DATA SHEET

SA8877-XX
Very low noise, low dropout,
150 mA linear regulator

Product data

2002 Jun 20

Philips
Semiconductors

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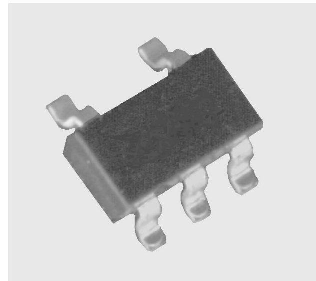
Very low noise, low dropout, 150 mA linear regulator

SA8877-XX

GENERAL DESCRIPTION



The SA8877-XX family are very low-noise, low-dropout, low quiescent-current linear regulators designed for battery-powered applications, although they can also be used for devices powered by AC-DC converters. The parts are available in a range of preset output voltages from 2.5 V to 4.5 V. Typical dropout voltages are only 165 mV at 150 mA, and 55 mV at 50 mA. Reverse battery current is extremely low, 0.5 μA typ.

For demanding applications, output noise voltage of typically 20 μV_{rms} is achieved with a 0.01 μF capacitor on the noise bypass pin. The input voltage can vary from 2.5 V_{DC} to 5.5 V_{DC}, providing up to150 mA output current.

An internal P-channel FET pass transistor maintains an 85 μA typical supply current, independent of the load current and dropout voltage. Other features include a 0.01 μA logic-controlled shutdown, short circuit and thermal shutdown protection, and reverse battery protection.

To accommodate high density layouts, it is packaged in the small footprint 5-pin SO5 (SOT23-5). The SA8877 is pin compatible with the industry standard ’2982 and a direct replacement for the MAX8877.

FEATURES

- Pin compatible with industry standard ’2982
- Low output noise: 20 μV_{rms}
- Low dropout voltages: 165 mV at 150 mA; 55 mV at 50 mA
- Thermal overload and short circuit protection
- Reverse battery protection
- 85 μA no-load supply current
- 100 μA typical operating supply current at I_{OUT} = 150 mA
- Preset output voltage of 2.5 V, 2.6 V, 2.8 V, 3.0 V, 3.3 V, 3.6 V, 4.2 V and 4.5 V; other voltages upon request in 100 mV increments
- Output current limit

APPLICATIONS

- Cordless, PCS, and cellular telephones
- PCMCIA cards and modems
- Handheld and portable instruments
- Palmtop computers and electronic planners

SIMPLIFIED SYSTEM DIAGRAM

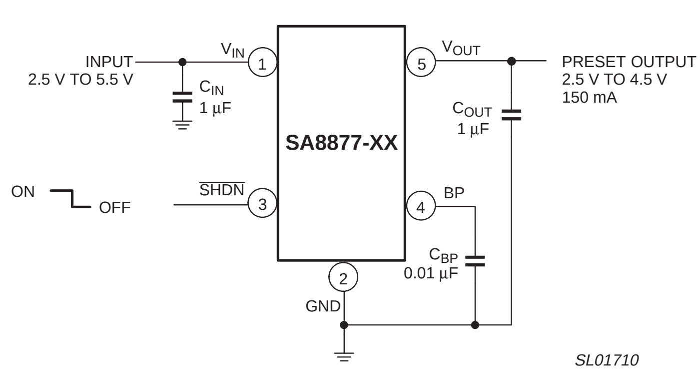


Figure 1. Simplified system diagram.

ORDERING INFORMATION

TYPE NUMBER	PACKAGE			TEMPERATURE RANGE
	NAME	DESCRIPTION	VERSION	
SA8877-**XX**D	SO5 (SOT23-5)	plastic small outline package; 5 leads; body width 1.6 mm	SOT680-1	–40 to +85 °C

NOTE:
The device has eight (8) voltage options, indicated by the **XX** on the Type Number.

XX	VOLTAGE (Typical)
SA8877-25	2.5 V
SA8877-26	2.6 V
SA8877-28	2.8 V
SA8877-30	3.0 V
SA8877-33	3.3 V
SA8877-36	3.6 V
SA8877-42	4.2 V
SA8877-45	4.5 V

PIN CONFIGURATION

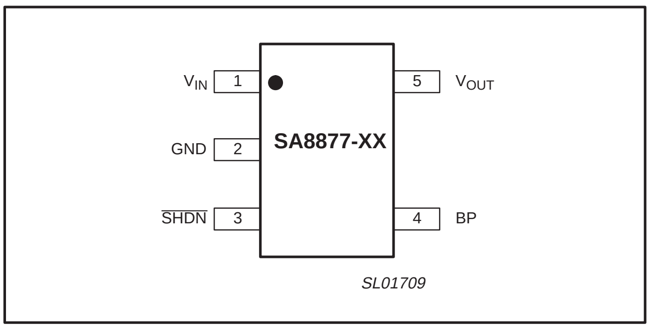


Figure 2. Pin configuration.

PIN DESCRIPTION

PIN	SYMBOL	DESCRIPTION
1	V_{IN}	Regulator Input. Supply voltage ranges from 2.5 V to 5.5 V. Bypass with a 1 μF capacitor to GND.
2	GND	Ground. The lead may also serve as heat spreader by soldering it to a large PCB pad or circuit board ground plane to maximize power dissipation.
3	$\overline{SHDN}$	Active-LOW Shutdown input. A logic LOW reduces the supply current to 10 μA. Connect to IN for normal operation.
4	BP	Noise bypass pin. Low noise of typically 30 μV_{rms} with optional 0.01 μF bypass capacitor. Larger bypass capacitor further reduces noise.
5	V_{OUT}	Regulator output. Sources up to 150 mA. Minimum output capacitor is 1 μF.

MAXIMUM RATINGS

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
V_{IN}	Input voltage		–5.5	+5.5	V_{DC}
V_{SHDN}	$\overline{SHDN}$ to GND voltage		–5.5	+5.5	V_{DC}
$V_{SHDN}–V_{IN}$	$\overline{SHDN}$ to IN voltage		–5.5	+0.3	V_{DC}
V_{OUT}, V_{BP}	OUT and BP to GND voltage		–0.3	V_{IN} + 0.3	V_{DC}
T_{stg}	Storage temperature range		–65	+150	°C
T_j	Junction temperature range		–55	+140	°C
T_{amb}	Ambient temperature range		–40	+85	°C
P_D	Power dissipation	T_{amb} = 25 °C	–	637	mW
		Power dissipation derating factor above 25 °C = 5.1 mW/°C			

NOTES:
1. Maximum Ratings are those values beyond which damage to the device may occur. Exposure to these conditions or conditions beyond those indicated may adversely affect device reliability. Functional operation under absolute maximum-rated condition is not implied. Functional operation should be restricted to the Recommended Operating Condition.

