Using the TPS59650EVM-753 Intel™ IMVP-7 3-Phase CPU/2-Phase GPU SVID Power System

The TPS59650EVM-753 evaluation module (EVM) is a complete solution for Intel™ IMVP7 Serial VID(SVID) Power System from a 9V-20V input bus. This EVM uses the TPS59650 for IMVP7 - 3-Phase CPU and 2-Phase GPU Vcore controller, the TPS51219 for 1.05VCCIO, TPS51916 for DDR3L/DDR4 Memory rail (1.2VDDQ, 0.6VTT and 0.6VTTREF) and also uses the (CSD87350Q5D) a 5mm x 6mm TI’s power block MOSFETs that uses Powerstack™ technology with high-side and low-side MOSFETs for high power density and superior thermal performance.

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Intel is a trademark of Intel.
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<td>CPU1 Output Load Release with OSR/USR middle level ........................................... 27</td>
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<td>CPU1 MOSFET ........................................................................................................... 28</td>
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<td>46</td>
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<td>GPU2 Load regulation .............................................................................................. 29</td>
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<td>GPU2 Enable Turn on .............................................................................................. 29</td>
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<td>GPU2 Enable Turn off ............................................................................................. 29</td>
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<td>GPU2 Switching Node and Ripple ............................................................................. 29</td>
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1 Description

The TPS59650EVM-753 is designed to use a 9V-20V Input bus to produce 6 regulated outputs for IMVP7 SVID CPU/GPU Power System. The TPS59650EVM-753 is specially designed to demonstrate the TPS59650 full IMVP7 mobile feature while providing GUI communication programing and a number of test points to evaluate the static and dynamic performance of TPS59650.

1.1 Typical Applications

• IMVP7 Vcore Applications for Adapter, Battery, NVDC or 3V/5V/12V rails

1.2 Features

The TPS59650EVM-753 features:

• Complete solution for 9V-20V Input Intel IMVP7 SVID Power System
• GUI communication to demonstrate full IMVP7 Mobile feature
• 3-Phase CPU Vcore can support up to 94A output current
• 2-Phase GPU Vcore can support up to 46A output current
• 8 Selectable Switching frequency for CPU and GPU power
• 8 Levels selectable current limit for CPU and GPU power
• Switches or Jumpers for each output enable
• On Board Dynamic Load for CPU, GPU Vcore and VCCIO output
• High efficiency and high density by using TI power block MOSFET
• Convenient test points for probing critical waveforms
• Eight Layer PCB with 1oz copper
Figure 1. TPS59650EVM-753 Power System Block Diagram
3 Electrical Performance Specifications

Table 1. TPS59650EVM-753 Electrical Performance Specifications

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
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<tbody>
<tr>
<td>INPUT CHARACTERISTICS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12VBAT input voltage range</td>
<td>VBAT</td>
<td>9</td>
<td>12</td>
<td>20</td>
<td>V</td>
</tr>
<tr>
<td>Maximum input current</td>
<td>VBAT = 12V, all full load (3-Phase CPU/2-Phase GPU)</td>
<td>15.5</td>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>No load input current</td>
<td>VBAT=12V, all no load (3-Phase CPU/2 Phase GPU)</td>
<td>0.14</td>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>5VIN input voltage range</td>
<td>Vin</td>
<td>4.5</td>
<td>5</td>
<td>5.5</td>
<td>V</td>
</tr>
<tr>
<td>Maximum input current</td>
<td>VBAT = 12 V, all full load</td>
<td>0.3</td>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>No load input current</td>
<td>VBAT=12V, all no load</td>
<td>0.1</td>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>OUTPUT CHARACTERISTICS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPU(TPS59650)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output voltage Vcore</td>
<td>SVID: Address:00 CPU, Payload: 1.05V</td>
<td>1.05</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Output voltage regulation</td>
<td>Line regulation</td>
<td>0.1%</td>
<td></td>
<td></td>
<td>%</td>
</tr>
<tr>
<td>Output voltage ripple</td>
<td>VBAT=12V, 1.05V/90A (3-Phase) at 300kHz</td>
<td>25</td>
<td></td>
<td></td>
<td>mVpp</td>
</tr>
<tr>
<td>Output load current</td>
<td>CPU 3-Phase operation</td>
<td>0</td>
<td>94</td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Output over current</td>
<td>Selectable per phase</td>
<td>0</td>
<td>37</td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Switching frequency</td>
<td>Selectable</td>
<td>250</td>
<td>300</td>
<td>600</td>
<td>kHz</td>
</tr>
<tr>
<td>Full load efficiency</td>
<td>VBAT=12V, 1.05V/95A at 300kHz</td>
<td>80.05%</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>GPU(TPS59650)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output voltage Vcore</td>
<td>SVID: Address:01 GPU, Payload: 1.23V</td>
<td>1.23</td>
<td></td>
<td></td>
<td>V</td>
</tr>
</tbody>
</table>

(1) Jumpers set to default locations, see section 6 of this user’s guide
Table 1. TPS59650EVM-753 Electrical Performance Specifications\(^{(1)}\) (continued)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output voltage regulation</td>
<td>Line regulation</td>
<td>0.1%</td>
<td></td>
<td></td>
<td>%</td>
</tr>
<tr>
<td>Output voltage ripple</td>
<td>VBAT=12V, 1.23V/50A 2 Phase at 385kHz</td>
<td>30</td>
<td></td>
<td></td>
<td>mVpp</td>
</tr>
<tr>
<td>Output load current</td>
<td></td>
<td>0</td>
<td>50</td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Output over current</td>
<td>Selectable per phase</td>
<td>37</td>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Switching frequency</td>
<td>Selectable</td>
<td>275</td>
<td>385</td>
<td>660</td>
<td>kHz</td>
</tr>
<tr>
<td>Full load efficiency</td>
<td>VBAT=12V, 1.23V/50A 2 Phase at 385kHz</td>
<td>86.58%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1.05V VCCIO (TPS51219)

| Output voltage                    |                                                      | 1.05|     |     | V     |
| Output voltage regulation        | Line regulation                                      | 0.1%|     |     | %     |
| Output voltage ripple            | VBAT=12V, 1.05V/10A                                  | 30  |     |     | mVpp  |
| Output load current              | VBAT=12V, 1.05V/10A                                  | 0   | 10  |     | A     |
| Output over current              |                                                      | 16  |     |     | A     |
| Switching frequency              | Selectable                                           | 500 |     |     | kHz   |
| Full load efficiency             | VBAT=12V, 1.05V/10A                                  | 89.87%|    |    |       |

DDR3L/DDR4 Memory Rail (TPS51916)

| Output voltage                    |                                                      | 1.2 |     |     | V     |
| Output voltage regulation        | Line regulation                                      | 0.1%|     |     | %     |
| Output voltage ripple            | VBAT=12V, 1.2V/8A                                    | 30  |     |     | mVpp  |
| Output load current              | VBAT=12V, 1.2V/8A                                    | 0   | 8   |     | A     |
| Output over current              |                                                      | 10  |     |     | A     |
| Switching frequency              | Selectable                                           | 500 |     |     | kHz   |
| Full load efficiency             | VBAT=12V, 1.2V/8A                                    | 89.07%|    |    |       |
| Operating temperature            |                                                      | 25  |     |     | °C    |

4 Test Setup

4.1 Test Equipment

4.1.1 PC Computer (Host Computer)

Microsoft Windows XP or newer with available USB port

4.1.2 USB Cable

The USB Cable: Standard USB_A to USB_B 5 Pin Mini-B cable. See Figure 3.

