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## Low-Voltage, Secondary-Side Shunt Regulator

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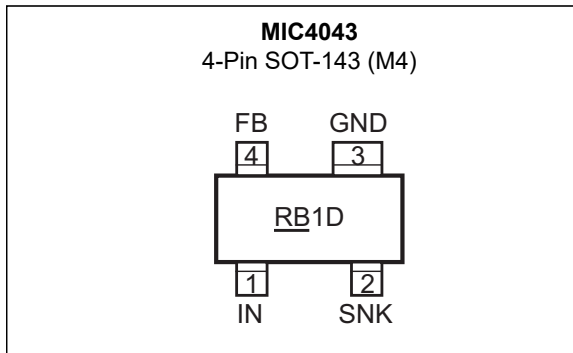
### Features

- Ideal for 1.8V Switching Converters
- Low-Voltage Operation:
  - 400 mV Maximum Saturation Over Operating Temperature Range
- Easy to Use
  - Voltage In, Current Out
- 2% Voltage Tolerance Over Operating Temperature Range

### Applications

- Optically Isolated, Low-Voltage Power Supplies
- Low-Voltage Discrete Regulator Control

### Package Type



### General Description

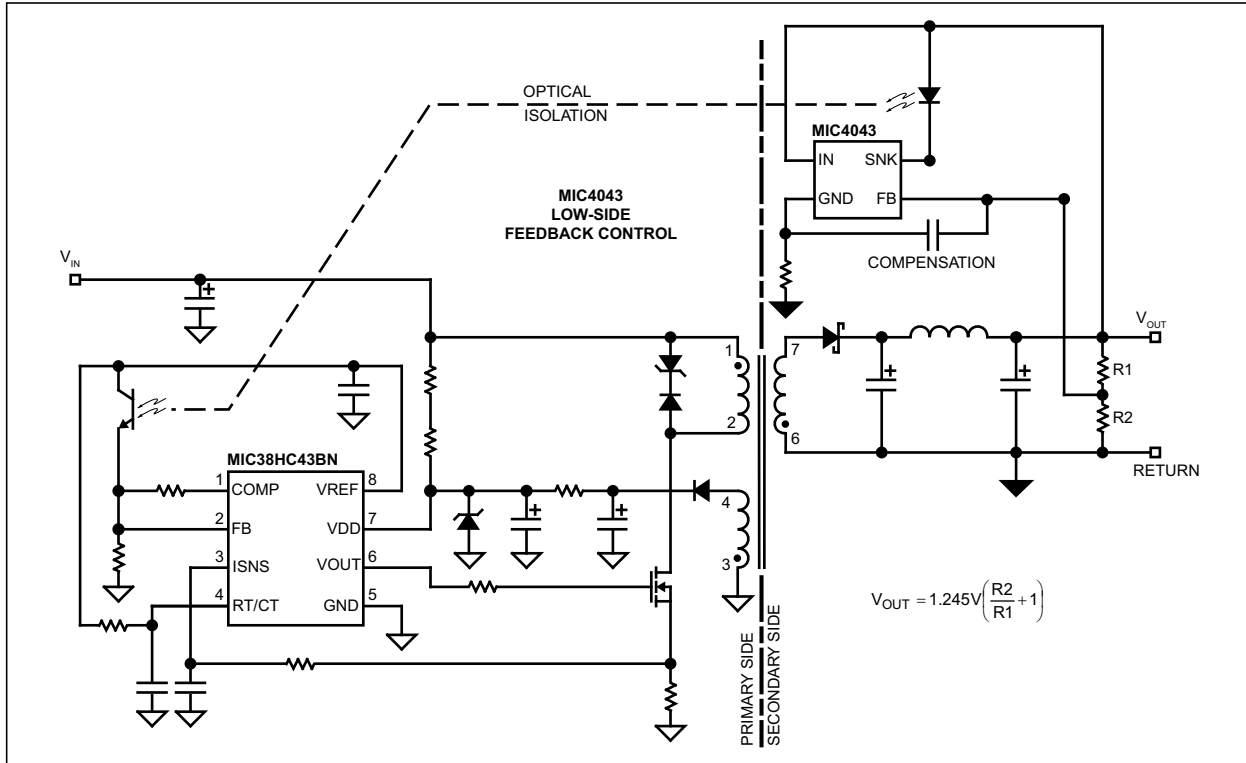
The MIC4043 is a shunt regulator optimized for secondary-side regulation in low-voltage power supplies. Featuring an output stage guaranteed to swing within 400 mV of ground, the MIC4043 can be used in power supplies operating down to 1.8V, even with opto-isolators requiring greater than 1.2V of headroom.

