
CONTENTS

<i>Preface</i>	<i>page xv</i>
1 INTRODUCTION	1
RF Circuits	2
Narrow-Band Nature of RF Signals	3
AC Circuit Analysis – A Brief Review	3
Impedance and Admittance	4
Series Resonance	4
Parallel Resonance	5
Nonlinear Circuits	5
Problems	5
2 IMPEDANCE MATCHING I	9
Transformer Matching	9
L-Networks	10
Quick Design Procedure for L-Networks	12
Higher Q : Pi and T Networks	13
Lower Q : The Double L-Network	14
Equivalent Series and Parallel Circuits	15
Lossy Reactors and Efficiency of Matching Networks	16
Q -Factor Summary	16
Problems	17
3 LINEAR AMPLIFIERS	19
Single-Loop Amplifiers	19
The Emitter Follower	20
Common-Emitter and Common-Base Amplifiers	21
One Transistor, Two Supplies	22
Two Transistors, Two Supplies	23
AC Amplifiers	25
Audio Amplifiers	25
RF Amplifiers	27
A Note on Matching a Power Amplifier to its Load	29
Problems	29
4 FILTERS I	32
Prototype Low-Pass Filters	33
A Low-Pass Filter Example	34
Conversion to Bandpass Filters	37

CONTENTS

Bibliography	39
Appendix 4.1	40
Problems	43
5 FREQUENCY CONVERTERS	46
The Ideal Multiplier as a Mixer	46
Switching Mixers	48
General Nonlinear Device Mixer	50
Diode Mixer	51
Problems	52
6 RADIO RECEIVERS	54
The Basic Requirements	54
Amplification	54
Crystal Sets	55
TRF Receivers	55
The Superheterodyne Receiver	56
Image Rejection	57
Solving the Image Problem	58
Double Conversion Superheterodyne Receiver	59
Automatic Gain Control	60
Noise Blankers	60
Digital Signal Processing in Receivers	60
Bibliography	61
Problems	61
7 CLASS-C AND CLASS-D AMPLIFIERS	63
Class-C Amplifiers	63
Simplified Analysis of Class-C Operation	64
General Analysis of a Class-C Operation with a Nonideal Tube or Transistor	66
Drive Considerations	67
Series-Fed and Shunt-Fed Circuits	67
The Class-C Amplifier as a Voltage Multiplier	68
High-Power Class-C Amplifiers	68
Modified Class-C Amplifiers for Higher Efficiency	69
Class-D Amplifiers	69
Series Resonant Class-D Amplifier	69
Parallel Resonant Class-D Amplifier	71
Which Circuit to Use: Class C or Class D?	71
Bibliography	72
Problems	72
8 TRANSMISSION LINES	73
Fundamentals	73
Determination of Characteristic Impedance and Propagation Velocity	74
Modification of an Impedance by a Transmission Line	76
Problems	78

CONTENTS

9 IMPEDANCE MATCHING II	81
Impedances Specified by Reflection Coefficient	81
Problems	87
10 POWER SUPPLIES	89
Full-Wave Rectifier	89
Inherent Regulation of the Choke-Input Power Supply	90
Ripple	91
Half-Wave Rectifier	91
Electronically Regulated Power Supplies	92
Three-Phase Rectifiers	93
Problems	94
11 AMPLITUDE MODULATION	97
AM in the Time Domain	97
AM in the Frequency Domain	99
High-Level Modulation	100
Class-A Modulator	101
Class-B Modulator	101
Class-S Modulator	102
Digital-to-Analog Modulator	103
Current Practice	104
Problems	104
12 SUPPRESSED CARRIER AM	106
Single Sideband	108
Product Detector	108
Other Advantages of SSB	109
Generation of SSB	110
Filter Method	110
Phasing Method	110
Weaver Method	111
SSB with Class-C or Class-D Amplifiers	112
Bibliography	112
Problems	113
13 OSCILLATORS	115
Relaxation Oscillators	115
Sine Wave Electronic Oscillators	117
An Unintentional Oscillator	119
Series Resonant Oscillators	120
Negative-Resistance Oscillators	121
Oscillator Dynamics	122
Stability	123
Design Example – Colpitts Oscillator	123
Numerical Example	125
Problems	126

