FP6861E-C/E/F/H

Single-Channel Power Distribution Switch

Description

The FP6861E-C/E/F/H is a cost-effective, low voltage, single N-Channel MOSFET high-side power switch, optimized for self-powered and bus-powered Universal Serial Bus (USB) applications.

The FP6861E-C/E/F/H 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.

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-C/E/F/H in single port in accordance with the USB power requirements. FP6861E-C/E/F/H will prevent reverse current when it is disabled and VOUT is higher than VIN.

The FP6861E-C/E/F/H is available in MSOP-8, SOP-8 and SOT-23-5 packages with smallest components.

Features

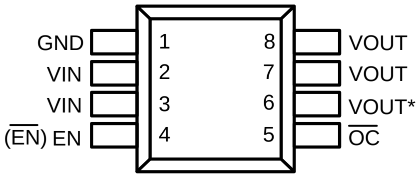
- Compliant to USB Specifications
- Built-In Low $R_{DS(ON)}$ N-Channel MOSFET
- Output can be Forced Higher than Input (Off-State)
- Low Supply Current:
  65μA Typical at Switch On State
  0.1μA Typical at Switch Off State
- 2.7V to 5.5V Input Voltage Range
- Open-Drain Fault Flag Output
- Hot Plug-In Application (Soft-Start)
- 2.2V Typical Under-Voltage Lockout (UVLO)
- Current Limit Protection
- Thermal Shutdown Protection
- Reverse Current Flow Blocking (No Body Diode)
- Logic Level Enable Pin
- MSOP-8, SOP-8 and SOT-23-5 Packages
- RoHS Compliant
- UL NO.E322418 (Approved model: FP6861 Series)
- CB Test Certified, Ref. Certif. No. JPTUV-101402

Applications

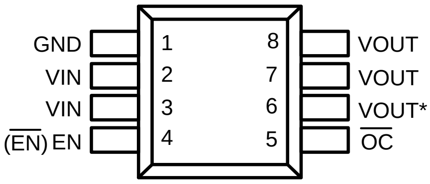
- USB Bus/Self Powered Hub
- USB Peripheral
- ACPI Power Distribution
- Notebook, Motherboard PC
- Battery-Charger Circuit

Pin Assignments

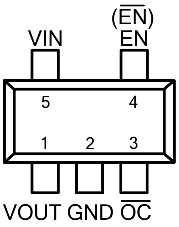
MS Package (MSOP-8)



SO Package (SOP-8)



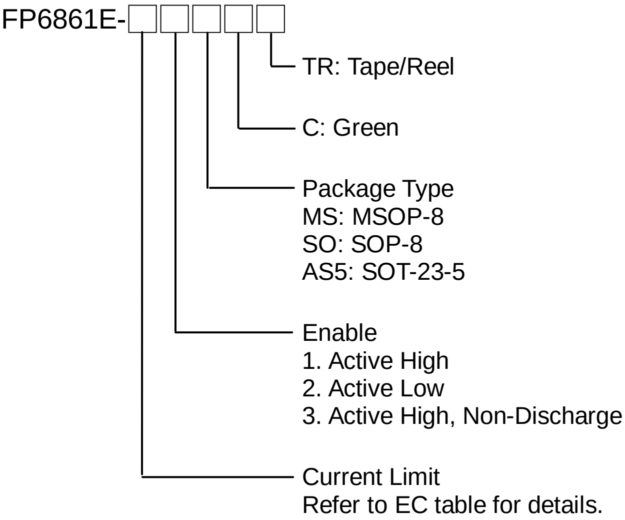
AS5 Package (SOT-23-5)



* The pin 6 should be considered as VOUT when circuit design and PCB layout, but it is NC pin actually.

