

# NE/SE5535

## Dual High Slew Rate Op Amp

### Product Specification

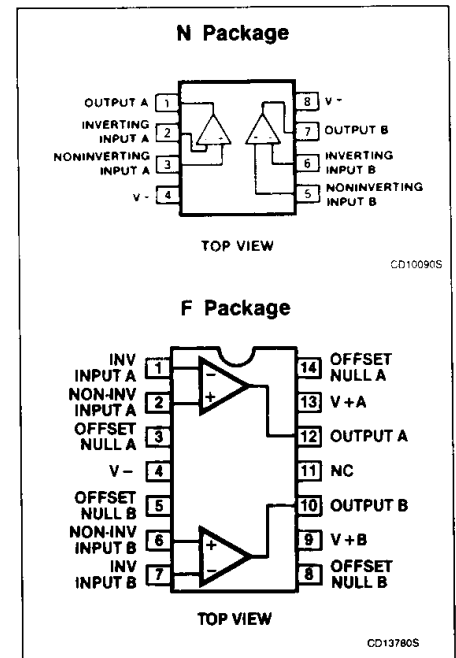
#### DESCRIPTION

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  $10\text{V}/\mu\text{s}$  with  $4\text{mV}$  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.

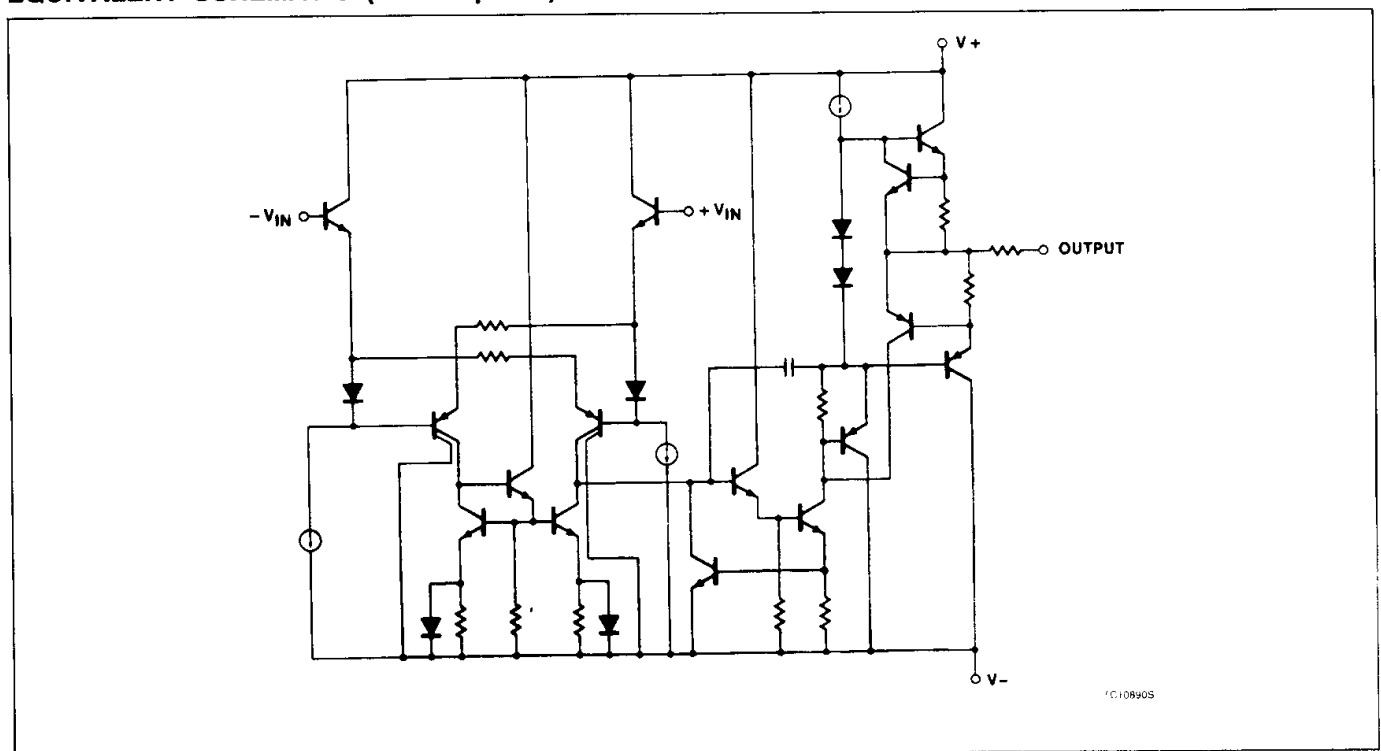
#### FEATURES

- $15\text{V}/\mu\text{s}$  unity gain slew rate
- Internal frequency compensation
- Low input offset voltage —  $2\text{mV}$
- Low input bias current  $80\text{nA}$  max
- Short-circuit protected
- Large common-mode and differential voltage ranges
- Pin compatibility  $\frac{5535}{747, 1558}$
- Dual configuration
- Low noise current  $0.15\text{pA}/\sqrt{\text{Hz}}$  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	$\pm 22$	$\pm 18$	V
$P_D$	Internal power dissipation <sup>1</sup> N package F package	1275 1250	1275 1250	mW mW
$V_{IN}$	Differential input voltage	$\pm 30$	$\pm 30$	V
$V_{IN}$	Input voltage <sup>2</sup>	$\pm 15$	$\pm 15$	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 <sup>3</sup>	Indefinite	Indefinite	

## NOTES:

- Rating applies at  $T_A = 25^\circ\text{C}$  for thermal resistances junction to ambient of  $98^\circ\text{C/W}$  and  $100^\circ\text{C/W}$  for N and F packages, respectively. Maximum junction temperature is  $150^\circ\text{C}$ .
