

### POWER MANAGEMENT

#### Description

USB power distribution switches are high-side N-channel MOSFET switches with built-in overcurrent protection and low on-state resistance. The SC5826 switch is designed to meet the USB requirements for power switching and maintenance-free fault protection for self-powered and bus-powered hub applications.

The SC5826 features low on-state resistance to meet the USB requirement for voltage drop and regulation. The switch is controlled by an enable input that is compatible with 3V and 5V logic. The enable input is available with an active high (EN, SC5826-1) or active low (SHDN, SC5826-2) input for maximum design flexibility.

The device provides short circuit current limiting at a value of less than 1.5A, well below the USB limit of 5A. During an overcurrent condition the device provides a fault notification to signal the USB controller. An integrated thermal protection circuit automatically shuts the switches off when the junction temperature reaches its thermal limit. The switches remain off until the junction temperature drops approximately 5°C. The switches will continue to cycle on and off until the fault is removed.

Inrush current limiting prevents the voltage drop on an upstream port when the switches are enabled. An undervoltage lockout circuit guarantees the switches are initially off during start-up.

The SC5826 is available in the popular SO-8 surface mount package.

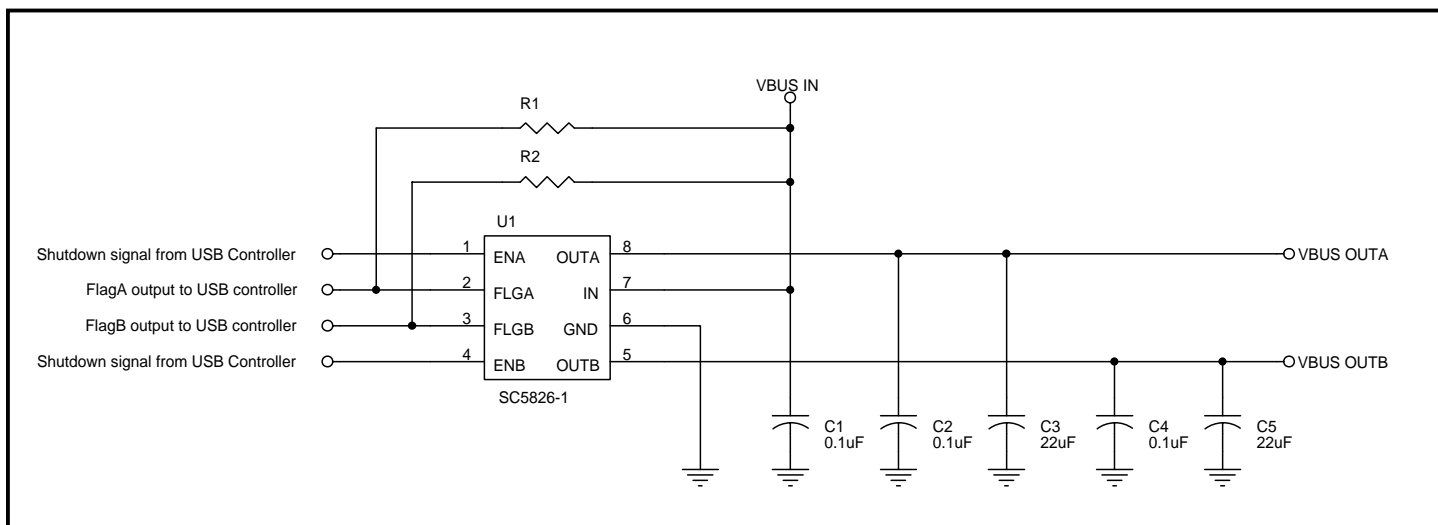
#### Features

- ◆ Designed to meet USB specification revisions 1.1 and 2.0 power management requirements
- ◆ UL recognized
- ◆ 500mA continuous load current
- ◆ High-side MOSFET switches with low  $R_{DS(ON)}$
- ◆ Short-circuit current protection
- ◆ Internal thermal shutdown
- ◆ Undervoltage lockout
- ◆ Open drain fault output
- ◆ Soft start circuit with slow turn-on time
- ◆ Wide supply voltage range: 2.8V to 5.5V
- ◆ Full industrial temperature range
- ◆ SO-8 surface mount package

#### Applications

- ◆ Universal Serial Bus (USB) power management
- ◆ Self-powered or bus-powered USB hubs
- ◆ Root hubs in desktop PCs and servers
- ◆ Notebook PCs
- ◆ Peripherals

#### Typical Application Circuit



**POWER MANAGEMENT**
**Absolute Maximum Ratings**

Parameter	Symbol	Maximum	Units
Input Voltage Range	$V_{IN}$	-0.3 to +7	V
Output Voltage Range	$V_{OUT}$	-0.3 to +7	V
Enable Input	$V_{EN}$	-0.3 to +7	V
Flag Output	$V_{FLG}$	-0.3 to ( $V_{IN} + 0.3$ )	V
Continuous Output Current	$I_{OUT}$	Internally Limited	mA
Thermal Impedance Junction to Ambient	$\theta_{JA}$	163	°C/W
Thermal Impedance Junction to Case	$\theta_{JC}$	39	°C/W
Operating Ambient Temperature Range	$T_A$	-40 to +85	°C
Operating Junction Temperature Range	$T_J$	-40 to +125	°C
Storage Temperature Range	$T_{STG}$	-65 to +150	°C
Lead Temperature (Soldering) 10 seconds	$T_L$	300	°C

**Electrical Characteristics<sup>(1)</sup>**

Unless specified:  $T_A = 25^\circ\text{C}$ ,  $V_{IN} = 5\text{V}$ ,  $V_{EN} = 5\text{V}$  (SC5826-1),  $V_{SHDN} = 0\text{V}$  (SC5826-2),  $I_{OUTA} = I_{OUTB} = 500\text{mA}$ . Values in **bold** apply over the full operating temperature range.

Parameter	Symbol	Conditions	Min	Typ	Max	Units
IN						
Supply Voltage Range	V <sub>IN</sub>		2.8		5.5	V
Supply Current	I <sub>Q</sub>	V <sub>IN</sub> = 3.3V		80	115	μA
					150	
		V <sub>IN</sub> = 5.0V		100	130	μA
					200	
		V <sub>IN</sub> = 5.5V, both outputs OFF <sup>(2)</sup>		0.02	10	μA
Power Switch						
On Resistance	r <sub>ON</sub>	V <sub>IN</sub> = 3.3V		110	150	mΩ
					200	
		V <sub>IN</sub> = 5.0V		100	140	mΩ
					190	
OUT						
Output Leakage Current	I <sub>L(OFF)</sub>	V <sub>IN</sub> = 5.5V, both outputs OFF <sup>(2)</sup> , V <sub>OUT</sub> = 0V		0.02	20	μA
Output Turn On Delay <sup>(3)</sup>	t <sub>d(ON)</sub>	R <sub>OUT</sub> = 10Ω, C <sub>OUT</sub> = 1μF		0.25		ms

## POWER MANAGEMENT

### Electrical Characteristics<sup>(1)</sup>

Unless specified:  $T_A = 25^\circ\text{C}$ ,  $V_{IN} = 5\text{V}$ ,  $V_{EN} = 5\text{V}$  (SC5826-1),  $V_{SHDN} = 0\text{V}$  (SC5826-2),  $I_{OUTA} = I_{OUTB} = 500\text{mA}$ . Values in **bold** apply over the full operating temperature range.

