WA3721,WA3722

10MHz, RRIO CMOS Operational Amplifiers

1. General Description

The WA3721(single)，WA3722 (dual) are low noise, low voltage and micro power operational amplifiers. With an excellent bandwidth of 10MHz, a slew rate of 9V/μs and a quiescent current of 1000μA per amplifier at 5V, the WA372x family can be designed into a wide range of applications.

The WA372x op-amps are designed to provide optimal performance in low voltage and low noise systems. The input common-mode voltage range includes ground, and the maximum input offset voltage are 3.5mV. These parts provide rail-to-rail output swing into heavy loads. The WA372x family is specified for single or dual power supplies of +2.5V to +5.5V. All models are specified over the extended industrial temperature range of −40℃ to +125℃.

The WA3721 is available in SOT353 package. The WA3722 is available in MSOP-8, DFN2*2-8, and SOP-8 packages.

2. Features

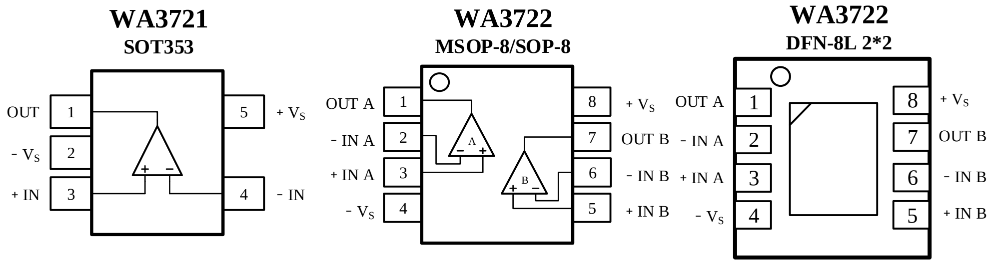
- High Slew Rate: 9V/μs
- Wide Bandwidth: 10MHz
- Low Power: 1000μA per Amplifier Supply Current
- Settling Time to 0.1% with 2V Step: 0.25μs
- Low Noise: 20nV/√Hz@10kHz
- Low Offset Voltage: 3.5 mV Maximum
- Unit Gain Stable
- Rail-to-Rail Input and Output
- Input Voltage Range: -0.1V to +5.1V at 5V Supply
- Operating Power Supply: +2.5V to +5.5V
- Operating Temperature Range: -40℃ to +125℃

3. Applications

- Photodiode Amplification
- Sensor Interfaces
- Audio Outputs
- Active Filters
- Driving A/D Converters
- Portable Equipment & Battery-Powered Instrumentation

4. Pin Configuration

(Top View)



5. Pin Description

Symbol	Description
-INA, -INB	Inverting Input of the Amplifier. The Voltage range can go from (V_{S-} – 0.1V) to (V_{S+} + 0.1V).
+INA, +INB	Non-Inverting Input of Amplifier. This pin has the same voltage range as –IN.
+V_S	Positive Power Supply. The voltage is from 2.5V to 5.5V. Split supplies are possible as long as the voltage between V_{S+} and V_{S-} is between 2.5V and 5.5V. A bypass capacitor of 0.1μF 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 2.5V 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.
OUTA, OUTB	Amplifier Output.

6. Absolute Maximum Ratings（T_A=25℃）

SYMBOL	DESCRIPTION	VALUE	UNIT
V_{S+},V_{S-}	Supply Voltage, V_{S+} to $V_{S–}$	7.0	V
V_{CM}	Common-Mode Input Voltage	$V_{S–}$ – 0.3 to V_{S+} + 0.3	V
ESD	Electrostatic Discharge Voltage	HBM ±4000	V
		CDM ±2000	V
T_{STG}	Storage Temperature Range	-65 to 150	°C
T_J	Junction Temperature	160	°C
T_{JL}	Lead Temperature Range (Soldering 10 sec)	260	°C

NOTE1: 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.

NOTE2: Provided device does not exceed maximum junction temperature (T_J) at any time.

7. Electrical Characteristics（T_A=25℃）

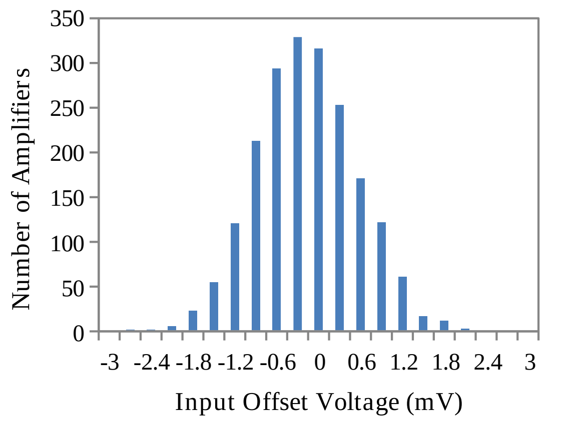
(V_S=5.0V ,T_A=+25℃ ,V_{CM}=V_S /2 ,V_O=V_S/2, R_L=10kΩ connected to V_S/2, unless otherwise noted)

