

DUAL HIGH SLEW RATE OP AMP

SE/NE5535

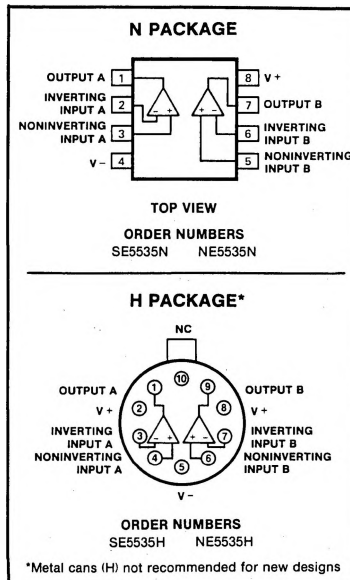
DESCRIPTION

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 $10\text{V}/\mu\text{s}$ 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

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

PIN CONFIGURATIONS



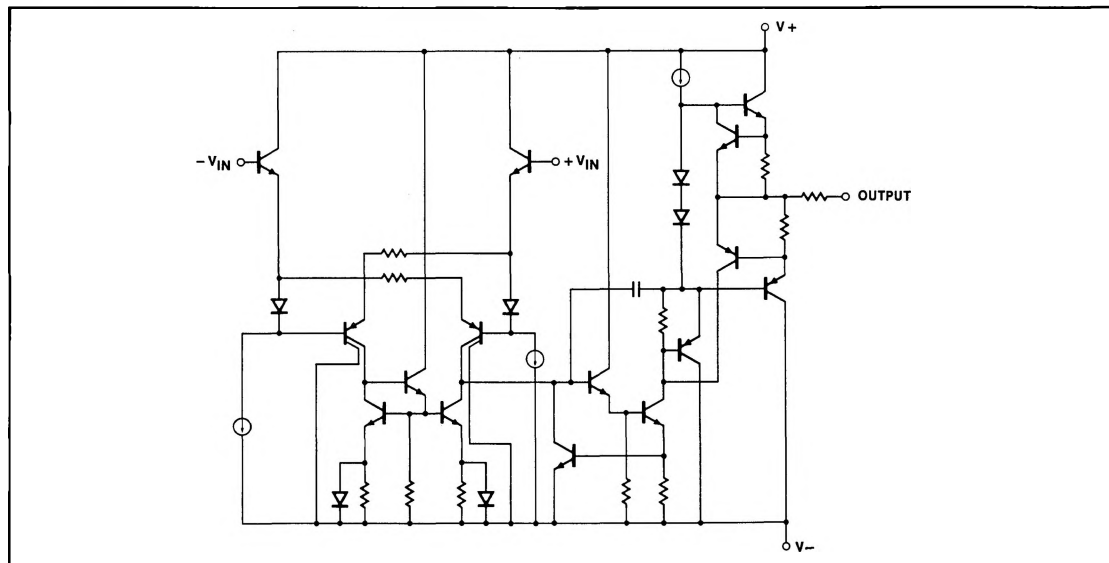
ABSOLUTE MAXIMUM RATINGS

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 $+70$	$^{\circ}\text{C}$
Storage temperature range	-65 to $+150$	-65 to $+150$	$^{\circ}\text{C}$
Lead temperature (solder, 60sec)	300	300	$^{\circ}\text{C}$
Output short circuit ³	Indefinite	Indefinite	

NOTES

1. Rating applies for thermal resistances junction to ambient of $240^{\circ}\text{C}/\text{W}$ and $150^{\circ}\text{C}/\text{W}$ for N and H packages, respectively. Maximum chip temperature is 150°C .
2. For supply voltages less than $\pm 15\text{V}$, 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 $T_A = 25^\circ\text{C}$, $V_S = \pm 15\text{V}$ unless otherwise specified.*

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
ΔV_{OS} Input offset voltage drift	$R_S = 0\Omega$, 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
ΔI_{OS} Input offset current	Over temp.		25			40		$\text{pA}/^\circ\text{C}$
I_B Input current	Over temp.		45	80 200		65	150 200	nA nA
ΔI_B Input current	Over temp.		50			80		$\text{pA}/^\circ\text{C}$
V_{CM} Common mode voltage range	$R_S \leq 10\text{k}\Omega$, over temp.	± 12	± 13		± 12	± 13		V
CMRR Common mode rejection ratio		70	90		70	90		dB
PSRR Power supply rejection	$R_S \leq 10\text{k}\Omega$, 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	$R_L \geq 2\text{k}\Omega$, $V_{OUT} = \pm 10\text{V}$ $R_L \geq 2\text{k}\Omega$, $V_{OUT} = \pm 10\text{V}$, 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 $0^\circ\text{C} \leq T_A \leq 70^\circ\text{C}$

