300-mA Ultra Low-Noise LDO Regulator With Discharge Option

FEATURES

- Ultra Low Dropout—300 mV at 300-mA Load
- Ultra Low Noise—30 μV_{RMS} (10-Hz to 100-kHz)
- Shutdown Control
- 130-μA Ground Current at 300-mA Load
- 1.5% Guaranteed Output Voltage Accuracy
- 400-mA Peak Output Current Capability
- Uses Low ESR Ceramic Capacitors
- Fast Start-Up (50 μs)
- Fast Line and Load Transient Response (≤ 30 μs)
- 1-μA Maximum Shutdown Current
- Output Current Limit
- Reverse Battery Protection
- Built-in Short Circuit and Thermal Protection

Pb-free Available

- Output, Auto-Discharge In Shutdown Mode
- Fixed 1.2, 1.8, 2.5, 2.6, 2.8, 3.0, 3.3, 5.0-V Output Voltage Options
- MLP33-5 PowerPAK® Package

APPLICATIONS

- Cellular Phones, Wireless Handsets
- Noise-Sensitive Electronic Systems, Laptop and Palmtop Computers
- PDAs
- Pagers
- Digital Cameras
- MP3 Player
- Wireless Modem

DESCRIPTION

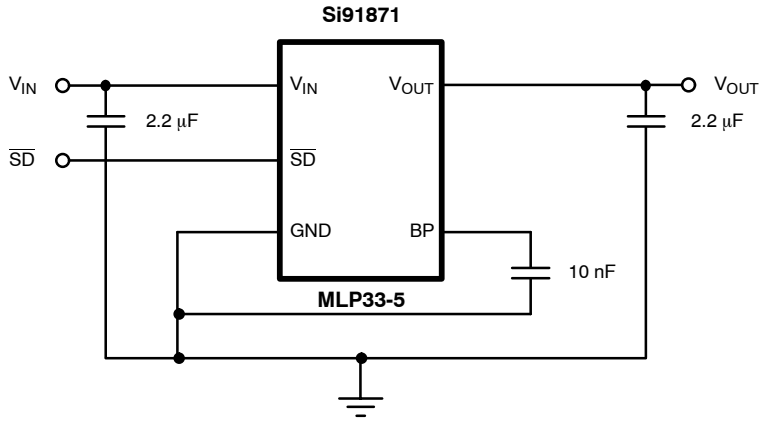
The Si91871 is a 300-mA CMOS LDO (low dropout) voltage regulator. It is the perfect choice for low voltage, low power applications. An ultra low ground current makes this part attractive for battery operated power systems. The Si91871 also offers ultra low dropout voltage to prolong battery life in portable electronics. Systems requiring a quiet voltage source, such as RF applications, will benefit from the Si91871's ultra low output noise. An external noise bypass capacitor connected to the device's BP pin can further reduce the noise level. The Si91871 is designed to maintain regulation while delivering 400-mA peak current, making it ideal for systems that have a high surge current upon turn-on.

For better transient response and regulation, an active pull-down circuit is built into the Si91871 to clamp the output voltage when it rises beyond normal regulation. The Si91871 automatically discharges the output voltage by connecting the output to ground through a 100-Ω n-channel MOSFET when the device is put in shutdown mode.

The Si91871 features reverse battery protection to limit reverse current flow to approximately 1-μA in the event reversed battery is applied at the input, thus preventing damage to the IC.

The Si91871 is available in both the standard and lead (Pb)-free 5-pin MLP33 PowerPAK packages and is specified to operate over the industrial temperature range of –40°C to 85°.

TYPICAL APPLICATION CIRCUIT



ABSOLUTE MAXIMUM RATINGS

Absolute Maximum Ratings
Input Voltage, V_{IN} to GND . . . . . –6.0 to 6.5 V
$V_{\overline{SD}}$ (See Detailed Description) . . . . . –0.3 V to V_{IN}
Output Current, I_{OUT} . . . . . Short Circuit Protected
Output Voltage, V_{OUT} . . . . . –0.3 V to V_{IN} + 0.3 V
Package Power Dissipation, $(P_d)^b$ . . . . . 2.3 W

Thermal Resistance $(\theta_{JA})^a$ . . . . . 55°C/W
$R_{(\theta JA)}{}^a$ . . . . . 8°C/W
Maximum Junction Temperature, $T_{J(max)}$ . . . . . 150°C
Storage Temperature, T_{STG} . . . . . –65°C to 150°C
Notes
a. Device mounted with all leads soldered or welded to PC board.
b. Derate 20 mW/°C above T_A = 25°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 in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Input Voltage, V_{IN} . . . . . 2 V to 6 V
Input Voltage, $V_{\overline{SD}}$ . . . . . 0 V to V_{IN}
Output Current . . . . . 0 to 300 mA
C_{IN}, $C_{OUT}{}^a$ (Ceramic) . . . . . 2.2 µF

C_{EB} (Ceramic) . . . . . 0.01 µF
Operating Ambient Temperature, T_A . . . . . –40°C to 85°C
Operating Junction Temperature, T_J . . . . . –40°C to 125°C
Notes
a. Maximum ESR of C_{OUT}: 0.2 Ω.

