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

FEATURES

- **AEC-Q100 qualified for automotive applications**
- **Low Offset Voltage:**
  TS2168AQ-H: ±0.5mV (MAX)
  TS2168AQ: ±3.5mV(MAX)
- **High Gain: 105dB (TYP)**
- **High Gain Bandwidth Product: 6.5MHz**
- **Rail-to-Rail Input and Output**
- **Low I_B: 1pA (TYP)**
- **Low Supply Voltage: +2.5V to +5.5V**
- **Low Power Consumption: 580µA at 5V**
- **Extended Temperature: -40°C to +125°C**

PRODUCT DESCRIPTION

The TS2168AQ of product is low noise, low voltage and low power operational amplifiers with high gain-bandwidth product of 6.5MHz and slew rate of 5V/µs. The maximum input offset voltage is only 0.5mV (TS2168AQ-H) and the input common mode range extends beyond the supply rails.

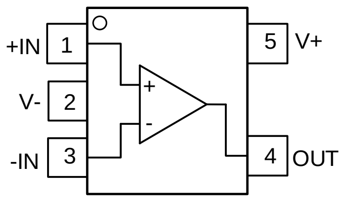
TS2168AQ of operational amplifier are specified at the full temperature range of −40°C to +125°C under single or dual power supplies of 2.7V to 5.5V, however this product will operate under an extended supply range from 2.5V to 5.5V at a reduced temperatures range.

APPLICATIONS

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

PIN ASSIGNMENTS

TS2168AQ



SOT-353 (SC70)

ORDERING INFORMATION

Model	Part Number	Eco Plan	Package	AMP	Container, Pack Qty
TS2168AQ-H	TS2168AQHSOT353R	RoHS	SOT-353	1	Reel,3000
TS2168AQ	TS2168AQSOT353R	RoHS	SOT-353	1	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		±300	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
I_S	Supply Current	I_O = 0			580	750	μA
PSRR	Power Supply Rejection Ratio	V_S = 2.7V to 5.5V, V_{CM} < (V+) - 2V			25	125	μV/V
		T_A = −40°C to +125°C				**150**	**μV/V**
Input Characteristics							
V_{OS}	Input Offset Voltage	TS2168AQ-H		-0.5		0.5	mV
		TS2168AQ		-3.5	1	3.5	mV
dV_{OS}/dT	**Average Drift**				**2.5**		**μV/℃**
I_B	Input Bias Current				1		pA
I_{OS}	Input Offset Current				1		pA
V_{CM}	**Input Common Voltage Range**	**T_A = −40°C to +125°C**		**(V-) - 0.2**		**(V+) + 0.2**	**V**
CMRR	Common Mode Rejection Ratio	V_S = 5.5V	(V-) - 0.2V < V_{CM} < (V+) - 2V	76	88		dB
			T_A = −40°C to +125°C	**68**	**72**		**dB**
			(V−) − 0.2V < V_{CM} < (V+) + 0.2V	64			dB
			T_A = −40°C to +125°C	**58**			**dB**
AOL	Open-Loop Gain	Vs = 5V, R_L = 5kΩ (V-) + 125mV < Vout < (V+) – 125mV		95	104		dB
		T_A = −40°C to +125°C		**85**			**dB**
		Vs = 5V, R_L = 100kΩ (V-) + 25mV < Vout < (V+) - 25mV		96	105		dB
		T_A = −40°C to +125°C		**85**			**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				±50		mA
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	Vin * Gain > V_S			0.2		μs
SR	Slew Rate	G = +1			5		V/μs

