SGM2523
Programmable Current Limit Switch

GENERAL DESCRIPTION

The SGM2523 is a compact, feature rich eFuse with a full suite of protection functions. The wide operating voltage allows control of many popular DC buses. The precision ±10% current limit, at room temperature, provides excellent accuracy and makes the SGM2523 well suited for many system protection applications.

The SGM2523 protects input from undesired shorts and transients coming from the output.

The SGM2523 is available in a Green SOT-23-6 package and operates over a temperature range of -40℃ to +125℃.

FEATURES

- **Wide Input Voltage Range from 2.5V to 24V with Surge up to 30V**
- **$R_{DS(ON)}$ Protection Switch: 78mΩ**
- **Programmable Soft-Start Time**
- **Programmable Current Limit from 100mA to 1.2A**
- **Short-Circuit Protection**
- **OCP Hiccup Protection**
  SGM2523A: Limited Current Model
  SGM2523B: Shutdown Model
- **Thermal Shutdown Protection**
  SGM2523A: Auto-Recovery
  SGM2523B: Latched-Off
- **Enable Interface Pin**
- **-40℃ to +125℃ Operating Temperature Range**
- **Available in a Green SOT-23-6 Package**

APPLICATIONS

Hot Swap in Industry/Telecom
E-Meter
Automotive
USB Power Distribution
USB3.1 Power Delivery
Adapter Power Devices

TYPICAL APPLICATION

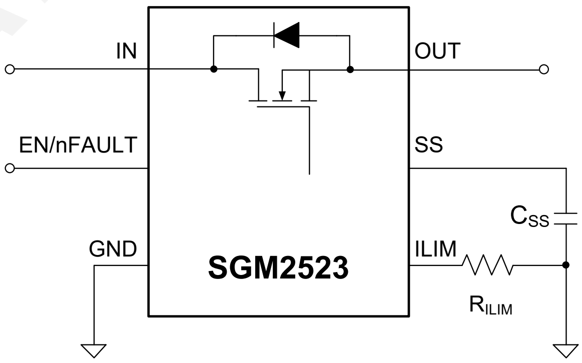


Figure 1. Typical Application Circuit

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM2523A	SOT-23-6	-40℃ to +125℃	SGM2523AXN6G/TR	MP2XX	Tape and Reel, 3000
SGM2523B	SOT-23-6	-40℃ to +125℃	SGM2523BXN6G/TR	CJDXX	Tape and Reel, 3000

MARKING INFORMATION

NOTE: XX = Date Code.

YYY X X

- X (last) — Date Code - Week
- X — Date Code - Year
- YYY — Serial Number

Green (RoHS & HSF): SG Micro Corp defines "Green" to mean Pb-Free (RoHS compatible) and free of halogen substances. If you have additional comments or questions, please contact your SGMICRO representative directly.

ABSOLUTE MAXIMUM RATINGS

IN, OUT, EN/nFAULT to GND .... -0.3V to 30V
SS, ILIM to GND .... -0.3V to 6V
Package Thermal Resistance
SOT-23-6, θ_{JA} .... 220℃/W
Junction Temperature ....+150℃
Storage Temperature Range........................-65℃ to +150℃
Lead Temperature (Soldering, 10s) ....+260℃
ESD Susceptibility
HBM...4000V
CDM 1000V

RECOMMENDED OPERATING CONDITIONS

Supply Input Voltage..2.5V to 24V
Operating Ambient Temperature Range.......-40℃ to +125℃
Operating Junction Temperature Range......-40℃ to +125℃

OVERSTRESS CAUTION

Stresses beyond those listed in Absolute Maximum Ratings may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect reliability. Functional operation of the device at any conditions beyond those indicated in the Recommended Operating Conditions section is not implied.

ESD SENSITIVITY CAUTION

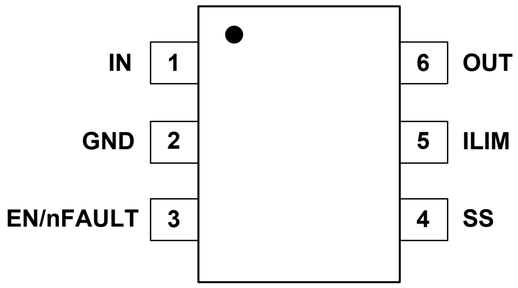
This integrated circuit can be damaged by ESD if you don’t pay attention to ESD protection. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

DISCLAIMER

SG Micro Corp reserves the right to make any change in circuit design, or specifications without prior notice.

PIN CONFIGURATION

SGM2523 (TOP VIEW)



SOT-23-6

PIN DESCRIPTION

PIN	NAME	DESCRIPTION
1	IN	Power Input Pin. Power input and supply voltage of the device.
2	GND	Ground.
3	EN/nFAULT	Enable Input or Alert Output (OTP, OCP, UVP, SCP). Asserting EN/nFAULT pin high enables the device. When any of over-temperature protection, over-current protection, under-voltage protection or short-circuit protection occurs, the device sinks current from EN/nFAULT, pulling the pin down to alert the host (pin as output port).
4	SS	Soft-Start Pin. A capacitor from this pin to GND sets the ramp rate of output voltage at device turn-on.
5	ILIM	Current Limit Program Pin. A resistor from this pin to GND will set the over-load and short-circuit limit. Do not float this pin.
6	OUT	Power Output Pin. Power output of the device.

