DUAL-OUTPUT, LOW DROPOUT VOLTAGE REGULATORS WITH INTEGRATED SVS FOR SPLIT VOLTAGE SYSTEMS

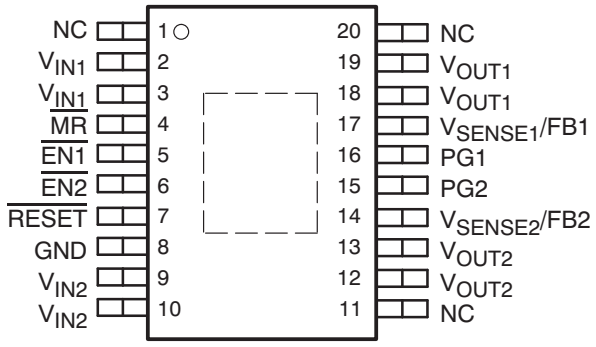
FEATURES

- **Dual Output Voltages for Split-Supply Applications**
- **Independent Enable Functions (See Part Number TPS701xx for Sequenced Outputs)**
- **Output Current Range of 500mA on Regulator 1 and 250mA on Regulator 2**
- **Fast Transient Response**
- **Voltage Options: 3.3V/2.5V, 3.3V/1.8V, 3.3V/1.5V, 3.3V/1.2V, and Dual Adjustable Outputs**
- **Open Drain Power-On Reset with 120ms Delay**
- **Open Drain Power Good for Regulator 1 and Regulator 2**
- **Ultralow 190μA (typ) Quiescent Current**
- **1μA Input Current During Standby**
- **Low Noise: 65μV_{RMS} Without Bypass Capacitor**
- **Quick Output Capacitor Discharge Feature**
- **One Manual Reset Input**
- **2% Accuracy Over Load and Temperature**
- **Undervoltage Lockout (UVLO) Feature**
- **20-Pin PowerPAD™ TSSOP Package**
- **Thermal Shutdown Protection**

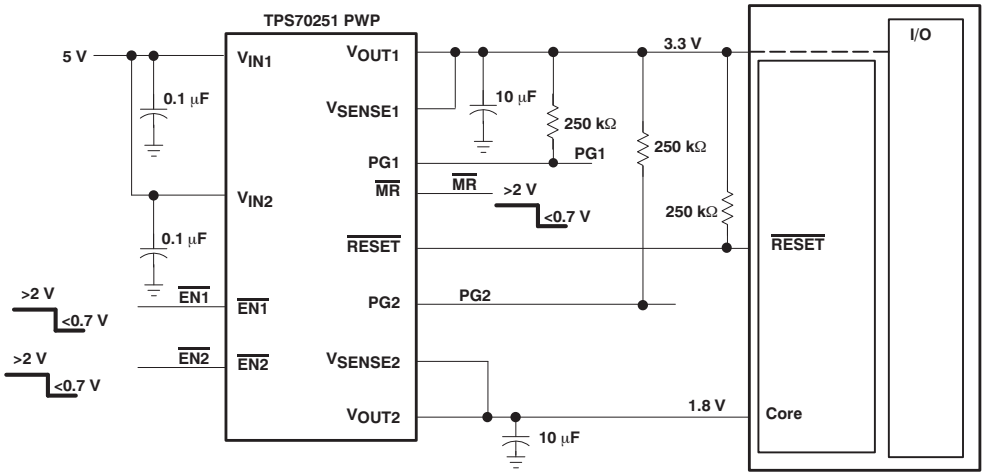
DESCRIPTION

The TPS702xx is a low dropout voltage regulator with integrated SVS ($\overline{\text{RESET}}$, POR, or power on reset) and power good (PG) functions. These devices are capable of supplying 500mA and 250mA by regulator 1 and regulator 2 respectively. Quiescent current is typically 190μA at full load. Differentiated features, such as accuracy, fast transient response, SVS supervisory circuit (power on reset), manual reset input, and independent enable functions provide a complete system solution.

PWP PACKAGE
(TOP VIEW)



NC = No internal connection



The TPS702xx family of voltage regulators offers very low dropout voltage and dual outputs. These devices have extremely low noise output performance without using any added filter bypass capacitors and are designed to have a fast transient response and be stable with 10μF low ESR capacitors.

These devices have fixed 3.3V/2.5V, 3.3V/1.8V, 3.3V/1.5V, 3.3V/1.2V, and adjustable voltage options. Regulator 1 can support up to 500mA, and regulator 2 can support up to 250mA. Separate voltage inputs allow the designer to configure the source power.

Because the PMOS device behaves as a low-value resistor, the dropout voltage is very low (typically 170mV on regulator 1) 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 (maximum of 230μA over the full range of output current and full range of temperature). This LDO family also features a sleep mode; applying a high signal to $\overline{EN1}$ or $\overline{EN2}$ (enable) shuts down regulator 1 or regulator 2, respectively. When a high signal is applied to both $\overline{EN1}$ and $\overline{EN2}$, both regulators enter sleep mode, thereby reducing the input current to 2μA at T_J = +25°C.

For each regulator, there is an internal discharge transistor to discharge the output capacitor when the regulator is turned off (disabled).

The PG1 pin reports the voltage condition at V_{OUT1}. The PG1 pin can be used to implement a SVS ($\overline{RESET}$, POR, or power on reset) for the circuitry supplied by regulator 1. The PG2 pin reports the voltage conditions at V_{OUT2}. The PG2 pin can be used to implement a SVS (power on reset) for the circuitry supplied by regulator 2.

The TPS702xx features a $\overline{RESET}$ (SVS, POR, or power on reset). $\overline{RESET}$ output initiates a reset in the event of an undervoltage condition. $\overline{RESET}$ also indicates the status of the manual reset pin ($\overline{MR}$). When $\overline{MR}$ is in the logic high state, $\overline{RESET}$ goes to a high impedance state after a 120ms delay. To monitor V_{OUT1}, the PG1 output pin can be connected to $\overline{MR}$. To monitor V_{OUT2}, the PG2 output pin can be connected to $\overline{MR}$.

The device has an undervoltage lockout UVLO circuit that prevents the internal regulators from turning on until V_{IN1} reaches 2.5V.

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.

ORDERING INFORMATION(1)

PRODUCT	VOLTAGE (V)(2)		PACKAGE-LEAD (DESIGNATOR)	SPECIFIED TEMPERATURE RANGE (T_J)	ORDERING NUMBER	TRANSPORT MEDIA, QUANTITY
	V_{OUT1}	V_{OUT2}				
TPS70202	Adjustable	Adjustable	HTSSOP-20 (PWP)	-40°C to +125°C	TPS70202PWP	Tube, 70
					TPS70202PWPR	Tape and Reel, 2000
TPS70245	3.3V	1.2V	HTSSOP-20 (PWP)	-40°C to +125°C	TPS70245PWP	Tube, 70
					TPS70245PWPR	Tape and Reel, 2000
TPS70248	3.3V	1.5V	HTSSOP-20 (PWP)	-40°C to +125°C	TPS70248PWP	Tube, 70
					TPS70248PWPR	Tape and Reel, 2000
TPS70251	3.3V	1.8V	HTSSOP-20 (PWP)	-40°C to +125°C	TPS70251PWP	Tube, 70
					TPS70251PWPR	Tape and Reel, 2000
TPS70258	3.3V	2.5V	HTSSOP-20 (PWP)	-40°C to +125°C	TPS70258PWP	Tube, 70
					TPS70258PWPR	Tape and Reel, 2000

(1) For the most current package and ordering information see the Package Option Addendum located at the end of this document, or see the TI web site at www.ti.com.
(2) For fixed 1.20V operation, tie FB to OUT.

ABSOLUTE MAXIMUM RATINGS(1)

Over operating free-air temperature range (unless otherwise noted).

	TPS702xx	UNIT
Input voltage range: V_{IN1}, V_{IN2}(2)	–0.3 to +7	V
Voltage range at $\overline{EN1}$, $\overline{EN2}$	–0.3 to +7	V
Output voltage range (V_{OUT1}, V_{SENSE1})	5.5	V
Output voltage range (V_{OUT2}, V_{SENSE2})	5.5	V
Maximum $\overline{RESET}$, PG1, PG2 voltage	7	V
Maximum $\overline{MR}$ voltage	V_{IN1}	V
Peak output current	Internally limited	—
Continuous total power dissipation	See Dissipation Ratings Table	—
Operating virtual junction temperature range, T_J	–40 to +150	°C
Storage temperature range, T_{stg}	–65 to +150	°C
ESD rating, HBM	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 voltages are tied to network ground.

DISSIPATION RATINGS

PACKAGE	AIR FLOW (CFM)	$T_A \le +25°C$	DERATING FACTOR	$T_A = +70°C$	$T_A = +85°C$
PWP (1)	0	3.067W	30.67mW/°C	1.687W	1.227W
	250	4.115W	41.15mW/°C	2.265W	1.646W

(1) This parameter is measured with the recommended copper heat sink pattern on a 4-layer PCB, 1 oz. copper on a 4-in by 4-in ground layer. For more information, refer to TI technical brief SLMA002.

RECOMMENDED OPERATING CONDITIONS

Over operating temperature range (unless otherwise noted).

	MIN	MAX	UNIT
Input voltage, V_I (1) (regulator 1 and 2)	2.7	6	V
Output current, I_O (regulator 1)	0	500	mA
Output current, I_O (regulator 2)	0	250	mA
Output voltage range (for adjustable option)	1.22	5.5	V
Operating virtual junction temperature, T_J	–40	+125	°C

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

ELECTRICAL CHARACTERISTICS

Over recommended operating junction temperature range (T_J = –40°C to +125°C), V_{IN1} or V_{IN2} = $V_{OUT(nom)}$ + 1V, I_O = 1mA, $\overline{EN1}$ = 0V, $\overline{EN2}$ = 0V, and C_O = 33µF (unless otherwise noted).

PARAMETER			TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_O	Output voltage (1), (2)	Reference voltage	2.7V < V_{IN} < 6V, T_J = +25°C	FB connected to V_O		1.22		V
			2.7V < V_{IN} < 6V,	FB connected to V_O	1.196		1.244	
		1.2V Output	2.7V < V_{IN} < 6V,	T_J = +25°C		1.2		
			2.7V < V_{IN} < 6V,		1.176		1.224	
		1.5V Output	2.7V < V_{IN} < 6V,	T_J = +25°C		1.5		
			2.7V < V_{IN} < 6V,		1.47		1.53	
		1.8V Output	2.8V < V_{IN} < 6V,	T_J = +25°C		1.8		
			2.8V < V_{IN} < 6V,		1.764		1.836	
		2.5V Output	3.5V < V_{IN} < 6V,	T_J = +25°C		2.5		
			3.5V < V_{IN} < 6V,		2.45		2.55	
		3.3V Output	4.3V < V_{IN} < 6V,	T_J = +25°C		3.3		
			4.3V < V_{IN} < 6V,		3.234		3.366	
Quiescent current (GND current) for regulator 1 and regulator 2, $\overline{EN1}$ = $\overline{EN2}$ = 0V (1)			See (2)	T_J = +25°C		190		µA
			See (2)				230	
Output voltage line regulation ($\Delta V_O/V_O$) for regulator 1 and regulator 2 (3)			V_O + 1V < V_{IN} ≤ 6V,	T_J = +25°C (1)		0.01		%V
			V_O + 1V < V_{IN} ≤ 6V	(1)			0.1	
Load regulation for $V_{OUT\ 1}$ and V_{OUT2}			T_J = +25°C			1		mV
V_n	Output noise voltage	Regulator 1	BW = 300Hz to 50kHz,	C_O = 33µF, T_J = +25°C		65		μV_{RMS}
		Regulator 2				65		
Output current limit		Regulator 1	V_{OUT} = 0V			1.6	1.9	µA
		Regulator 2				0.750	1	
Thermal shutdown junction temperature						+150		°C
I_I (standby)	Standby current	Regulator 1	$\overline{EN1}$ = V_{IN}, $\overline{EN2}$ = V_I	T_J = +25°C			2	µA
		Regulator 2	$\overline{EN1}$ = V_{IN}, $\overline{EN2}$ = V_I				6	
PSRR	Power-supply ripple rejection	Regulator 1	f = 1kHz, C_O = 33µF, I_{OUT1} = 500mA	T_J = +25°C (1)		60		dB
		Regulator 2	f = 1kHz, C_O = 33µF, I_{OUT2} = 250mA	T_J = +25°C (1)		50		
UVLO threshold					2.4		2.65	V
RESET Terminal								
Minimum input voltage for valid $\overline{RESET}$			I_{RESET} = 300µA,	$V_{(RESET)}$ ≤ 0.8V		1.0	1.3	V
$t_{(\overline{RESET})}$			$\overline{RESET}$ pulse duration		80	120	160	ms
Output low voltage			V_{IN} = 3.5V,	$I_{(RESET)}$ = 1mA		0.15	0.4	V
Leakage current			$V_{(RESET)}$ = 6V				1	µA

(1) Minimum input operating voltage is 2.7V or $V_{O(typ)}$ + 1V, whichever is greater. Maximum input voltage = 6V, minimum output current = 1mA.

(2) I_O = 1mA to 500mA for Regulator 1 and 1mA to 250mA for Regulator 2.

