MIC5376/7/8

High Performance Low Dropout 150 mA LDO

Features

- 4-Lead 1 mm x 1 mm Thin DFN: MIC5376
- 8-Lead 1.2 mm x 1.2 mm Thin QFN: MIC5377/8
- Low-Cost 5-Lead SC-70 Package Available
- Low Dropout Voltage: 120 mV at 150 mA
- Input Voltage Range: 2.5V to 5.5V
- 150 mA Guaranteed Output Current
- Stable with 0402 Ceramic Capacitors as Low as 1 µF
- Low Quiescent Current: 29 µA
- Excellent Load/Line Transient Response
- Fixed Output Voltages: MIC5376
- Adjustable Output Voltages: MIC5377/8
- Output Discharge Circuit: MIC5376/8
- High Output Accuracy
  - ±2% Initial Accuracy
- Thermal Shutdown and Current Limit Protection

Applications

- Mobile Phones
- Digital Cameras
- GPS, PDAs, PMP, Handhelds
- Portable Electronics

General Description

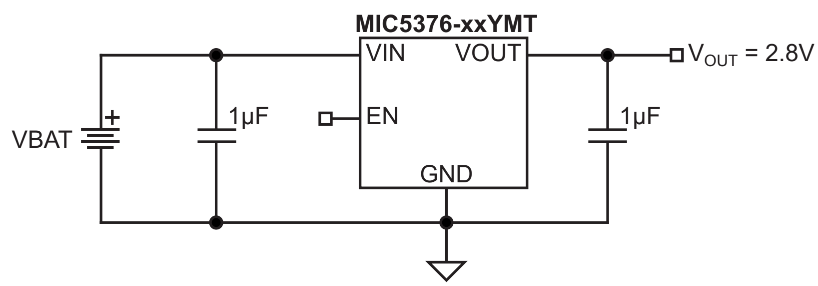
The MIC5376, MIC5377, and MIC5378 are advanced, general purpose linear regulators that offer low dropout in ultra-small packages. The MIC5376 provides a fixed output voltage in a 1 mm x 1 mm Thin DFN package while the MIC5377 and MIC5378 provide adjustable output voltages in a 1.2 mm x 1.2 mm Thin QFN package. When the MIC5376 or MIC5378 are disabled, an internal resistive load is automatically applied to the output to discharge the output capacitor. The MIC5376/7/8 are capable of sourcing 150 mA output current with low dropout, making it an ideal solution for any portable electronic application.

Ideal for battery-powered applications, the MIC5376/7/8 offer 2% initial accuracy, low dropout voltage (120 mV at 150 mA), and ground current (typically 29 µA). The MIC5376/7/8 can also be put into a zero-off-mode current state, drawing virtually no current when disabled.

The MIC5376 is available in lead-free (RoHS compliant) 1 mm x 1 mm Thin DFN and SC-70-5 packages. The MIC5377/8 are available in lead-free (RoHS compliant) 1.2 mm x 1.2 mm Thin QFN and SC-70-5 packages.

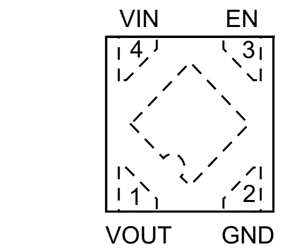
The MIC5376/7/8 have an operating junction temperature range of –40°C to 125°C.

Typical Application Circuit

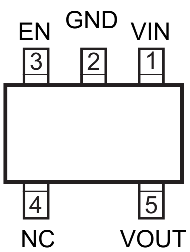


Package Types

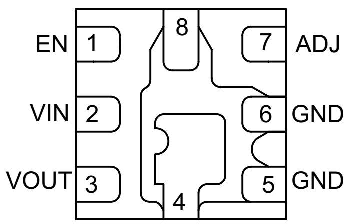
MIC5376 (Fixed Output)
4-Lead 1 mm x 1 mm TDFN (MT)
(Top View)



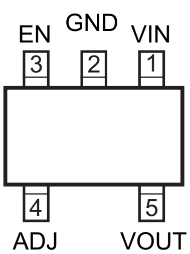
MIC5376 (Fixed Output)
5-Lead SC-70 (C5)
(Top View)



MIC5377/8 (Adjustable Output)
8-Lead 1.2 mm x 1.2 mm TQFN (MT)
(Top View)

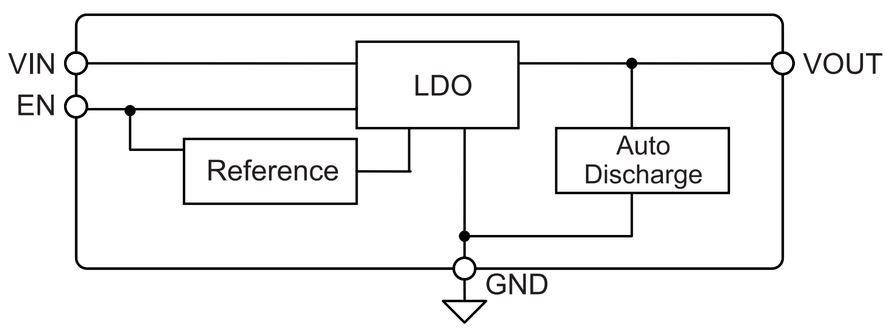


MIC5377/8 (Adjustable Output)
5-Lead SC-70 (C5)
(Top View)