FUNCTIONAL BLOCK DIAGRAM

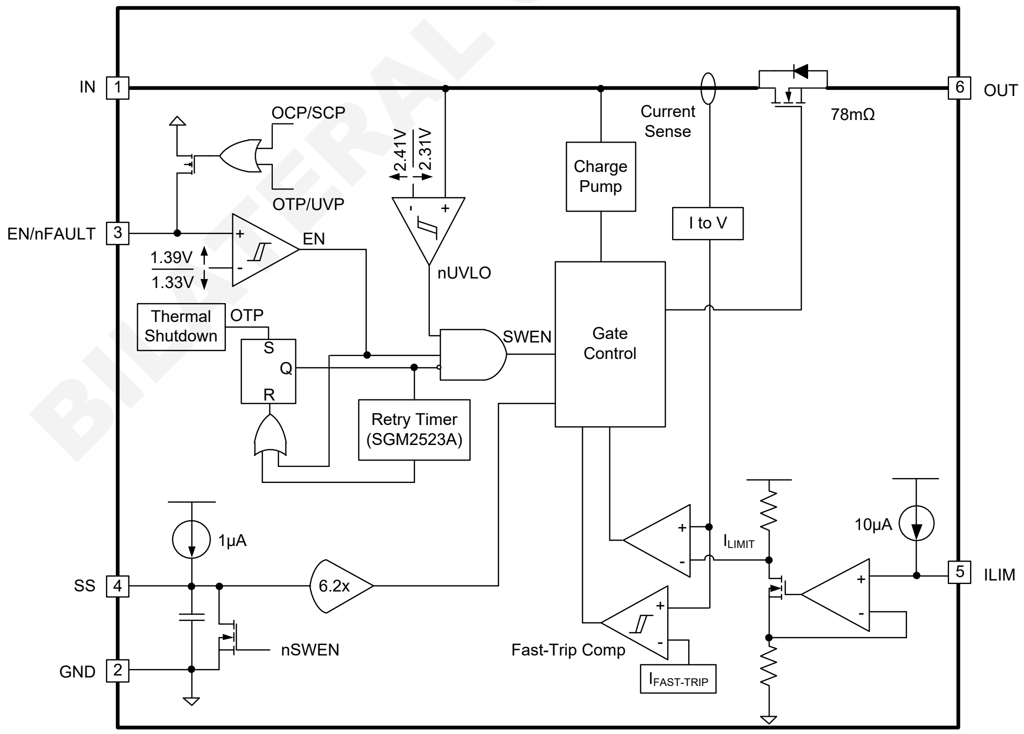


Figure 2. Functional Block Diagram

ELECTRICAL CHARACTERISTICS

(T_J = +25℃, V_{IN} = 2.5V to 24V, $V_{EN/nFAULT}$ = 2V, R_{ILIM} = 95.3kΩ, C_{SS} = Open, unless otherwise noted.)