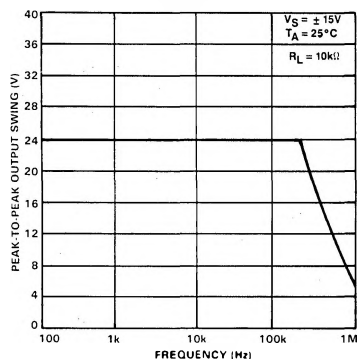
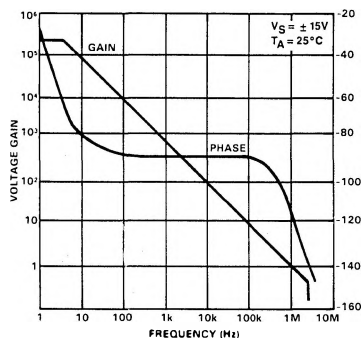
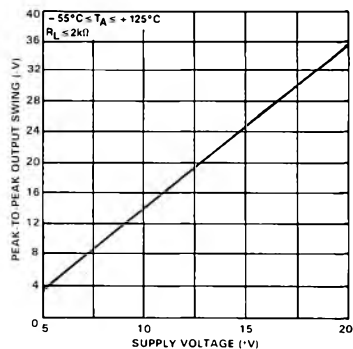
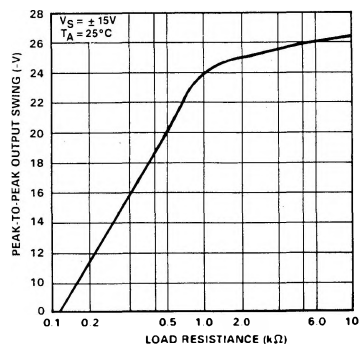
DUAL HIGH SLEW RATE OP AMP

SE/NE5535

AC ELECTRICAL CHARACTERISTICS $T_A = 25^\circ\text{C}$ 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			3			3		μs
Slew rate	To 0.1% $R_L \geq 10\text{k}\Omega$, unity gain, non-inverting	10	15		10	15		$\text{V}/\mu\text{s}$
Input noise voltage	$f = 1\text{kHz}$, $T_A = 25^\circ\text{C}$		30			30		$\text{nV}/\sqrt{\text{Hz}}$

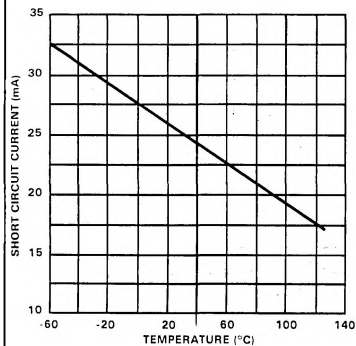
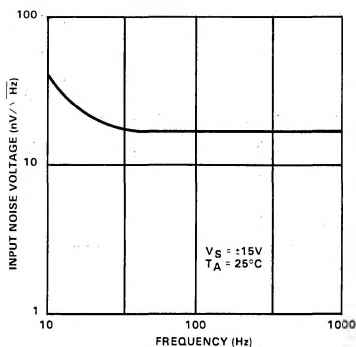
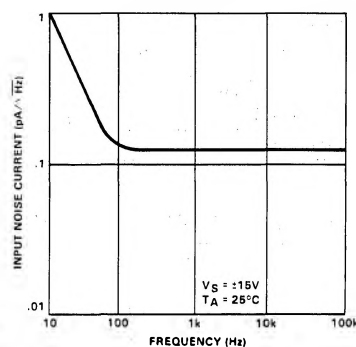
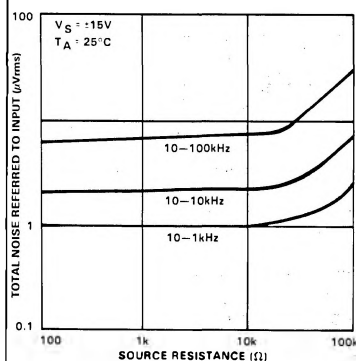
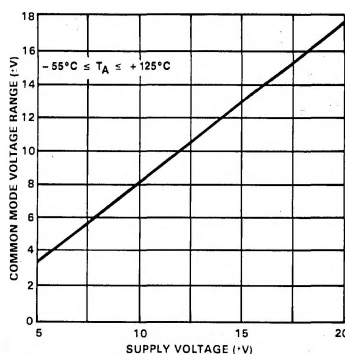
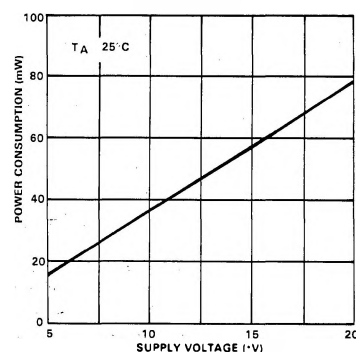
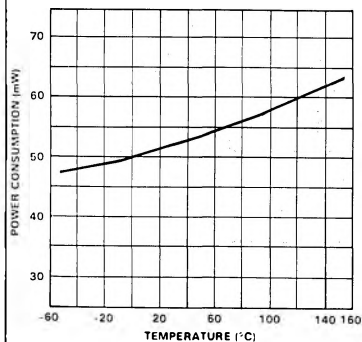
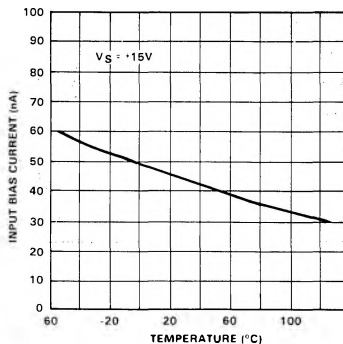
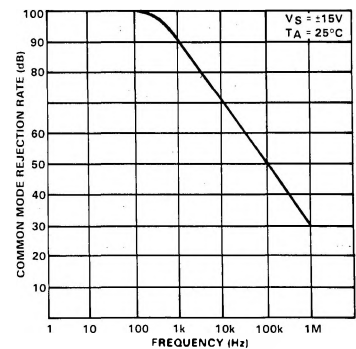
TYPICAL PERFORMANCE CHARACTERISTICS

