

6.5MHz, Rail-to-Rail I/O CMOS Operational Amplifier

FEATURES

- Low Offset Voltage: 1mV (TYP)
- High Gain: 105dB (TYP)
- High Gain Bandwidth Product: 6.5MHz
- Rail-to-Rail Input/Output
- Low I_B : 5pA (TYP)
- Low Supply Voltage: +2.5V to +5.5V
- Low Power Consumption: 580 μ A 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

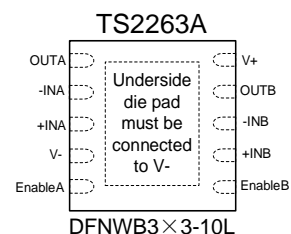
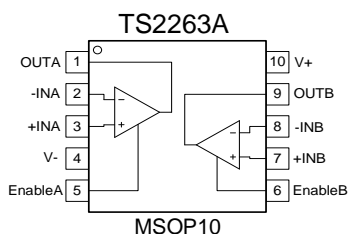
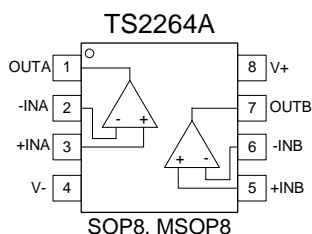
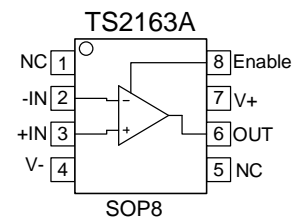
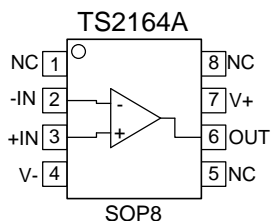
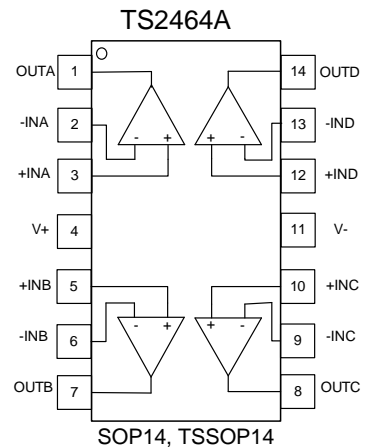
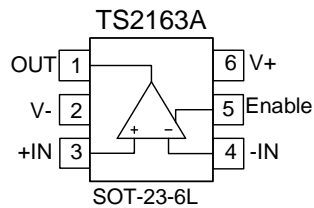
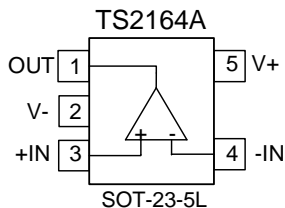
PRODUCT DESCRIPTION

The TS2163A/TS2164A families of products are low noise, low voltage and low power operational amplifiers with high gain-bandwidth product of 6.5MHz and slew rate of 5V/ μ s. The maximum input offset voltage is only 3.5mV and the input common mode range extends beyond the supply rails.

TS2163A/TS2164A 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 TS2163A and TS2263A have a power-down feature that reduces the supply current to 1 μ A.

PIN ASSIGNMENTS



ORDERING INFORMATION

Model	Part Number	Eco Plan	Package	AMP	Shutdown	Container, Pack Qty
TS2164A	TS2164ASOT235LR	RoHS	SOT-23-5L	1	NO	Reel, 3000
TS2164A	TS2164ASOP8R	RoHS	SOP8	1	NO	Reel, 2500
TS2163A	TS2163ASOT236LR	RoHS	SOT-23-6L	1	YES	Reel, 3000
TS2163A	TS2163ASOP8R	RoHS	SOP8	1	YES	Reel, 2500
TS2263A	TS2263AMSOP10R	RoHS	MSOP10	2	YES	Reel, 3000
TS2264A	TS2264ASOP8R	RoHS	SOP8	2	NO	Reel, 2500
TS2264A	TS2264AMSOP8R	RoHS	MSOP8	2	NO	Reel, 3000
TS2464A	TS2464ASOP14R	RoHS	SOP14	4	NO	Reel, 2500
TS2464A	TS2464ATSSOP14R	RoHS	TSSOP14	4	NO	Reel, 3000
TS2263A	TS2263ADFNWB3310LR	RoHS	DFNWB3x3-10L	2	YES	Reel, 5000

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, $T_A = -40^{\circ}C$ to $+125^{\circ}C$.

At $T_A = +25^{\circ}C$, $R_L = 10k\Omega$ 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
I_S	Supply Current (Per Amplifier)	$I_O = 0$			580	750	μA
PSRR	Power Supply Rejection Ratio	$V_S = 2.7V$ to $5.5V$, $V_{CM} < (V+) - 2V$ $T_A = -40^{\circ}C$ to $+125^{\circ}C$			25	125 150	$\mu V/V$ $\mu V/V$
Input Characteristics							
V_{OS}	Input Offset Voltage	$V_S = 5.5V$			1	3.5	mV
dV_{OS}/dT	Average Drift				3		$\mu V/^{\circ}C$
I_B	Input Bias Current				5		pA
I_{OS}	Input Offset Current				5		pA
CMRR	Common Mode Rejection Ratio	$V_S = 5.5V$	$(V-) - 0.2V < V_{CM} < (V+) - 2V$ $T_A = -40^{\circ}C$ to $+125^{\circ}C$	76	88		dB
				68	72		dB
			$(V-) - 0.2V < V_{CM} < (V+) + 0.2V$ $T_A = -40^{\circ}C$ to $+125^{\circ}C$	64			dB
			$T_A = -40^{\circ}C$ to $+125^{\circ}C$	58			dB
AOL	Open-Loop Gain	$V_S = 5V$, $R_L = 5k\Omega$ $(V-) + 0.125V < V_{out} < (V+) - 0.125V$ $T_A = -40^{\circ}C$ to $+125^{\circ}C$		95	104		dB
			$V_S = 5V$, $R_L = 100k\Omega$ $(V-) + 25mV < V_{out} < (V+) - 25mV$ $T_A = -40^{\circ}C$ to $+125^{\circ}C$	96	105		dB
			$T_A = -40^{\circ}C$ to $+125^{\circ}C$	85			dB
			$T_A = -40^{\circ}C$ to $+125^{\circ}C$	85			dB
Output Characteristics							
V_{OUT}	Output Voltage Swing from Rail	$R_L = 100k\Omega$			18	25	mV
		$T_A = -40^{\circ}C$ to $+125^{\circ}C$				25	mV
		$R_L = 5k\Omega$			100	125	mV
		$T_A = -40^{\circ}C$ to $+125^{\circ}C$				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				6.5		MHz
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	$V_{in} * Gain > V_S$			0.2		μs
SR	Slew Rate	$G = +1$			5		V/ μs
THD+N	Total Harmonic Distortion+ Noise	$V_S = 5V$, $V_o = 3V_{pp}$, $G = +1$, $f = 1kHz$			TBD		%

