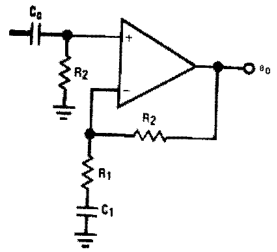
Loop AC Gain
quency −3dB Corner
mpedance

rting AC Amplifier

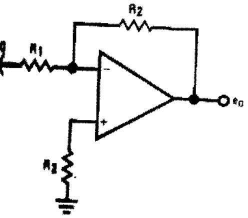


$A_V = 1 + \frac{R_2}{R_1}$

$R_{in} = R_2$

$f_o = \frac{1.56}{2\pi T}$ where $T = R_2C_o = R_1C_1$

AC Amplifier

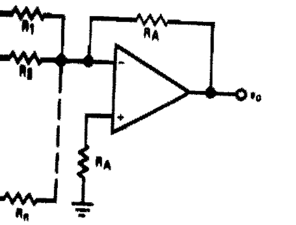


$A_V = -\frac{R_2}{R_1}$

$R_{in} = R_1$

$f_o = \frac{1}{2\pi R_1 C_o}$

mming Amplifier



$e_o = -R_A\left(\frac{e_1}{R_1} + \frac{e_2}{R_2} + \cdots + \frac{e_n}{R_N}\right)$

IF $R_1 = R_2 = \cdots = R_N$ THEN

$e_o = -\frac{R_A}{R_1}(e_1 + e_2 + \cdots + e_n)$

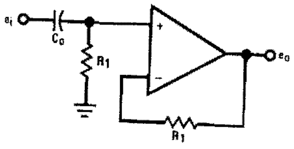
General Comments:

Power supply connections omitted for clarity.

Split supplies assumed.

Single supply biasing per A4.9 or A4.10.

A4.4 Non-Inverting Buffer

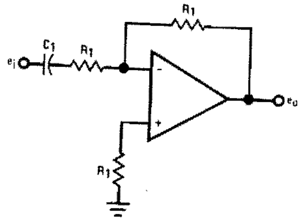


$A_V = 1$

$R_{in} = R_1$

$f_o = \frac{1}{2\pi R_1 C_o}$

A4.5 Inverting Buffer

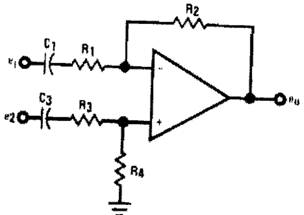


$A_V = -1$

$R_{in} = R_1$

$f_o = \frac{1}{2\pi R_1 C_1}$

A4.6 Difference Amplifier



$e_o = \left(\frac{R_1 + R_2}{R_3 + R_4}\right)\frac{R_4}{R_1}e_2 - \frac{R_2}{R_1}e_1$

IF $R_1 = R_3$* AND $R_2 = R_4$* THEN

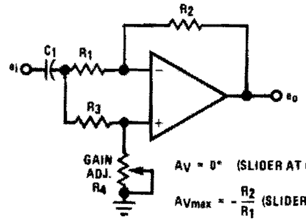
$e_o = \frac{R_2}{R_1}(e_2 - e_1)$

$f_o = \frac{1.56}{2\pi T}$ where $T = R_1C_1 = (R_3 + R_4)C_3$

$R_2 = R_4$ FOR MINIMAL OFFSET ERROR

* 0.1% MATCH FOR MAX CMRR

A4.7 Variable Gain AC Amplifier



$R_1 = R_3$
$R_2 = R_4$

$A_V = 0$* (SLIDER AT GROUND)

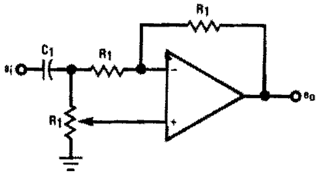
$A_{Vmax} = -\frac{R_2}{R_1}$ (SLIDER AT POS. INPUT)

$R_{in} = \frac{R_1}{2}$ (MINIMUM)

$f_o = \frac{1}{2\pi\left(\frac{R_1}{2}\right)C_1}$

* LIMITED BY CMRR OF AMPLIFIER AND MATCH OF $R_1 = R_3$, $R_2 = R_4$, e.g., LF356 AND 0.1% MATCH EQUALS > 80dB FOR A_{Vmax} = 20dB.

