

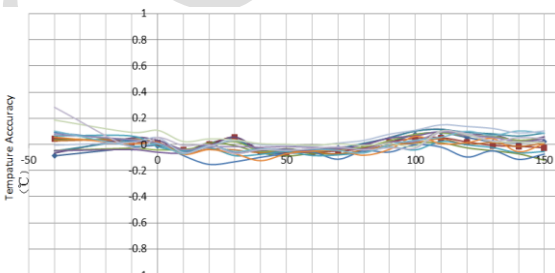
● Description

The NST1001 device is accurate 2-pin digital output temperature sensor with pulse count interface, which belongs to D-NTC™ series in NOVOSENSE. The NST1001 has digital pulse count output and high accuracy over a wide temperature range allow pairing with any GPIO from MCU without concern for integrated ADC quality or availability. NST1001 device works over a temperature range of -50°C to 150°C , which makes it suitable for onboard and off board applications in automotive, industrial, and consumer markets. The NST1001 device can apply to 2 wire temperature probe or replace the NTC directly since the device only has 2 pins. Comparing to NTC, the NST1001 device is easy to use, digital out and more accurate, which can achieve high accuracy without system calibration or hardware and software compensation. The NST1001 integrated EMI suppression and simple 2-pin architecture makes it suitable for onboard and offboard temperature sensing in a noisy environment. The NST1001 is very low power device, which can be powered by MCU's GPIO and also can be applied in IoT.

● Applications

- Digital Output Wired Probes
- Industrial Internet of Things (IoT)
- White Goods
- Battery Management

NST1001 Accuracy

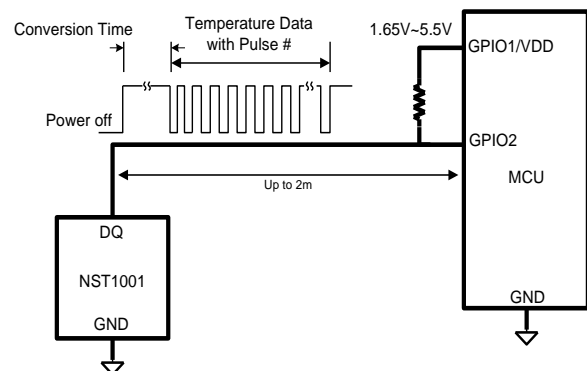


● Features :

- High Accuracy Over -50°C to 150°C Wide Temperature Range
 - ✓ $-20^{\circ}\text{C} \sim 85^{\circ}\text{C}$: $\pm 0.5^{\circ}\text{C}$ (Maximum)
 - ✓ $-50^{\circ}\text{C} \sim -20^{\circ}\text{C}$: $\pm 0.75^{\circ}\text{C}$ (Maximum)
 - ✓ $85^{\circ}\text{C} \sim 150^{\circ}\text{C}$: $\pm 0.75^{\circ}\text{C}$ (Maximum)
- Proportional to Temperature with 0.0625°C Resolution
- Pulse Count Easily Read by Processor without ADC
- Continuous Conversion Plus Data-Transmission is 50ms
- Supply Operation rang from 1.65V to 5.5V
- Can replace the NTC directly
- Package
 - ✓ TO-92s (4mm x 3mm)
 - ✓ DFN2L (1.6mm x 0.8mm) (note1)

Note1: Which has the same size with 0603 resistor

2-Pin IC Temperature Sensor



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1.0 ABSOLUTE MAXIMUM RATINGS

Parameters	Symbol	Min	Typ	Max	Unit	Comments
DQ voltage	VDQ	-0.3		6.5	V	
Storage temperature		-60		155	°C	
Operation temperature	TB _{operation}	-50		150	°C	
Maximum junction temperature				155	°C	
ESD susceptibility	HBM	±8			KV	
	CDM	±1250			V	

2.0 ELECTRICAL CHARACTERISTICS

2.1. Electrical characteristics

Parameters	Symbol	Min	Typ	Max	Unit	Comments
Supply						
Supply voltage Range	V _{pu}	1.65	3.3	5.5	V	pull up resistor 5kohm
Pull up resistor Range	R _{pu}	0.5	5	10	KΩ	
Supply sensitivity					m°C /V	VDQ voltage range from 1.65V to 5.5V
Operation current	I _{conv}		30	45	uA	Conversion
	I _{com}		1	5	uA	Communication
Temperature Range and Resolution						
Temperature Range		-50		150	°C	
Resolution			0.0625		°C	
Accuracy		-0.5		0.5	°C	From -20°C to 85°C
		-0.75		0.75	°C	From -50°C to -20°C
		-0.75		0.75	°C	From 85°C to 150°C
Pulse count transfer function						
Pulse count @ 0°C			801			
Pulse count rang		1		3201		
Resolution of one pulse			0.0625		°C	

NST1001

High-level input logic	VH	V _{pu} -0.3			V	pull up resistor 5kohm
Low-level input logic	VL			0.2	V	
Parasitic cap in DQ Pin	C _{DQ}			2/R _{pu}	uF	When R _{pu} =5k ohm, C _{DQmax} =400 pF
Rest time when DQ pull down						
Rest time when DQ pull down	T _{RST}			5	ms	NST1001 will pull down if DQ pull down more than 5ms
Thermal response						
Stirred oil thermal response time to 63% of final value (package only)			0.73		s	TO-92s
			0.21		s	DFN2L
Still air thermal response time to 63% of final value (package only)			9.95		s	TO-92s
			2.94		s	DFN2L
Drift						
Drift ¹					°C	

Notes: 1. Drift data is based on a 1000-hour stress test at +125 °C with V_{DD} = 5.5V.

