

April 1993

## Precision Operational Amplifiers

### Features

- Low Offset Voltage.....25 $\mu$ V Max
- Low Offset Voltage Drift .....0.4 $\mu$ V/ $^{\circ}$ C
- Low Noise.....9nV/ $\sqrt{\text{Hz}}$
- Open Loop Gain.....140dB
- Unity Gain Bandwidth.....2.5MHz
- All Bipolar Construction

### Applications

- High Gain Instrumentation
- Precision Data Acquisition
- Precision Integrators
- Biomedical Amplifiers
- Precision Threshold Detectors

### Ordering Information

PART NUMBER	TEMP. RANGE	PACKAGE
HA2-5130-2	-55 $^{\circ}$ C to +125 $^{\circ}$ C	8 Pin Can
HA2-5130-5	0 $^{\circ}$ C to +75 $^{\circ}$ C	8 Pin Can
HA2-5135-2	-55 $^{\circ}$ C to +125 $^{\circ}$ C	8 Pin Can
HA2-5135-5	0 $^{\circ}$ C to +75 $^{\circ}$ C	8 Pin Can
HA7-5130-2	-55 $^{\circ}$ C to +125 $^{\circ}$ C	8 Lead Ceramic DIP
HA7-5130-5	0 $^{\circ}$ C to +75 $^{\circ}$ C	8 Lead Ceramic DIP
HA7-5135-2	-55 $^{\circ}$ C to +125 $^{\circ}$ C	8 Lead Ceramic DIP
HA7-5135-5	0 $^{\circ}$ C to +75 $^{\circ}$ C	8 Lead Ceramic DIP

### Description

The Harris HA-5130/5135 are precision operational amplifiers manufactured using a combination of key technological advancements to provide outstanding input characteristics.

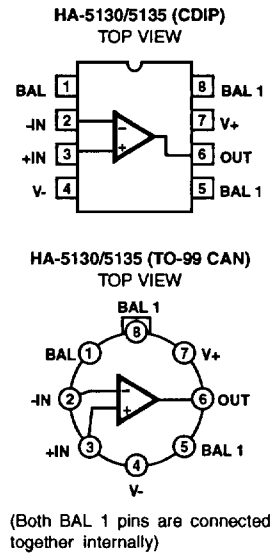
A Super Beta input stage is combined with laser trimming, dielectric isolation and matching techniques to produce 25 $\mu$ V (Maximum) input offset voltage and 0.4 $\mu$ V/ $^{\circ}$ C input offset voltage average drift. Other features enhanced by this process include 9nV/ $\sqrt{\text{Hz}}$  (Typ.) Input Noise Voltage, 1nA Input Bias Current and 140dB Open Loop Gain.

These features coupled with 120dB CMRR and PSRR make HA-5130/5135 an ideal device for precision DC instrumentation amplifiers. Excellent input characteristics in conjunction with 2.5MHz bandwidth and 0.8V/ $\mu$ s slew rate, make this amplifier extremely useful for precision integrator and biomedical amplifier designs. These amplifiers are also well suited for precision data acquisition and for accurate threshold detector applications.

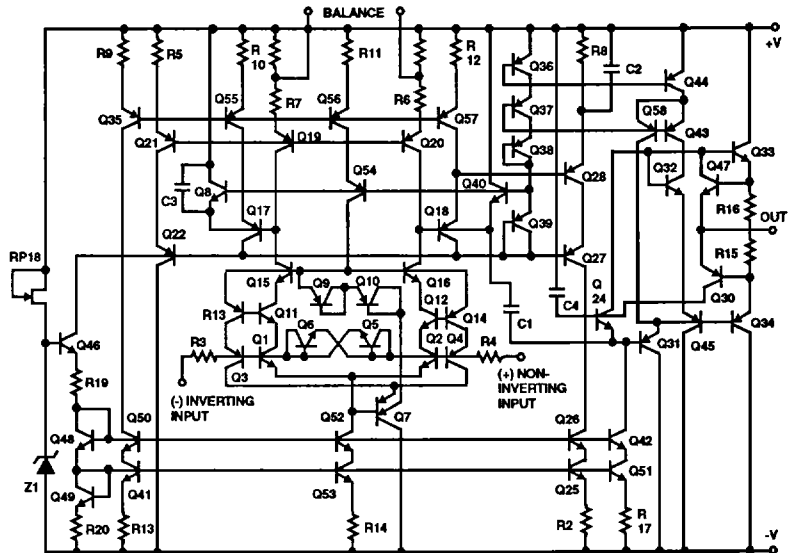
HA-5130/5135 offers added features over the industry standard OP-07 in regards to bandwidth and slew rate specifications. For the military grade product, refer to the HA-5135/883 data sheet.