(3) If V_O < 1.8V then V_{Imax} = 6V, V_{Imin} = 2.7V: $$\text{Line regulation (mV)} = (\%/V) \times V_o \frac{(V_{Imax} - 2.7)}{100} \times 1000$$

If V_O > 2.5V then V_{Imax} = 6V, V_{Imin} = V_O + 1V: $$\text{Line regulation (mV)} = (\%/V) \times V_o \frac{[V_{Imax} - (V_o + 1)]}{100} \times 1000$$

ELECTRICAL CHARACTERISTICS (continued)

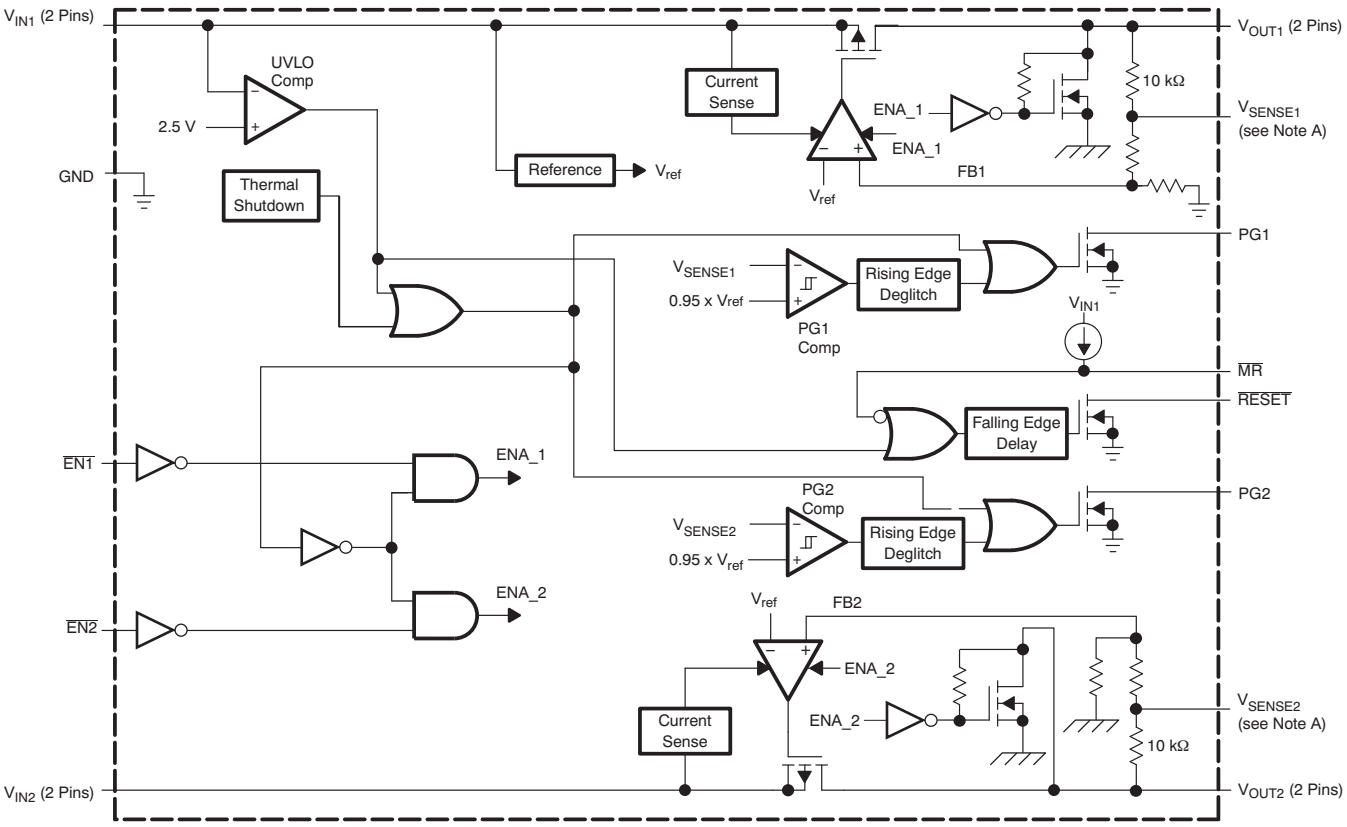
Over recommended operating junction temperature range (T_J = –40°C to +125°C), V_{IN1} or V_{IN2} = $V_{OUT(nom)}$ + 1V, I_O = 1mA, $\overline{EN1}$ = 0V, $\overline{EN2}$ = 0V, and C_O = 33µF (unless otherwise noted).

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
PG1/PG2 Terminal					
Minimum input voltage for valid PGx	$I_{(PGx)}$ = 300µA, $V_{(PGx)}$ ≤ 0.8V		1.0	1.3	V
Trip threshold voltage	V_O decreasing	92	95	98	$\%V_{OUT}$
Hysteresis voltage	Measured at V_O		0.5		$\%V_{OUT}$
$t_{r(PGx)}$	Rising edge deglitch		30		µs
Output low voltage	V_{IN} = 2.7V, $I_{(PGx)}$ = 1mA		0.15	0.4	V
Leakage current	$V_{(PGx)}$ = 6V			1	µA
EN1/EN2 Terminal					
High-level $\overline{ENx}$ input voltage		2			V
Low-level $\overline{ENx}$ input voltage				0.7	V
Input current ($\overline{ENx}$)		–1		1	µA
$\overline{MR}$ Terminal					
High-level input voltage		2			V
Low-level input voltage				0.7	V
Falling edge delay	Measured at V_O		140		µs
Pull-up current source			6		µA
V_{OUT1} Terminal					
Dropout voltage(4)	I_O = 500mA, V_{IN1} = 3.2V T_J = +25°C		170		mV
	I_O = 500mA, V_{IN1} = 3.2V			275	
Peak output current	2ms pulse width		750		mA
Discharge transistor current	V_{OUT1} = 1.5V		7.5		mA
V_{OUT2} Terminal					
Peak output current	2ms pulse width		375		mA
Discharge transistor current	V_{OUT2} = 1.5V		7.5		mA
FB Terminal					
Input current: TPS70202	FB = 1.8V		1		µA

(4) Input voltage (V_{IN1} or V_{IN2}) = $V_{O(typ)}$ – 100mV. For 1.5V, 1.8V and 2.5V regulators, the dropout voltage is limited by input voltage range. The 3.3V regulator input is set to 3.2V to perform this test.

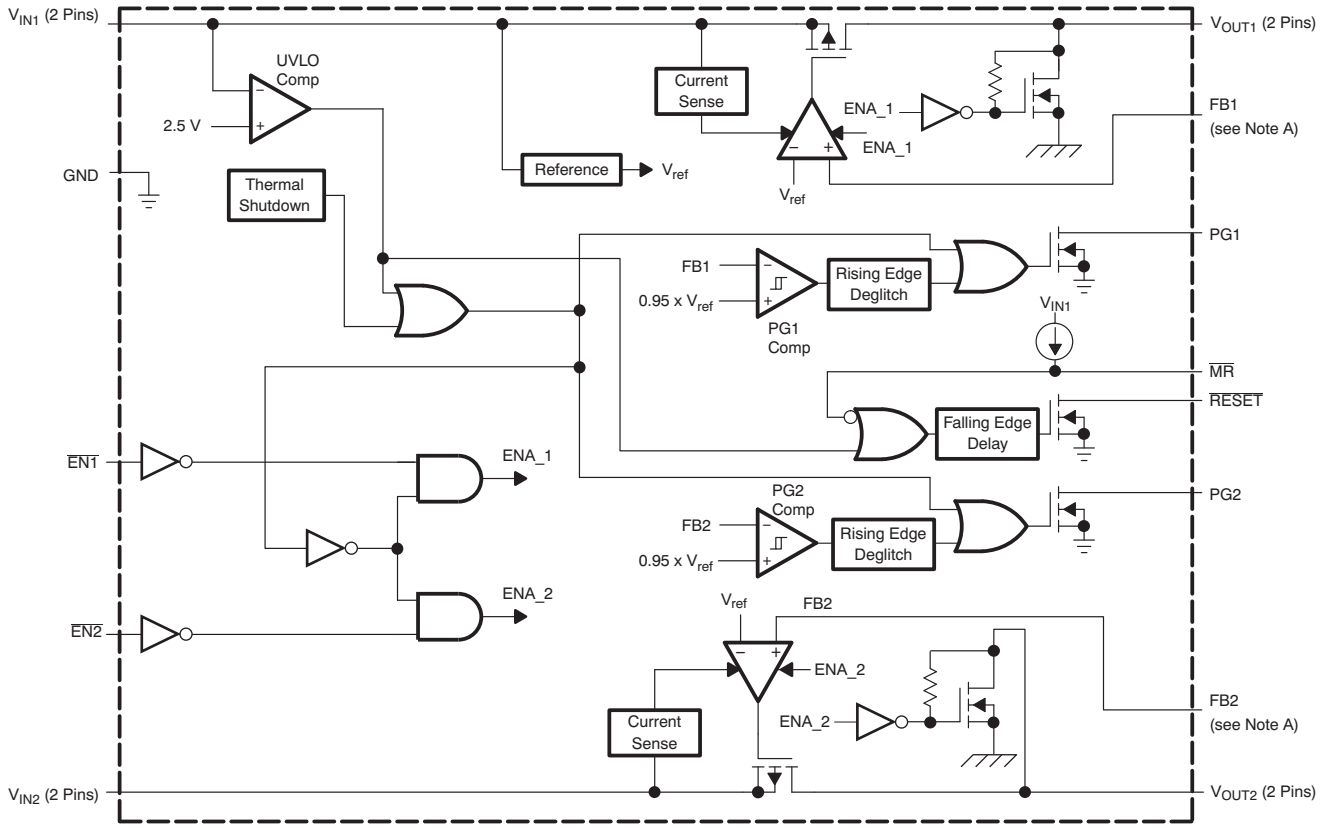
DEVICE INFORMATION

Fixed Voltage Version



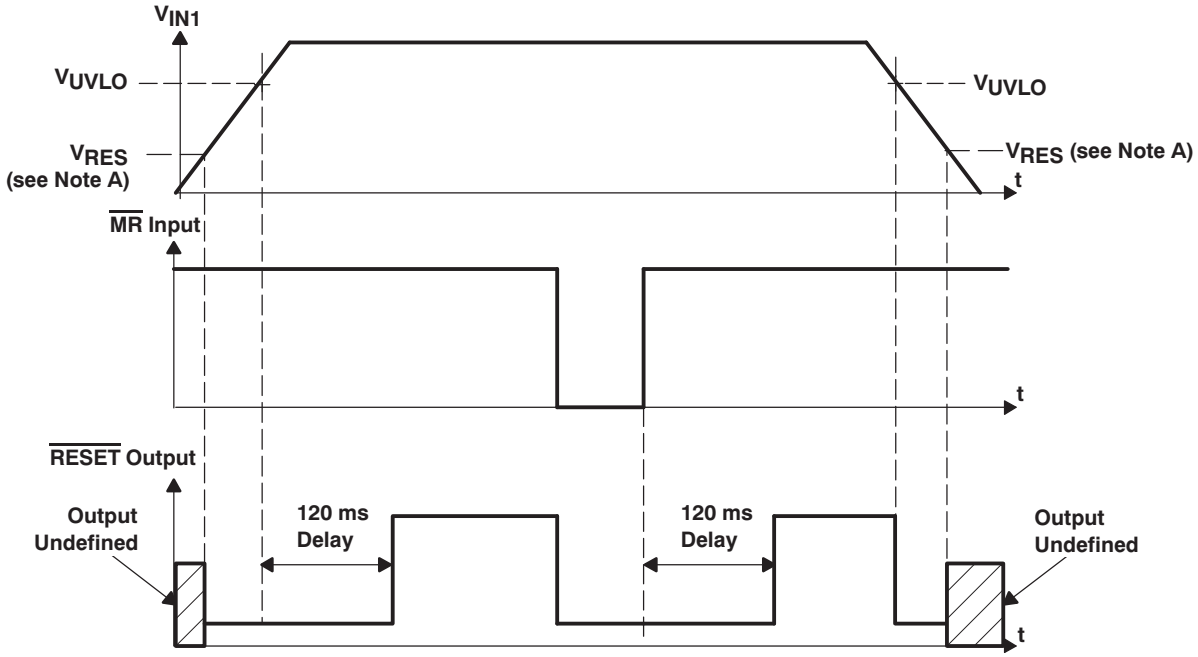
A. For most applications, V_{SENSE1} and V_{SENSE2} should be externally connected to V_{OUT1} and V_{OUT2}, respectively, as close as possible to the device. For other implementations, refer to SENSE terminal connection discussion in the ***Application Information*** section.

Adjustable Voltage Version



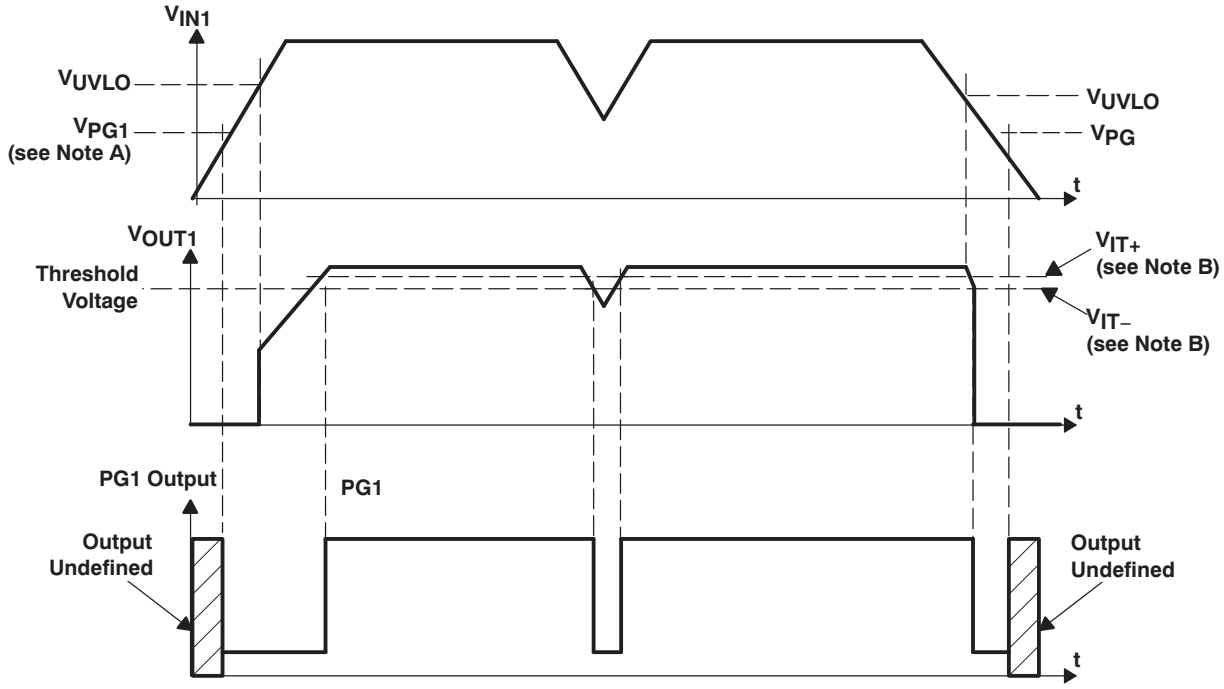
A. For most applications, FB1 and FB2 should be externally connected to resistor dividers as close as possible to the device. For other implementations, refer to FB terminals connection discussion in the ***Application Information*** section.

$\overline{\text{RESET}}$ Timing Diagram



NOTE A: V_{RES} is the minimum input voltage for a valid $\overline{\text{RESET}}$. The symbol V_{RES} is not currently listed within EIA or JEDEC standards for semiconductor symbology.

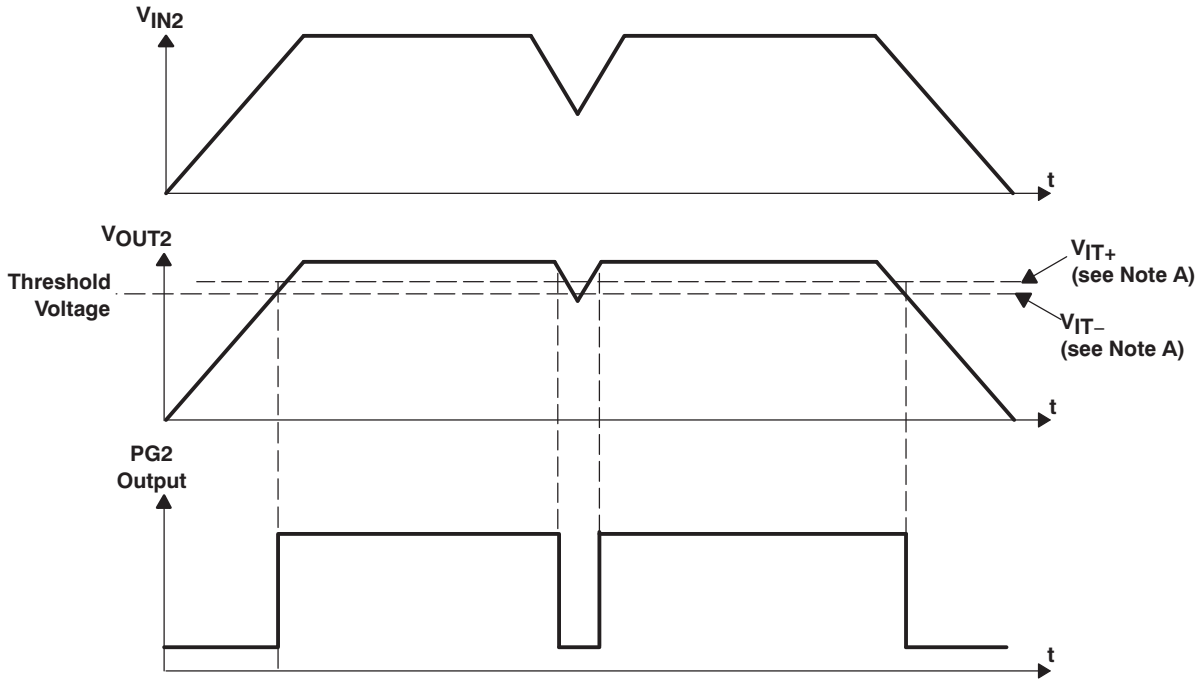
PG1 Timing Diagram



NOTES: A. V_{PG1} is the minimum input voltage for a valid PG1. The symbol V_{PG1} is not currently listed within EIA or JEDEC standards for semiconductor symbology.