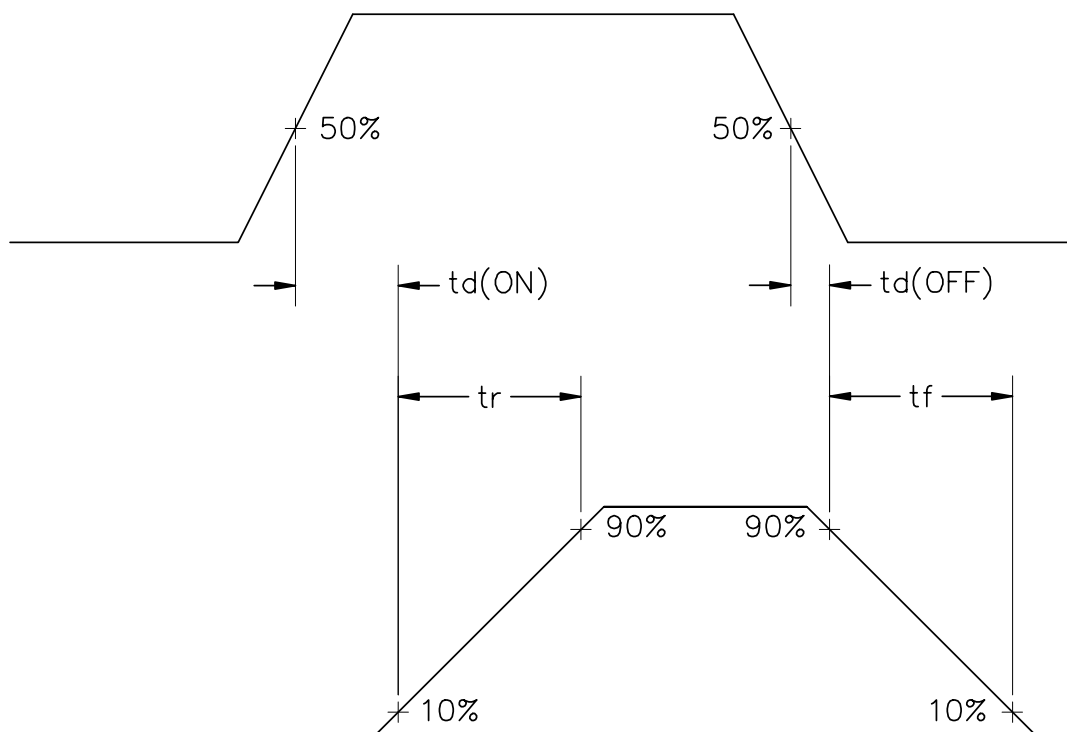
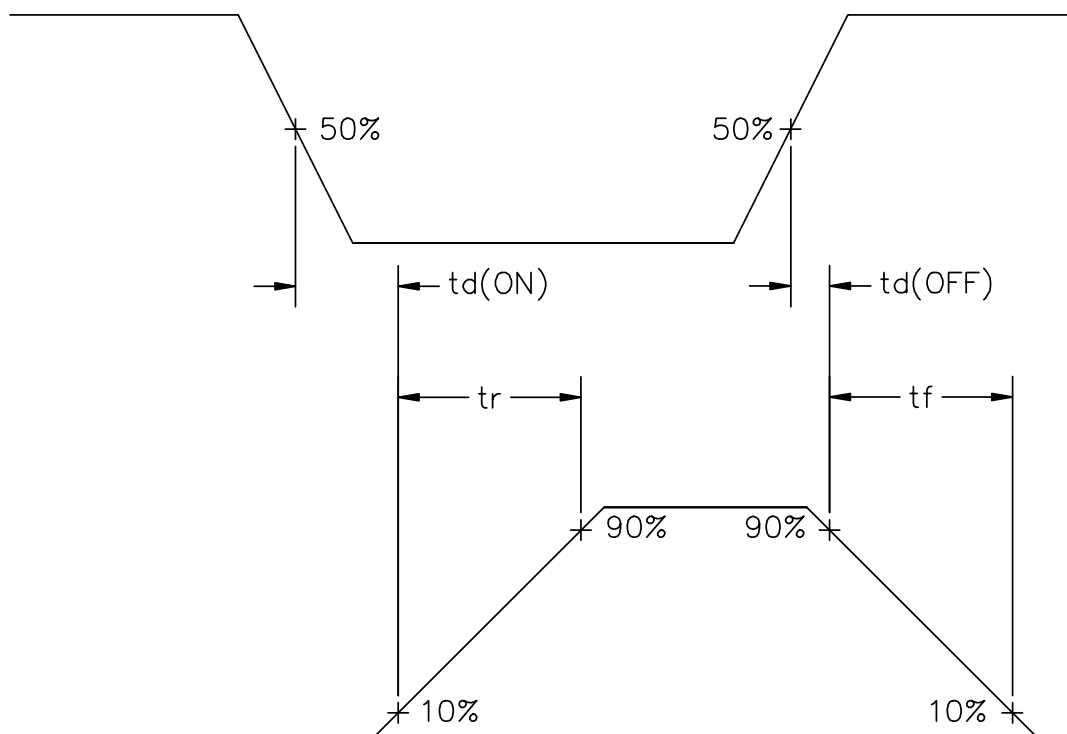
Parameter	Symbol	Conditions	Min	Typ	Max	Units
<b>OUT (Cont.)</b>						
Output Turn On Rise Time <sup>(3)</sup>	$t_r$	$R_{OUT} = 10\Omega$ , $C_{OUT} = 1\mu\text{F}$		0.55		ms
Output Turn Off Delay <sup>(3)</sup>	$t_{d(OFF)}$	$R_{OUT} = 10\Omega$ , $C_{OUT} = 1\mu\text{F}$		35		$\mu\text{s}$
Output Turn Off Fall Time <sup>(3)</sup>	$t_f$	$R_{OUT} = 10\Omega$ , $C_{OUT} = 1\mu\text{F}$		0.1		ms
<b>Current Limit</b>						
Short Circuit Current Limit	$I_{CL}$	$V_{OUT} = 0\text{V}$	<b>0.50</b>	0.85	<b>1.50</b>	A
Current Limit Trip Threshold	$I_{TH(CL)}$			1.5		A
<b>EN/SHDN</b>						
High Level Input Voltage	$V_{IH}$	$2.8\text{V} \leq V_{IN} \leq 5.5\text{V}$	<b>2.4</b>			V
Low Level Input Voltage	$V_{IL}$	$2.8\text{V} \leq V_{IN} \leq 5.5\text{V}$			<b>0.8</b>	V
Input Current	$I_{EN}, I_{SHDN}$	$V_{IN} = 5.5\text{V}$ , $V_{OUT} = \text{OPEN}$ , $0\text{V} \leq (V_{EN} \text{ or } V_{SHDN}) \leq V_{IN}$	<b>-1</b>		<b>1</b>	$\mu\text{A}$
<b>Undervoltage Lockout</b>						
UVLO Threshold	$V_{UVLO}$	$V_{IN}$ rising	<b>2.3</b>	2.5	<b>2.7</b>	V
UVLO Hysteresis	$V_{HYST}$	$V_{IN}$ falling		125		mV
<b>FLG</b>						
Output Resistance	$r_{FLG}$	$I_{FLG} = 10\text{mA}$ , $V_{OUT} = 0\text{V}$			<b>50</b>	$\Omega$
Leakage Current (OFF) <sup>(2)</sup>	$I_{FLG}$	$V_{FLG} = 5.0\text{V}$ , both outputs OFF			<b>1</b>	$\mu\text{A}$
<b>Over Temperature Protection</b>						
High Trip Level	$T_{HI}$			160		$^\circ\text{C}$
Hysteresis	$T_{HYST}$			5		$^\circ\text{C}$

#### Notes:

(1) This device is ESD sensitive. Use of standard ESD handling precautions is required.

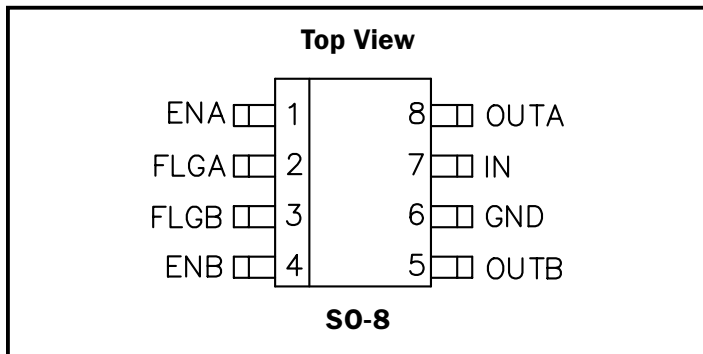
(2) Both outputs are OFF when  $V_{EN} = 0\text{V}$  (SC5826-1) or  $V_{SHDN} = V_{IN}$  (SC5826-2).

(3) See Timing Diagrams on page 4.

**POWER MANAGEMENT**
**Timing Diagrams**
 $V_{EN}$ 

**SC5826-1**
 $V_{OUT}$ 
 $V_{SHDN}$ 

**SC5826-2**
 $V_{OUT}$

## POWER MANAGEMENT

### Pin Configuration



#### Note for Pin Configuration and Block Diagram:

(1) SC5826-1 shown. For SC5826-2, pins 1 and 4 are SHDNA and SHDNB.

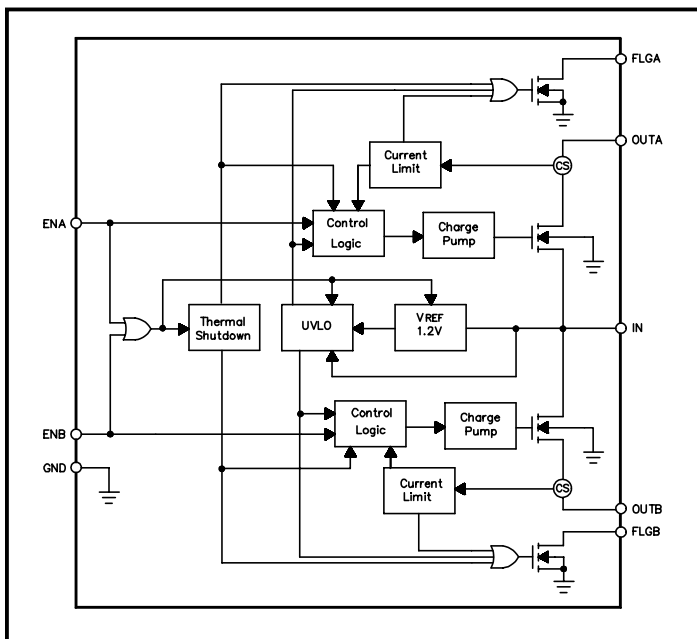
### Ordering Information

Device <sup>(1)</sup>	Enable/Shutdown	Package
SC5826-1CS.TR	Enable (Active High)	SO-8
SC5826-2CS.TR	Shutdown (Active Low)	SO-8

#### Note:

(1) Only available in tape and reel packaging. A reel contains 2500 devices.