ELECTRICAL CHARACTERISTICS

$V_{IN} = V_{OUT(nom)}$ + 0.5 V; –40 °C ≤ T_{amb} ≤ +85 °C unless otherwise noted. Typical values are at T_{amb} = +25 °C. (See Note 1.)

SYMBOL	PARAMETER	CONDITIONS		MIN.	TYP.	MAX.	UNIT
V_{IN}	Input voltage			2.5	–	5.5	V
	Output voltage accuracy	I_{OUT} = 0.1 mA; T_{amb} = +25 °C; V_{OUT} ≥ 2.5 V		–1.4	–	1.4	%
		I_{OUT} = 0.1 mA to 120 mA; –40 °C ≤ T_{amb} ≤ +85 °C; V_{OUT} ≥ 2.5 V		–3.0	–	2.0	%
		I_{OUT} = 0.1 mA; T_{amb} = +25 °C; V_{OUT} < 2.5 V		–3.0	–	3.0	%
		I_{OUT} = 0.1 mA to 120 mA; –40 °C ≤ T_{amb} ≤ +85 °C; V_{OUT} < 2.5 V		–3.5	–	3.5	%
$I_{OUT(max)}$	Maximum output current			150	–	–	mA
I_{LIM}	Current limit			160	390	–	mA
I_Q	Ground pin current	no load		–	85	180	µA
		I_{OUT} = 150 mA		–	100	–	µA
I_{RBC}	Reverse batter current			–	0.5	–	µA
ΔV_{lnr}	Line regulation	2.5 V or (V_{OUT} + 0.1 V) ≤ V_{IN} ≤ 5.5 V; I_{OUT} = 1 mA		–0.125	0	0.125	%/V
ΔV_{ldr}	Load regulation	0.1 mA ≤ I_{OUT}; C_{OUT} = 1.0 µF		–	0.01	0.02	%/mA
	Dropout voltage (note 2)	I_{OUT} = 1 mA		–	1.0	–	mV
		I_{OUT} = 50 mA		–	55	90	mV
		I_{OUT} = 150 mA		–	165	–	mV
$V_{n(o)}$	Output voltage noise	f = 10 Hz to 100 kHz; C_{BP} = 0.01 µF	C_{OUT} = 10 µF	–	28	–	μV_{rms}
			C_{OUT} = 100 µF	–	20	–	μV_{rms}
		f = 10 Hz to 100 kHz; C_{BP} = 0.1 µF	C_{OUT} = 10 µF	–	13	–	μV_{rms}
			C_{OUT} = 100 µF	–	12	–	μV_{rms}
Shutdown							
V_{IH}	HIGH-level $\overline{SHDN}$ input threshold	2.5 ≤ V_{IN} ≤ 5.5 V		$0.7V_{IN}$	–	–	V
V_{IL}	LOW–level $\overline{SHDN}$ input threshold	2.5 ≤ V_{IN} ≤ 5.5 V		–	–	$0.3V_{IN}$	V
$I_{\overline{SHDN}}$	$\overline{SHDN}$ input bias current	$V_{\overline{SHDN}} = V_{IN}$	T_{amb} = +25 °C	–	0.01	100	nA
			T_{amb} = +85 °C	–	0.5	–	nA
$I_{Q(SHDN)}$	Shutdown supply current	V_{OUT} = 0 V	T_{amb} = +25 °C	–	0.01	1	µA
			T_{amb} = +85 °C	–	0.2	–	µA
	Shutdown exit delay (note 3)	C_{BP} = 0.01 µF; C_{OUT} = 1.0 µF; no load	T_{amb} = +25 °C	–	30	150	µs
			–40 °C ≤ T_{amb} ≤ +85 °C	–	–	300	µs
Thermal protection							
T_{SHDN}	Thermal shutdown junction temperature			–	140	–	°C
DT_{SHDN}	Thermal shutdown hysteresis			–	15	–	°C

NOTES:

1. Limits are 100% production tested at T_{amb} = +25 °C. Limits over the operating temperature range are guaranteed through correlation using Statistical Quality Control (SQC) methods.
2. The dropout voltage is defined as $V_{IN} – V_{OUT}$, when V_{OUT} is 100 mV below the value of V_{OUT} for $V_{IN} = V_{OUT}$ + 0.5 V. (Only applicable for V_{OUT} = +2.5 V to +4.5 V.)
3. Time needed for V_{OUT} to reach 95% of final value.

TYPICAL PERFORMANCE CURVES

SA8877-33 with conditions: $V_{IN} = V_{OUT(nom)} + 0.5$ V; T_{amb} = –40 °C to +85 °C unless otherwise noted. Typical values are at T_{amb} = +25 °C.

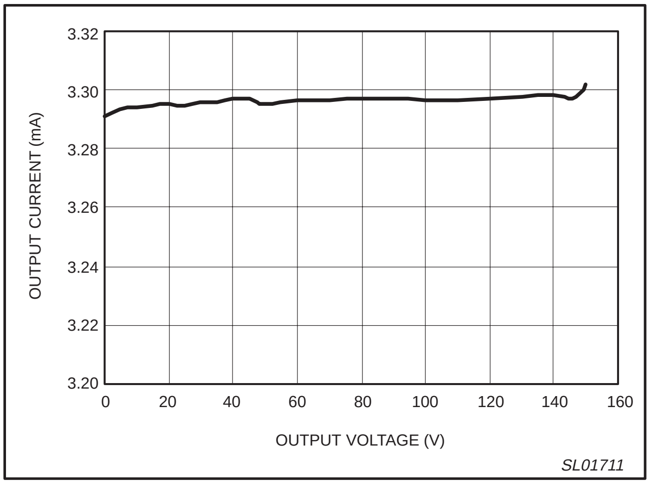


Figure 3. Output voltage versus output current.

