

NE/SE5535

Dual High Slew Rate Op Amp

Product Specification

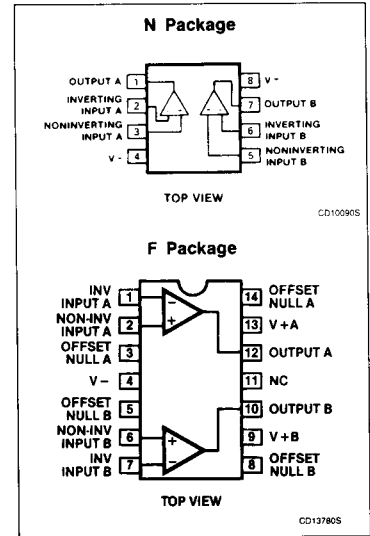
DESCRIPTION

The NE/SE5535 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 $10V/\mu s$ with 4mV maximum offset voltage. Industry standard pinout and internal compensation allow the user to upgrade system performance by directly replacing general purpose amplifiers, such as 747 and 1558.

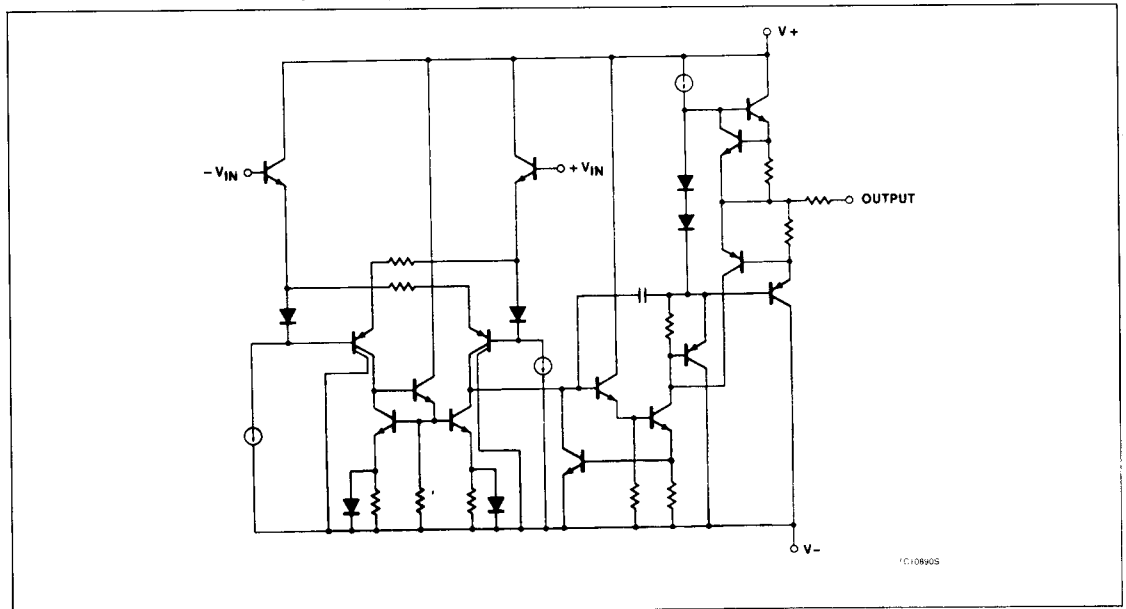
FEATURES

- $15V/\mu s$ 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 $\frac{5535}{747, 1558}$
- Dual configuration
- Low noise current $0.15pA/\sqrt{Hz}$ typ.

PIN CONFIGURATION



EQUIVALENT SCHEMATIC (one amplifier)



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ORDERING INFORMATION

| DESCRIPTION | TEMPERATURE RANGE | ORDER CODE |
|-------------------|-------------------|------------|
| 8-Pin Plastic DIP | 0 to +70°C | NE5535N |
| 8-Pin Plastic DIP | -55°C to +125°C | SE5535N |
| 14-Pin Cerdip | 0 to +70°C | NE5535F |
| 14-Pin Cerdip | -55 to +125°C | SE5535F |

