RRIO CMOS Operational Amplifiers

Primary characteristics		
Parameter	**Value**	**Unit**
Supply current per amplifier (max.)	4.2	µA
Gain bandwidth	90	kHz
Operating power supply	2.3 ~ 5.5	V

General Description

The SL 8521 (single), SL 8522 (dual) and SL 8524 (quad) are ultra-low power operational amplifiers that provide 90kHz bandwidth with only 3.4µA quiescent current.

These rail-to-rail input and output amplifiers are specifically designed for battery-powered applications. The input common-mode voltage range extends 300mV beyond the power-supply rails and the output swings to only 6.0mV of the rails, maintaining wide dynamic range. Unlike some micro-power op-amps, these parts are unity-gain stable. The SL 852x family features a low input bias current that allows the use of large source and feedback resistors.

The SL 852x op-amps are specified for single or dual power supplies of +2.3V to +5.5V. All models are specified over the extended industrial temperature range of −40°C to +125°C.

The SL 8521 is available in 5-lead SC70 and SOT-23 packages.
The SL 8522 is available in 8-lead MSOP and SOIC packages.
The SL 8524 is available in 14-lead TSSOP and SOIC packages.

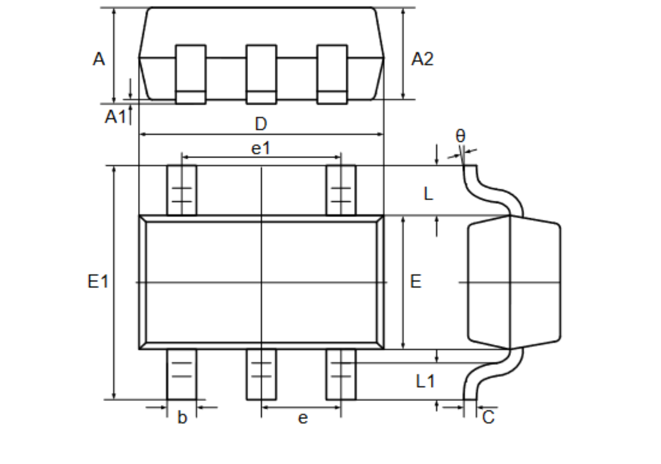
Features

- **SOT-23-5** case for easy automatic insertion.
- Pb-free and **RoHS** compliant
- Low amplifier supply current
- Unity gain stable
- Low offset voltage
- Rail-to-rail input and output

Applications

- Battery powered systems
- Sensor Interfaces, Remote Sensing
- Supply Current Sensing
- Safety Monitoring
- Portable Medical Instruments
- Analog Active Filters
- ASIC Input or Output Amplifier

Case dimensions

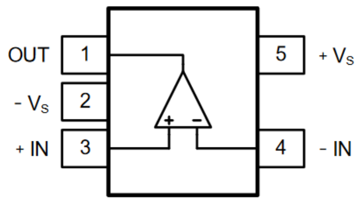


SOT-23-5

All measurements in [mm]

	A	A1	A2	b	c	D	E
MIN MAX	1.04 1.35	0.04 0.15	1.0 1.2	0.38 0.48	0.11 0.21	2.72 3.12	1.4 1.8
	E1	**e**	**e1**	**L**	**L1**	**θ**	
MIN MAX	2.6 3.0	0.95 Typ.	1.9 Typ.	0.7 Ref.	0.3 0.6	0° 8°	

Pin Configuration



Pin description	
Symbol	**Description**
-IN	Inverting input of the amplifier. The voltage range can go from (V_{S-} -0.3V) to (V_{S+} +0.3V).
+IN	Non-inverting input of amplifier. This pin has the same voltage range as -IN.
+V_S	Positive power supply. The voltage is from 2.3V to 5.5V. Split supplies are possible as long as the voltage between V_{S+} and V_{S-} is between 2.3V and 5.5V. A bypass capacitor of 100nF as close to the part as possible should be used between power supply pins or between supply pins and ground.
-V_S	Negative Power Supply. It is normally tied to ground. It can also be tied to a voltage other than ground as long as the voltage between V_{S+} and V_{S-} is from 2.3V to 5.5V. If it is not connected to ground, bypass it with a capacitor of 0.1µF as close to the part as possible.
OUT	Amplifier output

Absolute maximum ratings

Characteristics		Value Min.	Max.	Unit
Supply voltage		-	7.0	V
Common mode input voltage		-0.5	0.5	V
Storage temperature range		-65	150	°C
Junction temperature		-	160	°C
Lead temperature range (soldering 10s)		-	260	°C
Electrostatic discharge voltage	HBM	-4000	4000	V
	CDM	-2000	2000	
	MM	-400	400	

Note 1. Measurements in accordance with the Absolute Maximum Rating System (IEC 60134).
Note 2. Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under Recommended Operating Conditions. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
Note 3. Provided device does not exceed maximum junction temperature (T_J) at any time.