Figure1. Pin Assignment of FP6861E-C/E/F/H

Ordering Information



Available Product List

FP6861E-C1MSCTR	FP6861E-F1MSCTR
FP6861E-C1SOCTR	FP6861E-F1SOCTR
FP6861E-C1AS5CTR	FP6861E-F1AS5CTR
FP6861E-C2MSCTR	FP6861E-F2MSCTR
FP6861E-C2SOCTR	FP6861E-F2SOCTR
FP6861E-C2AS5CTR	FP6861E-F2AS5CTR
FP6861E-C3MSCTR	FP6861E-F3MSCTR
FP6861E-C3SOCTR	FP6861E-F3SOCTR
FP6861E-C3AS5CTR	FP6861E-F3AS5CTR
FP6861E-E1MSCTR	FP6861E-H1MSCTR
FP6861E-E1SOCTR	FP6861E-H1SOCTR
FP6861E-E1AS5CTR	FP6861E-H1AS5CTR
FP6861E-E2MSCTR	FP6861E-H2MSCTR
FP6861E-E2SOCTR	FP6861E-H2SOCTR
FP6861E-E2AS5CTR	FP6861E-H2AS5CTR
FP6861E-E3MSCTR	FP6861E-H3MSCTR
FP6861E-E3SOCTR	FP6861E-H3SOCTR
FP6861E-E3AS5CTR	FP6861E-H3AS5CTR

SOT-23-5 Marking

Part Number	Product Code	Part Number	Product Code
FP6861E-C1AS5C	**FG7**	FP6861E-F1AS5C	**FH2**
FP6861E-C2AS5C	**FG8**	FP6861E-F2AS5C	**FH3**
FP6861E-C3AS5C	**FM7**	FP6861E-F3AS5C	**FM9**
FP6861E-E1AS5C	**FG9**	FP6861E-H1AS5C	**FH4**
FP6861E-E2AS5C	**FH1**	FP6861E-H2AS5C	**FH5**
FP6861E-E3AS5C	**FM8**	FP6861E-H3AS5C	**FN1**

Typical Application Circuit

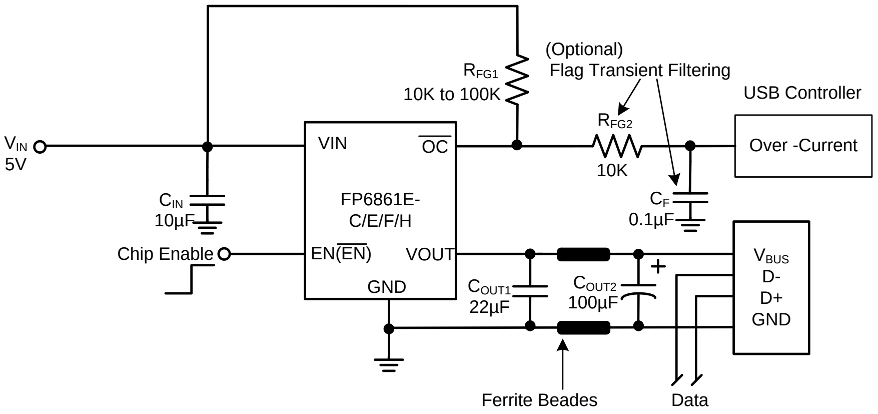
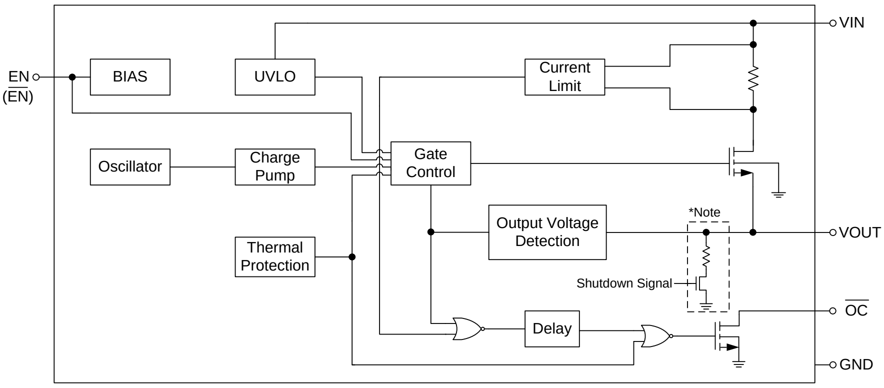


Figure 2. Typical Application Circuit

Functional Pin Description

Pin Name	Pin Function
VIN	Input power supply.
VOUT	Switch output.
GND	Ground.
EN	Chip enable. Pull the pin high to enable IC; Pull the pin low to shutdown IC. Do not let the pin floating.
$\overline{\text{EN}}$	Chip shutdown. Pull the pin high to shutdown IC; Pull the pin low to enable IC. Do not let the pin floating.
$\overline{\text{OC}}$	Open-drain fault flag output.

Block Diagram



*Note: There is no discharge circuit for FP6861E-x3xxx series.