ABSOLUTE MAXIMUM RATINGS

| SYMBOL | PARAMETER | SE5535 | NE5535 | UNIT |
|------------|---|-------------|-------------|------|
| V_S | Supply voltage | ± 22 | ± 18 | V |
| P_D | Internal power dissipation ¹ | | | |
| | N package | 1275 | 1275 | mW |
| | F package | 1250 | 1250 | mW |
| V_{IN} | Differential input voltage | ± 30 | ± 30 | V |
| V_{IN} | Input voltage ² | ± 15 | ± 15 | V |
| T_A | Operating temperature range | -55 to +125 | 0 to +70 | °C |
| T_{STG} | Storage temperature range | -65 to +150 | -65 to +150 | °C |
| T_{SOLD} | Lead soldering temperature (10sec max) | 300 | 300 | °C |
| I_{SC} | Output short-circuit ³ | Indefinite | Indefinite | |

NOTES:

- Rating applies at $T_A = 25^\circ\text{C}$ for thermal resistances junction to ambient of $98^\circ\text{C}/\text{W}$ and $100^\circ\text{C}/\text{W}$ for N and F packages, respectively. Maximum junction temperature is 150°C .
- For supply voltages less than $\pm 15\text{V}$, the absolute maximum input voltage is equal to the supply voltage.
- Short-circuit may be to ground or either supply. Rating applies to 125°C case temperature or 75°C ambient temperature.

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DC ELECTRICAL CHARACTERISTICS $T_A = 25^\circ\text{C}$, $V_S = \pm 15\text{V}$, unless otherwise specified.*

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

NOTE:

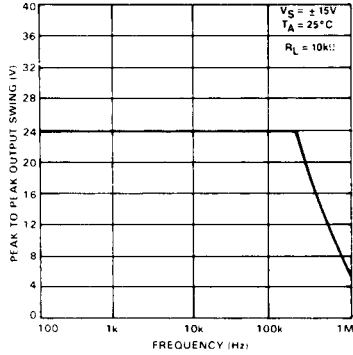
* Temperature range:
SE types $-55^\circ\text{C} \leq T_A \leq 125^\circ\text{C}$
NE types $0^\circ\text{C} \leq T_A \leq 70^\circ\text{C}$

AC ELECTRICAL CHARACTERISTICS $T_A = 25^\circ\text{C}$, unless otherwise specified.

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

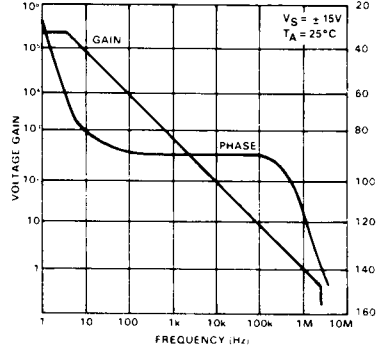
TYPICAL PERFORMANCE CHARACTERISTICS

Output Voltage Swing as a Function of Frequency



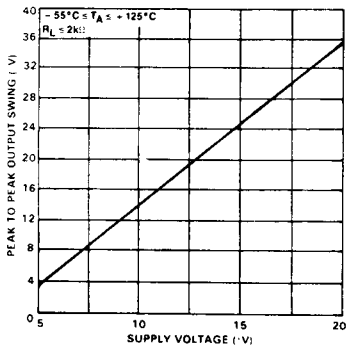
OP067805

Open-Loop Voltage Gain as a Function of Frequency



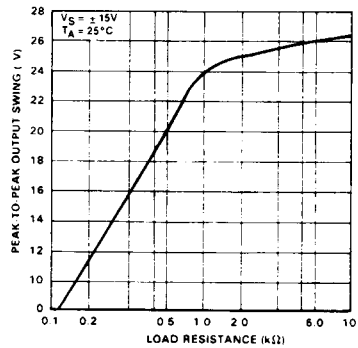
OP067805

Output Voltage Swing as a Function of Supply Voltage



OP068008

Output Voltage Swing as a Function of Load Resistance



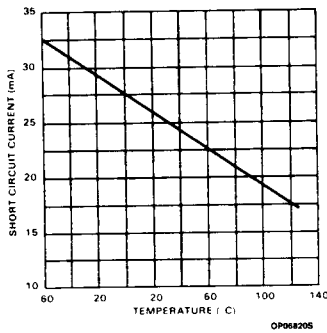
OP068108

Dual High Slew Rate Op Amp

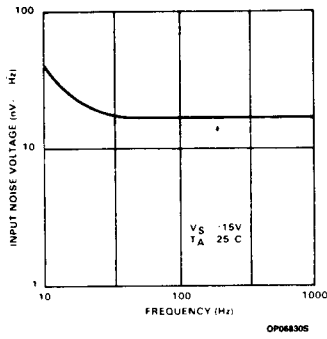
NE/SE5535

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

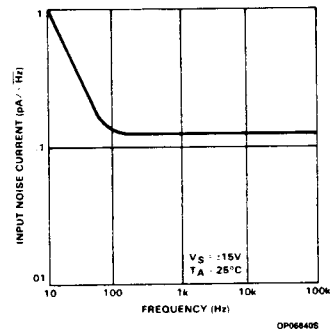
Output Short-Circuit Current as a Function of Ambient Temperature



