



MIC4043

Low-Voltage, Secondary-Side Shunt Regulator

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 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.

Datasheets and support documentation are available on Micrel's web site at: www.micrel.com.

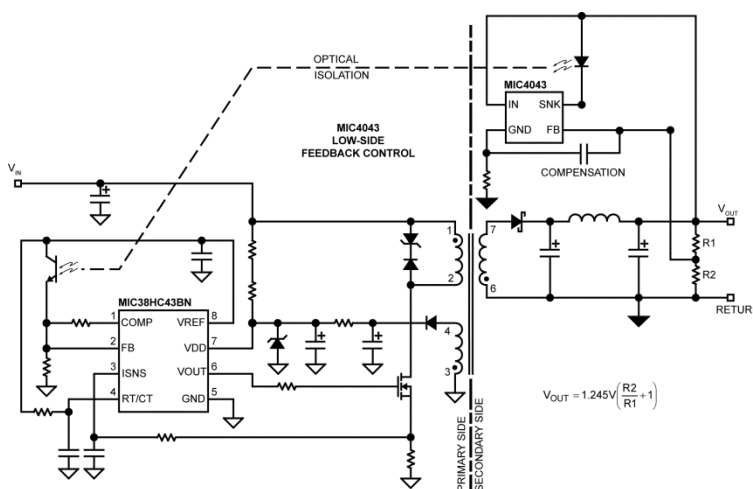
Features

- 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-to-DC Flyback Converter

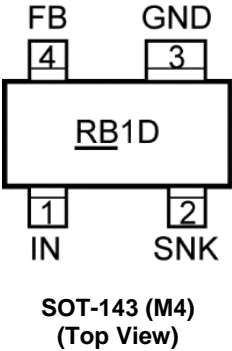
Ordering Information

Part Number ⁽¹⁾	Marking	Voltage (V)	Tolerance	Configuration	Temperature Range	Package
MIC4043YM4	<u>RB</u> 1D	1.245	1%	Open Collector	−40°C to +85°C	SOT-143

Note:

1. Underbar () symbol may not be to scale.

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): Feedback input from external voltage-divider network.

Absolute Maximum Ratings⁽²⁾

Input Voltage (V_{IN})	+15V
Output Voltage (V_{SNK})	+15V
Storage Temperature (T_S)	-65°C to +150°C
ESD Rating ⁽⁴⁾	
Human Body Model	2kV
Machine Model	200V

Operating Ratings⁽³⁾

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⁽⁵⁾

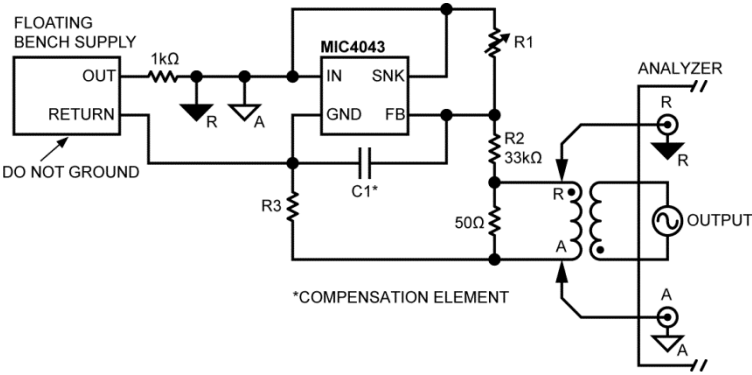
$T_A = +25^\circ\text{C}$, **bold** values indicate $-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$, unless noted.

Parameter	Condition	Min.	Typ.	Max.	Units
Reference Voltage ⁽⁵⁾			1.245		V
Reference Voltage Tolerance				± 1	%
				± 2	
Supply Current	$I_{SNK} = 0\text{mA}$		35	65	μA
				70	
Transconductance ($\Delta I_{SNK} / \Delta V_{IN}$)	$1\text{mA} < I_{SNK} < 15\text{mA}$	3.5	150		S
		2			
Output Transistor Saturation Voltage	$I_{SNK} = 15\text{mA}$		160	250	mV
				400	
Output Leakage	$V_{SNK} = 5\text{V}$, output transistor off			0.5	μA
				1	

