

### 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 400mV of ground, the MIC4043 can be used in power supplies operating down to 1.8V, even with optoisolators 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 optoisolator's LED (secondary side); the optoisolator'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 optoisolator. Replacing '431-type devices requires only a minor change to the way that the resistive-divider values are calculated.

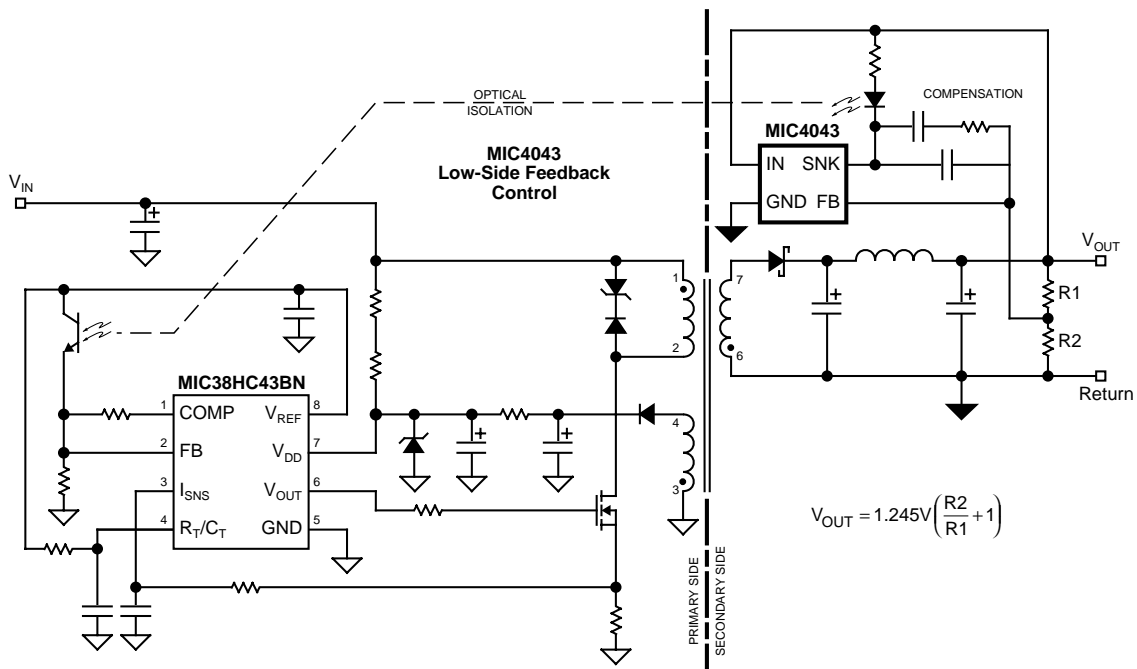
### Features

- Ideal for 1.8V switching converters
- Low-voltage operation  
400mV 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

### Typical Application

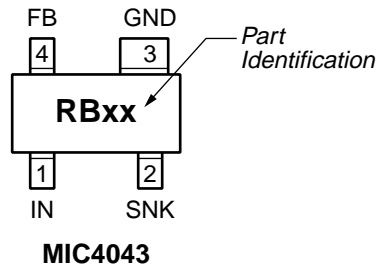


200kHz DC-DC Flyback Converter

## Ordering Information

| Part Number | Marking | Voltage | Tolerance | Configuration  | Temperature Range | Package |
|-------------|---------|---------|-----------|----------------|-------------------|---------|
| MIC4043BM4  | RBAD    | 1.245V  | 1%        | Open Collector | -40°C to +85°C    | SOT-143 |

## Pin Configuration



## Pin Description

| Pin Number | Pin Name | Pin Function   |
|------------|----------|--|
| 1          | IN       | Input: Supply voltage input.   |
| 2          | SNK      | Sink (Output): NPN open collector output.                                      |
| 3          | GND      | Ground   |
| 4          | FB       | Feedback (Input): 1.245V feedback input from external voltage-divider network. |

