DATA SHEET

MAX8877/MAX8878-XX
Very low noise, very low dropout, 150 mA linear regulator, CMOS process technology

Product data
Supersedes data of 2003 May 14
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Philips
Semiconductors

PHILIPS

Very low noise, very low dropout, 150 mA linear regulator, CMOS process technology

MAX8877/MAX8878-XX

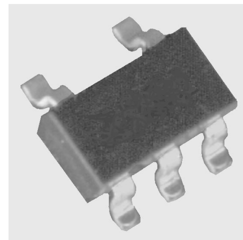
GENERAL DESCRIPTION

The MAX8877/MAX8878-XX family are very low-noise, very 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 41 mV at 50 mA. Reverse battery current is extremely low, 0.5 μA typ.

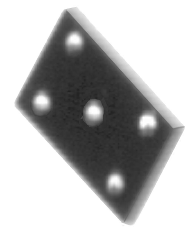
For demanding applications, output noise voltage of typically 30 μV_{rms} is achieved with a 0.01 μF capacitor on the bypass pin. The input voltage can vary from 2.5 V_{DC} to 6.5 V_{DC}, providing up to 150 mA output current.

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. The MAX8878 also includes an auto-discharge function which actively discharges the output voltage to ground when the device is placed in shutdown.

To accommodate high density layouts, it is packaged in the 5-pin SOT23-5 and wafer-level chip-scale package (WL-CSP).



SO5 (SOT23-5)



WL-CSP5
(bottom view)

FEATURES

- Low output noise: 30 μV_{rms}
- Low dropout voltages: 165 mV at 150 mA; 41 mV at 50 mA
- Thermal overload and short circuit protection
- Reverse battery protection
- Output current limit
- 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, 2.7 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

APPLICATIONS

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

SIMPLIFIED SYSTEM DIAGRAM

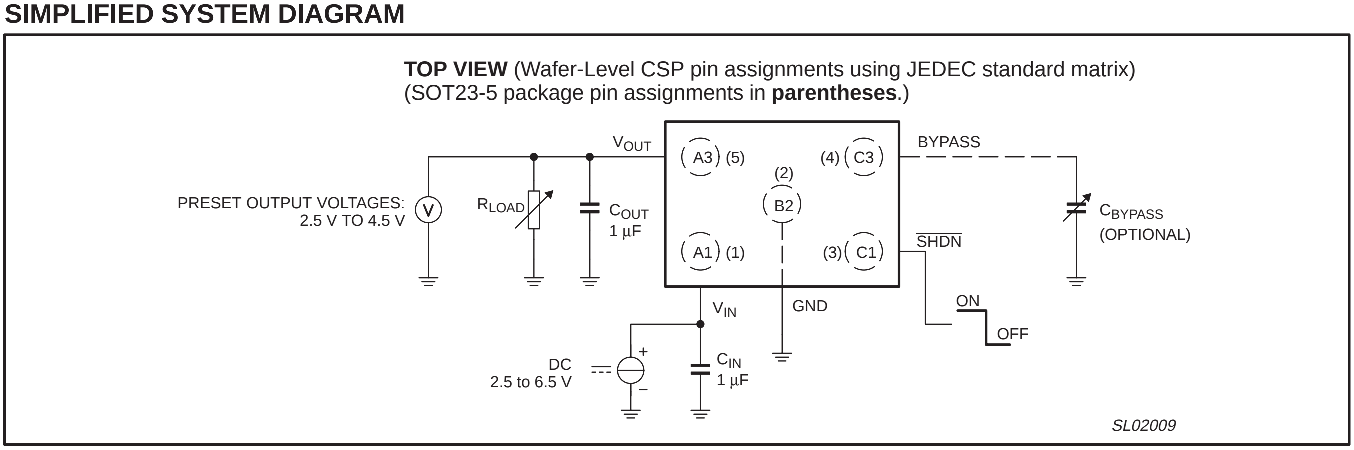


Figure 1. Simplified system diagram.

ORDERING INFORMATION

TYPE NUMBER	PACKAGE		TEMPERATURE RANGE
	NAME	DESCRIPTION	
MAX8877-**XX**D MAX8878-**XX**D	SO5 (SOT23-5)	plastic small outline package; 5 leads; body width 1.6 mm	–40 °C to +85 °C
MAX8877-**XX**UK MAX8878-**XX**UK	WL-CSP5	wafer-level, chip-scale package; 5 bumps	–40 °C to +85 °C

NOTE:
The device has nine (9) voltage options, indicated by the **XX** on the Type Number.

DEVICE	PACKAGE	PRESET OUTPUT VOLTAGE	DEVICE	PACKAGE	PRESET OUTPUT VOLTAGE
MAX8877-25	SO5 (SOT23-5), WL-CSP5	2.5 V	MAX8878-25	SO5 (SOT23-5), WL-CSP5	2.5 V
MAX8877-26	SO5 (SOT23-5), WL-CSP5	2.6 V	MAX8878-26	SO5 (SOT23-5), WL-CSP5	2.6 V
MAX8877-27	SO5 (SOT23-5), WL-CSP5	2.7 V	MAX8878-27	SO5 (SOT23-5), WL-CSP5	2.7 V
MAX8877-28	SO5 (SOT23-5), WL-CSP5	2.8 V	MAX8878-28	SO5 (SOT23-5), WL-CSP5	2.8 V
MAX8877-30	SO5 (SOT23-5), WL-CSP5	3.0 V	MAX8878-30	SO5 (SOT23-5), WL-CSP5	3.0 V
MAX8877-33	SO5 (SOT23-5), WL-CSP5	3.3 V	MAX8878-33	SO5 (SOT23-5), WL-CSP5	3.3 V
MAX8877-36	SO5 (SOT23-5), WL-CSP5	3.6 V	MAX8878-36	SO5 (SOT23-5), WL-CSP5	3.6 V
MAX8877-42	SO5 (SOT23-5), WL-CSP5	4.2 V	MAX8878-42	SO5 (SOT23-5), WL-CSP5	4.2 V
MAX8877-45	SO5 (SOT23-5), WL-CSP5	4.5 V	MAX8878-45	SO5 (SOT23-5), WL-CSP5	4.5 V

Marking code

Each device is marked with a four letter code. The first three letters designate the product. The fourth, represented by an ‘x’, designates the date tracking code.

