

### FEATURES

- LOW OFFSET VOLTAGE 10 $\mu$ V
- LOW OFFSET VOLTAGE DRIFT 0.4 $\mu$ V/ $^{\circ}$ C
- LOW NOISE 9nV/ $\sqrt{\text{Hz}}$
- OPEN LOOP GAIN 10<sup>7</sup>
- BANDWIDTH (UNITY GAIN) 2.5MHz
- ALL BIPOLAR CONSTRUCTION
- PIN CONFIGURATION SAME AS OP-07

### APPLICATIONS

- HIGH GAIN INSTRUMENTATION
- PRECISION DATA ACQUISITION
- PRECISION INTEGRATORS
- BIOMEDICAL AMPLIFIERS
- PRECISION THRESHOLD DETECTORS

### DESCRIPTION

The HA-OP07 is a precision operational amplifier 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 10 $\mu$ V (Max.) input offset voltage and 0.4 $\mu$ V/ $^{\circ}$ C input offset voltage average drift. Other features enhanced by this process include 9nV (Typ.) Input Noise Voltage, 1nA Input Bias Current, and 140dB Open Loop Gain.

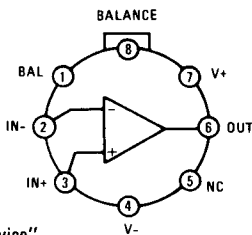
These features coupled with 120dB CMRR and PSRR make the HA-OP07 an ideal device for precision DC instrumentation amplifiers. Excellent input characteristics in conjunction with 2.5MHz bandwidth and 0.8V/ $\mu$ s slew rate, makes this amplifier extremely useful for precision integrator and biomedical amplifier designs. These amplifiers are also well suited for precision data acquisition and for accurate threshold detector applications.

The HA-OP07 is packaged in an 8 pin (TO-99) can, an 8 lead Cerdip, an 8 pin epoxy DIP and is compatible with OP-07 configuration.

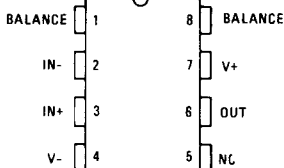
HA-OP07/HA-OP07A are specified for -55 $^{\circ}$ C to +125 $^{\circ}$ C operation while the HA-OP07C/HA-OP07E operate from 0 $^{\circ}$ C to +75 $^{\circ}$ C.

### PINOUTS

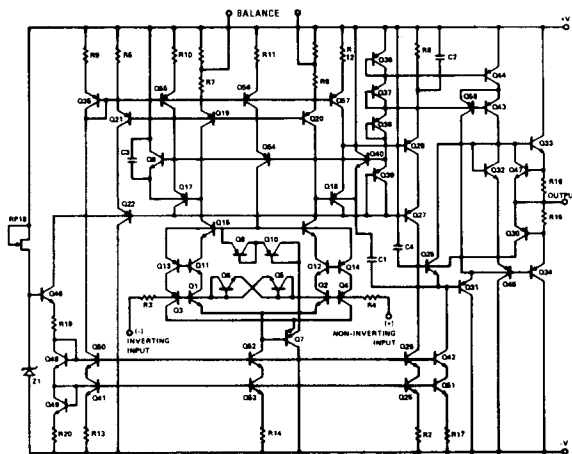
TOP VIEWS



"Caution:  
ESD Sensitive Device"



### SCHEMATIC



# SPECIFICATIONS

## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage	$\pm 22V$	Storage Temperature Range	$-65^{\circ}C$ to $+150^{\circ}C$
Internal Power Dissipation (Note 2)	500mW	J and Z Packages	
Differential Input Voltage	$\pm 15V$		
Input Voltage	$\pm V$ Supplies	Operating Temperature Range	$-55^{\circ}C$ to $+125^{\circ}C$
Output Short Circuit Duration	Indefinite	OP-07A, OP-07 OP-07E, OP-07C	$0^{\circ}C$ to $+75^{\circ}C$