- 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  $125^\circ\text{C}$  case temperature or  $75^\circ\text{C}$  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		$\text{pA}/^\circ\text{C}$
$I_B$	Input bias current	Over temp.		45	80 200		65	150 200	nA nA
$\Delta I_B/\Delta T$		Over temp.		50			80		$\text{pA}/^\circ\text{C}$
$V_{CM}$	Common-mode voltage range		$\pm 12$	$\pm 13$		$\pm 12$	$\pm 13$		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		$\text{M}\Omega$
$A_{VOL}$	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	500		50	500		V/mV
			25			25			V/mV
$V_{OUT}$	Output voltage	$R_L \geq 2\text{k}\Omega$ , over temp. $R_L \geq 10\text{k}\Omega$ , over temp.	$\pm 10$	$\pm 13$		$\pm 10$	$\pm 13$		V
			$\pm 12$	$\pm 14$		$\pm 12$	$\pm 14$		V
$I_{CC}$	Supply current	Per amplifier		1.8	2.8		1.8	2.8	mA
		Per amplifier, over temp.		2	3.3		2		mA
$P_D$	Power dissipation	Per amplifier		54	84		54	84	mW
		Per amplifier, over temp.		60	99		60		mW
$I_{SC}$	Output short-circuit current		10	25	50	10	25	50	mA
$R_{OUT}$	Output resistance			100			100		$\Omega$

**NOTE:**

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

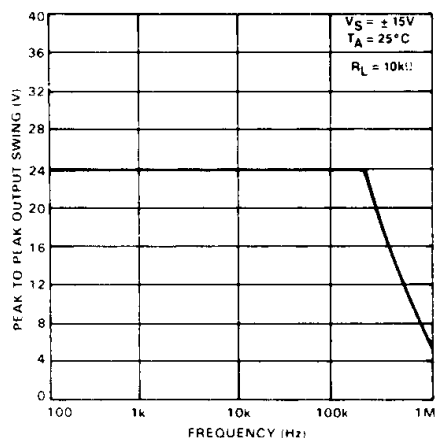
**AC ELECTRICAL CHARACTERISTICS**  $T_A = 25^\circ\text{C}$ , unless otherwise specified.

