WP7470H

Reverse Voltage Protection Ideal Diode Controller

1. General Description

The WP7470H is an automotive-compliant ideal diode controller which operates in conjunction with an external N-channel MOSFET as an ideal diode rectifier for low loss reverse polarity protection with a 20mV forward voltage drop.

The WP7470H supports wide input voltage range from 3.2V to 85V and can control many DC rail voltage such as 12V, 24V or higher automotive battery systems. The WP7470H withstands reverse voltage down to -85V and protects loads.

The WP7470H has a built-in charge pump that controls the GATE of the MOSFET, regulating the forward voltage drop of the MOSFET to about 20mV. Its internal gate driver quickly shuts down the MOSFET in the event of reverse current and ensures that no DC reverse current flows. Fast reverse current blocking response of less than 0.75μs makes it suitable for systems with output voltage holdup requirements during ISO7637 pulse testing as well as power fail and input micro-short conditions.

The WP7470H's high voltage rating simplifies system design for automotive ISO7637 protection. When the enable pin is low, the controller is in a shutdown state with a typical current of about 1μA.

The WP7470H is available in SOT23-6 green package.

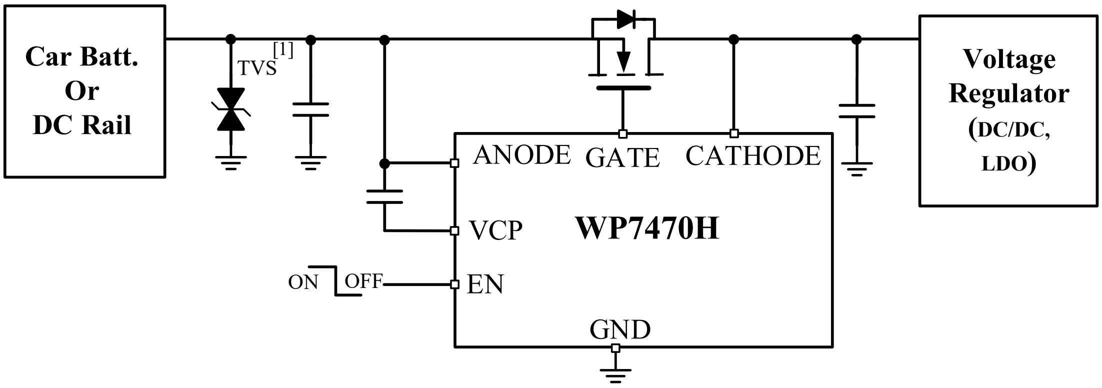
2. Features

- Input Voltage Range from 3.2V to 85V (3.9V Start-up)
- -85V Reverse Battery Voltage
- Charge Pump for External N-Channel Power MOSFET
- Low Shutdown Current of 1μA when Disabled
- Low Quiescent Current of 80μA when Enabled
- Fast Reverse Current Block Response Time of less than 0.75μs
- Active High Enable Operation
- ESD Protection 2kV of HBM and 2kV of CDM
- Compliant with Automotive Transient Requirements with Appropriate TVS:
  - ISO7637-2 Transient Pulses
  - ISO16750-2 Load Dump Suppression

3. Applications

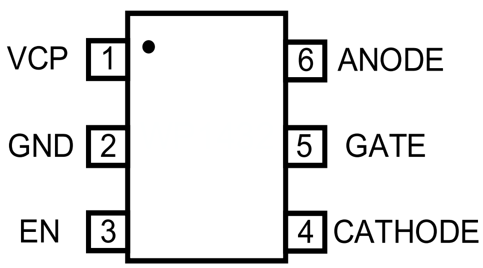
- Automotive infotainment systems - clusters
- Automotive ADAS systems - cameras
- Automotive lighting systems
- Automotive power trains

4. Typical Application



Note1: Appropriate TVS is required to meet ISO7632-2 and ISO16750-2 requirements for automotive applications.

5. Pin Configuration



SOT23-6

6. Pin Description

PIN NUMBER	PIN NAME	I/O	PIN FUNCTION
1	VCP	O	Charge pump voltage output pin. Connects to external capacitor.
2	GND	-	Ground pin.
3	EN	I	Enable pin. Active high.
4	CATHODE	I	CATHODE pin. Connects to the drain of external MOSFET.
5	GATE	O	Gate driver out pin. Connects to gate of external MOSFET.
6	ANODE	I	Input supply and ANODE pin. Connects to the source of external MOSFET.

7. Absolute Maximum Ratings

Operating free-air temperature range (unless otherwise noted)[2]

SYMBOL	PARAMETER	RATINGS	UNIT
ANODE to GND	Input Voltage at ANODE	-85 to +85	V
EN to GND	ANODE ＞ 0V	-0.3 to +85	V
	ANODE ≤ 0V	ANODE to (85 + ANODE)	V
GATE to ANODE	Gate to ANODE Voltage	-0.3 to +15	V
VCP to ANODE	Charge Pump Voltage	-0.3 to +15	V
CATHODE to ANODE	CATHODE to ANODE Voltage	-5 to 75	V
$T_{J(max)}$	Maximum Junction Temperature	-40 to +150	℃
T_{STG}	Storage Temperature	-40 to +150	℃
$R_{\theta JA}$	Junction-to-Ambient Thermal Resistance[3]	100	℃/W
$R_{\theta JC(top)}$	Junction-to-Case (Top) Thermal Resistance[3]	46	℃/W
ESD(HBM)	Human Body ESD Protection	±2	kV
ESD(CDM)	Charged Device Model ESD Protection	±1.5	kV

NOTE2: Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under Recommended Operating Conditions. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTE3: RθJA and RθJC are measured at TA = +25°C on a high effective thermal conductivity four-layer test board per JEDEC 51-7.

8. Recommended Operating Conditions

SYMBOL	PARAMETER	MIN	MAX	UNIT
ANODE to GND	Input Voltage at ANODE	-75	+75	V
CATHODE to GND	Input Voltage at CATHODE	-	+75	V
EN to GND	Enable Pin	-75	+75	V
CATHODE to ANODE	CATHODE to ANODE Voltage	-	+ 75	V
Anode Cap	Input Capacitor [4]	22	-	nF
Cathode Cap	Output Capacitor [4]	1	-	uF
VCP to Anode Cap	Charge Pump Capacitor [4]	0.1	-	uF
External MOSFET V_{GS} Max	Gate to Anode [4]	15	-	V
T_A	Operating Ambient Temperature	-40	+125	℃

NOTE4: Refer to the typical application circuit.

9. Electrical Characteristics

(T_J = -40° C to +125℃, V_{ANODE} = 12V, C_{VCP} = 0.1 μ F, V_{EN} = 5.0V, typical values are at T_J = +25° C, unless otherwise specified.)

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
ANODE Supply						
V_{ANODE}	Operating Input Voltage	-	4	-	75	V
V_{UVLO_ANODE}	ANODE UVLO Rising Threshold	V_{ANODE} Rising, V_{EN}=5V	-	-	3.9	V
	ANODE UVLO Falling Threshold	V_{ANODE} Falling, V_{EN}=5V	2.2	2.6	3.1	V
I_{ANODE_OFF}	Shutdown Supply Current	V_{EN}=0V	-	1	1.9	μA
I_{ANODE_Q}	Operating Quiescent Current	V_{EN}=5V	-	80	205	μA
EN Input						
V_{IL}	Enable Input Low Threshold	V_{EN} Falling, V_{ANODE}=12V	0.6	1.05	1.45	V
V_{IH}	Enable Input High Threshold	V_{EN} Rising, V_{ANODE}=12V	1.3	2.3	2.9	V
I_{EN}	Enable Sink Current	V_{ANODE}=12V, V_{EN}=12V	-	3	5	μA
ANODE and CATHODE by Operation Modes						
V_{ACTIVE_REG}	Regulated Forward Threshold	-	11	20	29	mV
V_{ACTIVE_FULL}	Threshold for Full Conduction Mode	-	34	50	57	mV
V_{ACTIVE_REV}	Threshold for Reverse Current Blocking	-	-17	-10	-2	mV
Gm	Regulation Error AMP Transconductance [5]	-	1000	1650	2200	μA /V

