

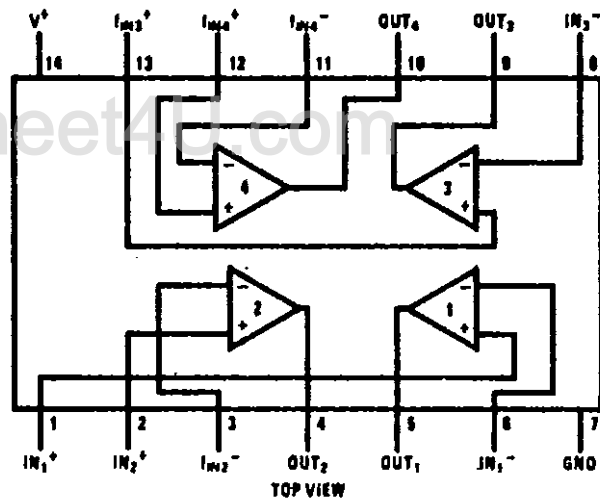
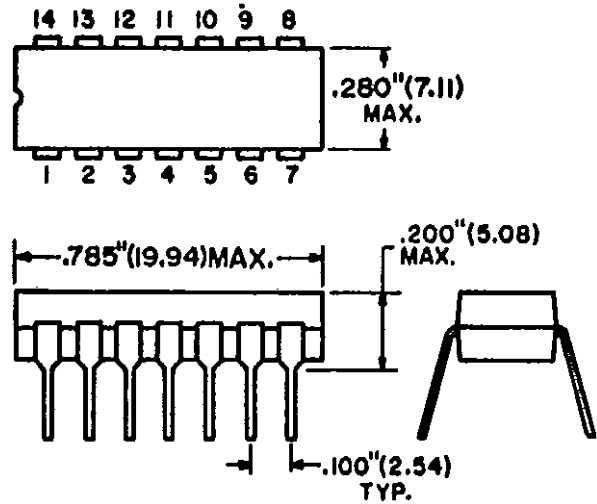
# ECG992

## 4 Independent Operational Amplifiers

### Features

- Wide single supply voltage range or dual supplies  
 $4V_{DC}$  to  $36V_{DC}$   
 $\pm 2V_{DC}$  to  $\pm 18V_{DC}$
- Supply current drain independent of supply voltage
- Low input biasing current  $30nA$
- High open-loop gain  $70dB$
- Wide bandwidth  $2.5MHz$  (Unity Gain)
- Large output voltage swing  
 $(V^+ - 1) V_{p-p}$
- Internally frequency compensated for unity gain
- Output short-circuit protection

The ECG992 consists of four independent, dual input, internally compensated amplifiers which were designed specifically to operate off a single power supply voltage and to provide a large output voltage swing. This amplifier makes use of a current mirror to achieve the non-inverting input function. Application areas include: ac amplifiers, RC active filters, low frequency triangle, squarewave and pulse waveform generation circuits, tachometers and low speed, high voltage digital logic gates.

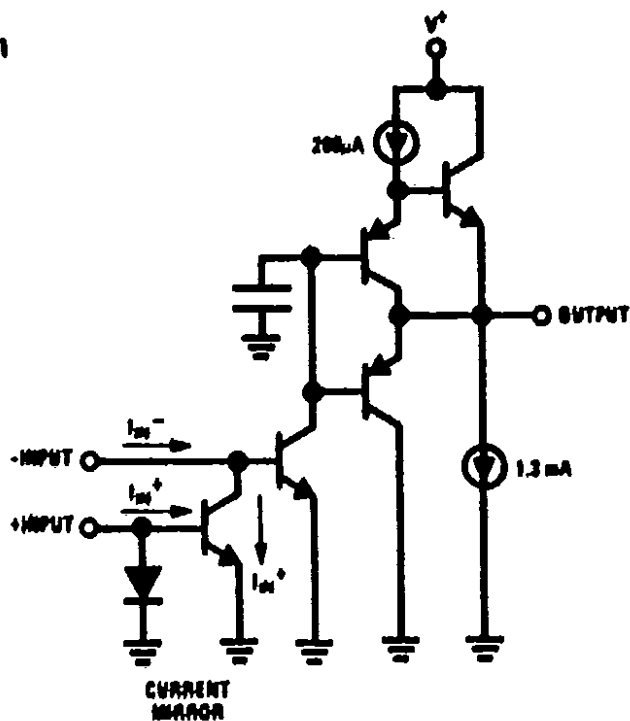


### Absolute Maximum Ratings

Supply Voltage .....	$32V_{DC}$ $\pm 16V_{DC}$
Power Dissipation ( $T_A = 25^\circ C$ )(Note 1) .....	$570mW$
Input Currents, $I_{IN}^+$ or $I_{IN}^-$ .....	$20mA_{DC}$
Output Short-Circuit Duration—One Amplifier .....	Continuous
$T_A = 25^\circ C$ (See Application Hints)	
Operating Temperature Range .....	$-40^\circ C$ to $+85^\circ C$
Storage Temperature Range .....	$-65^\circ C$ to $+150^\circ C$
Lead Temperature (Soldering, 10 seconds) .....	$300^\circ C$

**Note 1:** For operating at high temperatures, the device must be derated based on a  $125^\circ C$  maximum junction temperature and a thermal resistance of  $175^\circ C/W$  which applies for the device soldered in a printed circuit board, operating in a still air ambient.