2.2. Timing Diagram

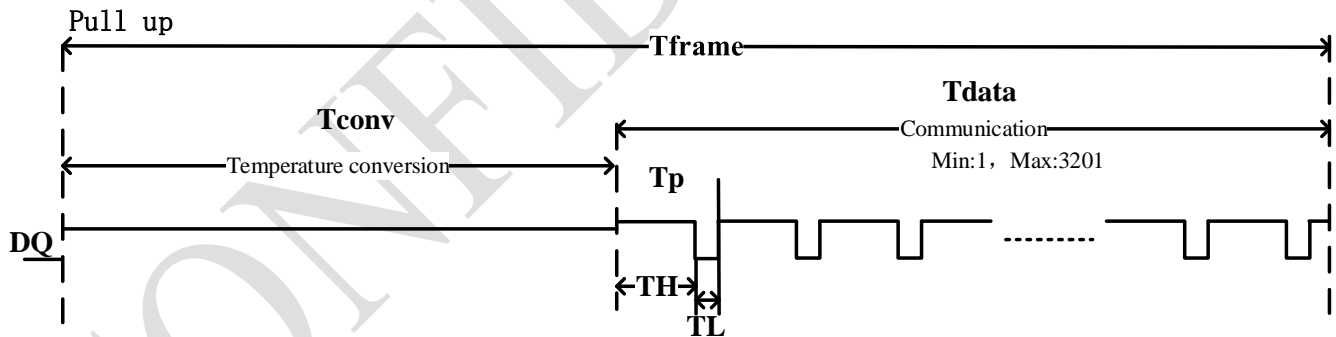


Figure 2.1 NST1001 Timing Diagram

2.3. Timing characteristics

Parameters	Symbol	Min	Typ	Max	Unit	Comments
single frame period	T _{frame}	32	50	70	ms	
conversion period	T _{CONV}	16	24	32	ms	
Communication period	T _{data}	17	26	35	ms	
Sigle pulse period	T _p	5	8	11	us	

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Single pulse period logical high	TH	4	6	8.3	us	
Single pulse period logical low	TL	1.3	2	3	us	
Digital output code		1		3201		

