MIC2778

Voltage Monitor with Adjustable Hysteresis

Features

- Optimized for battery-powered devices
- Independently adjustable high- and low-voltage thresholds
- Internal logic prevents battery-voltage-fluctuation chatter
- High ±2% voltage threshold accuracy; 1% available
- Built in 140 ms (minimum) delay de-glitches output
- Extremely low 1 µA typical supply current
- For applications not requiring built-in delay, see MIC841
- Immune to brief power supply transients
- 5-lead SOT-23 package

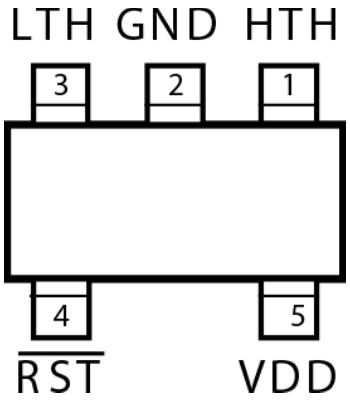
Applications

- Consumer electronics
- Embedded controllers
- Personal electronics

Package Types

MIC2778

SOT-23-5 (M5)



General Description

The MIC2778 is a voltage monitor—uniquely designed to detect two separate voltage thresholds—combined with a delay generator and logic. It is designed for monitoring the battery supply of portable digital systems.

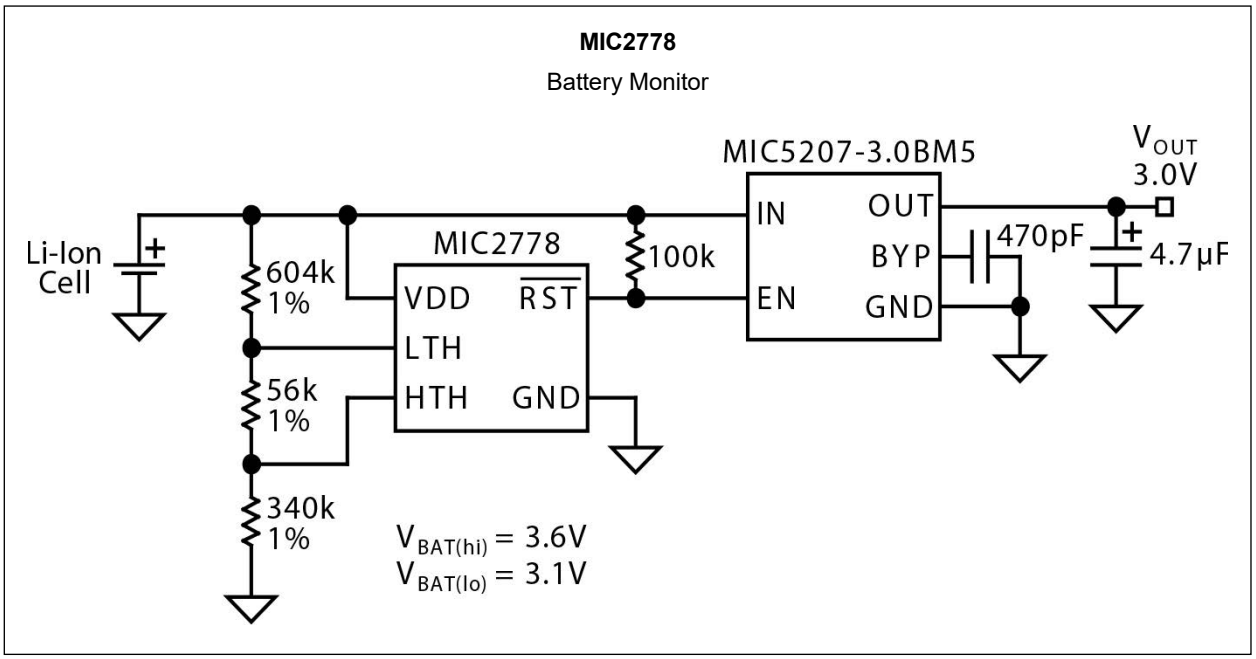
High- and low-voltage thresholds can be adjusted independently, allowing for wide hysteresis. Voltage detection thresholds are accurate to 2%.

If the battery voltage falls below the low-voltage threshold, the output ($\overline{RST}$) is asserted and latched, preventing system operation until the battery is replaced or recharged. Internal logic prevents the output from chattering due to battery recovery or load removal. The output is asserted for 140 ms (minimum) when a fresh battery is inserted. For applications not requiring built-in delay, see MIC841.

