MIC2544/48

Programmable Current-Limit High-Side Switch

Features

- 2.7V to 5.5V Input
- Adjustable Current-Limit up to 1.5A
- Reverse Current Flow Blocking (No “Body Diode”)
- 75 µA Typical On-State Supply Current
- 1 µA Typical Off-State Supply Current
- 120 mΩ Maximum On-Resistance
- Open-Drain Fault Flag
- Thermal Shutdown
- Thermal Shutdown Output Latch (MIC2548)
- 2 ms (Slow) Turn-On and Fast Turn-Off
- Available with Active-High or Active-Low Enable

Applications

- USB Power Distribution
- PCI Bus Power Switching
- Notebook PC
- ACPI Power Distribution
- PC Card Hot Swap Applications
- Inrush Current-Limiting

General Description

The MIC2544 and MIC2548 are integrated, high-side power switches optimized for low-loss DC power switching and other power management applications, including Advanced Configuration and Power Interface (ACPI). The MIC2544/48 are cost-effective, highly integrated solutions that require few external components to satisfy USB and ACPI requirements.

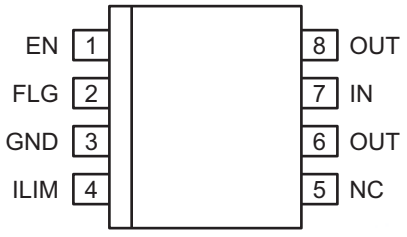
Load current management features include a precision resistor-programmable output current-limit and a soft-start circuit that minimizes inrush current when the switch is enabled. Thermal shutdown, along with current-limit, protects the switch and the attached device.

The MIC2544/48’s open-drain flag output is used to indicate current-limiting or thermal shutdown to a local controller. The MIC2548 has an additional internal latch that turns the output off upon thermal shutdown, providing robust fault control. The enable signal is compatible with both 3V and 5V logic, and is also used as the thermal shutdown latch reset for the MIC2548.

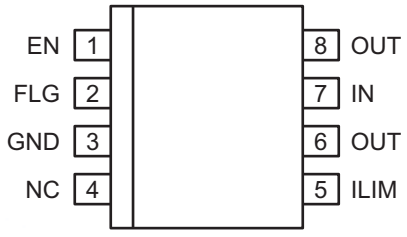
The MIC2544 and MIC2548 are available in active-high and active-low enable versions in the 8-pin SOIC and 8-pin MSOP packages.

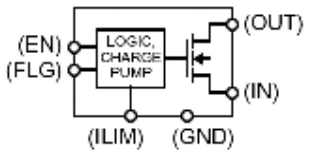
Package Types

MIC2544/MIC2548
8-PIN SOIC (M)



MIC2544/MIC2548
8-PIN MSOP (MM)

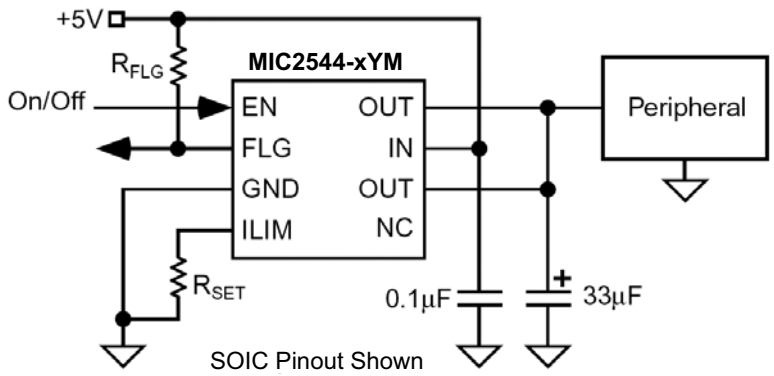




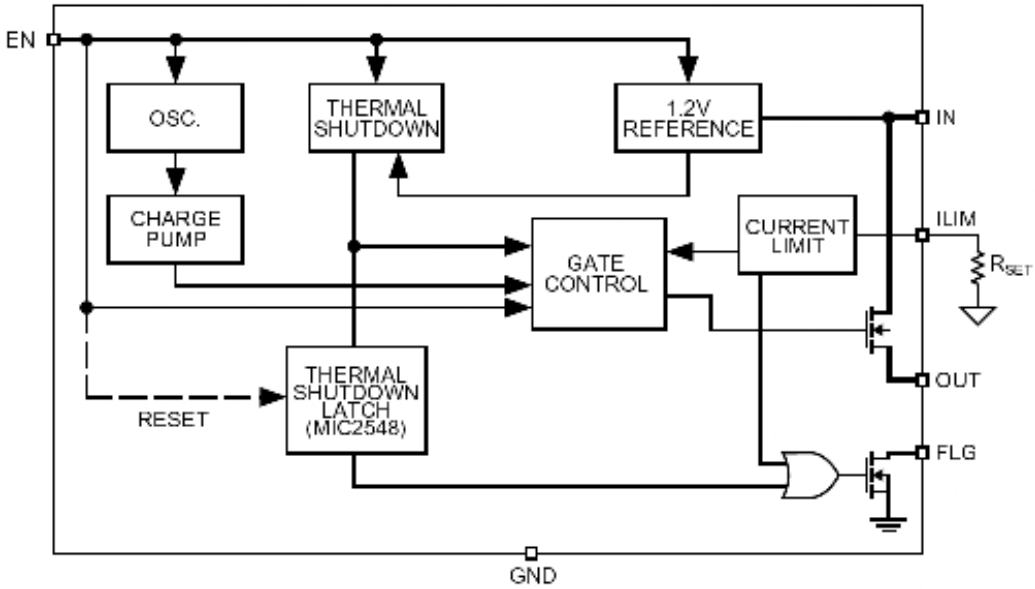
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Typical Application Circuit

TYPICAL ADVANCED CONFIGURATION AND POWER INTERFACE (ACPI) APPLICATION



Functional Diagram



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1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

Supply Voltage (V_{IN}) ..... +7.0V
Output Voltage (V_{OUT}) ..... –0.3V to +7.0V
Output Current (I_{OUT}) ..... Internally Limited
Enable Input (V_{EN}) ..... –0.3V to V_{IN}+0.3V
Fault Flag Voltage (V_{FLG}) ..... +7.0V
Fault Flag Current (I_{FLG}) ..... 50 mA
ESD Rating (Note 1) ..... 2 kV

Operating Ratings ‡

Supply Voltage (V_{IN}) ..... +2.7V to +5.5V
Current Limit Set Range ..... 0.1A to 1.5A

† 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 recommended. Human body model, 1.5 kΩ in series with 100 pF.

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TABLE 1-1: ELECTRICAL CHARACTERISTICS (Note 1)

Electrical Characteristics: V_{IN} = +5V; T_A = 25°C, bold values indicate –40°C to +85°C, unless noted.

