

# Contents

<b>1</b>	<b>Dynamics of Open Quantum Systems</b>	1
1.1	Conventions	2
1.2	Evolution of Closed Systems	2
1.3	Master Equations	4
1.3.1	Definition	4
1.3.2	Examples	6
1.4	Density Matrix Formalism	10
1.4.1	Density Matrix	10
1.4.2	Dynamical Evolution of a Density Matrix	12
1.4.3	Tensor Product	15
1.4.4	The Partial Trace	16
1.5	Lindblad Quantum Master Equation	17
1.5.1	Representations	17
1.5.2	Preservation of Positivity	19
1.5.3	Rate Equation Representation	21
1.5.4	Examples	21
1.6	Superoperator Notation	23
	References	26
<b>2</b>	<b>Microscopic Derivation</b>	27
2.1	Tensor Product Representation of Fermionic Tunnel Couplings	28
2.2	A Mapping for Short Times or Weak Couplings	29
2.3	Master Equation in the Weak Coupling Limit	35
2.3.1	Coarse-Graining Master Equation	35
2.3.2	Quantum Optical Master Equation	39
2.3.3	Properties of the Quantum Optical Master Equation	40
2.4	Strong Coupling Limit	43
	References	44
<b>3</b>	<b>Exactly Solvable Models</b>	47
3.1	Pure Dephasing Spin-Boson Model	47

3.1.1	Time Evolution Operator . . . . .	48
3.1.2	Reduced Dynamics . . . . .	49
3.1.3	Master Equation Approach . . . . .	51
3.2	Quantum Dot Coupled to Two Fermionic Leads . . . . .	52
3.2.1	Heisenberg Picture Dynamics . . . . .	53
3.2.2	Stationary Occupation . . . . .	54
3.2.3	Stationary Current . . . . .	57
	References . . . . .	60
<b>4</b>	<b>Technical Tools . . . . .</b>	<b>61</b>
4.1	Analytic Techniques for Solving Master Equations . . . . .	61
4.1.1	Laplace Transform . . . . .	62
4.1.2	Equation of Motion Technique . . . . .	62
4.1.3	Quantum Regression Theorem . . . . .	63
4.2	Numerical Techniques for Solving Master Equations . . . . .	64
4.2.1	Numerical Integration . . . . .	64
4.2.2	Simulation as a Piecewise Deterministic Process (PDP) . . . . .	66
4.3	Shannon's Entropy Production . . . . .	71
4.3.1	Balance Equation Far from Equilibrium . . . . .	73
4.3.2	Linear Response for Two Terminals . . . . .	75
4.4	Full Counting Statistics: Phenomenological Introduction . . . . .	76
4.4.1	Discrete Particle Counting Statistics . . . . .	76
4.4.2	Continuous Energy Counting Statistics . . . . .	78
4.4.3	Moments and Cumulants . . . . .	79
4.4.4	Convenient Calculation of Lower Cumulants . . . . .	81
4.4.5	Fluctuation Theorems . . . . .	82
	References . . . . .	85
<b>5</b>	<b>Composite Non-equilibrium Environments . . . . .</b>	<b>87</b>
5.1	Single Electron Transistor (SET) . . . . .	88
5.1.1	Model . . . . .	88
5.1.2	Thermodynamic Interpretation . . . . .	91
5.2	Serial Double Quantum Dot . . . . .	93
5.2.1	Model . . . . .	93
5.2.2	Thermodynamic Interpretation . . . . .	98
5.3	Interacting Transport Channels: Two Coupled SETs . . . . .	99
5.3.1	Model . . . . .	100
5.3.2	Thermodynamic Interpretation . . . . .	102
5.3.3	Reduced Dynamics . . . . .	102
5.3.4	Drag Current . . . . .	105
5.4	SET Monitored by a Low-Transparency QPC . . . . .	106
5.4.1	Model . . . . .	107
5.4.2	Detector Limit . . . . .	114
5.5	Monitored Charge Qubit . . . . .	116
5.5.1	Model . . . . .	116
5.5.2	Thermalization and Decoherence . . . . .	120

5.6	High-Transparency QPC . . . . .	121
5.6.1	Model . . . . .	121
5.6.2	Detector Backaction . . . . .	127
5.7	Phonon-Assisted Tunneling . . . . .	129
5.7.1	Model . . . . .	129
5.7.2	Thermodynamic Interpretation . . . . .	132
5.7.3	Thermoelectric Performance . . . . .	134
5.8	Beyond Weak Coupling: Phonon-Coupled Single Electron Transistor . . . . .	135
5.8.1	Model . . . . .	136
5.8.2	Reservoir Equilibrium in the Polaron Picture . . . . .	138
5.8.3	Polaron Rate Equation for Discrete Phonon Modes . . . . .	139
5.8.4	Polaron Rate Equation for Continuum Phonon Modes . . . . .	144
5.8.5	Thermodynamic Interpretation . . . . .	146
	References . . . . .	148
<b>6</b>	<b>Piecewise Constant Control . . . . .</b>	<b>151</b>
6.1	Piecewise Constant Open-Loop Control . . . . .	152
6.2	Piecewise Constant Feedback Control . . . . .	152
6.3	Wiseman–Milburn Quantum Feedback . . . . .	155
6.4	Further Roads to Feedback . . . . .	157
	References . . . . .	158
<b>7</b>	<b>Controlled Systems . . . . .</b>	<b>159</b>
7.1	Single Junction . . . . .	159
7.1.1	Open-Loop Control . . . . .	162
7.1.2	Closed-Loop Control . . . . .	163
7.2	Electronic Pump . . . . .	169
7.2.1	Power-Consuming Pump . . . . .	170
7.2.2	Open-Loop Control at Zero Power Consumption . . . . .	174
7.3	Encoding Maxwell’s Demon as Feedback Control . . . . .	177
7.3.1	Feedback Control Loop . . . . .	178
7.3.2	Current . . . . .	179
7.3.3	Entropy Production . . . . .	182
7.4	Self-Controlling Systems: A Complete Description of Maxwell’s Demon . . . . .	183
7.4.1	Derivation of the Rate Equation . . . . .	184
7.4.2	Counting Statistics and Entropy . . . . .	185
7.4.3	Global View: A Thermoelectric Device . . . . .	188
7.4.4	Local View: A Feedback-Controlled Device . . . . .	191
7.5	Qubit Stabilization . . . . .	195
7.5.1	Model . . . . .	195
7.5.2	Feedback Liouvillian . . . . .	199
7.5.3	Phenomenological Consequences . . . . .	200
	References . . . . .	203
	<b>Index . . . . .</b>	<b>205</b>

<http://www.springer.com/978-3-319-03876-6>

Open Quantum Systems Far from Equilibrium

Schaller, G.

2014, IX, 207 p. 44 illus., 10 illus. in color., Softcover

ISBN: 978-3-319-03876-6