



*The Infinite Bandwidth Company™*

## MIC2545A/2549A

### Programmable Current Limit High-Side Switch

#### Final Information

### General Description

The MIC2545A and MIC2549A 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 MIC2545A/49A is a cost-effective, highly integrated solution that requires 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, which minimizes inrush current when the switch is enabled. Thermal shutdown, along with adjustable current-limit, protects the switch and the attached device.

The MIC2545A/49A's open-drain flag output is used to indicate current-limiting or thermal shutdown to a local controller. The MIC2549A has an additional internal latch which 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 MIC2549A.

The MIC2545A and MIC2549A are available in active-high and active-low enable versions in 8-pin DIP, SOIC, and TSSOP packages.

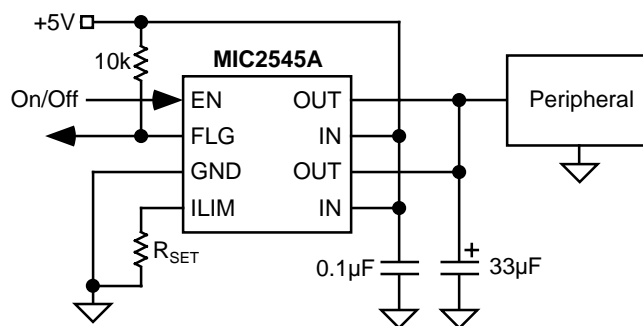
### Features

- 2.7V to 5.5V input
- Adjustable current-limit up to 3A
- Reverse current flow blocking
- 90 $\mu$ A typical on-state supply current
- 1 $\mu$ A typical off-state supply current
- 50m $\Omega$  maximum on-resistance
- Open-drain fault flag
- Thermal shutdown
- Thermal shutdown output latch (MIC2549A)
- 2ms (slow) soft-start turn-on, fast turnoff
- 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

### Typical Application



Typical Advanced Configuration and Power Interface (ACPI) Application

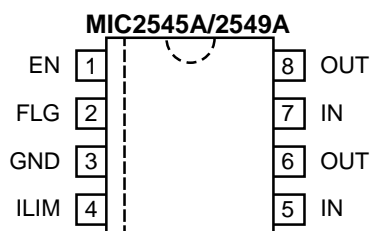


UL Recognized Component

## Ordering Information

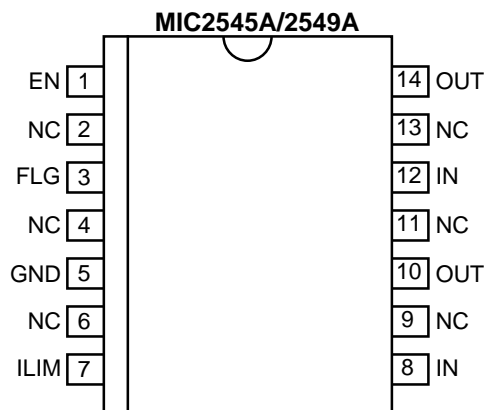
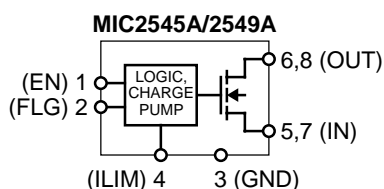
Part Number	Enable	Latch*	Temperature Range	Package
MIC2545A-1BM	Active High		–40°C to +85°C	8-lead SOP
MIC2545A-1BN	Active High		–40°C to +85°C	8-pin DIP
MIC2545A-1BTS	Active High		–40°C to +85°C	14-lead TSSOP
MIC2545A-2BM	Active Low		–40°C to +85°C	8-lead SOP
MIC2545A-2BN	Active Low		–40°C to +85°C	8-pin DIP
MIC2545A-2BTS	Active Low		–40°C to +85°C	14-lead TSSOP
MIC2549A-1BM	Active High	•	–40°C to +85°C	8-lead SOP
MIC2549A-1BN	Active High	•	–40°C to +85°C	8-pin DIP
MIC2549A-1BTS	Active High	•	–40°C to +85°C	14-lead TSSOP
MIC2549A-2BM	Active Low	•	–40°C to +85°C	8-lead SOP
MIC2549A-2BN	Active Low	•	–40°C to +85°C	8-pin DIP
MIC2549A-2BTS	Active Low	•	–40°C to +85°C	14-lead TSSOP

## Pin Configuration



**8-Lead SOP (M)**

**8-Pin DIP (N)**



**14-Lead TSSOP (TS)**

## Pin Description

Pin Number SOP, DIP	Pin Number TSSOP	Pin Name	Pin Function
1	1	EN	Enable (Input): Logic-compatible enable input (-1 version is active high, -2 version is active low). High input >1.8V typical; low input <1.4V typical. Do not float. MIC2549A only: Also resets thermal shutdown latch.
2	3	FLG	Fault Flag (Output): Active-low, open-drain output. Indicates overcurrent or thermal shutdown. MIC2549A only: latched low on thermal shutdown.
3	5	GND	Ground: Supply return.
4	7	ILIM	Current Limit: Sets current limit threshold using an external resistor ( $R_{SET}$ ) connected to ground. $76.8\Omega < R_{SET} < 459\Omega$ .
5, 7	8, 12	IN	Supply Input: Output MOSFET drain. Also powers internal circuitry. Both IN pins must be externally connected together.
6, 8	10, 14	OUT	Switch Output: Output MOSFET source. Both OUT pins must be externally connected together.
	2,4,6,9,11,13	NC	not internally connected