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Gate Drive						
I_{GATE}	Peak Source Current	$V_{ANODE} – V_{CATHODE}$ = 100mV $V_{GATE} – V_{ANODE}$ = 5V	3	11	-	mA
	Peak Sink Current	$V_{ANODE} – V_{CATHODE}$ = -20mV $V_{GATE} – V_{ANODE}$ = 5V		1850		mA
	Regulation Max Sink Current	$V_{ANODE} – V_{CATHODE}$ = 0V $V_{GATE} – V_{ANODE}$ = 5V		18		μA
R_{DIS}	Discharge Switch Resistance	$V_{ANODE} – V_{CATHODE}$ = -20mV $V_{GATE} – V_{ANODE}$ = 5V	0.4		4	Ω
Charge Pump						
I_{VCP}	Charge Pump Source Current (Charge Pump On)	$V_{VCP} – V_{ANODE}$ = 7V	160	220	600	μA
	Charge Pump Sink Current (Charge Pump Off)	$V_{VCP} – V_{ANODE}$ = 14V	-	6	10	μA
V_{VCP}-V_{ANODE}	Charge Pump Voltage at V_{ANODE} = 3.2V	$I_{VCP} \le 30μA$	8	-	-	V
	Charge Pump Turn On Voltage	V_{ANODE}=12V,V_{EN}=5V	11	12	13	V
	Charge Pump Turn Off Voltage	V_{ANODE}=12V,V_{EN}=5V	12	13	14	V
V_{VCP_UVLO}	$V_{VCP} – V_{ANODE}$ UV Release at Rising Edge	$V_{ANODE} – V_{CATHODE}$ = 100mV	5.8	6.6	7.7	V
	$V_{VCP} – V_{ANODE}$ UV Threshold at Falling Edge	$V_{ANODE} – V_{CATHODE}$ = 100mV	4.6	5.4	6	V
CATHODE						
$I_{CATHODE}$	CATHODE Sink Current	V_{ANODE} = 12V $V_{ANODE} – V_{CATHODE}$ = -100mV	-	1.4	2	μA
		$V_{ANODE} – V_{CATHODE}$ = 100mV	-	1.0	2.2	μA
		V_{ANODE} = -12V, $V_{CATHODE}$ = 12V	-	1.25	4.7	μA

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Switching Characteristics						
t_{EN_DELAY}	Delay from Enable Switching High to Gate Turn On	$V_{VCP} > V_{VCP\_UVLO}$	-	70	-	µs
t_{REV_GATE}	Gate Turn Off Time when Reverse Voltage is Detected[6]	$V_{ANODE} – V_{CATHODE}$ = 100mV to -100mV	-	0.45	0.75	µs
t_{FWD_GATE}	Gate Turn On Time when Forward Conducting Voltage Detected [6]	$V_{ANODE} – V_{CATHODE}$ = -100mV to 700mV	-	2.2	3.5	µs

NOTE 5: Parameter guaranteed by design and characterization.

NOTE 6: Parameter guaranteed by bench characterization.

10. Typical Performance Characteristics

(V_{ANODE} = 12V, V_{EN} = High, C_{VCP}=0.1µF, T_A=25℃, unless otherwise noted)

