

Contents

1 Bipolar Junction Transistors (BJT)	1
1.1 Introduction	1
1.2 Semiconductors	1
1.3 PN junction diode	2
1.4 BJT Physical construction basics	5
1.5 BJT characteristics	7
1.6 BJT biasing	9
1.6.1 Fixed-bias	10
1.6.2 Emitter stabilized biasing	11
1.6.3 Voltage divider biasing	13
1.6.4 Dual power supply biasing	16
1.6.5 Feedback resister biasing	17
1.6.6 Constant current source biasing	19
1.7 AC analysis of BJT circuits	21
1.8 Basic amplifiers configurations	25
1.8.1 Characterizing Amplifiers	26
1.8.2 Common emitter amplifier	28
1.8.3 Common Base amplifier	30
1.8.4 Common Collector (emitter follower) amplifier	33
1.8.5 Resistance reflection:	37
1.9 Practical discrete BJT amplifiers	40
1.9.1 Common emitter amplifier	40
1.9.2 Common base amplifier	45
1.9.3 Common collector (emitter follower) amplifier using Constant current source	47
1.9.4 Common emitter amplifier with emitter resistance using Constant current source	49
1.10 BJT design examples	51
1.11 PNP transistor	58
2 Field Effect Transistors (FET)	60
2.1 Introduction	60
2.2 FET types	60
2.3 E-MOSFET operation	61
2.4 FET characteristics	63
2.4.1 Enhancement MOSFET	64
2.4.2 JFET and depletion type MOSFET	64
2.5 FET biasing	66

2.5.1	Self-biasing	67
2.5.2	Feedback resistor biasing	68
2.5.3	Voltage divider biasing	71
2.5.4	Constant current source biasing analysis	72
2.6	AC analysis of FET circuits	76
2.7	Basic amplifier configurations	83
2.7.1	Common source amplifier	83
2.7.2	Common gate amplifier	84
2.7.3	Common drain (source follower) amplifier	86
2.8	Practical discrete FET amplifiers	89
2.8.1	Common source amplifier	90
2.8.2	Common gate amplifier	94
2.8.3	Common drain (source follower) amplifier	97
2.9	MOS output (drain) resistance	103
2.10	PMOS	104
2.11	Final remarks	106
3	Multistage Amplifiers	107
3.1	Analyzing multistage amplifiers techniques	107
3.2	Multistage amplifiers analysis examples	107
3.2.1	Two stage NMOS-BJT amplifier	107
3.2.2	Two stage NMOS CS-CS amplifier	112
3.2.3	Two stage NMOS CS-CD amplifier	115
3.2.4	Two stage BJT CE-CE amplifier	118
3.2.5	Three stage NMOS-BJT-BJT amplifier	122
3.3	Simplified method for analyzing multistage amplifiers	124
3.4	Darlington Pair	129
3.5	The cascode configuration	129
4	Basic building blocks for integrated circuits amplifiers	135
4.1	Introduction	135
4.2	Basic Gain Cell	135
4.3	The cascode configuration	137
4.3.1	MOSFET cascode configuration	138
4.3.2	BJT cascode configuration	142
4.4	Current source load implementation	146
4.4.1	MOS Current source load	146
4.4.2	BJT Current source load	149
4.5	Current mirrors	153
4.5.1	Basic current mirrors	153
4.5.2	Wilson current mirror	155
4.5.3	Output resistance of current mirrors	158
4.5.4	PMOS and PNP current mirrors	163

5 Differential Amplifiers	169
5.1 Basics	169
5.2 DC Analysis of Differential amplifier	170
5.3 AC Analysis of Differential amplifier	172
5.3.1 Differential Mode - Double ended	172
5.3.2 Differential Mode - Single ended voltage gain	174
5.3.3 Common mode DA	177
5.3.4 Use of T-Model	182
5.3.5 MOSFET Differential Amplifiers	184
5.3.6 Input and output resistances	186
5.4 Differential to single Ended output conversion	188
6 Operational Amplifiers	191
6.1 Basics	191
6.2 Op amp circuits	193
6.2.1 Inverting Amplifier	193
6.2.2 Non-inverting amplifier	196
6.2.3 Unity follower	196
6.2.4 Summing amplifier	197
6.2.5 Integrator	198
6.2.6 Differentiator	198
6.2.7 Difference amplifiers	199
6.2.8 Summary	201
6.2.9 Op amp circuit example	203
6.3 Op Amp as a Comparator	204
6.4 Nonlinear operation of Op Amp	205
6.4.1 Offset voltage (V_{IO})	205
6.4.2 Gain-Bandwidth product	206
6.4.3 Slew rate (SR) and maximum Signal Frequency	206
7 Power Amplifiers	208
7.1 Classifications	208
7.2 Series-fed class-A amplifiers	209
7.3 Transformer coupled class A amplifiers	213
7.3.1 Transformer coupled class A amplifier's efficiency	215
7.4 Class B Amplifiers	219
7.5 Class B Power Amplifiers circuit	220
7.6 Class AB amplifiers	224
7.6.1 Class AB amplifier circuit	225
7.7 Class C amplifiers	228
8 Frequency Response	230
8.1 Introduction	230
8.2 Low frequency response analysis	231
8.2.1 Low frequency response of MOS amplifier	235
8.2.2 Low frequency response of BJT amplifier	241
8.3 High frequency response	246
8.3.1 High frequency response of BJT amplifier	248

8.3.2	High frequency response of FET amplifier	250
9	Feedback Circuits	254
9.1	Introduction	254
9.2	Main Feedback properties	256
9.2.1	Gain stability	256
9.2.2	Bandwidth extension	257
9.3	Feedback connection types	259
9.3.1	Input and Output resistances	260
9.4	Practical feedback circuits	268
9.4.1	Series-shunt feedback	268
9.4.2	Shunt-series feedback	274
9.4.3	Series-series feedback	277
9.4.4	Shunt-shunt feedback	279
9.4.5	Loading effect	283
9.5	Feedback circuit stability	283
9.5.1	Oscillators	285
Appendix A	Mathcad program example 1	290
Appendix B	BJT paramters summary	292
Appendix C	Other FET symbols used in the literature	293
Appendix D	Definaton of k in terms of MOSFET physical parameters	294
Appendix E	Mathcad program example 2	295
Appendix F	Naming convention of feedback connections	297