

# DATA SHEET

## **SA58601; SA58604**

Dual and quad operational amplifiers  
with shunt regulator

Product data  
Supersedes data of 2001 Oct 03

2002 Nov 08

# Dual and quad operational amplifiers with shunt regulator

## SA58601; SA58604

### GENERAL DESCRIPTION

The SA58601 is comprised of a low offset voltage dual operational amplifier and a shunt regulator; the SA58604 combines a low offset voltage quad operational amplifier and shunt regulator. The input offset voltage is typically 200  $\mu\text{V}$ .

They are used in battery chargers, switching power supplies, and other voltage and current controlled applications. With low input offset voltage, they are well suited for handling current detection signals and other low amplitude signals.

### FEATURES

#### Op amp section

- Low supply current: 600  $\mu\text{A}$  per amplifier (typical)
- Low input offset voltage: 200  $\mu\text{V}$  (typical)
- Low input offset current: 5 nA (typical)
- Low input bias current: 30 nA (typical)
- Common mode input: Ground to  $V_{\text{CC}} - 1\text{ V}$
- Operating supply: 2 V to 20 V

#### Shunt regulator section

- Reference voltage: 2.5 V (typical)
- Reference voltage fluctuations ( $-20$  to  $+80\text{ }^\circ\text{C}$ ): 5 mV (typ)
- Minimum cathode current: 0.4 mA (typical)

### APPLICATIONS

- Signal conditioning and sensing amplification
- Switching power supply
- AC adapter
- Battery charger

### SIMPLIFIED DEVICE DIAGRAM

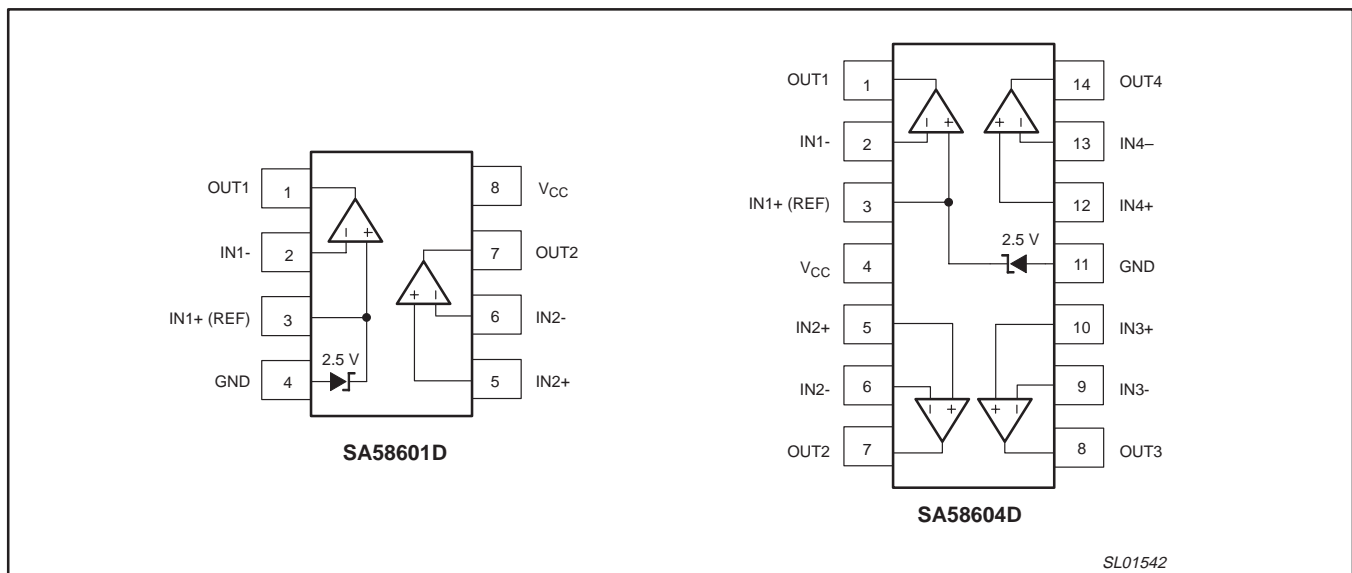


Figure 1. Simplified device diagram.

# Dual and quad operational amplifiers with shunt regulator

SA58601; SA58604

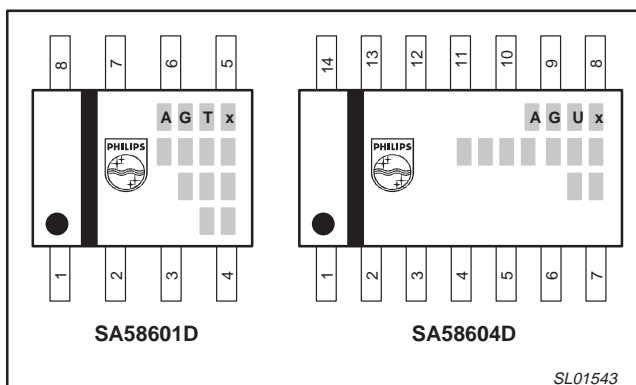
## ORDERING INFORMATION

TYPE NUMBER	PACKAGE		TEMPERATURE RANGE
	NAME	DESCRIPTION	
SA58601D	SO8	plastic small outline package; 8 leads; body width 3.9 mm	-40 to +85 °C
SA58604D	SO14	plastic small outline package; 14 leads; body width 4.4 mm	-40 to +85 °C

## Part number marking

Each device is marked with three or four lines of alphanumeric codes. The first three letters of the top line designate the product. The fourth letter, represented by 'x', is a date tracking code. The remaining lines of characters are internal manufacturing codes.

Part number	Marking
SA58601D	A G T x
SA58604D	A G U x



## SA58601 PIN CONFIGURATION

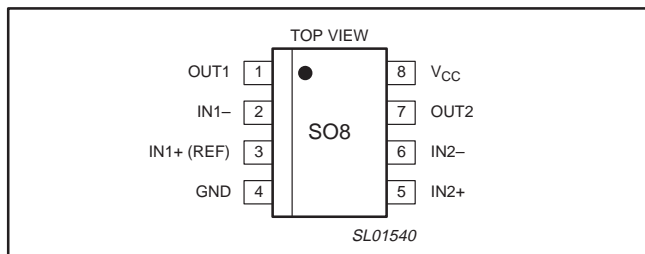


Figure 2. Pin configuration.

