

### Product Overview

NSM2013-Q1 is an integrated path current sensor with a very low on-resistance of 0.85mΩ, reducing heat loss on the chip.

NOVOSENSE innovative isolation technology and signal conditioning design can meet high isolation levels while sensing the current flowing through the internal Busbar. A differential Hall pair is used internally, so it has a strong immunity to external stray magnetic fields.

NSM2013-Q1 senses the magnetic field generated by the Busbar current flowing under the chip to indirectly detect the current. Compared with the current sampling method of the Shunt+ isolated op-amp, NSM2013-Q1 eliminates the need for the primary side power supply and has a simple and convenient layout. At the same time, it has extremely high isolation withstand voltage and Lifetime stability.

In high-side current monitoring applications, NSM2013-Q1 can reach a working voltage of 1550Vpk, and it can withstand 10kV surge voltage and 13kA surge current without adding any protection devices.

The NSM2013-Q1 has a pseudo-differential output mode (fixed output) with a fixed sensitivity that does not vary with the supply voltage, eliminating LDO on the system, making BOM simpler.

Due to NSM2013-Q1 internal accurate temperature compensation algorithm and factory accuracy calibration, this current sensor can maintain good accuracy in the full temperature working range, and the customer does not need to do secondary programming or calibration.

Support 3.3V/5V power supply (different version)

### Key Features

- High bandwidth and fast response time
- 240kHz bandwidth
- 2.2μs response time
- High-precision current measurement
- Differential Hall sets can immune stray field
- High isolation level that meets UL standards

- Maximum repeated isolation withstand voltage (VIROM): 1550Vpk
- Maximum working isolation withstand voltage (VIOWM): 1097Vrms
- Withstand isolation voltage (VISO): 5000Vrms
- Maximum surge isolation withstand voltage (VIOSM): 10kV
- Maximum surge current (Isurge): 13kA
- CMTI > 100V/ns
- CTI (I)
- Creepage distance/Clearance distance: 8mm
- NOVOSENSE innovative 'Spin Current' technology makes offset temperature drift very small
- Fixed output with Vref
- Working temperature: -40°C ~ 125°C
- Primary internal resistance: 0.85mΩ
- Wide body SOIC16 (SOW16) package
- UL62368/EN62368 safety certification
- ROHS compliance
- AEC-Q100 Grade1



Certificate Number:  
CBS 112807 0002 Rev.00  
B 112807 0001 Rev.00



Certificate Number: E520654

### Applications

- Solar system
- Industrial power supply
- Motor control
- OBC/DCDC/PTC Heater
- Charging pile

### Device Information

Part Number	Package	Body Size
NSM2013-Q1	SOW16 (WB)	10.30mm × 7.50mm

### Functional Block Diagrams

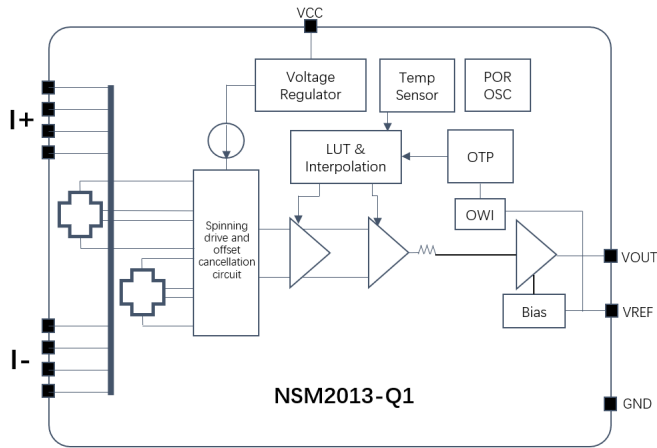


Figure 1. NSM2013-Q1 Block Diagram

## INDEX

1. PIN CONFIGURATION AND FUNCTIONS .....	4
2. ABSOLUTE MAXIMUM RATINGS .....	5
3. ESD RATINGS .....	5
4. ISOLATION CHARACTERISTICS .....	5
5. SPECIFICATIONS .....	6
5.1. COMMON CHARACTERISTICS (TA= -40°C TO 125°C, VCC = 5VOR3.3V, UNLESS OTHERWISE SPECIFIED) .....	6
5.2. NSM2013-65B3F-Q1SWR CHARACTERISTICS (TA= -40°C TO 125°C, VCC = 3.3V, UNLESS OTHERWISE SPECIFIED) .....	7
5.3. NSM2013-Q1 POWER-ON TIME WAVE .....	8
5.4. NSM2013-Q1 RISE TIME AND RESPONSE TIME WAVE.....	9
6. FUNCTION DESCRIPTION .....	10
6.1. OVERVIEW .....	10
6.2. NSM2013-Q1 F VERSION(FIXED OUTPUT) .....	10
6.3. DEFINITION OF NSM2013-Q1 TERMS .....	10
7. APPLICATION NOTE .....	13
7.1. TYPICAL APPLICATION CIRCUIT .....	13
7.2. PCB LAYOUT .....	13
7.3. THERMAL EVALUATION.....	13
8. PACKAGE INFORMATION .....	15
9. ORDER INFORMATION .....	16
10. TAPE AND REEL INFORMATION .....	17
11. REVISION HISTORY .....	19

## 1. Pin Configuration and Functions

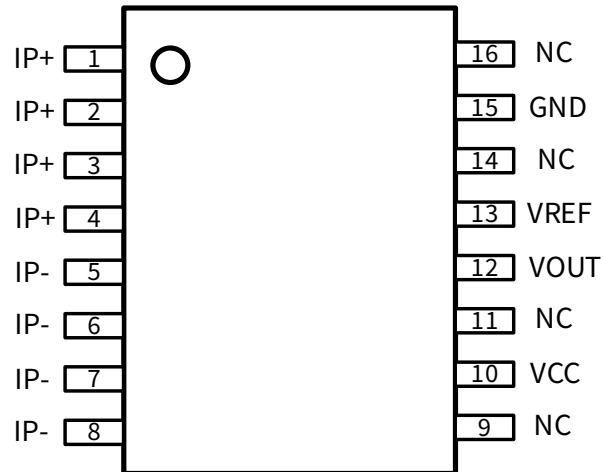


Figure 1.1 NSM2013-Q1 Package

Table 1.1 NSM2013-Q1 Pin Configuration and Description

<b>NSM2013-Q1 PIN NO.</b>	<b>Symbol</b>	<b>Function</b>
1-4	IP+	Current flows into the chip, positive direction
5-8	IP-	Current flows out of the chip, negative direction
9	NC	Not connection (Internal circuit connection, recommend NC)
10	VCC	Power supply
11	NC	Not connection (Internal circuit connection, recommend NC)
12	VOUT	Output voltage
13	VREF	Reference voltage (for "R" version, this Pin can connection to GND)
14	NC	Not connection (Internal circuit connection, this Pin can also connect to GND)
15	GND	Ground
16	NC	Not connection (Internal circuit connection, this Pin can also connect to GND)