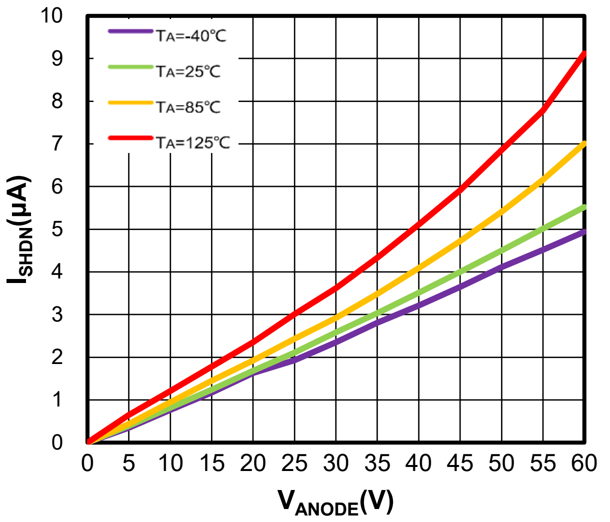


Figure 1. Shutdown Current vs. Input voltage

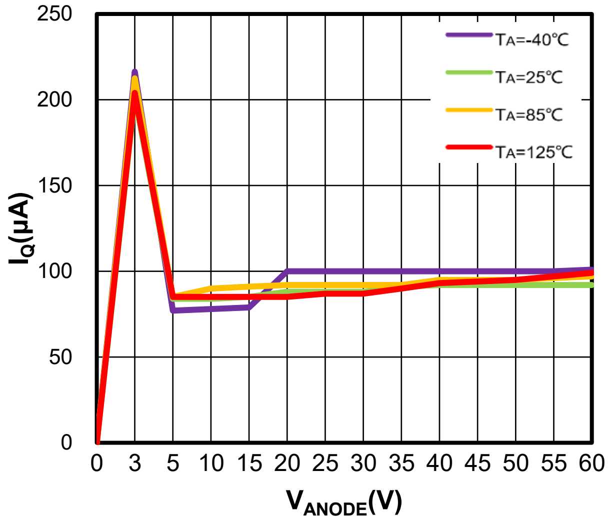


Figure 2. Quiescent Current vs. Input voltage

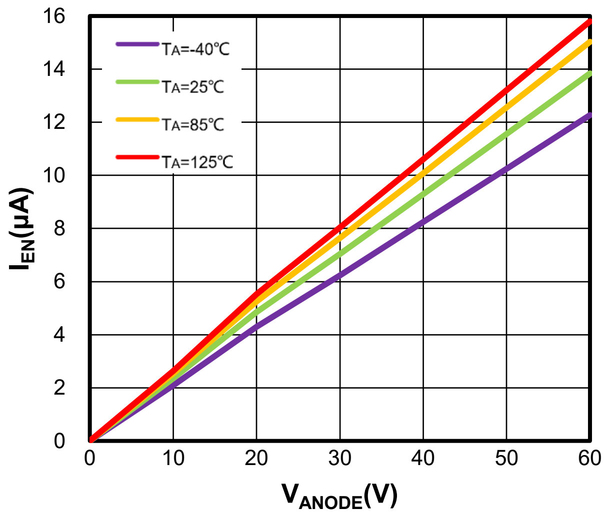


Figure 3. Enable Sink Current vs. Input voltage

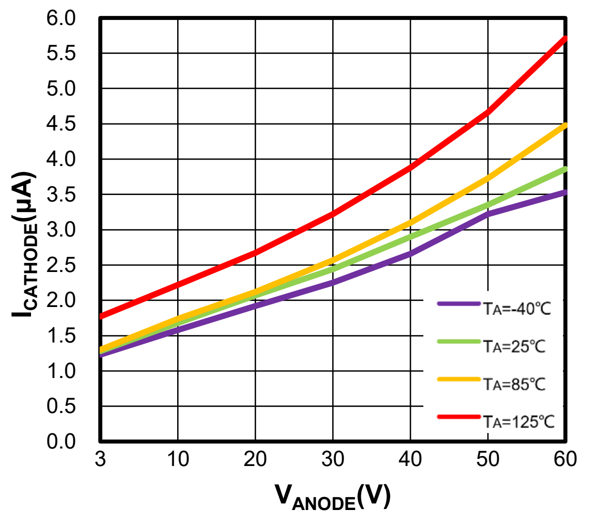


Figure 4. CATHODE Sink Current vs. Input voltage

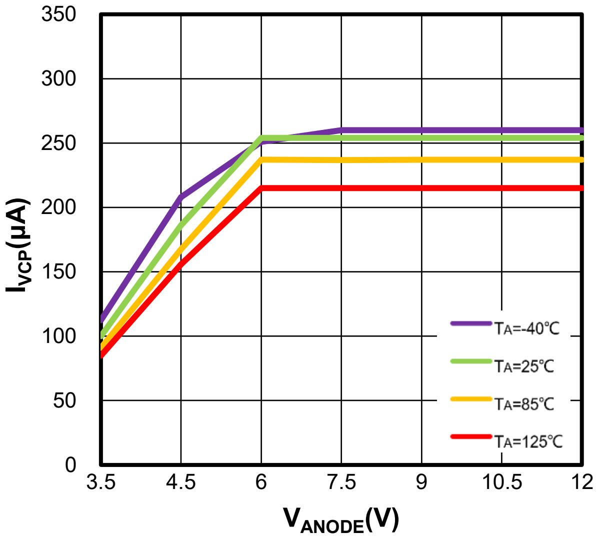


Figure 5. Charge pump Current vs. Input voltage at VVCP=6V

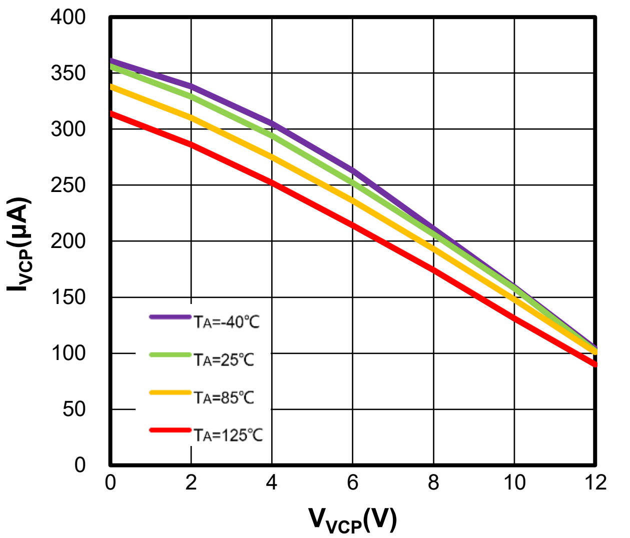


Figure 6. Charge pump V-I vs. Input voltage ≥12V

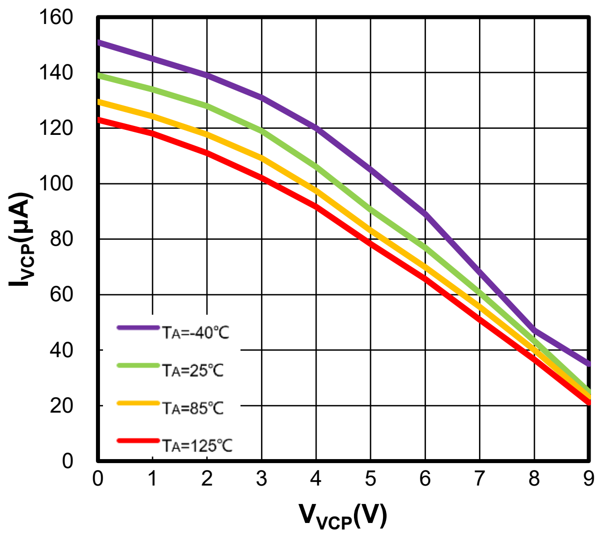


Figure 7. Charge pump V-I vs. Input voltage =3.2V

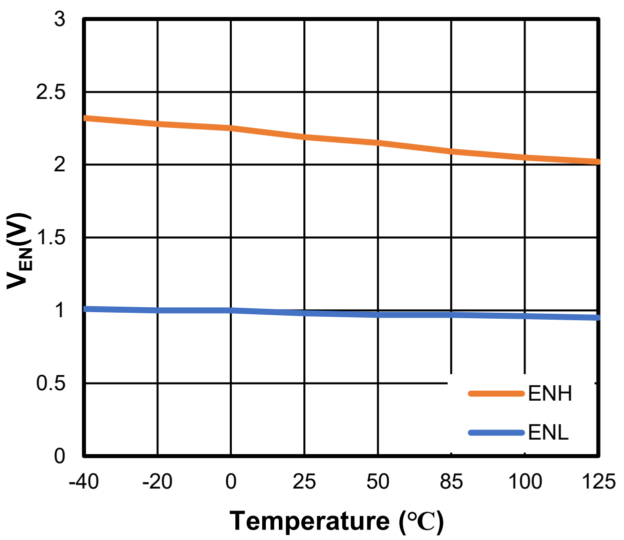


Figure 8. EN Threshold vs. Temperature

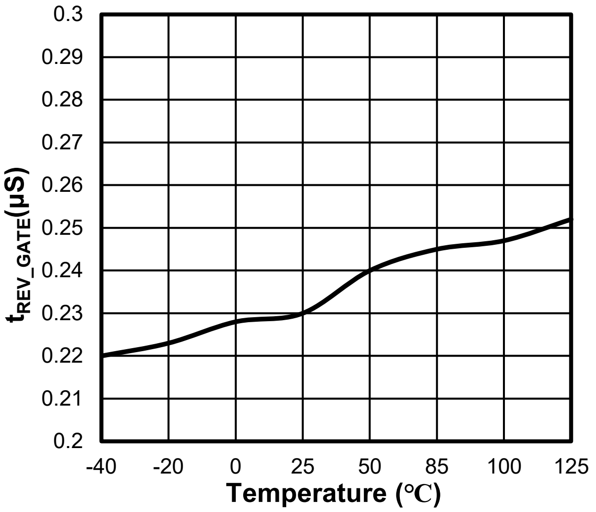


Figure 9. Reverse Current Blocking Delay vs. Temperature

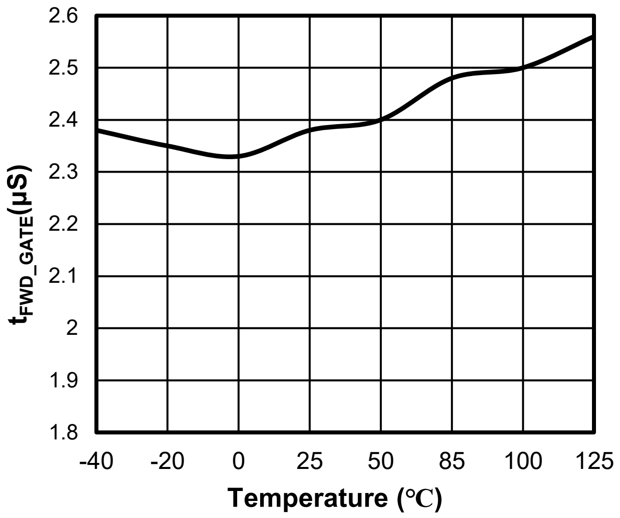


Figure 10. Forward Recovery Delay vs. Temperature

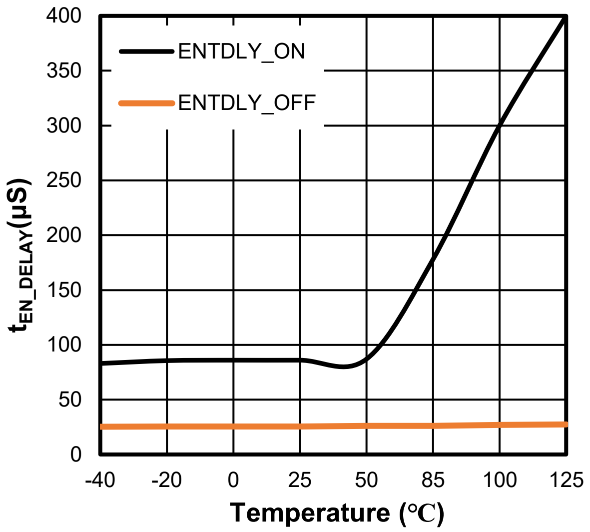


Figure 11. Enable to Gate Delay vs. Temperature

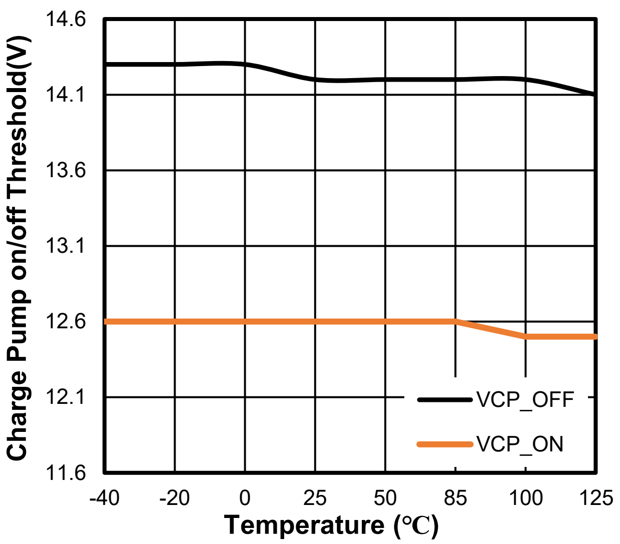


Figure 12. Enable to Gate Delay vs. Temperature

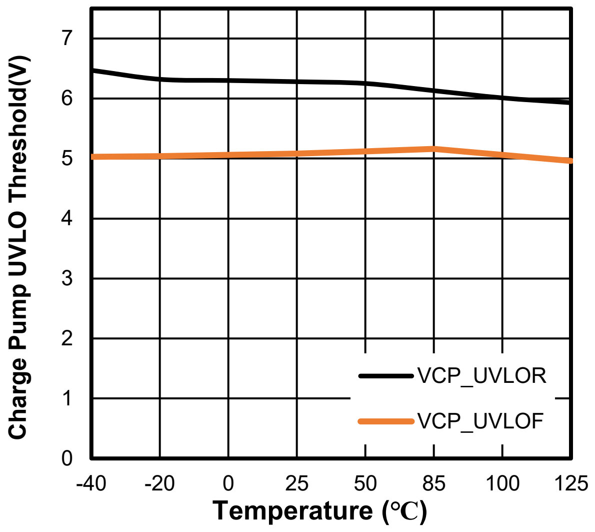


Figure 13. Charge Pump UVLO Threshold vs. Temperature

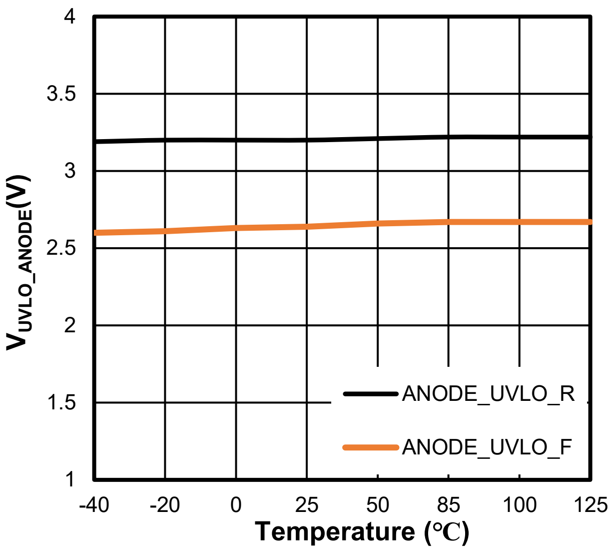


Figure 14. Input Undervoltage Lockout vs. Temperature

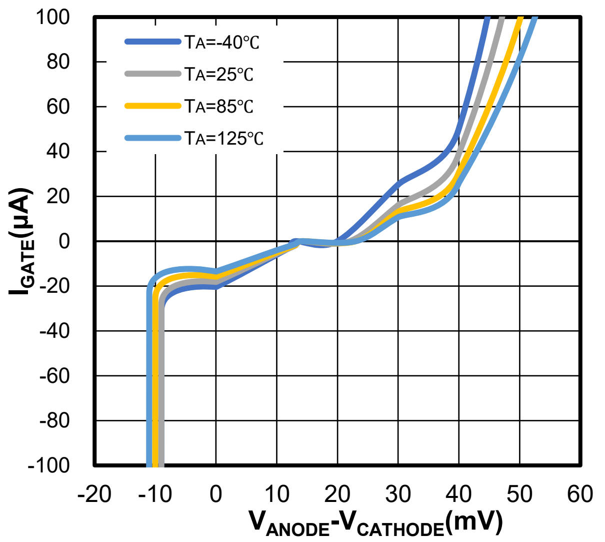
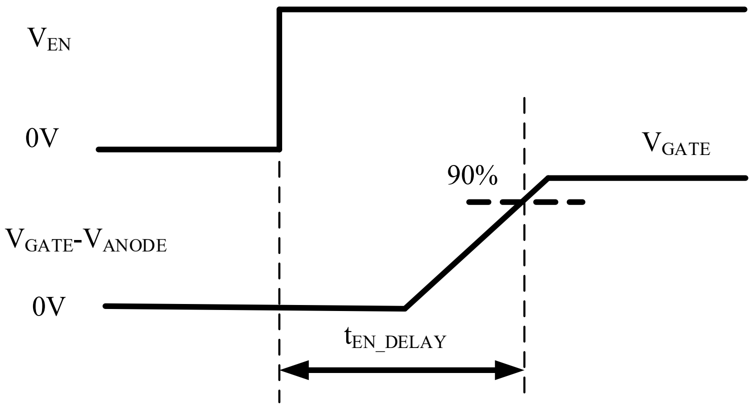
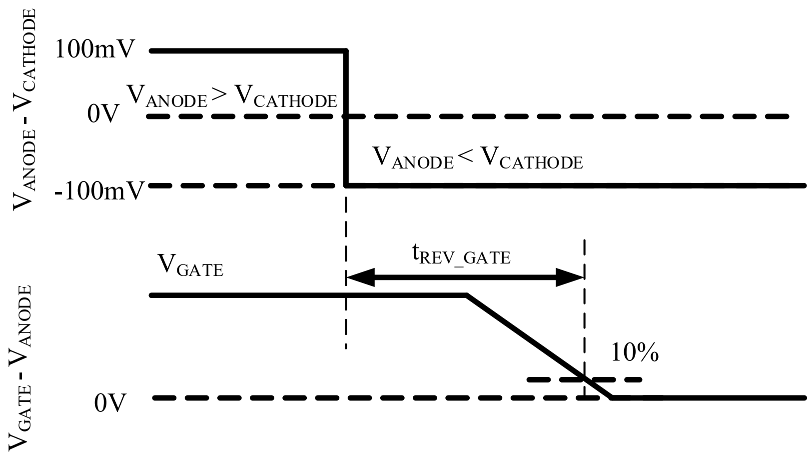
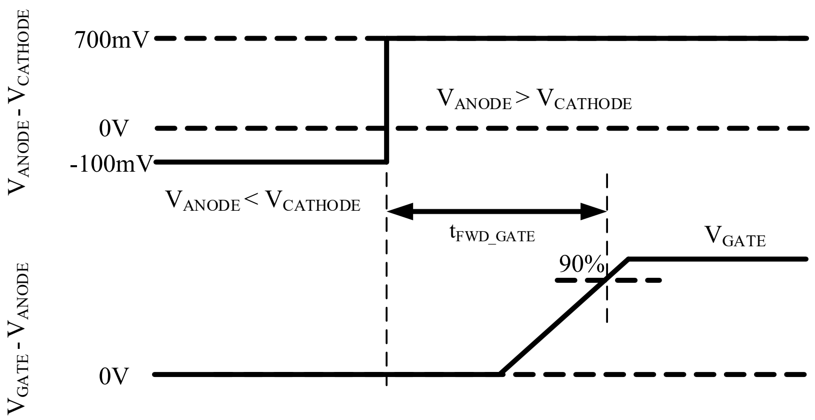


Figure 15. Gate Current vs. IN-OUT Voltage

11. Switching Waveforms





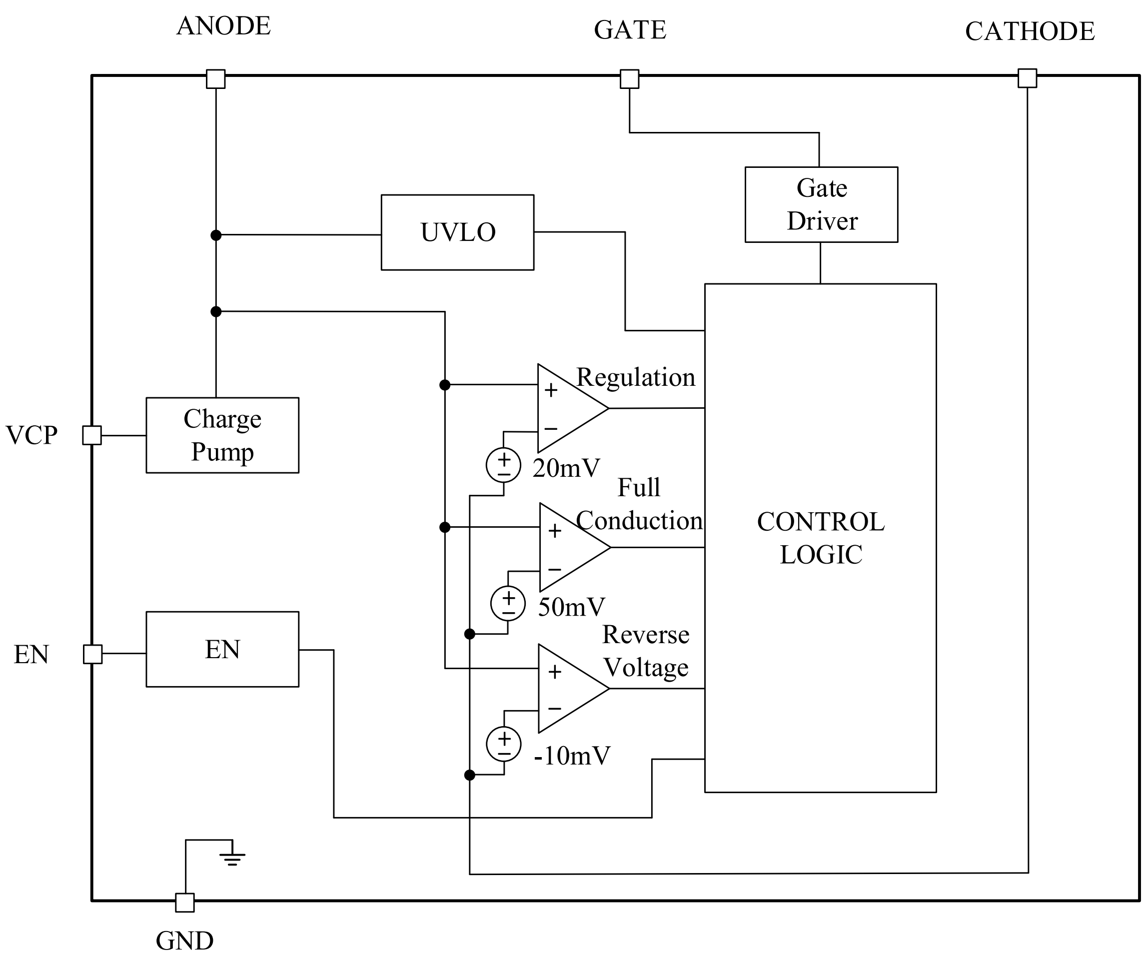