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OPERATIONAL  
AMPLIFIERS

### Pinouts



### Schematic Diagram



CAUTION: These devices are sensitive to electrostatic discharge. Users should follow proper I.C. Handling Procedures.  
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File Number 2907.1

## Specifications HA-5130, HA-5135

### Absolute Maximum Ratings

$T_A = +25^\circ\text{C}$ Unless Otherwise Stated	
Voltage Between V+ and V- Terminals	40.0V
Differential Input Voltage	7V
Output Short Circuit Duration	Indefinite
Junction Temperature (Note 1)	+175°C
Lead Temperature (Soldering 10 Sec.)	300°C

### Operating Conditions

Operating Temperature Ranges		
HA-5130/5135-2	-55°C ≤ $T_A$ ≤ +125°C	
HA-5130/5135-5	0°C ≤ $T_A$ ≤ +75°C	
Storage Temperature Range		
-65°C ≤ $T_A$ ≤ +150°C		
Thermal Resistance (°C/W)		
	$\theta_{JA}$	$\theta_{JC}$
Ceramic DIP Package	113	34
TO-99 Metal Can	108	33

**CAUTION:** Stresses above those listed in "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

### Electrical Specifications $V_+ = +15V, V_- = -15V$

PARAMETER	TEMP	HA-5130-2/-5			HA-5135-2/-5			UNITS	
		MIN	TYP	MAX	MIN	TYP	MAX		
<b>INPUT CHARACTERISTICS</b>									
Offset Voltage	+25°C	-	10	25	-	10	75	μV	
	Full	-	50	60	-	50	130	μV	
Average Offset Voltage Drift	Full	-	0.4	0.6	-	0.4	1.3	μV/°C	
Bias Current	+25°C	-	±1	±2	-	±1	±4	nA	
	Full	-	-	±4	-	-	±6	nA	
Bias Current Average Drift	Full	-	0.02	0.04	-	0.02	0.04	nA/°C	
Offset Current	+25°C	-	-	2	-	-	4	nA	
	Full	-	-	4	-	-	5.5	nA	
Offset Current Average Drift	Full	-	0.02	0.04	-	0.02	0.04	nA/°C	
Common Mode Range	Full	±12	-	-	±12	-	-	V	
Differential Input Resistance	+25°C	20	30	-	20	30	-	MΩ	
Input Noise Voltage 0.1Hz to 10Hz (Note 2)	+25°C	-	-	0.6	-	-	0.6	μV <sub>p-p</sub>	
Input Noise Voltage Density (Note 2)	+25°C	f = 10Hz	-	13.0	18.0	-	13.0	18.0	nV/√Hz
		f = 100Hz	-	10.0	13.0	-	10.0	13.0	nV/√Hz
		f = 1000Hz	-	9.0	11.0	-	9.0	11.0	nV/√Hz
Input Noise Current 0.1Hz to 10Hz (Note 2)	+25°C	-	15	30	-	15	30	pA <sub>p-p</sub>	
Input Noise Current Density (Note 2)	+25°C	f = 10Hz	-	0.4	0.8	-	0.4	0.8	pA/√Hz
		f = 100Hz	-	0.17	0.23	-	0.17	0.23	pA/√Hz
		f = 1000Hz	-	0.14	0.17	-	0.14	0.17	pA/√Hz
<b>TRANSFER CHARACTERISTICS</b>									
Large Signal Voltage Gain (Note 3)	+25°C	120	140	-	120	140	-	dB	
	Full	120	-	-	120	-	-	dB	
Common Mode Rejection Ratio (Note 4)	Full	110	120	-	106	120	-	dB	
Closed Loop Bandwidth ( $A_{VCL} = +1$ )	+25°C	0.6	2.5	-	0.6	2.5	-	MHz	