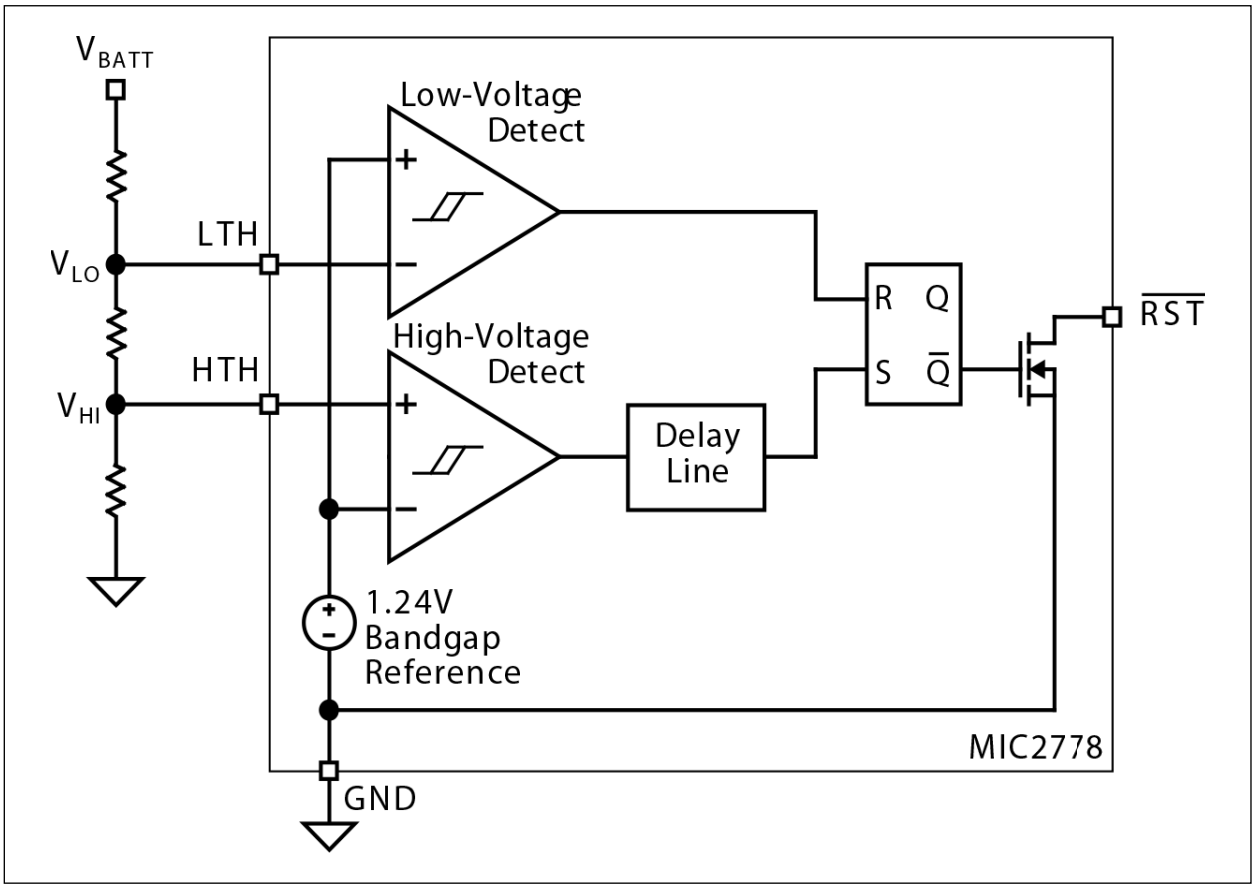
The IC's power supply input is separate from the detector inputs, allowing the MIC2778 to be powered from a downstream supply, such a boost converter. Supply current is extremely low (1 µA, typical), making it ideal for portable applications.

A high-precision 1% grade is available. The MIC2778 is supplied in Microchip's IttyBitty™ 5-lead SOT-23 package.

