36-V Input, 2-A Synchronous Isolated-Buck Voltage Regulator

Features

- Wide Supply Voltage: 4.5 V to 36 V
- Absolute Maximum Voltage: 42 V
- Internal Power FET: 180 mΩ and 90 mΩ
- 0.6-V Reference Voltage with 2% Accuracy
- High-Efficiency Synchronous-Mode Operation
- 500-kHz Fixed Switching Frequency
- Low 2-μA Shutdown, 70-μA Quiescent Current
- Forced-PWM Mode for Low-Output Ripple
- Internal 2-ms Soft-Start Timer
- Internal Loop Compensation
- Over-Current Protection with Hiccup Mode
- Output over Voltage Protection
- Thermal Shutdown
- Small Outline Package TSOT23-6
- −40°C to 125°C Operation Ambient Temperature Range

Applications

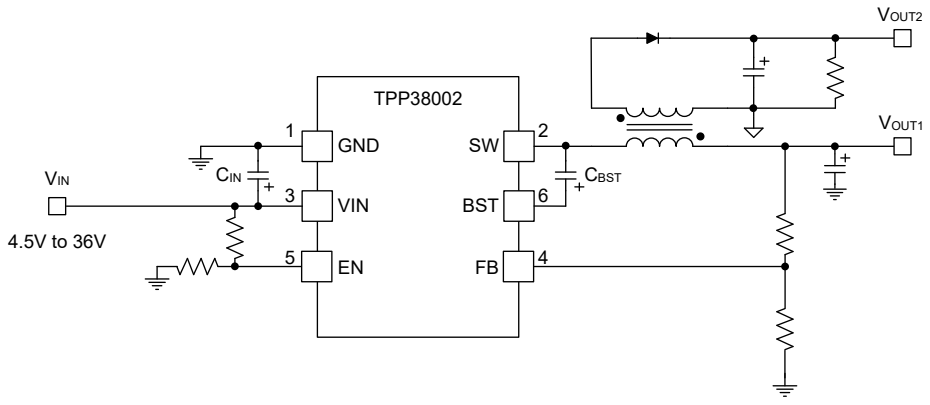
- 12-V, 24-V Isolated Power Supply
- Industrial Applications
- General Purpose

Description

The TPP38002 regulator is a low-cost, efficient, isolated bias regulator. This high-voltage regulator contains two 42-V N-channel MOSFET switches — a high-side buck switch and a low-side synchronous switch. The Peak Current Mode control scheme employed in the TPP38002 device requires no external loop compensation and provides excellent transient response with fixed switching frequency. The device also has over current protection and over temperature protection to improve system robustness.

The device is available in the 6-pin TSOT23-6 package with the support of a wide operation ambient temperature range from −40 °C to 125 °C.

Typical Application Circuit



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Revision History

Date	Revision	Notes
2024-02-01	Rev A.0	Initial release

Pin Configuration and Functions

TPP38002
TSOT23-6 Package
Top View

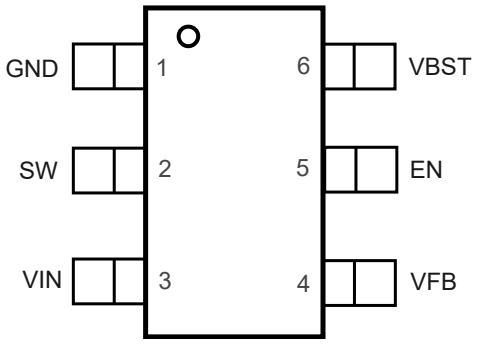


Table 1. Pin Functions: TPP38002

Pin	Name	I/O	Description
1	GND	G	Ground pin. Power and controller circuit ground. Use star connection to GND pin with good contact.
2	SW	O	Switching node pin. Voltage switching between high-side FET and low-side FET.
3	VIN	P	Supply input pin. Connect decoupling 2 × 10-μF and 1 × 0.1-μF capacitors between VIN and GND pins.
4	VFB	I	Voltage feedback pin. Connect to output voltage with a feedback resistor divider.
5	EN	I	Enable input. Active high. Internal weak pull-up.
6	VBST	O	High-side MOSFET gate supply pin. Connect 0.1-μF between the VBST pin and the SW pin.

Specifications

Absolute Maximum Ratings (1)

Parameter		Min	Max	Unit
V_{IN}	Supply Voltage	−0.3	42	V
SW	Switching Node Voltage	−0.3	V_{IN} + 0.3	V
	Switching Node Voltage (50 ns)	−3	42	V
	Switching Node Voltage (20 ns)	−5	42	V
VBST-SW	Bootstrap Voltage	−0.3	6	V
FB	Feedback Voltage	−0.3	6	V
EN	Enable Input	−0.3	42	V
T_J	Maximum Junction Temperature	−40	150	°C
T_A	Operating Temperature Range	−40	125	°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) The inputs are protected by ESD protection diodes to each power supply. If the input extends more than 300 mV beyond the power supply, the input current should be limited to less than 10 mA.
(3) A heat sink may be required to keep the junction temperature below the absolute maximum. This depends on the power supply voltage and how many amplifiers are shorted. Thermal resistance varies with the amount of PC board metal connected to the package. The specified values are for short traces connected to the leads.

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)	1.5	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	Typ	Max	Unit
VIN	Supply Input Voltage Range	4.5		36	V
EN	EN Input Voltage Range	0		36	V
FB	FB Input Voltage Range	0		5.5	V
BOOT – SW	BOOT Voltage Range	0		5.5	V
SW	FB Input Voltage Range	0		VIN	V
T_J	Operating Junction Temperature	–40		150	°C

Thermal Information

Package Type	θ_{JA}	θ_{JC}	Unit
TSOT23-6	100	67	°C/W

Electrical Characteristics

All test conditions: V_{IN} = 12 V, T_A = −40°C to +125°C, unless otherwise noted.

