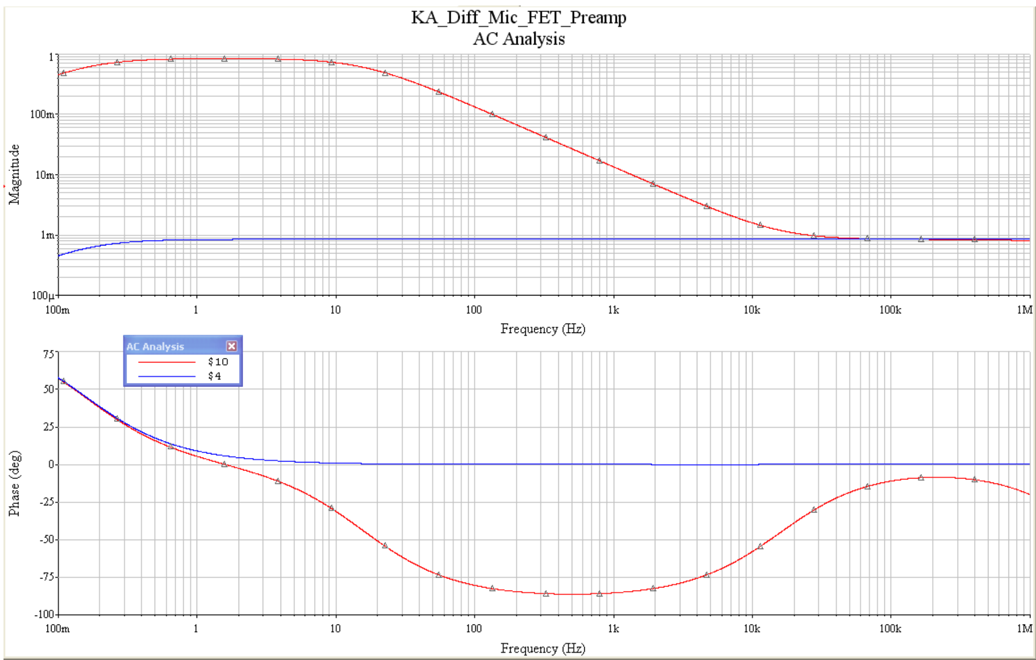
The (complex) frequency response of the simple op-amp integrator preamplifier circuit is:

$$\tilde{H}_{oai}(\omega) = \left(R_{fb}/R_1\right)\cdot\frac{1}{1+i\omega R_{fb}C} = \left(R_{fb}/R_1\right)\cdot\frac{1}{1+i\omega\tau_{fb}} \quad \{\text{using: } \tau_{fb} \equiv R_{fb}C \ (sec)\}$$

At low frequencies, such that $\omega \ll 1/R_{fb}C = 1/\tau_{fb}$: $\tilde{H}_{oai}\left(\omega \ll 1/R_{fb}C\right) \simeq \left(R_{fb}/R_1\right)$ is a purely ***real*** quantity – *i.e.* the output of the op-amp integrator is ***in-phase*** with the input. At high frequencies, such that $\omega \gg 1/R_{fb}C = 1/\tau_{fb}$ then: $\tilde{H}_{oai}\left(\omega \gg 1/R_{fb}C\right) \simeq \left(R_{fb}/R_1\right)\cdot\frac{1}{i\omega R_{fb}C} = -i\frac{\left(R_{fb}/R_1\right)}{\omega R_{fb}C}$ and thus we see that the high-frequency output response of the op-amp integrator is proportional to $1/\omega$ and is -90^o ***out-of-phase*** with the input signal. The frequency and phase response of the simple op-amp integrator circuit (alone) is shown in the figure below.



Note that the phase response of this op-amp integrator circuit is ~ constant in the frequency range ~ 50 *Hz* < *f* < ~ 4 *KHz*, which is of primary interest for most musical instruments.

This simple op-amp integrator circuit is used in conjunction with a modified version of the Knowles Electronics EK-23132 subminiature electret condenser microphone (with back plate removed and replaced with a very fine-mesh copper screen {electrically connected to mic case using conductive epoxy paint for RFI/EMI suppression}) for a 1-D particle velocity microphone. Note that well above the –3 dB low-frequency pole of the op-amp integrator circuit (*i.e.* $\omega \gg 1/R_f C$) but still well below $\omega \ll c/d$, the combined response of the differential pressure microphone + op-amp integrator circuit is constant, independent of (angular) frequency ω:

$$\tilde{H}_{u-mic}(\omega,\Theta)\Big|_{1/R_fC\ll\omega\ll c/d} = \tilde{H}_{diff-mic}(\omega,\Theta)\cdot\tilde{H}_{oai}(\omega)\Big|_{1/R_fC\ll\omega\ll c/d} \simeq \left(\frac{d}{c}\right)\left[\frac{R_{fb}/R_1}{R_{fb}C}\right]\cos\Theta$$