

Contents

CHAPTER 1 INTRODUCTION

1.1	OVERVIEW	1
1.2	ADSP-2100 FAMILY PROCESSORS	1
1.2.1	ADSP-2100 Family Base Architecture	4
1.2.2	ADSP-2101 Architecture	7
1.2.3	ADSP-2111 Architecture	9
1.2.4	ADSP-21msp50 Architecture	10
1.3	ASSEMBLY LANGUAGE OVERVIEW	11
1.4	DEVELOPMENT SYSTEM	13
1.5	CONVENTIONS OF NOTATION	14
1.6	PROGRAMS ON DISK	15
1.7	FOR FURTHER SUPPORT	15

CHAPTER 2 MODEMS

2.1	OVERVIEW	17
2.2	V.32 MODEM DEFINITION	17
2.2.1	Transmitter Algorithms	18
2.2.2	Receiver Algorithms	20
2.2.3	Scrambler	21
2.2.4	Descrambling	22
2.2.5	ADSP-2100 Family Implementation	24
2.2.6	Scrambler/Descrambler Programs	25
2.2.7	Raised Cosine Filter	32
2.2.8	ADSP-2100 Family Implementation	33
2.2.9	Trellis Encoding	37
2.2.10	ADSP-2100 Family Implementation	39
2.2.11	Viterbi Decoding	47
2.2.12	Data Constellation	50
2.2.13	Viterbi Algorithm	50
2.2.14	ADSP-2100 Family Implementation	52
2.2.15	Shortest Path Through Trellis Diagram	53

Contents

2.2.16	Viterbi Program	55
2.2.16.1	Initialization	55
2.2.16.2	Data Input & Euclidean Distance	55
2.2.16.3	Shortest Path	55
2.2.16.4	Last Surviving Path	55
2.2.16.5	Determination Of Error Corrected Data	56
2.3	QUADRATURE AMPLITUDE MODULATION	75
2.3.1	QAM Methodology	75
2.3.2	ADSP-2100 Family Implementation	78
2.4	ECHO CANCELLATION	81
2.4.1	Echo Cancellation Algorithm	82
2.4.2	ADSP-2100 Family Implementation Of LMS Algorithm	84
2.4.3	Frequency Offset Compensation	88
2.4.4	Family Implementation Of Hilbert Transform	91
2.4.5	V.32 Modem Implementation	96
2.5	ADAPTIVE EQUALIZATION	98
2.5.1	History Of Adaptive Filters	98
2.5.2	Applications Of Adaptive Filters	99
2.5.3	Channel Equalization In A Modem	101
2.5.3.1	Equalization	102
2.5.3.2	Performance Index	105
2.5.4	Equalizer Architectures	105
2.5.4.1	Real Or Complex	106
2.5.4.2	Sampling Rates	107
2.5.5	Least Mean Squared (LMS) Algorithm	109
2.5.6	Program Structure	112
2.5.6.1	Input New Sample	113
2.5.6.2	Filtering (Equalizing)	113
2.5.6.3	Training Sequence	114
2.5.6.4	Decision-Directed Adaptation	115
2.5.6.5	Tap Update (LMS Algorithm)	117
2.5.6.6	Output	118
2.5.7	Practical Considerations	119
2.5.7.1	Viterbi Decoder	119
2.5.7.2	Pseudo-Random Training Sequence	119
2.5.7.3	Delay Line Length	119
2.6	CONTINUOUS PHASE MODULATION	120
2.6.1	CPFSK Methodology	120
2.6.2	ADSP-2100 Family Implementation	121
2.7	V.27 <i>ter</i> & V.29 MODEM TRANSMITTERS	126
2.7.1	V.27 <i>ter</i> Transmitter	126
2.7.2	V.29 Transmitter	141
2.8	REFERENCES	155