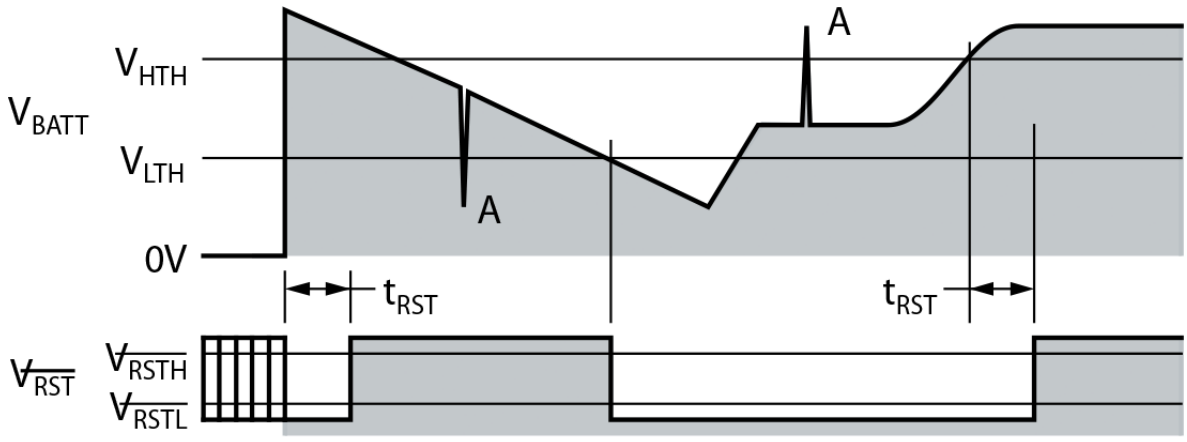
Typical Application Circuits



Functional Block Diagram



Timing Diagram



Propagation delays not shown for clarity.

Note A. The MIC2778 ignores very brief transients. See “Applications Information” for details.

1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

Supply Voltage (V_{DD}) .....–0.3V to +7V
Input Voltages (V_{HI}, V_{LO}).....–0.3V to +7V
$\overline{RST}$ Output Current ($I_{\overline{RST}}$) .....20 mA
ESD Rating, Note 1 .....2 kV

Operating Ratings ‡

Supply Voltage (V_{DD}) .....+1.5V to +5.5V
Input Voltages ($V_{\overline{RST}}$, V_{LTH}, V_{HTH}).....–0.3V to +6.0V

† Notice: Exceeding the absolute maximum rating may damage the device.

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

Note 1: Devices are ESD sensitive. Handling precautions recommended. Human body model, 1.5k in series with 100 pF.

ELECTRICAL CHARACTERISTICS (Note 1)

1.5V ≤ V_{DD} ≤ 5.5V; T_A = +25°C, **bold** values indicate –40°C ≤ T_A ≤ +85°C; unless noted.

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Supply Current	I_{DD}	—	1	**2**	µA	$\overline{RST}$ not asserted
Input Leakage Current	I_{LTH}	—	5	—	pA	—
	I_{HTH}	—	—	**10**	nA	—
Reference Voltage	V_{REF}	—	1.240	—	V	—
		1.215	—	**1.265**	V	MIC2778-2
		1.228	—	**1.252**	V	MIC2778-1
Propagation Delay	t_D	—	5	—	µs	V_{LTH} = $V_{REF(max)}$ +100 mV to $V_{REF(min)}$ – 100 mV
Reset Pulse Width	t_{RESET}	**140**	—	**420**	ms	—
Voltage-low Reset	$V_{\overline{RST}}$	—	—	**0.3**	V	$\overline{RST}$ asserted, I_{SINK} = 1.6 mA, V_{DD} ≥ 1.6V
		—	—	**0.4**	V	$\overline{RST}$ asserted, I_{SINK} = 100 µA, V_{DD} ≥ 1.2V,

Note 1: V_{DD} operating range is 1.5V to 5.5V. Output is guaranteed to be held low down to V_{DD} = 1.2V.

TEMPERATURE SPECIFICATIONS

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Ambient Temperature Range	T_A	–40	—	+85	°C	—
Storage Temperature Range	T_S	–65	—	+150	°C	—
Package Thermal Resistance	θ_{JA}	—	+256	—	°C/W	—

2.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in Table 2-1.