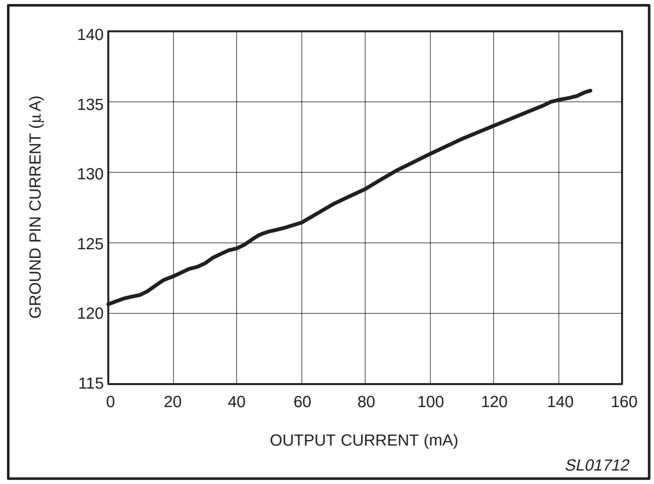


Figure 4. GND pin current versus output current.

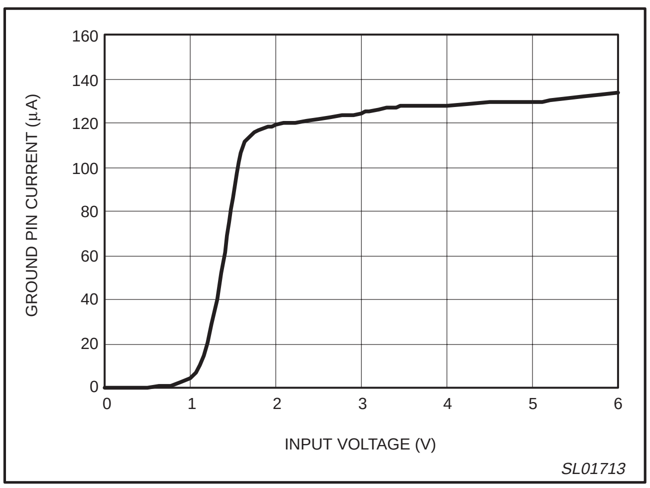


Figure 5. GND pin current (no load) versus input voltage.

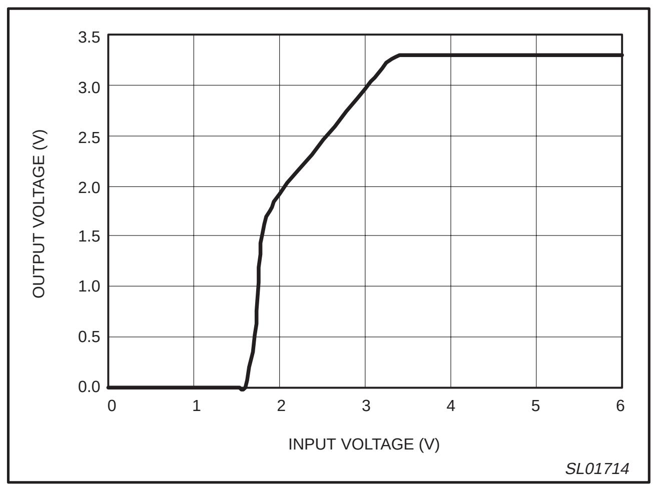


Figure 6. Output voltage (I_{OUT} = 50 mA) versus input voltage.

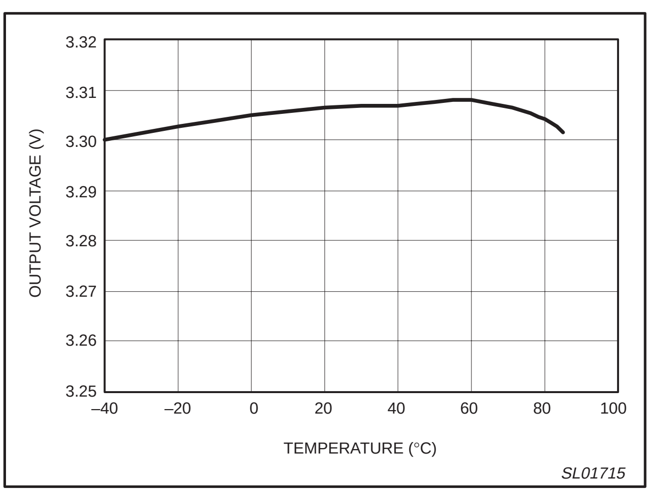


Figure 7. Output voltage (50 mA load) versus temperature.

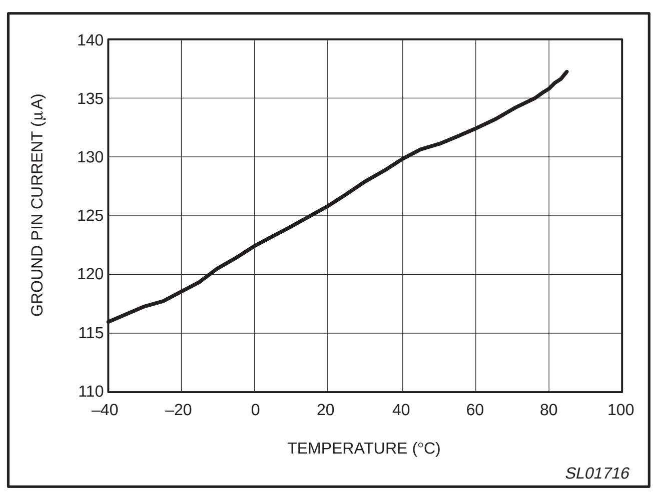


Figure 8. GND pin current (50 mA load) versus temperature.

