NOVOSENSE

NSCSA240

-4V to 80V, Ultra-Precise Current Sense Amplifier With Enhanced PWM Rejection

Datasheet (EN) 1.0

Product Overview

The NSCSA240 is a high-precise, bidirectional current sense amplifier than can measure voltage drops across shunt resistors over a wide common mode range from –4 V to 80 V, independent of the supply voltage. The high-precision current measurement is achieved through a combination of low offset voltage (±5 µV typical), small gain error (0.05%, typical) and a high DC CMRR (135 dB, typical). The NSCSA240 is designed for high voltage, bidirectional measurements in switching systems that see large common-mode voltage transients at the device's inputs. The enhanced PWM rejection circuitry inside the NSCSA240 ensures minimal signal disturbance at the output due to the common-mode voltage transitions at the input.

The NSCSA240 operates from a single 2.7 V to 5.5 V supply, drawing 2.6 mA of supply current. The NSCSA240 is available in four gain options: 20V/V, 50V/V, 100V/V, and 200V/V. Multiple gain options allow for optimization between available shunt resistor values and wide output dynamic range requirements.

Key Features

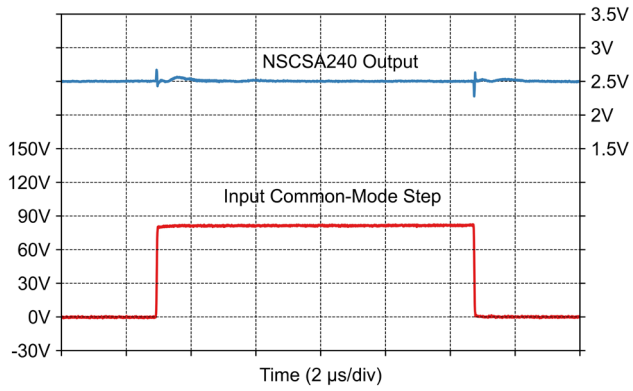
- Operating Temperature Range: –40°C to +125°C
- Enhanced PWM Rejection
- Wide Common-Mode Range: –4 V to 80 V
- Excellent CMRR:
  - 135-dB DC CMRR (Typical)
  - 90-dB AC CMRR at 50 kHz
- Accuracy:
  - Gain Error: 0.05% (Typical)
  - Offset Voltage: ±5µV (Typical)
- Gain Options:
  - NSCSA240A1: 20 V/V
  - NSCSA240A2: 50 V/V
  - NSCSA240A3: 100 V/V
  - NSCSA240A4: 200 V/V
- ROHS&REACH Compliance

Device Information

Part Number	Package	Body Size
NSCSA240	TSSOP (8)	3.00 mm × 4.40 mm
	SOIC (8)	4.90 mm × 3.91 mm

Typical Application

- Motor Controls
- Solenoid and Valve Controls
- Power Management
- Actuator Controls
- Pressure Regulators
- Telecom Equipment



Enhanced PWM Rejection

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1. Pin Configuration and Function

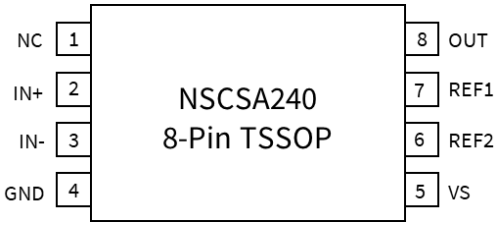


Figure 1-1 8-Pin TSSOP Package Top View

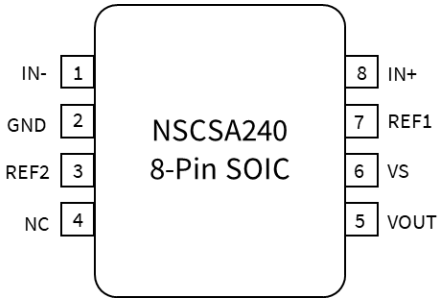


Figure 1-2 8-Pin SOIC Package Top View

Table 1-1 Pin Functions

SYMBOL	TSSOP	SOIC	FUNCTION
GND	4	2	Ground
IN-	3	1	Current-sense amplifier negative input
IN+	2	8	Current-sense amplifier positive input
NC	1	4	Connect to ground
OUT	8	5	Output voltage
REF1	7	7	Reference1 voltage. Connect to 0 V to V_S
REF2	6	3	Reference2 voltage. Connect to 0 V to V_S
V_S	5	6	Power supply

2. Specifications

2.1. Absolute Maximum Ratings[1]

Parameters	Symbol	Min	Max	Unit
Supply voltage	V_S	-0.3	6	V
Differential, +IN to −IN inputs			±80	V
Common-Mode, +IN, −IN to GND		−5	85	V
REF1, REF2, NC inputs		GND − 0.3	V_S + 0.3	V
Output		−0.3	V_S + 0.3	V
Junction temperature	T_J		150	°C
Storage temperature	T_{stg}	−55	150	°C

2.2. ESD Ratings

Ratings		Value	Unit
Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001 • All pins	±2000	V
	Charged device model (CDM), per JEDEC specification JESD22-C101 • All pins	±2000	V

2.3. Recommended Operating Conditions

Parameters	Symbol	Min	Max	Unit
Common-mode input voltage	V_{CM}	-4	80	V
Operating supply voltage	V_S	2.7	5.5	V
Operating free-air temperature	T_A	-40	125	°C

2.4. Thermal Information

Parameters	Symbol	TSSOP	SOIC	Unit
IC Junction-to-Air Thermal Resistance	θ_{JA}	149.1	113.5	°C/W
Junction-to-case (top) thermal resistance	$\theta_{JC(TOP)}$	33.2	51.9	°C/W
Junction-to-board thermal resistance	θ_{JB}	78.4	57.8	°C/W

[1] Stresses at or above those listed under Absolute Maximum Ratings may cause permanent damage to the product. This is a stress rating only; functional operation of the product at these or any other conditions above those indicated in the operational section of this specification is not implied. Operation beyond the maximum operating conditions for extended periods may affect product reliability

3. Electrical Characteristics

T_A = 25 °C, V_S = 5 V, $V_{SENSE} = V_{IN+} – V_{IN–}$, V_{SENSE} = 0 mV, V_{CM} = 12 V, and $V_{REF1} = V_{REF2} = V_S / 2$ (unless otherwise noted)

Parameters	Symbol	Condition	Min	Typ	Max	Unit
INPUT						
Common-mode input range	V_{CM}	V_{IN+} = –4V to 80V, V_{SENSE} = 0 mV T_A = – 40°C to 125°C(1)	-4		80	V
Common-mode rejection ratio	CMRR	V_{IN+} = –4V to 80V, V_{SENSE} = 0 mV	125	135		dB
		T_A = –40°C to 125°C(1)	110			
		f = 50 kHz		90		
Offset voltage, input-referred	V_{OS}	V_{SENSE} = 0		±5	±25	μV
Offset voltage Drift	dV_{OS}/dT	V_{SENSE} = 0, T_A = –40°C to 125°C(2)		±0.06	±0.25	uV/°C
Power-supply rejection ratio	PSRR	V_S = 2.7 V to 5.5 V V_{SENSE} = 0, T_A = –40°C to 125°C(1)		±5	±15	μV/V
Input bias current	I_B	I_{B+}, $I_{B–}$, V_{SENSE} = 0, V_{CM} = 12 V		92		μA
		I_{B+}, $I_{B–}$, V_{SENSE} = 0, V_{CM} = 80 V		225		
Reference input range			GND		V_S	
OUTPUT						
Gain	G	NSCSA240A1		20		V/V
		NSCSA240A2		50		
		NSCSA240A3		100		
		NSCSA240A4		200		
Gain error	GE	GND + 50 mV ⩽ V_{OUT} ⩽ V_S – 0.1V		±0.05 %	±0.1%	
Gain drift		T_A = –40°C to 125°C(2)		±2	±3	ppm/°C
Non-linearity error		GND + 0.1V ⩽ V_{OUT} ⩽ V_S – 0.1V		±0.01 %		
Reference divider accuracy		V_{OUT} = | (V_{REF1} – V_{REF2}) | / 2, A1(Gain=20), A2(Gain=50), A4(Gain=200)		0.02%	0.1%	
Reference divider accuracy		A3(Gain=100)		0.02%	0.15%	
Reference voltage rejection ratio (input-referred)	RVRR	$V_{REF1} = V_{REF2}$ = GND + 0.1V ⩽ V_{OUT} ⩽ V_S –0.1V T_A = –40°C to +125°C(1)		±3	±15	μV/V
VOLTAGE OUTPUT						
Swing to V_S		R_L = 10 kΩ to GND T_A = –40°C to 125°C(1)		V_S −0.02	V_S −0.05	V
Swing to GND		R_L = 10 kΩ to GND T_A = –40°C to 125°C(1)		0.005	0.01	V

(1) All devices are 100% production tested at T_A = 25°C. All temperature limits are guaranteed by characterization results
(2) Temperature drift-related limits are guaranteed by characterization results