OUTPUT VOLTAGE SWING
AS A FUNCTION OF
FREQUENCYOPEN LOOP VOLTAGE GAIN
AS A FUNCTION OF
FREQUENCYOUTPUT VOLTAGE SWING
AS A FUNCTION OF
SUPPLY VOLTAGEOUTPUT VOLTAGE SWING
AS A FUNCTION OF
LOAD RESISTANCE

DUAL HIGH SLEW RATE OP AMP

SE/NE5535

TYPICAL PERFORMANCE CHARACTERISTICS (Cont'd)

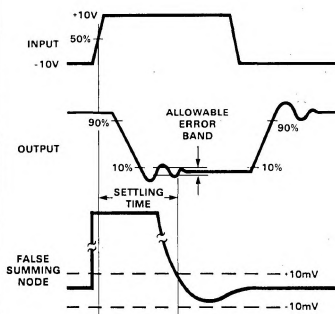
OUTPUT SHORT-CIRCUIT CURRENT
AS A FUNCTION OF
AMBIENT TEMPERATUREINPUT NOISE VOLTAGE
AS A FUNCTION OF
FREQUENCYINPUT NOISE CURRENT
AS A FUNCTION OF
FREQUENCYBROADBAND NOISE FOR
VARIOUS BANDWIDTHSINPUT COMMON MODE
VOLTAGE RANGE AS A
FUNCTION OF SUPPLY VOLTAGEPOWER CONSUMPTION
AS A FUNCTION OF
SUPPLY VOLTAGEPOWER CONSUMPTION
AS A FUNCTION OF
AMBIENT TEMPERATUREINPUT BIAS CURRENT
AS A FUNCTION OF
AMBIENT TEMPERATURECOMMON MODE REJECTION
RATIO AS A FUNCTION OF
FREQUENCY

