INTERNALLY COMPENSATED DUAL LOW NOISE OP AMP — SE/NE5532/5532A

DESCRIPTION

The 5532 is a dual high-performance low noise operational amplifier. Compared to most of the standard operational amplifiers, such as the 1458, it shows better noise performance, improved output drive capability and considerably higher small-signal and power bandwidths.

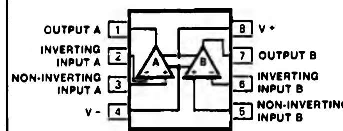
This makes the device especially suitable for application in high quality and professional audio equipment, instrumentation and control circuits, and telephone channel amplifiers. The op amp is internally compensated for gains equal to one. If very low noise is of prime importance, it is recommended that the 5532A version be used which has guaranteed noise voltage specifications.

FEATURES

- Small-signal bandwidth: 10MHz
- Output drive capability: 600Ω, 10V (rms)
- Input noise voltage: $5nV/\sqrt{Hz}$ (typical)
- DC voltage gain: 50000
- AC voltage gain: 2200 at 10kHz
- Power bandwidth: 140kHz
- Slew-rate: $9V/\mu s$
- Large supply voltage range: ±3 to ±20V
- Compensated for unity gain

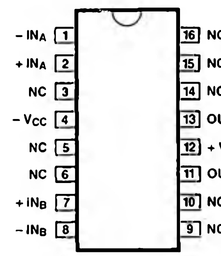
PIN CONFIGURATION

FE,N PACKAGE



TOP VIEW
ORDER NUMBERS
NE5532FE, N SE5532FE
NE5532AFE, N SE5532AFE

D^2 PACKAGE



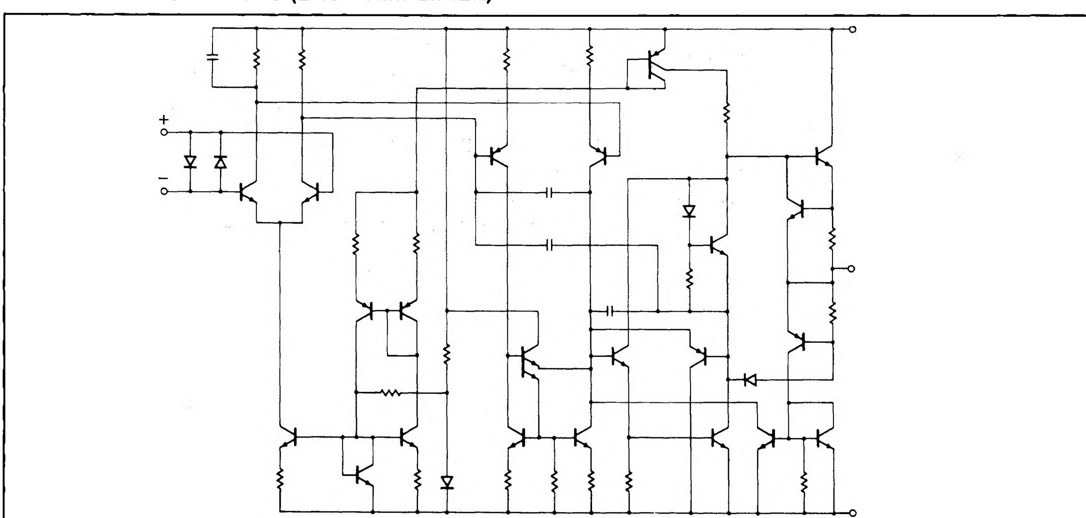
TOP VIEW
ORDER NUMBER
NG5532D

ABSOLUTE MAXIMUM RATINGS

PARAMETER		RATING	UNIT
V_S	Supply voltage	±22	V
V_{IN}	Input voltage	±V supply	V
V_{DIFF}	Differential input voltage[1]	±.5	V
T_A	Operating temperature range		
	NE5532/A	0 to 70	°C
	SE5532/A	−55 to +125	°C
T_{STG}	Storage temperature	−65 to +150	°C
T_J	Junction temperature	150	°C
P_D	Power dissipation		
	5532FE	1000	mW
	Lead temperature (soldering, 10 sec)	300	°C

NOTES:
1. Diodes protect the inputs against over-voltage. Therefore, unless current-limiting resistors are used, large currents will flow if the differential input voltage exceeds 0.6V. Maximum current should be limited to ± 10mA.
2. Thermal resistance of the FE package is 125°C/W.

EQUIVALENT SCHEMATIC (EACH AMPLIFIER)



INTERNALLY COMPENSATED DUAL LOW NOISE OP AMP — SE/NE5532/5532A

DC ELECTRICAL CHARACTERISTICS $T_A = 25°C$, $V_S = \pm 15V$ unless otherwise specified.[1,2]