**Specifications HA-5130, HA-5135**

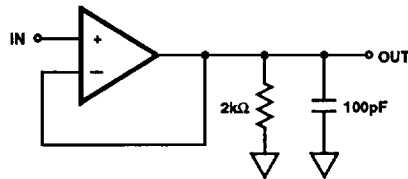
**Electrical Specifications**  $V_+ = +15V, V_- = -15V$  (Continued)

PARAMETER	TEMP	HA-5130-2/-5			HA-5135-2/-5			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
<b>OUTPUT CHARACTERISTICS</b>								
Output Voltage Swing (Note 5)	+25°C	±10	±12	-	±10	±12	-	V
	Full	±10	-	-	±10	-	-	V
Full Power Bandwidth (Note 6)	+25°C	8	10	-	8	10	-	kHz
Output Current (Note 7)	+25°C	±15	±20	-	±15	±20	-	mA
Output Resistance (Note 8)	+25°C	-	45	-	-	45	-	Ω
<b>TRANSIENT RESPONSE (Note 9)</b>								
Rise Time	+25°C	-	340	-	-	340	-	ns
Slew Rate	+25°C	0.5	0.8	-	0.5	0.8	-	V/μs
Settling Time (Note 10)	+25°C	-	11	-	-	11	-	μs
<b>POWER SUPPLY CHARACTERISTICS</b>								
Supply Current	Full	-	1.0	1.7	-	1.0	1.7	mA
Power Supply Rejection Ratio (Note 11)	Full	100	130	-	94	130	-	dB

**NOTES:**

- Maximum power dissipation, including output load, must be designed to maintain the maximum junction temperature below +175°C.
- Not tested. 90% of units meet or exceed these specifications.
- $V_{OUT} = \pm 10V; R_L = 2K$ . Gain dB =  $20 \log_{10} A_v$ .  
 $\therefore 120dB = 1MV/V$   
 $140dB = 10MV/V$
- $V_{CM} = \pm 10V$  DC
- $R_L = 600\Omega$ .
- $R_L = 2K$ ; Full power bandwidth guaranteed based on slew rate measurement using  $FPBW = \frac{\text{Slew Rate}}{2\pi V_{PEAK}}$
- $V_{OUT} = 10V$
- Output resistance measured under open loop conditions ( $f = 100Hz$ ).
- Refer to test circuits section of the data sheet.
- Settling time is measured to 0.1% of final value for a 10V output step and  $A_v = -1$ .
- $V_{SUPPLY} = \pm 5V$  DC to  $\pm 20V$  DC.

**Test Circuits**



**FIGURE 1. SLEW RATE AND TRANSIENT RESPONSE TEST CIRCUIT**

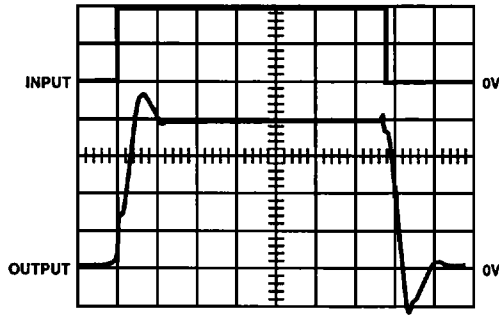
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**OPERATIONAL AMPLIFIERS**

Test Circuits (Continued)

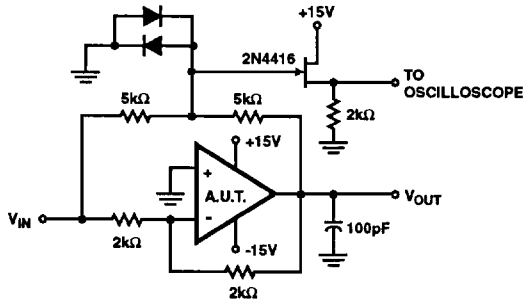
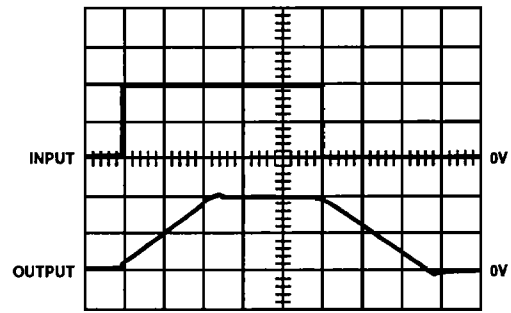
SMALL SIGNAL RESPONSE

Vertical Scale: Volts: 50mV/Div. Output  
 Volts: 100mV/Div. Input  
 Horizontal Scale: Time: 1μs/Div.



