

## ADJUSTABLE LDO AND SWITCH WITH DUAL CURRENT LIMIT FOR USB HIGH-POWER PERIPHERAL POWER MANAGEMENT

### FEATURES

- **Complete Power Management Solution for USB High-Power Peripherals**
- **250 mA Low-Dropout Regulator (LDO) With Enable and 325 mA (Typ) Current Limit**
- **LDO Supports 2.7 V to 5.5 V  $V_{IN}$  and 0.9 V to 3.3 V Adjustable  $V_{OUT}$**
- **40 m $\Omega$  (Typ) High-Side MOSFET With Dual Current Limit**
- **Undervoltage Lockout and Power Good for LDO and Switch**
- **CMOS- and TTL-Compatible Enable Inputs**
- **85  $\mu$ A (Typ) Supply Current**
- **5  $\mu$ A (Typ) Standby Supply Current**
- **Available in 14-Pin HTSSOP (PowerPAD™)**
- **–40°C to 85°C Ambient Temperature Range**
- **Alternative to TPS2148/58 3.3-V LDO With 3.3-V Switch and 5-V Switch**

### APPLICATIONS

- **High-Power USB™ Peripherals**
  - ADSL Modems
  - Digital Still and PC Cameras
  - Zip Drives
  - Speakers
- **DSP Sequencing**

### DESCRIPTION

The TPS2140/41/50/51 is a USB 1.0 and 2.0 Specification-compatible IC containing a dual-current-limiting power switch and an adjustable low dropout regulator (LDO). Both the switch and LDO limit inrush current by controlling the turnon slew rate. The unique dual-current-limiting feature of the switch allows USB peripherals to utilize high-value capacitance at the output of the switch, while keeping the inrush current low. During turnon, the switch limits the current delivered to the capacitive load to less than 100 mA. When the output voltage from the switch reaches about 93% of the input voltage, the switch power good output goes high, and the switch current limit increases to 800mA (minimum), at which point higher current loads can be turned on. The higher current limit provides short circuit protection while allowing the peripheral to draw maximum current from the USB bus.

The switch and LDO function independently, providing flexibility in DSP applications requiring separate core and I/O voltages. For example, in a DSP application operating from a 3.3-V rail, the LDO can supply the DSP core voltage down to 0.9 V, while the switch powers the 3.3-V (typical) DSP I/O supply. If supply sequencing is required, the LDO power good output can be used to enable the switch.

### AVAILABLE OPTIONS

T <sub>A</sub>	DESCRIPTION	TARGET APPLICATION	PACKAGE AND PIN COUNT	PACKAGED DEVICES	
				ACTIVE LOW (SWITCH)	ACTIVE HIGH (SWITCH)
–40°C to 85°C	Adjustable LDO and 3.3 V switch with dual current limit	DSP	HTSSOP-14	TPS2140IPWP	TPS2150IPWP
	Adjustable LDO and 5 V switch with dual current limit	USB	HTSSOP-14	TPS2141IPWP	TPS2151IPWP

NOTE: All options available taped and reeled. Add an R suffix (e.g., TPS2140IPWPR)



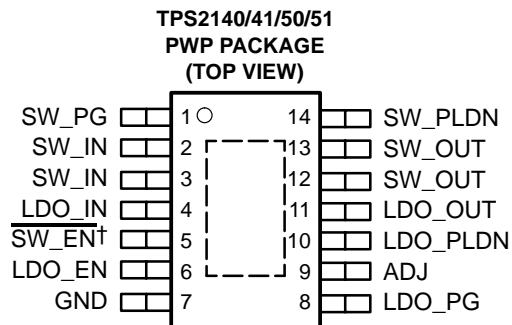
Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

PowerPAD is a trademark of Texas Instruments.  
USB is a trademark of Universal Serial Bus Association.

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

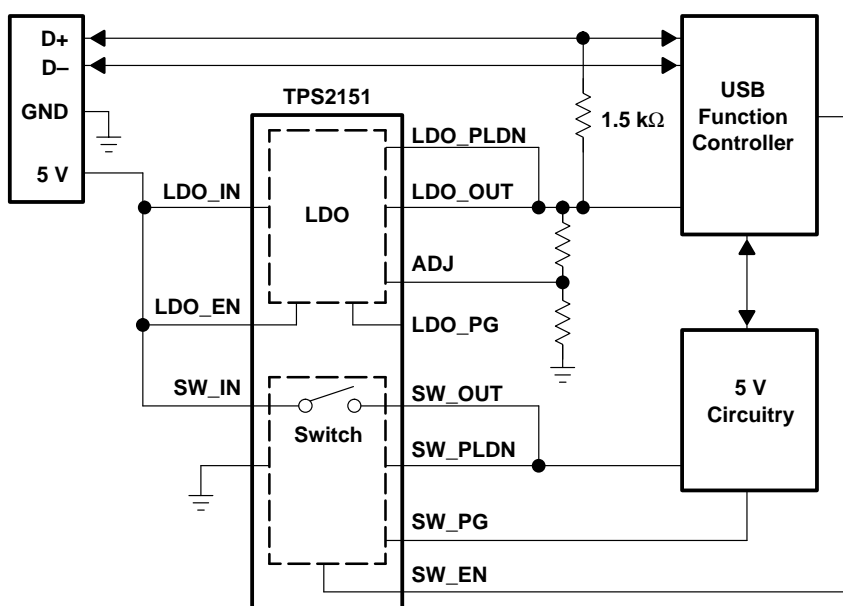
# TPS2140, TPS2141 TPS2150, TPS2151

SLVS399 – JANUARY 2002



† Pin 5 is active high for TPS2150 and TPS2151.

## USB peripheral application



## Terminal Functions

TERMINAL NAME	NO.	I/O	DESCRIPTION
ADJ	9	I	Feedback adjustment of LDO regulator to set output voltage
GND	7		Ground
LDO_EN	6	I	Enable signal for LDO regulator, active high, no internal pullup or pulldown
LDO_IN	4	I	Input of LDO regulator
LDO_OUT	11	O	Output of LDO regulator
LDO_PG	8	O	Power good signal for LDO output, open-drain, active high
LDO_PLDN	10	I	Output pulldown pin used for LDO when connected to LDO_OUT
SW_EN or SW_EN	5	I	Active-high enable for switch on TPS2150 and TPS2151 devices with internal pulldown Active-low enable for switch on TPS2140 and TPS2141 devices with internal pullup
SW_IN	2, 3	I	Input of the switch
SW_OUT	12, 13	O	Output of switch
SW_PG	1	O	Power good signal for switch output, active high logic-level signal, no external pullup required.
SW_PLDN	14	I	Output pulldown pin used for switch when connected to SW_OUT.

## **detailed description**

### **GND**

Ground

### **SW\_IN**

SW\_IN is the input to an integrated N-channel MOSFET, which has a maximum on-state resistance of 65 mΩ. Configured as a high-side switch, the power switch prevents current, flow from OUT to IN and IN to OUT when disabled. The power switch is rated at 500 mA, continuous current and has a dual current limit feature.

### **dual current limit**

The current limiter for the switch limits the initial current drawn from SW\_IN to 100 mA maximum. The user can estimate the amount of time it takes to charge a capacitor (CL) connected to SW\_OUT by using the following relationship:

$$CL \times V_{I(SW\_IN)} / 0.1 < t_{CHG} < CL \times V_{I(SW\_IN)} / 0.05$$

Capacitance in farads. If  $V_{I(SW\_IN)} = 5\text{ V}$ , then

$$50 \times CL < t_{CHG} < 100 \times CL$$

When the voltage at output SW\_OUT rises above 93% of the voltage at SW\_IN, the current limit is increased to 1800 mA maximum. The SW\_PG can be used to turn on loads which may draw more than 50 mA.

In the event of an overload on SW\_OUT, the protection circuit limits the current delivered to 1800 mA maximum. As the output voltage drops and it crosses 80% of the SW\_IN voltage, the current limiter reverts back to the low-current limit mode of 100 mA maximum.

SW\_IN also serves as one of the two inputs to an internal voltage selector that provides operating voltage to the whole device. The other input to the selector is LDO\_IN.

### **SW\_OUT**

SW\_OUT is the output of the internal power-distribution switch.

### **SW\_EN or SW\_EN**

The logic input disables or enables the power switch. This signal is active low ( $\overline{SW\_EN}$ ) for TPS2140/41 and active high (SW\_EN) for TPS2150/51. SW\_EN has an internal pullup and SW\_EN has an internal pulldown.

### **SW\_PG**

SW\_PG signals the presence of an undervoltage condition on SW\_OUT. The pin is driven by a CMOS output buffer and is pulled low during an undervoltage condition. To minimize erroneous SW\_PG responses from transients on the voltage rail, the voltage sense circuit incorporates a rising and falling edge deglitch filter. When SW\_OUT voltage is lower than 88% of 3.3 V for TPS2140/50, or 5 V for TPS2141/51, SW\_PG goes low to indicate an undervoltage condition on SW\_OUT.

### **SW\_PLDN**

SW\_PLDN is an open drain output incorporated to provide a discharge path. When the power switch is on, this pin is open; otherwise it is pulled down to ground. When this pin is connected to SW\_OUT, the output voltage fall time is reduced but the rise time remains unaffected.

### **LDO\_IN**

The LDO\_IN serves as the input to the internal LDO. The adjustable LDO has a dropout voltage of 0.5 V maximum and is rated for 250 mA of continuous current. LDO\_IN is also used as one of the two inputs for  $V_{CC}$  selection.

## **detailed description (continued)**

### **LDO\_OUT**

LDO\_OUT is the output of the internal LDO. It has an output voltage range of 0.9 V to 3.3 V.

### **LDO\_EN**

LDO\_EN is used to enable or disable the internal LDO and is compatible with CMOS and TTL logic. LDO\_EN is an active high input.

### **ADJ**

ADJ is used to adjust the LDO output voltage (LDO\_OUT) anywhere between 0.9 V and 3.3 V by connecting a resistor divider from LDO\_OUT to ground (ADJ connects to the center point of the resistor divider).

### **LDO\_PG**

LDO\_PG signals the presence of an undervoltage condition on LDO\_OUT. LDO\_PG is an open-drain output and is pulled low during an undervoltage condition. To minimize erroneous LDO\_PG responses from transients on the voltage rail, the voltage sense circuit incorporates a 150- $\mu$ s falling deglitch filter. When the LDO\_OUT voltage is lower than 94% of a threshold voltage (set by an external resistor divider), LDO\_PG goes low to indicate an undervoltage condition. A pullup resistor from LDO\_PG to a power rail is required for proper operation.

### **LDO\_PLDN**

LDO\_PLDN is an open drain output incorporated to provide a discharge path. When the LDO is on, this pin is open; otherwise, it is pulled down to ground. When this pin is connected to LDO\_OUT, the output voltage fall time is reduced but the rise time remains unaffected.

### **current sense**

Both the power switch and the LDO have integrated current sense circuits. When an overload or short circuit is encountered, the current-sense circuitry sends a control signal to the driver. The driver reduces the gate voltage until the current drops back to the limiting value.