Parameter		Conditions	Min	Typ	Max	Unit
Power Supply						
V_{IN}	Supply Voltage Range		4.5		36	V
I_Q	Operating Supply Current	Non-switching, EN = 5 V, V_{FB} = 1 V		70		μA
I_{QSD}	Shut Down Supply Current	EN = GND		2		μA
V_{UVLO_rising}	UVLO Rising Threshold		3.9	4.3	4.5	V
$V_{UVLO\_falling}$	UVLO Falling Threshold		3.7	3.9	4.1	V
Enable						
V_{ENH}	EN Input Rising Threshold		1.15	1.28	1.35	V
V_{ENL}	EN Input Falling Threshold		1	1.15	1.2	V
I_{EN_L}	EN Current, EN = L (1)	V_{EN} = 0.9 V	0.65	1.04	1.5	μA
I_{EN_H}	EN Current, EN = H	V_{EN} = 1.5 V	3.6	4.3	5.2	μA
I_{EN_HYS}	EN Hysteresis Current	V_{EN} = 1.5 V		3.3		μA
Feedback and Power Stage						
V_{FB}	V_{FB} Feedback Voltage		588	600	612	mV
$R_{ds(on)\_HSD}$	High-side FET On-Resistance	I_{SW} = 1 A		180		mΩ
$R_{ds(on)\_LSD}$	Low-side FET On-Resistance	I_{SW} = 1 A		90		mΩ
f_{SW}	Switching Frequency		390	500	590	kHz
t_{ss}	Soft-Start Time			2		ms
t_{ss_done}	Soft Start Transition time		14	18	24	ms
I_{skip}	Pulse-Skip Mode Peak Inductor Current Threshold	V_{IN} = 12 V, V_{OUT} = 5 V, L = 15 μH		300		mA
Current Limit						
I_{Limit_HS}	High-side Current Limit	Inductor peak current	2.5	3.2	3.9	A
I_{Limit_LS}	Low-side Current Limit	Inductor valley current		2.5		A
$I_{Limit\_LS\_neg}$	Negative Low-side Current Limit			2		A
Diagnostics and Protection						
$V_{FB\_UVP\_rising}$	FB Hiccup Protection Rising Ratio			33		%
$V_{FB\_UVP\_falling}$	FB Hiccup Protection Falling Ratio			40		%
$V_{FB\_OVP\_rising}$	FB Over-Voltage Protection Rising Ratio			108		%
$V_{FB\_OVP\_falling}$	FB Over-Voltage Protection Falling Ratio			107		%
t_{HIC_wait}	Hiccup Protection Wait Time			128		Cycles
$t_{HIC\_restart}$	Hiccup Protection Restart Time			60		ms

Parameter		Conditions	Min	Typ	Max	Unit
Thermal Shutdown						
T_{SD}	Thermal Shut Down Temperature			160		°C
T_{SD_hys}	Thermal Hysteresis			10		°C

