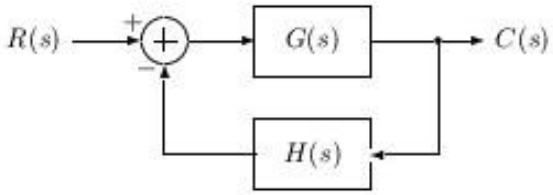
DC-DC Fundamentals

1.5 Converter Control

What is Converter Control?

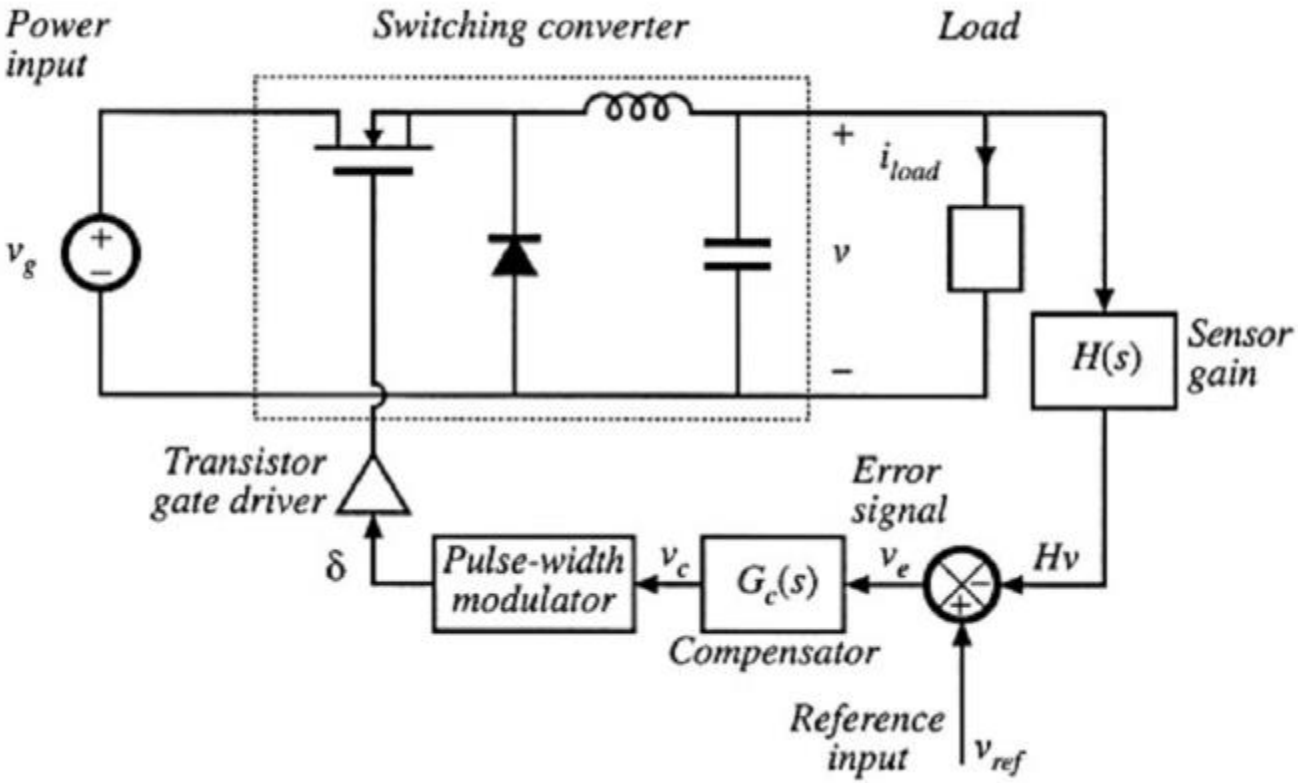
- A converter can provide a constant voltage output at various condition because of the closed-loop control system implemented in the circuit
- A simple control system has a feedback path from output to input
  - System gain is the ratio of controlled output to the reference input: without the feedback path H, it's open loop system and the gain is G; with the feedback, it's closed loop system and the gain is G/(1+G*H)



$R(s)$	reference input
$C(s)$	controlled output
$G(s)$	forward path
$H(s)$	feedback path