Electrical Characteristics (continued)

T_A = 25 °C, V_S = 5 V, V_{SENSE} = V_{IN+} – $V_{IN–}$, V_{SENSE} = 0 mV, V_{CM} = 12 V, and V_{REF1} = V_{REF2} = V_S / 2 (unless otherwise noted)

FREQUENCY RESPONSE					
–3dB bandwidth	BW	NSCSA240A1, G = 20		600	KHz
		NSCSA240A2, G = 50		550	
		NSCSA240A3, G = 100		500	
		NSCSA240A4, G = 200		450	
Settling time	T_S	Output settles to 0.1%		10	µs
Slew rate	SR			4	V/µs
NOISE (INPUT REFERRED)					
Voltage noise density		Input referred		40	nV/ √ Hz
0.1-Hz to 10-Hz Voltage Noise		Input referred		0.8	µV
POWER SUPPLY					
Operating voltage range	V_S		2.7	5.5	V
Quiescent current	I_Q		2.6	2.9	mA
		T_A = –40°C to 125°C[1]		3	
TEMPERATURE RANGE					
Specified Range	T_A		-40	125	°C

[1] All devices are 100% production tested at T_A = 25°C. All temperature limits are guaranteed by characterization results

4. Typical Performance Characteristics

T_A = 25 °C, V_S = 5 V, V_{SENSE} = V_{IN+} – $V_{IN–}$, V_{SENSE} = 0 mV, V_{CM} = 12 V, and V_{REF1} = V_{REF2} = V_S / 2 (unless otherwise noted)

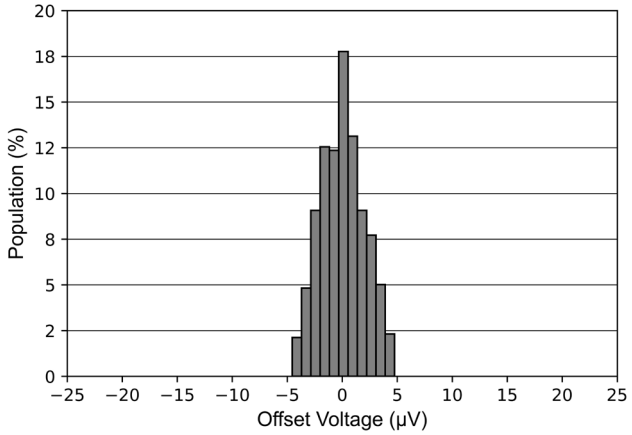


Figure 4-1 Input Offset Voltage Distribution

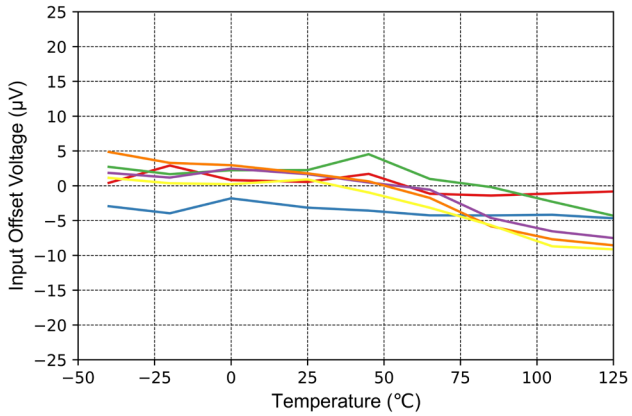


Figure 4-2 Input Offset Voltage vs Temperature

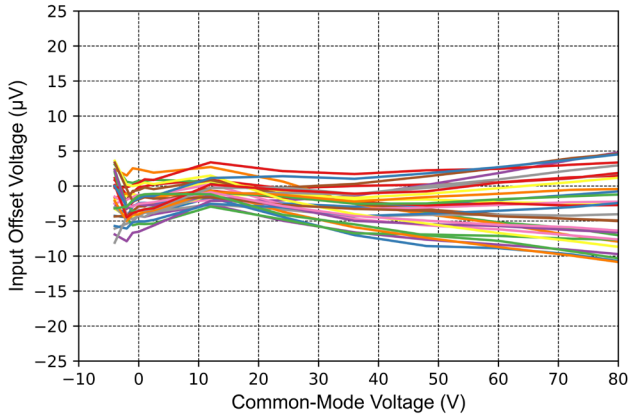


Figure 4-3 Input Offset Voltage vs Common-Mode Voltage

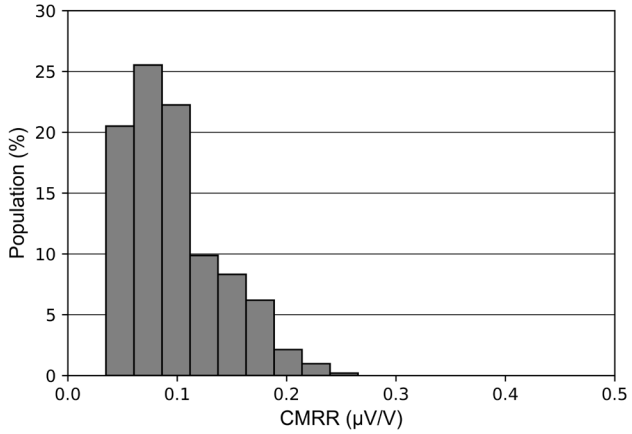


Figure 4-4 Common-Mode Rejection Ratio Distribution

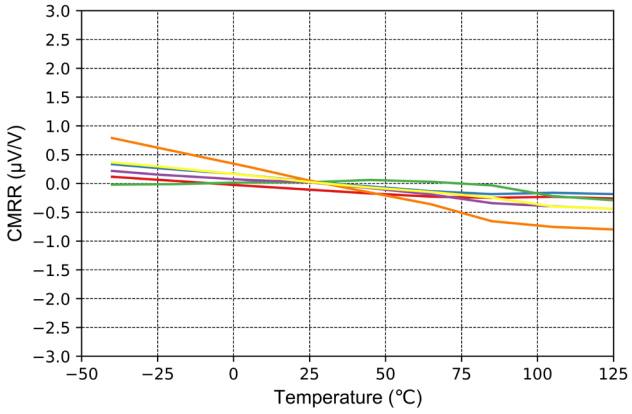


Figure 4-5 Common-Mode Rejection Ratio vs Temperature

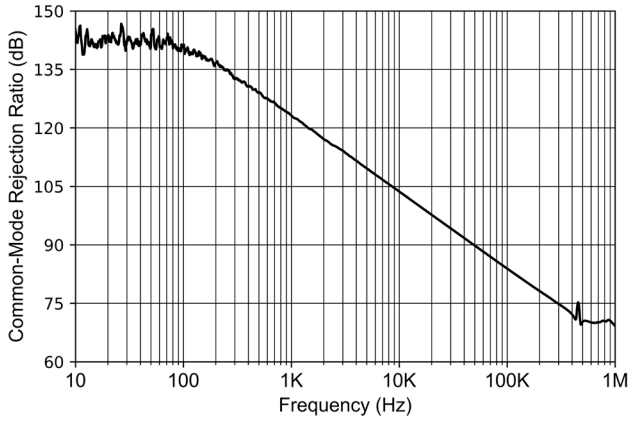


Figure 4-6 Common-Mode Rejection Ratio vs Frequency

Typical Performance Characteristics (continued)

T_A = 25 °C, V_S = 5 V, V_{SENSE} = V_{IN+} – $V_{IN–}$, V_{SENSE} = 0 mV, V_{CM} = 12 V, and V_{REF1} = V_{REF2} = V_S / 2 (unless otherwise noted)

