# DUAL HIGH SLEW RATE OP AMP

# SE/NE5535

## DESCRIPTION

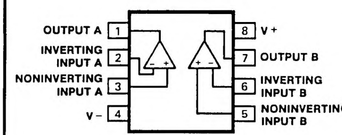
The 5535 is a new generation operational amplifier featuring high slew rates combined with improved input characteristics. The 5535 is a dual configuration. Internally compensated for unity gain, the SE5535 features a guaranteed unity gain slew rate of 10V/μs with 2mV maximum offset voltage. Industry standard pin out and internal compensation allow the user to upgrade system performance by directly replacing general purpose amplifiers, such as 747 and 1558.

## FEATURES

- **15V/μs unity gain slew rate**
- **Internal frequency compensation**
- **Low input offset voltage—2mV**
- **Low input bias current 80nA max**
- **Short circuit protected**
- **Large common mode and differential voltage ranges**
- **Pin compatibility 5535 747,1558**
- **Configuration Dual**
- **Low noise current 0.15 pA/$\sqrt{Hz}$ typ.**

## PIN CONFIGURATIONS

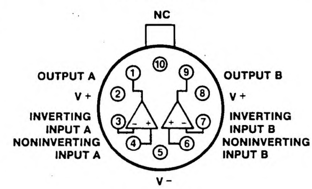
**N PACKAGE**




**TOP VIEW**

**ORDER NUMBERS**
SE5535N NE5535N

**H PACKAGE***




**ORDER NUMBERS**
SE5535H NE5535H

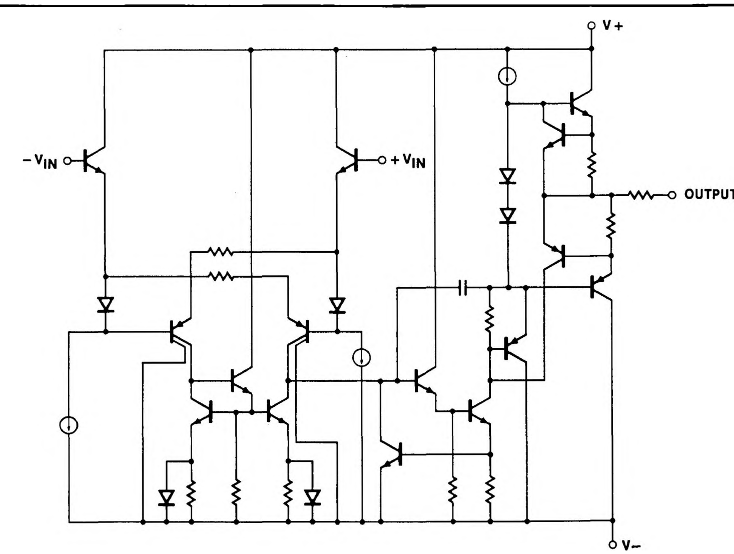
*Metal cans (H) not recommended for new designs

## ABSOLUTE MAXIMUM RATINGS

| PARAMETER | SE5535 | NE5535 | UNIT |
|---|---|---|---|
| Supply voltage | ±22 | ±18 | V |
| Internal power dissipation[1] | | | |
| N Package | 500 | 500 | mW |
| H Package | 800 | 800 | mW |
| F Package | 1000 | 1000 | mW |
| Differential input voltage | ±30 | ±30 | V |
| Input voltage[2] | ±15 | ±15 | V |
| Operating temperature range | -55 to +125 | 0 to +70 | °C |
| Storage temperature range | -65 to +150 | -65 to +150 | °C |
| Lead temperature (solder, 60sec) | 300 | 300 | °C |
| Output short circuit[3] | Indefinite | Indefinite | |

NOTES
1. Rating applies for thermal resistances junction to ambient of 240°C/W and 150°C/W for N and H packages, respectively. Maximum chip temperature is 150°C.
2. For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.
3. Short circuit may be to ground or either supply. Rating applies to 125°C case temperature or 75°C ambient temperature.