### Absolute Maximum Ratings (Note 1)

|                               |                 |
|-------------------------------|-----------------|
| Input Voltage ( $V_{IN}$ )    | +15V            |
| Output Voltage ( $V_{SNK}$ )  | +15V            |
| Storage Temperature ( $T_S$ ) | -65°C to +150°C |
| ESD Rating, <b>Note 3</b>     |                 |
| human body model              | 2kV             |
| machine model                 | 200V            |

### Operating Ratings (Note 2)

|                                      |                |
|--------------------------------------|----------------|
| Input Voltage ( $V_{IN}$ )           | +10V           |
| Output Voltage ( $V_{SNK}$ )         | +10V           |
| Maximum Output Current ( $I_{SNK}$ ) | 15mA           |
| Temperature Range ( $T_A$ )          | -40°C to +85°C |

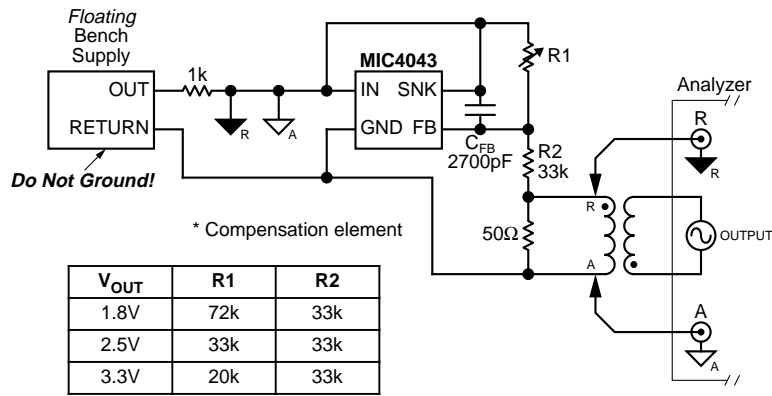
# Electrical Characteristics

$T_A = 25^\circ\text{C}$ , **bold** values indicate  $-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$ ; unless noted

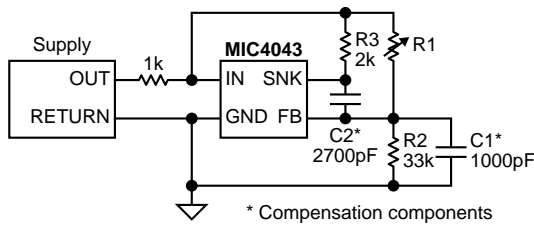
| Parameter  | Condition  | Min             | Typ   | Max                                  | Units                          |
|--|--|-----------------|-------|--------------------------------------|--------------------------------|
| Reference Voltage  |  |                 | 1.245 |                                      | V                              |
| Reference Voltage Tolerance                                      |  |                 |       | $\pm 1$<br><b><math>\pm 2</math></b> | %<br>%                         |
| Supply Current   | $I_{\text{SNK}} = 0\text{mA}$                        |                 | 35    | 65<br><b>70</b>                      | $\mu\text{A}$<br>$\mu\text{A}$ |
| Transconductance<br>$\Delta I_{\text{SNK}}/\Delta V_{\text{IN}}$ | $1\text{mA} < I_{\text{SNK}} < 15\text{mA}$          | 3.5<br><b>2</b> | 150   |                                      | S<br>S                         |
| Output Transistor Saturation Voltage                             | $I_{\text{SNK}} = 15\text{mA}$                       |                 | 160   | 250<br><b>400</b>                    | mV<br>mV                       |
| Output Leakage   | $V_{\text{SNK}} = 5\text{V}$ , output transistor off |                 |       | 0.5<br><b>1</b>                      | $\mu\text{A}$<br>$\mu\text{A}$ |

- Note 1.** Exceeding the absolute maximum rating may damage the device.
- Note 2.** The device is not guaranteed to function outside its operating rating.
- Note 3.** Devices are ESD sensitive. Handling precautions recommended. Human body model, 1.5k in series with 100pF. Machine model, 200pF.

