Current Sense Amplifier, 80 V Common-Mode Voltage, Unidirectional

Product Preview

NCS7030, NCS7031, NCV7030, NCV7031

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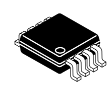
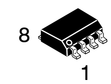
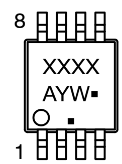


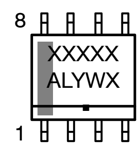
Micro8
CASE 846A−02



SOIC−8 NB
CASE 751−07

MARKING DIAGRAM

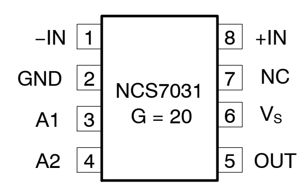


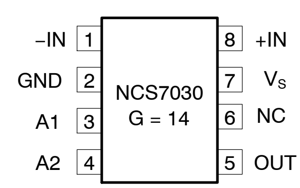


XXXXX = Specific Device Code
A = Assembly Location
L = Wafer Lot
Y = Year
W = Work Week
▪ = Pb−Free Package

(Note: Microdot may be in either location)

PIN CONNECTIONS





ORDERING INFORMATION

See detailed ordering and shipping information on page 10 of this data sheet.

The NCS7030 and NCS7031 are high voltage, current sense amplifiers. They are available with gain options of 14 V/V and 20 V/V, with a maximum ±0.3 % gain error over the entire temperature range. Each part consists of a preamplifier and buffer with access to output and input via A1 and A2 pins for an intermediate filter network or modified gain. The current sense amplifiers offer excellent input common−mode rejection from −5 V to 80 V. They can perform unidirectional current measurements across a sense resistor in a variety of applications. Automotive qualified options are available under NCV prefix. All versions are specified over the extended operating temperature range from −40°C to 125°C.

Features

- Bandwidth: 100 kHz
- Input Offset Voltage: ±300 μV Max Over Temp
- Offset Drift over Temperature: ±3 μV/°C max
- Gain Error: ±0.3 % Max Over Temp
- Quiescent Current: 3 mA Typ
- Supply Voltage: 4.5 V to 5.5 V
- Common−Mode Input Voltage Range: −5 V to 80 V Operating, −14 V to 85 V Survival
- CMRR: 90 dB Min
- PSRR: 70 dB Min
- Low−Pass Filter (1−pole or 2−pole)
- These are Pb−free Devices

Typical Applications

- Telecom Equipment
- Power Supply Designs
- Diesel Injection Control
- Automotive
- Motor Control

This document contains information on a product under development. ON Semiconductor reserves the right to change or discontinue this product without notice.