PARAMETER		TEST CONDITIONS	SE5532/55232A			NE5532/5532A			UNIT
			Min	Typ	Max	Min	Typ	Max	
V_{OS}	Offset voltage			0.5	2		0.5	4	mV
		Over temperature			3			5	mV
$\Delta V_{OS}/\Delta T$				5			5		µV/°C
I_{OS}	Offset current				100		10	150	nA
		Over temperature			200			200	nA
$\Delta I_{OS}/\Delta T$				200			200		pA/°C
I_B	Input current			200	400		200	800	nA
		Over temperature			700			1000	nA
$\Delta I_B/\Delta T$				5			5		mA/°C
I_{CC}	Supply current						8	16	mA
		Over temperature			13				mA
V_{CM}	Common mode input range		± 12	± 13		± 12	± 13		V
CMRR	Common mode rejection ratio		80	100		70	100		dB
PSRR	Power supply rejection ratio			10	50		10	100	µV/V
A_{VOL}	Large signal voltage gain	$R_L \geq 2k\Omega$, $V_0 = \pm 10V$	50			25	100		V/mV
		Over temperature	25			15			V/mV
		$R_L \geq 600\Omega$, $V_0 = \pm 10V$	40			15	50		V/mV
		Over temperature	20			10			V/mV
V_{OUT}	Output swing	$R_L \geq 600\Omega$				± 12	± 13		V
		Over temperature				± 10	± 12		V
		$R_L \geq 600\Omega$, $V_S = \pm 18V$	± 15	± 16					V
		Over temperature				± 12	± 14		V
		$R_L \geq 2k\Omega$ over temp.	± 12	± 13		± 10	± 13		V
R_{IN}	Input resistance		30	300		30	300		kΩ
I_{SC}	Output short circuit current		10	38	60	10	38	60	mA

AC ELECTRICAL CHARACTERISTICS $T_A = 25°C$, $V_S = \pm 15V$ unless otherwise specified.

PARAMETER		TEST CONDITIONS	SE/NE5532/5532A			UNIT
			Min	Typ	Max	
R_{OUT}	Output resistance	$A_V = 30dB$ Closed loop $f = 10kHz$, $R_L = 600\Omega$		0.3		Ω
	Overshoot	Voltage follower $V_{IN} = 100mV$ p-p $C_L = 100pF$ $R_L = 600\Omega$		10		%
	Gain	$f = 10kHz$		2.2		V/mV
	Gain bandwidth product	$C_L = 100pF$ $R_L = 600\Omega$		10		MHz
	Slew rate			9		V/µs
	Power bandwidth	$V_{OUT} = \pm 10V$		140		kHz
		$V_{OUT} = \pm 14V$, $R_L = 600\Omega$, $V_{CC} = \pm 18V$		100		kHz

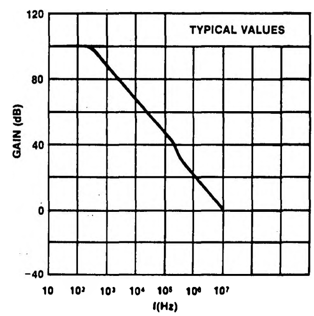
ELECTRICAL CHARACTERISTICS $T_A = 25°C$, $V_S = \pm 15V$ unless otherwise specified.

PARAMETER	TEST CONDITIONS	SE/NE5532			SE/NE5532A			UNIT
		Min	Typ	Max	Min	Typ	Max	
Input noise voltage	$f_o = 30Hz$		8			8	12	$nV/\sqrt{Hz}$
	$f_o = 1kHz$		5			5	6	$nV/\sqrt{Hz}$
Input noise current	$f_o = 30Hz$		2.7			2.7		$pA/\sqrt{Hz}$
	$f_o = 1kHz$		0.7			0.7		$pA/\sqrt{Hz}$
Channel separation	$f = 1kHz$, $RS = 5k\Omega$		110			110		dB

