DESCRIPTION

The A4778 is an integrated power switch for self-powered and bus-powered Universal Serial Bus (USB) applications. Several protection functions include current limit and thermal shutdown to prevent catastrophic switch failure caused by increasing power dissipation when continuous heavy load or short circuit occur.
A built-in 52mΩ P-channel MOSFET with true shutdown function to eliminate any reversed current flowing across the switch when the device is powered off. When the output voltage is higher than input voltage, the power switch will be turned off by the internal output reverse-voltage comparator. $\overline{FLG}$ is an open-drain output, which reports over-current or over-temperature event and has a typical 8ms deglitch timeout period. In addition, $\overline{FLG}$ also has typical 3ms deglitch timeout period and reports output reverse-voltage condition.

The A4778 is available in SOT-25 and MSOP8 Packages.

ORDERING INFORMATION

Package Type	Part Number	
SOT-25 SPQ: 3,000pcs/Reel	E5	A4778ZE5R-TD
		A4778ZE5VR-TD
MSOP8 SPQ: 3,000pcs/Reel	MS8	A4778ZMS8R-TD
		A4778ZMS8VR-TD
Note	Z: Continuous Current A : 1.5A / E : 2.1A F : 2.5A T: Active H: High; L: Low D: Output Discharge N: No Output Discharge Y: Output Discharge V: Halogen free Package R: Tape & Reel	
AiT provides all RoHS products		

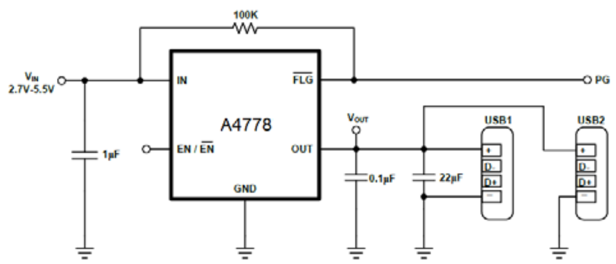
FEATURES

- "Best-in-Class" Quiescent Supply Current
- A4778A: 1.5 A Continuous Current
- A4778E: 2.1 A Continuous Current
- A4778F: 2.5 A Continuous Current
- 52mΩ High-side P-channel MOSFET Switch
- Available with Three Versions Built-in Current Limits
- Operating Range: 2.7V to 5.5V
- 0.2ms Typical Rise Time
- Fast Over-current Response 5μs (typ.)
- Under Voltage Lockout
- 1μA Maximum Shutdown Supply Current
- No Reverse Current when Power Off
- Output Reverse-voltage Protection
- Deglitched Open-drain Over-current Flag Output
- Enable Logic: Active-high or Active-low Versions
- Optional Feature: Output Auto Discharge
- Available in SOT-25 and MSOP8 Packages

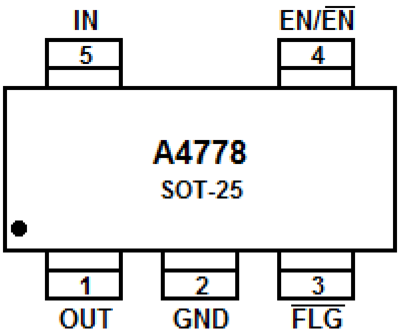
APPLICATION

- High-Side Power Protection Switch
- USB Host and Self-Powered Hubs
- USB Bus-Powered Hubs
- Set Top Box
- Smart TV
- MID and Notebook Computer

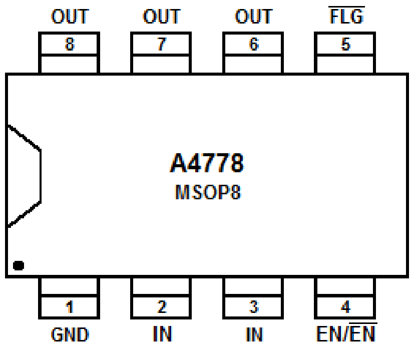
TYPICAL APPLICATION



PIN DESCRIPTION



Top View



Top View

Pin #		Symbol	Function
SOT-25	MSOP8		
1	6,7,8	OUT	Switch Output: Connected to the drain of the internal MOSFET. Typically connect to switched side of load.
2	1	GND	Ground.
3	5	$\overline{FLG}$	Open-drain Fault Flag Output. 3ms delay for thermal shutdown.
4	4	EN($\overline{EN}$)	Enable: Logic level enable input. Make sure EN pin never floating.
5	2,3	IN	Input Supply: Connected to the Source of the internal MOSFET and provides internal DC current to operate the control circuitry.

