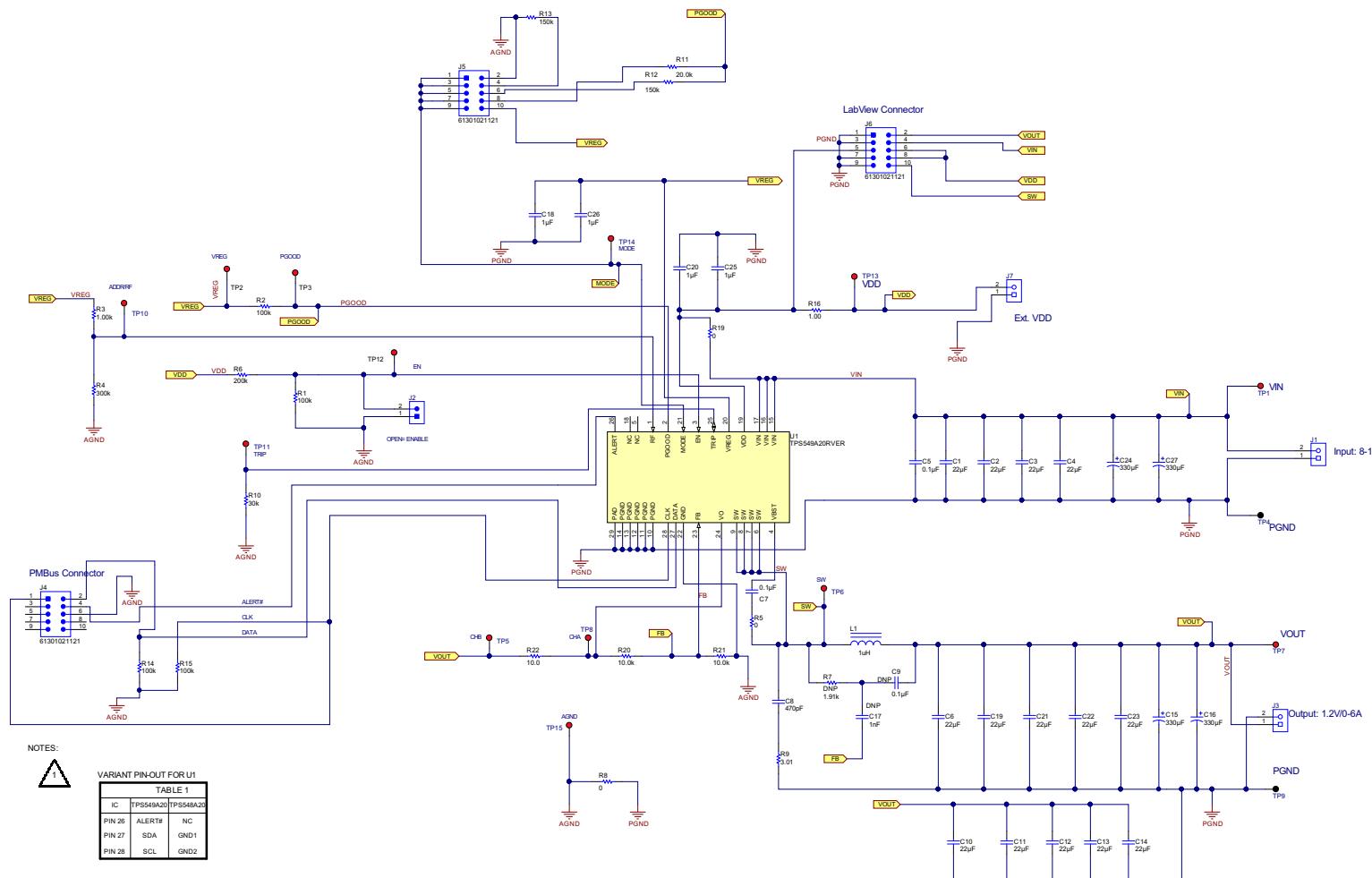


Figure 1. TPS549A20EVM-737 Schematic

5 Test Setup

5.1 Test Equipment

Oscilloscope— A digital or analog oscilloscope measures the output ripple. The oscilloscope must be set for the following: 1-MΩ impedance, 20-MHz bandwidth, AC coupling, 1-μs / division horizontal resolution, 20-mV / division vertical resolution. Test points TP7 and TP9 measure the output ripple voltage by placing the oscilloscope probe tip through TP7 and holding the ground barrel on TP9 as shown in [Figure 2](#). Using a leaded ground connection can induce additional noise due to the large ground loop.

Voltage Source— The input voltage source VIN must be a 0 to 14-V variable-DC source capable of supplying 10 ADC. Connect VIN to J1 as shown in [Figure 3](#).

Multimeters— V1: VIN at TP1 (VIN) and TP4 (GND).
V2: VOUT at TP7 (VOUT) and TP9 (GND).

Output Load— The output load must be an electronic constant-resistance-mode load capable of 0 to 15 ADC at 1.2 V.

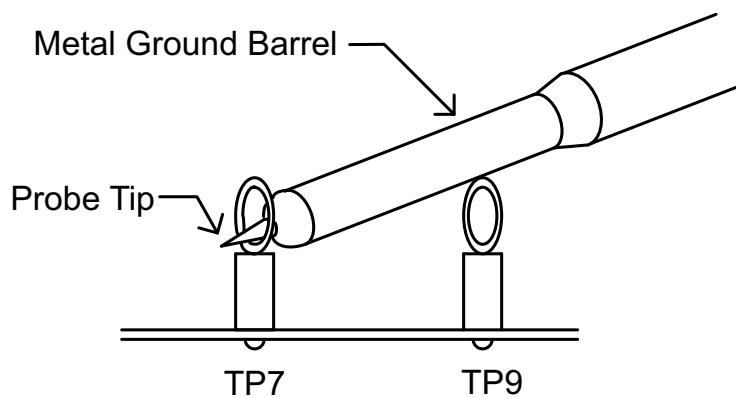


Figure 2. Tip and Barrel Measurement for VOUT Ripple

Recommended Wire Gauge:

1. V_{IN} to J1 (12-V input)
 - The recommended wire size is 1x AWG number 14 per input connection, with the total length of wire less than 4 feet (2 feet input, 2 feet return).
2. J3 to LOAD
 - The minimum recommended wire size is 2x AWG number 14, with the total length of wire less than 4 feet (2 feet output, 2 feet return).