TABLE 2-1: PIN FUNCTION TABLE

Pin Number	Pin Name	Description
1	HTH	High-Voltage Threshold (Input): Analog input to a comparator. When the level on this pin initially rises above V_{REF}, the delay generator cycles and the $\overline{RST}$ remains low for a minimum of 140 ms.
2	GND	Ground.
3	LTH	Low-Voltage Threshold (Input): Analog input to a comparator. This is the voltage monitor input assigned to detect a low voltage condition. When the level on this pin falls below V_{REF}, $\overline{RST}$ is asserted and the condition is latched until $V_{HTH} > V_{REF}$.
4	$\overline{RST}$	Reset (Output): Active-low, open-drain output. This output is asserted and latched when $V_{LTH} < V_{REF}$, indicating a low voltage condition. This state remains latched until $V_{HTH} > V_{REF}$.
5	VDD	Power Supply (Input): Independent supply input for internal circuitry.

3.0 FUNCTIONAL DESCRIPTION

The MIC2778 monitors the voltage of a battery and detects when it is discharged below a programmed level. Upon being replaced, or being recharged above a second higher programmed trip point, the output remains low for a minimum of 140 ms and then sends a reset signal to a microprocessor or other downstream component.

3.1 Voltage Low Output

The voltage-low output ($\overline{RST}$) is an active-low, open-drain output which sinks current when the MIC2778 detects a low input voltage.

3.2 Trip Points

Battery voltage is monitored by a comparator via a voltage divider network. The divided voltage is compared to an internal reference voltage. When the voltage at the LTH input pin drops below the internal reference voltage, the output pulls low. At this point, the voltage at HTH is assumed to be below the reference voltage.

3.3 Delay

At power-on or when the battery is replaced or recharged, and the voltage at HTH exceeds the reference voltage, the output goes high after a minimum delay of 140 ms.

4.0 APPLICATION INFORMATION

Since the MIC2778 output is an open-drain MOSFET, most applications will require a pull-up resistor. The value of the resistor should not be too large or leakage effects may dominate. The maximum recommended value is 470 kΩ.

4.1 Programming the Thresholds

The low-voltage threshold is calculated using Equation 4-1, where V_{REF} = 1.240V:

EQUATION 4-1:

$$V_{BAT(lo)} = V_{REF} \times \left(\frac{R1 + R2 + R3}{R2 + R3}\right)$$

The high-voltage threshold is calculated using Equation 4-2, where V_{REF} = 1.240V again:

EQUATION 4-2:

$$V_{BAT(hi)} = V_{REF} \times \left(\frac{R1 + R2 + R3}{R3}\right)$$

In order to provide the additional criteria needed to solve for the resistor values, the resistors can be selected such that they have a given total value, that is, R1 + R2 + R3 = R_{TOTAL}. A value such as 1 MΩ for R_{TOTAL} is a reasonable value because it draws minimum battery current but has no significant effect on accuracy.

When working with large resistors, a small amount of leakage current can cause voltage offsets that degrade system accuracy. The maximum recommended total resistance from V_{BAT} to ground is 3 MΩ.

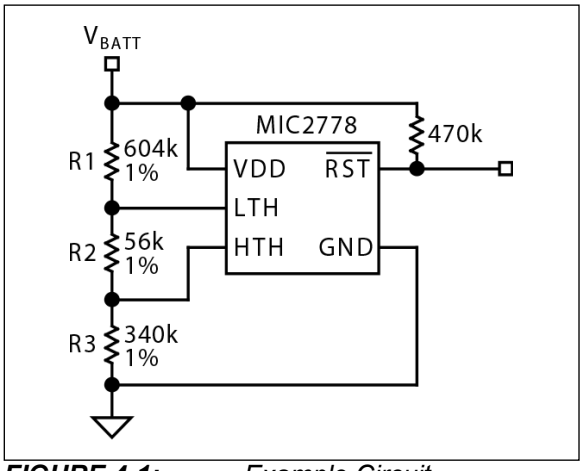


FIGURE 4-1: *Example Circuit.*

Once the desired trip points are determined, set the $V_{BAT(hi)}$ threshold first.

For example, use a total of 1MΩ = R1 + R2 + R3. For a typical single-cell lithium ion battery, 3.6V is a good "high threshold" because at 3.6V the battery is moderately charged. Solving for R3 can be done using Equation 4-3:

EQUATION 4-3:

$$V_{BAT(hi)} = 1.24 \times \left(\frac{1M\Omega}{R3}\right)$$

$$R3 = 344k\Omega$$

Once R3 is determined, Equation 4-4 can be used to determine R2. A single lithium-ion cell should not be discharged below 2.5V. Many applications limit the drain to 3.1V. Using 3.1V for the $V_{BAT(lo)}$ threshold allows calculation of the two remaining resistor values.