## EQUIVALENT SCHEMATIC (One Amplifier)



# DUAL HIGH SLEW RATE OP AMP SE/NE5535

## DC ELECTRICAL CHARACTERISTICS

$T_A = 25°C$, $V_S = \pm15V$ unless otherwise specified.*

| PARAMETER | | TEST CONDITIONS | SE5535 | | | NE5535 | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | Min | Typ | Max | |
| $V_{OS}$ | Input offset voltage | $R_S \le 10k\Omega$<br>$R_S \le 10k\Omega$, over temp. | | 0.7 | 4.0<br>5.0 | | 2.0 | 6.0<br>7.0 | mV<br>mV |
| $\Delta V_{OS}$ | Input offset voltage drift | $R_S = 0\Omega$, over temp. | | 4.0 | | | 6.0 | | μV/°C |
| $I_{OS}$ | Input offset current | <br>Over temp. | | 5 | 20<br>40 | | 15 | 40<br>80 | nA<br>VnA |
| $\Delta I_{OS}$ | Input offset current | Over temp. | | 25 | | | 40 | | pA/°C |
| $I_B$ | Input current | <br>Over temp. | | 45 | 80<br>200 | | 65 | 150<br>200 | nA<br>nA |
| $\Delta I_B$ | Input current | Over temp. | | 50 | | | 80 | | pA/°C |
| $V_{CM}$<br>CMRR | Common mode voltage range<br>Common mode rejection ratio | <br>$R_S \le 10k\Omega$, over temp. | ±12<br>70 | ±13<br>90 | | ±12<br>70 | ±13<br>90 | | V<br>dB |
| PSRR | Power supply rejection | $R_S \le 10k\Omega$, over temp. | | 30 | 150 | | 30 | 150 | μV/V |
| $R_{IN}$ | Input resistance | | 3 | 10 | | 1 | 6 | | MΩ |
| $A_{VOL}$ | Large signal voltage gain | $R_L \ge 2k\Omega$, $V_{OUT} = \pm10V$<br>$R_L \ge 2k\Omega$, $V_{OUT} = \pm10V$, over temp. | 50<br>25 | 500 | | 50<br>25 | 500 | | V/mV<br>V/mV |
| $V_{OUT}$ | Output voltage | $R_L \ge 2k\Omega$, over temp.<br>$R_L \ge 10k\Omega$, over temp. | ±10<br>±12 | ±13<br>±14 | | ±10<br>±12 | ±13<br>±14 | | V<br>V |
| $I_{CC}$ | Supply current | Per amplifier<br>Per amplifier, over temp. | | 1.8<br>2 | 2.8<br>3.3 | | 1.8<br>2 | 2.8 | mA<br>mA |
| $P_D$ | Power dissipation | Per amplifier<br>Per amplifier, over temp. | | 54<br>60 | 84<br>99 | | 54<br>60 | 84 | mW<br>mW |
| $I_{SC}$ | Output short circuit current | | 10 | 25 | 50 | 10 | 25 | 50 | mA |
| $R_{OUT}$ | Output resistance | | | 100 | | | 100 | | Ω |

*NOTE

Temperature range

SE types $-55°C \le T_A \le 125°C$

NE types $0°C \le T_A \le 70°C$

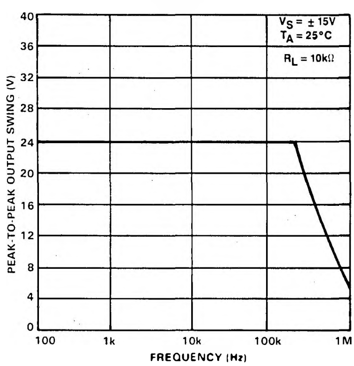
# DUAL HIGH SLEW RATE OP AMP — SE/NE5535