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions
Supply Current	I_{IN}	—	0.75	5	µA	Switch off, OUT = Open (Note 2)
		—	75	160		Switch on, OUT = Open (Note 2)
Enable Input Voltage	V_{EN}	2.4	1.7	—	V	Enable High, (Note 2)
		—	1.5	0.8		Enable Low, (Note 2)
Enable Input Capacitance	—	—	1	—	pF	Note 3
Switch Resistance	$R_{DS(ON)}$	—	80	120	mΩ	I_{OUT} = 500 mA
Current Limit Factor	—	184	230	276	V	I_{OUT} = 100 mA to 1A, V_{OUT} = 1V to 4V, (Note 4)
		161	230	299		I_{OUT} = 500 mA to 1.5A, V_{OUT} = 1V to 4V, (Note 4)
Output Leakage Current	—	—	1	10	µA	Switch off
Output Turn-On Delay	t_{ON}	1	2	5	ms	R_L = 10Ω, C_L = 1 µF, Figure 4-2, Figure 4-3
Output Turn-On Rise Time	t_R	1	2	5	ms	R_L = 10Ω, C_L = 1 µF, Figure 4-2, Figure 4-3
Output Turn-Off Delay	t_{OFF}	—	22	—	µs	R_L = 10Ω, C_L = 1 µF, Figure 4-2, Figure 4-3
Output Turn-Off Fall Time	t_F	—	21	—	µs	R_L = 10Ω, C_L = 1 µF, Figure 4-2, Figure 4-3
Overtemperature Threshold Shutdown	—	—	140	—	°C	T_J increasing
		—	130	—		T_J decreasing
Error Flag Output Resistance	—	—	4	15	Ω	V_{IN} = 5V, I_L = 10 µA
		—	5	20		V_{IN} = 3.3V, I_L = 10 µA
Error Flag Off Current	—	—	0.01	1	µA	V_{FLG} = 5V
EN Pulse Reset Width	—	5	—	—	µs	MIC2548 thermal shutdown latch
V_{IN} to EN Set-Up	—	0	—	—	µs	MIC2548, (Note 4)
Current-Limit Response Time	—	—	25	—	µs	V_{OUT} = 0V, (Note 4)
Overcurrent Flag Response Time	—	—	5	—	µs	V_{OUT} = V_{IN}/2 to FLG low.

Note 1: Specification for packaged product only.

2: Off is ≤ 0.8V and on is ≥ 2.4V for the MIC2544-1 and MIC2548-1. Off is ≥ 2.4V and on is ≤ 0.8V for the MIC2544-2 and MIC2548-2. The enable input has about 200 mV of hysteresis.

3: Guaranteed by design but not production tested.

4: Current limit threshold is determined by I_{LIMIT} = 230V/R_{SET}, where R_{SET} is in ohms.

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TEMPERATURE SPECIFICATIONS (Note 1)

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Temperature Ranges						
Storage Temperature Range	T_S	–65	—	+150	°C	—
Lead Temperature	—	—	—	+260	°C	Soldering, 5 sec.
Junction Temperature	T_J	—	—	—	°C	Internally Limited
Ambient Temperature	T_A	–40	—	+85	°C	—
Package Thermal Resistance						
Thermal Resistance, 8-Ld SOIC	θ_{JA}	—	160	—	°C/W	—
Thermal Resistance, 8-Ld MSOP	θ_{JA}	—	206	—	°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.

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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.

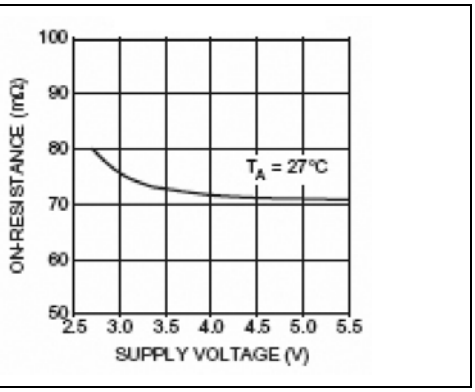


FIGURE 2-1: *Output On-Resistance vs. Supply Voltage.*

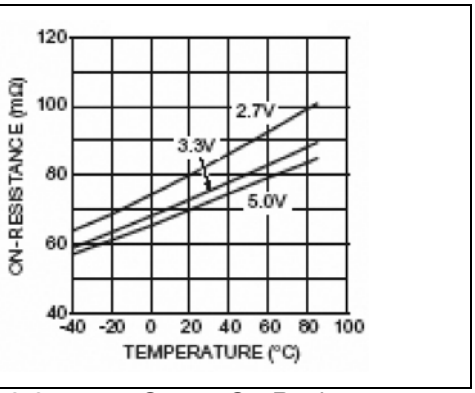


FIGURE 2-2: *Output On-Resistance vs. Temperature.*

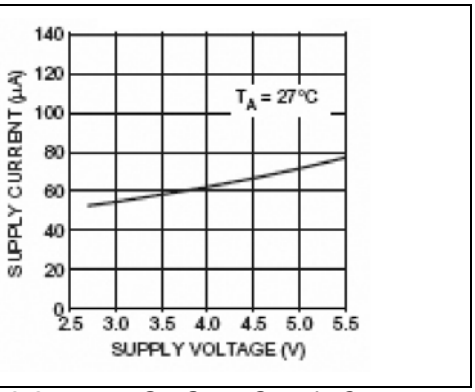


FIGURE 2-3: *On-State Supply Current vs. Supply Voltage.*

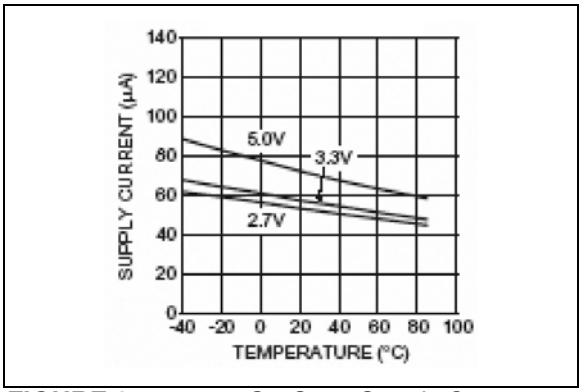


FIGURE 2-4: *On-State Supply Current vs. Temperature.*

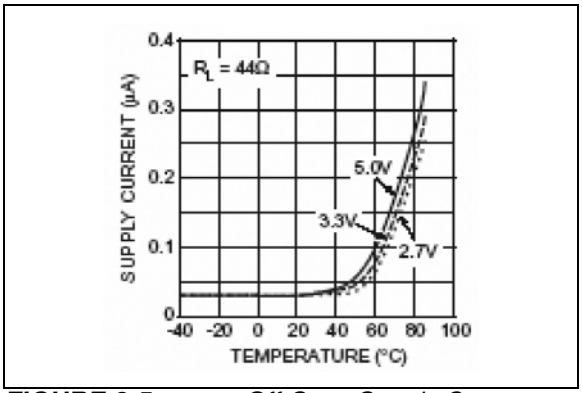


FIGURE 2-5: *Off-State Supply Current vs. Temperature.*

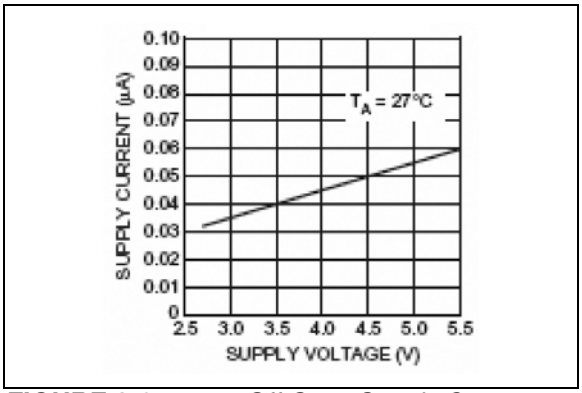


FIGURE 2-6: *Off-State Supply Current vs. Supply Voltage.*

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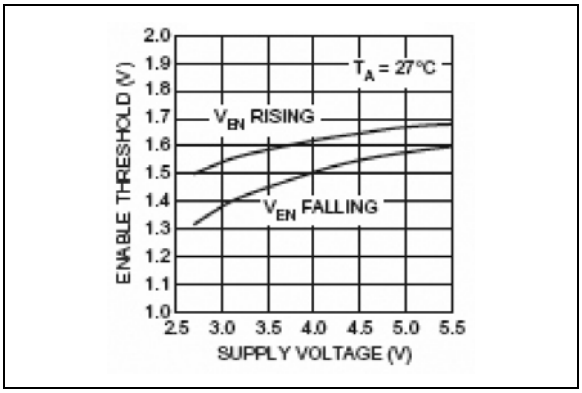