Part	Marking	Part	Marking
MAX8877		**MAX8878**	
MAX8877-25D, UK	AMGx	MAX8878-25D, UK	APNx
MAX8877-26D	APBx	MAX8878-26D, UK	APPx
MAX8877-27D	ANKx	MAX8878-27D, UK	APJx
MAX8877-28D, UK	AMHx	MAX8878-28D, UK	APRx
MAX8877-30D, UK	AMJx	MAX8878-30D, UK	APSx
MAX8877-33D, UK	AMKx	MAX8878-33D, UK	APTx
MAX8877-36D, UK	AMLx	MAX8878-36D, UK	APUx
MAX8877-42D, UK	AMMx	MAX8878-42D, UK	APVx
MAX8877-45D, UK	AMNx	MAX8878-45D, UK	APWx

PIN CONFIGURATION

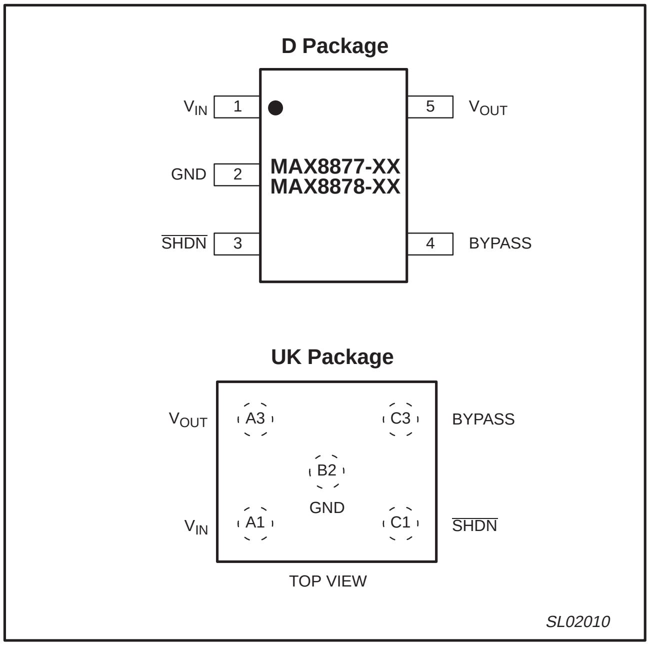


Figure 2. Pin configurations.

PIN DESCRIPTION

BALL	PIN	SYMBOL	DESCRIPTION
A1	1	V_{IN}	Regulator Input. Supply voltage ranges from 2.5 V to 6.5 V. Bypass with a 1 μF capacitor to GND.
B2	2	GND	Ground. The bump may also serve as heat spreader by soldering it to a large PCB pad or circuit board ground plane to maximize power dissipation.
C1	3	$\overline{SHDN}$	Active-LOW Shutdown input. This pin must be actively terminated. Tie to V_{IN} if this function is not used.
C3	4	BYPASS	Noise bypass pin. Low noise of typically 30 μV_{rms} with optional 0.01 μF bypass capacitor. Larger bypass capacitor further reduces noise.
A3	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		–6.5	+6.5	V_{DC}
$V_{\overline{SHDN}}$	$\overline{SHDN}$ to GND voltage		–6.5	+6.5	V_{DC}
$V_{\overline{SHDN}}–V_{IN}$	$\overline{SHDN}$ to V_{IN} voltage		–6.5	+0.3	V_{DC}
V_{OUT}, V_{BYPASS}	V_{OUT} and BYPASS 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 (derating factor above 25 °C = 5.1 mW/°C)	–	637	mW

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.

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	–	6.5	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 150 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} = 1 mA to 150 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	I_{OUT} = 0 mA	–	85	180	μA
		I_{OUT} = 150 mA	–	100	–	μA
I_{RBC}	Reverse battery current		–	0.5	–	μA
ΔV_{lnr}	Line regulation	2.5 V or (V_{OUT} + 0.1 V) ≤ V_{IN} ≤ 6.5 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	–	41	90	mV
		I_{OUT} = 150 mA	–	165	–	mV
$V_{n(o)}$	Output voltage noise	C_{OUT} = 10 μF	–	28	–	μV_{rms}
		C_{OUT} = 100 μF	–	20	–	μV_{rms}
		f = 10 Hz to 100 kHz; C_{BYPASS} = 0.1 μF; C_{OUT} = 10 μF	–	13	–	μV_{rms}
		f = 10 Hz to 100 kHz; C_{BYPASS} = 0.1 μF; C_{OUT} = 100 μF	–	12	–	μV_{rms}
Shutdown						
V_{IH}	HIGH-level $\overline{SHDN}$ input threshold	2.5 ≤ V_{IN} ≤ 6.5 V	2.0	–	–	V
V_{IL}	LOW–level $\overline{SHDN}$ input threshold	2.5 ≤ V_{IN} ≤ 6.5 V	–	–	0.4	V
$I_{\overline{SHDN}}$	$\overline{SHDN}$ input bias current	$V_{\overline{SHDN}} = V_{IN}$; T_{amb} = +25 °C	–	–	100	μA
$I_{Q(\overline{SHDN})}$	$\overline{SHDN}$ supply current	V_{OUT} = 0 V; T_{amb} = +25 °C	–	0.01	1	μA
$t_{\overline{SHDN}-Delay}$	Shutdown exit delay (note 3)	C_{BYPASS} = 0.01 μF; C_{OUT} = 1.0 μF; no load; T_{amb} = +25 °C	–	30	150	μs
		C_{BYPASS} = 0.01 μF; C_{OUT} = 1.0 μF; no load; –40 °C ≤ T_{amb} ≤ +85 °C	–	–	300	μs
RSD	Resistance Shutdown Discharge	MAX8878-XX only	–	300	–	Ω
Thermal protection						
$T_{\overline{SHDN}}$	Thermal shutdown junction temperature		–	140	–	°C
$\Delta T_{\overline{SHDN}}$	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

MAX8877/MAX8878 with conditions: $V_{IN} = V_{OUT(nom)}$ + 0.5 V; T_{amb} = –40 °C to +85 °C; C_{IN} = 1 µF, C_{OUT} = 1 µF unless otherwise noted. Typical values are at T_{amb} = +25 °C.

