6-MHz, 600-µA, RRIO, Op Amps

Features

- Supply Voltage: 2.7 V to 5.5 V
- Low Supply Current: Typical 600-µA per Channel
- Rail-to-Rail Input and Output
- Bandwidth: Typical 6 MHz
- Slew Rate: Typical 4.5 V/µs
- Excellent EMI Suppress Performance
- Offset Voltage: Maximum ±3 mV
- Offset Voltage Temperature Drift: Typical 1 µV/°C
- Low Noise: Typical 19 nV/√Hz at 1 kHz
- High Output Capability: Typical 100 mA
- −40°C to 125°C Operation Temperature Range
- Qualified for Automotive Applications with AEC-Q100 Reliability Test

Applications

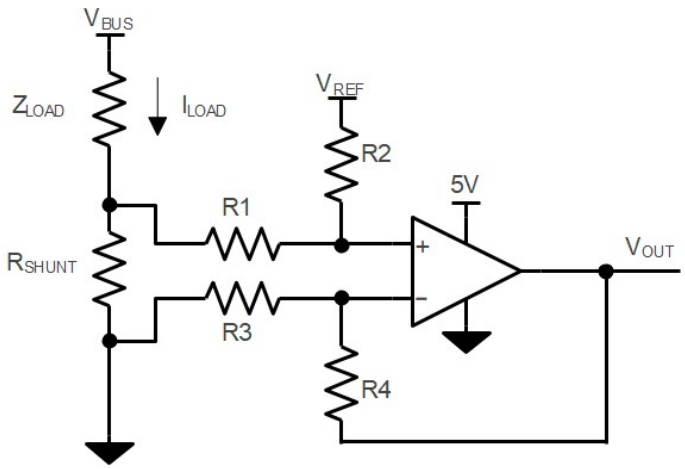
- Automotive Motor Control
- On-Board Charger

Description

The TP156xAL1 series of products are CMOS 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 very good AC performance with 6-MHz bandwidth, 4.5-V/µs slew rate, and low distortion while drawing only 600 µA of quiescent current per amplifier. The input common-mode voltage range extends 300 mV beyond V− and V+, and the outputs swing rail-to-rail. The TP156xAL1 family can be used as plug-in replacements for many commercially available op-amps to reduce power consumption and improve input/output range and performance.

The combination of features makes the TP156xAL1 ideal choice for motor control and automotive applications. The ability to swing rail-to-rail at the inputs and outputs enables designers to buffer CMOS DACs, ASICs, or other wide output swing devices in single-supply systems.

Typical Application Circuit



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

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

Table of Contents

Revision History

Date	Revision	Notes
2022-11-20	Rev.A.0	Initial version.
2023-02-01	Rev.A.1	Updated the status of AEC-Q100 test in Features.
2023-02-15	Rev.A.2	Corrected typo.

Pin Configuration and Functions

TP1561AL1

SOT23-5 Package

Top View

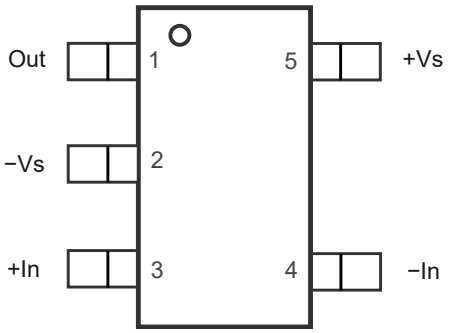


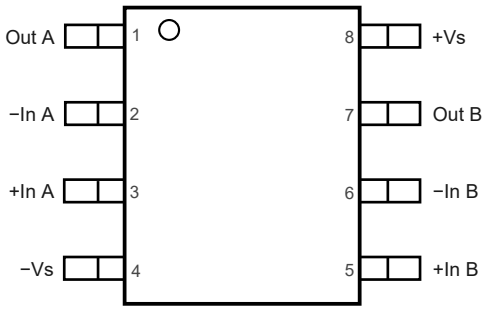
Table 1. Pin Functions: TP1561AL1

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

TP1562AL1

SOP8 Package

Top View



TP1562AL1

MSOP8 Package

Top View

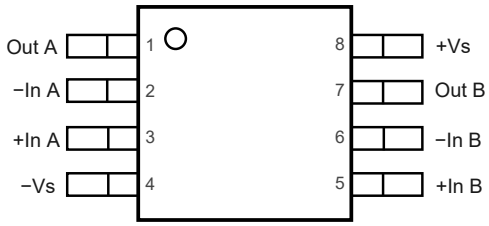


Table 2. Pin Functions: TP1562AL1

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

TP1564AL1

SOP14 Package

Top View

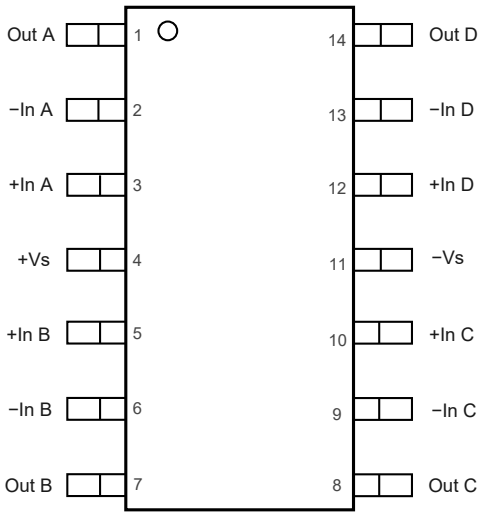


Table 3. Pin Functions: TP1564AL1

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

Specifications

Absolute Maximum Ratings (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 Short-Circuit Duration (3)		Infinite	
T_J	Maximum 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

