## 100 V, precision, bidirectional current sense amplifier

SO8

MiniSO8

Maturity status link
TSC2020, TSC2021, TSC2022

Features

- Wide common-mode voltage: -4 to 100 V
- High common-mode rejection CMR: 100 dB min.
- Offset voltage: ±150 µV max.
- Offset drift: 0.5 µV/°C max.
- Enhanced PWM rejection
- 2.7 to 5.5 V supply voltage
- Internal fixed gain
  - TSC2020: 20 V/V
  - TSC2021: 50 V/V
  - TSC2022: 100 V/V
- Gain error: 0.3% max.
- Gain drift: 3.5 ppm/°C max.
- SO8 and MiniSO8 package
- AEC-Q100 qualified

Applications

- High-side/low-side current sensing
- Battery management system
- 48 V power distribution
- 48 V power tools
- Motor control
- Automotive

Description

TSC2020, TSC2021 and TSC2022 are a series of precision bidirectional current sense amplifier. They can sense current via a shunt resistor over a wide range of common-mode voltages, from -4 to +100 V, whatever the supply voltage is. It is able to sense very low drop voltages, minimizing measurement error.

TSC2020, TSC2021 and TSC2022 are current sense amplifiers that may be used for various functions like precision current measurement, overcurrent protection, current monitoring, and feedback loops. These devices fully operate over the supply voltage range of 2.7 to 5.5 V, and over an ambient temperature range of -40 to 125 °C.

DS14393 - **Rev 2** - **May 2024**
For further information contact your local STMicroelectronics sales office.

www.st.com

1   Block diagram and pin description

Figure 1. **Block diagram**
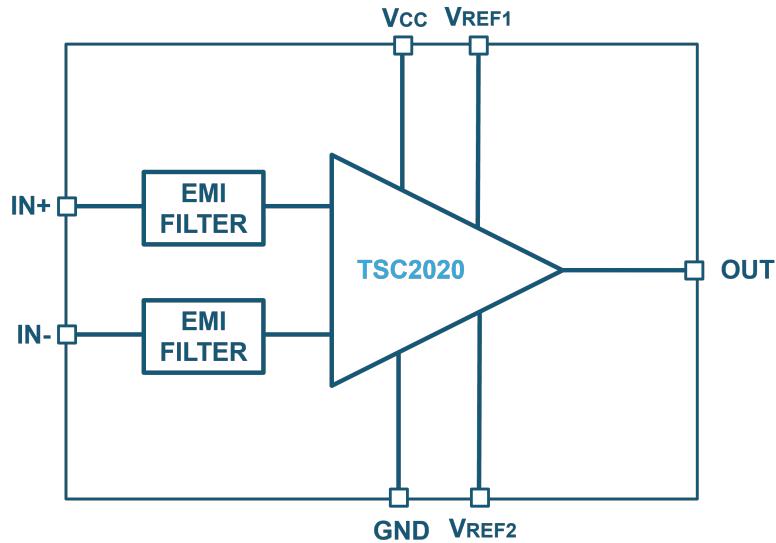
Figure 2. **Pin connections (top view)**
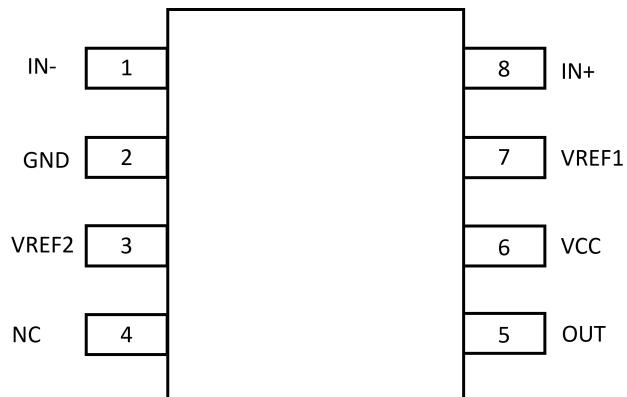
Table 1. **Pin description**

Pin	Pin name	Description
1	IN-	Negative input
2	GND	Ground
3	VREF2	Reference voltage 2
4	NC	Not connected
5	OUT	Output
6	VCC	Supply voltage
7	VREF1	Reference voltage 1
8	IN+	Positive input

2 Absolute maximum ratings and operation conditions

Table 2. Absolute maximum ratings

Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage [1]	-0.3 to 5.8	V
V_{ICM}	Common-mode voltage on input pins	-5 to 105	V
V_{DIF}	Differential voltage between input pins (IN+, IN-)	±70	V
V_{REF1}, V_{REF2}, V_{OUT}	Voltage present on pins REF1, REF2, and OUT	GND - 0.3 to V_{CC} + 0.3	V
I_{IN}	Input current on V_{IN+}, V_{IN-} [2]	1.5	mA
T_J	Junction temperature	150	°C
T_{STG}	Storage temperature	-65 to 150	°C
ESD	Human body model (HBM) [3]	2000	V
	Charged device model (CDM) [4] SO8	750	V
	MiniSO8	1000	
RTH$_{JA}$	Thermal resistance junction to ambient [5][6] SO8	125	°C/W
	MiniSO8	190	

1. All voltage values, except the differential voltage, are with respect to the network ground terminal.
2. Input voltage can go beyond the supply voltage, but input current must be limited. Using a serial resistor with the input is highly recommended in that case.
3. According to JEDEC standard JESD22-A114F.
4. According to ANSI/ESD STM 5.3.1.
5. Short-circuits can cause excessive heating and destructive dissipation.
6. The RTHs are typical values.

Table 3. Operating conditions

Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage	2.7 to 5.5	V
V_{ICM}	Common-mode voltage on input pins	-4 to +100	V
V_{REF}	Output offset adjustment range	0 to V_{CC}	V
T	Operating free-air temperature range	-40 to 125	°C

3 Electrical characteristics

Table 4. Electrical characteristics - V_{CC} = 2.7 V, V_{ICM} = 48 V, T = 25 °C (unless otherwise specified).

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
Power supply						
I_{CC}	Current consumption	V_{ICM} = -4 to 100 V		1.7	2.3	mA
		Tmin < T < Tmax			2.3	
Input						
$\|Vos\|$	Offset voltage (RTI) [1]	V_{ICM} = 12 V, V_{REF} = 1.35 V			150	µV
		Tmin < T < Tmax			200	
		V_{ICM} = 48 V, V_{REF} = 1.35 V			400	
		Tmin < T < Tmax			500	
$\|\Delta Vos/\Delta T\|$	Offset drift vs. temperature	V_{ICM} = 12 V, Tmin < T < Tmax			0.5	µV/°C
		V_{ICM} = 48 V, Tmin < T < Tmax			1	
CMR	Common-mode rejection	V_{ICM} = - 4 to 100 V, DC mode	100	112		dB
		Tmin < T < Tmax	100			
I_{IB}	Input bias current	V_{ICM} = 12 V, Vsense = 0		100	130	µA
		Tmin < T < Tmax			140	
		V_{ICM} = 48 V, Vsense = 0		200	230	
		Tmin < T < Tmax			240	
$\|Vsense\|$	Vsense operating range with Eg ≤ 0.3% [2]	TSC2020			123.8	mV
		Tmin < T < Tmax			123.6	
		TSC2021			49.1	
		Tmin < T < Tmax			48.8	
		TSC2022			24.1	
		Tmin < T < Tmax			23.9	
Output						
G	Gain	TSC2020		20		V/V
		TSC2021		50		
		TSC2022		100		
Eg	Gain error	ΔV_{OUT} = 100 mV to (V_{CC} - 100 mV)	0.01		0.3	%
		Tmin < T < Tmax			0.35	
$\Delta Eg/\Delta T$	Gain error drift	Tmin < T < Tmax			3.5	ppm/°C
NLE	Linearity error	V_{ICM} = - 4 to 100 V		0.01		%
$V_{CC} - V_{OH}$	Drop voltage output high	Isource = 0.2 mA		11	25	mV
		Tmin < T < Tmax			35	
		Isource = 2 mA		115	150	
		Tmin < T < Tmax			200	
V_{OL}	Output voltage low	Isink = 0.2 mA		24	40	
		Tmin < T < Tmax			55	
		Isink = 2 mA		200	240	
		Tmin < T < Tmax			390	