EQUATION 4-4:

$$V_{BAT(lo)} = 3.1V = 1.24 \times \left(\frac{1M\Omega}{R2 + 344k\Omega}\right)$$

$$R2 = 56k\Omega$$

$$R1 = 1M\Omega - R2 - R3$$

$$R1 = 600k\Omega$$

The accuracy of the resistors can be chosen based upon the accuracy required by the system.

4.2 Input Transients

The MIC2778 is inherently immune to very short negative-going "glitches." Very brief transients may exceed the $V_{BAT(lo)}$ threshold without tripping the output.

As shown in Figure 4-2, the narrower the transient, the deeper the threshold overdrive that will be ignored by the MIC2778. The graph represents the typical allowable transient duration for a given amount of threshold overdrive that will not generate a reset.

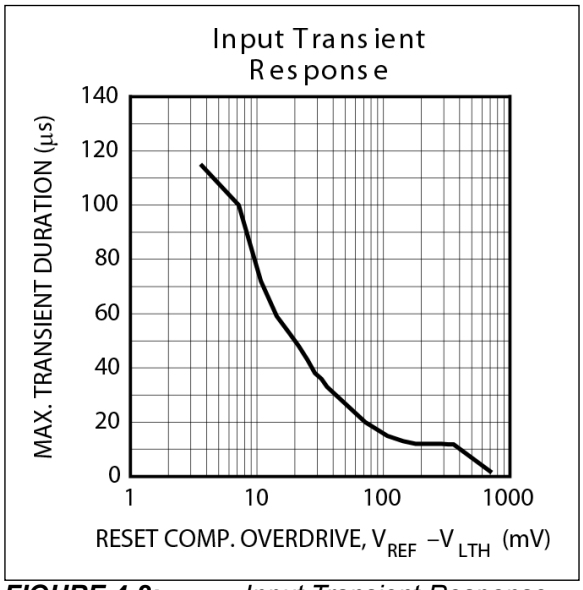


FIGURE 4-2: *Input Transient Response.*

4.3 Interfacing to Processors with Bidirectional Reset Pins

Some microprocessors have reset signal pins that are bidirectional, rather than input only. Because the MIC2778's output is open drain, it can be connected directly to the processor's reset pin using only the pull-up resistor normally required. See Figure 4-3.

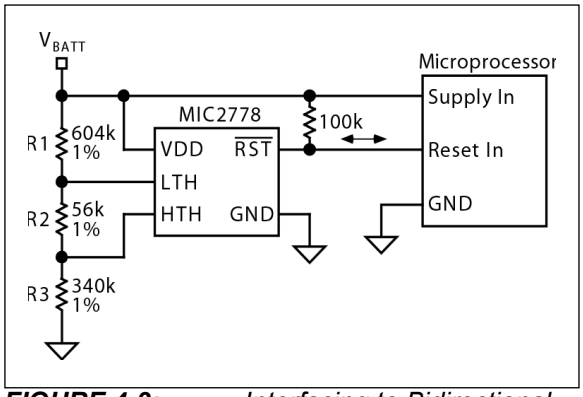
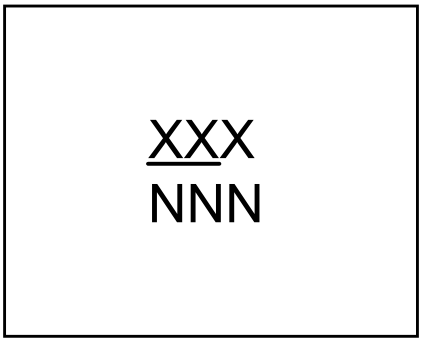