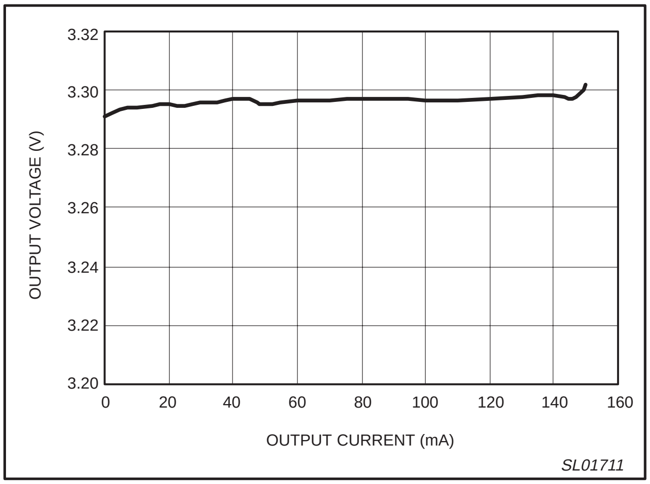


Figure 3. Output voltage versus output current.

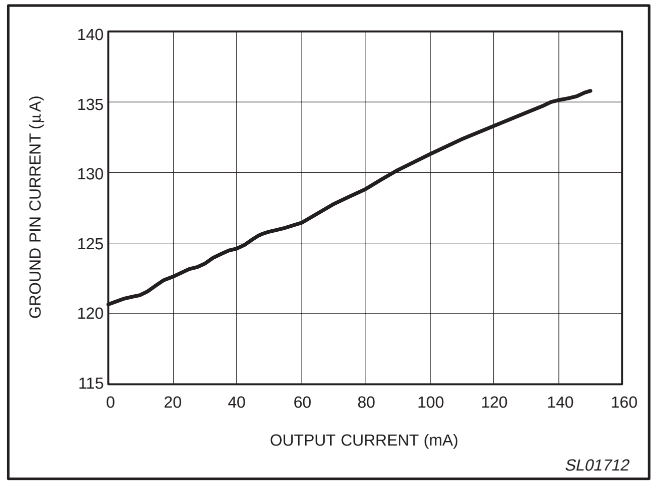


Figure 4. GND pin current versus output current.

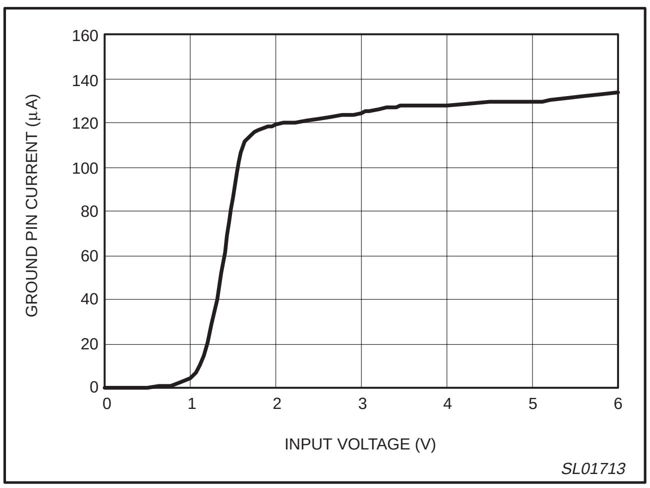


Figure 5. GND pin current (no load) versus input voltage.

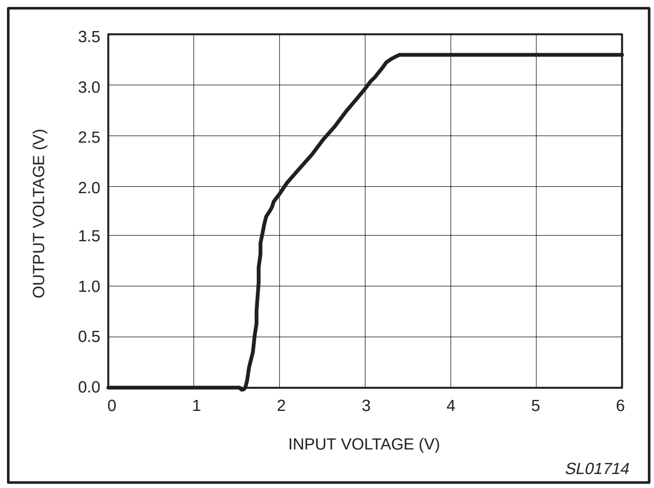


Figure 6. Output voltage (I_{OUT} = 50 mA) versus input voltage.

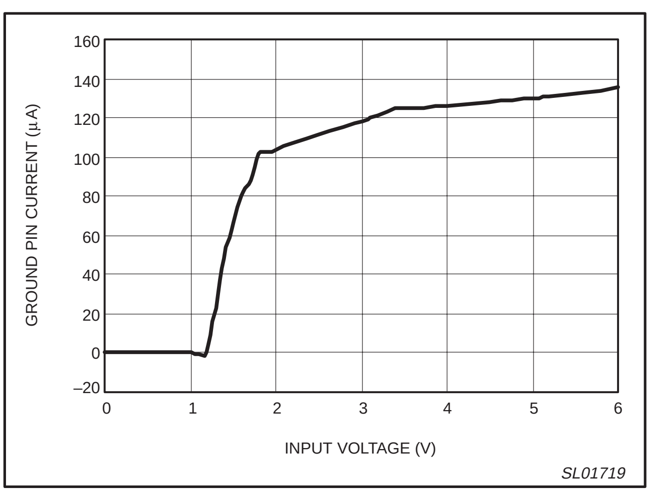


Figure 7. GND pin current (50 mA) versus input voltage.

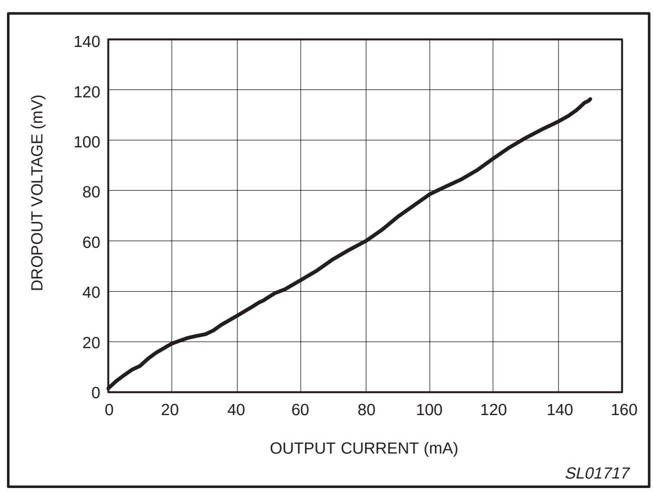


Figure 8. Dropout voltage versus output current.

