SQ24802K1

4.2V to 16V, 5A, 31mΩ eFuse with Over-voltage Protection

General Description

The SQ24802K1 is a compact and fully integrated eFuse that provides power management and circuit protection capabilities. The SQ24802K1 requires minimal external components and provides various protection modes. It can effectively protect against overvoltage, overload, short circuit, and excessive inrush current conditions.

The current limit threshold can be easily configured using an external resistor. Additionally, internal output clamping circuit can effectively limit the occurrence of overvoltage events without the need for external components.

Applications with specific voltage ramp requirements can use a single capacitor to regulate dV/dT and ensure the desired output ramp rate.

The SQ24802K1 is available in a compact DFN 2mm×2mm – 8pin package.

Features

- Low Power Path Resistance
  $R_{DS(ON)}$=31mΩ (Typical)
- Overvoltage Protection Clamp at 14V
- Adjustable Current Limit (I_{LIMIT}) : 1A to 5A
- Adjustable Output Slew Rate Control (SLEW)
- Overtemperature Protection (OTP)
- Fault Indication Pin (FLT_N)
- Protection Mode: Auto-Restart
- Operating Voltage Range: 4.2V to 16V,
  V_{ABSMAX} = 18V
- Compact Package: DFN2×2-8

Applications

- Industrial Systems
- Hot-Swap Applications
- Digital Televisions
- SSDs and HDDs
- Adapter Powered Systems

Typical Application

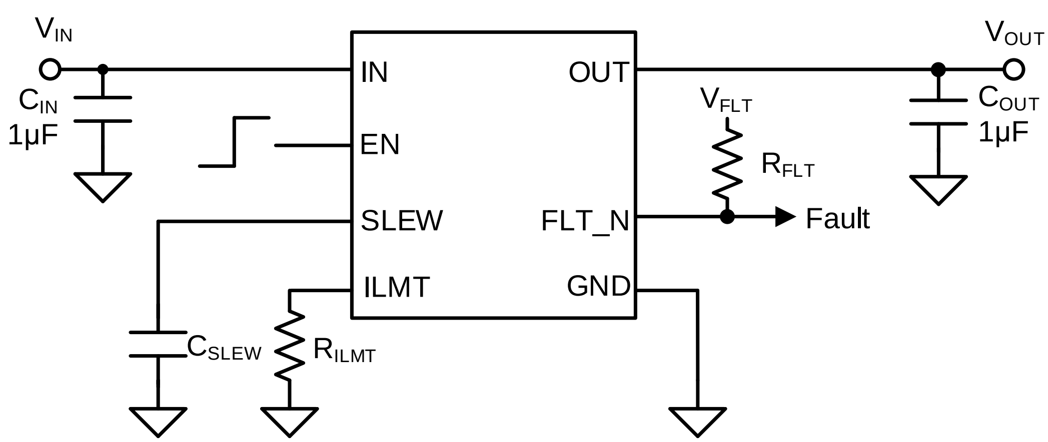


Figure1. Schematic Diagram

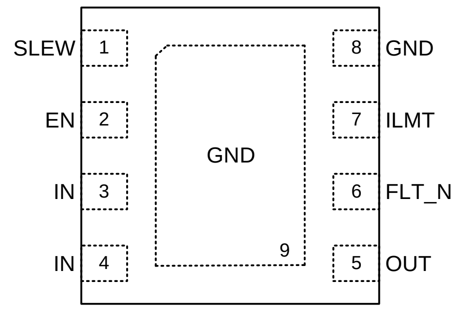
Ordering Information

Ordering Part Number	Package Type	Top Mark
SQ24802K1DFD	**DFN2×2-8** RoHS Compliant and Halogen Free	***4nxyz***

Device code: 4n

x=year code, y=week code, z= lot number code

Pinout (top view)



Pin Name	Pin Number	Pin Description
SLEW	1	Connect a capacitor from this pin to the GND to control the ramp rate of OUT at the device turn-on.
EN	2	Active high enable. A resistor divider can be used to adjust the undervoltage lockout threshold. Do not leave floating.
IN	3, 4	Input and supply voltage. Connect a 1μF or greater ceramic capacitor from IN to GND placed as close to the device as possible.
OUT	5	Power-switch output.
FLT_N	6	The fault event indicator is pulled low when a fault is detected. It is an open drain output that requires an external pull up resistance. Leave it floating if not used.
ILMT	7	A resistor from this pin to GND will set the overcurrent and short-circuit limits.
GND	8, 9	GND.

Block Diagram

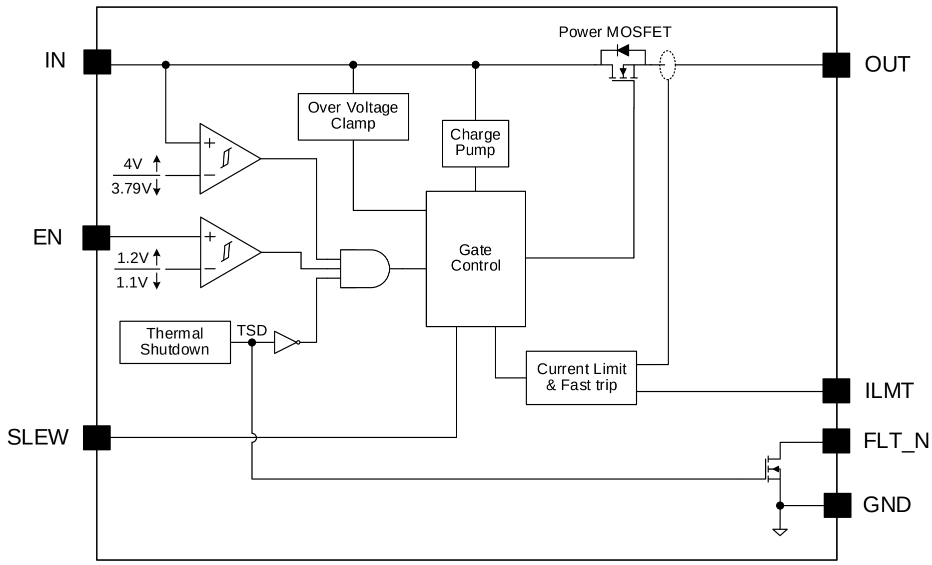


Figure2. Block Diagram

Absolute Maximum Ratings

Parameter (Note1)		Min	Max	Unit
IN, EN		-0.3	18	V
OUT		-0.3	IN+0.3	
FLT_N		-0.3	7	
ILMT,SLEW		-0.3	3.6	
Lead Temperature (Soldering, 10 sec.)			260	°C
Junction Temperature, Operating		-40	150	
Storage Temperature		-65	150	
Electrostatic Discharge	HBM (Human Body Mode)		±2500	V
	CDM (Charged Device Mode)		±500	