TYPICAL PERFORMANCE CURVES (continued)

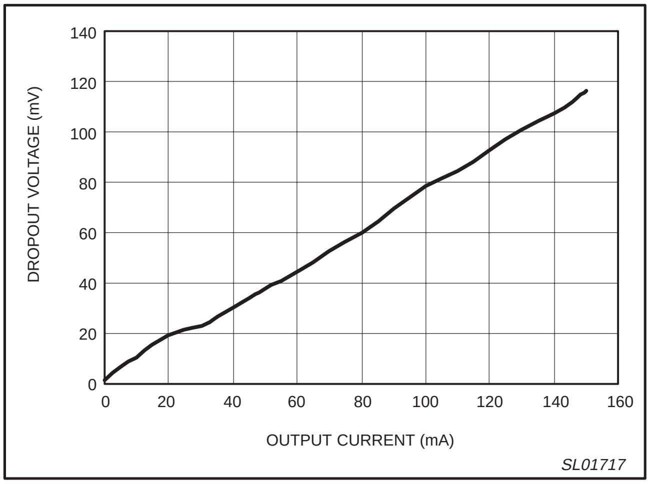


Figure 9. Dropout voltage versus output current.

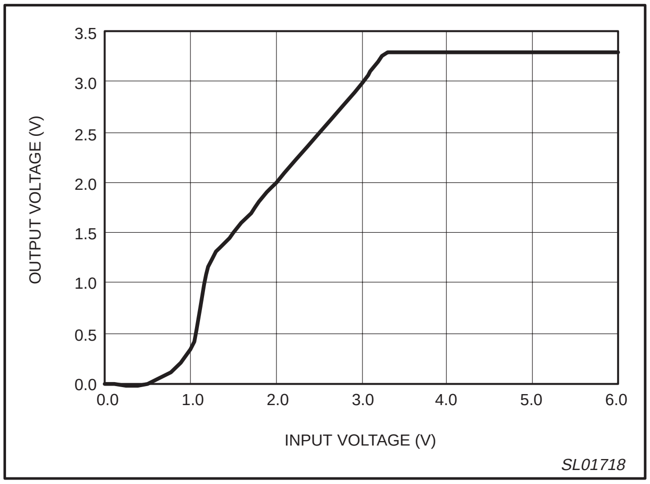


Figure 10. Output voltage (no load) versus input voltage.

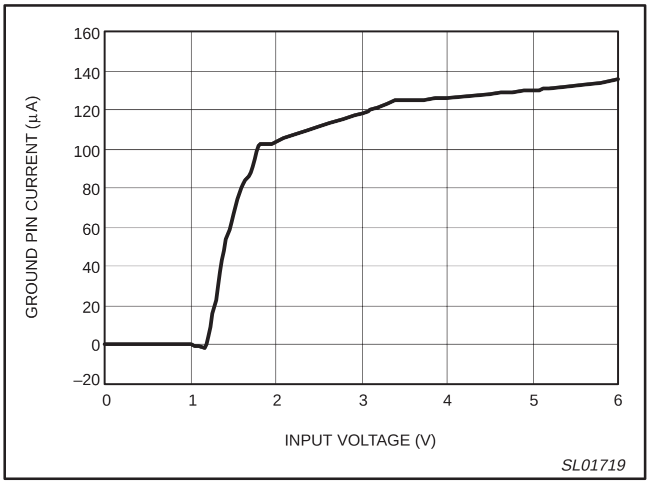


Figure 11. GND pin current (50 mA) versus input voltage.

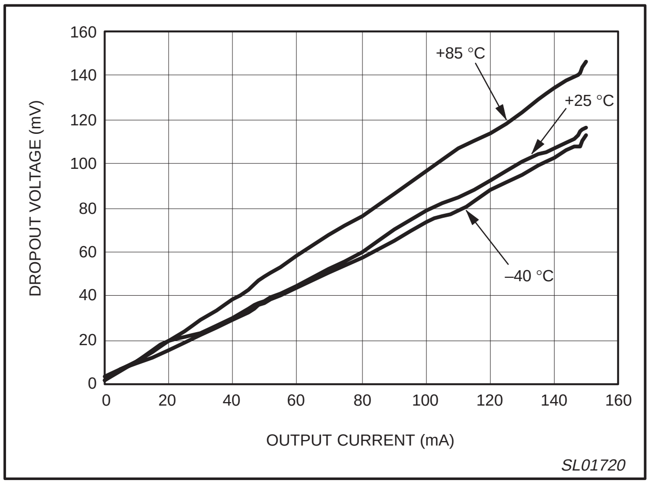


Figure 12. Dropout voltage versus output current.

TYPICAL PERFORMANCE CURVES (continued)

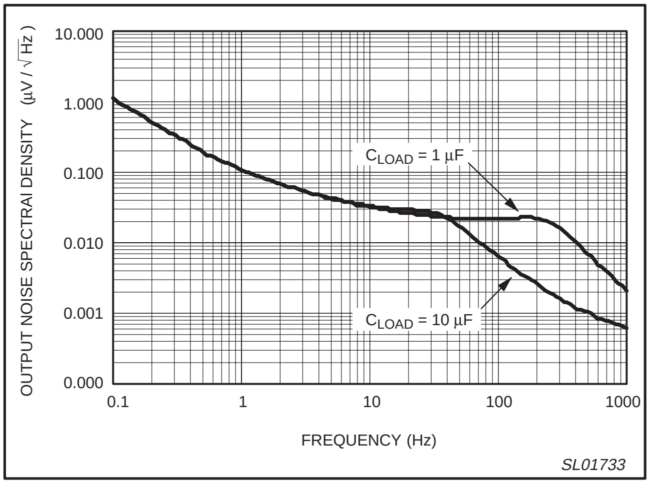


Figure 13. Output noise spectral density versus frequency.

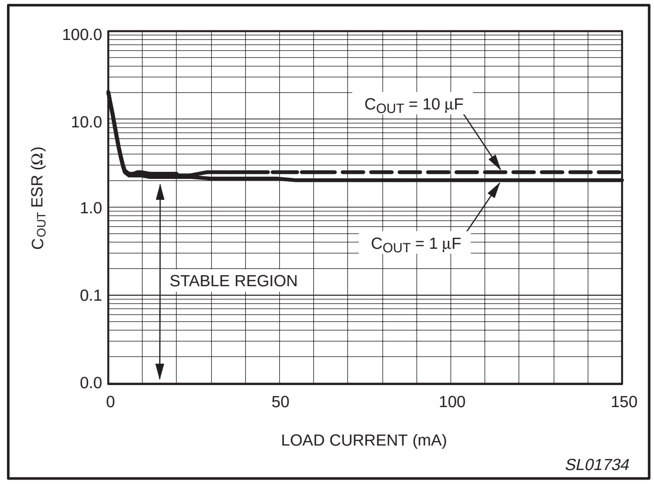


Figure 14. Region of stable C_{OUT} ESR versus load current.

