●新特器件应用

双路USB功率分配开关MIC2536及其应用电路

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Dual USB Power Distribution Switch MIC2536 and Its Application Circuit

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摘要：MIC2536是MICREL公司生产的一种性能价格比很高的双路USB功率分配开关。它具有两个独立的控制通道。可广泛应用于带有UAB板的总线电源集线器、USB总线电源对接系统、笔记本型PC机和个人数字助理（PDAs）、通用型电源适配器、PC板的热插拔以及浪涌电流的限制等应用场合。文中介绍了MIC2536的主要特点、引脚功能和工作原理，给出了由它组成的一个二端口总线电源集线器的应用电路。

关键词：电源；　功率开关；　USB；　热关断；　MIC2536

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1　概述

MIC2536是MICREL公司生产的一种性能价格比很高的双路USB功率开关。它具有两个独立的控制通道，每一个控制通道均可为USB电源总线所连接的后继电路提供100mA的驱动电流，同时，它可用最少的外围元器件满足USB电源的应用需求。因而是UAB电源总线应用方面的最佳选择。

MIC2536的故障电流门限典型值为275mA，如果电路发生故障，那么电路中的故障电流限制电路将作出反应，并输出故障信号。需要说明的是：MIV2536中的USB控制器能够自动识别并滤除由于热插拔而产生的浪涌电流信号，从而保证热插拔操作的正常使用。

当MIC2536被激活时，它可以通过软启动来消除其它端口上可能发生的瞬时电压跌落。同时，MIC2536还具有热关断功能，因而可防止开关由于负载短路或者与3V/5V逻辑兼容的使能输入等方面的问题而产生的过电流损坏。

MIC2536双路USB功率分配开关集成电路具有8脚SOP和MSOP两种封装形式。同时它还有如下主要特点：

●符合USB操作规范；

●具有2.7V~5.5V的操作电压范围；

●每通道的最小持续负载电流为 150mA；

●具有 400mΩ 的典型在片阻抗；

●可采用热关断方式来对电路芯片进行快速短路保护；

●内含综合滤波器，可消除过流尖峰噪声并发出标记警告；

●可通过瞬态滤波器来对故障标记引脚进行单独处理；

●可接受 3V/5V 兼容的使能输入；

●可在激活高电平(-1)和激活低电平(-2)之间自由转换；

●内含软启动电路；

●在关闭模式时，MIC2536 仍然带有反向电流闭锁功能；

●最大开态电源电流为 100μA；

●关态电源电流典型值小于 1μA；

●具有 -40℃ ~ +85℃的工作温度范围。

MIC2536 是一种带有两个独立控制通道的双路 USB 功率分配开关控制芯片。可广泛应用于带有 USB 接口的总线电源集线器、USB 总线电源对接系统、笔记本型 PC 机、个人数字助理(PDAs)、通用型电源适配器、PC 板的热插拔以及浪涌电流的限制等应用场合。

表 1　MIC2536 的型号使能和封装表

型　　号	使能状态	封装形式
MIC2536-1BM	激活高电平	8 脚 SOP 封装
MIC2536-2BM	激活低电平	8 脚 SOP 封装
MIC2536-1BMM	激活高电平	8 脚 MSOP 封装
MIC2536-2BMM	激活低电平	8 脚 MSOP 封装

MIC2536 采用 8 脚 SOP 和 8 脚 MSOP 两种封装形式，并具有激活高电平和激活低电平两种使能状态，表 1 是 MIC2536 系列芯片的型号、使能状态和封装形式对照表。

2　引脚功能及参数

2.1　引脚排列和功能

MIC2536 采用 8 脚封装形式，图 1 是其引脚排列图，各引脚的功能说明如表 2 所列。

2.2　主要参数

由于 MIC2536 型 USB 功率分配开关的工作参数范围比较宽。因而它具有较强的使用适用性。但在使用时，如果超出了它的极性参数，那么，仍然可能会造成工作不能正常进行或者器件损坏。因此，这一点应当引起注意。

MIC2536 的主要极限参数如下：

●正常电源电压范围(V_{IN})：2.7V ~ 5.5V；

●最高电源电压(V_{IN})：6V；

●故障标记电压(V_{FLG})：6V；

●故障标记电流(I_{FLG})：25mA；

●短路限流最小值：150mA；

●短路限流最大值：400mA；

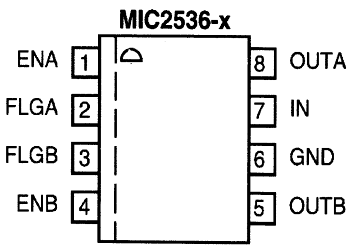

图 1　MIC2536 的引脚排列

表 2　MIC2536 的引脚功能说明

引脚号	引脚名称	功　　能
1	ENA	A 通道使能输入引脚，用于对 A 通道的激活高电平或激活低电平进行输入控制
2	FLGA	A 通道标记输出，用于输出 A 通道的故障标记信号以指示其过电流或热关断状态。需要说明的是：过流条件应当比判断 FLG 标记所用的时间 t_D 更长一些
3	FLGB	B 通道标记输出，用于输出 B 通道的故障标记信号以指示其过电流或热关断状态。与 A 通道相同：过流条件也应当比判断 FLG 标记所用的时间 tD 更长一些
4	ENB	B 通道使能输入引脚，用于对 B 通道的激活高电平或激活低电平进行输入控制
5	OUTB	B 通道的开关输出端口
6	GND	接地引脚
7	IN	正向开关和逻辑电源输入引脚
8	OUTA	A 通道的开关输出端口

●限流响应时间:10μs;

●最大输出电压(V_{OUT}):6V;

●输出电流(I_{OUT}):内部限定;

●使能控制输入(V_{EN}):-0.3V~V_{IN}+2V;

●工作温度范围:-40℃~+85℃;

●ESD等级:1kV。

3 工作原理

MIC2536-1和MIC2536-2分别是激活高电平和激活低电平使能输入的双向高端开关器件。其故障条件的关断或打开由MIC2536输出端的一个或多个晶体管依据故障的具体情况来决定。通过激活缓释故障标记，晶体管可使电路将过量的电流下泄到地端。

MIC2536功率开关内含热关断电路及输出MOSFET,同时含有电流限制电路、延迟电路、门控制电路、电荷泵、振荡器、1.2V电压参考以及故障监测标记电路等。图2所示是MIC2536的内部组成框图。下面将MIC2536的主要工作过程作以介绍。

3.1 输入和输出

MIC2536的IN输入端口是电源和器件内每一个输出MOSFET的漏极之间进行连接的逻辑电路通道。而两个输出端口OUTA和OUTB则在器件内部被连到输出MOSFET的源极。在一般的典型连接电路中,电流通过开关从IN流向OUTA和OUTB,然后流向负载。如果输出电压V_{OUT}高于输入电压V_{IN},那么，在MOSFET使能激活期间，电流将从输出端口OUTA和OUTB流向IN。

