Contents

1.	**THERMAL NOISE**	**1**
1.1	Introduction	1
1.2	Noise power	3
1.3	Equipartition	3
1.4	The microscopic mechanism of thermal noise	4
1.5	Macroscopic equipartition	9
1.6	Nyquist	12
1.7	The quantum limit on linear amplifiers	15
1.8	Generalised circuits	17
1.9	The temperature of radiation resistance	19
1.10	Experimental evidence	20
1.11	Noise thermometry	20
1.12	Thermal noise in non-ohmic devices in thermal equilibrium	22
1.13	Thermal noise in non-equilibrium conditions	24
1.14	Salami methods	25
1.15	The impedance field method	27
1.16	Diffusion noise	29
1.17	The small-signal diode	30
1.18	Other types of noise	32
	References	33
2.	**$1/f$ NOISE AND BURST NOISE**	**35**
2.1	Introduction and characterisation of $1/f$ noise	35
2.2	Mathematical models	37
2.3	Two-stage or two-function models	39
2.4	The Allan variance	40
2.5	Fractional order integration	41
2.6	Infra-red divergence	42
2.7	Physical dimensions	43
2.8	Experimental evidence	44
2.9	Fluctuation in number or in mobility?	49
2.10	Is $1/f$ noise Gaussian?	51

2.11 Amorphous solids 52
2.12 Electrolytes 53
2.13 Burst noise 54
2.14 Summary 55
2.15 The sampling of $1/f$ noise 56
Bibliographies 56
References 57

3. NOISE IN FERROMAGNETIC AND FERROELECTRIC MATERIALS 61
3.1 Introduction 61
3.2 Ferromagnetic materials: Barkhausen noise and domains 61
3.3 The spectrum of Barkhausen noise 67
3.4 Thermal effects 71
3.5 Amorphous solids 72
3.6 Ferrites and semiconductors 73
3.7 Applications of ferromagnetic materials 74
3.8 Ferroelectric materials 77
3.9 Pyroelectric effects 79
References 81

4. HOT CARRIERS AND BALLISTIC TRANSPORT: AVALANCHE DEVICES AND THE GUNN EFFECT 83
4.1 Introduction 83
4.2 Diffusion noise 84
4.3 Monte Carlo simulation 86
4.4 Submicron devices 87
4.5 The Gunn effect 90
4.6 Avalanche multiplication 92
References 95

5. CRYOGENIC DEVICES 97
5.1 Introduction 97
5.2 The maser 99
5.3 Parametric amplifiers 101
5.4 The tunnel diode 105
5.5 SIS mixers 106
5.6 Super-Schottky diodes 108
5.7 Cooled FET amplifiers 110
5.8 The SQUID 111
References 114

6. OSCILLATOR NOISE 117
6.1 Introduction 117

6.2 The analytical approach 119
6.3 FM and AM noise 122
6.4 Other sources of noise 124
6.5 Practical results 125
6.6 Noise reduction by synchronisation 127
References 129

7. NOISE IN RADIATION DETECTORS 130
7.1 Introduction 130
7.2 Optical signals 130
7.3 Photon counting 133
7.4 Optical fibre communication systems 135
7.5 Detectors for medium and long wavelength infra-red 136
7.6 Heterodyne detectors 140
7.7 Pyroelectric detectors 141
7.8 Thermal detectors (bolometers) 143
7.9 Thermocouples 147
7.10 Cryogenic InSb bolometer 148
7.11 Theory of gravitational radiation 149
7.12 The role of Q 151
7.13 Practical design 152
7.14 Experimental detectors of gravitational radiation 154
References 155

8. FLUCTUATIONS IN CHARGE 157
8.1 Introduction 157
8.2 Charge-sensitive and charge-coupled devices (CCD) 158
8.3 Optical imaging 160
8.4 Switched capacitor networks (SCN) 161
8.5 The $(\sin x)^2/x^2$ distribution 164
References 165

APPENDIX I. SHOT NOISE 166
References 168

APPENDIX II. MATHEMATICAL NOTES 169
II.1 The Poisson distribution 169
II.2 Series approximation of a quantum correction 171
References 171

APPENDIX III. ROWLAND'S (CAMPBELL'S) THEOREMS 172
References 173
Index 174