HTC321A, HTC358A, HTC324A

1MHz, General Purpose, RRIO CMOS Amplifiers

General Description

The HTC321A (single), HTC358A (dual) and HTC324A (quad) are general purpose, low offset, high frequency response and micro power operational amplifiers. With an excellent bandwidth of 1MHz, a slew rate of 0.8V/μs, and a quiescent current of 80μA per amplifier at 5V, the HTC321A/358A/324A family can be designed into a wide range of applications.

The HTC321A/358A/324A op-amps are designed to provide optimal performance in low voltage and low power systems. The input common-mode voltage range includes ground, and the maximum input offset voltage are 4.5mV. These parts provide rail-to-rail output swing into heavy loads. The HTC321A/358A/324A family is specified for single or dual power supplies of +1.8V to +5.5V. All models are specified over the extended industrial temperature range of -40℃ to +125℃.

The HTC321A is available in 5-lead SOT-23 and SC70-5 package. The HTC358A is available in 8-lead SOP package. The HTC324A is available in 14-lead SOP package.

Features

- General Purpose 1MHz Amplifiers, Low Cost
- High Slew Rate: 0.8V/μs
- Low Offset Voltage: 4.5 mV Maximum
- Low Power: 80μA per Amplifier Supply Current
- Settling Time to 0.1% with 2V Step: 4.2 μs
- Unit Gain Stable
- Rail-to-Rail Input and Output
  - Input Voltage Range: -0.1V to +5.1V at 5V Supply
- Operating Power Supply: +1.8V to +5.5V
- Operating Temperature Range: -40℃ to +125℃
- ESD Rating: HBM-4kV, CDM-2kV
- Upgrade to LMV321A/LMV358A/LMV324A Family

Applications

- Smoke/Gas/Environment Sensors
- Audio Outputs
- Battery and Power Supply Control
- Portable Equipment and Mobile Devices
- Active Filters
- Sensor Interfaces

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Applications

- Battery-Powered Instrumentation
- Medical Instrumentation

Pin Configurations

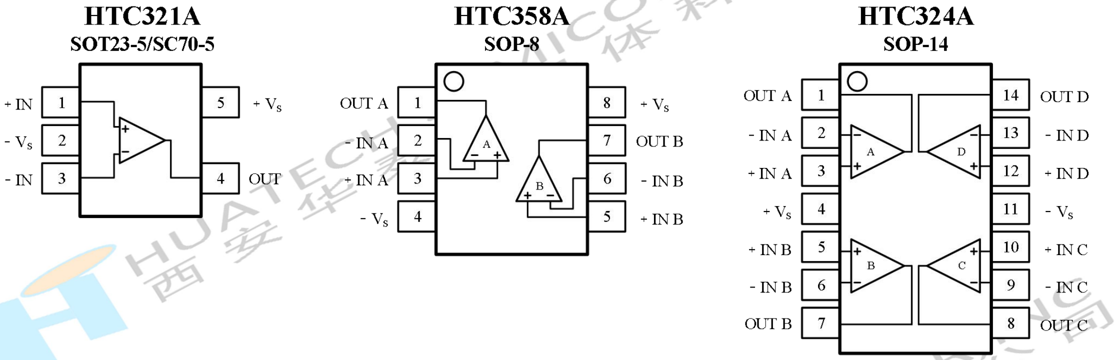


Figure 1 Pin Configurations

Pin Description

Symbol	Description
-IN	Negative (inverting) input.
+IN	Positive (noninverting) input.
-INA, -INB -INC, -IND	Inverting Input of the Amplifier. The Voltage range can go from (V_{S-} – 0.1V) to (V_{S+} + 0.1V).
+INA, +INB +INC, +IND	Non-Inverting Input of Amplifier. This pin has the same voltage range as -IN.
+V_S	Positive Power Supply. The voltage is from 1.8V to 5.5V. Split supplies are possible as long as the voltage between V_{S+} and V_{S-} is between 1.8V 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 1.8V 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	Output.
OUTA, OUTB OUTC, OUTD	Amplifier Output

Ordering Information

Type Number	Package	Number of package	Description
HTC321AXC5/R6	SC70-5	3000 PCS	C21YW
HTC321AXT5/R6	SOT23-5	3000 PCS	C21AYW
HTC358AXS8/R8	SOP-8	4000 PCS	C358A XXXXX
HTC324AXS14/R5	SOP-14	2500 PCS	C324A XXXXX

Absolute Maximum Ratings (T_A= 25℃)

Symbol	Description	Value	Units
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_J	Junction Temperature	160	°C
T_{STG}	Storage Temperature Range	-65 to +150	°C(T_J)
T_{JL}	Lead Temperature Range (Soldering 10 sec)	260	°C

Notes:

1. 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.
2. Provided device does not exceed maximum junction temperature (T_J) at any time.