Figure 3. Block Diagram

Absolute Maximum Ratings (Note 1)

- VIN, VOUT ---------- -0.3V to +6.5V
- EN ($\overline{EN}$) ---------- -0.3V to +6.5V
- $\overline{OC}$ ---------- -0.3V to +6.5V
- Power Dissipation @ T_A=25°C, (P_D)
  - MSOP-8 ---------- 0.63W
  - SOP-8 ---------- 0.91W
  - SOT-23-5 ---------- 0.4W
- Package Thermal Resistance, (θ_{JA})
  - MSOP-8 ---------- 160°C/W
  - SOP-8 ---------- 110°C/W
  - SOT-23-5 ---------- 250°C/W
- Package Thermal Resistance, (θ_{JC})
  - MSOP-8 ---------- 75°C/W
  - SOP-8 ---------- 39°C/W
  - SOT-23-5 ---------- 130°C/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 +5.5V
- Junction Temperature Range (T_{OPR}) ---------- -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.)

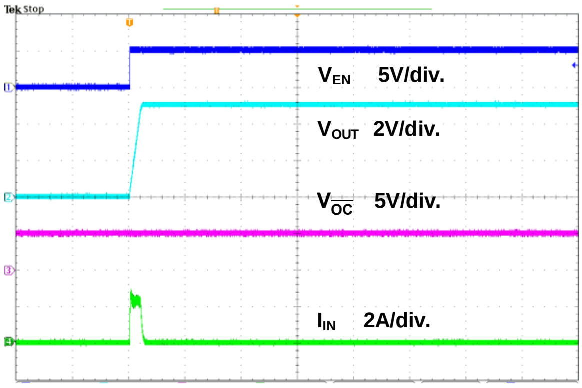
Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Switch On Resistance	$R_{DS(ON)}$	I_{OUT}=100mA, MSOP-8,SOP-8 package		100		mΩ
		I_{OUT}=100mA, SOT-23-5 package		100		
Supply Current	I_{SW_ON}	Switch on, V_{OUT} = Open		65		µA
	I_{SW_OFF}	Switch off, V_{OUT} = Open		0.1	1	
EN Threshold	V_{IL}	Switch off			0.7	V
	V_{IH}	Switch on	1.8			
EN Input Current	I_{EN}	V_{EN}=Enable		0.01	0.1	µA
Current Limit	I_{LIM}	R_{LOAD}=1Ω, FP6861E-C	2.1	2.45	2.8	A
		R_{LOAD}=1Ω, FP6861E-E	1.5	1.75	2.1	A
		R_{LOAD}=1Ω, FP6861E-F	0.7	1	1.35	A
		R_{LOAD}=1Ω, FP6861E-H	1.1	1.4	1.7	A
Short Circuit Fold-Back Current	I_{SC_FB}	V_{OUT}=0V, Measured Prior to Thermal Shutdown, FP6861E-C		1.47		A
		V_{OUT}=0V, Measured Prior to Thermal Shutdown, FP6861E-E		1.05		A
		V_{OUT}=0V, Measured Prior to Thermal Shutdown, FP6861E-F		0.6		A
		V_{OUT}=0V, Measured Prior to Thermal Shutdown, FP6861E-H		0.84		A
Output Leakage Current	$I_{LEAKAGE}$	V_{EN}=Disable, R_{LOAD}=0Ω		0.5	1	µA
$\overline{OC}$ Output Resistance	$R_{\overline{OC}}$	I_{SINK}=1mA		70		Ω
$\overline{OC}$ Off Current	$I_{\overline{OC}}$	$V_{\overline{OC}}$= 5V		0.01		µA
$\overline{OC}$ Delay Time	t_D	From Fault Condition to $\overline{OC}$ Assertion		10		ms
Under-Voltage Lockout	V_{UVLO}	V_{IN} Increasing		2.2		V
Under-Voltage Hysteresis	ΔV_{UVLO}	V_{IN} Decreasing		0.2		V
Shutdown Pull Low Resistance (Note 2)	R_{PD}			80		Ω
Thermal Shutdown Threshold (Note 3)	T_{SD}			135		°C
	ΔT_{SD}	Hysteresis		20		°C

Note 2: There is no resistor for FP6861E-x3xxx series.
Note 3: Guarantee by design.

