## DESCRIPTION

The A4788 is intended for applications where heavy capacitive loads and short circuits are likely to be encountered. The A4788 is an integrated 80mΩ (TYP) power switch for self-powered and bus powered universal series bus (USB) applications.

The A4788 is internally current limited and has thermal shutdown function to protect device and load from over-current damage. Thermal shutdown shuts off the output MOSFET and asserts the flag pin output if the die temperature exceeds 150°C until the die temperature drops to 130°C.

The soft-start circuit can minimize inrush current in applications where highly capacitive loads are employed.

The flag pin asserts low when during over-current and thermal conditions after a 13ms blanking time to prevent false reporting.

The A4788 is available in SOT-25 packages.

## ORDERING INFORMATION

| Package Type | Part Number | |
|---|---|---|
| SOT-25<br>SPQ:3,000/Reel | E5 | A4788E5R-X |
| | | A4788E5VR-X |
| Note | X=Maximum Current<br>A:1.1A<br>B:2.1A<br>C:2.6A<br>V: Halogen free Package<br>R: Tape & Reel | |
| AiT provides all RoHS products | | |

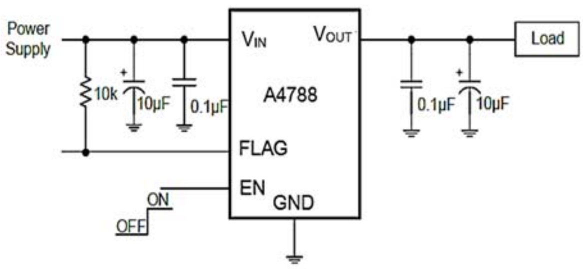
## FEATURES

- 80mΩ (TYP) High-side P-Channel MOSFET
- Low Quiescent Current
- Input Voltage from 2.5V to5.5V
- Three Current Limit Levels
  1.1A, 2.1A, 2.6A
- Maximum Shutdown Current ≤1uA
- Soft-Start Function
- Under-Voltage Lockout Protection for $V_{IN}$
- No Reversed Leakage Current
- Thermal Shutdown Protection
- Fast turn on response
- Operation temperature from -40°C to 85°C

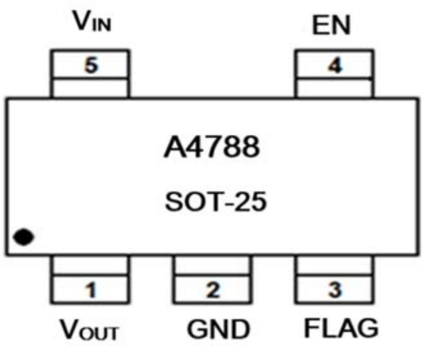
## APPLICATION

- Smart Phone & LCD TV
- Set-Top-Box
- VOIP
- USB Bus/Self Powered Hubs/Peripherals
- Portable Consumer or Medical Products

## TYPICAL APPLICATION



## PIN DESCRIPTION




SOT-25, E5
Top View

| Pin# SOT-25 | Symbol | Function |
|---|---|---|
| 1 | $V_{OUT}$ | Switch Output. The P-Channel Drain of Switch, Which Typically Connects to Load. |
| 2 | GND | Ground |
| 3 | FLAG | Flag pin. Active low, open-drain output. Indicates over-current or thermal shutdown conditions. Over-current condition must last longer than $t_D$ in order to assert Flag. |
| 4 | EN | Enable Input. Logic Level Enable Input, Active high available. |
| 5 | $V_{IN}$ | Power Supply Input. The P-Channel Source of Switch, Which also supplies IC's internal circuitry. Connect to Positive Supply. |

## ABSOLUTE MAXIMUM RATINGS

over operating free-air temperature range, (unless otherwise noted)*

| | | |
|---|---|---|
| $V_{IN}$, Supply Input Voltage | | -0.3V ~ 6.0V |
| $V_{OUT}$, Output Voltage | | -0.3V ~ 6.0V |
| $V_{EN}$, EN Input Voltage | | -0.3V ~ 6.0V |
| $V_{FLAG}$, FLAG Output Voltage | | -0.3V ~ 6.0V |
| $T_J$, Operating Junction Temperature | | -40℃ ~ 150℃ |
| $T_{STG}$, Storage Temperature | | -65℃ ~ 150℃ |
| $T_L$, Lead Temperature Soldering, 10secs | | 260℃ |
| **ESD Ratings** | | |
| $V_{(ESD)}$, Electrostatic Discharge | Human-body model (HBM) | ±3000V |
| | Charge device model (CDM) | ±1500V |

*Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under Recommended Operating Conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
*Voltages are with respect to the GND pin.

## RECOMMENDED OPERATING CONDITIONS

Over operating free-air temperature range (unless otherwise noted)

| Parameter | Symbol | Min. | Max. | Unit |
|---|---|---|---|---|
| Input Voltage | $V_{IN}$ | 2.5 | 5.5 | V |
| EN Voltage range | $V_{EN}$ | 0 | 5.5 | V |
| All other pins | | 0 | 5.5 | V |
| Operating temperature | $T_A$ | -40 | +85 | ℃ |
| Operating Junction Temperature Range | $T_J$ | -40 | +125 | ℃ |

## ELECTRICAL CHARACTERISTICS

$V_{IN}$=2.5V~5.5V , typical values are at $V_{IN}$=5V, $T_A$ = 25°C, unless otherwise noted.