SPECIFICATIONS

Parameter	Symbol	Test Conditions Unless Specified T_A = 25°C, V_{IN} = $V_{OUT(nom)}$ + 1 V I_{OUT} = 1 mA, C_{IN} = 2 µF, C_{OUT} = 2.0 µF $V_{\overline{SD}}$ = 1.5 V		Temp[a]	Limits –40 to 85°C Min[b]	Typ[c]	Max[b]	Unit
Start-Up BP Current	I_{OUT}	ON/$\overline{OFF}$ = High		Room		1		mA
Input Voltage Range	V_{IN}			Full	2		6	V
Output Voltage Accuracy		1 mA ≤ I_{OUT} ≤ 300 mA	V_{OUT} ≥ 1.8 V	Room	–2.0	1	2.0	%
				Full	–3.0	1	3.0	
			V_{OUT} = 1.2 V, 1.5 V	Room	–2.5	1	2.5	
				Full	–3.5	1	3.5	
Line Regulation (V_{OUT} ≤ 3 V)	$\frac{\Delta V_{OUT} \times 100}{\Delta V_{IN} \times V_{OUT(nom)}}$	From V_{IN} = $V_{OUT(nom)}$ + 1 V to $V_{OUT(nom)}$ + 2 V		Full	–0.06		0.18	%/V
Line Regulation (3.0 V < V_{OUT} ≤ 3.6 V)				Full	0		0.3	
Line Regulation (5-V Version)		From V_{IN} = 5.5 V to 6 V		Full	0		0.4	
Dropout Voltage[d, g] ($V_{OUT(nom)}$ ≥ 2.6 V)	$V_{IN} - V_{OUT}$	I_{OUT} = 1 mA		Room		1		mV
		I_{OUT} = 50 mA		Room		45	80	
				Full		50	90	
		I_{OUT} = 300 mA		Room		300	350	
				Full			415	
Dropout Voltage[d, g] ($V_{OUT(nom)}$ < 2.6 V, V_{IN} ≥ 2 V)		I_{OUT} = 50 mA		Room		65	100	
				Full			120	
		I_{OUT} = 300 mA		Room		400	520	
				Full			570	
Ground Pin Current[e, g] ($V_{OUT(nom)}$ ≤ 3 V)	I_{GND}	I_{OUT} = 0 mA		Room		100	150	µA
				Full			180	
		I_{OUT} = 300 mA		Room		130	200	
				Full			330	
Ground Pin Current[e] ($V_{OUT(nom)}$ > 3 V)		I_{OUT} = 0 mA		Room		110	170	
				Full			200	
		I_{OUT} = 300 mA		Room		150	225	
				Full			275	
Peak Output current	$I_{O(peak)}$	V_{OUT} ≥ 0.95 x $V_{OUT(nom)}$. t_{PW} = 2 ms		Full	400			mA

SPECIFICATIONS

Parameter	Symbol	Test Conditions Unless Specified T_A = 25°C, V_{IN} = $V_{OUT(nom)}$ + 1 V I_{OUT} = 1 mA, C_{IN} = 2 µF, C_{OUT} = 2.0 µF $V_{\overline{SD}}$ = 1.5 V		Temp[a]	Limits −40 to 85°C Min[b]	Typ[c]	Max[b]	Unit
Output Noise Voltage	e_N	V_{NOM} = 2.6 V, BW = 10 Hz to 100 kHz, 0 mA < I_{OUT} < 300 mA, C_{NOISE} = 0.01 µF		Room		30		µV(rms)
Ripple Rejection	$\Delta V_{OUT}/\Delta V_{IN}$	I_{OUT} = 300 mA	f = 1 kHz	Room		60		dB
			f = 10 kHz	Room		40		
			f = 100 kHz	Room		30		
Dynamic Line Regulation	$\Delta V_{O(line)}$	V_{IN} : $V_{OUT(nom)}$ + 1 V to $V_{OUT(nom)}$ + 2 V t_r/t_f = 2 µs, I_{OUT} = 300 mA		Room		20		mV
Dynamic Load Regulation	$\Delta V_{O(load)}$	I_{OUT} : 1 mA to 300 mA, t_r/t_f = 2 µs		Room		20		
Thermal Shutdown Junction Temperature	$T_{J(S/D)}$			Room		150		°C
Thermal Hysteresis	T_{HYST}			Room		20		
Reverse current	I_R	V_{IN} = −6.0 V		Room		1		µA
Short Circuit Current	I_{SC}	V_{OUT} = 0 V		Room		700		mA
Shutdown								
Shutdown Supply Current	$I_{CC(off)}$	$V_{\overline{SD}}$ = 0 V		Room		0.1	1	µA
$\overline{SD}$ Pin Input Voltage	$V_{\overline{SD}}$	High = Regulator ON (Rising)		Full	1.5		V_{IN}	V
		Low = Regulator OFF (Falling)		Full			0.4	
Auto Discharge Resistance	R_DIS			Room		100		Ω
$\overline{SD}$ Pin Input Current[f]	$I_{IN(\overline{SD})}$	$V_{\overline{SD}}$ = 1.5 V, V_{IN} = 6 V		Room		0.7		µA
$\overline{SD}$ Hysteresis	$V_{HYST(\overline{SD})}$			Full		150		mV
V_{OUT} Turn-On Time	t_{ON}	$V_{\overline{SD}}$ (See Figure 1), I_{LOAD} = 100 nA				50		µs

