MP5036

12V, 0.4A to 5A, Current Limit Switch with 15V Over-Voltage Clamp in TSOT23 Package

DESCRIPTION

The MP5036 is a protection device designed to protect circuitry on the output from transients on the input. It also protects the input from undesired shorts and transients coming from the output.

During start-up, the inrush current is limited by limiting the slew rate at the output. The slew rate is controlled by the DV/DT pin setting.

The maximum load at the output is current-limited. The magnitude of the current limit is controlled by an external resistor from ILIMIT to GND. There is a fixed 2.5A current limit when floating the ILIMIT pin.

The output voltage is limited by the output over-voltage protection (OVP) function.

The device is available in a TSOT23-6 package.

FEATURES

- Wide 2.9V to 14V Continued Operating Input Range
- 26V Absolute Maximum Transient Input Voltage
- Fixed 15V Over-Voltage Clamp Threshold
- Fast Output OVP Response
- Integrated 43mΩ Power FET
- Adjustable Current Limit or Fixed Current Limit when floating ILIMIT pin
- Soft Start Time Programmable through the DV/DT Pin
- Fast Response for Hard Short Protection
- OCP Hiccup Protection
- Thermal Shutdown and Auto Retry
- Available in TSOT23-6 Package

APPLICATIONS

- HDD, SSD
- Hot Swap
- Wireless Modem Data Cards
- PC Cards
- USB Power Distribution
- USB Protection
- USB3.1 Power Delivery

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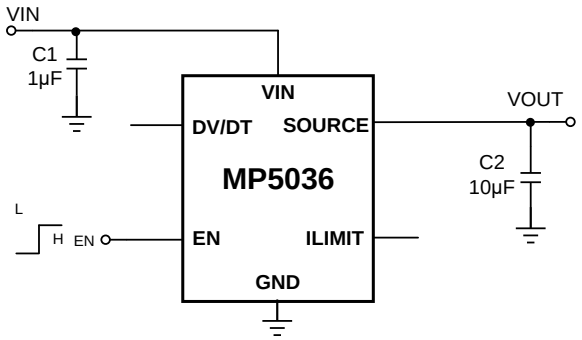
TYPICAL APPLICATION



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ORDERING INFORMATION

Part Number*	Package	Top Marking	MSL Rating
MP5036GJ	TSOT23-6	*See Below*	1

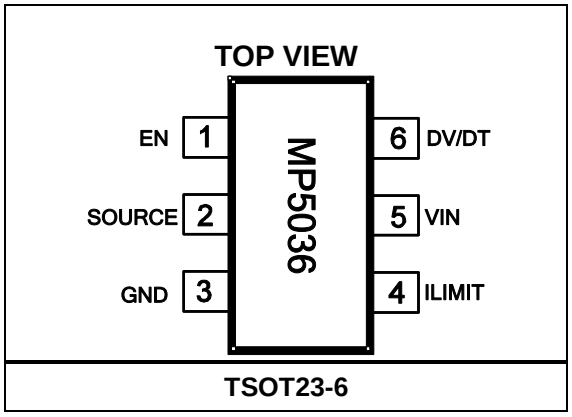
* For Tape & Reel, add suffix –Z (e.g. MP5036GJ–Z).

TOP MARKING

|BDKY

BDK: Product code of MP5036GJ
Y: Year code

PACKAGE REFERENCE



PIN FUNCTIONS

Pin #	Name	Description
1	EN	**Enable.** Force EN high to enable the MP5036. Float EN or pull EN to ground to disable the IC. For quick start-up, pull EN up to VIN through a 300kΩ resistor.
2	SOURCE	**Source of the internal power MOSFET and output terminal of the IC.**
3	GND	**System ground.**
4	ILIMIT	**Current limit set.** Place a resistor between ILIMIT and ground to set the value of the current limit. Float ILIMIT to achieve a 2.5A fixed current limit.
5	VIN	**Supply voltage.** The MP5036 operates from a 2.9V to 14V input rail. A ceramic capacitor is required to decouple the input rail. Connect VIN using a wide PCB trace.
6	DV/DT	**DV/DT.** Connect a capacitor from DV/DT to ground to set the DV/DT slew rate.

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ABSOLUTE MAXIMUM RATINGS (1)

VIN, SOURCE ..... -0.3V to +26V
All other pins..……-0.3V to +5.5 V
Junction remperature..... -40°C to +150°C
Lead Temperature ..... 260°C
Continuous Power Dissipation (T_A = 25°C) (2) (4)
TSOT23-6.....1.89W

ESD Rating

Human-body model (HBM) 2000V
Charged-device model (CDM).....750V

Recommended Operating Conditions (3)

Continued Operating V_{IN} ..... 2.9V to 14V
Operating Junction Temp. (T_J) . -40°C to +125°C

Thermal Resistance θ_{JA} θ_{JC}

TSOT23-6

EV5036-J-00A (4) .....66.....23.....°C/W
JESD51-7 (5).....100….55…..°C/W

Notes:

1) Exceeding these ratings may damage the device.
2) The maximum allowable power dissipation is a function of the maximum junction temperature T_J (MAX), the junction-to-ambient thermal resistance θ_{JA}, and the ambient temperature T_A. The maximum allowable continuous power dissipation on EV5036-J-00A board at any ambient temperature is calculated by P_D (MAX) = (T_J (MAX) - T_A) / θ_{JA}. Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the MP5036 will go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
3) The device is not guaranteed to function outside of its operating conditions.
4) Measured on EV5036-J-00A, 2-layer PCB, 50mmx50mm.
5) The value of θ_{JA} given in this table is only valid for comparison with other packages and cannot be used for design purposes. These values were calculated in accordance with JESD51-7, and simulated on a specified JEDEC board. They do not represent the performance obtained in an actual application..

