MIC5235

Ultra-Low Quiescent Current, 150 mA µCap LDO Regulator

Features

- Wide Input Voltage Range: 2.3V to 24V
- Ultra-Low Ground Current: 18 µA
- 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 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.

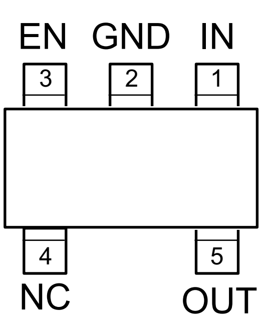
As a µCap LDO design, the MIC5235 is stable with either ceramic or tantalum output capacitor. It only requires a 2.2 µF capacitor for stability.

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

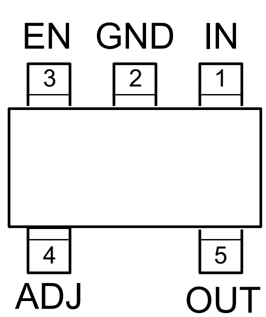
Available in fixed and adjustable output voltage versions, the MIC5235 is offered in the SOT-23-5 package with a junction temperature range of –40°C to +125°C.

Package Types

MIC5235 (FIXED)
5-Lead SOT-23 (M)
(Top View)

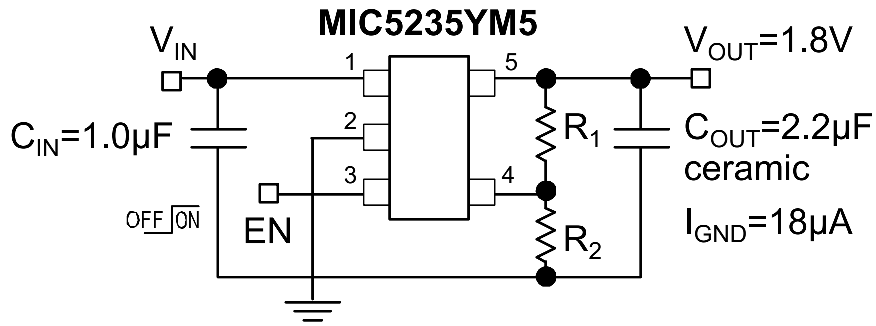


MIC5235 (ADJ.)
5-Lead SOT-23 (M)
(Top View)