5.2 Recommended Test Setup

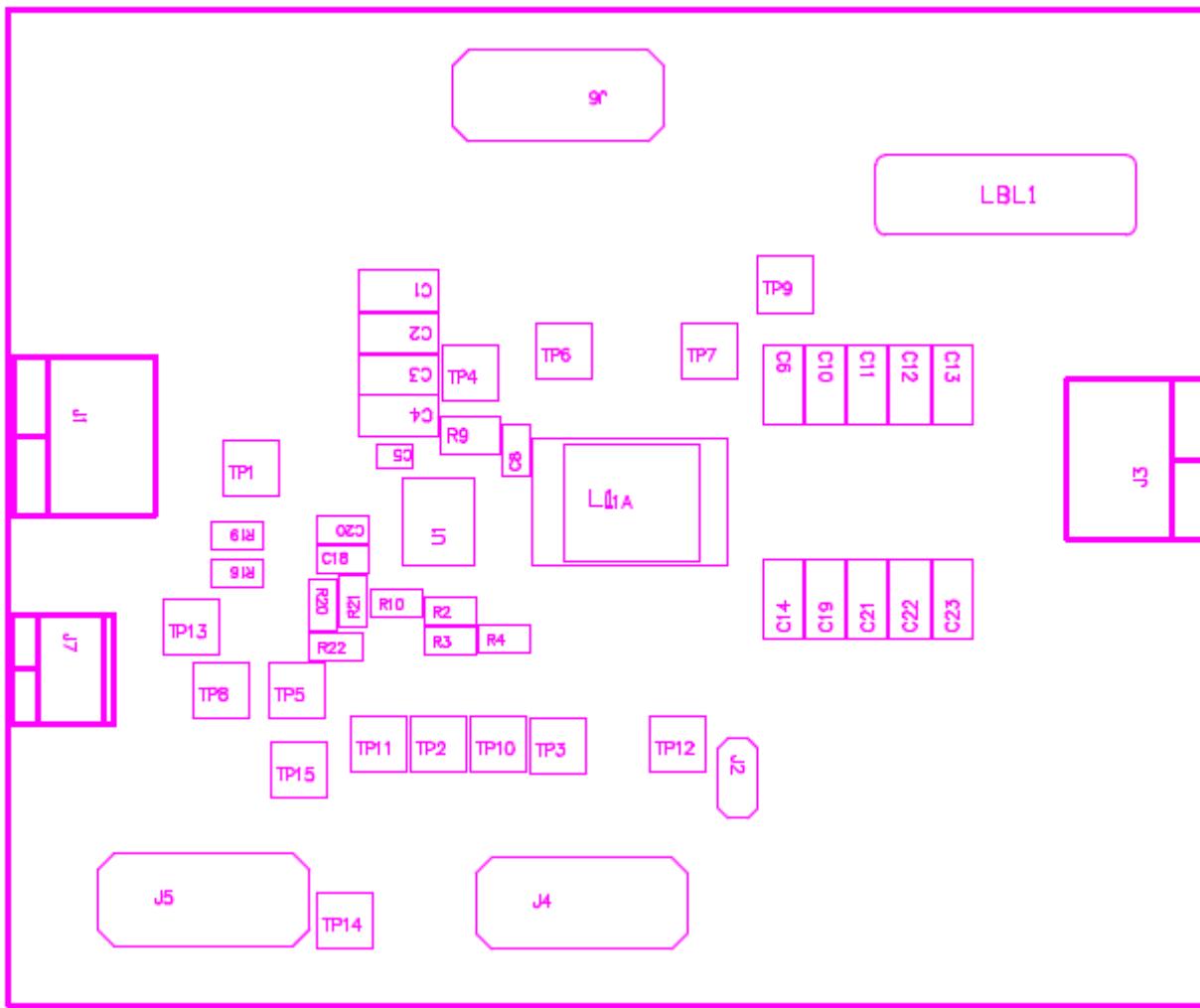


Figure 3. TPS549A20EVM-587 Top Layer for Test Setup

Input Connections:

1. Prior to connecting the DC input-source, VIN, TI recommends to limit the source current from VIN to 10 A maximum. Ensure that VIN is initially set to 0 V and connected as shown in [Figure 3](#).
2. Connect the voltmeter V1 at TP1 (VIN) and TP4 (GND) to measure the input voltage.

Output Connections:

1. Connect the load to J3 and set the load to constant-resistance-mode to sink 0 ADC before VIN is applied.
2. Connect the voltmeter V2 at TP7 (VOUT) and TP9 (GND) to measure the output voltage.

6 Configurations

All Jumper selections must be made prior to applying power to the EVM. Configure this EVM using the following configuration selections.

6.1 PMBus Address Selection

The PMBus address can be changed as shown in [Table 2](#).

Table 2. PMBus Address Selection Settings

| PMBus ADDRESS | RESISTOR DIVIDER RATIO (Ω) | | | (R_{HIGH}) (k Ω) HIGH-SIDE RESISTOR | (R_{LOW}) (k Ω) LOW-SIDE RESISTOR |
|---------------|-------------------------------------|--------|--------|---|---|
| | $(R_{LOW}/R_{LOW}+R_{HIGH})$ | MIN | MAX | | |
| 0011111 | > 0.557 | | | 1 | 300 |
| 0011110 | 0.5100 | 0.4958 | 0.5247 | 160 | 165 |
| 0011101 | 0.4625 | 0.4482 | 0.4772 | 180 | 154 |
| 0011100 | 0.4182 | 0.4073 | 0.4294 | 200 | 143 |
| 0011011 | 0.3772 | 0.3662 | 0.3886 | 200 | 120 |
| 0011010 | 0.3361 | 0.3249 | 0.3476 | 220 | 110 |
| 0011001 | 0.2985 | 0.2905 | 0.3067 | 249 | 105 |
| 0011000 | 0.2641 | 0.2560 | 0.2725 | 249 | 88.7 |
| 0010111 | 0.2298 | 0.2215 | 0.2385 | 240 | 71.5 |
| 0010110 | 0.1955 | 0.1870 | 0.2044 | 249 | 60.4 |
| 0010101 | 0.1611 | 0.1524 | 0.1703 | 249 | 47.5 |
| 0010100 | 0.1268 | 0.1179 | 0.1363 | 249 | 36.0 |
| 0010011 | 0.0960 | 0.0900 | 0.1024 | 255 | 27.0 |
| 0010010 | 0.0684 | 0.0622 | 0.0752 | 255 | 18.7 |
| 0010001 | 0.0404 | 0.0340 | 0.0480 | 270 | 11.5 |
| 0010000 | < 0.013 | | | 300 | 1 |

For different switching frequency setting, please change R3 and R4 as shown in [Table 2](#).