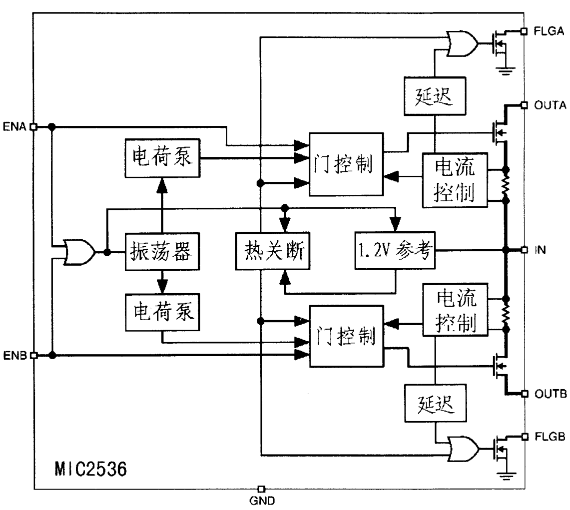

图2 MIC2536的内部结构

基于MIC2536的上述特性，可以在MOSFET之外设计一个电路来强行将输出MOSFET及其驱动电路的电压V_{OUTX}拉高到输入电压V_{IN}以上，以使得MIC2536在输出失效时，能够有效地防止反向电流的流入。

3.2 热关断

MIC2536芯片中的每一个输出MOSFET都带有它自己的温度传感器。如果一个通道温度或两个通道的温度都达到135℃以上，器件将关闭该通道并作出标记。由于MIC2536具有10℃的温度延迟，因此，只有当温度降到125℃以下时，器件才能重新被打开。

由于MIC2536具有自动重新复位功能，因此，在过热温度降到大约125℃左右时，MIC2536将会自动复位。但是，从此时起，MIC2536的输出和FLG信号将连续周期性的开或关，直到系统的故障被彻底清除为止。

受器件所在的PCB板以及器件封装和环境温度等方面的影响，MIC2536从发现故障到输出MOSFET被关断将会持续数百毫秒的时间。这一点是MIC2536型USB功率分配开关芯片热关断功能的一个不足之处。

3.3 电流检测和限制

MIC2536的电流限制参数是事先在器件内部设定的。每个通道通过输出MOSFET的最小允许电流被预先设定为150mA,这一设定值可有效防止输出MOSFET和外部负载的损坏。电流限制电路可用于对部分输出FET管的开关电流进行检测。但是应当注意:在图2中的电流检测电阻上是显示不出电压降的，而过流条件的变化主要是由以下三种情况来反映的:

(1) 开关使能到短路

如果一个被激活的开关被接入到一个很大的负载上或者出现短路，那么该开关将立即进入恒流模式，并减小输出电压，同时在FLG端口上显示过流状态。

(2) 短路到输出

当一个激活的开关上加入很大的负载或者负载短路时,那么在电流限制电路作出反应之前,系统中将有一个很大的瞬态电流流过。一旦这种情况发生，那么器件的电流限制参数将明显地小于这一瞬

态电流。

(3) 电流限制的负载响应

一旦MIC2536在恒流模式中的电流限制极限被超越，器件中的电流限制电路在某种程度上讲就相当于一个100mA的小型回馈系统。MIC2536的短路电流限制最小值为150mA，最大值为400mA，而其限流响应时间为10μs，这些参数对于那些当MIC2536加在负载上的电流超过了其电流限制极限，而器件限流操作还尚未动作的情况是十分有益的。

3.4 故障标记

MIC2536的故障标记信号是由器件内的开漏N沟道MOSFET管的输出产生的。并由器件的电流限制电路或者热关断激活。一旦电路出现过流，那么，FLG信号将在标记响应延迟时间 t_D 结束后立即产生。需要说明的是：如果电路上接入的是较高容性负载，那么在连接或插拔期间，电路将产生较高的瞬态浪涌电流，这种瞬态浪涌电流一旦超过了电流限制极限，那么电路将有可能出现虚假的过流状态。因此，设计时应考虑到器件的标记响应延迟时间，MIC2536的标记响应延迟时间 t_D 的典型值为12ms.

4 应用电路

MIC2536可用于多种具有通用串行总线(USB)的电源和接口电路，如总线电源集线器、笔记本型PC机和个人数字助理(PDAs)、通用电源适配器等。特别是在PC机与打印机接口之间的热插拔以及USB总线电源集线器等应用方面，MIC2536无疑是最佳选择。

4.1 打印卡热插拔电路

图3是一个简单的打印机热插拔卡的电路示意图。利用该电路可以使打印卡和PC机在热插拔时，使系统缓慢过渡到高阻抗或低阻抗状态。这种“软启动”功能可有效地减小在高容性负载插拔时所产生的较大瞬态浪涌电流。图中，IN脚和GND脚之间的旁路电容的容量范围为0.1μF～1μF。需要说明的是：该电容对于控制电源上的瞬变干扰是非常有用的。如果没有该旁路电容，一旦输出出现短路，MIC2536输入端的内部控制电路肯定会被烧坏。

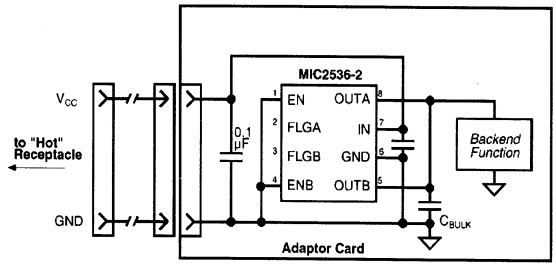

图3 PC机打印接口卡的热插拔电路

4.2 双端口总线电源集线器

图4所示是一个具有两个USB端口的总线电源集线器的应用电路。图中的MIC5207-3.3是一个三端电源调节器，主要用于为其后的USB控制器提供稳定的3.3V电源。而MIC2536功率分配开关的电源输入则直接从总线电源 V_{BUS} 上获取。电路工作时，一旦MIC2536中的电流限制电路从其USB端口上检测到有效的过流条件，MIC2536便立即通过故障标记端口向USB控制器发出故障标记信号，USB控制器在接到MIC2536发来的故障标记信号后，便从其ON/OFF端口向MIC2536输出开关发出使能信号，以使MIC2536对其USB端口的过流现象作出相应的响应。