(1) Guaranteed by design

Typical Performance Characteristics

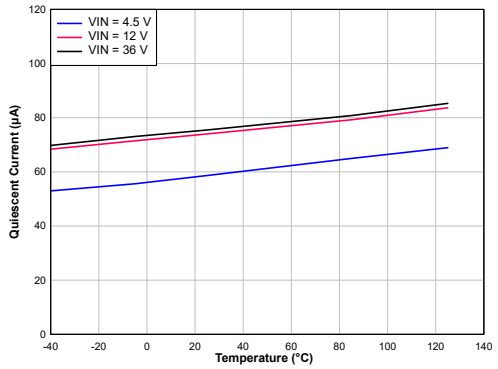


Figure 1. Quiescent Current vs. Supply Voltage

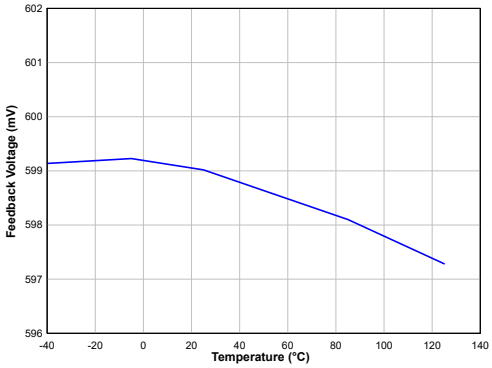


Figure 2. Reference Voltage vs. Temperature

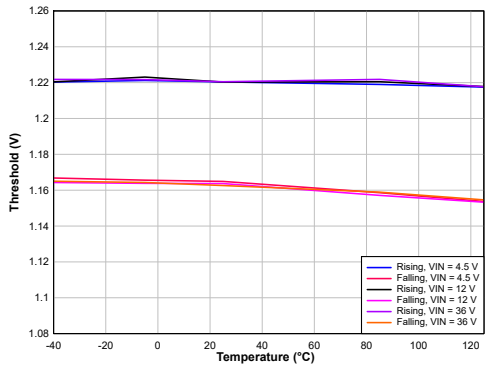


Figure 3. EN Threshold vs. Junction Temperature

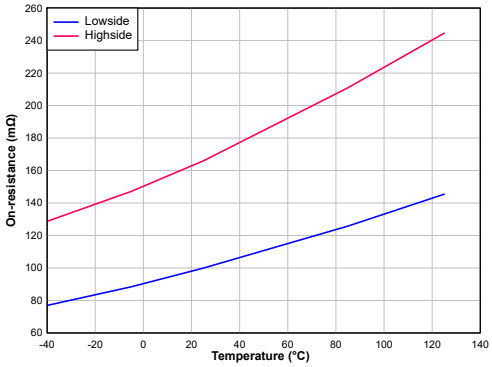


Figure 4. On-Resistance vs. Temperature

V_{IN} = 12 V

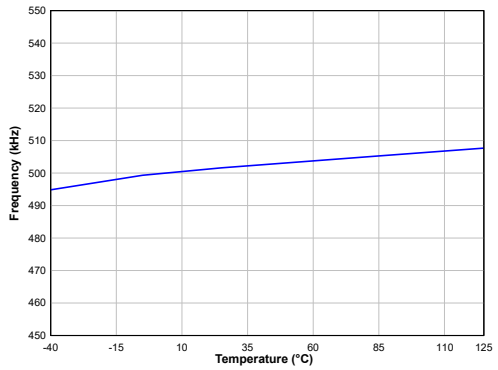


Figure 5. Switching Frequency vs. Temperature

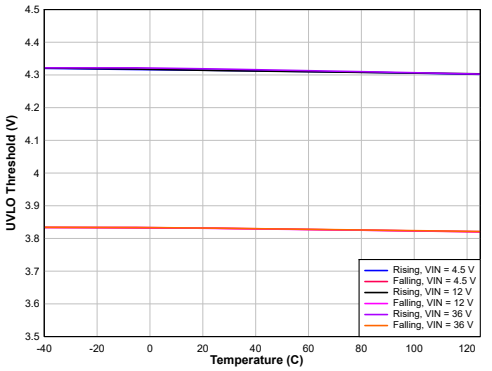


Figure 6. UVLO Threshold vs. Temperature

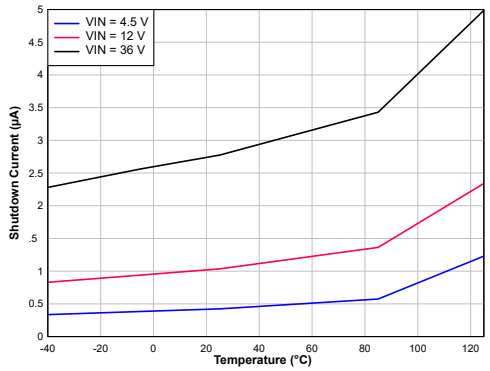


Figure 7. Shutdown Current vs. Junction Temperature

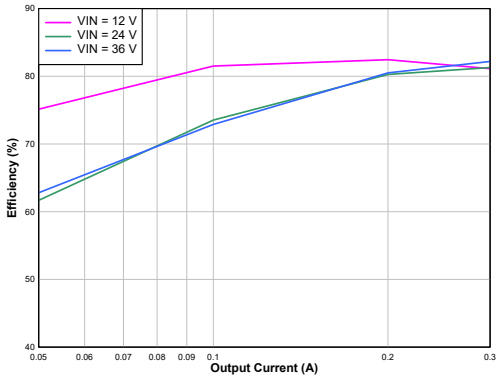


Figure 8. Efficiency vs. Secondary Output Current

V_{IN} = 12 V, V_{OUT} = 5 V

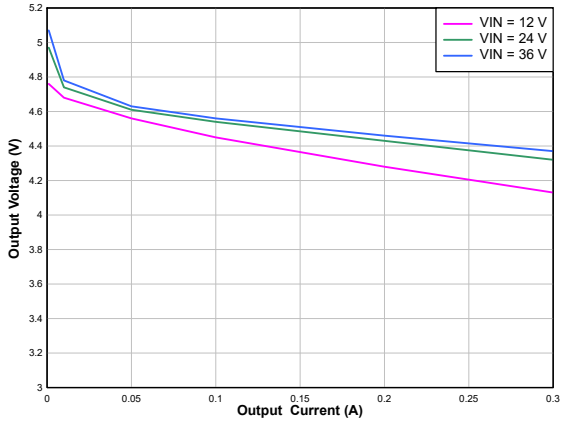


Figure 9. Load Regulation

V_{OUT} = 5 V

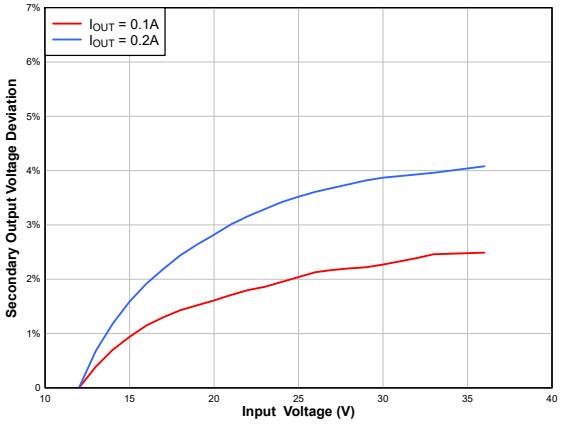


Figure 10. Line Regulation

V_{OUT}= 5 V

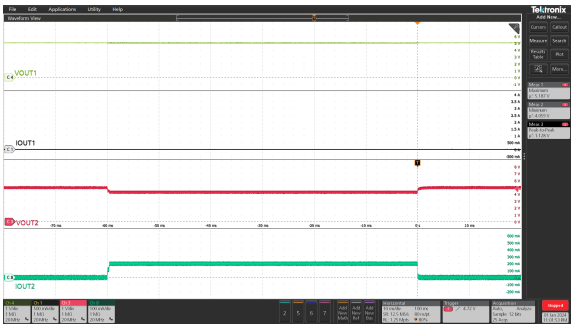


Figure 11. Load Transient

CH1: Primary side load current V_{OUT} , CH4: Primary side voltage output