Notes
a. Room = 25°C, Full = −40 to 85°C.
b. The algebraic convention whereby the most negative value is a minimum and the most positive a maximum.
c. Typical values are for DESIGN AID ONLY, not guaranteed nor subject to production testing. Typical values for dropout voltage at $V_{OUT} \geq$ 2 V are measured at V_{OUT} = 3.3 V, while typical values for dropout voltage at V_{OUT} < 2 V are measured at V_{OUT} = 1.8 V.
d. Dropout voltage is defined as the input to output differential voltage at which the output voltage drops 2% below the output voltage measured with a 1-V differential, provided that V_{IN} does not not drop below 2.0 V.
e. Ground current is specified for normal operation as well as “drop-out” operation.
f. The device’s shutdown pin includes a typical 2-MΩ internal pull-down resistor connected to ground.
g. $V_{OUT(nom)}$ is V_{OUT} when measured with a 1-V differential to V_{IN}.

TIMING WAVEFORMS

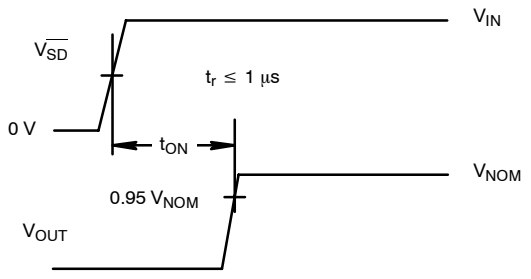
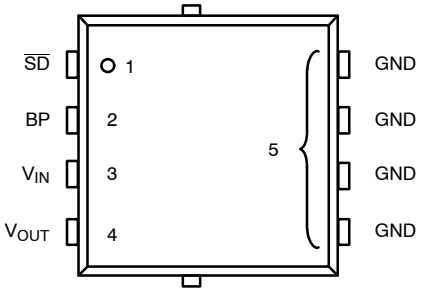


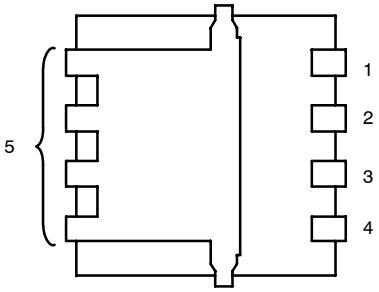
FIGURE 1. Timing Diagram for Power-Up

PIN CONFIGURATION

MLP33-5 PowerPAK



Top View



Bottom View

PIN DESCRIPTION

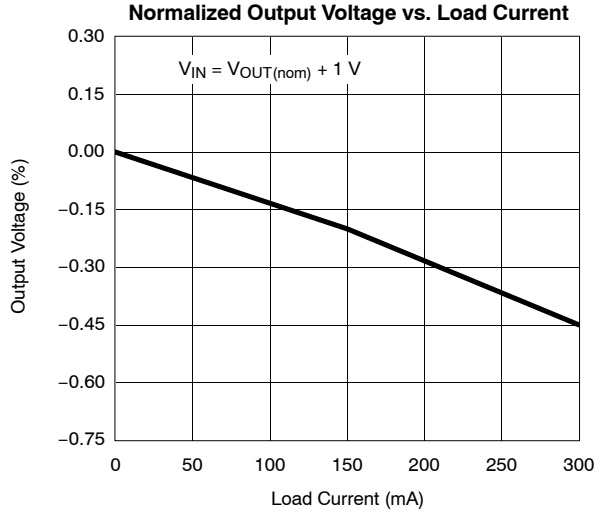
Pin Number	Name	Function
1	$\overline{SD}$	By applying less than 0.4 V to this pin, the device will be turned off. Connect this pin to V_{IN} if unused
2	BP	Noise bypass pin. For low noise applications, a 0.01 µF ceramic capacitor should be connected from this pin to ground.
3	V_{IN}	Input supply pin. Bypass this pin with a 1-µF ceramic or tantalum capacitor to ground
4	V_{OUT}	Output voltage. Connect C_{OUT} between this pin and ground.
5	GND	Ground pin. For better thermal capability, directly connected to large ground plane