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT
INPUT CHARACTERISTICS						
V_{OS}	Input offset voltage		-3.5	±0.8	+3.5	mV
V_{OS}TC	Offset voltage drift			3		μV/°C
I_B	Input bias current			1		pA
	Over temperature			800		pA
I_{OS}	Input offset current			1		pA
V_{CM}	Common-mode voltage range		V_{S-}–0.1		V_{S+}+0.1	V
CMRR	Common-mode rejection ratio	V_{CM} = 0.05V to 3.5V	70	84		dB
	Over temperature	V_{CM} = 0.05V to 3.5V		80		dB
		V_{CM} = V_{S-}–0.1 to V_{S+}+0.1 V	60	76		dB
A_{VOL}	Open-loop voltage gain	R_L = 10kΩ, V_O = 0.1 to 4.9 V	90	102		dB
	Over temperature	R_L = 10kΩ, V_O = 0.1 to 4.9 V		90		dB
		R_L = 600Ω, V_O = 0.2 to 4.8 V	80	89		dB
	Over temperature	R_L = 600Ω, V_O = 0.2 to 4.8 V		80		dB
R_{IN}	Input resistance			100		GΩ
C_{IN}	Input capacitance	Differential		2.0		pF
		Common mode		3.5		pF
OUTPUT CHARACTERISTICS						
V_{OH}	High output voltage swing	R_L = 600Ω		V_{S+}–100		mV
		R_L = 10kΩ		V_{S+}–8		mV
V_{OL}	Low output voltage swing	R_L = 600Ω		100		mV
		R_L = 10kΩ		8		mV
I_{SC}	Short-circuit current	Source current through 10Ω		40		mA
		Sink current through 10Ω		40		mA
OUTPUT CHARACTERISTICS						
Z_{OUT}	Closed-loop output impedance	f = 200kHz, G = +1		0.8		Ω
	Open-loop output impedance	f = 1MHz, IO = 0		3		Ω

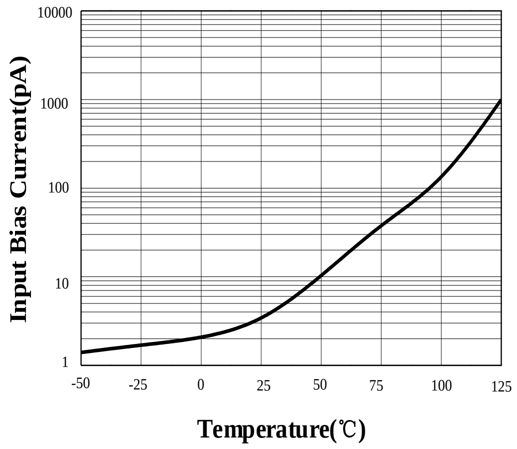
SYMBOL	PARAMETER	TEST CONDITIONS	MIN	TYP.	MAX	UNIT
DYNAMIC PERFORMANCE						
GBW	Gain bandwidth product	f = 1kHz		10		MHz
Φ_M	Phase margin	C_L = 100pF		60		°
SR	Slew rate	G = +1, C_L = 100pF, V_O = 1.5V to 3.5V		9		V/μs
BW_P	Full power bandwidth	<1% distortion		400		kHz
t_S	Settling time	To 0.1%, G = +1, 2V step		0.25		μs
		To 0.01%, G = +1, 2V step		0.28		
t_{OR}	Overload recovery time	V_{IN} * Gain > V_S		0.5		μs
NOISE PERFORMANCE						
V_n	Input voltage noise	f = 0.1 to 10 Hz		12		μV_{P-P}
e_n	Input voltage noise density	f = 10kHz		90		nV/√Hz
I_n	Input current noise density	f = 10kHz		5		fA/ √ Hz
POWER SUPPLY						
V_S	Operating supply voltage		2.5		5.5	V
PSRR	Power supply rejection ratio	V_S = 2.7V to 5.5V, V_{CM} < V_{S+} +0.5V	70	95		dB
	Over temperature			80		
I_Q	Quiescent current (per amplifier)			1000	1300	μA
	Over temperature			1200	1600	
THERMAL CHARACTERISTICS						
T_A	Operating temperature range		-40		+125	°C
θ_{JA}	Package thermal resistance	MSOP-8		216		°C /W
		SOP-8		125		
		DFN-8L		201		

8. Typical Performance Characteristics

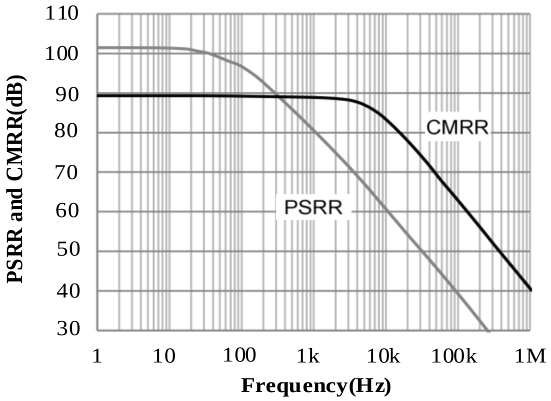
T_A = +25℃, V_{CM} = V_S/2, and R_L=10kΩconnected to V_S/2, unless otherwise noted.