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ELECTRICAL CHARACTERISTICS

V_{IN} = 12V, R_{LIMIT} = NS, C_{OUT} = 10uF, T_J = -40°C to +125°C (6), typical value is tested at T_J = 25°C, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Supply Current						
Supply current (quiescent)	I_Q	EN = HIGH		72		μA
Supply current (shutdown)	I_S	EN = GND		17		μA
Power FET						
On resistance	$R_{DS(ON)}$	I_{OUT} = 1A		43		mΩ
Turn-on delay	t_{delay}			500		μs
Off-state leakage current	I_{OFF}	EN = 0V		0.1	1	μA
Under/Over Voltage Protection						
Under-voltage lockout rising threshold	V_{UVLO}		2.55	2.7	2.85	V
UVLO hysteresis	$V_{UVLOHYS}$			200		mV
Output over-voltage clamp voltage	V_{CLAMP}	T_J = 25°C	14	15	16	V
DV/DT						
DV/DT slew rate	dv/dt	DV/DT float	1.3	2	2.7	V/ms
DV/DT current	$I_{DV/DT}$	$V_{DV/DT}$ = 0.5V	4.5	6.5	8.5	μA
Current Limit						
Current limit at normal operation	I_{Limit_NO}	Float ILIMIT pin, T_J = 25°C	2.3	2.5	2.7	A
		R_{LIMIT} = 402Ω, T_J = 25°C	3.2	3.5	3.8	A
		R_{LIMIT} = 1.91kΩ, T_J = 25°C	0.68	0.75	0.82	A
Enable						
Enable rising threshold	V_{EN_RISING}		1.86	2	2.16	V
Enable hysteresis	V_{EN_HYS}			350		mV
Enable pull-down resistor	R_{EN_DOWN}			2.2		MΩ
Output Discharge						
Discharge resistance	R_{DIS}	V_{IN} = 5V		540		Ω
OTP						
Thermal shutdown (7)	T_{SD}			175		°C
Thermal hysteresis (7)	T_{SD_HYS}			50		°C

Notes:

6) Not tested in production. Guaranteed by over-temperature correlation.

7) Guaranteed by design and engineering sample characterization

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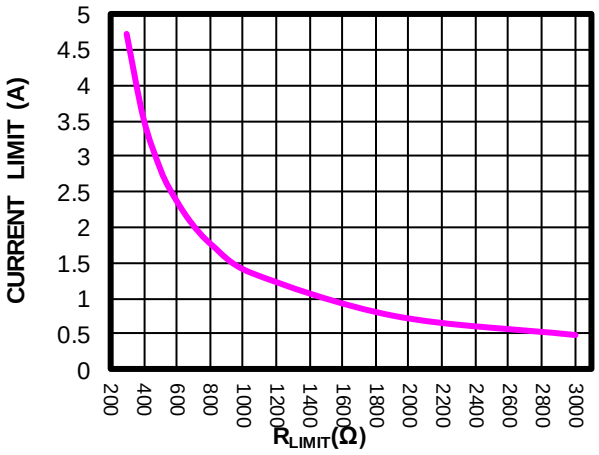
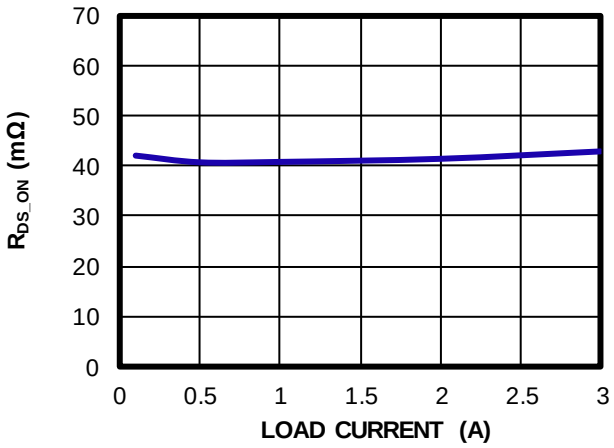
TYPICAL PERFORMANCE CHARACTERISTICS

V_{IN} = 12V, V_{EN} = 5V, R_{LIMIT} = 402Ω, C_{OUT} = 10μF, T_A = 25°C, unless otherwise noted.