ABSOLUTE MAXIMUM RATINGS

IN	-0.3V ~ 7V
OUT	-0.3V ~ V_{IN}
EN/ $\overline{EN}$	-0.3V ~ V_{IN}+0.3V
$\overline{FLG}$	-0.3V ~ V_{IN}+0.3V
ESD Rating per ESDA/JEDEC JDS-001-2014	
Human Body Mode	±6kV[NOTE1]
ESD Ratings per IEC61000-4-2[NOTE2]	
Contact Discharge	±8kV
Air Discharge	±15kV
Package Thermal Resistance [NOTE3]	
θ_{JA}, SOT-25	250°C/W
θ_{JA}, MSOP8	200°C/W
θ_{JC}, SOT-25	60°C/W
θ_{JC}, MSOP8	55°C/W
Continuous Power Dissipation (T_A = 25°C)	
SOT-25	0.5W
MSOP8	0.6W
Max Junction Temperature[NOTE4]	150°C
T_S, Storage Temperature	-65°C ~ +150°C
Lead Temperature (Soldering 10 sec.)	260°C

Stress beyond above listed “Absolute Maximum Ratings” may lead permanent damage to the device. These are stress ratings only and operations of the device at these or any other conditions beyond those indicated in the operational sections of the specifications are not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

OPERATING RATINGS

Parameter	Symbol	Min	Max	Unit
Supply Voltage	V_{IN}	2.7	5.5	V
Operating Temperature	T_A	-40	85	°C

ELECTRICAL CHARACTERISTICS[NOTE5]

V_{IN} = 5V, C_{IN}=1μF, C_{OUT}=1μF, T_A = 25°C, unless otherwise noted.

Parameter	Symbol	Conditions		Min	Typ.	Max	Unit
Input Supply Voltage							
Input Voltage	V_{IN}			2.7	-	5.5	V
Quiescent Current	I_{IN_ON}	V_{IN}=5.5V, I_{OUT} = 0mA		-	30	-	μA
Shutdown Current	I_{IN_OFF}	V_{IN}=5.5V, I_{OUT} = 0mA		-	0.1	1	μA
Output Leakage Current	$I_{LEAKAGE}$	V_{OUT}=5.5V, V_{IN}=0V		-	2	5	μA
UVLO Threshold	V_{UVLO_ON}	V_{IN} Rising		-	2.45	2.60	V
UVLO Hysteresis	V_{UVLO_HYS}			-	25	-	mV
Power switch							
Output MOSFET	$R_{DS(ON)}$	I_{LOAD}=1A		30	52	85	mΩ
Enable and Soft-start							
Enable High Level Threshold	V_{EN_H}	V_{IN}=5.5V		1.2	-	-	V
Enable Low Level Threshold	V_{EN_L}	V_{IN}=2.5V		-	-	0.7	V
EN Input Current	I_{EN}	V_{EN}=5.5V or 0V		-0.5	5	10	μA
Turn-On Time	t_{ON}	C_L=1μF, R_{LOAD}=100Ω		-	0.2	-	ms
Turn-Off Time	t_{OFF}	C_L=1μF, R_{LOAD}=100Ω		-	0.3	-	ms
Output and Current Limit							
Over Current CC Regulation	I_{LIMIT}	V_{IN} = 5V, V_{OUT}=3.5V	A4778F	3.1	3.2	3.7	A
			A4778E	2.6	2.75	2.9	A
			A4778A	1.8	2.0	2.2	A
Reverse Voltage Protection	$V_{REVERSE}$	V_{OUT}-V_{IN}		5	20	50	mV
Reverse Current Protection	$I_{REVERSE}$			0.1	0.4	1	A
Output Rise Time	t_R	C_{OUT}=1μF, R_{LOAD}=100Ω		-	0.1	-	ms
Output Fall Time	t_F	C_{OUT}=1μF, R_{LOAD}=100Ω		-	0.3	-	ms
Output Auto Discharge Resistance	R_{OUT}	Optional feature, V_{IN} = 5V, V_{OUT} = 5V, Shutdown Mode		-	300	-	Ω

Parameter	Symbol	Conditions	Min	Typ.	Max	Unit
FAULT FLAG $\overline{FLG}$						
Output low Voltage	V_{FLG_LOW}	I_{FLG}=1mA	-	-	180	mV
Continuous Sink Current	I_{FLG_SINK}		-	-	10	mA
Off-state Leakage	$I_{FLG\_LEAKAGE}$		-	-	1	μA
FLG Deglitch Time	t_{FLG}		-	8	-	ms
Thermal Shutdown						
Thermal Shutdown Threshold NOTE6	T_{SD}		-	150	-	℃
Thermal Shutdown Hysteresis NOTE6	T_{SD_HYS}		-	20	-	℃
Thermal shutdown Threshold in Current Limit NOTE6	$T_{CURRENT\_LIMIT}$		-	130	-	℃

NOTE1: Class 3A per ESDA/JEDEC JDS-001-2014 classification.

