Switch-Mode Power Supplies SPICE Simulations and Practical Designs

OrCAD/PSpice Simulation Libraries and Design Templates

Christophe Basso – 2007

Revision 0.3
May 2007

The present Word file describes the content of the OrCAD/PSpice simulation templates available with the release of the book « Switch-Mode Power Supply SPICE Simulations and Practical Designs ». The purpose of these templates is to simplify the design and test of several key topologies among the most popular ones. The files are sorted out by the book chapters where design examples are described. Numerous simulation circuits are given away along with the book (*italic green*), the rest are only available on a set of files separately distributed. Please check http://perso.orange.fr/cbasso/Spice.htm for more details on how to order the library.

Chapter 1 – dc-dc and regulation theory

OrCAD PSpice : chapter 1.opj

Regulator 2 step Rload w comp: step load response of a simplified linear regulator
Boost converter: a simplified boost converter running open loop
Boost EMI: the EMI signature of a simplified boost converter
Buck converter: a simplified buck converter running open loop
Buck-boost: a simplified buck-boost converter running open loop
Dampled RLC: a damped RLC network loaded by a negatic impedance converter
Non dampled RLC: a non-damped RLC network loaded by a negatic impedance converter
PWM modulator: a simple Pulse Width Modulator circuitry
Regulator 1: a simple bipolar-based linear regulator
Regulator 2 audio: the audio susceptibility of a simple bipolar-based linear regulator
Regulator 2 stepped Vin: regulator response with a stepped input
Regulator 2 Zout: output impedance of the regulator 2
Regulator step Rload no comp: un-compensated step load response
RLC zout: output impedance of the uncompensated RLC network

Chapter 2 – Small-signal theory

OrCAD PSpice : chapter2_1.opj

test buck open-loop VM: a simple buck converter in voltage-mode
basic CCM-DCM buck: a basic buck configuration using the PWM switch model
boost PWM switch large signal: the large-signal boost model in VM
boost PWM switch small-signal: the small-signal boost model in VM
CCM-DCM buck CL: small-signal model of the buck with closed-loop control
Large signal buck: the large-signal buck model in VM
Non-linear diode: a diode operated in a non-linear zone
small-signal buck SSA: small-signal response based on the SSA canonical model
small-signal buck SSA Zout CL: closed-loop output impedance of the buck using the SSA canonical model
small-signal buck SSA Zout OL: open-loop output impedance of the buck using the SSA canonical model
test buck closed-loop CM: small-signal response of the CM buck operated in closed-loop
test buck closed-loop tran VM: transient response of the compensated VM buck
test buck cycle-by-cycle CM: the cycle-by-cycle CM simplified buck transient response
test buck cycle-by-cycle VM: the cycle-by-cycle VM simplified buck transient response
test buck open-loop CM: small-signal response of the CM buck operated in open-loop

OrCAD PSpice : chapter2_2.opj

BCM current-mode averaged: averaged transient response of a boost operated in BCM CM
BCM current-mode cycle-by-cycle: cycle-by-cycle response of a boost operated in BCM CM
BCM voltage-mode averaged: averaged transient response of a boost operated in BCM VM
BCM voltage-mode cycle-by-cycle: cycle-by-cycle response of a boost operated in BCM VM
Lossy buck CM: the lossy current-mode model demonstrated in a a buck converter
Lossy buck VM: the lossy voltage-mode model demonstrated in a buck converter

OrCAD PSpice : collection of Copec circuits.opj

Boost VM: an auto-toggling voltage-mode boost converter
Buck CPM: a current-programmed buck converter example
Buck VM: an auto-toggling voltage-mode buck converter
Buck-boost VM: an auto-toggling voltage-mode buck-boost converter
Flyback VM: an auto-toggling voltage-mode flyback converter
Isolated CUK VM: an isolated CUK converter operated in voltage-mode
Non-isolated CUK: a non-isolated CUK converter operated in voltage-mode
Sepic VM: a voltage-mode SEPIC