Parameter		Condition	Minimum Level	Unit
HBM	Human Body Model ESD	AEC-Q100-002	4	kV
CDM	Charged Device Model ESD	AEC-Q100-011	1.5	kV

Recommended Operating Conditions

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

Thermal Information

Package Type	θ_{JA}	θ_{JC}	Unit
SOT23-5	250	81	°C/W
SOP8	158	43	°C/W
MSOP8	210	45	°C/W
SOP14	120	36	°C/W

Electrical Characteristics

All test condition is at V_S = 5 V, T_A = 25°C, R_L = 2 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			600	900	µA
		T_A = −40°C to 125°C			1200	µA
PSRR	Power Supply Rejection Ratio	V_S = 2.7 V to 5.5 V, V_{CM} = 0.1 V	75	90		dB
		V_S = 2.7 V to 5.5 V, V_{CM} = 0.1 V, T_A = −40°C to 125°C	65			dB
Input Characteristics						
V_{OS}	Input Offset Voltage	V_{CM} = 0 V to 3 V	−3		3	mV
V_{OS}	Input Offset Voltage	V_{CM} = 0 V to 3 V, T_A = −40°C to 125°C	−5		5	mV
V_{OS} TC	Input Offset Voltage Drift	T_A = −40°C to 125°C		1		µV/°C
I_B	Input Bias Current	T_A = 25 °C	−200	1	200	pA
		T_A = 125 °C	−2000	25	2000	pA
I_{OS}	Input Offset Current			10		pA
C_{IN}	Input Capacitance	Differential Mode		8		pF
		Common Mode		7		pF
Av	Open-loop Voltage Gain	V_{OUT} = 0.1 V to 4.9 V, R_{LOAD} = 100 kΩ	80	100		dB
		V_{OUT} = 0.1 V to 4.9 V, R_{LOAD} = 100 kΩ, T_A = −40°C to 125°C	70			dB
V_{CMR}	Common-mode Input Voltage Range		(−V_S) − 0.1		(+V_S) + 0.1	V
CMRR	Common Mode Rejection Ratio	V_{CM} = 0 V to 2.5 V	70	100		dB
		V_{CM} = 0 V to 2.5 V, T_A = −40°C to 125°C	60			dB
Xtalk	Channel Separation	f = 1 kHz, RL = 2 kΩ		110		dB
Output Characteristics						
	Maximum Output Voltage Swing	R_{LOAD} = 10 kΩ		3	15	mV
		R_{LOAD} = 10 kΩ, T_A = −40°C to 125°C			30	mV
I_{SC}	Output Short-Circuit Current		80	100		mA
		T_A = −40°C to 125°C	50			mA

Parameter		Conditions	Min	Typ	Max	Unit
AC Specifications						
GBW	Gain-Bandwidth Product			6		MHz
SR	Slew Rate	A_V = 1, V_{OUT} = 1.5 V to 3.5 V, C_{LOAD} = 60 pF, R_{LOAD} = 1 kΩ		4.5		V/µs
t_S	Settling Time, 0.1%	AV = 1, 2 V Step, C_{LOAD} = 60 pF, R_{LOAD} = 1 kΩ		0.8		µs
	Settling Time, 0.01%			1		µs
PM	Phase Margin	R_{LOAD} = 1 kΩ, C_{LOAD} = 60 pF		60		°
GM	Gain Margin	R_{LOAD} = 1 kΩ, C_{LOAD} = 60 pF		15		dB
Noise Performance						
E_N	Input Voltage Noise	f = 0.1 Hz to 10 Hz		8		μV_{PP}
e_N	Input Voltage Noise Density	f = 1 kHz		19		nV/√Hz
i_N	Input Current Noise	f = 1 kHz		2		fA/√Hz

Typical Performance Characteristics

All test condition: V_S = 5 V, V_{CM} = 2.5 V, RL = Open, unless otherwise noted.