Notes:

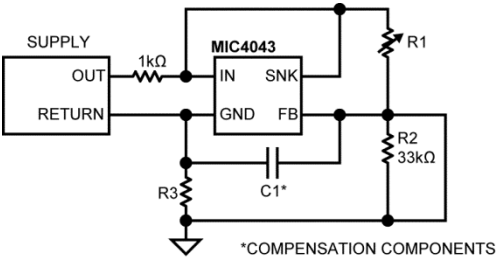
- Exceeding the absolute maximum ratings may damage the device.
- The device is not guaranteed to function outside its operating ratings.
- Devices are ESD sensitive. Handling precautions are recommended. Human body model, 1.5k Ω in series with 100pF. Machine model, 200pF.
- Reference voltage is not referenced to ground. The reference is between the IN and FB pins.

Test Circuit



V _{OUT}	R1	R2	R3	C1
1.8V	72kΩ	33kΩ	20kΩ	0.001μF
2.5V	33kΩ	33kΩ	40kΩ	0.001μF
3.3V	20kΩ	33kΩ	150kΩ	0.001μF

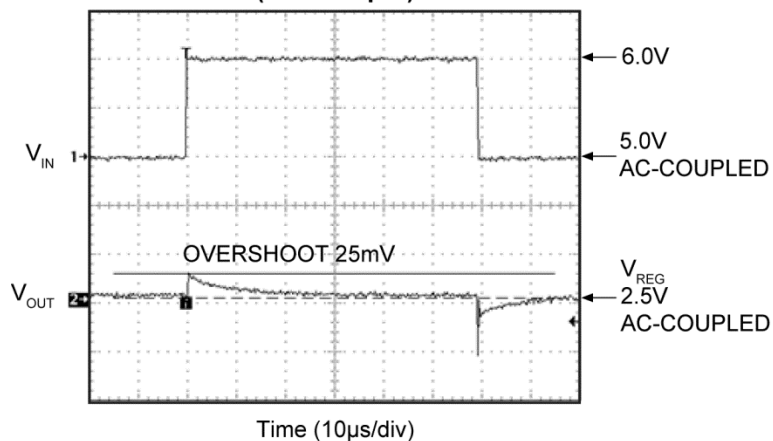
Test Circuit 1: Compensation (Bode Plot) Circuit



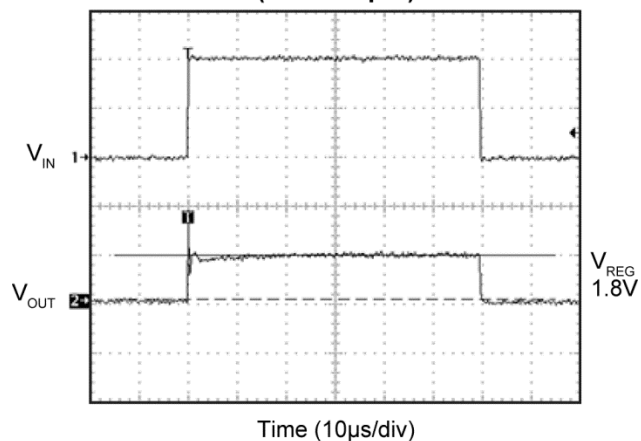
Test Circuit 2: Transient Response Circuit

