# Control Systems

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# 1 Op-amps

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 $A_O L$ for the differential signal
- Zero gain for the common-mode signal
- Zero output impedance
- Infinite bandwidth

**Slewrate**

The slewrate is the maximum rate of change of the output voltage and is given by:

$$|\frac{dv_{out}}{dt}| <= SR$$

**Full power bandwidth**

The full power bandwidth of an op amp is the range of frequencies for which the op amp can produce an undistorted sinusoidal output with peak amplitude equall to the guaranteed maximum output voltage.

The full power bandwidth is given by:

$$f_{FP} = \frac{SR}{2\pi V_{omax}}$$

# 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 $\beta$ 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 |

Definition of dB gain: Rewriting voltage gain to dB:

$$20 \log_{10}(\frac{v_0}{v_s})$$

Rewriting current gain to dB:

$$20 \log_{10}(\frac{i_0}{i_s})$$

Rewriting power gain to dB:

$$10 \log_{10}(\frac{p_0}{p_s})$$

# 3 Frekvensbegrænsninger

# 4 Offset- og biasfejl

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# 6 Differensforstærkerne

# 7 Applikationer