TYPICAL PERFORMANCE CURVES (continued)

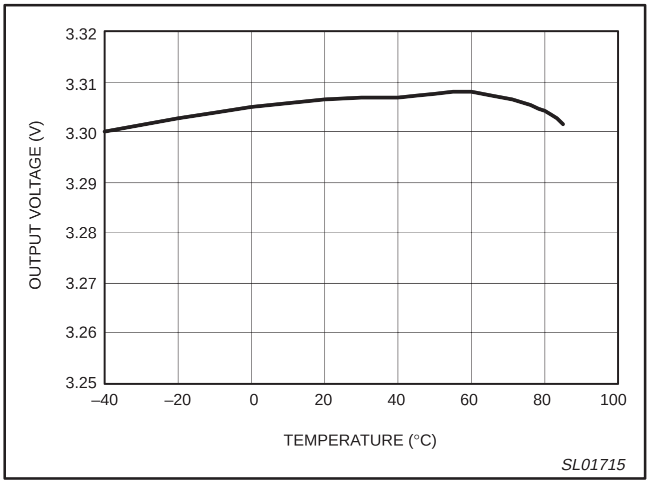


Figure 9. Output voltage (50 mA load) versus temperature.

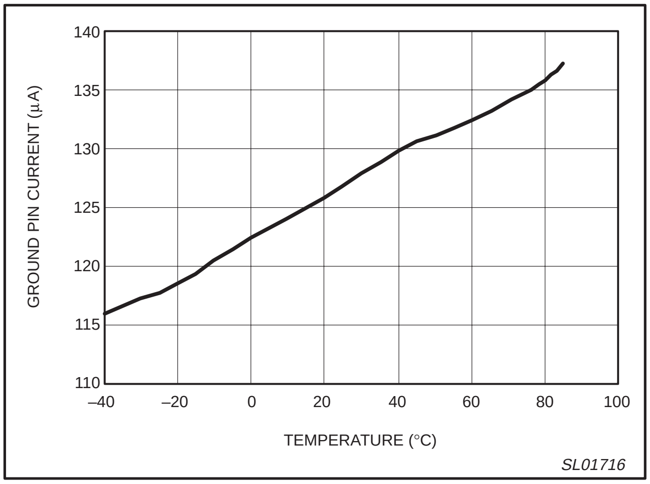


Figure 10. GND pin current (50 mA load) versus temperature.

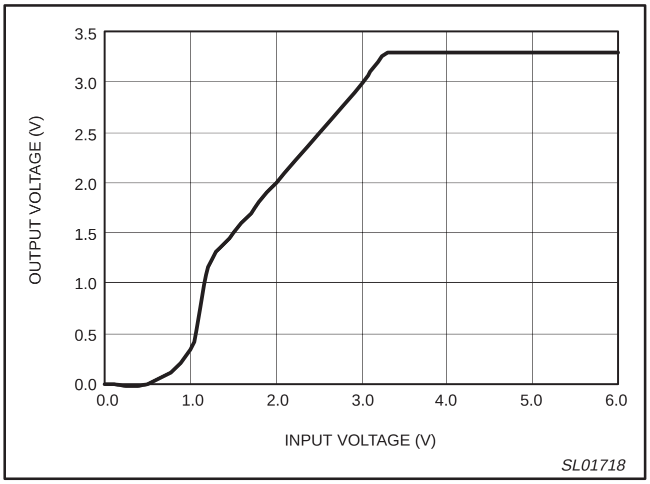


Figure 11. Output voltage (no load) versus input voltage.

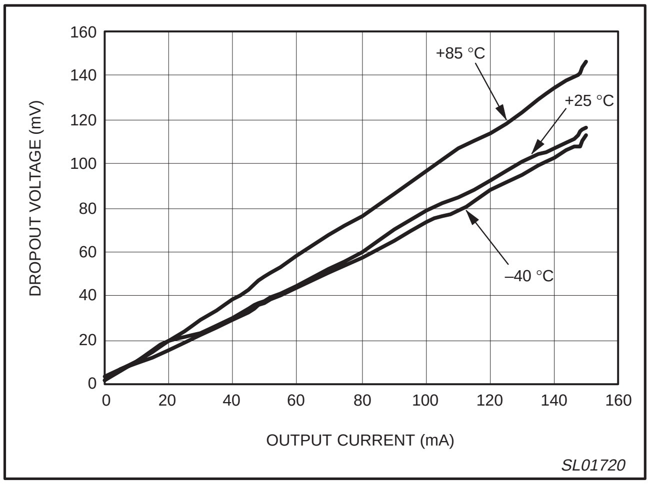


Figure 12. Dropout voltage versus output current.

TYPICAL PERFORMANCE CURVES (continued)

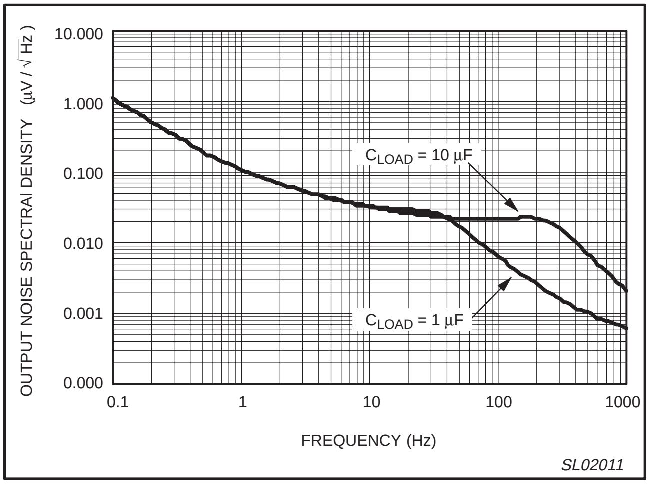


Figure 13. Output noise spectral density versus frequency.

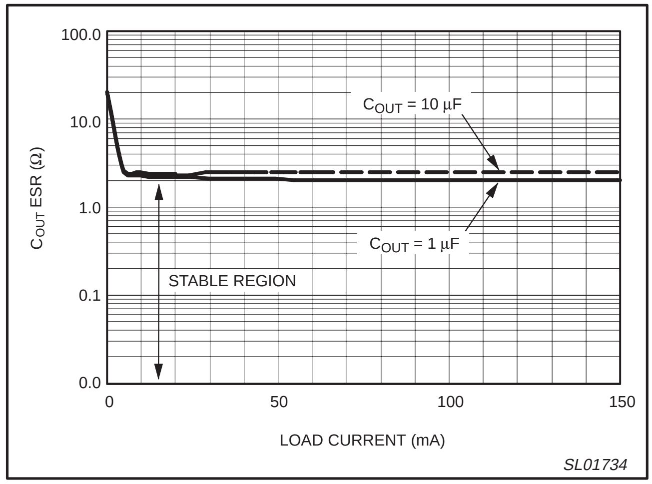


Figure 14. Region of stable C_{OUT} ESR versus load current.