Contents

CHAPTER 3 LINEAR PREDICTIVE CODING

3.1	OVERVIEW	157
3.2	LINEAR PREDICTION	157
3.3	7.8 kbits/s LPC	159
3.4	2.4 kbits/s LPC	163
3.5	LPC SUBROUTINES	169

CHAPTER 4 GSM CODEC

4.1	OVERVIEW	205
4.1.1	Speech Codec	205
4.1.2	Software Comments	206
4.1.2.1	Multiply With Rounding	206
4.1.2.2	Arithmetic Saturation Results	206
4.1.2.3	Temporary Arrays	207
4.1.2.4	Shared Subroutines	207
4.2	ENCODER	207
4.2.1	Down Scaling & Offset Compensation Of The Input	208
4.2.2	Pre-Emphasis Filtering	208
4.2.3	Auto-Correlation	209
4.2.4	The Schur Recursion	209
4.2.5	Transformation Of The Reflection Coefficients	211
4.2.6	Quantization & Coding Of Logarithmic-Area-Ratios	212
4.2.7	Decoding Of Logarithmic-Area-Ratios	212
4.2.8	Short Term Analysis Filtering	213
4.2.8.1	Transformation Of The LARs Into Coefficients	214
4.2.8.2	Short Term Analysis Filtering	215
4.2.9	Calculation Of The Long Term Parameters	215
4.2.9.1	Long Term Analysis Filtering	216
4.2.9.2	Long Term Synthesis Filtering	217
4.2.10	Residual Pulse Excitation Encoding Section	217
4.2.10.1	Weighting Filter	217
4.2.10.2	Adaptive Sample Rate Decimation	218
4.2.10.3	APCM Quantization Of Selected Sequence	218
4.2.10.4	APCM Inverse Quantization	219
4.2.10.5	Update Of The Short Term Residual Signal	219
4.3	DECODER	220
4.3.1	Short Term Synthesis Filtering	220
4.3.1.1	Short Term Synthesis Filter	221
4.3.2	Long Term Synthesis Filtering	221
4.3.3	Post Processing	222
4.4	BENCHMARKS & MEMORY REQUIREMENTS	222
4.5	LISTINGS	223

Contents

CHAPTER 5 SUB-BAND ADPCM

5.1	OVERVIEW	293
5.2	SUB-BAND ADPCM ALGORITHM.....	294
5.3	TRANSMIT PATH.....	294
5.3.1	Transmit Quadrature Mirror Filter	294
5.3.2	Higher Sub-Band Encoder	296
5.3.3	Lower Sub-Band Encoder	296
5.4	RECEIVE PATH.....	298
5.4.1	Higher Sub-Band Decoder	298
5.4.2	Lower Sub-Band Decoder	299
5.4.3	Receive Quadrature Mirror Filter.....	300
5.5	ADSP-2100 FAMILY IMPLEMENTATION	300
5.6	SUBROUTINE DESCRIPTIONS	301
5.6.1	reset_mem	301
5.6.2	filtez	301
5.6.3	filtep	301
5.6.4	quantl	301
5.6.5	invqxl	302
5.6.6	logsch	302
5.6.7	scalel	302
5.6.8	upzero	302
5.6.9	uppol2	302
5.6.10	uppol1	302
5.6.11	limit	303
5.6.12	quanth	303
5.6.13	invqah	303
5.6.14	logsch	303
5.7	BENCHMARKS	328

CHAPTER 6 SPEECH RECOGNITION

6.1	OVERVIEW	329
6.2	SPEECH RECOGNITION SYSTEMS	330
6.2.1	Voice Production & Modeling	330
6.2.2	Training Phase.....	332
6.2.3	Recognition Phase.....	333
6.3	SOFTWARE IMPLEMENTATION	334
6.3.1	Word Acquisition & Analysis	335
6.3.1.1	Receive Shell	335
6.3.1.2	Frame Analysis.....	336
6.3.1.3	Endpoint Detection.....	337

Contents

6.3.1.4	Coefficient Conversion	338
6.3.2	Isolated Word Recognition	340
6.3.2.1	Library Routines	340
6.3.2.2	Comparison	341
6.3.2.3	Dynamic Time Warping	342
6.3.2.4	Ranking	346
6.3.3	Main Shell Routines	346
6.3.3.1	Executive Shell	347
6.3.3.2	Demonstration Shell	348
6.4	HARDWARE IMPLEMENTATION	349
6.5	LISTINGS	349
6.6	REFERENCES	440

