



SY24644WMS

Small Size, Low-Power, Unidirectional, Zero-Drift Current-sense Amplifier

General Description

The SY24644 is a high-side voltage output current-sense amplifier that can sense drops across shunts at common-mode voltages from +1.8V to +5.5V with a gain of 100V/V. The small size makes it suitable for applications in cell phones, mobile accessories, notebooks, portable medical, and all battery-operated portable devices where the precision and space of current sensing are critical.

The device operates from a single +1.8V to +5.5V power supply, drawing 18 μ A (typical) of supply current. The SY24644 operating temperature range is from -40°C to +125°C.

Supply voltage for the device is shared with the IN+ pin to reduce the pin count.

The SY24644 is available in a 4-bump, ultra-thin CSP package.

Features

- Voltage-output, Current-sense Amplifier
- Common-mode Range: +1.8V to +5.5V
- Gain=100V/V
- Low offset Voltage: $\pm 7\mu$ V (typical)
- Offset Drift: 0.2 μ V/°C (maximum)
- Gain Error: 0.06% (typical)
- Gain Drift: 1 ppm/°C (maximum)
- Quiescent Current: 18 μ A (typical)
- Buffered Voltage Output: No Additional OP-AMP Needed
- Compact Package: CSP0.76 \times 0.76-4

Applications

- Notebook Computers
- Cell Phones
- Telecom Equipment
- Power Management
- Battery Chargers

Simplified Application and Function Block

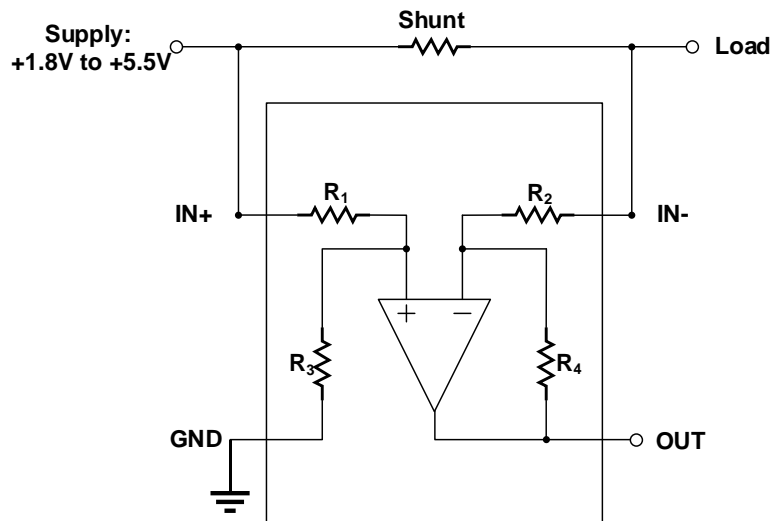


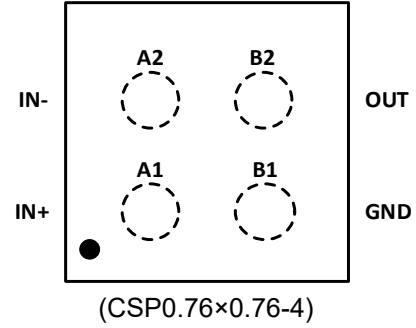
Figure 1. Simplified Application Circuit

Ordering Information

Ordering Number	Package Type	Top Mark
SY24644WMS	CSP0.76x0.76-4	GQQxyz

Device code: **GQQ**,
x=year code, y=week code, z=lot number code

Pin out (Top View)



Pin Description

Name	Number	Description
IN+	A1	Supply voltage and positive sense input.
IN-	A2	Negative sense input.
GND	B1	Ground.
OUT	B2	Output Voltage.

Absolute Maximum Ratings

Parameter (Note 1)	Min	Max	Unit
Supply Voltage		6	V
Differential $V_{IN+} - V_{IN-}$	-5.5	5.5	
Common mode, V_{IN+}, V_{IN-}	GND-0.3	5.5	
Output	GND-0.3	(V+)+0.3	
Input Current into Any Pin	5		mA
Junction Temperature, Operating	-40	150	°C
Storage Temperature	-65	150	
ESD: HBM (Human Body Model)	± 2500		V
ESD: CDM (Charged Device Model)	± 1000		V

Thermal Information

Parameter (Note 2)	Value	Unit
θ_{JA} Junction-to-Ambient Thermal Resistance	315	°C/W
θ_{JC} Junction-to-Case Thermal Resistance	3.5	
ψ_{JT} Junction-to-Top Characterization Parameter	2.5	
θ_{JB} Junction-to-Board Thermal Resistance	70	

Parameter (Note 3)	Min	Max	Unit
Supply Voltage	1.8	5.5	mV
Common mode, V_{IN+}, V_{IN-}	1.8	5.5	V
Operating free-air Temperature	-40	125	°C

Electrical Characteristics

$T_A=25^{\circ}\text{C}$, $V_{CM}=V_{IN+}=4.2\text{V}$, unless otherwise noted (Note 4).