12. Function Description

12.1 Overview

The WP7470H is a ±85V reverse protection ideal diode controller that enables efficient and fast reverse polarity protection circuits and can also be used in ORing configurations. When used with a suitable external N-channel MOSFET, it provides a lower loss alternative to other reverse polarity solutions such as P-channel MOSFETs or Schottky diodes. An internal charge pump is used to drive the external N-channel MOSFET to a maximum gate drive voltage of about 15V. The voltage drop across the MOSFET is continuously monitored between the ANODE and CATHODE pins, and the GATE to ANODE voltage is adjusted as needed to regulate the forward voltage drop at 20mV. When reverse current is detected from ANODE to CATHODE, the MOSFET will shut down within a fast reverse current response time of 0.75μs by connecting the GATE internally to ANODE to avoid DC reverse current flow. When the enable pin EN is low, the WP7470H enters shutdown mode, which shuts down the external N-channel MOSFET and minimizes the standby current of the WP7470H.

12.2 Block Diagram



12.3 Feature Description

12.3.1 Input Voltage

The ANODE pin is used to power the internal circuitry of the WP7470H and typically draws 80μA when enabled and 1μA when disabled. If the ANODE pin voltage is greater than the UVLO rising threshold, then WP7470H operates in either shutdown mode or conduction mode in depending on the EN pin voltage. The voltage from ANODE to GND can withstand 85V to -85V, enabling the WP7470H to withstand negative transient voltages.