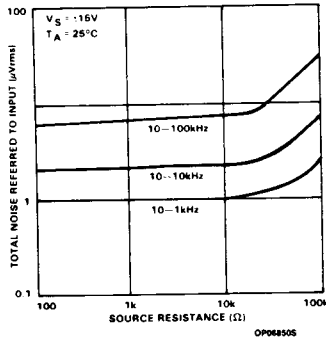
Input Noise Voltage as a Function of Frequency



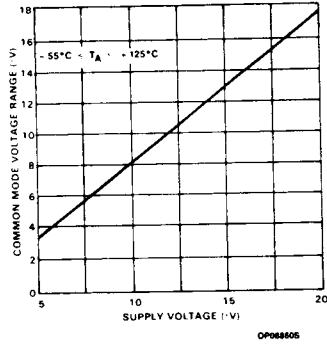
Input Noise Current as a Function of Frequency



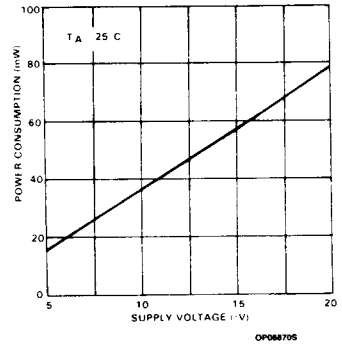
Broadband Noise for Various Bandwidths



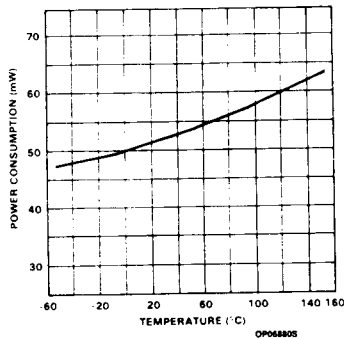
Input Common-Mode Voltage Range as a Function of Supply Voltage



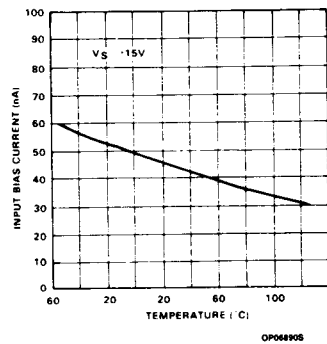
Power Consumption as a Function of Supply Voltage



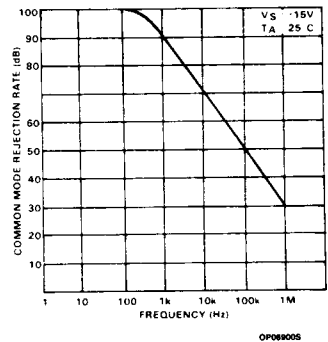
Power Consumption as a Function of Ambient Temperature



Input Bias Current as a Function of Ambient Temperature



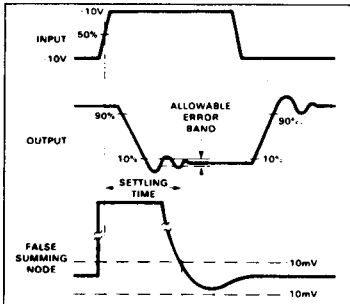
Common-Mode Rejection Ratio as a Function of Frequency



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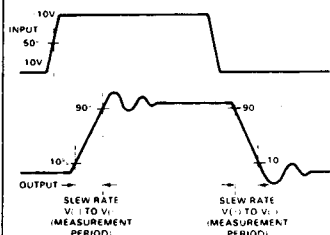
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VOLTAGE WAVEFORMS