In power supply applications, the MIC4043 normally drives the LED of an optically isolated feedback circuit. The MIC4043 monitors a resistively divided output voltage and sinks error current through the opto-isolator's LED (secondary side); the opto-isolator's transistor (primary side) provides this signal to the controller's feedback input. The MIC4043 is also practical for other voltage-monitoring applications requiring an open-collector output.

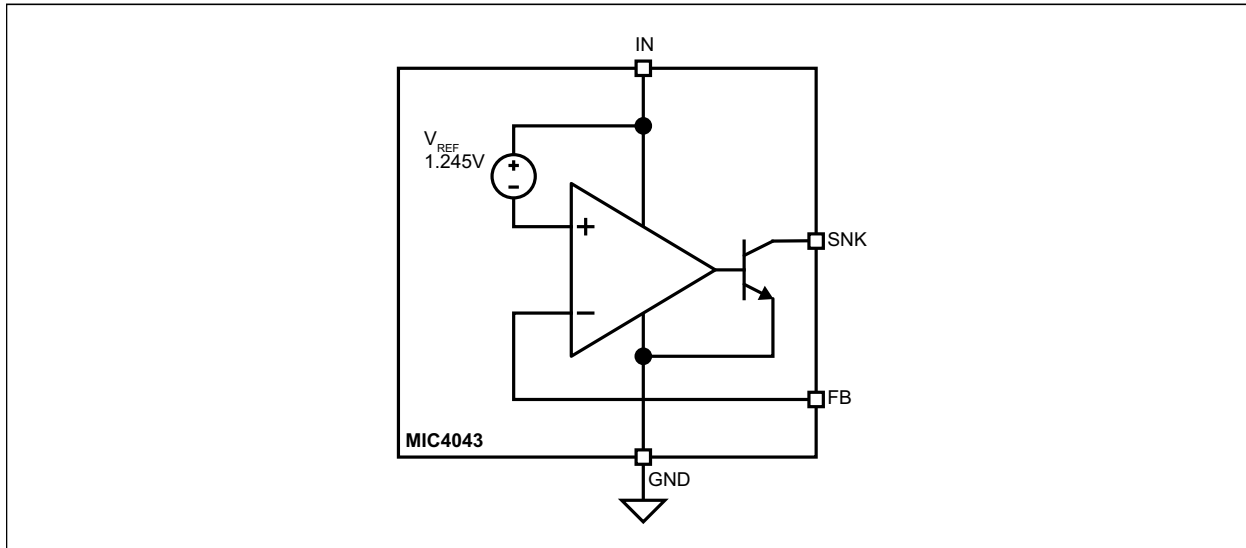
The MIC4043 replaces conventional '431-type shunt regulators to allow low-voltage applications where there is inadequate headroom for a 2.5V regulator in series with an opto-isolator. Replacing '431-type devices requires only a minor change to the way that the resistive-divider values are calculated.

# MIC4043

## Typical Application Diagram



## Functional Block Diagram



## 1.0 ELECTRICAL CHARACTERISTICS

### Absolute Maximum Ratings †

Input Voltage ( $V_{IN}$ ) .....	+15V
Output Voltage ( $V_{SNK}$ ).....	+15V
Output Current ( $I_{SNK}$ ).....	15 mA
ESD Rating (HBM; <a href="#">Note 1</a> ) .....	.2 kV
ESD Rating (MM; <a href="#">Note 1</a> ) .....	200V

### Operating Ratings ‡

Input Voltage ( $V_{IN}$ ) .....	+10V
Output Voltage ( $V_{SNK}$ ).....	+10V

**† 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 k $\Omega$  in series with 100 pF. Machine model, 200 pF.

# MIC4043

## ELECTRICAL CHARACTERISTICS

$T_A = +25^\circ\text{C}$ , unless noted.