| Parameter | | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{IN}$ | Input Voltage | | 2.5 | - | 5.5 | V |
| $I_Q$ | Quiescent supply current | Switch on, $V_{OUT}$ = open | - | 30 | - | μA |
| $I_{SD}$ | Shutdown supply current | Switch off, $V_{OUT}$ = open | - | 0.1 | - | μA |
| $I_{LKG(VIN)}$ | Leakage current of VIN & FLAG | Switch off, $V_{OUT}$ = 0V | - | 0.1 | 10 | μA |
| $V_{OC-L}$ | FLAG Output Low Voltage | $C_{IN}$=10uF, $I_{SINK}$ =2mA | - | - | 0.4 | V |
| $V_{IL}$ | Enable input threshold | $V_{IN}$ =2.5V to 5.5V | - | - | 0.4 | V |
| $V_{IH}$ | | $V_{IN}$ =2.5V to 5.5V | 16 | - | - | V |
| $I_{EN}$ | EN input current | $V_{EN}$=0V to 5.5V | - | 10 | - | μA |
| $R_{DS(ON)}$ | Switch resistance | $I_{OUT}$ = 500mA | - | 80 | - | mΩ |
| $t_{ON}$ | Output turn-on delay time | $R_L$ =10Ω, $C_L$ =1μF | - | 2 | - | ms |
| $t_{OFF}$ | Output turn-off delay time | $R_L$ =10Ω, $C_L$ =1μF | - | 20 | - | μs |
| A4788-A | Current limit threshold | Ramped load | - | 1.1 | - | A |
| A4788-B | | | - | 2.1 | - | A |
| A4788-C | | | - | 2.6 | - | A |
| $t_D$ | Over-current FLAG response delay time | Apply $V_{OUT}$= 0 until FLAG is low | - | 13 | - | ms |
| $R_{FLAG}$ | FLAG output resistance | FLAG is low and $I_{SINK}$ =10mA | - | 20 | - | Ω |
| $R_{DIS}$ | $V_{OUT}$ shutdown discharge resistance | Switch off | - | 300 | - | Ω |
| $T_{SD}$ | Thermal shutdown temperature | $T_J$ Increasing | - | 150 | - | ℃ |
| $T_{SD\_HY}$ | Thermal shutdown hysteresis | Apply $V_{OUT}$= 0 until FLAG is low | - | 30 | - | ℃ |

