FP6861E-A

Adjustable Current-Limit Single-Channel Power Distribution Switch

Description

FP6861E-A is a cost-effective, low voltage, adjustable current limit, single N-Channel MOSFET high-side power switch, optimized for self-powered and bus-powered Universal Serial Bus (USB) applications.

FP6861E-A is equipped with a charge pump circuitry to drive the internal MOSFET switch. The switch's low $R_{DS(ON)}$ meets USB voltage drop requirement, and a flag output is available to indicate fault conditions to the local USB controller. FP6861E-A also provides adjustable current limit threshold between 0.125~3.76A through an external resistor.

Additional features include soft-start to limit inrush current during plug-in, thermal shutdown to prevent catastrophic switch failure from high-current loads, and Under-Voltage Lockout (UVLO) to ensure that the device remains off unless there is a valid input voltage present. Besides, fault current is limited to specific current for FP6861E-A in single port in accordance with the USB power requirements. FP6861E-A will prevent reverse current with reverse voltage protection.

FP6861E-A is available in SOT-23-6 and TDFN-6 (2mm×2mm) packages with smallest components.

Features

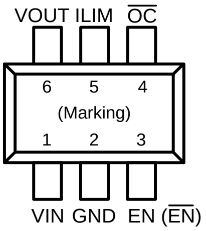
- Compliant to USB Specifications
- Adjustable Current Limit: 0.125~3.76A
- Built-in Low $R_{DS(ON)}$ N-Channel MOSFET
- Output can be Forced Higher than Input
- Low Supply Current:
  80μA Typical at Switch On State (R_{ILIM}=20kΩ)
  0.1μA Typical at Switch Off State
- Wide Input Voltage Ranges: 2.7V to 6V
- Open-Drain Fault Flag Output
- Hot Plug-In Application (Soft-Start)
- 2.2V Typical Under-Voltage Lockout (UVLO)
- Thermal Shutdown Protection
- Reverse Current Flow Blocking (No Body Diode)
- Reverse Voltage Protection
- Logic Level Enable Pin
- SOT-23-6 and TDFN-6 (2mm×2mm) Packages
- RoHS Compliant
- UL NO.E322418 (Approved model: FP6861 series)
- CB Test Certified, Ref. Certif. No. DK-104880-M1-UL

Applications

- USB Bus/Self Powered Hub
- USB Peripheral
- ACPI Power Distribution
- Notebook, Motherboard PC
- Battery-Charger Circuit

Pin Assignments

S6 Package: SOT-23-6



WD Package: TDFN-6 (2mm×2mm)

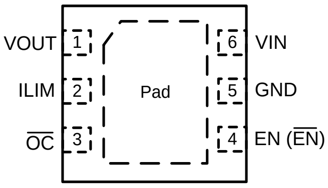
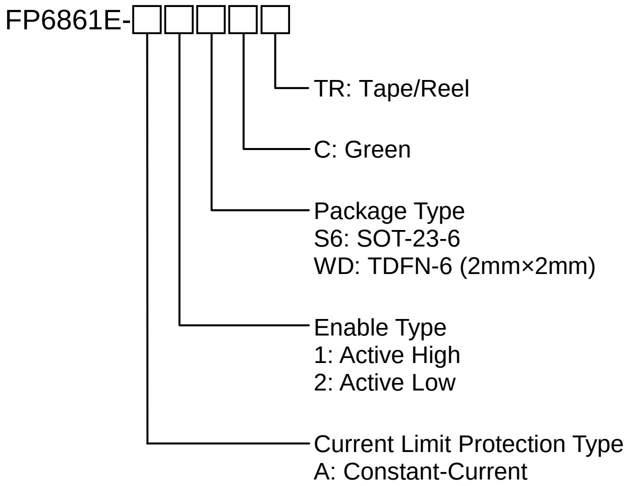


