

CURRENT-LIMITED, POWER-DISTRIBUTION SWITCHES

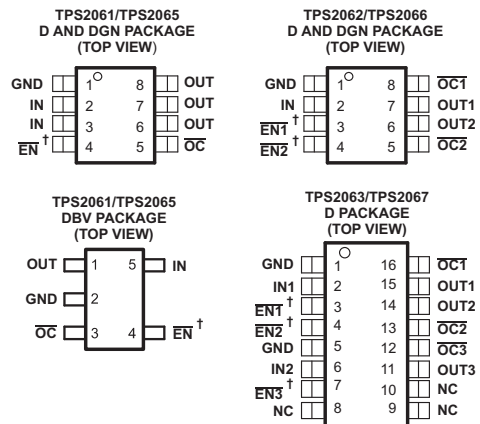
 Check for Samples: [TPS2061](#) [TPS2062](#) [TPS2063](#) [TPS2065](#) [TPS2066](#) [TPS2067](#)

FEATURES

- 70-mΩ High-Side MOSFET
- 1-A Continuous Current
- Thermal and Short-Circuit Protection
- Accurate Current Limit (1.1 A min, 1.9 A max)
- Operating Range: 2.7 V to 5.5 V
- 0.6-ms Typical Rise Time
- Undervoltage Lockout
- Deglitched Fault Report (\overline{OC})
- No \overline{OC} Glitch During Power Up
- 1-μA Maximum Standby Supply Current
- Bidirectional Switch
- Ambient Temperature Range: -40°C to 85°C
- Built-in Soft-Start
- UL Listed - File No. E169910

APPLICATIONS

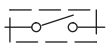
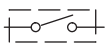
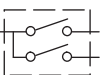
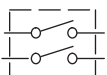
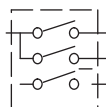
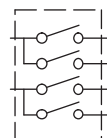
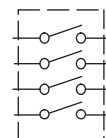
- Heavy Capacitive Loads
- Short-Circuit Protections



† All Enable Inputs Are Active High For TPS2065, TPS2066, and TPS2067

DESCRIPTION

The TPS206x power-distribution switches are intended for applications where heavy capacitive loads and short-circuits are likely to be encountered. This device incorporates 70-mΩ N-channel MOSFET power switches for power-distribution systems that require multiple power switches in a single package. Each switch is controlled by a logic enable input. Gate drive is provided by an internal charge pump designed to control the power-switch rise times and fall times to minimize current surges during switching. The charge pump requires no external components and allows operation from supplies as low as 2.7 V.

| GENERAL SWITCH CATALOG | | | | | | |
|---|---|---|--|--|---|--|
| 33 mΩ, Single | 80 mΩ, Single | 80 mΩ, Dual | 80 mΩ, Dual | 80 mΩ, Triple | 80 mΩ, Quad | 80 mΩ, Quad |
|  |  |  |  |  |  |  |
| TPS201xA 0.2 A to 2 A TPS202x 0.2 A to 2 A TPS203x 0.2 A to 2 A | TPS2014 600 mA TPS2015 1 A TPS2041B 500 mA TPS2051B 500 mA TPS2045A 250 mA TPS2049 100 mA TPS2055A 250 mA TPS2061 1 A TPS2065 1 A TPS2068 1.5 A TPS2069 1.5 A | TPS2042B 500 mA TPS2052B 500 mA TPS2046B 250 mA TPS2056 250 mA TPS2062 1 A TPS2066 1 A TPS2060 1.5 A TPS2064 1.5 A | TPS2080 500 mA TPS2081 500 mA TPS2082 500 mA TPS2090 250 mA TPS2091 250 mA TPS2092 250 mA | TPS2043B 500 mA TPS2053B 500 mA TPS2047B 250 mA TPS2057A 250 mA TPS2063 1 A TPS2067 1 A | TPS2044B 500 mA TPS2054B 500 mA TPS2048A 250 mA TPS2058 250 mA | TPS2085 500 mA TPS2086 500 mA TPS2087 500 mA TPS2095 250 mA TPS2096 250 mA TPS2097 250 mA |



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

PowerPAD is a trademark of Texas Instruments.

UNLESS OTHERWISE NOTED this document contains PRODUCTION DATA information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

DESCRIPTION (CONTINUED)

When the output load exceeds the current-limit threshold or a short is present, the device limits the output current to a safe level by switching into a constant-current mode, pulling the overcurrent (\overline{OCx}) logic output low. When continuous heavy overloads and short-circuits increase the power dissipation in the switch, causing the junction temperature to rise, a thermal protection circuit shuts off the switch to prevent damage. Recovery from a thermal shutdown is automatic once the device has cooled sufficiently. Internal circuitry ensures that the switch remains off until valid input voltage is present. This power-distribution switch is designed to set current limit at 1.5 A typically.

AVAILABLE OPTION AND ORDERING INFORMATION

| T _A | ENABLE | RECOMMENDED MAXIMUM CONTINUOUS LOAD CURRENT | TYPICAL SHORT- CIRCUIT CURRENT LIMIT AT 25°C | NUMBER OF SWITCHES | PACKAGED DEVICES ⁽¹⁾ | | |
|----------------|-------------|---|---|-----------------------|------------------------------------|----------|----------------------------|
| | | | | | MSOP (DGN) | SOIC (D) | SOT23 (DBV) ⁽²⁾ |
| -40°C to 85°C | Active low | 1 A | 1.5 A | Single | TPS2061DGN | TPS2061D | - |
| | Active high | | | | TPS2065DGN | TPS2065D | - |
| | Active low | | | Dual | TPS2062DGN | TPS2062D | - |
| | Active high | | | | TPS2066DGN | TPS2066D | - |
| | Active low | | | Triple | - | TPS2063D | - |
| | Active high | | | | - | TPS2067D | - |
| | Active low | | | Single | - | - | TPS2061DBV |
| | Active high | | | | - | - | TPS2065DBV |

(1) The package is available taped and reeled. Add an R suffix to device types (e.g., TPS2062DR).

(2) The printed circuit board layout is important for control of temperature rise when operated at high ambient temperatures.

ORDERING INFORMATION

| T _A | SOIC(D) ⁽¹⁾ | STATUS | MSOP (DGN) ⁽¹⁾ | STATUS | SOT23 (DBV) ⁽²⁾ | STATUS |
|----------------|------------------------|--------|---------------------------|--------|----------------------------|--------|
| -40°C to 85°C | TPS2061DG4 | Active | TPS2061DGNG4 | Active | - | - |
| | TPS2062DG4 | Active | TPS2062DGNG4 | Active | - | - |
| | TPS2065DG4 | Active | TPS2065DGNG4 | Active | - | - |
| | TPS2066DG4 | Active | TPS2066DGNG4 | Active | - | - |
| | - | - | - | - | TPS2061DBV | Active |
| | - | - | - | - | TPS2065DBV | Active |

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI website at www.ti.com.

(2) The printed circuit board layout is important for control of temperature rise when operated at high ambient temperatures.

ABSOLUTE MAXIMUM RATINGS

 over operating free-air temperature range unless otherwise noted⁽¹⁾

| | | UNIT |
|--|---------------------------|------------------------------|
| Input voltage range, $V_{I(IN)}$ ⁽²⁾ | | -0.3 V to 6 V |
| Output voltage range, $V_{O(OUT)}$ ⁽²⁾ , $V_{O(OUTx)}$ | | -0.3 V to 6 V |
| Input voltage range, $V_{I(EN)}$, $V_{I(EN)}$, $V_{I(ENx)}$, $V_{I(ENx)}$ | | -0.3 V to 6 V |
| Voltage range, $V_{I(OOC)}$, $V_{I(OOCx)}$ | | -0.3 V to 6 V |
| Continuous output current, $I_{O(OUT)}$, $I_{O(OUTx)}$ | | Internally limited |
| Continuous total power dissipation | | See Dissipation Rating Table |
| Operating virtual junction temperature range, T_J | | -40°C to 150°C |
| Electrostatic discharge (ESD) protection | Human body model | 2 kV |
| | Charge device model (CDM) | 500 V |

- (1) Stresses beyond those listed under *absolute maximum ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *recommended operating conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) All voltages are with respect to GND.

DISSIPATING RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 70^\circ\text{C}$ POWER RATING | $T_A = 85^\circ\text{C}$ POWER RATING |
|----------------------|---|---|--|--|
| D-8 ⁽¹⁾ | 585.82 mW | 5.8582 mW/°C | 322.20 mW | 234.32 mW |
| DGN-8 ⁽²⁾ | 1712.3 mW | 17.123 mW/°C | 941.78 mW | 684.33 mW |
| D-16 ⁽¹⁾ | 898.47 mW | 8.9847 mW/°C | 494.15 mW | 359.38 mW |
| DBV-5 ⁽³⁾ | 285 mW | 2.85 mW/°C | 155 mW | 114 mW |
| | 704 mW | 7.04 mW/°C | 387 mW | 281 mW |

- (1) Power ratings are based on the low-k board (1 signal, 1 layer).
- (2) Power ratings are based on the high-k board (2 signal, 2 plane) with PowerPAD™ vias to the internal ground plane.
- (3) Lower ratings are for low-k printed circuit board layout (single -sided). Higher ratings are for enhanced high-k layout, (2 signal, 2 plane) with a 1mm² copper pad on pin 2 and 2 vias to the ground plane.

RECOMMENDED OPERATING CONDITIONS

| | MIN | MAX | UNIT |
|--|-----|-----|------|
| Input voltage, $V_{I(IN)}$ | 2.7 | 5.5 | V |
| Input voltage, $V_{I(EN)}$, $V_{I(EN)}$, $V_{I(ENx)}$, $V_{I(ENx)}$ | 0 | 5.5 | V |
| Continuous output current, $I_{O(OUT)}$, $I_{O(OUTx)}$ | 0 | 1 | A |
| Operating virtual junction temperature, T_J | -40 | 125 | °C |

ELECTRICAL CHARACTERISTICS

 over recommended operating junction temperature range, $V_{I(IN)} = 5.5\text{ V}$, $I_O = 1\text{ A}$, $V_{I(ENx)} = 0\text{ V}$, or $V_{I(ENx)} = 5.5\text{ V}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS ⁽¹⁾ | | MIN | TYP | MAX | UNIT |
|---------------------|--|---|---|------|-----|-----|------|
| POWER SWITCH | | | | | | | |
| $r_{DS(on)}$ | Static drain-source on-state resistance, 5-V operation and 3.3-V operation | $V_{I(IN)} = 5\text{ V}$ or 3.3 V , $I_O = 1\text{ A}$, $-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$ | | 70 | 135 | | mΩ |
| | Static drain-source on-state resistance, 2.7-V operation | $V_{I(IN)} = 2.7\text{ V}$, $I_O = 1\text{ A}$, $-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$ | | 75 | 150 | | mΩ |
| t_r | Rise time, output | $V_{I(IN)} = 5.5\text{ V}$ | $C_L = 1\text{ }\mu\text{F}$, $R_L = 5\text{ }\Omega$, $T_J = 25^\circ\text{C}$ | 0.6 | 1.5 | | ms |
| | | $V_{I(IN)} = 2.7\text{ V}$ | | 0.4 | 1 | | |
| t_f | Fall time, output | $V_{I(IN)} = 5.5\text{ V}$ | | 0.05 | 0.5 | | |
| | | $V_{I(IN)} = 2.7\text{ V}$ | | 0.05 | 0.5 | | |

- (1) Pulse-testing techniques maintain junction temperature close to ambient temperature; thermal effects must be taken into account separately.

ELECTRICAL CHARACTERISTICS (continued)

over recommended operating junction temperature range, $V_{I(IN)} = 5.5\text{ V}$, $I_O = 1\text{ A}$, $V_{I(\overline{ENx})} = 0\text{ V}$, or $V_{I(ENx)} = 5.5\text{ V}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS ⁽¹⁾ | MIN | TYP | MAX | UNIT | |
|--|--|--|---|-----|-----|------------------|-----|
| ENABLE INPUT \overline{EN} OR EN | | | | | | | |
| V_{IH} | High-level input voltage | $2.7\text{ V} \leq V_{I(IN)} \leq 5.5\text{ V}$ | 2 | | | V | |
| V_{IL} | Low-level input voltage | $2.7\text{ V} \leq V_{I(IN)} \leq 5.5\text{ V}$ | | | 0.8 | | |
| I_I | Input current | $V_{I(\overline{ENx})} = 0\text{ V}$ or 5.5 V , $V_{I(ENx)} = 0\text{ V}$ or 5.5 V | -0.5 | | 0.5 | μA | |
| t_{on} | Turnon time | $C_L = 100\text{ }\mu\text{F}$, $R_L = 5\text{ }\Omega$ | | | 3 | ms | |
| t_{off} | Turnoff time | $C_L = 100\text{ }\mu\text{F}$, $R_L = 5\text{ }\Omega$ | | | 10 | | |
| CURRENT LIMIT | | | | | | | |
| I_{OS} | Short-circuit output current | $V_{I(IN)} = 5\text{ V}$, OUT connected to GND, device enabled into short-circuit | $T_J = 25^\circ\text{C}$ | 1.1 | 1.5 | 1.9 | A |
| | | | $-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$ | 1.1 | 1.5 | 2.1 | |
| I_{OC_TRIP} | Overcurrent trip threshold | $V_{I(IN)} = 5\text{ V}$, current ramp ($\leq 100\text{ A/s}$) on OUT | TPS2061, TPS2062, TPS2065, TPS2066 | 1.6 | 2.3 | 2.7 | A |
| | | | TPS2063, TPS2067 | 1.6 | 2.4 | 3.0 | |
| SUPPLY CURRENT (TPS2061, TPS2065) | | | | | | | |
| Supply current, low-level output | No load on OUT, $V_{I(\overline{ENx})} = 5.5\text{ V}$, or $V_{I(ENx)} = 0\text{ V}$ | $T_J = 25^\circ\text{C}$ | | 0.5 | 1 | μA | |
| | | | $-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$ | | 0.5 | | 5 |
| Supply current, high-level output | No load on OUT, $V_{I(\overline{ENx})} = 0\text{ V}$, or $V_{I(ENx)} = 5.5\text{ V}$ | $T_J = 25^\circ\text{C}$ | | 43 | 60 | μA | |
| | | | $-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$ | | 43 | | 70 |
| Leakage current | OUT connected to ground, $V_{I(\overline{EN})} = 5.5\text{ V}$, or $V_{I(EN)} = 0\text{ V}$ | $-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$ | | 1 | | μA | |
| Reverse leakage current | $V_{I(OUTx)} = 5.5\text{ V}$, IN = ground | $T_J = 25^\circ\text{C}$ | | 0 | | μA | |
| SUPPLY CURRENT (TPS2062, TPS2066) | | | | | | | |
| Supply current, low-level output | No load on OUT, $V_{I(\overline{ENx})} = 5.5\text{ V}$, or $V_{I(ENx)} = 0\text{ V}$ | $T_J = 25^\circ\text{C}$ | | 0.5 | 1 | μA | |
| | | | $-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$ | | 0.5 | | 5 |
| Supply current, high-level output | No load on OUT, $V_{I(\overline{ENx})} = 0\text{ V}$, or $V_{I(ENx)} = 5.5\text{ V}$ | $T_J = 25^\circ\text{C}$ | | 50 | 70 | μA | |
| | | | $-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$ | | 50 | | 90 |
| Leakage current | OUT connected to ground, $V_{I(\overline{ENx})} = 5.5\text{ V}$, or $V_{I(ENx)} = 0\text{ V}$ | $-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$ | | 1 | | μA | |
| Reverse leakage current | $V_{I(OUTx)} = 5.5\text{ V}$, IN = ground | $T_J = 25^\circ\text{C}$ | | 0.2 | | μA | |
| SUPPLY CURRENT (TPS2063, TPS2067) | | | | | | | |
| Supply current, low-level output | No load on OUT, $V_{I(\overline{ENx})} = 0\text{ V}$ | $T_J = 25^\circ\text{C}$ | | 0.5 | 2 | μA | |
| | | | $-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$ | | 0.5 | | 10 |
| Supply current, high-level output | No load on OUT, $V_{I(\overline{ENx})} = 5.5\text{ V}$ | $T_J = 25^\circ\text{C}$ | | 65 | 90 | μA | |
| | | | $-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$ | | 65 | | 110 |
| Leakage current | OUT connected to ground, $V_{I(\overline{ENx})} = 5.5\text{ V}$, or $V_{I(ENx)} = 0\text{ V}$ | $-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$ | | 1 | | μA | |
| Reverse leakage current | $V_{I(OUTx)} = 5.5\text{ V}$, INx = ground | $T_J = 25^\circ\text{C}$ | | 0.2 | | μA | |
| UNDERVOLTAGE LOCKOUT | | | | | | | |
| Low-level input voltage, IN | | | 2 | | 2.5 | V | |
| Hysteresis, IN | | | $T_J = 25^\circ\text{C}$ | | 75 | mV | |
| OVERCURRENT $\overline{OC1}$ and $\overline{OC2}$ | | | | | | | |
| Output low voltage, $V_{OL(OCx)}$ | | $I_{O(\overline{OCx})} = 5\text{ mA}$ | | | 0.4 | V | |
| Off-state current | | $V_{O(\overline{OCx})} = 5\text{ V}$ or 3.3 V | | | 1 | μA | |
| \overline{OC} deglitch | | \overline{OCx} assertion or deassertion | 4 | 8 | 15 | ms | |
| THERMAL SHUTDOWN ⁽²⁾ | | | | | | | |
| Thermal shutdown threshold | | | | | 135 | $^\circ\text{C}$ | |
| Recovery from thermal shutdown | | | | | 125 | $^\circ\text{C}$ | |
| Hysteresis | | | | | 10 | $^\circ\text{C}$ | |