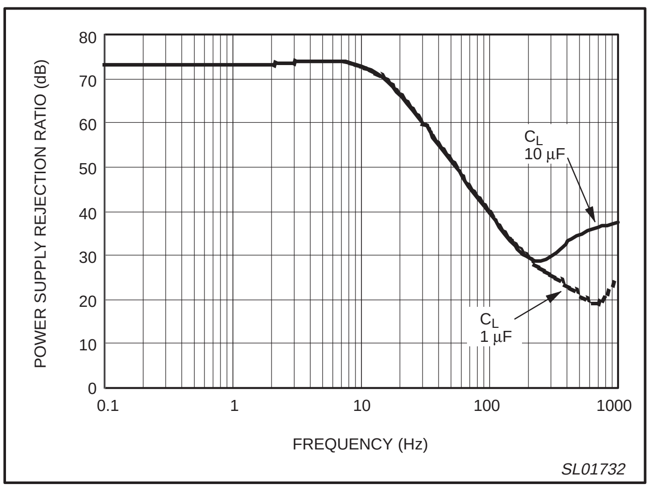


Figure 15. Power supply rejection ratio versus frequency.

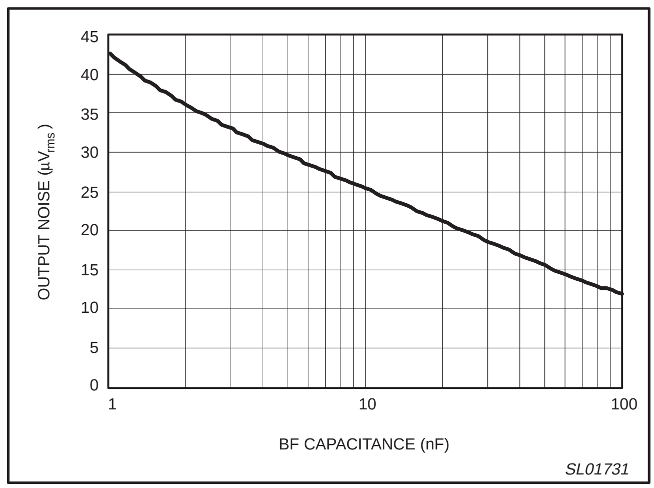


Figure 16. Output noise versus BP capacitance

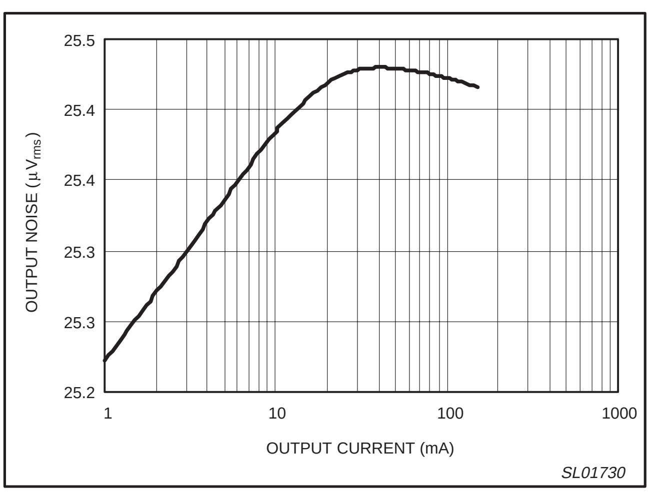


Figure 17. Output noise versus output current.

TYPICAL PERFORMANCE CURVES (continued)

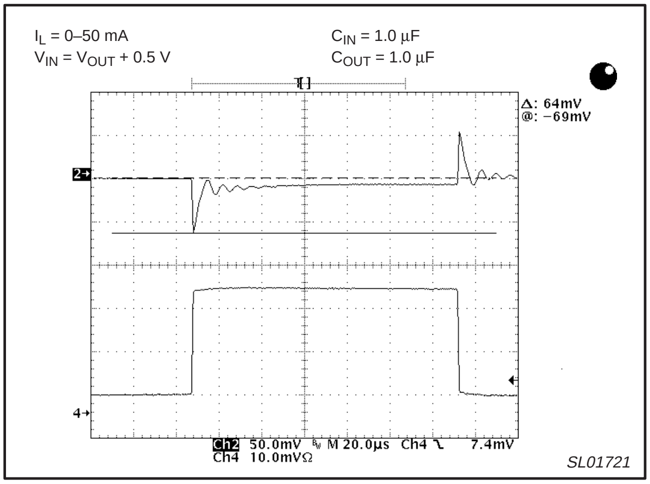


Figure 18. Load transient response (with power supply source).

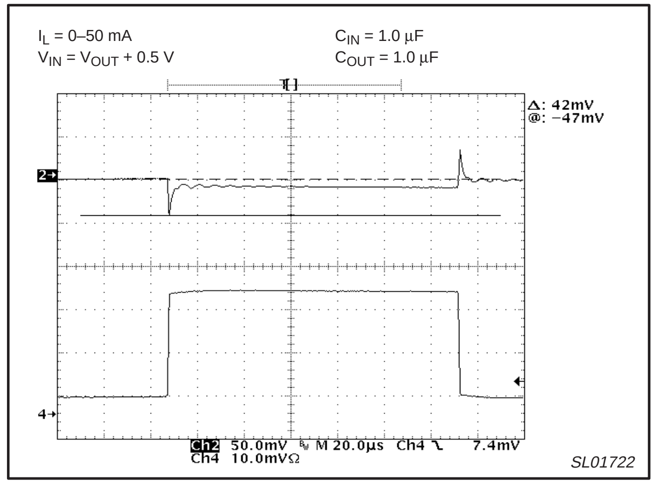


Figure 19. Load transient response (with AA battery source).