Thermal Information

Parameter (Note2)	Typ	Unit
θ_{JA} Junction-to-ambient Thermal Resistance	60	°C/W
θ_{JC} Junction-to-case Thermal Resistance	36	
P_D Power Dissipation T_A = 25°C	1.67	W

Recommended Operating Conditions

Parameter (Note 3)	Min	Max	Unit
IN	4.2	16	V
EN, FLT_N	0	6	
SLEW, ILMT	0	3	
OUT Continuous Output Current	0	5	A
Junction Temperature	-40	125	°C

Electrical Characteristics

(V_{IN} = 12 V, V_{EN} = 5 V, R_{ILMT} =487Ω, C_{SLEW}= OPEN. R_{OUT} [between OUT to GND] = open, schematic of figure 1. T_J = -40°C to 125°C, typical values are at T_J=25°C, unless otherwise specified (Note 4))

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Input Voltage Range	V_{IN}		4.2		16	V
IN Undervoltage Protection Threshold	V_{UVLO_R}	V_{IN} rising	3.8	4	4.2	V
	V_{UVLO_F}	V_{IN} falling	3.59	3.79	3.99	V
Shutdown Current	I_{SHDN}	V_{EN}<0.5V, V_{IN} ≤ 5 V		2		μA
		V_{EN}<0.5V, 5V ≤V_{IN} ≤ 18 V		2	5	μA
Quiescent Current	I_Q	V_{EN}≥V_{ENR}		72	120	μA
Output Voltage While Clamping	V_{CLAMP}	V_{IN} rising, R_{OUT} = 10 kΩ, -40°C to 85°C	13.3	14	14.7	V
		V_{IN} rising, R_{OUT} = 10 kΩ, 0°C to 85°C	13.3	14	14.7	V
Peak Output Clamp Response Time	t_{CLPF}	I_{OUT} = 4 A		300		μs
		I_{OUT} = 100 mA		300		μs
EN Turn On to 95%×V_{OUT}	t_{ON}	R_{OUT}=100Ω	210	410	660	μs
		C_{SLEW}=3300pF, R_{OUT}=100Ω	850	1400	2100	μs
EN Threshold Voltage, rising	V_{ENR}		1.13	1.2	1.27	V
EN Threshold Voltage, falling	V_{ENF}		1.03	1.1	1.17	V
EN Input Leakage Current	I_{EN}	0 V ≤ V_{EN} ≤ 5 V	-100	0	100	nA
MOSFET On Resistance	R_{ON}	T_J = 25°C	21	31	37	mΩ
				39	53	mΩ
Current Monitor Gain As Measured on ILMT Pin (I_{ILMT} / I_{OUT})	G_{IMON}	I_{OUT} = 4A	213	228	243	μA/A
		I_{OUT} = 1A	206	224	242	
Overload Current Limit	I_{LIMIT}		3.55	4.19	4.6	A
		R_{ILMT} = 1780Ω	0.97	1.175	1.29	A
		R_{ILMT} = 4420Ω	0.39	0.485	0.54	A
Current Limit Response Time	t_{LIM}	I_{OUT} > I_{LIMIT} + 20% to I_{OUT} ≤ I_{LIMIT}		300		μs
Short-Circuit Response Time	t_{SC}	I_{OUT} > I_{SC} to MOSFET shutdown		1		μs
FLT_N Pin Resistance	R_{FLT_N}	FLT_N falling		20		Ω
FLT_N Pin Leakage Current	I_{FLT_N}	V_{EN} = 2 V, V_{FLT_N} = 0 V to 6 V	-0.1		0.1	μA
Thermal Shutdown Threshold	T_{SD}			157		°C
Thermal Shutdown Hysteresis	T_{SDHYS}			15		°C
Thermal Shutdown Auto-Retry Interval	$t_{TSD,RST}$	Device enabled and T_J < T_{SD} -T_{SDHYS}		4		ms
Output Rising Slew Rate R_{OUT} = 100Ω	SR_{ON}	V_{IN} = 5V		48.3		V/ms
		V_{IN} = 5V, C_{SLEW} = 3.3nF		11.4		
				39.7		
		C_{SLEW} = 3.3nF		10.5		
Turn On Delay R_{OUT} = 100Ω	$t_{D,ON}$	V_{IN} = 5V		154		μs
		V_{IN} =5 V, C_{SLEW} = 3.3nF		196		
				158		
		C_{SLEW} = 3.3nF		245		

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Rise Time R_{OUT} = 100Ω	t_R	V_{IN} = 5V		93.3		μs
		V_{IN} = 5V, C_{SLEW} = 3.3nF		396		
				242		
		C_{SLEW} = 3.3nF		915		
Turn Off Delay R_{OUT} = 100Ω	$t_{D,OFF}$	V_{IN} = 5V		7.1		μs
		V_{IN} = 5V, C_{SLEW} = 3.3nF		7.3		
				7		
		C_{SLEW} = 3.3nF		7.1		

Note 1: Stresses beyond the "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Note 2: θ_{JA} is measured with natural convection at T_A = 25°C on a Silergy test board.

Note 3: The device is not guaranteed to function outside its operating conditions.

Note 4: Production tested at 25˚C. Limits are guaranteed by design, test or statistical correlation.

