

## Fast-Transient-Response 2-A Low-Dropout Voltage Regulator with Reset

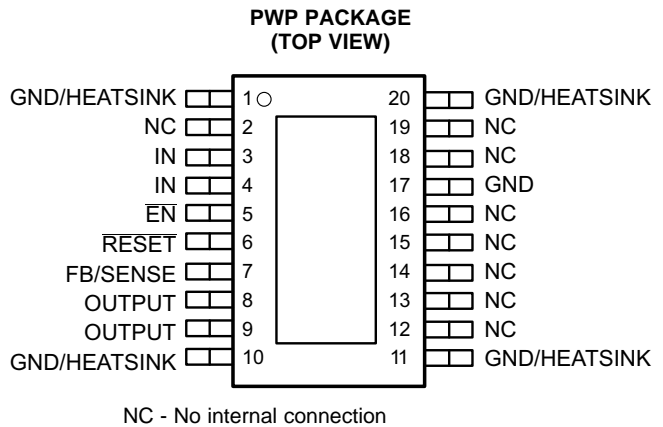
Check for Samples: [TPS75201M-EP](#)

### FEATURES

- **Controlled Baseline**
  - One Assembly/Test Site, One Fabrication Site
- **Enhanced Diminishing Manufacturing Sources (DMS) Support**
- **Enhanced Product-Change Notification**
- **Qualification Pedigree <sup>(1)</sup>**
- **2-A Low-Dropout (LDO) Voltage Regulator**
- **Open-Drain Power-On Reset With 100-ms Delay**
- **Ultralow 75- $\mu$ A Typ Quiescent Current**

(1) Component qualification in accordance with JEDEC and industry standards to ensure reliable operation over the specified temperature range. This includes, but is not limited to, Highly Accelerated Stress Test (HAST) or biased 85/85, temperature cycle, autoclave or unbiased HAST, electromigration, bond intermetallic life, and mold compound life. Such qualification testing should not be viewed as justifying use of this component beyond specified performance and environmental limits.

- **Fast Transient Response**
- **2% Tolerance Over Specified Conditions for Fixed-Output Versions**
- **20-Pin TSSOP (PWP) PowerPAD™ Package**
- **Thermal Shutdown Protection**



### DESCRIPTION

The TPS75201M-EP is a low dropout regulator with an integrated power-on reset ( $\overline{\text{RESET}}$ ) function. This device is capable of supplying 2 A of output current with a dropout of 210 mV. Quiescent current is 75  $\mu$ A at full load and drops down to 1  $\mu$ A when the device is disabled. The TPS75201M-EP is designed to have fast transient response for larger load current changes.

Because the PMOS device operates like a low-value resistor, the dropout voltage is very low (typically 210 mV at an output current of 2 A) and is directly proportional to the output current. Additionally, since the PMOS pass element is a voltage-driven device, the quiescent current is very low and independent of output loading (75  $\mu$ A typ over the full range of output current, 1 mA to 2 A). These two key specifications yield a significant improvement in operating life for battery-powered systems.

The device is enabled when the enable ( $\overline{\text{EN}}$ ) input is connected to a low-level input voltage. This low-dropout (LDO) device also features a sleep mode; applying a TTL high signal to  $\overline{\text{EN}}$  shuts down the regulator, reducing the quiescent current to 1  $\mu$ A at  $T_J = 25^\circ\text{C}$ .

The  $\overline{\text{RESET}}$  (SVS, POR, or power-on reset) output of the TPS75201M-EP initiates a reset in microcomputer and microprocessor systems in the event of an undervoltage condition. An internal comparator in the TPS75201M-EP monitors the output voltage of the regulator to detect an undervoltage condition on the regulated output voltage. When the output reaches 95% of its regulated voltage,  $\overline{\text{RESET}}$  goes to a high-impedance state after a 100-ms delay.  $\overline{\text{RESET}}$  goes to a logic-low state when the regulated output voltage is pulled below 95% (i.e., overload condition) of its regulated voltage.

The TPS75201M-EP is adjustable (programmable over the range of 1.5 V to 5 V). Output voltage tolerance is specified as a maximum of 2% over line, load, and temperature ranges.

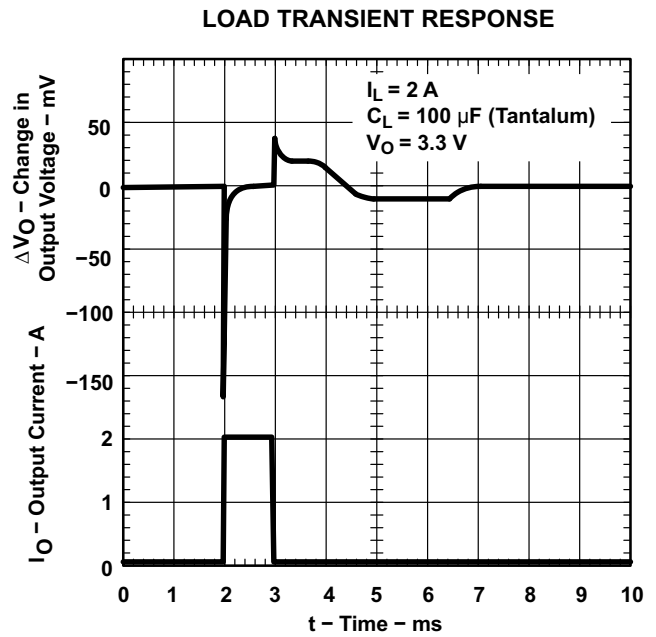
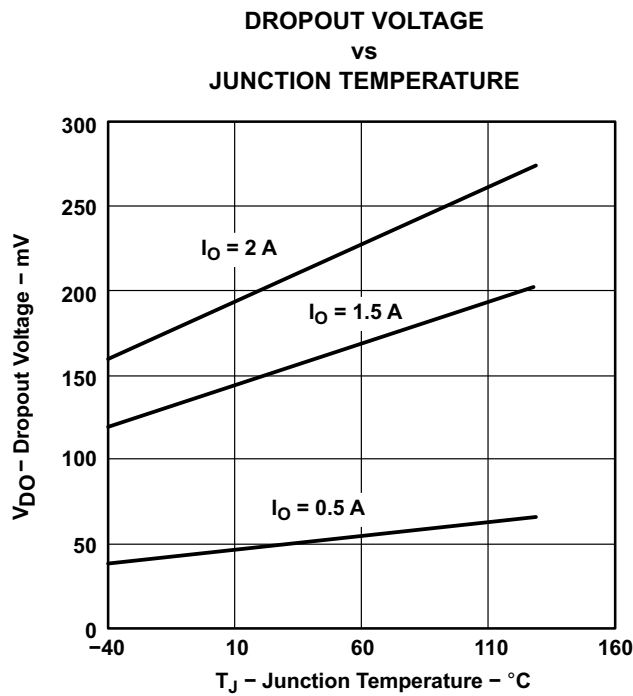


Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

PowerPAD is a trademark of Texas Instruments.



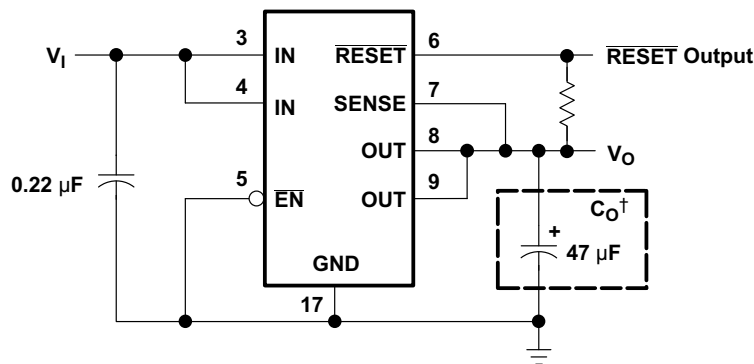
These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.



### ORDERING INFORMATION<sup>(1)</sup>

$T_J$	OUTPUT VOLTAGE (TYP)	PACKAGE <sup>(2)</sup>		ORDERABLE PART NUMBER
-55°C to 125°C	Adjustable 1.5 V to 5 V	TSSOP – PWP	Tape and reel	TPS75201MPWPREP

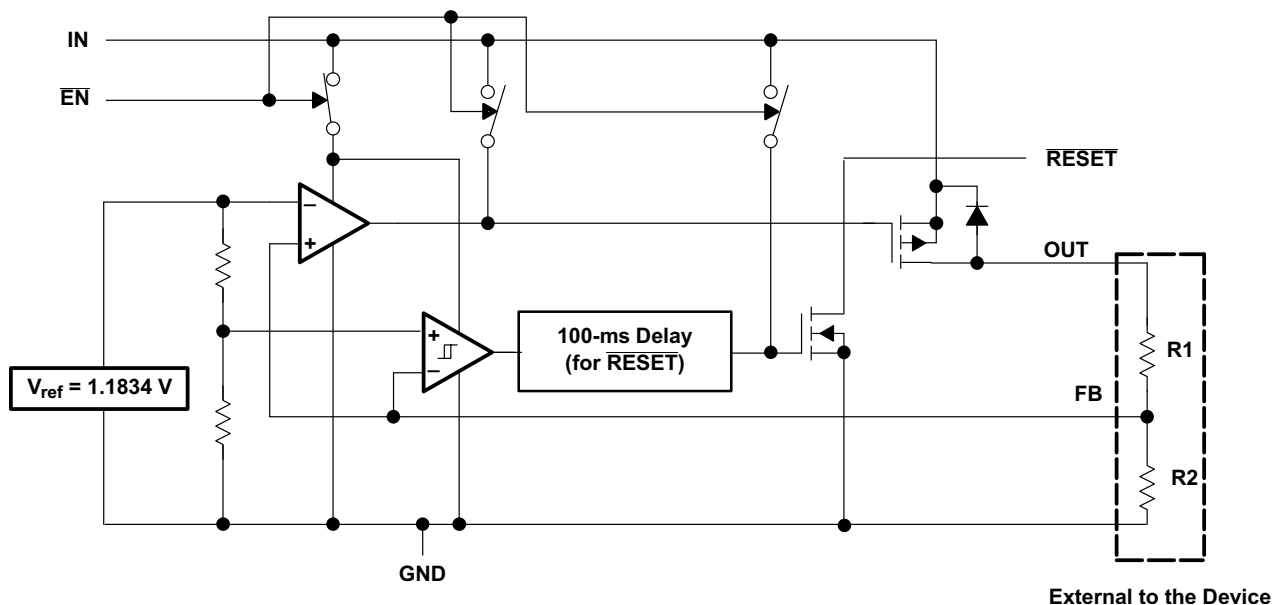
- (1) The TPS75201M-EP is programmable using an external resistor divider (see Application Information).
- (2) Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at [www.ti.com/sc/package](http://www.ti.com/sc/package).



