MICROCHIP

MIC5233

High Input Voltage, Low I_Q µCap LDO Regulator

Features

- AEC-Q100 Qualified and PPAP Capable; Available for 5-Lead SOT23 Package Only
- Wide Input Voltage Range: 2.3V to 36V
- Ultra-Low Ground Current: 18 µA
- Low Dropout Voltage of 270 mV at 100 mA
- High Output Accuracy of ±2.0% Overtemperature
- µCap: Stable with Ceramic or Tantalum Capacitors
- Excellent Line and Load Regulation Specifications
- Near Zero Shutdown Current: Typical 0.1 µA
- Reverse Battery Protection
- Reverse Leakage Protection
- Thermal Shutdown and Current Limit Protection
- 5-Lead SOT23 and 3-Lead SOT223 Packages

Applications

- Keep-Alive Supply in Notebook and Portable Computers
- USB Power Supply
- Logic Supply for High-Voltage Batteries
- Automotive Electronics
- Battery-Powered Systems
- 3-4 Cell Li-Ion Battery Input Range

General Description

The MIC5233 is a 100 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 MIC5233 ideal for multicell Li-Ion battery systems.

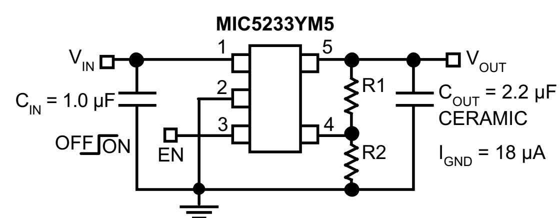
A µCap LDO design, the MIC5233 is stable with either ceramic or tantalum output capacitors. It only requires a 2.2 µF output capacitor for stability.

Features of the MIC5233 include enable input, thermal shutdown, current limit and reverse battery protection, and reverse leakage protection.

Available in fixed and adjustable output voltage versions, the MIC5233 is offered in the 5-lead SOT23 and 3-lead SOT223 packages with a junction temperature range of –40°C to +125°C.

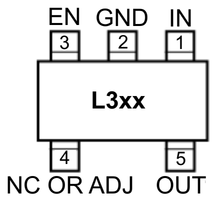
Typical Application Circuit

Ultra-Low Current Adjustable Regulator Application

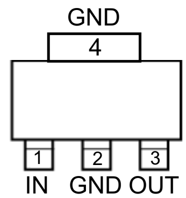


Package Types

MIC5233
5-Pin SOT23
(Top View)

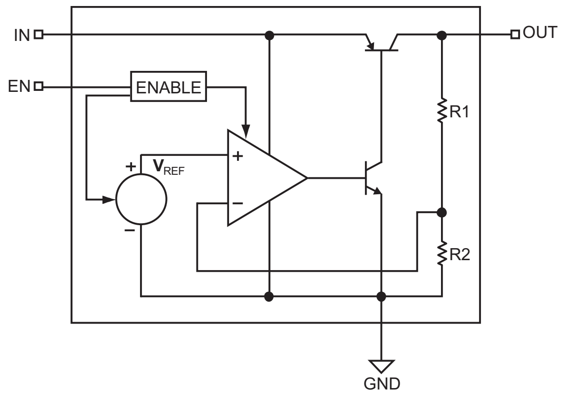


MIC5233
3-Pin SOT223
(Top View)

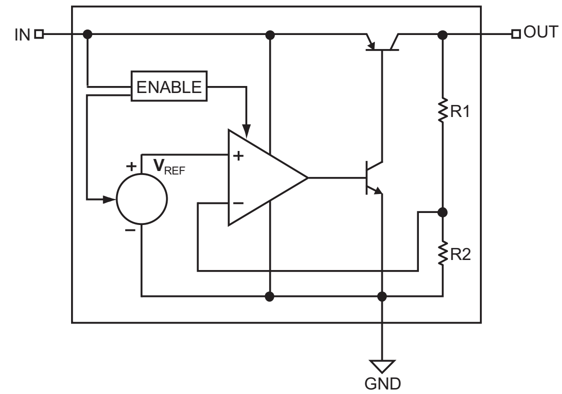


Functional Block Diagrams

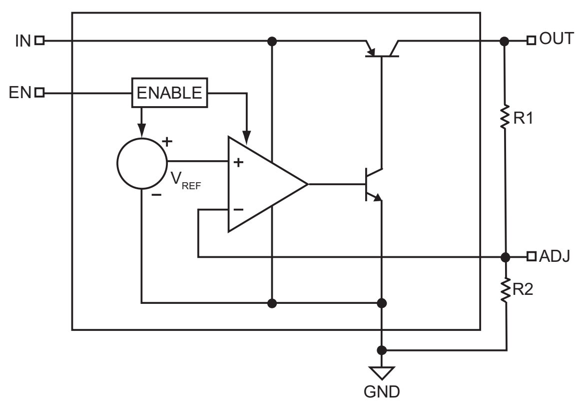
Fixed Output Voltage (SOT23 Package)