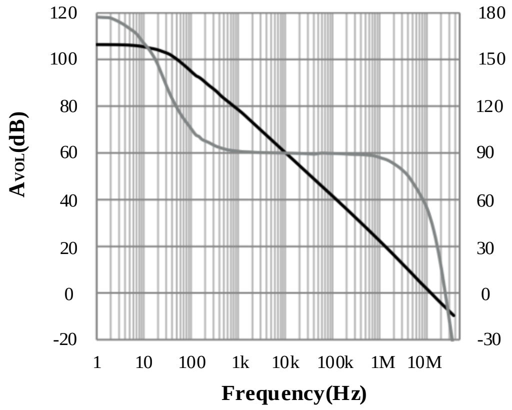
Input Offset Voltage Production



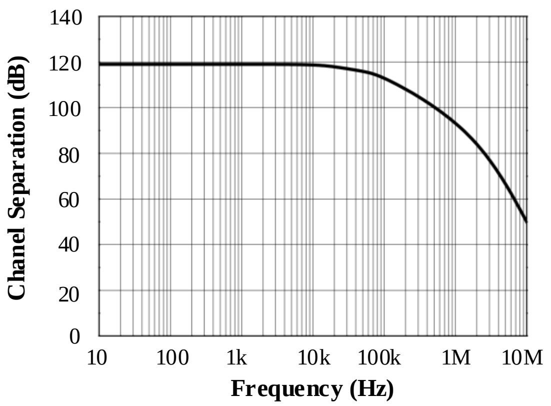
Input Bias Current as a Function of Temperature



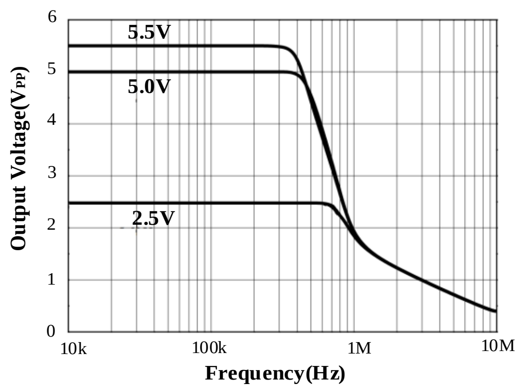
Power Supply and Common-mode Rejection Ratio as a Function of Frequency



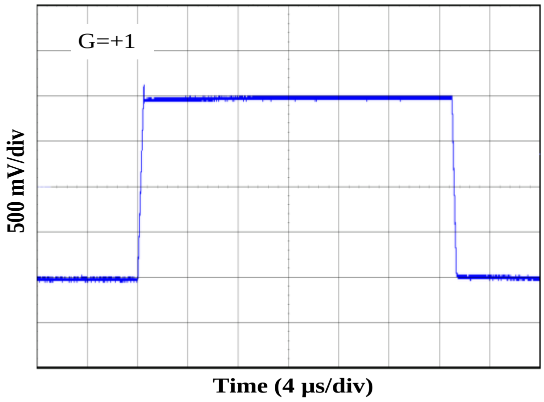
Open-loop Gain and Phase as a function of Frequency



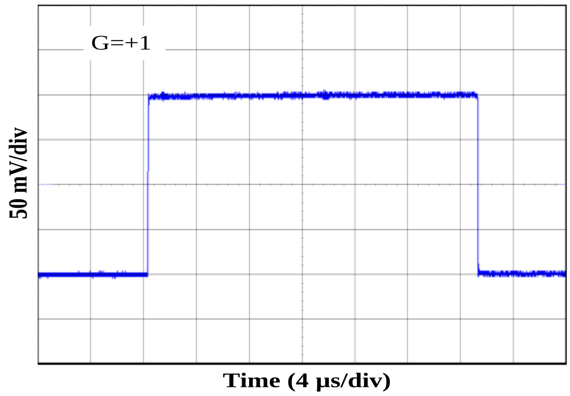
Channel Separation as a function of Frequency