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.**

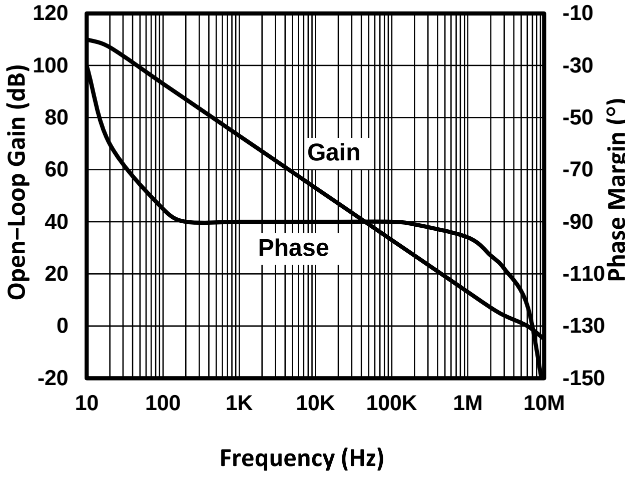
At T_A = +25°C, R_L = 10kΩ connected to V_S / 2, and V_{OUT} = V_S / 2 (unless otherwise noted)

Parameter		Operating Conditions	Min	Type	Max	Unit
Noise Performance						
V_{noise}	Input Voltage Noise	f = 0.1Hz to 10Hz		5		μVpp
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	ºC
	Operating Range		-50		+150	ºC
$θ_{JA}$	Storage Range		-65		+150	ºC
	Thermal Resistance					
	SOT-353			270		ºC/W

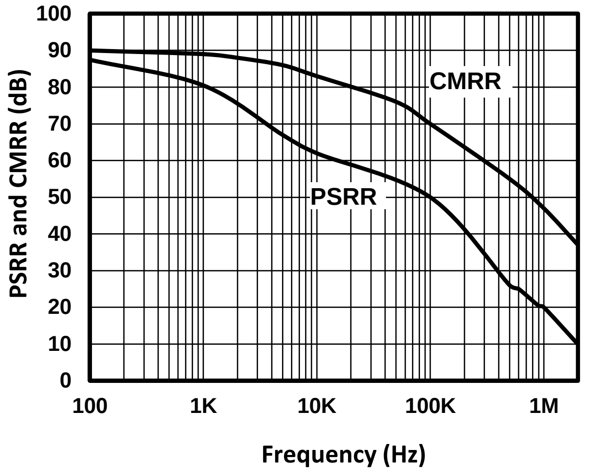
TYPICAL CHARACTERISTICS

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

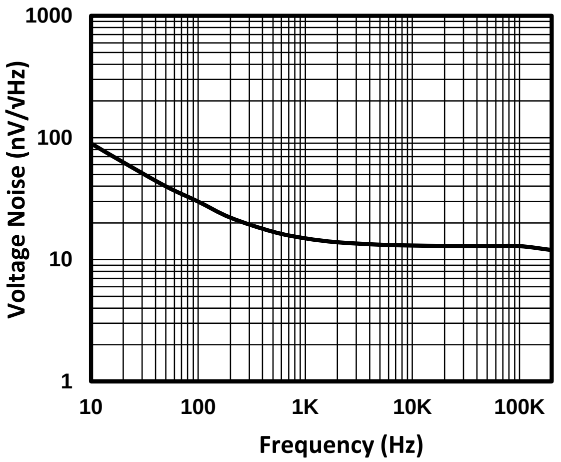
Open–Loop Gain and Phase vs Frequency



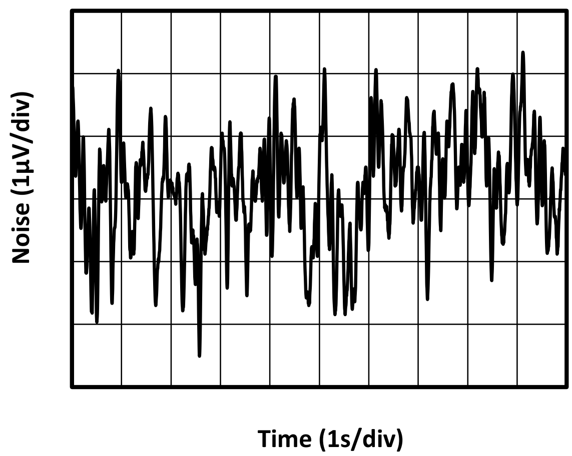
Power–Supply and Common–Mode Rejection Ratio vs Frequency



