MIC5238

Ultra-Low Quiescent Current, 150 mA μCap LDO Regulator

Features

- Ultra-Low Input Voltage Range:1.5V to 6V
- Ultra-Low Output Voltage:1.0V Minimum Output Voltage
- Low Dropout Voltage: 310 mV at 150 mA
- High Output Accuracy: ±2.0% over Temperature
- μCap: Stable with Ceramic or Tantalum Capacitors
- Excellent Line and Load Regulation Specifications
- Zero Shutdown Current
- Reverse Leakage Protection
- Thermal Shutdown and Current Limit Protection
- 5-Lead SOT-23 Package

Applications

- PDAs and Pocket PCs
- Cellular Phones
- Battery-Powered Systems
- Low Power Microprocessor Power Supplies

General Description

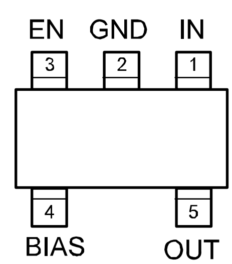
The MIC5238 is an ultra-low voltage output, 150 mA LDO regulator. Designed to operate in a single supply or dual supply mode, the MIC5238 consumes only 23 μA of bias current, which improves efficiency. When operating in dual supply mode, the efficiency greatly improves as the higher voltage supply is only required to supply the 23 μA bias current while the output and base drive comes off of the much lower input supply voltage.

As a μCap regulator, the MIC5238 operates with a 2.2 μF ceramic capacitor on the output, offering a smaller overall solution. It also incorporates a logic-level enable pin that allows the MIC5238 to be put into a zero off-current mode when disabled.

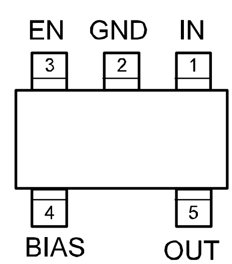
The MIC5238 is fully protected with current limit and thermal shutdown. It is offered in the 5-lead SOT-23 package with an operating junction temperature range of –40°C to +125°C.

Package Types

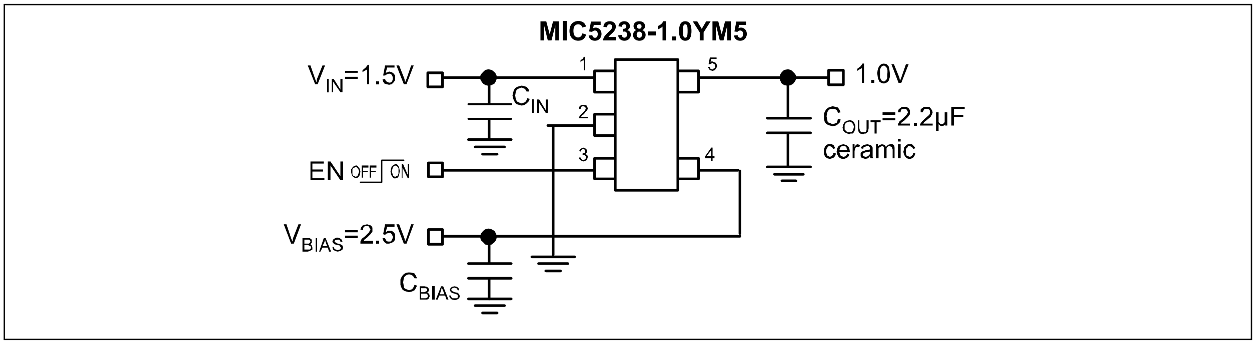
MIC5238
5-Lead SOT-23 (M5)
(Top View)



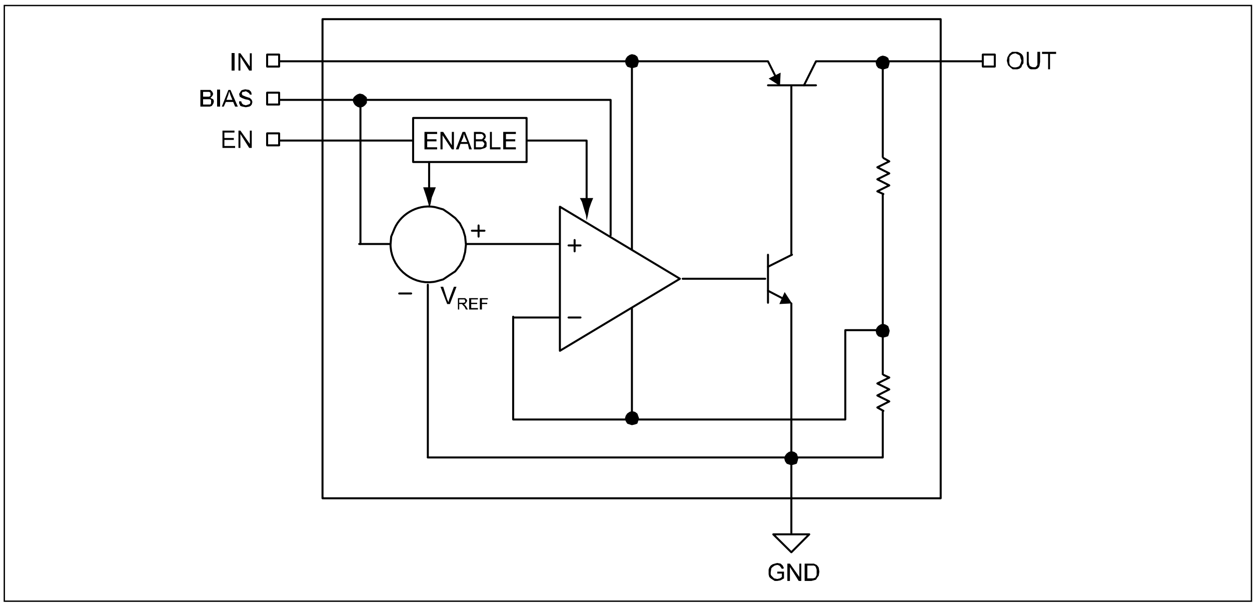
MIC5238
5-Lead TSOT-23 (D5)
(Top View)



Typical Application Circuit



Functional Block Diagram



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

Input Supply Voltage (V_{IN}) .... –0.3V to +7V
BIAS Supply Voltage (V_{BIAS}).......... –0.3V to +7V
Enable Supply Voltage (V_{EN}) .... –0.3V to +7V
Power Dissipation (P_D) .... Internally Limited
ESD Rating (Note 1) .... 1.5 kV HBM

Operating Ratings ‡

Supply Voltage (V_{IN}) .... +1.5V to +6V
BIAS Supply Voltage (V_{BIAS}).......... +2.3V to +6V
Enable Supply Voltage (V_{EN}) .... 0V to +6V