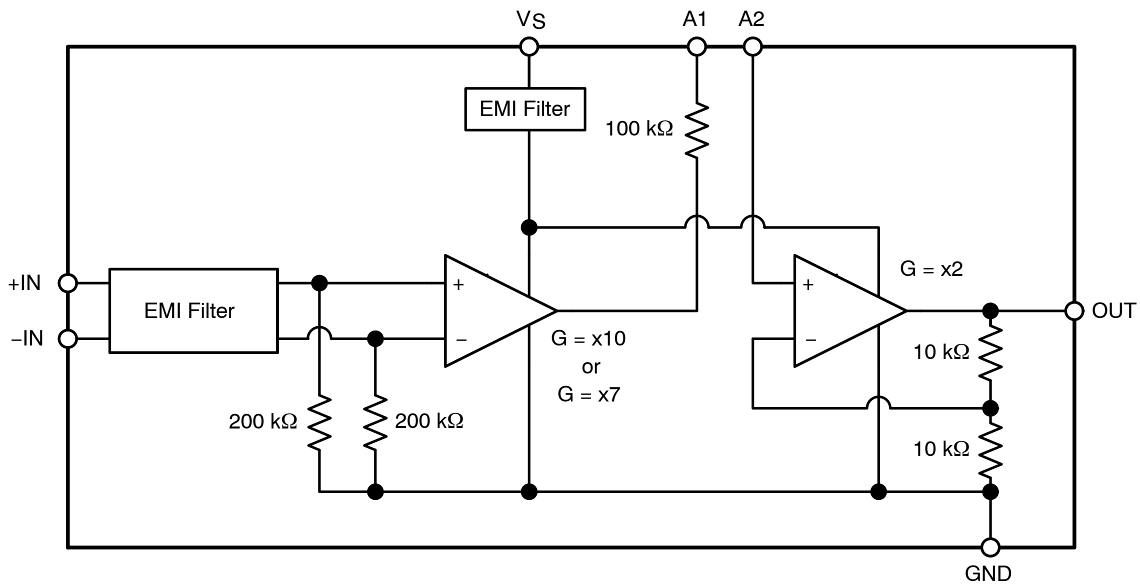


Figure 1. Simplified Block Diagram

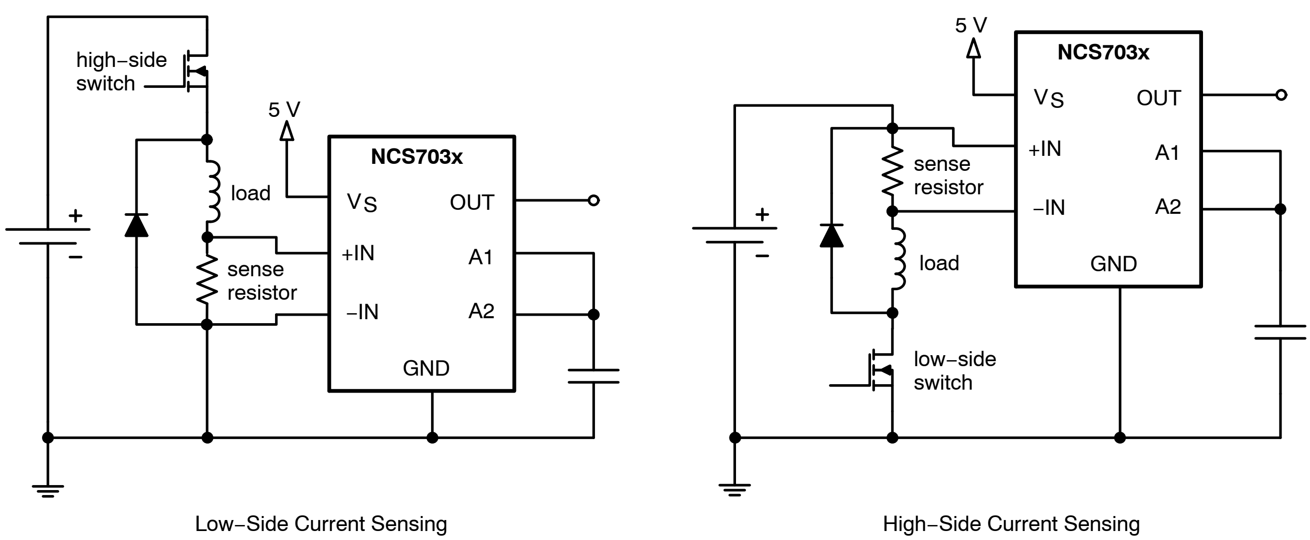


Figure 2. Application Schematic

PIN FUNCTION DESCRIPTION

NCS7031 (G = 20) Pinout	NCS7030 (G = 14) Pinout	Pin Name	Description
1	1	–IN	Inverting input – connect to sense resistor
2	2	GND	Device ground
3	3	A1	Pre–amp output connection
4	4	A2	Buffer amp input connection
5	5	OUT	Device output
6	7	V_S	Power supply connection
7	6	NC	No connect
8	8	+IN	Non–inverting input – connect to sense resistor

ABSOLUTE MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Supply Voltage Range (Note 1)	V_S	7	V
Input Common−Mode Range	V_{CM}	−14 to 85	V
Differential Input Voltage	V_{ID}	$\pm V_S$	V
Maximum Input Current	I_I	±10	mA
Maximum Output Current	I_O	±50	mA
Continuous Total Power Dissipation	P_D	200	mW
Maximum Junction Temperature	$T_{J(max)}$	150	°C
Storage Temperature Range	T_{STG}	−65 to 150	°C
ESD Capability (Note 2) Human Body Model, Input pins Human Body Model, All other pins Charged Device Model	 HBM HBM CDM	 ±8000 ±4000 TBD	V
Latch−Up Current (Note 3)		±100	mA
Moisture Sensitivity Level	MSL	Level 1	−
Lead Temperature Soldering Reflow (SMD Styles Only), Pb−Free Versions (Note 4)	T_{SLD}	260	°C

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

1. Refer to ELECTRICAL CHARACTERISTICS and APPLICATION INFORMATION for Safe Operating Area.
2. This device series incorporates ESD protection and is tested by the following methods:
   ESD Human Body Model tested per JS−001−2017 (AEC−Q100−002)
   ESD Charged Device Model tested per JS−002−2014 (AEC−Q100−011)
3. Latch−up current maximum rating: ≤ 100 mA per JEDEC standard JESD78E (AEC−Q100−004).
4. For information, please refer to our Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

THERMAL CHARACTERISTICS (Note 5)

Rating	Symbol	Package	Value (Note 6)	Unit
Thermal Resistance, Junction−to−Air	θ_{JA}	Micro8	166	°C/W
		SOIC−8	130	°C/W

5. Refer to ELECTRICAL CHARACTERISTICS and APPLICATION INFORMATION for Safe Operating Area.
6. Values based on four layer board with copper area of 200 mm^2 of 1 oz copper thickness and FR4 PCB substrate.

