

---

# Contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
----------	---------------------	----------

---

## Part I Modelling

---

<b>2</b>	<b>Modelling of DC-to-DC Power Converters</b>	<b>11</b>
2.1	Introduction	11
2.2	The Buck Converter	13
2.2.1	Model of the Converter	14
2.2.2	Normalization	15
2.2.3	Equilibrium Point and Static Transfer Function	16
2.2.4	A Buck Converter Prototype	18
2.3	The Boost Converter	20
2.3.1	Model of the Converter	22
2.3.2	Normalization	23
2.3.3	Equilibrium Point and Static Transfer Function	23
2.3.4	Alternative Model of the Boost Converter	24
2.3.5	A Boost Converter Prototype	25
2.4	The Buck-Boost Converter	27
2.4.1	Model of the Converter	27
2.4.2	Normalization	28
2.4.3	Equilibrium Point and Static Transfer Function	29
2.4.4	A Buck-Boost Converter Prototype	30
2.5	The Non-inverting Buck-Boost Converter	31
2.5.1	Model of the Converter	31
2.5.2	Normalization	32
2.5.3	Equilibrium Point and Static Transfer Function	33
2.6	The Cúk Converter	34
2.6.1	Model of the Converter	35
2.6.2	Normalization	36
2.6.3	Equilibrium Point and Static Transfer Function	37

2.7	The Sepic Converter .....	38
2.7.1	Model of the Converter .....	39
2.7.2	Normalization.....	39
2.7.3	Equilibrium Point and Static Transfer Function .....	40
2.8	The Zeta Converter .....	41
2.8.1	Model of the Converter .....	41
2.8.2	Normalization.....	43
2.8.3	Equilibrium Point and Static Transfer Function .....	43
2.9	The Quadratic Buck Converter.....	44
2.9.1	Model of the Converter .....	44
2.9.2	Normalized Model .....	45
2.9.3	Equilibrium Point .....	45
2.9.4	Static Transfer Function.....	46
2.10	The Boost-Boost Converter .....	46
2.10.1	Model of the Boost-Boost Converter .....	47
2.10.2	Average Normalized Model .....	47
2.10.3	Equilibrium Point and Static Transfer Function .....	47
2.10.4	Alternative Model of the Boost-Boost Converter.....	49
2.10.5	A Boost-Boost Converter Experimental Prototype .....	50
2.11	The Double Buck-Boost Converter.....	50
2.11.1	Model of the Double Buck-Boost Converter .....	51
2.11.2	Average Normalized Model .....	51
2.11.3	Equilibrium Point and Static Transfer Function .....	51
2.12	Power Converter Models with Non-ideal Components .....	52
2.13	A General Mathematical Model for Power Electronics Devices..	54
2.13.1	Some Illustrative Examples of the General Model.....	56

---

## Part II Controller Design Methods

---

<b>3</b>	<b>Sliding Mode Control .....</b>	<b>61</b>
3.1	Introduction .....	61
3.2	Variable Structure Systems .....	62
3.2.1	Control of Single Switch Regulated Systems .....	62
3.2.2	Sliding Surfaces .....	64
3.2.3	Notation .....	65
3.2.4	Equivalent Control and the Ideal Sliding Dynamics ....	65
3.2.5	Accessibility of the Sliding Surface.....	67
3.2.6	Invariance Conditions for Matched Perturbations .....	69
3.3	Control of the Boost Converter.....	71
3.3.1	Direct Control .....	71
3.3.2	Indirect Control.....	72
3.3.3	Simulations .....	74
3.3.4	Experimental Implementation.....	75
3.4	Control of the Buck-Boost Converter.....	78