## ELECTRICAL CHARACTERISTICS at $V_S = \pm 15V$ , $T_A = +25^{\circ}C$ , unless otherwise stated.

SYMBOL	PARAMETER	CONDITIONS	HA-0P07A			HA-0P07			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{OS}$	Input Offset Voltage		-	10	25	-	10	75	$\mu V$
$I_{OS}$	Input Offset Current				2.0			2.8	nA
$I_B$	Input Bias Current		-	$\pm 1.0$	$\pm 2.0$	-	$\pm 1.0$	$\pm 3.0$	nA
$e_{np-p}$	Input Noise Voltage	0.1Hz to 10Hz	-	-	0.6	-	-	0.6	$\mu V_{p-p}$
$e_n$	Input Noise Voltage Density	$f_o = 10Hz$	-	13.0	18.0	-	13.0	18.0	$nV/\sqrt{Hz}$
		$f_o = 100Hz$	-	10.0	13.0	-	10.0	13.0	
		$f_o = 1000Hz$	-	9.6	11.0	-	9.6	11.0	
$i_{np-p}$	Input Noise Current	0.1Hz to 10Hz	-	15.0	30	-	15.0	30	$pA_{p-p}$
$i_n$	Input Noise Current Density	$f_o = 10Hz$	-	0.4	0.80	-	0.4	0.80	$pA/\sqrt{Hz}$
		$f_o = 100Hz$	-	0.17	0.23	-	0.17	0.23	
		$f_o = 1000Hz$	-	0.14	0.17	-	0.14	0.17	
$R_{IN}$	Input Resistance - Differential Mode		20	30	-	20	30	-	$M\Omega$
$IVR$	Input Voltage Range		$\pm 12$	-	-	$\pm 12$	-	-	V
$CMRR$	Common Mode Rejection Ratio	$V_{CM} = \pm 10V$	110	120	-	110	120	-	dB
$PSRR$	Power Supply Rejection Ratio	$V_S \pm 3V$ to $\pm 18V$	100	130	-	100	130	-	dB
$AV_0$	Large Signal Voltage Gain	(Note 3)	120	140	-	120	140	-	dB
$V_O$	Output Voltage Swing	$R_L = 2k\Omega$	-	$\pm 12$	-	$\pm 12$	-	-	V
		$R_L = 600\Omega$	-	$\pm 10$	$\pm 12$	-	$\pm 10$	$\pm 12$	
$SR$	Slewing Rate	$R_L \geq 2k\Omega$	0.5	0.8	-	0.5	0.8	-	$V/\mu s$
$BW$	Closed Loop Bandwidth	$AV_{CL} = +1.0$	0.6	2.5	-	0.6	2.5	-	MHz
$R_O$	Open Loop Output Resistance	$f = 100Hz$	-	45	-	-	45	-	$\Omega$
$I_{CC}$	Supply Current	No Load	-	1.0	1.3	-	1.0	1.3	mA
$P_D$	Power Consumption	$V_{CC} = \pm 15V$		30	39		30	39	mW
		$V_{CC} = \pm 3V$		6.0	7.8		6.0	7.8	

## ELECTRICAL CHARACTERISTICS at $V_S = \pm 15V$ , $-55^{\circ}C \leq T_A \leq +125^{\circ}C$ , unless otherwise stated.

SYMBOL	PARAMETER	CONDITIONS	HA-0P07E			HA-0P07C			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{OS}$	Input Offset Voltage		-	50	130	-	50	250	$\mu V$
$TCV_{OS}$	Avg. Input Offset Voltage Drift Without External Trim		-	0.4	0.6	-	0.4	1.3	$\mu V/^{\circ}C$
$I_{OS}$	Input Offset Current		-	-	5.3	-	-	8.0	nA
$TCI_{OS}$	Avg. Input Offset Current Drift		-	20	40	-	20	50	$pA/^{\circ}C$
$I_B$	Input Bias Current		-	-	5.5	-	-	9.0	nA
$TCI_B$	Avg. Input Bias Current Drift		-	20	40	-	20	50	$pA/^{\circ}C$
$IVR$	Input Voltage Range		$\pm 12$	-	-	$\pm 12$	-	-	V
$CMRR$	Common Mode Rejection Ratio	$V_{CM} = \pm 10V$	110	120	-	106	120	-	dB
$PSRR$	Power Supply Rejection Ratio	$V_S = \pm 3V$ to $\pm 18V$	100	130	-	94	130	-	dB