OPERATING RANGES (Note 7)

Rating	Symbol	Min	Max	Unit
Supply Voltage	V_S	4.5	5.5	V
Common−Mode Input Voltage Range	V_{CM}	−5	80	V
Ambient Temperature	T_A	−40	125	°C

7. Refer to ELECTRICAL CHARACTERISTICS and APPLICATION INFORMATION for Safe Operating Area.
   Errata Note: Engineering samples have a low voltage supply characteristic that will cause sinusoidal oscillation on the output under the following conditions: Vs < 4.5V and VCM < 1.2V. The oscillation is large signal (approximately 1 Vpp with a frequency around 32 kHz). This is a known issue for samples that will be corrected on production devices.

ELECTRICAL CARACTERISTICS At V_S = 5 V, T_A = +25°C, V_{CM} = 12 V, $R_L \geq$ 10 kΩ, unless otherwise noted.
Boldface limits apply over the specified temperature range, T_A = –40°C to 125°C, guaranteed by characterization and/or design.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
GAIN						
Total Gain, Preamplifier and Buffer	G	NCS7030 NCS7031		14 20		V/V
Gain Error	G_e	T_A = –40°C to +125°C			**±0.3**	%
Gain Drift	ΔG/ΔT	T_A = –40°C to +125°C			**±20**	ppm / °C
INPUT						
Input Offset Voltage	V_{OS}	T_A = +25°C		±100	**±300**	µV
		T_A = –40°C to +125°C			**±300**	
Input Offset Voltage Drift	ΔV/ΔT	T_A = –40°C to +125°C			**±3**	µV / °C
Common–Mode Rejection Ratio	CMRR	V_{CM} = –5 to 80 V, f = DC to 20 kHz	**90**			dB
Input Bias Current (Note 8)	I_{IB}			TBD	TBD	µA
PREAMPLIFIER						
Gain	G	NCS7030 NCS7031		7 10		V/V
Gain Error	G_e	T_A = –40°C to +125°C			**±0.3**	%
Output Voltage High	V_{OH}		**V_S – 0.1**	V_S – 0.05		V
Output Voltage Low	V_{OL}				**25**	mV
Output Resistance	R_{PRE}		98	100	102	kΩ
OUTPUT BUFFER						
Gain	G			2		V/V
Gain Error	G_e				**±0.3**	%
Output Voltage High	V_{OH}		**V_S – 0.1**	V_S – 0.05		V
Output Voltage Low	V_{OL}				**50**	mV
Input Bias Current	I_{IB}			40	**50**	nA
DYNAMIC PERFORMANCE						
Signal Bandwidth (–3dB)	BW	V_{ID} = 0.1 V_{p-p}		100		kHz
Slew Rate	SR	V_{ID} = 0 to 200 mV step		1		V / µs
NOISE						
Voltage Noise, Peak–to–Peak	V_n	f = 0.1 Hz to 10 Hz		10		μV_{p-p}
Voltage Noise Density	e_N	f = 1 kHz		275		nV / √Hz
POWER SUPPLY						
Quiescent Current	I_{DD}	T_A = +25°C		3	TBD	mA
		T_A = –40°C to +125°C			**TBD**	
Power Supply Rejection Ratio	PSRR		**70**			dB

8. Guaranteed by characterization and/or design.

GRAPHS (TBD)

APPLICATION INFORMATION

The NCS7030 and NCS7031 are current sense amplifiers featuring a wide common mode voltage up to 80 V independent of the supply voltage. The NCS703x current−sense amplifiers can be configured for both low−side and high−side current sensing.

Current Sensing Techniques

Low−side sensing appears to have the advantage of being straightforward, inexpensive, and can be implemented with a simple op amp circuit. However, the NCS703x series of devices provides the full differential input necessary to get accurate shunt connections, while also providing a built−in gain network with precision difficult to obtain with external resistors. The NCS703x is shown in a low−side configuration in Figure 3 below.