3.4.1	Direct Control .....	79
3.4.2	Indirect Control .....	80
3.4.3	Simulations .....	81
3.5	Control of the Cúk Converter .....	82
3.5.1	Direct Control .....	83
3.5.2	Indirect Control .....	84
3.5.3	Simulations .....	86
3.6	Control of the Zeta Converter .....	87
3.6.1	Direct Control .....	88
3.6.2	Indirect Control .....	88
3.6.3	Simulations .....	90
3.7	Control of the Quadratic Buck Converter .....	91
3.7.1	Direct Control .....	92
3.7.2	Indirect Control .....	93
3.7.3	Simulations .....	95
3.8	Multi-variable Case .....	95
3.8.1	Sliding Surfaces .....	97
3.8.2	Equivalent Control and Ideal Sliding Dynamics .....	99
3.8.3	Invariance with Respect to Matched Perturbations .....	100
3.8.4	Accessibility of the Sliding Surface .....	101
3.9	Control of the Boost-Boost Converter .....	102
3.9.1	Direct Control .....	103
3.9.2	Indirect Control .....	104
3.9.3	Simulations .....	105
3.9.4	Experimental Sliding Mode Control Implementation ..	105
3.10	Control of the Double Buck-Boost Converter .....	108
3.10.1	Direct Control .....	109
3.10.2	Indirect Control .....	110
3.10.3	Simulations .....	111
3.11	$\Sigma - \Delta$ Modulation .....	112
3.11.1	$\Sigma - \Delta$ -Modulators .....	113
3.11.2	Average Feedbacks and $\Sigma - \Delta$ -Modulation .....	115
3.11.3	A Hardware Realization of a $\Sigma - \Delta$ -Modulator .....	118
4	<b>Approximate Linearization in the Control of Power Electronics Devices</b> .....	123
4.1	Introduction .....	123
4.2	Linear Feedback Control .....	124
4.2.1	Pole Placement by Full State Feedback .....	124
4.2.2	Pole Placement Based on Observer Design .....	126
4.2.3	Reduced Order Observers .....	128
4.2.4	Flatness .....	130
4.2.5	Generalized Proportional Integral Controllers .....	133
4.2.6	Passivity Based Control .....	136
4.2.7	A Hamiltonian Systems Viewpoint .....	139

4.3	The Buck Converter .....	142
4.3.1	Generalities about the Average Normalized Model .....	142
4.3.2	Controller Design by Pole Placement .....	144
4.3.3	Proportional-Derivative Control via State Feedback .....	145
4.3.4	Trajectory Tracking .....	146
4.3.5	Fliess' Generalized Canonical Forms .....	150
4.3.6	State Feedback Control via Observer Design .....	152
4.3.7	GPI Controller Design .....	154
4.3.8	Passivity Based Control .....	156
4.3.9	The Hamiltonian Systems Viewpoint .....	159
4.3.10	Implementation of the Linear Passivity Based Control for the Buck Converter .....	162
4.4	The Boost Converter .....	168
4.4.1	Generalities about the Average Normalized Model .....	168
4.4.2	Control via State Feedback .....	172
4.4.3	Proportional-Derivative State Feedback Control .....	174
4.4.4	Trajectory Tracking .....	176
4.4.5	Fliess' Generalized Canonical Form .....	181
4.4.6	State Feedback Control via Observer Design .....	182
4.4.7	GPI Controller Design .....	183
4.4.8	Passivity Based Control .....	185
4.4.9	The Hamiltonian Systems Viewpoint .....	187
4.5	The Buck-Boost Converter .....	189
4.5.1	Generalities about the Model .....	189
4.5.2	State Feedback Controller Design .....	193
4.5.3	Dynamic Proportional-Derivative State Feedback Control .....	195
4.5.4	Trajectory Tracking .....	198
4.5.5	Fliess' Generalized Canonical Forms .....	199
4.5.6	Control via Observer Design .....	200
4.5.7	GPI Controller Design .....	202
4.5.8	Passivity Based Control .....	204
4.5.9	The Hamiltonian Systems Viewpoint .....	205
4.5.10	Experimental Passivity based Control of the Buck-Boost Converter .....	207
4.6	The Cúk Converter .....	210
4.6.1	Generalities about the Model .....	210
4.6.2	The Hamiltonian System Approach .....	213
4.7	The Zeta Converter .....	214
4.7.1	Generalities about the Model .....	214
4.7.2	The Hamiltonian System Approach .....	218
4.8	The Quadratic Buck Converter .....	219
4.8.1	Generalities about the Model .....	219
4.8.2	State Feedback Controller Design .....	223
4.8.3	The Hamiltonian System Approach .....	227

4.9	The Boost-Boost Converter .....	229
4.9.1	Generalities about the Model .....	229
4.9.2	The Hamiltonian System Approach .....	233
<b>5</b>	<b>Nonlinear Methods in the Control of Power Electronics</b>	
	<b>Devices</b> .....	235
5.1	Introduction .....	235
5.2	Feedback Linearization .....	236
5.2.1	Isidori's Canonical Form .....	236
5.2.2	Input-Output Feedback Linearization .....	238
5.2.3	State Feedback Linearization .....	240
5.2.4	The Boost Converter .....	243
5.2.5	The Buck-Boost Converter .....	246
5.2.6	The Cúk Converter .....	249
5.2.7	The Sepic Converter .....	254
5.2.8	The Zeta Converter .....	258
5.2.9	The Quadratic Buck Converter .....	261
5.3	Passivity Based Control .....	261
5.3.1	The Boost Converter .....	263
5.3.2	The Buck-Boost Converter .....	266
5.3.3	The Cúk Converter .....	269
5.3.4	The Sepic Converter .....	272
5.3.5	The Zeta Converter .....	274
5.3.6	The Quadratic Buck Converter .....	279
5.4	Exact Error Dynamics Passive Output Feedback Control .....	282
5.4.1	A General Result .....	282
5.4.2	The Boost Converter .....	286
5.4.3	Experimental Implementation .....	288
5.4.4	The Buck-Boost Converter .....	291
5.4.5	The Cúk Converter .....	293
5.4.6	The Sepic Converter .....	294
5.4.7	The Zeta Converter .....	298
5.4.8	The Quadratic Buck Converter .....	301
5.4.9	The Boost-Boost Converter .....	304
5.4.10	The Double Buck-Boost Converter .....	306
5.5	Error Dynamics Passive Output Feedback .....	309
5.5.1	The Boost Converter .....	312
5.5.2	Experimental Results .....	315
5.6	Control via Fliess' Generalized Canonical Form .....	316
5.6.1	The Boost Converter .....	317
5.6.2	The Buck-Boost Converter .....	322
5.6.3	The Quadratic Buck Converter .....	326
5.7	Nonlinear Observers for Power Converters .....	331
5.7.1	Full Order Observers .....	331
5.7.2	The Boost Converter .....	333

