



LP295x-N Series of Adjustable Micropower Voltage Regulators

1 Features

- Input Voltage Range: 2.3 V to 30 V
- 5-V, 3-V, and 3.3-V Output Voltage Versions Available
- High Accuracy Output Voltage
- Ensured 100-mA Output Current
- Extremely Low Quiescent Current
- Low Dropout Voltage
- Extremely Tight Load and Line Regulation
- Very Low Temperature Coefficient
- Use as Regulator or Reference
- Needs Minimum Capacitance for Stability
- Current and Thermal Limiting
- Stable With Low-ESR Output Capacitors (10 mΩ to 6 Ω)
- LP2951-N Versions Only:
 - Error Flag Warns of Output Dropout
 - Logic-Controlled Electronic Shutdown
 - Output Programmable From 1.24 V to 29 V

2 Applications

- High-Efficiency Linear Regulator
- Regulator with Undervoltage Shutdown
- Low Dropout Battery-powered Regulator
- Snap-ON/Snap-OFF Regulator

3 Description

The LP2950-N and LP2951-N are micropower voltage regulators with very low quiescent current (75 μA typical) and very low dropout voltage (typical 40 mV at light loads and 380 mV at 100 mA). They are ideally suited for use in battery-powered systems. Furthermore, the quiescent current of the device increases only slightly in dropout, prolonging battery life.

Careful design of the LP2950-N/LP2951-N has minimized all contributions to the error budget. This includes a tight initial tolerance (0.5% typical), extremely good load and line regulation (0.05% typical) and a very low output voltage temperature coefficient, making the part useful as a low-power voltage reference.

One such feature is an error flag output which warns of a low output voltage, often due to falling batteries on the input. It may be used for a power-on reset. A second feature is the logic-compatible shutdown input which enables the regulator to be switched on and off. Also, the part may be pin-strapped for a 5-V, 3-V, or 3.3-V output (depending on the version), or programmed from 1.24 V to 29 V with an external pair of resistors.

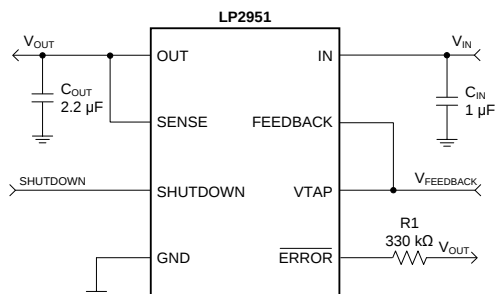
The LP2950-N is available in the surface-mount TO-252 package and in the popular 3-pin TO-92 package for pin-compatibility with older 5-V regulators. The 8-pin LP2951-N is available in plastic, ceramic dual-in-line, WSON, or metal can packages and offers additional system functions.

Device Information⁽¹⁾

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LP2950-N	TO-92 (3)	4.30 mm × 4.30 mm
	TO-252 (3)	9.91 mm × 6.58 mm
LP2951-N	SOIC (8)	4.90 mm × 3.91 mm
	VSSOP (8)	3.00 mm × 3.00 mm
	WSON (8)	4.00 mm × 4.00 mm
	PDIP (8)	9.81 mm × 6.35 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

LP2951 Simplified Schematic



LP2950-N Simplified Schematic

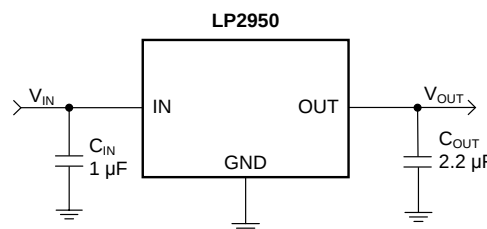


Table of Contents

1 Features	1	8.4 Device Functional Modes.....	18
2 Applications	1	9 Application and Implementation	19
3 Description	1	9.1 Application Information.....	19
4 Revision History	2	9.2 Typical Applications	20
5 Voltage Options	3	10 Power Supply Recommendations	32
6 Pin Configuration and Functions	4	11 Layout	32
7 Specifications	5	11.1 Layout Guidelines	32
7.1 Absolute Maximum Ratings	5	11.2 Layout Example	32
7.2 ESD Ratings.....	5	11.3 WSON Mounting	33
7.3 Recommended Operating Conditions.....	5	12 Device and Documentation Support	34
7.4 Thermal Information: LP2950-N.....	6	12.1 Documentation Support	34
7.5 Thermal Information: LP2951-N.....	6	12.2 Related Links	34
7.6 Electrical Characteristics.....	7	12.3 Community Resources.....	34
7.7 Typical Characteristics	10	12.4 Trademarks	34
8 Detailed Description	16	12.5 Electrostatic Discharge Caution.....	34
8.1 Overview	16	12.6 Glossary	34
8.2 Functional Block Diagrams	16	13 Mechanical, Packaging, and Orderable Information	34
8.3 Feature Description.....	17		

4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision O (December 2014) to Revision P	Page
• Added rows to <i>ESD Ratings</i> table to differentiate values for pins 3 and 7 of the LP2951-N device.....	5
• Added footnotes 2 and 3 to both <i>Thermal Information</i> tables	6

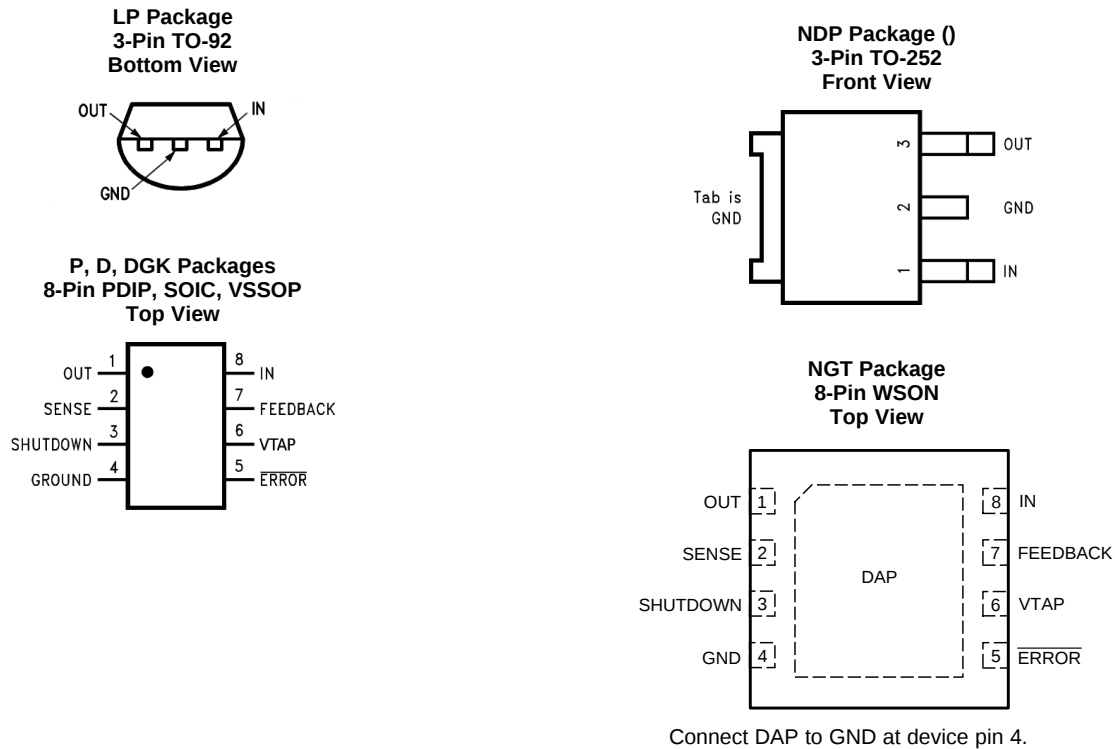
Changes from Revision N (May 2013) to Revision O	Page
• Added <i>Device Information</i> and <i>ESD Rating</i> tables, <i>Feature Description</i> , <i>Device Functional Modes</i> , <i>Application and Implementation</i> , <i>Power Supply Recommendations</i> , <i>Layout</i> , <i>Device and Documentation Support</i> , and <i>Mechanical, Packaging, and Orderable Information</i> sections; moved some curves to <i>Application Curves</i> section; update pin names; change package nomenclature from National to TI	1

Changes from Revision M (April 2013) to Revision N	Page
• Changed layout of National Data Sheet to TI format	1

5 Voltage Options

DEVICE NUMBER	PACKAGE	VOLTAGE OPTION (V)
LP2950-N	TO-92 (LP)	3 ($\pm 0.5\%$, $\pm 1\%$)
		3.3 ($\pm 0.5\%$, $\pm 1\%$)
		5 ($\pm 0.5\%$, $\pm 1\%$)
	TO-252 (NDP)	3 ($\pm 1\%$)
		3.3 ($\pm 1\%$)
		5 ($\pm 1\%$)
LP2951-N	SOIC (D)	3 ($\pm 0.5\%$, $\pm 1\%$)
		3.3 ($\pm 0.5\%$, $\pm 1\%$)
		5 ($\pm 0.5\%$, $\pm 1\%$)
	VSSOP (DGK)	3 ($\pm 0.5\%$, $\pm 1\%$)
		3.3 ($\pm 0.5\%$, $\pm 1\%$)
		5 ($\pm 0.5\%$, $\pm 1\%$)
	WSON (NGT)	3 ($\pm 0.5\%$, $\pm 1\%$)
		3.3 ($\pm 0.5\%$, $\pm 1\%$)
		5 ($\pm 0.5\%$, $\pm 1\%$)
	PDIP (P)	5 ($\pm 0.5\%$, $\pm 1\%$)
		5 ($\pm 0.5\%$, $\pm 1\%$)

6 Pin Configuration and Functions



Pin Functions: LP2950-N

PIN			I/O	DESCRIPTION
NAME	LP2950			
	LP	NDP		
GND	2	2	—	Ground
IN	3	1	I	Input supply voltage
OUT	1	3	O	Regulated output voltage

Pin Functions: LP2951-N

PIN			I/O	DESCRIPTION
NAME	LP2951			
	D, DGK, P	NGT		
ERROR	5	5	O	Error output
FEEDBACK	7	7	I	Voltage feedback input
GROUND	4	4	—	Ground
IN	8	8	I	Input supply voltage
OUT	1	1	O	Regulated output voltage
SENSE	2	2	I	Output voltage sense
SHUTDOWN	3	3	I	Disable device
VTAP	6	6	O	Internal resistor divider

7 Specifications

7.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)⁽¹⁾⁽²⁾

		MIN	MAX	UNIT
Input supply voltage - SHUTDOWN input voltage error comparator output voltage ⁽³⁾		−0.3	30	V
FEEDBACK input voltage ⁽³⁾⁽⁴⁾		−1.5	30	V
Power dissipation		Internally Limited		
Junction temperature, T _J		150		°C
Soldering dwell time, temperature	Wave	4 seconds, 260		
	Infrared	10 seconds, 240		
	Vapor phase	75 seconds, 219		
Storage temperature, T _{stg}		−65	150	°C

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) If Military/Aerospace specified devices are required, contact the Texas Instruments Sales Office/Distributors for availability and specifications.
- (3) May exceed input supply voltage.
- (4) When used in dual-supply systems where the output terminal sees loads returned to a negative supply, the output voltage should be diode-clamped to ground.

7.2 ESD Ratings

			VALUE	UNIT
LP2950-N				
V _(ESD)	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 ⁽¹⁾	±2500	V
LP2951-N				
V _(ESD)	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 ⁽¹⁾	All pins except 3 and 7	±2500
			Pin 3 (SHUTDOWN) only	±2000
			Pin 7 (FEEDBACK) only	±1000

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

7.3 Recommended Operating Conditions

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

		MIN	MAX	UNIT
Maximum input supply voltage			30	V
Junction temperature, T _J ⁽²⁾	LP2950AC-XX, LP2950C-XX	−40	125	°C
	LP2951	−55	150	°C
	LP2951AC-XX, LP2951C-XX	−40	125	°C

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) The junction-to-ambient thermal resistances are as follows: 157.4°C/W for the TO-92 (LP) package, 51.3°C/W for the TO-252 (NDP) package, 56.3°C/W for the molded PDIP (P), 117.7°C/W for the molded plastic SOIC (D), 171°C/W for the molded plastic VSSOP (DGK). The above thermal resistances for the P, D, and DGK packages apply when the package is soldered directly to the PCB. The value of R_{θJA} for the WSON (NGT) package is typically 43.3°C/W but is dependent on the PCB trace area, trace material, and the number of layers and thermal vias. For details of thermal resistance and power dissipation for the WSON package, refer to AN-1187 *Leadless Leadframe Package (LLP)* (SNOA401).

7.4 Thermal Information: LP2950-N

THERMAL METRIC ⁽¹⁾		LP2950-N		UNIT
		LP (TO-92)	NDP (TO-252)	
		3 PINS		
R _{θJA} ⁽²⁾	Junction-to-ambient thermal resistance, High-K	157.4	51.3 ⁽³⁾	°C/W
R _{θJC(top)}	Junction-to-case (top) thermal resistance	81.2	53.5	°C/W
R _{θJB}	Junction-to-board thermal resistance	153.6	30.4	°C/W
ψ _{JT}	Junction-to-top characterization parameter	25.2	5.5	°C/W
ψ _{JB}	Junction-to-board characterization parameter	n/a	30	°C/W
R _{θJC(bot)}	Junction-to-case (bottom) thermal resistance	n/a	2.2	°C/W

- (1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, [SPRA953](#).
- (2) Thermal resistance value $R_{\theta JA}$ is based on the EIA/JEDEC High-K printed circuit board defined by JESD51-7 - *High Effective Thermal Conductivity Test Board for Leaded Surface Mount Packages*.
- (3) The PCB for the TO-252 (NDP) package $R_{\theta JA}$ includes twelve (12) thermal vias under the tab per EIA/JEDEC JESD51-5.