Electrical characteristics

V_S=5.0V, T_A=25°C, $V_{CM}=V_S/2$, $V_O=V_S/2$, and R_L=10kΩ connected to $V_S/2$, unless otherwise noted

Over temperature refers to the specified temperature range: T_A: -40 ~ 125°C

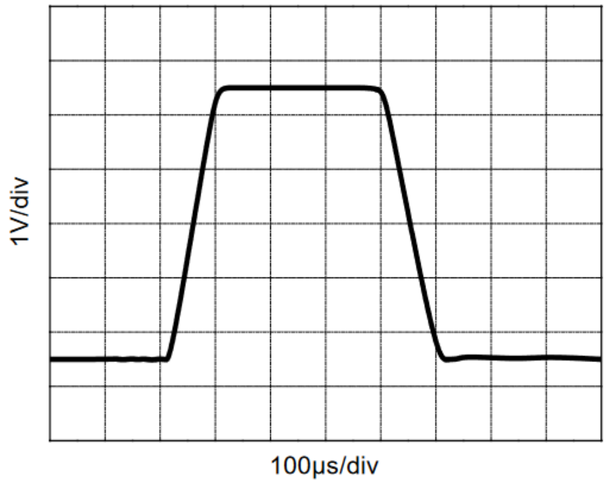
Characteristic	Test condition	Symbol	Value Min.	Typ.	Max.	Unit
Input characteristics						
Input offset voltage		V_{OS}	-4.2	±0.5	4.2	mV
over temperature			-4.5	-	4.5	
Offset voltage drift	over temperature	V_{OS}, TC	-	2.0	-	µV/°C
Input bias current		I_B	-	1.0	20	pA
over temperature			-	-	800	
Input offset current		I_{OS}	-	1.0	-	pA
Common mode voltage range		V_{CM}	-0.3 (V_{S-})	-	0.3 (V_{S+})	V
Common mode rejection ratio	V_{CM}=0.05V to 3.5V	CMRR	80	102	-	dB
over temperature			70	-	-	
over temperature	$V_{CM}=V_{S-}$ -0.1V ~ V_{S+} -0.1V		72	88	-	
			60	-	-	
Open loop voltage gain	V_O=0.05V ~ 3.5V	A_{VOL}	90	110	-	dB
over temperature			82	-	-	
Input resistance		R_{IN}	100	-	-	GΩ
Input capacitance	Differential	C_{IN}	-	2.0	-	pF
	Common mode		-	3.5	-	

Electrical characteristics V_S=5.0V, T_A=25°C, V_{CM}=V_S/2, V_O=V_S/2, and R_L=10kΩ connected to V_S/2, unless otherwise noted **Over temperature refers to the specified temperature range: T_A: -40 ~ 125°C**						
Characteristic	**Test condition**	**Symbol**	**Value**			**Unit**
			Min.	**Typ.**	**Max.**	
Output characteristics						
High output voltage swing		V_{OH}	-	V_{S+}-6.0	-	mV
Low output voltage swing		V_{OL}	-	6.0	-	
Short circuit current	Source current through 10Ω	I_{SC}	-	52	-	mA
	Source current through 10Ω		-	41	-	
Dynamic performance						
Gain bandwidth product	f=1.0kHz	GBW	-	90	-	kHz
Phase margin	C_L=100pF	ϕ_M	-	66	-	°
Slew rate	G=+1, C_L=100pF, V_O=1.5V to 3.5V	SR	-	0.04	-	V/µs
Settling time	To 0.1%, G=+1, 2V step	t_S	-	51	-	µs
	To 0.01%, G=+1, 2V step		-	55	-	
Noise performance						
Input voltage noise	f=0.1Hz ~ 10Hz	V_n	-	12	-	µV_{P-P}
Input voltage noise density	f=10kHz	e_n	-	90	-	nV/√Hz
Power supply						
Operating supply voltage		V_S	2.3	-	5.5	V
Power supply rejection ratio	V_S=2.7V ~ 5.5V, V_{CM}<V_{S+} -2.0V	PSRR	80	102	-	dB
over temperature			75	-	-	
Quiescent current (per amplifier)		I_Q	-	3.4	4.2	µA
over temperature			-	-	5.0	
Thermal characteristics						
Specified temperature range		T_A	-40	-	125	°C
Package thermal resistance	SOT23-5	Θ_{JA}	-	190	-	°C/W