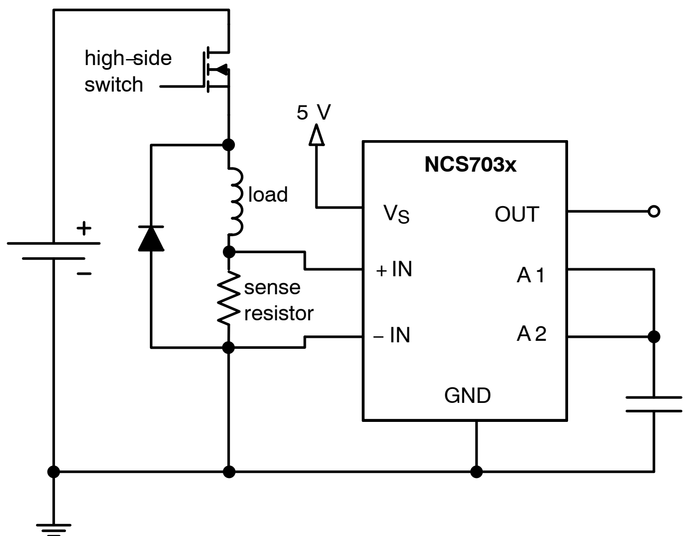


Figure 3. Low−side Current Sensing

While at times the application requires low−side sensing, only high−side sensing can detect a short from the positive supply line to ground. Furthermore, high−side sensing avoids adding resistance to the ground path of the load being measured. The sections below focus primarily on high−side current sensing. Figure 4 shows the NCS703x configured for high−side current sensing.

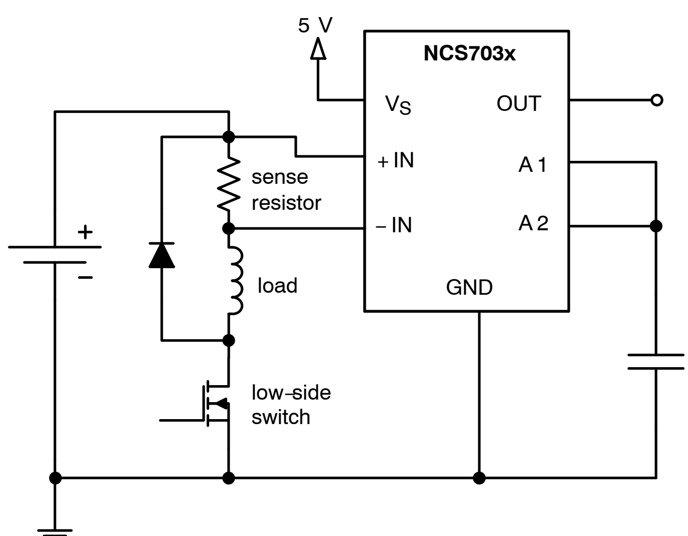


Figure 4. High−side Current Sensing

Unidirectional Operation

In unidirectional current sensing, the measured load current always flows in the same direction. Common applications for unidirectional operation include power supplies and load current monitoring.

NCS703x is internally referenced to ground; therefore, it can only measure current flowing in one direction. The +IN pin of the NCS703x should be connected to the positive side of the sense resistor, while the −IN pin should be connected to the negative side of the sense resistor.

When no current is flowing though the R_{SHUNT}, the NCS703x output is expected to be within 50 mV of ground. When current is flowing through R_{SHUNT}, the output will swing positive, up to within 100 mV of the applied supply voltage, V_S.

Power Supplies

The NCS703x can be connected to the same power supply that it is monitoring current from, or it can be connected to a separate power supply. If it is necessary to detect short circuit current on the load power supply, which may cause the load power supply to sag to near zero volts, a separate power supply must be used on the NCS703x. When using multiple supplies, there are no restrictions on power supply sequencing.

A1 and A2 Pins

A1 is the preamplifier output and the A2 is the buffer input. These pins can be used to make adjustments to the gain or to create a low−pass filter. The output of the preamplifier integrates a precision resistor of 100 kΩ ±2%, which can be utilized for either of these purposes.

The high impedances at the A1 and A2 pins make this connection particularly sensitive, and a careful layout is necessary if the high frequency response is required. Trace lengths should be kept at a minimum and test points should be avoided when possible at these pins. Even a small capacitance of 20 pF from the PCB can lower the −3dB signal bandwidth to 80 kHz. This filtering effect is useful for decreasing noise, and is further discussed in the upcoming ”Filtering with A1 and A2” section.

Lowering the Gain with A1 and A2

The gain can be lowered by using the A1 and A2 pins. Connecting A1 to A2 and adding a resistor from this net to GND creates a resistor divider network in combination with the internal 100 kΩ resistor, as shown by Figure 5. For example, adding an external 100 kΩ resistor, reduces the voltage going into A2 by half, reducing the overall gain by half.