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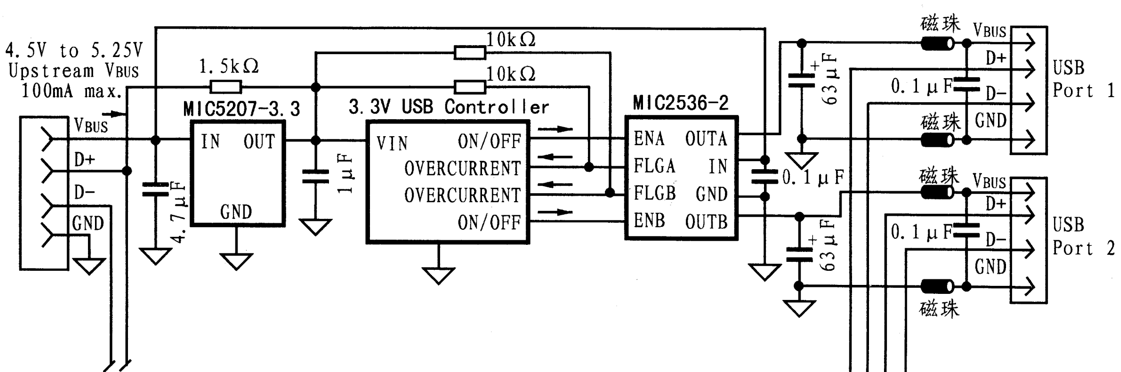


图4 双端口总线电源集线器应用电路

The Infinite Bandwidth Company™

MIC2536

Dual USB Power Distribution Switch

Final Information

General Description

The MIC2536 is a cost-effective high-side power switch, with two independently controlled channels, optimized for bus-powered Universal Serial Bus (USB) applications. Few external components are necessary to satisfy USB requirements.

Each switch channel of the MIC2536 will supply up to 100mA as required for USB bus-powered downstream devices. Fault current is limited to typically 275mA by fast-acting current-limit circuitry which minimizes voltage droop on the upstream port during fault conditions. A flag output with transient filter indicates fault conditions to the local USB controller but will ignore short flag signals resulting from inrush current during hot plug-in events.

Soft start eliminates the momentary voltage droop on other ports that may occur when the switch is enabled in bus-powered applications. Additional features include thermal shutdown to prevent catastrophic switch failure from high-current loads and 3.3V and 5V logic compatible enable inputs.

The MIC2536 is available in active-high and active-low versions in 8-lead SOP and MSOP.

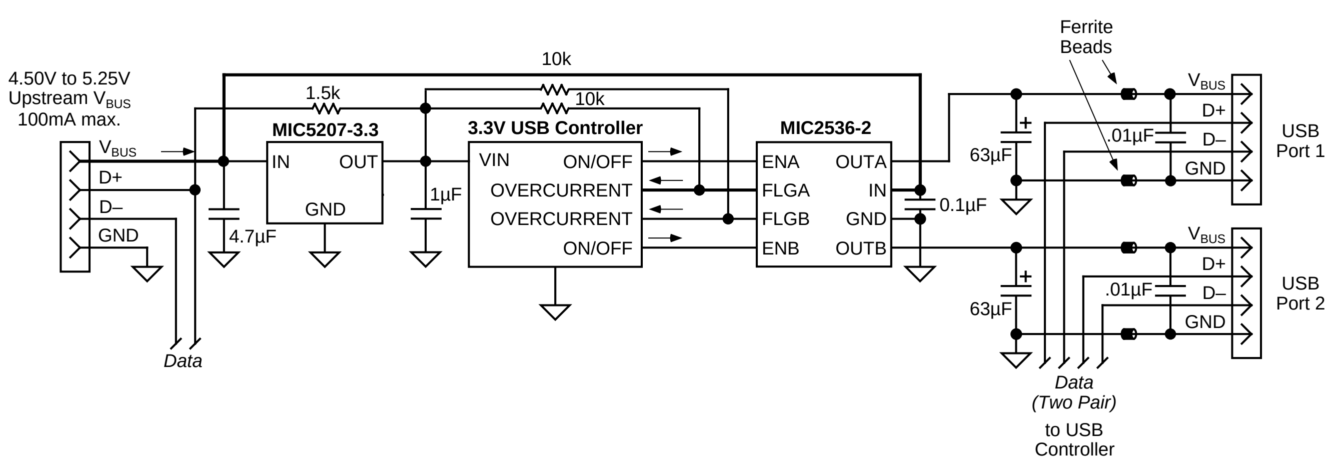
Features

- Compliant to USB specifications
- 2.7V to 5.5V operating range
- 150mA minimum continuous load current per channel
- 400mΩ typical on-resistance
- Fast-acting short circuit protection with thermal shutdown
- Integrated filter eliminates false overcurrent flag assertions
- Individual open-drain fault flag pins with transient filter
- 3V/5V-compatible enable inputs
- Active-high (-1) and active-low (-2) versions
- Reverse-current blocking in off mode (no “body diode”)
- Soft-start circuit
- 100µA maximum on-state supply current
- <1µA typical off-state supply current
- –40°C to 85°C operation

Applications

- USB keyboard bus-powered hubs
- USB bus-powered docking stations
- Note Book PCs
- PDAs
- General purpose power distribution applications
- PC board hot swap
- Inrush current-limiting

Typical Application



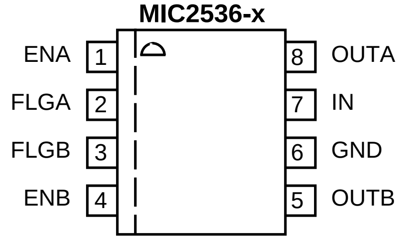
Typical Two-Port Bus-Powered Hub

UL Recognized Component

Ordering Information

Part Number	Enable	Temperature Range	Package
MIC2536-1BM	Active High	–40°C to +85°C	8-Lead SOP
MIC2536-2BM	Active Low	–40°C to +85°C	8-Lead SOP
MIC2536-1BMM	Active High	–40°C to +85°C	8-Lead MSOP
MIC2536-2BMM	Active Low	–40°C to +85°C	8-Lead MSOP

Pin Configuration



8-Lead SOP (M)
8-Lead MSOP (MM)

Pin Description

Pin Number	Pin Name	Pin Function
1	ENA	Enable A (Input): Channel A control input. Active high (–1) or active low (–2) input.
2	FLGA	Flag A: (Output): Channel A open-drain fault flag output. Indicates overcurrent or thermal shutdown conditions. Overcurrent conditions must last longer than t_D in order to assert FLG.
3	FLGB	Flag B (Output): Channel B open-drain fault flag output. Indicates overcurrent or thermal shutdown conditions. Overcurrent conditions must last longer than t_D in order to assert FLG.
4	ENB	Enable B (Input): Channel B control input. Active high (–1) or active low (–2) input.
5	OUTB	Output B: Channel B switch output.
6	GND	Ground
7	IN	Positive Switch and Logic Supply Input
8	OUTA	Output A: Channel A switch output.

