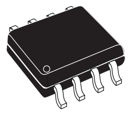
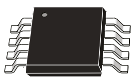
TSC2020, TSC2021, TSC2022

Datasheet

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.

1 Block diagram and pin description

Figure 1. Block diagram

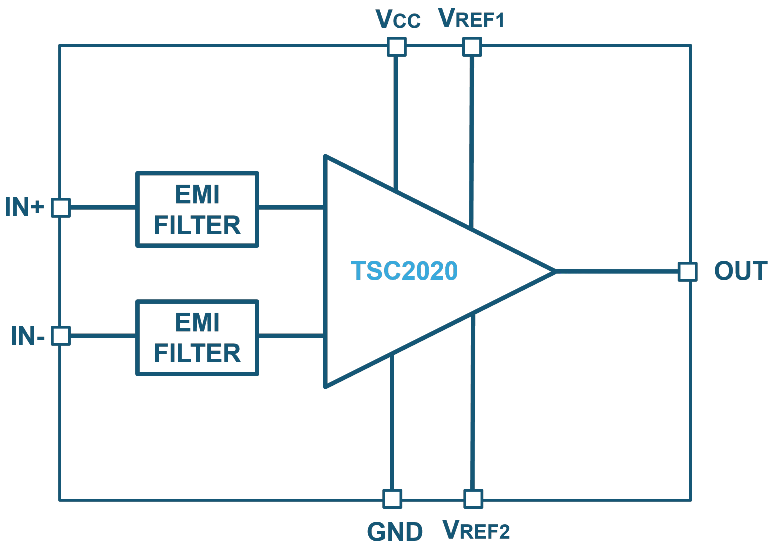


Figure 2. Pin connections (top view)

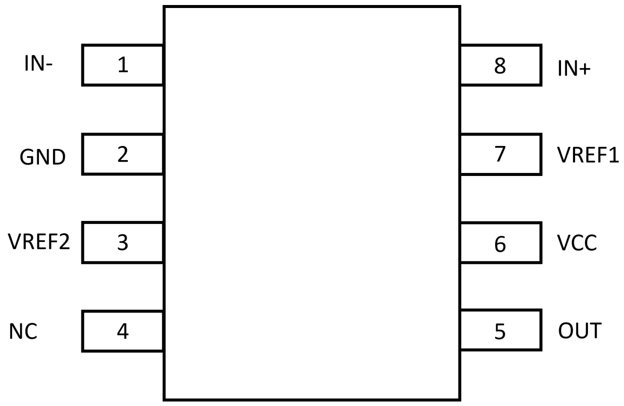


Table 1. Pin description

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	-10 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
T_J	Junction temperature	150	°C
T_{STG}	Storage temperature	-65 to 150	°C
ESD	Human body model (HBM) [2]	2000	V
	Charged device model (CDM) [3] SO8 MiniSO8	 750 1000	V
RTH_{JA}	Thermal resistance junction to ambient [4][5] SO8 MiniSO8	 125 190	°C/W

1. *All voltage values, except the differential voltage, are with respect to the network ground terminal.*
2. *According to JEDEC standard JESD22-A114F.*
3. *According to ANSI/ESD STM 5.3.1.*
4. *Short-circuits can cause excessive heating and destructive dissipation.*
5. *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 Tmin < T < Tmax		1.7	2.3 2.3	mA
Input						
|Vos|	Offset voltage (RTI) [(1)]	V_{ICM} = 12 V, V_{REF} = 1.35 V Tmin < T < Tmax			150 200	µV
		V_{ICM} = 48 V, V_{REF} = 1.35 V Tmin < T < Tmax			400 500	
|ΔVos/ΔT|	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 Tmin < T < Tmax	100 100	112		dB
I_{IB}	Input bias current	V_{ICM} = 12 V, Vsense = 0 Tmin < T < Tmax		100	130 140	µA
		V_{ICM} = 48 V, Vsense = 0 Tmin < T < Tmax		200	230 240	
|Vsense|	Vsense operating range with Eg ≤ 0.3% [(2)]	TSC2020 Tmin < T < Tmax			123.8 123.6	mV
		TSC2021 Tmin < T < Tmax			49.1 48.8	
		TSC2022 Tmin < T < Tmax			24.1 23.9	
Output						
G	Gain	TSC2020 TSC2021 TSC2022		20 50 100		V/V
Eg	Gain error	ΔV_{OUT} = 100 mV to (V_{CC} - 100 mV) Tmin < T < Tmax		0.01	0.3 0.35	%
ΔEg/ΔT	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 Tmin < T < Tmax		11	25 35	mV
		Isource = 2 mA Tmin < T < Tmax		115	150 200	
V_{OL}	Output voltage low	Isink = 0.2 mA Tmin < T < Tmax		24	40 55	
		Isink = 2 mA Tmin < T < Tmax		200	240 390	

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						
RT	V_{REF} gain	OUT/V_{REF} gain for either V_{REF} pin		0.5		V/V
Acc	Accuracy, RT	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						
|Vos|	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	
|ΔVos/ΔT|	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	
ΔEg/ΔT	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	
		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	OUT/V_{REF} gain for either V_{REF} pin		0.5		V/V
Acc	Accuracy, RT	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