NOTE2: Output was surged on the EVM with input and output bypassing per the Typical Application Circuit on the first page with no device failures.

NOTE3: Thermal Resistance is measured in the natural convection at TA = 25 °C on a low effective single layer thermal conductivity test board of JEDEC 51-3 thermal measurement standard.

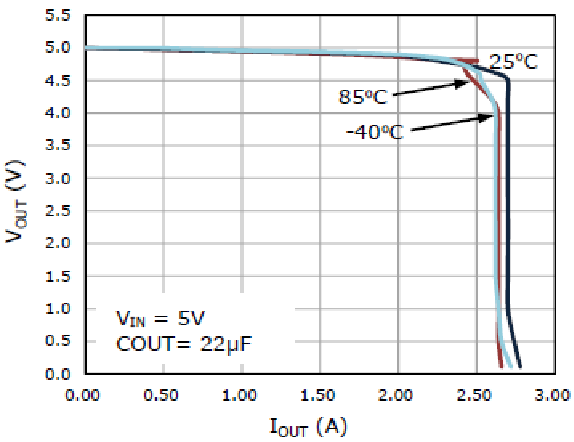
NOTE4: T_J is calculated from the ambient temperature T_A and power dissipation P_D.

NOTE5: 100% production test at +25°C. Specifications over the temperature range are guaranteed by design and characterization. The device is not guaranteed to function outside its operating conditions.

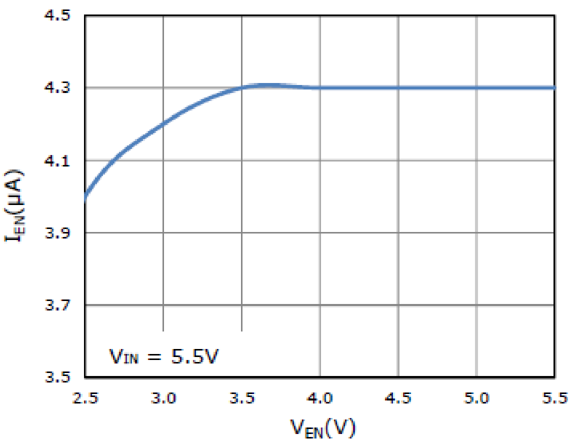
NOTE6: Guaranteed by design and characterization only.

TYPICAL PERFORMANCE CHARACTERISTICS

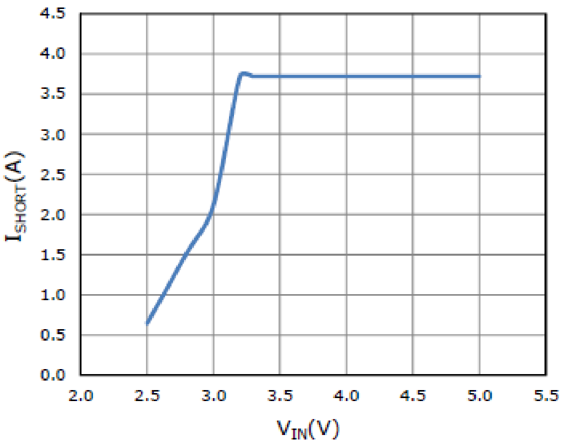
1. Over-current Protection Characteristics (A4778E)



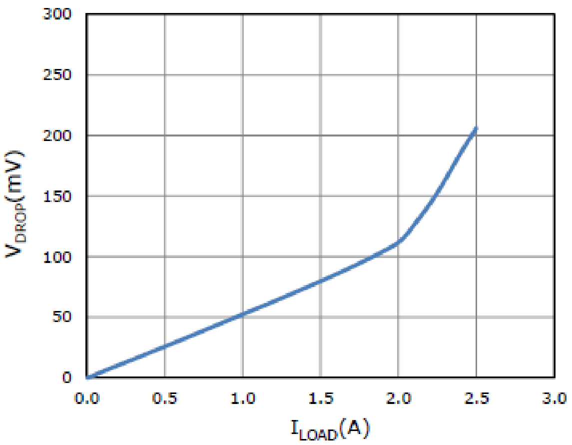
2. I_{EN} vs. V_{EN} Characteristics



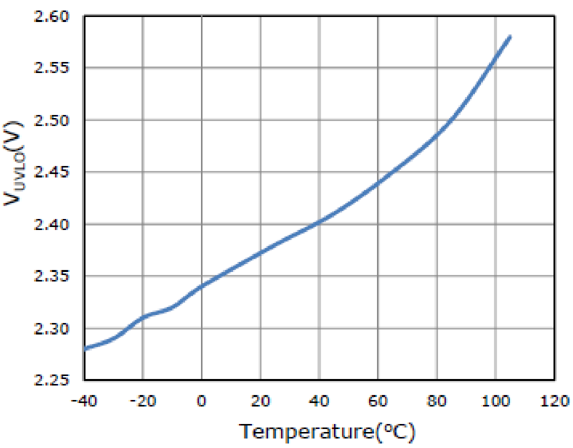
3. Short Circuit Output Current (A4778E)