## Schematic Diagram

Electrical Characteristics ( $-55^{\circ}\text{C} < T_A < +125^{\circ}\text{C}$  unless otherwise stated)

Characteristic	Conditions	Min	Typ	Max	Units
Open Loop Voltage Gain Input Resistance Output Resistance	$T_A = 25^{\circ}\text{C}$ , $f = 100\text{Hz}$ $T_A = 25^{\circ}\text{C}$ , Inverting Input	1.2	2.8 1 8		V/mV M $\Omega$ k $\Omega$
Unity Gain Bandwidth	$T_A = 25^{\circ}\text{C}$ , Inverting Input		2.5		MHz
Input Bias Current	$T_A = 25^{\circ}\text{C}$ , Inverting Input		30	200	nA
Slew Rate	$T_A = 25^{\circ}\text{C}$ , Positive Output Swing $T_A = 25^{\circ}\text{C}$ , Negative Output Swing		0.5 20		V/ $\mu\text{s}$ V/ $\mu\text{s}$
Supply Current	$T_A = 25^{\circ}\text{C}$ , $R_L = \infty$ On All Amplifiers		6.2	10	mADC
Output Voltage Swing $V_{\text{OUT High}}$ $V_{\text{OUT Low}}$ $V_{\text{OUT High}}$	$T_A = 25^{\circ}\text{C}$ , $R_L = 2\text{k}$ , $V_{\text{CC}} = 15.0\text{VDC}$ $I_{\text{IN}^-} = 0$ , $I_{\text{IN}^+} = 0$ $I_{\text{IN}^-} = 10\mu\text{A}$ , $I_{\text{IN}^+} = 0$ $I_{\text{IN}^-} = 0$ , $I_{\text{IN}^+} = 0$ , $R_L = \infty$ , $V_{\text{CC}} = 30\text{VDC}$	13.5	0.09 29.5	0.2	VDC VDC VDC
Output Current Capability Source Sink $I_{\text{SINK}}$	$T_A = 25^{\circ}\text{C}$  (Note 2) $V_{\text{OL}} = 1\text{V}$ , $I_{\text{IN}} = 5\mu\text{A}$	6 0.5	18 1.3 5		mADC mADC mADC
Power Supply Rejection	$T_A = 25^{\circ}\text{C}$ , $f = 100\text{Hz}$		70		dB
Mirror Gain	@ $20\mu\text{A}$ (Note 3) @ $200\mu\text{A}$ (Note 3)	0.90 0.90	1.0 1.0	1.1 1.1	$\mu\text{A}/\mu\text{A}$ $\mu\text{A}/\mu\text{A}$
$\Delta$ Mirror Gain	@ $20\mu\text{A}$ to $200\mu\text{A}$ (Note 3)		2	5	%
Mirror Current	(Note 4)		10	500	$\mu\text{ADC}$
Negative Input Current	$T_A = 25^{\circ}\text{C}$ (Note 5)		1.0		mADC

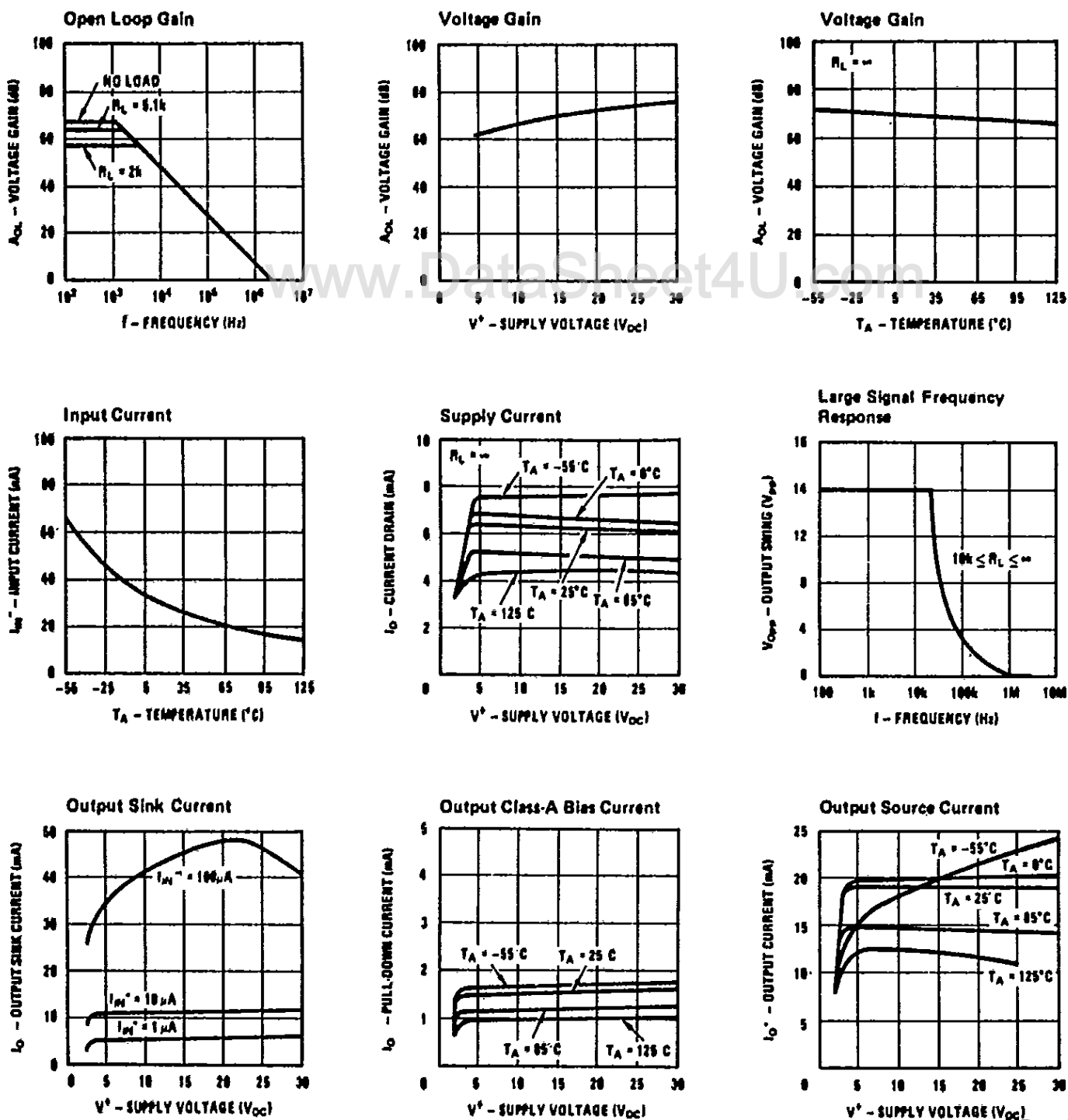
**Note 2:** The output current sink capability can be increased for large signal conditions by overdriving the inverting input. This is shown in the section on Typical Characteristics.

