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Z8000®

Z8000® ASSEMBLY LANGUAGE PROGRAMMING

BY LANCE A. LEVENTHAL, ADAM OSBORNE & CHUCK COLLINS

Z8000

Z8000 Assembly Language Programming

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Contents

1. Introduction to Assembly Language Programming

The Meaning of Instructions 1-2

A Computer Program 1-2

The Binary Programming Problem 1-3

Using Octal or Hexadecimal 1-3

Instruction Code Mnemonics 1-5

The Assembler Program 1-5

Additional Features of Assemblers 1-6

Disadvantages of Assembly Language 1-7

High-Level Languages 1-8

FORTRAN — A High-Level Language 1-8

Advantages of High-Level Languages 1-8

Disadvantages of High-Level Languages 1-9

Summary of Advantages and Disadvantages 1-10

High-Level Languages for Microprocessors 1-11

Which Level Should You Use? 1-12

Future Trends in Language Levels 1-13

References 1-15

2. Features of Assemblers

Assembly Language Fields 2-2

Format 2-2

Delimiters 2-2

Syntax 2-3

Label Field 2-3

| | |
|-------------------------------------|------|
| Operation Field | 2-6 |
| Operand Field | 2-6 |
| Comment Field | 2-11 |
| Assembler Directives | 2-13 |
| Origin Directive | 2-14 |
| Data Directive | 2-16 |
| Constant Directive | 2-17 |
| Internal, External and Global Names | 2-19 |
| Printout Control Directives | 2-20 |
| End Directive | 2-20 |
| Labels with Directives | 2-20 |
| Conditional Assembly | 2-21 |
| Macros | 2-22 |
| Advantages of Macros | 2-23 |
| Disadvantages of Macros | 2-23 |
| Types of Assemblers | 2-24 |
| Cross Assembler | 2-24 |
| Resident Assembler | 2-24 |
| Macroassembler | 2-24 |
| Microassembler | 2-24 |
| Meta-Assembler | 2-24 |
| One-Pass Assembler | 2-24 |
| Two-Pass Assembler | 2-25 |
| Errors | 2-25 |
| Loaders | 2-26 |
| Bootstrap Loader | 2-26 |
| Relocating Loader | 2-26 |
| Linking Loader | 2-26 |
| References | 2-27 |

3. The Z8000 Assembly Language Instruction Set

| | |
|--|------|
| Operating Modes | 3-5 |
| System and Normal Modes | 3-5 |
| Segmented and Non-Segmented Modes | 3-5 |
| CPU Registers and Status Flags | 3-7 |
| Programmable Registers | 3-7 |
| Status | 3-11 |
| Register Designations | 3-14 |
| Memory Addressing Modes | 3-16 |
| Segmented and Non-Segmented Modes | 3-17 |
| Effective Memory Address | 3-18 |
| Operands in Memory | 3-20 |
| Immediate Memory Addressing | 3-21 |
| Direct Addressing | 3-24 |
| Implied, or Register Indirect Addressing | 3-32 |
| Implied Addressing with Auto Increment or Auto Decrement | 3-32 |
| Direct Indexed Addressing | 3-32 |
| Base Relative Addressing | 3-42 |
| Base Indexed Addressing | 3-43 |

- Program Relative Addressing 3-46
- Indirect Addressing 3-49
- String Handling Instructions 3-53
- The Instruction Set 3-55
- Standard Operand Addressing Methods 3-101
- Assembly Language Syntax 3-103
- Z8000 Instruction Descriptions 3-105
- 4. Simple Programs**
 - Example Format 4-1
 - Program Initialization 4-4
 - Special Conditions 4-4
 - Use of the Stack 4-4
 - Programming Guidelines for Solving Problems 4-4
 - Program Examples 4-6
 - Problems 4-16
 - References 4-20
- 5. Simple Program Loops**
 - Program Loop Instructions 5-5
 - Program Examples 5-7
 - Problems 5-24
- 6. Character-Coded Data**
 - Handling Data in ASCII 6-1
 - Program Examples 6-4
 - Problems 6-20
- 7. Code Conversion**
 - Program Examples 7-2
 - Problems 7-17
 - References 7-20
- 8. Arithmetic Problems**
 - Multiple-Word and Decimal Arithmetic 8-1
 - Program Examples 8-3
 - Floating Point Numbers 8-17
 - Normalizing Numbers 8-18
 - Alignment (Scaling) 8-20
 - Floating Point Arithmetic 8-24
 - Problems 8-36
- 9. Tables and Lists**
 - Programming Examples 9-2
 - Problems 9-18
 - References 9-23

