FAIRCHILD
SEMICONDUCTOR®

October 2007

FPF2193/4/5
Full Function Load Switch with Adjustable Current Limit

Features

- 1.8 to 5.5V Input Voltage Range
- Controlled Turn-On
- 0.15-1.5A Adjustable Current Limit
- Undervoltage Lockout
- Thermal Shutdown
- <2uA Shutdown Current
- Auto Restart
- Fast Current limit Response Time
  - 5us to Moderate Over Currents
  - 30ns to Hard Shorts
- Fault Blanking
- Reverse Current Blocking
- RoHS Compliant

Applications

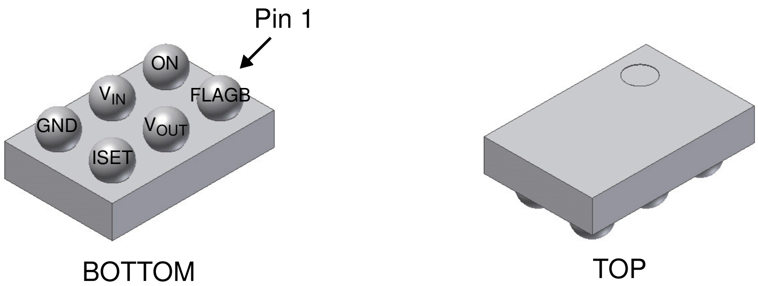
- PDAs
- Cell Phones
- GPS Hand-held Devices
- Portable Enterprise / Industrial Devices
- Digital Cameras
- Peripheral Ports and Accessories
- Portable Medical Equipment
- Hot Swap Supplies

General Description

The FPF2193, FPF2194, and FPF2195 is a series of load switches which provides full protection to systems and loads which may encounter large current conditions. These devices contain a 55mΩ current-limited P-channel MOSFET which can operate over an input voltage range of 1.8-5.5V. Internally, current is prevented from flowing when the MOSFET is off and the output voltage is higher than the input voltage. Switch control is by a logic input (ON) capable of interfacing directly with low voltage control signals. Each part contains thermal shutdown protection which shuts off the switch to prevent damage to the part when a continuous over-current condition causes excessive heating.

When the switch current reaches the current limit, the parts operate in a constant-current mode to prohibit excessive currents from causing damage. For the FPF2193 and FPF2194, if the constant current condition still persists after 30ms, these parts will shut off the switch and pull the fault signal pin (FLAGB) low. The FPF2193 has an auto-restart feature which will turn the switch on again after 450ms if the ON pin is still active. The FPF2194 does not have this auto-restart feature so the switch will remain off until the ON pin is cycled. The FPF2195 will not turn off after a current limit fault, but will rather remain in the constant current mode indefinitely. The minimum current limit is 150mA.

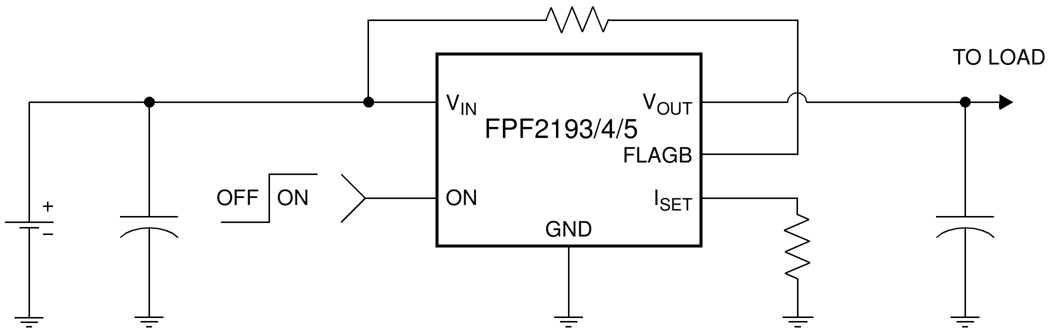
These parts are available in a space-saving 6 ball advanced. Pb-Free 1 x 1.5 mm CSP package.