G*H is called the loop gain

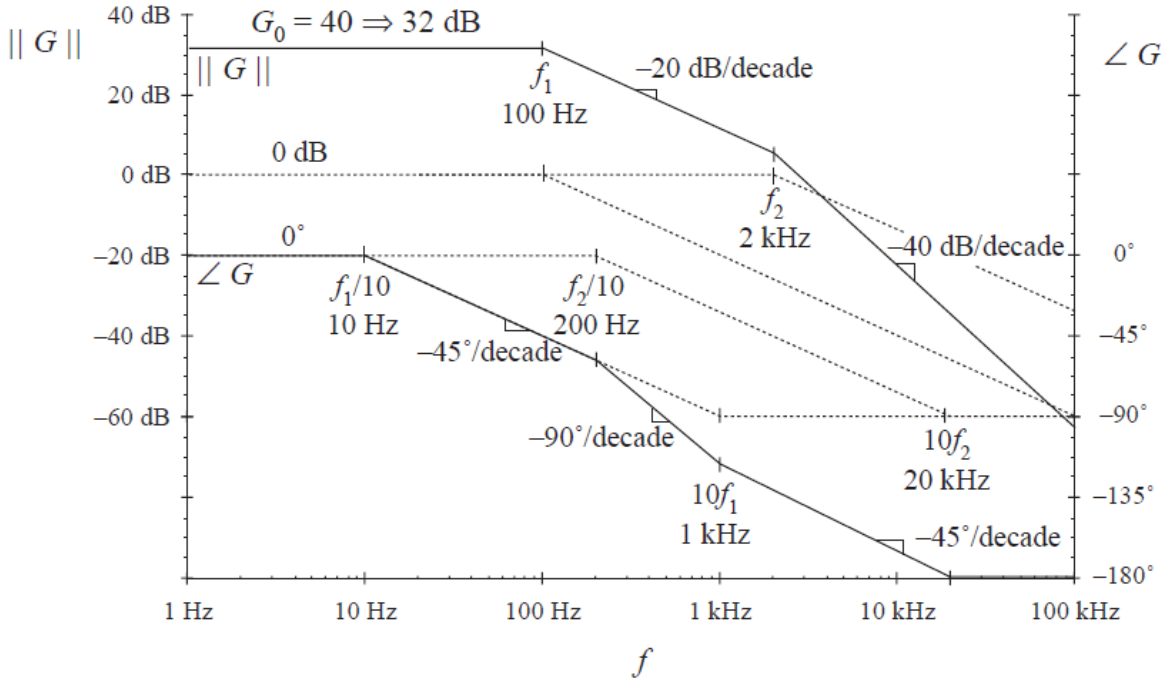
How Does a Control System Work?



Bode Plots

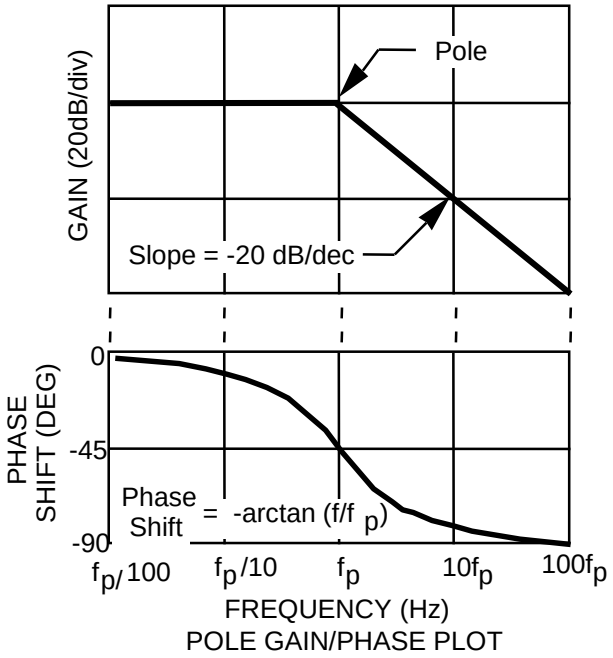
- A control system is often analyzed in the plot of the gain magnitude and phase over the frequency domain, known as the Bode plot
- A control system can be expressed in transfer functions and therefore be plotted in Bode plots
- The gain magnitude is shown in dB (20log) unit, the phase is in angle degree, and the frequency is usually plotted in logarithmic scale

$$G(s) = \frac{G_0}{\left(1 + \frac{s}{\omega_1}\right)\left(1 + \frac{s}{\omega_2}\right)}$$

