48-V 8-Ch Smart Low-side Driver Array

Features

- 8-Channel Smart Low-side Driver Array
  - 40-V Max Operating Voltage, 48-V Abs Max Voltage
  - 500-mΩ Low-$R_{DS(ON)}$ with Maximum 1.5-A Driver Capability
  - Integrated Free-wheeling Diodes for Inductive Loads
  - Parallel Channel Driving Capability
- 10-MHz High-speed 16-bit Shift Register Interface
  - Input Noise Filtering with Daisy-chain Communication
- Diagnostics and Protection
  - Power On Reset
  - Over-Current Protecion
  - Short-Circuit Protection
  - Over-Temperature Protection
  - Open-drain Fault Alarm

Description

The TPM8860 provides an 8-ch low-side driver with channel independent protection and diagnostics. It has low $R_{DS(ON)}$ MOSFET array with free-wheeling diodes to support all kinds of loads, resistive, inductive and capacitive. It supports single high-voltage supply

It supports high-speed shift register interface with daisychain individually control each channel. Over-current protection, short-circuit and open-circuit allows controller to protect the system from faulty loads. Open-drain fault output allows controller to respond to fault scneario with interrupt input.

Multiple devices can be connected in daisy-chain configuration to save MCU I/Os. The device also provides undervoltage lockout, over-temperature shutdown protection.

Applications

- Relays, Solenoids, Unipolar Stepper Motors
- Electric Expension Valves, Linear Valves
- LEDs and Heaters
- PLC Digital Outputs
- Electromagnetic Loads

Typical Application Circuit

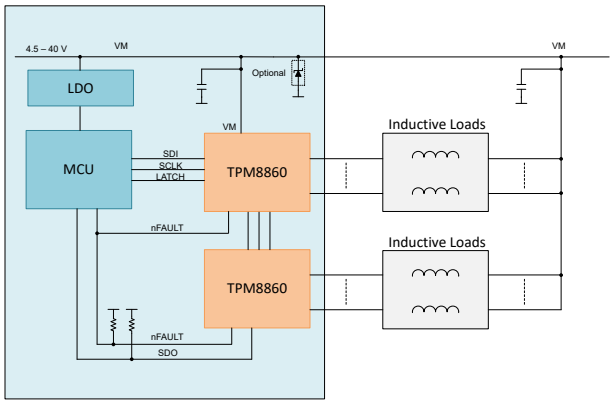


Table of Contents

Revision History

Date	Revision	Notes
2023-07-11	Rev.P0	Initial revision
2023-10-24	Rev.P1	Updated application diagram

Pin Configuration and Functions

TPM8860-TSBR
ETSSOP16 Package
Top View

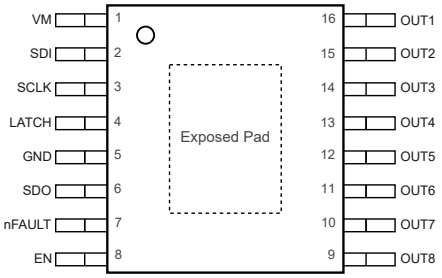


Table 1. Pin Functions: TPP8860-TSBR

Pin	Name	I/O	Description
1	VM	P	Motor power supply, connect to 10μF capacitor with 0.1μF close to VM pin
2	SDI	I	Serial interface data input
3	SCLK	I	Serial interface clock input
4	LATCH	I	Serial interface latch input
5	GND	G	Device ground
6	SDO	O	Serial interface data output, push-pull output
7	nFAULT	OD	Open-drain fault output
8	EN	I	Output enable. Logic high to enable all outputs, logic low to disable all outputs.
9	OUT8	O	Output channel 8
10	OUT7	O	Output channel 7
11	OUT6	O	Output channel 6
12	OUT5	O	Output channel 5
13	OUT4	O	Output channel 4
14	OUT3	O	Output channel 3
15	OUT2	O	Output channel 2
16	OUT1	O	Output channel 1

Specifications

Absolute Maximum Ratings (1)

Parameter		Min	Max	Max
VM	Power Supply Voltage	−0.3	48	V
	Power Supply Voltage (100-ns Pulse)	−0.3	50	V
EN, LATCH, SCLK, SDI	Input Voltage	−0.3	7	V
SDO, nFAULT	Output Voltage	−0.3	7	V
V_{OUTx}	Power Output Voltage	−0.3	48	V
	Power Output Voltage (100-ns Pulse)	−0.3	50	V
T_J	Maximum Junction Temperature		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.

ESD, Electrostatic Discharge Protection

Symbol	Parameter	Condition	Minimum Level	Unit
HBM	Human Body Model ESD	ANSI/ESDA/JEDEC JS-001 (1)	4	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 JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

Recommended Operating Conditions

Parameter		Min	Max	Unit
VM	Power Supply Voltage	5	40	V
EN, SDI, SCLK, LATCH	Logic Input Voltage	0	5.5	V
SDO, nFAULT	Open Drain Output Voltage	0	5.5	V
V_{OUTx}	Output Voltage	0	40	V
I_{OUTx}	Continuous Output Current		1.5	A
	Peak Output Current		2	A
I_{VM}	Reverse Current		4	A
I_{GND}	Ground Current		4	A
T_J	Maximum Junction Temperature		150	°C
T_A	Operating Temperature Range	−40	125	°C