## SPECIFICATIONS (Continued)

**ELECTRICAL CHARACTERISTICS** at  $V_S = \pm 15V$ ,  $T_A = 250C$ , unless otherwise stated.

SYMBOL	PARAMETER	CONDITIONS	HA-OP07E			HA-OP07C			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{OS}$	Input Offset Voltage		-	10	75	-	60	150	$\mu V$
$I_{OS}$	Input Offset Current		-	-	3.8	-	-	6.0	nA
$I_B$	Input Bias Current		-	$\pm 1.0$	$\pm 4.0$	-	$\pm 1.0$	$\pm 7.0$	nA
$e_{np-p}$	Input Noise Voltage	0.1Hz to 10Hz	-	-	0.6	-	-	0.65	$\mu V_{p-p}$
$e_n$	Input Noise Voltage Density	$f_0 = 10Hz$	-	13.0	18.0	-	13.0	20.0	$nV/\sqrt{Hz}$
		$f_0 = 100Hz$	-	10.0	13.0	-	10.2	13.5	
		$f_0 = 1000Hz$	-	9.6	11.0	-	9.8	11.5	
$i_{np-p}$	Input Noise Current	0.1Hz to 10Hz	-	15.0	30	-	15.0	35	$pA_{p-p}$
$i_n$	Input Noise Current Density	$f_0 = 10Hz$	-	0.4	0.80	-	0.4	0.80	$pA/\sqrt{Hz}$
		$f_0 = 100Hz$	-	0.17	0.23	-	0.17	0.27	
		$f_0 = 1000Hz$	-	0.14	0.17	-	0.14	0.18	
$R_{IN}$	Input Resistance - Differential Mode		20	30	-	20	30	-	$M\Omega$
$IVR$	Input Voltage Range		$\pm 12$	-	-	$\pm 12$	-	-	V
$CMRR$	Common Mode Rejection Ratio	$V_{CM} = \pm 10V$	110	120	-	106	120	-	dB
$PSRR$	Power Supply Rejection Ratio	$V_S \pm 3V$ to $\pm 18V$	100	130	-	94	130	-	dB
$A_{VQ}$	Large Signal Voltage Gain	(Note 3)	120	140	-	100	140	-	dB
$V_O$	Output Voltage Swing	$R_L = 2k\Omega$	$\pm 12$	-	-	$\pm 11.5$	-	-	V
		$R_L = 600\Omega$	$\pm 10$	$\pm 12$	-	$\pm 10$	$\pm 12$	-	
$SR$	Slewing Rate	$R_L \geq 2k\Omega$	0.5	0.8	-	0.5	0.8	-	$V/\mu s$
$BW$	Closed Loop Bandwidth	$A_{VCL} = +1.0$	0.6	2.5	-	0.6	2.5	-	MHz
$R_O$	Open Loop Output Resistance	$f = 100Hz$	-	45	-	-	45	-	$\Omega$
$I_{CC}$	Supply Current	No Load	-	1.0	1.3	-	1.0	1.7	mA
$P_D$	Power Consumption	$V_{CC} = \pm 15V$	-	-	35	-	-	50	mW
		$V_{CC} = \pm 3V$	-	-	6.0	-	-	8	

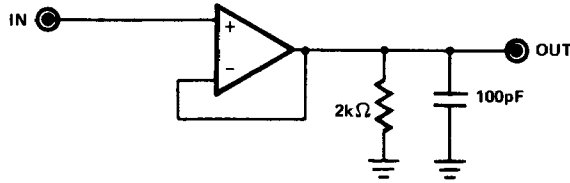
**ELECTRICAL CHARACTERISTICS** at  $V_S = \pm 15V$ ,  $00C \leq T_A \leq +700C$ , unless otherwise stated.