7.5 Thermal Information: LP2951-N

THERMAL METRIC ⁽¹⁾		LP2951-N				UNIT
		P (PDIP)	D (SOIC)	DGK (VSSOP)	NGT (WSON)	
		8 PINS	8 PINS	8 PINS	8 PINS	
$R_{\theta JA}$ ⁽²⁾	Junction-to-ambient thermal resistance, High K	56.3	117.7	171.0	43.3 ⁽³⁾	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	45.7	63.7	62.3	35.0	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	33.5	57.9	91.4	23.3	°C/W
ψ_{JT}	Junction-to-top characterization parameter	22.9	15.9	8.9	0.5	°C/W
ψ_{JB}	Junction-to-board characterization parameter	33.3	57.5	90.1	20.5	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	n/a	n/a	n/a	9.1	°C/W

- (1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, [SPRA953](#).
- (2) Thermal resistance value $R_{\theta JA}$ is based on the EIA/JEDEC High-K printed circuit board defined by JESD51-7 - *High Effective Thermal Conductivity Test Board for Leaded Surface Mount Packages*.
- (3) The PCB for the WSON (NGT) package $R_{\theta JA}$ includes six (6) thermal vias under the exposed thermal pad per EIA/JEDEC JESD51-5.

7.6 Electrical Characteristics

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

PARAMETER	TEST CONDITIONS ⁽¹⁾	LP2951 ⁽²⁾			LP2950AC-XX LP2951AC-XX			LP2950C-XX LP2951C-XX			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
3-V VERSIONS ⁽³⁾											
Output voltage	T _J = 25°C	2.985	3	3.015	2.985	3	3.015	2.970	3	3.030	V ⁽⁴⁾
	−25°C ≤ T _J ≤ 85°C				2.970	3	3.030	2.955	3	3.045	V ⁽⁵⁾
	Full operating temperature range	2.964	3	3.036							V ⁽⁴⁾
Output voltage	100 μA ≤ I _L ≤ 100 mA, 100 μA ≤ I _L ≤ 100 mA, T _J ≤ T _{JMAX}	2.955	3	3.045							V ⁽⁴⁾
					2.958	3	3.042	2.928	3	3.072	V ⁽⁵⁾
3.3-V VERSIONS ⁽³⁾											
Output voltage	T _J = 25°C	3.284	3.3	3.317	3.284	3.3	3.317	3.267	3.3	3.333	V ⁽⁴⁾
	−25°C ≤ T _J ≤ 85°C		3.3		3.267	3.3	3.333	3.251	3.3	3.350	V ⁽⁵⁾
	Full operating temperature range	3.260	3.3	3.340							V ⁽⁴⁾
Output voltage	100 μA ≤ I _L ≤ 100 mA, T _J ≤ T _{JMAX}	3.251	3.3	3.350							V ⁽⁴⁾
					3.254	3.3	3.346	3.221	3.3	3.379	V ⁽⁵⁾
5-V VERSIONS ⁽³⁾											
Output voltage	T _J = 25°C	4.975	5	5.025	4.975	5	5.025	4.95	5	5.05	V ⁽⁴⁾
	−25°C ≤ T _J ≤ 85°C		5		4.95	5	5.05	4.925	5	5.075	V ⁽⁵⁾
	Full operating temperature range	4.94	5	5.06							V ⁽⁴⁾
Output voltage	100 μA ≤ I _L ≤ 100 mA, T _J ≤ T _{JMAX}	4.925	5	5.075							V ⁽⁴⁾
					4.925	5	5.075	4.88	5	5.12	V ⁽⁵⁾
ALL VOLTAGE OPTIONS											
Output voltage temperature coefficient	See ⁽⁶⁾ , −40°C ≤ T _J ≤ 125°C	20	120								ppm/°C ⁽⁴⁾
					20	100		50	150		ppm/°C ⁽⁵⁾
Line regulation ⁽⁷⁾	(V _O NOM + 1 V) ≤ V _{in} ≤ 30 V ⁽⁸⁾	0.03%	0.1%		0.03%	0.11%		0.04%	0.2%		See ⁽⁴⁾
	(V _O NOM + 1 V) ≤ V _{in} ≤ 30 V ⁽⁸⁾ , −40°C ≤ T _J ≤ 125°C	0.03%	0.5%								See ⁽⁴⁾
						0.03%	0.2%		0.04%	0.4%	
Load regulation ⁽⁷⁾	100 μA ≤ I _L ≤ 100 mA	0.04%	0.1%		0.04%	0.1%		0.1%	0.2%		See ⁽⁴⁾
	100 μA ≤ I _L ≤ 100 mA, −40°C ≤ T _J ≤ 125°C	0.04%	0.3%								See ⁽⁴⁾
						0.04%	0.2%		0.1%	0.3%	

- Unless otherwise noted, all limits apply for $T_A = T_J = 25^\circ\text{C}$ as well as specified for $V_{\text{IN}} = (V_{\text{O}}\text{NOM} + 1\ \text{V})$, $I_L = 100\ \mu\text{A}$ and $C_L = 1\ \mu\text{F}$ for 5-V versions and $2.2\ \mu\text{F}$ for 3-V and 3.3-V versions. Additional conditions for the 8-pin versions are FEEDBACK tied to VTAP, OUTPUT tied to SENSE, and $V_{\text{SHUTDOWN}} \leq 0.8\ \text{V}$.
- A Military RETS specification is available on request.
- All LP2950 devices have the nominal output voltage coded as the last two digits of the part number. In the LP2951 products, the 3-V and 3.3-V versions are designated by the last two digits, but the 5-V version is denoted with no code at this location of the part number (refer to the *Package Option Addendum* at end of data sheet).
- Ensured and 100% production tested.
- Ensured but not 100% production tested. These limits are not used to calculate outgoing AQL levels.
- Output or reference voltage temperature coefficient is defined as the worst case voltage change divided by the total temperature range.
- Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output voltage due to heating effects are covered under the specification for thermal regulation.
- Line regulation for the LP2951-N is tested at 150°C for $I_L = 1\ \text{mA}$. For $I_L = 100\ \mu\text{A}$ and $T_J = 125^\circ\text{C}$, line regulation is specified by design to 0.2%. See [Typical Characteristics](#) for line regulation versus temperature and load current.

Electrical Characteristics (continued)

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

PARAMETER	TEST CONDITIONS ⁽¹⁾	LP2951 ⁽²⁾			LP2950AC-XX LP2951AC-XX			LP2950C-XX LP2951C-XX			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Dropout voltage ⁽⁹⁾	$I_L = 100\ \mu\text{A}$		50	80		50	80		50	80	mV ⁽⁴⁾
	$I_L = 100\ \mu\text{A}, -40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$			150							mV ⁽⁴⁾
							150			150	mV ⁽⁵⁾
	$I_L = 100\ \text{mA}$		380	450		380	450		380	450	mV ⁽⁴⁾
	$I_L = 100\ \text{mA}, -40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$			600			600			600	mV ⁽⁴⁾
Ground current							600			600	mV ⁽⁵⁾
	$I_L = 100\ \mu\text{A}$		75	120		75	120		75	120	μA ⁽⁴⁾
	$I_L = 100\ \mu\text{A}, -40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$			140							μA ⁽⁴⁾
							140			140	μA ⁽⁵⁾
	$I_L = 100\ \text{mA}$		8	12		8	12		8	12	mA ⁽⁴⁾
Dropout ground current											mA ⁽⁴⁾
	$I_L = 100\ \text{mA}, -40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$			14			14			14	mA ⁽⁵⁾
	$V_{IN} = (V_{ONOM} - 0.5)\text{V}, I_L = 100\ \mu\text{A}$		110	170		110	170		110	170	μA ⁽⁴⁾
	$V_{IN} = (V_{ONOM} - 0.5)\text{V}, I_L = 100\ \mu\text{A}, -40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$			200			200			200	μA ⁽⁴⁾
							200			200	μA ⁽⁵⁾
Current limit	$V_{OUT} = 0\ \text{V}$		160	200		160	200		160	200	mA ⁽⁴⁾
	$V_{OUT} = 0\ \text{V}, -40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$			220							mA ⁽⁴⁾
							220			220	mA ⁽⁵⁾
Thermal regulation	See ⁽¹⁰⁾		0.05	0.2		0.05	0.2		0.05	0.2	%/W ⁽⁴⁾
Output noise 10 Hz to 100 kHz	$C_L = 1\ \mu\text{F}$ (5 V Only)		430			430			430		μV_{RMS}
	$C_L = 200\ \mu\text{F}$		160			160			160		μV_{RMS}
	$C_L = 3.3\ \mu\text{F}$ (Bypass = 0.01 μF Pins 7 to 1 (LP2951-N))		100			100			100		μV_{RMS}
8-PIN VERSIONS ONLY		LP2951			LP2951AC-XX			LP2951C-XX			
Reference voltage		1.22	1.235	1.25	1.22	1.235	1.25	1.21	1.235	1.26	V ⁽⁴⁾
	$-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$		1.2	1.26							V ⁽⁴⁾
					1.2		1.26	1	1.2	1.27	V ⁽⁵⁾
Reference voltage	See ⁽¹¹⁾ , $-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$	1.19		1.27							V ⁽⁴⁾
					1.19		1.27	1.185		1.285	V ⁽⁵⁾
Feedback pin bias current			20	40		20	40		20	40	nA ⁽⁴⁾
	$-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$			60							nA ⁽⁴⁾
							60			60	nA ⁽⁵⁾
Reference voltage temperature coefficient	See ⁽⁶⁾		20			20			50		ppm/°C
Feedback pin bias current temperature coefficient			0.1			0.1			0.1		nA/°C

(9) Dropout voltage is defined as the input to output differential at which the output voltage drops 100 mV below its nominal value measured at 1-V differential. At very low values of programmed output voltage, the minimum input supply voltage of 2 V (2.3 V over temperature) must be taken into account.

(10) Thermal regulation is defined as the change in output voltage at a time T after a change in power dissipation is applied, excluding load or line regulation effects. Specifications are for a 50 mA load pulse at $V_{IN} = 30\ \text{V}$ (1.25-W pulse) for $T = 10\ \text{ms}$.

(11) $V_{REF} \leq V_{OUT} \leq (V_{IN} - 1\ \text{V})$, $2.3\ \text{V} \leq V_{IN} \leq 30\ \text{V}$, $100\ \mu\text{A} \leq I_L \leq 100\ \text{mA}$, $T_J \leq T_{J\text{MAX}}$.

Electrical Characteristics (continued)

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

PARAMETER	TEST CONDITIONS ⁽¹⁾	LP2951 ⁽²⁾			LP2950AC-XX LP2951AC-XX			LP2950C-XX LP2951C-XX			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
ERROR COMPARATOR											
Output leakage current	V _{OH} = 30 V	0.01		1	0.01		1	0.01		1	μA ⁽⁴⁾
	V _{OH} = 30 V, –40°C ≤ T _J ≤ 125°C	2									μA ⁽⁴⁾
					2			2			μA ⁽⁵⁾
Output low voltage	V _{IN} = (V _{ONOM} – 0.5 V), I _{OL} = 400 μA	150	250		150	250		150	250		mV ⁽⁴⁾
	V _{IN} = (V _{ONOM} – 0.5 V), I _{OL} = 400 μA, –40°C ≤ T _J ≤ 125°C	400			400			400			mV ⁽⁴⁾
					400			400			mV ⁽⁵⁾
Upper threshold voltage	See ⁽¹²⁾	40	60		40	60		40	60		mV ⁽⁴⁾
	See ⁽¹²⁾ , –40°C ≤ T _J ≤ 125°C	25									mV ⁽⁴⁾
					25			25			mV ⁽⁵⁾
Lower threshold voltage	See ⁽¹²⁾	75	95		75	95		75	95		mV ⁽⁴⁾
	See ⁽¹²⁾ , –40°C ≤ T _J ≤ 125°C	140									mV ⁽⁴⁾
					140			140			mV ⁽⁵⁾
Hysteresis	See ⁽¹²⁾	15			15			15			mV
SHUTDOWN INPUT											
Input		1.3			1.3			1.3			V
Logic voltage	Low (Regulator ON), –40°C ≤ T _J ≤ 125°C	0.6									V ⁽⁴⁾
					0.7			0.7			V ⁽⁵⁾
Logic voltage	High (Regulator OFF), –40°C ≤ T _J ≤ 125°C	2									V ⁽⁴⁾
					2			2			V ⁽⁵⁾
Shutdown pin input current	V _{shutdown} = 2.4 V	30	50		30	50		30	50		μA ⁽⁴⁾
	V _{shutdown} = 2.4 V –40°C ≤ T _J ≤ 125°C	100									μA ⁽⁴⁾
					100			100			μA ⁽⁵⁾
	V _{shutdown} = 30 V	450	600		450	600		450	600		μA ⁽⁴⁾
	V _{shutdown} = 30 V, –40°C ≤ T _J ≤ 125°C	750									μA ⁽⁴⁾
			750			750			μA ⁽⁵⁾		
Regulator output current in shutdown	See ⁽¹³⁾	3	10		3	10		3	10		μA ⁽⁴⁾
	–40°C ≤ T _J ≤ 125°C	20									μA ⁽⁴⁾
					20			20			μA ⁽⁵⁾

(12) Comparator thresholds are expressed in terms of a voltage differential at the FEEDBACK pin below the nominal reference voltage measured at V_{IN} = (V_{O(NOM)} + 1) V. To express these thresholds in terms of output voltage change, multiply by the error amplifier gain = V_{OUT}/V_{REF} = (R1 + R2) / R2. For example, at a programmed output voltage of 5 V, the ERROR output is specified to go low when the output drops by 95 mV × 5 V / 1.235 V = 384 mV. Thresholds remain constant as a percent of V_{OUT} as V_{OUT} is varied, with the dropout warning occurring at typically 5% below nominal, 7.5% ensured.

