Automotive 10-MHz, 5-V, RRIO, Operational Amplifiers

Features

- AEC-Q100 Qualified for Automotive Applications
  - Grade 1: −40℃ to 125℃ T_A
- Supply Voltage: 2.7 V to 5.5 V
- Offset Voltage: ± 0.3 mV Typical
- Unit-Gain Bandwidth: 10 MHz
- Slew Rate: 8 V/μs
- Low Power: 1.2 mA per channel
- Rail-to-Rail Input and Output
- Low 1/f Noise: 10 nV/$\sqrt{Hz}$ at 1 kHz
- No Significant Output Glitch when Power on and off
- –40°C to 125°C Operation Temperature Range

Description

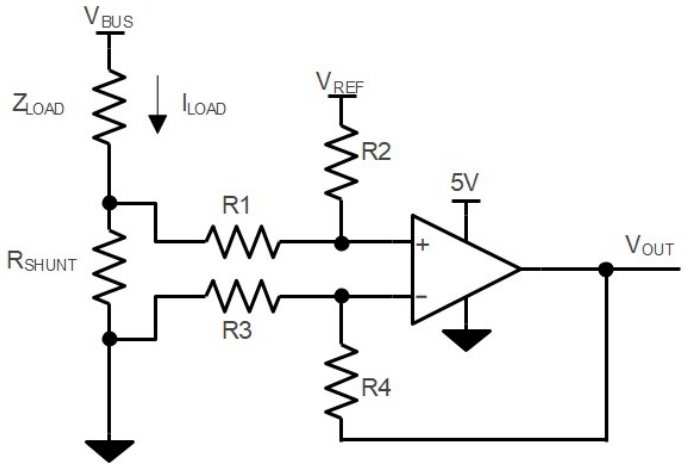
The TPA658xQ is a series of CMOS single, dual, and quad RRIO op-amps with low offset, low power, and stable high-frequency response. They incorporate 3PEAK's proprietary and patented design techniques to achieve high-performance AC with 10-MHz bandwidth, 8-V/μs slew rate, and low distortion while drawing only 1.2 mA of quiescent current per amplifier. The TPA658xQ devices are suitable for automotive motor control and on-board charger applications.

The TPA658xQ series is suitable for low operating voltage (2.7 V to 5.5 V) circuits. 3PEAK offers several channel versions and packages for different needs. This series is widely used in miniaturized and cost-sensitive designs.

Applications

- Automotive Motor Control
- Thermal Management Systems
- On-board Charger

Typical Application Circuit



$V_{OUT} = (I_{LOAD} \times R_{SHUNT}) \times (R2 / R1) + V_{REF}$

When R3 = R1, R2 = R4, $R_{SHUNT} << R1$

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Revision History

Date	Revision	Notes
2025-09-23	Rev.A.0	Initial version.

Pin Configuration and Functions

TPA6581Q
SOT23-5 Package
Top View

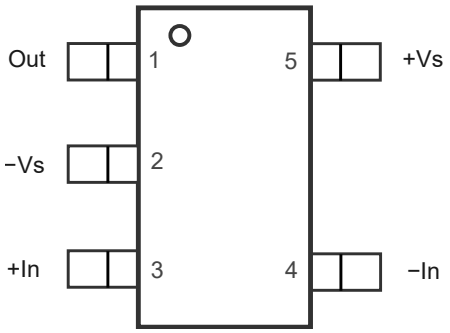
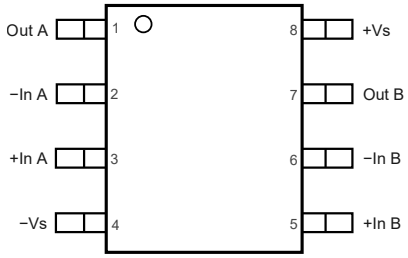


Table 1. Pin Functions: TPA6581Q

Pin No.	Name	I/O	Description
1	Out	O	Output
2	$-V_S$		Negative power supply
3	+In	I	Non-inverting input
4	-In	I	Inverting input
5	$+V_S$		Positive power supply

TPA6582Q
SOP8
Top View



TPA6582Q
MSOP8
Top View

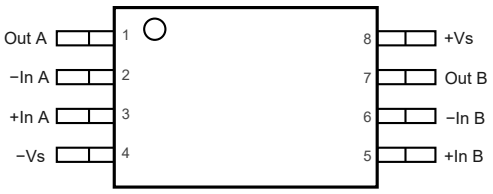
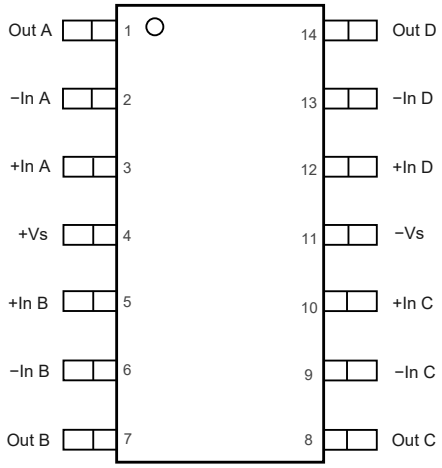


Table 2. Pin Functions: TPA6582Q

Pin No.		Name	I/O	Description
SOP8	MSOP8			
1	1	Out A	O	Output
2	2	−In A	I	Inverting input
3	3	+In A	I	Non-inverting input
4	4	$-V_S$		Negative power supply
5	5	+In B	I	Non-inverting input
6	6	−In B	I	Inverting input
7	7	Out B	O	Output
8	8	$+V_S$		Positive power supply

TPA6584Q
SOP14 Package
Top View



TPA6584Q
TSSOP14 Package
Top View

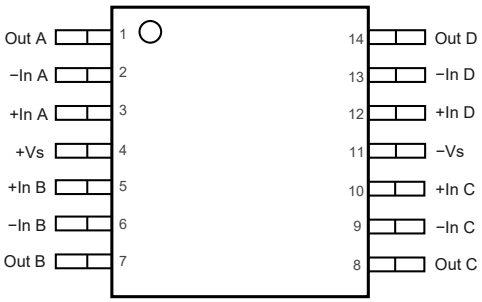


Table 3. Pin Functions: TPA6584Q

Pin No.		Name	I/O	Description
SOP14	TSSOP14			
1	1	Out A	O	Output
2	2	−In A	I	Inverting input
3	3	+In A	I	Non-inverting input
4	4	$+V_S$		Positive power supply
5	5	+In B	I	Non-inverting input
6	6	−In B	I	Inverting input
7	7	Out B	O	Output
8	8	Out C	O	Output
9	9	−In C	I	Inverting input
10	10	+In C	I	Non-inverting input
11	11	$-V_S$		Negative power supply
12	12	+In D	I	Non-inverting input
13	13	−In D	I	Inverting input
14	14	Out D	O	Output

Specifications

Absolute Maximum Ratings (1)

Over operating ambient temperature (unless otherwise noted) (1) .

Parameter		Min	Max	Unit
	Supply Voltage, ($+V_S$) – ($-V_S$)		6.5	V
	Input Voltage	($-V_S$) – 0.3	($+V_S$) + 0.3	V
	Differential Input Voltage	($-V_S$) − ($+V_S$)	($+V_S$) − ($-V_S$)	V
	Input Current: +IN, –IN (2)	−10	10	mA
	Output Voltage	($-V_S$) − 0.3	($+V_S$) + 0.3	V
	Output Short-Circuit Duration (3)		Infinite	
T_J	Maximum Operating Junction Temperature		150	°C
T_A	Operating Temperature Range	−40	125	°C
T_{STG}	Storage Temperature Range	–65	150	°C
T_L	Lead Temperature (Soldering 10 sec)		260	°C

(1) Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.
(2) The inputs are protected by ESD protection diodes to each power supply. If the input extends more than 300 mV beyond the power supply, the input current should be limited to less than 10 mA.
(3) A heat sink may be required to keep the junction temperature below the absolute maximum. This depends on the power supply voltage and how many amplifiers are shorted. Thermal resistance varies with the amount of PC board metal connected to the package. The specified values are for short traces connected to the leads.

