5.5-V 6-A High-Current Load Switch with Accurate Current Limit

Features

- Operating Voltage Range: 2.5 V to 5.5 V
- Integrated High-Side MOSFET
  - 13-mΩ Turn-On Resistance
- 6-A Maximum Continuous Current
  - 1.2-A to 6-A Adjustable Output Current Limit
  - ±5% Current Limit Accuracy at 4.7 A
- 2-μA Low Standby Current
- Build-in Soft-Start and Inrush Control
- Integrated Protection:
  - Over-Current Protection
  - Hard Short-to-Ground Protection
  - Reverse Current Block Protection
  - Over-Temperature Protection
- Temperature Range: −40°C to 125°C
- Package: DFN3X3-10

Applications

- Wireless Communication, Telecom
- Optical Module
- Notebook, Portable Computer, Server
- USB Ports, USB Hub
- TV and Set-Top Box

Description

The TPS05S60 is a high-output current load switch with low turn-on resistance, low standby current, and accurate output current limit control. It integrates a MOSFET with typically 13-mΩ turn-on resistance and can handle a continuous current of up to 6 A. The output current limit is adjustable between 1.2 A and 6 A through an external resistor, with a precision of ±5% at 4.7 A.

The TPS05S60 has integrated fault detection and protection functions. The nFLT pin pulls low when an over-current or an over-temperature fault occurs. This device offers protection against output over-current, short circuits to ground, reverse current from output to input, and over-temperature situations, safeguarding the TPS05S60 from potential damage.

The TPS05S60 is designed to operate over a wide ambient temperature range, from -40°C to +125°C. It comes in a thermal-enhanced DFN3X3-10 package to enable sustained operation despite significant dissipation across the device.

Typical Application Circuit

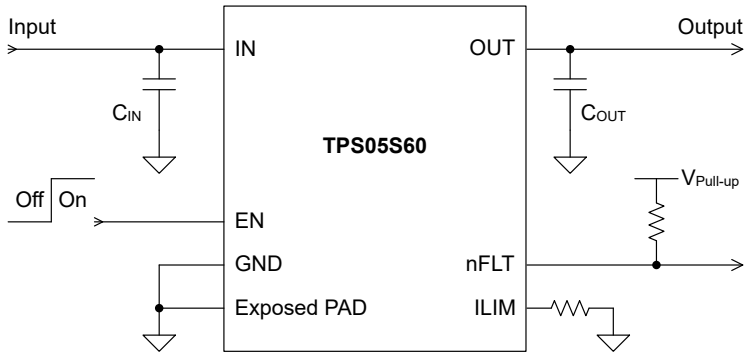


Table of Contents

Product Family Table

Order Number	Turn-On Resistance (mΩ)	OCP Fault Response	Package
TPS05S60A-DF8R-S	13	Auto Retry	DFN3X3-10

Revision History

Date	Revision	Notes
2023-06-30	Rev.Pre.0	Preliminary datasheet.
2024-08-31	Rev.Pre.1	Updated Electrical Characteristics table.
2024-10-31	Rev.A.0	Initial released.

Pin Configuration and Functions

TPS05S60
DFN3X3-10 Package
Top View

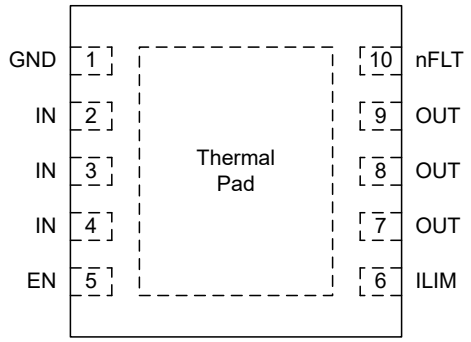


Table 1. Pin Functions: TPS05S60

Pin No.	Pin Name	I/O	Description
5	EN	I	Device enable pin. Drive EN high to turn on the device and drive EN low to turn it off.
1	GND	–	Ground reference pin. Connect the GND pin directly to the PCB ground plane.
6	ILIM	O	Output current limit set pin. Connect an external resistor from the ILIM pi to the GND pin to set the current limit threshold.
2, 3, 4	IN	I	Input voltage pin. It is recommended to connect a 0.1 μF or greater ceramic capacitor from the IN pin to the GND pin closely by the device.
10	nFLT	O	Fault indication pin. The nFLT pin is an active-low open-drain output. Connect the nFLT pin to V_{OUT} or to a pull-up voltage through an external resistor.
7, 8, 9	OUT	O	Output voltage pin. An output capacitor is not required. 3PEAK recommends adding a 1 μF or greater ceramic capacitor from the OUT pin to the GND pin to improve transient performance.
–	Thermal Pad	–	Exposed Thermal PAD **MUST** be connected to the PCB ground plane directly.

