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

$\tilde{\bar{\imath}}_{vp}$
$-$ 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

$\bar{\imath}_L$ $-$ average inductor current

$\bar{\imath}_{cp}$
$-$ average value of current at current port of ideal transformer model of a Buck converter

$\tilde{\imath}_{cp}$
$-$ small signal value of current at current port of ideal transformer model of a Buck converter

$\bar{\imath}_{vp}$
$-$ 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

$G_P(s)_{\varphi\ at\ f_c}$ $-$ 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

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

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

$G_{loop}(s)_{\varphi\ at\ f_c}$ $-$ 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 atcurrent 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 ofPWM duty cycle*

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

f_{pole} $-$ *frequency in Hertz at which transfer fuction pole occurs*

f_{zero} $-$ *frequency in Hertz at which transfer fuction 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*

$i_{in}(t) - input\ current\ over\ time$

$i_{vp} - current\ at\ voltage\ port\ of\ ideal\ transformer\ model\ of\ a\ Buck\ converter$

$k_F - sensing\ equipment\ feedback\ gain$

$k_{ctrl} -\ gain\ of\ feedback\ amplifier$

$v_L(t) - voltage\ across\ inductor\ over\ time$

$v_c(t) - control\ voltage$

$v_{cp} - voltage\ at\ current\ port\ of\ ideal\ transformer\ model\ of\ a\ Buck\ converter$

$v_d(t) - voltage\ across\ diode\ over\ time$

$v_r - ramp\ voltage\ of\ constant\ frequency, output\ by\ UC3824\ IC$

$v_{vp} - voltage\ at\ voltage\ port\ of\ ideal\ transformer\ model\ of\ a\ Buck\ converter$

$\varphi_{lift} - phase\ lift\ required\ of\ the\ controller\ to\ maintain\ loop\ stability$

$\varphi_{margin} - phase\ margin\ required\ for\ stability$

$\omega_{pole} - frequency\ in\ radians\ at\ which\ transfer\ fuction\ pole\ occurs$

$\omega_{zero} - frequency\ in\ radians\ at\ which\ transfer\ fuction\ zero\ occurs$

$\Delta i_L - change\ in\ inductor\ current\ over\ one\ cycle$

$Boost - step\ up\ DC\ converter$

$Buck\ Boost - hybrid\ DC\ converter$

$Buck - step\ down\ DC\ converter$

$C - value\ of Buck\ converter\ output\ capacitor\ in\ Farads$

$D - duty\ cycle\ of\ PWM$

$ICAP - Electrical\ simulator\ by\ Intusoft$

$K - K\ factor\ according\ to\ Venable$ [2]

$L - inductor\ value\ of\ Buck\ converter\ in\ Henrys$

$MATLAB - simulator\ program\ by\ the\ Mathworks$

$N - turns\ ratio\ \ of\ a\ transformer$

$PSpice - Electrical\ simulator\ by\ OrCAD$

$Power\ Pole\ board$
$- experimental\ laboratory\ designed\ by\ UMN\ and\ used\ for\ teaching\ Power\ Electronics$

$R - load\ resistor\ value\ in\ Ohms$

$UC3824 - high\ speed\ pulse\ width\ modualtion\ controller, integrated\ circuit\ chip$

$d(t) - duty\ cycle\ of\ PWM\ over\ time$

$q(t) - switching\ function\ variable$

$r - ESR\ of\ Buck\ converter\ output\ capacitor$