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Input						
Common Mode Input Voltage	V_{CM}	$T_A=-40^{\circ}\text{C}$ to 125°C	1.8		5.5	V
Common-mode Rejection Ratio, RTI	CMRR	$V_{IN+}=+1.8\text{V}$ to $+5.5\text{V}$ $T_A=-40^{\circ}\text{C}$ to 125°C	100	120		dB
Offset Voltage, RTI	V_{OS}			± 7	± 45	μV
Offset Voltage Drift	dV_{OS}/dT	$T_A=-40^{\circ}\text{C}$ to 125°C		0.02	0.2	$\mu\text{V}/^{\circ}\text{C}$
Power-supply Rejection Ratio, RTI	PSRR	$T_A=-40^{\circ}\text{C}$ to 125°C	100	120		dB
Input Bias Current (Note 5)	I_N			3		μA
Output						
Gain	G			100		V/V
Gain Error				0.06	± 0.18	%
		$T_A=-40^{\circ}\text{C}$ to 125°C		0.23	1	ppm/ $^{\circ}\text{C}$
Non-linearity Error		$\text{GND} + 10\text{mV} \leq V_{OUT} \leq V_S - 200\text{mV}$		± 0.01		%
Maximum Capacitive Load (Note 5)		No sustained oscillation		2		nF
Voltage Output						
Swing to V_S Power-supply Rail		$R_L=10\text{k}\Omega$ to GND, $T_A=-40^{\circ}\text{C}$ to 125°C		$(V_+)-0.1$	$(V_+)-0.3$	V
Swing to GND		$R_L=10\text{k}\Omega$ to GND, $T_A=-40^{\circ}\text{C}$ to 125°C		$(V_{GND})+1$	$(V_{GND})+2$	mV
Frequency Response						
Bandwidth (Note 5)	BW	$C_{LOAD}=10\text{pF}$		5		kHz
Slew Rate (Note 5)	SR			0.03		V/ μs
Noise (Input Referred)						
Voltage Noise Density (Note 5)				70		nV/ $\sqrt{\text{Hz}}$
Power Supply						
Supply Voltage	V_{IN+}	$T_A=-40^{\circ}\text{C}$ to 125°C	1.8		5.5	V
Quiescent Current	I_Q			18	22	μA
		I_Q vs temperature, $T_A=-40^{\circ}\text{C}$ to 125°C			30	
Turn-on Time (Note 5)		$V_{IN+}=0$ to $+2.5\text{V}$; $V_{SENSE}=10\text{mV}$; $V_{OUT} \pm 0.5\%$		200		μs
Specified Temperature Range			-40		125	$^{\circ}\text{C}$

Note 1: Stresses beyond the “Absolute Maximum Ratings” may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Note 2: θ_{JA} is measured in the natural convection at $T_A = 25^{\circ}\text{C}$ on a low effective single-layer test board per JESD51-3. $\theta_{JC(top)}$ is measured in accordance with JESD51-14.

Note 3: The device is not guaranteed to function outside its operating conditions.

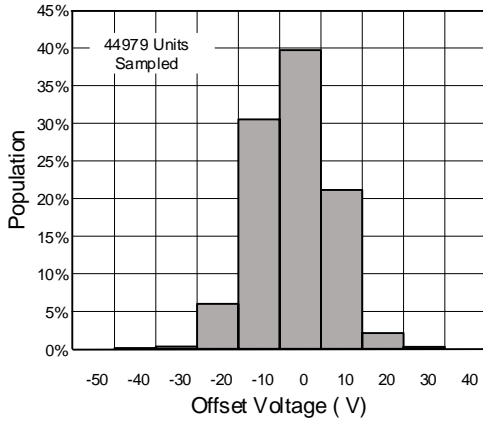
Note 4: Unless otherwise stated, limits are 100% production tested under pulsed load conditions such that $T_A \cong T_J = 25^{\circ}\text{C}$. Limits over the operating temperature range (See recommended operating conditions) and relevant voltage range(s) are guaranteed by design, test, or statistical correlation.