Figure 3. USB Cable
### 4.1.3 TPS59650 USB driver and SVID GUI Installation

1. Copy the both files: setup.exe and setup.msi to the host computer.
2. Run this setup.exe.
3. Following installation Instructions, this will install the driver and the Texas Instruments SVID GUI.
4. It will add the below icon

![SVID EVM v2](image)

### 4.1.4 DC Source

**12VBAT DC Source:** The 12VBAT DC source should be a 0-20V variable DC source capable of supplying 20Adc current. Connect 12VBAT to J21 as shown in Figure 4.

**5Vin DC Source:** The 5Vin DC source should be a 0-5V variable DC source capable of supplying 1Adc current. Connect 5Vin to J22 as shown in Figure 4.

### 4.1.5 Meters

- **V1:** 5Vin at TP81(5Vin) and TP83(GND)
- **V2:** 12VBAT at TP82(VBAT) and TP24(GND)
- **V3:** CPU Vcore sense voltage at J7; GPU Vcore sense voltage at J9; VDDQ sense voltage at J20, VCCIO sense voltage at J16
- **A1:** 12VBAT input current

### 4.1.6 Load

The output load should be an electronic constant current load capable of 0-90Adc.

### 4.1.7 Oscilloscope

A digital or analog oscilloscope can be used to measure the output ripple. The oscilloscope should be set for 1MΩ impedance, 20MHz Bandwidth, AC coupling, 2us/division horizontal resolution, 50mV/division vertical resolution. Test point TP30 and TP46 can be used to measure the output ripple voltage for CPU and GPU. Do not use a leaded ground connection as this may induce additional noise due to the large ground loop.

### 4.2 Recommended Wire Gauge

1. **V5in to J22(5V input):**
   The recommended wire size is 1x AWG #18 per input connection, with the total length of wire less than 4 feet (2 feet input, 2 feet return).
2. **12VBAT to J21(12V input):**
   The recommended wire size is 1x AWG #16 per input connection, with the total length of wire less than 4 feet (2 feet input, 2 feet return).
3. **J1, J2, J3(CPU) to LOAD or J4, J5 (GPU) to LOAD or J19 (VDDQ) to LOAD or J15(VCCIO) to LOAD:**
   The minimum recommended wire size is 2x AWG #16, with the total length of wire less than 4 feet (2 feet output, 2 feet return)

### 4.3 Recommended Test Setup

*Figure 4* is the recommended test set up to evaluate the TPS59650EVM-753. Working at an ESD workstation, make sure that any wrist straps, bootstraps or mats are connected referencing the user to earth ground before handling the EVM.
4.4 **USB Cable Connections**

A standard USB_A and 5 pin Mini_B USB cable needed to connect between host computer and J34 USB port (left bottom side). A GREEN LED(D13) will light up near the USB port on the EVM. This just means USB cable is connected.

4.5 **Input Connections**

1. Prior to connecting the 5Vin DC source, it is advisable to limit the source current from 5Vin to 1A maximum. Make sure 5Vin is initially set to 0V and connected as shown in Figure 4.
2. Prior to connecting the 12VBAT DC source, it is advisable to limit the source current from 12VBAT to 10A maximum. Make sure 12VBAT is initially set to 0V and connected as shown in Figure 4.
3. Connect voltmeters V1 at TP81 (5Vin) and TP83 (GND) to measure 5Vin voltage, V2 at TP82 (VBAT) and TP24 (GND) to measure 12VBAT voltage as shown in Figure 4.
4. Connect a current meter A1 between 12VBAT DC source and J21 to measure the 12VBAT input current.
4.6 Output Connections
1. Connect Load to J1, J2, J3 and set Load to constant resistance mode to sink 0Adc before 5Vin and 12VBAT are applied. This is for CPU operation.
2. Connect a voltmeter V3 at J7 to measure CPU Vcore sense voltage.

5 Configuration
All Jumper selections should be made prior to applying power to the EVM. User can configure this EVM per following configurations.

5.1 CPU and GPU Configuration

5.1.1 CPU/GPU Current Limit Trip Selection (J10 for CPU and J12 for GPU)
The current limit trip can be set by J10(COCP) and J12(GOCP).
Default setting: Level 5 for both CPU and GPU.

<table>
<thead>
<tr>
<th>Jumper set to</th>
<th>Connected Resistor</th>
<th>COCP/GOCP Limit (Typ.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left (1-2 pin shorted)</td>
<td>150k</td>
<td>Max</td>
</tr>
<tr>
<td>2nd(3-4 pin shorted)</td>
<td>100k</td>
<td>Level 7</td>
</tr>
<tr>
<td>3nd(5-6 pin shorted)</td>
<td>75k</td>
<td>Level 6</td>
</tr>
<tr>
<td>4th(7-8 pin shorted)</td>
<td>56.2k</td>
<td>Level 5</td>
</tr>
<tr>
<td>5th(9-10 pin shorted)</td>
<td>39.2k</td>
<td>Level 4</td>
</tr>
<tr>
<td>6th(11-12 pin shorted)</td>
<td>30.1k</td>
<td>Level 3</td>
</tr>
<tr>
<td>7th(13-14 pin shorted)</td>
<td>24.3k</td>
<td>Level 2</td>
</tr>
<tr>
<td>Right(15-16 pin shorted)</td>
<td>20.0k</td>
<td>Min</td>
</tr>
</tbody>
</table>

5.1.2 CPU Frequency Selection (J11)
The operating frequency can be set by J11
Default setting: 300 kHz for CPU

<table>
<thead>
<tr>
<th>Jumper set to</th>
<th>Connected Resistor</th>
<th>CPU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left (1-2 pin shorted)</td>
<td>150k</td>
<td>600 kHz</td>
</tr>
<tr>
<td>2nd(3-4 pin shorted)</td>
<td>100k</td>
<td>550 kHz</td>
</tr>
<tr>
<td>3nd(5-6 pin shorted)</td>
<td>75k</td>
<td>500 kHz</td>
</tr>
<tr>
<td>4th(7-8 pin shorted)</td>
<td>56.2k</td>
<td>450 kHz</td>
</tr>
<tr>
<td>5th(9-10 pin shorted)</td>
<td>39.2k</td>
<td>400 kHz</td>
</tr>
<tr>
<td>6th(11-12 pin shorted)</td>
<td>30.1k</td>
<td>350 kHz</td>
</tr>
<tr>
<td>7th(13-14 pin shorted)</td>
<td>24.3k</td>
<td>300 kHz</td>
</tr>
<tr>
<td>Right(15-16 pin shorted)</td>
<td>20.0k</td>
<td>250 kHz</td>
</tr>
</tbody>
</table>
5.1.3 **GPU Frequency Selection (J13)**

The operating frequency can be set by J13

**Default setting:** 385 kHz for GPU.

**Table 4. GPU Frequency Selection**

<table>
<thead>
<tr>
<th>Jumper set to</th>
<th>Connected Resistor</th>
<th>GPU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left (1-2 pin shorted)</td>
<td>150k</td>
<td>660 kHz</td>
</tr>
<tr>
<td>2nd(3-4 pin shorted)</td>
<td>100k</td>
<td>605 kHz</td>
</tr>
<tr>
<td>3rd(5-6 pin shorted)</td>
<td>75k</td>
<td>550 kHz</td>
</tr>
<tr>
<td>4th(7-8 pin shorted)</td>
<td>56.2k</td>
<td>495 kHz</td>
</tr>
<tr>
<td>5th(9-10 pin shorted)</td>
<td>39.2k</td>
<td>440 kHz</td>
</tr>
<tr>
<td>6th(11-12 pin shorted)</td>
<td>30.1k</td>
<td>385 kHz</td>
</tr>
<tr>
<td>7th(13-14 pin shorted)</td>
<td>24.3k</td>
<td>330 kHz</td>
</tr>
<tr>
<td>Right(15-16 pin shorted)</td>
<td>20.0k</td>
<td>275 kHz</td>
</tr>
</tbody>
</table>

5.1.4 **F2808 DSP Program Mode Selection (J39)**

The F2808 DSP Program Mode(GUI) Selection can be set by J39.