Electrical Characteristics

V_S = 5.0V, T_A = +25℃, V_{CM} = $V_S/2$, V_O = $V_S/2$, and 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		-4.5	±1.0	+4.5	mV
	Over temperature		-4.8		+4.8	
V_{OS} TC	Offset voltage drift	Over Temperature		2.3		µV/°C
I_B	Input bias current			1		pA
	Over temperature			500		
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		90		dB
	Over temperature			85		
		V_{CM} = V_{S-}–0.1 to V_{S+}+0.1 V		80		
	Over temperature			75		
A_{VOL}	Open-loop voltage gain	V_O = 0.05 to 3.5 V		110		dB
	Over temperature			100		
R_{IN}	Input resistance		100			GΩ
C_{IN}	Input capacitance	Differential		2.0		pF
		Common mode		3.5		
OUTPUT CHARACTERISTICS						
V_{OH}	High output voltage swing			V_{S+}–8		mV
V_{OL}	Low output voltage swing			8		mV
Z_{OUT}	Closed-loop output impedance	f = 200kHz, G = +1		0.4		Ω
	Open-loop output impedance	f = 1MHz, I_O = 0		2.6		
I_{SC}	Short-circuit current	Source current through 10Ω		40		mA
		Sink current through 10Ω		40		
DYNAMIC PERFORMANCE						
GBW	Gain bandwidth product			1.0		MHz
Φ_M	Phase margin	C_L = 100pF		62		°
SR	Slew rate	G = +1, C_L = 100pF, V_O = 1.5V to 3.5V		0.8		V/µs

Electrical Characteristics

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

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
t_S	Settling time	To 0.1%, G = +1, 2V step		4.2		µs
		To 0.01%, G = +1, 2V step		5.2		
t_{OR}	Overload recovery time	V_{IN} * Gain > V_S		2		µs
THD+N	Total harmonic distortion+Noise	f = 1kHz, G = +1, V_O=3V_{PP}		0.003		%
NOISE PERFORMANCE						
V_n	Input voltage noise	f = 0.1 to 10 Hz		13		µV_{P-P}
e_n	Input voltage noise density	f = 1kHz		35		nV/√Hz
I_n	Input current noise density	f = 10kHz		6		fA/√Hz
POWER SUPPLY						
V_S	Operating supply voltage		1.8		5.5	V
PSRR	Power supply rejection ratio	V_S = 2.7V to 5.5V, V_{CM} < V_{S+} − 2V		98		dB
	Over temperature			85		
I_Q	Quiescent current (per amplifier)			80	120	µA
	Over temperature			85	130	
THERMAL CHARACTERISTICS						
T_A	Operating temperature range		-40		+125	°C
$θ_{JA}$	Package thermal resistance	SOT23-5		190		℃/W
		SO-8		125		
		SO-14		115		