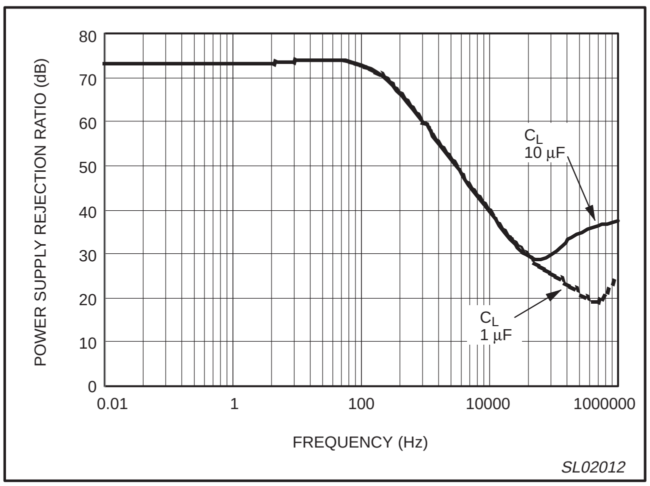


Figure 15. Power supply rejection ratio versus frequency.

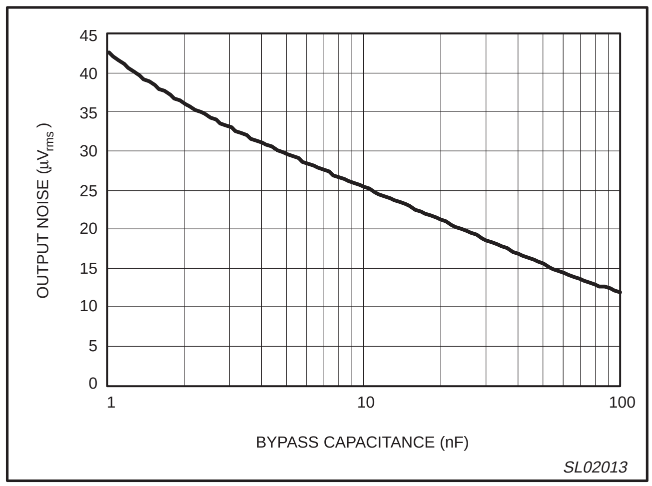


Figure 16. Output noise versus BYPASS capacitance

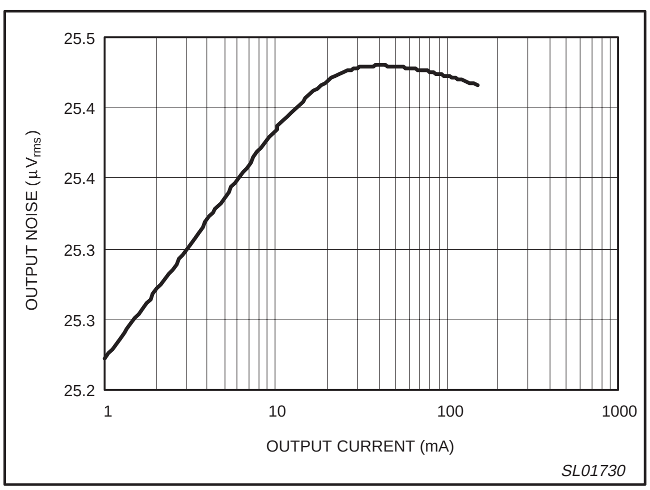


Figure 17. Output noise versus output current.

TYPICAL PERFORMANCE CURVES (continued)

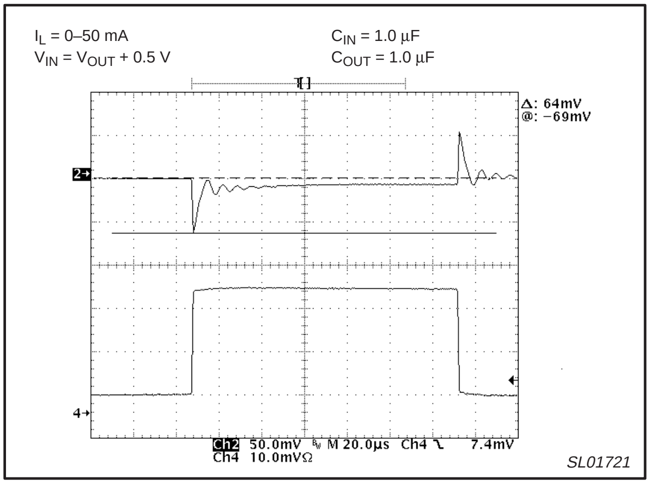


Figure 18. Load transient response (with power supply source).

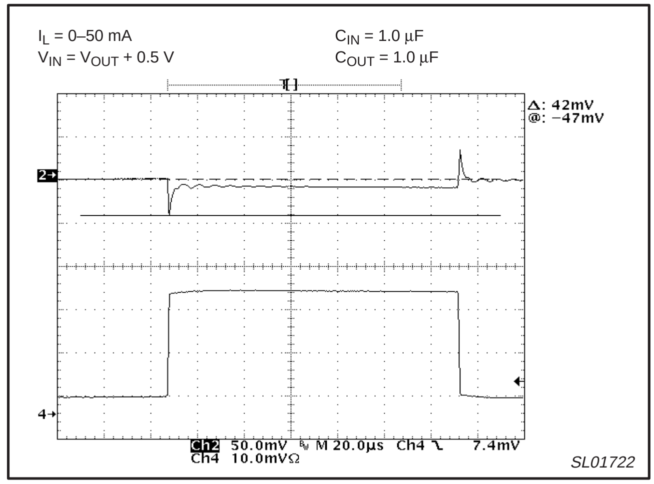


Figure 19. Load transient response (with AA battery source).