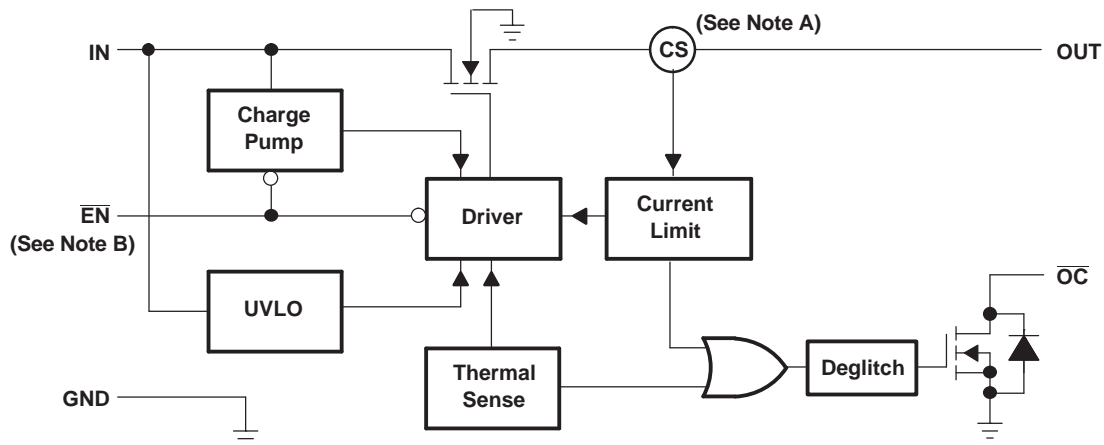
(2) The thermal shutdown only reacts under overcurrent conditions.

DEVICE INFORMATION

Pin Functions (TPS2061 and TPS2065)

| NAME | PINS | | | | I/O | DESCRIPTION |
|------------------------|------------------|---------|-------------|---------|-----|--|
| | D or DGN Package | | DBV Package | | | |
| | TPS2061 | TPS2065 | TPS2061 | TPS2065 | | |
| $\overline{\text{EN}}$ | 4 | - | 4 | - | I | Enable input, logic low turns on power switch |
| EN | - | 4 | - | 4 | I | Enable input, logic high turns on power switch |
| GND | 1 | 1 | 2 | 2 | | Ground |
| IN | 2, 3 | 2,3 | 5 | 5 | I | Input voltage |
| $\overline{\text{OC}}$ | 5 | 5 | 3 | 3 | O | Overcurrent, open-drain output, active-low |
| OUT | 6, 7, 8 | 6, 7, 8 | 1 | 1 | O | Power-switch output |
| PowerPAD™ | - | - | - | - | | Internally connected to GND; used to heat-sink the part to the circuit board traces. Should be connected to GND pin. |

Functional Block Diagram



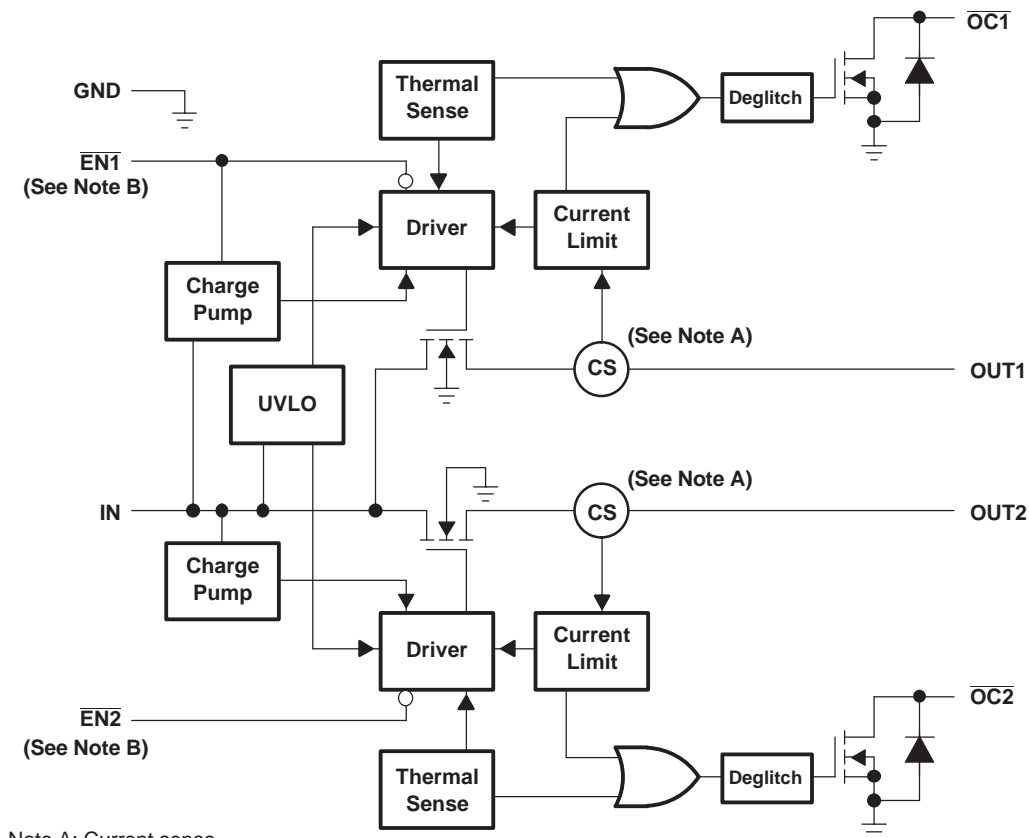
Note A: Current sense

Note B: Active low ($\overline{\text{EN}}$) for TPS2061. Active high (EN) for TPS2065.

Pin Functions (TPS2062 and TPS2066)

| NAME | PINS | | I/O | DESCRIPTION |
|-------------------------|---------|---------|-----|--|
| | NO. | | | |
| | TPS2062 | TPS2066 | | |
| $\overline{\text{EN1}}$ | 3 | - | I | Enable input, logic low turns on power switch IN-OUT1 |
| $\overline{\text{EN2}}$ | 4 | - | I | Enable input, logic low turns on power switch IN-OUT2 |
| EN1 | - | 3 | I | Enable input, logic high turns on power switch IN-OUT1 |
| EN2 | - | 4 | I | Enable input, logic high turns on power switch IN-OUT2 |
| GND | 1 | 1 | | Ground |
| IN | 2 | 2 | I | Input voltage |
| $\overline{\text{OC1}}$ | 8 | 8 | O | Overcurrent, open-drain output, active low, IN-OUT1 |
| $\overline{\text{OC2}}$ | 5 | 5 | O | Overcurrent, open-drain output, active low, IN-OUT2 |
| OUT1 | 7 | 7 | O | Power-switch output, IN-OUT1 |
| OUT2 | 6 | 6 | O | Power-switch output, IN-OUT2 |
| PowerPAD™ | - | - | | Internally connected to GND; used to heat-sink the part to the circuit board traces. Should be connected to GND pin. |

Functional Block Diagram



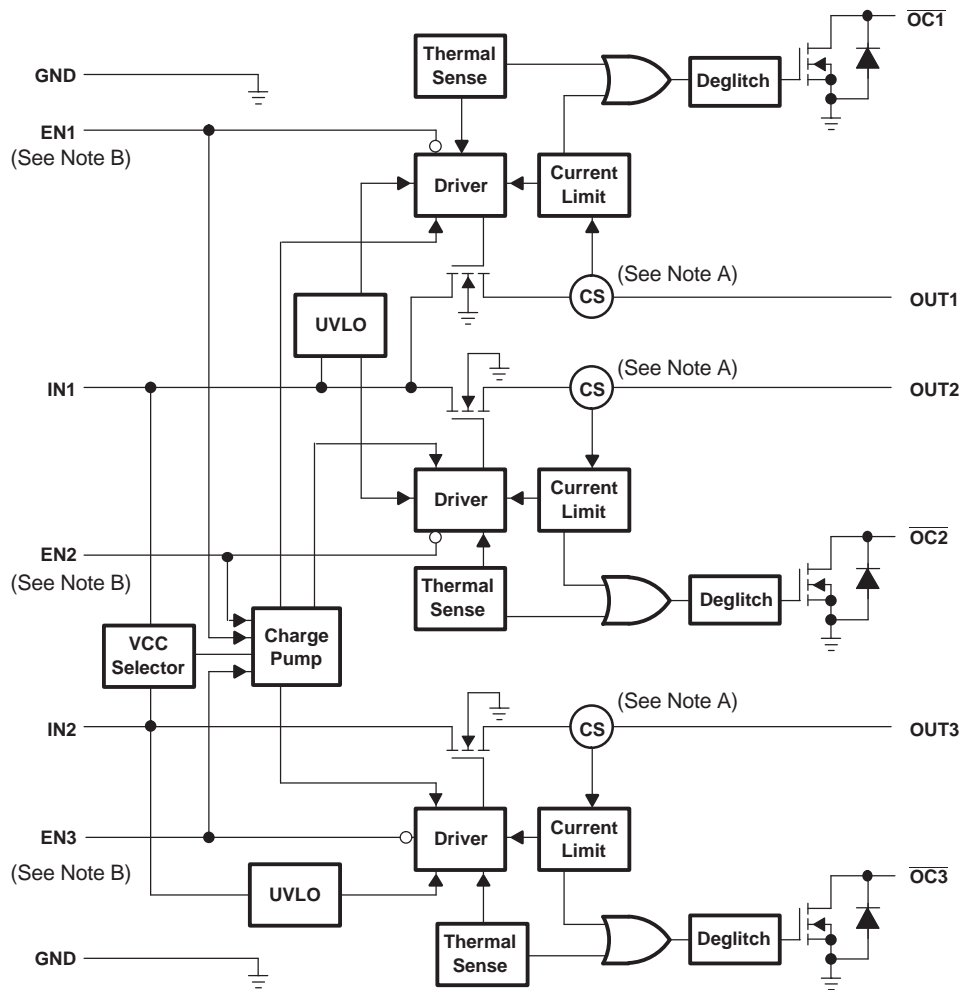
Note A: Current sense

Note B: Active low ($\overline{\text{ENx}}$) for TPS2062. Active high (ENx) for TPS2066.

