

CHAPTER HEADINGS

PREFACE & ACKNOWLEDGEMENTS

CHAPTER		PAGE
PART 1: THE RADIO VALVE		
1	INTRODUCTION TO THE RADIO VALVE	1
2	VALVE CHARACTERISTICS	13
3	THE TESTING OF OXIDE-COATED CATHODE HIGH-VACUUM RECEIVING VALVES	68
PART 2: GENERAL THEORY AND COMPONENTS		
4	THEORY OF NETWORKS	128
5	TRANSFORMERS AND IRON-CORED INDUCTORS	199
6	MATHEMATICS	254
7	NEGATIVE FEEDBACK	306
8	WAVE MOTION AND THE THEORY OF MODULATION	403
9	TUNED CIRCUITS	407
10	CALCULATION OF INDUCTANCE	429
11	DESIGN OF RADIO FREQUENCY INDUCTORS	450
PART 3: AUDIO FREQUENCIES		
12	AUDIO FREQUENCY VOLTAGE AMPLIFIERS	481
13	AUDIO FREQUENCY POWER AMPLIFIERS	544
14	FIDELITY AND DISTORTION	603
15	TONE COMPENSATION AND TONE CONTROL	635
16	VOLUME EXPANSION, COMPRESSION AND LIMITING	679
17	REPRODUCTION FROM RECORDS	701
18	MICROPHONES, PRE-AMPLIFIERS, ATTENUATORS AND MIXERS	775
19	UNITS FOR THE MEASUREMENT OF GAIN AND NOISE	806
20	LOUDSPEAKERS	831
21	THE NETWORK BETWEEN THE POWER OUTPUT STAGE AND THE LOUDSPEAKER	880
PART 4: RADIO FREQUENCIES		
22	AERIALS AND TRANSMISSION LINES	890
23	RADIO FREQUENCY AMPLIFIERS	912
24	OSCILLATORS	947
25	FREQUENCY CONVERSION AND TRACKING	962
26	INTERMEDIATE FREQUENCY AMPLIFIERS	1020
27	DETECTION AND AUTOMATIC VOLUME CONTROL	1072
28	REFLEX AMPLIFIERS	1140
29	LIMITERS AND AUTOMATIC FREQUENCY CONTROL	1147
PART 5: RECTIFICATION, REGULATION, FILTERING AND HUM		
30	RECTIFICATION	1161
31	FILTERING AND HUM	1192
32	VIBRATOR POWER SUPPLIES	1202
33	CURRENT AND VOLTAGE REGULATORS	1213
PART 6: COMPLETE RECEIVERS		
34	TYPES OF A-M RECEIVERS	1223
35	DESIGN OF SUPERHETERODYNE A-M RECEIVERS	1228
36	DESIGN OF F-M RECEIVERS	1287
37	RECEIVER AND AMPLIFIER TESTS AND MEASUREMENTS	1297
PART 7: SUNDRY DATA		
38	TABLES, CHARTS AND SUNDRY DATA	1328
	See next page for detailed List of Contents.	
	SUPPLEMENT	1475
INDEX		1433

CONTENTS

PART 1 : THE RADIO VALVE

SECTION	PAGE
CHAPTER 1. INTRODUCTION TO THE RADIO VALVE	
1. ELECTRICITY AND EMISSION	1
2. THE COMPONENT PARTS OF RADIO VALVES	4
(i) Filaments, cathodes and heaters	4
(ii) Grids	5
(iii) Plates	5
(iv) Bulbs	5
(v) Voltages with valve operation	5
3. TYPES OF RADIO VALVES	6
(i) Diodes	6
(ii) Triodes	7
(iii) Tetrodes	7
(iv) Pentodes	7
(v) Pentode power amplifiers	8
(vi) Combined valves	8
(vii) Pentagrid converters	8
4. MAXIMUM RATINGS AND TOLERANCES	9
(i) Maximum ratings and their interpretation	9
(ii) Tolerances	9
5. FILAMENT AND HEATER VOLTAGE/CURRENT CHARACTERISTICS	10
6. VALVE NUMBERING SYSTEMS	10
7. REFERENCES	12
CHAPTER 2. VALVE CHARACTERISTICS	
1. VALVE COEFFICIENTS	13
2. CHARACTERISTIC CURVES	15
(i) Plate characteristics	15
(ii) Mutual characteristics	17
(iii) Grid current characteristics	18
(iv) Suppressor characteristics	21
(v) Constant current curves	22
(vi) "G" curves	23
(vii) Drift of characteristics during life	23
(viii) Effect of heater-voltage variation	24
3. RESISTANCE-LOADED AMPLIFIERS	24
(i) Triodes	24
(ii) Pentodes	26
4. TRANSFORMER-COUPLED AMPLIFIERS	27
(i) With resistive load	27
(ii) Effect of primary resistance	28
(iii) With i-f voltage amplifiers	28
(iv) R-F amplifiers with sliding screen	28

CONTENTS

SECTION	PAGE
(v) Cathode loadlines	29
(vi) With reactive loads	30
5. TRIODE OPERATION OF PENTODES	34
(i) Triode operation of pentodes	34
(ii) Examples of transconductance calculation	34
(iii) Triode amplification factor	35
(iv) Plate resistance	36
(v) Connection of suppressor grid	36
6. CONVERSION FACTORS, AND THE CALCULATION OF CHARACTERISTICS OTHER THAN THOSE PUBLISHED	36
(i) The basis of valve conversion factors	36
(ii) The use of valve conversion factors	37
(iii) The calculation of valve characteristics other than those published	40
(iv) The effect of changes in operating conditions	42
7. VALVE EQUIVALENT CIRCUITS AND VECTORS	45
(i) Constant voltage equivalent circuit	45
(ii) Constant current equivalent circuit	46
(iii) Valve vectors	47
8. VALVE ADMITTANCES	49
(i) Grid input impedance and admittance	49
(ii) Admittance coefficients	50
(iii) The components of grid admittance-input resistance-input capacitance-grid input admittance	51
(iv) Typical values of short-circuit input conductance	55
(v) Change of short-circuit-input capacitance with transconductance	55
(vi) Grid-cathode capacitance	56
(vii) Input capacitances of pentodes (published values)	56
(viii) Grid-plate capacitance	57
9. MATHEMATICAL RELATIONSHIPS	57
(i) General	57
(ii) Resistance load	58
(iii) Power and efficiency	59
(iv) Series expansion; resistance load	61
(v) Series expansion; general case	63
(vi) The equivalent plate circuit theorem	63
(vii) Dynamic load line-general case-	64
(viii) Valve networks-general case-	64
(ix) Valve coefficients as partial differentials	64
(x) Valve characteristics at low plate currents	65
10. REFERENCES	66

CHAPTER 3. THE TESTING OF OXIDE-COATED CATHODE HIGH-VACUUM RECEIVING VALVES

1. BASIS OF TESTING PRACTICE	68
(i) Fundamental physical properties	69
(ii) Basic functional characteristics	70
(iii) Fundamental characteristic tests	73
(iv) Valve ratings and their limiting effect on operation	75
(A) Limiting ratings	75
(B) Characteristics usually rated	75
(C) Rating systems	77
(D) Interpretation of maximum ratings	77
(E) Operating conditions	80
(v) Recommended practice and operation	80
(a) Mounting	80
(b) Ventilation	81

CONTENTS

SECTION	PAGE
(c) Heater-cathode insulation	81
(d) Control grid circuit resistance	82
(e) Operation at low screen voltages	84
(f) Microphony	84
(g) Hum	84
(h) Stand-by operation	84
2. CONTROL OF CHARACTERISTICS DURING MANUFACTURE	85
(i) Importance of control over characteristics	85
(ii) Basic manufacturing test specification	85
(iii) Systematic testing	86
(iv) Tolerances on characteristics	88
3. METHODS OF TESTING CHARACTERISTICS	89
(i) General conventions	90
(ii) General characteristics	91
(a) Physical dimensions	91
(b) Shorts and continuity	91
(c) Heater (or filament) current	93
(d) Heater to cathode leakage	94
(e) Inter-electrode insulation	94
(f) Emission	94
(g) Direct inter-electrode capacitances	95
(iii) Specific diode characteristics	99
(a) Rectification test	99
(b) Sputter and arcing	100
(c) Back emission	100
(d) Zero signal or standing diode current	101
(iv) Specific triode, pentode and beam tetrode characteristics	101
(A) Reverse grid current	101
(B) Grid current commencement voltage	102
(C) Positive grid current	102
(D) Positive voltage electrode currents	103
(E) Transconductance or mutual conductance	103
(F) Amplification factor	104
(G) Plate resistance	104
(H) A.C. amplification	105
(I) Power output	105
(J) Distortion	106
(K) Microphony	107
(L) Audio frequency noise	107
(M) Radio frequency noise	107
(N) Blocking	107
(O) Stage gain testing	108
(P) Electrode dissipation	108
(v) Specific converter characteristics	108
(A) Methods of operation including oscillator excitation	108
(1) Oscillator self-excited	108
(2) Oscillator driven	109
(3) Static operation	109
(B) Specific characteristics	109
(a) Reverse signal grid current	109
(b) Signal-grid current commencement	109
(c) Mixer positive voltage electrode currents	109
(d) Mixer conversion transconductance	109
(e) Mixer plate resistance	111
(f) Mixer transconductance	111
(g) Oscillator grid current	111