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
I_{OUT}	Output current	Sink mode	8	12.5	18	mA
		Tmin < T < Tmax	5		24	
		Source mode	10	14.5	25	
		Tmin < T < Tmax	5		30	
Reg Load	Load regulation	I_{OUT} = -5 to +5 mA		0.2	1.5	$\frac{mV}{mA}$
C_L	Maximum capacitive load	No sustained oscillation		1		nF
Offset adjustment						
R_T	V_{REF} gain	Voltage applied on one V_{REF} pin		0.5		V/V
Acc	V_{REF} gain error	One V_{REF} pin connected to V_{CC} the other to GND		0.2		%
Dynamic performances						
BW	Small signal -3 dB bandwidth	R_L = 10 kΩ, C_L = 100 pF	350	650		kHz
		Tmin < T < Tmax	350			
SR	Slew rate	C_L = 100 pF				V/µs
		TSC2020, Vsense = 108 mV	1.1	1.8		
		TSC2020, Tmin < T < Tmax	1			
		TSC2021, Vsense = 43 mV	1.5	2.4		
		TSC2021, Tmin < T < Tmax	1.4			
		TSC2022, Vsense = 22 mV	1.9	3		
		TSC2022, Tmin < T < Tmax	1.8			
E_N	Spectral density (RTI) [1]	f = 1 kHz		63		nV/√Hz

1. RTI stands for "Related to input."

2. Vsense = (Vin+) – (Vin-).

Table 5. Electrical characteristics - V_{CC} = 5 V, V_{ICM} = 48 V, T = 25 °C (unless otherwise specified).

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
Power supply						
I_{CC}	Current consumption	V_{ICM} = -4 to 100 V		1.8	2.4	mA
		Tmin < T < Tmax			2.4	
Input						
$\vert Vos \vert$	Offset voltage (RTI) [1]	V_{ICM} = 12 V, V_{REF} = 2.5 V			150	µV
		Tmin < T < Tmax			200	
		V_{ICM} = 48 V, V_{REF} = 2.5 V			400	
		Tmin < T < Tmax			500	
$\vert \Delta Vos/\Delta T \vert$	Offset drift vs. temperature	V_{ICM} = 12 V, Tmin < T < Tmax			0.5	µV/°C
		V_{ICM} = 48 V, Tmin < T < Tmax			1	
CMR	Common-mode rejection	V_{ICM} = -4 to 100 V, DC mode	100	112		dB
		Tmin < T < Tmax	100			
SVR	Supply voltage rejection	V_{CC} = 2.7 to 5.5 V	100	118		dB
		Tmin < T < Tmax	100			
I_{IB}	Input bias current	V_{ICM} = 12 V, Vsense = 0		100	130	µA
		Tmin < T < Tmax			140	
		V_{ICM} = 48 V, Vsense = 0		200	230	
		Tmin < T < Tmax			240	
Vsense	Vsense operating range with Eg ≤ 0.3% [2]	TSC2020			238.5	mV
		Tmin < T < Tmax			238.2	
		TSC2021			94.9	
		Tmin < T < Tmax			94.7	
		TSC2022			47.1	
		Tmin < T < Tmax			46.8	
Output						
G	Gain	TSC2020		20		V/V
		TSC2021		50		
		TSC2022		100		
Eg	Gain error	ΔV_{OUT} = 100 mV to (V_{CC} - 100 mV)	0.01	0.3		%
		Tmin < T < Tmax		0.35		
$\Delta Eg/\Delta T$	Gain error drift	Tmin < T < Tmax			3.5	ppm/°C
NLE	Linearity error	V_{ICM} = - 4 to 100 V		0.01		%
V_{CC} - V_{OH}	Drop voltage output	Isource = 0.2 mA		18	35	mV
		Tmin < T < Tmax			45	
		Isource = 2 mA		122	155	
		Tmin < T < Tmax			210	
V_{OL}	Output voltage low	Isink = 0.2 mA		35	50	mV
		Tmin < T < Tmax			70	
		Isink = 2 mA		217	250	
		Tmin < T < Tmax			400	

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
I_{OUT}	Output current	Sink mode	8	13.5	20	mA
		Tmin < T < Tmax	5		24	
		Source mode	10	14.5	25	
		Tmin < T < Tmax	5		30	
Reg load	Load regulation	I_{OUT} = -5 to +5 mA		0.2	1.5	$\frac{mV}{mA}$
Offset adjustment						
RT	V_{REF} gain	Voltage applied on one V_{REF} pin		0.5		V/V
Acc	V_{REF} gain error	One V_{REF} pin connected to V_{CC} the other to GND		0.2		%
Dynamic performances						
BW	Small signal -3 dB bandwidth	R_L = 10 kΩ, C_L = 100 pF	450	700		kHz
		Tmin < T < Tmax	450			
SR	Slew rate	C_L = 100 pF				V/µs
		TSC2020, Vsense = 200 mV	1.4	2		
		TSC2020, Tmin < T < Tmax	1.2			
		TSC2021, Vsense = 80 mV	1.7	2.8		
		TSC2021, Tmin < T < Tmax	1.6			
		TSC2022, Vsense = 40 mV	2.4	3.9		
		TSC2022, Tmin < T < Tmax	2.2			
EN	Spectral density (RTI) [1]	f = 1 kHz		53		nV/√Hz
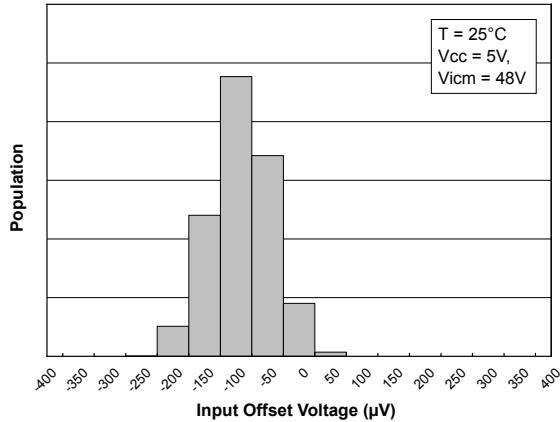
1. *RTI stands for "Related to input."*

