

Product Overview

The NSI1611S02/04-Q1 is a high-performance isolated amplifier with output separated from input based on NOVOSENSE capacitive isolation technology, which provides the amplifier with exceptional resistance to magnetic interference.

The device accepts an input range from 0.01V to 2V(for NSI1611S02-Q1) or 0.01V to 4V(for NSI1611S04-Q1) and provides a single ended output which can help to reduce the external differential to single ended amplifier. The low offset and gain drift ensure the accuracy over the entire temperature range.

The NSI1611S02/04-Q1 features high input impedance, making it an ideal choice for applications where large resistive dividers are used or when connecting any high-impedance voltage signal source to the input.

The high common-mode transient immunity ensures that the device is able to provide accurate and reliable measurements even in the presence of high-power switching such as in motor control applications.

Key Features

- Up to 5700V_{rms} Insulation voltage
- Single-Ended Output, Fixed Gain:
 - NSI1611S02-Q1: Gain = 1V/V
 - NSI1611S04-Q1: Gain = 0.5V/V
- linear Input Voltage Range:
 - NSI1611S02-Q1: 0.01V to 2V
 - NSI1611S04-Q1: 0.01V to 4V
- Low Offset Error and Drift:
 - NSI1611S02-Q1: $\pm 0.8\text{mV}$ (Max), $\pm 35\mu\text{V}/^\circ\text{C}$ (Max)
 - NSI1611S04-Q1: $\pm 1.5\text{mV}$ (Max), $\pm 45\mu\text{V}/^\circ\text{C}$ (Max)
- Low Gain Error and Drift:
 - $\pm 0.25\%$ (Max), $\pm 35\text{ppm}/^\circ\text{C}$ (Max)
- Low Nonlinearity and Drift:
 - $\pm 0.04\%$ (Max), $\pm 1\text{ppm}/^\circ\text{C}$ (Typ)

- SNR: 82dB (Typ, BW=10kHz), 71dB (Typ, BW=100kHz)
- Wide bandwidth: 330kHz (Typ)
- High CMTI: 150kV/ μs (Typ)
- Operation Temperature: $-40^\circ\text{C} \sim 125^\circ\text{C}$
- AEC-Q100 Qualified for Automotive Applications
- RoHS-Compliant Packages: SOP8(300mil)

Safety Regulatory Approvals

- UL recognition: 5700V_{rms} for 1 minute per UL1577
- CQC certification per GB4943.1
- CSA component notice 5A
- DIN EN IEC 60747-17 (VDE 0884-17)

Applications

- Traction Inverters
- Onboard Chargers
- DC/DC inverters
- Battery Management Units

Device Information

Part Number	Package	Body Size
NSI1611S02-Q1SWVR	SOP8 (300mil)	5.85mm × 7.50mm
NSI1611S04-Q1SWVR	SOP8 (300mil)	5.85mm × 7.50mm

Functional Block Diagrams

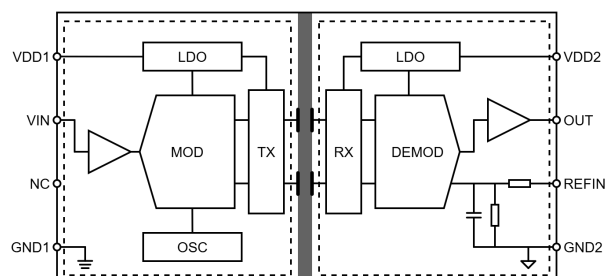


Figure 1. NSI1611S0x-Q1 Block Diagram

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1. Pin Configuration and Functions

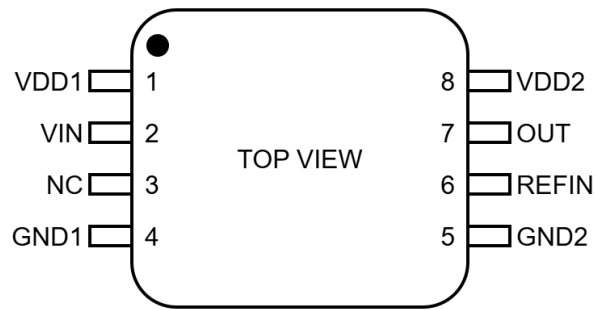


Figure 1.1 NSI1611S0x-Q1 Package(Not to scale)

Table 1.1 NSI1611S0x-Q1 Pin Configuration and Description

<i>NSI1611S0x-Q1 PIN NO.</i>	<i>SYMBOL</i>	<i>FUNCTION</i>
1	VDD1	Input side power supply
2	VIN	Single ended analog input
3	NC	Not internally connected, connecting to GND1 recommended
4	GND1	Input side ground
5	GND2	Output side ground
6	REFIN	Reference voltage input, connecting to GND2 recommended
7	OUT	Single-ended analog output
8	VDD2	Output side power supply

2. Absolute Maximum Ratings⁽¹⁾

Parameters	Symbol	Min	Typ	Max	Unit
Power Supply Voltage	VDDx to GNDx	-0.3		6.5	V
Analog Input Voltage	V _{IN}	GND-0.5		VDD1+0.5	V
Analog Output Voltage	OUT	GND-0.5		VDD2+0.5	V
Reference Input Voltage	REFIN	GND-0.5		VDD2+0.5	V
Input current per IO Pin	I _{IN}	-10		10	mA
Junction Temperature	T _J	-40		150	°C
Storage Temperature	T _{STG}	-55		150	°C

(1) The device cannot operate beyond the listed Absolute Maximum Ratings to prevent permanent device damage. The device is not fully functional if operating outside the Recommended Operating Conditions but within the Absolute Maximum Ratings. Long-time stress of the absolute maximum conditions may affect the device lifetime.

3. ESD Ratings ⁽¹⁾

Parameters	Test Condition	Value	Unit
Electrostatic discharge	Human body model (HBM), per AEC-Q100-002-RevD	±2.0	kV
	Charged device model (CDM), per AEC-Q100-011-RevB	±1.0	kV

(1) Though this device features proprietary protection circuitry, proper ESD precautions should be considered to avoid performance degradation or damage due to high energy ESD event. Charged devices and circuit boards may discharge without detection.

4. Recommended Operating Conditions

Parameters	Symbol	Min	Typ	Max	Unit
NSI1611S02-Q1					
Power supply voltage	VDD1 to GND1	3.0	5	5.5	V
	VDD2 to GND2	3.0	3.3	5.5	V
Maximum input voltage before clipping output	V _{Clipping}		2.15		V
Linear input full scale voltage	V _{FSR} ⁽¹⁾	0.01		2	V
Operating ambient temperature	T _A	-40		125	°C
NSI1611S04-Q1					
Power supply voltage	VDD1 to GND1	4.5	5	5.5	V
	VDD2 to GND2	3.0	3.3	5.5	V
Maximum input voltage before clipping output	V _{Clipping}		4.3		V
Linear input full scale voltage	V _{FSR} ⁽¹⁾	0.01		4	V
Operating ambient temperature	T _A	-40		125	°C

5. Thermal Information

<i>Parameters</i>	<i>Symbol</i>	<i>SOP8(300mil)</i>	<i>Unit</i>
Junction-to-ambient thermal resistance	$R_{\theta JA}$	86	°C/W
Junction-to-case (top) thermal resistance	$R_{\theta JC(top)}$	28	°C/W
Junction-to-board thermal resistance	$R_{\theta JB}$	42	°C/W
Junction-to-top characterization parameter	Ψ_{JT}	4	°C/W
Junction-to-board characterization parameter	Ψ_{JB}	42	°C/W

6. Specifications

6.1. Electrical Characteristics of NSI1611S02-Q1

(Minimum and maximum specifications apply across the following conditions: VDD1 = 3.0 ~ 5.5V, VDD2 = 3.0 ~ 5.5V, INP = 0.01V to 2V, REFIN = GND2 T_A = -40°C to 125°C. Unless otherwise noted, Typical values are measured at VDD1 = 5V, VDD2 = 3.3V, T_A = 25°C)

Parameters	Symbol	Min	Typ	Max	Unit	Comments
Power Supply						
Input side supply voltage	VDD1	3.0	5	5.5	V	
Input side supply current	IDD1		7.2	9	mA	
Output side supply voltage	VDD2	3.0	3.3	5.5	V	
Output side supply current	IDD2		4.7	6	mA	
Input side VDD undervoltage detection threshold voltage	VDD1 _{UV}	2.6	2.7	2.8	V	VDD1 rising threshold
		2.3	2.4	2.5	V	VDD1 falling threshold
Output side VDD undervoltage detection threshold voltage	VDD2 _{UV}	2.5	2.7	2.8	V	VDD2 rising threshold
		2.2	2.4	2.6	V	VDD2 falling threshold
Analog Input						
Input offset voltage	V _{OS}	-0.8	±0.2	0.8	mV	V _{IN} = 0.01V, at T _A = 25°C
Input offset drift ⁽¹⁾	TCV _{OS}	-35	±10	35	µV/°C	
Single-ended input resistance	R _{IN}		1		GΩ	
Input capacitance	C _I		5		pF	Single-ended input capacitance, f _{IN} =250kHz
Input bias current	I _{IIB}	-10	±2	10	nA	V _{IN} = GND1
REFIN input resistance	R _{REFIN}		100		kΩ	
Analog Output						
Nominal Gain	Gain		1		V/V	REFIN = GND2
Gain error	E _G	-0.25%	±0.05%	0.25%		at T _A = 25°C
Gain error thermal drift ⁽¹⁾	TCE _G	-35	±10	35	ppm/°C	
Nonlinearity		-0.04%	±0.01%	0.04%		
Nonlinearity drift ⁽¹⁾			±1		ppm/°C	
Total harmonic distortion ⁽³⁾	THD		-80		dB	V _{IN} = 0.01~2V _{pp} , f _{IN} = 10kHz, BW = 100kHz
Output noise			270		µV _{RMS}	V _{IN} = GNDI, BW = 100kHz
Signal to noise ratio	SNR		82		dB	V _{IN} = 0.01~2V _{pp} , f _{IN} = 1kHz, BW = 10kHz

Parameters	Symbol	Min	Typ	Max	Unit	Comments
	SNR		71		dB	$V_{IN} = 0.01 \sim 2V_{pp}$, $f_{IN} = 10kHz$, $BW = 100kHz$, 1MHz filter
Input clipping output voltage	$V_{clipout}$		2.15		V	$V_{IN} \geq V_{Clipping}$
Output bandwidth	BW		330		kHz	
Power supply rejection ratio (2) of VDD1	PSRR _{dc}		-90		dB	PSRR vs VDD1, from 3.0~5.5V at DC
	PSRR _{ac}		-80		dB	PSRR vs VDD1, 100mV and 10kHz ripple
Power supply rejection ratio (2) of VDD2	PSRR _{dc}		-90		dB	PSRR vs VDD2, from 3.0~5.5V at DC
	PSRR _{ac}		-76		dB	PSRR vs VDD2, 100mV and 10kHz ripple
Output resistance	R_{OUT}		0.2		Ω	
Swing to GND2	V_{swing}			10	mV	$V_{IN} = 0V$, $R_L = 10k\Omega$
Output limit current	I_{lim}		± 14		mA	
Common-mode transient immunity	CMTI	100	150		kV/ μs	Common-mode transient immunity
Timing						
Rising time of OUT	t_r		1.1		μs	
Falling time of OUT	t_f		1.1		μs	
VIN to OUT signal delay (50% - 50%)	t_{PD}		1.6	1.9	μs	
Analog settling time	t_{AS}		50	100	μs	VDD step to 5.0 V, to OUT valid, 0.1% settling

(1) The temperature drift is calculated within the whole temperature range (-40°C to 125°C).

(2) Input referred.

(3) THD is defined as the ratio of the sum of the rms value of first five higher harmonics to the amplitude of the fundamental (input referred).

(4) Not test covered, guaranteed by characterization.

(5) Not test covered, guaranteed by design.