Current Limit vs. R_{LIMIT}

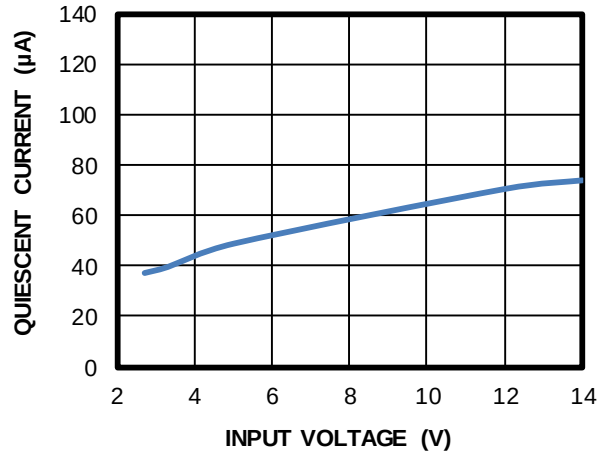


$R_{DS(ON)}$ vs. Load Current



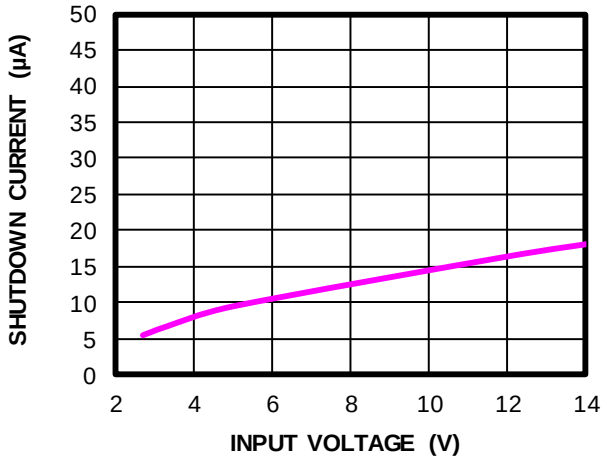
Quiescent Current vs. Input Voltage

V_{EN} = 3V



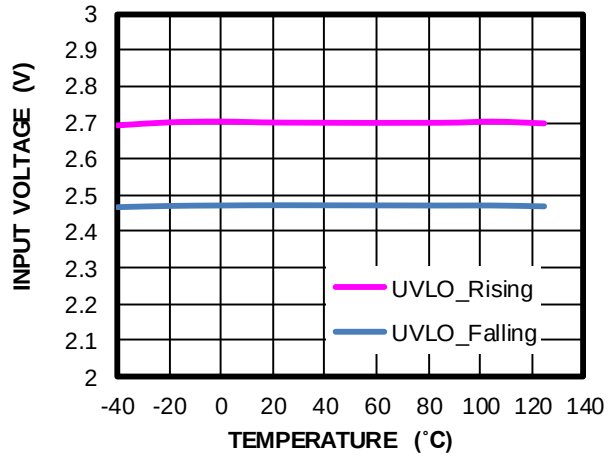
Shutdown Current vs. Input Voltage

V_{EN} = 0V



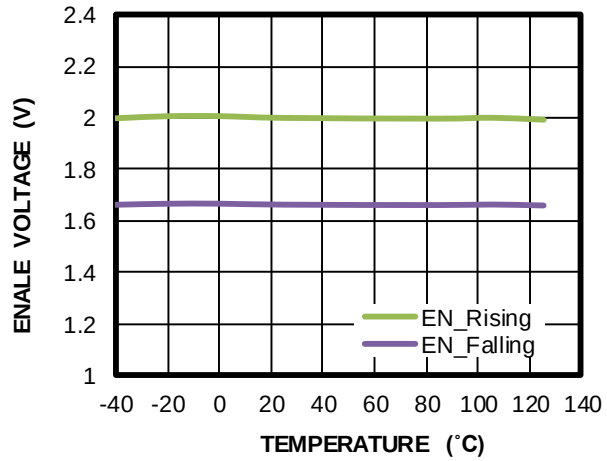
VIN UVLO Rising/Falling Threshold vs. Temperature

T_A = -40°C to +125°C



EN Rising/Falling Threshold vs. Temperature

T_A = -40°C to +125°C



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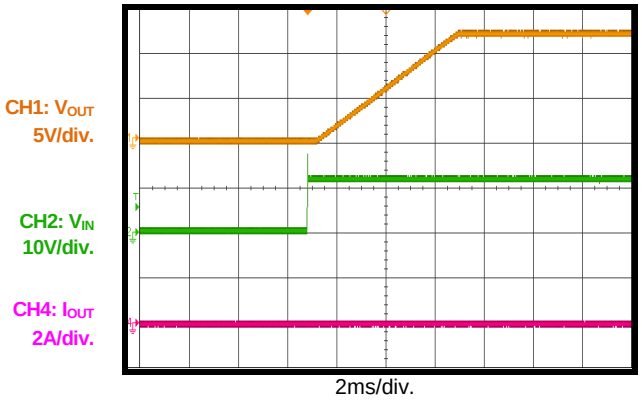
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{EN} = 5V, R_{LIMIT} = 402Ω, DV/DT float, C_{OUT} = 10μF, T_A = 25°C, unless otherwise noted.