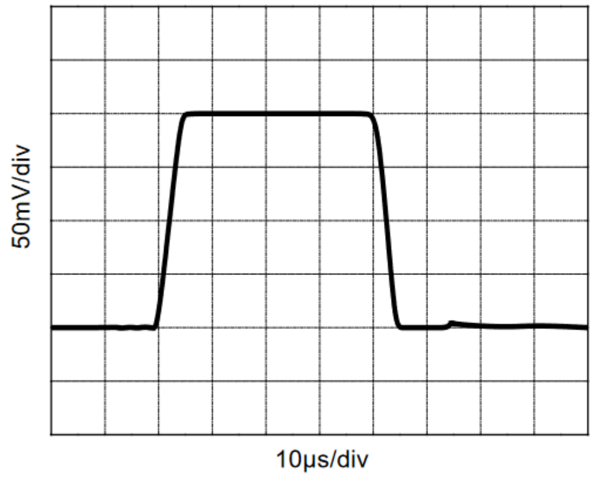
Typical Performance Characteristics

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

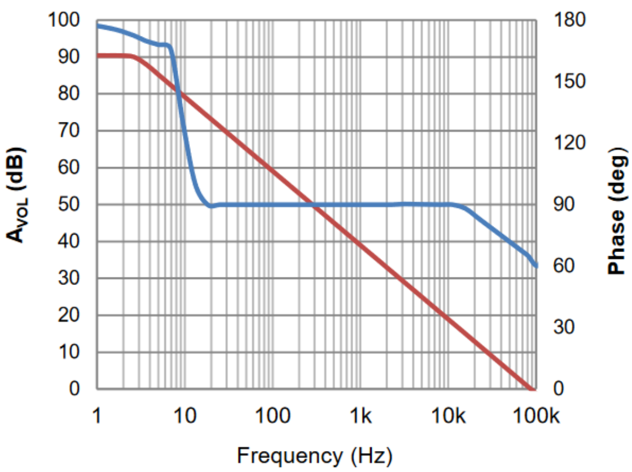
Large signal step response



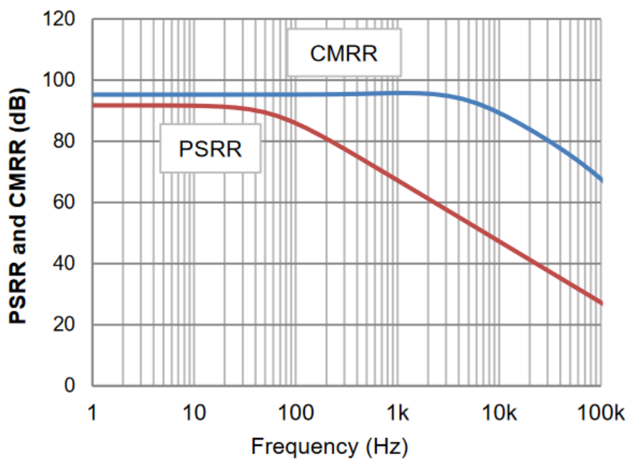
Small signal step response



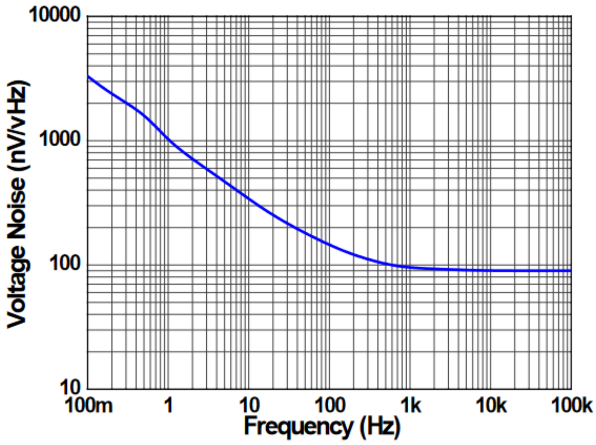
Open-loop gain and phase as a function of frequency