6.2 Mode Selection

The MODE can be set by J5.

Table 3. Mode Selection

| JUMPER SET TO: | MODE SELECTION |
|-----------------------------------|---|
| 1 to 2 pin shorted | FCCM with 2x RC time constant |
| 3 to 4 pin shorted ⁽¹⁾ | FCCM ⁽²⁾ with 1x RC time constant ⁽¹⁾ |
| 5 to 6 pin shorted | FCCM ⁽²⁾ with 2x RC time constant |
| 7 to 8 pin shorted | Auto-skip mode with 2x RC time constant |
| 9 to 10 pin shorted | Auto-skip mode with 1x RC time constant |

⁽¹⁾ Default setting.

⁽²⁾ The device enters FCCM after PGOOD goes high.

6.3 VDD Pin Supply Selection

The controller can be enabled and disabled by J7.

Table 4. Enable Selection

| SET ON CONNECTION | ENABLE SELECTION |
|---------------------------------|--|
| R19 = 0 Ω ⁽¹⁾ | VDD pin connected to VIN pins ⁽¹⁾ |
| R19 = Open | VDD pin disconnected to VIN pins |

⁽¹⁾ Default setting: the VDD pin connected to the VIN pins through R19.

For power-up, input J7 with proper voltage. The VDD pin input voltage range is from 4.5 V to 25 V.

7 Test Procedure

7.1 Line and Load Regulation and Efficiency Measurement Procedure

1. Set up the EVM as described in [Section 5](#) and [Figure 3](#).
2. Ensure the load is set to constant-resistance mode and to sink at 0 ADC.
3. Ensure all jumper setting are configured as shown in [Section 6](#).
4. Ensure the jumper provided in the EVM shorts on J2 before VIN is applied.
5. Increase VIN from 0 to 12 V. Use V1 to measure input voltage.
6. Remove the jumper on J2 to enable the controller.
7. Use V2 to measure the VOUT voltage.
8. Vary the load from 0 to 10 ADC, VOUT must remain in load regulation.
9. Vary VIN from 8 to 14 V, VOUT must remain in line regulation.
10. To disable the converter, place the jumper on J2.
11. Decrease the load to 0 A
12. Decrease VIN to 0 V.

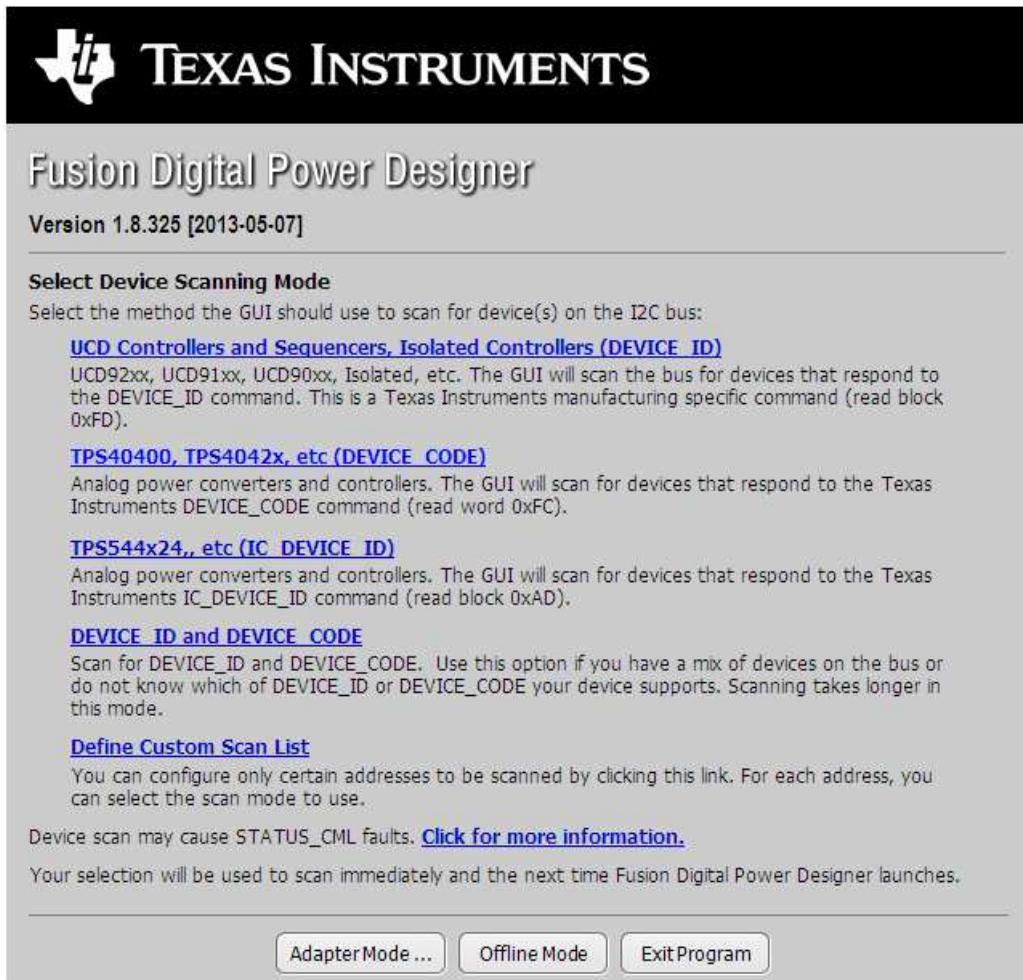
7.2 PMBUS Setup and Verification

The TPS549A20EVM-737 contains a 10- Ω series resistor in the feedback loop for loop response analysis.