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

ELECTRICAL CHARACTERISTICS

Electrical Characteristics: T_A = +25°C with V_{IN} = V_{OUT} + 1V; V_{BIAS} = 3.3V; I_{OUT} = 100 µA; V_{EN} = 2V, **bold** values valid for –40°C < T_J < +125°C, unless specified. Note 1

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions
Output Voltage Accuracy		–1.5	—	1.5	%	Variation from nominal V_{OUT}
		–2	—	**2**		
Line Regulation		—	0.25	0.5	%	V_{BIAS} = 2.3V to 6V, Note 2
Input Line Regulation		—	0.04	4	%	V_{IN} = (V_{OUT} 1V) to 6V
Load Regulation		—	0.7	1	%	Load = 100 µA to 150 mA
Dropout Voltage	V_{DO}	—	50	—	mV	I_{OUT} = 100 µA
		—	230	300		I_{OUT} = 50 mA
		—	—	**400**		
		—	270	—		I_{OUT} = 100 mA
		—	310	450		I_{OUT} = 150 mA
		—	—	**500**		
BIAS Current, Note 3	I_{BIAS}	—	23	—	µA	I_{OUT} = 100 µA
Input Current on Pin 1	I_{IN}	—	7	**20**	µA	I_{OUT} = 100 µA
		—	0.35	—	mA	I_{OUT} = 50 mA, Note 4
		—	1	—		I_{OUT} = 100 mA
		—	2	**2.5**		I_{OUT} = 150 mA
Ground Current in Shutdown	I_{GND_SD}	—	1.5	5	µA	V_{EN} ≤ 0.2V, V_{IN} = 6V, V_{BIAS} = 6V
		—	0.5	—		V_{EN} = 0V, V_{IN} = 6V, V_{BIAS} = 6V
Short Circuit Current	I_{SC}	—	350	**500**	mA	V_{OUT} = 0V
Reverse Leakage Current		—	5	—	µA	V_{IN} = 0V, V_{EN} = 0V, V_{OUT} = nominal V_{OUT}

ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Characteristics: T_A = +25°C with $V_{IN} = V_{OUT}$ + 1V; V_{BIAS} = 3.3V; I_{OUT} = 100 µA; V_{EN} = 2V, **bold** values valid for –40°C < T_J < +125°C, unless specified. Note 1

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions
Enable Input						
Input Low Voltage	V_{IL}	—	—	**0.2**	V	Regulator OFF
Input High Voltage	V_{IH}	**2.0**	—	—	V	Regulator ON
Enable Input Current	I_{EN}	–1.0	0.01	1.0	µA	V_{EN} = 0.2V, Regulator OFF
		—	0.1	1.0		V_{EN} = 0.2V, Regulator ON

Note 1: Specification for packaged product only.
2: Line regulation measures a change in output voltage due to a change in the bias voltage.
3: Current measured from bias input to ground.
4: Current differential between output current and main input current at rated load current.

TEMPERATURE SPECIFICATIONS

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Temperature Ranges						
Junction Temperature Range	T_J	–40	—	+125	°C	—
Storage Temperature	T_S	–65	—	+150	°C	—
Package Thermal Resistances						
Thermal Resistance, SOT-23 5-Ld	θ_{JA}	—	235	—	°C/W	—

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.