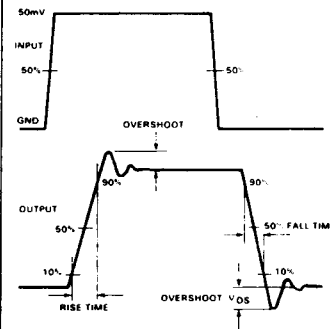
Settling Time Measurement

WF158108



Slew Rate Measurement

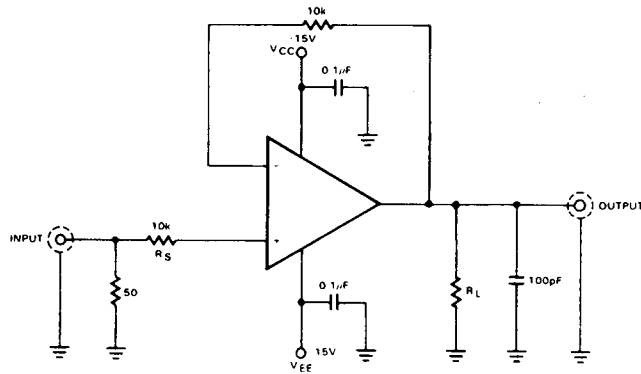
WF158208



Small-Signal Transient Response Definitions

WF158308

TEST CIRCUITS

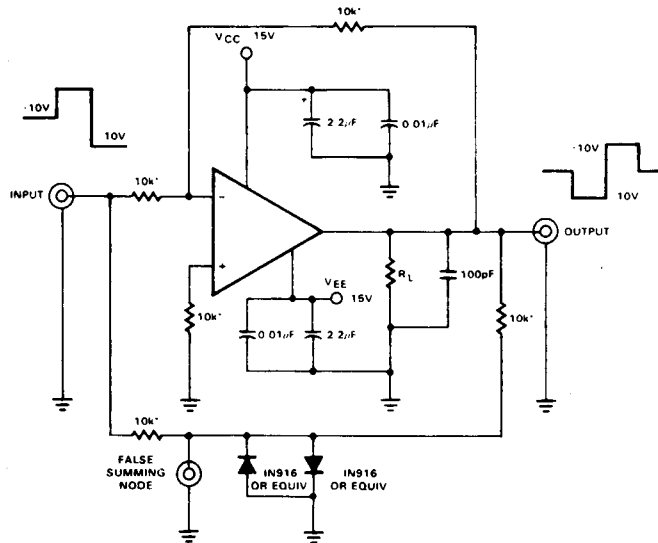


TC10900S

NOTES:

1. Pins not shown are not connected.
2. All resistor values are typical and in ohms.

Slew Rate and Small-Signal Transient Response



TC10811S

NOTES:

1. Pins not shown are not connected.
2. All resistor values are typical and in ohms.
*Match to within 0.01%.

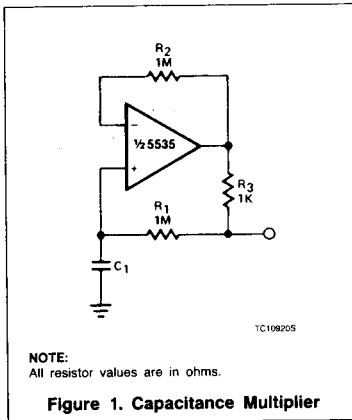
Settling Time

Dual High Slew Rate Op Amp

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INTRODUCTION

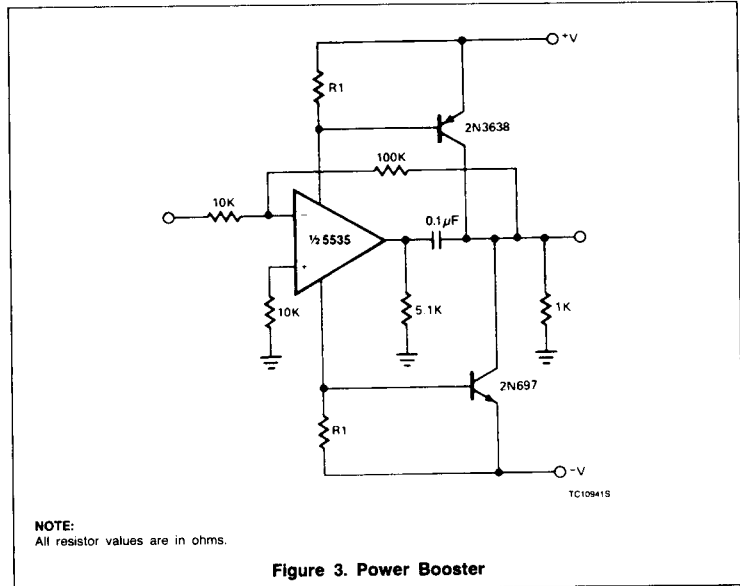
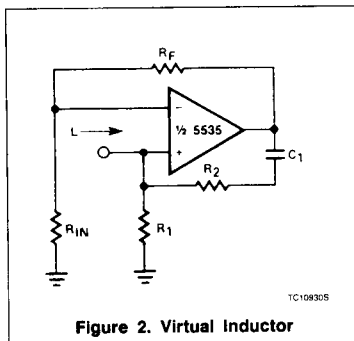
The NE5535 is a new generation monolithic op amp which features improved input characteristics. The device is compensated to unity gain and has a minimum guaranteed unity gain slew rate of $10V/\mu s$. This is achieved by employing a clamped super beta input stage which has lower input bias current.



