

## Dual-Output Low-Dropout Voltage Regulators with Power-Up Sequencing for Split-Voltage DSP Systems

### FEATURES

- **Dual Output Voltages for Split-Supply Applications**
- **Selectable Power-Up Sequencing for DSP Applications**
- **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**
- **Ultra Low 190 $\mu$ A (typ) Quiescent Current**
- **1 $\mu$ A Input Current During Standby**
- **Low Noise: 65 $\mu$ V<sub>RMS</sub> Without Bypass Capacitor**
- **Quick Output Capacitor Discharge Feature**
- **Two Manual Reset Inputs**
- **2% Accuracy Over Load and Temperature**
- **Undervoltage Lockout (UVLO) Feature**
- **20-Pin PowerPAD™ TSSOP Package**
- **Thermal Shutdown Protection**

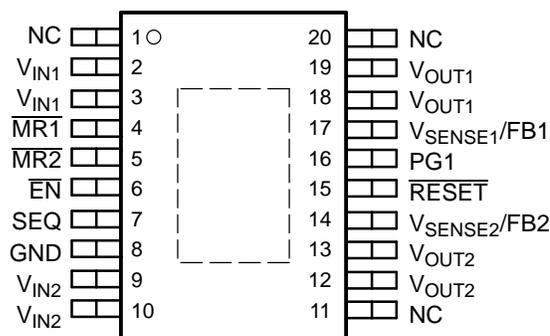
### DESCRIPTION

TPS701xx family devices are designed to provide a complete power management solution for the TMS320™ DSP family, processor power, ASIC, FPGA, and digital applications where dual output voltage regulators are required. Easy programmability of the sequencing function makes the TPS701xx family ideal for any TMS320 DSP applications with power sequencing requirements. Differentiated features, such as accuracy, fast transient response, SVS supervisory circuit, manual reset inputs, and an enable function, provide a complete system solution.

The TPS701xx family of voltage regulators offers very low dropout voltage and dual outputs with power-up sequence control, which is designed primarily for DSP applications. 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 10 $\mu$ F low ESR capacitors.

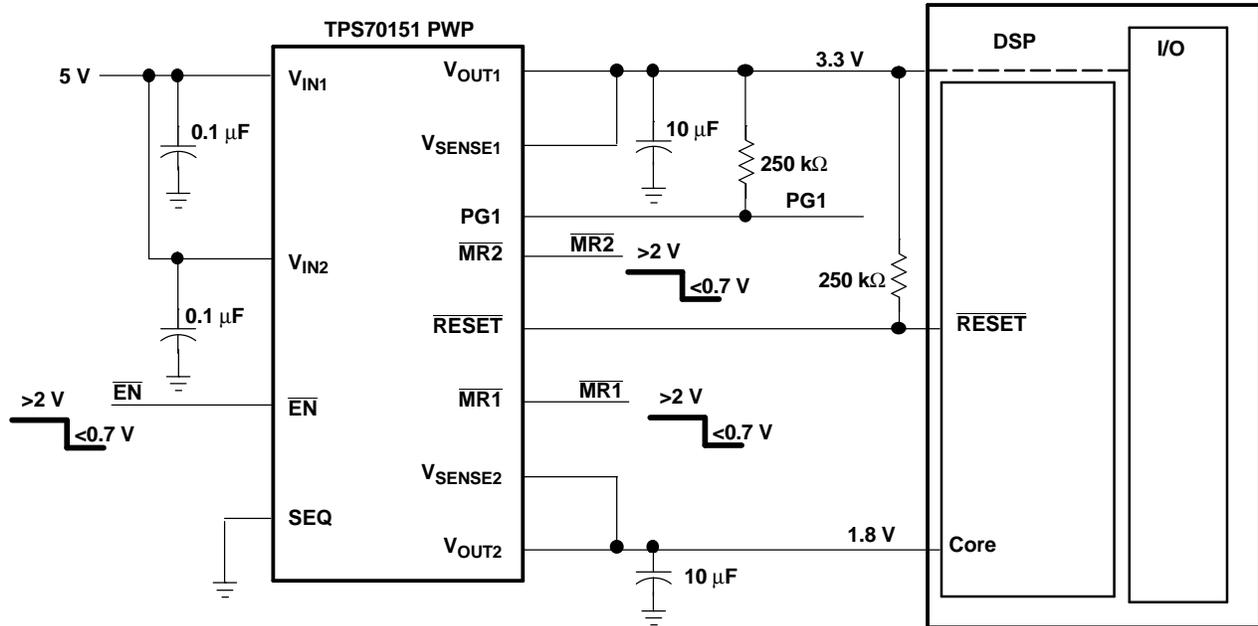
These devices have fixed 3.3V/2.5V, 3.3V/1.8V, 3.3V/1.5V, 3.3V/1.2V, and adjustable/adjustable voltage options. Regulator 1 can support up to 500mA, and regulator 2 can support up to 250mA. Separate voltage inputs allow the designer to configure the source power.

**PWP PACKAGE  
(TOP VIEW)**



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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). This LDO family also features a sleep mode; applying a high signal to  $\overline{\text{EN}}$  (enable) shuts down both regulators, reducing the input current to 1µA at  $T_J = 25^\circ\text{C}$ .

The device is enabled when the  $\overline{\text{EN}}$  pin is connected to a low-level input voltage. The output voltages of the two regulators are sensed at the  $V_{\text{SENSE1}}$  and  $V_{\text{SENSE2}}$  pins, respectively.

The input signal at the SEQ pin controls the power-up sequence of the two regulators. When the device is enabled and the SEQ terminal is pulled high or left open,  $V_{\text{OUT2}}$  turns on first and  $V_{\text{OUT1}}$  remains off until  $V_{\text{OUT2}}$  reaches approximately 83% of its regulated output voltage. At that time  $V_{\text{OUT1}}$  is turned on. If  $V_{\text{OUT2}}$  is pulled below 83% (for example, an overload condition),  $V_{\text{OUT1}}$  is turned off. Pulling the SEQ terminal low reverses the power-up order and  $V_{\text{OUT1}}$  is turned on first. The SEQ pin is connected to an internal pull-up current source.

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 conditions at  $V_{\text{OUT1}}$ , which can be used to implement an SVS for the circuitry supplied by regulator 1.

The TPS701xx features a  $\overline{\text{RESET}}$  (SVS, POR, or Power-On Reset).  $\overline{\text{RESET}}$  output initiates a reset in DSP systems and related digital applications in the event of an undervoltage condition.  $\overline{\text{RESET}}$  indicates the status of  $V_{\text{OUT2}}$  and both manual reset pins ( $\overline{\text{MR1}}$  and  $\overline{\text{MR2}}$ ). When  $V_{\text{OUT2}}$  reaches 95% of its regulated voltage and  $\overline{\text{MR1}}$  and  $\overline{\text{MR2}}$  are in the logic high state,  $\overline{\text{RESET}}$  goes to a high impedance state after a 120ms delay.  $\overline{\text{RESET}}$  goes to the logic low state when the  $V_{\text{OUT2}}$  regulated output voltage is pulled below 95% (for example, an overload condition) of its regulated voltage. To monitor  $V_{\text{OUT1}}$ , the PG1 output pin can be connected to  $\overline{\text{MR1}}$  or  $\overline{\text{MR2}}$ .

The device has an undervoltage lockout (UVLO) circuit which prevents the internal regulators from turning on until  $V_{\text{IN1}}$  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<sup>(1)</sup>

T <sub>J</sub>	REGULATOR 1 V <sub>O</sub> (V)	REGULATOR 2 V <sub>O</sub> (V)	TSSOP (PWP)
-40°C to +125°C	3.3V	1.2V	TPS70145PWP
	3.3V	1.5V	TPS70148PWP
	3.3V	1.8V	TPS70151PWP
	3.3V	2.5V	TPS70158PWP
	Adjustable (1.22V to 5.5V)	Adjustable (1.22V to 5.5V)	TPS70102PWP <sup>(2)</sup>

- (1) For the most current package and ordering information, see the Package Option Addendum located at the end of this data sheet.  
 (2) The TPS70102 is programmable using external resistor dividers (see **Application Information**). The PWP package is available taped and reeled. Add an R suffix to the device type (for example, TPS70102PWPR).

### ABSOLUTE MAXIMUM RATINGS

Over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

	TPS701xx	UNIT
Input voltage range: V <sub>IN1</sub> , V <sub>IN2</sub> <sup>(2)</sup>	-0.3 to +7	V
Voltage range at $\overline{\text{EN}}$	-0.3 to +7	V
Output voltage range (V <sub>OUT1</sub> , V <sub>SENSE1</sub> )	5.5	V
Output voltage range (V <sub>OUT2</sub> , V <sub>SENSE2</sub> )	5.5	V
Maximum RESET, PG1 voltage	7	V
Maximum $\overline{\text{MR1}}$ , $\overline{\text{MR2}}$ , and SEQ voltage	V <sub>IN1</sub>	V
Peak output current	Internally limited	—
Continuous total power dissipation	See Dissipation Ratings Table	—
Junction temperature range, T <sub>J</sub>	-40 to +150	°C
Storage temperature range, T <sub>stg</sub>	-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)	TA ≤ 25°C	DERATING FACTOR	TA = 70°C	TA = 85°C
PWP <sup>(1)</sup>	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, $V_I^{(1)}$	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 junction temperature, $T_J$	-40	+125	°C

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

## ELECTRICAL CHARACTERISTICS

Over recommended operating junction temperature range ( $T_J = -40^\circ\text{C}$  to  $+125^\circ\text{C}$ ),  $V_{IN1}$  or  $V_{IN2} = V_{OUT(\text{nom})} + 1\text{V}$ ,  $I_O = 1\text{mA}$ ,  $\overline{\text{EN}} = 0$ ,  $C_O = 33\mu\text{F}$ , (unless otherwise noted).

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_O$	Reference voltage	$2.7\text{V} < V_I < 6\text{V}$ , $T_J = 25^\circ\text{C}$	FB connected to $V_O$		1.22		V
		$2.7\text{V} < V_I < 6\text{V}$ ,	FB connected to $V_O$	1.196		1.244	
	1.2V Output	$2.7\text{V} < V_I < 6\text{V}$ ,	$T_J = 25^\circ\text{C}$		1.2		
		$2.7\text{V} < V_I < 6\text{V}$ ,		1.176		1.224	
	1.5V Output	$2.7\text{V} < V_I < 6\text{V}$ ,	$T_J = 25^\circ\text{C}$		1.5		
		$2.7\text{V} < V_I < 6\text{V}$ ,		1.47		1.53	
	1.8V Output	$2.7\text{V} < V_I < 6\text{V}$ ,	$T_J = 25^\circ\text{C}$		1.8		
		$2.7\text{V} < V_I < 6\text{V}$ ,		1.764		1.836	
	2.5V Output	$2.7\text{V} < V_I < 6\text{V}$ ,	$T_J = 25^\circ\text{C}$		2.5		
		$2.7\text{V} < V_I < 6\text{V}$ ,		2.45		2.55	
3.3V Output	$2.7\text{V} < V_I < 6\text{V}$ ,	$T_J = 25^\circ\text{C}$		3.3			
	$2.7\text{V} < V_I < 6\text{V}$ ,		3.234		3.366		
Quiescent current (GND current) for regulator 1 and regulator 2, $\overline{\text{EN}} = 0\text{V}^{(1)}$		<sup>(2)</sup>	$T_J = 25^\circ\text{C}$		190		$\mu\text{A}$
		<sup>(2)</sup>				230	
Output voltage line regulation ( $\Delta V_O/V_O$ ) for regulator 1 and regulator 2 <sup>(3)</sup>		$V_O + 1\text{V} < V_I \leq 6\text{V}$ ,	$T_J = 25^\circ\text{C}^{(1)}$		0.01%		V
		$V_O + 1\text{V} < V_I \leq 6\text{V}$	<sup>(1)</sup>			0.1%	
Load regulation for $V_{OUT1}$ and $V_{OUT2}$		$T_J = 25^\circ\text{C}$	<sup>(2)</sup>		1		mV
$V_n$	Output noise voltage	Regulator 1	BW 300Hz to 50kHz, $C_O = 33\mu\text{F}$ , $T_J = 25^\circ\text{C}$		65		$\mu\text{V}_{\text{RMS}}$
		Regulator 2			65		
Output current limit		Regulator 1	$V_{OUT} = 0\text{V}$		1.6	1.9	A
		Regulator 2			0.750	1	
Thermal shutdown junction temperature					150		°C
$I_i$	Standby current (standby)	Regulator 1	$\overline{\text{EN}} = V_I$ ,	$T_J = 25^\circ\text{C}$		1	$\mu\text{A}$
			$\overline{\text{EN}} = V_I$			3	
		Regulator 2	$\overline{\text{EN}} = V_I$ ,	$T_J = 25^\circ\text{C}$		1	$\mu\text{A}$
			$\overline{\text{EN}} = V_I$			3	
PSRR	Power-supply ripple rejection	$f = 1\text{kHz}$ , $C_O = 33\mu\text{F}$ ,	$T_J = 25^\circ\text{C}^{(1)}$		60		dB

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

(2)  $I_O = 1\text{mA}$  to 500mA for Regulator 1 and 1mA to 250mA for Regulator 2.

(3) If  $V_O \leq 1.8\text{V}$  then  $V_{I\text{max}} = 6\text{V}$ ,  $V_{I\text{min}} = 2.7\text{V}$ : 
$$\text{Line Reg. (mV)} = (\% / \text{V}) \times V_O \frac{(V_{I\text{max}} - 2.7\text{V})}{100} \times 1000$$
  
 If  $V_O \geq 2.5\text{V}$  then  $V_{I\text{max}} = 6\text{V}$ ,  $V_{I\text{min}} = V_O + 1\text{V}$ : 
$$\text{Line Reg. (mV)} = (\% / \text{V}) \times V_O \frac{(V_{I\text{max}} - (V_O + 1\text{V}))}{100} \times 1000$$

**ELECTRICAL CHARACTERISTICS (continued)**

Over recommended operating junction temperature range ( $T_J = -40^\circ\text{C}$  to  $+125^\circ\text{C}$ ),  $V_{IN1}$  or  $V_{IN2} = V_{OUT(nom)} + 1\text{V}$ ,  $I_O = 1\text{mA}$ ,  $\overline{\text{EN}} = 0$ ,  $C_O = 33\mu\text{F}$ , (unless otherwise noted).

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>RESET Terminal</b>					
Minimum input voltage for valid RESET	$I_{\text{RESET}} = 300\mu\text{A}$ , $V_{(\text{RESET})} \leq 0.8\text{V}$		1.0	1.3	V
Trip threshold voltage	$V_O$ decreasing	92%	95%	98%	$V_{\text{OUT}}$
Hysteresis voltage	Measured at $V_O$		0.5%		$V_{\text{OUT}}$
$t_{(\text{RESET})}$	RESET pulse duration	80	120	160	ms
$t_{r(\text{RESET})}$	Rising edge deglitch		30		$\mu\text{s}$
Output low voltage	$V_I = 3.5\text{V}$ , $I_{O(\text{RESET})} = 1\text{mA}$		0.15	0.4	V
Leakage current	$V_{(\text{RESET})} = 6\text{V}$			1	$\mu\text{A}$
<b>PG1 Terminal</b>					
Minimum input voltage for valid PG1	$I_{(\text{PG1})} = 300\mu\text{A}$ , $V_{(\text{PG1})} \leq 0.8\text{V}$		1.0	1.3	V
Trip threshold voltage	$V_O$ decreasing	92%	95%	98%	$V_{\text{OUT}}$
Hysteresis voltage	Measured at $V_O$		0.5%		$V_{\text{OUT}}$
$t_{r(\text{PG1})}$	Rising edge deglitch		30		$\mu\text{s}$
Output low voltage	$V_I = 2.7\text{V}$ , $I_{O(\text{PG1})} = 1\text{mA}$		0.15	0.4	V
Leakage current	$V_{(\text{PG1})} = 6\text{V}$			1	$\mu\text{A}$
<b>EN Terminal</b>					
High level $\overline{\text{EN}}$ input voltage		2			V
Low level $\overline{\text{EN}}$ input voltage				0.7	V
Input current ( $\overline{\text{EN}}$ )		-1		1	$\mu\text{A}$
Falling edge deglitch	Measured at $V_O$		140		$\mu\text{s}$
<b>SEQ Terminal</b>					
High level SEQ input voltage		2			V
Low level SEQ input voltage				0.7	V
Falling edge deglitch	Measured at $V_O$		140		$\mu\text{s}$
SEQ pull-up current source			6		$\mu\text{A}$
<b>MR1 / MR2 Terminals</b>					
High level input voltage		2			V
Low level input voltage				0.7	V
Falling edge deglitch	Measured at $V_O$		140		$\mu\text{s}$
Pull-up current source			6		$\mu\text{A}$
<b><math>V_{\text{OUT2}}</math> Terminal</b>					
$V_{\text{OUT2}}$ UV comparator: Positive-going input threshold voltage of $V_{\text{OUT2}}$ UV comparator		80% $V_O$	83% $V_O$	86% $V_O$	V
$V_{\text{OUT2}}$ UV comparator: Hysteresis			0.5% $V_O$		mV
$V_{\text{OUT2}}$ UV comparator: Falling edge deglitch	$V_{\text{SENSE}_2}$ decreasing below threshold		140		$\mu\text{s}$
Peak output current	2ms pulse width		375		mA
Discharge transistor current	$V_{\text{OUT2}} = 1.5\text{V}$		7.5		mA
<b><math>V_{\text{OUT1}}</math> Terminal</b>					
$V_{\text{OUT1}}$ UV comparator: Positive-going input threshold voltage of $V_{\text{OUT1}}$ UV comparator		80% $V_O$	83% $V_O$	86% $V_O$	V
$V_{\text{OUT1}}$ UV comparator: Hysteresis			0.5% $V_O$		mV
$V_{\text{OUT1}}$ UV comparator: Falling edge deglitch	$V_{\text{SENSE}_1}$ decreasing below threshold		140		$\mu\text{s}$