## 2. Absolute Maximum Ratings

Parameters	Symbol	Min	Typ	Max	Unit	Comments
V <sub>cc</sub>	V <sub>CC</sub>	-0.3		6.5	V	
V <sub>out</sub> /V <sub>ref</sub>		-0.3		V <sub>DD</sub> +0.3	V	
Other Pins		-0.3		V <sub>DD</sub> +0.3	V	
Storage Temperature	T <sub>Storage</sub>	-40		150	°C	
Ambient Temperature	T <sub>operation</sub>	-40		125	°C	
Junction Temperature	T <sub>j</sub>	-40		150	°C	

## 3. ESD Ratings

Ratings		Value	Unit
Electrostatic discharge	Human body model (HBM), per AEC-Q100-002-RevD ● All pins	±8	kV
	Charged device model (CDM), per AEC-Q100-011-RevB ● All pins	±2	kV

## 4. Isolation Characteristics

Parameters	Symbol	Rating	Unit	Comments
Surge Voltage	V <sub>surge</sub>	10	kV	Based on IEC61000-4-5 1.2μs /50μs waveform
Surge Current	I <sub>surge</sub>	13	kA	Based on IEC61000-4-5 8μs /20μs waveform
Dielectric Strength Test Voltage	V <sub>ISO</sub>	5000	V <sub>rms</sub>	60s isolation voltage parameters, according to UL62368-1, 6kV/ 1s insulation performance will be tested before delivery, and partial discharge is verified to be less than 5pC
Working Voltage for Basic Isolation	V <sub>WVBI</sub>	1097	V <sub>rms</sub>	Maximum approved working voltage for basic isolation according to UL60950-1 and UL62368-1
		1550	V <sub>dc</sub>	
Common-mode transient immunity	CMTI	>100	V/ns	The criterion for judging the failure is that the output peak is greater than 100mV and the duration is longer than 1μs
Creepage	Creepage	8	mm	Minimum Creepage
Clearance	Clearance	8	mm	Minimum Clearance
Comparative Tracking Index	CTI	>=600		CTI I

## 5. Specifications

### 5.1. Common Characteristics (TA= -40°C to 125°C, VCC = 5V or 3.3V, unless otherwise specified)

Parameters	Symbol	Min	Typ	Max	Unit	Comments
Supply Voltage	V <sub>CC</sub>	3	3.3	3.6	V	3.3V version
		4.5	5	5.5	V	5V version
Supply Current	I <sub>CC</sub>		12	15	mA	No load, V <sub>CC</sub> =5V, 'F' version
Primary Conductor Resistance	R <sub>P</sub>		0.85		mΩ	TA = 25°C
Power-On Time	T <sub>po</sub>		1		ms	Recommend customer to read output after 1ms power-on time, before 1ms internal OTP is loading, TA = 25°C
Output Capacitance Load <sup>[1][2]</sup>	C <sub>L</sub>			10	nF	
Output Resistance Load <sup>[1][2]</sup>	R <sub>L</sub>	10			kΩ	
Output Short Current	I <sub>short_Vout</sub>		±25		mA	V <sub>out</sub> is short to V <sub>CC</sub> and short to GND, TA = 25°C
Reference Short Current	I <sub>short_Vref</sub>		±25		mA	V <sub>ref</sub> is short to V <sub>CC</sub> and short to GND, TA = 25°C
Rail To Rail Output Voltage <sup>[1][2]</sup>	V <sub>s</sub>	0.1		V <sub>CC</sub> -0.1	V	TA = 25°C, C <sub>L</sub> =1nF, R <sub>L</sub> =10k to V <sub>CC</sub> or GND
Common Mode Field Rejection <sup>[1][2]</sup>	CMFR		>40		dB	
Power Supply Rejection Ratio	PSRR		-50		dB	DC to 1 kHz, 100 mV pk-pk ripple around V <sub>CC</sub> =5V, I <sub>P</sub> =0A
Rise Time <sup>[1][2]</sup>	T <sub>r</sub>		1.2		μs	V <sub>out</sub> =3V, TA = 25°C, C <sub>L</sub> =1nF, V <sub>CC</sub> =5V, 30AB
Propagation Delay <sup>[1][2]</sup>	T <sub>pd</sub>		1.2		μs	V <sub>out</sub> =3V, TA = 25°C, C <sub>L</sub> =1nF, V <sub>CC</sub> =5V, 30AB
Response Time <sup>[1][2]</sup>	T <sub>response</sub>		2.2	3	μs	V <sub>out</sub> =3V, TA = 25°C, C <sub>L</sub> =1nF, V <sub>CC</sub> =5V, 30AB
Bandwidth <sup>[1][2]</sup>	BW		240		kHz	-3dB bandwidth, TA = 25°C, C <sub>L</sub> =1nF, V <sub>CC</sub> =5V, 30AB
Noise Density <sup>[1][2]</sup>	ND		260		uArms/√Hz	TA = 25°C, C <sub>L</sub> =1nF, V <sub>CC</sub> = 5V
			370		uArms/√Hz	TA = 25°C, C <sub>L</sub> =1nF, V <sub>CC</sub> = 3.3V
Non-Linearity	E <sub>NL</sub>		±0.2		%	
Reference Voltage	V <sub>ref</sub>	2.49	2.5	2.51	V	FB Version, V <sub>CC</sub> =5V
		1.64	1.65	1.66	V	FB Version, V <sub>CC</sub> =3.3V

Parameters	Symbol	Min	Typ	Max	Unit	Comments
		0.49	0.5	0.51	V	FU Version, Vcc=5V
		0.32	0.33	0.34	V	FU Version, Vcc=3.3V

[1]: Guaranteed by design.