## SA58601 PIN DESCRIPTION

PIN	SYMBOL	DESCRIPTION
1	OUT1	Output of Amp 1
2	IN1-	Inverting input of Amp 1
3	IN1+ (REF)	Non-inverting input of Amp 1 and reference voltage output
4	GND	Ground
5	IN2+	Non-inverting input of Amp 2
6	IN2-	Inverting input of Amp 2
7	OUT2	Output of Amp 2
8	V <sub>CC</sub>	Positive supply

## SA58604 PIN CONFIGURATION

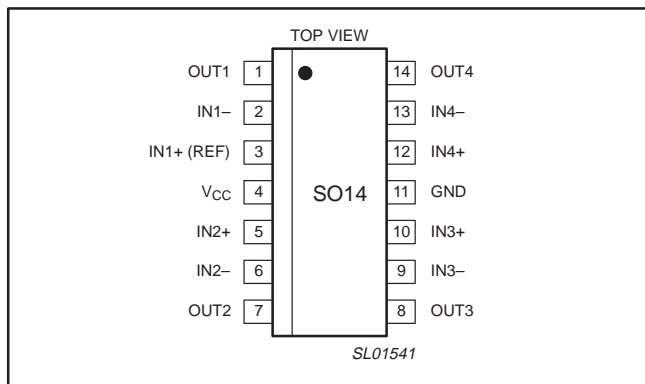


Figure 3. Pin configuration.

## SA58604 PIN DESCRIPTION

PIN	SYMBOL	DESCRIPTION
1	OUT1	Output of Amp 1
2	IN1-	Inverting input of Amp 1
3	IN1+ (REF)	Non-inverting input of Amp 1 and reference voltage output
4	V <sub>CC</sub>	Positive supply
5	IN2+	Non-inverting input of Amp 2
6	IN2-	Inverting input of Amp 2
7	OUT2	Output of Amp 2
8	OUT3	Output of Amp 3
9	IN3-	Inverting input of Amp 3
10	IN3+	Non-inverting input of Amp 3
11	GND	Ground
12	IN4+	Non-inverting input of Amp 4
13	IN4-	Inverting input of Amp 4
14	OUT4	Output of Amp 4

# Dual and quad operational amplifiers with shunt regulator

SA58601; SA58604

## MAXIMUM RATINGS

SYMBOL	PARAMETER		MIN.	MAX.	UNIT
$V_{CC}$	Single supply voltage		-0.3	+24	V
$V_{IN}$	Input voltage		-0.3	+10	V
$T_{stg}$	Storage temperature		-40	+125	°C
$T_{amb}$	Operating temperature		-40	+85	°C
$P_D$	Power dissipation	SA58601	-	300	mW
		SA58604	-	350	mW

## ELECTRICAL CHARACTERISTICS

$V_{CC} = 5\text{ V}$ ;  $T_{amb} = 25\text{ °C}$ , unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
$V_{CC}$	Power supply voltage operating range (Note 1)		2.0	3.0	20	V
<b>Op amp</b>						
$V_{IO}$	Input offset voltage		-	0.2	0.9	mV
$I_{IO}$	Input offset current (excluding Amp 1)		-	1	50	nA
$I_{i(bias)}$	Input bias current		-	50	150	nA
$V_{IN}$	Common mode Input voltage range (excluding Amp 1)		0	-	$V_{CC} - 1.0$	V
$I_{CC}$	Supply current	SA58601D $R_L = \infty$	-	0.6	1.0	mA
		SA58604D $R_L = \infty$	-	1.2	2.0	mA
$G_{ol}$	Open loop gain		-	100	-	dB
$V_{OL}$	LOW-level output voltage	$R_L = \infty$	-	10	100	mV
$V_{OH}$	HIGH-level output voltage	$R_L = \infty$	$V_{CC} - 1.1$	$V_{CC} - 0.8$	-	V
CMRR	Common mode rejection ratio		65	85	-	dB
PSRR	Power supply rejection ratio		65	100	-	dB
$I_{O(source)}$	Output current source		20	35	-	mA
$I_{O(sink)}$	Output current sink		10	20	-	mA
<b>Shunt regulator</b>						
$V_{ref}$	Reference voltage		2.450	2.500	2.550	V
$\Delta V_{ref}$	Reference voltage fluctuation	$T_{amb} = -40\text{ to }+85\text{ °C}$	-	5	17	mV
$I_{min}$	Minimum cathode current		-	0.4	1.0	mA
$ Z_{KA} $	Dynamic impedance		-	0.4	0.7	$\Omega$

### NOTES:

1. Minimum value of operating voltage is for op amp only.

# Dual and quad operational amplifiers with shunt regulator

SA58601; SA58604

## TYPICAL CHARACTERIZATION CURVES

$V_{CC} = 5\text{ V}$ ,  $T_{amb} = 25\text{ }^\circ\text{C}$ , unless otherwise specified.

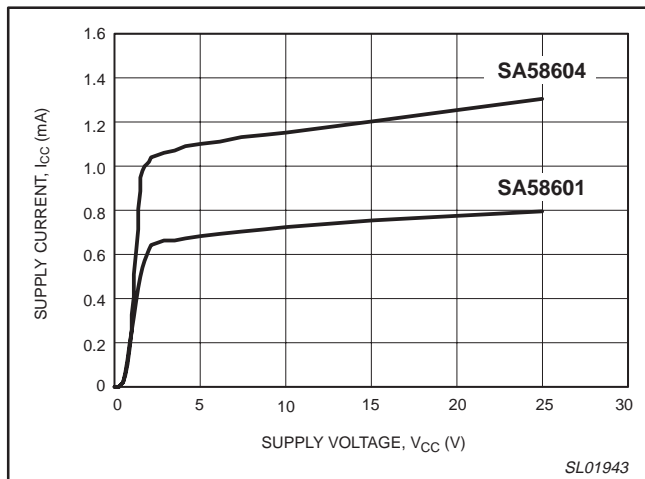


Figure 4. Supply current versus supply voltage.