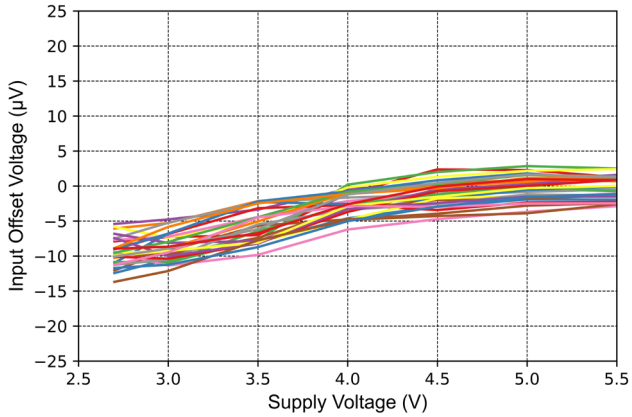


Figure 4-7 Input Offset Voltage vs Supply Voltage

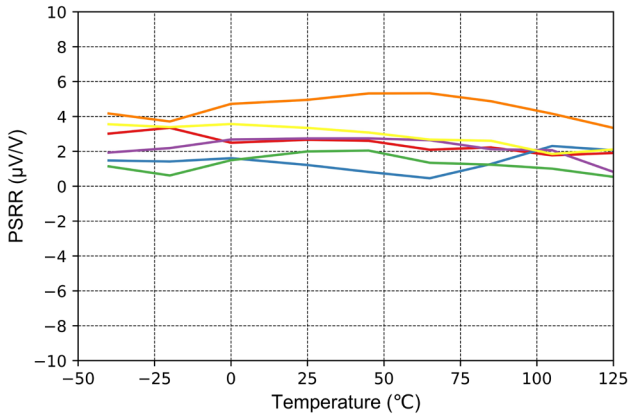


Figure 4-8 Power-Supply Rejection vs Temperature

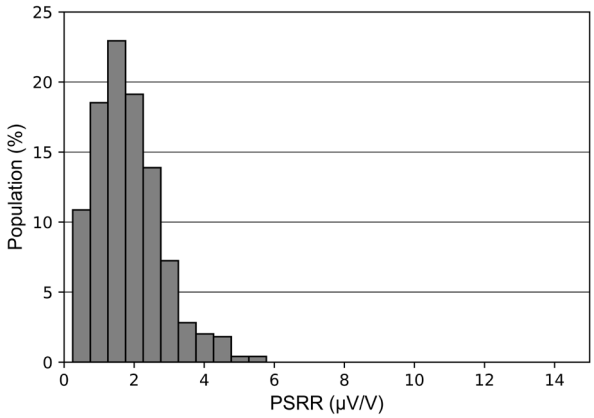


Figure 4-9 Power-Supply Rejection Ratio Distribution

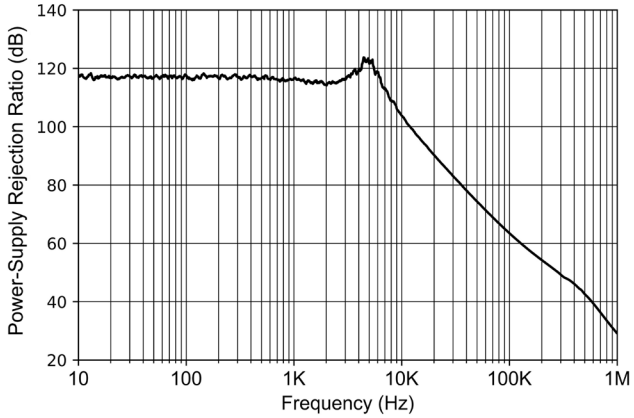


Figure 4-10 Power-Supply Rejection Ratio vs Frequency

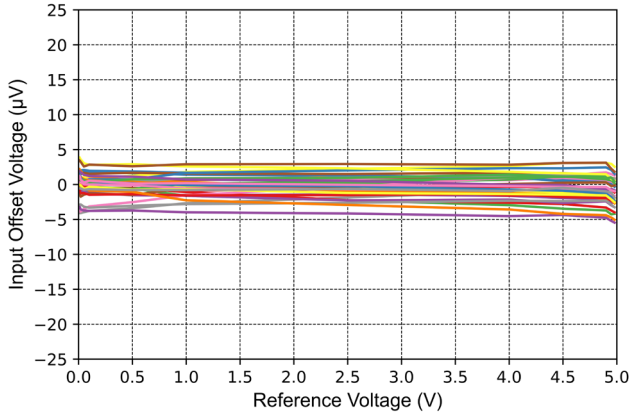


Figure 4-11 Input Offset Voltage vs Reference Voltage

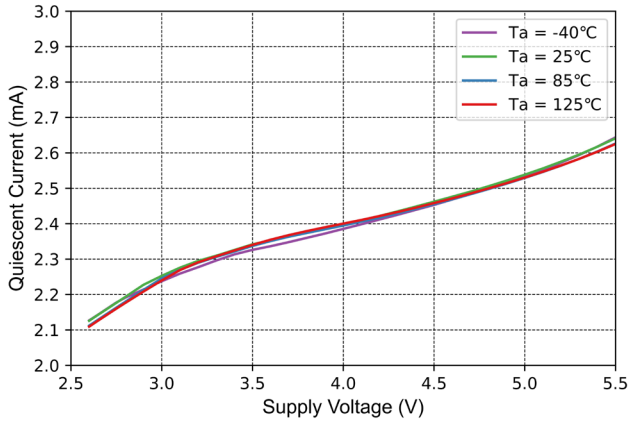


Figure 4-12 Quiescent Current vs Supply Voltage

Typical Performance Characteristics (continued)

T_A = 25 °C, V_S = 5 V, V_{SENSE} = V_{IN+} – $V_{IN–}$, V_{SENSE} = 0 mV, V_{CM} = 12 V, and V_{REF1} = V_{REF2} = V_S / 2 (unless otherwise noted)

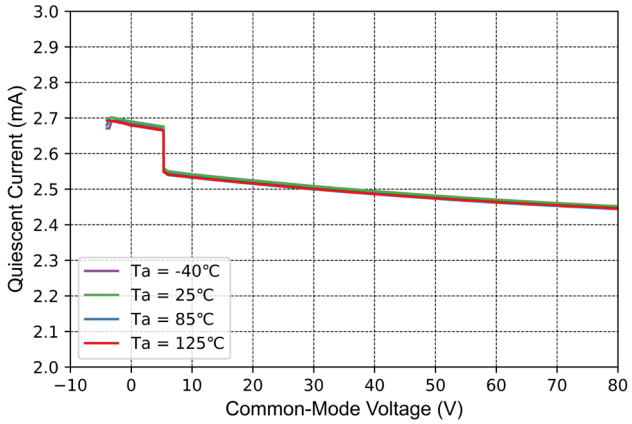


Figure 4-13 Quiescent Current vs Common-Mode Voltage

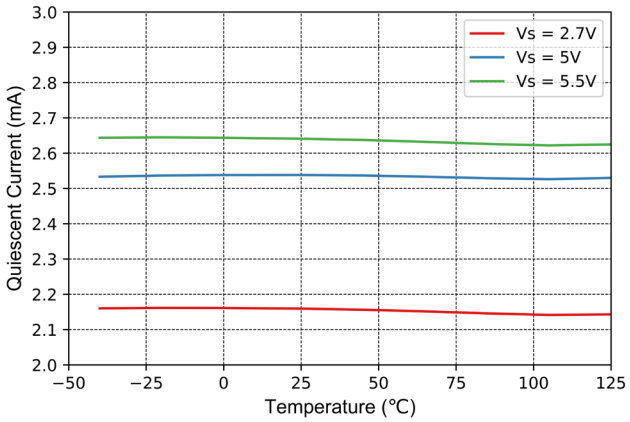


Figure 4-14 Quiescent Current vs Temperature

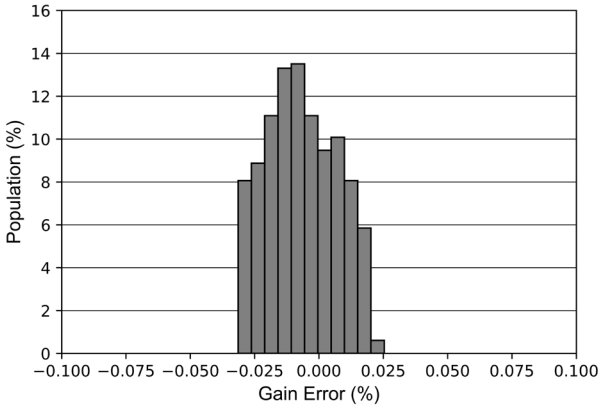


Figure 4-15 Gain Error Production Distribution

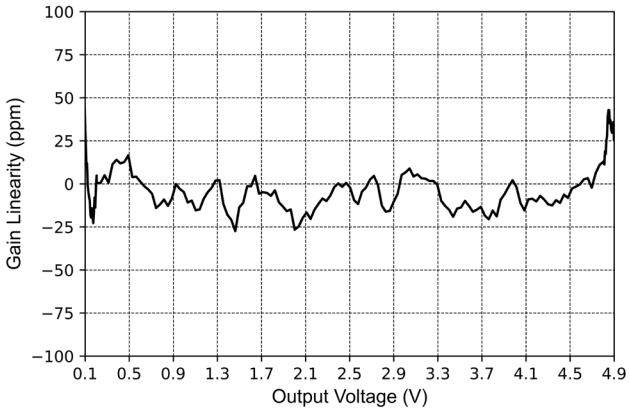


Figure 4-16 Gain Nonlinearity vs. vs Output Voltage

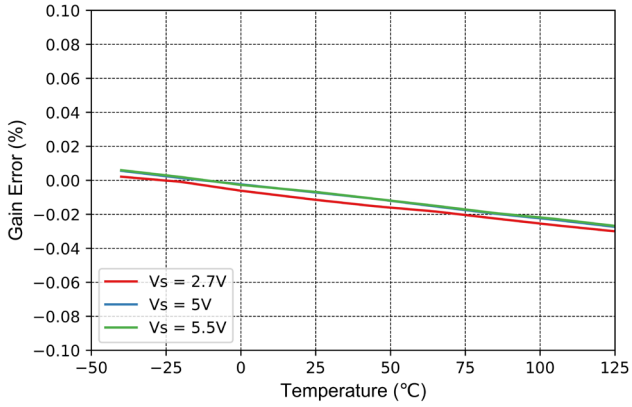


Figure 4-17 Gain Error vs Temperature

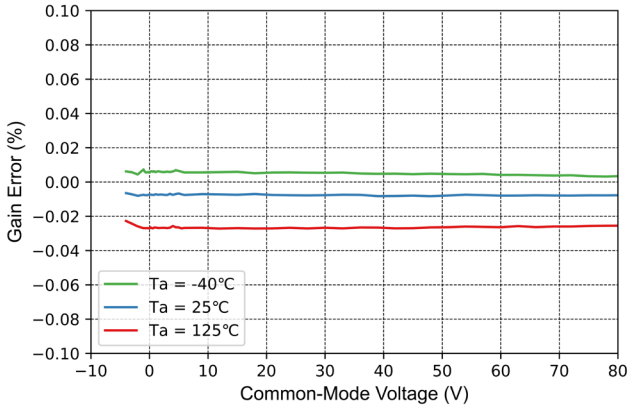


Figure 4-18 Gain Error *vs Common-Mode Voltage*

Typical Performance Characteristics (continued)