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

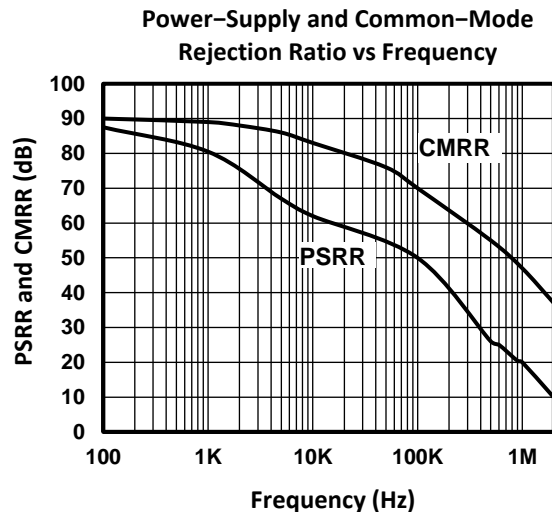
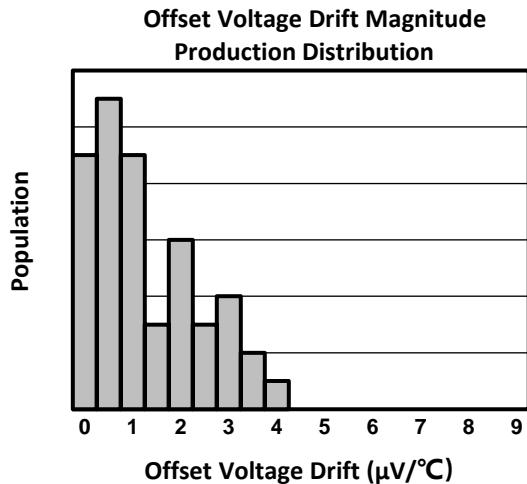
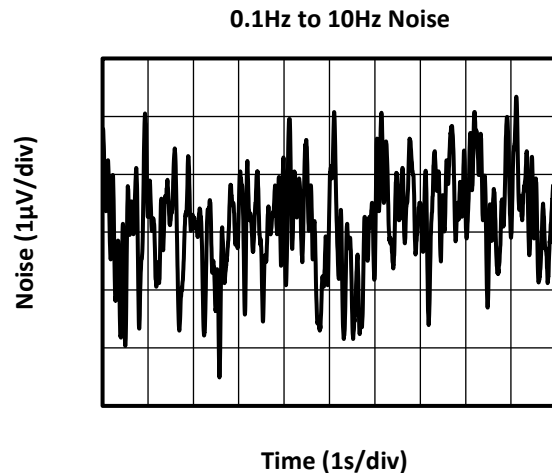
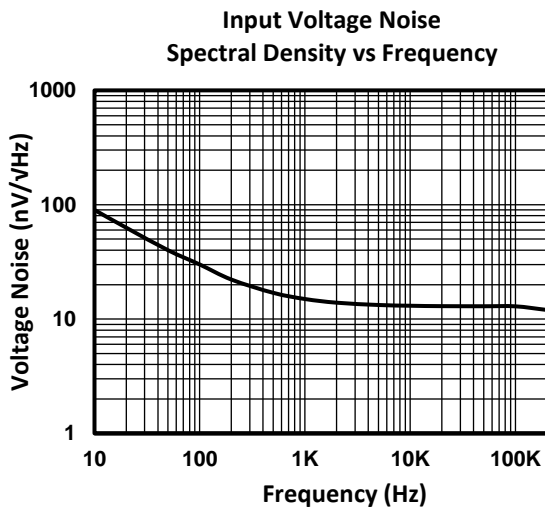
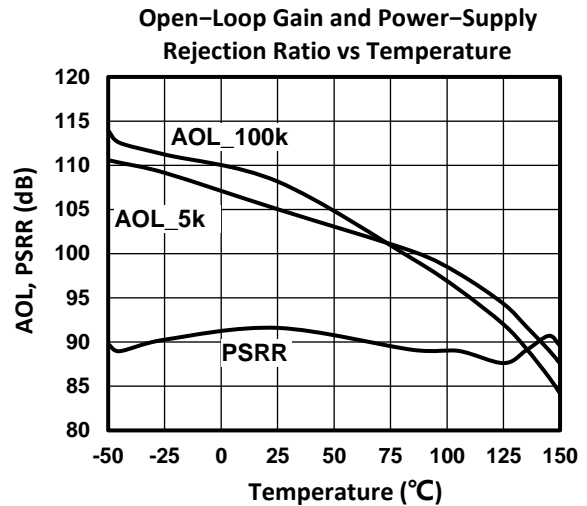
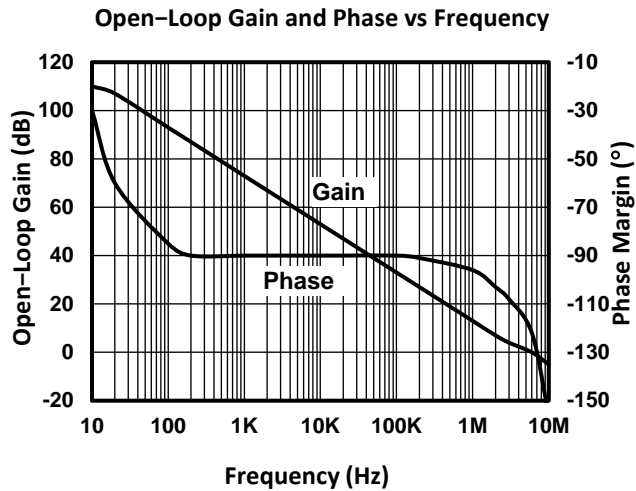
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At $T_A = +25^{\circ}C$, $R_L = 10k\Omega$ connected to $V_S / 2$, and $V_{OUT} = V_S / 2$ (unless otherwise noted)