### **thermal sense**

A dual-threshold thermal trip is implemented to protect the device. The lower thermal trip point is used to protect the device during an overcurrent condition. The higher thermal trip point is used to protect the device when the junction temperature rises but not due to an overcurrent condition.

### **undervoltage lockout**

A voltage sense circuit monitors both input voltages on SW\_IN and LDO\_IN. When the input voltage is below its respective threshold, a control signal turns off the related channel (the power switch or the LDO).

**absolute maximum ratings over operating free-air temperature (unless otherwise noted)†**

Input voltage range for bus switch and LDO:	$V_{I(SW\_IN)}$ .....	–0.3 V to 6 V
	$V_{I(LDO\_IN)}$ .....	–0.3 V to 6 V
Output voltage range for bus switch and LDO:	$V_{O(SW\_OUT)}$ .....	–0.3 V to 6 V
	$V_{O(LDO\_OUT)}$ .....	–0.3 V to 6 V
Input voltage range for pulldown transistors:	$V_{I(SW\_PLDN)}, V_{I(LDO\_PLDN)}$ .....	–0.3 V to 6 V
Logic input/output voltage range:	$V_{I(SW\_EN)}$ or $V_{I(/SW\_EN)}, V_{I(LDO\_EN)}, V_{I(ADJ)}, V_{I(SW\_PG)},$ $V_{I(LDO\_PG)}$ .....	–0.3 V to 6 V
Continuous total power dissipation	.....	See Dissipation Rating Table
Output current for bus switch and LDO:	$I_{O(SW\_OUT)}$ .....	Internally Limited
	$I_{O(LDO\_OUT)}$ .....	Internally Limited
Sink current for pulldown switches:	$I_{I(SW\_PLDN)}$ .....	0 mA to 30 mA
	$I_{I(LDO\_PLDN)}$ .....	0 mA to 30 mA
Output current for logic outputs:	$I_{O(SW\_PG)}$ .....	–10 mA to 10 mA
	$I_{O(LDO\_PG)}$ .....	0 mA to 10 mA
Operating virtual junction temperature range, $T_J$	.....	–40°C to 125°C
Storage temperature range, $T_{stg}$	.....	–65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	.....	260°C

† 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.

**DISSIPATION RATING TABLE**

PACKAGE	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 70^\circ\text{C}$ POWER RATING	$T_A \leq 85^\circ\text{C}$ POWER RATING
PWP-14	2266.7 mW	26.7 mW/°C	1066.7 mW	666.7 mW

NOTE: This device is mounted on an JEDEC low-k board (2 oz traces on surface), 1 W power applied with no air flow.

**recommended operating conditions**

		MIN	MAX	UNIT
Input voltage, $V_I$	$V_{I(SW\_IN)}$ , TPS2140 and TPS2150	2.7	5.5	V
	$V_{I(SW\_IN)}$ , TPS2141 and TPS2151	4.1	5.5	
	$V_{I(LDO\_IN)}$	2.7	5.5	
	$V_{I(SW\_EN)}$ or $V_{I(/SW\_EN)}, V_{I(LDO\_EN)}$	0	5.5	
	$V_{I(SW\_PLDN)}, V_{I(LDO\_PLDN)}$	0	5.5	
Output current, $I_O$	$I_{O(SW\_OUT)}$ at $T_J = 110^\circ\text{C}$		0.6	A
	$I_{O(LDO\_OUT)}$ at $T_J = 110^\circ\text{C}$		0.25‡	
Operating virtual junction temperature, $T_J$		–40	110	°C

‡ Assuming the power dissipation does not exceed the device's thermal limit. Refer to the *power dissipation and junction temperature* section for the power dissipation calculation.

electrical characteristics over recommended operating junction temperature range,  
 $V_{I(SW\_IN)} = 3.3\text{ V}$  for TPS2140/50,  $V_{I(SW\_IN)} = 5\text{ V}$  for TPS2141/51,  $V_{I(LDO\_IN)} = 5\text{ V}$ , all outputs unloaded  
(unless otherwise noted)

general

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Power switch operating supply current $I_{OP\_SW}$	TPS2140, TPS2150	$2.7\text{ V} < V_{I(SW\_IN)} < 5.5\text{ V}$ , $V_{I(LDO\_IN)} = 0$ , $V_{I(SW\_EN)} = 5.5\text{ V}$ or $V_{I(SW\_EN)} = 0\text{ V}$ , $V_{I(LDO\_EN)} = 0\text{ V}$ , No load		85	110	$\mu\text{A}$
	TPS2141, TPS2151	$4.1\text{ V} < V_{I(SW\_IN)} < 5.5\text{ V}$ , $V_{I(LDO\_IN)} = 0$ , $V_{I(SW\_EN)} = 5.5\text{ V}$ or $V_{I(SW\_EN)} = 0\text{ V}$ , $V_{I(LDO\_EN)} = 0\text{ V}$ , No load		85	110	
Power switch standby supply current $I_{STBY\_SW}$	TPS2140, TPS2150	$2.7\text{ V} < V_{I(SW\_IN)} < 5.5\text{ V}$ , $V_{I(LDO\_IN)} = 0$ , $V_{I(SW\_EN)} = 0\text{ V}$ or $V_{I(SW\_EN)} = 5.5\text{ V}$ , $V_{I(LDO\_EN)} = 0\text{ V}$ , No load		5	10	
	TPS2141, TPS2151	$4.1\text{ V} < V_{I(SW\_IN)} < 5.5\text{ V}$ , $V_{I(LDO\_IN)} = 0$ , $V_{I(SW\_EN)} = 0\text{ V}$ or $V_{I(SW\_EN)} = 5.5\text{ V}$ , $V_{I(LDO\_EN)} = 0\text{ V}$ , No load		5	10	
LDO operating supply current $I_{OP\_LDO}$		$2.7\text{ V} < V_{I(LDO\_IN)} < 5.5\text{ V}$ , $V_{I(SW\_IN)} = 0\text{ V}$ , $V_{I(SW\_EN)} = 0\text{ V}$ or $V_{I(SW\_EN)} = 5.5\text{ V}$ , $V_{I(LDO\_EN)} = 5\text{ V}$ , No load		90	120	$\mu\text{A}$
LDO standby supply current $I_{STBY\_LDO}$		$2.7\text{ V} < V_{I(LDO\_IN)} < 5.5\text{ V}$ , $V_{I(SW\_IN)} = 0\text{ V}$ , $V_{I(SW\_EN)} = 0\text{ V}$ or $V_{I(SW\_EN)} = 5.5\text{ V}$ , $V_{I(LDO\_EN)} = 0\text{ V}$ , No load		5	10	
Power switch and LDO total operating supply current $I_{OP\_TOTAL}$	TPS2140, TPS2150	$2.7\text{ V} < V_{I(SW\_IN)} < 5.5\text{ V}$ , $V_{I(SW\_EN)} = 5.5\text{ V}$ or $V_{I(SW\_EN)} = 0\text{ V}$ , $V_{I(LDO\_EN)} = 5\text{ V}$ , No load $2.7\text{ V} < V_{I(LDO\_IN)} < 5.5\text{ V}$			150	$\mu\text{A}$
	TPS2141, TPS2151	$4.1\text{ V} < V_{I(SW\_IN)} < 5.5\text{ V}$ , $V_{I(SW\_EN)} = 5.5\text{ V}$ or $V_{I(SW\_EN)} = 0\text{ V}$ , $V_{I(LDO\_EN)} = 5\text{ V}$ , No load $2.7\text{ V} < V_{I(LDO\_IN)} < 5.5\text{ V}$			150	
Power switch and LDO total standby supply current $I_{STBY\_TOTAL}$	TPS2140, TPS2150	$2.7\text{ V} < V_{I(SW\_IN)} < 5.5\text{ V}$ , $V_{I(SW\_EN)} = 0\text{ V}$ or $V_{I(SW\_EN)} = 5.5\text{ V}$ , $V_{I(LDO\_EN)} = 0\text{ V}$ , No load $2.7\text{ V} < V_{I(LDO\_IN)} < 5.5\text{ V}$			10	
	TPS2141, TPS2151	$4.1\text{ V} < V_{I(SW\_IN)} < 5.5\text{ V}$ , $V_{I(SW\_EN)} = 0\text{ V}$ or $V_{I(SW\_EN)} = 5.5\text{ V}$ , $V_{I(LDO\_EN)} = 0\text{ V}$ , No load $2.7\text{ V} < V_{I(LDO\_IN)} < 5.5\text{ V}$			10	

# TPS2140, TPS2141 TPS2150, TPS2151

SLVS399 – JANUARY 2002

**electrical characteristics over recommended operating junction temperature range,  
 $V_{I(SW\_IN)} = 3.3\text{ V}$  for TPS2140/50,  $V_{I(SW\_IN)} = 5\text{ V}$  for TPS2141/51,  $V_{I(LDO\_IN)} = 5\text{ V}$ , all outputs unloaded  
(unless otherwise noted) (continued)**

## power switch

PARAMETER		TEST CONDITIONS†	MIN	TYP	MAX	UNIT
Switch on resistance (SW_IN to SW_OUT)	TPS2140, TPS2150	$T_J = 25^\circ\text{C}$ , $I = 500\text{ mA}$ , $V_{I(SW\_EN)} = 3.3\text{ V}$ or $V_{I(SW\_EN)} = 0\text{ V}$		40	50	$\text{m}\Omega$
		$T_J = 110^\circ\text{C}$ , $I = 500\text{ mA}$ , $V_{I(SW\_EN)} = 3.3\text{ V}$ or $V_{I(SW\_EN)} = 0\text{ V}$			65	
	TPS2141, TPS2151	$T_J = 25^\circ\text{C}$ , $I = 500\text{ mA}$ , $V_{I(SW\_EN)} = 5\text{ V}$ or $V_{I(SW\_EN)} = 0\text{ V}$		40	50	
		$T_J = 110^\circ\text{C}$ , $I = 500\text{ mA}$ , $V_{I(SW\_EN)} = 5\text{ V}$ or $V_{I(SW\_EN)} = 0\text{ V}$			65	
Switch current limit	Switch low-current-limit cutoff threshold, $V_{COFF(SW\_OUT)}$	Low current limit is disabled when $V_{O(SW\_OUT)}$ is above this $\%V_{I(SW\_IN)}$ level	91%	93%	96%	
	Switch low-current-limit cutoff threshold, $V_{CIN(SW\_OUT)}$	Low current limit is enabled $V_{O(SW\_OUT)}$ is below this $\%V_{I(SW\_IN)}$ level	76%	79%	82%	
	Low-current-limit mode: Ramp-up current limit, $I_{RCL}$		50	75	99	$\text{mA}$
	Low-current-limit mode: Short-circuit dc current limit, $I_{OS}$	SW_OUT is enabled into a short to ground	$T_J = 25^\circ\text{C}$	50	75	99
			$T_J = 110^\circ\text{C}$	47	75	99
	High-current-limit mode: Overload dc current limit, $I_{OL}$		$T_J = 25^\circ\text{C}$	900	1300	1800
			$T_J = 110^\circ\text{C}$	800	1300	1800
Switch forward leakage current $I_{LK\_SW}$	Current into pin SW_OUT	$V_{O(SW\_OUT)} = 0\text{ V}$ , $V_{I(SW\_IN)} = 5.5\text{ V}$ , $V_{I(SW\_EN)} = 0\text{ V}$ or $V_{I(SW\_EN)} = 5\text{ V}$		10		$\mu\text{A}$
Switch reverse leakage current $I_{RLK\_SW}$	Current into pin SW_OUT	$V_{O(SW\_OUT)} = 5.5\text{ V}$ , $V_{I(SW\_IN)} = 0\text{ V}$ , $V_{I(SW\_EN)} = 0\text{ V}$ or $V_{I(SW\_EN)} = 5\text{ V}$		10		
Switch pulldown transistor current		$V_{I(SW\_PLDN)} = 3.3\text{ V}$	9	15		$\text{mA}$
		$V_{I(PLDN\_SW)} = 1\text{ V}$		5		