Typical Performance Curves

V_{IN}= V_{OUT}=5V, C_{IN}=100μF, C_{OUT}=120μF, TA=+25°C, unless otherwise noted. This is measured by using FP6861E-C1AS5C.

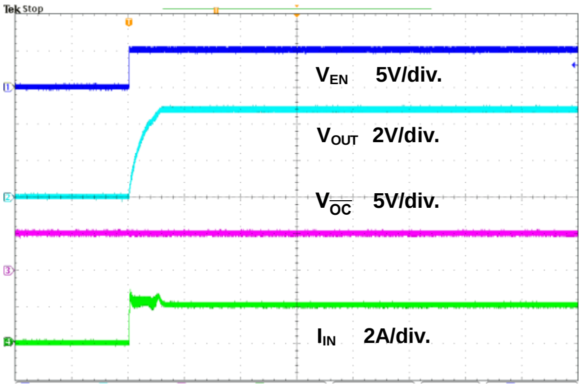
I_{OUT}=0A



1ms/div.

Figure 4. EN Start-Up with No Load

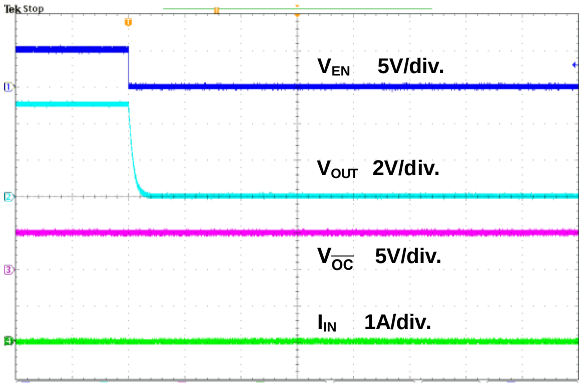
I_{OUT}=2.1A (2.38Ω)



1ms/div.

Figure 5. EN Start-Up with Heavy Load

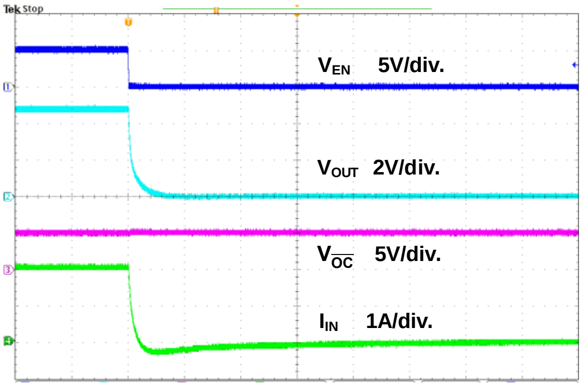
I_{OUT}=0A



2ms/div.

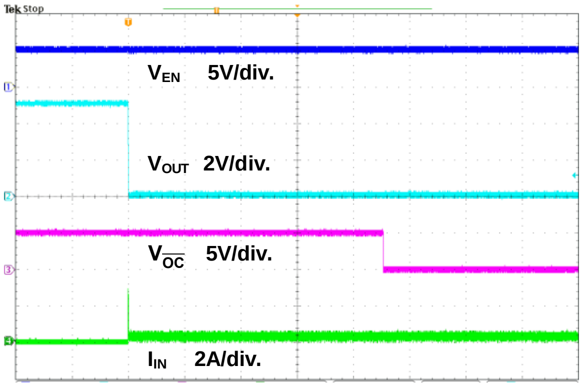
Figure 6. EN Power Off with No Load

I_{OUT}=2.1A (2.38Ω)



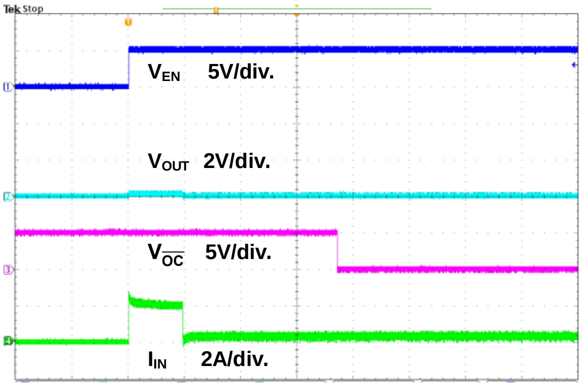
40μs/div.

Figure 7. EN Power Off with Heavy Load



2ms/div.