CHAPTER 7 DISCRETE COSINE TRANSFORM

7.1	OVERVIEW	443
7.2	BACKGROUND	444
7.3	COMPUTATIONAL METHODS	449
7.4	HOU'S FAST DISCRETE COSINE ALGORITHM	449
7.5	ZIG-ZAG SCANNING OF DCT COEFFICIENTS	453
7.6	ZIG-ZAG SCANNING & ADSP-21XX PROCESSORS	454
7.7	LISTINGS	455
7.8	REFERENCES	480

CHAPTER 8 DIGITAL TONE DETECTION

8.1	OVERVIEW	481
8.2	IMPLEMENTATION	482
8.2.1	Choosing A Sampling Frequency	482
8.2.2	Picking The Best Value Of N	483
8.2.2.1	Leakage Loss	483
8.2.2.2	Frequency Resolution	484
8.2.2.3	Detection Time	484
8.2.2.4	Tone Detection Categories	484
8.2.2.5	Tone Detection Example	485
8.3	BENCHMARKS FOR THE EXAMPLE PROGRAM	489
8.4	LISTINGS	490

Contents

CHAPTER 9 DIGITAL CONTROL SYSTEM DESIGN

9.1	OVERVIEW	503
9.2	DIGITAL CONTROL SYSTEMS OVERVIEW	503
9.3	DIGITAL CONTROL SYSTEM MODEL	504
9.4	DIGITAL CONTROL SYSTEM HARDWARE	505
9.5	DIGITAL CONTROL SYSTEM SOFTWARE	507
9.6	DIGITAL PID CONTROLLER DESIGN	508
9.7	PID CONTROLLER IMPLEMENTATION	511
9.8	N'TH ORDER DIGITAL CONTROLLER DESIGN	513
9.8.1	Analog-Controller-Based Digital Design	513
9.8.2	Direct Digital Design	514
9.8.3	State-Space Design	515
9.9	N'TH ORDER DIGITAL CONTROLLER STRUCTURES	515
9.10	N'TH ORDER CONTROLLER IMPLEMENTATION	517
9.11	NOTCH FILTER EXAMPLE FOR THE ADSP-2100A	520
9.12	REFERENCES	523

CHAPTER 10 VARIATIONS ON IIR BIQUAD FILTERS

10.1	OVERVIEW	525
10.1.1	IIR Biquad Filter	525
10.1.2	Biquad Filter Subroutine	525
10.2	MULTIPRECISION FILTERS	527
10.2.1	Multiprecision Mult On ADSP-2100 Family DSPs	528
10.2.2	Double-Precision Biquad	531
10.2.3	Half, Double-Precision Biquad	537
10.2.4	Half, Triple-Precision Biquad	540
10.3	OPTIMIZED 16-BIT BIQUADS	544
10.4	CONCLUSION	549

CHAPTER 11 SOFTWARE UART

11.1	OVERVIEW	551
11.2	HARDWARE	551
11.3	SOFTWARE	552
11.3.1	Program Flow	553
11.3.2	Initialization & Timer Interrupt Routines	554
11.3.3	Transmit & Receive Subroutines	563
11.4	BAUD RATES	564
11.5	AUTOBAUD FEATURE	564
11.6	CHARACTER ECHO EXAMPLE	567
11.7	PROGRAM FILES	569