(13) V_{SHUTDOWN} ≥ 2 V, V_{IN} ≤ 30 V, V_{OUT} = 0, FEEDBACK pin tied to V_{TAP}.

7.7 Typical Characteristics

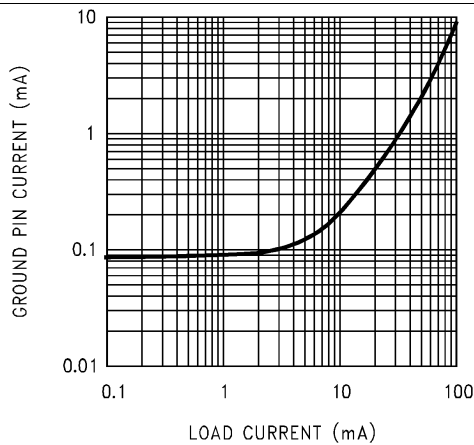


Figure 1. Quiescent Current

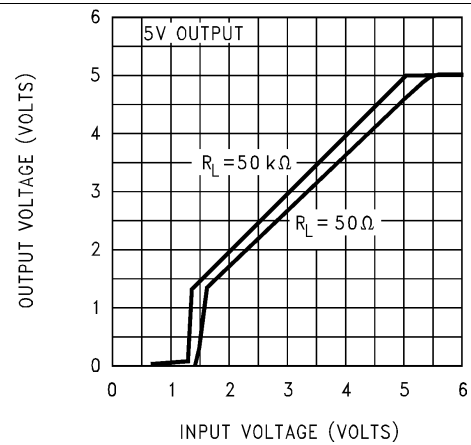


Figure 2. Dropout Characteristics

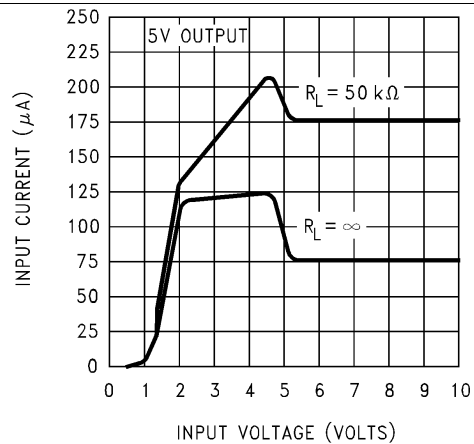


Figure 3. Input Current

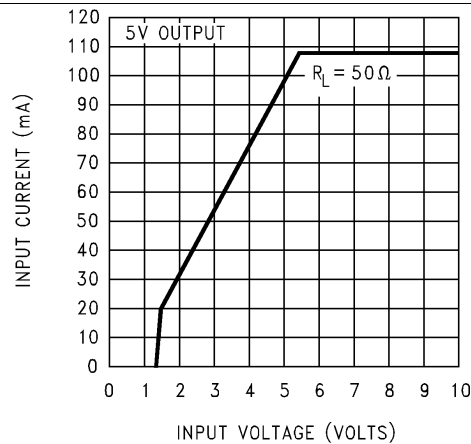


Figure 4. Input Current

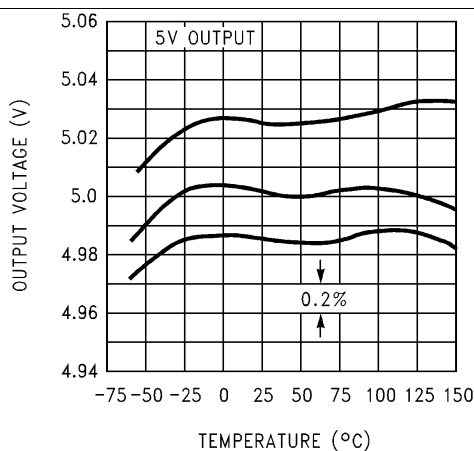


Figure 5. Output Voltage vs. Temperature of 3 Representative Units

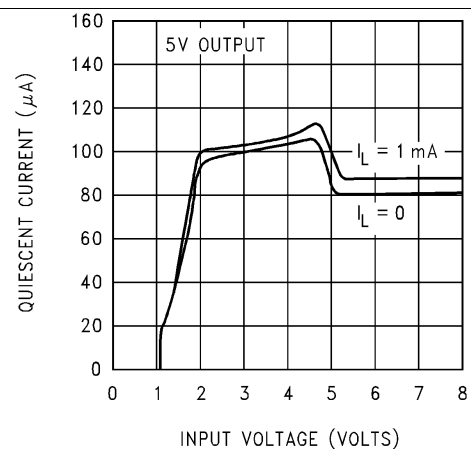


Figure 6. Quiescent Current

Typical Characteristics (continued)

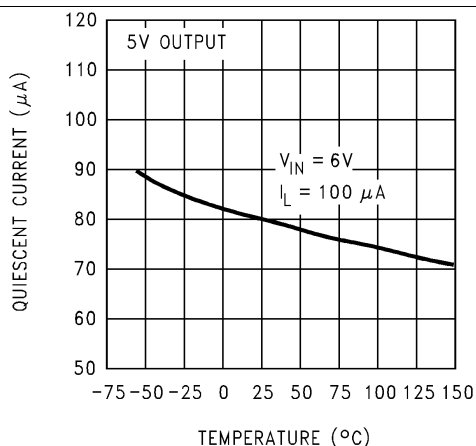


Figure 7. Quiescent Current

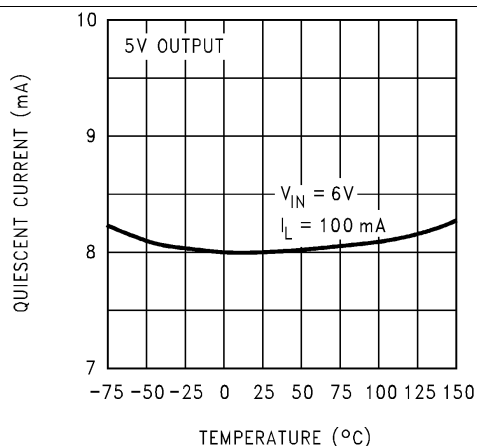


Figure 8. Quiescent Current

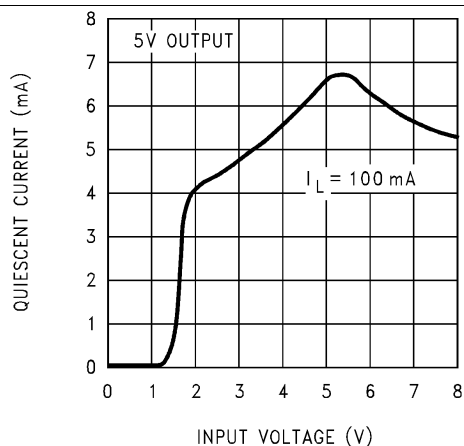


Figure 9. Quiescent Current

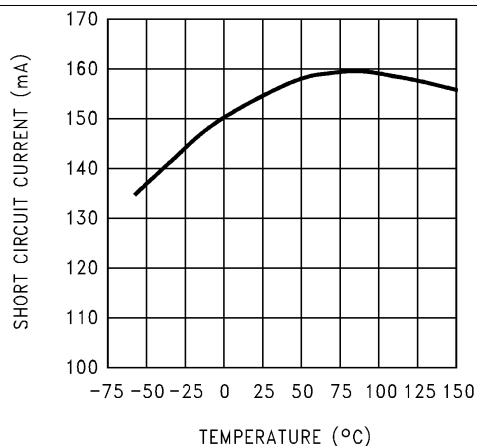


Figure 10. Short Circuit Current

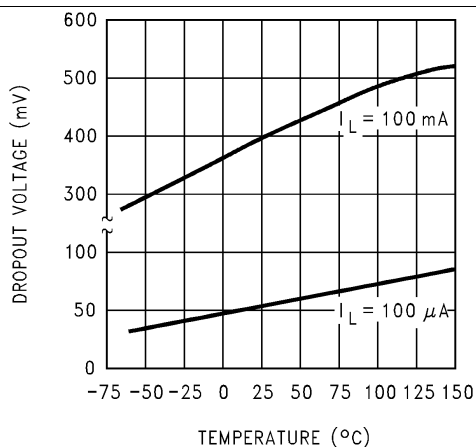


Figure 11. Dropout Voltage

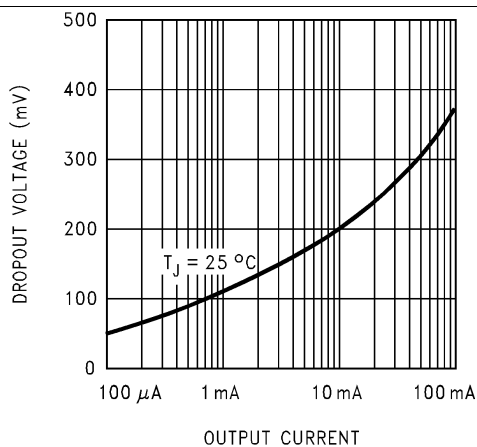


Figure 12. Dropout Voltage

Typical Characteristics (continued)

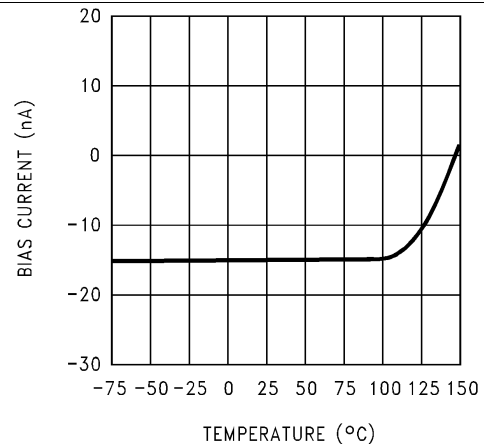
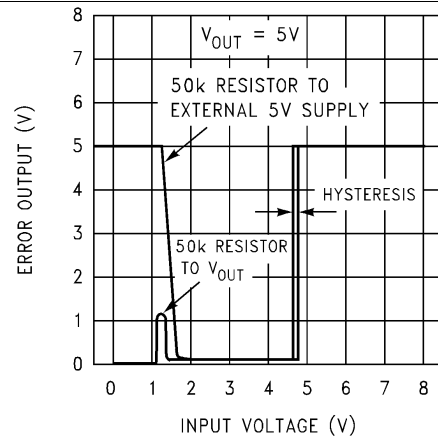
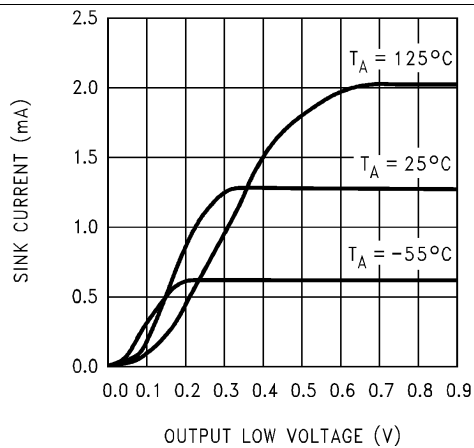
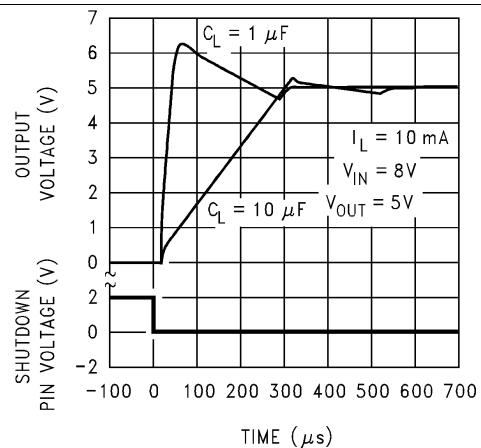
Figure 13. LP2951-N Minimum Operating Voltage

Figure 14. LP2951-N Feedback Bias Current

Figure 15. LP2951-N Feedback Pin Current

Figure 16. LP2951-N Error Comparator Output

Figure 17. LP2951-N Comparator Sink Current

Figure 18. LP2951-N Enable Transient

Typical Characteristics (continued)