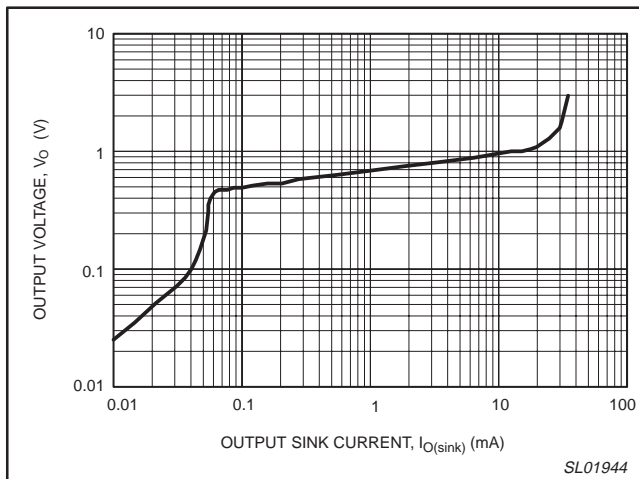


Figure 5. Output voltage versus sink current.

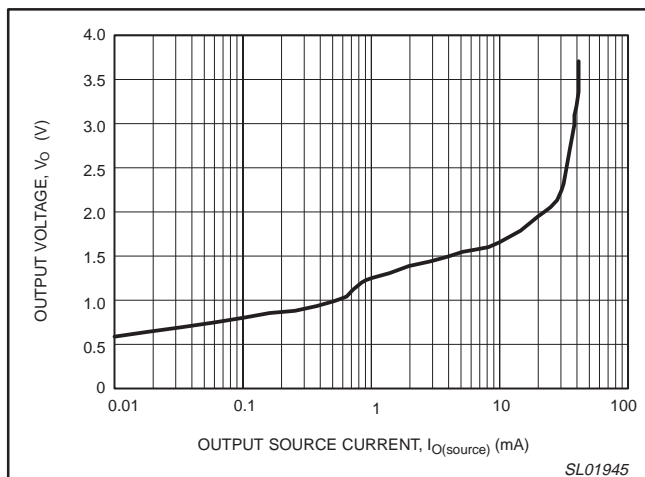


Figure 6. Output voltage versus source current.

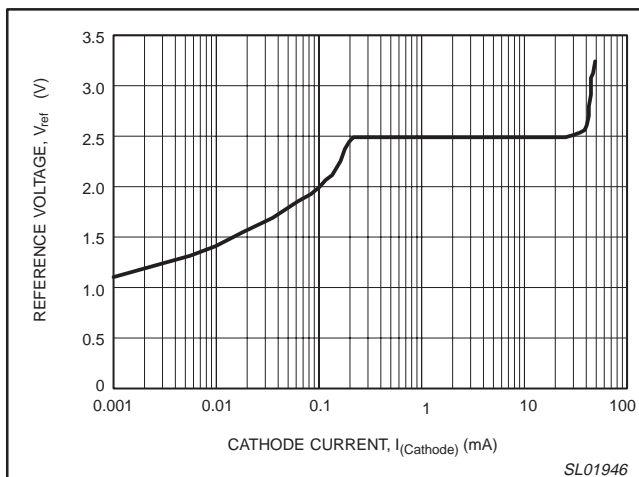


Figure 7. Reference voltage versus cathode current.

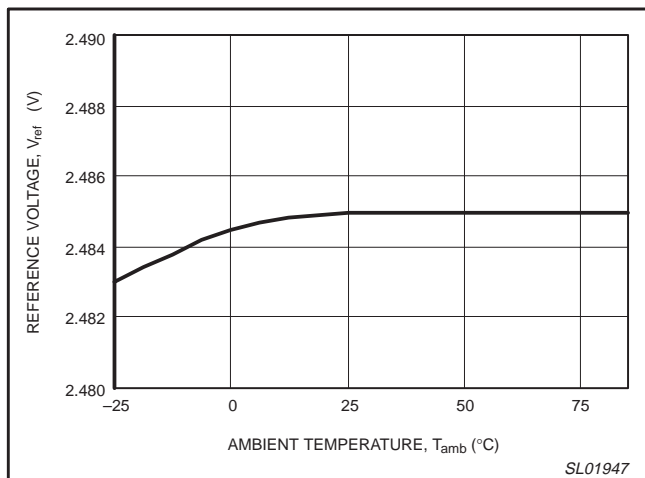


Figure 8. Reference voltage versus ambient temperature.

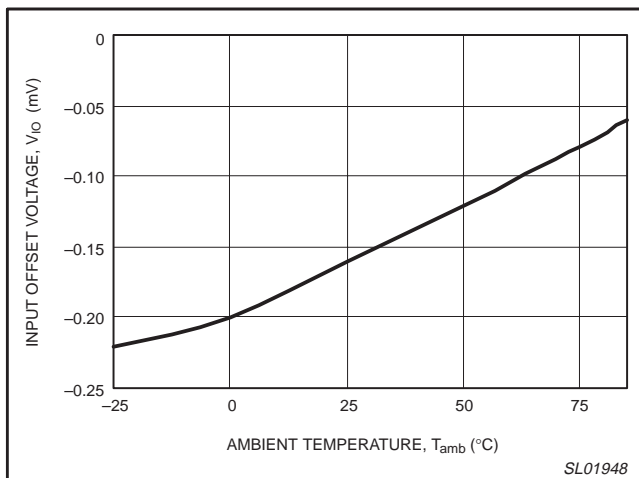


Figure 9. Input offset voltage versus ambient temperature.

# Dual and quad operational amplifiers with shunt regulator

SA58601; SA58604

## TYPICAL CHARACTERIZATION CURVES (continued)

$V_{CC} = 5\text{ V}$ ,  $T_{amb} = 25\text{ }^\circ\text{C}$ , unless otherwise specified.