## AC ELECTRICAL CHARACTERISTICS $T_A = 25°C$ unless otherwise specified.

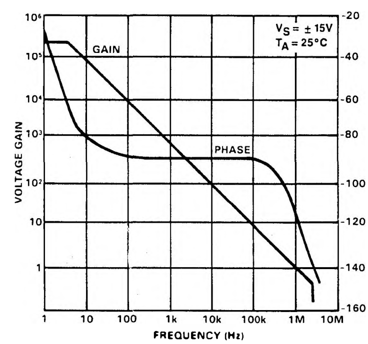
| PARAMETER | TEST CONDITIONS | SE5535 | | | NE5535 | | | UNIT |
|---|---|---|---|---|---|---|---|---|
| | | Min | Typ | Max | Min | Typ | Max | |
| Gain/bandwidth product | | | 1 | | | 1 | | MHz |
| Transient response | | | | | | | | |
| Small signal rise time | | | 0.25 | | | 0.25 | | μs |
| Small signal overshoot | | | 6 | | | 6 | | % |
| Settling time | To 0.1% | | 3 | | | 3 | | μs |
| Slew rate | $R_L \geq 10k\Omega$, unity gain, non-inverting | 10 | 15 | | 10 | 15 | | V/μs |
| Input noise voltage | f = 1kHz, $T_A = 25°C$ | | 30 | | | 30 | | nV/√Hz |

## TYPICAL PERFORMANCE CHARACTERISTICS

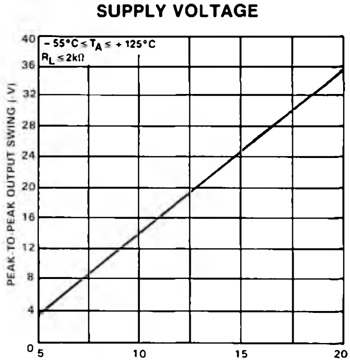
**OUTPUT VOLTAGE SWING AS A FUNCTION OF FREQUENCY**



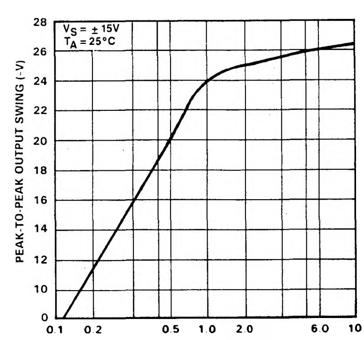

**OPEN LOOP VOLTAGE GAIN AS A FUNCTION OF FREQUENCY**




**OUTPUT VOLTAGE SWING AS A FUNCTION OF SUPPLY VOLTAGE**



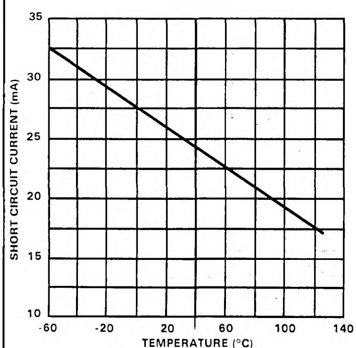

**OUTPUT VOLTAGE SWING AS A FUNCTION OF LOAD RESISTANCE**



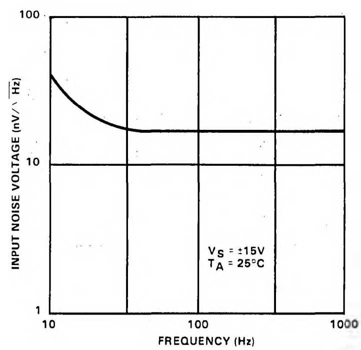
# DUAL HIGH SLEW RATE OP AMP — SE/NE5535