CH3: Secondary side voltage output, CH8: Secondary side load current

V_{IN} = 12 V, V_{OUT} = 5 V, I_L = 0 A to 0.2 A

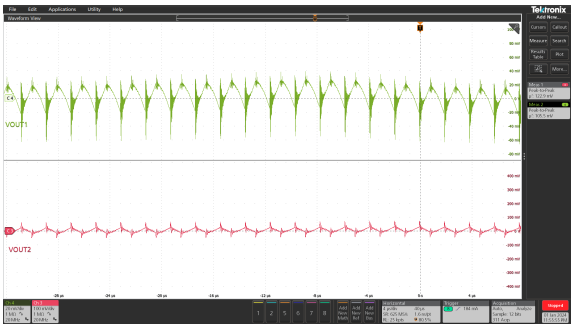


Figure 12. Ripple Voltage

CH4: V_{OUT1} Primary Side Output, CH3: V_{OUT2} Secondary Side Output

V_{IN} = 12 V, I_L = 0.2 A

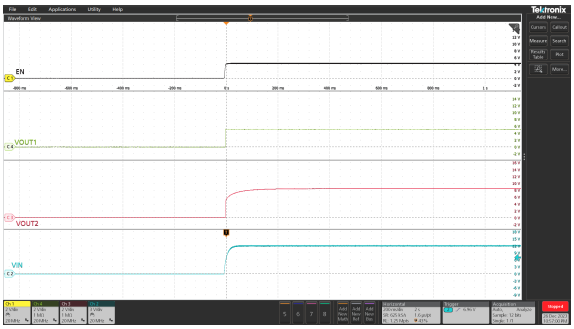


Figure 13. Start-Up by VIN

CH1: EN, CH2: V_{IN}, CH3: V_{OUT2}, CH4: V_{OUT1}

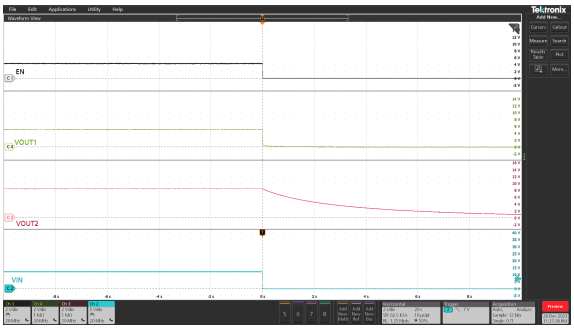


Figure 14. Power-Down by VIN

CH1: EN, CH2: V_{IN}, CH3: V_{OUT2}, CH4: V_{OUT1}

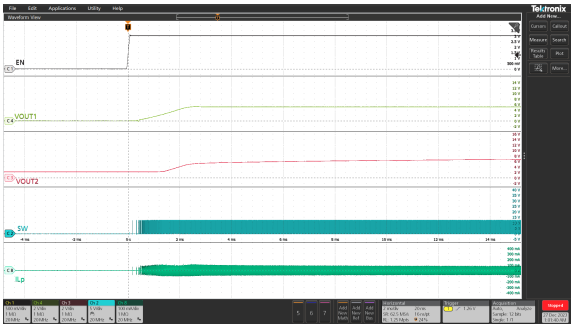


Figure 15. Start-Up by EN

CH1: EN, CH2: V_{IN}, CH3: V_{OUT2}, CH4: V_{OUT1}

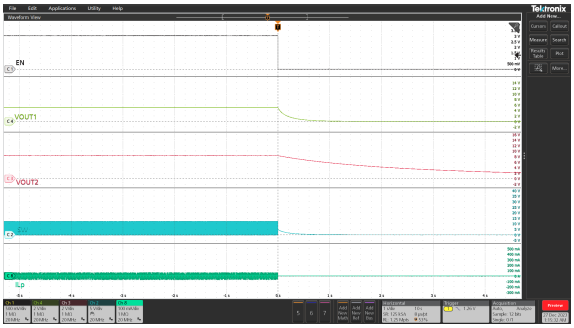


Figure 16. Power-Down by EN

CH1: EN, CH2: V_{IN}, CH3: V_{OUT2}, CH4: V_{OUT1}

Detailed Description

Overview

The TPP38002 is a 2-A synchronous step-down converter for low-cost, high-efficiency isolated bias supply. The current mode control topology provides a fast transient response and supports low ESR output capacitors, such as specialty polymer capacitors and multi-layer ceramic capacitors, without extra compensation circuitry.