ESD, Electrostatic Discharge Protection

Symbol	Parameter	Condition	Minimum Level	Unit
HBM	Human Body Model ESD	AEC-Q100-002	2	kV
CDM	Charged Device Model ESD	AEC-Q100-011	1.5	kV
LU	Latch Up	AEC-Q100-004, 25°C	500	mA
		AEC-Q100-004, 125°C	500	mA

Recommended Operating Conditions

Parameter		Min	Typ	Max	Unit
V_S	Supply Voltage, ($+V_S$) – ($-V_S$)	2.7		5.5	V
T_A	Operating Temperature Range	–40		125	°C

Thermal Information

Package Type	θ_{JA}	θ_{JB}	θ_{JC}	Unit
SOT23-5	201	121	73	°C/W
SOP8	141	111	66	°C/W
MSOP8	163	126	61	°C/W
SOP14	101	53	41	°C/W
TSSOP14	137	87	50	°C/W

Electrical Characteristics

All test conditions: T_A = 25°C, R_L = 10 kΩ, C_L = 100 pF, unless otherwise noted.

Parameter		Conditions	Min	Typ	Max	Unit
Power Supply						
V_S	Supply Voltage Range		2.7		5.5	V
I_Q	Quiescent Current per Amplifier	V_S = 2.7 V to 5.5 V		1.2	1.5	mA
		V_S = 2.7 V to 5.5 V, T_A = −40°C to 125°C			1.8	mA
PSRR	Power Supply Rejection Ratio	V_S = 2.7 V to 5.5 V	90	120		dB
		V_S = 2.7 V to 5.5 V, T_A = −40°C to 125°C	85			dB
Input Characteristics						
V_{OS}	Input Offset Voltage	V_{CM} = 0 V to 2.5 V	−2	0.3	2	mV
		V_{CM} = 0 V to 2.5 V, T_A = −40°C to 125°C	−2.5		2.5	mV
		V_{CM} = 3.5 V to 5 V	−2.5	0.4	2.5	mV
		V_{CM} = 3.5 V to 5 V, T_A = −40°C to 125°C	−3		3	mV
V_{OS} TC	Input Offset Voltage Drift	V_{CM} = 0 V to 2.5 V, T_A = −40°C to 125°C		0.1		µV/°C
		V_{CM} = 3.5 V to 5 V, T_A = −40°C to 125°C		0.3		µV/°C
I_B	Input Bias Current	V_{CM} = 2.5 V		10		pA
		V_{CM} = 2.5 V, T_A = −40°C to 125°C	−1000	100	1000	pA
I_{OS}	Input Offset Current	V_{CM} = 2.5 V		10		pA
		V_{CM} = 2.5 V, T_A = −40°C to 125°C	−1000	100	1000	pA
C_{IN}	Input Capacitance	Differential Mode		2		pF
		Common Mode		4		pF
Av	Open−Loop Voltage Gain	V_O = 0.1 V to 4.9 V	100	120		dB
		V_O = 0.1 V to 4.9 V, T_A = −40°C to 125°C	90			dB
V_{CMR}	Common−Mode Input Voltage Range	T_A = −40°C to 125°C	($-V_S$) − 0.1		($+V_S$) + 0.1	V
CMRR	Common Mode Rejection Ratio	V_{CM} = 0 V to 3.5 V	65	90		dB
		V_{CM} = 0 V to 3.5 V, T_A = −40°C to 125°C	60			dB
		V_{CM} = 0 V to 5 V	65	90		dB
		V_{CM} = 0 V to 5 V, T_A = −40°C to 125°C	60			dB
Output Characteristics						
	Output Voltage Swing from Positive Rail or Negative Rail	V_S = 5.5 V, R_L = 10 kΩ to V_S/2		3	15	mV
		V_S = 5.5 V, R_L = 10 kΩ to V_S/2, T_A = −40°C to 125°C			20	mV
		V_S = 5.5 V, R_L = 2 kΩ to V_S/2		15	50	mV
		V_S = 5.5 V, R_L = 2 kΩ to V_S/2, T_A = −40°C to 125°C			65	mV

Electrical Characteristics (continued)

All test conditions: V_S = 5 V, T_A = 25°C, R_L = 10 kΩ, C_L = 100 pF, unless otherwise noted.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
I_{SC}	Output Short−Circuit Current	V_S = 5.5 V, Source	45	60		mA
		V_S = 5.5 V, Source, T_A = −40°C to 125°C	35			mA
		V_S = 5.5 V, Sink	51	60		mA
		V_S = 5.5 V, Sink, T_A = −40°C to 125°C	40			mA
AC Specifications						
GBW	Gain−Bandwidth Product			10		MHz
SR	Slew Rate	G = 1, 2 V step	6	8		V/μs
t_{OR}	Overload Recovery			400		ns
t_S	Settling Time, 0.1%	G = 1, 2 V step		200		ns
	Settling Time, 0.01%			250		ns
PM	Phase Margin	R_L= 10 kΩ, C_L= 100 pF		40		°
GM	Gain Margin	R_L= 10 kΩ, C_L= 100 pF		10		dB
Noise Performance						
E_N	Input Voltage Noise	f = 0.1 Hz to 10 Hz, V_{CM} = 1 V		0.3		μV_{RMS}
		f = 0.1 Hz to 10 Hz, V_{CM} = 4 V		1		μV_{RMS}
e_N	Input Voltage Noise Density	f = 1 kHz, V_{CM} = 1 V		10		nV/√Hz
		f = 1 kHz, V_{CM} = 4 V		33		nV/√Hz
i_N	Input Current Noise	f = 1 kHz		20		fA/√Hz
THD+N	Total Harmonic Distortion and Noise	f = 1 kHz, G = 1, R_L = 10 kΩ, V_{OUT} = 1 V_{RMS}		0.001		%

Typical Performance Characteristics

All test conditions: V_S = 5 V, T_A = +25℃, unless otherwise noted.