Absolute Maximum Ratings (Note 1)

Supply Voltage (V_{IN}) ..... +6V
Fault Flag Voltage (V_{FLG}) ..... +6V
Fault Flag Current (I_{FLG}) 25mA
Output Voltage (V_{OUT}) ..... +6V
Output Current (I_{OUT}) ..... Internally Limited
Control Input (V_{EN}) ..... –0.3V to V_{IN} +2V
Storage Temperature (T_S) ..... –65°C to +150°C
Lead Temperature (Soldering 5 sec.) ..... 260°C
ESD Rating, **Note 3** 1kV

Operating Ratings (Note 2)

Supply Voltage (V_{IN}) ..... +2.7V to +5.5V
Ambient Operating Temperature (T_A) ..... –40°C to +85°C
Thermal Resistance
SOP (θ_{JA}) ..... 160°C/W
MSOP (θ_{JA}) ..... 206°C/W

Electrical Characteristics

V_{IN} = +5V; T_A = 25°C, **bold** values indicate –40°C ≤ T_A ≤ +85°C; unless noted

Parameter	Condition	Min	Typ	Max	Units
Supply Current	both switches off, OUTA–B = open, **Note 4**		0.75	5	µA
	both switches on, OUTA–B = open, **Note 4**		60	100	µA
Enable Input Threshold	low-to-high transition, **Note 4**		1.7	2.4	V
	high-to-low transition, **Note 4**	0.8	1.5		V
Enable Input Current	V_{EN} = 0V to 5.5V		0.01	1	µA
Enable Input Capacitance	**Note 5**		1		pF
Switch Resistance	single switch, I_{OUT} = 100mA		400	**700**	mΩ
Output Turn-On Delay, t_{ON}	R_L = 50Ω, C_L = 1µF		1.5		ms
Output Turn-On Rise Time, t_R	R_L = 50Ω, C_L = 1µF		1.4		ms
Output Turnoff Delay, t_{OFF}	R_L = 50Ω, C_L = 1µF		130		µs
Output Turnoff Fall Time, t_F	R_L = 50Ω, C_L = 1µF		115		µs
Output Leakage Current	each output (switch off)		1	10	µA
Current Limit Threshold	ramped load applied to enable output			**500**	mA
Short Circuit Current Limit	each output (enabled into load), V_{OUT} = 0V	150	275	**400**	mA
Current Limit Response	V_{OUT} = 0V to I_{OUT} = I_{LIMIT} (short applied to output), **Note 5**		10		µs
Flag Response Delay, t_D	V_{IN} = 5V, apply V_{OUT} = 0V until FLG low	5	13	20	ms
	V_{IN} = 3.3V, apply V_{OUT} = 0V until FLG low		13		ms
Overtemperature Shutdown	T_J increasing, **Note 5**		135		°C
Threshold	T_J decreasing, **Note 5**		125		°C
Error Flag Output Resistance	V_{IN} = 5V, I_L = 10mA		10	20	Ω
	V_{IN} = 3.3V, I_L = 10mA		15	30	Ω
Error Flag Off Current	V_{FLAG} = 5V		0.01	**1**	µA

Note 1. Exceeding the absolute maximum rating may damage the device.

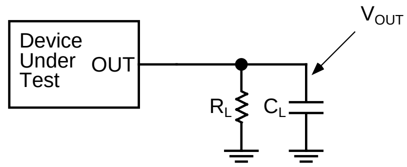
Note 2. The device is not guaranteed to function outside its operating rating.

Note 3. Devices are ESD sensitive. Handling precautions recommended. Human body model, 1.5kΩ in series with 100pF.

Note 4. Off is ≤ 0.8V and on is ≥ 2.4V for the MIC2536-1. Off is ≥ 2.4V and on is ≤ 0.8V for the MIC2536-2. The enable input has approximately 200mV of hysteresis.

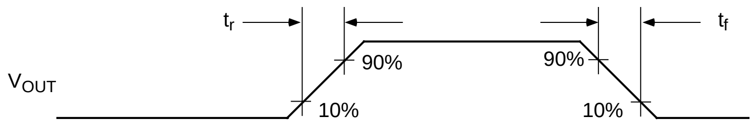
Note 5. Guaranteed by design. Not production tested.

Test Circuit

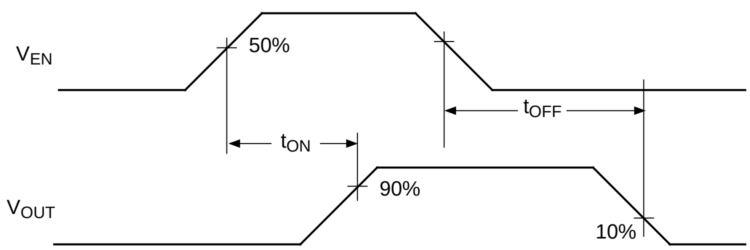


Functional Characteristics Test Circuit

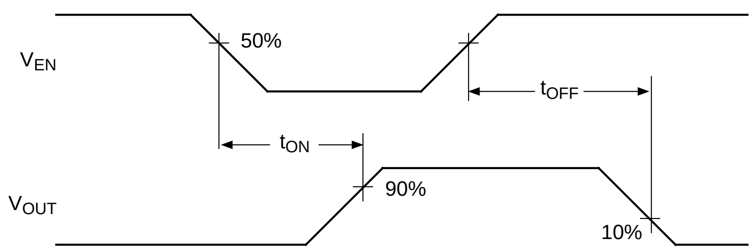
Timing Diagrams



Output Rise and Fall Times

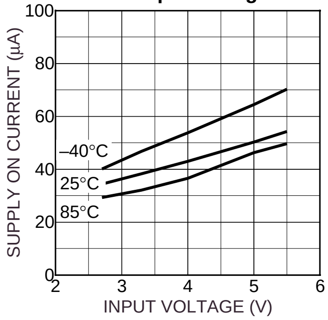


Active-High Switch Delay Times (MIC2536-1)

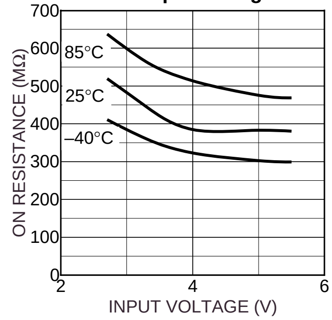


Active-Low Switch Delay Times (MIC2536-2)