Parameter	Operating Conditions	Min	Type	Max	Unit
Noise Performance					
V_{noise}	Input Voltage Noise	$f = 0.1Hz$ to $10Hz$		5	μV_{pp}
e_n	Input Voltage Noise Density	$f = 10kHz$		15	nV/\sqrt{Hz}
i_n	Input Current Noise Density	$f = 10kHz$		4	fA/\sqrt{Hz}
Temperature Range					
	Specified Range			-40	+125 $^{\circ}C$
	Operating Range			-50	+150 $^{\circ}C$
	Storage Range			-65	+150 $^{\circ}C$
θ_{JA}	Thermal Resistance				
	SOT-23-5L, SOT-23-6L			200	$^{\circ}C/W$
	MSOP10, SOP8, MSOP8			150	$^{\circ}C/W$
	SOP14, TSSOP14			100	$^{\circ}C/W$
	DFNWB3x3-10L			56	$^{\circ}C/W$

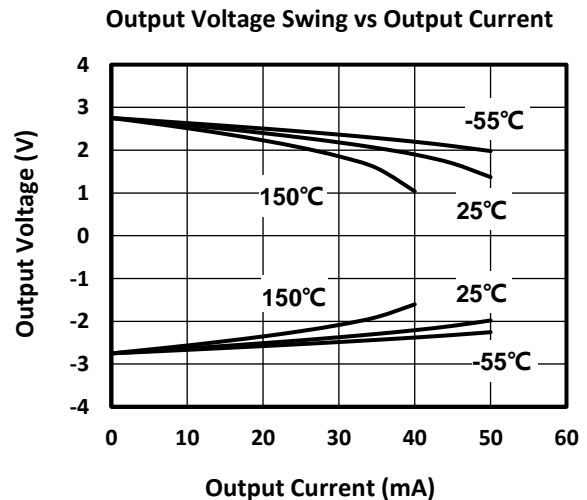
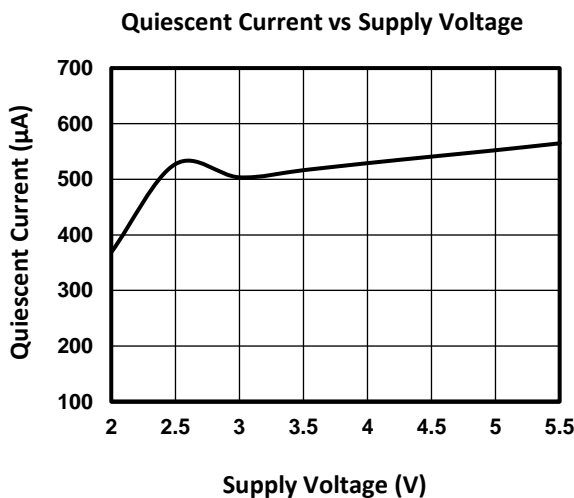
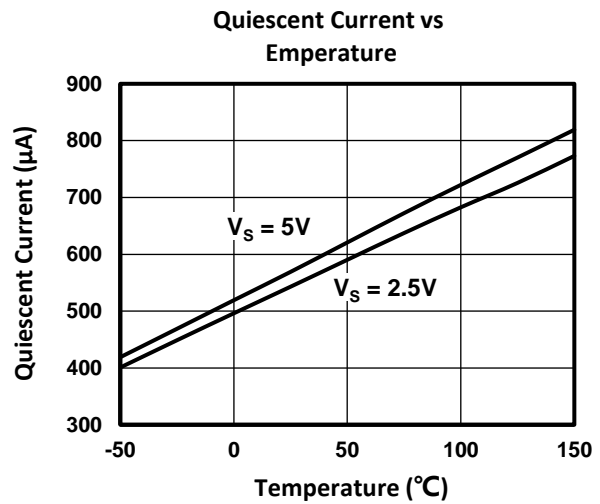
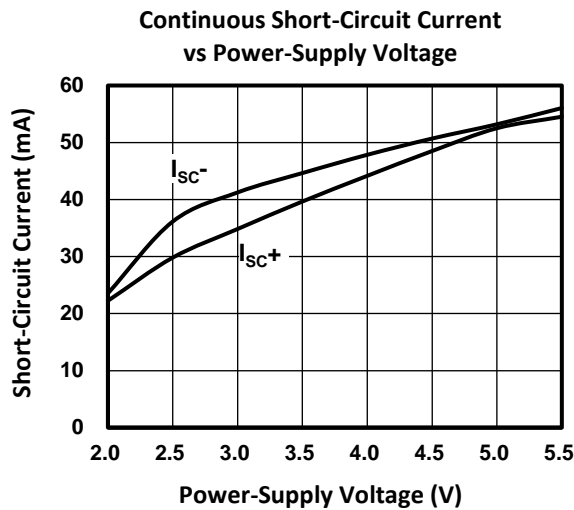
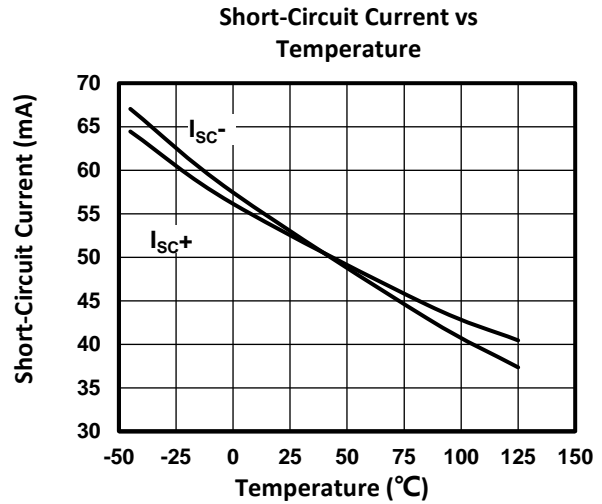
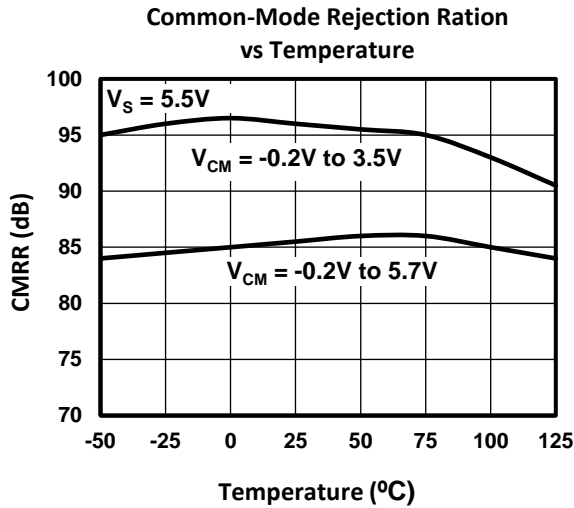
TYPICAL CHARACTERISTICS