**Note 3:** This spec indicates the current gain of the current mirror which is used as the non-inverting input.

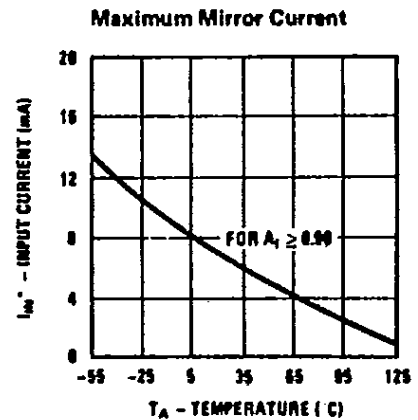
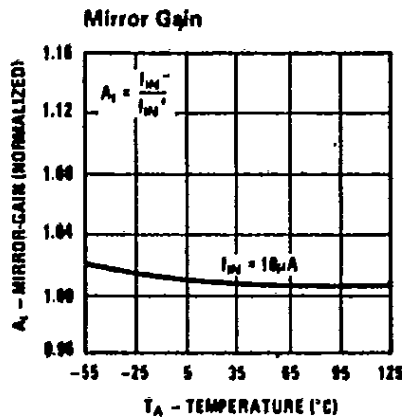
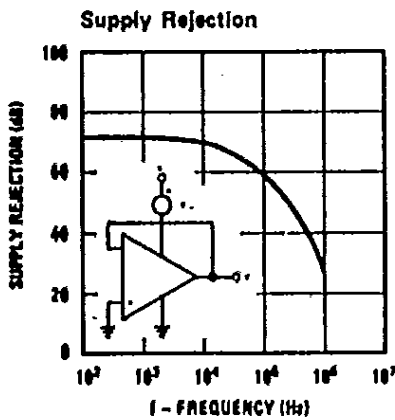
**Note 4:** Input  $V_{BE}$  match between the non-inverting and the inverting inputs occurs for a mirror current (non-inverting input current) of approximately  $10\mu A$ . This is therefore a typical design center for many of the application circuits.

**Note 5:** Clamp transistors are included on the IC to prevent the input voltages from swinging below ground more than approximately  $-0.3 V_{DC}$ . The negative input currents which may result from large signal overdrive with capacitance input coupling need to be externally limited to values of approximately  $1mA$ . Negative input currents in excess of  $4mA$  will cause the output voltage to drop to a low voltage. This maximum current applies to any one of the input terminals. If more than one of the input terminals are simultaneously driven negative smaller maximum currents are allowed. Common-mode current biasing can be used to prevent negative input voltages; see for example, the "Differentiator Circuit" in the applications section.

## Typical Performance Characteristics



## Typical Characteristics (Cont.)



## Application Hints

When driving either input from a low-impedance source, a limiting resistor should be placed in series with the input lead to limit the peak input current. Currents as large as 20mA will not damage the device, but the current mirror on the non-inverting input will saturate and cause a loss of mirror gain at mA current levels—especially at high operating temperatures.

Precautions should be taken to insure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is not inadvertently installed backwards in a test socket as an unlimited current surge through the resulting forward diode within the IC could cause fuzing of the internal conductors and result in a destroyed unit.

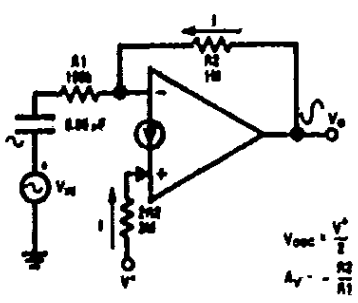
Output short circuits either to ground or to the positive power supply should be of short time duration. Units can be destroyed, not as a result of the short circuit current causing metal fuzing, but rather due to the large increase in IC chip dissipation which will cause eventual failure due to excessive junction temperatures. For example, when operating from a well-regulated  $+5V_{DC}$  power supply at  $T_A = 25^{\circ}C$  with a 100k $\Omega$  shunt-feedback resistor (from the output to the inverting input) a short directly to the power supply will not cause catastrophic failure but the current magnitude will be approximately 50mA and the junction temperature will be above  $T_J$  max. Larger feedback resistors will reduce the current, 11M $\Omega$  provides approximately 30mA, an open circuit provides 1.3mA, and a direct connection from the output to the non-inverting input will result in catastrophic failure when the output is shorted to  $V^+$  as this then places the base-emitter junction of the input transistor directly across the power supply. Short-circuits to ground will have magnitudes of approximately 30mA and will not cause catastrophic failure at  $T_A = 25^{\circ}C$ .