3.0 TYPICAL CHARACTERISTICS

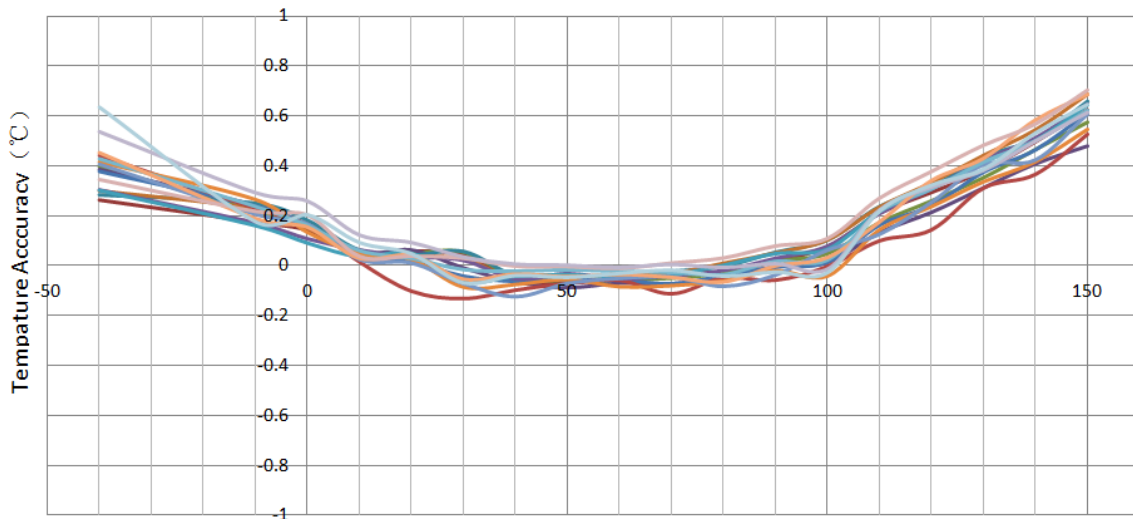


Figure 3.1 Using To-92s test, $V_{pu}=3.3V$

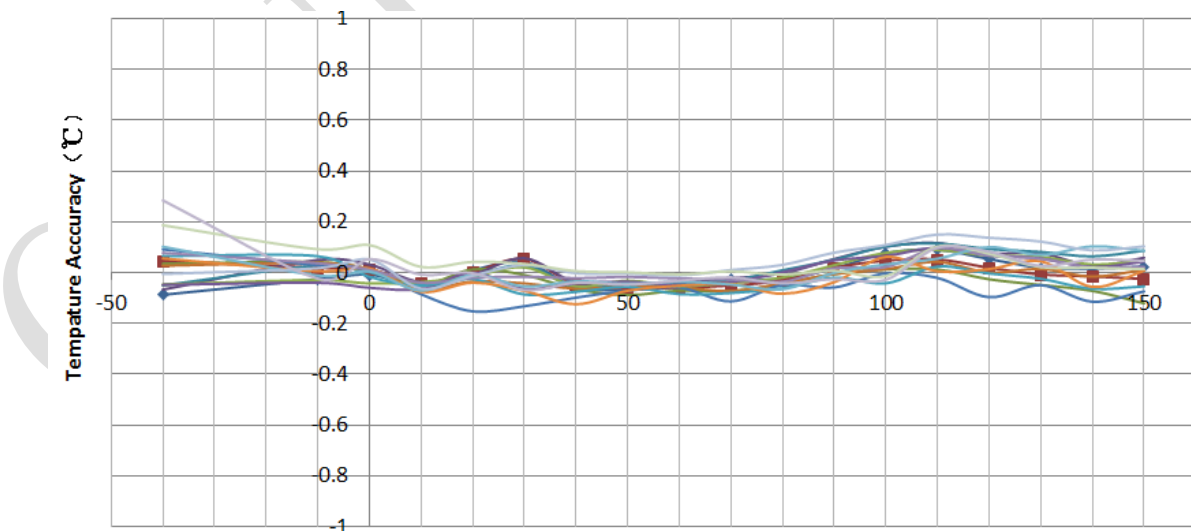


Figure 3.2 Using To-92s test with modifier formula, $V_{pu}=3.3V$

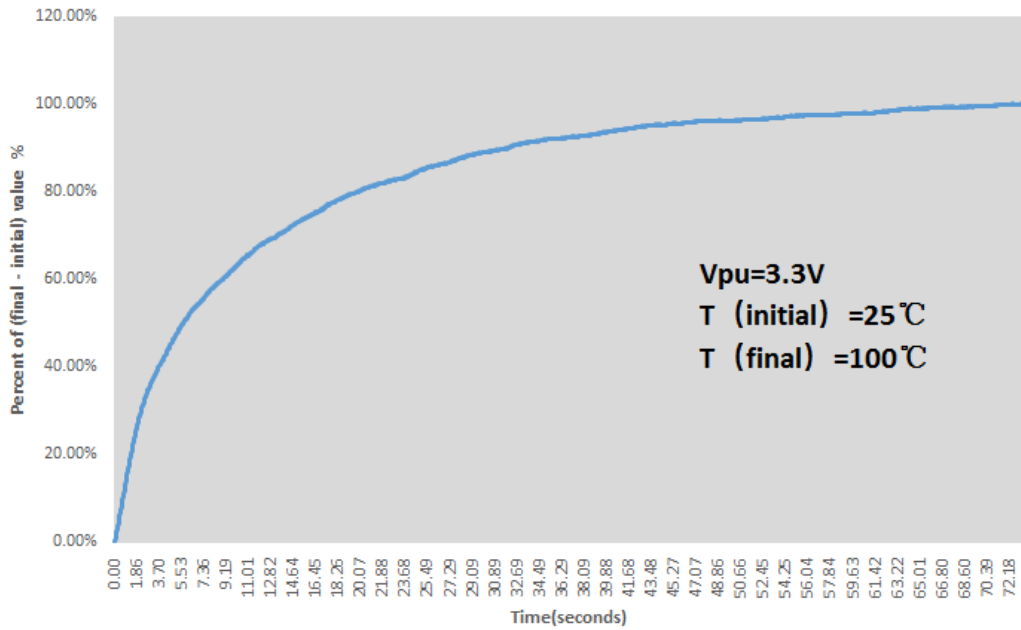


Figure 3.3 Thermal Response in stilling Air (To-92s)