Pin Functions (TPS2063 and TPS2067)

| NAME | PINS | | I/O | DESCRIPTION |
|-------------------------|----------|----------|-----|---|
| | TPS2063 | TPS2067 | | |
| $\overline{\text{EN1}}$ | 3 | – | I | Enable input, logic low turns on power switch IN1-OUT1 |
| $\overline{\text{EN2}}$ | 4 | – | I | Enable input, logic low turns on power switch IN1-OUT2 |
| $\overline{\text{EN3}}$ | 7 | – | I | Enable input, logic low turns on power switch IN2-OUT3 |
| EN1 | – | 3 | I | Enable input, logic high turns on power switch IN1-OUT1 |
| EN2 | – | 4 | I | Enable input, logic high turns on power switch IN1-OUT2 |
| EN3 | – | 7 | I | Enable input, logic high turns on power switch IN2-OUT3 |
| GND | 1, 5 | 1, 5 | | Ground |
| IN1 | 2 | 2 | I | Input voltage for OUT1 and OUT2 |
| IN2 | 6 | 6 | I | Input voltage for OUT3 |
| NC | 8, 9, 10 | 8, 9, 10 | | No connection |
| $\overline{\text{OC1}}$ | 16 | 16 | O | Overcurrent, open-drain output, active low, IN1-OUT1 |
| $\overline{\text{OC2}}$ | 13 | 13 | O | Overcurrent, open-drain output, active low, IN1-OUT2 |
| $\overline{\text{OC3}}$ | 12 | 12 | O | Overcurrent, open-drain output, active low, IN2-OUT3 |
| OUT1 | 15 | 15 | O | Power-switch output, IN1-OUT1 |
| OUT2 | 14 | 14 | O | Power-switch output, IN1-OUT2 |
| OUT3 | 11 | 11 | O | Power-switch output, IN2-OUT3 |

Functional Block Diagram



Note A: Current sense

Note B: Active low (\overline{ENx}) for TPS2063; Active high (ENx) for TPS2067

PARAMETER MEASUREMENT INFORMATION

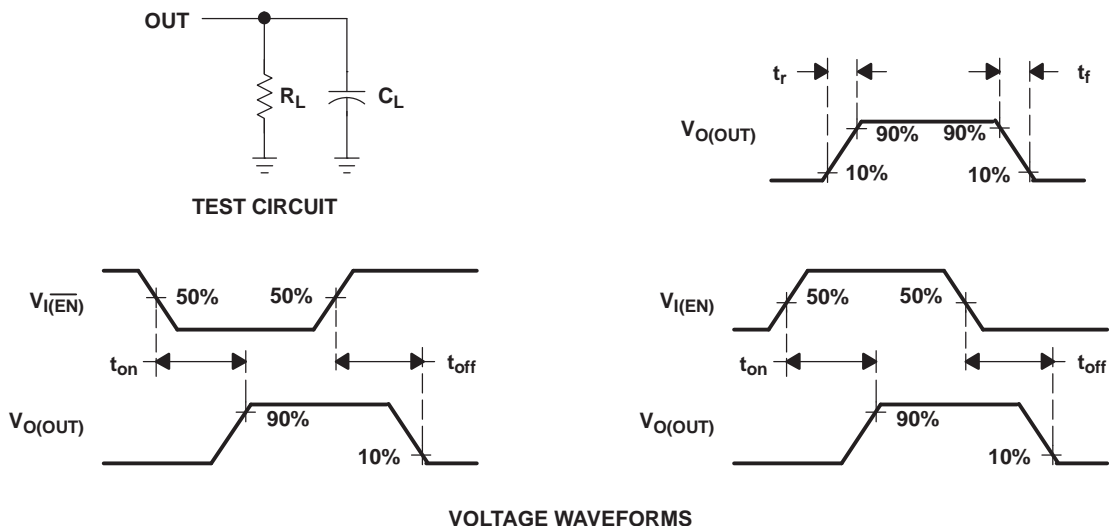


Figure 1. Test Circuit and Voltage Waveforms

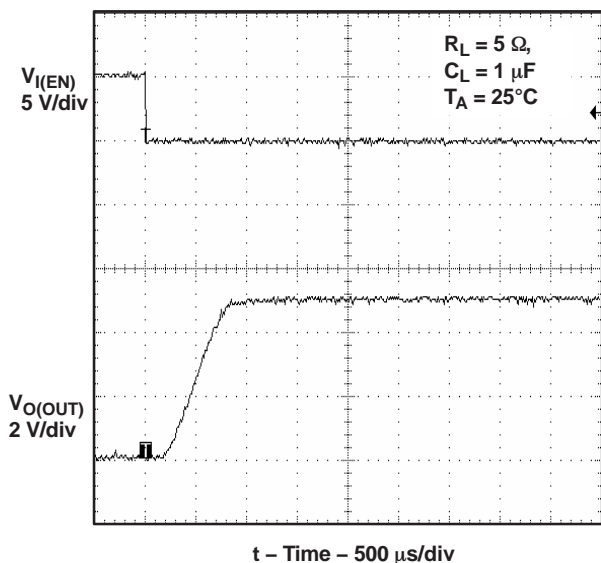


Figure 2. Turnon Delay and Rise Time With 1- μ F Load

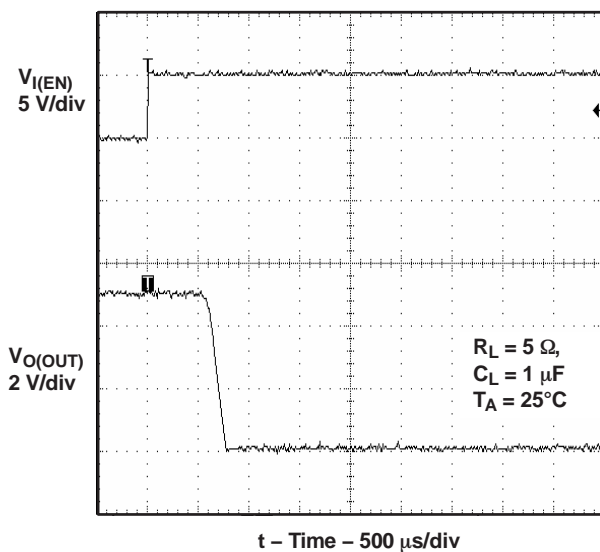


Figure 3. Turnoff Delay and Fall Time With 1- μ F Load

PARAMETER MEASUREMENT INFORMATION (continued)

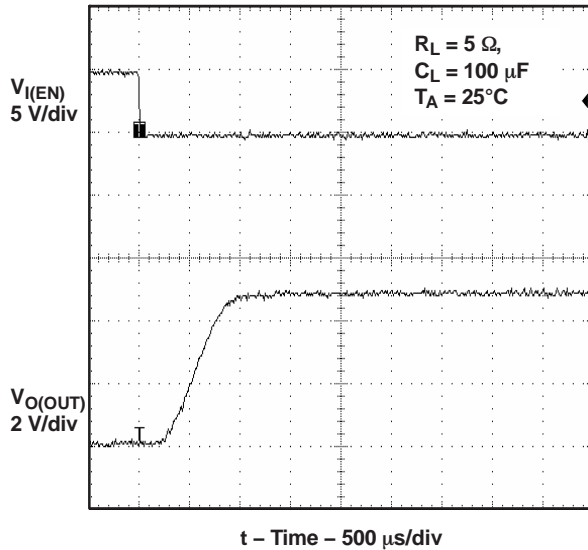


Figure 4. Turnon Delay and Rise Time With 100-µF Load

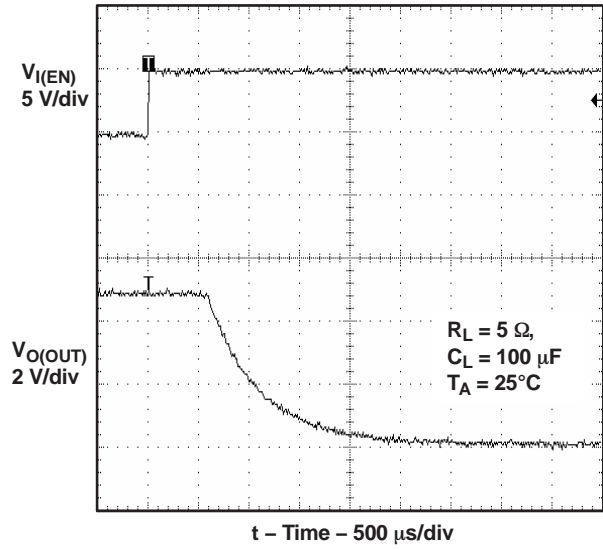


Figure 5. Turnoff Delay and Fall Time With 100-µF Load

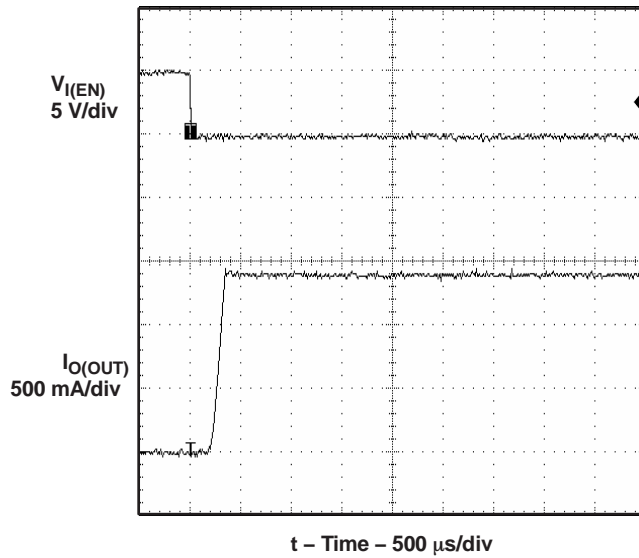


Figure 6. Short-Circuit Current, Device Enabled Into Short

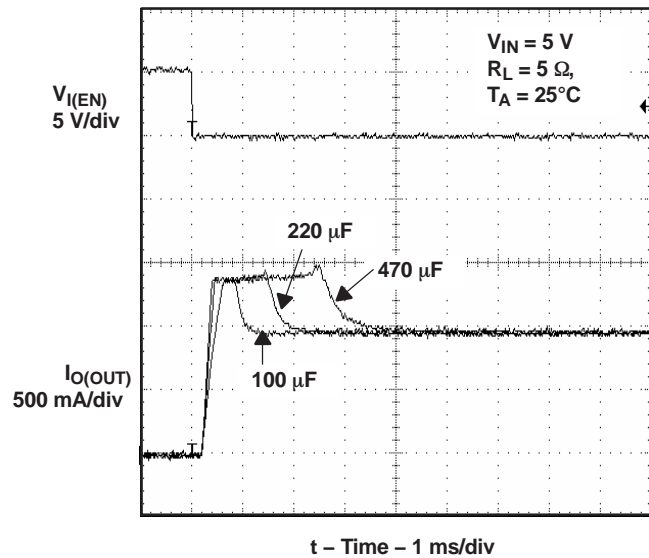


Figure 7. Inrush Current With Different Load Capacitance

PARAMETER MEASUREMENT INFORMATION (continued)

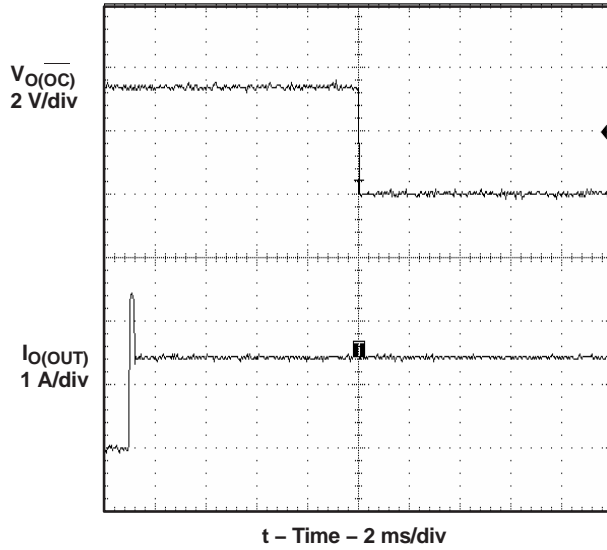


Figure 8. 2-Ω Load Connected to Enabled Device

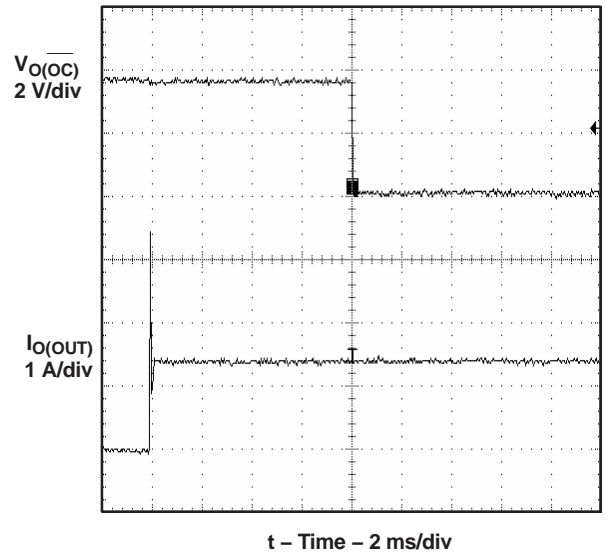


Figure 9. 1-Ω Load Connected to Enabled Device

TYPICAL CHARACTERISTICS

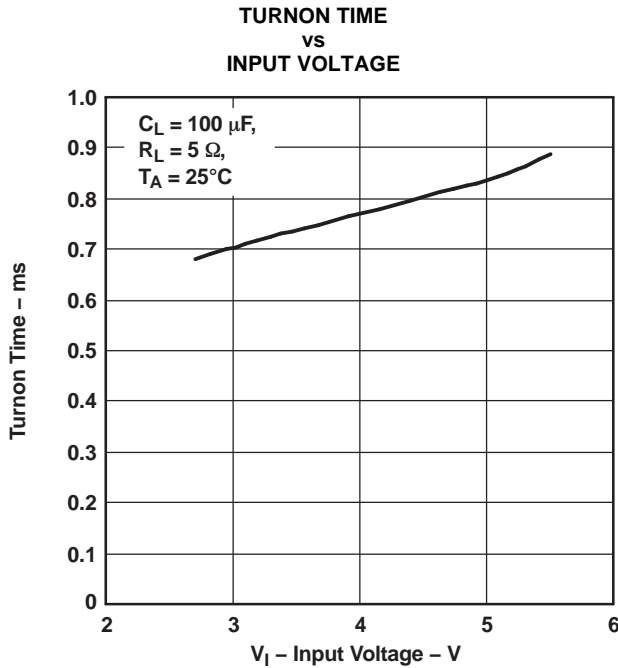


Figure 10.

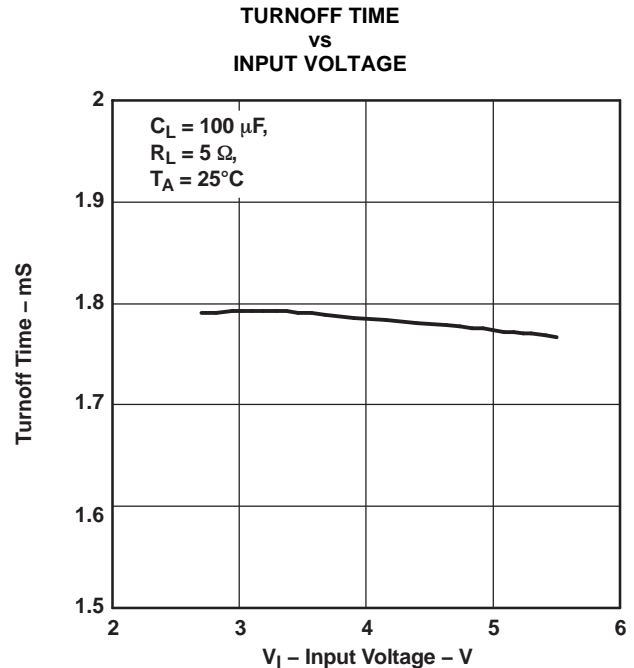


Figure 11.