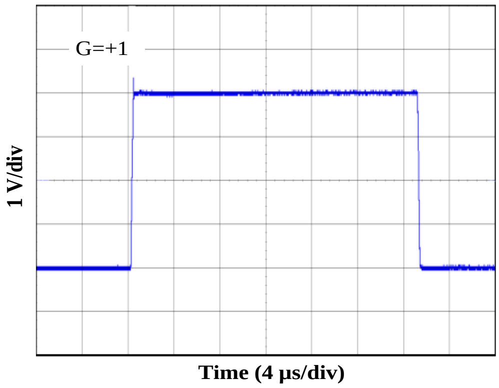
Maximum Output Voltage as a function of Frequency



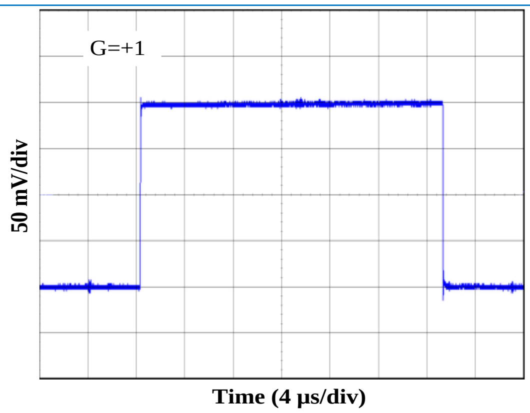
Large-Signal Step Response at 2.7V



Small-Signal Step Response at 2.7V



Large-Signal Step Response at 5V



Small-Signal Step Response at 5V

9. Application Notes

9.1 Low Input Bias Current

The WA372x family is a CMOS op-amp family and features 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.

9.2 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 1012Ω. A 5V difference would cause 5pA of current to flow, which is greater than the WA372x’s input bias current at +25℃ (±1pA, 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 12 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.

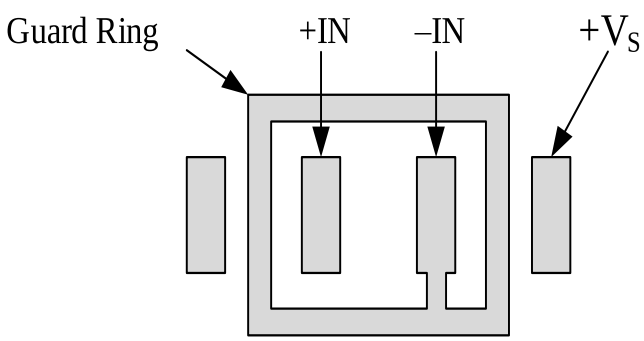


Figure 1 Use a Guard Ring around Sensitive Pins

9.3 Ground Sensing And Rail To Rail

The input common-mode voltage range of the WA372x series extends 300mV beyond the supply rails. This is achieved with a complementary input stage—a 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-} − 0.1V) to (V_{S+} + 0.1V), the WA372x op-amps can easily perform 'true ground' sensing.

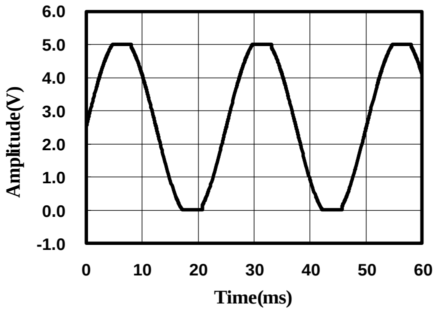


Figure 2 No Phase Inversion with Inputs Greater Than the Power-Supply Voltage

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 5mV 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.

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℃ 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.

9.4 Capacitive Load And Stability

The WA372x can directly drive 1nF 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 R_{ISO} forms a voltage divider with the R_L.

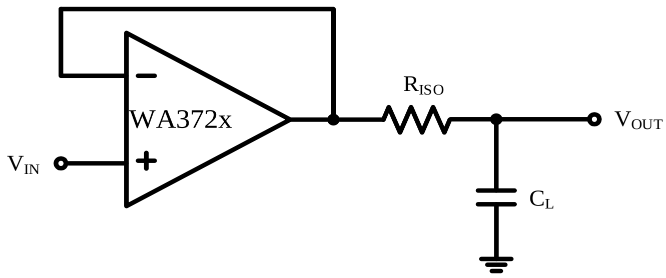


Figure 3 Indirectly Driving Heavy Capacitive Load

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.

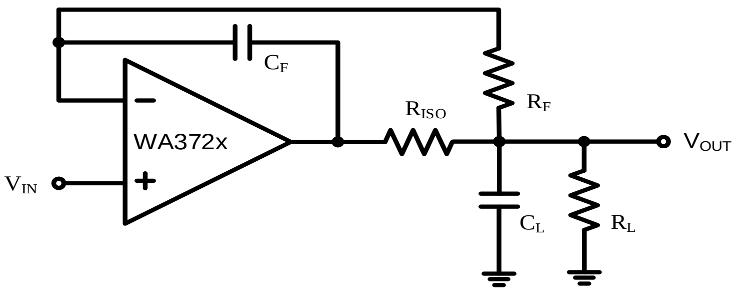


Figure 4. Indirectly Driving Heavy Capacitive Load with DC Accuracy

For no-buffer configuration, there are two 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.