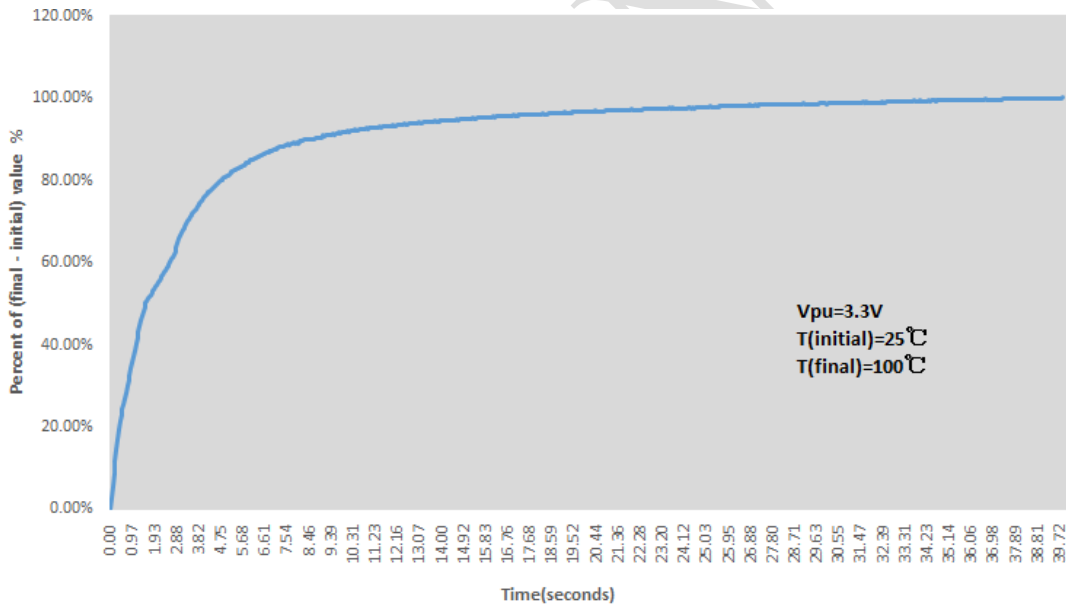


Figure 3.4 Thermal Response in stilling Air (DFN2L)

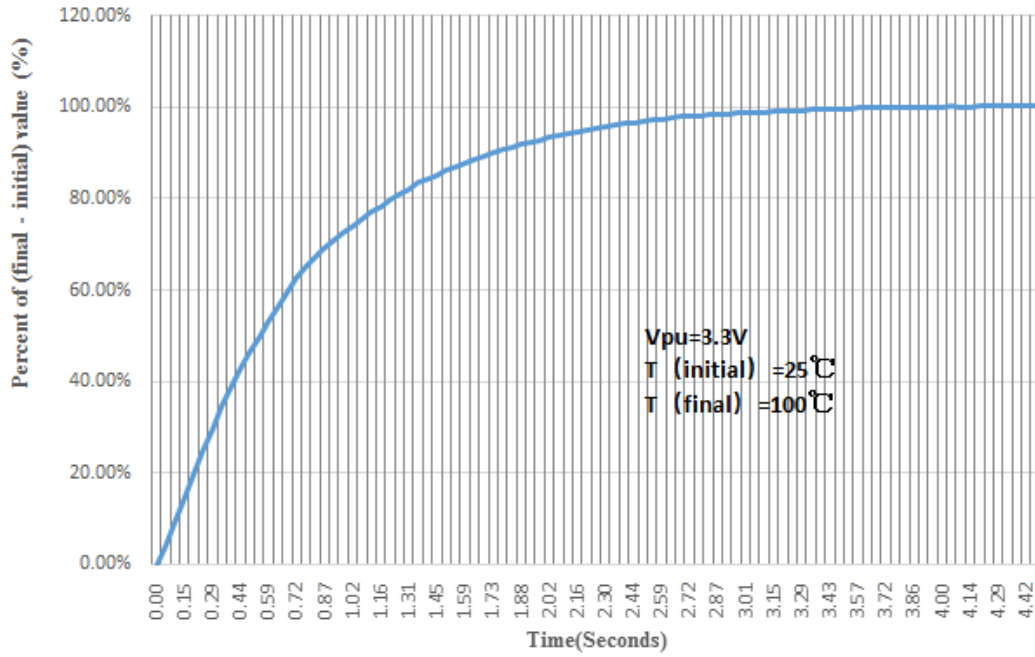


Figure 3.5 Thermal Response in stilling Oil (To-92s)

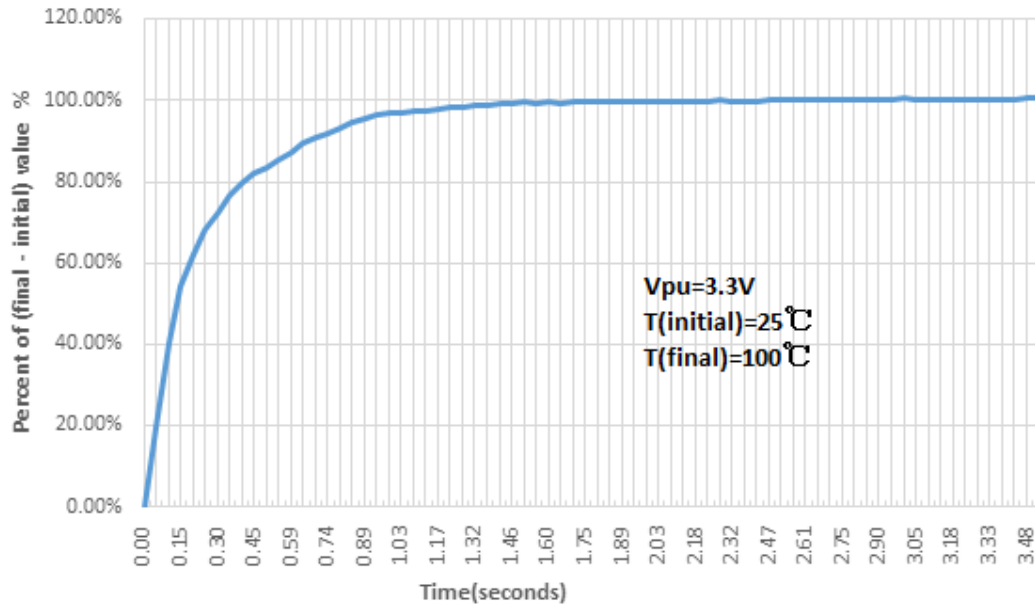


Figure 3.6 Thermal Response in stilling Oil (DFN2L)