5.7.3	The Buck-Boost Converter .....	335
5.8	Reduced Order Observers .....	337
5.8.1	The Boost Converter .....	337
5.8.2	The Buck-Boost Converter .....	341
5.9	GPI Sliding Mode Control .....	343
5.9.1	The Buck Converter .....	344
5.9.2	The Boost Converter .....	350
5.9.3	The Buck-Boost Converter .....	355
<hr/>		
<b>Part III Applications</b>		
<hr/>		
<b>6</b>	<b>DC-to-AC Power Conversion .....</b>	<b>361</b>
6.1	Introduction .....	361
6.2	Nominal Trajectories in DC-to-AC Power Conversion .....	363
6.2.1	The Buck Converter .....	363
6.2.2	Two-Sided $\Sigma - \Delta$ Modulation .....	365
6.2.3	The Boost Converter .....	366
6.2.4	The Buck-Boost Converter .....	370
6.3	An Approximate Linearization Approach .....	371
6.3.1	The Boost Converter .....	371
6.3.2	The Buck-Boost Converter .....	373
6.4	A Flatness Based Approach .....	374
6.4.1	The Double Bridge Buck Converter .....	374
6.4.2	The Boost Converter .....	375
6.4.3	The Buck-Boost Converter .....	376
6.5	A Sliding Mode Control Approach .....	378
6.5.1	The Boost Converter .....	378
6.5.2	A Feasible Indirect Input Current Tracking Approach ..	378
6.6	Exact Tracking Error Dynamics Passive Output Feedback Control .....	380
6.6.1	The Double Bridge Buck Converter .....	380
6.6.2	The Boost Converter .....	381
6.6.3	The Buck-Boost Converter .....	383
<b>7</b>	<b>AC Rectifiers .....</b>	<b>385</b>
7.1	Introduction .....	385
7.2	Boost Unit Power Factor Rectifier .....	386
7.2.1	Model of the Monophasic Boost Rectifier .....	386
7.2.2	The Control Objectives .....	387
7.2.3	Steady State Considerations .....	387
7.2.4	Exact Open Loop Tracking Error Dynamics and Controller Design .....	388
7.2.5	Simulations .....	389

7.2.6	The Use of the Differential Flatness Property in the Passive Controller Design.....	389
7.2.7	Simulations .....	392
7.3	Three Phase Boost Rectifier .....	392
7.3.1	The Three Phase Boost Rectifier Average Model .....	393
7.3.2	A Static Passivity Based Controller.....	395
7.3.3	Trajectory Planning .....	395
7.3.4	Switched Implementation of the Average Design .....	398
7.3.5	Simulations .....	399
7.4	A Unit Power Factor Rectifier-DC Motor System .....	400
7.4.1	The Combined Rectifier-DC Motor Model .....	400
7.4.2	The Exact Tracking Error Dynamics Passive Output Feedback Controller .....	403
7.4.3	Trajectory Generation .....	403
7.4.4	Simulations .....	405
7.5	A Three Phase Rectifier-DC Motor System .....	408
7.5.1	The Combined Three Phase Rectifier DC Motor Model .....	408
7.5.2	The Exact Tracking Error Dynamics Passive Output Feedback Controller .....	409
7.5.3	Trajectory Generation .....	410
7.5.4	Simulations .....	412
<b>References .....</b>		<b>415</b>
<b>Index .....</b>		<b>421</b>

<http://www.springer.com/978-1-84628-458-8>

Control Design Techniques in Power Electronics Devices

Sira-Ramirez, H.; Silva-Ortigoza, R.

2006, XVII, 423 p., Hardcover

ISBN: 978-1-84628-458-8