CONTENTS		PAGE
SECTION		
	(h) Oscillator plate current	113
	(i) Oscillator transconductance	113
	(j) Oscillator amplification factor	113
	(k) Oscillator plate resistance	113
	(l) Signal-grid blocking	113
	(m) Microphony	113
	(n) R-F noise	113
(vi)	Tests for special characteristics	113
	(A) Short-circuit input admittance	113
	(B) Short-circuit feedback admittance	117
	(C) Short-circuit output admittance	117
	(D) Short-circuit forward admittance	117
	(E) Perveance	117
(vii)	Characteristics by pulse methods-point by point -	118
(viii)	Characteristics by curve tracer methods	119
4.	ACCEPTANCE TESTING	120
	(i) Relevant characteristics	120
	(ii) Valve specifications	120
	(iii) Testing procedure	120
5.	SERVICE TESTING AND SERVICE TESTER PRACTICE	121
	(i) Purpose and scope of service testing and discussion of as- sociated problems	121
	(ii) Fundamental characteristics which should be tested	122
	(iii) Types of commercial testers	122
	(iv) Methods of testing characteristics in commercial service testers	123
	(a) Shorts testing	123
	(b) Continuity testing	123
	(c) Heater to cathode leakage	123
	(d) Emission testing	123
	(e) Mutual conductance testing	123
	(f) Plate conductance testing	124
	(g) Reverse grid current testing	124
	(h) Power output testing	124
	(i) Conversion conductance testing	124
	(j) Oscillator mutual conductance testing	124
	(k) Noise testing	124
	(l) A.C. amplification testing	124
	(v) A.C. versus d.c. electrode voltages in testers	124
	(vi) Pre-heating	125
	(vii) Testing procedure	125
6.	REFERENCES	125

PART 2: GENERAL THEORY AND COMPONENTS
CHAPTER 4. THEORY OF NETWORKS

1.	CURRENT AND VOLTAGE	128
	(i) Direct current	128
	(ii) Alternating current	129
	(iii) Indications of polarity and current flow	130
2.	RESISTANCE	130
	(i) Ohm's Law for d.c.	130
	(ii) Ohm's Law for a.c.	131
	(iii) Resistances in series	131
	(iv) Resistances in parallel	132
	(v) Conductance in resistive circuits	133

CONTENTS

SECTION	PAGE
3. POWER	133
(i) Power in d.c. circuits	133
(ii) Power in resistive a.c. circuits	133
4. CAPACITANCE	134
(i) Introduction to capacitance	134
(ii) Condensers in parallel and series	135
(iii) Calculation of capacitance	135
(iv) Condensers in d.c. circuits	136
(v) Condensers in a.c. circuits	137
5. INDUCTANCE	140
(i) Introduction to inductance	140
(ii) Inductances in d.c. circuits	141
(iii) Inductances in series and parallel	141
(iv) Mutual inductance	142
(v) Inductances in a.c. circuits	142
(vi) Power in inductive circuits	143
6. IMPEDANCE AND ADMITTANCE	144
(i) Impedance, a complex quantity	144
(ii) Series circuits with L, C and R	144
(iii) Parallel combinations of L, C and R	147
(iv) Series-parallel combinations of L, C and R	149
(v) Conductance, susceptance and admittance	153
(vi) Conversion from series to parallel impedance	157
7. NETWORKS	158
(i) Introduction to networks	158
(ii) Kirchhoff's Laws	160
(iii) Potential dividers	161
(iv) Thevenin's Theorem	164
(v) Norton's Theorem	165
(vi) Maximum Power Transfer Theorem	165
(vii) Reciprocity Theorem	165
(viii) Superposition Theorem	165
(ix) Compensation Theorem	166
(x) Four-terminal networks	166
(xi) Multi-mesh networks	167
(xii) Non-linear components in networks	170
(xiii) Phase shift networks	170
(xiv) Transients in networks	171
(xv) References to networks	171
8. FILTERS	172
(i) Introduction to filters	172
(ii) Resistance-capacitance filters, high-pass and low-pass	172
(iii) Special types of resistance-capacitance filters	176
(iv) Iterative impedances of four terminal networks	176
(v) Image impedances and image transfer constant of four terminal networks	177
(vi) Symmetrical networks	179
(vii) "Constant k " filters	179
(viii) M-derived filters	182
(ix) Practical filters	184
(x) Frequency dividing networks	184
(xi) References to filters	185

CONTENTS

SECTION	PAGE
9. PRACTICAL RESISTORS, CONDENSERS AND INDUCTORS	186
(i) Practical resistors	186
(ii) Practical condensers	191
(iii) Combination units	197
(iv) Practical inductors	197
(v) References to practical resistors and condensers	198
CHAPTER 5. TRANSFORMERS AND IRON-CORED INDUCTORS	
1. IDEAL TRANSFORMERS	199
(i) Definitions	199
(ii) Impedance calculations-single load-	200
(iii) Impedance calculations-multiple loads-	201
2. PRACTICAL TRANSFORMERS	204
(i) General considerations	204
(ii) Effects of losses	205
3. AUDIO-FREQUENCY TRANSFORMERS	206
(i) General considerations	206
(ii) Core materials	207
(iii) Frequency response and distortion	
(a) Interstage transformers	209
(b) Low level transformers	210
(c) Output transformers	211
(iv) Designing for low leakage inductance	217
(v) Winding capacitance	219
(vi) Tests on output transformers	227
(vii) Specifications for a-f transformers	228
4. MAGNETIC CIRCUIT THEORY	229
(i) Fundamental magnetic relationships	229
(ii) The magnetic circuit	231
(iii) Magnetic units and conversion factors	232
5. POWER TRANSFORMERS	233
(i) General	233
(ii) Core material and size	234
(iii) Primary and secondary turns	235
(iv) Currents in windings	236
(v) Temperature rise	236
(vi) Typical design	237
(vii) Specifications for power transformers	241
6. IRON-CORED INDUCTORS	242
(i) General	242
(ii) Calculations-general-	242
(iii) Effective permeability	243
(iv) Design with no d.c. flux	243
(v) Design of high Q inductors	245
(vi) Design with d.c. flux	247
(vii) Design by Hanna's method	248
(viii) Design of inductors for choke-input filters	249
(ix) Measurements	250
(x) Iron-cored inductors in resonant circuits	251
7. REFERENCES	252

CONTENTS

SECTION	CHAPTER 6. MATHEMATICS	PAGE
1. ARITHMETIC AND THE SLIDE RULE		255
(i) Figures		255
(ii) Powers and roots		255
(iii) Logarithms		255
(iv) The slide rule		257
(v) Short cuts in arithmetic		258
2. ALGEBRA		259
(i) Addition		260
(ii) Subtraction		260
(iii) Multiplication		260
(iv) Division		260
(v) Powers		260
(vi) Roots		261
(vii) Brackets and simple manipulations		261
(viii) Factoring		262
(ix) Proportion		262
(x) Variation		262
(xi) Inequalities		262
(xii) Functions		263
(xiii) Equations		263
(xiv) Formulae and laws		265
(xv) Continuity and limits		265
(xvi) Progressions, sequences and series		266
(xvii) Logarithmic and exponential functions		267
(xviii) Infinite series		268
(xix) Hyperbolic functions		269
(xx) General approximations		271
3. GEOMETRY AND TRIGONOMETRY		272
(i) Plane figures		272
(ii) Surfaces and volumes of solids		275
(iii) Trigonometrical relationships		275
4. PERIODIC PHENOMENA		278
5. GRAPHICAL REPRESENTATION AND j NOTATION		279
(i) Graphs		279
(ii) Finding the equation to a curve		281
(iii) Three variables		281
(iv) Vectors and j notation		282
6. COMPLEX ALGEBRA AND DE MOIVRE'S THEOREM		285
(i) Complex algebra with regular coordinates		285
(ii) Complex algebra with polar coordinates		286
(iii) De Moivre's Theorem		287
7. DIFFERENTIAL AND INTEGRAL CALCULUS		289
(i) Slope and rate of change		289
(ii) Differentiation		291
(iii) Integration		294
(iv) Taylor's Series		298
(v) Maclaurin's Series		299
8. FOURIER SERIES AND HARMONICS		299
(i) Periodic waves and the Fourier Series		299
(ii) Other applications of the Fourier Series		302
(iii) Graphical Harmonic Analysis		302
9. REFERENCES		304