9.5 Power Supply Layout And Bypass

The WA372x family operates from either a single +2.5V to +5.5V supply or dual ±1.25V to ±2.25V 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 2mm 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. 2.2 μF 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).

9.6 Grounding

A ground plane layer is important for the WA372x 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.

9.7 Input To Output Coupling

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

10. Typical Application Circuits

10.1 Differential Amplifier

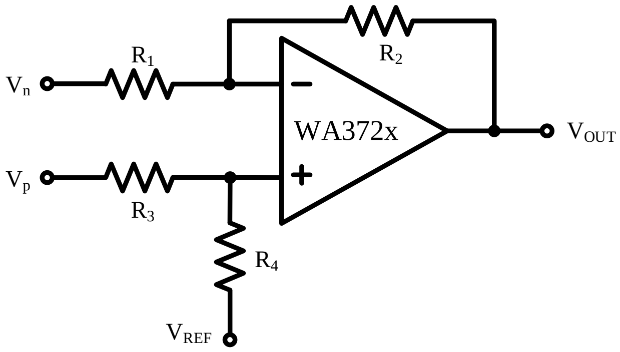
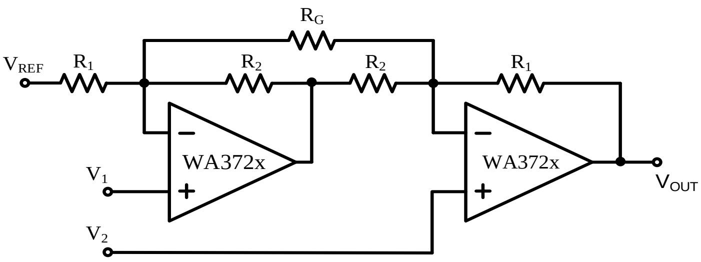


Figure 5 Differential Amplifier

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:

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

10.2 Instrumentation Amplifier



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

Figure 6 Instrumentation Amplifier

The WA372x family is well suited for conditioning sensor signals in battery-powered applications. Figure 6 shows a two op-amp instrumentation amplifier, using the WA372x 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 VREF is typically $V_S/2$.

10.3 Buffered Chemical Sensors

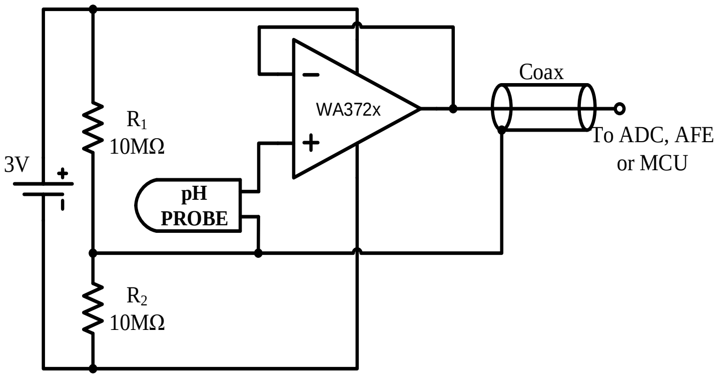


Figure 7 Buffered pH Probe

The WA372x 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 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 WA372x 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.

10.4 Shunt-Based Current Sensing Amplifier

The current sensing amplification shown in Figure 8 has a slew rate of 2πf V_{PP} for the output of sine wave signal, and has a slew rate of 2fVPP for the output of triangular wave signal. In most of motor control systems, the PWM frequency is at 10kHz to 20kHz, and one cycle time is 100μs for a 10kHz of PWM frequency. In current shunt monitoring for a motor phase, the phase current is converted to a phase voltage signal for ADC sampling. This sampling voltage signal must be settled before entering the ADC. As the Figure 8 shown, the total settling time of a current shunt monitor circuit includes: the rising edge delay time (t_{SR}) due to the op-amp's slew rate, and the measurement settling time (t_{SET}). If the minimum duty cycle of the PWM is defined at 5%, and the t_{SR} is required at 20% of a total time window for a phase current monitoring, in case of a 3.3V motor control system (3.3V MCU with 12-bit ADC), the op-amp's slew rate should be more than:

$$3.3\text{V} / (100\mu\text{s} \times 5\% \times 20\%) = 3.3\ \text{V}/\mu\text{s}$$

At the same time, the op-amp's bandwidth should be much greater than the PWM frequency, like 10 time at least.