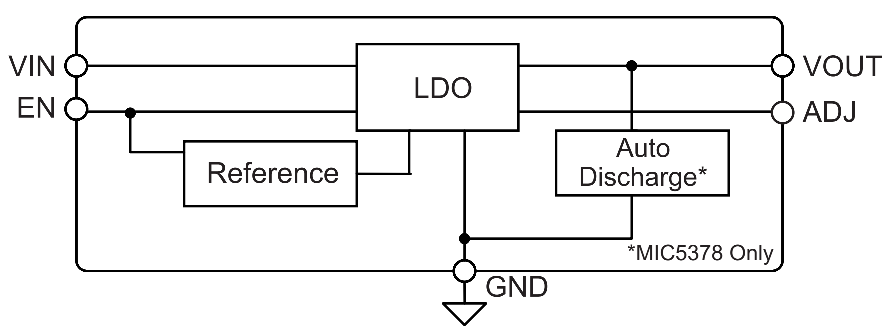


Functional Block Diagram

MIC5376 Block Diagram



MIC5377/8 Block Diagram



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

Supply Voltage (V_{IN}) .... 0V to +6V
Enable Voltage (V_{EN}) .... 0V to V_{IN}
Power Dissipation (P_D) (Note 1) .... Internally Limited
Lead Temperature (Soldering, 5 sec.) .... +260°C
Junction Temperature (T_J) .... –40°C to +125°C
Storage Temperature (T_S) .... –65°C to +150°C
ESD Rating (Note 2) .... 2 kV

Operating Ratings ††

Supply Voltage (V_{IN}) .... 2.5V to 5.5V
Enable Voltage (V_{EN}) .... 0V to V_{IN}
Junction Temperature (T_J) .... –40°C to +125°C
Package Thermal Resistance
1 mm x 1 mm TDFN-4 (θ_{JA}) .... 250°C/W
1.2 mm x 1.2 mm TQFN-8 (θ_{JA}) .... 250°C/W
SC-70-5 (θ_{JA}) .... 256.5°C/W

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

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

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

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

ELECTRICAL CHARACTERISTICS

Electrical Characteristics: $V_{IN} = V_{EN} = V_{OUT}$ + 1V; $C_{IN} = C_{OUT}$ = 1 µF for $V_{OUT} \geq$ 2.5V, $C_{IN} = C_{OUT}$ = 2.2 µF for V_{OUT} < 2.5V; I_{OUT} = 100 µA; T_J = +25°C, **bold** values indicate –40°C to +125°C, unless noted. Note 1

Parameter	Sym.	Min.	Typ.	Max.	Units	Conditions
Output Voltage Accuracy	V_{OUT}	–2.0	—	2.0	%	Variation from nominal V_{OUT}
		–3.0	—	**3.0**		
Line Regulation	$\Delta V_{OUT}/V_{OUT}$	—	0.02	**0.3**	%	$V_{IN} = V_{OUT}$ +1V to 5.5V; I_{OUT} = 100 µA
Load Regulation (Note 2)	$\Delta V_{OUT}/V_{OUT}$	—	0.3	1.0	%	I_{OUT} = 100 µA to 150 mA
Dropout Voltage (Note 3)	V_{DO}	—	45	**100**	mV	I_{OUT} = 50 mA
		—	120	**200**		I_{OUT} = 150 mA
Ground Pin Current (Note 4)	I_{GND}	—	29	**45**	µA	I_{OUT} = 0 mA
Ground Pin Current in Shutdown	$I_{GND-SHDN}$	—	0.05	1	µA	$V_{EN} \leq$ 0.2V
Ripple Rejection	PSRR	—	60	—	dB	f = 1 kHz; C_{OUT} = 1 µF
		—	50	—		f = 10 kHz; C_{OUT} = 1 µF
Current Limit	I_{LIM}	200	370	550	mA	V_{OUT} = 0V
Output Voltage Noise	e_n	—	200	—	μV_{RMS}	C_{OUT} = 1 µF, 10 Hz to 100 kHz
Auto-Discharge NFET Resistance	$R_{DS(ON)}$	—	30	—	Ω	V_{EN} = 0V; V_{IN} = 3.6V
Reference Voltage (MIC5377/8)						
Reference Voltage Accuracy	V_{REF}	**0.97**	1	**1.03**	V	—
Adjust Pin Input Current	$I_{ADJ-BIAS}$	—	0.01	—	µA	—
Enable Input						
Enable Input Voltage	V_{EN}	—	—	**0.2**	V	Logic low.
		1.2	—	—		Logic high.
Enable Input Current	I_{EN}	—	0.01	**1**	µA	$V_{IL} \leq$ 0.2V
		—	0.01	**1**		$V_{IH} \geq$ 1.2V
Turn-On Time	t_{ON}	—	45	**100**	µs	C_{OUT} = 1 µF; I_{OUT} = 150 mA

Note 1: Specification for packaged product only.

2: Regulation is measured at constant junction temperature using low duty cycle pulse testing.

3: Dropout voltage is defined as the input-to-output differential at which the output voltage drops 2% below its nominal value measured at 1V differential. For outputs below 2.5V, dropout voltage is the input-to-output differential with the minimum input voltage 2.5V.

4: Ground pin current is the regulator quiescent current. The total current drawn from the supply is the sum of the load current plus the ground pin current.

TEMPERATURE SPECIFICATIONS

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Temperature Ranges						
Junction Temperature Range	T_J	–40	—	+125	°C	—
Lead Temperature	—	—	—	+260	°C	Soldering, 5 sec.
Storage Temperature	T_S	–65	—	+150	°C	—
Package Thermal Resistances						
Thermal Resistance, 1x1 TDFN 4-Ld	θ_{JA}	—	250	—	°C/W	—
Thermal Resistance, 1.2x1.2 TQFN 8-Ld	θ_{JA}	—	250	—	°C/W	—
Thermal Resistance, SC-70-5	θ_{JA}	—	256.5	—	°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.