†See application information section for capacitor selection details.

**Figure 1. Typical Application Configuration (for Fixed-Output Options)**

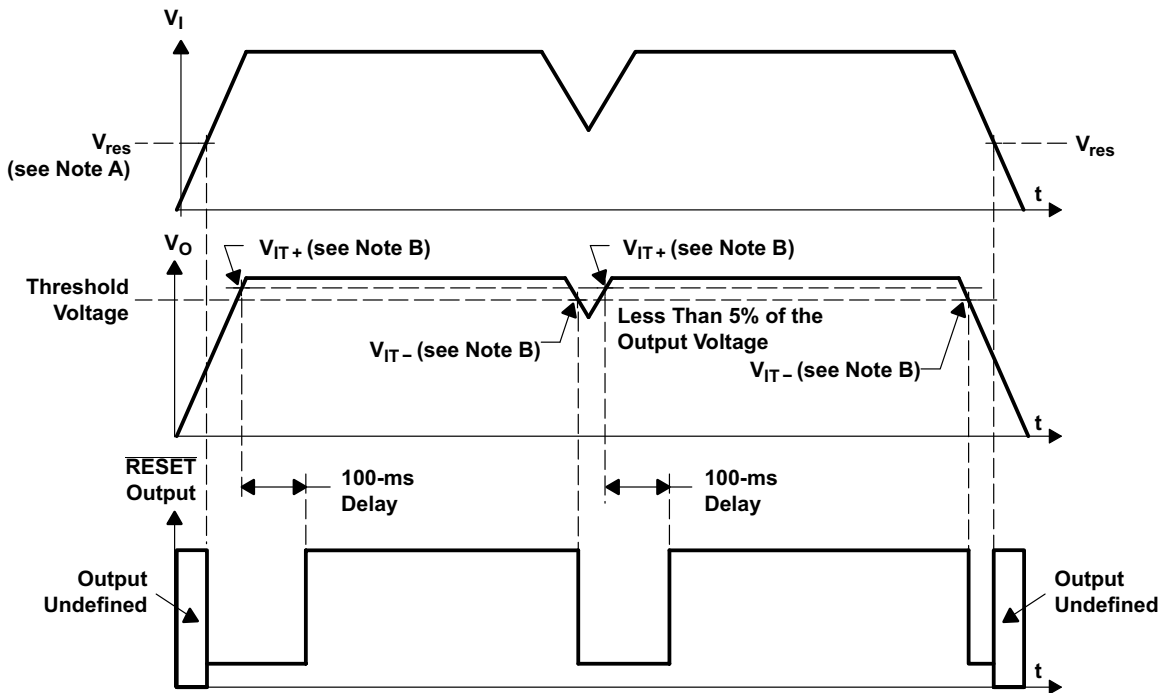
FUNCTIONAL BLOCK DIAGRAM



PIN FUNCTIONS

PIN		I/O	DESCRIPTION
NAME	NO.		
EN	5	I	Enable
FB/SENSE	7	I	Feedback input voltage for adjustable device (sense input for fixed-voltage option)
GND	17		Regulator ground
GND/HEATSINK	1, 10, 11, 20		Ground/heat sink
IN	3, 4	I	Input voltage
NC	2, 12, 13, 14, 15, 16, 18, 19		No connection
OUTPUT	8, 9	O	Regulated output voltage
$\overline{\text{RESET}}$	6	O	Reset

**RESET TIMING DIAGRAM**



- A.  $V_{res}$  is the minimum input voltage for a valid  $\overline{RESET}$ . The symbol  $V_{res}$  is not currently listed within EIA or JEDEC standards for semiconductor symbology.
- B.  $V_{IT-}$  – Trip voltage typically is 5% lower than the output voltage ( $95\% V_O$ ).  $V_{IT-}$  to  $V_{IT+}$  is the hysteresis voltage.

**ABSOLUTE MAXIMUM RATINGS**

over operating junction temperature range (unless otherwise noted) <sup>(1)</sup>

		MIN	MAX	UNIT
$V_I$	Input voltage range <sup>(2)</sup>	-0.3	6	V
	Voltage range at $\overline{EN}$	-0.3	16.5	V
	Maximum $\overline{RESET}$ voltage		16.5	V
	Peak output current	Internally limited		V
$V_O$	Output voltage (OUTPUT, FB)		5.5	V
	Continuous total power dissipation	See Dissipation Rating Table		
$T_J$	Operating virtual junction temperature range	-55	125	°C
$T_{stg}$	Storage temperature range	-65	150	°C
	ESD rating, Human-Body Model		2	kV

- (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 voltage values are with respect to network terminal ground.

**DISSIPATION RATING TABLE – FREE-AIR TEMPERATURES**

PACKAGE	AIR FLOW (CFM)	$T_A < 25^\circ\text{C}$ 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
PWP <sup>(1)</sup>	0	2.9 W	23.5 mW/°C	1.9 W	1.5 W
	300	4.3 W	34.6 mW/°C	2.8 W	2.2 W

- (1) This parameter is measured with the recommended copper heat- sink pattern on a one-layer PCB, 5-in x 5-in PCB, 1-oz copper, 2-in x 2-in coverage (4 in<sup>2</sup>).

**DISSIPATION RATING TABLE – FREE-AIR TEMPERATURES (continued)**

PACKAGE	AIR FLOW (CFM)	T <sub>A</sub> < 25°C POWER RATING	DERATING FACTOR ABOVE T <sub>A</sub> = 25°C	T <sub>A</sub> = 70°C POWER RATING	T <sub>A</sub> = 85°C POWER RATING
PWP <sup>(2)</sup>	3	3 w	23.6 mW/°C	1.9 W	1.5 W
	300	7.2 W	57.9 mW/°C	4.6 W	3.8 W

(2) This parameter is measured with the recommended copper heat-sink pattern on an eight-layer PCB, 1.5-in x 2-in PCB, 1-oz copper with layers 1, 2, 4, 5, 7, and 8 at 5% coverage (0.9 in<sup>2</sup>), and layers 3 and 6 at 100% coverage (6 in<sup>2</sup>). For more information, refer to TI technical brief [SLMA002](#).

**RECOMMENDED OPERATING CONDITIONS**

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

	MIN	MAX	UNIT
V <sub>I</sub> Input voltage <sup>(1)</sup>	2.7	5.5	V
V <sub>O</sub> Output voltage range	1.5	5	V
I <sub>O</sub> Output current	0	2.0	A
T <sub>J</sub> Operating virtual junction temperature	-55	125	°C

(1) To calculate the minimum input voltage for your maximum output current, use the following equation:  $V_{I(\min)} = V_{O(\max)} + V_{DO(\max \text{ load})}$ .

# TPS75201M-EP

SGLS325A – JANUARY 2006 – REVISED JULY 2013

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## ELECTRICAL CHARACTERISTICS

over recommended operating junction temperature range ( $T_J = -55^\circ\text{C}$  to  $125^\circ\text{C}$ ),  $V_I = V_{O(\text{typ})} + 1\text{ V}$ ,  $I_O = 1\text{ mA}$ ,  $\overline{\text{EN}} = 0\text{ V}$ ,  $C_O = 47\text{ }\mu\text{F}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output voltage <sup>(1)(2)</sup>	Adjustable voltage	$1.5\text{ V} \leq V_O \leq 5\text{ V}$	$T_J = 25^\circ\text{C}$	$V_O$		V
				0.98 $V_O$	1.02 $V_O$	
Quiescent current (GND current) <sup>(1)</sup>		$T_J = 25^\circ\text{C}$ <sup>(2)</sup>	75		125	$\mu\text{A}$
Output voltage line regulation ( $\Delta V_O/V_O$ ) <sup>(1)(3)</sup>			$V_O + 1\text{ V} < V_I \leq 5\text{ V}$	$T_J = 25^\circ\text{C}$		
Load regulation <sup>(2)</sup>					1	
Output noise voltage		BW = 300 Hz to 50 kHz, $V_O = 1.5\text{ V}$ , $C_O = 100\text{ }\mu\text{F}$	$T_J = 25^\circ\text{C}$	60		$\mu\text{Vrms}$
Output current limit		$V_O = 0\text{ V}$		3.3	4.5	
Thermal shutdown junction temperature			150			$^\circ\text{C}$
Standby current		$\overline{\text{EN}} = V_I$	$T_J = 25^\circ\text{C}$	1		$\mu\text{A}$
FB input current				-1		
High-level enable input voltage			2			V
Low-level enable input voltage					0.7	V
Power-supply ripple rejection <sup>(3)</sup>		$f = 100\text{ Hz}$ , $C_O = 100\text{ }\mu\text{F}$ , $T_J = 25^\circ\text{C}$ , $I_O = 2\text{ A}$ , <sup>(1)</sup>	60			dB
Reset	Minimum input voltage for valid $\overline{\text{RESET}}$	$I_{O(\text{RESET})} = 300\text{ }\mu\text{A}$ , $V_{(\text{RESET})} \leq 0.8\text{ V}$	1		1.3	V
	Trip threshold voltage	$V_O$ decreasing	92		98	
	Hysteresis voltage	Measured at $V_O$	0.5			% $V_O$
	Output low voltage	$V_I = 2.7\text{ V}$ , $I_{O(\text{RESET})} = 1\text{ mA}$	0.15		0.4	V
	Leakage current	$V_{(\text{RESET})} = 5\text{ V}$			1	$\mu\text{A}$
	RESET time-out delay		100			ms

(1) Minimum IN operating voltage is 2.7 V or  $V_{O(\text{typ})} + 1\text{ V}$ , whichever is greater. Maximum IN voltage is 5 V.