T_A = 25 °C, V_S = 5 V, $V_{SENSE} = V_{IN+} – V_{IN–}$, V_{SENSE} = 0 mV, V_{CM} = 12 V, and $V_{REF1} = V_{REF2} = V_S / 2$ (unless otherwise noted)

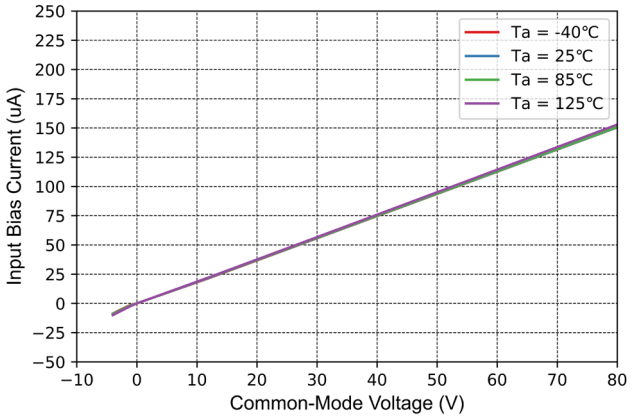


Figure 4-19 Input Bias Current vs Common-Mode Voltage V_S = 0

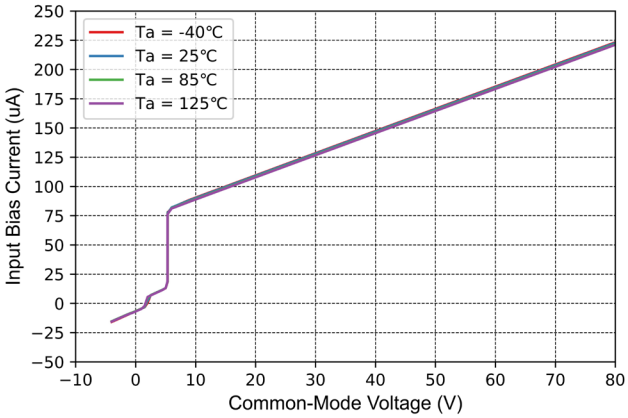


Figure 4-20 Input Bias Current vs Common-Mode Voltage V_S = 5 V

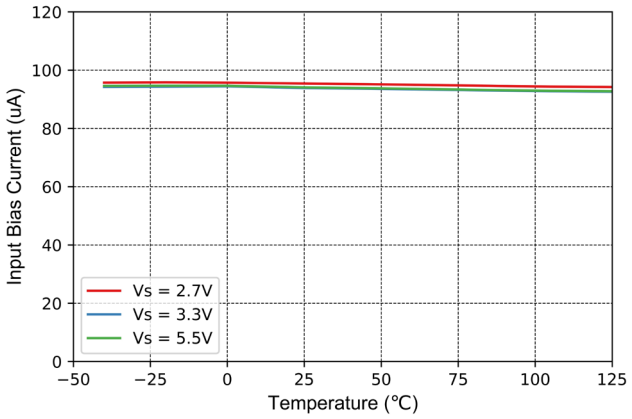


Figure 4-21 Input Bias Current vs Temperature

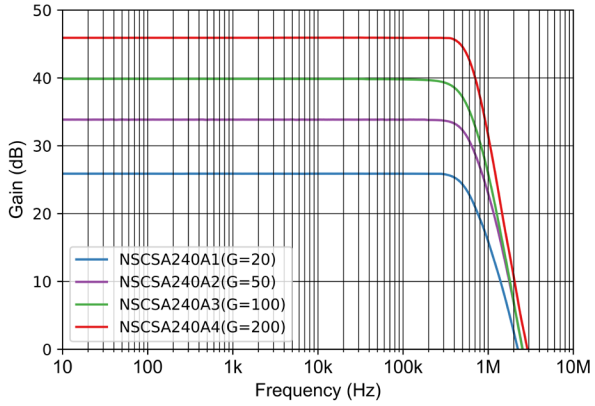


Figure 4-22 Gain vs Frequency

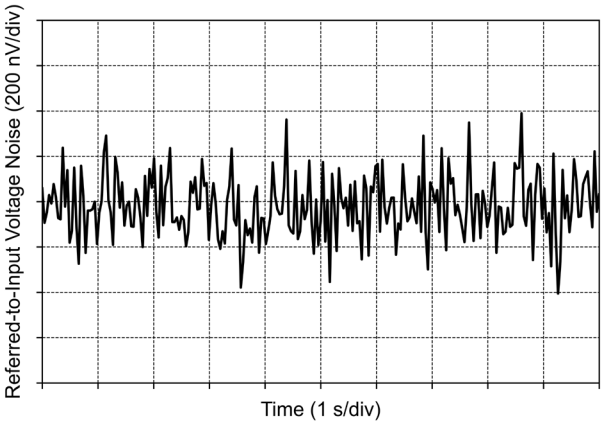


Figure 4-23 0.1-Hz to 10-Hz Voltage Noise

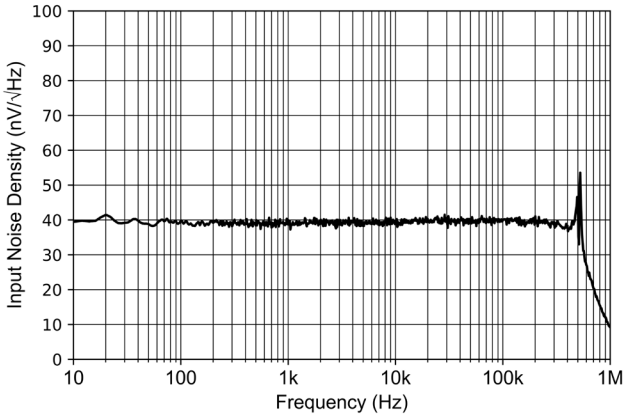


Figure 4-24 Input-Referred Voltage Noise vs Frequency

Typical Performance Characteristics (continued)

T_A = 25 °C, V_S = 5 V, V_{SENSE} = V_{IN+} – $V_{IN–}$, V_{SENSE} = 0 mV, V_{CM} = 12 V, and V_{REF1} = V_{REF2} = V_S / 2 (unless otherwise noted)