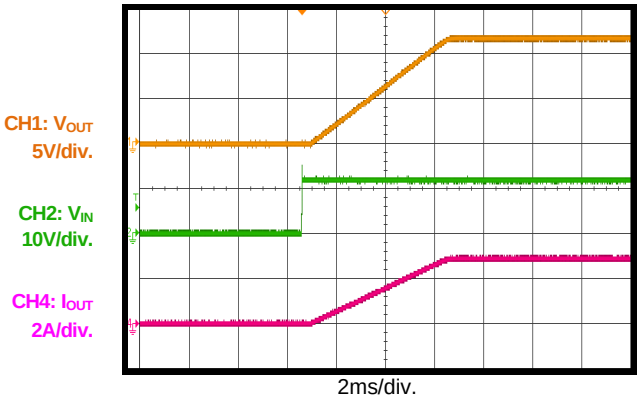
Start-Up through Input Voltage

I_{OUT} = 0A



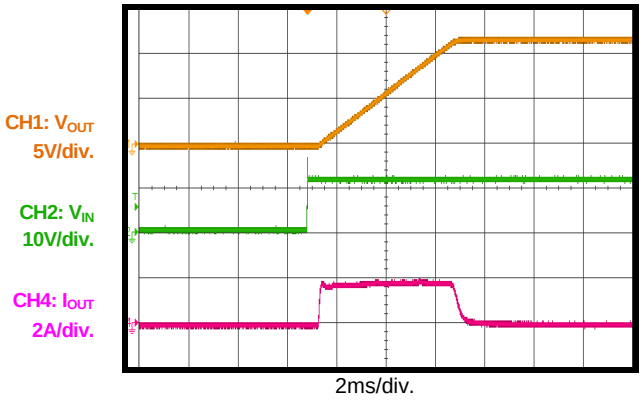
Start-Up through Input Voltage

I_{OUT} = 3A



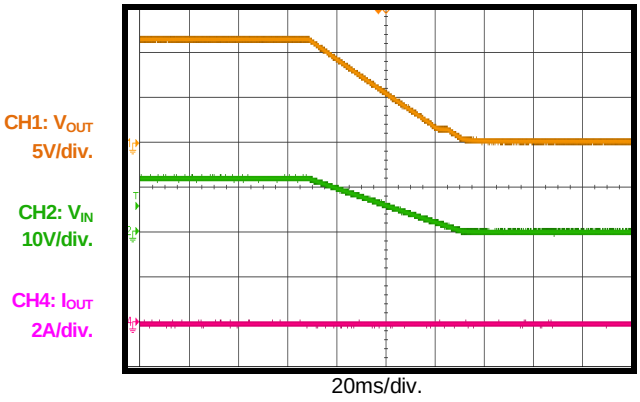
Start-Up through Input Voltage

I_{OUT} = 0A, C_{OUT} = 1000μF



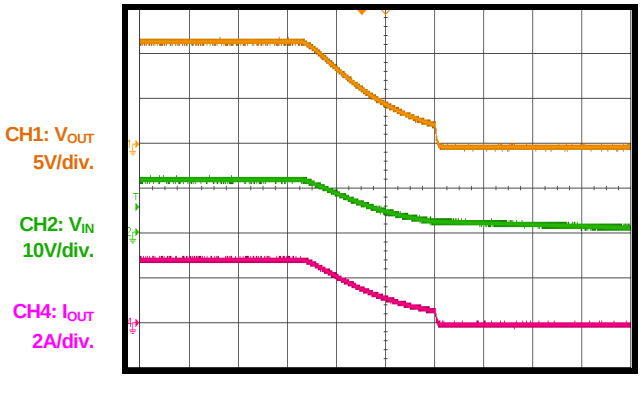
Shutdown through Input Voltage

I_{OUT} = 0A



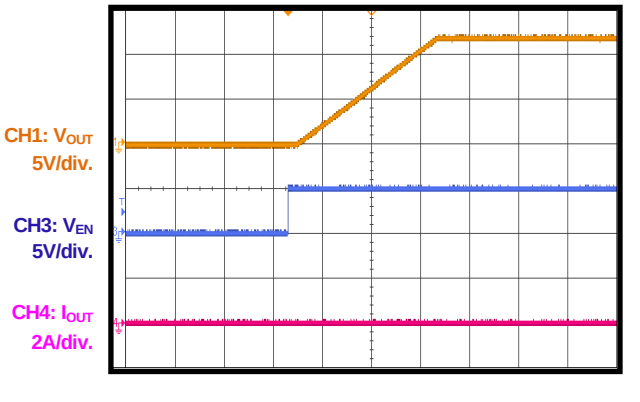
Shutdown through Input Voltage

I_{OUT} = 3A



Start-Up through Enable

I_{OUT} = 0A



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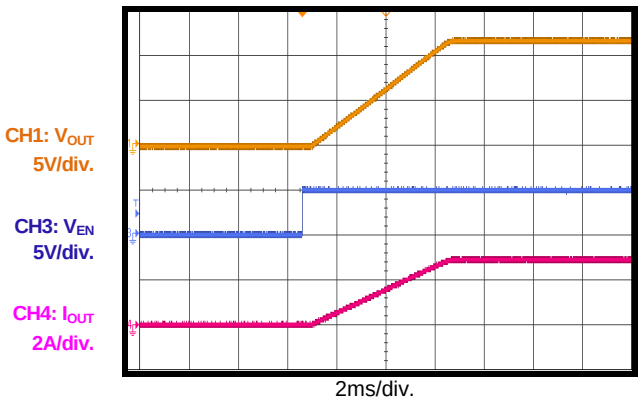
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{EN} = 5V, R_{LIMIT} = 402Ω, DV/DT float, C_{OUT} = 10µF, T_A = 25°C, unless otherwise noted.