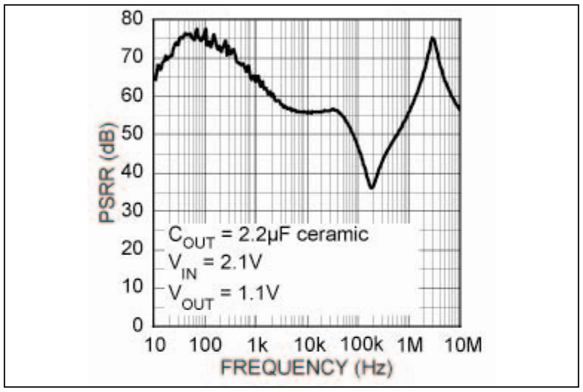


FIGURE 2-1: *PSRR 150 mA Load.*

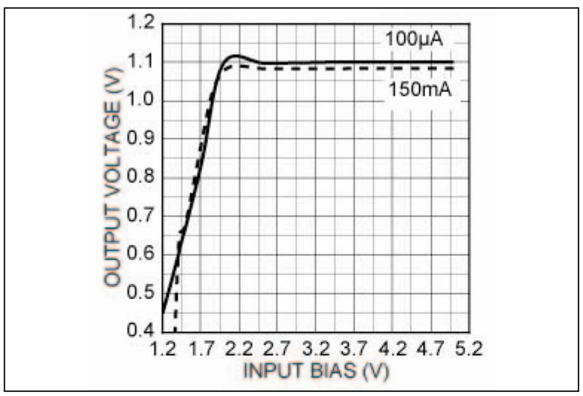


FIGURE 2-2: *Output Voltage vs. V_{BIAS}.*

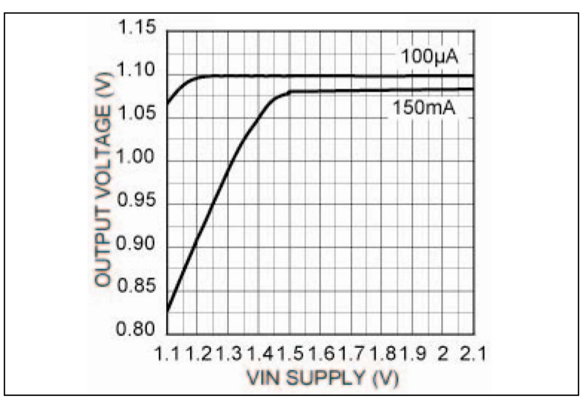


FIGURE 2-3: *Output Voltage vs. V_{IN} Supply.*

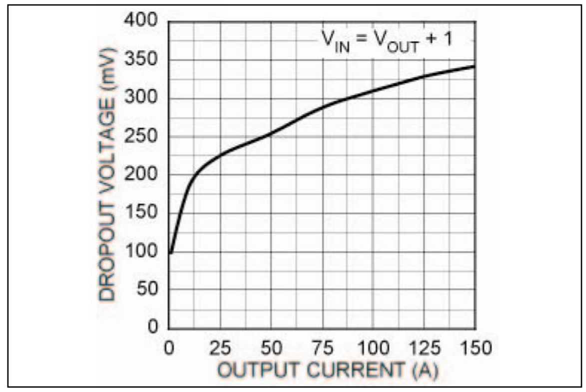


FIGURE 2-4: *Dropout Voltage vs Load.*

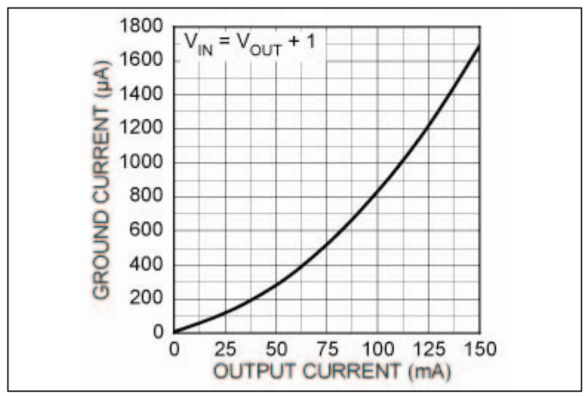


FIGURE 2-5: *Ground Current (V_{IN}) vs. Output Current.*

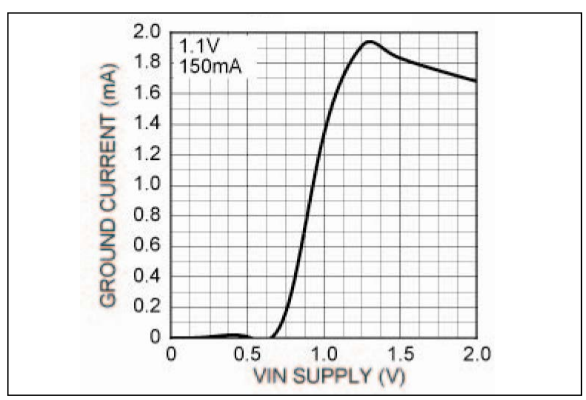


FIGURE 2-6: *Ground Current (V_{IN}) vs. V_{IN} Supply.*

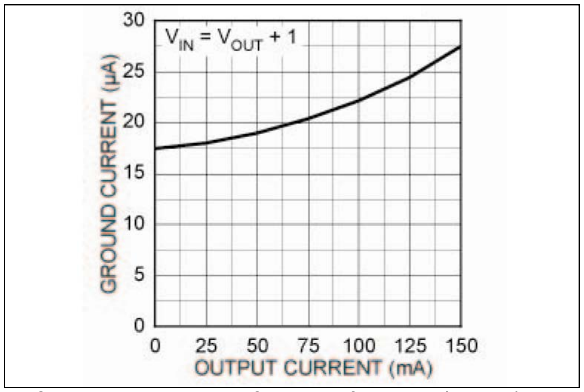


FIGURE 2-7: *Ground Current (V_{BIAS}) vs. Output Current.*

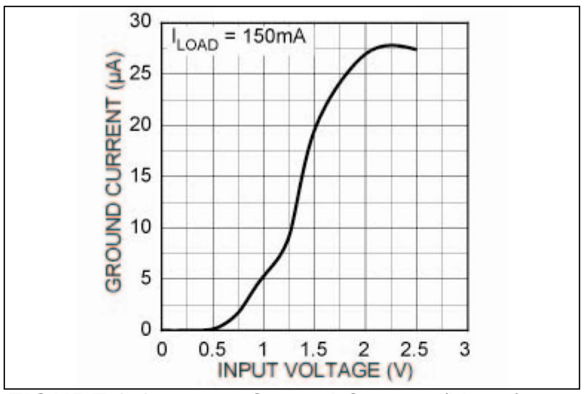


FIGURE 2-8: *Ground Current (V_{BIAS}) vs. Input Voltage.*

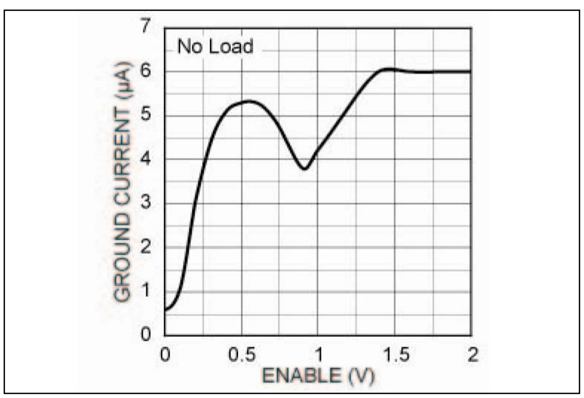


FIGURE 2-9: *Shutdown Current of V_{IN}.*

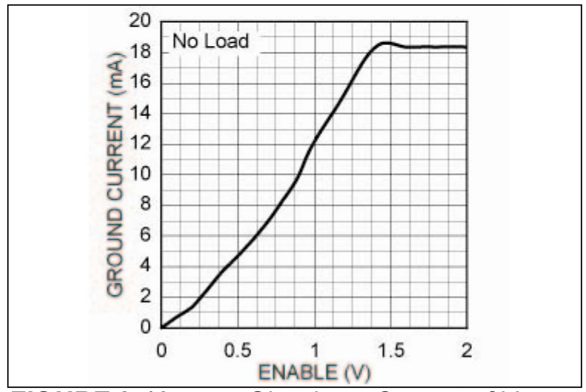


FIGURE 2-10: *Shutdown Current of V_{BIAS}.*

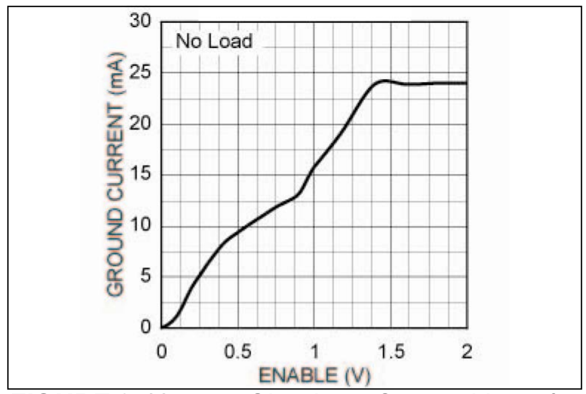


FIGURE 2-11: *Shutdown Current V_{BIAS} & V_{IN} Tied.*

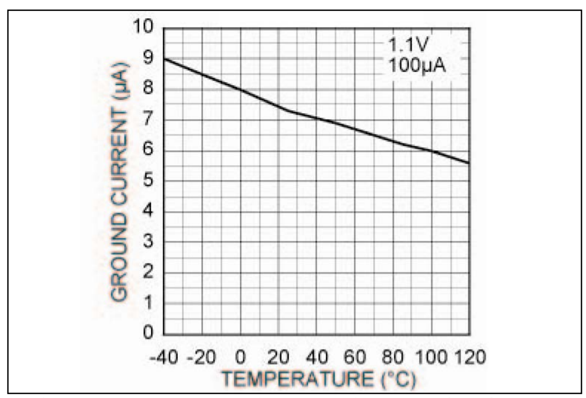


FIGURE 2-12: *Ground Current (V_{IN}) vs. Temperature.*

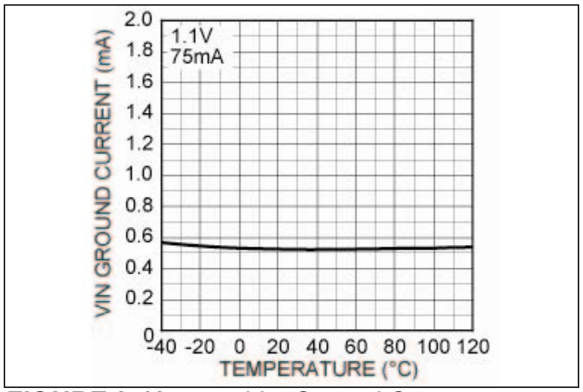


FIGURE 2-13: *V_{IN} Ground Current vs. Temperature.*

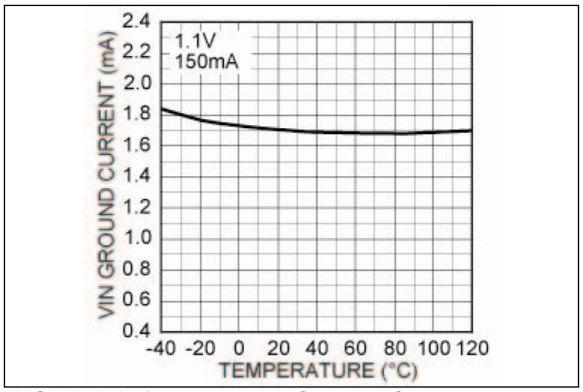


FIGURE 2-14: *V_{IN} Ground Current vs. Temperature.*

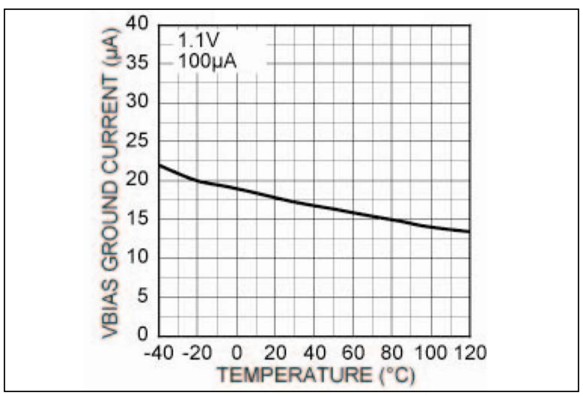


FIGURE 2-15: *V_{BIAS} Ground Current vs. Temperature.*

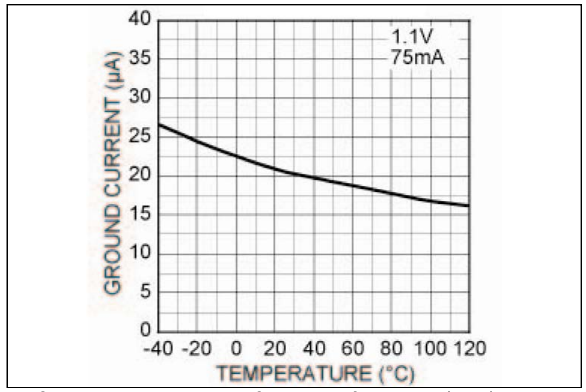


FIGURE 2-16: *Ground Current (V_{IN}) vs. Temperature.*

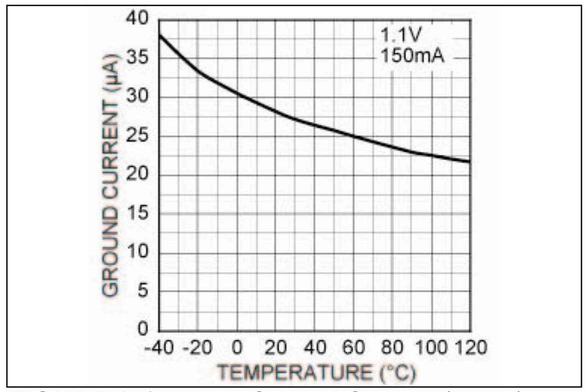


FIGURE 2-17: *Ground Current (V_{BIAS}) vs. Temperature.*

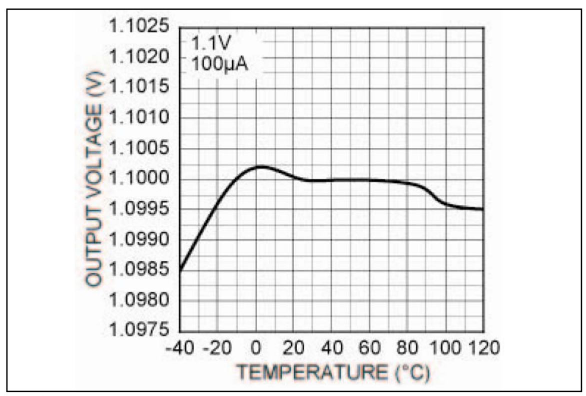


FIGURE 2-18: *Output Voltage vs. Temperature.*

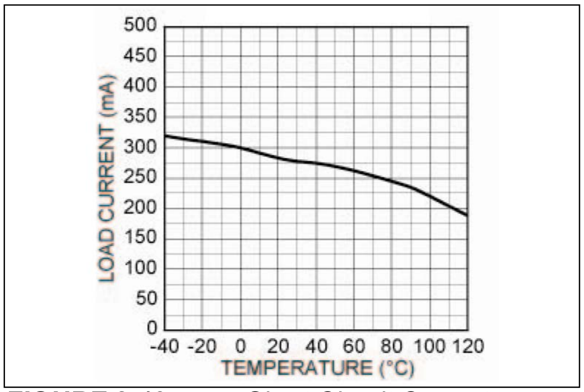


FIGURE 2-19: *Short Circuit Current vs. Temperature.*

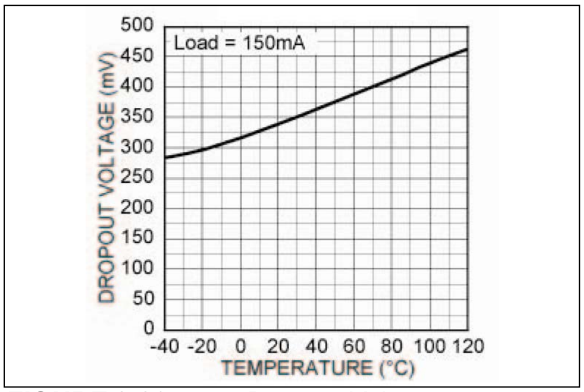


FIGURE 2-20: *Dropout Voltage vs. Temperature.*

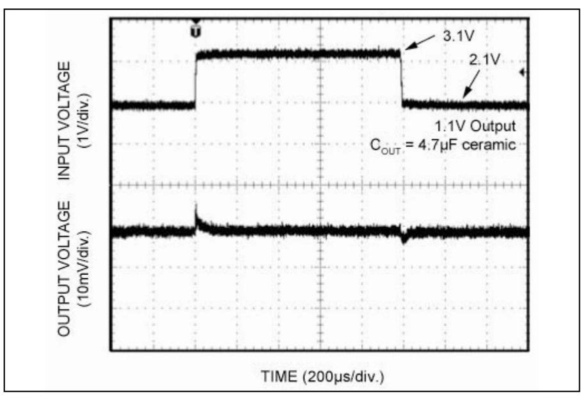


FIGURE 2-21: *Line Transient Response.*

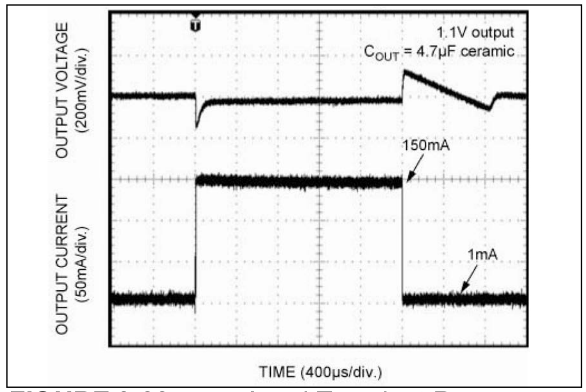


FIGURE 2-22: *Load Transient Response.*

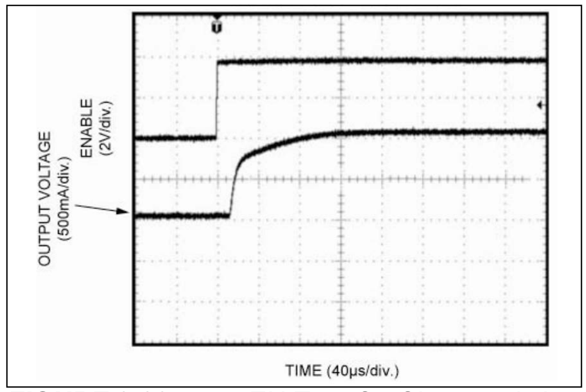


FIGURE 2-23: *EN Turn-On Characteristic.*