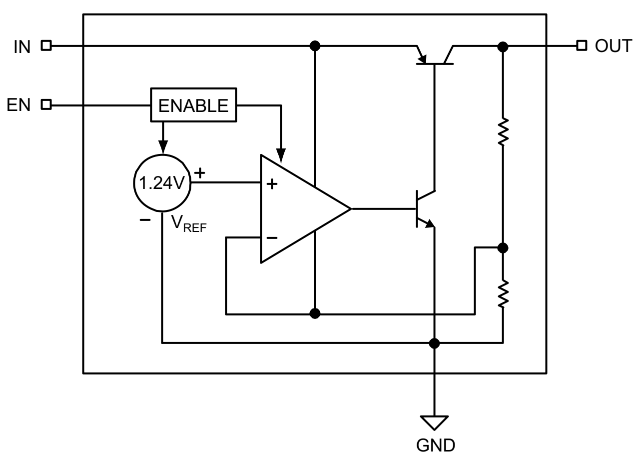
Typical Application Circuit

Ultra-Low Current Adjustable Regulator Application

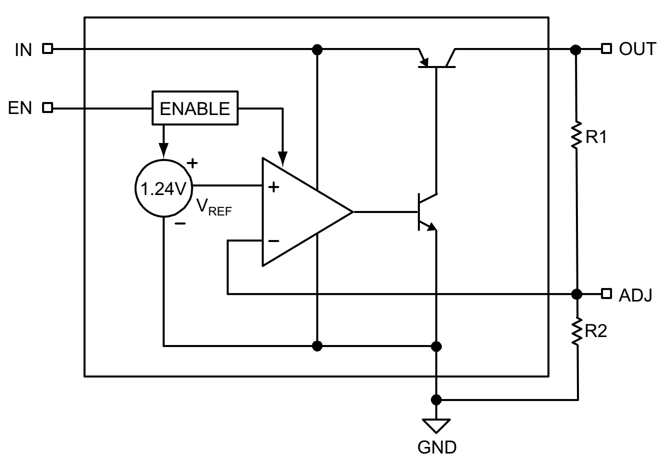


Functional Block Diagrams

Fixed Output Voltage



Adjustable Output Voltage



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°C with $V_{IN} = V_{OUT}$ + 1V; I_{OUT} = 100 µA, **bold** values valid for –40°C ≤ T_J ≤ +85°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	—	%	$V_{IN} = V_{OUT}$ + 1V to 24V
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 µA
		—	230	300		I_{OUT} = 50 mA
		—	—	**400**		
		—	270	400		I_{OUT} = 100 mA
		—	—	**450**		
		—	310	450		I_{OUT} = 150 mA
		—	—	**500**		
Reference Voltage	V_{REF}	1.22	1.24	1.25	V	—
Ground Current	IGND	—	18	30	µA	I_{OUT} = 100 µA
		—	—	**35**	µA	—
		—	0.35	0.7	mA	I_{OUT} = 50 mA
		—	1	2	mA	I_{OUT} = 100 mA
		—	2	4	mA	I_{OUT} = 150 mA
Ground Current in Shutdown	I_{SHDN}	—	0.1	1	µA	V_{EN} ≤ 0.6V; V_{IN} = 24V
Short-Circuit Current	I_{SC}	—	350	**500**	µA	V_{OUT} = 0V

Note 1: Specification for packaged product only.

ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Characteristics: T_A = +25°C with $V_{IN} = V_{OUT}$ + 1V; I_{OUT} = 100 µA, **bold** values valid for –40°C ≤ T_J ≤ +85°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} = –15V
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} = 0.6V; Regulator Off
	I_{IH}	—	0.1	1.0		V_{EN} = 2.0V; Regulator On
		—	0.5	2.5		V_{EN} = 24V; 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	°C	Note 1
Storage Temperature Range	T_S	–65	—	+150	°C	—
Package Thermal Resistance						
Thermal Resistance, SOT-23 5-Ld	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}). Exceeding the maximum allowable power dissipation will cause the device operating junction temperature to exceed the maximum +125°C rating. Sustained junction temperatures above +125°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.

