10MHz, Rail-to-Rail I/O CMOS Operational Amplifier

FEATURES

- **Low Offset Voltage: 1mV (TYP)**
- **High Gain: 102dB (TYP)**
- **High Gain Bandwidth Product: 10MHz**
- **Rail-to-Rail Input/Output**
- **Low I_B: 5pA (TYP)**
- **Low Supply Voltage: +2.5V to +5.5V**
- **Low Power Consumption: 1.1mA at 5V (Per Amplifier)**
- **Extended Temperature: -40°C to +125°C**

APPLICATIONS

- **Signal Conditioning**
- **Current Sensor Amplifier**
- **Battery-Powered Applications**
- **Portable Devices**
- **Active Filtering**
- **Weight Scale Sensor**
- **Medical/Industrial Instrumentation**
- **Power Converter/Inverter**

PRODUCT DESCRIPTION

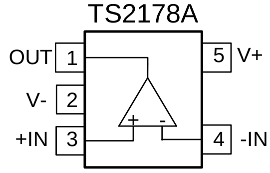
The TS2177A/TS2178A families of products are low noise, low voltage and low power operational amplifiers with high gain-bandwidth product of 10MHz and slew rate of 10V/μs. The maximum input offset voltage is only 3.5mV and the input common mode range extends beyond the supply rails.

TS2177A/TS2178A families of operational amplifiers are specified at the full temperature range of −40°C to +125°C under single or dual power supplies of 2.7V to 5.5V, however these products will operate under an extended supply range from 2.5V to 5.5V at a reduced temperatures range.

The TS2177A and TS2277A have a power-down feature that reduces the supply current to 1μA.

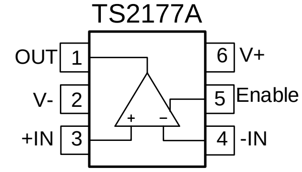
PIN ASSIGNMENTS

TS2178A



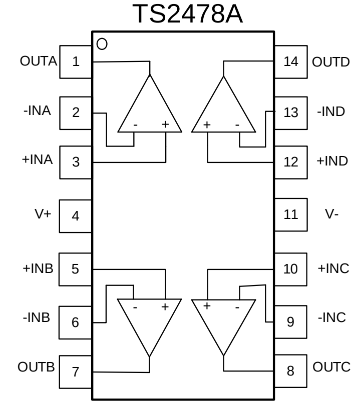
SOT-23-5L

TS2177A



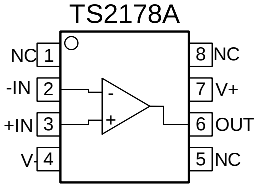
SOT-23-6L

TS2478A



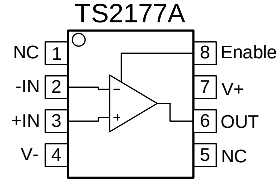
SOP14, TSSOP14

TS2178A



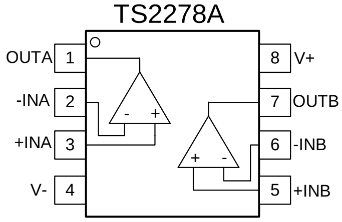
SOP8

TS2177A



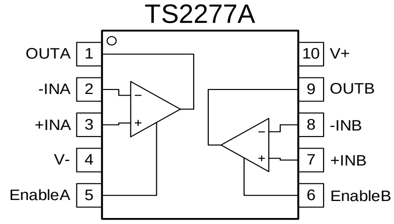
SOP8

TS2278A



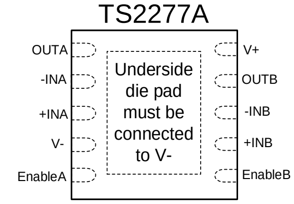
SOP8, MSOP8, TSSOP8

TS2277A



MSOP10

TS2277A



DFNWB3×3-10L

ORDERING INFORMATION

Model	Part Number	Eco Plan	Package	AMP	Shutdown	Container, Pack Qty
TS2178A	TS2178ASOT235LR	RoHS	SOT-23-5L	1	NO	Reel, 3000
TS2178A	TS2178ASOP8R	RoHS	SOP8	1	NO	Reel, 2500
TS2177A	TS2177ASOT236LR	RoHS	SOT-23-6L	1	YES	Reel, 3000
TS2177A	TS2177ASOP8R	RoHS	SOP8	1	YES	Reel, 2500
TS2277A	TS2277ADFNWB3310LR	RoHS	DFNWB3×3-10L	2	YES	Reel, 5000
TS2277A	TS2278AMSOP10R	RoHS	MSOP10	2	YES	Reel, 3000
TS2278A	TS2278ASOP8R	RoHS	SOP8	2	NO	Reel, 2500
TS2278A	TS2278AMSOP8R	RoHS	MSOP8	2	NO	Reel, 3000
TS2278A	TS2278ATSSOP8R	RoHS	TSSOP8	2	NO	Reel, 4000
TS2478A	TS2478ASOP14R	RoHS	SOP14	4	NO	Reel, 2500
TS2478A	TS2478ATSSOP14R	RoHS	TSSOP14	4	NO	Reel, 3000

ABSOLUTE MAXIMUM RATINGS

Over operating free-air temperature range (unless otherwise noted) (1)

Parameter	Min	Max	Unit
Supply Voltage		7	V
Signal Input Terminal voltage	(V-) - 0.5	(V+) + 0.5	V
Operating Temperature	-40	150	°C
Junction Temperature		150	°C
Storage Temperature Range	-65	150	°C
Lead Temperature (Soldering, 10s)		260	°C
ESD HBM		±3000	V
ESD MM		±400	V
ESC CDM		±1000	V

(1) Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ESD CAUTION

ESD (electrostatic discharge) sensitive device.
Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjects to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

ELECTRICAL CHARACTERISTICS: V_S = +2.7V to +5.5V

Boldface limits apply over the specified temperature range, **T_A = −40°C to +125°C.**

At T_A = +25°C, V_S =5V, R_L = 10kΩ connected to V_S / 2, and V_{OUT} = V_S / 2 (unless otherwise noted)