At $T_A = +25\text{ }^\circ\text{C}$, $R_L = 10\text{k}\Omega$ connected to $V_S / 2$, and $V_{OUT} = V_S / 2$ (unless otherwise noted)



TYPICAL CHARACTERISTICS (CONTINUE)

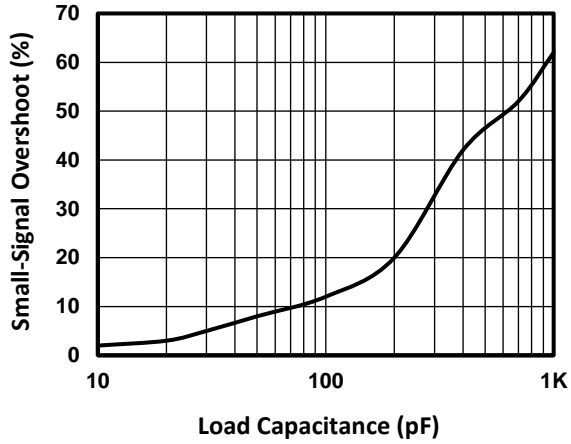
At $T_A = +25^\circ\text{C}$, $R_L = 10\text{k}\Omega$ connected to $V_S / 2$, and $V_{OUT} = V_S / 2$ (unless otherwise noted)



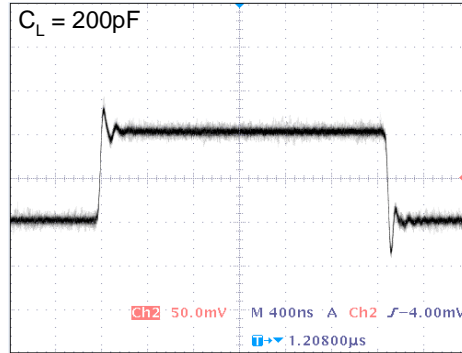
TYPICAL CHARACTERISTICS (CONTINUE)

At $T_A = +25\text{ }^\circ\text{C}$, $R_L = 10\text{ k}\Omega$ connected to $V_S / 2$, and $V_{OUT} = V_S / 2$ (unless otherwise noted)

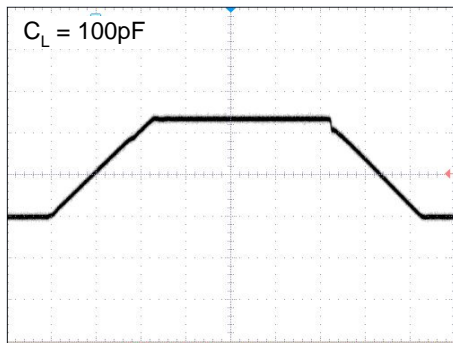
**Small-Signal Overshoot vs
Load Capacitance**



Small-Signal Step Response



Large-Signal Step Response



APPLICATION NOTES

The TS2163A and TS2164A 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 TS2163A and TS2164A 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 0.1 μ F ceramic capacitors.

POWER SUPPLY

The TS2163A and TS2164A families operate from a single +2.5V to +5.5V supply or dual \pm 1.25V to \pm 2.75V supplies. For single supply operation, bypass the power supply +V_S with a 0.1 μ F 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 0.1 μ F ceramic capacitors. 2.2 μ F tantalum capacitor can be added for better performance.

The TS2163A and TS2164A families are ideal for battery-powered instrumentation and handheld devices because it can operate at the end of discharge voltage of most popular batteries.

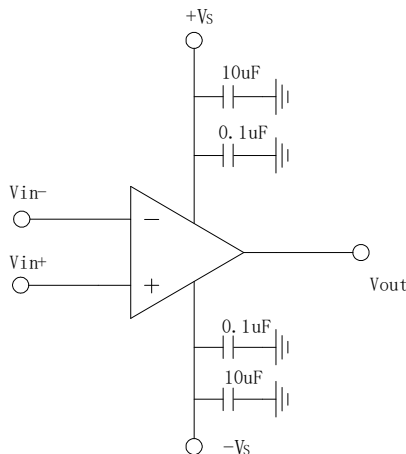


Figure1. Amplifier with Bypass Capacitors

DRIVING CAPACITIVE LOADS

The TS2163A and TS2164A 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}.

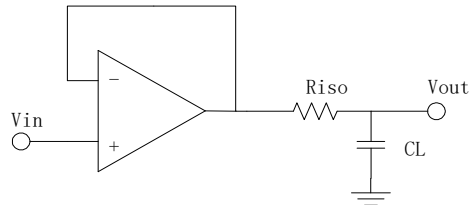


Figure 2. Indirectly Driving Heavy Capacitive Load

An improved circuit is shown in Figure 3. It provides DC accuracy as well as AC stability. R_f provides the DC accuracy by connecting the inverting signal with the output. C_f 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.