6.2. Electrical Characteristics of NSI1611S04-Q1

(Minimum and maximum specifications apply across the following conditions: VDD1 = 4.5 ~ 5.5V, VDD2 = 3.0 ~ 5.5V, INP = 0.01V to 4V, REFIN = GND2 T_A = -40°C to 125°C. Unless otherwise noted, Typical values are measured at VDD1 = 5V, VDD2 = 3.3V, T_A = 25°C)

Parameters	Symbol	Min	Typ	Max	Unit	Comments
Power Supply						
Input side supply voltage	VDD1	4.5	5	5.5	V	
Input side supply current	IDD1		7.2	9	mA	
Output side supply voltage	VDD2	3.0	3.3	5.5	V	
Output side supply current	IDD2		4.7	6	mA	
Input side VDD undervoltage detection threshold voltage	VDD1 _{UV}	3.9	4.1	4.2	V	VDD1 rising threshold
		3.7	3.8	3.9	V	VDD1 falling threshold
Output side VDD undervoltage detection threshold voltage	VDD2 _{UV}	2.6	2.7	2.8	V	VDD2 rising threshold
		2.3	2.4	2.5	V	VDD2 falling threshold
Analog Input						
Input offset voltage	V _{OS}	-1.5	±0.3	1.5	mV	V _{IN} = 0.01V, at T _A = 25°C
Input offset drift ⁽¹⁾	TCV _{OS}	-45	±10	45	μV/°C	
Single-ended input resistance	R _{IN}		1		GΩ	
Input capacitance	C _I		5		pF	Single-ended input capacitance, f _{IN} =250kHz
Input offset current	I _{IO}		10		nA	V _{IN} = GND1
REFIN input resistance	R _{REFIN}		100		kΩ	
Analog Output						
Nominal Gain	Gain		0.5		V/V	REFIN = GND2
Gain error	E _G	-0.25%	±0.05%	0.25%		at T _A = 25°C
Gain error thermal drift ⁽¹⁾	TCE _G	-35	±10	35	ppm/°C	
Nonlinearity		-0.04%	±0.01%	0.04%		
Nonlinearity drift ⁽¹⁾			±1		ppm/°C	
Total harmonic distortion ⁽³⁾	THD		-80		dB	V _{IN} = 0.01~4V _{pp} , f _{IN} = 10kHz, BW = 100kHz
Output noise			270		μV _{RMS}	V _{IN} = GNDI, BW = 100kHz
Signal to noise ratio	SNR		82		dB	V _{IN} = 0.01~4V _{pp} , f _{IN} = 1kHz, BW = 10kHz

Parameters	Symbol	Min	Typ	Max	Unit	Comments
	SNR		71		dB	$V_{IN} = 0.01 \sim 4V_{pp}$, $f_{IN} = 10kHz$, $BW = 100kHz$, 1MHz filter
Input clipping output voltage	$V_{clipout}$		4.3		V	$V_{IN} \geq V_{Clipping}$
Output bandwidth	BW		330		kHz	
Power supply rejection ratio (2) of VDD1	PSRR _{dc}		-90		dB	PSRR vs VDD1, from 3.0~5.5V at DC
	PSRR _{ac}		-80		dB	PSRR vs VDD1, 100mV and 10kHz ripple
Power supply rejection ratio (2) of VDD2	PSRR _{dc}		-90		dB	PSRR vs VDD2, from 3.0~5.5V at DC
	PSRR _{ac}		-76		dB	PSRR vs VDD2, 100mV and 10kHz ripple
Output resistance	R_{OUT}		0.2		Ω	
Swing to GND2	V_{swing}			10	mV	$V_{IN} = 0V$, $R_L = 10k\Omega$
Output limit current	I_{lim}		± 14		mA	
Common-mode transient immunity	CMTI	100	150		kV/ μs	Common-mode transient immunity
Timing						
Rising time of OUT	t_r		1.1		μs	
Falling time of OUT	t_f		1.1		μs	
VIN to OUT signal delay (50% - 50%)	t_{PD}		1.6	1.9	μs	
Analog setting time	t_{AS}		50	100	μs	VDD step to 5.0 V, to OUT valid, 0.1% settling

(1) The temperature drift is calculated within the whole temperature range (-40°C to 125°C).

(2) Input referred.

(3) THD is defined as the ratio of the sum of the rms value of first five higher harmonics to the amplitude of the fundamental (input referred).

(4) Not test covered, guaranteed by characterization.

(5) Not test covered, guaranteed by design.