SYMBOL	PARAMETER	CONDITIONS	HA-OP07E			HA-OP07C			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{OS}$	Input Offset Voltage		-	50	130	-	50	250	$\mu V$
$TCV_{OS}$	Avg. Input Offset Voltage Drift Without External Trim		-	0.4	0.6	-	0.4	1.3	$\mu V/0C$
$I_{OS}$	Input Offset Current		-	-	5.3	-	-	8.0	nA
$TCI_{OS}$	Avg. Input Offset Current Drift		-	20	40	-	20	50	$pA/0C$
$I_B$	Input Bias Current		-	-	5.5	-	-	9.0	nA
$TCI_B$	Avg. Input Bias Current Drift		-	20	40	-	20	50	$pA/0C$
$IVR$	Input Voltage Range		$\pm 12$	-	-	$\pm 12$	-	-	V
$CMRR$	Common Mode Rejection Ratio	$V_{CM} = \pm 10V$	110	120	-	106	120	-	dB
$PSRR$	Power Supply Rejection Ratio	$V_S = \pm 3V$ to $\pm 18V$	100	130	-	94	130	-	dB
$A_{VQ}$	Large Signal Voltage Gain	(Note 3)	120	-	-	100	-	-	dB
$V_O$	Output Voltage Swing	$R_L = 600\Omega$	$\pm 10$	-	-	$\pm 10$	-	-	V
		$R_L = 2k\Omega$	$\pm 12$	-	-	$\pm 11.5$	-	-	

- NOTES: 1. Absolute maximum ratings are limiting values, applied individually beyond which the serviceability of the circuit may be impaired. Functional operability under any of these conditions is not necessarily implied.
2. Derate at  $6.8mW/0C$  for operation at ambient temperatures above  $+750C$ .
3.  $V_{OUT} = \pm 10V$ ;  $R_L = 2k\Omega$ . Gain dB =  $20 \log_{10}$  Average  
 $\bullet$  120dB = 1000V/mV  
 $\bullet$  140dB = 10,000V/mV

# TEST CIRCUITS

## SLEW RATE AND TRANSIENT RESPONSE TEST CIRCUIT

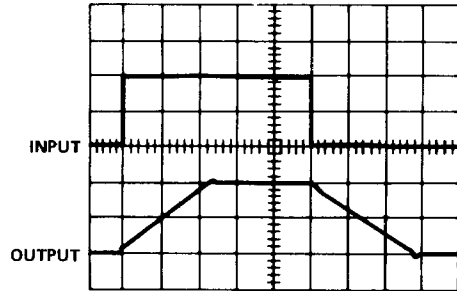
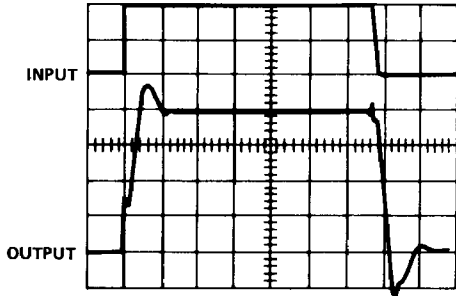


### SMALL SIGNAL RESPONSE

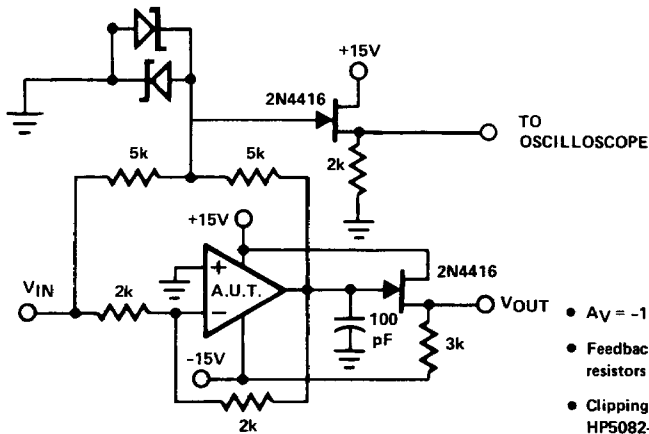
Vertical Scale: (Volts: 50mV/Div. Output)  
 (Volts: 100mV/Div. Input)  
 Horizontal Scale: (Time: 1μs/Div.)