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

## timing parameters, power switch

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{on}$	Turnon time	$C_L = 10\text{ }\mu\text{F}$ , No load		1		$\text{ms}$
$t_{off}$	Turnoff time	$C_L = 10\text{ }\mu\text{F}$ , SW_OUT is connected to SW_PLDN, No load		8		
$t_r$	Rise time	$C_L = 10\text{ }\mu\text{F}$ , No load		0.5		
$t_f$	Fall time	$C_L = 10\text{ }\mu\text{F}$ , SW_OUT is connected to SW_PLDN, No load		5		

## undervoltage lockout, SW\_IN

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Switch UVLO rising threshold	TPS2140, TPS2150				2.7	$\text{V}$
	TPS2141, TPS2151				4.1	
Switch UVLO falling threshold	TPS2140, TPS2150		2.3		2.45	
	TPS2141, TPS2151		3.5		3.9	
UVLO hysteresis‡			250			$\text{mV}$

‡ Not tested in production.



electrical characteristics over recommended operating junction temperature range,  
 $V_{I(SW\_IN)} = 3.3\text{ V}$  for TPS2140/50,  $V_{I(SW\_IN)} = 5\text{ V}$  for TPS2141/51,  $V_{I(LDO\_IN)} = 5\text{ V}$ , all outputs unloaded  
(unless otherwise noted) (continued)

adjustable voltage regulator ( $V_{set} = 0.9\text{ V}$  to  $3.3\text{ V}$ )

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{O(LDO\_OUT)}$	Output voltage total tolerance	$V_{I(LDO\_IN)} = V_{set} + 0.6\text{ V}$ to $5.5\text{ V}$ and $V_{I(LDO\_IN)} > 2.7\text{ V}$ , $I_{O(LDO\_OUT)} = 5\text{ mA}$ to $250\text{ mA}$	-4%		3%	
$V_{O(LDO\_OUT)}$	Line regulation	$V_{I(LDO\_IN)} = V_{O(LDO\_OUT)} + 0.6\text{ V}$ to $5.5\text{ V}$ and $V_{I(LDO\_IN)} > 2.7\text{ V}$ , $I_{O(LDO\_OUT)} = 5\text{ mA}$		0.03	0.1	%/V
$V_{O(LDO\_OUT)}$	Load regulation	$V_{I(LDO\_IN)} = V_{O(LDO\_OUT)} + 0.6\text{ V}$ to $5.5\text{ V}$ and $V_{I(LDO\_IN)} > 2.7\text{ V}$ , $I_{O(LDO\_OUT)} = 5\text{ mA}$ to $250\text{ mA}$ (a percentage of $V_{set}$ )		0.6%	1.3%	
$V_{SET}$	Regulated output voltage set range	$V_{I(LDO\_IN)} \geq V_{O(LDO\_OUT)} + 0.6\text{ V}$ $V_{I(LDO\_IN)} \geq 2.7\text{ V}$ , $I_{O(LDO\_OUT)} = 0\text{ mA}$ to $250\text{ mA}$	0.9		3.3	V
$V_{ref}$	ADJ reference voltage			0.8		V
$V_{DROP}$	Drop-out voltage	$V_{I(LDO\_IN)} - V_{SET} = -0.1\text{ V}$ , $I_{O(LDO\_OUT)} = 250\text{ mA}$		0.18	0.5	V
PSRR	Power supply rejection ratio, $20 \log(V_{ac}/V_o)^{\ddagger}$	$V_{ac} = 1\text{ kHz}$ sine wave, $100\text{ mV}_{pp}$ superimposed on $LDO\_IN$ , $C_L = 4.7\text{ }\mu\text{F}$ , $ESR = 0.25\text{ }\Omega$ , $I_O = 5\text{ mA}$		50		dB
LDO current limit	Short circuit peak current $^{\ddagger}$	LDO_OUT is enabled into a short to ground $T_J = -40^{\circ}\text{C}$ to $110^{\circ}\text{C}$		0.7	2	A
	Overload or short circuit dc current limit	LDO_OUT is over-loaded or enabled into a short to ground $T_J = -40^{\circ}\text{C}$ to $110^{\circ}\text{C}$	250	325	500	mA
LDO forward leakage current $I_{LK\_LDO}$	Current into pin LDO_OUT	$V_{O(LDO\_OUT)} = 0\text{ V}$ , $V_{I(LDO\_IN)} = 5.5\text{ V}$ , $V_{I(EN\_LDO)} = 0\text{ V}$			10	$\mu\text{A}$
LDO reverse leakage current $I_{RLK\_LDO}$	Current into pin LDO_OUT	$V_{O(LDO\_OUT)} = 5.5\text{ V}$ , $V_{I(LDO\_IN)} = 0\text{ V}$ , $V_{I(EN\_LDO)} = 0\text{ V}$			10	$\mu\text{A}$
$t_{ON\_LDO}$	Turnon time	From 50% $V_{I(EN\_LDO)}$ to 90% $V_{O(LDO\_OUT)}$ , $R_L = V_{O(LDO\_OUT)}/0.2$ , $C_L = 10\text{ }\mu\text{F}$ (20%)	0.1	0.35	1	ms
$t_{OFF\_LDO}$	Turnoff time	From 50% $V_{I(EN\_LDO)}$ to 10% $V_{O(LDO\_OUT)}$ , $R_L = V_{O(LDO\_OUT)}/0.2$ , $C_L = 10\text{ }\mu\text{F}$ (20%)	0.1	0.4	1	
	$V_{O(LDO\_OUT)}$ ramp-up time (0% to 90%)	$V_{I(EN\_LDO)} = 5\text{ V}$ , $V_{I(LDO\_IN)}$ ramping up from 10% to 90% in $0.1\text{ ms}$ , $R_L = V_{O(LDO\_OUT)}/0.2$ , $C_L = 10\text{ }\mu\text{F}$ (20%)	0.1	0.65	1	
LDO pulldown transistor current		$V_{I(PLDN\_LDO)} = 3.3\text{ V}$	9	15		mA
		$V_{I(LDO\_PLDN)} = 1\text{ V}$		5		

$^{\ddagger}$  Not tested in production.

undervoltage lockout, LDO\_IN

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
LDO UVLO rising threshold				2.7	V
LDO UVLO falling threshold		2.25		2.45	V
UVLO hysteresis $^{\ddagger}$		250			mV

$^{\ddagger}$  Not tested in production.

# TPS2140, TPS2141 TPS2150, TPS2151

SLVS399 – JANUARY 2002

**electrical characteristics over recommended operating junction temperature range,  
 $V_{I(SW\_IN)} = 3.3\text{ V}$  for TPS2140/50,  $V_{I(SW\_IN)} = 5\text{ V}$  for TPS2141/51,  $V_{I(LDO\_IN)} = 5\text{ V}$ , all outputs unloaded  
(unless otherwise noted) (continued)**

**logic section ( $\overline{\text{SW\_EN}}$ , SW\_EN, LDO\_EN, ADJ, SW\_PG, LDO\_PG)**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Logic input current	$I_{I(SW\_EN)}$ , source	$V_{I(SW\_EN)} = 0\text{ V}$	1		5	$\mu\text{A}$
	$I_{I(SW\_EN)}$ , sink	$V_{I(SW\_EN)} = 5\text{ V}$	1		5	
	$I_{I(LDO\_EN)}$	$V_{I(EN\_LDO)} = 0\text{ V} - 5.5\text{ V}$	-1		1	
Logic input high level	$V_{IH\_MIN(SW\_EN)}$		2			V
	$V_{IH\_MIN(SW\_EN)}$		2			
	$V_{IH\_MIN(LDO\_EN)}$		2			
Logic input low level	$V_{IL\_MAX(SW\_EN)}$				0.8	V
	$V_{IL\_MAX(SW\_EN)}$				0.8	
	$V_{IL\_MAX(LDO\_EN)}$				0.8	
Floating input voltage	$V_{IF(SW\_EN)}$	$\overline{\text{SW\_EN}}$ pin is open	2.5			V
	$V_{IF(SW\_EN)}$	SW_EN pin is open			0.4	
LDO feedback input current	$I_{I(ADJ)}$	$V_{I(ADJ)} = 0\text{ V} - 5.5\text{ V}$	-1		1	$\mu\text{A}$
SW_PG sense threshold, $V_{TH\_SW}$	TPS2140, TPS2150	Percentage of $V_{I(SW\_IN)}$	85%	88%	90%	
	TPS2141, TPS2151					
LDO_PG sense threshold, $V_{TH\_LDO}$		A percentage of output voltage set point $V_{SET}$ , derived from a resistor divider	92%	94%	96%	
PG hysteresis (all) <sup>‡</sup>	$V_{TH\_HYS}$		2%	2.5%	3.5%	
SW_PG rising edge deglitch <sup>‡</sup>	$t_{d\_SWPG\_rise}$		1	2.5		ms
PG falling edge deglitches times (all) <sup>‡</sup>	$t_{d\_PG\_fail}$		50	150		$\mu\text{s}$
SW_PG minimum output high state voltage	$V_{OH\_MIN(SW\_PG)}$	Source current $I_{O(SW\_PG)} = 1\text{ mA}$ , $V_{I(SW\_OUT)} > V_{TH\_SW}$	$V_{I(SW\_IN)}$ -0.5			V
SW_PG maximum output low state voltage	$V_{OL\_MAX(SW\_PG)}$	Sink current $I_{O(SW\_PG)} = 1\text{ mA}$ , $V_{I(SW\_OUT)} < V_{TH\_SW}$			0.5	
LDO_PG maximum output low state voltage	$V_{OH\_MIN(LDO\_PG)}$	Sink current $I_{O(SW\_PG)} = 1\text{ mA}$ , $V_{I(LDO\_OUT)} < V_{TH\_LDO}$			0.5	
LDO_PG leakage current	$I_{LK(LDO\_PG)}$	$V_{O(LDO\_PG)} = 5.5\text{ V}$		1		$\mu\text{A}$

<sup>‡</sup> Not tested in production.