Specifications subject to changes without notice

Typical Performance Characteristics

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

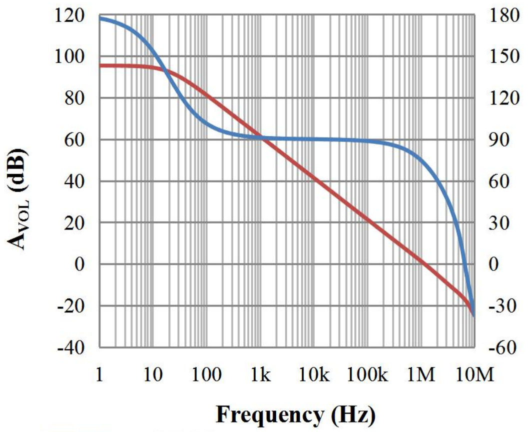


Figure 2 Open-loop Gain and Phase as a function of Frequency

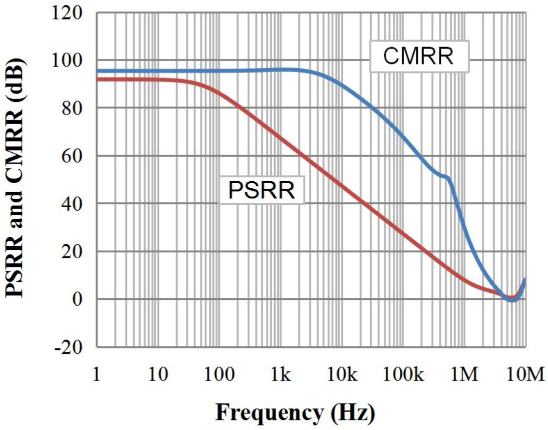


Figure 3 Power Supply and Common-mode RejectionRatio as a function of Frequency

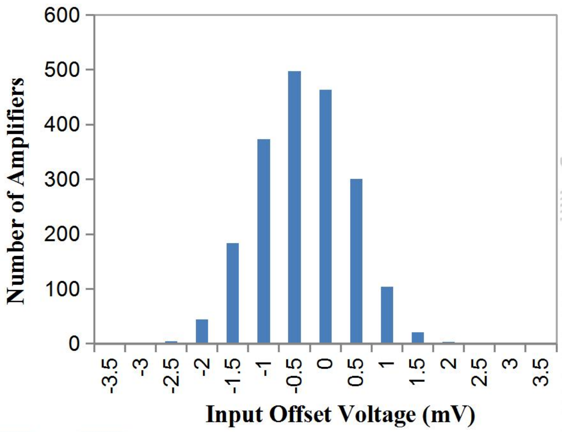


Figure 4 Input Offset Voltage Production Distribution

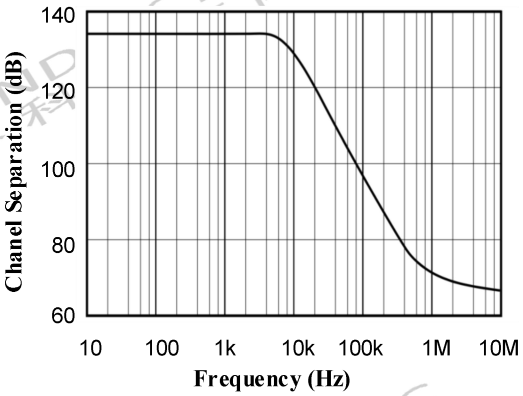


Figure 5 Channel Separation as a function of Frequency

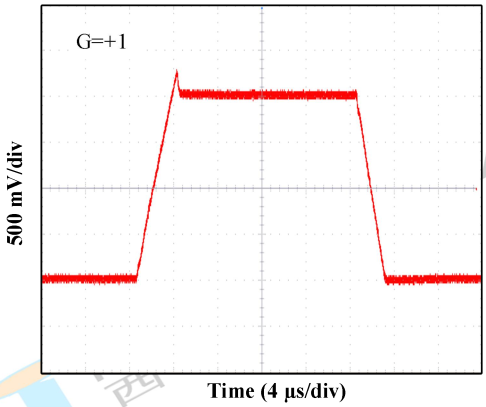


Figure 6 Large-Signal Step Response at 2.7V

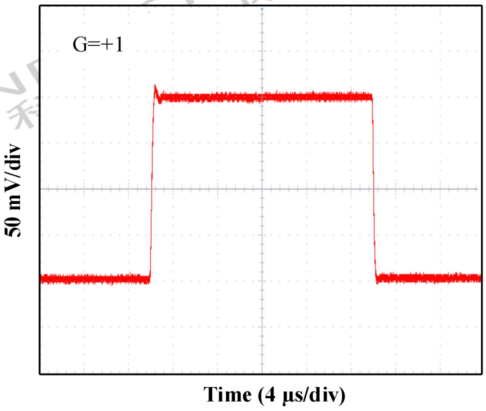


Figure 7 Small-Signal Step Response at 2.7V

Typical Performance Characteristics

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

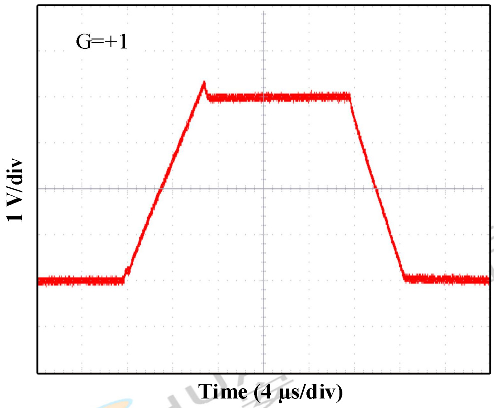


Figure 8 Large-Signal Step Response at 5V

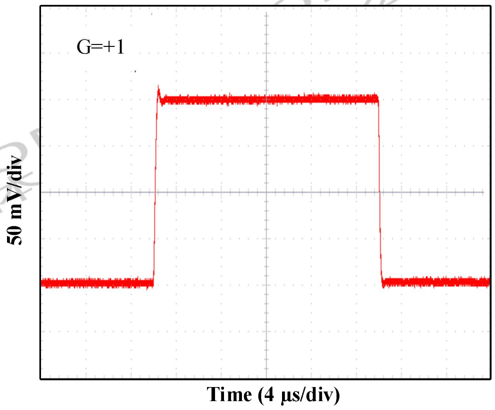


Figure 9 Small-Signal Step Response at 5V

Application Notes

1. LOW INPUT BIAS CURRENT

The HTC321A/358A/324A 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.

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 $10^{12}\Omega$. A 5V difference would cause 5pA of current to flow, which is greater than the HTC321A/358A/324A’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 10 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.

