ADDITIONAL TOPICS IN ADVANCED DIGITAL CONTROL

Example Topics

• Practical Implementation
  – Startup and Anti-windup
  – Fixed-point implementation
• CPM (Using generalized State Space)
• Adaptive Control / Gain Scheduling
• Autotuning
• Modern Control
• Time Optimal Control
• Hysteretic / Bang-Bang Control
• Sliding Mode Control
• ZVS / Dead Time control
Current Programmed Control


Adaptive Control

Figure 13. Comparison of state-space averaged and discrete root loci for a single pole system.
Adaptive Control

"Rough" stability criterion:
1. Each $G_{c,i}$ must stabilize $P_i$
2. Frozen designs must give reasonable local performance
3. Large-signal variations between $P_i$ must occur slowly relative to closed-loop time constants
4. $P_i$ must adequately describe nonlinear variations over region of operation
Gain Scheduling

\[ \begin{align*}
P(x,u,z) & \\
S(x,u) & \\
G_c(z, K_i) & \\
\end{align*} \]

\[ \begin{align*}
y & \\
c & \\
e & \\
\end{align*} \]

Example Gain-Scheduled Boost

Autotuning

Example Autotuning Controller

J. Morroni, R. Zane and D. Maksimovic, "Design and Implementation of an Adaptive Tuning System Based on Desired Phase Margin for Digitally Controlled DC–DC Converters," in *IEEE Transactions on Power Electronics*
Modern Control

\[
\begin{align*}
    x[k+1] &= \Phi x[k] + \Gamma c[k] \\
    y[k] &= \delta x[k] + \beta c[k]
\end{align*}
\]

State Feedback

\[
\begin{align*}
    x[k+1] &= (\Phi - \Gamma K)x[k] + \Gamma N r[k] \\
    y[k] &= (\delta - \beta K)x[k] + \beta N r[k]
\end{align*}
\]

*Linear Quadratic Regulator (LQR)*

Closed-form way to solve $K$ with penalty on control action.
Estimated State Feedback

Predictive Control
Predictive Control Example

FIGURE 3.18: Simulation of the VSI with the predictive controller. The depicted variable is the VSI output current $i_0$. (a) Controller response to a step reference amplitude change.

FIGURE 3.19: Simulation of the VSI with the predictive controller and different level of mismatch on parameter $L_0$. The figure shows the response to a step reference change of the sampled VSI output current $i_0$.

Time-Optimal Control

Fig. 20. Experimental 0–8 A load step response with conventional PID compensation ($v_{in} = 50$ mV/div, $i_L = 5$ A/div, time scale = 5 µs/div).

Fig. 23. Experimental 0–8 A load step response with proposed TOC controller, input voltage increased to $V_{in} = 6$ V ($v_{in} = 50$ mV/div, $i_L = 5$ A/div, time scale = 5 µs/div).
Time-Optimal Control

Resonant Conv. Optimal Trajectory Control

Fig. 8. Response of optimal trajectory control for step control change ($V_{th} = 0.5$).
Hysteretic Control
Thanks for all your hard work