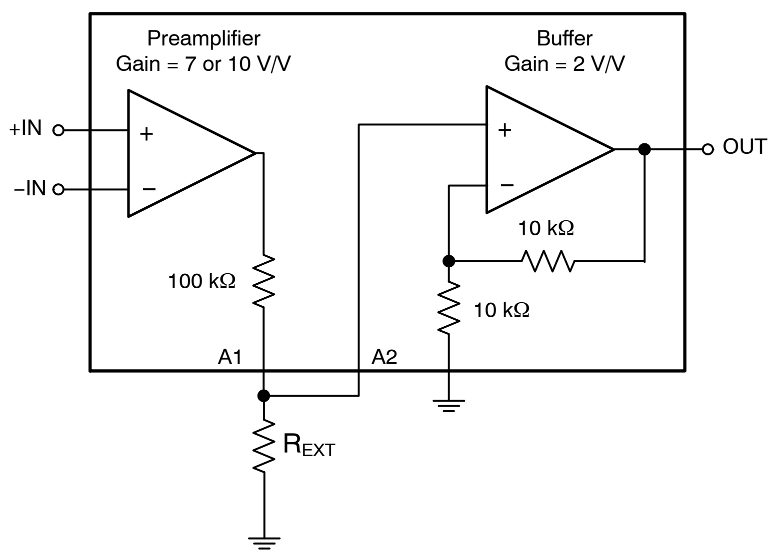


Figure 5. Lowering the Gain Using an External Resistor

The adjusted overall decreased gain, G_{ADJ-}, becomes a factor of the total nominal gain, G, and the external resistor, R_{EXT}.

$$G_{ADJ-} = \frac{G \times R_{EXT}}{R_{EXT} + 100\ k\Omega}$$

This equation can be rearranged to calculate the external resistor value for the desired gain value.

$$R_{EXT} = \frac{100\ k\Omega \times G_{ADJ-}}{G - G_{ADJ-}}$$

Increasing the Gain with A1 and A2

The gain can be increased by adding an external resistor in positive feedback as shown in Figure 6.

$$G_{ADJ+} = \frac{G \times R_{EXT}}{R_{EXT} - 100\ k\Omega}$$

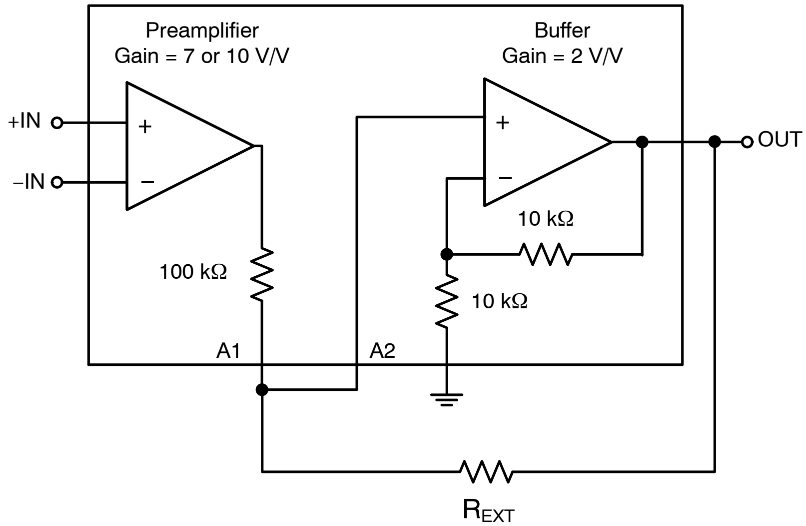


Figure 6. Increasing the Gain Using an External Resistor in Positive Feedback

Filtering with A1 and A2

In some applications, the current being measured may be inherently noisy. A low−pass filter can be created by connecting A1 and A2 together and adding a capacitor from the net to GND as shown in Figure 7. This creates a simple RC filter with the internal 100 kΩ resistor. This single pole filter has a 20 dB/decade attenuation.

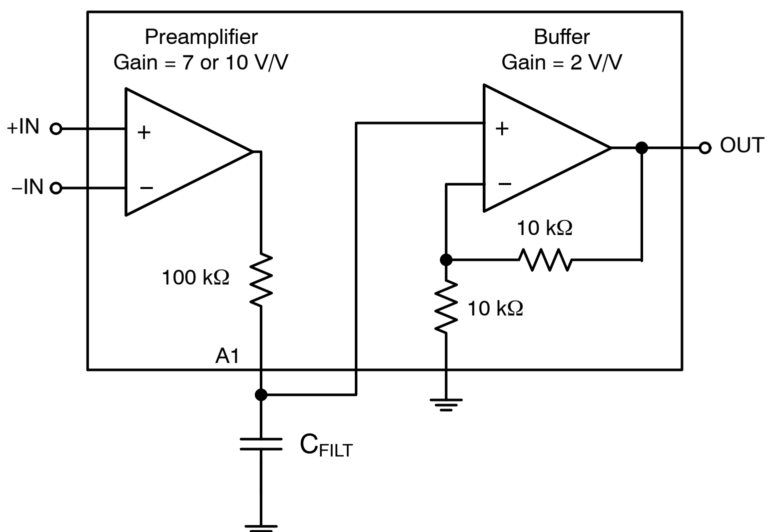


Figure 7. Implementing a Single−pole, Low−pass RC Filter

$$f_{FILT} = \frac{1}{2\pi(100\ k\Omega)C_{FILT}}$$

A two−pole filter with 40 dB/decade attenuation can be created with a Sallen−Key topology as shown in Figure 8.