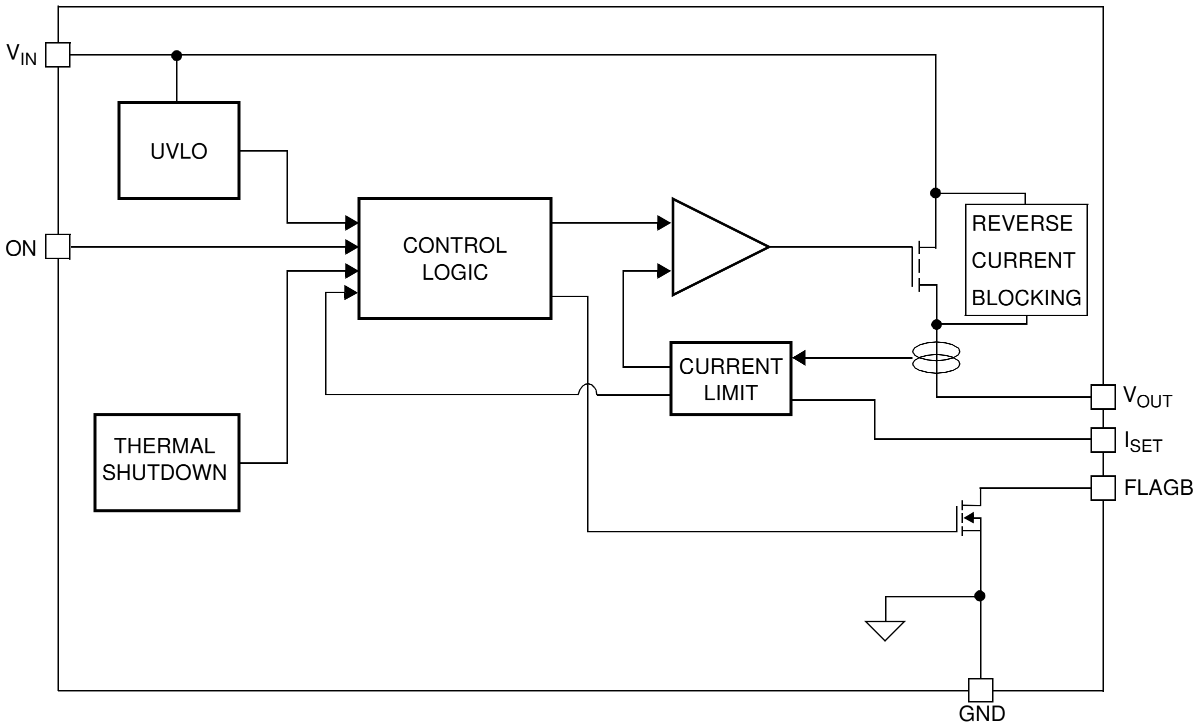
Ordering Information

Part	Current Limit [mA]	Current Limit Blanking Time [ms]	Auto-Restart Time [ms]	ON Pin Activity	Top Mark
FPF2193	150-1500	15/30/60	225/450/900	Active HI	G
FPF2194	150-1500	15/30/60	NA	Active HI	H
FPF2195	150-1500	0	NA	Active HI	J

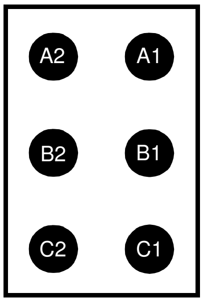
Typical Application Circuit



Functional Block Diagram



Pin Configuration



1.0 x 1.5 CSP Bottom View

Pin Description

Pin	Name	Function
C1	I_{SET}	Current Limit Set Input: A resistor from I_{SET} to ground sets the current limit for the switch.
B2	V_{IN}	Supply Input: Input to the power switch and the supply voltage for the IC
B1	V_{OUT}	Switch Output: Output of the power switch
A1	FLAGB	Fault Output: Active LO, open drain output which indicates an over current supply under voltage or over temperature state.
C2	GND	Ground
A2	ON	ON Control Input: Active Hi

Absolute Maximum Ratings

Parameter		Min.	Max.	Unit
V_{IN}, V_{OUT}, ON, FLAGB, ISET to GND		-0.3	6	V
Power Dissipation @ T_A = 25°C (Note 1)			1.2	W
Operating Temperature Range		-40	125	°C
Storage Temperature		-65	150	°C
Thermal Resistance, Junction to Ambient			85	°C/W
Electrostatic Discharge Protection	HBM	8000		V
	MM	400		V

Recommended Operating Range

Parameter	Min.	Max.	Unit
V_{IN}	1.8	5.5	V
Ambient Operating Temperature, T_A	-40	85	°C

Electrical Characteristics

V_{IN} = 1.8 to 5.5V, T_A = -40 to +85°C unless otherwise noted. Typical values are at V_{IN} = 3.3V and T_A = 25°C.

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Units
Basic Operation							
Operating Voltage	V_{IN}			1.8		5.5	V
Quiescent Current	I_Q	I_{OUT} = 0mA V_{ON} = V_{IN}	V_{IN} = 1.8V		70		µA
			V_{IN} = 3.3V		75		
			V_{IN} = 5.5V		80		
On-Resistance	R_{ON}	T_A = 25°C, I_{OUT} = 200mA			55	80	mΩ
		T_A = -40 to +85°C, I_{OUT} = 200mA				135	

Note 1: Package power dissipation on 1square inch pad, 2 oz. copper board.

Electrical Characteristics Cont.

V_{IN} = 1.8 to 5.5V, T_A = -40 to +85℃ unless otherwise noted. Typical values are at V_{IN} = 3.3V and T_A = 25℃.

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Units
ON Input Logic High Voltage (ON)	V_{IH}	V_{IN} = 1.8V	0.8			V
		V_{IN} = 5.5V	1.4			
ON Input Logic Low Voltage	V_{IL}	V_{IN} = 1.8V			0.5	V
		V_{IN} = 5.5V			1.0	
ON Input Leakage		V_{ON} = V_{IN} or GND	-1	0	1	μA
V_{IN} Shutdown Current		V_{ON} = 0V, V_{IN} = 5.5V, V_{OUT} = short to GND	-2		2	μA
FLAGB Output Logic Low Voltage		V_{IN} = 5V, I_{SINK} = 10mA		0.05	0.2	V
		V_{IN} = 1.8V, I_{SINK} = 10mA		0.12	0.3	
FLAGB Output High Leakage Current		V_{IN} = 5V, Switch ON			1	μA
Reverse Block						
V_{OUT} Shutdown Current		V_{ON} = 0V, V_{OUT} = 5.5V, V_{IN} = short to GND	-2		2	μA
Reverse Breakdown Voltage	$V_{breakdown}$	V_{IN} = V_{ON} = 0V, I_{OUT} = 200μA		9		V
Protections						
Current Limit	I_{LIM}	V_{IN} = 3.3V, V_{OUT} = 3.0V, R_{SET} = 690Ω	600	800	1000	mA
Min. Current Limit	$I_{LIM(min.)}$	V_{IN} = 3.3V, V_{OUT} = 3.0V		150		mA
Thermal Shutdown		Shutdown Threshold		140		℃
		Return from Shutdown		130		
		Hysteresis		10		
Under Voltage Lockout	V_{UVLO}	V_{IN} Increasing	1.55	1.65	1.75	V
Under Voltage Lockout Hysteresis				50		mV
Dynamic						
Delay On Time	td_{ON}	R_L=500Ω, C_L=0.1μF		20		μs
V_{OUT} Rise Time	t_R	R_L=500Ω, C_L=0.1μF		20		μs
Turn On Time	t_{ON}	R_L=500Ω, C_L=0.1μF		40		μs
Delay Off Time	td_{OFF}	R_L=500Ω, C_L=0.1μF		15		μs
V_{OUT} Fall Time	t_F	R_L=500Ω, C_L=0.1μF		110		μs
Turn Off Time	t_{OFF}	R_L=500Ω, C_L=0.1μF		125		μs
Over Current Blanking Time	t_{BLANK}	FPF2193, FPF2194	15	30	60	ms
Auto-Restart Time	t_{RSTRT}	FPF2193	225	450	900	ms
		FPF2194, FPF2195		NA		
Short Circuit Response Time		V_{IN} = V_{OUT} = 3.3V. Moderate Over-Current Condition.		5		μs
		V_{IN} = V_{OUT} = 3.3V. Hard Short.		30		ns