**Default setting:** No Jumper shorts on J39 for normal operation

**Table 5. F2808 DSP Program Mode Selection**

<table>
<thead>
<tr>
<th>Jumper set to</th>
<th>Program Mode Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Jumper on J39</td>
<td>Normal Operation</td>
</tr>
<tr>
<td>Jumper on J39</td>
<td>Flash the DSP program to the EVM</td>
</tr>
</tbody>
</table>

5.1.5 **5Vin Bias Voltage Option (J33)**

The 5Vin Bias Voltage can be used from USB or Externally

**Default setting:** No Jumper shorts on J33

**Table 6. 5Vin Bias Voltage Option (J33)**

<table>
<thead>
<tr>
<th>Jumper set to</th>
<th>Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Jumper</td>
<td>5Vin Bias from J22 external</td>
</tr>
<tr>
<td>Jumper on J39</td>
<td>5Vin Bias from USB, 5Vin from J22 should not be connected</td>
</tr>
</tbody>
</table>

5.1.6 **On Board Dynamic Load Selection (S3 for CPU, S2(upper) for GPU, S2(lower) for VCCIO)**

The on board dynamic load can be set by S2 and S3.

**Default setting:** Push S2 and S3 to “OFF” position to disable the on board dynamic load

**Table 7. On Board Dynamic Load Selection**

<table>
<thead>
<tr>
<th>Switch set to</th>
<th>Dynamic Load Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Push S3 to “ON” position</td>
<td>Enable 32A on board dynamic load at CPU</td>
</tr>
<tr>
<td>Push S3 to “OFF” position</td>
<td>Disable 32A on board dynamic load at CPU</td>
</tr>
<tr>
<td>Push S2(upper) to “ON” position</td>
<td>Enable 19A on board dynamic load at GPU</td>
</tr>
<tr>
<td>Push S2(upper) to “OFF” position</td>
<td>Disable 19A on board dynamic load at GPU</td>
</tr>
<tr>
<td>Push S2(lower) to “ON” position</td>
<td>Enable 10A on board dynamic load at VCCIO</td>
</tr>
<tr>
<td>Push S2(lower) to “OFF” position</td>
<td>Disable 10A on board dynamic load at VCCIO</td>
</tr>
</tbody>
</table>
5.1.7 IMVP-7 VR_ON Enable Selection (S4)

The IMVP-7 CPU/GPU can be enabled and disabled by S4.

Default setting: Push S4 to “OFF” position to disable both CPU and GPU.

<table>
<thead>
<tr>
<th>Switch set to</th>
<th>VR_ON Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Push S4 to “ON” position</td>
<td>Enable IMVP-7 CPU/GPU Vcore</td>
</tr>
<tr>
<td>Push S4 to “OFF” position</td>
<td>Disable IMVP-7 CPU/GPU Vcore</td>
</tr>
</tbody>
</table>

5.2 1.2VDDQ, 0.6V VTT and 0.6V VTTREF Configuration

5.2.1 VDDQ S3, S5 Enable Selection

The controller can be enabled and disabled by J18 and J17.

Default setting: Jumper shorts on Pin2 and Pin3 of J18, Jumper shorts on Pin2 and Pin3 of J17.

<table>
<thead>
<tr>
<th>State</th>
<th>J17 (S3) set to</th>
<th>J18(S5) set to</th>
<th>VDDQ</th>
<th>VTTREF</th>
<th>VTT</th>
</tr>
</thead>
<tbody>
<tr>
<td>S0</td>
<td>ON position</td>
<td>ON position</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>S3</td>
<td>OFF position</td>
<td>ON position</td>
<td>ON</td>
<td>ON</td>
<td>OFF(High-Z)</td>
</tr>
<tr>
<td>S4/S5</td>
<td>OFF position</td>
<td>OFF position</td>
<td>OFF(Discharge)</td>
<td>OFF(Discharge)</td>
<td>OFF(Discharge)</td>
</tr>
</tbody>
</table>

5.3 1.05V VCCIO Configuration

5.3.1 1.05V Enable Selection (S1)

1.05V Enable can be set by S1.

Default setting: Push S1 to “OFF” position.

<table>
<thead>
<tr>
<th>Jumper set to</th>
<th>Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Push S1 to “ON” position</td>
<td>1.05V Enabled</td>
</tr>
<tr>
<td>Push S1 to “OFF” position</td>
<td>1.05V Disabled</td>
</tr>
</tbody>
</table>

5.3.2 VCCIO Output Voltage Selection (J14)

The VCCIO Output Voltage can be selected by J14.

Default setting: Jumper shorts Pin1 and Pin2 of J14.

<table>
<thead>
<tr>
<th>Jumper set to</th>
<th>Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jumper shorts on Pin1 and Pin2</td>
<td>VCCIO: 1.05V</td>
</tr>
<tr>
<td>Jumper shorts on Pin2 and Pin3</td>
<td>VCCIO: 1.00V</td>
</tr>
</tbody>
</table>
5.3.3 On Board Dynamic Load Enable Pin (J23)

The on board dynamic load can be enabled or disabled by J23

**Default setting: Jumper shorts on J23**

<table>
<thead>
<tr>
<th>Jumper set to</th>
<th>Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jumper shorts</td>
<td>Enable on board dynamic load</td>
</tr>
<tr>
<td>No Jumper short</td>
<td>Disable on board dynamic load</td>
</tr>
</tbody>
</table>

6 Test Procedure

6.1 Line/Load Regulation and Efficiency Measurement Procedure

6.1.1 CPU

1. Set up EVM as described in Section 4.3 through Section 4.6 and Figure 4.
2. Ensure J39 no Jumper shorts on
3. Ensure all other Jumpers configuration setting by Section 5 before 5Vin and 12VBAT are applied.
4. Ensure Load is set to constant resistance mode and to sink 0Adc
5. Ensure S1 and S4 are in “OFF” position
6. Add scope probe on the TP30 for CPU Vcore ripple measurement
7. Ensure USB Cable is connected between host computer and USB port(J34) on the EVM
8. Increase 5Vin from 0V to 5V. Using V1 to measure 5Vin input voltage.
9. Increase 12VBAT from 0V to 12V. Using V2 to measure 12VBAT input voltage.
10. Double-Click the icon to launch the GUI program. The GUI window shown in Figure 5.
11. Push S4 to “ON” position to enable the VR_ON of TPS59650. VR_ON LED will light up.
12. Now the user is ready to send SVID commend. The GUI at start-up defaults: Address: 00 CPU, Commend: SetVIDslow, Payload: 1.05V (The user can select the SVID commend by using the pull-down menu)
13. Click “send Commend” and CPU CPGOOD LED will light up. See the GUI window as Figure 5.
14. Measure V3: CPU Vcore at J7 and A1: 12VBAT input current
15. Vary CPU LOAD from 0Adc to 94Adc, CPU Vcore must remain in load line
16. Vary 12VBAT from 9V to 20V CPU Vcore must remain in line regulation
17. Push S4 to “OFF” position to disable CPU Vcore controller.
18. Decrease LOAD to 0A and disconnect the LOAD from terminal J1, J2, J3
19. Disconnect V3 from J7.
20. Disconnect scope probe from TP30
6.1.2 GPU