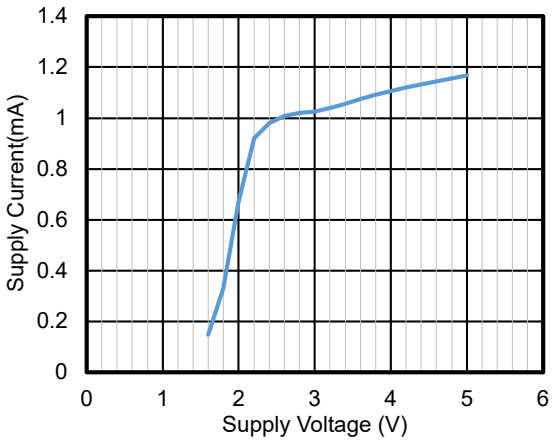


Figure 1. Supply Current vs. Supply Voltage

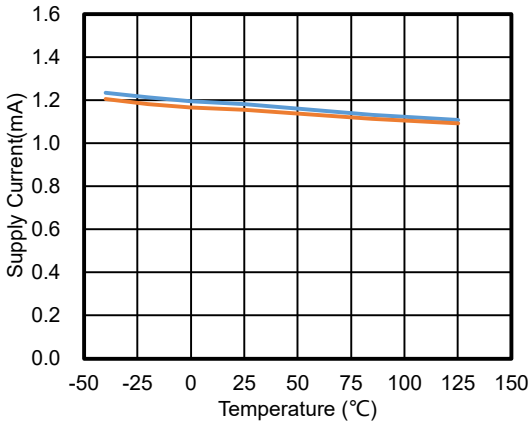


Figure 2. Supply Current vs. Temperature

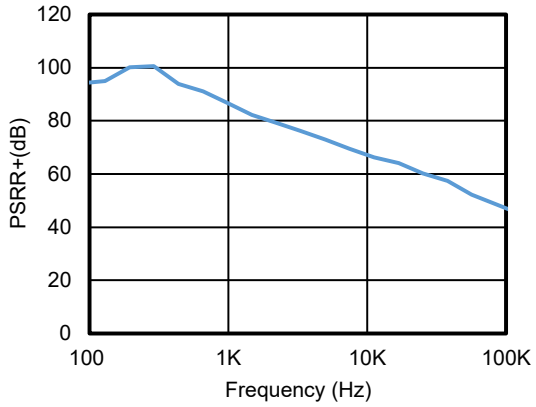


Figure 3. PSRR+ vs. Frequency

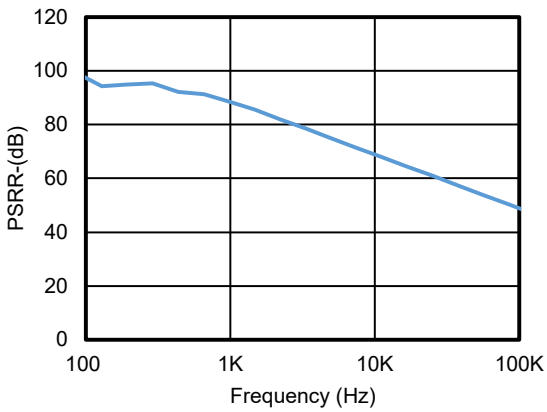


Figure 4. PSRR− vs. Frequency

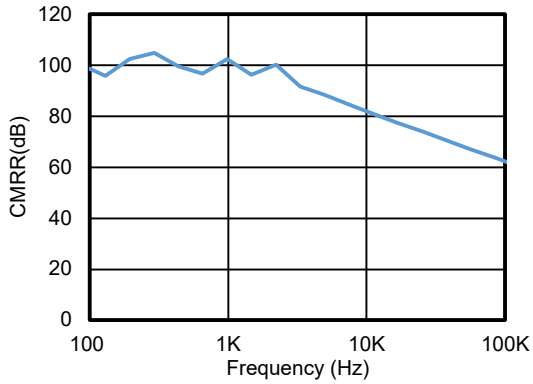


Figure 5. CMRR vs. Frequency

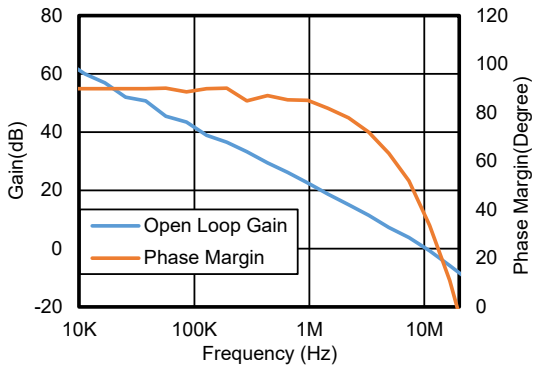


Figure 6. Open-Loop Gain and Phase Margin vs. Frequency, R_L = 10 kΩ, C_L = 100 pF