2. *Vsense = (Vin+) – (Vin-).*
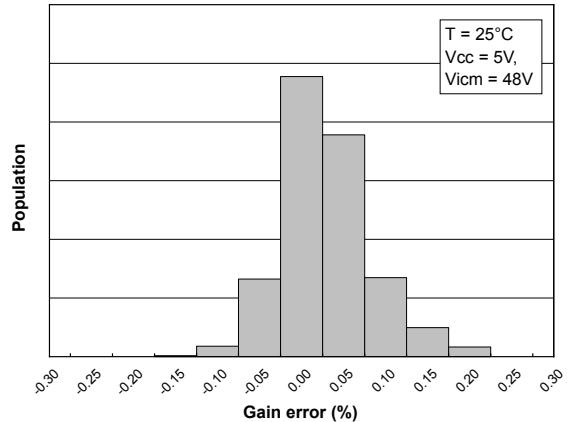
4 Typical characteristics

TSC2020 is used for typical characteristics, unless otherwise specified.
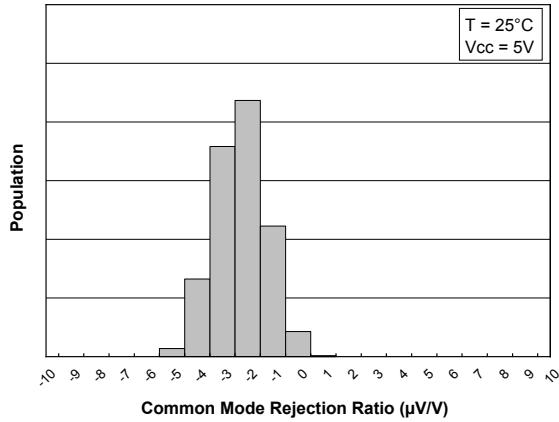
Figure 3. Input offset production distribution
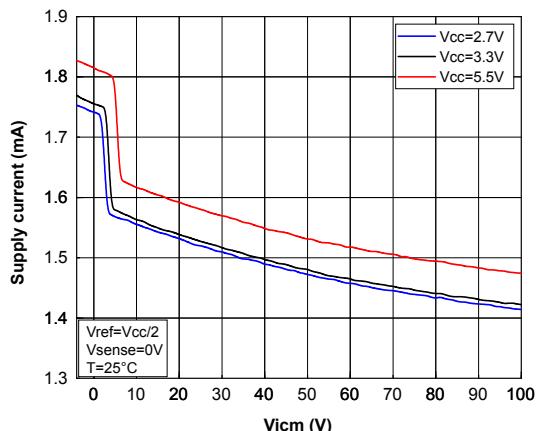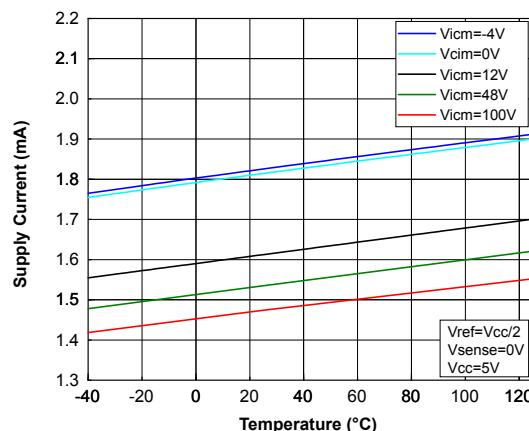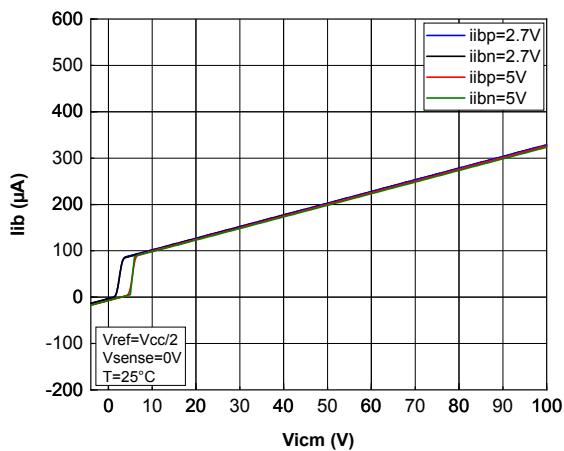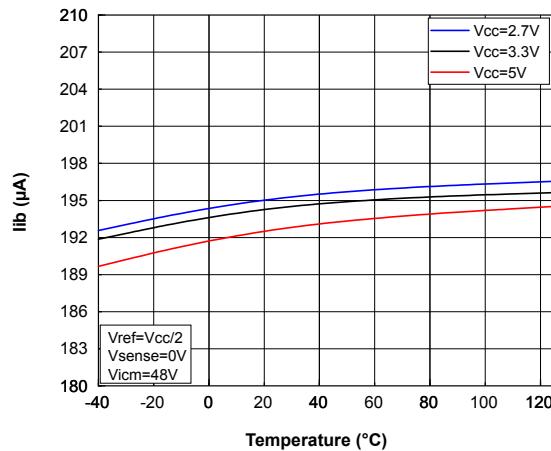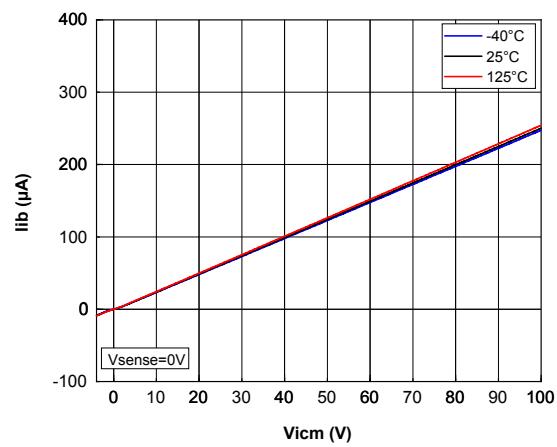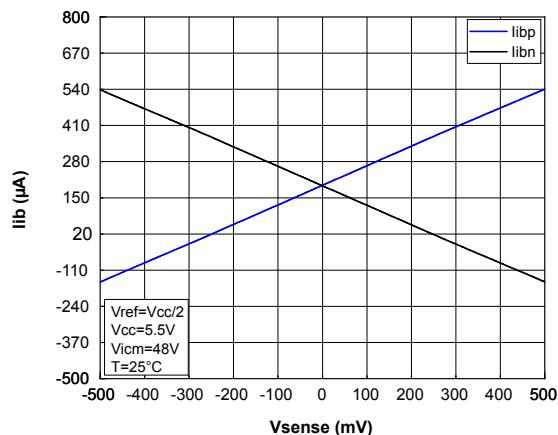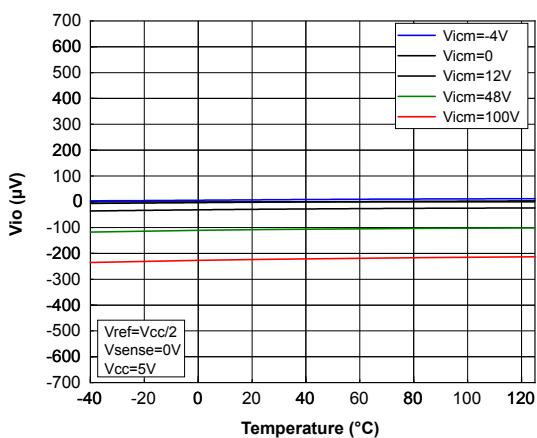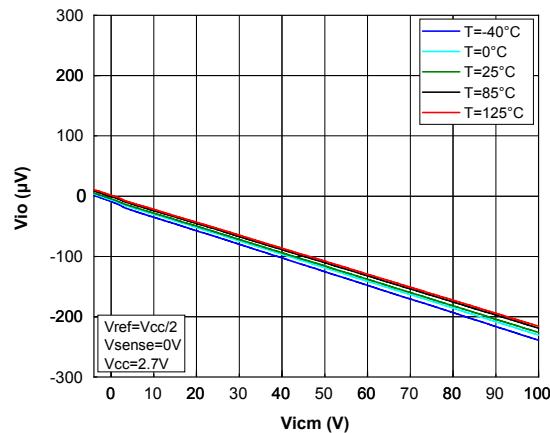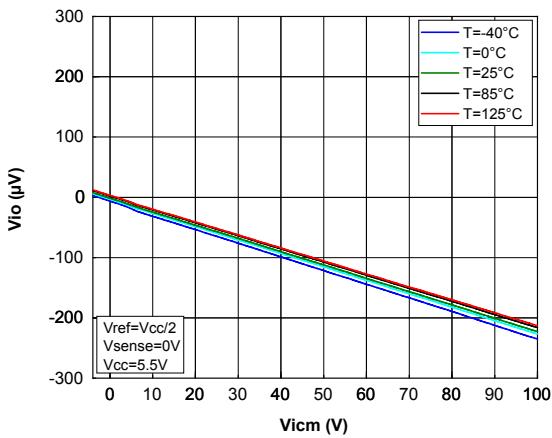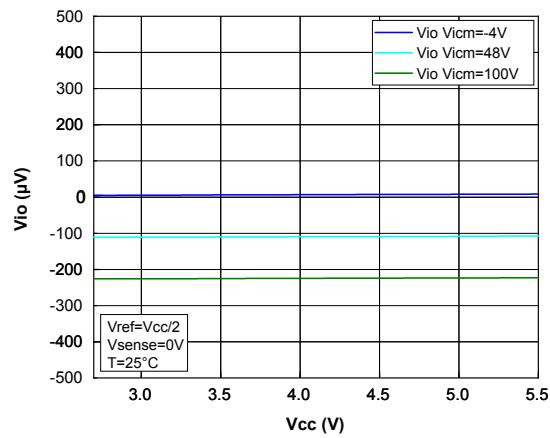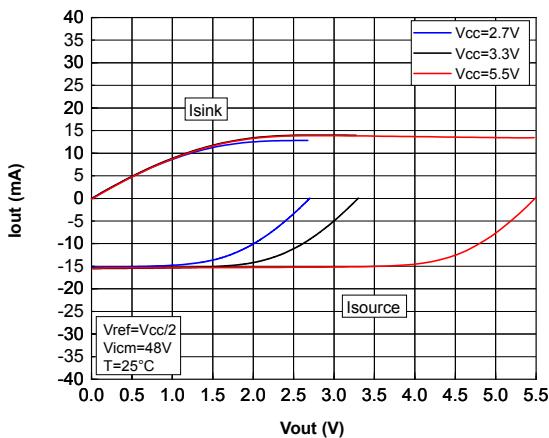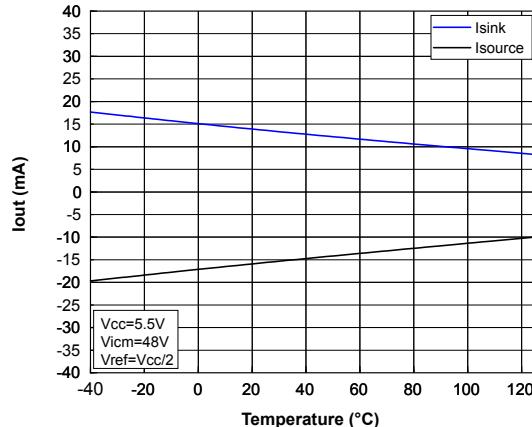