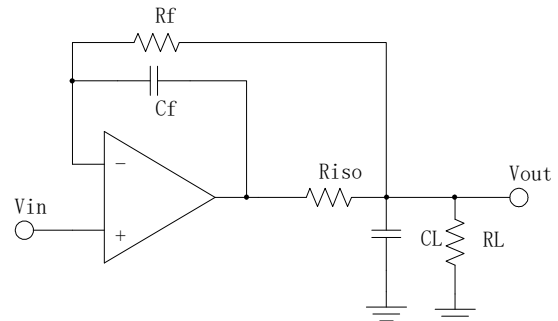


Figure 3. Indirectly Driving Heavy Capacitive Load with DC Accuracy

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 APPLICATION (CONTINUE)

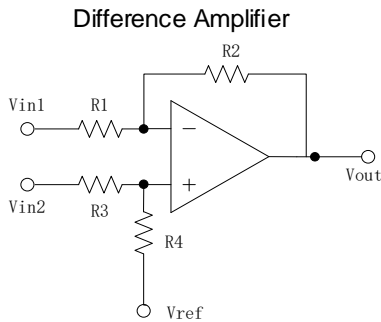


Figure 4. Differential Amplifier

The circuit shown in Figure 4 performs the difference function. If the resistor ratios are equal ($R4 / R3 = R2 / R1$) then $V_{out} = (V_{in2} - V_{in1}) \times R2 / R1 + V_{ref}$.

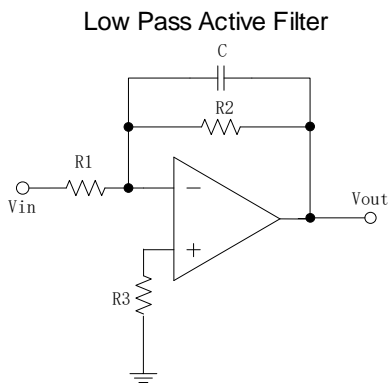


Figure 5. Low Pass Active Filter

The low pass filter shown in Figure 5 has a DC gain of $(-R2 / R1)$ and the -3dB corner frequency is $1/2\pi R2C$. Make sure the filter is 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.

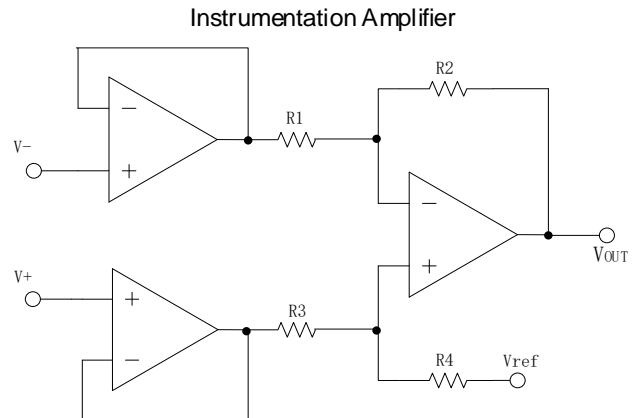
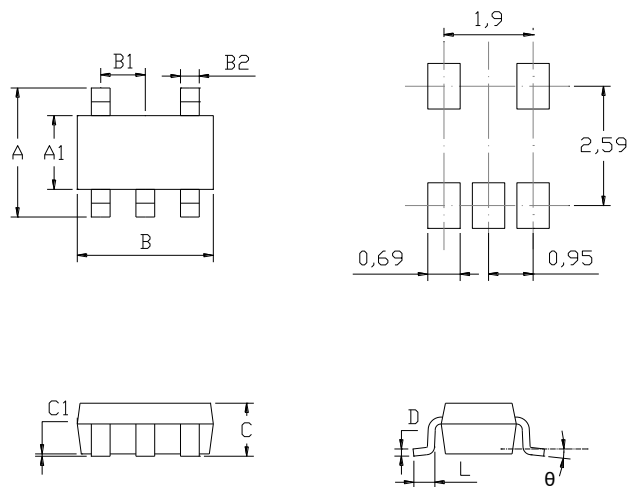


Figure 6. Instrumentation Amplifier

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

MECHANICAL DIMENSIONS

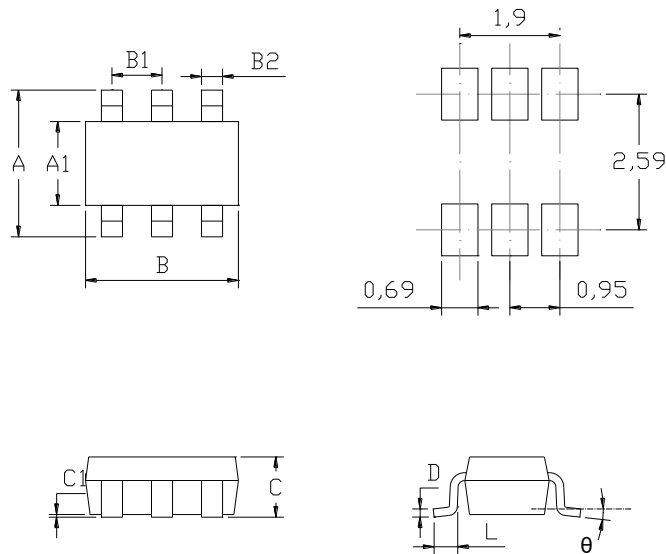
SOT-23-5L PACKAGE MECHANICAL DRAWING



SOT-23-5L PACKAGE MECHANICAL DATA

symbol	dimensions			
	millimeters		inches	
	min	max	min	max
A	2.65	2.95	0.104	0.116
A1	1.50	1.70	0.059	0.067
B	2.82	3.02	0.111	0.119
B1	0.95		0.0374	
B2	0.30	0.50	0.012	0.020
C		1.25		0.049
C1	0.00	0.10	0.0000	0.004
L	0.30	0.60	0.012	0.024
D	0.10	0.20	0.004	0.008
θ	0°	8°	0°	8°