10. Subroutines

- Subroutine Instructions 10-1
- Subroutine Parameters 10-2
- Return Values 10-5
- Documentation 10-6
- Program Examples 10-7
- Problems 10-24
- References 10-26

11. Input/Output

- I/O and Memory 11-2
- I/O Device Categories 11-3
 - Interfacing Slow Devices 11-3
 - Interfacing Medium-Speed Devices 11-6
 - Interfacing High-Speed Devices 11-9
- Timing Intervals (Delays) 11-10
 - Basic Software Delay 11-10
 - Program Examples 11-11
- Z8000 I/O Instructions 11-14
 - I/O Instruction Examples 11-16
- The Z80 Parallel I/O Device (PIO) 11-43
 - PIO Addresses 11-44
 - PIO Mode Control 11-47
 - Configuring the PIO 11-49
- Complex I/O Devices 11-51
 - Program Example 11-54
- USART/UART 11-77
- The Z80 Serial I/O Devices (SIO) 11-78
 - SIO Addresses 11-78
 - SIO Registers 11-78
 - Special Features of SIO 11-85
- Standard Interfaces 11-88
- Other Interface Devices 11-89
 - Problems 11-90
- References 11-94

12. Interrupts

- Interrupt Enable 12-2
- Non-Maskable Interrupts 12-4
- Maskable Interrupts 12-4
- Interrupt Priority 12-5
- Vectoring 12-6
- Polling 12-6
- Disadvantages of Interrupts 12-6
- The Z8000 Interrupt System 12-8
 - Program Status Area 12-9
 - Z8000 Interrupt Acknowledgment 12-10
 - Interrupt Identifiers 12-17
 - Interrupt Priorities 12-17
 - Return from Interrupt 12-18

- The Z8000 Reset 12-18
- Z80 PIO Interrupt Logic 12-19
 - Interrupt Vector Address Register 12-19
 - Z80 PIO Modes 12-20
 - Z80 PIO Interrupt Configuration 12-22
 - Z80 PIO Interrupt Priority 12-23
- Z80 SIO Interrupt Logic 12-24
 - Program Examples 12-27
 - Problems 12-45
- References 12-47

13. Large Configurations

- Z8010 Memory Management Unit 13-2
 - Memory Address Translation 13-2
 - Segment Descriptor Registers 13-5
 - Control Registers 13-8
 - Configuring Z8010 Memory Management Units 13-10
 - Program Examples 13-13
 - Segmentation Trap Acknowledgement 13-16
 - Multiple CPU Configurations 13-21
 - Program Example 13-22
- References 13-25

14. Problem Definition and Program Design

- Stages of Software Development 14-2
- Problem Definition 14-5
 - Inputs 14-5
 - Outputs 14-6
 - Processing Section 14-6
 - Error Handling 14-7
 - Human Interaction 14-8
 - Examples: Problem Definition 14-9
 - Review 14-18
- Program Design 14-19
 - Basic Principles 14-19
 - Examples: Flowchart 14-22
 - Modular Programming 14-30
 - Examples: Modular Programming 14-32
 - Structured Programming 14-35
 - Examples: Structured Programming 14-41
 - Review of Structured Programming 14-47
 - Top-Down Design 14-48
 - Examples: Top-Down Design 14-49
 - Review of Top-Down Design 14-53
 - Chapter Review 14-54
- References 14-54

15. Debugging and Testing

- Debugging 15-1
 - Simple Debugging Tools 15-2
 - More Advanced Debugging Tools 15-7
 - Debugging with Checklists 15-10
 - Debugging Interrupt-Driven Programs 15-14
 - Program Examples 15-15
- Testing 15-25
 - Testing Aids 15-26
 - Selecting Test Data 15-27
 - Testing Precautions 15-28
 - Conclusions 15-29
- References 15-30