Parameter		Operating Conditions	Min	Typ	Max	Unit
V_S	Power Supply Voltage		2.7		5.5	V
$V_{IN +/-}$	Input Voltage Range		(V-) - 0.2		(V+) + 0.2	V
	Differential Input Voltage Range	V_{IN+} - V_{IN-}	$-V_S$		$+V_S$	V
I_S	Supply Current (Per Amplifer)	I_O = 0		1.1	1.65	mA
P_D	Power Dissipation (Per Amplifer)	I_O = 0, P_D = V_S * I_S		5.5		mW
PSRR	Power Supply Rejection Ratio	V_S = 2.7V to 5.5V, V_{CM} < (V+) - 2V		30	125	μV/V
		T_A = −40°C to +125°C			**150**	**μV/V**
Input Characteristics						
V_{OS}	Input Offset Voltage	V_S = 5.5V		1	3.5	mV
dV_{OS}/dT	**Average Drift**			**3**		**μV/°C**
I_B	Input Bias Current			1		pA
I_{OS}	Input Offset Current			1		pA
R_{IN}	Differential Input Impedance			10^{13}||3		Ω||pF
	Common-mode Input Impedance			10^{13}||3		Ω||pF
CMRR	Common Mode Rejection Ratio	V_S = 5.5V, (V-) - 0.2V < V_{CM} < (V+) - 2V	76	90		dB
		T_A = −40°C to +125°C	**68**			**dB**
		V_S = 5.5V, (V−) − 0.2V < V_{CM} < (V+) + 0.2V	62	78		dB
		T_A = −40°C to +125°C	**60**			**dB**
AOL	Open-Loop Gain	Vs = 5V, R_L = 5kΩ (V-) + 0.125V < Vout < (V+) - 0.125V	96	102		dB
		T_A = −40°C to +125°C	**84**			**dB**
		Vs = 5V, R_L = 100kΩ (V-) + 25mV < Vout < (V+) - 25mV	93	98		dB
		T_A = −40°C to +125°C	**77**			**dB**
Output Characteristics						
V_{OUT}	Output Voltage Swing from Rail	R_L = 100kΩ		18	25	mV
		T_A = −40°C to +125°C			**25**	**mV**
		R_L = 5kΩ		100	125	mV
		T_A = −40°C to +125°C			**125**	**mV**
I_{OUT}	Output Current	See Typical Characteristics				
R_{OUT}	Open-Loop Output Impedance	f = 1MHz, I_O = 0mA		40		Ω
Dynamic Performance						
GBW	Gain Bandwidth Product			10		MHz
SR	Slew Rate	G = +1		10		V/μs
t_S	Settling Time to 0.1%	V_{OUT} = 2V step, G = +1		1		μs
	Settling Time to 0.01%	V_{OUT} = 2V step, G = +1		1.5		μs
	Overload Recovery Time	Vin * Gain > V_S		0.2		μs
THD+N	Total Harmonic Distortion+ Noise	V_S = 5V, Vo = 3Vpp, G = +1, f = 1kHz		TBD		%

ELECTRICAL CHARACTERISTICS: V_S = +2.7V to +5.5V (CONTINUE)

Boldface limits apply over the specified temperature range, **T_A = −40°C to +125°C.**

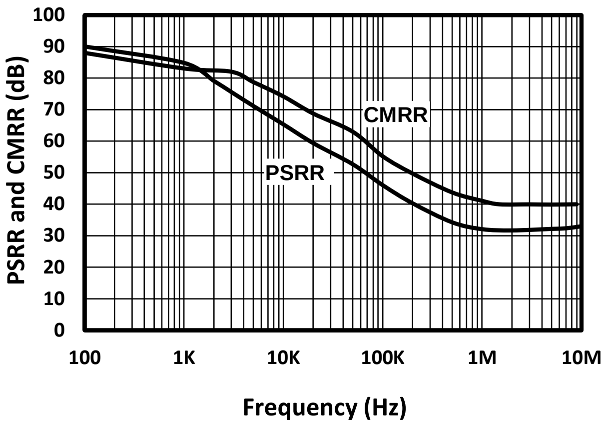
At T_A = +25°C, R_L = 10kΩ connected to V_S / 2, and V_{OUT} = V_S / 2 (unless otherwise noted)

Parameter		Operating Conditions	Min	Type	Max	Unit
Noise Performance						
i_n	Input Current Noise Density	f = 10kHz		4		$fA/\sqrt{Hz}$
e_n	Input Voltage Noise Density	f = 10kHz		15		$nV/\sqrt{Hz}$
V_{noise}	Input Voltage Noise	f = 0.1Hz to 10Hz		6		μVpp
Temperature Range						
	Specified Range		−40		+125	ºC
	Operating Range		-50		+150	ºC
	Storage Range		-65		+150	ºC
	Thermal Resistance					
θ_{JA}	SOT-23-5L, SOT-23-6L, MSOP8			200		ºC/W
	MSOP10, SOP8, TSSOP8			150		ºC/W
	SOP14, TSSOP14			100		ºC/W
	DFNWB3×3-10L			56		ºC/W

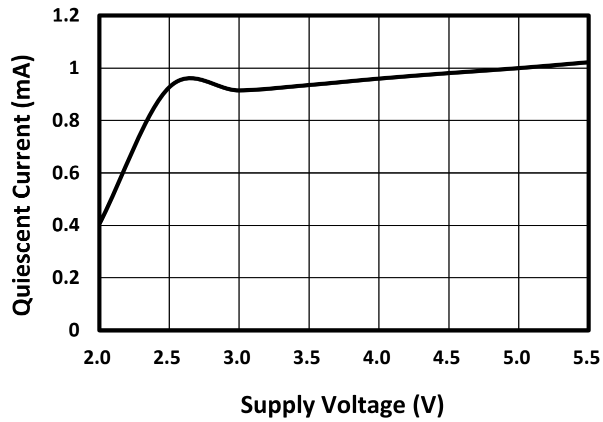
TYPICAL CHARACTERISTICS

At T_A = +25°C, R_L = 10kΩ connected to V_S / 2, and V_{OUT} = V_S / 2 (unless otherwise noted)

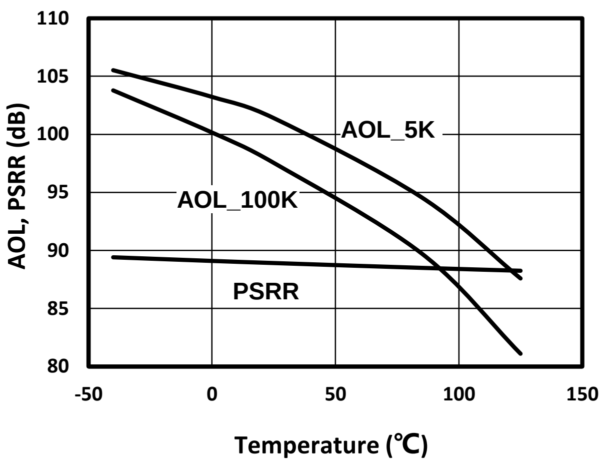
Power–Supply and Common–Mode Rejection Ratio vs Frequency



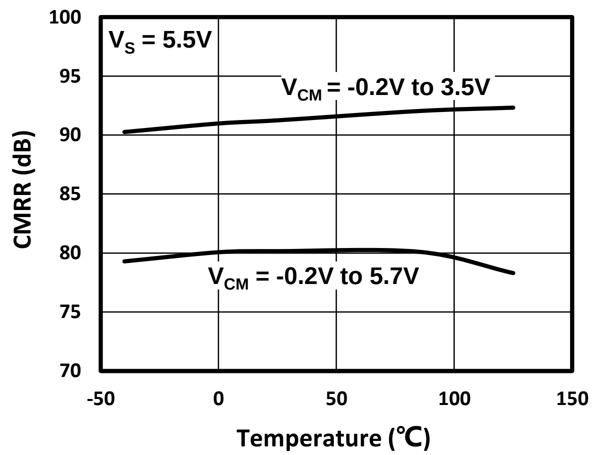
Quiescent Current vs Supply Voltage



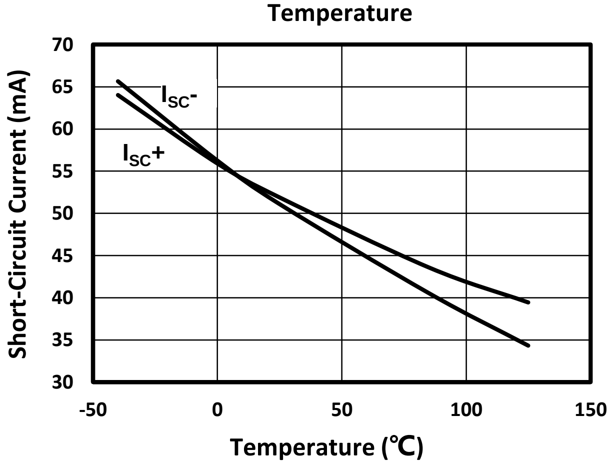
Open-Loop Gain and Power-Supply Rejection Ratio vs Temperature