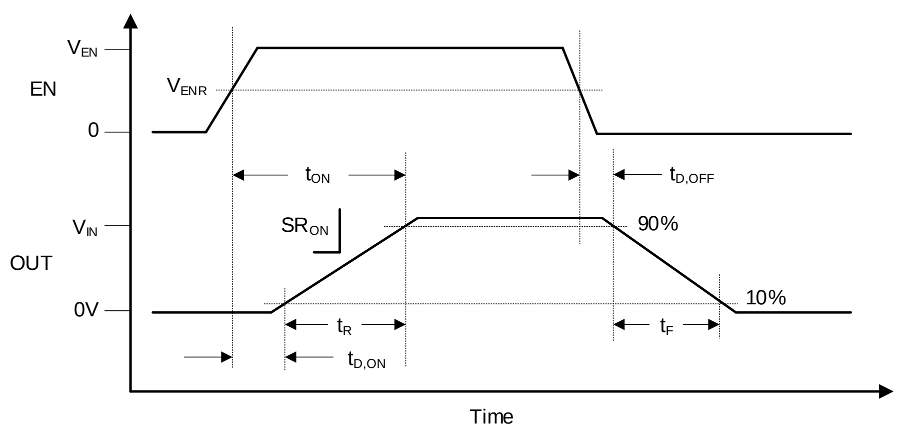
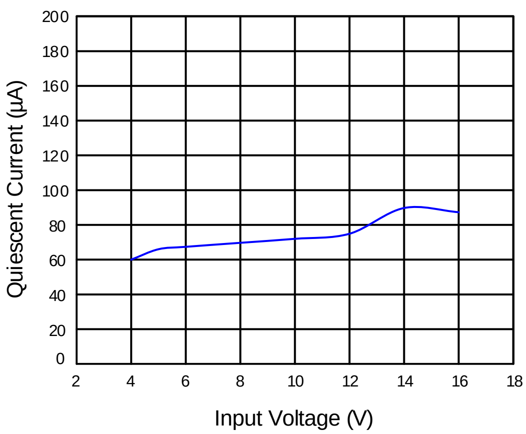


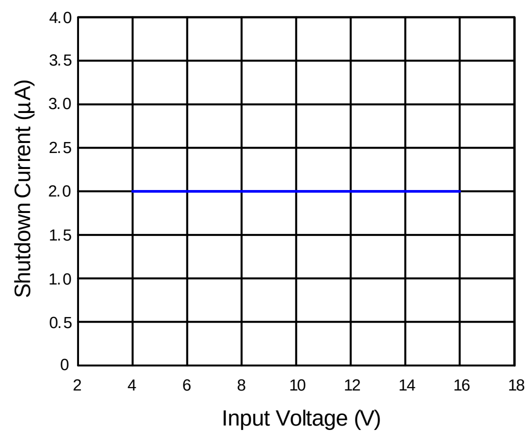
Figure 3. Switching Time

Typical Performance Characteristics

Quiescent Current vs. Input Voltage

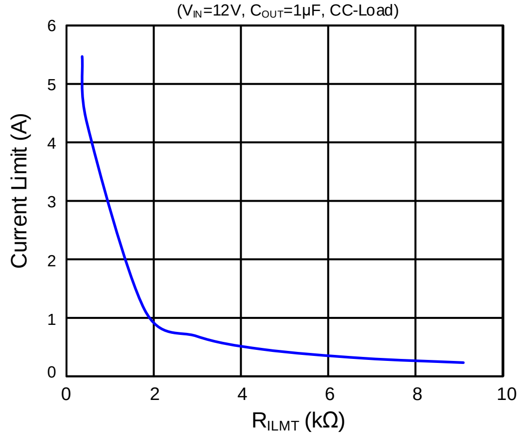


Shutdown Current vs. Input Voltage



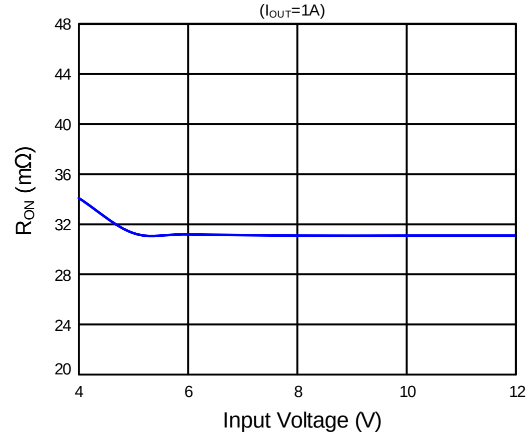
Current Limit vs. R_{ILMT}

(V_{IN}=12V, C_{OUT}=1μF, CC-Load)

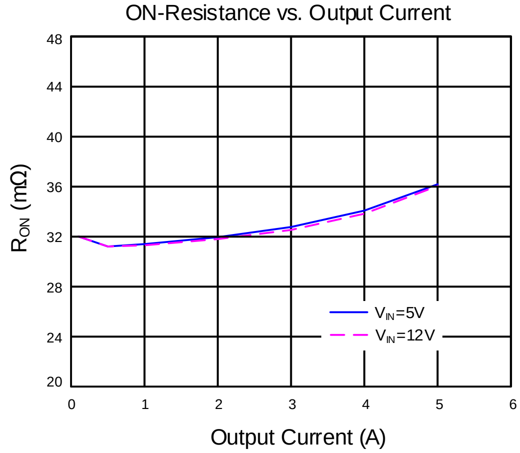


ON-Resistance vs. Input Voltage

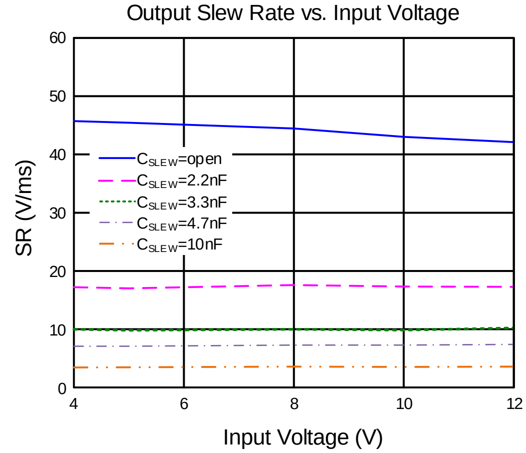
(I_{OUT}=1A)