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	$T_O$ 0.1% $R_L \geq 10\text{k}\Omega$ , unity gain, non-inverting		0.25			0.25		$\mu\text{s}$
	Small-signal overshoot			6			6		%
$t_S$	Settling time			3			3		$\mu\text{s}$
SR	Slew rate		10	15		10	15		V/ $\mu\text{s}$
	Input noise voltage	$f = 1\text{kHz}$ , $T_A = 25^\circ\text{C}$		30			30		nV/ $\sqrt{\text{Hz}}$

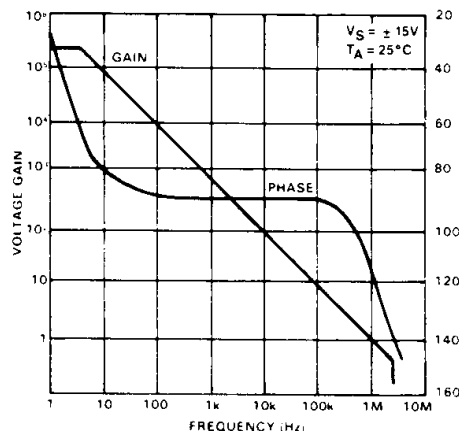
## Dual High Slew Rate Op Amp

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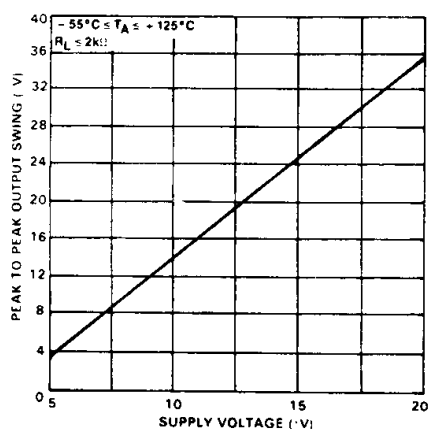
## TYPICAL PERFORMANCE CHARACTERISTICS