Fixed Output Voltage (SOT223 Package)



Adjustable Output Voltage
(SOT223 and SOT23 Packages)



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings†

Input Supply Voltage (V_{IN})..–20V to +38V
Enable Input Voltage (V_{EN})..–0.3V to +38V
Power Dissipation (P_{DIS})..Internally Limited
ESD Rating (**Note 1**)..ESD Sensitive

Operating Ratings‡

Input Supply Voltage (V_{IN})..+2.3V to +36V
Enable Input Voltage (V_{EN})..0V to +36V

† **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. Specifications are for packaged product only.

‡ The device is not ensured to function outside its operating ratings.

Note 1: Devices are ESD sensitive. Handling precautions are recommended.

TABLE 1-1: ELECTRICAL CHARACTERISTICS

Electrical Characteristics: T_J = +25°C with $V_{IN} = V_{OUT}$ + 1V; I_{OUT} = 100 µA; **Bold** values indicate –40°C ≤ T_J ≤ +125°C, unless otherwise specified. Specifications for packaged product only.

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	$\Delta V_{OUT}/\Delta V_{IN}$	—	0.04	0.5	%	$V_{IN} = V_{OUT}$ + 1V to 36V
Load Regulation	$\Delta V_{OUT}/V_{OUT}$	—	0.25	1	%	I_{OUT} = 100 µA to 100 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**		
Ground Current	I_{GND}	—	18	30	µA	I_{OUT} = 100 µA
		—	—	**35**		
		—	0.25	0.70	mA	I_{OUT} = 50 mA
		—	1	2		I_{OUT} = 100 mA
Ground Current in Shutdown	I_{SHDN}	—	0.1	1	µA	V_{EN} ≤ 0.6V; V_{IN} = 36V (SOT23 package only)
Short-Circuit Current	I_{SC}	—	190	**350**	mA	V_{OUT} = 0V
Output Leakage, Reverse Polarity Input (**Note 2**)	V_{OUT}	—	–0.1	—	V	Load = 500Ω; V_{IN} = –15V
Enable Input (SOT23 Package Only)						
Input Low Voltage	V_{EN}	—	—	0.6	V	Regulator off
Input High Voltage		2.0	—	—	V	Regulator on
Enable Input Current	I_{EN}	–1.0	0.01	1.0	µA	V_{EN} = 0.6V; regulator off
		—	0.1	1.0		V_{EN} = 2.0V; regulator on
		—	0.5	2.5		V_{EN} = 36V; regulator on
Start-up Time	t_{START}	—	1.7	**7**	ms	V_{IN} applied before EN signal

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: Design guidance only, not production tested.

TEMPERATURE SPECIFICATIONS[1]

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Temperature Ranges						
Junction Operating Temperature Range	T_J	–40	—	+125	°C	—
Storage Temperature Range	T_S	–65	—	+150	°C	—
Package Thermal Resistances						
Thermal Resistance 5-Lead SOT23	θ_{JA}	—	235	—	°C/W	—
Thermal Resistance 3-Lead SOT223	θ_{JA}	—	50	—	°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: Design guidance only, not production tested.

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.

