

Product Overview

NSD12416-Q1 is a 160mΩ 2 channel low-side switch with 48V clamp voltage for automotive applications. It's designed for driving resistive or inductive loads with one side connected to the battery. Internal 48V clamp circuit protects device from surge energy when fast demagnetization at turn-off.

With internal output current limitation, the device is protected in overload condition. Built-in thermal shutdown protects the chip from over-temperature and short-circuit. A thermal swing mechanism is built to limit dissipated power to decelerate power accumulation. Thermal shutdown, with automatic restart, allows the devices to recover normal operation as soon as a fault condition disappears.

An internal diagnose function is built to indicate any faults when thermal shutdown through an open-drain status output pin. This device operates in ambient temperatures from -40°C to 125°C .

Applications

- Automotive Relays
- Valves
- Solenoid drivers
- Lighting

Device Information

Part Number	Package	Body Size
NSD12416-Q1SPR	SO-8	4.9mm x 3.9mm

Key Features

- AEC-Q100 (Grade 1) qualified for automotive application
- Drain current limitation: 2.5A
- 48V overvoltage clamp
- Thermal shutdown protection
- Thermal swing protection
- Fault diagnostic block
 - Thermal shutdown diagnosis
- Very low standby current
- Very low electromagnetic susceptibility
- ESD protection
- RoHS & REACH Compliance

Typical Application

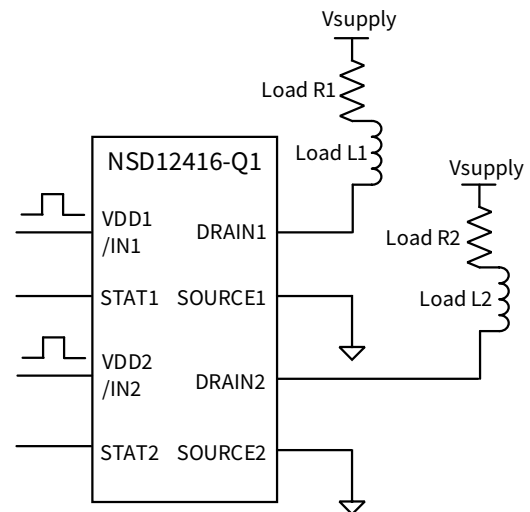


Figure 0.1 NSD12416-Q1 Typical Application

INDEX

1. PIN CONFIGURATION AND FUNCTIONS	3
2. BLOCK DIAGRAM.....	3
3. ABSOLUTE MAXIMUM RATINGS	4
4. ESD RATINGS.....	4
5. THERMAL INFORMATION.....	4
6. SPECIFICATIONS	5
6.1. ELECTRICAL CHARACTERISTICS	5
6.2. TYPICAL PERFORMANCE CHARACTERISTICS	6
6.2.1. TRUE TABLE	6
6.2.2. SWITCHING CHARACTERISTICS	6
7. PROTECTIONS.....	7
7.1. CURRENT LIMITATION	7
7.2. THERMAL SHUTDOWN AND THERMAL SWING	7
8. APPLICATION INFORMATION	7
8.1. MCU I/O PROTECTION.....	7
8.2. THE VALUE OF STATUS PULLS UP RESISTOR.....	8
9. PACKAGE INFORMATION.....	9
9.1. SO-8 PACKAGE INFORMATION.....	9
9.2. SO-8 PACKAGING INFORMATION	9
10. ORDERING INFORMATION	11
11. REVISION HISTORY	11

1. Pin Configuration and Functions

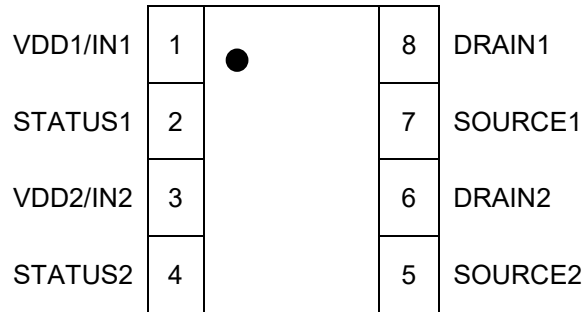


Figure 1.1 NSD12416-Q1SPR Pinout

Table 1.1 NSD12416-Q1SPR Pin Configuration and Description

Pin No.	Symbol	Function
1,3	VDD1,2/IN1,2	Voltage controlled input pin with hysteresis, CMOS compatible. They control output switch state
2,4	STATUS1,2	Open drain digital diagnostic pin
8,6	DRAIN1,2	PowerMOS drain
7,5	SOURCE1,2	PowerMOS source and ground reference for the control section