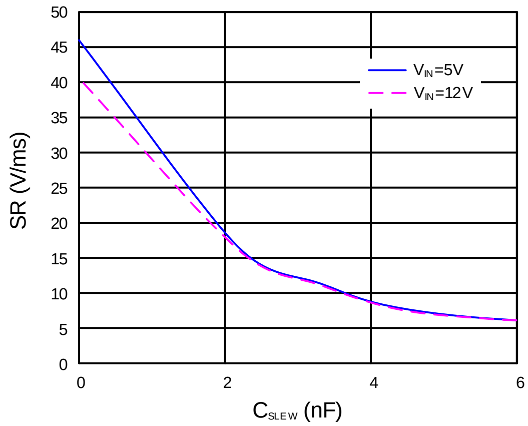
ON-Resistance vs. Output Current



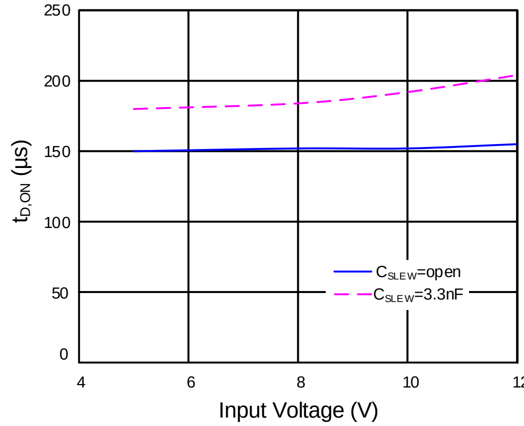
Output Slew Rate vs. Input Voltage



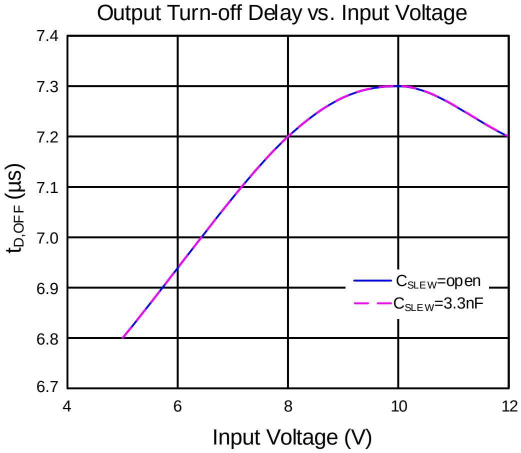
Output Slew Rate vs. C_{SLEW}



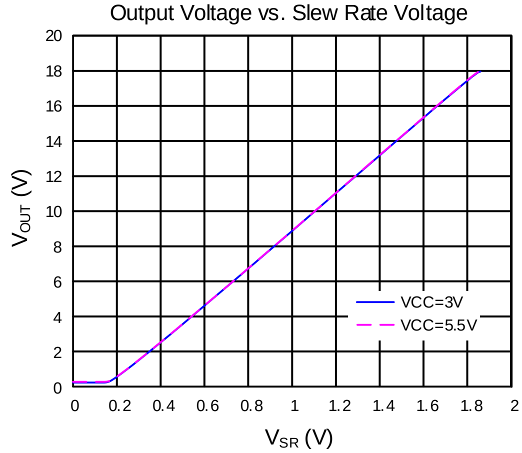
Output Turn-on Delay vs. Input Voltage



Output Turn-off Delay vs. Input Voltage

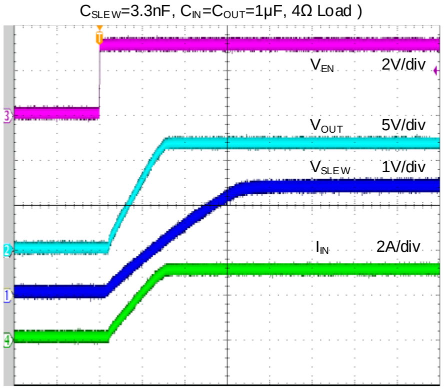


Output Voltage vs. Slew Rate Voltage



Startup from EN

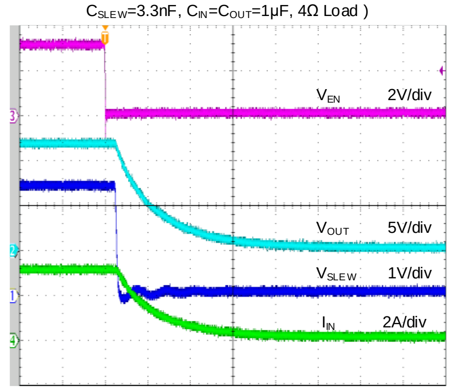
(V_{IN}=12V, EN=0V to 3V, R_{ILMT}=470Ω, R_{FLT}=100kΩ, C_{SLEW}=3.3nF, C_{IN}=C_{OUT}=1µF, 4Ω Load)



Time (800µs/div)

Shutdown from EN

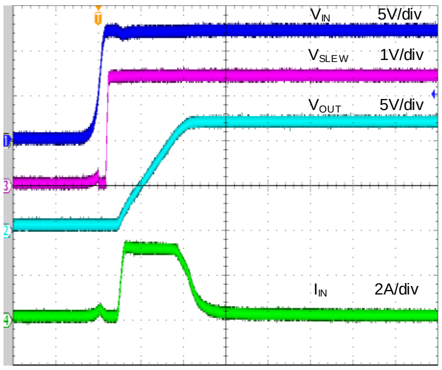
(V_{IN}=12V, EN=3V to 0V, R_{ILMT}=470Ω, R_{FLT}=100kΩ, C_{SLEW}=3.3nF, C_{IN}=C_{OUT}=1µF, 4Ω Load)



Time (4µs/div)

