

MURDOCH UNIVERSITY

Feedback Controller Design for Power Pole Electronics Laboratory Buck Converter Module

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Abstract

This thesis paper details the design of a feedback control compensator device to suit a Buck converter. The apparatus that was used is a configurable experimental laboratory device made by the University of Minnesota. The author had aims to provide a fast and stable response to both input voltage disturbances and change in load resistance type disturbances. The voltage output was required to remain constant or return to steady state as fast as possible, without oscillation, after one of these types of disturbances. The design was found to work quite well but there is definitely scope for future students to improve the design or approach the project from an embedded systems perspective.

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List of Abbreviations

AC – Alternating Current

CCM – Continuous Conduction Mode

DC – Direct Current

DCM – Continuous Conduction Mode

ESR – equivalent series resistance

IC – Integrated Circuit

LED – light emitting diode

MOSFET – Metal oxide semiconductor field effect transistor

PWM – Pulse Width Modulation

UMN – University of Minnesota

Nomenclature

\bar{i}_{vp}

– small signal value of current at voltage port of ideal transformer model of a Buck converter

\hat{V}_r – amplitude of ramp voltage v_r

\bar{i}_L – average inductor current

\bar{i}_{cp}

– average value of current at current port of ideal transformer model of a Buck converter

\tilde{i}_{cp}

– small signal value of current at current port of ideal transformer model of a Buck converter

\bar{i}_{vp}

– average value of current at voltage port of ideal transformer model of a Buck converter

\bar{v}_{cp}

– average value of voltage at current port of ideal transformer model of a Buck converter

\tilde{v}_{cp}

– small signal value of voltage at current port of ideal transformer model of a Buck converter

\tilde{v}_{eq} – small signal equivalent value of input voltage

\tilde{v}_i – small signal voltage input

$\tilde{v}_{o,ref}$ – small signal reference voltage output setpoint

\tilde{v}_o – small signal voltage output

\bar{v}_{vp}

– average value of voltage at voltage port of ideal transformer model of a Buck converter

\tilde{v}_{vp}

– small signal value of voltage at voltage port of ideal transformer model of a Buck converter

$G_P(s)_\phi$ at f_c – Buck power stage phase angle at the crossover frequency

$G_P(s)$ – transfer function of Buck power stage

$G_{PWM}(s)$ – transfer function of Buck PWM

$G_{ctrl}(s)_\phi$ at f_c – controller phase angle at the crossover frequency

$G_{ctrl}(s)$ – transfer function of Buck feedback controller

$G_{loop}(s)_\phi$ at f_c – loop phase angle i at the crossover frequency

$G_{loop}(s)$ – loop transfer function of Buck

I_L – average inductor current

I_{cp}
 – steady state DC current at current port of ideal transformer model of a Buck converter

I_{in} – input current

I_o – output current

I_p – current at primary winding of transformer

I_s – current at secondary winding of transformer

I_{vp}
 – steady state DC current at voltage port of ideal transformer model of a Buck converter

K_{lift} – K factor according to Mohan [1]

T_{off} – switching cycle time when MOSFET is off

T_{on} – switching cycle time when MOSFET is on

T_s – switching cycle time of MOSFET

V_L – voltage across inductor

V_{cp}
 – steady state DC voltage at current port of ideal transformer model of a Buck converter

V_d – voltage across diode

V_{in} – DC converter Voltage input

V_o – DC converter voltage output

V_p – voltage at primary winding of transformer

V_s – voltage at secondary winding of transformer

V_{vp}
 – steady state DC voltage at voltage port of ideal transformer model of a Buck converter

\tilde{d} – small signal value of PWM duty cycle

$f_{c,loop}$ – crossover frequency of the loop transfer function

f_{pole} – frequency in Hertz at which transfer function pole occurs

f_{zero} – frequency in Hertz at which transfer function zero occurs

$i_{L,ripple}$ – ripple current through the inductor

$i_L(t)$ – inductor current over time

$i_c(t)$ – capacitor current over time

i_{cp} – current at current port of ideal transformer model of a Buck converter

$i_{in}(t)$ – input current over time

i_{vp} – current at voltage port of ideal transformer model of a Buck converter

k_F – sensing equipment feedback gain

k_{ctrl} – gain of feedback amplifier

$v_L(t)$ – voltage across inductor over time

$v_c(t)$ – control voltage

v_{cp} – voltage at current port of ideal transformer model of a Buck converter

$v_d(t)$ – voltage across diode over time

v_r – ramp voltage of constant frequency, output by UC3824 IC

v_{vp} – voltage at voltage port of ideal transformer model of a Buck converter

ϕ_{lift} – phase lift required of the controller to maintain loop stability

ϕ_{margin} – phase margin required for stability

ω_{pole} – frequency in radians at which transfer function pole occurs

ω_{zero} – frequency in radians at which transfer function zero occurs

Δi_L – change in inductor current over one cycle

Boost – step up DC converter

Buck Boost – hybrid DC converter

Buck – step down DC converter

C – value of Buck converter output capacitor in Farads

D – duty cycle of PWM

ICAP – Electrical simulator by Intusoft

K – K factor according to Venable [2]

L – inductor value of Buck converter in Henrys

MATLAB – simulator program by the Mathworks

N – turns ratio of a transformer

PSpice – Electrical simulator by OrCAD

Power Pole board

– experimental laboratory designed by UMN and used for teaching Power Electronics

R – load resistor value in Ohms

UC3824 – high speed pulse width modulation controller, integrated circuit chip

d(t) – duty cycle of PWM over time

q(t) – switching function variable

r – ESR of Buck converter output capacitor