Unintentional signal coupling from the output to the non-inverting input can cause oscillations. This is likely only in breadboard hook-ups with long component leads and can be prevented by a more careful lead dress or by locating the non-inverting input biasing resistor close to the IC. A quick check of this condition is to bypass the non-inverting input to ground with a capacitor. High impedance biasing resistors used in the non-inverting input circuit make this input lead highly susceptible to unintentional ac signal pickup.

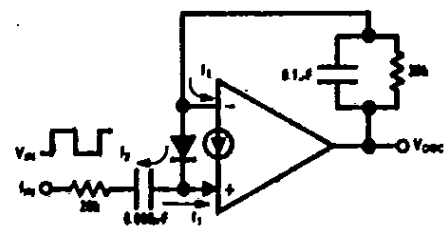
Operation of this amplifier can be best understood by noticing that input currents are differenced at the inverting-input terminal and this difference current then flows through the external feedback resistor to produce the output voltage. Common-mode current biasing is generally useful to allow operating with signal levels near ground or even negative as this maintains the inputs biased at  $+V_{BE}$ . Internal clamp transistors (see note 5) catch negative input voltages at approximately  $-0.3V_{DC}$  but the magnitude of current flow has to be limited by the external input network. For operation at high temperature, this limit should be approximately 100 $\mu A$ .

This new "Norton" current-differencing amplifier can be used in most of the applications of a standard IC op amp. Performance as a dc amplifier using only a single supply is not as precise as a standard IC op amp operating with split supplies but is adequate in many less critical applications. New functions are made possible with this amplifier which are useful in single power supply systems. For example, biasing can be designed separately from the ac gain as was shown in the "inverting amplifier," the "difference integrator" allows controlling the charging and the discharging of the integrating capacitor both with positive voltages, and the "frequency doubling tachometer" provides a simple circuit which reduces the ripple voltage on a tachometer output dc voltage.

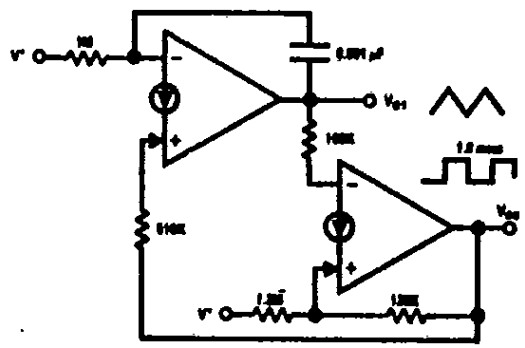
# Typical Applications ( $V^+ = 15V_{DC}$ )