CONTENTS

SECTION	CHAPTER 7. NEGATIVE FEEDBACK	PAGE
1. FUNDAMENTAL TYPES OF FEEDBACK		306
(i) Feedback positive and negative		306
(ii) Negative voltage feedback at the mid-frequency		307
(iii) Negative current feedback at the mid-frequency		312
(iv) Bridge negative feedback at the mid-frequency		313
(v) Combined positive and negative at the mid-frequency		314
(vi) Comparison between different fundamental types at the mid-frequency		315
2. PRACTICAL FEEDBACK CIRCUITS		316
(i) The cathode follower		316
(ii) The cathode degenerative amplifier and phase splitter		327
(iii) Voltage feedback from secondary of output transformer		330
(iv) Voltage feedback from plate-transformer input-		332
(v) Voltage feedback from plate-r.c.c. input-		332
(vi) Voltage feedback over two stages		334
(vii) Voltage feedback over three stages		344
(viii) Cathode coupled phase inverters and amplifiers		347
(ix) Hum		348
(x) Some special features of feedback amplifiers		352
(xi) Combined positive and negative feedback		352
(xii) Choke-coupled phase inverter		355
3. STABILITY, PHASE SHIFT AND FREQUENCY RESPONSE		356
(i) Stability and instability		356
(ii) Conditions for stability		356
(iii) Relationship between phase shift and attenuation		359
(iv) Design of 1 and 2 stage amplifiers		364
(v) Design of multistage amplifiers		365
(vi) Effect of feedback on frequency response		378
(vii) Design of amplifiers with flat frequency response		379
(viii) Constancy of characteristics with feedback		388
(ix) Effect of feedback on phase shift		389
4. SPECIAL APPLICATIONS OF FEEDBACK		389
5. VALVE CHARACTERISTICS AND FEEDBACK		390
(i) Triode cathode follower		390
(ii) Pentode cathode follower		393
(iii) Triode with voltage feedback		394
(iv) Pentode with voltage feedback, transformer coupled		395
(v) Cathode degenerative triode		397
(vi) Cathode degenerative pentode		399
(vii) Cathode-coupled triodes		399
(viii) Feedback over two stages		399
6. REFERENCES TO FEEDBACK		399
7. OVERLOADING OF FEEDBACK AMPLIFIERS ON TRANSIENTS		1477
CHAPTER 8. WAVE MOTION AND THE THEORY OF MODULATION		
1. INTRODUCTION TO ELECTROMAGNETIC WAVES		403
(i) Wave motion		403
(ii) Electromagnetic spectrum		404
(iii) Wave propagation		404
2. TRANSMISSION OF INTELLIGENCE		405
(i) Introduction		405
(ii) Radio telegraphy		405
(iii) Radio telephony		405
3. REFERENCES		406

CONTENTS

SECTION		PAGE
	CHAPTER 9. TUNED CIRCUITS	
1.	INTRODUCTION	407
2.	DAMPED OSCILLATIONS	408
3.	SERIES RESONANCE	409
4.	PARALLEL RESONANCE	410
5.	GENERAL CASE OF SERIES RESONANCE	412
6.	SELECTIVITY AND GAIN	412
	(i) Single tuned circuit	412
	(ii) Coupled circuits-tuned secondary-	413
	(iii) Coupled circuits-tuned primary, tuned secondary-	414
	(iv) Coupled circuits of equal Q	415
	(v) Coupled circuits of unequal Q	416
7.	SELECTIVITY-GRAPHICAL METHODS-	416
	(i) Single tuned circuit	416
	(ii) Two identical coupled tuned circuits	417
8.	COUPLING OF CIRCUITS	418
	(i) Mutual inductive coupling	418
	(ii) Miscellaneous methods of coupling	418
	(iii) Complex coupling	420
9.	RESPONSE OF IDENTICAL AMPLIFIER STAGES IN CASCADE	421
10.	UNIVERSAL SELECTIVITY CURVES	421
11.	SUMMARY OF FORMULAE FOR TUNED CIRCUITS	423
12.	REFERENCES	427
	CHAPTER 10. CALCULATION OF INDUCTANCE	
1.	SINGLE LAYER COILS OR SOLENOIDS	429
	(i) Current-sheet inductance	429
	(ii) Solenoids wound with spaced round wires	430
	(iii) Approximate formulae	432
	(iv) Design of single layer solenoid	433
	(v) Magnitude of the differences between L_s and L_o	435
	(vi) Curves for the determination of the "current-sheet" inductance	437
	(vii) Effect of concentric, non-magnetic screen	438
2.	MULTILAYER SOLENOIDS	441
	(i) Formula for current sheet inductance	441
	(ii) Correction for insulation thickness	442
	(iii) Approximate formulae	442
	(iv) Design of multilayer coils	443
	(v) Effect of a concentric screen	444
3.	TOROIDAL COILS	445
	(i) Toroidal coil of circular section with single layer winding	445
	(ii) Toroidal coil of rectangular section with single layer winding	445
	(iii) Toroidal coil of rectangular section with multilayer winding	445
4.	FLAT SPIRALS	445
	(i) Accurate formulae	445
	(ii) Approximate formulae	446
5.	MUTUAL INDUCTANCE	446
	(i) Accurate methods	446
	(ii) Approximate methods	448
6.	LIST OF SYMBOLS	448
7.	REFERENCES	448

CONTENTS

SECTION		PAGE
	CHAPTER 11. DESIGN OF RADIO FREQUENCY INDUCTORS	
1.	INTRODUCTION	450
2.	SELF-CAPACITANCE OF COILS	451
	(i) Effects of self-capacitance	451
	(ii) Calculation of self-capacitance of single-layer solenoids	451
	(iii) Measurement of self-capacitance	453
3.	INTERMEDIATE-FREQUENCY WINDINGS	453
	(i) Air-cored coils	453
	(ii) Iron-cored coils	454
	(iii) Expanding selectivity i-f transformers	455
	(iv) Calculation of gear ratios for universal coils	456
	(v) Miscellaneous considerations	458
4.	MEDIUM WAVE-BAND COILS	459
	(i) Air-cored coils	459
	(ii) Iron-cored coils	460
	(iii) Permeability tuning	461
	(iv) Matching	462
5.	SHORT-WAVE COILS	463
	(i) Design	463
	(ii) Miscellaneous features	468
6.	RADIO-FREQUENCY CHOKES	474
	(i) Pie-wound chokes	474
	(ii) Other types	475
7.	TROPIC PROOFING	476
	(i) General considerations	476
	(ii) Baking	476
	(iii) Impregnation	477
	(iv) Flash dipping	477
	(v) Materials	477
8.	REFERENCES	478
	PART 3: AUDIO FREQUENCIES	
	CHAPTER 12. AUDIO FREQUENCY VOLTAGE AMPLIFIERS	
1.	INTRODUCTION	481
	(i) Voltage amplifiers	481
2.	RESISTANCE-CAPACITANCE COUPLED TRIODES	482
	(i) Choice of operating conditions	482
	(ii) Coupling condenser	483
	(iii) Cathode bias	484
	(iv) Fixed bias	487
	(v) Grid leak bias	489
	(vi) Plate voltage and current	489
	(vii) Gain and distortion at the mid-frequency	490
	(viii) Dynamic characteristics	491
	(ix) Maximum voltage output and distortion	491
	(x) Conversion factors with r.c.c. triodes	493
	(xi) Input impedance and Miller effect	493
	(xii) Equivalent circuit of r.c.c. triode	494
	(xiii) Voltage gain and phase shift	494
	(xiv) Comments on tabulated characteristics of resistance-coupled triodes	495

CONTENTS

SECTION	PAGE
3. RESISTANCE-CAPACITANCE COUPLED PENTODES	496
(i) Choice of operating conditions	496
(ii) Coupling condenser	496
(iii) Screen by-pass	496
(iv) Cathode bias	499
(v) Fixed bias	501
(vi) Dynamic characteristics of pentodes	504
(vii) Gain at the mid-frequency	506
(viii) Dynamic characteristics of pentodes and comparison with triodes	508
(ix) Maximum voltage output and distortion	510
(x) Conversion factors with r.c.c. pentodes	511
(xi) Equivalent circuit of r.c.c. pentode	512
(xii) Voltage gain and phase shift	512
(xiii) Screen loadlines	513
(xiv) Combined screen and cathode loadlines and the effect of tolerances	515
(xv) Remote cut-off pentodes as r.c.c. amplifiers	516
(xvi) Multigrid valves as r.c.c. amplifiers	516
(xvii) Special applications	516
(xviii) Comments on tabulated characteristics of resistance-coupled pentodes	517
4. TRANSFORMER-COUPLED VOLTAGE AMPLIFIERS	517
(i) Introduction	517
(ii) Gain at the mid-frequency	517
(iii) Gain at low frequencies	517
(iv) Desirable valve characteristics	517
(v) Equivalent circuits	518
(vi) Gain and phase shift at all frequencies	518
(vii) Transformer characteristics	518
(viii) Fidelity	518
(ix) Valve loadlines	518
(x) Maximum peak output voltage	518
(xi) Transformer loading	518
(xii) Parallel feed	518
(xiii) Auto-transformer coupling	520
(xiv) Applications	520
(xv) Special applications	520
5. CHOKE-COUPLED AMPLIFIERS	521
(i) Performance	521
(ii) Application	521
6. METHODS OF EXCITING PUSH-PULL AMPLIFIERS	521
(i) Methods involving iron-cored inductors	521
(ii) Phase splitter	522
(iii) Phase inverter	524
(iv) Self-balancing phase inverter	524
(v) Self-balancing paraphase inverter	524
(vi) Common cathode impedance self-balancing inverters	526
(vii) Balanced output amplifiers with highly accurate balance	527
(viii) Cross coupled phase inverter	527
7. PUSH-PULL VOLTAGE AMPLIFIERS	527
(i) Introduction	527
(ii) Cathode resistors	527
(iii) Output circuit	527
(iv) Push-pull impedance-coupled amplifiers—mathematical treatment	528
(v) Phase compressor	528