Typical Characteristics

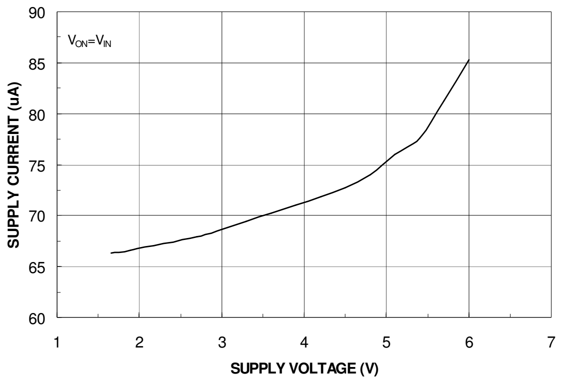


Figure 1. Quiescent Current vs. Input Voltage

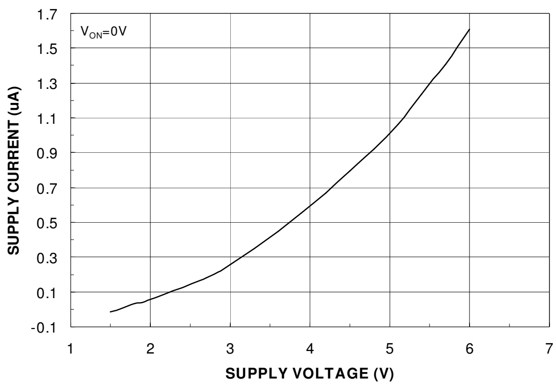


Figure 2. Quiescent Current vs. Input Voltage

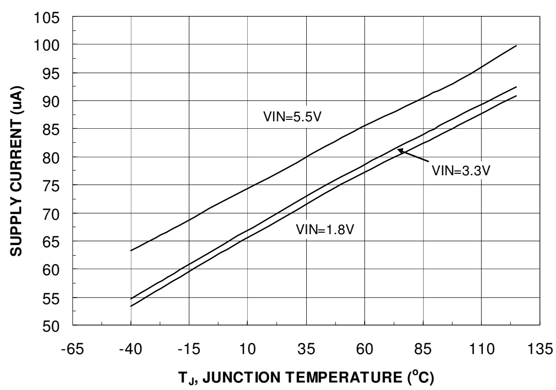


Figure 3. Quiescent Current vs. Temperature

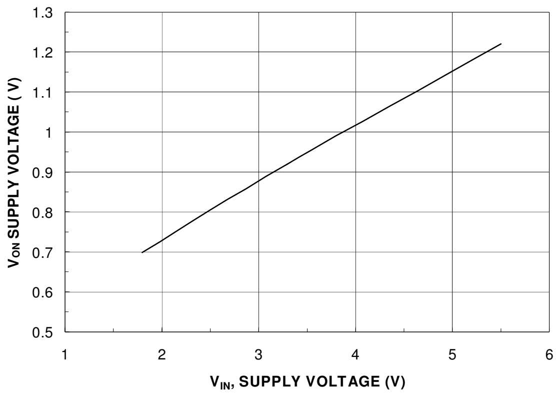


Figure 4. V_{ON} High Voltage vs. Input Voltage

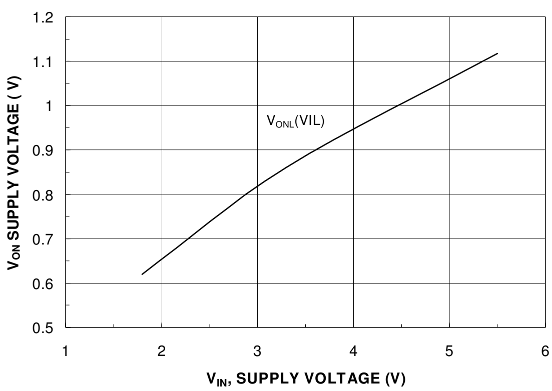


Figure 5. V_{ON} Low Voltage vs. Input Voltage

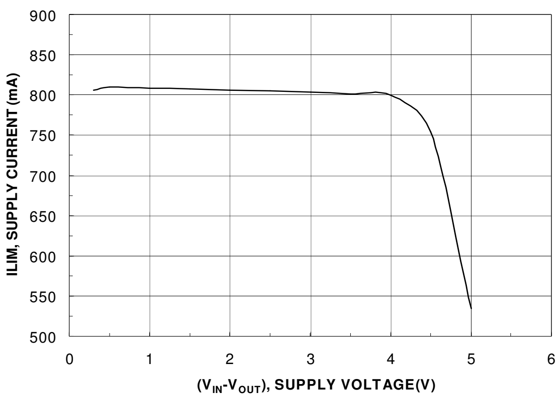


Figure 6. Current Limit vs. Output Voltage

Typical Characteristics

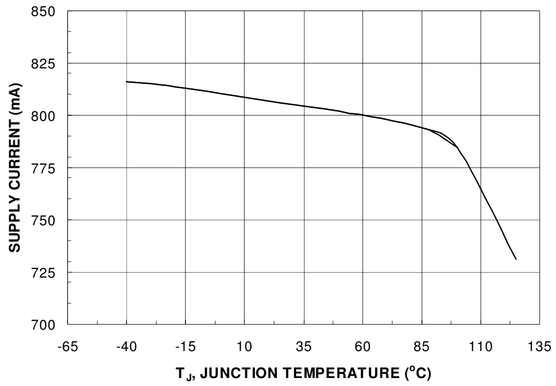