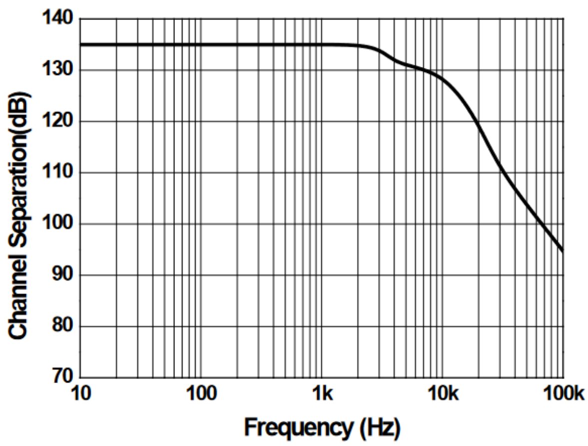
Power supply and common mode rejection ratio as a function of frequency



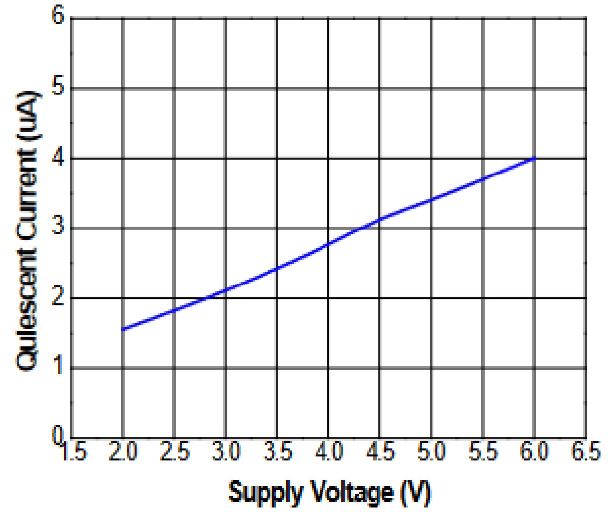
Input voltage noise spectral density as a function of frequency



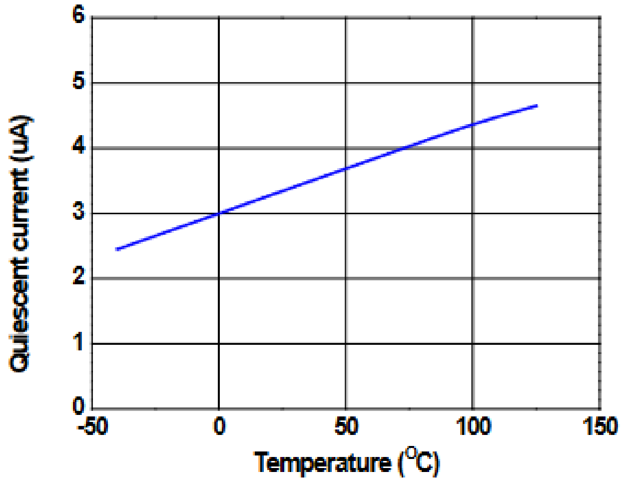
Channel separation as a function of frequency



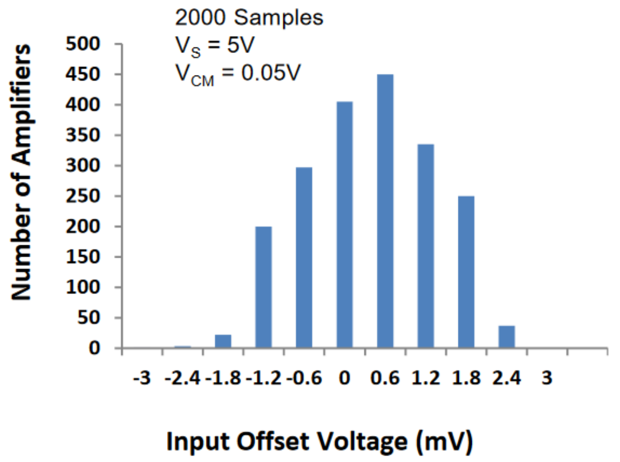
Quiescent current as a function of supply voltage