Functional Block Diagram

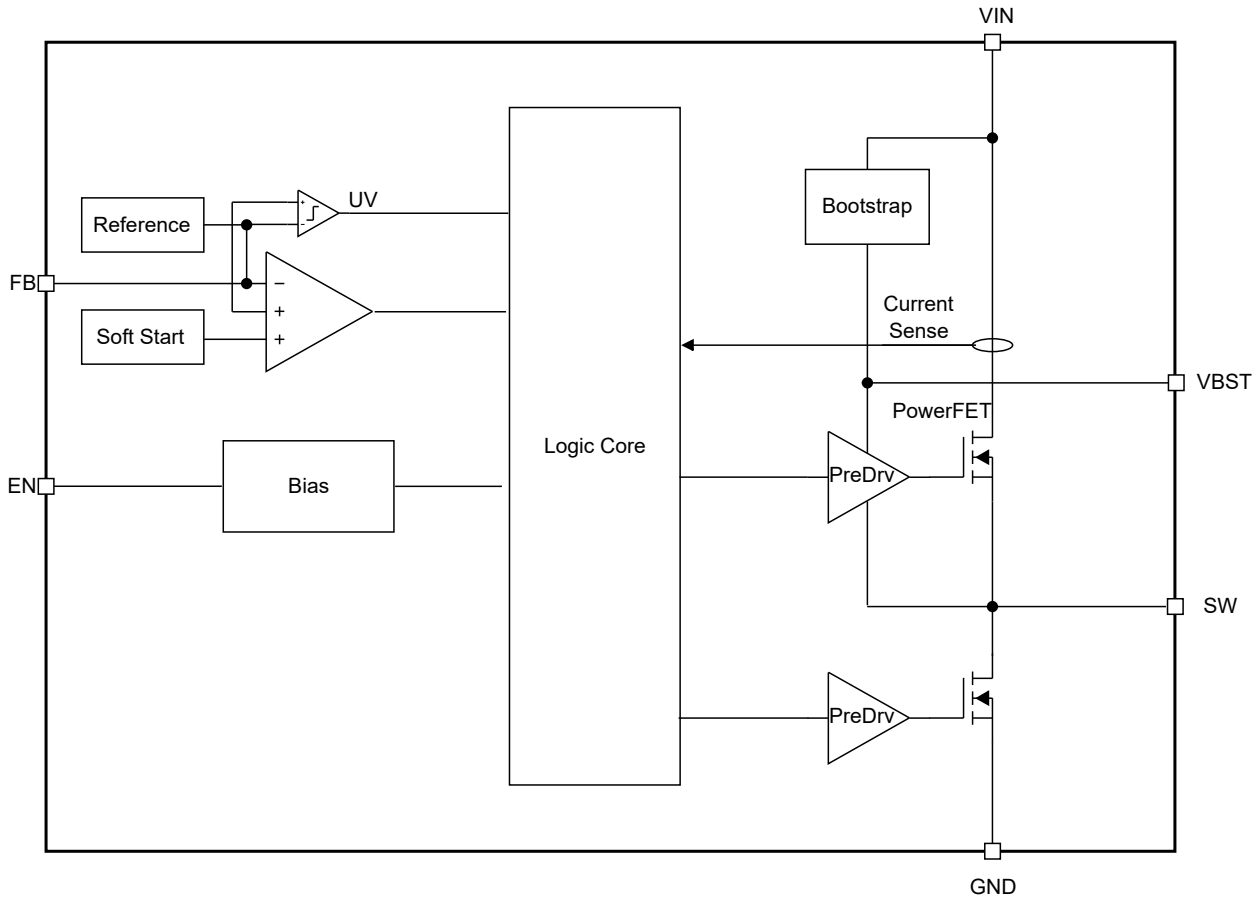


Figure 17. Functional Block Diagram

Feature Description

Current Mode Control

The TPP38002 uses the current mode control topology. The current mode topology supports fixed frequency operation thus optimizing ripple performance. With integrated low $R_{ds(on)}$, the device can achieve high efficiency in a small physical footprint.

Switching Frequency

TPP38002 supports 500-kHz switching frequency.

Forced-PWM Mode

The TPP38002 has a forced-PWM mode to support isolated buck applications. When the inductor ripple valley current reaches zero, the device will automatically enter the forced-PWM mode with a fixed switching frequency. In this mode, the negative current limit of low-side FET is enabled.

Enable Input

The device EN has two current sources to pull EN up high. I_{EN} and I_{HYS}. When EN is low, the I_{EN} is enabled as I_{EN_L}. When EN rises above the threshold and turns hysteresis current I_{EN_SYS}on, the total current is I_{EN_H}.

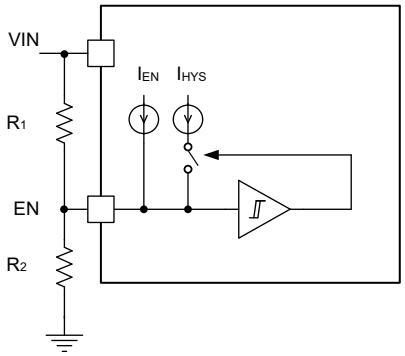


Figure 18. EN Block Diagram

The EN threshold can be set via below the equations:

$$R_1 = \frac{V_{ENL}\left(V_{IN\_START} - V_{ENH}\right) - V_{ENH}\left(V_{IN\_STOP} - V_{ENL}\right)}{V_{ENH} \cdot I_{ENH} - V_{ENL} \cdot I_{ENL}} \quad (1)$$

$$R_2 = \frac{V_{ENH}}{I_{ENL} + \frac{V_{IN\_START} - V_{ENH}}{R_1}} \quad (2)$$

Soft-Start with Pre-Biased Capability

Once EN becomes high, the device ramps up its internal reference voltage with a fixed 2-ms rise time. When the output capacitor is pre-charged, the soft-start ramp will only enable output switching after the internal reference ramps above the FB voltage.

Over Current Protection

The device has a cycle-by-cycle current limit. During the OFF state, once overcurrent is detected at ripple current valley by measuring the low-side FET current, the device keeps the low-side FET OFF until the current falls below the over-current protection (OCP) threshold. The device has a negative current and can block reverse current when the reverse inductor current is higher than the threshold.

Output Undervoltage Hiccup Protection

When the device output voltage falls below the hiccup voltage threshold, the device turns into the hiccup mode by turning off the device and restarts after the hiccup timer (typically 60 ms) expires.

To support large output capacitance as large as 1 mF, the device has an extended soft start transition timer. Upon power up, the device gets into soft-start and prevents the device from output under voltage hiccup protection mode until soft start transition time t_{ss_done} is over.

Undervoltage Lockout (UVLO) Protection

Once the input voltage falls below the UVLO threshold, the device is shut off. Once the device recovers above the UVLO threshold, the device returns to normal operation.

Over-Temperature Shutdown

Once the junction temperature rises above the internal over-temperature shutdown threshold, the device shuts off and recovers when the temperature falls below the threshold with hysteresis.

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

As an easy-to-use isolated buck voltage regulator, the TPP38002 usually converts a higher input voltage to the desired output voltage set by the VFB resistor divider. With a transformer, the device can generate a primary side output voltage together with a secondary output voltage simultaneously. The below section depicts a simplified design flow of circuitry for the TPP38002.

Typical Application

The isolated buck circuit based on TPP38002 is listed below. Primary side voltage can be set via FB resistor divider, and the secondary side voltage can be set via transformer ratio. Diode drop also needs to be considered.

3PEAK recommends adding a minimal resistive load on the secondary side output to avoid high voltage during light load scenarios.