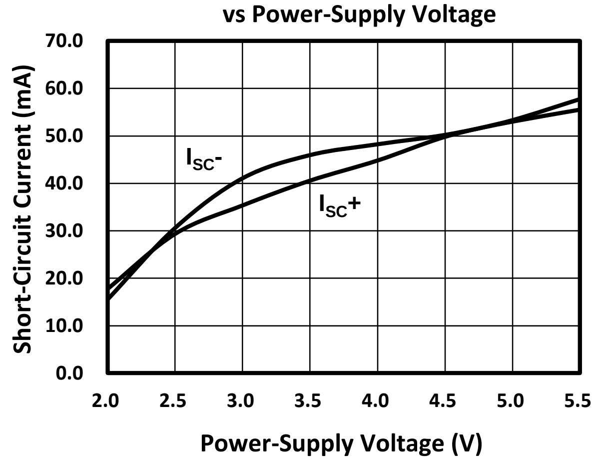
Common-Mode Rejection Ration vs Temperature



Short-Circuit Current vs Temperature



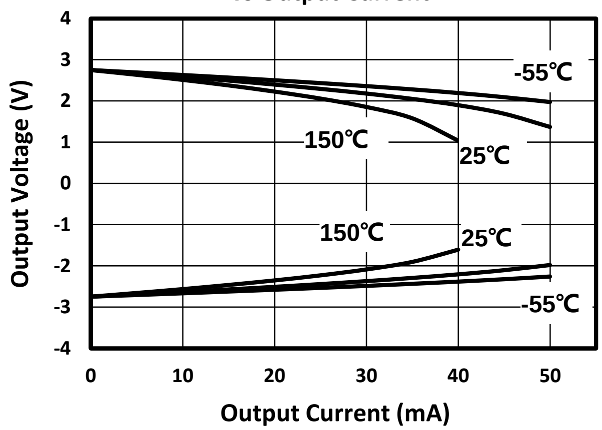
Continuous Short-Circuit Current vs Power-Supply Voltage



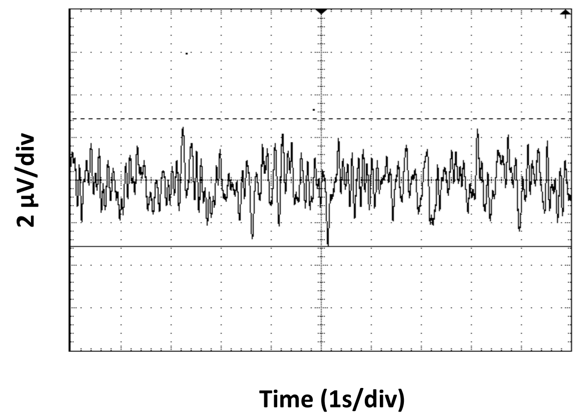
TYPICAL CHARACTERISTICS (CONTINUE)

At T_A = +25°C, R_L = 10kΩ connected to V_S / 2, and V_{OUT} = V_S / 2 (unless otherwise noted)

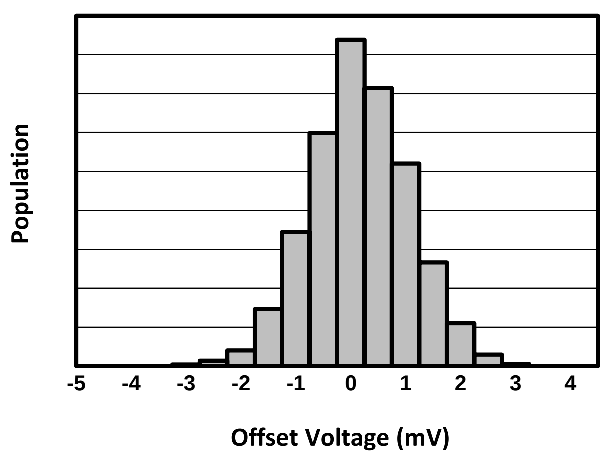
Output Voltage Swing vs Output Current



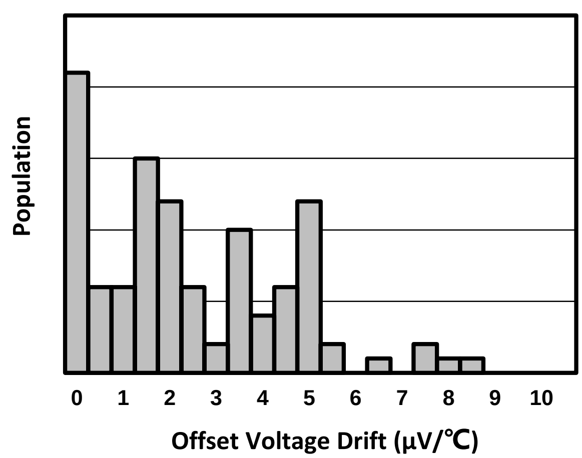
0.1Hz to 10Hz Noise



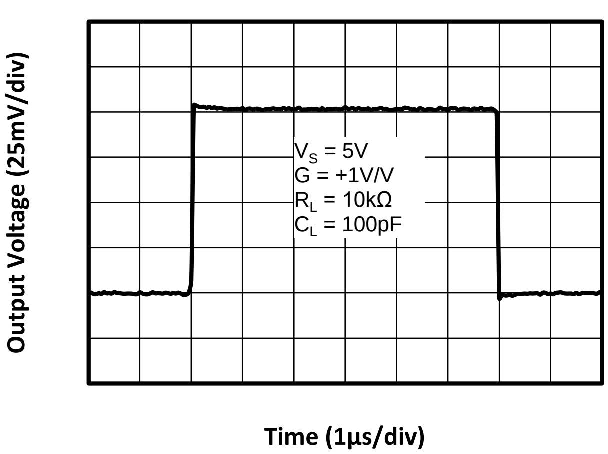
Offset Voltage Production Distribution



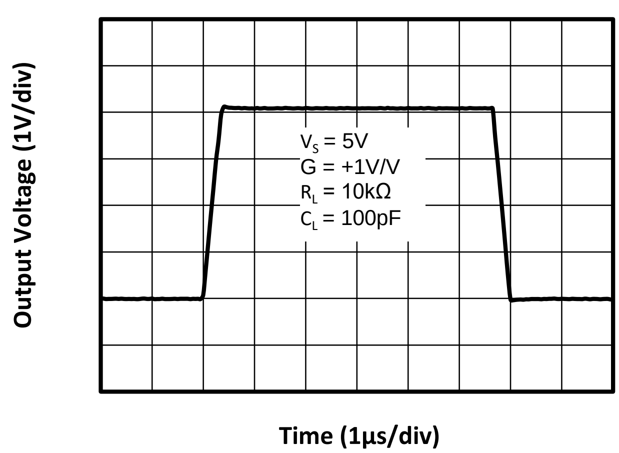
Offset Voltage Drift Magnitude Production Distribution