4.0 FUNCTION DESCRIPTION

4.1. Function description

The NST1001 temperature output is transmitted over a single wire using a train of pluse, and the function diagram is deccribed in figure 4.1. There are tempature core, ADC, OSC, signal processing circuit and control circuit in the temperature sensor. The NST1001 uses thermal diode analog circuitry to detect the temperature. The temperature signal is then amplified and applied to the input of a $\Sigma\Delta$ ADC that is driven by an internal reference voltage. The $\Sigma\Delta$ ADC output is then processed through the interface circuitry into a digital pulse train. Each NST1001 device was calibrated before delivery with OTP, so the device has very high accurate in Operation rang. The NST1001 is almost no selfheat, since the device power consumption is 15uA.

The NST1001 has 2 pinout: DQ and GND. The NST1001 powered with the 1-Wire pullup resistor via the DQ pin when the bus is high. The high bus signal also charges an internal capacitor, which then supplies power to the device when the bus is low. A simple the microcontroller can process properly through a GPIO pin. The temperature can be determined by gating a simple counter on for a specific time interval to count the total number of output pulses. After power is first applied to the device, the NST1001 is start to temperature conversion. When the temperature is determined, the pulse train begins. Then the NST1001 will send the temperature pluse every 50ms.

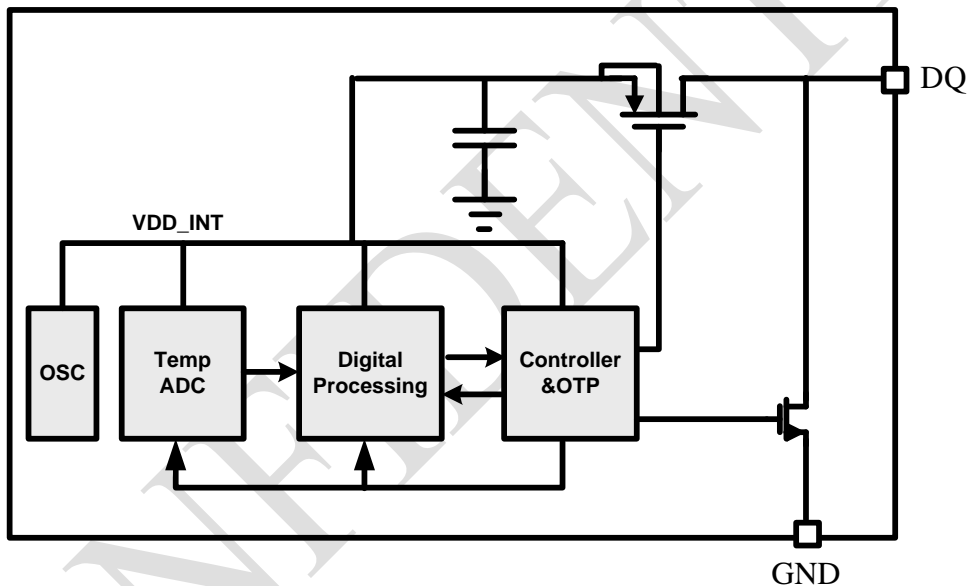


Figure 4.1 NST1001Functional Block Diagram

4.2. Feature Description

The NST1001 provides a digital output in the form of a pulse count that is transmitted by a train of pulses. when power up, the device start to temperature conversion and send the temperature pluse repeatly. The pulse train total time interval is at maximum 50 ms, including about 24ms the conversion period and 26ms send temperature pluse period. The power consumption is 30uA in conversion period and 1 uA in send temperature pluse period. The NST1001 output pluse diagram is shown in figure 4.2 and figure 4.3. Note: The second temperature data is not send out in order to let one time temperature conversion apply more easily.