Note 5: Guaranteed by design or statistical correlation and not production tested.

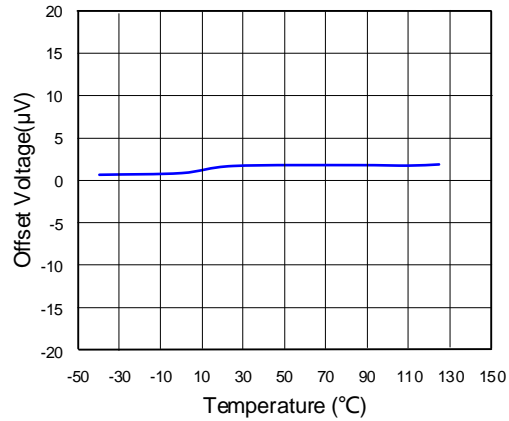
Typical Performance Characteristics

$T_A=25^{\circ}\text{C}$, $V_{\text{CM}}=V_{\text{IN}+}=4.2\text{V}$, unless otherwise noted

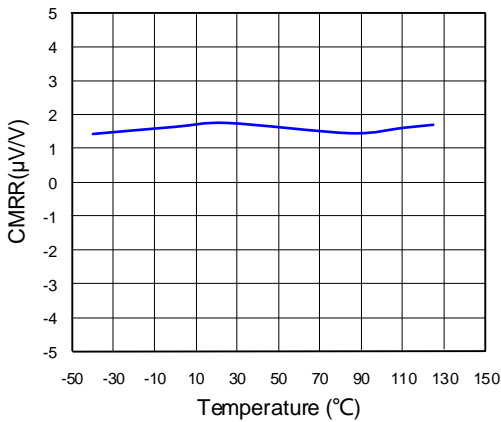
Input Offset Voltage Production Distribution



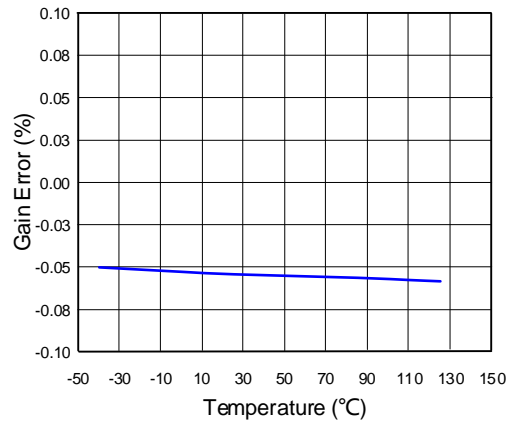
Offset Voltage vs Temperature



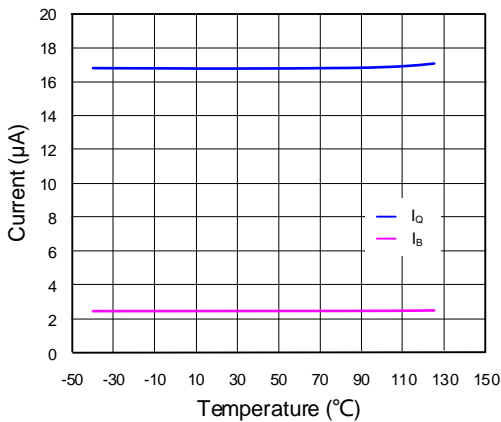
Common-mode Rejection Ratio vs Temperature