2. Block Diagram

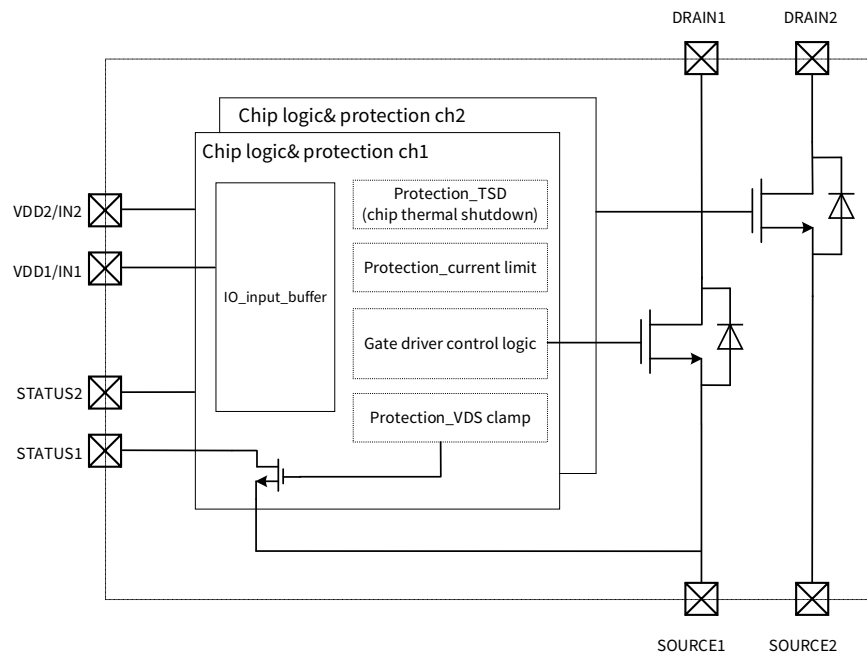


Figure 2.1 NSD12416-Q1SPR Block diagram

3. Absolute Maximum Ratings

Parameters	Symbol	Min	Typ	Max	Unit
Drain-to-Source Voltage	V_{DS}			Internally clamped	V
DC Drain Current	I_D			Thermal limited	A
Junction Temperature	T_J	-40		150	°C
Storage Temperature	T_{stg}	-55		150	°C
Single pulse avalanche energy ($L = 12\text{mH}$; $T_J = 150\text{ °C}$; $R_L = 0\Omega$; $I_{OUT} = I_{lim}$)	E_{AS}			40	mJ

4. ESD Ratings

Parameters	Symbol	Value	Unit
V(ESD) Electrostatic discharge	Human-body model, per AEC-Q100-002-RevD , $V_{ESD-HBM}$	±4000	V
	Charged-device model, per AEC-Q100-011-RevB , $V_{ESD-CDM}$	±750	V

5. Thermal Information

Parameters	Symbol	SO-8	Unit
Junction-to-ambient Thermal Resistance	θ_{JA}	77.8	°C/W
Junction-to-top characterization parameter	ψ_{JT}	4.25	°C/W
Junction-to-case (top) thermal resistance	$\theta_{JC (top)}$	25	°C/W

The thermal data is based on the JEDEC standard high-K profile, JESD 51-7, four layers board.

6. Specifications

6.1. Electrical Characteristics

($V_{DD} = V_{IN} = 4.5 \text{ V}$ to 5.5 V , $T_J = -40^\circ\text{C}$ to 150°C . Unless otherwise noted.)