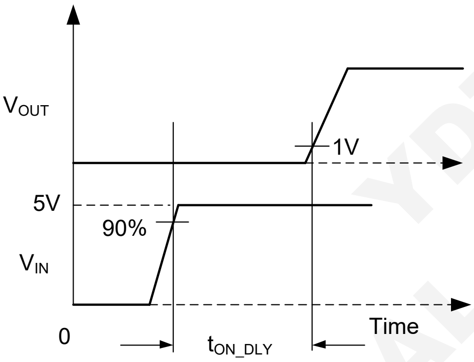
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Supply Voltage and Internal Under-Voltage Lockout						
Operating Input Voltage	V_{IN}		2.5		24	V
UVLO Threshold Voltage, Rising	V_{UVR}			2.41		V
UVLO Hysteresis	V_{UVHYS}			103		mV
Supply Current, Enabled	I_{Q_ON}	$V_{EN/nFAULT}$ = 2V, V_{IN} = 12V		0.16		mA
Supply Current, Disabled	I_{Q_OFF}	$V_{EN/nFAULT}$ = 0V, V_{IN} = 12V		0.8		μA
Enable and Under-Voltage Lockout (En/nFAULT) Input						
EN/nFAULT Threshold Voltage, Rising	V_{ENR}			1.39		V
EN/nFAULT Threshold Voltage, Falling	V_{ENF}			1.33		V
EN/nFAULT Threshold Voltage to Reset Thermal Fault, Falling	V_{ENF_RST}			0.7		V
EN/nFAULT Input Leakage Current	I_{EN}	0 ≤ $V_{EN/nFAULT}$ ≤ 18V		0		nA
Soft-Start: Output Ramp Control (SS)						
SS Charging Current	I_{SS}	V_{SS} = 0V		1		μA
SS to OUT Gain	$GAIN_{SS}$	$\Delta V_{OUT}/\Delta V_{SS}$		6.2		V/V
Current Limit Programming (I_{LIMIT})						
ILIM Pin Bias Current	I_{ILIM}			10		μA
Current Limit	I_{LIMIT}	R_{ILIM} = 35.7kΩ, V_{IN} - V_{OUT} = 1V		0.378		A
		R_{ILIM} = 45.3kΩ, V_{IN} - V_{OUT} = 1V		0.479		
		R_{ILIM} = 95.3kΩ, V_{IN} - V_{OUT} = 1V, T_J = +25℃		1.0		
		R_{ILIM} = 95.3kΩ, V_{IN} - V_{OUT} = 1V		1.0		
		R_{ILIM} = 150kΩ, V_{IN} - V_{OUT} = 1V		1.57		
Fast-Trip Comparator Threshold	$I_{FAST-TRIP}$	R_{ILIM} in kΩ		1.6 × I_{LIMIT}		A
ILIM Open Resistor Detect Threshold	V_{ILIM_OPEN}	V_{ILIM} rising, R_{ILIM} = Open		3.0		V
MOSFET-Power Switch						
FET On-Resistance	$R_{DS(ON)}$	-40℃ ≤ T_J ≤ +85℃		78		mΩ
Pass FET Output (OUT)						
OUT Bias Current in Off State	I_{LKG_OUT}	$V_{EN/nFAULT}$ = 0V, V_{OUT} = 0V (Sourcing)		0		μA
	I_{SINK_OUT}	$V_{EN/nFAULT}$ = 0V, V_{OUT} = 300mV (Sinking)		0.05		
Fault Flag (EN/nFAULT): Active Low						
EN/nFAULT Pull-Down Resistance	$R_{EN/nFAULT}$	Device in fault condition, $V_{EN/nFAULT}$ = 0V, $I_{EN/nFAULT}$ = 100mA		30		Ω
EN/nFAULT Input Leakage Current	$I_{EN/nFAULT}$	Device not in fault condition, $V_{EN/nFAULT}$ = 0V, 18V		0		μA
Thermal Shutdown (TSD)						
Thermal Shutdown Threshold, Rising	T_{TSD}			150		℃
Thermal Shutdown Hysteresis	T_{TSDHYS}			20		℃

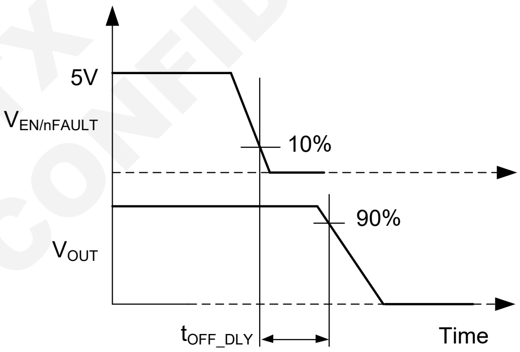
TIMING REQUIREMENTS

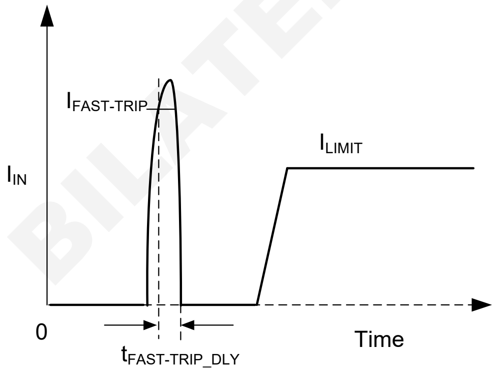
(T_J = +25℃, V_{IN} = 12V, $V_{EN/nFAULT}$ = 2V, R_{ILIM} = 95.3kΩ, C_{SS} = Open, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Enable and Under-Voltage Lockout (EN/nFAULT) Input						
Turn-Off Delay	t_{OFF_DLY}	EN/nFAULT↓ to V_{OUT} = 10.8V, C_{OUT} = 2.2μF		83		μs
Turn-On Delay	t_{ON_DLY}	EN/nFAULT↑ to V_{OUT} = 1V, C_{SS} = Open, C_{OUT} = 2.2μF		74		μs
Soft-Start: Output Ramp Control (SS)						
Output Ramp Time	t_{SS}	EN/nFAULT↑ to V_{OUT} = 11V, with C_{SS} = Open, C_{OUT} = 2.2μF		0.359		ms
		EN/nFAULT↑ to V_{OUT} = 11V, with C_{SS} = 1.2nF, C_{OUT} = 2.2μF		2.24		
Current Limit Programming (I_{LIM})						
Fast-Trip Comparator Delay	$t_{FAST\text{-}TRIP\_DLY}$	I_{OUT} > $I_{FAST\text{-}TRIP}$		0.3		μs
Thermal Shutdown (TSD)						
Retry Delay after Thermal Shutdown Recovery, T_J < [T_{TSD} - 20℃]	t_{TSD_DLY}	SGM2523A only, V_{IN} = 12V		700		ms
		SGM2523A only, V_{IN} = 2.5V		750		

PARAMETRIC MEASUREMENT INFORMATION







DETAILED DESCRIPTION

Overview

SGM2523 is a smart eFuse with enhanced built-in protection circuitry. It provides robust protection for all systems and applications powered from 2.5V to 24V.