TYPICAL CHARACTERISTICS (continued)

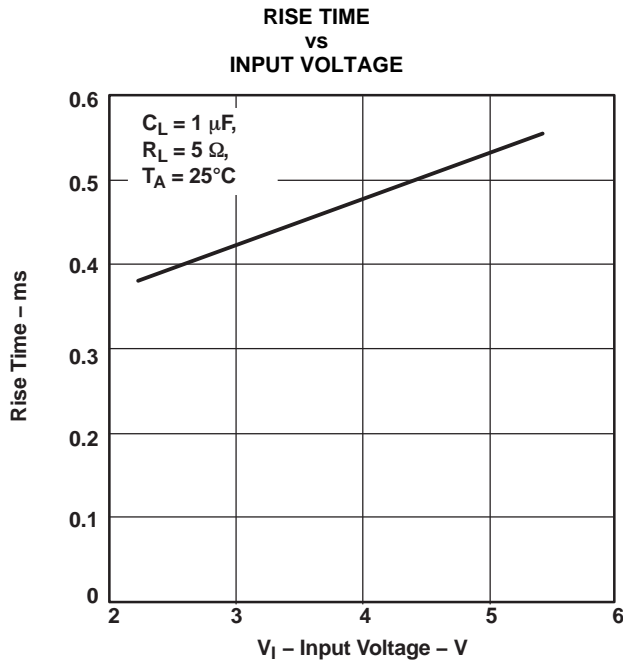


Figure 12.

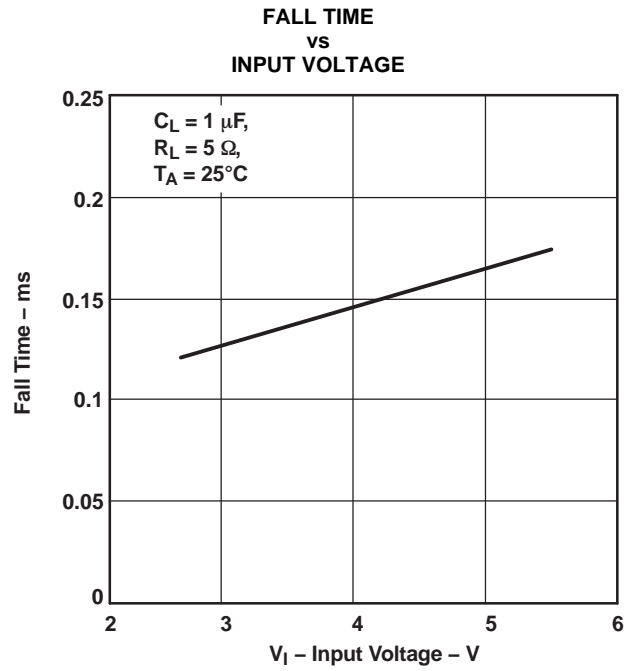


Figure 13.

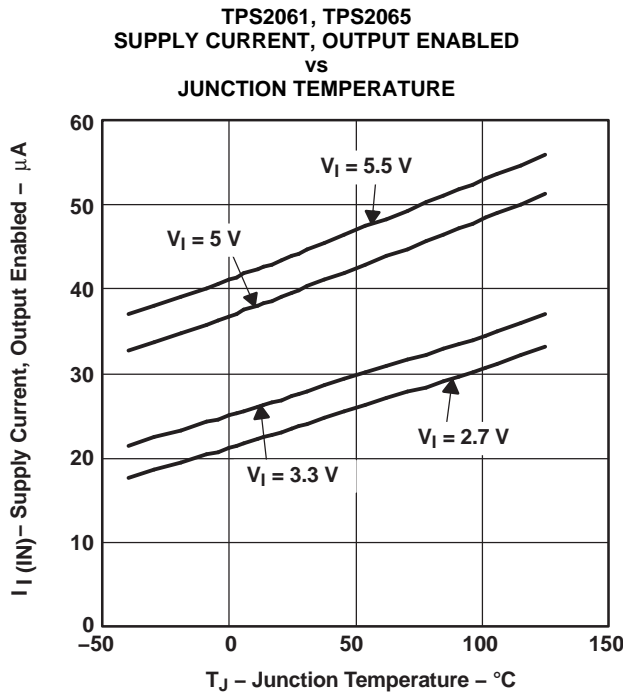


Figure 14.

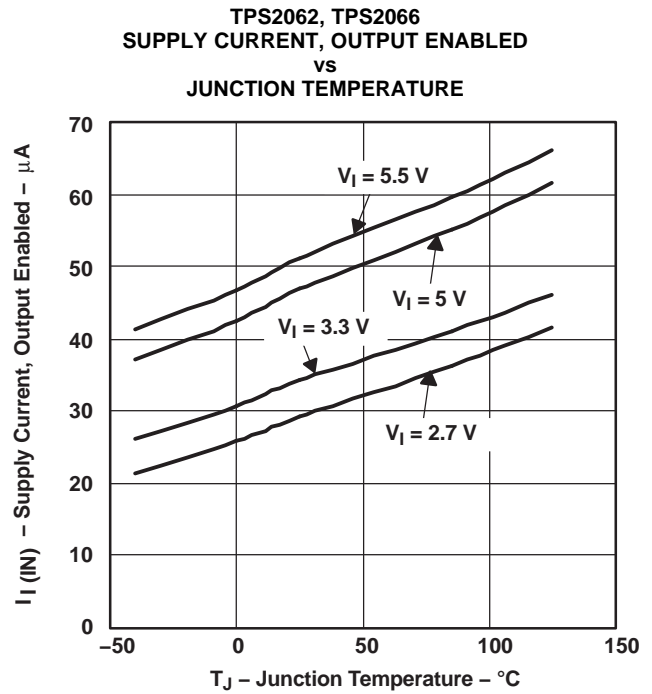


Figure 15.

TYPICAL CHARACTERISTICS (continued)

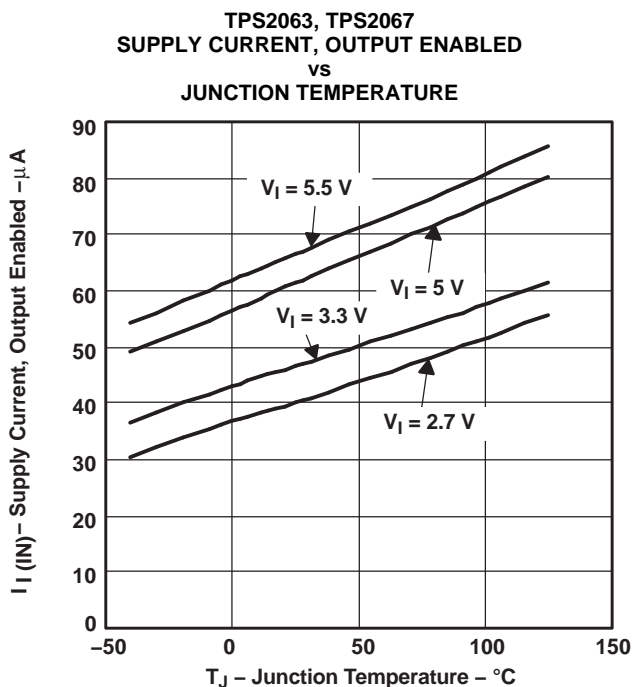


Figure 16.

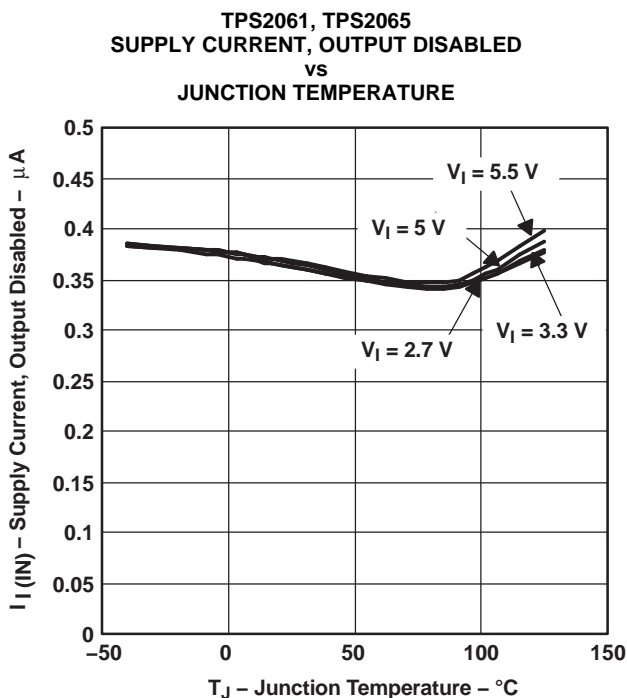


Figure 17.

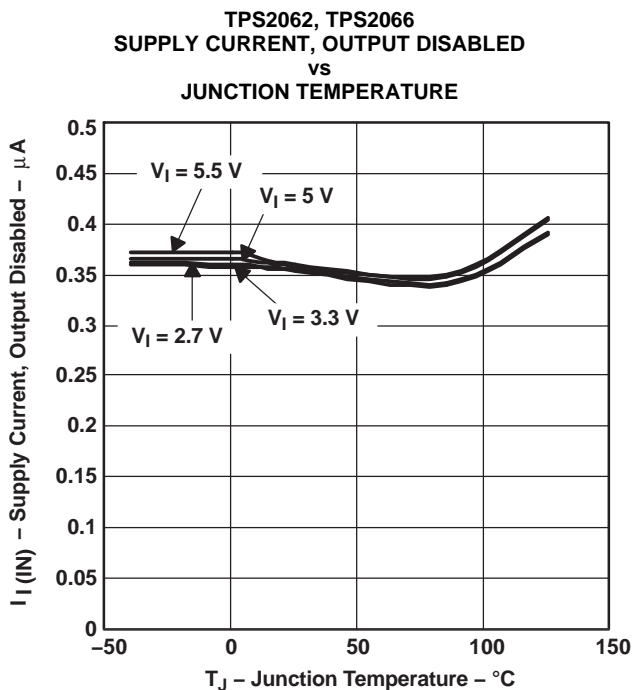


Figure 18.

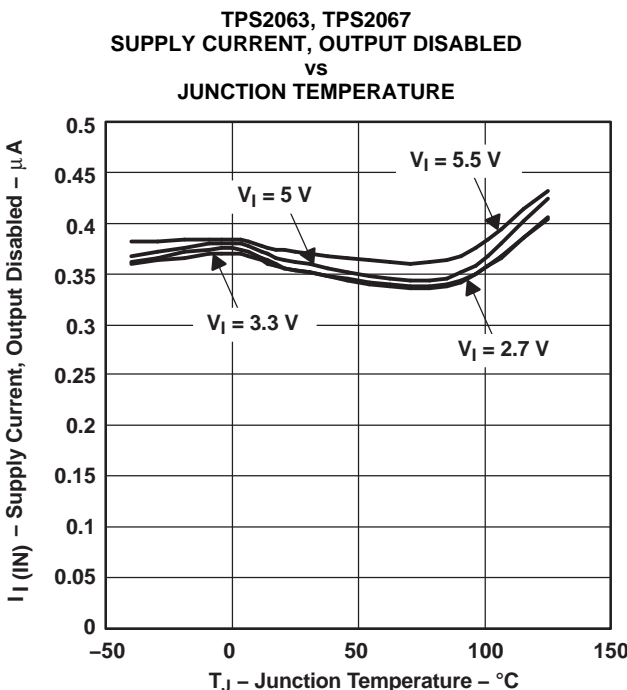


Figure 19.

TYPICAL CHARACTERISTICS (continued)

STATIC DRAIN-SOURCE ON-STATE RESISTANCE
 VS
 JUNCTION TEMPERATURE

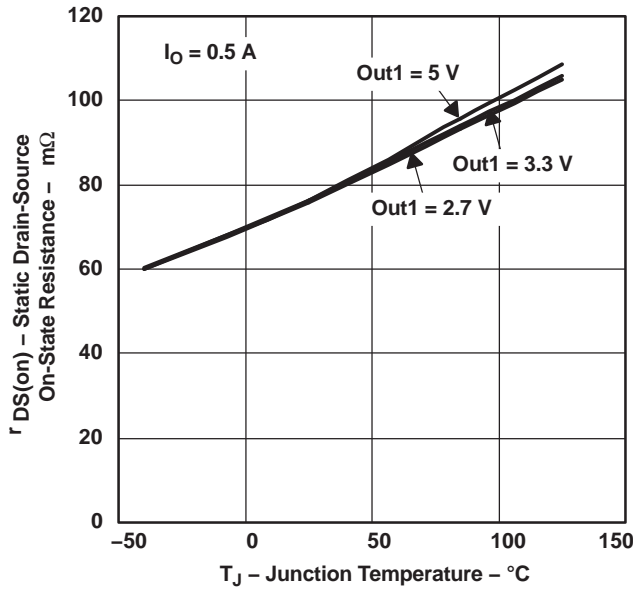


Figure 20.

SHORT-CIRCUIT OUTPUT CURRENT
 VS
 JUNCTION TEMPERATURE

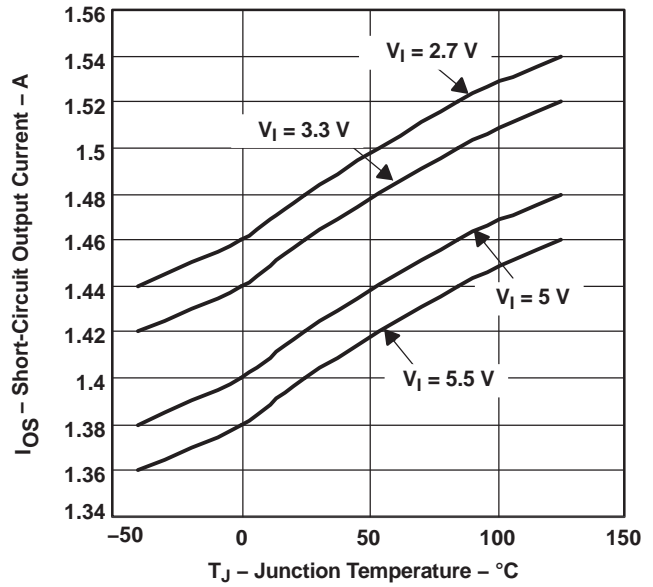


Figure 21.

THRESHOLD TRIP CURRENT
 VS
 INPUT VOLTAGE

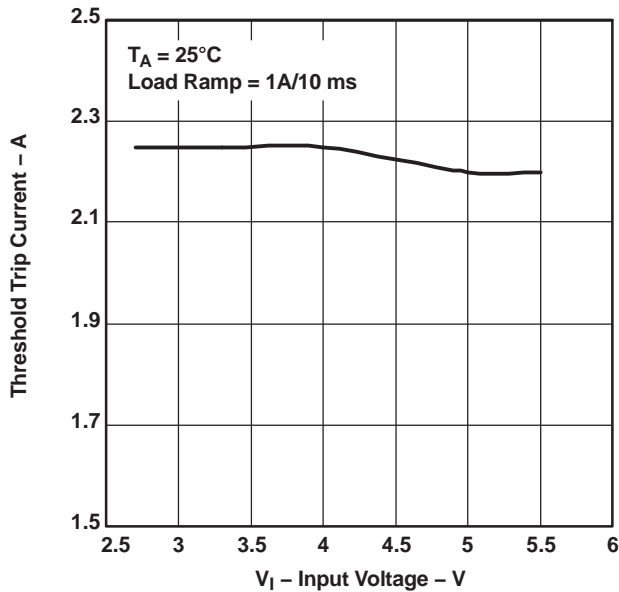


Figure 22.