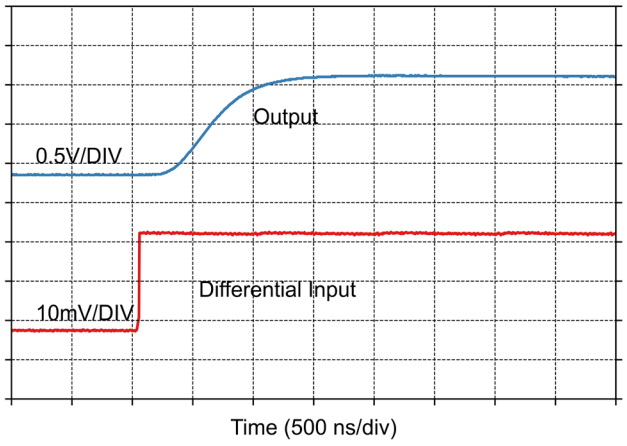


Figure 4-25 Small Signal Response, Raising

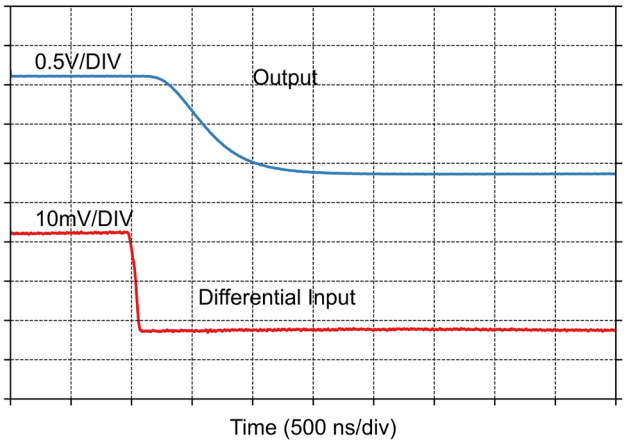


Figure 4-26 Small Signal Response, Falling

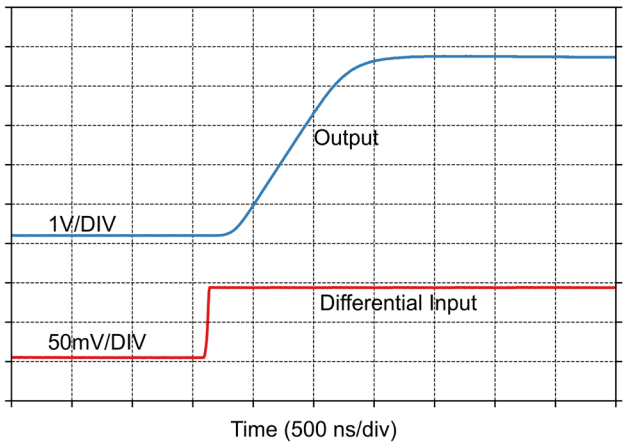


Figure 4-27 Large Signal Response, Raising

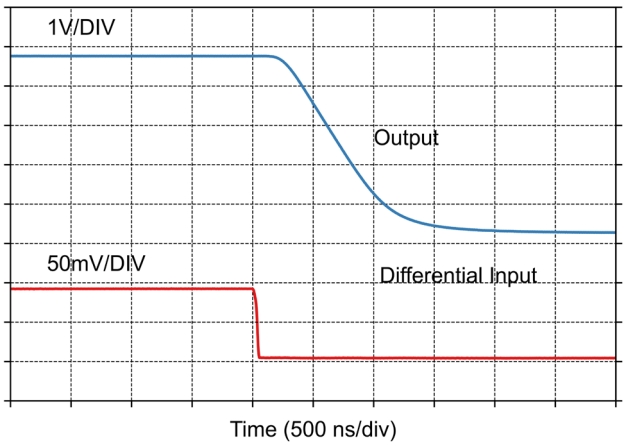


Figure 4-28 Large Signal Response, Falling

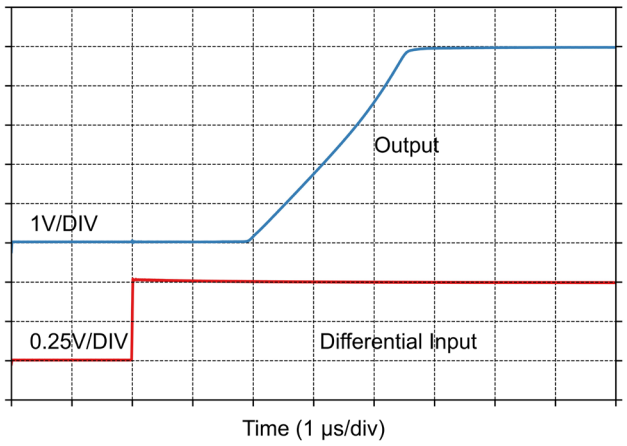


Figure 4-29 Differential Overload Recovery, Rising

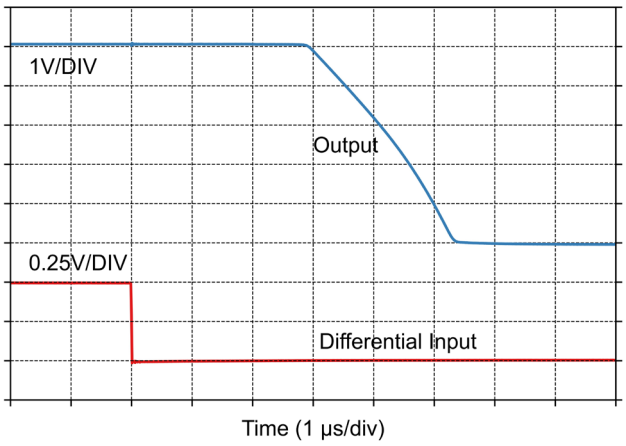


Figure 4-30 Differential Overload Recovery, Falling

Typical Performance Characteristics (continued)

T_A = 25 °C, V_S = 5 V, V_{SENSE} = V_{IN+} – $V_{IN–}$, V_{SENSE} = 0 mV, V_{CM} = 12 V, and V_{REF1} = V_{REF2} = V_S / 2 (unless otherwise noted)

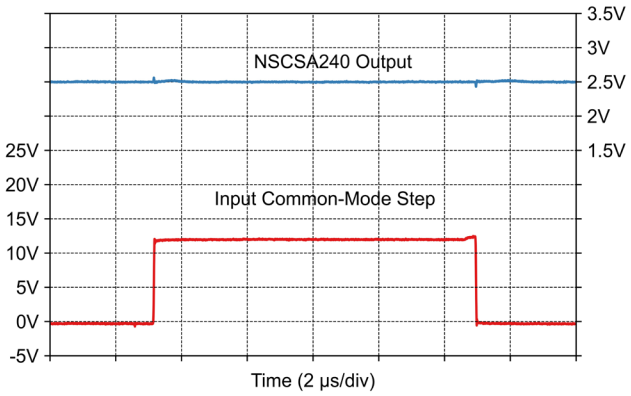


Figure 4-31 12V Common-Mode Voltage Transient Response

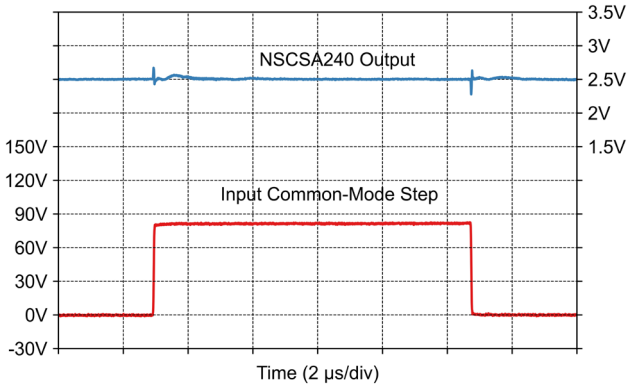


Figure 4-32 80V Common-Mode Voltage Transient Response

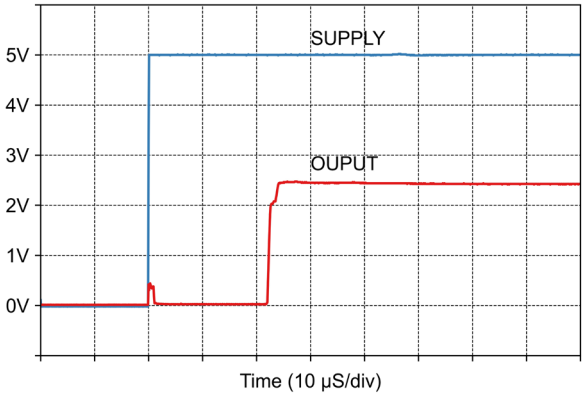


Figure 4-33 Start-Up Response

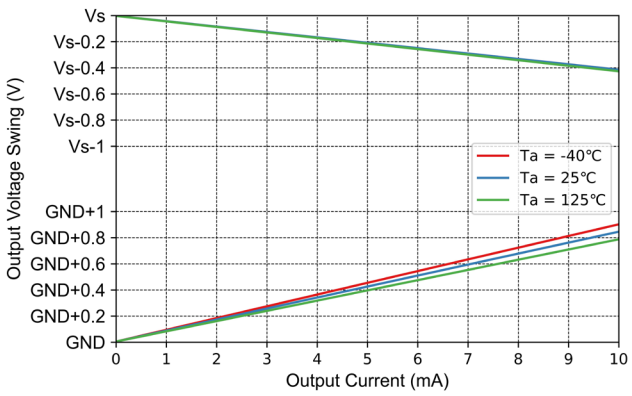


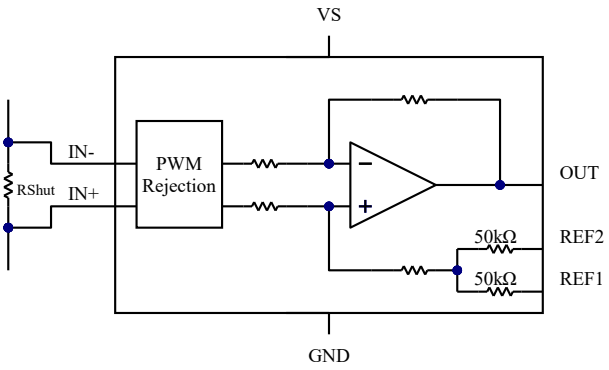
Figure 4-34 Output Voltage Swing vs Output Current

5. Detailed Description

5.1. Overview

NSCSA240 is a current-sense amplifier that offers a wide common-mode range, precision, zero-drift topology, excellent common-mode rejection ratio (CMRR), and features enhanced pulse width modulation (PWM) rejection. Enhanced PWM rejection reduces the effect of common-mode transients on the output signal that are associated with PWM signals. Multiple gain versions are available to allow for the optimization of the desired full-scale output voltage based on the target current range expected in the application.