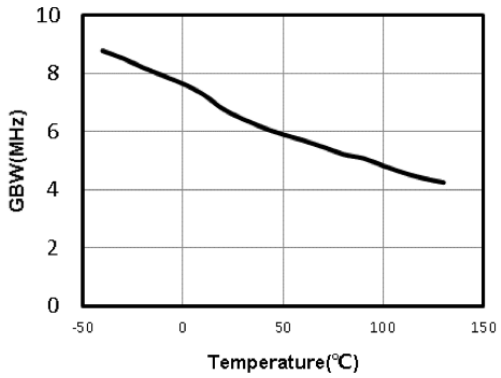


Figure 1. Unity Gain Bandwidth vs. Temperature

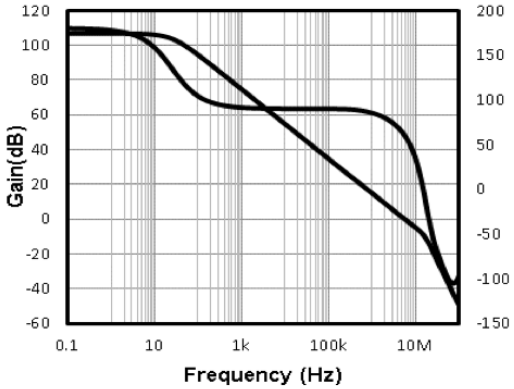


Figure 2. Open-Loop Gain and Phase

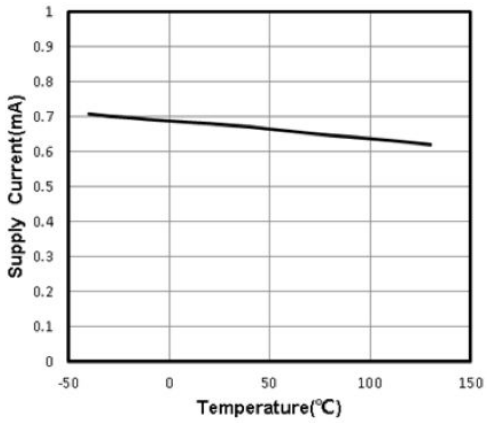


Figure 3. Supply Current vs. Temperature

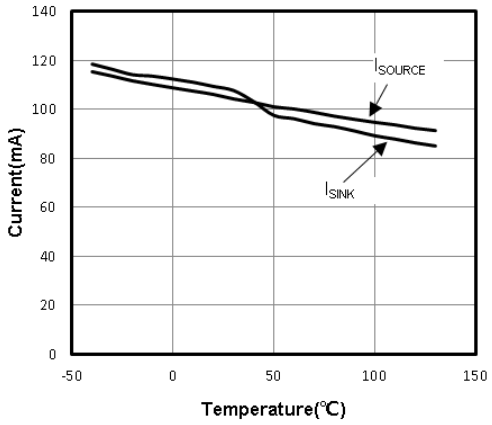


Figure 4. Short Circuit Current vs. Temperature

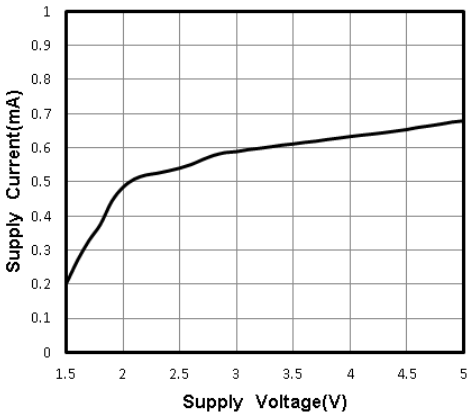


Figure 5. Quiescent Current vs. Supply Voltage

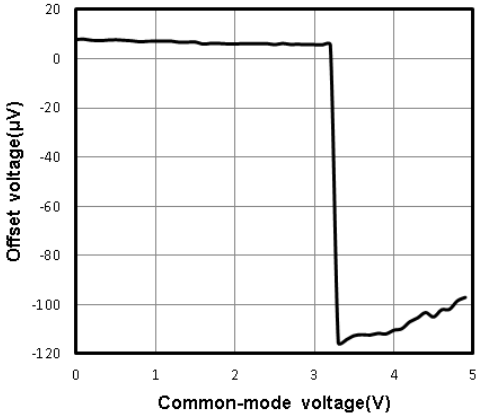


Figure 6. Offset Voltage vs. Common-Mode Voltage

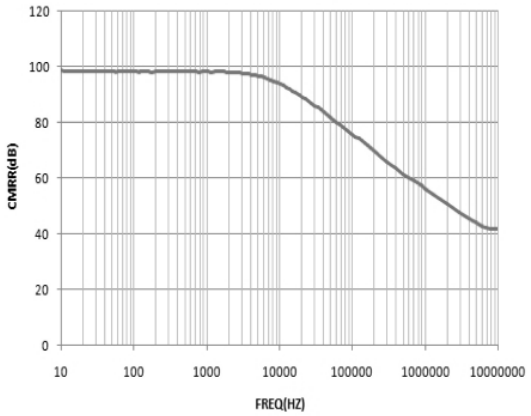