[2]: Guaranteed by Bench Validation.

[3]: The increase or decrease of data in 5.X will not send a PCN to the customer if the evaluation does not affect the customer's use.

## 5.2. NSM2013-65B3F-Q1SWR Characteristics (TA= -40°C to 125°C, VCC = 3.3V, unless otherwise specified)

Parameters	Symbol	Min	Typ	Max	Unit	Comments
Current Sensing Range	I <sub>pr</sub>	-65		65	A	
Sensitivity	Sens		20.3		mV/A	I <sub>prmin</sub> <I <sub>pr</sub> <I <sub>prmax</sub>
Zero Current Output Voltage	VQVO		2.5		V	I <sub>pr</sub> =0A
Sensitivity Error <sup>[1][2]</sup>	E <sub>sens</sub>	-2		2	%	TA = 25°C~125°C
		-2		2	%	TA = -40°C~25°C
Offset Error <sup>[2]</sup>	V <sub>OE</sub>	-10		10	mV	TA = 25°C~125°C, I <sub>pr</sub> =0A
		-10		10	mV	TA = -40°C~25°C, I <sub>pr</sub> =0A
Reference Error <sup>[2]</sup>	V <sub>RE</sub>	-10		10	mV	TA = 25°C~125°C, I <sub>pr</sub> =0A, Vref=1.65V
		-15		15	mV	TA = -40°C~25°C, I <sub>pr</sub> =0A, Vref=1.65V
Total Output Error <sup>[1]</sup>	E <sub>total</sub>	-2		2	%	TA = 25°C~125°C
		-2		2	%	TA = -40°C~25°C
Sensitivity Error Lifetime Drift <sup>[2][3]</sup>	E <sub>sens_drift</sub>	-2.5		2.5	%	After reliability test, TA = 25°C
Offset Lifetime Drift <sup>[2][3]</sup>	V <sub>OE_drift</sub>	-15		15	mV	After reliability test, TA = 25°C
Reference Lifetime Drift <sup>[2][3]</sup>	V <sub>RE_drift</sub>	-15		15	mV	After reliability test, TA = 25°C
Total Output Error Lifetime Drift <sup>[2][3]</sup>	E <sub>total_drift</sub>	-2.8		2.8	%	After reliability test, TA = 25°C

[1]: In production, total error and sensitivity error are measured and calculated at 30A, A single part will not have both the maximum/minimum sensitivity error and maximum/minimum offset voltage.

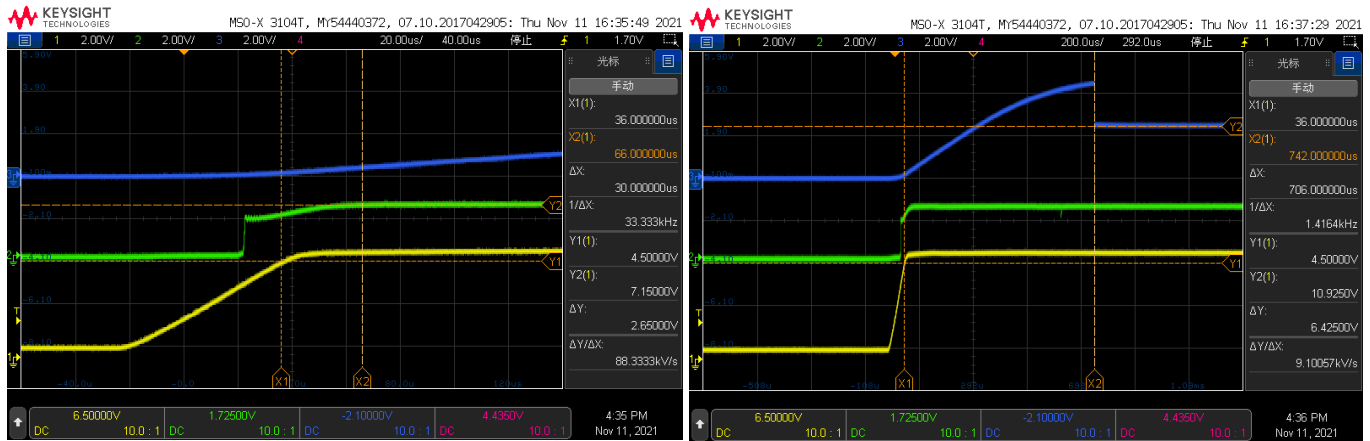
[2]: When TA = 25°C~125°C, Min/Max value is the mean value +/-3sigma; When TA = -40°C~25°C, Typical value is the mean value +/-3sigma. according to the statistical law, 99.73% of the data is in this range Inside.

[3]: The reliability data is implemented in accordance with the AEC-Q100 standard. This item is derived from the experimental results with the largest change after the PC, HTS, HAST, UHAST, HTOL, TC and other test data required by AEC-Q100 Grade1 as a reference, is the worst case.

\*In the chapter 5, the increase or decrease of the material number and the tightening of the parameter range, NOVOSENSE reserves the right not to send PCN to the customer, unless the expansion of the parameter range affects the customer's use and product performance.

### 5.3. NSM2013-Q1 Power-On Time Wave

Yellow: VCC、 Green: VOUT、 Blue: VREF, the output is not stable because OTP loading is not finished. The maximum OTP loading time is 1ms. Recommend customer to read output after 1ms power-on time.



(a) VOUT detail

(b) VREF detail

Figure 5.1 NSM2013-Q1 Power-on time waveform

If the customer wants the waveform of VOUT and VREF follow the VCC waveform during power-on time, a 10kΩ resistance can be connected between VOUT pin and VREF pin.

