MIC5309

Low V_{IN}/V_{OUT} 300 mA High PSRR ULDO™ with Ultra-Low IQ

Features

- Input Voltage Range: 1.7V to 5.5V
- Guaranteed 300 mA Over Temperature
- Ultra Low Dropout Voltage of 100 mV Typical 300 mA
- High PSRR, Up to 90 dB at 1 kHz
- Output Voltage Range: 0.8V to 2.0V
- Very Low Ground Current – 23 µA Under Full Load
- Bias Supply Voltage Range: 2.5V to 5.5V
- Stable with 1 µF Ceramic Output Capacitor
- 300 mA Maximum Output Current at 1.7V Input Voltage
- Very Fast Transient Response – Ideal for Digital Loads
- Thermal Shutdown and Current Limit Protection
- 6-Lead 1.6 mm × 1.6 mm × 0.6 mm UDFN Package
- Cost Effective 6-Lead TSOT-23 Package

Applications

- Mobile Phones
- PDAs
- GPS Receivers
- Portable Electronics

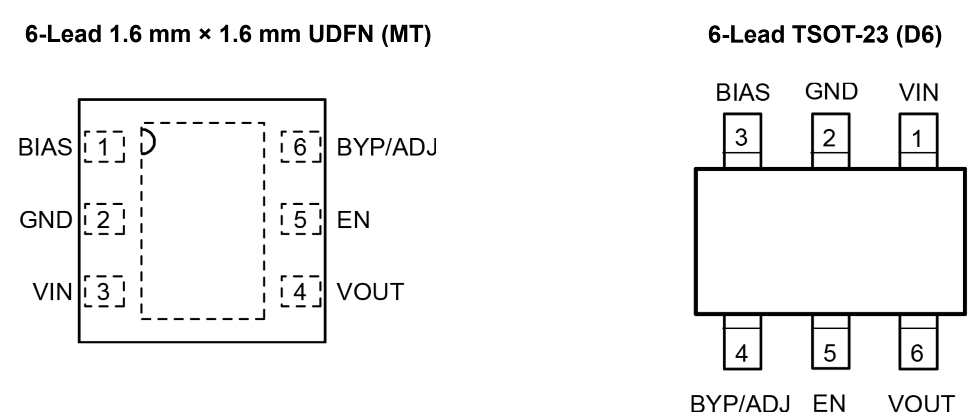
General Description

The MIC5309 is a high performance, µCap low dropout regulator, offering ultra-low operating current while maintaining very fast transient response. The MIC5309 can source up to 300 mA of output current and can regulate down from a low input supply voltage to increase system efficiency.

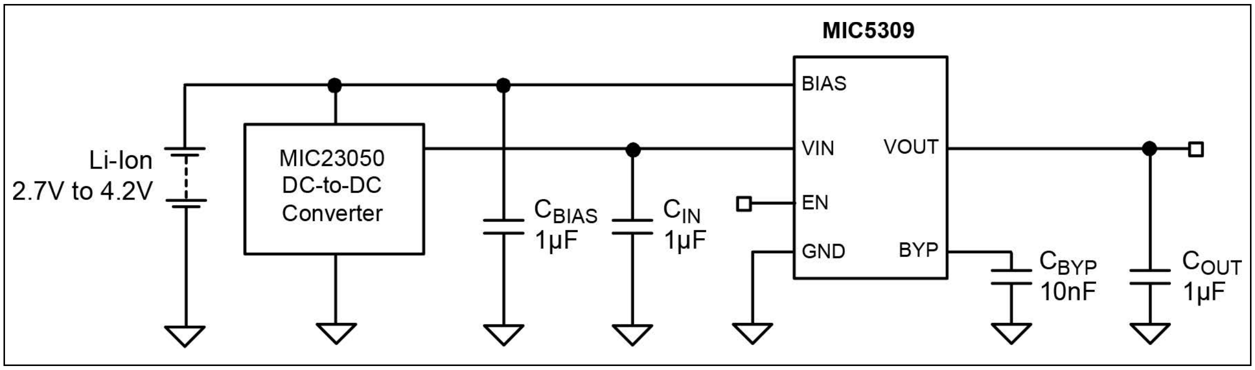
Ideal for battery operated applications; the MIC5309 offers extremely low dropout voltage 100 mV typically at 300 mA load, and low ground current at all load conditions (typically 23 µA). The MIC5309 can also be put into a zero-off mode current state, drawing virtually no current when disabled.

The MIC5309 is available in fixed output voltages in the tiny 6-lead 1.6 mm × 1.6 mm × 0.6 mm UDFN package as well as the 6-lead TSOT-23 for cost sensitive applications.