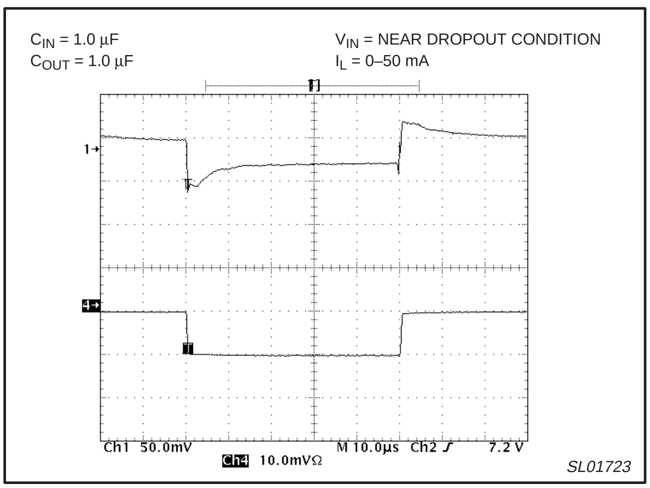


Figure 20. Load transient response.

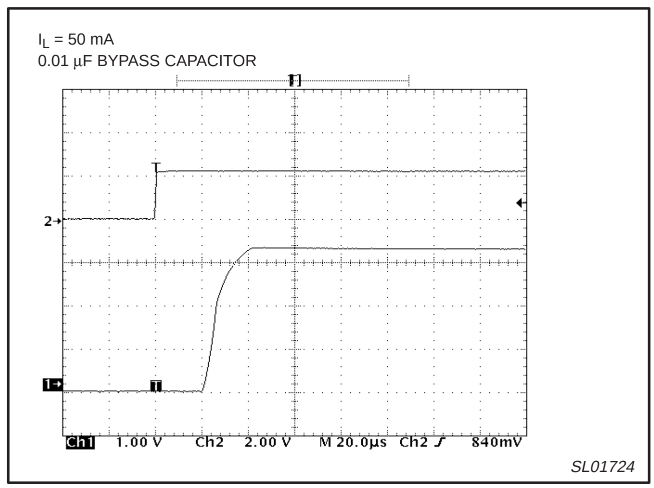


Figure 21. Shutdown exit delay.

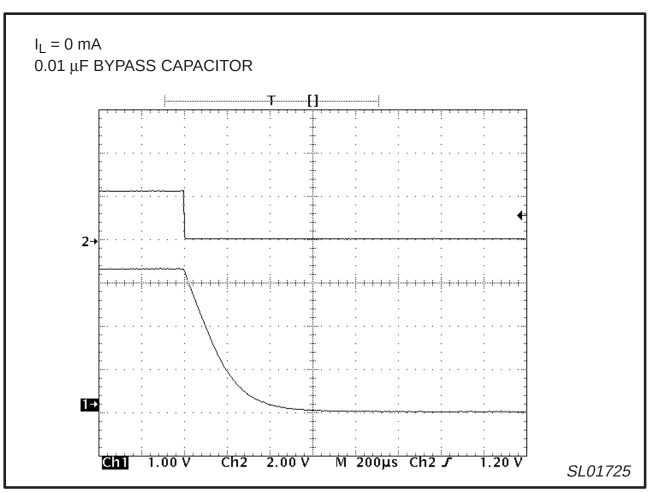


Figure 22. Entering shutdown (no load).

TECHNICAL DISCUSSION

The MAX8877/MAX8878-XX family are very low-noise, very 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 MAX8877/MAX8878-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 MAX8877/MAX8878-XX uses a 1.0 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 MAX8877/MAX8878-XX uses 100 µA of quiescent current under any load conditions.

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

Power dissipation

The MAX8877/MAX8878'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 MAX8877/MAX8878 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 BYPASS, in conjunction with an internal 200 Ω resistor, creates an 80 Hz low-pass filter for noise reduction. The MAX8877/MAX8878 produces 30 μV_{RMS} of output voltage noise with C_{BYPASS} = 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 BYPASS capacitance' (Figure 16), 'Output noise versus output current' (Figure 17), and 'Output noise spectral density versus frequency' (Figure 13).

Device protection

The MAX8877/MAX8878-XX 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 $V_{\overline{SHDN}}$ 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 MAX8877/MAX8878-XX 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 BYPASS pin 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 MAX8877/MAX8878 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 MAX8877/MAX8878 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 73 dB at low frequencies and rolls off above 10 kHz. See Figure 15, 'Power supply rejection ratio versus frequency'.

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 MAX8877/MAX8878 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