Yellow: VCC、 Green: VOUT、 Blue: VREF



(a) VOUT detail

(b) VREF detail

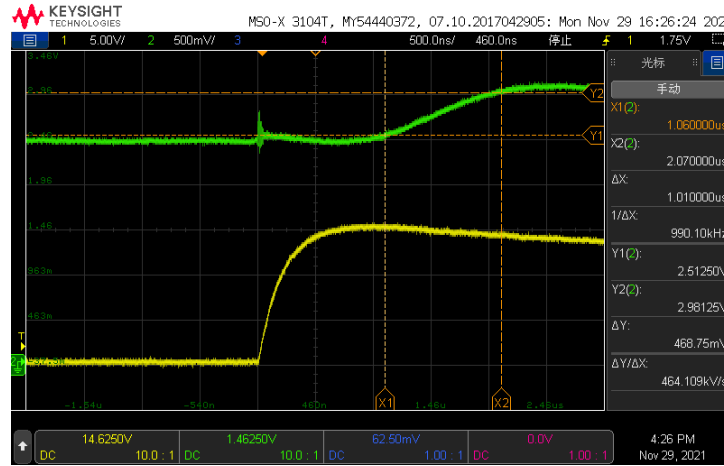
Figure 5.2 NSM2013-Q1 Power-on time wave (10kΩ Resistance connected between VOUT and VREF)

**Note:** The above waveform DUT is NSM2013-50B5F-Q1SWR

### 5.4. NSM2013-Q1 Rise Time and Response Time Wave

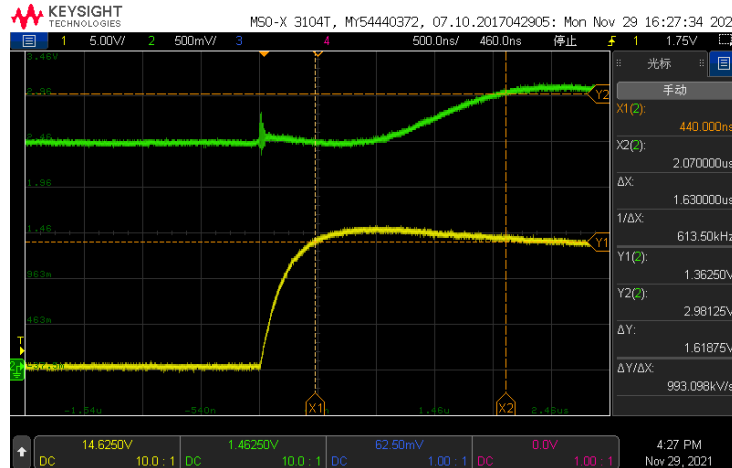
(1) Rise time

Yellow: primary current, Green: VOUT



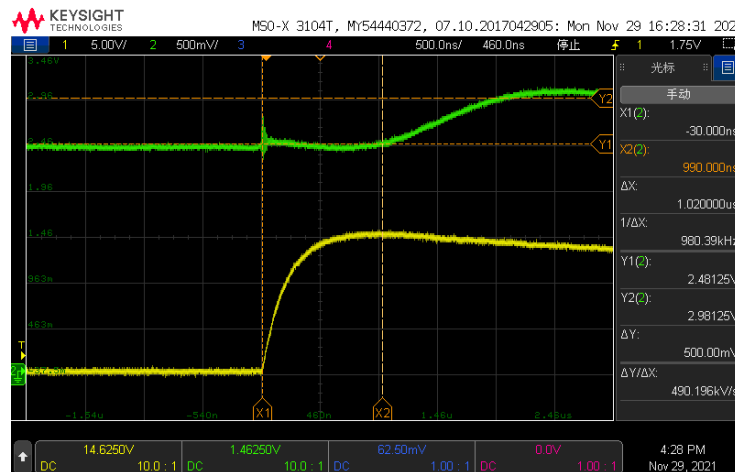
(2) Response time

Yellow: primary current, Green: VOUT



(3) Propagation Delay time

Yellow: primary current, Green: VOUT



Note: The above waveform DUT is NSM2013-50B5F-Q1SWR

## 6. Function Description

### 6.1. Overview

NSM2013-Q1 current sensor can accurately measure AC/DC current while minimizing the overall measurement cost. Current sensors based on the Hall principle can be widely used in all current monitoring applications such as consumer, industry, and automotive. Compared with current transformers, the extremely small size of NSM2013-Q1 SOW16 can help customers reduce the overall PCB area; compared to Shunt+isolated op amps, NSM2013-Q1 only needs low-voltage side power supply, reducing the inconvenience of isolated op amps requiring power supply for both high side and low side. When using NSM2013-Q1, you only need to string the primary side pin into the measured current. According to the part of Maxwell equations about electricity and magnetism, a magnetic field will be generated around the energized conductor of the primary side. The Hall and conditioning amplifier circuits in NSM2013-Q1 will convert magnetic field into an output voltage, and the output voltage increases or decreases in proportion to the input current.

Benefiting from the typical value of the primary resistance of NSM2013-Q1 is only 0.85mohm, as long as the customer conducts a reasonable heat dissipation design, the temperature rise brought by the measurement of large current can be effectively reduced.

At the same time, NSM2013-Q1 uses dual Hall sampling internally, the common mode magnetic field brought by the outside world can be effectively reduced. According to the measured typical value, if the 100G common mode magnetic field acts vertically on the chip, it will only bring an error of less than 1G in the output. (Equivalent to input). Because NSM2013-Q1 has a good ability to resist common-mode magnetic fields, it can still maintain excellent performance in motor control or some harsh current measurement environments.

### 6.2. NSM2013-Q1 F Version(Fixed Output)

In some applications, the ADC and the current sensor do not share a power rail, so the sensor needs to have absolute sensitivity that does not vary with the power supply voltage. The value of the sensing current can be obtained by  $(v_{out}-v_{ref})/Sensitivity$ . For  $\pm 50A$  measurement range, if  $V_{out}$  measures 3.7V and  $V_{REF}$  measures 2.5V, then the input current is  $(3.7V-2.5V)/40mV/A=30A$ . In practical applications,  $V_{out}$  and  $V_{REF}$  can be directly collected by differential ADC to obtain input current, and the measurement accuracy will not be affected by power supply changes.