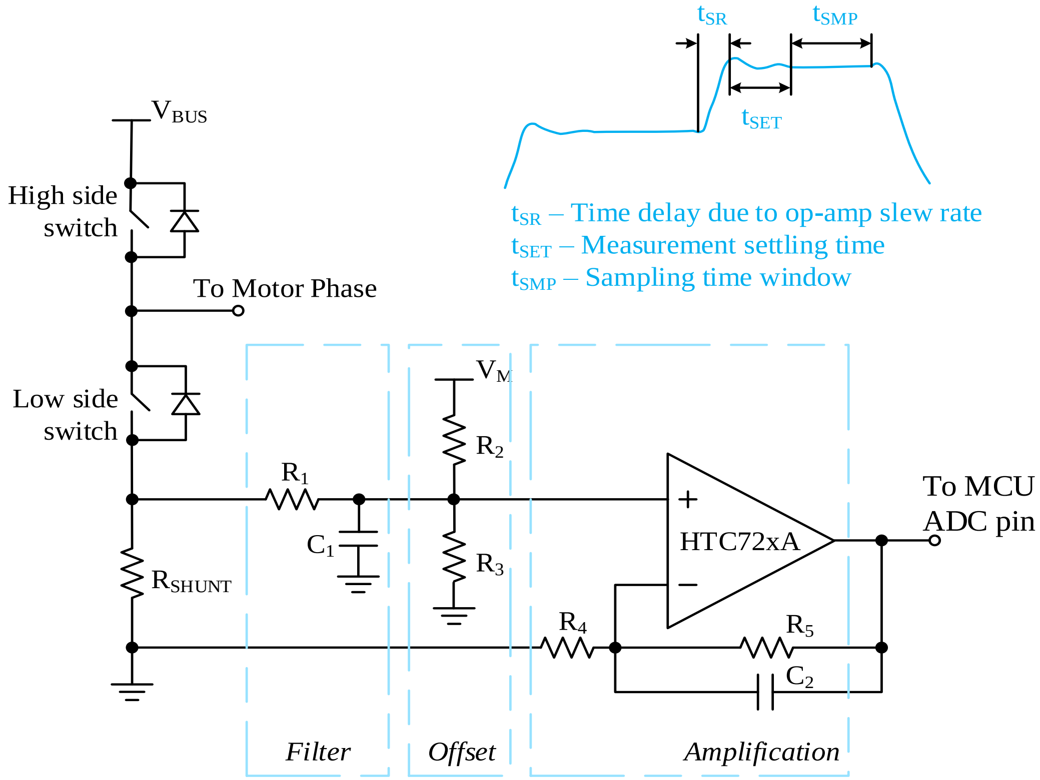
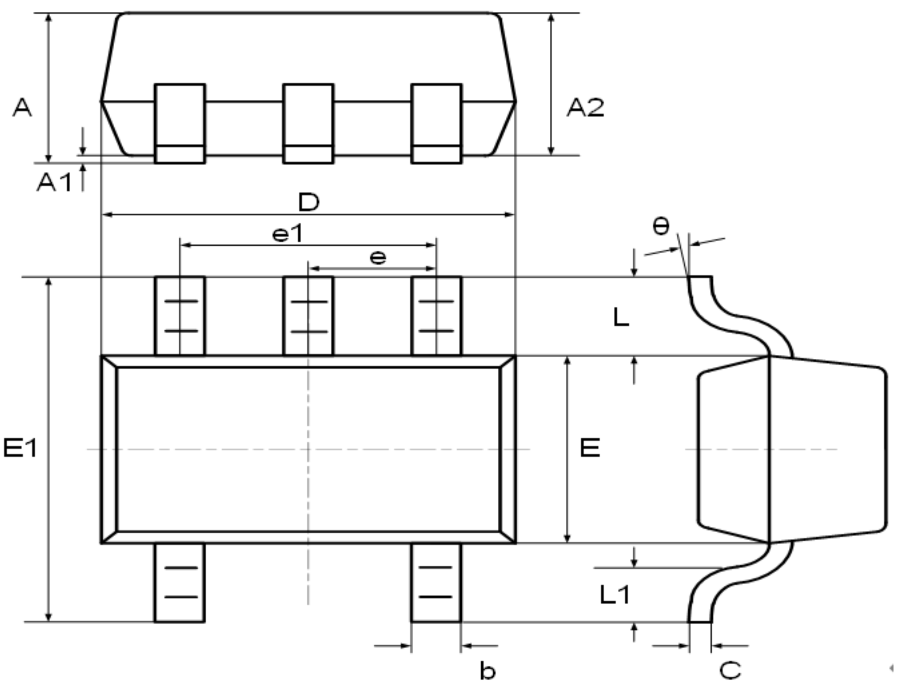