Figure 7. Current Limit vs. Temperature

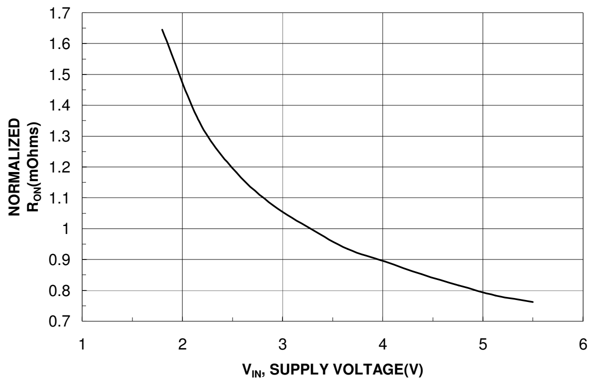


Figure 8. R_{ON} vs. V_{IN}

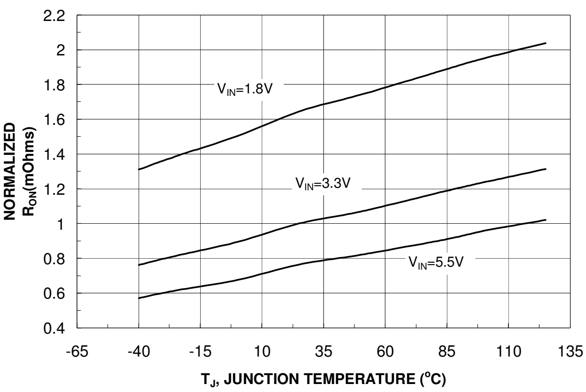


Figure 9. R_{ON} vs. Temperature

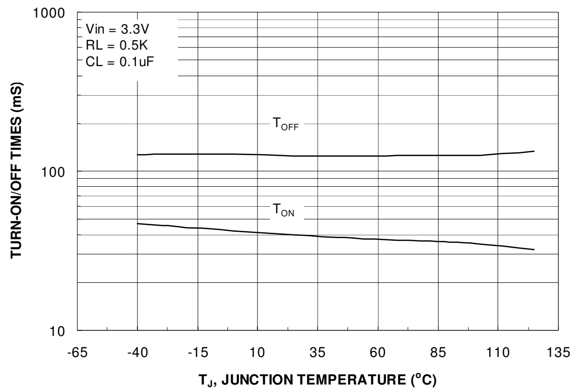


Figure 10. T_{ON} / T_{OFF} vs. Temperature

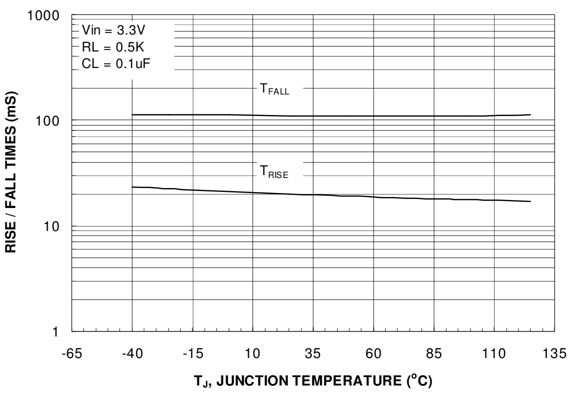


Figure 11. T_{RISE} / T_{FALL} vs. Temperature

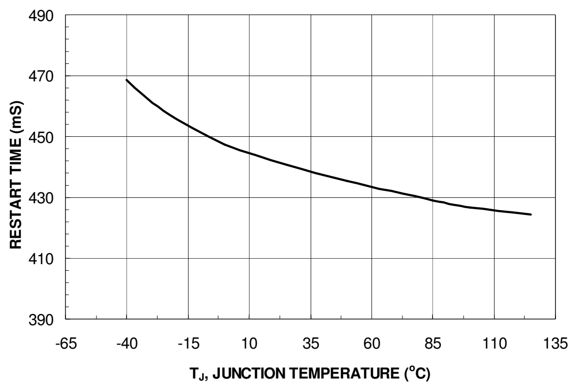


Figure 12. $T_{RESTART}$ vs. Temperature

Typical Characteristics

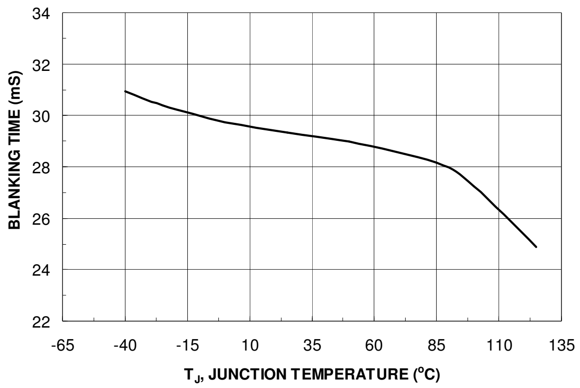


Figure 13. T_{BLANK} vs. Temperature

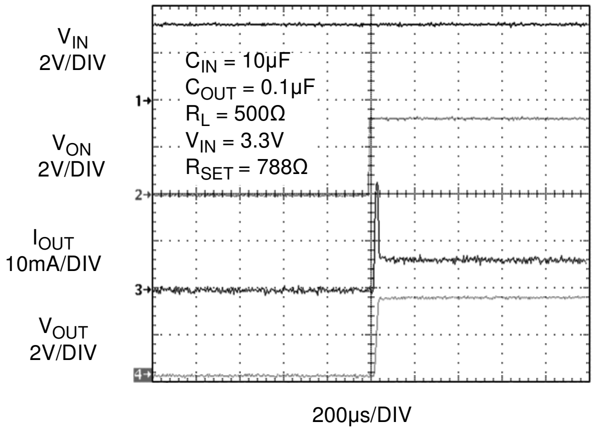


Figure 14. T_{ON} Response

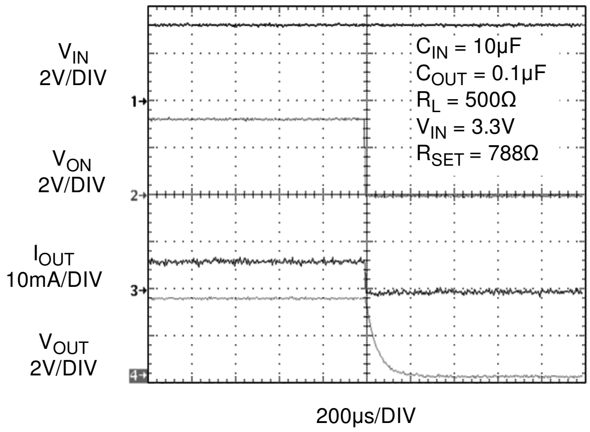