## thermal shutdown characteristics

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Low thermal shutdown (whole device)	Over temperature trip point <sup>‡</sup>	Switch and/or LDO in current limit	125		137	°C
	Hysteresis <sup>‡</sup>			10		
High thermal shutdown (whole device)	Over temperature trip point <sup>‡</sup>	Switch and LDO are not in current limit	155		170	°C
	Hysteresis <sup>‡</sup>			10		

<sup>‡</sup> Not tested in production.

## PARAMETER MEASUREMENT INFORMATION

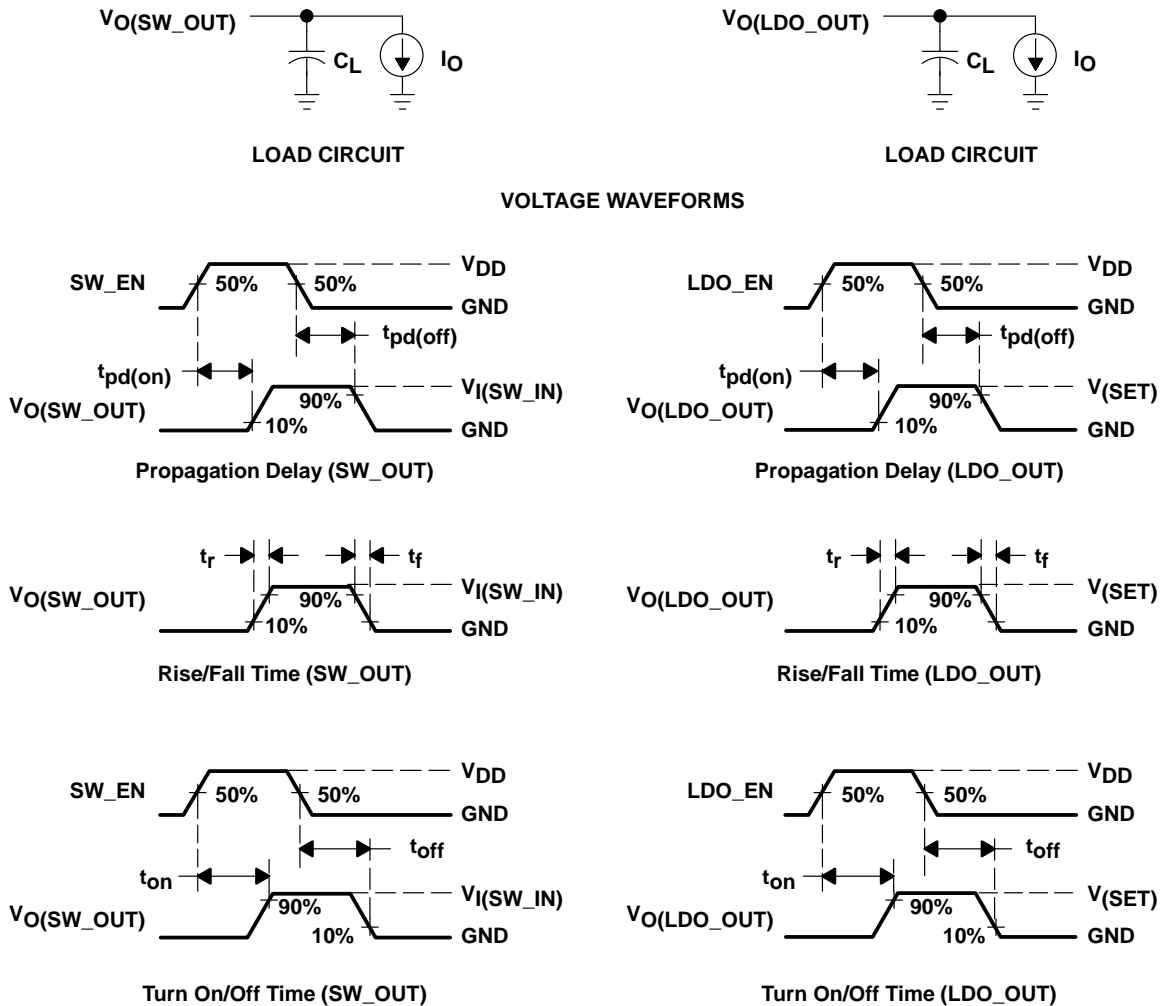


Figure 1. Test Circuits and Voltage Waveforms

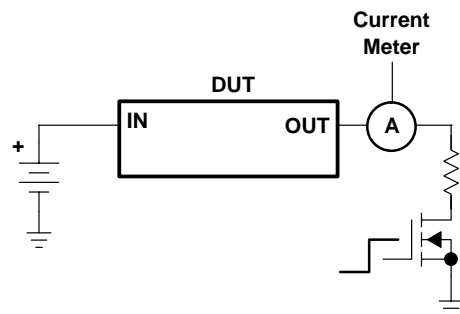


Figure 2. Current Limit Test Circuit

## PARAMETER MEASUREMENT INFORMATION

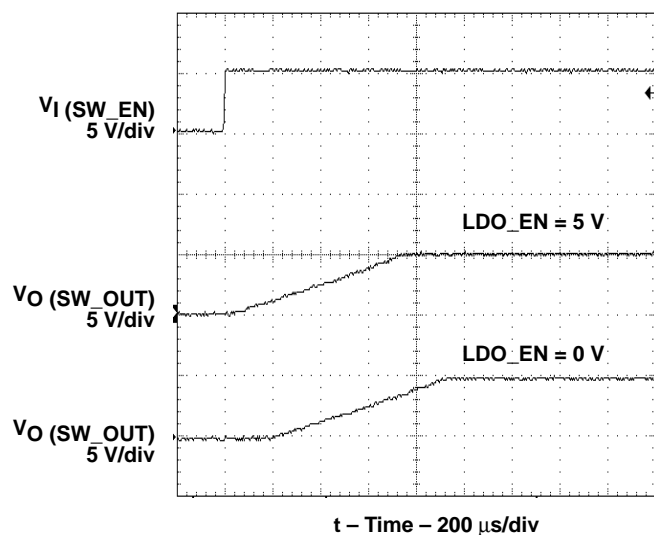


Figure 3. Switch Turnon Delay and Rise Time With 10-μF Load (SW\_OUT Shorted With SW\_PLDN)

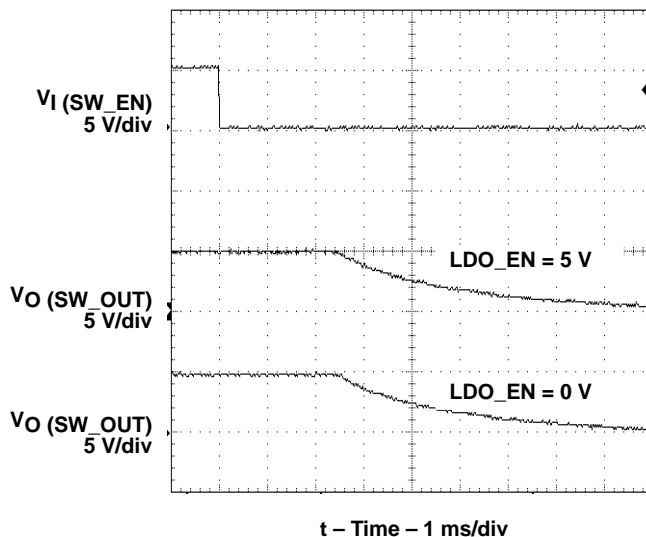


Figure 4. Switch Turnoff Delay and Fall Time With 10-μF Load (SW\_OUT Shorted With SW\_PLDN)

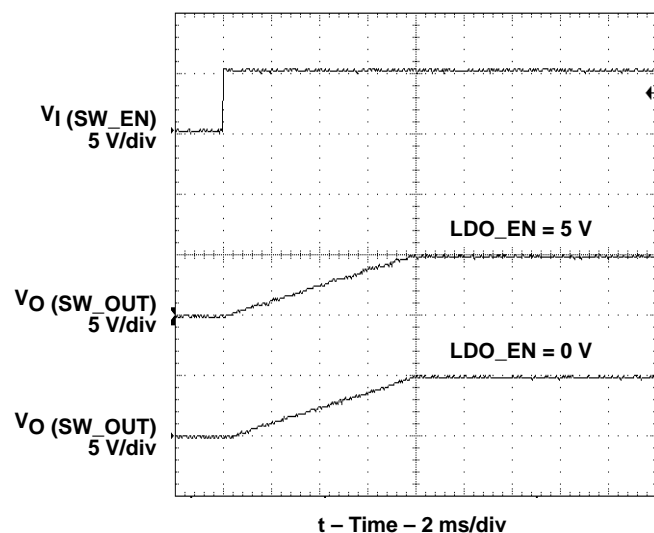


Figure 5. Switch Turnon Delay and Rise Time With 120-μF Load (SW\_OUT Shorted With SW\_PLDN)

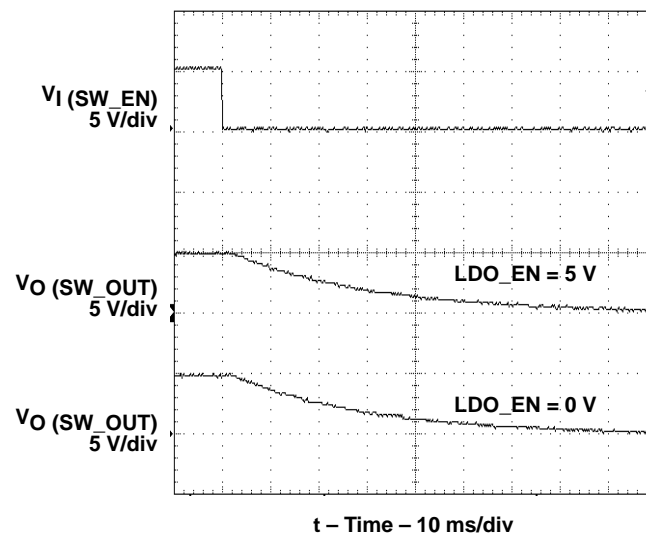


Figure 6. Switch Turnoff Delay and Fall Time With 120-μF Load (SW\_OUT Shorted With SW\_PLDN)