## TYPICAL PERFORMANCE CHARACTERISTICS

Fig1 Turn-On Rise Time vs Temperature

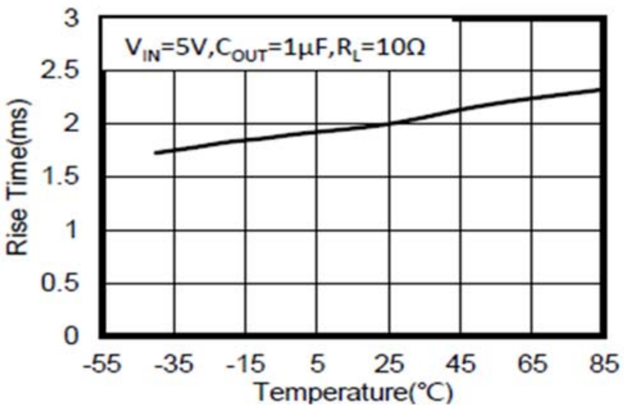



Fig2 Turn-On Rise Time vs Input Voltage

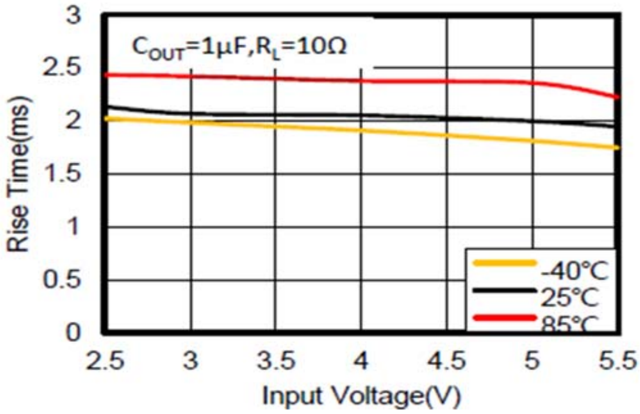



Fig3 Turn-Off Fall Time vs Temperature

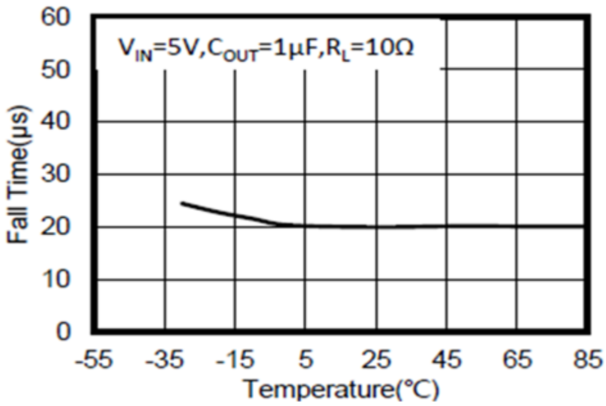



Fig4 Turn-Off Fall Time vs Input Voltage

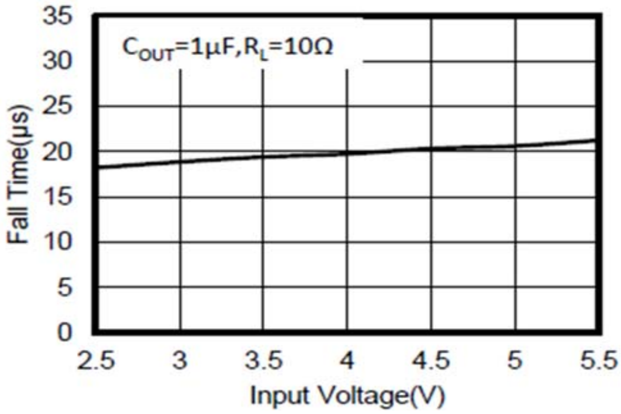



Fig5 UVLO Threshold vs Temperature

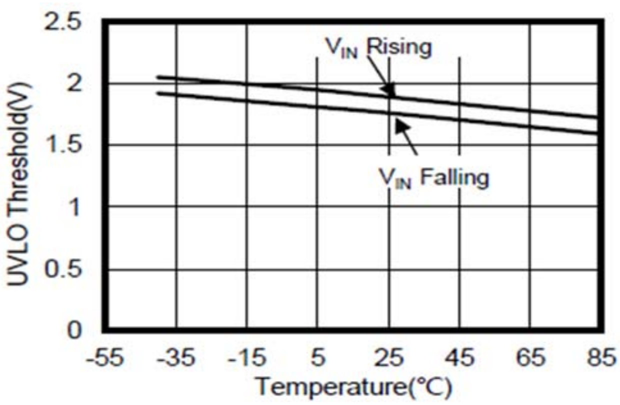



Fig6 Output Leakage Current vs Temperature

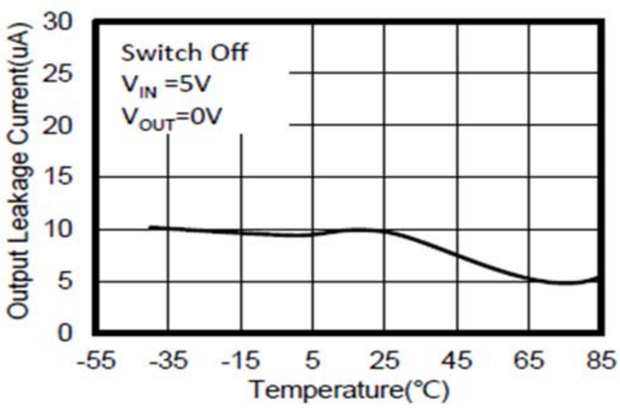


Fig7 Shutdown Supply Current vs Temperature

