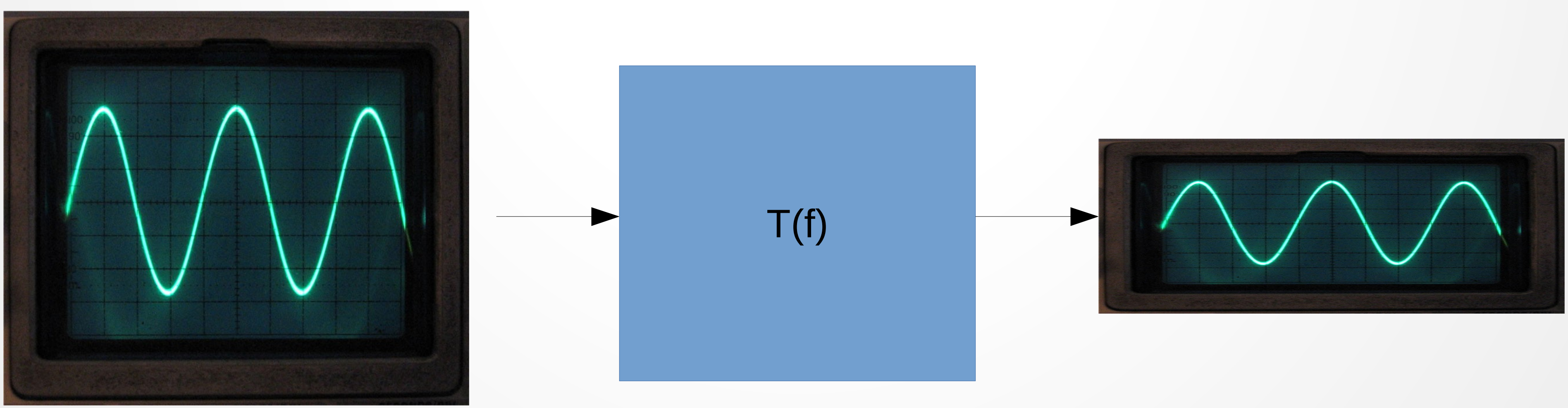
How to measure Open Loop Gain (and UGF)