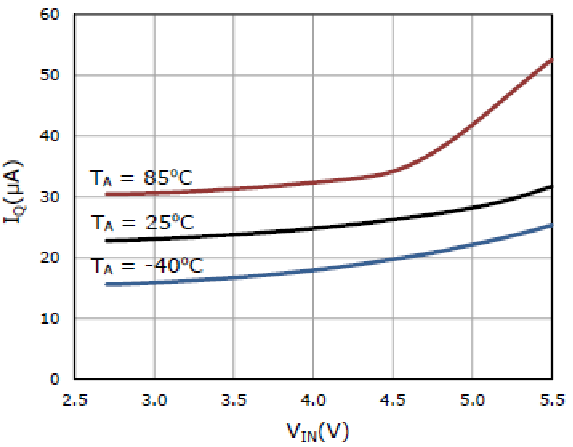
4. Voltage Drop vs. I_{LOAD}



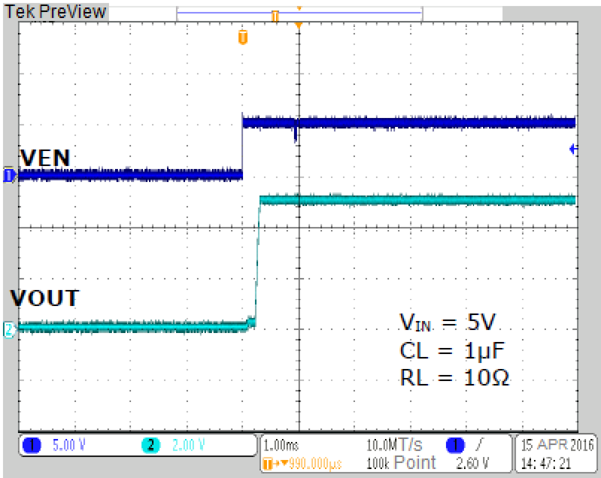
5. UVLO Voltage



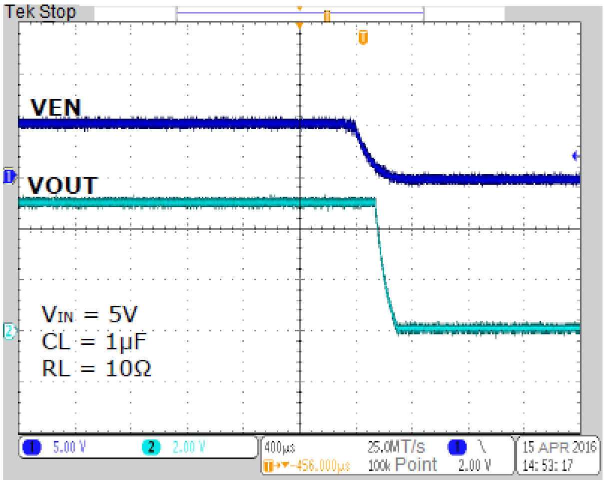
6. Quiescent Supply Current



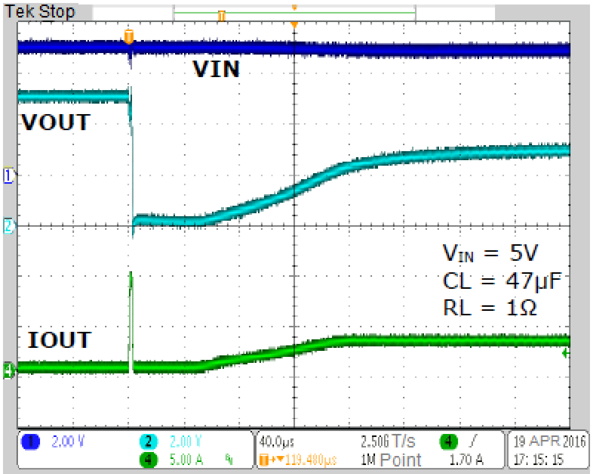
7. Turn on Delay Time and Rise Time



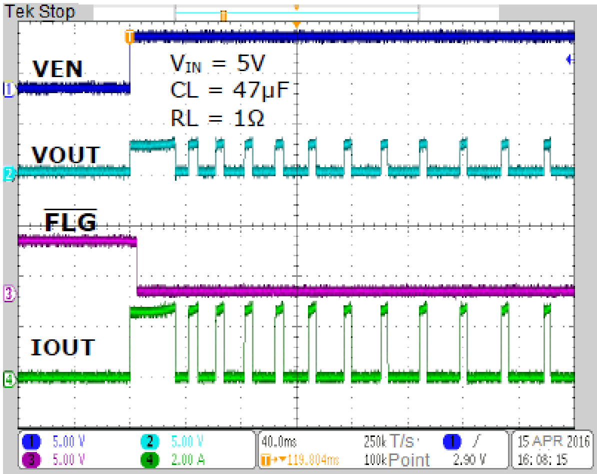
8. Turn off Delay Time and Fall Time



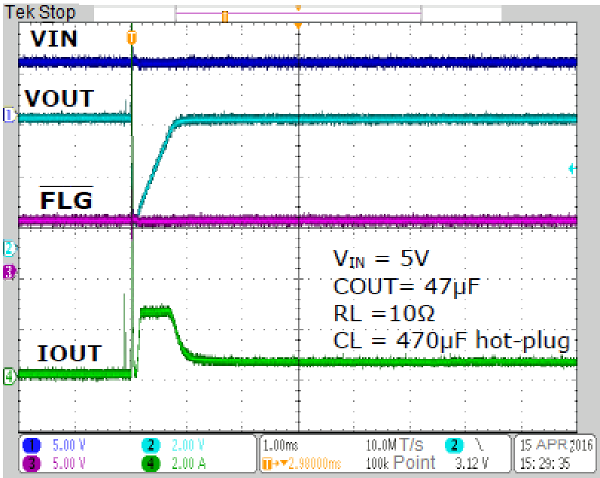
9. Resistance Load Inrush Response



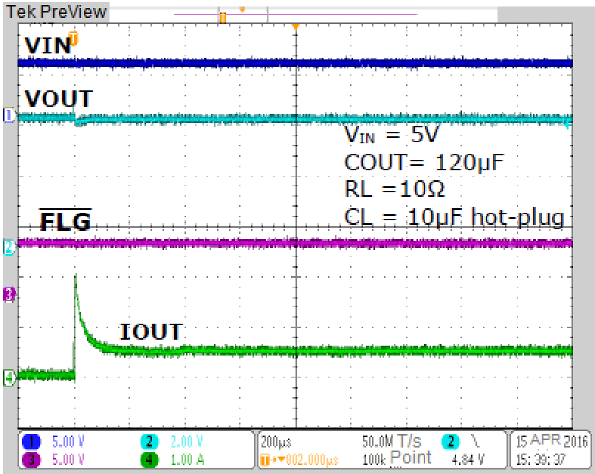
10. Thermal Shutdown Response



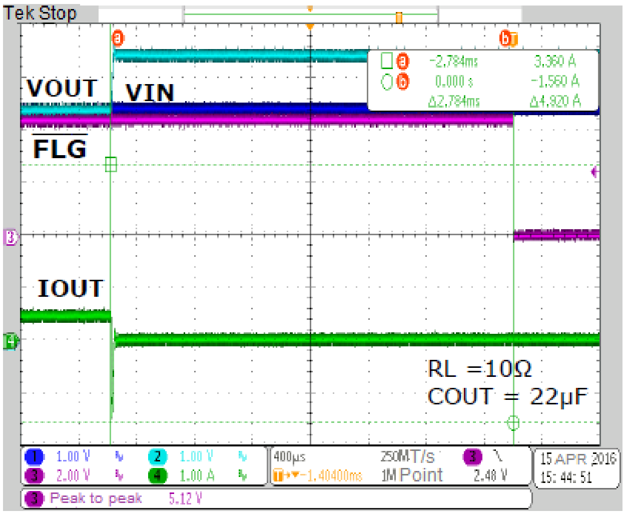
11. Capacitance Load Inrush Response



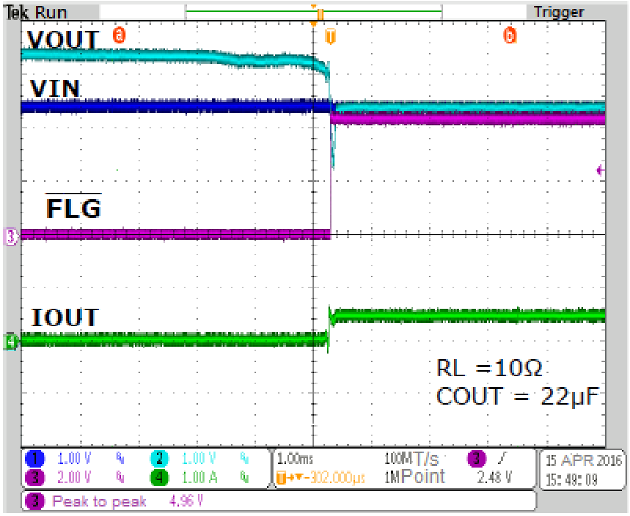
12. Capacitance Load Inrush Response



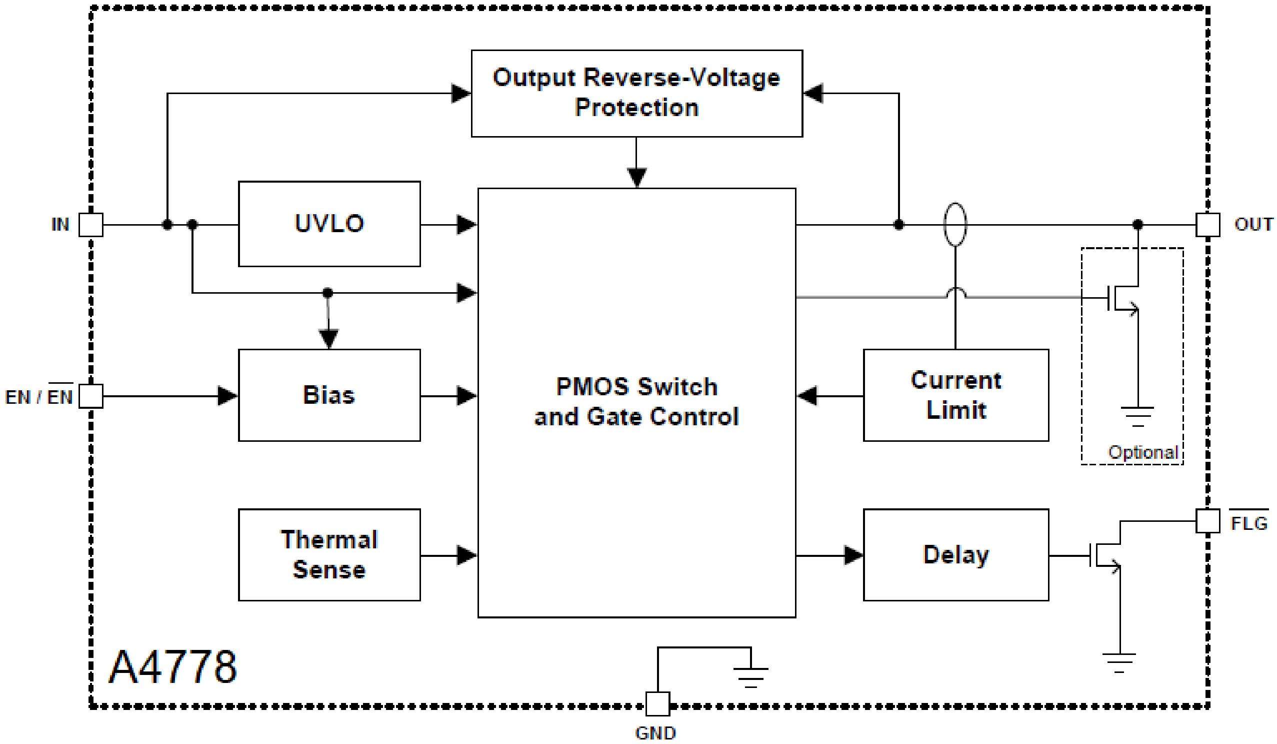
13. Reverse-Voltage Protection Response



14. Reverse-Voltage Protection Recovery



BLOCK DIAGRAM



DETAILED INFORMATION

Input and Output