Figure 8. Inrush Short Circuit Response



2ms/div.

Figure 9. Short Circuit Response at Start Up

Typical Performance Curves (Continued)

V_{IN}= V_{OUT}=5V, C_{IN}=100μF, C_{OUT}=120μF, TA=+25°C, unless otherwise noted. This is measured by using FP6861E-C1AS5C.

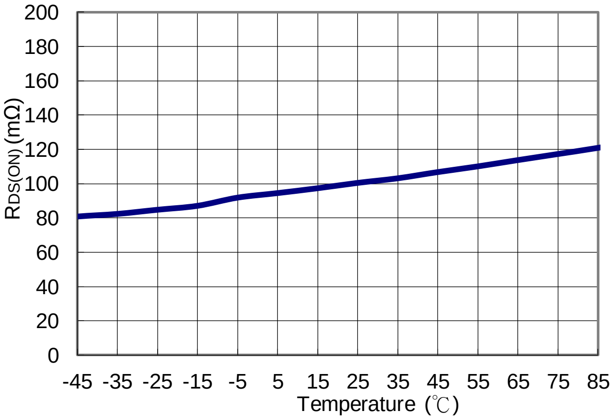


Figure 10. $R_{DS(ON)}$ vs. Temperature

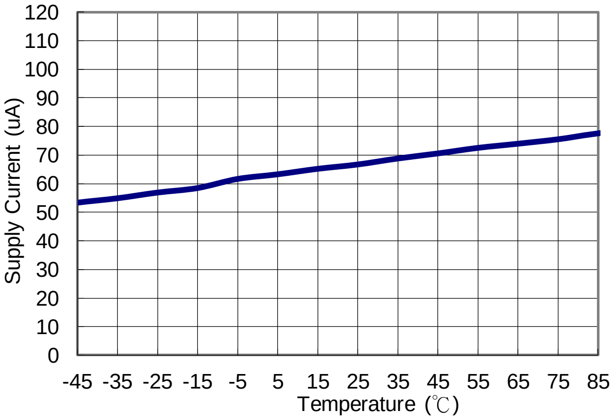


Figure 11. Supply Current vs. Temperature

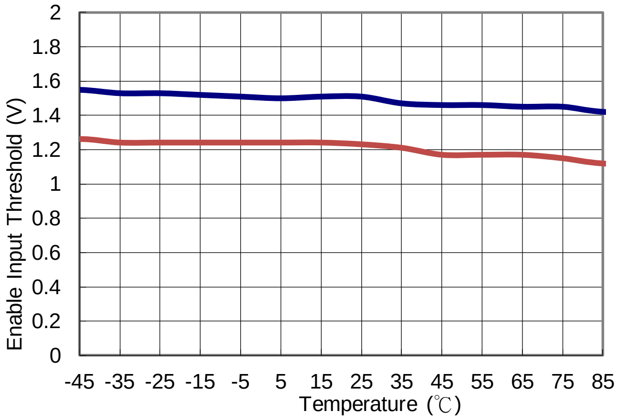


Figure 12. Enable Input Threshold vs. Temperature

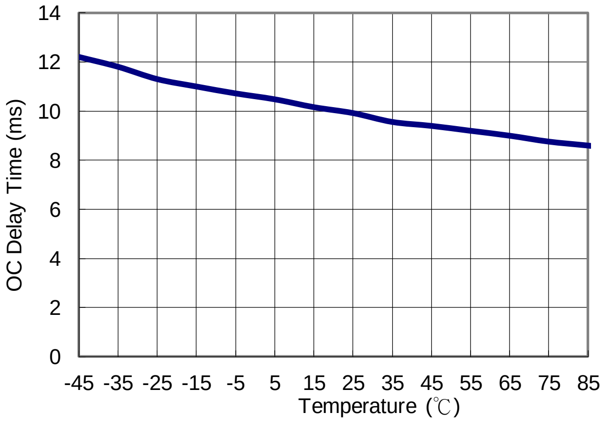


Figure 13. OC Delay Time vs. Temperature

Application Information

The FP6861E-C/E/F/H is a single N-Channel MOSFET high-side power switch, optimized for self-powered and bus-powered Universal Serial Bus (USB) applications. The FP6861E-C/E/F/H operates from 2.7V to 5.5V input voltage range and provides low supply current. The switch's low $R_{DS(ON)}$, 100mΩ, 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.