### Block Diagram

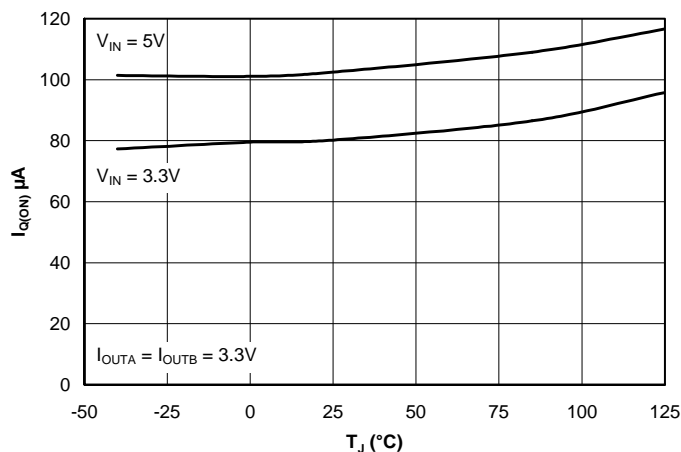


### Pin Descriptions

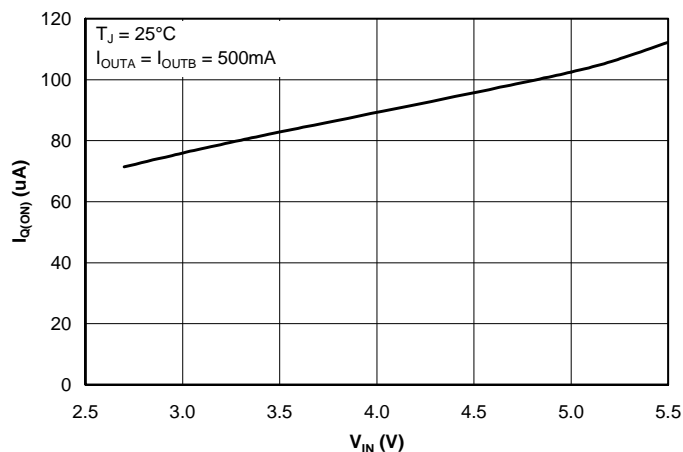
Pin	Pin Name	Pin Function
1, 4	ENA/B (SC5826-1) SHDNA/B (SC5826-2)	Enable inputs: TTL compatible. OUTA/B N-channel power MOSFETs are turned on when these pins are pulled high. Shutdown inputs: TTL compatible. OUTA/B N-channel power MOSFETs are turned on when these pins are pulled low.
2, 3	FLGA/B	Error flag outputs: FLG is asserted active low during a fault condition (overcurrent, input undervoltage or thermal shutdown).
6	GND	Ground.
7	IN	Input voltage: drain of N-channel power MOSFETs. Connect to supply voltage.
5, 8	OUTA/B	Power switch output: source of N-channel power MOSFETs. Connect to load.

**POWER MANAGEMENT**
**Typical Characteristics**

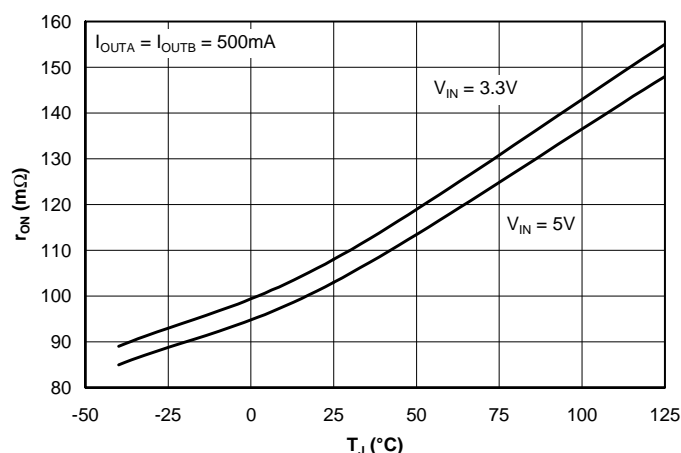
**On-State Quiescent Current vs. Junction Temperature vs. Input Voltage**



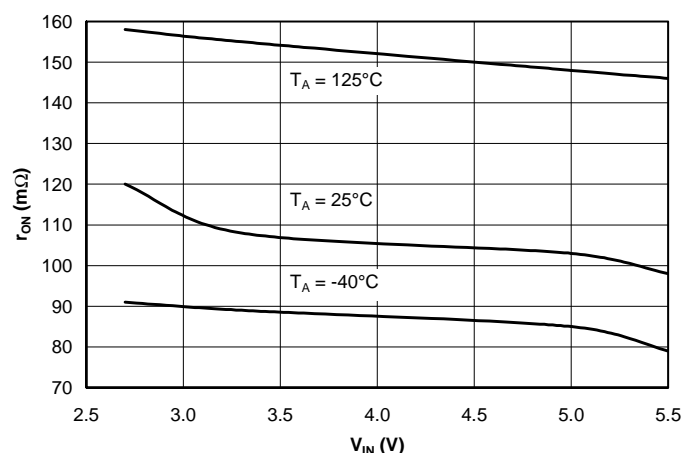
**On-State Quiescent Current vs. Input Voltage**



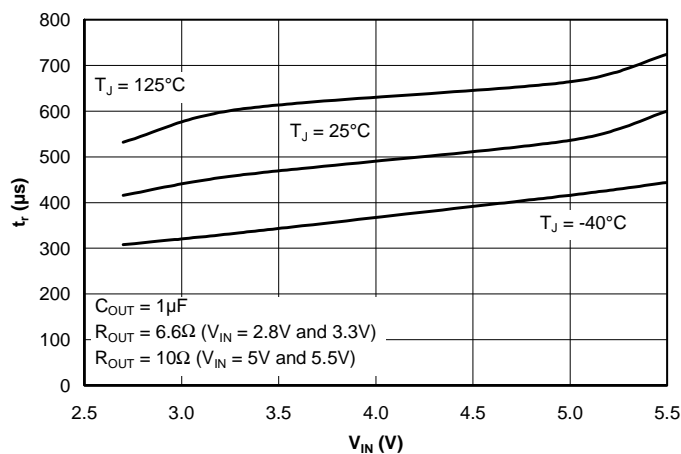
**Power Switch On Resistance vs. Junction Temperature vs. Input Voltage**



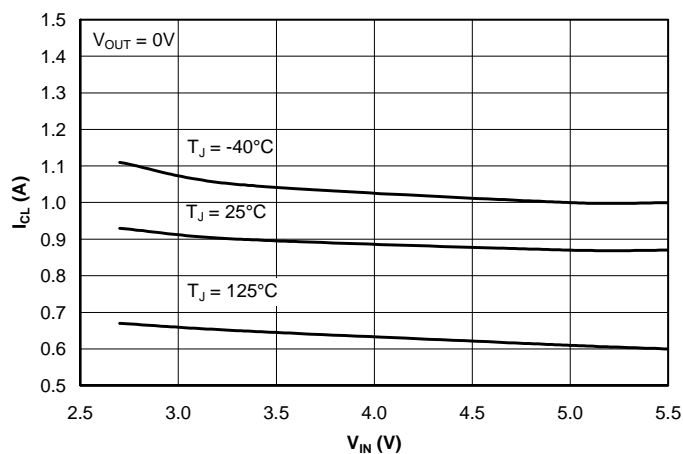
**Power Switch On Resistance vs. Input Voltage vs. Junction Temperature**