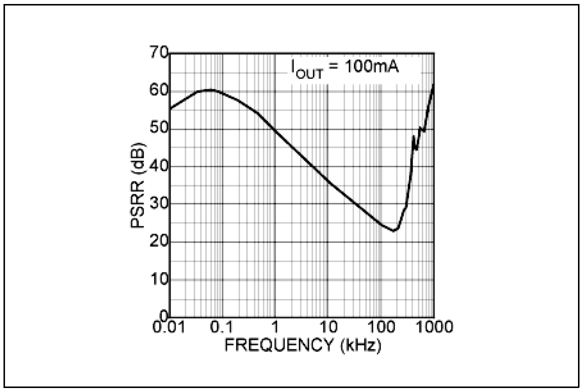


FIGURE 2-1: *Power Supply Rejection Ratio.*

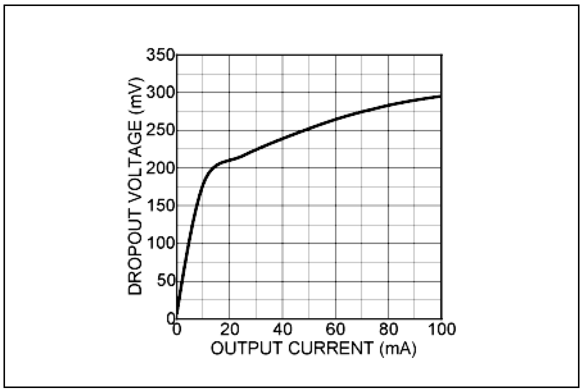


FIGURE 2-2: *Dropout Voltage vs. Output Current.*

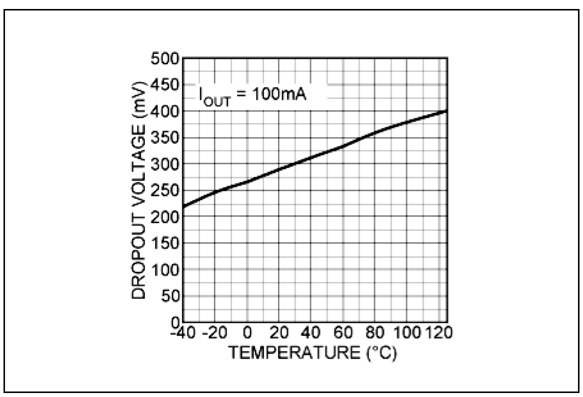


FIGURE 2-3: *Dropout Voltage vs. Temperature.*

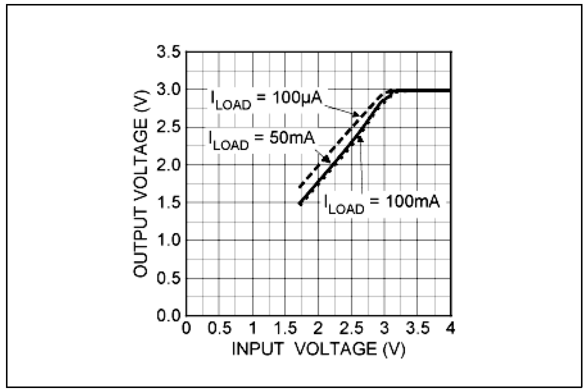


FIGURE 2-4: *Dropout Characteristics.*

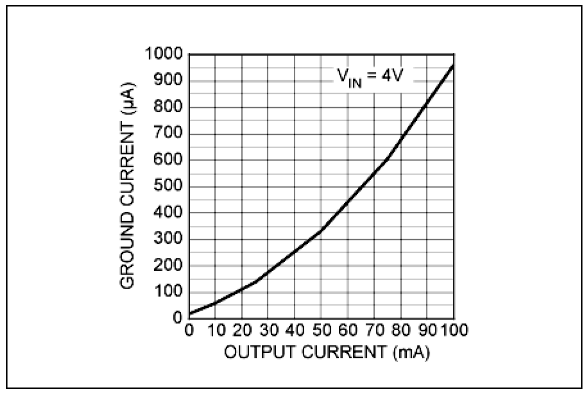


FIGURE 2-5: *Ground Pin Current vs. Output Current.*

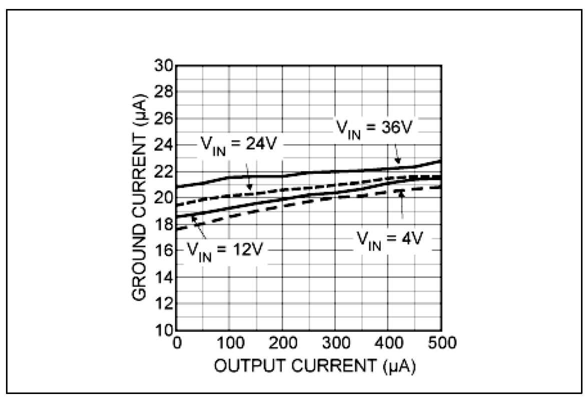


FIGURE 2-6: *Ground Pin Current vs. Output Current.*

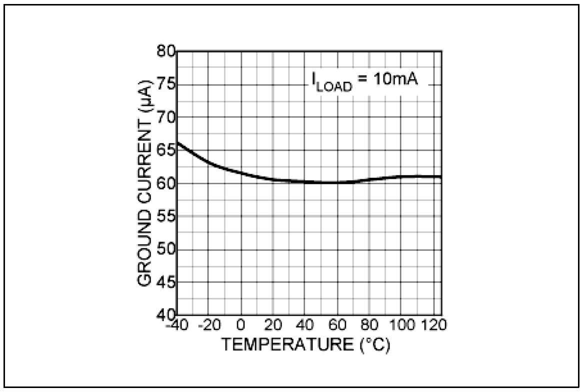


FIGURE 2-7: *Ground Pin Current vs. Temperature.*

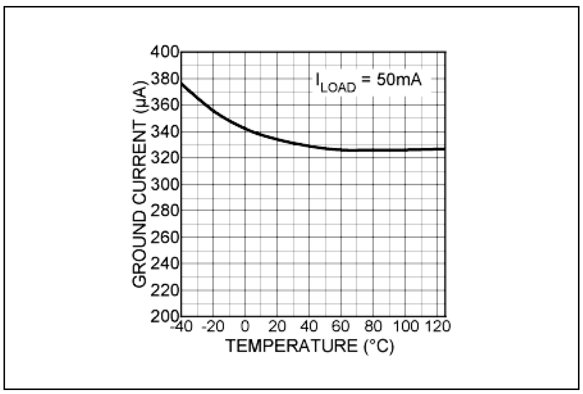


FIGURE 2-8: *Ground Pin Current vs. Temperature.*

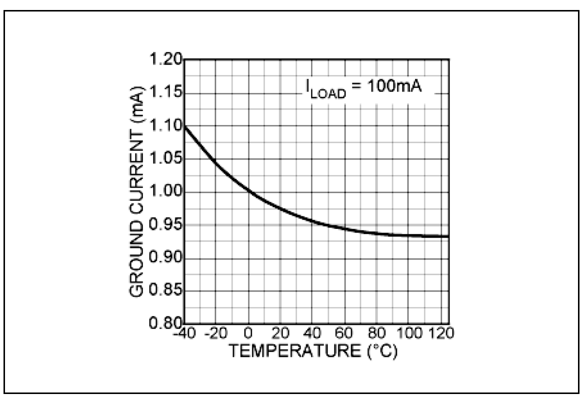


FIGURE 2-9: *Ground Pin Current vs. Temperature.*