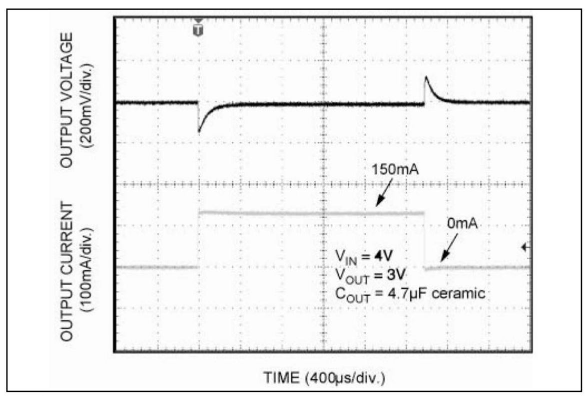


FIGURE 2-24: *Load Transient Response.*

3.0 PIN DESCRIPTIONS

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

TABLE 3-1: PIN FUNCTION TABLE

Pin Number	Pin Name	Description
1	IN	Supply Input
2	GND	Ground
3	EN	Enable (Input): Logic Low = shutdown; Logic High = enable. Do not leave open.
4	BIAS	Bias Supply Input
5	OUT	Regulator Output

4.0 APPLICATION INFORMATION

4.1 Enable/Shutdown

The MIC5238 comes with an 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.

4.2 Input Bias Capacitor

The input capacitor must be rated to sustain voltages that may be used on the input. An input capacitor may be required when the device is not near the source power supply or when supplied by a battery. Small, surface mount, ceramic capacitors can be used for bypassing. Larger values may be required if the source supply has high ripple.

4.3 Output Capacitor

The MIC5238 requires an output capacitor for stability. The design requires 2.2 µF or greater on the output to maintain stability. The design is optimized for use with low-ESR ceramic chip capacitors. High ESR capacitors may cause high frequency oscillation. The maximum recommended ESR is 3Ω. The output capacitor can be increased without limit. Larger valued capacitors help to improve transient response.

X7R/X5R dielectric-type ceramic capacitors are recommended because of their temperature performance. X7R-type 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 a X7R ceramic capacitor to ensure the same minimum capacitance over the equivalent operating temperature range.

4.4 No-Load Stability

The MIC5238 will remain stable and in regulation with no load unlike many other voltage regulators. This is especially important in CMOS RAM keep-alive applications.

4.5 Thermal Considerations

The MIC5238 is designed to provide 150 mA of continuous current in a very small package. Maximum power dissipation can be calculated based on the output current and the voltage drop across the part. To determine the maximum power dissipation of the package, use the junction-to-ambient thermal resistance of the device and the following basic equation:

