Application Report
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# TPS7B4253-Q1 Pin FMEA

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**ABSTRACT**

For automotive off-board sensors and small current off-board modules, the power supply comes through a long cable from the main board. In such cases, protection is required in the power devices for the off-board loads to prevent the onboard components from damage during a short to GND or short to battery caused by a broken cable. Off-board sensors require consistent power supply as onboard components to secure high accuracy of data acquisition.

The TPS7B4253-Q1 device is designed for automotive applications with a 45-V load dump. The device can either be used as one tracking low-dropout (LDO) regulator or voltage tracker to build one closed power loop for off-board sensors with an onboard main supply. The output of the device is accurately regulated by a reference voltage at the ADJ pin.

To provide an accurate power supply to the off-board modules, the device offers a 4-mV ultra-low tracking tolerance between the ADJ and FB pins across temperature. The back-to-back PMOS topology eliminates the need for an external diode under reverse polarity conditions. The TPS7B4253-Q1 device also includes thermal shutdown, inductive clamp, overload, and short-to-battery protection to prevent damage to onboard components during extreme conditions.

## Pin FMEA

This application note provides a Failure Modes and Effects Analysis (FMEA) for the device pins of the TPS7B4253-Q1 Voltage-Tracking LDO Regulator. The failure conditions covered in this document include the typical pin-by-pin failure scenarios:

- Pin short-circuited to Ground
- Pin short-circuited to TPS7B4253-Q1 $V_{IN}$
- Pin short-circuited to car battery voltage
- Pin short-circuited to an adjacent pin
- Pin is open-circuited

This application note also details how these pin conditions affect the device:

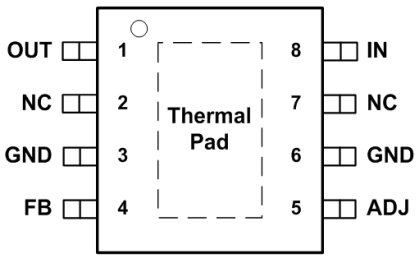
- Does the pin condition cause permanent damage?
- Is the device functional under the pin condition?
- How does the particular pin condition affect the device operation?

For purposes of this report:

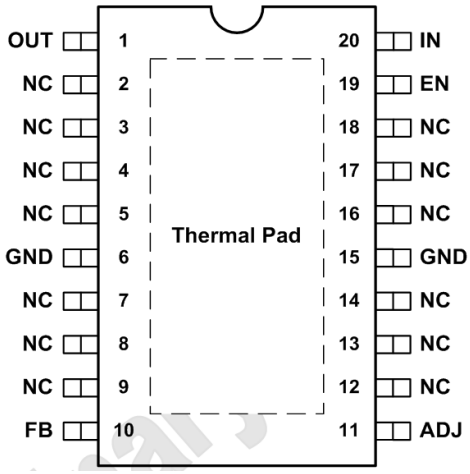
- Unless otherwise specified, the voltage applied to the $V_{IN}$ pin is within the TPS7B4253-Q1 recommended operating range.
- The ADJ/EN pin is driven from an external source.
- Functionality = YES indicates the normal device operation.
- Damage = YES indicates damage to the device

## Pin Configuration and Functions

**DDA Package**
**8-pin SO PowerPAD**
**Top View**




**PWP Package**
**20-Pin HTSSOP with Exposed Thermal Pad**
**Top View**




| Pin | | | Type | Description |
|---|---|---|---|---|
| Name | SO PowerPAD | HTSSOP | | |
| ADJ | 5 | 11 | I | Connect the reference to this pin. A low signal disables the device and a high signal enables the device. The reference voltage can be connected directly or by a voltage divider for lower output voltages. To compensate for line influences, connect a capacitor close to the device pins. |
| EN | - | 19 | I | This pin is the enable pin. The device goes to the STANDBY state when the enable pin goes lower than the threshold value. |
| FB | 4 | 10 | I | This pin is the feedback pin which can connect to external resistor divider to select the output voltage |
| GND | 3 | 6 | G | Ground reference |
| | 6 | 15 | | |
| IN | 8 | 20 | I | This pin is the device supply. To compensate for line influences, connect a capacitor close to the device pins. |
| NC | 2 | 2 | NC | Not connected |
| | | 3 | | |
| | | 4 | | |
| | | 5 | | |
| | | 7 | | |
| | | 8 | | |
| | | 9 | | |
| | 7 | 12 | | |
| | | 13 | | |
| | | 14 | | |
| | | 16 | | |
| | | 17 | | |
| | | 18 | | |
| OUT | 1 | 1 | O | Block to GND with a capacitor close to the device pins with respect to the capacitance and ESR requirements given in the Output Capacitor section |
| Exposed thermal pad | | | - | Connect the thermal pad to the GND pin or leave it floating. |