Functional Characteristics

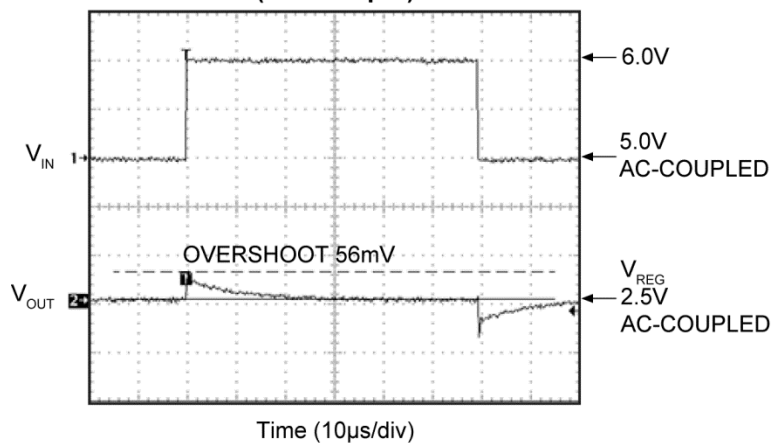
**Transient Response
(1.8V Output)**



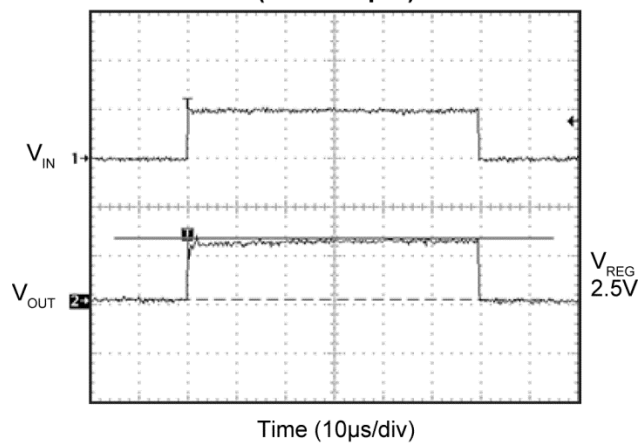
**Turn-On Transient Response
(1.8V Output)**



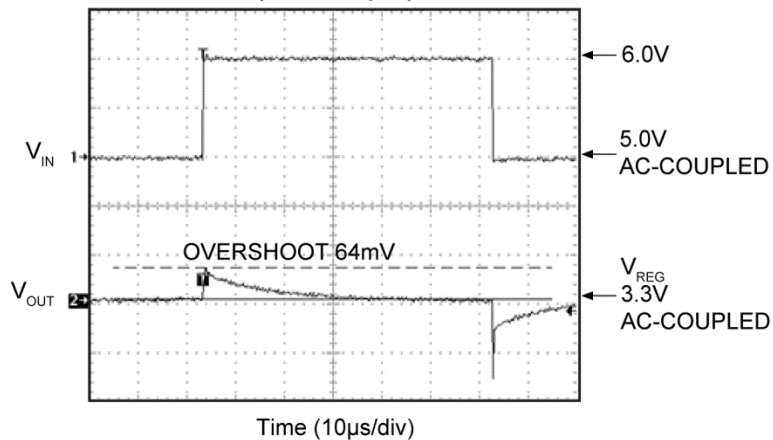
**Transient Response
(1.8V Output)**



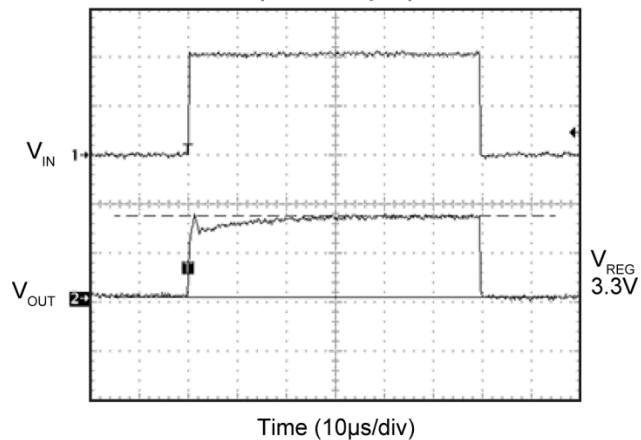
**Turn-On Transient Response
(1.8V Output)**