Small Signal Non-Inverting Pulse Response

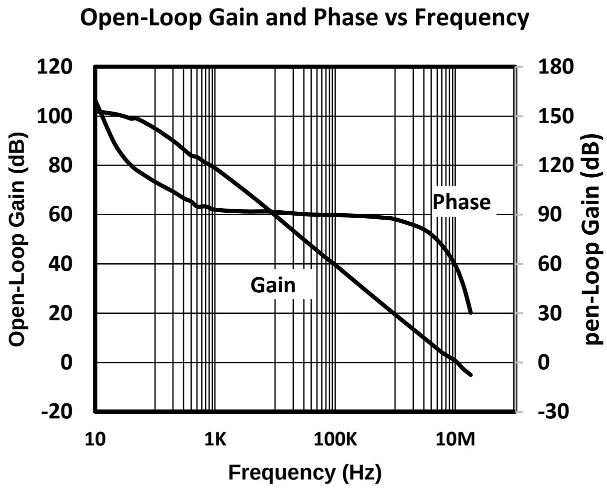


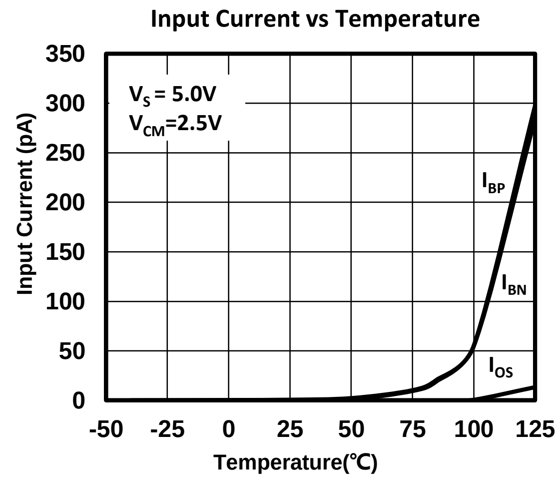
Large Signal Non-Inverting Pulse Response

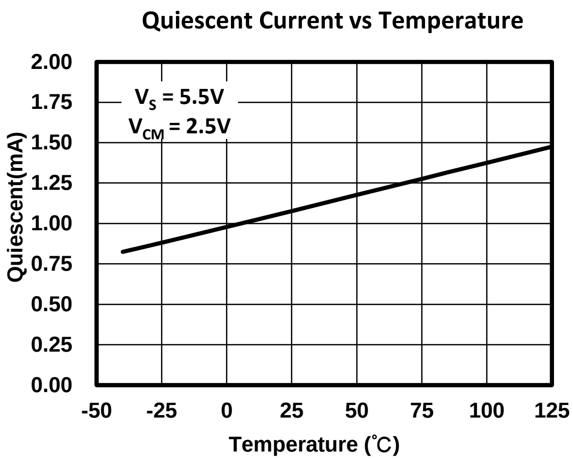


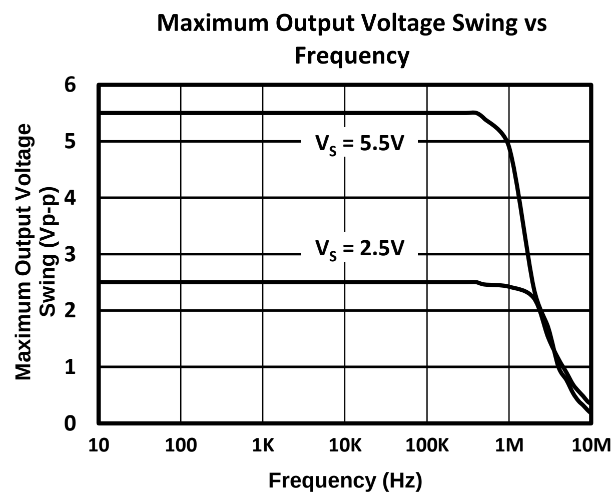
TYPICAL CHARACTERISTICS (CONTINUE)

At T_A = +25°C, R_L = 10kΩ connected to V_S / 2, and V_{OUT} = V_S / 2 (unless otherwise noted)









APPLICATION NOTES

The TS2177A and TS2178A families of op amps are suitable for a wide range of general-purpose applications. They provide Rail-to-rail input and output. Excellent ac performance makes them well-suited for audio and sensor applications. The input common-mode voltage range includes both rails, allowing the TS2177A and TS2178A families op amps to be used in bipolar and unipolar application. Rail-to-rail input and output swing significantly increases dynamic range, especially in low-supply applications. Power-supply pins should be bypassed with 0.1μF ceramic capacitors.

POWER SUPPLY

The TS2177A and TS2178A families operate from a single +2.5V to +5.5V supply or dual ±1.25V to ±2.75V supplies. For single supply operation, bypass the power supply $+V_S$ with a 0.1μF capacitor which should be placed close to the $+V_S$ pin. For dual-supply operation, both the $+V_S$ and the $-V_S$ supplies should be bypassed to ground with separate 0.1μF ceramic capacitors. 2.2μF tantalum capacitor can be added for better performance.

The TS2177A and TS2178A families are ideal for battery-powered instrumentation and handheld devices because it can operate at the end of discharge voltage of most popular batteries.

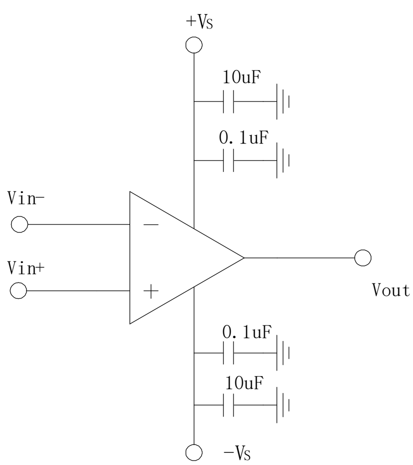


Figure1. Amplifier with Bypass Capacitors

DRIVING CAPACITIVE LOADS

The TS2177A and TS2178A families can directly drive 1000pF in unity-gain without oscillation. The unity-gain follower (buffer) is the most sensitive configuration to capacitive loading. Direct capacitive loading reduces the phase margin of amplifiers and this result in ringing or even oscillation. Applications that require greater capacitive driving capability should use an isolation resistor between the output and the capacitive load like the circuit in Figure2. The isolation resistor R_{ISO} and the load capacitor CL form a zero to increase stability. The bigger the R_{ISO} resistor value, the more stable V_{OUT} will be. Note that this method results in a loss of gain accuracy because R_{ISO} forms a voltage divider with the R_{LOAD}.