FIGURE 2-7: *Enable Threshold Voltage vs. Supply Voltage.*

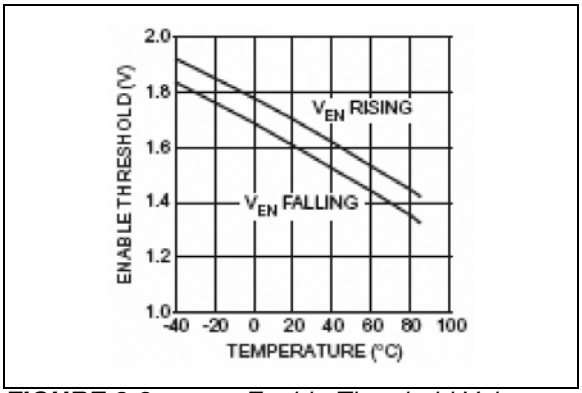


FIGURE 2-8: *Enable Threshold Voltage vs. Temperature.*

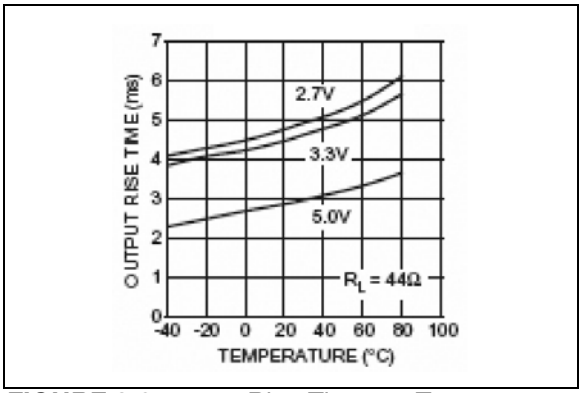


FIGURE 2-9: *Rise Time vs. Temperature.*

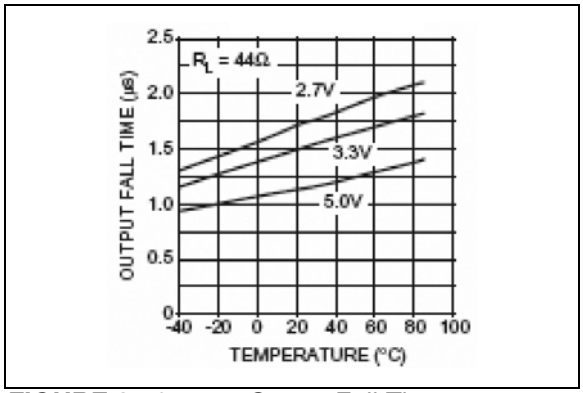


FIGURE 2-10: *Output Fall Time vs. Temperature.*

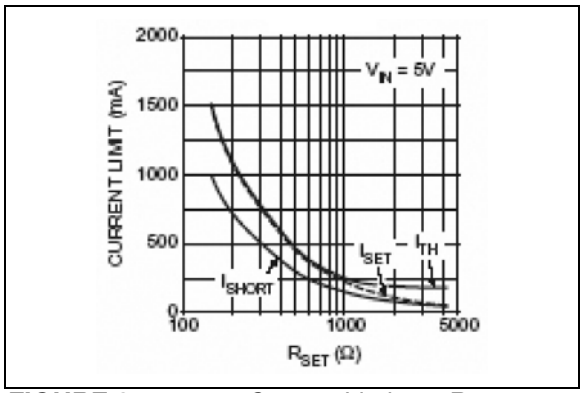


FIGURE 2-11: *Current Limit vs. R_{SET}.*

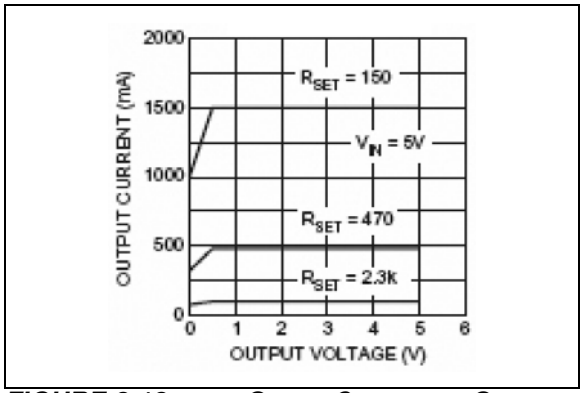


FIGURE 2-12: *Output Current vs. Output Voltage.*

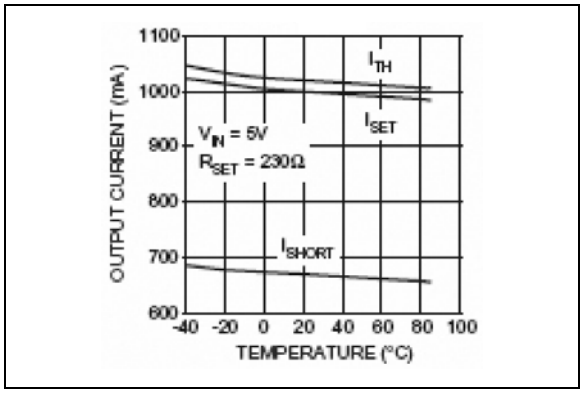


FIGURE 2-13: *Current Limit vs. Temperature.*

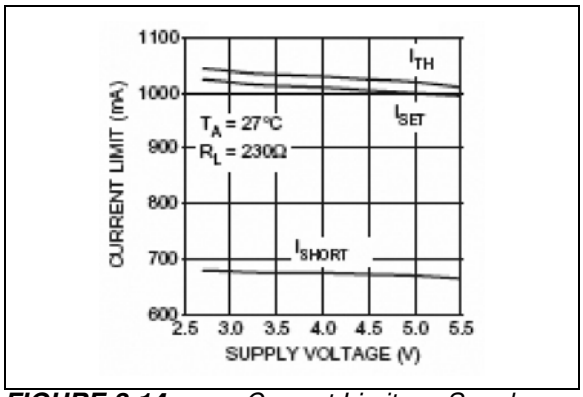


FIGURE 2-14: *Current Limit vs. Supply Voltage.*

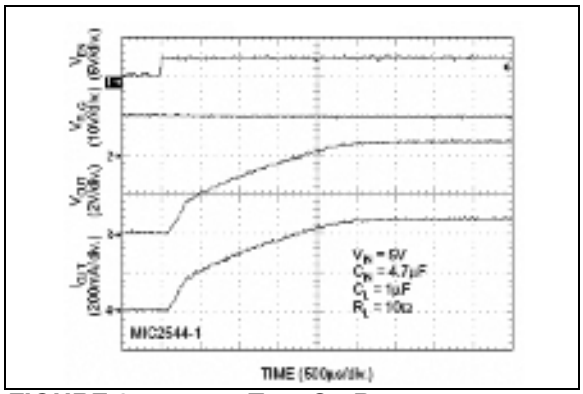


FIGURE 2-15: *Turn-On Response.*

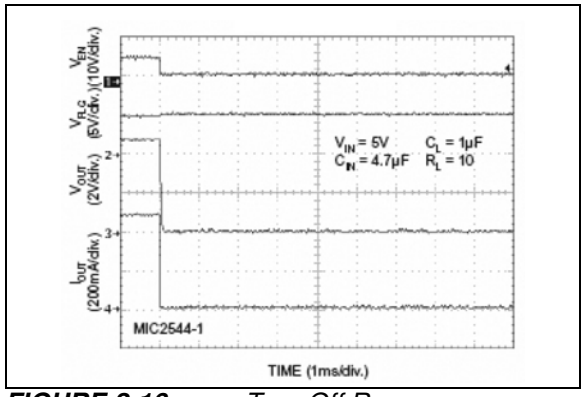


FIGURE 2-16: *Turn-Off Response.*

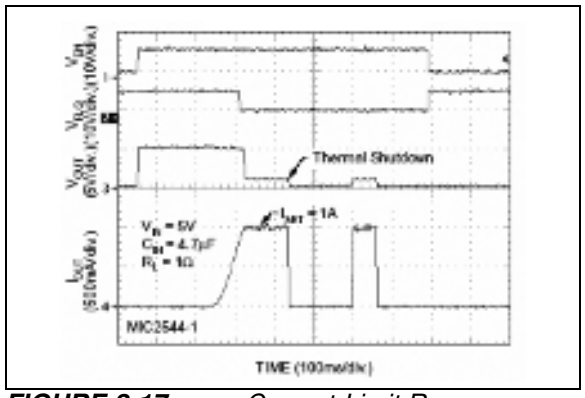


FIGURE 2-17: *Current-Limit Response.*

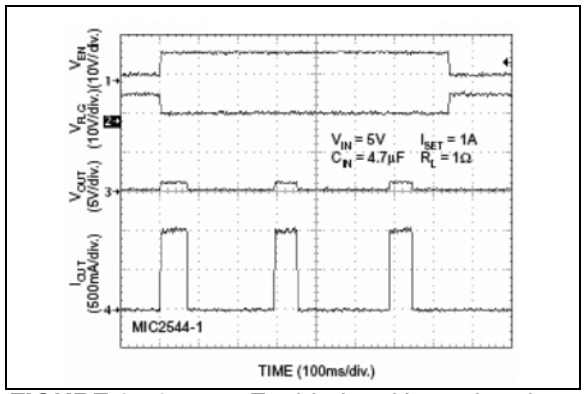


FIGURE 2-18: *Enable Into Heavy Load.*

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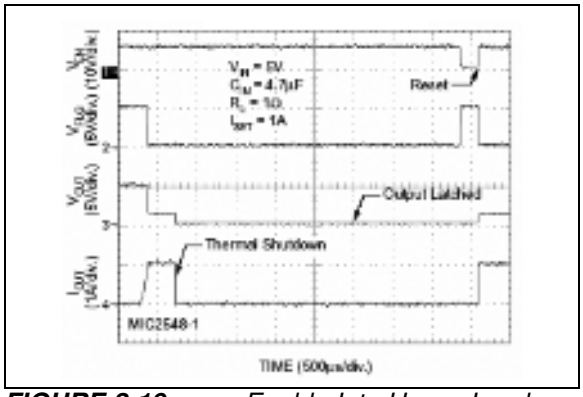