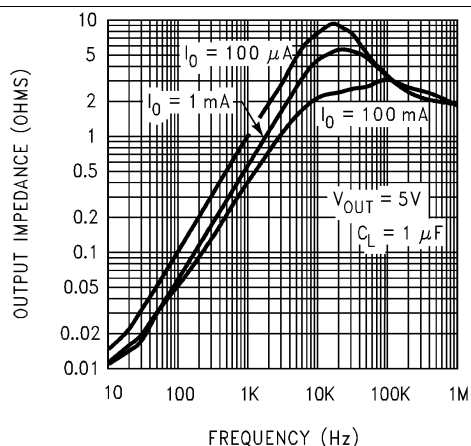


Figure 19. Output Impedance

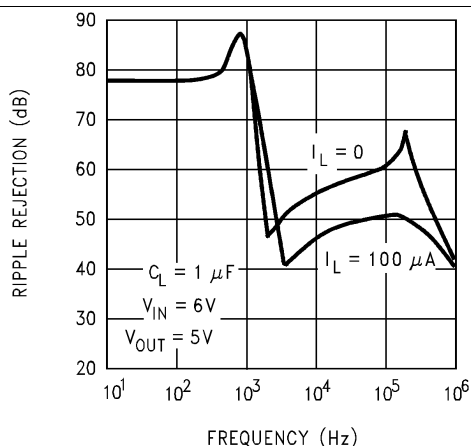


Figure 20. Ripple Rejection

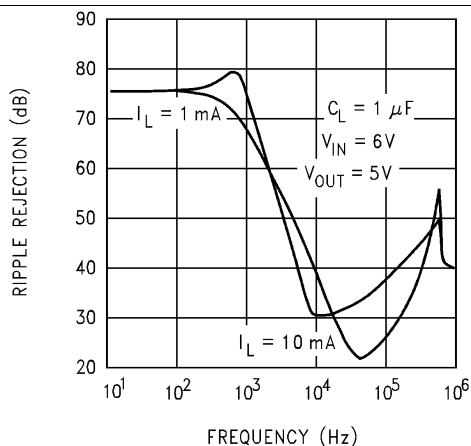


Figure 21. Ripple Rejection

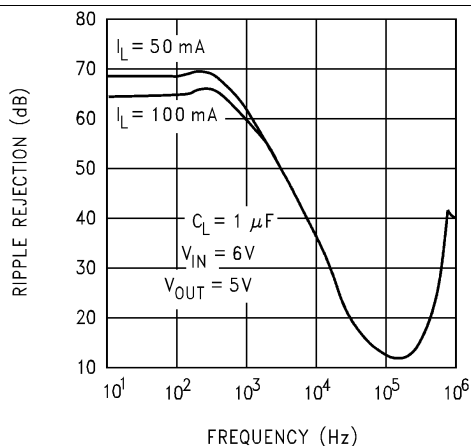


Figure 22. Ripple Rejection

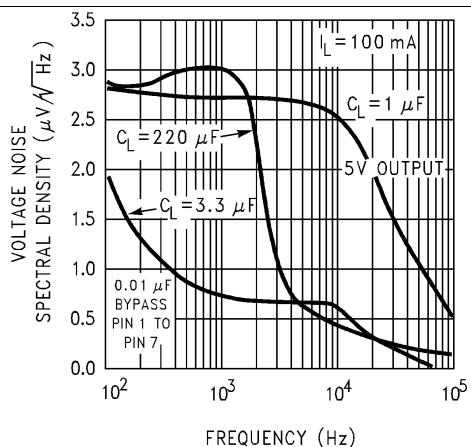


Figure 23. LP2951-N Output Noise

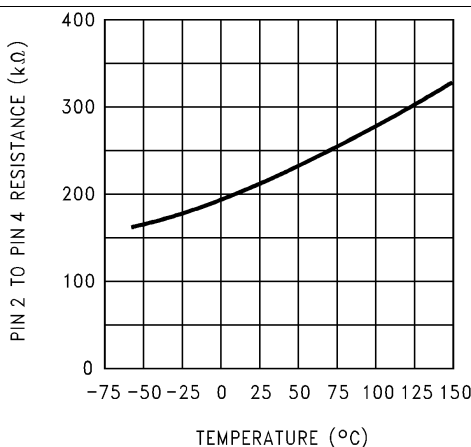


Figure 24. LP2951-N Divider Resistance

Typical Characteristics (continued)



Figure 25. Shutdown Threshold Voltage

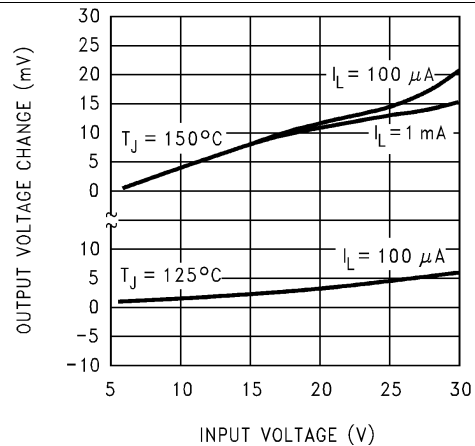


Figure 26. Line Regulation



Figure 27. LP2951-N Maximum Rated Output Current

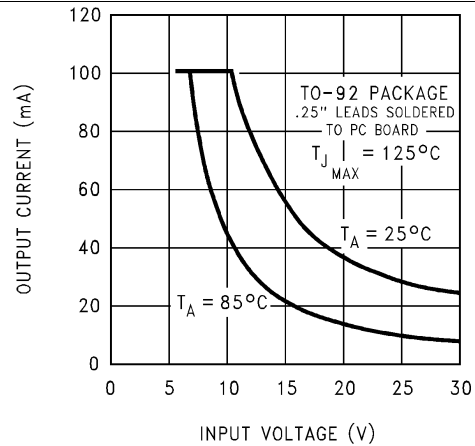


Figure 28. LP2950-N Maximum Rated Output Current



Figure 29. Thermal Response

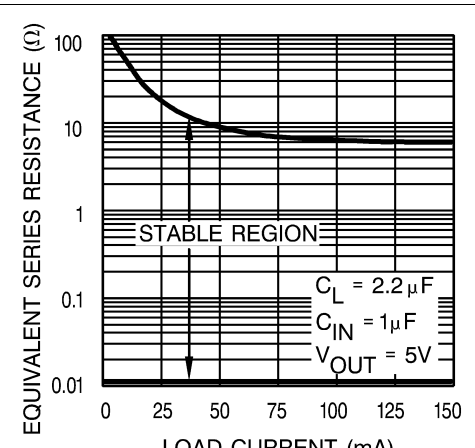


Figure 30. Output Capacitor ESR Range

Typical Characteristics (continued)

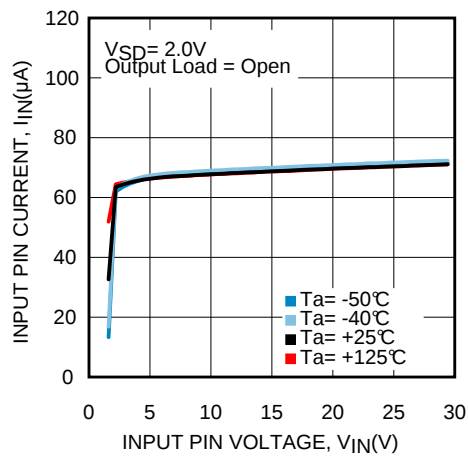


Figure 31. LP2951-N Input Pin Current vs Input Voltage

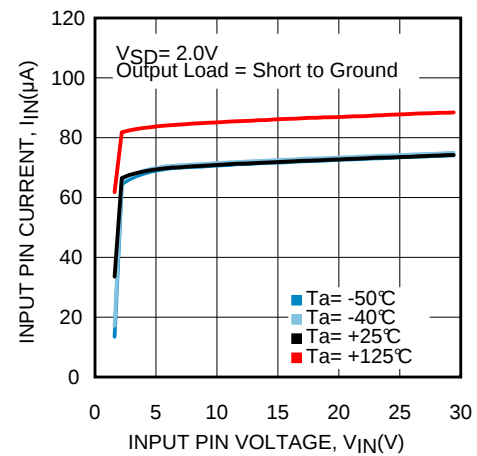


Figure 32. LP2951-N Input Pin Current vs Input Voltage

8.3 Feature Description

8.3.1 Fixed Voltage Options and Programmable Voltage Version

The LP2950-N and LP2951-N provide 3 fixed output options: 3 V, 3.3 V, and 5 V. Please consult factory for custom voltages. In order to meet different application requirements, LP2951-N can also be used as a programmable voltage regulator, with an external resistors network; please refer to [Application and Implementation](#) for more details.

8.3.2 High Accuracy Output Voltage

With special careful design to minimize all contributions to the output voltage error, the LP2950-N/LP2951-N distinguished itself as a very high output voltage accuracy micro power LDO. This includes a tight initial tolerance (0.5% typical), extremely good load and line regulation (.05% typical) and a very low output voltage temperature coefficient, making the part an ideal a low-power voltage reference.

8.3.3 Low Dropout Voltage

Generally speaking, the dropout voltage often refers to the voltage difference between the input and output voltage ($V_{DO} = V_{IN} - V_{OUT}$), where the main current pass-FET is fully on in the ohmic region of operation and is characterized by the classic $R_{DS(ON)}$ of the FET. V_{DO} indirectly specifies a minimum input voltage above the nominal programmed output voltage at which the output voltage is expected to remain within its accuracy boundary.

8.3.4 Shutdown Mode

When the SHUTDOWN pin is pulled to high level, LP2951-N enters shutdown mode and a very low quiescent current is consumed. This function is designed for the application which needs a shutdown mode to effectively enhance battery life cycle.

8.3.5 Error Detection Comparator Output

The LP2951-N generates a logic low output whenever its output falls out of regulation by more than approximately 5%. Please refer to [Application and Implementation](#) for more details.

8.3.6 Internal Protection Circuitry

8.3.6.1 Short-Circuit Protection (Current Limit)

The internal current limit circuit is used to protect the LDO against high-load current faults or shorting events. The LDO is not designed to operate in a steady-state current limit. During a current-limit event, the LDO sources constant current. Therefore, the output voltage falls when load impedance decreases. Note also that if a current limit occurs and the resulting output voltage is low, excessive power may be dissipated across the LDO, resulting in a thermal shutdown of the output. A fold back feature limits the short-circuit current to protect the regulator from damage under all load conditions. If OUT is forced below 0 V before EN goes high and the load current required exceeds the fold back current limit, the device may not start up correctly.

8.3.6.2 Thermal Protection

The device contains a thermal shutdown protection circuit to turn off the output current when excessive heat is dissipated in the LDO. The thermal time-constant of the semiconductor die is fairly short, and thus the output cycles on and off at a high rate when thermal shutdown is reached until the power dissipation is reduced. The internal protection circuitry of the device is designed to protect against thermal overload conditions. The circuitry is not intended to replace proper heat sinking. Continuously running the device into thermal shutdown degrades its reliability.

8.3.7 Enhanced Stability

The LP2950-N and LP2951-N is designed specifically to work with ceramic output capacitors, utilizing circuitry which allows the regulator to be stable across the entire range of output current with an output capacitor whose ESR is as low as 6 mΩ. For output capacitor requirement, please refer to [Application and Implementation](#).

8.4 Device Functional Modes

8.4.1 Operation with $30\text{ V} \geq V_{\text{IN}} > V_{\text{OUT(TARGET)}} + 1\text{ V}$

The device operate if the input voltage is equal to, or exceeds $V_{\text{OUT(TARGET)}} + 1\text{ V}$. At input voltages below the minimum V_{IN} requirement, the devices do not operate correctly and output voltage may not reach target value.

8.4.2 Operation with Shutdown Control

If the voltage on the SHUTDOWN pin is higher than 1.3 V, the device is disabled. Decreasing shutdown below 0.7 V initiates the start-up sequence of the device.

9 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

9.1 Application Information

The LP2950-N and LP2951-N are linear voltage regulator operating from 2.3 V to 30 V on the input and regulates voltages between 1.24 V to 29 V with 0.5% accuracy and 160 mA maximum outputs current. Efficiency is defined by the ratio of output voltage to input voltage because the LP2950-N and LP2951-N is a linear voltage regulator. To achieve high efficiency, the dropout voltage ($V_{IN} - V_{OUT}$) must be as small as possible, thus requiring a very low dropout LDO. Successfully implementing an LDO in an application depends on the application requirements. If the requirements are simply input voltage and output voltage, compliance specifications (such as internal power dissipation or stability) must be verified to ensure a solid design. If timing, start-up, noise, PSRR, or any other transient specification is required, the design becomes more challenging.