OrCAD PSpice : collection of PWM switch circuits.opj

Boost CM: small-signal response of the current-mode boost converter
Boost VM: small-signal response of the voltage-mode boost converter
Buck CM: small-signal response of the current-mode buck converter
Buck VM: small-signal response of the current-mode buck converter
Buck-boost CM: small-signal response of the current-mode buck-boost converter
Buck-boost VM: small-signal response of the voltage-mode buck-boost converter
Flyback VM: small-signal response of the voltage-mode flyback converter
Flyback CM: small-signal response of the current-mode flyback converter
Forward CM: small-signal response of the current-mode forward converter
Forward VM: small-signal response of the voltage-mode forward converter
Isolated CUK VM: small-signal response of the isolated voltage-mode CUK converter
Non-isolated CUK VM: small-signal response of the non-isolated voltage-mode CUK converter
SEPIC VM: small-signal response of the voltage-mode SEPIC
Tapped boost: small-signal response of the isolated voltage-mode tapped boost converter
Tapped buck: small-signal response of the isolated voltage-mode tapped buck converter

Chapter 3 – Control loop theory

OrCAD PSpice : chapter3_2.opj

Buck CM k factor ac: a current-mode buck converter using the OPAMP-based k factor compensation
Buck CM k factor tran: the step load response of the CM buck converter using the k factor compensation
Buck VM k factor ac: a voltage-mode buck converter using the OPAMP-based k factor compensation
Buck VM k factor tran: the step load response of the VM buck converter using the k factor compensation
Buck VM manual ac: a voltage-mode buck converter using the OPAMP-based manual compensation
Buck VM manual tran: the step load response of the VM buck converter using manual compensation
Error amplifier types: all types 1, 2, 2a, 2b and 3 compensation networks using OPAMPs
Poles and zeros: passive implementation of poles and zeroes
Type 1: the type-1 compensation built with an OPAMP and k factor
Type 2: the type-2 compensation built with an OPAMP and k factor
Type 2 manual: the type-2 compensation built with an OPAMP with manual pole / zero placement
Type 3: the type-3 compensation built with an OPAMP and k factor
Type 3 manual split: the type-3 compensation built with an OPAMP with manual poles / zeros placement

OrCAD PSpice : chapter3_2.opj

Flyback CM opto 1: ac small-signal response with the optocoupler pole in the feedback path
Flyback CM opto 2: ac small-signal response without the optocoupler pole
Flyback CM opto 3: transient step response of the compensated flyback converter
Flyback shuntreg AC: ac small-signal model for a shunt-regulated flyback converter (TOPSwitch®-like)
Flyback shunt reg TRAN: stepload response of the compensated shunt-regulated flyback converter
Opto pole: test fixture used to extract the pole of the optocoupler model
TL431 bias current: TL431 test fixture to check the bias current circulating in the regulator
TL431-based type 2: the type-2 regulator based on the TL431 using k factor
TL431-based type 3: the type-3 regulator based on the TL431 using k factor
TL431-based type 3 manual: the type-3 regulator based on the TL431 using manual pole-zero placement

Chapter 4 – Generic model descriptions

OrCAD PSpice : chapter4.opj

UC384X OPAMP: the UC384X modeled operational amplifier
Astable generator: a simple square-wave generator built with a comparator
Buck CM: a current-mode buck converter using a generic model
DeadTime: a dead-time generator using AND gates
Fanout source: a source featuring a finite maximum output current
Forward VM: a voltage-mode forward using a generic model
Generic passive: passive elements using ABM equations
HB deadtime: a half-bridge generator including a deadtime
Jiles-Atherton: PSpice model of the Jiles-Atherton magnetic material, hysteresis plot
Power VCO LLC: a power voltage-controlled oscillator used to drive a resonant LLC circuit
Power VCO w DT: a power VCO used to drive a resonant LLC circuit with a half-bridge
Reactor wo hysteresis: a simple reactor model without the hysteresis cycle
Saturable core: a simple saturable core model
Sw Hysteresis clock: a square-wave generator built using a new hysteresis switch model
UVLO: a simple Under Voltage LockOut (UVLO) sub-circuit

Chapter 5 – dc-dc design examples

OrCAD PSpice : dc-dc converters.opj

Boost CM: a battery-powered current-mode boost converter delivering 6 V / 800 mA , cycle-by-cycle simulation
Push-pull CM: a 5 V / 10 A telecom converter using a push-pull configuration, cycle-by-cycle simulation
Buck CM : a 5 V / 2 A from a 12 V car battery