**Absolute Maximum Ratings (Note 1)**

Supply Voltage ( $V_{IN}$ )	+7.0V
Output Voltage ( $V_{OUT}$ )	+7.0V
Output Current ( $I_{OUT}$ )	Internally Limited
Enable Input ( $V_{EN}$ )	–0.3V to +7V
Fault Flag Voltage ( $V_{FLG}$ )	+7.0V
Fault Flag Current ( $I_{FLG}$ )	50mA
Storage Temperature ( $T_S$ )	–65°C to +150°C
Junction Temperature ( $T_J$ )	Internally Limited
Lead Temperature (soldering 5 sec.)	260°C
ESD Rating, <b>Note 3</b>	2001V

**Operating Ratings (Note 2)**

Supply Voltage ( $V_{IN}$ )	+2.7V to +5.5V
Ambient Temperature Range ( $T_A$ )	–40°C to +85°C
Package Thermal Resistance	
PDIP ( $\theta_{JA}$ )	130°C/W
SOIC ( $\theta_{JA}$ )	160°C/W
TSSOP ( $\theta_{JA}$ ), <b>Note 6</b>	100°C/W
Current Limit Set Range, <b>Note 5</b>	0.5A to 3A

**Electrical Characteristics**

$V_{IN} = +5V$ ;  $T_A = 25^\circ C$ , **bold** indicates –40°C to +85°C; unless noted

Symbol	Parameter	Condition	Min	Typ	Max	Units
	Supply Current	Switch off, OUT = open, <b>Note 4</b>		0.75	<b>5</b>	$\mu A$
		Switch on, OUT = open, <b>Note 4</b>		90	125 <b>150</b>	$\mu A$ $\mu A$
$V_{EN}$	Enable Input Voltage	Enable high transition, <b>Note 4</b>	2.4	1.6		V
		Enable low transition, <b>Note 1</b>		1.5	<b>0.8</b>	<b>V</b>
	Enable Input Current	$V_{EN} = V_{OH(min)} = 2.4V$		0.01	<b>1</b>	$\mu A$
		$V_{EN} = V_{OL(max)} = 0.8V$		0.01	<b>1</b>	$\mu A$
	Enable Input Capacitance	<b>Note 7</b>		1		pF
$R_{DS(on)}$	Switch Resistance	$I_{OUT} = 500mA$		35	<b>50</b>	m $\Omega$
	Current Limit Factor	$I_{LIMIT} = 0.5A$ to 3A, $V_{OUT} = 1V$ to 4V, <b>Note 5</b>	160	230	300	V
		$I_{LIMIT} = 1A$ to 2.5A, $V_{OUT} = 1V$ to 4V, <b>Note 5</b>	184	230	276	V
	Output Leakage Current	Switch off, $V_{OUT} = 0V$		1	<b>10</b>	$\mu A$
$t_{ON}$	Output Turn-On Delay	$R_L = 10\Omega$ , $C_L = 1\mu F$ , <b>Figures 1a, 1b</b>	1	2	5	ms
$t_R$	Output Turn-On Rise Time	$R_L = 10\Omega$ , $C_L = 1\mu F$ , <b>Figure 1a, 1b</b>	0.75	1.8	4.9	ms
$t_{OFF}$	Output Turnoff Delay	$R_L = 10\Omega$ , $C_L = 1\mu F$ , <b>Figure 1a, 1b</b>		25		$\mu s$
$t_F$	Output Turnoff Fall Time	$R_L = 10\Omega$ , $C_L = 1\mu F$ , <b>Figure 1a, 1b</b>		23		$\mu s$
	Overtemperature Threshold Shutdown	$T_J$ increasing		135		°C
		$T_J$ decreasing		120		°C
	Error Flag Off Current	$V_{FLG} = 5V$		0.01	<b>1</b>	$\mu A$
	EN Pulse Reset Width	MIC2549A thermal shutdown latch, <b>Note 7</b>	1			$\mu s$
$t_{SU}$	$V_{IN}$ to EN Set-Up	MIC2549A, <b>Note 7, Figure 1c</b>	0			$\mu s$
	Current-Limit Response Time	$V_{OUT} = 0V$ to $I_{OUT} = 2A$ , $I_{SET} = 1A$ , <b>Note 7</b>		40		$\mu s$
$V_{OL}$	Error Flag Output Resistance	$I_{FLG} = 10mA$		4	15	$\Omega$