Figure 4. Gain error production distribution
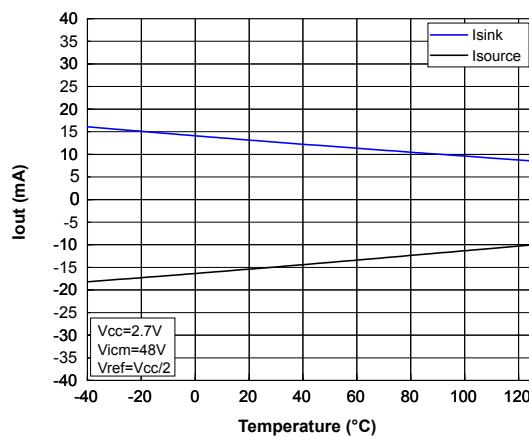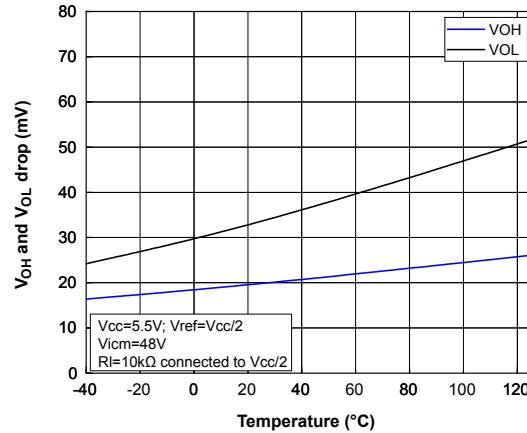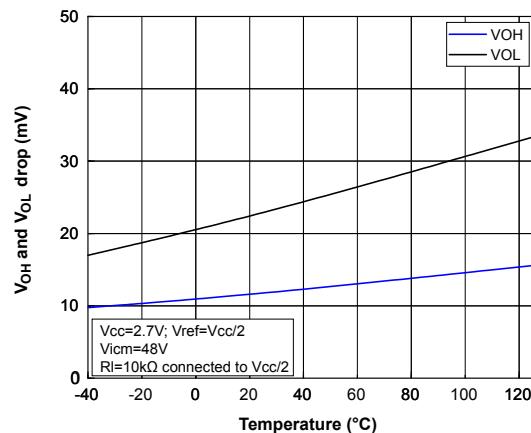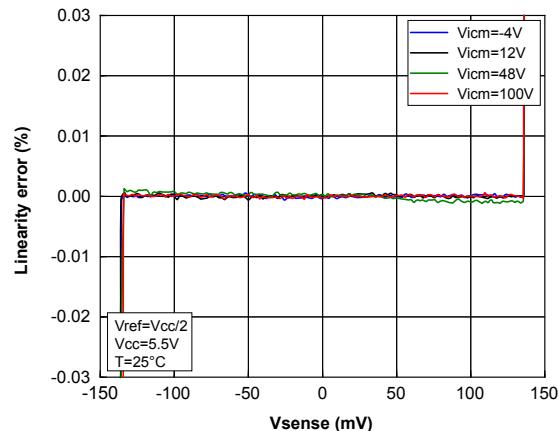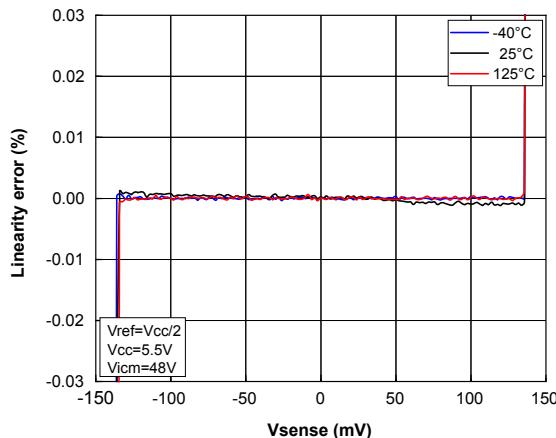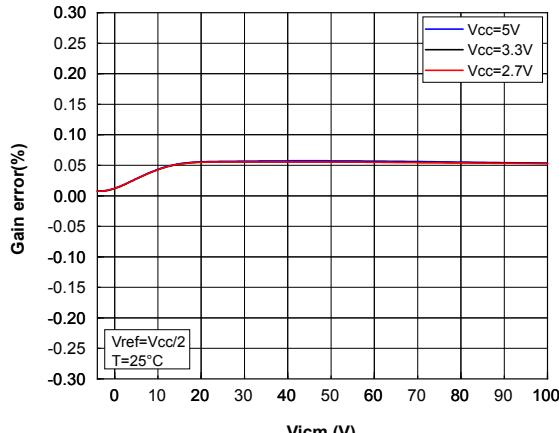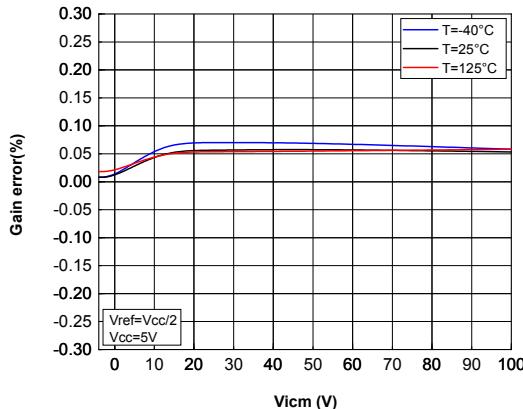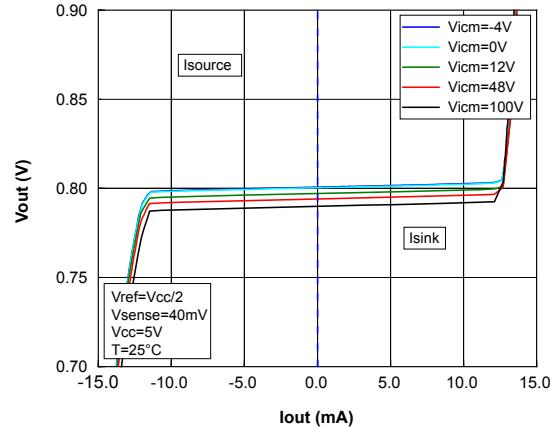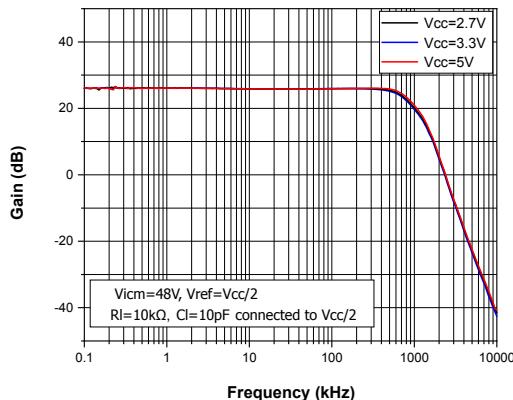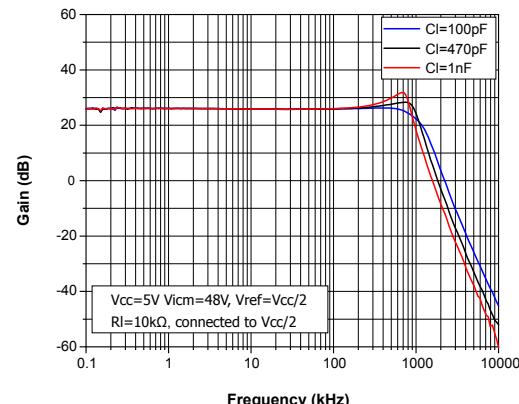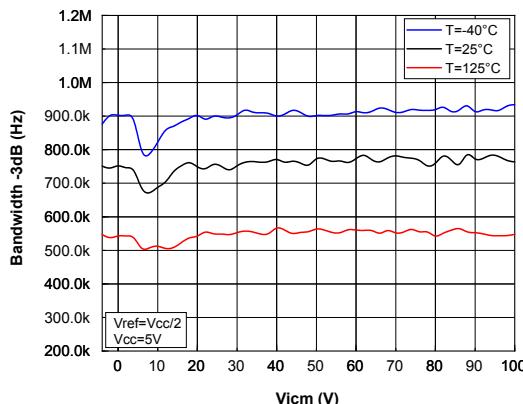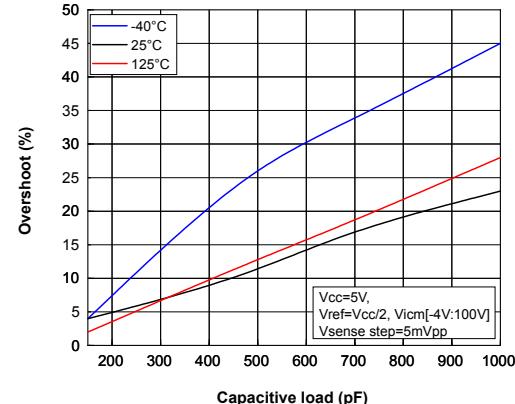
Figure 5. Common-mode rejection ratio production distribution