OrCAD PSpice : chapter5.opj

Buck CM synchro: a 10 V to 5 V / 10 A synchronous buck converter in current-mode.
Buck CM transient: a 10 V to 5 V / 10 A buck converter in current-mode, steady-state operation
Buck CM step load: a 10 V to 5 V / 10 A buck converter in current-mode, step load response
Buck CM ac sweep: a 10 V to 5 V / 10 A buck converter in current-mode, ac stability analysis
Buck VM transient: a 24 V to 12 V / 4 A voltage-mode buck converter, steady-state operation
Buck VM transient load step: a 24 V to 12 V / 4 A voltage-mode buck converter, step load response
Buck VM Zin: a 24 V to 12 V / 4 A voltage-mode buck, input impedance sweep
Buck VM ac sweep with filter: a 24 V to 12 V / 4 A voltage-mode buck, stability analysis
Buck-boost VM transient: a buck-boost voltage-mode 10 V to –12V / 2 A, steady-state operation
Buck-boost VM step load: a buck-boost voltage-mode 10 V to –12V / 2 A, step load response
Buck-boost VM ac sweep: a buck-boost voltage-mode 10 V to –12V / 2 A, ac stability analysis
Buck-boost CM transient: a buck-boost current-mode 10 V to –12V / 2 A, steady-state operation
Buck-boost CM step load: a buck-boost current-mode 10 V to –12V / 2 A, step load response
Buck-boost CM ac sweep: a buck-boost current-mode 10 V to –12V / 2 A, ac stability analysis
Boost CM ac sweep: a boost current-mode 2.7 V to 5 V / 1 A, ac stability analysis
Boost CM step load: a boost current-mode 2.7 V to 5 V / 1 A, step load response without filter
Boost CM transient: a boost current-mode 2.7 V to 5 V / 1 A, steady-state operation
Boost CM Zin : a boost current-mode 2.7 V to 5 V / 1 A, input impedance sweep
Boost CM transient step load: a boost current-mode 2.7 V to 5 V / 1 A, step load response with filter
Boost VM transient: a boost voltage-mode 12 V to 48 V / 2 A, steady-state response
Boost VM step load: a boost voltage-mode 12 V to 48 V / 2 A, step load response
Boost VM ac sweep: a boost voltage-mode 12 V to 48 V / 2 A, ac stability analysis

Chapter 6 – Power Factor Correction circuit examples

OrCAD PSpice : chapter6.opj

CCM peak average PFC: a CCM PFC using peak-current mode control using an average model.

BCM 150 W averaged PFC: a borderline conduction PFC delivering 150 W with a 33262 average model
BCM 150 W cycle-by-cycle PFC: a borderline conduction PFC delivering 150 W with a cycle-by-cycle model
BCM 150 W voltage-mode PFC: a bordeline PFC delivering 150 W and operated in VM. Average model.
BCM Flyback average PFC: a PFC delivering 100 W based on a flyback converter operated in BCM
CCM average PFC Lloyd Dixon: an average current-mode PFC after Lloyd Dixon example. Average model.
CCM boost average PFC: 1 kW average current-mode PFC built with average model.
DCM boost average PFC: 100 W PFC operated in voltage-mode control.
Hysteretic cycle-by-cycle PFC: a PFC using the hysteretic regulation mode delivering 150 W

doubler: a diode bridge in a doubler configuration.
Fullwave in-rush: this template simulates the power-on sequence with a diode bridge
Fullwave mains impedance: this schematic models the mains output impedance
Fullwave rectifier passive PFC: power factor correction made passive
valley-fill PFC: the valley-fill type of passive PFC
Fullwave rectifier: a full-wave rectifier loaded by a constant power load
Hold-up time: the hold-up time simulation on a full-wave rectifier

Chapter 7 – Flyback converters

OrCAD PSpice : flyback.opj

2-switch flyback: a 12 V / 31 A 2-switch flyback converter operated in current-mode control from a PFC
1-switch flyback: a 19 V / 5 A 1-switch flyback converter operated in current-mode control from the mains

OrCAD PSpice : flyback1.opj

2-switch flyback: a 12 V / 31 A 2-switch flyback converter operated in current-mode control from the mains
flyback ac design 1 ac no opto: ac analysis of a 20 W universal mains flyback operated in current-mode control
flyback ac design 1 ac tran: step load response of the above using an averaged model
flyback ac design 1 ac w opto: ac analysis of a 20 W universal mains flyback, optocoupler in the ac path
flyback tran design 1: cycle-by-cycle simulation of the 20 W flyback using a generic model
flyback tran design 1 stepload: cycle-by-cycle step load response of the 20 W flyback using a generic model
flyback design 1 UC384 stepload : transient simulation of the 20 W flyback with a UC384X controller
flyback design 1 UC3843 ac : ac analysis of the 20 W flybacj built with a UC384X controller
flyback tran design 1 UC3843: cycle-by-cycle step response of the 20 W flyback using a UC384X controller

