

Ultra-Low Quiescent Current, 150 mA μ Cap LDO Regulator

Features

- Wide Input Voltage Range: 2.3V to 24V
- Ultra-Low Ground Current: 18 μ A
- Low Dropout Voltage: 310 mV at 150 mA
- High Output Accuracy: $\pm 2.0\%$ over Temperature
- μ Cap: Stable with Ceramic or Tantalum Capacitors
- Excellent Line and Load Regulation Specifications
- Zero Shutdown Current
- Reverse Battery Protection
- Reverse Leakage Protection
- Thermal Shutdown and Current Limit Protection
- SOT-23-5 Package
- Adjustable Output from 1.24V to 20V

Applications

- USB Power Supply
- Cellular Phones
- Keep-Alive Supply in Notebook and Portable Computers
- Logic Supply for High-Voltage Batteries
- Automotive Electronics
- Battery-Powered Systems

General Description

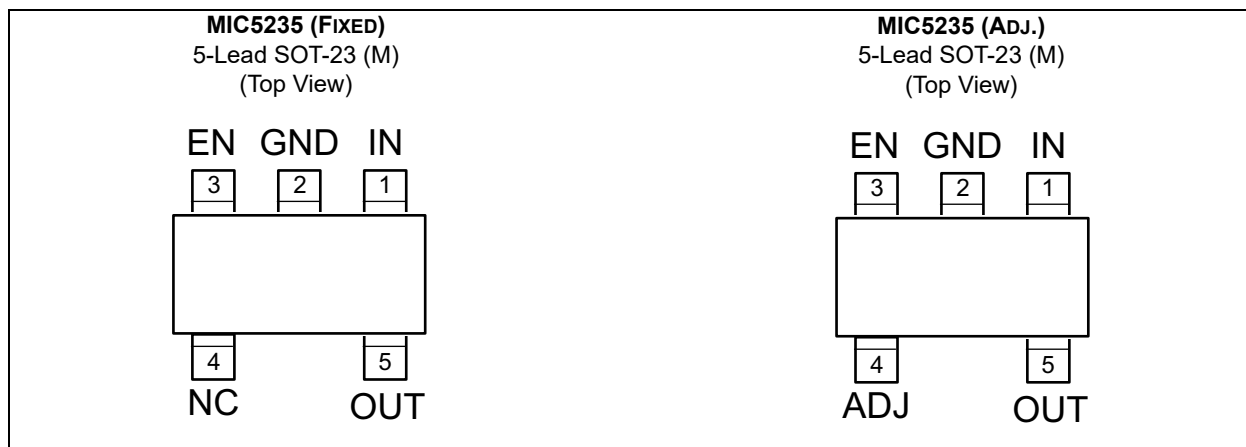
The MIC5235 is a 150 mA highly accurate, low dropout regulator with high input voltage and ultra-low ground current. This combination of high voltage and low ground current makes the MIC5235 ideal for USB and portable electronics applications, using 1-cell, 2-cell, or 3-cell Li-Ion battery inputs.

As a μ Cap LDO design, the MIC5235 is stable with either ceramic or tantalum output capacitor. It only requires a 2.2 μ F capacitor for stability.

Features of the MIC5235 includes enable input, thermal shutdown, current limit, reverse battery protection, and reverse leakage protection.

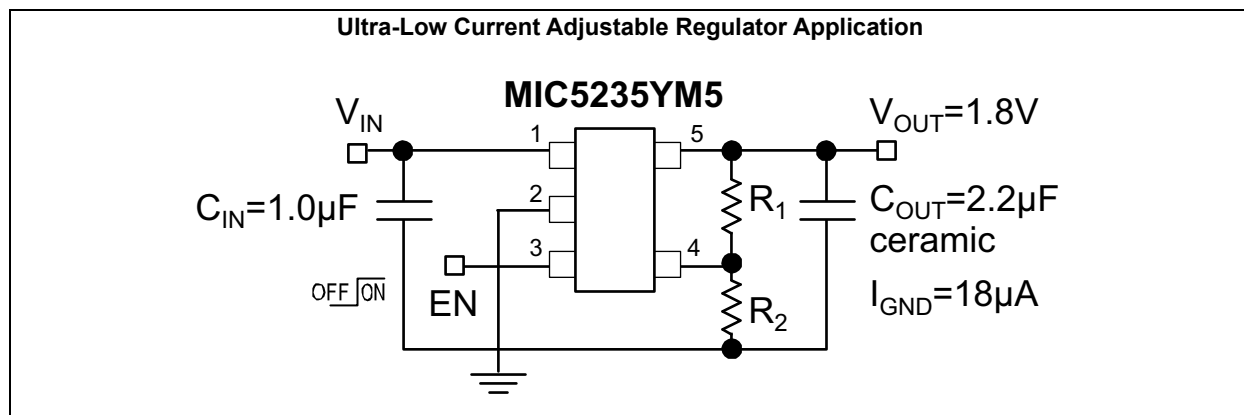
Available in fixed and adjustable output voltage versions, the MIC5235 is offered in the SOT-23-5 package with a junction temperature range of -40°C to $+125^{\circ}\text{C}$.