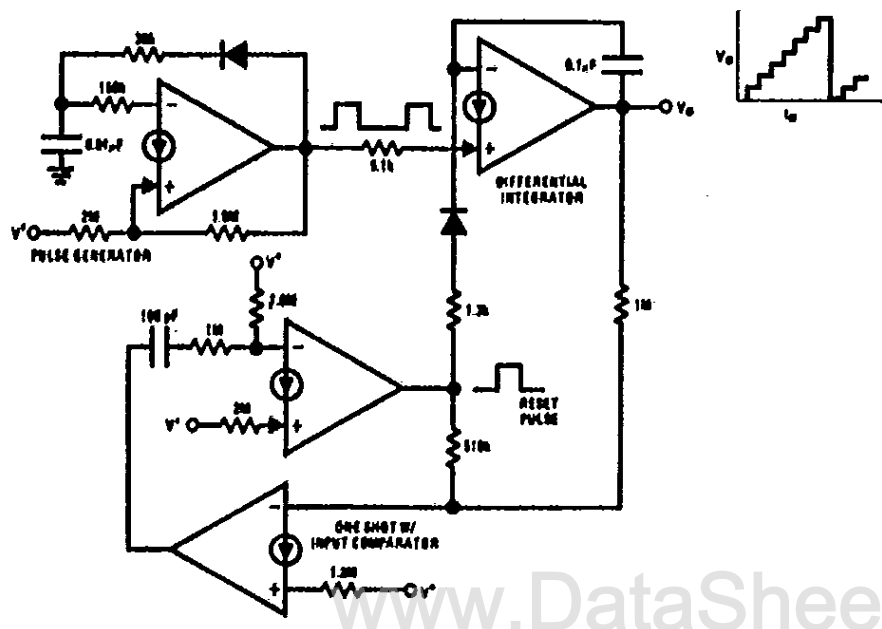
Inverting Amplifier



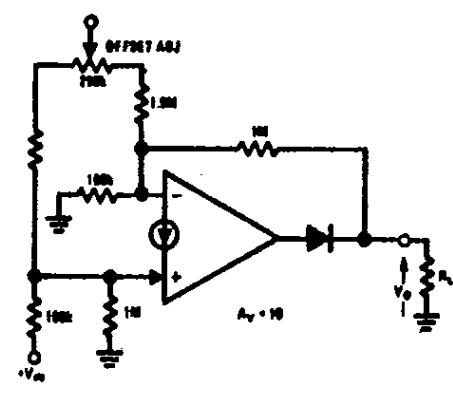
Frequency-Doubling Tachometer



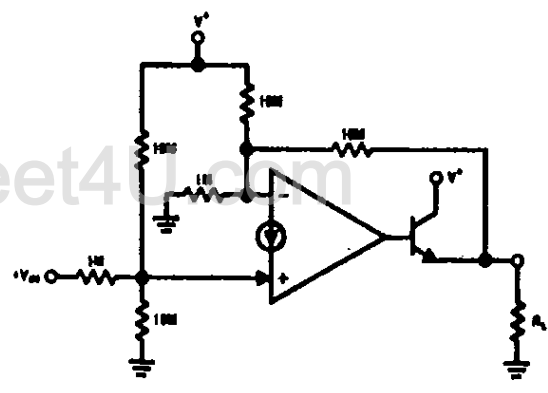
Triangle/Square Generator



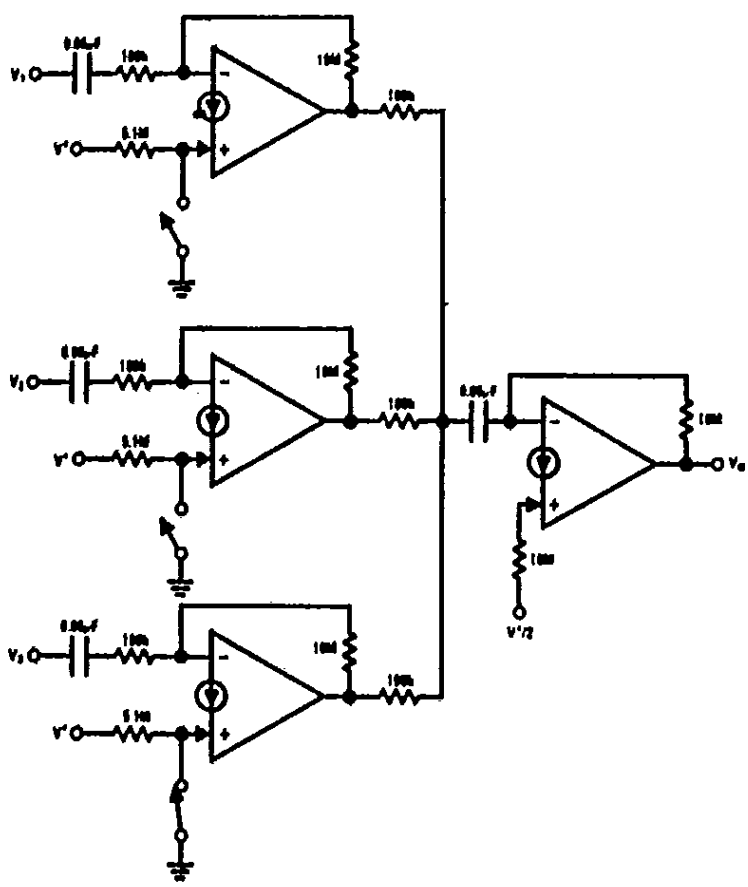
Free-Running Staircase Generator/Pulse Counter



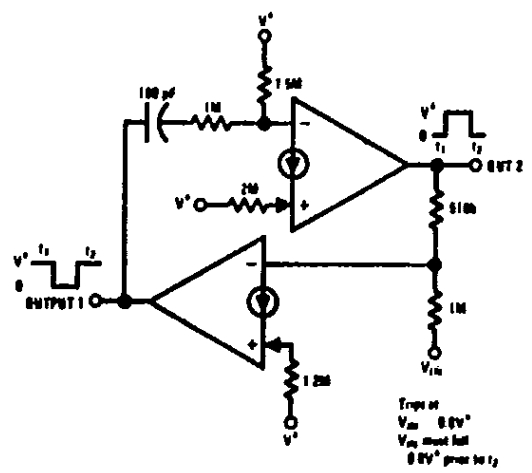
Non-Inverting DC Gain to (0,0)



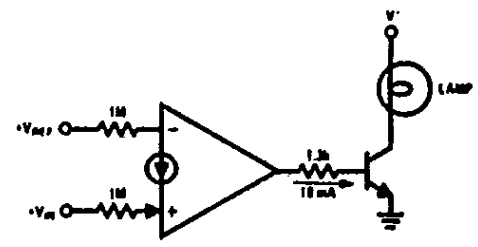
Power Amplifier



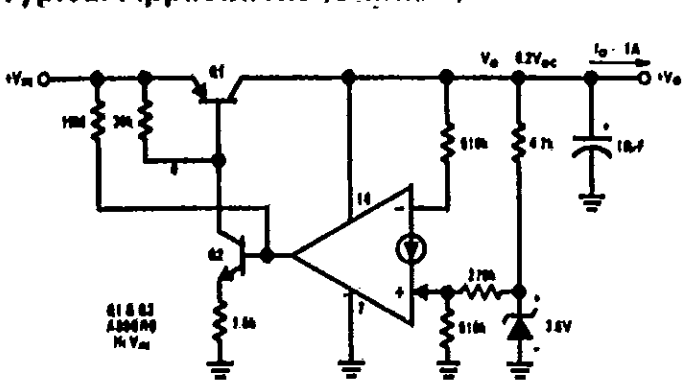
Channel Selection by DC Control (or Audio Mixer)



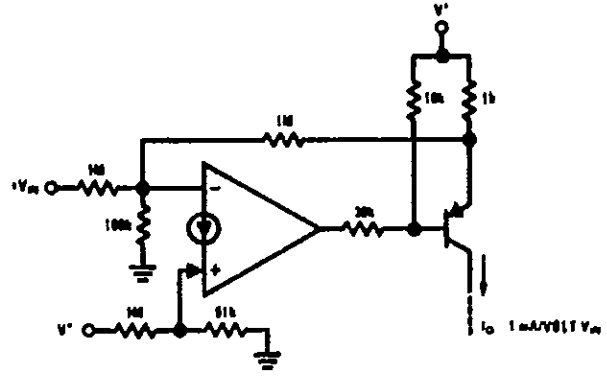
One-Shot with DC Input Comparator



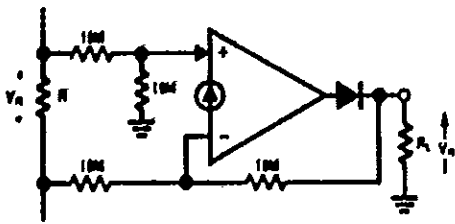
### Typical Applications (Continued)