ORDERING INFORMATION

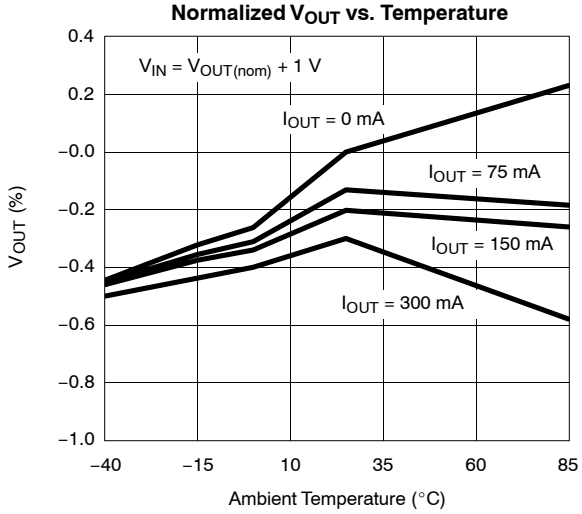
Standard Part Number	Lead (Pb)-Free Part Number	Marking	Voltage	Temp. Range	Pkg.
Si91871DMP-12-T1	Si91871DMP-12-E3	7112	1.2	–40 to 85°C	MLP33-5
Si91871DMP-18-T1	Si91871DMP-18-E3	7118	1.8		
Si91871DMP-25-T1	Si91871DMP-25-E3	7125	2.5		
Si91871DMP-26-T1	Si91871DMP-26-E3	7126	2.6		
Si91871DMP-28-T1	Si91871DMP-28-E3	7128	2.8		
Si91871DMP-30-T1	Si91871DMP-30-E3	7130	3.0		
Si91871DMP-33-T1	Si91871DMP-33-E3	7133	3.3		
Si91871DMP-50-T1	Si91871DMP-50-E3	7150	5.0		

TYPICAL CHARACTERISTICS (INTERNALLY REGULATED, 25°C UNLESS NOTED)

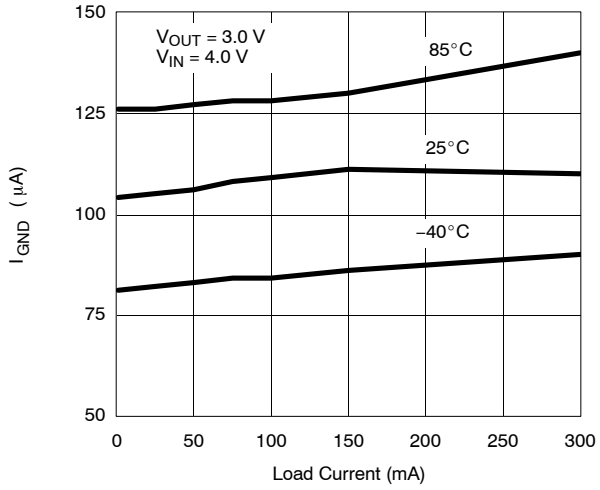
Normalized Output Voltage vs. Load Current