## PARAMETER MEASUREMENT INFORMATION

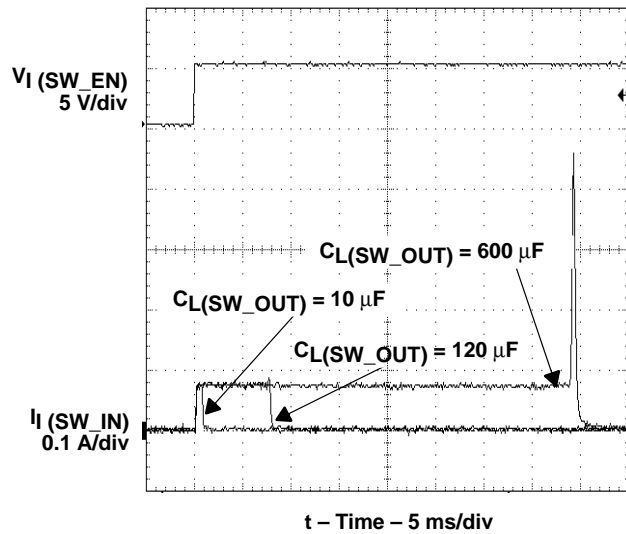


Figure 7. Switch Turnon Inrush Current With Different Load Capacitance

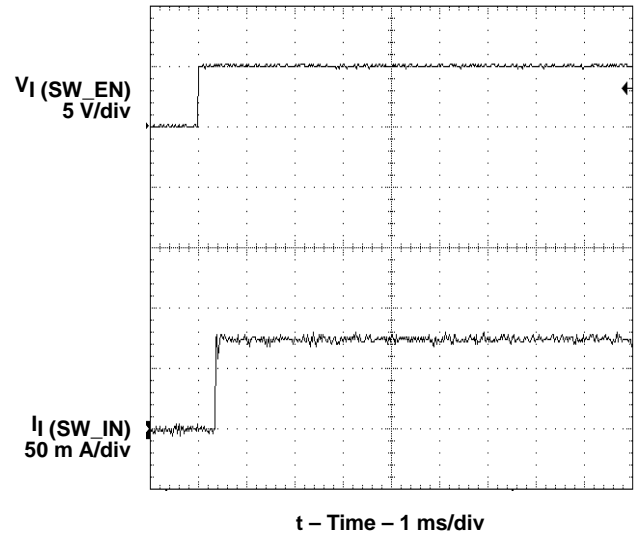


Figure 8. Switch Short-Circuit Current, With Switch Enabled Into a Short Circuit

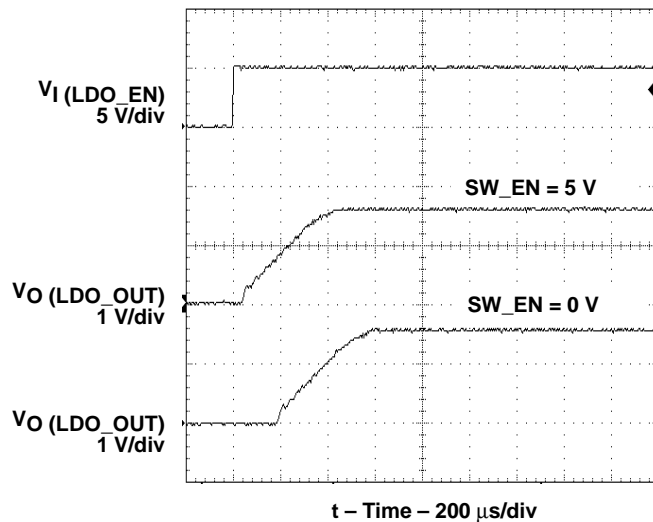


Figure 9. LDO Turnon Delay and Rise Time With 4.7  $\mu F$  Load (LDO\_OUT Shorted With LDO\_PLDN)

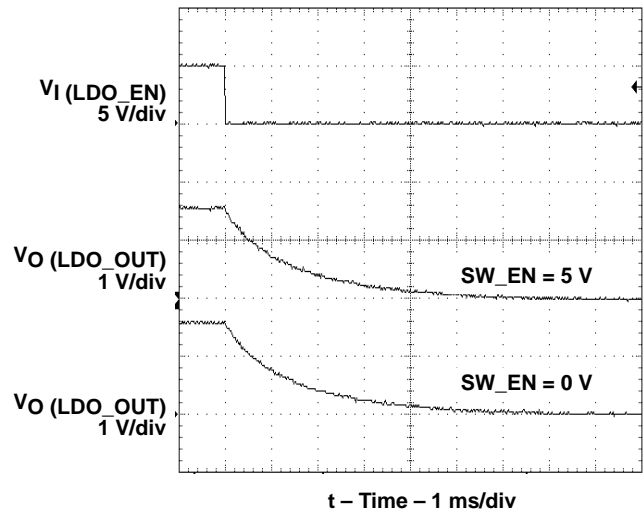


Figure 10. LDO Turnoff Delay and Fall Time With 4.7  $\mu F$  Load (LDO\_OUT Shorted With LDO\_PLDN)

## PARAMETER MEASUREMENT INFORMATION

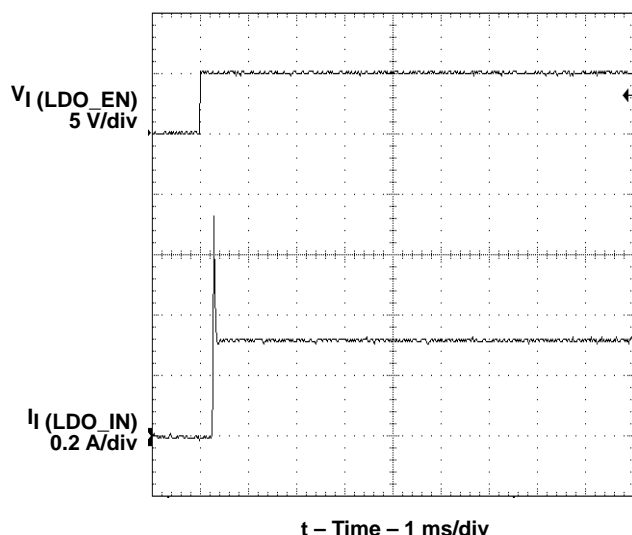


Figure 11. LDO Short-Circuit Current, With LDO Enabled Into a Short Circuit

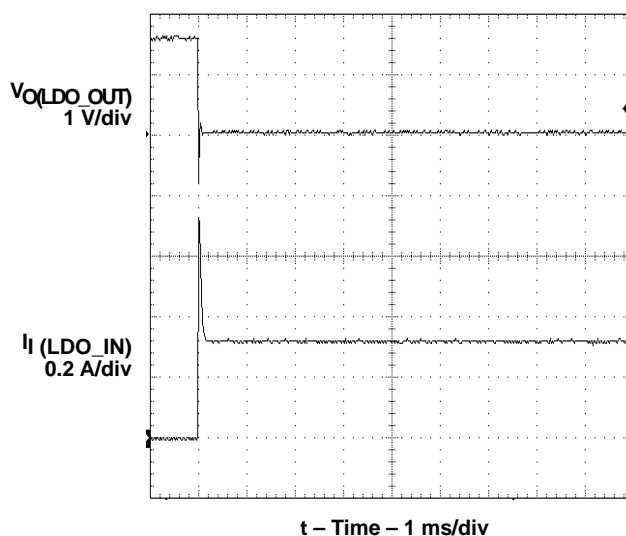


Figure 12. LDO Short-Circuit Current, With Short Circuit Connected Into Enabled LDO