**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.

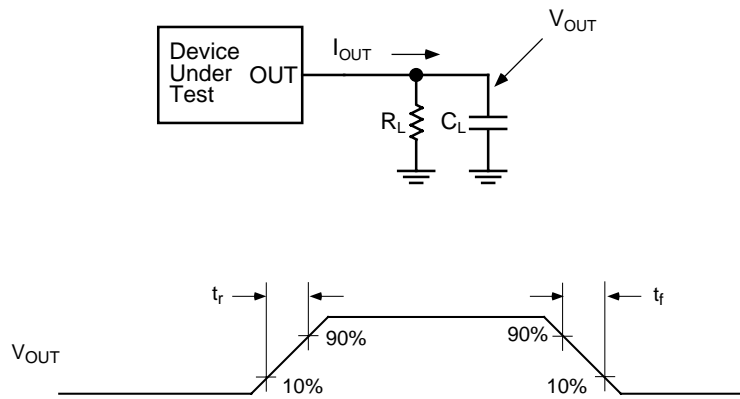
**Note 4.** Off is  $\leq 0.8V$  and on is  $\geq 2.4V$  for the MIC2545A-1 and MIC2549A-1. Off is  $\geq 2.4V$  and on is  $\leq 0.8V$  for the MIC2545A-2 and MIC2549A-2. The enable input has about 100mV of hysteresis.

**Note 5.** Current limit is determined by:  $I_{LIMIT} = \frac{230}{R_{SET}}$ , where  $R_{SET}$  is in ohms, and 230 is typical current limit factor in volts.

**Note 6.** Assumes 4 layer PCB is used.

**Note 7.** Guaranteed by design but not production tested.

## Test Circuit



## Functional Characteristics Test Circuit

## Timing Diagrams

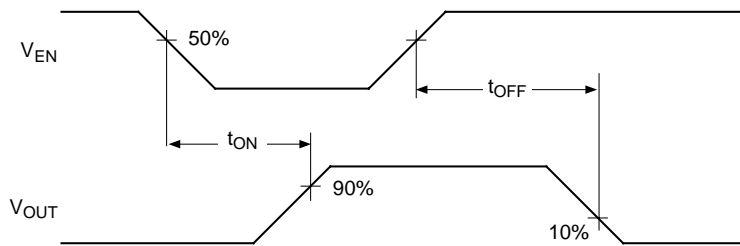


Figure 1a. MIC2545A/49A-2

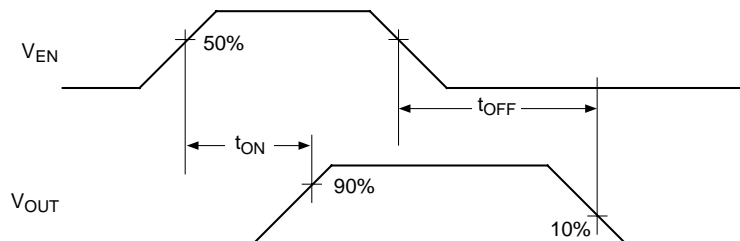


Figure 1b. MIC2545A/49A-1

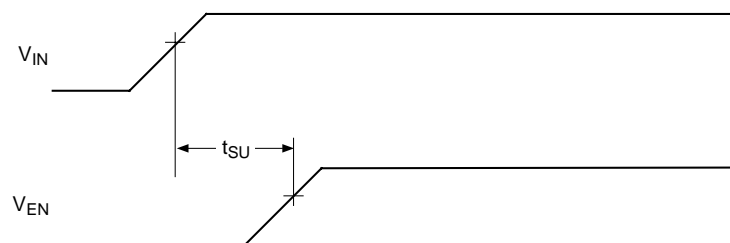
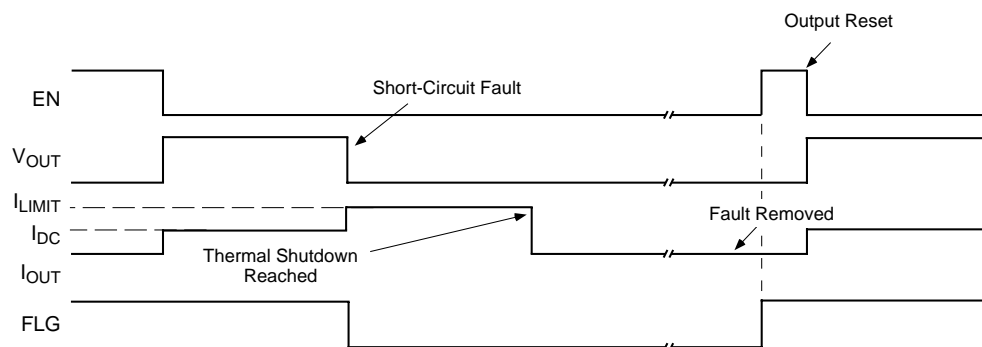
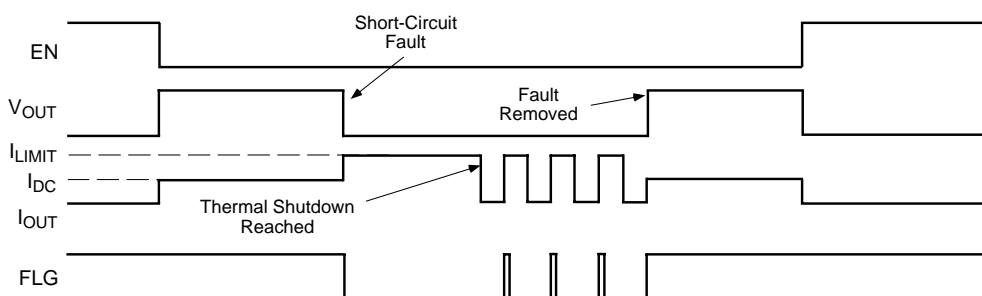


