

CpE 213

Digital Systems Design

Lecture 14
Tuesday 10/14/2003

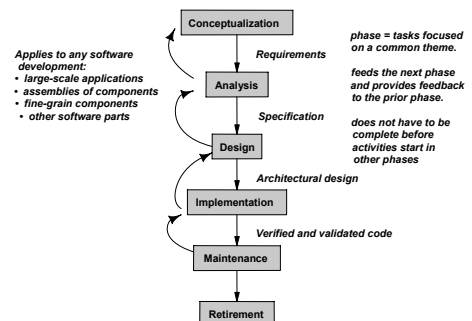
Announcements

- Exam 1 has been graded.
- Exams can be picked up during office hours.
- Send me one email per group with names of all group members. Indicate which members are taking CpE 214.
- Assignment #5 has been posted. Work on it as soon as possible after this lecture.

Assembly Language Programming for the 8051 ISM Chapter 7 Sections 7.1 – 7.5

Some slides adapted from Microprocessor Systems Notes by
K.T. Ng

Generic Software Development Cycle



8051 Assembly Programming

- Machine instructions show basic capabilities of 8051.
- Assembly language (ASM) is built around these capabilities.
- Our version of ASM is slightly different than that of the textbook.

Machine Language vs. Assembly

7D 25 7F 34 74 00 2D	MOV R5,#25H
	MOV R7,#34H
	MOV A,#0
	ADD A,R5
Machine Language	Assembly Language

- Machine language is a binary sequence interpreted by the computer as a sequence of instructions.
- Assembly language is a form of machine language that uses mnemonics (memory aid) for the instruction type, and operands and is easier for humans to read.
- Generally, one-to-one correspondence between assembly instructions and machine instructions.

Why Study Assembly Language ?

Some notable advantages:

- The object code is usually very efficient and may execute many times faster than object code generated by a high level language.
- Memory can be much more efficiently used in assembly language.
- It provides direct contact with the hardware.
- It provides a good understanding of computer architecture (e.g. data representation, instruction execution, etc.)
- Ideal for embedded controllers where cost needs to be minimized (CPU speed & memory size).

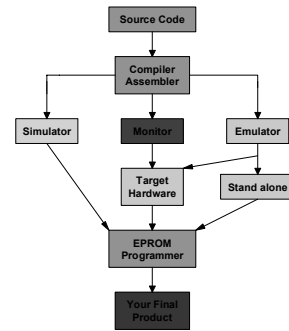
Disadvantages of Assembly Language

- The source code is often very lengthy as compared to high level languages.
- It is machine-dependent, and hence not very portable.
- It takes considerably more time to develop a program in assembly language than with a high-level language.
- It requires a lot of programming experience to be used effectively.

Use of Assembly Language

- The use of assembly language programming is normally restricted to relatively small programs or sections of programs in applications where:
 - Speed of execution is important, e.g., real-time systems.
 - Memory cost or size is a factor.
 - More I/O and control is involved than computation.

Embedded Development Cycle



Tools for Developing Assembly Language Programs

- The program development utilities enable the user to write, assemble, and test assembly language programs; they include:
 - Editor
 - Assembler
 - Linking Loader
 - Monitor and
 - Simulator

Types of Assemblers

- Translation from assembly language to machine instructions done by a program called the assembler.
- There are several types of assemblers, the most common of which are
 - one-pass assembler: The one-pass assembler was the first type to be developed and is therefore the most primitive. Because of the forward reference problem, it is seldom in use nowadays.
 - two-pass assembler: In a two-pass assembler the source code is processed twice. It is the most popular type of assembler currently in use.

Two-Pass Assemblers

- First pass
 - records any known address information
 - records all labels and symbols
 - Assembles opcode and operands
 - Determines how much space each section of code will take
- Second pass
 - Fills in missing addressing information for labels and symbols
 - Produces final object code

From ASM to Executable Code

- Create the assembly source file test.a51
- Assemble the ASM file
 - Assembler produces error and code list in test.lst
 - If no errors, assembler produces .obj file
- Link the .obj files to produce an .abs file
 - May also produce a listing file
- Create hex file from the .abs file
 - Most assemblers directly produce the .hex file
- Download the .hex file onto the board or burn it into an EPROM.

Why the Link Step ?

- The linker is a program that combines relocatable object programs (modules) and produces an absolute object program that is executable by a computer.
- A linker is sometimes called a “linker/locator” to reflect its separate functions of combining relocatable modules (linking) and setting the address for execution (locating).
- Relocatable means that addresses in the object code can be changed (relocated) so that the program can be loaded and executed anywhere in memory.