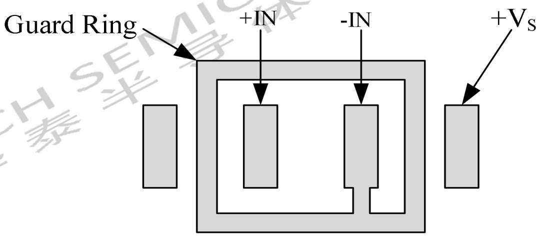


Figure 10 Use a guard ring around sensitive pins

Application Notes

3. GROUND SENSING AND RAIL TO RAIL

The input common-mode voltage range of the HTC321A/358A/324A series extends 100mV 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 300mV 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 11. Since the input common-mode range extends from (V_{S-} − 0.1V) to (V_{S+} + 0.1V), the HTC321A/358A/324A op-amps can easily perform ‘true ground’ sensing.

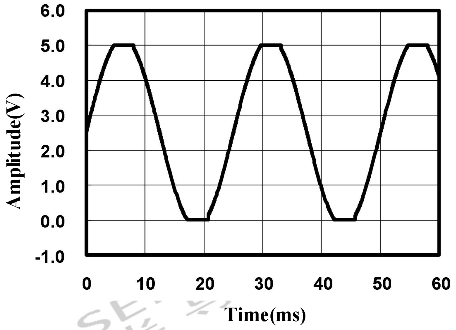


Figure 11 No Phase Inversion with Inputs Greater Than the Power-Supply Voltage

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°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.

4. CAPACITIVE LOAD AND STABILITY

The HTC321A/358A/324A 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

Application Notes

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 12. 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.

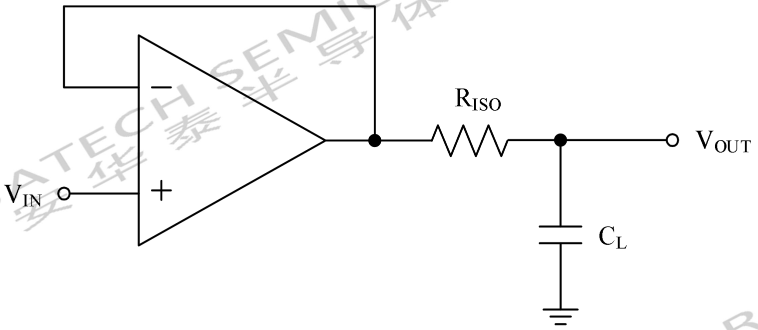


Figure 12 Indirectly Driving Heavy Capacitive Load

An improvement circuit is shown in Figure 13. 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.