Thermal Information

Package Type	θ_{JA}	θ_{JC}	Unit
ETSSOP16	62.8	52.6	°C/W

Electrical Characteristics

All test condition is at V_M = 12 V, T_A = −40°C to +125°C, unless otherwise noted.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Power Supply						
I_{VM}	VM Operating Supply Current	VM = 24 V		1	4	mA
V_{UVLO_rising}	VM Under-voltage-lock-out Rising Edge	VM rising edge			4.4	V
$V_{UVLO\_falling}$	VM Under-voltage-lock-out Falling Edge	VM falling edge			4.4	V
Logic Inputs / Outputs (EN, LATCH, SDI, SCLK, nFAULT, SDO)						
V_{IL}	Input Low Voltage Threshold		0.7		1.3	V
V_{IH}	Input High Voltage Threshold		1		1.5	V
I_{IL}	Input Low Current	V_{IN} = 0 V	-20		20	μA
I_{IH}	Input High Current	V_{IN} = 3.3 V			100	μA
R_{PD}	Input Pull-down Resistance		60	100	130	kΩ
V_{OL}	Output Low Voltage	I_O = 5 mA			0.5	V
$I_{OH(nFAULT)}$	nFAULT Output High Leakage Current	V_O = 3.3 V	−1		1	μA
R_{PU}	SDO Pull-up Resistance	Pull up to internal regulator		1.4		kΩ
V_{SDO_H}	Output High Voltage	I_O = 0.1 mA, VM = 5 V - 40 V, steady state	2.5	4.5	5.9	V
I_{SDO_SRC}	SDO Source Current	VM = 24 V, V_{SDO} = V_{SDO_H} − 0.5V		10		mA
I_{SDO_SINK}	SDO Sink Current	VM = 24 V, V_{SDO} = 0.3 V		50	250	mA
Outputs						
$R_{ds(ON)}$	Output Low-side MOSFET on-resistance	VM = 24 V, I_O= 500 mA, T_J= 25°C		0.5		Ω
$R_{ds(ON)}$	Output Low-side MOSFET on-resistance	VM = 24 V, I_O= 500 mA, T_J= 150°C		0.8	1.2	Ω
I_{OPEN_OFF}	Open Load Detection Current during off State			30	50	μA
V_F	Highside Diode Forward Voltage	VM = 24 V, I_{SINK}= 500 mA, T_J = 25°C		0.9		V
I_{HSD_lkg}	Highside Diode Leakage Current	VM = 24 V, T_J = 25°C	−50		50	μA
$t_{OUT\_risetime}$	Output Risetime	VM = 24 V, T_J = 25°C, Resistive load		90		ns
$t_{OUT\_falltime}$	Output Falltime	VM = 24 V, T_J = 25°C, Resistive load		90		ns
Diagnostics and Protection						

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$I_{(OCP\_TH)}$	Over-current Protection Threshold		1.65		2.8	A
$t_{(OCP\_deg)}$	Over-current Protection Deglitch Time			3.5		μs
$V_{(OL\_TH)}$	Open Load Detection Threshold			1.2		V
$t_{(OL\_deg)}$	Open Load Detection Deglitch Time		7		17	μs
$I_{(OL\_off)}$	Off-time Open-Load Source Current			30	50	μA
t_{RETRY}	Over-current Retry Timer			100		ms
t_{TSD}	Thermal Shutdown Threshold		150	175		°C
t_{TSD_HYS}	Thermal Shutdown Threshold Hysteresis			15		°C

Typical Performance Characteristics

All test condition: V_{IN} =12 V, T_A =+ 25°C, unless otherwise noted.