Figure 6. Supply current vs. supply voltage
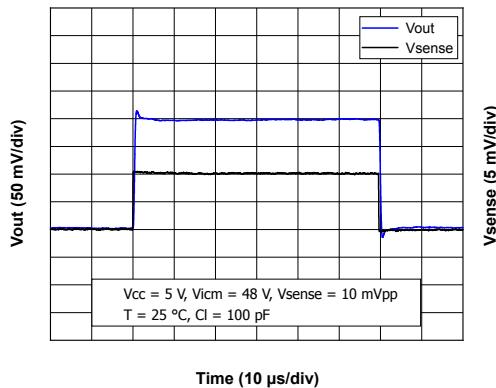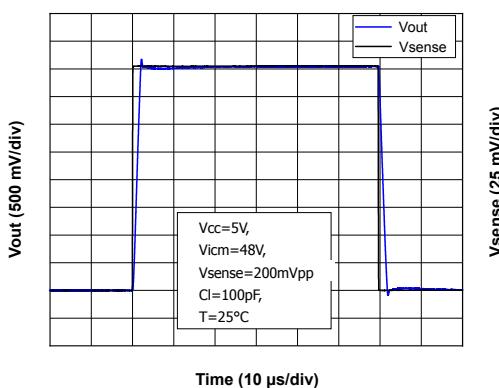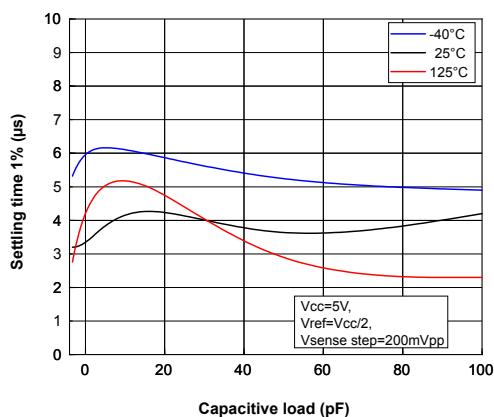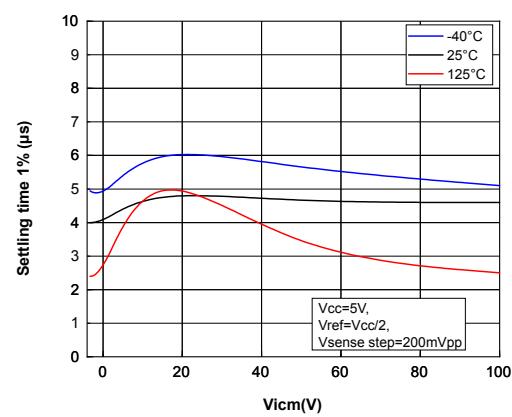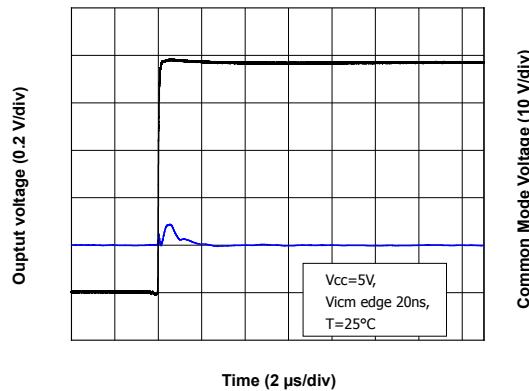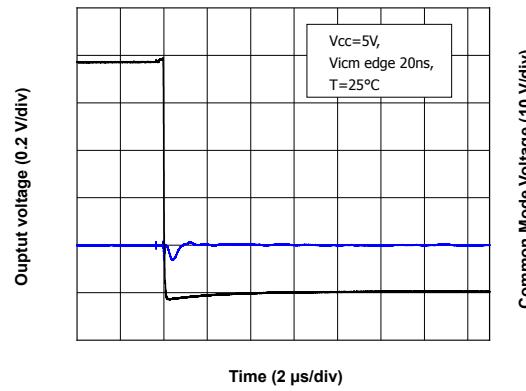
Figure 7. Supply current vs. input common-mode