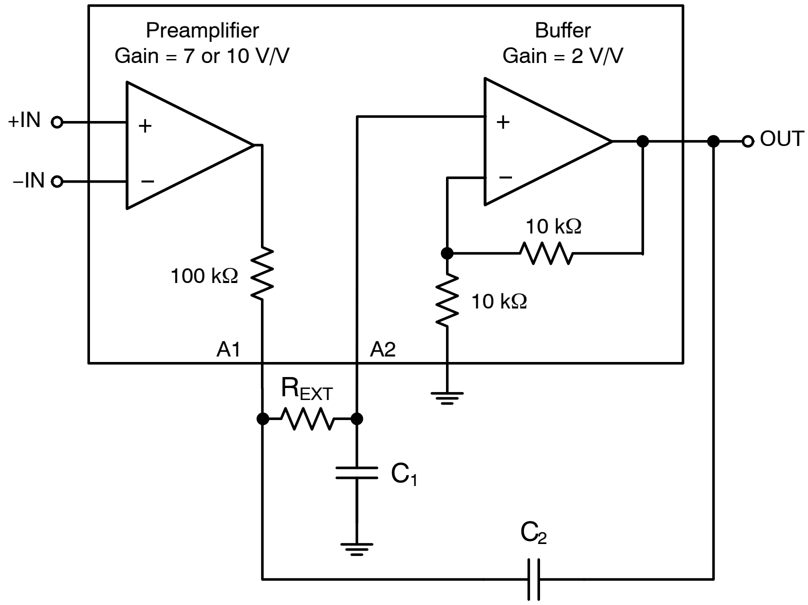


Figure 8. Implementing a Two−pole, Low−pass Filter using the Sallen−Key Topology

Input Filtering

Some applications may require filtering at the input of the current sense amplifier. Figure 9 shows the recommended schematic for input filtering.

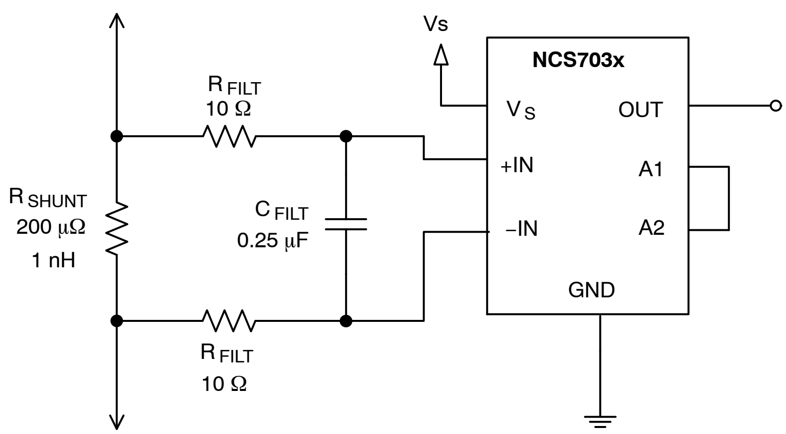


Figure 9. Input Filtering Compensates for Shunt Inductance on Shunts Less than 1 mΩ, as Well as High Frequency Noise in any Application

Input filtering is complicated by the fact that the added resistance of the filter resistors and the associated resistance mismatch between them can adversely affect gain, CMRR, and V_{OS}. The effect on V_{OS} is partly due to input bias currents as well. As a result, the value of the input resistors should be limited to 10 Ω or less.

As the shunt resistors decrease in value, shunt inductance can significantly affect frequency response. At values below 1 mΩ, the shunt inductance causes a zero in the transfer function that often results in corner frequencies in the low 100’s of kHz. This inductance increases the amplitude of high frequency spike transient events on the current sensing line that can overload the front end of any shunt current sensing IC. This problem must be solved by filtering at the input of the amplifier. Note that all current sensing IC’s are vulnerable to this problem, regardless of manufacturer claims. Filtering is required at the input of the device to resolve this problem, even if the spike frequencies are above the rated bandwidth of the device.