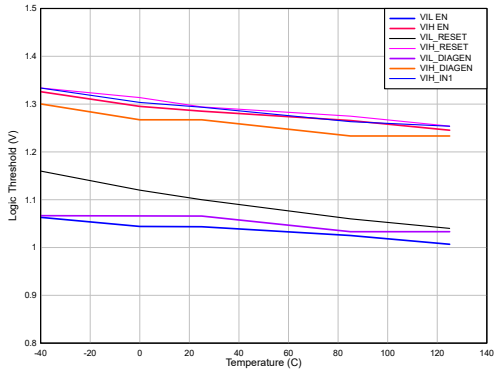


Figure 1. Logic Input Threshold vs. Temperature

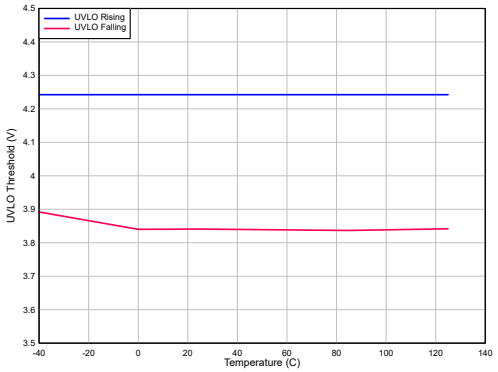


Figure 2. UVLO Threshold vs. Temperature

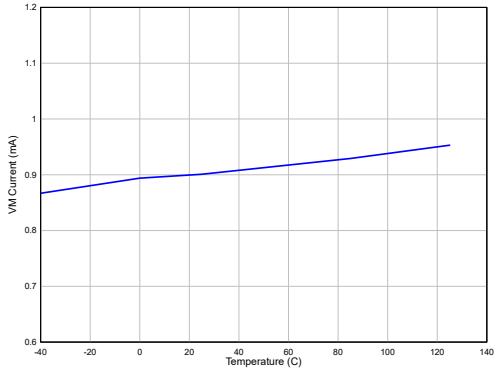


Figure 3. Quiescent Current vs. Temperature

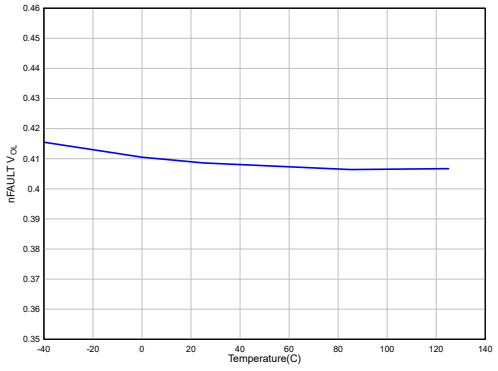


Figure 4. nFAULT V_{OL} vs. Temperature

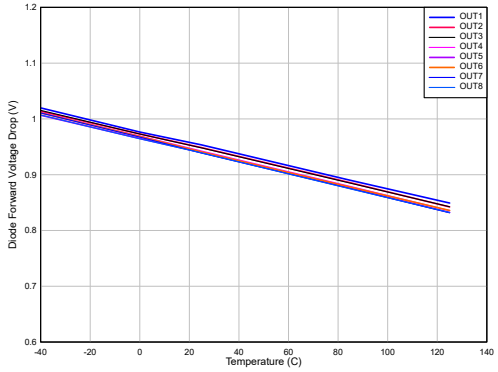


Figure 5. Forward Diode Drop vs. Temperature

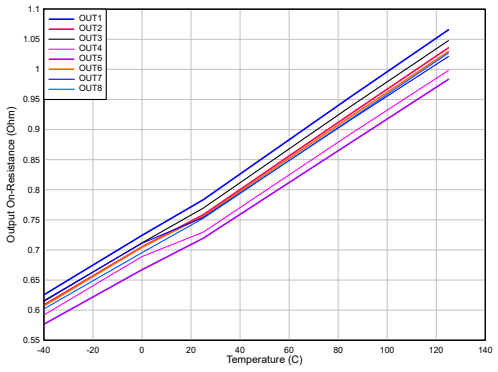


Figure 6. On-resistance vs. Temperature

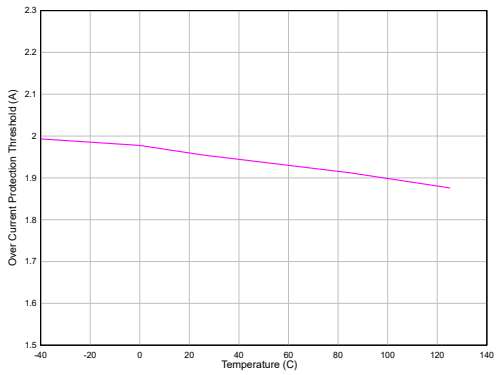


Figure 7. Over Current Protection Threshold vs. Temperature

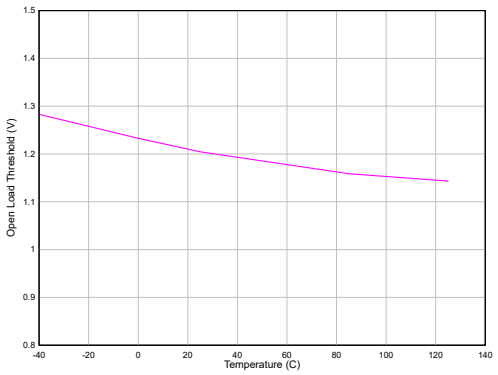


Figure 8. Open-Load Protection Threshold vs. Temperature

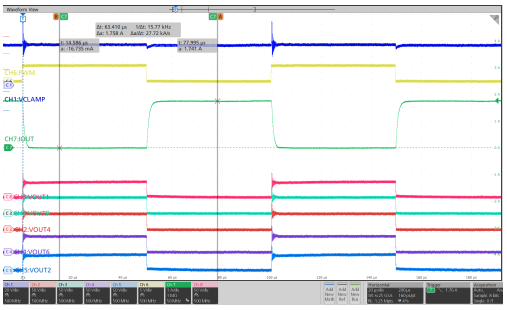


Figure 9. Inductive Load Driving

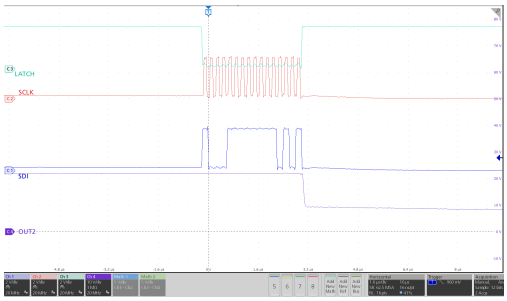


Figure 10. Serial Interface

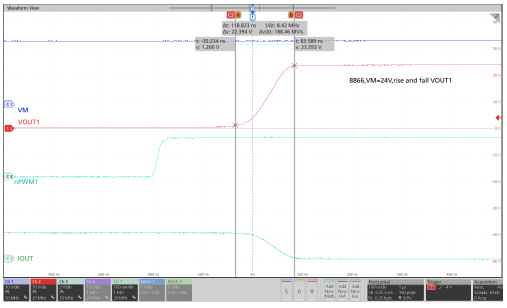


Figure 11. Output Rising Edge

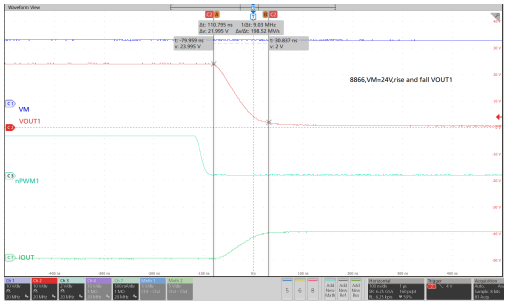


Figure 12. Output Falling Edge

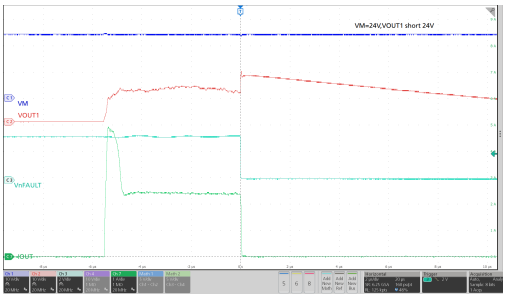


Figure 13. Short Circuit Protection

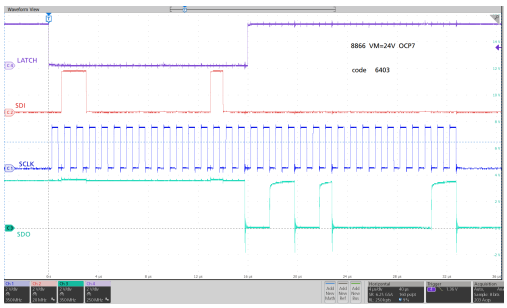


Figure 14. Output Fault Readback

Detailed Description

Overview

The TPM8860 is a smart high-voltage high-current low-side driver array with full diagnostics and protection. The device supports maximum 40-V seperated supply and driver voltage. 8-Ch lowside driver can be controlled individually via serial interface. Each output channel has integrated free-wheeling diode path for inductive loads such as solenoids, motors, electric expansion valves and relays. The device has protection features includes supply undervoltage monitoring, over-current protection, load open-circuit and short-circuit diagnostics, and over-temperature protection. Open-drain fault bus allows hardware interrupt for MCU to handle fault scenarios easily.

The device supports daisychain connection of multiple devices together as well as isolated interface with 3PEAK digital isolators.