(2)  $I_O = 1\text{ mA}$  to 2 A

(3) If  $V_O \leq 1.8\text{ V}$ ,  $V_{\text{imin}} = 2.7\text{ V}$ ,  $V_{\text{imax}} = 5\text{ V}$ :

$$\text{Line regulation (mV)} = (\% / \text{V}) \times \frac{V_O (V_{\text{imax}} - 2.7\text{ V})}{100} \times 1000$$

If  $V_O \geq 2.5\text{ V}$ ,  $V_{\text{imin}} = V_O + 1\text{ V}$ ,  $V_{\text{imax}} = 5\text{ V}$ :

$$\text{Line regulation (mV)} = (\% / \text{V}) \times \frac{V_O [V_{\text{imax}} - (V_O + 1\text{ V})]}{100} \times 1000$$

## ELECTRICAL CHARACTERISTICS

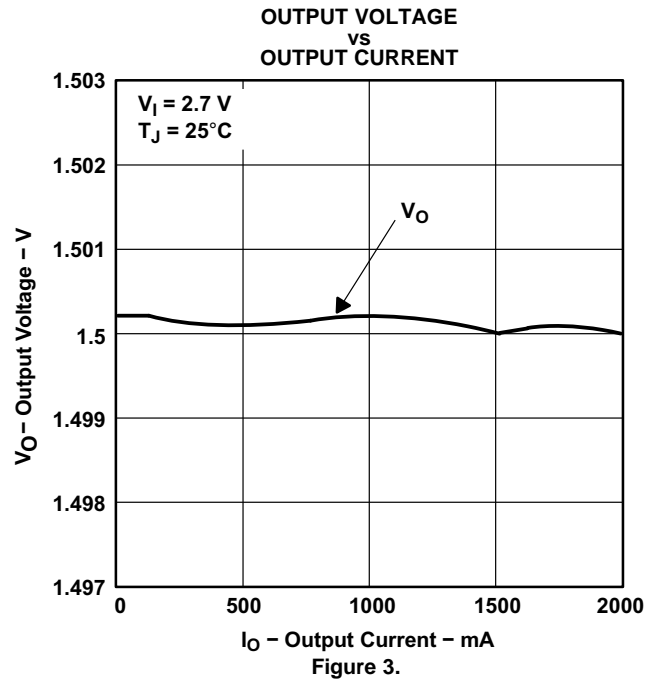
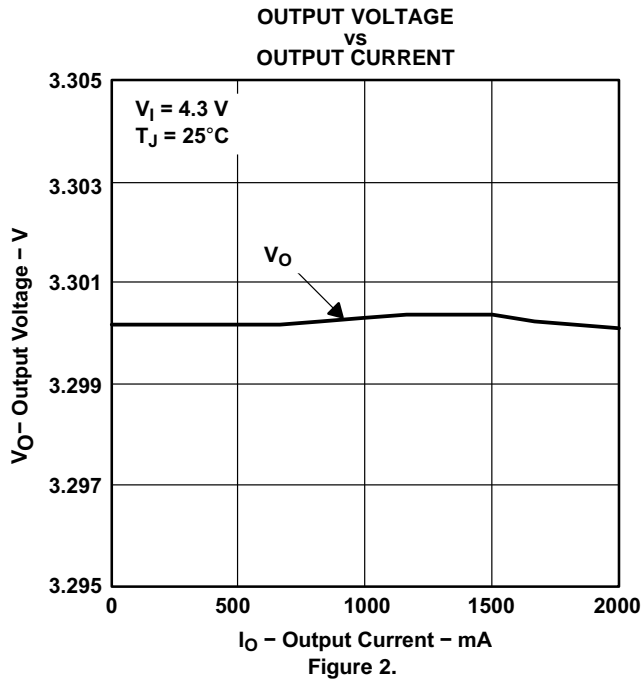
over recommended operating junction temperature range ( $T_J = -40^\circ\text{C}$  to  $125^\circ\text{C}$ ),  $V_I = V_{O(\text{typ})} + 1\text{ V}$ ,  $I_O = 1\text{ mA}$ ,  $\text{EN} = 0\text{ V}$ ,  $C_O = 47\text{ }\mu\text{F}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input current ( $\overline{\text{EN}}$ )	$\overline{\text{EN}} = V_I$	-1		1	$\mu\text{A}$
	$\overline{\text{EN}} = 0\text{ V}$	-1	0	1	$\mu\text{A}$
High-level $\overline{\text{EN}}$ input voltage		2			V
Low-level $\overline{\text{EN}}$ input voltage				0.7	V
Dropout voltage (3.3-V output)	$I_O = 2\text{ A}$ , $V_I = 3.2\text{ V}$ , $T_J = 25^\circ\text{C}$	210			mV
	$I_O = 2\text{ A}$ , $V_I = 3.2\text{ V}$			400	

TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
$V_O$	Output voltage	vs Output current	Figure 2 and Figure 3
		vs Junction temperature	Figure 4 and Figure 5
	Ground current	vs Junction temperature	Figure 6
	Power-supply ripple rejection	vs Frequency	Figure 7
	Output spectral noise density	vs Frequency	Figure 8
$Z_o$	Output impedance	vs Frequency	Figure 9
$V_{DO}$	Dropout voltage	vs Input voltage	Figure 10
		vs Junction temperature	Figure 11
	Input voltage (min)	vs Output voltage	Figure 12
	Line transient response		Figure 13 and Figure 16
	Load transient response		Figure 14 and Figure 16
$V_O$	Output voltage	vs Time (startup)	Figure 17
	Equivalent series resistance (ESR)	vs Output current	Figure 19 and Figure 20



OUTPUT VOLTAGE  
vs  
JUNCTION TEMPERATURE

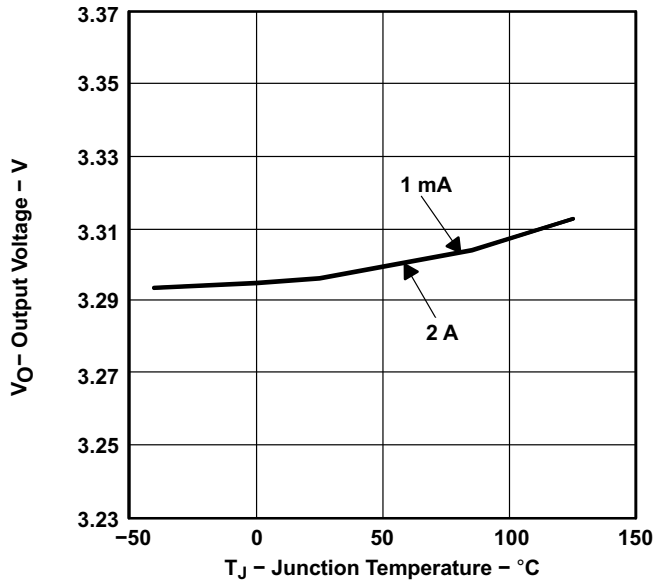


Figure 4.

OUTPUT VOLTAGE  
vs  
JUNCTION TEMPERATURE

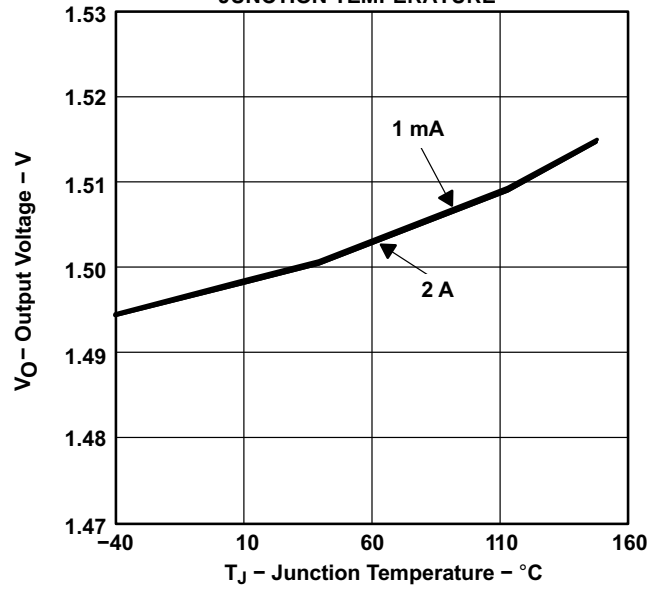


Figure 5.

GROUND CURRENT  
vs  
JUNCTION TEMPERATURE

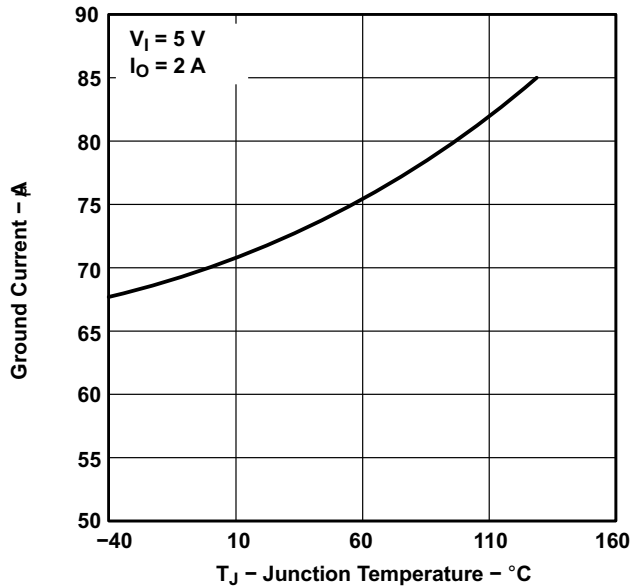


Figure 6.

POWER-SUPPLY RIPPLE REJECTION  
vs  
FREQUENCY

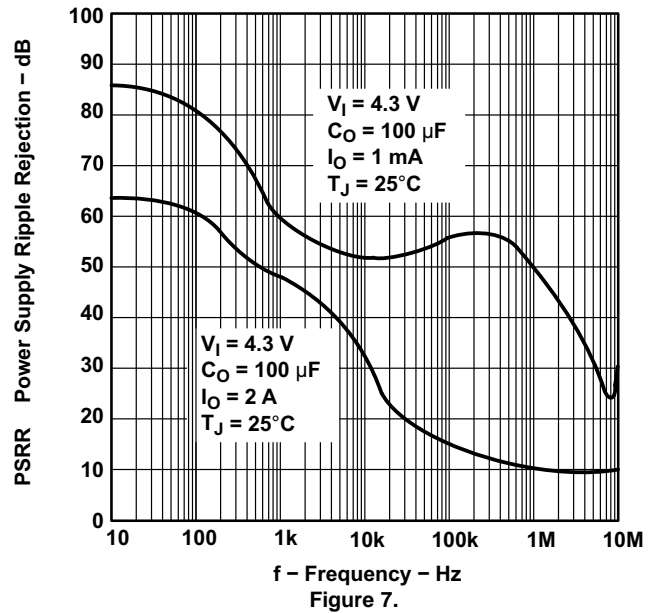


Figure 7.