6.3. Timing Diagrams

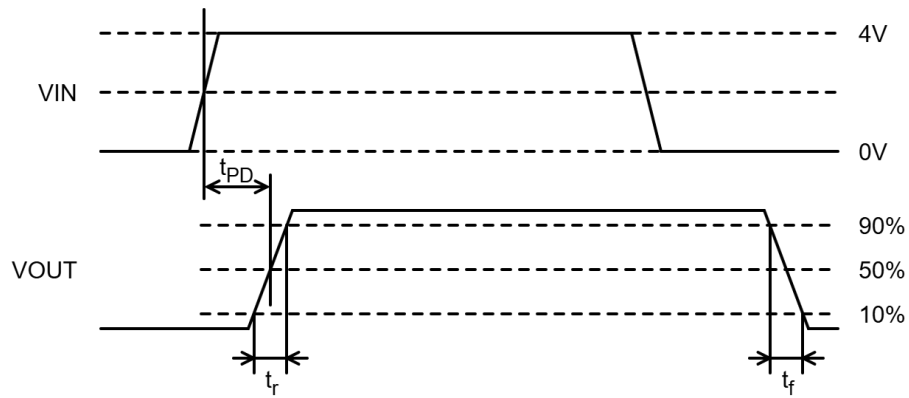


Figure 6.1 Propagation Delay and Output Fall Time Definition

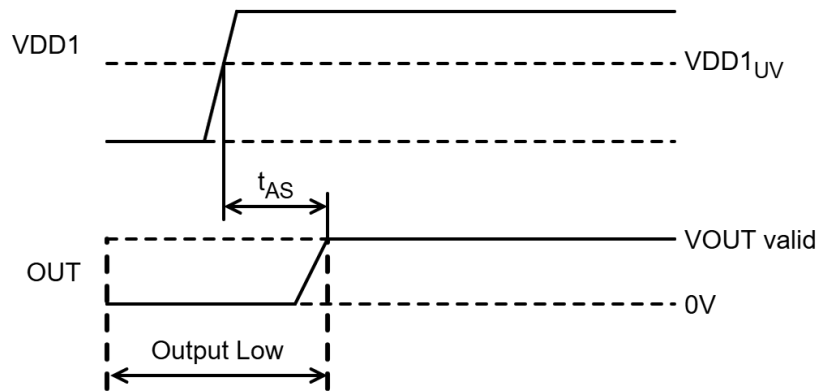


Figure 6.2 Analog Settling Time Definition

6.4. Typical Performance Characteristics of NSI1611S02-Q1

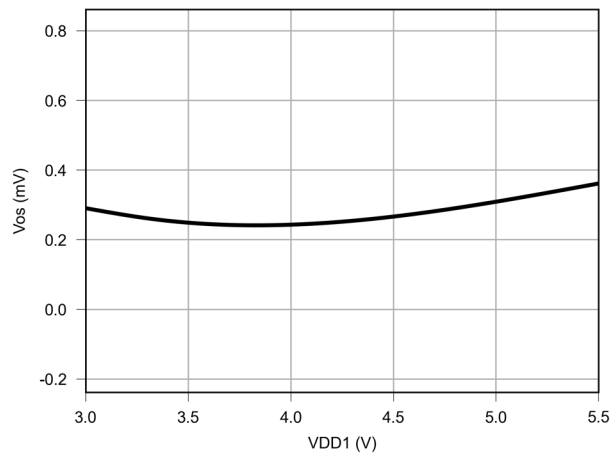


Figure 6.3 Vos vs VDD1

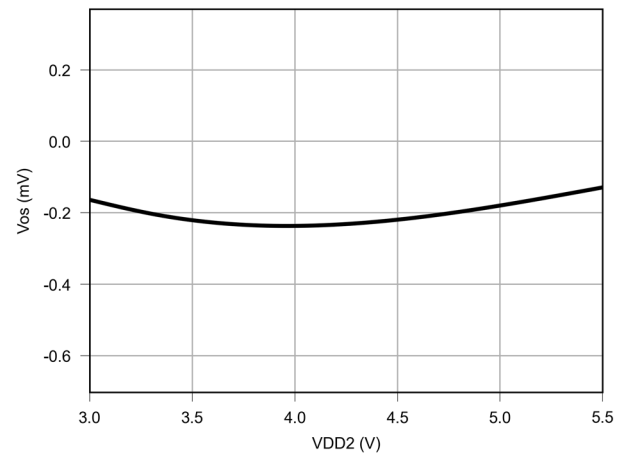


Figure 6.4 Vos vs VDD2

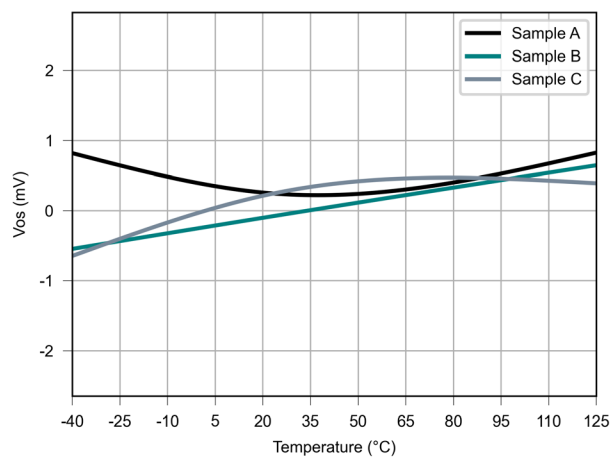


Figure 6.5 Vos vs Temperature

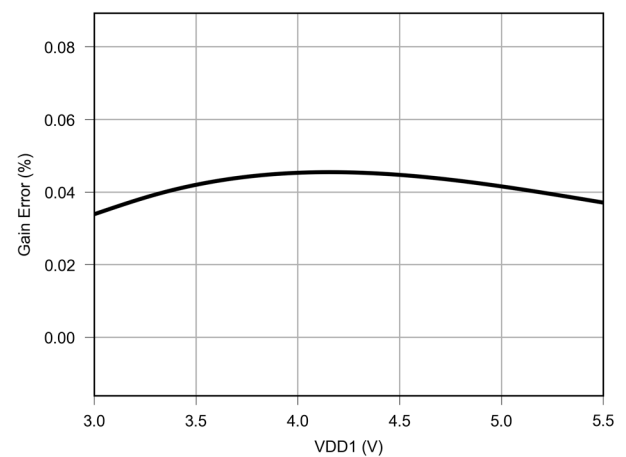


Figure 6.6 EG vs VDD1

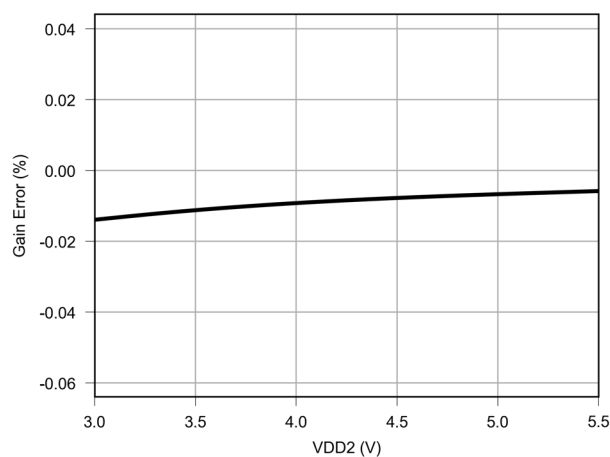


Figure 6.7 EG vs VDD2

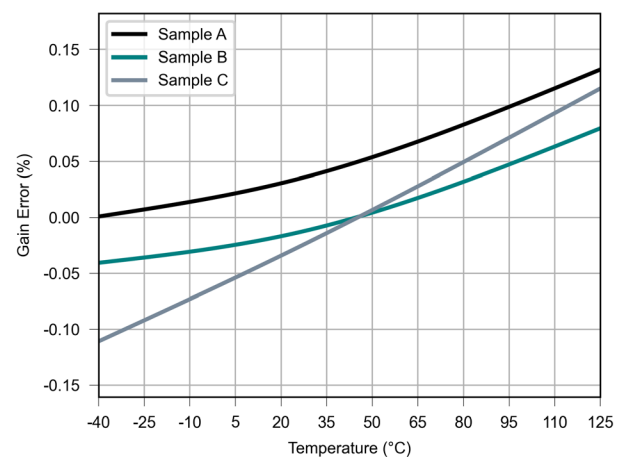


Figure 6.8 EG vs Temperature

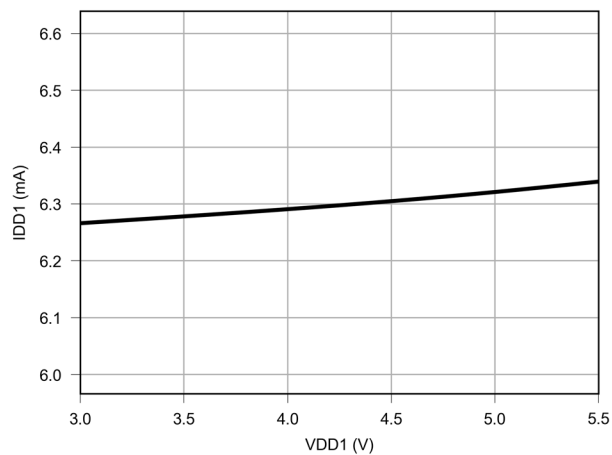


Figure 6.9 IDD1 vs VDD1

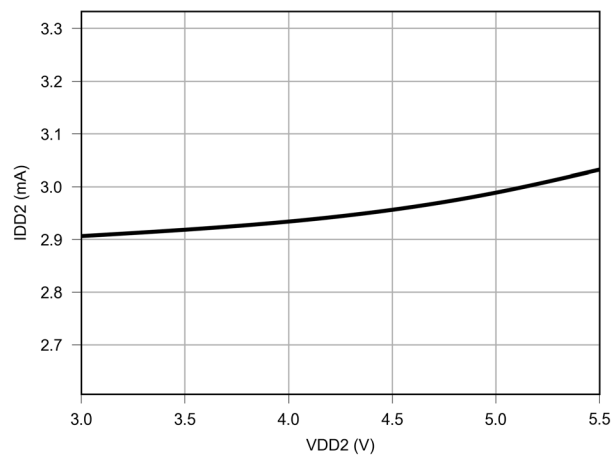


Figure 6.10 IDD2 vs VDD2

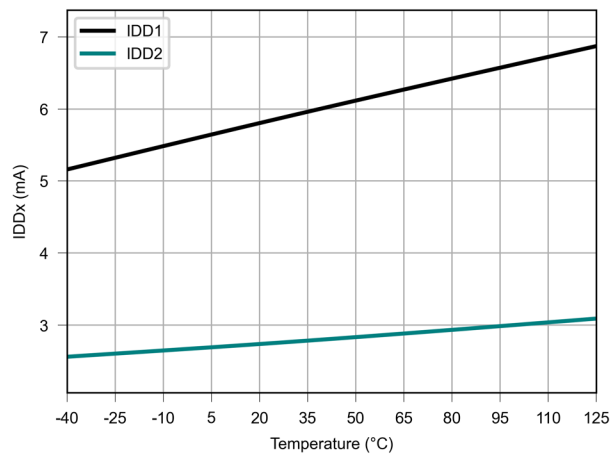


Figure 6.11 IDDX vs Temperature

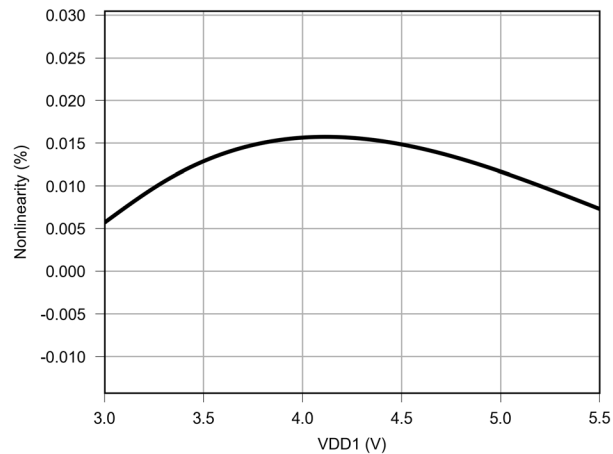


Figure 6.12 Nonlinearity vs VDD1

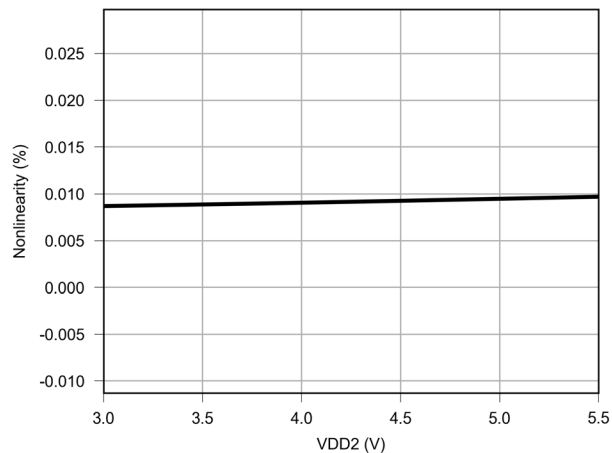


Figure 6.13 Nonlinearity vs VDD2

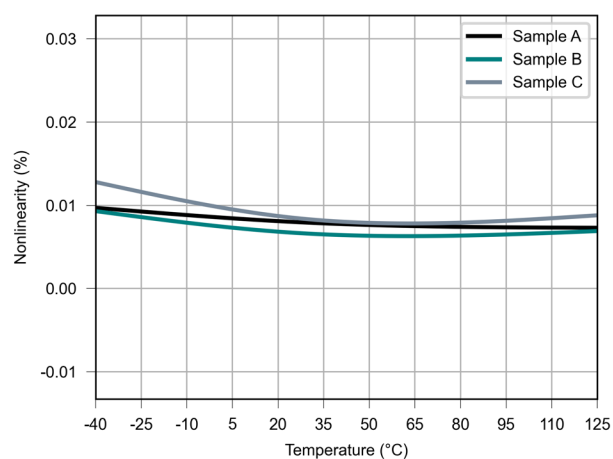


Figure 6.14 Nonlinearity vs Temperature

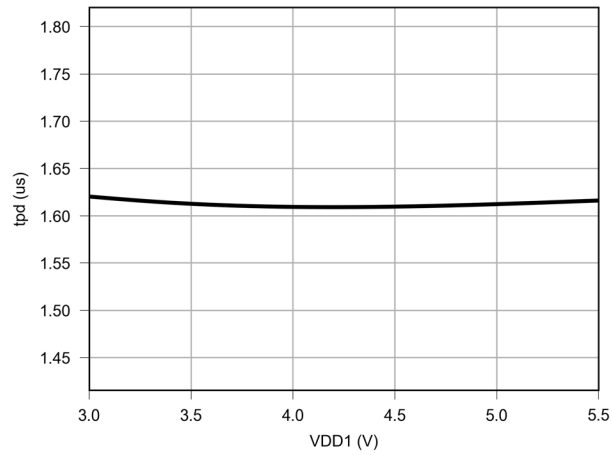


Figure 6.15 Propagation Delay vs VDD1

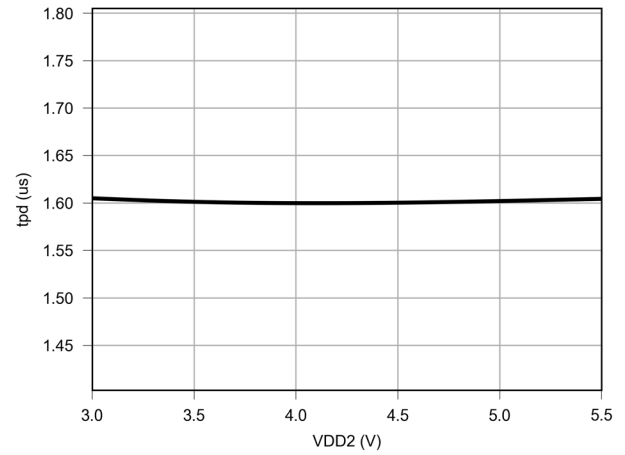


Figure 6.16 Propagation Delay vs VDD2

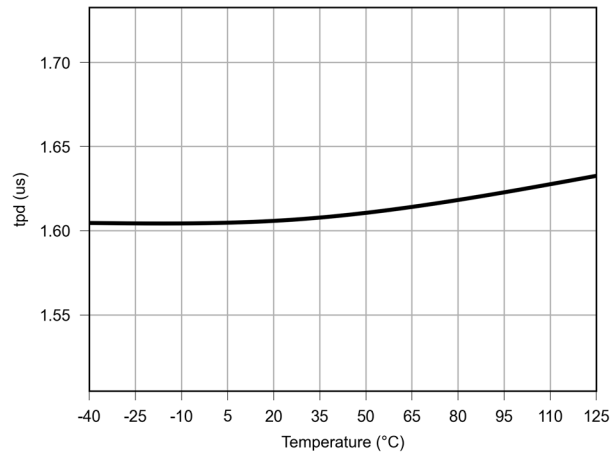


Figure 6.17 Propagation Delay vs Teperature

6.5. Typical Performance Characteristics of NSI1611S04-Q1

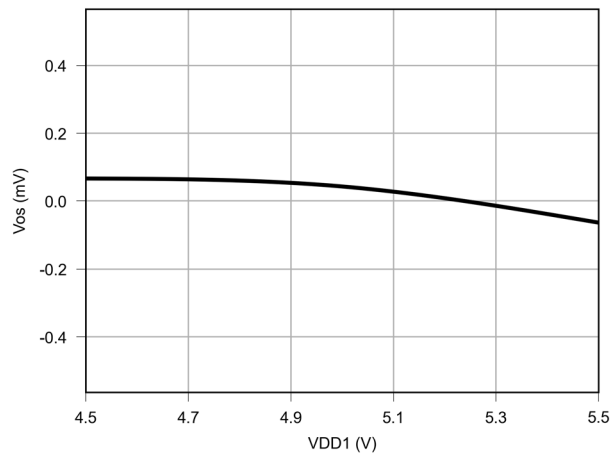


Figure 6.18 Vos vs VDD1