**Table 1. Pin FMEA Analysis for Pin Short-Circuit to Ground**

| Pin | | | Short to Ground | | |
|---|---|---|---|---|---|
| **Name** | **SO PowerPAD** | **HTSSOP** | **Damage** | **Functionality** | **Comments** |
| OUT | 1 | 1 | No | No | No output voltage. Output current limit is triggered, and thermal shutdown may be activated. |
| NC | 2 | 2 | No | Yes | No effect |
| | | 3 | | | |
| | | 4 | | | |
| | | 5 | | | |
| | | 7 | | | |
| | | 8 | | | |
| | | 9 | | | |
| GND | 3 | 6 | No | Yes | Normal operation |
| FB | 4 | 10 | No | No | 1. FB connected to OUT directly. No output voltage. Output current limit is triggered, and thermal shutdown may be activated.<br>2. FB connected to OUT with resistors divider. Device will work in switch mode.<br>3. FB connected to GND (switch mode). No effect. |
| ADJ | 5 | 11 | No | No | Device is disabled |
| GND | 6 | 15 | No | Yes | Normal operation |
| NC | 7 | 12 | No | Yes | No effect |
| | | 13 | | | |
| | | 14 | | | |
| | | 16 | | | |
| | | 17 | | | |
| | | 18 | | | |
| EN | - | 19 | No | No | Device is disabled |
| IN | 8 | 20 | No | No | No output voltage. Either input supply is at 0 V, or input fuse is blown. |

**Table 2. Pin FMEA Analysis for Pin Short-Circuit to $V_{IN}$**

| Pin | | | Short to $V_{IN}$ | | |
|---|---|---|---|---|---|
| **Name** | **SO PowerPAD** | **HTSSOP** | **Damage** | **Functionality** | **Comments** |
| OUT | 1 | 1 | No | No | Internal power MOSFET is switched off. |
| NC | 2 | 2 | No | Yes | No effect |
| | | 3 | | | |
| | | 4 | | | |
| | | 5 | | | |
| | | 7 | | | |
| | | 8 | | | |
| | | 9 | | | |
| GND | 3 | 6 | No | No | $V_{IN}$ is short to ground. Either input supply is at 0 V, or input fuse is blown. |
| FB | 4 | 10 | No | No | 1. If FB voltage is larger than ADJ voltage, the internal Power MOSFET is switched off.<br>2. If FB voltage is smaller than ADJ voltage, device will work in switch mode.<br>3. If FB is connected to GND (switch mode), $V_{IN}$ is shorted to ground. Either input supply is at 0 V, or input fuse is blown. |
| ADJ | 5 | 11 | No | No | When $V_{IN}$ voltage is larger than 1.5 V, output voltage will follow the $V_{IN}$ voltage, and ADJ voltage is clamped at 18 V when $V_{IN}$ is larger than 18 V |
| GND | 6 | 15 | No | No | $V_{IN}$ is short to ground. Either input supply is at 0 V, or input fuse is blown. |
| NC | 7 | 12 | No | Yes | No effect |
| | | 13 | | | |
| | | 14 | | | |
| | | 16 | | | |
| | | 17 | | | |
| | | 18 | | | |
| EN | - | 19 | No | Yes | Device works with normal regulation, but cannot be shut down by EN pin |
| IN | 8 | 20 | No | Yes | Normal operation |

**Table 3. Pin FMEA Analysis for Pin Short-Circuit to Car Battery Voltage**

| Pin | | | Short to Car Battery Voltage | | |
|---|---|---|---|---|---|
| **Name** | **SO PowerPAD** | **HTSSOP** | **Damage** | **Functionality** | **Comments** |
| OUT | 1 | 1 | No | No | No OUT regulation. Internal Power MOSFET is switched off. |
| NC | 2 | 2 | No | Yes | No effect |
| | | 3 | | | |
| | | 4 | | | |
| | | 5 | | | |
| | | 7 | | | |
| | | 8 | | | |
| | | 9 | | | |
| GND | 3 | 6 | No | No | Battery is shorted to ground. Either input supply is at 0 V, or input fuse is blown. |
| FB | 4 | 10 | No | No | 1. If FB voltage is larger than ADJ voltage, the internal Power MOSFET is switched off.<br>2. If FB voltage is smaller than ADJ voltage, device will work in switch mode.<br>3. If FB is connected to GND (switch mode), battery is shorted to ground. Either input supply is at 0 V, or input fuse is blown. |
| ADJ | 5 | 11 | Yes | No | Output voltage will follow $V_{IN}$, when $V_{IN}$ equals to car battery voltage, and ADJ voltage is clamped at 18 V when the car battery voltage is larger than 18 V. Car battery voltages greater than $V_{IN}$+18 V will damage the device. |
| GND | 6 | 15 | No | No | Battery is shorted to ground. Either input supply is at 0 V, or input fuse is blown. |
| NC | 7 | 12 | No | Yes | No effect |
| | | 13 | | | |
| | | 14 | | | |
| | | 16 | | | |
| | | 17 | | | |
| | | 18 | | | |
| EN | - | 19 | No | Yes | Device works with normal regulation, but cannot be shut down by EN pin. |
| IN | 8 | 20 | No | Yes | Normal operation |