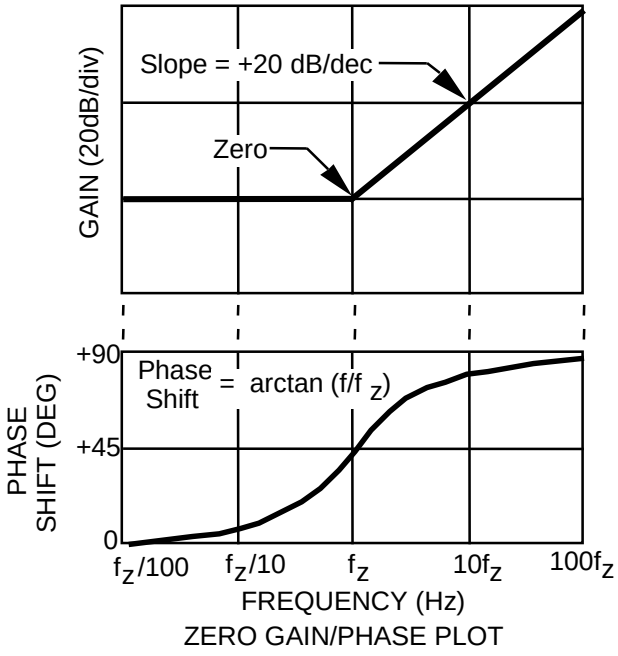


Poles and Zeros

$$\frac{1}{1+s}$$



- Slope changes by -20 dB/ decade
- Phase shift of -90^0 (max)
- Most of the effect is within one decade (up or down) of f_p

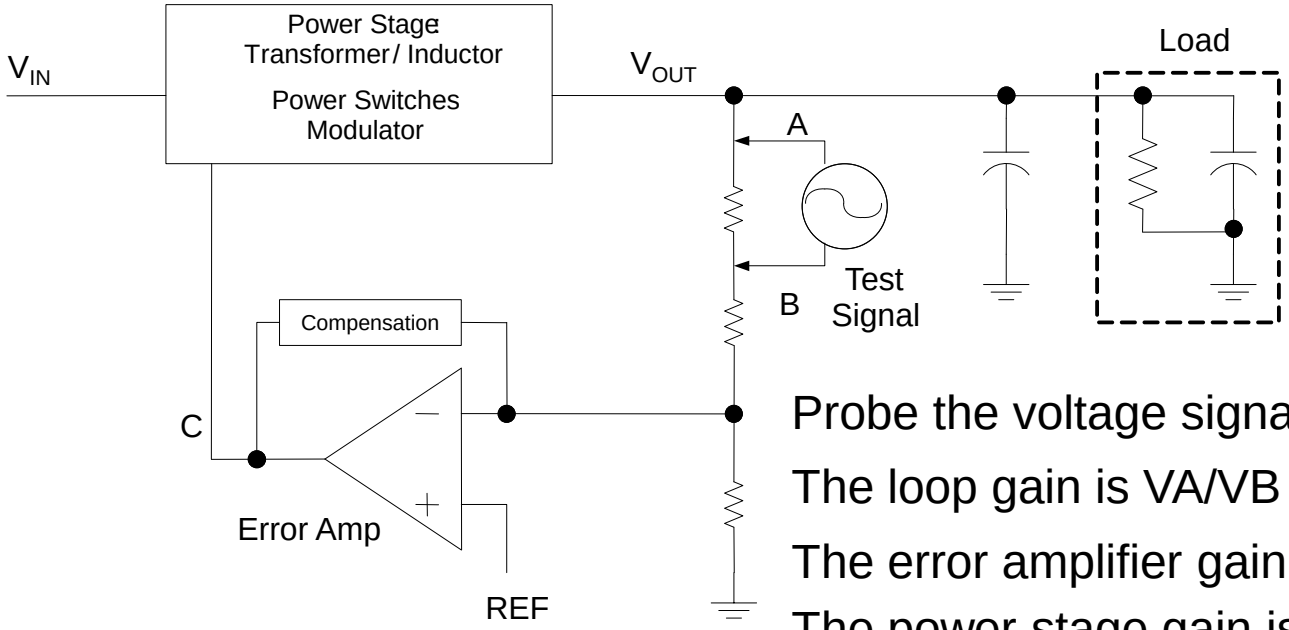


$$\frac{1+s}{1}$$

- Slope changes by +20 dB/decade
- Phase shift of $+90^0$ (max)
- Acts like an “anti-pole”, which means it can cancel out the pole

How to Get a Bode Plot

- The transfer function of a converter can be derived from its circuit model, then the Bode plot can be obtained from it
- Or, the Bode plot can be measured on a network analyzer by injecting a small AC signal into the feedback loop, sweeping its frequency and probing and comparing the signals