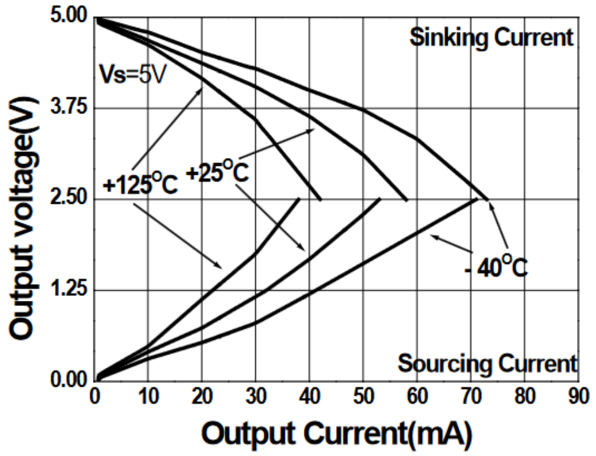
Quiescent current as a function of temperature



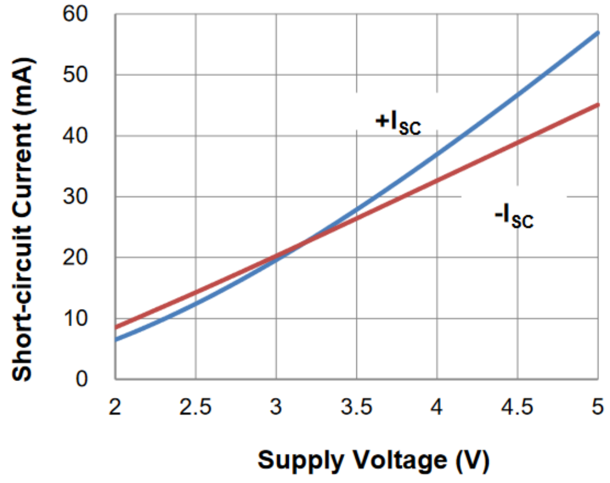
Input offset voltage production distribution



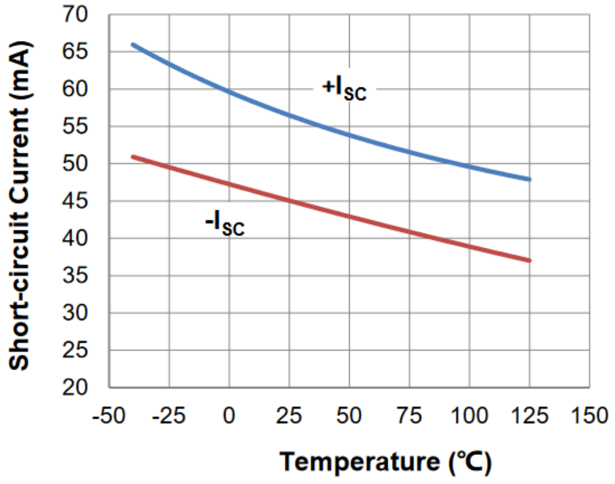
Output voltage swing as a function of output current



Short-circuit current as a function of supply voltage



Short-circuit current as a function of temperature



Application Notes

Low input bias current

The SL 852x op-amps are a CMOS op-amp family and feature very low input bias current in pA range. The low input bias current allows the amplifiers to be used in applications with high resistance sources. Care must be taken to minimize PCB Surface Leakage. See below section on “PCB Surface Leakage” for more details.

PCB surface leakage

In applications where low input bias current is critical, Printed Circuit Board (PCB) surface leakage effects need to be considered. Surface leakage is caused by humidity, dust or other contamination on the board. Under low humidity conditions, a typical resistance between nearby traces is $10^{12}\Omega$. A 5.0V difference would cause 5.0pA of current to flow, which is greater than the SL852x’s input bias current at 25°C (±1.0fA, typical). It is recommended to use multi-layer PCB layout and route the op-amp’s –IN and +IN signal under the PCB surface. The effective way to reduce surface leakage is to use a guard ring around sensitive pins (or traces). The guard ring is biased at the same voltage as the sensitive pin. An example of this type of layout is shown in Figure 1 for Inverting Gain application.

1. For Non-Inverting Gain and Unity-Gain Buffer:
   a) Connect the non-inverting pin (+IN) to the input with a wire that does not touch the PCB surface.
   b) Connect the guard ring to the inverting input pin (–IN). This biases the guard ring to the Common Mode input voltage.
2. For Inverting Gain and Trans-impedance Gain Amplifiers (convert current to voltage, such as photo detectors):
   a) Connect the guard ring to the non-inverting input pin (+IN). This biases the guard ring to the same reference voltage as the op-amp (e.g., $V_S/2$ or ground).
   b) Connect the inverting pin (–IN) to the input with a wire that does not touch the PCB surface.