Ideally, select the capacitor to exactly match the time constant of the shunt resistor and its inductance; alternatively, select the capacitor to provide a pole below that point. Make the input filter time constant equal to or larger than the shunt and its inductance time constant:

$$\frac{L_{SHUNT}}{R_{SHUNT}} \le 2R_{FILT}C_{FILT}$$

To determine the value of C_{FILT} based on using 10 Ω resistors for each R_{FILT}, the equation simplifies to:

$$C_{FILT} \ge \frac{L_{SHUNT}}{20R_{SHUNT}}$$

If the main purpose is to filter high frequency noise, the capacitor should be increased to a value that provides the desired filtering. As an example, a filtering frequency of 10 kHz would require an 0.8 μF capacitor.

$$f_{FILT} = \frac{1}{2\pi(2R_{FILT})C_{FILT}}$$

Advantages When Used For Low−Side Current Sensing

The NCS703x series offers many advantages for low−side current sensing. The true differential input is ideal for connection to either Kelvin Sensing shunts or conventional shunts. Additionally, the true differential input rejects the common−mode noise often present even in low−side current sensing. Providing all of this in a tiny package makes it very competitive when compared to discrete op amp solutions.

Selecting the Shunt Resistor

The desired accuracy of the current measurement determines the precision, shunt size, and the resistor value. The larger the resistor value, the more accurate the measurement possible, but a large resistor value also results in greater power loss.

For the most accurate measurements, use four terminal current sense resistors. It provides two terminals for the current path in the application circuit, and a second pair for the voltage detection path of the sense amplifier. This technique is also known as *Kelvin Sensing*. This insures that the voltage measured by the sense amplifier is the actual voltage across the resistor and does not include the small resistance of a combined connection. When using non−Kelvin shunts, closely follow manufacturers recommendations on how to lay out the sensing traces.

Shutting Down the NCS703x

While the NCS703x does not provide a shutdown pin, a simple MOSFET, power switch, or logic gate can be used to switch off the power to the NCS703x and eliminate the quiescent current. Note that the shunt input pins will always have a current flow via the input and feedback resistors. The input pins support the rated common mode voltage even when the NCS703x does not have power applied.

ORDERING INFORMATION

Gain	Device	Marking	Package	Shipping†
14	NCS7030D2G014RG (In Development*)	7030	SOIC−8	2500 / Tape & Reel
	NCS7030DM2G014R2G (In Development*)	7030	Micro8	4000 / Tape & Reel
20	NCS7031D1G020R2G (In Development*)	7031	SOIC−8	2500 / Tape & Reel
	NCS7031DM1G020R2G (In Development*)	7031	Micro8	4000 / Tape & Reel

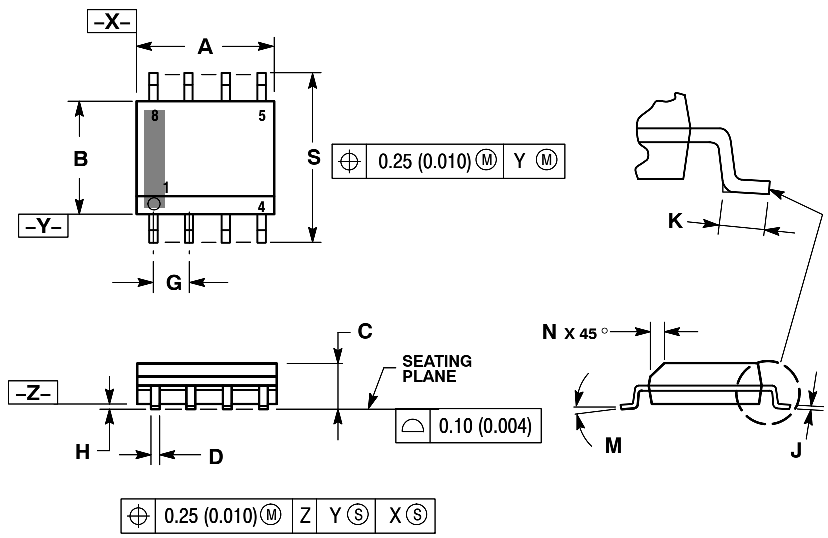
AUTOMOTIVE QUALIFIED

Gain	Device	Marking	Package	Shipping†
14	NCV7030D2G014RG (In Development*)	7030	SOIC−8	2500 / Tape & Reel
	NCV7030DM2G014R2G (In Development*)	7030	Micro8	4000 / Tape & Reel
20	NCV7031D1G020R2G (In Development*)	7031	SOIC−8	2500 / Tape & Reel
	NCV7031DM1G020R2G (In Development*)	7031	Micro8	4000 / Tape & Reel

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specification Brochure, BRD8011/D.
*Contact local sales office for more information.