## Test Circuits

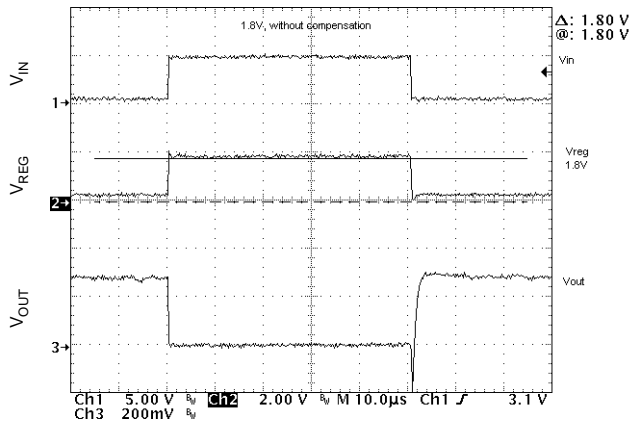


**Test Circuit 1. Compensation (Bode Plot) Circuit**

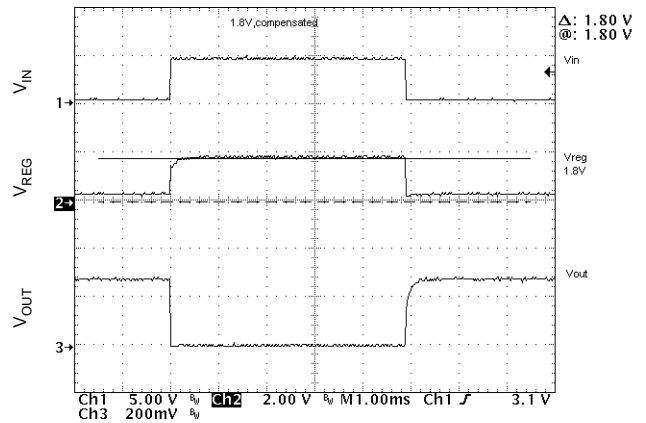


**Test Circuit 2. Transient Response Circuit**

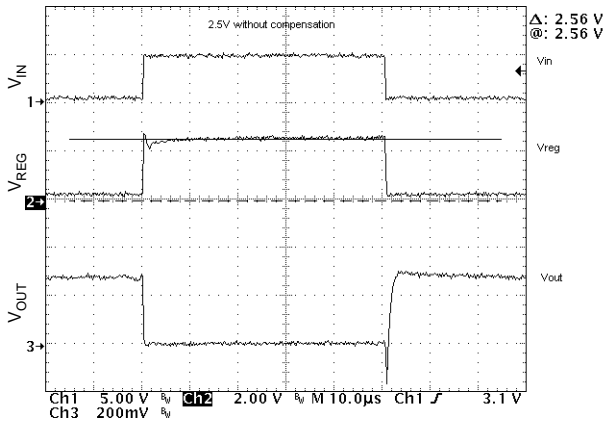
**Transient Response 1a.**  
**1.8V Output Without Compensation**



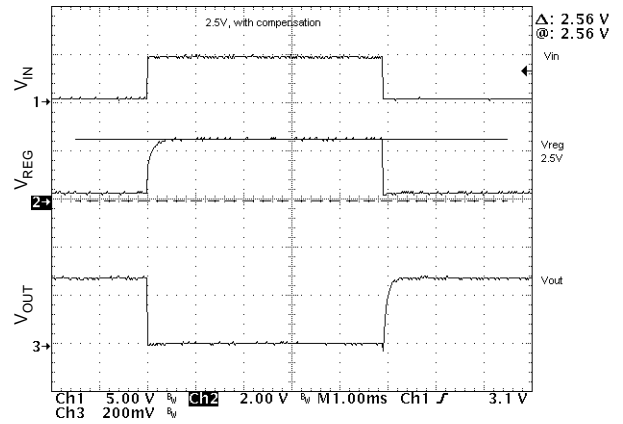
**Transient Response 1b.**  
**1.8V Output With Compensation**