LARGE SIGNAL RESPONSE

Vertical Scale: Volts: 5V/Div.  
 Horizontal Scale: Time: 5μs/Div.



$A_V = -1$

Feedback and summing resistors should be 0.1% matched.

Clipping diodes are optional. HP5082-2810 recommended.

FIGURE 2. SETTLING TIME CIRCUIT

Typical Performance Curves

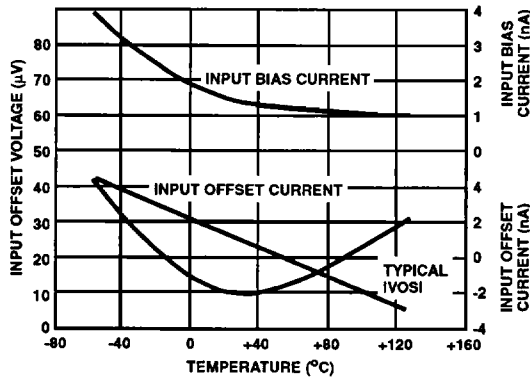


FIGURE 3. INPUT OFFSET VOLTAGE INPUT BIAS AND OFFSET CURRENT vs TEMPERATURE

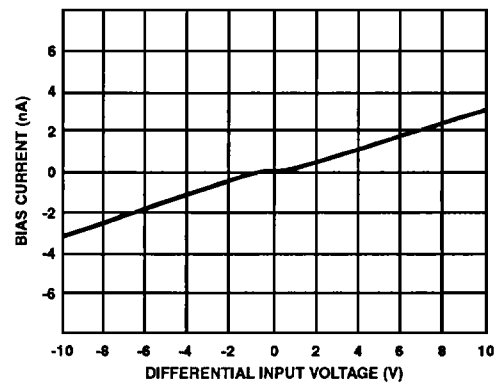


FIGURE 4. INPUT BIAS CURRENT vs DIFFERENTIAL INPUT VOLTAGE

Typical Performance Curves (Continued)