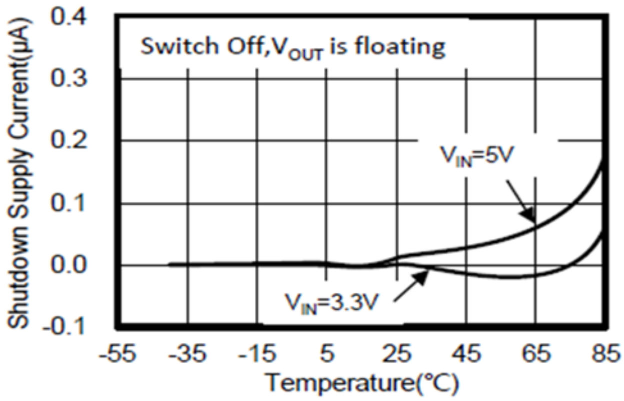



Fig8 Shutdown Supply Current vs Input Voltage

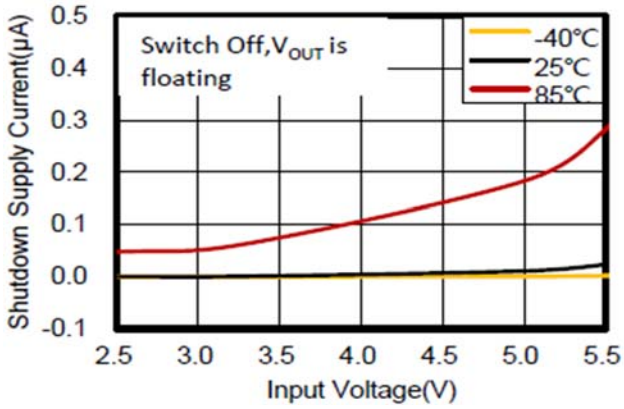



Fig9 Quiescent Supply Current vs Temperature

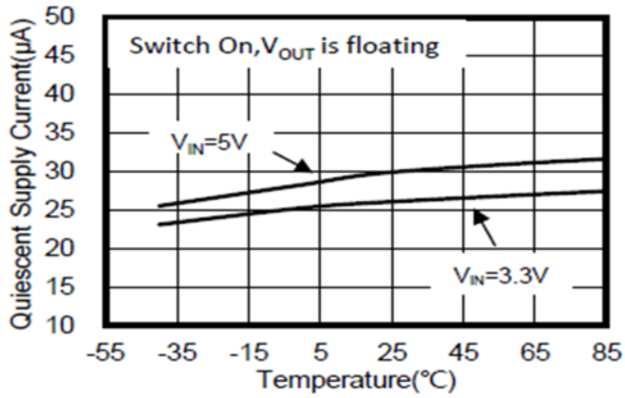



Fig10 Quiescent Supply Current vs Input Voltage

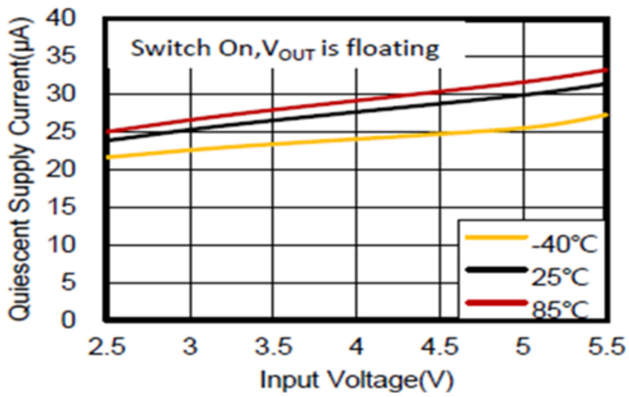



Fig11 Enable Threshold vs Temperature

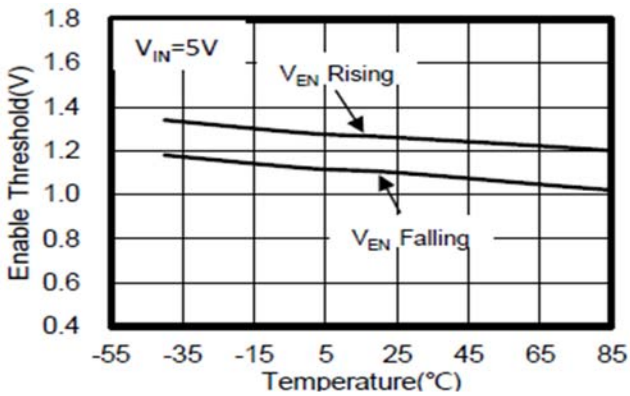



Fig12 Enable Threshold vs Input Voltage

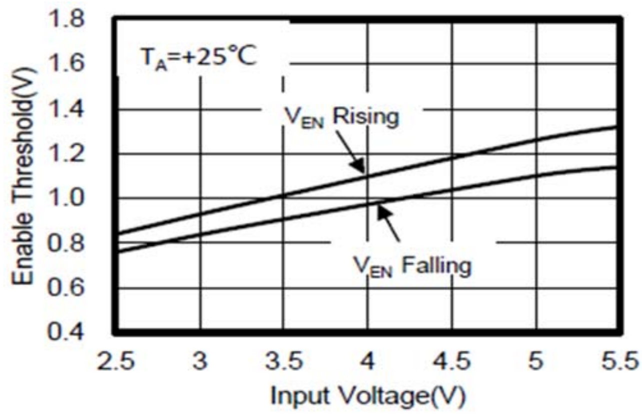


Fig13 On Resistance vs Temperature

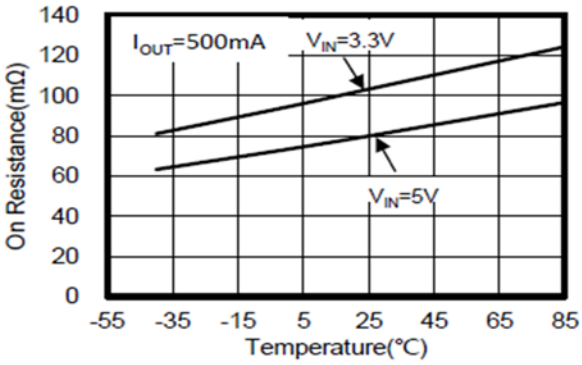