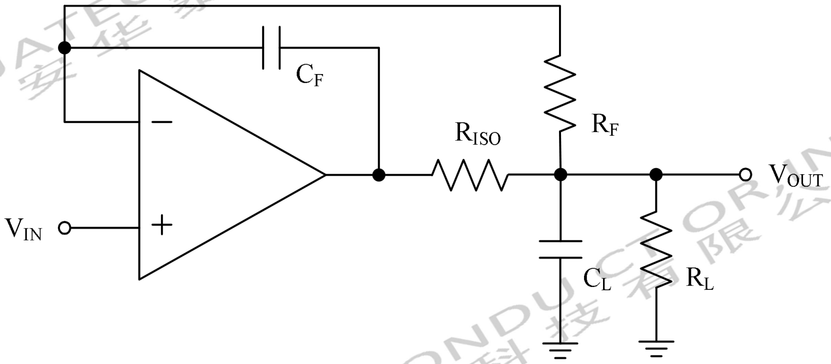


Figure 13 Indirectly Driving Heavy Capacitive Load with DC Accuracy

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.

5. POWER SUPPLY LAYOUT AND BYPASS

The HTC321A/358A/324A family operates from either a single +1.8V to +5.5V supply or dual ±0.9V to ±2.75V supplies. For single-supply operation, bypass the power supply V_S

Application Notes

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. 2.2μF 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).

6. GROUNDING

A ground plane layer is important for the HTC321A/358A/324A 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.

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.

Typical Application Circuits

1. DIFFERENTIAL AMPLIFIER

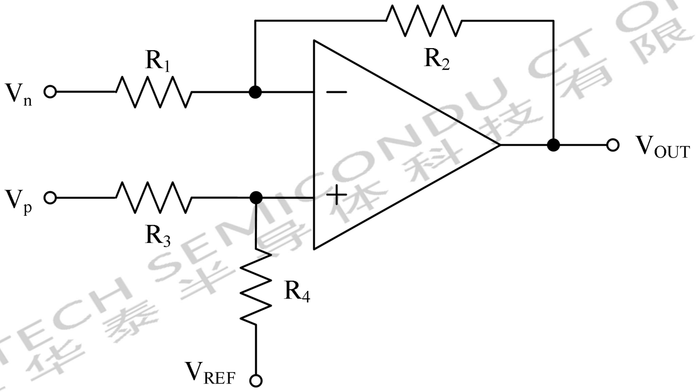
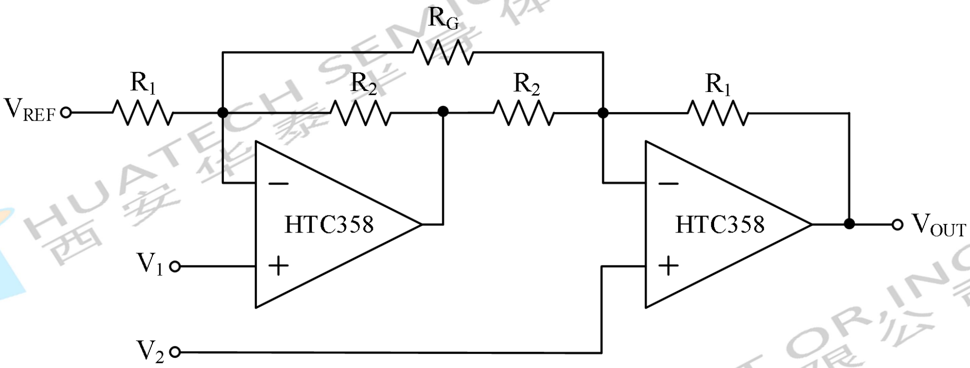


Figure 14 Differential Amplifier

The circuit shown in Figure 14 performs the difference function. If the resistors ratios are equal $R_4/R_3 = R_2/R_1$, then:

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

2. INSTRUMENTATION AMPLIFIER



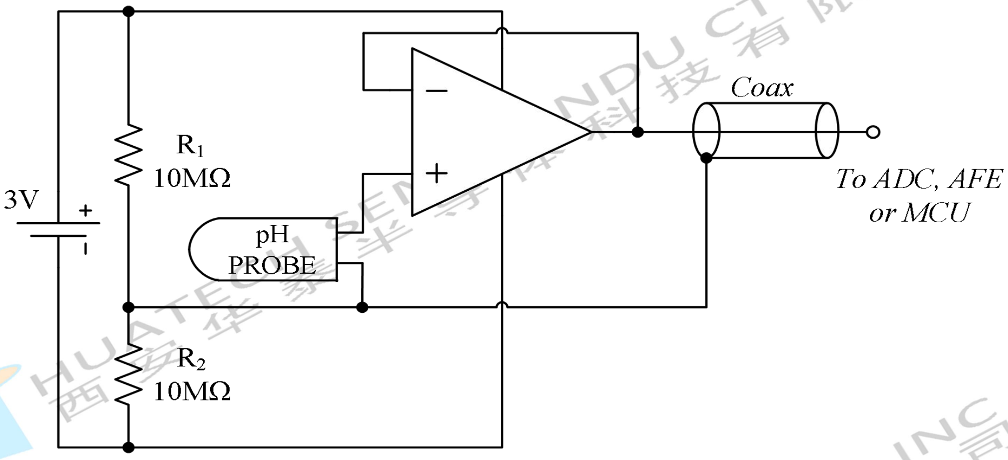
$$V_{OUT} = (V_1 - V_2) \times (1 + R_1/R_2 + 2R_1/R_G) + V_{REF}$$