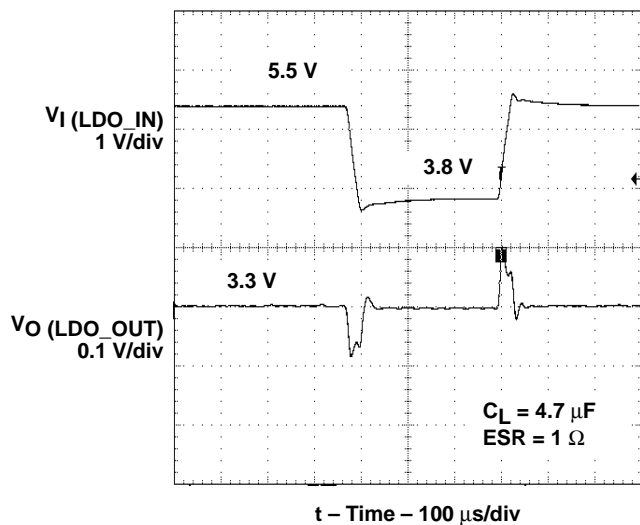


Figure 13. LDO Line Transient Response

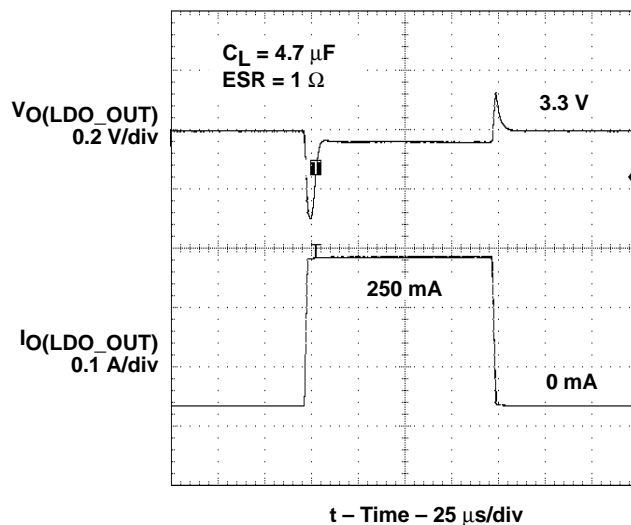


Figure 14. LDO Load Transient Response

## PARAMETER MEASUREMENT INFORMATION

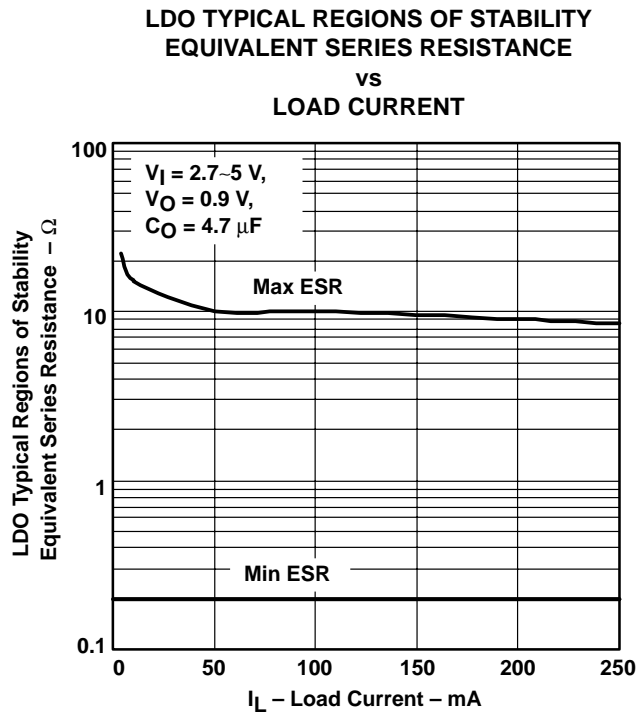


Figure 15

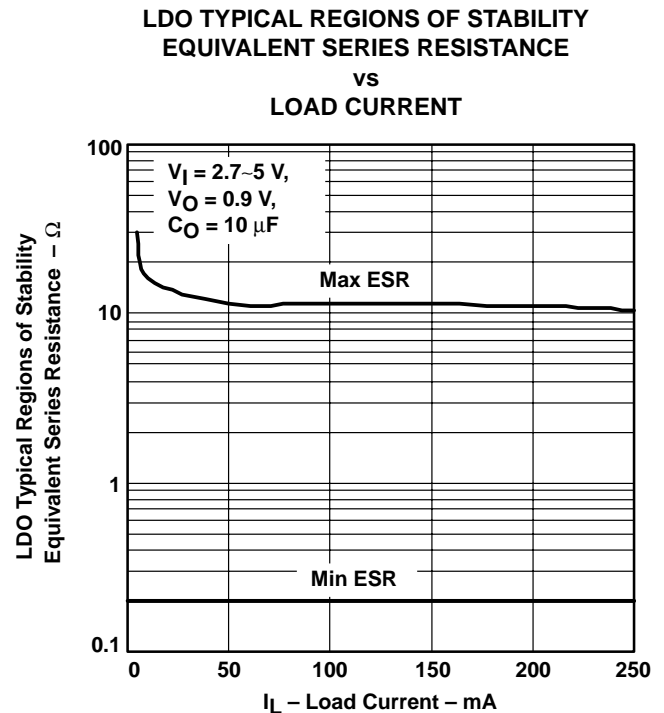


Figure 16

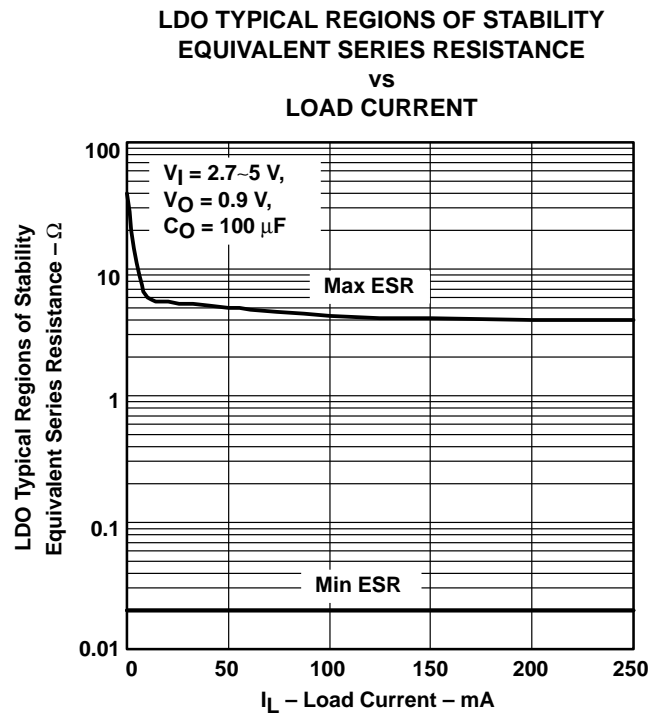


Figure 17

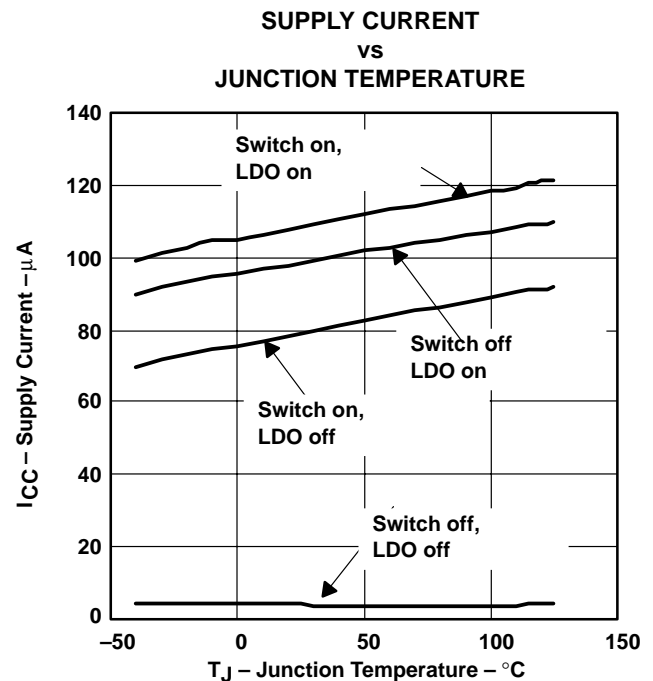


Figure 18

## PARAMETER MEASUREMENT INFORMATION

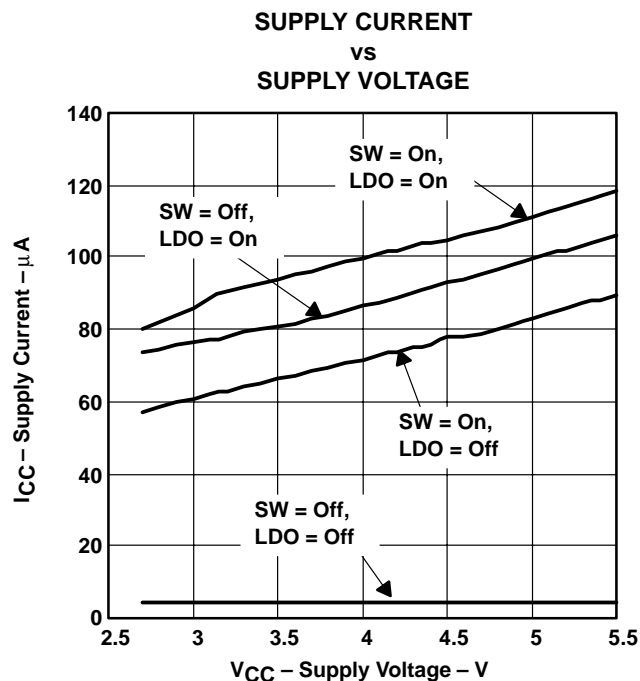


Figure 19

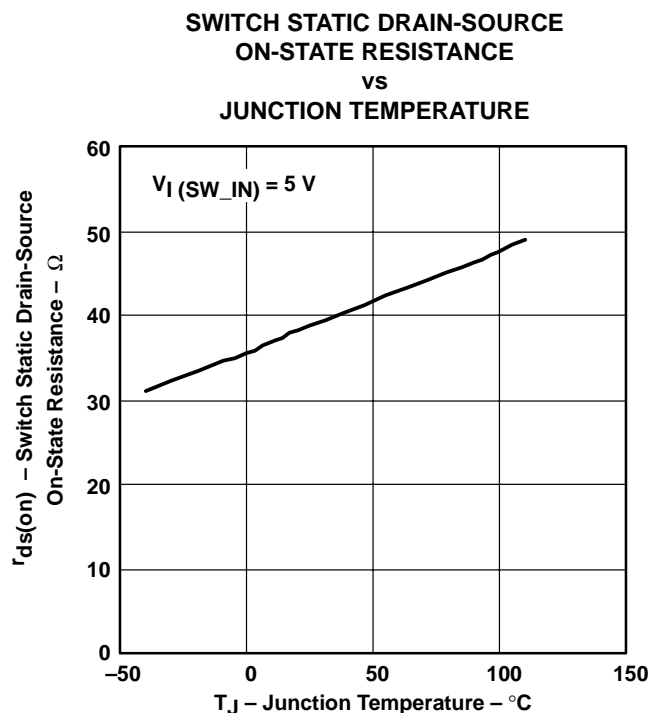


Figure 20

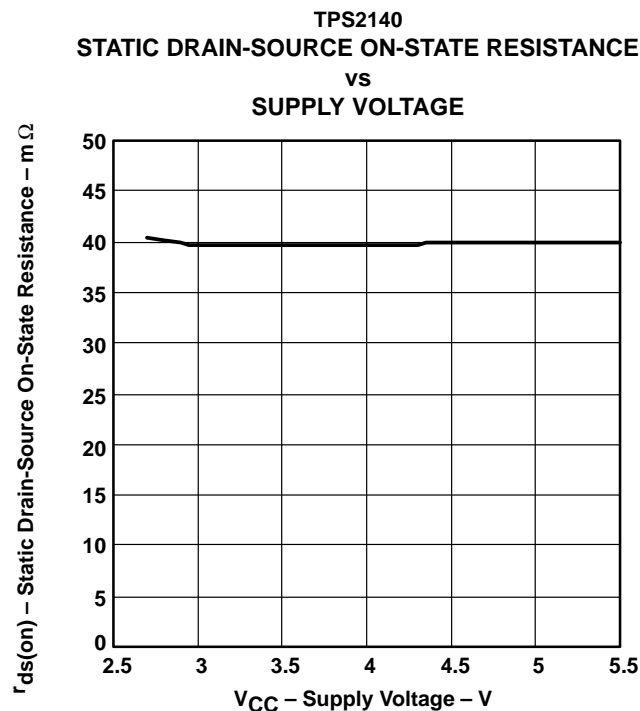


Figure 21

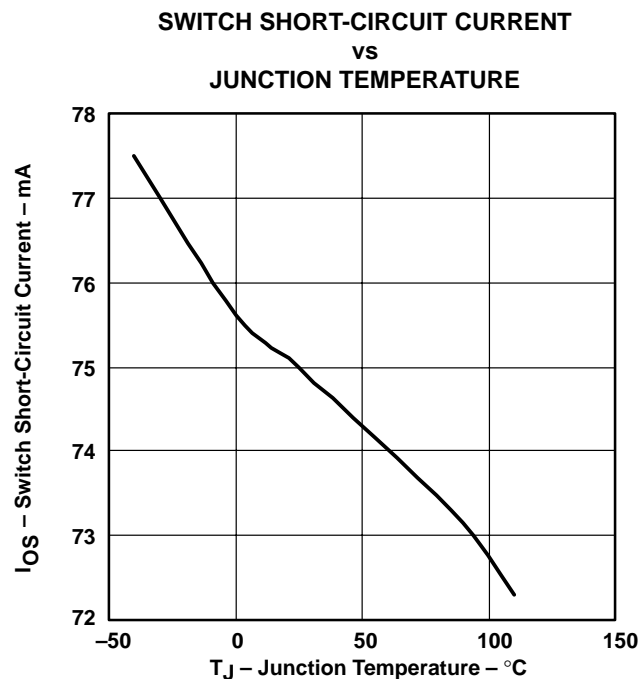


Figure 22



## PARAMETER MEASUREMENT INFORMATION

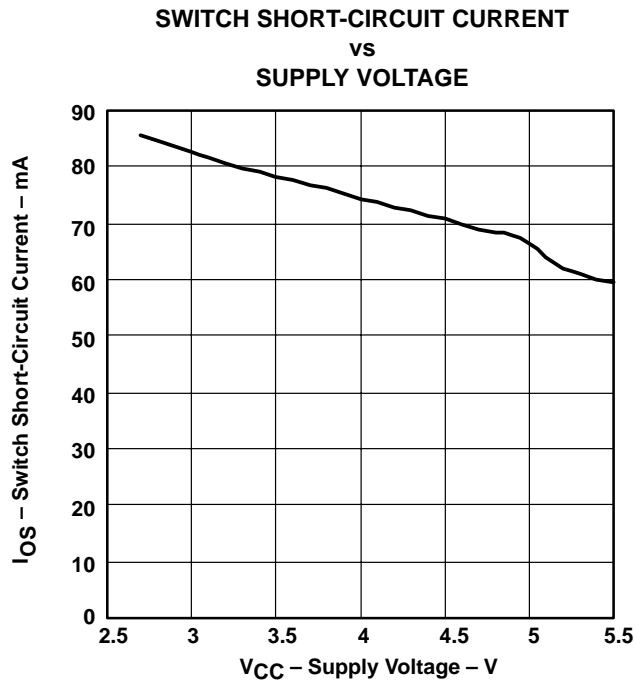


Figure 23

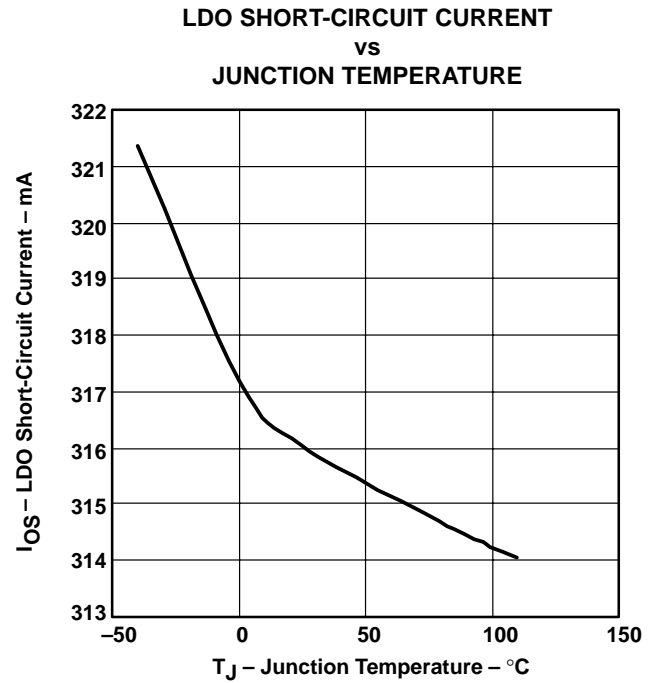


Figure 24

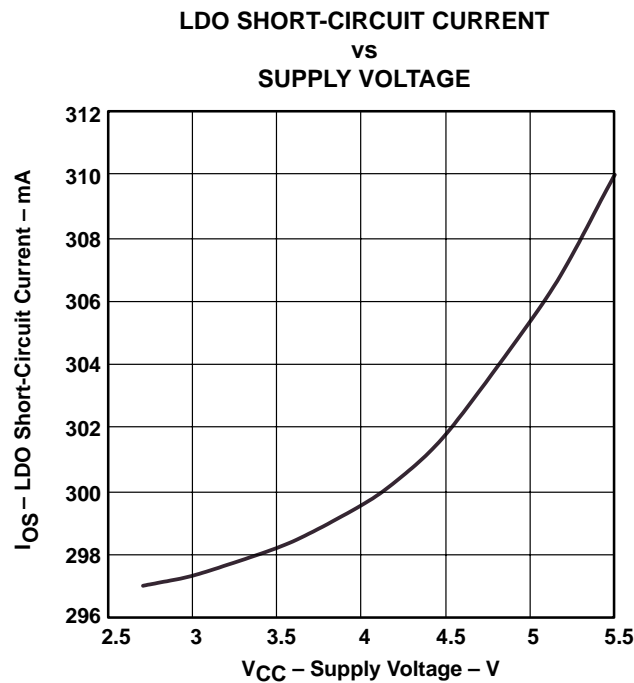


Figure 25

## APPLICATION INFORMATION

### external capacitor requirements on power lines

Ceramic bypass capacitors (0.01  $\mu$ F to 0.1  $\mu$ F) between SW\_IN and GND and LDO\_IN and GND, close to the device, are recommended to improve load transient response and noise rejection. Bulk capacitors (4.7  $\mu$ F or higher) between SW\_IN and GND and LDO\_IN and GND are also recommended, especially if load transients in the hundreds of milliamps with fast rise times are anticipated. A 66- $\mu$ F bulk capacitor is recommended from SW\_OUT to ground, especially when the output load is heavy. This precaution helps reduce transients seen on the power rails. Additionally, bypassing the outputs with a 0.1- $\mu$ F ceramic capacitor improves the immunity of the device to short-circuit transients.

### LDO output capacitor requirements

Stabilizing the internal control loop of the LDO requires an output capacitor connected between LDO\_OUT and GND. The minimum recommended capacitance is 4.7  $\mu$ F with an ESR value between 200 m $\Omega$  and 8.5  $\Omega$ . Solid tantalum electrolytic, aluminum electrolytic and multilayer ceramic capacitors are all suitable, provided they meet the ESR requirements (see Figures 15, 16, and 17). The adjustable LDO (for output voltages lower than 3 V) requires a bypass capacitor across the feedback resistor as shown in Figure 26. The nominal value of this capacitor is determined by using the following equation:

$$C_f = \frac{1}{(63.7 \times 10^3 \times 2 \times 3.14 \times R1)} - 4 \text{ pF} \quad (1)$$

where R1 is derived by programming the adjustable LDO (see programming the adjustable LDO regulator section shown below).

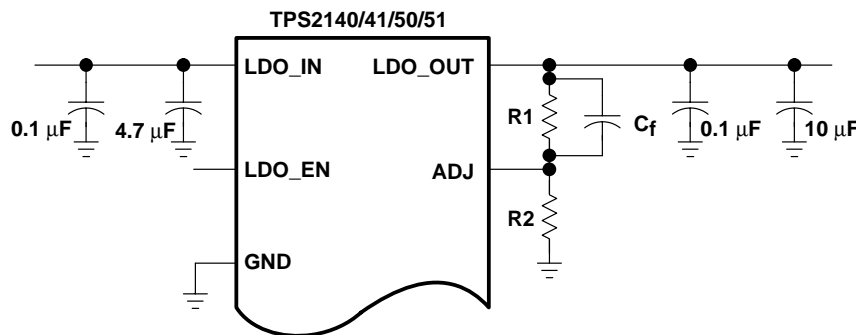


Figure 26. LDO External Resistor Divider

### programming the adjustable LDO regulator

The output voltage of the TPS2140/41/50/51 adjustable regulator is programmed using an external resistor divider as shown in Figure 26. The output voltage is calculated using equation 2:

$$LDO\_OUT = V_{ref} \left( 1 + \frac{R1}{R2} \right) \quad (2)$$

where  $V_{ref} = 0.8 \text{ V}$  typical (internal reference voltage).

Resistors R1 and R2 should be chosen for approximately 4- $\mu$ A (minimum) divider current. Lower value resistors can be used but offer no inherent advantage and waste more power. Higher values should be avoided as a minimum load is required to sink the LDO forward leakage and maintain regulation. The recommended design procedure is to choose  $R2 = 200 \text{ k}\Omega$  to set the divider current at 4- $\mu$ A and then solve the LDO\_OUT equation for R1.

## APPLICATION INFORMATION

### programming the adjustable LDO regulator (continued)

**Table 1. Output Voltage Programming Guide**

OUTPUT VOLTAGE	R1	R2	Cf
3.3	625 k $\Omega$	200 k $\Omega$	NR <sup>†</sup>
3.0	550 k $\Omega$	200 k $\Omega$	NR <sup>†</sup>
2.5	425 k $\Omega$	200 k $\Omega$	2 pF
1.8	250 k $\Omega$	200 k $\Omega$	6 pF
1.5	175 k $\Omega$	200 k $\Omega$	10.3 pF
1.0	50 k $\Omega$	200 k $\Omega$	46 pF

<sup>†</sup> NR – Not required

### overcurrent

When an overcurrent condition is detected, the device maintains a constant output current. Complete shutdown occurs only if the fault is present long enough to activate thermal limiting.