FIGURE 2-19: *Enable Into Heavy Load.*

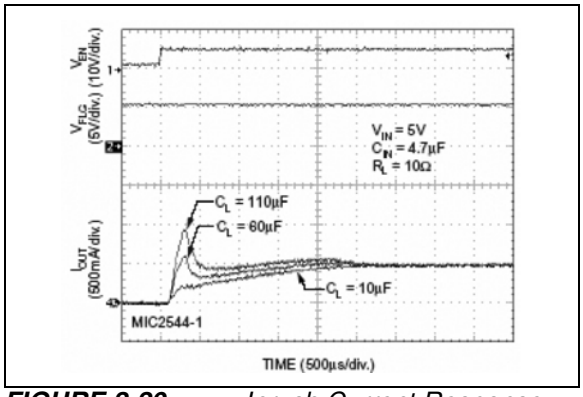


FIGURE 2-20: *Inrush Current Response.*

3.0 PIN DESCRIPTIONS

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

TABLE 3-1: PIN FUNCTION TABLE

Pin Number 8-Pin MSOP	Pin Number 8-Pin SOIC	Pin Name	Description
1	1	EN	Enable (Input): Logic-compatible enable input. Active-high (-1) or active-low (-2). High input >1.7V typical; low input <1.5V typical. Do not float. MIC2548 only: Also resets thermal shutdown latch.
2	2	FLG	Fault Flag (Output): Active-low, open-drain output. Indicates overcurrent or thermal shutdown conditions. MIC2548 only: latched low on thermal shutdown.
3	3	GND	Ground.
5	4	ILIM	Current Limit: Sets current-limit threshold using an external resistor, R_{SET}, connected to ground. 154Ω < R_{SET} < 2.29 kΩ.
7	7	IN	Input: Output MOSFET drain. Also powers internal circuitry.
6, 8	6, 8	OUT	Switch (Output): Output MOSFET source. Pins 6 and 8 must be externally connected.
4	5	NC	Not internally connected.

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4.0 TEST CIRCUIT AND TIMING DIAGRAMS