### LARGE SIGNAL RESPONSE

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



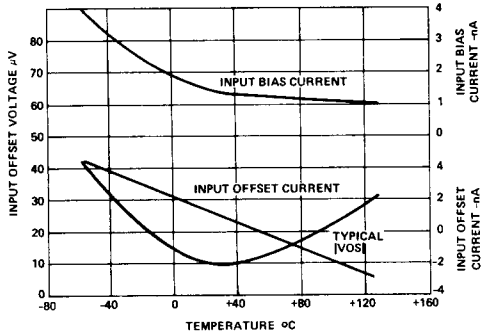
## SETTLING TIME CIRCUIT



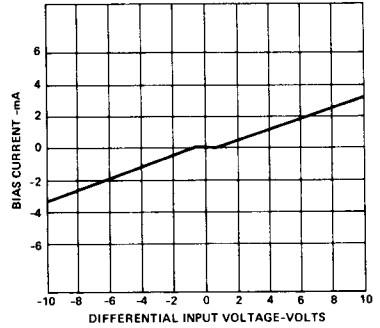
- $A_V = -1$ .
- Feedback and summing resistors should be 0.1%.
- Clipping diodes are optional. HP5082-2810 recommended.

# PERFORMANCE CURVES

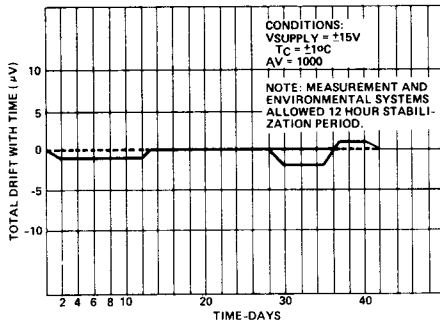
## INPUT OFFSET VOLTAGE, INPUT BIAS AND OFFSET CURRENT VS. TEMPERATURE



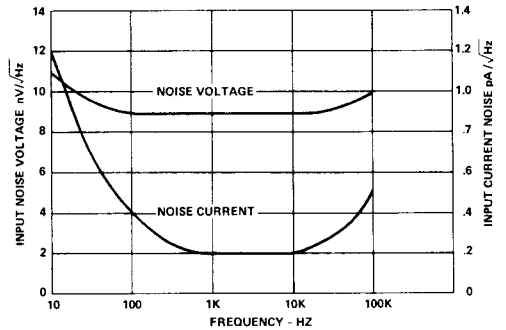
## INPUT BIAS CURRENT VS. DIFFERENTIAL INPUT VOLTAGE



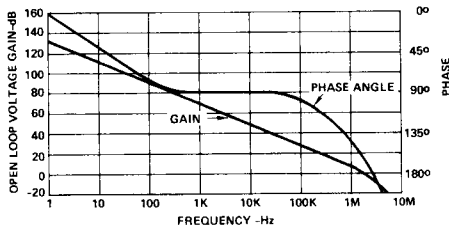
## OFFSET VOLTAGE STABILITY VS. TIME



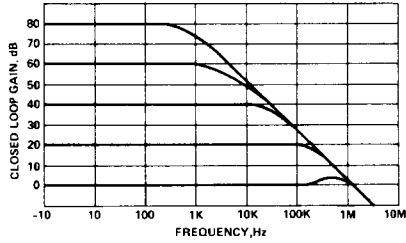
## INPUT - NOISE VS. FREQUENCY



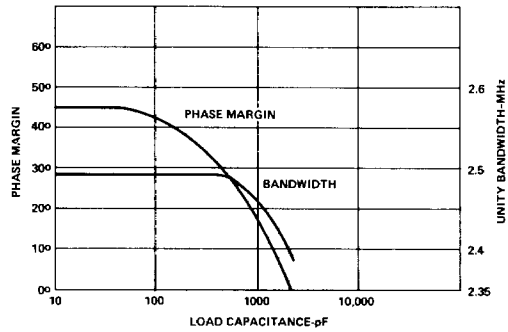
## OPEN LOOP FREQUENCY RESPONSE



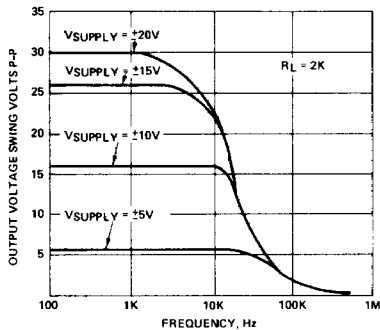
CLOSED LOOP FREQUENCY RESPONSE  
FOR VARIOUS CLOSED LOOP GAINS



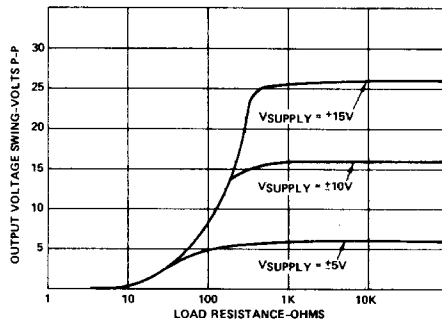
SMALL SIGNAL BANDWIDTH AND  
PHASE MARGIN VS. LOAD CAPACITANCE



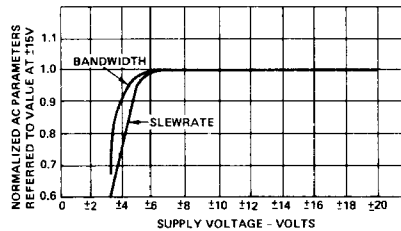
OUTPUT VOLTAGE SWING VS.  
FREQUENCY AND SUPPLY VOLTAGE



MAXIMUM OUTPUT VOLTAGE SWING VS.  
LOAD RESISTANCE AND SUPPLY VOLTAGE