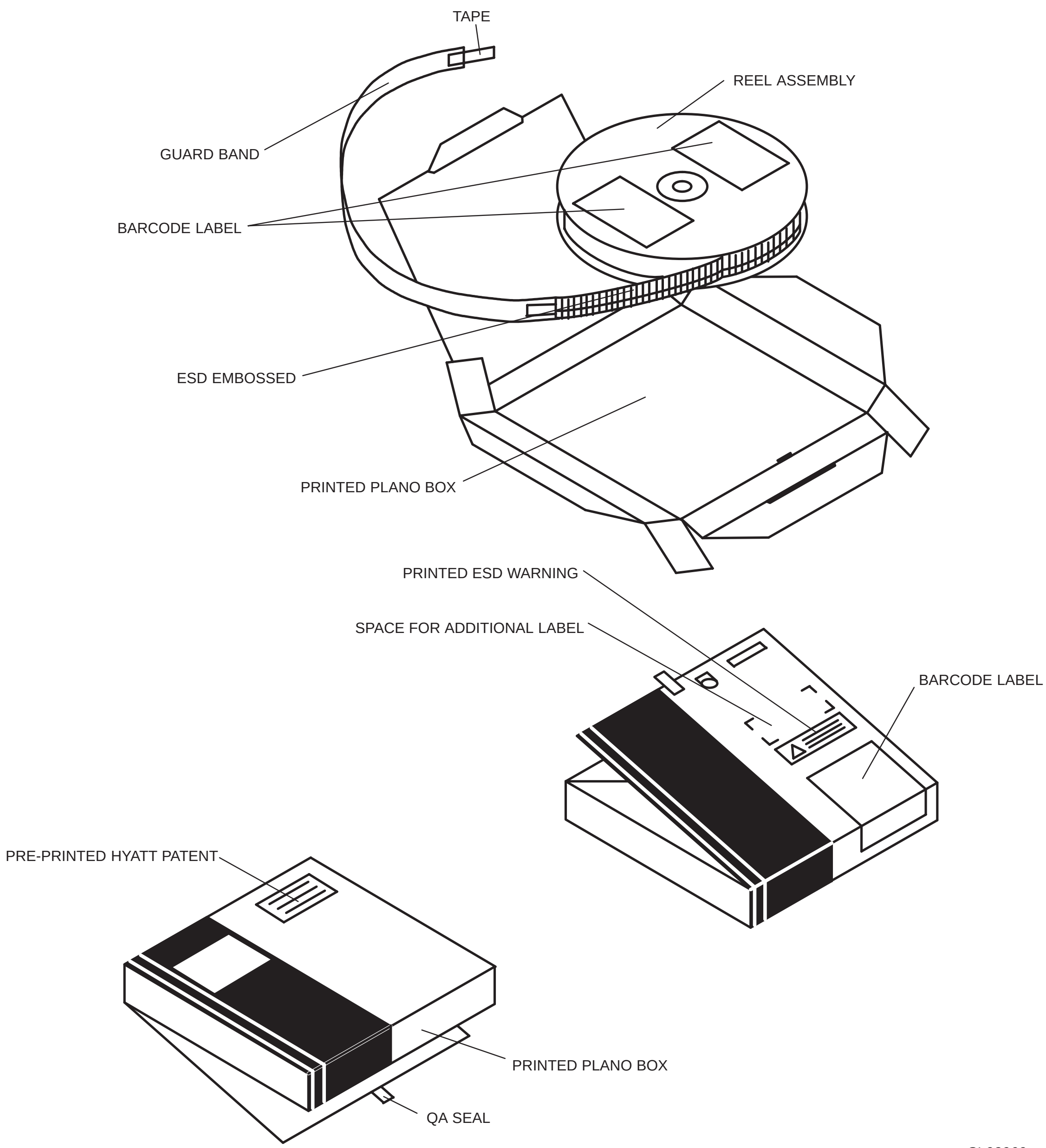
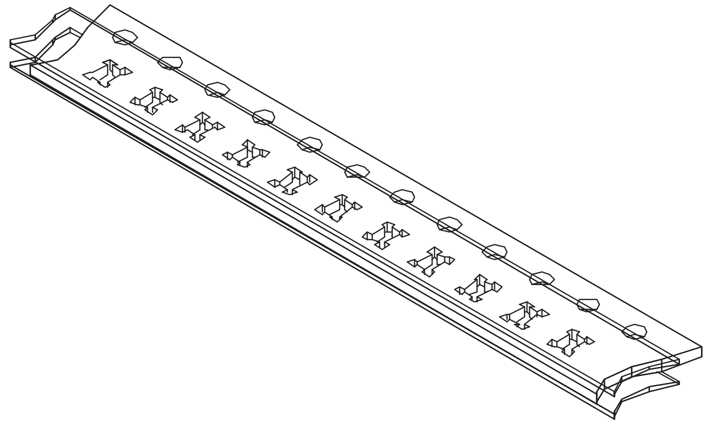
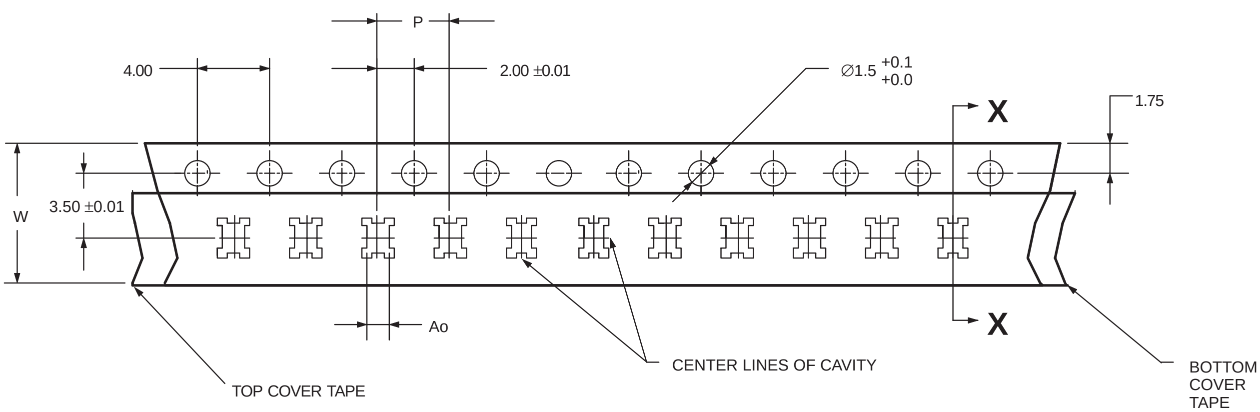


Figure 23. WL-CSP5 tape and reel packing method.

LOADED TAPE DIRECTION OF FEED



NOTES:
All dimensions in millimeters.
10 sprocket hole pitch cumulative tolerance ±0.20
Material: conductive polystyrene
Camber not to exceed 1.0 mm in 100 mm.
Cover tape shown for illustrative purposes only.



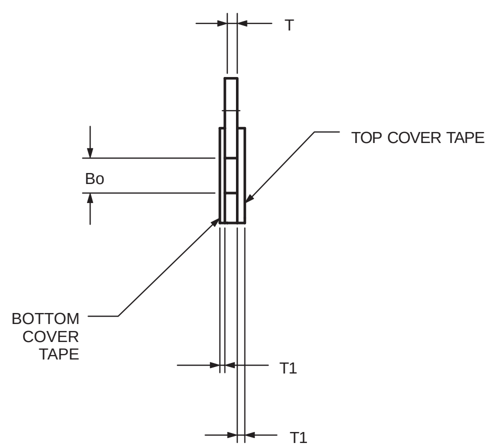
DIMENSIONS (mm are the original dimensions)

UNIT	Ao	Bo	T	T1	P	W
mm	1.09 0.99	1.598 1.498	0.76 0.74	0.10 (max.)	4.05 3.95	8.3 7.9

Heat seal cover tape for carrier tape width 8 mm

Type tape: clear static dissipative tape
Base material: transparent polyester
Cover tape width: 5.3 ± 0.1 mm
Cover tape length: 480 m/reel