Fig14 On Resistance vs Input Voltage

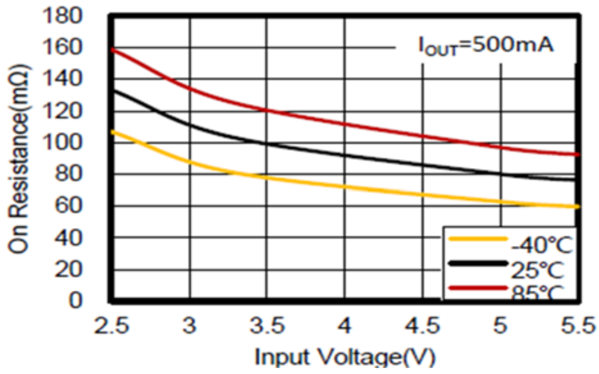



Fig15 FLAG Response Delay Time vs Temperature

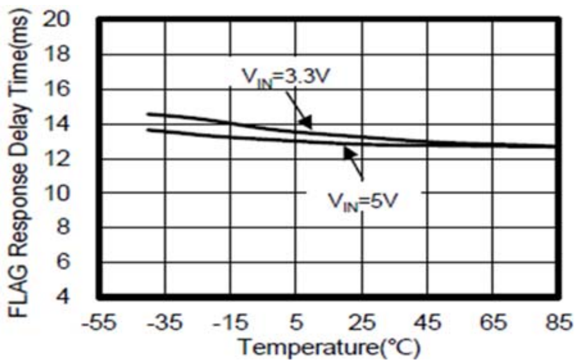



Fig16 FLAG Response Delay Time vs input Voltage

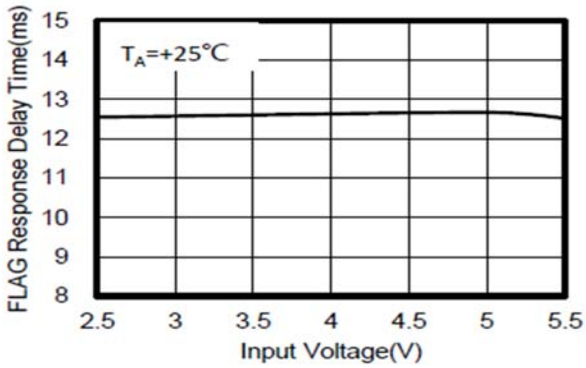



Fig17 Short-Circuit Current Limit vs Temperature

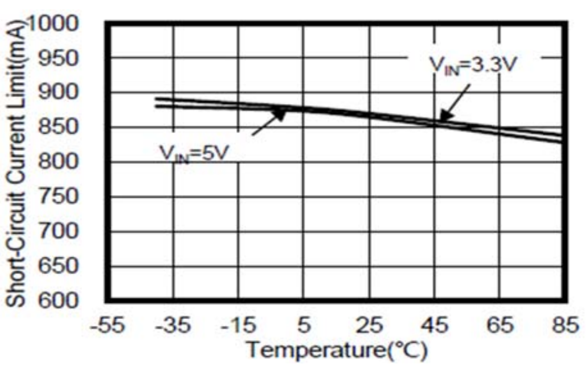



Fig18 Short-Circuit Current Limit vs Input Voltage

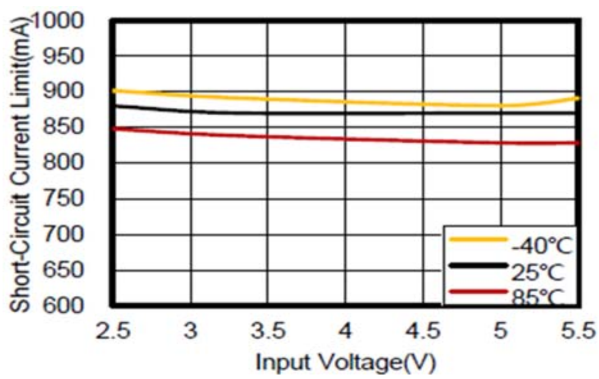


Fig19 Current Limit Threshold vs Temperature

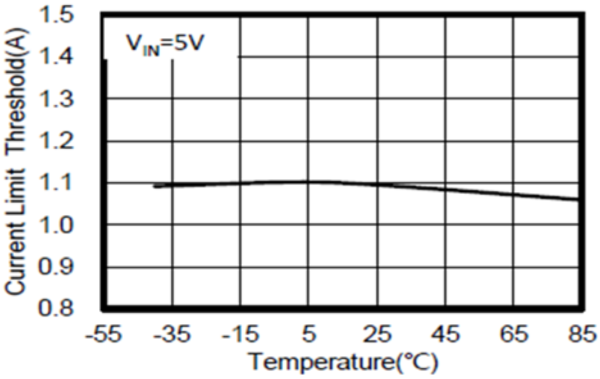



Fig20 Current Limit Threshold vs Temperature