16. Documentation and Redesign

- Documentation 16-1
 - Self-Documenting Programs 16-1
 - Comments 16-3
 - Commenting Examples 16-5
 - Flowcharts as Documentation 16-10
 - Structured Programs as Documentation 16-10
 - Memory Maps 16-10
 - Parameter and Definition Lists 16-11
 - Library Routines 16-13
 - Library Examples 16-14
 - Total Documentation 16-17
- Redesign 16-18
 - Reorganizing to Use Less Memory 16-19
 - Major Reorganization 16-20
- References 16-22

17. Sample Projects

- Project 1: A Digital Stopwatch 17-1
- Project 2: A Digital Thermometer 17-16

Index**Z8000 Instructions**

Program Examples

- 4-1. 16-Bit Addition 4-6
- 4-2. Using a Stack 4-8
- 4-3. Setting Up the Stack 4-9
- 4-4. Ones Complement 4-10
- 4-5. Shift Left One Bit 4-11
- 4-6. Word Disassembly 4-12
- 4-7. Find Larger of Two Numbers 4-14
- 4-8. Indirect Memory Addressing 4-15

- 5-1. 16-Bit Sum of Data 5-7
- 5-2. 32-Bit Sum of Data 5-10
- 5-3. Number of Negative Elements 5-13
- 5-4. Find Maximum 5-16
- 5-5. Find Maximum Using Indexed Addressing 5-19
- 5-6. Normalize a Binary Number 5-22

- 6-1. Length of a String of Characters 6-4
- 6-2. Find First Non-Blank Character 6-8
- 6-3. Replace Leading Zeros with Blanks 6-10
- 6-4. Add Even Parity to ASCII Characters 6-12
- 6-5. Compare Two Strings 6-15

- 7-1. Hex to ASCII 7-2
- 7-2. Decimal to Seven-Segment 7-5
- 7-3. ASCII to Decimal 7-8
- 7-4. BCD to Binary 7-10
- 7-5. Binary Number to ASCII String 7-13
- 7-6. Lower Case to Upper Case Alphabetic Conversion 7-16

- 8-1. 64-Bit Binary Addition 8-3
- 8-2. Add a 16-Bit Value to a Multiple Precision Value 8-6
- 8-3. Decimal Addition 8-8
- 8-4. 16-Bit Binary Multiplication 8-11
- 8-5. A Binary Multiplication Algorithm 8-12
- 8-6. Normalize a Floating Point Number 8-19
- 8-7. Scale a Floating Point Number 8-21
- 8-8. Floating Point Arithmetic Comparison 8-25
- 8-9. Floating Point Addition and Subtraction 8-28
- 8-10. Floating Point Multiplication and Division 8-32

- 9-1. Add an Entry to a List 9-2
- 9-2. Check an Ordered List 9-5
- 9-3. Remove an Element from a Queue 9-9
- 9-4. 8-Bit Sort 9-11
- 9-5. Using a Jump Table 9-16

- 10-1. Hex to ASCII 10-8
- 10-2. Hex Word to ASCII String 10-10
- 10-3. 64-Bit Add 10-13
- 10-4. Length of a Message 10-15
- 10-5. Find Minimum Value in a List 10-18
- 10-6. String Comparison 10-21

- 11-1. Delay Program Using Accumulators 11-11
- 11-2. A Pushbutton Switch 11-18
- 11-3. A Toggle Switch 11-23
- 11-4. A Multiple-Position (Rotary, Selector, or Thumbwheel) Switch 11-27
- 11-5. A Single LED 11-32
- 11-6. Seven-Segment LED Display 11-35
- 11-7. An Unencoded Keyboard 11-54
- 11-8. An Encoded Keyboard 11-61
- 11-9. Digital-to-Analog Converter 11-64
- 11-10. Analog-to-Digital Converter 11-68
- 11-11. A Teletypewriter (TTY) 11-72
- 11-12. Teletypewriter Interface Using the SIO 11-86

- 12-1. A Startup Interrupt 12-27
- 12-2. A Keyboard Interrupt 12-30
- 12-3. A Printer Interrupt 12-33
- 12-4. A Real-Time Clock Interrupt 12-35
- 12-5. A Teletypewriter Interrupt 12-41