Figure 1c. Input-to-Enable Setup Timing



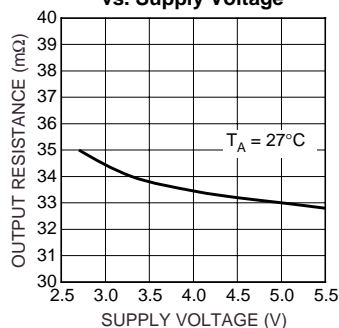
**Figure 2a. MIC2549A-2 Timing: Output Is Reset By Toggling EN**



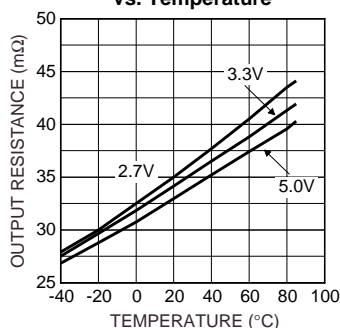
**Figure 2b. MIC2545A-2 Timing**

# Typical Characteristics

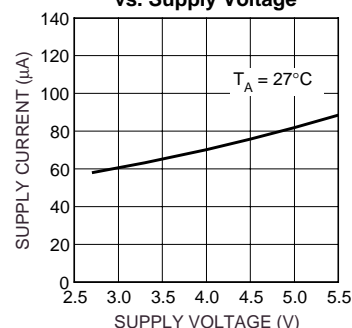
**Output On-Resistance vs. Supply Voltage**



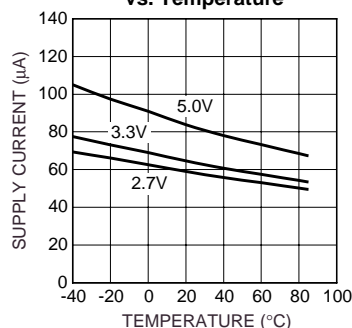
**Output On-Resistance vs. Temperature**



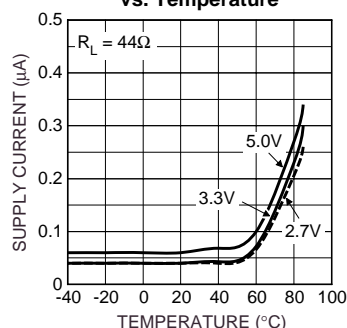
**On-State Supply Current vs. Supply Voltage**



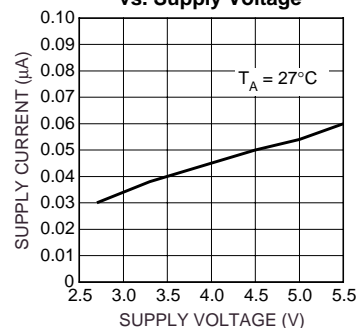
**On-State Supply Current vs. Temperature**



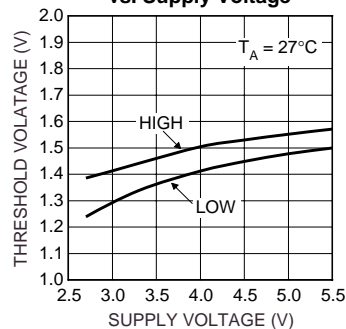
**Off-State Supply Current vs. Temperature**



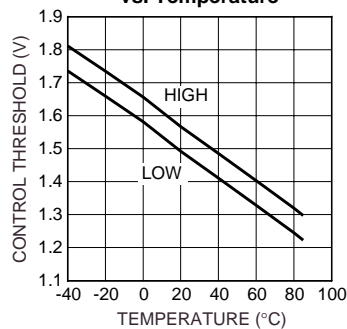
**Off-State Supply Current vs. Supply Voltage**



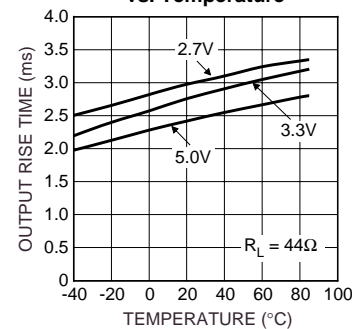
**Control Threshold Voltage vs. Supply Voltage**



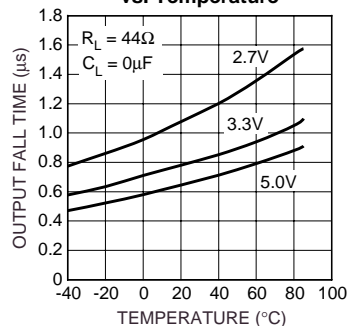
**Control Threshold Voltage vs. Temperature**