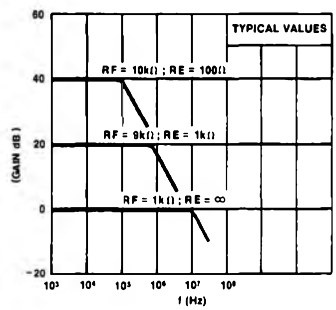
INTERNALLY COMPENSATED DUAL LOW NOISE OP AMP SE/NE5532/5532A

TYPICAL PERFORMANCE CHARACTERISTICS

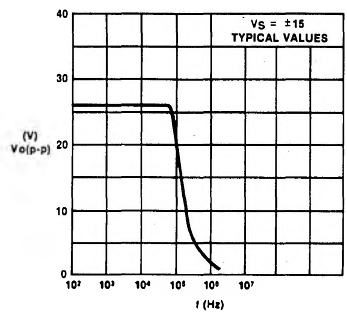
OPEN LOOP FREQUENCY RESPONSE



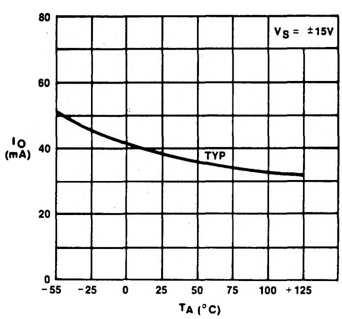
CLOSED LOOP FREQUENCY RESPONSE



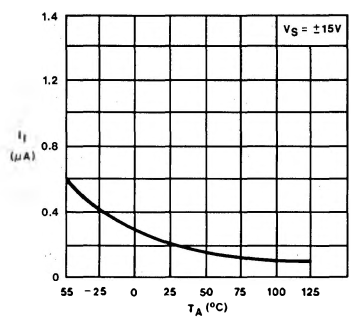
LARGE-SIGNAL FREQUENCY RESPONSE



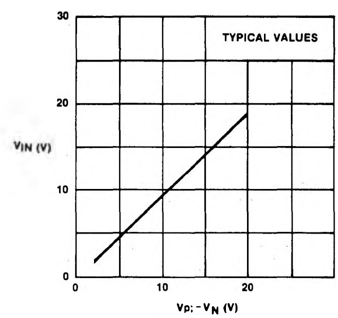
OUTPUT SHORT-CIRCUIT CURRENT



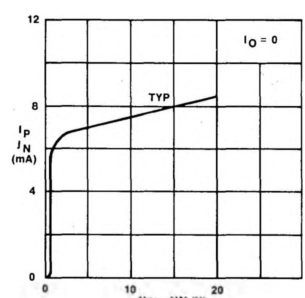
INPUT BIAS CURRENT



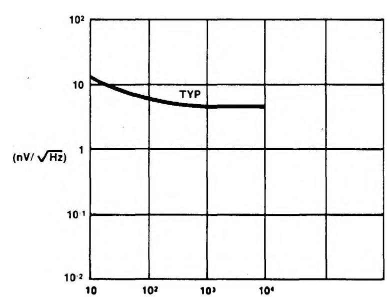
INPUT COMMON MODE VOLTAGE RANGE



SUPPLY CURRENT



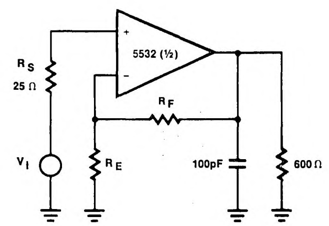
INPUT NOISE VOLTAGE DENSITY



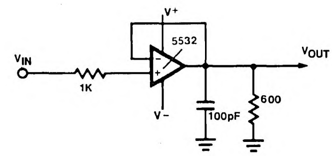
INTERNALLY COMPENSATED DUAL LOW NOISE OP AMP SE/NE5532/5532A

TEST CIRCUITS

CLOSED LOOP FREQUENCY RESPONSE



VOLTAGE FOLLOWER



AUDIO CIRCUITS USING THE NE5532/33/34

More detailed information is available in the communications section of this manual, regarding other audio circuits. The following will explain the Signetics line of low noise op amps and show their use in some audio applications.

DESCRIPTION

The 5532 is a dual high-performance low noise operational amplifier. Compared to most of the standard operational amplifiers, such as the 1458, it shows better noise performance, improved output drive capability and considerably higher small-signal and power bandwidths.

This makes the device especially suitable for application in high quality and professional audio equipment, instrumentation and control circuits, and telephone channel amplifiers. The op amp is internally compensated for gains equal to one. If very low noise is of prime importance, it is recommended that the 5532A version be used which has guaranteed noise voltage specifications.

APPLICATIONS

The Signetics 5532 High Performance Op Amp is an ideal amplifier for use in high quality and professional audio equipment which requires low noise and low distortion.

The circuit included in this application note has been assembled on a P.C. board, and tested with actual audio input devices (Tuner and Turntable). It consists of an RIAA pre-amp, input buffer, 5-band equalizer, and mixer. Although the circuit design is not new, its performance using the 5532 has been improved.

The RIAA pre-amp section is a standard compensation configuration with low frequency boost provided by the Magnetic cartridge and the RC network in the op amp feedback loop. Cartridge loading is accomplished via R1. 47k was chosen as a typical value, and may differ from cartridge to cartridge.

The Equalizer section consists of an input buffer, 5 active variable band pass/notch (depending on R9's setting) filters, and an output summing amplifier. The input buffer is a standard unity gain design providing impedance matching between the pre amplifiers and the equalizer section. Because the 5532 is internally compensated, no external compensation is required. The 5-band active filter section is actually 5 individual active filters with the same feedback design for all 5. The main differance in all five stages is the values of C5 and C6 which are responsible for setting the center frequency of each stage. Linear pots are recommended for R9. To simplify use of this circuit, a component value table is provided, which lists center frequencies and their associated capacitor values. Notice that C5 equals (10) C6, and that the Value of R8 and R10 are related to R9 by a factor of 10 as well. The values listed in the table are common and easily found standard values.

RIAA EQUALIZATION AUDIO PREAMPLIFIER USING NE5532A

With the onset of new recording techniques along with sophisticated playback equipment, a new breed of low noise operational amplifiers was developed to complement the state-of-the-art in audio reproduction. The first ultra low noise op amp introduced by Signetics was called the NE5534A. This is a single operational amplifier with less than $4nV/\sqrt{Hz}$ input noise voltage. The NE5534A is internally compensated at a gain of three. This device has been used in many audio preamp and equalizer (active filter) applications since its introduction early last year.

Many of the amplifiers that are being designed today are dc coupled. This means that very low frequencies (2-15Hz) are being amplified. These low frequencies are common to turntables because of rumble and tone arm resonancies. Since the amplifiers can reproduce these sub-audible tones, they become quite objectionable because the speakers try to reproduce these tones. This causes non-linearities when the actual recorded material is amplified and converted to sound waves.