- 13-1. Translate Segment 00 Addresses 13-13
- 13-2. Initialize Segment Descriptors 13-14
- 13-3. Request Shared Resource 13-22

- 14-1. Response to a Switch (Problem Definition) 14-9
- 14-2. The Switch-Based Memory Loader (Problem Definition) 14-11
- 14-3. The Verification Terminal (Problem Definition) 14-14
- 14-4. Response to a Switch (Flowchart) 14-22
- 14-5. The Switch-Based Memory Loader (Flowchart) 14-22
- 14-6. The Credit-Verification Terminal (Flowchart) 14-25
- 14-7. Response to a Switch (Modular Programming) 14-32
- 14-8. The Switch-Based Memory Loader (Modular Programming) 14-32
- 14-9. The Verification Terminal (Modular Programming) 14-33
- 14-10. Response to a Switch (Structured Programming) 14-41
- 14-11. The Switch-Based Memory Loader (Structured Programming) 14-42
- 14-12. The Credit-Verification Terminal (Structured Programming) 14-43
- 14-13. Response to a Switch (Top-Down Design) 14-49
- 14-14. The Switch-Based Memory Loader (Top-Down Design) 14-50
- 14-15. The Verification Terminal (Top-Down Design) 14-51

- 15-1. Decimal to Seven-Segment Conversion 15-15
- 15-2. Sort into Decreasing Order 15-18

1

Introduction to Assembly Language Programming

This book describes assembly language programming. It assumes that you are familiar with *An Introduction to Microcomputers: Volume 1 – Basic Concepts* (Berkeley: Osborne/McGraw-Hill, 1980). Chapters 6 and 7 of that book are especially relevant. This book does not discuss the general features of computers, microcomputers, addressing methods, or instruction sets; you should refer to *An Introduction to Microcomputers: Volume 1* for that information.

HOW THIS BOOK HAS BEEN PRINTED

Notice that text in this book has been printed in boldface type and lightface type. This has been done to help you skip those parts of the book that cover subject matter with which you are familiar. You can be sure that lightface type only expands on information presented in the previous boldface type. Therefore, read only boldface type until you reach a subject about which you want to know more, at which point start reading the lightface type.

THE MEANING OF INSTRUCTIONS

The instruction set of a microprocessor is the set of binary inputs which produce defined actions during an instruction cycle. An instruction set is to a microprocessor what a function table is to a logic device such as a gate, adder, or shift register. Of course, the actions that the microprocessor performs in response to the instruction inputs are far more complex than the actions that combinatorial logic devices perform in response to their inputs.

An instruction is simply a binary bit pattern — it must be available at the data inputs to the microprocessor at the proper time in order to be interpreted as an instruction. For example, when the Z8000 microprocessor receives the 16-bit binary pattern 1000000000001000 as the input during an instruction fetch operation, the pattern means:

“Add the contents of Register RH0 to the contents of Register RL0.”

Similarly, the pattern 1100100011111111 means:

“Load 11111111 into Register RL0.”

The microprocessor (like any other computer) recognizes only binary patterns as instructions or data; it does not recognize words or octal, decimal, or hexadecimal numbers.

A COMPUTER PROGRAM

A program is a series of instructions that cause a computer to perform a particular task.

Actually, a computer program includes more than instructions; it also contains the data and the memory addresses that the microprocessor needs to accomplish the task defined by the instructions. Clearly, if the microprocessor is to perform an addition, it must have two numbers to add and a destination for the result. The computer program must determine the sources of the data and the destination of the result as well as specifying the operation to be performed.

All microprocessors execute instructions sequentially unless one of the instructions changes the execution sequence or halts the computer (i.e., the processor gets the next instruction from the next consecutive memory address unless the current instruction specifically directs it to do otherwise).

Ultimately every program becomes translated into a set of binary numbers. For example, this is the Z8000 program that adds the contents of memory locations 6000₁₆ and 6002₁₆ and places the result in memory location 6004₁₆:

```
0110000100000000
0110000000000000
0100000100000000
0110000000000010
0110111100000000
011000000000100
```

This is a machine language, or object, program. If this program were entered into the memory of a Z8000-based microcomputer, the microcomputer would be able to execute it directly.