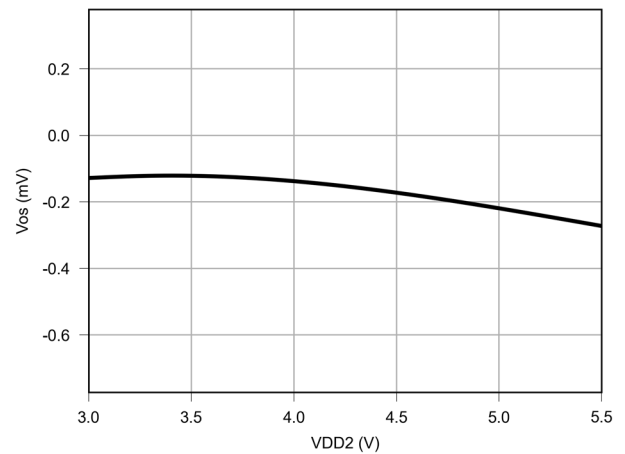


Figure 6.19 Vos vs VDD2

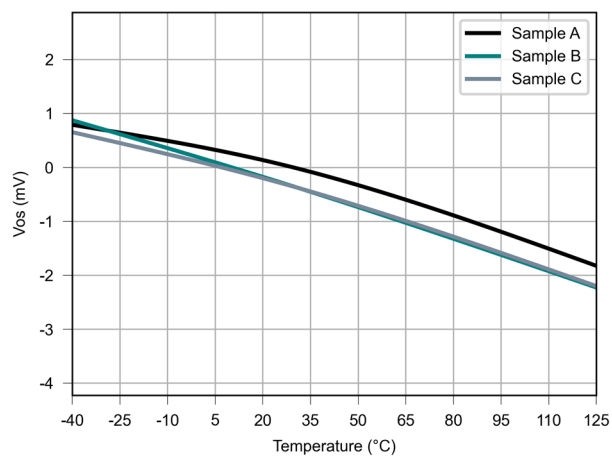


Figure 6.20 Vos vs Temperature

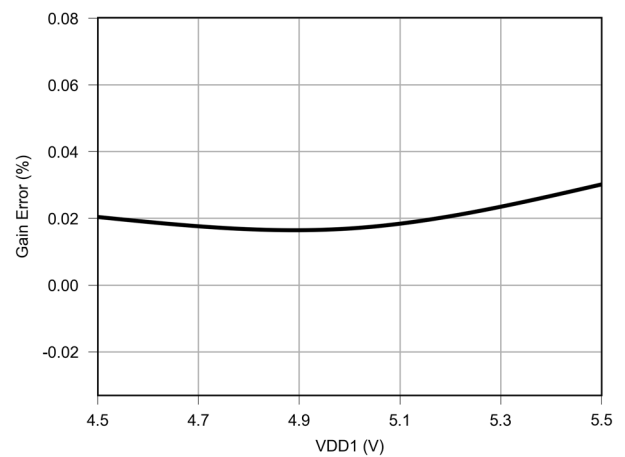


Figure 6.21 EG vs VDD1

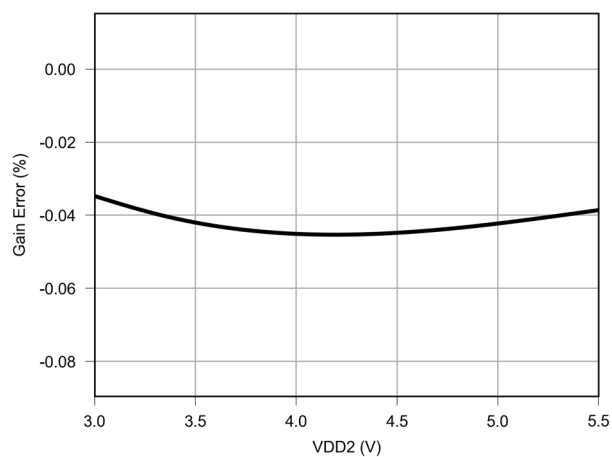


Figure 6.22 EG vs VDD2

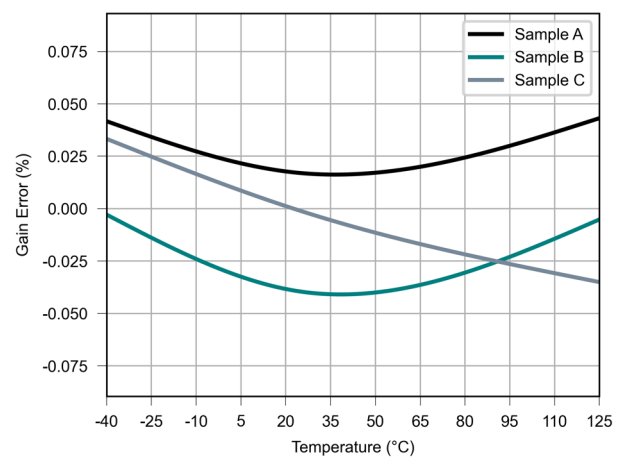


Figure 6.23 EG vs Temperature

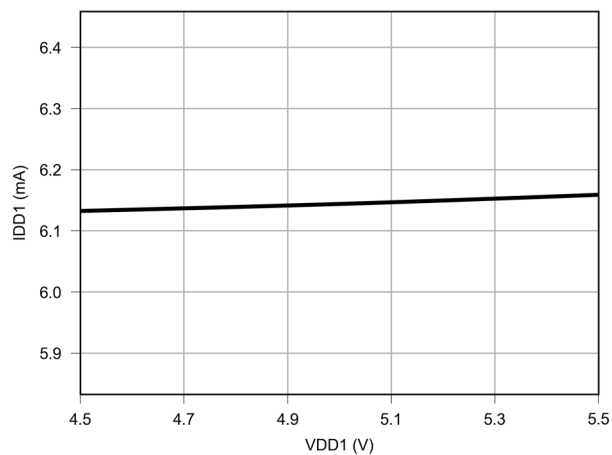


Figure 6.24 IDD1 vs VDD1

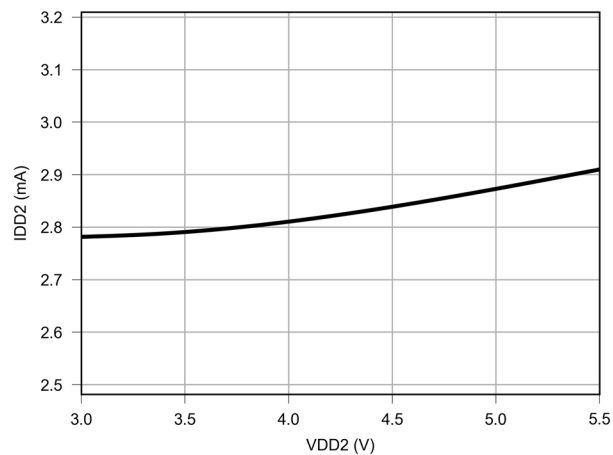


Figure 6.25 IDD2 vs VDD2

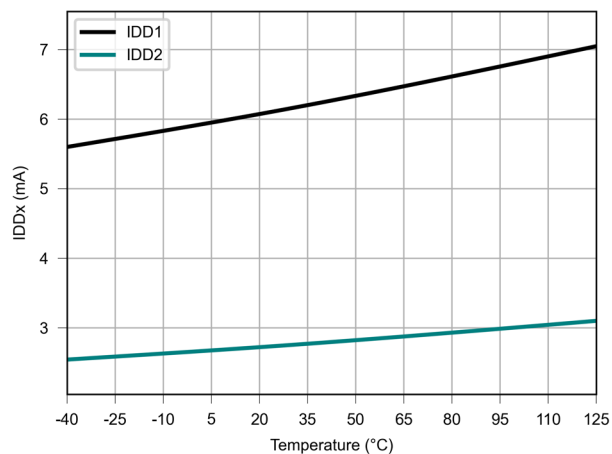


Figure 6.26 IDDX vs Temperature

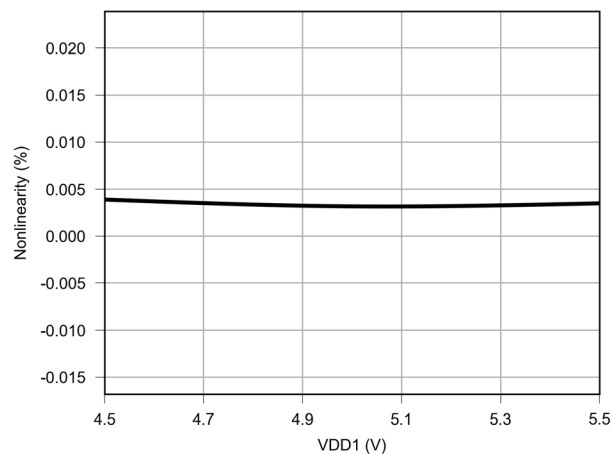


Figure 6.27 Nonlinearity vs VDD1

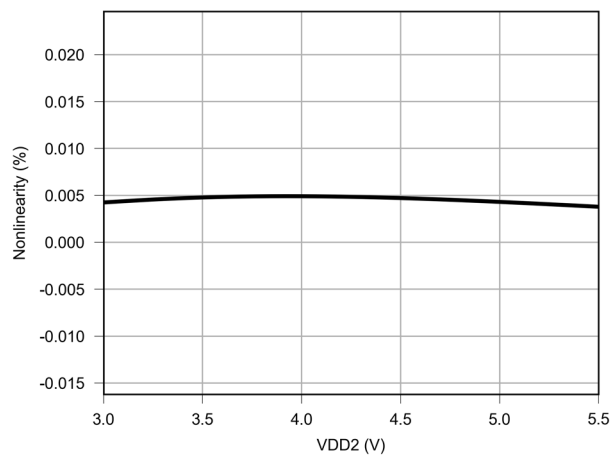


Figure 6.28 Nonlinearity vs VDD2

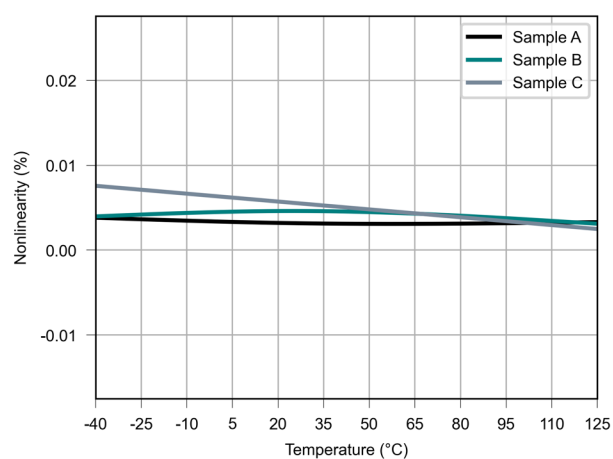


Figure 6.29 Nonlinearity vs Temperature

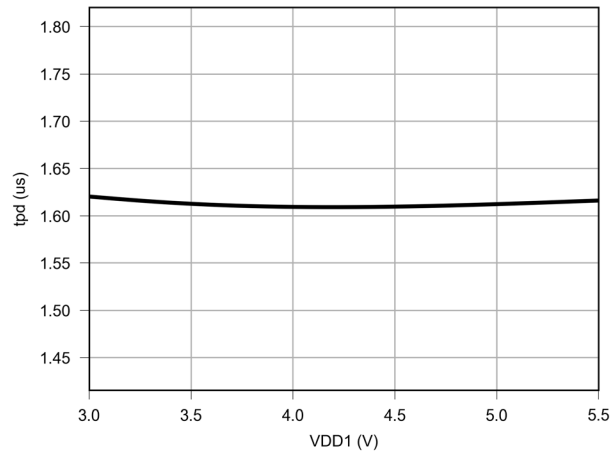


Figure 6.30 Propagation Delay vs VDD1

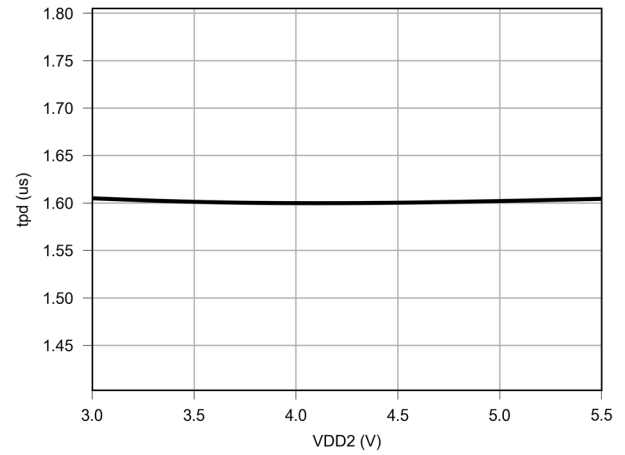


Figure 6.31 Propagation Delay vs VDD2

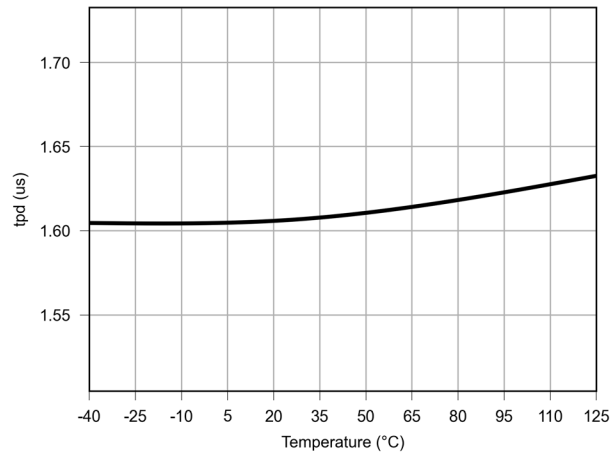


Figure 6.32 Propagation Delay vs Teperature

7. High Voltage Feature Description

7.1. Insulation and Safety Related Specifications

Parameters	Symbol	Value	Unit	Comments
Minimum External Clearance	CLR	8.5	mm	IEC 60664-1:2007
Minimum External Creepage	CPG	8.5	mm	IEC 60664-1:2007
Distance Through Insulation	DTI	18	μm	Distance through insulation (internal clearance – capacitive signal isolation)
Tracking Resistance (Comparative Tracking Index)	CTI	>600	V	DIN EN 60112 (VDE 0303-11); IEC 60112
Material Group		I		IEC 60664-1