### 6.3. Definition of NSM2013-Q1 Terms

#### Power-on time ( $T_{po}$ )

When the power supply climbs from 0 to the chip's working range, NSM2013-Q1 needs some time to establish the internal working logic.  $T_{po}$  time is defined as: the time from the power supply climbing to  $V_{ccmin}$  to the output reaching the steady state within  $\pm 10\%$ , As shown below:

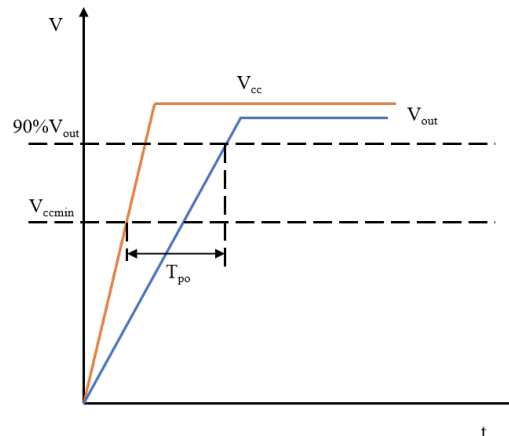


Figure 6.1 NSM2013-Q1 Power-on time

#### Rise Time ( $T_r$ )

The time from 10% to 90% of the output signal is defined as the output rise time. For step input signals, there is such an approximate relationship between the rise time and bandwidth of the output signal:  $f(-3dB) = 0.35/T_r$ .

#### Propagation Delay ( $T_{pd}$ )

The time from 20% of the primary current to 20% of the output signal is defined as the output propagation delay time.

**Response Time (Tresponse)**

The time from 90% of the primary current to 90% of the output signal is defined as the output response time.

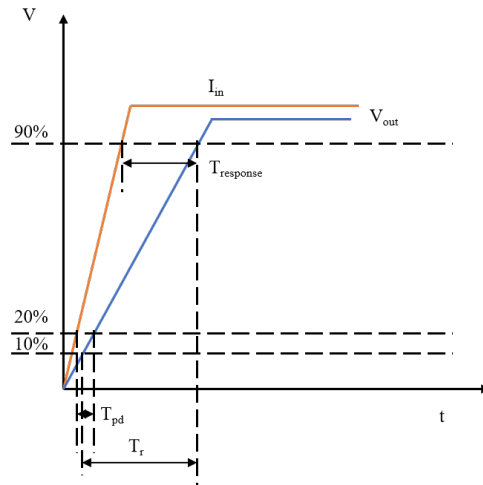


Figure 6.2 NSM2013-Q1 response time

**Sensitivity and Sensitivity Error**

Sensitivity is defined as the ratio of the output voltage proportional to the primary input current. Sensitivity is the slope of the curve in the figure below.

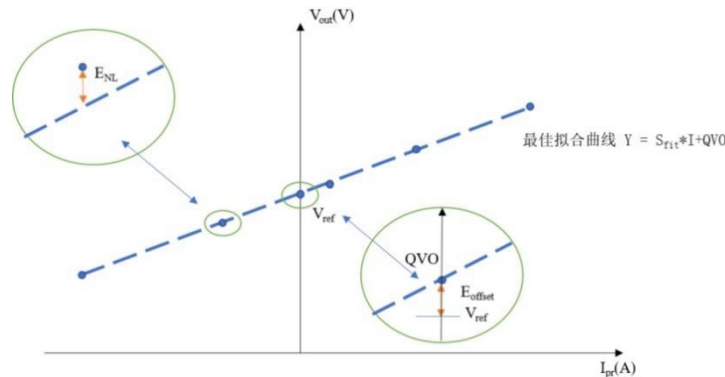


Figure 6.3 NSM2013-Q1 Sensitivity and error

The sensitivity error is defined as the deviation between the slope of the best-fit curve and the slope of the ideal curve. The slope of the best-fit curve comes from the measured value:

$$E_{sens} = \frac{(S_{fit} - S_{ideal})}{S_{ideal}} * 100\%$$

**Offset Error**

The zero current output error is defined as the difference between the output voltage curve and the reference voltage when the primary current is 0A, V\_ref here is VCC/2 or 0.1\*VCC (F version):

$$E_{offset} = QVO - V_{ref}$$

**Non-linear Error**

The linearity error is defined as the error from the maximum deviation point of the best-fit curve to the full scale. The mathematical expression is as follows:

$$E_{NL} = \frac{V_{NL}}{FS} * 100\%$$

among them:

$$V_{NL} = V_{outmax} - (S_{fit} * I_{max} + QVO), V_{NL} \text{ is the output error of the maximum deviation point;}$$

$FS$  is Full scale of output voltage;

$V_{outmax}$  is the output voltage furthest from the fitted curve;

$I_{max}$  is the primary current furthest from the fitted curve;

#### **Total Error**

The total error is defined as the error between the actual given current and the current measured by the chip, in other words, the difference between the actual output voltage and the ideal output voltage. It should be known that in different current ranges, the factors that dominate the total error are different. If it is under low current measurement, the zero point error is the main source of error; if under high current measurement, the total error caused by the zero point error is very small, and the dominant error is the sensitivity error.