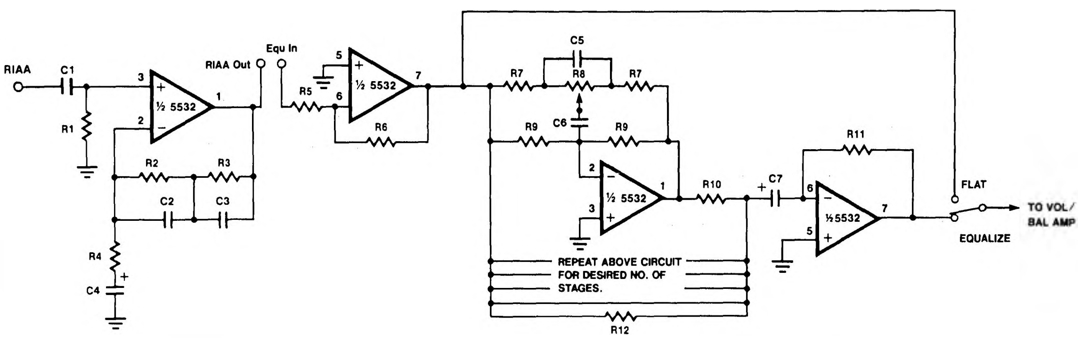
The RIAA has proposed a change in its standard playback response curve in order to alleviate some of the problems that were previously discussed. The changes occur primarily at the low frequency range with a slight modification to the high frequency range. (See Figure 2). Note that the response peak for the bass section of the playback curve now occurs at 31.5Hz and begins to roll off below that frequency. The rolloff occurs by introducing a fourth R/C network occurs by introducing a fourth R/C network with a 7950μs time constant to the three existing networks that make up the equalization circuit. The high end of the equalization curve is extended to 20kHz, because recordings at these frequencies are achievable on many current discs.

NE5533/34 DESCRIPTION

The 5533/5534 are dual and single high-performance low noise operational amplifiers. Compared to other operational amplifiers

INTERNALLY COMPENSATED DUAL LOW NOISE OP AMP SE/NE5532/5532A

RIAA—EQUALIZER SCHEMATIC



COMPONENT VALUE TABLES

R8 = 25k R7 = 2.4k R9 = 240k			R8 = 50k R7 = 5.1k R9 = 510k			R8 = 100k R7 = 10k R9 = 1meg		
fo	C5	C6	fo	C5	C6	fo	C5	C6
23 Hz	1μF	.1μF	25 Hz	.47μF	.047μF	12 Hz	.47μF	.047μF
50 Hz	.47μF	.047μF	36 Hz	.33μF	.033μF	18 Hz	.33μF	.033μF
72 Hz	.33μF	.033μF	54 Hz	.22μF	.022μF	27 Hz	.22μF	.022μF
108 Hz	.22μF	.022μF	79 Hz	.15μF	.015μF	39 Hz	.15μF	.015μF
158 Hz	.15μF	.015μF	119 Hz	.1μF	.01μF	59 Hz	.1μF	.01μF
238 Hz	.1μF	.01μF	145 Hz	.082μF	.0082μF	72 Hz	.082μF	.0082μF
290 Hz	.082μF	.0082μF	175 Hz	.068μF	.0068μF	87 Hz	.068μF	.0068μF
350 Hz	.068μF	.0068μF	212 Hz	.056μF	.0056μF	106 Hz	.056μF	.0056μF
425 Hz	.056μF	.0056μF	253 Hz	.047μF	.0047μF	126 Hz	.047μF	.0047μF
506 Hz	.047μF	.0047μF	360 Hz	.033μF	.0033μF	180 Hz	.033μF	.0033μF
721 Hz	.033μF	.0033μF	541 Hz	.022μF	.0022μF	270 Hz	.022μF	.0022μF
1082 Hz	.022μF	.0022μF	794 Hz	.015μF	.0015μF	397 Hz	.015μF	.0015μF
1588 Hz	.015μF	.0015μF	1191 Hz	.01μF	.001μF	595 Hz	.01μF	.001μF
2382 Hz	.01μF	.001μF	1452 Hz	.0082μF	820pF	726 Hz	.0082μF	820pF
2904 Hz	.0082μF	820pF	1751 Hz	.0068μF	680pF	875 Hz	.0068μF	680pF
3502 Hz	.0068μF	680pF	2126 Hz	.0056μF	560pF	1063 Hz	.0056μF	560pF
4253 Hz	.0056μF	560pF	2534 Hz	.0047μF	470pF	1267 Hz	.0047μF	470pF
5068 Hz	.0047μF	470pF	3609 Hz	.0033μF	330pF	1804 Hz	.0033μF	330pF
7218 Hz	.0033μF	330pF	5413 Hz	.0022μF	220pF	2706 Hz	.0022μF	220pF
10827 Hz	.0022μF	220pF	7940 Hz	.0015μF	150pF	3970 Hz	.0015μF	150pF
15880 Hz	.0015μF	150pF	11910 Hz	.001μF	100pF	5955 Hz	.001μF	100pF
23820 Hz	.001μF	100pF	14524 Hz	820pF	82pF	7262 Hz	820pF	82pF
			17514 Hz	680pF	68pF	8757 Hz	680pF	68pF
			21267 Hz	560pF	56pF	10633 Hz	560pF	56pF
						12670 Hz	470pF	47pF
						18045 Hz	330pF	33pF

COMPONENT VALUES

R1	1meg	C1	.22μF
R2	100k	C2	750pF
R3	1meg	C3	.0033μF
R4	1.1k	C4	33μF
R5	100k	C5	SEE TABLE
R6	100k	C6	SEE TABLE
R7	SEE TABLE	C7	2.2μF
R8	(pol) SEE TABLE		
R9	SEE TABLE		
R10	100k		
R11	100k		
R12	20k (5 STAGES)		

Figure 1

such as TL083, they show better noise performance, improved output drive capability and considerably higher small-signal and power bandwidths.