OUTPUT SPECTRAL NOISE DENSITY  
VS  
FREQUENCY

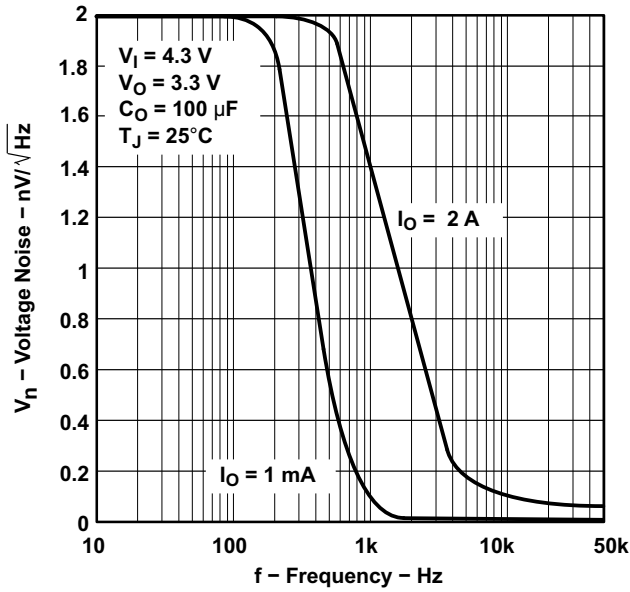


Figure 8.

OUTPUT IMPEDANCE  
VS  
FREQUENCY

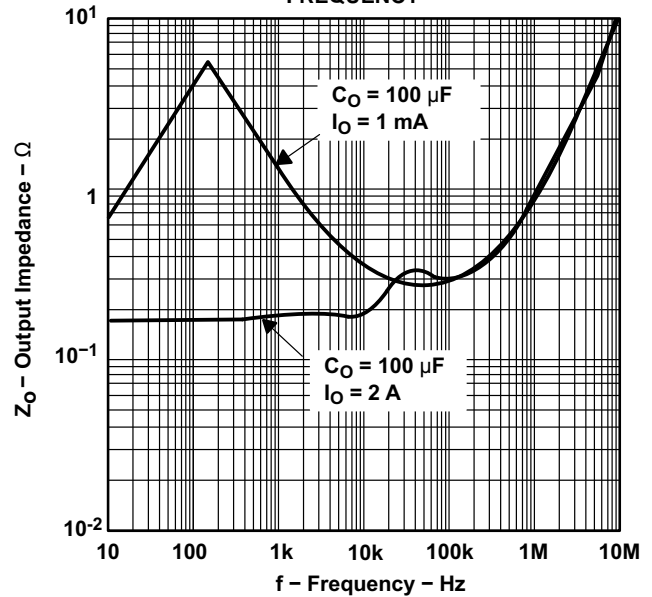


Figure 9.

DROPOUT VOLTAGE  
VS  
INPUT VOLTAGE

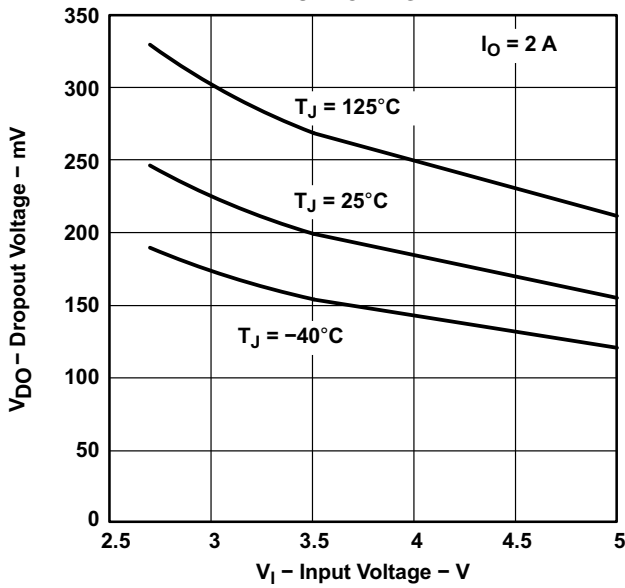


Figure 10.

DROPOUT VOLTAGE  
VS  
JUNCTION TEMPERATURE

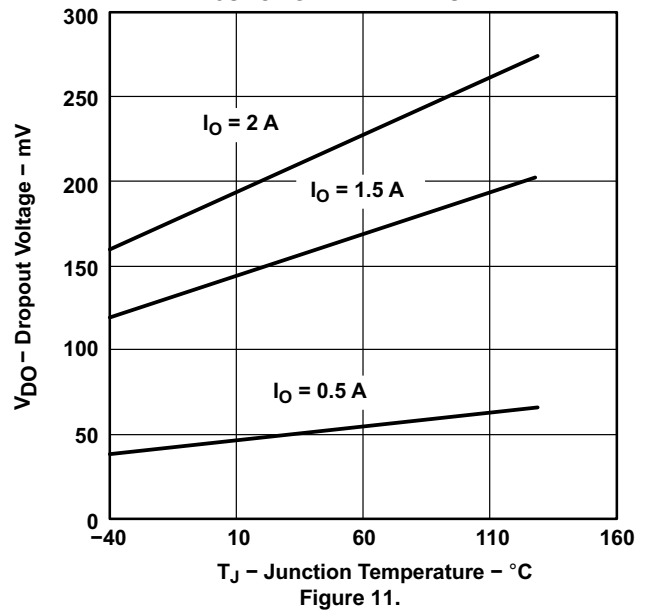


Figure 11.

INPUT VOLTAGE (MIN)  
vs  
OUTPUT VOLTAGE

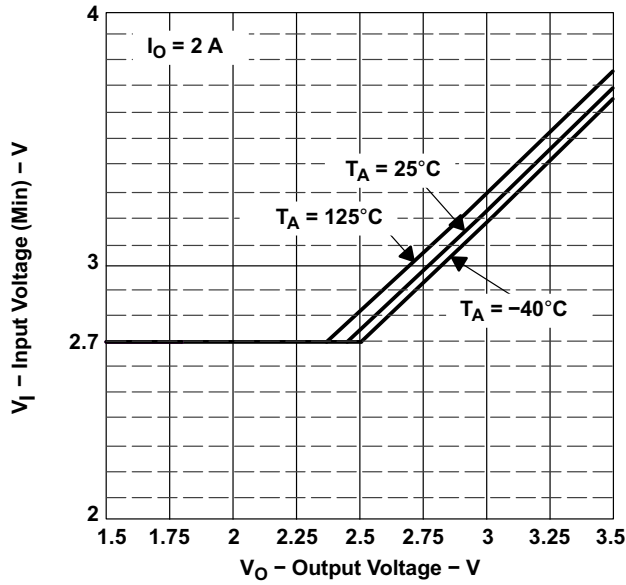


Figure 12.

LINE TRANSIENT RESPONSE

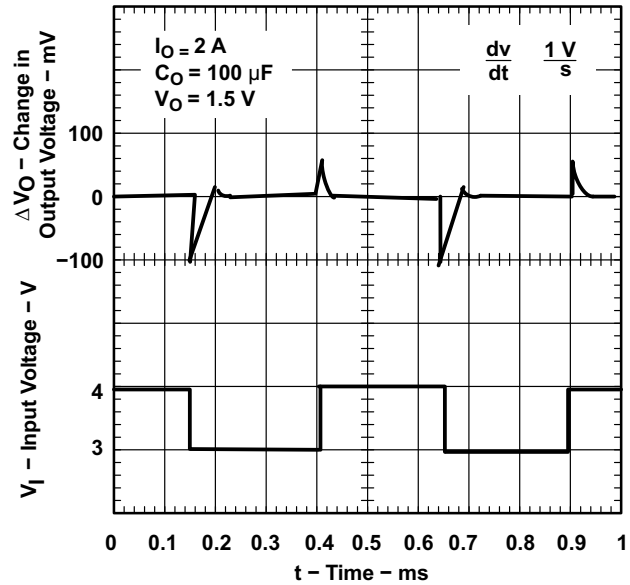


Figure 13.

LOAD TRANSIENT RESPONSE

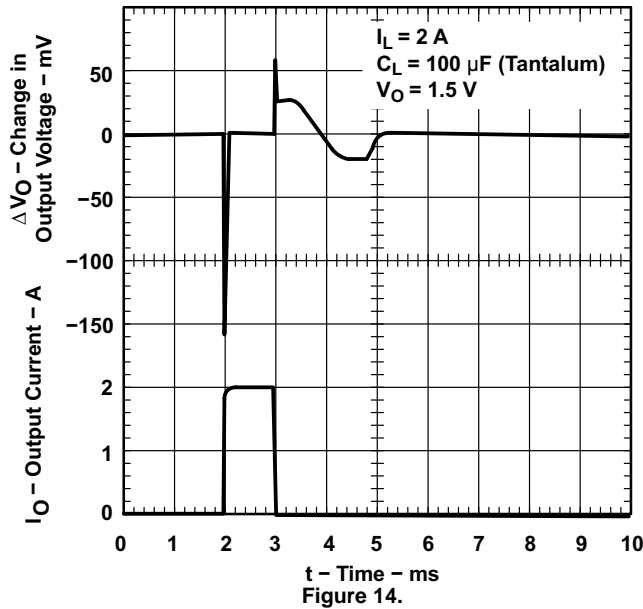


Figure 14.