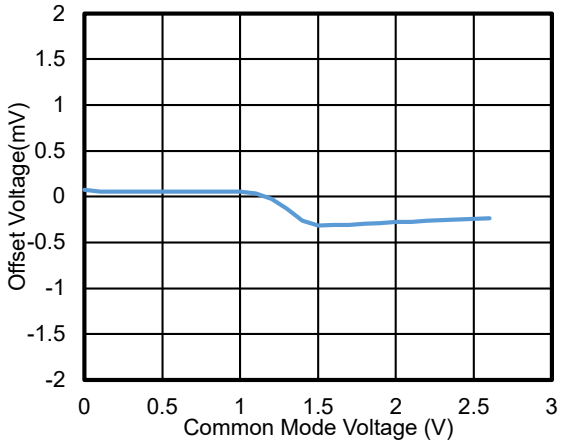


Figure 7. V_{OS} vs. V_{CM}, V_S = 2.7 V

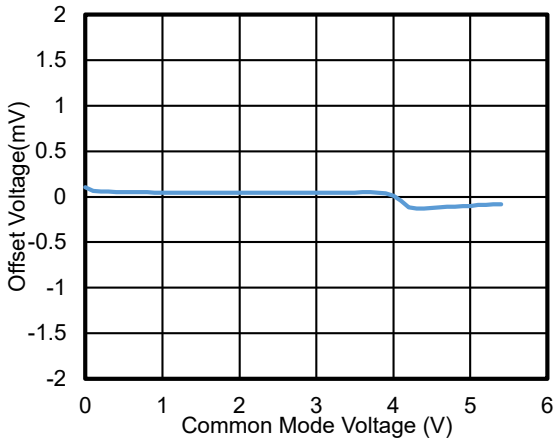


Figure 8. V_{OS} vs. V_{CM}, V_S = 5.5 V

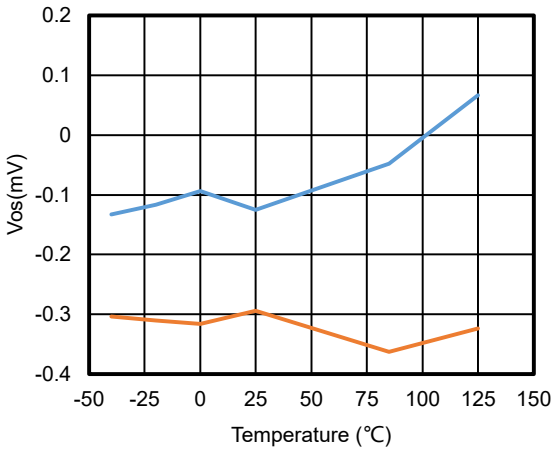


Figure 9. V_{OS} vs. Temperature

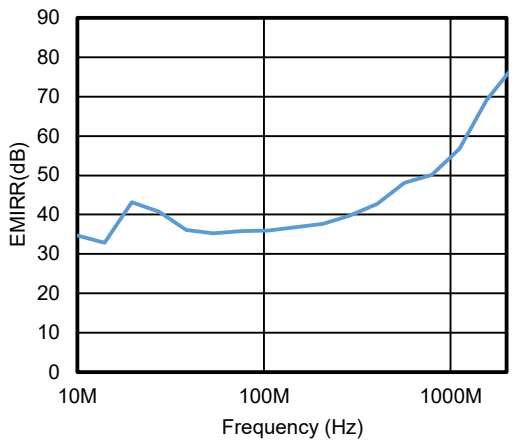


Figure 10. EMIRR vs. Frequency

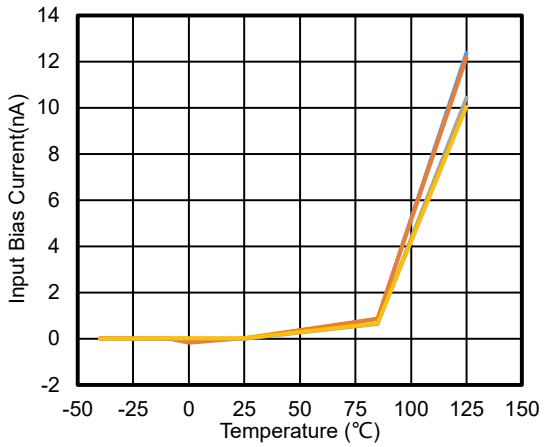


Figure 11. I_B vs. Temperature

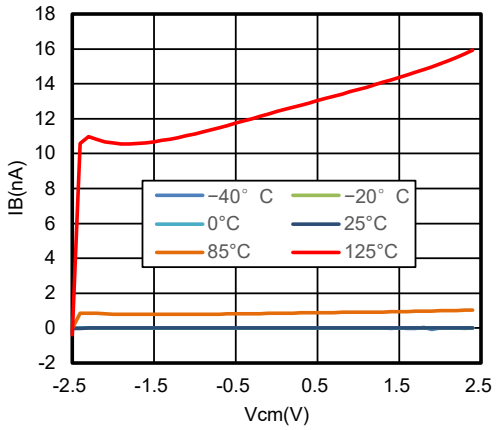


Figure 12. I_B vs. Common Voltage, ($-V_S$) = −2.5 V, ($+V_S$) = 2.5 V

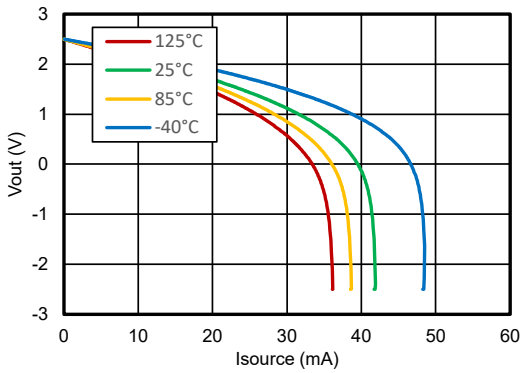


Figure 13. Output Voltage vs. Output Current, (−VS) = −2.5 V, (+VS) = 2.5 V

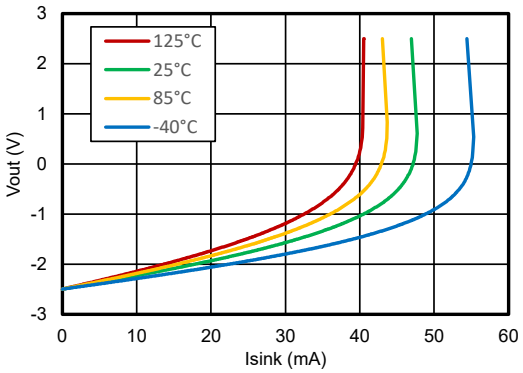


Figure 14. Output Voltage vs. Output Current, (−VS) = −2.5 V, (+VS) = 2.5 V

Figure 15. Overload Recovery at Negative Rail

Figure 16. Overload Recovery at Positive Rail

Figure 17. Small-Signal Step Response

Figure 18. Large-Signal Step Response

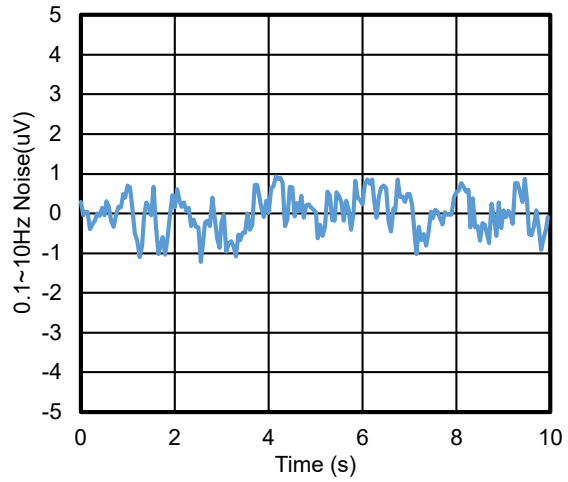


Figure 19. 0.1-Hz to 10-Hz Voltage Noise, V_{CM} = 1 V

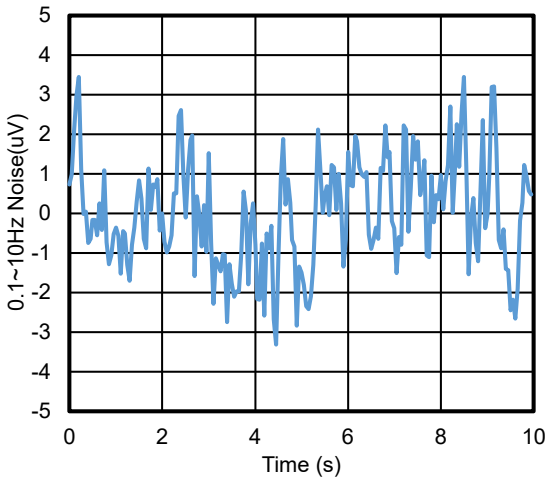


Figure 20. 0.1-Hz to 10-Hz Voltage Noise, V_{CM} = 4 V

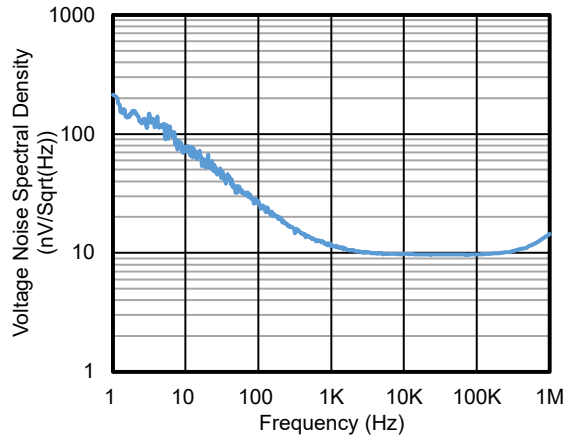


Figure 21. Voltage Noise Spectral Density vs. Frequency, V_{CM} = 1 V

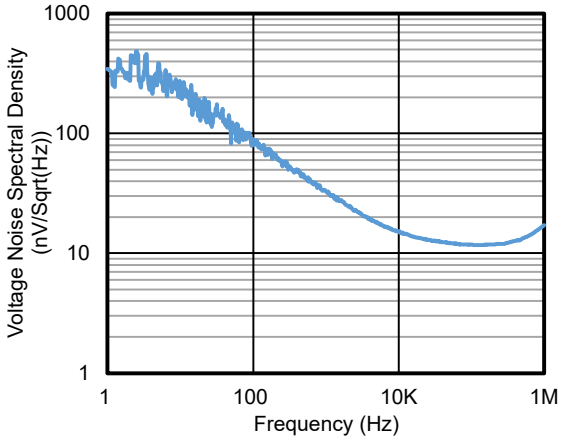