Figure 8 Current Shunt Monitor Circuit

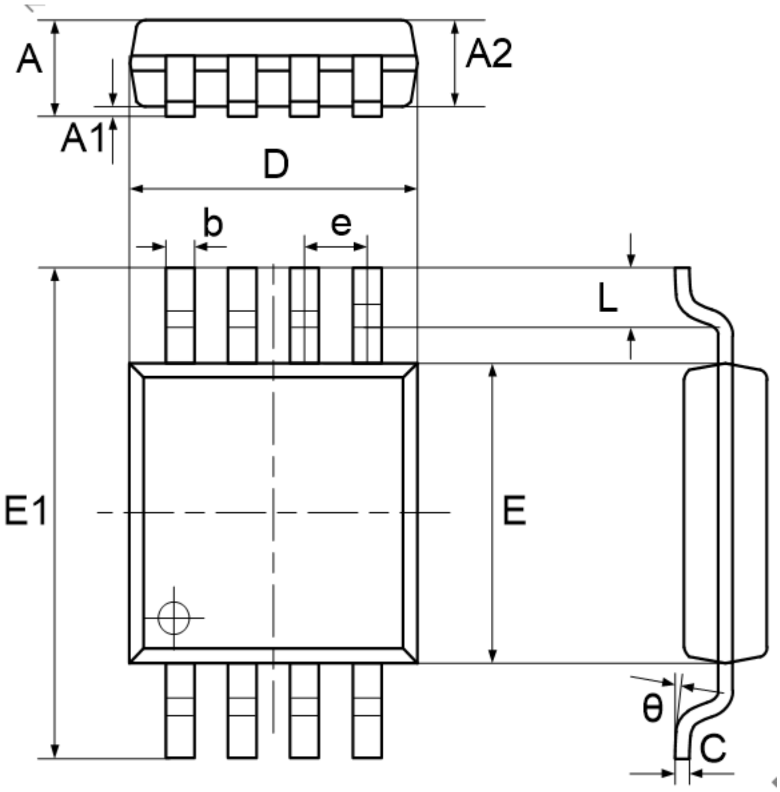
11. Package Information

SOT353



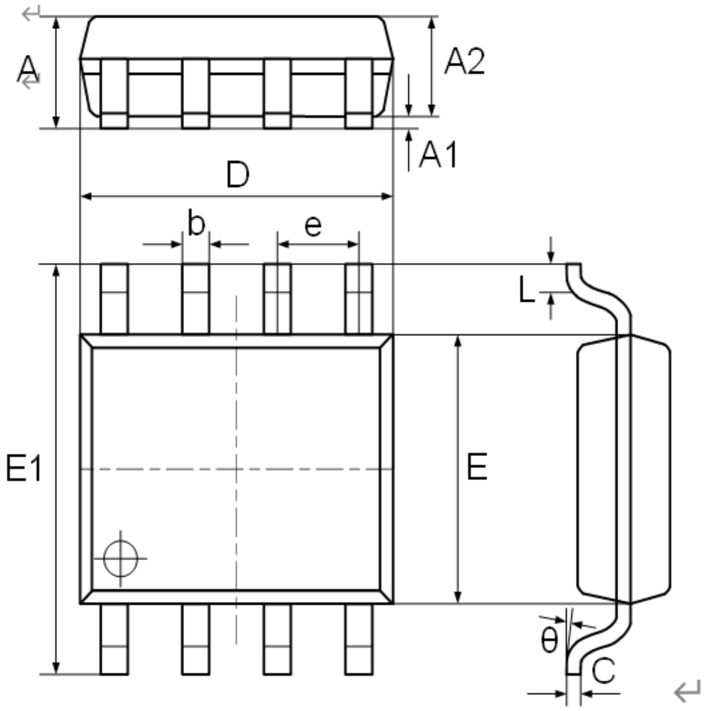
SYMBOL	DIMENSIONS IN MILLIMETERS		DIMENSIONS IN INCHES	
	MIN	MAX	MIN	MAX
A	0.800	1.100	0.035	0.043
A1	0.000	0.100	0.000	0.004
A2	0.800	0.900	0.035	0.039
b	0.150	0.350	0.006	0.014
C	0.080	0.150	0.003	0.006
D	1.850	2.150	0.079	0.087
E	1.100	1.400	0.045	0.053
E1	1.950	2.200	0.085	0.096
e	0.850 typ.		0.026 typ.	
e1	1.200	1.400	0.047	0.055
L	0.42 ref.		0.021 ref.	
L1	0.260	0.460	0.010	0.18
θ	0°	8°	0°	8°