THE BINARY PROGRAMMING PROBLEM

There are many difficulties associated with creating programs as object, or binary machine language, programs. These are some of the problems:

1. The programs are difficult to understand or debug (binary numbers all look the same, particularly after you have looked at them for a few hours).
2. The programs are slow to enter since you must enter each bit individually using front panel switches.
3. The programs do not describe the task which you want the computer to perform in anything resembling a human readable format.
4. The programs are long and tiresome to write.
5. The programmer often makes careless errors that are very difficult to find.

For example, the following version of the addition program shown above has two numbers transposed. Try to find the error:

```
0110000100000000
0110000000000000
0010000100000000
0110000000000010
0110111100000000
0110000000000100
```

Although the computer handles binary numbers with ease, people do not. People find binary programs long, tiresome, confusing, and meaningless. Eventually, a programmer may start remembering some of the binary codes, but such effort should be spent more productively.

USING OCTAL OR HEXADECIMAL

We can improve the situation somewhat by writing instructions using octal or hexadecimal, rather than binary, numbers. We will use hexadecimal numbers in this book because they are shorter, and because they are the standard for the microprocessor industry. Table 1-1 shows the hexadecimal digits and their binary equivalents. The Z8000 program to add two numbers now becomes:

```
6100
6000
4100
6002
6F00
6004
```

At the very least, the hexadecimal version is shorter to write and not quite so tiring to examine.

Errors are somewhat easier to find in a sequence of hexadecimal digits. The erroneous version of the addition program, in hexadecimal form, becomes:

```
6100
6000
2100
6002
6F00
6004
```

The mistake is easier to spot.

What do we do with this hexadecimal program? The microprocessor understands only binary instruction codes. If your front panel has a hexadecimal keyboard instead of bit switches, you can key the hexadecimal program directly into memory — the keyboard logic translates the hexadecimal digits into binary numbers. But what if your front panel has only bit switches? You can convert the hexadecimal digits to binary by yourself, but this is a repetitive, tiresome task. People who attempt it make all sorts of petty mistakes, such as looking at the wrong line, dropping a bit, or transposing a bit or a digit. Besides, once we have converted our hexadecimal program we must still place the bits in memory through the switches on the front panel.

Hexadecimal Loader

These repetitive, grueling tasks are, however, perfect jobs for a computer. The computer never gets tired or bored and never makes mistakes. **The idea then is to write a program that accepts hexadecimal numbers, converts them into binary numbers, and places them in memory. This is a standard program provided with many microcomputers; it is called a hexadecimal loader.**

The hexadecimal loader is a program like any other. It occupies memory space: in some systems, only long enough to load another program; in others, it occupies a reserved, read-only section of memory. Your microcomputer may not have bit switches on its front panel; it may not even have a front panel. This reflects the machine designer's decision that binary programming is not only impossibly tedious but also wholly unnecessary. The hexadecimal loader in your system may be part of a larger program called a monitor, which also provides a number of tools for program debugging and analysis.

A hexadecimal loader certainly does not solve every programming problem. The hexadecimal version of the program is still difficult to read or understand; for example, it does not distinguish instructions from data or addresses, nor does the program listing provide any suggestion as to what the program does. What does 6100 or 6F00 mean? Memorizing a card full of codes is hardly an appetizing proposition. Furthermore, the codes will be entirely different for a different microprocessor, and the program will require a large amount of documentation.

Table 1-1. Hexadecimal Conversion Table

| Hexadecimal Digit | Binary Equivalent | Decimal Equivalent |
|-------------------|-------------------|--------------------|
| 0 | 0000 | 0 |
| 1 | 0001 | 1 |
| 2 | 0010 | 2 |
| 3 | 0011 | 3 |
| 4 | 0100 | 4 |
| 5 | 0101 | 5 |
| 6 | 0110 | 6 |
| 7 | 0111 | 7 |
| 8 | 1000 | 8 |
| 9 | 1001 | 9 |
| A | 1010 | 10 |
| B | 1011 | 11 |
| C | 1100 | 12 |
| D | 1101 | 13 |
| E | 1110 | 14 |
| F | 1111 | 15 |

INSTRUCTION CODE MNEMONICS

An obvious programming improvement is to assign a name to each instruction code. The instruction code name is called a "mnemonic," or memory jogger. The instruction mnemonic should describe in some way what the instruction does.