Probe the voltage signals at A, B,C

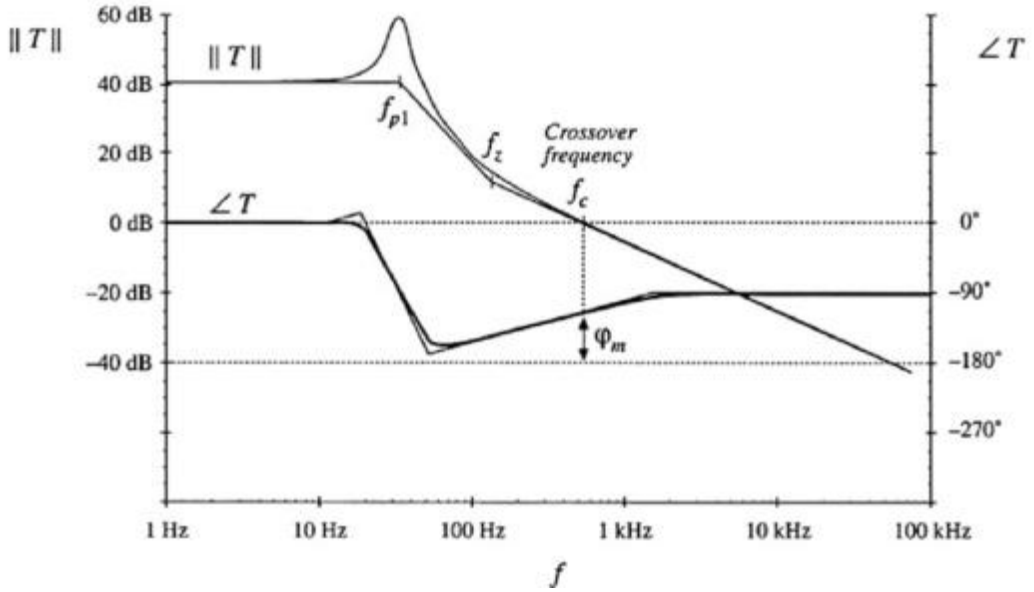
The loop gain is VA/VB

The error amplifier gain is VC/VB

The power stage gain is VC/VA

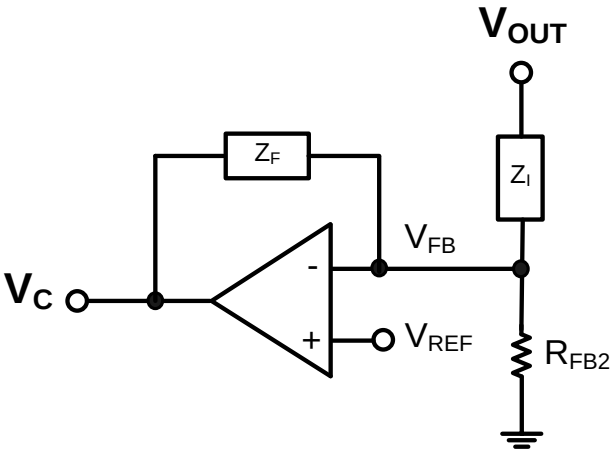
Control Stability

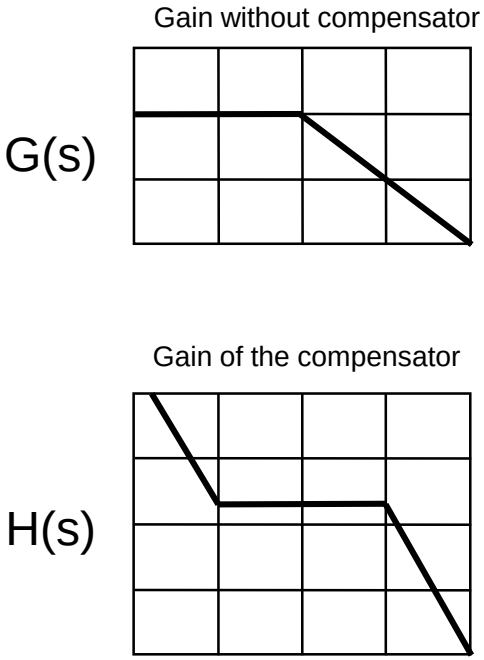
- A closed-loop system becomes unstable when the phase of the loop gain approaches 180 degree while the gain is still positive
- To ensure the stability, the phase margin must be positive at the crossover frequency
  - Crossover frequency f_c is the frequency where the loop gain magnitude is unity
  - Phase margin φ_m is the phase different of the loop gain and -180 degree at crossover frequency



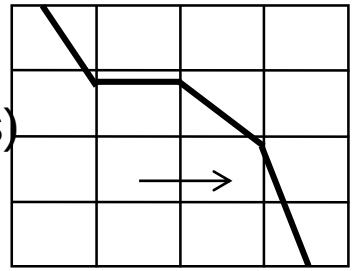
Compensator

- A compensator is included in the closed loop system to tune the loop gain that it ensure the system is stable and good transient response
- The compensation is usually adjusted by changing the R-C components around the error amplifier





=>G(s)H(s)



Effectively push the loop bandwidth higher

Summary

- Introduction to converter control
- Bode plot basics
- Control stability and compensation

Thank you!