Figure1. Pin Assignment of FP6861E-A

Ordering Information



SOT-23-6 Marking

Part Number	Product Code
FP6861E-A1S6CTR	**GC5**
FP6861E-A2S6CTR	**GC6**

TDFN-6 (2mm×2mm) Marking

Part Number	Product Code
FP6861E-A1WDCTR	**GC9**
FP6861E-A2WDCTR	**GD0**

Typical Application Circuit

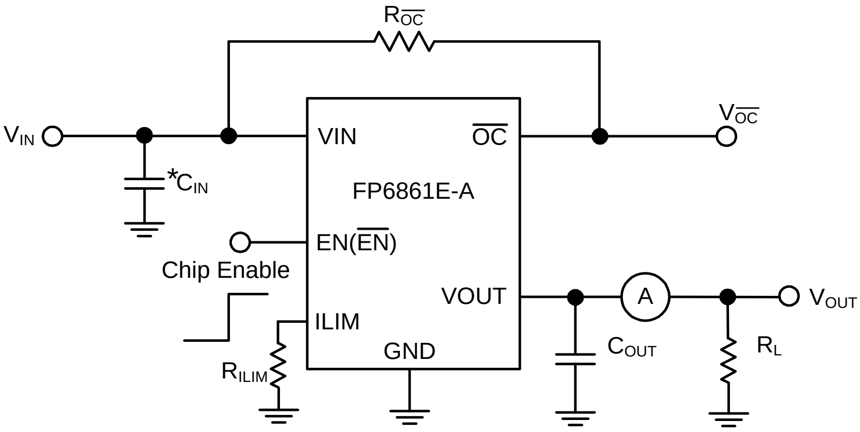
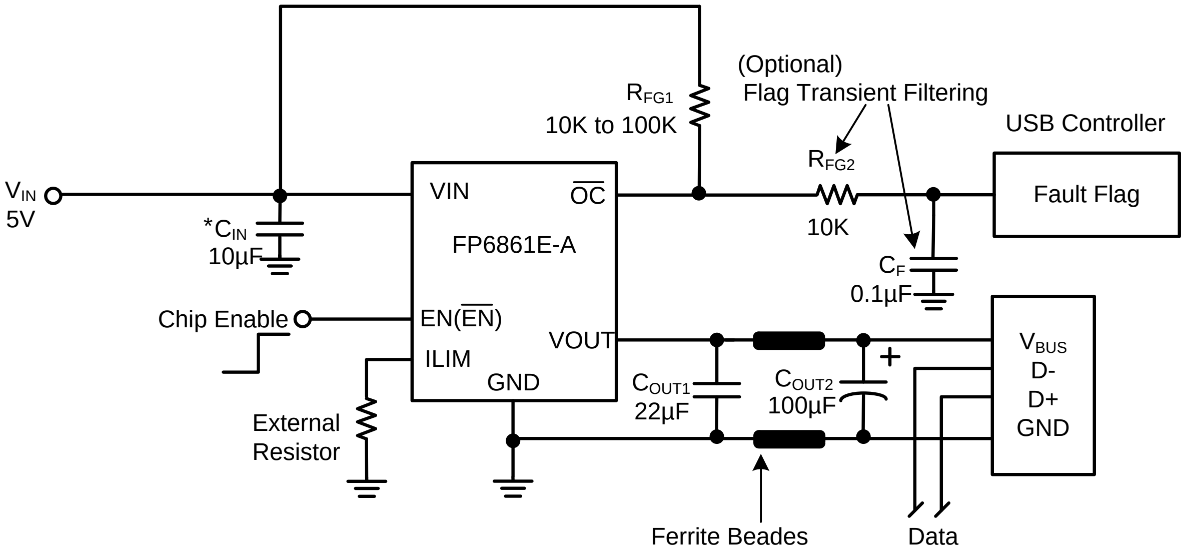


Figure 2. Electrical Characteristic Test Circuit



*Note: In most applications, adding one 10µF capacitor is enough. If the trace to VIN is long in PCB, placing larger input capacitor is needed.

Figure 3. Typical Application Circuit for USB Power Switch

Functional Pin Description

Pin Name	Pin No. (SOT-23-6)	Pin No. (TDFN-6)	Pin Function
VIN	1	6	Input power supply.
GND	2	5	Ground. Connect GND to exposed pad.
EN/$\overline{EN}$	3	4	Chip enable/chip shutdown. Pull the pin high to enable IC; Pull the pin low to shutdown IC. Do not let the pin floating.
$\overline{OC}$	4	3	Fault flag. Open-drain output.
ILIM	5	2	Use external resistor to set current-limit; recommended 6.98kΩ$\leqq R_{ILIM} \leqq$160kΩ.
VOUT	6	1	Switch output.

Block Diagram

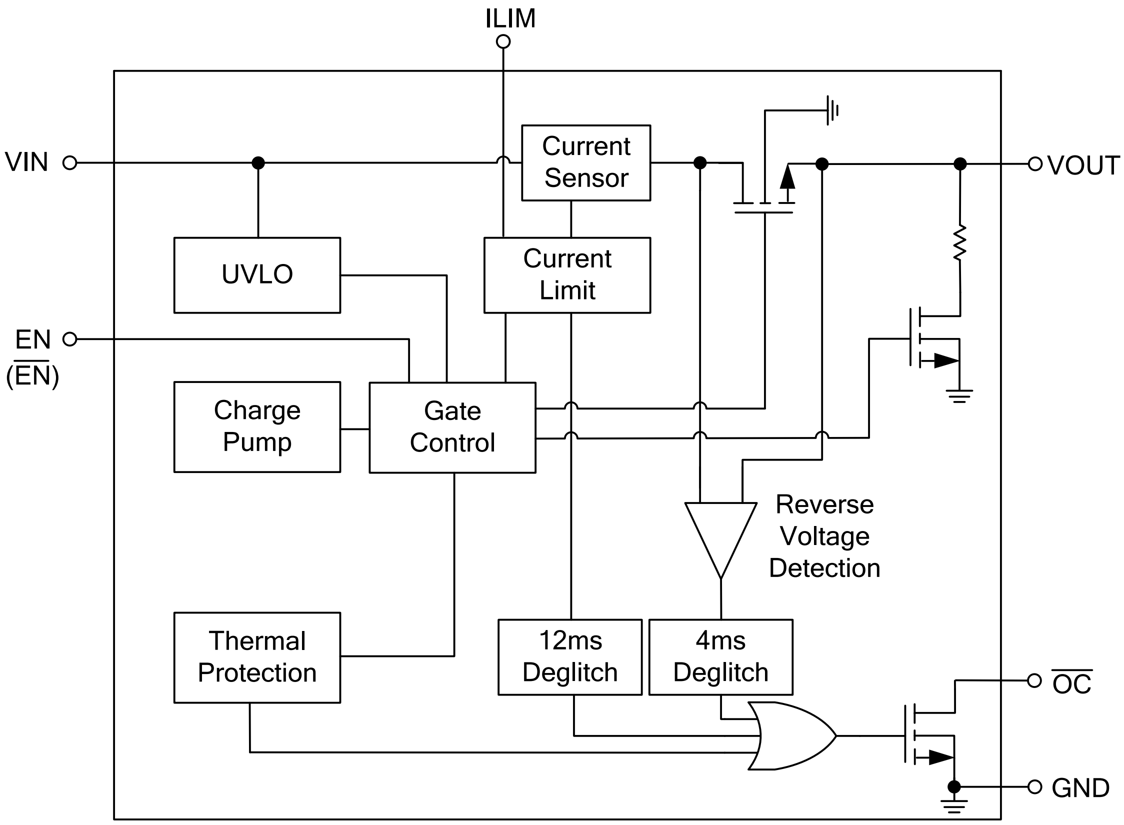


Figure 4. Block Diagram

Absolute Maximum Ratings (Note 1)

- VIN, VOUT -- -0.3V to +7V
- All Other Pins Voltage-- -0.3V to +7V
- Power Dissipation @T_A=25°C & T_J=125°C (P_D)
  - SOT-23-6 --- 0.4W
  - TDFN-6 (2mm×2mm) -- 0.74W
- Package Thermal Resistance, (θ_{JA})
  - SOT-23-6 --- 250°C/W
  - TDFN-6 (2mm×2mm) -- 136ºC/W
- Package Thermal Resistance, (θ_{JC})
  - SOT-23-6 --- 110°C/W
  - TDFN-6 (2mm×2mm) -- 56ºC/W
- Junction Temperature -- +150°C
- Lead Temperature (Soldering,10 sec.) -- +260°C
- Storage Temperature Range --- -65°C to +150°C

Note 1: Stresses beyond those listed under “Absolute Maximum Ratings" may cause permanent damage to the device.