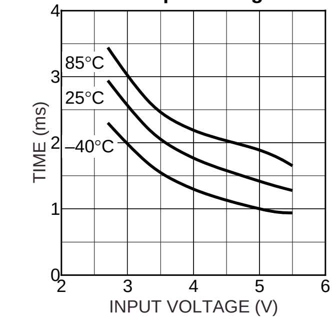
Supply On Current vs. Input Voltage



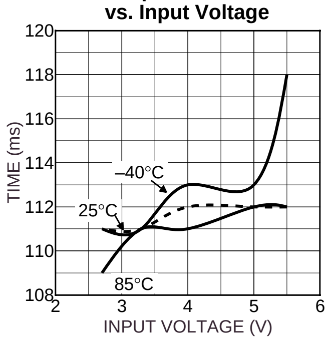
Output On-Resistance vs. Input Voltage



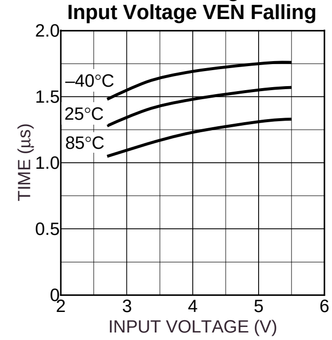
Output Rise Time vs. Input Voltage



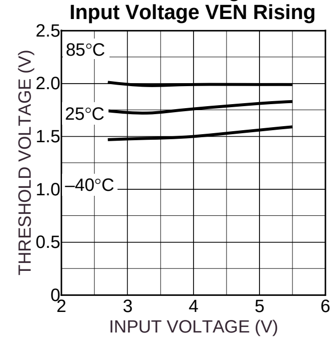
Output Fall Time vs. Input Voltage



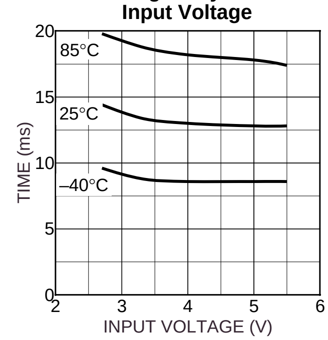
Control Voltage vs. Input Voltage VEN Falling



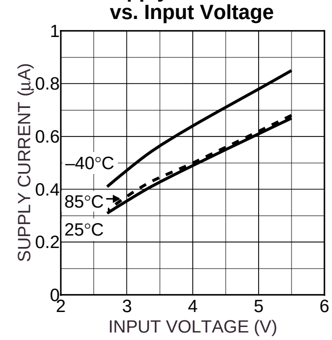
Control Voltage vs. Input Voltage VEN Rising



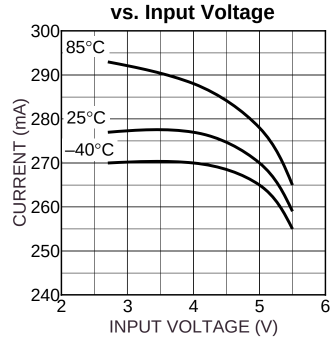
Flag Delay vs. Input Voltage



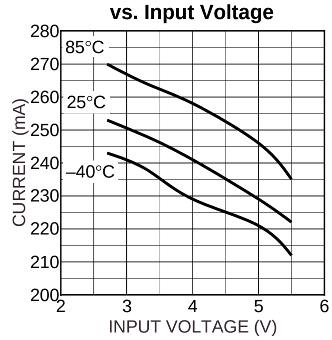
Supply Off Current vs. Input Voltage



Current Limit Threshold vs. Input Voltage

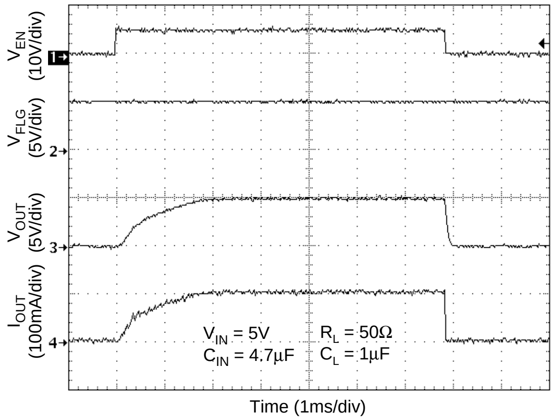


Short Circuit Current Limit vs. Input Voltage

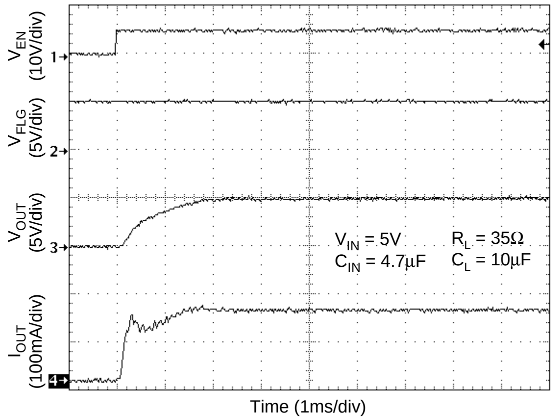


Functional Characteristics

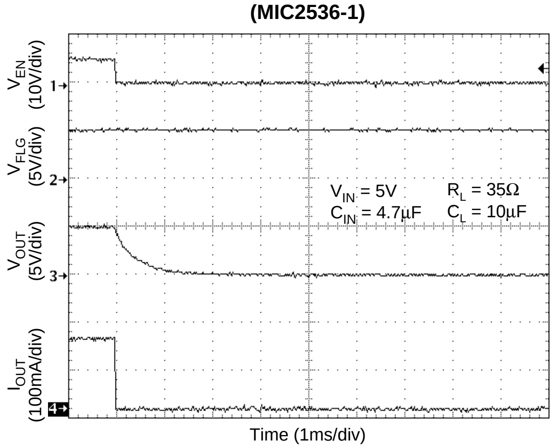
Turn-On / Turnoff (MIC2536-1)



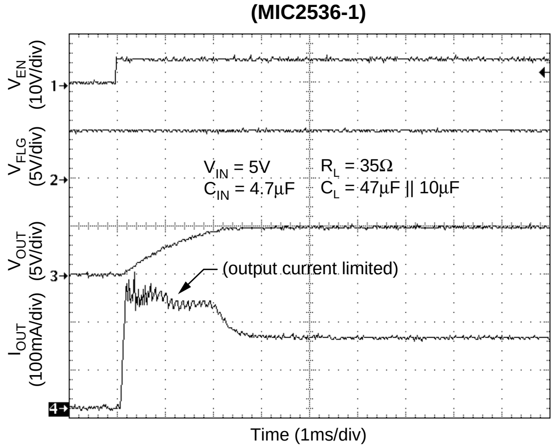
Turn-On (MIC2536-1)



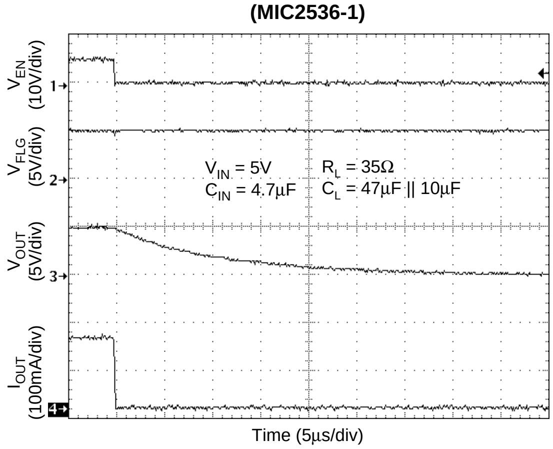
Turnoff (MIC2536-1)



