Digital Signal Processing: Laboratory Experiments Using C and the TMS320C31 DSK
Rulph Chassaing

Print ISBN 0-471-29362-8   Electronic ISBN 0-471-20065-4

Digital Signal Processing

WILEY SERIES ON TOPICS IN DIGITAL SIGNAL PROCESSING

- DFT/FFT and Convolution Algorithms and Implementation
  by C. S. Burrus and T. W. Parks
- Digital Signal Processing: Laboratory Experiments Using C and the TMS320C31 DSK
  by Rulph Chassaing
- Digital Signal Processing with the TMS320C25
  by Rulph Chassaing and Darrell W. Horning
- A Simple Approach to Digital Signal Processing
  by Craig Marven and Gillian Ewers
- Digital Filter Design
  by T. W. Parks and C. S. Burrus
- Theory and Design of Adaptive Filters
  by John R. Treichler and C. Richard Johnson

Digital Signal Processing

Laboratory Experiments
Using C and the TMS320C31 DSK

RULPH CHASSAING
University of Massachusetts, Dartmouth

A Wiley-Interscience Publication
JOHN WILEY & SONS, INC.
New York • Chichester • Weinheim • Brisbane • Singapore • Toronto

ISBN 0-471-20065-4.

This title is also available in print as ISBN 0-471-29362-8.

For more information about Wiley products, visit our web site at www.Wiley.com.

Contents

Preface

Digital signal processors, such as the TMS320 family of processors, are found in a wide range of applications such as in communications and controls, speech processing, and so on. They are used in Fax, modems, cellular phones, etc. These devices have also found their way into the university classroom, where they provide an economical way to introduce real-time digital signal processing (DSP) to the student.

With the introduction of Texas Instruments' third-generation TMS320C3x processor, floating-point instructions and a new architecture that supports features which facilitate the development of high-level language compilers appeared. The C optimizing compiler takes advantage of the special features of the TMS320C3x processor such as parallel instructions and delayed branches. Throughout the book, we refer to the C/C++ language as simply C. Generally, the price paid for going to a high-level language is a reduction in speed and a similar increase in the size of the executable file. Although TMS320C3x/assembly language produces fast code, problems with documentation and maintenance may exist. A compromise solution is to write time-critical routines in TMS320C3x code that can be called from C.

This book is intended primarily for senior undergraduate and first-year graduate students in electrical and computer engineering and as a tutorial for the practicing engineer. It is written with the conviction that the principles of DSP can best be learned through interaction in a laboratory setting, where the student can appreciate the concepts of DSP through real-time implementation of experiments and projects. The background assumed is a system course and some knowledge of assembly language or a high-level language such as C.

Most chapters begin with a theoretical discussion, followed by representative examples that provide the necessary background to perform the concluding experiments. There are a total of 60 solved programming examples using both TMS320C3x and C code. Several sample projects are also discussed.

Programming examples using both TMS320C3x and C code are included throughout the text. This can be useful to the reader who is familiar with both DSP and C programming, but who is not necessarily an expert in both. Although the reader who elects to study the programming examples in either TMS320C3x or C code will benefit from this book, the ideal reader is one with an appreciation for both TMS320C3x and C code.

This book can be used in the following ways:

1. For a laboratory course using many of the Examples and Experiments from Chapters 1-7. The beginning of the semester can be devoted to short programming examples and experiments and the remainder of the semester used for a final project.
2. For a senior undergraduate or first-year graduate design project course, using Chapters 1-5, selected materials from Chapters 6-8, and Appendices C and D.
3. For the practicing engineer as a tutorial and for workshops and seminars.

Chapter 1 introduces the tools through three examples. These tools include an assembler and a debugger that are provided with the DSP Starter Kit (DSK). Program examples in C can be tested without a C compiler since all associated executables files are on the accompanying disk. Chapter 2 covers the architecture and the instructions available for the TMS320C3x processor. Special instructions and assembler directives that are useful in DSP are discussed. Chapter 3 illustrates input and output (I/O) with the two-input analog interface chip (AIC) on the DSK board through several programming examples. An alternative I/O with a 16-bit stereo audio codec that can be interfaced with the DSK is described.