Figure 7. CMRR vs. Frequency

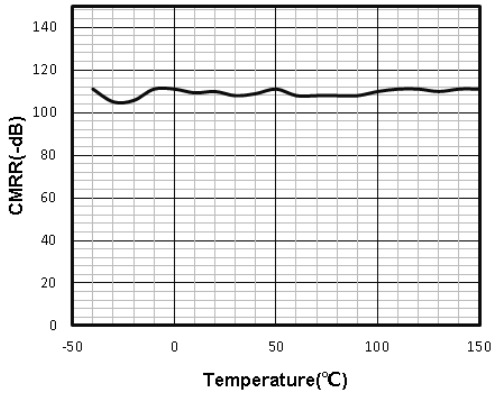


Figure 8. CMRR vs. Temperature

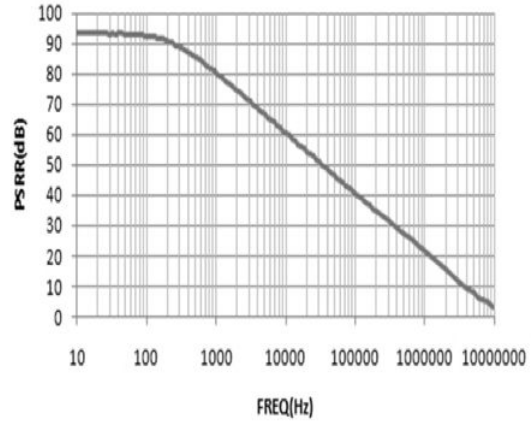


Figure 9. PSRR vs. Frequency

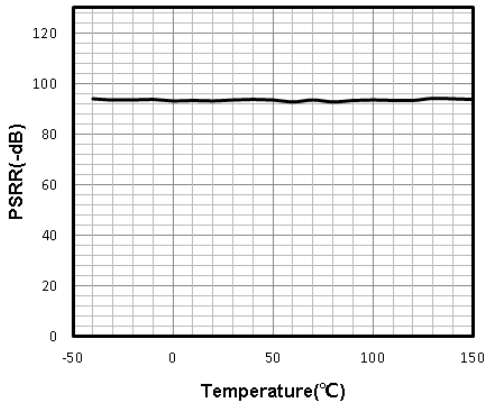


Figure 10. PSRR vs. Temperature

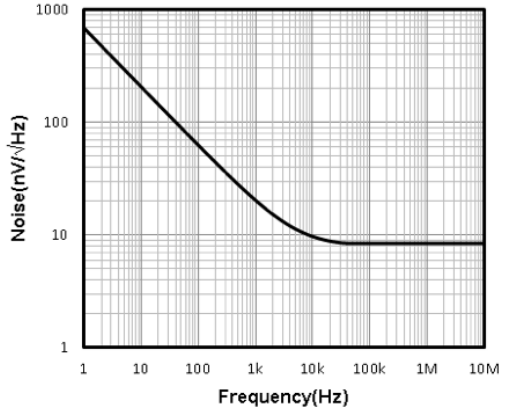


Figure 11. Input Voltage Noise Spectral Density

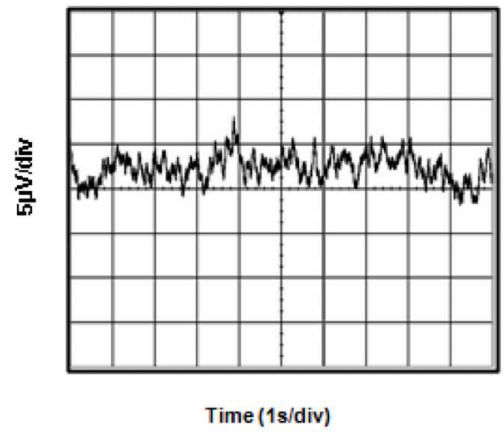


Figure 12. 0.1-Hz to 10-Hz Input Voltage Noise

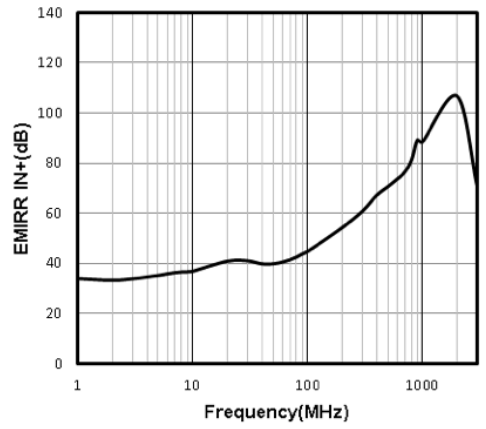


Figure 13. EMIRR IN+ vs. Frequency

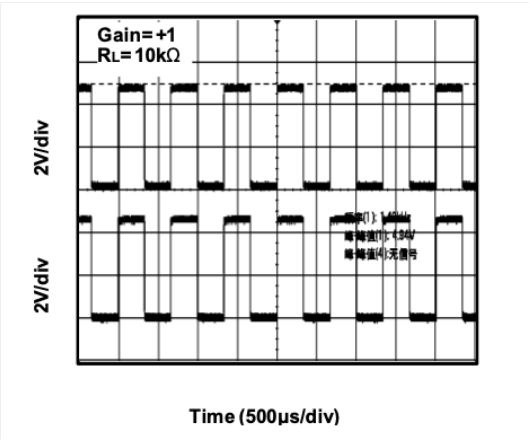


Figure 14. Large-Scale Step Response