Functional Block Diagram

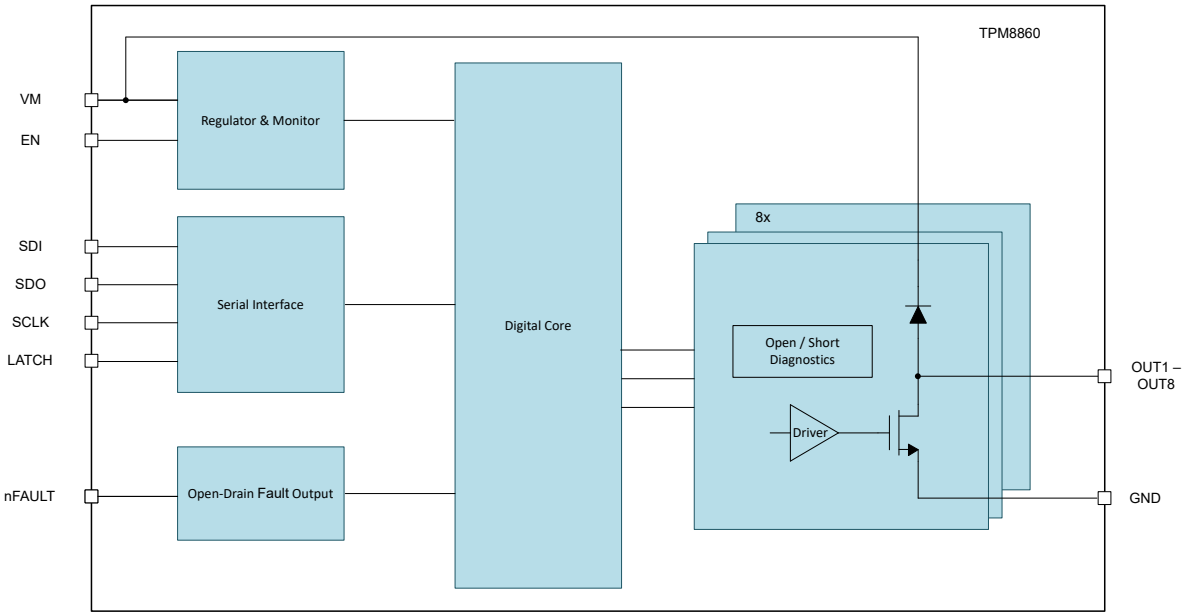


Figure 15. Functional Block Diagram

Feature Description

Supply and Reference

The TPM8860 supports single voltage rail VM. VM includes an undervoltage lockout (UVLO) monitor to prevent issues at low supply voltages. It is recommended to use 10-μF capacitors on each rail to suppress voltage transients when driving inductive loads. When inductive loads may surge higher than 40-V, 3PEAK recommends to use TVS to supress transient voltage.

The device has a EN input with an internal pull-down. When EN is low, the device is in a reset state, clearing register maps and tri-stating the SDO pin. When RESET is high, the device is in normal operation and can communicate via the serial interface.

Output Enable

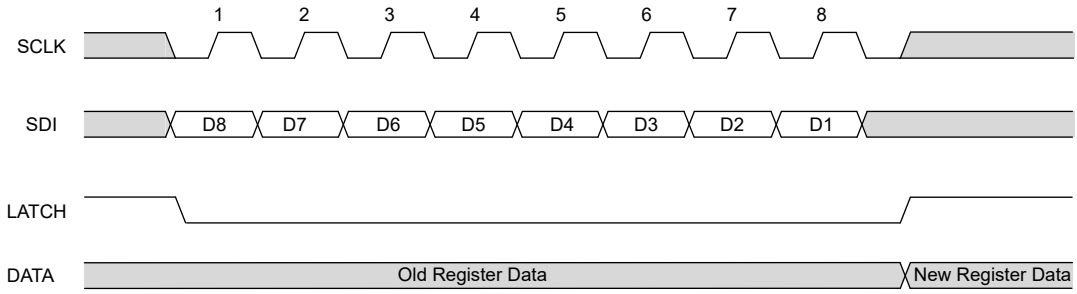
The TPM8860 provides an active high output enable, EN, to control the device outputs. When EN is low, the outputs are disabled with register map cleared; When EN is high, the outputs are enabled. It has an internal pull-down resistor and can be left unconnected or connected to ground for desired functionality.

Serial Communication

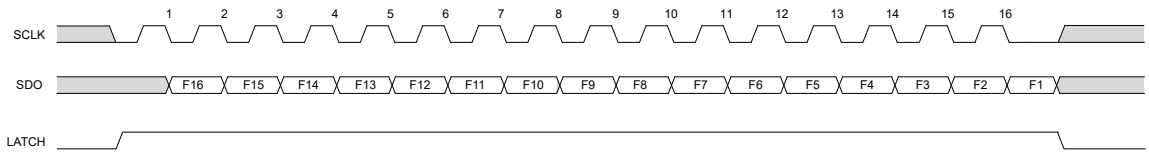
Serial Interface

The TPM8860 device supports a high-speed shift-register serial interface with daisy-chain capability. The Serial Data Output (SDO) pin is configured as a push-pull output, connected to the internal 3.3-V voltage rail to enable high-speed communication.

During a write operation, when the device selection LATCH is low, on each rising edge of the serial clock (SCLK), the device shifts the Serial Data Input (SDI) into the internal shift register and updates the Serial Data Output (SDO) with the last bit of the shift register.



During a read operation, when LATCH is high, microcontroller sends out the serial clock and shift internal fault indicator registers out. On each falling edge of SCLK, the device shifts out the 16-bit data from the internal register to SDO.



Output Driver

The device features an array of 8 low-side drivers, each consisting of a low-side MOSFET and a high-side recirculation diode. Each channel is capable of handling a maximum current of 1.5 A, although the total device current should also consider thermal effects. The drivers can accommodate both inductive and resistive loads.

When a channel is turned on, the low-side MOSFET conducts, allowing current to flow from the external load through the low-side MOSFET to the device ground. When the channel is turned off, the inductive current will continue to flow, but it will be recirculated through the internal diode to the VCLAMP pin.

It is crucial to ensure that the VCLAMP pin can handle the inductive energy. To protect against overvoltage, we recommend using an external clamp diode connected to the VCLAMP pin. The other side of the external clamp diode can be connected to either the VM or GND, depending on the specific application requirements.