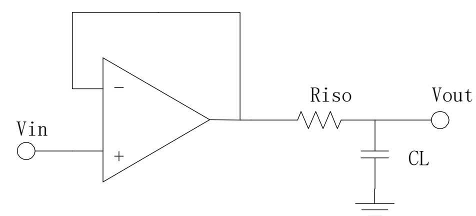


Figure 2. Indirectly Driving Heavy Capacitive Load

An improved circuit is shown in Figure 3. It provides DC accuracy as well as AC stability. Rf provides the DC accuracy by connecting the inverting signal with the output. Cf and R_{ISO} serve to counteract the loss of phase margin by feeding the high frequency component of the output signal back to the amplifier's inverting input, thereby preserving phase margin in the overall feedback loop.

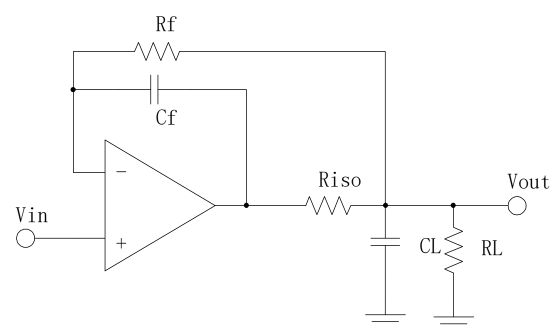


Figure 3. Indirectly Driving Heavy Capacitive Load with DC Accuracy

For non-buffer configuration, there are two other ways to increase the phase margin: (a) by increasing the amplifier's gain or (b) by placing a capacitor in parallel with the feedback resistor to counteract the parasitic capacitance associated with inverting node.

TYPICAL APPLICATIONS

Difference Amplifier

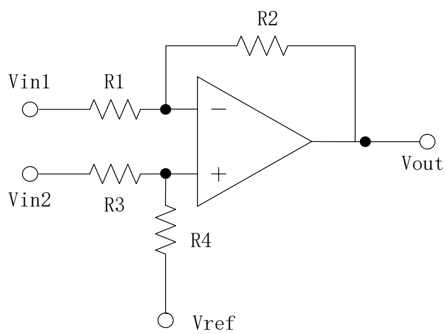


Figure 4. Differential Amplifier

The circuit shown in Figure 4 performs the difference function. If the resistor ratios are equal (R4 / R3 = R2 / R1) then Vout = (Vin2 – Vin1) × R2 / R1 + Vref.

Low Pass Active Filter

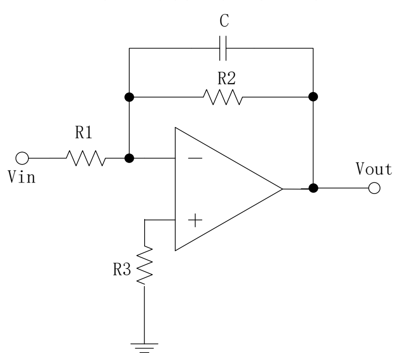


Figure 5. Low Pass Active Filter

The low pass filter shown in Figure 5 has a DC gain of (-R2 / R1) and the –3dB corner frequency is 1/2πR2C. Make sure the filter within the bandwidth of the amplifier. The Large values of feedback resistors can couple with parasitic capacitance and cause undesired effects such as ringing or oscillation in high-speed amplifiers. Keep resistors value as low as possible and consistent with output loading consideration.

Instrumentation Amplifier

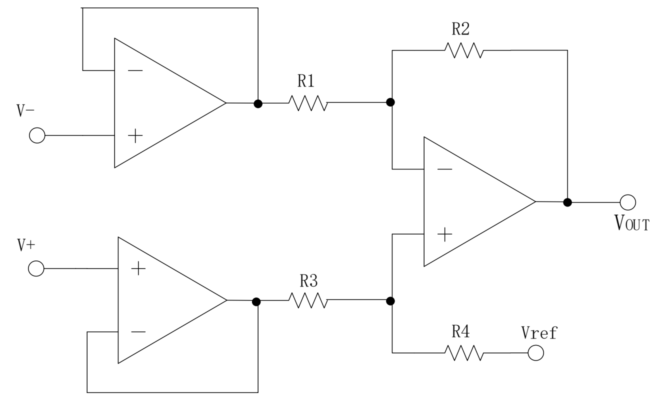
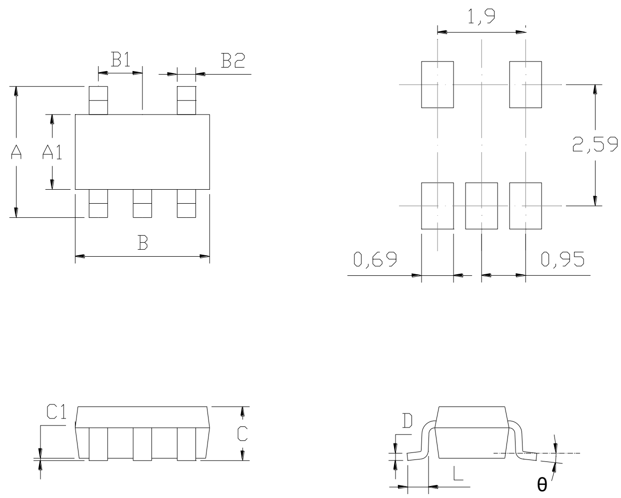


Figure 6. Instrumentation Amplifier

The circuit in Figure 6 performs the same function as that in Figure 4 but with the high input impedance.

MECHANICAL DIMENSIONS

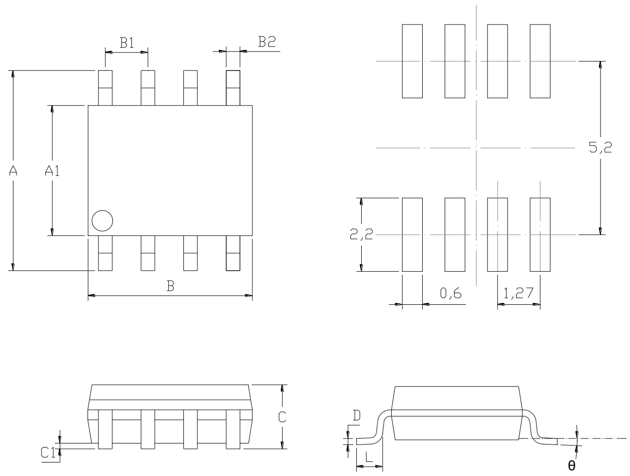
SOT-23-5L PACKAGE MECHANICAL DRAWING



SOT-23-5L PACKAGE MECHANICAL DATA

symbol	dimensions			
	millimeters		inches	
	min	max	min	max
A	2.650	2.950	0.104	0.116
A1	1.500	1.700	0.059	0.067
B	2.820	3.020	0.111	0.119
B1	0.95		0.037	
B2	0.300	0.500	0.012	0.020
C		1.250		0.049
C1	0	0.100	0	0.004
L	0.300	0.600	0.012	0.024
D	0.100	0.200	0.004	0.008
θ	0º	8º	0º	8º