Specifications

Absolute Maximum Ratings (1)

Parameter		Min	Max	Unit
IN	Input Supply Voltage	−0.3	6	V
EN	Enable Voltage	−0.3	6	V
OUT	Output Voltage	−0.3	6	V
ILIM, nFLT		−0.3	6	V
Continuous Output Current, I_{OUT}		Internal Limited		A
T_J	Junction Temperature Range	−40	150	°C
T_{STG}	Storage Temperature Range	−65	150	°C
T_L	Lead Temperature (Soldering 10 sec)		260	°C

(1) Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.
(2) All voltage values are with respect to GND.
(3) Not subject to production test, specified by design.

ESD, Electrostatic Discharge Protection

Parameter		Condition	Minimum Level	Unit
HBM	Human Body Model ESD	ANSI/ESDA/JEDEC JS-001 (1)	±2	kV
CDM	Charged Device Model ESD	ANSI/ESDA/JEDEC JS-002 (2)	±1	kV

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

Recommended Operating Conditions

Parameter		Min	Max	Unit
V_{IN}	Input Voltage	2.5	5.5	V
V_{EN}	Enable Voltage	0	V_{IN}	V
R_{LIM}	Current Limit Resistor	24.9	100	kΩ
T_J	Junction Temperature	−40	125	°C

Thermal Information

Package Type	θ_{JA}	θ_{JB}	$\theta_{JC,TOP}$	Unit
DFN3X3-10	43.3	8.7	54.7	°C/W

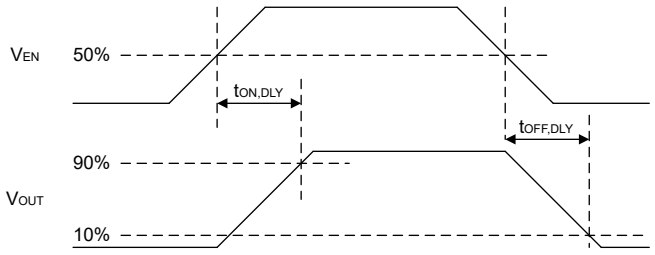
Electrical Characteristics

All test conditions: V_{IN} = 2.5 V to 5.5 V, V_{EN} = 2 V, R_{ILIM} = 49.9 kΩ, R_L = 100 Ω, C_L = 1 µF, T_J = −40°C to +125°C. Typical value at T_J = +25°C. All voltages are with respect to GND, and the positive currents are into pins (unless otherwise noted).

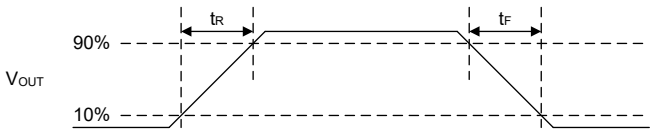
Parameter		Conditions	Min	Typ	Max	Unit
Input Power Supply						
UVLO	V_{IN} Under-Voltage Lockout Threshold	V_{IN} rising, I_{OUT} = 10 mA		2.36	2.495	V
	Hysteresis			130		mV
I_Q	Quiescent Current	V_{EN} = 2 V, R_{LIM} = 100 kΩ, I_{OUT} = 0 mA		230	390	µA
		V_{EN} = 2 V, R_{LIM} = 24.9 kΩ, I_{OUT} = 0 mA		230	390	µA
I_{SD}	Shutdown Current	V_{EN} = 0 V, IOUT = 0 mA, T_J = −40°C to +85°C		1.27	2	µA
		V_{EN} = 0 V, IOUT = 0 mA, T_J = −40°C to +125°C		1.27	8	µA
$V_{REV,TH}$	Reverse Protection Threshold (1)	V_{OUT} − V_{IN}		50	100	mV
I_{REV}	Reverse Leakage Current	V_{OUT} = 5.5 V, V_{IN} = 0 V, TJ = –40°C to +85°C, measure I_{OUT}		0.01	1	µA
Enable Voltage and Current						
$V_{IH,EN}$	EN Logic Input High Level (Enable)		1.1			V
$V_{IL,EN}$	EN Logic Input Low Level (Disable)				0.5	V
$V_{HYST,EN}$	Hysteresis			130		mV
I_{EN}	EN Pin Leakage Current	V_{EN} = 0 V to 5 V	−1		1	µA
$t_{ON,DLY}$	OUT Turn-On Delay Time (1) (3)	V_{IN} = 5 V, from EN × 50% to V_{OUT} ≥ V_{IN} × 90%		10	15	ms
$t_{OFF,DLY}$	OUT Turn-Off Delay Time (1) (3)	V_{IN} = 5 V, from EN × 50% to V_{OUT} ≤ V_{IN} × 10%		6	8	ms
Output Stage						
R_{ON}	Turn-On Resistance (2)	T_J = 25°C		13	17	mΩ
		T_J = −40 to 125°C			22	mΩ
t_R	OUT Voltage Rising Time (1) (4)	V_{IN} = 5.5 V, from V_{OUT} = V_{IN} × 10% to V_{OUT} = V_{IN} × 90%		4	6	ms
		V_{IN} = 2.5 V, from V_{OUT} = V_{IN} × 10% to V_{OUT} = V_{IN} × 90%		2.5	4	ms
t_F	OUT Voltage Falling Time (1) (4)	V_{IN} = 5.5 V, from V_{OUT} = V_{IN} × 90% to V_{OUT} = V_{IN} × 10%		1.5	2	ms