Output Control by Serial Interface

Each channel of the device can be individually enabled or disabled. This can be achieved through the serial interface. When Dx is set to 1, the corresponding channel is turned on, and when it is set to 0, the channel is turned off.

Output Diagnostics

Open-drain Fault

The TPM8860 features an open-drain output called nFAULT. This output is used to indicate the occurrence of a fault. When a fault condition occurs, the nFAULT pin is pulled down, signaling the fault status to the external circuitry. The microcontroller can also force the nFAULT pin low by setting the FORCE_FAULT bit to 1. This allows the microcontroller to actively monitor the fault feedback loop by simulating a fault condition and observing the corresponding response through the nFAULT pin.

Open-Load Diagnostics

During the off time of each channel, the TPM8860 has the capability to detect open loads. This is done by applying a small current of 30 μA to the OUTx pin and comparing the voltage at OUTx with an internal threshold called Vth_open. If the output is open (no load connected), the small current will pull down the voltage at OUTx to ground, triggering the open comparator.

It's important to note that an open load condition will not prevent the channel from turning on.

If any of the channels trigger an open load fault, the nFAULT pin will be pulled low, indicating the occurrence of a fault.

Short & Over Current Protection

Each channel of the device is equipped with a short-circuit protection circuit to limit the output current and shut down the channel if an overcurrent fault is detected. If an output channel is shorted to the supply, the output current will be internally clamped to protect the channel.

During the on-time of the channel, it continuously monitors the output current. If the current exceeds a predefined threshold for a duration longer than the deglitch timer, an overcurrent fault is triggered.

By default, the overcurrent protection is set to latched off.

In the event of an OCP fault on any channel, the nFAULT pin will be pulled low to indicate the fault condition.

By default, the overcurrent protection is latched off, meaning it remains active until manually cleared. To clear the overcurrent fault, user can use commands like CLR_FAULT, CLR_OCP, or set the MASK_OCPx bit.

To enhance system reliability, the TPM8866 offers an autoretry feature. When CONF_AUTORECOVERY is set to 1, a channel that experiences an overcurrent fault will automatically retry after a 100-ms delay. During the retry time, the overcurrent flags (FLAG_OCPx and FLAG_FAULT) remain set. The retry timer is synchronized between channels, eliminating the need for separate timers for each channel.

Each channel has an independent overcurrent protection fault mask bit, MASK_OCPx. If MASK_OCPx is set to 1, the channel will mask the overcurrent protection, allowing the channel to remain on even if an overcurrent condition occurs. If the current exceeds the short protection threshold, the current will be clamped at the short protection threshold.

The extended OCP deglitch timer, enabled by setting CONF_EXTOCP to 1, is specifically designed to support capacitive loads in situations where an overcurrent protection (OCP) event may occur. Capacitive loads can cause a momentary surge in current when initially connected, which might trigger the OCP fault detection mechanism.

By increasing the deglitch timer from the standard duration of 3.5 μs to 10 μs in the extended mode, the device allows for a longer duration to evaluate the current waveform before considering it as an overcurrent condition. This extended timer helps prevent false triggering of the OCP fault due to capacitive loads and allows the device to operate effectively with such loads.

In the event of an OCP fault in any of the channels, the FLAG_OCP and FLAG_FAULT will be set, and the nFAULT pin will be pulled low to indicate the fault condition.

Thermal Protection

The TPM8860 device includes thermal protection to prevent damage from excessive temperatures. When the junction temperature surpasses over temperature threshold, the thermal shutdown (FLAG_TSD) feature is triggered, turning off all output channels. Once the temperature drops below the threshold with hystersis, normal operation resumes. Thermal protection ensures safe operation by monitoring and reacting to high temperatures.

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.

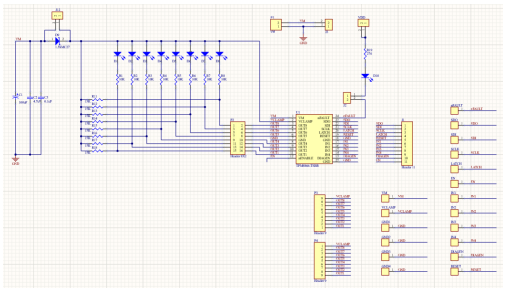
Application Information

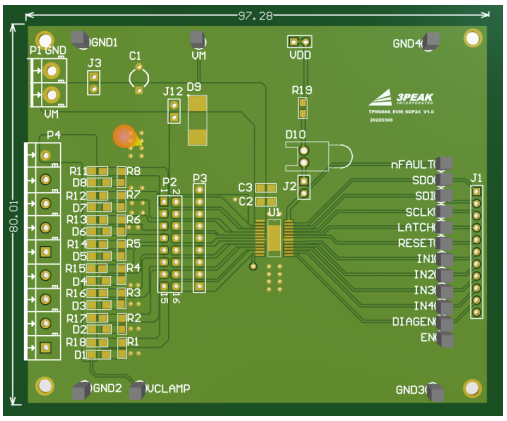
PLC Digital Output

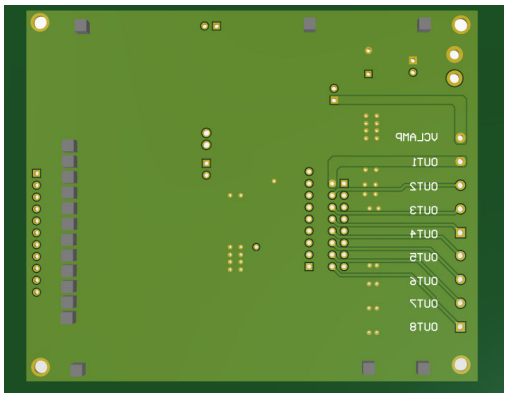
Serial Communication

The TPM8866 is designed for digital output control in industrial PLC (Programmable Logic Controller) applications. It features SPI communication interface and integration with digital isolators to provide reliable output control.

In industrial PLC applications, digital outputs are commonly used to control various external devices such as motors, valves, lights, etc. The TPM8866 offers an 8-channel low-side driver array, with each channel capable of independent switching control. Through the SPI interface, the main controller can send commands to TPM8866 to control the on/off state of each channel.