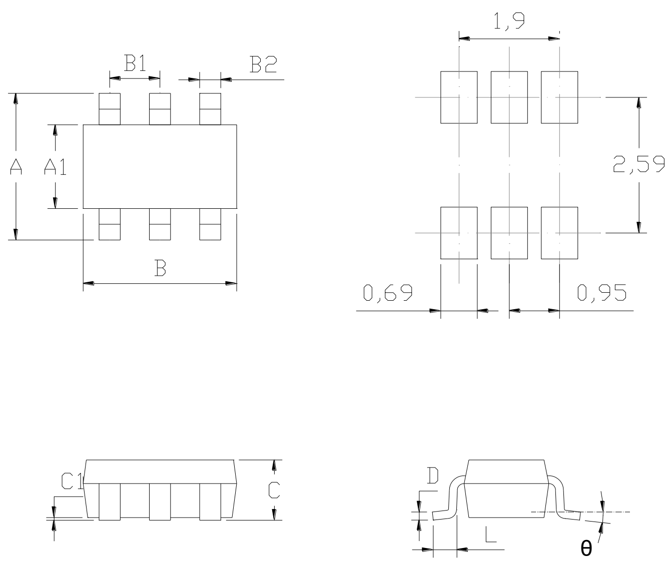
SOP8 PACKAGE MECHANICAL DRAWING



SOP8 PACKAGE MECHANICAL DATA

symbol	dimensions			
	millimeters		inches	
	min	max	min	max
A	5.800	6.200	0.228	0.244
A1	3.800	4.000	0.150	0.157
B	4.700	5.100	0.185	0.201
B1	1.270		0.050	
B2	0.330	0.510	0.013	0.020
C		1.750		0.069
C1	0.100	0.250	0.004	0.010
L	0.400	1.270	0.016	0.050
D	0.170	0.250	0.007	0.010
θ	0º	8º	0º	8º

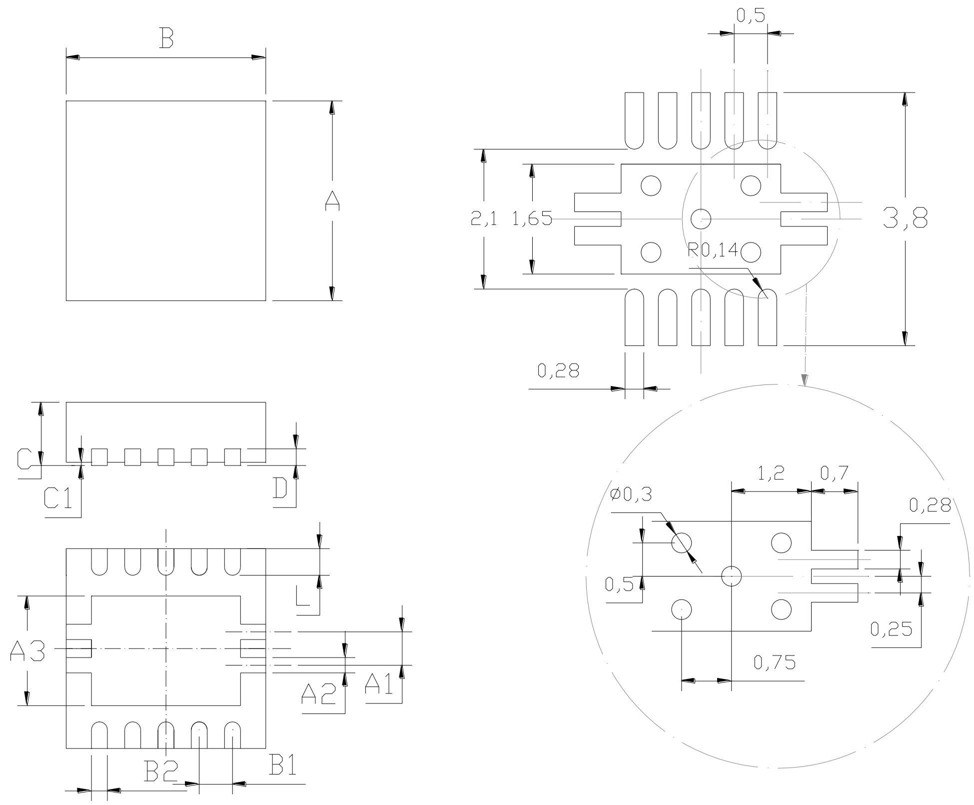
SOT-23-6L PACKAGE MECHANICAL DRAWING



SOT-23-6L PACKAGE MECHANICAL DATA

symbol	dimensions			
	millimeters		inches	
	min	max	min	max
A	2.650	2.950	0.104	0.116
A1	1. 500	1.700	0.059	0.067
B	2.820	3.020	0.111	0.119
B1	0.950		0.037	
B2	0.300	0.500	0.012	0.020
C		1.250		0.049
C1	0	0.100	0	0.004
L	0.300	0.600	0.012	0.024
D	0.100	0.200	0.004	0.008
θ	0º	8º	0º	8º

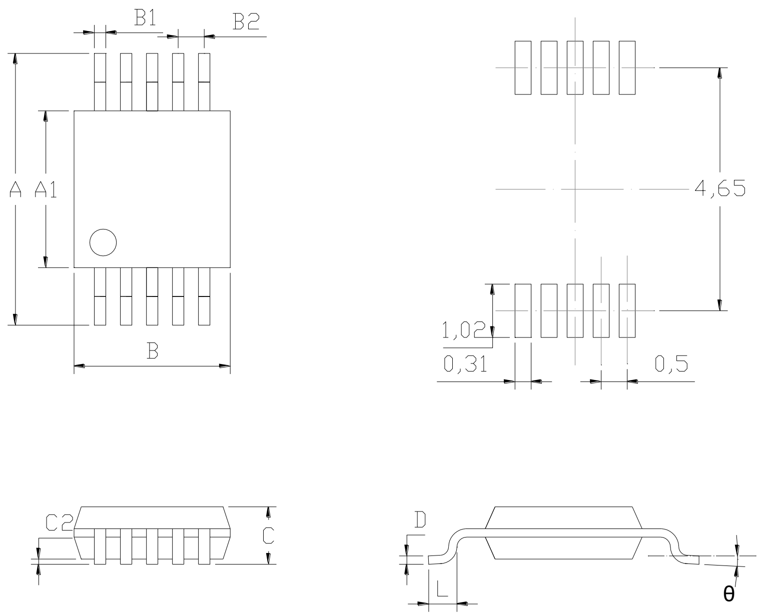
DFNWB3×3-10L PACKAGE MECHANICAL DRAWING



DFNWB3×3-10L PACKAGE MECHANICAL DATA

symbol	dimensions			
	millimeters		inches	
	min	max	min	max
A	2.924	3.076	0.115	0.121
A1	0.500		0.020	
A2	0.200		0.300	
A3	1.550	1.750	0.061	0.069
B	2.924	3.076	0.115	0.121
B1	0.500		0.020	
B2	0.200	0.300	0.008	0.012
C	0.700	0.900	0.028	0.035
C1	0.000	0.050	0.000	0.002
L	0.324	0.476	0.013	0.019
D	0.203		0.008	