This makes the devices especially suitable for application in high quality and professional audio equipment, in instrumentation and control circuits and telephone channel amplifiers. The op amps are internally compensated for gain equal to, or higher than, three. The frequency response can be optimized with an external compensation capacitor for various applications (unity gain amplifier, capacitive load, slew-rate, low overshoot, etc.) If very low noise is of prime importance, it is recommended that the 5533A/5534A version be used which has guaranteed noise specifications.

APPLICATIONS

Diode Protection of Input

The input leads of the device are protected from differential transients above ±0.6V by internal back-to-back diodes. Their presence imposes certain limitations on the amplifier dynamic characteristics related to closed-loop gain and slew rate.

INTERNALLY COMPENSATED DUAL LOW NOISE OP AMP SE/NE5532/5532A

PROPOSED RIAA PLAYBACK EQUALIZATION

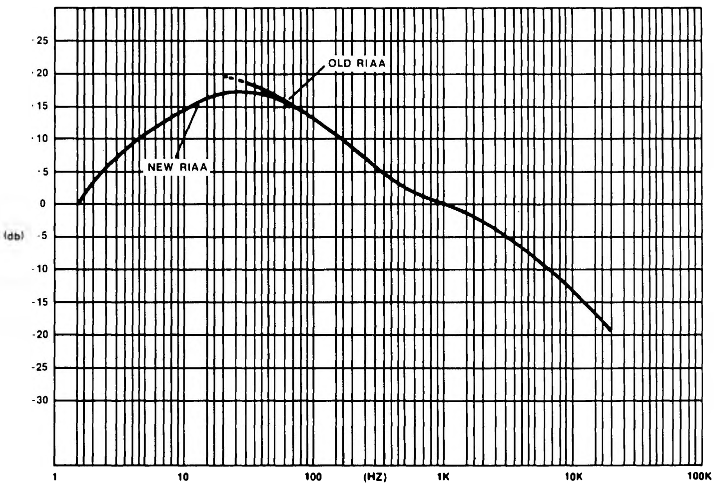
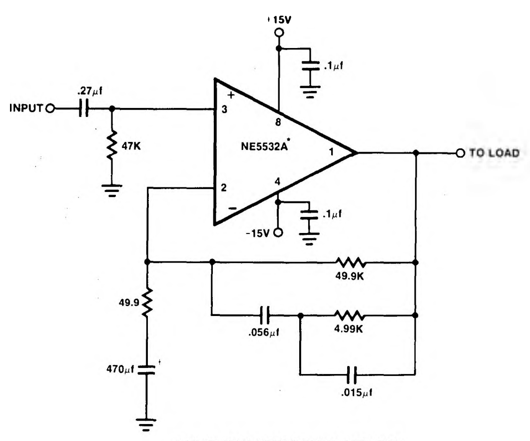


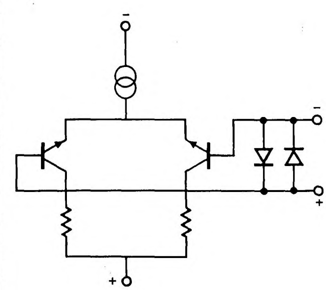
Figure 2

RIAA PHONOGRAPH PREAMPLIFIER USING THE NE5532A



NOTE
All resistors are 1% metal film and are valued in

Figure 3

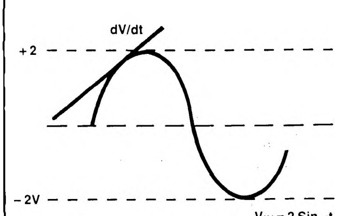


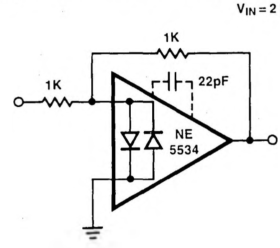
Consider the unity gain follower as an example:

Assume a signal input square wave with dV/dt of 250V per μs and 2V peak amplitude as shown. If a 22 pF compensation capacitor is inserted and the R_1 C_1 circuit deleted, the device slew rate falls to approximately 7V/μs. The input waveform will reach 2V/250V/μs or 8 ns, while the output will have changed (8×10^{-3}) (7) only 56 mV. The differential input signal is then $(V_{IN} - V_O)$ $R_i/R_i + R_f$ or approximately 1V.

The diode limiter will definitely be active and output distortion will occur; therefore, $V_{in} < 1V$ as indicated.

Next, a sine wave input is used with a similar circuit.