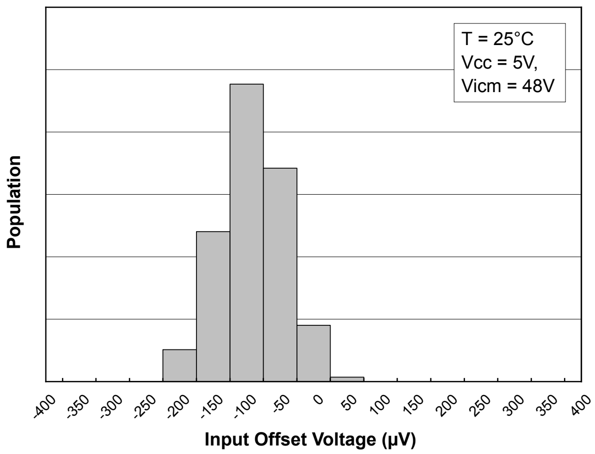


Figure 4. Gain error production distribution

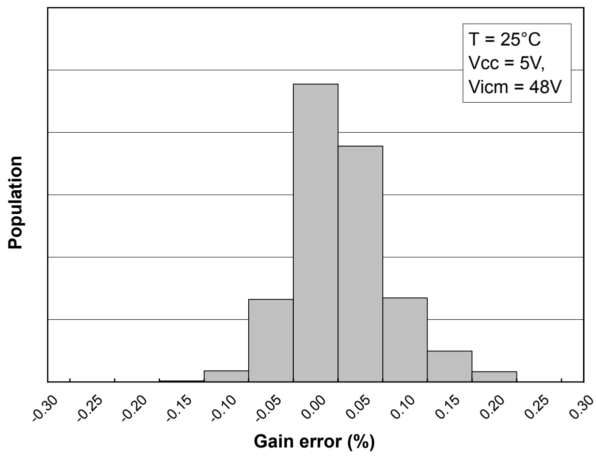


Figure 5. Common-mode rejection ratio production distribution

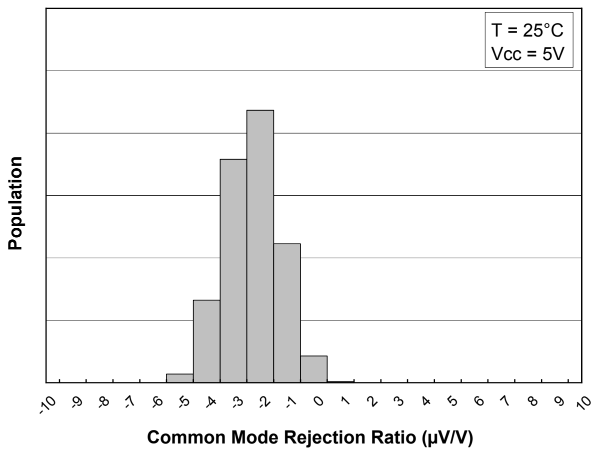


Figure 6. Supply current vs. supply voltage

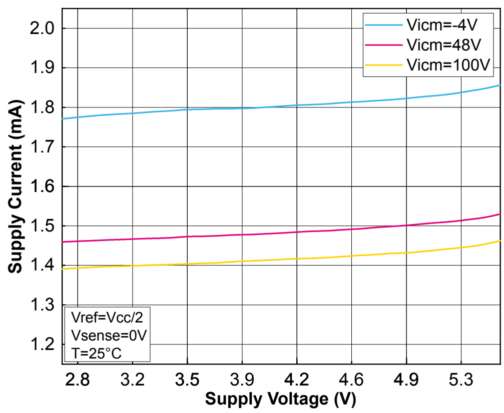


Figure 7. Supply current vs. input common-mode

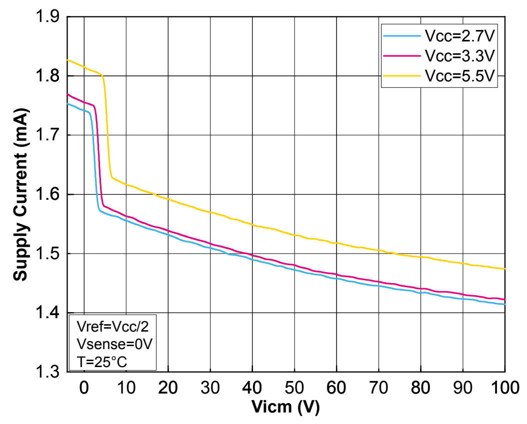


Figure 8. Supply current vs. temperature

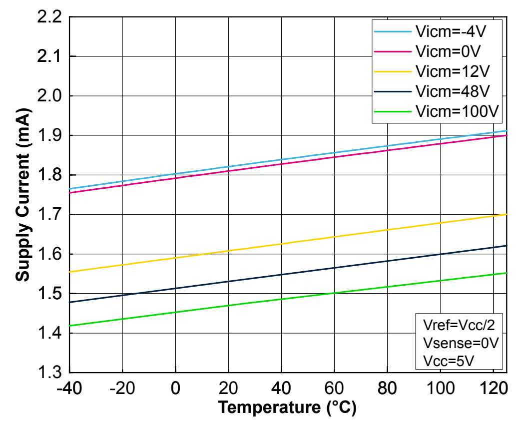


Figure 9. Input bias current vs. input common-mode

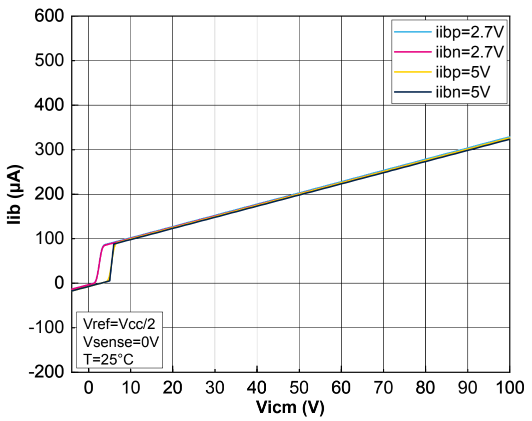


Figure 10. Input bias current vs. temperature

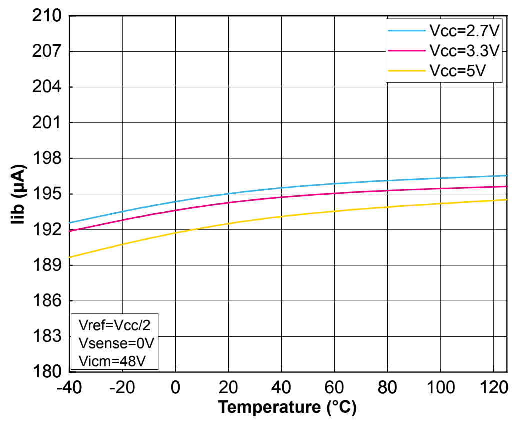


Figure 11. Input bias current vs. input common-mode

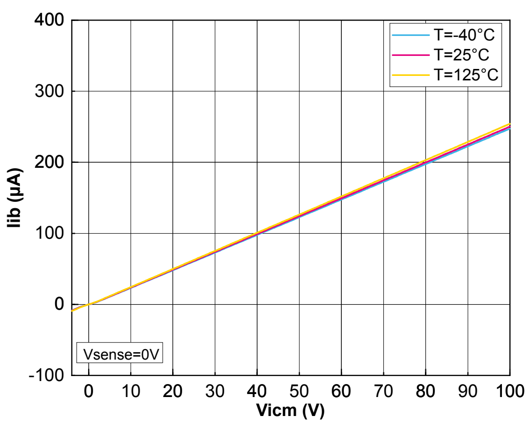