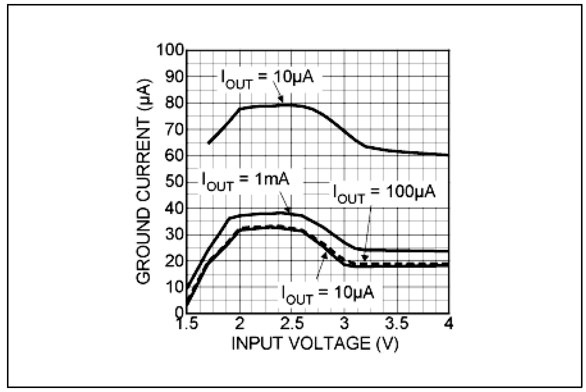


FIGURE 2-10: *Ground Pin Current vs. Input Voltage.*

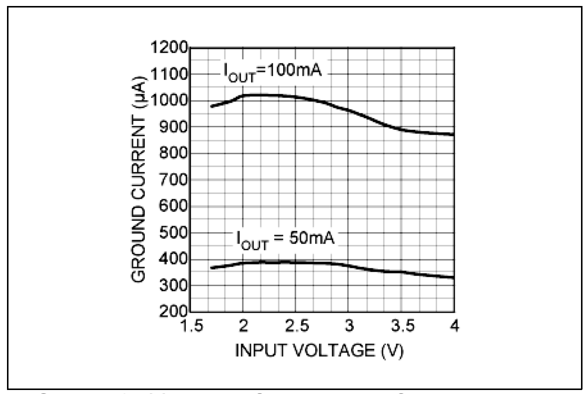


FIGURE 2-11: *Ground Pin Current vs. Input Voltage.*

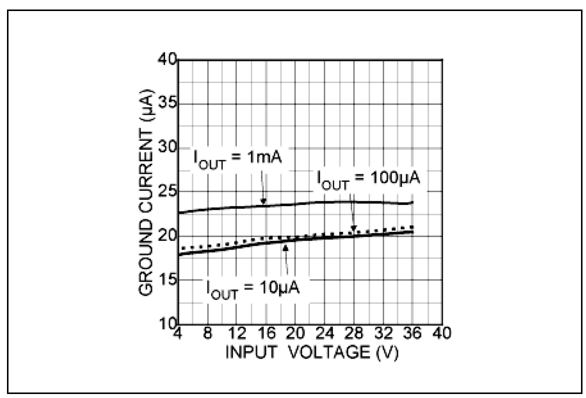


FIGURE 2-12: *Ground Pin Current vs. Input Voltage.*

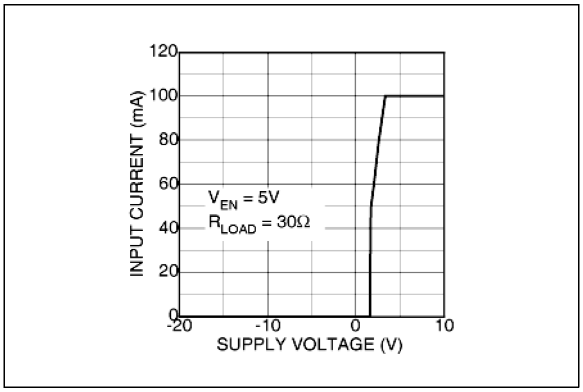


FIGURE 2-13: *Input Current vs. Supply Voltage.*

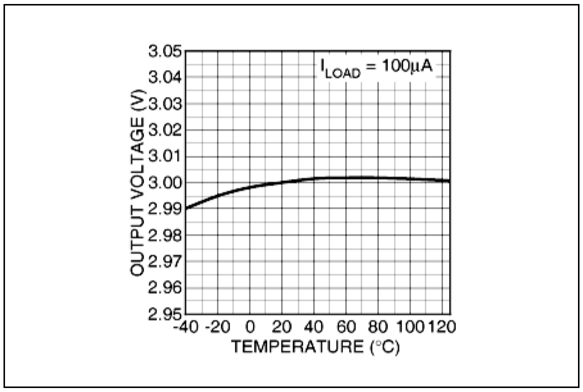


FIGURE 2-14: *Output Voltage vs. Temperature.*

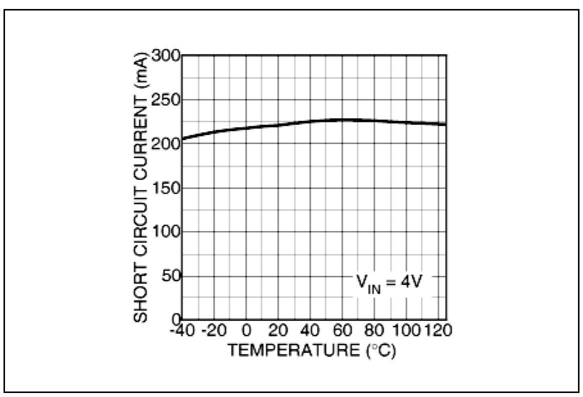


FIGURE 2-15: *Short-Circuit Current vs. Temperature.*

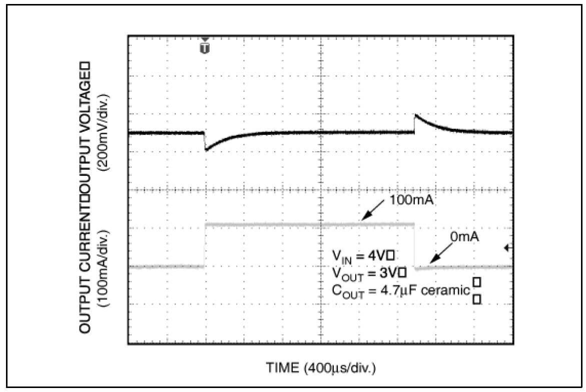


FIGURE 2-16: *Load Transient Response.*

3.0 PIN DESCRIPTIONS

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

TABLE 3-1: PIN FUNCTION TABLE

Pin Number SOT223	Pin Number SOT23	Pin Name	Description
1	1	IN	Supply Input.
2	2	GND	Ground.
—	3	EN	Enable (Input). Logic Low = Shutdown; Logic High = Enable.
—	4	NC	No Connect.
		ADJ	Adjustable (Input). Feedback Input; Connect to Resistive Voltage Divider Network.
3	5	OUT	Regulator Output.
4	—	EP	Exposed Pad. Internally Connected to Ground.

4.0 APPLICATION INFORMATION

4.1 Enable/Shutdown

The MIC5233 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, consuming a typical 0.1 µA. Forcing the enable pin high enables the output voltage.

4.2 Input Capacitor

The MIC5233 has a high input voltage capability, up to 36V. 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. A larger value may be required if the source supply has high ripple.

4.3 Output Capacitor

The MIC5233 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 an X7R ceramic capacitor to ensure the same minimum capacitance over the equivalent operating temperature range.