Parameter		Conditions	Min	Typ	Max	Unit
		V_{IN} = 2.5 V, from V_{OUT} = V_{IN} × 90% to V_{OUT} = V_{IN} × 10%		1	1.5	ms
Output Current						
I_{SC}	OUT Short-Circuit Current Limit	R_{ILIM} = 0 Ω	5800	6650	7460	mA
		R_{ILIM} = 24.9 kΩ	4460	4731	4960	mA
		R_{ILIM} = 44.2 kΩ	2470	2665	2775	mA
		R_{ILIM} = 49.9 kΩ	2200	2360	2460	mA
		R_{ILIM} = 61.9 kΩ	1750	1902	1990	mA
		R_{ILIM} = 100 kΩ (1)	1050	1176	1245	mA
		R_{ILIM} = open (1)			100	mA
t_{SC}	OUT Short-Circuit Response Time (1)	V_{IN} = 5 V, R_{SHORT} = 50 mΩ, OUT short to I_{OUT} falls below I_{SC} × 1.2		3.5		µs
Fault Indication						
$V_{OL,nFLT}$	nFLT Output Low Voltage	I_{nFLT} = 1 mA			180	mV
I_{nFLT}	nFLT Pin Leakage Current	V_{nFLT} = 5.5 V			1	µA
t_{nFLT}	nFLT Deglitch Time (1)	From fault condition to nFLT ≤ $V_{OL,nFLT}$		10	15	ms
Temperature Range						
T_{SD} (1)	Thermal Shutdown Temperature		155			°C
	Thermal Shutdown Temperature in Current Limit		135			°C
	Thermal Shutdown Hysteresis	Auto retry		20		°C

(1) Not subject to production test, specified by design.
(2) Measured with pulse-testing conditions to keep the junction temperature close to the ambient temperature.
(3) Output turn-on and turn-off delay time.



(4) Output voltage rising and falling time.



Typical Performance Characteristics

All test conditions: V_{IN} = 2.5 V to 5.5 V, V_{EN} = 2 V, R_{ILIM} = 49.9 kΩ, R_L = 100 Ω, C_L = 1 µF, T_J = −40°C to +125°C. Typical value at T_J = +25°C. All voltages are with respect to GND, and the positive currents are into pins (unless otherwise noted).