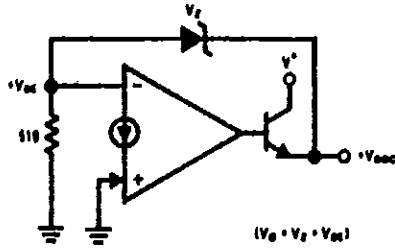
Hi  $V_{IN}$ , Lo ( $V_{IN} - V_O$ ) Self-Regulator



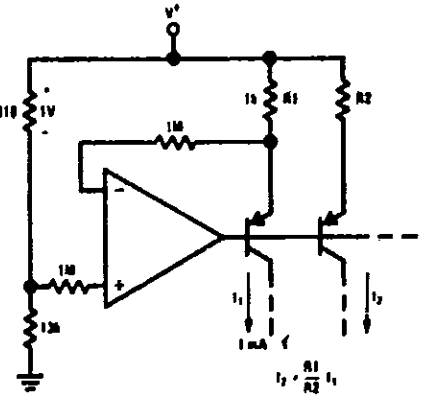
Voltage-Controlled Current Source (Transconductance Amplifier)



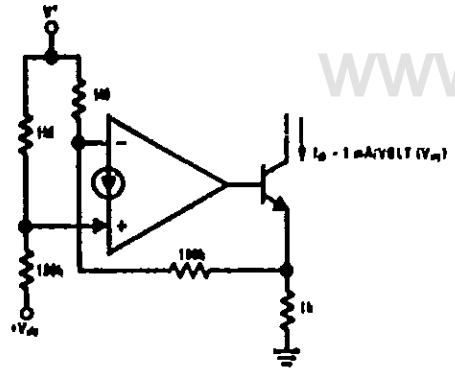
Ground-Referencing a Differential Input Signal



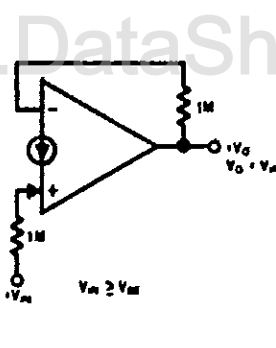
Voltage Regulator



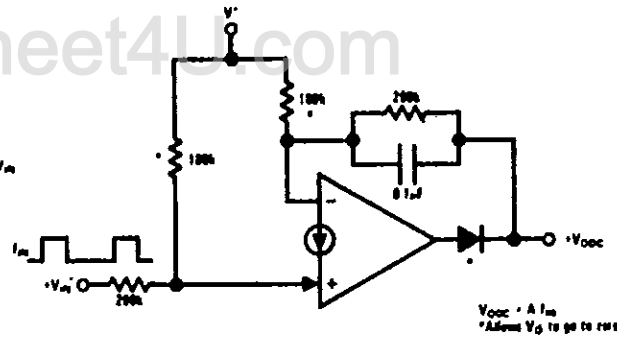
Fixed Current Sources



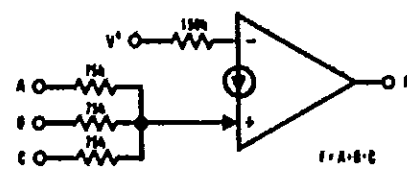
Voltage-Controlled Current Sink (Transconductance Amplifier)