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Reference Voltage (Note 1)	$V_{REF}$	—	1.245	—	V	—
Reference Voltage Tolerance	—	—	—	$\pm 1$	%	—
		—	—	$\pm 2$		$-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$
Supply Current	$I_{OZ}$	—	35	65	$\mu\text{A}$	$I_{SNK} = 0 \text{ mA}$
		—	—	70		$I_{SNK} = 0 \text{ mA}$ , $-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$
Transconductance	$\frac{\Delta I_{SNK}}{\Delta V_{IN}}$	3.5	150	—	S	$1 \text{ mA} < I_{SNK} < 15 \text{ mA}$
		2	—	—		$1 \text{ mA} < I_{SNK} < 15 \text{ mA}$ , $-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$
Output Transistor Saturation Voltage	—	—	160	250	mV	$I_{SNK} = 15 \text{ mA}$
		—	—	400		$I_{SNK} = 15 \text{ mA}$ , $-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$
Output Leakage	—	—	—	0.5	$\mu\text{A}$	$V_{SNK} = 5\text{V}$ , output transistor off
		—	—	1		$V_{SNK} = 5\text{V}$ , output transistor off, $-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$

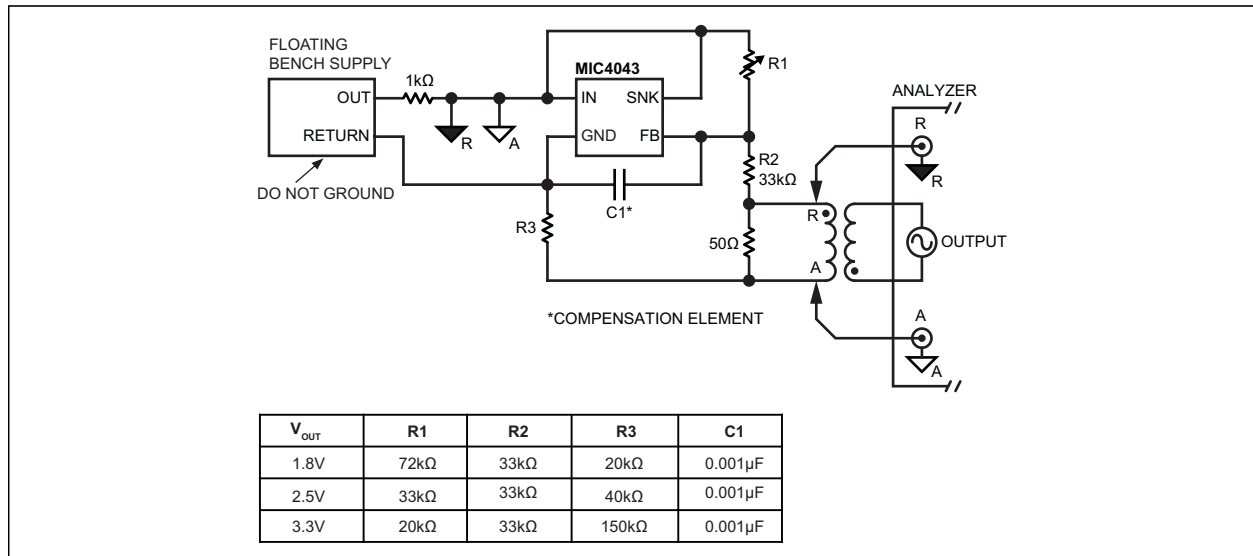
**Note 1:** Reference voltage is not referenced to ground. The reference is between the IN and FB pins.

## TEMPERATURE SPECIFICATIONS (Note 1)

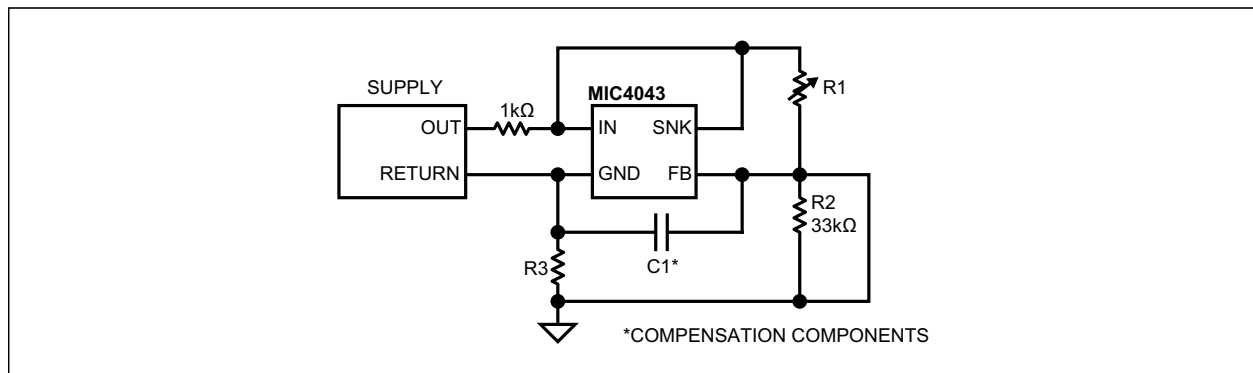
Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
<b>Temperature Ranges</b>						
Operating Temperature Range	$T_A$	-40	—	+85	°C	—
Storage Temperature	$T_S$	-65	—	+150	°C	—

**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.,  $T_A$ ,  $T_J$ ,  $\theta_{JA}$ ). Exceeding the maximum allowable power dissipation will cause the device operating junction temperature to exceed the maximum +85°C rating. Sustained junction temperatures above +85°C can impact the device reliability.