Parameters	Symbol	Min	Typ	Max	Unit	Comments
Power MOSFET						
ON-state resistance	R _{ON}		160		mΩ	I _D = 1 A; T _J = 25°C; V _{DD} = V _{IN} = 5 V
				320	mΩ	I _D = 1 A; T _J = 150°C; V _{DD} = V _{IN} = 5 V
Drain-source clamp voltage	V _{CLAMP}	46	48	56	V	V _{IN} = 0V, I _D = 1A
Drain-source clamp threshold voltage	V _{CLTH}	40			V	V _{IN} = 0V, I _D = 2 mA
OFF-state output current	I _{DSS}	0		3	μA	V _{IN} = 0 V; V _{DS} = 13 V; T _J = 25°C
		0		5	μA	V _{IN} = 0 V; V _{DS} = 13 V; T _J = 125°C
Body diode forward voltage	V _{BD}		0.8		V	I _D = 1A; V _{IN} = 0 V
Input section						
Supply current from input pin	I _{ISS}		30	65	μA	ON-state; V _{DD} =V _{IN} = 5 V; V _{DS} = 0 V
Input clamp voltage	V _{ICL}	5.5		8	V	I _{ICL} = 1 mA
			-0.7			I _{ICL} = -1 mA
Input threshold voltage	V _{INTH}	1		3.5	V	V _{DS} = V _{IN} ; I _D = 1 mA
Status indicator						
Status low output voltage	V _{STAT}			0.5	V	I _{STAT} = 1 mA
Status leakage current	I _{LSTAT}			10	μA	V _{STAT} = 5 V
Status pin input capacitance	C _{STAT}			100	pF	V _{STAT} = 5 V
Status clamp voltage	V _{STCL}	5.5		8	V	I _{STAT} = 1 mA
			-0.7			I _{STAT} = - 1 mA
Switching characteristics						
Turn-on delay time	t _{d (ON)}		9		μs	R _L = 13 Ω, V _{DS} = 13 V
Turn-off delay time	t _{d (OFF)}		9		μs	R _L = 13 Ω, V _{DS} = 13 V
Rise time	t _r		9		μs	R _L = 13 Ω, V _{DS} = 13 V
Fall time	t _f		5		μs	R _L = 13 Ω, V _{DS} = 13 V
Switching energy losses at turn-on	W _{ON}		26		μJ	R _L = 13 Ω, V _{DS} = 13 V

Parameters	Symbol	Min	Typ	Max	Unit	Comments
Switching energy losses at turn-off	W_{OFF}		23		μJ	$R_L = 13 \Omega$, $V_{DS} = 13 V$
Protection and diagnostics						
DC short-circuit current	I_{lim}	1.6	2.5	3	A	$V_{DS} = 13 V$, $V_{DD} = V_{IN} = 5V$
Shutdown temperature	T_{TSD}	150	175	200	$^{\circ}C$	
Reset temperature	T_R	$T_{RS} + 1$	$T_{RS} + 5$		$^{\circ}C$	
Thermal reset of STATUS	T_{RS}	135			$^{\circ}C$	
Thermal hysteresis ($T_{TSD} - T_R$)	T_{HYST}		7		$^{\circ}C$	
Dynamic temperature	ΔT_J		40		K	$T_J = -40^{\circ}C$, $V_{DS} = 13V$
Dynamic temperature hysteresis	$\Delta T_J (HYS)$		15		K	

6.2. Typical Performance Characteristics

6.2.1. True Table

Conditions	Input	Drain	Status
Normal operation	L	H	H
	H	L	H
Current limitation	L	H	H
	H	X	H
Over-temperature limitation	L	H	H
	H	H	L
VDD under-voltage	L	H	X
	H	H	X

6.2.2. Switching Characteristics

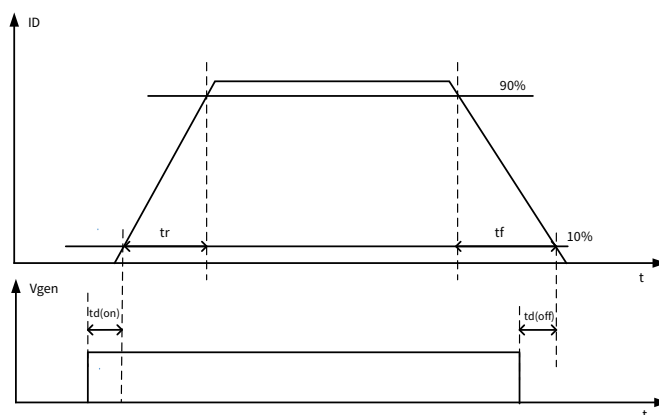


Figure 6.2.2 NSD12416-Q1 Switching Characteristics

7. Protections

7.1. Current Limitation

NSD12416-Q1 has current limitation to protect the silicon and bonding wire in case of overload or short circuit to battery.