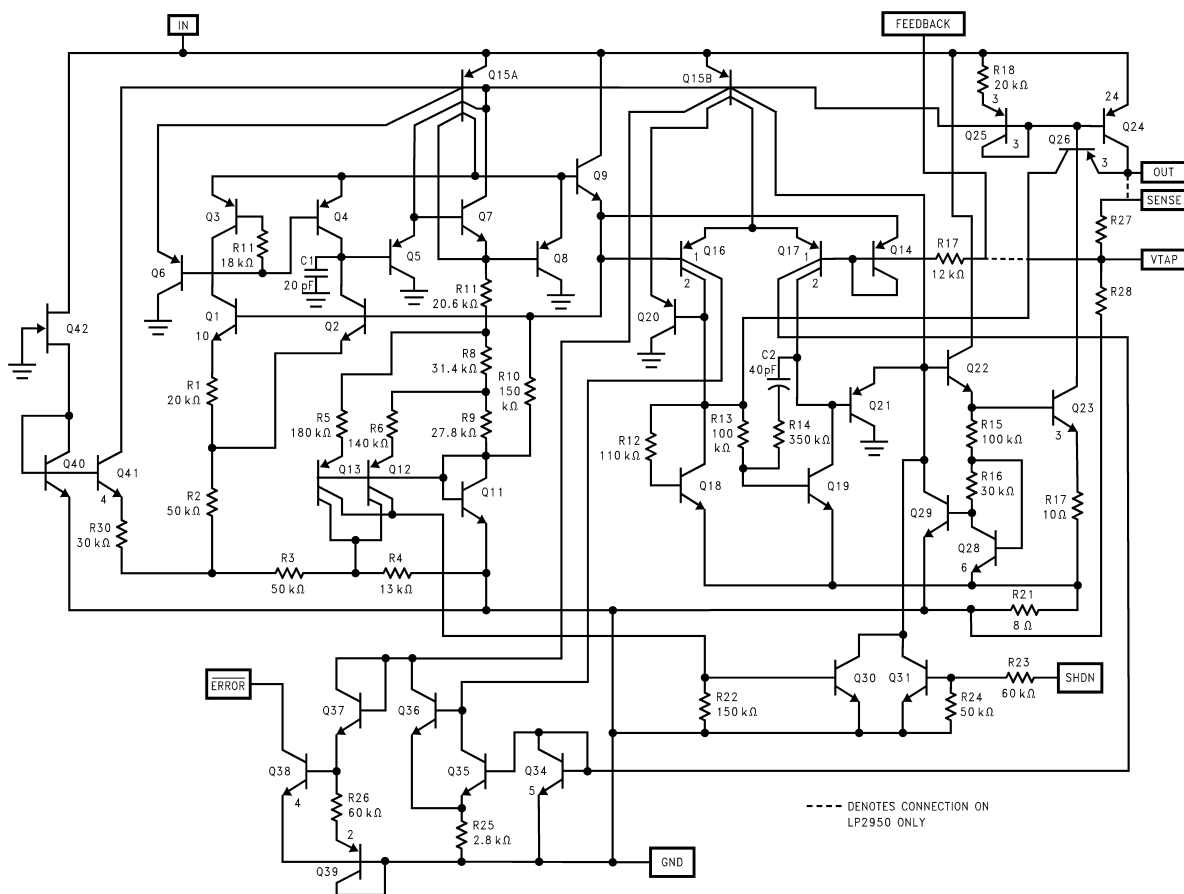


Figure 35. Schematic Diagram

9.2 Typical Applications

9.2.1 1-A Regulator with 1.2-V Dropout

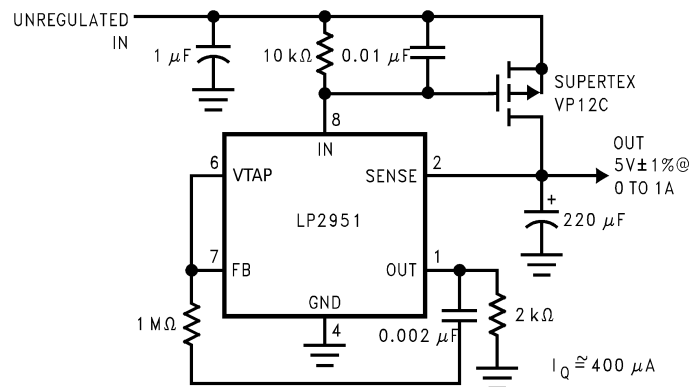


Figure 36. 1-A Regulator with 1.2-V Dropout

9.2.1.1 Design Requirements

For this design example, use the parameters listed in [Table 1](#) as the input parameters.

Table 1. Design Parameters

DESIGN PARAMETER	DESIGN REQUIREMENT
Input voltage	6.5 V, $\pm 10\%$, provided by the DC-DC converter switching at 1 MHz
Output voltage	5 V, $\pm 1\%$
Output current	100 mA (maximum), 1 mA (minimum)
RMS noise, 10 Hz to 100 kHz	$< 200 \mu\text{V}_{\text{RMS}}$
PSRR at 1 KHz	$> 50 \text{ dB}$

9.2.1.2 Detailed Design Procedure

At 100-mA loading, the dropout of the LP2950-N/LP2951-N has 600 mV maximum dropout over temperature, thus an 1500-mV headroom is sufficient for operation over both input and output voltage accuracy. The efficiency of the LP2950-N/LP2951-N in this configuration is $V_{\text{OUT}} / V_{\text{IN}} = 76.9\%$. To achieve the smallest form factor, the TO-92 package is selected. Input and output capacitors are selected in accordance with the Capacitor Recommendation section. Ceramic capacitances of 1 μF for the input and one 2.2- μF capacitors for the output are selected. With an efficiency of 73.3% and a 100-mA maximum load, the internal power dissipation is 150 mW, which corresponds to a 18.9°C junction temperature rise for the TO-92 package. With an 85°C maximum ambient temperature, the junction temperature is at 103.9°C. To minimize noise, a bypass capacitance (C_{BYPASS}) of 0.01- μF is selected between pin 7 to pin 1 for LP2951-N.

9.2.1.2.1 Output Capacitor Requirements

A 1- μF (or greater) capacitor is required between the output and ground for stability at output voltages of 5 V or higher. At lower output voltages, more capacitance is required (2.2 μF or more is recommended for 3-V and 3.3-V versions). Without this capacitor the device oscillates. Most types of tantalum or aluminum electrolytic work fine here; even film types work but are not recommended for reasons of cost. Many aluminum electrolytics have electrolytes that freeze at about -30°C , so solid tantalums are recommended for operation below -25°C . The important parameters of the capacitor are an ESR of about 5 Ω or less and a resonant frequency above 500 kHz. The value of this capacitor may be increased without limit.

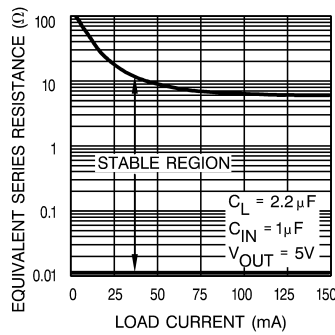


Figure 37. Output Capacitor ESR Range

The reason for the lower ESR limit is that the loop compensation of the feedback loop relies on the capacitance value and the ESR value of the output capacitor to provide the zero that gives added phase lead (See Figure 37).

$$f_z = (1 / (2 \times \pi \times C_{OUT} \times ESR)) \quad (1)$$

Using the 2.2 μF value from the *Output Capacitor ESR Range* curve (Figure 37), a useful range for f_z can be estimated:

$$f_{z(MIN)} = (1 / (2 \times \pi \times 2.2 \mu\text{F} \times 5 \Omega)) = 14.5 \text{ kHz} \quad (2)$$

$$f_{z(MAX)} = (1 / (2 \times \pi \times 2.2 \mu\text{F} \times 0.05 \Omega)) = 318 \text{ kHz} \quad (3)$$

For ceramic capacitors, the low ESR produces a zero at a frequency that is too high to be useful, so meaningful phase lead does not occur. A ceramic output capacitor can be used if a series resistance is added (recommended value of resistance about 0.1 Ω to 2 Ω) to simulate the needed ESR. Only X5R, X7R, or better, MLCC types should be used, and should have a DC voltage rating at least twice the $V_{OUT(NOM)}$ value.

At lower values of output current, less output capacitance is required for stability. The capacitor can be reduced to 0.33 μF for currents below 10 mA or 0.1 μF for currents below 1 mA. Using the adjustable versions at voltages below 5 V runs the error amplifier at lower gains so that *more* output capacitance is needed. For the worst-case situation of a 100-mA load at 1.23 V output (output shorted to Feedback) a 3.3- μF (or greater) capacitor should be used.

Unlike many other regulators, the LP2950-N remains stable and in regulation with no load in addition to the internal voltage divider. This is especially important in CMOS RAM keep-alive applications. When setting the output voltage of the LP2951-N versions with external resistors, a minimum load of 1 μA is recommended.

Applications having conditions that may drive the LP2950-N/51 into nonlinear operation require special consideration. Nonlinear operation occurs when the output voltage is held low enough to force the output stage into output current limiting while trying to pull the output voltage up to the regulated value. The internal loop response time controls how long it takes for the device to regain linear operation when the output has returned to the normal operating range. There are three significant nonlinear conditions that need to be considered, all can force the output stage into output current limiting mode, all can cause the output voltage to over-shoot with low value output capacitors when the condition is removed, and the recommended generic solution is to set the output capacitor to a value not less than 10 μF . Although the 10 μF value for C_{OUT} may not eliminate the output voltage over-shoot in all cases, it should lower it to acceptable levels (< 10% of $V_{OUT(NOM)}$) in the majority of cases. In all three of these conditions, applications with lighter load currents are more susceptible to output voltage over-shoot than applications with higher load currents.

1. At power-up, with the input voltage rising faster than output stage can charge the output capacitor.

$$V_{IN} t_{RISE(MIN)} > ((C_{OUT} / 100 \text{ mA}) \times \Delta V_{IN})$$

where

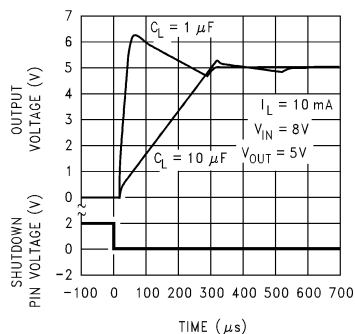
$$\Delta V_{IN} = V_{OUT(NOM)} + 1 \text{ V} \quad (4)$$

2. Recovery from an output short circuit to ground condition.

$$C_{OUT(MIN)} \approx (160 \text{ mA} - I_{LOAD(NOM)}) / ((V_{OUT(NOM)} / 10) / 25 \mu\text{s}) \quad (5)$$

3. Toggling the LP2951-N SHUTDOWN pin from high (OFF) to low (ON).

$$C_{OUT(MIN)} \approx (160 \text{ mA} - I_{LOAD(NOM)}) / ((V_{OUT(NOM)} / 10) / 25 \mu\text{s}) \quad (6)$$


Figure 38. LP2951-N Enable Transient

9.2.1.2.2 Input Capacitor Requirements

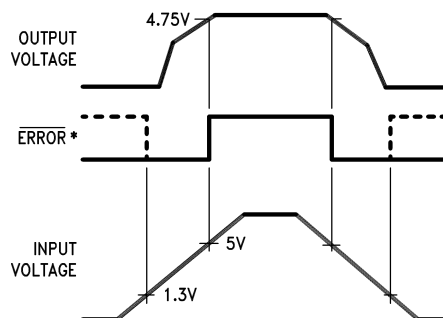
A minimum 1 μF tantalum, ceramic or aluminum electrolytic capacitor should be placed from the LP2950-N/LP2951-N input pin to ground if there is more than 10 inches of wire between the input and the AC filter capacitor or if a battery is used as the input.

9.2.1.2.3 Error Detection Comparator Output

The comparator produces a logic low output whenever the LP2951-N output falls out of regulation by more than approximately 5%. This figure is the comparator's built-in offset of about 60 mV divided by the 1.235 reference voltage. (Refer to the block diagram in the front of the datasheet.) This trip level remains "5% below normal" regardless of the programmed output voltage of the 2951. For example, the error flag trip level is typically 4.75 V for a 5-V output or 11.4 V for a 12-V output. The out of regulation condition may be due either to low input voltage, current limiting, or thermal limiting.

[Figure 39](#) below gives a timing diagram depicting the $\overline{\text{ERROR}}$ signal and the regulated output voltage as the LP2951-N input is ramped up and down. For 5 V versions, the $\overline{\text{ERROR}}$ signal becomes valid (low) at about 1.3-V input. It goes high at about 5-V input (the input voltage at which $V_{\text{OUT}} = 4.75 \text{ V}$). Because the LP2951-N dropout voltage is load-dependent (see curve in typical performance characteristics), the **input** voltage trip point (about 5 V) varies with the load current. The **output** voltage trip point (approx. 4.75 V) does not vary with load.

The error comparator has an open-collector output which requires an external pull up resistor. This resistor may be returned to the output or some other supply voltage depending on system requirements. In determining a value for this resistor, note that while the output is rated to sink 400 μA , this sink current adds to battery drain in a low battery condition. Suggested values range from 100 k to 1 M Ω . The resistor is not required if this output is unused.



*When $V_{\text{IN}} \leq 1.3 \text{ V}$, the error flag pin becomes a high impedance, and the error flag voltage rises to its pullup voltage. Using V_{OUT} as the pullup voltage (see [Figure 40](#)), rather than an external 5-V source, keeps the error flag voltage under 1.2 V (typical) in this condition. The user may wish to divide down the error flag voltage using equal-value resistors (10 k Ω suggested), to ensure a low-level logic signal during any fault condition, while still allowing a valid high logic level during normal operation.

Figure 39. $\overline{\text{ERROR}}$ Output Timing

9.2.1.2.4 Programming the Output Voltage (LP2951-N)

The LP2951-N may be pin-strapped for the nominal fixed output voltage using its internal voltage divider by tying the output and sense pins together, and also tying the FEEDBACK and VTAP pins together. Alternatively, it may be programmed for any output voltage between its 1.235-V reference and its 30-V maximum rating. As seen in Figure 40, an external pair of resistors is required.

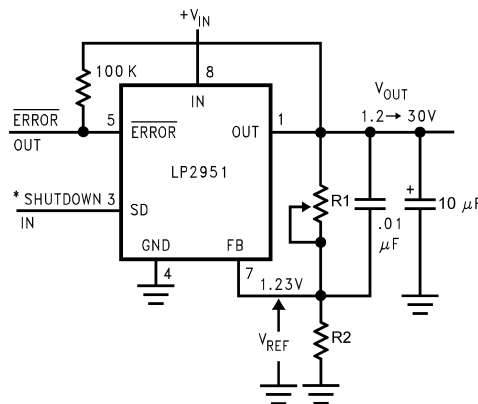
The complete equation for the output voltage is

$$V_{OUT} = V_{REF} \cdot \left(1 + \frac{R_1}{R_2} \right) + I_{FB} R_1$$

where

- V_{REF} is the nominal 1.235-V reference voltage and I_{FB} is the FEEDBACK pin bias current, nominally –20 nA (7)

The minimum recommended load current of 1 μ A forces an upper limit of 1.2 M Ω on the value of R_2 , if the regulator must work with no load (a condition often found in CMOS in standby). I_{FB} produces a 2% typical error in V_{OUT} which may be eliminated at room temperature by trimming R_1 . For better accuracy, choosing $R_2 = 100$ k Ω reduces this error to 0.17% while increasing the resistor program current to 12 μ A. Because the LP2951-N typically draws 60 μ A at no load with pin 2 open-circuited, this is a small price to pay.



$$V_{out} = V_{Ref} \left(1 + \frac{R_1}{R_2} \right)$$

*Drive with TTL-high to shut down. Ground or leave open if shutdown feature is not to be used.