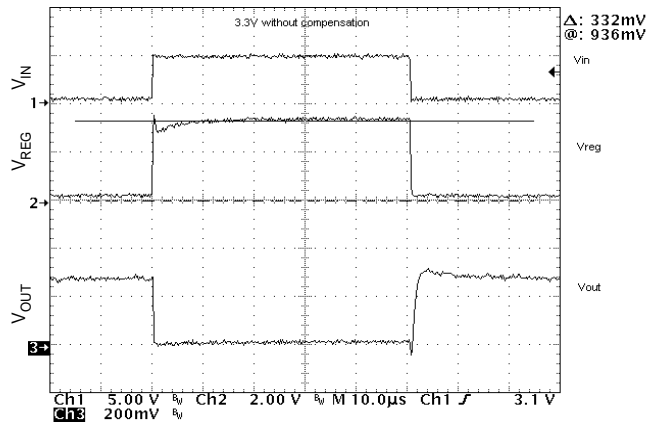
**Transient Response 2a.**  
**2.5V Output Without Compensation**



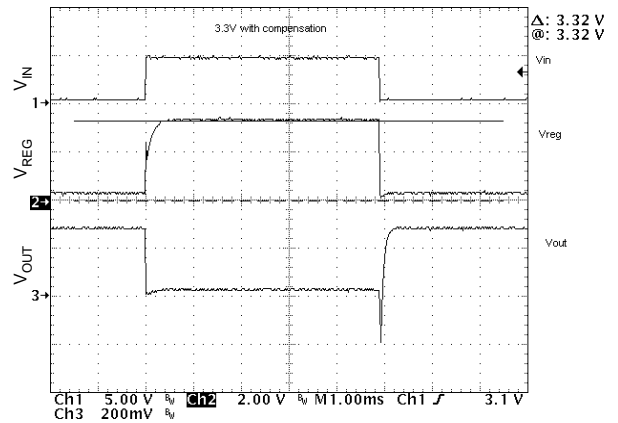
**Transient Response 2b.**  
**2.5V Output With Compensation**



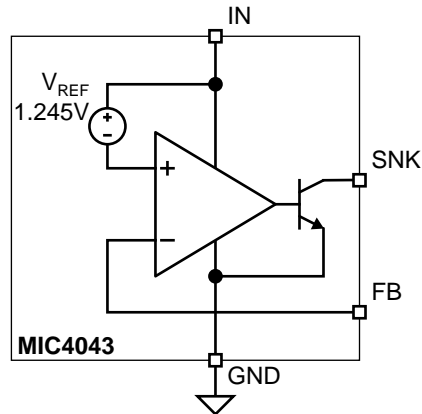
**Transient Response 3a.**  
**3.3V Output Without Compensation**



**Transient Response 3b.**  
**3.3V Output With Compensation**



## Functional Diagram



## 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.

## 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.

## 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 voltage is greater than  $V_{IN} - V_{REF}$ , the amplifier drives the pass transistor which sinks current to ground.

## Applications Information

### Replacement of '431-Type Devices

Since 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 effectively puts the regulator reference voltage in parallel with the LED and drives the LED with a single, series NPN transistor. The headroom required by this transistor is its saturation voltage of 400mV over its operating temperature range, reducing the overall headroom requirement to  $1.4V + 0.4V = 1.8V$ .

### Compensation

The noninverting 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 small value of capacitance is necessary between the FB pin and SNK pin. The value of the feedback capacitance is application specific, but for most applications 100pF to 3000pF 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  $V_{OUT}$ .