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 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 $\mu A741$ with higher input resistance which will improve such designs as active filters, sample and hold, as well as voltage-followers.

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

Capacitance Multiplier

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

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:

$$L = R_1 R_2 C$$

The Q of this inductance depends upon R_1 being equal to R_2 . At the same time, however, the positive and negative feedback paths of the amplifier are equal leading to the distinct

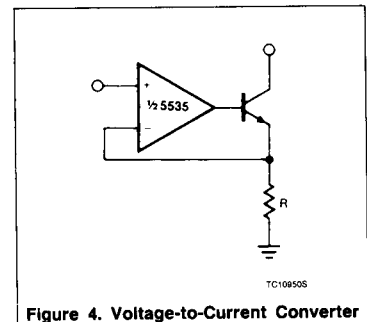
possibility of instability at high frequencies. R_1 should therefore always be slightly smaller than R_2 to assure stable operation.

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.

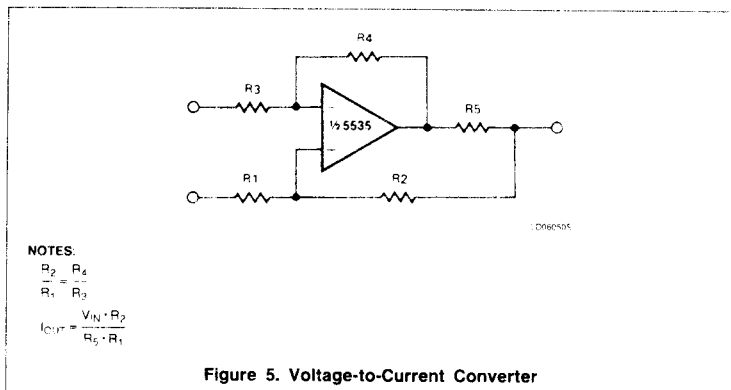
The circuit as shown uses an NE5535 device. Other amplifiers may be substituted only if R_1 values are changed because of the I_{CC} current required by the amplifier. R_1 should be calculated from the expression

$$R_1 = \frac{600mV}{I_{CC}}$$



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**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 R_2 and the limited current available.

Active Clamp-Limiting Amplifier

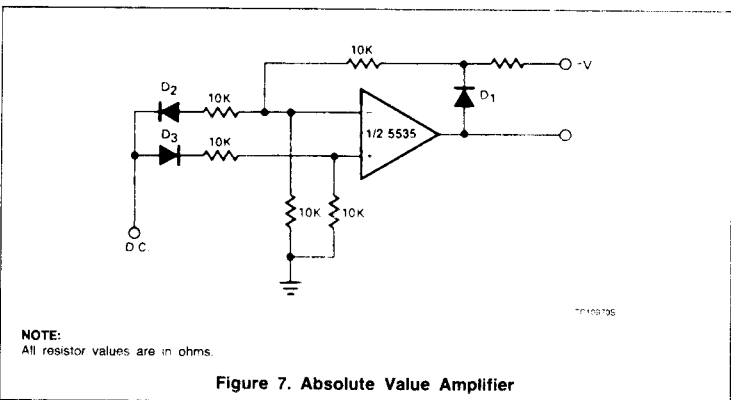
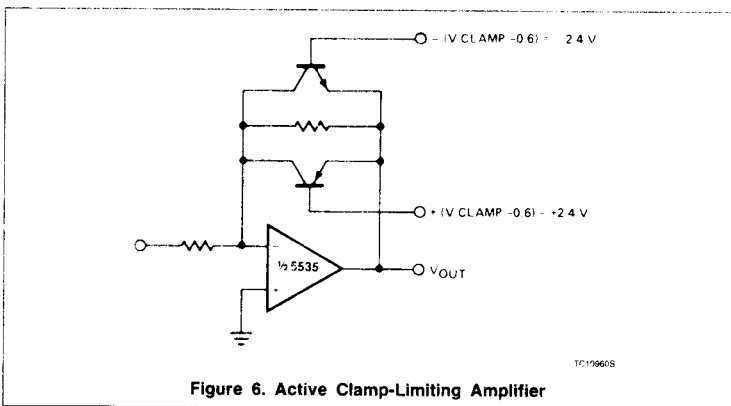
The modified inverting amplifier in Figure 6 uses an active clamp to limit the output swing with precision. Allowance must be made for the V_{BE} of the transistors. The swing is limited by the base-emitter breakdown of the transistors. A simple circuit uses two back-to-back zener diodes across the feedback 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 noninverting 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.