FIGURE 4-3: *Interfacing to Bidirectional Reset Pin.*

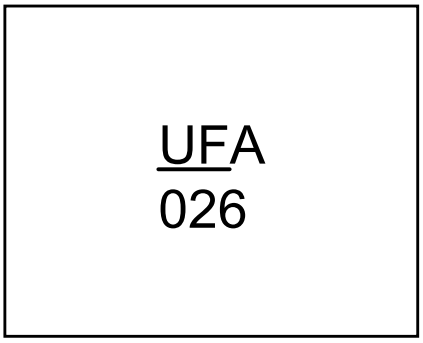
5.0 PACKAGING INFORMATION

5.1 Package Marking Information

5-Lead SOT-23*



Example



PACKAGE MARKING DRAWING SYMBOLS LEGEND

Symbol	Definition
XX . . . X	Product code or customer-specific information. (Note 1, Note 2)
YYWW	Date code, where YY is the last 2 digits of calendar year and WW is the work week (i.e., week of January 1 is week 01). (Note 3)
M	Month of assembly (if applicable). January is represented by “A” and each month thereafter follows the order of the alphabet through “L” for December.
NNN	Alphanumeric traceability code. (Note 3, Note 4)
(e3)	Pb-free JEDEC designator for Matte Tin (Sn).
*	Indicates this package is Pb-free. The Pb-free JEDEC designator (the symbol in the row above this one) 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 1: If the full Microchip part number cannot fit on one line, it will be carried over to the next line, limiting the number of available characters for customer-specific information. The package may or may not include the corporate logo.

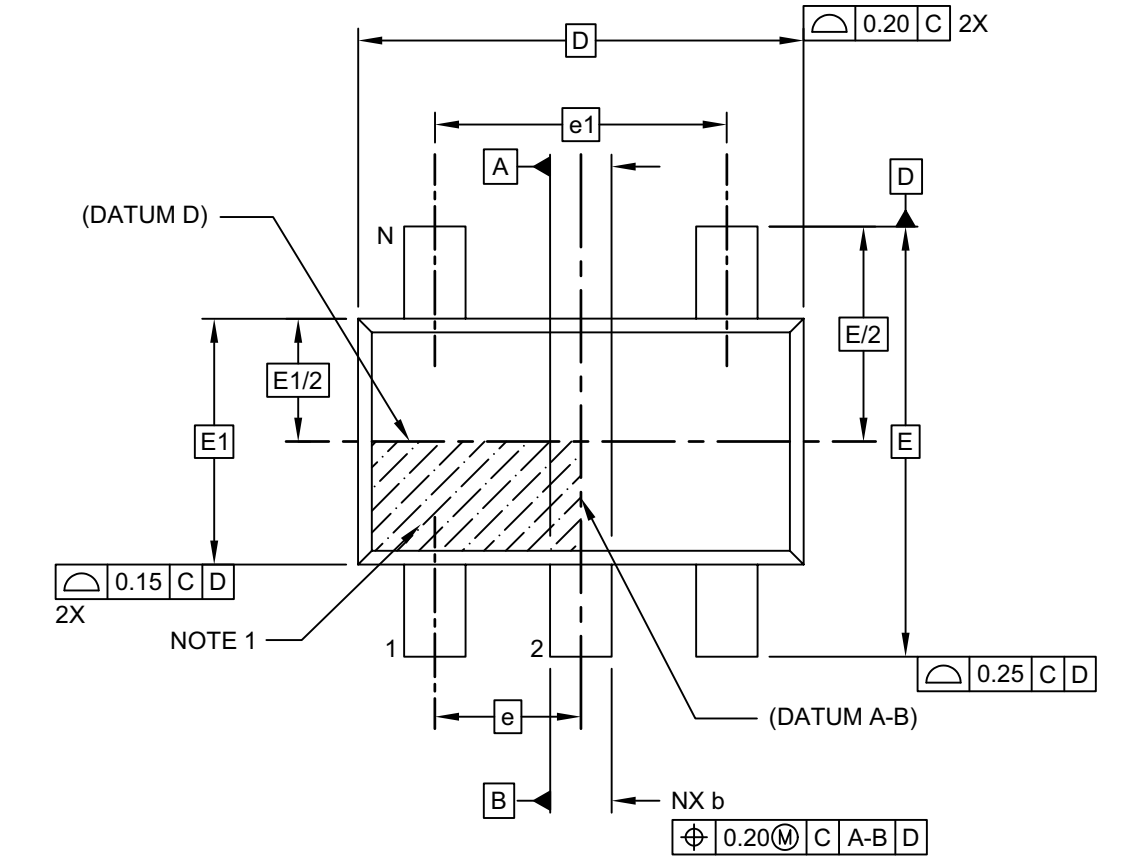
2: Any underbar (_) and/or overbar (‾) symbols shown in a package marking drawing may not be to scale.