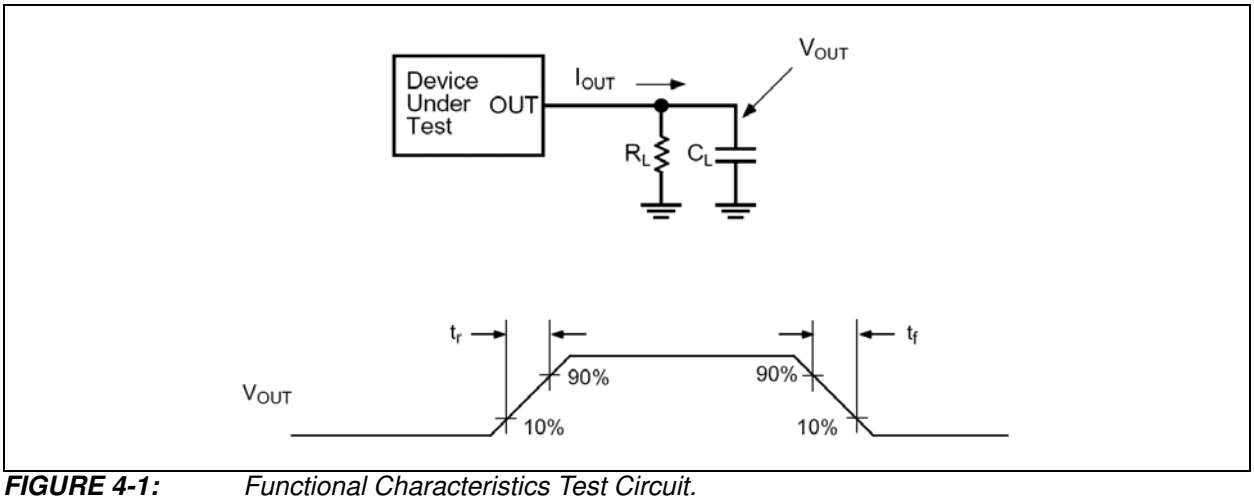


FIGURE 4-1: *Functional Characteristics Test Circuit.*

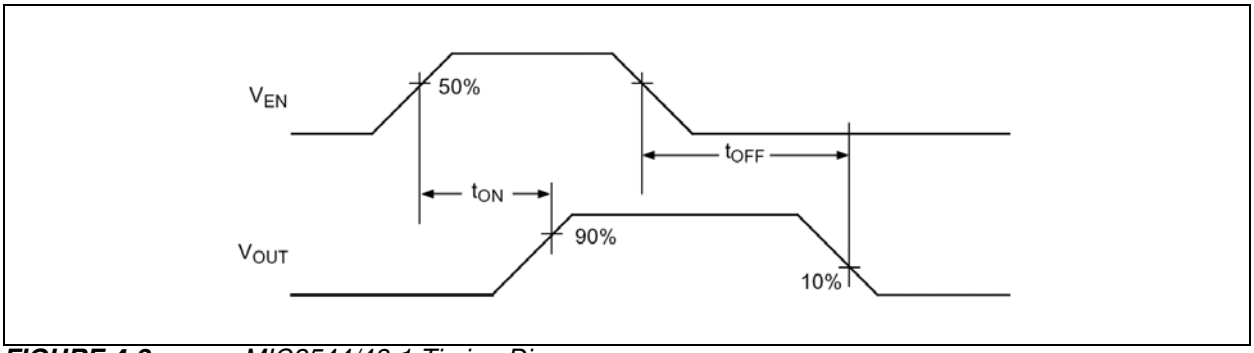


FIGURE 4-2: *MIC2544/48-1 Timing Diagram.*

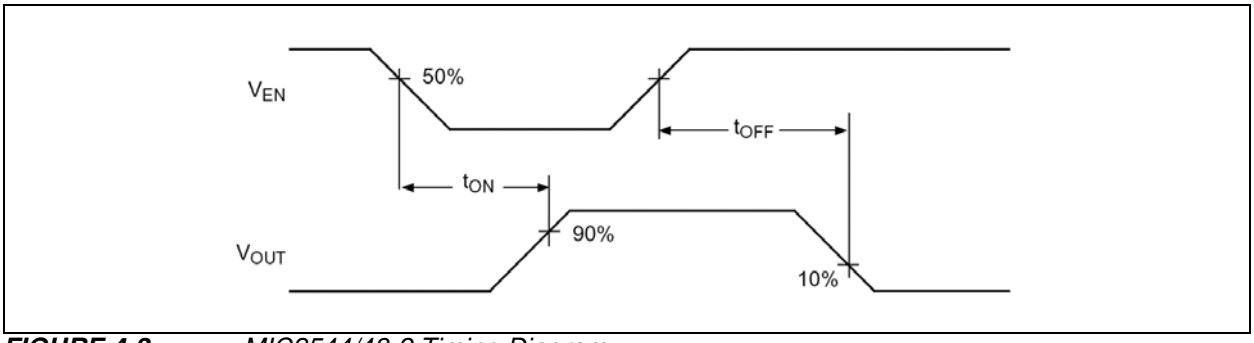


FIGURE 4-3: *MIC2544/48-2 Timing Diagram.*

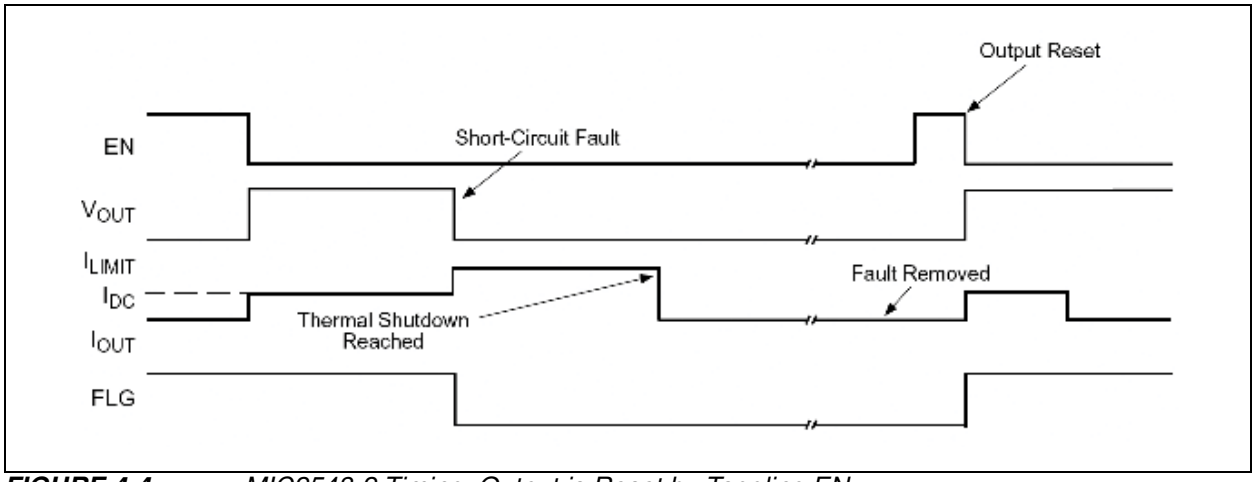


FIGURE 4-4: *MIC2548-2 Timing: Output is Reset by Toggling EN.*

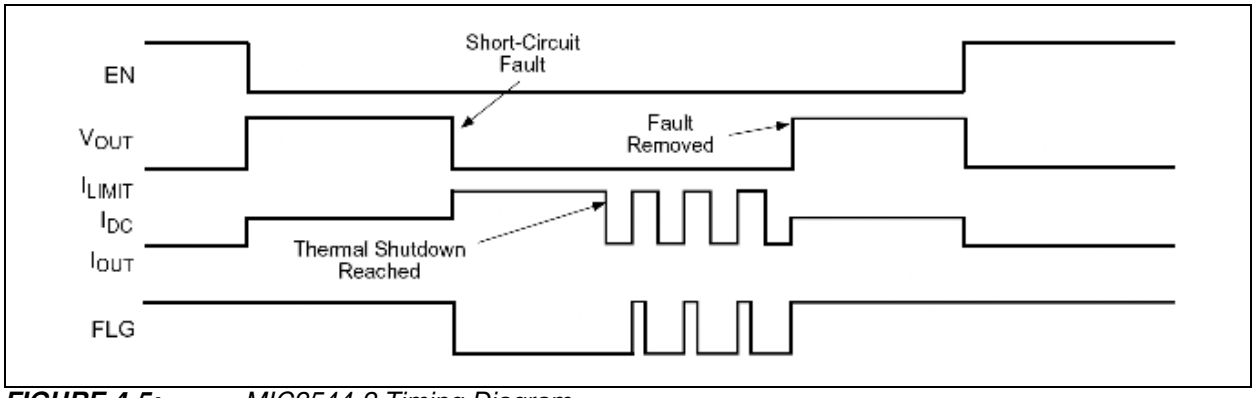


FIGURE 4-5: *MIC2544-2 Timing Diagram.*

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5.0 FUNCTIONAL DESCRIPTION

The MIC2544 and MIC2548 are high-side N-channel switches available with active-high or active-low enable inputs. Fault conditions turn-off or inhibit turn-on of the output transistor and activate the open-drain error flag transistor making it sink current to ground.