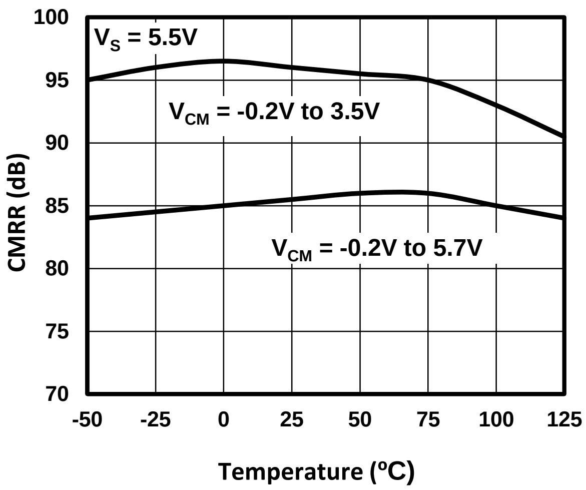
Input Voltage Noise Spectral Density vs Frequency



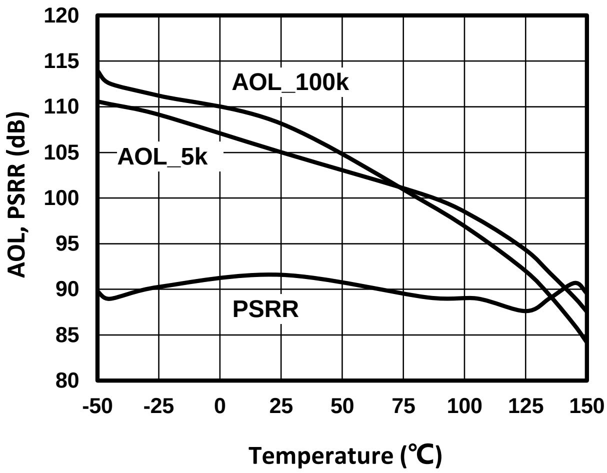
0.1Hz to 10Hz Noise



Common-Mode Rejection Ration vs Temperature

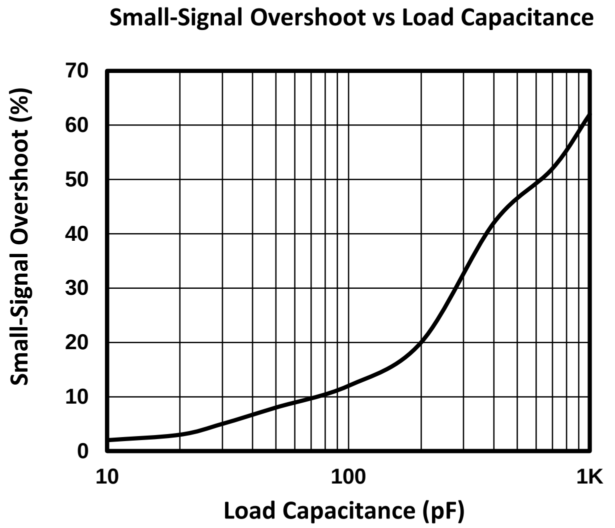


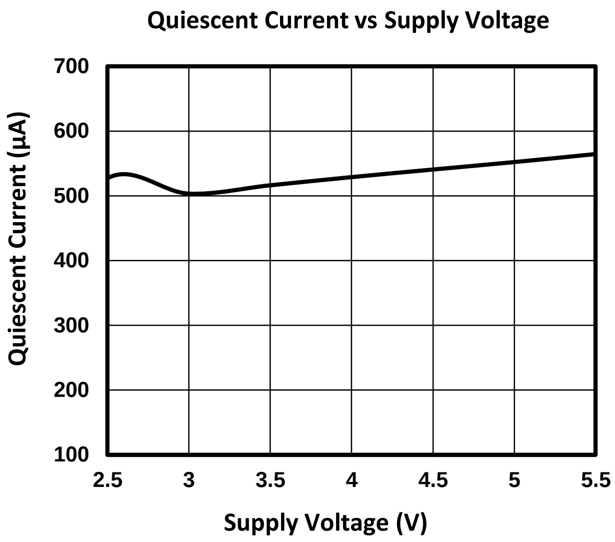
Open–Loop Gain and Power–Supply Rejection Ratio vs Temperature