2. Add scope probe on the TP46 for GPU Vcore_G ripple measurement
3. Push S4 to “ON” position to enable the VR_ON of TPS59650. The VR_ON LED will light up.
4. Now you are ready to send SVID commands for GPU. Using pull-down menu:
   Address: 01 GPU, Command: SetVIDslow, Payload: 1.23V
5. Click “send Command” and GPU GPOOD LED will light up, See the GUI window as Figure 6.
7. Vary GPU LOAD from 0Adc to 50Adc, GPU Vcore must remain in load line
8. Vary 12VBAT from 9V to 20V GPU Vcore must remain in line regulation
9. Push S4 to “OFF” position to disable GPU Vcore controller.
10. Decrease LOAD to 0A and disconnect the LOAD from terminal J11
12. Disconnect scope probe from TP46
13. Exit SVID GUI window: click File → click Exit
14. Disconnect the USB cable between host Computer and EVM
6.1.3 VDDQ
2. Remove Jumper from J17, J18 from pin2 and pin3 and put this Jumper on pin1 and pin 2 of J18, J17 to enable S5 of VDDQ controller. VDDQ PGOOD LED will light up.
3. Measure V3: VDDQ at J20 and A1: 12Vin input current
4. Vary VDDQ LOAD from 0Adc to 8Adc, VDDQ must remain in the load regulation
5. Vary 12VBAT from 9V to 20V, VDDQ must remain in the line regulation
6. Remove Jumper of J17, J18 and shorts back on pin2 and pin3 of J17, J18 to disable VDDQ controller.
7. Decrease LOAD to 0A and disconnect the LOAD from terminal J19
8. Disconnect V3 from J20.

6.1.4 VCCIO
2. Push S1 to “ON” position to enable the VCCIO controller. VCCIO EN and PGOOD LED will light up.
3. Measure V3: VCCIO at J16 and A1: 12Vin input current
4. Vary VDDQ LOAD from 0Adc to 10Adc, VCCIO must remain in the load regulation
5. Vary 12VBAT from 9V to 20V, VCCIO must remain in the line regulation
6. Push S1 to “OFF” position to disable VCCIO controller.
7. Decrease LOAD to 0A and disconnect the LOAD from terminal J15
8. Disconnect V3 from J16.

6.2 Equipment Shutdown
1. Shut down Load
2. Shut down 12VBAT and 5Vin
3. Shut down oscilloscope
4. Shut down host computer
7 Performance Data and Typical Characteristic Curves

Figure 7 through Figure 91 present typical performance curves for TPS59650EVM-753. Jumpers set to default locations, see section 6 of this user’s guide.

7.1 CPU 3-Phase Operation
CPU 3 Phase operation

CH1: CSW1
CH2: CSW2
CH3: CSW3
CH4: 1.05V core Ripple

CPU Dynamic VID: Set VID-Slow/Slow

Test condition: 12 Vin, 1.05V/1A

CPU 3 Operation

CH4: VDIO
CH1: CSW1
CH2: CSW2
CH3: 1.05V core

CPU Dynamic VID: Set VID-Decay/Fast

Test condition: 12 Vin, 1.05V/1A

CPU 3 Operation

CH4: VDIO
CH1: CSW1
CH2: CSW2
CH3: 1.05V core

Figure 11. CPU3 Switching Node(Ripple)

Figure 12. CPU3 Dynamic VID: SetVID-Slow/Slow

Figure 13. CPU3 Dynamic VID: SetVID-Fast/Fast

Figure 14. CPU3 Dynamic VID: SetVID-Decay/Fast
Figure 15. CPU3 Output Load Insertion with OSR/USR middle level

Figure 16. CPU3 Output Load Release with OSR/USR middle level

Figure 17. CPU3 Bode Plot at 12Vin, 1.05V/60A

Test condition: CPU3 12Vin, 1.05V/60A no airflow
7.2 **CPU 2-Phase Operation**

![Figure 18. CPU3 MOSFET](image)

![Figure 19. CPU3 IC](image)

![Figure 20. CPU2 Efficiency](image)

![Figure 21. CPU2 Load regulation](image)
CPU 2 Phase Operation

Figure 22. CPU2 Enable Turn on

Figure 23. CPU2 Enable Turn off

Figure 24. CPU2 Switching Node (Ripple)

Figure 25. CPU2 Dynamic VID: SetVID-Slow/Slow
CPU Dynamic VID: Set VID-Decay/Fast
Test condition: 12 Vin, 1.05V/1A
CPU 2 Operation
CH1: CSW1
CH2: CSW2
CH3: 1.05Vcore
CH4: VDIO

CPU Dynamic VID: Set VID-Slow/Slow
Test condition: 12 Vin, 1.05V/1A
CPU 2 Operation
CH1: CSW1
CH2: CSW2
CH3: 1.05Vcore
CH4: VDIO

CPU Output Load Release with OSR/USR middle level
Test condition: 12 Vin, 0.05V/0A-51A
CPU 3 Phase on board dynamic load
CH2: CSW1
CH1: DYN_C
CH3: CSW2
CH4: 1.05Vcore

CPU Output Load Insertion with OSR/USR middle level
Test condition: 12 Vin, 0.05V/0A-51A
CPU 3 Phase on board dynamic load
CH1: DYN_C
CH2: CSW1
CH3: CSW2
CH4: 1.05Vcore

Figure 26. CPU2 Dynamic VID:SetVID-Fast/Fast
Figure 27. CPU2 Dynamic VID:SetVID-Decay/Fast
Figure 28. CPU2 Output Load Insertion with OSR/USR middle level
Figure 29. CPU2 Output Load Release with OSR/USR middle level
Figure 30. CPU2 Bode Plot at 12Vin, 1.05V/55A

Test condition: CPU2 12Vin, 1.05V/55A no airflow

Figure 31. CPU2 MOSFET

Figure 32. CPU2 IC
### 7.3 CPU1-Phase Operation

**Figure 33. CPU1 Efficiency**

- V\textsubscript{IN} = 12 V
- V\textsubscript{IN} = 9 V
- V\textsubscript{IN} = 20 V

**Figure 34. CPU1 Load regulation**

- V\textsubscript{IN} = 12 V
- V\textsubscript{IN} = 20 V
- V\textsubscript{IN} = 9 V

**Figure 35. CPU1 Enable Turn on**

**Figure 36. CPU1 Enable Turn off**

Test condition: 12 Vin, 1.05V/20A
CPU 3 Phase on board dynamic load

CPU VR\textsubscript{ON} Turn off
Test condition: 12 Vin, 1.05V/20A
CPU 1 Phase operation

CH1: VDIO
CH2: CSW1
CH3: 1.05Vcore
CH4: CPGOOD

CH1: VR\textsubscript{ON}
CH2: CSW1
CH3: 1.05Vcore
CH4: CPGOOD
TPS59650EVM
CPU Switching Node
Test condition: 12 Vin, 1.05V/20A
CPU 1 Phase operation