Figure 15. T_{OFF} Response

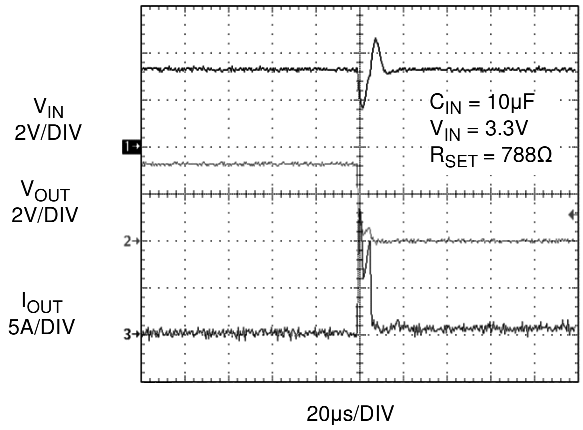


Figure 16. Short Circuit Response Time
(Output shorted to GND)

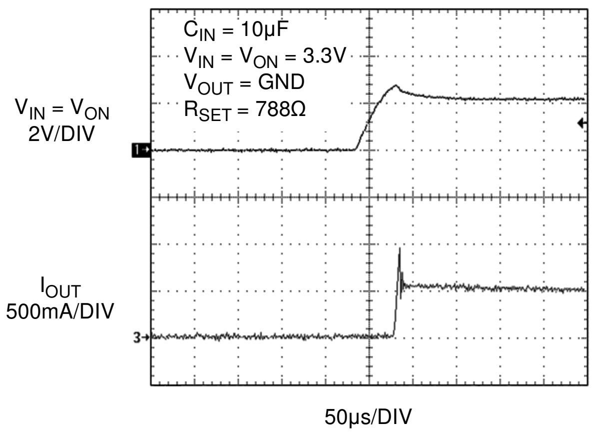


Figure 17. Current Limit Response Time
(Switch is powered into a short)

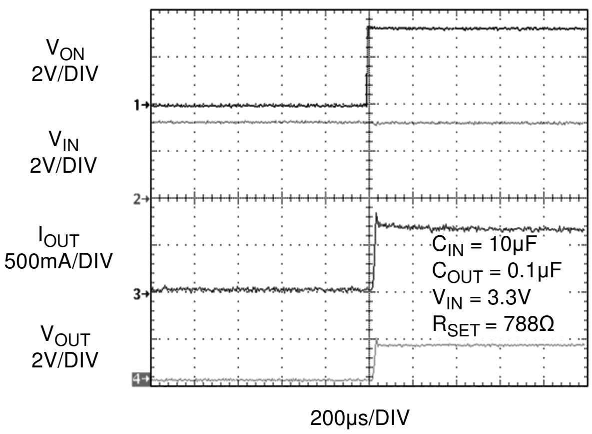


Figure 18. Current Limit Response Time
(Output is loaded by 2.2Ω, C_{OUT} = 0.1µF)

Typical Characteristics

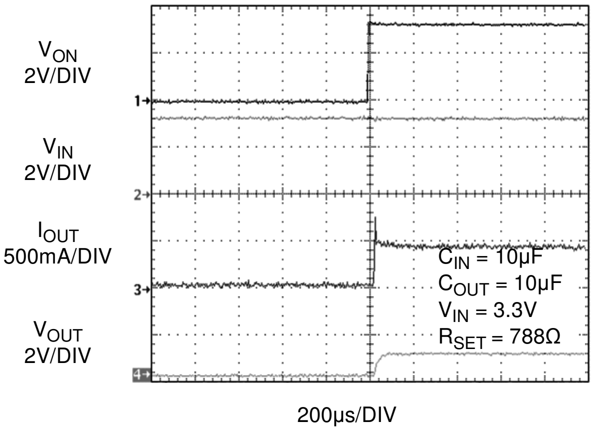


Figure 19. Current Limit Response Time
(Output is loaded by 2.2Ω, C_{OUT} = 10µF)

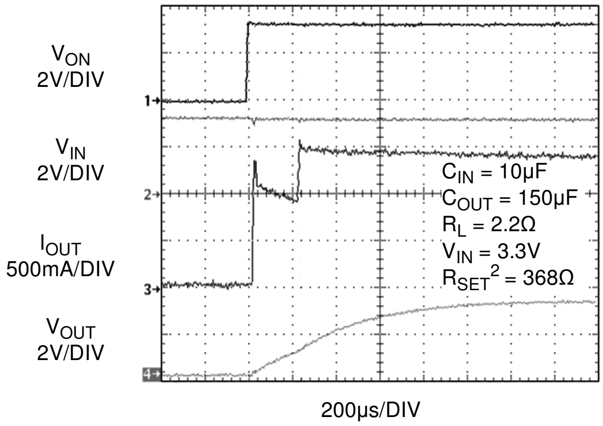


Figure 20. Short Circuit Detection Function (Note 2)