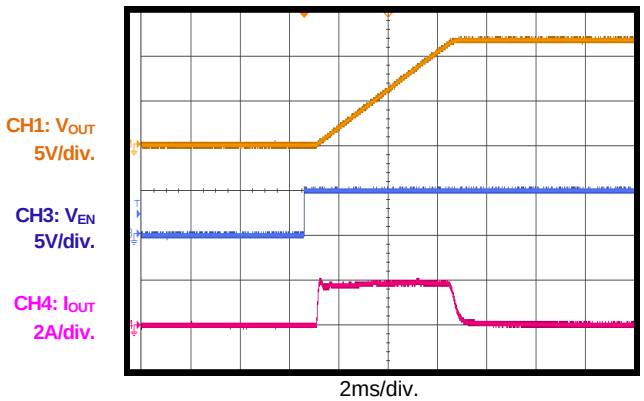
Start-Up through Enable

I_{OUT} = 3A



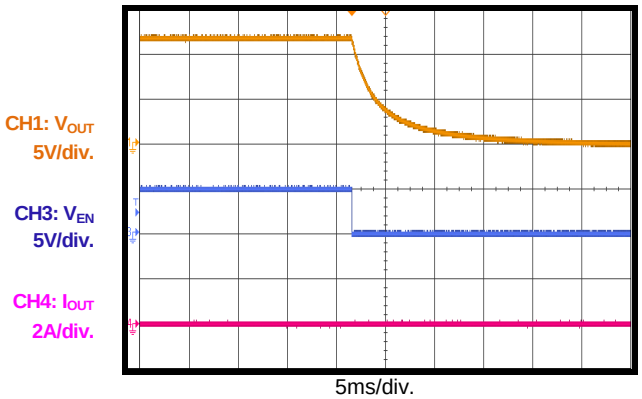
Start-Up through Enable

I_{OUT} = 0A, C_{OUT} = 1000µF



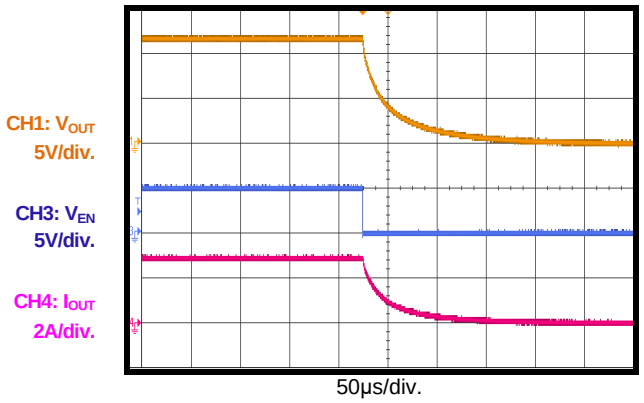
Shutdown through Enable

I_{OUT} = 0A



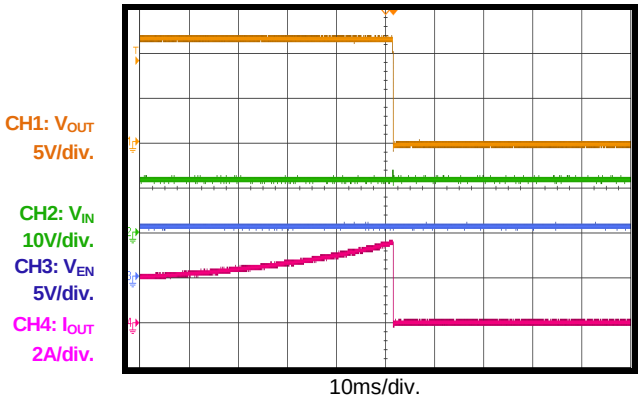
Shutdown through Enable

I_{OUT} = 3A

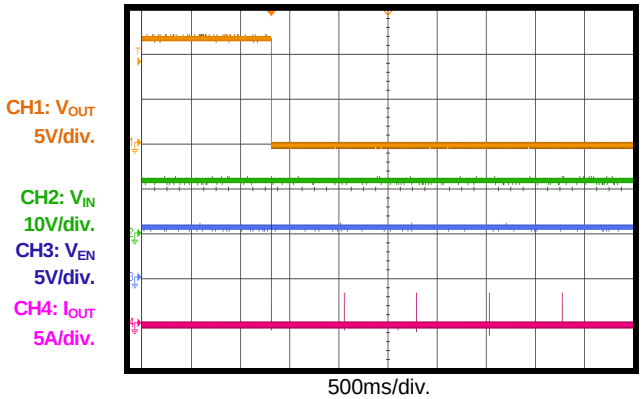


Current Limit

Increase I_{OUT} slowly



Short Circuit during Normal Operation and Hiccup



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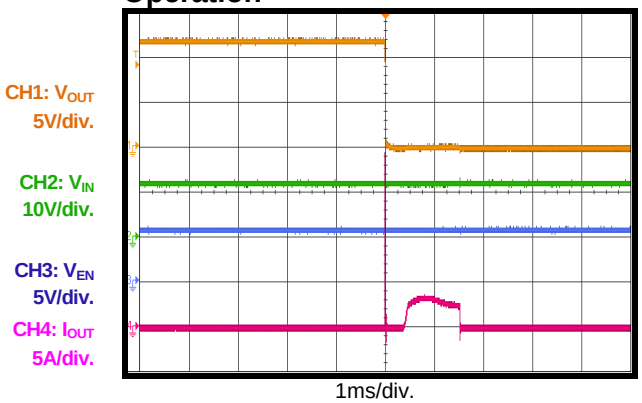
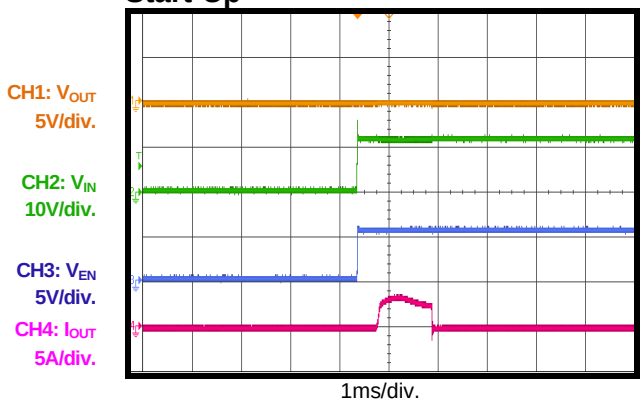
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{EN} = 5V, R_{LIMIT} = 402Ω, DV/DT float, C_{OUT} = 10µF, T_A = 25°C, unless otherwise noted.