Recommended Operating Conditions

- Supply Voltage (V_{IN}) --- +2.7V to +6V
- Junction Temperature-- -40°C to +125°C
- Operation Temperature Range (T_{OPR}) -- -40°C to +85°C

Electrical Characteristics

(V_{IN}=5V, T_A=25°C, unless otherwise specified.)

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Switch On Resistance	$R_{DS(ON)}$	I_{OUT}=1A		55	80	mΩ
Supply Current	I_{SW_ON}	R_{ILIM}=20kΩ		80		μA
	I_{SW_OFF}	Switch OFF, V_{OUT}=Open		0.1	1	
EN Threshold	V_{IH}	Switch ON	1.8			V
	V_{IL}	Switch OFF			0.7	
EN Input Current	I_{EN}	V_{EN}=5V		0.01	0.1	μA
Current Limit	I_{LIM}	R_{ILIM}=6.98kΩ	3.196	3.76	4.324	A
		R_{ILIM}=10kΩ	2.21	2.6	2.99	
		R_{ILIM}=12.75kΩ	1.8	2	2.2	
		R_{ILIM}=15.5kΩ	1.598	1.7	1.802	
		R_{ILIM}=20kΩ	1.217	1.295	1.372	
		R_{ILIM}=61.5kΩ	0.34	0.4	0.46	
		R_{ILIM}=68kΩ	0.297	0.374	0.449	
		R_{ILIM}=160kΩ	0.095	0.125	0.155	
		R_{ILIM} Shorted to V_{IN} (Note 2)	0.147	0.21	0.273	
Short Circuit Fold-Back Current	I_{SC_FB}	R_{ILIM}=6.98kΩ		2.256		A
		R_{ILIM}=10kΩ		1.560		
		R_{ILIM}=12.75kΩ		1.200		
		R_{ILIM}=15.5kΩ		1.020		
		R_{ILIM}=20kΩ		0.777		
		R_{ILIM}=61.5kΩ		0.240		
		R_{ILIM}=68kΩ		0.224		
		R_{ILIM}=160kΩ		0.075		
		R_{ILIM} Shorted to V_{IN} (Note 2)		0.126		
Output Leakage Current	$I_{LEAKAGE}$	V_{EN}=Disable, R_L=0Ω		0.5	1	μA
Output Turn-On Rise Time	T_{ON_RISE}	R_{ILIM}=20kΩ, C_L=1μF		2		ms
$\overline{OC}$ Output Resistance	$R_{\overline{OC}}$	I_{SINK}=1mA		70		Ω
$\overline{OC}$ Off Current	$I_{\overline{OC}}$	$V_{\overline{OC}}$=5V		0.01		μA
$\overline{OC}$ Deglitch Time	t_D	From Fault Condition to $\overline{OC}$ Assertion or De-assertion		12		ms

Electrical Characteristics (Continued)

(V_{IN}=5V, T_A=25°C, unless otherwise specified.)

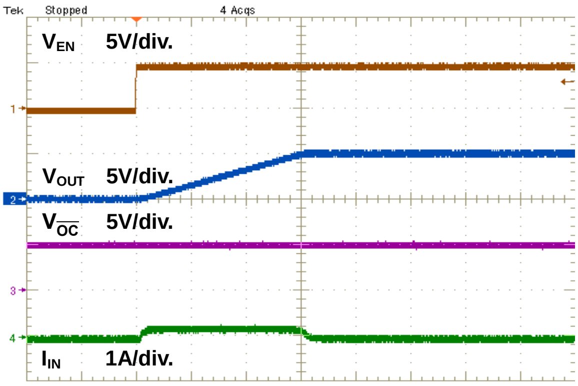
Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Under-Voltage Lockout	V_{UVLO}	V_{IN} Increasing		2.2		V
Under-Voltage Hysteresis	ΔV_{UVLO}	V_{IN} Decreasing		0.2		V
V_{OUT} Discharge Resistance	R_{DIS}	V_{EN}=0V		70		Ω
Thermal Shutdown Threshold (Note 2)	T_{SD}			150		°C
	ΔT_{SD}	Hysteresis		20		°C

Note 2: Guarantee by design.

Typical Performance Curves

V_{IN}= V_{OUT}=5V, C_{IN}=100μF, C_{OUT}=120μF, R_{ILIM}=6.98kΩ, TA=+25°C, unless otherwise noted. This is measured by using FP6861E-A1S6.

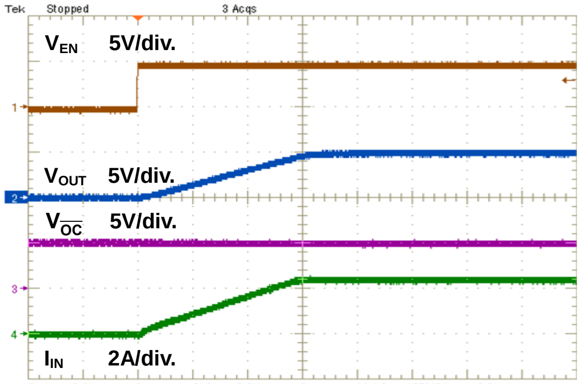
I_{OUT}=0A



1ms/div.