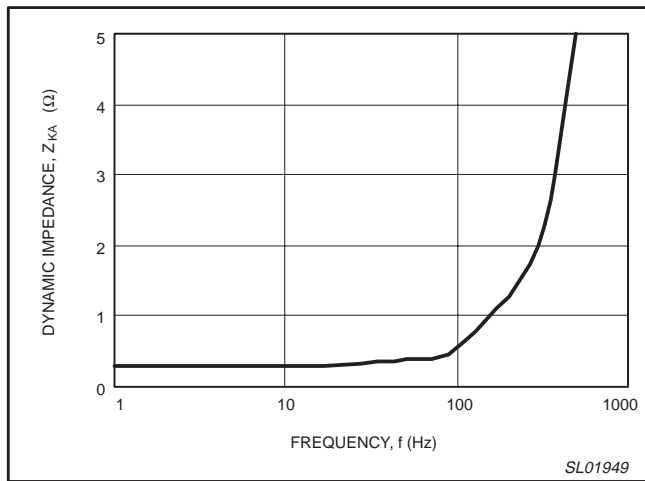


Figure 10. Dynamic impedance versus frequency.

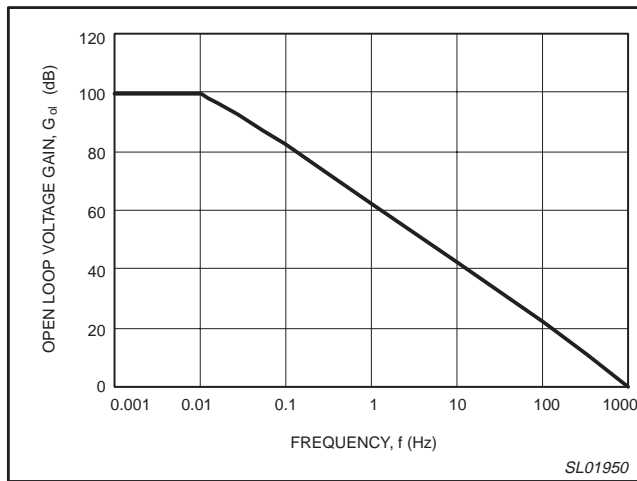


Figure 11. Open loop voltage gain versus frequency.

## FUNCTIONAL DESCRIPTION

### General description

The SA58601 and SA58604 are dual and quad, low power, precision, single supply operational amplifiers with a shunt voltage reference connected to the non-inverting terminal of the first amplifier. The internal circuit diagrams for the amplifiers and reference circuits are shown in Figures 12 and 13. With the ability to operate over a wide supply voltage range of 2 V to 20 V, they may be used in various applications, such as battery chargers, switching power supplies, AC adapters, instrumentation and sense amplifiers.

### Amplifiers

The amplifiers have low input offset voltage of typically 200  $\mu\text{V}$ . They are well suited for handling current detection signals and other low amplitude signals. With low supply current of 600  $\mu\text{A}$  per amplifier and the ability to operate from a single supply down to 2 V makes them suitable for battery powered applications.

### Shunt regulator

The on-chip shunt regulator circuit has its cathode internally connected to the non-inverting terminal of the first amplifier. The cathode is externally biased by a pull-up resistor. At power supply voltage of 5 V or greater, the reference is set at 2.5 V. Figure 7, "Reference voltage versus cathode current", may be used to determine typical cathode current to achieve a desired reference voltage. The typical minimum cathode current needed for 2.5 V is 400  $\mu\text{A}$ . To achieve 2.5 V over voltage and temperature, a cathode current of 1 mA is recommended.

For operation at less than 5 V supply voltage, the reference voltage should be set midway between  $V_{CC}$  and ground.

# Dual and quad operational amplifiers with shunt regulator

SA58601; SA58604

## EQUIVALENT CIRCUITS

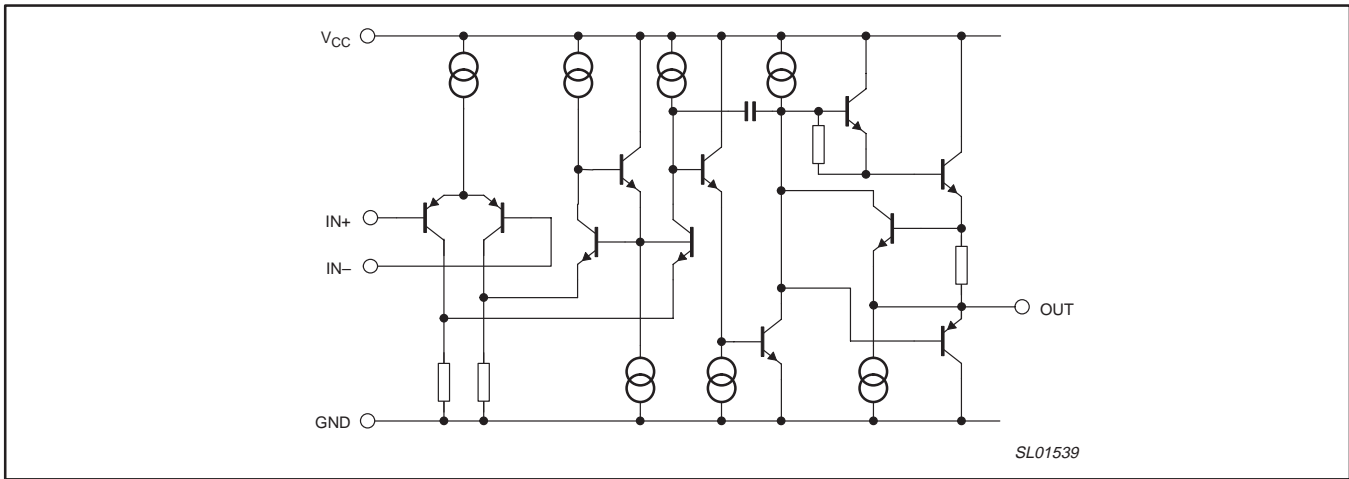


Figure 12. Amplifier equivalent circuit.