Short Circuit Entry during Normal Operation



Short Circuit before Input Voltage Start-Up



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FUNCTIONAL BLOCK DIAGRAM

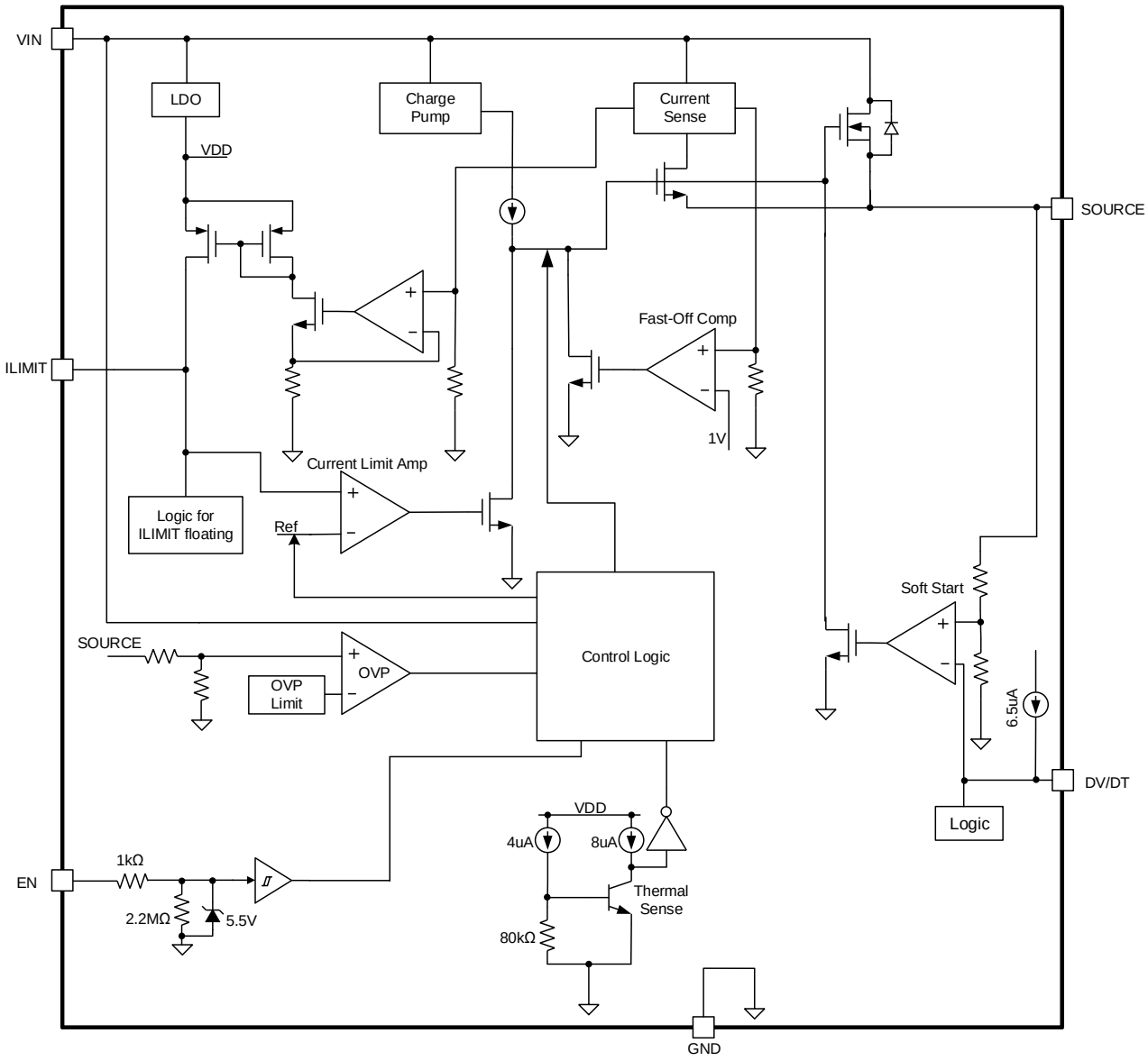

Figure 1: Functional Block Diagram

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OPERATION

The MP5036 limits the inrush current to the load when a circuit card is inserted into a live backplane power source. This limits the backplane's voltage drop and the dv/dt of the voltage to the load. It offers an integrated solution to monitor the input voltage, output voltage, output current, and die temperature. These features eliminate the requirement of an external current sense power resistor, a power MOSFET, and a thermal sense device.

Under-Voltage Lockout (UVLO)

The MP5036 can be used in the 2.9V to 14V input supply system, and there are high energy transients during normal operation or during hot swaps. The transients depend on the parasitic inductance and resistance of the wire along with capacitor at VIN node. If a power clamp (TVS, Tranzorb) diode is not used, the e-fuse must be able to withstand this transient voltage.

The device integrates a high voltage MOSFET with up to 14V of continuous voltage and 26V of maximum transient input voltage. It also uses a high voltage circuit for the VIN node to guarantee safe operation.

Soft Start

The soft start time (t_{SS}) is related to the dv/dt slew rate and input voltage. It can be calculated with Equation (1):

$$t_{SS}(ms) = \frac{Vin(V)}{dv/dt\ (V/ms)} \quad (1)$$

The dv/dt slew rate is controlled by the DV/DT pin setting. For more details, see Application Information on page 12.

Fast Output Over-Voltage Protection (OVP)

To protect the downstream load when there is a voltage surge at the input, the MP5036 provides an output OVP function. An accurate and fast comparator monitors the over-voltage condition of the output. If the output voltage rises above the threshold (about 15V), the gate of the internal MOSFETs quickly pulls down and regulates to a certain value to keep the output voltage clamped at the OVP threshold. The fast loop response speed keeps the over-voltage overshoot small.

Current Limit

The MP5036 provides a constant current limit that can be programmed by an external resistor.

The desired current limit (I_{LIMIT}) is a function of the external current limit resistor. It can be estimated with Equation (2):

$$I_{LIMIT}(A) = \frac{0.37(V)}{R_{LIMIT}(\Omega)} \times 3840 \quad (2)$$

Where 3840 is the current sense ratio.

When the current limit threshold is reached, the internal circuit regulates the gate voltage to hold the current in the power MOSFET constant. To limit the current, the gate to the source voltage must be regulated from 5V to about 1V. The typical response time is about 15µs. During this period, the output current may have a small overshoot.

If the current limit condition lasts longer than 2ms, the IC enters hiccup mode with 700ms of off-time.

The MP5036 allows ILIMIT to float during operation. If ILIMIT floats, the current limit is set at a fixed 2.5A internally.

When shorting ILIMIT to GND, the normal current limit is disabled, but the secondary current limit still works. The secondary current limit is set to 8A internally. When the secondary current limit triggers, the IC shuts down the power MOSFET.

Short Circuit Protection (SCP)

If the load current increases rapidly due to a short circuit event, the current may exceed the current limit threshold before the control loop can respond. If the current reaches the 8A secondary current limit level, a fast turn-off circuit activates to turn off the power MOSFET. This limits the peak current through the switch, keeping the input voltage from dropping too much.

The total short circuit response time is about 1µs. After the MOSFET has switched off, the part restarts. If the short still exists during the restart process, the MP5036 regulates the gate voltage to hold the current at the normal current limit level. The IC enters hiccup mode for 700ms of off-time.

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To prevent safe operating area (SOA) damage during a high input voltage short-circuit protection (SCP) condition, the IC current limit folds back when the power MOSFET's voltage (V_{DS}) exceeds the typical 11V and the junction temperature is above 110°C.

Output Discharge

The MP5036 has a discharge function that provides a resistive discharge path for the external output capacitor. The function is active when the part is disabled (V_{IN} UVLO, EN shutdown) and is done in a very limited time.