Thermal Shutdown

Thermal shutdown is employed to protect the device from damage if the die temperature exceeds safe margins mainly due to short-circuit or current-limit. Thermal shutdown will shut the switch off and cause the $\overline{OC}$ output to go low.

Reverse Current Blocking

The USB specification does not allow an output device to source current back into the USB port. However, the FP6861E-C/E/F/H 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 is bidirectional when it is enabled.

Error Flag

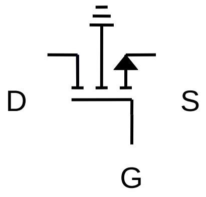
The FP6861E-C/E/F/H provides an open drain error flag output for the switch. For most applications, connect $\overline{OC}$ to VIN through a pull-up resistor. $\overline{OC}$ will go low when any following condition occurs:

a. The thermal shutdown occurs.

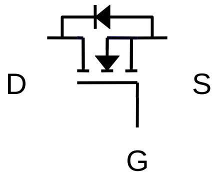
b. The switch is in current limit or short circuit conditions.

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-C/E/F/H will prevent reverse current flow if VOUT externally forces a higher voltage than VIN when the output is disabled.



FP6861E-C/E/F/H



Normal MOSFET

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.

Current Limit and Short-Circuit Protection

The current limit circuitry prevents damage to the MOSFET switch and the hub downstream port but can deliver load current up to the current limit threshold through the switch of FP6861E-C/E/F/H. When a heavy load or short circuit is applied to an enabled switch, a large transient current may flow until the current limit circuitry responds. Once exceeds the current limit threshold, the device will enter constant current mode until the thermal shutdown occurs or the fault is removed.

Fast Shutdown Load Discharge

The FP6861E provides a pull down resistance when the device is off. The resistance could discharge the load capacitor fast (refer to the block diagram). (FP6861E-x3xxx series is non-discharge.)

Application Information (Continued)

Supply Filter/Bypass Capacitor

The input capacitor must be at least 1µF 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 6.5V of the absolute maximum supply voltage even for a short duration.

Output Filter Capacitor

Output is recommended to use a 22µF 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.

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-23-5 package, the thermal resistance θ_{JA} is 250°C/W on the standard JEDEC 51-3 single-layer thermal test board.

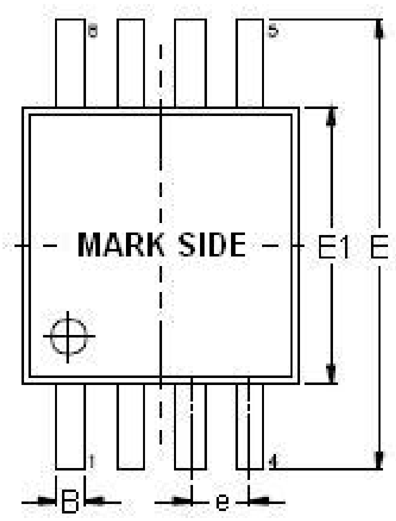
PCB Layout

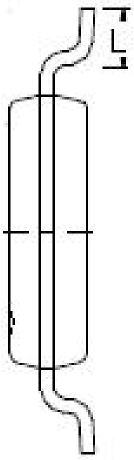
In order to meet the voltage drop and EMI requirements, careful PCB layout is necessary. The following guidelines must be considered:

- Keep all V_{BUS} traces as short as possible, and use at least 50-mil and 2 ounce copper for all V_{BUS} traces.
- Locate the FP6861E-C/E/F/H as close to the output port as possible to limit switching noise.
- Locate the ceramic bypass capacitors as close to the VIN pins of the FP6861E-C/E/F/H as possible.
- Avoid vias as much as possible. If vias are necessary, make them as large as feasible.
- 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).
- Place cuts in the ground plane between ports to help reducing the coupling of transients between ports.
- 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.