EQUATION 4-1:

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

$T_{J(MAX)}$ is the maximum junction temperature of the die, 125°C, and T_A is the ambient operating temperature. θ_{JA} is layout-dependent. The Temperature Specifications table shows the junction-to-ambient thermal resistance for the MIC5238.

The actual power dissipation of the regulator circuit can be determined using the following equation:

EQUATION 4-2:

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

Substituting $P_{D(MAX)}$ for P_D and solving for the operating conditions that are critical to the application will give the maximum operating conditions for the regulator circuit. For example, when operating the MIC5238-1.0YM5 at 50°C with a minimum footprint layout, the maximum input voltage for a set output current can be determined as follows.

EQUATION 4-3:

$$P_{D(MAX)} = \frac{125°C - 50°C}{235°\text{C/W}} = 319mW$$

The junction-to-ambient (θ_{JA}) thermal resistance for the minimum footprint is 235°C/W, from the Temperature Specifications table. It is important that the maximum power dissipation not be exceeded to ensure proper operation. With very high input-to-output voltage differentials, the output current is limited by the total power dissipation. Total power dissipation is calculated using the following equation:

EQUATION 4-4:

$$P_{D(MAX)} = (V_{IN} - V_{OUT})I_{OUT} + V_{IN} \times I_{GND} + V_{BIAS} \times I_{BIAS}$$

Because the bias supply draws only 18 µA, that contribution can be ignored for this calculation.

If we know the maximum load current, we can solve for the maximum input voltage using the maximum power dissipation calculated for a 50°C ambient, 319 mV.

EQUATION 4-5:

$$P_{D(MAX)} = (V_{IN} - V_{OUT}) \times I_{OUT} + V_{IN} \times I_{GND}$$

$$319mW = (V_{IN} - 1V) \times 150mA + V_{IN} \times 2.8mA$$

Ground pin current is estimated using the typical characteristics of the device.

EQUATION 4-6:

$$469mW = V_{IN} \times 152.8mA$$

$$V_{IN} = 3.07V$$

For higher current outputs only a lower input voltage will work for higher ambient temperatures.