B. V_{IT-} trip voltage is typically 5% lower than the output voltage (95%V_O). V_{IT-} to V_{IT+} is the hysteresis voltage.

PG2 Timing Diagram (assuming V_{IN1} already powered up)



NOTE A: V_{IT-} trip voltage is typically 5% lower than the output voltage (95%V_O). V_{IT-} to V_{IT+} is the hysteresis voltage.

TERMINAL FUNCTIONS

TERMINAL		I/O	DESCRIPTION
NAME	NO.		
$\overline{EN1}$	5	I	Active low enable for V_{OUT1}
$\overline{EN2}$	6	I	Active low enable for V_{OUT2}
GND	8	—	Ground
$\overline{MR}$	4	I	Manual reset input, active low, pulled up internally
NC	1, 11, 20	—	No connection
PG1	16	O	Open drain output, low when V_{OUT1} voltage is less than 95% of the nominal regulated voltage
PG2	15	O	Open drain output, low when V_{OUT2} voltage is less than 95% of the nominal regulated voltage
$\overline{RESET}$	7	I	Open drain output, SVS (power-on reset) signal, active low
V_{IN1}	2, 3	I	Input voltage of regulator 1
V_{IN2}	9, 10	I	Input voltage of regulator 2
V_{OUT1}	18, 19	O	Output voltage of regulator 1
V_{OUT2}	12, 13	O	Output voltage of regulator 2
V_{SENSE2}/FB2	14	I	Regulator 2 output voltage sense/regulator 2 feedback for adjustable
V_{SENSE1}/FB1	17	I	Regulator 1 output voltage sense/regulator 1 feedback for adjustable

Detailed Description

The TPS702xx low dropout regulator family provides dual regulated output voltages with independent enable functions. These devices provide fast transient response and high accuracy with small output capacitors, while drawing low quiescent current. Other features are integrated SVS (power-on reset, $\overline{\text{RESET}}$) and power good (PG1, PG2) that monitor output voltages and provide logic output to the system. These differentiated features provide a complete power solution.

The TPS702xx, unlike many other LDOs, features very low quiescent current that remains virtually constant even with varying loads. Conventional LDO regulators use a pnp pass element, the base current of which is directly proportional to the load current through the regulator ($I_B = I_C/\beta$). The TPS702xx uses a PMOS transistor to pass current; the gate of the PMOS is voltage-driven, so operating current is low and stable over the full load range.

Pin Functions

Enable ($\overline{\text{EN1}}$ and $\overline{\text{EN2}}$)

The $\overline{\text{EN}}$ terminals are inputs that enable or shut down each respective regulator. If $\overline{\text{EN}}$ is at a voltage high signal, the respective regulator is in shutdown mode. When $\overline{\text{EN}}$ goes to voltage low, the respective regulator is enabled.

Power-Good (PG1 and PG2)

The PG terminal is an open drain, active high output terminal that indicates the status of each respective regulator. When V_{OUT1} reaches 95% of its regulated voltage, PG1 will go to a high impedance state. When V_{OUT2} reaches 95% of its regulated voltage, PG2 will go to a high impedance state. Each PG will go to a low impedance state when its respective output voltage is pulled below 95% (that is, goes to an overload condition) of its regulated voltage. The open drain outputs of the PG terminals require a pull-up resistor.

Manual Reset Pin

$\overline{\text{MR}}$ is an active low input terminal used to trigger a reset condition. When $\overline{\text{MR}}$ is pulled to logic low, a POR ($\overline{\text{RESET}}$) occurs. The terminal has a 6μA pull-up current to V_{IN1}.

Sense (V_{SENSE1}, V_{SENSE2})

The sense terminals of fixed-output options must be connected to the regulator outputs, and the connection should be as short as possible. Internally, the sense terminal connects to high-impedance, wide-bandwidth amplifiers 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 as to minimize or avoid noise pickup. Adding RC networks between sense terminals and V_{OUTS} to filter noise is not recommended because these networks can cause the regulators to oscillate.

FB1 and FB2

FB1 and FB2 are input terminals used for adjustable-output devices and must be connected to the external feedback resistor divider. FB1 and FB2 connections should be as short as possible. It is essential to route them in such a way as to minimize or avoid noise pickup. Adding RC networks between FB terminals and V_{OUTS} to filter noise is not recommended because these networks can cause the regulators to oscillate.

$\overline{\text{RESET}}$ Indicator

The TPS702xx features a $\overline{\text{RESET}}$ (SVS, POR, or power on reset). $\overline{\text{RESET}}$ can be used to drive power on reset circuitry or a low-battery indicator. $\overline{\text{RESET}}$ is an active low, open drain output that indicates the status of the manual reset pin ($\overline{\text{MR}}$). When $\overline{\text{MR}}$ is in a high impedance state, $\overline{\text{RESET}}$ goes to a high impedance state after a 120 ms delay. To monitor V_{OUT1}, the PG1 output pin can be connected to $\overline{\text{MR}}$. To monitor V_{OUT2}, the PG2 output pin can be connected to $\overline{\text{MR}}$. The open drain output of the $\overline{\text{RESET}}$ terminal requires a pull-up resistor. If $\overline{\text{RESET}}$ is not used, it can be left floating.

V_{IN1} and V_{IN2}

V_{IN1} and V_{IN2} are inputs to each regulator. **Internal bias voltages are powered by V_{IN1}.**

V_{OUT1} and V_{OUT2}

V_{OUT1} and V_{OUT2} are output terminals of each regulator.

TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
V_O	Output voltage	vs Output current	Figure 1 to Figure 3
		vs Junction temperature	Figure 4 to Figure 5
	Ground current	vs Junction temperature	Figure 6
PSRR	Power-supply rejection ratio	vs Frequency	Figure 7 to Figure 10
	Output spectral noise density	vs Frequency	Figure 11 to Figure 14
Z_O	Output impedance	vs Frequency	Figure 15 to Figure 18
	Dropout voltage	vs Temperature	Figure 19 and Figure 20
		vs Input voltage	Figure 21 and Figure 22
	Load transient response		Figure 23 and Figure 24
	Line transient response (V_{OUT1})		Figure 25
	Line transient response (V_{OUT2})		Figure 26
V_O	Output voltage	vs Time (start-up)	Figure 27 and Figure 28
	Equivalent series resistance (ESR)	vs Output current	Figure 30 to Figure 33

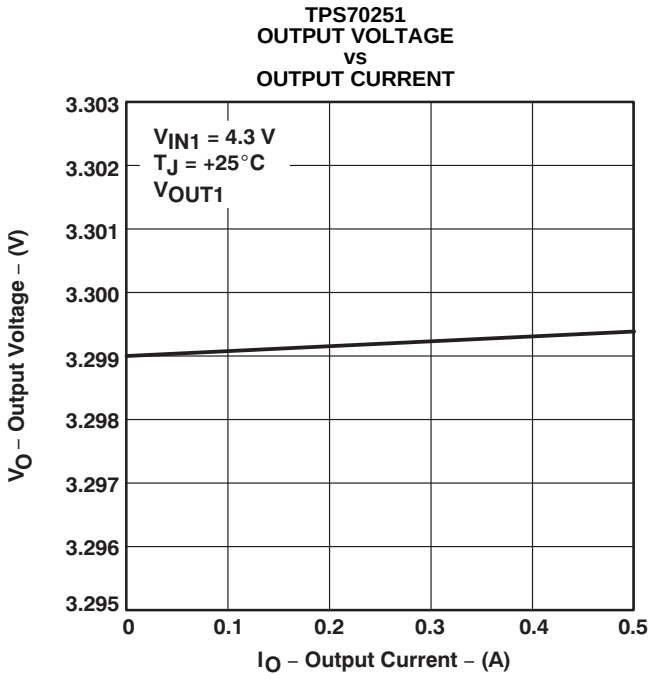


Figure 1.

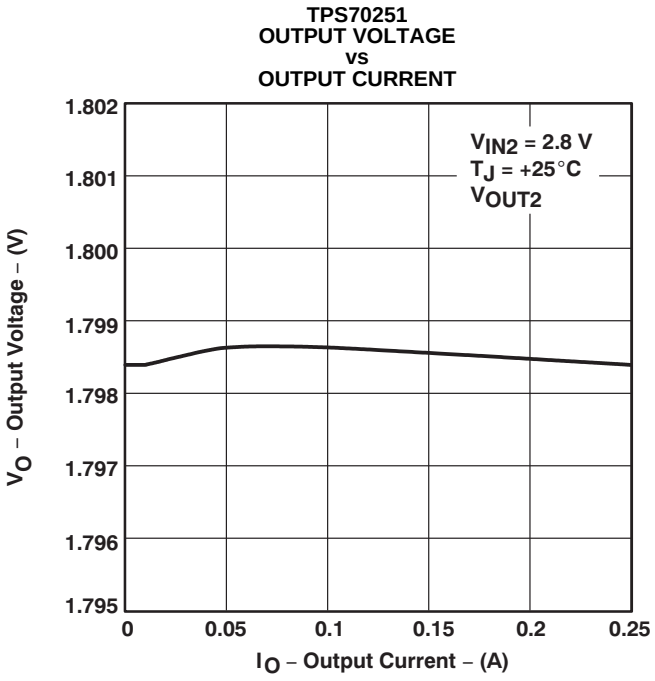


Figure 2.

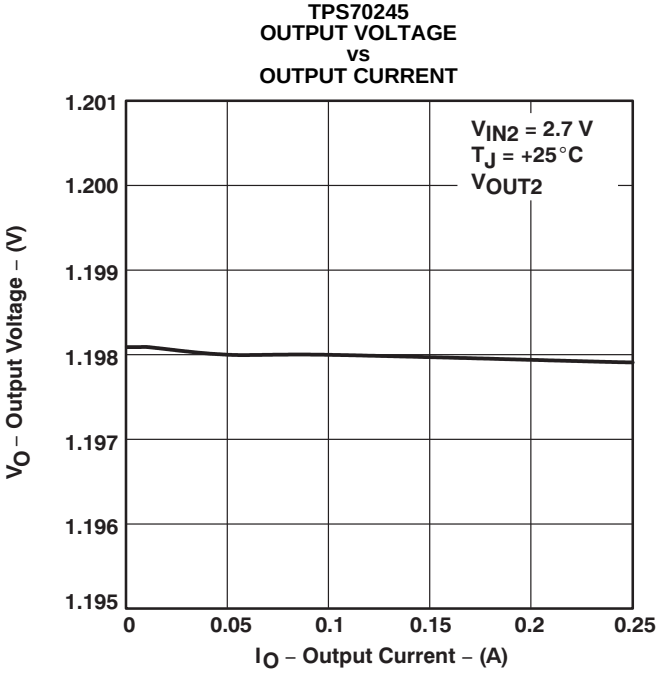


Figure 3.

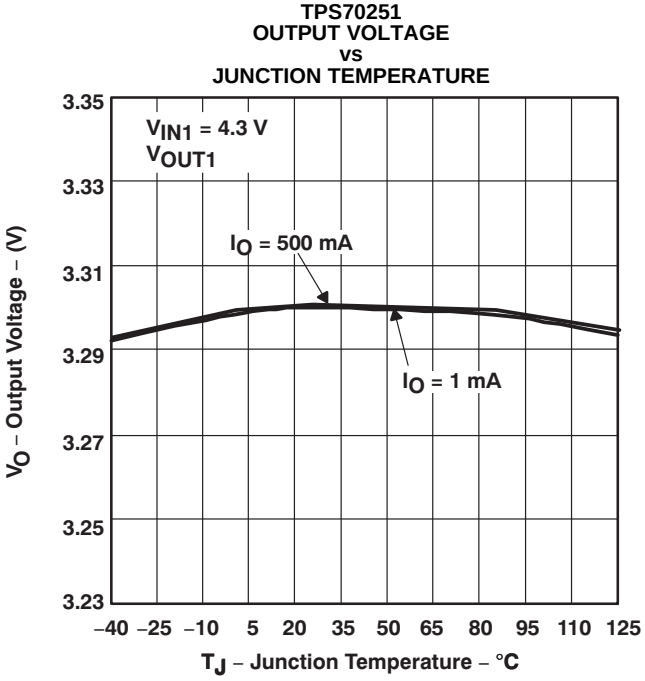


Figure 4.

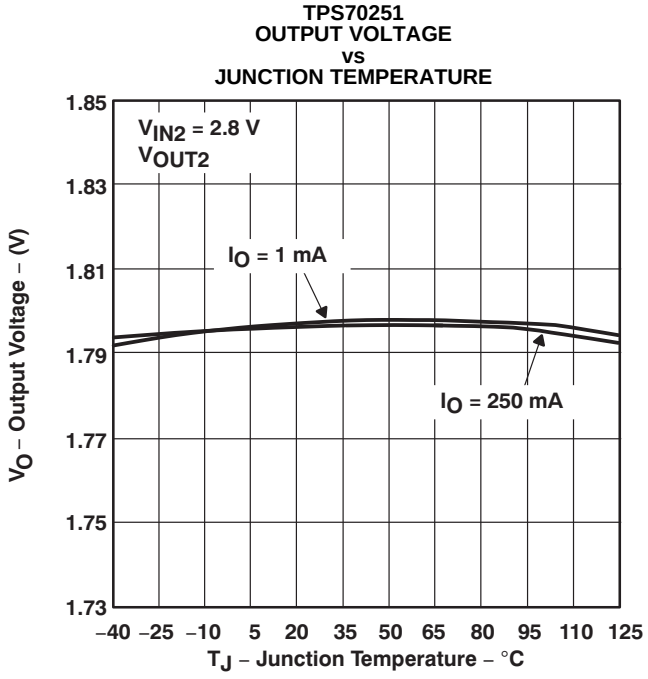


Figure 5.