### Voltage Detector

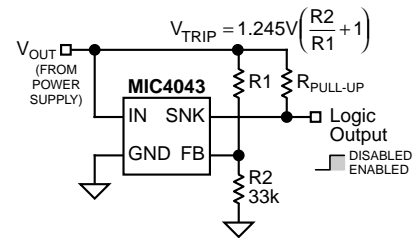


Figure 1. Voltage Detector

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

### High-Current Regulator

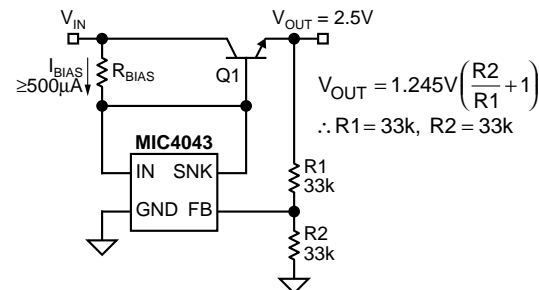


Figure 2. High-Current Regulator

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



Off-Line 2.5V/2A Power Supply

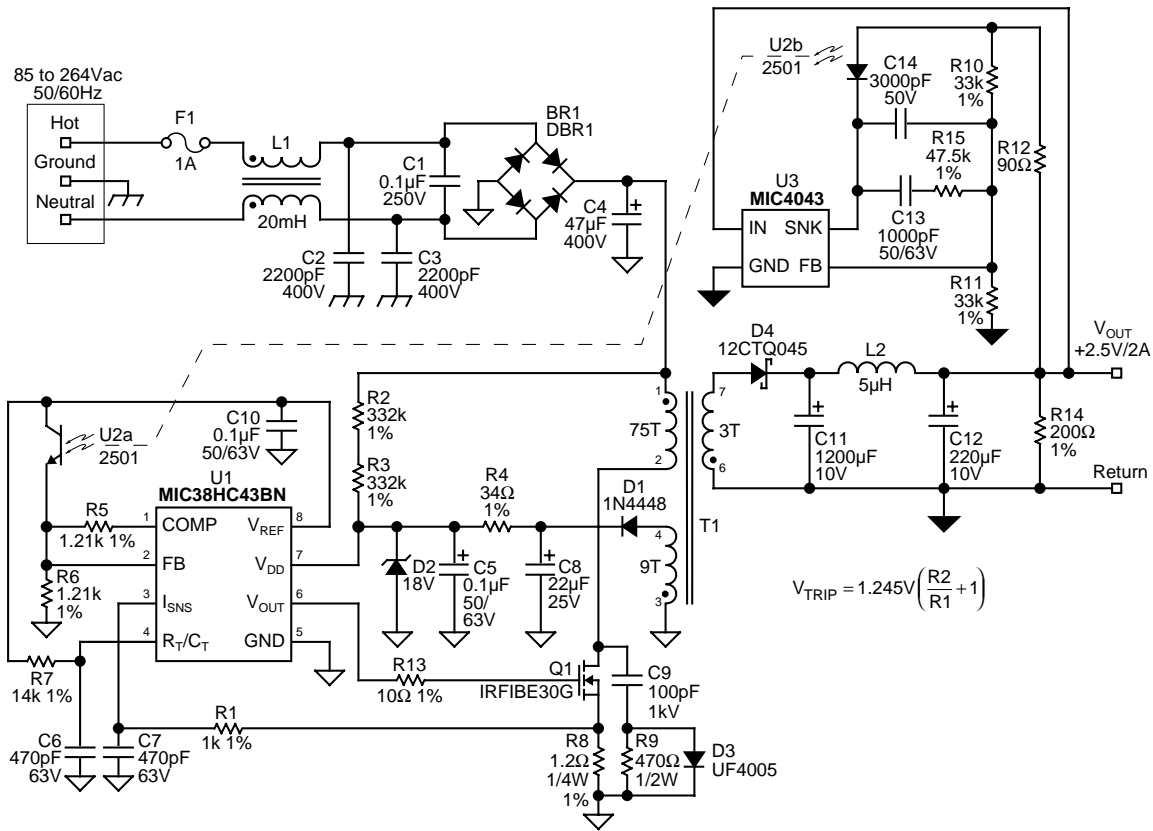


Figure 4. Off-Line 2.5V/2A Power Supply

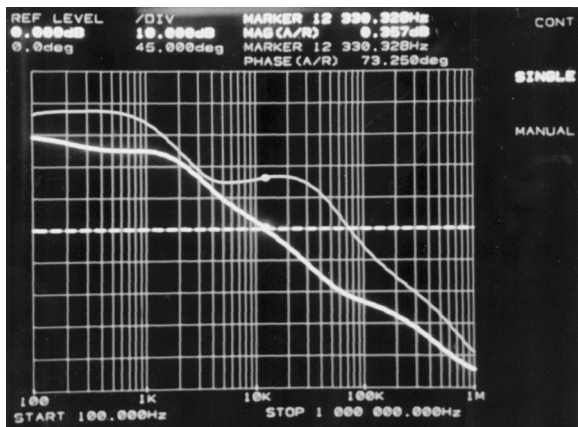


Figure 4a. 2.5V/1A Bode Plot  
( $\theta$  margin = 73°)