1. Download the Graphical User Interface (GUI) from [www.TI.com](#).
2. Type *fusion* in the TI search bar.
3. Select *FUSION_DIGITAL_POWER_DESIGNER* from the search result.
4. Download and install the latest release version of the software. The most current version to date is version 1.8.325 of the Fusion Digital Power Designer.
5. Connect the USB Interface Adaptor EVM (see [www.ti.com](#) for more information) to J4 of the EVM. Ensure that Pin 1 of the USB interface adaptor (red wire) is connected correctly to Pin 1 of J4 on the EVM.
6. Connect the USB wire of the USB interface adaptor to one of the USB ports on the computer tower.
7. Ensure that the EVM is powered up and connected to the USB interface adaptor before opening the Fusion Designer GUI.
8. Double click the shortcut icon on the desktop for the Fusion Designer GUI. **Use the *online* version.**
9. Double click on the *TPS40400, TPS4042x, ect (DEVICE CODE)* from the *Select Device Scanning Mode* window as shown in [Figure 4](#).
10. When the GUI is loaded (see [Figure 5](#)), verify communication between the GUI and the EVM by changing the frequency of the EVM.

NOTE: The TPS549A20EVM is pre-set to a 400-KHz switching frequency.

11. Use the oscilloscope to monitor the switching frequency on the EVM on TP6.
12. Select a different frequency by clicking on the drop down box of the *FREQUENCY_CONFIG:TPS53819 (TPS5391X)*.
13. Click on *Write to Hardware* and monitor the change of the switching frequency on the oscilloscope.
14. See the TPS549A20 datasheet ([SLUSAS9](#)) for more information regarding PMBUS registers.



The screenshot shows the Texas Instruments Fusion Digital Power Designer software interface. At the top, the Texas Instruments logo and the text "TEXAS INSTRUMENTS" are displayed. Below this, the title "Fusion Digital Power Designer" and the version "Version 1.8.325 [2013-05-07]" are shown. The main content area is titled "Select Device Scanning Mode" and contains the following sections:

- UCD Controllers and Sequencers, Isolated Controllers (DEVICE_ID)**
UCD92xx, UCD91xx, UCD90xx, Isolated, etc. The GUI will scan the bus for devices that respond to the DEVICE_ID command. This is a Texas Instruments manufacturing specific command (read block 0xFD).
- TPS40400, TPS4042x, etc (DEVICE_CODE)**
Analog power converters and controllers. The GUI will scan for devices that respond to the Texas Instruments DEVICE_CODE command (read word 0xFC).
- TPS544x24, etc (IC DEVICE_ID)**
Analog power converters and controllers. The GUI will scan for devices that respond to the Texas Instruments IC_DEVICE_ID command (read block 0xAD).
- DEVICE_ID and DEVICE_CODE**
Scan for DEVICE_ID and DEVICE_CODE. Use this option if you have a mix of devices on the bus or do not know which of DEVICE_ID or DEVICE_CODE your device supports. Scanning takes longer in this mode.
- Define Custom Scan List**
You can configure only certain addresses to be scanned by clicking this link. For each address, you can select the scan mode to use.

At the bottom of the dialog box, there is a note: "Device scan may cause STATUS_CML faults. [Click for more information.](#)". Below this, a message states: "Your selection will be used to scan immediately and the next time Fusion Digital Power Designer launches." At the very bottom of the dialog box are three buttons: "AdapterMode ...", "Offline Mode", and "Exit Program".