CONTENTS

SECTION	PAGE
8. IN-PHASE AMPLIFIERS	529
(i) Cathode-coupled amplifiers	529
(ii) Grounded-grid amplifiers	529
(iii) Inverted input amplifiers	529
(iv) Other forms of in-phase amplifiers	529
9. DIRECT-COUPLED AMPLIFIERS	529
(i) Elementary d-c amplifiers	529
(ii) Bridge circuit	530
(iii) Cathode-coupled	531
(iv) Cathode follower	531
(v) Phase inverter	532
(vi) Screen coupled	532
(vii) Gas tube coupled	532
(viii) Modulation systems	532
(ix) Compensated d.c. amplifiers	533
(x) Bridge-balanced direct current amplifiers	533
(xi) Cascode amplifiers	533
10. STABILITY, DECOUPLING AND HUM	535
(i) Effect of common impedance in power supply	535
(ii) Plate supply by-passing	535
(iii) Plate circuit decoupling	535
(iv) Screen circuit decoupling	537
(v) Grid circuit decoupling	538
(vi) Hum in voltage amplifiers	538
11. TRANSIENTS AND PULSES IN AUDIO FREQUENCY AMPLIFIERS	540
(i) Transient distortion	540
(ii) Rectangular pulses	540
12. MULTISTAGE VOLTAGE AMPLIFIERS	541
(i) Single-channel amplifiers	541
(ii) Multi-channel amplifiers	541
13. REFERENCES	542
CHAPTER 13. AUDIO FREQUENCY POWER AMPLIFIERS	
1. INTRODUCTION	544
(i) Types of a-f power amplifiers	544
(ii) Class of operation	545
(iii) Some characteristics of power amplifiers	545
(iv) Effect of power supply on power amplifiers	547
2. CLASS A SINGLE TRIODES	548
(i) Simplified graphical conditions, power output and distortion	548
(ii) General graphical case, power output and distortion	550
(iii) Optimum operating conditions	555
(iv) Loudspeaker load	558
(v) Plate circuit efficiency and power dissipation	559
(vi) Power sensitivity	559
(vii) Choke-coupled amplifier	559
(viii) Effect of a.c. filament supply	560
(ix) Overloading	560
(x) Regulation and by-passing of power supply	560

CONTENTS

SECTION	PAGE
3. CLASS A MULTI-GRID VALVES	560
(i) Introduction	560
(ii) Ideal pentodes	561
(iii) Practical pentodes—operating conditions-	561
(iv) Graphical analysis—power output and distortion-	563
(v) Rectification effects	565
(vi) Cathode bias	565
(vii) Resistance and inductance of transformer primary	566
(viii) Loudspeaker load	566
(ix) Effects of plate and screen regulation	568
(x) Beam power valves	569
(xi) Space charge tetrodes	569
(xii) Partial triode (" ultra-linear") operation of pentodes	570
4. PARALLEL CLASS A AMPLIFIERS	570
5. PUSH-PULL TRIODES CLASS A, AB ₁	571
(i) Introduction	571
(ii) Theory of push-pull amplification	573
(iii) Power output and distortion	577
(iv) Average plate current	579
(v) Matching and the effects of mismatching	580
(vi) Cathode bias	582
(vii) Parasitics	582
6 PUSH-PULL PENTODES AND BEAM POWER AMPLIFIERS, CLASS A, AB ₁	583
(i) Introduction	583
(ii) Power output and distortion	583
(iii) The effect of power supply regulation	584
(iv) Matching and the effects of mismatching	584
(v) Average plate and screen currents	584
(vi) Cathode bias	585
(vii) Parasitics	585
(viii) Phase inversion in the power stage	585
(ix) Extended Class A	587
(x) Partial triode (" ultra-linear ") operation	587
7. CLASS B AMPLIFIERS AND DRIVERS	587
(i) Introduction	587
(ii) Power output and distortion—ideal conditions—Class B ₂	588
(iii) Power output and distortion—practical conditions—Class B ₂	588
(iv) Grid driving conditions	590
(v) Design procedure for Class B ₂ amplifiers	592
(vi) Earthed-grid cathode coupled amplifiers	592
(vii) Class B ₁ amplifiers—quiescent push-pull	592
8. CLASS AB ₂ AMPLIFIERS	593
(i) Introduction	593
(ii) Bias and screen stabilized Class AB ₂ amplifier	593
(iii) McIntosh amplifier	594
9. CATHODE-FOLLOWER POWER AMPLIFIERS	596
10. SPECIAL FEATURES	596
(i) Grid circuit resistance	596
(ii) Grid bias sources	597
(iii) Miller Effect	598
(iv) 26 volt operation	598
(v) Hum from plate and screen supplies	599
11. COMPLETE AMPLIFIERS	599
(i) Introduction	599
(ii) Design procedure and examples	599
(iii) Loudspeaker load	600
12. REFERENCES	601

CONTENTS

SECTION	CHAPTER 14. FIDELITY AND DISTORTION	PAGE
1. INTRODUCTION		603
(i) Fidelity		603
(ii) Types of distortion		604
(iii) Imagery for describing reproduced sound		604
2. NON-LINEAR DISTORTION AND HARMONICS		605
(i) Non-linearity		605
(ii) Harmonics		606
(iii) Permissible harmonic distortion		607
(iv) Total harmonic distortion		609
(v) Weighted distortion factor		610
(vi) The search for a true criterion of non-linearity		610
3. INTERMODULATION DISTORTION		611
(i) Introduction		611
(ii) Modulation method of measurement—r.m.s. sum		612
(iii) Difference frequency intermodulation method		613
(iv) Individual side-band method		613
(v) Modulation method of measurement—peak sum		614
(vi) Le Bel's oscillographic method		614
(vii) Comparison between different methods		616
(viii) Synthetic bass		616
4. FREQUENCY DISTORTION		617
(i) Frequency range		617
(ii) Tonal balance		617
(iii) Minimum audible change in frequency range		617
(iv) Sharp peaks		618
5. PHASE DISTORTION		618
6. TRANSIENT DISTORTION		619
(i) General survey		619
(ii) Testing for transient response		619
7. DYNAMIC RANGE AND ITS LIMITATIONS		620
(i) Volume range and hearing		620
(ii) Effect of volume level on frequency range		621
(iii) Acoustical power and preferred listening levels		623
(iv) Volume range in musical reproduction		623
(v) The effect of noise		624
8. SCALE DISTORTION		625
9. OTHER FORMS OF DISTORTION		626
(i) Frequency-modulation distortion		626
(ii) Variation of frequency response with output level		626
(iii) Listener fatigue		626
10. FREQUENCY RANGE PREFERENCES		627
(i) Tests by Chinn and Eisenberg		627
(ii) Tests by Olson		627
(iii) Single channel versus dual-channel tests		627
(iv) Summing up		628
11. SPEECH REPRODUCTION		628
(i) The characteristics of speech		628
(ii) Articulation		628
(iii) Masking of speech by noise		629
(iv) Distortion in speech reproduction		629
(v) Frequency ranges for speech		630

CONTENTS

SECTION	PAGE
12. HIGH FIDELITY REPRODUCTION	630
(i) The target of high fidelity	630
(ii) Practicable high fidelity	630
(iii) The ear as a judge of fidelity	632
13. REFERENCES	632

CHAPTER 15. TONE COMPENSATION AND TONE CONTROL

1. INTRODUCTION	635
(i) The purpose of tone compensation	635
(ii) Tone control	636
(iii) General considerations	636
(iv) Distortion due to tone control	636
(v) Calculations involving decibels per octave	637
(vi) Attenuation expressed as a time constant	638
(vii) The elements of tone control filters	639
(viii) Fundamental circuit incorporating R and C	639
(ix) Damping of tuned circuits	639
(x) Tolerances of elements	639
2. BASS BOOSTING	640
(i) General remarks	640
(ii) Circuits not involving resonance or negative feedback	640
(iii) Methods incorporating resonant circuits	644
(iv) Circuits involving feedback	645
(v) Regeneration due to negative resistance characteristic	648
3. BASS ATTENUATION	649
(i) General remarks	649
(ii) Bass attenuation by grid coupling condensers	649
(iii) Bass attenuation by cathode resistor by-passing	649
(iv) Bass attenuation by screen by-passing	650
(v) Bass attenuation by reactance shunting	650
(vi) Bass attenuation by negative feedback	651
(vii) Bass attenuation by Parallel-T network	651
(viii) Bass attenuation using Constant k filters	652
(ix) Bass attenuation using M-derived filters	652
4. COMBINED BASS TONE CONTROLS	653
(i) Stepped controls	653
(ii) Continuously variable controls	653
5. TREBLE BOOSTING	653
(i) General remarks	653
(ii) Circuits not involving resonance or negative feedback	653
(iii) Methods incorporating resonant circuits	654
(iv) Circuits involving feedback	655
6. TREBLE ATTENUATION	655
(i) General remarks	655
(ii) Attenuation by shunt capacitance	655
(iii) Treble attenuation by filter networks	657
(iv) Treble attenuation in negative feedback amplifiers	657
7. COMBINED TREBLE TONE CONTROLS	658
8. COMBINED BASS AND TREBLE TONE CONTROLS	658
(i) Stepped controls-general—	658
(ii) Quality switch	659
(iii) Universal step-type tone control not using inductors	660
(iv) Universal step-type tone control using inductors	661
(v) Fixed bass and treble boosting	662