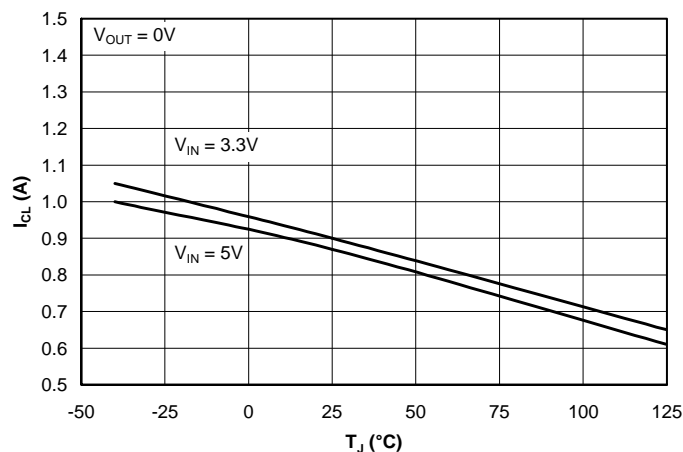
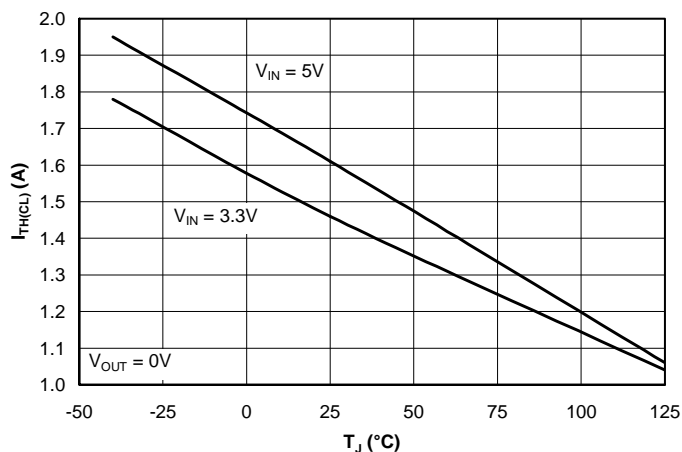
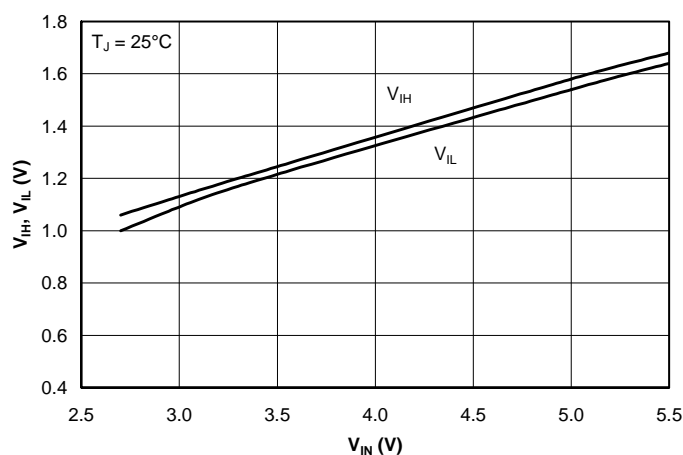
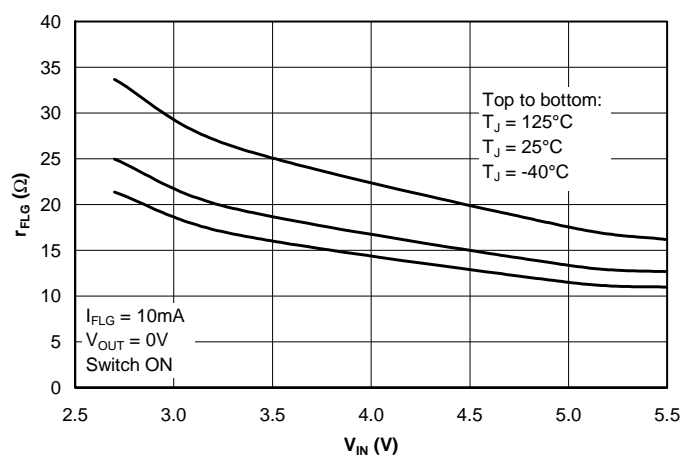
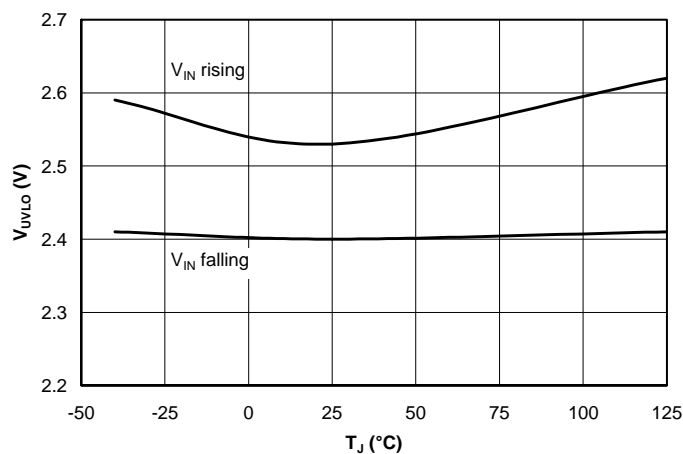


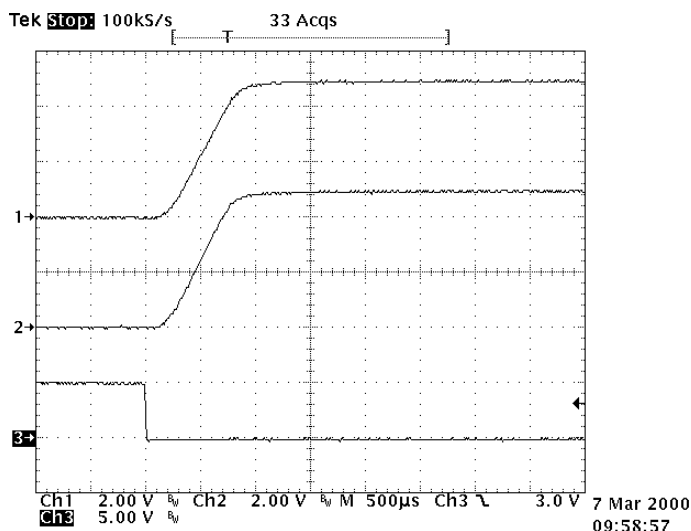
**Output Turn-On Rise Time vs. Input Voltage vs. Junction Temperature**



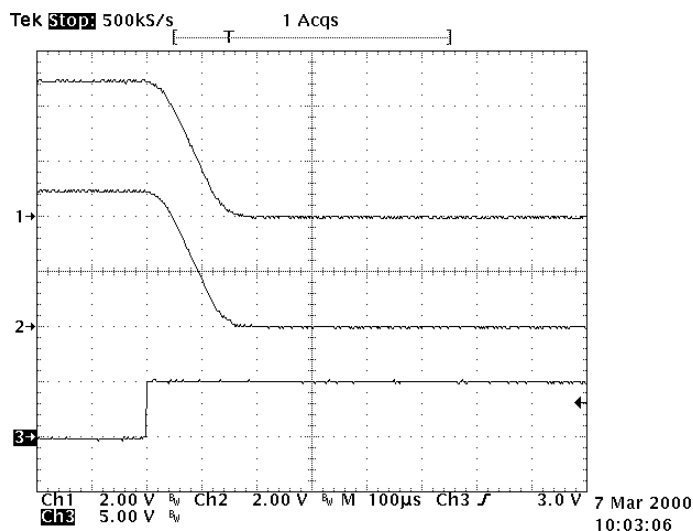
**Short Circuit Current Limit vs. Input Voltage vs. Junction Temperature**



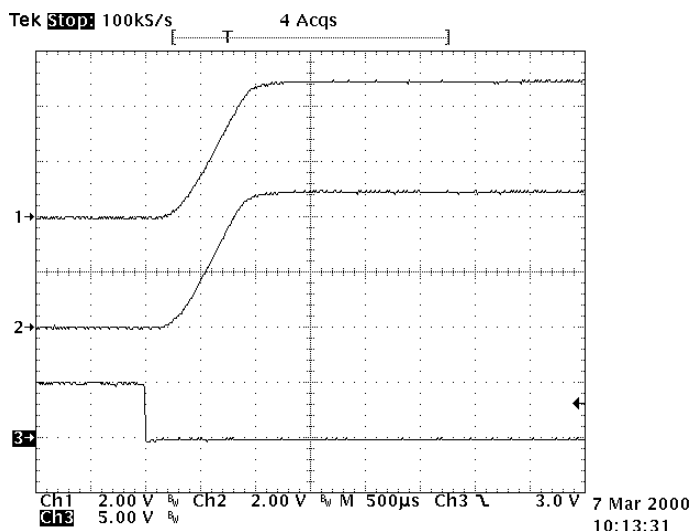
**POWER MANAGEMENT**
**Typical Characteristics (Cont.)**
**Short Circuit Current Limit vs. Junction**
**Temperature vs. Input Voltage**

**Current Limit Trip Threshold vs. Junction**
**Temperature vs. Input Voltage**

**Enable/Shutdown Threshold**
**vs. Input Voltage**

**Error Flag Output Resistance vs. Input**
**Voltage vs. Junction Temperature**

**Undervoltage Lockout vs.**
**Junction Temperature**


**POWER MANAGEMENT**
**Typical Characteristics (Cont.)**
**Figure 1: Output Turn On Delay and Rise Time with 1 $\mu$ F Output Capacitor and 10 $\Omega$  Load**


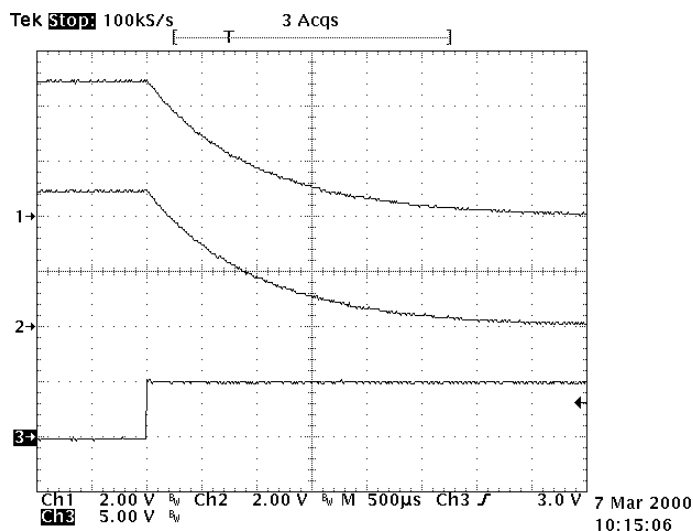
Trace 1:  $V_{OUTA}$  2V/div.  
 Trace 2:  $V_{OUTB}$  2V/div.  
 Trace 3:  $V_{SHDNA/B}$  5V/div.  
 Timebase: 500 $\mu$ s/div.  
 SC5826-2 shown.