## ELECTRICAL CHARACTERISTICS (continued)

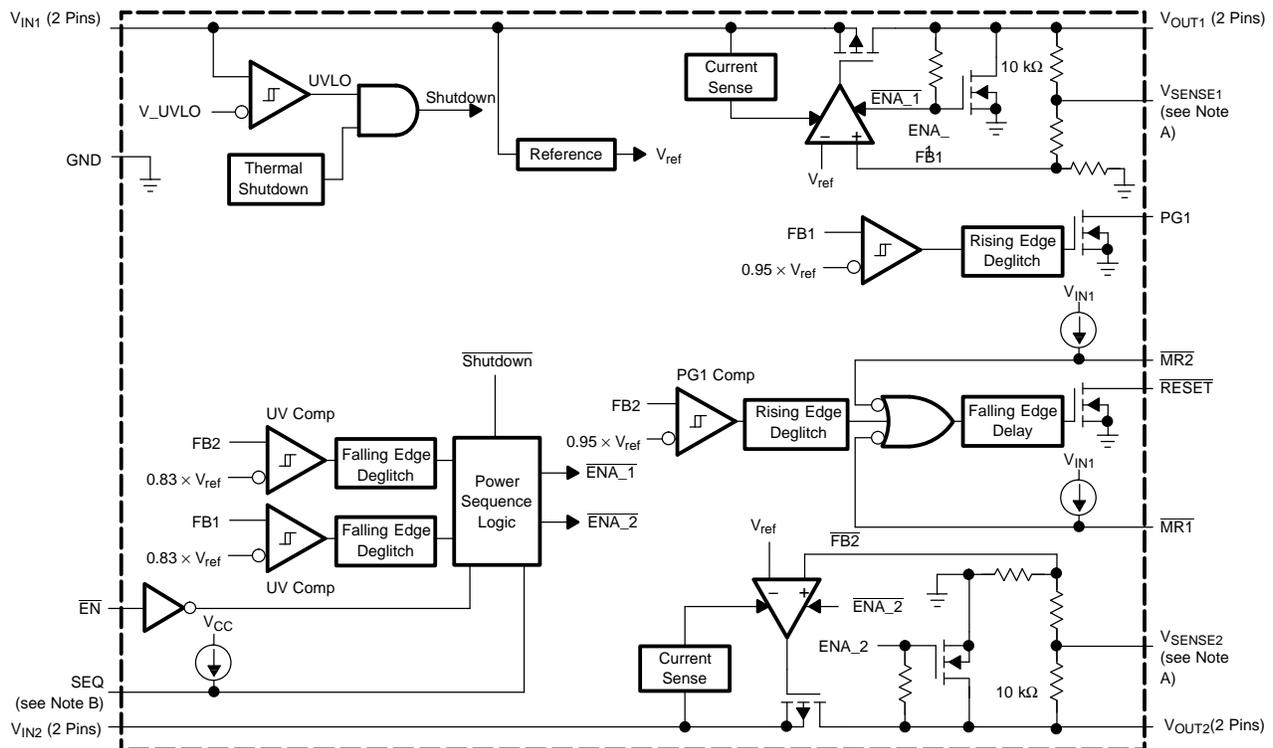
Over recommended operating junction temperature range ( $T_J = -40^\circ\text{C}$  to  $+125^\circ\text{C}$ ),  $V_{IN1}$  or  $V_{IN2} = V_{OUT(nom)} + 1\text{V}$ ,  $I_O = 1\text{mA}$ ,  $\overline{\text{EN}} = 0$ ,  $C_O = 33\mu\text{F}$ , (unless otherwise noted).

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Dropout voltage <sup>(4)</sup>	$I_O = 500\text{mA}$ , $T_J = 25^\circ\text{C}$ $V_{IN1} = 3.2\text{V}$		170		mV
Dropout voltage <sup>(4)</sup>	$I_O = 500\text{mA}$ , $V_{IN1} = 3.2\text{V}$			275	mV
Peak output current <sup>(4)</sup>	2ms pulse width		750		mA
Discharge transistor current	$V_{OUT1} = 1.5\text{V}$		7.5		mA
UVLO threshold		2.4		2.65	V
<b>FB Terminal</b>					
Input current: TPS70102	$\text{FB} = 1.8\text{V}$		1		$\mu\text{A}$

(4) Input voltage ( $V_{IN1}$  or  $V_{IN2}$ ) =  $V_{O(typ)} - 100\text{mV}$ . 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

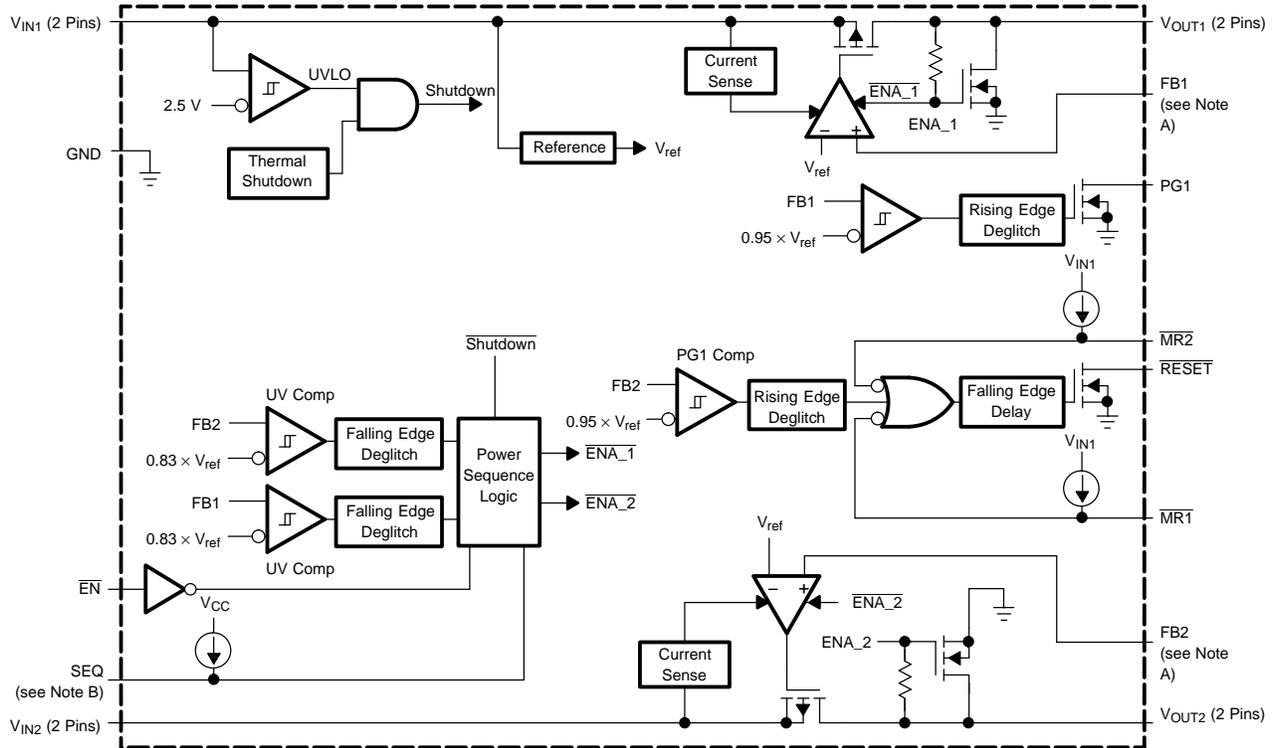
### Fixed Voltage Version



- For most applications,  $V_{SENSE1}$  and  $V_{SENSE2}$  should be externally connected to  $V_{OUT}$  as close as possible to the device. For other implementations, refer to SENSE terminal connection discussion in the **Application Information** section.
- If the SEQ terminal is floating at the input,  $V_{OUT2}$  powers up first.

**DEVICE INFORMATION (continued)**

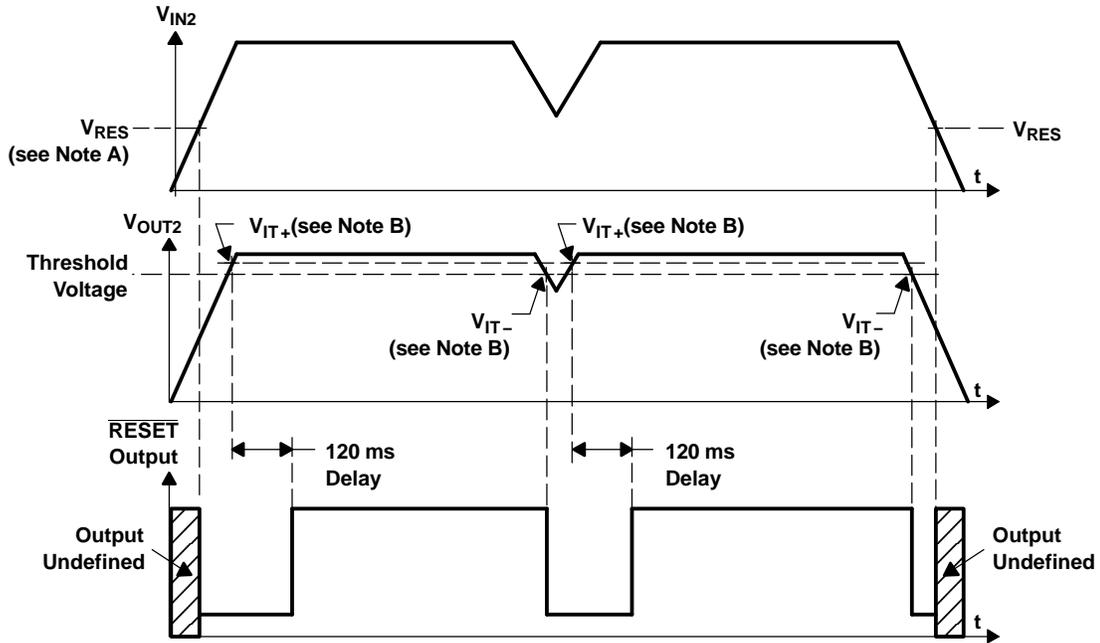
**Adjustable Voltage Version**



- 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.
- B. If the SEQ terminal is floating at the input, V<sub>OUT2</sub> powers up first

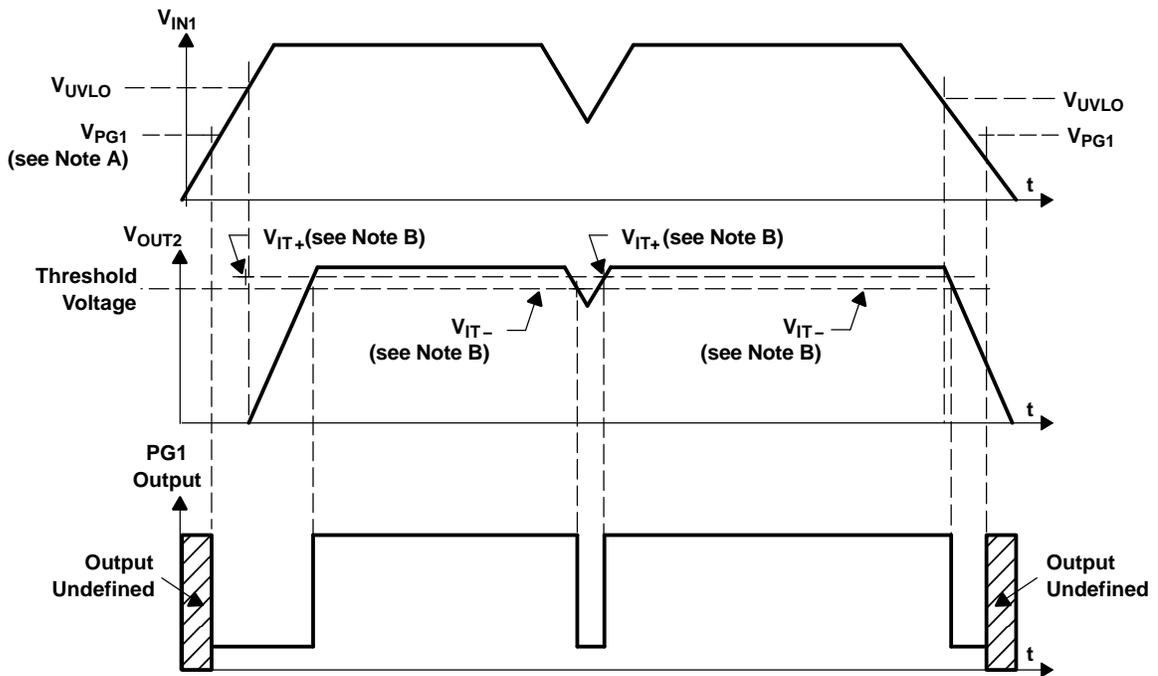
DEVICE INFORMATION (continued)

RESET Timing Diagram (with  $V_{IN1}$  Powered Up)



- NOTES: A.  $V_{RES}$  is the minimum input voltage for a valid RESET. The symbol  $V_{RES}$  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.

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.

## DEVICE INFORMATION (continued)

**Table 1. TERMINAL FUNCTIONS**

TERMINAL		I/O	DESCRIPTION
NAME	NO.		
$\overline{\text{EN}}$	6	I	Active low enable
GND	8	—	Ground
MR1	4	I	Manual reset input 1, active low, pulled up internally
$\overline{\text{MR2}}$	5	I	Manual reset input 2, active low, pulled up internally
NC	1, 11, 20	—	No connection
PG1	16	O	Open drain output, low when $V_{\text{OUT1}}$ voltage is less than 95% of the nominal regulated voltage
RESET	15	O	Open drain output, SVS (power-on reset) signal, active low
SEQ	7	I	Power-up sequence control: SEQ = High, $V_{\text{OUT2}}$ powers up first; SEQ = Low, $V_{\text{OUT1}}$ powers up first, SEQ terminal pulled up internally.
$V_{\text{IN1}}$	2, 3	I	Input voltage of regulator 1
$V_{\text{IN2}}$	9, 10	I	Input voltage of regulator 2
$V_{\text{OUT1}}$	18, 19	O	Output voltage of regulator 1
$V_{\text{OUT2}}$	12, 13	O	Output voltage of regulator 2
$V_{\text{SENSE2}}/\text{FB2}$	14	I	Regulator 2 output voltage sense/regulator 2 feedback for adjustable
$V_{\text{SENSE1}}/\text{FB1}$	17	I	Regulator 1 output voltage sense/regulator 1 feedback for adjustable

### Detailed Description

The TPS701xx low dropout regulator family provides dual regulated output voltages for DSP applications which require high performance power management solutions. These devices provide fast transient response and high accuracy with small output capacitors, while drawing low quiescent current. Programmable sequencing provides a power solution for DSPs without any external component requirements. This reduces the component cost and board space while increasing total system reliability. The TPS701xx family has an enable feature which puts the device in sleep mode reducing the input currents to less than 3 $\mu\text{A}$ . Other features are integrated SVS (Power-On Reset, RESET) and Power Good (PG1) that monitor output voltages and provide logic output to the system. These differentiated features provide a complete DSP power solution.

The TPS701xx, unlike many other LDOs, feature very low quiescent current which 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 TPS701xx uses a PMOS transistor to pass current; because the gate of the PMOS is voltage-driven, operating current is low and stable over the full load range.

### Pin Functions

#### Enable

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

#### Sequence

The SEQ terminal is an input that programs which output voltage ( $V_{\text{OUT1}}$  or  $V_{\text{OUT2}}$ ) is turned on first. When the device is enabled and the SEQ terminal is pulled high or left open,  $V_{\text{OUT2}}$  turns on first and  $V_{\text{OUT1}}$  remains off until  $V_{\text{OUT2}}$  reaches approximately 83% of its regulated output voltage. At that time,  $V_{\text{OUT1}}$  is turned on. If  $V_{\text{OUT2}}$  is pulled below 83% (for example, an overload condition)  $V_{\text{OUT1}}$  is turned off. These terminals have a 6 $\mu\text{A}$  pullup current to  $V_{\text{IN1}}$ .

Pulling the SEQ terminal low reverses the power-up order and  $V_{\text{OUT1}}$  is turned on first. For detailed timing diagrams, refer to Figure 40 through Figure 44.

### Power-Good

The PG1 is an open drain, active high output terminal which indicates the status of the  $V_{OUT1}$  regulator. When the  $V_{OUT1}$  reaches 95% of its regulated voltage, PG1 will go to a high impedance state. It will go to a low impedance state when it is pulled below 95% (for example, an overload condition) of its regulated voltage. The open drain output of the PG1 terminal requires a pull-up resistor.