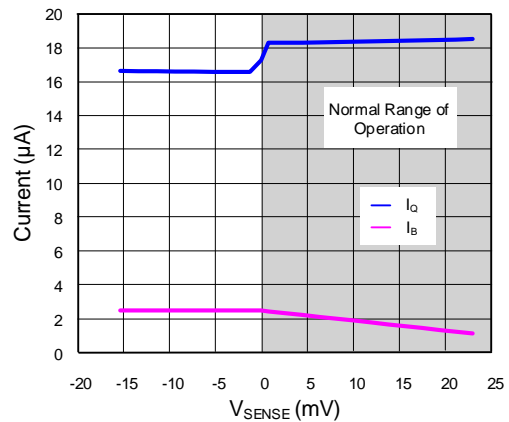
Gain Error vs Temperature



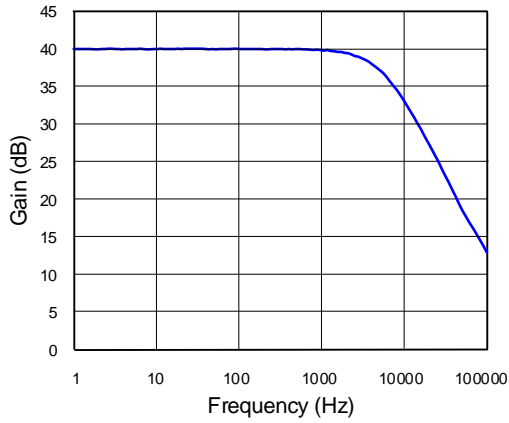
Quiescent Current and Negative Input Bias Current vs Temperature



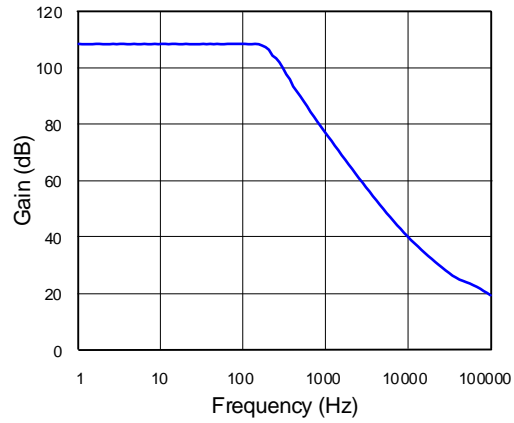
Quiescent Current and Negative Input Bias Current vs V_{SENSE}



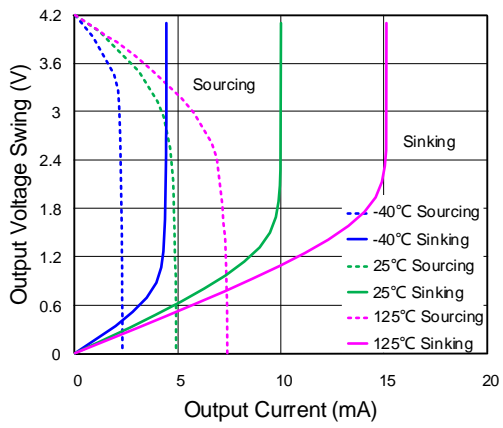
Gain vs Frequency



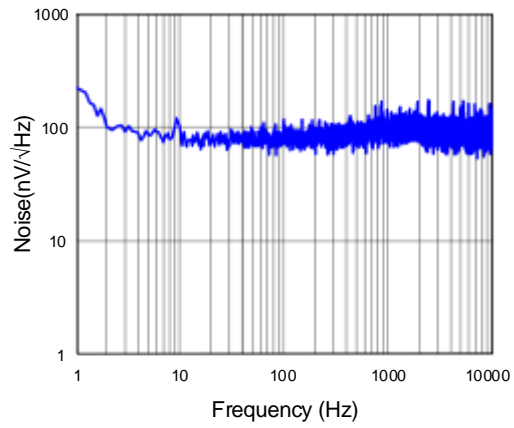
Common-mode Rejection Ratio vs Frequency



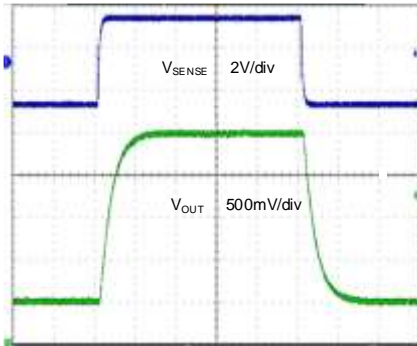
Output Voltage Swing vs Output Current



Input- Referred Voltage Noise vs Frequency

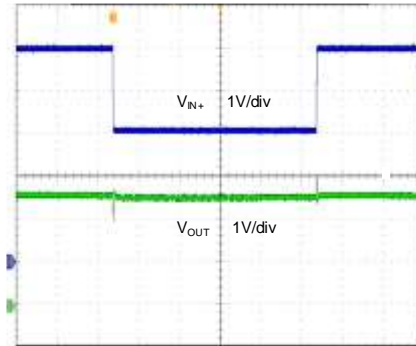


Step Response



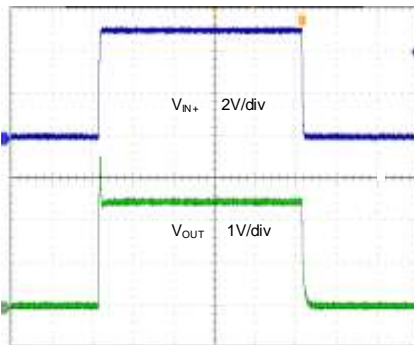
Time (100 μ s/div)