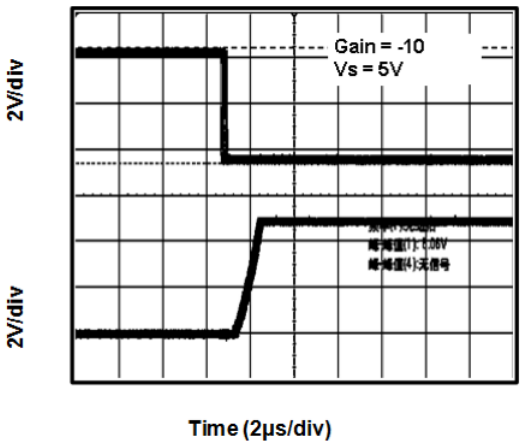


Figure 15. Negative Over-Voltage Recovery

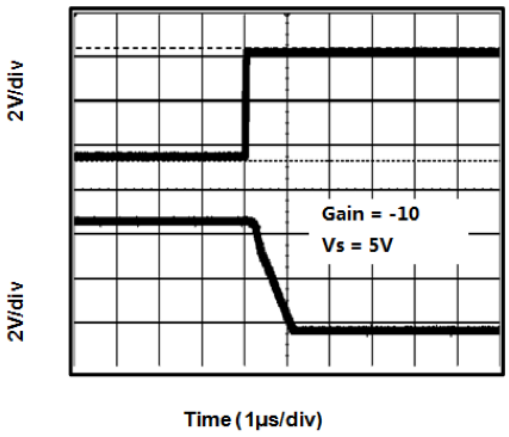


Figure 16. Positive Over-Voltage Recovery

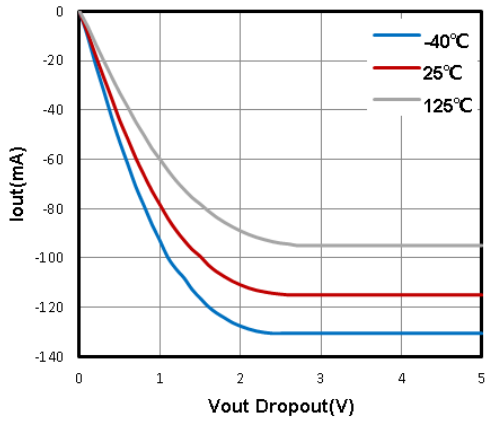


Figure 17. Negative Output Swing vs. Load Current

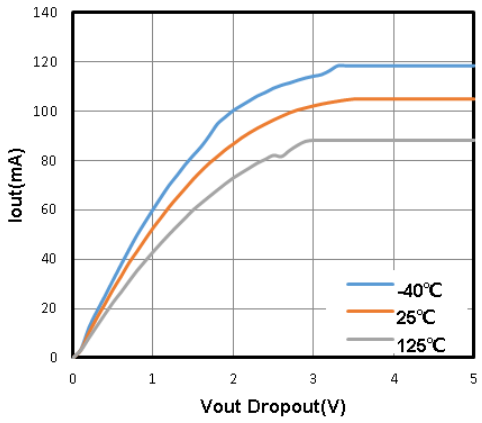


Figure 18. Positive Output Swing vs. Load Current

Detailed Description

Functional Block Diagram

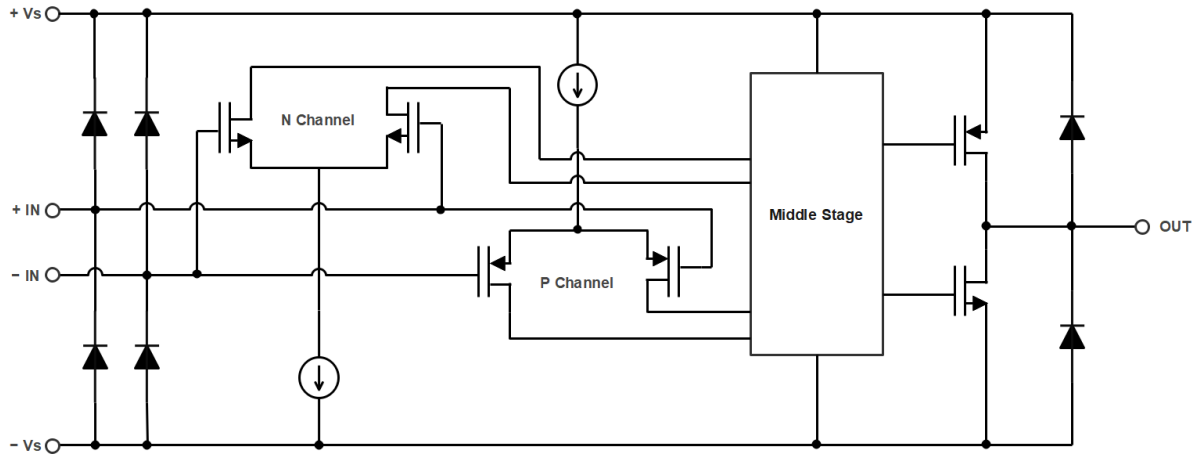


Figure 19. Functional Block Diagram

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 Supply Voltage and Low Power Consumption