Output Voltage Swing as a  
Function of Frequency

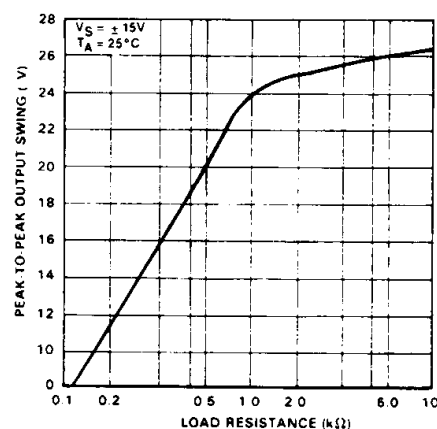
OP06780S

Open-Loop Voltage Gain as a  
Function of Frequency

OP06790S

Output Voltage Swing as a  
Function of Supply Voltage

OP06800S

Output Voltage Swing as a  
Function of Load Resistance

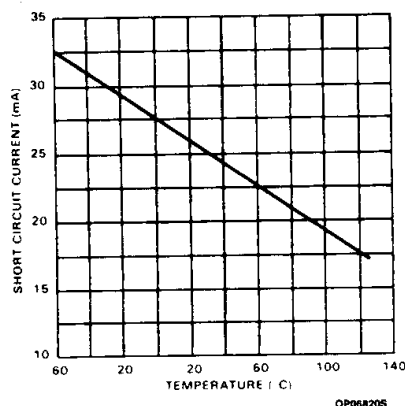
OP06810S

## Dual High Slew Rate Op Amp

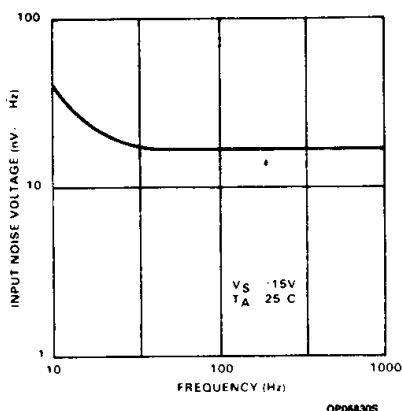
NE/SE5535

## TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

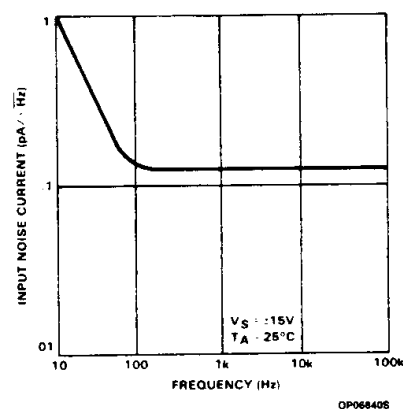
Output Short-Circuit Current as a Function of Ambient Temperature



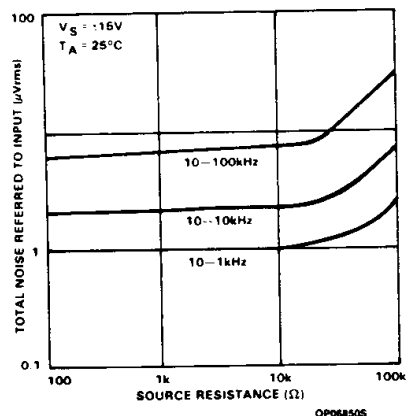
Input Noise Voltage as a Function of Frequency



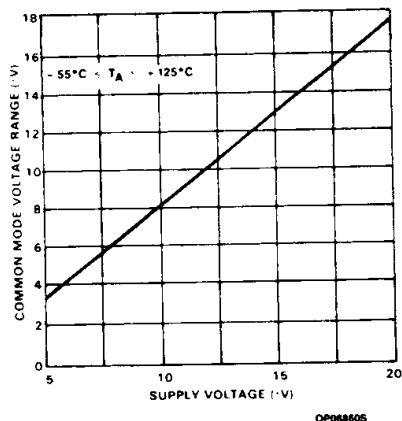
Input Noise Current as a Function of Frequency



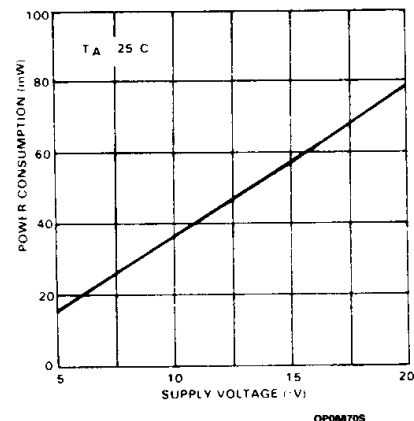
Broadband Noise for Various Bandwidths



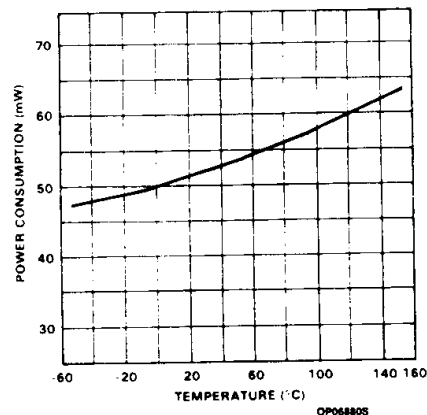
Input Common-Mode Voltage Range as a Function of Supply Voltage



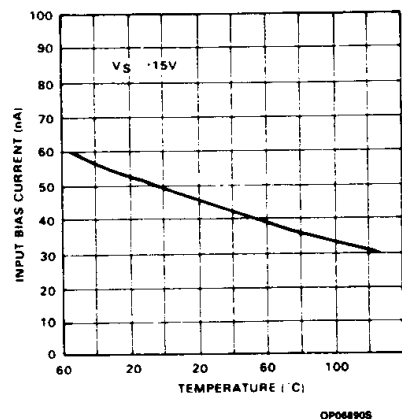
Power Consumption as a Function of Supply Voltage