PACKAGE DIMENSIONS

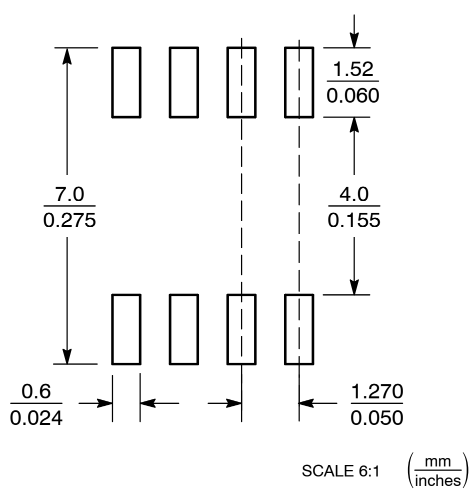
SOIC−8 NB
CASE 751−07
ISSUE AK



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION A AND B DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
5. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 (0.005) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION.
6. 751−01 THRU 751−06 ARE OBSOLETE. NEW STANDARD IS 751−07.

	MILLIMETERS		INCHES	
DIM	MIN	MAX	MIN	MAX
A	4.80	5.00	0.189	0.197
B	3.80	4.00	0.150	0.157
C	1.35	1.75	0.053	0.069
D	0.33	0.51	0.013	0.020
G	1.27 BSC		0.050 BSC	
H	0.10	0.25	0.004	0.010
J	0.19	0.25	0.007	0.010
K	0.40	1.27	0.016	0.050
M	0 °	8 °	0 °	8 °
N	0.25	0.50	0.010	0.020
S	5.80	6.20	0.228	0.244

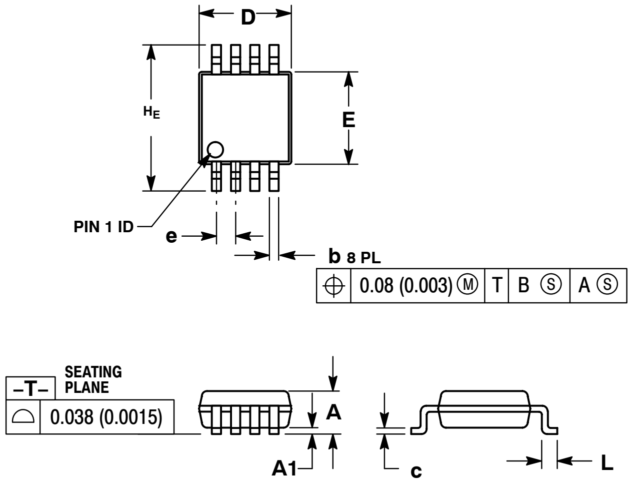
SOLDERING FOOTPRINT*



*For additional information on our Pb−Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

PACKAGE DIMENSIONS

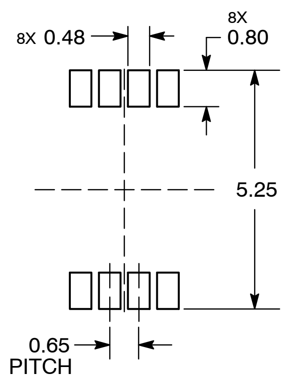
Micro8
CASE 846A−02
ISSUE J



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION A DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.15 (0.006) PER SIDE.
4. DIMENSION B DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSION. INTERLEAD FLASH OR PROTRUSION SHALL NOT EXCEED 0.25 (0.010) PER SIDE.
5. 846A−01 OBSOLETE, NEW STANDARD 846A−02.

	MILLIMETERS			INCHES		
DIM	MIN	NOM	MAX	MIN	NOM	MAX
A	−−	−−	1.10	−−	−−	0.043
A1	0.05	0.08	0.15	0.002	0.003	0.006
b	0.25	0.33	0.40	0.010	0.013	0.016
c	0.13	0.18	0.23	0.005	0.007	0.009
D	2.90	3.00	3.10	0.114	0.118	0.122
E	2.90	3.00	3.10	0.114	0.118	0.122
e	0.65 BSC			0.026 BSC		
L	0.40	0.55	0.70	0.016	0.021	0.028
HE	4.75	4.90	5.05	0.187	0.193	0.199

RECOMMENDED SOLDERING FOOTPRINT*



DIMENSION: MILLIMETERS

*For additional information on our Pb−Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

PUBLICATION ORDERING INFORMATION

LITERATURE FULFILLMENT:
Email Requests to: orderlit@onsemi.com

ON Semiconductor Website: www.onsemi.com

TECHNICAL SUPPORT
North American Technical Support:
Voice Mail: 1 800−282−9855 Toll Free USA/Canada
Phone: 011 421 33 790 2910

Europe, Middle East and Africa Technical Support:
Phone: 00421 33 790 2910
For additional information, please contact your local Sales Representative