**Figure 2: Output Turn Off Delay and Fall Time with 1 $\mu$ F Output Capacitor and 10 $\Omega$  Load**


Trace 1:  $V_{OUTA}$  2V/div.  
 Trace 2:  $V_{OUTB}$  2V/div.  
 Trace 3:  $V_{SHDNA/B}$  5V/div.  
 Timebase: 100 $\mu$ s/div.  
 SC5826-2 shown.

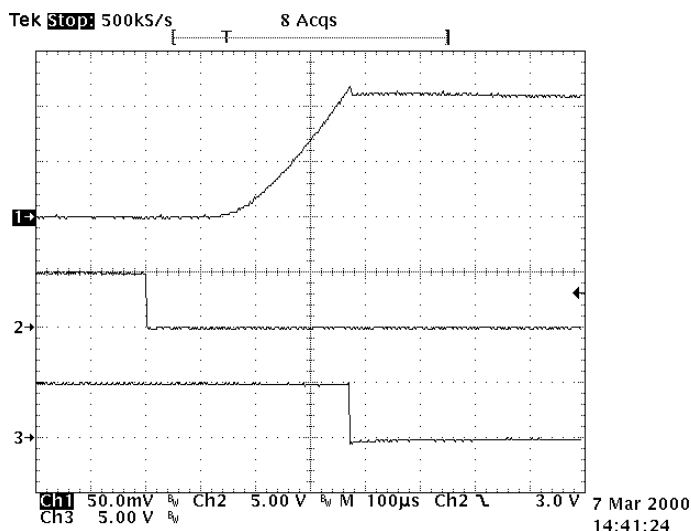
**Figure 3: Output Turn On Delay and Rise Time with 100 $\mu$ F Output Capacitor and 10 $\Omega$  Load**


Trace 1:  $V_{OUTA}$  2V/div.  
 Trace 2:  $V_{OUTB}$  2V/div.  
 Trace 3:  $V_{SHDNA/B}$  5V/div.  
 Timebase: 500 $\mu$ s/div.  
 SC5826-2 shown.

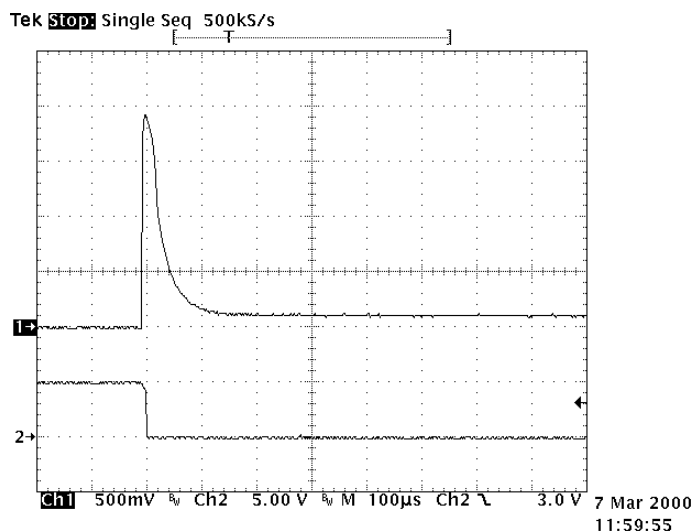
**Figure 4: Output Turn Off Delay and Fall Time with 100 $\mu$ F Output Capacitor and 10 $\Omega$  Load**


Trace 1:  $V_{OUTA}$  2V/div.  
 Trace 2:  $V_{OUTB}$  2V/div.  
 Trace 3:  $V_{SHDNA/B}$  5V/div.  
 Timebase: 500 $\mu$ s/div.  
 SC5826-2 shown.

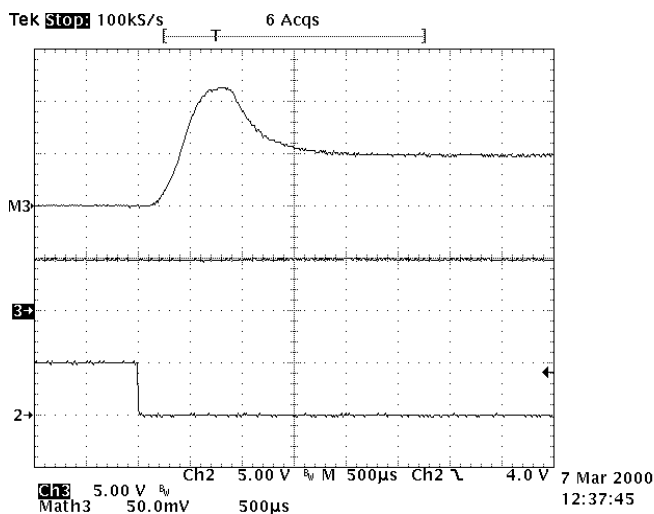


**POWER MANAGEMENT**
**Typical Characteristics (Cont.)**
**Figure 5: Short Circuit Current, Output Enabled Into Short**


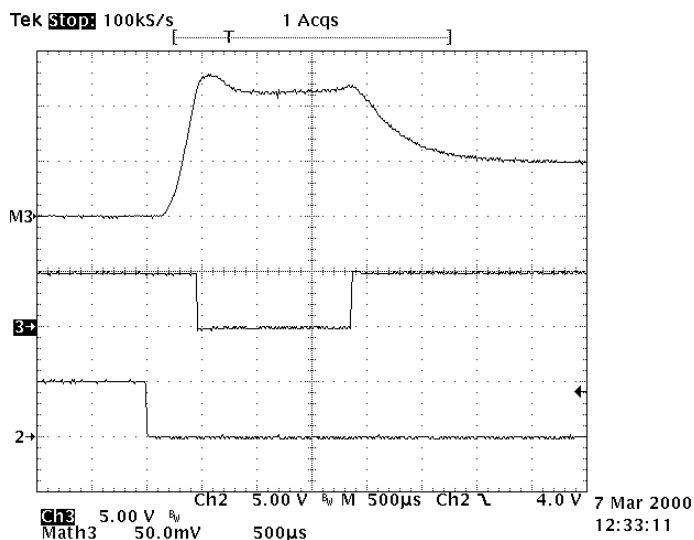
Trace 1:  $I_{OUTA/B}$ , 0.5A/div.  
 Trace 2:  $V_{SHDNA/B}$ , 5V/div.  
 Trace 3:  $V_{FLGA/B}$ , 5V/div.  
 Timebase: 100µs/div.  
 SC5826-2 shown.

**Figure 6: Short Circuit Current, Short Applied to Enabled Device ( $C_{OUT} = 100\mu F$ )**


Trace 1:  $I_{OUTA/B}$ , 5A/div.  
 Trace 2:  $V_{SHDNA/B}$ , 5V/div.  
 Timebase: 100µs/div.  
 Note: initial peak current supplied by output capacitor.  
 SC5826-2 shown.

**Figure 7: Inrush Current, Device Enabled Into 100µF Output Capacitor and 10Ω Load**


Trace M3:  $I_{OUTA/B}$ , 0.5A/div.  
 Trace 3:  $V_{FLGA/B}$ , 5V/div.  
 Trace 2:  $V_{SHDNA/B}$ , 5V/div.  
 Timebase: 500µs/div.  
 SC5826-2 shown.

**Figure 8: Inrush Current, Device Enabled Into 330µF Output Capacitor and 10Ω Load**


Trace M3:  $I_{OUTA/B}$ , 0.5A/div.  
 Trace 3:  $V_{FLGA/B}$ , 5V/div.  
 Trace 2:  $V_{SHDNA/B}$ , 5V/div.  
 Timebase: 500µs/div.  
 SC5826-2 shown.