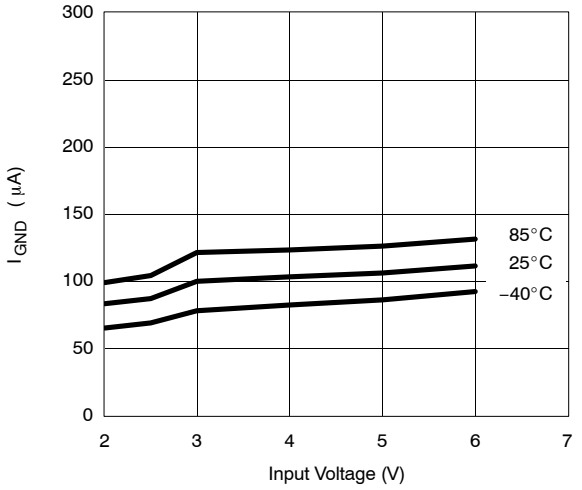
Normalized V_{OUT} vs. Temperature



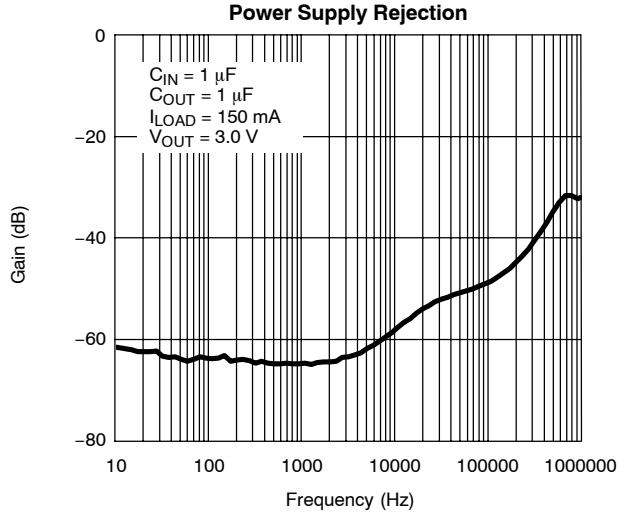
GND Current vs. Load Current



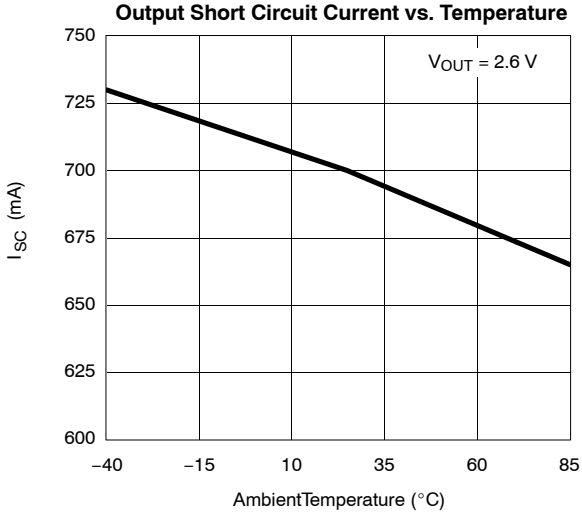
No Load GND Pin Current vs. Input Voltage



Power Supply Rejection

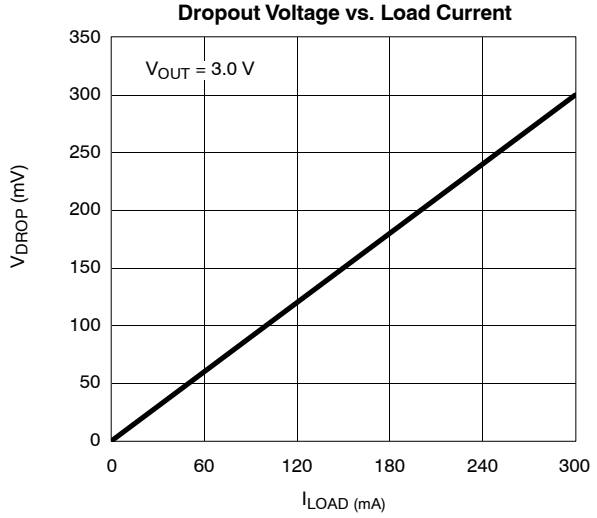


Output Short Circuit Current vs. Temperature

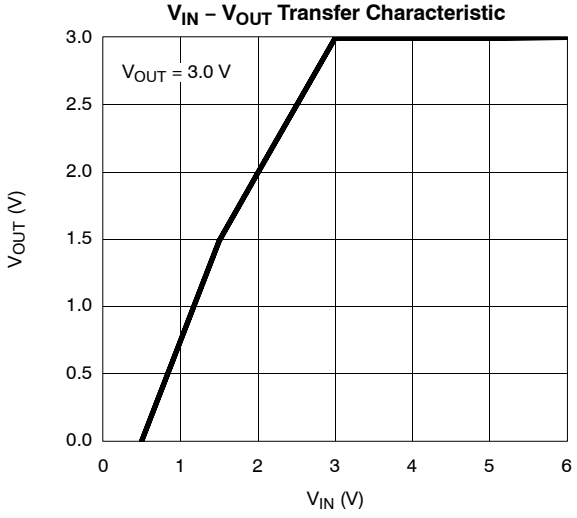


TYPICAL CHARACTERISTICS (INTERNALLY REGULATED, 25°C UNLESS NOTED)