Chapter 4 introduces the z-transform and discusses finite impulse response (FIR) filters and the effect of window functions on these filters. Chapter 5 covers infinite impulse response (IIR) filters. Programming examples to implement FIR and IIR filters, in both TMS320C3x and C code, are included.

Chapter 6 covers the development of the fast Fourier transform (FFT). Programming examples on FFT are included. Chapter 7 demonstrates the usefulness of the adaptive filter for a number of applications with the least mean square (LMS). Chapter 8 discusses a number of DSP applications.

A disk included with this book contains all the programs discussed in the text. See page xv for a list of the programs/files included on the disk.

During the summers of 1996-1998, a total of 115 faculty members from over 100 Institutions took my DSP and Applications workshops supported by grants from the National Science Foundation (NSF). I am thankful to them for their encouragement, participation and feedback on this book. In particular, Dr. Hisham Alnajjar from the University of Hartford, Dr. Armando Barreto from Florida International University, Dr. Paul Giolma from Trinity University, Dr. William Monaghan from the College of Staten Island—CUNY, and Dr. Mark Wickert from the University of Colorado at Colorado Springs. I also thank Dr. Darrell Horning from the University of New Haven, with whom I coauthored the text *Digital Signal Processing with the TMS320C25,* for introducing me to book-writing. I thank all the students who have taken my DSP and Senior Design Project courses. I am particularly indebted to two former students, Bill Bitler and Peter Martin, who have worked with me for many years and have contributed to this book as well as to my previous book *Digital Signal Processing with C and the TMS320C30.*

The support of the National Science Foundation's Undergraduate Faculty Enhancement (UFE) Program in the Division of Undergraduate Education, Texas Instruments, and the Roger Williams University Research Foundation is appreciated.

RULPH CHASSAING

List of Examples

List of Programs/Files on Accompanying Disk

README	TXT	169
EGAVGA	BGI	5363

Directory of CH1

MATRIX	ASM	1628
SINE4P	ASM	1118
MATRIXC	ASM	6860
MATRIXC	C	482
MATRIXC	CMD	750
MATRIXC	OUT	1901
AICCOM31	ASM	5308

Directory of CH2

ADD4	ASM	702
MULT4	ASM	1150
FIR4	ASM	3016
MATRIXMF	ASM	1369
ADDMFUNC	ASM	556
ADDM	ASM	4179
FIR11	ASM	2595
ADDM	C	393
MATRIXM	C	488
ADDM	CMD	804
ADDM	OUT	1878
MATRIXM	OUT	2053
FIR11L	DAT	190
FIR11X	DAT	242

Directory of CH3

INTERR	ASM	1915
SINEALL	ASM	3093
LOOP	ASM	838
LOOPI	ASM	1076
SINE8I	ASM	1539
PRNOISE	ASM	1829
PRNOISEI	ASM	2214
VECS_DSK	ASM	222
LOOPALL	ASM	8525
LOOPC	ASM	9635
PCLOOP	EXE	212306
C31COM	ASM	3169
DAQ	EXE	250093
DAQ	ASM	9627
LOOPALL	C	2488
AICCOMC	C	2271
LOOPC	C	610
LOOPCI	C	740
C31COM	C	439
C31LOOP	C	873
LOOPALL	CMD	991
LOOPCI	CMD	1029
C31COM	CMD	905
C31LOOP	CMD	905
LOOPALL	OUT	2100
LOOPC	OUT	2146
LOOPCI	OUT	2422

C31LOOP	OUT	2856
C31COM	OUT	1664
PCCOM	CPP	1309
PCLOOP	CPP	1033
DAQ	CPP	1632
DAQ	DAT	3117
DSKLIB	LIB	143872
SYMBOLS	H	4190
DSKLIB	H	293
VECS_DSK	OBJ	427
SINEFM	ASM	2622