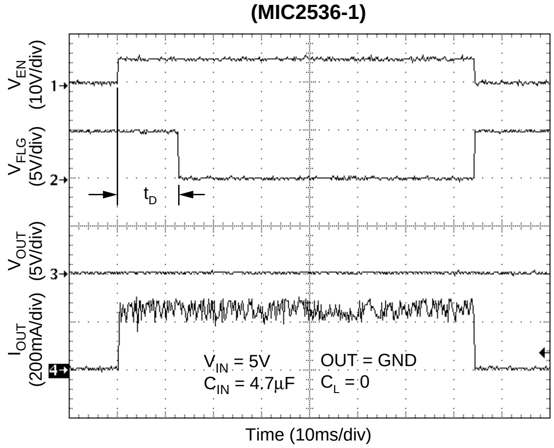
Turn-On (MIC2536-1)



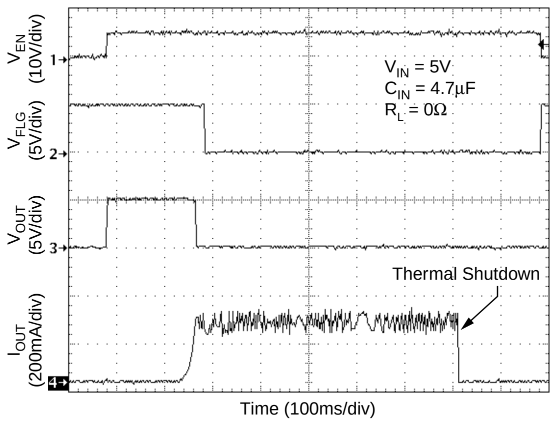
Turnoff (MIC2536-1)



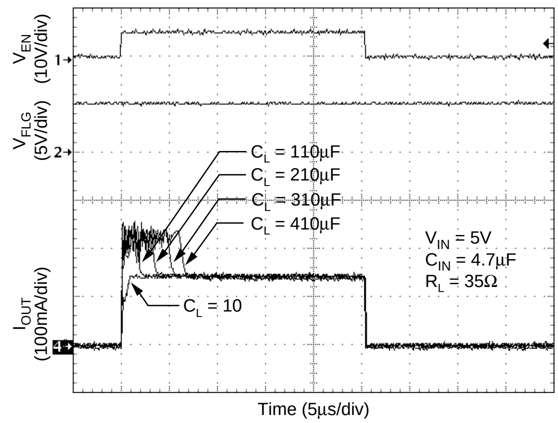
Enabled Into Short Circuit (MIC2536-1)



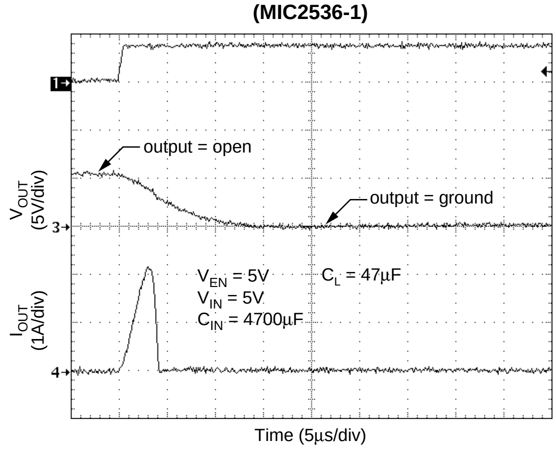
Ramped Into Short Circuit (MIC2536-1)



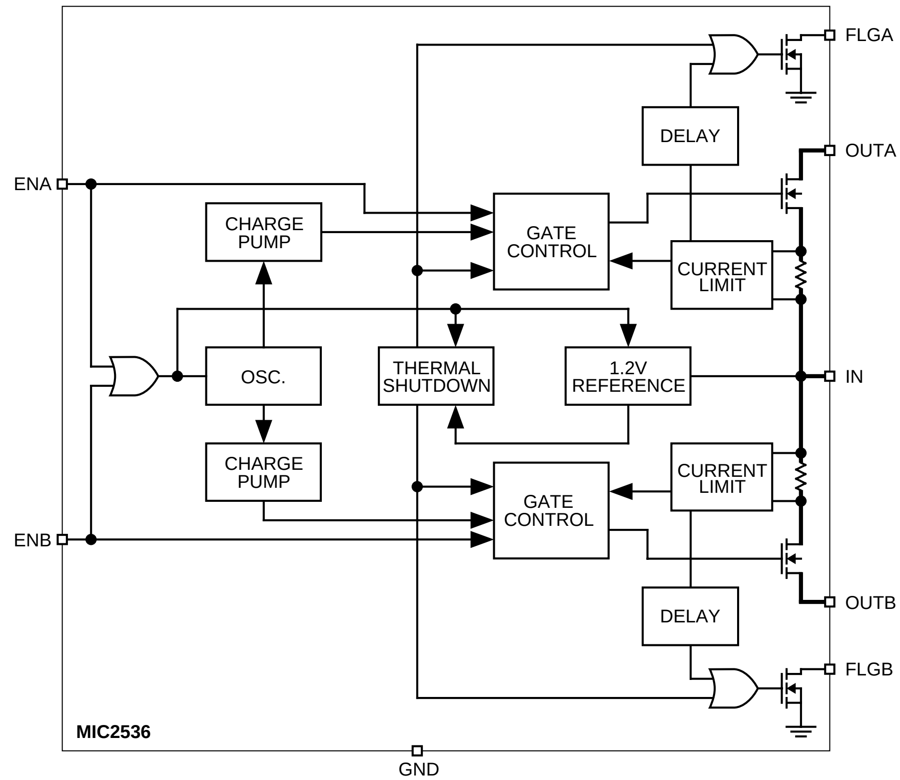
Inrush Current (MIC2536-1)



Current-Loop Response (MIC2536-1)



Block Diagram



Functional Description

The MIC2536-1 and MIC2536-2 are dual high-side switches with active-high and active-low enable inputs, respectively. Fault conditions turn off or inhibit turn-on of one or more of the output transistors, depending upon the type of fault, and activate the open-drain error flag transistors making them sink current to ground.

Input and Output

IN (input) is the power supply connection to the logic circuitry and the drain of each output MOSFET. OUTx (output) is the source of each respective MOSFET. In a typical circuit, current flows through the switch from IN to OUTx toward the load. If V_{OUT} is greater than V_{IN}, current will flow from OUT to IN during an on-condition since the MOSFET 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 ($V_{OUTx} > V_{IN}$) when the output is disabled. In this situation, the MIC2536 prevents reverse current flow.