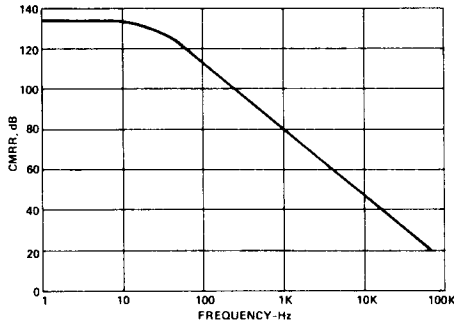


NORMALIZED AC PARAMETERS  
VS. SUPPLY VOLTAGE

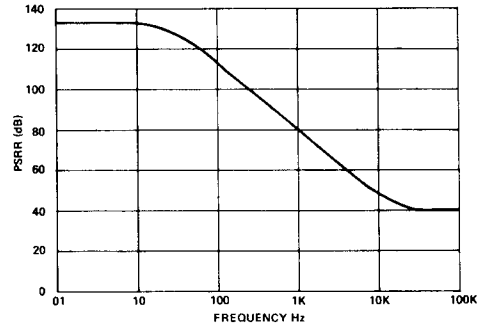


## PERFORMANCE CURVES (Continued)

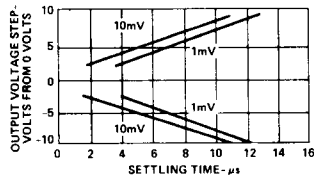
### CMRR VS. FREQUENCY



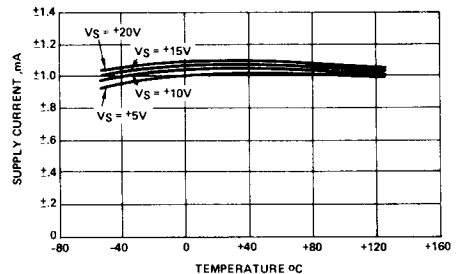
### PSRR VS. FREQUENCY



### SETTLING TIME FOR VARIOUS OUTPUT STEP VOLTAGES



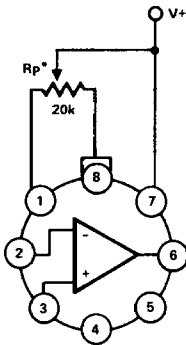
### POWER SUPPLY CURRENT VS. TEMPERATURE AND SUPPLY VOLTAGE



## APPLYING THE HA-OP07 OPERATIONAL AMPLIFIERS

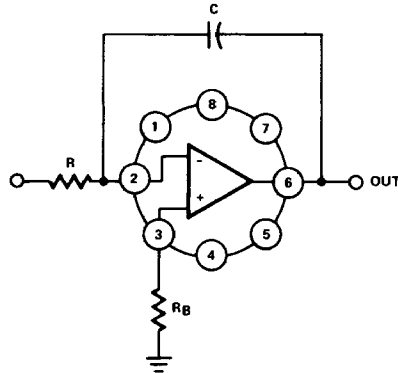
1. **POWER SUPPLY DECOUPLING:** Although not absolutely necessary, it is recommended that all power supply lines be decoupled with  $.01\mu$  F ceramic capacitors to ground. Decoupling capacitors should be located as near to the amplifier terminals as possible.
2. **CONSIDERATIONS FOR PROTOTYPING:** 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 ( $> 500\text{pF}$ ), 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  $20\text{K}\Omega$  balance potentiometer is recommended if offset nulling is required. However, other potentiometer values such as  $10\text{K}\Omega$ ,  $50\text{K}\Omega$ , and  $100\text{K}\Omega$  may be used. The minimum adjustment range for given values is  $\pm 2\text{mV}$ .