The slew rate of the input waveform now depends on frequency and the exact expression is

$$\frac{dv}{dt} = 2\omega \cos \omega t$$

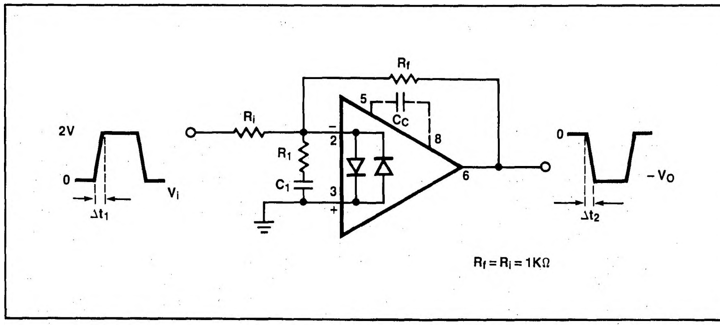
The upper limit before slew rate distortion occurs for *small signal* ($V_{IN} < 100$ mV) conditions is found by setting the slew rate to 7V/μs. That is:

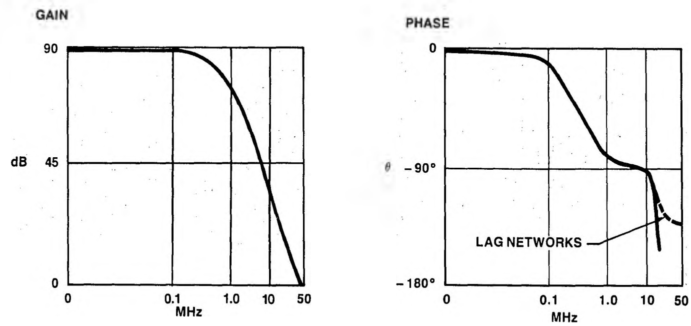
$$7 \times 10^6 \text{ V}/\mu\text{s} = 2\omega \cos \omega t$$

at $\omega t = 0$

$$\omega_{LIMIT} = \frac{7 \times 10^6}{2} = 3.5 \times 10^6 \text{ rad/s}$$

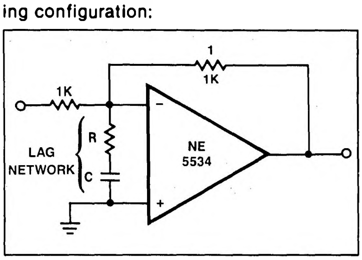
$$f_{LIMIT} \frac{3.5 \times 10^6}{2\pi} \cong 560 \text{ kHz}$$





External Compensation Network Improves Bandwidth

By using an external lead-lag network, the follower circuit slew rate and small signal bandwidth can be increased. This may be useful in situations where a closed-loop gain less than 3 to 5 is indicated. A number of examples are shown in subsequent figures. The principle benefit of using the network approach is that the full slew rate and bandwidth of the device is retained, while impulse-related parameters such as damping and phase margin are controlled by choosing the appropriate circuit constants. For example, consider the following configuration:



The major problem to be overcome is poor phase margin leading to instability.

By choosing the lag network break frequency one decade below the unity gain crossover frequency (30-50 MHz), the phase and gain margin are improved. An appropriate value for R is 270Ω. Setting the lag network break frequency at 5 MHz, C may be calculated

$$C = \frac{1}{2\pi \cdot 270 \cdot 5 \times 10^6}$$

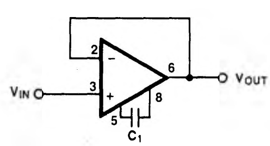
$$118 = \text{pF}$$

A single pole and zero inserted in the transfer function will give an added 45° of phase margin depending on the network values.

RULES AND EXAMPLES

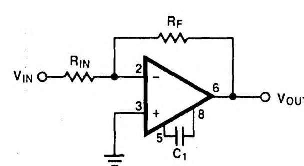
Compensation Using Pins 5 and 8

(Limited Bandwidth and Slew Rate)



$C_1 = C_C(1)$
$C_C = 22$pF for NE5533/34
∴ $C_1 = 22$pF [SEE GRAPH UNDER TYPICAL PERFORMANCE CHARACTERISTICS]

Figure 4. Unity Gain Non-Inverting Configuration



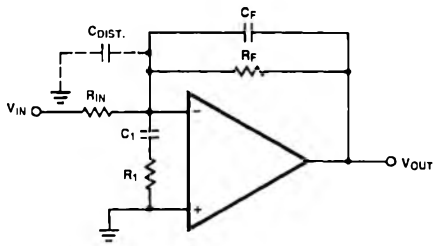
$R_F = R_{IN}$

$$C_1 = C_C\left[\frac{R_{IN}}{R_F + R_{IN}}\right] = \frac{C_C}{2}$$

∴ $C_1 = 11$pF

Figure 5. Unity Gain Inverting Configuration

External Compensation for Wideband Voltage Follower



NOTE: Input diodes limit differential to < 0.5V

Figure 6 . External Compensation for Wideband Voltage Follower

3.75 IPS TAPE EQUALIZATION

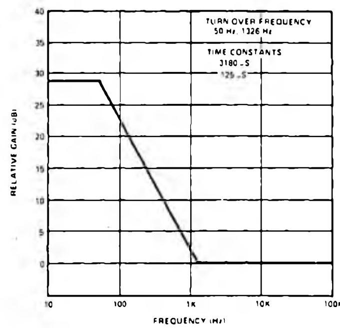


Figure 7c

Calculating the Lead-Lag Network

$$C_1 = \frac{1}{2\pi F_1 R_1} \qquad \text{Let } R_1 = \frac{R_{IN}}{10}$$

where $F_1 = \frac{1}{10}(\text{UGBW})$

UGBW = 30 MHz

Shunt Capacitance Compensation

$$C_F = \frac{1}{2\pi F_F R_F},\ F_F \cong 30\ \text{MHz}$$

or

$$C_F \cong \frac{C_{DIST}}{A_{CL}}$$

$C_{DIST} \cong$ Distributed Capacitance $\cong$ 2-3pF

Many audio circuits involve carefully tailored frequency responses. Pre-emphasis is used in all recording mediums to reduce noise and produce flat frequency response. The most often used de-emphasis curves for broadcast and home entertainment systems are shown in Figure 7. Operational amplifiers are well suited to these applications because of their high gain and easily tailored frequency response.