Assuming a lower output current of 20 mA, the maximum input voltage can be recalculated:

EQUATION 4-7:

$$319mW = (V_{IN} - 1V) \times 20mA + V_{IN} \times 0.2mA$$

$$339mW = V_{IN} \times 20.2mA$$

$$V_{IN} = 16.8V$$

Maximum input voltage for a 20 mA load current at 50°C ambient temperature is 16.8V. Because the device has a 6V rating, it will operate over the whole input range.

4.6 Dual Supply Mode Efficiency

By utilizing a bias supply the conversion efficiency can be greatly enhanced. This can be realized as the higher bias supply will only consume a few microamps while the input supply will require a few milliamps. This equates to higher efficiency saving valuable power in the system. As an example, consider an output voltage of 1V with an input supply of 2.5V at a load current of 150 mA. The input ground current under these conditions is 2 mA, while the bias current is only 20 µA. If we calculate the conversion efficiency using the single supply approach, it is as follows:

Input power = V_{IN} × output current + V_{IN} × (V_{BIAS} ground current + V_{IN} ground current)

Input power = 2.5V × 150 mA + 2.5 × (0.0002+0.002) = 380.5 mW

Output power = 1V × 0.15 = 150 mW

Efficiency = 150/380.5 × 100 = 39.4%

Now, using a lower input supply of 1.5V, and powering the bias voltage only from the 2.5V input, the efficiency is as follows:

Input power = V_{IN} × output current + V_{IN} × V_{IN} ground current + V_{BIAS} x V_{BIAS} ground current

Input power = 1.5 × 150 mA + 1.5 × 0.002 + 2.5 × 0.0002 = 225 mW

Output power = 1V × 150 mA = 150 mW

Efficiency = 150/225 × 100 = 66.6%

Therefore, by using the dual supply MIC5238 LDO the efficiency is nearly doubled over the single supply version.

This is a valuable asset in portable power management applications equating to longer battery life and less heat being generated in the application.

This in turn will allow a smaller footprint design and an extended operating life.

5.0 PACKAGING INFORMATION

5.1 Package Marking Information

5-Lead SOT-23* (Front)	Example	5-Lead TSOT-23* (Front)	Example
XXXX	L411	XXXX	N410

5-Lead SOT-23* (Back)	Example	5-Lead TSOT-23* (Back)	Example
NNN	H93	NNN	P4N

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).

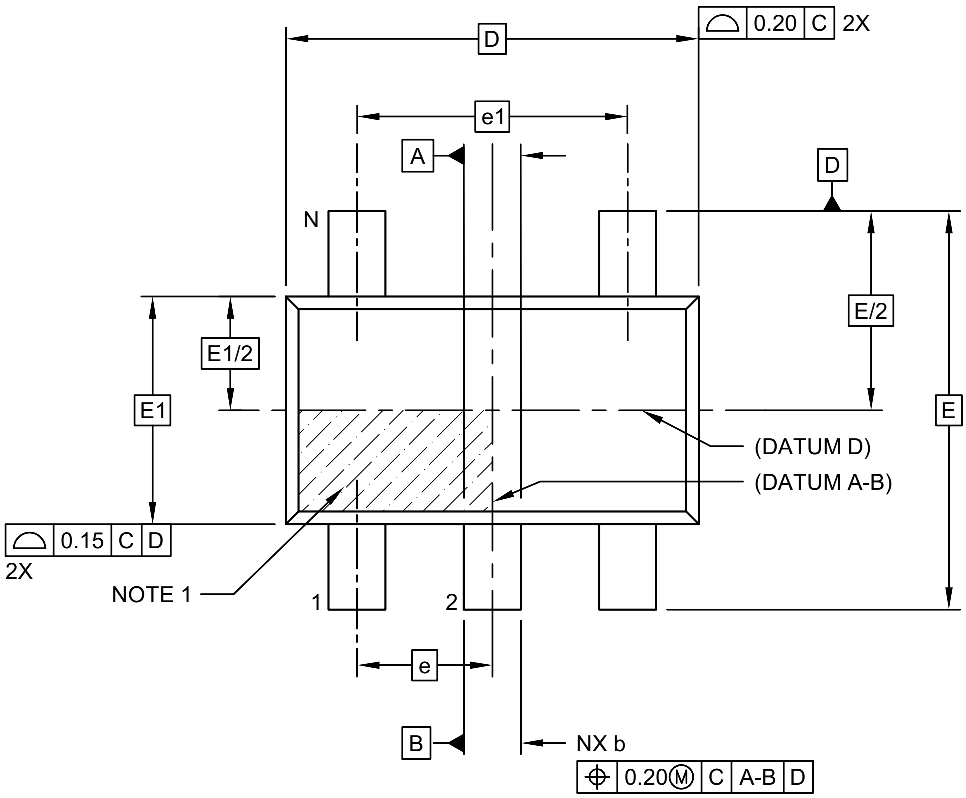
Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information. Package may or may not include the corporate logo.

Underbar (_) symbol may not be to scale.

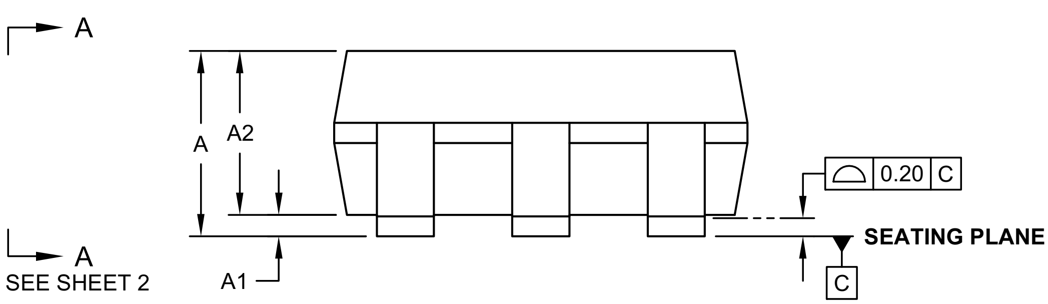
Note: If the full seven-character YYWWNNN code cannot fit on the package, the following truncated codes are used based on the available marking space:
6 Characters = YWWNNN; 5 Characters = WWNNN; 4 Characters = WNNN; 3 Characters = NNN;
2 Characters = NN; 1 Character = N

5-Lead Plastic Small Outline Transistor (6BX) [SOT23]