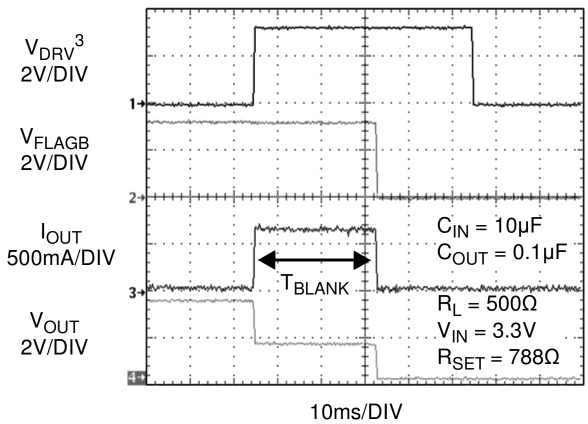


Figure 21. T_{BLANK} Response

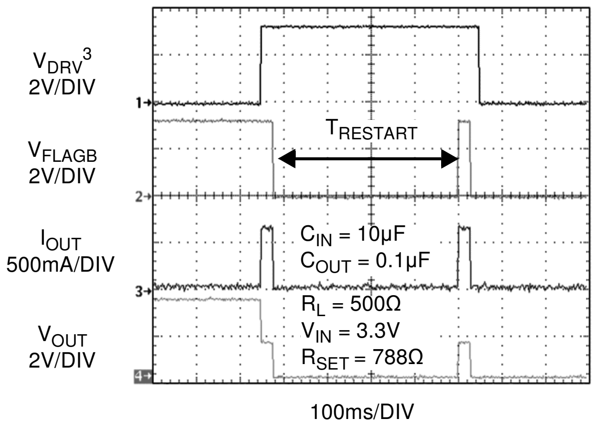


Figure 22. $T_{RESTART}$ Response

Note 2: When the output voltage is below VSCTH=1.1V, the current limit value is set at 62.5% of the current limit value.
Note 3: V_{DRV} signal forces the device to go into overcurrent condition by loading.

Description of Operation

The FPF2193, FPF2194, and FPF2195 are current limited switches that protect systems and loads which can be damaged or disrupted by the application of high currents. The core of each device is a 55mΩ P-channel MOSFET and a controller capable of functioning over a wide input operating range of 1.8-5.5V. The controller protects against system malfunctions through current limiting, under-voltage lockout and thermal shutdown. The current limit is adjustable from 150mA to 1.5A through the selection of an external resistor.

On/Off Control

The ON pin controls the state of the switch. When ON is high, the switch is in the on state. Activating ON continuously holds the switch in the on state so long as there is no fault. For all versions, an under-voltage on V_{IN} or a junction temperature in excess of 140°C overrides the ON control to turn off the switch. In addition, excessive currents will cause the switch to turn off in the FPF2193 and FPF2194. The FPF2193 has an Auto-Restart feature which will automatically turn the switch on again after 450ms. For the FPF2194, the ON pin must be toggled to turn-on the switch again. The FPF2195 does not turn off in response to an over current condition but instead remains operating in a constant current mode so long as ON is active and the thermal shutdown or under-voltage lockout have not activated.

Fault Reporting

Upon the detection of an over-current, an input under-voltage, or an over-temperature condition, the FLAGB signals the fault mode by activating LO. For the FPF2193 and FPF2194, the FLAGB goes LO at the end of the blanking time while FLAGB goes LO immediately for the FPF2195. FLAGB remains LO through the Auto-Restart Time for the FPF2195. For the FPF2194, FLAGB is latched LO and ON must be toggled to release it. With the FPF2195, FLAGB is LO during the faults and immediately returns HI at the end of the fault condition. FLAGB is an open-drain MOSFET which requires a pull-up resistor between VIN and FLAGB. During shutdown, the pull-down on FLAGB is disabled to reduce current draw from the supply.

Current Limiting

The current limit ensures that the current through the switch doesn't exceed a maximum value while not limiting at less than a minimum value. The current at which the parts will limit is adjustable through the selection of an external resistor connected to ISET. Information for selecting the resistor is found in the Application Info section. The FPF2193 and FPF2194 have a blanking time of 30ms, nominally, during which the switch will act as a constant current source. At the end of the blanking time, the switch will be turned-off. The FPF2195 has no current limit blanking period so it will remain in a constant current state until the ON pin is deactivated or the thermal shutdown turns-off the switch.

For preventing the switch from large power dissipation during heavy load a short circuit detection feature is introduced. Short circuit condition is detected by observing the output voltage. The switch is put into short circuit current limiting mode if the switch is loaded with a heavy load. When the output voltage drops below VSCTH, short circuit detection threshold voltage, the current limit value re-conditioned and short circuit current limit value is decreased to 62.5% of the current limit value. This keeps the power dissipation of the part below a certain limit even at dead short conditions at 5.5V input voltage. The VSCTH value is set to be 1V. At around 1.1V of output voltage the switch is removed from short circuit current limiting mode and the current limit is set to the current limit value.

Under-Voltage Lockout

The under-voltage lockout turns-off the switch if the input voltage drops below the under-voltage lockout threshold. With the ON pin active the input voltage rising above the under-voltage lockout threshold will cause a controlled turn-on of the switch which limits current over-shoots.