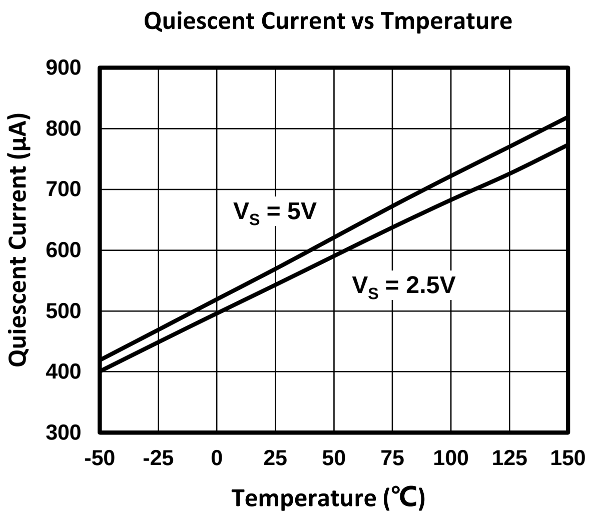


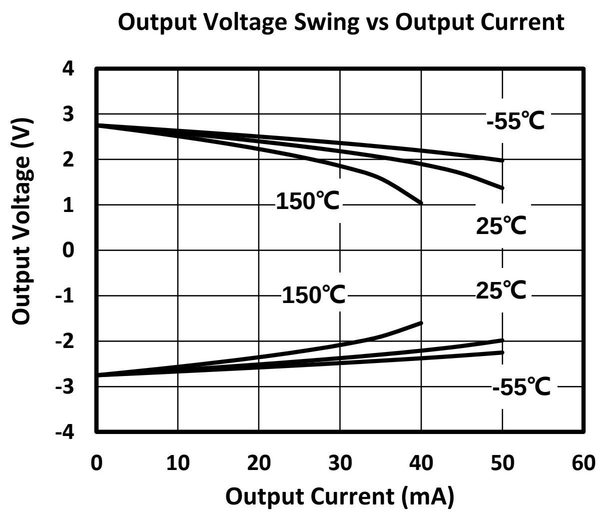
TYPICAL CHARACTERISTICS (CONTINUE)

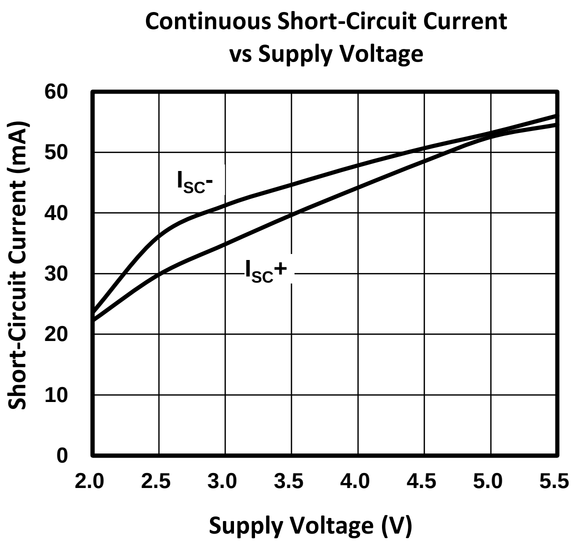
At T_A = +25 ºC, R_L = 10kΩ connected to V_S / 2, and V_{OUT} = V_S / 2 (unless otherwise noted)