Figure 12. Input bias current vs. Vsense

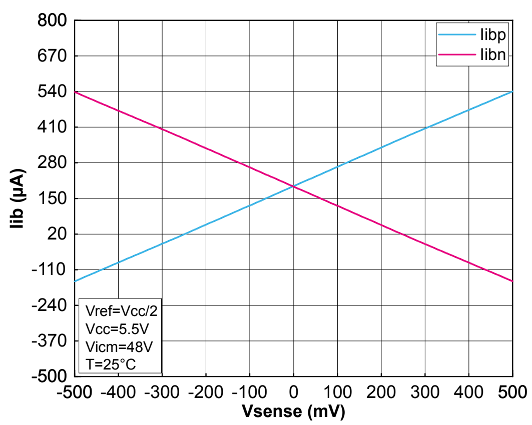


Figure 13. Input offset voltage vs. temperature

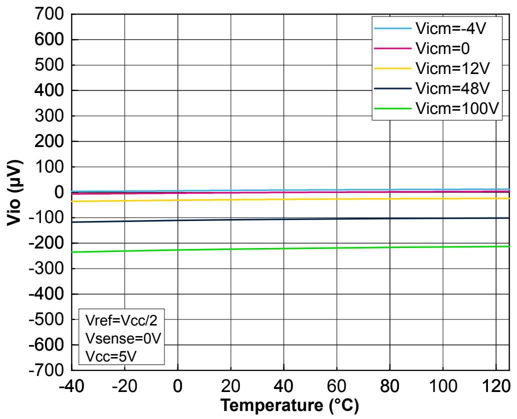


Figure 14. Input offset voltage vs. input common-mode with V_{CC} = 5.5 V

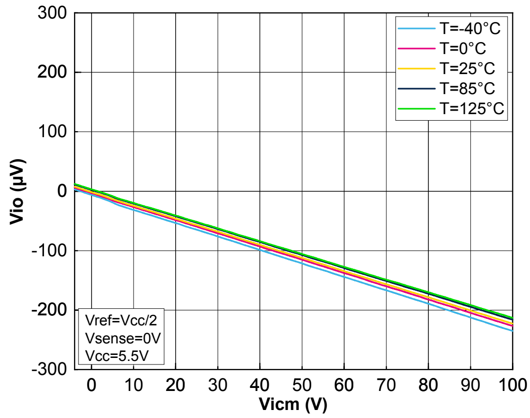


Figure 15. Input offset voltage vs. input common-mode with V_{CC} = 2.7 V

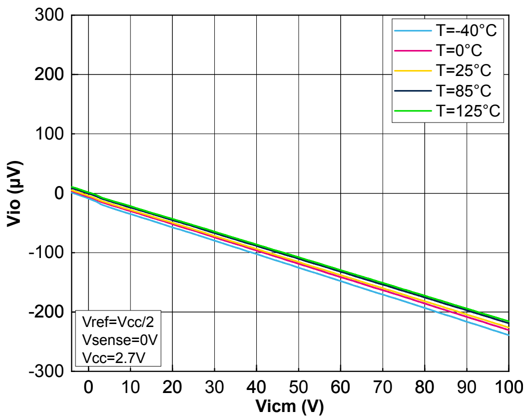


Figure 16. Input offset voltage vs. supply voltage

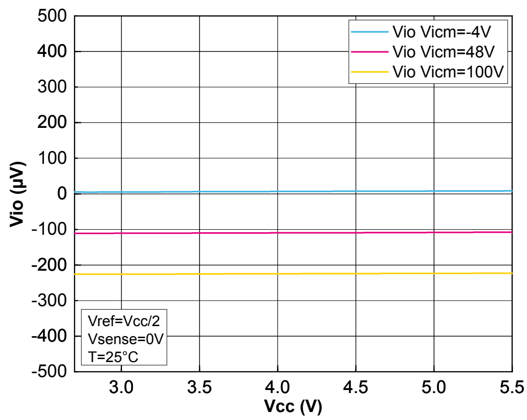


Figure 17. Output current vs. output voltage

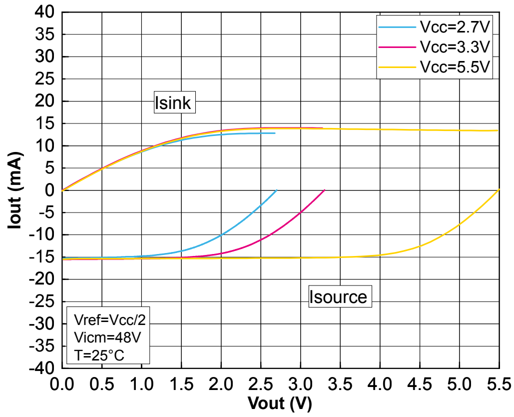


Figure 18. Output current vs. temperature with V_{CC} = 5.5 V

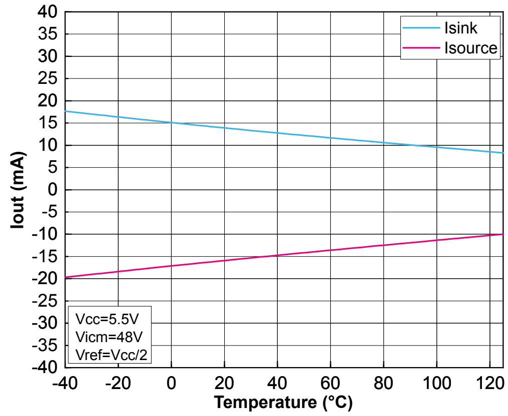


Figure 19. Output current vs. temperature with V_{CC} = 2.7 V