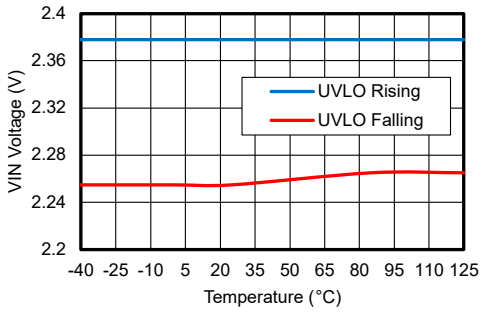


Figure 1. V_{IN} Supply Voltage UVLO

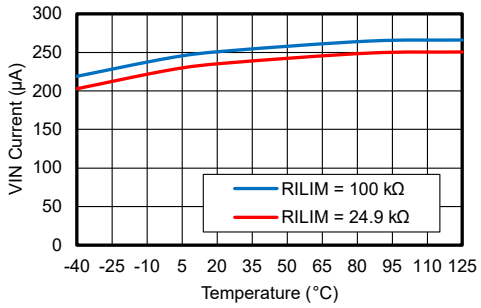


Figure 2. V_{IN} Quiescent Current

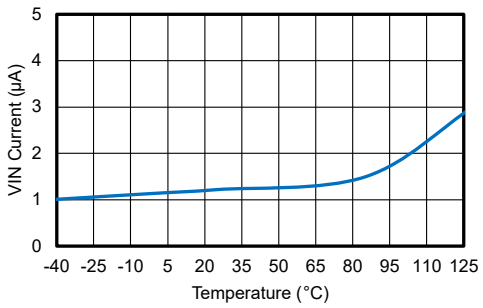


Figure 3. V_{IN} Shutdown Current

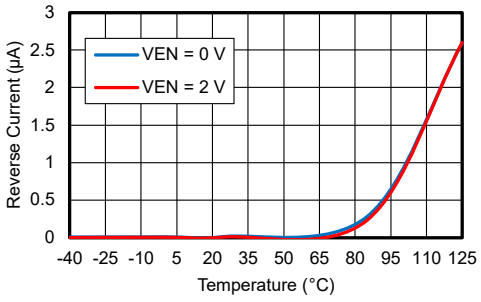


Figure 4. Reverse Current

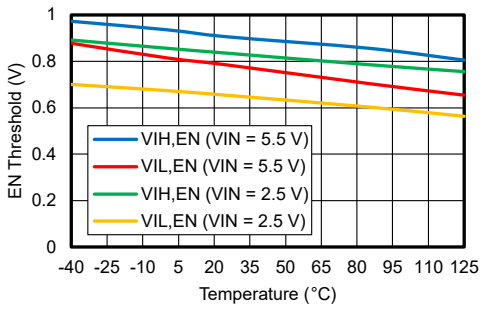


Figure 5. Enable Threshold

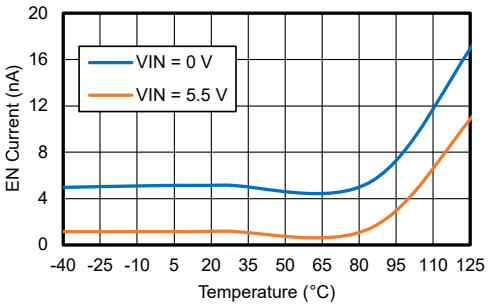


Figure 6. EN Pin Leakage Current

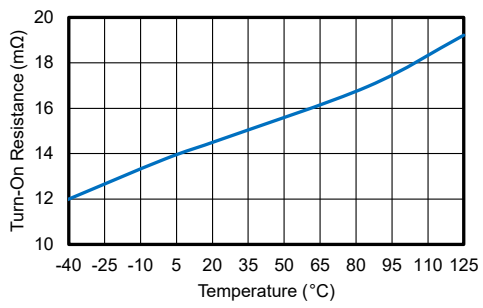


Figure 7. Turn-On Resistance

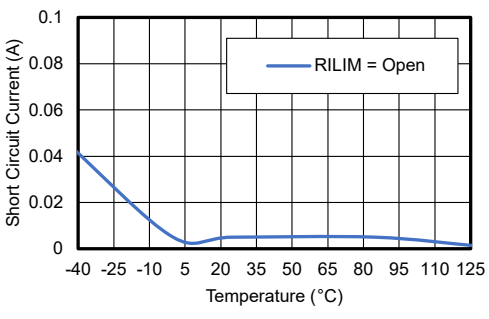


Figure 8. OUT Short-Circuit Current Limit

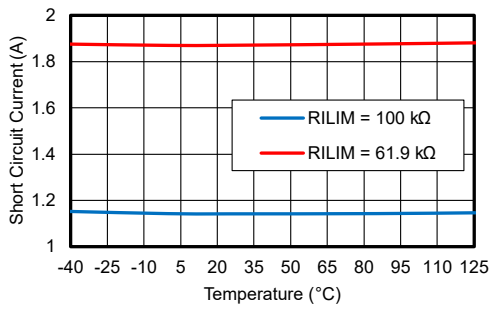


Figure 9. OUT Short-Circuit Current Limit

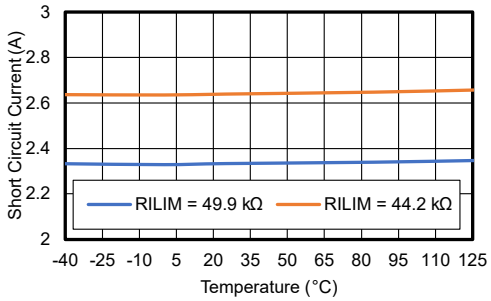


Figure 10. OUT Short-Circuit Current Limit

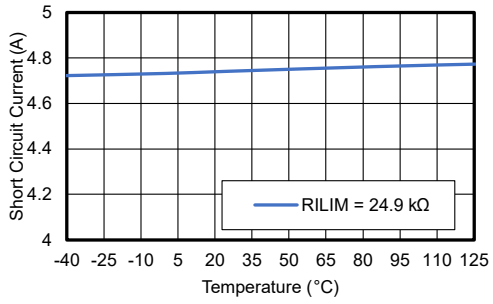


Figure 11. OUT Short-Circuit Current Limit

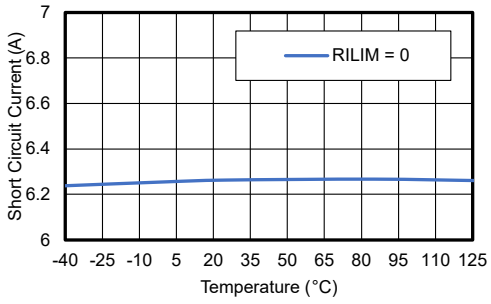


Figure 12. OUT Short-Circuit Current Limit

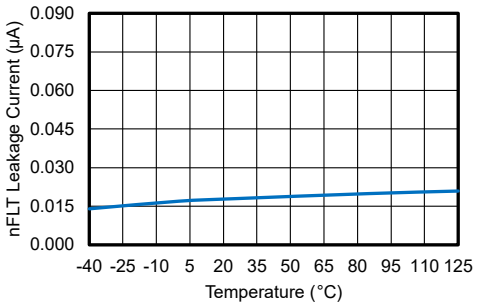


Figure 13. nFLT Pin Leakage Current

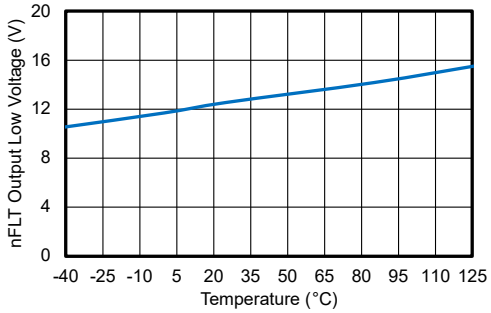


Figure 14. nFLT Output Low Voltage

Detailed Description

Overview

The TPS05S60 is a high-output current load switch with low turn-on resistance, low standby current, and accurate output current limit control. It integrates a MOSFET with typically 13-mΩ turn-on resistance and can handle a continuous current of up to 6 A. The output current limit is adjustable between 1.2 A and 6 A through an external resistor, with a precision of ±5% at 4.7 A.