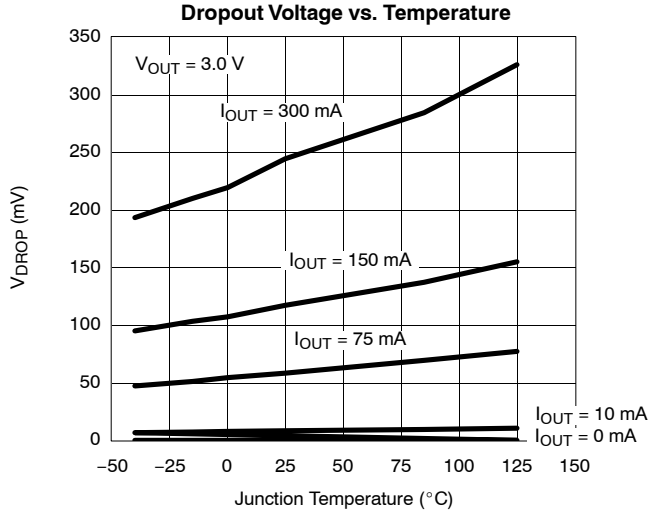
Dropout Voltage vs. Load Current



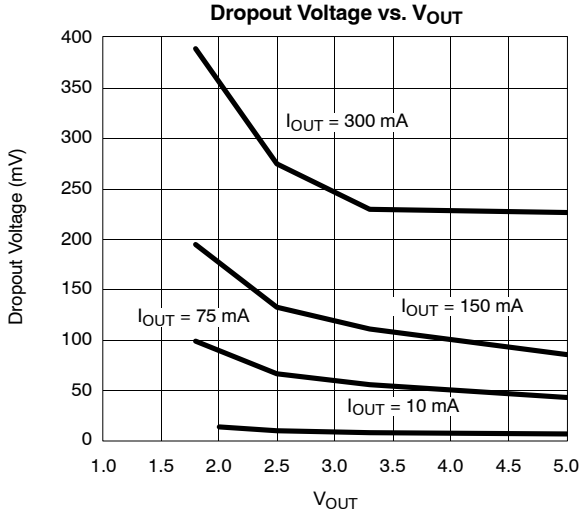
V_{IN} – V_{OUT} Transfer Characteristic



Dropout Voltage vs. Temperature

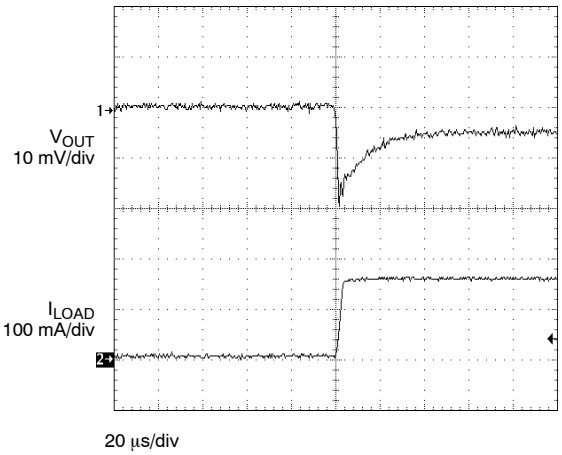


Dropout Voltage vs. V_{OUT}



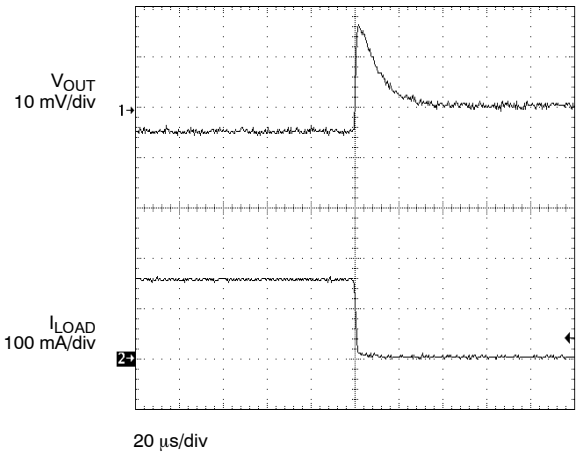
TYPICAL WAVEFORMS

Load Transient Response-1



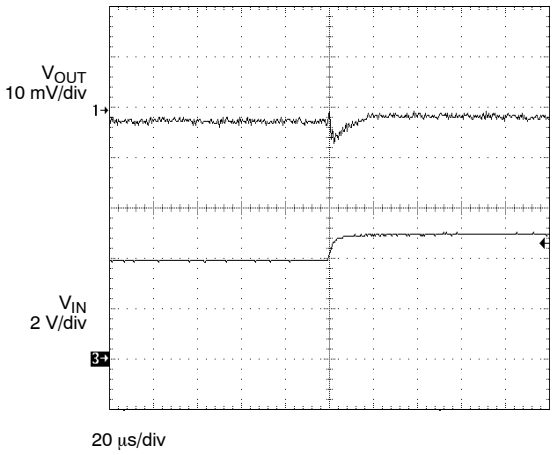
V_{OUT} = 3.0 V
C_{OUT} = 1 µF
I_{LOAD} = 1 to 150 mA
t_{rise} = 2 µsec

Load Transient Response-2



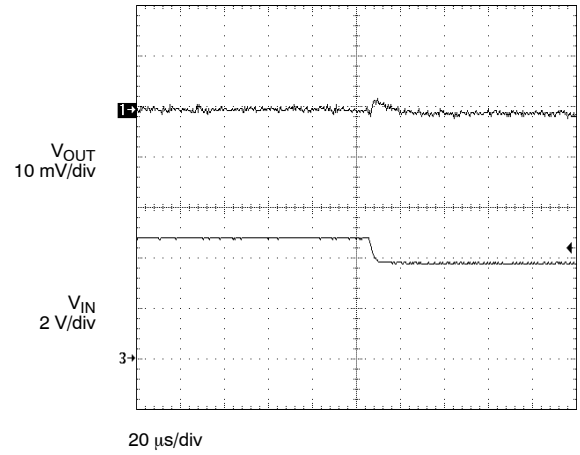
V_{OUT} = 3.0 V
C_{OUT} = 1 µF
I_{LOAD} = 150 to 1 mA
t_{fall} = 2 µsec