RIAA EQUALIZATION

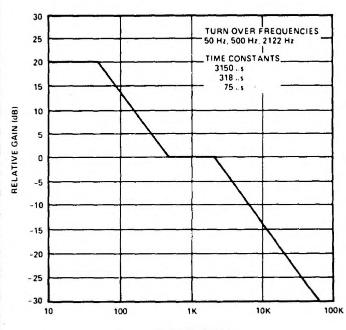


Figure 7a

BASE TREBLE CONTROL CURVE

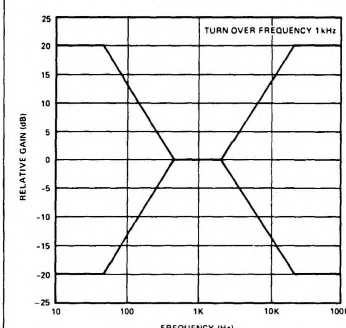


Figure 7d

NAB STANDARD PLAYBACK 7 1/2 IPS

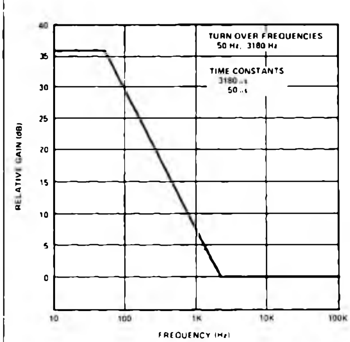


Figure 7b

STANDARD FM BROADCAST EQUALIZATION

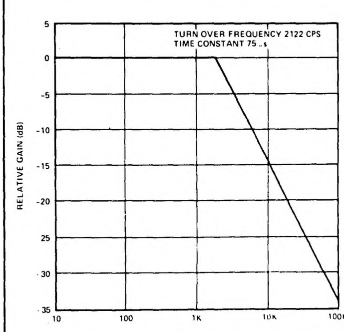


Figure 7c

INTERNALLY COMPENSATED DUAL LOW NOISE OP AMP SE/NE5532/5532A

RIAA PREAMP USING THE NE5534

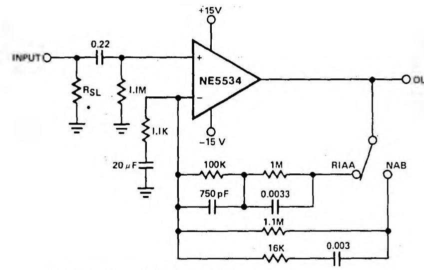
The preamplifier for phono equalization is shown in Figure 8 along with the theoretical and actual circuit response.

Low frequency boost is provided by the inductance of the magnetic cartridge with the RC network providing the necessary break points to approximate the theoretical RIAA curve.

RUMBLE FILTER

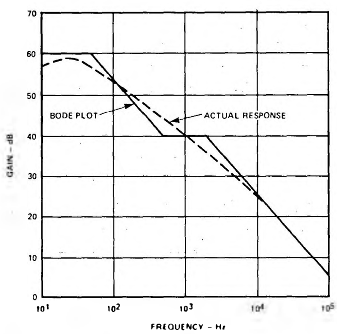
Following the amplifier stage, rumble and scratch filters are often used to improve overall quality. Such a filter designed with op amps uses the 2 pole Butterworth approach and features switchable break points. With the circuit of Figure 9 any degree of filtering from fairly sharp to none at all is switch selectable.

PREAMPLIFIER—RIAA/NAB COMPENSATION



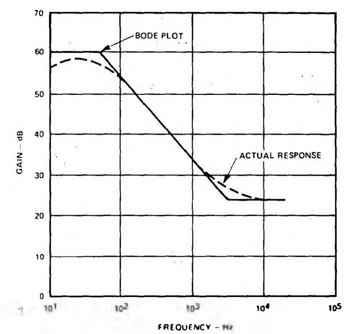
*Select to provide specified transducer loading.
Output Noise > 0.8mV rms (with input shorted)
All resistor values are in ohms.

Figure 8a



Bode Plot of RIAA Equalization and the response realized in an actual circuit using the 531

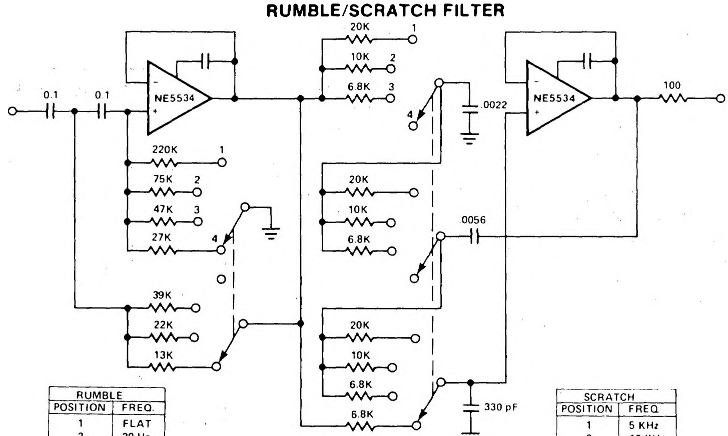
Figure 8b



Bode Plot of NAB Equalization and the response realized in the actual circuit using the 531

