CONTENTS

iii

Preface

List of Symbols	xiii
1 Problems of Circuit Design and Applications The circuit relations problem, 2; The temperature problem, 3; The transistor variability problem, 3; Transistor circuit analysis, 4; Design, 6.	1
2 Static Characteristics and Transistor Parameters Transistors as coupled diodes, 8; Transistor static characteristics, 9; The CB Q-point parameters and the static input characteristics, 11; CB static collector characteristics, 13; CE static input characteristics, 14; CE static collector characteristics, 15; CC input-out characteristics, 18; Current transfer and transconductance curves, 18; Symmetrical transistors and inverse alpha, 19; Summary, 19.	8
3 The Emitter Diode and Shockley's Relation Semiconductor diode theory, 21; Shockley's relation derived, 25; Implications of Shockley's relation, 26; Silicon transistors—the exceptions, 28; Summary, 29.	21
4 Equivalent Circuits, Gain and Impedance Formulas The CB T -equivalent, 31; The CE T -equivalent, 34; The hybrid CB equivalent, 35; The short-circuited T -equivalent, 35; Gain and impedance relations of the CB amplifier, 37; Gain and impedance relations of the CE amplifier, 38; Gain and impedance relations of the CC amplifier, 39; The CE amplifier with external resistors, 41; CE amplifier gain dependence on R_g and R_E , 42; The internal output resistance of the CB and CE amplifiers, 44; The transistor gain-impedance relation, 45; Summary, 47.	31
5 Temperature Problems Diode saturation currents, 49; I_{CBO} effects in practical transistors, 51; The I_{CO} equivalent generator, 52; The temperature dependence of V_{BE} , 55; Temperature variation of transistor parameters, 56; Transistor selection for low I_{CO} or high temperature operation, 59; Summary, 60.	49

6	Bias	and	Temperature	Instability
---	------	-----	-------------	-------------

Transistor biasing and bias temperature problems, 62; Emitter feedback biasing for I_{CO} control, and the S-factor, 62; Emitter feedback biasing: an example, 65; Collector feedback biasing, 69; Collector feedback bias with a Zener diode, 72; Feedback biasing to reduce V_{BE} temperature shift, 72; Feedback biasing and beta changes, 73; Q-point shift with V_{BE} and beta, 74; Summary, 75.

7 Common-Base Amplifiers

CB amplifier characteristics, 77; CB amplifier circuit: an example, 78; The gain-impedance relation with transformers, 79; Temperature effects, 79; Summary, 80.

8 Common-Emitter Amplifiers

CE amplifier characteristics, 81; CE amplifier circuit: an example, 83; Summary, 86.

9 Common-Collector Amplifiers

CC amplifier characteristics, 87; CC amplifier circuits: examples, 88; The CC filter (or impedance reducer), 91; Summary, 93.

10 Direct-Coupled Pairs

Voltage-gain relations, 95; Voltage gain and limited supply voltage, 98; Voltage gain and the emitter currents, 98; The choice between npn or pnp transistors, 100; A direct-coupled pair: an example, 101; The CC-CC or Darlington compound, 104; CC-CC high input impedance amplifiers, 107; Transistor compounds, 109; Parallel-connected and complementary-symmetry compounds, 112; Summary, 113.

11 Feedback Amplifiers

Feedback, 117; Series-current feedback, 118; Loop feedback, 121; Shunt-voltage feedback, 123; Miller feedback, 125; Black-equivalent or series-voltage feedback, 126; Positive feedback, 128; Miller feedback: an example, 129; Shunt feedback to control gain, 130; Black feedback: an example, 131; Double feedback: an example, 132; Amplifier S-factors, 134; Feedback loop stabilization, 134; Summary, 135.

12 Direct-Coupled Amplifiers

Single-sided dc amplifiers, 139; A practical single-sided amplifier, 142; High-impedance dc amplifiers, 143; Drift, 145; The drift equations, 146; The V_{BE} drift, 147; The I_{CO} drift, 148; The alpha drift, 148; The drift of later stages, and residual drifts, 149; Related design problems, 150; Dc chopper amplifiers, 151; Differential dc amplifiers: an example, 152; Summary, 154.

61

77

81

87

94

116

138

13 Noise in Transistor Amplifiers

156

Noise, 156; Resistance noise, 156; Shot noise, 158; Excess (or 1/f) noise, 158; High-frequency (or cutoff) noise, 159; Signal-to-noise ratio, 159; Noise factor, 160; Spot noise, 161; Wide-band (or average noise) factors, 161; Transistor noise, 163; Transistor noise representations, 165; Transistor noise calculations, 167; Summary, 168.