Figure 4. Select Device Scanning Mode

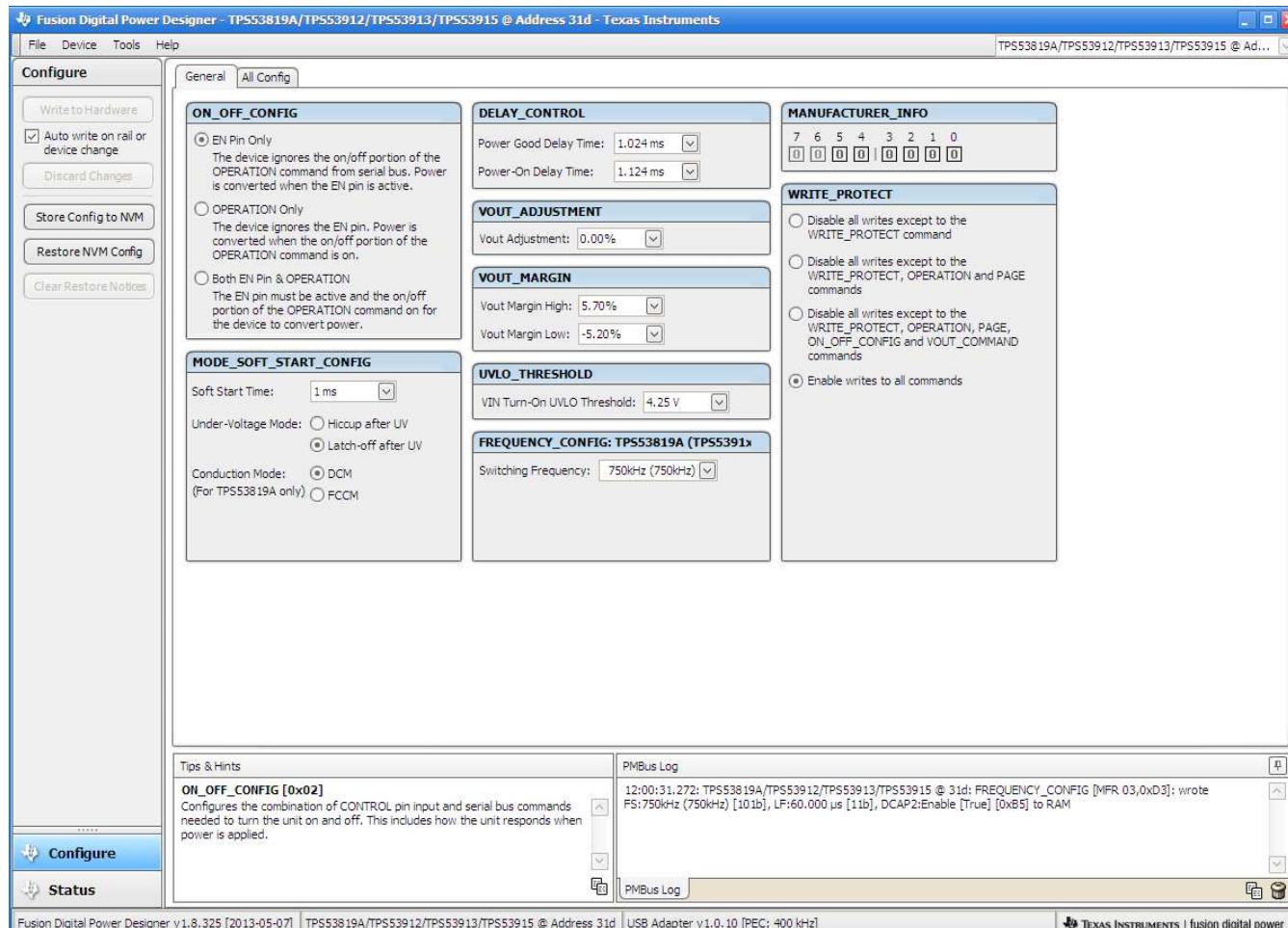


Figure 5. GUI for the Fusion Digital Power Designer

7.3 Control-Loop Gain and Phase-Measurement Procedure

The TPS549A20EVM-737 contains a $10\text{-}\Omega$ series resistor in the feedback loop for loop response analysis.

1. Set up the EVM as described in [Section 5](#) and [Figure 3](#).
2. Connect the isolation transformer to the test points marked TP5 and TP8.
3. Connect the input-signal amplitude-measurement probe (channel A) to TP10. Connect the output-signal amplitude-measurement probe (channel B) to TP11.
4. Connect the ground lead of channel A and channel B to TP15.
5. Inject around 20 mV or less signal through the isolation transformer.
6. To measure control-loop gain and phase margin, change the frequency from 100 Hz to 1 MHz using a 10-Hz or less post filter.
7. Disconnect the isolation transformer from the bode-plot test points before making other measurements.
 - Signal injection into feedback can interfere with the accuracy of other measurements.

7.4 List of Test Points

Table 5. Test Point Functions

| TEST POINTS | NAME | DESCRIPTION |
|-------------|-------|--------------------------------|
| TP1 | VIN | Converter input supply voltage |
| TP2 | VREG | LDO voltage |
| TP3 | PGOOD | Power good output |
| TP4 | PGND | Power ground |
| TP5 | CHB | Input B for loop injection |
| TP6 | SW | Switch Node |
| TP7 | VOUT | VOUT terminal + |
| TP8 | CHA | Input A for loop injection |
| TP9 | PGND | Power ground |
| TP10 | RF | RF pin |
| TP11 | TRIP | TRIP pin |
| TP12 | EN | Enable pin |
| TP13 | VDD | VDD pin |
| TP14 | MODE | MODE pin |
| TP15 | AGND | Analog ground |

7.5 Equipment Shutdown

Follow these steps when shutting down the equipment.

1. Shut down load
2. Shut down VIN

8 EVM Assembly Drawing and PCB Layout

The following figures show the design of the TPS549A20EVM-737 printed circuit board (see [Figure 6](#), [Figure 7](#), [Figure 8](#), [Figure 9](#), [Figure 10](#), [Figure 11](#), [Figure 12](#), and [Figure 13](#)). The EVM has been designed using a six-layer 2-oz copper-circuit board.