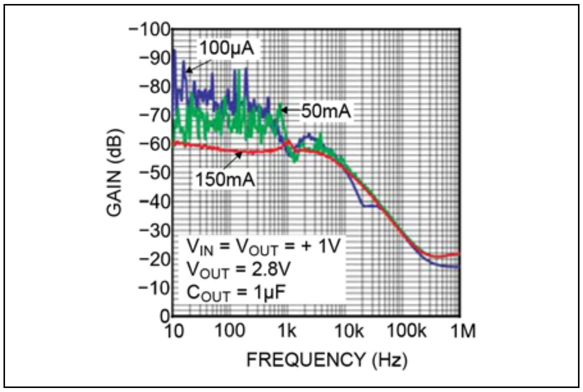


FIGURE 2-1: *Power Supply Rejection Ratio.*

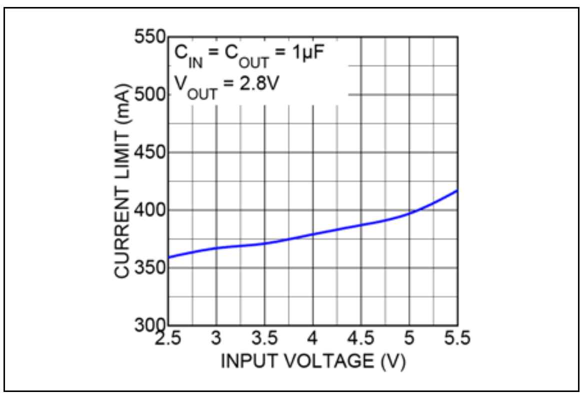


FIGURE 2-2: *Current Limit vs. Input Voltage.*

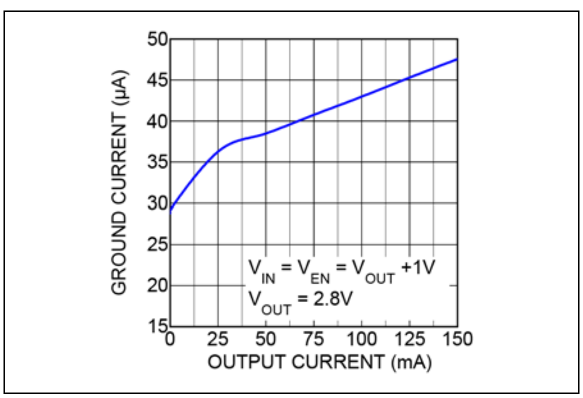


FIGURE 2-3: *Ground Current vs. Output Current.*

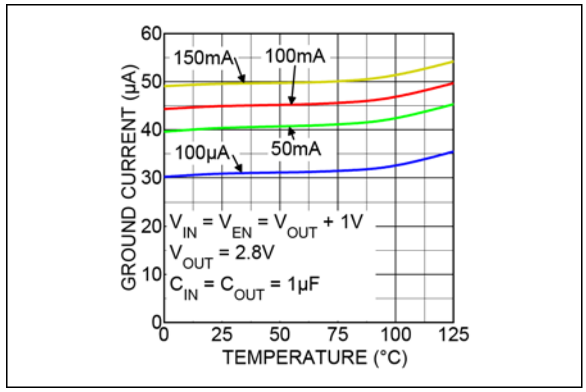


FIGURE 2-4: *Ground Current vs. Temperature.*

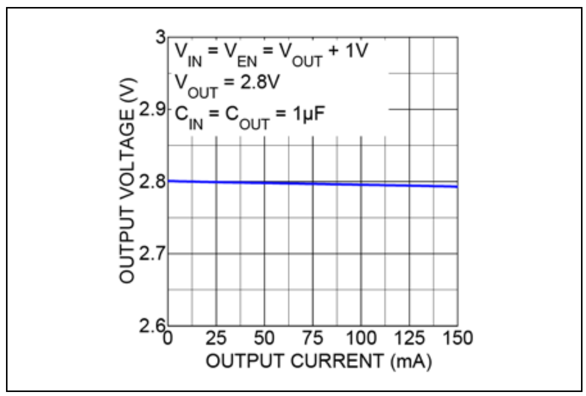


FIGURE 2-5: *Output Voltage vs. Load Current.*

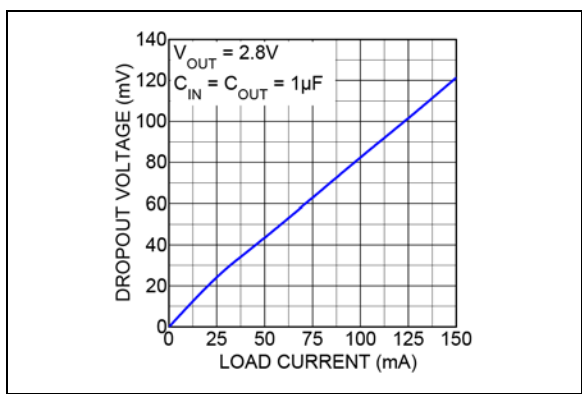


FIGURE 2-6: *Dropout Voltage vs. Load Current.*

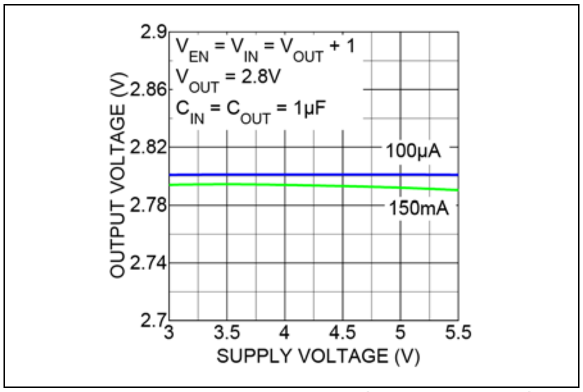


FIGURE 2-7: *Output Voltage vs Supply Voltage.*

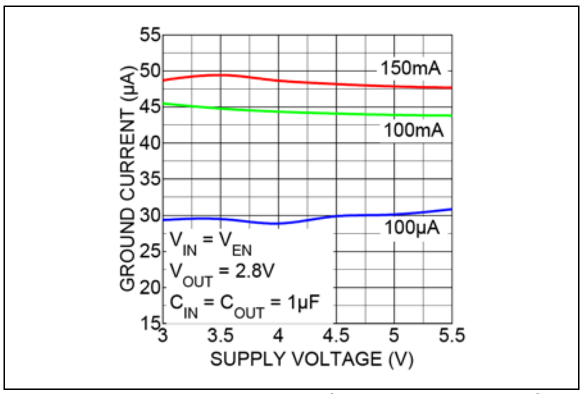


FIGURE 2-8: *Ground Current vs Supply Voltage.*

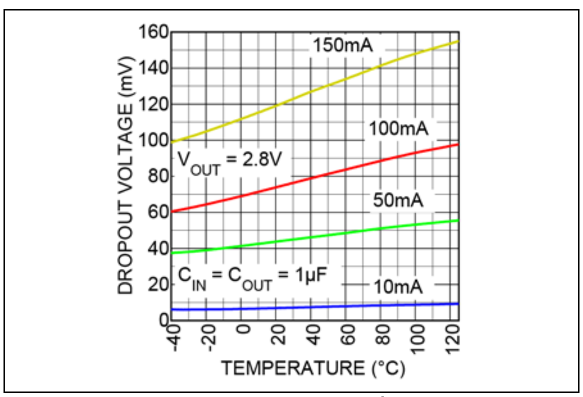


FIGURE 2-9: *Dropout Voltage vs Temperature.*

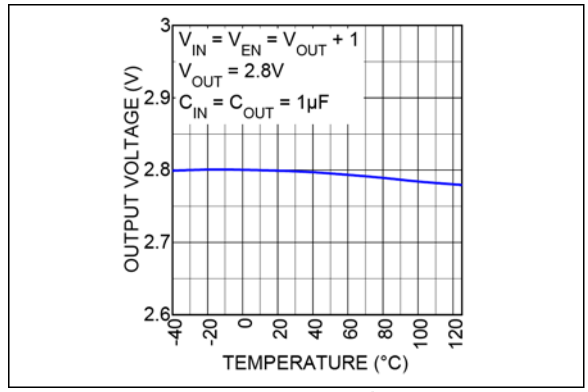


FIGURE 2-10: *Output Voltage vs Temperature.*

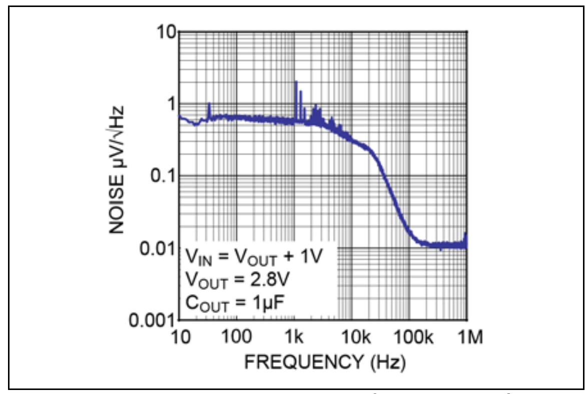


FIGURE 2-11: *Output Noise Spectral Density.*

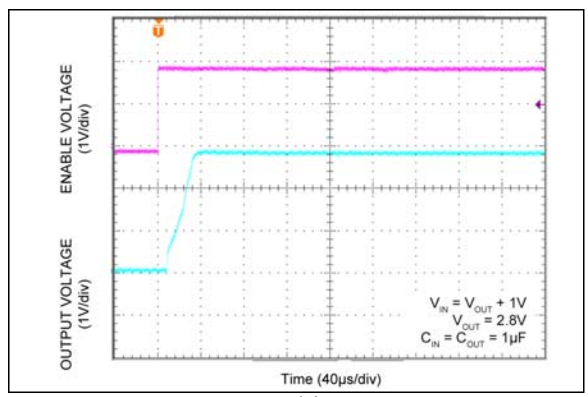


FIGURE 2-12: *Enable Turn-On.*

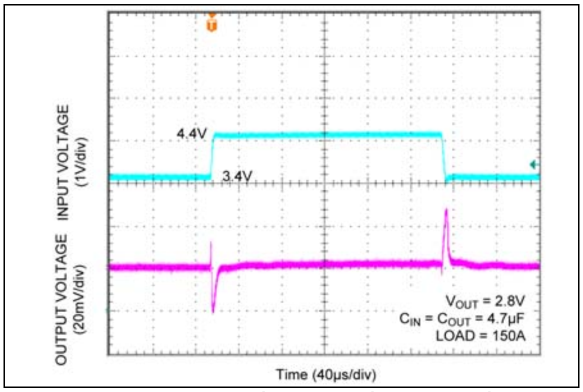


FIGURE 2-13: *Line Transient 2.8V (3.4V to 4.4V).*

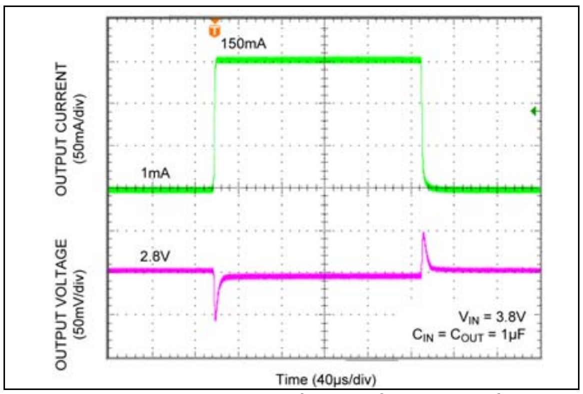


FIGURE 2-14: *Load Transient 2.8V (1 mA to 150 mA).*

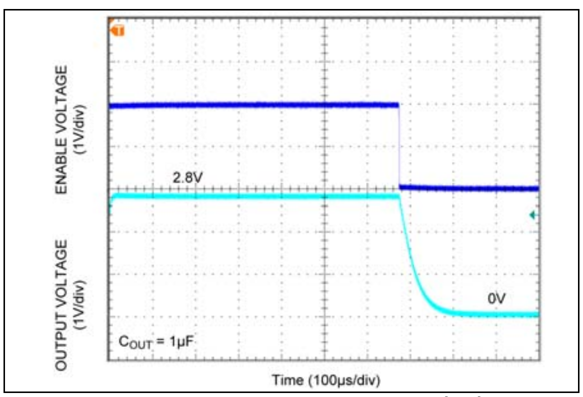


FIGURE 2-15: *MIC5376 Auto-Discharge (No Load).*

3.0 PIN DESCRIPTIONS

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

TABLE 3-1: PIN FUNCTION TABLE

Pin Number MIC5376 TDFN 4-Ld	Pin Number MIC5376 SC-70-5	Pin Number MIC5377/8 TQFN 8-Ld	Pin Number MIC5377/8 SC-70-5	Pin Name	Description
3	3	1	3	EN	Enable Input. Active-High. High = on, low = off. Do not leave floating.
4	1	2	1	VIN	Supply Input.
1	5	3	5	VOUT	Output Voltage.
2	2	4, 5, 6, 8	2	GND	Ground.