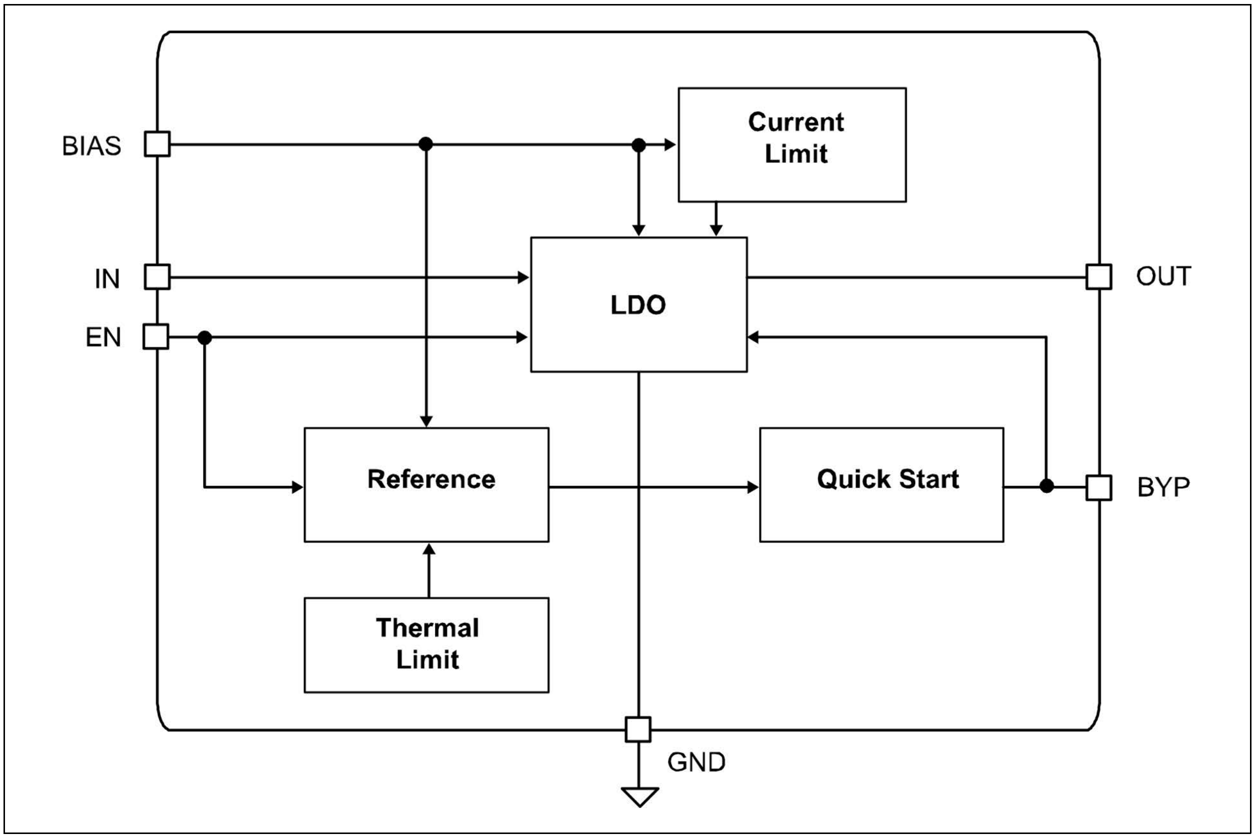
Package Types



Typical Application Circuits



Functional Block Diagram



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

Supply Voltage (V_{IN}) .... 0V to V_{BIAS}
Bias Supply Voltage (V_{BIAS}) .... 0V to +6V
Enable Voltage (V_{EN}) .... 0V to V_{BIAS}
Power Dissipation .... Internally Limited (Note 1)
ESD Rating (Note 2) .... 3 kV

Operating Ratings ‡

Supply Voltage (V_{IN}) .... +1.7V to V_{BIAS}
Bias Supply Voltage (V_{BIAS}) .... +2.5V to +5.5V
Enable Input Voltage (V_{EN}) .... 0V to V_{BIAS}

† Notice: Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational sections of this specification is not intended. Exposure to maximum rating conditions for extended periods may affect device reliability.

‡ Notice: The device is not guaranteed to function outside its operating ratings.

Note 1: The maximum allowable power dissipation of any T_A (ambient temperature) is $P_{D(max)} = T_{J(max)} – T_A) / \theta_{JA}$. Exceeding the maximum allowable power dissipation will result in excessive die temperature, and the regulator will go into thermal shutdown.

2: Devices are ESD sensitive. Handling precautions recommended. Human body model, 1.5 kΩ in series with 100 pF.

ELECTRICAL CHARACTERISTICS

V_{BIAS} = 3.6V; $V_{IN} = V_{OUT}$ + 1V; $V_{IN} \le V_{BIAS}$; C_{OUT} = 1.0 µF; I_{OUT} = 100 µA; T_J = 25°C, **bold** values indicate –40°C to +125°C, unless noted.

Parameter	Symbol	Min.	Typ.	Max.	Units	Condition
Output Voltage Accuracy	—	**–2.0**	—	**+2.0**	%	Variation from nominal V_{OUT}
Reference Voltage	V_{ADJ}	**0.7595**	0.775	**0.7905**	V	ADJ pin voltage
V_{BIAS} Line Regulation	ΔV_{OUT} / (V_{OUT} × ΔV_{BIAS})	—	0.01	**0.3**	%/V	V_{BIAS} = 3.6 to 5.5V, $V_{IN} = V_{OUT}$ + 1V
V_{IN} Line Regulation	ΔV_{OUT} / (V_{OUT} × ΔV_{IN})	—	0.02	**0.2**	%/V	$V_{IN} = V_{OUT}$ + 1V, V_{BIAS} = 5.5V
Load Regulation	ΔV_{OUT}/ V_{OUT}	—	0.4	**2**	%	I_{OUT} = 100 µA to 300 mA
Dropout Voltage	V_{DROP}	—	100	**200**	mV	I_{OUT} = 300 mA
Ground Pin Current (Note 1)	I_{GND}	—	23	**35**	µA	I_{OUT} = 100 µA to 300 mA, $V_{EN} = V_{BIAS}$
Ground Pin Current in Shutdown	I_{GND_SHDN}	—	0.01	2.0	µA	$V_{EN} \le$ 0.2V

Note 1: $I_{GND} = I_{IN} + I_{BIAS} – I_{OUT}$.

ELECTRICAL CHARACTERISTICS (CONTINUED)

V_{BIAS} = 3.6V; V_{IN} = V_{OUT} + 1V; $V_{IN} \le V_{BIAS}$; C_{OUT} = 1.0 µF; I_{OUT} = 100 µA; T_J = 25°C, **bold** values indicate –40°C to +125°C, unless noted.

Parameter	Symbol	Min.	Typ.	Max.	Units	Condition
V_{IN} Ripple Rejection	PSRR	—	70	—	dB	f = up to 1 kHz; C_{OUT} = 1.0 µF; no C_{BYP}
		50	90	—	dB	f = up to 1 kHz; C_{OUT} = 1.0 µF; C_{BYP} = 10 nF
		—	80	—	dB	f = 20 kHz; C_{OUT} = 1.0 µF; C_{BYP} = 10 nF
Current Limit	I_{LIM}	350	550	800	mA	V_{OUT} = 0V
Output Voltage Noise	e_N	—	28	—	μV_{RMS}	C_{OUT} = 1.0 µF, C_{BYP} = 10 nF, 10 Hz to 100 kHz
Enable Inputs (EN)						
Enable Input Voltage	V_{SHDN_LOW}	—	—	**0.2**	V	Logic Low
	V_{SHDN_HIGH}	**1.2**	—	—	V	Logic High
Enable Input Current	I_{SHDN}	—	0.17	**1**	µA	$V_{IL} \le 0.2V$
		—	1.5	**1**	µA	$V_{IH} \ge 1.2V$
Turn-on Time	t_{ON}	—	150	**500**	µs	C_{OUT} = 1.0 µF, C_{BYP} = 10 nF

Note 1: $I_{GND} = I_{IN} + I_{BIAS} – I_{OUT}$.

TEMPERATURE SPECIFICATIONS (Note 1)

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Temperature Ranges						
Junction Temperature Range	T_J	–40	—	+125	°C	—
Maximum Junction Temperature	$T_{J(MAX)}$	—	—	+125	°C	—
Lead Temperature	—	—	—	+260	°C	Soldering, 10 µseconds
Storage Temperature	T_S	–65	—	+150	°C	—
Package Thermal Resistance						
Thermal Resistance, 1.6 x 1.6 UDFN	θ_{JA}	—	90	—	°C/W	—
Thermal Resistance, TSOT-23-6	θ_{JA}	—	235	—	°C/W	—

Note 1: The maximum allowable power dissipation is a function of ambient temperature, the maximum allowable junction temperature and the thermal resistance from junction to air (i.e., T_A, T_J, θ_{JA}). The maximum allowable power dissipation at any ambient temperature is calculated using: $P_{D(max)} = (T_{J(max)} – A) \div \theta_{JA}$. Exceeding the maximum allowable power dissipation will cause the device operating junction temperature to exceed the maximum rating. Sustained junction temperatures above that maximum can impact device reliability.