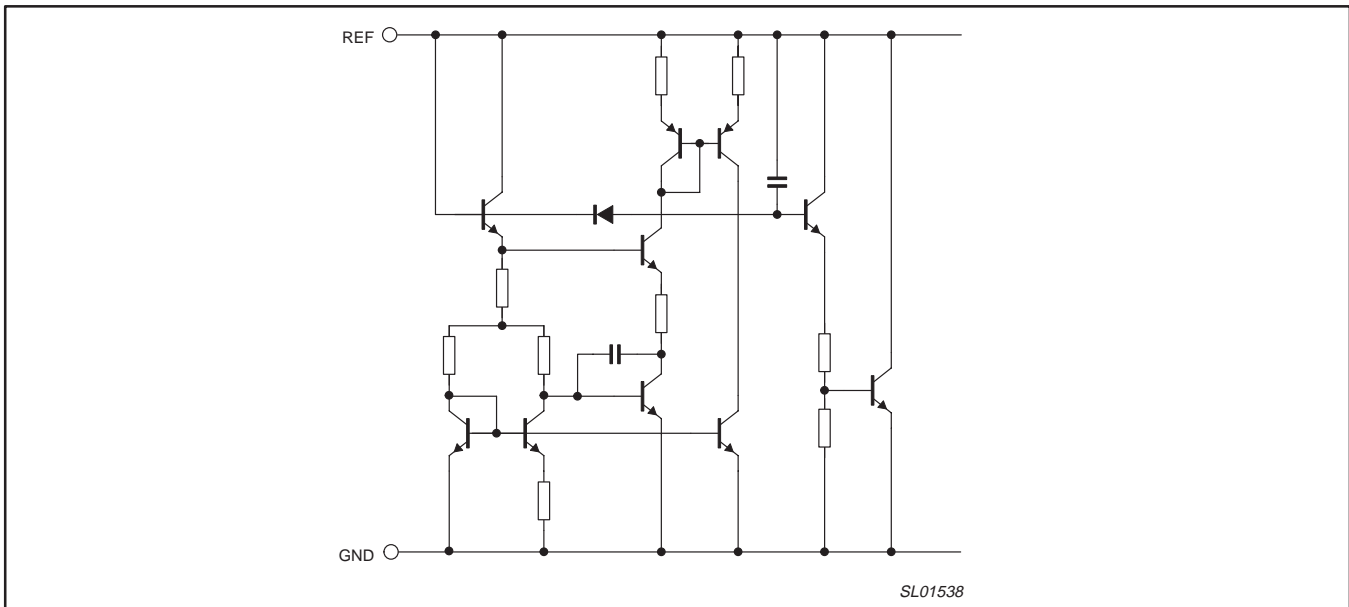


Figure 13. Reference/Shunt regulator equivalent circuit.

# Dual and quad operational amplifiers with shunt regulator

## SA58601; SA58604

### APPLICATION INFORMATION

#### Common Mode Rejection (CMR) errors

When used with high resistance sensors, differential amplifiers will have high CMR errors due to their relatively low input impedance. CMR errors also are caused by input resistor mismatch. CMR performance is greatly improved with a configuration that eliminate the effects of external resistance matching errors.

#### Biasing of single supply op amps

The resistor-divider biasing network shown in Figure 14 is low cost and keeps the op amp output voltage at  $V_{CC}/2$ . However, the op amp's CMR depends entirely upon the RC time constant which is formed by the biasing resistors, RB1 and RB2 and decoupling capacitor, C2. As a rule of thumb, the time constant of the RC biasing network should be 10 times longer than the time constant of the input coupling network ( $R_{IN}$  and  $C_{IN}$ ) to ensure satisfactory CMR.

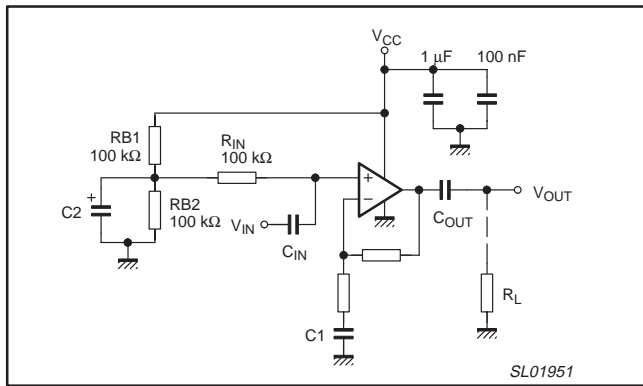


Figure 14. Resistor-divider biasing network.

Another way to provide the necessary  $V_{CC}/2$  biasing for single supply operation is to use a zener diode shunt regulator. The SA58601 and SA58604 provides a zener diode shunt regulator that is internally connected to the non-inverting input of the AMP1. The shunt regulator reference voltage versus the cathode current is shown in Figure 7. The reference voltage of the internal diode is adjusted by externally adjusting the cathode current. Typically 400  $\mu$ A cathode current provides 2.5 V; values of cathode current less than 200  $\mu$ A provides a lower reference voltage. For example, 5  $\mu$ A provides typically 1.3 V. The recommended cathode current range is from 1  $\mu$ A to 10 mA.

#### SA58601 instrumentation amplifier

Figure 15 is a SA58601 instrumentation amplifier which has few external parts. The differential gain is expressed as:

$$\frac{V_{OUT}}{(V1 - V2)} = - \left[ 1 + \frac{R2}{R1} + 2 \left( \frac{R2}{Rg} \right) \right]$$

To achieve minimum gain,  $R1 = R2$ ;  $Rg = \text{infinity}$  (open). The minimum gain is approximately  $-4$  to  $-5$ .

At frequencies above the flat response of the amplifier's gain response, V1 attenuates more than V2. the unequal attenuation causes the signal to unbalance, which reduces CMR at high frequencies.

This circuit provides excellent CMR in low voltage, single supply applications. The SA58601 has a internal shunt regulator that is used to provide bias to the non-inverting input of AMP1. To set the reference at 2.5 V, approximately 1 mA of cathode current is required. For  $V_{CC}$  of 5 V, the non-inverting input and cathode of the internal shunt regulator (pin 3) is pulled up to  $V_{CC}$ . The external pull-up resistor is determined by the following expression:

$$R_{PU} = \frac{(V_{CC} - V_{ref})}{1 \text{ mA}}$$

where:  $V_{CC} = 5 \text{ V}$   
 $V_{ref} = 2.5 \text{ V}$

then  $R_{PU} = 2.5 \text{ k}\Omega$

Choose the closest standard value of 2.4 k $\Omega$ .