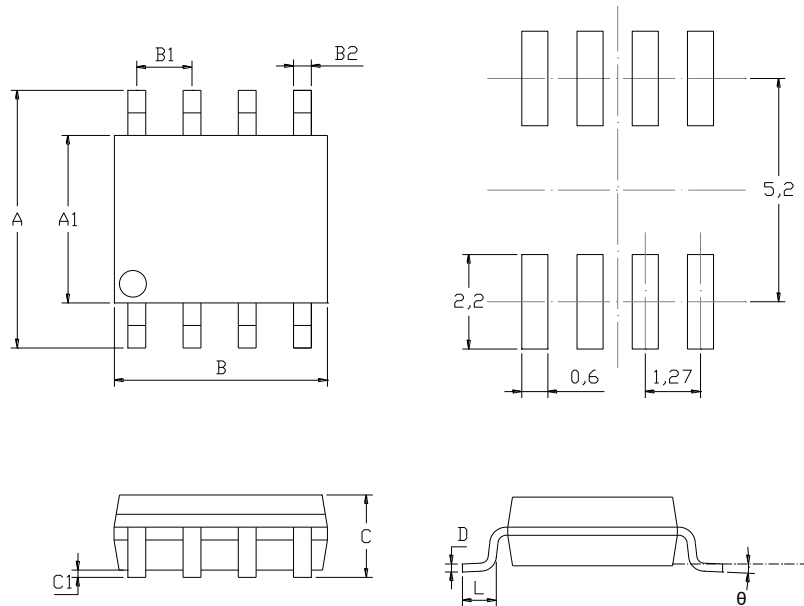
SOT-23-6L PACKAGE MECHANICAL DRAWING



SOT-23-6L PACKAGE MECHANICAL DATA

symbol	dimensions			
	millimeters		inches	
	min	max	min	max
A	2.65	2.95	0.104	0.116
A1	1.50	1.70	0.059	0.067
B	2.82	3.02	0.111	0.119
B1	0.95		0.037	
B2	0.30	0.50	0.012	0.020
C		1.25		0.049
C1	0.00	0.10	0.000	0.004
L	0.30	0.60	0.012	0.024
D	0.10	0.20	0.004	0.008
θ	0°	8°	0°	8°

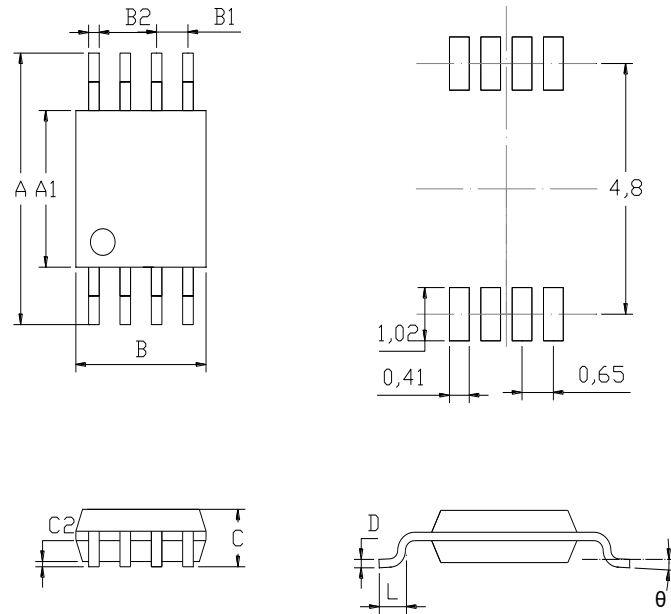
SOP8 PACKAGE MECHANICAL DRAWING



SOP8 PACKAGE MECHANICAL DATA

symbol	dimensions			
	millimeters		inches	
	min	max	min	max
A	5.80	6.20	0.228	0.244
A1	3.80	4.00	0.150	0.157
B	4.70	5.10	0.185	0.201
B1	1.27		0.050	
B2	0.33	0.51	0.013	0.020
C		1.75		0.069
C1	0.10	0.25	0.004	0.010
L	0.40	1.27	0.016	0.050
D	0.17	0.25	0.007	0.010
θ	0°	8°	0°	8°