## Test Circuits



**FIGURE 1-1:** Compensation (Bode Plot) Circuit.

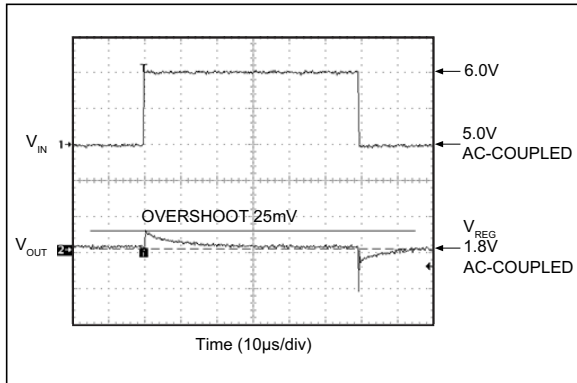


**FIGURE 1-2:** Transient Response Circuit.

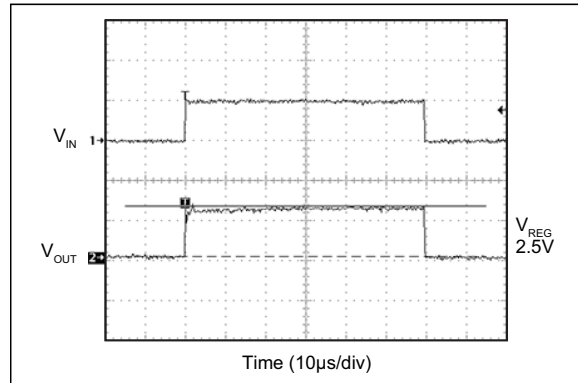
# MIC4043

## 2.0 TYPICAL PERFORMANCE CURVES

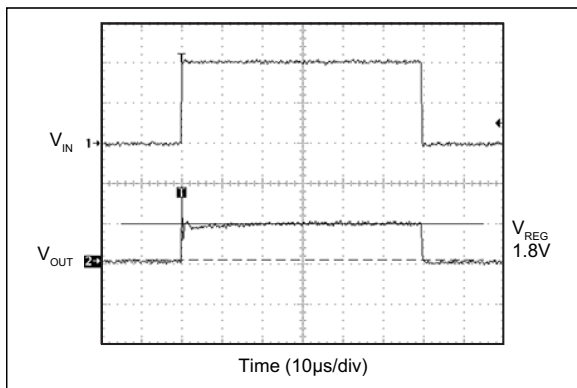
**Note:** The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.



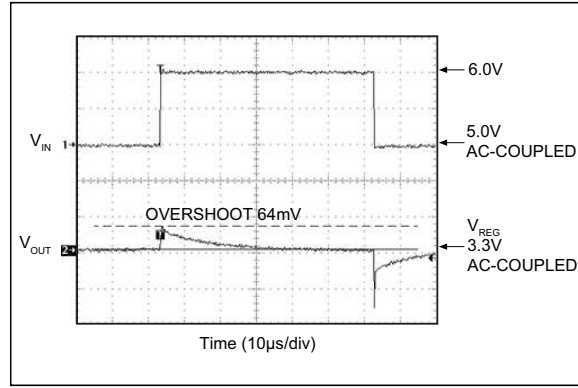
**FIGURE 2-1:** Transient Response (1.8V Output).



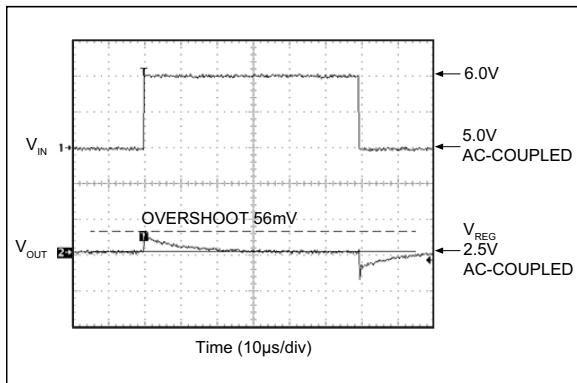
**FIGURE 2-4:** Turn-On Transient Response (2.5V Output).