### Manual Reset Pins ( $\overline{MR1}$ and $\overline{MR2}$ )

$\overline{MR1}$  and  $\overline{MR2}$  are active low input terminals used to trigger a reset condition. When either  $\overline{MR1}$  or  $\overline{MR2}$  is pulled to logic low, a POR ( $\overline{RESET}$ ) will occur. These terminals have a 6 $\mu$ A pull-up current to  $V_{IN1}$ .

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

The sense terminals of fixed-output options must be connected to the regulator output, and the connection should be as short as possible. Internally, sense 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 to minimize/avoid noise pickup. Adding RC networks between the  $V_{SENSE}$  terminals and  $V_{OUT}$  terminals to filter noise is not recommended because it 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/avoid noise pickup. Adding RC networks between the FB terminals and  $V_{OUT}$  terminals to filter noise is not recommended because it can cause the regulators to oscillate.

### $\overline{RESET}$ Indicator

The TPS701xx features a  $\overline{RESET}$  (SVS, POR, or Power-On Reset).  $\overline{RESET}$  can be used to drive power-on reset circuitry or a low-battery indicator.  $\overline{RESET}$  is an active low, open drain output which indicates the status of the  $V_{OUT2}$  regulator and both manual reset pins ( $\overline{MR1}$  and  $\overline{MR2}$ ). When  $V_{OUT2}$  exceeds 95% of its regulated voltage, and  $\overline{MR1}$  and  $\overline{MR2}$  are in the high impedance state,  $\overline{RESET}$  will go to a high-impedance state after 120ms delay.  $\overline{RESET}$  will go to a low-impedance state when  $V_{OUT2}$  is pulled below 95% (for example, an overload condition) of its regulated voltage. To monitor  $V_{OUT1}$ , the PG1 output pin can be connected to  $\overline{MR1}$  or  $\overline{MR2}$ . The open drain output of the  $\overline{RESET}$  terminal requires a pullup resistor. If  $\overline{RESET}$  is not used, it can be left floating.

### $V_{IN1}$ and $V_{IN2}$

$V_{IN1}$  and  $V_{IN2}$  are input to the regulators. Internal bias voltages are powered by  $V_{IN1}$ .

### $V_{OUT1}$ and $V_{OUT2}$

$V_{OUT1}$  and  $V_{OUT2}$  are output terminals of the LDO.

## TYPICAL CHARACTERISTICS

Table 2. Table of Graphs

			FIGURE
$V_O$	Output voltage	vs Output current	1 - 3
		vs Temperature	4 - 7
	Ground current	vs Junction temperature	8
PSRR	Power-supply rejection ratio	vs Frequency	9 - 12
		Output spectral noise density	vs Frequency
$Z_O$	Output impedance	vs Frequency	17 - 20
		vs Temperature	21, 22
		vs Input voltage	23, 24
	Load transient response		25, 26
	Line transient response		27, 28
$V_O$	Output voltage and enable voltage	vs Time (start-up)	29, 30
		Equivalent series resistance	vs Output current
	Test circuit for typical regions of stability (equivalent series resistance) performance		39

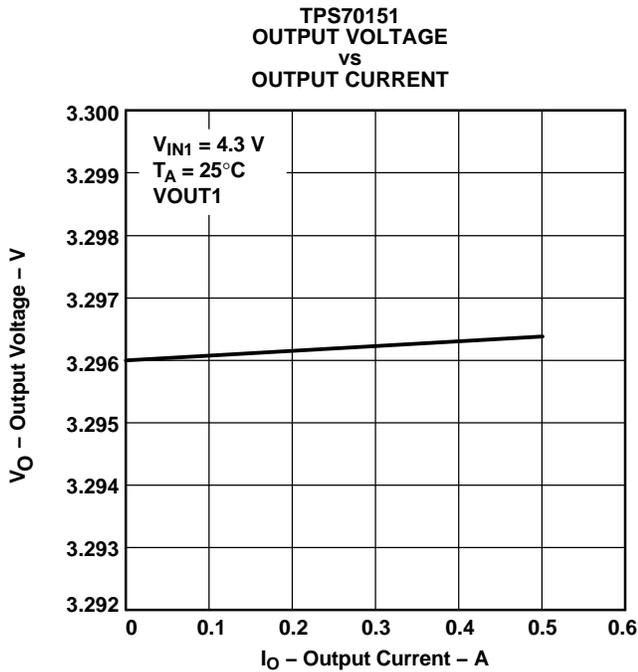


Figure 1.

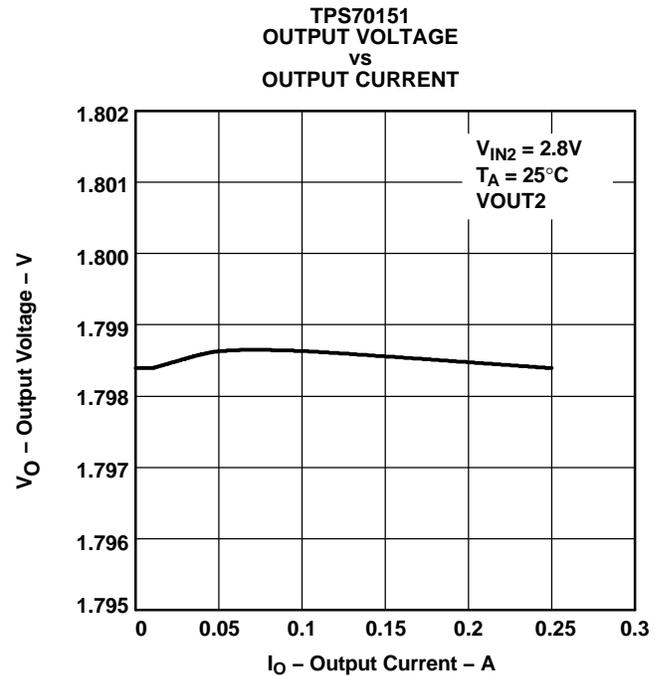


Figure 2.

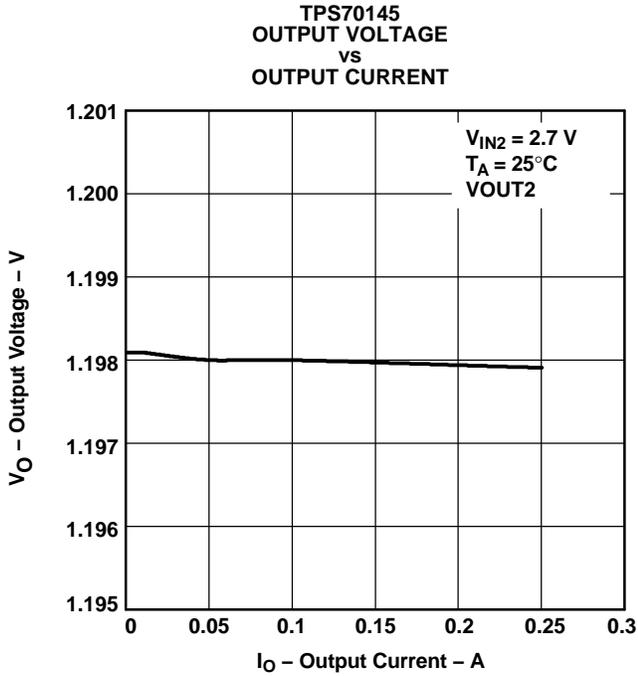


Figure 3.

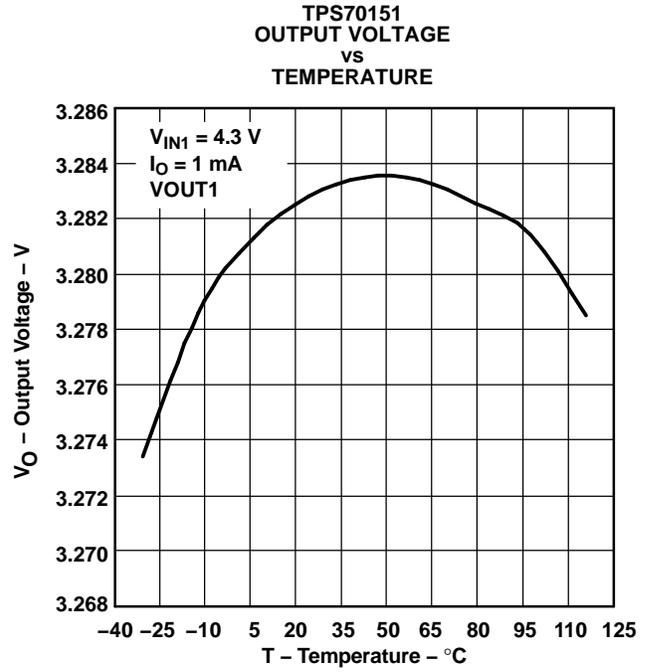


Figure 4.

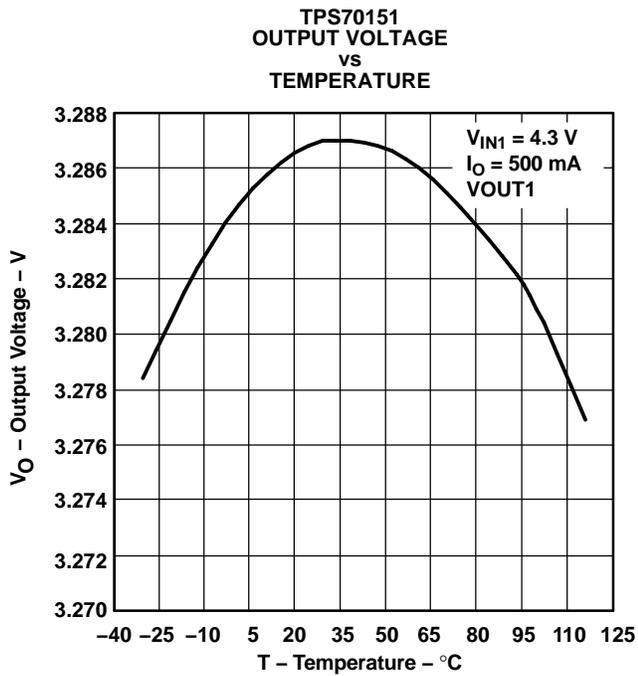


Figure 5.

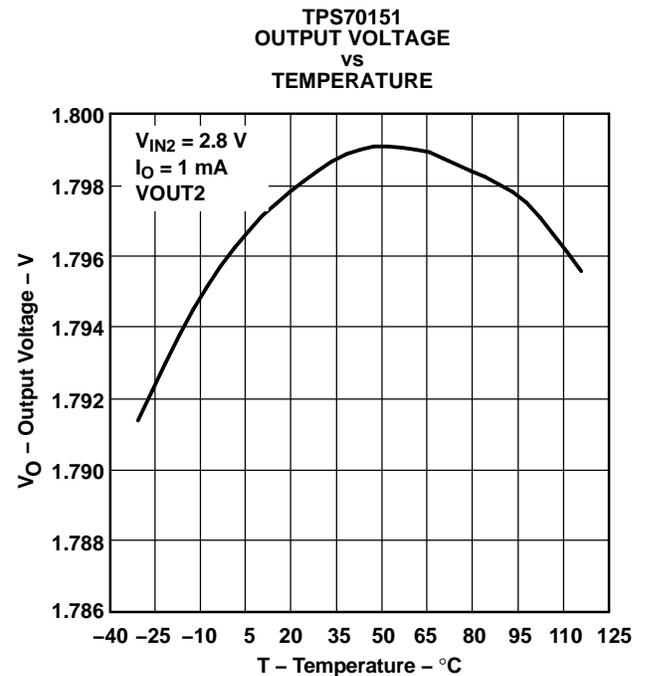


Figure 6.

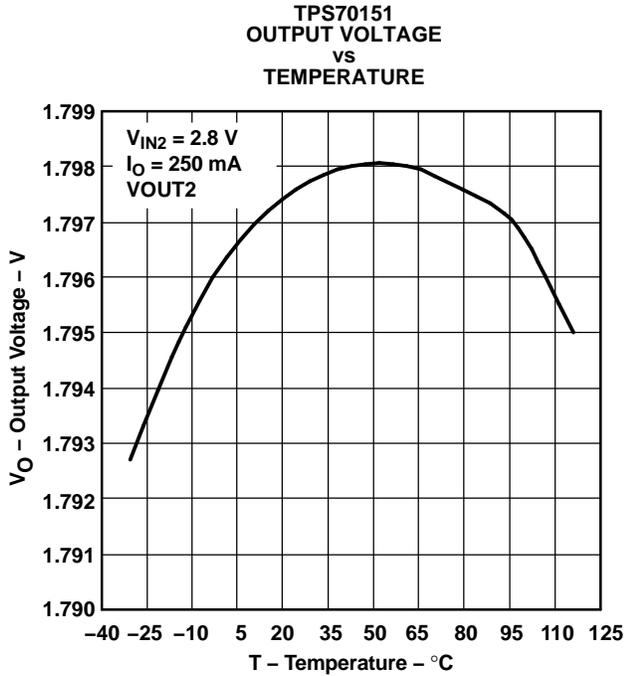


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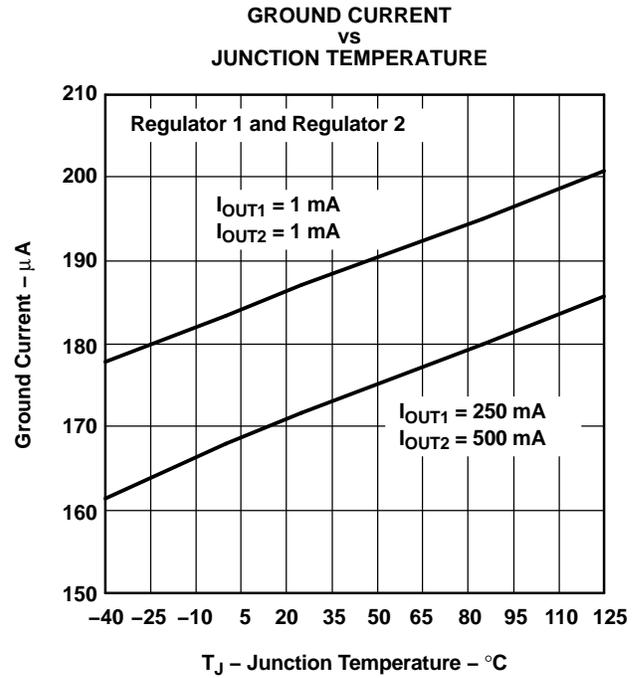


Figure 8.

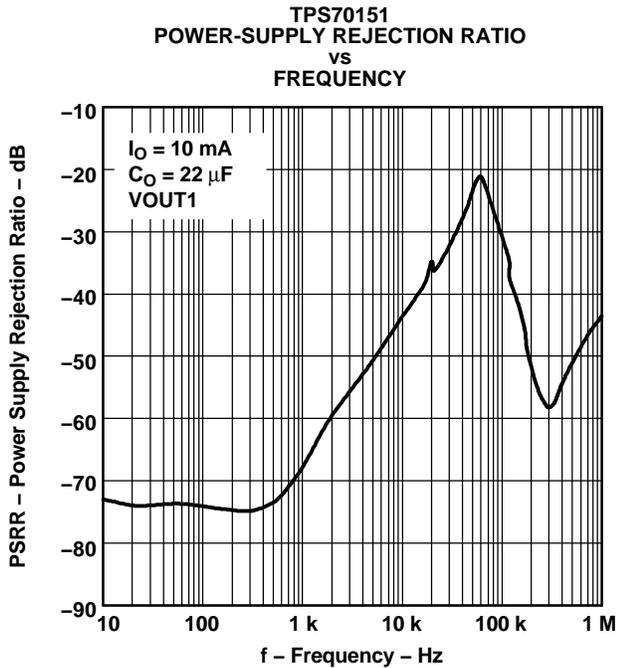


Figure 9.

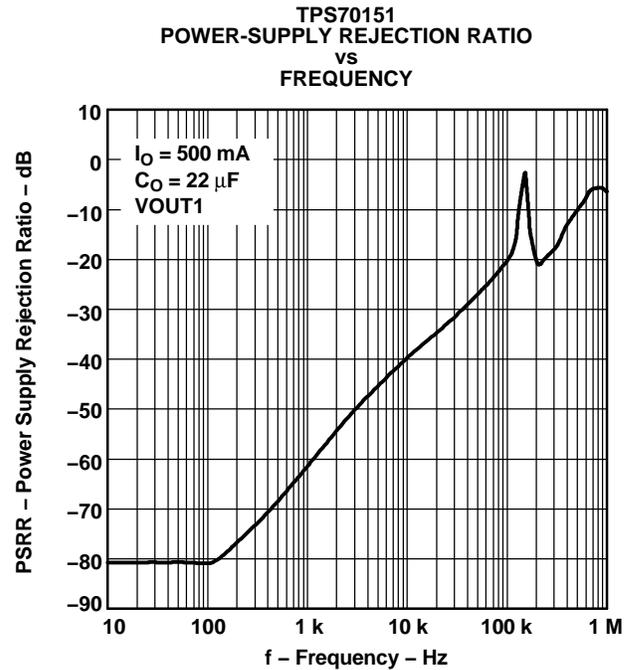


Figure 10.