Figure 22. Voltage Noise Spectral Density vs. Frequency, V_{CM} = 4 V

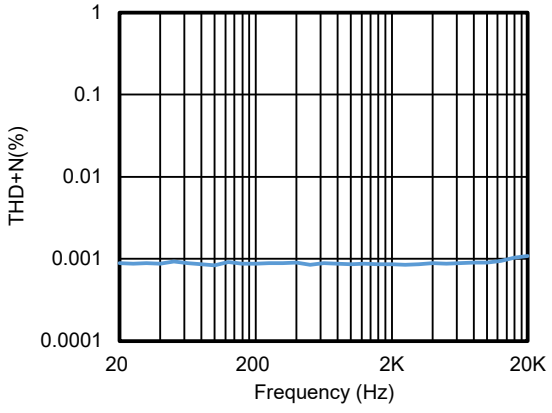


Figure 23. THD vs. Frequency, G = 1, V_{IN} = 1 V_{RMS}

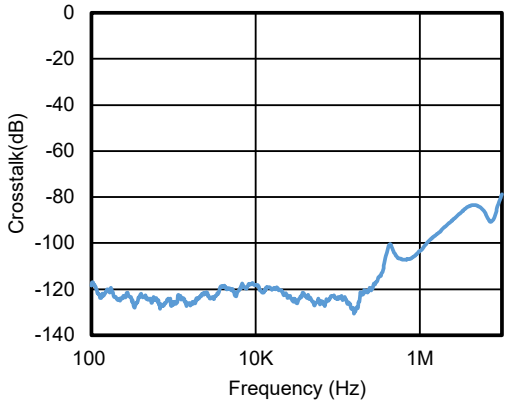


Figure 24. Crosstalk vs. Frequency, TPA6584Q

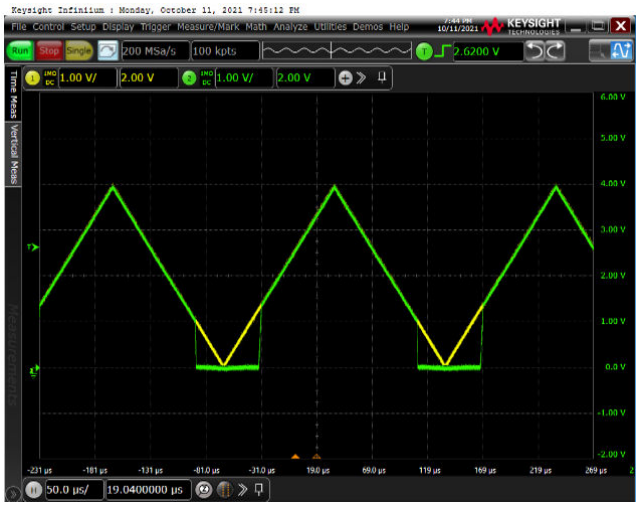


Figure 25. Power On and Off Behavior

G = 1, V_{IN} = 4 V during power-on and power-off;
Yellow: $+V_S$; Green: Output

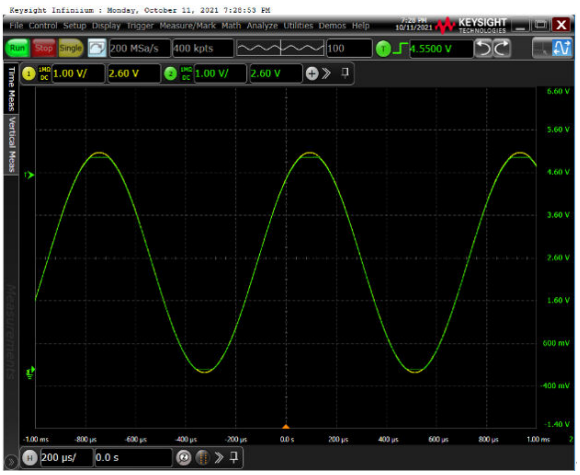


Figure 26. No Phase Reversal

Yellow: Input; Green: Output

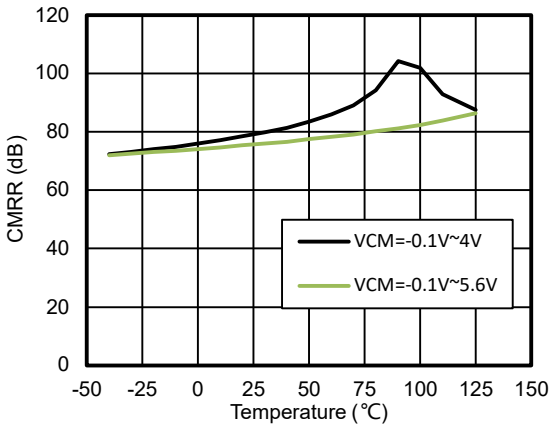


Figure 27. CMRR vs. Temperature, R_L = 600 Ω

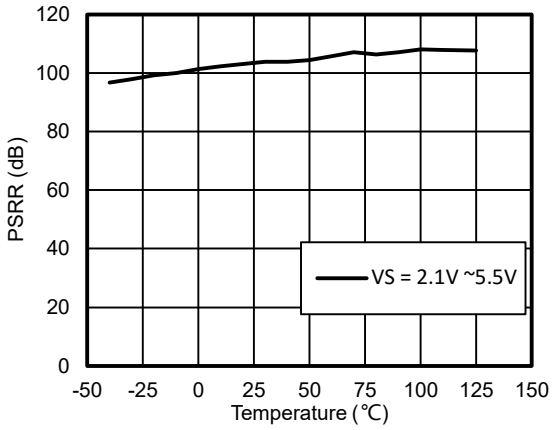


Figure 28. PSRR vs. Temperature, R_L = 600 Ω

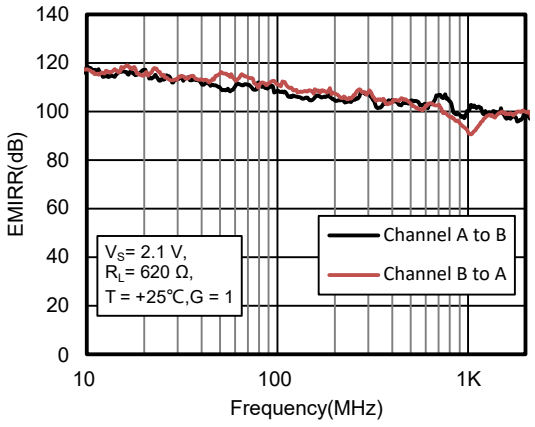


Figure 29. Channel Separation vs. Frequency

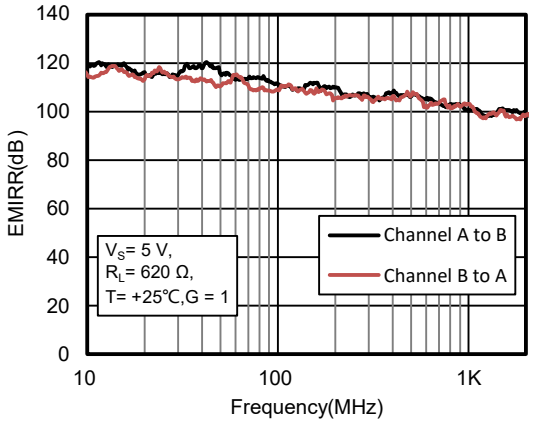


Figure 30. Channel Separation vs. Frequency

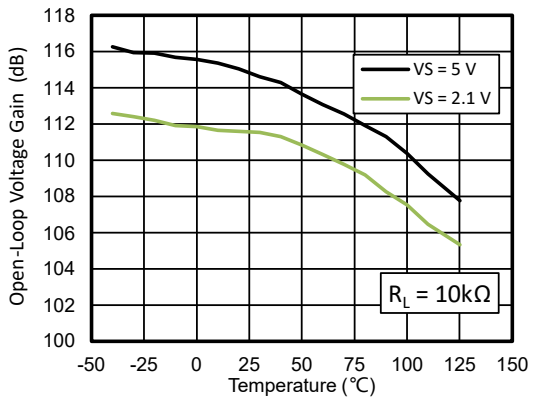


Figure 31. Open-Loop Voltage Gain vs. Temperature

Detailed Description

Overview

The TPA658xQ series is a new family of automotive, low-power, rail-to-rail input and output op amplifiers. These devices operate from 2.7 V to 5.5 V, are unity-gain stable and designed for a wide range of general-purpose applications.