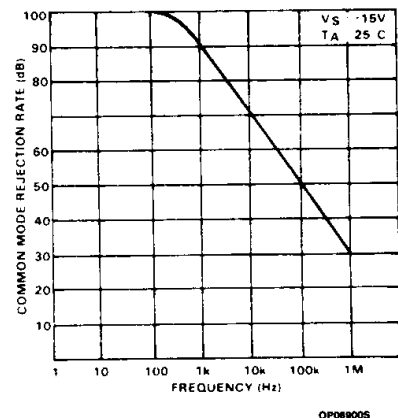
Power Consumption as a Function of Ambient Temperature



Input Bias Current as a Function of Ambient Temperature



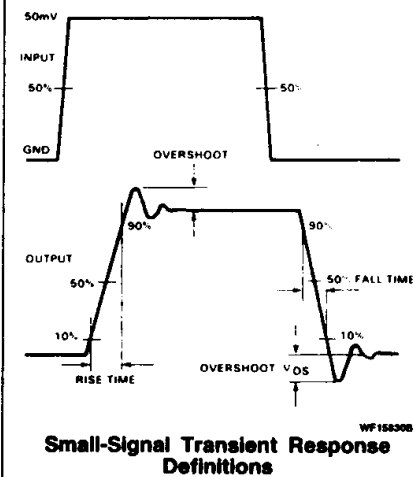
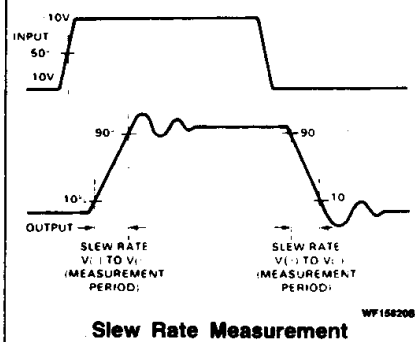
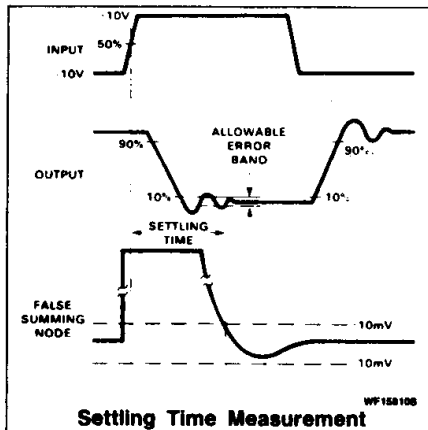
Common-Mode Rejection Ratio as a Function of Frequency