CH1: CSW1

CH2: 1.05Vcore Ripple

Figure 37. CPU1 Switching Node

Figure 38. CPU1 Switching node and Ripple

TPS59650EVM
CPU Dynamic VID: Set VID-Slow/Slow
Test condition: 12 Vin, 1.05V/21A
CPU 1 Operation

CH1: CSW1

CH3: 1.05Vcore

CH4: VDIO

Figure 39. CPU1 Dynamic VID:SetVID-Slow/Slow

Figure 40. CPU1 Dynamic VID:SetVID-Fast/Fast

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CPU Dynamic VID: Set VID-Decay/Fast

Test condition: 12 Vin, 1.05V/1A

Figure 41. CPU1 Dynamic VID: Set VID-Decay/Fast

CPU Output Load Insertion with OSR/USR middle level

Test condition: 12 Vin, 1.05V/0A-27A

CPU 1 Phase on board dynamic load

Figure 42. CPU1 Output Load Insertion with OSR/USR middle level

CPU Output Load Release with OSR/USR middle level

Test condition: 12 Vin, 1.05V/0A-27A

CPU 1 Phase on board dynamic load

Figure 43. CPU1 Output Load Release with OSR/USR middle level
Performance Data and Typical Characteristic Curves

Figure 44. CPU1 Bode Plot at 12Vin, 1.05V/33A

Test condition: CPU1 12Vin, 1.05V/33A no airflow

Figure 45. CPU1 MOSFET

Figure 46. CPU1 IC
7.4 GPU 2 Phase Operation

**Figure 47. GPU2 Efficiency**

- $V_{\text{IN}} = 20$ V
- $V_{\text{IN}} = 12$ V
- $V_{\text{IN}} = 9$ V

**Figure 48. GPU2 Load regulation**

- $V_{\text{IN}} = 20$ V
- $V_{\text{IN}} = 12$ V
- SPEC(min)
- SPEC(nom)
- SPEC(max)

**Figure 49. GPU2 Enable Turn on**

- CH1: GSW1
- CH2: GSW2
- CH3: 1.23Vcore
- CH4: GPGOOD

**Figure 50. GPU2 Enable Turn off**

- CH1: GSW1
- CH2: GSW2
- CH3: 1.23Vcore
- CH4: GPGOOD
Performance Data and Typical Characteristic Curves

Figure 51. GPU2 Switching Node and Ripple

Figure 52. GPU2 Dynamic VID: SetVID-Slow/Slow

Figure 53. GPU2 Dynamic VID: SetVID-Fast/Fast

Figure 54. GPU2 Dynamic VID: SetVID-Decay/Fast

Using the TPS59650EVM-753 Intel™ IMVP-7 3-Phase CPU/2-Phase GPU
SVID Power System

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Figure 55. GPU2 Output Load Insertion with OSR/USR

OFF

Figure 56. GPU2 Output Load Release with OSR/USR

OFF

Figure 57. GPU2 Bode Plot at 12Vin, 1.23V/50A

Test condition: GPU2 12Vin, 1.23V/50A no airflow
7.5  

**GPU 1 Phase Operation**

![Figure 58. GPU2 MOSFET](image)

![Figure 59. GPU2 IC](image)

![Figure 60. GPU1 Efficiency](image)

![Figure 61. GPU1 Load regulation](image)
CH3: 1.23Vcore
CH1: VDIO
TPS59650EVM
GPU VDIO Turn on
Test condition: 12 Vin, 1.05V/20A
GPU 1 Phase operation
CH2: GSW1
CH4: GPGOOD

CH1: VR_ON
TPS59650EVM
GPU VR_ON Turn on
Test condition: 12 Vin, 1.23V/20A
GPU 1 Phase operation
CH2: GSW1

TPS59650EVM
GPU Switching Node
Test condition: 12 Vin, 1.23V/0A-18A
GPU 1 Phase operation
CH1: GSW1

TPS59650EVM
GPU Switching Node and Output Ripple
Test condition: 12 Vin, 1.23V/20A
GPU 1 Phase operation
CH2: GSW1
CH3: 1.23Vcore Ripple

FIGURE 62. GPU1 Enable Turn on
FIGURE 63. GPU1 Enable Turn off
FIGURE 64. GPU1 Switching Node
FIGURE 65. GPU1 Switching Node and Ripple
TPS59650EVM
CPU Dynamic VID: Set VID-Fast/Fast
Test condition: 12 Vin, 1.23V/1A
GPU 1 Operation
CH1: CSW1
CH3: 1.23Vcore_G
CH4: VDIO

TPS59650EVM
GPU Dynamic VID: Set VID-Slow/Slow
CH1: GSW1
CH3: 1.23Vcore_G
CH4: VDIO

TPS59650EVM
GPU Dynamic VID: Set VID-Decay/Fast
Test condition: 12 Vin, 1.23V/1A
GPU 1 Operation
CH1: GSW1
CH3: 1.23Vcore_G
CH4: VDIO

TPS59650EVM
GPU Output Load Insertion with OSR/USR
Test condition: 12 Vin, 1.23V/0A-18A
GPU 1 Phase on board dynamic load
CH2: GSW1
CH3: 1.23Vcore

Figure 66. GPU1 Dynamic VID:SetVID-Slow/Slow
Figure 67. GPU1 Dynamic VID:SetVID-Fast/Fast
Figure 68. GPU1 Dynamic VID:SetVID-Decay/Fast
Figure 69. GPU1 Output Load Insertion with OSR/USR
OFF
CH1: DYN_G
TPS59650EVM
GPU Output Load Release with OSR/USR least reduction
Test condition: 12 Vin, 1.23V/0A-18A
GPU 1 Phase on board dynamic load
CH2: GSW1
CH3: 1.23Vcore

Figure 70. GPU1 Output Load Release with OSR/USR OFF

Figure 71. GPU1 Bode Plot at 12Vin, 1.23V/33A

Test condition: GPU1 12Vin, 1.23V/33A no airflow
7.6 1.05V VCCIO

Figure 74. 1.05V Efficiency

Figure 75. 1.05V Load regulation
Figure 76. 1.05V Enable Turn on
Figure 77. 1.05V Enable Turn off
Figure 78. 1.05V Switching Node
Figure 79. 1.05V Ripple
Figure 80. 1.05V Transient DCM TO CCM
Test condition: 12Vin, 1.05V/10A no airflow

Figure 81. 1.05V Transient CCM to DCM
Test condition: 12Vin, 1.05V/10A no airflow

Figure 82. TPS51219 Thermal
7.7 1.2V VDDQ

Figure 83. 1.2V Efficiency

Figure 84. 1.2V Load regulation

Figure 85. 1.2V Enable Turn on

Figure 86. 1.2V Enable Turn off
Figure 87. 1.2V Switching Node

Test condition: 12Vin, 1.2V/7.5A no airflow

Figure 88. 1.2V Ripple

Figure 89. 1.2V Transient DCM TO CCM

Figure 90. 1.2V Transient CCM to DCM
Figure 91. TPS51916 Thermal
8 EVM Assembly Drawings and PCB Layout

The following figures (Figure 92 through Figure 101) show the design of the TPS59650EVM-753 printed circuit board. The EVM has been designed using 8 Layers circuit board with 1oz copper on outside layers.