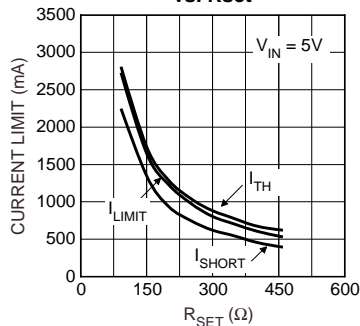
**Rise Time vs. Temperature**



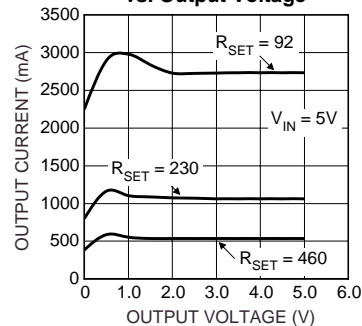
**Output Fall Time vs. Temperature**

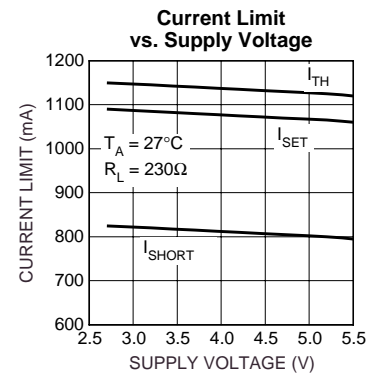
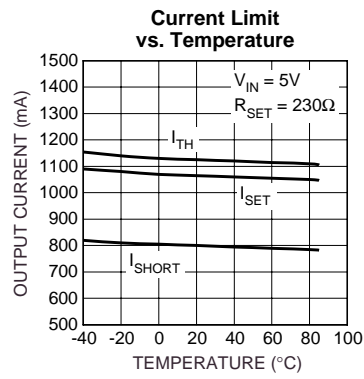


**Current Limit vs. Rset**

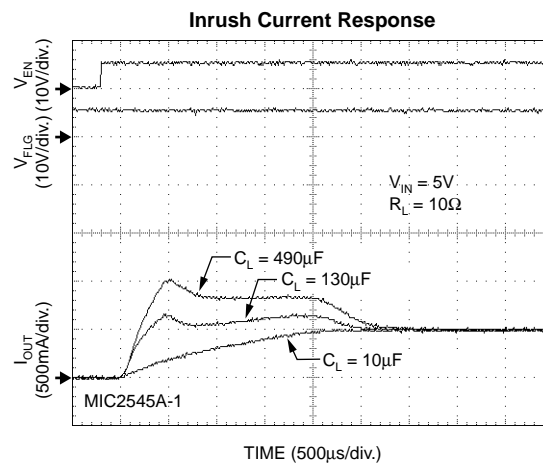
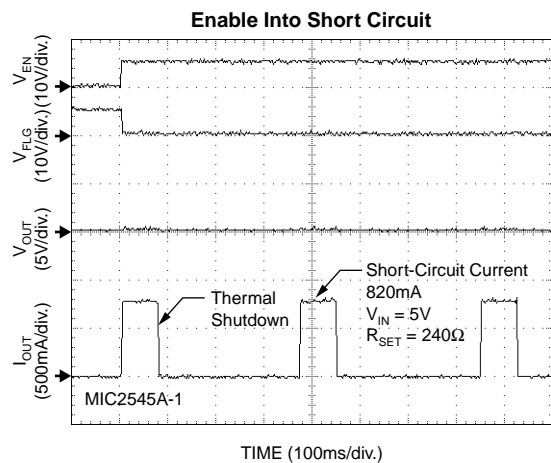
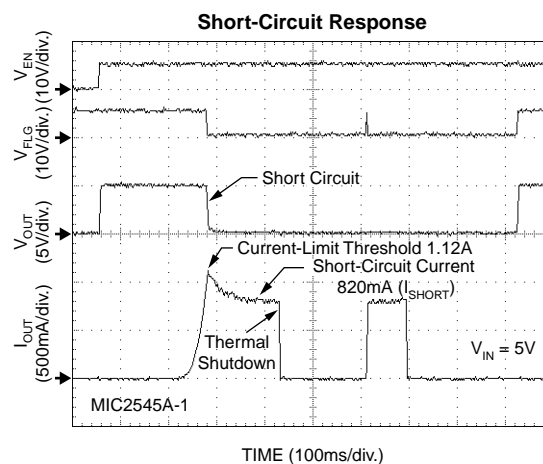
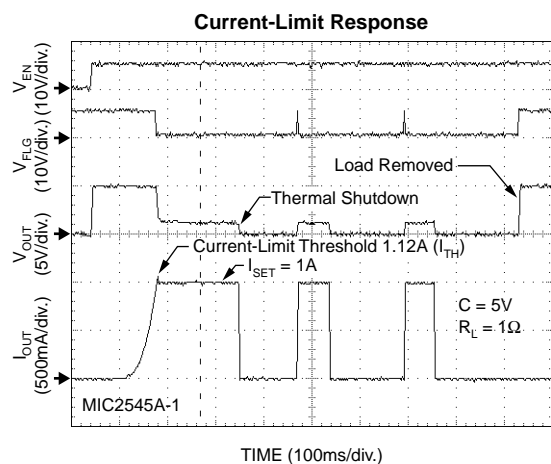
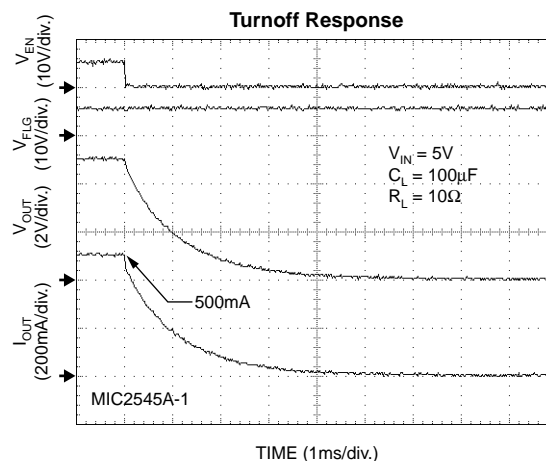
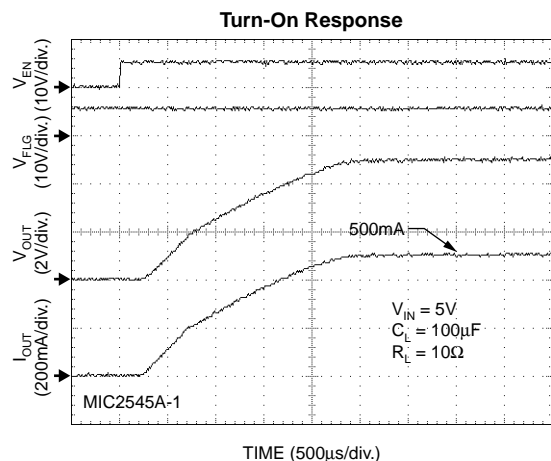