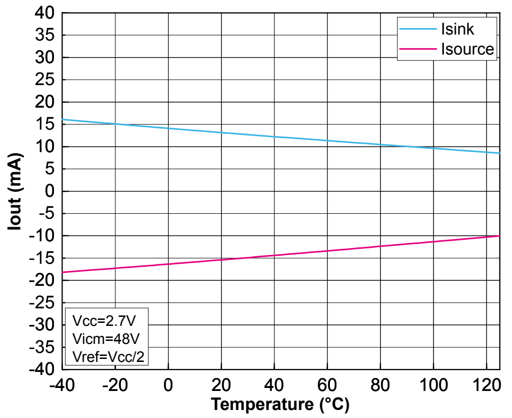


Figure 20. V_{oh} and V_{ol} vs. temperature with V_{CC} = 5.5 V

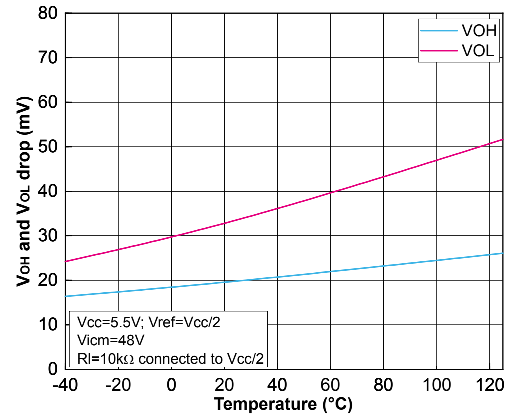


Figure 21. V_{oh} and V_{ol} vs. temperature with V_{CC} = 2.7 V

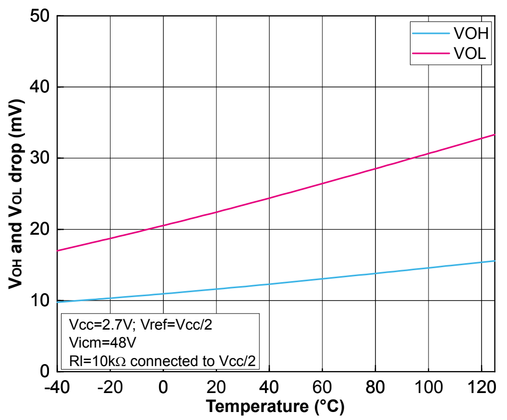


Figure 22. Linearity vs. Vsense with V_{CC} = 5.5 V

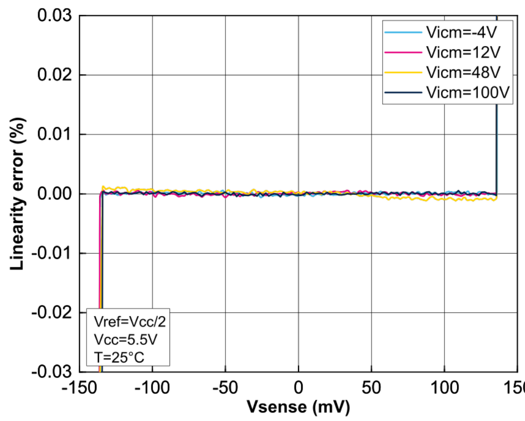


Figure 23. Linearity vs. Vsense

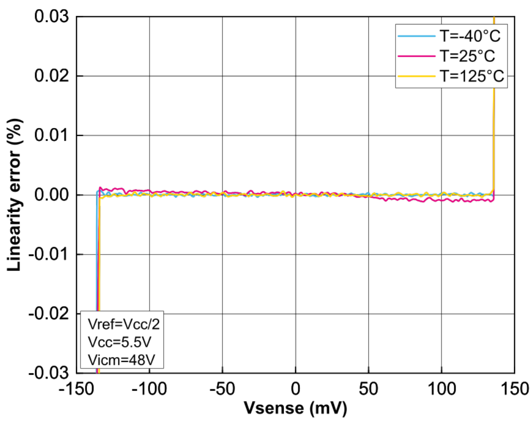


Figure 24. Gain error vs. input common-mode different V_{CC}

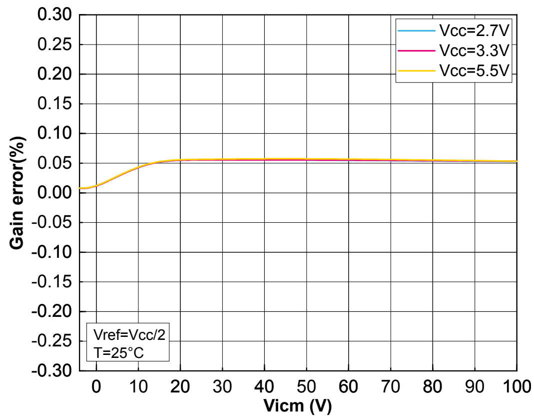


Figure 25. Gain error vs. input common-mode voltage different temperature

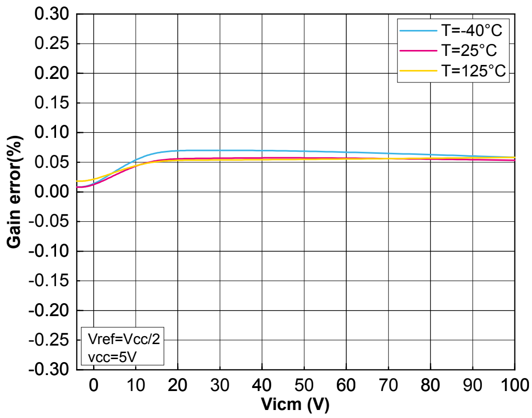


Figure 26. Load regulation with V_{CC} = 5 V

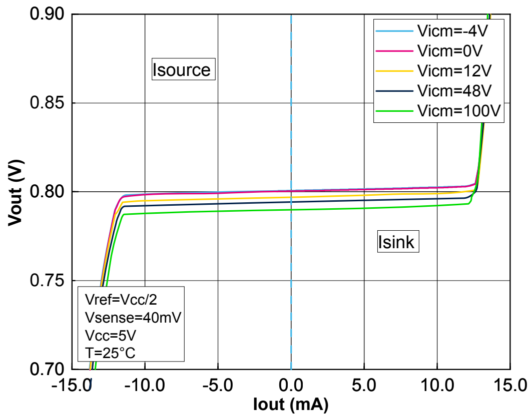


Figure 27. Gain vs. frequency