Note: Pins 2 and 6 are left open.

Figure 40. Adjustable Regulator

Stray capacitance to the LP2951-N FEEDBACK pin can cause instability. This may especially be a problem when using high value external resistors to set the output voltage. Adding a 100-pF capacitor between the OUT pin and the FEEDBACK pin, and increasing the output capacitor to at least 3.3 μ F, fixes this problem.

9.2.1.2.5 Reducing Output Noise

In reference applications it may be advantageous to reduce the AC noise present at the output. One method is to reduce the regulator bandwidth by increasing the size of the output capacitor. This is the only way noise can be reduced on the 3-lead LP2950-N but is relatively inefficient, as increasing the capacitor from 1 μ F to 220 μ F only decreases the noise from 430 μ V_{RMS} to 160 μ V_{RMS} for a 100-kHz bandwidth at 5-V output.

Noise can be reduced fourfold by a bypass capacitor across R_1 , because it reduces the high frequency gain from 4 to unity. Pick

$$C_{BYPASS} \cong \frac{1}{2\pi R_1 \cdot 200 \text{ Hz}} \quad (8)$$

or about 0.01 μ F. When doing this, the output capacitor must be increased to 3.3 μ F to maintain stability. These changes reduce the output noise from 430 μ V to 100 μ V rms for a 100-kHz bandwidth at 5-V output. With the bypass capacitor added, noise no longer scales with output voltage so that improvements are more dramatic at higher output voltages.

9.2.1.3 Application Curves


Figure 41. Line Transient Response

Figure 42. Load Transient Response

Figure 43. Load Transient Response

9.2.2 300-mA Regulator with 0.75-V Dropout

In Figure 44, by paralleling the LP2951 together with 2x2N5432 (150-mA N channel JFET), a user can get a higher output current capability around 300 mA.

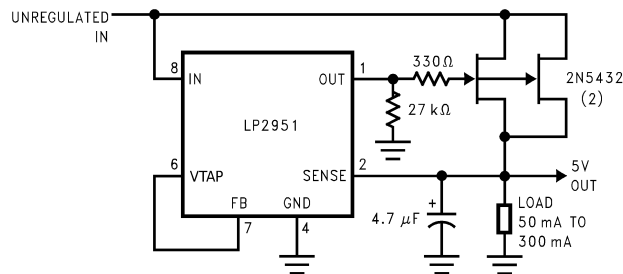
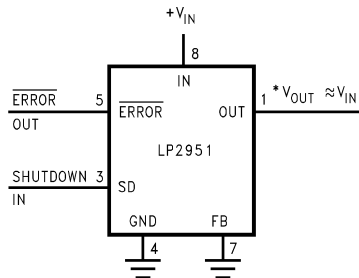


Figure 44. 300-mA Regulator with 0.75-V Dropout

9.2.3 Wide Input Voltage Range Current Limiter

The LP2951 can be used as a 160-mA current limiter as Figure 45. When FB is connected to ground, the pass element is fully turned on and out voltage will be close to input voltage. Input-output voltage ranges from 40 mV to 400 mV, depending on load current.



*Minimum input-output voltage ranges from 40 mV to 400 mV, depending on load current. Current limit is typically 160 mA.

Figure 45. Wide Input Voltage Range Current Limiter

9.2.4 Low Drift Current Source

The LP2951 can be used as a low drift current source as [Figure 46](#) shows. By connected V_{out} to FB, V_{out} will regulated at 1.235 V, and current consumption at R is $I_L = 1.23/R$.

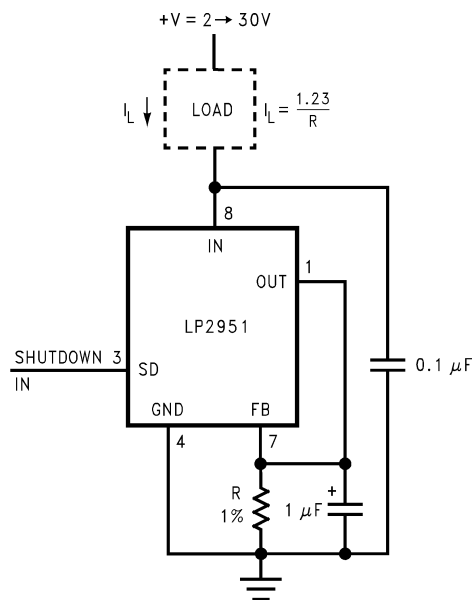
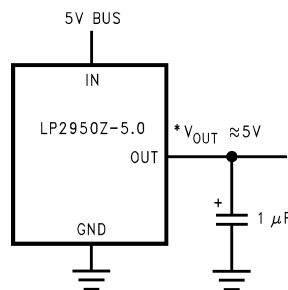


Figure 46. Low Drift Current Source

9.2.5 5-V Current Limiter

The LP2950 internal current limit function can be leveraged to build 5-V current limiter as [Figure 47](#) shows. The minimum input-output voltage ranges from 40 mV to 400 mV, depending on load current. Current limit is typically 160 mA.



*Minimum input-output voltage ranges from 40 mV to 400 mV, depending on load current. Current limit is typically 160 mA.

Figure 47. 5-V Current Limiter

9.2.6 Regulator with Early Warning and Auxiliary Output

The LP2951 can be used to build a Regulator with early warning and auxiliary output as Figure 48 shows. it has below features:

- Early warning flag on low input voltage
- Main output latches off at lower input voltages
- Battery backup on auxiliary output
- Operation: V_{OUT} of regulator 1 is programmed one diode drop above 5 V. Its error flag becomes active when $V_{IN} \leq 5.7$ V. When V_{IN} drops below 5.3 V, the error flag of regulator 2 becomes active and via Q1 latches the main output off. When V_{IN} again exceeds 5.7 V regulator 1 is back in regulation and the early warning signal rises, unlatching regulator 2 via D3.

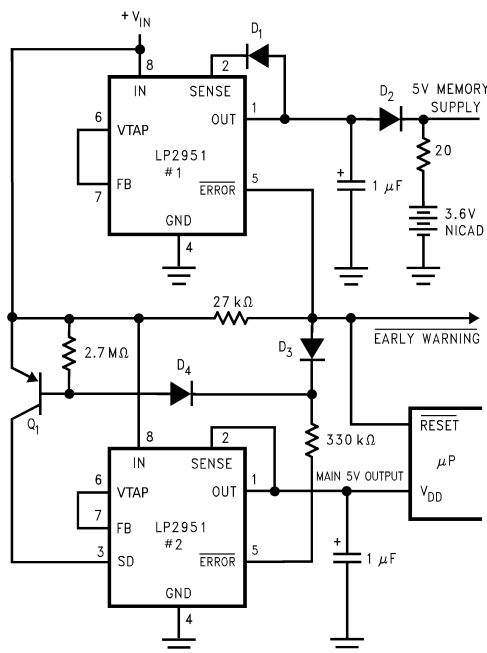


Figure 48. Regulator With Early Warning and Auxiliary Output

9.2.7 Latch Off When Error Flag Occurs

As Figure 49 presents, a latch off when error flag occurs circuit works in below two mode:

When output is within $\pm 95\%$ of V_{OUT} option, the error flag pin keep output high, which turns off PNP bipolar and pulls SD pin to low, then the LP2951 keeps output regulated voltage.

When output drop to less than 95% of V_{OUT} option, it triggers error flag output a low voltage, which turns on PNP bipolar and pulls SD pin to high, then the device enters shutdown mode and turns off output voltage. During a shutdown sequence, the $\overline{\text{ERROR}}$ pin continues output low, and the LP2951 device latches in shutdown mode.

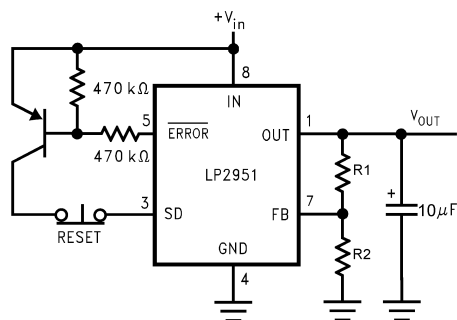


Figure 49. Latch Off When Error Flag Occurs

9.2.8 2-A Low Dropout Regulator

As Figure 50 shows, the 2-A low dropout regulator has below features:

$$V_{out} = 1.23V \left(1 + \frac{R_1}{R_2} \right)$$

For 5 V_{OUT}, use internal resistors. Wire pin 6 to pin 7 and wire pin 2 to + V_{OUT} bus.

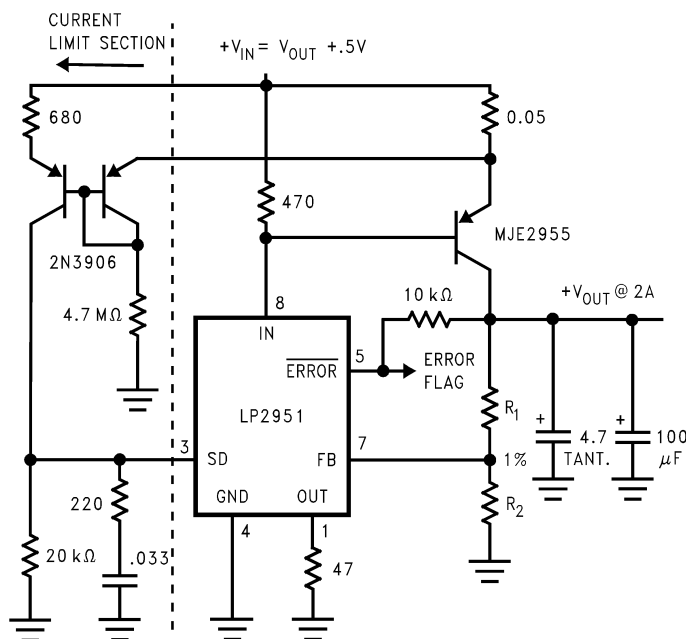


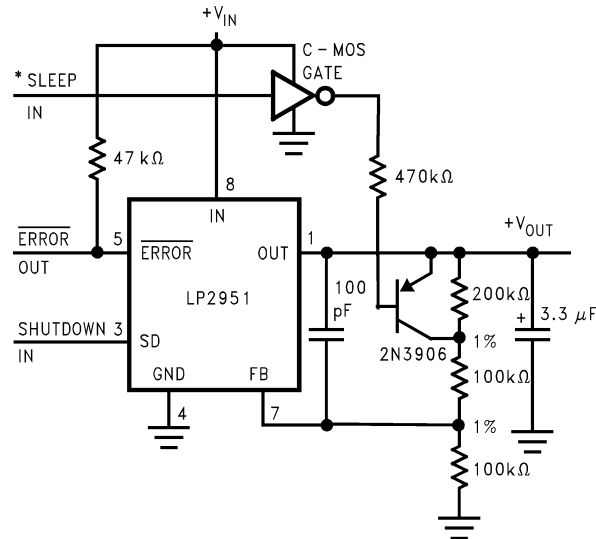
Figure 50. 2-A Low Dropout Regulator

9.2.9 5-V Regulator with 2.5-V Sleep Function

In Figure 51, the 5-V regulator with 2.5-V sleep function works in below mode:

When sleep input is low, C-MOS output a high voltage and 2N3906 is off, then $V_{out} = (1 + 300\text{ K}\Omega/100\text{ K}\Omega) \times V_{FB} \approx 5\text{ V}$

when sleep input is high, C-MOS output a low voltage, turns on 2N3906, then 200-KΩ resistor is bypassed from circuit, and $V_{OUT} = (1+100\text{ K}\Omega/100\text{ K}\Omega) \times V_{FB} \approx 2.5\text{ V}$.



*High input lowers V_{out} to 2.5 V.

Figure 51. 5-V Regulator with 2.5-V Sleep Function

9.2.10 Open Circuit Detector for 4 → 20-mA Current Loop

Figure 52 shows the open circuit detector for $4 \rightarrow 20$ -mA current loop. The circuit outputs a high level while input current is less than 3.5 mA.