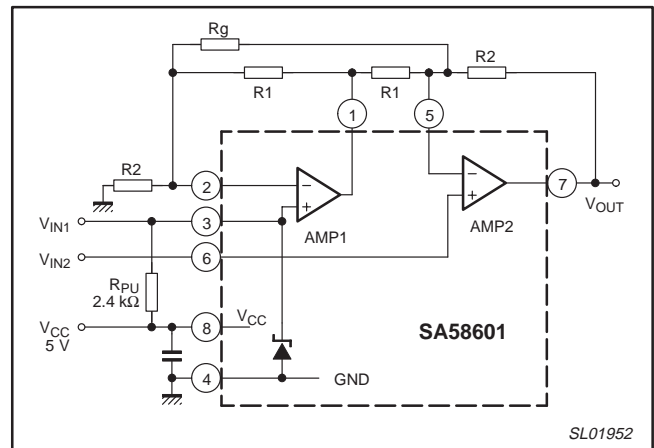


Figure 15. SA58601 instrumentation amplifier.



# Dual and quad operational amplifiers with shunt regulator

SA58601; SA58604

## SA58604 instrumentation amplifier

Figure 16 is an instrumentation amplifier using the SA58604 Quad Op Amp with Shunt Regulator. This three op amp configuration provides very high input resistance, matched input resistance, and good bandwidth. The differential gain is expressed in the following equation:

$$\frac{V_{OUT}}{(V1 - V2)} = 1 + \frac{2Rf}{Rg}$$

AMP2 and AMP3 are buffer amplifiers that provide high impedance inputs. Rg is the gain adjust which is common to both amplifiers. When Rg is open, the gain is 1. The large differential gain with respect to the common mode gain available from the first stage buffer amplifiers ensures that the CMRR in the differential amplifier output stage is greatly improved. AMP4 is used as a difference amplifier. The differential amplifier output stage is usually used with low (x2) or unity gain. For unity gain operation, R3 = R4 and are closely matched within 1% or less tolerance. The resistors should have low drift with temperature.

The reference voltage, Vref may be sourced from AMP1, as detailed in the biasing section.

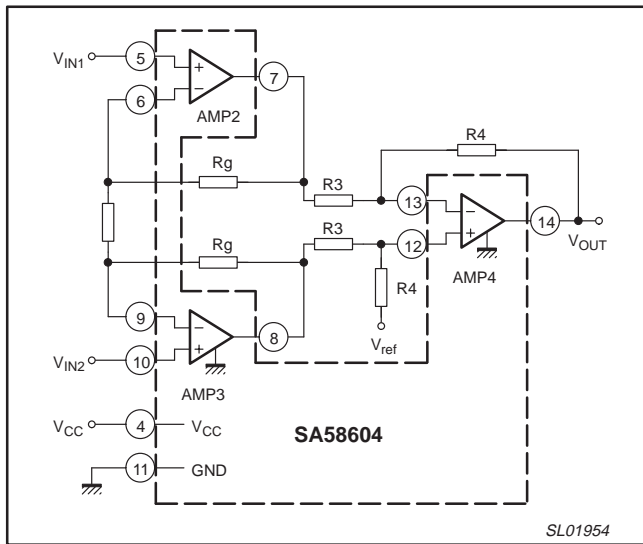


Figure 16. SA58604 instrumentation amplifier.

## Comparator circuit

Figure 17 is an application circuit in which AMP1 is configured as a comparator. The non-inverting input, IN+ is logic HIGH (internally connected to Vref), and the inverting input, IN- is pulled LOW (to ground), then the the output goes HIGH (VCC - 1.1 V). Conversely, if the inverting input is pulled HIGH (to VCC), then the output goes LOW (see Table 1).

Table 1. Logic table for AMP1

IN+ (Vref)	IN-	OUT	Vout level
H	L	H	VCC - 1.1 V
H	H	L	10 mV

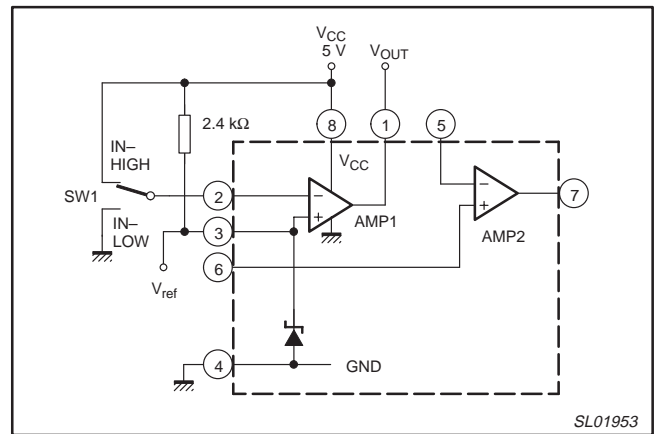


Figure 17. Comparator configuration, AMP1.