For hot-plug-in boards, the device provides in-rush current control and programmable output ramp rate. SGM2523 integrates over-current and short-circuit protection. The precision over-current limit helps to minimize over design of the input power supply, while the fast response short-circuit protection immediately isolates the load from input when a short-circuit case is detected. The device allows the user to program the over-current limit threshold between 0.1A and 1.2A via an external resistor. Its threshold accuracy of 3% ensures tight supervision of bus, eliminating the need for a separate supply voltage supervisor chip. SGM2523 is designed to protect systems such as white goods, STBs, DTVs, smart meters and gas analyzers.

The additional features include:

- Over-temperature protection to safely shut down in the event of an over-current event
- Fault reporting for brown-out
- A choice of latched-off or auto-recovery restart mode

Enable and Adjusting Under-Voltage Lockout (UVLO)

The EN/nFAULT pin controls the on/off state of the internal FET. A voltage $V_{EN/nFAULT} < V_{ENF}$ on this pin turns off the internal FET, thus disconnecting IN from OUT.

Toggling the EN/nFAULT pin below V_{ENF_RST} resets the SGM2523B that has latched-off due to a fault condition. The internal de-glitch delay on EN/nFAULT falling edge is kept low for quick detection of power failure. For applications where a higher de-glitch delay on EN/nFAULT is desired, or when the supply is particularly noisy, it is recommended to use an external filter capacitor from the EN/nFAULT terminal to GND.

The under-voltage lockout threshold can be programmed by using an external resistor divider from the supply IN terminal to the EN/nFAULT terminal to GND as shown in Figure 3. When an under-voltage or input power fail event is detected, the internal FET is quickly turned off. If the under-voltage lockout function is not needed, the EN/nFAULT pin should be connected to the IN terminal. The EN/nFAULT terminal should not be left floating.

SGM2523 implements internal under-voltage lockout (UVLO) circuitry on the IN pin. The device gets disabled when the IN terminal voltage falls below internal UVLO threshold V_{UVF}.

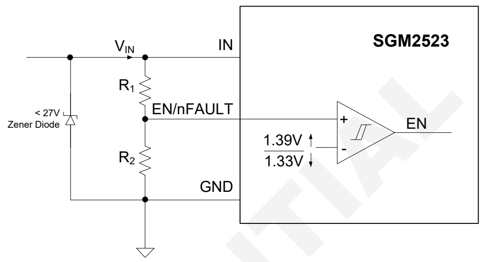


Figure 3. UVLO Thresholds Set by R_1 and R_2

When the switching voltage of SGM2523 is more than 15V, customer should add a no more than 27V (> 0.5W) zener diode to prevent the input voltage spike from damaging the SGM2523 (as shown in Figure 3).

Hot-Plug-In and In-Rush Current Control

SGM2523 is designed to control the in-rush current upon insertion of a card into a live backplane or other "hot" power source. This limits the voltage sag on the backplane's supply voltage and prevents unintended resets of the system power. A slew rate controlled start-up (SS) also helps to eliminate conductive and radiated interference. An external capacitor from the SS pin to GND defines the slew rate of the output voltage at power-on (as shown in Figure 4). The equation governing slew rate at start-up is shown in Equation 1:

$$I_{SS} = \frac{C_{SS}}{Gain_{SS}} \times \frac{dV_{OUT}}{dt} \quad (1)$$

where:

I_{SS} = 1μA (TYP)

dV_{OUT}/dt = Desired output slew rate

$GAIN_{SS} = \Delta V_{OUT}/\Delta V_{SS}$ gain = 6.2

C_{SS} (MAX) must be less than 1μF.

DETAILED DESCRIPTION (continued)

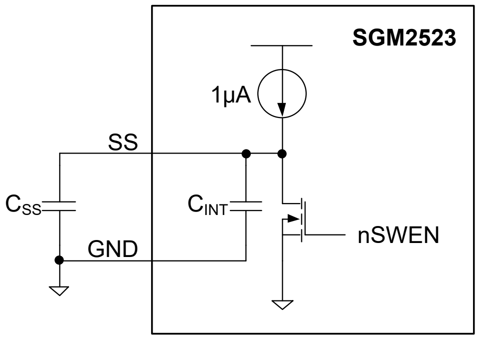


Figure 4. Output Ramp Time t_{dVdT} is Set by C_{dVdT}

The total ramp time (t_{SS}) of V_{OUT} for 0 to V_{IN} can be calculated using Equation 2:

$$t_{SS} = 16.1 \times 10^4 \times V_{IN} \times C_{SS} \quad (2)$$

where C_{SS} is in Farad.
The in-rush current, $I_{IN\text{-}RUSH}$ can be calculated as

$$I_{IN\text{-}RUSH} = C_{OUT} \times \frac{V_{IN}}{t_{SS}} \quad (3)$$

The SS pin can be left floating to obtain a predetermined slew rate (t_{SS}) on the output. When terminal is left floating, the device sets an internal ramp rate of ~50V/ms for output (V_{OUT}) ramp.