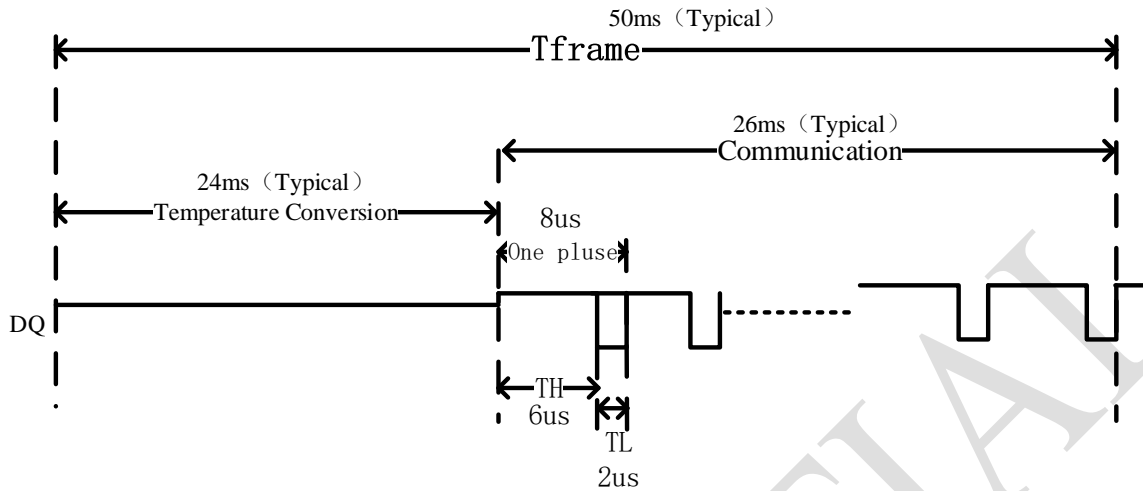


Figure 4.2 One pluse

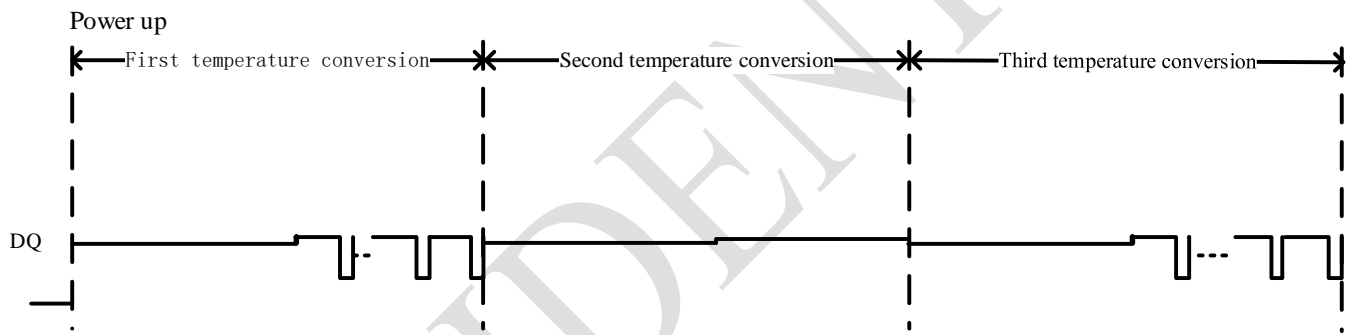


Figure 4.3 Multle Temperature conversions

4.3. Output Transfer Function

The NST1001 outputs at minimum 1 pulse and a theoretical maximum 3201 pulses. Each pulse has a weight of 0.0625 °C. One pulse corresponds to a temperature less than -50 °C while a pulse count of 3201 corresponds to a temperature greater than 150 °C. Note that the NST1001 is only ensured to operate up to 150 °C. Exceeding this temperature by may damage the device. The output transfer function appears to be linear and can be approximated by Equation 4.1:

$$Temp = Num * 0.0625^{\circ}C - 50.0625^{\circ}C, \quad (4.1)$$

Where

Temp is the temperature reading

Num the Pulse Count (1 ~ 3201) ;

Table 4-1 Shows some sample calculations using Equation 4.1.

Temperature (°C)	NUMBER OF PULSES
-50	1
-40	161
-20	481
0	801
30	1281
50	1601
100	2401
150	3201

In order to get the better temperature accuracy and eliminate the temperature error, the modifier formula is show as below (Equation 4.2).

$$\begin{aligned}
 T &= Temp + (Temp - 30) * 0.005 & Temp < 30^{\circ}\text{C}; \\
 T &= Temp & 30 \leq Temp \leq 100^{\circ}\text{C}; \\
 T &= Temp + (100 - Temp) * 0.012 & 100 < Temp < 150^{\circ}\text{C};
 \end{aligned}
 \tag{4.2}$$

Where the *Temp* is the initial temperature which come from equation 4.1. Using the equation 4.2, the better temperature accuracy is obtained as shown in Figure 3.2.

5.0 TYPICAL APPLICATION

The NST1001 works in parasite power mode, Power is instead supplied through the 1-Wire pullup resistor via the DQ pin when the bus is high. The high bus signal also charges an internal capacitor, which then supplies power to the device when the bus is low. The output pulse of the device can be read with a GPIO, the MCU will count the pluse number and then Convert to temperature.

5.1. Single GPIO application

As shown in figure 5.1, the pinout DQ connect to GPIO and also connect to VDD with pull up resistor R_{pu} . The output pulse of the device can be read with a GPIO, the MCU will count the pluse number. There is only 1 GPIO needed in this application, saving the GPIO resource in the system. NST1001 will pull down if DQ pull down the GPIO more than 5ms.

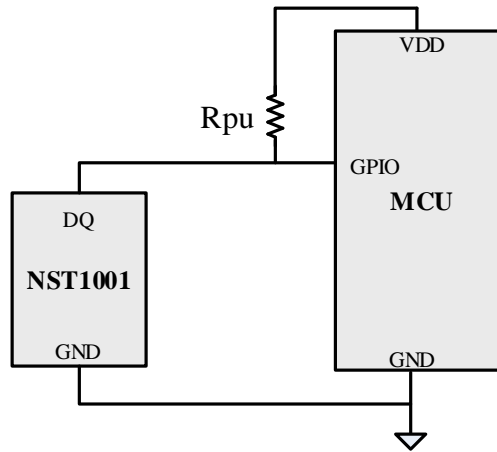


Figure 5.1 Single GPIO application

Table 5-1 Design parameter

Design parameter	Value
Rpu	0.5 KΩ~10KΩ
VDD	1.65V~5.5V
Microcontroller	Interrupt resource

Note: the NST1001 max Operation temperature is 30 uA (typical), and the min Operation voltage will be effected by pull up resistor Rpu .For example, the min Operation voltage is 1.65V while the Rpu =5 K Ω .