Figure 15 Instrumentation Amplifier

The HTC321A/358A/324A family is well suited for conditioning sensor signals in battery-powered applications. Figure 15 shows a two op-amp instrumentation amplifier, using the HTC358A 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 $V_S/2$.

Typical Application Circuits

3. BUFFERED CHEMICAL SENSORS



All components contained within the pH probe

Figure 16 Buffered pH Probe

The HTC321A/358A/324A 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 16 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 HTC321A/358A/324A 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.

4. SHUNT-BASED CURRENT SENSING AMPLIFIER

The current sensing amplification shown in Figure 8 has a slew rate of $2\pi fV_{PP}$ for the output of sine wave signal, and has a slew rate of $2fV_{PP}$ 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 19 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}). For a 3-shunt solution in motor phase current sensing, if the smaller duty cycle of the PWM is defined at 45% (In fact, the phase with minimum PWM duty cycle, such as 5%, is not detected current directly, and it can be calculated from the other two phase currents), 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:

Typical Application Circuits

$$\mathbf{3.3V / (100\mu s \times 45\% \times 20\%) = 0.37\ V/\mu s}$$

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

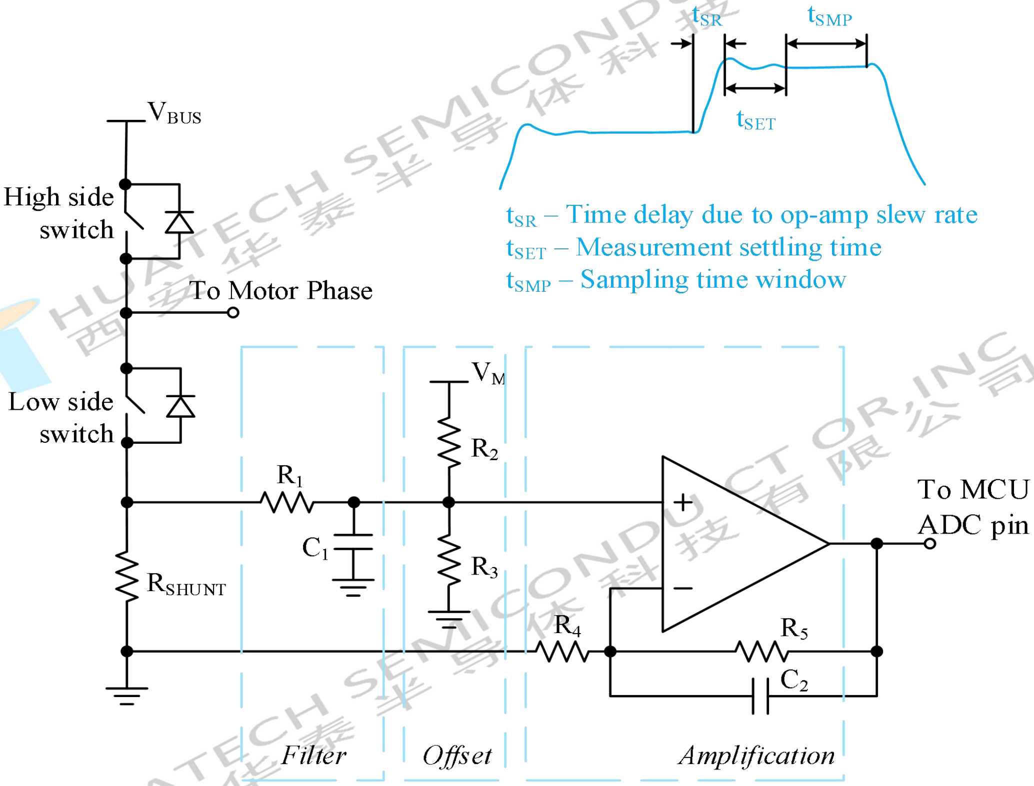
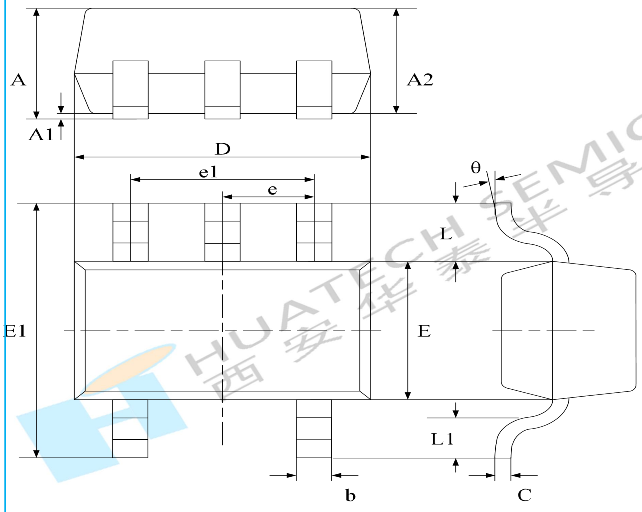