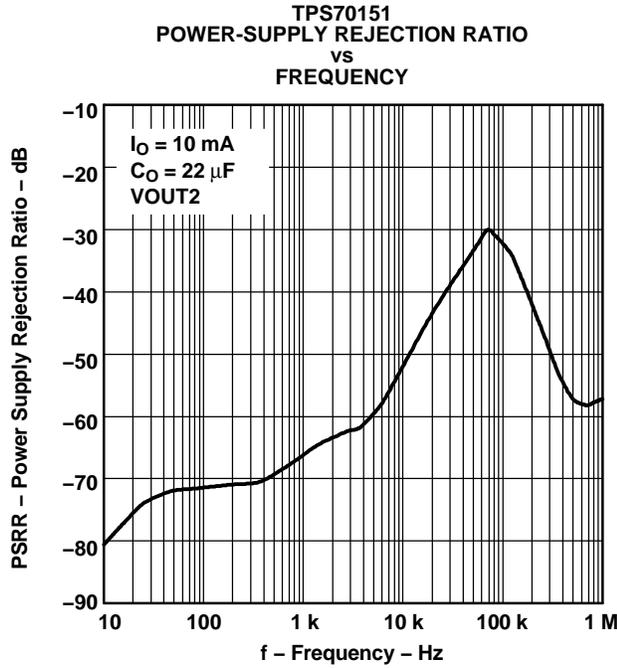


Figure 11.

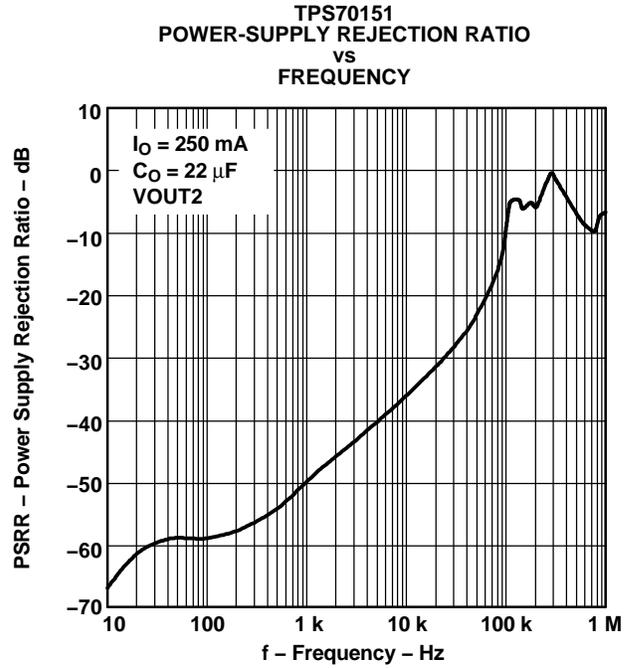


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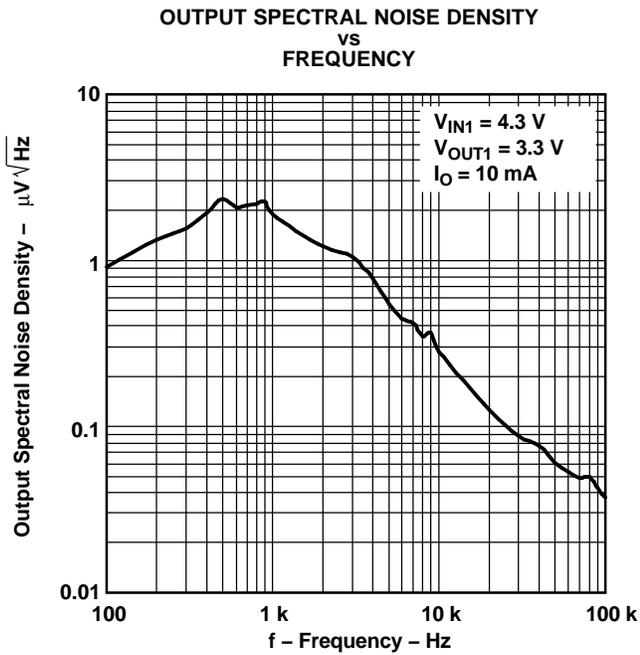


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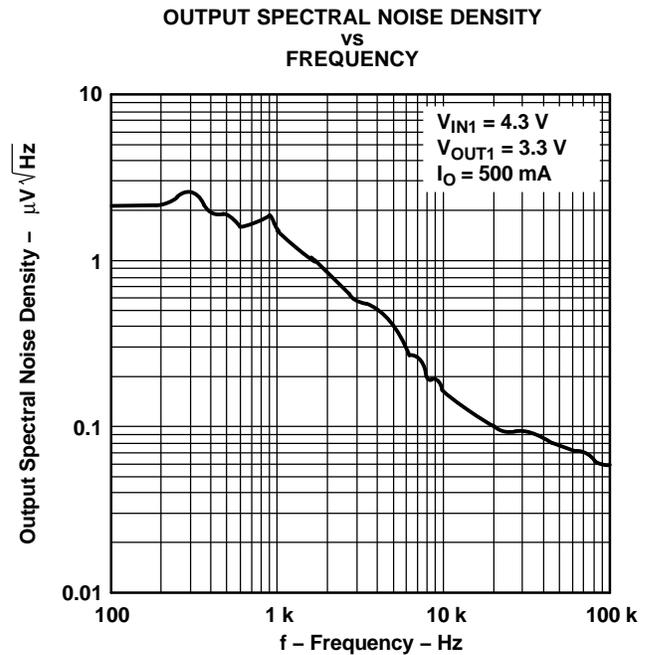


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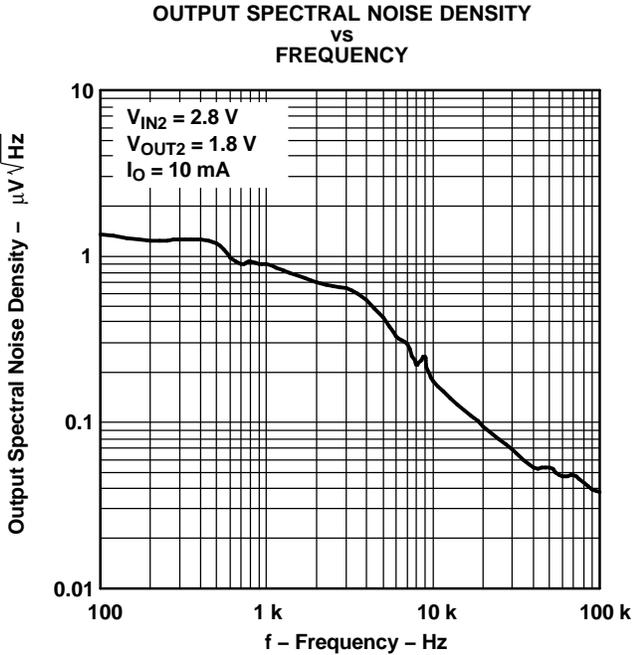


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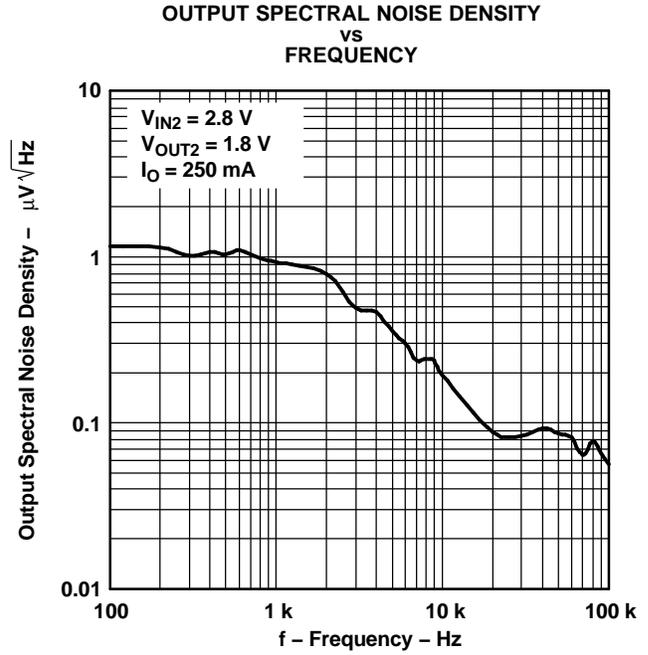


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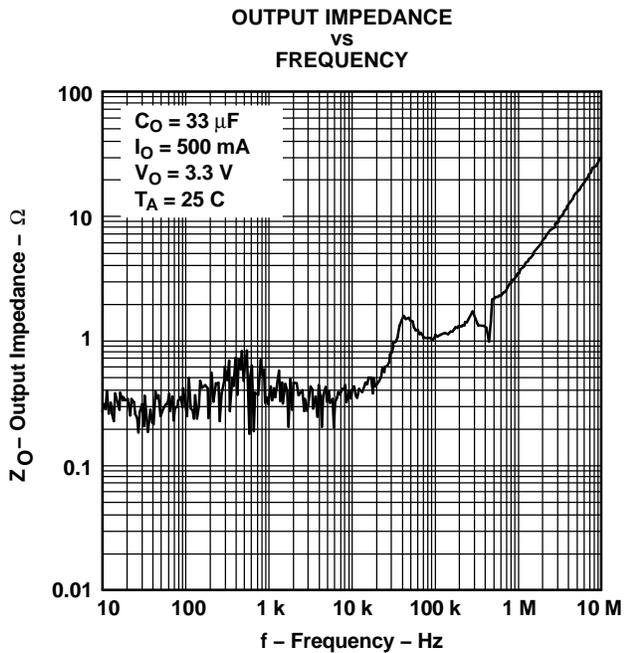


Figure 17.

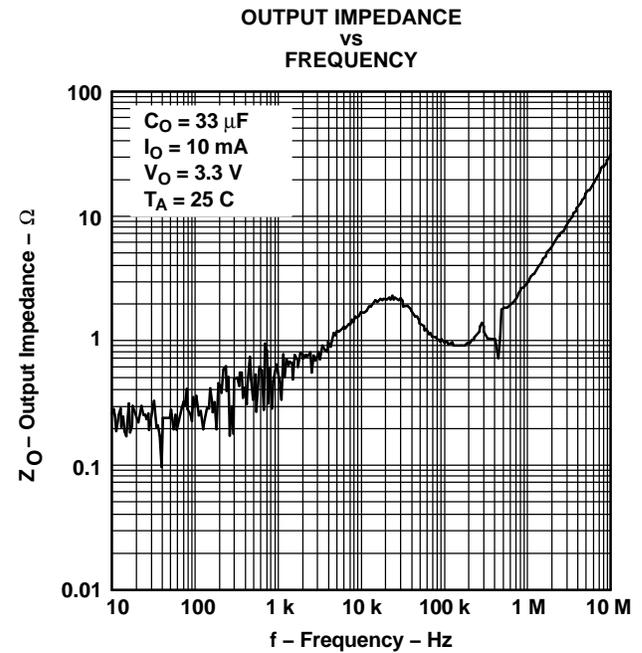


Figure 18.

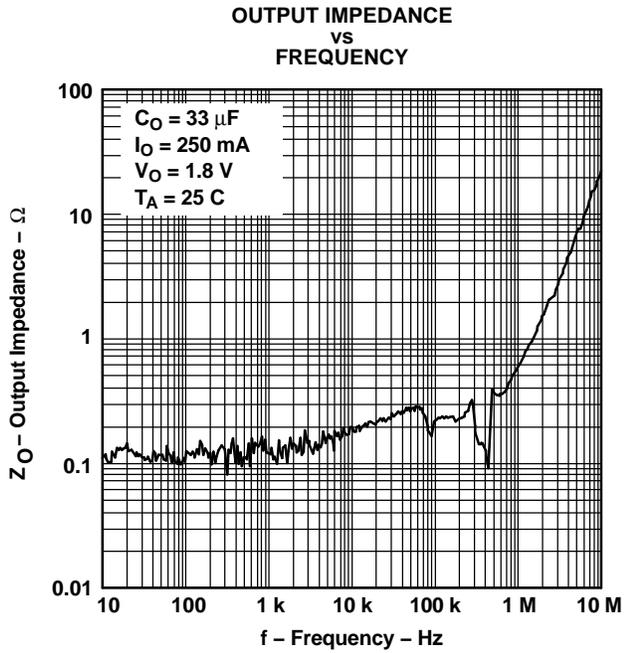


Figure 19.

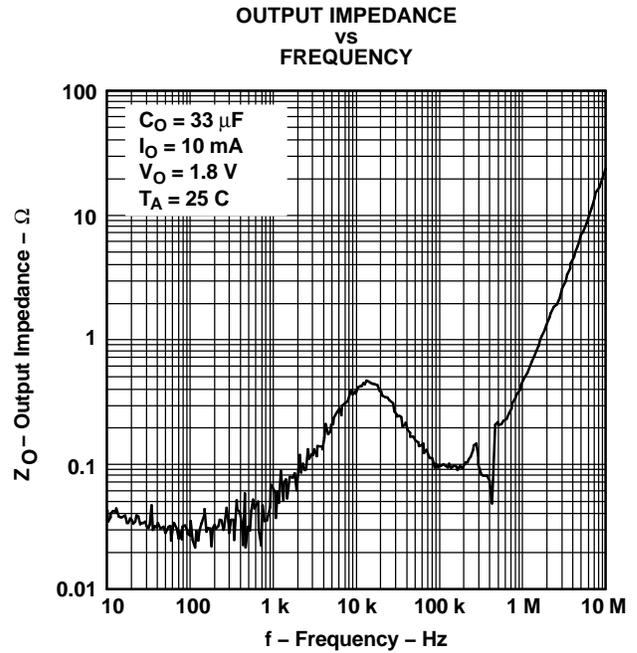


Figure 20.

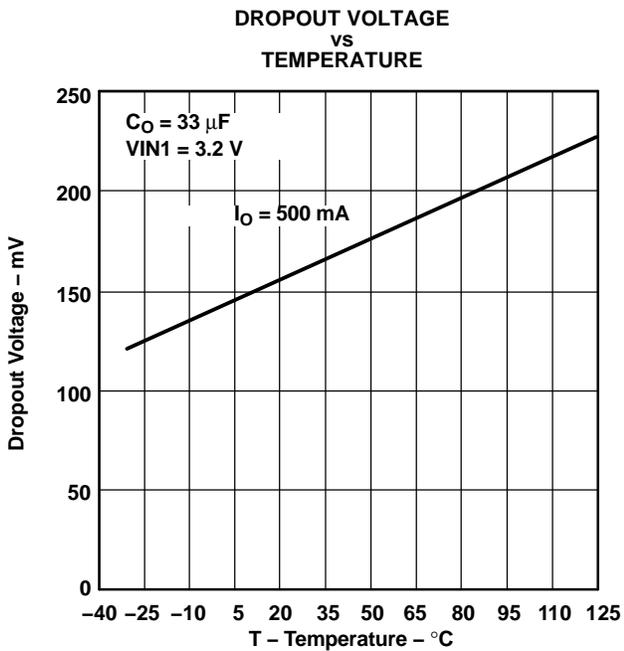


Figure 21.