2.0 TYPICAL PERFORMANCE CURVES

Note: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

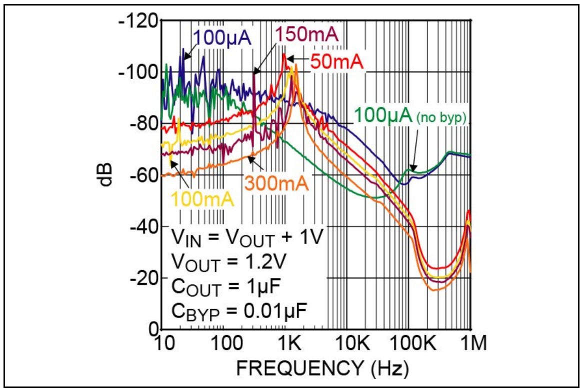


FIGURE 2-1: *Power Supply Rejection Ratio (V_{IN}).*

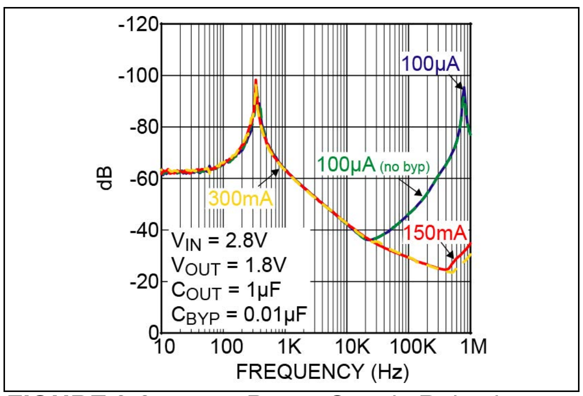


FIGURE 2-2: *Power Supply Rejection Ratio (V_{BIAS}).*

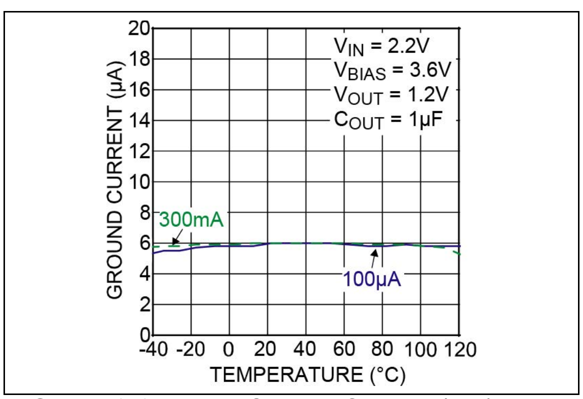


FIGURE 2-3: *Ground Current (V_{IN}) vs. Temperature.*

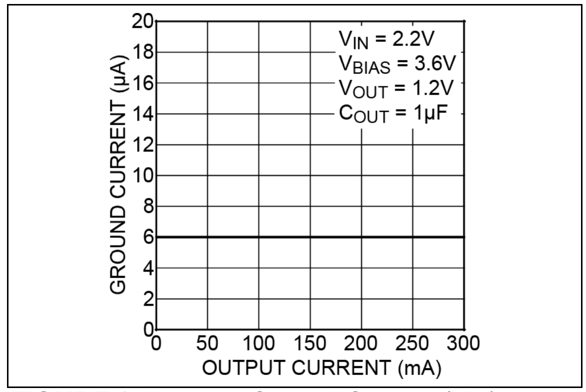


FIGURE 2-4: *Ground Current (V_{IN}) vs. Output Current.*

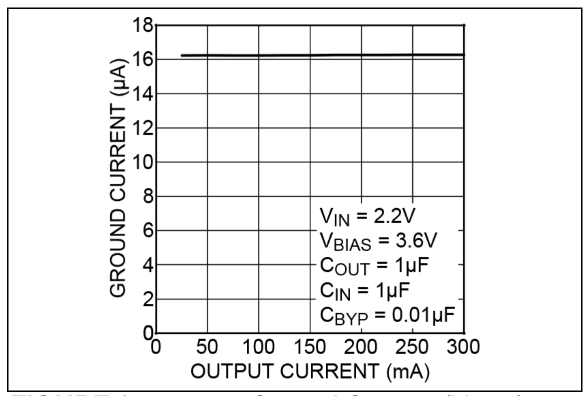


FIGURE 2-5: *Ground Current (V_{BIAS}) vs. Output Current.*

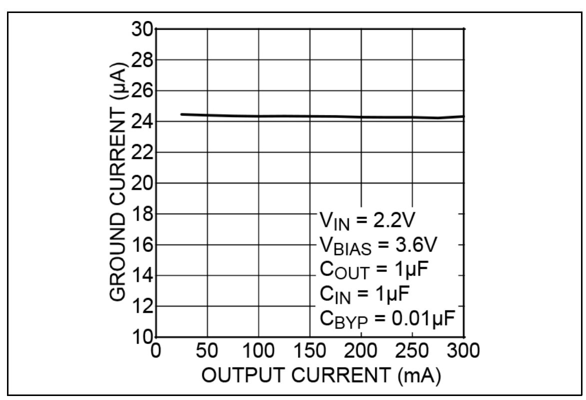


FIGURE 2-6: *Ground Current (Total) vs. Output Current.*

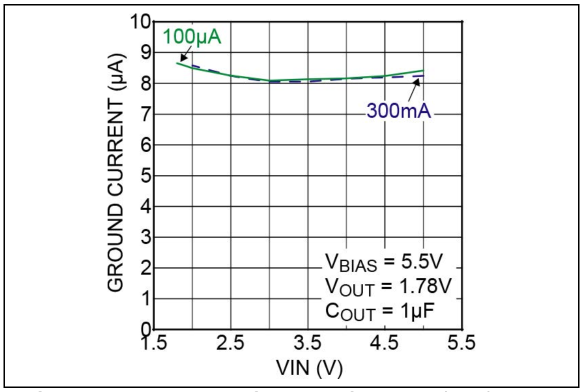


FIGURE 2-7: *Ground Current (V_{IN}) vs. V_{IN}.*

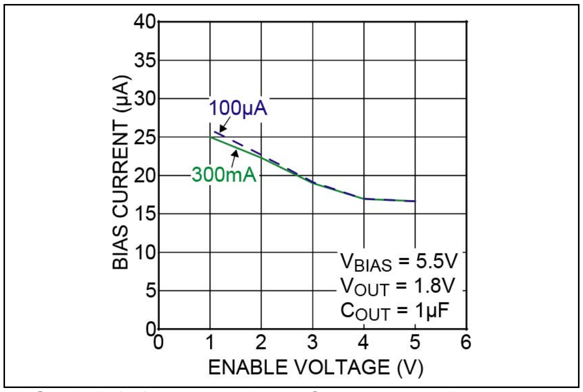


FIGURE 2-8: *Bias Current vs. Enable Voltage.*

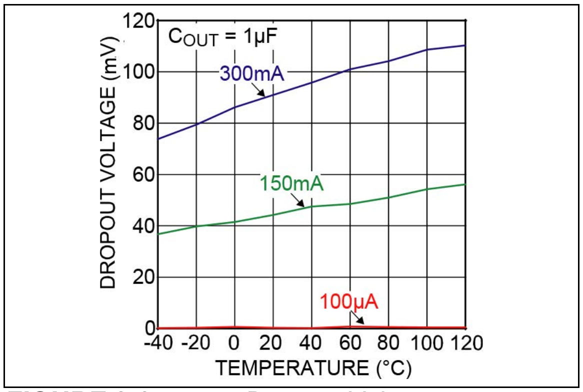


FIGURE 2-9: *Dropout Voltage vs. Temperature.*

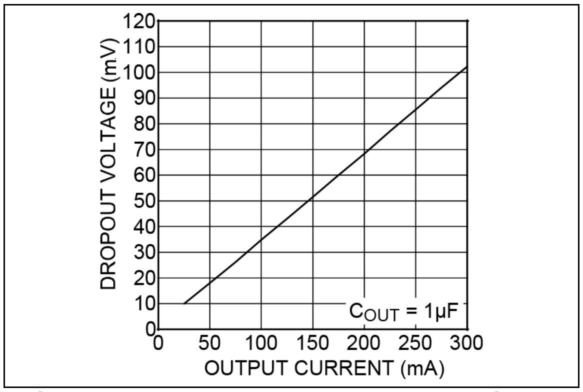


FIGURE 2-10: *Dropout Voltage vs. Output Current.*

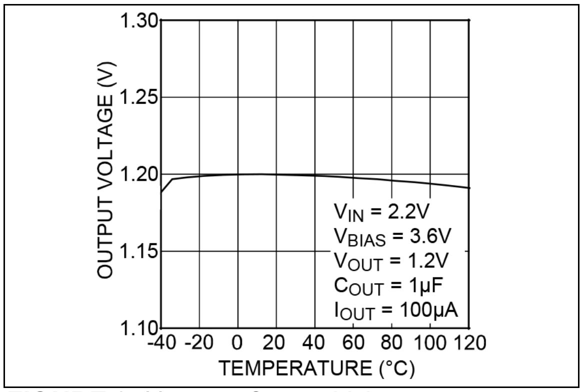


FIGURE 2-11: *Output Voltage vs. Temperature.*

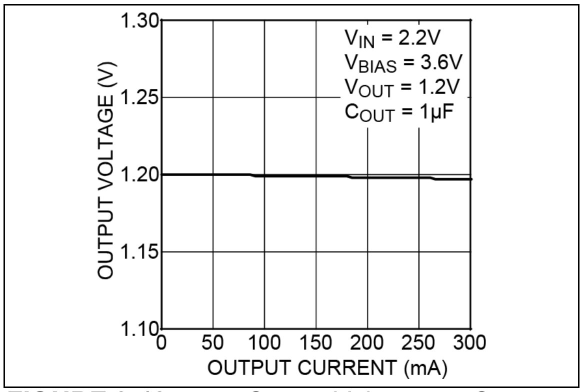


FIGURE 2-12: *Output Voltage vs. Output Current.*

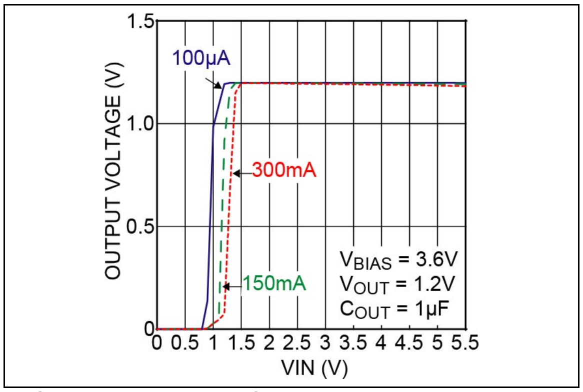


FIGURE 2-13: *Output Voltage vs. V_{IN}.*

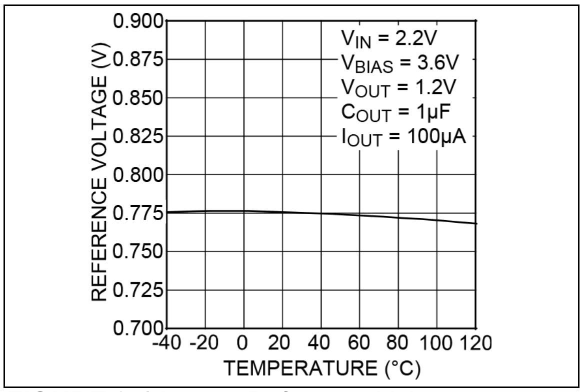


FIGURE 2-14: *Reference Voltage vs. Temperature.*

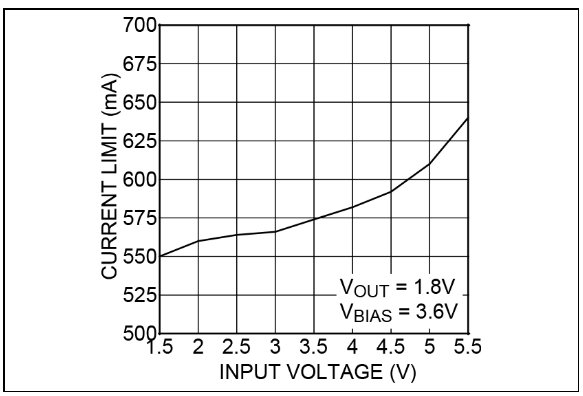


FIGURE 2-15: *Current Limit vs. V_{IN}.*

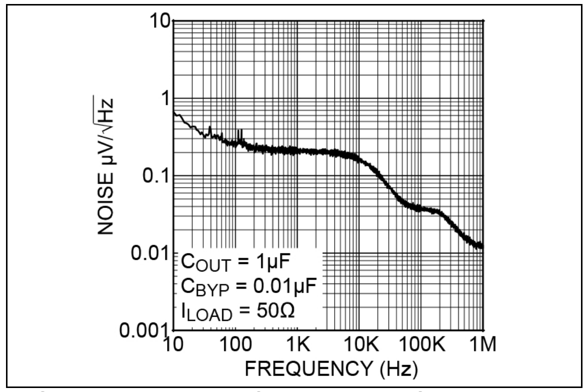


FIGURE 2-16: *Output Noise Spectral Density.*

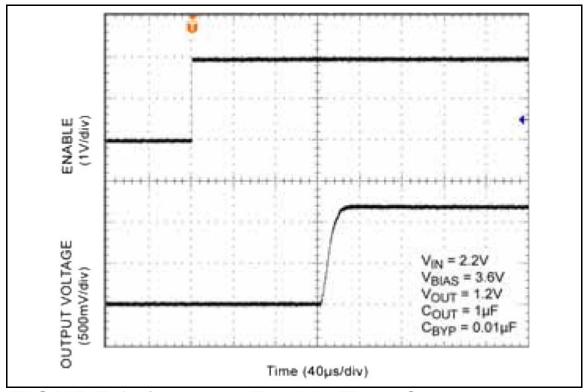


FIGURE 2-17: *Enable Turn-On.*

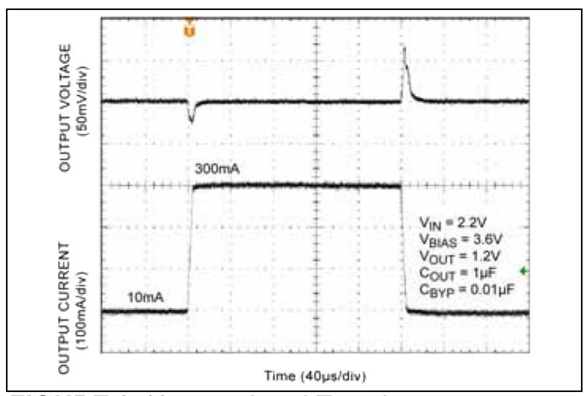


FIGURE 2-18: *Load Transient.*

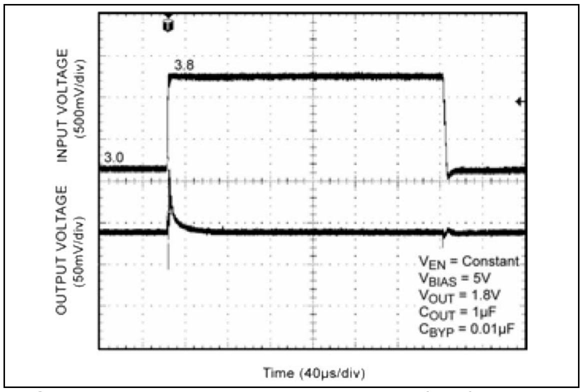


FIGURE 2-19: *Line Transient (V_{IN}).*

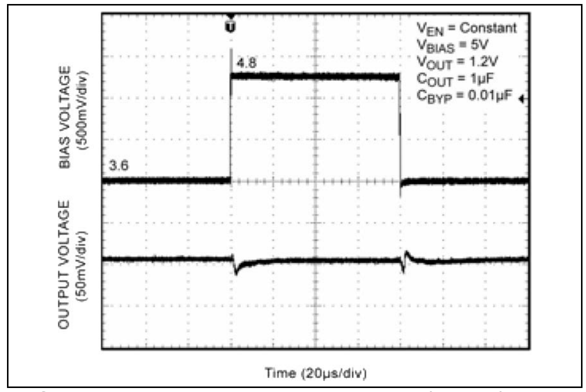


FIGURE 2-20: *Line Transient (V_{BIAS}).*

3.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in Table 3-1.

TABLE 3-1: PIN FUNCTION TABLE

Pin Number Thin UDFN	Pin Number TSOT-23-6	Pin Name	Description