Thermal Shutdown

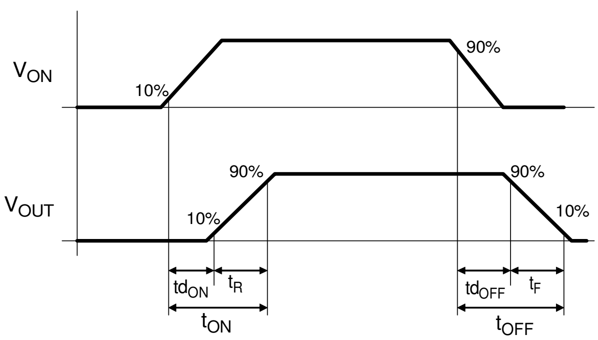
The thermal shutdown protects the die from internally or externally generated excessive temperatures. During an over-temperature condition the FLAGB is activated and the switch is turned-off. The switch automatically turns-on again if temperature of the die drops below the threshold temperature.

Reverse Current Blocking

The entire FPF2193/95 family has a Reverse Current Blocking feature that protects input source against current flow from output to input. For a standard USB power design, this is an important feature which protects the USB host from being damaged due to reverse current flow on V_{BUS}.

When the load switch is OFF, no current flows from the output to the input. If the switch is turned on and the output voltage is greater than input voltage this feature is activated and turns off the switch. This will prevent any current flow from output to input. The reverse current blocking feature will be deactivated if the V_{OUT} - V_{IN} is smaller than a typically 50mV threshold. During this time some current (50mV/R_{ON}) will flow from the output to input until input voltage become greater than output voltage. The FLAGB operation is independent of the Reverse Current blocking and will not report a fault condition if this feature is activated.

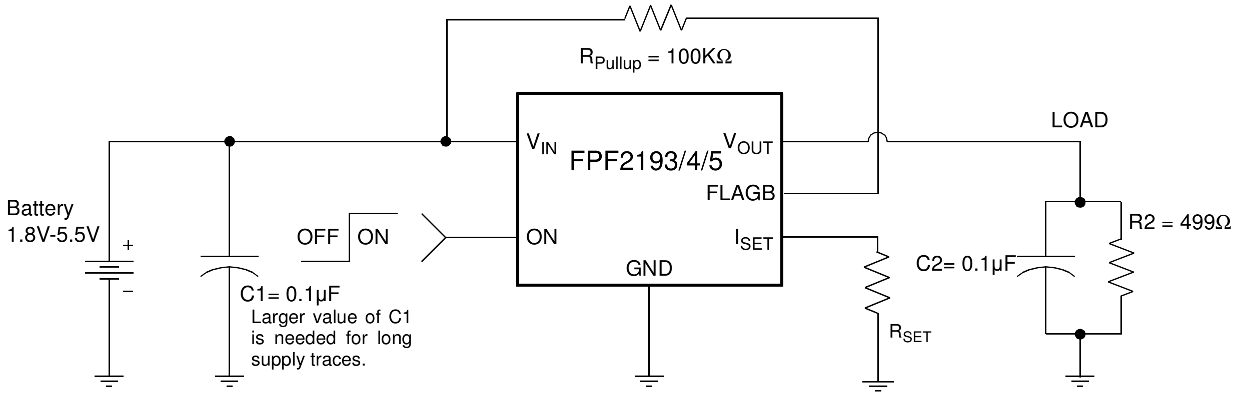
Timing Diagram



where:
td_{ON} = Delay On Time
t_R = V_{OUT} Rise Time
t_{ON} = Turn On Time
td_{OFF} = Delay Off Time
t_F = V_{OUT} Fall Time
t_{OFF} = Turn Off Time

Application Information

Typical Application



Setting Current Limit

The FPF2193, FPF2194, and FPF2195 have a current limit which is set with an external resistor connected between ISET and GND. This resistor is selected by using the following equation,

$$R_{SET} = \frac{551.6}{I_{LIM}} \quad (1)$$

R_{SET} is in Ohms and that of I_{SET} is Amps

The table below can also be used to select R_{SET}. A typical application would be the 500mA current that is required by a single USB port. Using the table below an appropriate selection for the R_{SET} resistor would be 788Ω. This will ensure that the port load could draw 525mA, but not more than 875mA. Likewise for a dual port system, an R_{SET} of 368Ω would always deliver at least 1125mA and never more than 1875mA.

Current Limit Various R_{SET} Values

R_{SET} [Ω]	Min. Current Limit [mA]	Typ. Current Limit [mA]	Max. Current Limit [mA]
368	1125	1500	1875
441	938	1250	1562
552	750	1000	1250
613	675	900	1125
690	600	800	1000
788	525	700	875
919	450	600	750
1103	375	500	625
1226	338	450	563
1379	300	400	500
1576	263	350	438
1839	225	300	375
2206	188	250	313
2758	150	200	250
3677	113	150	188

Input Capacitor

To limit the voltage drop on the input supply caused by transient in-rush currents when the switch is turned on into a discharged load capacitor or a short-circuit, a capacitor needs to be placed between V_{IN} and GND. A 0.1uF ceramic capacitor, C_{IN}, placed close to the pins is usually sufficient. Higher values of C_{IN} can be used to further reduce the voltage drop.