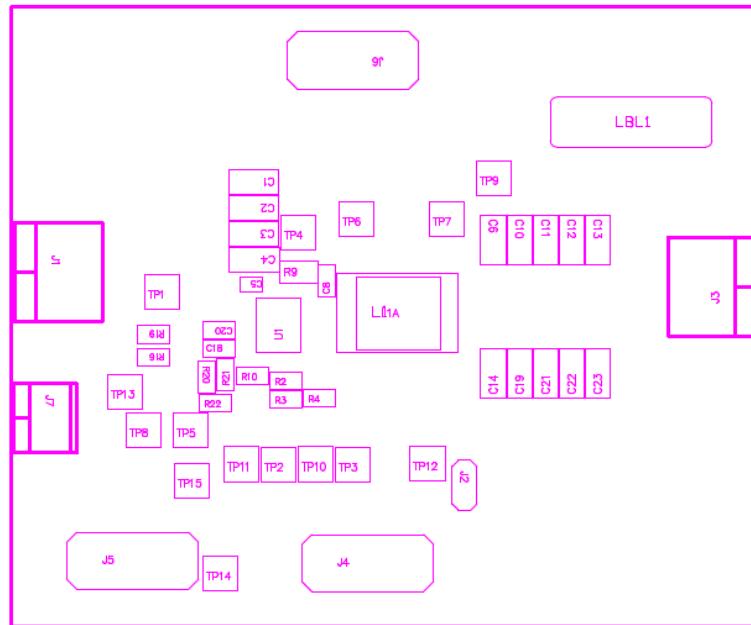


Figure 6. TPS549A20EVM-587 Top-Layer Assembly Drawing

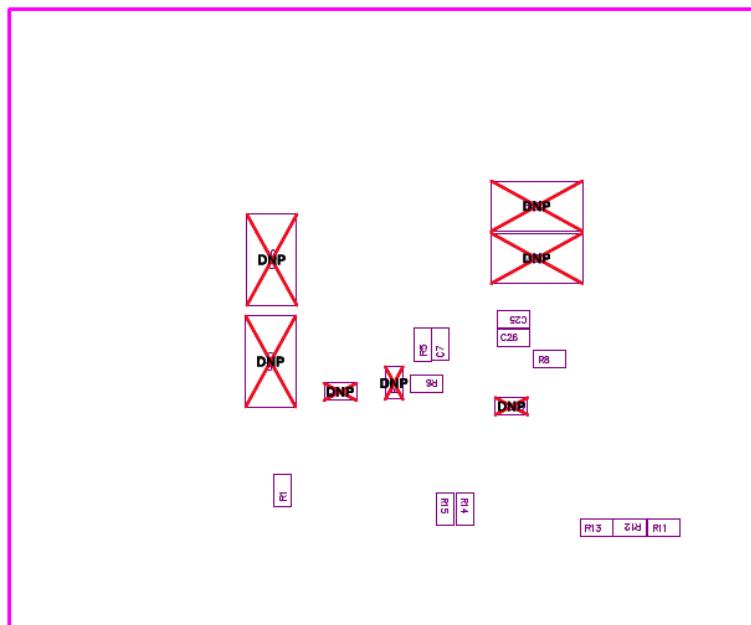


Figure 7. TPS549A20EVM-587 Bottom-Layer Assembly Drawing

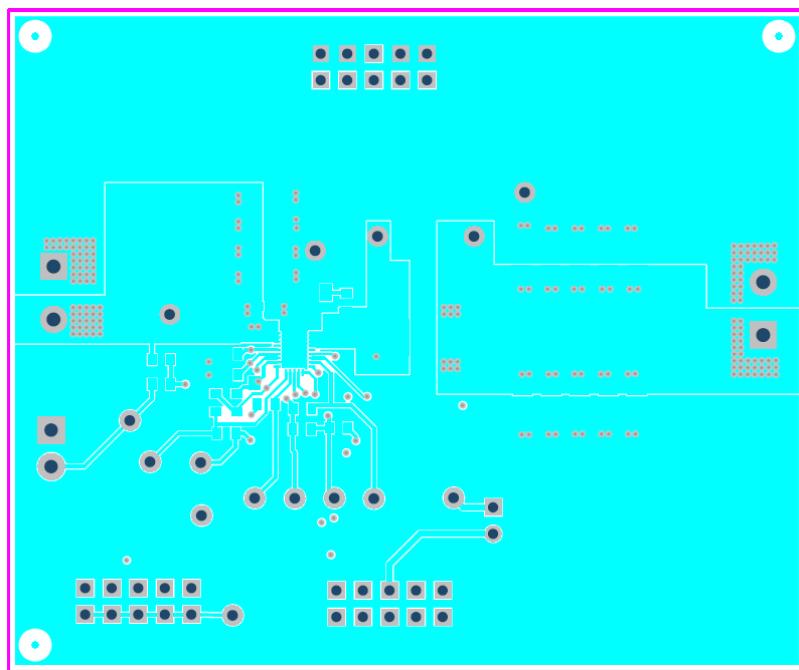


Figure 8. TPS549A20EVM-587 Top Layer, Copper

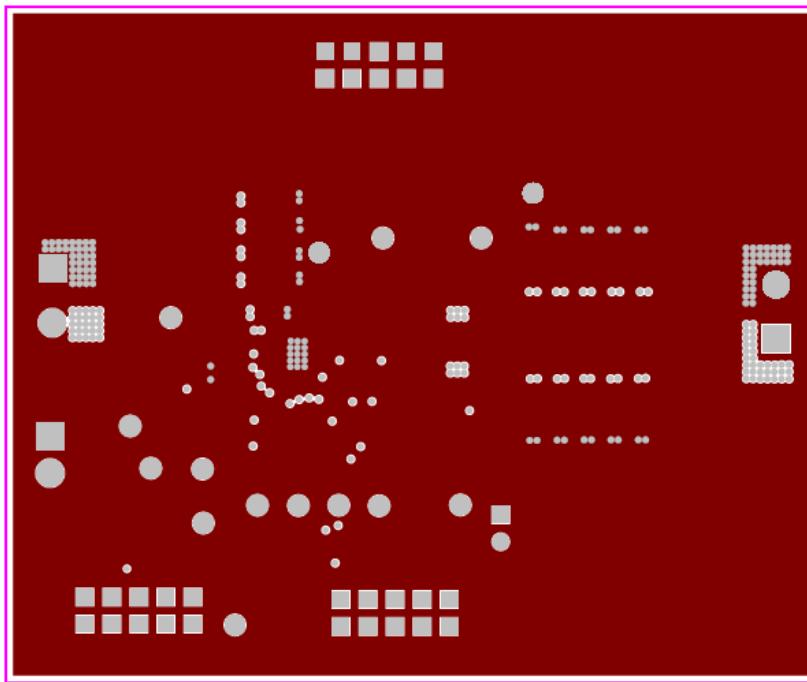


Figure 9. TPS549A20EVM-587 Layer Two, Copper

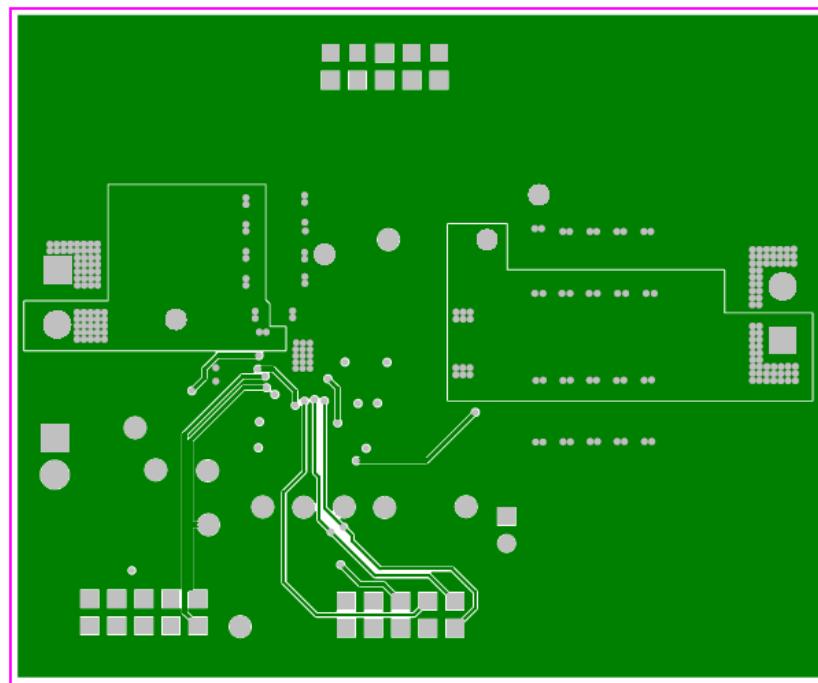