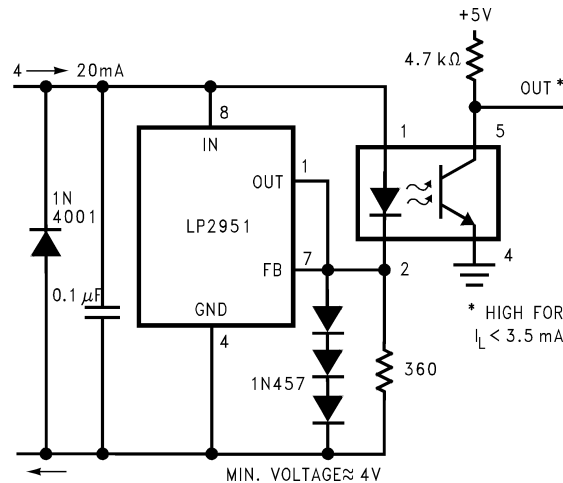
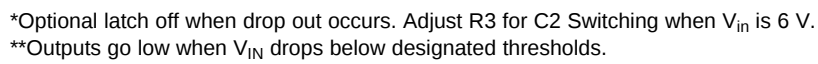


Figure 52. Open Circuit Detector for 4 → 20-mA Current Loop

9.2.11 Regulator with State-of-Charge Indicator

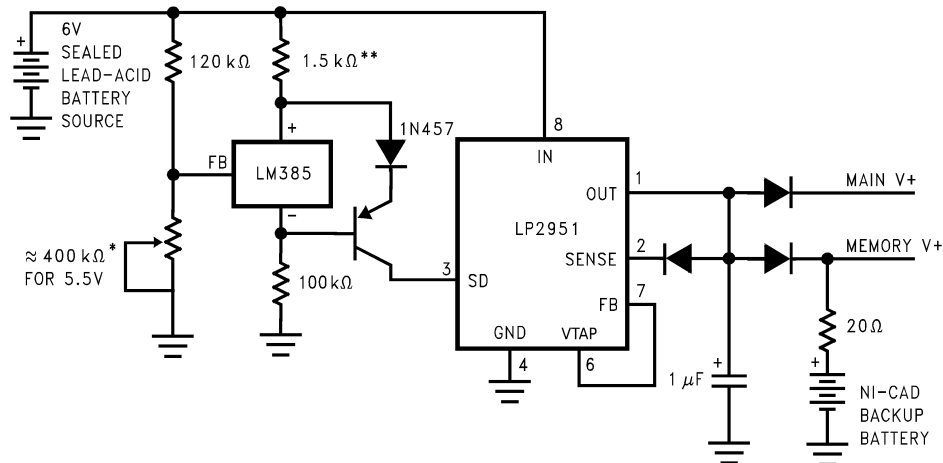
In [Figure 53](#), the LP339, a quad comparator, is used to indicate battery voltage state. The comparator's negative input voltage is equal to the LP2951 1.235-V feedback voltage. By adjusting R3, we can adjust positive input voltage of C1~C3 to target value.



Product Folder Links: [LP2950-N](#) [LP2951-N](#)

9.2.12 Low Battery Disconnect

In [Figure 54](#), a band-gap voltage reference LM385 is used to generate shutdown signal, when $V_{in} < 5.5$ V, the LP2951 turns off and turns on again when $V_{in} > 6$ V.



For values shown, regulator shuts down when $V_{in} < 5.5$ V and turns on again at 6 V. Current drain in disconnected mode is approximately 150 μ A.

*Sets disconnect voltage.

**Sets disconnect hysteresis.

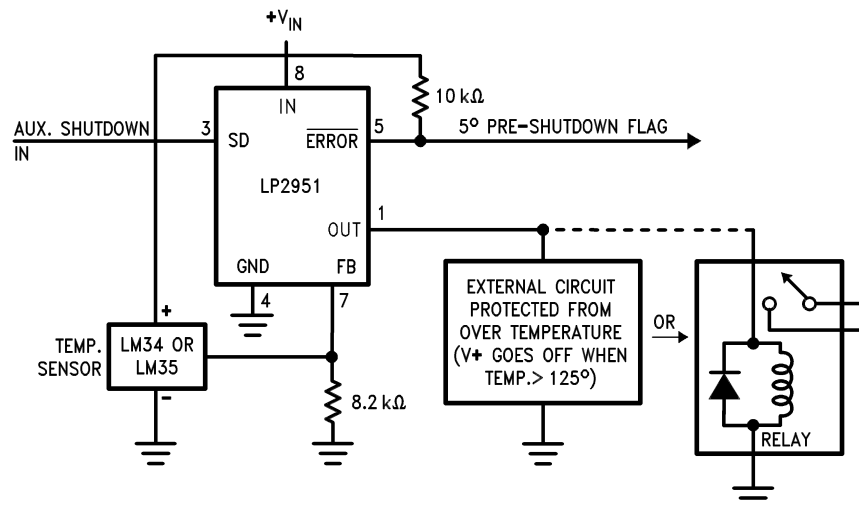
Figure 54. Low Battery Disconnect

9.2.13 System Overtemperature Protection Circuit

In [Figure 55](#), temperature sensors LM34/35's output voltage is linearly proportional to the Celsius (Centigrade) temperature.

At room temperature, LM34/35's output voltage is lower than 1.235-V feedback voltage, the internal pass transistor fully turns on, and the LP2951 output voltage is close to V_{IN} .

When ambient temperature raise higher than protection target, LM34/35's output voltage is higher than 1.235-V feedback voltage, the internal pass transistor turns off, and the LP2951 output goes off.



LM34 for 125°F shutdown

LM35 for 125°C shutdown

Figure 55. System Overtemperature Protection Circuit

10 Power Supply Recommendations

The LP2950-N and LP2951-N are designed to operate from an input voltage supply range between 2.3 V and 30 V. The input voltage range provides adequate headroom in order for the device to have a regulated output. This input supply must be well regulated. If the input supply is noisy, additional input capacitors with low ESR can help improve the output noise performance.

11 Layout

11.1 Layout Guidelines

For best overall performance, place all circuit components on the same side of the circuit board and as near as practical to the respective LDO pin connections. Place ground return connections to the input and output capacitor, and to the LDO ground pin as close to each other as possible, connected by a wide, component-side, copper surface. The use of vias and long traces to create LDO circuit connections is strongly discouraged and negatively affects system performance. This grounding and layout scheme minimizes inductive parasitics, and thereby reduces load-current transients, minimizes noise, and increases circuit stability.

A ground reference plane is also recommended and is either embedded in the PCB itself or located on the bottom side of the PCB opposite the components. This reference plane serves to assure accuracy of the output voltage, shield noise, and behaves similar to a thermal plane to spread (or sink) heat from the LDO device. In most applications, this ground plane is necessary to meet thermal requirements.

11.2 Layout Example

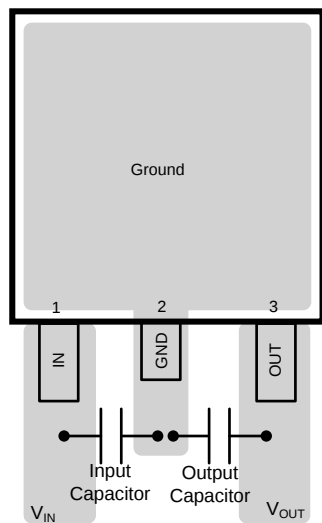


Figure 56. LP2950 Board Layout

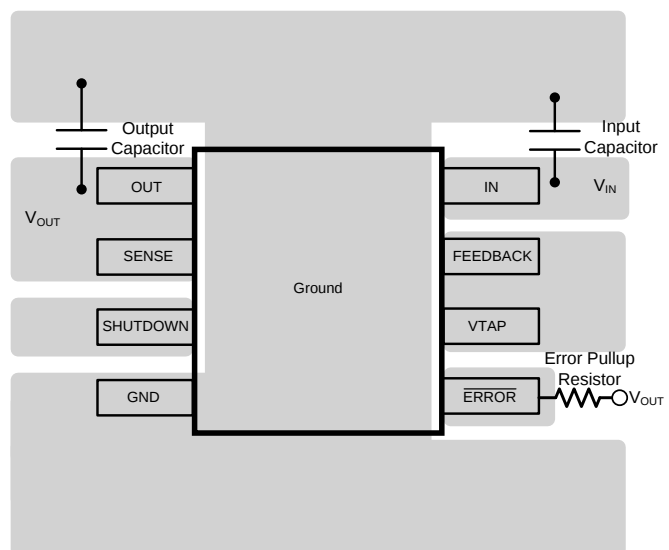


Figure 57. LP2951 VSSOP Board Layout

Layout Example (continued)

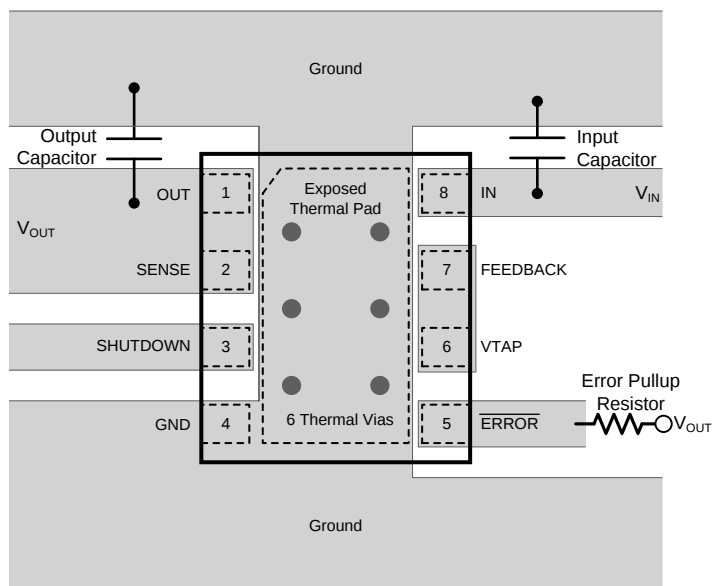


Figure 58. LP2951 WSON Board Layout

11.3 WSON Mounting

The NGT (no pullback) 8-lead WSON package requires specific mounting techniques which are detailed in *AN-1187 Leadless Leadframe Package (LLP) (SNOA401)*. Referring to the PCB Design Recommendations section, note that the pad style which should be used with the WSON package is the NSMD (non-solder mask defined) type. Additionally, TI recommends that the PCB terminal pads to be 0.2 mm longer than the package pads to create a solder fillet to improve reliability and inspection.

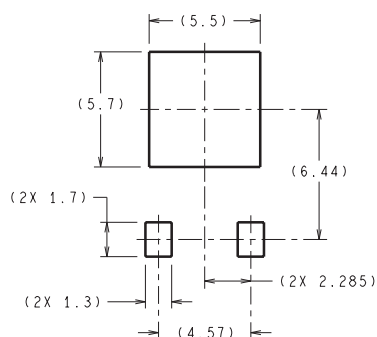
The thermal dissipation of the WSON package is directly related to the printed circuit board construction and the amount of additional copper area connected to the DAP.

For the LP2951-N in the NGT 8-lead WSON package, the junction-to-case thermal rating, $R_{\theta JC}$, is 35°C/W, where the case is the bottom of the package at the center of the DAP.

The DAP (exposed pad) on the bottom of the WSON package is connected to the die substrate with a conductive die attach adhesive. The DAP has no direct electrical (wire) connection to any of the eight pins. There is a parasitic PN junction between the die substrate and the device ground. As such, it is strongly recommend that the DAP be connected directly to the ground at device lead 4 (that is, GND). Alternately, but not recommended, the DAP may be left floating (that is, no electrical connection). The DAP must not be connected to any potential other than ground.

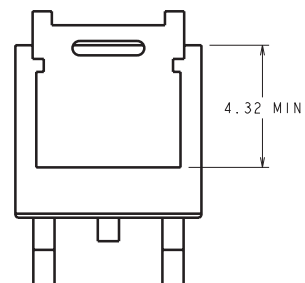
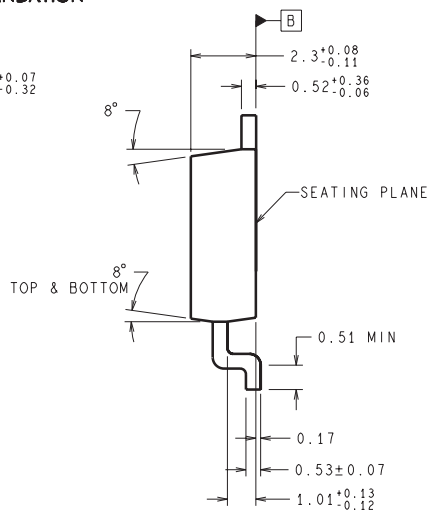
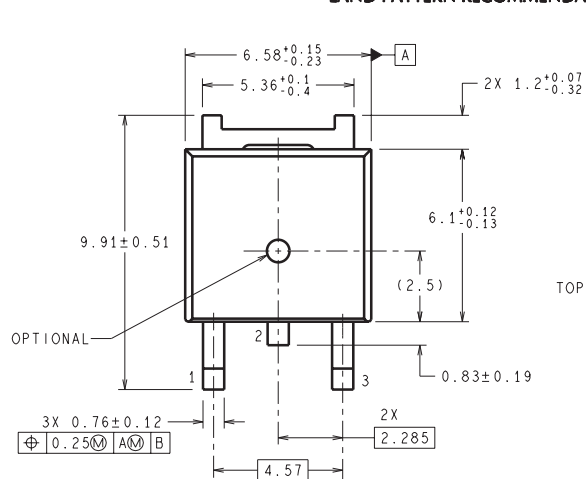
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LP2951ACSDX/NOPB	WSO	NGT	8	4500	367.0	367.0	35.0
LP2951CMM	VSSOP	DGK	8	1000	210.0	185.0	35.0
LP2951CMM-3.0/NOPB	VSSOP	DGK	8	1000	210.0	185.0	35.0
LP2951CMM-3.3/NOPB	VSSOP	DGK	8	1000	210.0	185.0	35.0
LP2951CMM/NOPB	VSSOP	DGK	8	1000	210.0	185.0	35.0
LP2951CMMX	VSSOP	DGK	8	3500	367.0	367.0	35.0
LP2951CMMX-3.0/NOPB	VSSOP	DGK	8	3500	367.0	367.0	35.0
LP2951CMMX-3.3	VSSOP	DGK	8	3500	367.0	367.0	35.0
LP2951CMMX-3.3/NOPB	VSSOP	DGK	8	3500	367.0	367.0	35.0
LP2951CMMX/NOPB	VSSOP	DGK	8	3500	367.0	367.0	35.0
LP2951CMX	SOIC	D	8	2500	367.0	367.0	35.0
LP2951CMX-3.0/NOPB	SOIC	D	8	2500	367.0	367.0	35.0
LP2951CMX-3.3/NOPB	SOIC	D	8	2500	367.0	367.0	35.0
LP2951CMX/NOPB	SOIC	D	8	2500	367.0	367.0	35.0
LP2951CSD-3.0/NOPB	WSO	NGT	8	1000	203.0	203.0	35.0
LP2951CSD-3.3/NOPB	WSO	NGT	8	1000	210.0	185.0	35.0
LP2951CSD/NOPB	WSO	NGT	8	1000	203.0	203.0	35.0
LP2951CSDX-3.3/NOPB	WSO	NGT	8	4500	367.0	367.0	35.0
LP2951CSDX/NOPB	WSO	NGT	8	4500	346.0	346.0	35.0