—	—	7	4	ADJ	Adjust Pin: Feedback input from external divider.
—	4	—	—	NC	No connection.
HS Pad	—	—	—	ePAD	Exposed Heat Sink Pad. Connected to ground internally.

4.0 APPLICATION INFORMATION

MIC5376, MIC5377, and MIC5378 are low-noise 150 mA LDO regulators. The MIC5376 and MIC5378 include an auto-discharge circuit that is switched on when the regulator is disabled through the enable pin. The MIC5376/7/8 regulators are protected from damage due to fault conditions, offering linear current limiting and thermal shutdown.

4.1 Input Capacitor

The MIC5376/7/8 are high-performance, high bandwidth devices. An input capacitor of 1 µF is required from the input to ground to provide stability. Low-ESR ceramic capacitors provide optimal performance at a minimum of space. Additional high-frequency capacitors, such as small-valued NPO dielectric-type capacitors, help filter out high-frequency noise and are good practice in any RF-based circuit. X5R or X7R dielectrics are recommended for the input capacitor. Y5V dielectrics lose most of their capacitance over temperature and are, therefore, not recommended.

4.2 Output Capacitor

For output voltages ≥ 2.5V, the MIC5376/7/8 require a minimum 1 µF output capacitor. For output voltages below 2.5V, a 2.2 µF minimum output capacitor is required. The design is optimized for use with low-ESR ceramic chip capacitors. High-ESR capacitors are not recommended because they may cause high frequency oscillation. The output capacitor can be increased, but performance does not improve significantly with larger capacitance.

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.

4.3 No-Load Stability

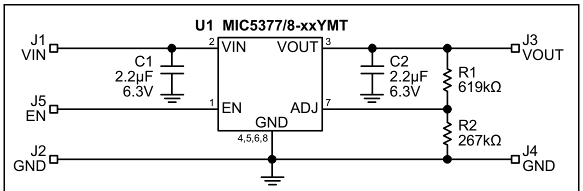