CONTENTS		PAGE
SECTION		
	(vi) Step-type tone control using negative feedback	662
	(vii) Continuously-variable controls—general	662
	(viii) Single control continuously-variable tone controls	662
	(ix) Ganged continuously-variable tone controls	664
	(x) Dual control continuously-variable tone controls	664
9.	FEEDBACK TO PROVIDE TONE CONTROL	669
	(i) Introduction	669
	(ii) Amplifiers with feedback providing tone control	669
	(iii) Whistle filters using feedback	672
10.	AUTOMATIC FREQUENCY-COMPENSATED VOLUME CONTROL	672
	(i) Introduction	672
	(ii) Methods incorporating a tapped potentiometer	672
	(iii) Methods incorporating step-type controls	673
	(iv) Method incorporating inverse volume expansion with multi-channel amplifier	673
11.	WHISTLE FILTERS	673
	(i) Resonant circuit filters	673
	(ii) Narrow band rejection filter	675
	(iii) Crystal filters	675
	(iv) Parallel-T network	675
	(v) Filters incorporating L and C	676
12.	OTHER METHODS OF TONE CONTROL	676
	(i) Multiple-channel amplifiers	676
	(ii) Synthetic bass	676
13.	THE LISTENER AND TONE CONTROL	677
14.	EQUALIZER NETWORKS	677
15.	REFERENCES	677

CHAPTER 16. VOLUME EXPANSION, COMPRESSION AND LIMITING

1.	GENERAL PRINCIPLES	679
	(i) Introduction	679
	(ii) An ideal system	680
	(iii) Practical problems in volume expansion	680
	(iv) Distortion	681
	(v) General comments	681
2.	VOLUME COMPRESSION	681
	(i) Introduction	681
	(ii) Peak limiters	682
	(iii) Volume limiters	683
	(iv) Distortion caused by peak limiters or volume limiters	683
	(v) Volume compression	683
	(vi) Volume compression plus limiting	684
	(vii) Compression of commercial speech	684
3.	GAIN CONTROL DEVICES	684
	(i) Remote cut-off pentodes	684
	(ii) Pentagrids and triode-hexodes	685
	(iii) Plate resistance control	685
	(iv) Negative feedback	685
	(v) Lamps	685
	(vi) Suppressor-grid control	686

CONTENTS

SECTION	PAGE
4. VOLUME EXPANSION	686
(i) Introduction	686
(ii) Expanders incorporating lamps	687
(iii) Expanders utilizing feedback	688
(iv) Expanders incorporating remote cut-off pentodes	688
(v) Expanders incorporating remote cut-off triodes	689
(vi) Expanders incorporating suppressor-grid controlled pentodes	689
(vii) Expanders incorporating valves with five grids	691
(viii) Expanders incorporating plate resistance control	692
5. PUBLIC ADDRESS A.V.C.	693
6. SPEECH CLIPPERS	693
7. NOISE PEAK AND OUTPUT LIMITERS	694
(i) Introduction	694
(ii) Instantaneous noise peak limiters	694
(iii) Output limiters	698
(iv) General remarks	699
8. REFERENCES	699
 CHAPTER 17. REPRODUCTION FROM RECORDS	
1. INTRODUCTION TO DISC RECORDING	701
(i) Methods used in sound recording	701
(ii) Principles of lateral recording	702
(iii) Frequency range	704
(iv) Surface noise and dynamic range	704
(v) Processing	705
(vi) Turntables and driving mechanism	705
(vii) Automatic record changers	705
2. DISCS AND STYLI	706
(i) General information on discs	706
(ii) Dimensions of records and grooves	706
(iii) Styli	709
(iv) Pinch effect	711
(v) Radius compensation	711
(vi) Record and stylus wear	712
3. PICKUPS	714
(i) General survey	714
(ii) Electro-magnetic (moving iron) pickups	717
(iii) Dynamic (moving coil) pickups	719
(iv) Piezo-electric (crystal) pickups	720
(v) Magnetostriction pickups	721
(vi) Strain-sensitive pickups	721
(vii) Ribbon pickups	722
(viii) Capacitance pickups	722
(ix) Eddy-current pickups	723
4. TRACKING	723
(i) General survey of the problem	723
(ii) How to design for minimum distortion	725
(iii) The influence of stylus friction	726
5. RECORDING CHARACTERISTICS, EQUALIZERS AND AMPLIFIERS	727
(i) Recording characteristics	727
(ii) Pre-amplifiers for use with pickups	732
(iii) Introduction to equalizers	732
(iv) High-frequency attenuation (scratch filter)	737
(v) Equalizers for electro-magnetic pickups	738

CONTENTS

SECTION	PAGE
(vi) Equalizers for crystal pickups	741
(vii) Equalizers applying negative feedback to the pickup	743
(viii) Miscellaneous details regarding equalizing amplifiers	743
(ix) Complete amplifiers	744
(x) Pickups for connection to radio receivers	751
(xi) Frequency test records	752
6. DISTORTION AND UNDESIRABLE EFFECTS	757
(i) Tracing distortion and pinch effect	757
(ii) Playback loss	760
(iii) Wow, and the effects of record warping	760
(iv) Distortion due to stylus wear	761
(v) Noise modulation	761
(vi) Pickup distortion	762
(vii) Acoustical radiation	762
(viii) Distortion in recording	762
7. NOISE REDUCTION	763
(i) Analysis of noise	763
(ii) High-frequency attenuation	763
(iii) High-frequency pre-emphasis and de-emphasis	763
(iv) Volume expansion	763
(v) Olson noise suppressor	763
(vi) Scott dynamic noise suppressor	764
(vii) Price balanced clipper noise suppressor	765
8. LACQUER DISC HOME RECORDING (DIRECT PLAYBACK)	766
(i) General description	766
(ii) Recording characteristic	766
(iii) Cutting stylus	767
(iv) Cutter head	767
(v) Equalization of cutter	767
(vi) Motor and turntable	767
(vii) Amplifier	767
(viii) Pickups for use on lacquer discs	768
(ix) Recording with embossed groove	768
9. REPRODUCTION FROM TRANSCRIPTION DISCS	769
(i) Introduction	769
(ii) Characteristics of record material, wear and noise	769
(iii) Sound track	770
(iv) Recording characteristics and equalization	770
(v) Translation loss and radius compensation	770
10. REFERENCES TO LATERAL DISC RECORDING	771
CHAPTER 18. MICROPHONES, PRE-AMPLIFIERS, ATTENUATORS AND MIXERS	
1. MICROPHONES	775
(i) General survey	775
(ii) Carbon microphones	777
(iii) Condenser microphones	778
(iv) Crystal and ceramic microphones	778
(v) Moving coil (dynamic) microphones	779
(vi) Pressure ribbon microphones	779
(vii) Velocity ribbon microphones	779
(viii) Throat microphones	780
(ix) Lapel microphones	780
(x) Lip microphones	780

CONTENTS

SECTION	PAGE
(xi) The directional characteristics of microphones	780
(xii) The equalization of microphones	781
(xiii) Microphone transformers	781
(xiv) Standards for microphones	781
2. PRE-AMPLIFIERS	782
(i) Introduction	782
(ii) Noise	782
(iii) Hum	784
(iv) Microphony	786
(v) Valves for use in pre-amplifiers	786
(vi) Microphone pre-amplifiers	788
(vii) Pickup pre-amplifiers	793
(viii) Gain-controlled pre-amplifiers	793
(ix) Standard pre-amplifiers for broadcasting	793
(x) Standard pre-amplifiers for sound equipment	793
3. ATTENUATORS AND MIXERS	794
(i) Potentiometer type attenuators (volume controls)	794
(ii) Single section attenuators-constant impedance—	795
(iii) Single section attenuators-constant impedance in one direction— only	795
(iv) Multiple section attenuators	796
(v) Electronic attenuators	797
(vi) Mixers and faders—general	798
(vii) Non-constant impedance mixers and faders	798
(viii) Constant impedance mixers and faders	801
4. REFERENCES	804

CHAPTER 19. UNITS FOR THE MEASUREMENT OF GAIN AND NOISE

1. BELS AND DECIBELS	806
(i) Power relationships expressed in bels and decibels	806
(ii) Voltage and current relationships expressed in decibels	807
(iii) Absolute power and voltage expressed in decibels	807
(iv) Microphone output expressed in decibels	808
(v) Pickup output expressed in decibels	810
(vi) Amplifier gain expressed in decibels	810
(vii) Combined microphone and amplifier gain expressed in decibels	811
(viii) Loudspeaker output expressed in decibels	812
(ix) Sound system rating	812
(x) Tables and charts of decibel relationships	813
(xi) Nomogram for adding decibel-expressed quantities	821
(xii) Decibels, slide rules and mental arithmetic	822
2. VOLUME INDICATORS AND VOLUME UNITS	823
(i) Volume indicators	823
(ii) Volume units	824
3. INDICATING INSTRUMENTS	825
(i) Decibel meters	825
(ii) Power output meters	825
(iii) Volume indicators	825
(iv) Acoustical instruments	825
4. NEPERS AND TRANSMISSION UNITS	825
(i) Nepers	825
(ii) Transmission units	826