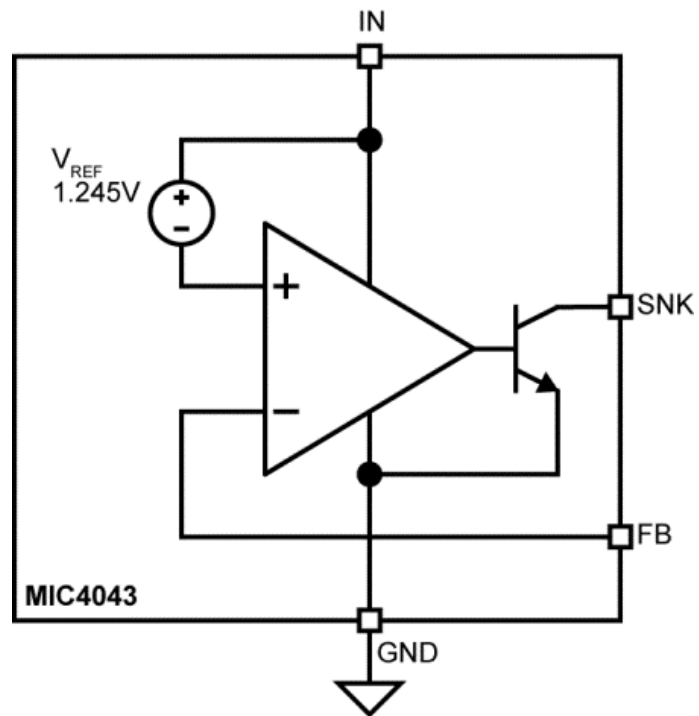
**Transient Response
(1.8V Output)**



**Turn-On Transient Response
(1.8V Output)**



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

Application 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 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 160mV at full load.

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 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 shows a simple voltage threshold detector with a logic output.

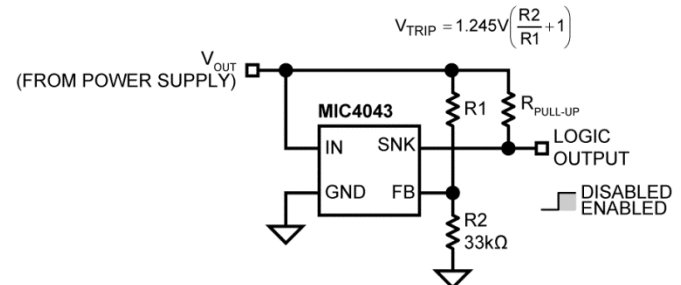


Figure 1. Voltage Detector

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 ($V_{SAT(MIN)} = 200\text{mV}$).