Description	Test Condition	Value
Overvoltage Category per IEC60664-1	For Rated Mains Voltage $\leq 150\text{Vrms}$	I to IV
	For Rated Mains Voltage $\leq 300\text{Vrms}$	I to IV
	For Rated Mains Voltage $\leq 600\text{Vrms}$	I to III
Climatic Classification		40/125/21
Pollution Degree per DIN VDE 0110		2

7.2. Insulation Characteristics

Description	Test Condition	Symbol	Value	Unit
DIN EN IEC 60747-17 (VDE 0884-17)				
Maximum repetitive isolation voltage		V_{IORM}	1500	V_{PEAK}
Maximum working isolation voltage	AC Voltage	V_{IOWM}	1060	V_{RMS}
	DC Voltage		1500	V_{DC}
Apparent Charge	Method a, after Input/output safety test subgroup 2/3, $V_{ini}=V_{IOTM}$, $t_{ini}=60\text{ s}$, $V_{pd(m)}=1.2*V_{IORM}$, $t_m=10\text{s}$.	q_{pd}	<5	pC
	Method a, after environmental tests subgroup 1, $V_{ini}=V_{IOTM}$, $t_{ini}=60\text{s}$, $V_{pd(m)}=1.6*V_{IORM}$, $t_m=10\text{s}$			pC
	Method b, $V_{ini}=1.2*V_{IOTM}$, $t_{ini}=1\text{s}$ $V_{pd(m)}=1.875*V_{IORM}$, $t_m=1\text{s}$ (method b1) or $V_{pd(m)}=V_{ini}$, $t_m=t_{ini}$ (method b2)			pC
Maximum transient isolation voltage	$t=60\text{sec}$	V_{IOTM}	8000	V_{PEAK}
Maximum impulse voltage	Tested in air, 1.2/50 μs waveform per IEC62368-1	V_{IMP}	7700	V_{PEAK}
Maximum Surge Isolation Voltage	Test method per IEC62368-1, 1.2/50 μs waveform, $V_{IOSM} \geq V_{IMP} \times 1.3$	V_{IOSM}	10000	V_{PEAK}

Description	Test Condition	Symbol	Value	Unit
Isolation resistance	$V_{IO} = 500V, T_{amb} = 25^{\circ}C$	R_{IO}	$>10^{12}$	Ω
	$V_{IO} = 500V, 100^{\circ}C \leq T_{amb} \leq 125^{\circ}C$	R_{IO}	$>10^{11}$	Ω
	$V_{IO} = 500V, T_{amb} = T_s$	R_{IO}	$>10^9$	Ω
Isolation capacitance	$f = 1MHz$	C_{IO}	0.8	pF
Safety total power dissipation	$V_I = 5.5V, T_J = 150^{\circ}C, T_A = 25^{\circ}C$	P_s	1430	mW
Safety input, output, or supply current	$\theta_{JA} = 82^{\circ}C/W$ for SOW8, $V_I = 5.5V, T_J = 150^{\circ}C, T_A = 25^{\circ}C$	I_s	260	mA
Maximum safety temperature		T_s	150	$^{\circ}C$
UL1577				
Insulation voltage per UL	$V_{TEST} = V_{ISO}, t = 60 s$ (qualification), $V_{TEST} = 1.2 \times V_{ISO}, t = 1s$	V_{ISO}	5700	V_{RMS}

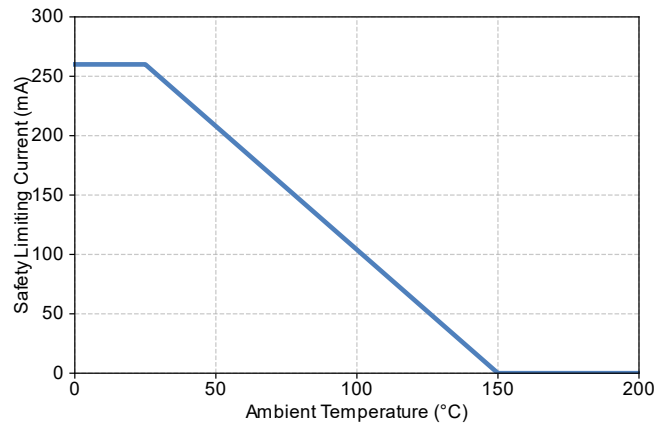


Figure 7.1 NSI1611S0x-Q1 Thermal Derating Curve, Dependence of Safety Limiting Values with Case Temperature per DIN VDE V 0884-11

7.3. Regulatory Information

The NSI1611S02/04-Q1SWVR are approved or pending approval by the organizations listed in table.

UL		CQC		TUV
UL 1577 Component Recognition Program	Approved under CSA Component Acceptance Notice 5A	Certified according to GB4943.1	Certified According to EN IEC 62368-1	DIN EN IEC 60747-17 (VDE 0884-17)
Single Protection, 5700V _{rms} Isolation voltage	Single Protection, 5700V _{rms} Isolation voltage	Reinforced insulation	5700V _{rms} for 1min	Reinforce Insulation $V_{IORM} = 1500 V_{PEAK}$ $V_{IOTM} = 8000 V_{PEAK}$ $V_{IOSM} = 10000 V_{PEAK}$
Pending	Pending	Pending	Pending	Pending

8. Function Description

8.1. Overview

The NSI1611S02/04-Q1 is a high-performance isolated amplifier with an input range of 0.01~2V(for NSI1611S02-Q1) or 0.01~4V (for NSI1611S04-Q1) and a single-ended output. The buffer at the input port ensures the input impedance is high enough for large resistive dividers input. Subsequently, the analog signal is modulated to a digital waveform to transfer through the isolation barrier. Both the modulator and the isolator drivers (designated as TX in the functional block diagram) are clocked by the inside oscillator. The isolator receiver (designated as RX in the functional block diagram) receives the modulated waveform and restores it to an analog form.

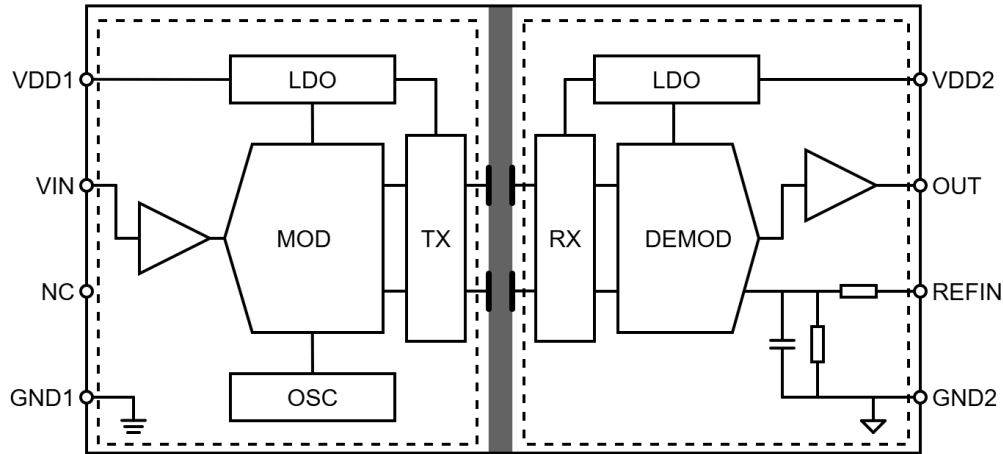


Figure 8.1 Function Block Diagram of NSI1611S0x-Q1

8.2. Analog Input

There are two restrictions on the analog input signals VIN

- If the input voltage exceeds the range from GND1-6V to VDD1+0.5V, the input current must be limited to 10 mA because the device input electrostatic discharge (ESD) diodes turn on.
- The linearity and noise performance of the device are ensured only when the analog input voltage remains within the specified linear full-scale range (V_{FSR}), V_{FSR} is 0.01V to 2V for NSI1611S02-Q1 and 0.01V to 4V for NSI1611S04-Q1, specified in Recommended Operating Conditions section.

8.3. Analog Output and Signal Chain Gain Selection

The NSI1611S0x-Q1 outputs a single-ended voltage relative to GND2. The voltage gain from input to output can be configured by the voltage on the pin REFIN. When REFIN is tied to GND2, the NSI1611S0x-Q1 works in fixed gain mode. The linear input range covers 0.01V~4.0V for NSI1611S04-Q1 and 0.01~2.0V for NSI1611S02-Q1. The input to output curve is shown in Figure 8.2(a)(b);

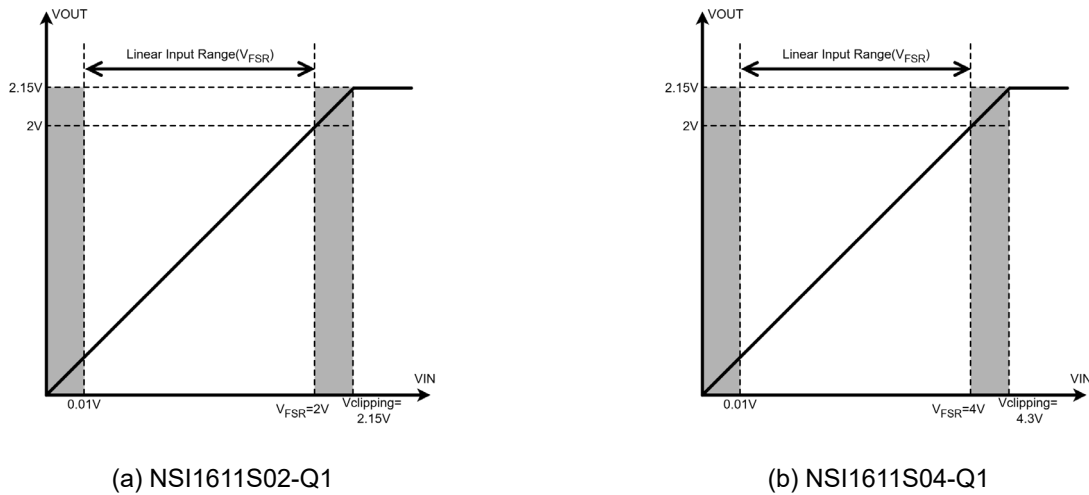


Figure 8.2 Input to Output Transfer Curve of the NSI1611S0x-Q1

8.4. Accuracy Guaranteed Range and Output Voltage Swing

The accuracy of NSI1611S0x-Q1 is not guaranteed when input voltage approaches zero volt, as the output buffer requires a minimum headroom above GND2. However, the device still retains the ability to provide an output close to zero volt, which is guaranteed by the parameter V_{swing} . As shown in Figure 8.3, all specs are tested and guaranteed from 0.01V to maximum input voltage. When input voltage is below 0.01V, the output voltage still follows input voltage while not all specs are covered in final test. The minimum voltage this device can output is tested and denoted as V_{swing} .