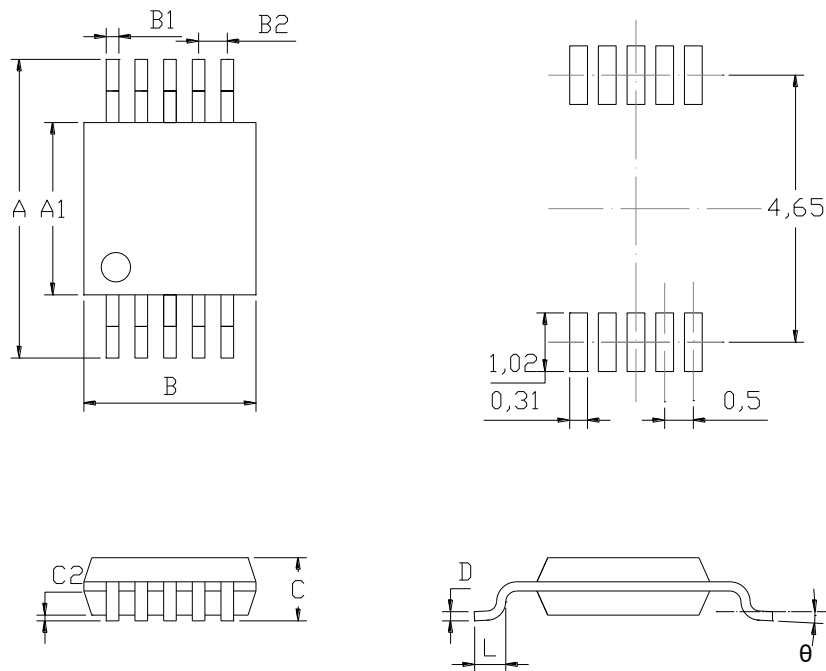
MSOP8 PACKAGE MECHANICAL DRAWING



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	0°	6°	0°	6°

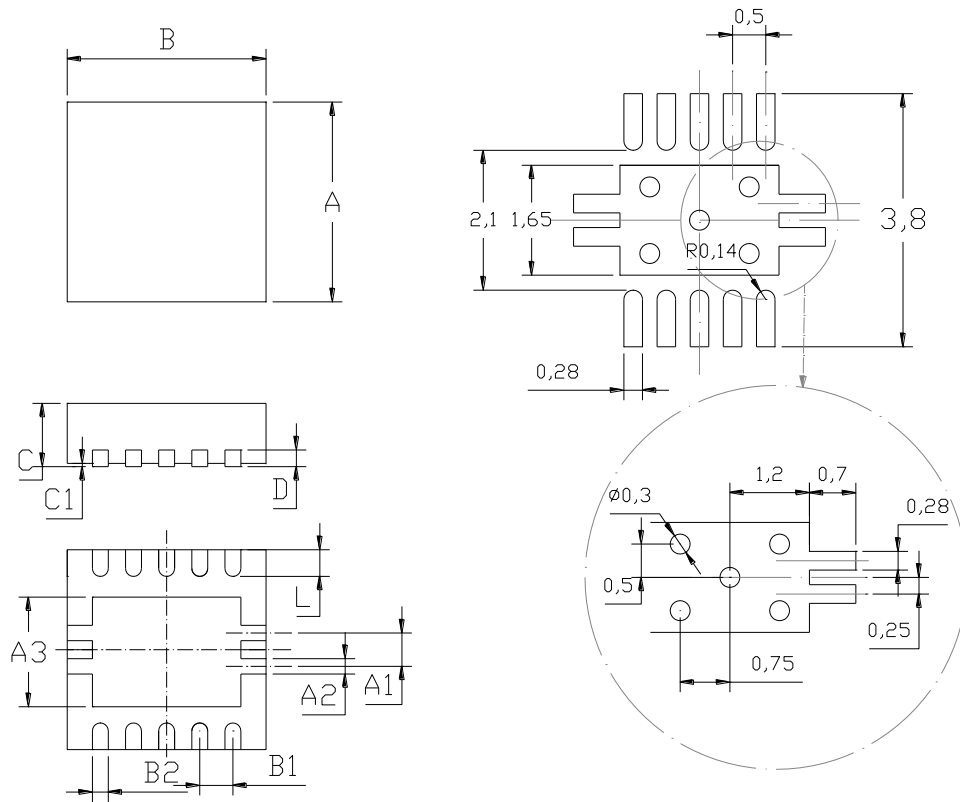
MSOP10 PACKAGE MECHANICAL DRAWING



MSOP10 PACKAGE MECHANICAL DATA

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	millimeters		inches	
	min	max	min	max
A	4.75	5.05	0.187	0.199
A1	2.90	3.10	0.114	0.122
B	2.90	3.10	0.114	0.122
B2	0.50		0.020	
B1	0.18	0.28	0.007	0.011
C		1.10		0.043
C2	0.02	0.15	0.001	0.006
L	0.40	0.80	0.016	0.031
D	0.09	0.23	0.004	0.009
theta	0°	6°	0°	6°

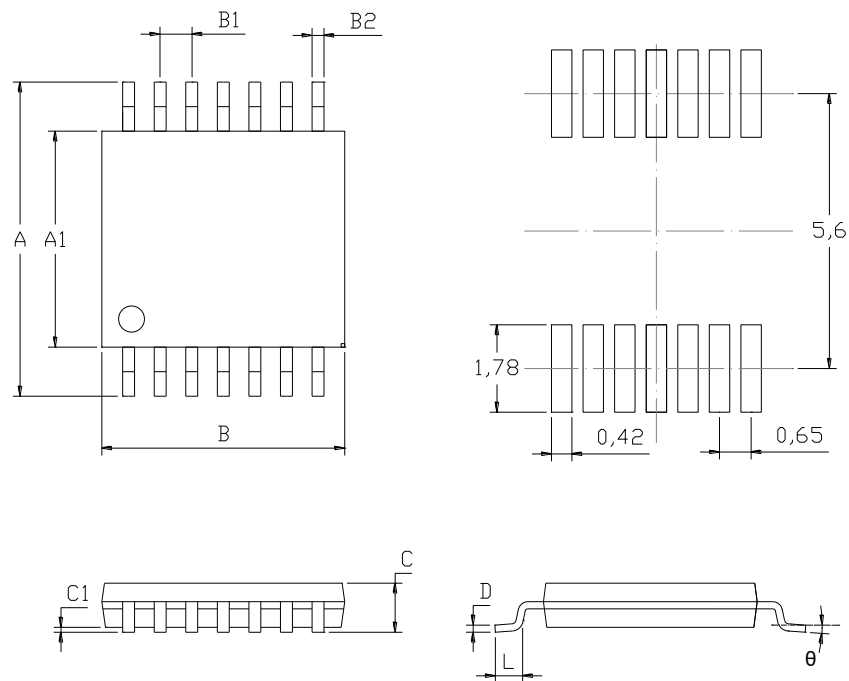
DFNWB3x3-10L PACKAGE MECHANICAL DRAWING



DFNWB3x3-10L 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	0.008	0.012
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	

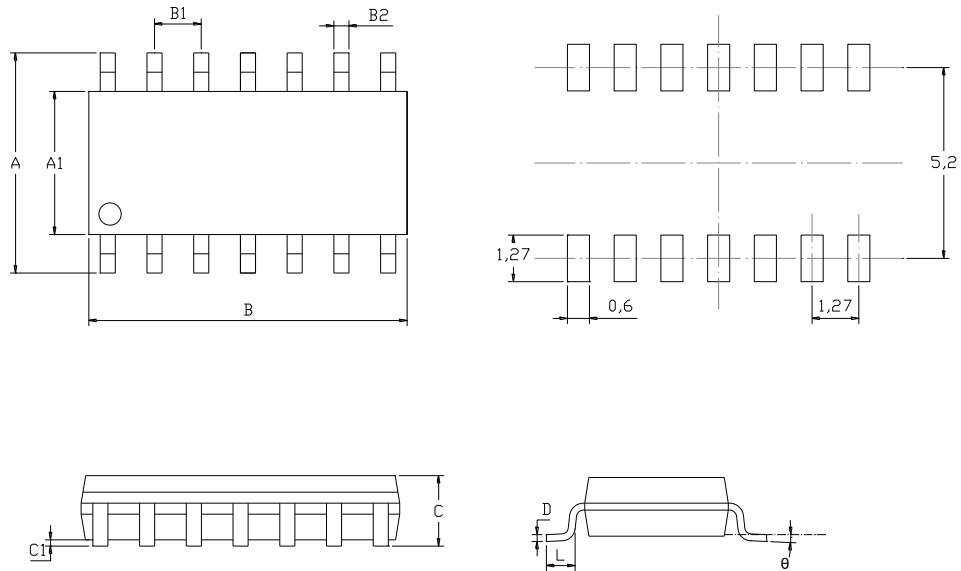
TSSOP14 PACKAGE MECHANICAL DRAWING



TSSOP14 PACKAGE MECHANICAL DATA

symbol	dimensions			
	millimeters		inches	
	min	max	min	max
A	6.25	6.55	0.246	0.258
A1	4.30	4.50	0.169	0.177
B	4.90	5.10	0.193	0.201
B1	0.65		0.026	
B2	0.19	0.30	0.007	0.012
C		1.20		0.047
C1	0.05	0.15	0.002	0.006
L	0.5	0.7	0.020	0.028
D	0.09	0.20	0.004	0.008
θ	1°	7°	1°	7°