Functional Block Diagram

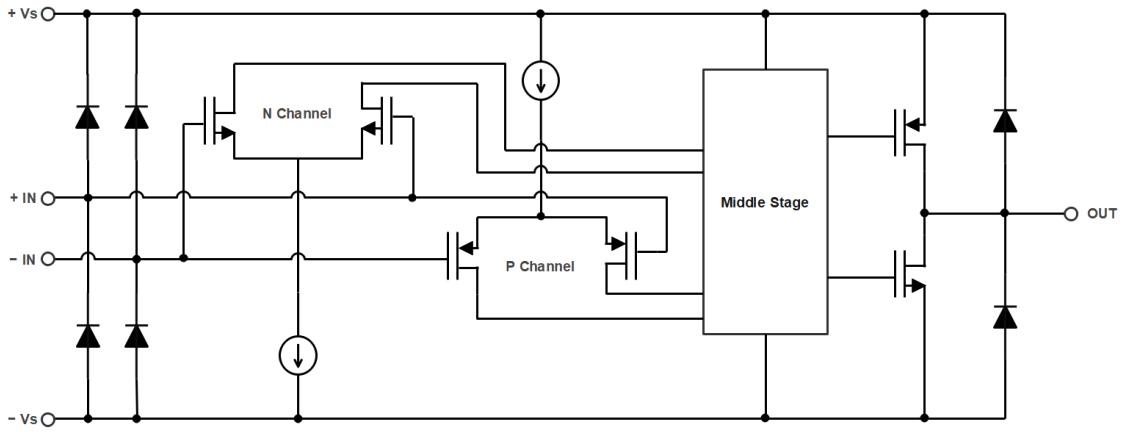


Figure 32. Functional Block Diagram

Feature Description

Operating Voltage

The TPA658xQ family is designed for single supply operation from 2.7 V to 5.5 V or dual supply operation from ±1.35 V to ±2.75 V.

Rail-to-Rail Input

The input common-mode voltage range of the TPA658xQ family extends 100 mV beyond the supply rails. This performance is achieved with a complementary input stage: a P-channel input differential pair in parallel with an N-channel differential pair. The P-channel pair is active for inputs from 100 mV below the negative supply to approximately ($+V_S$) – 1.5 V, whereas the N-channel pair is active for input voltages close to the positive rail, typically ($+V_S$) – 1.5 V to 100 mV above the positive supply. There is around a 200-mV transition region at ($+V_S$) – 1.5 V where both pairs are on. Within this transition region, PSRR, CMRR, offset voltage, offset drift, and THD can degrade compared to those operating outside this region.

Rail-to-Rail Output

The TPA658xQ family delivers rail-to-rail output swing capability with a class-AB output stage. Different load conditions change the ability of the amplifier to swing close to the rails.

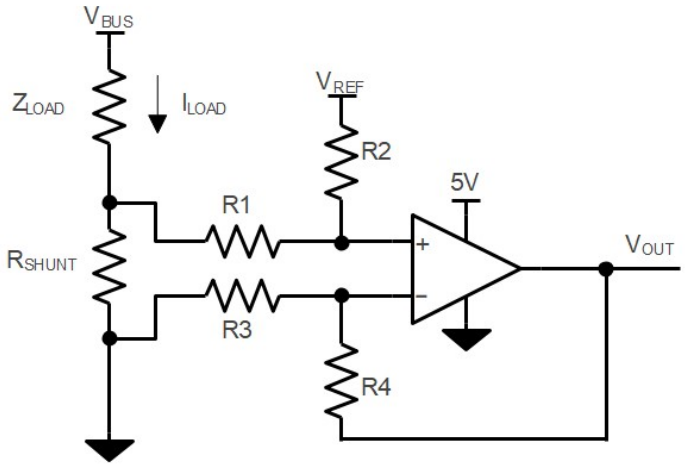
Application and Implementation

> Note
>
> Information in the following application sections is not part of the 3PEAK's component specification and 3PEAK does not warrant its accuracy or completeness. 3PEAK's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

Application Information

Low Side Current Sensing Application

Figure 33 shows the TPA658xQ configured in a low-side current sensing application. The low-side current sensing method consists of placing a sense resistor between the load and the circuit ground. The voltage dropping across the resistor is amplified by different amplifier circuits with the TPA658xQ. The V_{REF} can be used to add bias voltage to the output voltage. Particular attention must be paid to the matching and precision of R1, R2, R3, and R4, to maximize the accuracy of the measurement.



$$V_{OUT} = (I_{LOAD} \times R_{SHUNT}) \times (R2 / R1) + V_{REF}$$

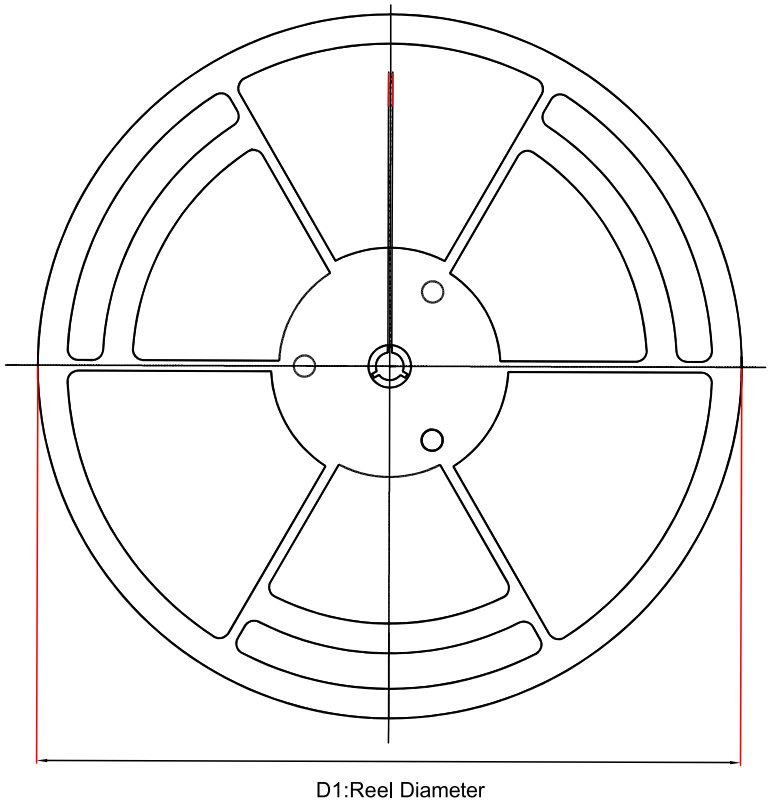
When R3 = R1, R2 = R4, R_{SHUNT} << R1

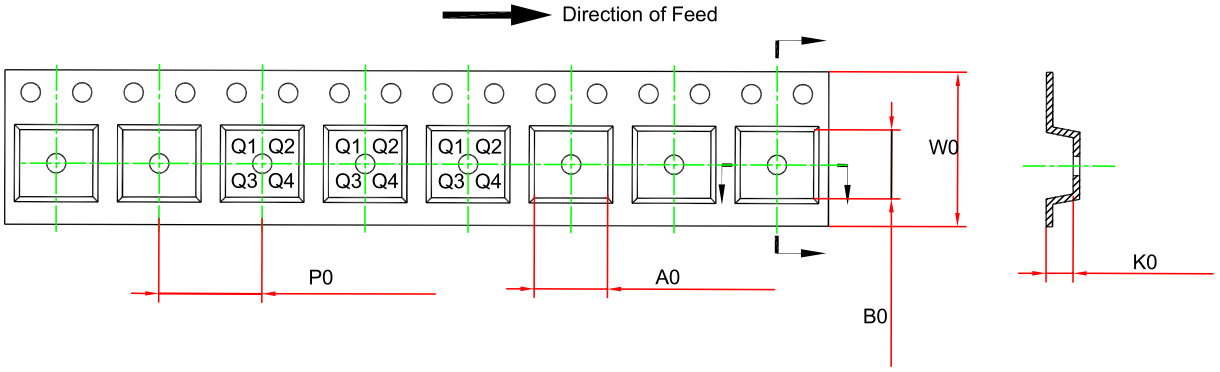
Figure 33. Dual Supply Operation Connections

Power Supply Recommendations

Place 0.1-μF bypass capacitors close to the power supply pins to reduce coupling errors from the noisy or high-impedance power supplies.