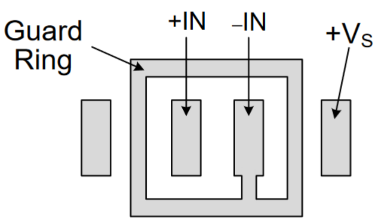


Figure 1. Use a guard ring around sensitive pins

Ground sensing and rail to rail

The input common-mode voltage range of the SL852x series extends 300mV beyond the supply rails. This is achieved with a complementary input stage—an N-channel input differential pair in parallel with a P-channel differential pair. For normal operation, inputs should be limited to this range. The absolute maximum input voltage is 500mV beyond the supplies. Inputs greater than the input common-mode range but less than the maximum input voltage, while not valid, will not cause any damage to the op-amp. Unlike some other op-amps, if input current is limited, the inputs may go beyond the supplies without phase inversion, as shown in Figure 2. Since the input common-mode range extends from (V_{S-} −0.3V) to (V_{S+} +0.3V), the SL852x op-amps can easily perform ‘true ground’ sensing.

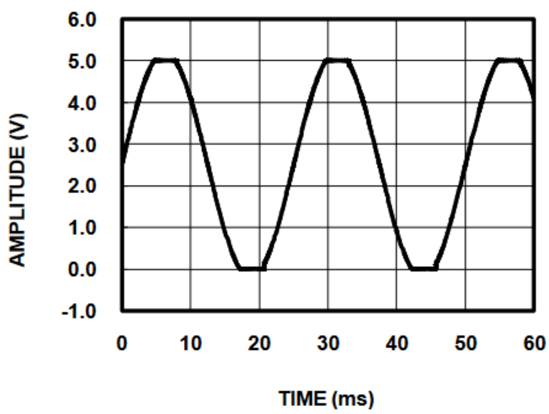


Figure 2. No phase inversion with inputs greater than the power-supply voltage

Application Notes

A topology of class AB output stage with common-source transistors is used to achieve rail-to-rail output. For light resistive loads (e.g. 100kΩ), the output voltage can typically swing to within 5.0mV from the supply rails. With moderate resistive loads (e.g. 10kΩ), the output can typically swing to within 10mV from the supply rails and maintain high open-loop gain. See the Typical Characteristic curve, Output Voltage Swing as a function of Output Current, for more information.

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 0.5V beyond either supply, otherwise current will flow through these diodes.

Capacitive load and stability

The SL852x can directly drive 1.0nF 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 results in ringing or even oscillation. Applications that require greater capacitive drive capability should use an isolation resistor between the output and the capacitive load like the circuit in Figure 3. 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 RISO forms a voltage divider with the R_L.

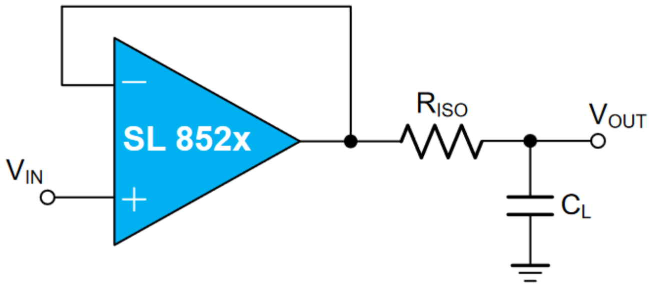


Figure 3. Indirectly Driving Heavy Capacitive Load

An improvement circuit is shown in Figure 4. It provides DC accuracy as well as AC stability. The R_F provides the DC accuracy by connecting the inverting signal with the output. The 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.

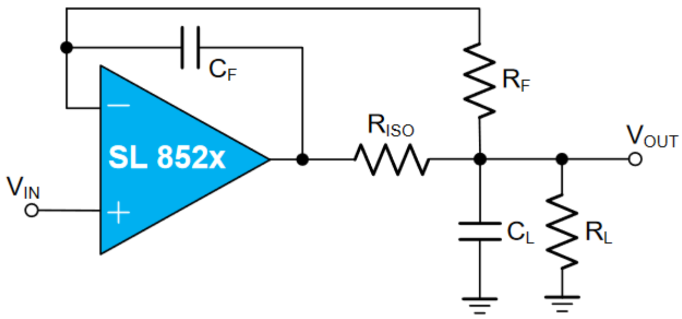


Figure 4. Indirectly Driving Heavy Capacitive Load with DC Accuracy

For no-buffer configuration, there are two others 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.