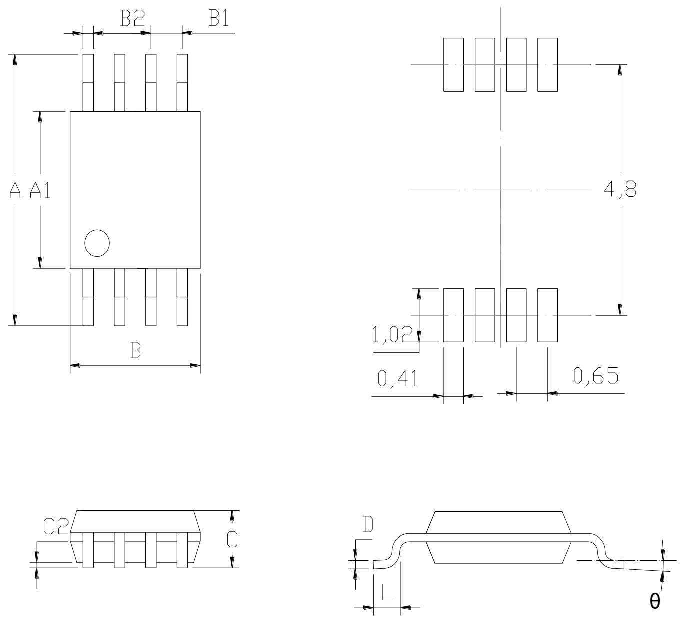
MSOP10 PACKAGE MECHANICAL DRAWING



MSOP10 PACKAGE MECHANICAL DATA

symbol	dimensions			
	millimeters		inches	
	min	max	min	max
A	4.750	5.050	0.187	0.199
A1	2.900	3.100	0.114	0.122
B	2.900	3.100	0.114	0.122
B2	0.500		0.020	
B1	0.180	0.280	0.007	0.011
C		1.100		0.043
C1	0.020	0.150	0.001	0.006
L	0.400	0.800	0.016	0.031
D	0.090	0.230	0.004	0.009
θ	0º	6 º	0º	6 º

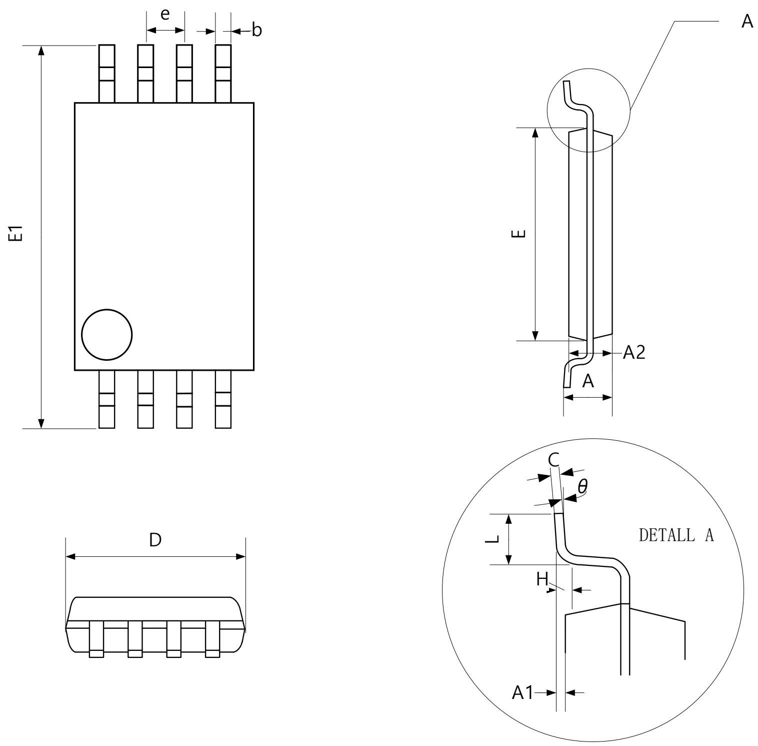
MSOP8 PACKAGE MECHANICAL DRAWING



MSOP8 PACKAGE MECHANICAL DATA

symbol	dimensions			
	millimeters		inches	
	min	max	min	max
A	4.750	5.050	0.187	0.199
A1	2.900	3.100	0.114	0.122
B	2.900	3.100	0.114	0.122
B1	0.650		0.026	
B2	0.250	0.380	0.010	0.015
C	0.820	1.100	0.032	0.043
C2	0.020	0.150	0.001	0.006
L	0.400	0.800	0.016	0.031
D	0.090	0.230	0.004	0.009
θ	0º	6 º	0º	6 º

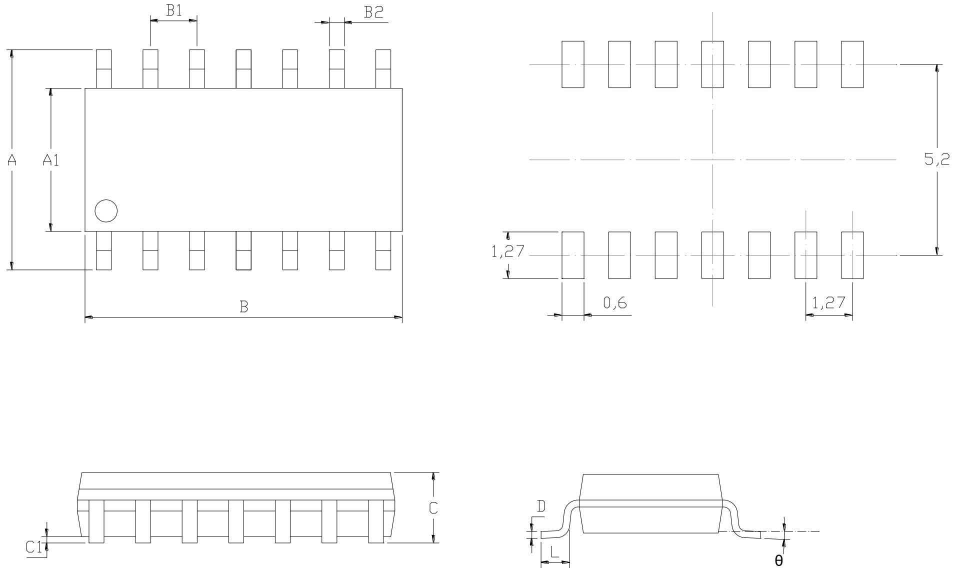
TSSOP8 PACKAGE MECHANICAL DRAWING



TSSOP8 PACKAGE MECHANICAL DATA

symbol	dimensions			
	millimeters		inches	
	min	max	min	max
D	2.900	3.100	0.114	0.122
E	4.300	4.500	0.169	0.177
b	0.190	0.300	0.007	0.012
c	0.090	0.200	0.004	0.008
E1	6.250	6.550	0.246	0.258
A		1.200		0.047
A2	0.800	1.000	0.031	0.039
A1	0.050	0.150	0.002	0.006
e	0.650		0.026	
L	0.500	0.700	0.020	0.028
H	0.250		0.010	
θ	1º	7º	1º	7º