Startup from IN

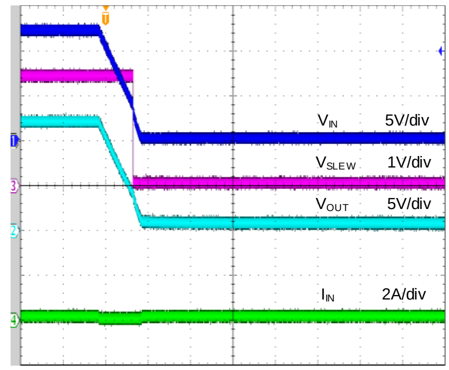
(V_{IN}=0V to 12V, EN=3V, R_{ILMT}=470Ω, R_{FLT}=100kΩ, C_{SLEW}=Open, C_{IN}=1μF, C_{OUT}=1μF+100μF)



Time (200μs/div)

Shutdown from IN

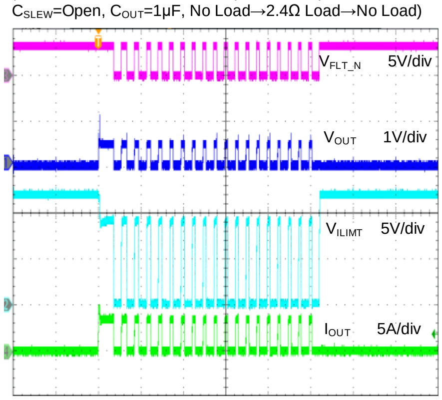
(V_{IN}=12V to 0V, EN=3V, R_{ILMT}=470Ω, R_{FLT}=100kΩ, C_{SLEW}=Open, C_{IN}=1μF, C_{OUT}=1μF+100μF)



Time (10ms/div)

Current Limit

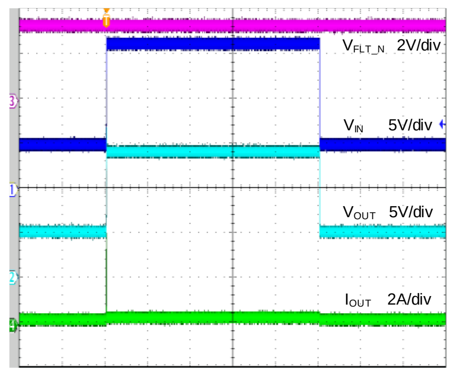
(V_{IN}=12V, EN=3V, R_{ILMT}=470Ω (I_{LIMIT}=4.29A), R_{FLT}=100kΩ, C_{SLEW}=Open, C_{OUT}=1μF, No Load→2.4Ω Load→No Load)



Time (20ms/div)

Over-voltage Clamp

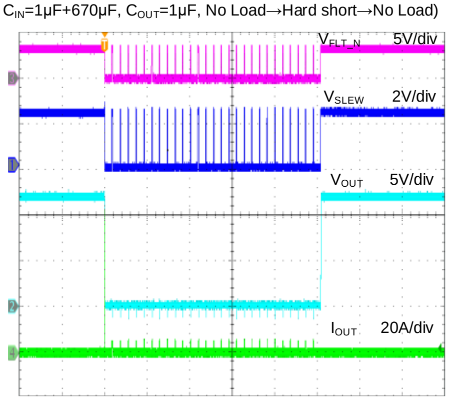
(V_{IN}=5V to 16V to 5V (20μs) , EN=3V, R_{ILMT}=470Ω, R_{FLT}=100kΩ, C_{IN}=C_{OUT}=1μF)



Time (20ms/div)

Short Circuit Response

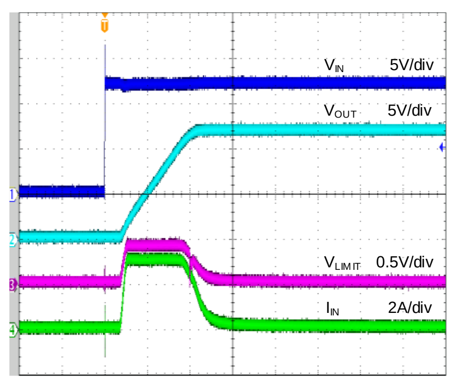
(V_{IN}=12V, EN=3V, R_{ILMT}=470Ω, R_{FLT}=100kΩ, C_{SLEW}=Open, C_{IN}=1μF+670μF, C_{OUT}=1μF, No Load→Hard short→No Load)



Time (20ms/div)

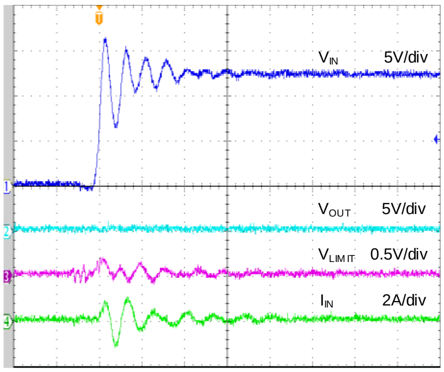
Hot Plug

(V_{IN}=EN=12V, R_{ILMT}=470Ω, R_{FLT}=100kΩ, C_{SLEW}=Open, C_{IN}=Open, C_{OUT}=1μF+100μF)



Time (200μs/div)

Hot Plug
(V_{IN}=EN=12V, R_{ILMT}=470Ω, R_{FLT}=100kΩ, C_{SLEW}=Open, C_{IN}=Open, C_{OUT}=1μF+100μF)



Time (100ns/div)

Application Information

Overvoltage Clamp (OVC)

OVC limits the OUT voltage to protect the load if the input supply exceeds the preset clamp threshold, V_{CLAMP}. This reduces the need to rely on conventional external protection devices such as TVS or Zener diodes.

If the input voltage exceeds the V_{CLAMP}, the device will clamp the output voltage to the V_{CLAMP} within a short response time (t_{CLPF}). If the input voltage remains below the clamp threshold, the output voltage will be equal to the input voltage.