IN (input) is the power supply connection to the logic circuitry and the source of the internal P-channel MOSFET. OUT (output) is the drain of the internal P-channel MOSFET. In a typical application, current flows through the switch from IN to OUT toward the load.

Thermal Shutdown

The A4778 protects itself with two independent thermal sensing circuits that monitor the operating temperature of the power-switch and disables operation if the temperature exceeds recommended operating conditions. The device operates in constant-current mode during an over-current condition, which increases the voltage drop across power-switch. The power dissipation in the package is proportional to the voltage drop across the power-switch, so the junction temperature rises during an over-current condition. The first thermal sensor turns off the power-switch when the die temperature exceeds 130°C and the device is in current limit. The second thermal sensor turns off the power-switch when the die temperature exceeds 150°C regardless of whether the power-switch is in current limit. Hysteresis is built into both thermal sensors, and the switch turns on after the device has cooled down approximately 20°C (thermal shutdown threshold hysteresis in current-limit is 20°C). The switch continues to cycle off and on until the fault is removed. The open-drain $\overline{\text{FLG}}$ is asserted (active low) immediately during an over-temperature shutdown condition.

Under-voltage Lockout

UVLO (under-voltage lockout) prevents the internal MOSFET switch from turning on until V_{IN} (input voltage) exceeds 2.45V typically. After the switch turns on, if the input voltage drops below 2.425V typically, UVLO shuts off the switch.