Contents

CHAPTER 12 **HARDWARE INTERFACING**

12.1	OVERVIEW	571
12.2	SOUNDPORT INTERFACES	571
12.2.1	ADSP-2111/AD1849 SoundPort Interface	572
12.2.2	ADSP-2105/AD1849 SoundPort Interface	578
12.2.3	ADSP-2101/AD1847 SoundPort Interface	585
12.3	INTERFACING DRAMS WITH THE ADSP-2100 FAMILY	603
12.3.1	DRAM Configuration	606
12.3.2	Multiplexed Memory Addressing	607
12.3.3	DSP & DRAM Control Signals	607
12.3.3.1	DSP Read/Write Timing	607
12.3.3.2	DRAM Read/Write Timing	608
12.3.3.3	<u>RAS</u> Generation	609
12.3.3.4	<u>CAS</u> Generation	610
12.3.3.5	<u>WRITE</u> & <u>OE</u> Generation	611
12.3.4	DSP To DRAM Interface Timing	611
12.3.4.1	DRAM Read Timing	611
12.3.4.2	DRAM Write Timing	612
12.3.5	Memory Access Modes	613
12.3.5.1	Page Mode	613
12.3.5.2	Enhanced Or Fast Page Mode	613
12.3.6	DRAM Refresh	614
12.3.7	DRAM Refresh Timing	615
12.3.8	EZ-LAB Implementation	617
12.3.9	DRAM Program Listings	618
12.3.10	DRAM Interfacing References	630
12.4	LOADING AN ADSP-2101 PROGRAM/SERIAL PORT	631
12.4.1	A Monitor	631
12.4.2	Implementation	632
12.5	MEMORY INTERFACING FOR THE ADSP-2105	637
12.5.1	Ex System 1: Boot Pages For Program Memory	637
12.5.2	Ex System 2: Booting With the -loader Option	638
12.5.3	Ex System 3: Internal & External PM RAM	639
12.5.4	Ex System 4: Using External PM ROM	640
12.5.5	Hardware Implications	640
12.5.6	Use Of The C-Compiler With ADSP-2105 Systems	641
12.5.7	Linking Modules Generated By The C-Compiler	642
12.5.8	Additional Suggestions	642
12.5.9	About The Example Programs	643
12.5.10	Appendix: Example System 1	645

Contents

FIGURES

Figure 1.1	ADSP-2100 Family Base Architecture	5
Figure 1.2	ADSP-2101 Architecture	8
Figure 1.3	ADSP-2111 Architecture	10
Figure 1.4	ADSP-21msp50 Architecture	11
Figure 2.1	Transmitter Block Diagram	19
Figure 2.2	Receiver Block Diagram	20
Figure 2.3	Call Mode Scrambler	22
Figure 2.4	Answer Mode Scrambler	23
Figure 2.5	Call Mode Descrambler	23
Figure 2.6	Answer Mode Descrambler	23
Figure 2.7	Circular Buffer Implementation For Scrambler	24
Figure 2.8	Raised Cosine Pulse Shaping Filter	34
Figure 2.9	Modem Transmitter	35
Figure 2.10	Encoder Block Diagram	38
Figure 2.11	V.32 Signal Constellation	39
Figure 2.12	Convolutional Encoder Block Diagram	41
Figure 2.13	Trellis Diagram For Convolutional Encoding	49
Figure 2.14	Signal Constellation Showing Encoder Output	51
Figure 2.15	Accumulated Distance Table Update Example	54
Figure 2.16	QAM Modulator Block Diagram	76
Figure 2.17	QAM Demodulator Block Diagram	77
Figure 2.18	Telephone Channel Block Diagram	81
Figure 2.19	Echo Canceller	83
Figure 2.20	LMS Adaptive Filter	84
Figure 2.21	Flowchart For LMS Stochastic Gradient Algorithm	85
Figure 2.22	Block Diagram Of Echo Canceller	89
Figure 2.23	Block Diagram Of Hilbert Transform	90
Figure 2.24	Spectrum Of Hilbert Frequency Shift	91
Figure 2.25	V.32 Modem Block Diagram	97
Figure 2.26	Example Short Impulse Response	102
Figure 2.27	Pure Delay Impulse Response	103
Figure 2.28	Equalizer Impulse Response	103
Figure 2.29	Transversal (FIR) Delay Line	106
Figure 2.30	IIR Delay Line	106
Figure 2.31	Fractionally Spaced Delay Line (FSE)	107
Figure 2.32	Adaptive Equalizer Flowchart	112
Figure 2.33	CPFSK Flow Diagram	122
Figure 2.34	Modem Transmitter Block Diagram	127
Figure 2.35	8-Point V.27 <i>ter</i> Constellation	128
Figure 2.36	4-Point V.27 <i>ter</i> Constellation	129