4.4 No-Load Stability

The MIC5233 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 Consideration

The MIC5233 is designed to provide 100 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 Equation 4-1:

EQUATION 4-1:

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

Where:

$T_{J(MAX)}$ = Maximum junction temperature of the die at +125°C

T_A = The ambient operating temperature

θ_{JA} = Layout dependent

Table 4-1 shows examples of the junction-to-ambient thermal resistance for the MIC5233:

TABLE 4-1: 5-LEAD SOT23 AND SOT-223 THERMAL RESISTANCE

Package	θ_{JA} Recommended Minimum Footprint
SOT23-5	235°C/W
SOT223	50°C/W

The actual power dissipation of the regulator circuit can be determined using Equation 4-2:

EQUATION 4-2:

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

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 MIC5233-3.0YM5 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:

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

Where:

$P_{D(max)}$ = 319 mW

The junction-to-ambient (θ_{JA}) thermal resistance for the minimum footprint is +235°C/W from Table 4-1. It is important that the maximum power dissipation not be exceeded to ensure proper operation. Because the MIC5233 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:

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

Due to the potential for input voltages up to 36V, 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:

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

$$319mW = (V_{IN} - 3V)100mA + V_{IN} \times 2.8mA$$

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

EQUATION 4-6:

$$619mW = V_{IN}(102.8mA)$$

Where:

V_{IN} = 6.02V

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

Assuming a lower output current of 10 mA, the maximum input voltage can be recalculated:

EQUATION 4-7:

$$319mW = (V_{IN} - 3V)10mA + V_{IN} \times 0.1mA$$

$$349mW = V_{IN} \times 10.1mA$$

Where:

V_{IN} = 34.55V

Maximum input voltage for a 10 mA load current at 50°C ambient temperature is 34.55V, utilizing virtually the entire operating voltage range of the device.

4.6 Adjustable Regulator Application

The MIC5233M5 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:

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

Where

V_{REF} = 1.24V

Feedback resistor R2 should be no larger than 300 kΩ.

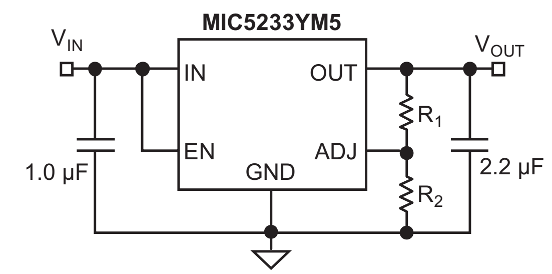
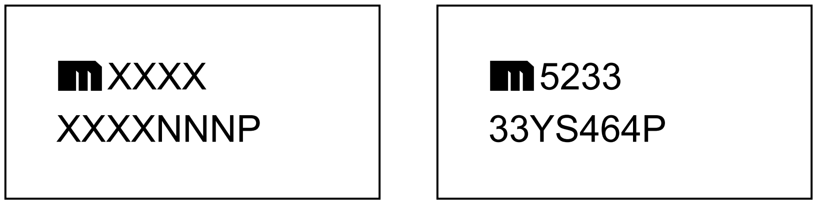


FIGURE 4-1: *Adjustable Voltage Application.*

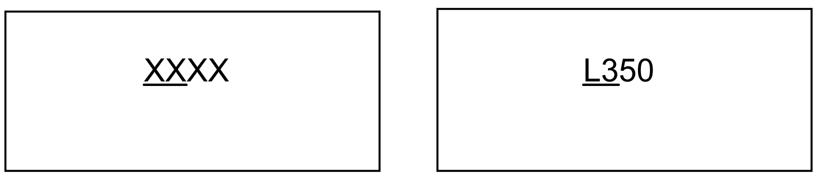
5.0 PACKAGING INFORMATION

5.1 Package Marking Information

5-Lead SOT23* Example



3-Lead SOT223* Example



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).