CONTENTS

SECTION	PAGE
5. LOUDNESS	826
(i) Introduction to loudness	826
(ii) The phon	826
(iii) Loudness units	827
6. THE MEASUREMENT OF SOUND LEVEL AND NOISE	827
(i) Introduction	827
(ii) The sound level meter	828
(iii) The measurement of noise in amplifiers	829
(iv) The measurement of radio noise	829
7. REFERENCES	830

CHAPTER 20. LOUSPEAKERS

1. INTRODUCTION	831
(i) Types of loudspeakers	831
(ii) Direct radiator loudspeakers	831
(iii) Horn loudspeakers	832
(iv) Headphones	832
(v) Loudspeaker characteristics	833
(vi) Amplitude of cone movement	834
(vii) Good qualities of loudspeakers	834
(viii) Loudspeaker grilles	835
2. CHARACTERISTICS OF MOVING-COIL CONE LOUSPEAKERS	835
(i) Rigid (piston) cone in an infinite flat baffle	835
(ii) Practical cones	835
(iii) Special constructions for wide frequency range	836
(iv) Impedance and phase angle	837
(v) Frequency response	838
(vi) Efficiency	839
(vii) Directional characteristics	839
(viii) Field magnet	840
(ix) Hum bucking coil	840
(x) Damping	840
3. Baffles and Enclosures for Direct-Radiator Loudspeakers	842
(i) Flat baffles	842
(ii) Open back cabinets	842
(iii) Enclosed cabinet loudspeakers	843
(iv) Acoustical phase inverter ("vented baffle")	845
(v) Acoustical labyrinth loudspeakers	850
(vi) The R-J loudspeaker	850
(vii) Design of exterior of cabinet	850
4. Horn Loudspeakers	851
(I) Introduction	851
(ii) Conical horns	851
(iii) Exponential horns	851
(iv) Hyperbolic exponential horns	853
(v) Horn loudspeakers-general—	854
(vi) Folded horn loudspeakers	856
(vii) High-frequency horns	858
(viii) Combination horn and phase inverter loudspeakers for personal radio receivers	859
(ix) Material for making horns	859
5. Dual and Triple System Loudspeakers	860
(i) Introduction	860
(ii) Choice of the cross-over frequency	860

CONTENTS

SECTION	PAGE
(iii) The overlap region	861
(iv) Compromise arrangements	861
6. LOUDSPEAKERS IN OPERATION	861
(i) Loudness	861
(ii) Power required	861
(iii) Acoustics of rooms	864
(iv) Loudspeaker placement	865
(v) Stereophonic reproduction	865
(vi) Sound reinforcing systems	866
(vii) Open air Public Address	867
(viii) Inter-communicating systems	867
(ix) Background music in factories	867
7. DISTORTION IN LOUDSPEAKERS	868
(i) Non-linearity	868
(ii) Frequency-modulation distortion in loudspeakers	869
(iii) Transient distortion	869
(iv) Sub-harmonics and sub-frequencies	871
(v) Intermodulation distortion	871
8. SUMMARY OF ACOUSTICAL DATA	871
(i) Definitions in acoustics	871
(ii) Electrical, mechanical and acoustical equivalents	872
(iii) Velocity and wavelength of sound	872
(iv) Musical scales	873
9. STANDARDS FOR LOUDSPEAKERS	874
(i) Voice coil impedance for radio receivers	874
(ii) Loudspeaker standard ratings for sound equipment	874
10. REFERENCES TO LOUDSPEAKERS	876

CHAPTER 21. THE NETWORK BETWEEN THE POWER VALVE AND THE LOUDSPEAKER

1. LOUDSPEAKER "MATCHING"	880
(i) Loudspeaker characteristics and matching	880
(ii) Optimum plate resistance	880
(iii) Procedure for " matching " loudspeakers to various types of amplifiers	881
2. MULTIPLE AND EXTENSION LOUDSPEAKERS	882
(i) Multiple loudspeakers—general	882
(ii) Sound systems	883
(iii) Extension loudspeakers	883
(iv) Operation of loudspeakers at long distances from amplifier	886
3. LOUDSPEAKER DIVIDER NETWORKS	887
4. REFERENCES	889

PART 4: RADIO FREQUENCIES CHAPTER 22. AERIALS AND TRANSMISSION LINES

1. INTRODUCTION	890
2. THE TRANSMISSION LINE	890
(i) Introduction	890
(ii) The correct termination for a transmission line	890
(iii) Impedance-transforming action of a transmission line	891

CONTENTS

SECTION	PAGE
3. AERIALS AND POWER TRANSFER	892
(i) Introduction	892
(ii) Power transfer	892
4. CHARACTERISTICS OF AERIALS	893
(i) Effective area of a receiving aerial	893
(ii) The power gain of an aerial	894
(iii) The beam-width of an aerial	894
5. EFFECTS OF THE EARTH ON THE PERFORMANCE OF AN AERIAL	894
(i) Introduction	894
(ii) A perfectly-conducting earth	894
(iii) An imperfectly conducting earth	896
(iv) The attenuation of radio waves in the presence of an imperfectly-reflecting earth	896
6. THE EFFECT OF THE IONOSPHERE ON THE RECEPTION OF RADIO SIGNALS	901
7. THE IMPEDANCE OF AN AERIAL	901
(i) Introduction	901
(ii) Resistive component of impedance	902
(iii) Reactive component of impedance	903
(iv) Characteristic impedance of aerial	903
(v) Examples of calculations	903
(vi) Dipoles	904
(vii) Loop aerials	905
8. DUMMY AERIALS	906
9. TYPES OF AERIAL USED FOR BROADCAST RECEPTION	907
(i) Introduction	907
(ii) Medium-frequency receiving aerials	907
(iii) Short-wave receiving aerials	908
(iv) V-H-F aerials	909
10. REFERENCES	911

CHAPTER 23. RADIO FREQUENCY AMPLIFIERS

1. INTRODUCTION	912
(i) Aerial coupling	912
(ii) Tuning methods	913
(iii) R-F amplifiers	913
(iv) Design considerations	914
2. AERIAL STAGES	915
(i) Difficulties involved	915
(ii) Generalized coupling networks	915
(iii) Mutual inductance coupling	916
(iv) Tapped inductance	920
(v) Capacitance coupling	921
(vi) General summary	921
3. R-F AMPLIFIERS	922
(i) Reasons for using r-f stage	922
(ii) Mutual-inductance-coupled stage	922
(iii) Parallel tuned circuit	923
(iv) Choke-capacitance coupling	924
(v) Untuned and pre-tuned stages	924
(vi) Grounded grid stages	925
4. IMAGE REJECTION	925
(i) Meaning of image rejection	925
(ii) Image rejection due to aerial stage	926
(iii) Other considerations	926

CONTENTS

SECTION	PAGE
5. EFFECTS OF VALVE INPUT ADMITTANCE	927
(i) Important general considerations	927
(ii) Input loading of receiving valves at radio frequencies	928
(A) Input conductance	929
(B) Cold input conductance	929
(C) Hot input conductance	930
(D) Change in input capacitance	932
(E) Reduction of detuning effect	933
6. VALVE AND CIRCUIT NOISE	935
(i) Thermal agitation noise	935
(ii) Shot noise	936
(iii) Induced grid noise	939
(iv) Total noise calculations	940
(v) Sample circuit calculations	941
(vi) Conclusions	942
7. INSTABILITY IN R-F AMPLIFIERS	942
(i) Causes of instability	942
(ii) Inter-electrode capacitance coupling	943
(iii) Summary	944
8. DISTORTION	944
(i) Modulation envelope distortion	945
(ii) Cross modulation distortion	945
9. BIBLIOGRAPHY	945

CHAPTER 24. OSCILLATORS

1. INTRODUCTION	947
2. TYPES OF OSCILLATOR CIRCUITS	949
(i) Tuned plate oscillator	949
(ii) Tuned grid oscillator	950
(iii) Hartley oscillator	951
(iv) Colpitts oscillator	952
(v) Electron-coupled oscillator	953
(vi) Negative transconductance oscillators	953
3. CLASS A ₁ , B AND C OSCILLATORS	954
4. CAUSES OF OSCILLATOR FREQUENCY VARIATION	955
(i) General	955
(ii) Changes due to supply voltage	955
(iii) Temperature and humidity changes	955
(iv) Oscillator harmonics	956
5. METHODS OF FREQUENCY STABILIZATION	957
6. UNSTABLE OSCILLATION	958
7. PARASITIC OSCILLATION	959
8. METHODS USED IN PRACTICAL DESIGN	959
9. BEAT FREQUENCY OSCILLATORS	960
10. BIBLIOGRAPHY	961

CHAPTER 25. FREQUENCY CONVERSION AND TRACKING

1. THE OPERATION OF FREQUENCY CONVERTERS AND MIXERS	962
(i) Introduction	962
(ii) General analysis of operation common to all types	964
(iii) The oscillator section of converter tubes	968
(iv) The detailed operation of the modulator or mixer section of the converter stage	968