Tape and Reel Information



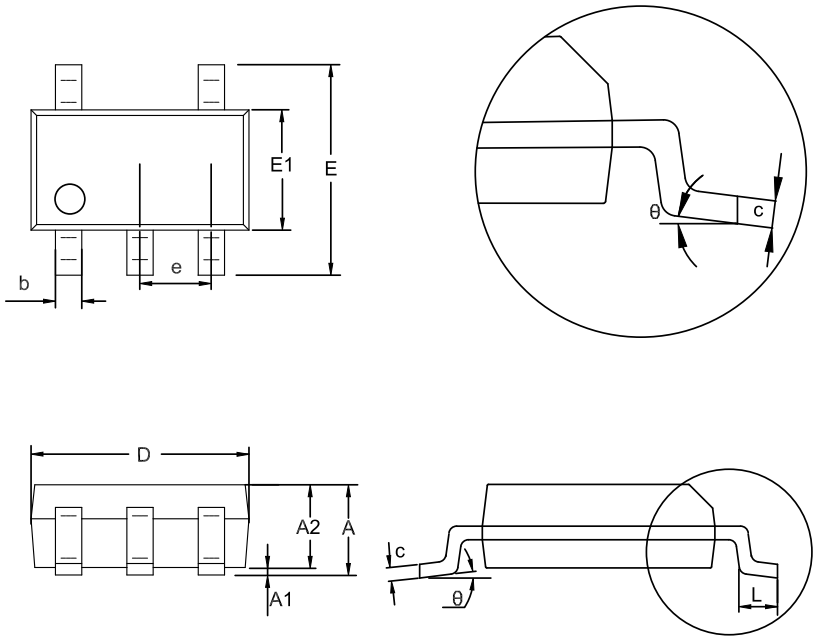


Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TPA6581Q-S5TR-S	SOT23-5	180.0	12	3.3	3.25	1.4	4.0	8.0	Q3
TPA6582Q-SO1R-S	SOP8	330.0	17.6	6.5	5.4	2.0	8.0	12.0	Q1
TPA6582Q-VS1R-S	MSOP8	330.0	17.6	5.3	3.4	1.3	8.0	12.0	Q1
TPA6584Q-SO2R-S	SOP14	330.0	21.6	6.5	9.0	2.1	8.0	16.0	Q1
TPA6584Q-TS2R-S	TSSOP14	330.0	17.6	6.8	5.5	1.5	8.0	12.0	Q1

Package Outline Dimensions

SOT23-5

Package Outline Dimensions S5T(SOT23-5-A)



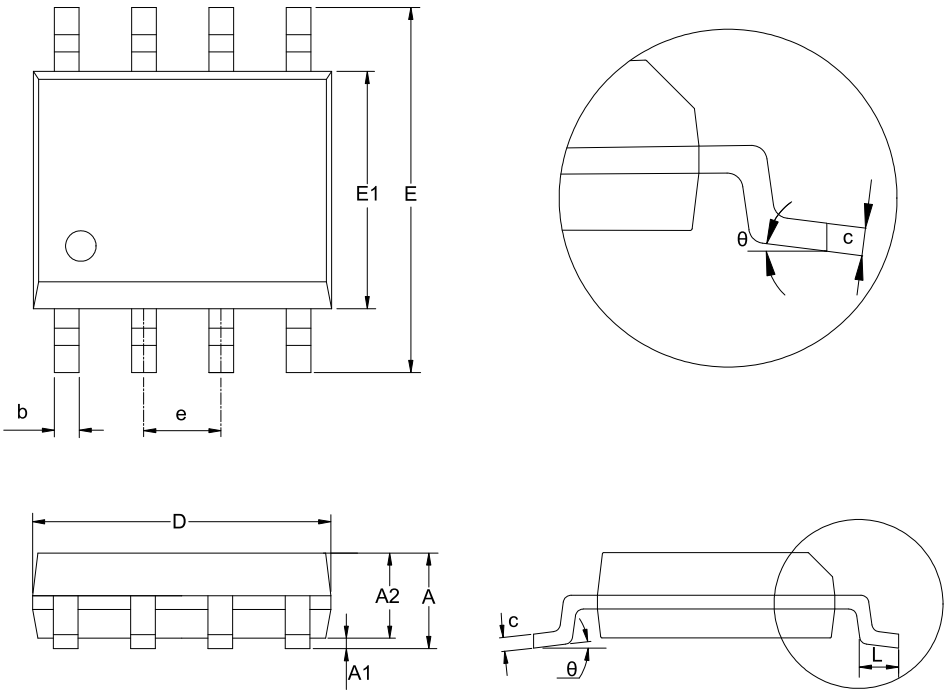
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.150	0.000	0.006
A2	1.000	1.200	0.039	0.047
b	0.280	0.500	0.011	0.020
c	0.100	0.230	0.004	0.009
D	2.820	3.020	0.111	0.119
E	2.600	3.000	0.102	0.118
E1	1.500	1.720	0.059	0.068
e	0.950 BSC		0.037 BSC	
L	0.300	0.600	0.012	0.024
θ	0	8°	0	8°

NOTES

1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

SOP8

Package Outline Dimensions SO1(SOP-8-B)



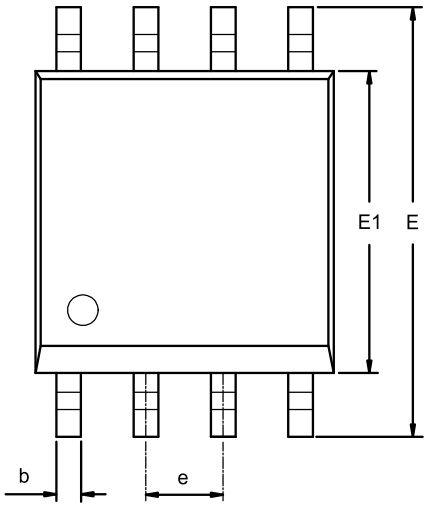
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.250	1.550	0.049	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.007	0.010
D	4.700	5.100	0.185	0.201
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270 BSC		0.050 BSC	
L	0.400	1.000	0.016	0.039
θ	0	8°	0	8°

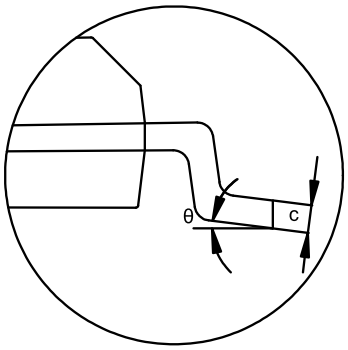
NOTES

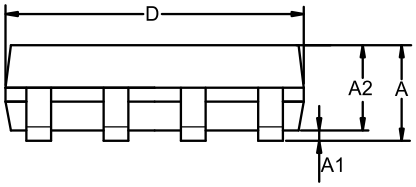
1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