3	1	VIN	Power Input for LDO.
2	2	GND	Ground.
1	3	BIAS	Bias Input Voltage.
6	4	BYP	Bypass: Connect a capacitor to ground to reduce noise and reduce ripple rejection.
		ADJ	Adjustable: Feedback input from external resistor divider.
5	5	EN	Enable Input: Active High Input. Logic High = On; Logic Low = Off; Do not leave floating.
4	6	VOUT	Output of regulator.
HS Pad	—	EPAD	Exposed heat sink pad connected to ground internally.

4.0 APPLICATION INFORMATION

The MIC5309 is a high performance, low-dropout linear regulator designed for low current applications requiring fast transient response. The MIC5309 utilizes two input supplies, significantly reducing dropout voltage, perfect for low-voltage, DC-to-DC conversion. The MIC5309 requires a minimum of external components.

The MIC5309 regulator is fully protected from damage due to fault conditions, offering linear current limiting and thermal shutdown.

4.1 Bias Supply Voltage

V_{BIAS}, requiring relatively light current, provides power to the control portion of the MIC5309. Bypassing on the bias pin is recommended to improve performance of the regulator during line and load transients. 1 µF ceramic capacitor from V_{BIAS} to ground helps reduce high frequency noise from being injected into the control circuitry from the bias rail and is good design practice.

4.2 Input Supply Voltage

V_{IN} provides the supply to power the LDO. The minimum input voltage is 1.7V, allowing conversion from low voltage supplies.

4.3 Output Capacitor

The MIC5309 requires an output capacitor of 1 µF or greater to maintain stability. The design is optimized for use with low-ESR ceramic chip capacitors. High ESR capacitors may cause high frequency oscillation. The output capacitor can be increased, but performance has been optimized for a 1 µF ceramic output capacitor and does not improve significantly with larger capacitance.

X7R/X5R dielectric-type ceramic capacitors are recommended due to their temperature performance. X7Rtype capacitors change capacitance by 15% over their operating temperature range and are the most stable type of ceramic capacitors.