Power supply layout and bypass

The SL852x family operates from either a single 2.3V to 5.5V supply or dual ±1.15V to ±3.0V supplies. For single-supply operation, bypass the power supply V_S with a ceramic capacitor (i.e. 0.01µF to 0.1µF) which should be placed close (within 2.0mm for good high frequency performance) 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. A bulk capacitor (i.e. 2.2µF or larger tantalum capacitor) within 100mm to provide large, slow currents and better performance. This bulk capacitor can be shared with other analog parts. Good PC board layout techniques optimize performance by decreasing the amount of stray capacitance at the op-amp's inputs and output. To decrease stray capacitance, minimize trace lengths and widths by placing external components as close to the device as possible. Use surface-mount components whenever possible. For the op-amp, soldering the part to the board directly is strongly recommended. Try to keep the high frequency big current loop area small to minimize the EMI (electromagnetic interfacing).

Grounding

A ground plane layer is important for the SL852x circuit design. The length of the current path speed currents in an inductive ground return will create an unwanted voltage noise. Broad ground plane areas will reduce the parasitic inductance.

Input-to-output coupling

To minimize capacitive coupling, the input and output signal traces should not be parallel. This helps reduce unwanted positive feedback.

Typical Application Circuits

Differential amplifier

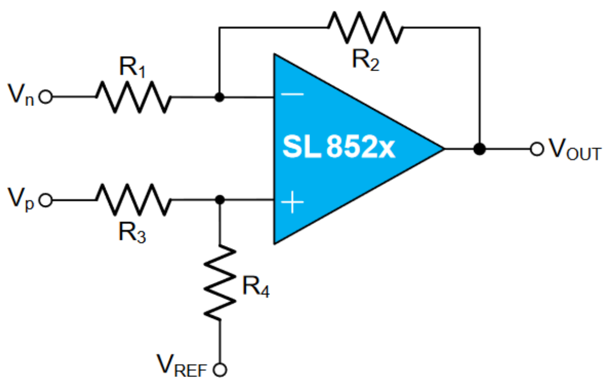


Figure 5. Differential amplifier

The circuit shown in Figure 5 performs the difference function. If the resistors ratios are equal $R_4/R_3=R_2/R_1$, then:

$$V_{OUT} = (V_p - V_n) \times \frac{R_2}{R_1} + V_{REF}$$

Instrumentation amplifier

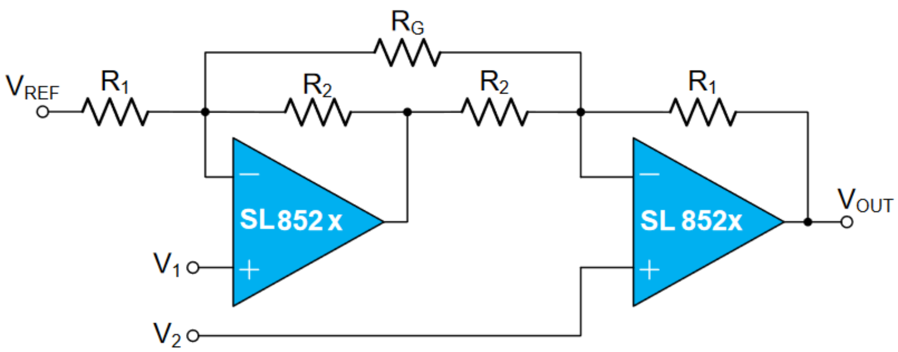


Figure 6. Instrumentation Amplifier

$$V_{OUT} = (V_1 - V_2)\left(1 + \frac{R_1}{R_2} + \frac{2R_1}{R_G}\right) + V_{REF}$$

The SL852x family is well suited for conditioning sensor signals in battery-powered applications. Figure 6 shows a two op-amp instrumentation amplifier, using the SL852x op-amps. The circuit works well for applications requiring rejection of common-mode noise at higher gains. The reference voltage (V_{REF}) is supplied by a low-impedance source. In single voltage supply applications, the V_{REF} is typically $V_S/2$.