UNDERVOLTAGE LOCKOUT
 VS
 JUNCTION TEMPERATURE

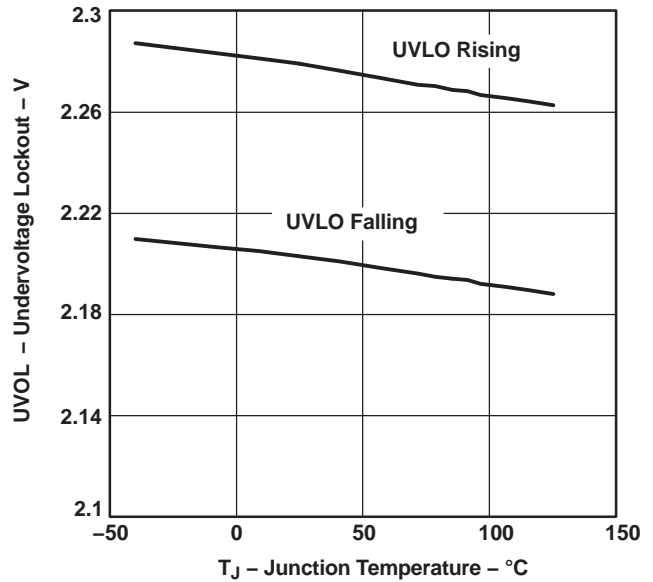
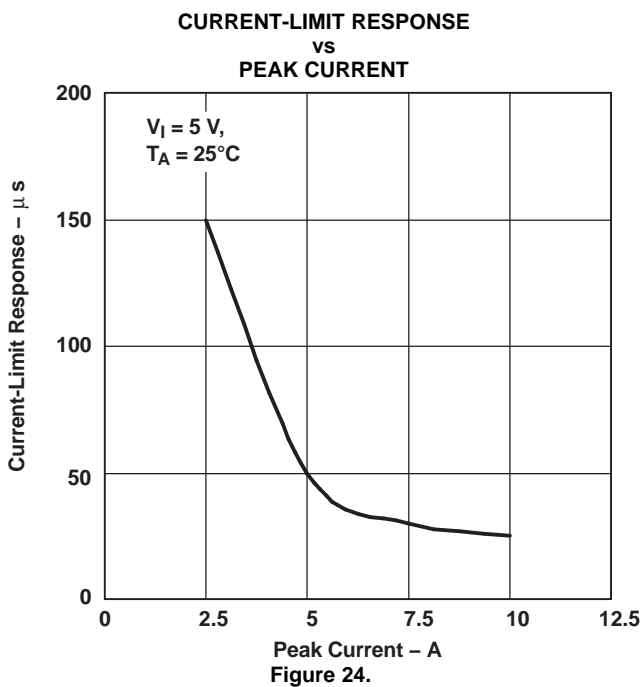


Figure 23.

TYPICAL CHARACTERISTICS (continued)



APPLICATION INFORMATION

POWER-SUPPLY CONSIDERATIONS

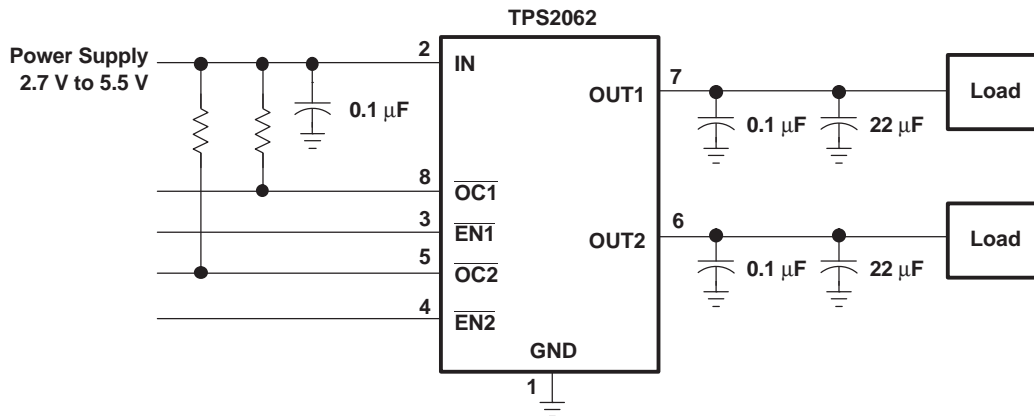


Figure 25. Typical Application

A 0.01- μF to 0.1- μF ceramic bypass capacitor between IN and GND, close to the device, is recommended. Placing a high-value electrolytic capacitor on the output pin(s) is recommended when the output load is heavy. This precaution reduces power-supply transients that may cause ringing on the input. Additionally, bypassing the output with a 0.01- μF to 0.1- μF ceramic capacitor improves the immunity of the device to short-circuit transients.

OVERCURRENT

A sense FET is employed to check for overcurrent conditions. Unlike current-sense resistors, sense FETs do not increase the series resistance of the current path. When an overcurrent condition is detected, the device maintains a constant output current and reduces the output voltage accordingly. Complete shutdown occurs only if the fault is present long enough to activate thermal limiting.

Three possible overload conditions can occur. In the first condition, the output has been shorted before the device is enabled or before $V_{I(IN)}$ has been applied (see Figure 15). The TPS206x senses the short and immediately switches into a constant-current output.

In the second condition, a short or an overload occurs while the device is enabled. At the instant the overload occurs, high currents may flow for a short period of time before the current-limit circuit can react. After the current-limit circuit has tripped (reached the overcurrent trip threshold), the device switches into constant-current mode.

In the third condition, the load has been gradually increased beyond the recommended operating current. The current is permitted to rise until the current-limit threshold is reached or until the thermal limit of the device is exceeded (see Figure 18). The TPS206x is capable of delivering current up to the current-limit threshold without damaging the device. Once the threshold has been reached, the device switches into its constant-current mode.

OC RESPONSE

The $\overline{\text{OCx}}$ open-drain output is asserted (active low) when an overcurrent or overtemperature shutdown condition is encountered after a 10-ms deglitch timeout. The output remains asserted until the overcurrent or overtemperature condition is removed. Connecting a heavy capacitive load to an enabled device can cause a momentary overcurrent condition; however, no false reporting on $\overline{\text{OCx}}$ occurs due to the 10-ms deglitch circuit. The TPS206x is designed to eliminate false overcurrent reporting. The internal overcurrent deglitch eliminates the need for external components to remove unwanted pulses. $\overline{\text{OCx}}$ is not deglitched when the switch is turned off due to an overtemperature shutdown.

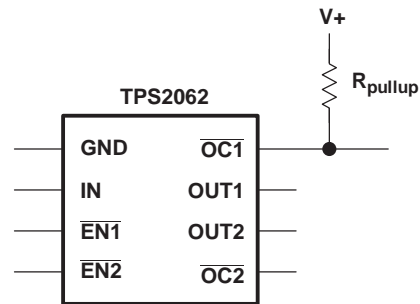


Figure 26. Typical Circuit for the \overline{OC} Pin

POWER DISSIPATION AND JUNCTION TEMPERATURE

The low on-resistance on the N-channel MOSFET allows the small surface-mount packages to pass large currents. The thermal resistances of these packages are high compared to those of power packages; it is good design practice to check power dissipation and junction temperature. Begin by determining the $r_{DS(on)}$ of the N-channel MOSFET relative to the input voltage and operating temperature. As an initial estimate, use the highest operating ambient temperature of interest and read $r_{DS(on)}$ from [Figure 20](#). Using this value, the power dissipation per switch can be calculated by:

- $P_D = r_{DS(on)} \times I^2$

Multiply this number by the number of switches being used. This step renders the total power dissipation from the N-channel MOSFETs.

The thermal resistance, $R_{\theta JA} = 1 / (\text{DERATING FACTOR})$, where DERATING FACTOR is obtained from the Dissipation Ratings Table. Thermal resistance is a strong function of the printed circuit board construction, and the copper trace area connecting the integrated circuit.

Finally, calculate the junction temperature:

- $T_J = P_D \times R_{\theta JA} + T_A$

Where:

- T_A = Ambient temperature °C
- $R_{\theta JA}$ = Thermal resistance
- P_D = Total power dissipation based on number of switches being used.

Compare the calculated junction temperature with the initial estimate. If they do not agree within a few degrees, repeat the calculation, using the calculated value as the new estimate. Two or three iterations are generally sufficient to get a reasonable answer.

THERMAL PROTECTION

Thermal protection prevents damage to the IC when heavy-overload or short-circuit faults are present for extended periods of time. The TPS206x implements a thermal sensing to monitor the operating junction temperature of the power distribution switch. In an overcurrent or short-circuit condition, the junction temperature rises due to excessive power dissipation. Once the die temperature rises above a minimum of 135°C due to overcurrent conditions, the internal thermal sense circuitry turns the power switch off, thus preventing the power switch from damage. Hysteresis is built into the thermal sense circuit, and after the device has cooled approximately 10°C, the switch turns back on. The switch continues to cycle in this manner until the load fault or input power is removed. The OCx open-drain output is asserted (active low) when an overtemperature shutdown or overcurrent occurs.

UNDERVOLTAGE LOCKOUT (UVLO)

An undervoltage lockout ensures that the power switch is in the off state at power up. Whenever the input voltage falls below approximately 2 V, the power switch is quickly turned off. This facilitates the design of hot-insertion systems where it is not possible to turn off the power switch before input power is removed. The UVLO also keeps the switch from being turned on until the power supply has reached at least 2 V, even if the switch is enabled. On reinsertion, the power switch is turned on, with a controlled rise time to reduce EMI and voltage overshoots.

UNIVERSAL SERIAL BUS (USB) APPLICATIONS

The universal serial bus (USB) interface is a 12-Mb/s, or 1.5-Mb/s, multiplexed serial bus designed for low-to-medium bandwidth PC peripherals (e.g., keyboards, printers, scanners, and mice). The four-wire USB interface is conceived for dynamic attach-detach (hot plug-unplug) of peripherals. Two lines are provided for differential data, and two lines are provided for 5-V power distribution.

USB data is a 3.3-V level signal, but power is distributed at 5 V to allow for voltage drops in cases where power is distributed through more than one hub across long cables. Each function must provide its own regulated 3.3 V from the 5-V input or its own internal power supply.

The USB specification defines the following five classes of devices, each differentiated by power-consumption requirements:

- Hosts/self-powered hubs (SPH)
- Bus-powered hubs (BPH)
- Low-power, bus-powered functions
- High-power, bus-powered functions
- Self-powered functions

SPHs and BPHs distribute data and power to downstream functions. The TPS206x has higher current capability than required by one USB port; so, it can be used on the host side and supplies power to multiple downstream ports or functions.

HOST/SELF-POWERED AND BUS-POWERED HUBS

Hosts and SPHs have a local power supply that powers the embedded functions and the downstream ports (see [Figure 27](#)). This power supply must provide from 5.25 V to 4.75 V to the board side of the downstream connection under full-load and no-load conditions. Hosts and SPHs are required to have current-limit protection and must report overcurrent conditions to the USB controller. Typical SPHs are desktop PCs, monitors, printers, and stand-alone hubs.

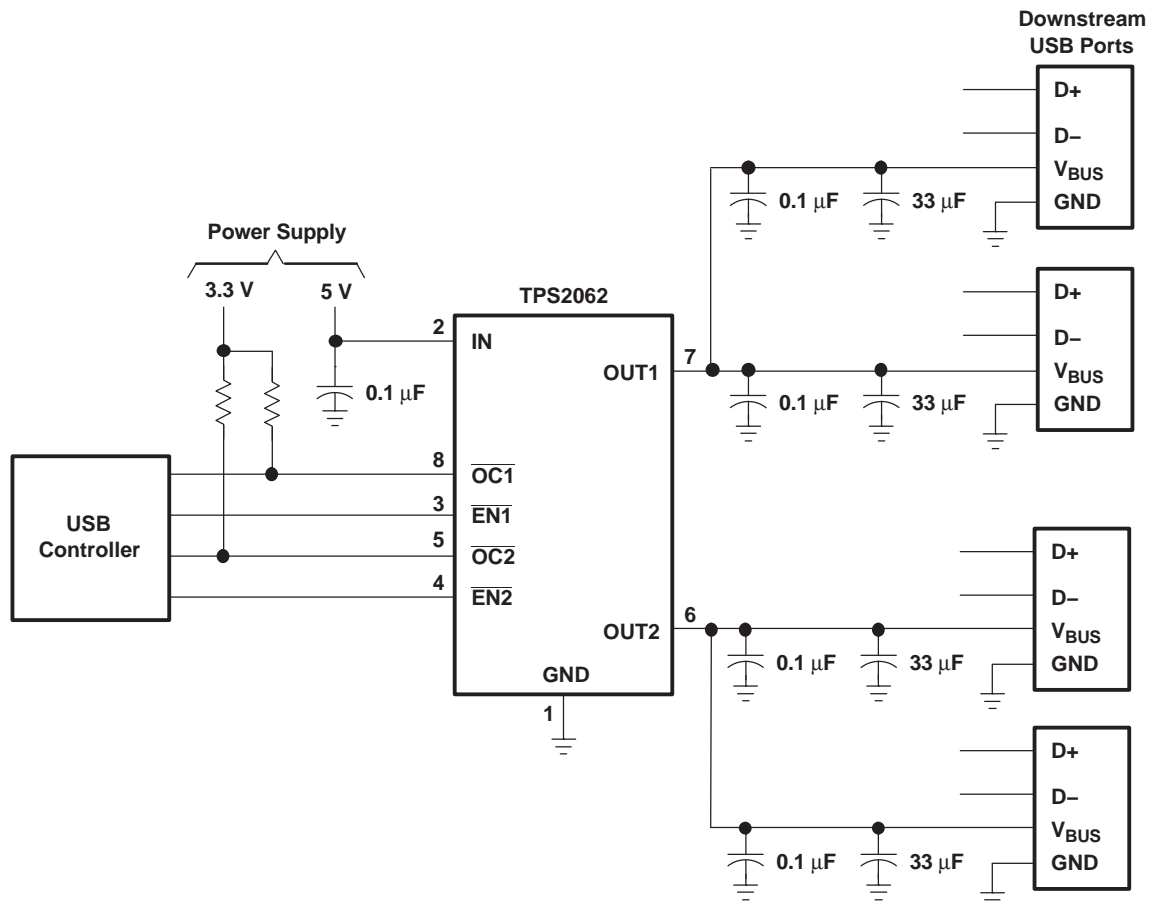


Figure 27. Typical Four-Port USB Host / Self-Powered Hub

BPHs obtain all power from upstream ports and often contain an embedded function. The hubs are required to power up with less than one unit load. The BPH usually has one embedded function, and power is always available to the controller of the hub. If the embedded function and hub require more than 100 mA on power up, the power to the embedded function may need to be kept off until enumeration is completed. This can be accomplished by removing power or by shutting off the clock to the embedded function. Power switching the embedded function is not necessary if the aggregate power draw for the function and controller is less than one unit load. The total current drawn by the bus-powered device is the sum of the current to the controller, the embedded function, and the downstream ports, and it is limited to 500 mA from an upstream port.