14 The Ebers and Moll Large-Signal Relations

171

The Ebers and Moll relations, 171; Large-signal relations in the cutoff region, 174; Large-signal relations in the active region, 175; Large-signal relations in the saturated *ON* region, 177; Summary, 179.

15 Linear Power Amplifiers

181

Power amplifier principles, 182; Single-sided power amplifiers, 182; Power amplifiers for higher frequencies, 184; Class-A power amplifier design, 185; Push-pull Class-B amplifiers, 186; Complementary-symmetry amplifiers, 189; Quasi-complementary-symmetry amplifiers, 191; Driver-stage requirements, 193; Power transistor ratings, 193; Control of I_{co} effects in power amplifiers, 195; Power-supply requirements, 196; Summary, 197.

16 The Dissipation of Heat and Thermal Runaway

199

Power dissipation and heat transfer, 199; Thermal resistance calculation, 201; Thermal resistance of solid conductors, 201; Thermal resistance of transistors, 202; Free convection cooling, 204; Forced air and liquid cooling, 205; Thermal runaway, 206; Runaway and heat sinks: an example, 210; Prevention of runaway damage, 212; Thermal capacity and pulse power ratings, 213; Summary 215.

17 Power Switching Amplifiers and Inverters

217

Large-signal characteristics, 219; Base drive requirements, 221; Base input curves and an equivalent circuit, 222; Base driver transformers, 224; Output transformers, 227; Switching transformer construction, 228; Voltage and current waveforms, 228; Operating frequency and switching power loss, 231; Load diagrams, 232; Switching amplifier performance, 233; Transistor inverters, 234.

18 Medium-Frequency Amplifiers

238

The hybrid pi-equivalent circuit, 239; The current-gain-bandwidth product, 240; The Miller effect in transistors, 241; Input impedance and series feedback, 243; Series feedback and beta cutoff, 243; Shunt feedback and beta cutoff, 244; Tuned amplifiers and stability problems, 246; Wide-band single-stage amplifier, 247; Summary, 249.

CONTENTS

Tetre	Tetrode Transistors ode biasing, 251; High-frequency tetrodes, 252; Automatic control tetrodes, 253; Power tetrodes, 253; Summary, 255.	
Stati equiv chara- tions ples,	The Field-Effect Transistor of characteristics, 257; Dynamic characteristics, 260; An valent circuit, 262; Frequency effects, 263; Temperature acteristics, 264; Noise characteristics, 265; FET applicated, 267; FET-transistor compounds, 268; FET-amplifier exam-269; Automatic gain-control amplifier, 273; FET choppers, Summary, 274.	257
Prince perate Noise single fiers,	Insulated-Gate Field-Effect Transistors (MOS) cipal characteristics, 277; Static characteristics, 278; Temcure characteristics, 279; Dynamic characteristics, 280; e characteristics, 280; Applications, 281; MOS biasing and e-stage amplifiers, 281; Multistage resistance-coupled ampli-283; High-input-impedance, wide-band amplifier, 284; MOS delay relay circuit, 285; Summary, 286.	
	Appendices	
Ι	 (A) Characteristics of a Silicon Planar Transistor; NPN Amplifier and Switching Type 2N1613 (B) Typical Characteristic Curves of Transistor Type 2N1613 	288
II	Low-Frequency Transistor Approximations	290
III	Hybrid T-Equivalent Conversions	290 291
IV	 (A) Transistor Gain and Impedance Formulas (B) Current Gains and Voltage Gains Versus Load Resistance (C) Power Gains Versus Load Resistance (D) Input Resistance Versus Load Resistance (E) Output Resistance Versus Generator Resistance 	291
V	Shea's Gain and Stability Factor Relations	
VI	 (A) Collector Cutoff Current Versus Temperature (B) Thermal Resistance Formulas (C) Thermal Resistances, Resistivities, and Thermal Capacities 	

CON	TE	N7	ΓS

	٠
x	1

- (D) Thermal Resistance of Heat Sinks
- (E) Temperature Conversion
- VII (A) Typical Low-Power Transistors
 - (B) Typical Power Transistors
- VIII Resistance Noise Chart
 - IX Alpha-Beta Table
 - X Reactance Chart

Index

305