# Dual and quad operational amplifiers with shunt regulator

SA58601; SA58604

## PACKING METHOD

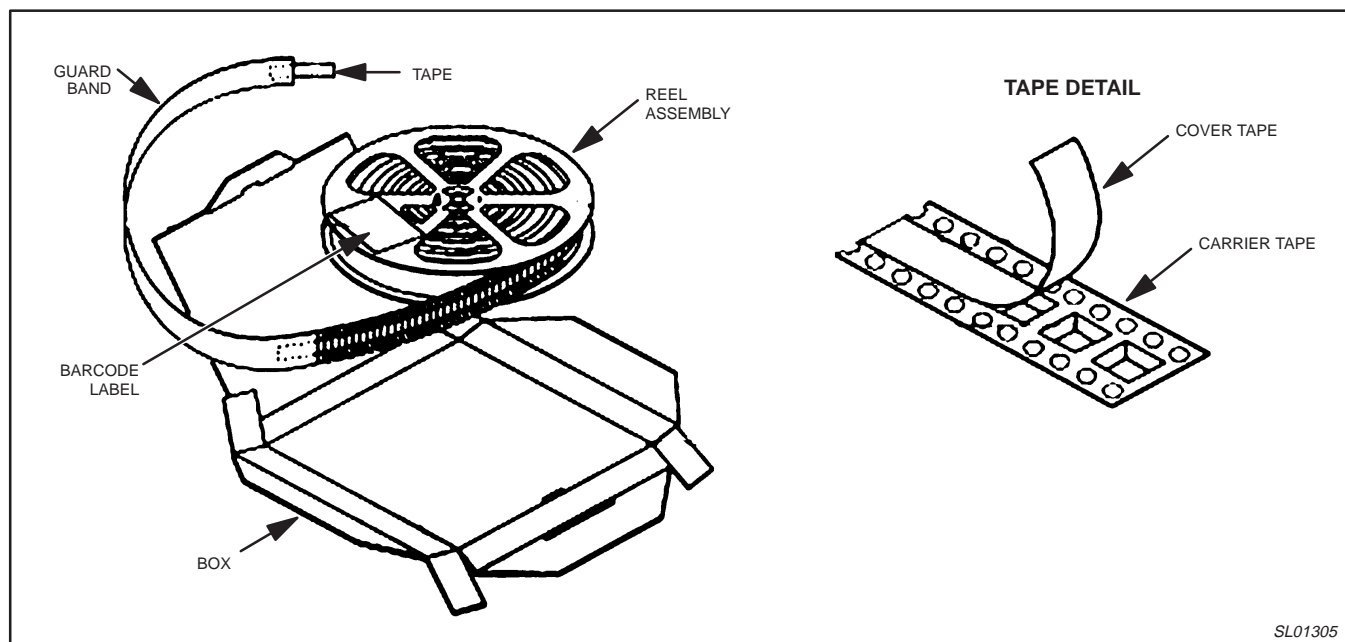


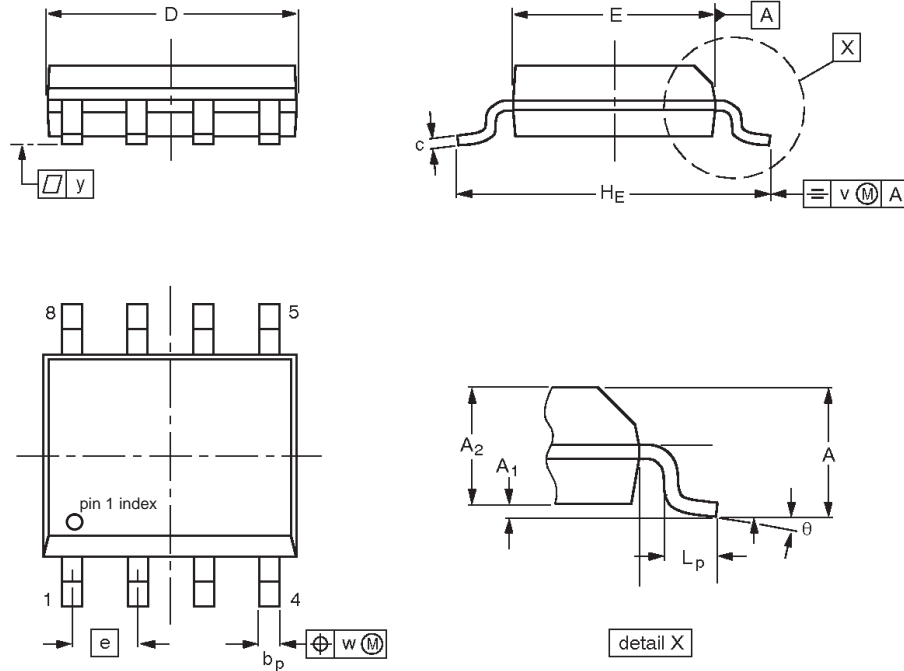
Figure 18. Tape and reel packing method.

SL01305

# Dual and quad operational amplifiers with shunt regulator

SA58601; SA58604

**SO8: plastic small outline package; 8 leads; body width 3.9 mm**



**DIMENSIONS (inch dimensions are derived from the original mm dimensions)**

UNIT	A max.	A <sub>1</sub>	A <sub>2</sub>	B <sub>2</sub>	b <sub>p</sub>	c	D <sup>(1)</sup>	E <sup>(2)</sup>	e	H <sub>E</sub>	L <sub>p</sub>	y	θ
mm	1.73	0.25 0.10	1.45 1.25	4.95 4.80	0.51 0.33	0.25 0.19	4.95 4.80	4.0 3.8	1.27	6.2 5.8	1.27 0.38	0.076	8° 0°
inches	0.068	0.010 0.004	0.057 0.049	0.189 0.195	0.013 0.020	0.0100 0.0075	0.20 0.19	0.16 0.15	0.050	0.244 0.228	0.050 0.015	0.003	