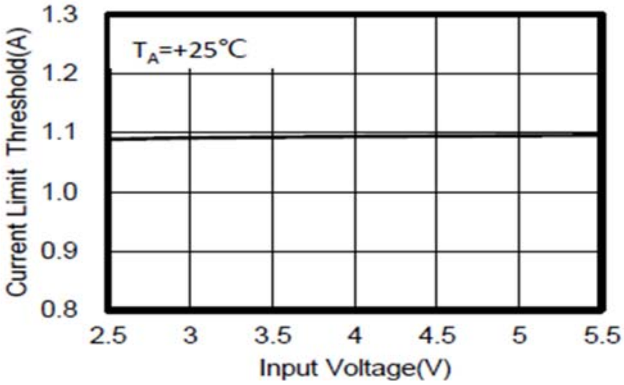



Fig21 Turn-On Response

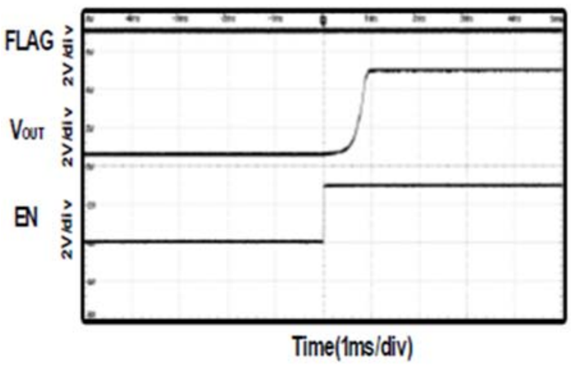



Fig22 Turn-Off Response

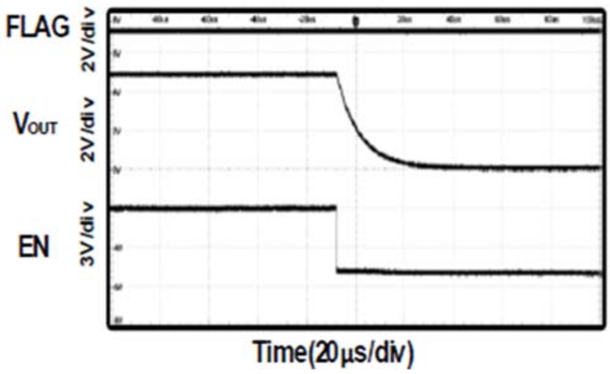



Fig23 UVLO at $V_{IN}$ Rising

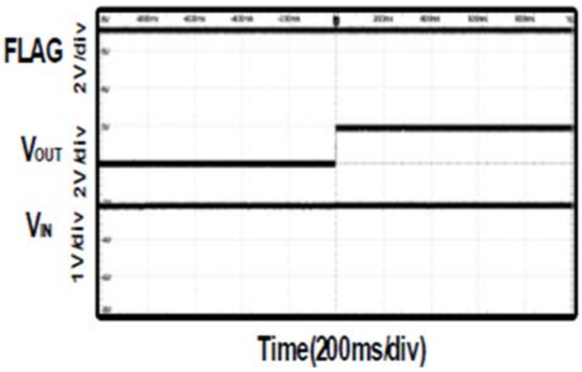



Fig24 UVLO at $V_{IN}$ Falling

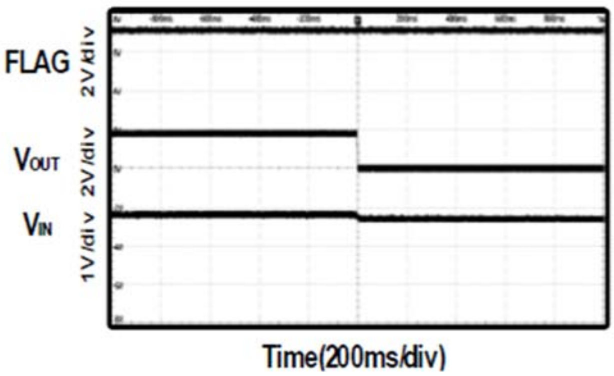


Fig25 NO Loaf into Short-Circuit

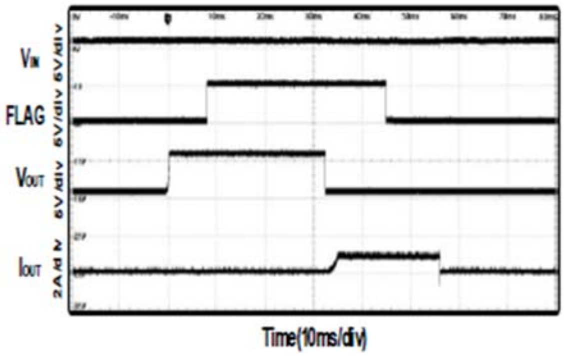



Fig26 Device Enabled into Short-Circuit

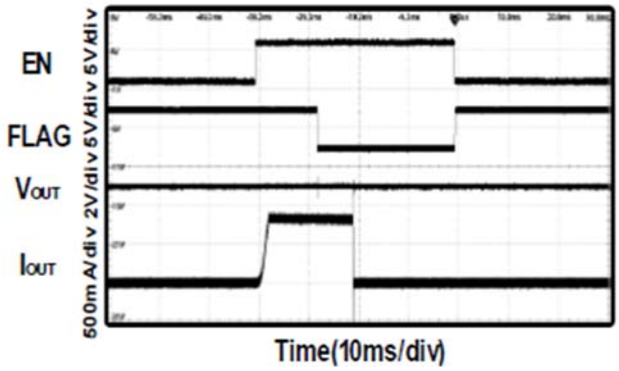
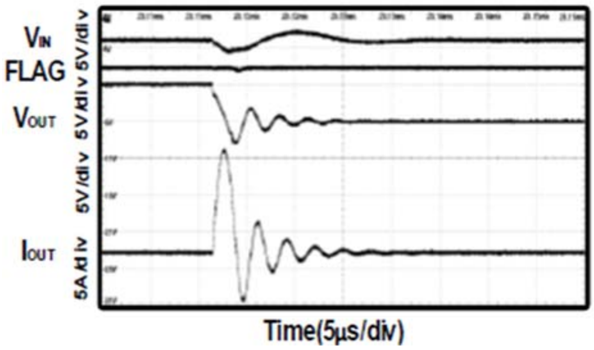
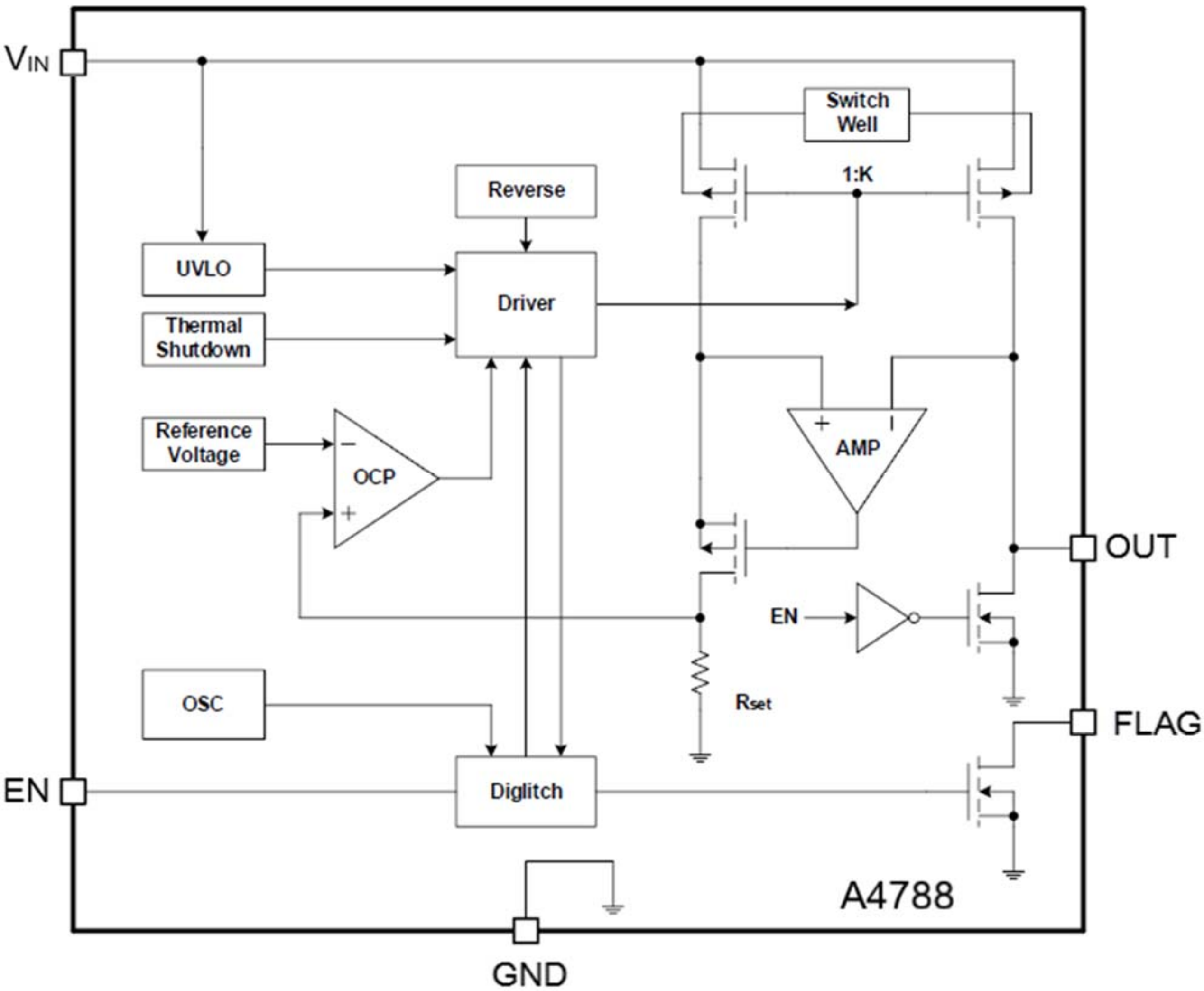