A4.8 Switch Hitter (Polarity Switcher, or 4-Quadrant Gain Control)



$A_V = +1$ (SLIDER AT C_1)

$A_V = 0$* (SLIDER MIDPOSITION)

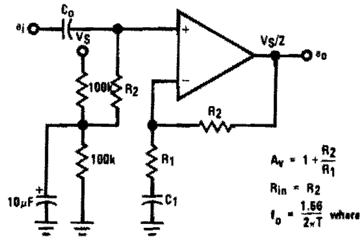
$A_V = -1$ (SLIDER AT GROUND)

$R_{in} = \frac{R_1}{2}$ (MINIMUM)

$f_o = \frac{1}{2\pi\left(\frac{R_1}{2}\right)C_1}$

* WITHIN CMRR OF AMPLIFIER

A4.9 Single Supply Biasing of Non-Inverting AC Amplifier

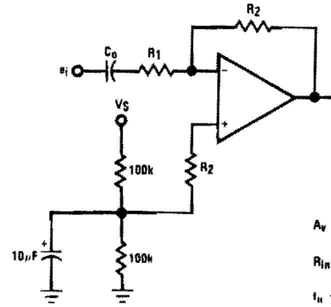


$A_V = 1 + \frac{R_2}{R_1}$

$R_{in} = R_2$

$f_o = \frac{1.56}{2\pi T}$ where $T = R_2C_o = R_1C_1$

A4.10 Single Supply Biasing of Inverting AC Amplifier



$A_V = -\frac{R_2}{R_1}$

$R_{in} = R_1$

$f_o = \frac{1}{2\pi R_1 C_o}$

A5.0 MAGNETIC PHONO CARTRIDGE NOISE ANALYSIS

A5.1 Introduction

Present methods of measuring signal-to-noise (S/N) ratios do not represent the true noise performance of phono preamps under real operating conditions. Noise measurements with the input shorted are only a measure of the preamp noise voltage, ignoring the two other noise sources: the preamp current noise and the noise of the phono cartridge.

Modern phono preamps have typical S/N ratios in the 70dB range (below 2mV @ 1kHz), which corresponds to an input noise voltage of 0.64μV, which looks impressive but is quite meaningless. The noise of the cartridge[1] and input network is typically *greater* than the preamp noise voltage, ultimately limiting S/N ratios. This must be considered when specifying preamplifier noise performance. A method of analyzing the noise of complex networks will be presented and then used in an example problem.

A5.2 Review of Noise Basics

The noise of a passive network is thermal, generated by the real part of the complex impedance, as given by Nyquist's Relation:

$$\overline{V_n^2} = 4kT\,Re(Z)\,\Delta f \qquad (A5.2.1)$$

where: $\overline{V_n^2}$ = mean square noise voltage
k = Boltzmann's constant (1.38×10^{-23} W-sec/°K)
T = absolute temperature (°K)
Re(Z) = real part of complex impedance (Ω)
Δf = noise bandwidth (Hz)

The total noise voltage over a frequency band can be readily calculated if it is white noise (i.e., Re(Z) is frequency independent). This is not the case with phono cartridges or most real world noise problems. Rapidly changing cartridge network impedance and the RIAA equalization of the preamplifier combine to complicate the issue. The total input noise in a non-ideal case can be calculated by breaking the noise spectrum into several small bands where the noise is nearly white and calculating the noise of each band. The total input noise is the RMS sum of the noise in each of the bands $N_1, N_2, \ldots, N_n$.

$$V_{noise} = (V_{N1}^2 + V_{N2}^2 + \ldots + V_{Nn}^2)^{1/2} \qquad (A5.2.2)$$

This expression does not take into account gain variations of the preamp, which will also change the character of the noise at the preamp output. By reflecting the RIAA equalization to the preamp input and normalizing the gain to 0dB at 1kHz, the equalized cartridge noise may then be calculated.

$$V_{EQ} = (|A_1|^2 V_{N1}^2 + |A_2|^2 + \ldots + |A_n|^2 V_{Nn}^2)^{1/2} \qquad (A5.2.3)$$

where: V_{EQ} = equalized preamp input noise
$|A_n|$ = magnitude of the equalized gain at the center of each noise band (V/V)

6