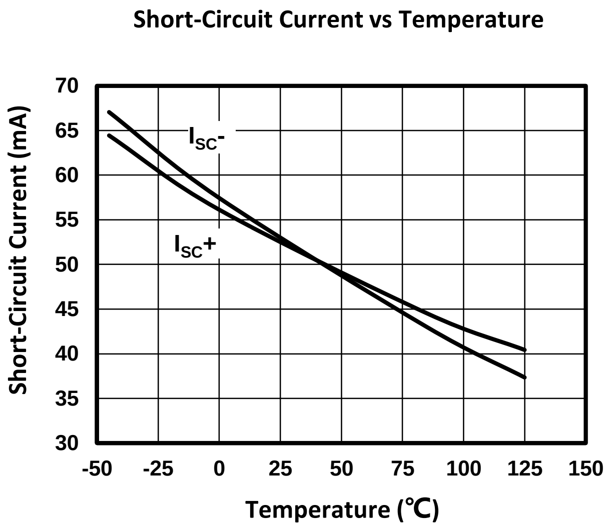








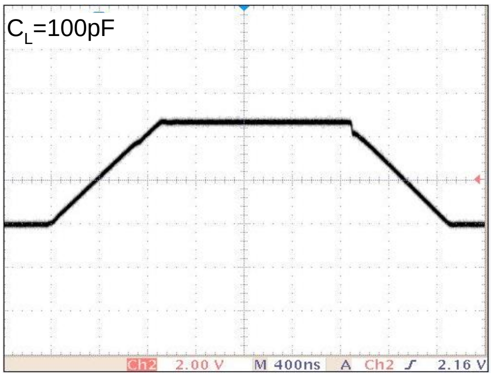




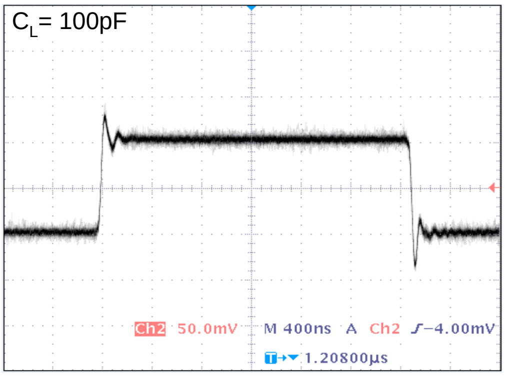
TYPICAL CHARACTERISTICS (CONTINUE)

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

Large-Signal Step Response



Small-Signal Step Response



APPLICATION NOTES

TS2168A 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 and TS2168A 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

TS2168A 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.

TS2168A families are ideal for battery-powered instrumentation and handheld devices because it can operate at the end of discharge voltage of most popular batteries.

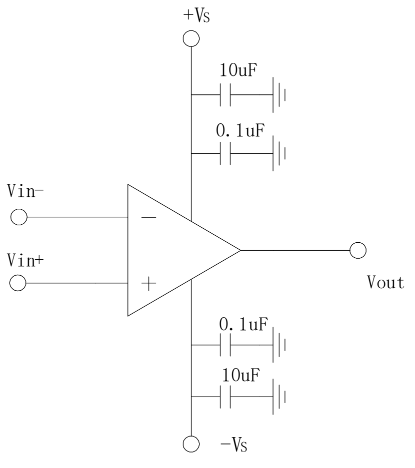


Figure1. Amplifier with Bypass Capacitors

DRIVING CAPACITIVE LOADS

TS2168A 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 C_L 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}.

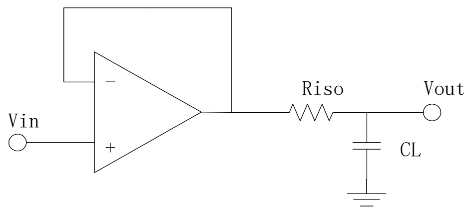


Figure 2. Indirectly Driving Heavy Capacitive Load

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.