Figure 8. Supply current vs. temperature

Figure 9. Input bias current vs. input common-mode

Figure 10. Input bias current vs. temperature

Figure 11. Input bias current vs. input common-mode at $V_{CC} = 0$ V

Figure 12. Input bias current vs. Vsense
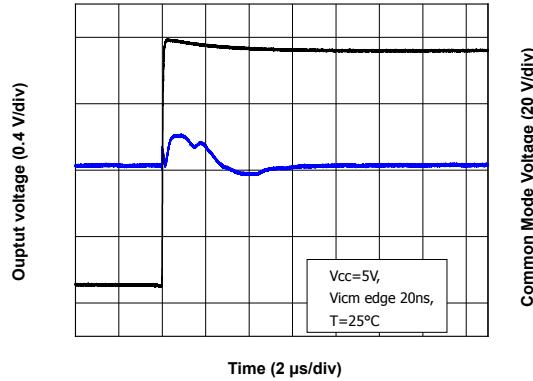
Figure 13. Input offset voltage vs. temperature

Figure 14. Input offset voltage vs. input common-mode with V_{CC} = 2.7 V

Figure 15. Input offset voltage vs. input common-mode with V_{CC} = 5.5 V

Figure 16. Input offset voltage vs. supply voltage

Figure 17. Output current vs. output voltage

Figure 18. Output current vs. temperature with V_{CC} = 5.5 V

Figure 19. Output current vs. temperature with V$_{CC}$ = 2.7 V

Figure 20. V$_{oh}$ and V$_{ol}$ vs. temperature with V$_{CC}$ = 5.5 V

Figure 21. V$_{oh}$ and V$_{ol}$ vs. temperature with V$_{CC}$ = 2.7 V

Figure 22. Linearity vs. Vense with V$_{CC}$ = 5.5 V

Figure 23. Linearity vs. Vsense and temperature

Figure 24. Gain error vs. input common-mode
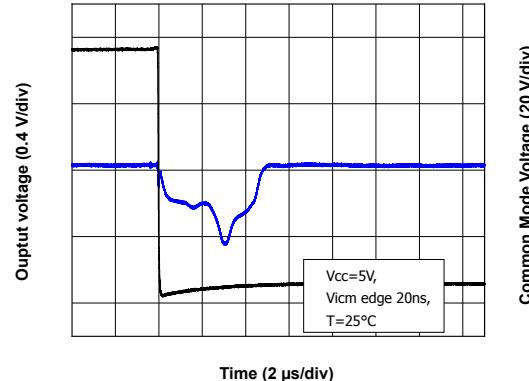
Figure 25. Gain error vs. input common mode at V$_{CC}$ = 5 V