Figure 92. TPS59650EVM-753 Top Layer Assembly Drawing (Top view)

Figure 93. TPS59650EVM-753 Bottom Assembly Drawing (Bottom view)
Figure 94. TPS59650EVM-753 Top Copper

Figure 95. TPS59650EVM-753 Bottom Copper
Figure 96. TPS59650EVM-753 Internal Layer 2

Figure 97. TPS59650EVM-753 Internal Layer 3
Figure 98. TPS59650EVM-753 Internal Layer 4

Figure 99. TPS59650EVM-753 Internal Layer 5
Figure 100. TPS59650EVM-753 Internal Layer 6

Figure 101. TPS59650EVM-753 Internal Layer 7
The EVM major components list according to the schematic shown in the following pages.

Table 13. EVM Major Components List

<table>
<thead>
<tr>
<th>QTY</th>
<th>REF DES</th>
<th>Description</th>
<th>MFR</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>C1, C12, C31, C69, C74, C124, C159, C121, C130, C184, C204</td>
<td>Capacitor, Ceramic, 1nF, 50V, X7R, 10%, 0603</td>
<td>STD</td>
<td>STD</td>
</tr>
<tr>
<td>5</td>
<td>C104, C108, C112, C115, C118</td>
<td>Capacitor, Ceramic, 33nF, 25V, X7R, 10%, 0603</td>
<td>STD</td>
<td>STD</td>
</tr>
<tr>
<td>29</td>
<td>C128, C164, C198, C199, C201, C127, C172, C188, C192, C203, C207, C190, C209, C210, C216, C217, C218, C219, C220, C221, C222, C223, C224, C225, C226, C227, C228, C229, C230</td>
<td>Capacitor, Ceramic, 0.1uF, 25V, X7R, 10%, 0603</td>
<td>STD</td>
<td>STD</td>
</tr>
<tr>
<td>3</td>
<td>C129, C133, C168</td>
<td>Capacitor, Polymer, 330uF, 2V, 6mohm, 20%, 7343</td>
<td>Sanyo</td>
<td>2TPF330M6</td>
</tr>
<tr>
<td>2</td>
<td>C13, C26</td>
<td>Capacitor, Ceramic, 100pF, 50V, C0G, 10%, 0603</td>
<td>STD</td>
<td>STD</td>
</tr>
<tr>
<td>3</td>
<td>C131, C239, C246</td>
<td>Capacitor, Ceramic, 10nF, 50V, X7R, 10%, 0603</td>
<td>STD</td>
<td>STD</td>
</tr>
<tr>
<td>6</td>
<td>C15, C16, C19, C20, C76, C77</td>
<td>Capacitor, Polymer, 470uF, 2V, 4mohm, 20%, D2T</td>
<td>Sanyo</td>
<td>2TPLF470M4E</td>
</tr>
<tr>
<td>1</td>
<td>C166</td>
<td>Capacitor, Ceramic, 2.2uF, 6.3V, X5R, 10%, 0805</td>
<td>STD</td>
<td>STD</td>
</tr>
<tr>
<td>1</td>
<td>C17</td>
<td>Capacitor, Ceramic, 0.33uF, 6.3V, X7R, 10%, 0603</td>
<td>STD</td>
<td>STD</td>
</tr>
<tr>
<td>1</td>
<td>C171</td>
<td>Capacitor, Ceramic, 0.22uF, 50V, X7R, 10%, 0603</td>
<td>STD</td>
<td>STD</td>
</tr>
<tr>
<td>15</td>
<td>C18, C23, C33, C75, C80, C196, C202, C208, C195, C200, C242, C250, C22, C233, C234</td>
<td>Capacitor, Ceramic, 1uF, 25V, X7R, 10%, 0603</td>
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<td>C193, C36, C79, C82, C135, C170</td>
<td>Capacitor, Ceramic, 2.2uF, 6.3V, X5R, 10%, 0603</td>
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<td>C194, C197, C215</td>
<td>Capacitor, Ceramic, 0.01uF, 50V, X7R, 10%, 0603</td>
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<td>C2, C3, C4, C5, C8, C9, C10, C11, C27, C28, C29, C30, C65, C66, C67, C68, C70, C71, C72, C73, C122, C123, C125, C126, C160, C161, C162, C163</td>
<td>Capacitor, Ceramic, 10uF, 25V, X7R, 10%, 0603</td>
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<td>Capacitor, Ceramic, 10pF, 50V, C0G, 10%, 0603</td>
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<td>Capacitor, Ceramic, 22pF, 50V, C0G, 10%, 0603</td>
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<td>C240, C248</td>
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<td>C243, C251</td>
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<td>C247, C254</td>
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<td>Capacitor, Ceramic, 22uF, 6.3V, X5R, 10%, 0805</td>
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<td>C44, C46, C57, C58, C59, C60, C61, C62, C63, C64, C173, C174, C175, C176, C180, C182, C165, C185, C186, C189, C191</td>
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<td>D1, D2, D3, D9, D10, D12, D13, D14</td>
<td>Diode, LED, Green Clear, 20mcd, 0.079x0.049</td>
<td>Lite On</td>
<td>LTST-C170GKT</td>
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### Table 13. EVM Major Components List (continued)

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<tr>
<th>QTY</th>
<th>REF DES</th>
<th>Description</th>
<th>MFR</th>
<th>Part Number</th>
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<td>D4, D5, D7, D8, D11</td>
<td>Diode, LED, Red Clear, 20mA, 0.079x0.049</td>
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<td>Diode, Schottky, 200mA, 30V, SOT-23</td>
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<td>FB1</td>
<td>Bead, SMD, Ferrite, 10MHz Max, 200mA, +/-25%, 0603</td>
<td>WE</td>
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<td>Inductor, SMT, 0.36uH, 35A, 0.82mohm, 10x11.5mm</td>
<td>TDK</td>
<td>FCUL1040-H-R36M</td>
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<td>Inductor, SMT, 0.42uH, 17A, 1.5mohm, 8.7x7.0mm</td>
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<td>Inductor, SMT, 1.0uH, 8.1A, 6.9mohm, 7.3x6.6mm</td>
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<td>Q1, Q2, Q3, Q4, Q5, Q8, Q10</td>
<td>MOSFET, Synchronous Buck NexFET Power Block SON 5x6mm</td>
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<td>Q11, Q12, Q13, Q14</td>
<td>MOSFET, Nch, 25V, 31A, 2.5mohm, QFN5x6mm</td>
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</table>
Table 13. EVM Major Components List (continued)

<table>
<thead>
<tr>
<th>QTY</th>
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<th>Description</th>
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<th>Part Number</th>
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<td>R43, R49, R51, R60, R65, R71, R75, R85, R87, R93, R200, R201, R208, R209, R243, R249, R253, R254, R263, R265</td>
<td>Resistor, Chip, 0, 1/16W, 1%, 0402</td>
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<td>IC, Dual-bit dual-supply bus transceiver, RSW-10</td>
<td>TI</td>
<td>SN74AVC2T245RSW</td>
</tr>
<tr>
<td>3</td>
<td>U2, U3, U4</td>
<td>IC, Dual high voltage, efficient synchronous MOSFET buck driver, QFN-8</td>
<td>TI</td>
<td>TPS51601ADR</td>
</tr>
<tr>
<td>1</td>
<td>U5</td>
<td>IC, High performance, single synchronous step down controller, QFN-16</td>
<td>TI</td>
<td>TPS51219RTE</td>
</tr>
<tr>
<td>1</td>
<td>U6</td>
<td>IC, Complete DDR2, DDR3 and DDR3L memory power solution, QFN-20</td>
<td>TI</td>
<td>TPS51916RUJ</td>
</tr>
<tr>
<td>1</td>
<td>U7</td>
<td>IC, Dual low dropout regulator, 500mA and 250mA outputs, PWP20</td>
<td>TI</td>
<td>TPS70102PWP</td>
</tr>
<tr>
<td>1</td>
<td>U8</td>
<td>IC, 150mA, low Iq, wide bandwidth, LDO, SC70</td>
<td>TI</td>
<td>TPS71712DKC</td>
</tr>
</tbody>
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Table 13. EVM Major Components List (continued)