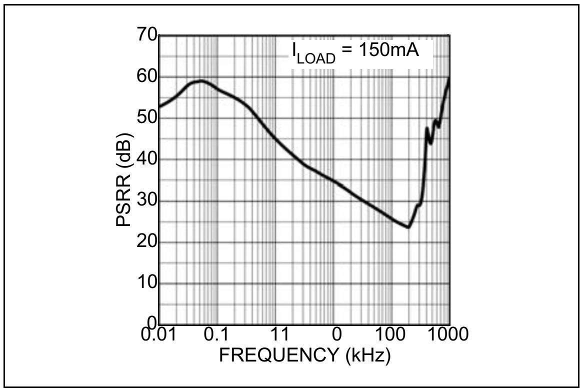


FIGURE 2-1: *Power Supply Rejection Ratio.*

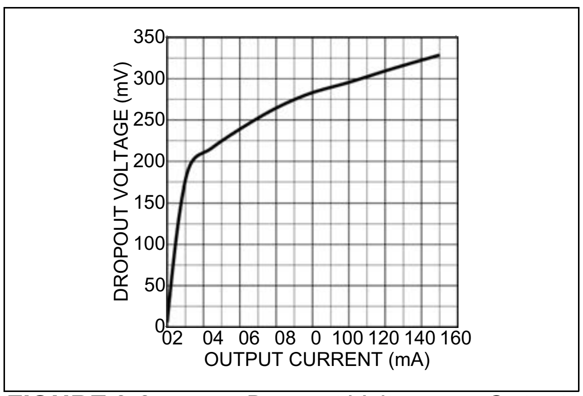


FIGURE 2-2: *Dropout Voltage vs. Output Current.*

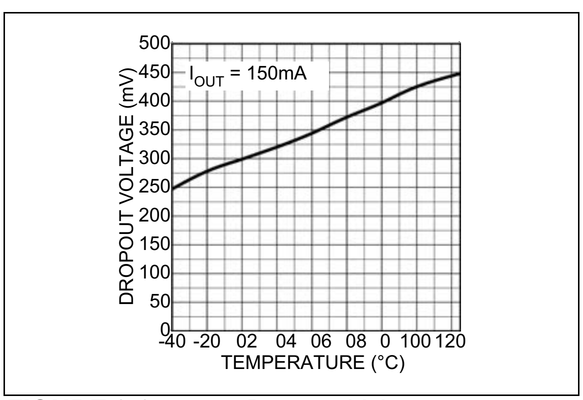


FIGURE 2-3: *Dropout Voltage vs. Temperature.*

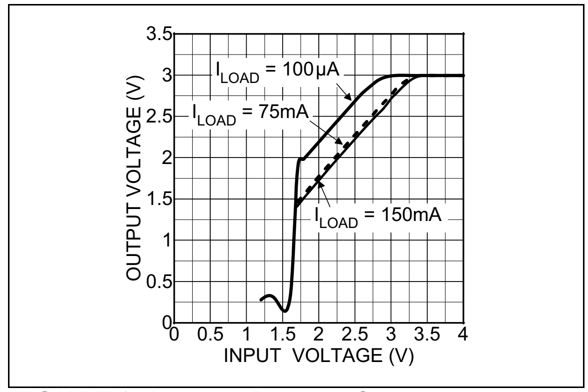


FIGURE 2-4: *Dropout Characteristics.*

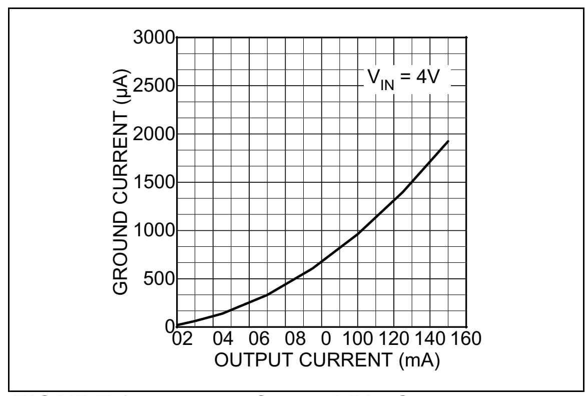


FIGURE 2-5: *Ground Pin Current vs. Output Current.*

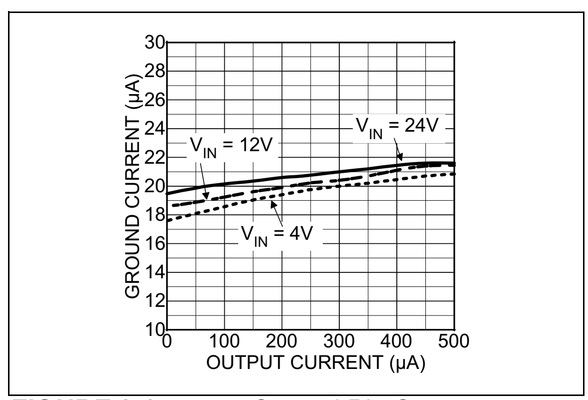


FIGURE 2-6: *Ground Pin Current vs. Output Current.*

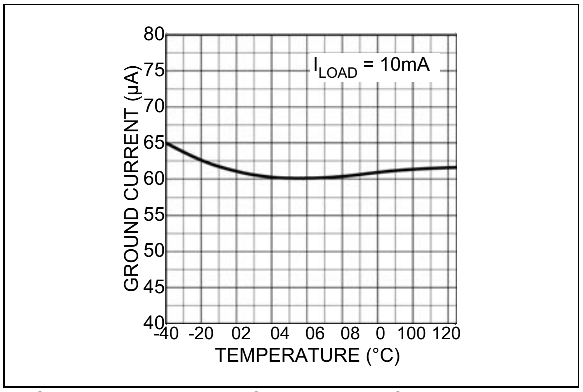


FIGURE 2-7: *Ground Pin Current vs. Temperature.*

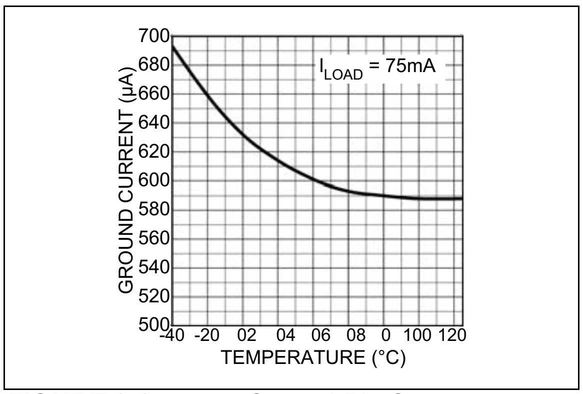