For systems where load is present during start-up, the current never exceeds the over-current limit set by R_{ILIM} resistor for the application.

Over-Load and Short-Circuit Protections

At all times load current is monitored by sensing voltage across an internal sense resistor. During over-load events, current is limited to the current limit (I_{LIMIT}) programmed by R_{ILIM} resistor:

$$I_{LIMIT} = 10.5 \times 10^{-3} \times R_{ILIM} \quad (4)$$

$$R_{ILIM} = \frac{I_{LIMIT}}{10.5 \times 10^{-3}} \quad (5)$$

where:
I_{LIMIT} is over-load current limit in Ampere.
R_{ILIM} is the current limit programming resistor in kΩ.

SGM2523 incorporates two distinct over-current protection levels: the current limit (I_{LIMIT}) and the fast-trip threshold ($I_{FAST\text{-}TRIP}$). The fast-trip and current limit operations are shown in Figure 5.

Bias current on ILIM pin directly controls current limiting behavior of the device, and PCB routing of this node must be kept away from any noisy (switching) signals.

Over-Load Protection

For over-load conditions, the internal current limit amplifier regulates the output current to I_{LIMIT}. The output voltage droops during current limit regulation, resulting in increased power dissipation in the device. SGM2523 allows ILIM pin floating operation. If ILIM pin is floating, the current limit will be set as fixed 0.2A internally.

When the over-current limit condition lasts more than 2ms, the SGM2523A enters the hiccup mode with 2ms on time and 700ms off time, whereas the SGM2523B enters shutdown mode.

Short-Circuit Protection

During a transient short-circuit event, the current through the device increases very rapidly. As current limit amplifier cannot respond quickly to this event due to its limited bandwidth, the device incorporates a fast-trip comparator, with a threshold $I_{FAST\text{-}TRIP}$. When the current through the internal FET exceeds $I_{FAST\text{-}TRIP}$ ($I_{OUT} > I_{FAST\text{-}TRIP}$), this comparator shuts down the pass device within 0.3μs and terminates the rapid short-circuit peak current. The $I_{FAST\text{-}TRIP}$ threshold is dependent on programmed over-load current limit and function of R_{ILIM}. See Equation 6 for the calculation.

$$I_{FAST\text{-}TRIP} = 1.6 \times I_{LIMIT} \quad (6)$$

where:
$I_{FAST\text{-}TRIP}$ is fast-trip current limit in Ampere.

The fast-trip circuit holds the internal FET off for only a few microseconds, after which the device attempts to turn back on normally, allowing the current limit loop to regulate the output current to I_{LIMIT}. Then, device behaves similar to over-load condition.

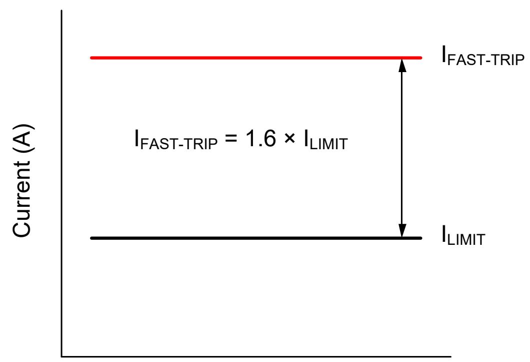


Figure 5. Over-Current Protection Levels

DETAILED DESCRIPTION (continued)

Start-Up with Short on Output

During start-up into a short-circuit current is limited to I_{LIMIT}. This feature helps in quick fault isolation and hence ensures stability of the DC bus.

EN/nFAULT as Output Port

When any of over-current protection, under-voltage protection or over-temperature protection occurs, the device sinks current from EN/nFAULT, pulling the pin down to alert the host.

EN/nFAULT changes back to an input port, only after the device is released from a protection action.

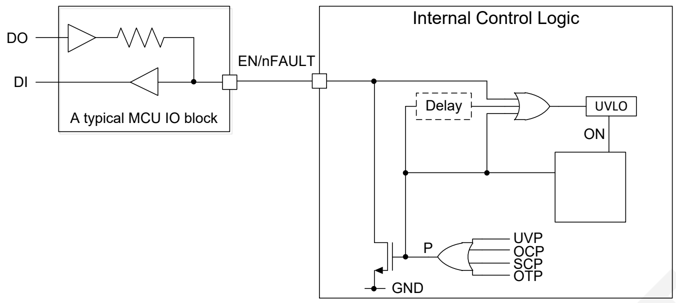


Figure 6. EN/nFAULT Application

IN, OUT and GND Pins

The IN pin should be connected to the power source. A ceramic bypass capacitor close to the device from IN to GND is recommended to alleviate bus transients. The recommended operating voltage range is 2.5V to 24V. The OUT pin should be connected to the load. V_{OUT} in the ON condition, is calculated using the Equation 7:

$$V_{OUT} = V_{IN} - (R_{DS(ON)} \times I_{OUT}) \quad (7)$$

where $R_{DS(ON)}$ is the on-resistance of the internal FET.

GND terminal is the most negative voltage in the circuit and is used as a reference for all voltage reference unless otherwise specified.