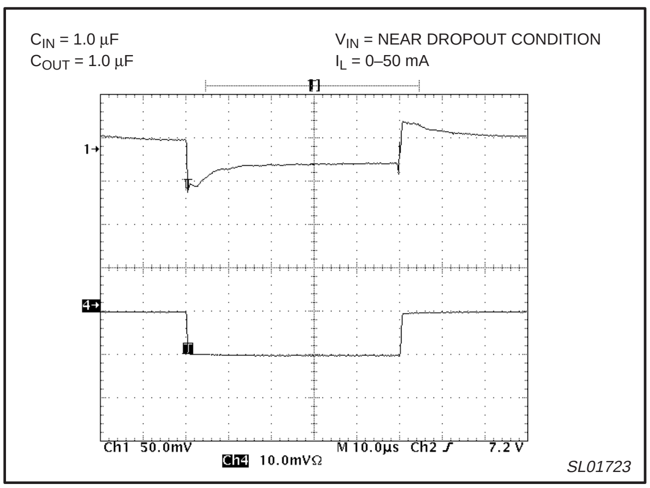


Figure 20. Load transient response.

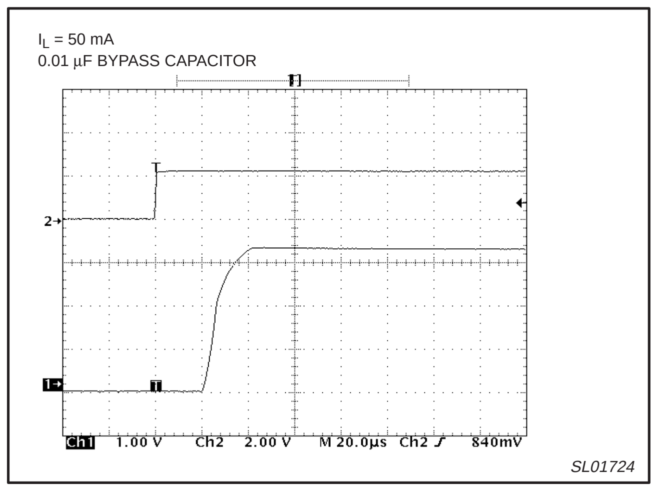


Figure 21. Shutdown exit delay.

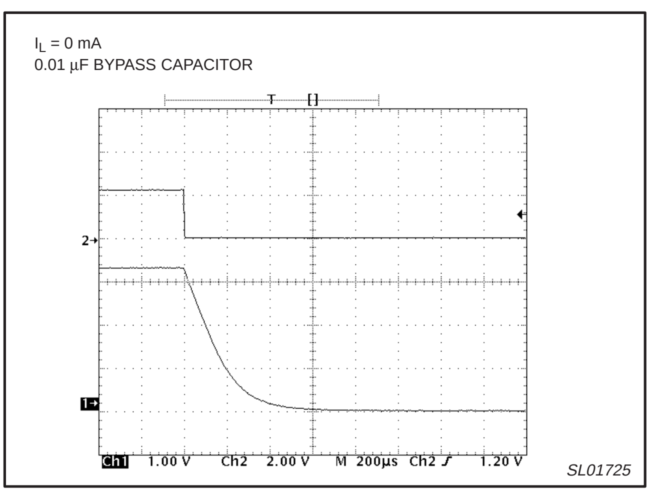


Figure 22. Entering shutdown (no load).

TECHNICAL DISCUSSION

The SA8877-XX family are very low-noise, low-dropout, low quiescent-current linear regulators designed for battery-powered applications, although they can also be used for devices powered by AC-DC converters.

The voltage regulation components of the SA8877-XX consist of a 1.23 V reference, an error amplifier, a P-channel pass transistor, and an internal feed-back voltage divider. The device also contains a reverse battery protection circuit, a thermal sensor, a current limiter, and shutdown logic.

Voltage regulation

The 1.23 V bandgap reference is connected to the error amplifier's inverting input. The error amplifier compares this reference with the feedback voltage and amplifies the difference. If the feedback voltage is lower than the reference voltage, the pass-transistor gate is pulled lower, which allows more current to pass to the output and increases the output voltage. If the feedback voltage is too high, the pass-transistor gate is pulled up, allowing less current to pass to the output. The output voltage is fed back through an internal resistor voltage divider connected to the V_{OUT} pin.

The SA8877 uses a 1.1 Ω typical P-channel MOSFET pass transistor. The P-channel MOSFET requires no base drive, therefore the device has lower quiescent current than a comparable PNP transistor-based design. The SA8877-XX uses 100 μA of quiescent current under any load conditions.

An optional external bypass capacitor connected between the BP pin and ground reduces noise at the output.

Power dissipation

The SA8877's maximum power dissipation depends on the thermal resistance of the case and circuit board, the temperature difference between the die junction and ambient air, and the rate of air flow. The power dissipation across the device is $P = I_{OUT} (V_{IN} – V_{OUT})$. The maximum power dissipation is:

$$P_{MAX} = (T_j – T_{amb}) / (\Theta_{JB} + \Theta_{BA})$$

where $T_j – T_{amb}$ is the temperature difference between the SA8877 die junction and the surrounding air, Θ_{JB} (or Θ_{JC}) is the thermal resistance of the package, and Θ_{BA} is the thermal resistance through the printed circuit board, copper traces, and other materials to the surrounding air.

The GND pin provides an electrical connection to ground and a path for heat transfer away from the junction. Connect the GND pin to ground using a large pad or ground plane to maximize heat transfer.

Noise reduction

An optional external 0.01 μF bypass capacitor at BP, in conjunction with an internal 200 Ω resistor, creates an 80 Hz low-pass filter for noise reduction. The SA8877 produces 30 μV_{RMS} of output voltage noise with C_{BP} = 0.01 μF and C_{OUT} = 10 μF. This is negligible in most applications.

Start-up time is minimized by a power-on circuit that pre-charges the bypass capacitor. The 'Typical Performance Curves' section shows graphs of 'Output noise versus BP capacitance' (Figure 16), 'Output noise versus output current' (Figure 17), and 'Output noise spectral density versus frequency' (Figure 13).

Device protection

The SA8877 has several built-in protection circuits.

Current limiter: The current limiter controls the the pass transistor's gate voltage so the output current cannot exceed 390 mA. We recommend using 160 mA minimum to 500 mA maximum in the design parameters. Because of the current limiter, the output can be shorted to ground for an indefinite amount of time with no damage to the part.