## POWER MANAGEMENT

### Applications Information

#### Theory Of Operation

The SC5826 contains dual current limited 100mΩ power switches with error reporting and enable features. The power switches are N-channel MOSFETs with their gates driven by an internal charge pump. The switches have been designed to turn on slowly (0.55ms typical) to minimize inrush currents at turn-on.

The Shutdown pins (SHDNA/B for SC5826-2) are compatible with 3V or 5V logic, and when pulled high, shut off the related power switches. When both are shut down, the device enters a very low power shutdown mode, where it will draw less than 10μA from the supply. While enabled, the SC5826 draws only 100μA from the supply. The SC5826-1 has active high Enable pins for each output (ENA/B).

The power switches have current limit detection circuitry which will limit the current through the switch to 0.85A (typical) and reduce the output voltage accordingly. When current limit is entered, the open drain Flag pin (FLGA/B) is asserted low, indicating a fault condition. If an overcurrent or short condition is continuous, the power dissipation in the switch will cause the junction

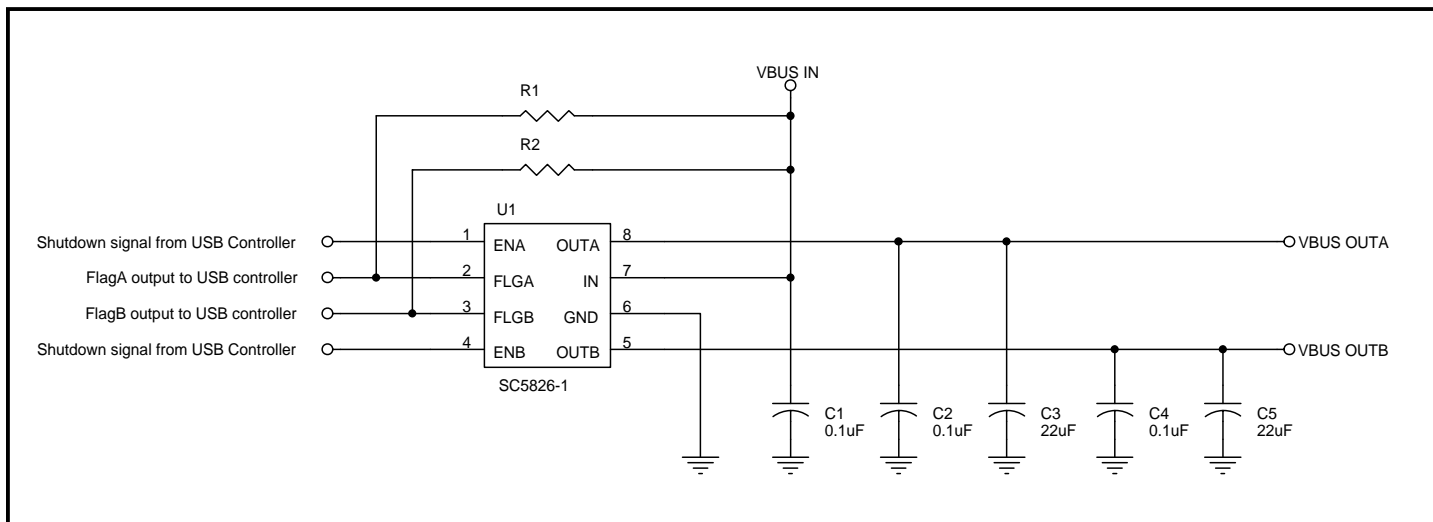
2.8V, and internal undervoltage lockout circuitry ensures that the power switches will be turned off at power-up, even if the device is enabled. Once the UVLO threshold voltage (2.5V typical) is reached, the switches will turn on (if enabled) and slowly ramp up the outputs.

The SC5826 has been designed for use in USB applications such as:

- 1) **hosts or self-powered hubs** that need to current limit downstream ports and report overcurrent conditions;
- 2) **bus powered hubs** that need to be able to switch power to downstream ports, limit inrush currents at power-up (to less than a 44Ω resistor in parallel with a 10μF capacitor) and power-up and draw less than 100mA;
- 3) **bus powered functions** that need to limit inrush currents at power-up (to less than a 44Ω resistor in parallel with a 10μF capacitor) and power-up and draw less than 100mA.

#### Component Selection - General

A 0.1μF or greater ceramic bypass capacitor is recommended at the device input. This should be placed close to the input pin (IN) and routed directly to ground. A low ESR electrolytic capacitor is recommended at each



temperature to rise, triggering the thermal protection circuitry to shut the switch down (at  $T_j = 160^\circ\text{C}$  typical). This will shut off the output current altogether, and also cause the Flag pin to be asserted low. Once the junction temperature has dropped by  $5^\circ\text{C}$  (typical), the device will start up once more in a controlled manner.

output, higher values should be used for heavy loads to reduce ringing at the output (and hence input). Bypass the output with a 0.1μF to 1μF ceramic capacitor to improve immunity to short circuit transients.

#### Enable/Shutdown

The SC5826 will operate from supply voltages as low as

The shutdown pins (SHDN) are active-low (enable pins

## POWER MANAGEMENT

### Applications Information (Cont.)

are active high) and compatible with 3V or 5V logic. Pulling the shutdown pins high shuts down the power switches and the SC5826 will draw < 10μA from the supply. Pulling these pins low will enable the device. For the enable pins the device will be shutdown if pulled low.

#### Error Flags

The error flag (FLG) outputs are open drain N-channel MOSFETs. Each output is pulled low during overcurrent, input undervoltage and thermal shutdown conditions. Connection of high capacitance loads to the output can cause momentary overcurrent conditions due to inrush current and trigger false error flag assertion. This can be reduced by using low ESR output capacitors to provide a low impedance source for hot-plug events. The addition of an RC filter between FLG and the USB controller can resolve this easily. These pins also require a pull-up resistor for a high signal when not asserted.

#### Overcurrent

There are three overcurrent situations to be considered:

1) the output is already short before the device is enabled or power is applied. In this case, the SC5826 immediately detects the short, and the output current will slowly ramp up to the current limit value, and FLG will assert low. Refer to Figure 5 on Page 9.

2) a short occurs while the device is enabled. In this case, very high current may flow initially while the overcurrent circuitry reacts. Once the current limit circuitry trips, the current is limited to 0.85A (typ.) and FLG is asserted low. Refer to Figure 6 on Page 9.

3) the load gradually increases beyond 500mA. In this case, the current will be allowed to rise until it reaches the Current Limit Trip Threshold, at which point the current will drop back to 0.85A and FLG will assert low.

#### Thermal Sensing

An internal thermal shutdown circuit turns off the power switch when the die temperature exceeds 160°C (typical). The FLG pin asserts low signaling a fault condition. Built-in hysteresis prevents the switch from turning back on until the die temperature has cooled approximately 5°C. The switch will continue to cycle on

and off until the fault condition is removed. The thermal sense circuit functions only when the switches are enabled.

#### Undervoltage Lockout

An undervoltage lockout circuit monitors the input voltage and prevents the power switches from turning on until the input voltage (IN) exceeds 2.5V (typical). If the input voltage falls and drops below 2.375V (typical), the undervoltage circuitry turns off the power switches and the FLG pins assert low. The undervoltage lockout functions only when the switches are enabled.

#### Thermal Considerations

Since the on-resistance of the power switch is so low, the SC5826 can pass large currents without requiring a large package to dissipate the heat. The worst-case power dissipation (under normal operating conditions) is given by:

$$P_{D(MAX)} = (I_{OUTA})^2 \cdot r_{ON(A)(MAX)} + (I_{OUTB})^2 \cdot r_{ON(B)(MAX)}$$

So for  $I_{OUTA} = I_{OUTB} = 500\text{mA}$  and  $r_{ON(MAX)} = 200\text{m}\Omega$  (at  $V_{IN} = 3.3\text{V}$ ), the maximum power dissipation is:

$$P_{D(MAX)} = 2 \cdot (0.5)^2 \cdot 0.2 = 100\text{mW}$$

The junction temperature can be calculated using the following equation:

$$T_J = T_A + \theta_{JA} \cdot P_{D(MAX)}$$

Inserting  $T_A = 85^\circ\text{C}$ ,  $\theta_{JA} = 163^\circ\text{C/W}$  (package thermal impedance for minimum line widths and no internal power planes) and  $P_{D(MAX)} = 100\text{mW}$ , we calculate the worst-case  $T_J$  to be:

$$T_J = 85 + 163 \cdot 0.1 = 101^\circ\text{C}$$

Thus it can be seen that this device does not require any additional copper area for heatsinking under normal operating conditions. Sustained overcurrents or short circuits will rapidly heat  $T_J > 160^\circ\text{C}$ , thus activating the thermal shutdown circuitry.

**POWER MANAGEMENT****Applications Information (Cont.)****Layout Considerations**

The ceramic bypass capacitors for IN and OUT should be connected as close to the relevant device pins as possible.