5.2. No power consumption in standby mode application

There are 2 GPIO needed in this application in order to achieve the no power consumption in standby mode. As shown in figure 5.3, the DQ pin connected to GPIO2 and connects to GPIO1 with pull up resistor Rpu. The GPIO1 will set to high, and provide the power though the pull up resistor Rpu as VDD. The GPIO2 set to input mode and count the pluse number and then convert to temperature. If the temperature is calculated, and pulls down the GPIO1, there is no power consumption in standby mode.

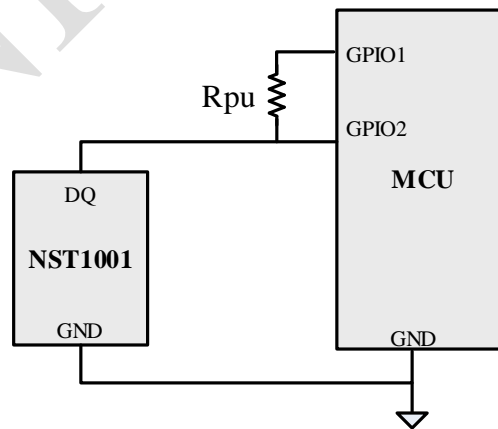


Figure 5.2 No power consumption in standby mode application

5.3. Pull down resistor application

As shown in Figure 5.3, the DQ Pin connected to GPIO1 or VDD, the GND Pin connect to GPIO2 and also connect to GND with pull down resistor R_{pd} like most NTC resistor temperature sensor application. In the traditional NTC temperature measure application, there is no external circuit modify just replace the NST1001 as NTC resistor.

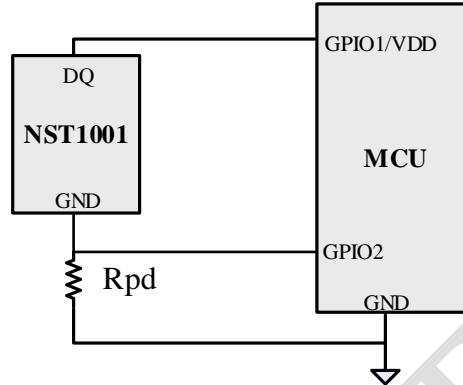


Figure 5.3 Pull down resistor application

5.4. Multicast temperature gathering application

As show in figure 5.4, multiple nst1001 device DQ pinout connect to GPIO0 together and share the pull up resistor R_{pu} . Pull down one of the GPIO (GPIO1~GPIO n) to measure the temperature, and the set the other GPIO (GPIO1~GPIO n) to high impedance state. Note: Cann't pull down 2 GPIO (GPIO1~GPIO n) at the same time.

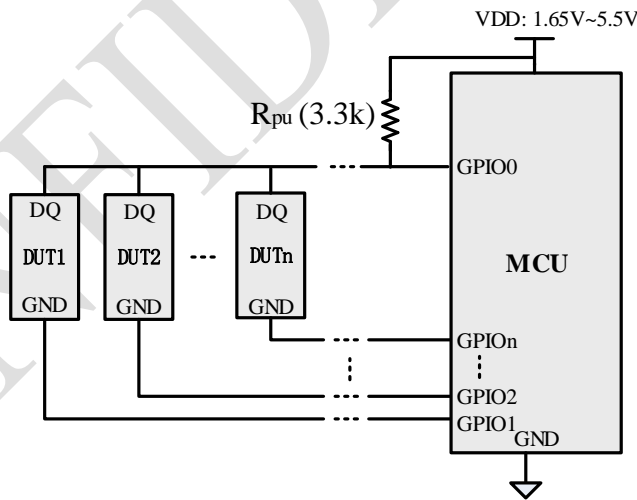


Figure 5.4 Multicast temperature gathering application

5.5. Isolation temperature gathering application

As shown in figure 5.5, the NST1001 device can work together with NSi8121 which also provide by Novosense for isolation temperature gathering application.