## TYPICAL PERFORMANCE CHARACTERISTICS (Cont'd)

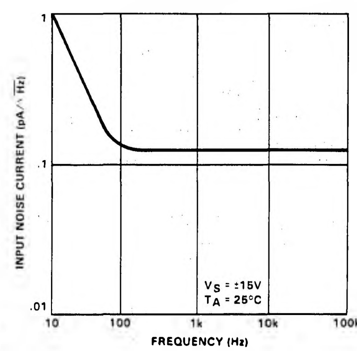
### OUTPUT SHORT-CIRCUIT CURRENT AS A FUNCTION OF AMBIENT TEMPERATURE



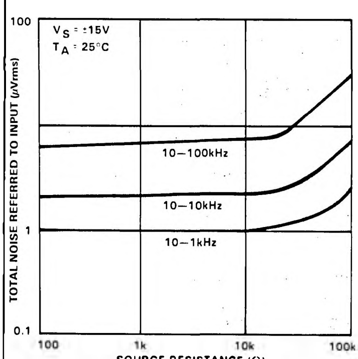

### INPUT NOISE VOLTAGE AS A FUNCTION OF FREQUENCY



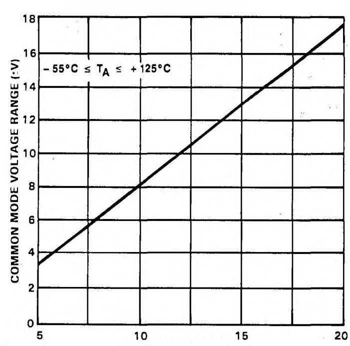

### INPUT NOISE CURRENT AS A FUNCTION OF FREQUENCY



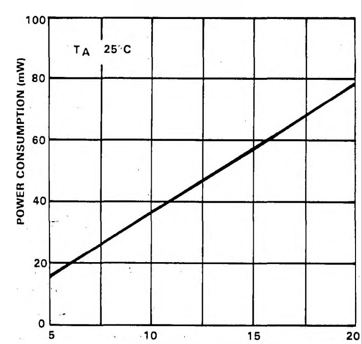

### BROADBAND NOISE FOR VARIOUS BANDWIDTHS



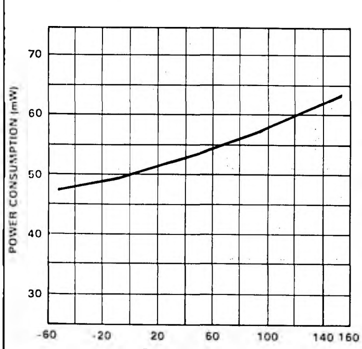

### INPUT COMMON MODE VOLTAGE RANGE AS A FUNCTION OF SUPPLY VOLTAGE



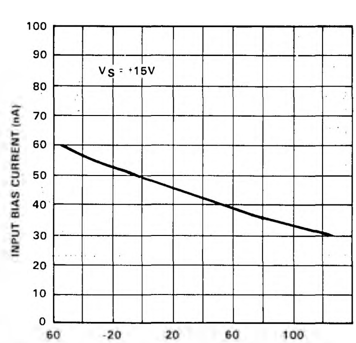

### POWER CONSUMPTION AS A FUNCTION OF SUPPLY VOLTAGE



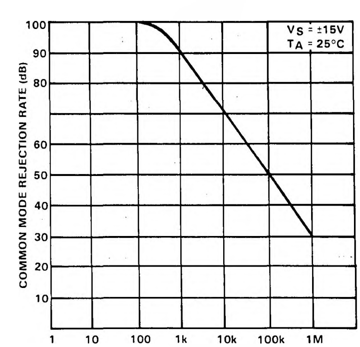

### POWER CONSUMPTION AS A FUNCTION OF AMBIENT TEMPERATURE




### INPUT BIAS CURRENT AS A FUNCTION OF AMBIENT TEMPERATURE

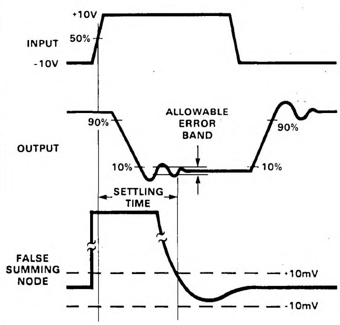



### COMMON MODE REJECTION RATIO AS A FUNCTION OF FREQUENCY

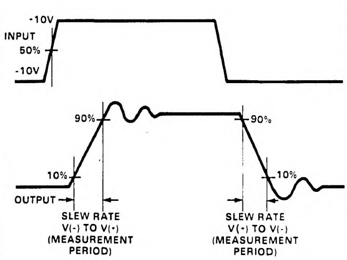


## VOLTAGE WAVEFORMS

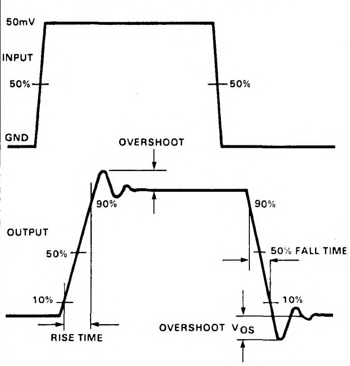
### SETTLING TIME MEASUREMENT




### SLEW RATE MEASUREMENT

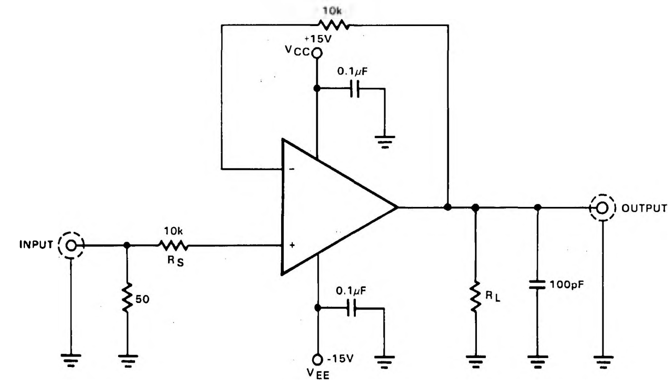



### SMALL-SIGNAL TRANSIENT RESPONSE DEFINITIONS



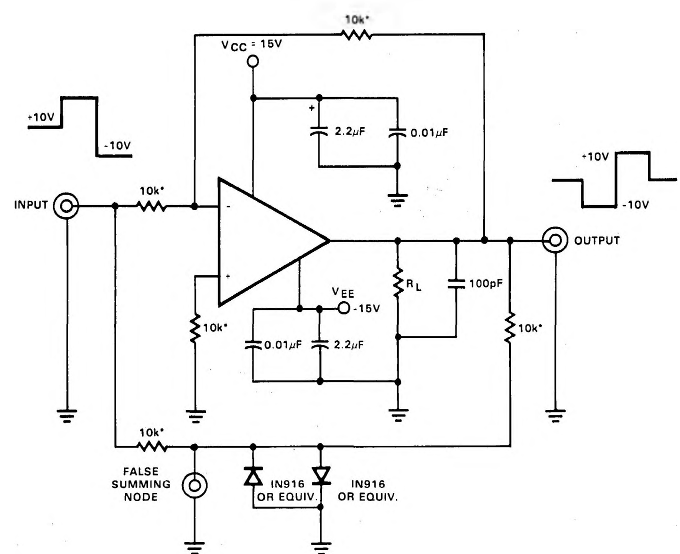

## TEST CIRCUITS

### SLEW RATE AND SMALL SIGNAL TRANSIENT RESPONSE




NOTE
Pins not shown are not connected.
All resistors values are typical and in ohms.

### SETTLING TIME




*Match to within 0.01%.