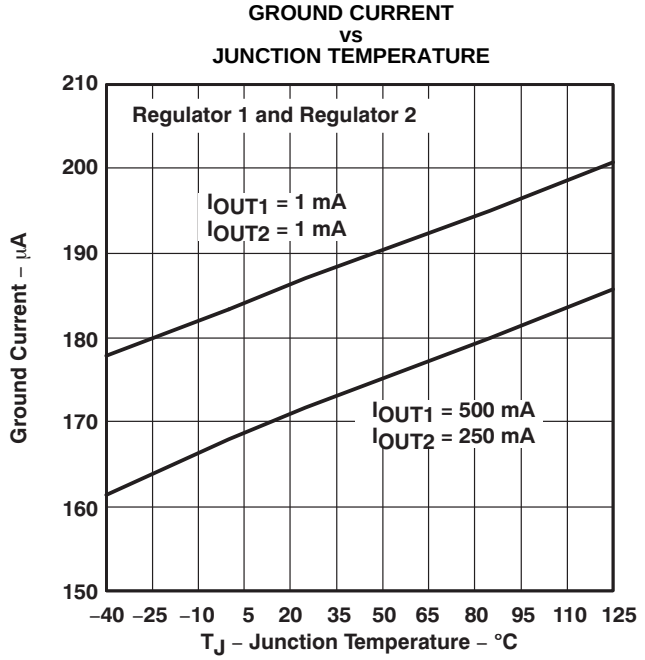
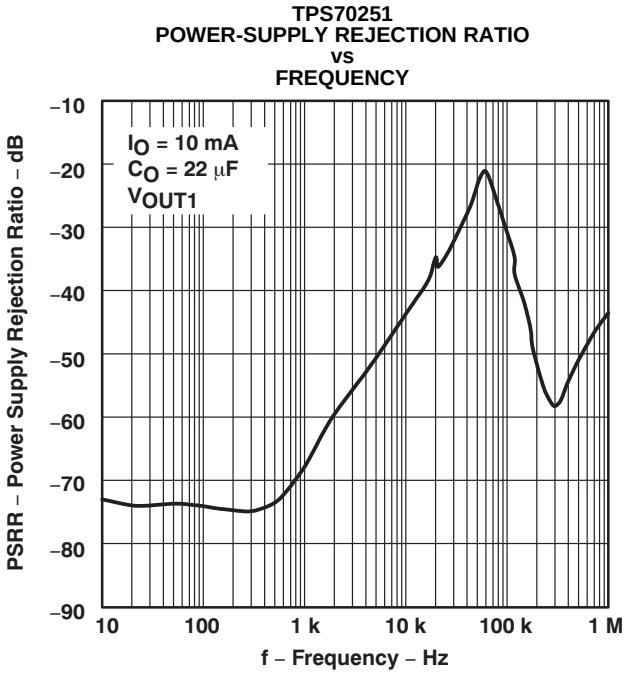


Figure 6.



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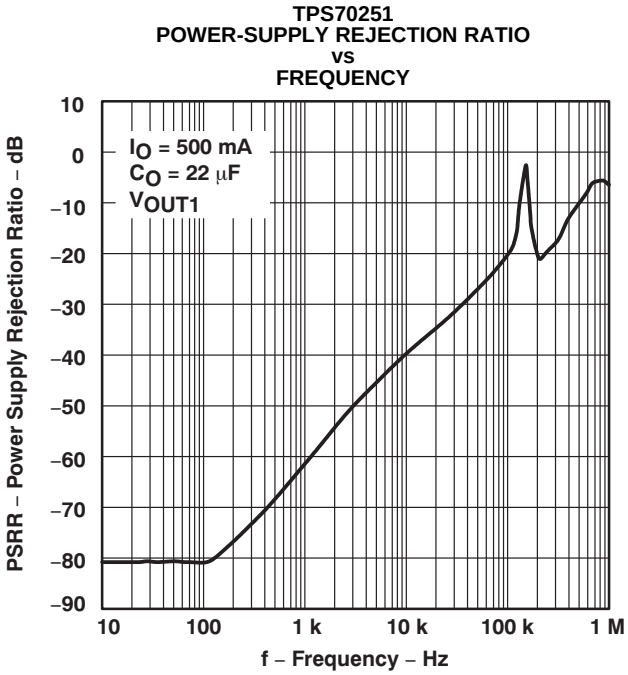

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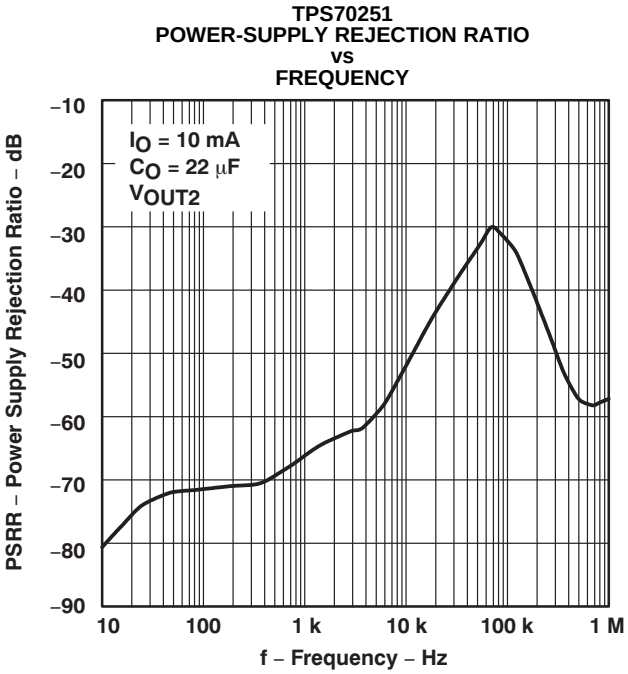

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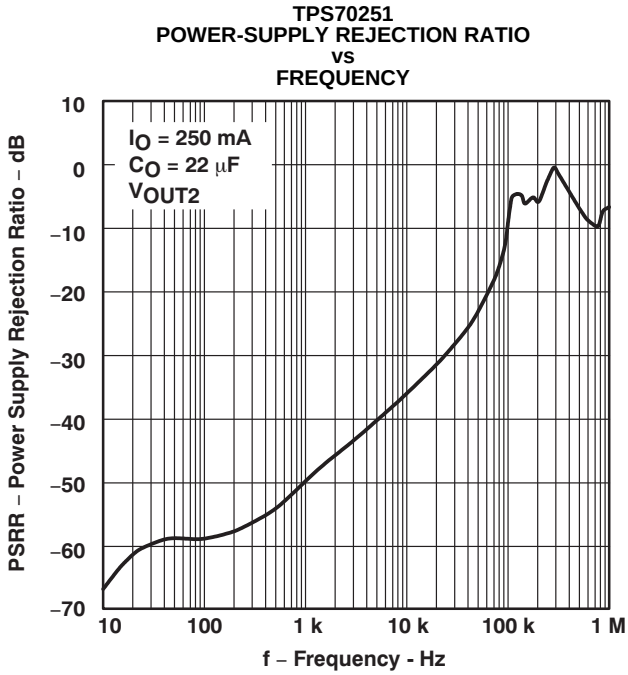

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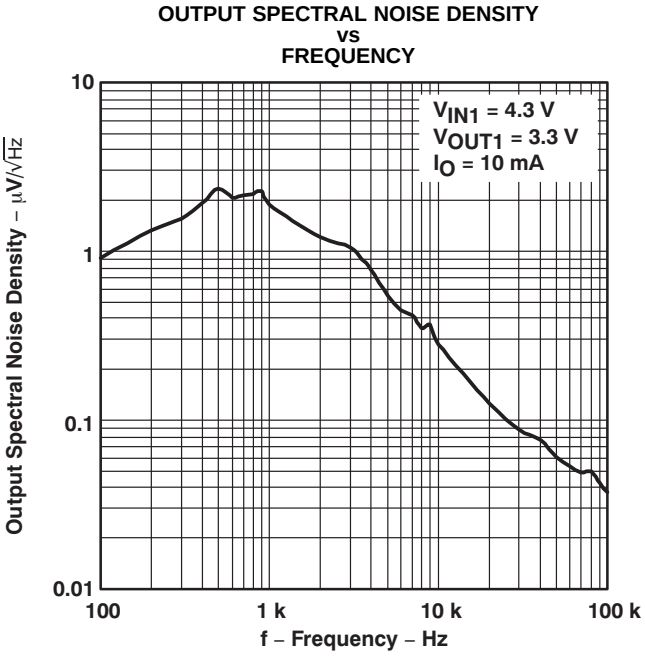

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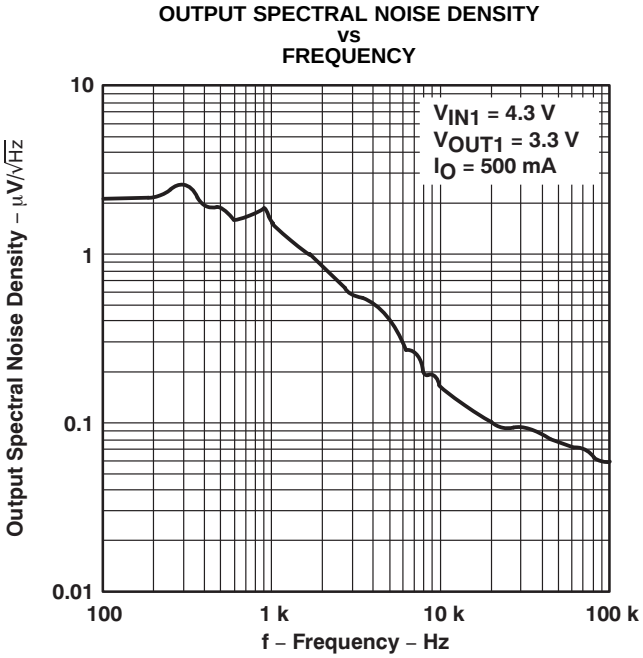

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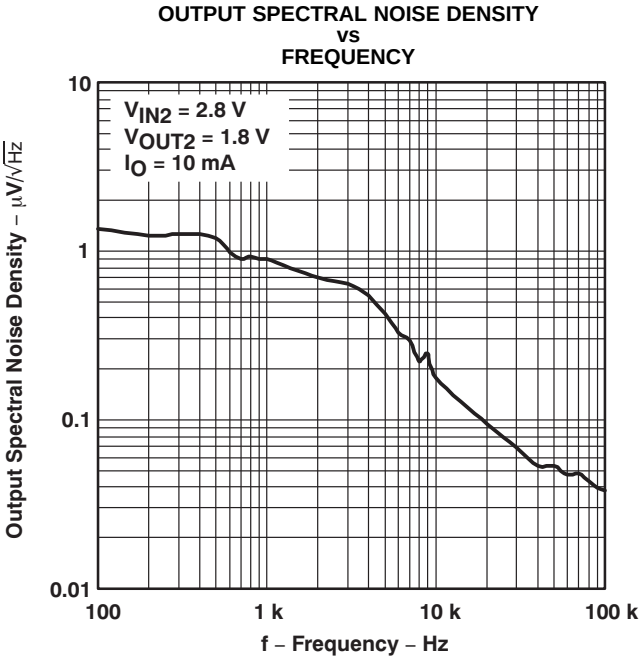

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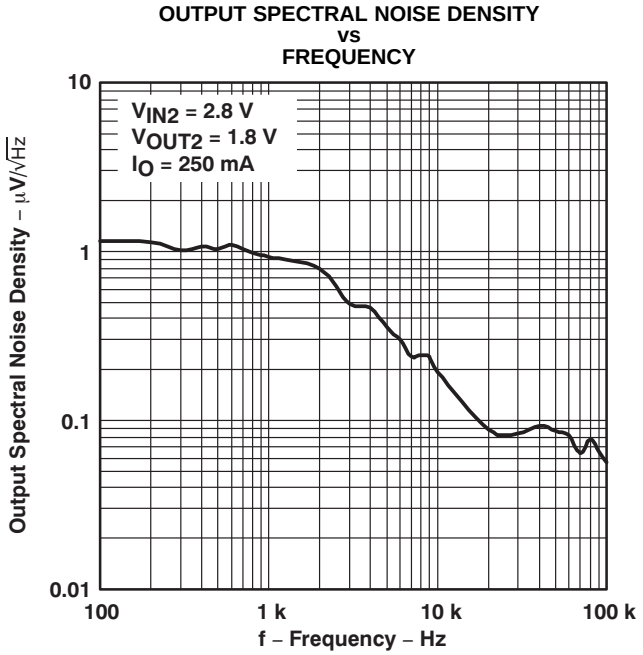

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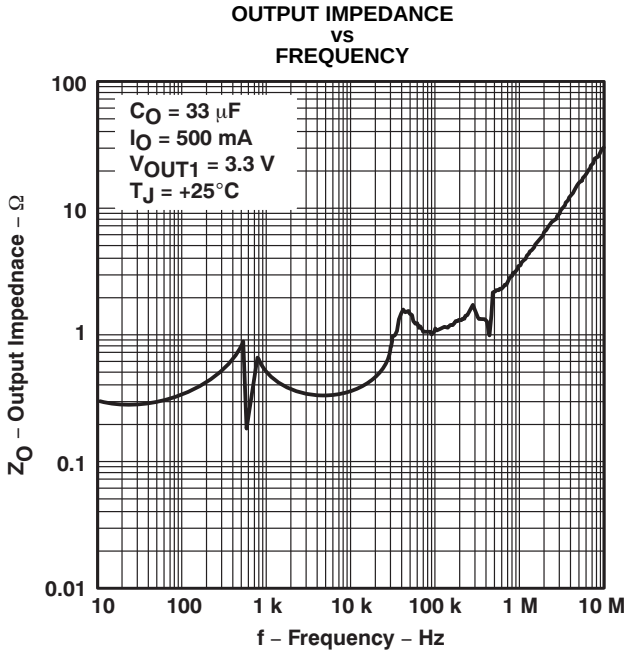

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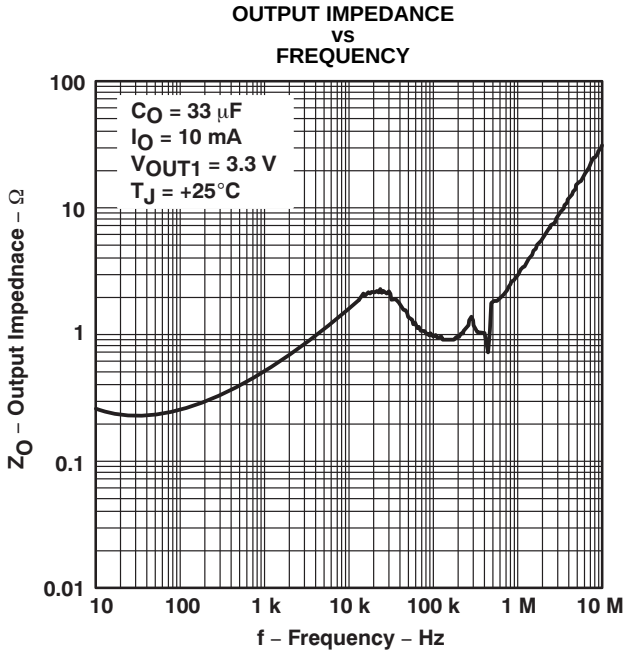