**Output Current vs. Output Voltage**

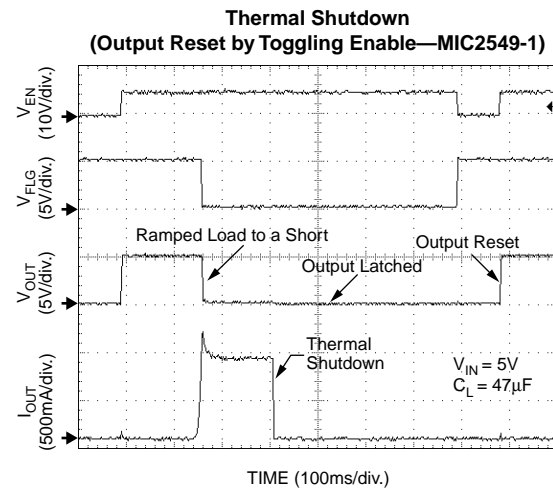




## Functional Characteristics







The block diagram illustrates the internal control logic of the MIC2549A. Key components and their interconnections include:

- EN (Enable):** A master enable pin that connects to the top of the **OSC.** block, the **THERMAL SHUTDOWN** block, and the **1.2V REFERENCE** block.
- OSC. (Oscillator):** Generates a clock signal for the **CHARGE PUMP**.
- CHARGE PUMP:** Provides a boosted gate drive signal to the **GATE CONTROL** block.
- THERMAL SHUTDOWN:** Monitors the device temperature. It receives inputs from **EN** and the **1.2V REFERENCE**. Its output is connected to the **GATE CONTROL** block and the **THERMAL SHUTDOWN LATCH (MIC2549A)**.
- 1.2V REFERENCE:** Provides a stable reference voltage for the **THERMAL SHUTDOWN** and the **CURRENT LIMIT** block.
- CURRENT LIMIT:** Monitors the load current via the **ILIM** pin (connected to a sense resistor  $R_{SET}$ ). Its output is connected to the **GATE CONTROL** block.
- GATE CONTROL:** Receives signals from the **CHARGE PUMP**, **THERMAL SHUTDOWN**, and **CURRENT LIMIT** to drive the MOSFET gate.
- THERMAL SHUTDOWN LATCH (MIC2549A):** Latches the thermal shutdown signal. It is reset by the **RESET** pin. Its output is connected to the **FLG** (Flag) pin via an OR gate.
- OUT (Output):** The regulated output voltage, taken from the MOSFET drain.
- FLG (Flag):** Indicates a fault condition (thermal shutdown or current limit).
- GND:** The common ground reference for the entire circuit.

## Functional Description

The MIC2545A and MIC2549A 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.

### 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 since 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 MIC2545A/49A avoids undesirable current flow from OUT to IN. Both IN pins must be connected together, and both OUT pins must be connected together.

### Thermal Shutdown

Thermal shutdown shuts off the output MOSFET and signals the fault flag if the die temperature exceeds 135°C. 10°C of hysteresis prevents the switch from turning on until the die temperature drops to 125°C. Overtemperature detection functions only when the switch is enabled.

The MIC2549A 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 2 for timing diagram. The flag remains low until reset.

### 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.

### Current-Limit Operation

The current limit is user adjustable with an external set resistor. Current limiting in the range of 500mA to 3A is available with a set point accuracy of better than  $\pm 30\%$  ( $\pm 20\%$  for  $I_{SET}$  1 to 2.5A). The current-limit circuit prevents damage to the output MOSFET and external load.