**Table 4. Pin FMEA Analysis for Pin Short-Circuit to an Adjacent Pin (SO PowerPAD)**

| Pin | | Shorted To | | Short to Adjacent Pin | | |
|---|---|---|---|---|---|---|
| Name | SO PowerPAD | Name | SO PowerPAD | Damage | Functionality | Comments |
| OUT | 1 | IN | 8 | No | No | Not considered. Pins located on opposite package side. |
| NC | 2 | OUT | 1 | No | Yes | No effect |
| GND | 3 | NC | 2 | No | Yes | No effect |
| FB | 4 | GND | 3 | No | No | 1. FB connected to OUT directly. No output voltage. Output current limit is triggered, and thermal shutdown may be activated.<br>2. FB connected to OUT with resistors divider. Device will work in switch mode.<br>3. FB connected to GND (switch mode). No effect. |
| ADJ | 5 | FB | 4 | No | No | Not considered. Pins located on opposite package side. |
| GND | 6 | ADJ | 5 | No | No | Device is disabled |
| NC | 7 | GND | 6 | No | Yes | No effect |
| IN | 8 | NC | 7 | No | Yes | No effect |

**Table 5. Pin FMEA Analysis for Pin Short-Circuit to an Adjacent Pin (HTSSOP)**

| Pin | | Shorted To | | Short to Adjacent Pin | | |
|---|---|---|---|---|---|---|
| Name | HTSSOP | Name | HTSSOP | Damage | Functionality | Comments |
| OUT | 1 | IN | 20 | No | No | Not considered. Pins located on opposite package side. |
| NC | 2 | OUT | 1 | No | Yes | No effect |
| NC | 3 | NC | 2 | No | Yes | No effect |
| NC | 4 | NC | 3 | No | Yes | No effect |
| NC | 5 | NC | 4 | No | Yes | No effect |
| GND | 6 | NC | 5 | No | Yes | No effect |
| NC | 7 | GND | 6 | No | Yes | No effect |
| NC | 8 | NC | 7 | No | Yes | No effect |
| NC | 9 | NC | 8 | No | Yes | No effect |
| FB | 10 | NC | 9 | No | Yes | No effect |
| ADJ | 11 | FB | 10 | No | No | Not considered. Pins located on opposite package side. |
| NC | 12 | ADJ | 11 | No | Yes | No effect |
| NC | 13 | NC | 12 | No | Yes | No effect |
| NC | 14 | NC | 13 | No | Yes | No effect |
| GND | 15 | NC | 14 | No | Yes | No effect |
| NC | 16 | GND | 15 | No | Yes | No effect |
| NC | 17 | NC | 16 | No | Yes | No effect |
| NC | 18 | NC | 17 | No | Yes | No effect |
| EN | 19 | NC | 18 | No | Yes | No effect |
| IN | 20 | EN | 19 | No | Yes | No effect |

**Table 6. Pin FMEA Analysis for Pin Open-Circuit**

| Pin | | | Open | | |
|---|---|---|---|---|---|
| **Name** | **SO PowerPAD** | **HTSSOP** | **Damage** | **Functionality** | **Comments** |
| OUT | 1 | 1 | No | No | No output voltage to load |
| NC | 2 | 2 | No | Yes | No effect |
| | | 3 | | | |
| | | 4 | | | |
| | | 5 | | | |
| | | 7 | | | |
| | | 8 | | | |
| | | 9 | | | |
| GND | 3 | 6 | No | Yes | Device still functions because pin 6 (SO PowerPAD)/15(HTSSOP) is still connected |
| FB | 4 | 10 | No | No | Device is out of control. |
| ADJ | 5 | 11 | No | No | When the voltage at ADJ pin is larger than 1.5 V, output voltage will follow the lower value of the input voltage and the ADJ voltage, and the maximum output voltage value is about 18 V |
| GND | 6 | 15 | No | Yes | Device still functions because pin 3 (SO PowerPAD)/6 (HTSSOP) is still connected. |
| NC | 7 | 12 | No | Yes | No effect |
| | | 13 | | | |
| | | 14 | | | |
| | | 16 | | | |
| | | 17 | | | |
| | | 18 | | | |
| EN | - | 19 | No | No | Device is disabled |
| IN | 8 | 20 | No | No | No output voltage |

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