5.1 Input and Output

IN is the power supply connection to the logic circuitry and the drain of the output MOSFET. OUT is the source of the output MOSFET. In a typical circuit, current flows from IN to OUT toward the load. If V_{OUT} is greater than V_{IN}, current will flow from OUT to IN because the switch is bidirectional when enabled.

The output MOSFET and driver circuitry are also designed to allow the MOSFET source to be externally forced to a higher voltage than the drain ($V_{OUT} > V_{IN}$) when the switch is disabled. In this situation, the MIC2544/48 avoids undesirable current flow from OUT to IN. Both OUT pins must be connected together.

5.2 Thermal Shutdown

Thermal shutdown shuts off the output MOSFET and signals the fault flag if the die temperature exceeds +140°C. 10°C of hysteresis prevents the switch from turning on until the die temperature drops to +130°C. Overtemperature detection functions only when the switch is enabled.

The MIC2548 features an internal latch which causes the part to remain off after thermal shutdown until a reset pulse is provided via the enable pin (pin 1). While in current-limit, the thermal shutdown latch prevents on/off cycling of the output.

Refer to Figure 4-4 and Figure 4-5 for timing diagrams. The flag remains low until reset.

5.3 Enable Input

EN must be driven logic high or logic low, or be pulled high or low for a clearly defined input. Floating the input may cause unpredictable operation. EN should not be allowed to go negative with respect to GND, and V_{EN} should be less than or equal to V_{IN}.

5.4 Adjustable Current-Limit

The short-circuit current-limit is user-adjustable with an external set resistor. Current-limit in the range of 100 mA to 1.5A is available with a set point accuracy of better than ±20%. The current-limit circuit prevents damage to the output MOSFET and external load.

The nominal current-limit value is set with an external resistor between ILIM and GND. For a desired current-limit, the value of the external set resistor is given by:

EQUATION 5-1:

$$R_{SET} = \frac{230V}{I_{LIMIT}}$$

Where:

$154\Omega < R_{SET} < 2.29\ k\Omega$

For example, to set a 1A nominal current-limit, R_{SET} is calculated as:

EQUATION 5-2:

$$\frac{230V}{1A} = 230\Omega$$

Current through R_{SET} increases with OUT current. The voltage across R_{SET} could be monitored with a high impedance comparator to provide an indication of output current. R_{SET} should be between 154Ω ±0.5% and 2.29 kΩ ±0.5%.

5.5 Short-Circuit Protection

In the event of a short circuit, the output current will fold back to approximately 80% of the short-circuit current-limit.

5.6 Fault Flag

FLG is an N-channel, open-drain MOSFET output. The fault flag is active (low) for current-limit or thermal shutdown conditions. The flag output MOSFET is capable of sinking a 10 mA load to typically 100 mV above ground.

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6.0 APPLICATION INFORMATION

6.1 Supply Filtering

A 0.1 µF to 1 µF bypass capacitor from IN to GND, located near the MIC2544 and MIC2548, is strongly recommended to control supply transients. Without a bypass capacitor, an output short may cause sufficient ringing on the input (from supply lead inductance) to damage internal control circuitry.

Input transients must not exceed the absolute maximum supply voltage ($V_{IN(ABS_MAX)}$ = 7V) even for a short duration.

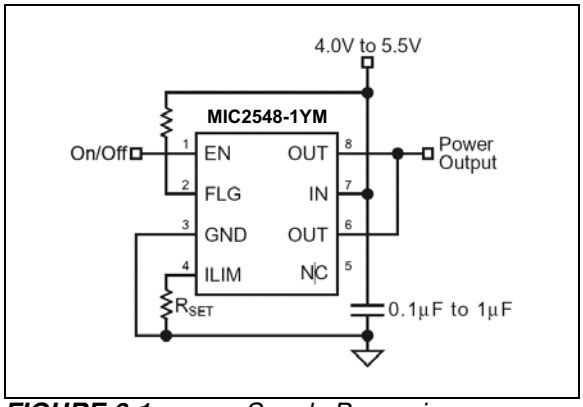


FIGURE 6-1: *Supply Bypassing.*

6.2 Power Dissipation

The device's junction temperature depends on several factors such as the load, PCB layout, ambient temperature, and package type. Equations that can be used to calculate power dissipation and junction temperature are found below.

Calculation of power dissipation can be accomplished by the following equation:

EQUATION 6-1:

$$PD = R_{DS(ON)} \times (I_{OUT})^2$$

To relate this to junction temperature, use the following equation:

EQUATION 6-2:

$$T_J = P_D \times \theta_{JA} + T_A$$

Where:

T_J	Junction temperature
T_A	Ambient temperature
θ_{JA}	Thermal resistance of the package

6.3 Transient Overcurrent Filter

The inrush current from the connection of a heavy capacitive load may cause the fault flag to fall for 10 µs to 200 µs while the switch is in a constant-current mode, charging the capacitance.

Adding an optional series resistor-capacitor (R_{SET2}) in parallel with R_{SET}, as shown in Figure 6-2, allows the transient current-limit to be set to a different value than steady state. A typical USB hot-plug inrush is 2A to 3A for 10 µs to 20 µs. If R_{SET} is 435Ω (510 mA), an R_{SET2} of 88Ω (2.5A) and C_{SET} of 1 µF (R_C = 100 µs) allows transient surge of 3A to pass for 100 µs without tripping the overcurrent flag (FLG).

6.4 USB Power Distribution

The MIC2544 is ideal for meeting USB power distribution requirements. Figure 6-2 depicts a USB Host application. R_{SET} should be set to a value providing a current-limit greater than 500 mA.

The accurate current-limit of the MIC2544 will reduce power supply current requirements. Also, fast reaction to short-circuit faults prevent voltage droop in mobile PC applications.

6.5 Printed Circuit Board Hot-Plug

The MIC2544/48 are ideal inrush current-limiters suitable for hot-plug applications. Due to the integrated charge pump, the MIC2544/48 presents a high impedance when off and slowly becomes a low impedance as it turns on.

This soft-start feature effectively isolates power supplies from highly capacitive loads by reducing inrush current during hot-plug events. Figure 6-3 shows how the MIC2544 may be used in a hot-plug application.