Thermal Shutdown

Each output MOSFET has its own thermal sensor. If either or both channels reach 135°C, affected channel(s) will be shut down and flag(s) asserted. 10°C of hysteresis prevents the switches from turning on until the die temperature drops to 125°C. Overtemperature detection functions only when at least one switch is enabled.

The MIC2536 will automatically reset its output when the die temperature cools to approximately 125°C. The MIC2536 output and FLG signal will continue to cycle on and off until the device is disabled or the fault is removed.

Depending on PCB layout, package, ambient temperature, etc., it may take several hundred milliseconds from the occurrence of the fault to the output MOSFET being shut off. Delay to reach thermal shutdown will be shortest with a dead short on the output.

Current-Limit Induced Thermal Shutdown

Internal circuitry increases the output MOSFET on-resistance until the series combination of the MOSFET on-resistance and the load impedance limits output current to approximately 275mA. The resulting increase in power dissipation may cause the shorted channel to go into thermal shutdown. In addition, even though individual channels are thermally isolated, it is possible they may shut down when an adjacent channel is shorted. When this is undesirable, thermal shutdown can be avoided by externally responding to the fault and disabling the current-limited channel before the shutdown temperature is reached. The delay between the flag indication of a current-limit fault and thermal shutdown will vary with ambient temperature, board layout, and load impedance, but is typically several seconds. The USB controller must therefore recognize a fault and disable the appropriate channel within this time.

Power Dissipation

Power dissipation 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 die temperature are found below:

Calculation of power dissipated by each channel can be accomplished by the following equation:

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

Total power dissipation of the device will be the summation of P_D for both channels. 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

θ_{JA} = is the thermal resistance of the package

Current Sensing and Limiting

The current-limit threshold is preset internally. The preset level prevents damage to the output MOSFET and external load but allows a minimum current of 150mA through the output MOSFET of each channel.

The current-limit circuit senses a portion of the output FET switch current. The current sense resistor shown in the block diagram is virtual and has no voltage drop. The reaction to an overcurrent condition varies with the following three scenarios:

Switch Enabled into Short Circuit

If a switch is enabled into a heavy load or short circuit, the switch immediately goes into a constant-current mode, reducing the output voltage. The FLG is asserted indicating an overcurrent condition.

Short Circuit Applied to Output

When a heavy load or short circuit is applied to an enabled switch, a large transient current may flow until the current-limit circuitry responds. Once this occurs, the device limits current to less than the maximum short-circuit current-limit specification.

Current-Limit Response Ramped Load

The MIC2536 current-limit profile exhibits a small foldback effect of approximately 100mA. Once this current-limit threshold is exceeded the device enters constant-current mode. This constant current is specified as the short-circuit current-limit in the “Electrical Characteristics” table. It is important to note that the MIC2536 will deliver load current up to the current-limit threshold before entering current-limited operation.

Fault Flag

FLGx is an open-drain N-channel MOSFET output. Fault flags are active (low) for current-limit or thermal shutdown. In the case where an overcurrent condition occurs, FLG will be asserted only after the flag response delay time, t_D has elapsed. This ensures that FLG is asserted only upon valid overcurrent conditions and that erroneous error reporting is eliminated. False overcurrent conditions can occur during hot-plug events when a highly capacitive load is connected and causes a high transient inrush current that exceeds the current-limit threshold. The flag response delay time is typically 12ms.

Applications Information

Supply Filtering

A 0.1µF to 1µF bypass capacitor from IN to GND, located at the device, 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 or output transients must not exceed the absolute maximum supply voltage ($V_{IN(max)}$ = 6V) even for a short duration.

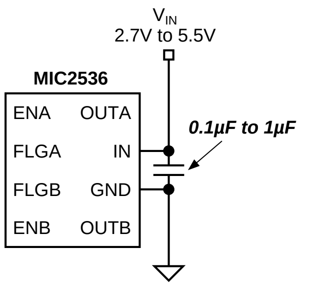


Figure 1. Supply Bypassing

Enable Input

EN must be driven logic high or logic 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.

Printed Circuit Board Hot-Plug

The MIC2536 is an ideal inrush current-limiter for hot-plug applications. Due to the integrated charge pump, the MIC2536 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. Figure 2 shows how the MIC2536 may be used in a hot-plug card application.

Overcurrent Transients

The MIC2536 incorporates an internal circuit designed to prevent FLG from being asserted due to transient inrush current. Overcurrent events <12ms (typ.) will not assert FLG.

In case of large capacitive loads (i.e., >430µF), the length of the transient due to inrush current may exceed the delay provided by the integrated filter. Since this inrush current exceeds the current-limit delay specification, FLG will be asserted during this time. To prevent the logic controller from responding to FLG being asserted, an external RC filter, as shown in Figure 3, can be used to filter out transient FLG assertion. The value of the RC time constant should be selected to match the length of the transient, minus flag t_D.

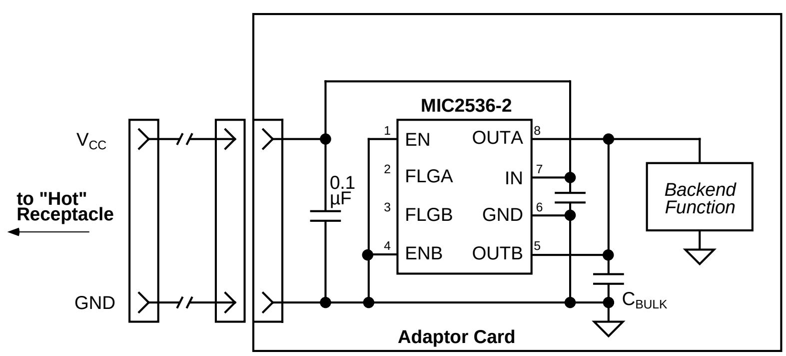


Figure 2. Hot-Plug Card Application

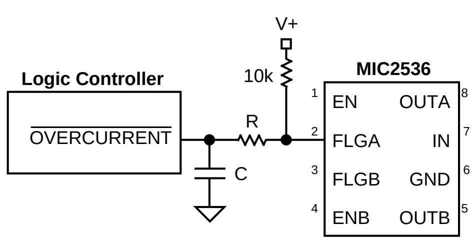


Figure 3. Transient Filter

Universal Serial Bus (USB) Power Distribution Applications

The MIC2536 is ideally suited for USB (Universal Serial Bus) power distribution applications. For Bus-Powered hubs, USB requires that each downstream port be switched on or off under control by the host. Up to four downstream ports each capable of supplying 100mA at 4.4V minimum are allowed. In additon, to reduce voltage droop on the upstream bus the hub must consume only 100mA max at start-up until it enumerates with the host prior to requesting more power. The same requirements apply for bus-powered peripherals that have no downstream ports. Figure 4 shows a two-port bus-powered hub.