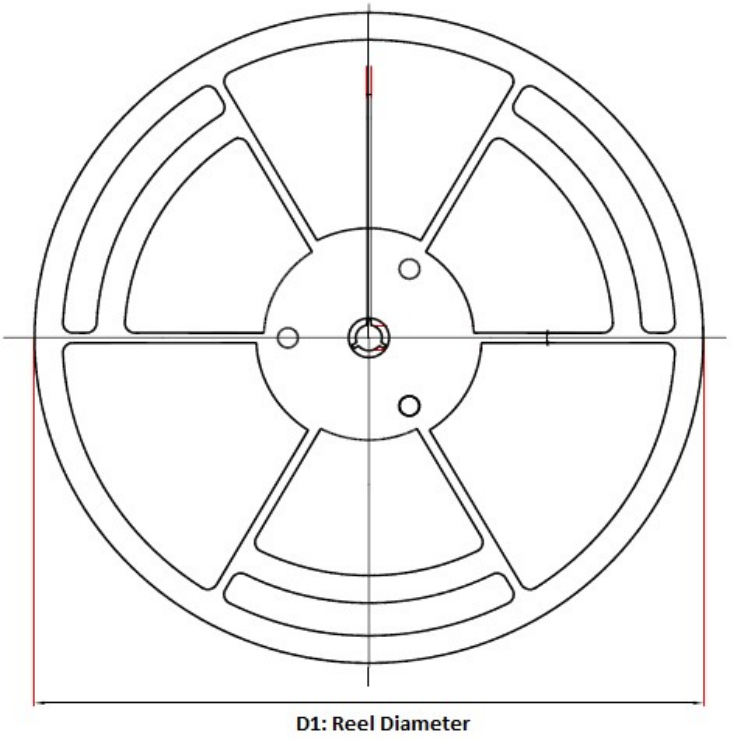
The TP156xAL1 family of operational amplifiers can operate with power supply voltages ranging from 2.7 V to 5.5 V. Each amplifier draws only 600-μA quiescent current. The low-supply voltage capability and low-supply current are ideal for portable applications demanding high capacitive load driving capability and stable wide bandwidth. The TP156xAL1 family is optimized for wide bandwidth and low-power applications. They have an industry leading high GBWP to power ratio and are unity gain stable for any capacitive load. When the load capacitance increases, the increased capacitance at the output pushed the non-dominant pole to lower frequency in the open loop frequency response, lowering the phase and gain margin. Higher gain configurations tend to have better capacitive drive capability than lower gain configurations due to lower closed loop bandwidth and hence higher phase margin.

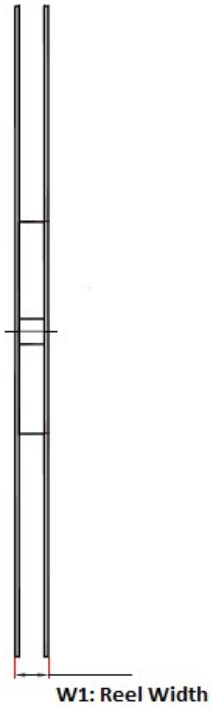
Ground Sensing and Rail-to-Rail Output

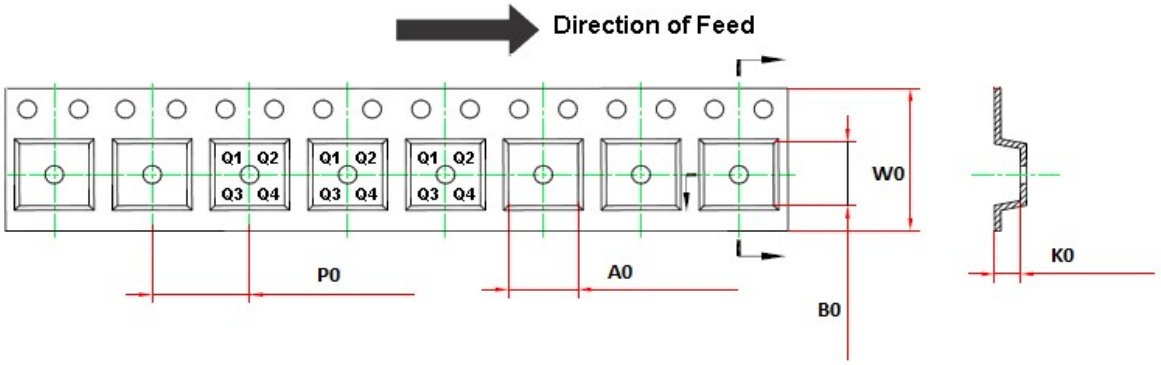
The TP156xAL1 family has excellent output drive capability, delivering over 100 mA of output drive current. The output stage is a rail-to-rail topology that is capable of swinging to within 10 mV of either rail. Since the inputs can go 300 mV beyond either rail, the op-amp can easily perform 'true ground' sensing.

The maximum output current is a function of total supply voltage. As the supply voltage to the amplifier increases, the output current capability also increases. Attention must be paid to keep the junction temperature of the IC below 150°C when the output is in continuous short-circuit. The output of the amplifier has reverse-biased ESD diodes connected to each supply. The output should not be forced more than 0.5 V beyond either supply, otherwise the current will flow through these diodes.