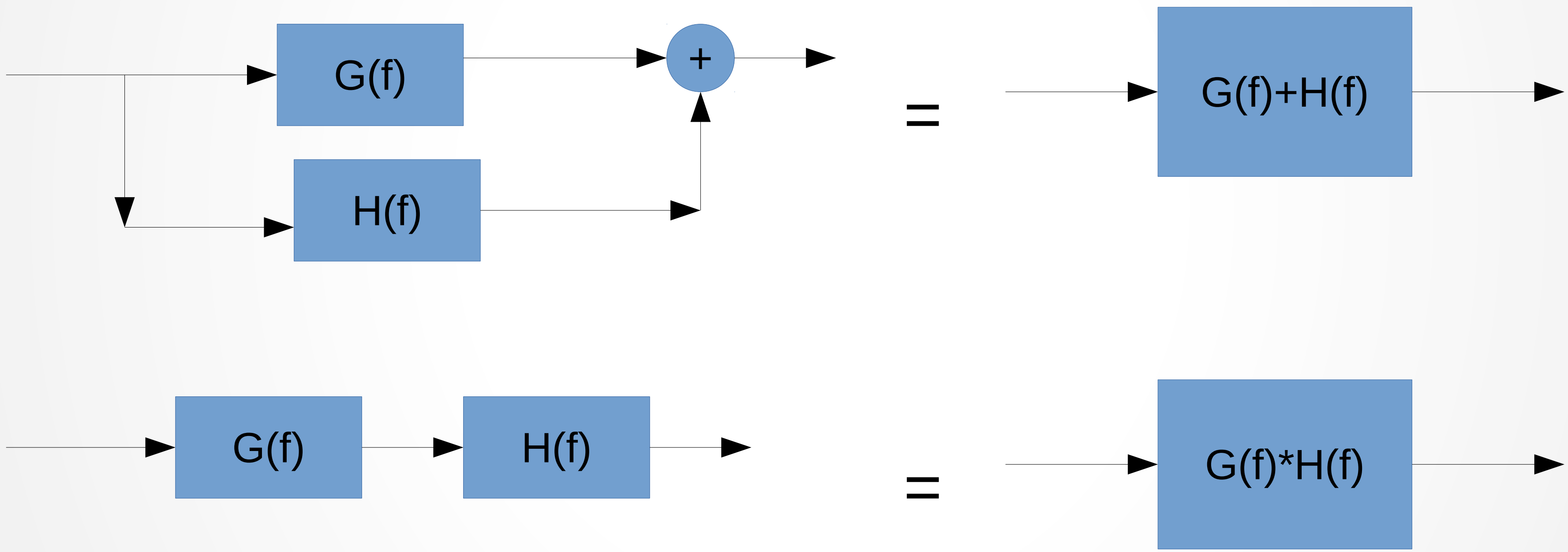
A Tutorial

Transfer Functions

- Linear systems can be characterized in the frequency domain by the amplitude and phase response to sinusoidal excitations, represented as a complex function of frequency.
- Can be measured with “swept sine” method



Features of linear systems

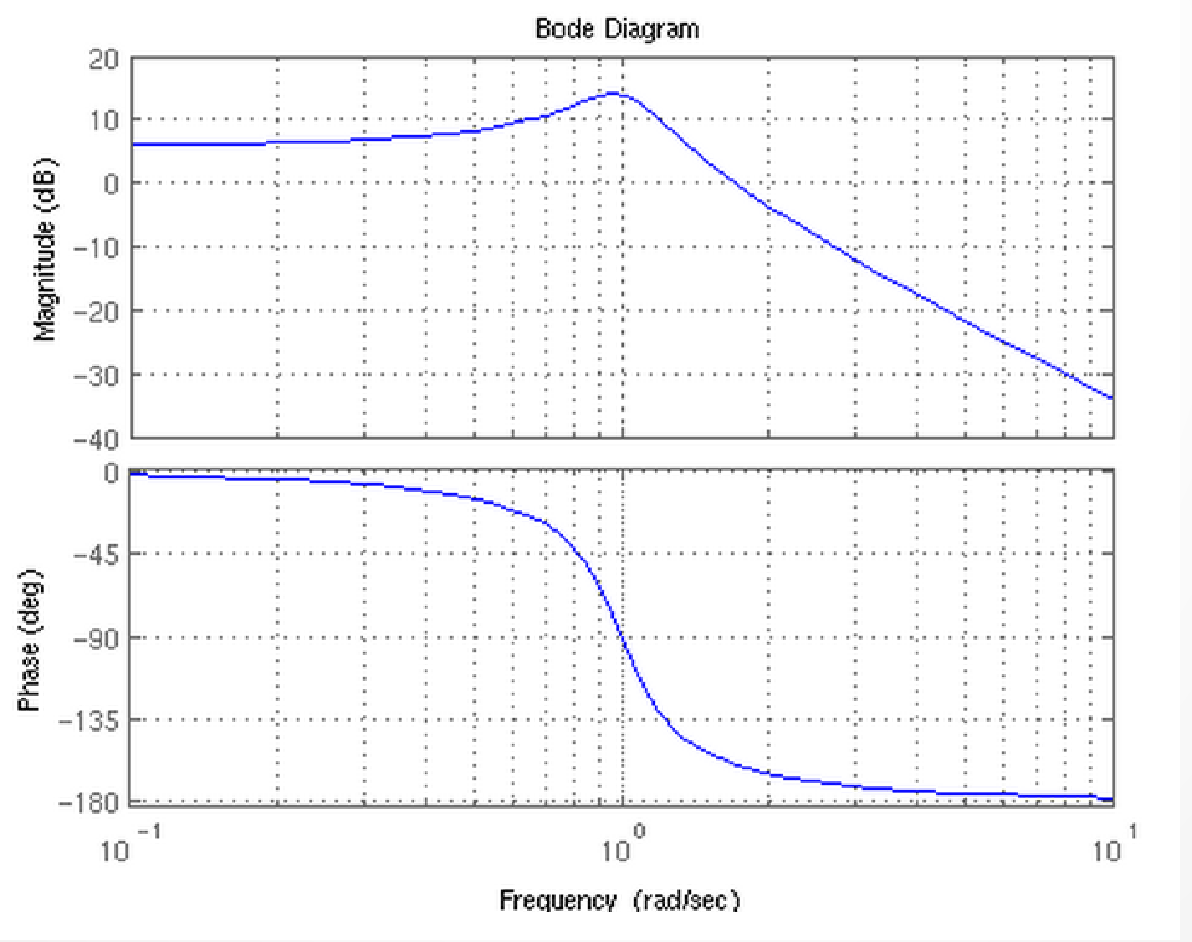


Bode Diagram

- A common graphical representation of transfer functions

|T(f)|

arg(T(f))