Enable (EN)

The MP5036 enables when EN is high. The MP5036 disables when EN is low. Floating the EN pin shuts down the MP5036 because there is an internal 2.2MΩ resistor pulling EN down to ground. For automatic start-up, connect a pull-up resistor from VIN to EN.

EN is clamped internally using a 5.5V Zener diode (see Figure 2). Connecting the EN input through a pull-up resistor to VIN limits the EN input current below 100μA to prevent damage to the Zener diode. For example, when connecting a 300kΩ pull-up resistor to 12V V_{IN}, I_Zener = (12V - 5.5V) / 300kΩ - 5.5V / 2.2MΩ = 19μA.

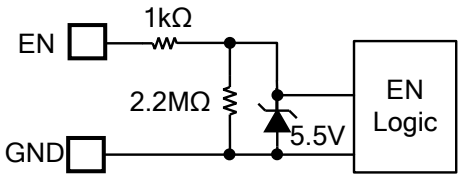

Figure 2: Zener Diode between EN and GND

When using a pull-up resistor to set the power-on threshold, avoid using a pull-up resistor that is too small and unable to increase the operation quiescent current.

Thermal Shutdown - Auto-Retry

Thermal shutdown prevents the chip from operating at exceedingly high temperatures. When the silicon die temperature exceeds 175°C, the entire chip shuts down. When the temperature drops below its lower threshold, about 125°C, the chip enables again after a typical 700ms delay.

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APPLICATION INFORMATION

Setting the Current Limit

The MP5036 current limit value should exceed the normal maximum load current, allowing for tolerances in the current sense value. The current limit is a function of the external current limit resistor (see Table 1).

Table 1: Typical Current Limit vs. Current Limit Resistor (8)

R_{LIMIT} (Ω)	1.91k	698	402	316
I_{LIMIT} (A)	0.75	2	3.5	4.5

Note:

8) The current limit in Table 1 is a typical value for the reference design.

Figure 3 shows the relationship between the current limit and the current limit resistor.

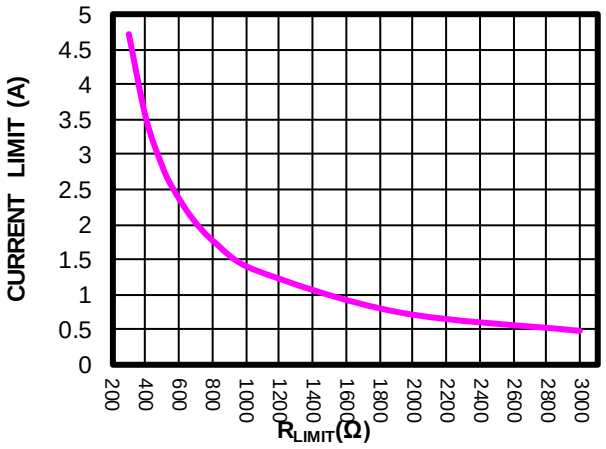

Figure 3: Current Limit vs. Current Limit Resistor

The MP5036's current limit can be programmed from 0.4A to 5A by connecting the correct R_{LIMIT} resistor. The current limit cannot be set too low, because the MP5036 typically works in sleep mode when the load is below 0.23A. The current limit logic is disabled in sleep mode.

Setting the Soft Start Time

The soft start time is related to the dv/dt slew rate and input voltage and can be calculated with Equation (3):

$$t_{SS}(ms) = \frac{Vin(V)}{dv/dt\ (V/ms)} \quad (3)$$

The dv/dt slew rate is controlled by the external DV/DT capacitor setting.

When DV/DT is floating, the dv/dt slew rate is 2V/ms.

If there is an external DV/DT capacitor, the dv/dt slew rate can be calculated with Equation (4):

$$dv/dt\ (V/ms) = \frac{6.5(\mu A)\times 15}{C_{DV/DT}(nF)} \quad (4)$$

For example, when the external DV/DT capacitor is 47nF, the dV/dt slew rate is 2.1V/ms.

Design Example

Table 2 is a design example following the application guidelines for the given specifications:

Table 2: Design Example

V_{IN} (V)	12
Current limit (A)	3.5
DV/DT slew rate (V/ms)	2

Figure 5 on page 13 shows the detailed application circuit. See page 5 for the Typical Performance Characteristics section. For more detailed device applications, see the related evaluation board datasheets.

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PCB Layout Guide

PCB layout is critical for optimal performance. For the best results, refer to Figure 4 and follow the guidelines below:

1. Place the high-current paths (VIN and VOUT) close to the device using short, direct, and wide traces.
2. Place the input capacitors close to the VIN and GND pins.
3. Connect the VIN and VOUT pads to large VIN and VOUT planes, respectively, to improve thermal performance.
4. Place a current limit resistor close to the ILIMIT pin.
5. Place a DV/DT capacitor close to the DV/DT pin.