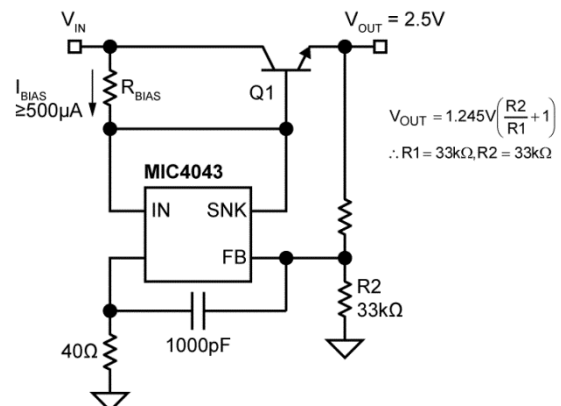


Figure 2. High-Current Regulator

Off-Line 1.8V/2A Power Supply

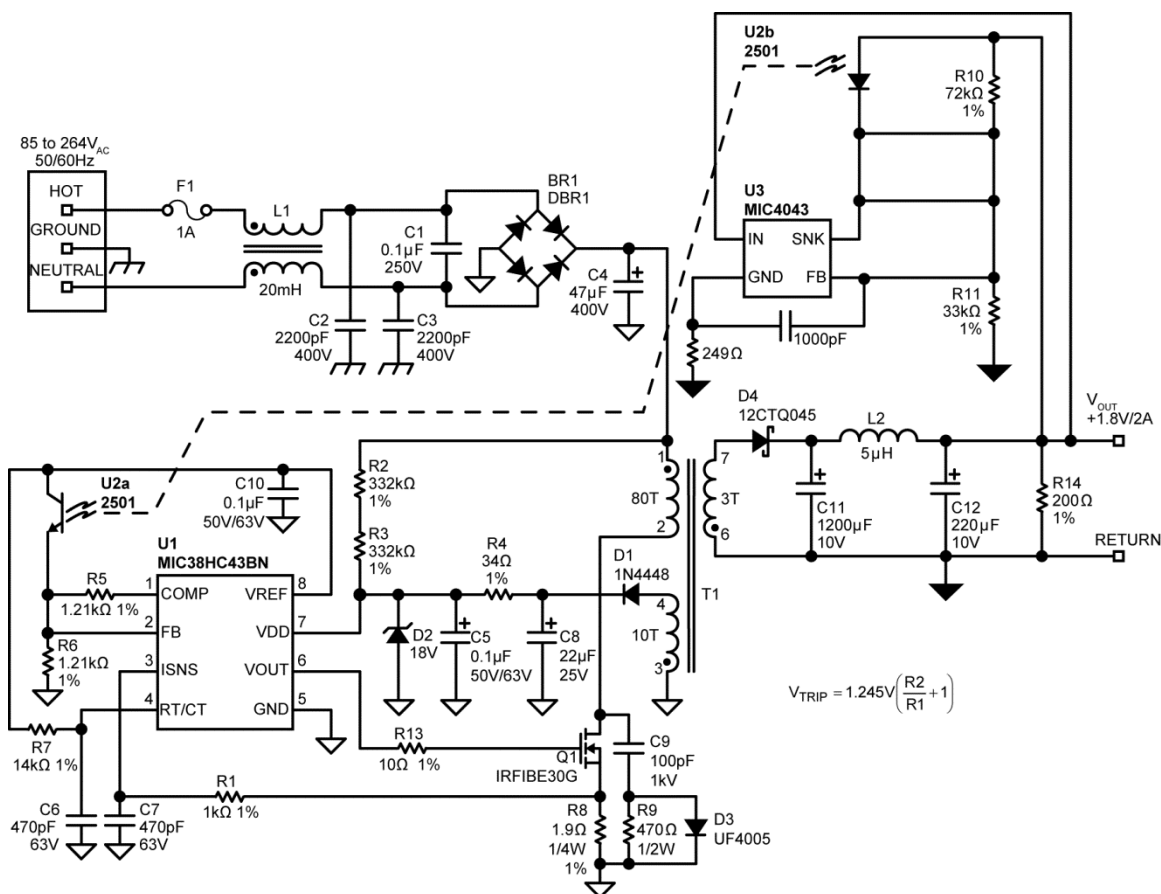


Figure 3. Off-Line 1V/2A Power Supply

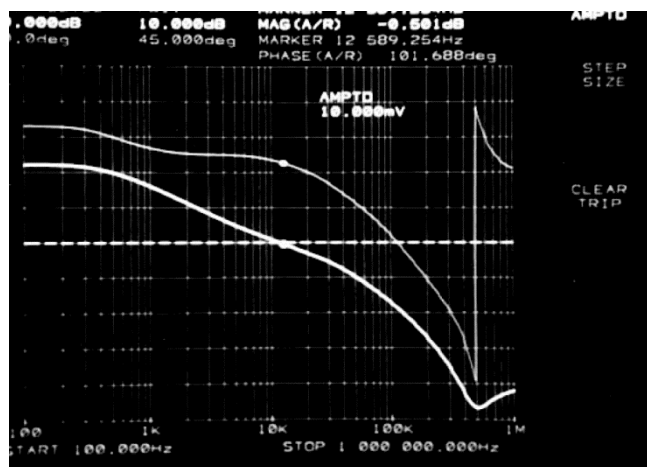


Figure 4. 1.8V/1A Output Bode Plot
(θ Margin = 102°)

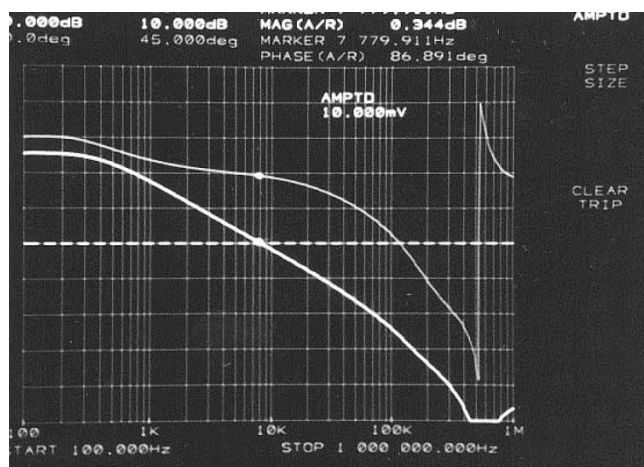


Figure 5. 1.8V/2A Output Bode Plot
(θ Margin = 87°)