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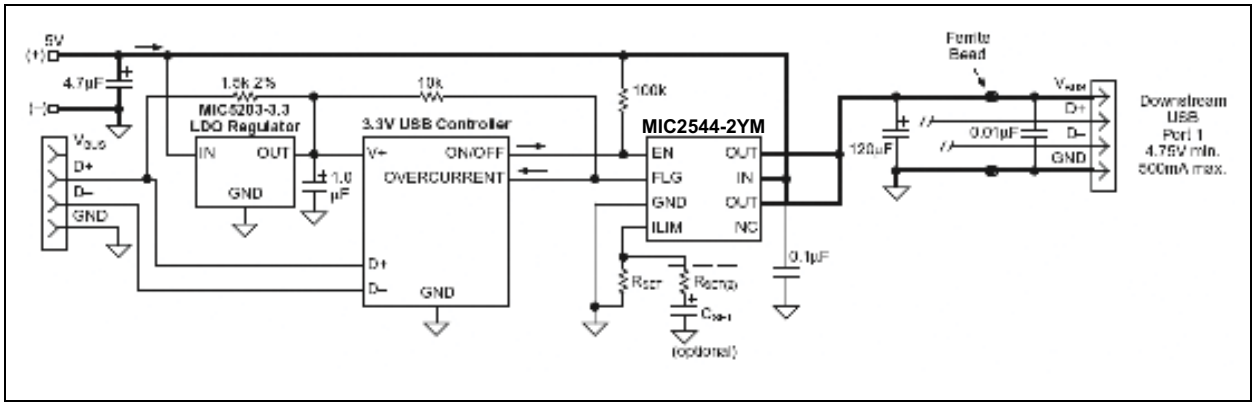


FIGURE 6-2: *USB Host Application.*

Please note that the MSOP package uses pin 5 for ILIM. Pin 4 is not connected (NC). Bold lines indicate 0.1” wide, 1 oz. copper high-current traces.

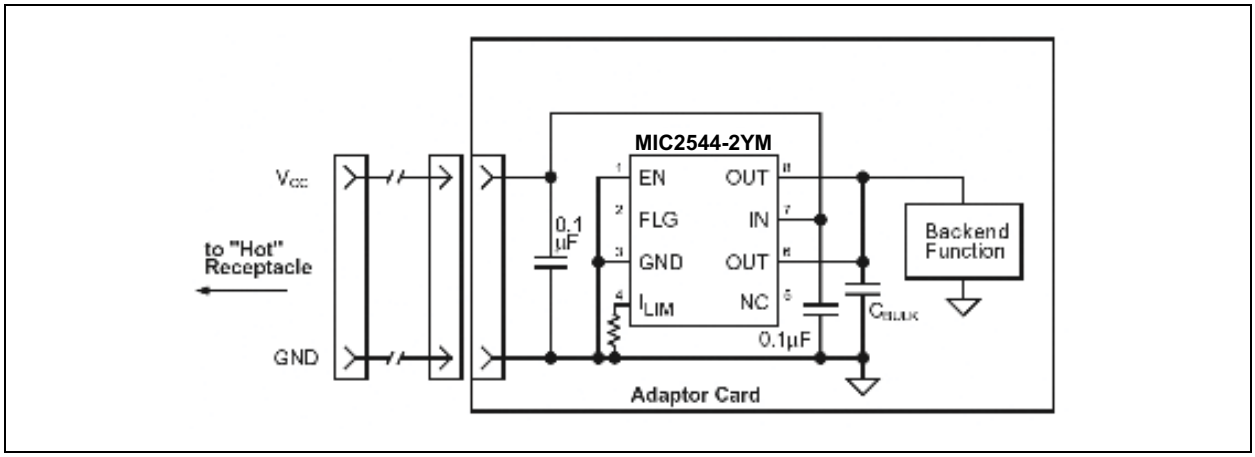


FIGURE 6-3: *Hot Plug Application.*

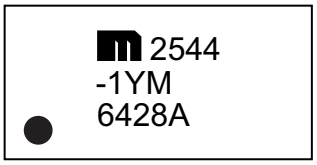
7.0 PACKAGING INFORMATION

7.1 Package Marking Information

SOIC-8*

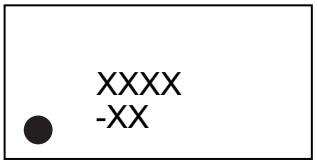


Example

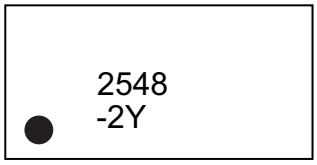


Note: The “A” in line 3 of the SOIC package appears only on MIC2544.

MSOP-8*



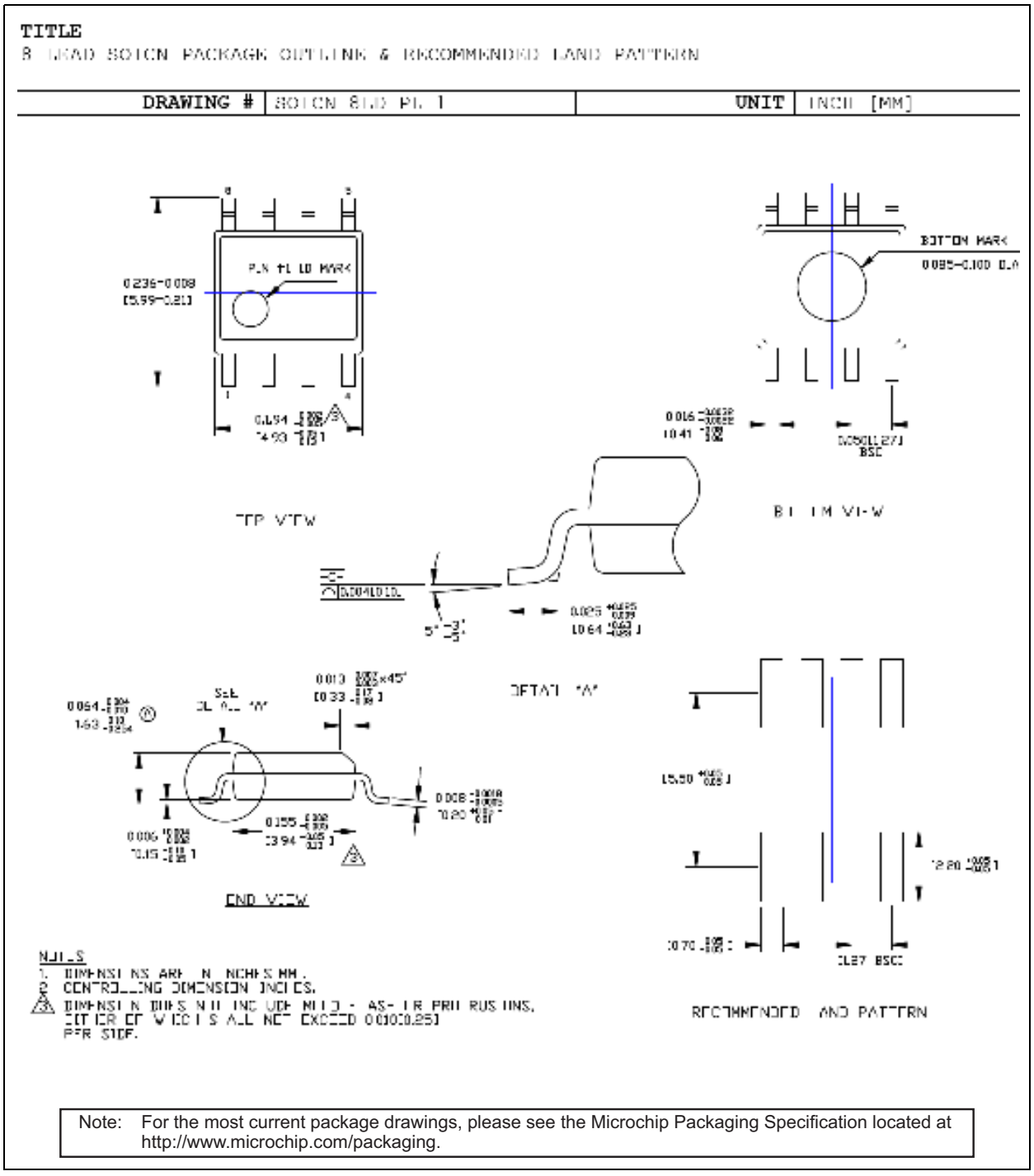
Example



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.	