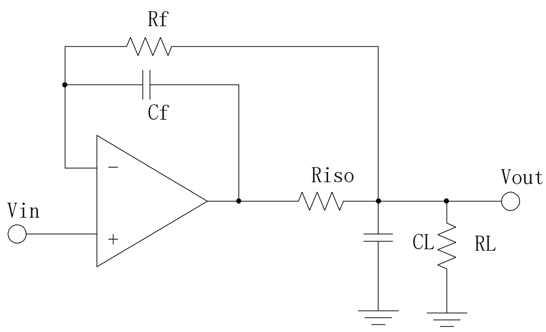


Figure 3. Indirectly Driving Heavy Capacitive Load with DC Accuracy

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 APPLICATION (CONTINUE)

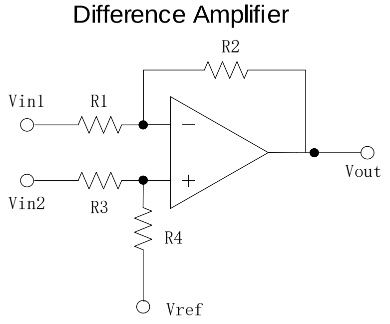


Figure 4. Differential Amplifier

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

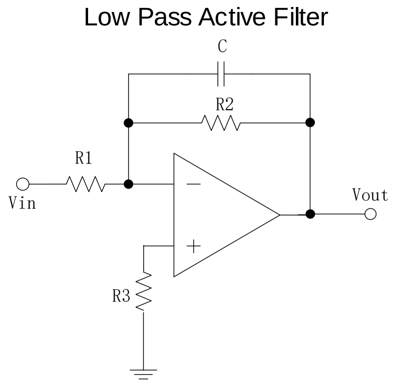


Figure 5. Low Pass Active Filter

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.

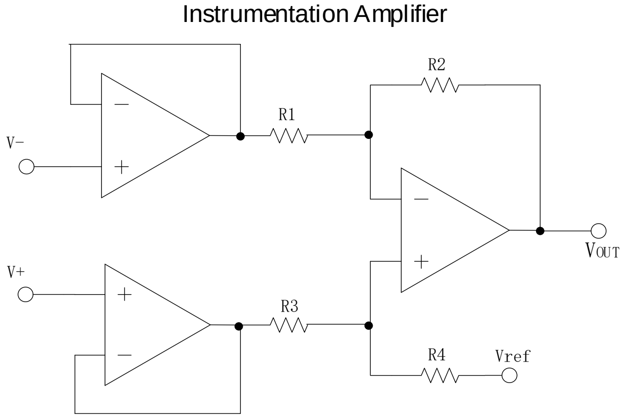
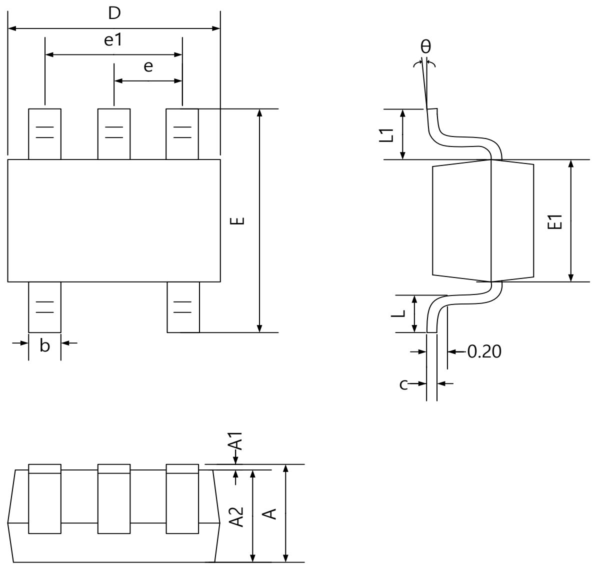


