PDHonline Course E277 (4 PDH)

Operational Amplifier Stability and Common-Mode Noise Rejection

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APPENDIX B
Derivation of the Inverting Amplifier's Gain Equation

$$A_v \cong -\frac{R_F}{R_1}$$

Because the open-loop gain A_{VOL} of the typical Op Amp is very large, the differential input voltage V_{id}, shown in Figure 1A below, is infinitesimal compared to the output voltage V_o. That is, since

$$A_{VOL} = \frac{V_o}{V_{id}}$$

then

$$V_{id} = \frac{V_o}{A_{VOL}}$$

This last equation shows that the larger A_{VOL} is with any typical V_o, the smaller V_{id} is compared to V_o. The point is, the voltage V_{id} across inputs 1 and 2 is *practically* zero because of the large open-loop gain A_{VOL} of the typical Op Amp. It follows that with *virtually* no potential difference between inputs 1 and 2, and with the noninverting input 2 grounded, the inverting input is *virtually at* ground potential too. This virtual grounding of the inverting Op Amp's inverting (-) input is also described as its *ground point restraint.*

Note in Figure 1A that the output voltage V_o is at the right end of R_F and that *virtual* ground is at its left end. Therefore, for practical purposes, the voltage across R_F is output voltage V_o.

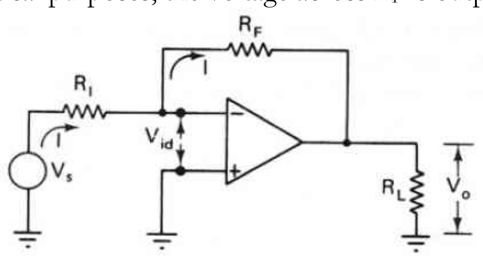

Figure 1A An Inverting Amplifier

We can see how resistors R_1 and R_F in the circuit of Figure 1A determine the closed-loop gain A_v if we analyze this circuit's current paths and voltage drops. For example, as shown in Figure 1A, the signal source V_S drives a current I through R_1. The input resistance $R_{i(eff)}$ of the typical Op Amp is very large compared to R_F. Therefore, for practical purposes, all of this current I is forced up through R_F. By Ohm's law we can show that the voltage drop across R_F is

$$V_o \approx R_F I$$

And similarly the voltage across R_1 is

$$V_S \approx R_1 I$$

The inverting amplifier's gain, therefore, can be shown as

$$\boxed{A_v = \frac{V_o}{V_s} \cong -\frac{R_F I}{R_1 I} \cong -\frac{R_F}{R_1}.} \qquad (3\text{-}4)$$

Of course, the current direction shown in this figure is instantaneous when the input signal voltage V_S is positive with respect to ground at the same instant.