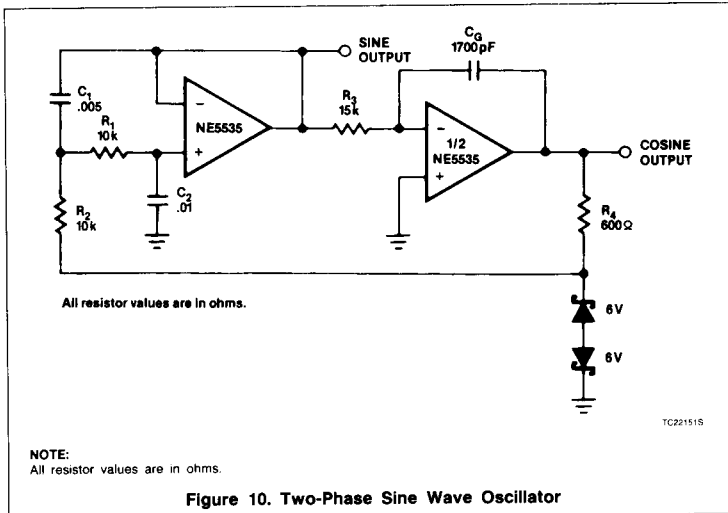
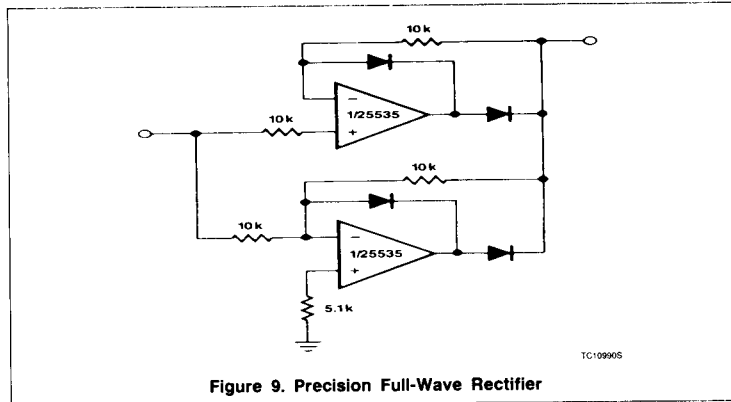
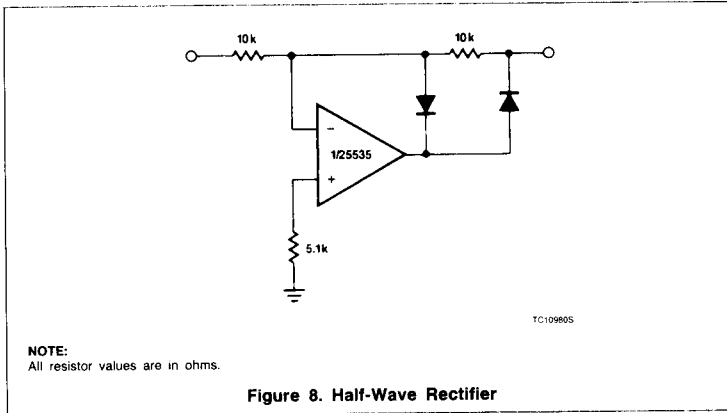
Half-Wave Rectifier

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.



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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 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 (refer to Figure 10) uses a 2-pole pass Butterworth, followed by a phase-shifting single-pole stage, fed back through a voltage limiter to achieve sine and cosine outputs. The values shown using the μA741 amplifiers give about 1.5% distortion at the sine output and about 3% distortion at the cosine output. By careful trimming of CG 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.