

CONTENTS

PRELUDE	v
DISCLAIMER	vii
1 INTRO	1
1.1 BASIC CONCEPTS OF MUSIC	1
1.1.1 Interpreting notes	2
1.1.2 A connection to physics	4
1.2 BASIC CONCEPTS OF PHYSICS	6
1.2.1 The differential vs. the derivative	6
1.2.2 The differential vs. the integral	9
1.2.3 Continuous time vs. discrete time	11
1.2.4 Fourier analysis vs. an amplitude spectrum	13
1.2.5 The concept of a decibel vs. an amplitude spectrum	29
1.2.6 The Laplace transform vs. a transfer function	32
1.3 BASIC CONCEPTS OF ELECTRONICS	39
1.3.1 Current and voltage	39
1.3.2 Elementary building blocks of electronics	44
1.3.3 Properties of resistors	44
1.3.4 Properties of capacitors	47
1.3.5 Properties of inductors	51
1.3.6 Circuit analysis methods	55
1.3.7 Properties of semiconductors	60
1.3.8 Properties of transistors	67
1.3.9 Transistor circuit DC analysis	70
1.3.10 Transistor circuit AC analysis	74
1.3.11 Input and output impedances	80
1.3.12 Circuit simulations with SPICE	81
2 VIBES	87
2.1 A MATHEMATICAL MODEL OF A GUITAR STRING	87
2.1.1 Setting up the coordinates	87
2.1.2 The ideal string model	89
2.1.3 Setting up the equations	93
2.1.4 Solving the transverse wave equation	97
2.1.5 The significance of A_n : the amplitude spectrum	104
2.1.6 Alternative solutions of the wave equation	107
2.2 NONLINEAR EFFECTS IN STRING VIBRATION	109
2.2.1 The effect of amplitude	109
2.2.2 The effect of friction	112
2.2.3 The effect of stiffness	116
2.2.4 The effect of end supports	121
2.2.5 Coupling between directions of vibration	130
2.3 NONLINEAR EQUATIONS OF MOTION	138
2.4 MEASURING THE STRING VIBRATIONS	149
2.4.1 Properties of the measured string	150

2.4.2	The measurement setup	150
2.4.3	Error limit calculations	153
2.4.4	Measurement results - Amplitude spectrum	155
2.4.5	Measurement results - Decay of upper partials	164
2.4.6	Measurement results - Pitch glide	168
3	GUITAR PICKUPS	173
3.1	THE EFFECT OF PICKUP POSITIONING	173
3.2	MAGNETIC PICKUPS	175
3.2.1	The basic construction and function of a magnetic pickup	176
3.2.2	The magnetic field of a pickup magnet	177
3.2.3	Magnetic interaction between a pickup and strings	182
3.2.4	Electromagnetic induction in a magnetic pickup	189
3.2.5	The magnetic field generated by the coil of a pickup	195
3.2.6	A single-coil pickup vs. a humbucker	197
3.2.7	A magnetic pickup as part of an electric circuit	200
3.2.8	Measurements on a magnetic pickup	207
3.3	OPTICAL PICKUPS	214
3.3.1	An optical transducer as a guitar pickup	215
3.3.2	An optical pickup as a signal source	218
3.3.3	An optical pickup as part of an electric circuit	224
3.3.4	Measurements on an optical pickup	226
3.4	PIEZOELECTRIC PICKUPS	230
3.4.1	The piezoelectric effect	231
3.4.2	A piezoelectric transducer as a signal source	232
3.4.3	A piezoelectric pickup as part of an electric circuit	237
3.4.4	Measurements on a piezoelectric pickup	244
4	GUITAR TONE CONTROL CIRCUITS	249
4.1	A BASIC TONE CONTROL CIRCUIT	249
4.2	MODIFIED TONE CONTROL CIRCUITS	255
4.3	THE 'BIG MUFF π ' TONE CONTROL CIRCUIT	260
4.4	AMPLIFIER TONE CONTROLS FOR GUITAR MOUNTING	264
5	GUITAR CABLES	269
5.1	THE GENERAL TRANSMISSION LINE THEORY	269
5.2	PRACTICAL GUITAR CABLES	274
5.2.1	A shielded instrument cable	274
5.2.2	A parallel wire cable	279
5.3	IMPEDANCE MATCHING	282
5.4	A CABLE AS PART OF A GUITAR TONE CONTROL CIRCUIT	287
6	EFFECT DEVICES	291
6.1	AMPLITUDE EFFECTS	292
6.2	FUZZ BOX VOODOO	293
6.2.1	The DC bias analysis of the fuzz effect	295
6.2.2	The AC analysis of the fuzz effect	297
6.2.3	A SPICE model for the fuzz circuit	300
6.2.4	Results of simulations, calculations and measurements	310
6.3	TREMOLO = AMPLITUDE MODULATION	317
6.3.1	The DC bias analysis of the tremolo effect	320
6.3.2	The AC analysis of the tremolo effect	321
6.3.3	Side effect: the JFET as a resistor	324