**Notes**

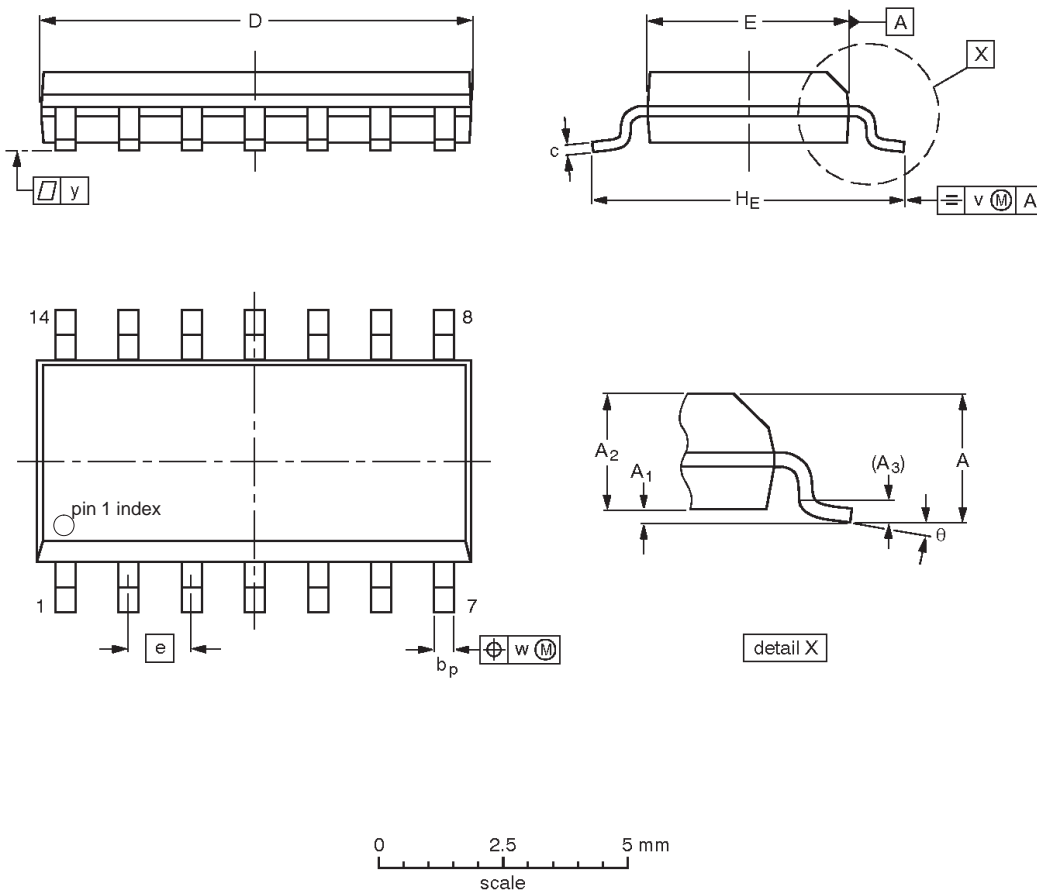
1. Plastic or metal protrusions of 0.15 mm maximum per side are not included.
2. Plastic or metal protrusions of 0.25 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES		
	IEC	JEDEC	EIAJ
SO8	076E03	MS-012	

# Dual and quad operational amplifiers with shunt regulator

SA58601; SA58604

**SO14: plastic small outline package; 14 leads; body width 3.9 mm; body thickness 1.45 mm**



**DIMENSIONS (inch dimensions are derived from the original mm dimensions)**

UNIT	A max.	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	b <sub>p</sub>	c	D <sup>(1)</sup>	E <sup>(1)</sup>	e	H <sub>E</sub>	θ
mm	1.73	0.25 0.10	1.45	0.20	0.51 0.33	0.25 0.19	8.74 8.53	3.99 3.81	1.27	6.2 5.8	8° 0°
inches	0.068	0.010 0.004	0.057	0.008	0.020 0.013	0.0100 0.0075	0.35 0.34	0.16 0.15	0.050	0.244 0.228	

**Note**

1. Plastic or metal protrusions of 0.15 mm maximum per side are not included.

REFERENCES				
	JEDEC	EIAJ		
SO14	MS-012			

---

**Dual and quad operational amplifiers  
with shunt regulator**

---

SA58601; SA58604

---

**REVISION HISTORY**

Rev	Date	Description
_2	20021108	<b>Product data; second version (9397 750 10676).</b> <b>Supersedes SA58601_SA58604_1 of 2001 Oct 03 (9397 750 08957).</b> Engineering Change Notice 853-2287 29165 (date: 20021107). <b>Modifications:</b> <ul style="list-style-type: none"><li>• Add "Typical characterization curves" and "Application information" sections.</li></ul>
_1	20011003	<b>Product data; initial version (9397 750 08957).</b> Engineering Change Notice 853-2287 27197 (date: 20011003).

# Dual and quad operational amplifiers with shunt regulator

SA58601; SA58604

## Data sheet status

Level	Data sheet status <sup>[1]</sup>	Product status <sup>[2] [3]</sup>	Definitions
I	Objective data	Development	This data sheet contains data from the objective specification for product development. Philips Semiconductors reserves the right to change the specification in any manner without notice.
II	Preliminary data	Qualification	This data sheet contains data from the preliminary specification. Supplementary data will be published at a later date. Philips Semiconductors reserves the right to change the specification without notice, in order to improve the design and supply the best possible product.
III	Product data	Production	This data sheet contains data from the product specification. Philips Semiconductors reserves the right to make changes at any time in order to improve the design, manufacturing and supply. Relevant changes will be communicated via a Customer Product/Process Change Notification (CPCN).

[1] Please consult the most recently issued data sheet before initiating or completing a design.

[2] The product status of the device(s) described in this data sheet may have changed since this data sheet was published. The latest information is available on the Internet at URL <http://www.semiconductors.philips.com>.

[3] For data sheets describing multiple type numbers, the highest-level product status determines the data sheet status.

## Definitions

**Short-form specification** — The data in a short-form specification is extracted from a full data sheet with the same type number and title. For detailed information see the relevant data sheet or data handbook.

**Limiting values definition** — Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 60134). Stress above one or more of the limiting values may cause permanent damage to the device. These are stress ratings only and operation of the device at these or at any other conditions above those given in the Characteristics sections of the specification is not implied. Exposure to limiting values for extended periods may affect device reliability.

**Application information** — Applications that are described herein for any of these products are for illustrative purposes only. Philips Semiconductors make no representation or warranty that such applications will be suitable for the specified use without further testing or modification.

## Disclaimers

**Life support** — These products are not designed for use in life support appliances, devices, or systems where malfunction of these products can reasonably be expected to result in personal injury. Philips Semiconductors customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify Philips Semiconductors for any damages resulting from such application.

**Right to make changes** — Philips Semiconductors reserves the right to make changes in the products—including circuits, standard cells, and/or software—described or contained herein in order to improve design and/or performance. When the product is in full production (status 'Production'), relevant changes will be communicated via a Customer Product/Process Change Notification (CPCN). Philips Semiconductors assumes no responsibility or liability for the use of any of these products, conveys no license or title under any patent, copyright, or mask work right to these products, and makes no representations or warranties that these products are free from patent, copyright, or mask work right infringement, unless otherwise specified.

## Contact information

For additional information please visit  
<http://www.semiconductors.philips.com>. Fax: +31 40 27 24825

© Koninklijke Philips Electronics N.V. 2002  
All rights reserved. Printed in U.S.A.

Date of release: 11-02

For sales offices addresses send e-mail to:  
[sales.addresses@www.semiconductors.philips.com](mailto:sales.addresses@www.semiconductors.philips.com)

Document order number:

9397 750 10676

*Let's make things better.*