LOW-POWER BUS-POWERED AND HIGH-POWER BUS-POWERED FUNCTIONS

Both low-power and high-power bus-powered functions obtain all power from upstream ports; low-power functions always draw less than 100 mA; high-power functions must draw less than 100 mA at power up and can draw up to 500 mA after enumeration. If the load of the function is more than the parallel combination of 44 Ω and 10 μF at power up, the device must implement inrush current limiting (see Figure 28). With TPS206x, the internal functions could draw more than 500 mA, which fits the needs of some applications such as motor driving circuits.

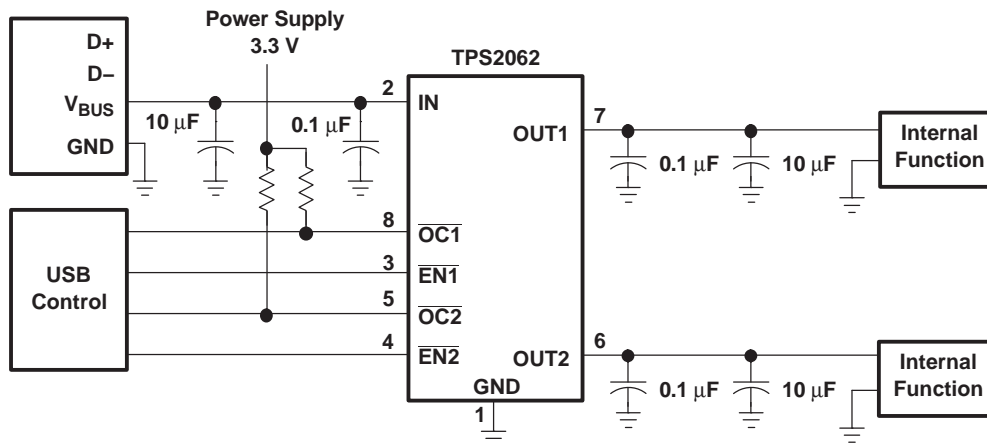


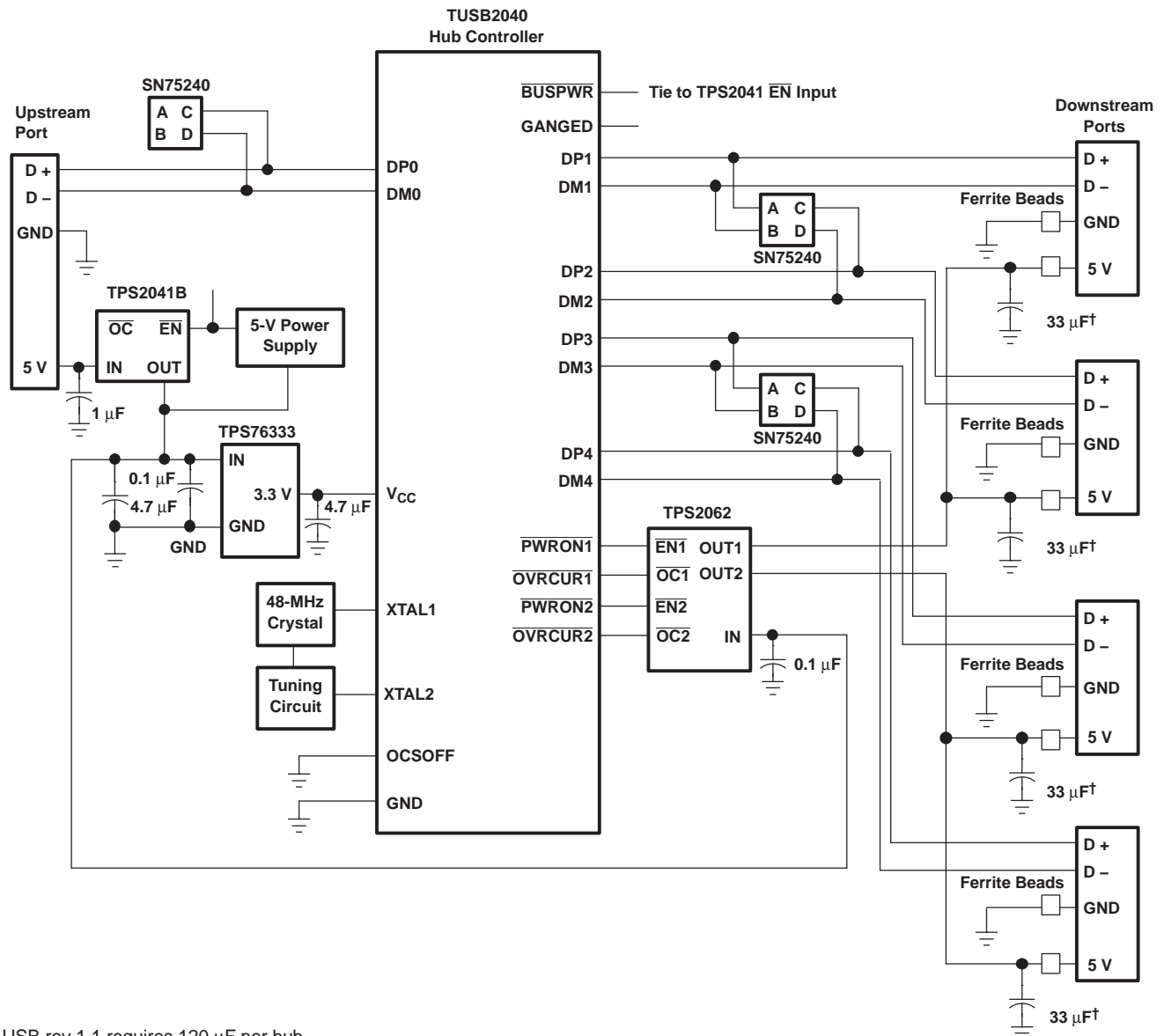
Figure 28. High-Power Bus-Powered Function

USB POWER-DISTRIBUTION REQUIREMENTS

USB can be implemented in several ways, and, regardless of the type of USB device being developed, several power-distribution features must be implemented.

- Hosts/SPHs must:
 - Current-limit downstream ports
 - Report overcurrent conditions on USB V_{BUS}
- BPHs must:
 - Enable/disable power to downstream ports
 - Power up at <100 mA
 - Limit inrush current (<44 Ω and 10 μF)
- Functions must:
 - Limit inrush currents
 - Power up at <100 mA

The feature set of the TPS206x allows them to meet each of these requirements. The integrated current-limiting and overcurrent reporting is required by hosts and self-powered hubs. The logic-level enable and controlled rise times meet the need of both input and output ports on bus-powered hubs, as well as the input ports for bus-powered functions (see [Figure 29](#)).



† USB rev 1.1 requires 120 μ F per hub.

Figure 29. Hybrid Self / Bus-Powered Hub Implementation

GENERIC HOT-PLUG APPLICATIONS

In many applications it may be necessary to remove modules or pc boards while the main unit is still operating. These are considered hot-plug applications. Such implementations require the control of current surges seen by the main power supply and the card being inserted. The most effective way to control these surges is to limit and slowly ramp the current and voltage being applied to the card, similar to the way in which a power supply normally turns on. Due to the controlled rise times and fall times of the TPS206x, these devices can be used to provide a softer start-up to devices being hot-plugged into a powered system. The UVLO feature of the TPS206x also ensures that the switch is off after the card has been removed, and that the switch is off during the next insertion. The UVLO feature insures a soft start with a controlled rise time for every insertion of the card or module.

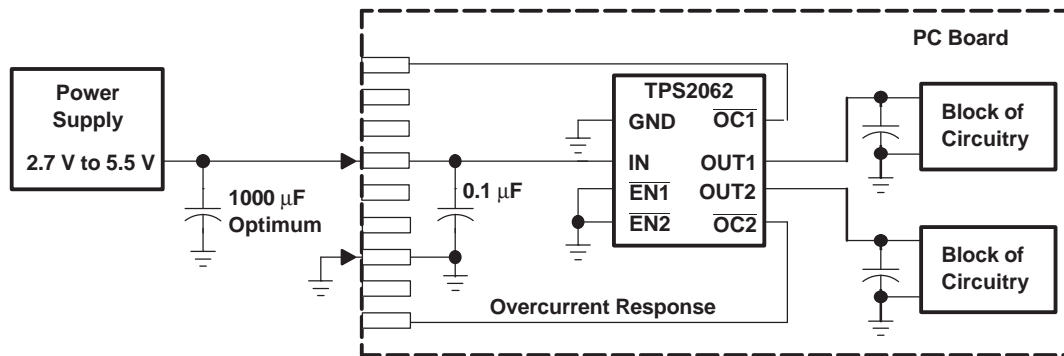


Figure 30. Typical Hot-Plug Implementation

By placing the TPS206x between the V_{CC} input and the rest of the circuitry, the input power reaches these devices first after insertion. The typical rise time of the switch is approximately 1 ms, providing a slow voltage ramp at the output of the device. This implementation controls system surge currents and provides a hot-plugging mechanism for any device.

DETAILED DESCRIPTION

Power Switch

The power switch is an N-channel MOSFET with a low on-state resistance. Configured as a high-side switch, the power switch prevents current flow from OUT to IN and IN to OUT when disabled. The power switch supplies a minimum current of 1 A.

Charge Pump

An internal charge pump supplies power to the driver circuit and provides the necessary voltage to pull the gate of the MOSFET above the source. The charge pump operates from input voltages as low as 2.7 V and requires little supply current.

Driver

The driver controls the gate voltage of the power switch. To limit large current surges and reduce the associated electromagnetic interference (EMI) produced, the driver incorporates circuitry that controls the rise times and fall times of the output voltage.

Enable (\overline{ENx} or ENx)

The logic enable disables the power switch and the bias for the charge pump, driver, and other circuitry to reduce the supply current. The supply current is reduced to less than 1 μA when a logic high is present on \overline{ENx} , or when a logic low is present on ENx . A logic zero input on \overline{ENx} , or a logic high input on ENx restores bias to the drive and control circuits and turns the switch on. The enable input is compatible with both TTL and CMOS logic levels.

Overcurrent (\overline{OCx})

The \overline{OCx} open-drain output is asserted (active low) when an overcurrent or overtemperature condition is encountered. The output remains asserted until the overcurrent or overtemperature condition is removed. A 10-ms deglitch circuit prevents the \overline{OCx} signal from oscillation or false triggering. If an overtemperature shutdown occurs, the \overline{OCx} is asserted instantaneously.

Current Sense

A sense FET monitors the current supplied to the load. The sense FET measures current more efficiently than conventional resistance methods. When an overload or short circuit is encountered, the current-sense circuitry sends a control signal to the driver. The driver in turn reduces the gate voltage and drives the power FET into its saturation region, which switches the output into a constant-current mode and holds the current constant while varying the voltage on the load.

Thermal Sense

The TPS206x implements a thermal sensing to monitor the operating temperature of the power distribution switch. In an overcurrent or short-circuit condition the junction temperature rises. When the die temperature rises to approximately 140°C due to overcurrent conditions, the internal thermal sense circuitry turns off the switch, thus preventing the device from damage. Hysteresis is built into the thermal sense, and after the device has cooled approximately 10 degrees, the switch turns back on. The switch continues to cycle off and on until the fault is removed. The open-drain false reporting output (\overline{OCx}) is asserted (active low) when an overtemperature shutdown or overcurrent occurs.

Undervoltage Lockout

A voltage sense circuit monitors the input voltage. When the input voltage is below approximately 2 V, a control signal turns off the power switch.

REVISION HISTORY

| Changes from Original (December 2003) to Revision A | Page |
|--|------|
| • Added devices to the data sheet- TPS2063, TPS2065, TPS2066, TPS2067 | 1 |
| • Added the General Switch Catalog | 1 |
| Changes from Revision A (July 2004) to Revision B | Page |
| • Changed Features Bullet From: UL Pending To: UL Listed - File No. E169910 | 1 |
| • Changed Electrical Characteristics - CURRENT LIMIT information. | 4 |
| Changes from Revision C (January 2006) to Revision D | Page |
| • Changed ORDERING INFORMATION table | 2 |
| Changes from Revision D (February 2007) to Revision E | Page |
| • Changed General Switch Catalog information. | 1 |
| Changes from Revision E (September 2007) to Revision F | Page |
| • Added the DBV-5 package. | 1 |
| • Added the DBV-5 package option. | 1 |
| • Added the DBV-5 package option to the Dissipation Ratings table. | 3 |
| • Changed Thermal Sense paragraph: From: Once the die temperature rises to approximately 140°C To: Once the die temperature rises above a minimum of 135°C | 17 |

Changes from Revision F (April 2008) to Revision G **Page**

- Changed DBV-5 to Product Preview. 1

Changes from Revision G (July 2008) to Revision H **Page**

- Deleted Product Preview from the DBV package 1
- Changed TPS2061DBV status From Preview to Active 2
- Changed TPS2065DBV status From Preview to Active 2

Changes from Revision H (December 2008) to Revision I **Page**

- Changed the ESD statement 2
- Deleted temp range of 0°C to 70°C from the Available Option table. 2
- Added Note to the Available Options table - The printed circuit board layout is important for control of temperature rise when operated at high ambient temperatures 2
- Deleted temp range of 0°C to 70°C from the Ordering Information table. 2
- Added Note to the Ordering Information table - The printed circuit board layout is important for control of temperature rise when operated at high ambient temperatures 2
- Changed the Abs Max Ratings table - Operating virtual junction temperature range From: -40°C to 125°C To: -40°C to 150°C 3
- Deleted Storage temperature range, T_{stg} from the Abs Max Ratings table 3
- Deleted MIL-STD-883C reference from ESD in the Abs Max table 3
- Added 3 table notes to the Dissipation Ratings table. 3
- Added Addition values for the DBV-5 option in the Dissipation Ratings table. 3
- Deleted Note - Not tested in production, specified by design from $r_{DS(on)}$ in the Electrical Characteristics table. 3
- Deleted Note - Not tested in production, specified by design from t_r in the Electrical Characteristics table. 3
- Deleted Note - Not tested in production, specified by design from t_f in the Electrical Characteristics table. 3
- Added text to the POWER DISSIPATION section - The thermal resistance, $R_{\theta JA}$ 17

PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|------------------|---------------|---------------|-----------------|------|-------------|-------------------------|----------------------------|----------------------|--------------|-------------------------|-------------------------|
| TPS2061D | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2061 | Samples |
| TPS2061DBVR | ACTIVE | SOT-23 | DBV | 5 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | 0 to 70 | 2061 | Samples |
| TPS2061DBVT | ACTIVE | SOT-23 | DBV | 5 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | 0 to 70 | 2061 | Samples |
| TPS2061DG4 | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2061 | Samples |
| TPS2061DGN | ACTIVE | MSOP-PowerPAD | DGN | 8 | 80 | Green (RoHS & no Sb/Br) | CU NIPDAU CU NIPDAUAG | Level-1-260C-UNLIM | -40 to 85 | 2061 | Samples |
| TPS2061DGNG4 | ACTIVE | MSOP-PowerPAD | DGN | 8 | 80 | Green (RoHS & no Sb/Br) | CU NIPDAUAG | Level-1-260C-UNLIM | -40 to 85 | 2061 | Samples |
| TPS2061DGNR | ACTIVE | MSOP-PowerPAD | DGN | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU CU NIPDAUAG | Level-1-260C-UNLIM | -40 to 85 | 2061 | Samples |
| TPS2061DGNRG4 | ACTIVE | MSOP-PowerPAD | DGN | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAUAG | Level-1-260C-UNLIM | -40 to 85 | 2061 | Samples |
| TPS2061DR | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2061 | Samples |
| TPS2061DRG4 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2061 | Samples |
| TPS2062D | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2062 | Samples |
| TPS2062DG4 | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2062 | Samples |
| TPS2062DGN | ACTIVE | MSOP-PowerPAD | DGN | 8 | 80 | Green (RoHS & no Sb/Br) | CU NIPDAU CU NIPDAUAG | Level-1-260C-UNLIM | -40 to 85 | 2062 | Samples |
| TPS2062DGNG4 | ACTIVE | MSOP-PowerPAD | DGN | 8 | 80 | Green (RoHS & no Sb/Br) | CU NIPDAUAG | Level-1-260C-UNLIM | -40 to 85 | 2062 | Samples |
| TPS2062DGNR | ACTIVE | MSOP-PowerPAD | DGN | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU CU NIPDAUAG | Level-1-260C-UNLIM | -40 to 85 | 2062 | Samples |
| TPS2062DGNRG4 | ACTIVE | MSOP-PowerPAD | DGN | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAUAG | Level-1-260C-UNLIM | -40 to 85 | 2062 | Samples |
| TPS2062DR | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2062 | Samples |

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|------------------|---------------|-------------------|--------------------|------|----------------|----------------------------|----------------------------|----------------------|--------------|-------------------------|-------------------------|
| TPS2062DRG4 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2062 | Samples |
| TPS2063D | ACTIVE | SOIC | D | 16 | 40 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2063 | Samples |
| TPS2063DG4 | ACTIVE | SOIC | D | 16 | 40 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2063 | Samples |
| TPS2063DR | ACTIVE | SOIC | D | 16 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2063 | Samples |
| TPS2063DRG4 | ACTIVE | SOIC | D | 16 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2063 | Samples |
| TPS2065D | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2065 | Samples |
| TPS2065DBVR | ACTIVE | SOT-23 | DBV | 5 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2065 | Samples |
| TPS2065DBVT | ACTIVE | SOT-23 | DBV | 5 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2065 | Samples |
| TPS2065DG4 | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2065 | Samples |
| TPS2065DGN | ACTIVE | MSOP- PowerPAD | DGN | 8 | 80 | Green (RoHS & no Sb/Br) | CU NIPDAU CU NIPDAUAG | Level-1-260C-UNLIM | -40 to 85 | 2065 | Samples |
| TPS2065DGNG4 | ACTIVE | MSOP- PowerPAD | DGN | 8 | 80 | Green (RoHS & no Sb/Br) | CU NIPDAUAG | Level-1-260C-UNLIM | -40 to 85 | 2065 | Samples |
| TPS2065DGNR | ACTIVE | MSOP- PowerPAD | DGN | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU CU NIPDAUAG | Level-1-260C-UNLIM | -40 to 85 | 2065 | Samples |
| TPS2065DGNRG4 | ACTIVE | MSOP- PowerPAD | DGN | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAUAG | Level-1-260C-UNLIM | -40 to 85 | 2065 | Samples |
| TPS2065DR | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2065 | Samples |
| TPS2065DRG4 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2065 | Samples |
| TPS2066D | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2066 | Samples |
| TPS2066DG4 | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2066 | Samples |
| TPS2066DGN | ACTIVE | MSOP- PowerPAD | DGN | 8 | 80 | Green (RoHS & no Sb/Br) | CU NIPDAU CU NIPDAUAG | Level-1-260C-UNLIM | -40 to 85 | 2066 | Samples |

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|------------------|---------------|---------------|-----------------|------|-------------|-------------------------|----------------------------|----------------------|--------------|-------------------------|-------------------------|
| TPS2066DGNG4 | ACTIVE | MSOP-PowerPAD | DGN | 8 | 80 | Green (RoHS & no Sb/Br) | CU NIPDAUAG | Level-1-260C-UNLIM | -40 to 85 | 2066 | Samples |
| TPS2066DGNR | ACTIVE | MSOP-PowerPAD | DGN | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU CU NIPDAUAG | Level-1-260C-UNLIM | -40 to 85 | 2066 | Samples |
| TPS2066DGNRG4 | ACTIVE | MSOP-PowerPAD | DGN | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAUAG | Level-1-260C-UNLIM | -40 to 85 | 2066 | Samples |
| TPS2066DR | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2066 | Samples |
| TPS2066DRG4 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2066 | Samples |
| TPS2067D | ACTIVE | SOIC | D | 16 | 40 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2067 | Samples |
| TPS2067DR | ACTIVE | SOIC | D | 16 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2067 | Samples |
| TPS2067DRG4 | ACTIVE | SOIC | D | 16 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2067 | Samples |

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSELETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

⁽⁶⁾ Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

Important Information and Disclaimer:The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

OTHER QUALIFIED VERSIONS OF TPS2062, TPS2065, TPS2066 :

- Automotive: [TPS2062-Q1](#), [TPS2065-Q1](#), [TPS2066-Q1](#)

NOTE: Qualified Version Definitions:

- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

TAPE AND REEL INFORMATION



QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE

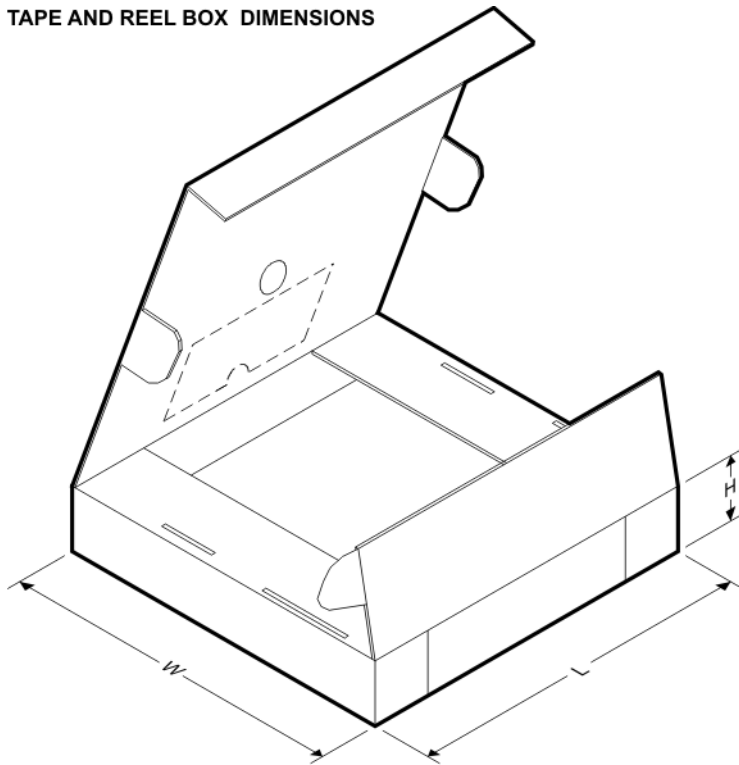


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|-------------|----------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TPS2061DBVR | SOT-23 | DBV | 5 | 3000 | 180.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS2061DBVT | SOT-23 | DBV | 5 | 250 | 179.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS2061DGNR | MSOP-Power PAD | DGN | 8 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| TPS2061DGNR | MSOP-Power PAD | DGN | 8 | 2500 | 330.0 | 12.4 | 5.3 | 3.3 | 1.3 | 8.0 | 12.0 | Q1 |
| TPS2061DR | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| TPS2062DGNR | MSOP-Power PAD | DGN | 8 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| TPS2062DR | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| TPS2063DR | SOIC | D | 16 | 2500 | 330.0 | 16.4 | 6.5 | 10.3 | 2.1 | 8.0 | 16.0 | Q1 |
| TPS2065DBVR | SOT-23 | DBV | 5 | 3000 | 178.0 | 9.0 | 3.3 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS2065DBVR | SOT-23 | DBV | 5 | 3000 | 179.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS2065DBVT | SOT-23 | DBV | 5 | 250 | 178.0 | 9.0 | 3.23 | 3.17 | 1.37 | 4.0 | 8.0 | Q3 |
| TPS2065DBVT | SOT-23 | DBV | 5 | 250 | 179.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS2065DGNR | MSOP-Power | DGN | 8 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|-------------|----------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| | PAD | | | | | | | | | | | |
| TPS2065DGNR | MSOP-Power PAD | DGN | 8 | 2500 | 330.0 | 12.4 | 5.3 | 3.3 | 1.3 | 8.0 | 12.0 | Q1 |
| TPS2065DR | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| TPS2066DGNR | MSOP-Power PAD | DGN | 8 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| TPS2066DGNR | MSOP-Power PAD | DGN | 8 | 2500 | 330.0 | 12.4 | 5.3 | 3.3 | 1.3 | 8.0 | 12.0 | Q1 |
| TPS2066DR | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| TPS2067DR | SOIC | D | 16 | 2500 | 330.0 | 16.4 | 6.5 | 10.3 | 2.1 | 8.0 | 16.0 | Q1 |

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|-------------|---------------|-----------------|------|------|-------------|------------|-------------|
| TPS2061DBVR | SOT-23 | DBV | 5 | 3000 | 203.0 | 203.0 | 35.0 |
| TPS2061DBVT | SOT-23 | DBV | 5 | 250 | 203.0 | 203.0 | 35.0 |
| TPS2061DGNR | MSOP-PowerPAD | DGN | 8 | 2500 | 364.0 | 364.0 | 27.0 |
| TPS2061DGNR | MSOP-PowerPAD | DGN | 8 | 2500 | 346.0 | 346.0 | 35.0 |
| TPS2061DR | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |
| TPS2062DGNR | MSOP-PowerPAD | DGN | 8 | 2500 | 364.0 | 364.0 | 27.0 |

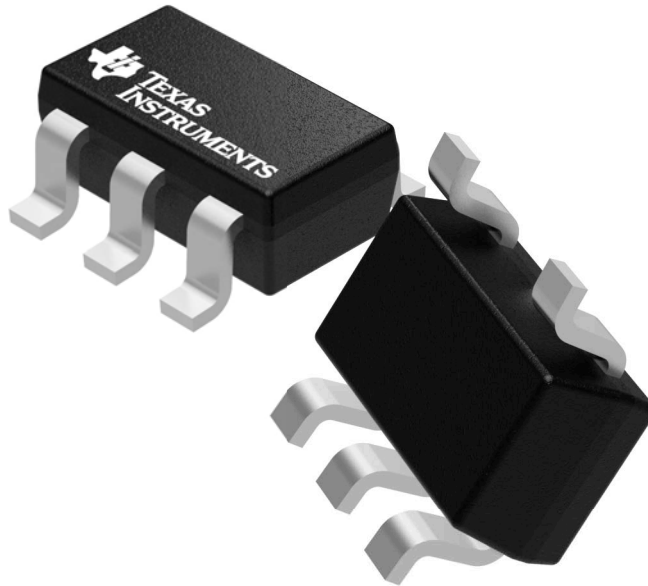
| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|-------------|---------------|-----------------|------|------|-------------|------------|-------------|
| TPS2062DR | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |
| TPS2063DR | SOIC | D | 16 | 2500 | 367.0 | 367.0 | 38.0 |
| TPS2065DBVR | SOT-23 | DBV | 5 | 3000 | 180.0 | 180.0 | 18.0 |
| TPS2065DBVR | SOT-23 | DBV | 5 | 3000 | 203.0 | 203.0 | 35.0 |
| TPS2065DBVT | SOT-23 | DBV | 5 | 250 | 180.0 | 180.0 | 18.0 |
| TPS2065DBVT | SOT-23 | DBV | 5 | 250 | 203.0 | 203.0 | 35.0 |
| TPS2065DGNR | MSOP-PowerPAD | DGN | 8 | 2500 | 364.0 | 364.0 | 27.0 |
| TPS2065DGNR | MSOP-PowerPAD | DGN | 8 | 2500 | 346.0 | 346.0 | 35.0 |
| TPS2065DR | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |
| TPS2066DGNR | MSOP-PowerPAD | DGN | 8 | 2500 | 364.0 | 364.0 | 27.0 |
| TPS2066DGNR | MSOP-PowerPAD | DGN | 8 | 2500 | 346.0 | 346.0 | 35.0 |
| TPS2066DR | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |
| TPS2067DR | SOIC | D | 16 | 2500 | 333.2 | 345.9 | 28.6 |

GENERIC PACKAGE VIEW

DBV 5

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



Images above are just a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.