Z5U and Y5V dielectric capacitors change value by as much as 50% and 60%, respectively, over their operating temperature ranges. To use a ceramic chip capacitor with Y5V dielectric, the value must be much higher than an X7R ceramic capacitor to ensure the same minimum capacitance over the equivalent operating temperature range.

4.4 Input Capacitor

The MIC5309 is a high-performance, high bandwidth device. Therefore, it requires a well-bypassed input supply for optimal performance.

A 1 µF capacitor is required from the input to ground to provide stability. Low-ESR ceramic capacitors provide optimal performance at a minimum of space. Additional high-frequency capacitors, such as small-valued NPO dielectric-type capacitors, help filter out high-frequency noise and are good practice in any RF-based circuit.

4.5 Bypass Capacitor

A capacitor can be placed from the noise bypass pin to ground to reduce output voltage noise. The capacitor bypasses the internal reference. A 0.01 µF capacitor is recommended for applications that require low-noise outputs.

The bypass capacitor can be increased, further reducing noise and improving PSRR. Turn-on time increases slightly with respect to bypass capacitance. A unique, quick-start circuit allows the MIC5309 to drive a large capacitor on the bypass pin without significantly slowing turn-on time.

4.6 Minimum Load Current

The MIC5309, unlike most other regulators, does not require a minimum load to maintain output voltage regulation.

4.7 Adjustable Regulator Design

The MIC5309 adjustable version allows programming the output voltage anywhere between 0.8V and 2V. Two resistors are used. The resistor values are calculated by:

EQUATION 4-1:

$$R1 = R2 \times \left(\frac{V_{OUT}}{0.775} - 1\right)$$

Where V_{OUT} is the desired output voltage.

4.8 Enable/Shutdown

The MIC5309 comes with a single active-high enable pin that allows the regulator to be disabled. Forcing the enable pin low disables the regulator and sends it into a zero-off mode current state. In this state, current consumed by the regulator goes nearly to zero.

