
Contents

1	Random Fluctuations	1
1.1	Introduction	1
1.2	Thermal Noise of Resistance	2
1.3	Shot Noise	5
1.3.1	Spectral Distribution	6
1.3.2	Photons	10
1.4	Flicker Noise	10
1.5	Generation–Recombination Noise	10
1.6	Thermal Radiation and Its Fluctuations	13
1.7	Temperature Fluctuations of Small Bodies	18
1.7.1	Absorption and Emission Fluctuations	20
2	Signal–Noise Relations	21
2.1	Signal Limitation	22
2.2	Background Limitation	22
2.2.1	Ideal Detection	24
2.3	Johnson Noise	27
2.4	Dark Current Noise	27
2.5	Noise and Sensitivity	28
2.6	Amplifier Noise and Mismatching	28
3	Thermal Detectors	31
3.1	Thermocouple and Thermopile	31
3.2	Bolometer	36
3.2.1	Metallic Bolometer	39
3.2.2	Thermistor	40
3.3	Pyroelectric Detector	44
4	Vacuum Photodetectors	51
4.1	Vacuum Photodiode	52
4.2	Photomultiplier	56

5	Semiconductor Photodetectors	61
5.1	Photoconductors	61
5.1.1	Analysis of the Detection Process.....	64
5.1.2	Frequency Response	69
5.2	Photodiodes	69
5.2.1	P–N Junction	70
5.2.2	Current–Voltage Characteristic.....	72
5.2.3	Photon Excitation	75
5.2.4	Operational Modes	79
5.2.5	Open Circuit	80
5.2.6	Current Circuit	82
5.2.7	Reverse-Biased Circuit	83
5.3	Avalanche Photodiodes.....	86
5.3.1	Multiplication Process	87
5.3.2	Multiplication Noise	89
5.3.3	Detectivity	90
5.3.4	Frequency Response	92
6	Correlation Analyses	95
6.1	AutoCorrelation.....	95
6.2	Cross Correlation.....	97
6.2.1	Signal Recovery by Cross Correlation	99
6.2.2	Periodic Signal Recovering by Autocorrelation	101
6.2.3	Autocorrelation of White Noise	103
6.2.4	Spectral Power Density from Shot Noise Correlation ...	104
6.2.5	Correlations of Linear Detector Systems.....	105
7	Signal Processing	107
7.1	Operational Amplifier.....	108
7.2	Lock-in Amplifier	111
7.2.1	Two-Phase Lock-in Amplifier	115
7.3	Signal Averagers	115
7.3.1	Pulse Train Averagers	116
7.3.2	Waveform Analyzer	118
7.4	Correlation Computer.....	119
8	Heterodyne Detection	121
8.1	Analysis of Signal Conversion and Noise	122
8.2	Signal Beam Profile.....	124
8.3	Optical System.....	127
8.4	Coherent versus Incoherent Detection	129
8.4.1	Photodetectors.....	129
8.4.2	Thermal Detector	130
8.4.3	Pyroelectric Detector	131
8.4.4	Heterodyne Detection of Incoherent Radiation	131

8.5	Heterodyne Lock-In Amplification	132
8.5.1	High-Spectral Resolution	137
8.6	Dual Signal Beam Heterodyne Detection	138
8.7	Dual Signal Heterodyne Lock-In Amplification	145
8.8	Dual Signal Wave Analyzer	147
8.8.1	Space Communication	148
8.8.2	Transmitting Photographs	149
8.8.3	Laser Radar	149
9	Fast Detection of Weak and Noisy Signals	153
9.1	Suppressing Amplifier Noise with Detection Discriminator	154
9.2	Photon Counting	156
A	Appendix	161
A.1	Microcurrent Pulse	161
A.2	Statistics	162
A.2.1	Binomial Distribution	162
A.2.2	Poisson Distribution	163
A.2.3	Gaussian Distribution	164
A.2.4	Photoelectron Statistics	165
A.3	Multiplication Factor M_n	166
A.4	Power Flow of Standing Wave Modes	167
	References	169
	Index	171