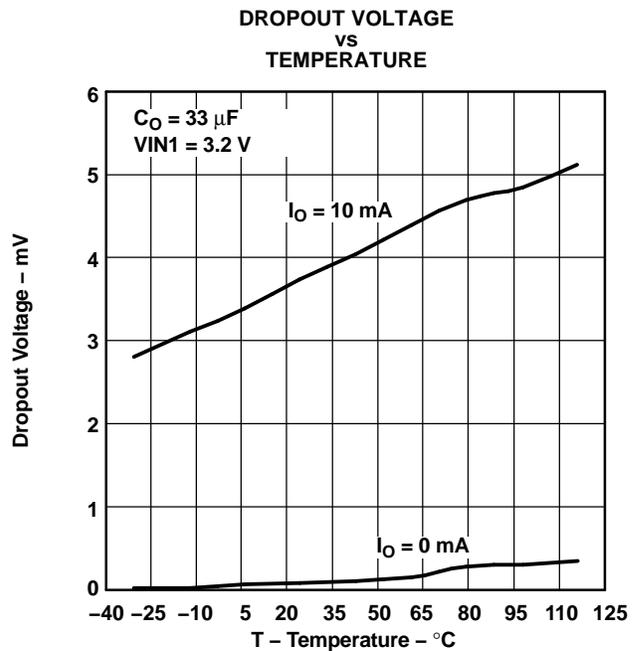


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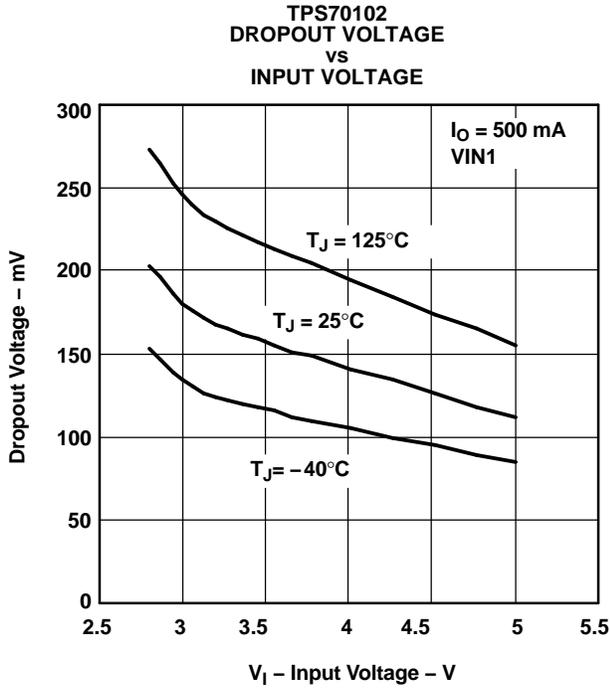


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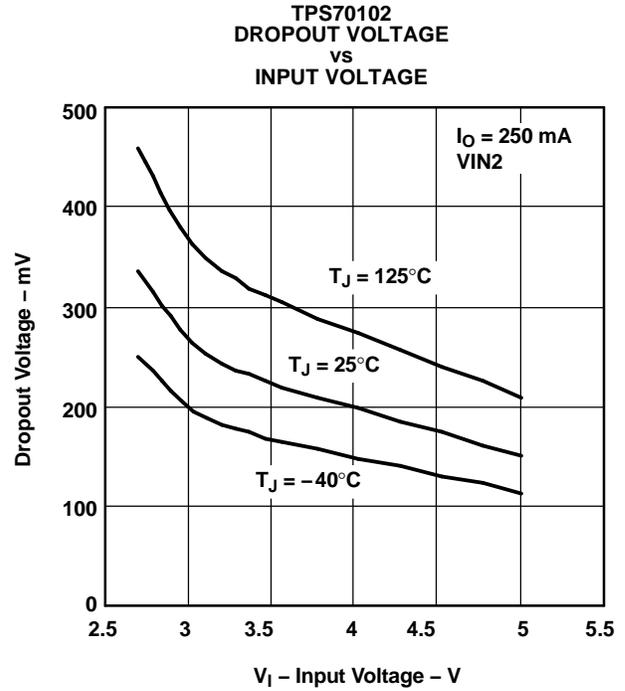


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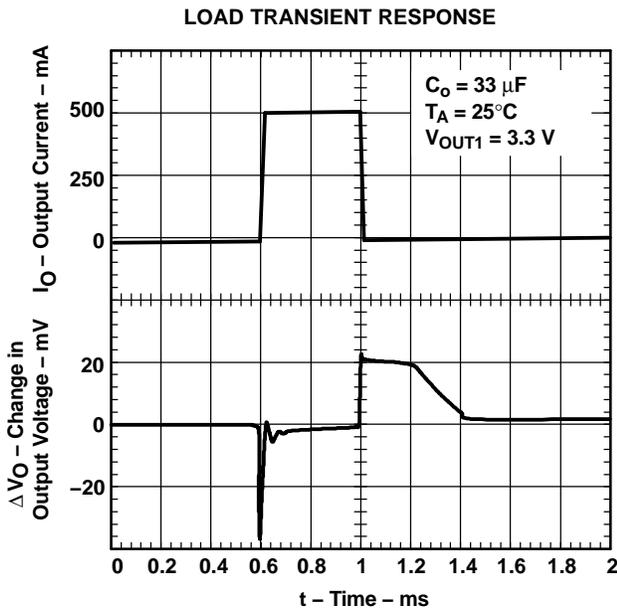


Figure 25.

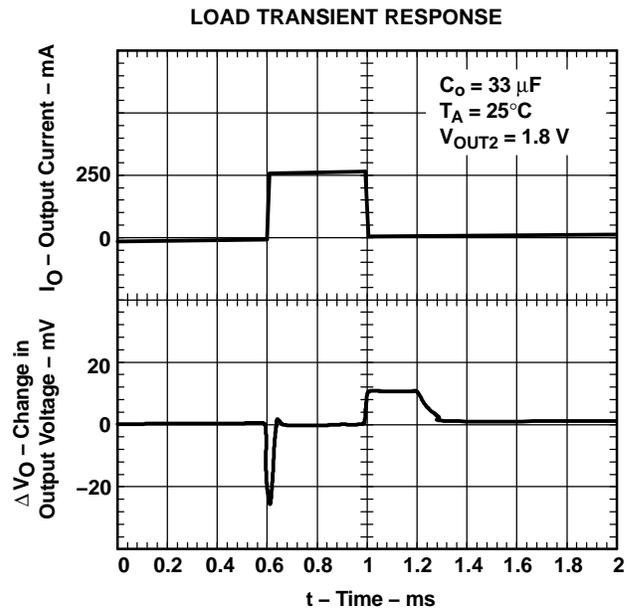


Figure 26.

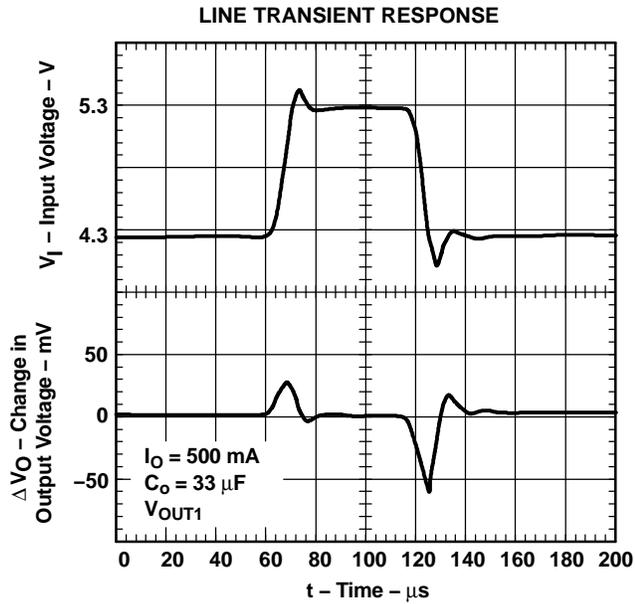


Figure 27.

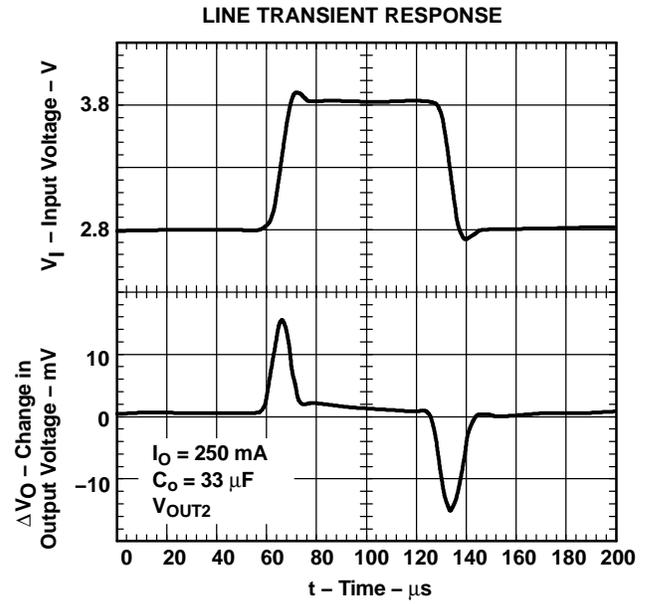


Figure 28.

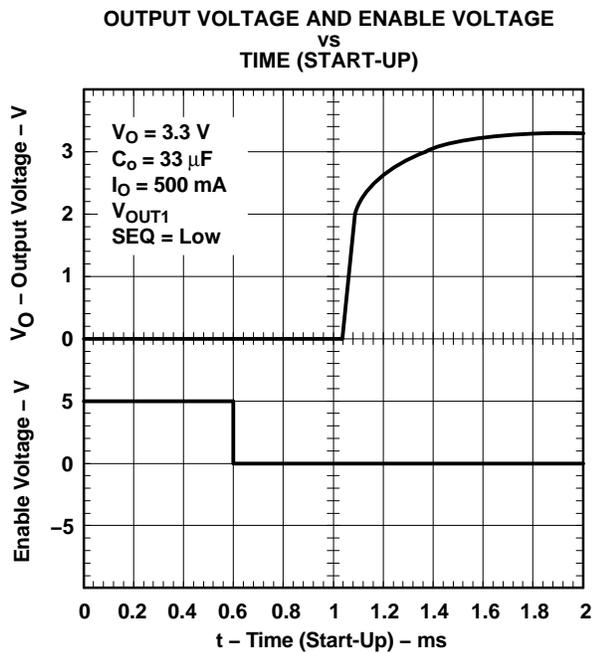


Figure 29.

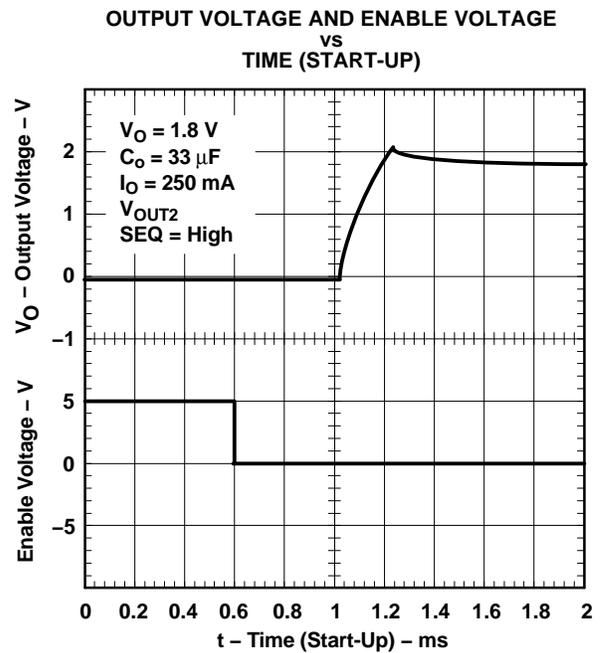


Figure 30.

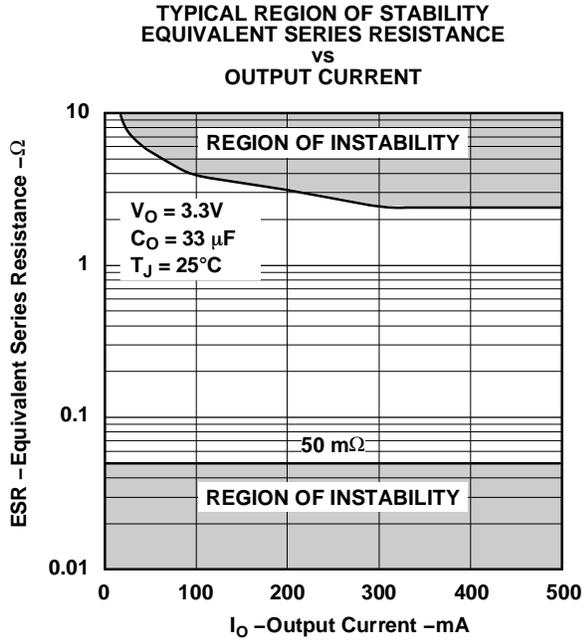


Figure 31.

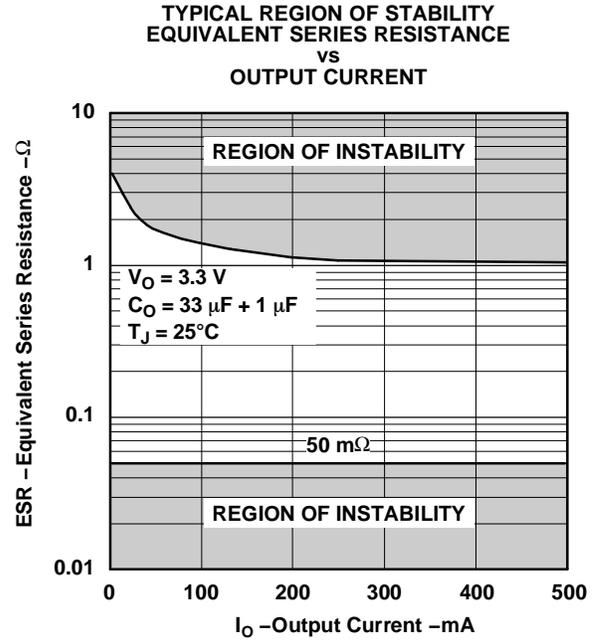


Figure 32.

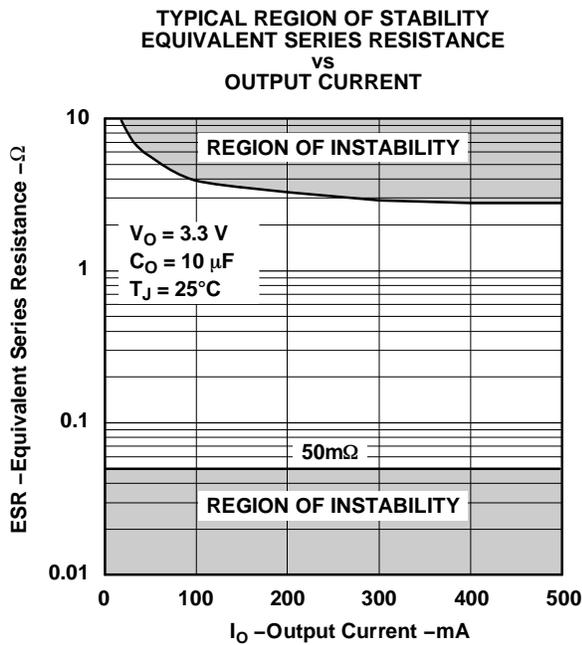


Figure 33.

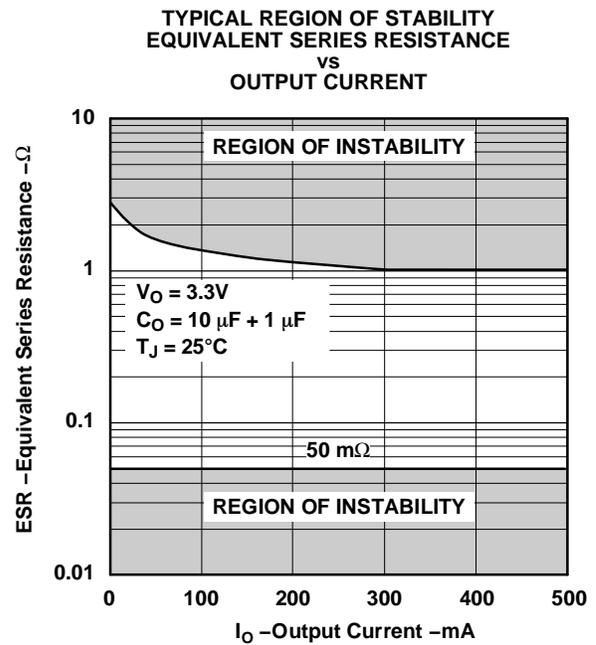


Figure 34.