Output Reverse-Voltage Protection

The output reverse-voltage protection turns off the MOSFET switch whenever the output voltage is higher than the input voltage by 20mV (typ.) and the MOSFET switch will turn on when output reverse-voltage condition is removed.

$\overline{\text{FLG}}$ Function

The $\overline{\text{FLG}}$ open-drain output is asserted (active low) when an over current condition is encountered after a 8ms deglitch timeout. The typical trigger point of A4778F is above 2.6A, A4778E is above 2.2 A, A4778A is above 1.6A. The $\overline{\text{FLG}}$ output remains asserted until the overcurrent condition is removed. Over temperature condition is also reported by $\overline{FLG}$ open-drain output. In addition, $\overline{FLG}$ is also asserted in output reverse-voltage condition.

Supply Filtering

A 1µF bypass capacitor from IN pin to GND pin, located near the A4778, is strongly recommended to control supply transients. Without a bypass capacitor, an output short may cause sufficient ringing on the input (from supply lead inductance) to damage internal control circuitry. Input transients must not exceed the absolute maximum supply voltage (V_{IN_MAX} = 7V) even for a short duration.

Enable Input

EN (enable) must be driven by a 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.

Short Circuit Condition

The current limit circuitry prevents the power-switch from damage due to overcurrent. When a heavy load or short circuit is applied to the output, a large transient current may flow through until the circuitry responses. Once the circuitry responds, it limits the output current to I_{SC}. Since the current-sense amplifier is overdriven during this time and the power-switch is disabled momentarily, the output current drops to nearly zero. The current-sense amplifier recovers and ramps the output current to I_{OS}. The output current keep at I_{OS} until the short circuit condition is removed or the device begins to thermal cycle. The duration and the amplitude of the large transient current at short circuit moment vary with the measurement setup and the external components, especially ESR of input capacitor. Figure 2 shows the recommended setup to measure the short circuit characteristic. The 'Short Device' in Figure 2 should be a low $R_{DS(ON)}$, high current and low gate charge N-channel MOSFET to simulate the real situation.

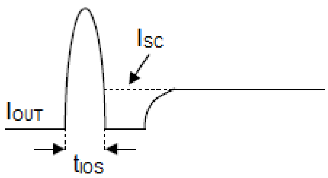


Figure 1. Output Current at Short Circuit Moment

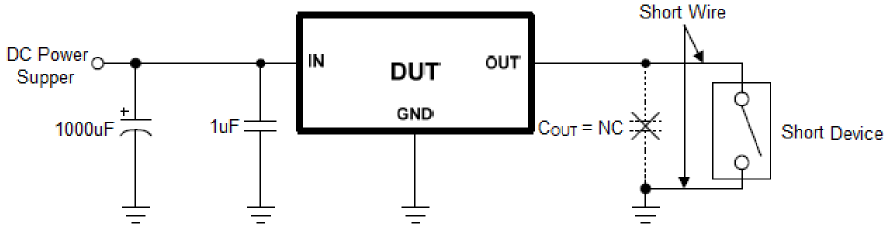


Figure 2. Setup to Measure the Short Circuit Characteristic

Note:
In order to identify the short circuit characteristic of the IC, avoid the interferences of parasitic inductor, output capacitor and contact resistance. It is recommended following the procedures below:
1. Add 1000μF of capacitor between V_{IN} and GND, and close to IC.
2. Remove output capacitor.
3. Short the output by using the Short Device.
4. Measure output current (I_{OUT}).

Layout Considerations

For best performance of the A4778 series, the following guidelines must be strictly followed:

1. Input and output capacitors should be placed close to the device and connected to ground plane to reduce noise coupling.
2. The GND pin should be connected to a strong ground plane for heat sink.
3. Keep the main current traces as short as possible and wide.