Devising Mnemonics

In fact, every microprocessor manufacturer (they can't remember hexadecimal codes either) provides a set of mnemonics for the microprocessor instruction set. **You do not have to abide by the manufacturer's mnemonics**; there is nothing sacred about them. However, they are standard for a given microprocessor and therefore understood by all users. These are the instruction names that you will find in manuals, cards, books, articles, and programs. The problem with selecting instruction mnemonics is that not all instructions have "obvious" names. Some instructions do have obvious names (e.g., ADD, AND, OR), others have obvious contractions (e.g., SUB for subtraction, XOR for exclusive OR), while still others have neither. The result is such mnemonics as WMP, PCHL, and even SOB (try and guess what that means!). Most manufacturers come up with mostly reasonable names and a few hopeless ones. However, users who devise their own mnemonics rarely seem to do much better than the manufacturer.

Along with the instruction mnemonics, the manufacturer will usually assign names to the CPU registers. As with the instruction names, some register names are obvious (e.g., A for Accumulator) while others may have only historical significance. Again, we will use the manufacturer's suggestions simply to promote standardization.

An Assembly Language Program

If we use standard Z8000 instruction and register mnemonics, as defined by Zilog, our Z8000 addition program becomes:

```
LD      R0,%6000
ADD     R0,%6002
LD      %6004,R0
```

The program is still far from obvious, but at least some parts are comprehensible. ADD R0,%6002 is a considerable improvement over 4100, and LD does suggest loading data into a register or memory location. **Such a program is an assembly language program.**

THE ASSEMBLER PROGRAM

How do we get the assembly language program into the computer? We have to translate it, either into hexadecimal or into binary numbers. **You can translate an assembly language program by hand**, instruction by instruction. This is called hand assembly.

Hand assembly of the addition program's instruction codes may be illustrated as follows:

| | Instruction Name | Hexadecimal Equivalent |
|-----|---------------------|---------------------------|
| LD | R0,%6000 | 61006000 |
| ADD | R0,%6002 | 41006002 |
| LD | %6004,R0 | 6F006004 |

As in the case of hexadecimal-to-binary conversion, hand assembly is a rote task which is uninteresting, repetitive, and subject to numerous minor errors. Picking the wrong line, transposing digits, omitting instructions, and misreading the codes are only a few of the mistakes that you may make. Most microprocessors complicate the task even further by having instructions with different word lengths. Some instructions are one word long while others are two or three words long. Some instructions require data in the second and third words; others require memory addresses, register numbers, or who knows what?

Assembly is another rote task that we can assign to the microcomputer. The microcomputer never makes any mistakes when translating codes; it always knows how many words and what format each instruction requires. The program that does this job is called an "assembler." The assembler program translates a user program, or "source" program written with mnemonics, into a machine language program, or "object" program, which the microcomputer can execute. The assembler's input is a source program and its output is an object program.

An assembler is a program, just as the hexadecimal loader is. However, assemblers are more expensive, occupy more memory, and require more peripherals and execution time than do hexadecimal loaders. While users may (and often do) write their own loaders, few care to write their own assemblers.

Assemblers have their own rules that you must learn to abide by. These include the use of certain markers (such as spaces, commas, semicolons, or colons) in appropriate places, correct spelling, the proper control information, and perhaps even the correct placement of names and numbers. These rules typically are a minor hindrance that can be quickly overcome.

ADDITIONAL FEATURES OF ASSEMBLERS

Early assembler programs did little more than translate the mnemonic names of instructions and registers into their binary equivalents. However, most assemblers now provide such additional features as:

1. Allowing the user to assign names to memory locations, input and output devices, and even sequences of instructions.
2. Converting data or addresses from various number systems (e.g., decimal or hexadecimal) to binary and converting characters into their ASCII or EBCDIC binary codes.
3. Performing some arithmetic as part of the assembly process.
4. Telling the loader program where in memory parts of the program or data should be placed.
5. Allowing the user to assign areas of memory as temporary data storage and to place fixed data in areas of program memory.
6. Providing the information required to include standard programs from program libraries, or programs written at some other time, in the current program.
7. Allowing the user to control the format of the program listing and the input and output devices employed.