LINE TRANSIENT RESPONSE

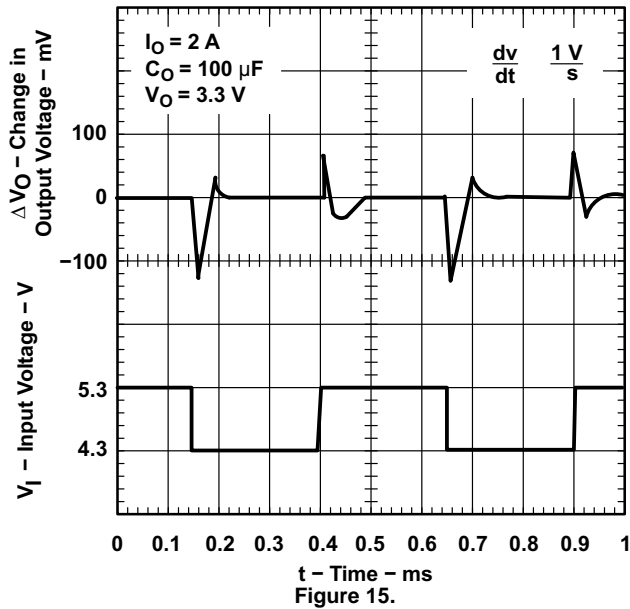
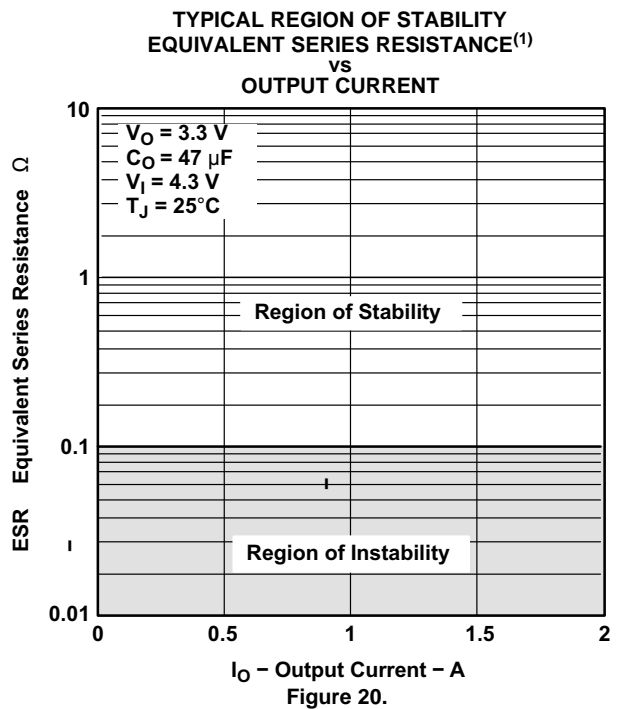
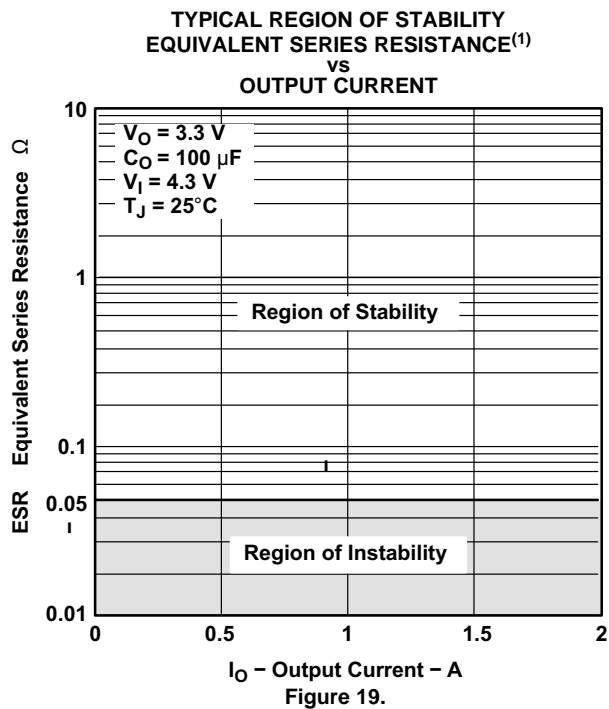
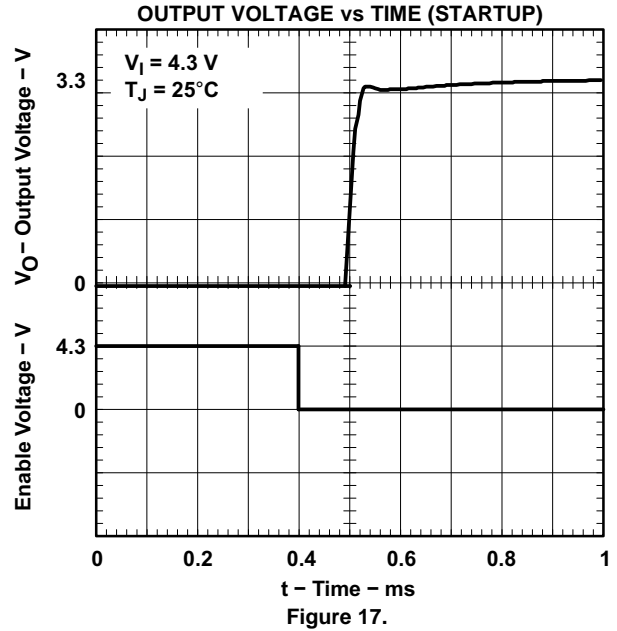
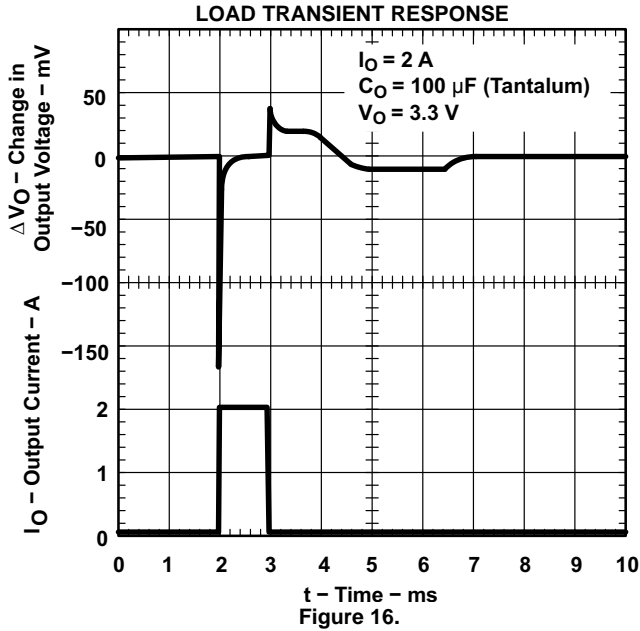


Figure 15.



(1) Equivalent series resistance (ESR) refers to the total series resistance, including the ESR of the capacitor, any series resistance added externally, and PWB trace resistance to  $C_O$ .

## APPLICATION INFORMATION

The TPS75201M-EP is an adjustable regulator (from 1.5 V to 5 V).

### MINIMUM LOAD REQUIREMENTS

The TPS75201M-EP is stable, even at no load; no minimum load is required for operation.

### PIN FUNCTIONS

#### Enable ( $\overline{\text{EN}}$ )

The  $\overline{\text{EN}}$  input enables or shuts down the device. If  $\overline{\text{EN}}$  is a logic high, the device is in shutdown mode. When  $\overline{\text{EN}}$  goes to logic low, the device is enabled.

#### Reset ( $\overline{\text{RESET}}$ )

The  $\overline{\text{RESET}}$  terminal is an open-drain, active-low output that indicates the status of  $V_O$ . When  $V_O$  reaches 95% of the regulated voltage,  $\overline{\text{RESET}}$  goes to a low-impedance state after a 100-ms delay.  $\overline{\text{RESET}}$  goes to a high-impedance state when  $V_O$  is below 95% of the regulated voltage. The open-drain output of  $\overline{\text{RESET}}$  requires a pullup resistor.

#### Sense (SENSE)

The SENSE terminal of the fixed-output options must be connected to the regulator output, and the connection should be as short as possible. Internally, SENSE connects to a high-impedance wide-bandwidth amplifier through a resistor-divider network, and noise pickup feeds through to the regulator output. It is essential to route the SENSE connection in such a way to minimize/avoid noise pickup. Adding RC networks between SENSE and  $V_O$  to filter noise is not recommended because it may cause the regulator to oscillate.

#### Feedback (FB)

FB is an input used for the adjustable-output options and must be connected to an external feedback resistor divider. The FB connection should be as short as possible. It is essential to route it in such a way to minimize/avoid noise pickup. Adding RC networks between FB and  $V_O$  to filter noise is not recommended because it may cause the regulator to oscillate.

#### Ground/Heat Sink (GND/HEATSINK)

All GND/HEATSINK terminals are connected directly to the mount pad for thermal-enhanced operation. These terminals could be connected to GND or left floating.

#### Input Capacitor

For a typical application, an input bypass capacitor (0.22  $\mu\text{F}$ –1  $\mu\text{F}$ ) is recommended for device stability. This capacitor should be as close to the input pins as possible. For fast transient condition, where droop at the input of the LDO may occur due to high in-rush current, it is recommended to place a larger capacitor at the input as well. The size of this capacitor is dependant on the output current and response time of the main power supply, as well as the distance to the load (LDO).

#### Output Capacitor

As with most LDO regulators, the TPS75201M-EP requires an output capacitor connected between OUT and GND to stabilize the internal control loop. The minimum recommended capacitance value is 47  $\mu\text{F}$ , and the ESR must be between 100 m $\Omega$  and 10  $\Omega$ . Solid tantalum electrolytic, aluminum electrolytic, and multilayer ceramic capacitors are all suitable, provided they meet the requirements described in this section. Larger capacitors provide a wider range of stability and better load transient response.

This information, along with the ESR graphs, is included to assist in selection of suitable capacitance for the user's application. When necessary to achieve low height requirements along with high output current and/or high load capacitance, several higher ESR capacitors can be used in parallel to meet these guidelines.

## ESR and Transient Response

LDOs typically require an external output capacitor for stability. In fast transient response applications, capacitors are used to support the load current while the LDO amplifier is responding. In most applications, one capacitor is used to support both functions.

Besides its capacitance, every capacitor also contains parasitic impedances. These parasitic impedances are resistive as well as inductive. The resistive impedance is called equivalent series resistance (ESR), and the inductive impedance is called equivalent series inductance (ESL). The equivalent schematic diagram of any capacitor therefore can be drawn as shown in Figure 21.



Figure 21. ESR and ESL

In most cases, the effect of inductive impedance ESL can be neglected. Therefore, the following application focuses mainly on the parasitic resistance ESR.

Figure 22 shows the output capacitor and its parasitic impedances in a typical LDO output stage.