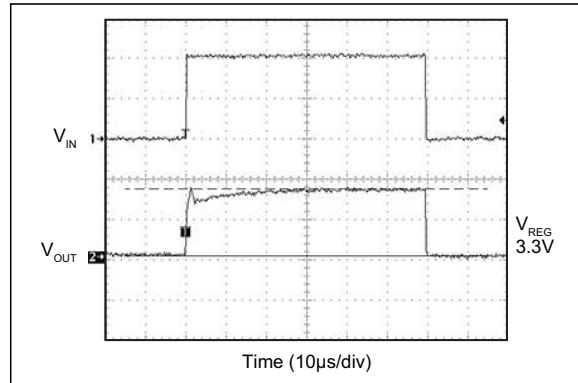
**FIGURE 2-2:** Turn-On Transient Response (1.8V Output).



**FIGURE 2-5:** Transient Response (3.3V Output).



**FIGURE 2-3:** Transient Response (2.5V Output).



**FIGURE 2-6:** Turn-On Transient Response (3.3V Output).

## 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	Input: Supply voltage input.
2	SNK	Sink (Output): NPN open-collector output.
3	GND	Ground.
4	FB	Feedback (Input): Feedback input from external voltage divider network.

## 4.0 FUNCTIONAL DESCRIPTION

The MIC4043 combines a  $g_M$  amplifier, precision 1.245V reference, and a pass transistor in a single package.

The operation of the MIC4043 is similar to conventional shunt regulators such as the industry standard '431. In a closed loop system, the MIC4043 maintains the desired feedback voltage at the FB pin by sinking current onto the SNK pin proportional to the error voltage at the FB pin. The ratio of sink current to error voltage is the transconductance of the device.

### 4.1 Reference

The MIC4043 uses a high-side reference. External voltage dividers providing feedback to the MIC4043 will be inverted when compared to those used with '431-equivalent devices.

### 4.2 Behavior

The external feedback voltage is compared to the internal high-side 1.245V reference.

If the feedback voltage,  $V_{FB}$ , is less than  $V_{IN} - V_{REF}$ , the amplifier provides no drive to the sink transistor. If the feedback voltages are greater than  $V_{IN} - V_{REF}$ , the amplifier drives the pass transistor which sinks current to ground.

## 5.0 APPLICATION INFORMATION

### 5.1 Replacement of '431-Type Devices

Because the MIC4043 uses a high-side reference, external voltage dividers providing the feedback voltage will be inverted when compared to those used with '431-equivalent devices.

The industry-standard '431 is also typically used in series with an opto-isolator LED. This configuration has a voltage drop of at least 2.5V for the '431, plus 1.4V for the LED (3.9V). More recent lower-voltage shunt regulators require at least 1.25V of headroom in addition to the 1.4V for the opto-isolator, for a total of 2.65V.

The MIC4043 removes the need to place the shunt reference in parallel with the opto-isolator. The MIC4043 combines a 1.245V reference in conjunction with an error amplifier that drives an NPN output transistor. The NPN transistor is connected in series with the opto-isolator and regulates the drive current in the opto-isolator. Unlike conventional shunt regulators, the MIC4043 does not have to connect the shunt reference in series with the opto-isolator, so the voltage drop is just the saturation voltage for one transistor, typically 160 mV at full load.

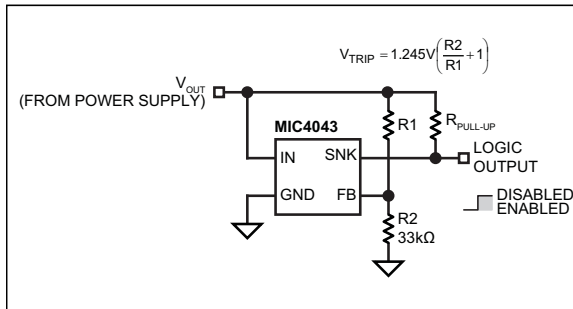
### 5.2 Compensation

The non-inverting side of the error amplifier is connected to the high-side reference; the reference is connected to the IN pin. The inverting side of the error amplifier is brought out to the FB pin. For some applications, no compensation is needed, but for most, some resistor capacitor network is necessary between the FB pin and GND pin. The value of the feedback capacitance is application specific, but for most applications 100 pF to 3000 pF is all that is needed. Changing the feedback capacitor changes the loop response; that is, phase and gain margin. An empirical way to check overall system loop response, if a network analyzer is not available, is to step load the output of the systems from 10% to 100% of nominal load. The resultant small signal response at the output of the systems will provide an idea of which direction to go based on the overshoot and settling time of  $V_{OUT}$ .