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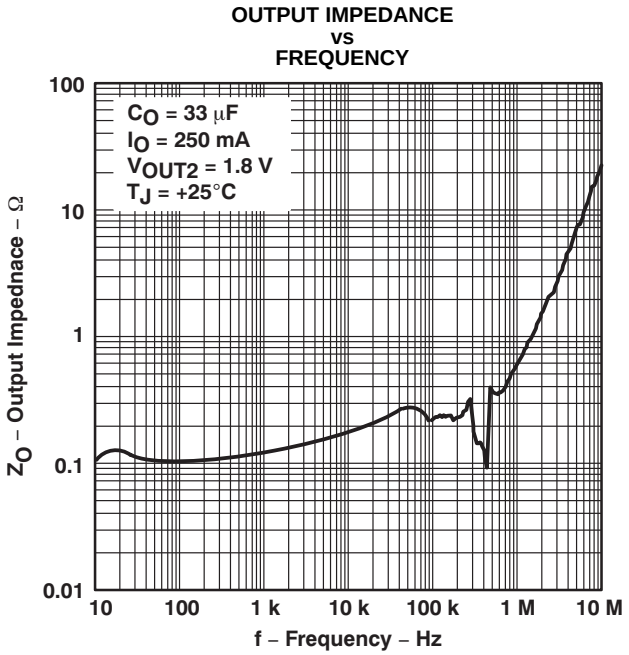

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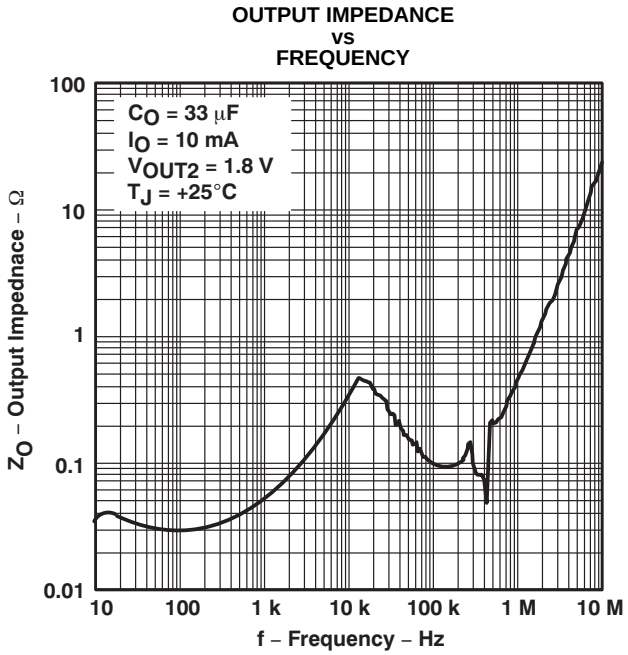

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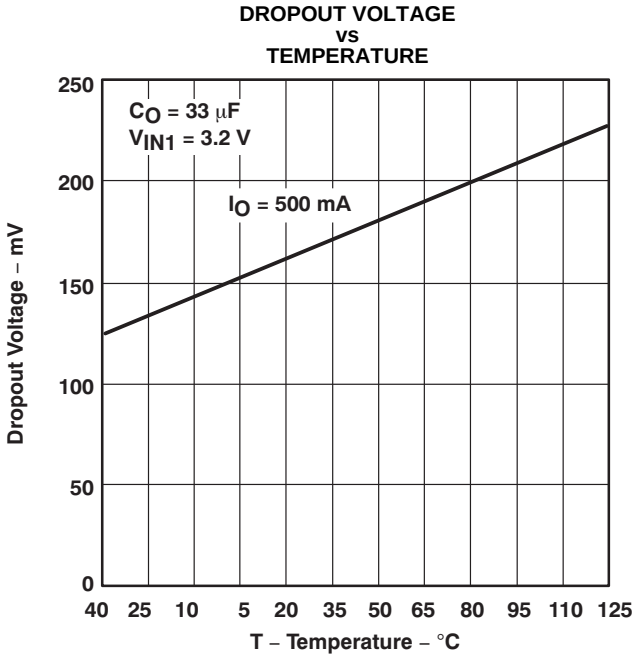

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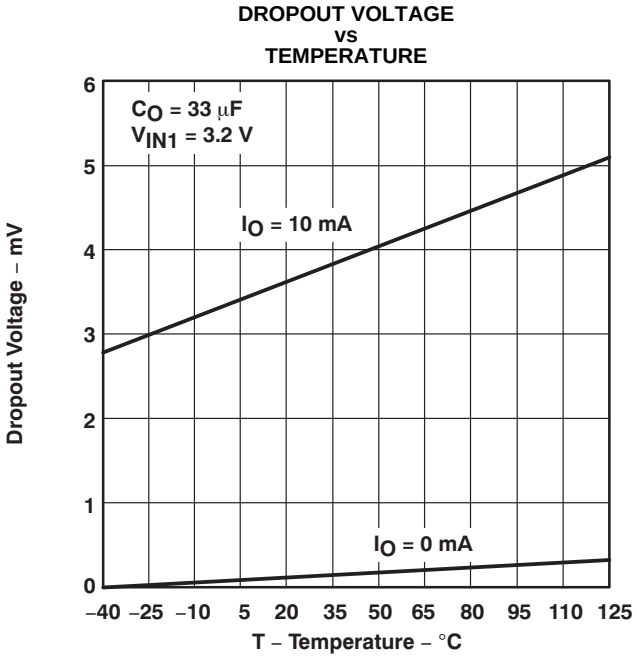

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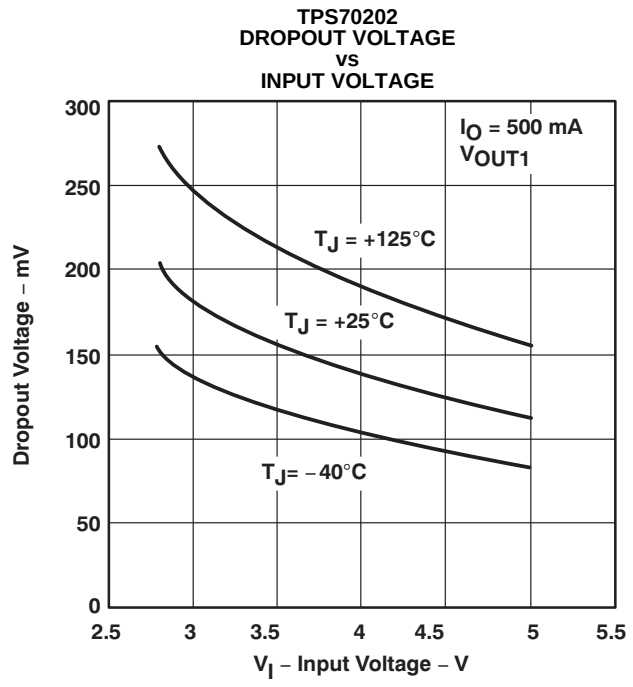

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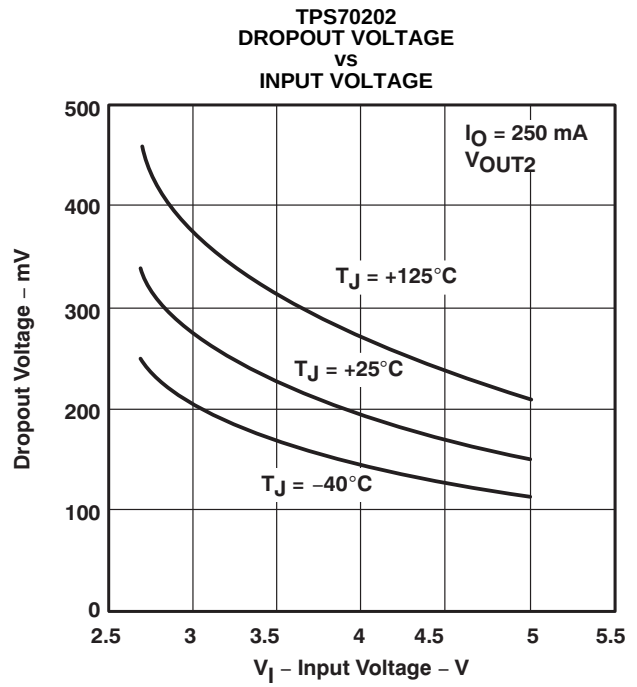

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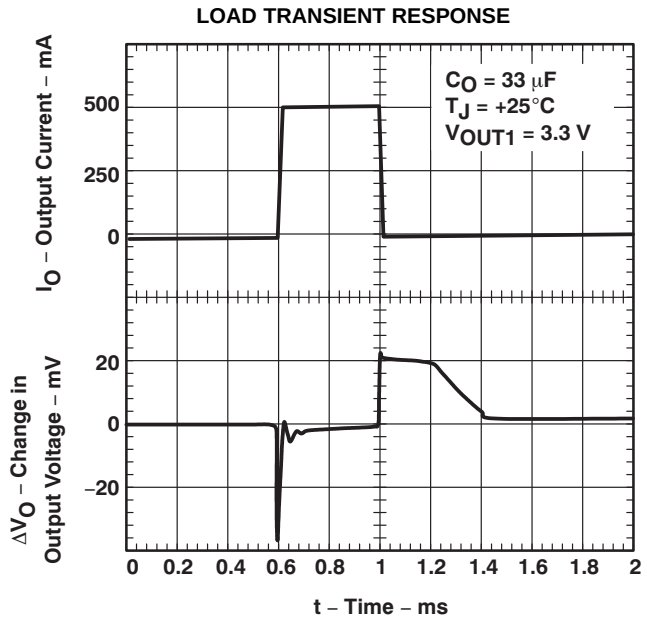

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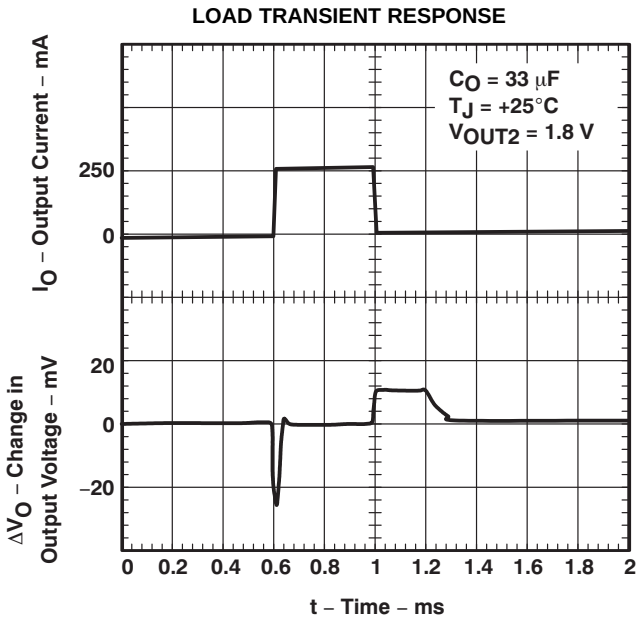

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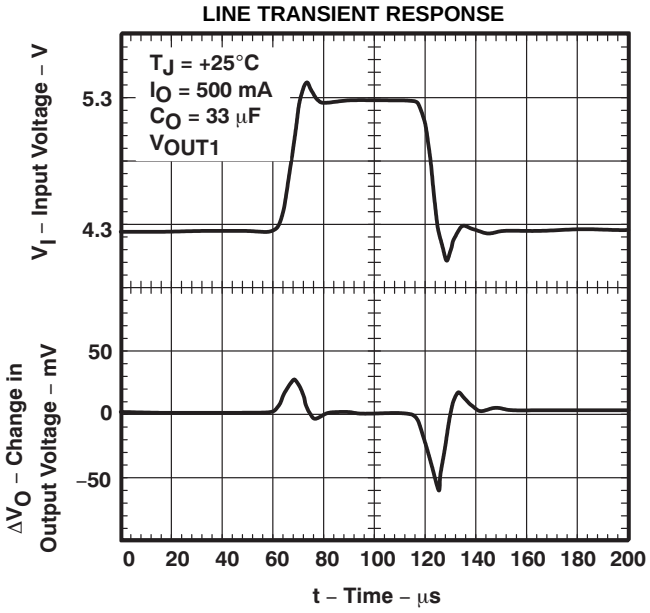

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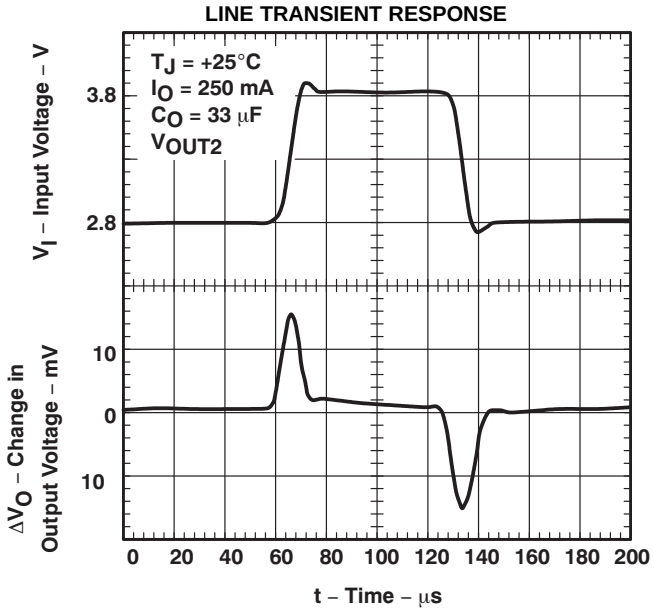

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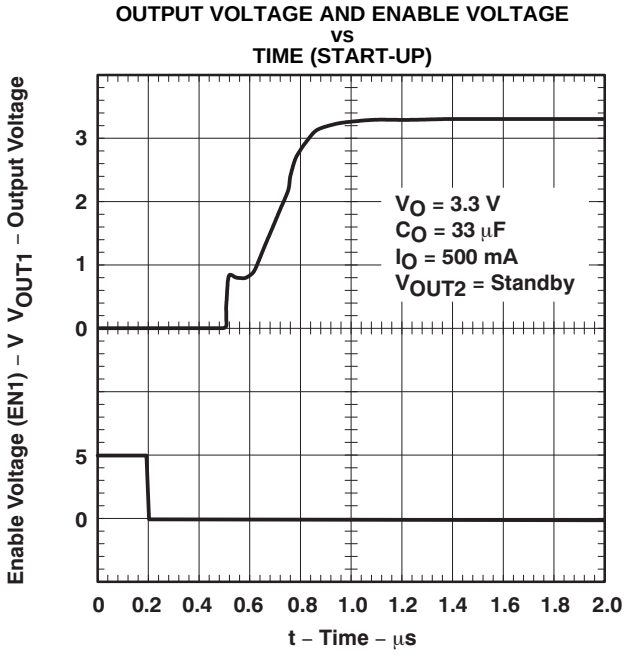


Figure 27.

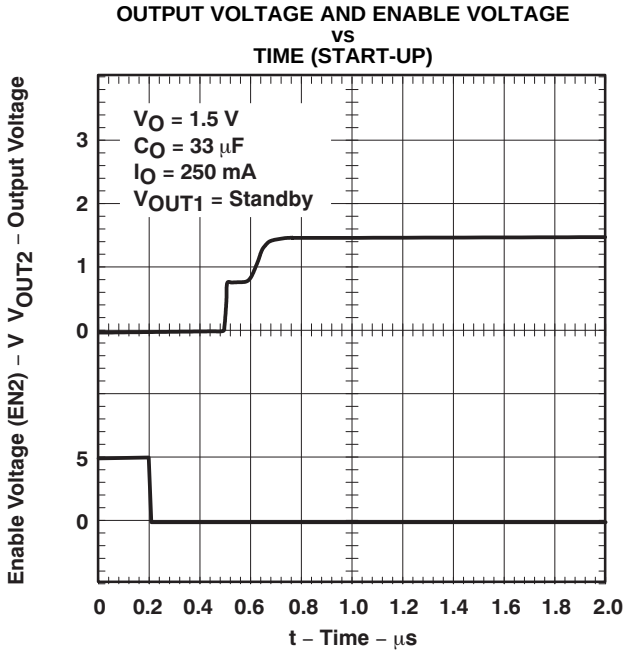


Figure 28.