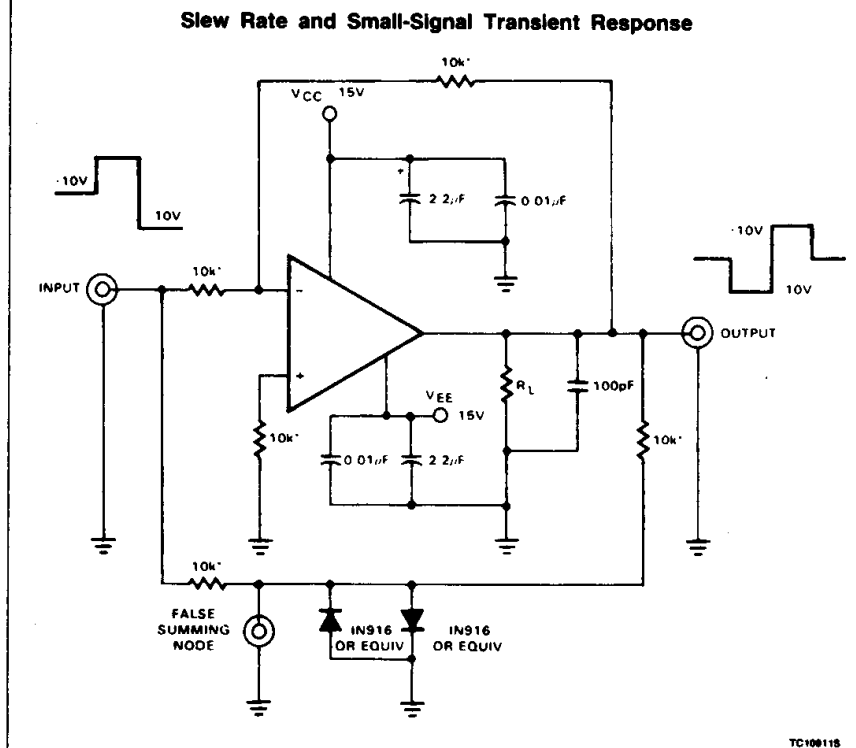
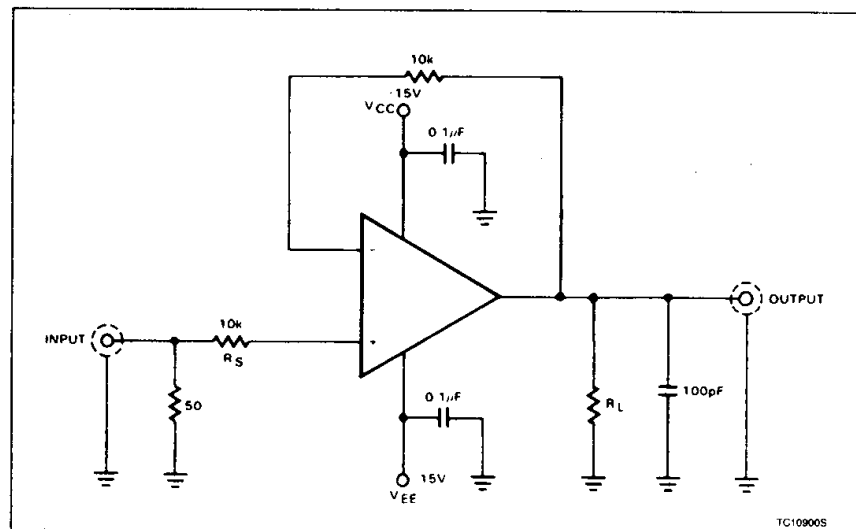
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## VOLTAGE WAVEFORMS



## TEST CIRCUITS



## 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  $10\text{V}/\mu\text{s}$ . This is achieved by employing a clamped super beta input stage which has lower input bias current.