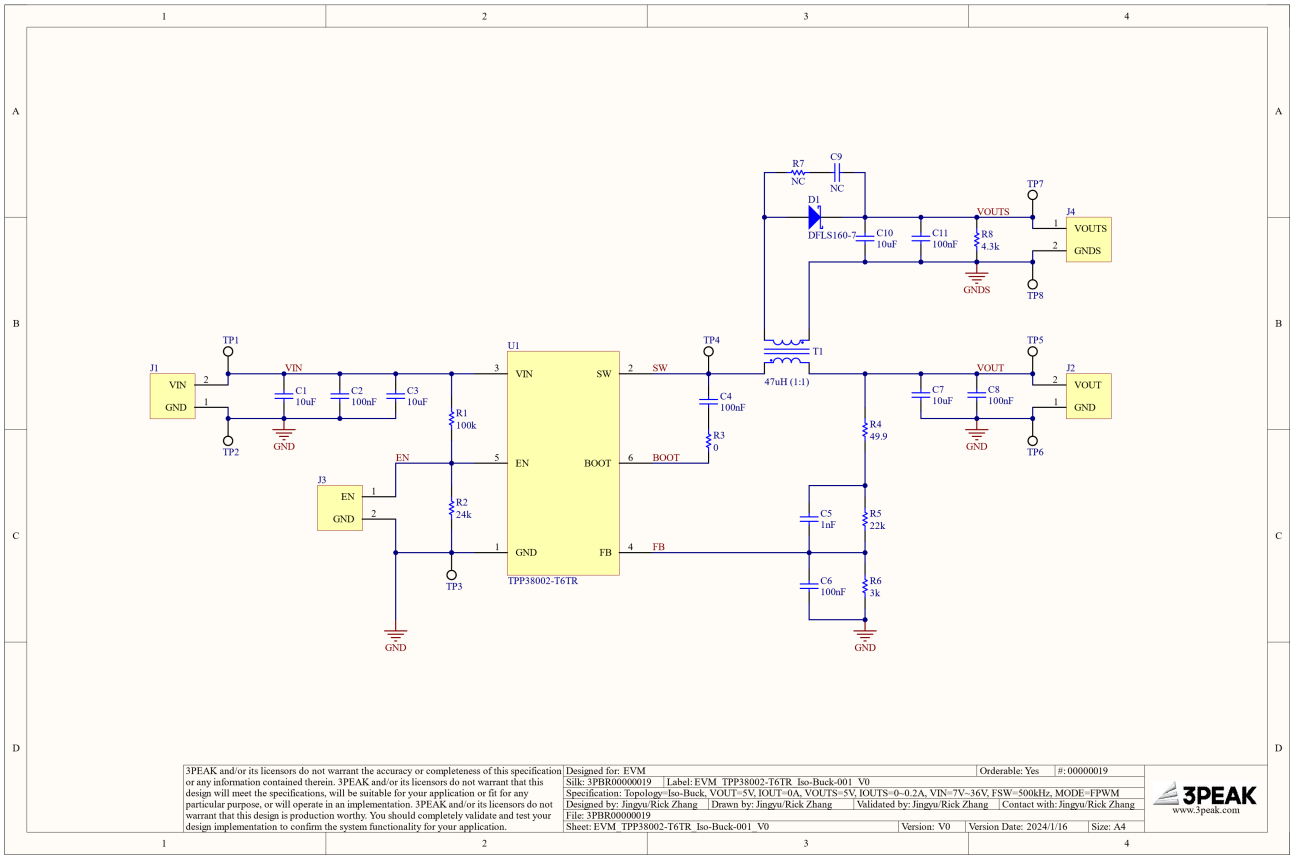


Figure 19. Typical Application Circuit

Component Selection

Designator	Value	Quantity	Part No.	Package	Manufacturer	Description
PCB		1	3PBR00000019		Any	Printed Circuit Board
U1	TPP38002-T6TR	1	TPP38002-T6TR	SOT23-6	3PEAK	Iso-Buck Converter, 36V, 2A, 500kHz, FPWM
C1	10uF	1	GRM31CD71H106KE11	1206	muRata	Capacitor, 10uF, 50VDC, X7T, ±10%
C2	100nF	1	GGD21BR71H104KA02	0805	muRata	Capacitor, 100nF, 50VDC, X7R, ±10%
C3	10uF	1	GRM31CD71H106KE11	1206	muRata	Capacitor, 10uF, 50VDC, X7T, ±10%
C4	100nF	1	GRM188R71C104KA01	0603	muRata	Capacitor, 100nF, 16VDC, X7R, ±10%
C5	1nF	1	GRM1885C1H102JA01	0603	muRata	Capacitor, 1nF, 50VDC, C0G, ±5%
C6	100nF	1	GRM188R71H104KA93	0603	muRata	Capacitor, 100F, 50VDC, X7R, ±10%
C7	10uF	1	GCM21BC71C106KE36	0805	muRata	Capacitor, 10uF, 16VDC, X7S, ±10%
C8	100nF	1	GGD21BR71H104KA02	0805	muRata	Capacitor, 100nF, 50VDC, X7R, ±10%
C9	NC	0				
C10	10uF	1	GCM21BC71C106KE36	0805	muRata	Capacitor, 10uF, 16VDC, X7S, ±10%
C11	100nF	1	GGD21BR71H104KA02	0805	muRata	Capacitor, 100nF, 50VDC, X7R, ±10%
R1	100K	1	ARG03FTC1003	0603	Viking	Resistor, 100K, ±1%, 0.1W
R2	24K	1	ARG03FTC2402	0603	Viking	Resistor, 24K, ±1%, 0.1W