Forcing the enable pin high enables the output voltage. The active-high enable pin uses CMOS technology and the enable pin cannot be left floating; a floating enable pin may cause an indeterminate state on the output.

4.9 Thermal Considerations

The MIC5309 is designed to provide 300 mA of continuous current in a very small package. Maximum ambient operating temperature can be calculated based on the output current and the voltage drop across the part. Given that the input voltage is 1.8V, the output voltage is 1.2V and the output current = 300 mA. The actual power dissipation of the regulator circuit can be determined using the equation:

EQUATION 4-2:

$$P_D = (V_{IN} - V_{OUT}) \times I_{OUT} + V_{IN} \times I_{GND}$$

Because this device is CMOS and the ground current is typically <100 µA over the load range, the power dissipation contributed by the ground current is < 1% and can be ignored for this calculation.

EQUATION 4-3:

$$P_D = (1.8V - 1.2V) \times 300mA$$
$$P_D = 0.18W$$

To determine the maximum ambient operating temperature of the package, use the junction-to-ambient thermal resistance of the device and the following basic equation:

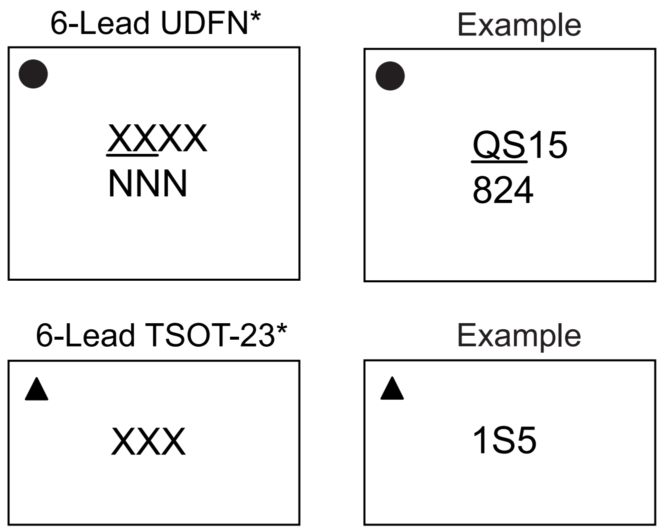
EQUATION 4-4:

$$P_{D(MAX)} = \left(\frac{T_{J(MAX)} - T_A}{\theta_{JA}}\right)$$

$T_{J(MAX)}$ = 125°C, the maximum junction temperature of the die θ_{JA} thermal resistance = 90°C/W.

5.0 PACKAGING INFORMATION

5.1 Package Marking Information



Legend:	XX...X	Product code or customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week ‘01’)
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC® designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator ((e3)) can be found on the outer packaging for this package.
	●, ▲, ▼	Pin one index is identified by a dot, delta up, or delta down (triangle mark).

Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information. Package may or may not include the corporate logo.

Underbar (_) and/or Overbar (‾) symbol may not be to scale.

Note: If the full seven-character YYWWNNN code cannot fit on the package, the following truncated codes are used based on the available marking space:
6 Characters = YWWNNN; 5 Characters = WWNNN; 4 Characters = WNNN; 3 Characters = NNN;
2 Characters = NN; 1 Character = N.

TABLE 5-1: ORDERING INFORMATION

Part Number	Voltage	Marking Codes	Temperature Range	Package
MIC5309-1.2YMT	1.2V	▲1S2	–40°C to +125°C	6-Lead 1.6 mm × 1.6 mm UDFN
MIC5309-1.5YMT	1.5V	▲1S5	–40°C to +125°C	6-Lead 1.6 mm × 1.6 mm UDFN
MIC5309-1.8YMT	1.8V	▲1S8	–40°C to +125°C	6-Lead 1.6 mm × 1.6 mm UDFN
MIC5309YMT	Adj.	▲ASA	–40°C to +125°C	6-Lead 1.6 mm × 1.6 mm UDFN
MIC5309-1.2YD6	1.2V	QS12	–40°C to +125°C	6-Lead TSOT-23
MIC5309-1.5YD6	1.5V	QS15	–40°C to +125°C	6-Lead TSOT-23
MIC5309-1.8YD6	1.8V	QS18	–40°C to +125°C	6-Lead TSOT-23
MIC5309YD6	Adj.	QSAA	–40°C to +125°C	6-Lead TSOT-23

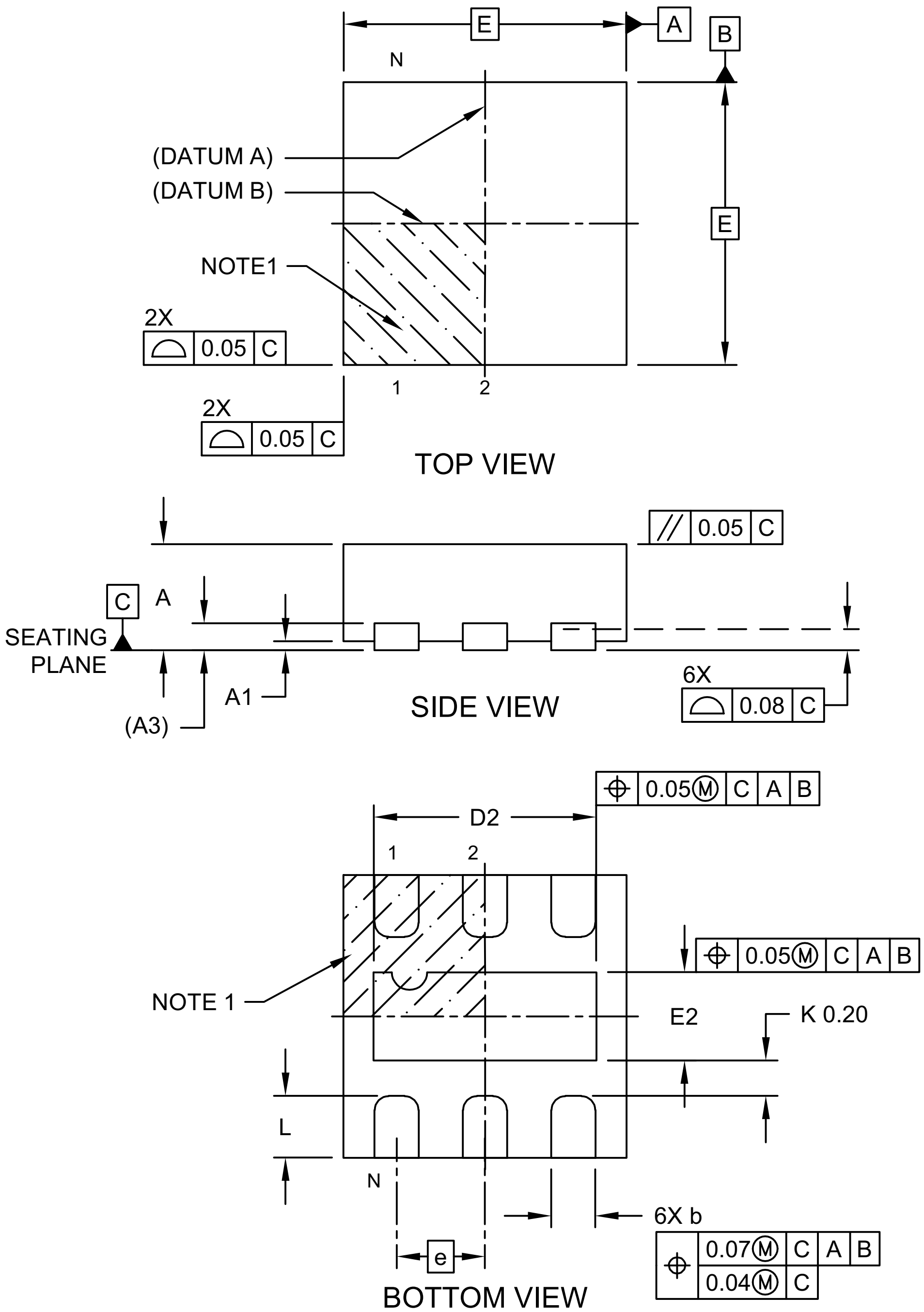
Note 1: For other voltage options.