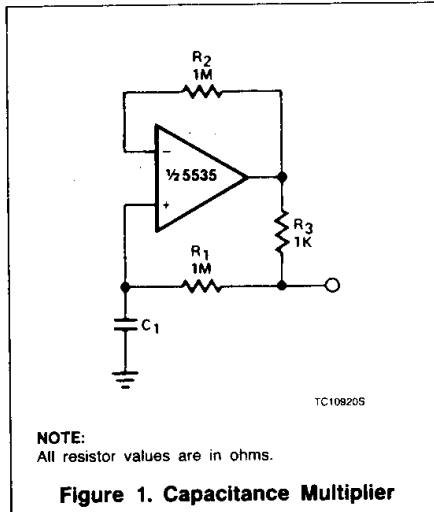


Figure 1. Capacitance Multiplier

## 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 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

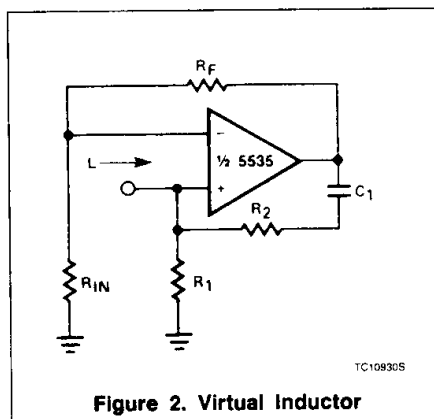


Figure 2. Virtual Inductor

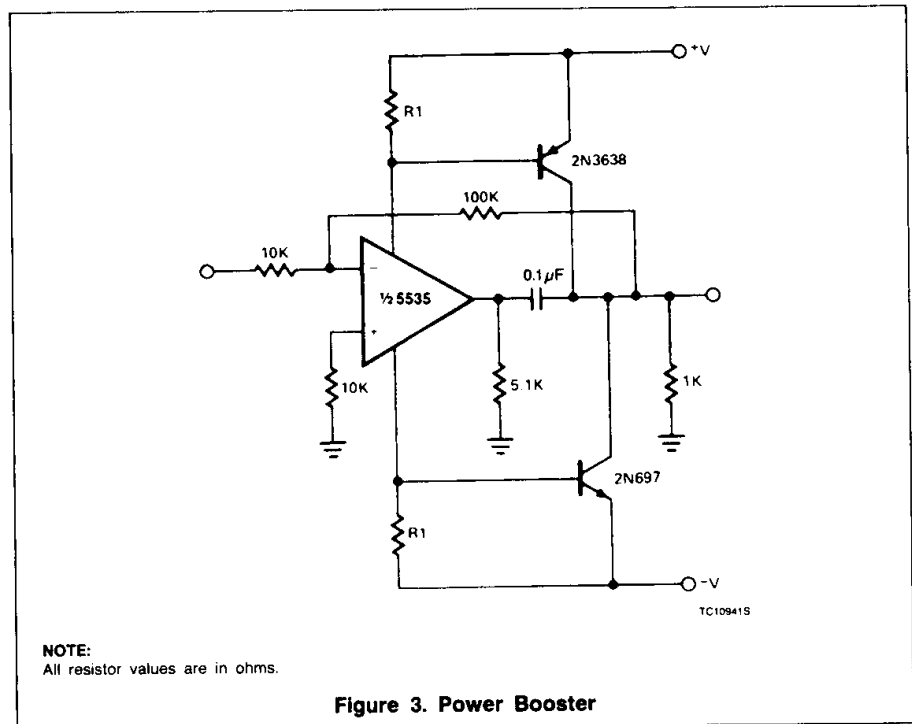


Figure 3. Power Booster

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 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  $C = 10\mu\text{F}$ , an effective capacitance of  $10,000\mu\text{F}$  was obtained. The Q available is limited by the effective series resistance. So  $R_1$  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

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

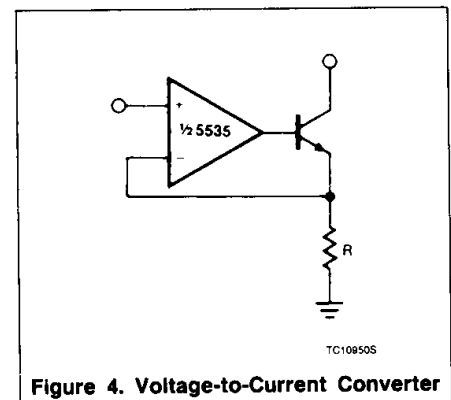
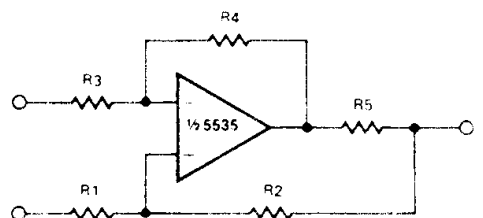


Figure 4. Voltage-to-Current Converter

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## NOTES:

$$R_2 = R_4$$

$$R_1 = R_3$$

$$I_{OUT} = \frac{V_{IN} \cdot R_2}{R_5 \cdot R_1}$$

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  $I_{OUT} \cong V_{IN}/R$ . 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.