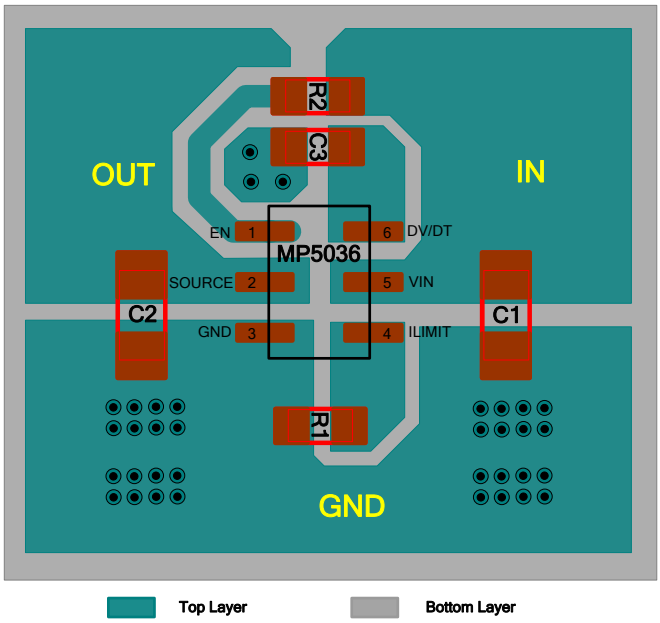

Figure 4: PCB Layout Example

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TYPICAL APPLICATION CIRCUIT

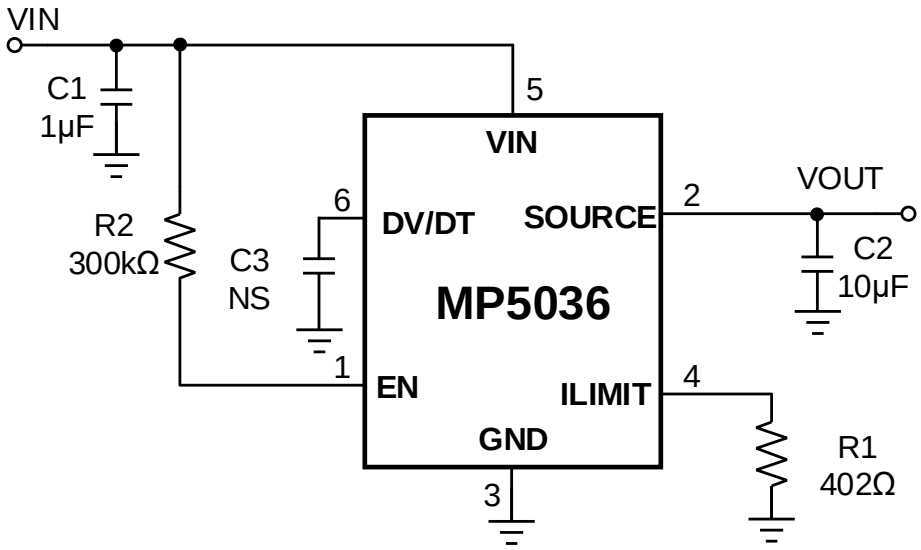

Figure 5: Typical Application Circuit

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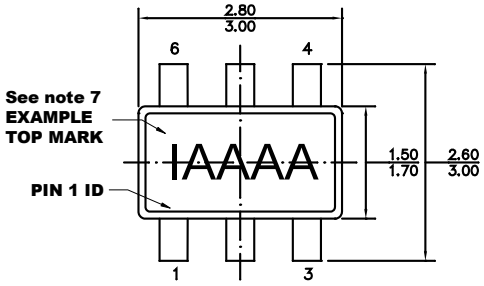
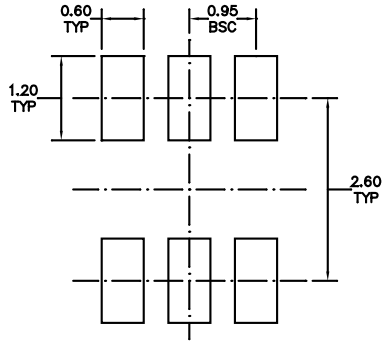
PACKAGE INFORMATION

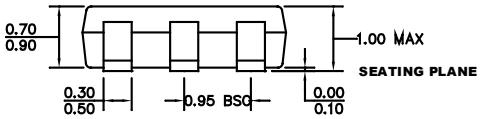
TSOT23-6



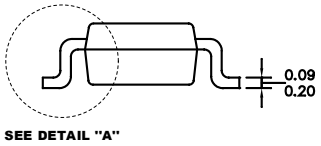
TOP VIEW



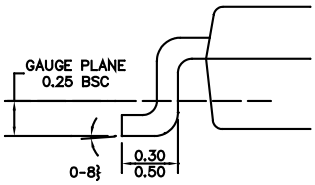
RECOMMENDED LAND PATTERN



FRONT VIEW



SIDE VIEW



DETAIL "A"

NOTE:

1) ALL DIMENSIONS ARE IN MILLIMETERS.
2) PACKAGE LENGTH DOES NOT INCLUDE MOLD FLASH, PROTRUSION OR GATE BURR.
3) PACKAGE WIDTH DOES NOT INCLUDE INTERLEAD FLAS OR PROTRUSION.
4) LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMI SHOULD BE 0.10 MILLIMETERS MAX.
5) DRAWING CONFORMS TO JEDEC MO-193, VARIATION AE
6) DRAWING IS NOT TO SCALE.
7) PIN 1 IS LOWER LEFT PIN WHEN READING TOP MARK FROM LEFT TO RIGHT, (SEE EXAMPLE TOP MARK)

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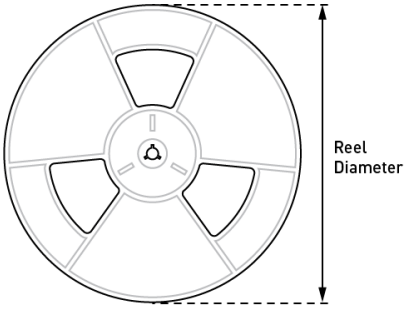
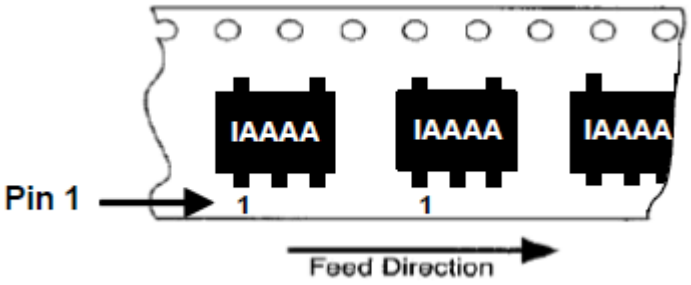
CARRIER INFORMATION





Part Number	Package Description	Quantity/Reel	Quantity/Tube	Reel Diameter	Carrier Tape Width	Carrier Tape Pitch
MP5036GJ-Z	TSOT23-6	3000	N/A	7 in.	8 mm	4 mm

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