MSOP-8



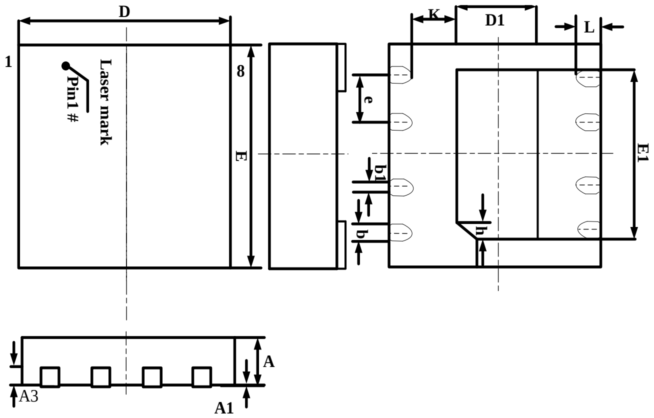
SYMBOL	DIMENSIONS IN MILLIMETERS	
	MIN	MAX
A	0.800	1.100
A1	0.050	0.150
A2	0.750	0.950
b	0.290	0.380
C	0.150	0.200
D	2.900	3.100
E	2.900	3.100
E1	4.700	5.100
e	0.650 typ.	
L	0.400	0.700
θ	0°	8°

SOP-8



SYMBOL	DIMENSIONS IN MILLIMETERS	
	MIN	MAX
A	1.370	1.670
A1	0.070	0.170
A2	1.300	1.500
b	0.306	0.506
C	0.203 typ.	
D	4.700	5.100
E	3.820	4.020
E1	5.800	6.200
e	1.270 typ.	
L	0.450	0.750
θ	0°	8°

DFN8-L 2*2



SYMBOL	Dimensions In Millimeters		
	Min	NOM	Max
A	0.700	0.750	0.800
A1	0.000	0.020	0.050
A3	0.203REF		
b	0.200	0.2500	0.300
b1	0.180REF		
D	1.900	2.000	2.100
E	1.900	2.000	2.100
e	0.500BSC		
D1	0.500	0.600	0.700
E1	1.100	1.200	1.300
L	0.300	0.350	0.40
K	0.35REF		
h	0.200REF		

12. Ordering Information

PART NUMBER	PACKAGE	PACKING QUANTITY
WA3721-C50R	SOT353	3k/Reel
WA3722-S80R	SOP-8	4k/Reel
WA3722-M80R	MSOP-8	3k/Reel
WA3722-F28R	DFN-8	3k/Reel

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WAYON website: http://www.way-on.com
For additional information, please contact your local Sales Representative.

Product Specification Statement

- The product specification aims to provide users with a reference regarding various product parameters, performance, and usage. It presents certain aspects of the product's performance in graphical form and is intended solely for users to select product and make product comparisons, enabling users to better understand and evaluate the characteristics and advantages of the product. It does not constitute any commitment, warranty, or guarantee.
- The product parameters described in the product specification are numerical values, characteristics, and functions obtained through actual testing or theoretical calculations of the product in an independent or ideal state. Due to the complexity of product applications and variations in test conditions and equipment, there may be slight fluctuations in parameter test values. WAYON shall not guarantee that the actual performance of the product when installed in the customer's system or equipment will be entirely consistent with the product specification, especially concerning dynamic parameters. It is recommended that users consult with professionals for product selection and system design. Users should also thoroughly validate and assess whether the actual parameters and performance when installed in their respective systems or equipment meet their requirements or expectations. Additionally, users should exercise caution in verifying product compatibility issues, and WAYON assumes no responsibility for the application of the product.
- WAYON strives to provide accurate and up-to-date information to the best of our ability. However, due to technical, human, or other reasons, WAYON cannot guarantee that the information provided in the product specification is entirely accurate and error-free. WAYON shall not be held responsible for any losses or damages resulting from the use or reliance on any information in these product specifications. WAYON reserves the right to revise or update the product specification and the products at any time without prior notice, and the user's continued use of the product specification is considered an acceptance of these revisions and updates. Prior to purchasing and using the product, users should verify the above information with WAYON to ensure that the product specification is the most current, effective, and complete. If users are particularly concerned about product parameters, please consult WAYON in detail or request relevant product test reports. Any data not explicitly mentioned in the product specification shall be subject to separate agreement.
- Users are advised to pay attention to the parameter limit values specified in the product specification and maintain a certain margin in design or application to ensure that the product does not exceed the parameter limit values defined in the product specification. This precaution should be taken to avoid exceeding one or more of the limit values, which may result in permanent irreversible damage to the product, ultimately affecting the quality and reliability of the system or equipment.
- The design of the product is intended to meet civilian needs and is not guaranteed for use in harsh environments or precision equipment. It is not recommended for use in systems or equipment such as medical devices, aircraft, nuclear power, and similar systems, where failures in these systems or equipment could reasonably be expected to result in personal injury. WAYON shall assume no responsibility for any consequences resulting from such usage.
- Users should also comply with relevant laws, regulations, policies, and standards when using the product specification. Users are responsible for the risks and liabilities arising from the use of the product specification and must ensure that it is not used for illegal purposes. Additionally, users should respect the intellectual property rights related to the product specification and refrain from infringing upon any third-party legal rights. WAYON shall assume no responsibility for any disputes or controversies arising from the above-mentioned issues in any form.