DUAL HIGH SLEW RATE OP AMP

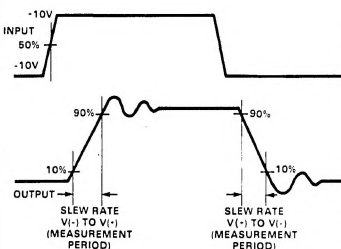
SE/NE5535

VOLTAGE WAVEFORMS

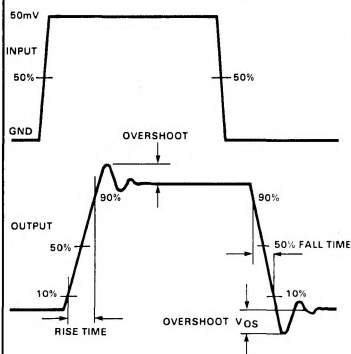
SETTLING TIME MEASUREMENT



SLEW RATE MEASUREMENT

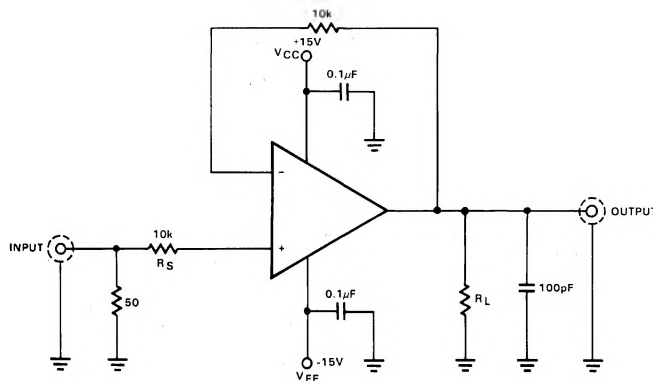


SMALL-SIGNAL TRANSIENT RESPONSE DEFINITIONS



TEST CIRCUITS

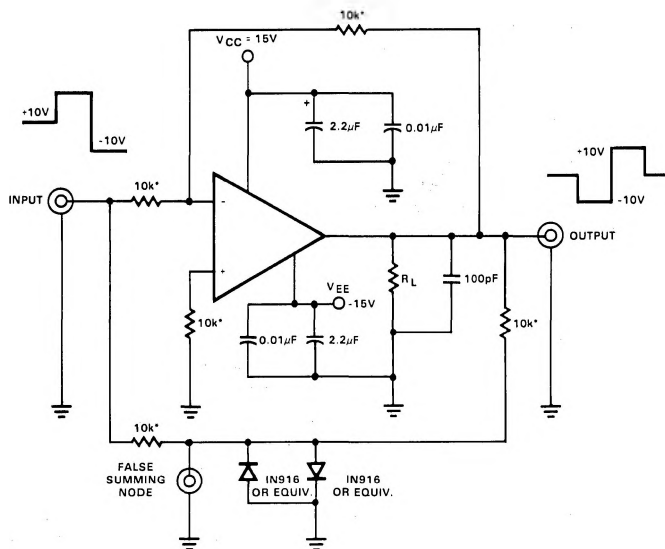
SLEW RATE AND SMALL SIGNAL TRANSIENT RESPONSE



NOTE

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

SETTLING TIME



*Match to within 0.01%.

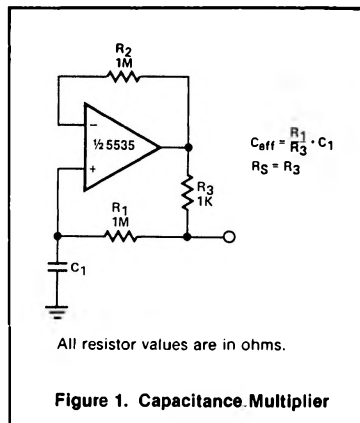
NOTE

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 characteristics. The device is compensated to unity gain and has a minimum guaranteed unity gain slew rate of $10\text{V}/\mu\text{s}$. 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 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 $\mu\text{A}741$ 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 $C = 10\mu\text{F}$, an effective capacitance of $10,000\mu\text{F}$ was obtained. The Q available is

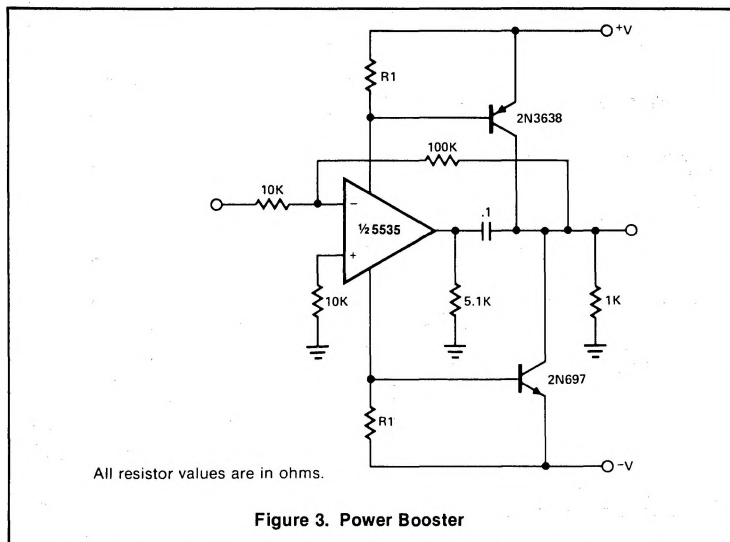
ability at high frequencies. R1 should therefore always be slightly smaller than R2 to assure stable operation.