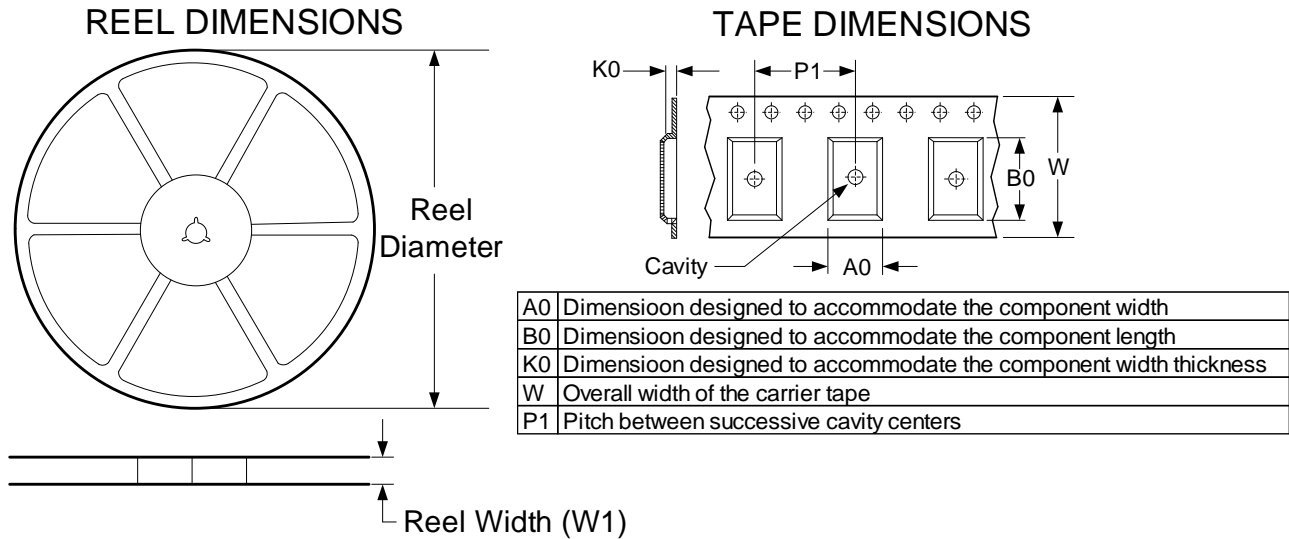
SOP14 PACKAGE MECHANICAL DRAWING



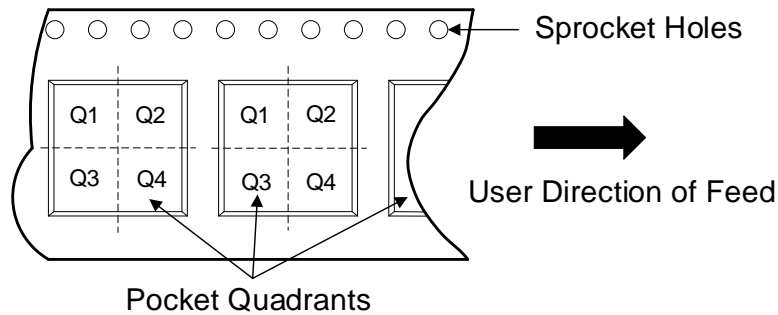
SOP14 PACKAGE MECHANICAL DATA

symbol	dimensions			
	millimeters		inches	
	min	max	min	max
A	5.80	6.20	0.228	0.244
A1	3.80	4.00	0.150	0.157
B	8.45	8.85	0.333	0.348
B1	1.27		0.050	
B2	0.31	0.51	0.012	0.020
C		1.75		0.069
C1	0.10	0.25	0.004	0.010
L	0.40	1.27	0.016	0.050
D	0.10	0.25	0.004	0.010
θ	0°	8°	0°	8°

TAPE AND REEL INFORMATION



QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



Device	Package Type	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TS2164ASOT235LR	SOT-23-5L	5	3000	180.0	9.0	3.2	3.3	1.4	4.0	8.0	Q3
TS2164ASOP8R	SOP8	8	2500	330.0	12.4	6.4	5.4	2.1	8.0	12.0	Q1
TS2163ASOT236LR	SOT-23-6L	6	3000	180.0	9.0	3.2	3.3	1.4	4.0	8.0	Q3
TS2163ASOP8R	SOP8	8	2500	330.0	12.4	6.4	5.4	2.1	8.0	12.0	Q1
TS2263AMSOP10R	MSOP10	10	3000	330.0	12.4	5.2	3.3	1.5	8.0	12.0	Q1
TS2264ASOP8R	SOP8	8	2500	330.0	12.4	6.4	5.4	2.1	8.0	12.0	Q1
TS2264AMSOP8R	MSOP8	8	3000	330.0	12.4	5.2	3.3	1.5	8.0	12.0	Q1
TS2464ASOP14R	SOP14	14	2500	330.0	12.4	6.5	9.0	2.1	8.0	16.0	Q1
TS2464ATSSOP14R	TSSOP14	14	3000	330.0	12.4	6.8	5.4	1.2	8.0	12.0	Q1
TS2263ADFNWB3310LR	DFNWB3x3-10L	10	5000	330.0	12.4	6.4	5.4	2.1	8.0	12.0	Q1

REVISION HISTORY

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

2020/7/7 — REV KY1.0.2B to REV KY1.0.3B

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

2021/07/13 — REV KY1.0.3B to REV KY1.1.3B

Updated MSOP10,DFNWB3x3-10L and TSSOP14 SPQ.....	2,18
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