Reverse battery protection: The reverse battery protection circuit prevents damage to the device if the supply battery is accidentally installed backwards. This circuit compares V_{IN} and V_{SHDN} to ground and disconnects the device's internal circuits if it detects reversed polarity. Reverse supply current is limited to 1 mA when this protective circuit is active, preventing the battery from rapidly discharging through the device.

Thermal overload protection: When the junction temperature exceeds +140 °C, the thermal sensor signals the shutdown logic to turn off the pass transistor. After the junction temperature has cooled by 15 °C the sensor signals the shutdown logic to turn the pass transistor on again. This will create a pulsed output during lengthy thermal overloads.

NOTE: Thermal overload protection is to protect the device during fault conditions. Do not exceed the maximum junction-temperature rating of T_j = +150 °C during continuous operation.

APPLICATION INFORMATION

Capacitor selection and regulator stability

Normally, use a 1 µF capacitor on the SA8877 input and a 1 µF to 10 µF capacitor on the output. To improve the supply-noise rejection and line-transient response, use input capacitor values and lower ESRs. To reduce noise and improve load-transient response, stability, and power-supply rejection, use use large output capacitors.

For stable operation over the full temperature range and with load currents up to 150 mA, a 1 µF (min.) ceramic capacitor is recommended.

Note that some ceramic dielectrics exhibit large capacitance and ESR variation with temperature. With dielectrics such as Z5U and Y5V, it may be necessary to increase the capacitance by a factor of 2 or more to ensure stability at temperatures below –10 °C. With X7R or X5R dielectrics, 1 µF should be sufficient at all operating temperatures for V_{OUT} = 2.5 V.

A graph of the Region of Stable C_{OUT} ESR versus Load Current is shown in Figure 14. Use a 0.01 µF bypass capacitor at BP for low output voltage noise. Increasing the capacitance will slightly decrease the output noise, but increase the start-up time. Values above 0.1 µF provide no performance advantage and are not recommended (see Figures 21 and 22 in the ‘Typical Performance Curves’).

Load-transient considerations

The SA8877 load-transient response graphs (Figures 18, 19, and 20) show two components of the output response: a DC shift from the output impedance due to the load current change, and the transient response. Typical transient for a step change in the load current from 0 mA to 50 mA is 40 mV. Increasing the output capacitor’s value and decreasing the ESR attenuates the overshoot.

PSRR and operation from sources other than batteries

The SA8877 is designed to deliver low dropout voltages and low quiescent currents in battery-powered systems. When operating from sources other than batteries, improved supply-noise rejection and transient response can be achieved by increasing the values of the input and output bypass capacitors, and through passive filtering techniques.

Power-supply rejection is 63 dB at low frequencies and rolls off above 10 kHz. See Figure 15, ‘Power supply rejection ratio versus frequency’. Figures 18, 19, and 20 show the SA8877’s line- and load-transient responses.

Input-output (dropout) voltage

For output voltage greater than the minimum input voltage (2.5 V), the regulator’s minimum input-output voltage differential (or dropout voltage) determines the lowest usable supply voltage. In battery-powered systems, this will determine the useful end-of-life battery voltage. Because the SA8877 uses a P-channel MOSFET pass transistor, the dropout voltage is a function of drain-to-source on-resistance ($R_{DS(ON)}$) multiplied by the load current (see ‘Typical Performance Curves’).

PACKING METHOD

The SA8877-XX is packed in reels, as shown in Figure 23.