CONTENTS

SECTION	PAGE
(v) Conclusion	984
(vi) Appendix	985
2. CONVERTER APPLICATIONS	987
(i) Broadcast frequencies	987
(ii) Short waves	990
(iii) Types of converters	996
3. SUPERHETERODYNE TRACKING	1002
(i) General	1002
(ii) (A) Formulae and charts for superheterodyne oscillator design	1005
(B) Worked examples	1011
(iii) (A) Padded signal circuits	1013
(B) Worked example	1015
4. REFERENCES	1017
CHAPTER 26. INTERMEDIATE FREQUENCY AMPLIFIERS	
1. CHOICE OF FREQUENCY	1020
(i) Reasons for selection of different frequencies	1020
(ii) Commonly accepted intermediate frequencies	1021
2. NUMBER OF STAGES	1021
3. COMMONLY USED CIRCUITS	1022
(i) Mutual inductance coupling	1023
(ii) Shunt capacitance coupling	1023
(iii) Composite i-f transformers	1024
4. DESIGN METHODS	1025
(i) General	1025
(ii) Critically-coupled transformers	1026
(A) Design equations and table	1026
(B) Example	1028
(C) Design extension	1029
(D) Conclusions	1030
(E) k measurement	1030
(iii) Over-coupled transformers	1031
(A) Design equations and table	1031
(B) Example	1033
(C) k measurement (when k is high)	1033
(iv) Under-coupled transformers and single tuned circuits	1034
(A) Single tuned circuit equations	1034
(B) Example	1035
(C) Under-coupled transformer equations	1035
(D) Example	1036
(v) F-M i-f transformers	1037
(vi) I-F transformer construction	1041
(vii) Appendix: Calculation of coupling co-efficients	1043
5. VARIABLE SELECTIVITY	1048
(i) General considerations	1048
(ii) Automatic variable selectivity	1049
6. VARIABLE BANDWIDTH CRYSTAL FILTERS	1050
(i) Behaviour of equivalent circuit	1050
(ii) Variable bandwidth crystal filters	1052
(iii) Design of variable bandwidth i-f crystal filter circuits	1053
(A) Simplifying assumptions	1053
(B) Gain	1053
(C) Gain variation with bandwidth change	1054
(D) Selectivity	1055

SECTION	CONTENTS	PAGE
	(E) Crystal constants	1056
	(F) Position of filter in circuit	1057
	(G) Other types of crystal filters	1057
	(iv) Design example	1057
7.	DETUNING DUE TO A.V.C.	1061
	(i) Causes of detuning	1061
	(ii) Reduction of detuning effects	1062
8.	STABILITY	1065
	(i) Design data	1065
	(ii) Neutralizing circuits	1065
9.	DISTORTION	1067
	(i) Amplitude modulation i-f stages	1067
	(ii) Frequency modulation i-f stages	1068
10.	REFERENCES	1069

CHAPTER 27. DETECTION AND AUTOMATIC VOLUME CONTROL

1.	A-M DETECTORS	1072
	(i) Diodes	1072
	(A) General	1072
	(B) Diode curves	1075
	(C) Quantitative design data	1075
	(D) Miscellaneous data	1081
	(ii) Other forms of detectors	1082
	(A) Grid detection	1082
	(B) Power grid detection	1084
	(C) Plate detection	1084
	(D) Reflex detection	1085
	(E) Regenerative detectors	1086
	(F) Superregenerative detectors	1087
2.	F-M DETECTORS	1088
	(i) Types of detectors in general use	1088
	(ii) General principles	1088
	(iii) Phase discriminators	1088
	(A) General	1088
	(B) Design data	1090
	(C) Design example	1091
	(iv) Ratio detectors	1095
	(A) General	1095
	(B) Operation	1097
	(C) Types of circuit	1098
	(D) Design considerations	1099
	(E) Practical circuits	1101
	(F) Measurement on ratio detectors	1102
3.	AUTOMATIC VOLUME CONTROL	1105
	(i) Introduction	1105
	(ii) Simple a.v.c.	1105
	(iii) Delayed a.v.c.	1106
	(iv) Methods of feed	1109
	(v) Typical circuits	1111
	(vi) A.V.C. application	1111
	(vii) Amplified a.v.c.	1112
	(viii) Audio a.v.c.	1113
	(ix) Modulation rise	1114

CONTENTS

SECTION	PAGE
(x) A.V.C. with battery valves	1114
(xi) Special case with simple a.v.c.	1115
(xii) The a.v.c. filter and its time constants	1115
(xiii) A.V.C. characteristics	1117
(xiv) An improved form of a.v.c. characteristic	1118
(xv) Design methods	1120
4. MUTING (Q.A.V.C.)	1125
(i) General operation	1125
(ii) Typical circuits	1125
(iii) Circuits used with F-M receivers	1128
5. NOISE LIMITING	1130
6. TUNING INDICATORS	1132
(i) Miscellaneous	1132
(ii) Electron Ray tuning indicators	1133
(iii) Null point indicator using Electron Ray tube	1134
(iv) Indicators for F-M receivers	1135
7. CRYSTAL DETECTORS	1136
(i) Old type crystal detectors	1136
(ii) Fixed germanium crystal detectors	1136
(iii) Fixed silicon crystal detectors	1137
(iv) Theory of crystal rectification	1138
(v) Transistors	1138
8. REFERENCES	1138

CHAPTER 28. REFLEX AMPLIFIERS

1. GENERAL DESCRIPTION	1140
(i) Description	1140
(ii) Advantages and disadvantages of reflex receivers	1140
2. SOME CHARACTERISTICS OF REFLEX SUPERHET. RECEIVERS	1142
(i) Playthrough (residual volume effect)	1142
(ii) Over-loading	1142
(iii) Automatic volume control	1142
(iv) Reduction in percentage modulation	1143
(v) Negative feedback	1143
(vi) Operating conditions of reflex stage	1143
3. DESIGN OF PLATE REFLEX SUPERHET. RECEIVERS	1143
(i) General considerations	1143
(ii) Full a.v.c. applied to both stages	1143
(iii) Fractional a.v.c. applied to both stages	1143
(iv) Full a.v.c. on converter, fractional a.v.c. on reflex stage	1144
4. DESIGN OF SCREEN REFLEX SUPERHET. RECEIVERS	1145
(i) Screen reflex receivers	1145
(ii) Comparison between plate and screen reflexing	1146
5. DESIGN OF T.R.F. REFLEX RECEIVERS	1146
6. REFERENCES TO REFLEX AMPLIFIERS AND REFLEX RECEIVERS	1146

CHAPTER 29. LIMITERS AND AUTOMATIC FREQUENCY CONTROL

1. LIMITERS	1147
(i) General	1147
(ii) Typical circuits for F-M receivers	1149
2. AUTOMATIC FREQUENCY CONTROL	1150
(i) General principles	1150
(ii) Discriminators for a.f.c.	1152
(iii) Electronic reactances	1156
3. REFERENCES	1160

CONTENTS

SECTION		PAGE
	PART 5: RECTIFICATION, REGULATION, FILTERING AND HUM	
	CHAPTER 30. RECTIFICATION	
1.	INTRODUCTION TO RECTIFICATION	1161
	(i) Principles of rectification	1161
	(ii) Rectifier valves and types of service	1164
	(iii) The use of published curves	1165
	(iv) Selenium and copper oxide rectifiers	1169
2.	RECTIFICATION WITH CONDENSER INPUT FILTER	1170
	(i) Symbols and definitions	1170
	(ii) Rectification with condenser input filter	1170
	(iii) To determine peak and average diode currents	1174
	(iv) To determine ripple percentage	1177
	(v) To determine the transformer secondary r.m.s. current	1177
	(vi) Procedure when complete published data are not available	1177
	(vii) Approximations when the capacitance is large	1180
	(viii) Peak hot-switching transient plate current	1180
	(ix) The effect of ripple	1181
3.	RECTIFICATION WITH CHOKE INPUT FILTER	1182
	(i) Rectification with choke input filter	1182
	(ii) Initial transient current	1185
4.	TRANSFORMER HEATING	1185
5.	VOLTAGE MULTIPLYING RECTIFIERS	1186
	(i) General	1186
	(ii) Voltage doublers	1186
	(iii) Voltage triplers	1187
	(iv) Voltage quadruplers	1187
6.	SHUNT DIODE BIAS SUPPLIES	1188
	CHAPTER 31. FILTERING AND HUM	
1.	INDUCTANCE-CAPACITANCE FILTERS	1192
2.	RESISTANCE-CAPACITANCE FILTERS	1194
3.	PARALLEL-T FILTER NETWORKS	1194
4.	HUM—GENERAL	1196
	(i) Hum due to conditions within the valves	1196
	(ii) Hum due to circuit design and layout	1198
	(iii) Hum levels in receivers and amplifiers	1199
5.	HUM NEUTRALIZING	1200
6.	REFERENCES	1201
	CHAPTER 32. VIBRATOR POWER SUPPLIES	
1.	VIBRATORS—GENERAL PRINCIPLES	1202
	(i) Operation	1202
	(ii) Vibrator types	1202
	(iii) Choice of vibrator	1203
	(iv) Coil energizing	1204
	(v) Waveform and time efficiency	1205
	(vi) Standards for vibrators for auto-radio	1205