NDP0003B



DIMENSIONS ARE IN MILLIMETERS
DIMENSIONS IN () FOR REFERENCE ONLY

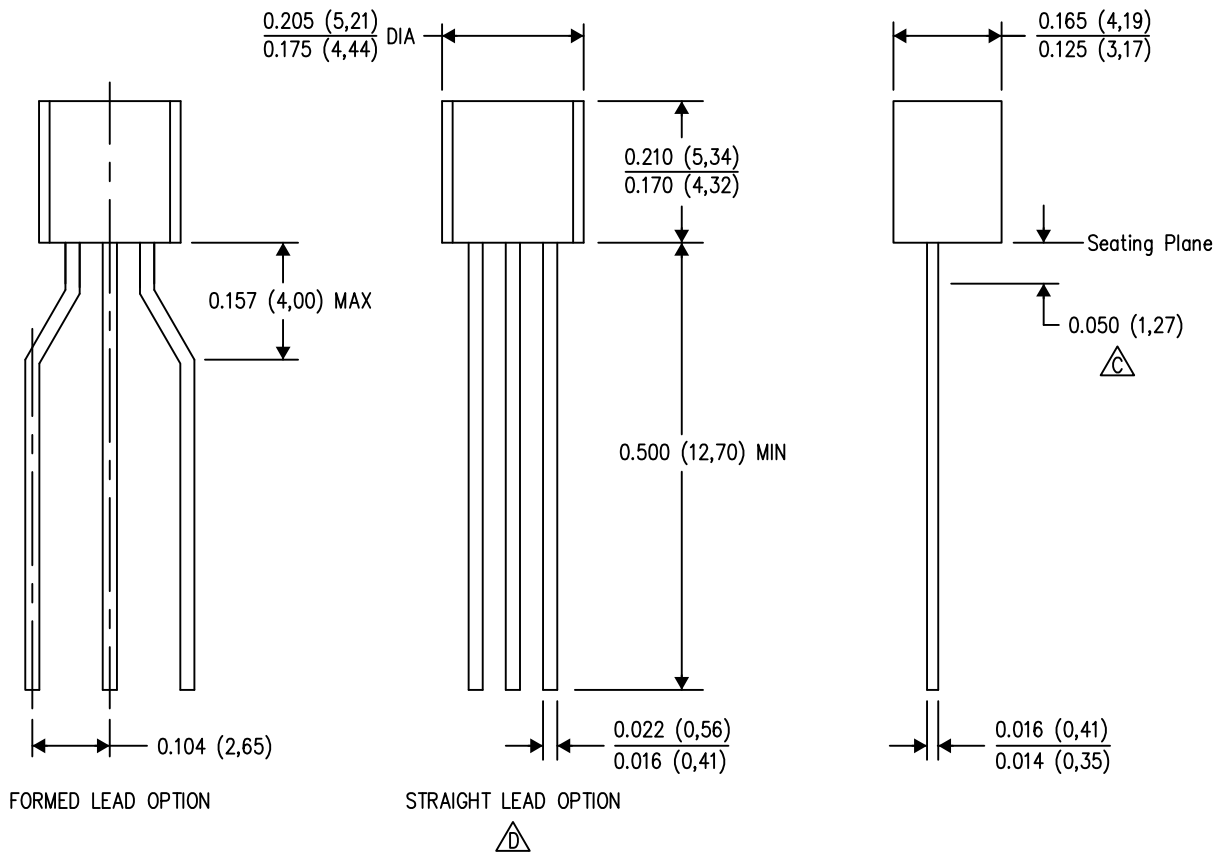
LAND PATTERN RECOMMENDATION



TD03B (Rev F)

LP (O-PBCY-W3)

PLASTIC CYLINDRICAL PACKAGE

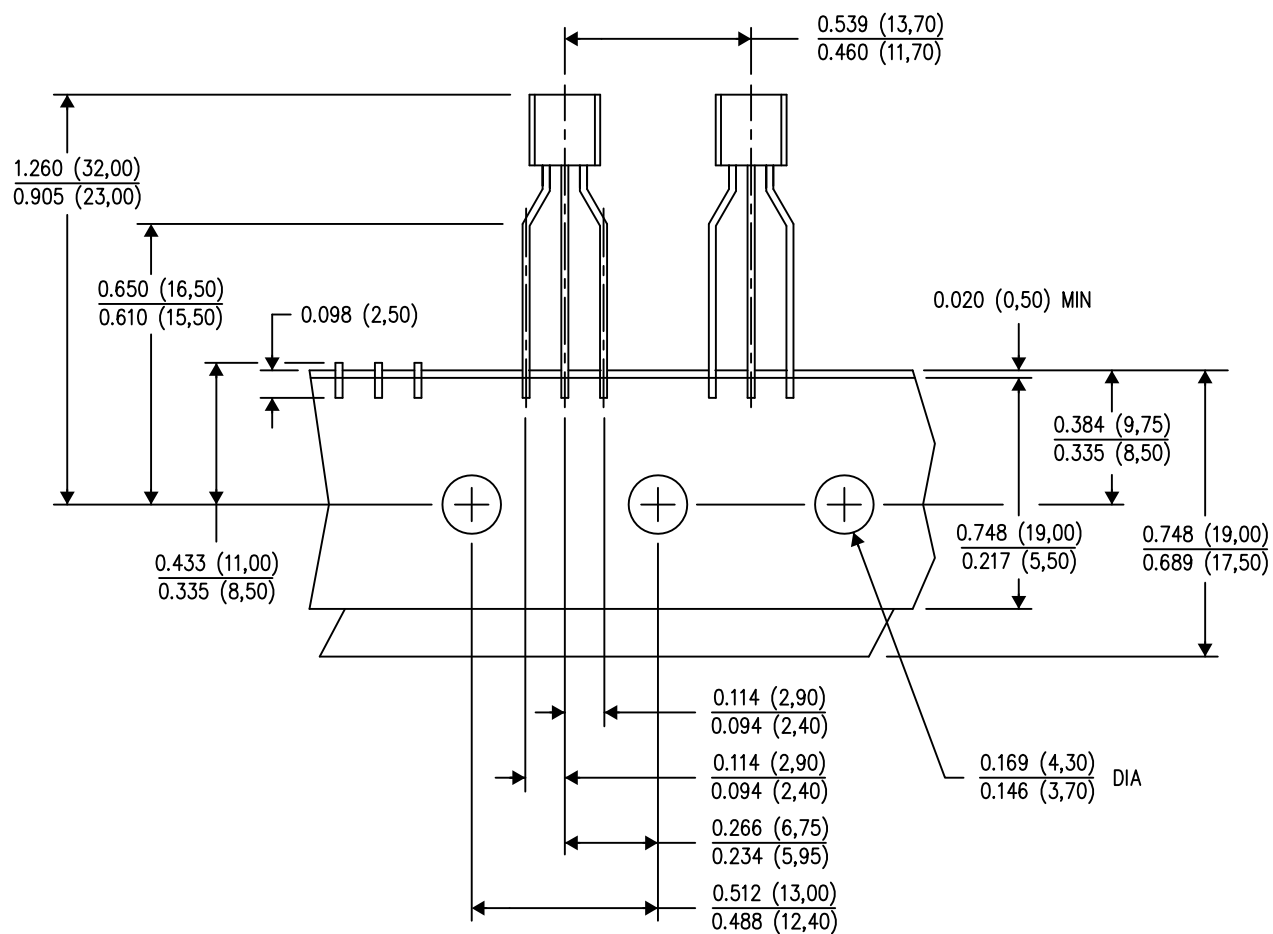


4040001-2/E 08/13

- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - C. Lead dimensions are not controlled within this area.
 - D. Falls within JEDEC TO-226 Variation AA (TO-226 replaces TO-92).
 - E. Shipping Method:
 Straight lead option available in bulk pack only.
 Formed lead option available in tape & reel or ammo pack.
 Specific products can be offered in limited combinations of shipping mediums and lead options.
 Consult product folder for more information on available options.

LP (O-PBCY-W3)

PLASTIC CYLINDRICAL PACKAGE



TAPE & REEL

4040001-3/E 08/13

- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - C. Tape and Reel information for the Formed Lead Option package.

D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



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

P (R-PDIP-T8)

PLASTIC DUAL-IN-LINE PACKAGE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - C. Falls within JEDEC MS-001 variation BA.

DGK (S-PDSO-G8)

PLASTIC SMALL-OUTLINE PACKAGE

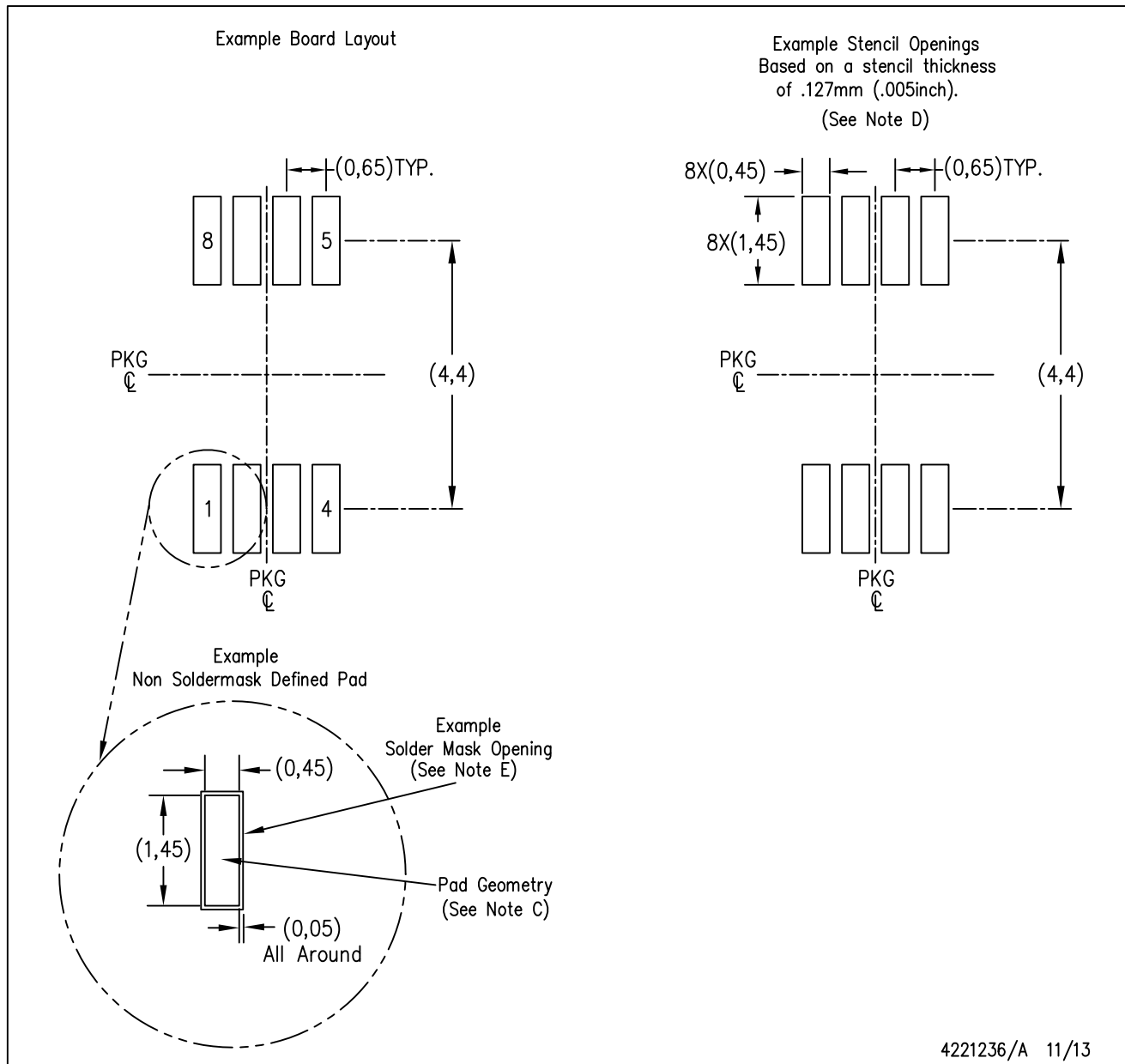


NOTES:

- A. All linear dimensions are in millimeters.
- B. This drawing is subject to change without notice.
- C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 per end.
- D. Body width does not include interlead flash. Interlead flash shall not exceed 0.50 per side.
- E. Falls within JEDEC MO-187 variation AA, except interlead flash.

DGK (S-PDSO-G8)

PLASTIC SMALL OUTLINE PACKAGE



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