12.3.2 Charge Pump

The charge pump provides the voltage needed to drive the external N-channel MOSFET. An external charge pump capacitor between the VCP and ANODE pins provides energy to turn on the external MOSFET. In order for the charge pump to supply current to the external capacitor, the EN pin voltage must be above the specified input high threshold V_{IH}. When enabled, the charge current of the charge pump is typically 220μA. If the EN pin is pulled low, the charge pump remains disabled. Before enabling the internal gate driver, the voltage from VCP to ANODE must be higher than the V_{VCP_UVLO} (typically 6.6V) in order to ensure that the external MOSFET drive voltage is higher than its specified threshold voltage. Initial gate driver enable delay can be calculated with following formula

$$T_{DRV\_EN} = 70\mu s + C_{VCP} \times \frac{V_{VCP\_UVLO}}{220\mu A}$$

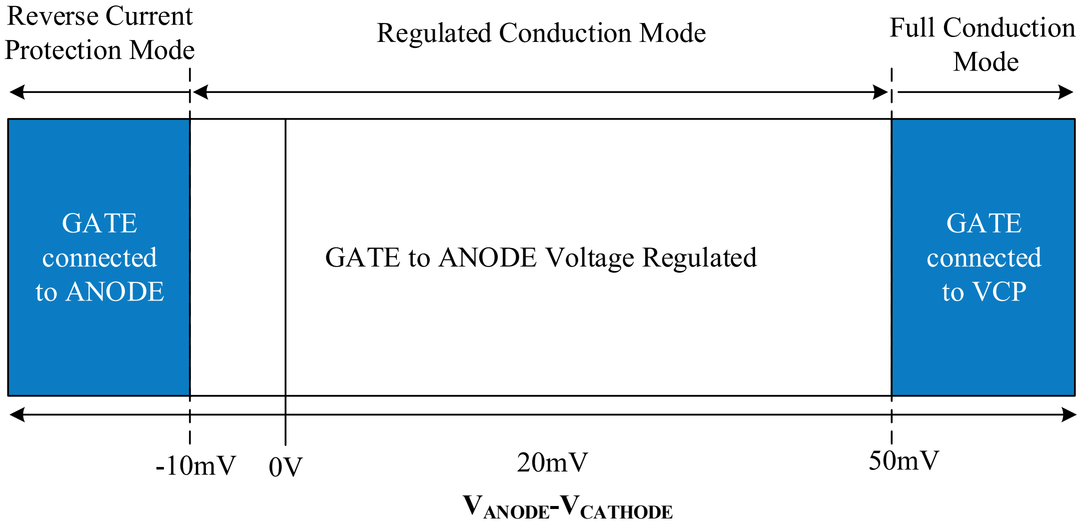
Where,

C_{VCP} is the charge pump capacitance connected across ANODE and VCP pins
V_{VCP_UVLO} = 6.6V (typical)

The charge pump remains enabled until the VCP to ANODE voltage reaches 13V, at which point the charge pump is disabled to reduce current consumption on the ANODE pin. The charge pump remains disabled until the VCP to ANODE voltage falls below 12V, at which point the charge pump is enabled. The voltage between VCP and ANODE continues to charge and discharge between 12V and 13V. The operating quiescent current of the WP7470H can be reduced by enabling and disabling the charge pump. When the charge pump is disabled, it has a typical quiescent current of 6μA.

12.3.3 Gate Driver

The gate driver controls the external N-channel MOSFET by driving the GATE to ANODE voltage to the corresponding mode of operation. There are three defined modes of operation that the gate driver operates under forward regulation, full conduction mode and reverse current protection, according to the ANODE to CATHODE voltage. Its mode varies according to the ANODE to CATHODE voltage of the WP7470H. The threshold between forward regulation mode and conduction mode is when the ANODE to CATHODE voltage is 50mV. The threshold between forward regulation mode and reverse current protection mode is when the ANODE to CATHODE voltage is -10mV.



12.3.4 Enable

The EN pin allows for the gate driver to be either enabled or disabled by an external signal. If the EN pin voltage is greater than the rising threshold, the gate driver and charge pump are activated. If the EN pin voltage is lower than the input low threshold, the charge pump and gate driver are disabled, placing the WP7470H in shutdown mode. The EN pin can withstand a voltage as high as 85V and as low as -85V. This allows for the EN pin to be connected directly to the ANODE pin if enable functionality is not needed. In conditions where EN is left floating, the internal sink current of 3μA pulls EN pin low and disables the device.

12.3.5 Operations

WP7470H has shutdown, regulated conduction, full conduction and reverse current protection mode in operation. Details are as follows.

V_{ANODE}	EN	V_{CP}-V_{ANODE}	V_{ANODE}-$V_{CATHODE}$	VCP	V_{GATE}	WP7470H Mode
-75V to 0V	Don't Care	Don't Care	Reverse Voltage	Off	NA	OFF(No Power)
0V to UVLO	Don't Care	Don't Care	Forward Voltage		NA	Shutdown
UVLO to 75V	< V_{IL}	Don't Care	Forward Voltage		ANODE	Shutdown
	> V_{IH}	< V_{VCP_UVLO}	Forward Voltage	On	ANODE	VCP Charging
		> V_{VCP_UVLO}	< -10mV		ANODE	Reverse Current Protection
			-10mV to 50mV		Regulated	Regulated Conduction
			> 50mV		VCP	Full Conduction

12.3.6 Shutdown Mode

When the EN pin voltage falls below the specified input low threshold V_{IL}, both the gate driver and the charge pump are disabled The WP7470H will enter shutdown mode. In shutdown mode, the forward current through the external MOSFET can continue to be conducted by the body diode of the MOSFET. The WP7470H enters a low IQ operation with only 1μA of current at the ANODE pin.

12.3.7 Regulated Conduction Mode

In regulated conduction mode, the WP7470H must enable the gate driver and the external MOSFET current from source to drain must be within a certain range, resulting in a voltage drop from ANODE to CATHODE of -10mV to 50mV. During forward regulation mode, the ANODE to CATHODE voltage is regulated to 20mV by adjusting the GATE to ANODE voltage. This regulation enables turning off of the MOSFET at very light loads and ensures there is no DC reverse current flow.

12.3.8 Full Conduction Mode

In full conduction mode, the WP7470H must have the gate driver enabled and the source to drain current of the external MOSFET must be large enough to make the ANODE to CATHODE voltage drop greater than 50mV typical. And the GATE pin is internally connected to the VCP pin so that the GATE to ANODE voltage is approximately the same as the VCP to ANODE voltage. By connecting the VCP to the GATE, the $R_{DS(ON)}$ of the external MOSFET can be minimized, thus reducing the power loss of the external MOSFET when the forward current is high.

12.3.9 Reverse Current Protection Mode

In reverse current protection mode, the WP7470H must have the gate driver enabled and current from the external MOSFET must flow from the drain to the source. When the ANODE to CATHODE voltage is typically below -10mV, the reverse current protection mode is entered and the GATE pin is internally connected to the ANODE pin and discharges the gate capacitance of the MOSFET to turn it off. When the external MOSFET is turned off, its body diode prevents any reverse current from flowing from the drain to the source.

12.3.10 MOSFET Selection

The important MOSFET electrical parameters include the maximum continuous drain current I_D, the maximum drain to source voltage $V_{DS(MAX)}$, the maximum source current through body diode and the drain-to-source on-resistance $R_{DS(ON)}$.

The maximum continuous drain current, I_D, rating must exceed the maximum continuous load current. The maximum drain-to-source voltage, $V_{DS(MAX)}$, must be high enough to withstand the highest differential voltage occurring in the application. This would include any anticipated fault conditions. It is recommended that a MOSFET rated up to 60V be used on the WP7470H since the maximum anode-cathode voltage is 85V. The maximum V_{GS} of WP7470H can drive is 13V, so a MOSFET with 15V minimum V_{GS} should be selected.

If a MOSFET rated at V_{GS} < 15V is selected, a Zener diode can be used to clamp the V_{GS} to a safe level. During startup, an inrush current flows through the body diode, charging the large capacity holding capacitor at the output. The maximum source current through the body diode must be higher than the inrush current that may occur in the application.

To reduce the conduction loss of the MOSFET, it is desirable to keep the $R_{DS(ON)}$ as low as possible, but it is not always advantageous to select a MOSFET based on a low $R_{DS(ON)}$. A higher $R_{DS(ON)}$ will provide more voltage information to the WP7470H's inverse comparator with a lower reverse current. The higher the $R_{DS(ON)}$, the better the reverse current detection. It is recommended to run the MOSFET in regulated conduction mode at rated load conditions and select $R_{DS(ON)}$ so that the forward voltage drop, V_{DS}, is close to the 20mV regulated point and does not exceed 50mV at rated operating current.