Figure 10. TPS549A20EVM-587 Layer Three, Copper

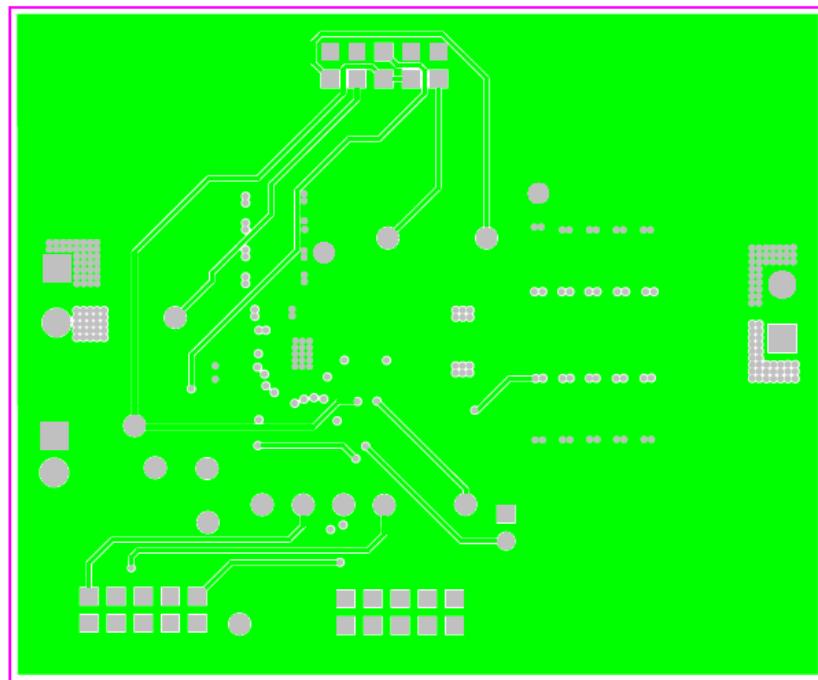


Figure 11. TPS549A20EVM-587 Layer Four, Copper

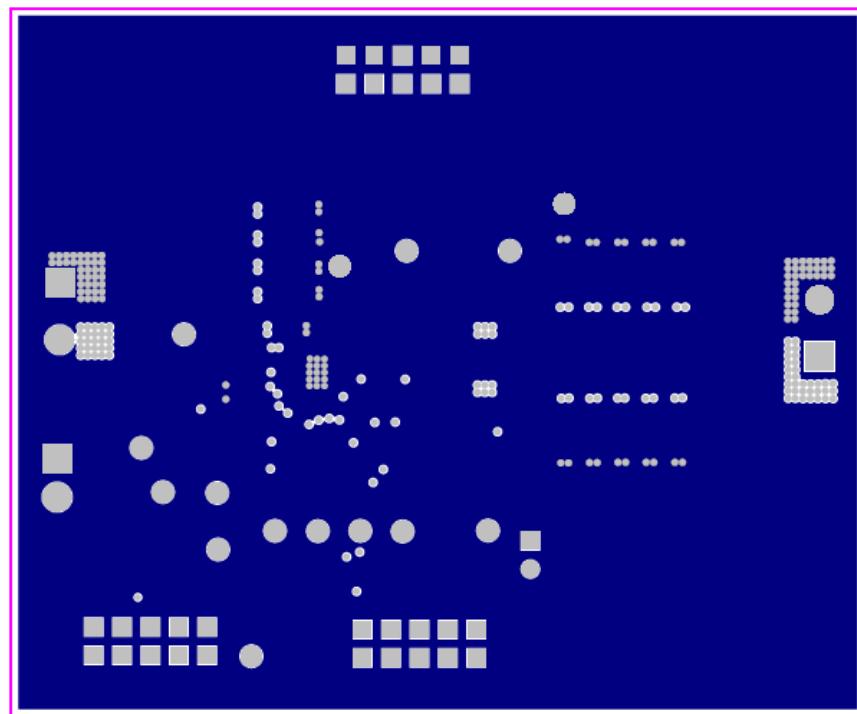


Figure 12. TPS549A20EVM-587 Layer Five, Copper

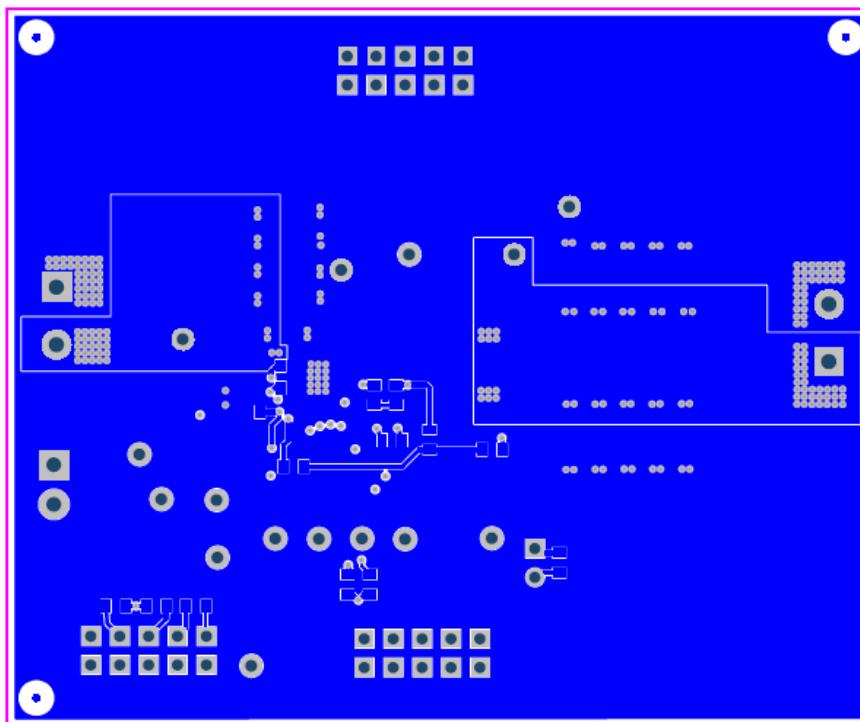


Figure 13. TPS549A20EVM-587 Bottom Layer, Copper

9 Bill of Materials

Table 6. EVM Components List (Based on the Schematic, see Figure 1)