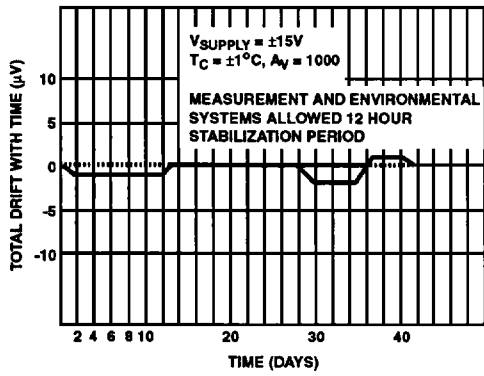


FIGURE 5. HA-5130 OFFSET VOLTAGE STABILITY vs TIME

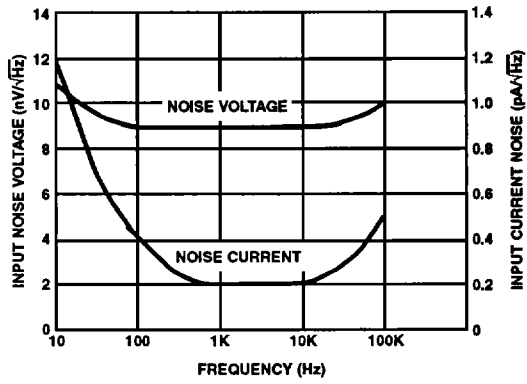


FIGURE 6. INPUT NOISE vs FREQUENCY

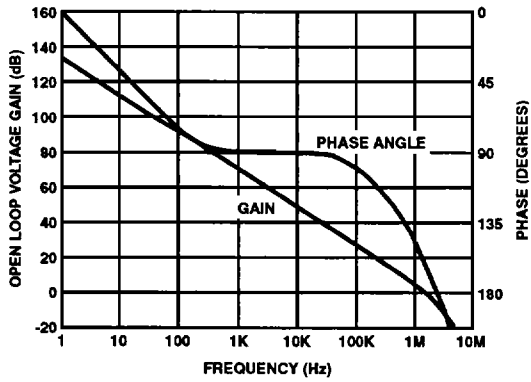


FIGURE 7. OPEN LOOP FREQUENCY RESPONSE

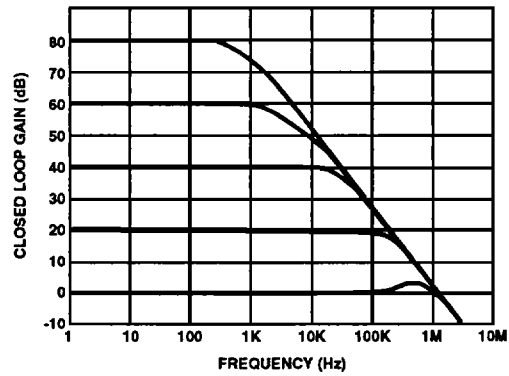


FIGURE 8. CLOSED LOOP FREQUENCY RESPONSE FOR VARIOUS CLOSED LOOP GAINS

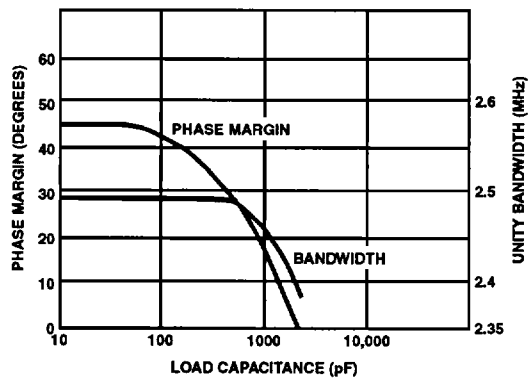


FIGURE 9. SMALL SIGNAL BANDWIDTH AND PHASE MARGIN vs LOAD CAPACITANCE

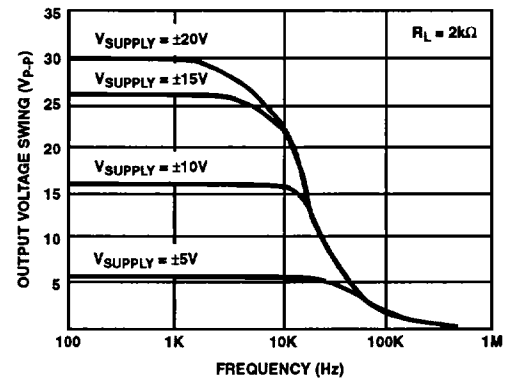


FIGURE 10. OUTPUT VOLTAGE SWING vs FREQUENCY AND SUPPLY VOLTAGE

Typical Performance Curves (Continued)