Common-Mode Voltage Transient



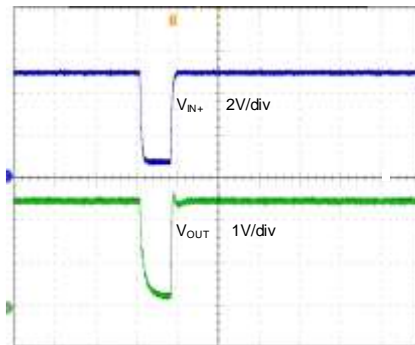
Time (1ms/div)

Startup Response



Time (1ms/div)

Brownout Recovery



Time (400 μ s/div)

Applications Information

The SY24644 is a high-side voltage output current-sense amplifier that offers chip-scale package, low-power, unidirectional, zero-drift and can sense drops across shunts at common-mode voltages from +1.8V to +5.5V without the need for an extra supply voltage terminal.

Basic Connections

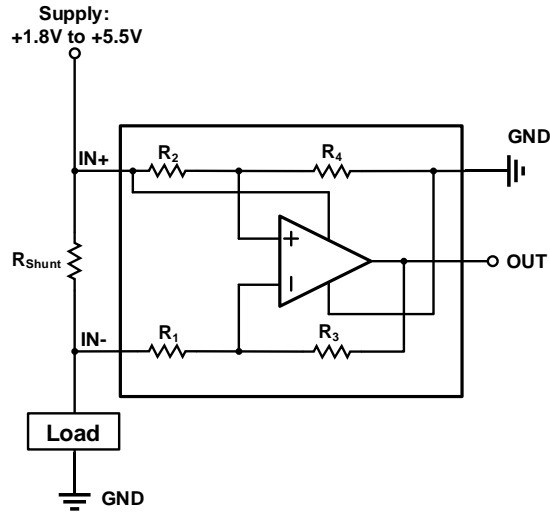


Figure 2. Typical Application

The shunt resistor should be placed as close as possible to the input pins (IN+ / IN-) to minimize any additional series resistance. The basic SY24644 connections are shown in Figure 2. In Figure 3, two R_P represent the additional trace resistance in series with the shunt resistance between the two current sense input pins. Since the shunt resistor value is typically very low, even a very low trace resistance (R_P) can impact the differential voltage at the SY24644 input pins significantly.

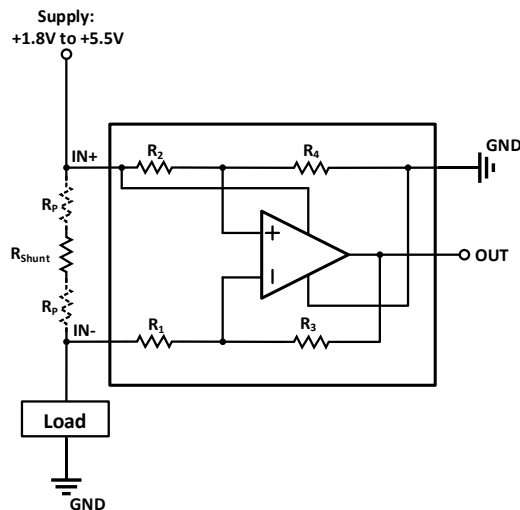


Figure 3. Shunt Resistance Measurement Including Trace Resistance

Kelvin Connections

In order to eliminate the effect of voltage drop on the lead wires in the circuit, a four-terminal current detection resistor or a Kelvin connection is typically used, as shown in Figure 4. This helps ensure that the only impedance seen between the current-sense amplifier input pins is the shunt resistor.