Off-Line 2.5V/2A Power Supply

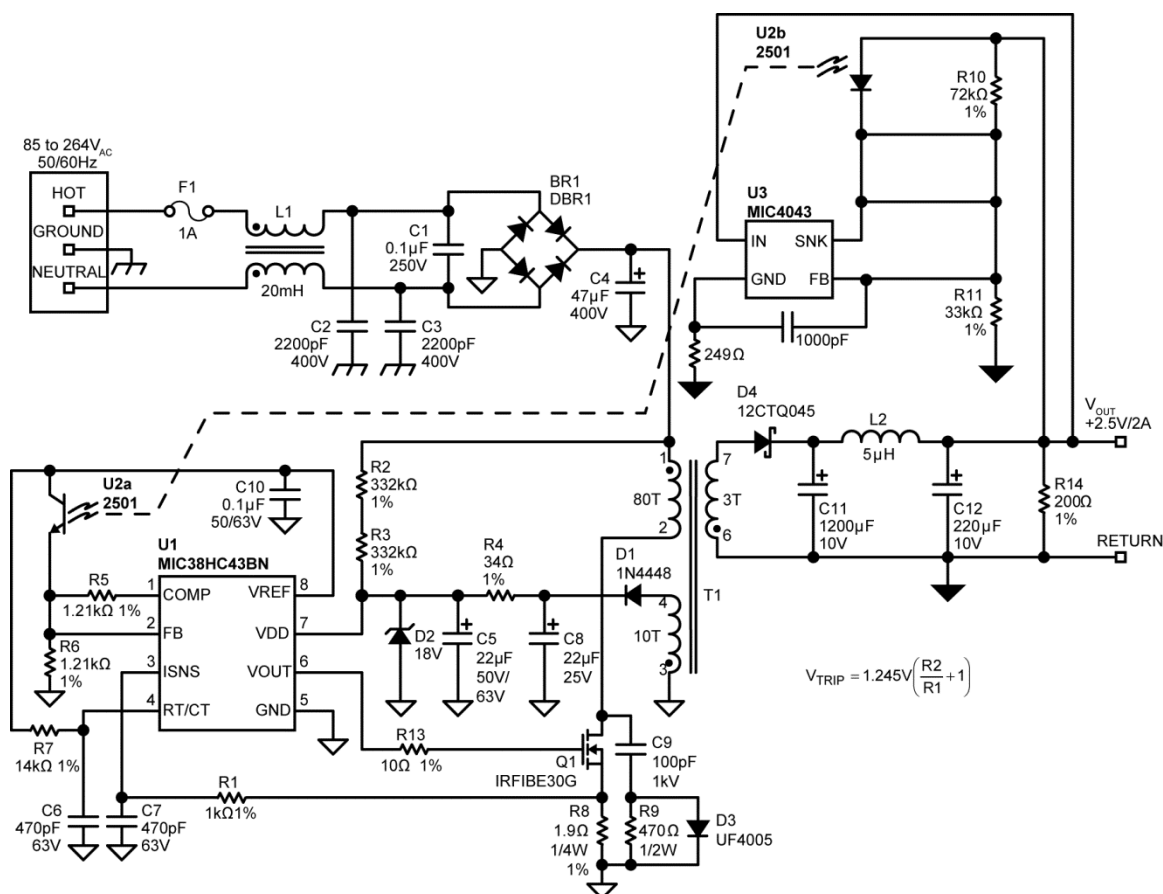
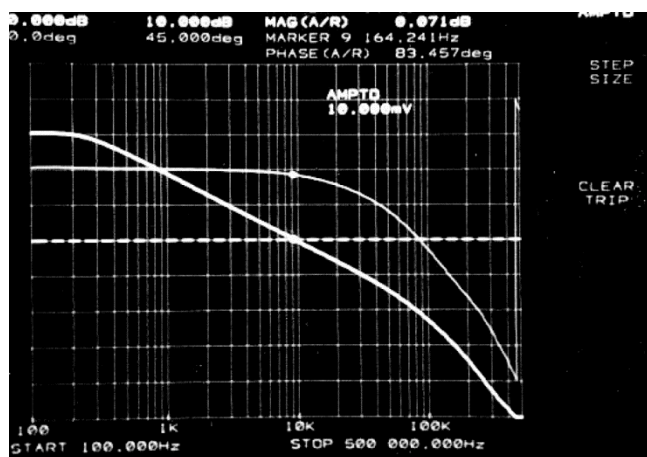
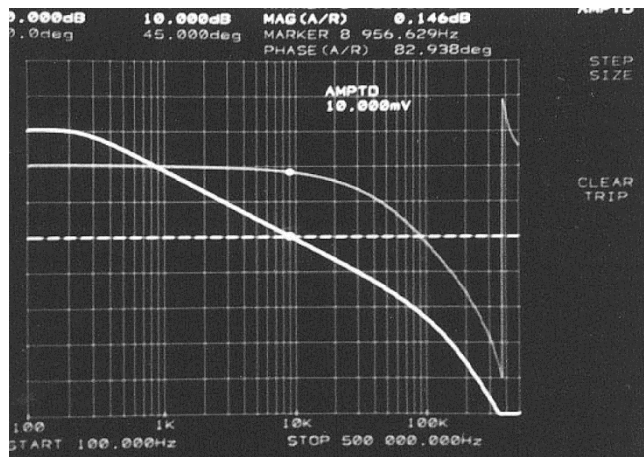