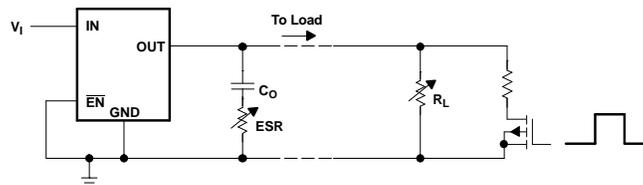
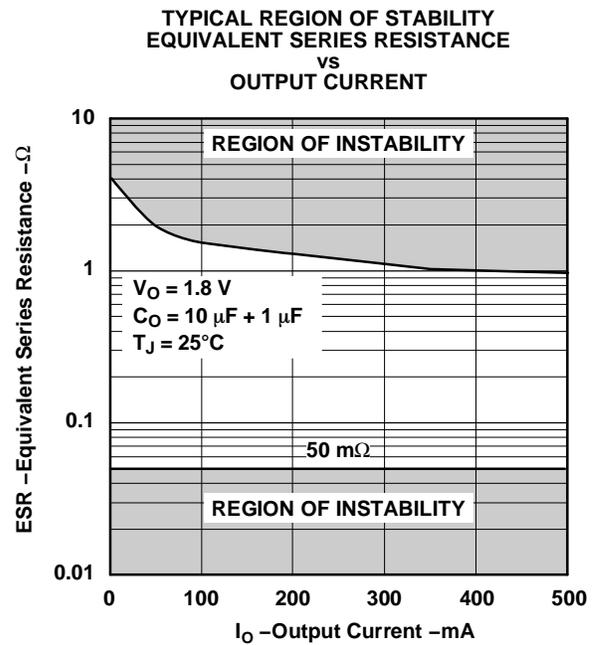
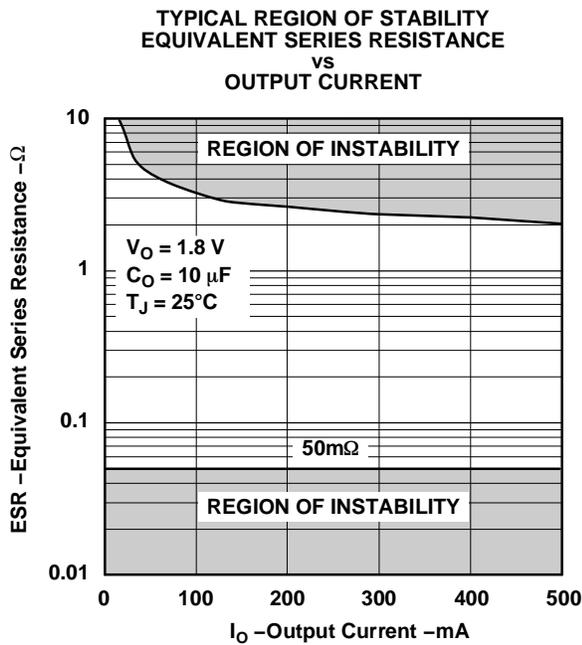
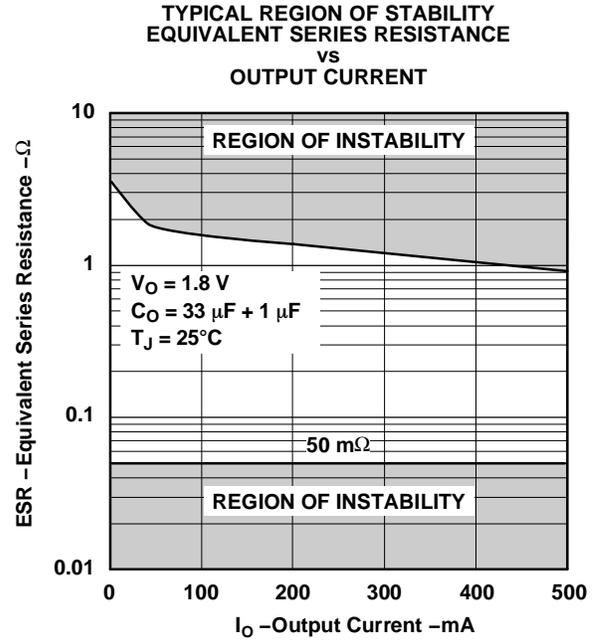
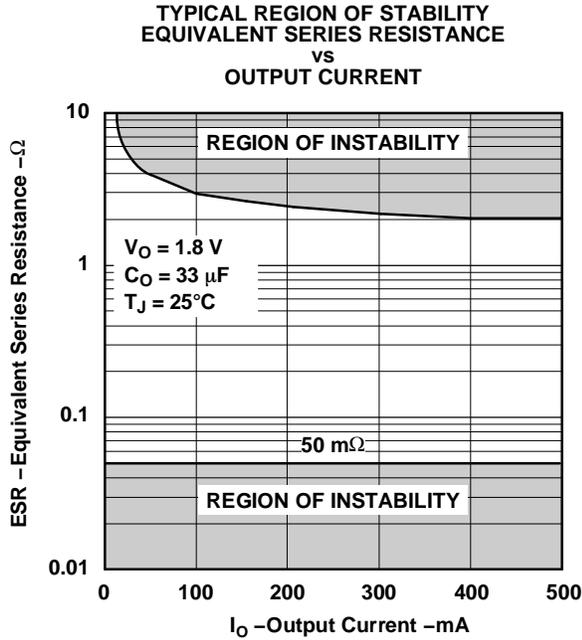


Figure 39. Test Circuit for Typical Regions of Stability

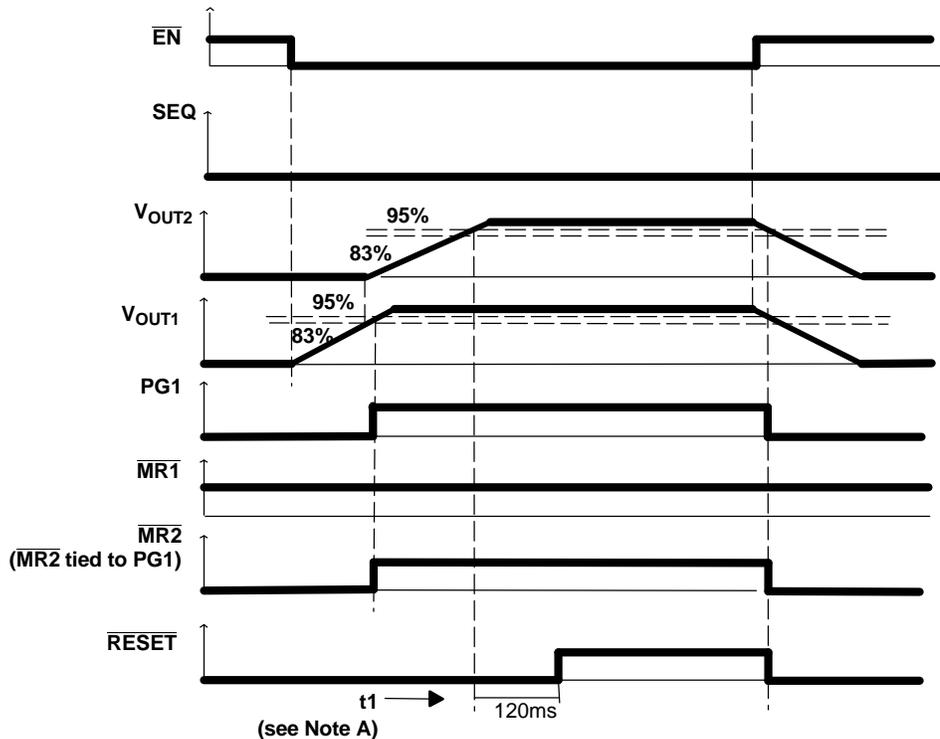
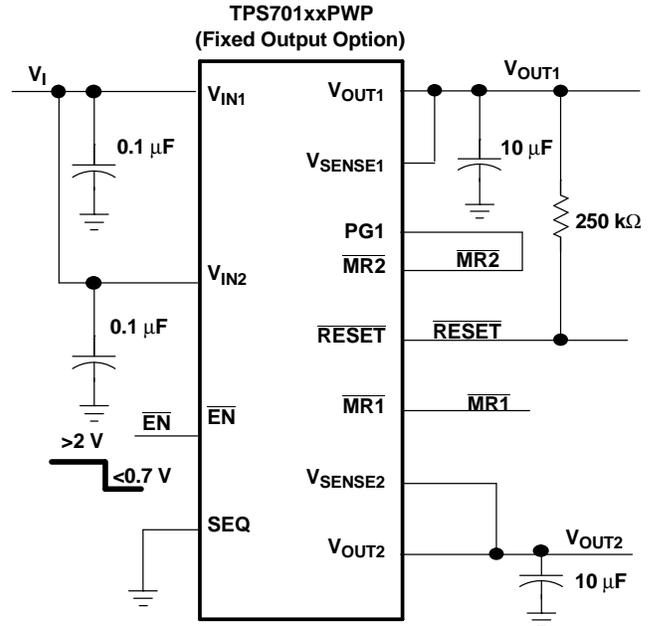
## APPLICATION INFORMATION

### Sequencing Timing Diagrams

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

Application condition:  $\overline{\text{MR2}}$  is tied to PG1,  $V_{\text{IN1}}$  and  $V_{\text{IN2}}$  are tied to the same input voltage, the SEQ pin is tied to logic low and the device is toggled with the enable (EN) function.

When the device is enabled ( $\overline{\text{EN}}$  is pulled low),  $V_{\text{OUT1}}$  turns on first and  $V_{\text{OUT2}}$  remains off until  $V_{\text{OUT1}}$  reaches approximately 83% of its regulated output voltage. At that time,  $V_{\text{OUT2}}$  is turned on. When  $V_{\text{OUT1}}$  reaches 95% of its regulated output, PG1 turns on (active high). Since  $\overline{\text{MR2}}$  is connected to PG1 for this application, it follows PG1. When  $V_{\text{OUT2}}$  reaches 95% of its regulated voltage,  $\overline{\text{RESET}}$  switches to high voltage level after a 120ms delay (see Figure 40).

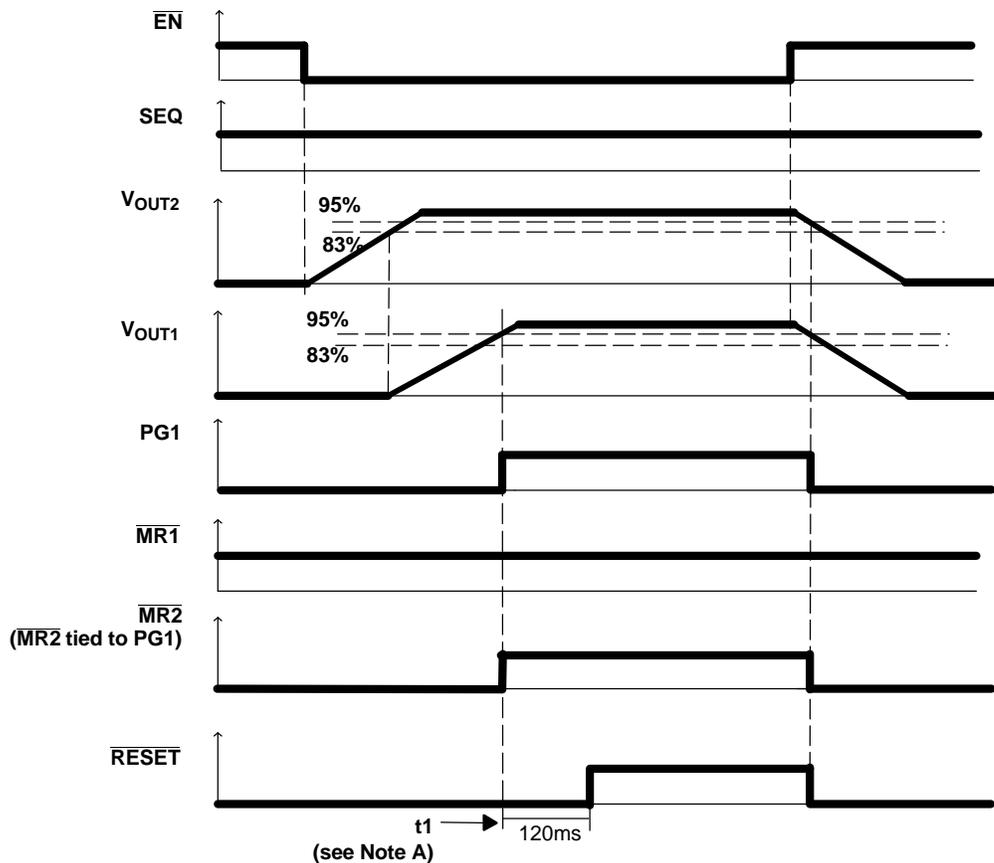
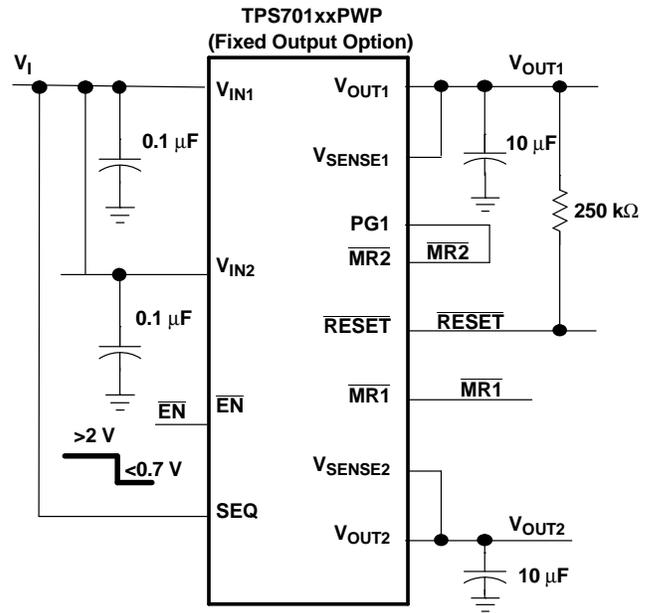


NOTE A:  $t_1$  – Time at which both  $V_{\text{OUT1}}$  and  $V_{\text{OUT2}}$  are greater than the PG1 thresholds and  $\overline{\text{MR1}}$  is logic high.

**Figure 40. Timing when SEQ = Low**

Application condition:  $\overline{MR2}$  is tied to PG1,  $V_{IN1}$  and  $V_{IN2}$  are tied to the same input voltage, the SEQ pin is tied to logic high and the device is toggled with the enable ( $\overline{EN}$ ) function.

When the device is enabled ( $\overline{EN}$  is pulled low),  $V_{OUT2}$  begins to power up. When it reaches 83% of its regulated voltage,  $V_{OUT1}$  begins to power up. PG1 turns on when  $V_{OUT1}$  reaches 95% of its regulated voltage, and since  $\overline{MR2}$  and PG1 are tied together,  $\overline{MR2}$  follows PG1. When  $V_{OUT1}$  reaches 95% of its regulated voltage,  $\overline{RESET}$  switches to high voltage level after a 120ms delay (see Figure 41).

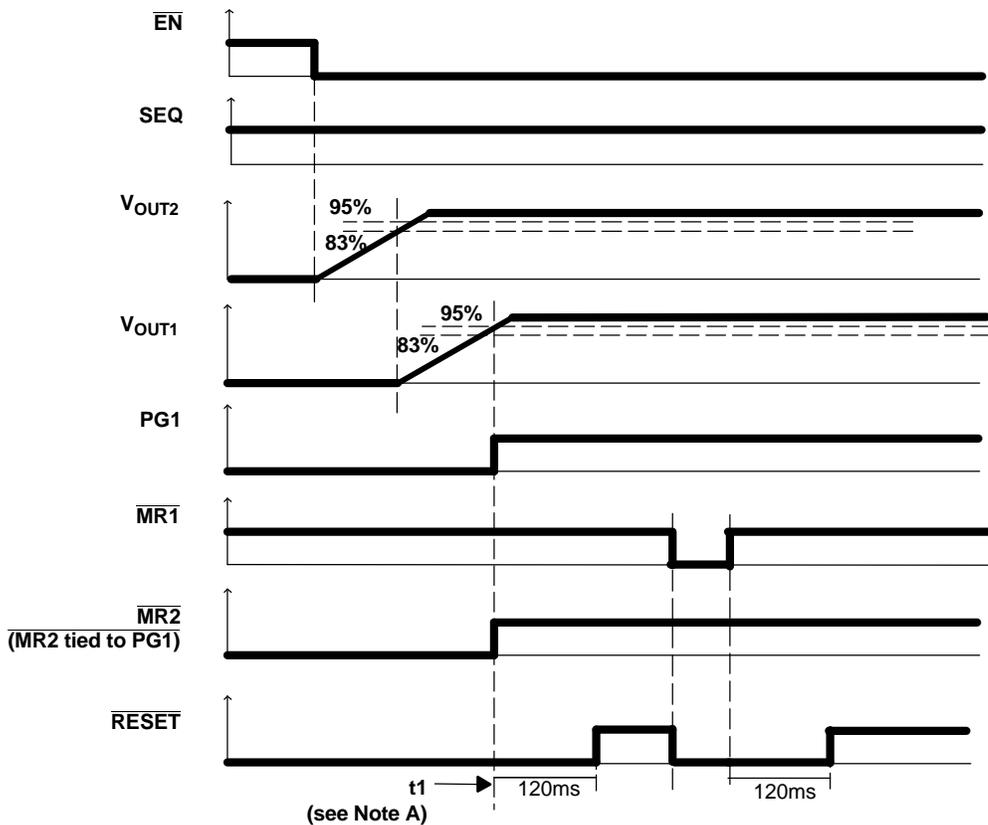
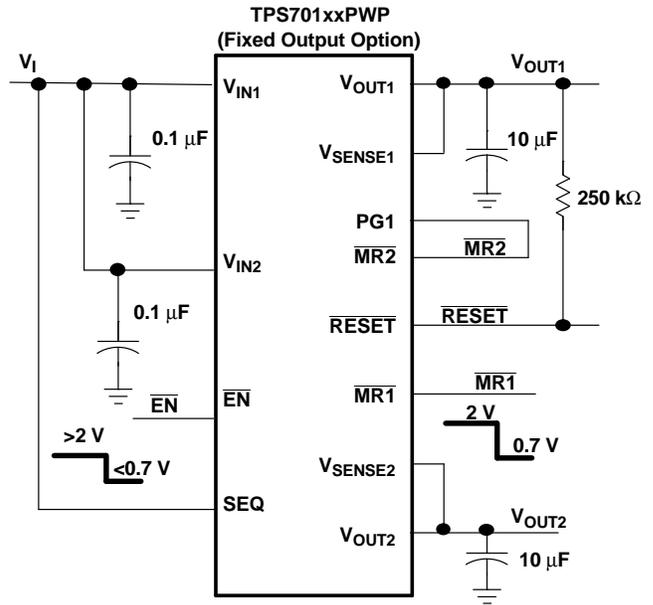


NOTE A:  $t_1$  – Time at which both  $V_{OUT1}$  and  $V_{OUT2}$  are greater than the PG1 thresholds and  $\overline{MR1}$  is logic high.

Figure 41. Timing when SEQ = High

Application condition:  $\overline{MR2}$  is tied to PG1,  $V_{IN1}$  and  $V_{IN2}$  are tied to the same input voltage, the SEQ pin is tied to logic high and  $\overline{MR1}$  is toggled.