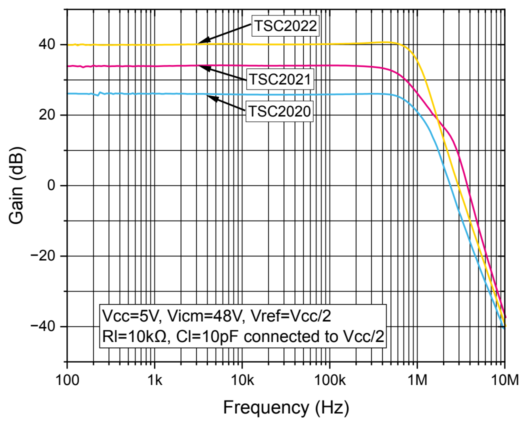


Figure 28. Gain vs. frequency with different capacitive load

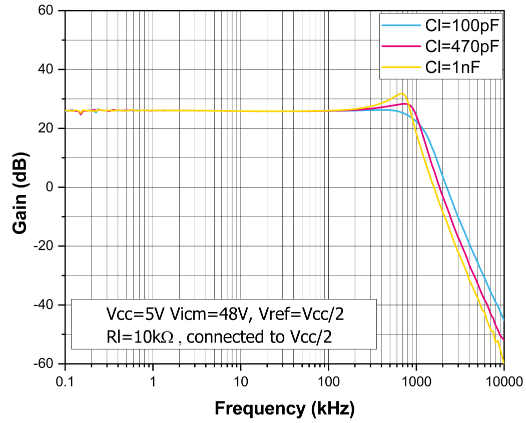


Figure 29. Gain vs. frequency with different capacitive load (TSC2021)

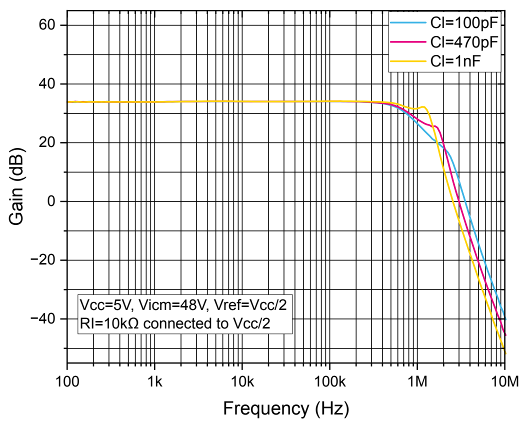


Figure 30. Gain vs. frequency with different capacitive load (TSC2022)

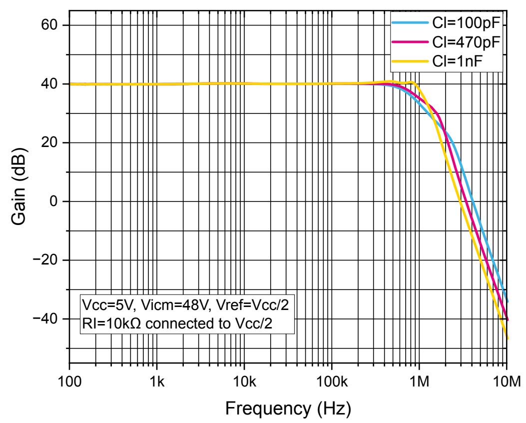


Figure 31. Bandwidth vs. input common-mode

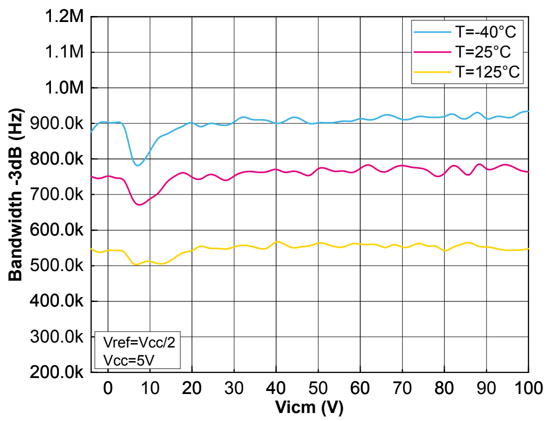


Figure 32. Overshoot vs. capacitive load

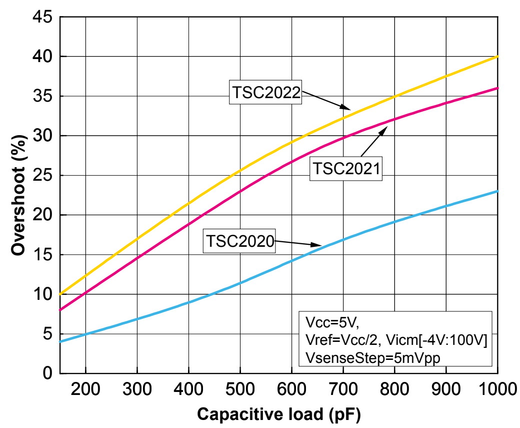


Figure 33. Small signal response with V_{CC} = 5 V

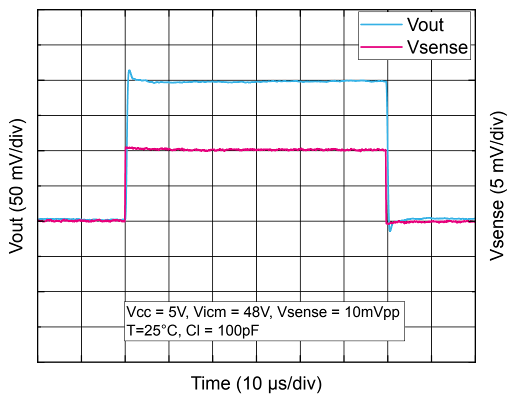


Figure 34. Large signal response with V_{CC} = 5 V

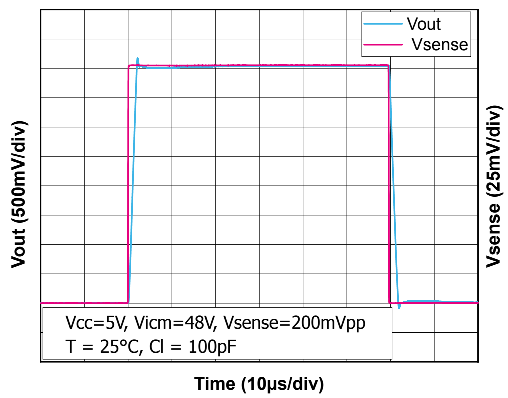


Figure 35. Large signal response with V_{CC} = 5 V (TSC2021)