LineTransient Response-1



V_{INSTEP} = 4 to 5 V
V_{OUT} = 3 V
C_{OUT} = 1 µF
C_{IN} = 1 µF
I_{LOAD} = 150 mA
t_{rise} = 5 µsec

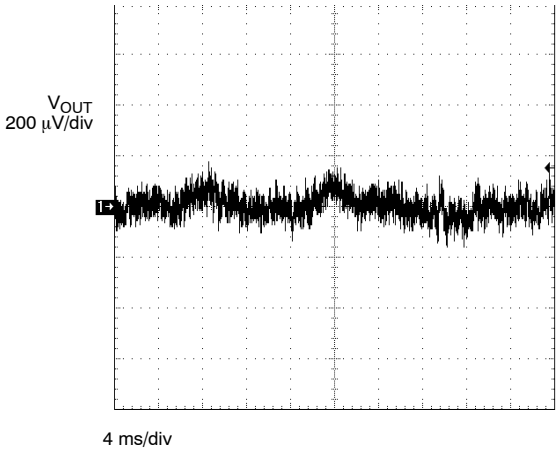
LineTransient Respons-2



V_{INSTEP} = 5 to 4 V
V_{OUT} = 3 V
C_{OUT} = 1 µF
C_{IN} = 1 µF
I_{LOAD} = 150 mA
t_{fall} = 5 µsec

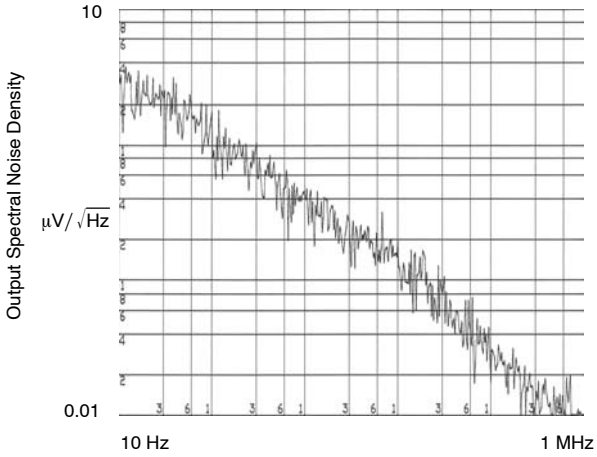
TYPICAL WAVEFORMS

Output Noise



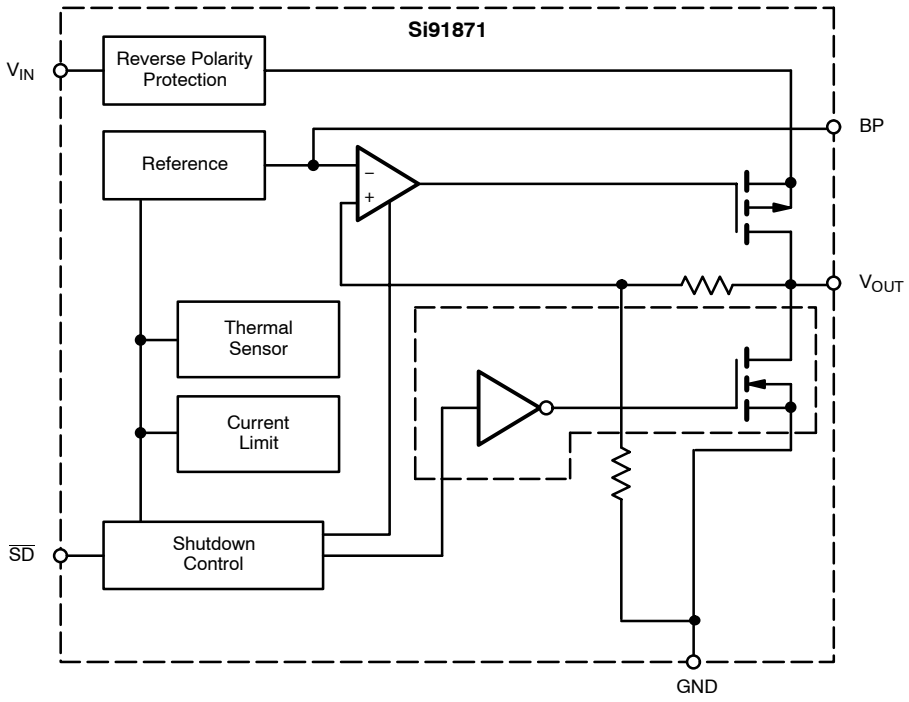
V_{IN} = 4 V
V_{OUT} = 3 V
I_{OUT} = 150 mA
C_{NOISE} = 0.01 µF
BW = 10 Hz to 100 kHz