Figure 5. EN Start Up with No Load

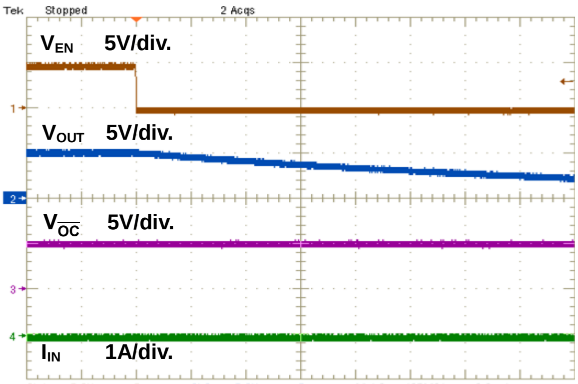
I_{OUT}=2.5A (R_L=2Ω)



1ms/div.

Figure 6. EN Start Up with Heavy Load

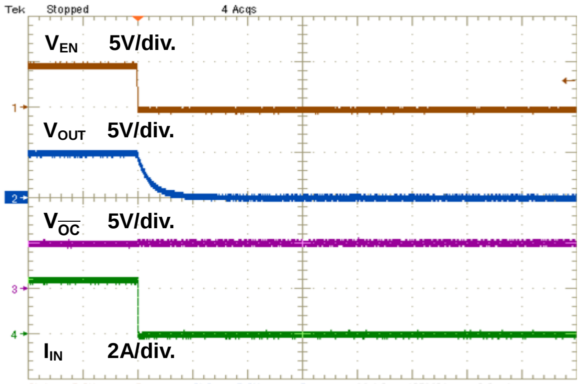
I_{OUT}=0A



1ms/div.

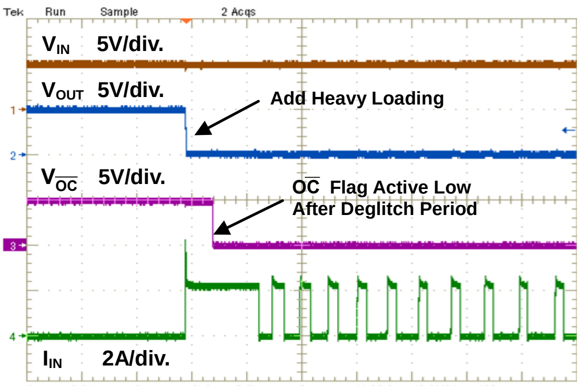
Figure 7. EN Power Off with No Load

I_{OUT}=2.5A (R_L=2Ω)



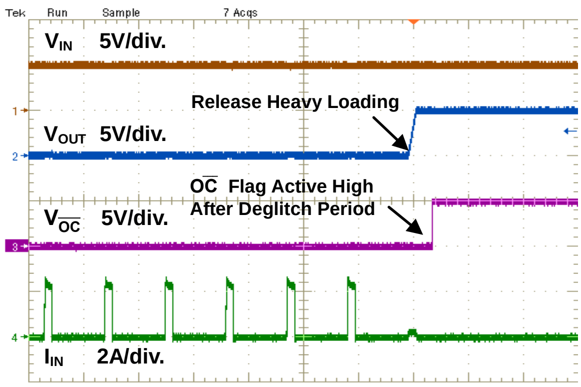
1ms/div.

Figure 8. EN Power Off with Heavy Load



20ms/div.

Figure 9. Short Circuit Transient Response

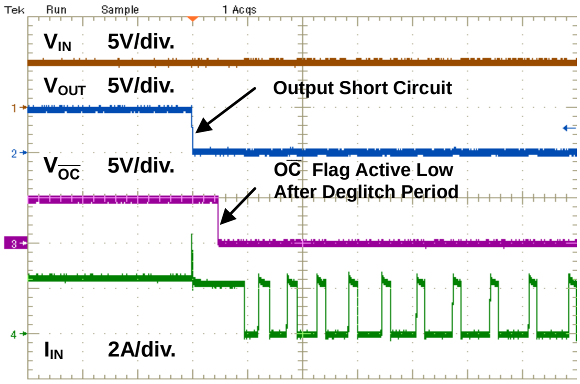


20ms/div.

Figure 10. Release Short Circuit Transient Response

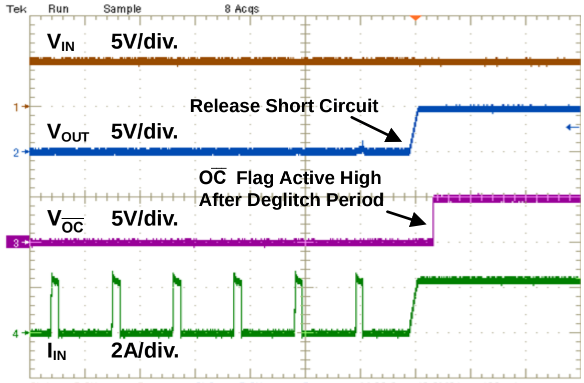
Typical Performance Curves (Continued)

V_{IN}= V_{OUT}=5V, C_{IN}=100µF, C_{OUT}=120µF, R_{ILIM}=6.98kΩ, TA=+25°C, unless otherwise noted. This is measured by using FP6861E-A1S6.



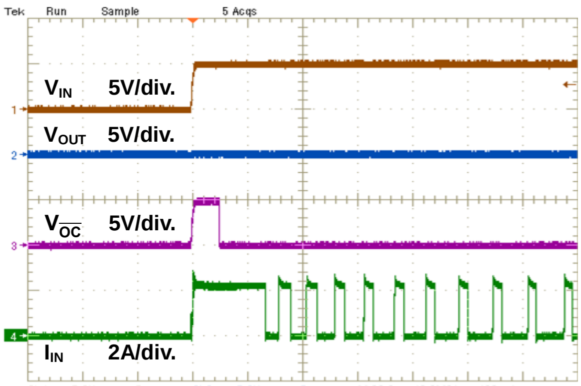
20ms/div.