Commonly used serial commands are as follows:

- OUT1 open - Register: 08, Hex Code: 8012, Binary Code: 1000,0000,0001,0010
  This command opens channel OUT1.
- OUT1-8 open - Register: 08, Hex Code: 8FF5, Binary Code: 1000,1111,1111,1001
  This command opens channels OUT1 to OUT8 simultaneously.
- OUT1-8 close - Register: 08, Hex Code: 8001, Binary Code: 1000,0000,0000,0001

This command closes channels OUT1 to OUT8 simultaneously.

- Read DOUT - Register: 00, Hex Code: 0000, Binary Code: 0000,0000,0000,0000
  This command reads the status of the DOUT register.
- Read Open fault register - Register: 05, Hex Code: 5006, Binary Code: 0101,0000,0000,0110
  This command reads the open fault register to check for any open circuit faults.
- Read OCP fault register - Register: 06, Hex Code: 6004, Binary Code: 0110,0000,0000,0100
  This command reads the over-current protection (OCP) fault register to check for any over-current faults.
- Wmask OCP fault - Register: 09, Hex Code: 9FFA, Binary Code: 1001,1111,1111,1010
  This command writes a mask to the OCP fault register to enable/disable OCP fault detection for specific channels.
- Rmask OCP fault - Register: 01, Hex Code: 100F, Binary Code: 0001,0000,0000,1111
  This command reads the OCP fault mask register to check the OCP fault detection mask for each channel.
- Wmask Open fault - Register: 0A, Hex Code: AFF8, Binary Code: 1010,1111,1111,1000
  This command writes a mask to the open fault register to enable/disable open circuit fault detection for specific channels.
- Rmask Open fault - Register: 02, Hex Code: 200D, Binary Code: 0010,0000,0000,1101
  This command reads the open fault mask register to check the open circuit fault detection mask for each channel.
- CONF OCP Autoretry - Register: 0B, Hex Code: B106, Binary Code: 1011,0001,0000,0110
  This command configures the automatic retry feature for over-current protection (OCP). Setting the bit enables auto retry after 100ms.
- CONF PWMMAP - Register: 0B, Hex Code: B209, Binary Code: 1011,0010,0000,1001
  This command configures the PWM mapping selection for the channels. The specific channel-to-PWM mapping is determined by the bits in this register.
- Read CONF - Register: 03, Hex Code: 3002, Binary Code: 0011,0000,0000,0010
  This command reads the CONF register to check the configuration settings.
- Read fault flag - Register: 04, Hex Code: 4009, Binary Code: 0100,0000,0000,1001
  This command reads the fault flag register to check for any fault flags.
- CLR register - Register: 0C, Hex Code

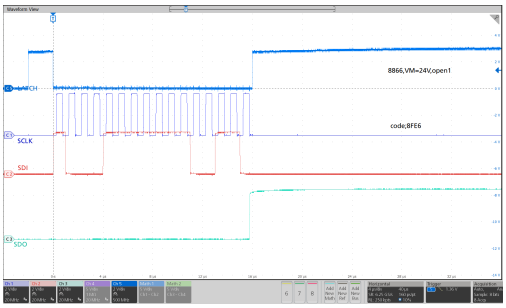


Figure 16. Serial Communication Write

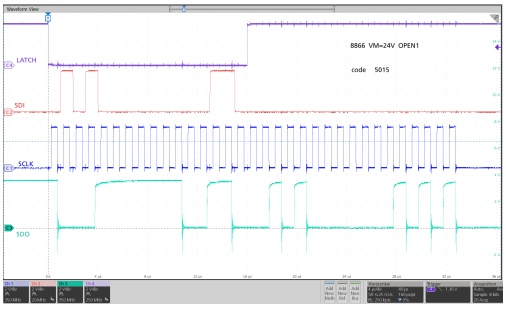


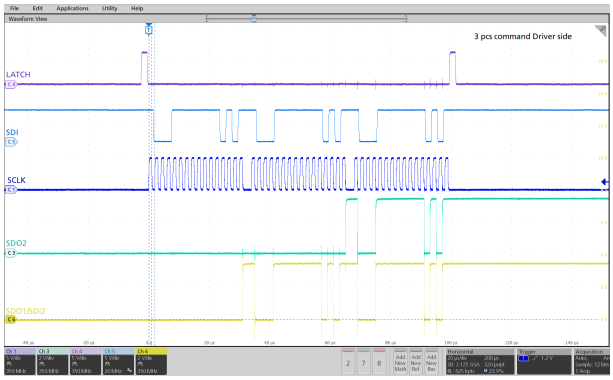
Figure 17. Serial Communication Read

Multiple Device in Daisy Chain with Digital Isolator

To ensure reliability and safety, digital isolators are incorporated into the system. These isolators provide signal isolation between the main controller and the TPM8866, protecting the signal transmission from noise, electromagnetic interference, and other detrimental factors. This isolation design enhances system stability and reliability, while safeguarding the main controller from external disturbances.

By combining SPI communication with digital isolators, the TPM8866 delivers a robust solution for digital output control in industrial PLC applications. It enables precise output control and shields the main controller from external interference. Whether in factory automation, machinery control, or other industrial domains, the TPM8866 provides reliable digital output control capabilities for industrial PLCs.

Below shows an example of 3pcs of devices in daisychain communication:



Typical Application

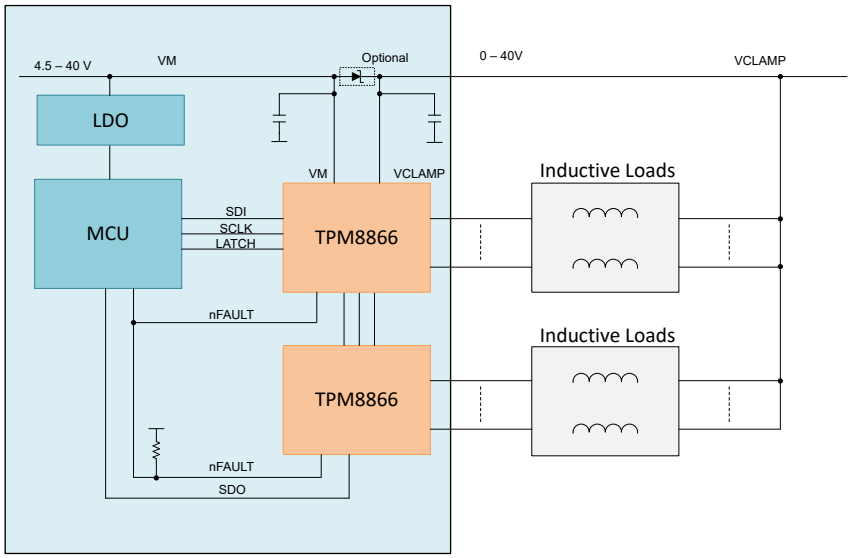


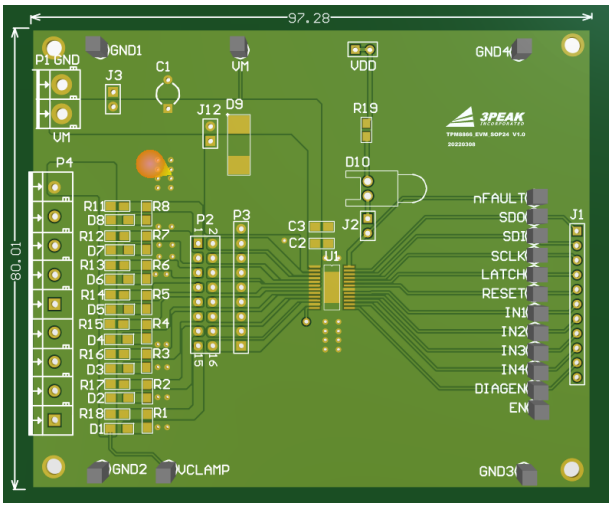
Figure 18. Typical Application Circuit

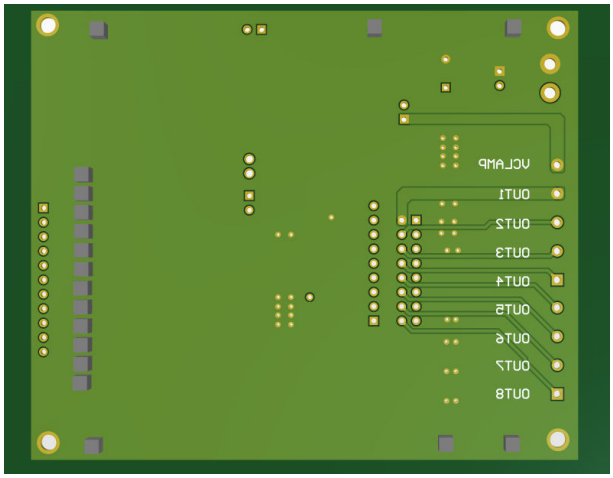
Layout

Layout Guideline

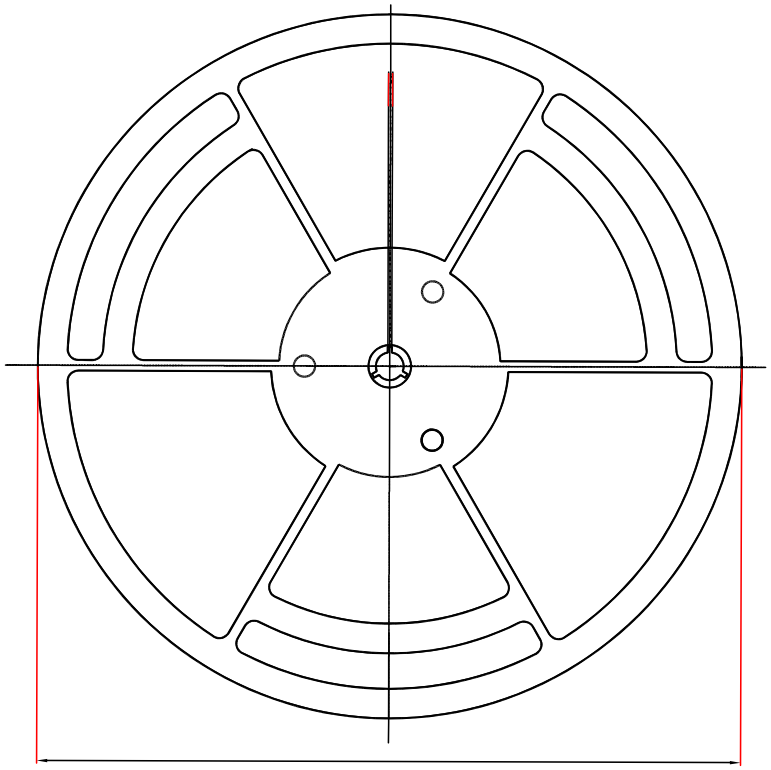
- Both input capacitors and output capacitors must be placed to the device pins as close as possible.
- It is recommended to bypass the input pin to ground with a 0.1-μF bypass capacitor.
- It is recommended to use wide and thick copper to minimize I×R drop and heat dissipation.
- Exposed pad must be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

