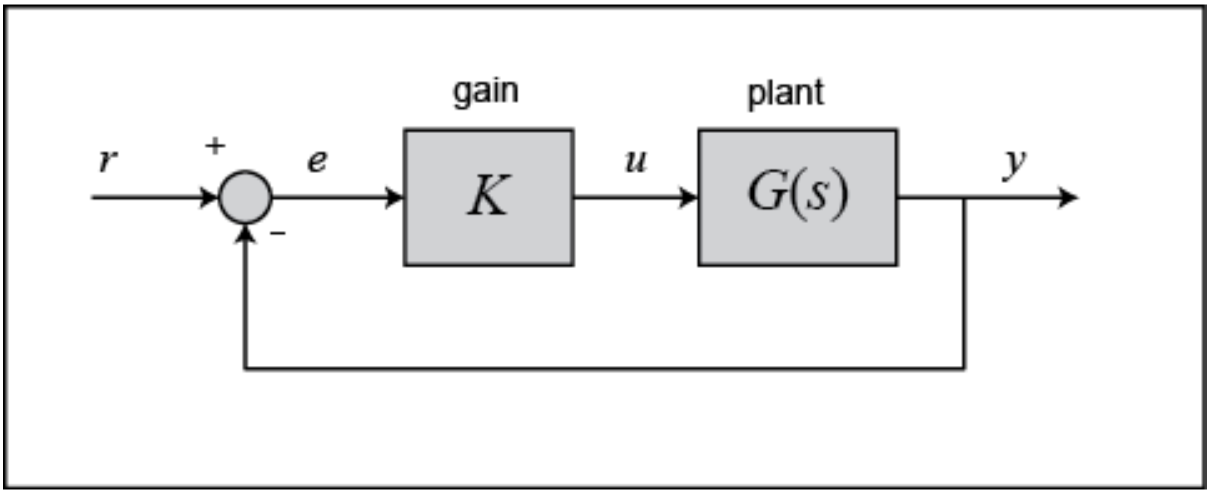
Simple guidelines for using Bode

Bode analysis gives a system's frequency response in terms of magnitude and phase, and we can think of this information as describing our system's *robustness*. For example, how close are we to the system becoming unstable? The two quantities that we've already mentioned, *gain margin* and *phase margin*, are used to indicate the margin (formally the *stability margin*) that the system has **before it goes unstable**.

Consider the following unity feedback system (recall Lecture 12a: *Applying the Gain Margin and the Phase Margin*).



where K is a variable (constant) gain and $G(s)$ is the plant. The gain margin can be defined in practical words as *the change in the open-loop gain required to make the closed-loop system unstable*. It's generally the case that systems with greater gain margins can withstand greater changes in system parameters before becoming unstable in the closed-loop. This comes from the simple rule that: **if $\boldsymbol{K \geq G_M}$ (dB) then the system will become unstable.** So, the bigger the gain margin G_M the bigger K can be before this inequality is satisfied. Remember that you need to convert K into dB to make this work properly (because G_M is necessarily in dB). If you use MATLAB to find your G_M and your forward gain K is less than this value then your system should be stable.

The phase margin is defined in words as *the change in the open-loop phase shift that's required in order to make the closed-loop system unstable*.

You can also introduce a simple calculation based on the phase margin which measures your system's tolerance to *time delay*, t_d. If $\boldsymbol{t_d \geq \frac{\Phi_M}{\omega_{gc}}}$ **in the closed loop system (where $\boldsymbol{\Phi_M}$ is in radians and $\boldsymbol{\omega_{gc}}$ is in rad/s) then the closed-loop system will become unstable**. The time delay, t_d, could be thought of as an extra block inserted into the forward path of the block diagram that adds phase lag to the system, but has no effect on the gain. Your system will have an inherent time delay of its own but this can be hard to find directly from a Simulink simulation. Just for interest here's a reference to an example where a 2.6 second delay to the plant dynamics has been deliberately introduced, through the $e^{-2.6s}$ term.

https://www.mathworks.com/help/control/ug/analyzing-control-systems-with-delays.html