7.2. Thermal Shutdown and Thermal Swing

This device has both absolute and dynamic temperature protection. There are two thermal sensors on the controller and the MOSFET, the one on the MOSFET is the hottest and the one on the controller is the coldest. The absolute temperature protection is to shut down the MOSFET when the hottest junction temperature exceeds the T_{TSD} , and the dynamic temperature protection is also to shut down the MOSFET when the temperature difference between the hottest and the coldest exceeds ΔT_J .

8. Application Information

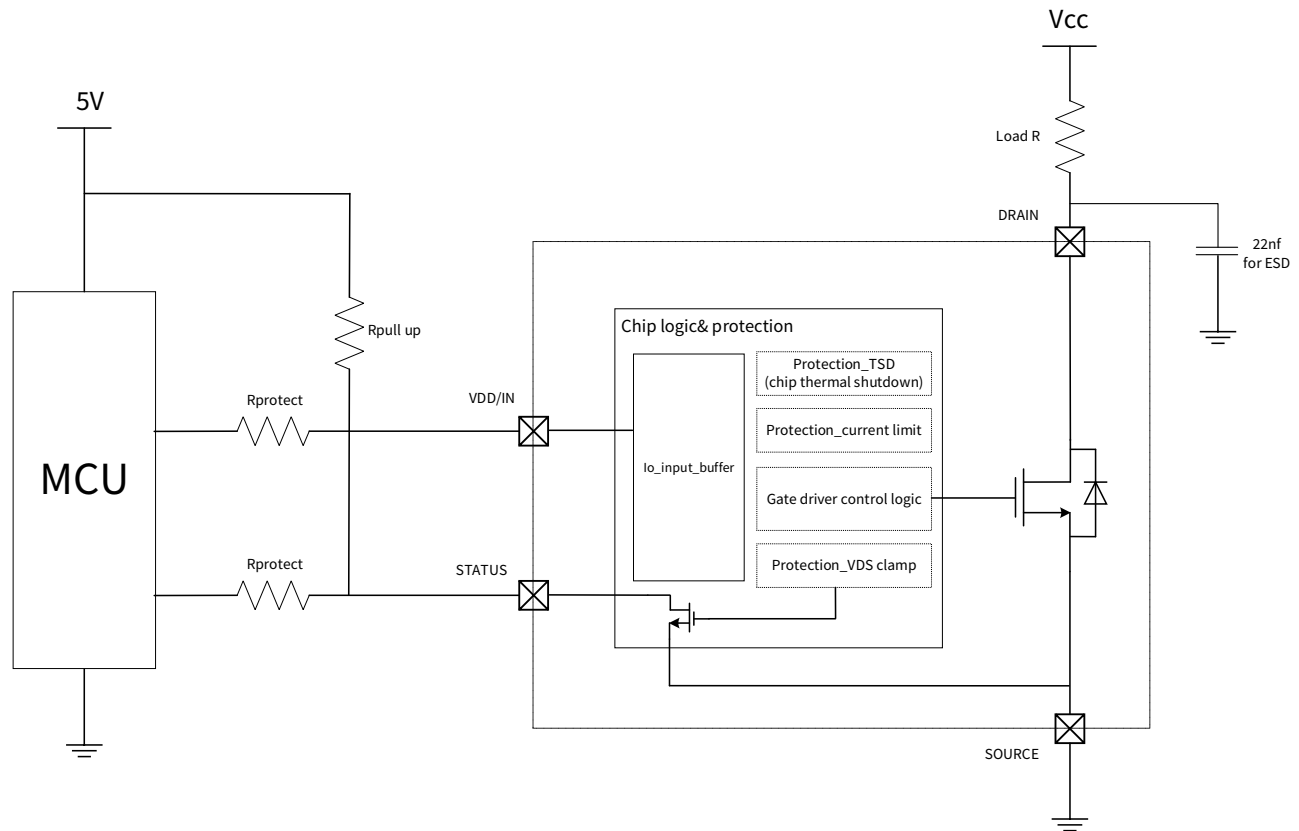


Figure 8.1 NSD12416-Q1SPR application schematic

8.1. MCU I/O Protection

NSD12416 has Zener diodes inside for ESD protection and the intrinsic NPN parasitic bipolar, so that resistors for protection are necessary in series with the digital inputs to limit the current to protect MCU I/Os during transient and reverse battery conditions.