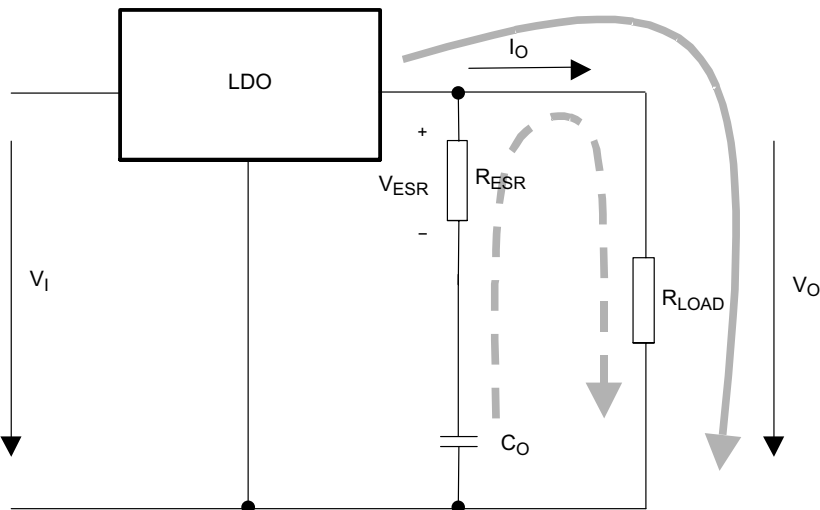


Figure 22. LDO Output Stage With Parasitic Resistances ESR and ESL

In steady state (dc state condition), the load current is supplied by the LDO (solid arrow), and the voltage across the capacitor is the same as the output voltage [ $V_{(CO)} = V_O$ ]. This means no current is flowing into the  $C_O$  branch. If  $I_O$  suddenly increases (transient condition), the following occurs:

- The LDO is not able to supply the sudden current need due to its response time ( $t_1$  in Figure 24). Therefore, capacitor  $C_O$  provides the current for the new load condition (dashed arrow).  $C_O$  now acts like a battery with an internal resistance, ESR. Depending on the current demand at the output, a voltage drop will occur at  $R_{ESR}$ . This voltage is shown as  $V_{ESR}$  in Figure 23.
- When  $C_O$  is conducting current to the load, initial voltage at the load is  $V_O = V_{(CO)} - V_{ESR}$ . Due to the discharge of  $C_O$ , the output voltage  $V_O$  drops continuously until the response time,  $t_1$ , of the LDO is reached and the LDO resumes supplying the load. From this point, the output voltage starts rising again until it reaches the regulated voltage. This period is shown as  $t_2$  in Figure 24.

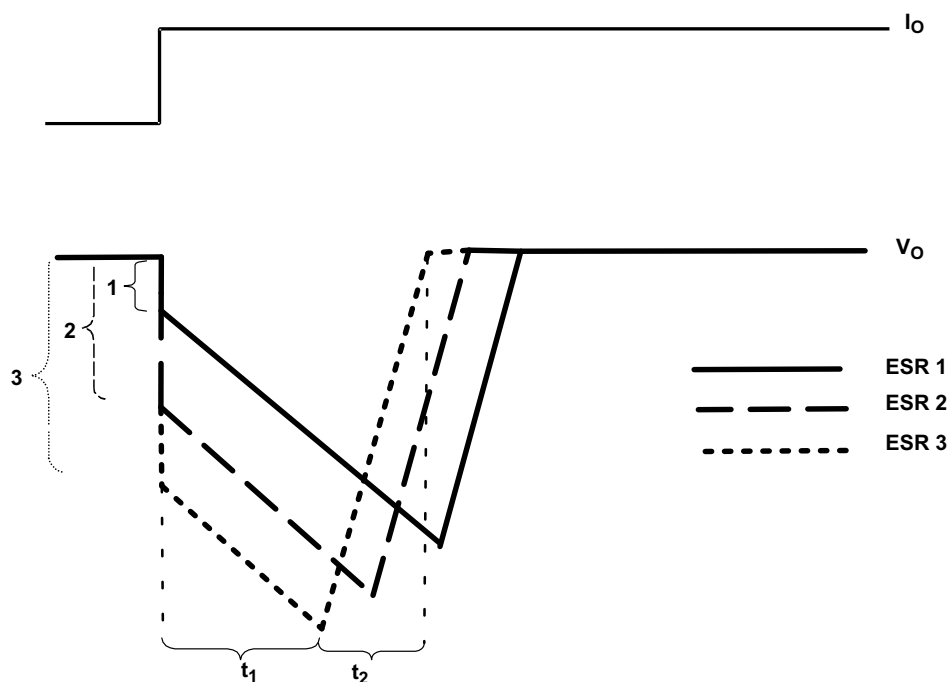
Figure 23 also shows the impact of different ESRs on the output voltage. The left brackets show different levels of ESRs, where number 1 displays the lowest and number 3 displays the highest ESR.

From the previous paragraphs, the following conclusions can be drawn:

- The higher the ESR, the larger the droop at the beginning of load transient.
- The smaller the output capacitor, the faster the discharge time and the bigger the voltage droop during the LDO response period.

## Conclusion

To minimize the transient output droop, capacitors must have a low ESR and be large enough to support the minimum output voltage requirement.



**Figure 23. Correlation of Different ESRs and Their Influence to Regulation of  $V_O$  at Load Step From Low-to-High Output Current**

## Programming the Adjustable LDO Regulator

The output voltage of the TPS75201M-EP adjustable regulator is programmed using an external resistor divider (see [Figure 24](#)). The output voltage is calculated using:

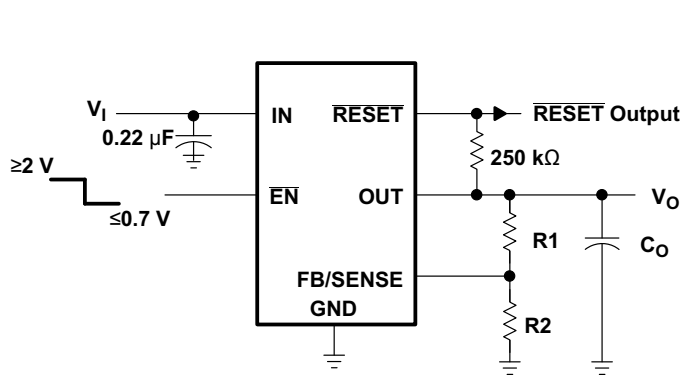
$$V_O = V_{\text{ref}} \times \left( 1 + \frac{R1}{R2} \right) \quad (1)$$

Where:

$V_{\text{ref}} = 1.1834 \text{ V typ}$  (the internal reference voltage)

Resistors R1 and R2 should be chosen for approximately 40- $\mu\text{A}$  divider current. Lower-value resistors can be used, but offer no inherent advantage and waste more power. Higher values should be avoided, as leakage currents at FB increase the output voltage error. The recommended design procedure is to choose  $R2 = 30.1 \text{ k}\Omega$  to set the divider current at 40  $\mu\text{A}$  and then calculate R1 using:

$$R1 = \left( \frac{V_O}{V_{\text{ref}}} - 1 \right) \times R2 \quad (2)$$



OUTPUT VOLTAGE  
PROGRAMMING GUIDE

OUTPUT VOLTAGE	R1	R2	UNIT
2.5 V	33.2	30.1	kΩ
3.3 V	53.6	30.1	kΩ
3.6 V	61.9	30.1	kΩ

NOTE: To reduce noise and prevent oscillation, R1 and R2 must be as close as possible to the FB/SENSE terminal.

Figure 24. Adjustable LDO Regulator Programming

## REGULATOR PROTECTION

The TPS75201M-EP PMOS-pass transistor has a built-in back diode that conducts reverse currents when the input voltage drops below the output voltage (e.g., during power down). Current is conducted from the output to the input and is not internally limited. When extended reverse voltage is anticipated, external limiting may be appropriate.

The TPS75201M-EP also features internal current limiting and thermal protection. During normal operation, the TPS75201M-EP limits output current to approximately 3.3 A. When current limiting engages, the output voltage scales back linearly until the overcurrent condition ends. While current limiting is designed to prevent gross device failure, care should be taken not to exceed the power dissipation ratings of the package. If the temperature of the device exceeds 150°C (typ), thermal-protection circuitry shuts it down. Once the device has cooled below 130°C (typ), regulator operation resumes.

## POWER DISSIPATION AND JUNCTION TEMPERATURE

Specified regulator operation is assured to a junction temperature of 125°C; the maximum junction temperature should be restricted to 125°C under normal operating conditions. This restriction limits the power dissipation the regulator can handle in any given application. To ensure the junction temperature is within acceptable limits, calculate the maximum allowable dissipation,  $P_{D(max)}$ , and the actual dissipation,  $P_D$ , which must be less than or equal to  $P_{D(max)}$ .

The maximum power dissipation limit is determined by using [Equation 3](#):

$$P_{D(max)} = \frac{T_{Jmax} - T_A}{R_{\theta JA}} \quad (3)$$

Where:

$T_{Jmax}$  is the maximum allowable junction temperature.

$R_{\theta JA}$  is the thermal resistance junction-to-ambient for the package, i.e., 34.6°C/W for the 20-terminal PWP with no airflow (see Dissipation Rating Table).

$T_A$  is the ambient temperature.

The regulator dissipation is calculated using:

$$P_D = (V_I - V_O) \times I_O \quad (4)$$

Power dissipation resulting from quiescent current is negligible. Excessive power dissipation will trigger the thermal protection circuit.

## THERMAL INFORMATION

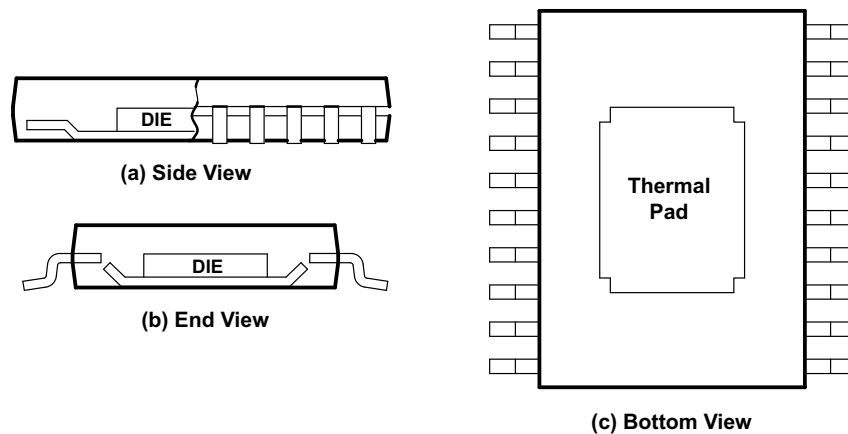
### THERMALLY-ENHANCED TSSOP-20 (PWP – PowerPAD™)

The thermally-enhanced PWP package is based on the 20-pin TSSOP, but includes a thermal pad [see [Figure 25\(c\)](#)] to provide an effective thermal contact between the IC and the PWB.

Traditionally, surface mount and power have been mutually-exclusive terms. A variety of scaled-down TO220-type packages have leads formed as gull wings to make them applicable for surface-mount applications. These packages, however, suffer from several shortcomings – they do not address the very low-profile requirements (<2 mm) of many of today’s advanced systems, and they do not offer a pin-count high enough to accommodate increasing integration. Conversely, traditional low-power surface-mount packages require power dissipation derating that severely limits the usable range of many high-performance analog circuits.