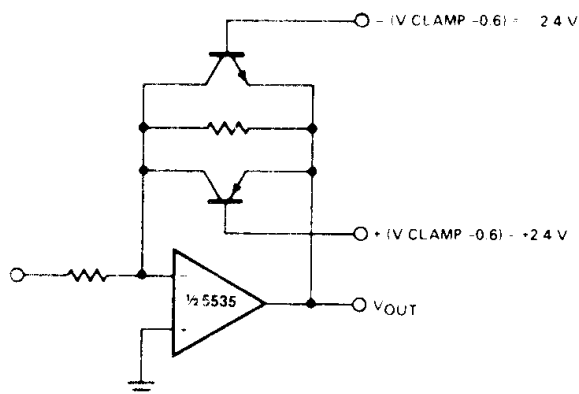


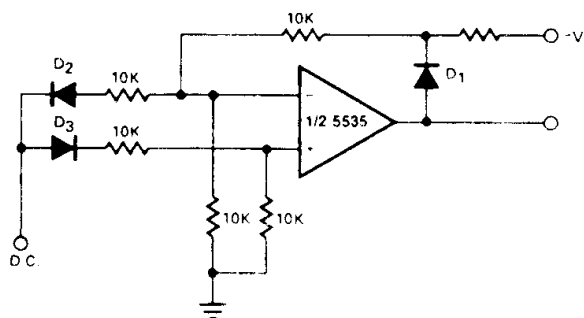
Figure 6. Active Clamp-Limiting Amplifier

## 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.



## NOTE:

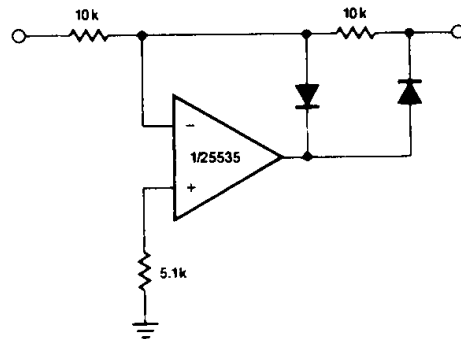
All resistor values are in ohms.

Figure 7. Absolute Value Amplifier



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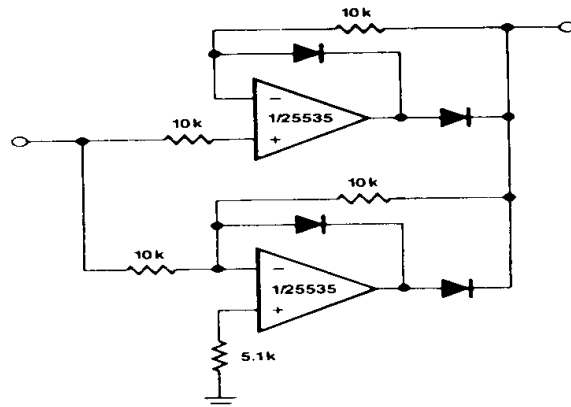
NE/SE5535



TC10980S

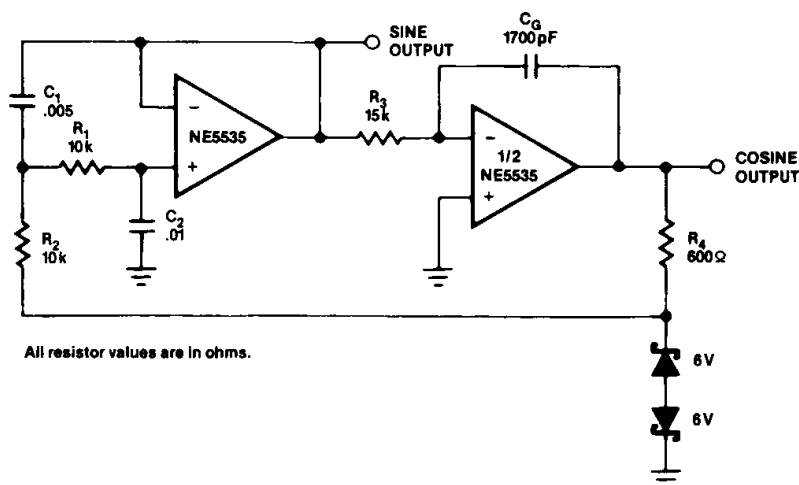
NOTE:  
All resistor values are in ohms.

Figure 8. Half-Wave Rectifier



TC10990S

Figure 9. Precision Full-Wave Rectifier



All resistor values are in ohms.

NOTE:  
All resistor values are in ohms.

Figure 10. Two-Phase Sine Wave Oscillator

## 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  $10k\Omega$  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  $\mu A741$  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.