Package Types

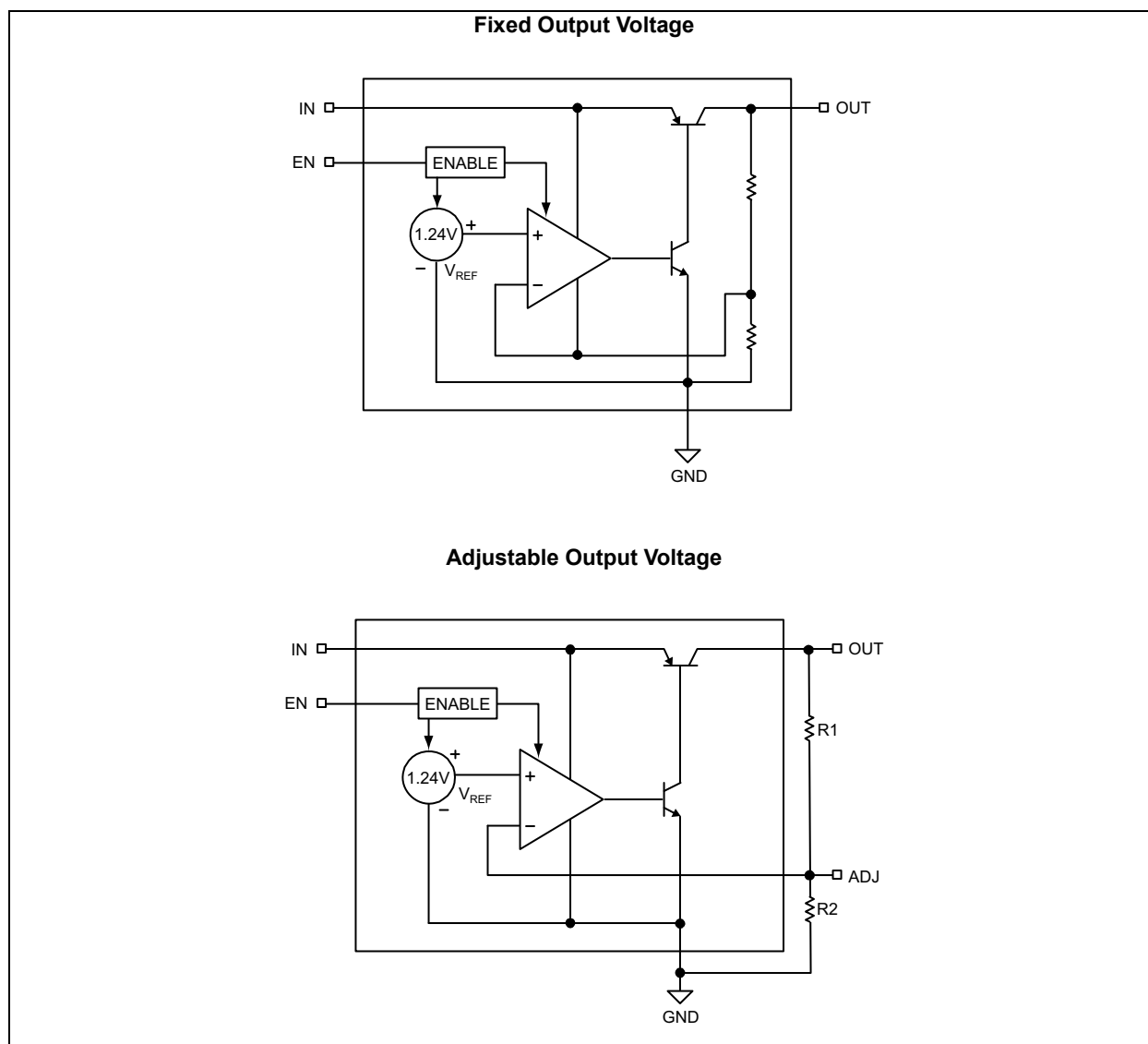


MIC5235

Typical Application Circuit



Functional Block Diagrams



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

Input Supply Voltage	–20V to +38V
Enable Input Voltage	–0.3V to +38V
Power Dissipation	Internally Limited
ESD Rating	Note 1

Operating Ratings ††

Input Supply Voltage	+2.3V to +24V
Enable Input Voltage	0V to +24V

† **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 are recommended. Human body model, 1.5 kΩ in series with 100 pF.