Figure 17 Current Shunt Monitor Circuit

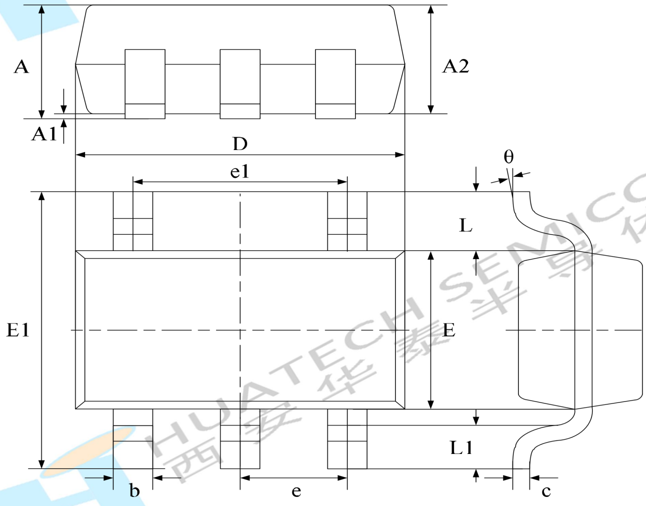
Package Information

SC70-5



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	1.8500	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	0.018
θ	0°	8°	0°	8°

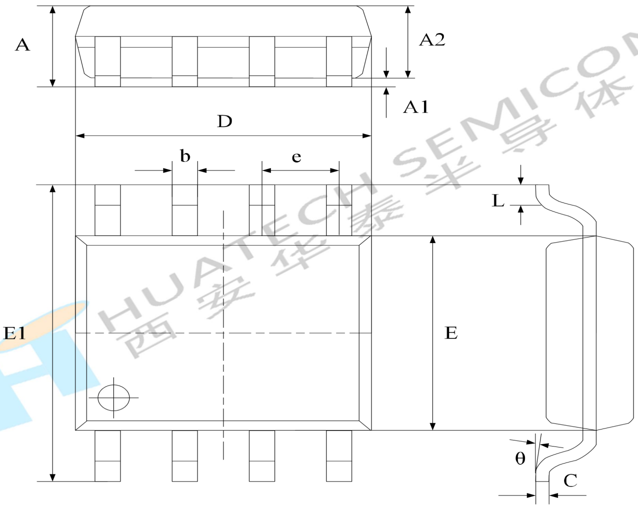
SOT23-5



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.040	1.350	0.042	0.055
A1	0.040	0.150	0.002	0.006
A2	1.000	1.200	0.041	0.049
b	0.380	0.480	0.015	0.020
c	0.110	0.210	0.004	0.009
D	2.720	3.120	0.111	0.127
E	1.400	1.800	0.057	0.073
E1	2.600	3.000	0.106	0.122
e	0.950 typ.		0.037 typ.	
e1	1.900 typ.		0.078 typ.	
L	0.700 ref.		0.028 ref.	
L1	0.300	0.600	0.012	0.024
θ	0°	8°	0°	8°