3: If the full date code (YYWW) and the alphanumeric traceability code (NNN)—usually marked together on the last or only line of a package marking as the seven-character YYWWNNN—cannot fit on the package together, the codes will be truncated based on the number of available character spaces, as follows: 6 characters = YWWNNN; 5 characters = WWNNN; 4 characters = WNNN; 3 characters = NNN; 2 characters = NN; 1 character = N.

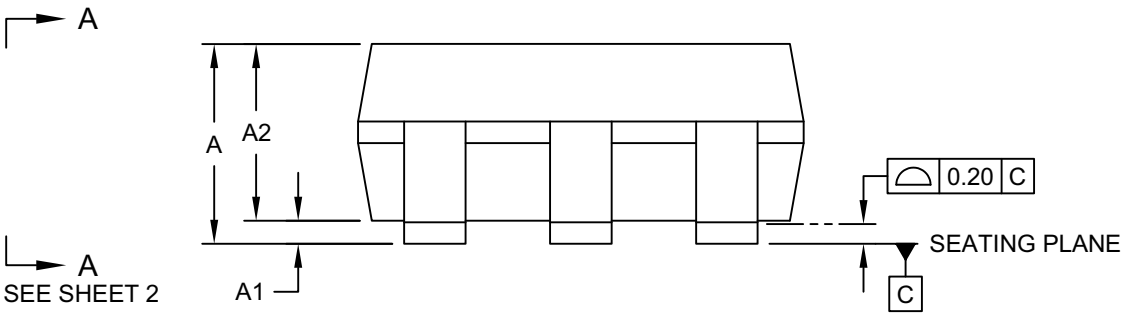
4: Some products might have a “Y” symbol at the end of the last or only line in a package marking, usually at the end of the alphanumeric traceability code (NNN or truncated versions), to indicate the product is Pb-free.

5-Lead SOT-23 [6BX] Package Outline and Recommended Land Pattern

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



TOP VIEW

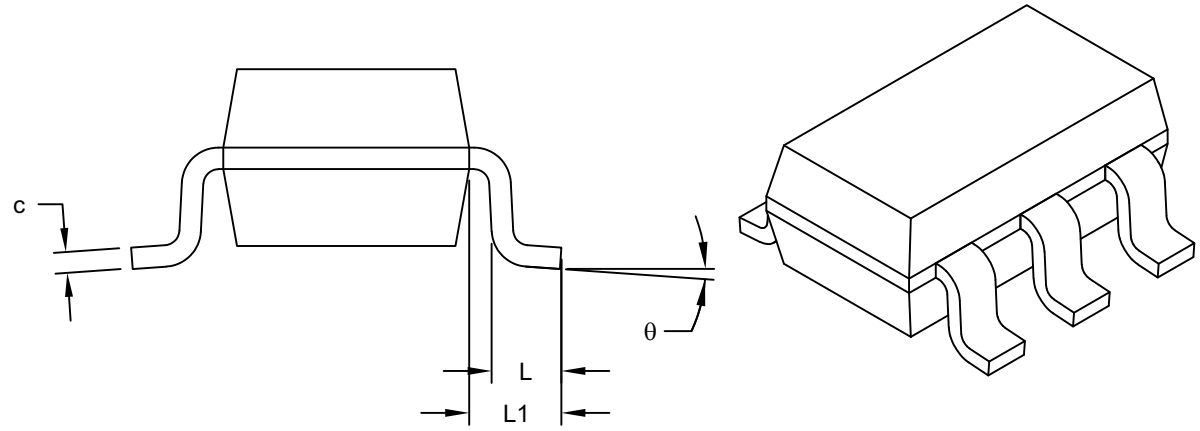


SIDE VIEW

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

5-Lead SOT-23 [6BX] Package Outline and Recommended Land Pattern

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	θ	0°	-	10°
Lead Thickness	c	0.08	-	0.26
Lead Width	b	0.20	-	0.51