ELECTRICAL CHARACTERISTICS

Electrical Characteristics: $T_A = +25^\circ\text{C}$ with $V_{IN} = V_{OUT} + 1\text{V}$; $I_{OUT} = 100\ \mu\text{A}$, **bold** values valid for $-40^\circ\text{C} \leq T_J \leq +85^\circ\text{C}$, unless noted. [Note 1](#)

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions
Output Voltage Accuracy	V_{OUT}	–1.0	—	1.0	%	Variation from nominal V_{OUT}
		–2.0	—	2.0		
Line Regulation	$\Delta V_{OUT}/V_{OUT}$	—	0.04	—	%	$V_{IN} = V_{OUT} + 1\text{V to } 24\text{V}$
Load Regulation	$\Delta V_{OUT}/V_{OUT}$	—	0.25	1	%	Load = 100 μA to 150 mA
Dropout Voltage	V_{DO}	—	50	—	mV	$I_{OUT} = 100\ \mu\text{A}$
		—	230	300		$I_{OUT} = 50\ \text{mA}$
		—	—	400		$I_{OUT} = 100\ \text{mA}$
		—	270	400		
		—	—	450		$I_{OUT} = 150\ \text{mA}$
		—	310	450		
		—	—	500		
Reference Voltage	V_{REF}	1.22	1.24	1.25	V	—
Ground Current	IGND	—	18	30	μA	$I_{OUT} = 100\ \mu\text{A}$
		—	—	35	μA	—
		—	0.35	0.7	mA	$I_{OUT} = 50\ \text{mA}$
		—	1	2	mA	$I_{OUT} = 100\ \text{mA}$
		—	2	4	mA	$I_{OUT} = 150\ \text{mA}$
Ground Current in Shutdown	I_{SHDN}	—	0.1	1	μA	$V_{EN} \leq 0.6\text{V}$; $V_{IN} = 24\text{V}$
Short-Circuit Current	I_{SC}	—	350	500	μA	$V_{OUT} = 0\text{V}$

Note 1: Specification for packaged product only.

ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Characteristics: $T_A = +25^{\circ}\text{C}$ with $V_{IN} = V_{OUT} + 1\text{V}$; $I_{OUT} = 100\text{ }\mu\text{A}$, **bold** values valid for $-40^{\circ}\text{C} \leq T_J \leq +85^{\circ}\text{C}$, unless noted. [Note 1](#)

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions
Output Leakage, Reverse Polarity Input	I_{LK}	—	-0.1	—	μA	Load = 500Ω , $V_{IN} = -15\text{V}$
Enable Input						
Input Low Voltage	V_{IL}	—	—	0.6	V	Regulator Off
Input High Voltage	V_{IH}	2.0	—	—	V	Regulator On
Enable Input Current	I_{IL}	-1.0	0.01	1.0	μA	$V_{EN} = 0.6\text{V}$; Regulator Off
	I_{IH}	—	0.1	1.0		$V_{EN} = 2.0\text{V}$; Regulator On
		—	0.5	2.5		$V_{EN} = 24\text{V}$; Regulator On

Note 1: Specification for packaged product only.

TEMPERATURE SPECIFICATIONS

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Temperature Ranges						
Junction Temperature Range	T_J	-40	—	+125	$^{\circ}\text{C}$	Note 1
Storage Temperature Range	T_S	-65	—	+150	$^{\circ}\text{C}$	—
Package Thermal Resistance						
Thermal Resistance, SOT-23 5-Ld	θ_{JA}	—	235	—	$^{\circ}\text{C/W}$	—

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}). Exceeding the maximum allowable power dissipation will cause the device operating junction temperature to exceed the maximum $+125^{\circ}\text{C}$ rating. Sustained junction temperatures above $+125^{\circ}\text{C}$ can impact the 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.

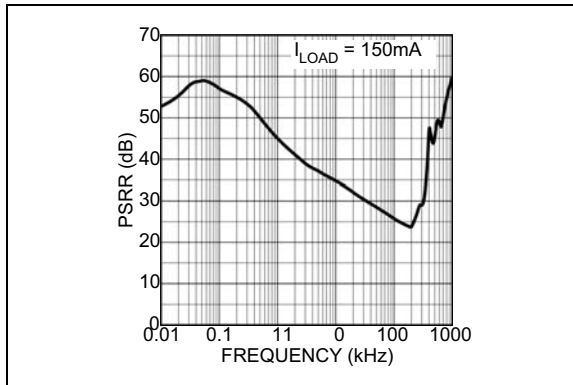


FIGURE 2-1: Power Supply Rejection Ratio.

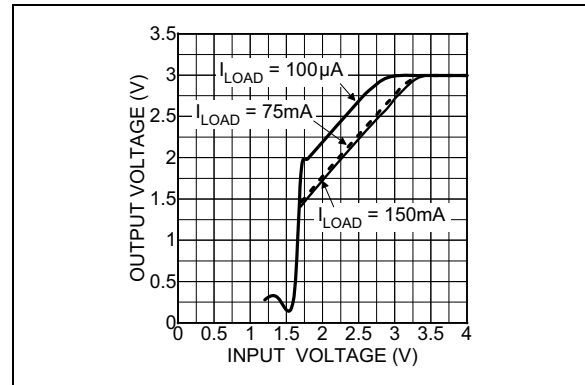


FIGURE 2-4: Dropout Characteristics.