Figure 11. Heavy Loading to Short Circuit Transient Response



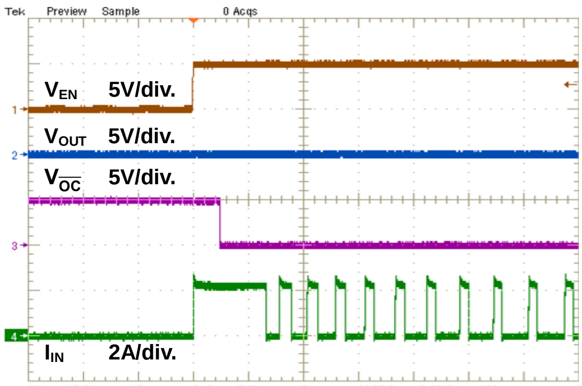
20ms/div.

Figure 12. Short Circuit to Heavy Loading Transient Response



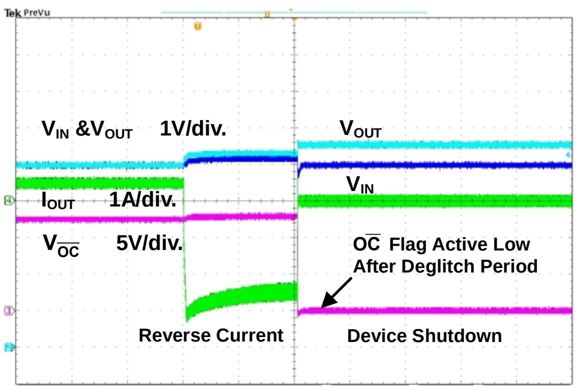
20ms/div.

Figure 13. Short Circuit Response at Start Up



20ms/div.

Figure 14. Short Circuit Response at Device Eable



2ms/div.

Figure 15. Reverse Voltage Protection Response

Typical Performance Curves (Continued)

V_{IN}= V_{OUT}=5V, C_{IN}=100μF, C_{OUT}=120μF, R_{ILIM}=6.98kΩ, TA=+25°C, unless otherwise noted. This is measured by using FP6861E-A1S6.