Thermal Shutdown

Internal over-temperature shutdown disables/turns off the FET when T_J > 150℃ (TYP). The SGM2523B latches off the internal FET, whereas SGM2523A commences an auto-recovery cycle t_{TSD_DLY} milliseconds after T_J drops below [T_{TSD} - 20℃]. During the thermal shutdown, the fault pin EN/nFAULT is pulled low to signal a fault condition.

Shutdown Control

The internal FET and hence the load current can be remotely switched off by taking the EN/nFAULT pin below its V_{ENF} threshold.

Operational Overview of Device Functions

The device functionality for various conditions are shown in Table 2.

Table 1. Operational Overview of Device Functions

Device	SGM2523
Start-Up	In-rush ramp controlled by capacitor at SS pin.
	In-rush limited to I_{LIMIT} level as set by R_{ILIM}.
	If T_J > T_{TSD} device shuts off.
Over-Current Response	Current is limited to I_{LIMIT} level as set by R_{ILIM}.
	Power dissipation increases as V_{IN} - V_{OUT} grows.
	Device turns off when T_J > T_{TSD}.
	SGM2523A will attempt restart t_{TSD_DLY} ms after T_J < [T_{TSD} -20°C].
	SGM2523B remains off.
Short-Circuit Response	Fast shut off when I_{LOAD} > $I_{FAST-TRIP}$.
	Quick restart and current limited to I_{LIMIT}, follows standard start-up cycle.

The SGM2523 provides simple solutions for current limiting, in-rush current control and supervision of power rails for wide range of applications operating at 2.5V to 24V and delivering up to 1.2A.

SYSTEM EXAMPLES

Protection and Current Limiting for Primary-Side Regulated Power Supplies

Primary-side regulated power supplies and adapters are dominant today in many of the applications such as smart-phones, portable hand-held devices, white goods, set-top-box and gaming consoles. These supplies provide efficient, low cost and low component count solutions for power needs ranging from 5W to 30W. But, these come with drawbacks of:

• No secondary-side protection for immediate termination of critical faults such as short-circuit
• Do not provide precision current limiting for over-load transients
• Have poor output voltage regulation for sudden change in AC input voltages, triggering output over-voltage condition

Many of the above applications require precision output current limiting and secondary side protection, driving the need for current sensing in the secondary side. This needs additional circuit implementation using precision operational amplifiers. This increases the complexity of the solution and also results in sensing losses The SGM2523 with their integrated low-ohmic N-channel FET provides a simple and efficient solution. Figure 7 shows the typical implementation using SGM2523.

During short-circuit conditions, the internal fast comparator of SGM2523 turns off the internal FET in less than 0.3μs (TYP) as soon as current exceeds $I_{FAST-TRIP}$, set by the current limit R_{ILIM} resistor.

In addition to above, the SGM2523 provide in-rush current limit when output is hot-plugged into any of the system loads.

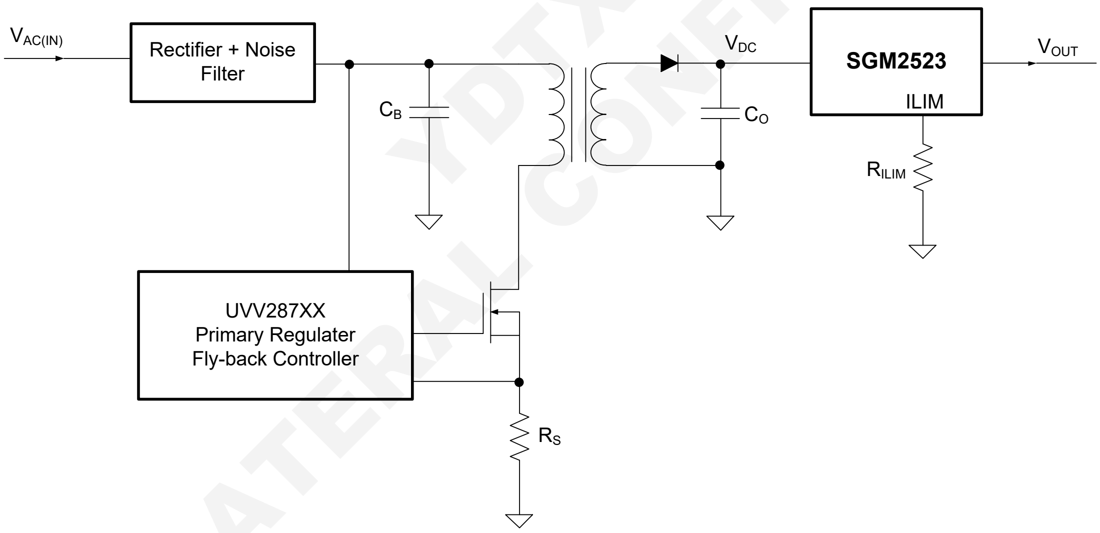


Figure 7. Current Limiting and Protection for AC-DC Power Supplies

SYSTEM EXAMPLES (continued)

Precision Current Limiting in Intrinsic Safety Applications

Intrinsic Safety (IS) is becoming prominent need for safe operation of electrical and electronic equipment in hazardous areas. Intrinsic Safety requires that equipment is designed such that the total amount of energy available in the apparatus is simply not enough to ignite an explosive atmosphere. The energy can be electrical, in the form of a spark, or thermal, in the form of a hot surface.