FIGURE 2-8: *Ground Pin Current vs. Temperature.*

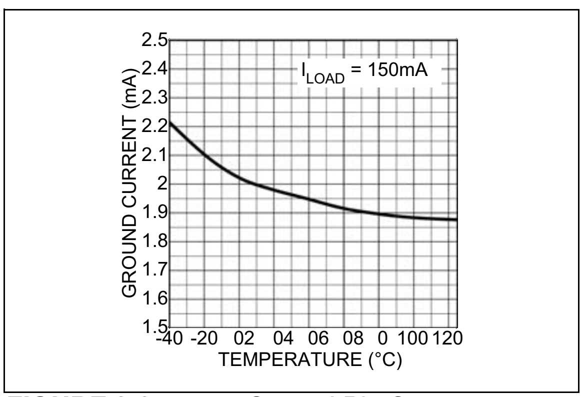


FIGURE 2-9: *Ground Pin Current vs. Temperature.*

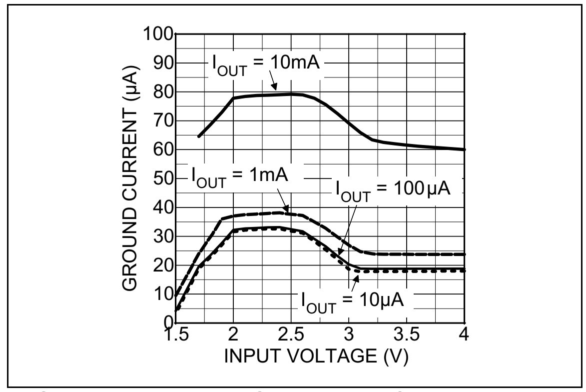


FIGURE 2-10: *Ground Pin Current vs Input Voltage.*

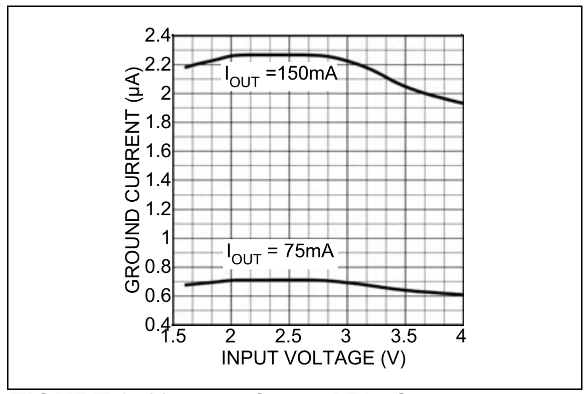


FIGURE 2-11: *Ground Pin Current vs. Input Voltage.*

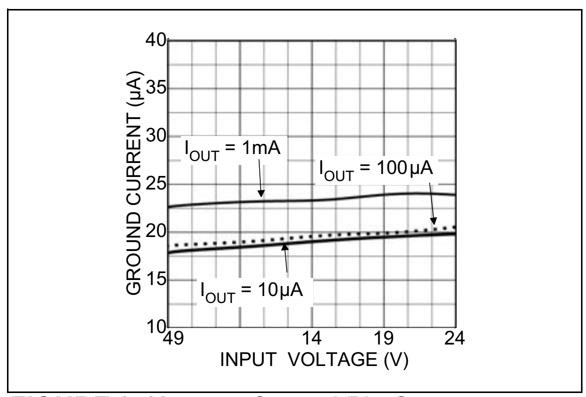


FIGURE 2-12: *Ground Pin Current vs. Input Voltage.*

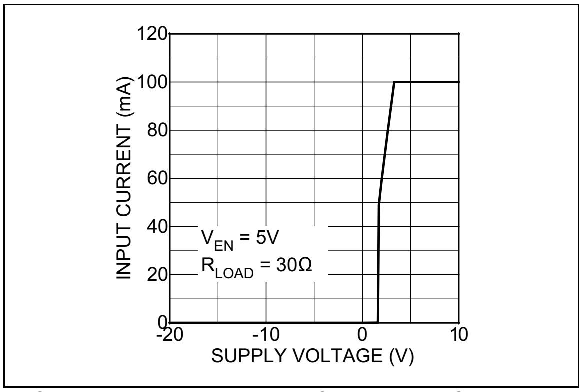


FIGURE 2-13: *Input Current vs. Supply Voltage.*

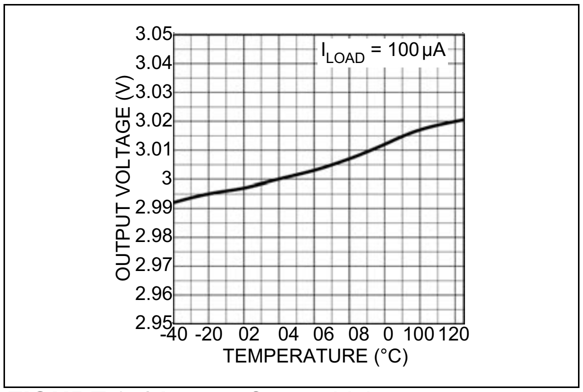


FIGURE 2-14: *Output Voltage vs. Temperature.*

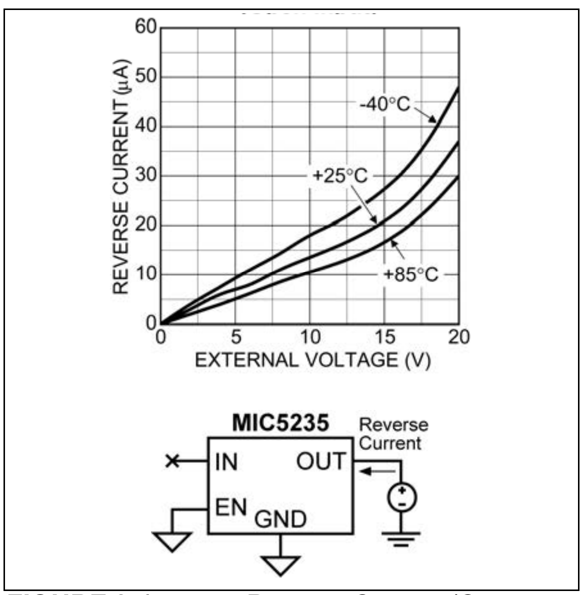


FIGURE 2-15: *Reverse Current (Open Input).*