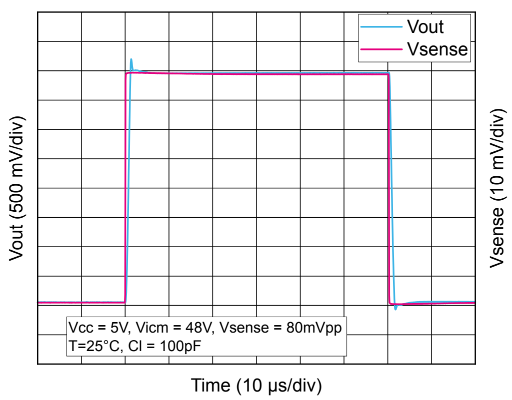


Figure 36. Large signal response with V_{CC} = 5 V (TSC2022)

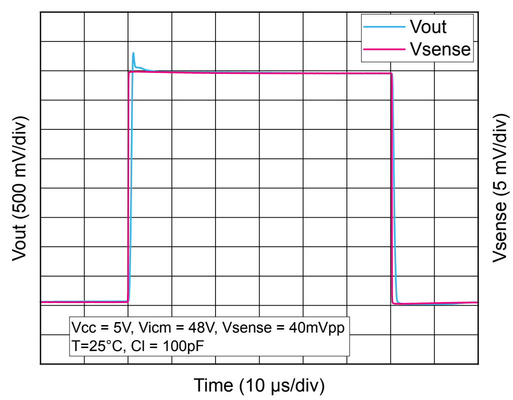


Figure 37. Positive settling time 1% vs. input common-mode

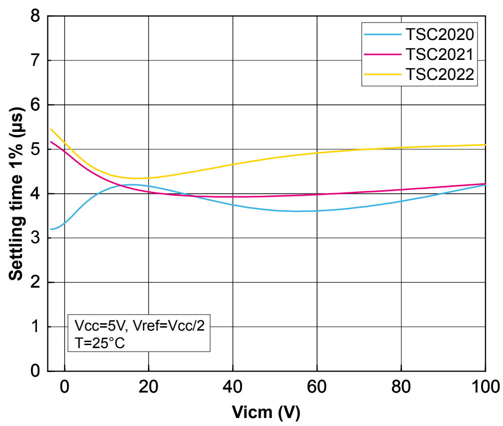


Figure 38. Negative settling time 1% vs. input common-mode

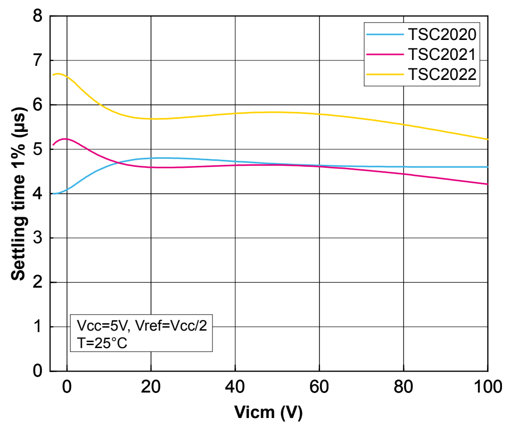


Figure 39. 48 V common-mode positive step response recovery

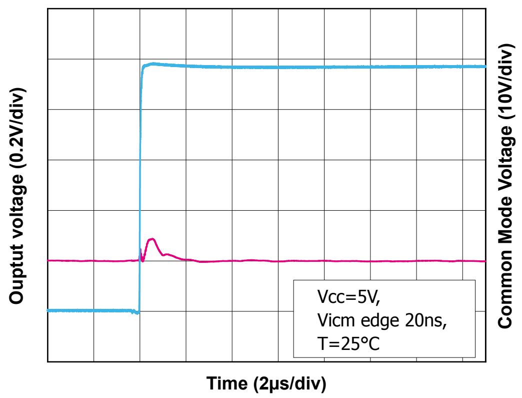


Figure 40. 48 V common-mode negative step response recovery

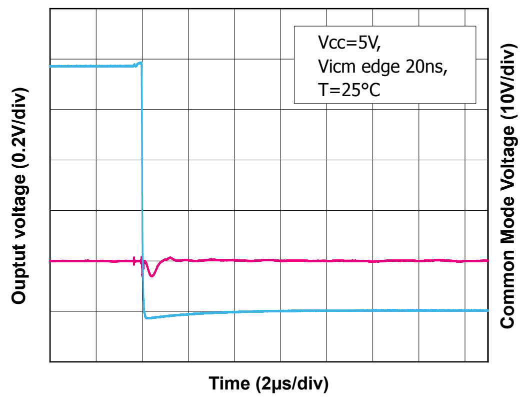


Figure 41. 100 V common-mode positive step response recovery

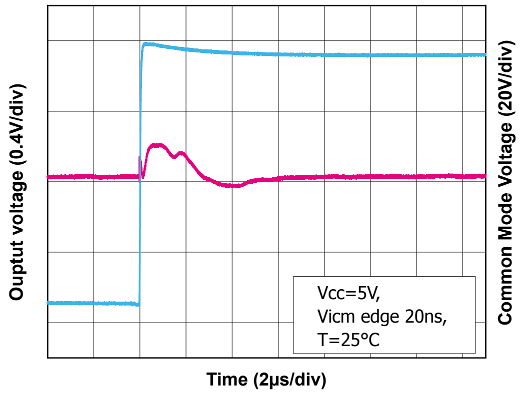


Figure 42. 100 V common-mode negative step response recovery

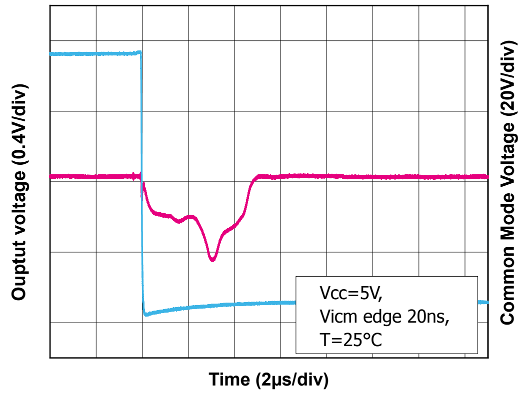


Figure 43. PSRR vs. frequency

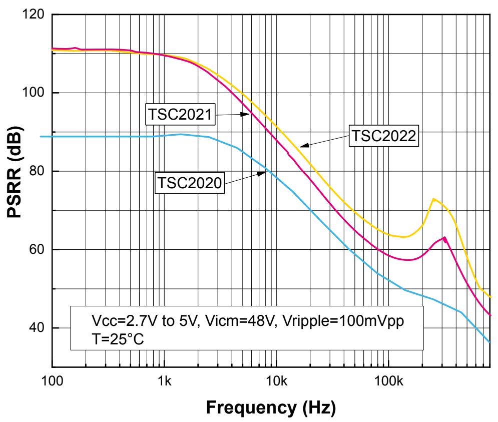


Figure 44. CMRR vs. frequency

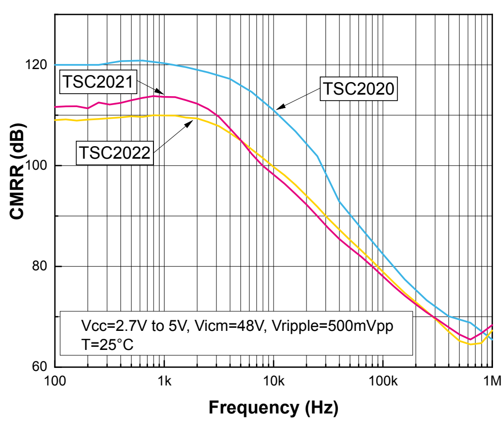


Figure 45. Positive overvoltage recovery

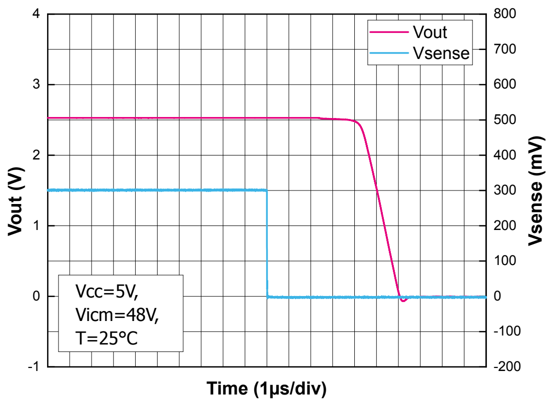
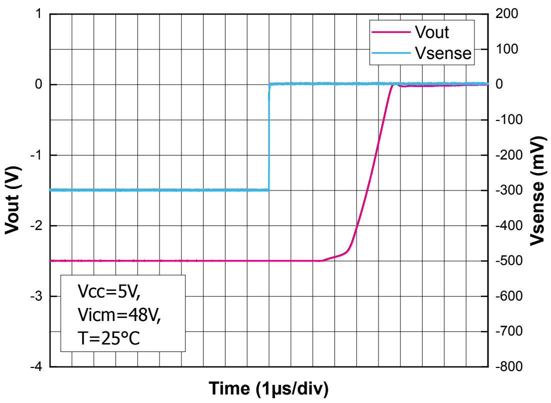