When the device is enabled ( $\overline{EN}$  is pulled low),  $V_{OUT2}$  begins to power up. When it reaches 83% of its regulated voltage,  $V_{OUT1}$  begins to power up. PG1 turns on when  $V_{OUT1}$  reaches to 95% of its regulated voltage, and since  $\overline{MR2}$  and PG1 are tied together,  $\overline{MR2}$  follows PG1. When  $V_{OUT1}$  reaches 95% of its regulated voltage, the RESET switches to high voltage level after a 120ms delay. When  $\overline{MR1}$  is pulled low, it causes  $\overline{RESET}$  to go low, but the regulators remains in regulation (see Figure 42).

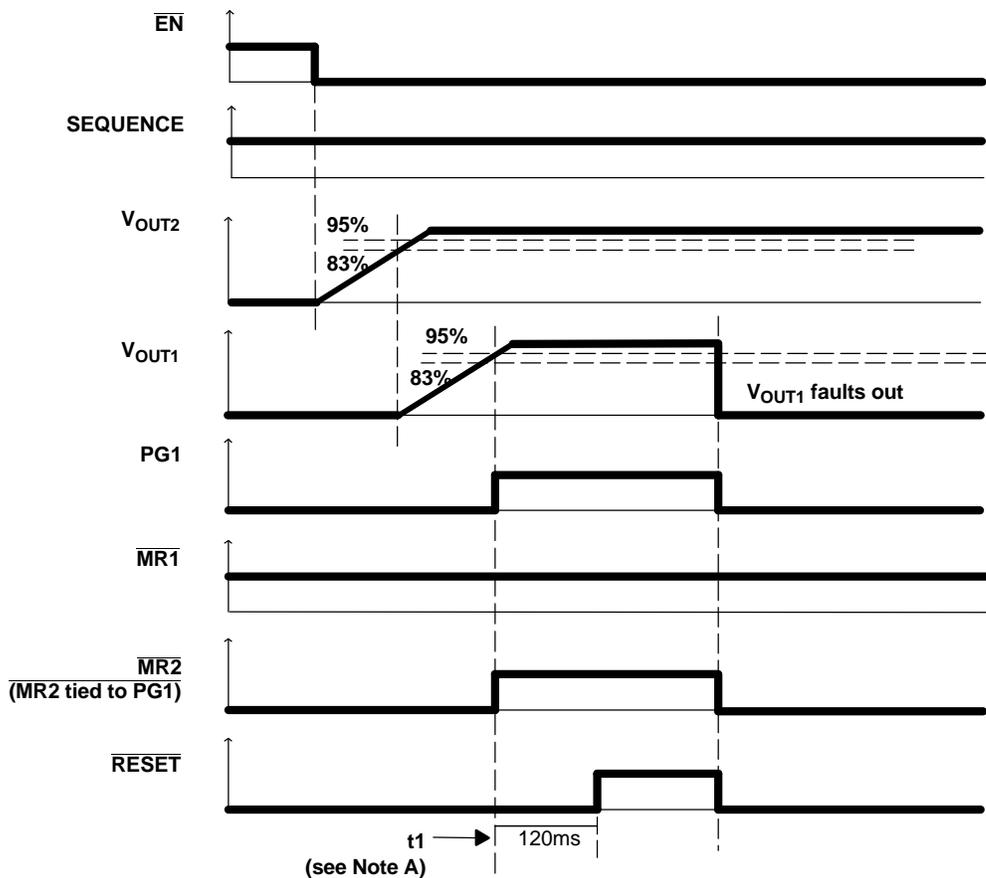
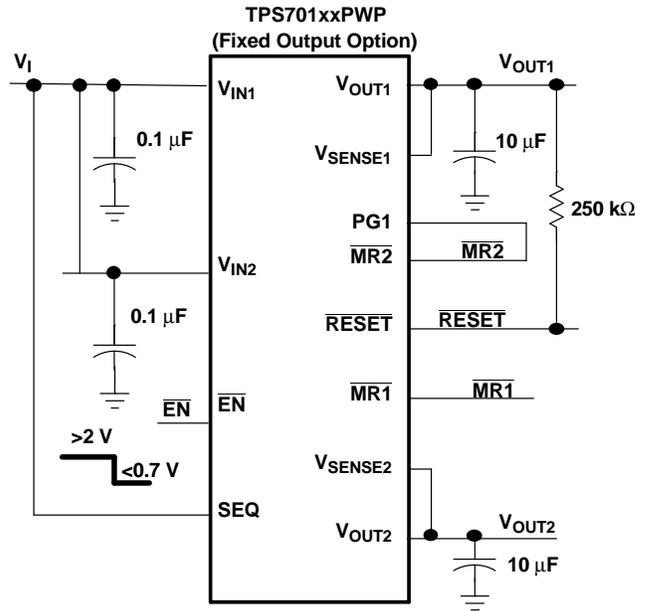


NOTE A:  $t_1$  – Time at which both  $V_{OUT1}$  and  $V_{OUT2}$  are greater than the PG1 thresholds and  $\overline{MR1}$  is logic high.

**Figure 42. Timing when  $\overline{MR1}$  is Toggled**

Application condition:  $\overline{MR2}$  is tied to PG1,  $V_{IN1}$  and  $V_{IN2}$  are tied to the same input voltage, the SEQ pin is tied to logic high and  $V_{OUT1}$  faults out.

$V_{OUT2}$  begins to power up when the device is enabled ( $\overline{EN}$  is pulled low). When  $V_{OUT2}$  reaches 83% of its regulated voltage, then  $V_{OUT1}$  begins to power up. When  $V_{OUT1}$  reaches 95% of its regulated voltage, PG1 turns on and  $\overline{RESET}$  switches to high voltage level after a 120ms delay. When  $V_{OUT1}$  faults out,  $V_{OUT2}$  remains powered on because the SEQ pin is high. PG1 is tied to  $\overline{MR2}$  and both change state to logic low.  $\overline{RESET}$  is driven by  $\overline{MR2}$  and goes to logic low when  $V_{OUT1}$  faults out (see Figure 43).

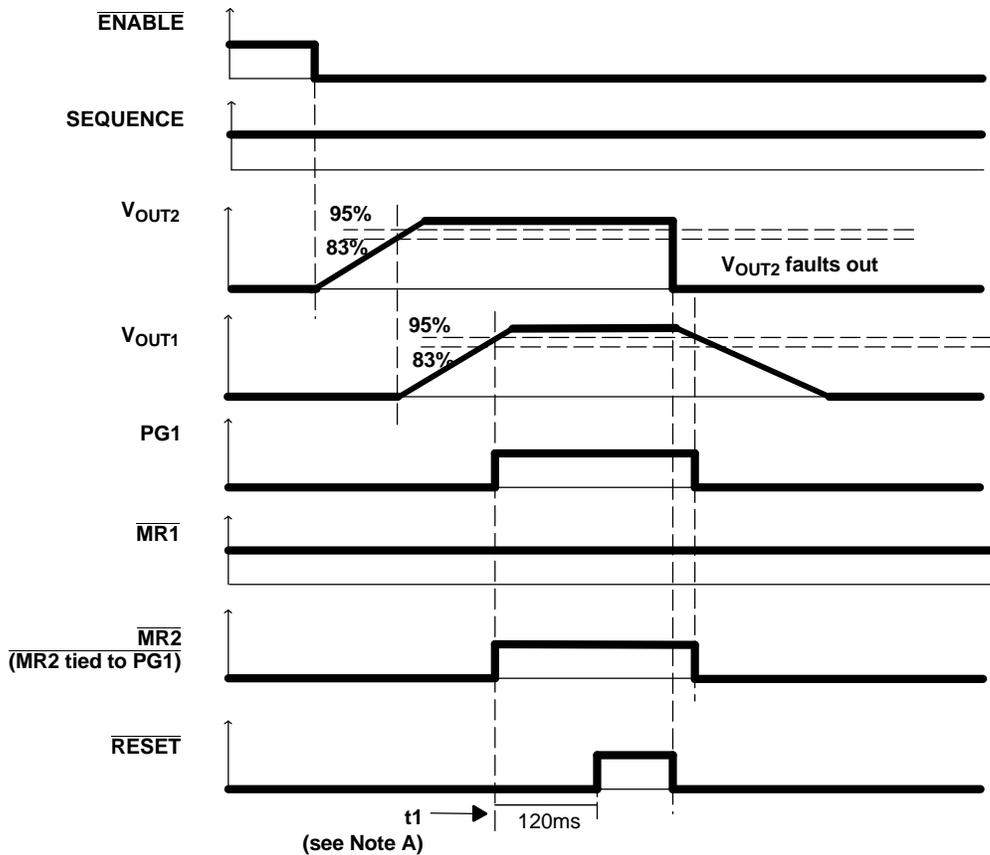
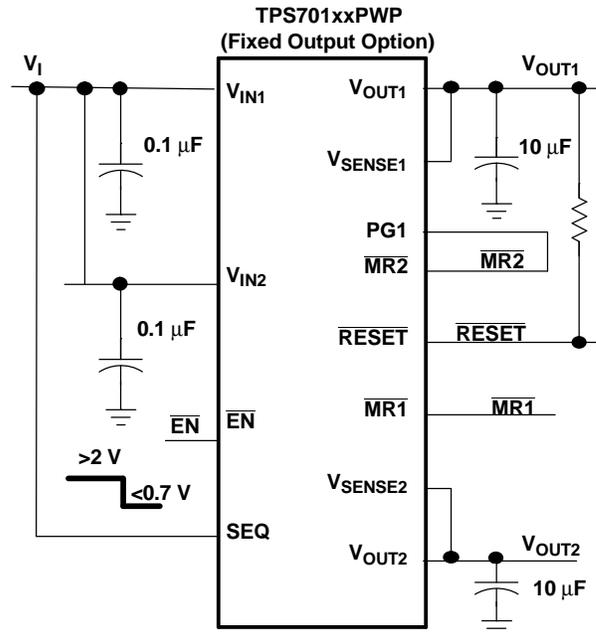


NOTE A:  $t_1$  – Time at which both  $V_{OUT1}$  and  $V_{OUT2}$  are greater than the PG1 thresholds and  $\overline{MR1}$  is logic high.

Figure 43. Timing when  $V_{OUT1}$  Faults Out

Application condition:  $\overline{MR2}$  is tied to PG1,  $V_{IN1}$  and  $V_{IN2}$  are tied to same input voltage, the SEQ is tied to logic high, the device is enabled, and  $V_{OUT2}$  faults out.

$V_{OUT2}$  begins to power up when the device is enabled ( $\overline{EN}$  is pulled low). When  $V_{OUT2}$  reaches 83% of its regulated voltage,  $V_{OUT1}$  begins to power up. When  $V_{OUT1}$  reaches 95% of its regulated voltage, PG1 turns on and  $\overline{RESET}$  switches to high voltage level after a 120ms delay. When  $V_{OUT2}$  faults out,  $V_{OUT1}$  is powered down because SEQ is high. PG1 is tied to  $\overline{MR2}$  and both change state to logic low.  $\overline{RESET}$  goes low when  $V_{OUT2}$  faults out (see Figure 44).

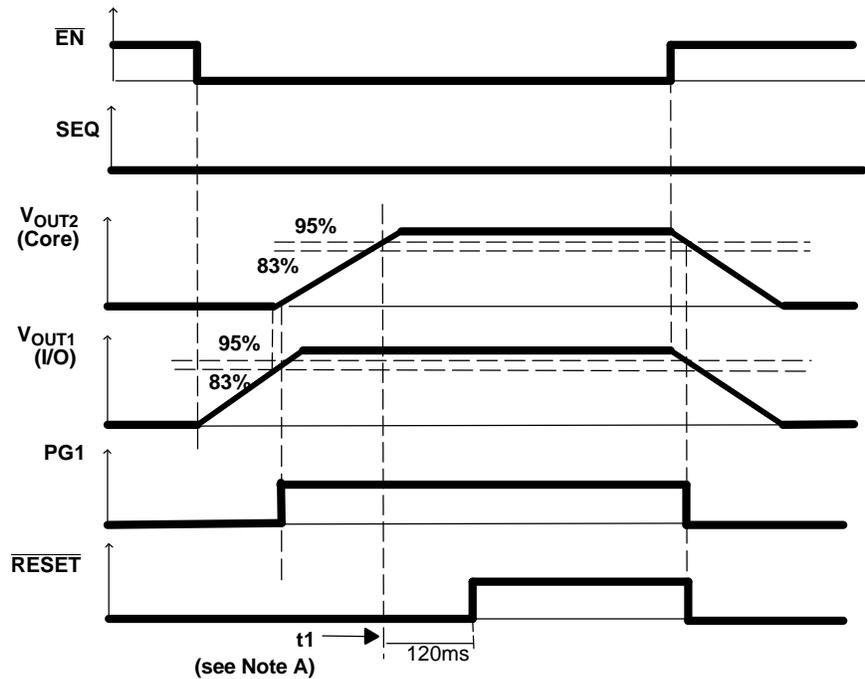
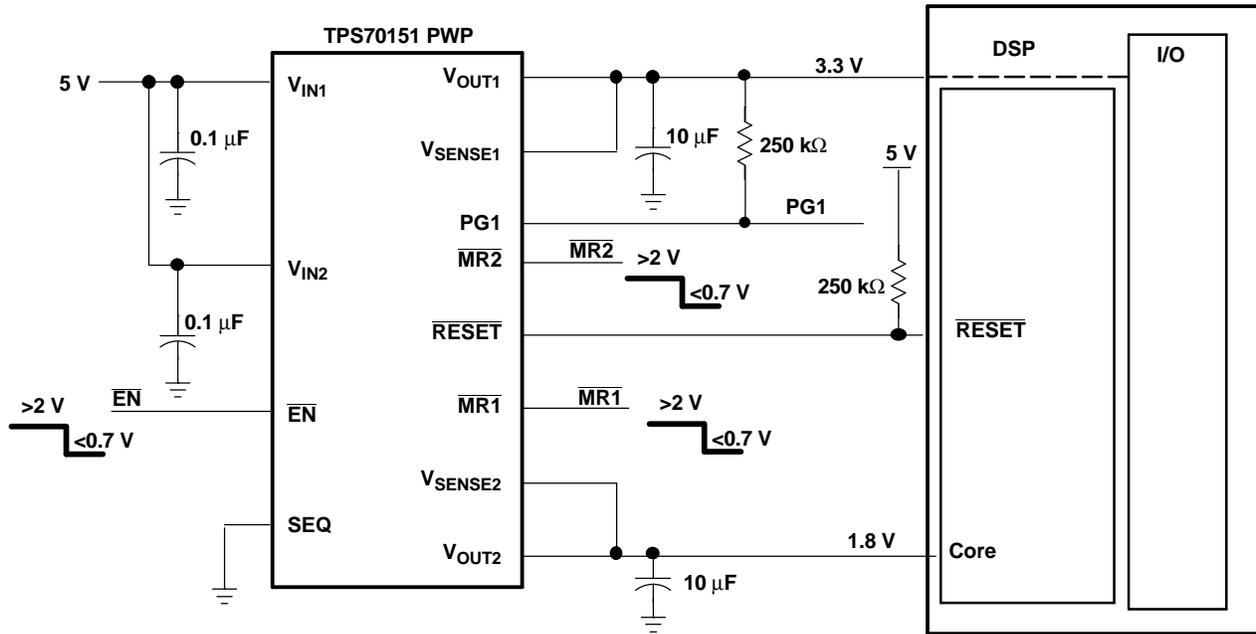


NOTE A:  $t_1$  – Time at which both  $V_{OUT1}$  and  $V_{OUT2}$  are greater than the PG1 thresholds and  $\overline{MR1}$  is logic high.