NST1001

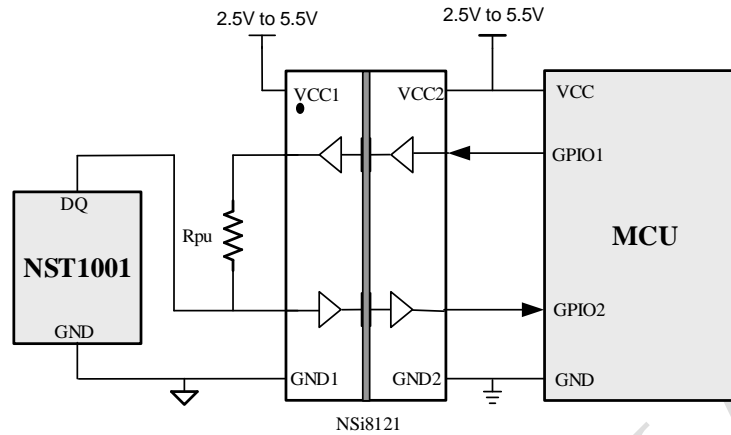


Figure 5.5 Isolation temperature gathering application

6.0 PACKAGE INFORMATION

6.1. To-92S package

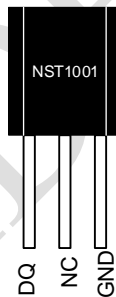
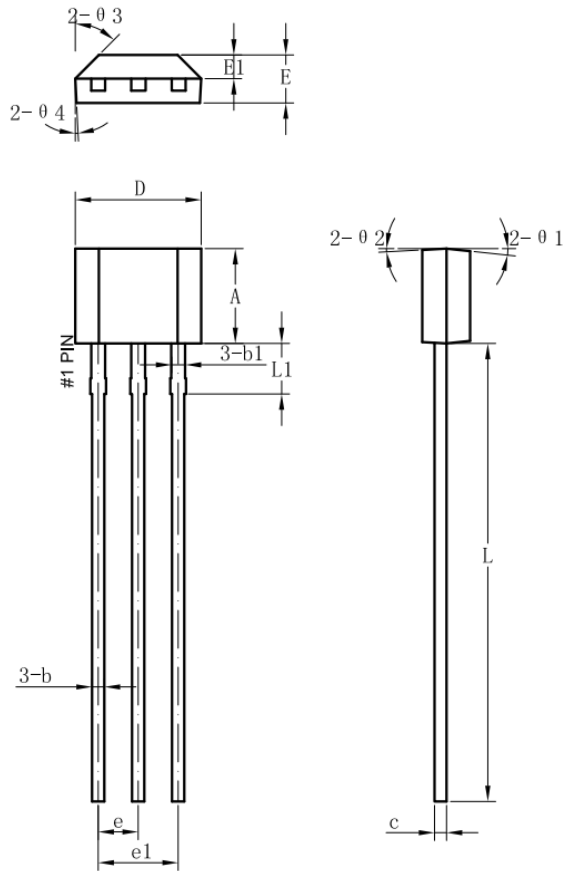


Table 6.1 To-92S Pin function

Pinout		Type	Description
Name	NO.		
DQ	1	I/O	Supply and digital IO
NC	2	NC	Floating (Cann't connect to GND)
GND	3	GND	GND

NST1001



SYMBOL	SIZE /mm		
	Min	Typ	Max
A	2.9	3.0	3.1
b	0.35	0.39	0.56
b1		0.44	
c	0.36	0.38	0.51
D	3.9	4.0	4.1
E	1.42	1.52	1.62
E1		0.75	
e		1.27	
e1		2.54	
L	13.5	14.5	15.5
L1		1.6	
0 1		6°	
0 2		3°	
0 3		45°	
0 4		3°	

6.2. DFN2L package

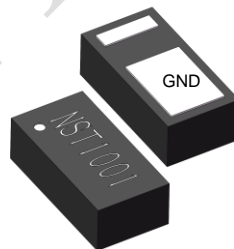
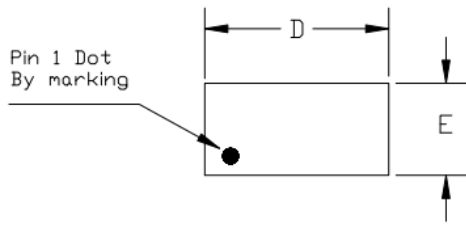


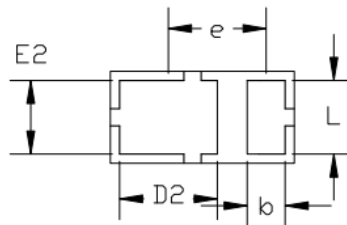
Table 6.2 DFN2L Pin function

Pinout	Type	Description
Name	NO.	
DQ	1	I/O Supply and digital IO
GND	2	GND (widely pad)

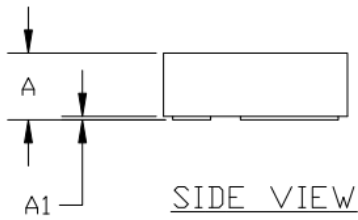
NST1001



TOP VIEW



BOTTOM VIEW



SIDE VIEW

PKG. REF.	COMMON DIMENSIONS(MM)		
	MIN.	NOM.	MAX.
A	0.40	0.45	0.50
A1	0.00	-	0.05
A3	0.125 REF.		
D	1.55	1.60	1.65
E	0.75	0.80	0.85
D2	0.75	0.85	0.95
E2	0.54	0.64	0.74
L	0.54	0.64	0.74
b	0.28	0.33	0.41
e	0.85 BSC		

CONFIDENTIAL

NST1001

7.0 ORDER INFORMATION

Type	Unit	Description
NST1001-QDNR	3000ea/Reel	DFN2L package
NST1001-QTOR	3000ea/Reel	TO-92S package

8.0 REVISION HISTORY

Revision	Description	Date
0.0	Initial Version	2018/6/7
0.1	Initial release Version	2018/9/10
1.1	MP Version	2018/12/17

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