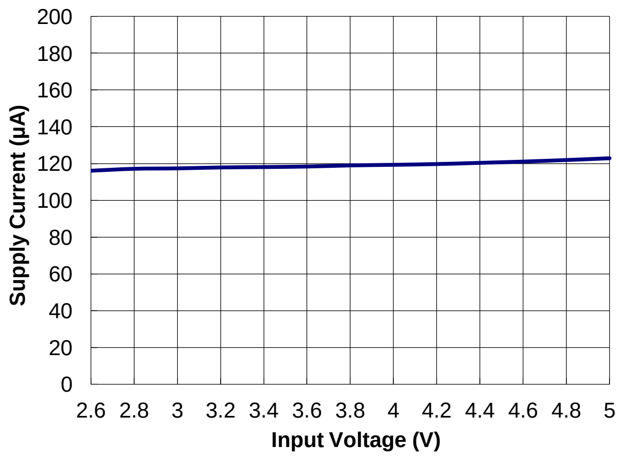


Figure 16. Supply Current vs. Input Voltage

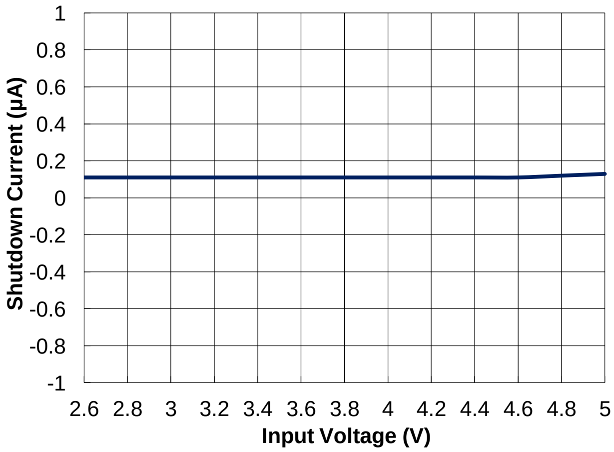


Figure 17. Shutdown Current vs. Input Voltage

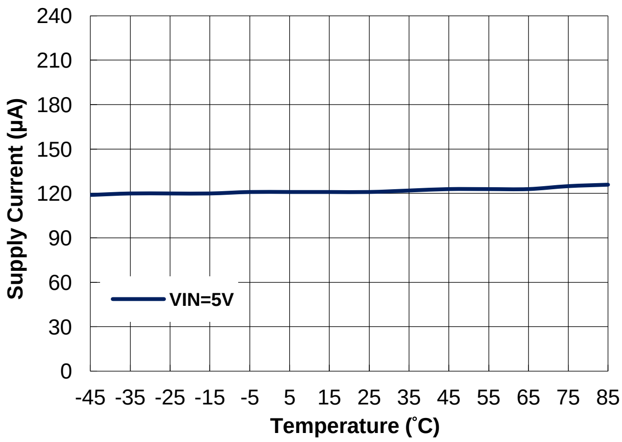


Figure 18. Supply Current vs. Temperature

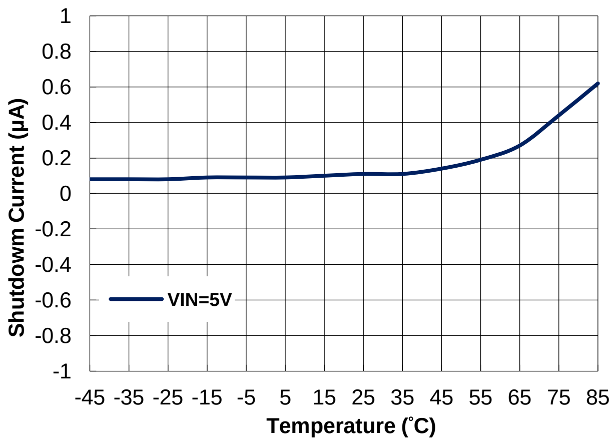


Figure 19. Shutdown Current vs. Temperature

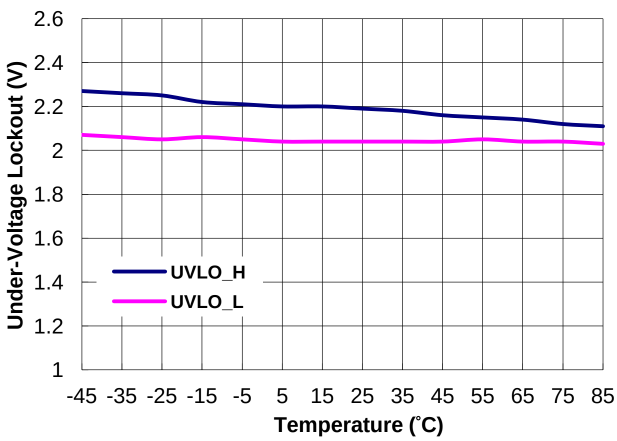


Figure 20. Under-Voltage Lockout vs. Temperature

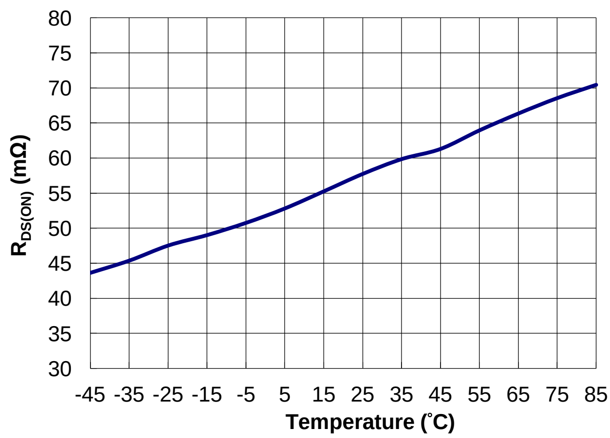


Figure 21. $R_{DS(ON)}$ vs. Temperature

Application Information

The FP6861E-A is a single N-Channel MOSFET high-side power switch, optimized for self-powered and bus-powered Universal Serial Bus (USB) applications. The FP6861E-A operates from 2.7V to 6V input voltage range and provides low supply current. The switch's low $R_{DS(ON)}$ can meets USB voltage drop requirements. It has one switch with enable control input. The switch has an error flag output to notify the USB controller when the current-limit, short-circuit or thermal-shutdown occurs.

Under Voltage-Lockout

Under-Voltage Lockout (UVLO) prevents the MOSFET switch from turning on until input voltage exceeds approximately 2.2V. If input voltage drops below approximately 2V, UVLO will turn off the MOSFET switch.

Soft Start for Hot Plug-In Application

In order to eliminate the upstream voltage drop caused by the large inrush current during hot-plug events, the “soft-start” feature effectively isolates the power source from extremely large capacitive loads, satisfying the USB voltage drop requirements.

Reverse Current Blocking

The USB specification does not allow an output device to source current back into the USB port. However, the FP6861E-A is designed to safely power noncompliant devices. When the device is disabled, the output will be switched to a high-impedance state, blocking reverse current flow from the output back to the input. The switch can pass the input to output when it is enabled.

Reverse Voltage Protection

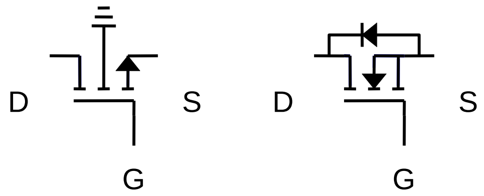
The reverse voltage protection will turn off N-channel MOSFET when output voltage is larger than input voltage 50mV for 4ms. Conversely, N-channel MOSFET will turn on when output voltage is lower than input voltage for 4ms.

Supply Filter/Bypass Capacitor

The input capacitor must be at least 10μF low-ESR ceramic capacitor connected from VIN to GND, but can be increased without limit. Output short may cause sufficient ringing on the input (from source lead inductance) to destroy the internal control circuitry. The input transient must not exceed 6V of the absolute maximum supply voltage even for a short duration.

Input and Output

VIN is the power source connection to the internal circuitry and the drain of the MOSFET. VOUT is the source of the MOSFET. In typical application, current flows through the switch from VIN to VOUT toward the load. If VOUT is greater than VIN, current will flow from VOUT to VIN since the MOSFET is bidirectional. There is no parasitic body diode between drain and source of the MOSFET, and the FP6861E-A will prevent reverse current flow if VOUT externally forces a higher voltage than VIN when the output is disabled.



FP6861E-A Normal MOSFET

Output Filter Capacitor

Output is recommended to use a 10μF ceramic capacitor in parallel with a 100μF electrolytic capacitor. Standard bypass methods should be used to minimize inductance and resistance between the bypass capacitor and the downstream connector which reduce EMI and decouple voltage drop caused when downstream cables are hot-insertion transients. Ferrite beads in series with V_{BUS}, the ground line and the 0.1μF bypass capacitors at the power connector pins are recommended for EMI and ESD protection. The bypass capacitor should have a low dissipation factor to allow decoupling at higher frequencies.