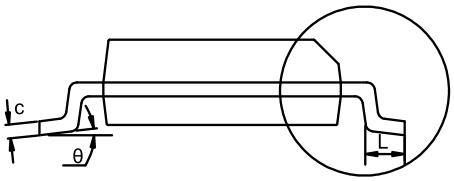
MSOP8

Package Outline Dimensions VS1(MSOP-8-A)









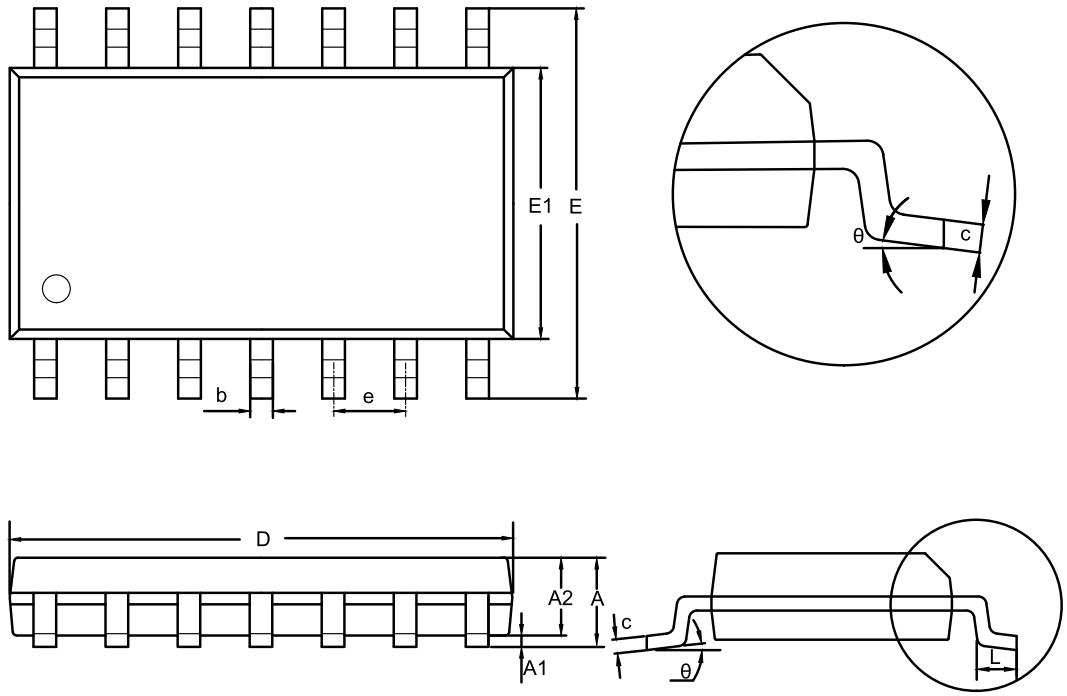
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.800	1.100	0.031	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
E	4.700	5.100	0.185	0.201
E1	2.900	3.100	0.114	0.122
e	0.650 BSC		0.026 BSC	
L	0.400	0.800	0.016	0.031
θ	0	8°	0	8°

NOTES

1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

SOP14

Package Outline Dimensions SO2(SOP-14-A)



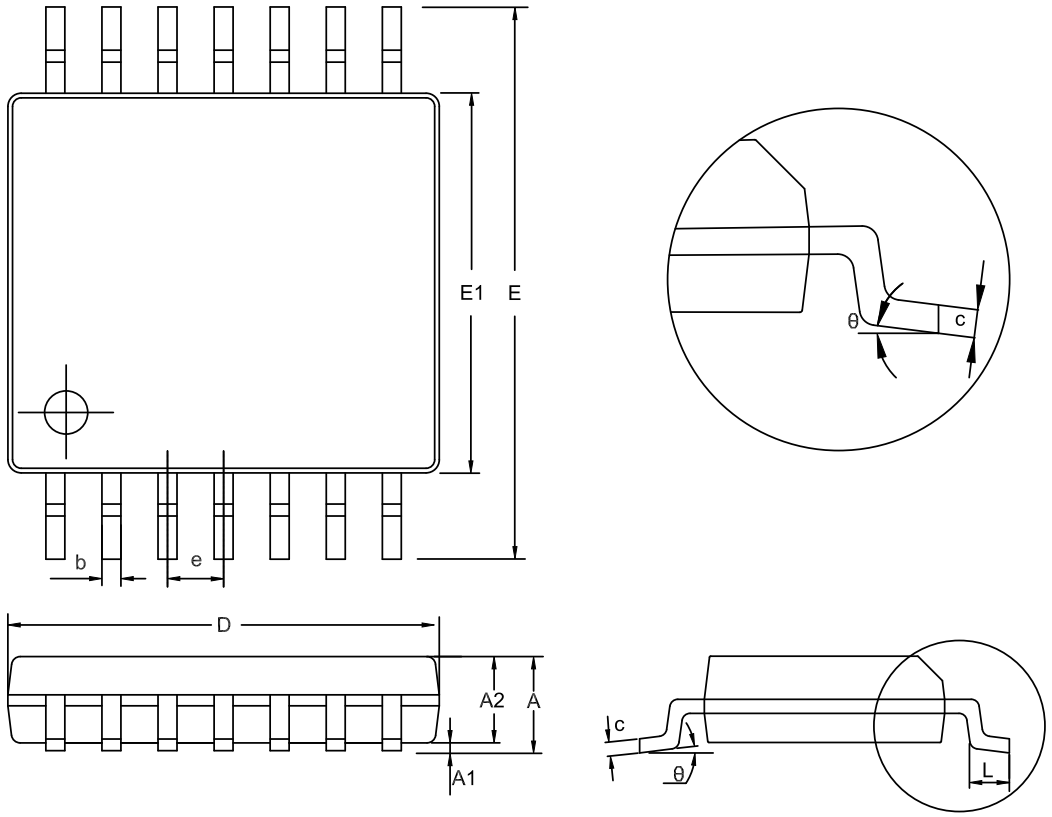
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.050	0.250	0.002	0.010
A2	1.250	1.650	0.049	0.065
b	0.310	0.510	0.012	0.020
c	0.100	0.250	0.004	0.010
D	8.450	8.850	0.333	0.348
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270 BSC		0.050 BSC	
L	0.400	1.270	0.016	0.050
θ	0	8°	0	8°

NOTES

1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

TSSOP14

Package Outline Dimensions TS2(TSSOP-14-A)



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.900	1.200	0.035	0.047
A1	0.050	0.150	0.002	0.006
A2	0.800	1.050	0.031	0.041
b	0.190	0.300	0.007	0.012
c	0.090	0.200	0.004	0.008
D	4.900	5.100	0.193	0.201
E	6.200	6.600	0.244	0.260
E1	4.300	4.500	0.169	0.177
e	0.650 BSC		0.026 BSC	
L	0.450	0.750	0.018	0.030
θ	0	8°	0	8°

NOTES

1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

Order Information

Order Number	Operating Temperature Range	Package	Marking Information	MSL	Transport Media, Quantity	Eco Plan
TPA6581Q-S5TR-S	−40 to 125°C	SOT23-5	A9W	1	Tape and Reel, 3000	Green
TPA6582Q-SO1R-S	−40 to 125°C	SOP8	6582Q	1	Tape and Reel, 4000	Green
TPA6582Q-VS1R-S	−40 to 125°C	MSOP8	6582Q	1	Tape and Reel, 3000	Green
TPA6584Q-SO2R-S	−40 to 125°C	SOP14	6584Q	1	Tape and Reel, 2500	Green
TPA6584Q-TS2R-S	−40 to 125°C	TSSOP14	6584Q	1	Tape and Reel, 3000	Green

Green: 3PEAK defines "Green" to mean RoHS compatible and free of halogen substances.

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