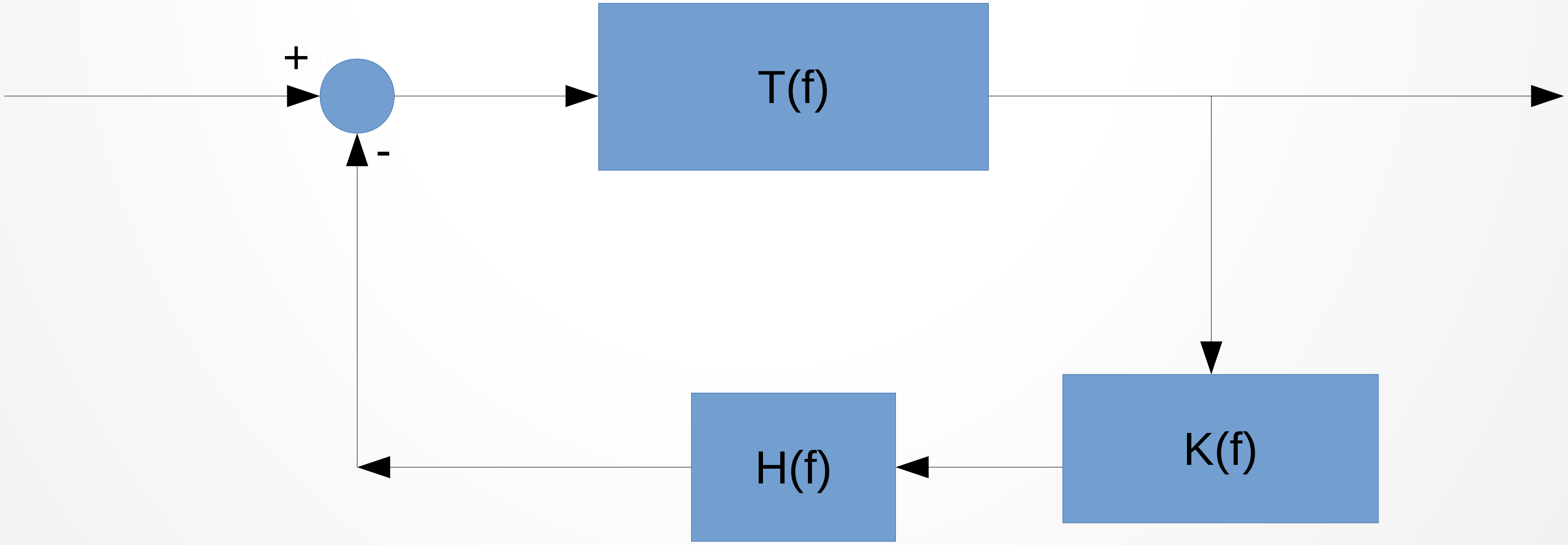


Coherence

- Important note: measurement signal to noise ratio is characterized by the coherence function
- Coherence ~ 1 means small uncertainty in data points
- Good Reference: “Random Data” Bendat and Piersol (Appendix)