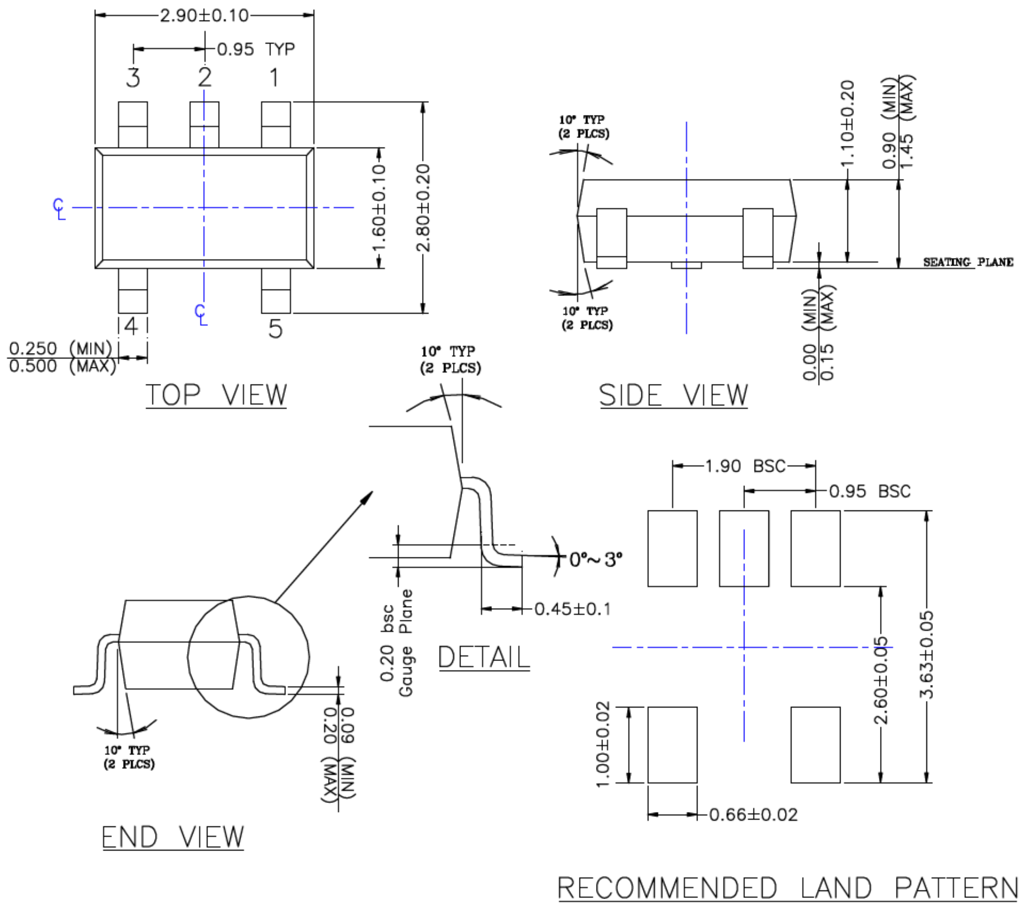
Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information. Package may or may not include the corporate logo.

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

5-Lead SOT23 Package Outline and Recommended Land Pattern

TITLE
5 LEAD SOT23 PACKAGE OUTLINE & RECOMMENDED LAND PATTERN

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



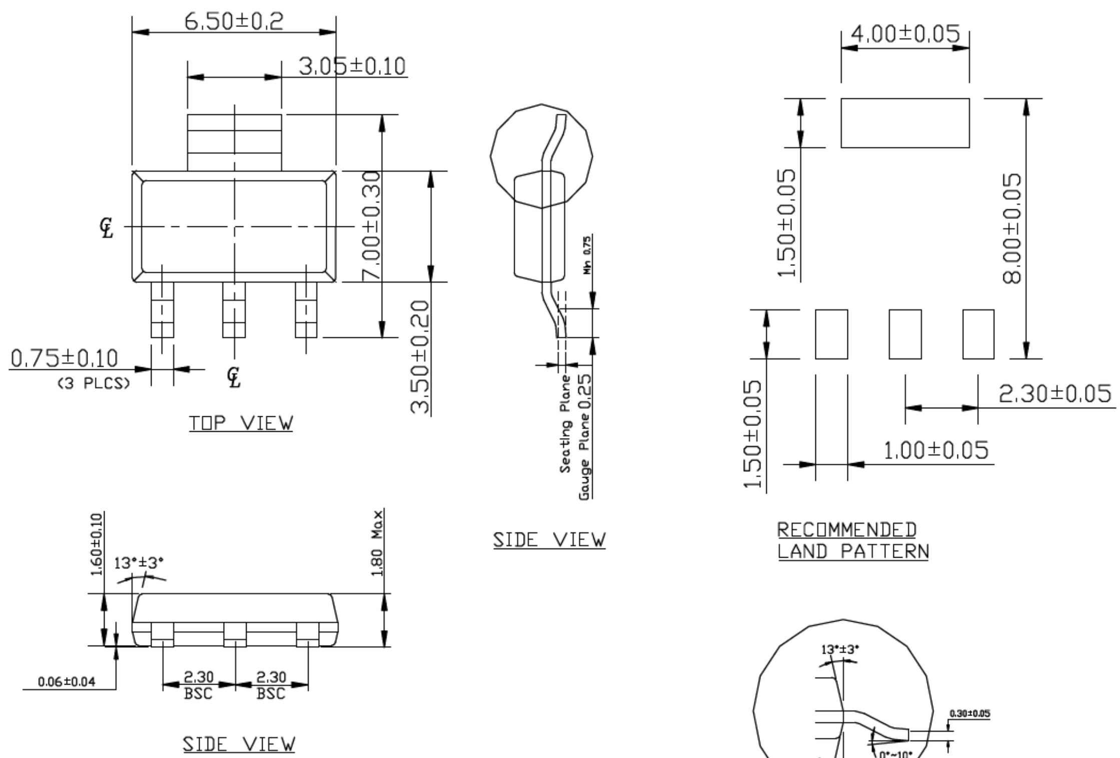
NOTE:
1. PACKAGE OUTLINE EXCLUSIVE OF MOLD FLASH & BURR.
2. PACKAGE OUTLINE INCLUSIVE OF SOLER PLATING.
3. DIMENSION AND TOLERANCE PER ANSI Y14.5M, 1982.
4. FOOT LENGTH MEASUREMENT BASED ON GAUGE PLANE METHOD.
5. DIE FACES UP FOR MOLD, AND FACES DOWN FOR TRIM/FORM.
6. ALL DIMENSIONS ARE IN MILLIMETERS.