Noise Spectrum



V_{IN} = 4 V
V_{OUT} = 3 V
I_{LOAD} = 150 mA
C_{NOISE} = 0.01 µF

FUNCTIONAL BLOCK DIAGRAM



DETAILED DESCRIPTION

The Si91871 is a low-noise, low drop-out and low quiescent current linear voltage regulator, packaged in a small footprint MLP33-5 package. The Si91871 can supply loads up to 300 mA. As shown in the block diagram, the circuit consists of a bandgap reference error, amplifier, p-channel pass transistor and feedback resistor string. An external bypass capacitor connected to the BP pin reduces noise at the output. Additional blocks, not shown in the block diagram, include a precise current limiter, reverse battery and current protection and thermal sensor.

Thermal Overload Protection

The thermal overload protection limits the total power dissipation and protects the device from being damaged. When the junction temperature exceeds 150°C, the device turns the p-channel pass transistor off.

Reverse Battery Protection

The Si91871 has a battery reverse protection circuitry that disconnects the internal circuitry when V_{IN} drops below the GND voltage. There is no current drawn in such an event. When the $\overline{SD}$ pin is hardwired to V_{IN}, the user must connect the $\overline{SD}$ pin to V_{IN} via a 100-kΩ resistor if reverse battery protection is desired. Hardwiring the $\overline{SD}$ pin directly to the V_{IN} pin is allowed when reverse battery protection is not desired.

Noise Reduction

An external 10-nF bypass capacitor at BP is used to create a low pass filter for noise reduction. The start-up time is fast, since a power-on circuit pre-charges the bypass capacitor. After the power-up sequence the pre-charge circuit is switched to standby mode in order to save current. It is therefore not recommended to use larger bypass capacitor values than 50 nF. When the circuit is used without a capacitor, stable operation is guaranteed.

Auto-Discharge

The Si91871 V_{OUT} has an internal 100-Ω (typ.) discharge path to ground when the $\overline{SD}$ pin is low.

Stability

The circuit is stable with only a small output capacitor equal to 6 nF/mA (= 2 µF @ 300 mA). Since the bandwidth of the error amplifier is around 1–3 MHz and the dominant pole is at the output node, the capacitor should be capacitive in this range, i.e., for 150-mA load current, an ESR <0.2 Ω is necessary. Parasitic inductance of about 10 nH can be tolerated.

Safe Operating Area

The ability of the Si91871 to supply current is ultimately dependent on the junction temperature of the pass device. Junction temperature is in turn dependent on power dissipation in the pass device, the thermal resistance of the package and the circuit board, and the ambient temperature. The power dissipation is defined as

$$P_D = (V_{IN} - V_{OUT}) * I_{OUT}.$$

Junction temperature is defined as

$$T_J = T_A + ((P_D * (R\theta_{JC} + R\theta_{CA})).$$

To calculate the limits of performance, these equations must be rewritten.

Allowable power dissipation is calculated using the equation

$$P_D = (T_J - T_A)/ (R\theta_{JC} + R\theta_{CA})$$

While allowable output current is calculated using the equation

$$I_{OUT} = (T_J - T_A)/ (R\theta_{JC} + R\theta_{CA}) * (V_{IN} - V_{OUT}).$$

Ratings of the Si91871 that must be observed are

T_{Jmax} = 125 °C, T_{Amax} = 85 °C, $(V_{IN} - V_{OUT})_{max}$ = 5.3 V, $R\theta_{JC}$ = 8 °C/W.

The value of $R\theta_{CA}$ is dependent on the PC board used. The value of $R\theta_{CA}$ for the board used in device characterization is approximately 46 °C/W.

Figure 1 shows the performance limits graphically for the Si91871 mounted on the circuit board used for thermal characterization.

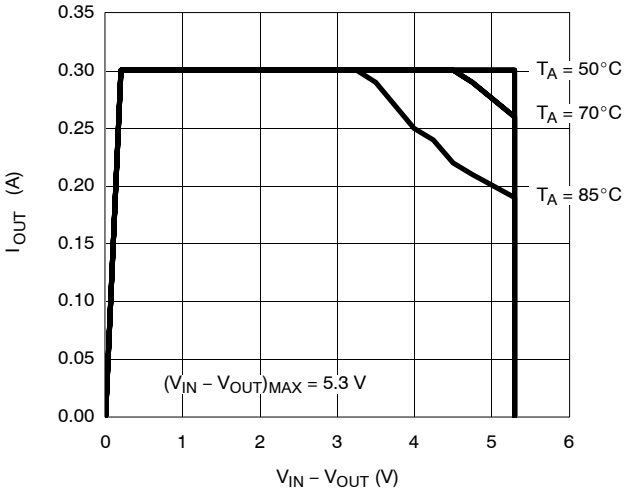


Figure 1. Safe Operating Area

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