5.2. Functional Block Diagram



5.3. Feature Description

5.3.1. Amplifier Input Signal

The NSCSA240 is designed to handle large common-mode transients over a wide voltage range. Input signals from current measurement applications for linear and PWM applications can be connected to the amplifier to provide a highly accurate output, with minimal common-mode transient artifacts.

5.3.2. Enhanced PWM Rejection Operation

The enhanced PWM rejection feature of the NSCSA240 provides increased attenuation of large common-mode ΔV/Δt transients. Large ΔV/Δt common-mode transients associated with PWM signals are employed in applications such as motor or solenoid drive and switching power supplies. Traditionally, large ΔV/Δt common mode transitions are handled strictly by increasing the amplifier signal bandwidth, which can increase chip size, complexity and ultimately cost. The NSCSA240 is designed with high common-mode rejection techniques to reduce large ΔV/Δt transients before the system is disturbed as a result of these large signals. The high AC CMRR, in conjunction with signal bandwidth, allows the NSCSA240 to provide minimal output transients and ringing compared with standard circuit approaches.

5.3.3. Input Signal Bandwidth

The NSCSA240 input signal, which represents the current being measured, is accurately measured with minimal disturbance from large ΔV/Δt common-mode transients as previously described. For PWM signals typically associated with motors, solenoids, and other switching applications, the current being monitored varies at a significantly slower rate than the faster PWM frequency. The NSCSA240 bandwidth is defined by the –3 dB bandwidth of the current-sense amplifier inside the device; see the Electrical Characteristics table. The device bandwidth provides fast throughput and fast response required for the rapid detection and processing of overcurrent events. Without the higher bandwidth, protection circuitry may not have adequate response time and damage may occur to the monitored application or circuit.

5.3.4. Selecting the Sense Resistor (R_{SENSE})

The NSCSA240 determines the current magnitude from measuring the differential voltage developed across a resistor. This resistor is referred to as a current-sensing resistor or a current-shunt resistor. The flexible design of the device allows a wide input signal range across this current-sensing resistor.

The current-sensing resistor is ideally chosen solely based on the full-scale current to be measured, the full-scale input range of the circuitry following the device, and the device gain selected. The minimum current sensing resistor is a design-based decision in order to maximize the input range of the signal chain circuitry. Full-scale output signals that are not

maximized to the full input range of the system circuitry limit the ability of the system to exercise the full dynamic range of system control.

Two important factors to consider when finalizing the current-sensing resistor value are: the required current measurement accuracy and the maximum power dissipation across the resistor. A larger resistor voltage provides for a more accurate measurement, but increases the power dissipation in the resistor. The increased power dissipation generates heat, which reduces the sense resistor accuracy because of the temperature coefficient. The voltage signal measurement uncertainty is reduced when the input signal gets larger because any fixed errors become a smaller percentage of the measured signal. The design trade-off to improve measurement accuracy increases the current-sensing resistor value. The increased resistance value results in an increased power dissipation in the system which can additionally decrease the overall system accuracy. Based on these relationships, the measurement accuracy is inversely proportional to both the resistance value and power dissipation contributed by the current-shunt selection.

By increasing the current-shunt resistor, the differential voltage is increased across the resistor. Larger input differential voltages require a smaller amplifier gain to achieve a full-scale amplifier output voltage. Smaller current-shunt resistors are desired but require large amplifier gain settings. The larger gain settings often have increased error and noise parameters, which are not attractive for precision designs. Historically, the design goals for high-performance measurements forced designers to accept selecting larger current-sense resistors and the lower gain amplifier settings. The NSCSA240 provides 100-V/V and 200-V/V gain options that offer the high-gain setting and maintains high-performance levels with offset values below 25 μV. These devices allow for the use of lower shunt resistor values to achieve lower power dissipation and still meet high system performance specifications.

6. Layout

6.1. Layout Guidelines

6.1.1. High-Precision Applications

For high-precision applications, verify accuracy and stability of the amplifier by:

• Providing a precision reference connected to REF1 and REF2

• Optimizing the layout of the power and sensing path of the sense resistor (see the Layout section)

• Providing adequate bypass capacitance on the supply pin.

6.1.2. Kelvin Connection from the Current-Sense Resistor

To provide accurate current measurements, verify the routing between the current-sense resistor and the amplifier uses a Kelvin connection. Use the information provided in Figure 6-1 and Figure 6-2.

6.2. Layout Example

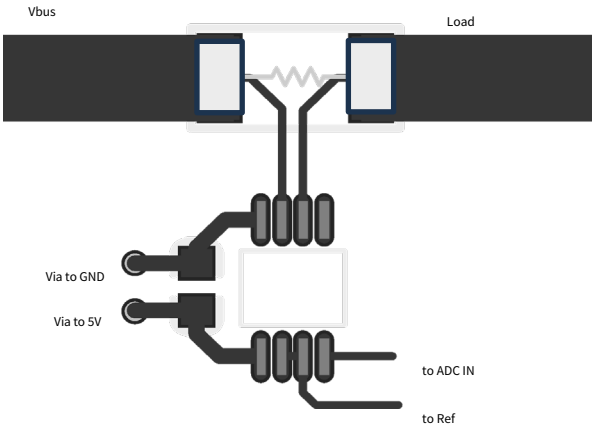


Figure 6-1 Example Layout Diagram for TSSOP8 Package

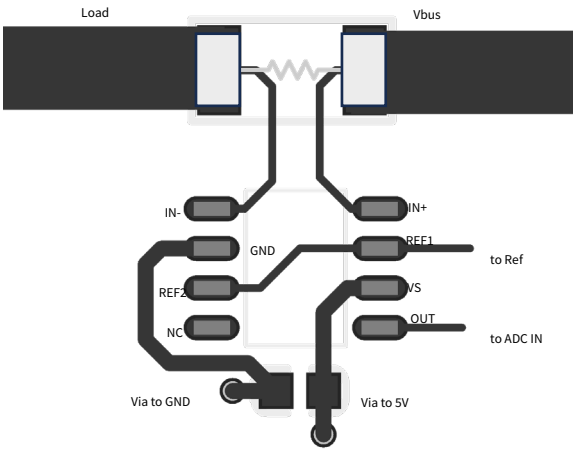
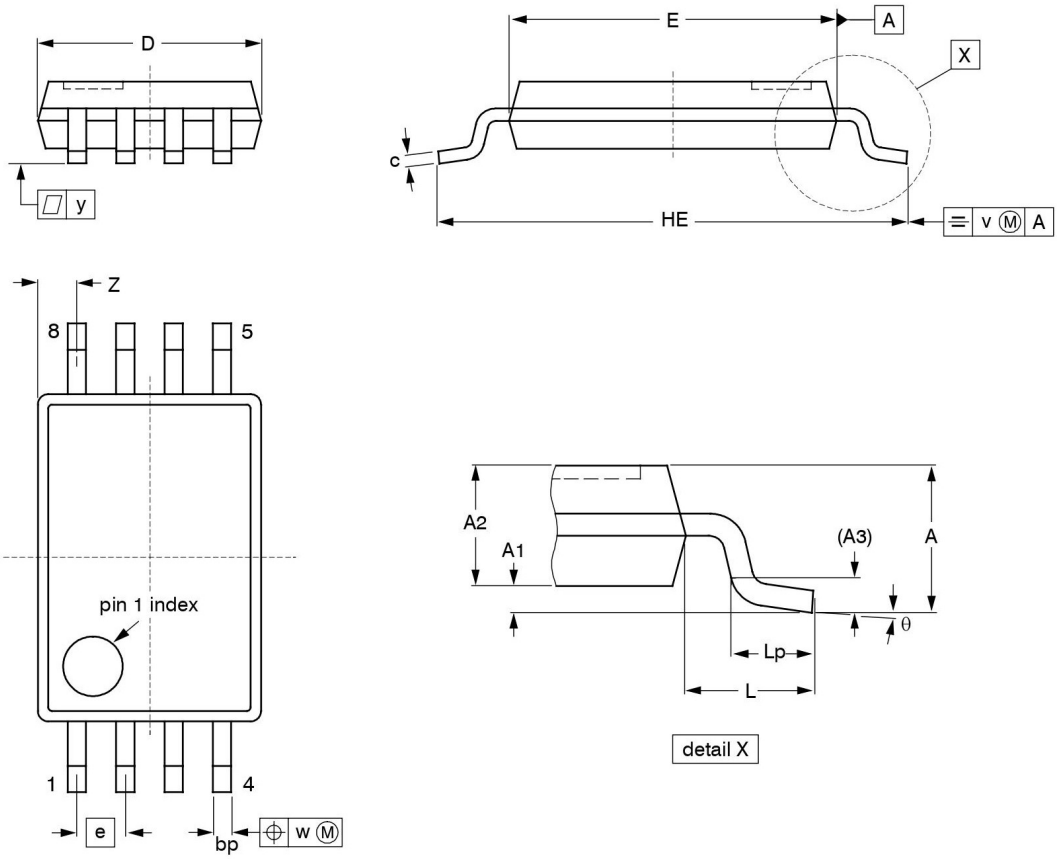