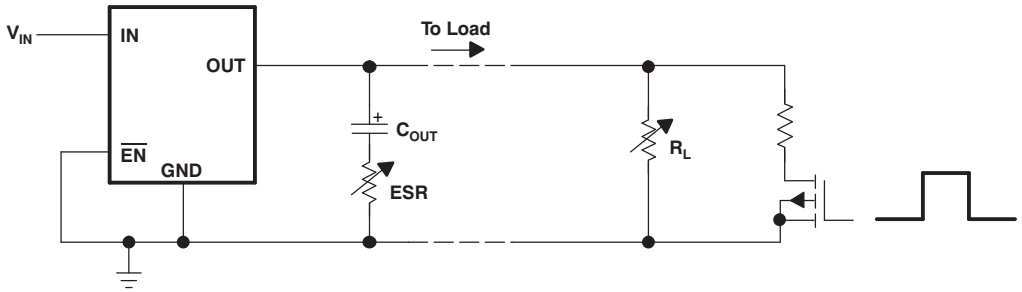


Figure 29. Test Circuit for Typical Regions of Stability

TYPICAL REGION OF STABILITY
EQUIVALENT SERIES RESISTANCE(1)
vs
OUTPUT CURRENT

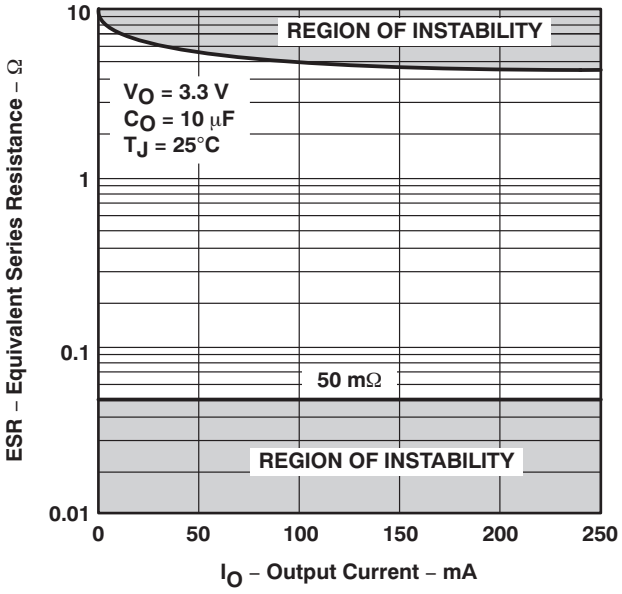


Figure 30.

TYPICAL REGION OF STABILITY
EQUIVALENT SERIES RESISTANCE(1)
vs
OUTPUT CURRENT

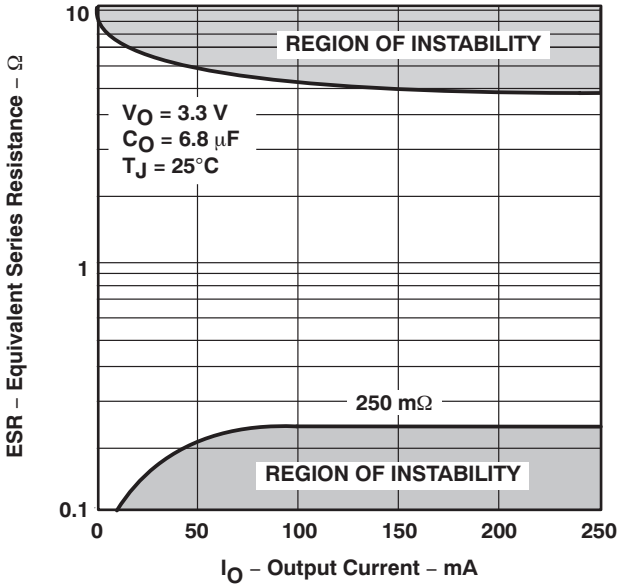


Figure 31.

TYPICAL REGION OF STABILITY
EQUIVALENT SERIES RESISTANCE(1)
vs
OUTPUT CURRENT

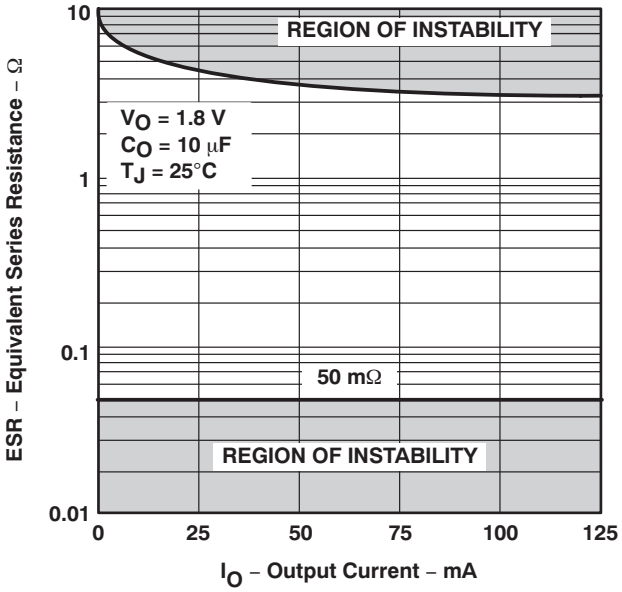


Figure 32.

TYPICAL REGION OF STABILITY
EQUIVALENT SERIES RESISTANCE(1)
vs
OUTPUT CURRENT

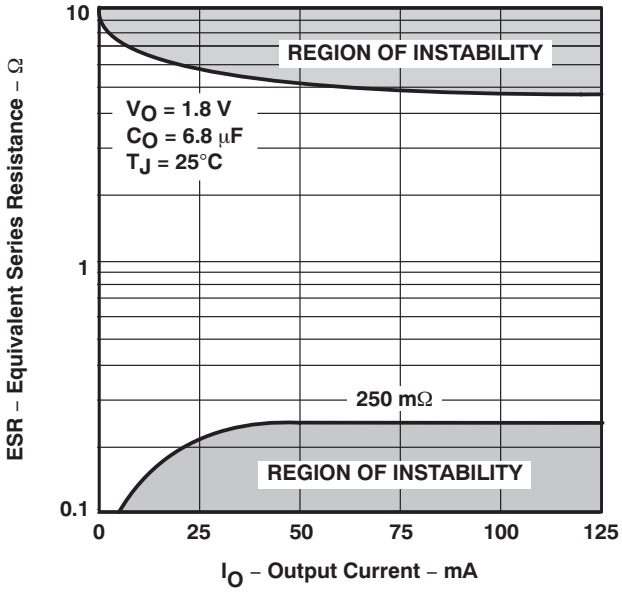


Figure 33.

(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.

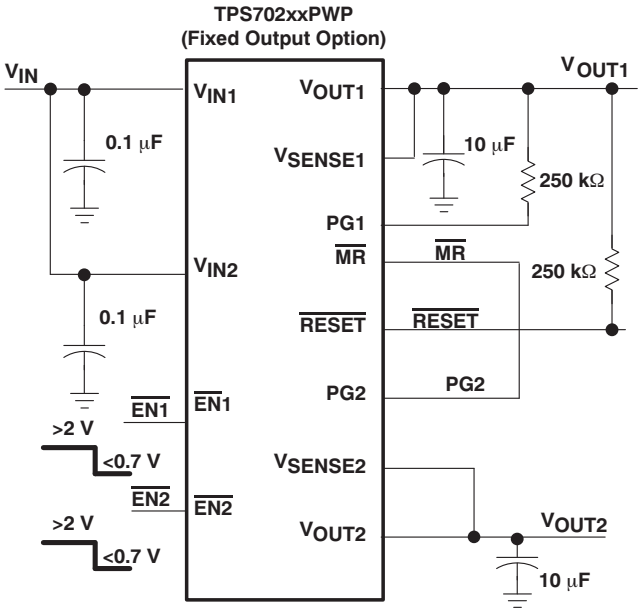
APPLICATION INFORMATION

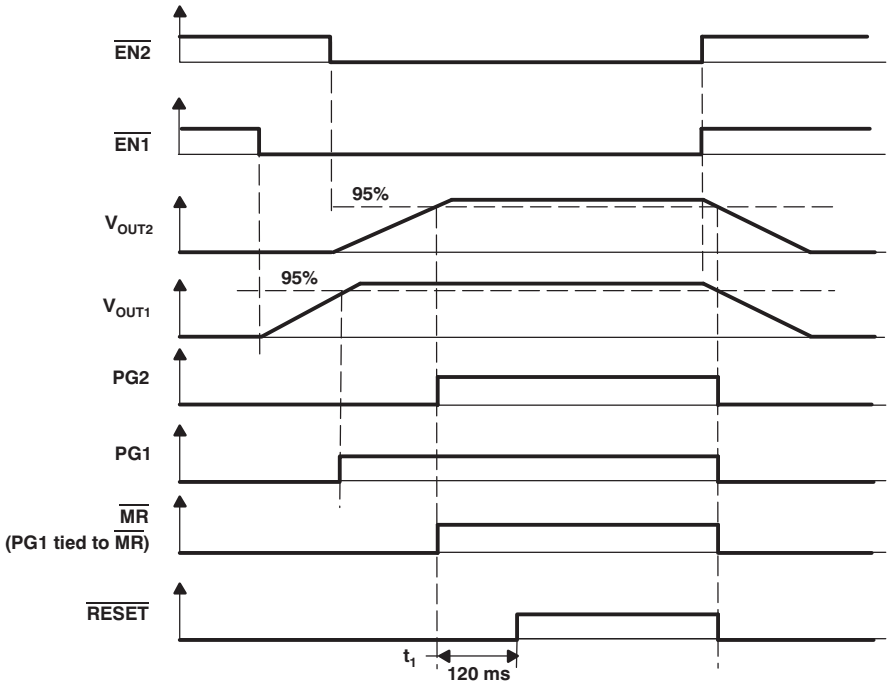
Sequencing Timing Diagrams

This section provides a number of timing diagrams showing how this device functions in different configurations.

Application condition: V_{IN1} and V_{IN2} are tied to the same fixed input voltage greater than V_{UVLO}. PG2 is tied to $\overline{MR}$.

$\overline{EN1}$ and $\overline{EN2}$ are initially high; therefore, both regulators are off, and PG1 and PG2 (tied to $\overline{MR}$) are at logic low. Since $\overline{MR}$ is at logic low, $\overline{RESET}$ is also at logic low. When $\overline{EN1}$ is taken to logic low, V_{OUT1} turns on. Later, when $\overline{EN2}$ is taken to logic low, V_{OUT2} turns on. When V_{OUT1} reaches 95% of its regulated output voltage, PG1 goes to logic high. When V_{OUT2} reaches 95% of its regulated output voltage, PG2 (tied to $\overline{MR}$) goes to logic high. When V_{IN1} is greater than V_{UVLO} and $\overline{MR}$ (tied to PG2) is at logic high, $\overline{RESET}$ is pulled to logic high after a 120ms delay. When $\overline{EN1}$ and $\overline{EN2}$ are returned to logic high, both devices power down and both PG1, PG2 (tied to $\overline{MR2}$), and $\overline{RESET}$ return to logic low.



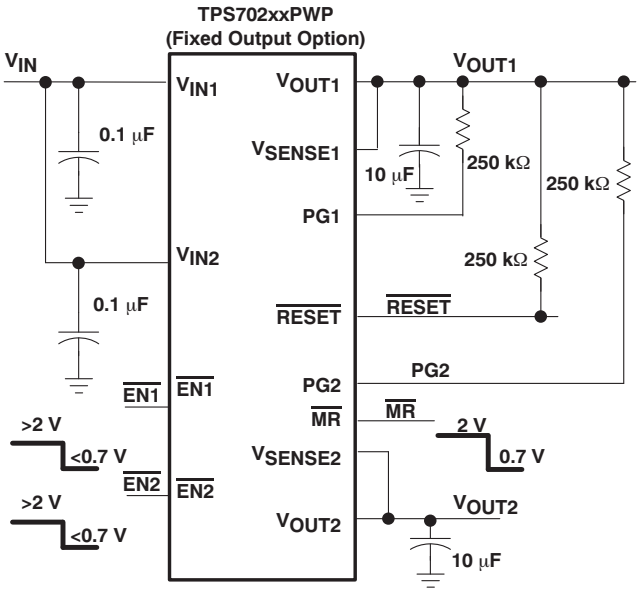


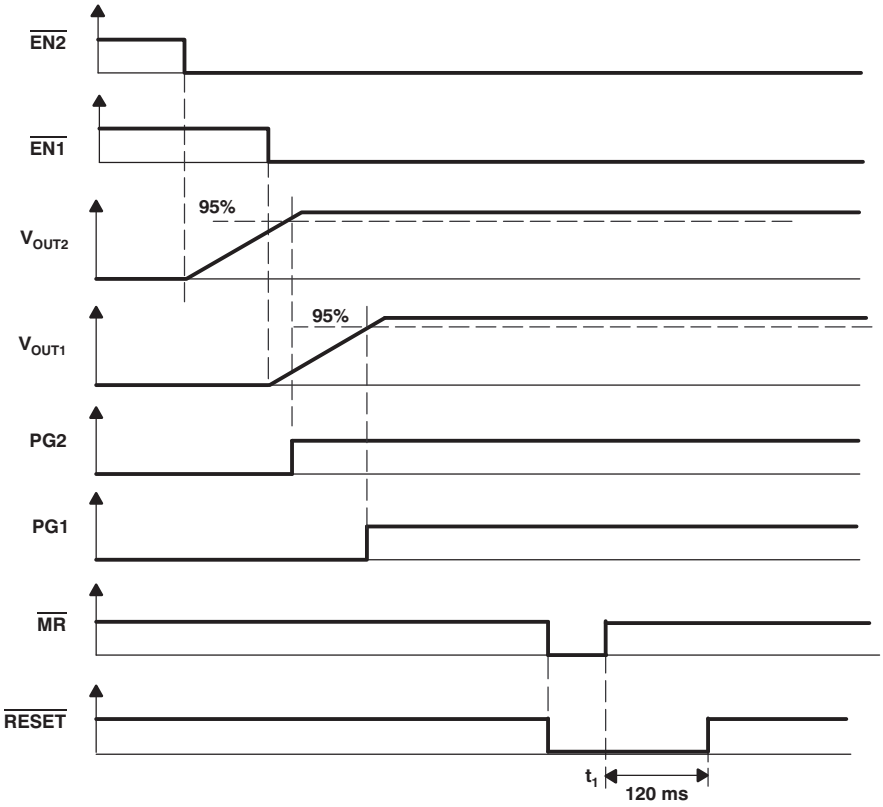
NOTES: A. t_1: Time at which V_{IN} is greater than V_{UVLO} and $\overline{MR}$ is logic high.
B. The timing diagram is not drawn to scale.