Supplier: Advanced Integrated Materials (AIM)
Part Number: CT5–00530–0480

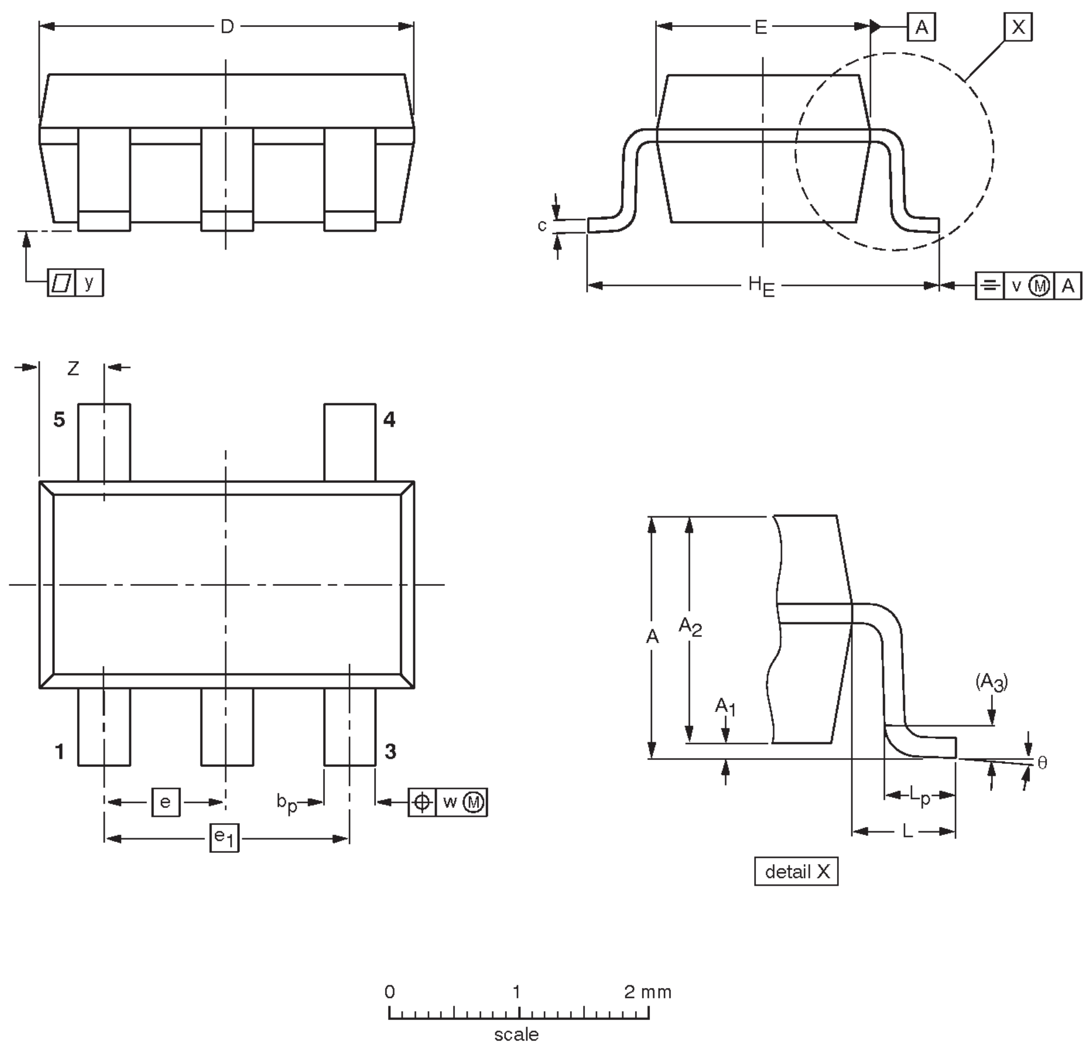


SECTION 'X – X'

SL02056

Figure 24. WL-CSP5 tape dimensions.

SOT23-5: plastic small outline package; 5 leads; body width 1.5 mm



DIMENSIONS (mm are the original dimensions)

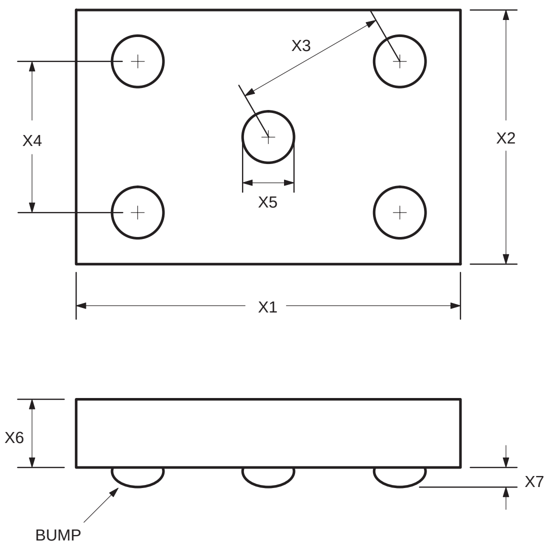
UNIT	A max.	A_1	A_2	A_3	b_p	c	$D^{(1)}$	$E^{(1)}$	e	e_1	H_E	L	L_p			y		θ
mm	1.35	0.15 0.05	1.2 1.0	0.25	0.55 0.41	0.22 0.08	3.00 2.70	1.70 1.50	0.95	1.90	3.00 2.60	0.60	0.55 0.35			0.1		8° 0°

Note

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

OUTLINE VERSION	REFERENCES			
	IEC	JEDEC	EIAJ	
		MO-178		

WL-CSP5: wafer level, chip-scale package; 5 bumps



DIMENSIONS (mm are the original dimensions)

UNIT	X1	X2	X3	X4	X5	X6	X7
mm	1.30 1.24	0.87 0.81	0.5	0.5	0.195 0.165	0.467 0.447	0.145 0.115

SL02055

REVISION HISTORY

Rev	Date	Description
_3	20030808	**Product data (9397 750 11891); ECN 853-2412 30183 dated 04 August 2003.** **Supersedes data of 2003 May 14 (9397 750 11487).** Modifications: ● Add ‘Marking code’ table to Ordering information on page 3. ● Electrical characteristics table on page 5: – Symbol $I_{\overline{SHDN}}$: condition Tamb = +25 5C: change Typ. value from ‘0.01 µA’ to ‘–’ remove condition ‘T_{amb} = +85 °C’ and its limits. – Symbol $I_{Q(\overline{SHDN})}$: remove condition ‘T_{amb} = +85 °C’ and its limits.
_2	20030514	**Product data (9397 750 11487); ECN 853-2412 29830 dated 17 April 2003.** **Supersedes data of 2003 Mar 28 (9397 750 10896).**
_1	20030328	**Product data (9397 750 10896); ECN 853-2412 29449 dated 31 January 2003.**

Very low noise, very low dropout, 150 mA linear regulator, CMOS process technology

MAX8877/MAX8878-XX

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Level	Data sheet status [1]	Product status [2] [3]	Definitions
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