Buffered chemical sensors

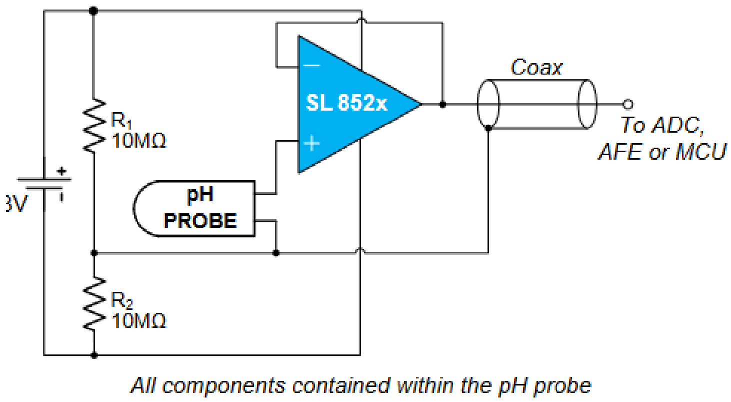


Figure 7. Buffered pH Probe.

The SL 852x family has input bias current in the pA range. This is ideal in buffering high impedance chemical sensors, such as pH probes. As an example, the circuit in Figure 7 eliminates expansive low-leakage cables that that is required to connect a pH probe (general purpose combination pH probes, e.g Corning 476540) to metering ICs such as ADC, AFE and/or MCU. An L852x op-amp and a lithium battery are housed in the probe assembly. A conventional low-cost coaxial cable can be used to carry the op-amp's output signal to subsequent ICs for pH reading.

Carbon monoxide (CO) gas sensor

A carbon monoxide (CO) gas detector is a device which detects the presence of carbon monoxide gas level. Usually this is battery powered and transmits audible and visible warnings. The sensor responds to CO gas by reducing its resistance proportionally to the amount of CO present in the air exposed to the internal element. On the sensor module, this variable is part of a voltage divider formed by the internal element and potentiometer R_1. The output of this voltage divider is fed into the non-inverting inputs of the SL 852x op-amps. The device is configured as a buffer with unity gain and is used to provide a non-loaded test point for sensor sensitivity. Because this sensor can be corrupted by parasitic electro-magnetic signals, the SL 852x op-amps can be used for conditioning this sensor. As the Figure 8 shown, the variable resistor is used to calibrate the sensor in different environments.

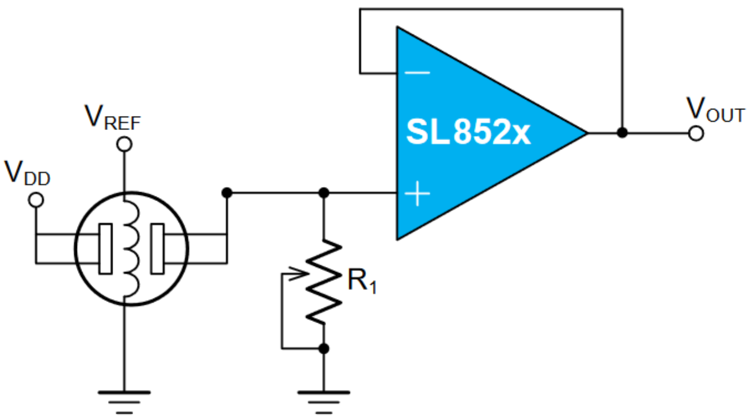
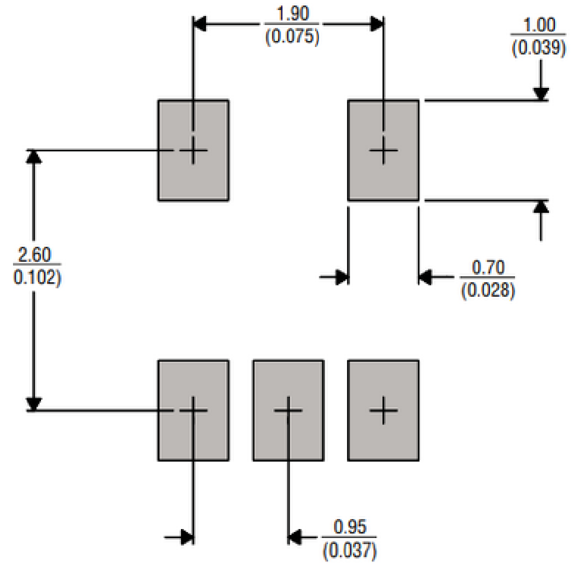


Figure 8. CO Gas Sensor Circuit

Soldering and Packing Information

Suggested soldering pad layout



SOD-23-5	
Units:	mm
	(inches)

Ordering information

Part Number	Package	Shipping Quantity
SL8521XT5	SOT-23-5	**3 000 pcs / reel**

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