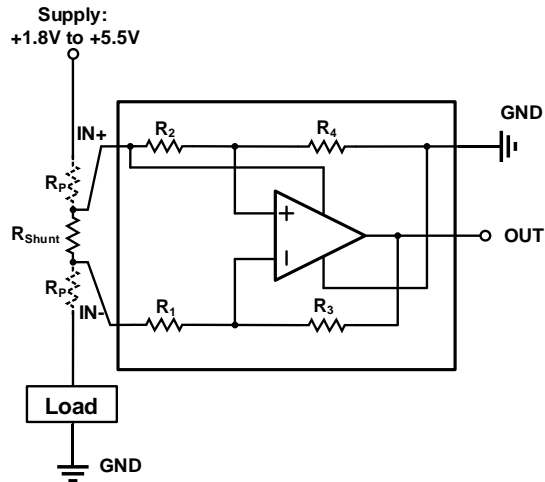


Figure 4. Kelvin Connection

Power Supply

To minimize the pin count, the SY24644 does not have a dedicated power-supply pin. Instead, the IN+ pin has dual function, with an internal connection to the power supply. Because the SY24644 is powered from the IN+ pin, the common-mode input range is limited on the low end to 1.8V. Therefore, the SY24644 cannot be used as a low-side current-sense amplifier.

Selecting Shunt Resistor

The selection of the shunt resistor value used for the SY24644 is based on the specific operating conditions and the application requirements. The starting point for selecting the resistor is to first determine the desired full-scale output from the SY24644. The SY24644 provides 100V/V gain and maintains high-performance levels with very low offset, allowing the use of lower shunt resistor values to achieve lower power dissipation and meet the performance specifications. Most applications have an allowable maximum voltage drop to ensure that the load can receive the required voltage to operate. If no maximum voltage drop is specified, the shunt resistor value can be selected based on the target accuracy.

Two important factors need to be considered when finalizing the current-sensing resistor value: the required current measurement accuracy and the maximum power dissipation across the resistor. A high shunt resistor value allows lower currents to be measured more accurately because offsets are less significant. When the sense voltage is larger, for extremely low input offset voltage and gain error that this part offers, this output voltage error will be insignificant. At high current levels, the losses in resistor can be significant. This needs to be considered when choosing the resistor value and its power dissipation rating. Furthermore, the shunt resistor value might drift if it heats up excessively. Due to the precise offset voltage of the SY24644, the device is capable of sensing very low currents using low sense resistor value, which reduces power dissipation. The sense current dynamic range is maximized due to the device's low V_{OS} and ability to operate using low sense resistors.

Input Filtering

It is not recommended to use an input filter in front of the SY24644 even though it is an ideal location because this will introduce an unwanted gain error to the device, which needs to be carefully considered. However, the input filter can be implemented if it is necessary. In the SY24644, the nominal current into the IN+ pin will be in the range of 18 μ A when the bias current into the IN- pin is in the range of approximately 3 μ A. The current flowing into the IN+ pin includes both the input

bias current and the quiescent current. The issue of input filtering becomes a bigger problem with the quiescent current of the SY24644 flowing through the IN+ pin. When the output starts driving the current, this additional current also flows through the IN+ pin, increasing the error.

A typical common-mode filter consisting of two 10Ω series resistors on each input and a 0.1μF capacitor across the input pins can serve as a filter, as shown in Figure 5. If an application uses the SY24644 with a full-scale output of 4V, the device will not drive any output current. To create a 4V output with a gain of 100, the shunt voltage needs to be 40mV. With 10Ω filter resistors on each input, a differential voltage is generated by subtracting from the 40mV full-scale differential current.

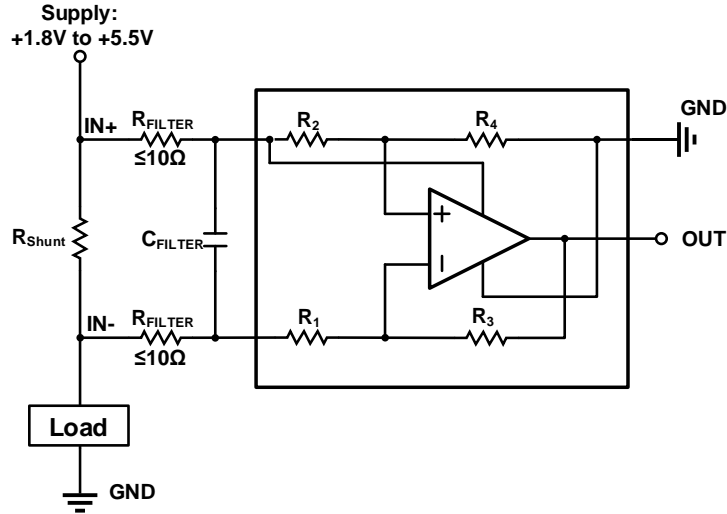
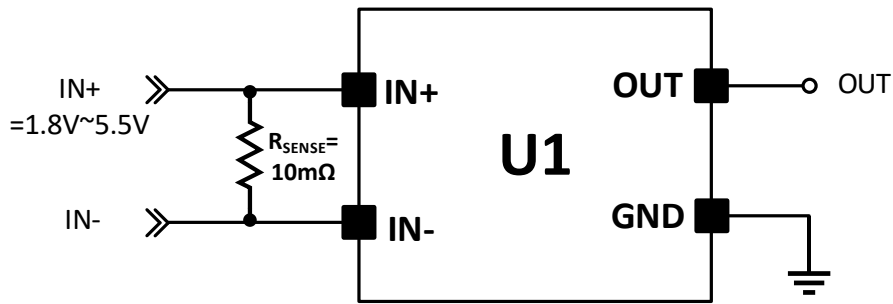