2: Pin 1 identifier = ▲.

3: MLF® is a GREEN RoHS compliant package. Lead finish is NiPdAu. Mold compound is Halogen Free.

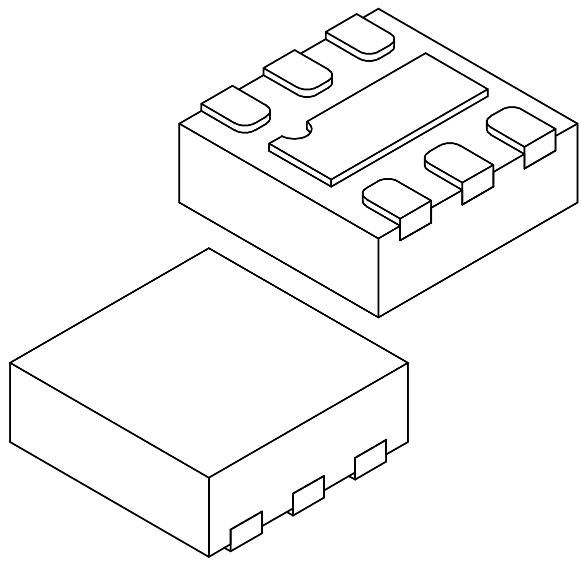
6-Lead 1.6 mm × 1.6 mm UDFN Package Outline and Recommended Land Pattern

Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



6-Lead 1.6 mm × 1.6 mm UDFN Package Outline and Recommended Land Pattern

Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



	Units	MILLIMETERS		
	Dimension Limits	MIN	NOM	MAX
Number of Terminals	N		6	
Pitch	e		0.50 BSC	
Overall Height	A	0.50	0.55	0.60
Standoff	A1	0.00	0.02	0.05
Terminal Thickness	A3		0.152 REF	
Overall Length	D		1.60 BSC	
Exposed Pad Length	D2	1.21	1.26	1.31
Overall Width	E		1.60 BSC	
Exposed Pad Width	E2	0.45	0.50	0.55
Terminal Width	b	0.20	0.25	0.30
Terminal Length	L	0.30	0.35	0.40
Terminal-to-Exposed-Pad	K	0.20	–	–

Notes:

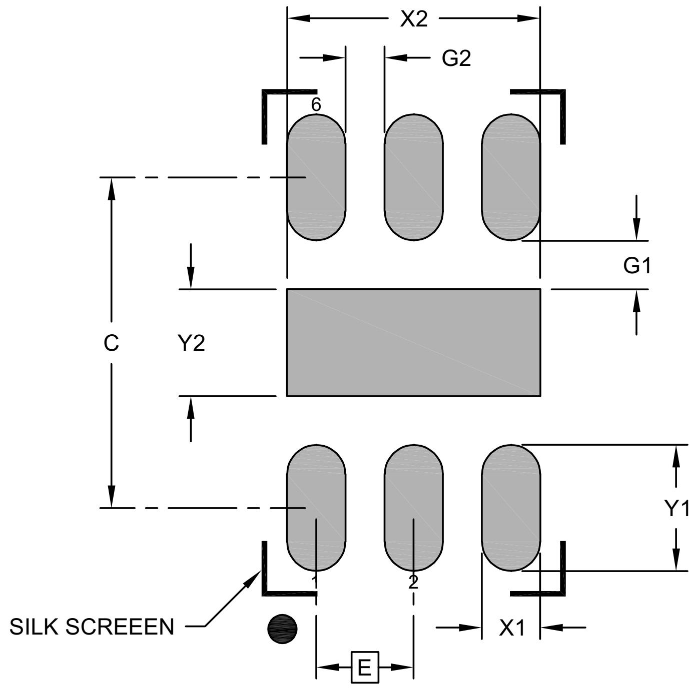
1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Package is saw singulated
3. Dimensioning and tolerancing per ASME Y14.5M

   BSC: Basic Dimension. Theoretically exact value shown without tolerances.

   REF: Reference Dimension, usually without tolerance, for information purposes only.