Unlike many other voltage regulators, the MIC5376/7/8 will remain stable and in regulation with no load. This is especially important in CMOS RAM keep-alive applications.

4.4 Enable/Shutdown

The MIC5376/7/8 is provided 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. The active-high enable pin uses CMOS technology and the enable pin cannot be left floating; a floating enable pin may cause an indeterminate state on the output.

4.5 Adjustable Regulator Design

The MIC5377/8 adjustable version allows setting the output voltage down to 1V with the use of two external feedback resistors.



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

FIGURE 4-1: Adjustable Regulator with Resistors.

4.6 Thermal Considerations

The MIC5376/7/8 are designed to provide 150 mA of continuous current in a very small package. Maximum ambient operating temperature can be calculated based on the output current and the voltage drop across the part. For example if the input voltage is 3.6V, the output voltage is 2.8V, and the output current is 150 mA, the actual power dissipation of the regulator circuit can be determined using the following equation:

EQUATION 4-1:

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

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

EQUATION 4-2:

$$P_D = (3.6V - 2.8V) \times 150mA = 0.12W$$

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

EQUATION 4-3:

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

The maximum junction temperature of the device is +125°C. The thermal resistance is 250°C/W for the TDFN/TQFN packages and 256.5°C/W for the SC-70-5.

Substituting P_D for $P_{D(MAX)}$ and solving for the ambient operating temperature will give the maximum operating conditions for the regulator circuit. The junction-to-ambient thermal resistance for the minimum footprint is 250°C/W.