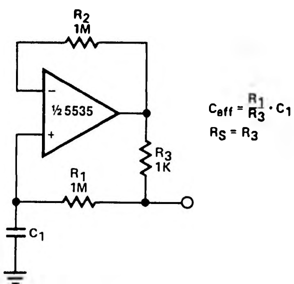
NOTE

Pins not shown are not connected.
All resistors values are typical and in ohms.

## APPLICATIONS

### Introduction

The NE5535 is a new generation monolithic op amp which features improved input characterisics. The device is compensated to unity gain and has a minimum guaranteed unity gain slew rate of 10V/μs. This is achieved by employing a clamped super beta input stage which has lower input bias current.




All resistor values are in ohms.

**Figure 1. Capacitance Multiplier**

### Applications

These improved parameters can be put to good use in applications such as sample and hold circuits which require low input current and in voltage follower circuits which require high slew rates. The circuit that follows will yield slew rates. The circuit that follows will yield maximum small signal transient response and slew rate for the NE5535 at unity gain.

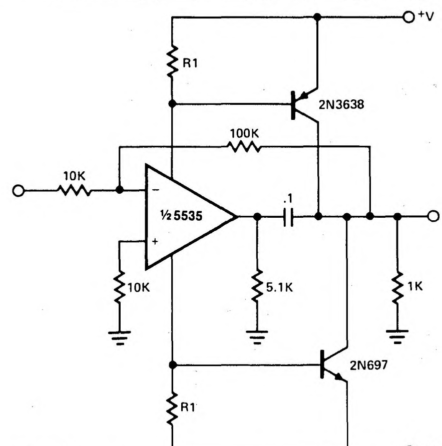
It is always good practice in designing a system to use dual tracking regulators to power the dual supply op amps. This will guarantee the positive and negative supply voltage will be equal during power up. With the NE5535, it is possible to degrade the input circuit characteristics by not applying the power supplies simultaneously. The NE5535 is capable of directly replacing the μA741 with higher input resistance which will improve such designed as active filters, sample and hold, as well as voltage followers.