The current-limit response of the MIC2545A/49A is based on the type of load that is applied to the output and is defined in three parts:

1. The first mode of operation is where the device enters a constant-current mode preventing further increases in output current. The value of this current,  $I_{LIMIT}$ , is defined by the value of  $R_{SET}$  as explained further in this section.
2. When a short circuit is applied to the output of an enabled device the output current immediately folds back to a value less than  $I_{LIMIT}$  called  $I_{SHORT}$ . This further protects the load and reduces device power dissipation. Refer to the "Typical Characteristics: Output Current vs. Output Voltage" graph for details.
3. When a load is increased, the output current will proportionally increase up to the current-limit threshold,  $I_{TH}$ , as shown in the "Functional Characteristics: Current-Limit Response" graph. The device in this case will supply current slightly higher than the current-limit set point defined by  $R_{SET}$ . As the load is increased further the current folds back to  $I_{LIMIT}$ .

The nominal current-limit value,  $I_{LIMIT}$ , is set with an external resistor between ILIM (pin 4) and GND (pin 3). For a desired current-limit, the value of the external set resistor is given by:

$$R_{SET} = \left( \frac{230}{I_{LIMIT}} \right)$$

where:

$$76.8\Omega < R_{SET} < 459\Omega$$

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

$$\left( \frac{230}{1A} \right) = 230\Omega$$

Refer to the "Typical Characteristics: Current-Limit vs  $R_{SET}$ " graph for more details.

Current through  $R_{SET}$  increases with output 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 76.8Ω and 459Ω (1% resistor value).

### 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 10mA load to typically 100mV above ground. For applications with  $V_{IN} \leq 3.6V$ , it is recommended that flag current be limited to 5mA or less.

## Applications Information

### Supply Filtering

A 0.1μF to 1μF bypass capacitor from IN to GND, located near the MIC2545A and MIC2549A, 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 ( $V_{IN\ max} = 6V$ ) even for a short duration.*

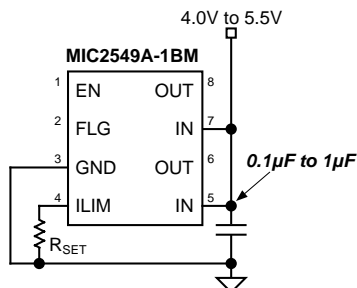


Figure 3. Supply Bypassing

### 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:

$$P_D = R_{DS(on)} \times (I_{OUT})^2$$

To relate this to junction temperature, the following equation can be used:

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

where:

$T_J$  = junction temperature

$T_A$  = ambient temperature

$\theta_{JA}$  = is the thermal resistance of the package

### Transient Overcurrent Filter

The inrush current from the connection of a heavy capacitive load may cause the fault flag to fall for 10μs to 200μs 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 4, 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 10μs to 20μs. If  $R_{SET}$  is 435Ω (530mA), an  $R_{SET2}$  of 88Ω (2.5A) and  $C_{SET}$  of 1μF ( $RC \approx 90\mu s$ ) allows transient surge of 3A to pass for 90μs without tripping the overcurrent flag (FLG).

### USB Power Distribution

The MIC2545A is ideal for meeting USB power distribution requirements. Figure 7 depicts a USB Host application.  $R_{SET}$  should be set to a value providing a current-limit >500mA. The accurate current-limit of the MIC2545A will reduce power supply current requirements. Also, fast reaction to short circuit faults prevent voltage droop in mobile PC applications.

### Printed Circuit Board Hot-Plug

The MIC2545A/49A is an ideal inrush current-limiter suitable for hot-plug applications. Due to the integrated charge pump, the MIC2545A/49A 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 5 shows how the MIC2545A may be used in a hot-plug application.