The PWP package (thermally-enhanced TSSOP) combines fine-pitch surface-mount technology, with thermal performance comparable to much larger power packages.

The PWP package is designed to optimize the heat transfer to the PWB. Because of the very small size and limited mass of a TSSOP package, thermal enhancement is achieved by improving the thermal conduction paths that remove heat from the component. The thermal pad is formed using a lead-frame design (patent pending) and manufacturing technique to provide the user with direct connection to the heat-generating IC. When this pad is soldered or otherwise coupled to an external heat dissipator, high power dissipation in the ultra-thin, fine-pitch, surface-mount package can be reliably achieved.



**Figure 25. Views of Thermally-Enhanced PWP Package**

Because the conduction path has been enhanced, power-dissipation capability is determined by the thermal considerations in the PWB design. For example, simply adding a localized copper plane (heat-sink surface), which is coupled to the thermal pad, enables the PWP package to dissipate 2.5 W in free air [reference [Figure 27\(a\)](#), 8 cm<sup>2</sup> of copper heat sink and natural convection]. Increasing the heat-sink size increases the power-dissipation range for the component. The power-dissipation limit can be further improved by adding airflow to a PWB/IC assembly (see [Figure 26](#) and [Figure 27](#)). The line drawn at 0.3 cm<sup>2</sup> in [Figure 26](#) and [Figure 27](#) indicates performance at the minimum recommended heat-sink size (see [Figure 29](#)).

The thermal pad is connected directly to the substrate of the IC, which for the TPS75201MPWPREP is a secondary electrical connection to device ground. The heat-sink surface that is added to the PWP can be a ground plane or left electrically isolated. In TO220-type surface-mount packages, the thermal connection also is the primary electrical connection for a given terminal, which is not always ground. The PWP package provides up to 16 independent leads that can be used as inputs and outputs (Note: leads 1, 10, 11, and 20 are connected internally to the thermal pad and the IC substrate).

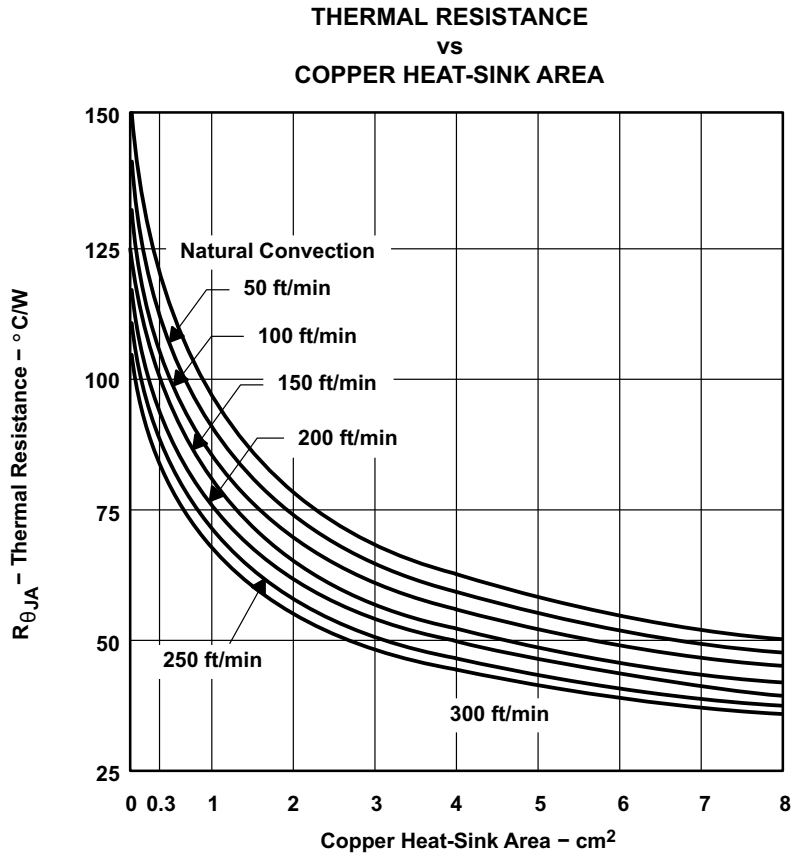


Figure 26.

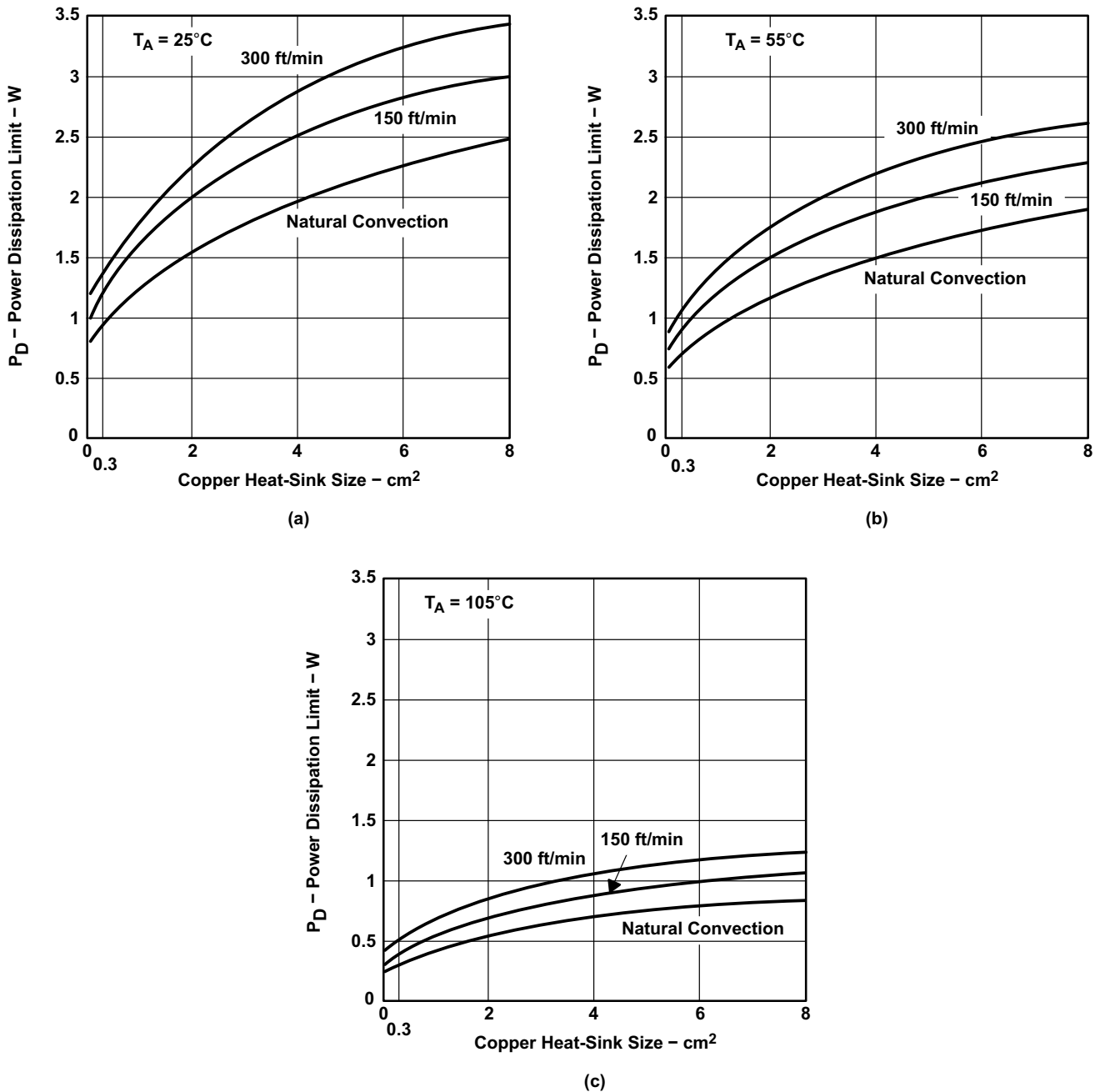
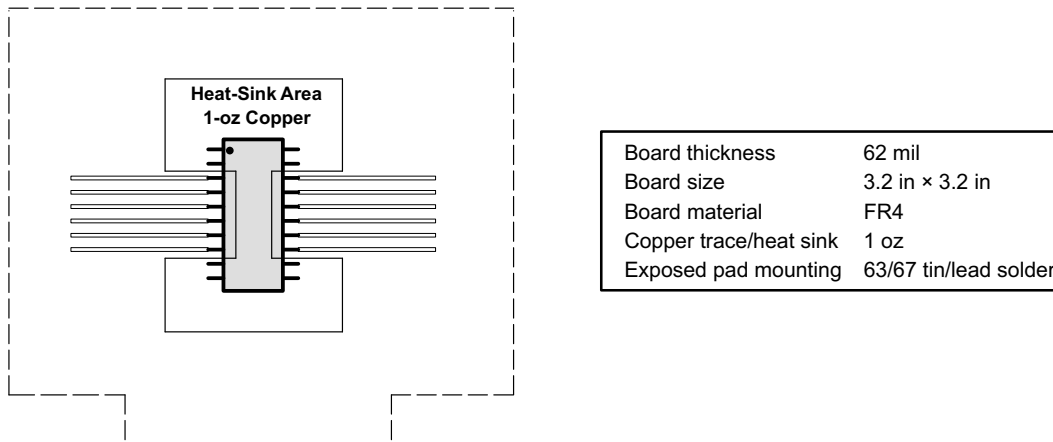


Figure 27. Power Ratings of PWP Package at T<sub>A</sub> = 25°C, 55°C, and 105°C

Figure 28 is an example of a thermally-enhanced PWB layout for use with the new PWP package. This board configuration was used in the thermal experiments that generated the power ratings shown in Figure 26 and Figure 27. As discussed earlier, copper has been added on the PWB to conduct heat away from the device. R<sub>θJA</sub> for this assembly is shown in Figure 26 as a function of heat-sink area. A family of curves is included to show the effect of airflow introduced into the system.



**Figure 28. PWB Layout (Including Copper Heat-Sink Area) for Thermally-Enhanced PWP Package**

From [Figure 26](#),  $R_{\theta JA}$  for a PWB assembly can be determined and used to calculate the maximum power-dissipation limit for the component/PWB assembly, with the equation:

$$P_{D(max)} = \frac{T_{Jmax} - T_A}{R_{\theta JA(system)}} \quad (5)$$

Where:

$T_{Jmax}$  is the maximum specified junction temperature (150°C absolute maximum limit, 125°C recommended operating limit) and  $T_A$  is the ambient temperature.