Figure 46. Negative overvoltage recovery



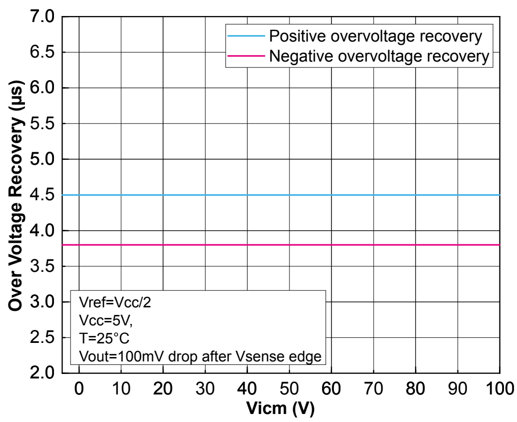


Figure 47. Overvoltage recovery vs input common-mode, V_{CC} = 5 V

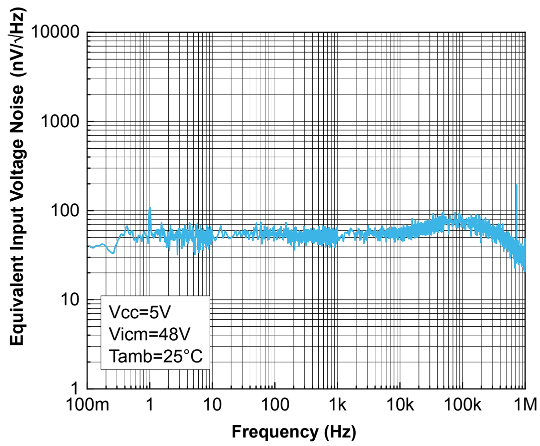


Figure 48. Noise vs. frequency

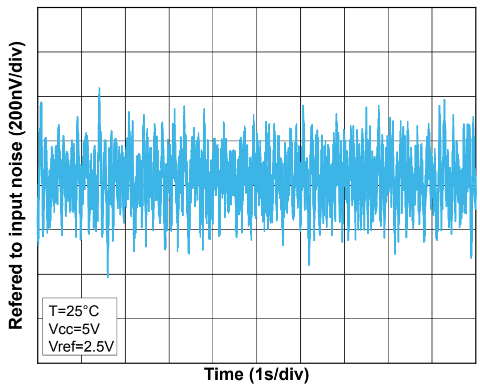


Figure 49. 0.1 Hz to 10 Hz voltage noise

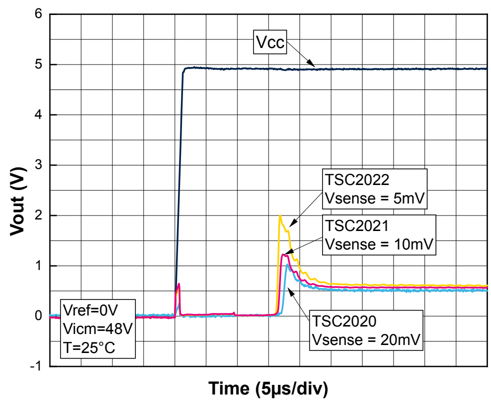


Figure 50. Power up time delay

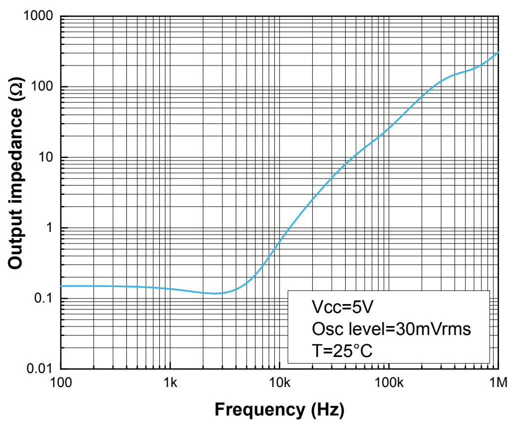


Figure 51. Output impedance vs. frequency

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 52. SO8 package outline

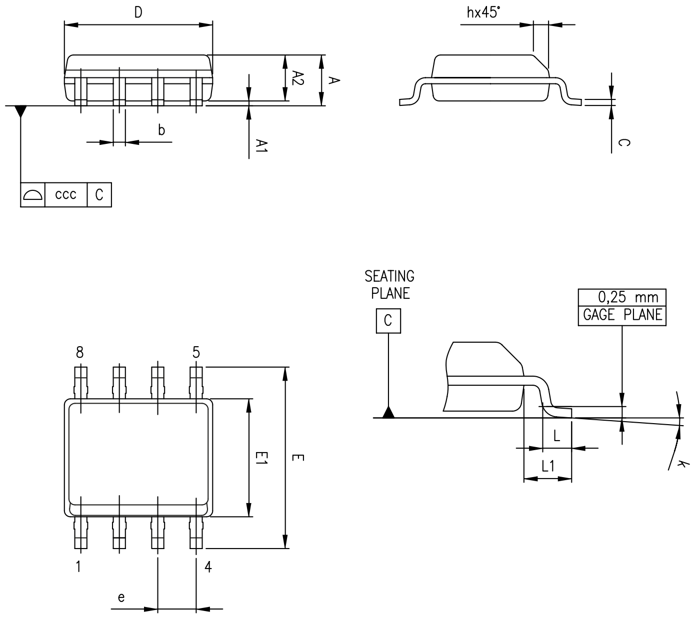