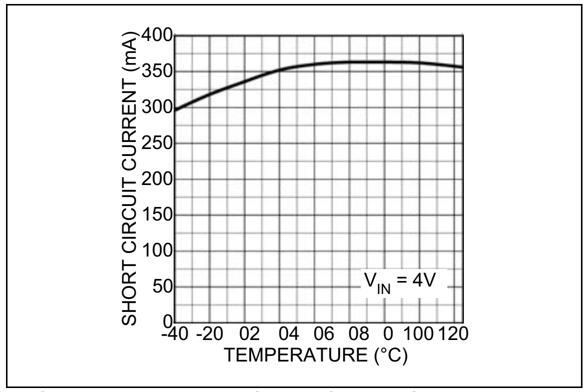


FIGURE 2-16: *Short-Circuit Current vs. Temperature.*

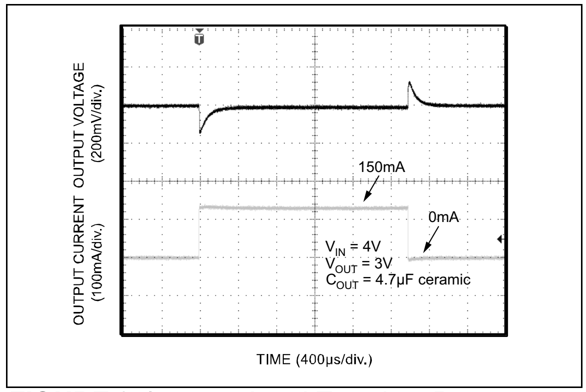


FIGURE 2-17: *Load Transient Response.*

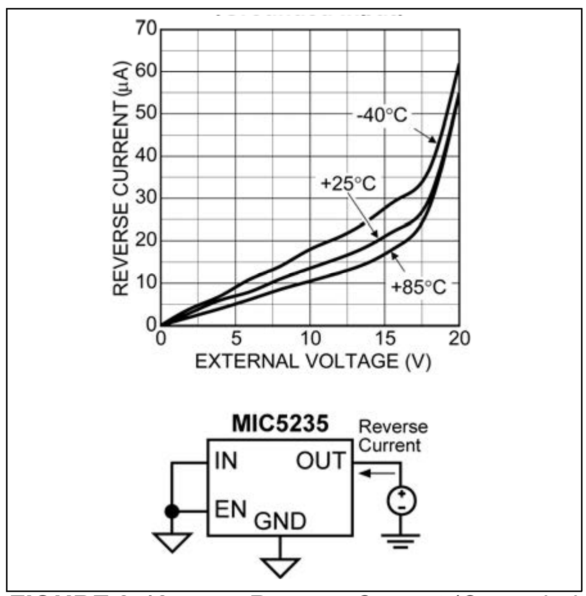


FIGURE 2-18: *Reverse Current (Grounded Input).*

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 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 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:

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

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. 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 current 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 mV.