## 5.3 Voltage Detector

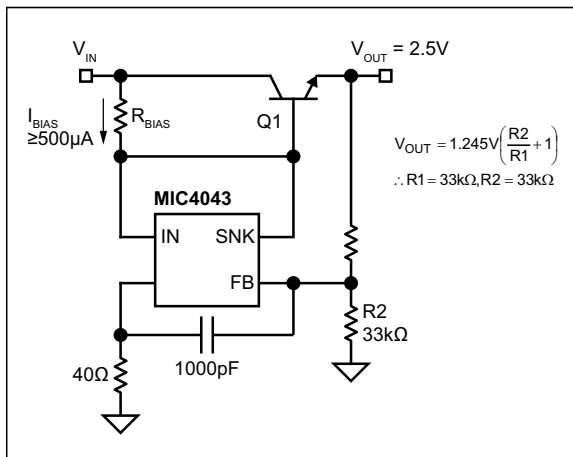
Figure 5-1 shows a simple voltage threshold detector with a logic output.



**FIGURE 5-1:** Voltage Detector.

## 5.4 High-Current Regulator

For the high-current regulator shown in Figure 5-2, headroom is equal to the saturation voltage of Q1 plus the saturation voltage of the MIC4043 ( $V_{SAT(MIN)} = 200\text{ mV}$ ).