Directory of CH4

BP45SIM	ASM	2383
LP11SIM	ASM	2385
FIRNC	ASM	2147
FIRPRN	ASM	3550
FIRMCF	ASM	2016
FIRMC	ASM	16714
AICCOMC	C	2233
FIRDMOVE	C	1106
FIRERIC	C	1509
FIRMC	C	713
FIRC	C	1376
FIRMC	CMD	1091
FIRDMOVE	OUT	3018
FIRERIC	OUT	3113
FIRMC	OUT	3040
FIRC	OUT	3089
BP45SIM	DAT	371
LP11SIM	DAT	190
FIR	BAT	97
FIRPROGA	BAS	20237
FIRPROG	BAS	17752
BP55	COF	1080
PASS2B	COF	1083
PASS3B	COF	1088
LP55	COF	1095
BS55	COF	1082
LP11	COF	578
HP55	COF	1079
PASS4B	COF	1084
STOP3B	COF	1086
BP23	COF	551
BP41	COF	804
BP45	COF	843
BP33	COF	706
COMB14	COF	273
KBP53	COF	2426
RBP53	COF	2424
BP45COEF	H	721

Directory of CH5

SINEA	ASM	1767
COSINEA	ASM	1833
IIR6BP	ASM	2335
SINEC	C	1971
IIR6BPC	C	1057
IIR6BPC	CMD	1033
SINEC	OUT	3986
IIR6BPC	OUT	3115
AMPLIT	CPP	17889
BLT	BAS	5363
IIR6COEF	H	639
SINECMOD	C	2456
SINESW	ASM	2553

Directory of CH6

TWID128	ASM	2096
FFT_RL	OBJ	1011
FFT_RL	ASM	6358
TWID8	ASM	221
FFT128C	C	2498
FFT	C	2294
SINEGEN	C	540
TWIDGEN	C	814
FFT8C	C	680
FFT8MC	C	1124
FFT128C	CMD	1033
FFT128C	OUT	8327
FFT8C	OUT	5837
FFT8MC	OUT	2985
TWIDDLE	H	8557
COMPLEX	H	212
FFT8C	CMD	922

Directory of CH7

ADAPTP	ASM	4110
NOTCH2W	ASM	4072

ADAPTER	ASM	3848
ADAPTC	C	1684
ADAPTDMV	C	1600
ADAPTIVE	C	7783
ADAPTSH	C	1938
ADAPTTB	C	1639
ADAPTDMV	CMD	983
ADAPTSH	CMD	746
ADAPTDMV	OUT	3414
ADAPTSH	OUT	5227
ADAPTTB	OUT	4543
SIN312		694
SIN312A		776
HCOS312		686
HCOS312A		749
COS312A		798
DPLUSN		730
DPLUSNA		840
SCDAT		3985
SIN1000		647
SHIFT	C	812
ADAPTERC	ASM	4321

Directory of CH8

MR7DSK	ASM	33624
FIR8SETS	ASM	10251
FIRALL	ASM	10311
MR10SRAM	ASM	46118
ALARMGEN	ASM	6053
SIM2	C	3803
FIRALL	CPP	1226
FIR8SETP		3057
FIRALL	EXE	212589
EISINE	C	1521
EISINE	CMD	1061
EISINE	OUT	4307
VEC_DSK	ASM	215
VEC_DSK1	ASM	290
SINE4INT	C	1454
SINE4INT	CMD	947
SINE4INT	OUT	4035
SINE4C	C	959
SINE4C	CMD	959
SINE4C	OUT	2317
FIREXT	ASM	11292

Directory of APPB

BP45SIMP	ASM	2573
BP45SIMP	DAT	788
DAQ	DAT	3117
MATBP33	COF	594
MAT33	M	523
MAT63	M	544
DAQ	M	752

Directory of APPC

SINEHEX	C	1254
BP45HEX	C	1580
TESTMEM	CPP	3690
C31DLHEX	CPP	2087
SINEHEX	CMD	1015
SINHEX30	CMD	448
BP45HEX	CMD	1048
BPHEX30	CMD	471
BP45HEX	OUT	3177
BP45HEX	A0	4717
SINEHEX	OUT	2632
SINEHEX	A0	3113
SINEHEX	MAP	4439

Directory of APPD

LOOPL_CS	ASM	865
LOOPR_CS	ASM	848
LOOPB_CS	ASM	1015
CSCOM	ASM	6646
BP45CS	ASM	2702

Index