Figure 6-2 Example Layout Diagram for SOP8 Package

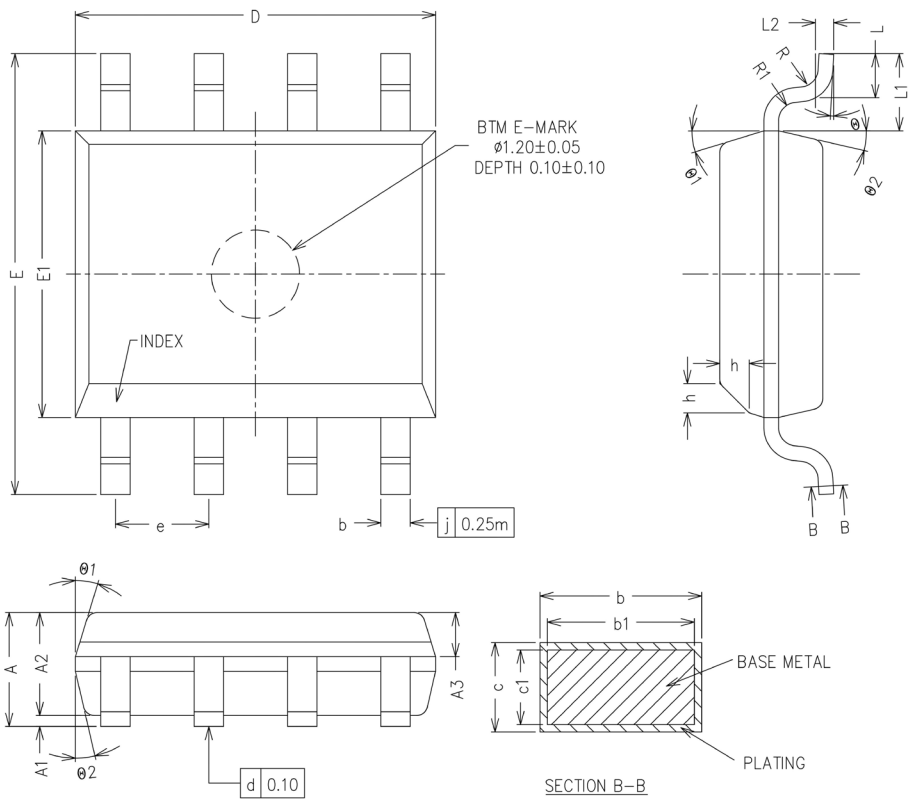
7. Package Information

7.1. TSSOP (8)



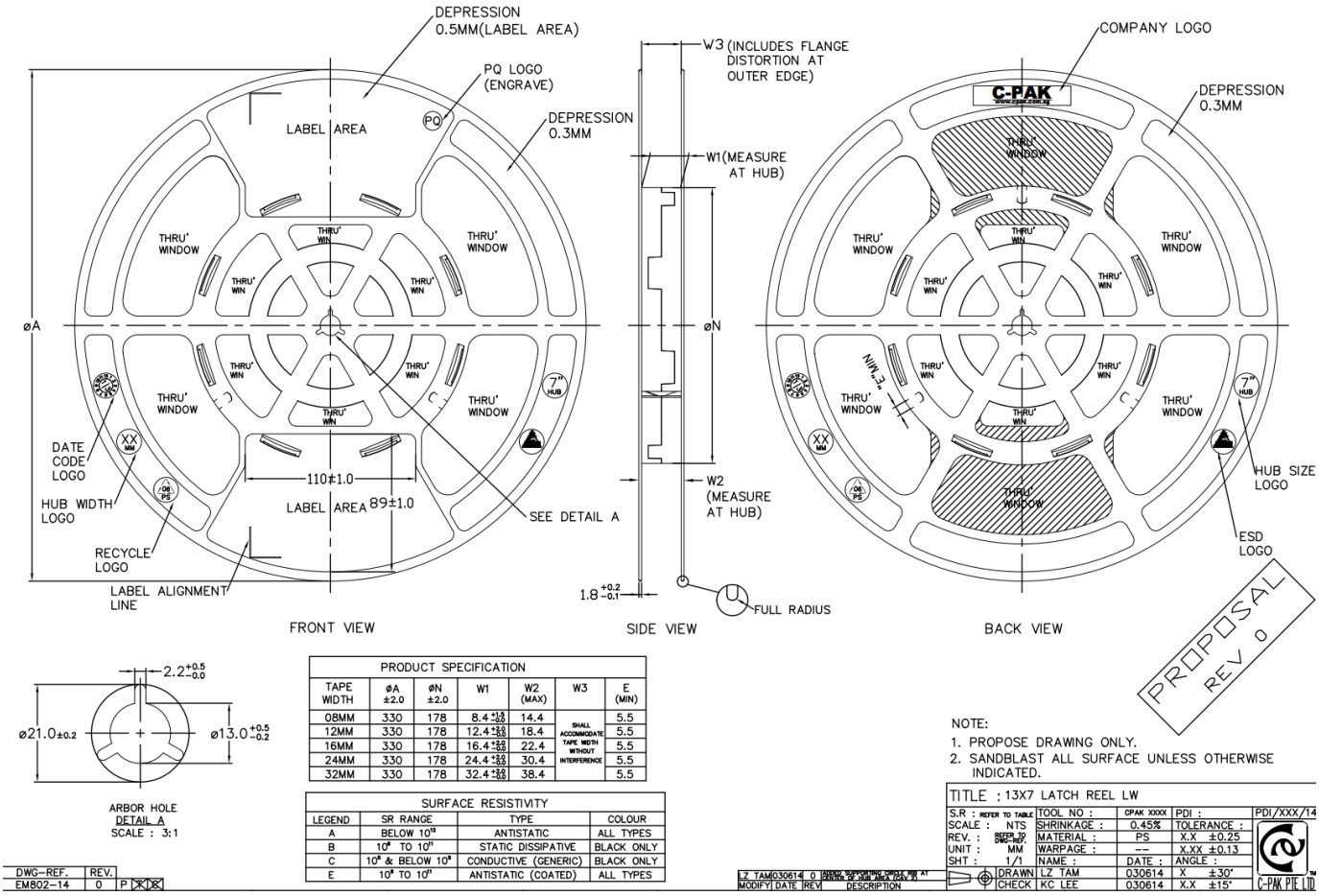
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	--	1.1	--	0.043
A1	0.01	0.15	0.000	0.006
A2	0.85	0.95	0.033	0.037
A3	0.20		0.008	
bp	0.19	0.3	0.007	0.012
D	2.90	3.10	0.114	0.122
E	4.30	4.50	0.169	0.177
e	0.65			
HE	6.3	6.5	0.248	0.256
L	0.45	0.80	0.018	0.031
Lp	0.5	0.7	0.020	0.028
v	0.1		0.004	
w	0.1		0.004	
y	0.1		0.004	
θ	0°	8°	0°	8°

7.2. SOIC (8)



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.35	1.75	0.053	0.069
A1	0.1	0.25	0.004	0.01
A2	1.30	1.50	0.051	0.059
A3	0.50	0.70	0.020	0.028
b	0.38	0.47	0.015	0.019
b1	0.37	0.40	0.015	0.016
D	4.80	5.00	0.189	0.197
E	5.80	6.20	0.228	0.244
E1	3.80	4.00	0.15	0.157
e	1.17	1.37	0.046	0.054
L	0.45	0.80	0.018	0.031
L1	1.04REF		0.041REF	
L2	0.25BSC		0.010BSC	
R	0.07	——	0.003	——
R1	0.07	——	0.003	——
h	0.30	0.50	0.012	0.020
θ	0°	8°	0°	8°
θ1	15°	19°	15°	19°
θ2	11°	15°	11°	15°

8. Tape and Reel Information



PRODUCT SPECIFICATION						
TAPE WIDTH	øA ±2.0	øN ±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^{5} & BELOW 10^{9}	CONDUCTIVE (GENERIC)	BLACK ONLY
E	10^{6} TO 10^{11}	ANTISTATIC (COATED)	ALL TYPES

NOTE:
1. PROPOSE DRAWING ONLY.
2. SANDBLAST ALL SURFACE UNLESS OTHERWISE INDICATED.