**Figure 44. Timing when  $V_{OUT2}$  Faults Out**

### Split Voltage DSP Application

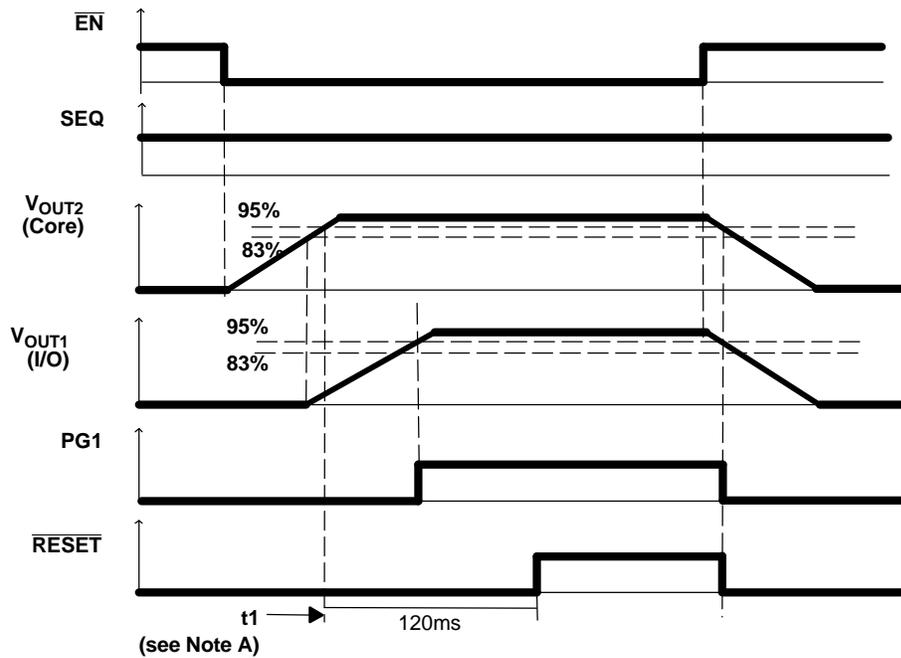
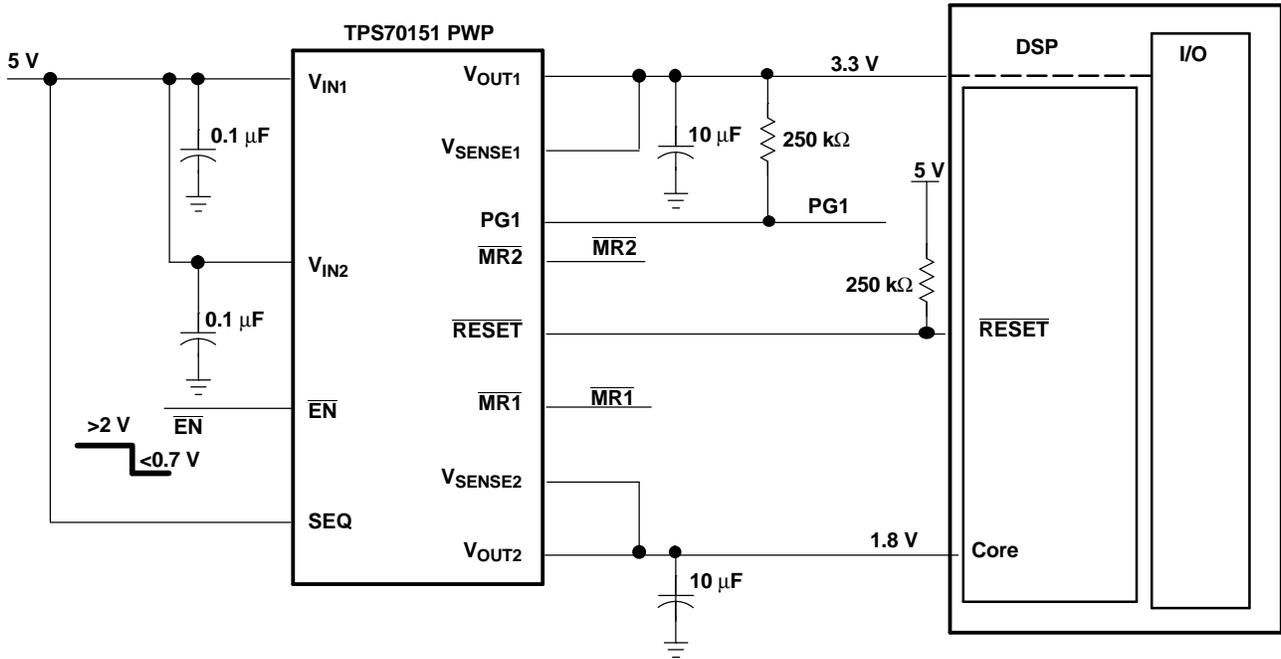
Figure 45 shows a typical application where the TPS70151 is powering up a DSP. In this application, by grounding the SEQ pin,  $V_{OUT1}$  (I/O) is powered up first, and then  $V_{OUT2}$  (core).



NOTE A:  $t_1$  – Time at which both  $V_{OUT1}$  and  $V_{OUT2}$  are greater than the PG1 thresholds and  $\overline{MR1}$  is logic high.

Figure 45. Application Timing Diagram (SEQ = Low)

Figure 46 shows a typical application where the TPS70151 is powering up a DSP. In this application, by pulling up the SEQ pin,  $V_{OUT2}$  (core) is powered up first, and then  $V_{OUT1}$  (I/O).



NOTE A:  $t_1$  – Time at which both  $V_{OUT1}$  and  $V_{OUT2}$  are greater than the PG1 thresholds and  $\overline{MR1}$  is logic high.

**Figure 46. Application Timing Diagram (SEQ = High)**

## Input Capacitor

For a typical application, an input bypass capacitor (0.1 $\mu$ F – 1 $\mu$ F) is recommended. This capacitor filters any high frequency noise generated in the line. For fast transient condition where droop at the input of the LDO may occur due to high inrush current, it is recommended to place a larger capacitor at the input as well. The size of this capacitor is dependent 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 TPS701xx requires an output capacitor connected between OUT and GND to stabilize the internal control loop. The minimum recommended capacitance value is 10 $\mu$ F and the ESR (equivalent series resistance) must be between 50m $\Omega$  and 2.5 $\Omega$ . Capacitor values 10 $\mu$ F or larger are acceptable, provided the ESR is less than 2.5 $\Omega$ . Solid tantalum electrolytic, aluminum electrolytic, and multilayer ceramic capacitors are all suitable, provided they meet the requirements described above. Larger capacitors provide a wider range of stability and better load transient response. Table 3 provides a partial listing of surface-mount capacitors usable with the TPS701xx for fast transient response application.

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 the guidelines above.

**Table 3. Partial Listing of TPS701xx-Compatible Surface-Mount Capacitors**

VALUE	MANUFACTURER	MAXIMUM ESR	MFR PART NO.
22 $\mu$ F	Kemet	345m $\Omega$	7495C226K0010AS
33 $\mu$ F	Sanyo	100m $\Omega$	10TPA33M
47 $\mu$ F	Sanyo	100m $\Omega$	6TPA47M
68 $\mu$ F	Sanyo	45m $\Omega$	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 47.



**Figure 47. 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 48 shows the output capacitor and its parasitic impedances in a typical LDO output stage.

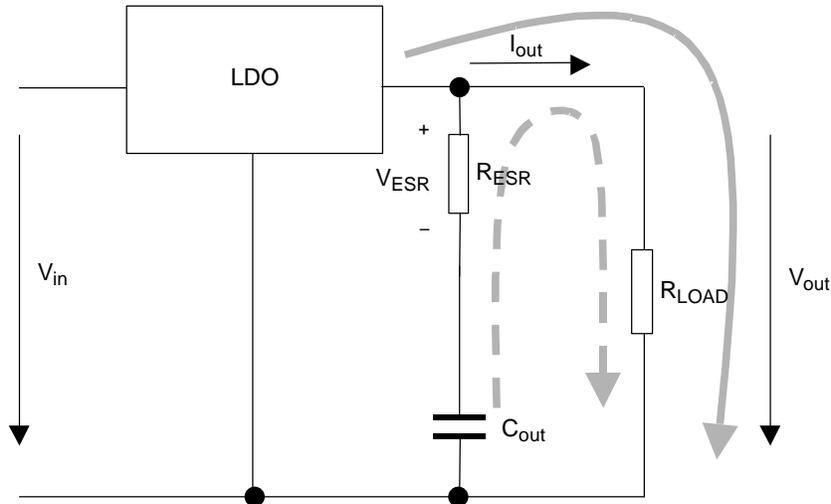


Figure 48. LDO Output Stage with Parasitic Resistances ESR

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 means no current is flowing into the  $C_O$  branch. If  $I_{OUT}$  suddenly increases (a 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 45). 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 occurs at  $R_{ESR}$ . This voltage is shown as  $V_{ESR}$  in Figure 44.
- When  $C_O$  is conducting current to the load, initial voltage at the load will be  $V_O = V_{(CO)} - V_{ESR}$ . 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 49.

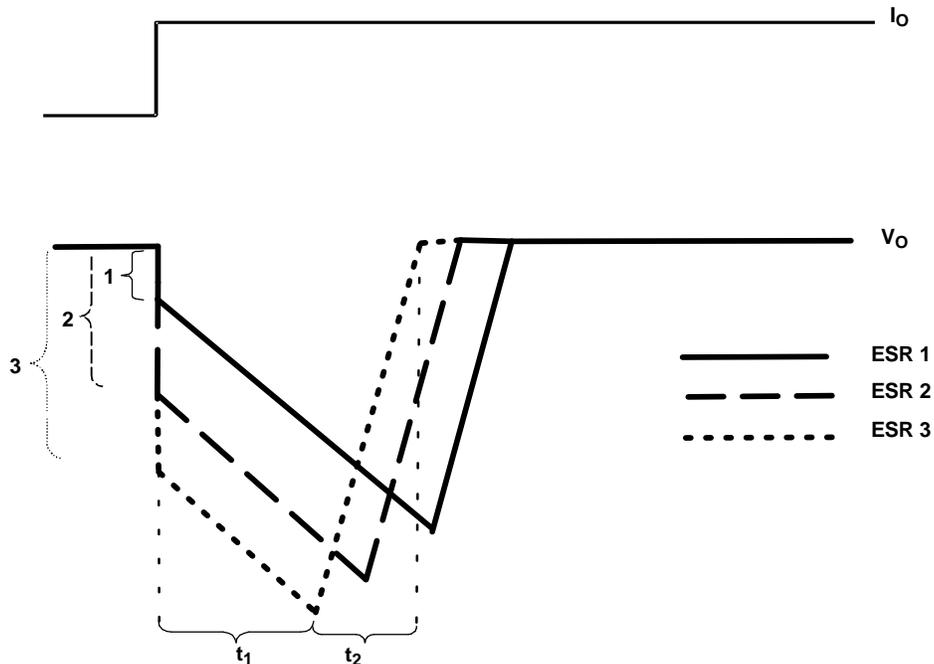


Figure 49. Correlation of Different ESRs and Their Influence on the Regulation of  $V_O$  at a Load Step from Low-to-High Output Current

The figure 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 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 TPS70102 Adjustable LDO Converter

The output voltage of the TPS70102 adjustable regulators are programmed using external resistor dividers as shown in Figure 50.

Resistors R1 and R2 should be chosen for approximately 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:

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

where:

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

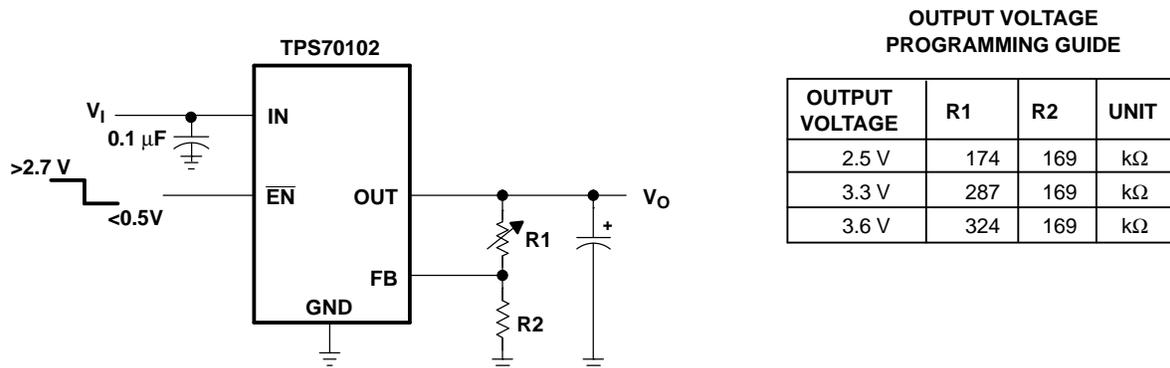


Figure 50. TPS70102 Adjustable LDO Regulator Programming

### Regulator Protection

Both TPS701xx 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 TPS701xx also features internal current limiting and thermal protection. During normal operation, the TPS701xx 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:

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

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 will trigger the thermal protection circuit.

**PACKAGING INFORMATION**

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/Ball Finish	MSL Peak Temp <sup>(3)</sup>
TPS70102PWP	ACTIVE	HTSSOP	PWP	20	70	None	CU NIPDAU	Level-1-220C-UNLIM
TPS70102PWPR	ACTIVE	HTSSOP	PWP	20	2000	None	CU NIPDAU	Level-1-220C-UNLIM
TPS70145PWP	ACTIVE	HTSSOP	PWP	20	70	None	CU NIPDAU	Level-1-220C-UNLIM
TPS70145PWPR	ACTIVE	HTSSOP	PWP	20	2000	None	CU NIPDAU	Level-1-220C-UNLIM
TPS70148PWP	ACTIVE	HTSSOP	PWP	20	70	None	CU NIPDAU	Level-1-220C-UNLIM
TPS70148PWPR	ACTIVE	HTSSOP	PWP	20	2000	None	CU NIPDAU	Level-1-220C-UNLIM
TPS70151PWP	ACTIVE	HTSSOP	PWP	20	70	None	CU NIPDAU	Level-1-220C-UNLIM
TPS70151PWPR	ACTIVE	HTSSOP	PWP	20	2000	None	CU NIPDAU	Level-1-220C-UNLIM
TPS70158PWP	ACTIVE	HTSSOP	PWP	20	70	None	CU NIPDAU	Level-1-220C-UNLIM
TPS70158PWPR	ACTIVE	HTSSOP	PWP	20	2000	None	CU NIPDAU	Level-1-220C-UNLIM

<sup>(1)</sup> The marketing status values are defined as follows:

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**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.

<sup>(2)</sup> Eco Plan - May not be currently available - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**None:** Not yet available Lead (Pb-Free).

**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.

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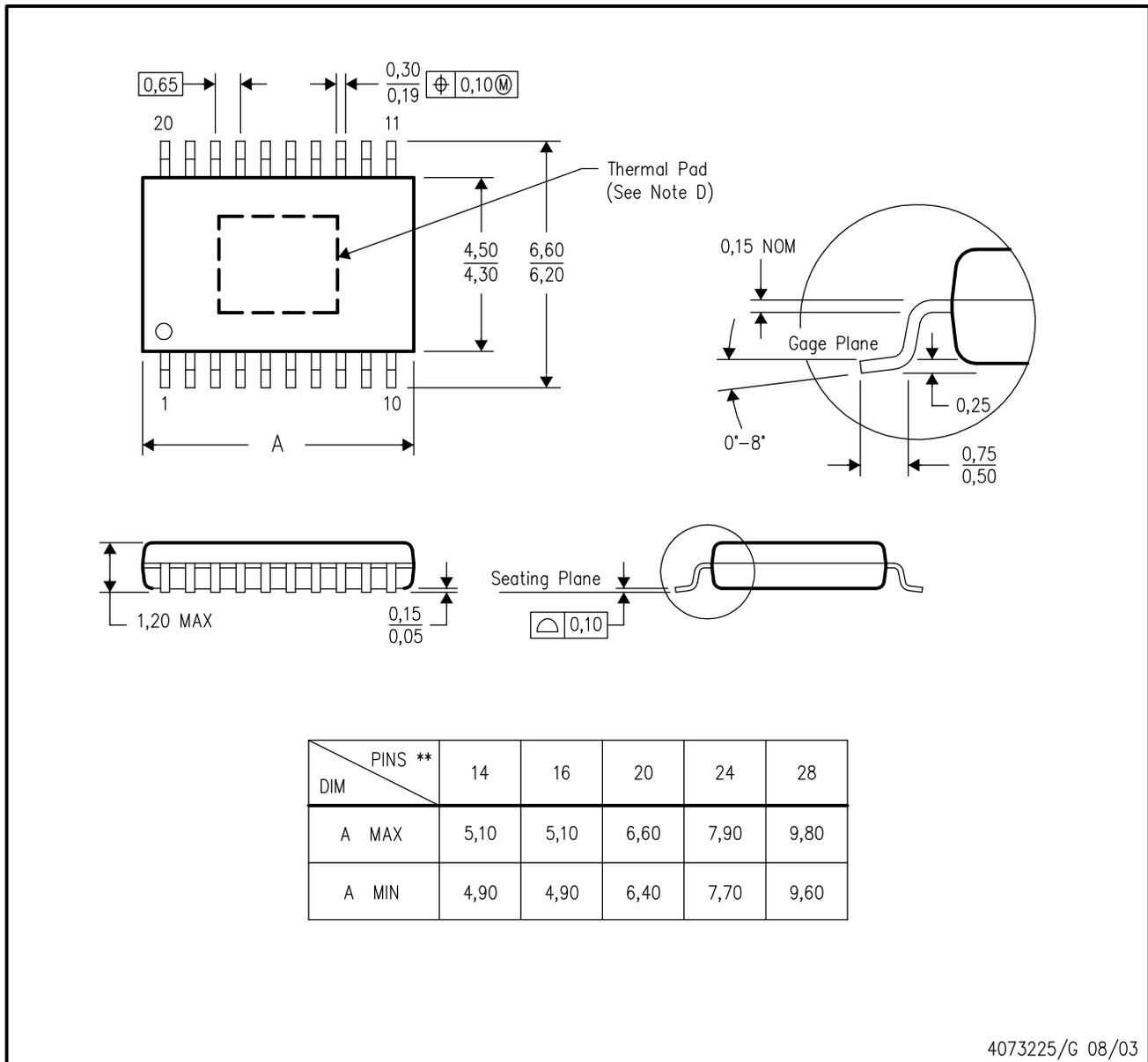
<sup>(3)</sup> MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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4073225/G 08/03

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  - 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) <<http://www.ti.com>>.
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Mailing Address: Texas Instruments  
Post Office Box 655303 Dallas, Texas 75265

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