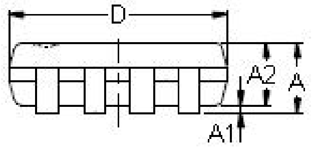
Outline Information

MSOP-8 Package (Unit: mm)

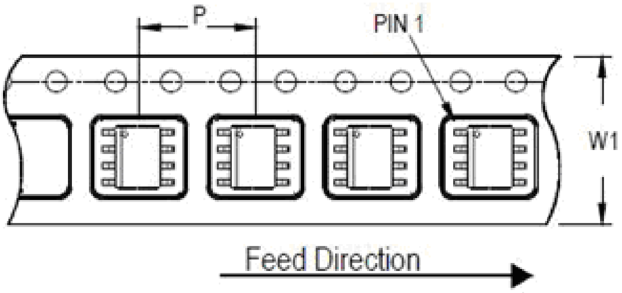


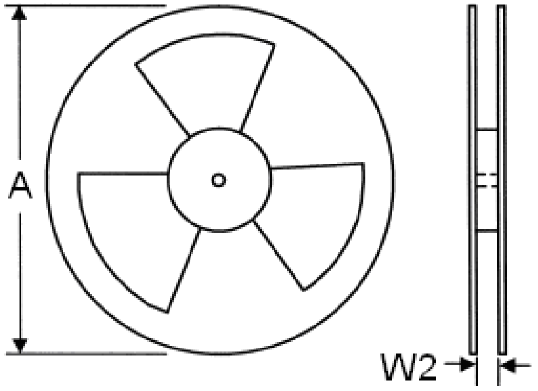


SYMBOLS UNIT	DIMENSION IN MILLIMETER	
	MIN	MAX
A	0.75	1.10
A1	0.00	0.15
A2	0.75	0.95
B	0.25	0.35
D	2.90	3.10
E	4.80	5.00
E1	2.90	3.10
e	0.60	0.70
L	0.40	0.80



Carrier Dimensions

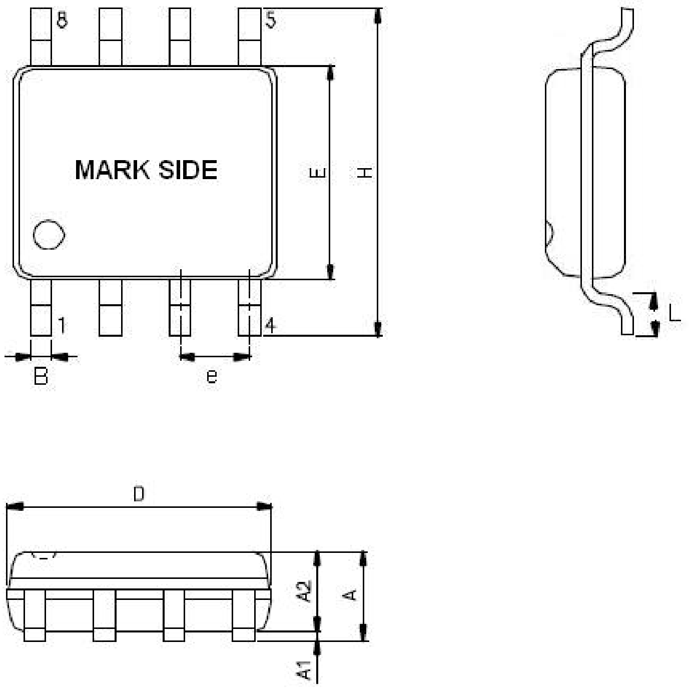




Tape Size (W1) mm	Pocket Pitch (P) mm	Reel Size (A)		Reel Width (W2) mm	Empty Cavity Length mm	Units per Reel
		in	mm			
12	8	13	330	12.4	400~1000	3,000

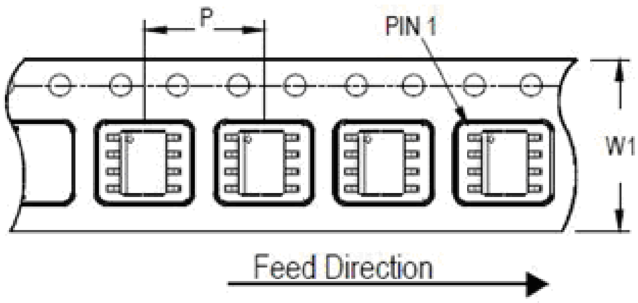
Outline Information (Continued)