**FIGURE 5-2:** High-Current Regulator.

# MIC4043

## 6.0 OFF-LINE POWER SUPPLY INFORMATION

### 6.1 Off-Line 1.8V/2A Power Supply

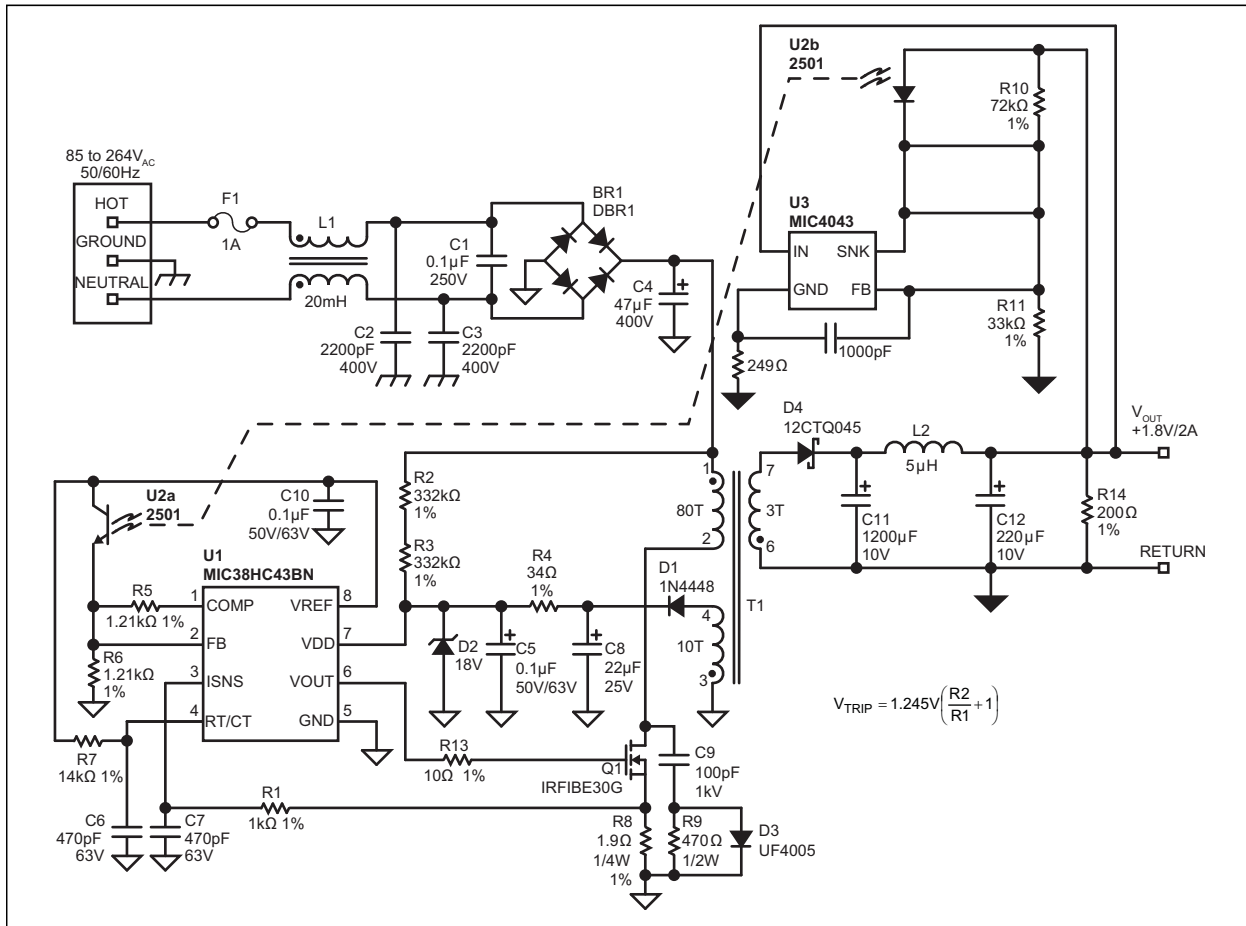


FIGURE 6-1: Off-Line 1.8V/2A Power Supply.

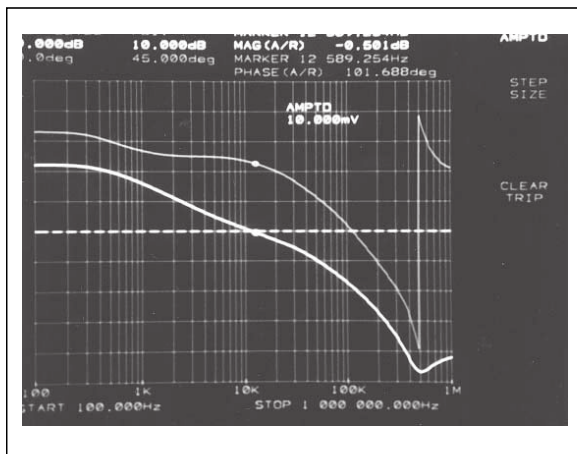


FIGURE 6-2: 1.8V/1A Output Bode Plot ( $\theta$  Margin =  $102^\circ$ ).

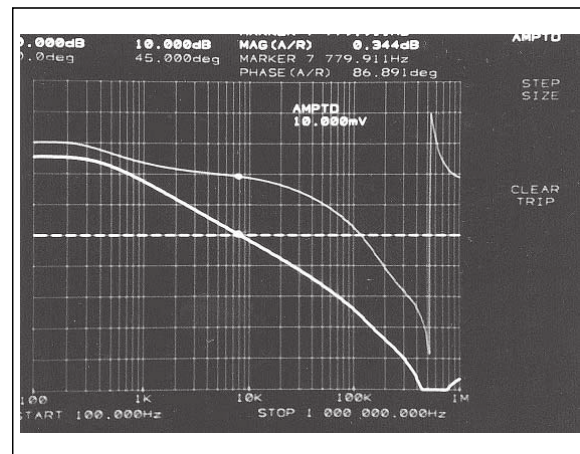


FIGURE 6-3: 1.8V/2A Output Bode Plot ( $\theta$  Margin =  $87^\circ$ ).







## 7.0 PACKAGE MARKING INFORMATION

### 7.1 Package Marking Information

4-Lead SOT143\*  
(Front)



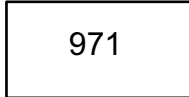
Example



4-Lead SOT143\*  
(Back)



Example



<p><b>Legend:</b> 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 Ⓔ3 Pb-free JEDEC<sup>®</sup> designator for Matte Tin (Sn) * This package is Pb-free. The Pb-free JEDEC designator (Ⓔ3) 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).</p>
<p><b>Note:</b> 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.</p>