As a guideline, it is suggested to choose $(20mV/I_{Load(Nominal)}) \le R_{DS(ON)} \le (50mV/I_{Load(Nominal)})$. MOSFET datasheets usually specify $R_{DS(ON)}$ at V_{GS}=4.5V and V_{GS}=10V. $R_{DS(ON)}$ increases drastically below V_{GS}=4.5V and $R_{DS(ON)}$ is highest when V_{GS} is close to MOSFET V_{TH}. For stable regulation at light load conditions, it is recommended to operate the MOSFET close to V_{GS}=4.5V, that is, much higher than MOSFET gate threshold voltage. It is recommended to choose MOSFET gate threshold voltage V_{TH} of 2V to 2.5V maximum. Choosing a lower V_{TH} MOSFET also reduces the turn on time. Based on the design requirements, preferred MOSFET ratings are:

- $V_{DS(MAX)}$= 60V and $V_{GS(MAX)}$=±20V
- $R_{DS(ON)}$ at 3A nominal current: 6.67mΩ ≤ $R_{DS(ON)}$ ≤ 16.67mΩ.
- MOSFET gate threshold voltage V_{TH}: 2V maximum

WMQ058NV6LG4 MOSFET is selected to meet this 12V reverse battery protection design requirements and it is rated at:

- $V_{DS(MAX)}$= 65V and $V_{GS(MAX)}$=±20V
- $R_{DS(ON)}$ =4.7mΩ typical and 6.2mΩ maximum rated at V_{GS} =4.5V
- MOSFET V_{TH}: 2.3V maximum

DMT6007LFGQ MOSFET is selected to meet this 12V reverse battery protection design requirements and it is rated at:

- $V_{DS(MAX)}$= 60V and $V_{GS(MAX)}$=±20V
- $R_{DS(ON)}$ =6.5mΩ typical and 8.5mΩ maximum rated at V_{GS} =4.5V
- MOSFET V_{TH}: 2V maximum

Thermal resistance of the MOSFET should be considered against the expected maximum power dissipation in the MOSFET to ensure that the junction temperature (T_J) is well controlled.

12.3.11 Charge Pump C_CP and C_{IN}/C_{OUT}

Minimum required capacitance for charge pump VCP and input/output capacitance are:

- C_CP: Minimum 0.1μF is required; recommended value of VCP (μF) ≥ 10 x CISS (MOSFET) (μF)
- C_{IN}: Minimum 22nF of input capacitance
- C_{OUT}: Minimum 1μF of output capacitance.

13. Application and Implementation

13.1 Application Information

13.1.1 TVS Selection for 12V Battery Protection Application

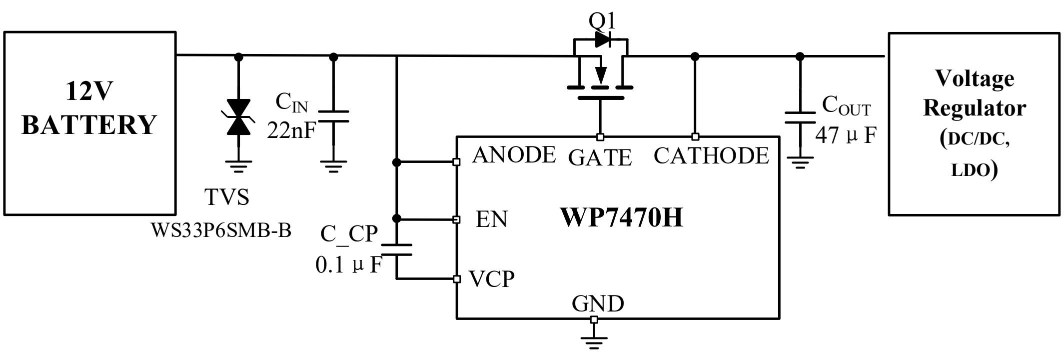
TVS diodes are used for transient protection in automotive systems. In the 12V battery protection application circuit shown below, a bidirectional TVS diode is used to protect the system from positive and negative transient voltages that occur during normal automotive operation, the levels and pulses of which are specified in the ISO7637-2 and ISO16750-2 standards.

There are two important specifications, breakdown voltage and clamping voltage of the TVS. Breakdown voltage is the voltage at which the TVS diode goes into avalanche similar to a Zener diode and is specified at a low current value typical 1mA, and the breakdown voltage should be higher than worst case steady state voltages seen in the system. The breakdown voltage of the TVS+ should be higher than jump start voltage (24V) and suppressed load dump voltage (35V) and less than the maximum ratings of WP7470H (85V). The breakdown voltage of TVS- should be beyond maximum reverse battery voltage(-16V), so that the TVS- is not damaged due to long time exposure to reverse connected battery.

Clamping voltage is the voltage the TVS diode clamps in high current pulse situations and this voltage is much higher than the breakdown voltage. TVS diodes are meant to clamp transient pulses and should not interfere with steady state operation.

The next criterion is that the absolute maximum rating of ANODE to CATHODE reverse voltage of the WP7470H (-75V) and the maximum V_{DS} rating MOSFET are not exceeded. In the design example, 60V rated MOSFET is chosen and maximum limit on the CATHODE to ANODE voltage is 60V. In case of ISO7637-2Pulse 1, the ANODE of WP7470H is pulled down by the ISO pulse and clamped by TVS-. The MOSFET is turned off quickly to prevent reverse current from discharging the bulk output capacitors. When the MOSFET turns off, the CATHODE to ANODE voltage seen is equal to (TVS clamping voltage + output capacitor voltage). If the maximum voltage on output capacitor is 16V (maximum battery voltage), then the clamping voltage of the TVS- should not exceed, (60V – 16V) = -44V.

The WS33P6SMB-B TVS diode can be used for 12V battery protection application. The breakdown voltage of 36.7V meets the jump start, load dump requirements on the positive side and 16V reverse battery connection on the negative side.



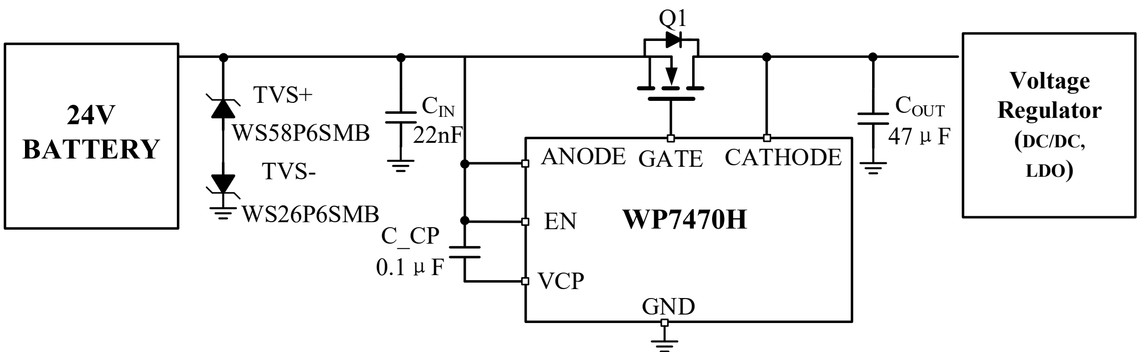
13.1.2 TVS Selection for 24V Battery Protection Application

Typical 24V battery protection application circuit shown below uses two unidirectional TVS diodes to protect the system from positive and negative transient voltages.

The breakdown voltage of the TVS+ should be higher than 48V jump start voltage, lower than the absolute maximum ratings of ANODE and EN pins of WP7470H (85V) and should withstand 65V suppressed load dump. The breakdown voltage of TVS- should be lower than maximum reverse battery voltage -32V, so that the TVS- is not damaged due to long time exposure to reverse connected battery.

During the ISO7637-2 Pulse, the ANODE to CATHODE voltage seen is equal to (-TVS clamping voltage + output capacitor voltage). For 24V battery application, the maximum battery voltage is 32V, then the clamping voltage of the TVS- should not exceed, 75V – 32V = 43V.