The NE5535 can be used either with single or split power supplies.

## APPLICATIONS

### CAPACITANCE MULTIPLIER

The circuit in Figure 1 can be used to simulate large capacitances using small value components. With the values shown and C = 10μF, an effective capacitance of 10,000μF was obtained. The Q available is limited by the effective series resistance. So R1 should be as large as practical.




All resistor values are in ohms.

**Figure 3. Power Booster**

### SIMULATED INDUCTOR

With a constant current excitation, the voltage dropped across an inductance increases with frequency. Thus, an active device whose output increases with frequency can be characterized as an inductance. The circuit of Figure 2 yields such a response with the effective inductance being equal to:

L = R1R2C

The Q of this inductance depends upon R1 being equal to R2. At the same time, however, the positive and negative feedback paths of the amplifier are equal leading to the distinct possibility of instability at high frequencies. R1 should therefore always be slightly smaller than R2 to assure stable operation.

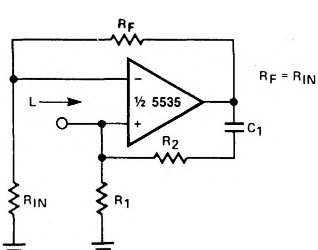



**Figure 2. Virtual Inductor**

### POWER AMPLIFIER

For most applications, the available power from op amps is sufficient. There are times when more power handling capability is necessary. A simple power booster capable of driving moderate loads is offered in Figure 3.

The circuit as shown uses a NE5535 device. Other amplifiers may be substituted only if R1 values are changed because of the ICC current required by the amplifier. R1 should be calculated from the expression

$$R1 = \frac{600mV}{ICC}$$

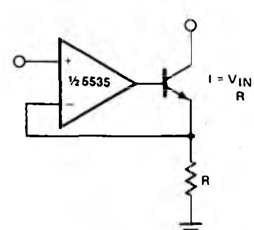



**Figure 4. Voltage to Current Converters**

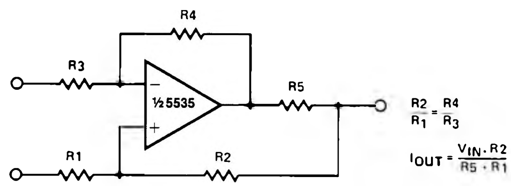



Figure 5. Voltage to Current Converter

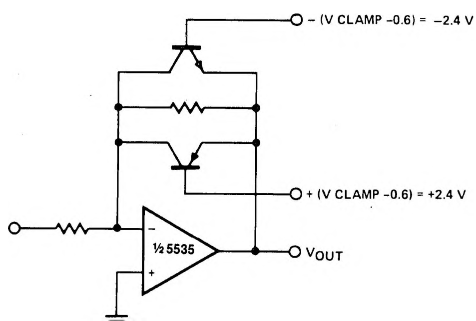
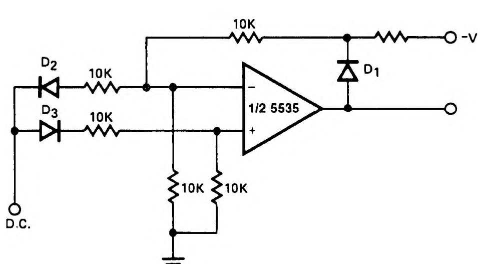



Figure 6. Active Clamp Limiting Amplifier




All resistor values are in ohms.

Figure 7. Absolute Value Amplifier

## VOLTAGE-TO-CURRENT CONVERTERS

A simple voltage-to-current converter is shown in Figure 4. The current out is $I_{out} \cong V_{in}/R$. For negative currents, a pnp can be used and, for better accuracy, a Darlington pair can be substituted for the transistor. With careful design, this circuit can be used to control currents of many amps. Unity gain compensation is necessary.