Figure 26. Load regulation with V$_{CC}$ = 5 V

Figure 27. Gain vs. frequency

Figure 28. Gain vs. frequency different capacitive load

Figure 29. Bandwidth vs. input common-mode

Figure 30. Overshoot vs. capacitive load

Figure 31. Small signal response with V$_{CC}$ = 5 V

Vcc = 5 V, Vicm = 48 V, Vsense = 10 mVpp
T = 25 °C, Cl = 100 pF

Figure 32. Large signal response with V$_{CC}$ = 5 V

Vcc=5V,
Vicm=48V,
Vsense=200mVpp
Cl=100pF,
T=25°C

Figure 33. Positive settling time 1%

Vcc=5V,
Vref=Vcc/2,
Vsense step=200mVpp

Figure 34. Negative settling time 1%

Vcc=5V,
Vref=Vcc/2,
Vsense step=200mVpp

Figure 35. 48 V common-mode positive step response recovery

Vcc=5V,
Vicm edge 20ns,
T=25°C

Figure 36. 48 V common-mode negative step response recovery

Vcc=5V,
Vicm edge 20ns,
T=25°C
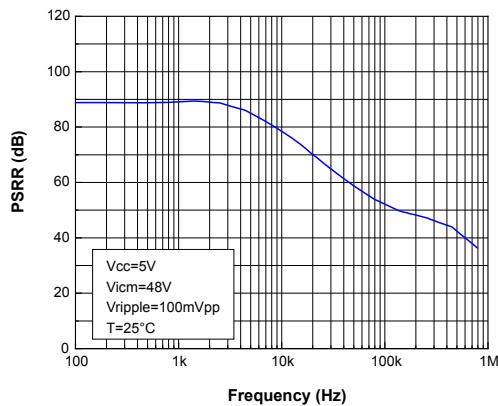
Figure 37. 100 V common-mode positive step response recovery
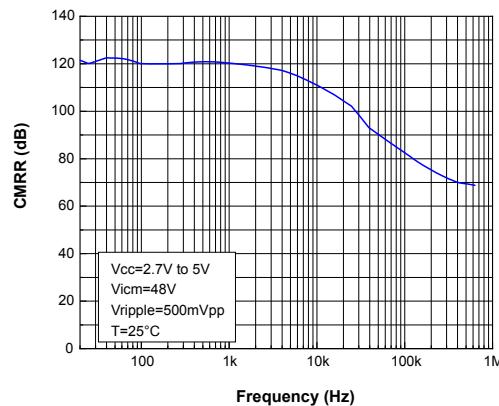
Figure 38. 100 V common-mode negative step response recovery
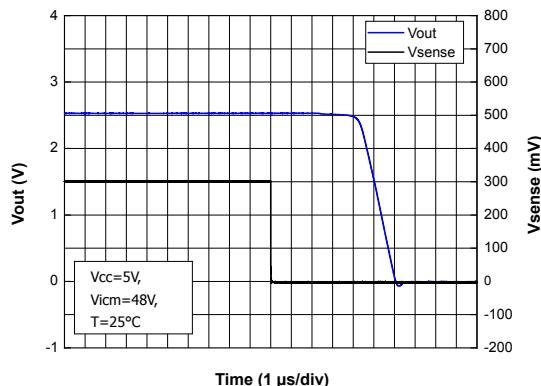
Figure 39. PSRR vs. frequency
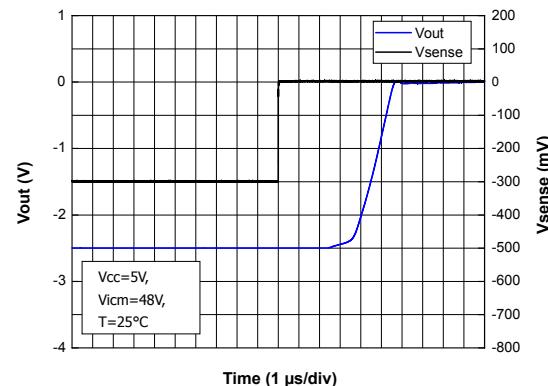
Figure 40. CMRR vs. frequency
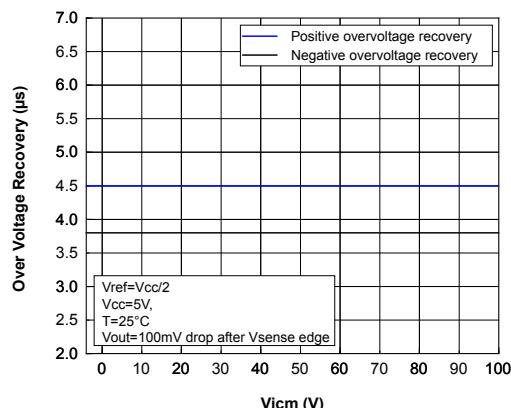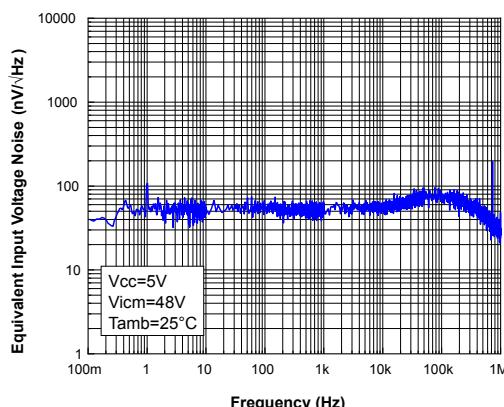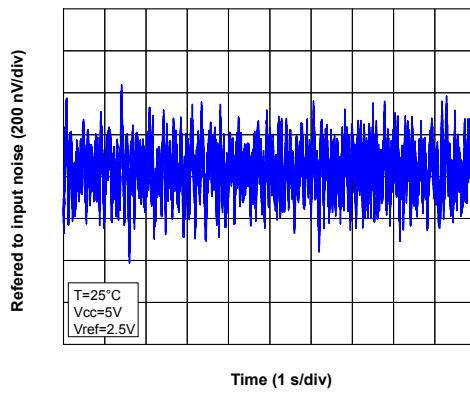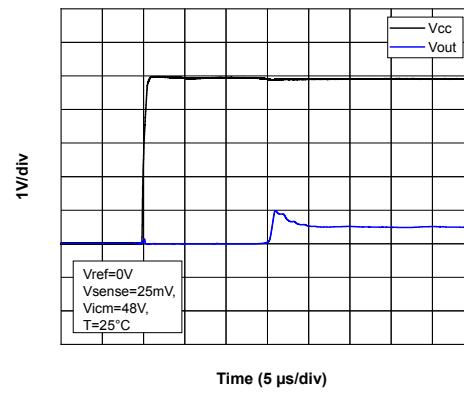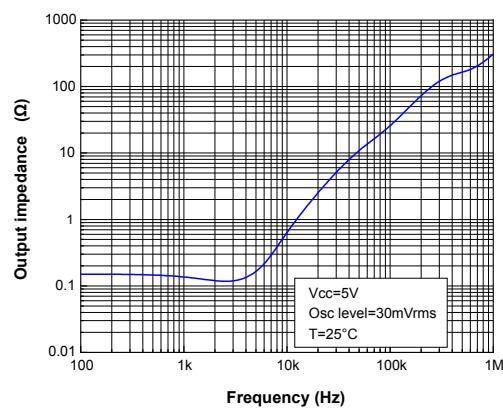
Figure 41. Positive overvoltage recovery