6.3.4	Side effect: the RC phase-shift oscillator	330
6.3.5	A SPICE model for the tremolo circuit	339
6.3.6	Results of simulations, calculations and measurements	342
6.4	A COMPRESSOR AND AN EXPANDER	350
6.5	FREQUENCY EFFECTS	357
6.6	THE ORIGINS OF THE WAH-WAH SOUND	358
6.6.1	The DC analysis of the wah effect	359
6.6.2	The AC analysis of the wah effect	362
6.6.3	Side effect: RLC circuit resonance	365
6.6.4	Side effect: the Miller theorem	367
6.6.5	A SPICE model for the wah circuit	370
6.6.6	Results of simulations, calculations and measurements	373
6.7	AN OCTAVE DOUBLER EFFECT	378
6.7.1	The DC analysis of the Green Ringer effect	379
6.7.2	The AC analysis of the Green Ringer effect	381
6.7.3	A SPICE model for the Green Ringer circuit	381
6.7.4	Results of simulations, calculations and measurements	383
6.8	PHASE EFFECTS	386
6.9	A PHASE SHIFTER	386
6.9.1	Side effect: the relaxation oscillator	389
6.9.2	Side effect: an op-amp all-pass filter	396
6.9.3	Side effect: the op-amp in the nodal matrix method	397
6.9.4	The DC analysis of the Phase 45 effect	399
6.9.5	The AC analysis of the Phase 45 effect	400
6.9.6	A SPICE model for the Phase 45 circuit	404
6.9.7	Results of simulations, calculations and measurements	408
6.10	A FLANGER	416
6.11	TIME EFFECTS	419
6.12	THEORETICAL PITCH SHIFT	420
6.13	A THEORETICAL REVERBERATION EFFECT	422
6.14	ANALOGUE DELAY ACTUATORS	424
6.15	A REVERBERATION EFFECT USING MECHANICAL SPRINGS	425
6.15.1	Wave propagation in a helical spring	426
6.15.2	Interfacing electrical and mechanical vibrations	435
6.15.3	A drive and recovery circuit for a reverberation unit	439
6.15.4	Measurements on the reverberation device	443
7	GUITAR AMPLIFIERS	449
7.1	COMMON GUITAR AMPLIFIER BUILDING BLOCKS	450
7.2	OPERATION MODE CLASSES OF AUDIO AMPLIFIERS	451
7.3	DISTORTION IN AUDIO POWER AMPLIFIERS	453
7.4	TUBE AMPLIFIERS	455
7.4.1	The anatomy of different tube types	456
7.4.2	A tube preamplifier	458
7.4.3	A tube amplifier tone control circuit	462
7.4.4	Tube phase splitters	465
7.4.5	A tube power amplifier	473
7.5	TRANSISTOR AMPLIFIERS	478
7.5.1	A solid-state preamplifier	479
7.5.2	A solid-state power amplifier	483
7.6	INTERFACING AMPLIFIERS WITH LOUDSPEAKERS	489
7.7	GUITAR AMPLIFIER SIMULATIONS WITH SPICE	490

8 LOUDSPEAKERS	497
8.1 THE CONSTRUCTION OF A MOVING-COIL LOUDSPEAKER ELEMENT	497
8.2 MODELLING THE VOICE COIL	500
8.3 ELECTROMECHANICAL ANALOGUES REVISITED	502
8.4 AN ELECTRICAL MODEL OF THE DRIVER	508
8.5 MEASURING THE ESSENTIAL DRIVER PARAMETERS	514
9 TUNING DEVICES	519
9.1 STATE VARIABLE BIQUAD FILTERS	520
9.2 A MONOSTABLE MULTIVIBRATOR	528
9.3 AN ANALOGUE GUITAR TUNING DEVICE	531
9.4 MEASUREMENTS ON THE TUNING CIRCUIT	540
9.5 THE STROBOTUNER	546
9.6 AUTOMATIC TUNING SYSTEMS FOR GUITARS	550
10 OUTRO	553
REFERENCES	559
NOMENCLATURE	563
ABBREVIATIONS	568
APPENDIX A	569
APPENDIX B	571
APPENDIX C	575
APPENDIX D	581
APPENDIX E	583