The maximum power dissipation must not be exceeded for proper operation.

For example, when operating the MIC5376-2.8YMT at an input voltage of 3.6V and 150 mA load with a minimum footprint layout, the maximum ambient operating temperature (T_A) can be determined as follows:

EQUATION 4-4:

$$0.12W = (125°C - T_A)/250°C/W$$

$$T_A = 95°C$$

Therefore, a maximum ambient operating temperature of +95°C is allowed for a 1 mm x 1 mm TDFN package. For a full discussion of heat sinking and thermal effects on voltage regulators, refer to the “Regulator Thermals” section of Microchip’s Designing with Low-Dropout Voltage Regulators handbook.

5.0 PACKAGING INFORMATION

5.1 Package Marking Information

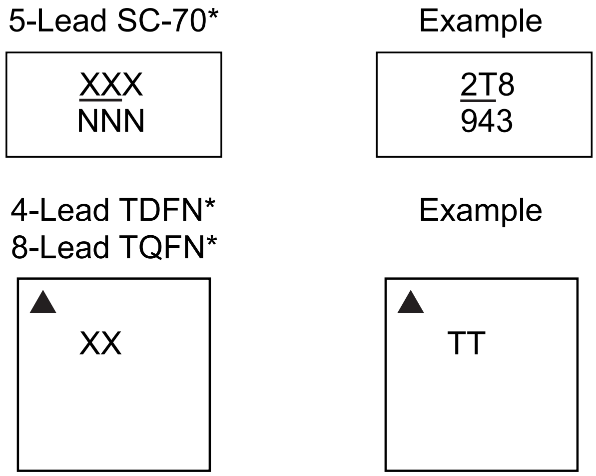


TABLE 5-1: DEVICE MARKING CODES

Part Number	Output Voltage	Marking Code
MIC5376-2.8YC5	2.8V	2T8
MIC5376-2.8YMT	2.8V	TT
MIC5377YC5	Adjustable	AHA
MIC5377YMT	Adjustable	AH
MIC5378YC5	Adjustable	A67
MIC5378YMT	Adjustable	67A

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).

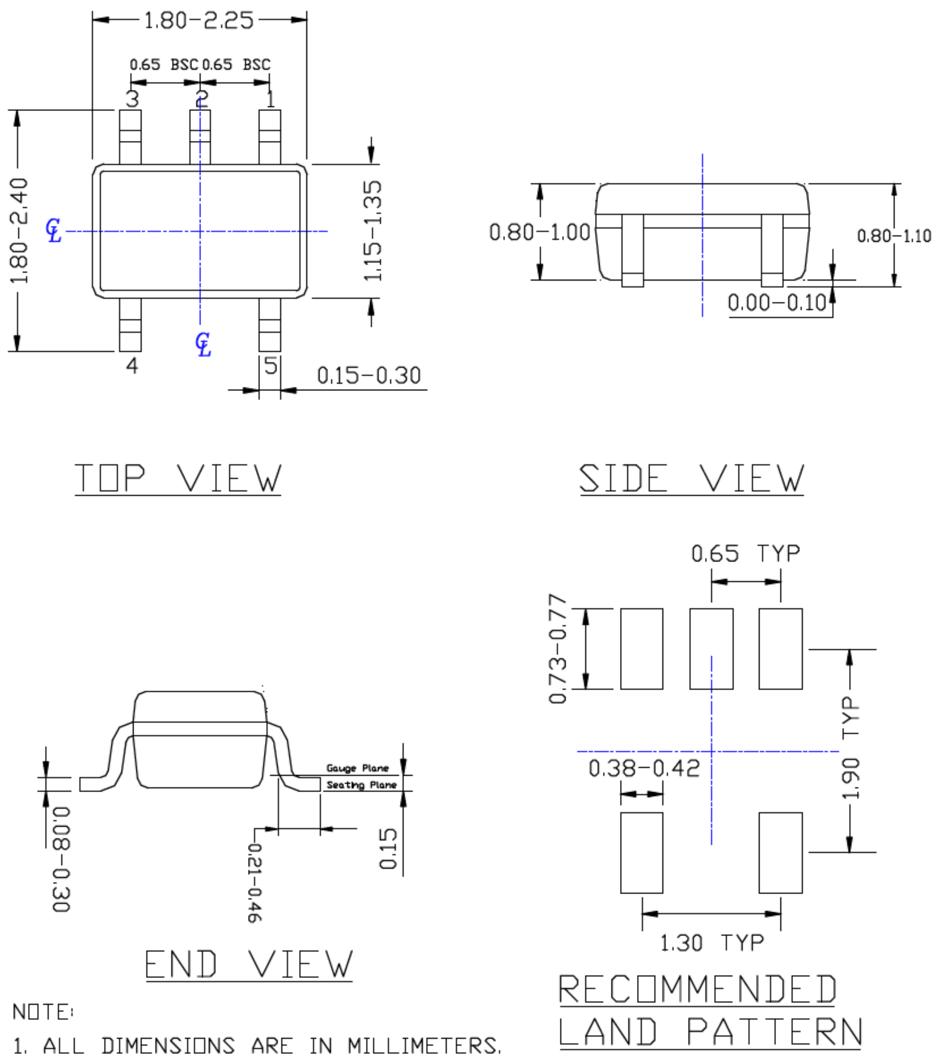
Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information. Package may or may not include the corporate logo.