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:

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

Where:
V_{REF} = 1.24V

Feedback resistor R2 should be no larger than 300 kΩ.

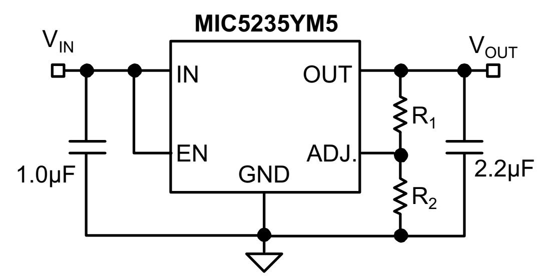


FIGURE 4-1: Adjustable Voltage Application.

5.0 PACKAGING INFORMATION

5.1 Package Marking Information

5-Lead SOT-23*	Example
XXXX NNN	L218 792

TABLE 5-1: MARKING CODES

Part Number	Marking Code	Voltage
MIC5235-1.5YM5	L215	1.5V
MIC5235-1.8YM5	L218	1.8V
MIC5235-2.5YM5	L225	2.5V
MIC5235-2.7YM5	L227	2.7V
MIC5235-2.8YM5	L228	2.8V
MIC5235-3.0YM5	L230	3.0V
MIC5235-3.3YM5	L233	3.3V
MIC5235-5.0YM5	L250	5.0V
MIC5235YM5	L2AA	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).