The TPS05S60 has integrated fault detection and protection functions. The nFLT pin pulls low when an over-current or the over-temperature fault occurs. This device offers protection against output over-current, short circuits to ground, reverse current from output to input, and over-temperature situations, safeguarding the TPS05S60 from potential damage.

Functional Block Diagram

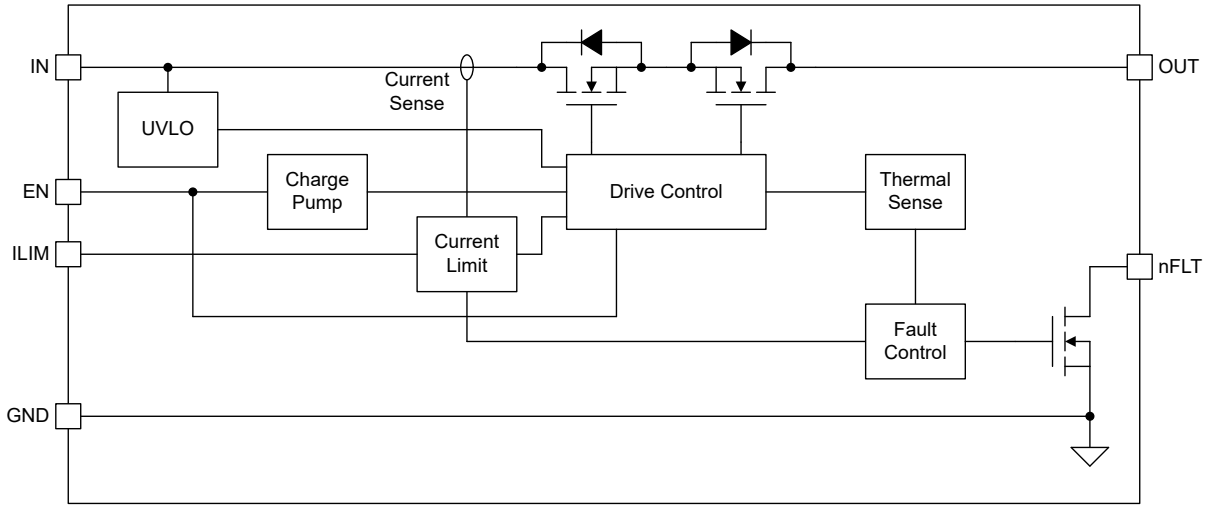


Figure 15. Functional Block Diagram

Feature Description

Input Power Supply Voltage (IN)

The TPS05S60 uses the IN pin to power up the internal circuitry with a supply voltage ranging from 2.5 V to 5.5 V.

When the V_{IN} voltage is lower than the UVLO falling threshold, the TPS05S60 stays in the shutdown mode. When the V_{IN} voltage is greater than the UVLO rising threshold and EN is high, the TPS05S60 enters operation mode.

Enable (EN)

The TPS05S60 uses the EN pin to control the internal power MOSFET. With the V_{IN} voltage of 2.5 V to 5.5 V,

- the device enters the shutdown mode when the EN pin voltage is lower than $V_{IL,EN}$. In this mode, the internal power MOSFET is turned off with a very low shutdown current (I_{SD}).
- the device enters normal operation mode when the EN pin voltage exceeds $V_{IH,EN}$. In this mode, the internal power MOSFET is turned on with a low quiescent current (I_Q).