The bulk output capacitors required by the USB specification should be placed close to the USB connector to provide a low impedance source for hot plug purposes.

Ferrite beads should be placed on the  $V_{BUS}$  and Ground pins of the downstream connectors to reduce the droop on adjacent ports during hot plug events.

## POWER MANAGEMENT

## Typical Applications Circuits

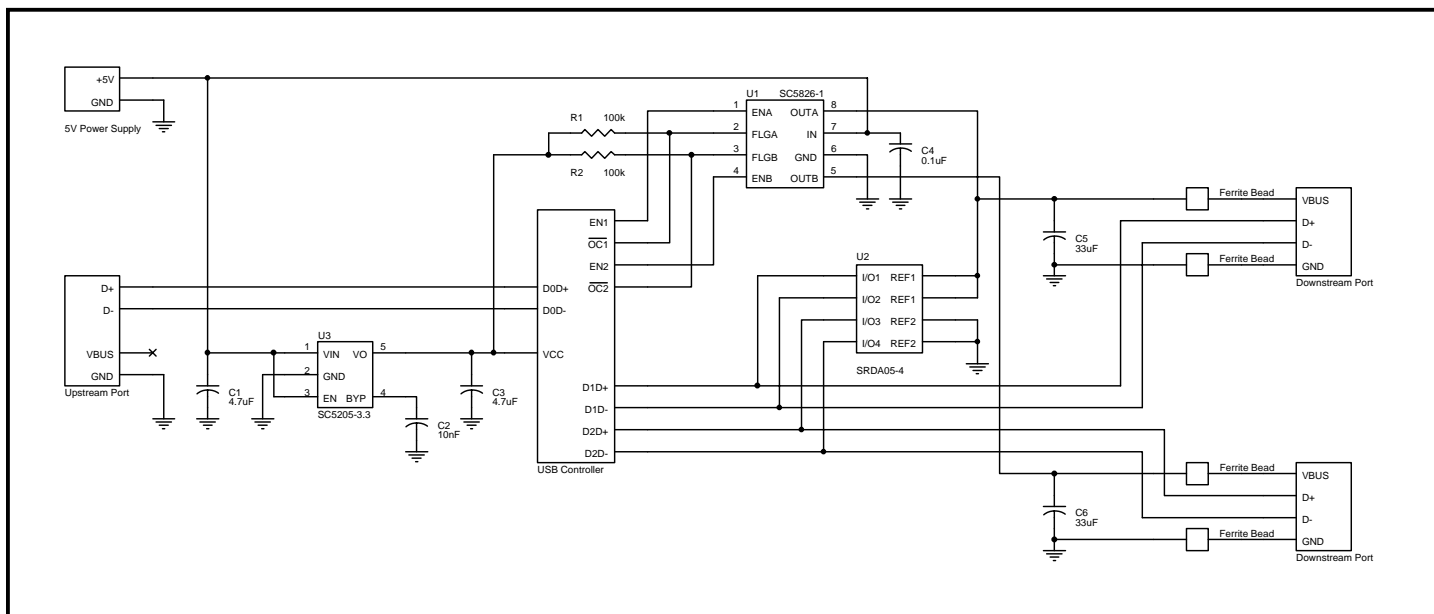
## Self-Powered Hub, Individual Port Power Management

A self-powered hub must supply a continuous 500mA of current to each downstream port. Since an internal power supply is used to supply the power, self-powered hubs are required to implement overcurrent protection for safety. The self-powered hub must also have a method to detect and report fault conditions to the USB controller. The circuit in Figure 9 below utilizes the SC5826 to provide individual port overcurrent protection & power switching for maximum port protection.

Under fault conditions, the SC5826 provides the short-circuit current limiting function and has a fault flag logic output for notifying the hub controller. The USB hub

can use the SC5826 to remove power from the faulty port, allowing the other ports to operate normally. Each SC5826 can control the power to two ports.

Since USB is a hot insertion and removal system, USB ports are subject to electrostatic discharge (ESD). The SRDA05-4 provides ESD protection on the downstream data and power lines. Each device will protect two USB ports. With proper layout the port is hardened to greater than 15kV, meeting the requirements of IEC 1000-4-2. The SC5205 LDO regulator is used to power the hub controller from the hub's 5V power supply.



### Figure 9: Self-Powered Hub

**Notes:**

- (1) Two ports only shown for simplicity.
- (2) 33 $\mu$ F output capacitor assumes four downstream ports for this hub, therefore meeting the USB specification requirement of 120 $\mu$ F minimum capacitance per hub.

## POWER MANAGEMENT

## Typical Applications Circuits (Cont.)

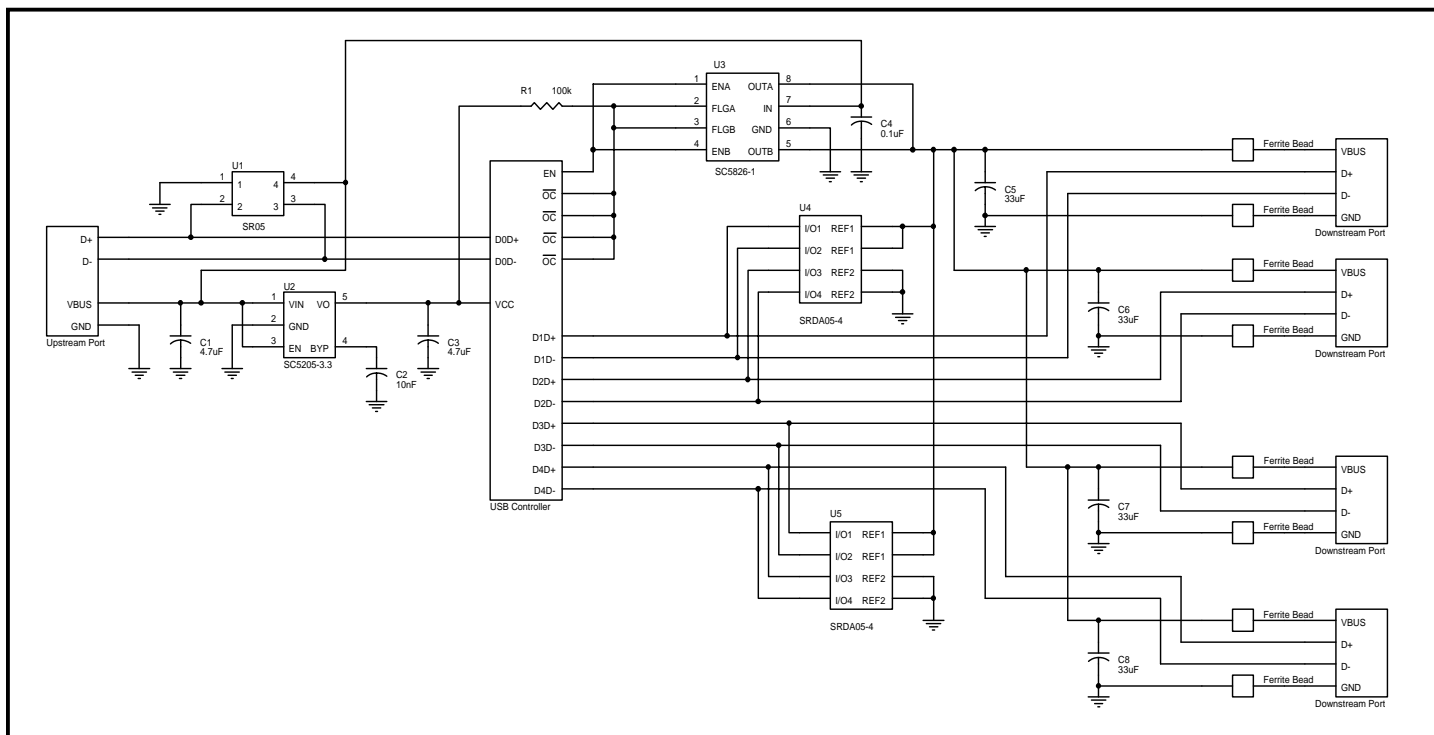
## Bus Powered Hub, Ganged-Port Power Management

A bus-powered hub distributes power and data from an input port to downstream ports. It must supply a continuous 100mA of current to each downstream port. A bus-powered hub must be able to switch power to downstream ports to prevent illegal device hook-up. Inrush current limiting is also required to prevent power supply drooping. The circuit in Figure 10 below utilizes the SC5826 to provide ganged port power switching, inrush current limiting and overcurrent protection for maximum port protection. In a ganged switch configuration, all ports are switched simultaneously.

Under fault conditions, the USB controller will remove

power to all of the ganged ports. For individual port management, one extra SC5826 may be used.

Since USB is a hot insertion and removal system, USB ports are subject to electrostatic discharge (ESD). The SRDA05-4 provides ESD protection on the downstream data and power lines. Each device will protect two USB ports. With proper layout the port is hardened to greater than 15kV, meeting the requirements of IEC 1000-4-2. On the upstream port, the SR05 provides ESD protection to the above levels for one line pair. The SC5205 LDO regulator is used to power the hub controller from the upstream bus.