Contents

Figure 2.37	V.29 Constellation	142
Figure 2.38	V.29 Constellation For 7200 bits/s Fallback Mode	142
Figure 2.39	V.29 Constellation For 4800 bits/s Fallback Mode	143
Figure 5.1	Sub-Band ADPCM Algorithm Block Diagram	295
Figure 5.2	Higher Sub-Band Encoder Block Diagram	296
Figure 5.3	Lower Sub-Band Encoder Block Diagram	297
Figure 5.4	Higher Sub-Band Decoder Block Diagram	298
Figure 5.5	Lower Sub-Band Decoder Block Diagram	299
Figure 6.1	Speech Training System Block Diagram	332
Figure 6.2	Speech Recognition System Block Diagram	333
Figure 6.3	Distance Matrix With Slope Constraints	343
Figure 6.4	Time Warping Paths Between Sums & Distances	345
Figure 6.5	EXECSHEL.DSP Link File Menu Tree	347
Figure 6.6	DEMOSHEL.DSP Link File Menu Tree	348
Figure 6.7	Speech Recognition System Circuit Board Schematic	350
Figure 7.1	A Two-Dimensional Discrete Cosine Transform	444
Figure 7.2	The DCT Reduces The Blocking Artifact	446
Figure 7.3	Implementation Of An N=16 DCT	451
Figure 7.4	Signal Flow Graph For A Fast DCT	452
Figure 7.5	Zig-Zag Scanning Of Quantized Addresses	454
Figure 9.1	General Digital Control System	504
Figure 9.2	Digital Control System Model	505
Figure 9.3	ADSP-2101-Based Actuator Controller	506
Figure 9.4	PID Block Diagram	509
Figure 9.5	PD, PI, & PID Controllers	510
Figure 9.6	Second-Order Biquad Structure	515
Figure 9.7	Cascaded Biquad Sections	516
Figure 9.8	Fourth-Order Direct Form Controller	517
Figure 10.1	Second-Order Biquad IIR Filter Section	526
Figure 10.2	Multiprecision Multiplication Of 32-Bit Numbers	530
Figure 10.3	Modulo Addressing & Delay Line Data	545
Figure 11.1	General System Configuration	551
Figure 11.2	Example System Configuration	552
Figure 11.3	Receive Data Timing	562

Contents

Figure 12.1	Functional Block Diagram Of DRAM Interface	605
Figure 12.2	DSP Read/Write Timing	608
Figure 12.3	DRAM Read Cycle Timing	608
Figure 12.4	DRAM Delayed-Write Cycle Timing	609
Figure 12.5	RAS & CAS Timing For DRAM Read	611
Figure 12.6	RAS & CAS Timing For DRAM Write	612
Figure 12.7	EZ-LAB/DRAM Interface Board Connection	617
Figure 12.8	Boot Program Flow Diagram	633

LISTINGS

Listing 2.1	Call Mode Scrambler Main Routine	26
Listing 2.2	Call Mode Scrambler Scrambling Routine	28
Listing 2.3	Call Mode Descrambler Routine	30
Listing 2.4	Raised Cosine Filter	35
Listing 2.5	Trellis Encoder Program	42
Listing 2.6	Convolutional Encoder Routine	44
Listing 2.7	Signal Mapping Routine	46
Listing 2.8	Viterbi Decoder	56
Listing 2.9	Modulator Code	78
Listing 2.10	Demodulator Code	80
Listing 2.11	LMS Stochastic Gradient Implementation	86
Listing 2.12	Hilbert Transform Implementation	93
Listing 2.13	Delay Line Routine, Complex Tap Weights	108
Listing 2.14	LMS Routine	111
Listing 2.15	Input Routine	113
Listing 2.16	Filter Routine	114
Listing 2.17	Training Sequence Routine	115
Listing 2.18	Decision-Directed Adaptation Routine	116
Listing 2.19	Tap Update Routine	118
Listing 2.20	Output Routine	118
Listing 2.21	CPFSK Program (ADSP-2101)	123
Listing 2.22	Main V.27 ter Routine (MAIN27.DSP)	129
Listing 2.23	Data Acquisition Routine (GET27.DSP)	134
Listing 2.24	Data Scrambler Routine (SCRAM27.DSP)	135
Listing 2.25	IQ Generator Routine (IQ27.DSP)	136
Listing 2.26	Pulse Shape Filter Routine (PSF.DSP)	138
Listing 2.27	Random Number Generator Routine (RAND.DSP)	139
Listing 2.28	Signal Modulation Routine (MODULATE.DSP)	140
Listing 2.29	Main V.29 Routine (MAIN29.DSP)	144
Listing 2.30	Data Acquisition Routine (GET29.DSP)	151
Listing 2.31	Data Scrambler Routine (SCRAM29.DSP)	152
Listing 2.32	IQ Generator Routine (IQ29.DSP)	153