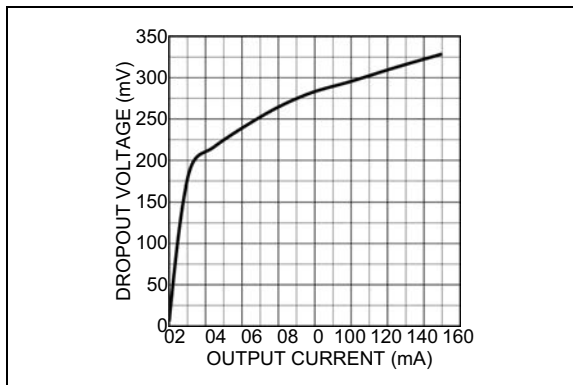


FIGURE 2-2: Dropout Voltage vs. Output Current.

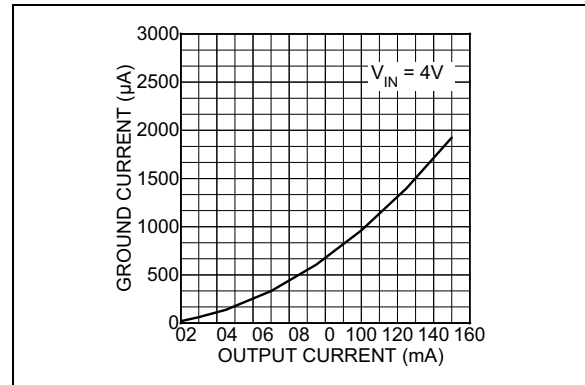


FIGURE 2-5: Ground Pin Current vs. Output Current.

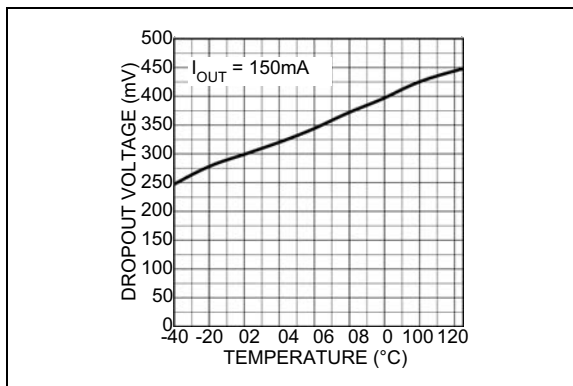


FIGURE 2-3: Dropout Voltage vs. Temperature.

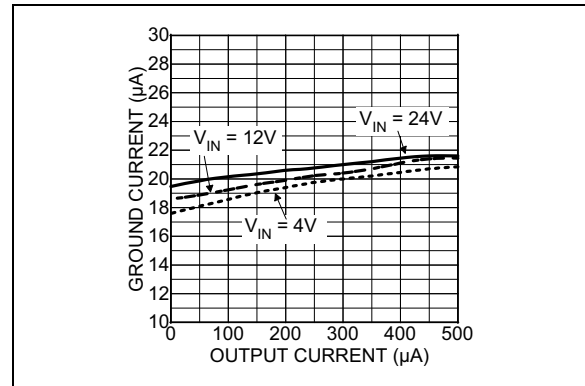


FIGURE 2-6: Ground Pin Current vs. Output Current.

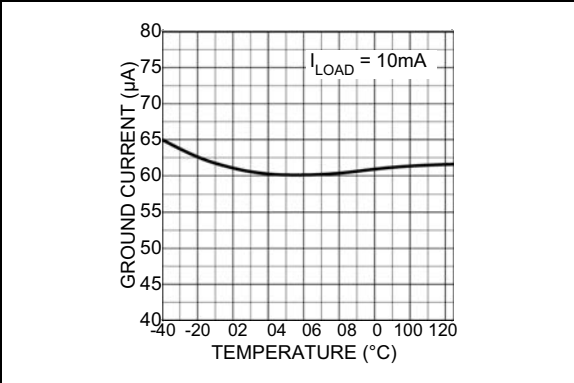


FIGURE 2-7: Ground Pin Current vs. Temperature.

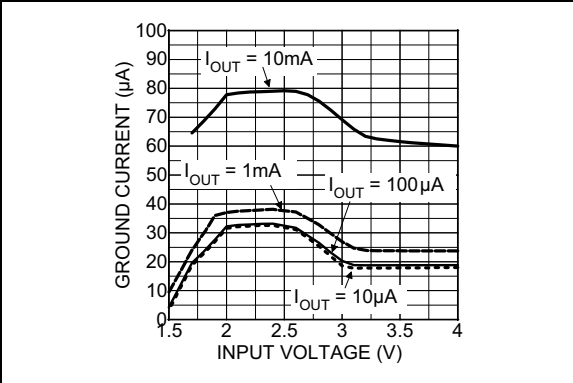


FIGURE 2-10: Ground Pin Current vs Input Voltage.