CONTENTS

14 PHASE LOCK LOOPS	128
Phase Adjustment by Means of Frequency Control	128
Mechanical Analog of a PLL	130
Loop Dynamics	132
Loop Filter	132
Linear Analysis of the PLL	133
Frequency Response of the Type I Loop	134
Frequency Response of the Type II Loop	134
Transient Response	135
Multiplier as a Phase Detector	136
Range and Stability	137
Acquisition Time	137
PLL Receiver	138
Bibliography	139
Problems	139
15 FREQUENCY SYNTHESIZERS	141
Direct Synthesis	141
Mix and Divide Direct Synthesis	142
Indirect Synthesis	143
Direct Digital Synthesis	144
Noise Spectrum of the DDS	145
Switching Speed and Phase Continuity	147
Phase Noise from Multipliers and Dividers	147
Bibliography	148
Problems	148
16 SWITCHING CONVERTERS	150
Basic Switcher Topologies	150
Buck Circuit	150
Continuous Mode	150
Discontinuous Mode	151
Buck/Boost Circuit	152
Continuous Mode	152
Discontinuous Mode	153
Boost Circuit	154
Continuous Mode	154
Discontinuous Mode	154
Other Converter Topologies	155
Transformer-Coupled Converters	155
The Horizontal Output Circuit in Cathode Ray Tube Terminals and Television Sets	157
Bibliography	159
Problems	159
17 DIRECTIONAL POWER METERS AND STANDING WAVES	161
An In-Line Directional Wattmeter	161
Resistive Impedance Bridge	163

CONTENTS

Standing Waves	164
Effect of Standing Waves on an Antenna Transmission Line	165
Problems	165
18 SMALL-SIGNAL RF AMPLIFIERS	167
Linear Two-Port Networks	167
Amplifier Specifications – Gain, Bandwidth, and Impedances	168
Amplifier Stability	169
Overload Characteristics	170
Intermodulation	170
Dynamic Range	171
Narrow-Band Amplifier Circuits	172
Wide-Band Amplifier Circuits	172
Transistor Equivalent Circuits	173
Amplifier Design	174
Simple Low-Frequency Amplifiers	174
Common-Base Amplifier	175
Bibliography	176
Problems	176
19 FILTERS II – COUPLED RESONATOR FILTERS	178
Impedance Inverters	179
Worked Example – A Bandpass Filter with 1% Fractional Bandwidth	182
Effects of Finite Q	184
Tuning Procedures	185
Other Filters	186
Bibliography	186
Problems	186
20 HYBRID COUPLERS	188
Directional Coupling	189
Transformer Hybrid	189
Applications of the Transformer Hybrid	190
Quadrature Hybrids	191
Balanced Amplifier	192
Power Combining	194
Other Hybrids	195
Wilkinson Power Divider (or combiner)	195
Ring Hybrid	195
Branch Line Hybrids	196
Lumped Element Hybrids	196
General Directional Couplers	198
Bibliography	198
Problems	199
21 AMPLIFIER NOISE I	201
Thermal Noise	201
Noise Figure	203

CONTENTS

Cascaded Amplifiers	204
Other Noise Parameters	205
Noise Figure Measurement	206
Problems	206
22 TRANSFORMERS AND BALUNS	208
Transformer Currents and the Ideal Transformer	209
Low-Frequency Equivalent Circuit of a Perfectly Coupled Lossless Transformer	209
Operation of the Perfectly Coupled Lossless Transformer	211
Mechanical Analog of a Perfectly Coupled Transformer	212
The Imperfectly Coupled Transformer	213
Double-Tuned Transformer	214
Conventional Transformers with Magnetic Cores	214
Eddy Currents and Laminated Cores	215
Design of Iron Core Transformers	215
Maximum Temperature and Transformer Size	217
Transmission Line Transformers	218
Baluns	220
Bibliography	223
Problems	223
23 WAVEGUIDE CIRCUITS	225
Waveguides	225
Simple Explanation of Waveguide Propagation	225
Propagation of the Fundamental Mode in a Rectangular Waveguide	226
Guide Wavelength	227
Form of the Magnetic Field	228
Wall Currents	229
Waveguide Versus Coaxial Cable for Low-Loss Power Transmission	229
Waveguide Impedance	230
Matching in Waveguide Circuits	231
Three-Port Waveguide Junctions	232
Four-Port Waveguide Junctions	232
Appendix 1: Lowest-Loss Waveguide Versus Lowest-Loss Coaxial Line	233
Appendix 2: Coaxial Line Dimensions for Lowest Loss, Highest Power, and	
Maximum Voltage	235
Lowest Loss	235
Highest Power	236
Maximum Voltage	236
Relative Performance of 50 Ohm Coaxial Line	236
Bibliography	236
Problems	237
24 TELEVISION SYSTEMS	238
Image Dissection	238
The Nipkow System	238
NTSC Television Standard	239
The Video Signal	241