Contents

Listing 3.1	7.8 kbits/s LPC Routine	159
Listing 3.2	2.4 kbits/s LPC Routine	164
Listing 3.3	AUTOCOR.DSP Subroutine	169
Listing 3.4	DECODE.DSP Subroutine	172
Listing 3.5	DEEMP.DSP Subroutine	174
Listing 3.6	DURBIN.DSP Subroutine	175
Listing 3.7	DURBIN2.DSP Subroutine	180
Listing 3.8	ENCODE.DSP Subroutine	186
Listing 3.9	GAIN.DSP Subroutine	189
Listing 3.10	OVERFLOW.DSP Subroutine	190
Listing 3.11	PITCH.DSP Subroutine	191
Listing 3.12	POLY.DSP Subroutine	195
Listing 3.13	PREEMP.DSP Subroutine	196
Listing 3.14	RANDOM.DSP Subroutine	197
Listing 3.15	SQRT.DSP Subroutine	198
Listing 3.16	SSYNTH.DSP Subroutine	200
Listing 4.1	Initialization Routine (GSM_RSET.DSP)	224
Listing 4.2	Codec Routine (GSM0610.DSP)	228
Listing 4.3	Voice Activity Detection Routine (GSM0632.DSP)	256
Listing 4.4	Comfort Noise Insertion Routine (GSM_SID.DSP)	273
Listing 4.5	Discontinuous Trans Routine (GSM_DTX.DSP)	276
Listing 4.6	Data Acquisition Shell Routine (DMR21xx.DSP)	280
Listing 5.1	Implementation Of The G.722 Algorithm	304
Listing 6.1	Executive Shell Subroutine (EXECSHEL.DSP)	351
Listing 6.2	Demonstration Shell Subroutine (DEMOSHEL.DSP)	354
Listing 6.3	Data Variable Initialization Routine (INITIZE.DSP)	359
Listing 6.4	Receive Word Routine (RECVSHEL.DSP)	362
Listing 6.5	Frame Analysis Routine (ANALYZE.DSP)	369
Listing 6.6	Endpoint Detection Routine (ENDPOINT.DSP)	377
Listing 6.7	Coefficient Conversion Routine (CONVERT.DSP)	380
Listing 6.8	Library Functions Routine (LIB_FUNC.DSP)	398
Listing 6.9	Word Comparison Routine (COMPLIB.DSP)	402
Listing 6.10	Word Ranking Routine (RANKDIST.DSP)	407
Listing 6.11	Library Template Routine (WARPSHEL.DSP)	409
Listing 6.12	Y Coordinate Range Routine (YMINMAX.DSP)	416
Listing 6.13	Dynamic Time Warping Routine (TIMEWARP.DSP)	418
Listing 6.14	Vector Distance Routine (VECTDIST.DSP)	422
Listing 6.15	Display Driver Routine (DEMOBOX.DSP)	425
Listing 6.16	DTMF Signal Generator Routine (DTMF.DSP)	431
Listing 6.17	Automatic Dialing Routine (DTMFMAIN.DSP)	435