This calls for precision current limiting ensuring that set current limits are not exceeded for wide operating temperature range and variable environmental conditions. Applications such as gas analyzers, medical equipment (such as electrocardiographs), portal industrial equipment, cabled power distribution systems and hand-held motor operated tools need to meet these critical safety standards.

The SGM2523 device can be used as simple protection solution for each of the internal rails. Figure 8 shows the typical implementation using SGM2523.

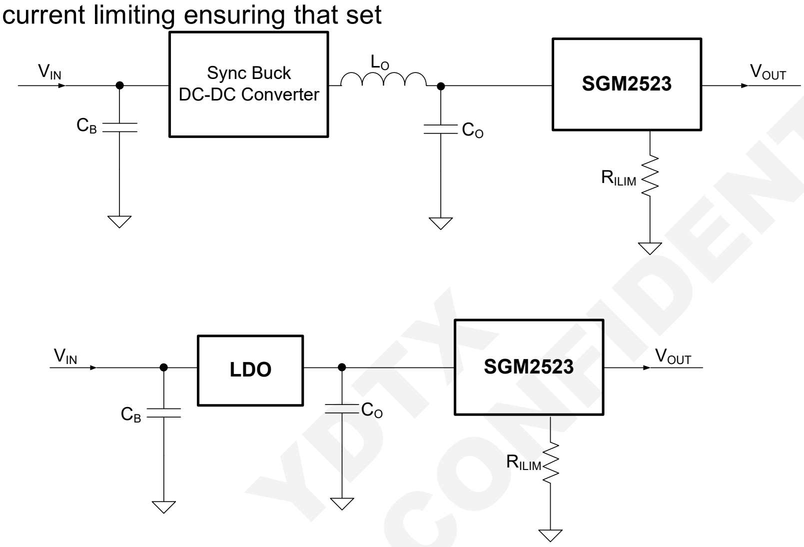


Figure 8. Precision Current Limit and Protection of Internal Rails

Smart Load Switch

A smart load switch is a series FET used for switching of the load (resistive or inductive). It also provides protection during fault conditions. Typical discrete implementation is shown in Figure 9. Discrete solutions have higher component count and require complex circuitry to implement each of the protection fault needs.

SGM2523 can be used as a smart power switch for applications ranging from 2.5V to 24V. SGM2523 provides programmable soft-start, programmable current limits, over-temperature protection, a fault flag, and under-voltage lockout.

Figure 9 shows typical implementation and usage as load switch. This configuration can be used for driving a solenoid and FAN control. It is recommended to use a freewheeling diode across the load when load is highly inductive.

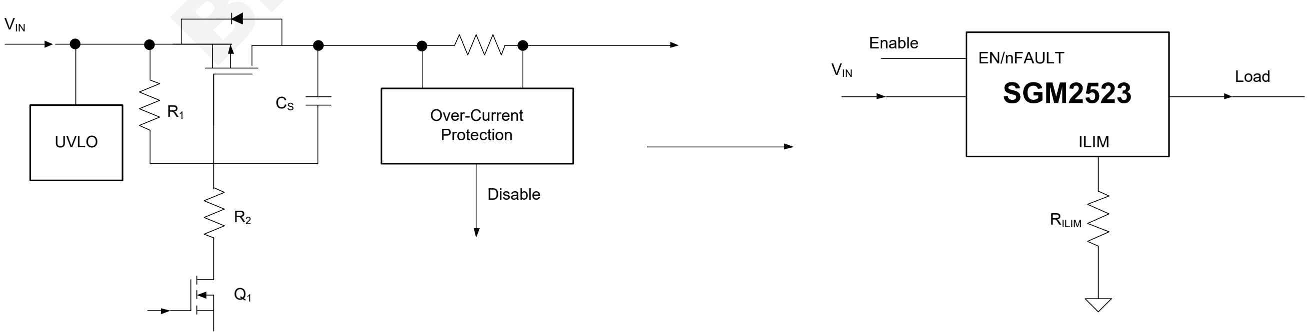
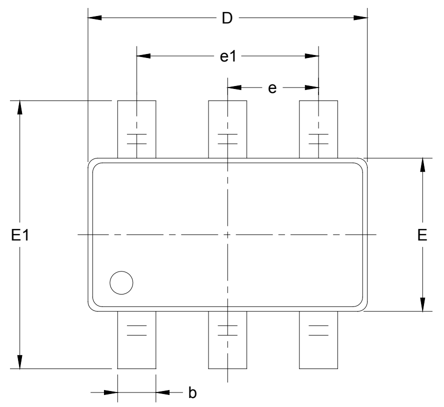
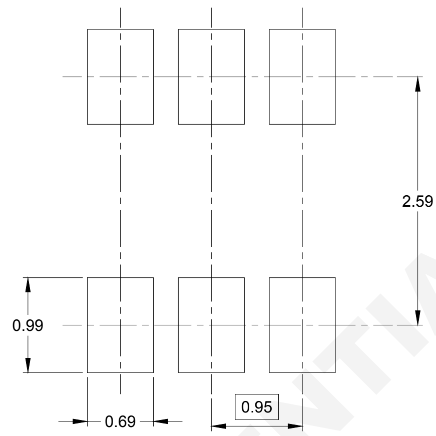