Designator	Value	Quantity	Part No.	Package	Manufacturer	Description
R3	0	1	ERJ-3GEY0R00V	0603	Panasonic	Resistor, 0Ω, 5%, 0.1W
R4	49.9	1	ARG03FTC49R9	0603	Viking	Resistor, 49.9Ω, ±1%, 0.1W
R5	22K	1	ARG03FTC2202	0603	Viking	Resistor, 22K, ±1%, 0.1W
R6	3K	1	ARG03FTC3001	0603	Viking	Resistor, 3K, ±1%, 0.1W
R7	NC	0				
R8	4.3K	1	ARG03FTC4301	0603	Viking	Resistor, 4.3K, ±1%, 0.1W
T1	47uH	1	MSD1038-473ME	10mm×4mm×10mm	Coilcraft	Coupled Inductor, 47uH, 1:1, 2250VRms, 2.2A
J1		1	691101710002	Terminal Block, 5.08mm, 2×1, Tin, TH	Wurth Elektronik eiSos	Terminal Block, 5.08mm, 2×1, Tin, TH
J2		1	691101710002	Terminal Block, 5.08mm, 2×1, Tin, TH	Wurth Elektronik eiSos	Terminal Block, 5.08mm, 2×1, Tin, TH
J3		1	61300211121	Header, 2.54mm, 2×1, Tin, TH	Wurth Elektronik eiSos	Header, 2.54mm, 2×1, Tin, TH
J4		1	691101710002	Terminal Block, 5.08mm, 2×1, Tin, TH	Wurth Elektronik eiSos	Terminal Block, 5.08mm, 2×1, Tin, TH
TP1		1	5010	Red Multipurpose Testpoint	Keystone	Test Point, Multipurpose, Red, TH
TP2		1	5011	Black Multipurpose Testpoint	Keystone	Test Point, Multipurpose, Black, TH
TP3		1	5011	Black Multipurpose Testpoint	Keystone	Test Point, Multipurpose, Black, TH
TP4		1	5013	Black Multipurpose Testpoint	Keystone	Test Point, Multipurpose, Orange, TH
TP5		1	5010	Red Multipurpose Testpoint	Keystone	Test Point, Multipurpose, Red, TH

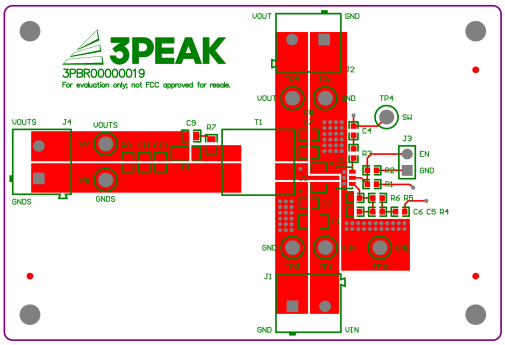
Designator	Value	Quantity	Part No.	Package	Manufacturer	Description
TP6		1	5011	Black Multipurpose Testpoint	Keystone	Test Point, Multipurpose, Black, TH
TP7		1	5010	Red Multipurpose Testpoint	Keystone	Test Point, Multipurpose, Red, TH
TP8		1	5011	Black Multipurpose Testpoint	Keystone	Test Point, Multipurpose, Black, TH
H1		1	NY PMS 440 0025 PH	Screw	B&F Fastener Supply	Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead
H2		1	NY PMS 440 0025 PH	Screw	B&F Fastener Supply	Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead
H3		1	NY PMS 440 0025 PH	Screw	B&F Fastener Supply	Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead
H4		1	NY PMS 440 0025 PH	Screw	B&F Fastener Supply	Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead
H5		1	1902C	Standoff	Keystone	Keystone
H6		1	1902C	Standoff	Keystone	Keystone
H7		1	1902C	Standoff	Keystone	Keystone
H8		1	1902C	Standoff	Keystone	Keystone
Label1	EVM_TPP38002-T6TR_Iso-Buck-001_V0	1		Adhesive Tape Printed	3PEAK	Topology=Iso-Buck Solution, V OUT=5V, IOUT=0A, VOUTS=5V, IOUTS=0~0.2A, VIN=7~36V, FSW=500kHz, MODE=FPWM
Labe2	2024/1/19	1		Adhesive Tape Printed	3PEAK	QR Code

Layout

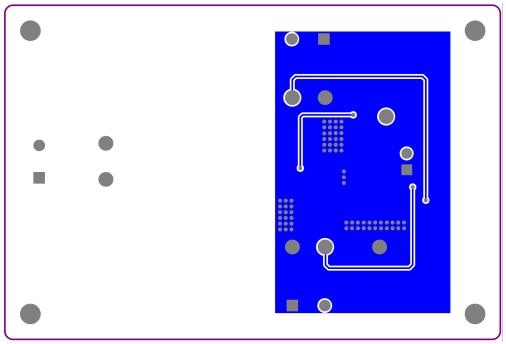
Layout Guideline

- Both input capacitors and output capacitors must be placed on the device pins as close as possible.
- It is recommended to bypass the input pin to ground with a 0.1-μF bypass capacitor.
- It is recommended to use wide and thick copper to minimize I×R drop and heat dissipation.
- The exposed pad must be connected to the PCB ground plane directly, the copper area must be as large as possible.