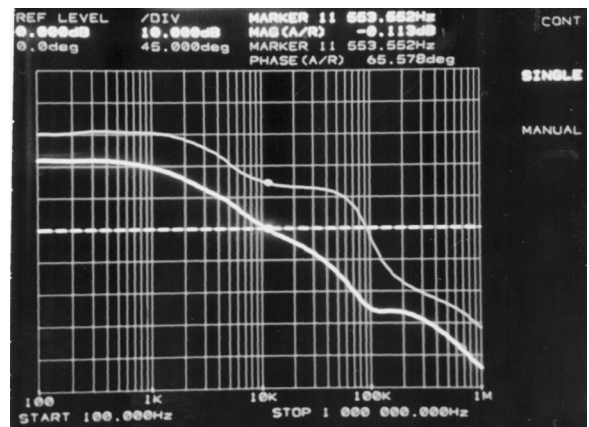


Figure 4b. 2.5V/2A Bode Plot  
( $\theta$  margin = 65°)



Off-Line 3.3V/2A Power Supply

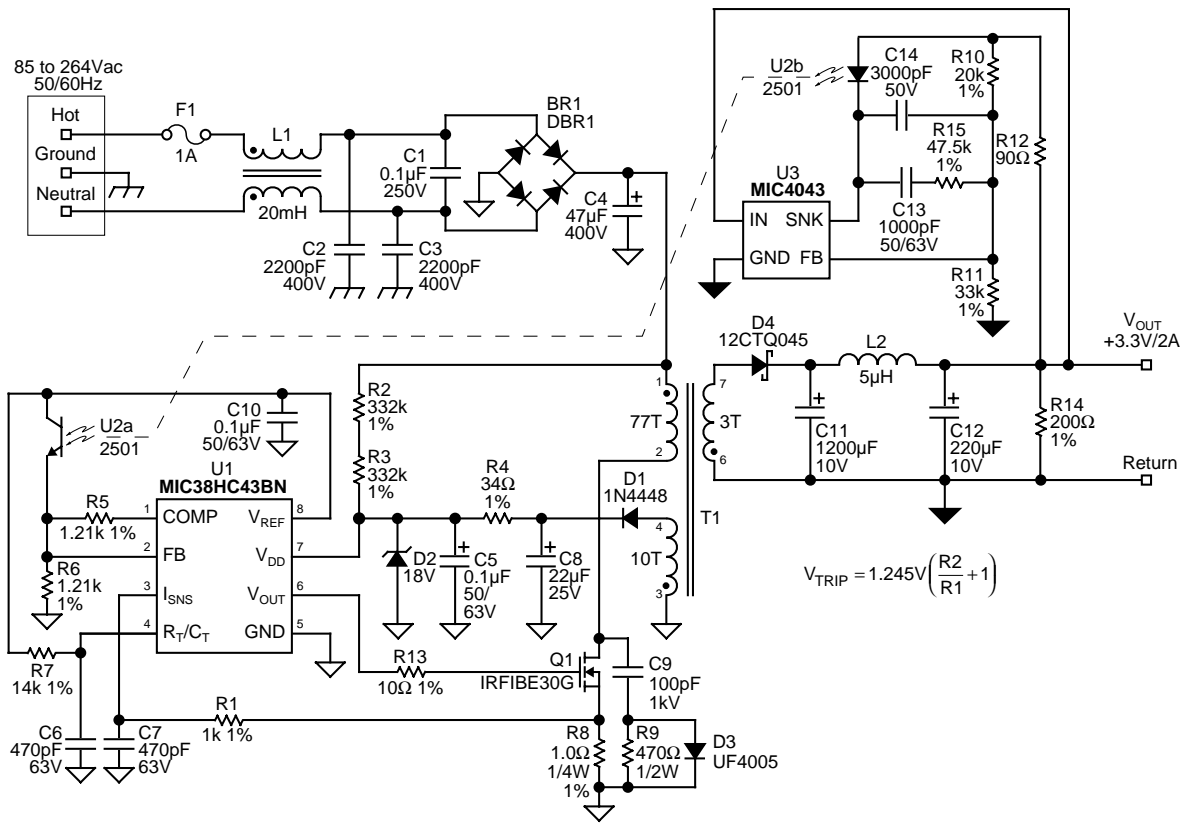


Figure 5. Off-Line 3.3V/2A Power Supply

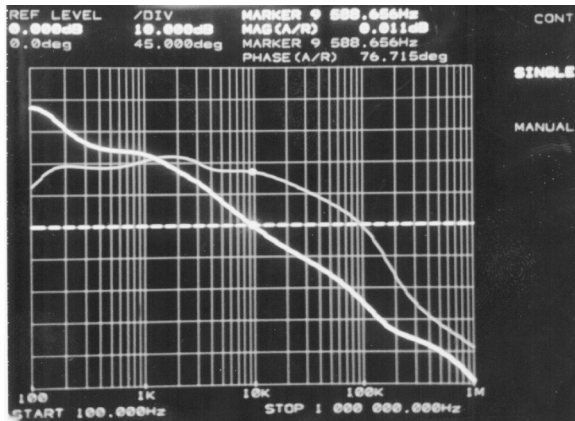


Figure 5a. 3.3V/1A Bode Plot  