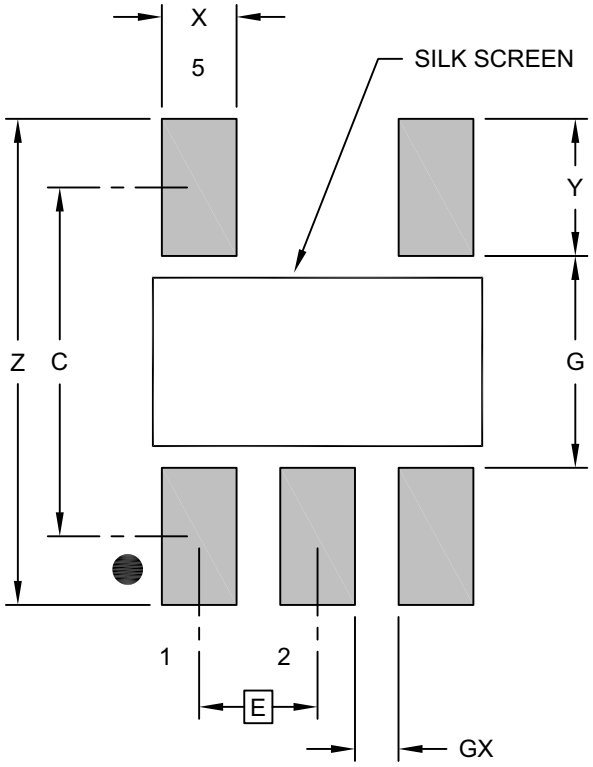
Notes:

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 H Sheet 2 of 2

5-Lead SOT-23 [6BX] Package Outline and Recommended Land Pattern

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 H

NOTES:

APPENDIX A: REVISION HISTORY

Revision A (March 2025)

- Converted Micrel document MIC2778 to Microchip data sheet DS20006907A.
- Minor text changes throughout.
- Updated backmatter information to latest version.

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	XX	-XX
Device	Accuracy	Ambient Temp. Range	Package Option	Media Type

Device:	MIC2778	=	Voltage Monitor with Adjustable Hysteresis
Accuracy:	-1	=	Accurate to 1%
	-2	=	Accurate to 2%
Ambient Temp. Range:	Y	=	–40°C to +85°C
Package Option:	M5	=	5-Lead SOT-23
Media Type:	-TR	=	3000/Reel

Examples:

a) MIC2778-1YM5-TR: MIC2778, Accurate to 1%, –40°C to +85°C Ambient Temp. Range, 4-Lead SOT-23, 3000/Reel

b) MIC2778-2YM5-TR: MIC2778, Accurate to 2%, –40°C to +85°C Ambient Temp. Range, 4-Lead SOT-23, 3000/Reel

Note1: 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:

Microchip Information

Trademarks

The “Microchip” name and logo, the “M” logo, and other names, logos, and brands are registered and unregistered trademarks of Microchip Technology Incorporated or its affiliates and/or subsidiaries in the United States and/or other countries (“Microchip Trademarks”). Information regarding Microchip Trademarks can be found at https://www.microchip.com/en-us/about/legal-information/microchip-trademarks.

ISBN: 979-8-3371-0782-0

Legal Notice

This publication and the information herein may be used only with Microchip products, including to design, test, and integrate Microchip products with your application. Use of this information in any other manner violates these terms. Information regarding device applications is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. Contact your local Microchip sales office for additional support or, obtain additional support at www.microchip.com/en-us/support/design-help/client-support-services.

THIS INFORMATION IS PROVIDED BY MICROCHIP "AS IS". MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTIES OF NON-INFRINGEMENT, MERCHANTABILITY, AND FITNESS FOR A PARTICULAR PURPOSE, OR WARRANTIES RELATED TO ITS CONDITION, QUALITY, OR PERFORMANCE.

IN NO EVENT WILL MICROCHIP BE LIABLE FOR ANY INDIRECT, SPECIAL, PUNITIVE, INCIDENTAL, OR CONSEQUENTIAL LOSS, DAMAGE, COST, OR EXPENSE OF ANY KIND WHATSOEVER RELATED TO THE INFORMATION OR ITS USE, HOWEVER CAUSED, EVEN IF MICROCHIP HAS BEEN ADVISED OF THE POSSIBILITY OR THE DAMAGES ARE FORESEEABLE. TO THE FULLEST EXTENT ALLOWED BY LAW, MICROCHIP'S TOTAL LIABILITY ON ALL CLAIMS IN ANY WAY RELATED TO THE INFORMATION OR ITS USE WILL NOT EXCEED THE AMOUNT OF FEES, IF ANY, THAT YOU HAVE PAID DIRECTLY TO MICROCHIP FOR THE INFORMATION.

Use of Microchip devices in life support and/or safety applications is entirely at the buyer's risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights unless otherwise stated.

Microchip Devices Code Protection Feature

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.