Error Flag

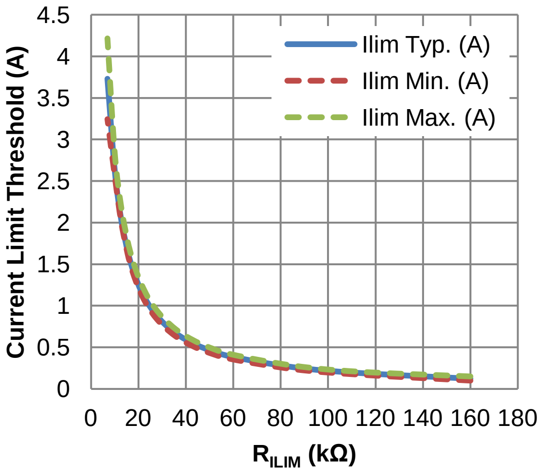
The FP6861E-A provides an open drain error flag output for the switch. For most applications, connect $\overline{OC}$ to VIN through a pull-up resistor. $\overline{OC}$ will go low when any following condition occurs:

1. The thermal shutdown occurs.
2. The switch is in current limit or short circuit conditions.
3. Reverse voltage protection occurs when output voltage exceeds the input voltage.

Application Information (Continued)

Adjustable Current Limit

The current limit circuitry prevents damage to the MOSFET switch but can deliver load current up to the current limit threshold through the switch. FP6861E-A provides adjustable current limit threshold between 0.125~3.76A through an external resistor. The current limit threshold(Typ.) and R_{ILIM} curve is show below：



Designer can use following equation to easy calculate the value of the external resistor for porposed typical current limit value：

$$I_{LIM(Typ.)}(A)=\frac{31.931}{R_{ILIM}(k\Omega)}$$

$$I_{LIM(Min.)}(A)=\frac{35.951}{R_{ILIM}(k\Omega)}$$

$$I_{LIM(Ma\ .)}(A)=\frac{34.559}{R_{ILIM}(k\Omega)}$$

Connect a resistor between I_{LIM} and ground to program the current limit threshold value for the FP6861E-A. The table below shows a recommended current limit value vs. R_{ILIM} resistor.

Design Current Limit (A)	1% Tolance Real R_{ILIM} (kΩ)	I_{LIM} Min. (A)	I_{LIM} Typ. (A)	I_{LIM} Max. (A)
0.125	160	0.098	0.124	0.151
0.2	113	0.170	0.193	0.207
0.3	85.6	0.235	0.261	0.279
0.4	59	0.359	0.391	0.418
0.5	47.5	0.458	0.494	0.528
0.6	40.2	0.553	0.591	0.633
0.8	30.9	0.745	0.785	0.841
1	24.9	0.951	0.992	1.063
1.2	21	1.152	1.192	1.278
1.4	18.2	1.354	1.391	1.492
1.5	16.9	1.472	1.507	1.617
1.6	16.2	1.544	1.577	1.693
1.7	15.5	1.622	1.654	1.776
2	12.75	2.012	2.042	2.194
2.6	10	2.574	2.644	2.855
3.76	6.98	3.246	3.729	4.214

Application Information (Continued)

Power Dissipation

The device's junction temperature depends on several factors, such as the load, PCB layout, ambient temperature and package type. However, the maximum output current must be decreased at higher ambient temperature to ensure the junction temperature does not exceed 125°C. With all possible conditions, the junction temperature must be within the range specified under operating conditions. Power dissipation can be calculated based on the output current and the $R_{DS(ON)}$ of switch as below:

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

Although the devices are rated by current limit, but the application may limit the amount of output current based on the total power dissipation and the ambient temperature. The final operating junction temperature for any set of conditions can be estimated by the following thermal equation:

$$P_{D(MAX)}=\frac{T_{J(MAX)}-T_A}{\theta_{JA}}$$

Where $T_{J(MAX)}$ is the maximum junction temperature 125°C, T_A is the ambient temperature and the θ_{JA} is the junction to ambient thermal resistance.

The junction to ambient thermal resistance θ_{JA} is related to layout. For SOT-23-6 package, the thermal resistance θ_{JA} is 250°C/W on the standard JEDEC 51-3 single-layer thermal test board.

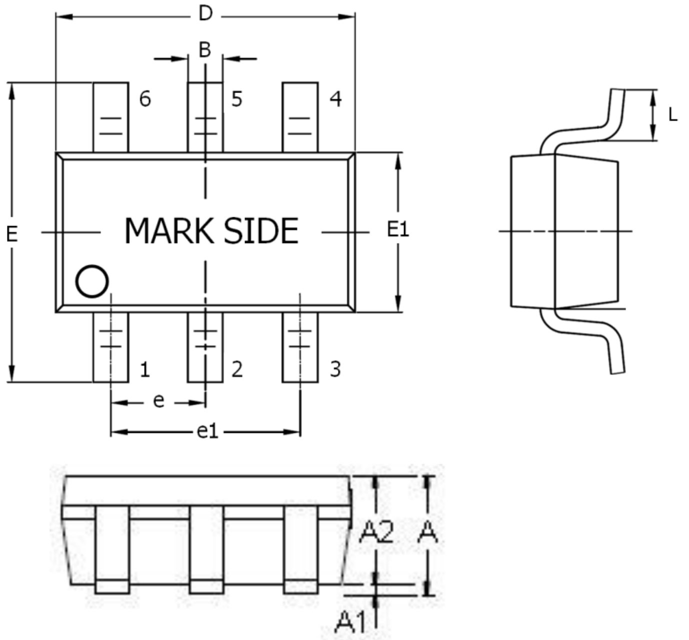
PCB Layout

In order to meet the voltage drop and EMI requirements, careful PCB layout is necessary. The following guidelines must be considered:

1. Keep all V_{BUS} traces as short as possible, and use at least 50-mil and 2 ounce copper for all V_{BUS} traces.
2. Locate the FP6861E-A as close to the output port as possible to limit switching noise.
3. Locate the ceramic bypass capacitors as close to the VIN pins of the FP6861E-A as possible.
4. Avoid vias as much as possible. If vias are necessary, make them as large as feasible.
5. Place a ground plane under all circuitry to lower both resistance and inductance, and improve DC and transient performance (use a separate ground and power plans if possible).
6. Place cuts in the ground plane between ports to help reducing the coupling of transients between ports.
7. Locate the output capacitor and ferrite beads as close to the USB connectors as possible to lower impedance (mainly inductance) between the port and the capacitor, and improve transient load performance.