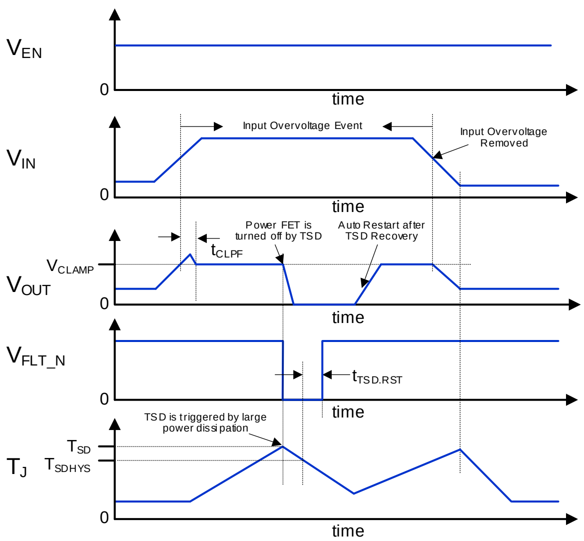


Figure 4. Overvoltage Clamp Response

Overcurrent Protection

The device continuously monitors the load current and keeps it limited to the value programmed by R_{ILMT}. After startup and during normal operation, the current limit is set to I_{LIMIT}. A 1% resistor is recommended for the R_{ILMT} to ensure stability of the internal regulation loop. Recommended formula for calculating R_{ILMT} based on the target current limit:

$$R_{ILMT} = \frac{2000}{I_{LIMIT}-0.04} (\Omega)$$

When an overcurrent condition occurs ($I_{LIMIT}<I_{LOAD}<2.5\times I_{LIMIT}$), the device will maintain a constant output current and the output voltage will start falling. Thermal shutdown protection will occur if the fault is present long enough to activate thermal limiting. The device will remain off until the junction temperature decreases by approximately 20°C, at which point the device will auto restart. The device will continue to cycle ON/OFF until the overcurrent condition is resolved.

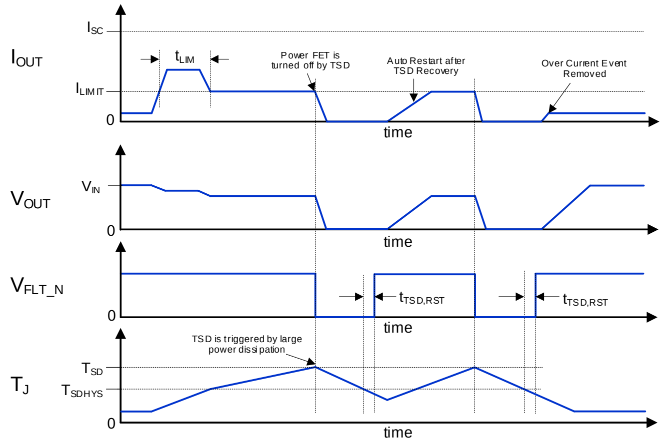


Figure5. Overcurrent Response

When a short-circuit condition is detected ($I_{LOAD}>2.5\times I_{LIMIT}$), the SQ24802K1 immediately turns off the power path. It employs a fast-trip comparator with a threshold I_{SC} ($2.5\times I_{LIMIT}$) to rapidly shut down the power MOSFET within 1μs. The fast-trip circuit briefly keeps the internal MOSFET off for a few microseconds, and then the device gradually powers on, enabling the current-limit loop to regulate the output current to I_{LIMIT}. After this, the device attempts to restart under current limit conditions.

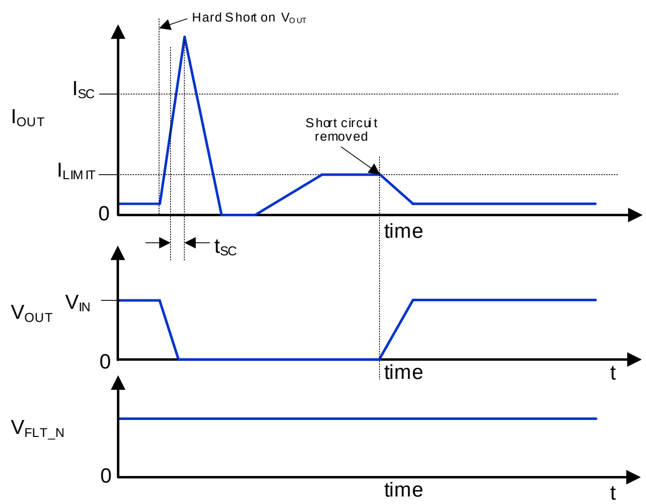


Figure 6. Short Circuit Response

Under Voltage Lockout (UVLO)

The SQ24802K1 features an integrated UVLO protection mechanism that turns off the MOSFET when the input voltage (V_{IN}) falls below the UVLO threshold. This device also offers a programmable UVLO threshold via the EN pin. Connect a voltage divider to the EN pin to monitor the input voltage. If EN drops below V_{ENF} (enable threshold, falling), the Power MOSFET will be turned off.

When maintaining the IN above the high UVLO upper threshold and EN above V_{ENR} (enable threshold, rising), the SQ24802K1 initiates the startup sequence and keeps the MOSFET in the ON state, ensuring power delivery from IN to OUT.

The design of both IN UVLO and EN includes hysteresis to prevent oscillation when the voltages at the IN or EN pins are near the threshold values.

Soft-start Time Programming

The SQ24802K1 integrates programmable output ramp control to minimize inrush current during startup. Connect a capacitor from SLEW to GND to control the slew rate of the output voltage at power-on. This pin can be left floating to obtain a predetermined slew rate (minimum t_R) on the output.

Recommended formula for calculating C_{SLEW} and Soft-start slew rate:

$$\text{Slew Rate}=\frac{32000}{C_{SLEW}(pF)}\left(\frac{V}{ms}\right)$$

$$t_R=0.8\times\frac{VIN}{\text{Slew Rate}}(ms)$$

FLT_N Response

The FLT_N open-drain output is pulled low during overtemperature condition. It is normally pulled high by an external pull-up resistor. The output will stay low until the fault condition is resolved. It is typically held high by an external pull-up resistor while in high-impedance state. The fault condition is cleared if the device loses power and T_J is below T_{SDHYS}. It is recommend that the pull up resistor is 100kΩ for 3.3V IO line.