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



TOP VIEW

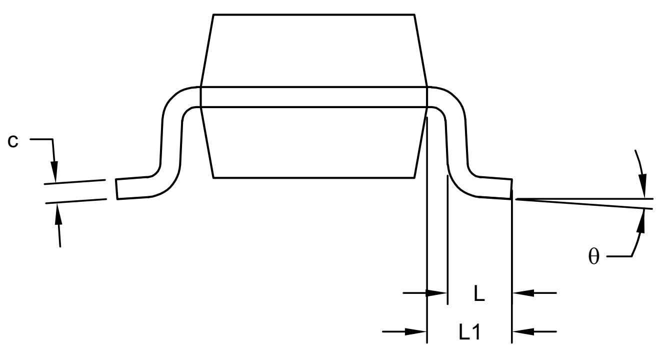


SIDE VIEW

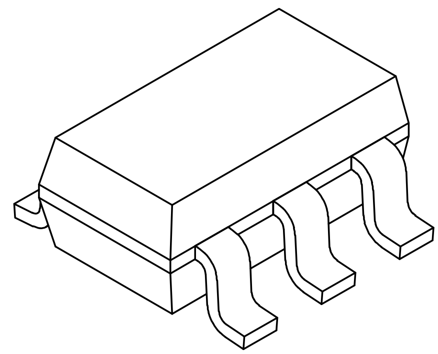
Microchip Technology Drawing C04-091-6BX Rev G Sheet 1 of 2

5-Lead Plastic Small Outline Transistor (6BX) [SOT23]

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



VIEW A-A
SHEET 1



Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Pins	N		5	
Pitch	e		0.95 BSC	
Outside lead pitch	e1		1.90 BSC	
Overall Height	A	0.90	-	1.45
Molded Package Thickness	A2	0.89	-	1.30
Standoff	A1	-	-	0.15
Overall Width	E		2.80 BSC	
Molded Package Width	E1		1.60 BSC	
Overall Length	D		2.90 BSC	
Foot Length	L	0.30	-	0.60
Footprint	L1		0.60 REF	
Foot Angle	ϕ	0°	-	10°
Lead Thickness	c	0.08	-	0.26
Lead Width	b	0.20	-	0.51

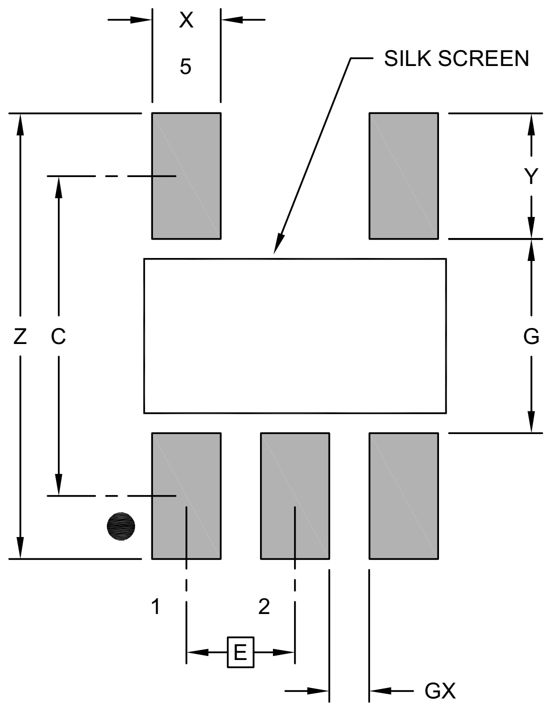
Notes:

1. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.25mm per side.
2. 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.

Microchip Technology Drawing C04-091-6BX Rev G Sheet 2 of 2

5-Lead Plastic Small Outline Transistor (6BX) [SOT23]

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	0.95 BSC		
Contact Pad Spacing	C		2.80	
Contact Pad Width (X5)	X			0.60
Contact Pad Length (X5)	Y			1.10
Distance Between Pads	G	1.70		
Distance Between Pads	GX	0.35		
Overall Width	Z			3.90

Notes:

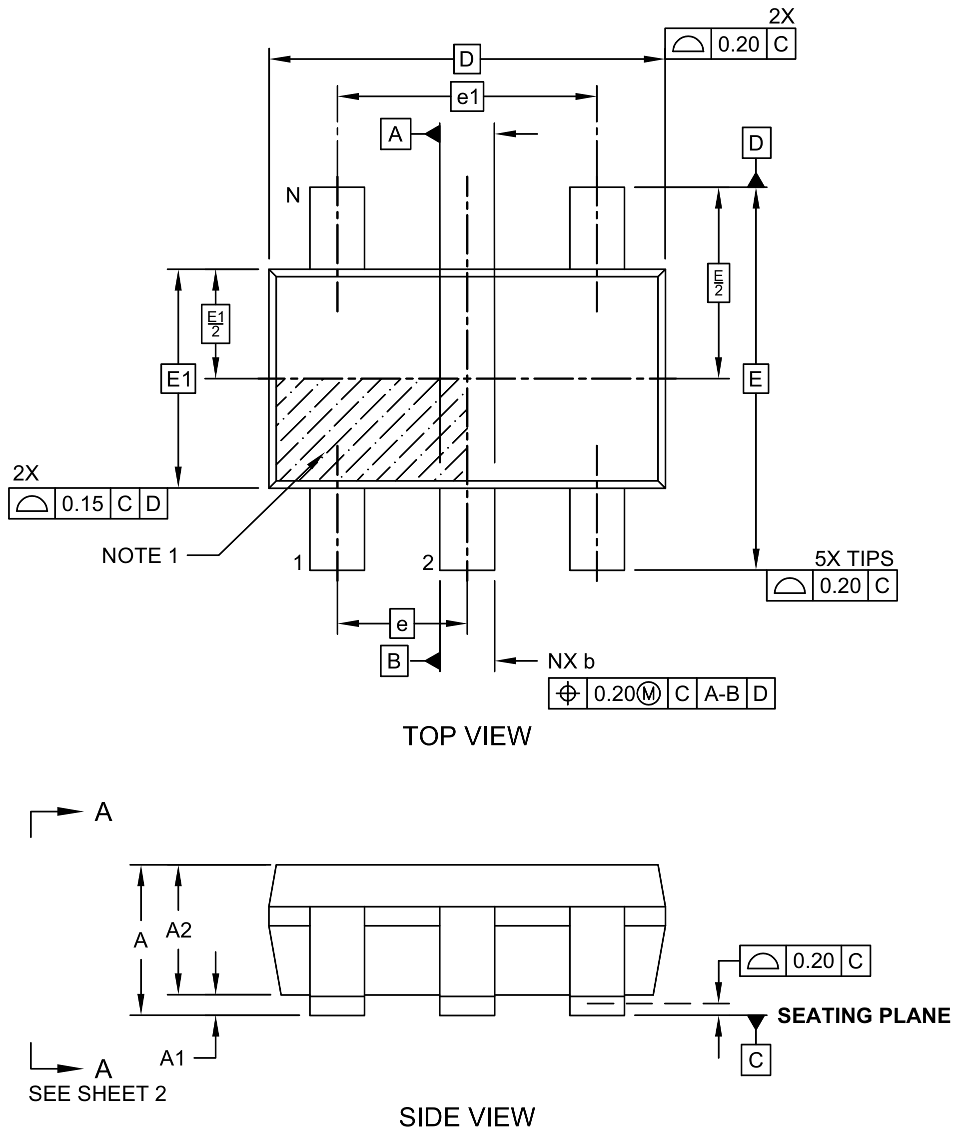
1. Dimensioning and tolerancing per ASME Y14.5M