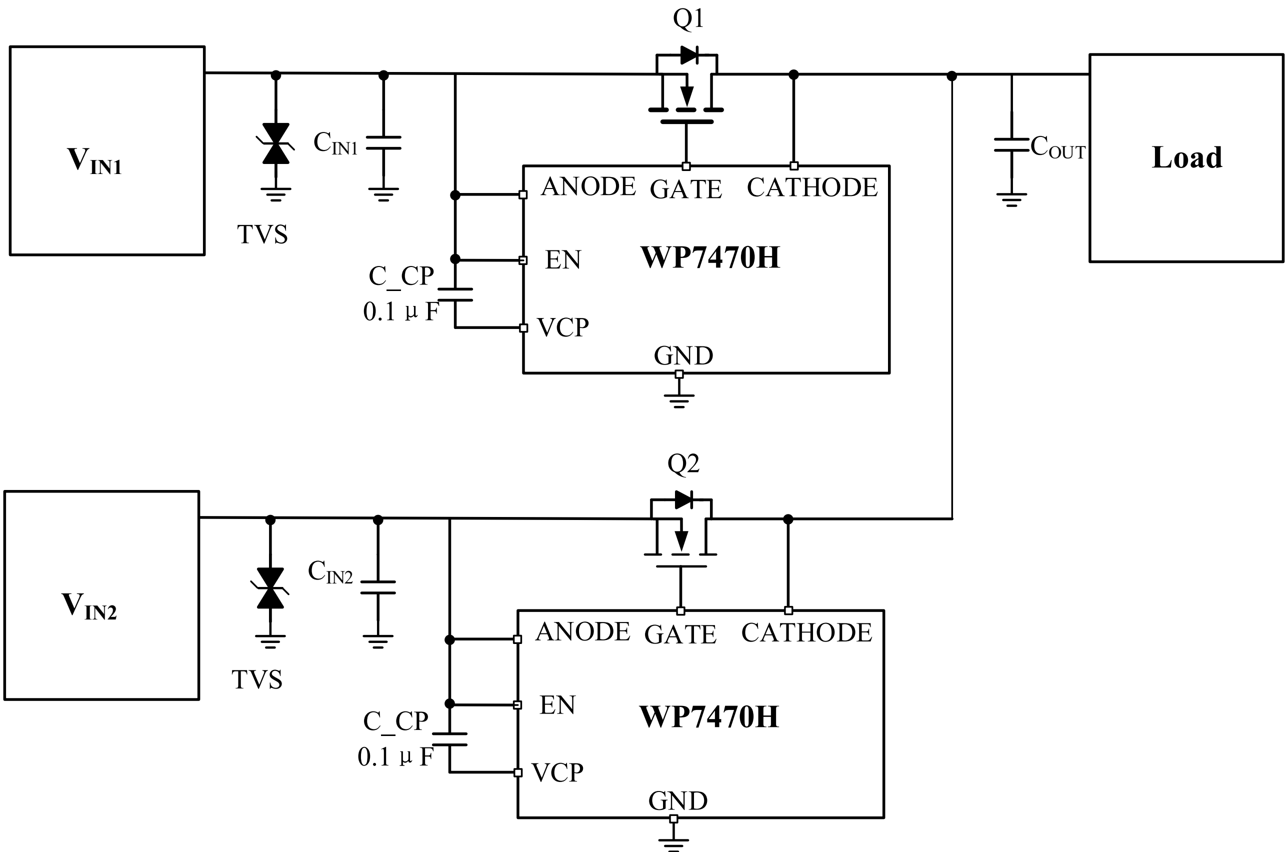
Single bidirectional TVS cannot be used for 24V battery protection because breakdown voltage for TVS+ ≥ 65V, maximum clamping voltage is ≤ 43V and the clamping voltage cannot be lower than the breakdown voltage. Two unidirectional TVS connected back-back needs to be used at the input. For positive side TVS+, WS58P6SMB with the breakdown voltage of 64.4V (minimum), 67.8V (typical) is recommended. For the negative side TVS-, WS26P6SMB with breakdown voltage close to 32V (to withstand maximum reverse battery voltage -32V) and maximum clamping voltage of 42.1V is recommended. For 24V battery protection, a 75V rated MOSFET is recommended to be used along with WS26P6SMB and WS58P6SMB connected back-back at the input.



13.1.3 ORing Application Implementation

The basic redundant power architecture consists of two or more voltage or power sources driving a single load. The simplest redundant power ORing solution consists of a Schottky ORing diode that protects the system in the event of an input power failure. Diode ORing devices provide an effective, low-cost solution requiring only a few components. However, the diodes forward voltage drops affect the efficiency of the system permanently, since each diode in an ORing application spends most of its time in forward conduction mode. These power losses increase the requirements for thermal management and allocated board space.

The WP7470H is combined with an external N-channel MOSFET for ORing solutions. During normal operation, the external N-channel MOSFET conducts, which reduces the forward diode drop, and the WP7470H quickly detects the reverse current and quickly pulls down the MOSFET gate, allowing the MOSFET's body diode to block the reverse current. An effective ORing solution requires extreme speed to limit the magnitude and duration of the reverse current. In an ORing configuration, the WP7470H device constantly senses the voltage difference between the ANODE pin and the CATHODE pin, which are the voltage levels at the power supply (V_{IN1}, V_{IN2}) and the common load point, respectively. The WP7470H's ANODE and CATHODE pins monitor the source-to-drain voltage, V_{DS}, of each MOSFET. Once V_{IN} - V_{OUT} falls below -10mV, the fast comparator switches off the gate driver with a fast pull-down in 0.45μs (typical). Once the differential forward voltage V_{IN} - V_{OUT} exceeds 50mV, it turns on the gate driver with a gate charge current of 10mA.