### Figure 10: Bus Powered Hub

**Note:**

(1) 33 $\mu$ F output capacitor per port meets the USB specification minimum capacitance requirement of 120 $\mu$ F per hub.

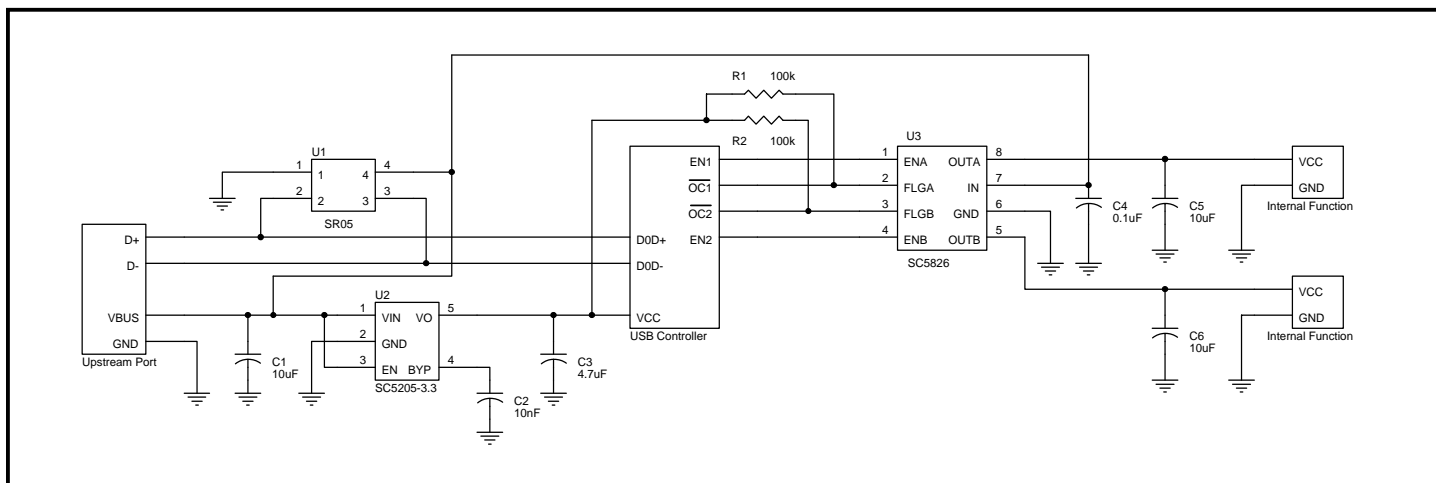
## POWER MANAGEMENT

## Typical Applications Circuits (Cont.)

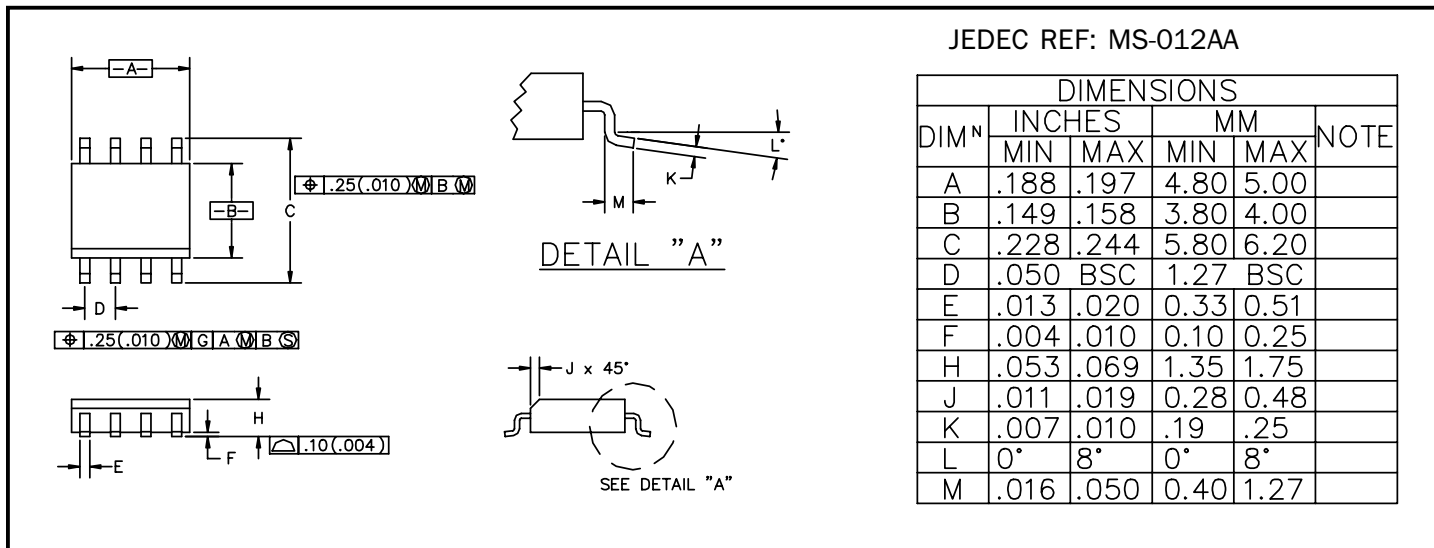
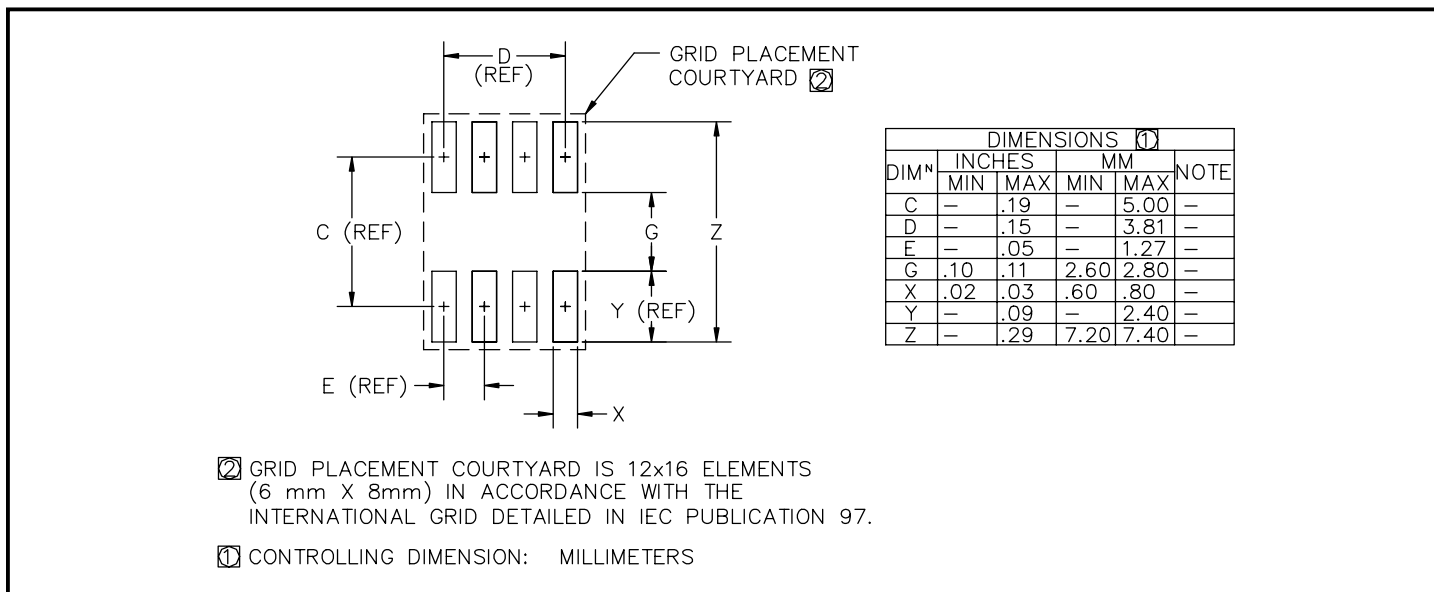
## High-Power or Low-Power Bus-Powered Functions

Both low-power and high-power bus-powered functions must draw less than 100mA at startup. At this time, they must also present a load of less than the parallel combination of a 44Ω resistor and a 10μF capacitor. After startup, high powered functions may then draw up to 500mA. The circuit in figure 11 below utilizes the SC5826 to provide inrush current limiting and power switching for two internal functions.

Since USB is a hot insertion and removal system, USB ports are subject to electrostatic discharge (ESD). The SR05 provides ESD protection on the upstream data and power lines. With proper layout the port is hardened to greater than 15kV, meeting the requirements of IEC 1000-4-2. The SC5205 LDO regulator is used to power the USB controller from the upstream bus.



### Figure 11: High-Power or Low-Power Bus-Powered Functions

**POWER MANAGEMENT**
**Outline Drawing - SO-8**

**Land Pattern - SO-8**

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