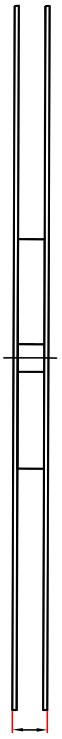
Layout Example

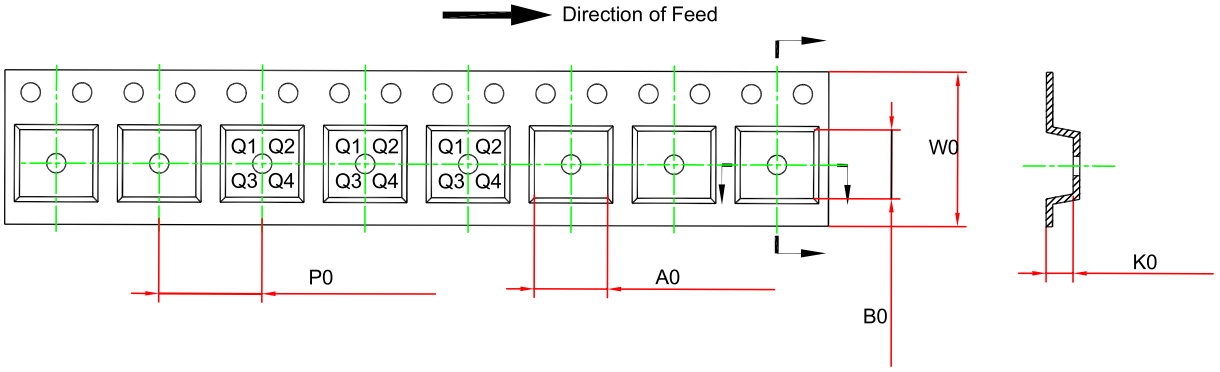




Tape and Reel Information





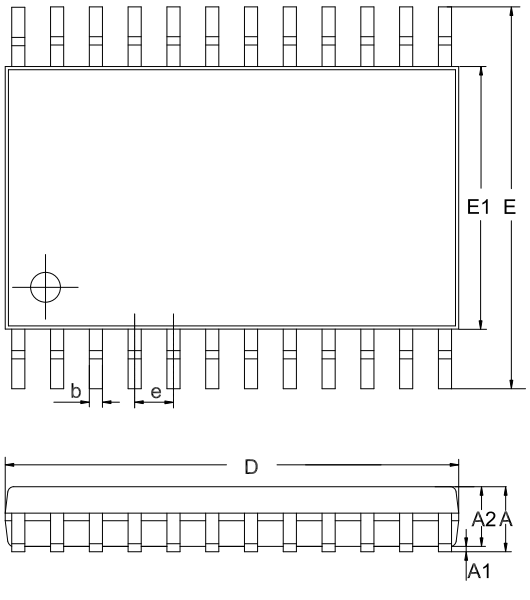


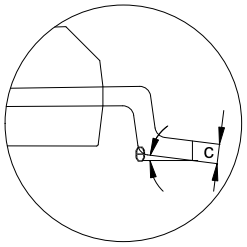
Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TPM8866-TSDR	ETSSOP24	330	17.4	6.9	8.3	1.6	8.0	16.0	Q1
TPM8866-TS5R	TSSOP24	330	17.4	6.8	8.3	1.6	8.0	16.0	Q1

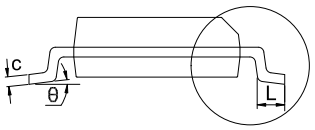
Package Outline Dimensions

TSSOP24

Package Outline Dimensions TS5(TSSOP-24-A)







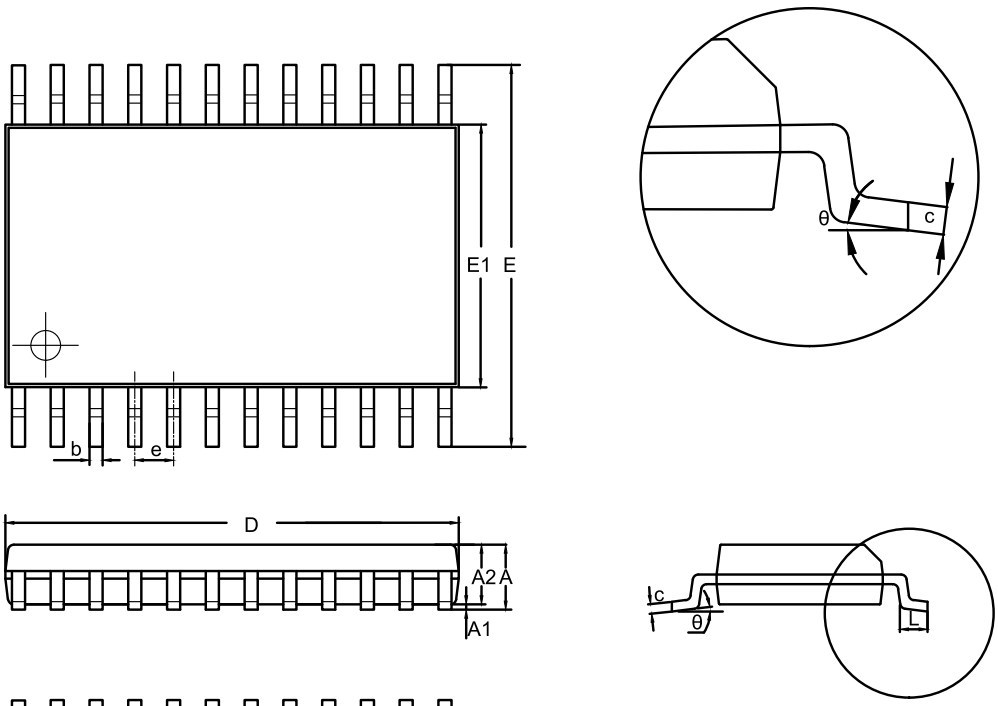
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.900	1.200	0.035	0.047
A1	0.050	0.150	0.002	0.006
A2	0.800	1.050	0.031	0.041
b	0.190	0.300	0.007	0.012
c	0.090	0.200	0.004	0.008
D	7.700	7.900	0.303	0.311
E	6.200	6.600	0.244	0.260
E1	4.300	4.500	0.169	0.177
e	0.650 BSC		0.026 BSC	
L	0.450	0.750	0.018	0.030
θ	0	8°	0	8°

NOTES

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

ETSSOP24

Package Outline Dimensions TSD(ETSSOP-24-A)



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.900	1.200	0.035	0.047
A1	0.050	0.150	0.002	0.006
A2	0.800	1.050	0.031	0.041
b	0.190	0.300	0.007	0.012
c	0.090	0.200	0.004	0.008
D	7.700	7.900	0.303	0.311
E	6.200	6.600	0.244	0.260
E1	4.300	4.500	0.169	0.177
D2	3.950	4.150	0.156	0.163
E2	2.750	2.950	0.108	0.116
e	0.650 BSC		0.026 BSC	
L	0.450	0.750	0.018	0.030
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
TPM8866-TSDR	−40 to 125°C	ETSSOP24	M8866	3	Tape and Reel, 4000	Green
TPM8866-TS6R	−40 to 125°C	TSSOP24	M8866	3	Tape and Reel, 4000	Green

(1) Future product, contact 3PEAK factory for more information and sample.3PEAK defines "Green" to mean RoHS compatible and free of halogen substances.

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

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