CONTENTS

Horizontal Synchronization	241
Vertical Synchronization	242
Modulation	243
Sound	245
Other Television Standards	245
Color Television	245
Three Colors through a Single Channel	246
Compatibility	246
Comb Filters	249
Television Transmitters	250
Television Receivers	250
Color Television Receiver	251
Digital Television	257
Video Compression	258
Color, Sound, and Packets	259
Bibliography	259
Problems	260
25 RADAR PULSE MODULATORS	261
Line Modulators	263
Bibliography	266
Problems	266
26 TR SWITCHING	268
Self-duplexing Radar Techniques	268
TR Switching Devices and Circuits	270
Branch Line TR Switches	270
Balanced Duplexers	271
Diode Switches	272
Diodes for RF Switching	274
Bibliography	275
Problems	275
27 DEMODULATORS AND DETECTORS	277
Diode Detector	277
Analysis Assuming an Ideal Rectifier	278
Analysis with a Real Diode	278
AC-Coupled Diode Detector	280
Single-Sideband (SSB) and Morse Code Detection	280
Product Detector for AM	281
Synchronous AM Detector	281
FM Demodulators	282
PLL FM Demodulator	282
Tachometer FM Detector	283
Delay Line FM Detector	283
Quadrature FM Demodulator	284
Slope Detector	284
The Foster–Seeley Discriminator	285

CONTENTS

Power Detectors	287
Bibliography	289
Problems	289
28 FREQUENCY AND PHASE MODULATION	291
Basics of Angle Modulation	291
Frequency Spectrum of FM	292
Very Narrow-Band FM or PM	293
Wide-Band FM Spectral Width	293
Frequency Multiplication of an FM Signal	294
Noise	294
Analysis of the SNR Improvement in FM	295
Output SNR for an AM Signal with the Same Carrier Power	296
Comparison of Noise, FM versus AM Under Strong Signal Conditions	296
Preemphasis and Deemphasis	297
FM, AM, and Channel Capacity	297
Bibliography	299
Problems	299
29 ANTENNAS AND RADIO WAVE PROPAGATION	301
Antennas	301
Electromagnetic Waves	301
Propagation in a Vacuum	302
Antenna Directivity and Gain	303
Effective Capture Area of an Antenna	304
A Spacecraft Radio Link	305
Terrestrial Radio Links	306
The Ionosphere	306
Wave Propagation in the Ionosphere	307
Reflection of Waves from the Ionosphere	308
Daytime Versus Nighttime Propagation	308
Other Modes of Propagation	309
Bibliography	309
Problems	309
30 AMPLIFIER NOISE II	311
Noise Matching	311
Equivalent Circuits for Noisy Two-Port Networks	312
Noise Figure of the Equivalent Circuit	312
Devices in Parallel	315
Noise Measure	315
Bibliography	316
Problems	317
31 OSCILLATOR NOISE	319
Power Spectrum of a Linear Oscillator	320
Sideband Shape	322
Phase Noise	322

CONTENTS

Effect of Nonlinearity	323
Bibliography	324
Problems	324
32 RADIO AND RADAR ASTRONOMY	326
The Discovery of Cosmic Noise	326
Radiometry	327
Spectrometry	328
Interferometry	329
Imaging Interferometry	329
Radar Astronomy	330
The Moon	331
Venus	332
Delay-Doppler Mapping	333
Overspreading	334
Bibliography	334
Problems	335
33 RADIO SPECTROMETRY	336
Filters and Filter Banks	337
Autocorrelation Spectrometry	337
Hardware Autocorrelators	338
One-Bit Autocorrelation	340
Fourier Transform Spectroscopy	341
Acousto-optical Spectrometry	341
Chirp-z Spectrometry	343
Radar Pulse Compression	344
Bibliography	345
Problems	345
34 LABORATORY TEST EQUIPMENT	347
Power Measurements	347
Voltage Measurements	347
Impedance Measurements	348
Swept Frequency Impedance Measurements	350
Problems	353
<i>Index</i>	355