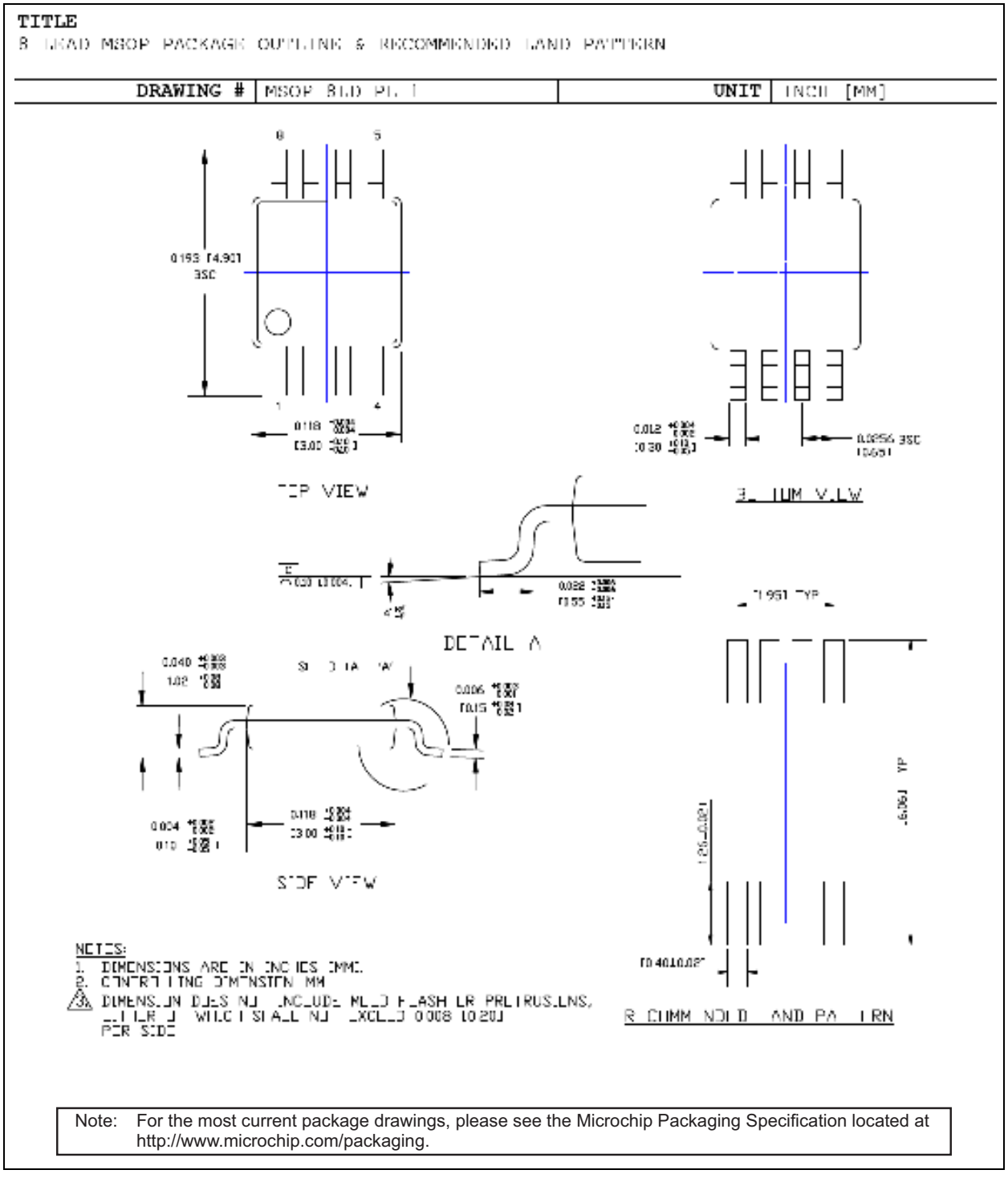
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8-Lead SOIC Package Outline and Recommended Land Pattern



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

8-Lead MSOP 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.

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APPENDIX A: REVISION HISTORY

Revision B (June 2017)

- Minor text changes in the Product Identification System section.

Revision A (March 2017)

- Converted Micrel document MIC2544/48 to Microchip data sheet DS20005725B.
- Minor text changes throughout.
- Updated absolute maximum Output Voltage values in Absolute Maximum Ratings † section and Application Information section.
- Removed all references to discontinued leaded parts (B-designated parts).

NOTES:

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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	X	–	XX
Device		Enable	Temperature	Package		Media Type

Device:	MIC2544:	Programmable Current-Limit High-Side Switch
	MIC2548:	Programmable Current-Limit High-Side Switch with Thermal Shutdown Latch
Enable:	1 =	Active-High
	2 =	Active-Low
Temperature:	Y =	–40°C to +125°C
Package:	M =	8-Lead SOIC
	MM =	8-Lead MSOP
Media Type:	TR =	2,500/Reel
	(blank)=	95/Tube (SOIC)
	(blank)=	100/Tube (MSOP)

Examples:

a) MIC2544-1YM: Programmable Current-Limit High-Side Switch, Active-High, –40°C to +125°C Temp. Range, 8-Lead SOIC, 95/Tube

b) MIC2544-1YM-TR: Programmable Current-Limit High-Side Switch, Active-High, –40°C to +125°C Temp. Range, 8-Lead SOIC, 2,500/Reel

c) MIC2544-2YM: Programmable Current-Limit High-Side Switch, Active-Low, –40°C to +125°C Temp. Range, 8-Lead SOIC, 95/Tube

d) MIC2544-2YM-TR: Programmable Current-Limit High-Side Switch, Active-Low, –40°C to +125°C Temp. Range, 8-Lead SOIC, 2,500/Reel

e) MIC2548-1YM: Programmable Current-Limit High-Side Switch, Thermal Shutdown Latch, Active-High, –40°C to +125°C Temp. Range, 8-Lead SOIC, 100/Tube

f) MIC2548-1YM-TR: Programmable Current-Limit High-Side Switch, Thermal Shutdown Latch, Active-High, –40°C to +125°C Temp. Range, 8-Lead SOIC, 2,500/Reel

g) MIC2548-2YM: Programmable Current-Limit High-Side Switch, Thermal Shutdown Latch, Active-Low, –40°C to +125°C Temp. Range, 8-Lead SOIC, 100/Tube

h) MIC2548-2YM-TR: Programmable Current-Limit High-Side Switch, Thermal Shutdown Latch, Active-Low, –40°C to +125°C Temp. Range, 8-Lead SOIC, 2,500/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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