Contents

Listing 7.1	One-Dimensional Fast DCT (16 Points) Routine	456
Listing 7.2	DIF16 Subroutine	458
Listing 7.3	DIF8 Subroutine	459
Listing 7.4	DIF4 Subroutine	460
Listing 7.5	DIF2 Subroutine	462
Listing 7.6	RLR4 Subroutine	463
Listing 7.7	RLR8 Subroutine	464
Listing 7.8	RLR16 Subroutine	465
Listing 7.9	DC_AND_BREV Subroutine	466
Listing 7.10	Two-Dimensional Fast DCT (16 X 16 Points) Routine ...	467
Listing 7.11	One-Dimensional Fast DCT (8 Points) Routine	470
Listing 7.12	DIF8_8 Subroutine	472
Listing 7.13	DIF4_8 Subroutine	473
Listing 7.14	DIF2_8 Subroutine	474
Listing 7.15	RLR4_8 Subroutine	475
Listing 7.16	RLR8_8 Subroutine	476
Listing 7.17	DC_AND_BREV_8 Subroutine	477
Listing 7.18	Two-Dimensional Fast DCT (8 X 8 Points) Routine	478
Listing 8.1	Prime Factors Routine (FACTOR.C)	491
Listing 8.2	Prime Numbers Routine (PRIMES.C)	492
Listing 8.3	Best Sampling Frequency Routine (BESTFS.C)	493
Listing 8.4	Best Number Of Samples Routine (BESTN.C)	495
Listing 8.5	Coefficient Generating Routine (COEFGEN.C)	497
Listing 8.6	Tone Detection Routine (EXAMPLE.DSP)	499
Listing 9.1	PID_CONTROLLER Routine	512
Listing 9.2	BIQUAD_CONTROLLER Routine	519
Listing 9.3	NOTCH_FILTER Routine	521
Listing 10.1	Basic Biquad Filter Subroutine	526
Listing 10.2	Double-Precision Multiply Routine	529
Listing 10.3	Double-Precision IIR Biquad Subroutine	532
Listing 10.4	Optimized Double-Precision IIR Biquad Subroutine	535
Listing 10.5	Half, Double-Precision IIR Biquad Subroutine	537
Listing 10.6	Half, Triple-Precision IIR Biquad Subroutine	540
Listing 10.7	Optimized Basic Biquad Filter Subroutine	545
Listing 10.8	Second-Level Optimization Of Basic Biquad Filter	547
Listing 11.1	UART.DSP Code	554
Listing 11.2	Autobaud Example Program	565
Listing 11.3	Character Echo Program	568

Contents

Listing 12.1	ADSP-2111/AD1849 Talk-Through Routine	573
Listing 12.2	ADSP-2105/AD1849 Talk-Through Routine	579
Listing 12.3	ADSP-2101/AD1847 Talk-Through Routine	586
Listing 12.4	ADSP-2101/AD1847 Demonstration Routine	590
Listing 12.5	DRAM Read Program	618
Listing 12.6	DRAM Write Program	619
Listing 12.7	DRAM Refresh Program	620
Listing 12.8	DRAM Test Program	621
Listing 12.9	DRAM Speech Sample Record/Playback Program	625
Listing 12.10	Monitor Program Listing	635

TABLES

Table 1.1	ADSP-2100 Family Functional Differences	3
Table 2.1	Differential Encoder Lookup Table	40
Table 2.2	State Table For Convolutional Encoder	48
Table 2.3	Lookup Table Of X & Y Coordinates	53
Table 2.4	ADSP-2100 Benchmarks For Echo Cancellation	97
Table 2.5	8-Point V.27 <i>ter</i> Phase Changes	127
Table 2.6	4-Point V.27 <i>ter</i> Phase Changes	128
Table 2.7	8-Point V.29 Phase Changes	141
Table 3.1	Parameter Set For The Sound Synthesis Model	158
Table 4.1	GSM Implementation Benchmarks	223
Table 5.1	Decoder Modes Of Operation	298
Table 5.2	Inverse Adaptive Quantizer Modes Of Operation	300
Table 5.3	Typical Benchmark Performance	328
Table 6.1	Time Warping Boundaries	344
Table 7.1	Cosine vs. Fourier Transform Characteristics	445
Table 7.2	Benchmark Times For Executing The DCT	447
Table 8.1	Sample Frequencies & Prime Factors	485
Table 8.2	Sorted Sampling Frequencies (BESTFS.ERR)	486
Table 8.3	Sorted Values For N (BESTN.ERR)	487
Table 8.4	Goertzel Coefficients	489
Table 8.5	Typical Benchmark Performance	490

Contents

Table 10.1	Filter Routine Characteristics Summary	549
Table 12.1	Test System Components	606
INDEX	647