Tape and Reel Information





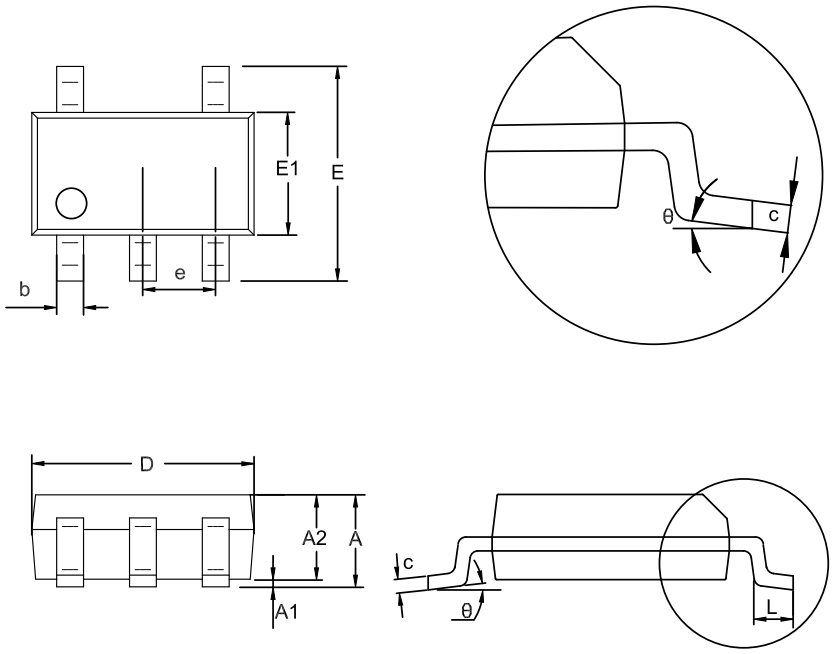


Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TP1561AL1-S5TR-S	SOT23-5	180.0	13.1	3.2	3.2	1.4	4.0	8.0	Q3
TP1562AL1-SO1R-S	SOP8	330.0	17.6	6.4	5.4	2.1	8.0	12.0	Q1
TP1562AL1-VS1R-S	MSOP8	330.0	17.6	5.2	3.3	1.5	8.0	12.0	Q1
TP1564AL1-SO2R-S	SOP14	330.0	21.6	6.5	9.0	2.1	8.0	16.0	Q1

Package Outline Dimensions

SOT23-5

Package Outline Dimensions S5T(SOT23-5-A)



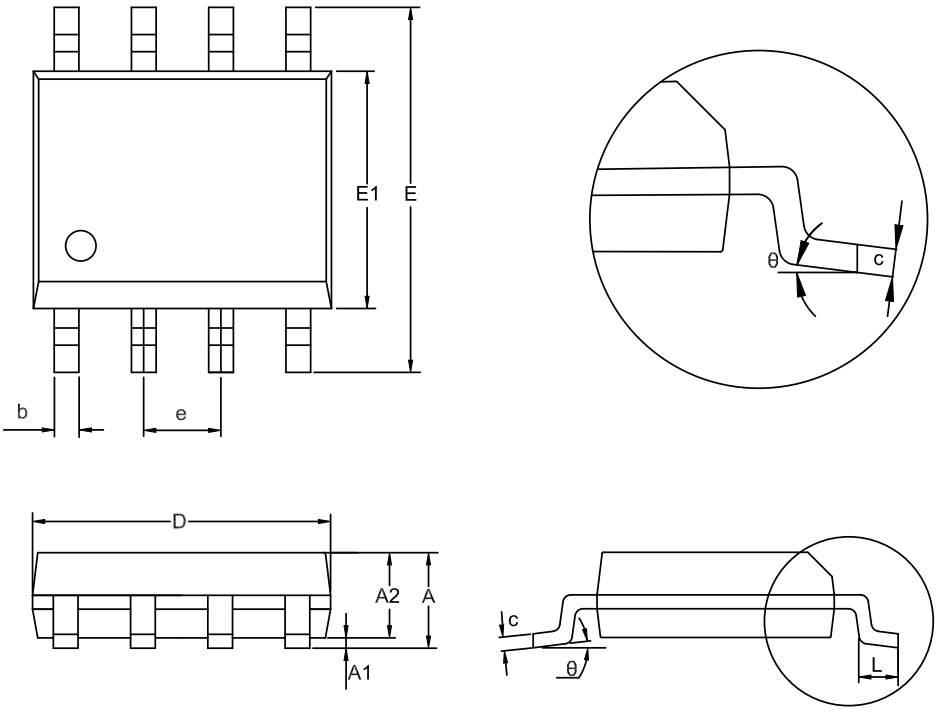
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.150	0.000	0.006
A2	1.000	1.200	0.039	0.047
b	0.280	0.500	0.011	0.020
c	0.100	0.230	0.004	0.009
D	2.820	3.020	0.111	0.119
E	2.600	3.000	0.102	0.118
E1	1.500	1.720	0.059	0.068
e	0.950 BSC		0.037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