Three possible overload conditions can occur. In the first condition, the output is shorted before the device is enabled. Once enabled the TPS2140/41/50/51 sense the short and immediately switch to a constant-current output.

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

In the third condition, the load has been gradually increased beyond the recommended operating current. The current is permitted to rise until the current-limit threshold is reached or until the thermal limit of the device is exceeded. The TPS2140/41/50/51 are capable of delivering current up to the current-limit threshold without damaging the device. Once the threshold has been reached, the device switches into its constant-current mode.

### dual current limit

The TPS2140/41/50/51 has a dual-current-limited power switch. When the output voltage of the power switch is below a defined power-good threshold voltage, the typical current the switch can conduct is approximately 75 mA. Therefore, the inrush current can be limited to about 75 mA even if there is a very large capacitor on the load. When the switch output voltage reaches the power-good threshold voltage, the internal controller enables the higher current limit, which is at least 0.8 A and at most 1.8 A. This dual-current-limit feature completely solves the large inrush current problems that most power management applications experience. Figure 7 shows the inrush currents with different load capacitance. The current spike at  $C_L = 600 \mu\text{F}$  is due to voltage difference between input and output once the higher current limit is enabled.

Because the lower current limit is only about 75 mA, the initial resistive load or equivalent load current on the switch output must be less than 50 mA, excluding the load capacitors.

---

## APPLICATION INFORMATION

### power dissipation and junction temperature

The major source of power dissipation for the TPS2140/41/50/51 comes from the internal voltage regulator and the N-channel MOSFET. Checking the power dissipation and junction temperature is always a good design practice and it starts with determining the  $r_{DS(on)}$  of the N-channel MOSFET according to the input voltage and operating temperature. As an initial estimate, use the highest operating ambient temperature of interest and read  $r_{DS(on)}$  from the graphs shown in the Typical Characteristics section of this data sheet. Using this value, the power dissipation per switch can be calculated using:

$$P_D = r_{DS(on)} \times I^2 \quad (3)$$

The power dissipation for the internal voltage regulator is calculated using:

$$P_D = (V_I - V_{O(min)}) \times I_O \quad (4)$$

The total power dissipation for the device becomes:

$$P_{D(total)} = P_{D(LDO)} + P_{D(switch)} \quad (5)$$

Finally, calculate the junction temperature:

$$T_J = P_D \times R_{\theta JA} + T_A \quad (6)$$

Where:

$T_A$  = Ambient temperature °C

$R_{\theta JA}$  = Thermal resistance °C/W, equal to inverting the derating factor found on the power dissipation table in this data sheet.

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

### thermal protection

Thermal protection prevents damage to the IC when heavy-overload or short-circuit faults are present for extended periods of time. The overcurrent faults force the TPS2140/41/50/51 into constant-current mode at first, which causes the voltage across the high-side switch to increase; under short-circuit conditions, the voltage across the switch is equal to the input voltage. The increased dissipation causes the junction temperature to rise to high levels.

If either the power distribution switch or the LDO is in overcurrent, a thermal sensor trips at approximately 135°C, turning off both circuits. Normal operation resumes when the die temperature drops approximately 10°C. If neither the power distribution switch nor the LDO is in overcurrent, a second thermal sensor trips at approximately 160°C. Normal operation resumes when the die temperature drops approximately 10°C.