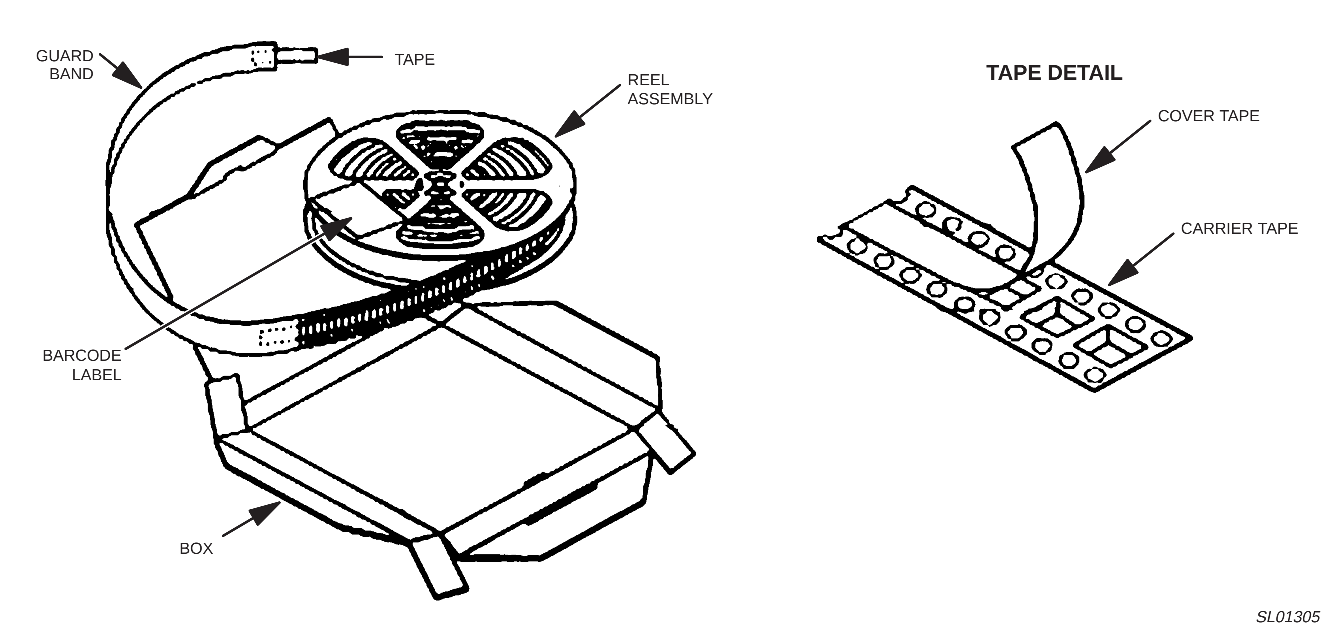
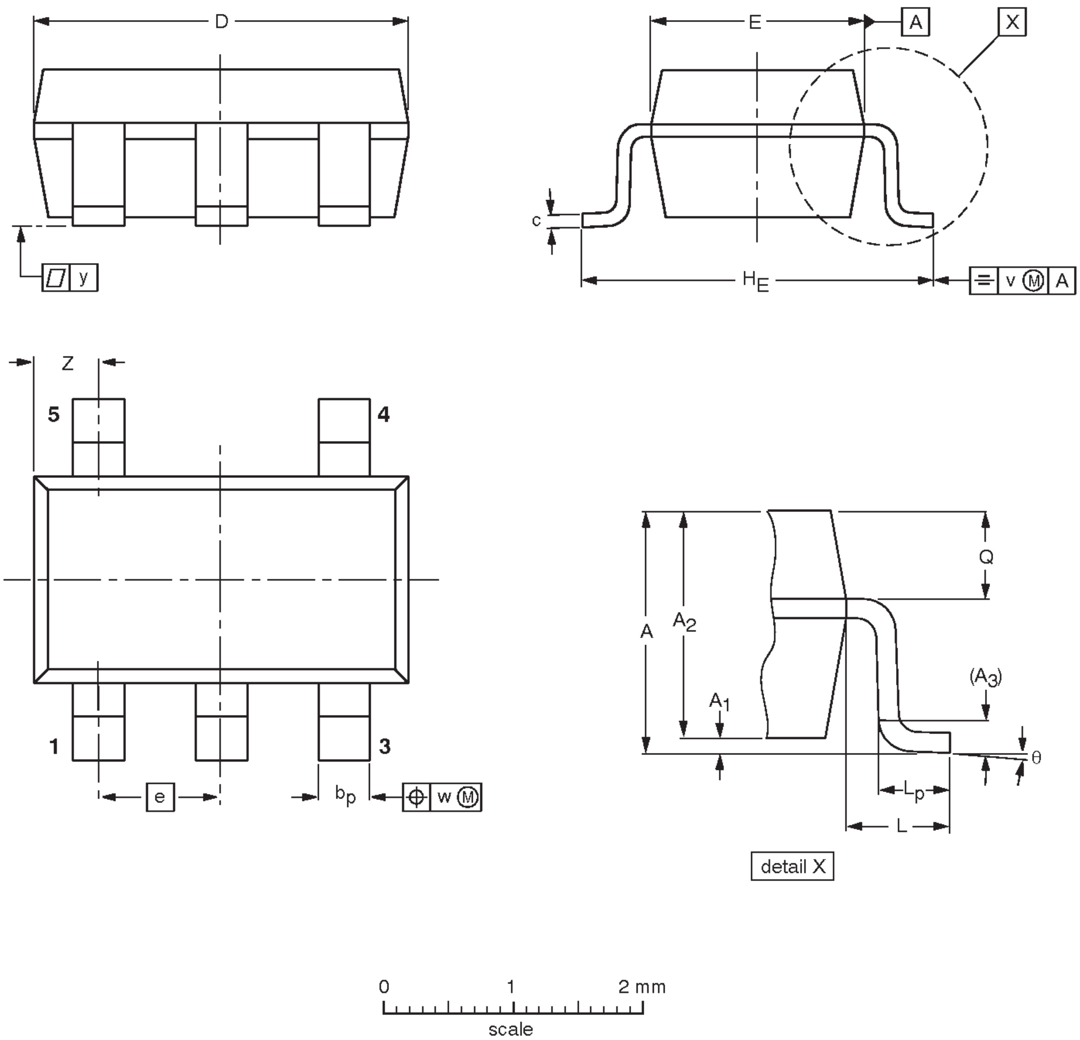


Figure 23. Tape and reel packing method.

SO5: plastic small outline package; 5 leads; body width 1.6 mm — SOT680-1



DIMENSIONS (mm are the original dimensions)

UNIT	A max.	A_1	A_2	A_3	b_p	c	$D^{(1)}$	$E^{(1)}$	e	H_E	L	L_p	Q	v	w	y	$Z^{(1)}$	θ
mm	1.45	0.15 0.05	1.3 0.9	0.2	0.5 0.3	0.22 0.08	3.05 2.75	1.75 1.45	0.95	3.0 2.6	0.6	0.6 0.3	0.45 0.35	0.2	0.2	0.1	0.75 0.25	8° 0°

Note

1. Plastic or metal protrusions of 0.25 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	JEITA			
SOT680-1		MO-178				~~01-03-22~~ 01-11-15

Very low noise, low dropout, 150 mA linear regulator

SA8877-XX

Data sheet status

Data sheet status [1]	Product status [2]	Definitions
Objective data	Development	This data sheet contains data from the objective specification for product development. Philips Semiconductors reserves the right to change the specification in any manner without notice.
Preliminary data	Qualification	This data sheet contains data from the preliminary specification. Supplementary data will be published at a later date. Philips Semiconductors reserves the right to change the specification without notice, in order to improve the design and supply the best possible product.
Product data	Production	This data sheet contains data from the product specification. Philips Semiconductors reserves the right to make changes at any time in order to improve the design, manufacturing and supply. Changes will be communicated according to the Customer Product/Process Change Notification (CPCN) procedure SNW-SQ-650A.

[1] Please consult the most recently issued data sheet before initiating or completing a design.

[2] The product status of the device(s) described in this data sheet may have changed since this data sheet was published. The latest information is available on the Internet at URL http://www.semiconductors.philips.com.

Definitions

Short-form specification — The data in a short-form specification is extracted from a full data sheet with the same type number and title. For detailed information see the relevant data sheet or data handbook.

Limiting values definition — Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 60134). Stress above one or more of the limiting values may cause permanent damage to the device. These are stress ratings only and operation of the device at these or at any other conditions above those given in the Characteristics sections of the specification is not implied. Exposure to limiting values for extended periods may affect device reliability.

Application information — Applications that are described herein for any of these products are for illustrative purposes only. Philips Semiconductors make no representation or warranty that such applications will be suitable for the specified use without further testing or modification.

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Date of release: 09-02

Document order number: 9397 750 10183

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