OrCAD PSpice : flyback2.opj

flyback tran design 2: cycle-by-cycle simulation of a 90 W CCM current-mode converter, generic model
flyback ac design 2 stepload: average simulation of a 90 W CCM current-mode converter, step load
flyback ac design 2 w opto: average simulation of a 90 W CCM current-mode converter, opto in the ac path
flyback ac design 2 wo opto: average simulation of a 90 W CCM current-mode converter, no opto in the ac path
flyback ac design UC38 stepload: : average simulation of a 90 W CCM current-mode converter, UC384X opamp
flyback ac design UC384X: average simulation of a 90 W CCM current-mode converter, ac sweep
flyback tran design 2 stepload: cycle-by-cycle of a 90 W CCM CM converter, generic, step load response
flyback tran design UC stepload: cycle-by-cycle of a 90 W CCM CM converter, UC384X, step load response
flyback tran design UC3842: cycle-by-cycle of a 90 W CCM CM converter, UC384X, steady-state

OrCAD PSpice : flyback active clamp.opj

Active clamp: a simple fixed frequency flyback current-mode implementing the active-clamp technique

OrCAD PSpice : flyback multioutput.opj

Multioutput tran stepload: cycle-by-cycle BCM CM flyback using a generic model, step load response
Multioutput ac stepload : average simulations of the BCM multioutput CM flyback converter
Multioutput ac sweep: small-signal response of the multi-output BCM flyback converter
Multioutput tran: cycle-by-cycle BCM CM flyback using a generic model, steady-state simulation

Chapter 8 – Forward converters

OrCAD PSpice : forward.opj

50 W forward: 50 W single switch 5 V / 10 A european mains, cycle-by-cycle simulation

OrCAD PSpice : foward designs 1.opj – Yes, I know, the « r » is missing…

2-switch forward: a telecom 2-switch forward converter delivering 5 V / 60 A
120 W single SW fwd loadstep: 120 W single switch 12 V / 10 A PFC input, transient step response
120 W single SW forward ac: 120 W single switch, ac response based on a UC384X OPAMP
120 W single SW forward ac step: 120 W single switch, load step response based on a UC384X OPAMP
120 W single SW forward TRAN: 120 W single switch cycle-by-cycle simulation based on a UC384X controller

OrCAD PSpice : forward designs 2.opj – the « r » is back!

simple SW forward: a 12 V / 20 A 2-switch forward converter using a simplified current-mode controller
2SW fwd design 12 V 20 A ac: ac sweep of the 12 V / 20 A 2-switch forward converter
2SW fwd design 12 V 20 A step: cycle-by-cycle 2-switch forward converter, transient response to a load step
2SW fwd design 12 V 20 A tran: cycle-by-cycle 2-switch forward converter, steady-state simulation
2SW fwd design 12V20A ac step: step load response using the average model

OrCAD PSpice : forward designs 3.opj

multi-output fwd tran loadstep: an ATX multi-output 5 V / 15 A and 3.3 V / 15 A 2-SW converter with UC3844
forward active clamp: an active clamp forward converter operating in open-loop
forward RCD clamp: a single switch forward converter featuring a RCD demagnetization
forward resonant reset: a single switch forward converter featuring a resonant demagnetization
multi-output fwd ac loadstep: step load response of an ATX multi-output using an average UC3844 OPAMP
multi-output forward ac: ac small-signal response of the ATX multi-output using coupled inductors
multi-output fwd tran: steady-state cycle-by-cycle response of the ATX multi-output using coupled inductors

OrCAD PSpice : forward designs 4.opj

multi-output fwd cycle b-c step: an ATX multi-output 5 V / 15 A and 12 V / 15 A 2-SW converter with UC3844
multi-output forward ac: small-signal response of the ATX multi-output using coupled inductors
multi-output fwd ac loadstep: loadstep response of the ATX multi-output forward featuring coupled inductors
mutli-output fwd cycle-b-cycle: an ATX multi-output 5 V / 15 A and 12 V / 15 A 2-SW converter with UC3844