Experiment #2 Objectives

• To test and understand steady-state behavior of a GaN-based converter
• To validate analytical loss models of a PWM converter
• To examine techniques for Maximum Power Point Tracking (MPPT)

Demo Board Circuit
Demo Board

LMG5200 GaN Power Stage

Figure 10. Functional Block Diagram
GaNFETs

Optimal Device Selection
Impact of WBG

Chapter 9: Controller Design

9.1. Introduction

9.2. Effect of negative feedback on the network transfer functions

9.2.1. Feedback reduces the transfer function from disturbances to the output

9.2.2. Feedback causes the transfer function from the reference input to the output to be insensitive to variations in the gains in the forward path of the loop

9.3. Construction of the important quantities $1/(1+T)$ and $T/(1+T)$ and the closed-loop transfer functions
Chapter 9: Controller Design

9.4. Stability
   9.4.1. The phase margin test
   9.4.2. The relation between phase margin and closed-loop damping factor
   9.4.3. Transient response vs. damping factor

9.5. Regulator design
   9.5.1. Lead (PD) compensator
   9.5.2. Lag (PI) compensator
   9.5.3. Combined (PID) compensator
   9.5.4. Design example

Closed-Loop Regulation

[Diagram of a closed-loop regulation system]
Open-Loop Behavior

Small signal model: open-loop converter

Output voltage can be expressed as

\[ \hat{v}(s) = G_{vd}(s) \hat{d}(s) + G_{vd}(s) \hat{v}_g(s) - Z_{vd}(s) \hat{i}_{load}(s) \]

where

\[ G_{vd}(s) = \left. \frac{\hat{v}(s)}{\hat{d}(s)} \right|_{\hat{i}_{load} = 0} \]
\[ G_{vd}(s) = \left. \frac{\hat{v}(s)}{\hat{v}_g(s)} \right|_{\hat{i}_{load} = 0} \]
\[ Z_{vd}(s) = -\left. \frac{\hat{v}(s)}{\hat{i}_{load}(s)} \right|_{\hat{i}_{load} = 0} \]

Small-Signal Closed-Loop Model

- Use small-signal converter model
- Perturb and linearize remainder of feedback loop:
  \[ v_{ref}(t) = V_{ref} + \hat{v}_{ref}(t) \]
  \[ v_r(t) = V_r + \hat{v}_r(t) \]
  etc.
Block Diagram

Closed-Loop Transfer Functions
Solution of Block Diagram

Manipulate block diagram to solve for \( \bar{v}(s) \). Result is

\[
\bar{v} = \bar{v}_{\text{ref}} \frac{G_s G_{eq} / V_m}{1 + H G_s G_{eq} / V_m} + \bar{v}_g \frac{G_{eq}}{1 + H G_s G_{eq} / V_m} - i_{\text{load}} \frac{Z_{out}}{1 + H G_s G_{eq} / V_m}
\]

which is of the form

\[
\bar{v} = \bar{v}_{\text{ref}} \frac{1}{H} \frac{T}{1 + T} + \bar{v}_g \frac{G_{eq}}{1 + T} - i_{\text{load}} \frac{Z_{out}}{1 + T}
\]

with \( T(s) = H(s) G_c(s) G_{eq}(s) / V_m = \text{"loop gain"} \)

Loop gain \( T(s) = \) products of the gains around the negative feedback loop.

Open-Loop and Closed-Loop

Original transfer functions, before introduction of feedback ("open-loop transfer functions"):

\[
G_{v}(s) \quad G_c(s) \quad Z_{out}(s)
\]

Upon introduction of feedback, these transfer functions become ("closed-loop transfer functions"):

\[
\frac{1}{H(s)} \frac{T(s)}{1 + T(s)} \quad \frac{G_c(s)}{1 + T(s)} \quad \frac{Z_{out}(s)}{1 + T(s)}
\]

The loop gain:

\( T(s) \)