Fig27 Short-Circuit Response Time



## BLOCK DIAGRAM



## PARAMETER MEASUREMENT INFORMATION

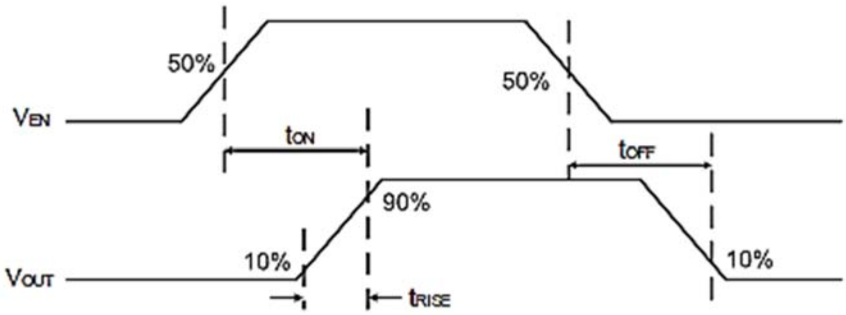



Fig1 Switch Turn-On and Turn-Off Delay Times

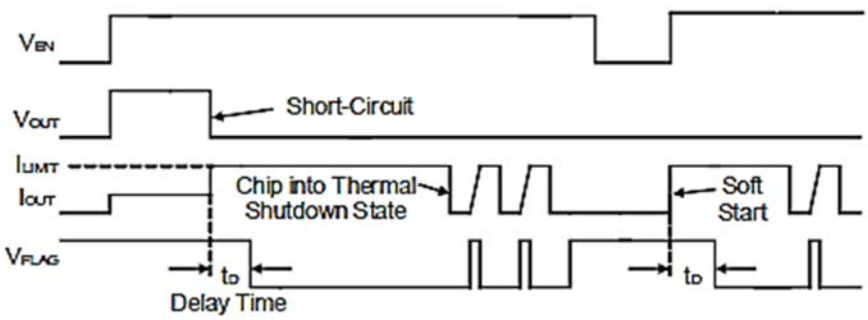



Fig2 Fault Timing: Output Reset by Toggling EN

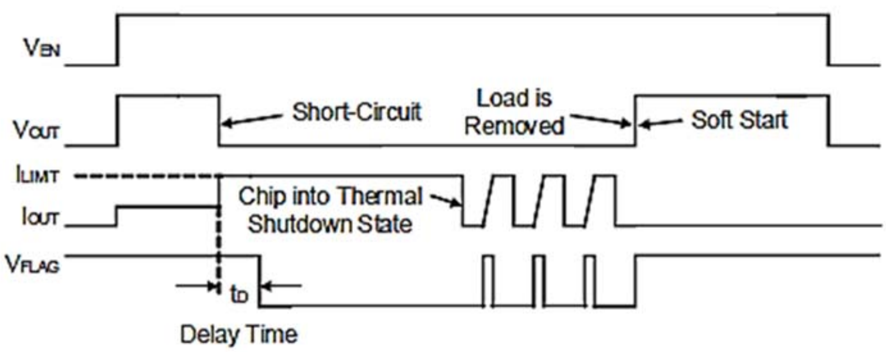



Fig3 Fault Timing: Output Reset by Removing Load

## DETAILED INFORMATION

**Input and output**

$V_{IN}$ is the power supply connection to the logic circuitry and the source of the P-channel MOSFET. $V_{OUT}$ is the drain of the P-channel MOSFET. In a typical circuit, current flows from VIN to $V_{OUT}$ toward the load. The output P-channel MOSFET and driver circuit are also designed to allow the MOSFET drain to be externally forced to a higher voltage than the source (VOUT > VIN) when the switch is disabled.

**Thermal Shutdown**

Thermal shutdown is employed to protect device and load from damage. It shuts off the output MOSFET and asserts the FLAG output, if the die temperature exceeds 150°C until the die temperature drops to 130°C.

**Soft-Start**

In order to eliminate the upstream voltage sag caused by the large inrush current during hot-plug events, the soft-start feature effectively isolates power supplies from such highly capacitive loads.