The value of resistors for protection R_{prot} is suggested 100ohm~1.5kohm.

8.2. The value of STATUS pulls up resistor

Because the STATUS pin is open drain output, a pull up resistor is needed to fix the high voltage during normal operation. When the fault occurs, the voltage level of STATUS is pulled down by the internal MOSFET on. The value of pull up resistor can be calculated by the formula as shown below:

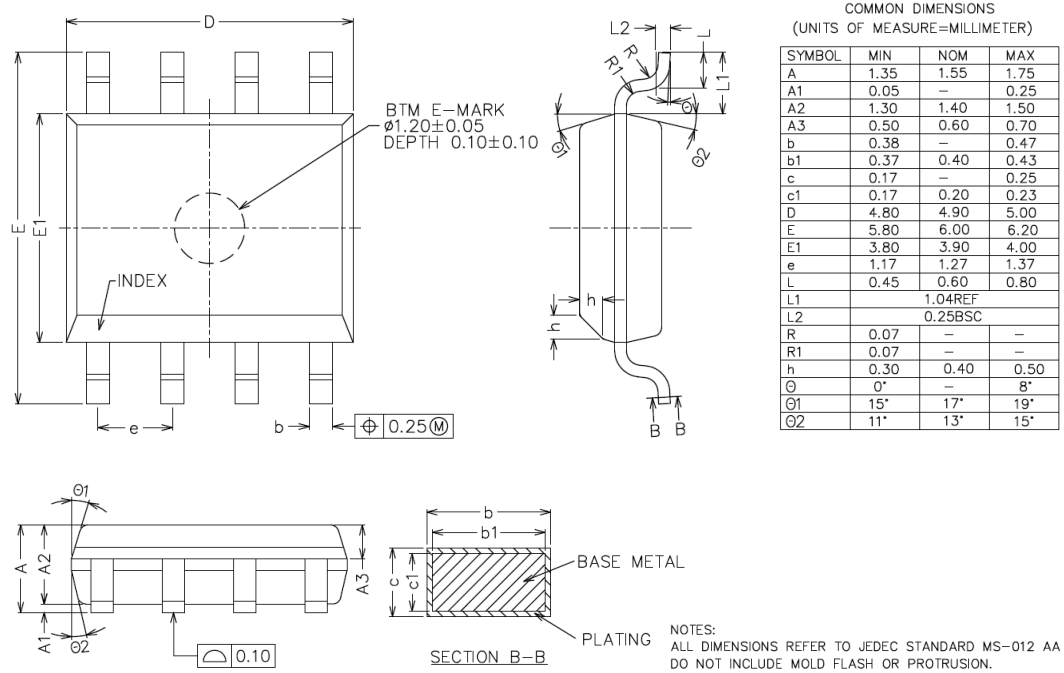
$$\left(\frac{V_{pull-up}}{V_{OL}} - 1\right) \cdot R_{on} < R_{pull-up} < \frac{V_{pull-up} - V_{OH}}{I_{leak}}$$

Where $V_{pull-up}$ is the minimum of pull-up supply, V_{OL} is the maximum of MCU logic low, R_{on} is the on resistance of the MOSFET of STATUS pin, V_{OH} is the minimum of MCU logic high, I_{leak} is the maximum leakage current of STATUS pin. Let: $V_{pull-up} = 4.5V$; $R_{on} = V_{STAT}/I_{STAT} = 500\Omega$, $V_{OL} = 0.9V$; $V_{OH} = 2.1V$; $I_{leak} = 10\mu A$, so $2k\Omega \leq R_{pull-up} \leq 240k\Omega$.