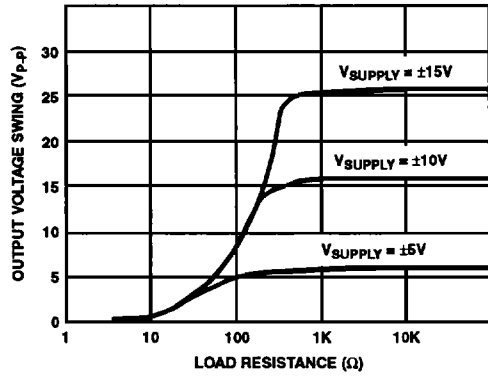


FIGURE 11. MAXIMUM OUTPUT VOLTAGE SWING vs LOAD RESISTANCE AND SUPPLY VOLTAGE

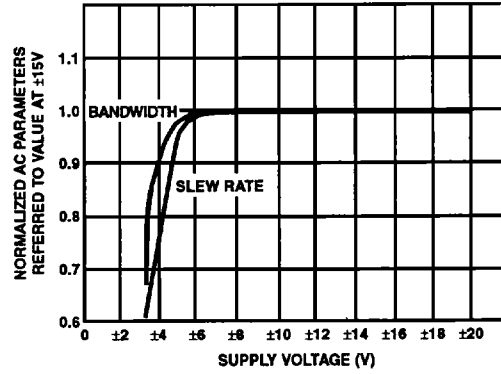


FIGURE 12. NORMALIZED AC PARAMETERS vs SUPPLY VOLTAGE

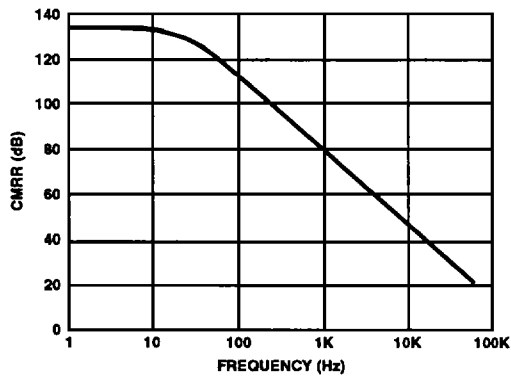


FIGURE 13. CMRR vs FREQUENCY

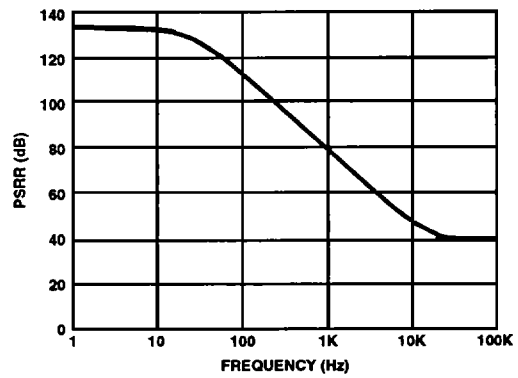


FIGURE 14. PSRR vs FREQUENCY

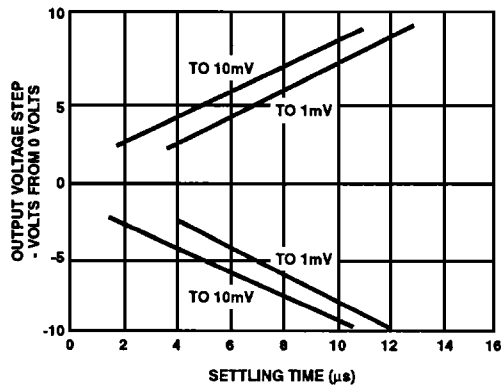


FIGURE 15. SETTLING TIME FOR VARIOUS OUTPUT STEP VOLTAGES

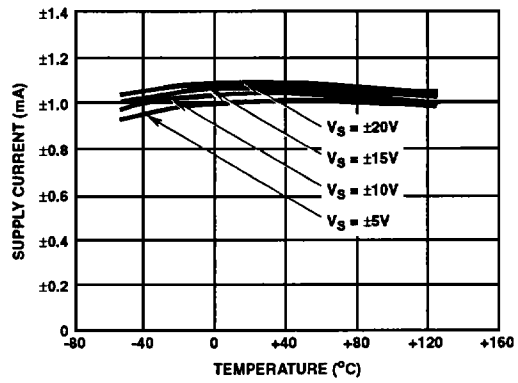
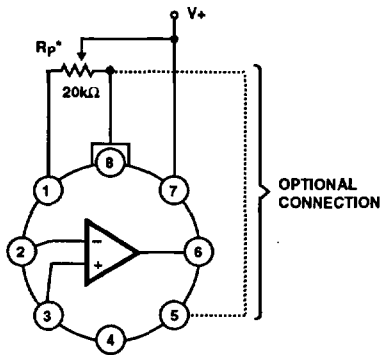