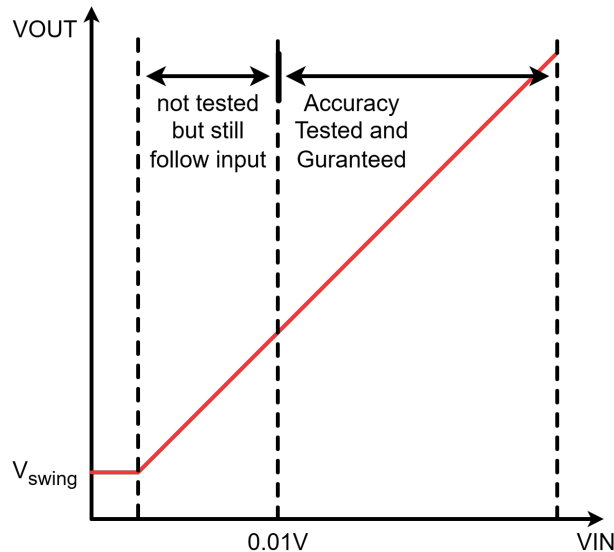


Figure 8.3 Output Curve near zero voltage (not to scale)

8.5. Device Operating States

The NSI1611S02-Q1 and NSI1611S04-Q1 can operate in the following states:

- **Missing low-side power supply state:** This state is entered when the low-side supply (VDD2) drops below the VDD2UV threshold. In this state, the device is unresponsive, and the output (OUT) is in a high-impedance (Hi-Z) state.
- **Missing high-side power supply state:** When the low-side of the device (VDD2) is properly powered and within the recommended operating conditions, but the high-side power supply (VDD1) is below the VDD1UV threshold, the OUT pin is driven to GND2.

- **Analog input overrange state:** With both VDD1 and VDD2 operating within the recommended conditions, if the analog input voltage (V_{IN}) exceeds the maximum clipping voltage ($V_{Clipping, MAX}$), the device outputs $V_{clipping}$ at the OUT pin.
- **Normal operating state:** When VDD1, VDD2, and V_{IN} all fall within their respective recommended operating ranges, the device enters normal operation, and the output delivers a voltage proportional to the input voltage.

OPERATING STATES	VDD1	VDD2	V_{IN}	DESCRIPTION
Missing low-side power supply state	No effect	$VDD2 < VDD2_{UV}$	No effect	The output (OUT) is in a high-impedance (Hi-Z) state.
Missing high-side power supply state	$VDD1 < VDD1_{UV}$	Valid ⁽¹⁾	No effect	The OUT pin is driven to GND2.
Analog input overrange state	Valid ⁽¹⁾	Valid ⁽¹⁾	$V_{IN} > V_{clipping}$	The device outputs the clipping voltage: $V_{clipping} * Gain$
Normal operating state	Valid ⁽¹⁾	Valid ⁽¹⁾	Valid ⁽¹⁾	The device outputs a voltage proportional to the input voltage.

(1) Valid denotes operation within the recommended operating conditions.

Figure 8.4 illustrates the operating states under different combination of power supply states.

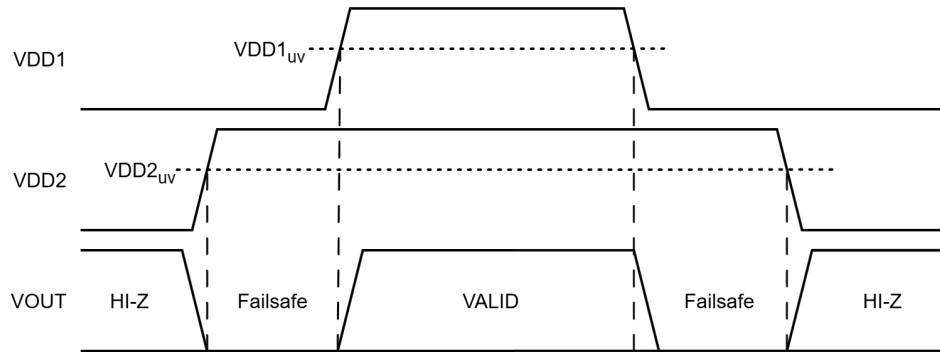


Figure 8.4 Waveform of NSI1611S0x-Q1 when power fails

9. Application Note

9.1. Typical Application Circuit

Figure 9.1 illustrates a typical application example of NSI1611S0x-Q1. On the input side, the HV_BUS voltage is divided down to 0~2V or 0~4V level across the bottom resistor of a high-impedance resistive divider. VDD1 needs a power supply from 3.0V to 5.5V for NSI1611S02-Q1 and 4.5V to 5.5V for NSI1611S04-Q1. A 0.1uF capacitor and a 10uF capacitor in parallel on VDDx are recommended to improve EOS and stability. On the output side, NSI1611S0x-Q1 provides an output proportional to the HV_BUS voltage

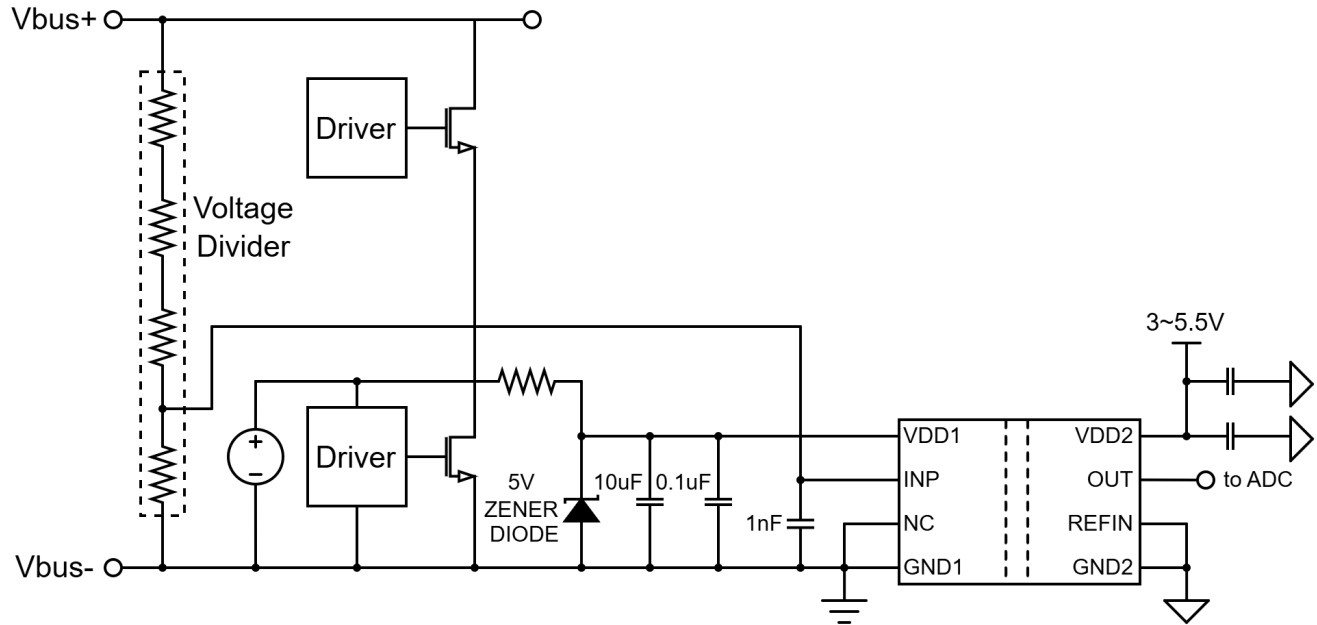


Figure 9.1 Typical Application Diagram of NSI1611S0x-Q1

9.2. High Voltage Dividing Resistor Selection

Two restrictions should be considered when choosing the proper value of the voltage-dividing resistors:

- The current through the resistor should be within its rated range. Using Ohm law to calculate the cross current ($I_{cross} = V_{max}/R_{total}$);
- The divided input voltage value should not exceed the linear input range of NSI1611S0x-Q1, in which case the output may be clipped.

9.3. Accuracy Related Parameters

Parameters related to the accuracy performance are explained in this section, including V_{os} and its drift, E_G and its drift, Nonlinearity. Other immunity parameters that affect accuracy like PSRR are also included.

9.3.1. Input Offset V_{os} and Gain Error E_G

V_{os} and E_G are the most significant factors influencing accuracy. The ideal curve and actual curve are shown in Figure 9.2.

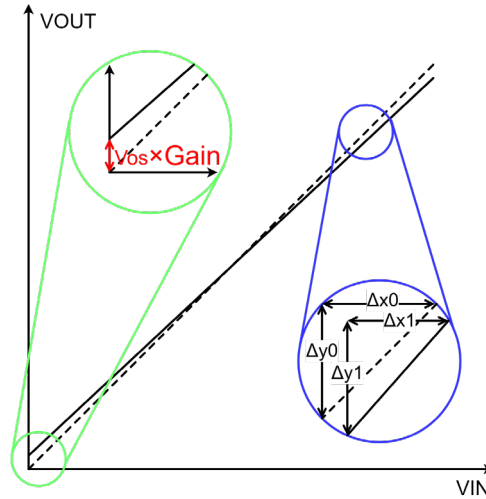


Figure 9.2 Vos and EG diagram

V_{OS} means the input offset voltage when input is 0.01V for NSI1611S0x-Q1. The tested output should be divided by nominal gain as V_{OS} is defined as the offset voltage referred to input (See Equation 1).

$$V_{OS} = V_O / \text{Nominal Gain} - 0.01V \quad \text{Equation 1}$$

where

- V_O is the output voltage tested when input is 0.01V for NSI1611S0x-Q1.
- Nominal Gain is 1.0 for NSI1611S02-Q1 and 0.5 for NSI1611S04-Q1.

Gain is the magnification of the amplifier, and the definition formula is shown in Equation 2. EG means the difference between actual and ideal slope. It should be noted that EG is tested across the whole input range to minimize test error (See Equation 3).

$$\text{Gain} = \frac{\Delta y_1}{\Delta x_1} = \frac{V_{O1} - V_{O2}}{V_{IN1} - V_{IN2}} \quad \text{Equation 2}$$

$$E_G = \frac{\text{Gain} - \text{Nominal Gain}}{\text{Nominal Gain}} \times 100\% \quad \text{Equation 3}$$

where V_{IN1} and V_{IN2} are the lower and upper limit of the input FSR separately, V_{O1} and V_{O2} are the output voltage corresponding to V_{IN1} and V_{IN2} .

9.3.2. Input Offset Drift TCV_{OS} and Gain Error Thermal Drift TCE_G

Input offset drift TCV_{OS} means the drift of V_{OS} over the whole operating temperature range, which is calculated as Equation 4.

$$TCV_{OS} = \frac{V_{OS_{max}} - V_{OS_{min}}}{\text{TempRange}} \quad \text{Equation 4}$$

where

- $V_{OS_{max}}$ and $V_{OS_{min}}$ are the maximum and minimum offset voltage over the whole operating ambient temperature range.
- TempRange covers the whole operating temperature, from -40°C to 125°C.

Gain error thermal drift TCE_G is the drift of E_G over the whole operating temperature range, which is calculated as Equation 5.

$$TCE_G = \frac{E_{G_{max}} - E_{G_{min}}}{\text{TempRange}} \quad \text{Equation 5}$$

where $E_{G_{max}}$ and $E_{G_{min}}$ are the maximum and minimum Gain Error over the whole temperature.

Both TCV_{OS} and TCE_G should be multiplied by the direction of temperature drift.

9.3.3. Nonlinearity

Nonlinearity describes the deviation between the actual output and the ideal linear output. Calculate the peak-to-peak value of the error between the actual output and the fitting curve, and nonlinearity is expressed as the ratio of half of the peak-to-peak error to the full-scale range of the output voltage (See Equation 6).

$$\text{Nonlinearity} = \frac{\text{Error_pkpk}}{2 \times V_{\text{OFSR}}} \times 100\% \quad \text{Equation 6}$$

where

- Error_pkpk is the peak-to-peak value of the error between the actual output and the fitting curve.
- V_{OFSR} represents the full-scale range of the output voltage (4V for NSI1611S04-Q1 and 2V for NSI1611S02-Q1).