Input Filter Capacitor

It is highly recommended to place a ceramic capacitor of 1μF or larger close to the device for optimal performance. The absence of an input capacitor can lead to ringing on the input in the event of an output short. This ringing can damage the internal circuitry if the input transient exceeds the absolute maximum supply voltage, even for a short duration..

Output Filter Capacitor

It is highly recommended to place a 1μF output ceramic capacitor close to the device and the output connector to reduce the voltage drop during load transients. Higher output capacitor values can further reduce the voltage drop. During a short-circuit scenario, parasitic wire inductance can pull the output to a negative voltage exceeding the normal operating conditions. A parallel Schottky diode is recommended to absorb large negative voltage transients, ensuring the output voltage remains within the absolute voltage ratings.

PCB Layout Guide

For the best performance of the SQ24802K1, the following guidelines must be strictly followed:

1. Keep all VBUS traces as short and wide as possible and use 2-ounce copper for connections.
2. Place the output capacitor as close to the connectors as possible to improve transient performance and reduce the impedance and inductance between the port and the capacitor.
3. The input and output capacitors should be placed closed to the device and connected to the ground plane to reduce noise coupling.

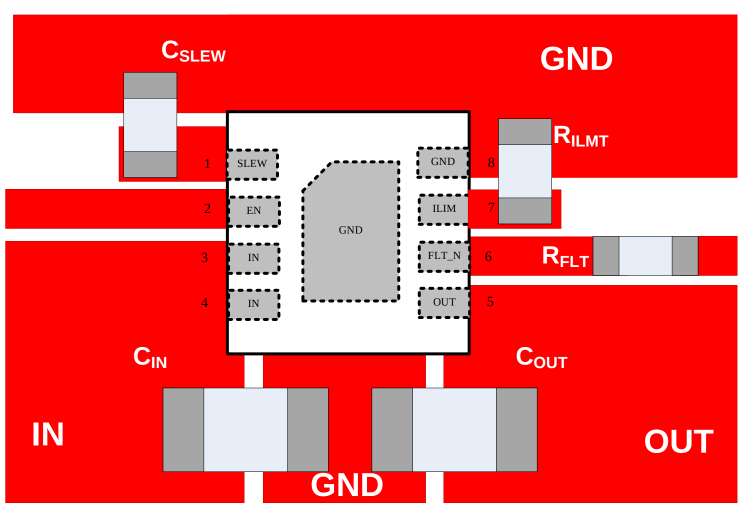
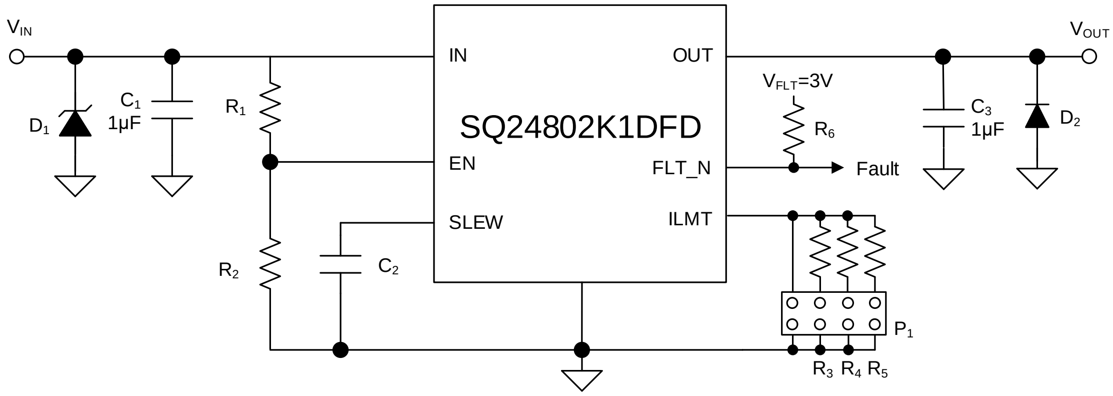