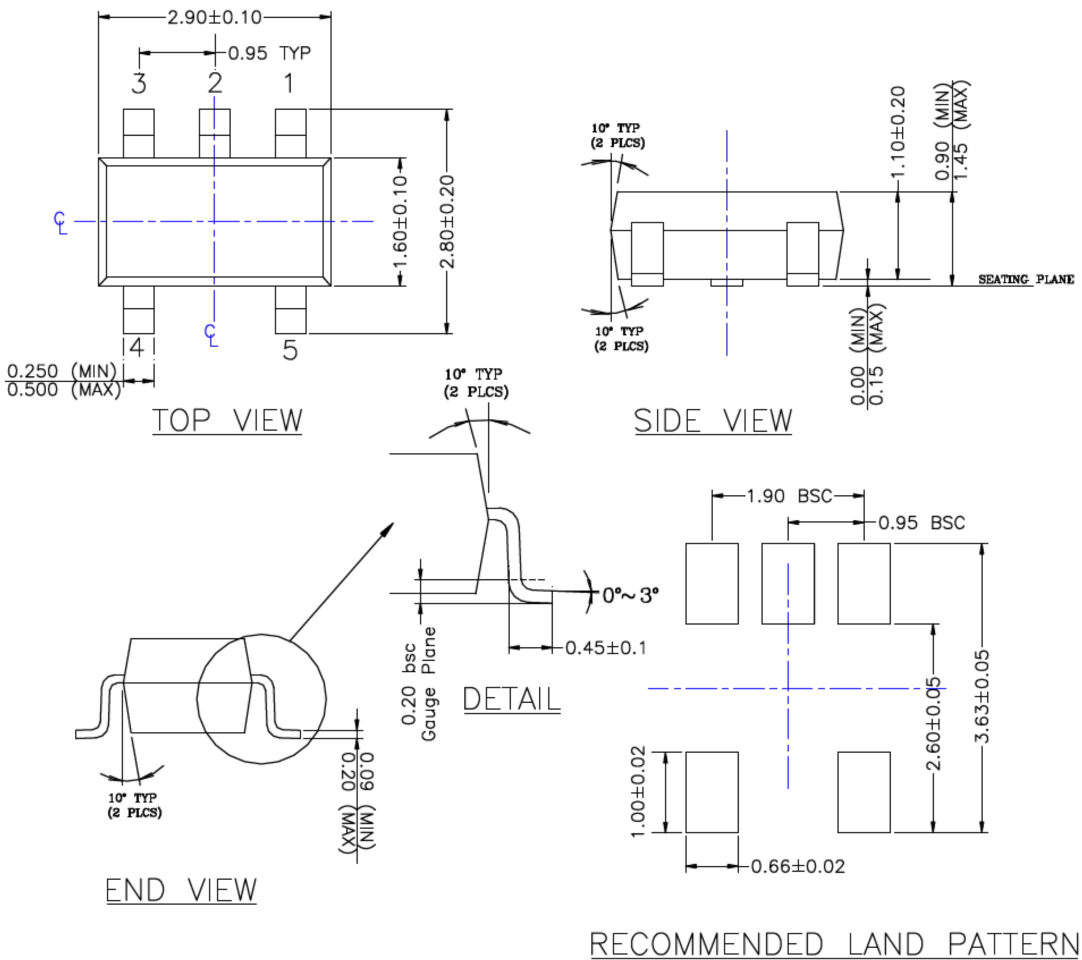
Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information. Package may or may not include the corporate logo.

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

DRAWING #	SOT23-5LD-PL-1	UNIT	MM



NOTE:
1. PACKAGE OUTLINE EXCLUSIVE OF MOLD FLASH & BURR.
2. PACKAGE OUTLINE INCLUSIVE OF SOLER 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.

NOTES:

PRODUCT IDENTIFICATION SYSTEM

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

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

Device:	MIC5235:	Ultra-Low Quiescent Current, 150 mA µCap 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.

NOTES:

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

- Microchip products meet the specifications contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is secure when used in the intended manner, within operating specifications, and under normal conditions.
- Microchip values and aggressively protects its intellectual property rights. Attempts to breach the code protection features of Microchip product is strictly prohibited and may violate the Digital Millennium Copyright Act.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of its code. Code protection does not mean that we are guaranteeing the product is “unbreakable”. Code protection is constantly evolving. Microchip is committed to continuously improving the code protection features of our products.

For information regarding Microchip’s Quality Management Systems, please visit www.microchip.com/quality.

Trademarks

ISBN: 978-1-5224-9212-2

Worldwide Sales and Service

AMERICAS

Corporate Office
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7200
Fax: 480-792-7277
Technical Support:
http://www.microchip.com/support
Web Address:
www.microchip.com

Atlanta
Duluth, GA
Tel: 678-957-9614
Fax: 678-957-1455

Austin, TX
Tel: 512-257-3370

Boston
Westborough, MA
Tel: 774-760-0087
Fax: 774-760-0088

Chicago
Itasca, IL
Tel: 630-285-0071
Fax: 630-285-0075

Dallas
Addison, TX
Tel: 972-818-7423
Fax: 972-818-2924

Detroit
Novi, MI
Tel: 248-848-4000

Houston, TX
Tel: 281-894-5983

Indianapolis
Noblesville, IN
Tel: 317-773-8323
Fax: 317-773-5453
Tel: 317-536-2380