$P_{D(max)}$  should then be applied to the internal power dissipated by the TPS75201M-EP regulator. The equation for calculating total internal power dissipation of the TPS75201M-EP is:

$$P_{D(total)} = (V_I - V_O) \times I_O + V_I \times I_Q \quad (6)$$

Since the quiescent current of the TPS75201M-EP is very low, the second term is negligible, further simplifying the equation to:

$$P_{D(total)} = (V_I - V_O) \times I_O \quad (7)$$

For the case where  $T_A = 55^\circ\text{C}$ , airflow = 200 ft /min, copper heat-sink area = 4 cm<sup>2</sup>, the maximum power-dissipation limit can be calculated. First, from [Figure 26](#), the system  $R_{\theta JA}$  is 50°C/W, therefore, the maximum power-dissipation limit is:

$$P_{D(max)} = \frac{T_{Jmax} - T_A}{R_{\theta JA(system)}} = \frac{125^\circ\text{C} - 55^\circ\text{C}}{50^\circ\text{C} / \text{W}} = 1.4\text{W} \quad (8)$$

If the system implements a TPS75201M-EP regulator, where  $V_I = 5\text{ V}$  and  $I_O = 800\text{ mA}$ , the internal power dissipation is:

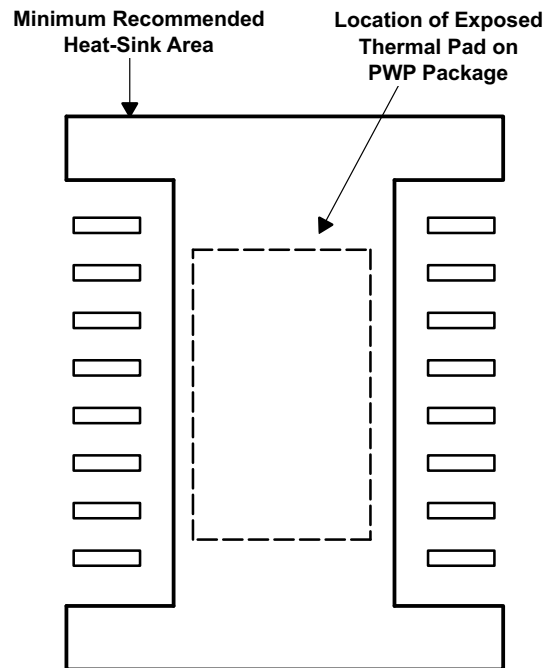
$$P_{D(total)} = (V_I - V_O) \times I_O = (5 - 3.3) \times 0.8 = 1.36\text{ W} \quad (9)$$

Comparing  $P_{D(total)}$  with  $P_{D(max)}$  reveals that the power dissipation in this example does not exceed the calculated limit. When it does, one of two corrective actions should be made – raising the power-dissipation limit by increasing the airflow or the heat-sink area, or lowering the internal power dissipation of the regulator by reducing the input voltage or the load current. In either case, the previous calculations should be repeated with the new system parameters.

**MOUNTING INFORMATION**

The primary requirement is to complete the thermal contact between the thermal pad and the PWB metal. The thermal pad is a solderable surface and is fully intended to be soldered at the time the component is mounted. Although voiding in the thermal-pad solder-connection is not desirable, up to 50% voiding is acceptable. The data included in [Figure 26](#) and [Figure 27](#) is for soldered connections with voiding between 20% and 50%. The thermal analysis shows no significant difference resulting from the variation in voiding percentage.

[Figure 29](#) shows the solder-mask land pattern for the PWP package. The minimum recommended heat-sink area also is shown. This is simply a copper plane under the body extent of the package, including metal routed under terminals 1, 10, 11, and 20.



**Figure 29. PWP Package Land Pattern**

**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
TPS75201MPWPREP	ACTIVE	HTSSOP	PWP	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-55 to 125	75201EP	<a href="#">Samples</a>
V62/03635-11XE	ACTIVE	HTSSOP	PWP	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-55 to 125	75201EP	<a href="#">Samples</a>

(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.

**OBSOLETE:** TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(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.

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**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
TPS75201MPWPREP	HTSSOP	PWP	20	2000	330.0	16.4	6.95	7.1	1.6	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)
TPS75201MPWPREP	HTSSOP	PWP	20	2000	367.0	367.0	38.0

# MECHANICAL DATA

PWP (R-PDSO-G20)

PowerPAD™ PLASTIC SMALL OUTLINE



4073225-4/1 05/11

- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Body dimensions do not include mold flash or protrusions. Mold flash and protrusion shall not exceed 0.15 per side.
  - 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) <<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-153

PowerPAD is a trademark of Texas Instruments.

## THERMAL PAD MECHANICAL DATA

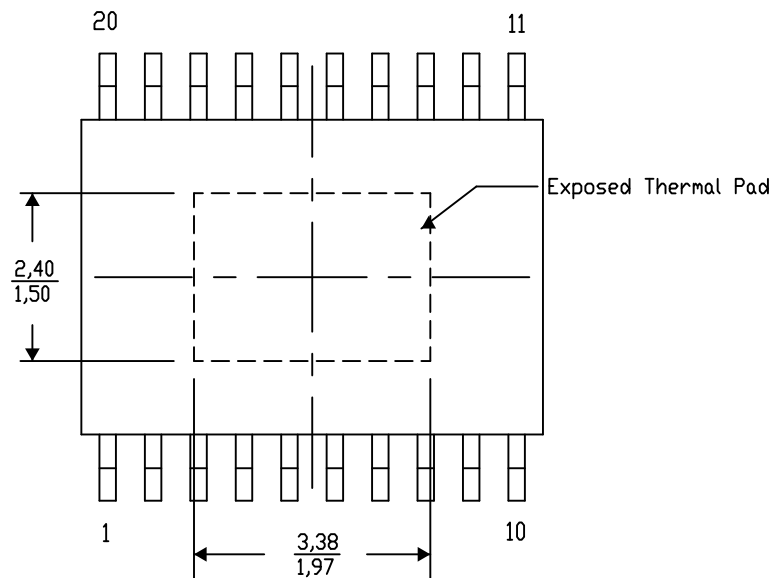
### PWP (R-PDSO-G20) PowerPAD™ SMALL PLASTIC OUTLINE

#### 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](http://www.ti.com).

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



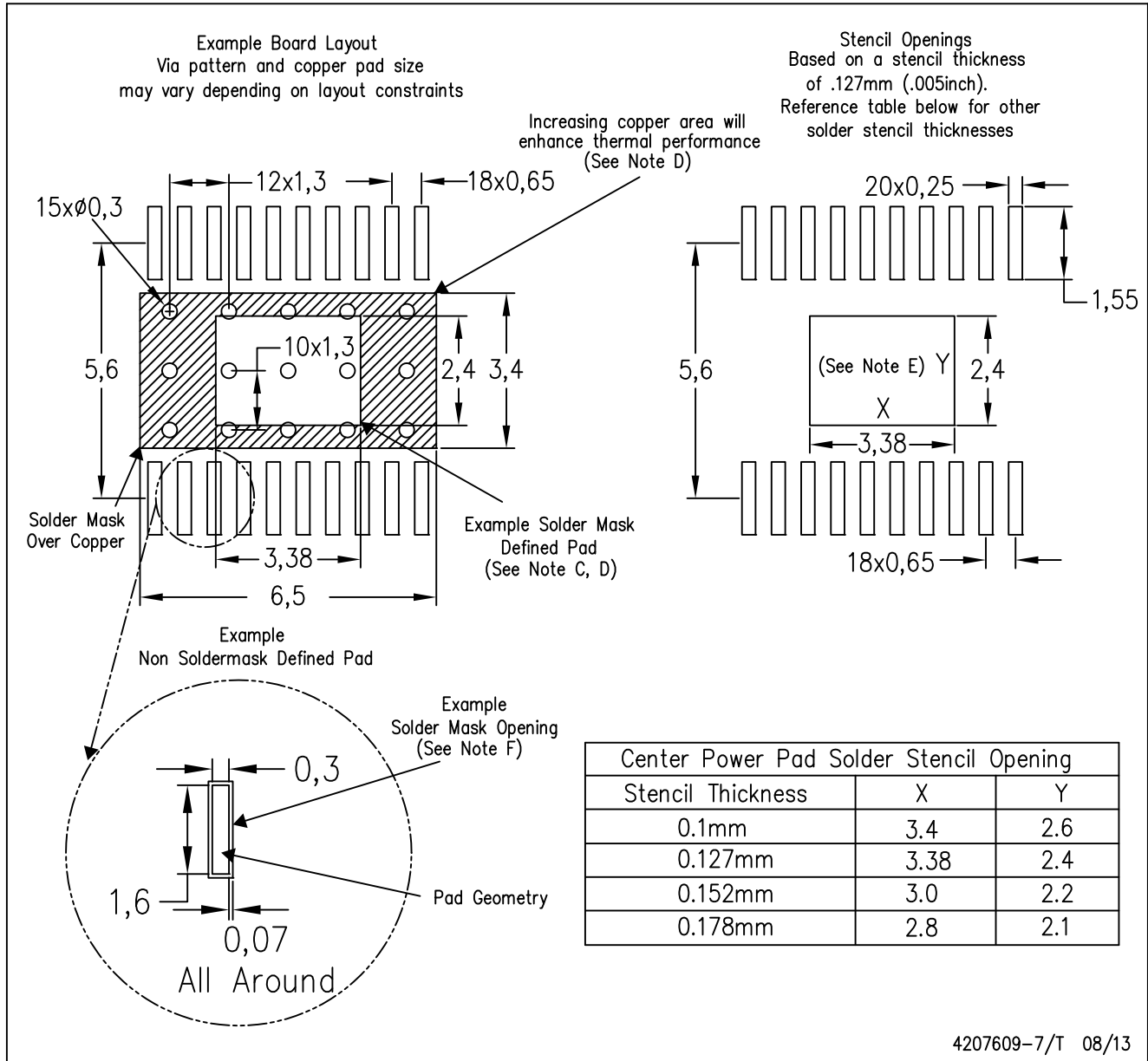
4206332-19/AH 11/13

NOTE: A. All linear dimensions are in millimeters

PowerPAD is a trademark of Texas Instruments

PWP (R-PDSO-G20)

PowerPAD™ PLASTIC SMALL OUTLINE



- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
  - 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) <<http://www.ti.com>>. 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. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC-7525 for other stencil recommendations.
  - Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

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