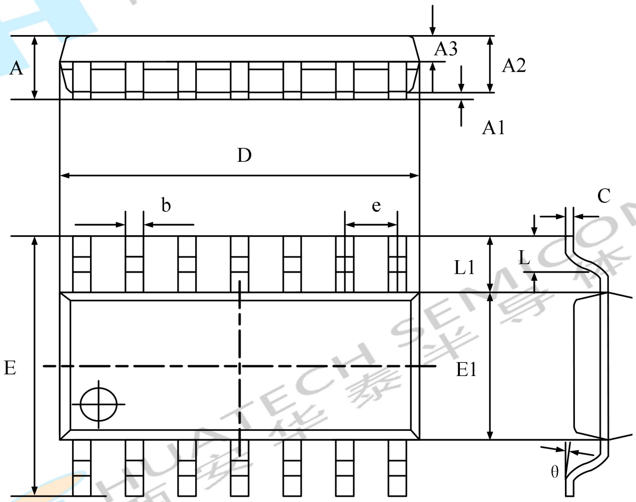
Package Information

SOP-8



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.370	1.670	0.056	0.068
A1	0.070	0.170	0.003	0.007
A2	1.300	1.500	0.053	0.061
b	0.306	0.506	0.013	0.021
C	0.203 typ.		0.008 typ.	
D	4.700	5.100	0.192	0.208
E	3.820	4.020	0.156	0.164
E1	5.800	6.200	0.237	0.253
e	1.270 typ.		0.050 typ.	
L	0.450	0.750	0.018	0.306
θ	0°	8°	0°	8°

SOP-14



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.450	1.850	0.059	0.076
A1	0.100	0.300	0.004	0.012
A2	1.350	1.550	0.055	0.063
A3	0.550	0.750	0.022	0.031
b	0.406typ.		0.017typ.	
C	0.203typ.		0.008typ.	
D	8.630	8.830	0.352	0.360
E	5.840	6.240	0.238	0.255
E1	3.850	4.050	0.157	0.165
e	1.270 typ.		0.050 typ.	
L1	1.040 ref.		0.041 ref.	
L	0.350	0.750	0.014	0.031
θ	2°	8°	2°	8°

Important Notice

As the HUATECH product improved gradually, we may have the untold change. HUATECH have the rights of correcting, changing, enhancing, improving and amending of the product and service they supply the rights of stopping the product and service. Before ordering, customer should achieve the latest information to verify whether it is the newest and integrity. All the product selling should abide HUATECH clause and terms as they make sure of the orders.

HUATECH guarantee the product they sell have suitable for the clause and terms of the semi-conductor selling. Only in the guarantee of HUATECH, HUATECH regards its necessary can they use the test and product quality control skills. Except the applicable laws make sure of hard and fast rule or it's not necessary to test the parameter of all products.

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HUATECH product don't obtain the FDA Class III (or the vitally important armarium) empowerment. HUATECH product don't design to damage human life and the property equipment and device (armarium, disaster prevention equipment, security equipment, fuel control equipment, infrastructure control equipment, vehicle equipment, transportation equipment, on-board equipment aeronautical equipment, space equipment, and nuclear equipment) HUATECH product can't use to life-sustaining, devices-implanting to influence human life. Unless the authorized officials of each expect have reached a special agreement to specifically control such use. Using and supplying (export) HUATECH product for the development of mass destruction weapons and the military use is strictly prohibited. HUATECH don't take any responsibility for supplying (export) to exploit, manufacture use and storage the nuclear weapons biology weapons chemical weapons missile and other military purpose. Only HUATECH especially notes belongs to military level or reinforce plastics are design and use to aerospace application. Purchaser approves and agrees. The risk takes separately by customer themselves if it is not allow to use. And the customer is solely responsible for meeting all legal and regulatory requirements related to such use.

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HUATECH products don't damage people health. But because it contains chemicals and heavy metals, please don't put them in your mouth. In addition, the fracture surface of the wafer and the chip may be sharp. Please pay attention to avoid injury when touching with bare hands. Semiconductor products may have a certain probability of failure or misoperation. In order to avoid the barrier and misoperation social damage caused by personal accidents, fire accidents, etc.

The customer please ask to be responsible for the lengthy design, measures to prevent the spread of fire and safety design such as misoperation themselves. Please make a full evaluation of the whole system, and the customer can judge whether it is applicable by himself.

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