Bus-Powered Hub Port Switching

The USB Specification requires that bus-powered hubs implement port switching on either a ganged or individual basis. The specific implementation must be reported via the Hub Descriptor Status Register. Individual port switching has advantages in that a fault on one port will not prevent the other ports from operating correctly. In addition, a soft-start circuit must be included in order to reduce inrush currents when the switch is enabled. To meet this requirement, the MIC2536 has been designed to slowly ramp its output.

Suspend Current

Universal Serial Bus Specification places a maximum suspend current requirement of 500µA on devices. For hubs, *Universal Serial Bus Specification Revision 1.1* clarifies this issue. Revision 1.1, section 7.2.3, stipulates that the maximum suspend current for a configured hub is 2.5mA. This number is derived by allocating 500µA for up to four downstream ports plus 500µA for the hub's internal functions. A nonconfigured hub is considered a low-power device and may not consume more than 500µA. In a nonconfigured state all downstream devices will be switched off. In most cases, a nonconfigured hub is not a practical state for the system. Therefore, the 2.5mA specification is the applicable target specification for the suspend state. In a bus-powered hub with less than 4 ports, the hub may use the additional current for internal functions.

The 500µA worst case suspend current must be further divided among the data port termination resistors and internal functions. The termination resistors will consume 3.6V ÷ (16.5KΩ – 5%) = 230µA. This leaves only 270µA for internal functions. Assuming 100µA as the maximum USB controller suspend current, 170µA remains for the rest of the system. The MIC2536 will consume 100µA maximum, leaving a margin of 70µA.

USB Voltage Regulation

USB specifications require a minimum downstream voltage supply of 4.40V from a bus-powered hub port (See *Application Note 17* for details). The USB specification allows for a 100mV drop across the hub, leaving 250mV for PCB, upstream cable, and connector resistance. Therefore, the on-resistance of the switch for each port, not including PCB resistance, must be <100mV ÷ 100mA = 1Ω. The MIC2536 has a maximum on-resistance of 700mΩ, which easily satisfies this requirement.

Overcurrent Indication

The USB Specification does not require bus-powered hubs to report overcurrent conditions to the host, since the hub is already current-limited at the upstream port. However, if it is desired to report overcurrent, the Hub Descriptor Status Register must be programmed to indicate this. The MIC2536 provides a flag output for this application.

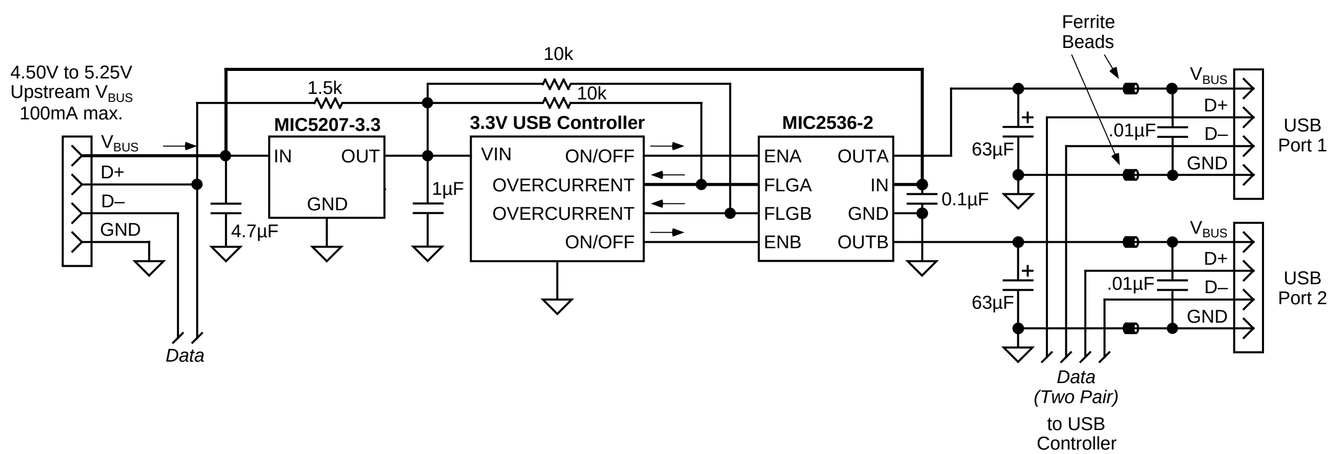
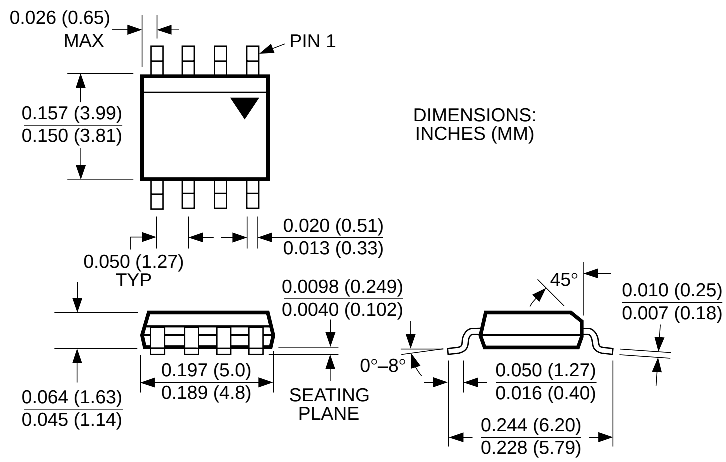
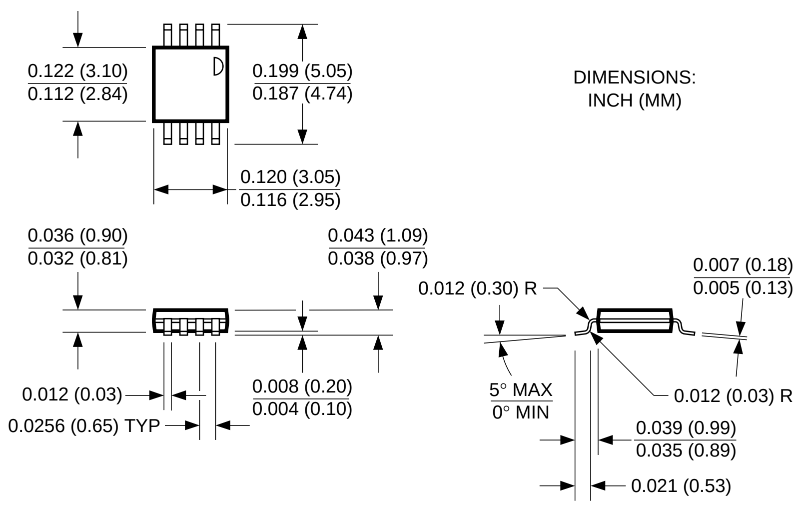


Figure 4. USB Two-Port Bus-Powered Hub

Package Information



8-Lead SOP (M)



8-Lead MSOP (MM)

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