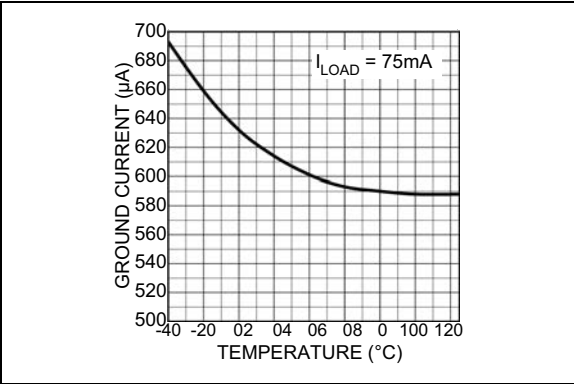


FIGURE 2-8: Ground Pin Current vs. Temperature.

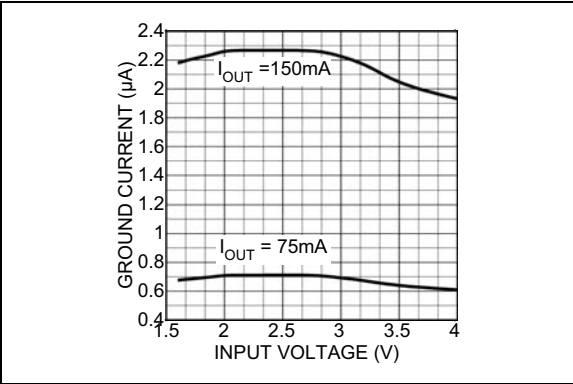


FIGURE 2-11: Ground Pin Current vs. Input Voltage.

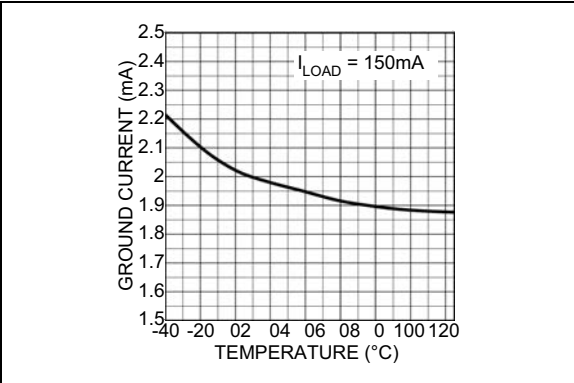


FIGURE 2-9: Ground Pin Current vs. Temperature.

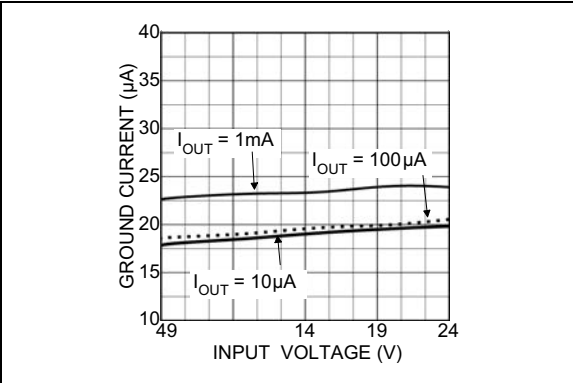


FIGURE 2-12: Ground Pin Current vs. Input Voltage.

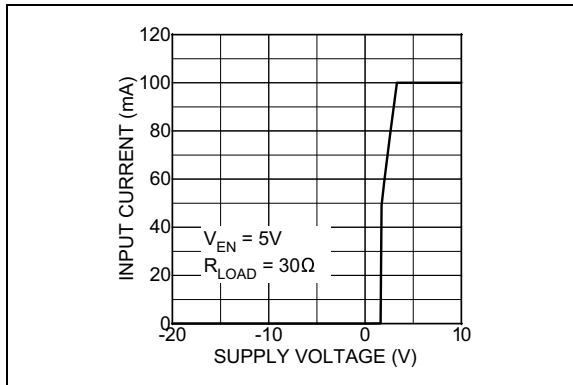


FIGURE 2-13: Input Current vs. Supply Voltage.

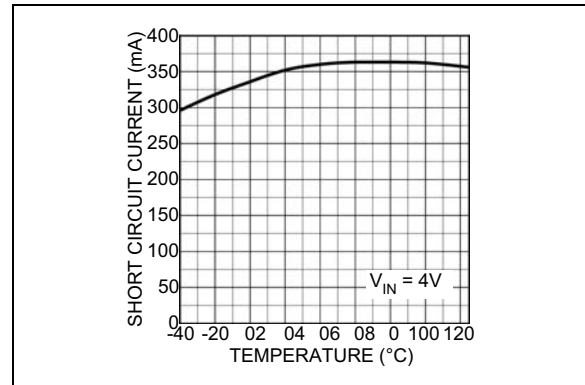


FIGURE 2-16: Short-Circuit Current vs. Temperature.