13.2 Application Curves

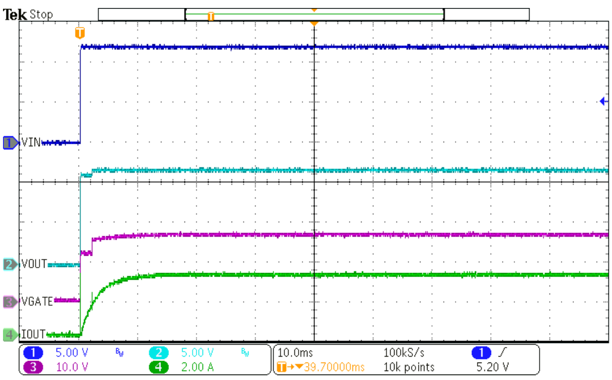


Figure 16. Start-up with 3A Load

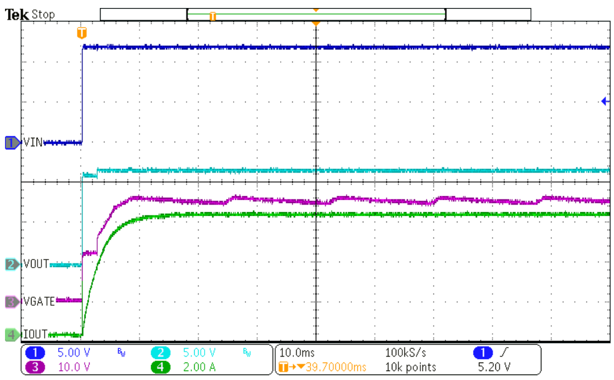


Figure 17. Start-up with 6A Load

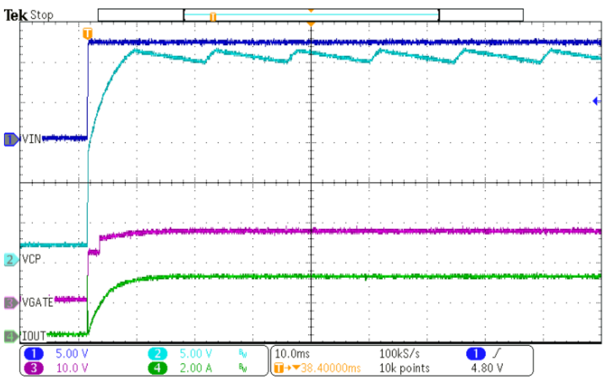


Figure 18. VCP During Start-up with 3A Load

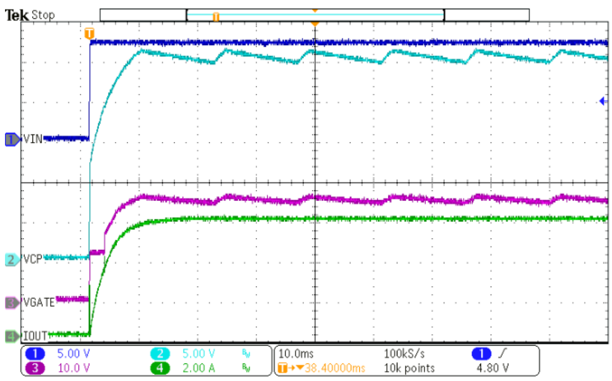


Figure 19. VCP During Start-up with 6A Load

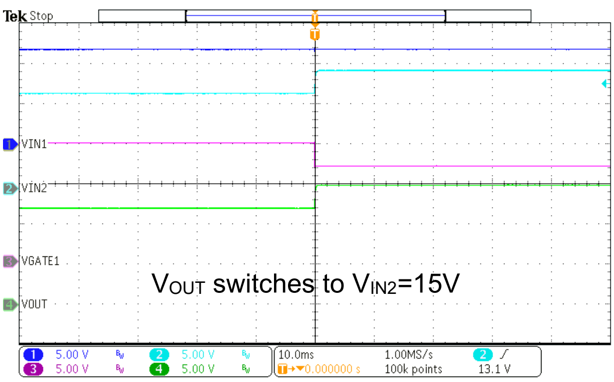


Figure 20. ORing V_{IN1} to V_{IN2} Switch Over

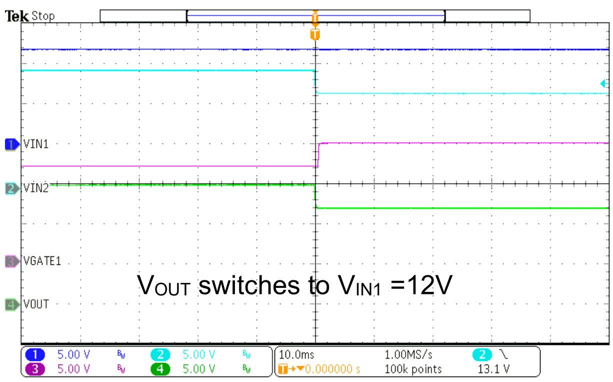


Figure 21. ORing V_{IN2} to V_{IN1} Switch Over

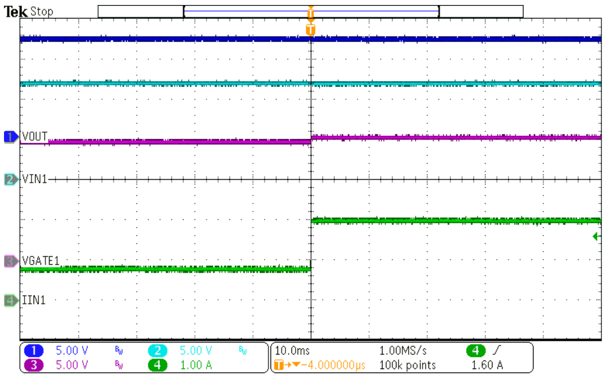


Figure 24. ORing V_{IN2} Failure and Switch Over to V_{IN1}

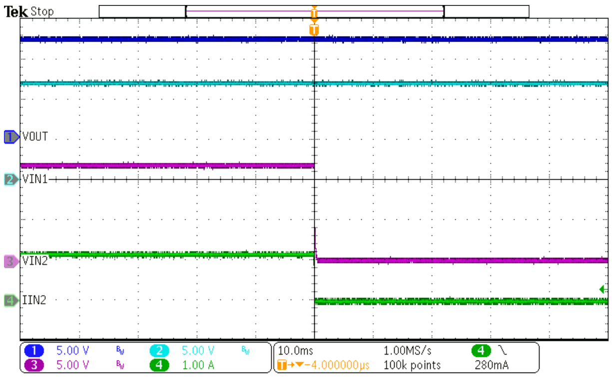


Figure 25. ORing V_{IN2} Failure and Switch Over to V_{IN1}

14. Evaluation Modules

Evaluation Modules (EVMs) are available to help evaluate initial circuit performance. You can contact us to get the evaluation module or schematic.

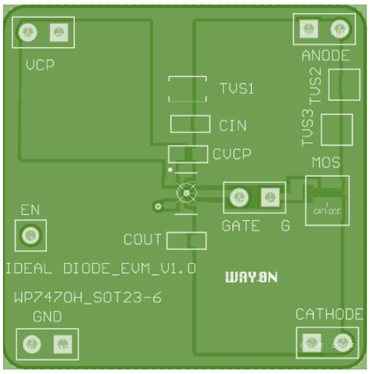
The module name is listed in the following table.

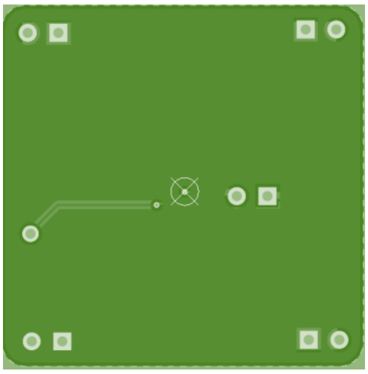
Name	Package	Evaluation Module
WP7470H-A60R	SOT23-6	IDEAL DIODE_EVM_V1.0 _WP7470H_SOT23-6

Layout Guidelines

- Connect ANODE, GATE and CATHODE pins of WP7470H close to the MOSFET's SOURCE, GATE and DRAIN pins.
- The high current path of for this solution is through the MOSFET, therefore it is important to use thick traces for source and drain of the MOSFET to minimize resistive losses.
- The charge pump capacitor across VCP and ANODE pins must be kept away from the MOSFET to lower the thermal effects on the capacitance value.
- The Gate pin of the WP7470H must be connected to the MOSFET gate with short trace. Avoid excessively thin and long trace to the Gate Drive.
- Keep the GATE pin close to the MOSFET to avoid increase in MOSFET turn-off delay due to trace resistance.
- Obtaining acceptable performance with alternate layout schemes is possible, however the layout shown in the Layout Example is intended as a guideline and to produce good results.

Layout Example





15. Naming Conventions

WP AAAAA-BBB C

WP: WAYON Protection IC;

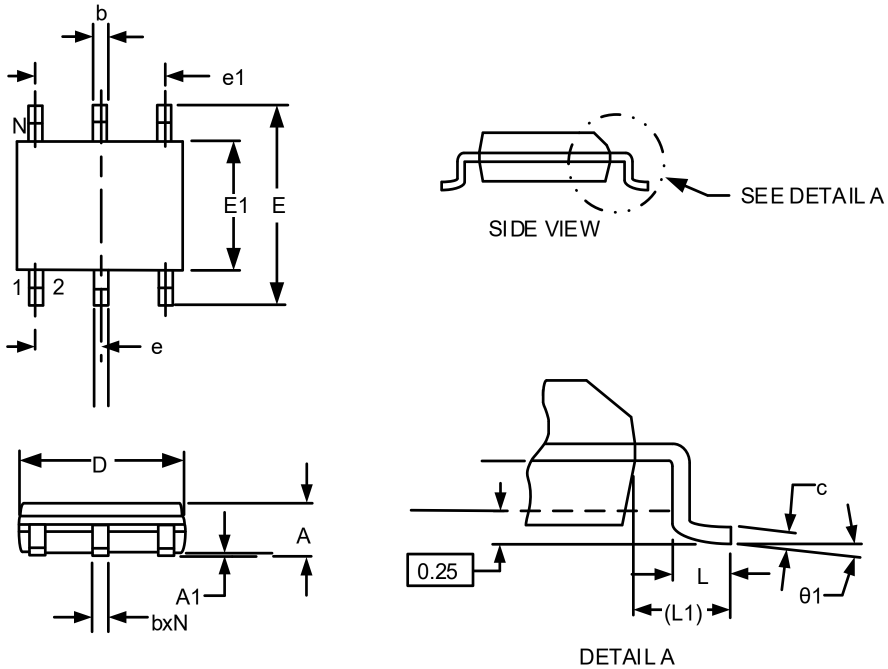
AAAAA: Product Name

BBB: Package – A60: SOT23-6

C: R-Reel

16. Package Information

SOT 23-6



SYMBOL	DIMENSIONS IN MILLIMETERS	
	MIN	MAX
A	0.90	1.45
A1	0.00	0.15
b	0.25	0.55
c	0.08	0.22
D	2.80	3.10
E1	1.50	1.75
E	2.60	3.00
e	0.95BSC	
e1	1.90BSC	
L	0.30	0.60
L1	0.55	0.75
Θ1	0°	8°

17. Ordering Information

PART NUMBER	Op Temp (°C)	PACKAGE	PACKING QUANTITY	MARKING*
WP7470H-A60R	-40 to 125	SOT23-6	3k/Reel	WP7470 XXXX

* XXXX is variable.

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WAYON website: http://www.way-on.com
For additional information, please contact your local Sales Representative.
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Product Specification Statement

1.The product specification aims to provide users with a reference regarding various product parameters, performance, and usage. It presents certain aspects of the product's performance in graphical form and is intended solely for users to select product and make product comparisons, enabling users to better understand and evaluate the characteristics and advantages of the product. It does not constitute any commitment, warranty, or guarantee.

2.The product parameters described in the product specification are numerical values, characteristics, and functions obtained through actual testing or theoretical calculations of the product in an independent or ideal state. Due to the complexity of product applications and variations in test conditions and equipment, there may be slight fluctuations in parameter test values. WAYON shall not guarantee that the actual performance of the product when installed in the customer's system or equipment will be entirely consistent with the product specification, especially concerning dynamic parameters. It is recommended that users consult with professionals for product selection and system design. Users should also thoroughly validate and assess whether the actual parameters and performance when installed in their respective systems or equipment meet their requirements or expectations. Additionally, users should exercise caution in verifying product compatibility issues, and WAYON assumes no responsibility for the application of the product.

3.WAYON strives to provide accurate and up-to-date information to the best of our ability. However, due to technical, human, or other reasons, WAYON cannot guarantee that the information provided in the product specification is entirely accurate and error-free. WAYON shall not be held responsible for any losses or damages resulting from the use or reliance on any information in these product specifications. WAYON reserves the right to revise or update the product specification and the products at any time without prior notice, and the user's continued use of the product specification is considered an acceptance of these revisions and updates. Prior to purchasing and using the product, users should verify the above information with WAYON to ensure that the product specification is the most current, effective, and complete. If users are particularly concerned about product parameters, please consult WAYON in detail or request relevant product test reports. Any data not explicitly mentioned in the product specification shall be subject to separate agreement.

4.Users are advised to pay attention to the parameter limit values specified in the product specification and maintain a certain margin in design or application to ensure that the product does not exceed the parameter limit values defined in the product specification. This precaution should be taken to avoid exceeding one or more of the limit values, which may result in permanent irreversible damage to the product, ultimately affecting the quality and reliability of the system or equipment.

5.The design of the product is intended to meet civilian needs and is not guaranteed for use in harsh environments or precision equipment. It is not recommended for use in systems or equipment such as medical devices, aircraft, nuclear power, and similar systems, where failures in these systems or equipment could reasonably be expected to result in personal injury. WAYON shall assume no responsibility for any consequences resulting from such usage.

6.Users should also comply with relevant laws, regulations, policies, and standards when using the product specification. Users are responsible for the risks and liabilities arising from the use of the product specification and must ensure that it is not used for illegal purposes. Additionally, users should respect the intellectual property rights related to the product specification and refrain from infringing upon any third-party legal rights. WAYON shall assume no responsibility for any disputes or controversies arising from the above-mentioned issues in any form.