Figure 6. Off-Line 2.5V/2A Power Supply



**Figure 7. 2.5V/1A Output Bode Plot
(θ Margin = 83°)**



**Figure 8. 2.5V/2A Output Bode Plot
(θ Margin = 83°)**

[illegible]

MAG (A/R) 0.00000
 0.0deg 15.000deg
 MARKER 10 282.303Hz
 PHASE (A/R) 82.156deg

STEP SIZE

AMPTD 10.000dB

CLEAR TRIP

100 1K 10K 100K

START 100.000Hz STOP 500 000.000Hz

0.000dB
0.0deg
10.000dB
45.000deg
MARKER 11 082.018Hz
PHASE (A/R) 80.207deg
AMPTD 10.000mV
STEP SIZE
CLEAR TRIP

100 1K 10K 100K
START 100.000Hz STOP 500 000.000Hz

Revision 2.0

85 to 264V_{AC}
50/60Hz

HOT
GROUND
NEUTRAL

F1
1A

L1
20mH

C1
0.1 μF
250V

C2
2200pF
400V

C3
2200pF
400V

BR1
DBR1

C4
47 μF
400V

U2a
2501

U1
MIC38HC43BN

R5
1.21kΩ
1%

R6
1.21kΩ
1%

C6
470pF
63V

C7
470pF
63V

R7
14kΩ
1%

R1
1kΩ
1%

R2
332kΩ
1%

R3
332kΩ
1%

R4
34Ω
1%

D2
18V

C5
0.1 μF
50/63V

C8
22 μF
25V

R13
10Ω
1%

Q1
IRFIB30G

R8
1.9Ω
1/4W
1%

R9
470Ω
1/2W

D3
UF4005

C9
100pF
1kV

D1
1N4448

T1

80T
3T
10T
6T

L2
5 μH

C11
1200 μF
10V

C12
220 μF
10V

R14
200Ω
1%

U2b
2501

U3
MIC4043

R10
72kΩ
1%

R11
33kΩ
1%

249Ω

1000pF

V_{OUT}
+3.3V/2A

RETURN

$V_{TRIP} = 1.245V \left(\frac{R2}{R1} + 1 \right)$

REF LEVEL 7.1V MARKER 15 300.930Hz
 0.000dB MAG (A/R) -0.328dB
 0.0deg 45.000deg MARKER 15 300.930Hz
 PHASE (A/R) 67.387deg