Figure 34. Timing When V_{OUT1} Is Enabled Before V_{OUT2}

Application condition: V_{IN1} and V_{IN2} are tied to the same fixed input voltage greater than V_{UVLO}. $\overline{MR}$ is initially logic high but is eventually toggled.

$\overline{EN1}$ and $\overline{EN2}$ are initially high; therefore, both regulators are off, and PG1 and PG2 are at logic low. Since V_{IN1} is greater than V_{UVLO} and $\overline{MR}$ is at logic high, $\overline{RESET}$ is also at logic high. When $\overline{EN2}$ is taken to logic low, V_{OUT2} turns on. Later, when $\overline{EN1}$ is taken to logic low, V_{OUT1} turns on. When V_{OUT2} reaches 95% of its regulated output voltage, PG2 goes to logic high. When V_{OUT1} reaches 95% of its regulated output voltage, PG1 goes to logic high. When $\overline{MR}$ is taken to logic low, $\overline{RESET}$ is taken low. When $\overline{MR}$ returns to logic high, $\overline{RESET}$ returns to logic high after a 120ms delay.



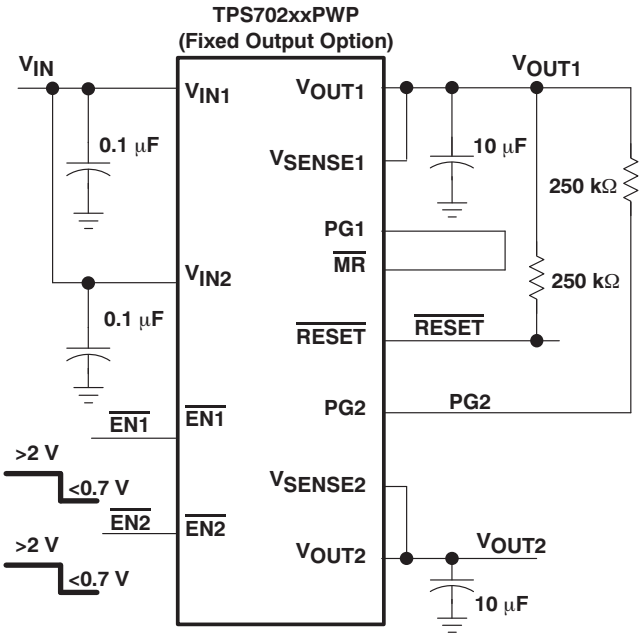


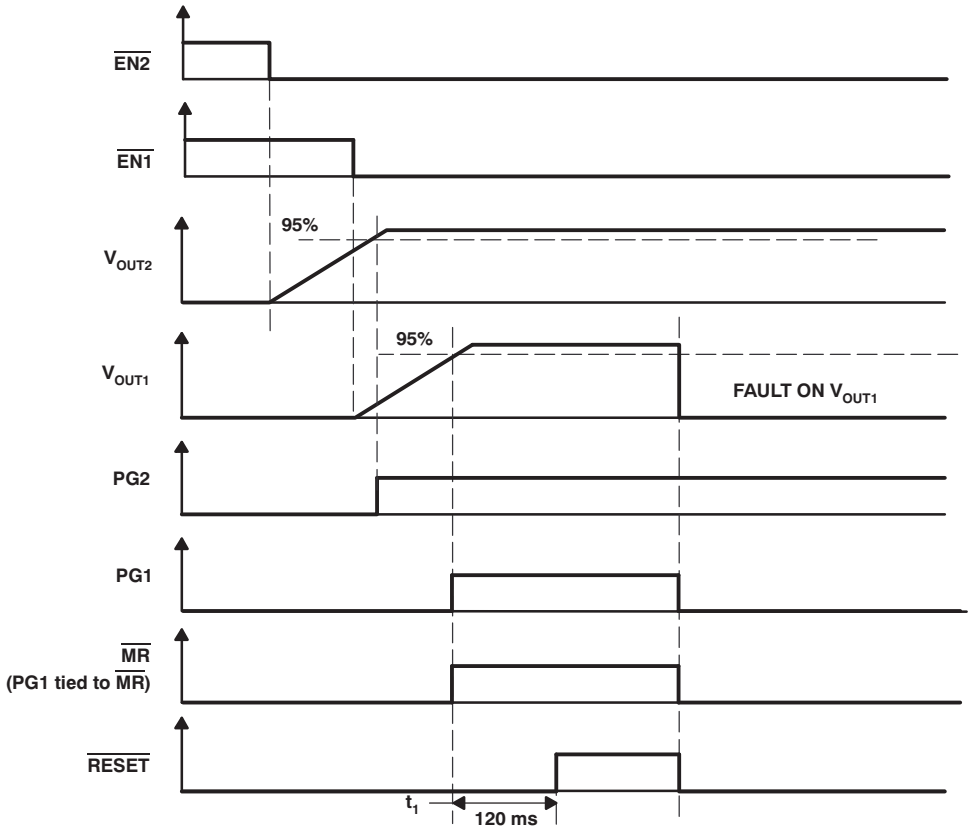
NOTES: A. t_1: Time at which V_{IN} is greater than V_{UVLO} and $\overline{MR}$ is logic high.
B. The timing diagram is not drawn to scale.

Figure 35. Timing When $\overline{MR}$ is Toggled

Application condition: V_{IN1} and V_{IN2} are tied to same fixed input voltage greater than V_{UVLO}. PG1 is tied to $\overline{MR}$.

$\overline{EN1}$ and $\overline{EN2}$ are initially high; therefore, both regulators are off, and PG1 (tied to $\overline{MR}$) and PG2 are at logic low. Since $\overline{MR}$ is at logic low, $\overline{RESET}$ is also at logic low. When $\overline{EN2}$ is taken to logic low, V_{OUT2} turns on. Later, when $\overline{EN1}$ is taken to logic low, V_{OUT1} turns on. When V_{OUT2} reaches 95% of its regulated output voltage, PG2 goes to logic high. When V_{OUT1} reaches 95% of its regulated output voltage, PG1 goes to logic high. When V_{IN1} is greater than V_{UVLO} and $\overline{MR}$ (tied to PG2) is at logic high, $\overline{RESET}$ is pulled to logic high after a 120ms delay. When a fault on V_{OUT1} causes it to fall below 95% of its regulated output voltage, PG1 (tied to $\overline{MR}$) goes to logic low. Since $\overline{MR}$ is logic low, $\overline{RESET}$ goes to logic low. V_{OUT2} is unaffected.





NOTES: A. t_1: Time at which V_{IN} is greater than V_{UVLO} and $\overline{MR}$ is logic high.
B. The timing diagram is not drawn to scale.

Figure 36. Timing When V_{OUT1} Faults Out

APPLICATION INFORMATION

Input Capacitor

For a typical application, an input bypass capacitor (0.1µF to 1µF) is recommended. This capacitor filters any high-frequency noise generated in the line. For fast transient conditions where droop at the input of the LDO may occur because of high inrush current, it is recommended to place a larger capacitor at the input as well. The size of this capacitor depends on the output current and response time of the main power supply, as well as the distance to the V_I pins of the LDO.

Output Capacitor

As with most LDO regulators, the TPS702xx requires an output capacitor connected between OUT and GND to stabilize the internal control loop. The minimum recommended capacitance values are 10µF ceramic capacitors with an ESR (equivalent series resistance) between 50mΩ and 2.5Ω or 6.8µF tantalum capacitors with ESR between 250mΩ and 4Ω. Solid tantalum electrolytic, aluminum electrolytic, and multilayer ceramic capacitors with capacitance values greater than 10µF are all suitable, provided they meet the requirements described above. Larger capacitors provide a wider range of stability and better load transient response. Table 1 gives a partial listing of surface-mount capacitors suitable for use with the TPS702xx for fast transient response applications.

This information, along with the ESR graphs, is included to assist in selection of suitable capacitance for user applications. 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 the guidelines above.

Table 1. Partial Listing of TPS702xx-Compatible Surface-Mount Capacitors

VALUE	MANUFACTURER	MAXIMUM ESR	MFR PART NO.
22µF	Kemet	345mΩ	7495C226K0010AS
33µF	Sanyo	100mΩ	10TPA33M
47µF	Sanyo	100mΩ	6TPA47M
68µF	Sanyo	45mΩ	10TPC68M

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 can therefore be drawn as shown in Figure 37.

Figure 37. ESR and ESL

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

Figure 38 shows the output capacitor and its parasitic impedances in a typical LDO output stage.

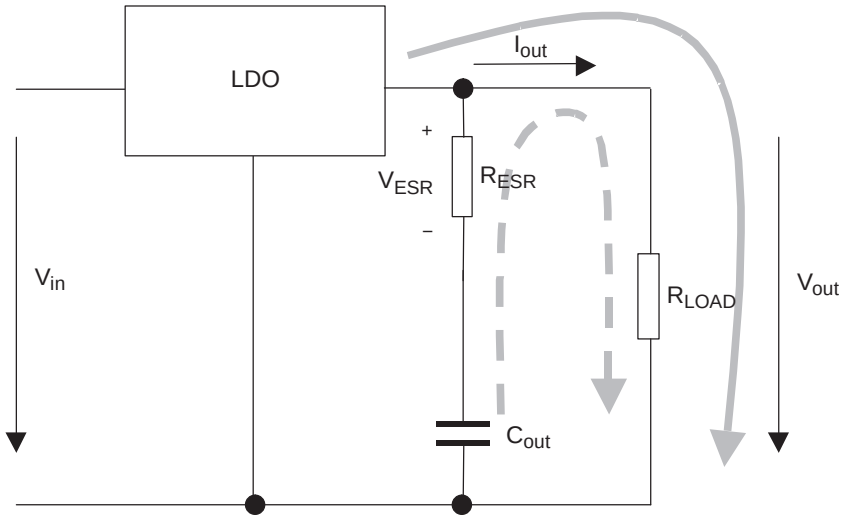


Figure 38. LDO Output Stage with Parasitic Resistances ESR

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 ($V_{(CO)} = V_{OUT}$). This condition means no current is flowing into the C_{OUT} branch. If I_{OUT} suddenly increases (a transient condition), the following results occur:

- The LDO is not able to supply the sudden current need because of its response time (t_1 in Figure 39). Therefore, capacitor C_{OUT} provides the current for the new load condition (dashed arrow). C_{OUT} now acts like a battery with an internal resistance, ESR. Depending on the current demand at the output, a voltage drop occurs at R_{ESR}. This voltage is shown as V_{ESR} in Figure 38.
- When C_{OUT} is conducting current to the load, initial voltage at the load will be $V_{OUT} = V_{(CO)} – V_{ESR}$. As a result of the discharge of C_{OUT}, the output voltage V_{OUT} 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 39.

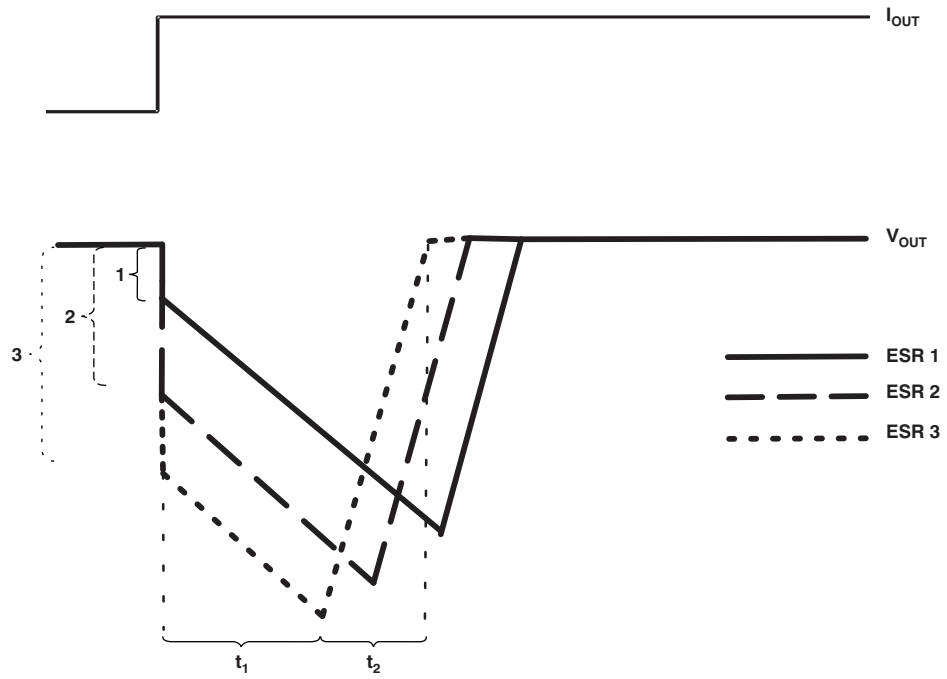


Figure 39. Correlation of Different ESRs and Their Influence on the Regulation of V_O at a Load Step from Low-to-High Output Current

Figure 39 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 above, the following conclusions can be drawn:

- The higher the ESR, the larger the droop at the beginning of the load transient.
- The smaller the output capacitor, the faster the discharge time and the greater 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.

Programming the TPS70202 Adjustable LDO Regulator

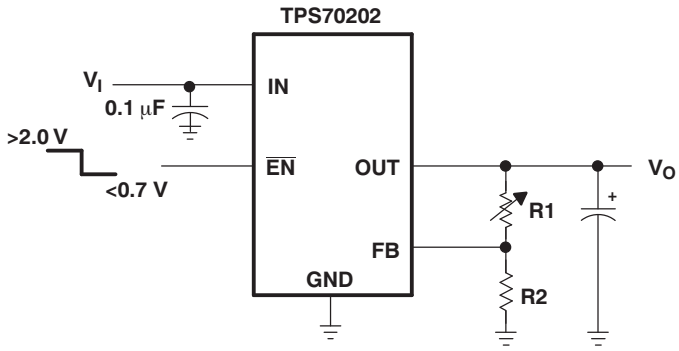
The output voltage of the TPS70202 adjustable regulators is programmed using external resistor dividers as shown in Figure 40.