Table 6. SO8 package mechanical data

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

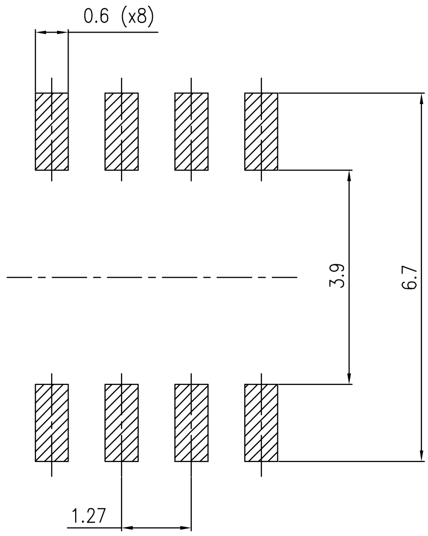


Figure 53. **SO8 recommended footprint**

5.2 MiniSO8 package information

Figure 54. MiniSO8 package outline

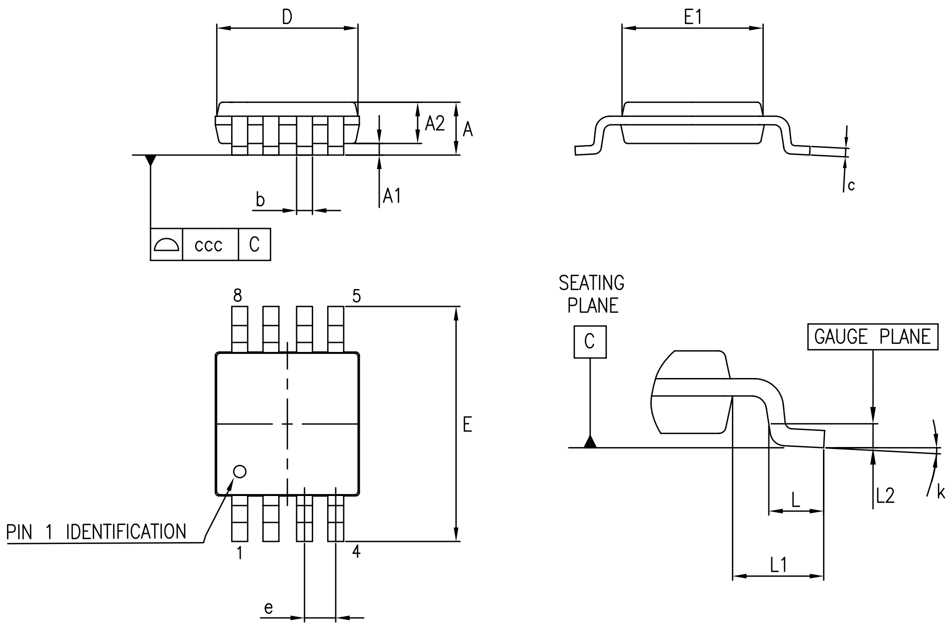
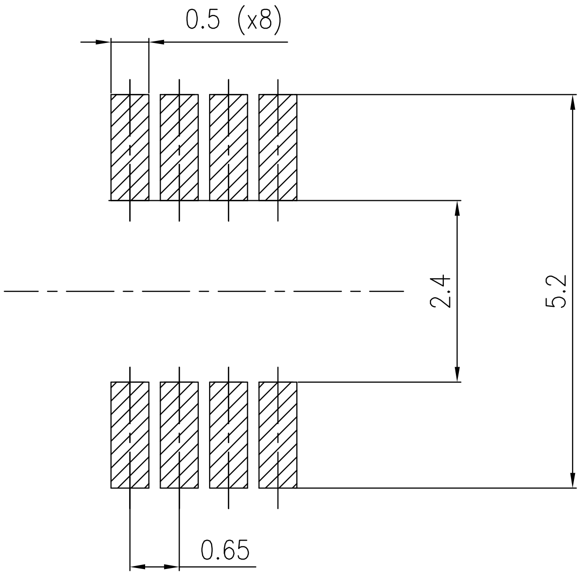


Table 7. MiniSO8 mechanical data

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 55. **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.
02-Jul-2024	3	Updated RT condition, Acc parameter in Table 4 and Section 4: Typical characteristics.

Contents

List of tables

List of figures