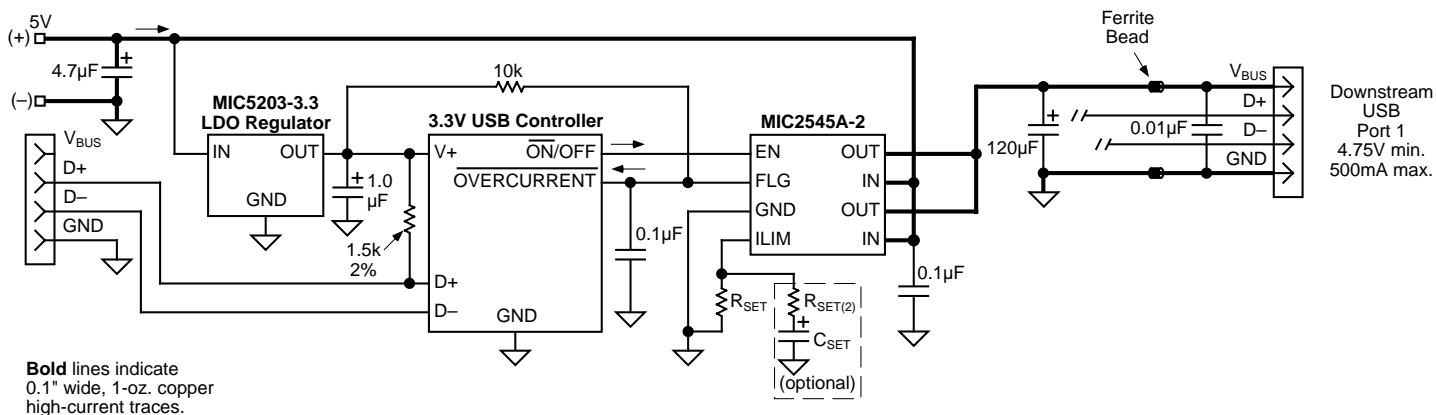
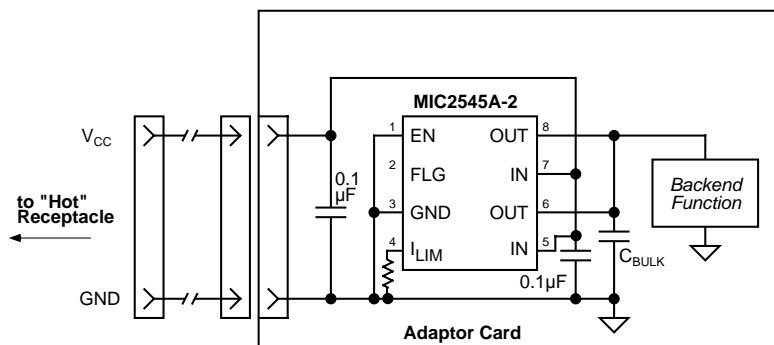
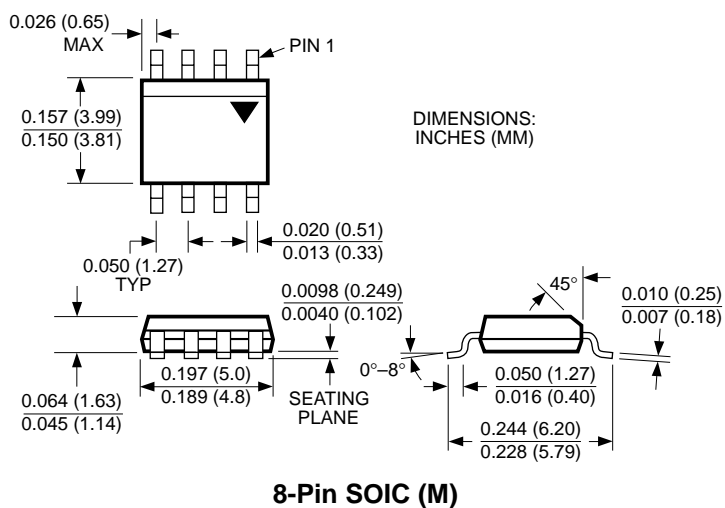
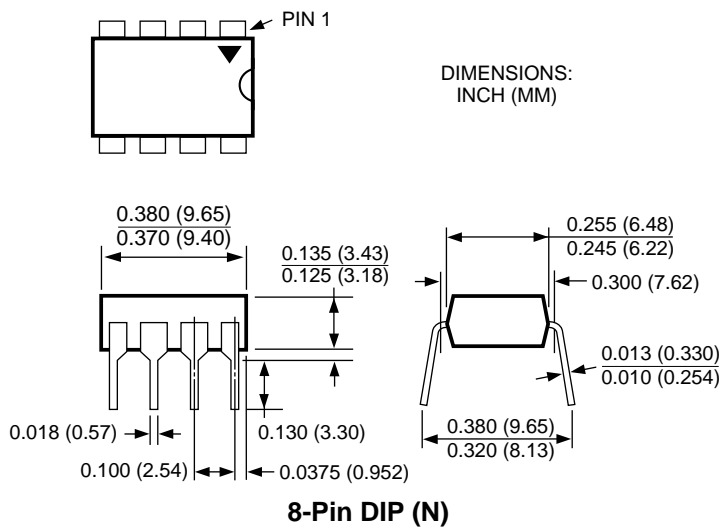


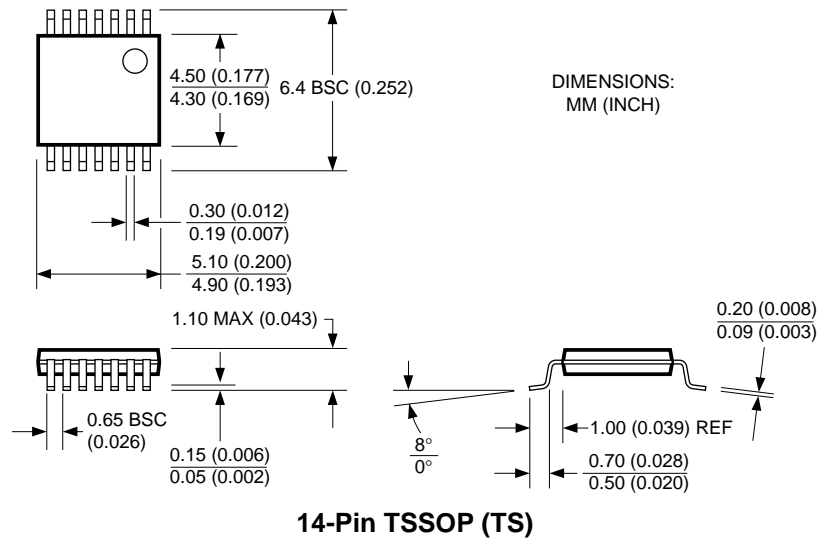
Figure 4. USB Host Application



**Figure 5. Hot-Plug Application**

## Package Information





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