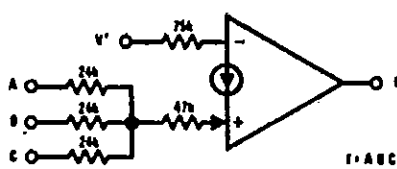
Buffer Amplifier



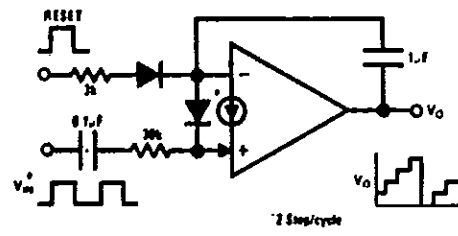
Tachometer



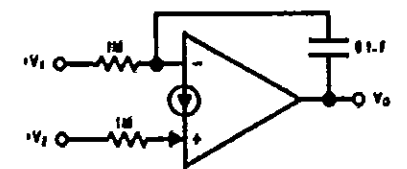
"OR" Gate



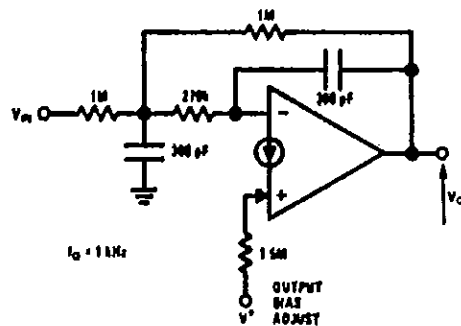
"AND" Gate



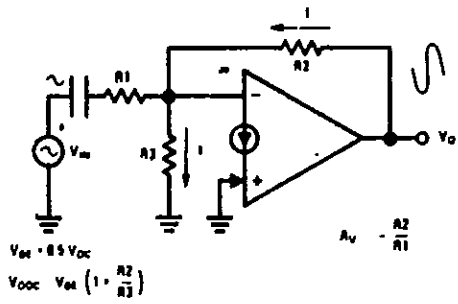
Staircase Generator



Difference Integrator

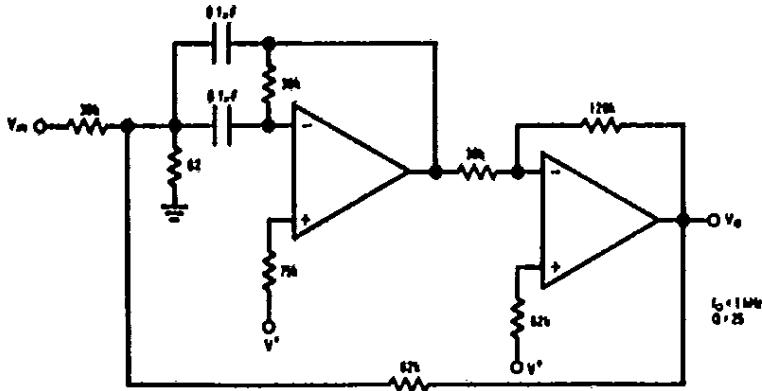


Low Pass Active Filter

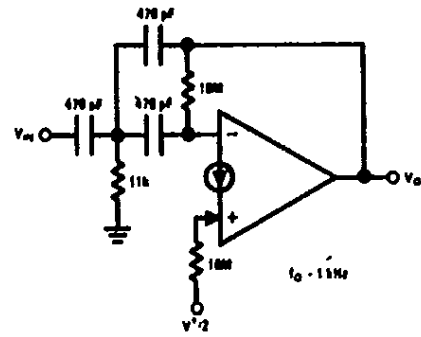


VBE Biasing

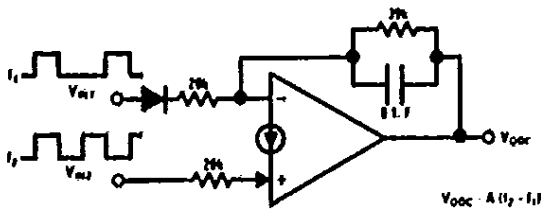
# Typical Applications (Continued)



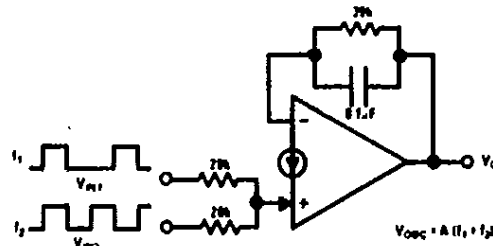
**Bandpass Active Filter**



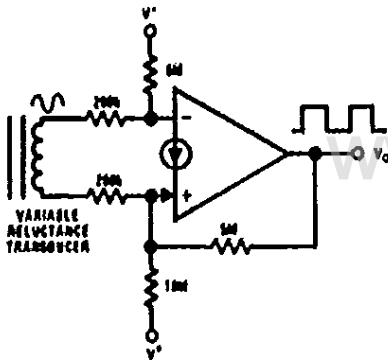
**High Pass Active Filter**



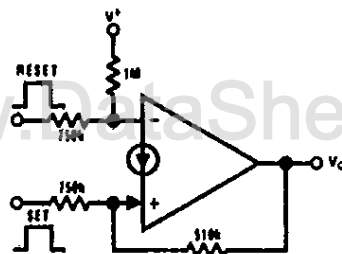
**Frequency Differencing Tachometer**



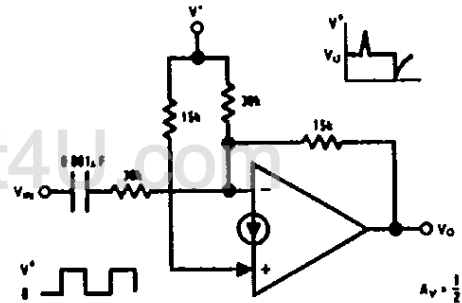
**Frequency Averaging Tachometer**



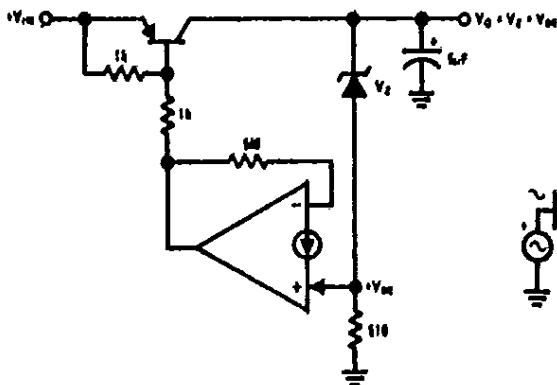
**Squaring Amplifier (W/Hysteresis)**



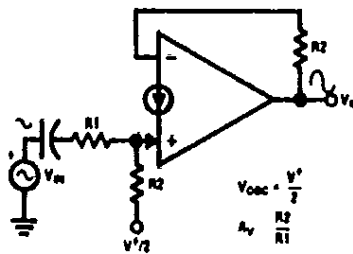
**Bi-Stable Multivibrator**



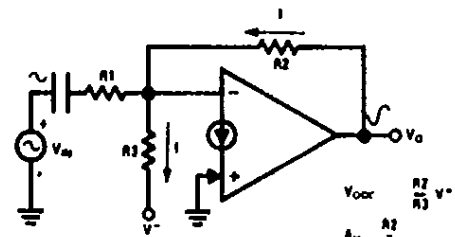
**Differentiator (Common-Mode Biasing Keeps Input at +VBE)**