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

Microchip Technology Drawing No. C04-2091-6BX Rev G

5-Lead Plastic Thin Small Outline Transistor (D5A) [TSOT]
Micrel Legacy Package TSOT-5LD-PL-1

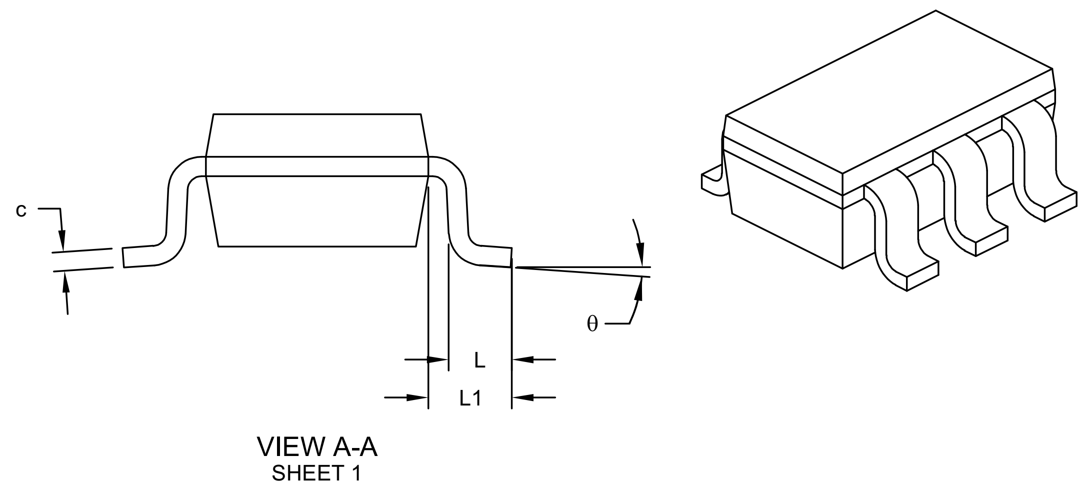
Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Microchip Technology Drawing C04-1179 Rev A Sheet 1 of 2

5-Lead Plastic Thin Small Outline Transistor (D5A) [TSOT]
Micrel Legacy Package TSOT-5LD-PL-1

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 Leads	N	5		
Pitch	e	0.95 BSC		
Outside lead pitch	e1	1.90 BSC		
Overall Height	A	-	-	1.00
Molded Package Thickness	A2	0.84	0.87	0.90
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	0.40	0.50
Footprint	L1	0.60 REF		
Foot Angle	ϕ	0°	-	4°
Lead Thickness	c	0.127 REF		
Lead Width	b	0.30	-	0.50

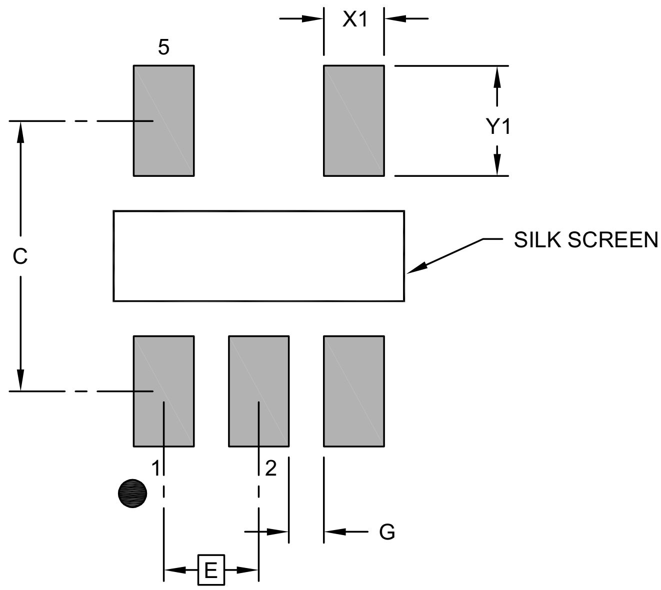
Notes:

1. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.25mm per side.
2. 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.

Microchip Technology Drawing C04-1179 Rev A Sheet 1 of 2

5-Lead Plastic Thin Small Outline Transistor (D5A) [TSOT]
Micrel Legacy Package TSOT-5LD-PL-1

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	0.95 BSC		
Contact Pad Spacing	C		2.60	
Contact Pad Width (X5)	X1			0.60
Contact Pad Length (X5)	Y1			1.10
Contact Pad to Center Pad (X2)	G	0.20		

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

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

Microchip Technology Drawing C04-3179 Rev A

APPENDIX A: REVISION HISTORY

Revision A (August 2023)

- Converted Micrel document MIC5238 to Microchip data sheet DS20006759A.
- 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 Number	-X.X	X	XX	-XX
Device	Output Voltage	Temp. Range	Package	Media Type

Device:	MIC5238:		Ultra-Low Quiescent Current, 150 mA µCap LDO Regulator
Output Voltage:	1.0	=	1.0V
	1.1	=	1.1V
	1.2	=	1.2V (Thin SOT-23 Only)
	1.3	=	1.3V
Temperature Range:	Y	=	–40°C to +125°C
Package:	M5	=	5-Lead SOT-23
	D5	=	5-Lead Thin SOT-23
Media Type:	TR	=	3,000/Reel
	TX	=	3,000/Reel Rev. (SOT-23 Only)

Examples:

a) MIC5238-1.0YM5-TR: MIC5238, 1.0V Output Voltage, –40°C to +125°C Temp. Range, 5-Lead SOT-23, 3,000/Reel

b) MIC5238-1.1YD5-TR: MIC5238, 1.1V Output Voltage, –40°C to +125°C Temp. Range, 5-Lead TSOT-23, 3,000/Reel

c) MIC5238-1.3YM5-TX: MIC5238, 1.3V Output Voltage, –40°C to +125°C Temp. Range, 5-Lead SOT-23, 3,000/Reel Reverse

d) MIC5238-1.2YD5-TR: MIC5238, 1.2V Output Voltage, –40°C to +125°C Temp. Range, 5-Lead TSOT-23, 3,000/Reel

e) MIC5238-1.1YM5-TR: MIC5238, 1.1V Output Voltage, –40°C to +125°C Temp. Range, 5-Lead SOT-23, 3,000/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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