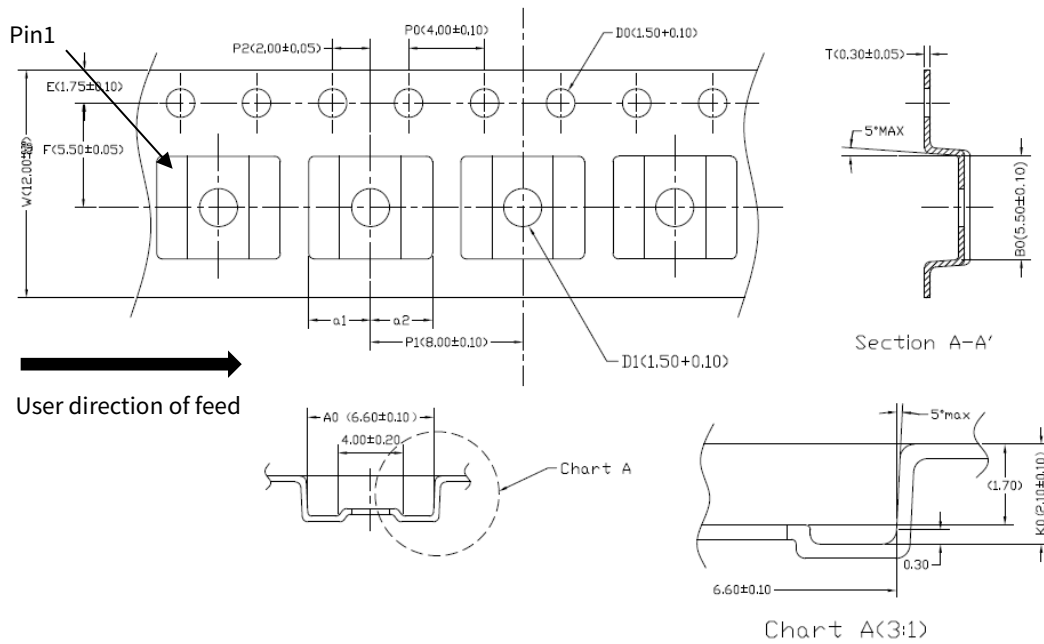
The recommended $R_{pull-up}$ value is $10k\Omega$.

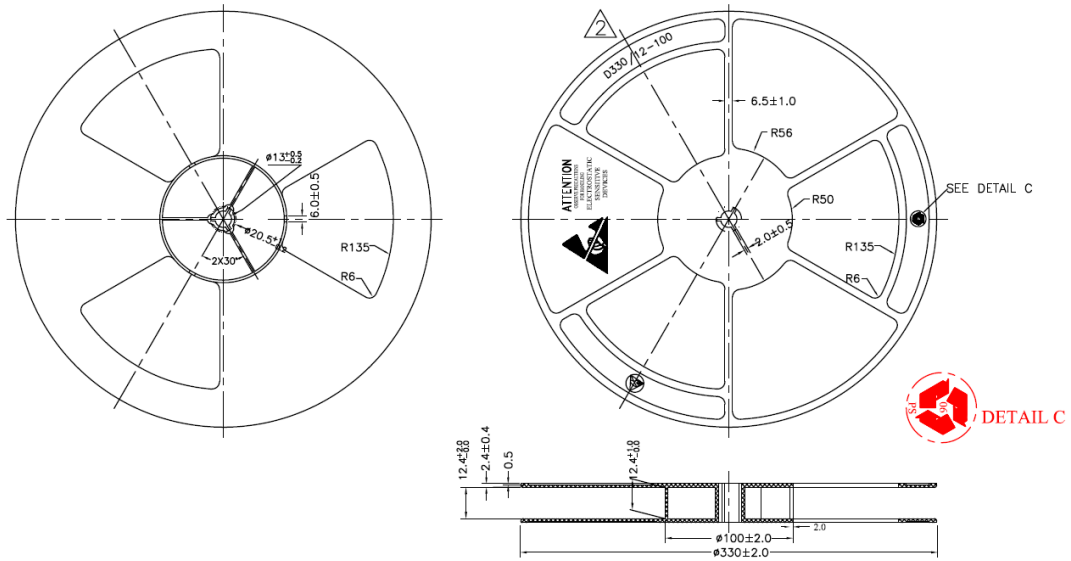
9. Package Information

9.1. SO-8 Package Information



9.2. SO-8 Packaging Information





10. Ordering Information

Part Number	Package	MSL	SPQ
NSD12416-Q1SPR	SO-8	3	2500
Note: All packages are ROHS compliant with peak reflow temperature of 260°C according to the JEDEC industry standard classifications and peak solder temperature.			

11. Revision History

Revision	Description	Date
1.0	Initial version	2024/2/1
1.1	Update key description	2024/3/26
1.2	Update format	2024/4/7
1.3	Update the recommended value of resistors for MCU I/O protection	2025/5/15

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