Resistors R1 and R2 should be chosen for approximately a 50µA 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 the sense terminal increase the output voltage error. The recommended design procedure is to choose R2 = 30.1kΩ to set the divider current at approximately 50µA, and then calculate R1 using Equation 1:

$$R1 = \left(\frac{V_{OUT}}{V_{REF}} - 1\right) \times R2 \quad (1)$$

where:

- V_{REF} = 1.224V typ (the internal reference voltage)



OUTPUT VOLTAGE PROGRAMMING GUIDE

OUTPUT VOLTAGE	R1	R2	UNIT
2.5 V	31.6	30.1	kΩ
3.3 V	51.1	30.1	kΩ
3.6 V	59.0	30.1	kΩ

Figure 40. TPS70202 Adjustable LDO Regulator Programming

Regulator Protection

Both TPS702xx PMOS-pass transistors have built-in back diodes that conduct reverse currents when the input voltage drops below the output voltage (for example, 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 TPS702xx also features internal current limiting and thermal protection. During normal operation, the TPS702xx regulator 1 limits output current to approximately 1.6A (typ) and regulator 2 limits output current to approximately 750mA (typ). 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 using Equation 2:

$$P_{D(max)} = \frac{T_J max - T_A}{R_{\theta JA}} \quad (2)$$

where:

- T_{Jmax} is the maximum allowable junction temperature
- $R_{\theta JA}$ is the thermal resistance junction-to-ambient for the package; that is, 32.6°C/W for the 20-terminal PWP with no airflow
- T_A is the ambient temperature

The regulator dissipation is calculated using Equation 3:

$$P_D = (V_I - V_O) \times I_O \quad (3)$$

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

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)
TPS70202PWP	ACTIVE	HTSSOP	PWP	20	70	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
TPS70202PWPG4	ACTIVE	HTSSOP	PWP	20	70	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
TPS70202PWPR	ACTIVE	HTSSOP	PWP	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
TPS70202PWPRG4	ACTIVE	HTSSOP	PWP	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
TPS70245PWP	ACTIVE	HTSSOP	PWP	20	70	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
TPS70245PWPG4	ACTIVE	HTSSOP	PWP	20	70	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
TPS70245PWPR	ACTIVE	HTSSOP	PWP	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
TPS70245PWPRG4	ACTIVE	HTSSOP	PWP	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
TPS70248PWP	ACTIVE	HTSSOP	PWP	20	70	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
TPS70248PWPG4	ACTIVE	HTSSOP	PWP	20	70	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
TPS70248PWPR	ACTIVE	HTSSOP	PWP	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
TPS70248PWPRG4	ACTIVE	HTSSOP	PWP	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
TPS70251PWP	ACTIVE	HTSSOP	PWP	20	70	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
TPS70251PWPG4	ACTIVE	HTSSOP	PWP	20	70	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
TPS70251PWPR	ACTIVE	HTSSOP	PWP	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
TPS70251PWPRG4	ACTIVE	HTSSOP	PWP	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
TPS70258PWP	ACTIVE	HTSSOP	PWP	20	70	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
TPS70258PWPG4	ACTIVE	HTSSOP	PWP	20	70	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
TPS70258PWPR	ACTIVE	HTSSOP	PWP	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
TPS70258PWPRG4	ACTIVE	HTSSOP	PWP	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR

(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.

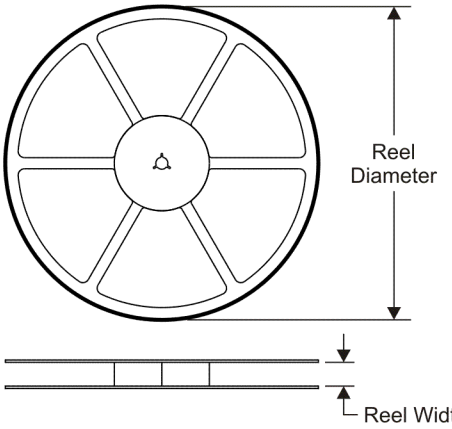
(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.

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)

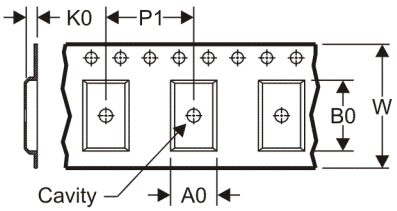
(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

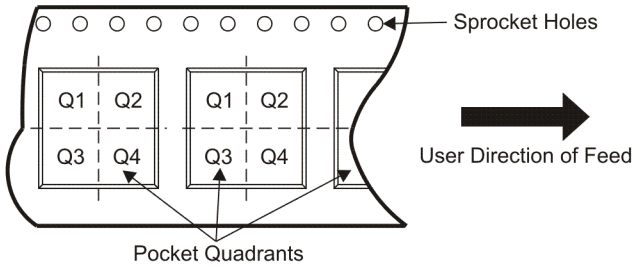


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

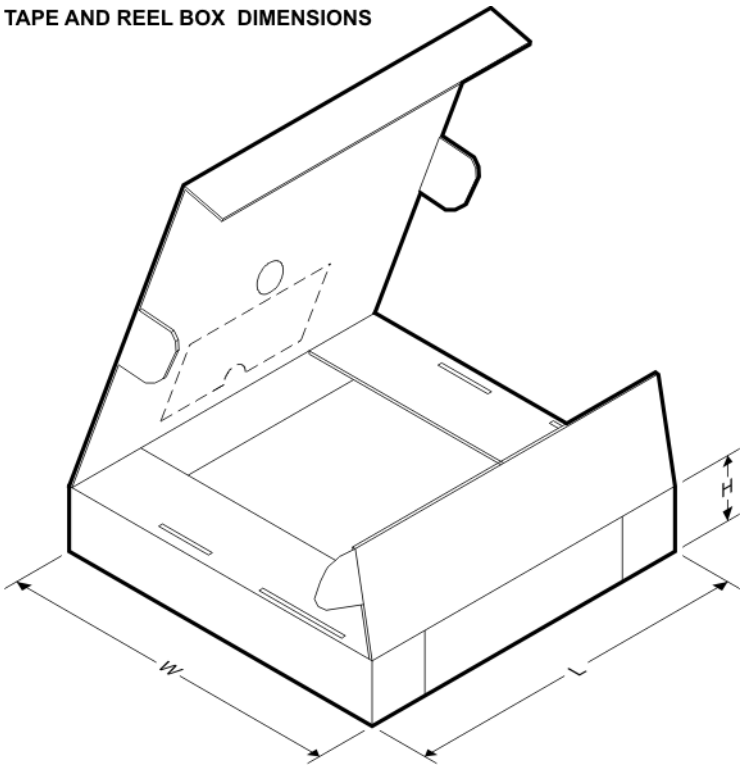
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
TPS70202PWPR	HTSSOP	PWP	20	2000	330.0	16.4	6.95	7.1	1.6	8.0	16.0	Q1
TPS70245PWPR	HTSSOP	PWP	20	2000	330.0	16.4	6.95	7.1	1.6	8.0	16.0	Q1
TPS70248PWPR	HTSSOP	PWP	20	2000	330.0	16.4	6.95	7.1	1.6	8.0	16.0	Q1
TPS70251PWPR	HTSSOP	PWP	20	2000	330.0	16.4	6.95	7.1	1.6	8.0	16.0	Q1
TPS70258PWPR	HTSSOP	PWP	20	2000	330.0	16.4	6.95	7.1	1.6	8.0	16.0	Q1

TAPE AND REEL BOX DIMENSIONS

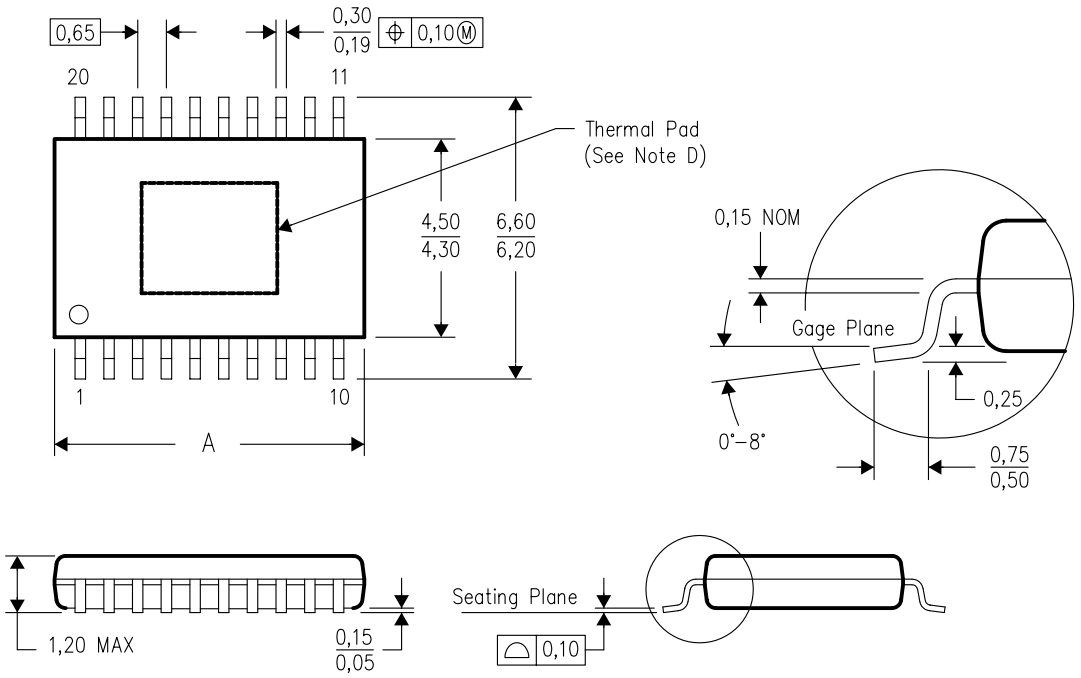


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPS70202PWPR	HTSSOP	PWP	20	2000	346.0	346.0	33.0
TPS70245PWPR	HTSSOP	PWP	20	2000	346.0	346.0	33.0
TPS70248PWPR	HTSSOP	PWP	20	2000	346.0	346.0	33.0
TPS70251PWPR	HTSSOP	PWP	20	2000	346.0	346.0	33.0
TPS70258PWPR	HTSSOP	PWP	20	2000	346.0	346.0	33.0

PWP (R–PDSO–G**) PowerPAD™ PLASTIC SMALL–OUTLINE PACKAGE

20 PIN SHOWN



DIM \ PINS **	14	16	20	24	28
A MAX	5,10	5,10	6,60	7,90	9,80
A MIN	4,90	4,90	6,40	7,70	9,60

4073225/H 12/05

NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusions. Mold flash and protrusion shall not exceed 0.15 per side.
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 for information regarding recommended board layout. This document is available at www.ti.com <http://www.ti.com>.
E. Falls within JEDEC MO–153

PowerPAD is a trademark of Texas Instruments.

THERMAL PAD MECHANICAL DATA

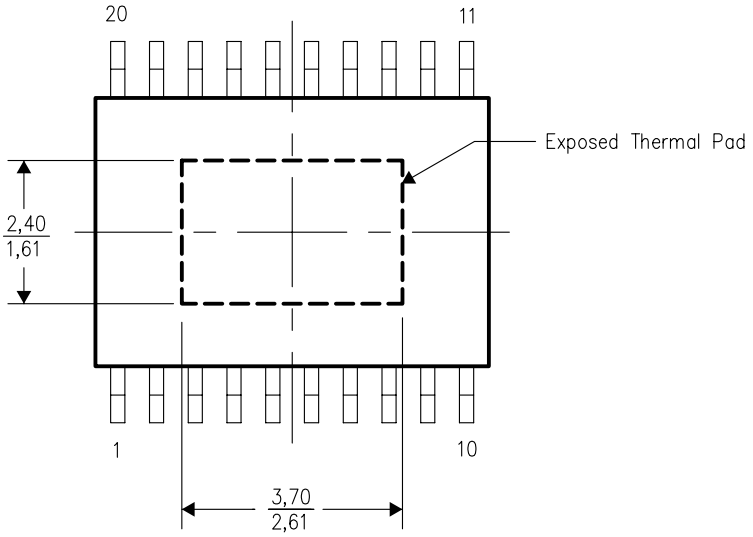
PWP (R–PDSO–G20)

THERMAL INFORMATION

This PowerPAD™ package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (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.

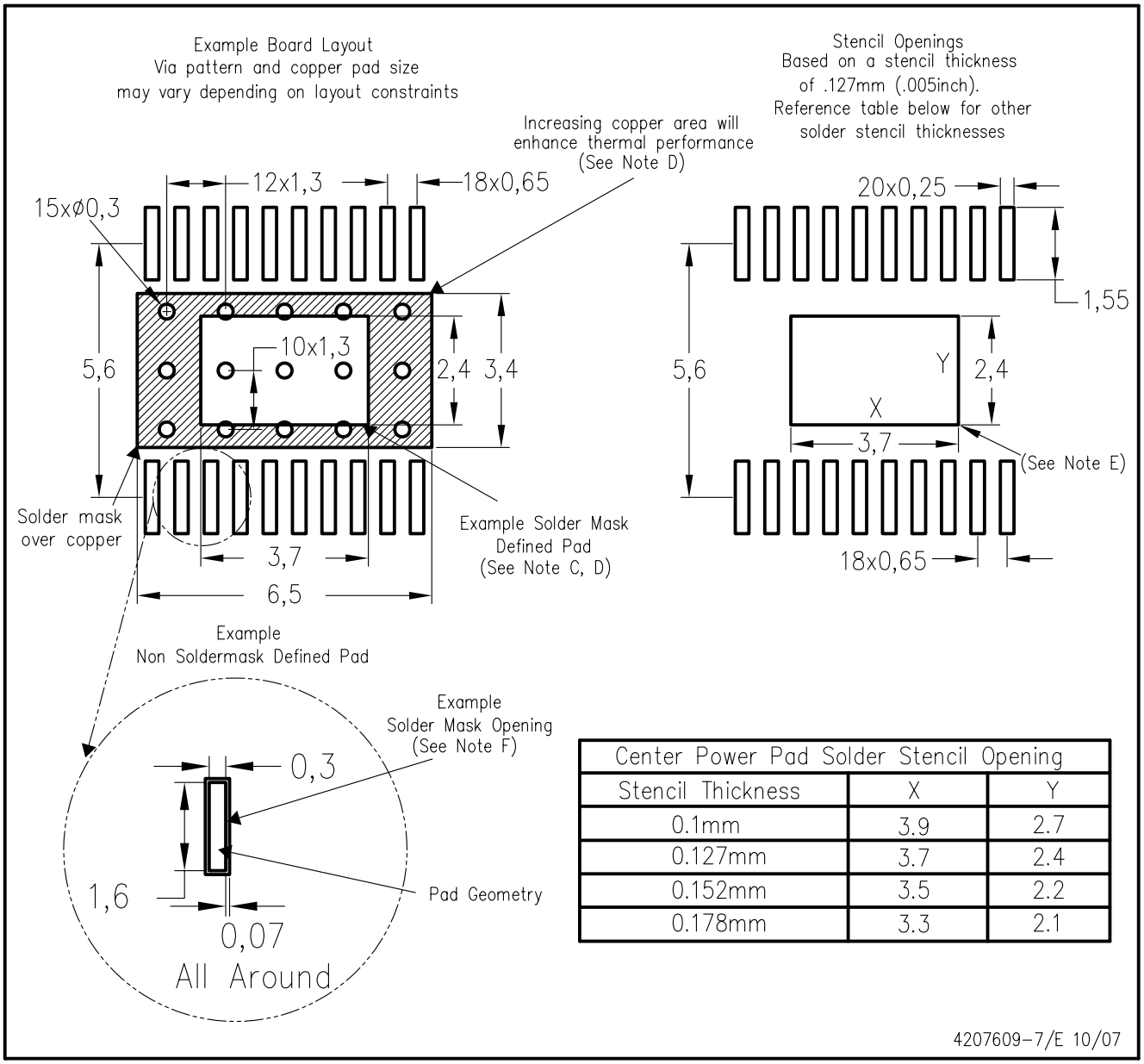


Top View

NOTE: All linear dimensions are in millimeters

Exposed Thermal Pad Dimensions

PWP (R–PDSO–G20) PowerPAD™



Center Power Pad Solder Stencil Opening		
Stencil Thickness	X	Y
0.1mm	3.9	2.7
0.127mm	3.7	2.4
0.152mm	3.5	2.2
0.178mm	3.3	2.1

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>. Publication IPC–7351 is recommended for alternate designs.
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.

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