Figure 42. Negative overvoltage recovery

Figure 43. Overvoltage recovery vs. V$_{icm}$, V$_{CC}$ = 5 V

Figure 44. Noise vs. frequency

Figure 45. 0.1 Hz to 10 Hz voltage noise

Figure 46. Power up time delay

Figure 47. Output impedance vs. frequency
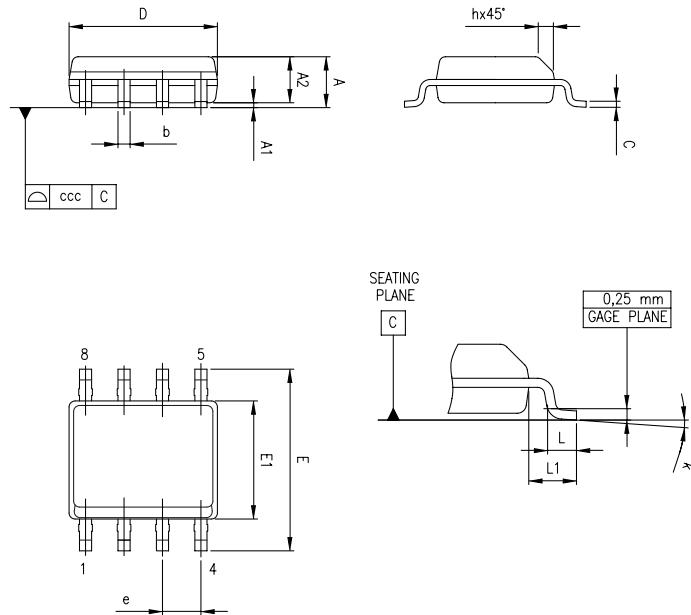
5 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions and product status are available at: www.st.com. ECOPACK is an ST trademark.
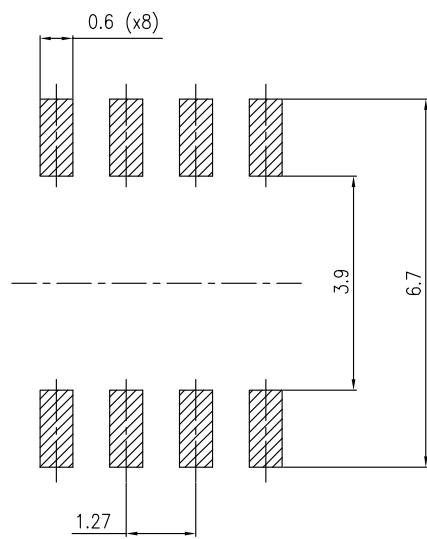
5.1 SO8 package information

Figure 48. SO8 package outline
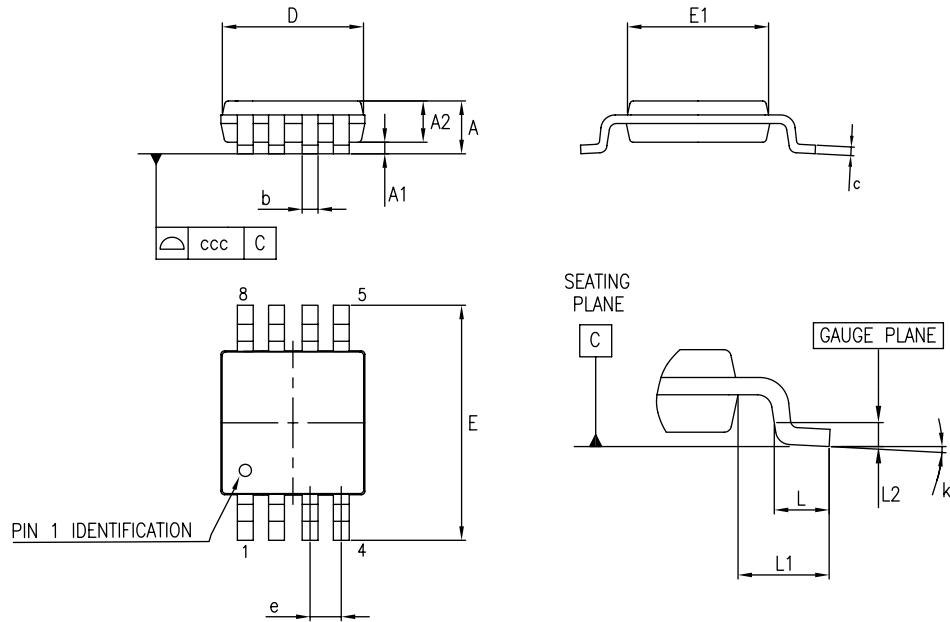
Table 6. SO8 package mechanical data

Ref.	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.75			0.069
A1	0.10		0.25	0.04		0.010
A2	1.25			0.049		
b	0.28	0.40	0.48	0.011	0.016	0.019
c	0.17		0.23	0.007		0.010
D	4.80	4.90	5.00	0.189	0.193	0.197
E	5.80	6.00	6.20	0.228	0.236	0.244
E1	3.80	3.90	4.00	0.150	0.154	0.157
e		1.27				0.050
h	0.25		0.50	0.010		0.020
L	0.40	0.635	1.27	0.016		0.050
L1		1.04			0.040	
k	1°		8°	1°		8°
ccc			0.10			0.004

Figure 49. SO8 recommended footprint
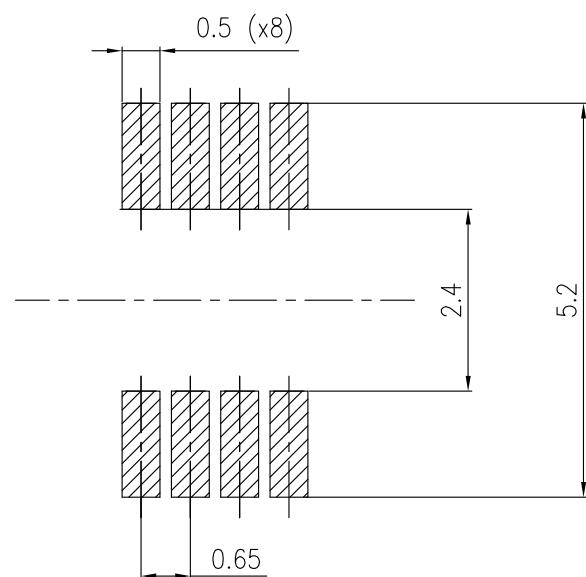
5.2 MiniSO8 package information

Figure 50. MiniSO8 package outline

Table 7. MiniSO8 mechanical data

Ref.	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.1			0.043
A1	0		0.15	0		0.006
A2	0.75	0.85	0.95	0.03	0.033	0.037
b	0.22		0.4	0.009		0.016
c	0.08		0.23	0.003		0.009
D	2.8	3	3.2	0.11	0.118	0.126
E	4.65	4.9	5.15	0.183	0.193	0.203
E1	2.8	3	3.1	0.11	0.118	0.122
e		0.65			0.026	
L	0.4	0.6	0.8	0.016	0.024	0.031
L1		0.95			0.037	
L2		0.25			0.01	
k	0°		8°	0°		8°
ccc			0.1			0.004

Figure 51. MiniSO8 recommended footprint

6 Ordering information

Table 8. Order codes

Order code	Gain (V/V)	Package	Packaging	Marking
TSC2020IDT	20	SO8	Tape & Reel	TSC2020
TSC2020IYDT [1]				TSC2020Y
TSC2020IST		MiniSO8		O129
TSC2020IYST [1]				O132
TSC2021IDT	50	SO8		TSC2021
TSC2021IYDT [1]				TSC2021Y
TSC2021IST		MiniSO8		O130
TSC2021IYST [1]				O133
TSC2022IDT	100	SO8		TSC2022
TSC2022IYDT [1]				TSC2022Y
TSC2022IST		MiniSO8		O131
TSC2022IYST [1]				O134

1. *Qualified and characterized according to AEC Q100 and Q003 or equivalent, advanced screening according to AEC Q001 & Q002 or equivalent.*

Revision history

Table 9. Document revision history

Date	Revision	Changes
22-Sep-2023	1	Initial release.
20-May-2024	2	Added new TSC2021 and TSC2022 order codes in Table 8.

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IMPORTANT NOTICE – READ CAREFULLY