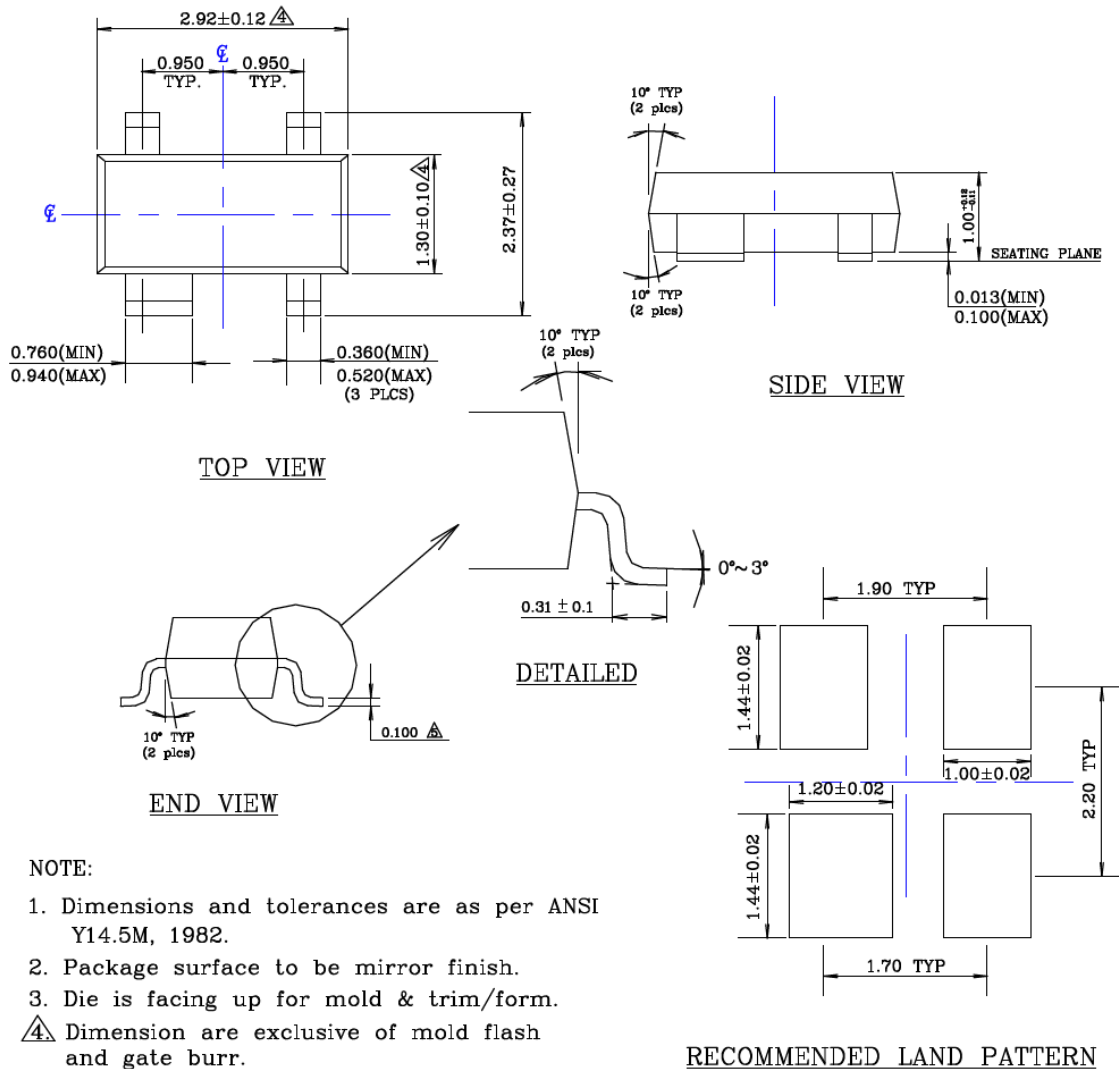


## 4-Lead SOT-143 Package Outline and Recommended Land Pattern

**TITLE**

4 LEAD SOT143 PACKAGE OUTLINE & RECOMMENDED LAND PATTERN

DRAWING #	SOT143-4LD-PL-1	UNIT	MM
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**NOTE:**

1. Dimensions and tolerances are as per ANSI Y14.5M, 1982.
2. Package surface to be mirror finish.
3. Die is facing up for mold & trim/form.
4. Dimension are exclusive of mold flash and gate burr.
5. Dimension are exclusive of solder plating.

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

# MIC4043

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NOTES:



## APPENDIX A: REVISION HISTORY

### Revision A (February 2020)

- Converted Micrel data sheet MIC4043 to Microchip DS20006299A.
- Minor text changes throughout.

# MIC4043

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NOTES:

## PRODUCT IDENTIFICATION SYSTEM

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

<u>PART NO.</u>		<u>X</u>	<u>XX</u>	<u>-XX</u>
Device		Temperature Range	Package	Media Type
<b>Device:</b>	MIC4043:	Low-Voltage, Secondary-Side Shunt Regulator		
<b>Temperature Range:</b>	Y	=	-40°C to +85°C (Industrial)	
<b>Package:</b>	M4	=	4-Lead SOT-143	
<b>Media Type:</b>	TR	=	3,000/Reel	

**Examples:**

a) MIC4043YM4-TR: Low-Voltage, Secondary-Side Shunt Regulator, -40°C to +85°C Temperature Range, 4-Lead SOT-143, 3,000/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.

# MIC4043

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NOTES:

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