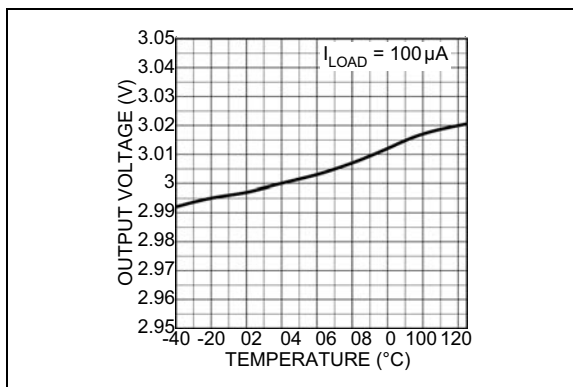


FIGURE 2-14: Output Voltage vs. Temperature.

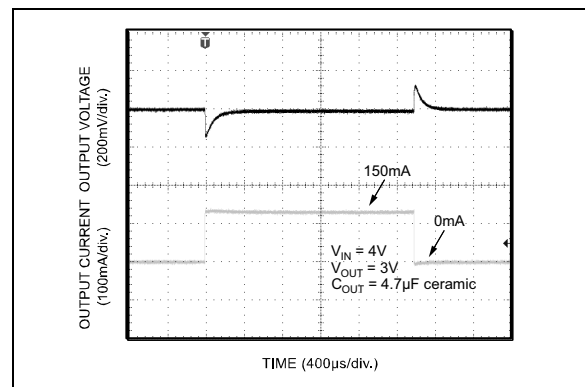


FIGURE 2-17: Load Transient Response.

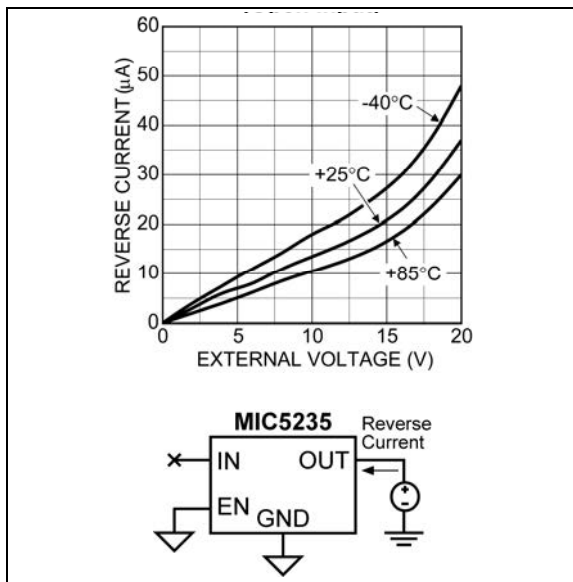


FIGURE 2-15: Reverse Current (Open Input).

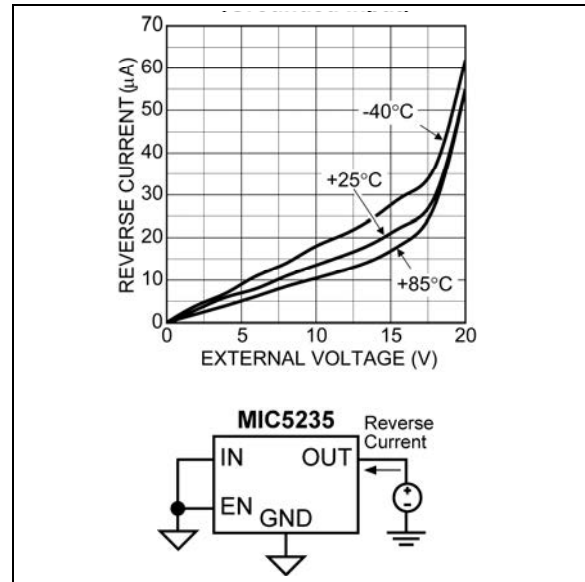


FIGURE 2-18: Reverse Current (Grounded Input).

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.
4	NC (fixed)	No connect.
	ADJ (adj)	Adjust (input): Feedback input. Connect to resistive voltage-divider network.
5	OUT	Regulator output.

4.0 APPLICATION INFORMATION

4.1 Enable/Shutdown

The MIC5235 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 Capacitor

The MIC5235 has high input voltage capability, up to 24V. 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 MIC5235 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 3 Ω . 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 MIC5235 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 MIC5235 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 an example of the junction-to-ambient thermal resistance for the MIC5235.

The actual power dissipation of the regulator circuit can be determined with 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 MIC5235-3.0YM5 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:

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

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. Because the MIC5235 was designed to operate with high input voltages, careful consideration must be given so as not to overheat the device. With very high input-to-output voltage differentials, the output power is limited by the total power dissipation. Total power dissipation is calculated using the following equation:

EQUATION 4-4:

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

Due to the potential for input voltages up to 24V, ground current must be taken into consideration. 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 mW.