Layout Recommendations

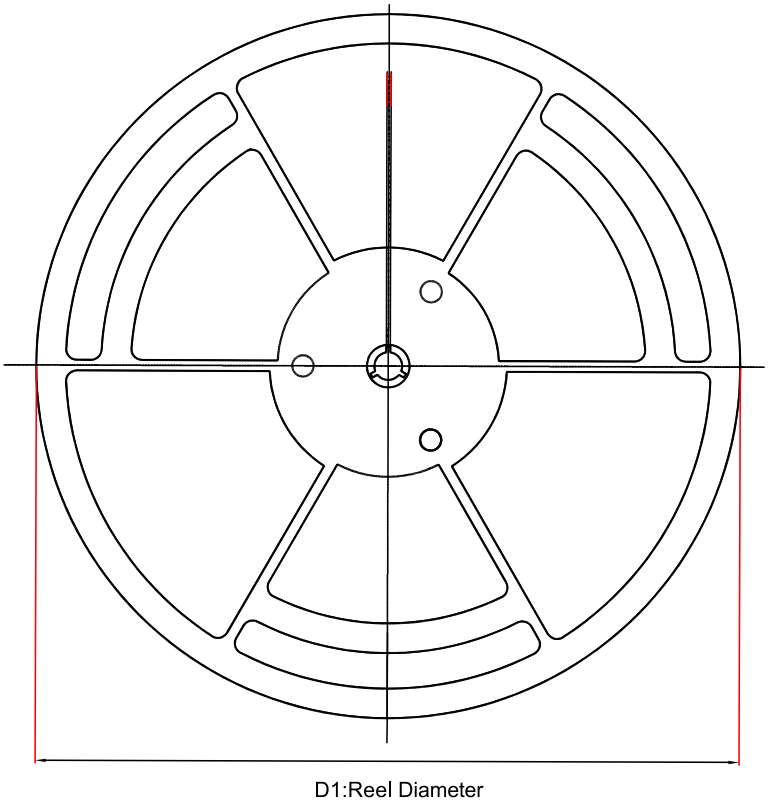


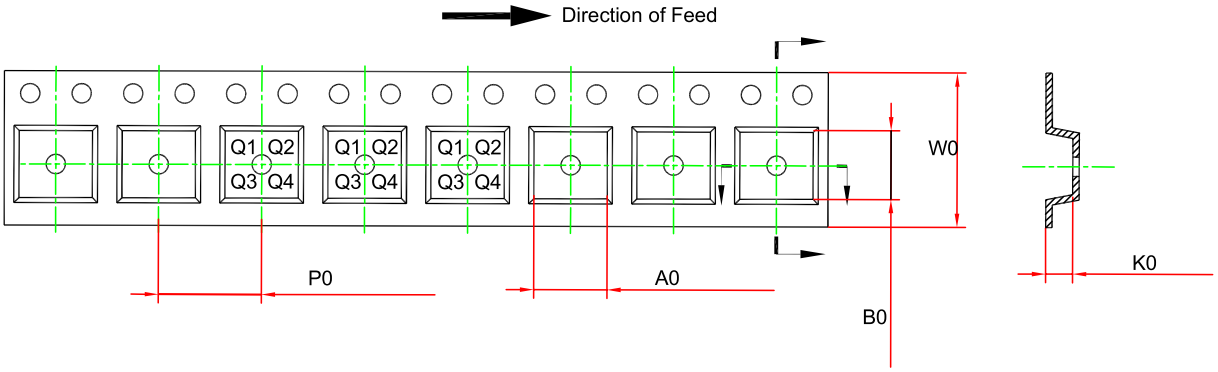
Top Layer



Bottom Layer

Tape and Reel Information



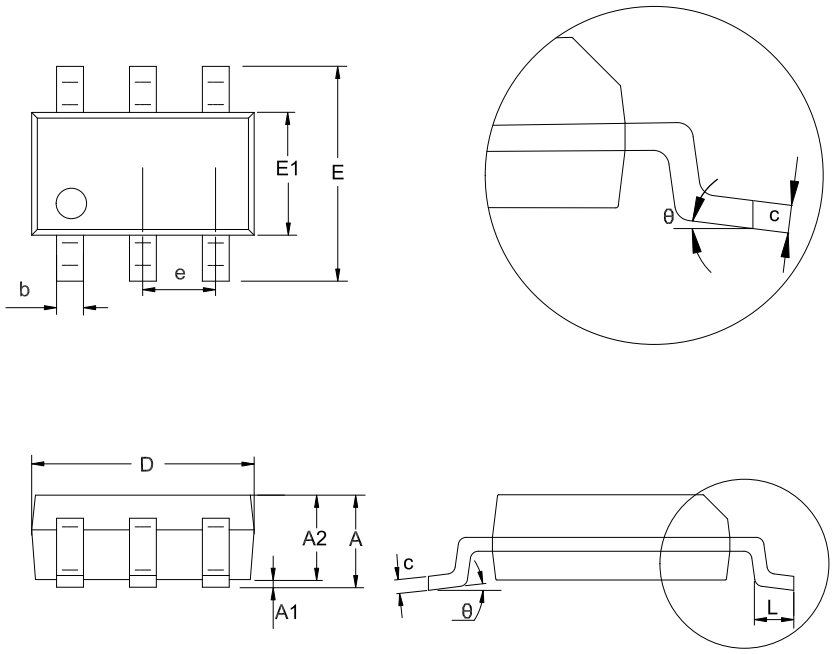


Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TPP38002-T6TR	TSOT23-6	180.0	12.3	3.2	3.2	1.1	4.0	8.0	Q3

Package Outline Dimensions

TSOT23-6

Package Outline Dimensions T6T(TSOT23-6-A)



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.700	0.950	0.028	0.037
A1	0.000	0.150	0.000	0.006
A2	0.650	0.850	0.026	0.033
b	0.360	0.500	0.014	0.020
c	0.130	0.230	0.005	0.009
D	2.820	3.050	0.111	0.120
E	2.600	3.000	0.102	0.118
E1	1.500	1.700	0.059	0.067
e	0.950 BSC		0.037 BSC	
L	0.300	0.600	0.012	0.024
θ	0	8°	0	8°

NOTES

1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

Order Information

Order Number	Operating Temperature Range	Package	Marking Information	MSL	Transport Media, Quantity	Eco Plan
TPP38002-T6TR	−40 to 125°C	TSOT23-6	382	MSL3	Tape and Reel, 3000	Green

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

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