9.3.4. Power-Supply Rejection Ratio

Power-Supply Rejection Ratio (PSRR) describes the level of the output error (input inferred) which is affected by the variation of power supply. PSRR is defined in dB and calculated as Equation 7.

$$\text{PSRR} = 20 \times \log_{10} \left(\frac{V_{\text{O_var}}}{\text{Nominal Gain} \times V_{\text{DD_var}}} \right) \quad \text{Equation 7}$$

Where $V_{\text{O_var}}$ and $V_{\text{DD_var}}$ are respectively the variation value of the output voltage and the supply voltage.

9.3.5. Total Error Calculation

The total error is contributed by parameters discussed above. It is helpful to know the respective contribution of all different parameters when something is wrong about system current sensing. This section will introduce the calculation method of total error.

Parameters which mainly affect sensing accuracy are V_{os} , EG and Nonlinearity and their drift. PSRR is not a dominant factor in most cases. However, PSRR can be a concern when the power supply has high-frequency ripple, in which case a larger decoupling capacitor and a better layout are highly recommended (Refer to Section 9.4).

The error introduced by V_{os} and its drift can be calculated as:

$$\text{Error_Vos} = \frac{V_{\text{os_max}} + \text{TCV}_{\text{os}} \times \Delta T}{V_{\text{IN}}} \times 100\% \quad \text{Equation 8}$$

where

- $V_{\text{os_max}}$ is the maximum value of input offset voltage at 25°C.
- TCV_{os} is the maximum drift of input offset voltage over the whole working temperature.
- ΔT is the range of temperature variation.
- V_{IN} is the input voltage in the application.

The error introduced by E_{G} and TCE_{G} can be calculated as :

$$\text{Error_E}_G = E_{\text{G}} + \text{TCE}_{\text{G}} \times \Delta T \quad \text{Equation 9}$$

where

- E_{G} is the maximum value of Gain Error when the temperature is 25°C.
- TCE_{G} is the maximum drift of Gain Error over the whole temperature.
- The error introduced by Nonlinearity is $\text{Nonlinearity}_{\text{max}}$, the maximum value of Nonlinearity in the entire temperature range, - 40°C to 125°C. The total error sensing error is expressed as:

$$\text{Total_Error} = \sqrt{\text{Error_Vos}^2 + \text{Error_E}_G^2 + \text{Nonlinearity}_{\text{max}}^2} \quad \text{Equation 10}$$

For example, consider an NSI1611S04-Q1 with the sensing input voltage of 0~4V and a - 40°C to 85°C temperature range. The total error calculation is shown in Table 9.2.

Table 9.1 Total Error Calculation of NSI1611S02-Q1 (-40°C to 85°C)

Error Component	Symbol	Equation	Error at $V_{\text{in}}=0.2\text{V}$	Error at $V_{\text{in}}=2.0\text{V}$
-----------------	--------	----------	--------------------------------------	--------------------------------------

Input offset error	Error_Vos	$\text{Error_Vos} = \frac{V_{os_{\max}} + TCV_{os} \times \Delta T}{V_{IN}} \times 100\%$ $= \frac{\pm 0.8\text{mV} \pm 35\mu\text{V}/^\circ\text{C} \times 60^\circ\text{C}}{V_{IN}} \times 100\%$	±1.45%	±0.145%
Gain error	Error_EG	$\text{Error_EG} = E_G + TCE_G \times \Delta T = \pm 0.25\% \pm 35\text{ppm}/^\circ\text{C} \times 60^\circ\text{C}$	±0.46%	±0.46%
Nonlinearity	Nonlinearity _{max}	$\text{Nonlinearity}_{\max} = \pm 0.04\%$	±0.04%	±0.04%
Total error	Total_Error	$\text{Total_Error} = \sqrt{\text{Error_Vos}^2 + \text{Error_EG}^2 + \text{Nonlinearity}_{\max}^2}$	±1.52%	±0.484%

Table 9.2 Total Error Calculation of NSI1611S04-Q1 (-40°C to 85°C)

Error Component	Symbol	Equation	Error at Vin=0.4V	Error at Vin=4.0V
Input offset error	Error_Vos	$\text{Error_Vos} = \frac{V_{os_{\max}} + TCV_{os} \times \Delta T}{V_{IN}} \times 100\%$ $= \frac{\pm 1.5\text{mV} \pm 45\mu\text{V}/^\circ\text{C} \times 60^\circ\text{C}}{V_{IN}} \times 100\%$	±1.05%	±0.105%
Gain error	Error_EG	$\text{Error_EG} = E_G + TCE_G \times \Delta T = \pm 0.25\% \pm 35\text{ppm}/^\circ\text{C} \times 60^\circ\text{C}$	±0.46%	±0.46%
Nonlinearity	Nonlinearity _{max}	$\text{Nonlinearity}_{\max} = \pm 0.04\%$	±0.04%	±0.04%
Total error	Total_Error	$\text{Total_Error} = \sqrt{\text{Error_Vos}^2 + \text{Error_EG}^2 + \text{Nonlinearity}_{\max}^2}$	±1.147%	±0.474%

Since the input offset voltage is independent of input voltage, it becomes the dominant factor of the total error when the input voltage is low. To improve the system accuracy, especially under low-input applications, it is recommended to perform software zero-point calibration and gain error calibration. With system-level calibration, the total error can also be reduced significantly. The reduced error is calculated as Table 9.3.

Table 9.3 Total Error Calculation with Software Calibration of NSI1611S04-Q1 (- 40°C to 85°C)

Error Component	Symbol	Equation	Error at Vin=0.4 V	Error at Vin=4.0V
Input offset error	Error_Vos	$\text{Error_Vos} = \frac{TCV_{os} \times \Delta T}{V_{IN}} \times 100\%$ $= \frac{45\mu\text{V}/^\circ\text{C} \times 60^\circ\text{C}}{V_{IN}} \times 100\%$	±0.675%	±0.0675%
Gain error	Error_EG	$\text{Error_EG} = TCE_G \times \Delta T = \pm 35\text{ppm}/^\circ\text{C} \times 60^\circ\text{C}$	±0.21%	±0.21%
Nonlinearity	Nonlinearity _{max}	$\text{Nonlinearity}_{\max} = \pm 0.04\%$	±0.04%	±0.04%
Total error	Error	$\text{Total_Error} = \sqrt{\text{Error_Vos}^2 + \text{Error_EG}^2 + \text{Nonlinearity}_{\max}^2}$	±0.708%	±0.224%

The maximum total error with and without calibration is shown in Figure 9.3, considering 0~4V input as full input range, NSI1611S04-Q1 can achieve <0.71% error at more than 10% input voltage(Vin≥0.4V) with software calibration, and <1.2% error at more than 10% load(Vin≥0.4V) without software calibration.

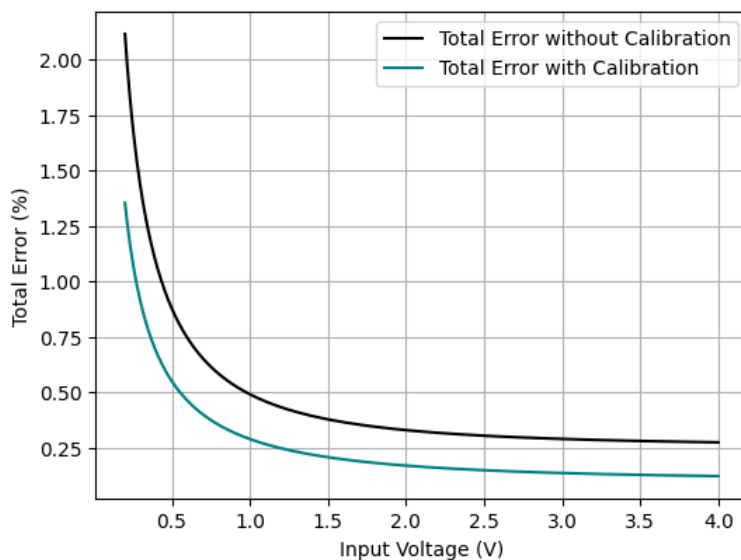


Figure 9.3 Total Error Over -40°C to 85°C vs Input Voltage

9.4. PCB Layout

Figure 9.4 shows a typical layout example of NSI1611S0x-Q1. To enhance power supply noise immunity and EOS robustness, it is recommended to use a low-ESR 100nF capacitor (C2, C4) in parallel with a low-ESR 1 μ F capacitor (C1, C3). These capacitors should be positioned as close as possible to the power supply pins, and the smaller-value capacitors should be in the inner place as they usually have a lower ESR and better immunity to high-frequency interference.

An additional capacitor (C5) is recommended to be added in parallel with lower side divided resistor (R3). The capacitor is also recommended to be positioned as close as possible to the input pin VIN.

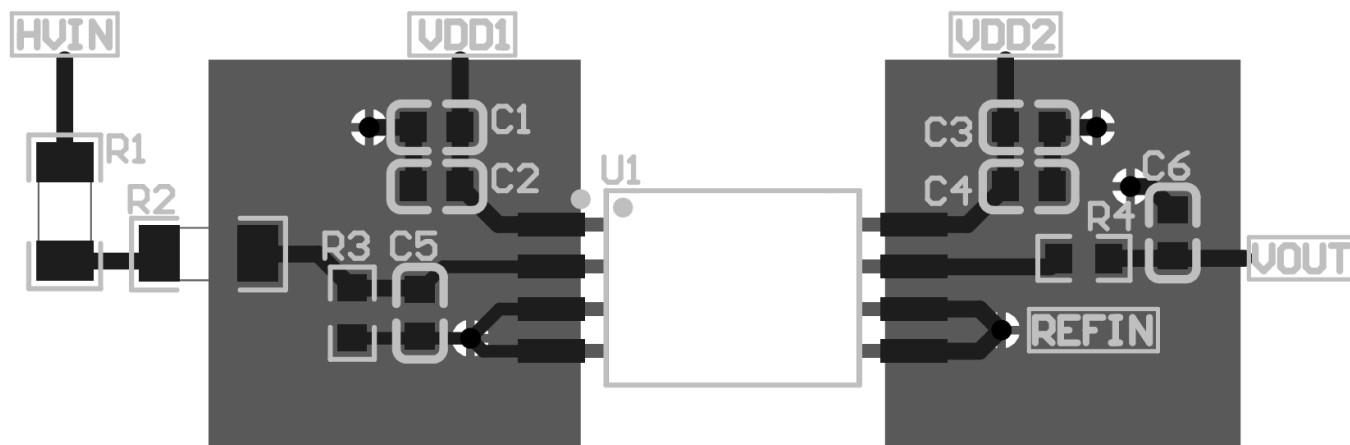
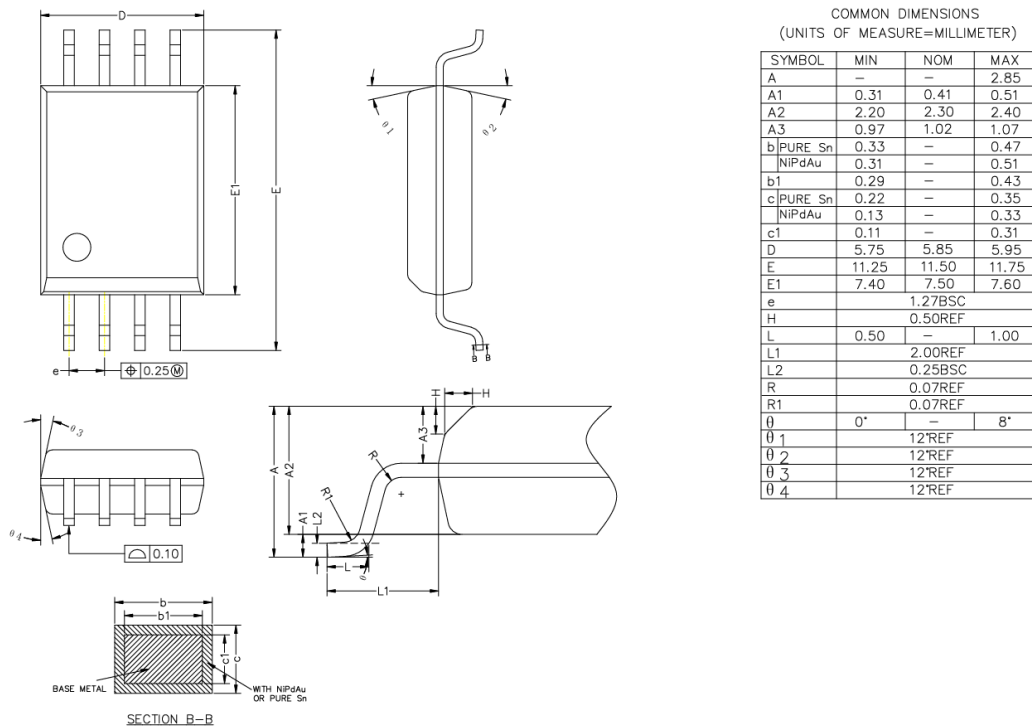


Figure 9.4 PCB layout example of NSI1611S0x-Q1

10. Package Information



NOTE: This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm, per side.