Outline Information

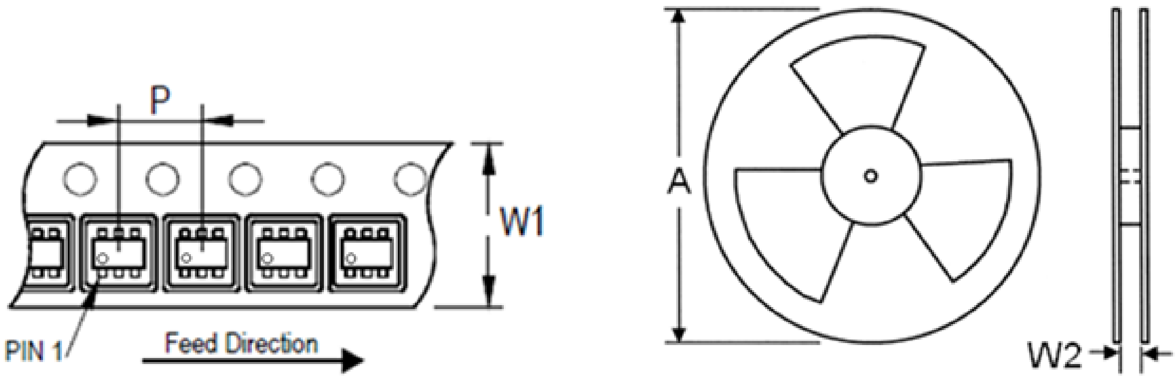
SOT-23-6 Package (Unit: mm)



SYMBOLS UNIT	DIMENSION IN MILLIMETER	
	MIN	MAX
A	0.90	1.30
A1	0.00	0.15
A2	0.90	1.15
B	0.28	0.50
D	2.80	3.00
E	2.60	3.00
E1	1.50	1.70
e	0.90	1.00
e1	1.80	2.00
L	0.30	0.60

Note 3: Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.3mm.
Note 4: Reference JEDEC MO-178.

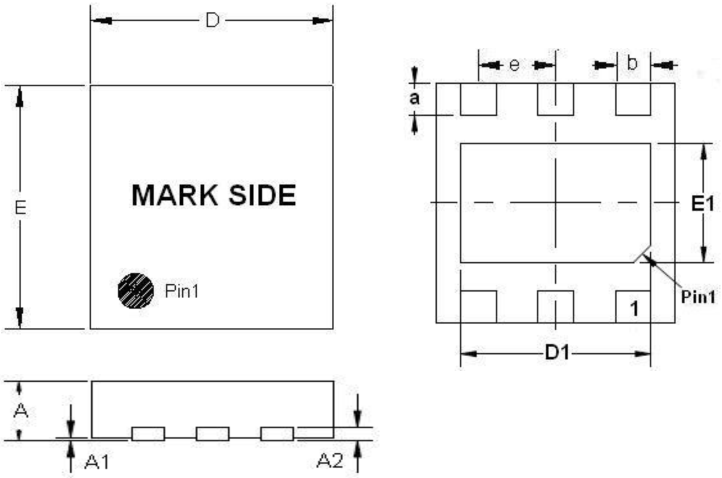
Carrier Dimensions



Tape Size (W1) mm	Pocket Pitch (P) mm	Reel Size (A)		Reel Width (W2) mm	Empty Cavity Length mm	Units per Reel
		in	mm			
8	4	7	180	8.4	300~1000	3,000

Outline Information (Continued)

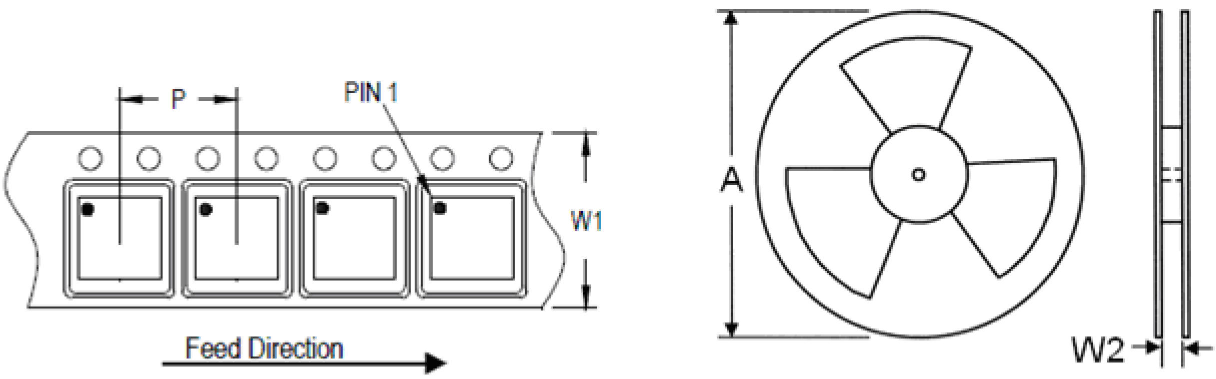
TDFN-6 (2mm×2mm) (pitch 0.65mm) Package (Unit: mm)



SYMBOLS UNIT	DIMENSION IN MILLIMETER MIN	MAX
A	0.70	0.80
A1	0.00	0.05
A2	0.19	0.22
D	1.95	2.05
E	1.95	2.05
a	0.20	0.40
b	0.25	0.35
e	0.60	0.70
D1	1.15	1.65
E1	0.55	1.05

Note 5: Followed From JEDEC MO-229.

Carrier Dimensions



Tape Size (W1) mm	Pocket Pitch (P) mm	Reel Size (A) in	Reel Size (A) mm	Reel Width (W2) mm	Empty Cavity Length mm	Units per Reel
8	4	7	180	8.4	400~1000	3,000