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 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

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



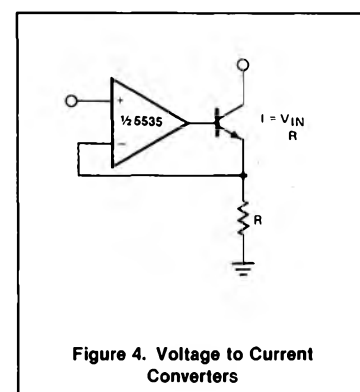
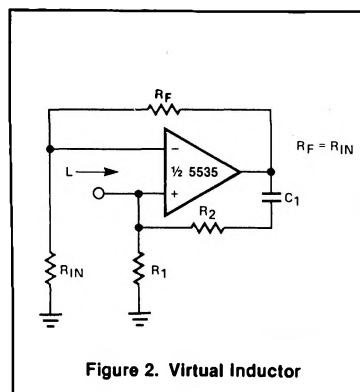
limited by the effective series resistance. So R1 should be as large as practical.

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:

$$L = R1R2C$$

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 insta-



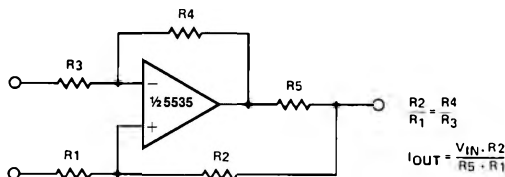


Figure 5. Voltage to Current Converter

VOLTAGE-TO-CURRENT CONVERTERS

A simple voltage-to-current converter is shown in Figure 4. The current out is $I_{out} \approx V_{in}/R$. 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.

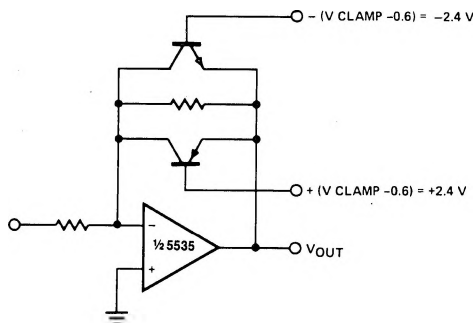


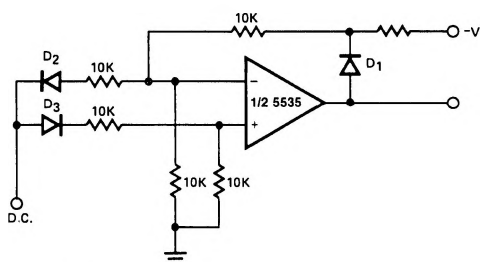
Figure 6. Active Clamp Limiting Amplifier

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 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.



All resistor values are in ohms.

Figure 7. Absolute Value Amplifier

HALF WAVE RECTIFIER

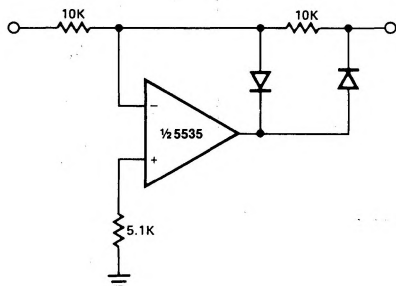
Figure 8 provides a circuit for accurate half wave rectification of the incoming signal. For positive signals, the gain is 0; for negative signals, the gain is -1 . By reversing both diodes, the polarity can be inverted. This circuit provides an accurate output, but the output impedance differs for the 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

DUAL HIGH SLEW RATE OP AMP

SE/NE5535



All resistor values are in ohms.

Figure 8. Half Wave Rectifier

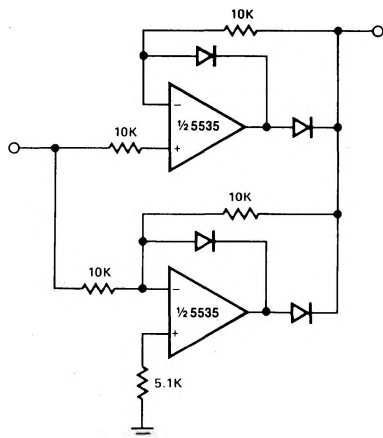
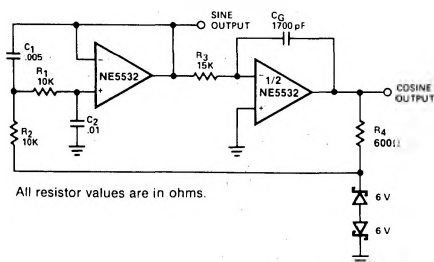


Figure 9. Precision Full Wave Rectifier

TWO-PHASE SINE WAVE
OSCILLATOR

All resistor values are in ohms.

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 voltage 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.