Figure 5. Input Filtering

For applications requiring the filter, which causes the circuit gain error to exceed the error budget, an RC filter can be added after the SY24644. It is not an ideal location for the filter at the output since it loses the benefit of low impedance output. To compensate for this, an additional buffer amplifier can be added after the post current-sense amplifier filter, if the impedance of the downstream ADC is not high enough.

Schematic, Layout, and BOM

Application Schematic



BOM List

Designator	Description	Part Number	MFR
R _{SENSE}	10mΩ/1W, 2512, 1%	RL2512FK-070R01L	YAGEO

PCB Layout Guide

For optimal design, follow these PCB layout guidelines:

Use a Kelvin connection to connect the input pins to the current-sense resistor R_{SENSE}. Due to the low resistance values of R_{SENSE}, poor PCB routing often leads to additional parasitic resistance between input pins, resulting in additional errors. This connection method ensures that only R_{SENSE} impedance is detected between the input pins. Minimize the loop formed by these connections.

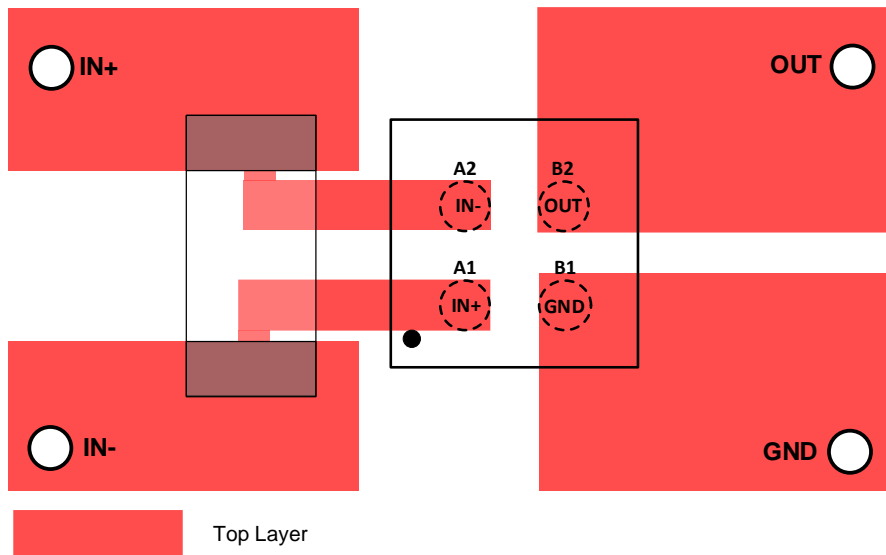
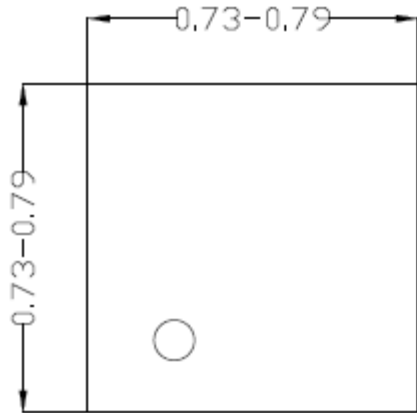
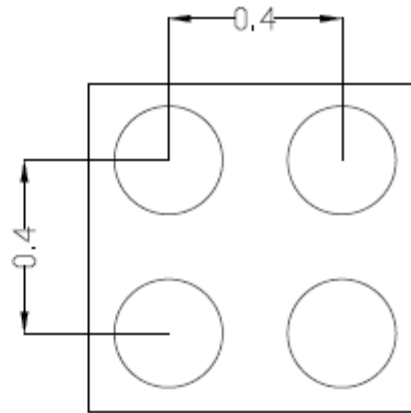