| Designator | Quantity | Value | Description | Package Reference | Part Number | Manufacturer |
|---|----------|--------------|--|---|---------------------------|---------------|
| C1, C2, C3, C4 | 4 | 22 μ F | Capacitor, Ceramic, 25 V, X5R, 10% | 1206 | GRM31CR61E226KE15L | Murata |
| C5 | 1 | 0.1 μ F | CAP CER 0.1 μ F 25 V 10% X5R 0402 | 0402 | GRM155R61E104KA87D | Murata |
| C6, C10, C11, C12, C13, C14, C19, C21, C22, C23 | 10 | 22 μ F | Capacitor, Ceramic, 6.3 V, X5R, 20% | 1206 | GRM31CR60J226KE19L | Murata |
| C7 | 1 | 0.1 μ F | CAP CER 0.1 μ F 50 V 10% X7R 0603 | 0603 | GRM188R71H104KA93D | Murata |
| C8 | 1 | 470 pF | CAP CER 470 pF 50 V 10% X7R 0603 | 0603 | GRM188R71H471KA01D | Murata |
| C9, C17 | 0 | Open | Capacitor, Ceramic, 50 V, X7R, 10% | 0603 | Standard | Standard |
| C15, C16, C24, C27 | 0 | Open | Capacitor, POSCAP, SMT, 2.5 V, 330 μ F, 8 m Ω | 7343(D) | 2R5TPE330M9 or 6TPE330MIL | Sanyo |
| C18, C20, C25, C26 | 4 | 1 μ F | CAP CER 1 μ F 16 V 10% X7R 0603 | 0603 | GRM188R71C105KA12J | Murata |
| FID1, FID2, FID3, FID4, FID5, FID6 | 0 | | Fiducial mark. There is nothing to buy or mount. | Fiducial | N/A | N/A |
| J1, J3 | 2 | ED120/2DS | Terminal Block, 2-pin, 15-A, 5.1 mm | 0.4 \times 0.35 inch | ED120/2DS | OST |
| J2 | 1 | PEC02SAAN | Header, Male 2-pin, 100-mil spacing, | 0.1 \times 2 inch | PEC02SAAN | Sullins |
| J4, J5, J6 | 3 | PEC05DAAN | Header, Male 2x5-pin, 100-mil spacing | 0.1 \times 2 \times 5 inch | PEC05DAAN | Sullins |
| J7 | 1 | ED555/2DS | Terminal Block, 2-pin, 6-A, 3.5 mm | 0.27 \times 0.25 inch | ED555/2DS | OST |
| L1 | 1 | 1 μ H | Inductor, Power Chokes SMD | 6.6 \times 7.1 mm | PIMB065T-1R0MS | Cyntec |
| LBL1 | 1 | | Thermal Transfer Printable Labels, 0.650 (W) \times 0.2 inch (H) — 10,000 per roll | PCB Label 0.65 (H) \times 0.2 inch (W) | THT-14-423-10 | Brady |
| R1, R2, R14, R15 | 4 | 100k | RES, 100 k Ω , 1%, 0.1 W, 0603 | 0603 | CRCW0603100KFKEA | Vishay-Dale |
| R3 | 1 | 1k | RES, 1 k Ω , 1%, 0.1 W, 0603 | 0603 | CRCW06031K00FKEA | Vishay-Dale |
| R4 | 1 | 300k | RES, 300 k Ω , 1%, 0.1 W, 0603 | 0603 | RC0603FR-07300KL | Yageo America |
| R5, R8, R19 | 3 | 0 | RES, 0 Ω , 5%, 0.1 W, 0603 | 0603 | CRCW06030000Z0EA | Vishay-Dale |
| R6 | 1 | 200k | RES, 200 k Ω , 1%, 0.1 W, 0603 | 0603 | CRCW0603200KFKEA | Vishay-Dale |
| R7 | 0 | Open | Resistor, Chip, 1/16 W, 1% | 0603 | Standard | Standard |
| R9 | 1 | 3.01 | RES, 3.01 Ω , 1%, 0.125 W, 0805 | 0805 | CRCW08053R01FKEA | Vishay-Dale |
| R10 | 1 | 57.6k | RES, 57.6 k Ω , 1%, 0.1 W, 0603 | 0603 | RC0603FR-0757K6L | Yageo America |
| R11 | 1 | 20k | RES, 20.0 k Ω , 1%, 0.1 W, 0603 | 0603 | CRCW060320KFKEA | Vishay-Dale |
| R12, R13 | 2 | 150k | RES, 150 k Ω , 1%, 0.1 W, 0603 | 0603 | CRCW0603150KFKEA | Vishay-Dale |
| R16 | 1 | 1 | RES, 1 Ω , 1%, 0.1 W, 0603 | 0603 | CRCW06031R00FKEA | Vishay-Dale |
| R20, R21 | 2 | 10k | RES, 10 k Ω , 1%, 0.1 W, 0603 | 0603 | CRCW060310KFKEA | Vishay-Dale |
| R22 | 1 | 10 | RES, 10 Ω , 1%, 0.1 W, 0603 | 0603 | CRCW060310R0FKEA | Vishay-Dale |
| TP1, TP2, TP3, TP5, TP6, TP7, TP8, TP10, TP11, TP12, TP13, TP14, TP15 | 13 | 5000 | Test Point, Red, Thru Hole Color Keyed | 0.1 \times 0.1 inch | 5000 | Keystone |
| TP4, TP9 | 2 | 5001 | Test Point, Black, Thru Hole Color Keyed | 0.1 \times 0.1 inch | 5001 | Keystone |
| U1 | 1 | TPS549A20RVE | IC, High Performance, 15-A Single Sync. Step-Down Converter with PMBus. | | TPS549A20RVE | TI |

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| Logic | logic.ti.com |
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