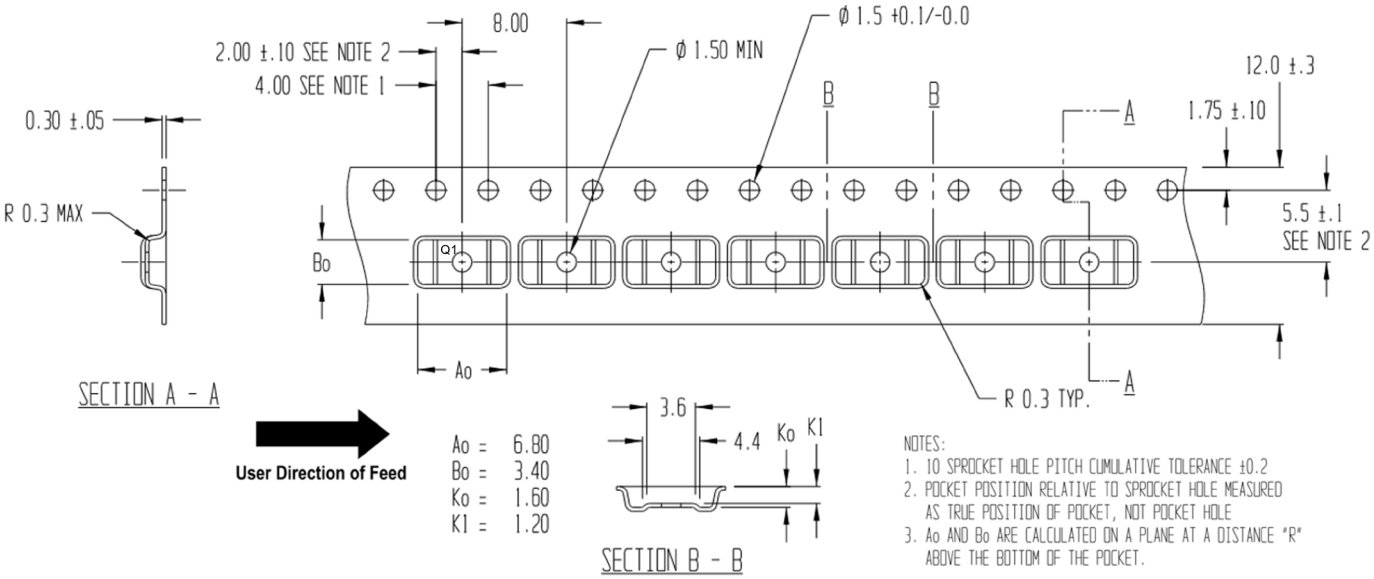
DWG-REF.	REV.
EM802-14	0

TITLE : 13X7 LATCH REEL LW				
S.R : REFER TO TABLE	TOOL NO :	CPAK XXXX	PDI :	PDI/XXX/14
SCALE : NTS	SHRINKAGE :	0.45%	TOLERANCE :	
REV. : REFER TO DWG NO.	MATERIAL :	PS	X.X ±0.25	
UNIT : MM	WARPAGE :	--	X.XX ±0.13	
SHT : 1/1	NAME :		DATE :	ANGLE :
DRAWN	LZ TAM	030614	X ±30'	
CHECK	KC LEE	030614	X.X ±15'	

C-PAK PTE LTD

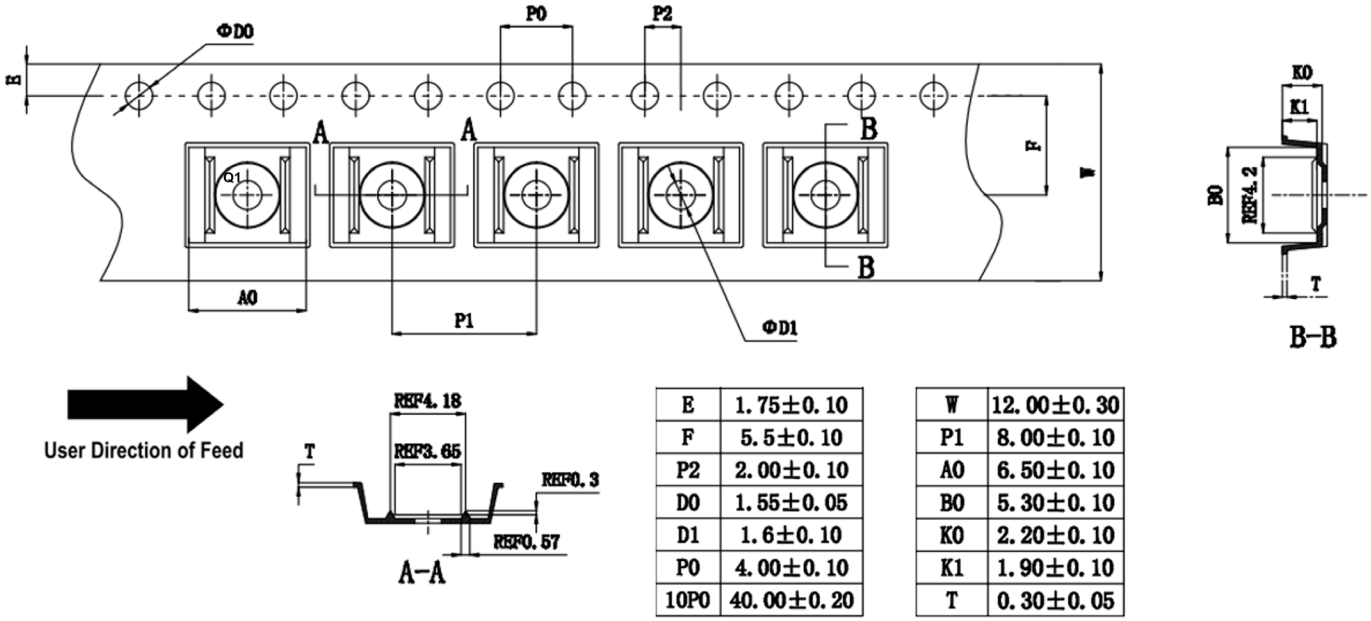
MODIFY	DATE	REV	DESCRIPTION
LZ TAM	030614	0	ADDED SUPPORTING CIRCLE DIA AT CENTRE OF SIDE HOLE (REV 0)

8.1. TSSOP (8)



Note: 3000ea/reel.

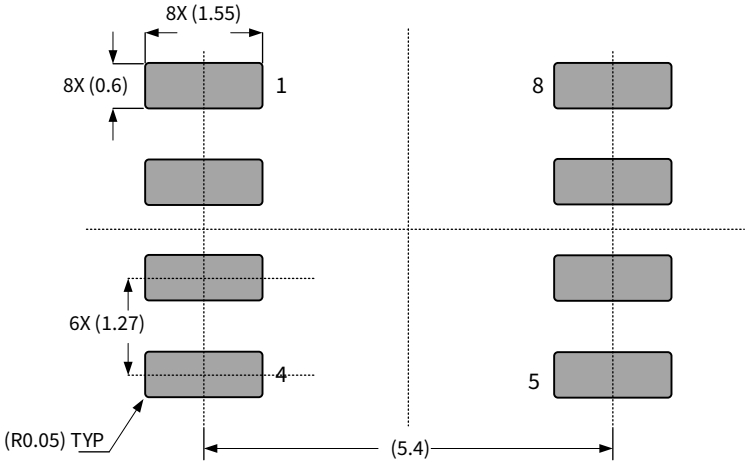
8.2. SOIC (8)



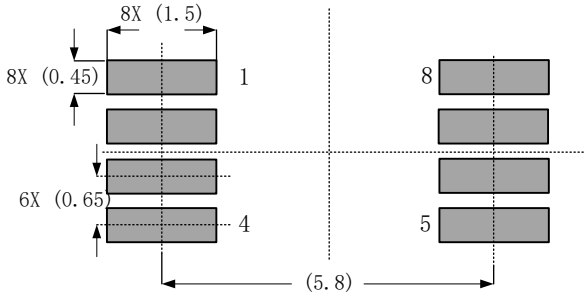
E	1.75±0.10
F	5.5±0.10
P2	2.00±0.10
D0	1.55±0.05
D1	1.6±0.10
P0	4.00±0.10
10P0	40.00±0.20

W	12.00±0.30
P1	8.00±0.10
A0	6.50±0.10
B0	5.30±0.10
K0	2.20±0.10
K1	1.90±0.10
T	0.30±0.05

9. Example of Solder Pads Dimensions



Example of solder pads dimensions of SOIC (8)



Example of solder pads dimensions of TSSOP (8)

10. Order Information

Part Number	Package	Gain	MSL Level	Op Temp (°C)	SPQ
NSCSA240A1-DTSPR	TSSOP (8)	20	1	-40~+125	3000
NSCSA240A2-DTSPR	TSSOP (8)	50	1	-40~+125	3000
NSCSA240A3-DTSPR	TSSOP (8)	100	1	-40~+125	3000
NSCSA240A4-DTSPR	TSSOP (8)	200	1	-40~+125	3000
NSCSA240A1-DSPR	SOIC (8)	20	3	-40~+125	2500
NSCSA240A2-DSPR	SOIC (8)	50	3	-40~+125	2500
NSCSA240A3-DSPR	SOIC (8)	100	3	-40~+125	2500
NSCSA240A4-DSPR	SOIC (8)	200	3	-40~+125	2500

11. Revision History

Revision	Description	Date
1.0	Initial Release version	2026/02

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