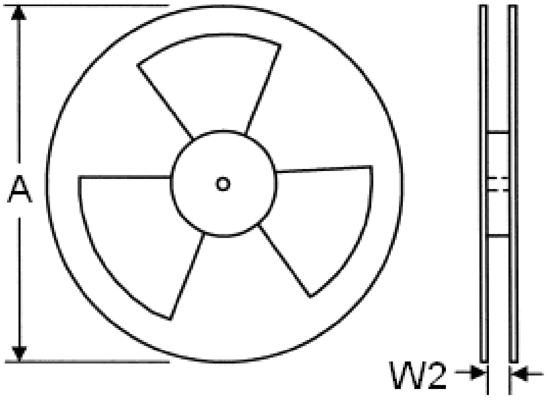
SOP-8 Package (Unit: mm)



SYMBOLS UNIT	DIMENSION IN MILLIMETER	
	MIN	MAX
A	1.35	1.75
A1	0.10	0.25
A2	1.25	1.50
B	0.31	0.51
D	4.80	5.00
E	3.80	4.00
e	1.20	1.34
H	5.80	6.20
L	0.40	1.27

Carrier Dimensions

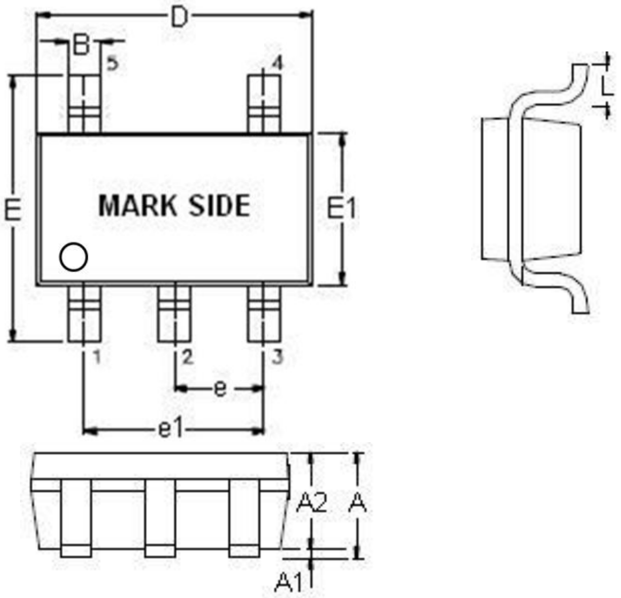




Tape Size (W1) mm	Pocket Pitch (P) mm	Reel Size (A)		Reel Width (W2) mm	Empty Cavity Length mm	Units per Reel
		in	mm			
12	8	13	330	12.4	400~1000	2,500

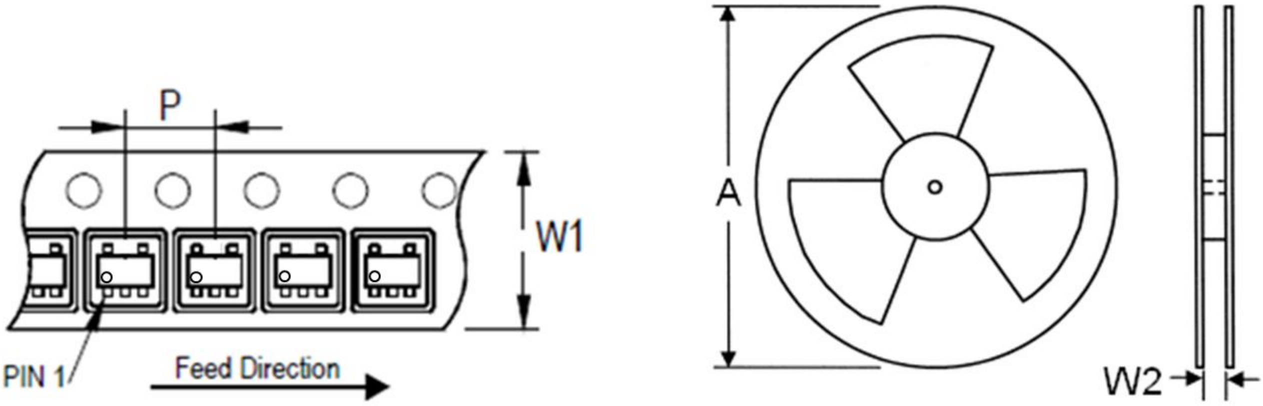
Outline Information (Continued)

SOT-23-5 Package (Unit: mm)



SYMBOLS UNIT	DIMENSION IN MILLIMETER	
	MIN	MAX
A	0.90	1.45
A1	0.00	0.15
A2	0.90	1.30
B	0.30	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

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