Figure 6. Recommended Layout

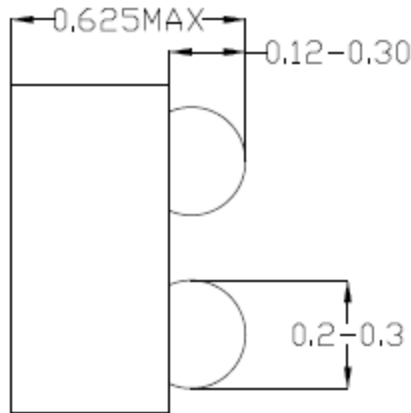
CSP0.76x0.76-4 Package Outline Drawing



Top view



Bottom view



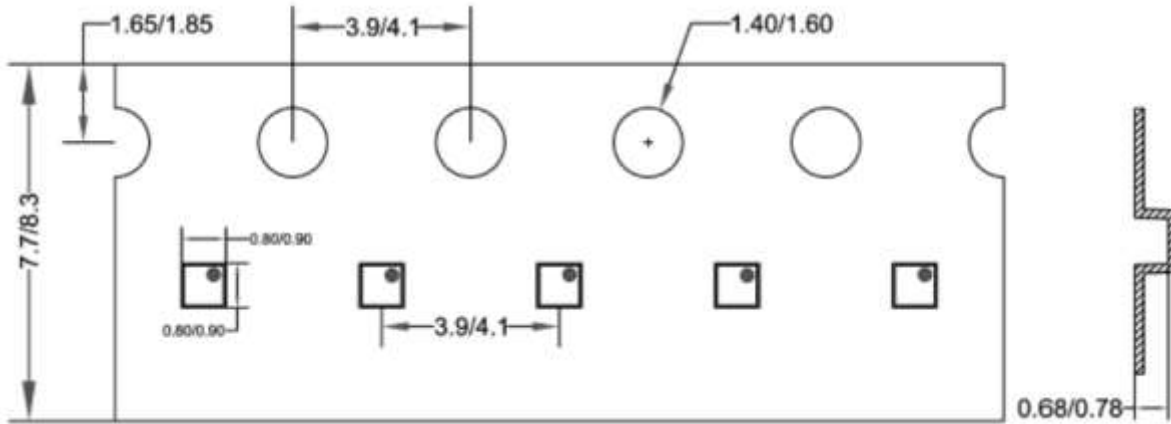
Side View

Note: All dimension in millimeter and exclude mold flash & metal burr.

Tape and Reel Specification

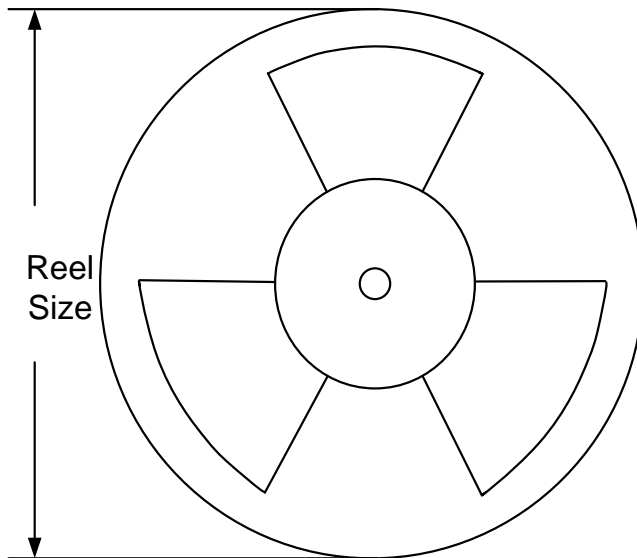
1. Taping Orientation

CSP0.76x0.76-4



Feeding Direction →

2. Reel Dimensions



Package types	Tape width (mm)	Pocket pitch(mm)	Reel size (Inch)	Trailer * length(mm)	Leader * length (mm)	Qty per reel
						(pcs)
CSP0.76x0.76-4	8	4	7"	400	160	3000

Revision History

The revision history provided is for informational purpose only and is believed to be accurate, however, not warranted. Please make sure that you have the latest revision.

Date	Revision	Change
Aug. 31, 2023	Revision 0.9	Initial Release
Aug. 31, 2024	Revision 1.0	Production Release

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