EQUATION 4-5:

$$319mW = (V_{IN} - 3V) \times 150mA + V_{IN} \times 2.8mA$$

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

EQUATION 4-6:

$$769mW = V_{IN} \times 152.8mA$$

$$V_{IN} = 5.03V$$

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:

$$319mW = (V_{IN} - 3V) \times 20mA + V_{IN} \times 0.2mA$$

$$319mW = V_{IN} \times 20.2mA$$

$$V_{IN} = 18.8V$$

Maximum input voltage for a 20 mA load current at +50°C ambient temperature is 18.8V, utilizing virtually the entire operating voltage range of the device.

4.6 Adjustable Regulator Application

The MIC5235YM5 can be adjusted from 1.24V to 20V by using two external resistors (Figure 4-1). The resistors set the output voltage based on the following equation:

EQUATION 4-8:

$$V_{OUT} = V_{REF} \times \left(1 + \frac{R_1}{R_2}\right)$$

Where:

$V_{REF} = 1.24V$

Feedback resistor R2 should be no larger than 300 kΩ.

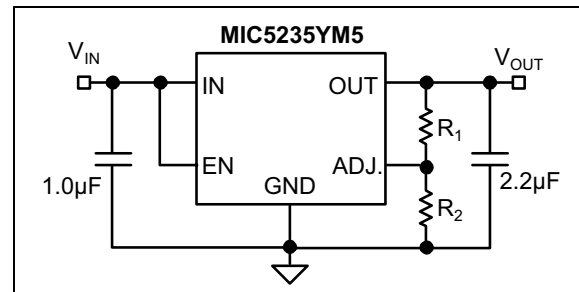


FIGURE 4-1: Adjustable Voltage Application.

5.0 PACKAGING INFORMATION

5.1 Package Marking Information

5-Lead SOT-23*

XXXX NNN

Example

<u>L</u>218 792

TABLE 5-1: MARKING CODES

Part Number	Marking Code	Voltage
MIC5235-1.5YM5	<u>L</u> 215	1.5V
MIC5235-1.8YM5	<u>L</u> 218	1.8V
MIC5235-2.5YM5	<u>L</u> 225	2.5V
MIC5235-2.7YM5	<u>L</u> 227	2.7V
MIC5235-2.8YM5	<u>L</u> 228	2.8V
MIC5235-3.0YM5	<u>L</u> 230	3.0V
MIC5235-3.3YM5	<u>L</u> 233	3.3V
MIC5235-5.0YM5	<u>L</u> 250	5.0V
MIC5235YM5	<u>L</u> 2AA	Adjustable

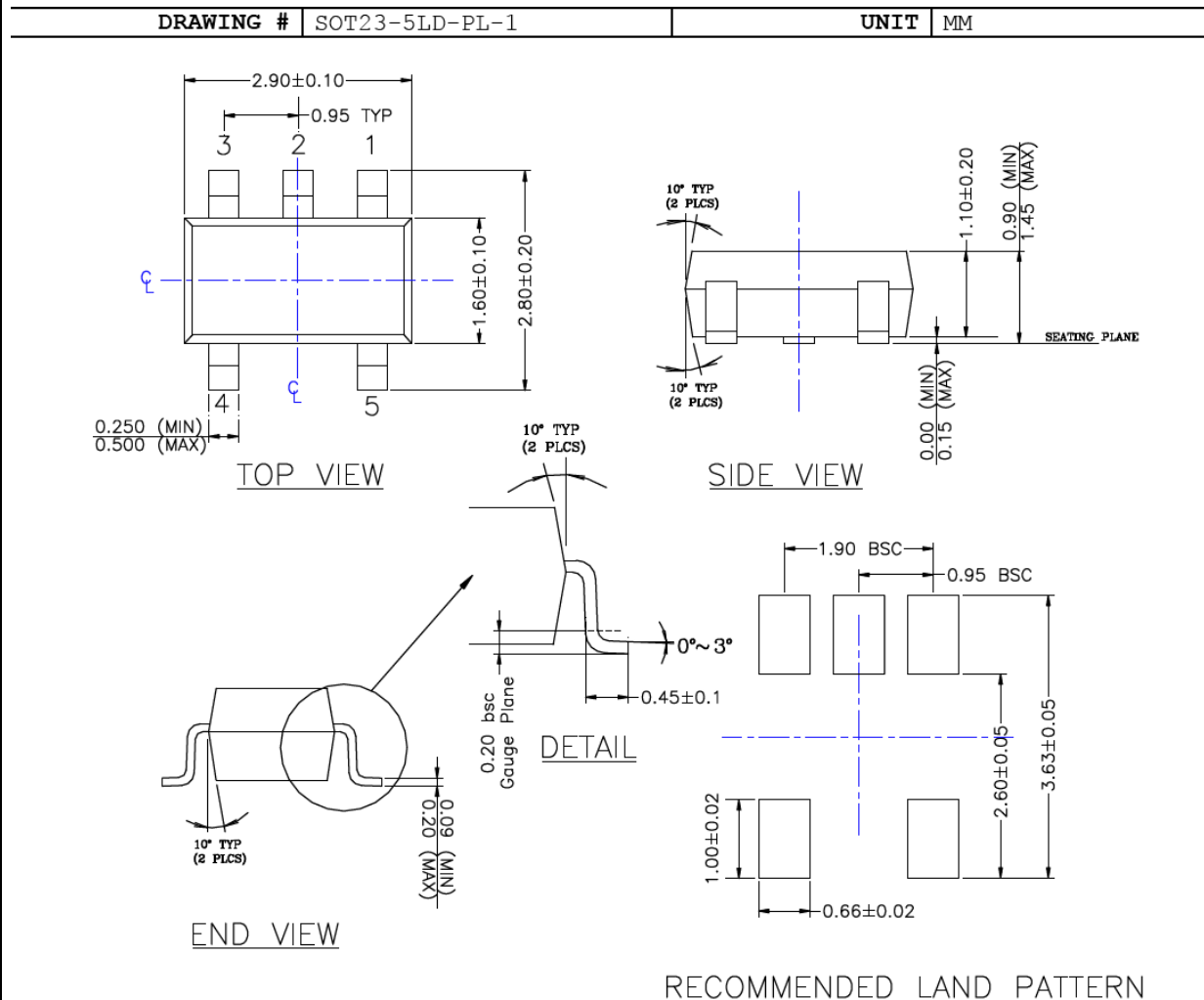
Legend: XX...X Product code or customer-specific information
Y Year code (last digit of calendar year)
YY Year code (last 2 digits of calendar year)
WW Week code (week of January 1 is week '01')
NNN Alphanumeric traceability code
(e3) Pb-free JEDEC® designator for Matte Tin (Sn)
* This package is Pb-free. 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.