Output Current Limit (ILIM)

The TPS05S60 uses an adjustable output current limit function to protect the device during fault conditions, e.g., output is overloaded or shorted to ground. The current limit value is set according to Equation 1.

$$I_{SC}(mA) = \frac{118079V}{R_{LIM}^{1.0003}(k\Omega)} \quad (1)$$

Where, R_{LIM} is the external resistor at the ILIM pin.

When device is operating in current-limit mode, the internal power dissipation (see Power Dissipation) will raise the junction temperature rapidly, and ultimately lead to over-temperature protection. It's recommended to use the R_{LIM} resistor with 1% or better accuracy, and the resistance range should be between 24.9 kΩ and 100 kΩ.

Over-Temperature Protection

The recommended operating junction temperature range is from −40°C to 125°C. When the junction temperature is between 125°C and the thermal shutdown (TSD) threshold, the regulator can still work well but will reduce the device lifetime for long-term use.

The over-temperature protection works when the junction temperature exceeds the thermal shutdown (TSD) threshold, which turns off the regulator immediately. When the device cools down and the junction temperature falls below the value, which equals the thermal shutdown threshold minus thermal shutdown hysteresis, the regulator turns on again.

Fault Indication (nFLT)

The TPS05S60 uses the nFLT pin to indicate the fault of the over-current condition or the over-temperature condition. When any of the two fault conditions occurs, the nFLT pin is pulled down below $V_{OL,nFLT}$.

The deglitch time t_{nFLT} is used to eliminate a false fault report. However, the behavior has a little difference between the two fault conditions. When entering or leaving the over-current condition, the nFLT signal is toggled after the t_{nFLT} delay. When leaving the over-temperature condition, the nFLT is pulled high after the t_{nFLT} delay, but when entering the over-temperature condition, the nFLT is pulled low immediately without any delay.

Application and Implementation

> Note
>
> Information in the following application sections is not part of the 3PEAK's component specification and 3PEAK does not warrant its accuracy or completeness. 3PEAK's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

Application Information

The TPS05S60 is a 6-A load switch with low turn-on resistance, low standby current, and accurate output current limit control. The following application schematic shows a typical usage of the TPS05S60.

Typical Application

Figure 16 shows the typical application schematic of the TPS05S60.

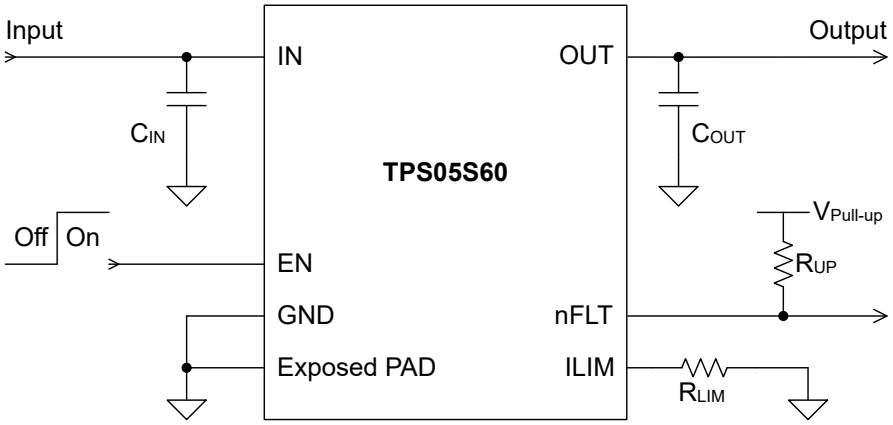


Figure 16. Typical Application Circuit

Input Capacitor and Output Capacitor

3PEAK recommends adding a 0.1 μF or grater ceramic capacitor closely at the IN pin to decouple the local noise and improve the transient performance. The voltage rating of the capacitors must be greater than the maximum input voltage. Additional input capacitance may be required at the input to prevent voltage undershoot from exceeding the UVLO threshold of other components sharing the same power rail with the TPS05S60, or to avoid overshoot from exceeding the device's absolute-maximum voltage rating during significant transient events.

The TPS05S60 is capacitor-free at the output. However, 3PEAK recommends adding a 1 μF or grater capacitor at the output pin to eliminate the undershoot during the large load transient condition.

Both input capacitors and output capacitors should be placed as close to the device pins as possible.

Power Dissipation

During normal operation, the junction temperature should meet the requirement in the Recommended Operating Conditions table. Use Equation 2 and Equation 3 to calculate the power dissipation and estimate the junction temperature.

The power dissipation (P_D) can be calculated using Equation 2.

$$P_D = I_{OUT}^2 \times R_{ON} + V_{IN} \times I_Q \quad (2)$$

Where,

- I_{OUT} is the output current,
- R_{ON} is the turn-on resistance,
- V_{IN} is the input supply voltage,
- I_Q is the quiescent current.

The junction temperature (T_J) can be estimated using Equation 3.

$$T_J = T_A + P_D \times \theta_{JA} \quad (3)$$

Where,

- T_A is the ambient temperature,
- P_D is the power dissipation,
- θ_{JA} is the junction-to-ambient thermal resistance.