**Current limiting and short protection**

The current limit circuit is designed to limit the output current to protect the upstream power supply. The typical current limit threshold is set by internally to approximately 1.1A, 2.1A and 2.6A. Under output short-circuit condition, the typical current limit folded back 75%. If the chip keeps at over-current condition for a long time. the junction temperature may exceed 150°C, and over-temperature protection will shut down the output until Supply Filtering temperature dops below 130°C or limit (short) condition is removed.

**Reverse-voltage protection**

The reverse-voltage protection feature turns off the P-MOSFT switch whenever the output voltage exceeds the input voltage by 40mV.

**FLAG output**

The FLAG signal is an open-drain output pin. FLAG is asserted when an over-current or thermal shutdown condition occurs, and active low output. In the case of an over-current condition, FLAG will be asserted only after the response delay time ($t_D$) has elapsed. This ensures that FLAG is asserted only upon valid over-current conditions and that erroneous error reporting is eliminated. For example, false over-current conditions can occur during hot-plug events when a highly capacitive load is connected and causes a high transient inrush current that exceeds the current limit threshold for up to 1ms, The FLAG response delay time $t_D$ is about 13ms.

**Power dissipation.**

The device's junction temperature depends on several factors such as the load, PCB layout, ambient temperature, and package type. Equations that can be used to calculate power dissipation and junction temperature are found below:

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

To relate this to junction temperature, the following equation can be used:

$T_J = P_D \times \theta_{JA} + T_A$

Where:

$T_J$ = junction temperature

$T_A$ = ambient temperature

$\theta_{JA}$ = the thermal resistance of the package

## APPLICATION INFORMATION

### Supply filter capacitor

In order to prevent the input voltage drooping during hot-plug events, connect a ceramic capacitor $C_{IN}$ from $V_{IN}$ to GND. The $C_{IN}$ is positioned close to $V_{IN}$ and GND of the device. However, higher capacitor values could reduce the voltage sag on the input further. Furthermore, an output short will cause ringing on the input without the input capacitor. It could destroy the internal circuitry when the input transient exceeds 6V which is the absolute maximum supply voltage even for a short duration.

If the upstream supply cable is long or the $V_{IN}$ transient exceeds 6V during the $V_{OUT}$ short, recommend adding a second filter capacitor (not less than 47μF) at the upstream supply output terminal

### Output filter capacitor

Between $V_{OUT}$ and GND, connect a low-ESR 10μF ceramic capacitor to meet the 330mV maximum drop requirement. Standard bypass methods should be used to minimize inductance and resistance between the bypass capacitor and the down-stream connector. This will reduce EMI and improve the transient performance. If long cables are connected to the output terminals, an anti-parallel schottky diode such as BAT54 is suggested to be placed in parallel with the output terminals to absorb the negative ringing due to the cable inductance.

### PCB layout guide

For best performance of the A4788, the following guidelines must be strictly followed:

(1) Keep all power line as short and wide as possible and use at least 2-ounce copper for all power line.

(2) Dual low-ESR 10μF ceramic capacitors between $V_{OUT}$ and GND, $V_{IN}$ and GND.

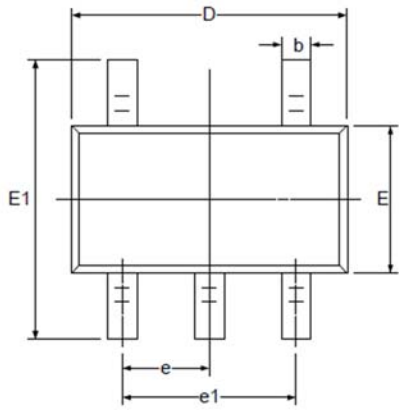
(3) Locate the output capacitor as close to the connectors as possible to lower impedance between the port and the capacitor and improve transient performance.

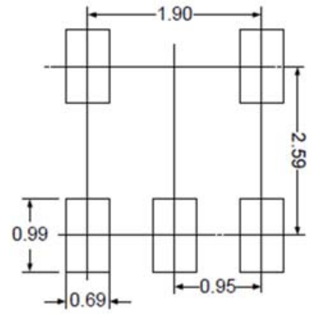
(4) Input and output capacitors should be placed closed to the chip and connected to ground plane to reduce noise coupling.

(5) Locate the ceramic bypass capacitors as close as possible to the $V_{IN}$ pin and $V_{OUT}$ pin.

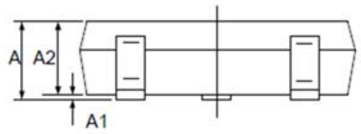
## PACKAGE INFORMATION

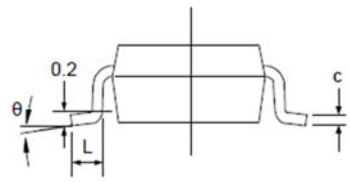
Dimension in SOT-25 (Unit: mm)




**RECOMMENDED LAND PATTERN**




| Symbol | Millimeters | |
|---|---|---|
| | Min | Max |
| A | 1.050 | 1.250 |
| A1 | 0.000 | 0.100 |
| A2 | 1.050 | 1.150 |
| b | 0.300 | 0.500 |
| c | 0.100 | 0.200 |
| D | 2.820 | 3.020 |
| E | 1.500 | 1.700 |
| E1 | 2.650 | 2.950 |
| e | 0.950 BSC | |
| E1 | 1.800 | 2.000 |
| L | 0.300 | 0.600 |
| θ | 0° | 8° |

## IMPORTANT NOTICE

AiT Semiconductor Inc. (AiT) reserves the right to make changes to any its product, specifications, to discontinue any integrated circuit product or service without notice, and advises its customers to obtain the latest version of relevant information to verify, before placing orders, that the information being relied on is current.

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