$$E_{total}(I_{pr}) = \frac{V_{outideal}(I_{pr}) - V_{out}(I_{pr})}{FS}$$

## 7. Application note

### 7.1. Typical Application Circuit

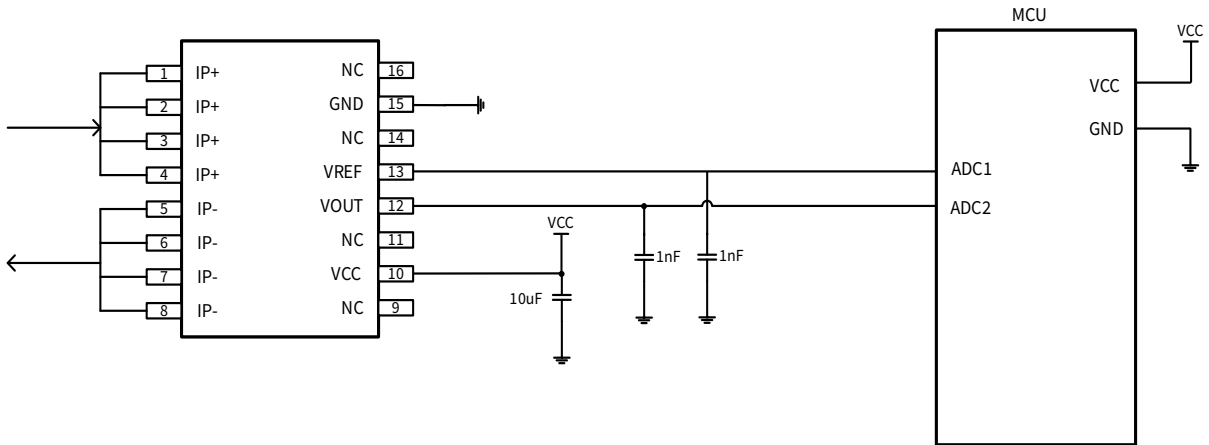


Figure 7.1 Typical application diagram of Fixed output mode

### 7.2. PCB Layout

For NSM2013-Q1 in high-current monitoring applications, a reasonable layout will make the system heat dissipation faster and better. The copper area on the NSM2013-Q1 Demo board is 21mm\*18mm (very small copper area is used to illustrate the worse situation, rather than a large copper area), the top layer and the bottom layer are 2oz copper thick. Under this layout, after 30 minutes, after the 35A current stabilizes, the surface temperature of the chip is as shown in the lower right picture. The highest point temperature is around 70°C. Foreign competitors can reach 90°C under the same layout. . The reason why NSM2013-Q1 is better than competitors for heat dissipation is due to the use of packaging materials with better heat dissipation coefficients and a copper frame with better heat dissipation coefficients. If customers want to achieve better heat dissipation, they can use multi-layer boards and thicken the copper thickness to achieve it, and can use active heat dissipation solutions in the system, such as adding heat sinks and fans. If you need to use the NSM2013-Q1 Demo board to evaluate the performance of this current sensor, please contact NOVOSENSE sales team for support.

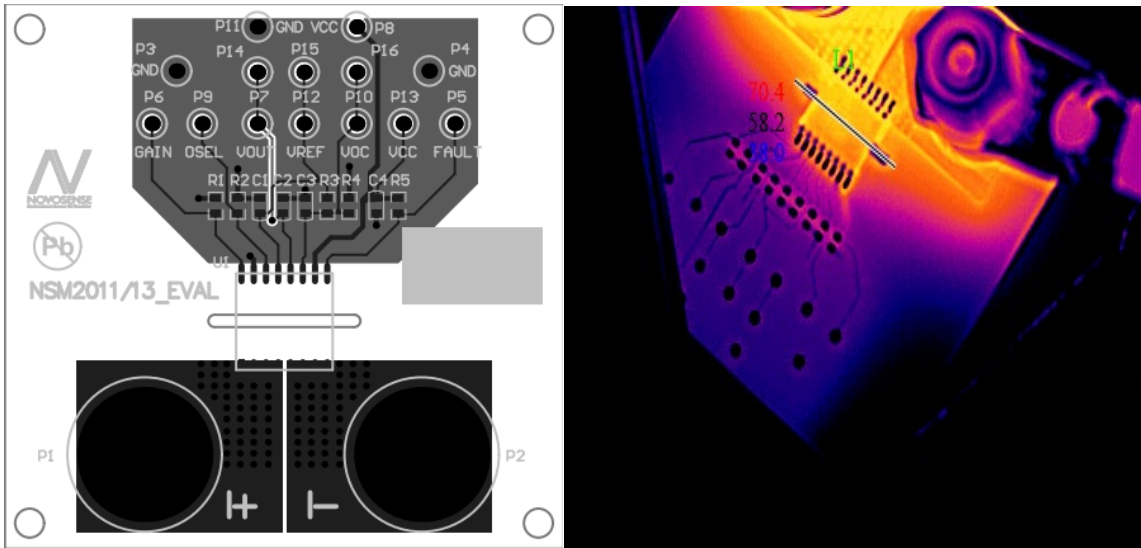


Figure 7.2 NSM2013-Q1 PCB Layout

### 7.3. Thermal Evaluation

The thermal evaluation experiment is tested at room temperature, which mainly illustrates the temperature rise of the NSM2013-Q1 current sensor under different currents. With these data and the above-mentioned layout guide, customers can design heat

dissipation according to actual application requirements. The ambient temperature in this experiment is room temperature. The surface is mounted on the above Demo board for temperature rise test. There is no external active heat dissipation device (such as a fan, etc.). The relationship between junction temperature and time is measured. 20 minutes of temperature data are collected. Under normal circumstances, the temperature rise It is basically fixed in about 10 minutes, and the specific test data are as follows:

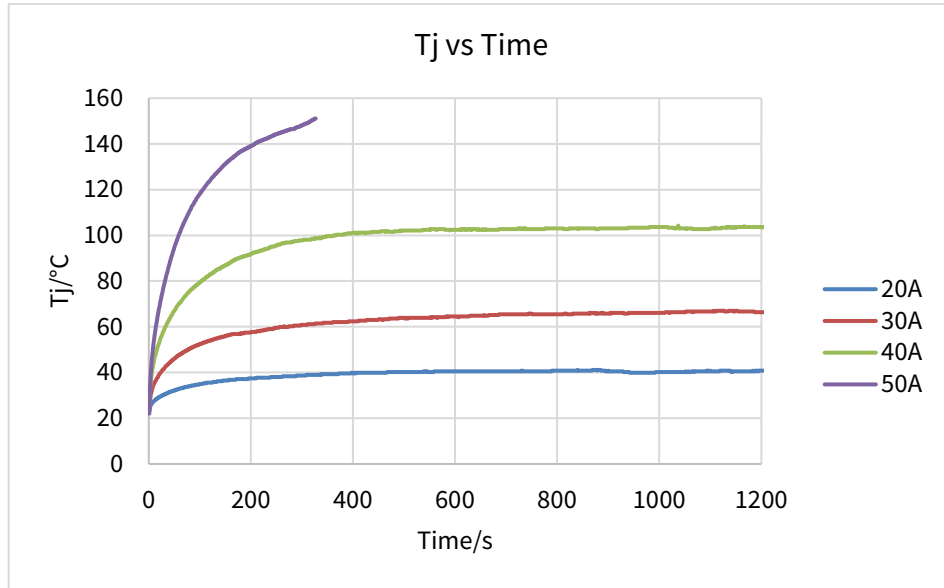


Figure 7.3 NSM2013-Q1 Junction temperature vs. Different continues current

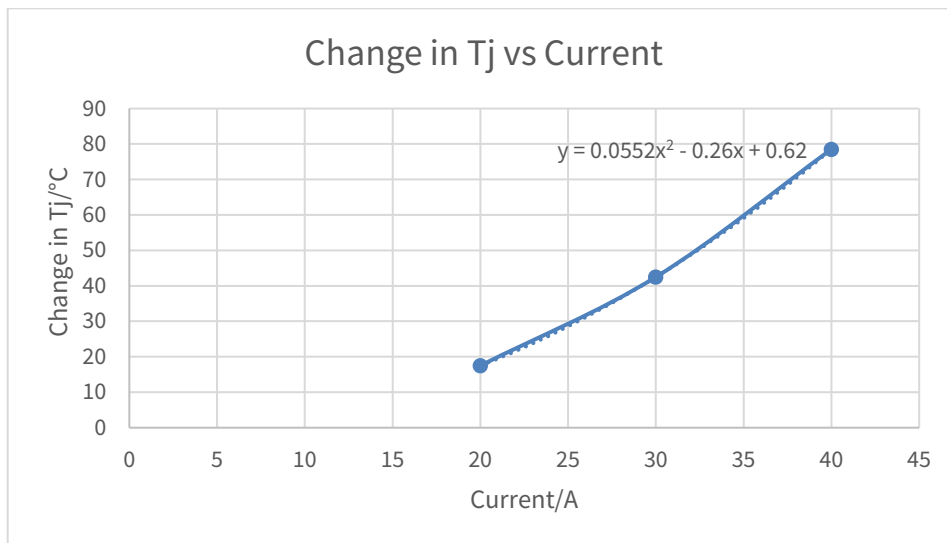


Figure 7.4 NSM2013-Q1 Estimation function of junction temperature at different currents (PCB is in worst case)

It is important to note that the above temperature rise experiment data is only based on the Demo board, in order to reflect the relationship between NSM2013-Q1 current and temperature in a worst case. Customers can reduce the temperature rise of Tj by increasing or thickening the copper area of the PCB, using multi-layer boards, or adding active heat dissipation devices such as fans (Tj<150°C). If customers compare NSM2013-Q1 with other competing products, please refer to the same PCB design instead of using specially designed PCB provided by competing products. NOVOSENSE can provide a 16-pin general-purpose Demo board for comparison of temperature rises of competing products.

### 8. Package Information

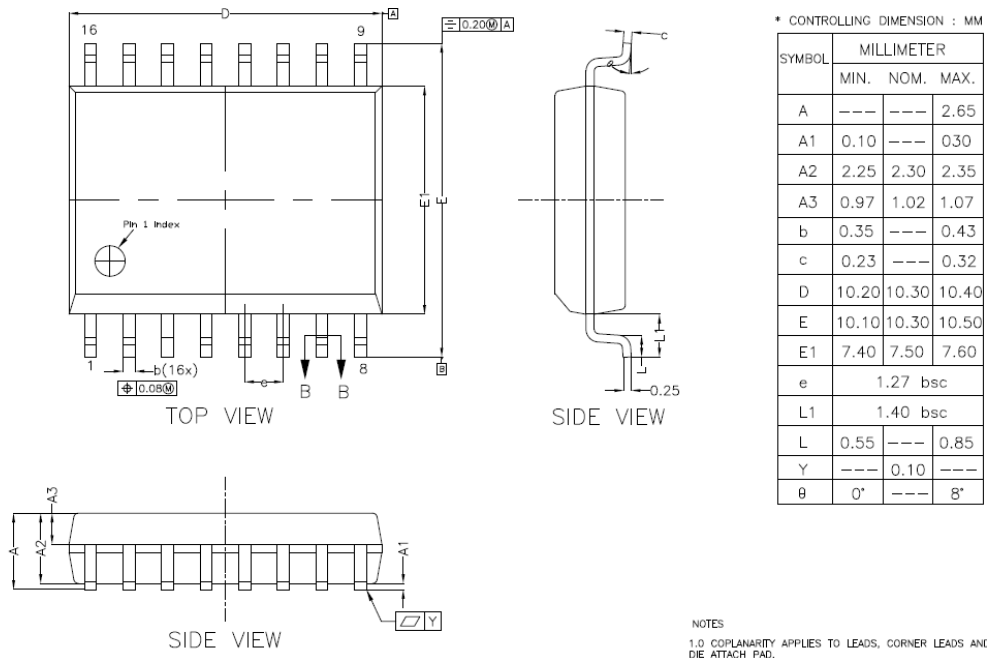


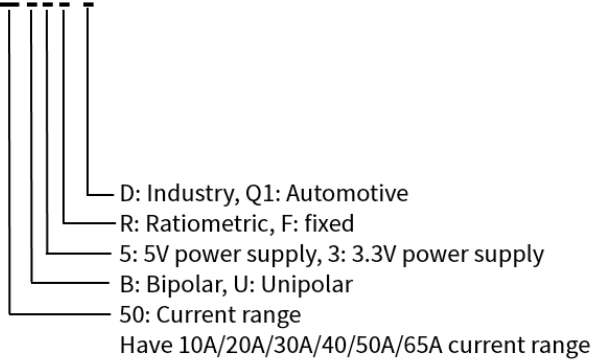
Figure 8.1 SOW16 Package Shape and Dimension in millimeters and (inches)