Figure 9. Smart Load Switch Implementation

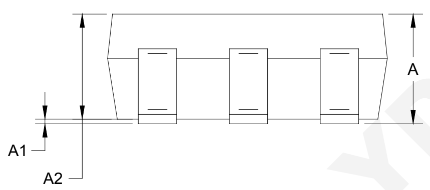
PACKAGE OUTLINE DIMENSIONS

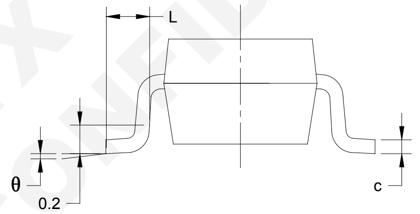
SOT-23-6





RECOMMENDED LAND PATTERN (Unit: mm)

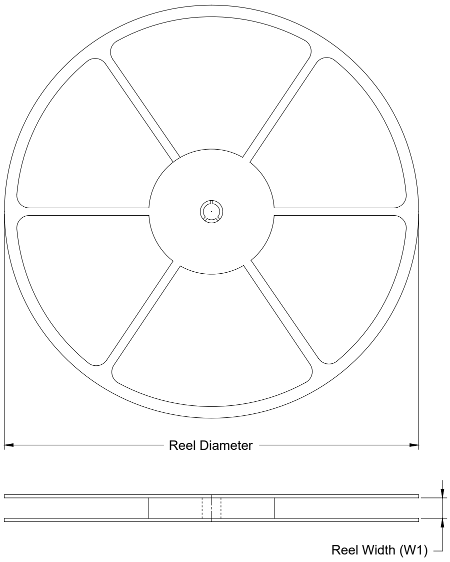




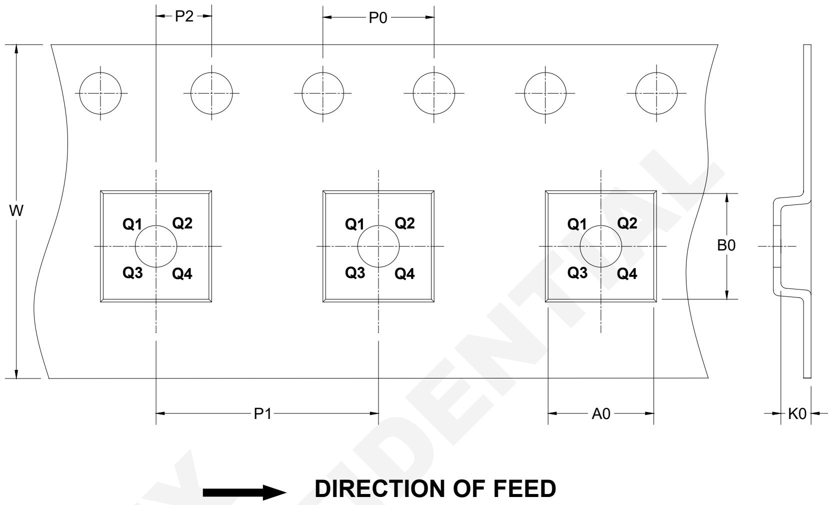
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950 BSC		0.037 BSC	
e1	1.900 BSC		0.075 BSC	
L	0.300	0.600	0.012	0.024
θ	0°	8°	0°	8°

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



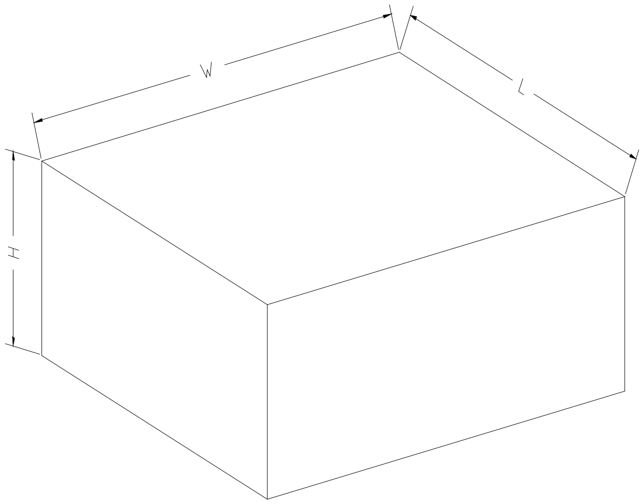
NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF TAPE AND REEL

Package Type	Reel Diameter	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
SOT-23-6	7″	9.5	3.17	3.23	1.37	4.0	4.0	2.0	8.0	Q3

DD0001

CARTON BOX DIMENSIONS



NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF CARTON BOX

Reel Type	Length (mm)	Width (mm)	Height (mm)	Pizza/Carton
7″ (Option)	368	227	224	8
7″	442	410	224	18

DD0002