FIGURE 16. POWER SUPPLY CURRENT vs TEMPERATURE AND SUPPLY VOLTAGE

**Applying the HA-5130, HA-5135 Operational Amplifiers**

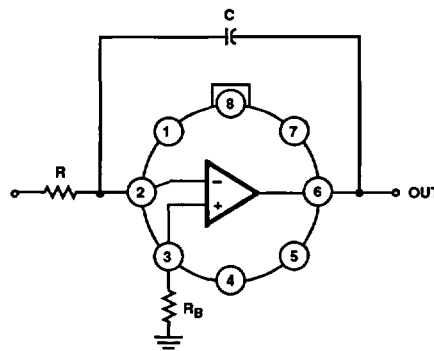
1. **POWER SUPPLY DECOUPLING:** Although not absolutely necessary, it is recommended that all power supply lines be decoupled with 0.01 $\mu$ F ceramic capacitors to ground. Decoupling capacitors should be located as near to the amplifier terminals as possible.
2. **CONSIDERATIONS FOR PROTOTYPING:** The following list of recommendations are suggested for prototyping.
  - Resolving low level signals requires minimizing leakage currents caused by external circuitry. Use of quality insulating materials, thorough cleaning of insulating surfaces and implementation of moisture barriers when required is suggested.
  - Error voltages generated by thermocouples formed between dissimilar metals in the presence of temperature gradients should be minimized. Isolation of low level circuitry from heat generating components is recommended.
  - Shielded cable input leads, guard rings and shield drivers are recommended for the most critical applications.
3. When driving large capacitive loads (> 500pF), a small value resistor ( $\approx$ 50 $\Omega$ ) should be connected in series with the output and inside the feedback loop.
4. **OFFSET VOLTAGE ADJUSTMENT:** A 20k $\Omega$  balance potentiometer is recommended if offset nulling is required. However, other potentiometer values such as 10k $\Omega$ , 50k $\Omega$  and 100k $\Omega$  may be used. The minimum adjustment range for given values is  $\pm$ 2mV.
5. **SATURATION RECOVERY:** Input and output saturation recovery time is negligible in most applications. However, care should be exercised to avoid exceeding the absolute maximum ratings of the device.
6. **DIFFERENTIAL INPUT VOLTAGES:** Inputs are shunted with back-to-back diodes for overvoltage protection. In applications where differential input voltages in excess of 1V are applied between the inputs, the use of limiting resistors at the inputs is recommended.

**Applications**



\* Although  $R_p$  is shown equal to 20k $\Omega$ , other values such as 50k $\Omega$ , 100k $\Omega$  and 1k $\Omega$  may be used. Range of adjustment is approximately  $\pm$ 2.5mV.  $V_{OS}$  TC of the amplifier is optimized at minimal  $V_{OS}$ .  
Tested Offset Adjustment is  $I_{V_{OS}} + 1mV$  minimum referred to output.

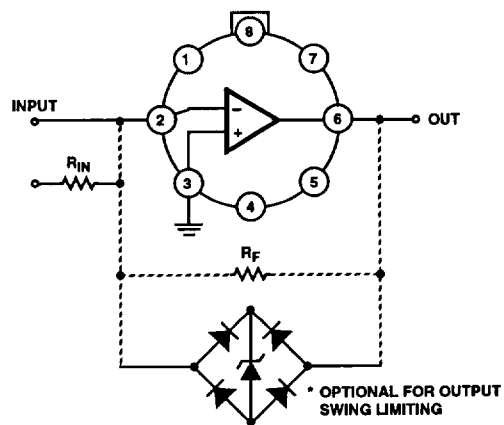
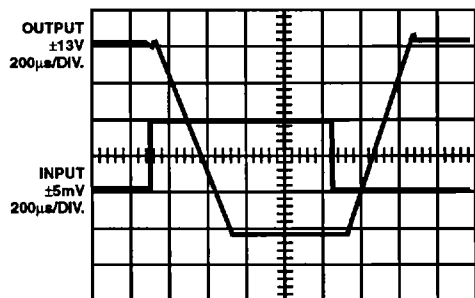
**FIGURE 17. OFFSET NULLING CONNECTIONS**



The excellent input and gain characteristics of HA-5130 are well suited for precision integrator applications. Accurate integration over seven decades of frequency using HA-5130, virtually nullifies the need for more expensive chopper-type amplifiers.

**FIGURE 18. PRECISION INTEGRATOR**

Applications (Continued)



Low  $V_{OS}$  coupled with high open loop Gain, high CMRR and high PSRR make HA-5130 ideally suited for precision detector applications.

FIGURE 19. ZERO CROSSING DETECTOR

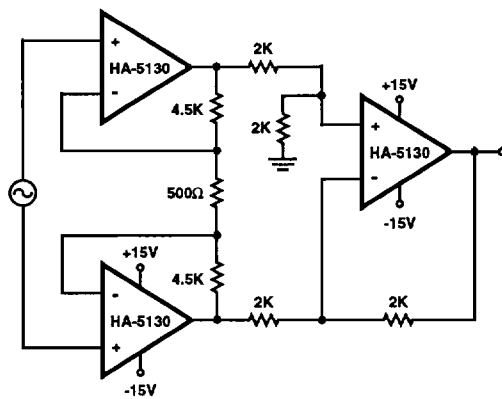


FIGURE 20. PRECISION INSTRUMENTATION AMPLIFIER ( $A_V = 100$ )