CONTENTS

SECTION	PAGE
2. VIBRATOR TRANSFORMER DESIGN	1205
(i) General considerations	1205
(ii) Transformer calculations	1206
(iii) Standards for vibrator power transformers	1207
3. TIMING CAPACITANCE	1207
(i) The use of the timing capacitance	1207
(ii) Calculation of timing capacitance value	1207
(iii) Percentage closure	1208
(iv) Effect of flux density on timing capacitance value	1208
4. ELIMINATION OF VIBRATOR INTERFERENCE	1210
5. 12, 24 AND 32 VOLT VIBRATOR SUPPLIES	1211
CHAPTER 33. CURRENT AND VOLTAGE REGULATORS	
1. CURRENT REGULATORS	1213
(i) Barretters	1213
(ii) Negative temperature coefficient resistors (Thermistors)	1214
2. VOLTAGE REGULATORS	1214
(i) Gaseous tube voltage regulators	1214
(ii) Valve voltage regulators	1215
3. REFERENCES	1222
PART 6: COMPLETE RECEIVERS	
CHAPTER 34. TYPES OF A-M RECEIVERS	
1. INTRODUCTION AND SIMPLE RECEIVERS	1223
(i) Types of receivers	1223
(ii) Crystal sets	1223
(iii) Regenerative receivers	1223
(iv) Superheterodyne receivers	1224
(v) Tuned radio-frequency receivers	1224
2. THE SUPERHETERODYNE	1225
3. THE SYNCHRODYNE	1226
4. REFERENCES	1227
CHAPTER 35. DESIGN OF SUPERHETERODYNE A-M RECEIVERS	
1. INTRODUCTION	1228
2. SPECIFICATIONS AND REQUIREMENTS	1229
3. GENERAL DESIGN	1229
(i) A.V.C. and noise	1229
(ii) Audio-frequency response	1234
(iii) Hum	1239
(iv) Microphony	1241
(v) Instability	1243
(vi) The local oscillator	1244
(vii) Cabinet design	1248
(viii) Ratings	1249
(ix) Field testing	1250
4. FREQUENCY RANGES	1250
(i) Medium frequency receivers	1250
(ii) Dual wave receivers	1251
(iii) Multiband receivers	1252
(iv) Bandsread receivers	1253

CONTENTS

SECTION	PAGE
5. A.C. OPERATED RECEIVERS	1256
(i) Four valve receivers	1256
(ii) Five valve receivers	1259
(iii) Larger receivers	1260
(iv) Communication receivers	1260
6. A.C./D.C. RECEIVERS	1264
(i) Series-resistor operation	1264
(ii) Barretter operation	1266
(iii) Dial lamps	1266
(iv) Miscellaneous features	1267
7. BATTERY OPERATED RECEIVERS	1268
(i) General features	1268
(ii) Vibrator-operated receivers	1270
(iii) Characteristics of dry batteries	1272
8. CAR RADIO	1275
(i) Interference suppression	1275
(ii) Circuit considerations	1276
(iii) Valve operating conditions	1277
9. MISCELLANEOUS FEATURES	1278
(i) Spurious responses	1278
(ii) Reduction of interference	1279
(iii) Contact potential biasing	1280
(iv) Fuses	1281
(v) Tropic proofing	1282
(vi) Parasitic oscillations	1283
(vii) Printed circuits	1283
(viii) Other miscellaneous features	1285
10. REFERENCES	1285

CHAPTER 36. DESIGN OF F-M RECEIVERS

1. F-M RECEIVERS	1287
(i) Comparison with A-M	1287
(ii) Aerial and r-f design	1287
(iii) Local oscillator design	1289
(iv) I-F amplifier	1290
(v) F-M detection and A-M rejection	1292
2. F-M/A-M RECEIVERS	1294
(i) R-F section	1294
(ii) I-F amplifier	1294
(iii) General considerations	1295
3. REFERENCES	1296

CHAPTER 37. RECEIVER AND AMPLIFIER TESTS AND MEASUREMENTS

1. A-M RECEIVERS	1297
(i) Introduction	1297
(ii) Definitions	1297
(iii) Equipment required	1298
(iv) Measurements and operating conditions	1300
(v) Measurements	1301
(vi) Tests	1302
2. F-M RECEIVERS	1314
(i) Definitions	1314
(ii) Testing apparatus	1315

CONTENTS

SECTION	PAGE
(iii) Test procedures and operating conditions	1315
(iv) Receiver adjustments	1316
(v) Performance tests	1317
3. AUDIO FREQUENCY AMPLIFIERS	1321
(i) Equipment and measurements	1321
(ii) Tests	1321
4. MEASUREMENTS ON COILS	1325
(i) Measurement of coefficient of coupling	1325
(ii) Measurement of primary resonant frequencies of aerial and r-f coils	1325
(iii) Measurement of distributed capacitance across coils	1325
5. REFERENCES	1327

PART 7: SUNDRY DATA

CHAPTER 38. TABLES, CHARTS AND SUNDRY DATA

1. UNITS	1329
(i) General physical units	1329
(ii) Electrical and magnetic units	1331
(iii) Photometric units	1334
(iv) Temperature	1334
2. COLOUR CODES	1335
(i) Colour code for fixed composition resistors	1335
(ii) Colour code for fixed wire wound resistors	1336
(iii) Table of R.M.A. colour code markings for resistors	1337
(iv) Colour code for moulded mica capacitors	1340
(v) Colour code for ceramic dielectric capacitors	1341
(vi) Colour code for i-f transformers	1342
(vii) Colour code for a-f transformers and output transformers	1342
(viii) Colour code for power transformers	1342
(ix) Colour code for loudspeakers	1343
(x) Colour code for chassis wiring	1343
(xi) Colour code for battery cables	1344
(xii) Colour code for metallized paper capacitors	1344
3. STANDARD RESISTORS AND CAPACITORS	1344
(i) Standard fixed composition resistors	1344
(ii) Standard fixed wire wound resistors	1346
(iii) Fixed paper dielectric capacitors in tubular non-metallic cases	1347
(iv) Metal encased fixed paper dielectric capacitors for d.c. application	1349
(v) Standard fixed mica dielectric capacitors	1351
(vi) Standard ceramic dielectric capacitors	1352
(vii) Standard variable capacitors	1354
(viii) Standard variable composition resistors	1356
(ix) Standard metallized paper dielectric capacitors	1357
(x) Standard electrolytic capacitors	1357
(xi) References to standard resistors and capacitors	1358
4. STANDARD FREQUENCIES	1361
(i) Standard frequency ranges	1361
(ii) Frequency bands for broadcasting	1361
(iii) Standard intermediate frequencies	1361
5. WAVELENGTHS AND FREQUENCIES	1362
(i) Wavelength-frequency conversion tables	1362
(ii) Wavelengths of electromagnetic radiations	1363
6. STANDARD SYMBOLS AND ABBREVIATIONS	1363
(i) Introduction	1363
(ii) Multipliers 1363	1363

CONTENTS

SECTION	PAGE
(iii) Some units and multipliers	1363
(iv) Magnitude letter symbols	1364
(v) Subscripts for magnitude letter symbols	1364
(vi) Magnitude letter symbols with subscripts	1365
(vii) Mathematical signs	1366
(viii) Abbreviations	1366
(ix) Abbreviations of titles of periodicals	1367
(x) References to periodicals	1369
(xi) References to standard symbols and abbreviations	1369
7. STANDARD GRAPHICAL SYMBOLS	1370
8. PROPERTIES OF MATERIALS AND CHEMICAL AND PHYSICAL CONSTANTS	1372
(i) Properties of insulating materials	1372
(ii) Properties of conducting materials	1374
(iii) Composition of some common plastics	1375
(iv) Weights of common materials	1375
(v) Resistance of a conductor at any temperature	1376
(vi) References to properties of materials	1376
(vii) Chemical and physical constants	1376
9. REACTANCE, IMPEDANCE AND RESONANCE	1377
(i) Inductive reactances	1377
(ii) Capacitive reactances	1378
(iii) Impedance of reactance and resistance in parallel	1380
(iv) Impedance of reactance and resistance in series	1382
(v) Resonance	1386
(vi) Approximations in the calculation of impedance for reactance and resistance in series and parallel	1386
(vii) Reactance chart	1387
10. SCREW THREADS, TWIST DRILLS AND SHEET GAUGES	1388
(i) Standard American screws used in radio manufacture	1388
(ii) B.A. screw threads	1389
(iii) Whitworth screw threads	1389
(iv) Unified screw threads	1390
(v) Drill sizes for self-tapping screws	1391
(vi) Wood screws	1391
(vii) Twist drill sizes	1392
(viii) Sheet steel gauges	1393
11. TEMPERATURE RISE AND RATINGS	1394
12. FUSES	1395
13. CHARACTERISTICS OF LIGHT; PANEL LAMPS	1396
(i) Visibility curves of the human eye and relative spectral energy curves of sunlight and tungsten lamp	1396
(ii) Velocity of light	1396
(iii) American panel lamp characteristics	1397
14. GREEK ALPHABET	1397
15. DEFINITIONS	1398
16. DECIMAL EQUIVALENTS OF FRACTIONS	1404
17. MULTIPLES AND SUB-MULTIPLES	1405
18. (i) Numerical values	1406
(ii) Factorials	1407
19. WIRE TABLES	1408
20. LOGARITHM TABLES	1418
21. TRIGONOMETRICAL TABLES	1420
Hyperbolic sines, cosines and tangents	1421
22. LOG SCALES AND LOG SCALE INTERPOLATOR	1422