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

3-Lead SOT223 Package Outline and Recommended Land Pattern

TITLE
3 LEAD SOT223 PACKAGE OUTLINE & RECOMMENDED LAND PATTERN

DRAWING #	SOT223-3LD-PL-1	**UNIT**	MM



NOTE:

1. Dimensions and tolerances are as per ANSI Y14.5M, 1982.
2. Controlling dimension: Millimeters.
3. Dimensions are exclusive of mold flash and gate burr.
4. All specification comply to Jedec spec TO261 Issue C.

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 D (July 2019)

- Updated the Features section.

Revision C (February 2019)

- Information about the Automotive Grade option added in Features but removed from Package Types, and the Product Identification System sections of the data sheet.
- Updated the Typical Application Circuit on the very first page.

Revision B (June 2018)

- Unbolded values for V_{EN} in Table 1-1.
- The condition for Start-Up Time in the Electrical Characteristics table is updated.

Revision A (May 2018)

- Converted Micrel document MIC5233 to Microchip data sheet DS20006033A.
- Minor text changes throughout.
- Information about the Automotive Grade option added in Features, Package Types, and the Product Identification System sections of the data sheet.

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.X	X	XXX	–XX
Device	Output Voltage	Junction Temperature Range	Package	Media Type

Device:	MIC5233:	High Input Voltage, Low I_Q µCap LDO Regulator
Output Voltage:	1.8 = 1.8V	
	2.5 = 2.5V	
	3.0 = 3.0V	
	3.3 = 3.3V	
	5.0 = 5.0V	
	Adjustable <blank> = Adjustable	
Junction Temperature Range:	Y =	–40°C to +125°C
Package:	M5 =	5-Lead SOT23
	S =	3-Lead SOT223
Media Type:	<blank> =	78/Tube (SOT223 Only)
	TR =	2,500/Reel (SOT223 Only)
	TR =	3000/Reel (SOT23 Only)

Examples:

a) MIC5233-1.8YM5-TR: High Input Voltage, Low I_Q µCap LDO Regulator, 1.8V, –40°C to +125°C, 5-Lead SOT23, 3000/Reel

b) MIC5233-2.5YM5-TR: High Input Voltage, Low I_Q µCap LDO Regulator, 2.5V, –40°C to +125°C, 5-Lead SOT23, 3000/Reel

c) MIC5233-3.0YM5-TR: High Input Voltage, Low I_Q µCap LDO Regulator, 3.0V, –40°C to +125°C, 5-Lead SOT23, 3000/Reel

d) MIC5233-3.3YM5-TR: High Input Voltage, Low I_Q µCap LDO Regulator, 3.3V, –40°C to +125°C, 5-Lead SOT23, 3000/Reel

e) MIC5233-5.0YM5-TR: High Input Voltage, Low I_Q µCap LDO Regulator, 5.0V, –40°C to +125°C, 5-Lead SOT23, 3000/Reel

f) MIC5233YM5-TR: High Input Voltage, Low I_Q µCap LDO Regulator, Adjustable, –40°C to +125°C, 5-Lead SOT23, 3000/Reel

g) MIC5233-3.3YS: High Input Voltage, Low I_Q µCap LDO Regulator, 3.3V, –40°C to +125°C, 3-Lead SOT223, 78/Tube

h) MIC5233-5.0YS: High Input Voltage, Low I_Q µCap LDO Regulator, 5.0V, –40°C to +125°C, 3-Lead SOT223, 78/Tube

i) MIC5233-5.0YS-TR: High Input Voltage, Low I_Q µCap LDO Regulator, 5.0V, –40°C to +125°C, 3-Lead SOT223, 2500/Reel

Note: 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:

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