( $\theta$  margin = 76°)

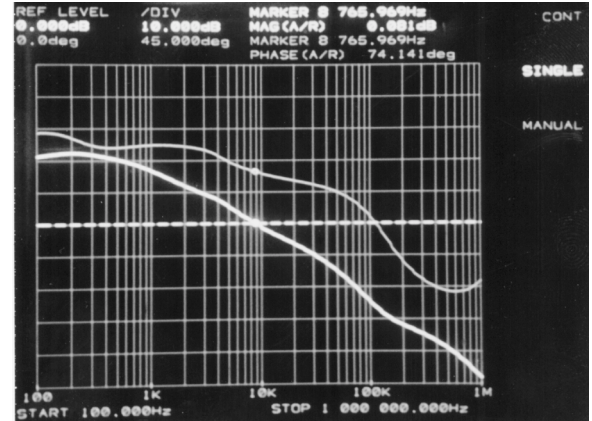
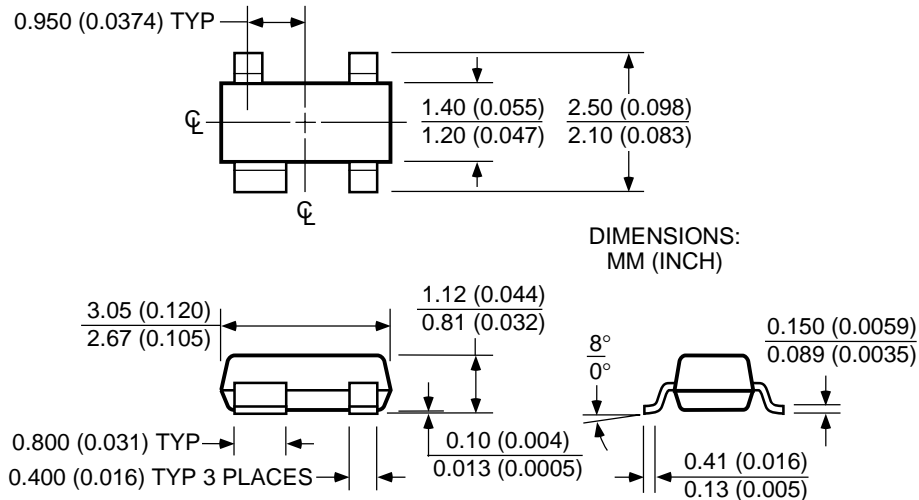


Figure 5b. 3.3V/2A Bode Plot  
( $\theta$  margin = 74°)



### Package Information



**SOT-143 (M4)**

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