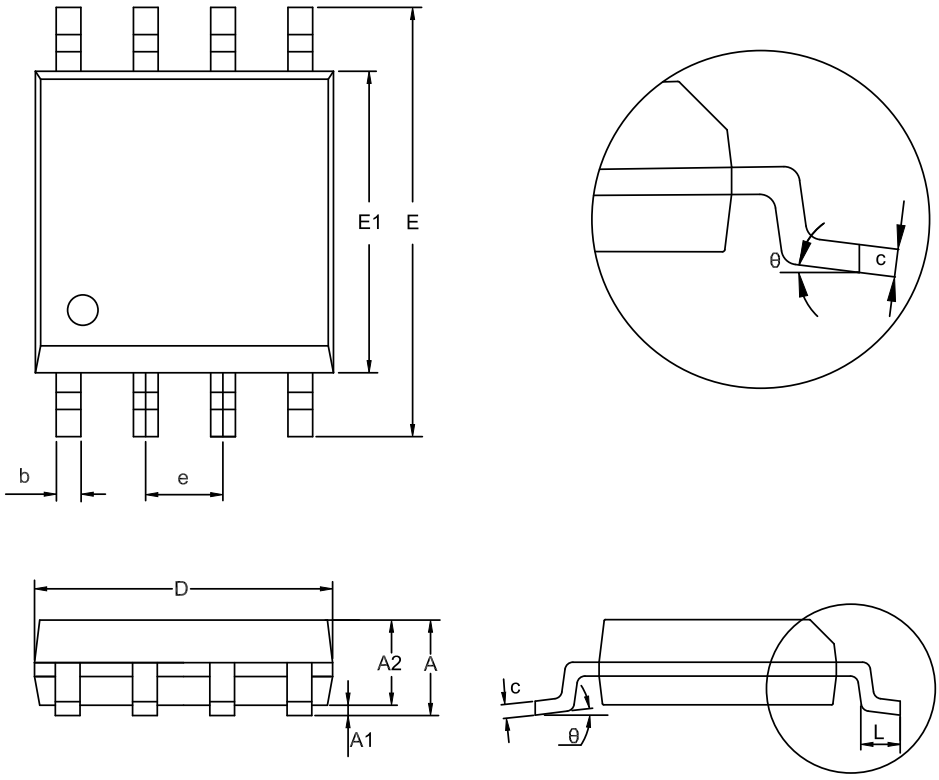
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.050	0.250	0.002	0.010
A2	1.250	1.550	0.049	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.007	0.010
D	4.700	5.100	0.185	0.201
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270 BSC		0.050 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)



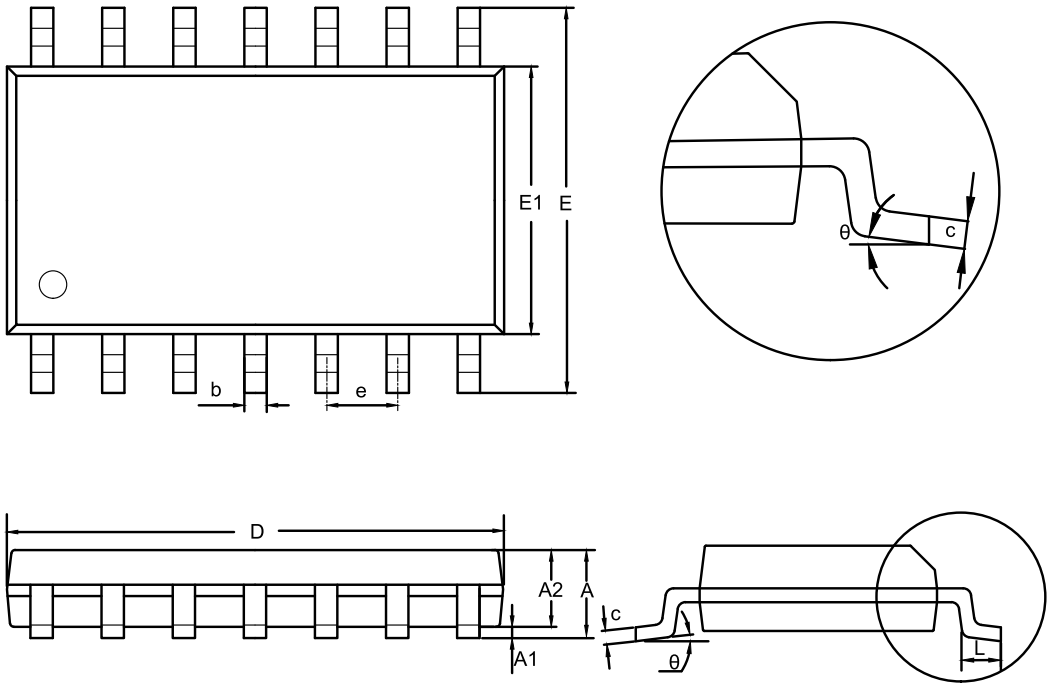
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.800	1.100	0.031	0.043
A1	0.050	0.150	0.002	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
E	4.700	5.100	0.185	0.201
E1	2.900	3.100	0.114	0.122
e	0.650 BSC		0.026 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.

Order Information

Order Number	Operating Temperature Range	Package	Marking Information	MSL	Transport Media, Quantity	Eco Plan
TP1561AL1-S5TR-S	−40 to 125°C	SOT23-5	61S	MSL 3	Tape and Reel, 3000	Green
TP1562AL1-SO1R-S	−40 to 125°C	SOP8	1562S	MSL 1	Tape and Reel, 4000	Green
TP1562AL1-VS1R-S	−40 to 125°C	MSOP8	1562S	MSL 1	Tape and Reel, 3000	Green
TP1564AL1-SO2R-S	−40 to 125°C	SOP14	1564S	MSL 1	Tape and Reel, 2500	Green

(1) For future products, contact the 3PEAK factory for more information and samples.

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