## APPLICATION INFORMATION

### undervoltage lockout (UVLO)

An undervoltage lockout ensures that the device (LDO and switch) is in the off state at power up. The UVLO also keeps the device from being turned on until the power supply has reached the start threshold (see undervoltage lockout table), even if the switches are enabled. The UVLO is also activated whenever the input voltage falls below the stop threshold as defined in the undervoltage lockout table. This function facilitates the design of hot-insertion systems where it is not possible to turn off the power switches before input power is removed. Upon reinsertion, the power switches are turned on with a controlled rise time to reduce EMI and voltage overshoots.

### universal serial bus (USB) applications

The universal serial bus (USB) interface is a multiplexed serial bus operating at either 12 Mbps, or 1.5 Mbps for USB 1.1, or 480 Mbps for USB 2.0. The USB interface is designed to accommodate the bandwidth required by PC peripherals such as keyboards, printers, scanners, and mice. The four-wire USB interface was conceived for dynamic attach-detach (hot plug-unplug) of peripherals. Two lines are provided for differential data, and two lines are provided for 5-V power distribution.

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

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

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

The TPS2140/41/50/51 are well suited for USB hub and peripheral applications. The internal LDO can be used to provide the 3.3-V power needed by the controller while the switch distributes power to the downstream functions.

### USB power-distribution requirements

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

- Hosts/self-powered hubs must:
  - Current-limit downstream ports
  - Report overcurrent conditions on USB VBUS
- Bus-powered hubs must:
  - Enable/disable power to downstream ports
  - Power up at <100 mA
  - Limit inrush current (<44  $\Omega$  and 10  $\mu$ F)
- Functions must:
  - Limit inrush currents
  - Power up at <100 mA

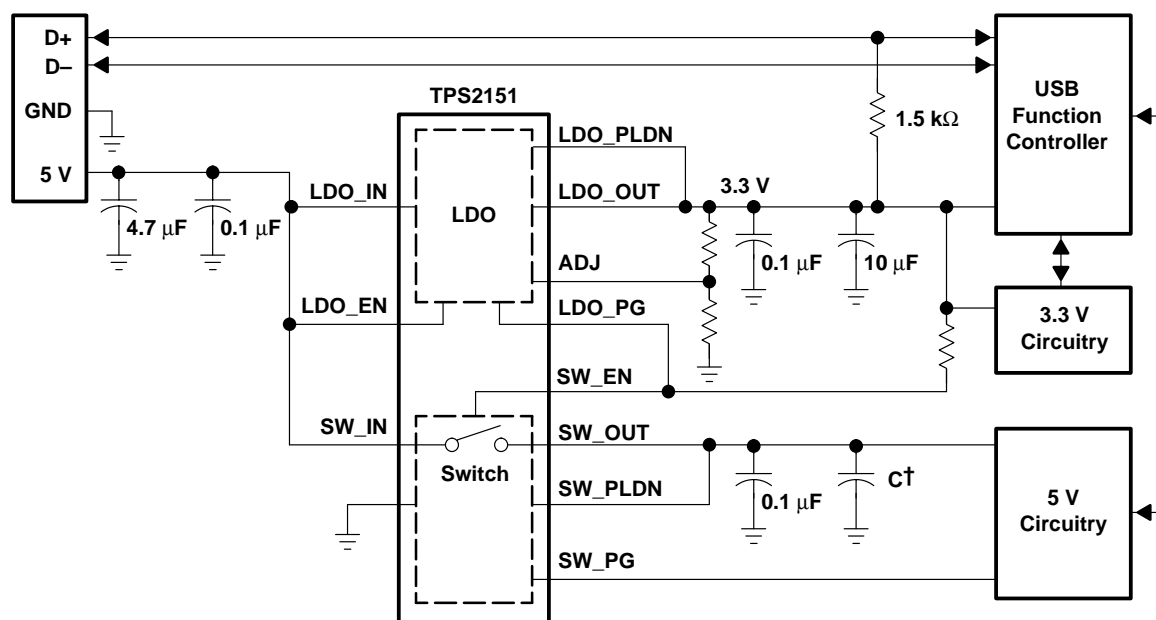
## APPLICATION INFORMATION

### USB power-distribution requirements (continued)

The feature set of the TPS2140/41/50/51 allows them to meet the requirements of functions. The integrated current-limiting is required by hubs and peripheral functions. The logic-level enable and controlled rise times meet the need of both input and output ports on bus-powered hubs, as well as the input ports for bus-powered functions.

### USB applications

Figure 27 shows the TPS2151 being used in a USB bus-powered peripheral design. The internal 3.3-V LDO is used to provide power for the USB function controller as well as to the 1.5-k $\Omega$  pullup resistor. One example of USB bus-powered peripheral applications is the USB ADSL modem, which needs several power rails and power sequencing.



† C can be very high-value capacitance

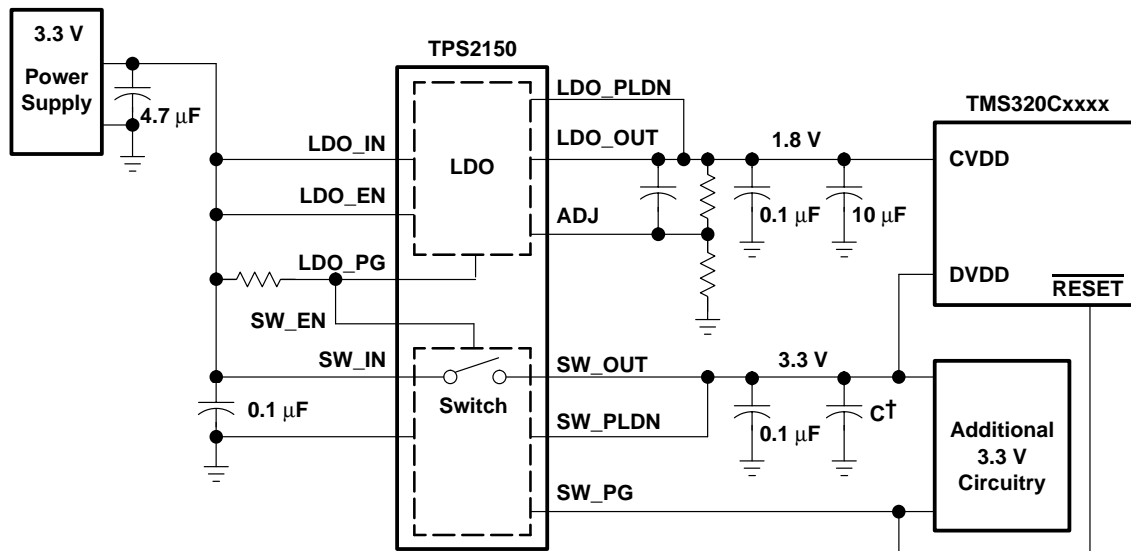
Figure 27. Bus-Powered USB Peripheral Application

## APPLICATION INFORMATION

### DSP applications

Figure 28 shows the TPS2150 in a DSP application. DSPs use 1.8-V core voltage and 3.3-V I/O voltage. In this type of application the TPS2150 adjustable LDO is configured for a 1.8-V output specifically for the DSP core voltage.

The additional 3.3-V circuitry is powered through the switch of the TPS2150 only after the DSP is up and running.



† C can be very high-value capacitance

Figure 28. DSP Power Sequencing Application

### system level design consideration of DSP power application

System level design considerations, such as bus contention, may require supply sequencing to be implemented. In this case, the core supply should be powered up at the same time as (or prior to and powered down after), the I/O buffers. This is to ensure that the I/O buffers receive valid inputs from the core before the output buffers are powered up, thus preventing bus contention with other chips on the board.

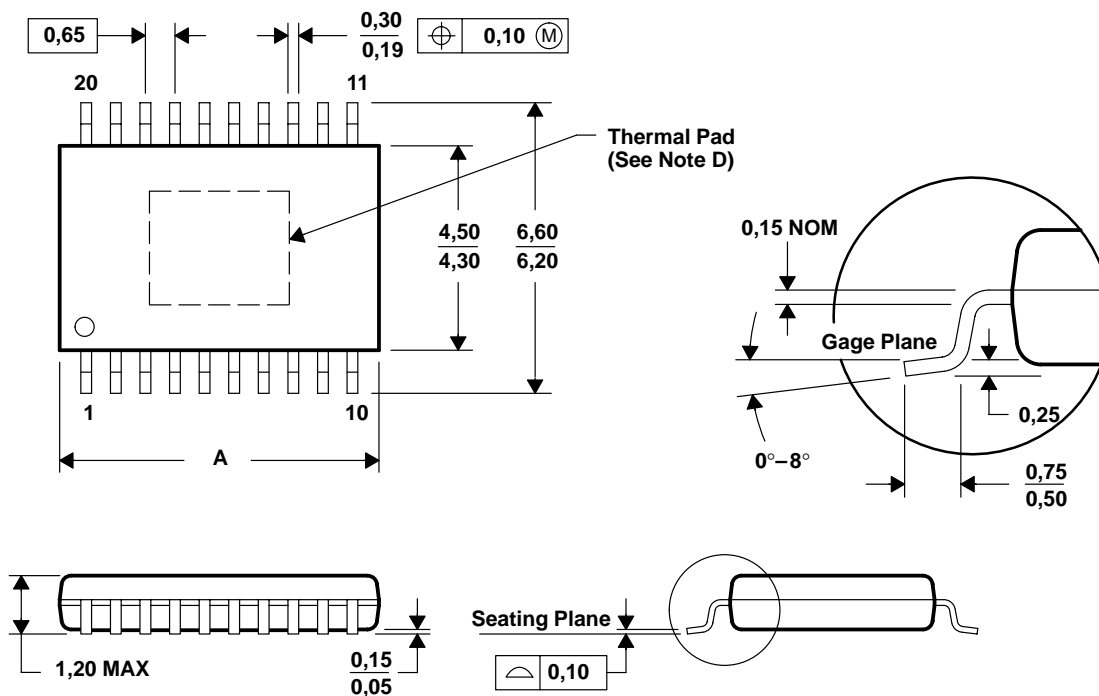
For some DSP systems, the core supply may be required to provide a considerable amount of current until the I/O supply is powered up. This extra current condition is a result of uninitialized logic within the DSP(s). Decreasing the amount of time between the core supply power up and the I/O supply power up can minimize the effects of this current draw.

## MECHANICAL DATA

PWP (R-PDSO-G\*\*)

PowerPAD™ PLASTIC SMALL-OUTLINE

20 PINS SHOWN



	PINS **	14	16	20	24	28
DIM						
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/F 10/98

- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Body dimensions do not include mold flash or protrusions.
  - The package thermal performance may be enhanced by bonding the thermal pad to an external thermal plane. This pad is electrically and thermally connected to the backside of the die and possibly selected leads.
  - Falls within JEDEC MO-153

PowerPAD is a trademark of Texas Instruments.



## **IMPORTANT NOTICE**

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Mailing Address:

Texas Instruments  
Post Office Box 655303  
Dallas, Texas 75265