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

5-Lead SC-70 Package Outline & Recommended Land Pattern

TITLE
5 LEAD SC70 PACKAGE OUTLINE & RECOMMENDED LAND PATTERN

DRAWING #	SC70-5LD-PL-1	**UNIT**	MM



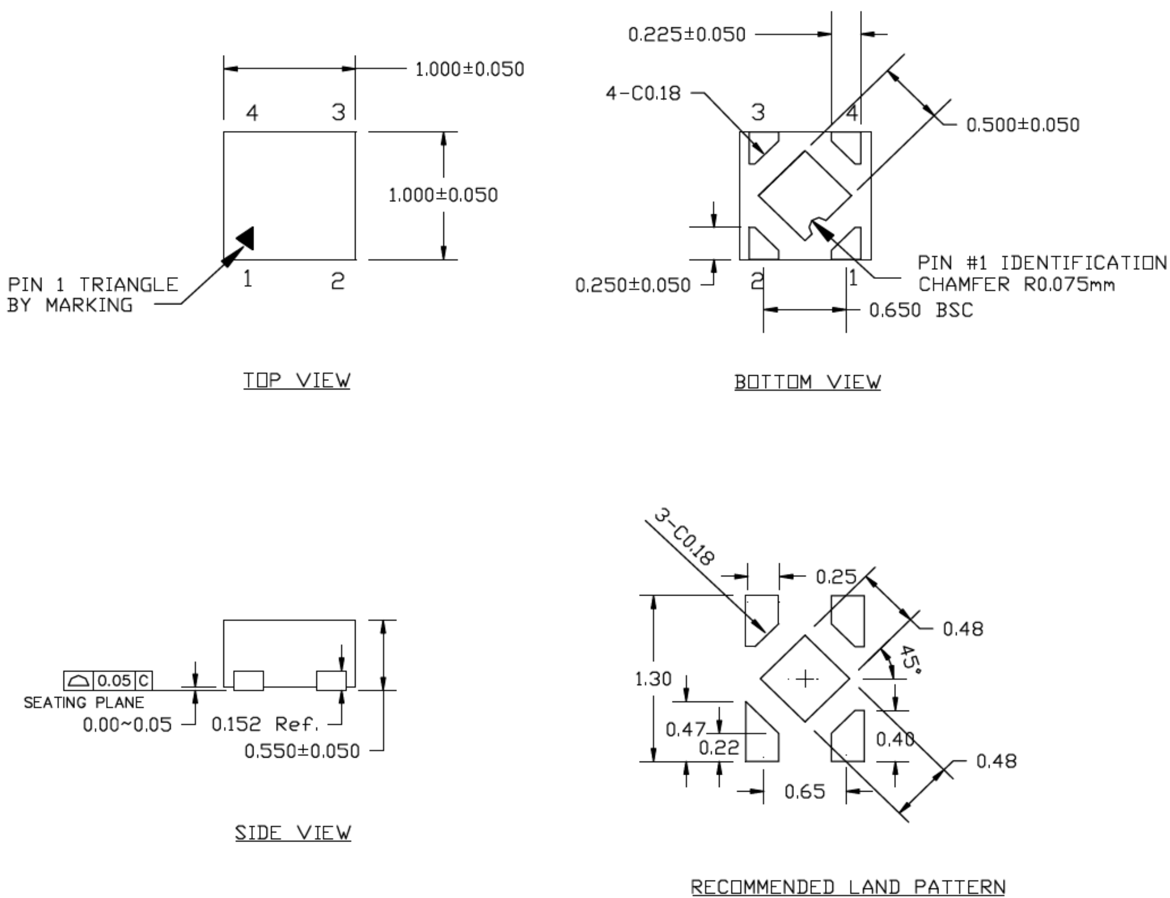
NOTE:
1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. DIMENSIONS ARE INCLUSIVE OF PLATING.
3. DIMENSIONS ARE EXCLUSIVE OF MOLD FLASH & METAL BURR.