Figure 6. Instrumentation Amplifier

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

MECHANICAL DIMENSIONS

SOT-353 PACKAGE MECHANICAL DRAWING

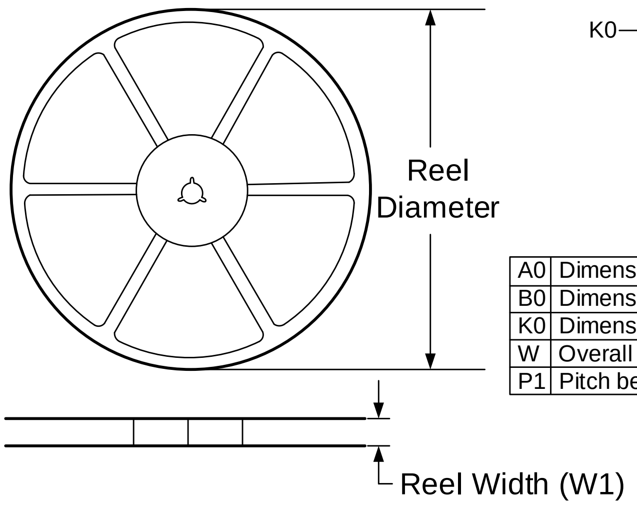


SOT-353 PACKAGE MECHANICAL DATA

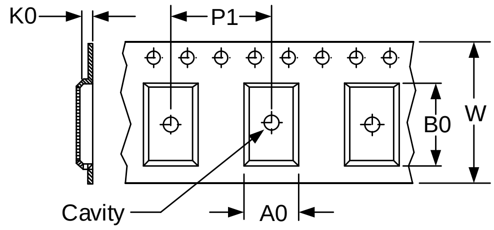
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	0.900	1.100	0.035	0.043
A1	0.000	0.100	0.000	0.004
A2	0.900	1.000	0.035	0.039
b	0.150	0.350	0.006	0.014
c	0.080	0.150	0.003	0.006
D	2.000	2.200	0.079	0.087
E	2.150	2.450	0.085	0.096
E1	1.150	1.350	0.045	0.053
e	0.650 TYP.		0.026 TYP.	
e1	1.200	1.400	0.047	0.055
L	0.260	0.460	0.010	0.018
L1	0.525 REF.		0.021 REF.	
θ	0°	8°	0°	8°

TAPE AND REEL INFORMATION

REEL DIMENSIONS

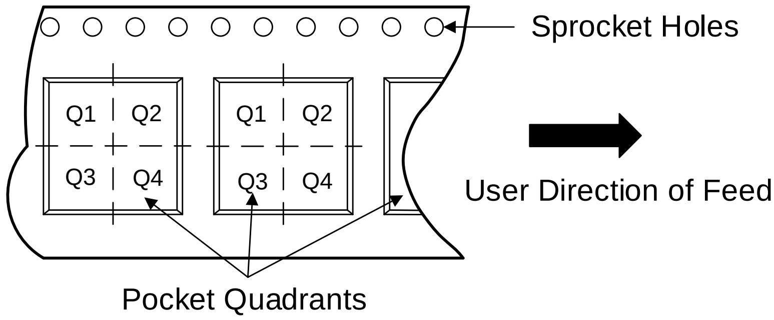


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component width thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

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
TS2168AQHSOT3535LR	SOT-353	5	3000	178.0	12.3	2.3	2.55	1.2	4.0	8.0	Q3
TS2168AQSOT3535LR	SOT-353	5	3000	178.0	12.3	2.3	2.55	1.2	4.0	8.0	Q3

REVISION HISTORY

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

2022/10/24 — REV KY0.0.0A
This Version Is Informal……..………………………………………………………….………………….All Pages

2023/03/20 — REV KY0.0.0A to REV KY1.0.0A
Add *AEC-Q100 qualified for automotive applications*……..……………… ………… ……… ………… ..………….1
Adjust Page Format…………………………………………………………..…………………………….All pages

CONTACT INFORMATION

Trusignal Microelectronics

Phone: +86 512-65923982
Fax: +86 512-65923995
Email: support@kunyuanic.com; sales@kunyuanic.com