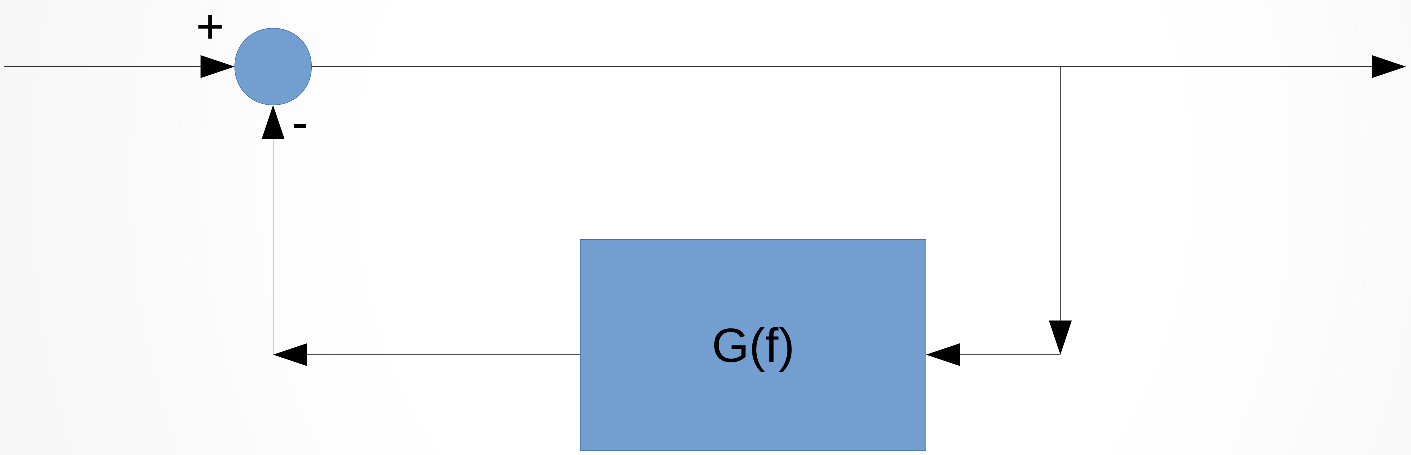
Negative Feedback System

- A linear system where signals propagate through loops
- Each piece is linear

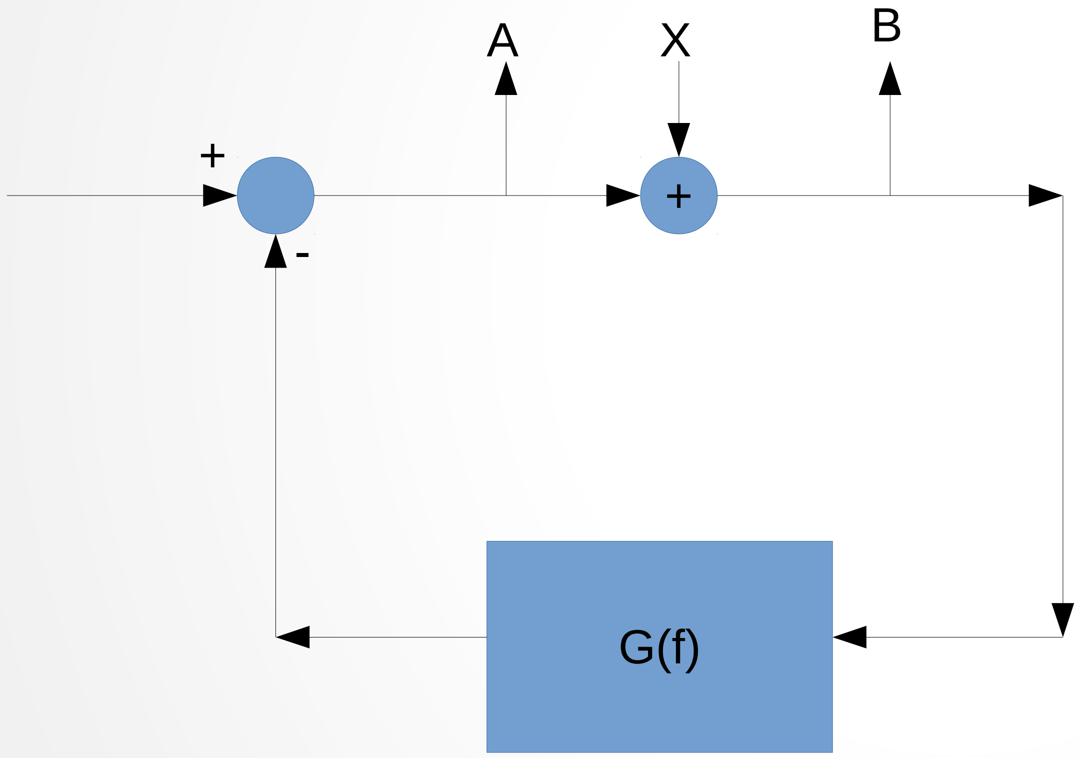


Open Loop Gain

- Collapse all TFs around the loop to a single TF



The response of the loop to excitations



$$\frac{B}{X} = \frac{1}{1 - G}$$

$$\frac{A}{X} = \frac{G}{1 - G}$$

Extracting the Open Loop Gain

- The ratio of the two measurements gives the open loop gain.
- Most network analyzers can perform the ratio in a single measurement. (One excitation port, two measurement ports)
- Important that coherence of both measurements is high. (Either by longer measurement or larger excitation amplitude)

$$\left(\frac{A}{X}\right) / \left(\frac{B}{X}\right) = G$$

The Unity Gain Frequency

- Defined as $|G(f\_U)| = 1$
- The UGF characterizes the time scale for the loop to stabilize against external excitations

|G(f)|

f_U

arg(G(f))