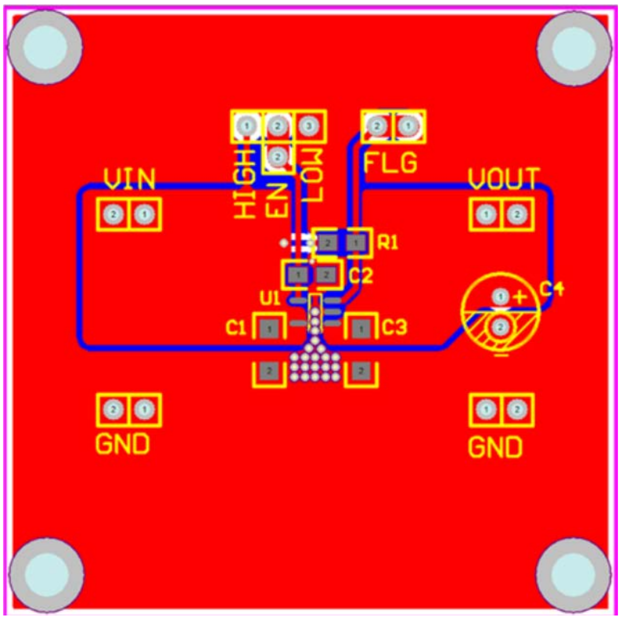
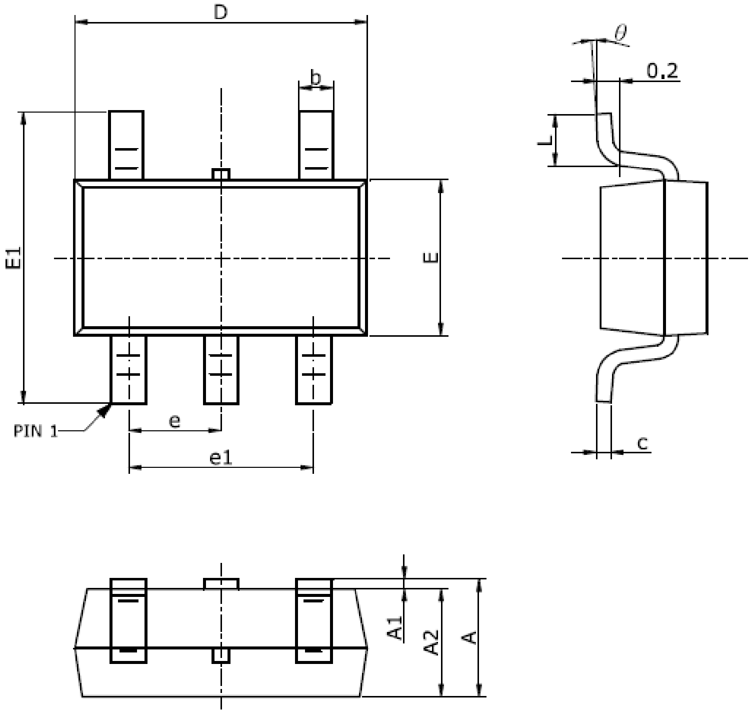


Figure 3. Recommended PCB Layout

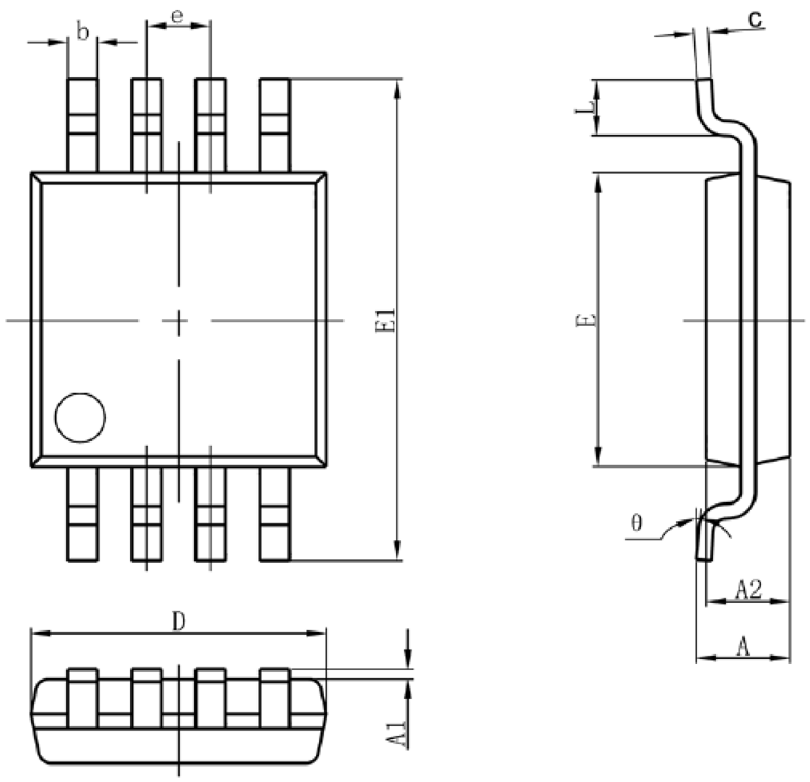
PACKAGE INFORMATION

Dimension in SOT-25 (Unit: mm)



Symbol	Millimeters		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	2.850	3.050	0.112	0.120
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	1.800	2.000	0.071	0.079
L	0.300	0.600	0.012	0.024
θ	0°	8°	0°	8°

Dimension in MSOP8 (Unit: mm)



Symbol	Millimeters		Inches	
	Min	Max	Min	Max
A	0.820	1.100	0.032	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
e	0.650(BSC)		0.026(BSC)	
E	2.900	3.100	0.114	0.122
E1	4.750	5.050	0.187	0.199
L	0.400	0.800	0.016	0.031
θ	0°	6°	0°	6°

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