Feedback and Oscillators

Introduction

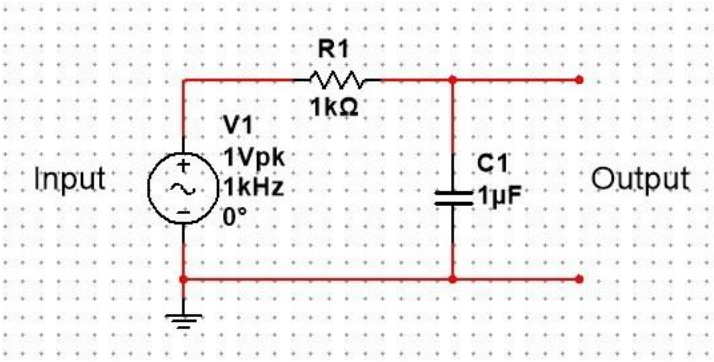
Most of you are currently studying Feedback Control in another course this semester or have already taken a Feedback Control systems course. In that course you worked hard to eliminate instabilities in a feedback control system while maximizing system performance. There are applications however where an oscillator is a necessary element of a system (e.g., a superheterodyne RF receiver). To build an oscillator, you need to design a circuit/system that is controllably unstable so that it will oscillate at the desired frequency.

Bode Plots and Phase Margin

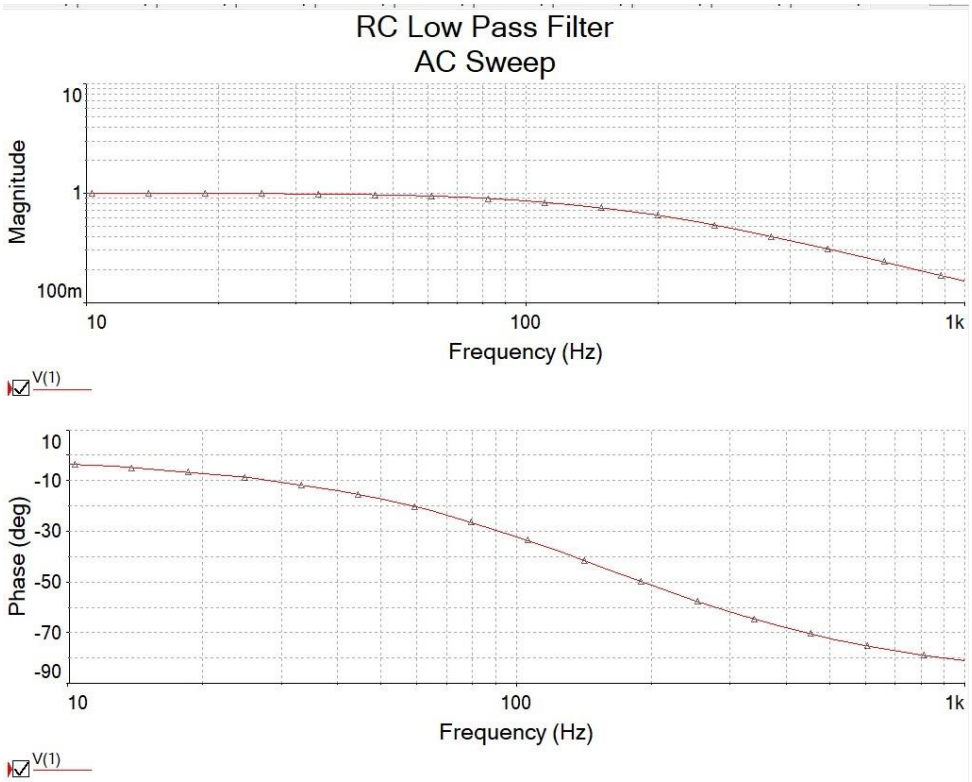
One of the feedback control analysis technique that you learn in the Feedback course is to look at the "open loop" (the gain and phase of the system transfer function starting at the input and looking at the output at the feedback point when the feedback is disconnected) Bode plot of the system.

Bode Plots

You first learned about Bode Plots in your AC Circuits course. Here is an example: a simple RC low pass filter.



This circuit has a time constant t = RC = 10^{-3} which corresponds to a 3 dB point at 1/(2pi*10^{-3}) which is approximately 159 Hz where the voltage gain is 0.7071 and the phase shift is 45°. The gain of this circuit is always less than 1 and the Phase shift never exceeds 90°.



So, if this were the open loop transfer function of a feedback control system, the resulting system would be stable.

Phase margin

Phase Margin is based on the amount of phase shift when the system open loop gain passes through 0dB.

It is basically a measure of how close a system is to being unstable. Phase starts to change on the order of a decade before each corner frequency. The phase shift must be maintained less than 180° until the loop gain drops below 0dB (unity gain) or the system will oscillate since the minus sign for negative feedback is 180° and another 180° will make the feedback positive. The "Phase Margin" is the number of degrees less than 180° of the open loop transfer function at the frequency where the gain drops to unity (0 dB). The higher the phase margin, the more stable the feedback system.

Oscillators

To make an oscillator we want to build an unstable system/circuit. Therefore, the open loop transfer function should have 180° phase shift when the gain is still somewhat above unity. We do not want an excessive gain as the output will tend to clip and not produce a clean sine wave at the desired frequency.