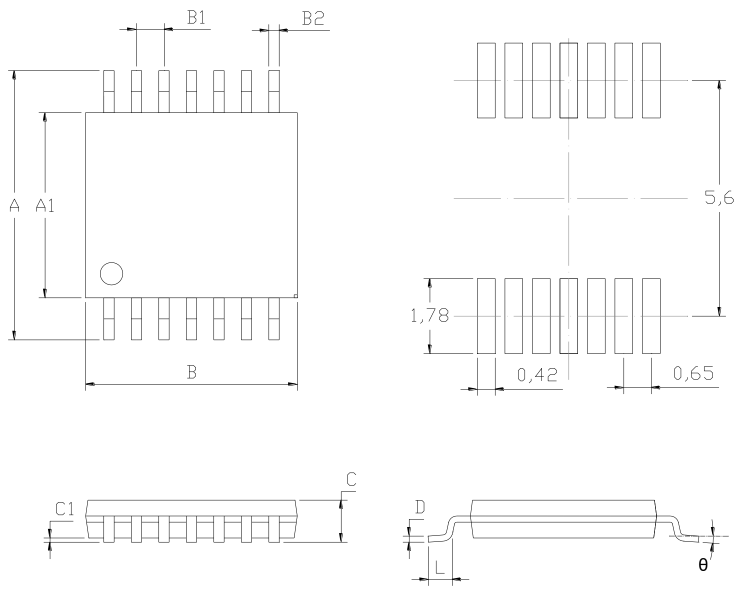
SOP14 PACKAGE MECHANICAL DRAWING



SOP14 PACKAGE MECHANICAL DATA

symbol	dimensions			
	millimeters		inches	
	min	max	min	max
A	5.800	6.200	0.228	0.244
A1	3.800	4.000	0.150	0.157
B	8.450	8.850	0.333	0.348
B1	1.270		0.050	
B2	0.310	0.510	0.012	0.020
C		1.750		0.069
C1	0.100	0.250	0.004	0.010
L	0.400	1.270	0.016	0.050
D	0.100	0.250	0.004	0. 010
θ	0º	8º	0º	8º

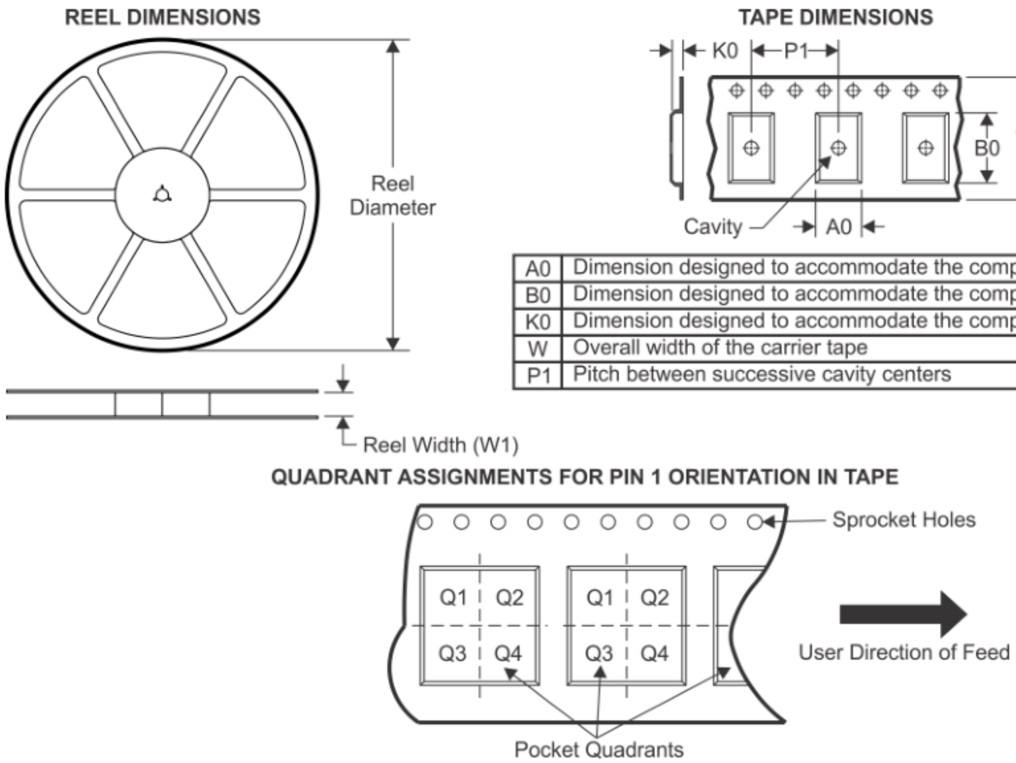
TSSOP14 PACKAGE MECHANICAL DRAWING



TSSOP14 PACKAGE MECHANICAL DATA

symbol	dimensions			
	millimeters		inches	
	min	max	min	max
A	6.250	6.550	0.246	0.258
A1	4.300	4.500	0.169	0.177
B	4.900	5.100	0.193	0.201
B1	0.650		0.026	
B2	0.190	0.300	0.007	0.012
C		1.200		0.047
C1	0.050	0.150	0.002	0.006
L	0.500	0.700	0.020	0.028
D	0.090	0.200	0.004	0.008
θ	1º	7º	1º	7º

TAPE AND REEL INFORMATION



Device	Package Type	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TS2178ASOT235LR	SOT-23-5L	5	3000	180.0	9.0	3.2	3.3	1.4	4.0	8.0	Q3
TS2178ASOP8R	SOP8	8	2500	330.0	12.4	6.4	5.4	2.1	8.0	12.0	Q1
TS2177ASOT236LR	SOT-23-6L	6	3000	180.0	9.0	3.2	3.3	1.4	4.0	8.0	Q3
TS2177ASOP8R	SOP8	8	2500	330.0	12.4	6.4	5.4	2.1	8.0	12.0	Q1
TS2277ADFNWB3310LR	DFNWB3×3-10L	10	5000	330.0	12.4	6.4	5.4	2.1	8.0	12.0	Q1
TS2277AMSOP10R	MSOP10	10	3000	330.0	12.4	5.2	3.3	1.5	8.0	12.0	Q1
TS2278ASOP8R	SOP8	8	2500	330.0	12.4	6.4	5.4	2.1	8.0	12.0	Q1
TS2278AMSOP8R	MSOP8	8	3000	330.0	12.4	5.2	3.3	1.5	8.0	12.0	Q1
TS2278ATSSOP8R	TSSOP8	8	4000	330.0	12.4	6.4	5.4	2.1	8.0	12.0	Q1
TS2478ASOP14R	SOP14	14	2500	330.0	12.4	6.5	9.0	2.1	8.0	16.0	Q1
TS2478ATSSOP14R	TSSOP14	14	3000	330.0	12.4	6.8	5.4	1.2	8.0	12.0	Q1

REVISION HISTORY

NOTE: Page numbers for previous revisions may be different from that of the current version.

2020/7/9 — REV KY1.0.1A to REV KY1.0.2A

Added notice to ABSOLUTE MAXIMUM RATINGS……………………………………………………………2
Updated the format of ELECTRICAL CHARACTERISTICS …………………………………………………3

2020/11/19 — REV KY1.0.2A to REV KY1.1.2A

Updated AOL and V_{OS} ……………………………………………………………………………………3

2021/07/07 — REV KY1.1.2A to REV KY1.2.2A

Updated the data of ELECTRICAL CHARACTERISTICS ………………………………………………3

2021/07/13 — REV KY1.2.2A to REV KY1.3.2A

Updated MSOP10 and TSSOP14 SPQ……………………………………………………………………..2,18

2022/10/21 — REV KY1.3.2A to REV KY1.4.2A

Add input bias current vs temperature……………………………………………………………………..7

CONTACT INFORMATION

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