<table>
<thead>
<tr>
<th>QTY</th>
<th>REF DES</th>
<th>Description</th>
<th>MFR</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>U9</td>
<td>IC, Quadruple 2-input positive –AND gates, SO-14</td>
<td>TI</td>
<td>SN74HC08D</td>
</tr>
<tr>
<td>2</td>
<td>U10, U11</td>
<td>IC, Dual 4A High speed low side power MOSFET drivers, SO-8</td>
<td>TI</td>
<td>UCC27324D</td>
</tr>
<tr>
<td>1</td>
<td>X1</td>
<td>Crystal, controlled oscillators, 0.150”x0.528”</td>
<td>ABRACON</td>
<td>ABLS-20.000MHZ-B2-T</td>
</tr>
<tr>
<td>1</td>
<td>Y1</td>
<td>Crystal, controlled oscillators, 0.150”x0.528”</td>
<td>ABRACON</td>
<td>ABLS-12.000MHZ-B2-T</td>
</tr>
<tr>
<td>1</td>
<td>XU1</td>
<td>Socket, CPU</td>
<td>Molex</td>
<td>rPGA989</td>
</tr>
</tbody>
</table>

10 Schematics
Current Feedback Selection and Filtering
Differential Voltage Feedback and termination

CPU

To processor

R51, R60 = 0 for DCR sense
R53, R57 = 0 for Resistor Sense

R51, R60 = 0 for DCR sense
R53, R57 = 0 for Resistor Sense

Note 4:
Not used

A phase can be disabled by pulling the corresponding xCSPx pin to 3.3V.
Default setting for CPU: 3 phase operation
Default setting for GPU: 2 phase operation

CPU
Phase disable can be done in reverse order: Phase 3, then 2, then 1.
1. CPU 3 Phase operation: R47, R55, R69 open
2. CPU 2 Phase operation: R69 used 0 ohm
3. CPU 1 Phase operation: R47, R55 used 0 ohm

GPU
1. GPU 2 Phase operation: R83, R89 open
2. GPU 1 Phase operation: R89 used 0 ohm

Current Feedback Selection and Filtering
Differential Voltage Feedback and termination
SWITCHING FREQUENCY SELECTION

CPU

J11

600kHz (MAX)
550kHz
500kHz
450kHz
400kHz
350kHz
300kHz
250kHz (MIN)

60kHz (MAX)
50kHz
49kHz
44kHz
38kHz
33kHz
27kHz (MIN)

GPU

J13

660kHz (MAX)
605kHz
550kHz
49kHz
44kHz
38kHz
33kHz
27kHz (MIN)

OSR / USR SETTING

CPU

Over-Shoot / Under-Shoot Reduction Selection:
1. CPU OSR / USR Default Setting: OSR / USR Reduction middle level
2. GPU OSR / USR Default Setting: OSR / USR Reduction off

OVER-CURRENT PROTECTION SELECTION

CPU

J10

Level 8 (MAX)
Level 7
Level 6
Level 5
Level 4
Level 3
Level 2
Level 1 (MIN)

GPU

J12

Level 8 (MAX)
Level 7
Level 6
Level 5
Level 4
Level 3
Level 2
Level 1 (MIN)

Note:
- Not used
- Switching Frequency Selection:
  1. CPU Switching Frequency Default Setting: Jumper shorts on pin 13 and pin 14 to set 300kHz
  2. GPU Switching Frequency Default Setting: Jumper shorts on pin 11 and pin 12 to set 385kHz
- Over Current Protection Selection:
  1. CPU Over Current Protection Per Phase Default Setting: Jumper shorts on pin 7 and pin 8 to level 5 (set 40A)
  2. GPU Over Current Protection Per Phase Default Setting: Jumper shorts on pin 7 and pin 8 to level 5 (set 40A)
- Over-Shoot / Under-Shoot Reduction Selection:
  1. CPU OSR / USR Default Setting: OSR / USR Reduction middle level
  2. GPU OSR / USR Default Setting: OSR / USR Reduction off
- Optional parts for using TPS51640

Frequency and OCP SELECTIONS for CPU and GPU
Not used

Note 6:
1. VCCIO Output Selection:
   1. Jumper shorts on pin1 and pin2 of J14 to set VCCIO: 1.05V (Default)
   2. Jumper shorts on pin2 and pin3 of J14 to set VCCIO: 1.00V
2. VCCIO Enable Rn
Not used

S4: IMVP-7 VR Enable:
1. Switch to "ON" position to Enable TPS59650 controller
2. Switch to "OFF" position to Disable TPS59650 controller (Default)

Default Trim: R117 = Not used, R116 = 1.00k

Logic Signal Termination and Status LED's
LED is ON when the logic signal is in the ACTIVE state

J24, J31 are labview connections for EVM testing
Jumper to use 5V from USB

Note:
- Not used
- 5V Bias option:
  1. Jumper shorts on J33, 5V Bias used from USB. If USB 5V is used, external 5V supply from J22 should not be used.
  2. No jumper shorts on J33, 5V Bias used from external J22 (Default)
- For internal software development

USB to DSP
Note 3:
- Not used

J42, J43: Optional VCCIO and VDDQ Enable
1. Jumper shorts on J42, J43 to Enable Optional VCCIO and VDDQ
2. No jumper shorts on J42, J43 to Disable Optional VCCIO and VDDQ

Optional Solution for VCCIO and VDDQ
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General Statement for EVMs including a radio

User Power/Frequency Use Obligations: This radio is intended for development/professional use only in legally allocated frequency and power limits. Any use of radio frequencies and/or power availability of this EVM and its development application(s) must comply with local laws governing radio spectrum allocation and power limits for this evaluation module. It is the user’s sole responsibility to only operate this radio in legally acceptable frequency space and within legally mandated power limitations. Any exceptions to this are strictly prohibited and unauthorized by Texas Instruments unless user has obtained appropriate experimental/development licenses from local regulatory authorities, which is responsibility of user including its acceptable authorization.

For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant

Caution

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation. Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

FCC Interference Statement for Class A EVM devices

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.
FCC Interference Statement for Class B EVM devices

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

• 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.

For EVMs annotated as IC – INDUSTRY CANADA Compliant

This Class A or B digital apparatus complies with Canadian ICES-003.

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

Concerning EVMs including radio transmitters

This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concerning EVMs including detachable antennas

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication.

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.

Concernant les EVMs avec appareils radio

Le présent appareil est conforme aux CNR d’Industrie Canada applicables aux appareils radio exempts de licence. L’exploitation est autorisée aux deux conditions suivantes : (1) l’appareil ne doit pas produire de brouillage, et (2) l’utilisateur de l’appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d’en compromettre le fonctionnement.

Concernant les EVMs avec antennes détaichables

Conformément à la réglementation d’Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d’un type et d’un gain maximal (ou inférieur) approuvé pour l’émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l’intention des autres utilisateurs, il faut choisir le type d’antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l’intensité nécessaire à l’établissement d’une communication satisfaisante.

Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d’antenne énumérés dans le manuel d’usage et ayant un gain admissible maximal et l’impédance requise pour chaque type d’antenne. Les types d’antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l’exploitation de l’émetteur.
【Important Notice for Users of this Product in Japan】

This development kit is NOT certified as Confirming to Technical Regulations of Radio Law of Japan

If you use this product in Japan, you are required by Radio Law of Japan to follow the instructions below with respect to this product:

1. Use this product in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use this product only after you obtained the license of Test Radio Station as provided in Radio Law of Japan with respect to this product, or
3. Use of this product only after you obtained the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to this product. Also, please do not transfer this product, unless you give the same notice above to the transferee. Please note that if you could not follow the instructions above, you will be subject to penalties of Radio Law of Japan.

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西新宿三井ビル

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EVALUATION BOARD/KIT/MODULE (EVM)  
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For Feasibility Evaluation Only, in Laboratory/Development Environments. Unless otherwise indicated, this EVM is not a finished electrical equipment and not intended for consumer use. It is intended solely for use for preliminary feasibility evaluation in laboratory/development environments by technically qualified electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems and subsystems. It should not be used as all or part of a finished end product.

Your Sole Responsibility and Risk. You acknowledge, represent and agree that:

1. You have unique knowledge concerning Federal, State and local regulatory requirements (including but not limited to Food and Drug Administration regulations, if applicable) which relate to your products and which relate to your use (and/or that of your employees, affiliates, contractors or designees) of the EVM for evaluation, testing and other purposes.

2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates, contractors or designees, using the EVM. Further, you are responsible to assure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard.

3. You will employ reasonable safeguards to ensure that your use of the EVM will not result in any property damage, injury or death, even if the EVM should fail to perform as described or expected.

4. You will take care of proper disposal and recycling of the EVM’s electronic components and packing materials.

Certain Instructions. It is important to operate this EVM within TI’s recommended specifications and environmental considerations per the user guidelines. Exceeding the specified EVM ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings please contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM User’s Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, some circuit components may have case temperatures greater than 60°C as long as the input and output are maintained at a normal ambient operating temperature. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified using the EVM schematic located in the EVM User’s Guide. When placing measurement probes near these devices during normal operation, please be aware that these devices may be very warm to the touch. As with all electronic evaluation tools, only qualified personnel knowledgeable in electronic measurement and diagnostics normally found in development environments should use these EVMs.

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Should this evaluation board/kit not meet the specifications indicated in the User’s Guide, the board/kit may be returned within 30 days from the date of delivery for a full refund. THE FOREGOING LIMITED WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE. EXCEPT TO THE EXTENT OF THE INDEMNITY SET FORTH ABOVE, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

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General Statement for EVMs including a radio

User Power/Frequency Use Obligations: This radio is intended for development/professional use only in legally allocated frequency and power limits. Any use of radio frequencies and/or power availability of this EVM and its development application(s) must comply with local laws governing radio spectrum allocation and power limits for this evaluation module. It is the user’s sole responsibility to only operate this radio in legally acceptable frequency space and within legally mandated power limitations. Any exceptions to this are strictly prohibited and unauthorized by Texas Instruments unless user has obtained appropriate experimental/development licenses from local regulatory authorities, which is responsibility of user including its acceptable authorization.

For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant

Caution

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation. Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

FCC Interference Statement for Class A EVM devices

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.
FCC Interference Statement for Class B EVM devices

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

• 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.

For EVMs annotated as IC – INDUSTRY CANADA Compliant

This Class A or B digital apparatus complies with Canadian ICES-003.

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

Concerning EVMs including radio transmitters

This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concerning EVMs including detachable antennas

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication.

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.

Cet appareil numérique de la classe A ou B est conforme à la norme NMB-003 du Canada.

Les changements ou les modifications pas expressément approuvés par la partie responsable de la conformité ont pu vider l'autorité de l'utilisateur pour actionner l'équipement.

Concernant les EVMs avec appareils radio

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante.

Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur.
【Important Notice for Users of this Product in Japan】

This development kit is NOT certified as Confirming to Technical Regulations of Radio Law of Japan

If you use this product in Japan, you are required by Radio Law of Japan to follow the instructions below with respect to this product:

1. Use this product in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan.
2. Use this product only after you obtained the license of Test Radio Station as provided in Radio Law of Japan with respect to this product, or
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EVALUATION BOARD/KIT/MODULE (EVM)
WARNINGS, RESTRICTIONS AND DISCLAIMERS

For Feasibility Evaluation Only, in Laboratory/Development Environments. Unless otherwise indicated, this EVM is not a finished
electrical equipment and not intended for consumer use. It is intended solely for use for preliminary feasibility evaluation in
laboratory/development environments by technically qualified electronics experts who are familiar with the dangers and application risks
associated with handling electrical mechanical components, systems and subsystems. It should not be used as all or part of a finished end
product.

Your Sole Responsibility and Risk. You acknowledge, represent and agree that:

1. You have unique knowledge concerning Federal, State and local regulatory requirements (including but not limited to Food and Drug
   Administration regulations, if applicable) which relate to your products and which relate to your use (and/or that of your employees,
   affiliates, contractors or designees) of the EVM for evaluation, testing and other purposes.
2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable
   regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates,
   contractors or designees, using the EVM. Further, you are responsible to assure that any interfaces (electronic and/or mechanical)
   between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to
   minimize the risk of electrical shock hazard.
3. You will employ reasonable safeguards to ensure that your use of the EVM will not result in any property damage, injury or death, even
   if the EVM should fail to perform as described or expected.
4. You will take care of proper disposal and recycling of the EVM’s electronic components and packing materials.

Certain Instructions. It is important to operate this EVM within TI’s recommended specifications and environmental considerations per the
user guidelines. Exceeding the specified EVM ratings (including but not limited to input and output voltage, current, power, and
environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings please contact
a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the
specified output range may result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or
interface electronics. Please consult the EVM User’s Guide prior to connecting any load to the EVM output. If there is uncertainty as to the
load specification, please contact a TI field representative. During normal operation, some circuit components may have case temperatures
greater than 60°C as long as the input and output are maintained at a normal ambient operating temperature. These components include
but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified using the
EVM schematic located in the EVM User’s Guide. When placing measurement probes near these devices during normal operation, please
be aware that these devices may be very warm to the touch. As with all electronic evaluation tools, only qualified personnel knowledgeable
in electronic measurement and diagnostics normally found in development environments should use these EVMs.

Agreement to Defend, Indemnify and Hold Harmless. You agree to defend, indemnify and hold TI, its licensors and their representatives
harmless from and against any and all claims, damages, losses, expenses, costs and liabilities (collectively, “Claims”) arising out of or in
connection with any use of the EVM that is not in accordance with the terms of the agreement. This obligation shall apply whether Claims
arise under law of tort or contract or any other legal theory, and even if the EVM fails to perform as described or expected.

Safety-Critical or Life-Critical Applications. If you intend to evaluate the components for possible use in safety critical applications (such
as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, such as devices
which are classified as FDA Class III or similar classification, then you must specifically notify TI of such intent and enter into a separate
Assurance and Indemnity Agreement.

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TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

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In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have not been so designated is solely at the Buyer’s risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components which meet ISO/TS16949 requirements, mainly for automotive use. Components which have not been so designated are neither designed nor intended for automotive use; and TI will not be responsible for any failure of such components to meet such requirements.

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