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

4-Lead 1 mm x 1 mm TDFN Package Outline and Recommended Land Pattern

TITLE
4 LEAD TDFN 1.0x1.0mm PACKAGE OUTLINE & RECOMMENDED LAND PATTERN

DRAWING #	TDFN1010-4LD-PL-2	**UNIT**	MM



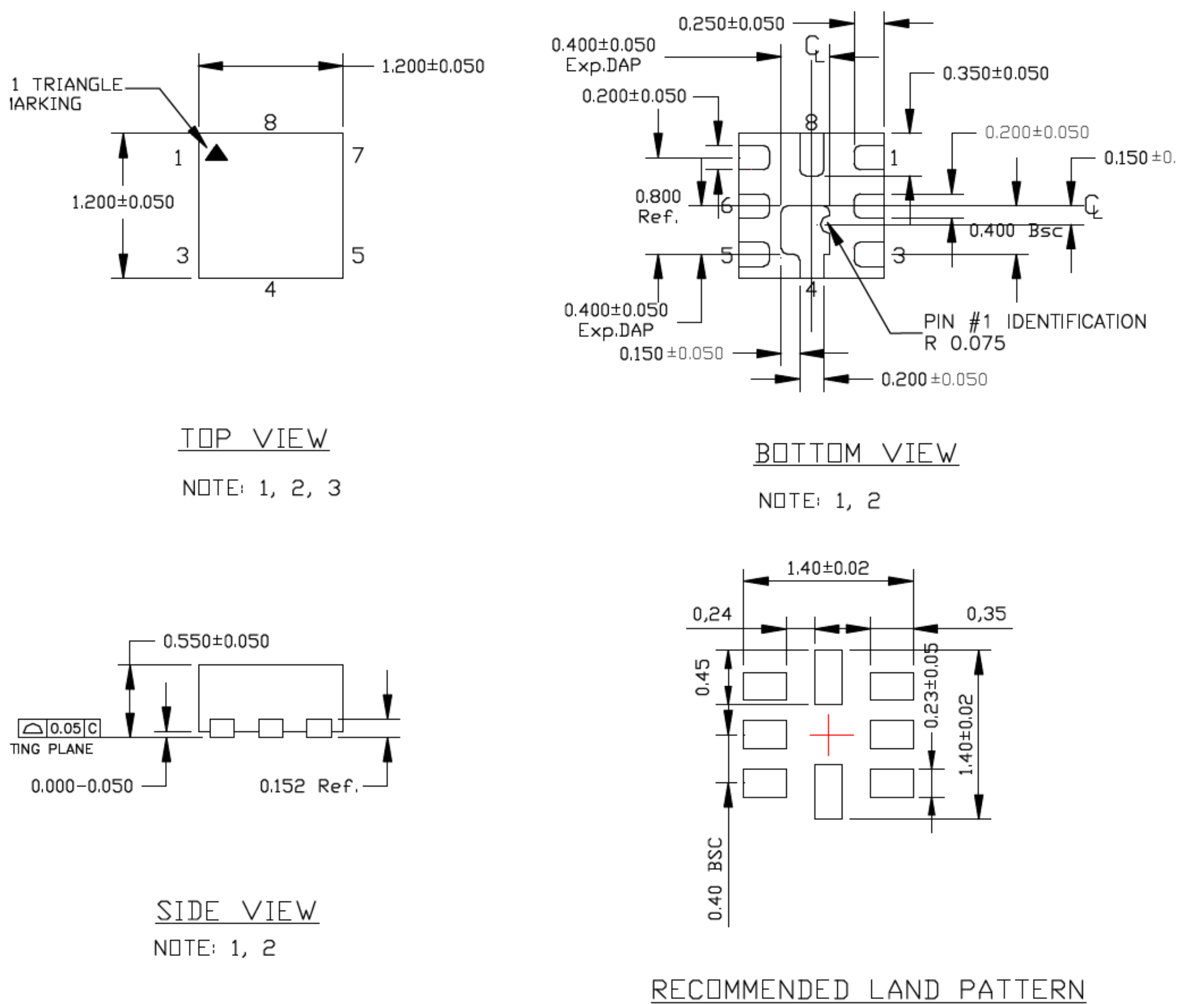
NOTE:
1. MAX PACKAGE WARPAGE IS 0.05 MM
2. MAX ALLOWABLE BURR IS 0.076MM IN ALL DIRECTIONS
3. PIN #1 IS ON TOP WILL BE LASER MARKED
4. UNSPECIFIED TOLERANCE IS +/- 0.05 MM

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

8-Lead 1.2 mm x 1.2 mm TQFN Package Outline and Recommended Land Pattern

TITLE
8 LEAD TQFN 1.2x1.2mm PACKAGE OUTLINE & RECOMMENDED LAND PATTERN

DRAWING #	TQFN1212-8LD-PL-1	**UNIT**	MM



NOTE:
1. MAX PACKAGE WARPAGE IS 0.05MM
2. MAX ALLOWABLE BURR IS 0.076MM IN ALL DIRECTIONS
3. PIN #1 IS ON TOP WILL BE LASER MARKED

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

NOTES:

APPENDIX A: REVISION HISTORY

Revision A (October 2018)

- Converted Micrel document MIC5376/7/8 to Microchip data sheet template DS20006080A.
- Minor grammatical text changes throughout.
- All reference to and information about the MIC5375 has been removed.

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	Junction Temp. Range	Package	Media Type

Device:	MIC5376:	High Performance Low Dropout 150 mA LDO with Fixed Output Voltage and Output Discharge Circuit
	MIC5377:	High Performance Low Dropout 150 mA LDO with Adjustable Output Voltage
	MIC5378:	High Performance Low Dropout 150 mA LDO with Adjustable Output Voltage and Output Discharge Circuit
Output Voltage:	2.8 =	2.8V
	<blank>=	Adjustable
Junction Temperature Range:	Y =	–40°C to +125°C, RoHS-Compliant
Package:	C5 =	5-Lead SC-70 (MIC5376/7/8)
	MT =	4-Lead 1 mm x 1 mm TDFN (MIC5376)
	MT =	8-Lead 1.2 mm x 1.2 mm TQFN (MIC5377/8)
Media Type:	TR =	3000/Reel (C5 package option)
	TR =	5000/Reel (MIC5377/8 MT package options)
	TZ =	10000/Reel (MIC5376 MT package option)

Examples:

a) MIC5376-2.8YC5-TR: MIC5376, 2.8V Output Voltage, –40°C to +125°C Temperature Range, 5-Lead SC-70, 3000/Reel

b) MIC5376-2.8YMT-TZ: MIC5376, 2.8V Output Voltage, –40°C to +125°C Temperature Range, 4-Lead TDFN, 10000/Reel

c) MIC5377YC5-TR: MIC5377, Adjustable Output Voltage, –40°C to +125°C Temperature Range, 5-Lead SC-70, 3000/Reel

d) MIC5377YMT-TR: MIC5377, Adjustable Output Voltage, –40°C to +125°C Temperature Range, 8-Lead TQFN, 5000/Reel

e) MIC5378YC5-TR: MIC5378, Adjustable Output Voltage, –40°C to +125°C Temperature Range, 5-Lead SC-70, 3000/Reel

f) MIC5378YMT-TR: MIC5378, Adjustable Output Voltage, –40°C to +125°C Temperature Range, 8-Lead TQFN, 5000/Reel

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

NOTES:

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