Control Systems

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1 Ideal op-amp

The common-mode signal v_{icm} is the average of the input voltages and given by:

$$v_{icm} = \frac{v_1 + v_2}{2}$$

The differential signal is the difference between the input voltages and given by:

$$v_{id} = v_1 - v_2$$

An opertional amplifier (op-amp) is an idealized amplifier with the following properties:

- Infinite input impedance
- Infinite open-loop gain A_OL for the differential signal
- Zero gain for the common-mode signal
- Zero output impedance
- Infinite bandwidth

2 Feedback

2.1 Negative feedback

In negative feedback, a portion of the output voltage is fed back to the inverting input.

Closed loop gain can be calculated using the formula:

$$A_f = \frac{A_{OL}}{1 + \beta A_{OL}}$$

Where A_f is the closed loop gain, A_{OL} is the open loop gain and β is the feedback factor.

The product $A * \beta$ is called the loop gain and is a measure of the feedback strength. The loop gain must be much larger than 1 for the feedback to be effective.

2.2 Positive feedback

In positive feedback, a portion of the output voltage is fed back to the non-inverting input

Positive feedback leads to poor gain stability.

Because of the probelms with gain instability and oscillation, positive feedback is almost never used intentionally in amplifiers.

2.3 Types of feedback

- Voltage feedback: If the feedback network samples the output voltage
- Current feedback: If the feedback network samples the output current
- Series feedback
- Parallel feedback

2.4 Effects of feedback

Feedback type	x_s	x_0	Gain stabilized	Input impedance	Output Impedance	Ideal Amplifier
Series voltage	v_s	v_0	$A_{vf} = \frac{A_v}{1+A_v\beta}$	$R_i(1 + A_v\beta)$	$\frac{R_0}{1+\beta A_{voc}}$	Voltage
Series current	v_s	i_0	$G_{mf} = \frac{G_m}{1+G_m\beta}$	$R_i(1 + G_m\beta)$	$R_0(1 + \beta G_{msc})$	Transconductance
Parallel voltage	i_s	v_0	$R_{mf} = \frac{R_m}{1+R_m\beta}$	$\frac{R_i}{1+R_m\beta}$	$\frac{R_0}{1+\beta R_{moc}}$	Transresistance
Parallel current	i_s	i_0	$A_{if} = \frac{A_i}{1+A_i\beta}$	$\frac{R_i}{1+A_i\beta}$	$R_0(1 + \beta A_{isc})$	Current

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