## 9. Order Information

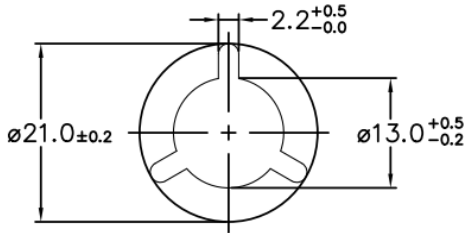
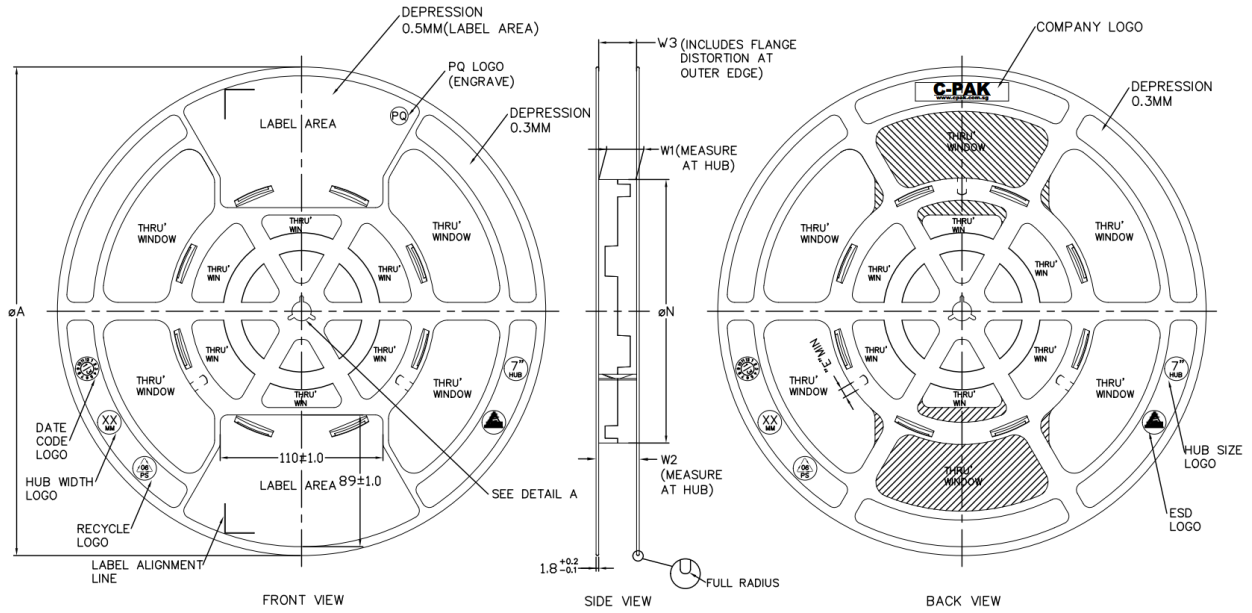
Part Number	Primary Current(A)	Power Supply(V)	Sensitivity(mV/A)	MSL	MPQ	Package
NSM2013-65B3F-Q1SWR	±65	3.3	20.3	3	1k	SOW16

**Naming Rules:**

**NSM2013-50B5F-DSWR**



### 10. Tape and Reel Information

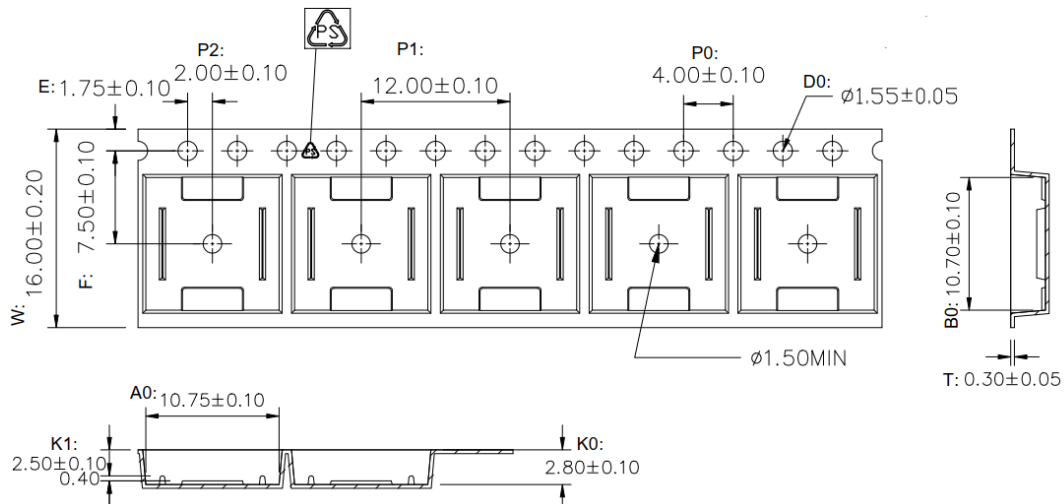


ARBOR HOLE  
DETAIL A  
SCALE : 3:1

PRODUCT SPECIFICATION						
TAPE WIDTH	$\phi A$ $\pm 2.0$	$\phi N$ $\pm 2.0$	W1	W2 (MAX)	W3	E (MIN)
08MM	330	178	$8.4^{+1.5}_{-0.0}$	14.4	SHALL ACCOMMODATE TAPE WIDTH WITHOUT INTERFERENCE	5.5
12MM	330	178	$12.4^{+2.0}_{-0.0}$	18.4		5.5
16MM	330	178	$16.4^{+2.0}_{-0.0}$	22.4		5.5
24MM	330	178	$24.4^{+2.0}_{-0.0}$	30.4		5.5
32MM	330	178	$32.4^{+2.0}_{-0.0}$	38.4		5.5

SURFACE RESISTIVITY			
LEGEND	SR RANGE	TYPE	COLOUR
A	BELOW $10^{12}$	ANTISTATIC	ALL TYPES
B	$10^9$ TO $10^{11}$	STATIC DISSIPATIVE	BLACK ONLY
C	$10^8$ & BELOW $10^8$	CONDUCTIVE (GENERIC)	BLACK ONLY
E	$10^9$ TO $10^{11}$	ANTISTATIC (COATED)	ALL TYPES

Note: MPQ(SOW16):1K



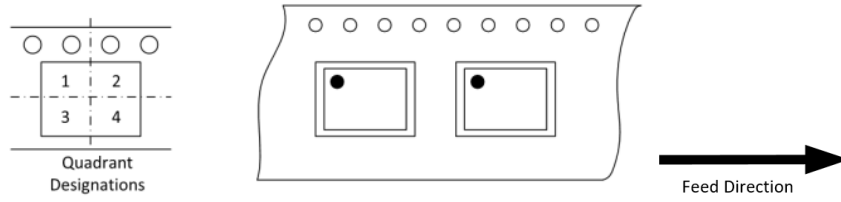


Figure 10.1 Tape and Reel Information of SOW16

## 11. Revision History

Revision	Description	Date
1.0	Released 1.0 Version.	2023/2/21
1.1	(a) Changed ESD description according to new template (b) Update part-number in chapter 5 and order information in chapter 9 (c) Add MPQ in order information (d) Delete the R version description	2024/8/21

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