Layout

Layout Guideline

- Both input capacitors and output capacitors must be placed as close to the device pins as possible.
- It is recommended to bypass the input pin to ground with a 0.1-μF bypass capacitor. The loop area formed by the bypass capacitor connection, IN pin, and the GND pin of the system must be as small as possible.
- It is recommended to use wide and thick copper to minimize I×R drop and heat dissipation.

Layout Example

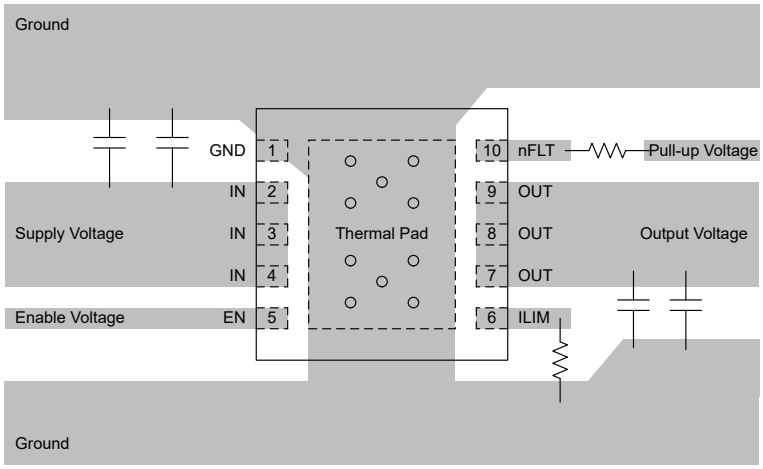
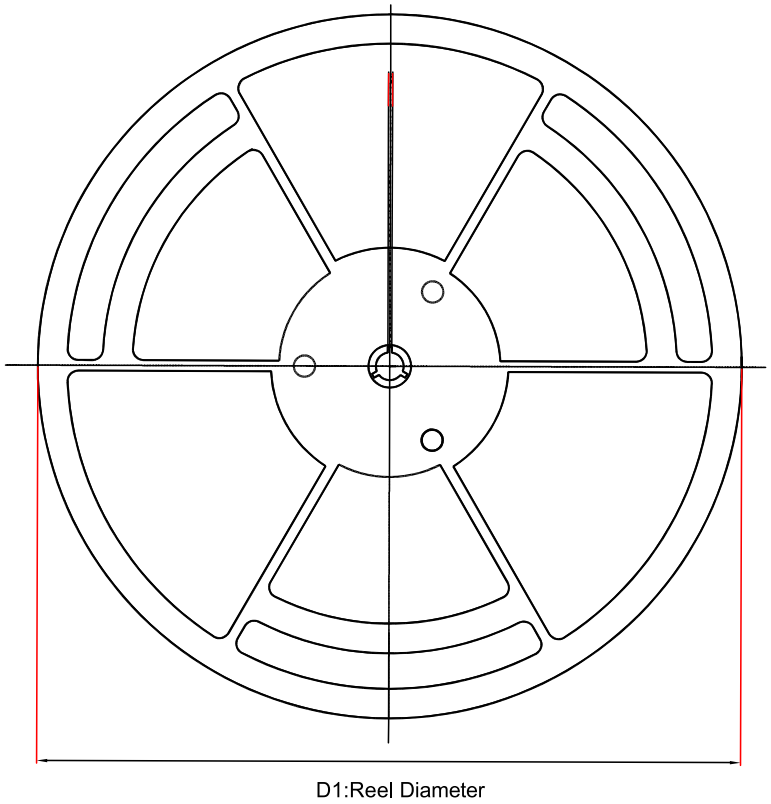
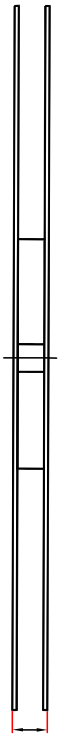
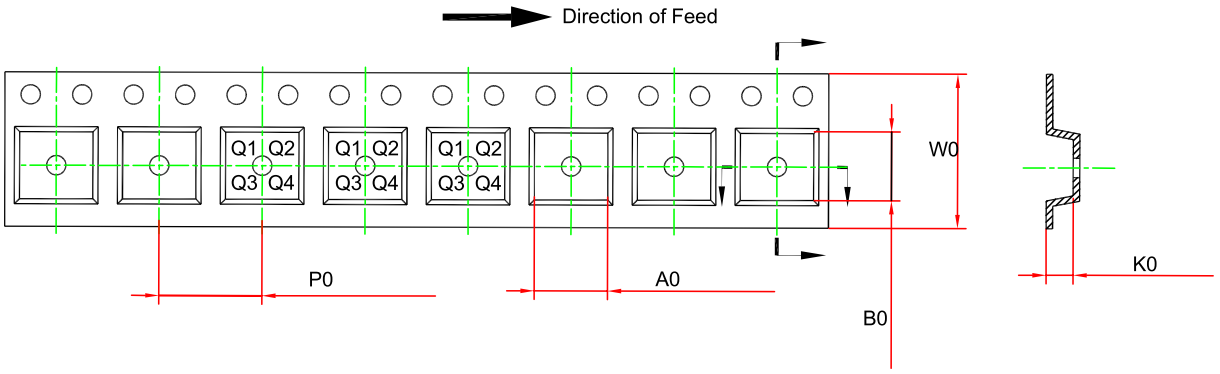