Figure 8c

RUMBLE/SCRATCH FILTER



RUMBLE	
POSITION	FREQ.
1	FLAT
2	30 Hz
3	50 Hz
4	80 Hz

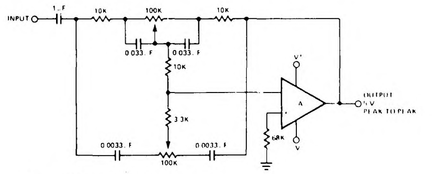
SCRATCH	
POSITION	FREQ.
1	5 KHz
2	10 KHz
3	15 KHz
4	FLAT

All resistor values are in ohms.

Figure 9

INTERNALLY COMPENSATED DUAL LOW NOISE OP AMP SE/NE5532/5532A

TONE CONTROL CIRCUIT FOR OPERATIONAL AMPLIFIERS



All resistor values are in ohms.

NOTES
1. Amplifier A may be a NE531 or 301. Frequency compensation, as for unity gain non-inverting amplifiers, must be used.
2. Turn-over frequency—1kHz.
3. Bass boost +20dB at 20Hz, bass cut -20dB at 20Hz, treble boost +19dB at 20kHz, treble cut -19dB at 20kHz.

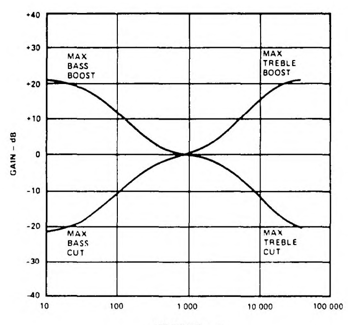


Figure 10

TONE CONTROL

Tone control of audio systems involves altering the flat response in order to attain more low frequencies or more high ones dependent upon listener preference. The circuit of Figure 10 provides 20dB of bass or treble boost or cut as set by the variable resistance. The actual response of the circuit is shown also.

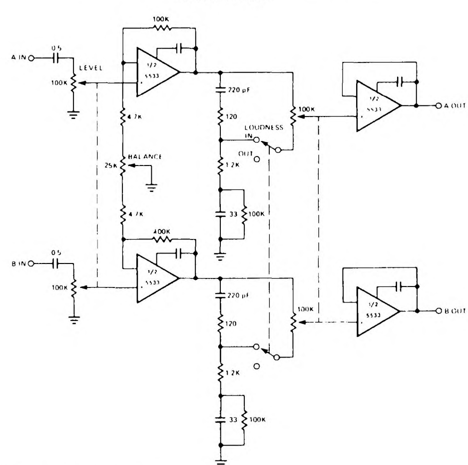
BALANCE AND LOUDNESS AMPLIFIER

Figure 11 shows a combination of balance and loudness controls. Due to the non-linearity of the human hearing system the low frequencies must be boosted at low listening levels. Balance, level, and loudness controls provide all the listening controls to produce the desired music response.

VOLTAGE AND CURRENT OFFSET ADJUSTMENTS

Many IC amplifiers include the necessary pin connections to provide external offset adjustments. Many times, however, it becomes necessary to select a device not possessing external adjustments. Figure 12, 13, and 14 suggest some possible arrangements for offset voltage adjust and bias current nulling circuitry. The circuitry of Figure 14 provides sufficient current into the input to cancel the bias current requirement. Although more simplified arrangements are possilb the addition of Q2 and Q3 provide a fixed current level to Q1, thus, bias cancellation can be provided without regard to input voltage level.

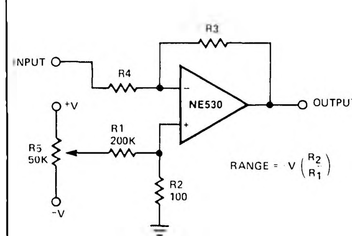
BALANCE AMPLIFIER WITH LOUDNESS CONTROL



All resistor values are in ohms.

Figure 11

UNIVERSAL OFFSET NULL FOR INVERTING AMPLIFIERS

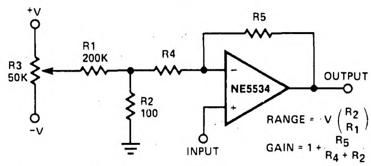


All resistor values are in ohms.

Figure 12

INTERNALLY COMPENSATED DUAL LOW NOISE OP AMP SE/NE5532/5532A

UNIVERSAL OFFSET NULL FOR NONINVERTING AMPLIFIERS



All resistor values are in ohms.

Figure 13

BIAS CURRENT COMPENSATION

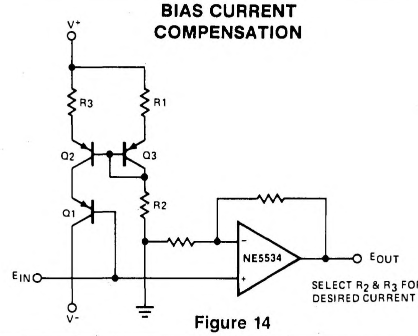


Figure 14

*For additional information, consult the Applications Section.