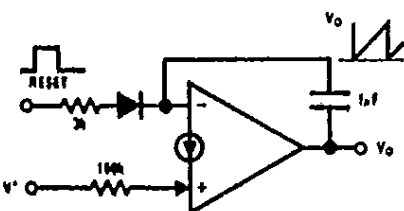
**Low VIN - VOUT Voltage Regulator**



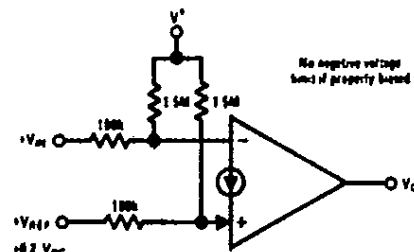
**Non-Inverting Amplifier**



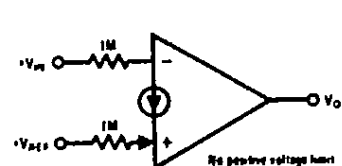
**Negative Supply Biasing**



**Sawtooth Generator**



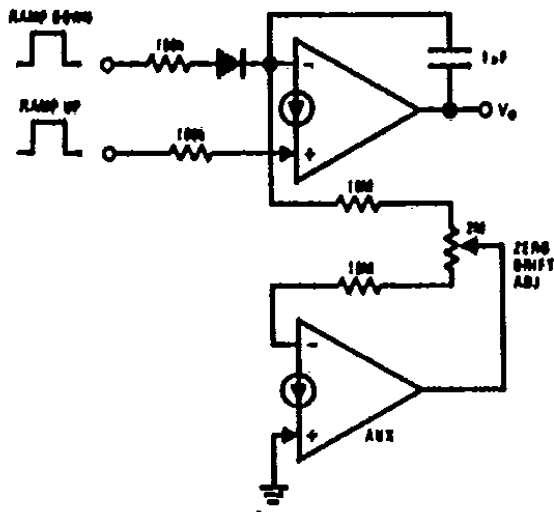
**Low-Voltage Comparator**



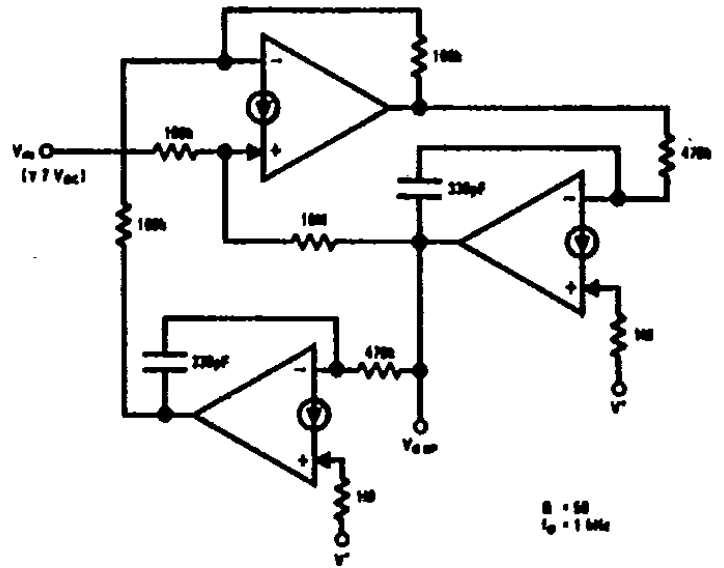
**Comparator**



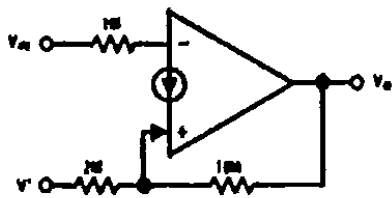
### Typical Applications (Continued)



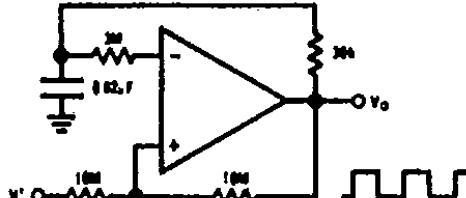
Low-Drift Ramp and Hold Circuit



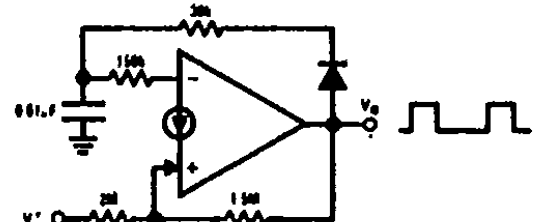
Bi-Quad Active Filter  
(2nd Degree State-Variable Network)



Schmitt-Trigger

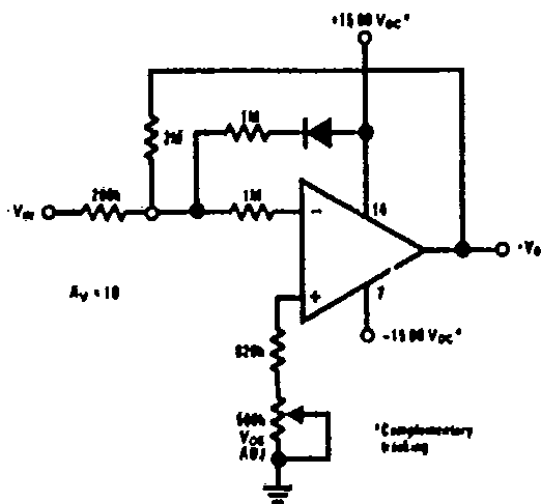


Square-Wave Oscillator

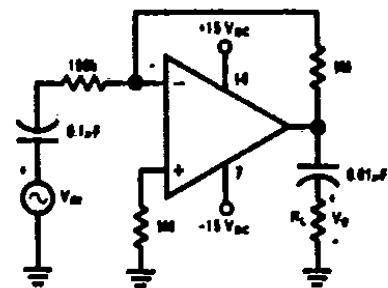


Pulse Generator

### Split-Supply Applications ( $V^+ = +15V_{DC}$ and $V^- = -15V_{DC}$ )



Non-Inverting DC Gain



AC Amplifier