AMPTD
 10.000mV

CLEAR
 TRIP

1 100 1K 10K 100K 100.000Hz
 START 100.000Hz STOP 500 000.000Hz

REF LEVEL 0.000dB
0.0deg

/DIV 10.000dB
45.000deg

MARKER 14 347.426Hz
MAG (A/R) 0.185dB
MARKER 14 347.426Hz
PHASE (A/R) 60.813deg

ANP10
10.000V

STEP
SIZE

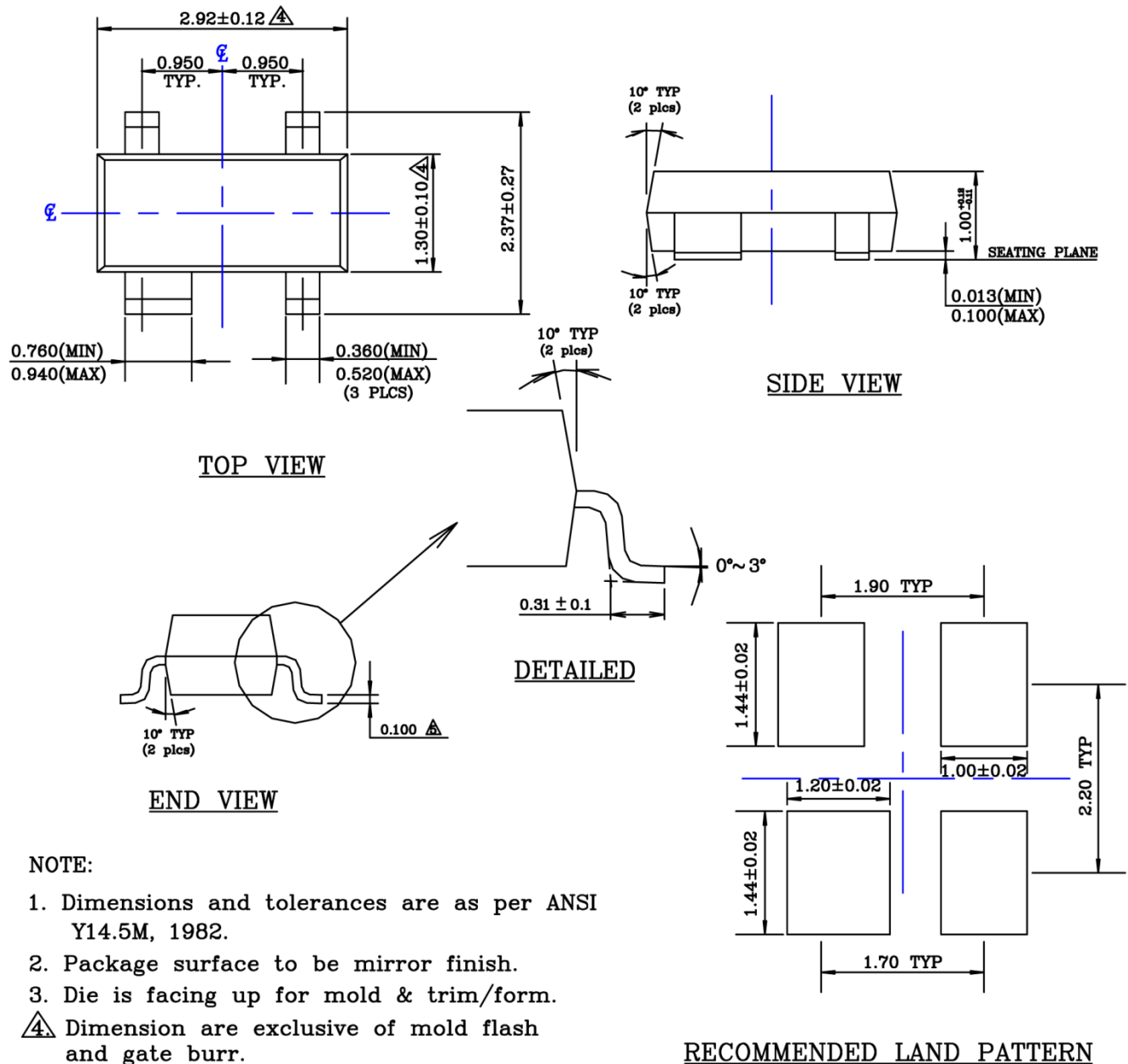
CLEAR
TRIP

100 1K 10K 100K 500 000.000Hz

START 100.000Hz STOP 500 000.000Hz

Revision 2.0

Package Information and Recommended Landing Pattern⁽⁶⁾



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.

SOT-143 (M4)

Note:

6. Package information is correct as of the publication date. For updates and most current information, go to www.micrel.com.

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