Figure 10.1 SOW8 package shape and dimension in millimeters

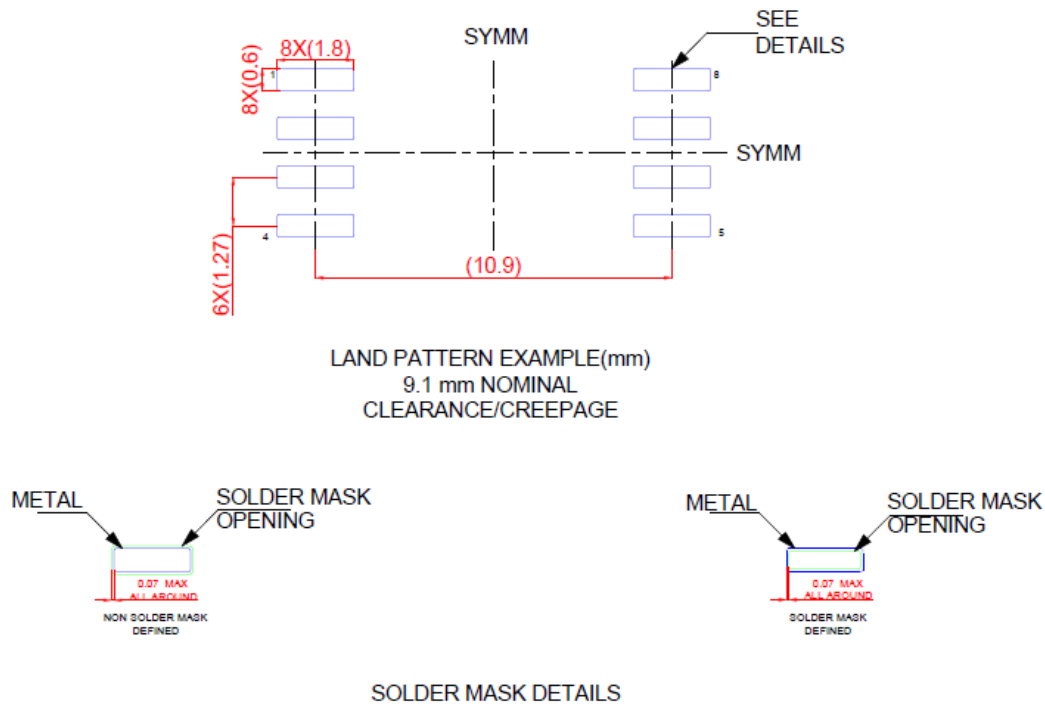


Figure 10.2 SOW8 Package Board Layout Example

11. Ordering Information

<i>Part No.</i>	<i>Isolation Rating(kV)</i>	<i>Linear Input Range</i>	<i>MSL</i>	<i>Device Marking</i>	<i>Temperature</i>	<i>Package Type</i>	<i>Package Drawing</i>	<i>SPQ</i>	<i>MPQ</i>
NSI1611S02-Q1SWVR	5	0.01 ~ 2V	Level-3	NSi16 11S02Q	-40 to 125°C	SOP8 (300mil)	SOW8	1000	1000
NSI1611S04-Q1SWVR	5	0.01 ~ 4V	Level-3	NSi16 11S04Q	-40 to 125°C	SOP8 (300mil)	SOW8	1000	1000

12. Documentation Support

<i>Part Number</i>	<i>Product Folder</i>	<i>Technical Documents</i>	<i>Isolator selection guide</i>
NSI1611S02-Q1	Click here	Click here	Click here
NSI1611S04-Q1	Click here	Click here	Click here

13. Tape and Reel Information

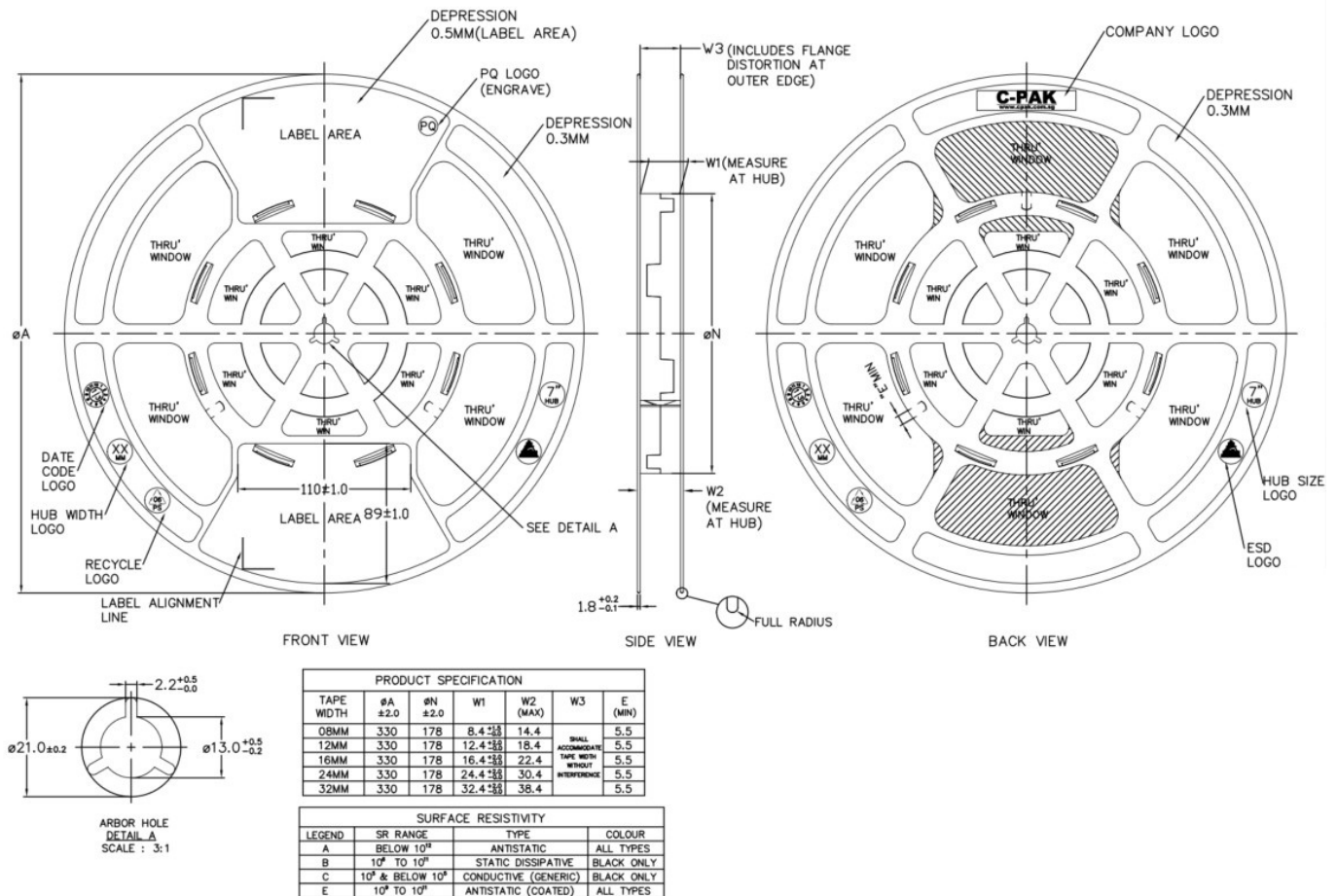


Figure 13.1 Tape Information

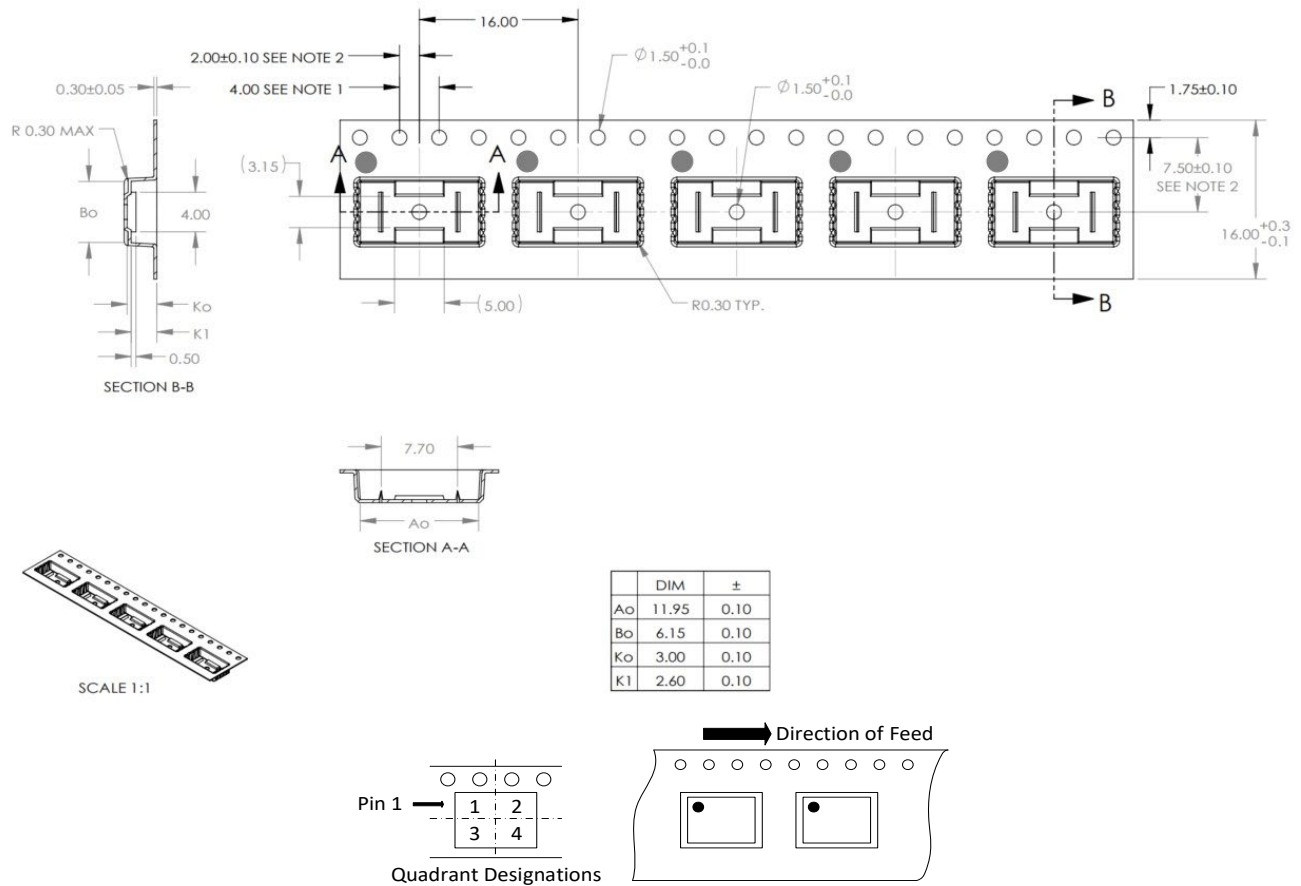


Figure 13.2 Reel Information of SOP8(300mil)

14. Revision History

Revision	Description	Date
1.0	Initial Version.	2026/3/18

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