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  $1\text{V}$  are applied between the inputs, the use of limiting resistors at the inputs is recommended.

OFFSET NULLING CONNECTIONS



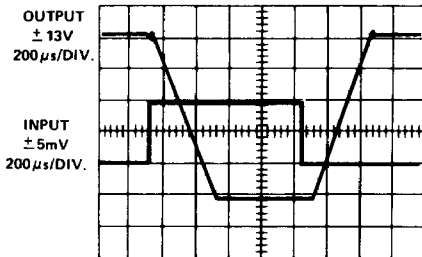
\* Although  $R_p$  is shown equal to 20k, other values such as 50k, 100k, and 1M may be used. Range of adjustment is approximately  $\pm 2.5\text{mV}$ .  $V_{OS}$  TC of the amplifier is optimized at minimal  $V_{OS}$ .

PRECISION INTEGRATOR

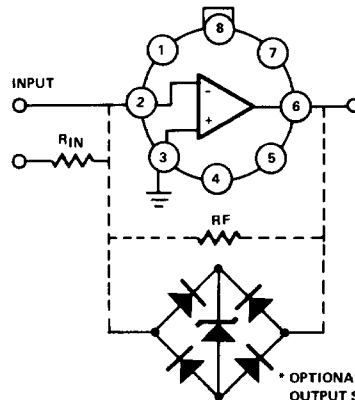


The excellent input and gain characteristics of HA-OP07 are well suited for precision integrator applications. Accurate integration over seven decades of frequency using HA-OP07, virtually nullifies the need for more expensive chopper-type amplifiers.

ZERO CROSSING DETECTOR



Low  $V_{OS}$  coupled with high open loop Gain, high CMRR, and high PSRR make HA-OP07 ideally suited for precision detector applications.



\* OPTIONAL FOR OUTPUT SWING LIMITING

PRECISION INSTRUMENTATION AMPLIFIER ( $A_V = 100$ )