5-Lead SOT-23 Package Outline and Recommended Land Pattern

TITLE

5 LEAD SOT23 PACKAGE OUTLINE & RECOMMENDED LAND PATTERN



- NOTE:
1. PACKAGE OUTLINE EXCLUSIVE OF MOLD FLASH & BURR.
 2. PACKAGE OUTLINE INCLUSIVE OF SOLDER PLATING.
 3. DIMENSION AND TOLERANCE PER ANSI Y14.5M, 1982.
 4. FOOT LENGTH MEASUREMENT BASED ON GAUGE PLANE METHOD.
 5. DIE FACES UP FOR MOLD, AND FACES DOWN FOR TRIM/FORM.
 6. ALL DIMENSIONS ARE IN MILLIMETERS.

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

APPENDIX A: REVISION HISTORY

Revision A (October 2021)

- Converted Micrel document MIC5235 to Microchip data sheet template DS20006603A.
- Minor grammatical text changes throughout.

MIC5235

NOTES:

PRODUCT IDENTIFICATION SYSTEM

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

<u>Device</u>	<u>-X.X</u>	<u>X</u>	<u>XX</u>	<u>-XX</u>
Part No.	Output Voltage	Temp. Range	Package	Media Type
Device: MIC5235: Ultra-Low Quiescent Current, 150 mA μ Cap LDO Regulator				
Output Voltage: 1.5 = 1.5V 1.8 = 1.8V 1.5 = 2.5V 2.7 = 2.7V 2.8 = 2.8V 3.0 = 3.3V 3.3 = 3.3V 5.0 = 5.0V <blank>= Adjustable				
Temperature Range: Y = -40°C to +125°C				
Package: M5 = 5-Lead SOT-23				
Media Type: TX = 3,000/Reverse Tape & Reel TR = 3,000/Reel				
Examples: a) MIC5235-1.5YM5-TR: MIC5235, 1.5V Output Voltage, -40°C to +125°C, 5-Lead SOT-23, 3,000/Reel b) MIC5235YM5-TR: MIC5235, Adjustable Output Voltage, -40°C to +125°C, 5-Lead SOT-23, 3,000/Reel c) MIC5235-2.5YM5-TR: MIC5235, 2.5V Output Voltage, -40°C to +125°C, 5-Lead SOT-23, 3,000/Reel d) MIC5235-3.3YM5-TX: MIC5235, 3.3V Output Voltage, -40°C to +125°C, 5-Lead SOT-23, 3,000/Reverse TR e) MIC5235-5.0YM5-TR: MIC5235, 5.0V Output Voltage, -40°C to +125°C, 5-Lead SOT-23, 3,000/Reel f) MIC5235-1.8YM5-TX: MIC5235, 1.8V Output Voltage, -40°C to +125°C, 5-Lead SOT-23, 3,000/Reverse TR 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.				

MIC5235

NOTES:

Note the following details of the code protection feature on Microchip products:

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