The circuit in Figure 5 has a different input and will produce either polarity of output current. The main disadvantages are the error current flowing in R2 and the limited current available.

## ACTIVE CLAMP LIMITING AMPLIFIER

The modified inverting amplifier in Figure 6 uses an active clamp to limit the output swing with precision. Allowance must be made for the Vbe of the transistors. The swing is limited by the base-emitter breakdown of the transistors. A simple circuit uses two back-to-back zener diodes across the feedback resistor, but tends to give less precise limiting and cannot be easily controlled.

## ABSOLUTE VALUE AMPLIFIER

The circuit in Figure 7 generates a positive output voltage for either polarity of input. For positive signals, it acts as a non-inverting amplifier and for negative signals, as an inverting amplifier. The accuracy is poor for input voltages under 1V, but for less stringent applications, it can be effective.

## HALF WAVE RECTIFIER

Figure 8 provides a circuit for accurate half wave rectification of the incoming signal. For positive signals, the gain is 0; for negative signals, the gain is −1. By reversing both diodes, the polarity can be inverted. This circuit provides an accurate output, but the output impedance differs for the two input polarities and buffering may be needed. The output must slew through two diode drops when the input polarity reverses. The NE5535 device will work up to 10kHz with less than 5% distortion.

## PRECISION FULL WAVE RECTIFIER

The circuit in Figure 9 provides accurate full wave rectification. The output impedance is low for both input polarities, and the errors are small at all signal levels. Note that the output will not sink heavy currents, except a small amount through

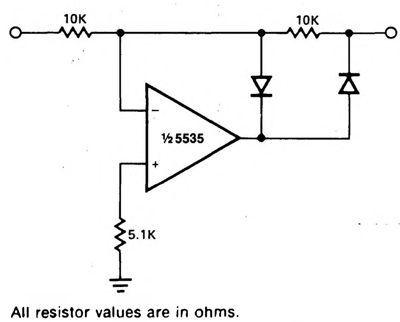



Figure 8. Half Wave Rectifier

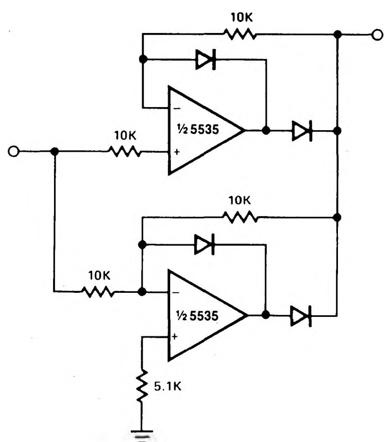



Figure 9. Precision Full Wave Rectifier

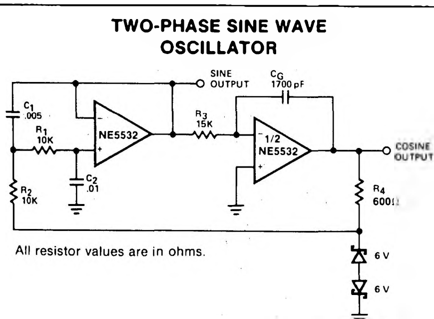



Figure 10. Two-Phase Sine Wave Oscillator

the 10kΩ resistors. Therefore, the load applied should be referenced to ground or a negative voltage. Reversal of all diode polarities will reverse the polarity of the output. Since the outputs of the amplifiers must slew through two diode drops when the input polarity changes, 741 type devices give 5% distortion at about 300Hz.

## TWO-PHASE SINE WAVE OSCILLATOR

The circuit (referring to Figure 10, uses a 2-pole pass Butterworth, followed by a phase shifting single pole stage, fed back through a voltge limiter to achieve sine and cosine outputs. The values shown using 741 amplifiers give about 1.5% distortion at the sine output and about 3% distortion at the cosine output. By careful trimming of $C_G$ and/or the limiting network, better distortion figures are possible. The component values shown give a frequency of oscillation of about 2kHz. The values can be readily selected for other frequencies. The NE5535 should be used at higher frequencies to reduce distortion due to slew limiting.