Figure7. PCB Layout Suggestion

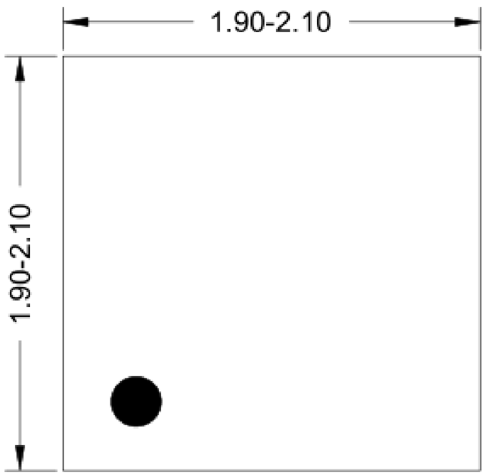
Schematic



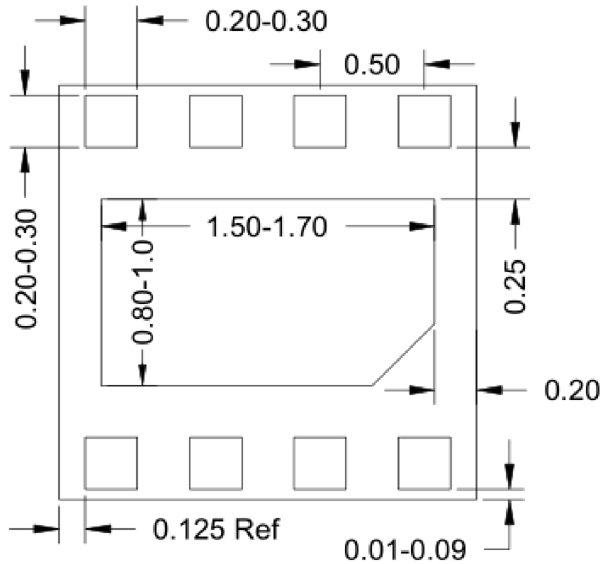
BOM List

Reference Designator	Description	Part Number	Manufacturer
C_1	1μF/25V, ±10%, X5R, 0805	GRM21BR61E105KA99L	Muruta
C_2	4.7nF/50V, ±10%, X7R, 0603	GRM188R71H472KA01D	Muruta
C_3	1μF/50V, ±10%, X5R, 1206	GRM31CR71H105KA61L	Muruta
R_1	91kΩ, 1%, 0.1W, 0603	RC0603FR-0791KL	YAGEO
R_2	12kΩ, 1%, 0.1W, 0603	RC0603FR-0712KL	YAGEO
R_3	487Ω, 1%, 0.1W, 0603	RC0603FR-07487RL	YAGEO
R_4	1780Ω, 1%, 0.1W, 0603	RC0603FR-071K78L	YAGEO
R_5	4420Ω, 1%, 0.1W, 0603	RC0603FR-074K42L	YAGEO
R_6	100kΩ, 1%, 0.1W, 0603	RC0603FR-07100KL	YAGEO
D_1	TVS(optional)		Any
D_2	Schottky(optional)		Any
P_1	Jumper, 2×4, Gold		Any

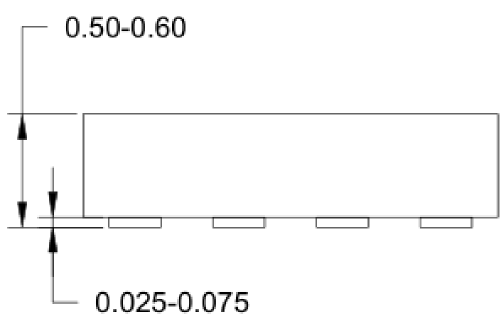
DFN2×2-8 Package Outline Drawing



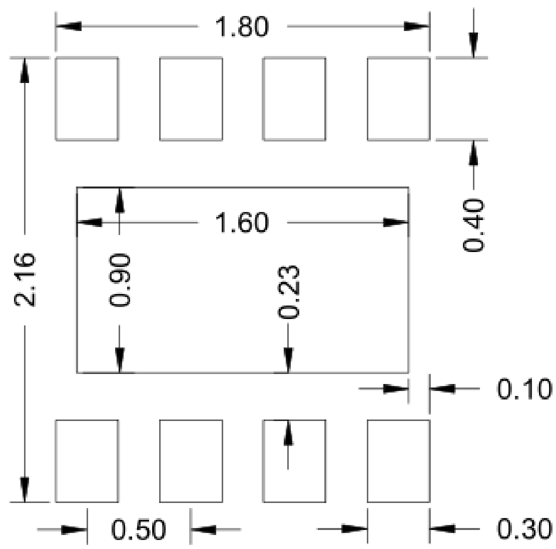
Top View



Bottom View



Side View

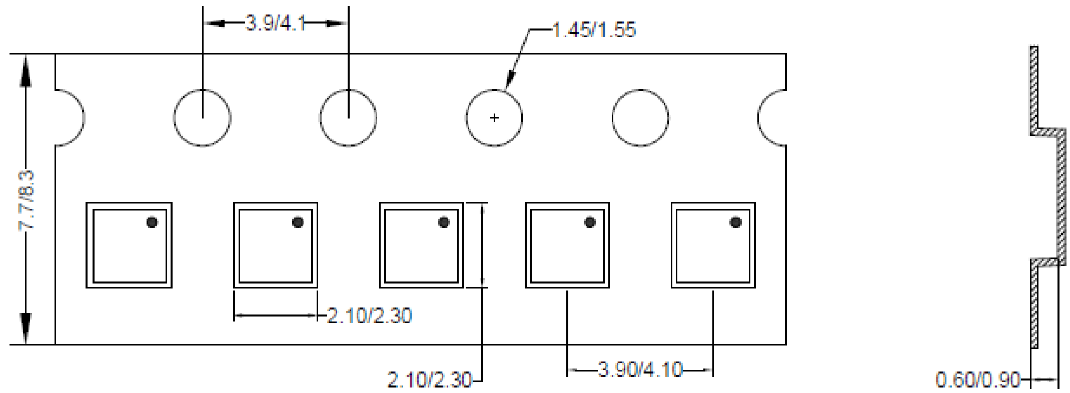


Recommended PCB layout
(Reference only)

Notes: All dimensions are in millimeters and don't include mold flash & metal burr.

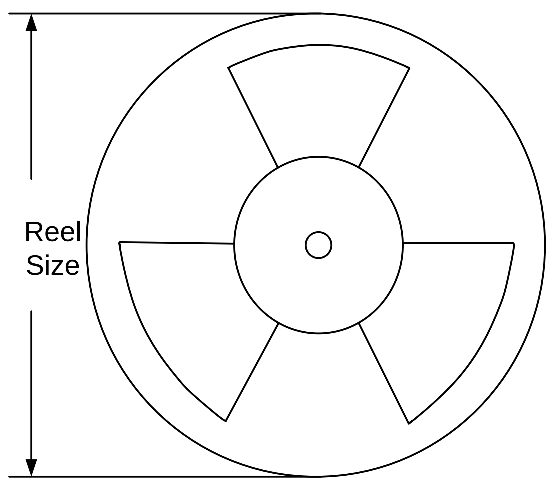
Taping & Reel Specification

1. DFN2×2-8 taping orientation



Feeding direction →

2. Carrier Tape & Reel specification for packages



Package types	Tape width (mm)	Pocket pitch(mm)	Reel size (Inch)	Trailer * length(mm)	Leader * length (mm)	Qty per reel (pcs)
DFN2×2-8	8	4	7"	280	160	3000

3. Others: NA

Revision History

The revision history provided is for informational purpose only and is believed to be accurate, however, not warranted. Please make sure that you have the latest revision.

Date	Revision	Change
Feb.23, 2024	Revision 1.0	Initial Release

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