6-Lead 1.6 mm × 1.6 mm UDFN Package Outline and Recommended Land Pattern

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



RECOMMENDED LAND PATTERN

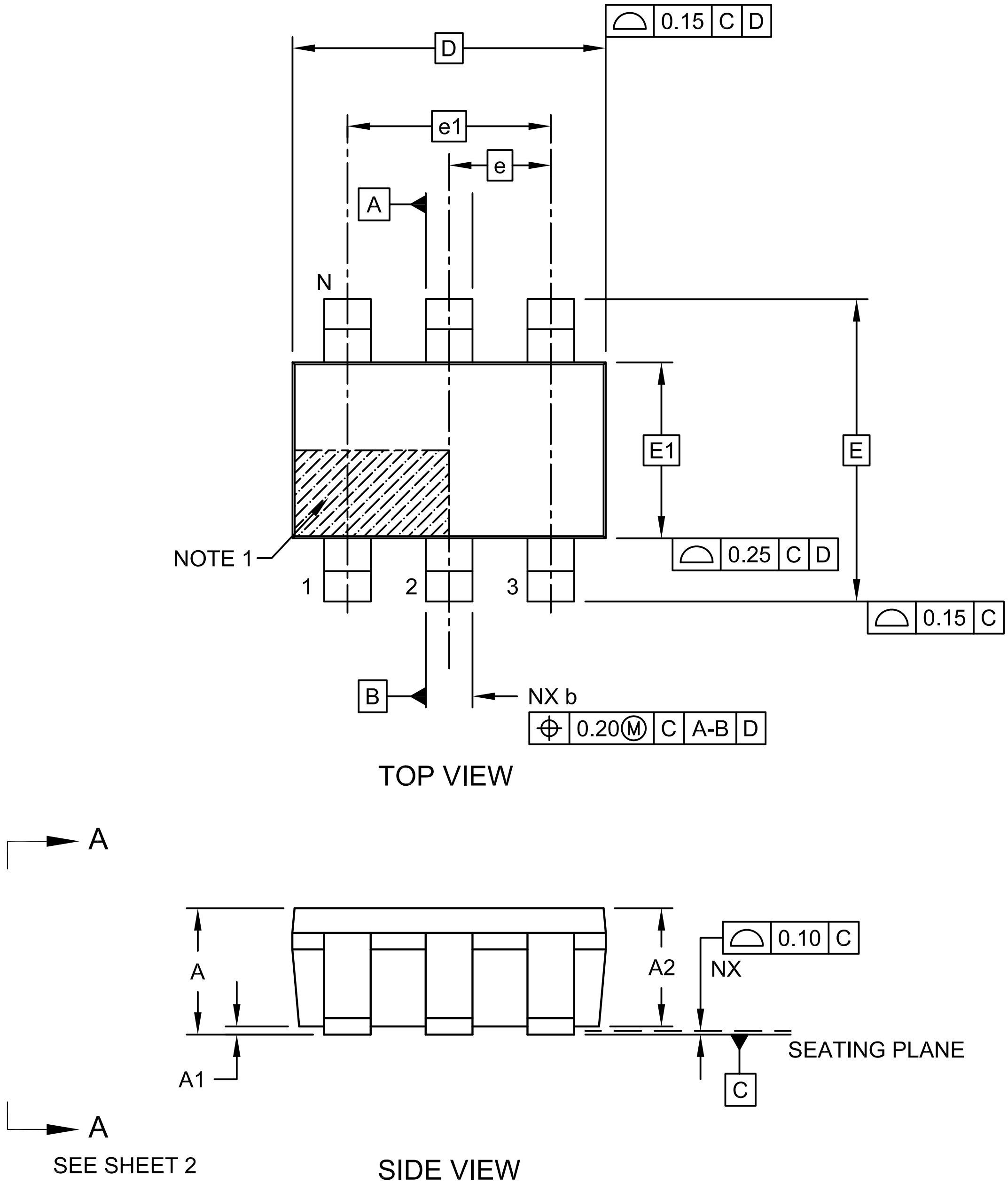
Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E		0.50 BSC	
Center Pad Width	X2			1.30
Center Pad Length	Y2			0.55
Contact Pad Spacing	C		1.70	
Contact Pad Width (X6)	X1			0.30
Contact Pad Length (X6)	Y1			0.65
Contact Pad to Center Pad (X6)	G1	0.25		
Contact Pad to Contact Pad (X4)	G2	0.20		

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.

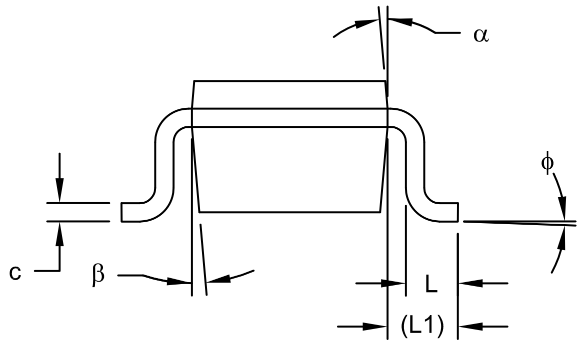
6-Lead TSOT-23 Package Outline and Recommended Land Pattern

Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging

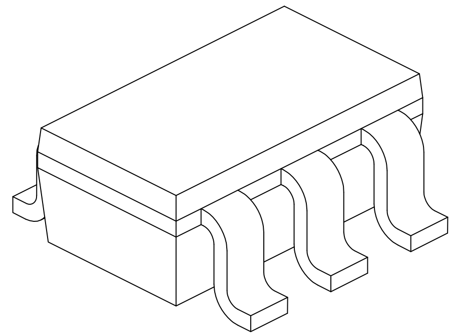


6-Lead TSOT-23 Package Outline and Recommended Land Pattern

Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



VIEW A-A



	Units	MILLIMETERS		
Dimension	Limits	MIN	NOM	MAX
Number of Leads	N		6	
Lead Pitch	e		0.95 BSC	
Outside Lead Pitch	e1		1.90 BSC	
Overall Height	A	-	-	1.10
Molded Package Thickness	A2	0.70	0.90	1.00
Standoff	A1	0.00	-	0.10
Overall Width	E		2.80 BSC	
Molded Package Width	E1		1.60 BSC	
Overall Length	D		2.90 BSC	
Foot Length	L	0.30	0.45	0.60
Footprint	L1		0.60 REF	
Foot Angle	φ	0°	4°	8°
Lead Thickness	c	0.08	-	0.20
Lead Width	θ	0.30	-	0.50
Mold Draft Angle Top	α	4°	10°	12°
Mold Draft Angle Botton	β	4°	10°	12°

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15mm per side.
3. Dimensioning and tolerancing per ASME Y14.5M.
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
   REF: Reference Dimension, usually without tolerance, for information purposes only.

APPENDIX A: REVISION HISTORY

Revision A (October 2022)

- Converted Micrel document MIC5309 to Microchip data sheet DS20006741A.
- Minor text changes throughout.

NOTES:

PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, contact your local Microchip representative or sales office.

PART No.	-X.XX	X	XX	-XX
Device	Output Voltage	Junction Temp. Range	Package	Media Type

Device:	MIC5309:	Low V_{IN}/V_{OUT} 300 mA High PSRR ULDO™ with Ultra-Low IQ
Output Voltage:	<blank> = Adjustable -1.2 = 1.2V -1.5 = 1.5V -1.8 = 1.8V	
Junction Temperature Range:	Y = –40°C to +125°C	
Package:	D6 = 6-lead TSOT-23 MT = 6-lead 1.6 mm × 1.6 mm × 0.6 mm UDFN	
Media Type:	<blank> = Adjustable TR = 3000/Reel (TSOT-23 option only) TR = 5000/Reel (UDFN option only)	

Examples:

a) MIC5309-1.2YD6-TR: MIC5309, 1.2V Output Voltage, –40°C to +125°C Temp. Range, 6-Lead TSOT-23, 3000/Reel

b) MIC5309-1.5YMT-TR: MIC5309, 1.5V Output Voltage, –40°C to +125°C Temp. Range, 6-Lead UDFN, 5000/Reel

c) MIC5309-1.8YD6-TR: MIC5309, 1.8V Output Voltage, –40°C to +125°C Temp. Range, 6-Lead TSOT-23, 3000/Reel

d) MIC5309YMT-TR: MIC5309, Adjustable Output Voltage, –40°C to +125°C Temp. Range, 6-Lead UDFN, 5000/Reel

Note 1: Tape and Reel identifier only appears in the catalog part number description. This identifier is used for ordering purposes and is not printed on the device package. Check with your Microchip Sales Office for package availability with the Tape and Reel option.

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