Los Angeles
Mission Viejo, CA
Tel: 949-462-9523
Fax: 949-462-9608
Tel: 951-273-7800

Raleigh, NC
Tel: 919-844-7510

New York, NY
Tel: 631-435-6000

San Jose, CA
Tel: 408-735-9110
Tel: 408-436-4270

Canada - Toronto
Tel: 905-695-1980
Fax: 905-695-2078

ASIA/PACIFIC

Australia - Sydney
Tel: 61-2-9868-6733

China - Beijing
Tel: 86-10-8569-7000

China - Chengdu
Tel: 86-28-8665-5511

China - Chongqing
Tel: 86-23-8980-9588

China - Dongguan
Tel: 86-769-8702-9880

China - Guangzhou
Tel: 86-20-8755-8029

China - Hangzhou
Tel: 86-571-8792-8115

China - Hong Kong SAR
Tel: 852-2943-5100

China - Nanjing
Tel: 86-25-8473-2460

China - Qingdao
Tel: 86-532-8502-7355

China - Shanghai
Tel: 86-21-3326-8000

China - Shenyang
Tel: 86-24-2334-2829

China - Shenzhen
Tel: 86-755-8864-2200

China - Suzhou
Tel: 86-186-6233-1526

China - Wuhan
Tel: 86-27-5980-5300

China - Xian
Tel: 86-29-8833-7252

China - Xiamen
Tel: 86-592-2388138

China - Zhuhai
Tel: 86-756-3210040

ASIA/PACIFIC

India - Bangalore
Tel: 91-80-3090-4444

India - New Delhi
Tel: 91-11-4160-8631

India - Pune
Tel: 91-20-4121-0141

Japan - Osaka
Tel: 81-6-6152-7160

Japan - Tokyo
Tel: 81-3-6880- 3770

Korea - Daegu
Tel: 82-53-744-4301

Korea - Seoul
Tel: 82-2-554-7200

Malaysia - Kuala Lumpur
Tel: 60-3-7651-7906

Malaysia - Penang
Tel: 60-4-227-8870

Philippines - Manila
Tel: 63-2-634-9065

Singapore
Tel: 65-6334-8870

Taiwan - Hsin Chu
Tel: 886-3-577-8366

Taiwan - Kaohsiung
Tel: 886-7-213-7830

Taiwan - Taipei
Tel: 886-2-2508-8600

Thailand - Bangkok
Tel: 66-2-694-1351

Vietnam - Ho Chi Minh
Tel: 84-28-5448-2100

EUROPE

Austria - Wels
Tel: 43-7242-2244-39
Fax: 43-7242-2244-393

Denmark - Copenhagen
Tel: 45-4485-5910
Fax: 45-4485-2829

Finland - Espoo
Tel: 358-9-4520-820

France - Paris
Tel: 33-1-69-53-63-20
Fax: 33-1-69-30-90-79

Germany - Garching
Tel: 49-8931-9700

Germany - Haan
Tel: 49-2129-3766400

Germany - Heilbronn
Tel: 49-7131-72400

Germany - Karlsruhe
Tel: 49-721-625370

Germany - Munich
Tel: 49-89-627-144-0
Fax: 49-89-627-144-44

Germany - Rosenheim
Tel: 49-8031-354-560

Israel - Ra'anana
Tel: 972-9-744-7705

Italy - Milan
Tel: 39-0331-742611
Fax: 39-0331-466781

Italy - Padova
Tel: 39-049-7625286

Netherlands - Drunen
Tel: 31-416-690399
Fax: 31-416-690340

Norway - Trondheim
Tel: 47-7288-4388

Poland - Warsaw
Tel: 48-22-3325737

Romania - Bucharest
Tel: 40-21-407-87-50

Spain - Madrid
Tel: 34-91-708-08-90
Fax: 34-91-708-08-91

Sweden - Gothenberg
Tel: 46-31-704-60-40

Sweden - Stockholm
Tel: 46-8-5090-4654

UK - Wokingham
Tel: 44-118-921-5800
Fax: 44-118-921-5820