Figure 17. Layout Example

Tape and Reel Information





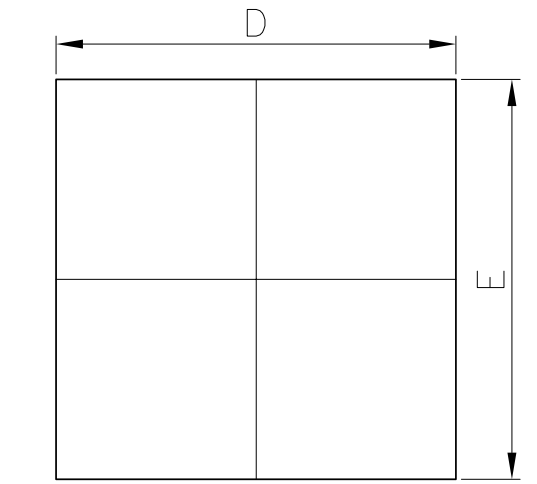


Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TPS05S60A-DF8R-S	DFN3X3-10	330	17.6	3.3	3.3	1.1	8	12	Q2

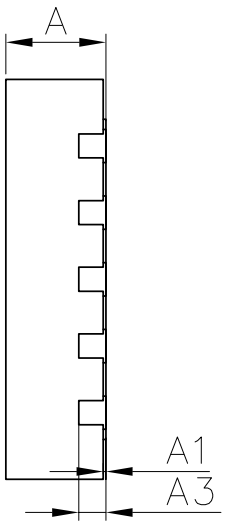
Package Outline Dimensions

DFN3X3-10-A

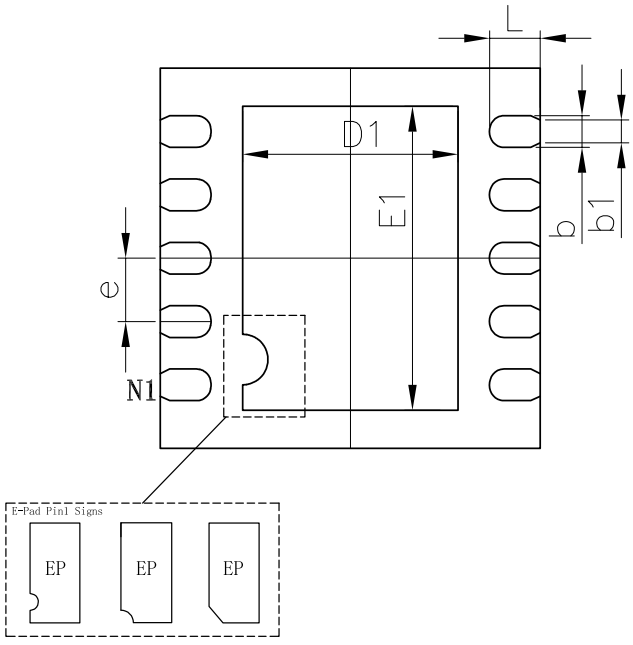
Package Outline Dimensions DF8(DFN3X3-10-A)



Top View



Side View



Bottom View

NOTES

1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.
3. The many types of E-pad Pin1 signs may appear in the product.

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
b	0.200	0.300	0.008	0.012
b1	0.180 REF		0.007 REF	
A3	0.150	0.250	0.006	0.010
D	2.900	3.100	0.114	0.122
D1	1.600	1.800	0.063	0.071
E	2.900	3.100	0.114	0.122
E1	2.300	2.500	0.091	0.098
e	0.500 BSC		0.020 BSC	
L	0.325	0.475	0.013	0.019

Order Information

Order Number	Operating Temperature Range	Package	Marking Information	MSL	Transport Media, Quantity	Eco Plan
TPS05S60A-DF8R-S	−40 to 125°C	DFN3X3-10	05S6A	MSL3	Tape and Reel, 4,000	Green

Green: 3PEAK defines "Green" to mean RoHS compatible and free of halogen substances.

IMPORTANT NOTICE AND DISCLAIMER

Performance Information. Performance tests or performance range contained in this document/material are either results of design simulation or actual tests conducted under designated testing environment. Any variation in testing environment or simulation environment, including but not limited to testing method, testing process or testing temperature, may affect actual performance of the product.

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