4073253/P

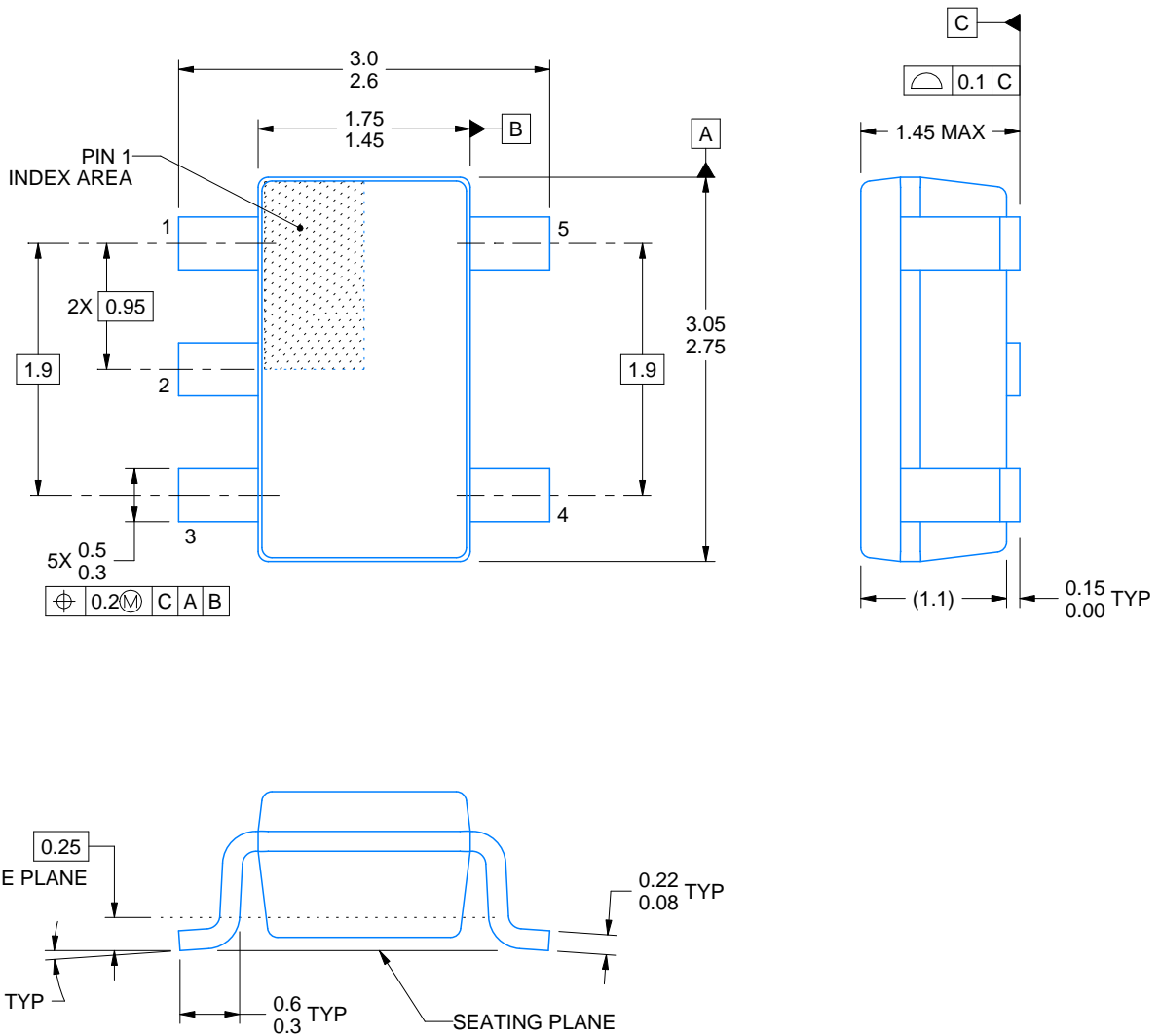
DBV0005A



PACKAGE OUTLINE

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



4214839/C 04/2017

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Reference JEDEC MO-178.

EXAMPLE BOARD LAYOUT

DBV0005A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X



SOLDER MASK DETAILS

4214839/C 04/2017

NOTES: (continued)

- 4. Publication IPC-7351 may have alternate designs.
- 5. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

DBV0005A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:15X

4214839/C 04/2017

NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
7. Board assembly site may have different recommendations for stencil design.

DBV0005A



PACKAGE OUTLINE

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



4214839/C 04/2017

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Reference JEDEC MO-178.

EXAMPLE BOARD LAYOUT

DBV0005A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X



SOLDER MASK DETAILS

4214839/C 04/2017

NOTES: (continued)

- 4. Publication IPC-7351 may have alternate designs.
- 5. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

DBV0005A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:15X

4214839/C 04/2017

NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
7. Board assembly site may have different recommendations for stencil design.

D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



4040047-3/M 06/11

- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - $\triangle C$ Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
 - $\triangle D$ Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
 - E. Reference JEDEC MS-012 variation AA.

D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Publication IPC-7351 is recommended for alternate designs.
 - D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
 - E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

DGN (S-PDSO-G8)

PowerPAD™ PLASTIC SMALL OUTLINE



- NOTES:
- All linear dimensions are in millimeters.
 - This drawing is subject to change without notice.
 - Body dimensions do not include mold flash or protrusion.
 - This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 for information regarding recommended board layout. This document is available at www.ti.com <<http://www.ti.com>>.
 - See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.
 - Falls within JEDEC MO-187 variation AA-T

PowerPAD is a trademark of Texas Instruments.

DGN (S-PDSO-G8)

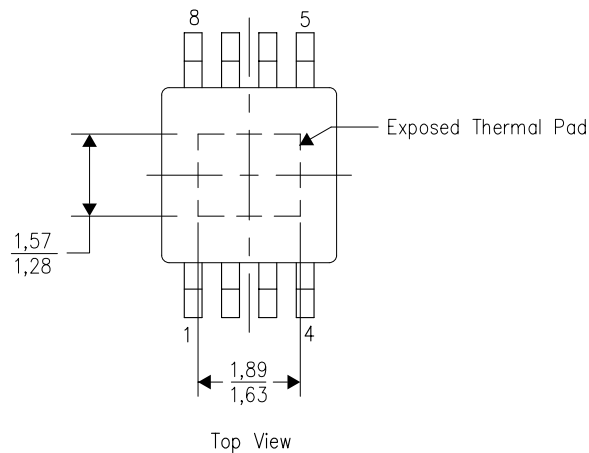
PowerPAD™ PLASTIC SMALL OUTLINE

THERMAL INFORMATION

This PowerPAD™ package incorporates an exposed thermal pad that is designed to be attached to a printed circuit board (PCB). The thermal pad must be soldered directly to the PCB. After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For additional information on the PowerPAD package and how to take advantage of its heat dissipating abilities, refer to Technical Brief, PowerPAD Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 and Application Brief, PowerPAD Made Easy, Texas Instruments Literature No. SLMA004. Both documents are available at www.ti.com.

The exposed thermal pad dimensions for this package are shown in the following illustration.



Exposed Thermal Pad Dimensions

4206323-2/1 12/11

NOTE: All linear dimensions are in millimeters

PowerPAD is a trademark of Texas Instruments



- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
 - D. This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002, SLMA004, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at www.ti.com <<http://www.ti.com>>.
 - E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC-7525 for other stencil recommendations.
 - F. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

PowerPAD is a trademark of Texas Instruments

DGN (S-PDSO-G8)

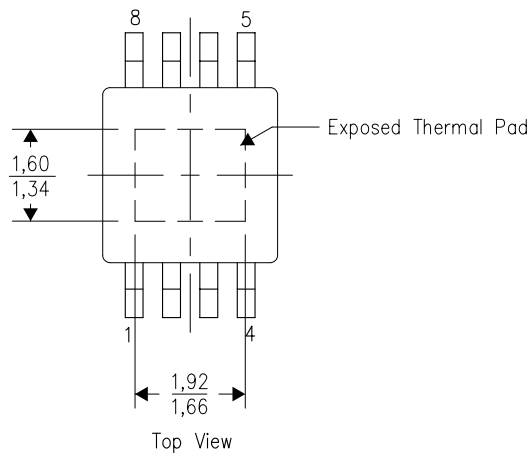
PowerPAD™ PLASTIC SMALL OUTLINE

THERMAL INFORMATION

This PowerPAD™ package incorporates an exposed thermal pad that is designed to be attached to a printed circuit board (PCB). The thermal pad must be soldered directly to the PCB. After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For additional information on the PowerPAD package and how to take advantage of its heat dissipating abilities, refer to Technical Brief, PowerPAD Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 and Application Brief, PowerPAD Made Easy, Texas Instruments Literature No. SLMA004. Both documents are available at www.ti.com.

The exposed thermal pad dimensions for this package are shown in the following illustration.



Exposed Thermal Pad Dimensions

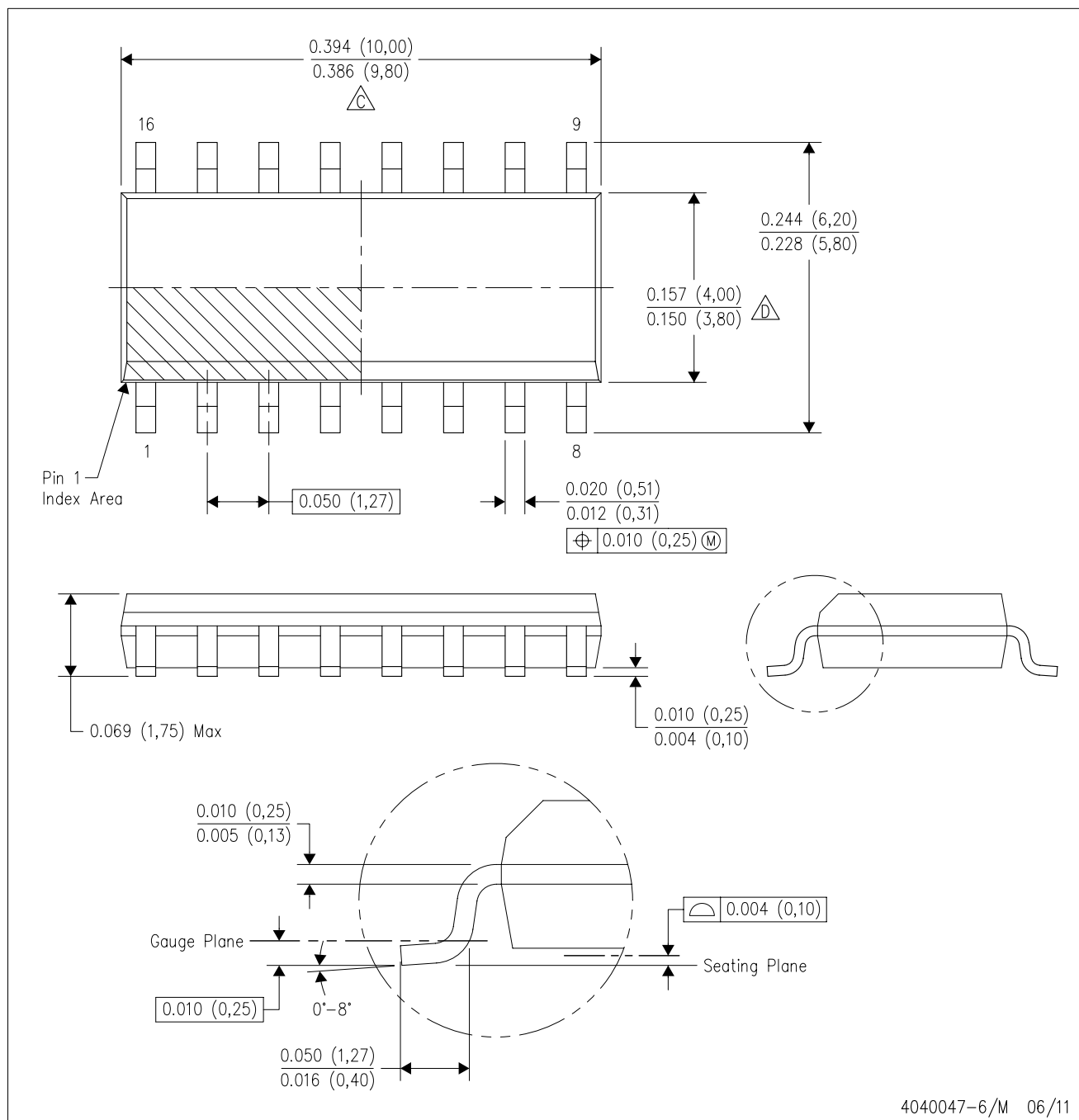
4206323-4/1 12/11

NOTE: All linear dimensions are in millimeters



PowerPAD is a trademark of Texas Instruments

D (R-PDSO-G16)

PLASTIC SMALL OUTLINE



4040047-6/M 06/11

- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 -  Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
 -  Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
 - E. Reference JEDEC MS-012 variation AC.

D (R-PDSO-G16)

PLASTIC SMALL OUTLINE



- NOTES:
- All linear dimensions are in millimeters.
 - This drawing is subject to change without notice.
 - Publication IPC-7351 is recommended for alternate designs.
 - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
 - Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

IMPORTANT NOTICE

Texas Instruments Incorporated (TI) reserves the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete.

TI's published terms of sale for semiconductor products (<http://www.ti.com/sc/docs/stdterms.htm>) apply to the sale of packaged integrated circuit products that TI has qualified and released to market. Additional terms may apply to the use or sale of other types of TI products and services.

Reproduction of significant portions of TI information in TI data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such reproduced documentation. Information of third parties may be subject to additional restrictions. Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyers and others who are developing systems that incorporate TI products (collectively, "Designers") understand and agree that Designers remain responsible for using their independent analysis, evaluation and judgment in designing their applications and that Designers have full and exclusive responsibility to assure the safety of Designers' applications and compliance of their applications (and of all TI products used in or for Designers' applications) with all applicable regulations, laws and other applicable requirements. Designer represents that, with respect to their applications, Designer has all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. Designer agrees that prior to using or distributing any applications that include TI products, Designer will thoroughly test such applications and the functionality of such TI products as used in such applications.

TI's provision of technical, application or other design advice, quality characterization, reliability data or other services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, "TI Resources") are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using TI Resources in any way, Designer (individually or, if Designer is acting on behalf of a company, Designer's company) agrees to use any particular TI Resource solely for this purpose and subject to the terms of this Notice.

TI's provision of TI Resources does not expand or otherwise alter TI's applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

Designer is authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information regarding or referencing third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of TI Resources may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

TI RESOURCES ARE PROVIDED "AS IS" AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING RESOURCES OR USE THEREOF, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS. TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY DESIGNER AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

Unless TI has explicitly designated an individual product as meeting the requirements of a particular industry standard (e.g., ISO/TS 16949 and ISO 26262), TI is not responsible for any failure to meet such industry standard requirements.

Where TI specifically promotes products as facilitating functional safety or as compliant with industry functional safety standards, such products are intended to help enable customers to design and create their own applications that meet applicable functional safety standards and requirements. Using products in an application does not by itself establish any safety features in the application. Designers must ensure compliance with safety-related requirements and standards applicable to their applications. Designer may not use any TI products in life-critical medical equipment unless authorized officers of the parties have executed a special contract specifically governing such use. Life-critical medical equipment is medical equipment where failure of such equipment would cause serious bodily injury or death (e.g., life support, pacemakers, defibrillators, heart pumps, neurostimulators, and implantables). Such equipment includes, without limitation, all medical devices identified by the U.S. Food and Drug Administration as Class III devices and equivalent classifications outside the U.S.

TI may expressly designate certain products as completing a particular qualification (e.g., Q100, Military Grade, or Enhanced Product). Designers agree that it has the necessary expertise to select the product with the appropriate qualification designation for their applications and that proper product selection is at Designers' own risk. Designers are solely responsible for compliance with all legal and regulatory requirements in connection with such selection.

Designer will fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of Designer's non-compliance with the terms and provisions of this Notice.