Output Capacitor

A 0.1uF capacitor C_{OUT}, should be placed between V_{OUT} and GND. This capacitor will prevent parasitic board inductances from forcing V_{OUT} below GND when the switch turns-off. For the FPF2193 and FPF2194, the total output capacitance needs to be kept below a maximum value, C_{OUT}(max), to prevent the part from registering an over-current condition and turning-off the switch. The maximum output capacitance can be determined from the following formula,

$$C_{OUT(max)} = \frac{I_{LIM}(max) \times t_{BLANK}(min)}{V_{IN}} \quad (2)$$

Power Dissipation

During normal operation as a switch, the power dissipated in the part will depend upon the level at which the current limit is set. The maximum allowed setting for the current limit is 1.5A and this will result in a power dissipation of,

$$P = (I_{LIM})^2 \times R_{ON} = (1.5)^2 \times 0.055 = 123.75mW \quad (3)$$

If the part goes into current limit the maximum power dissipation will occur when the output is shorted to ground. For the FPF2193, the power dissipation will scale by the Auto-Restart Time, t_{RSTRT}, and the Over Current Blanking Time, t_{BLANK}, so that the maximum power dissipated is,

$$P(max) = \frac{t_{BLANK}}{t_{BLANK} + t_{RSTRT}} \times V_{IN}(max) \times I_{LIM}(max)$$

$$= \frac{30}{30 + 450} \times 5.5 \times 1.5 = 515.6mW \quad (4)$$

This is more power than the package can dissipate, but the thermal shutdown of the part will activate to protect the part from damage due to excessive heating. When using the FPF2194, attention must be given to the manual resetting of the part. The junction temperature will only be able to increase to the thermal shutdown threshold. Once this temperature has been reached, toggling ON will not turn-on the switch until the junction temperature drops. For the FPF2195, a short on the output will cause the part to operate in a constant current state dissipating a worst case power of,

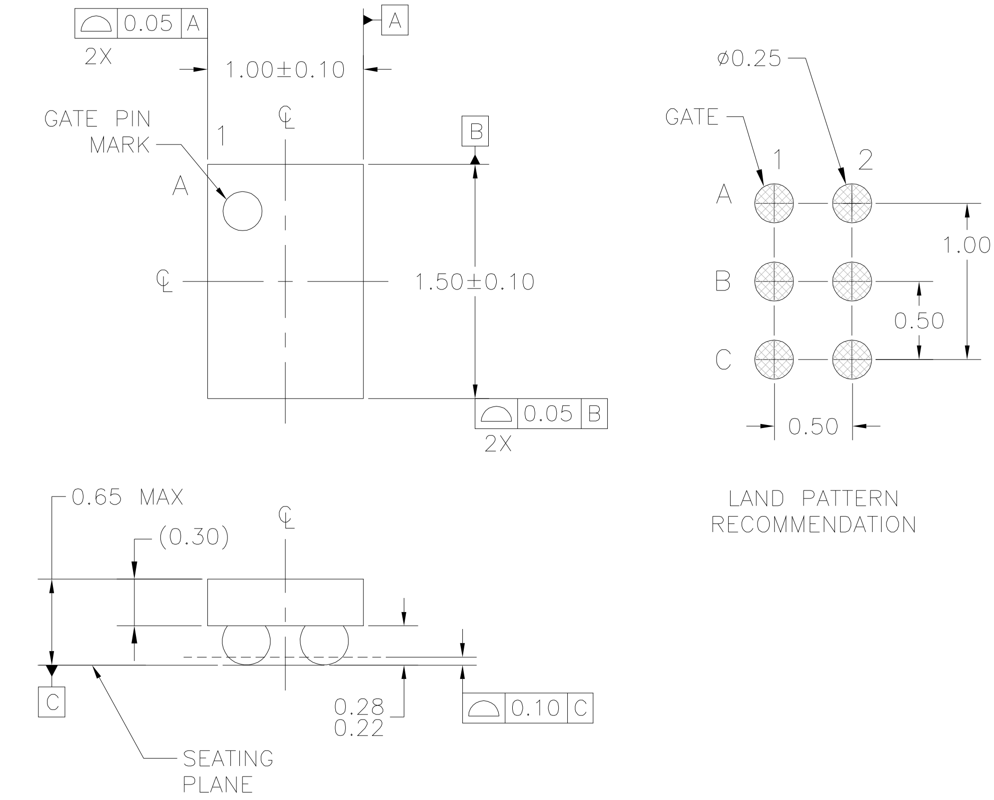
$$\begin{aligned} P(max) &= V_{IN}(max) \times I_{LIM}(max) \\ &= 5.5 \times 1.5 = 8.25W \end{aligned} \tag{5}$$

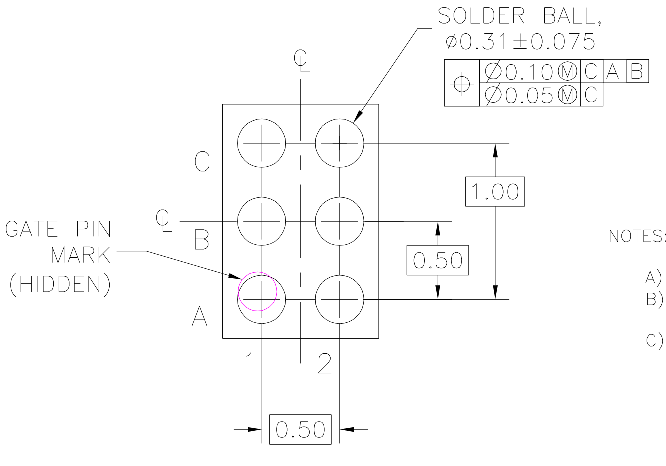
This large amount of power will activate the thermal shutdown and the part will cycle in and out of thermal shutdown so long as the ON pin is active and the short is present.

Board Layout

For best performance, all traces should be as short as possible. To be most effective, the input and output capacitors should be placed close to the device to minimize the effects that parasitic trace inductances may have on normal and short-circuit operation. Using wide traces for V_{IN}, V_{OUT} and GND will help minimize parasitic electrical effects along with minimizing the case to ambient thermal impedance.

Dimensional Outline and Pad Layout





NOTES: UNLESS OTHERWISE SPECIFIED

A) ALL DIMENSIONS ARE IN MILLIMETERS.
B) NO JEDEC REGISTRATION REFERENCE AS OF OCTOBER 2005.
C) TERMINAL CONFIGURATION TABLE.

POSITION	DESIGNATION
C1, C2	DRAIN
A1	GATE
A2, B1, B2	SOURCE

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