The Assembler Source File

```
$MOD51
$OBJECT(EXAMPLE1.OBJ) ← generate the intel hex object file
$PRINT(EXAMPLE1.LST) ← generate an listing file

ORG 800H ; Start (origin) at location 800H
MOV R5,#25H ; Load 25H into R5
MOV R7,#34H ; Load 34H into R7
MOV A,#0 ; Load 0 into A
ADD A,R5 ; Add contents of R5 to A
; Now A = R5
ADD A,R7 ; Add contents of R7 to A
; Now A = R5 + R7
ADD A,#12H ; Add to A value 12H
; Now A = R5 + R7 + 12H
HERE: SJMP HERE ; Stay in this loop
END ; End of ASM source file
```

The source code of EXAMPLE1.ASM

(written for Metalink 8051 cross assembler)

The Assembler Listing File

```

EXAMPLE1 1 00000001 PAGE 1
memory 2 $M0001
address 3 $OBJECT(EXAMPLE1.OBJ)
4 $PRINT(EXAMPLE1.LST)
5
6 0000 5 ORG 0000 ; Start (origin) at location 0000
7 0000 7035 6 MOV R5,25H ; Load 25H into R5
8 0002 7F34 7 MOV R7,03H ; Load 03H into R7
9 0004 7400 8 MOV A,0 ; Load 0 into A
10 0006 2D 9 ADD A,R5 ; Add contents of R5 to A
11 0007 2F 10 ADD A,R7 ; Add contents of R7 to A
12 0008 2412 11 ADD A,#12H ; Add to A value 12H
13 000A 00FE 12 HERE: SJMP HERE ; Stay in this loop
14 000B 00FE 13 END ; End of ASM source file
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```

Assembly Programs

- An assembly language file is a text file including:
 - Instructions
 - Pseudo-operations
 - Assembler directive
- Instructions are translated into machine language instructions to be stored in program memory and executed by the CPU.
- Pseudo-operations allocate space for variables or constants.
- Assembler directives are commands to the assembler program.

Structure of a Line of Assembly Language Code

- An assembly language instruction has 4 fields (optional ones are in brackets).
[label:] mnemonic [operands] [:comment]
- The label gives us a way to refer to a memory address so that it will be easier to find and remember.
- The mnemonic is an 8051 instruction or an assembler directive.
- Operands are the arguments of the instruction or directive.
- Comments make the program much easier to read and provide documentation.

Example

- Target 8051 dev system
 - Std 8051 device
 - 2K on-chip ROM running a monitor program
 - 32K external RAM at address 0x0000 to 0x7FFF
 - This RAM is both code and data
 - First 0x30 locations in external RAM are dedicated to the InterruptVector Table (IVT)

```
• Program to fill up the first 4 registers in the
  register bank with some numbers and find their
  sum

Start:    ORG 0x30 ;skip the IVT area
          mov R0, #10
          mov R1, #0A5H
          mov R2, #1
          mov R3, #0x20
clearA:   mov A, #0 ;now A = 0
Addup:   add A, R0 ;now A = A + R0
          add A, R1
          add A, R2
          add A, R3
          mov R4, A ;store sum in R4
          mov DPTR, #7FFF
          movx @DPTR, A ;store in ext. mem
          sjmp done ;loop here forever
Done:    END
```

Slide adapted from UT Dallas

The Label Field

- A label is used to associate a specific line of code, memory location, or constant definition with a text string. Rules are:
 - Labels must begin in the first column with an alphabetic character and end with a colon.
 - It must have a unique character pattern within the first 32 characters.
 - The first character MUST be either a letter or special character (? or _).
 - It must not be a reserved string (e.g. opcode and directives etc.).
 - Labels must not be redefined (reused).

Some Valid and Invalid Labels

- Serial_Port_Buffer: (valid) (invalid)
- less: (valid) (invalid)
- goback: (valid) (invalid)
- delay1: (valid) (invalid)
- 1ST_VARIABLE: (valid) (invalid)
- alpha#: (valid) (invalid)
- MOV (valid) (invalid)
- LOW (valid) (invalid)
- DATA (valid) (invalid)

The Mnemonic Field

- The mnemonic field contains the mnemonic names for machine instructions (e.g. MOV, SUB etc.) and assembler directives (e.g. EQU, ORG etc.).
- If a label is present, the opcode or directive must be separated from the label field by at least one space.
- If there is no label, the operation field must be at least one space from the left margin.

The Operand Field

- Not always present.
- If an operand field is present, it follows the mnemonic field and is separated from the mnemonic field by at least one space.
- The operand field may contain operands for instructions or arguments for assembler directives.

The Comment Field

- Comments begin after opcode/operand with a semi-colon (;), or after a semi-colon in the first column.
- Assembler ignores EVERYTHING that follows a semi-colon until a carriage return/line feed (CR/LF).
- Comments are critical to the source code documentation of an assembly file.

ASM Directive/Pseudo-opcode

- Directive (or known as pseudo-opcode) has the same format as assembler instruction (opcode), but it is **NOT** assembled into machine code.
- They function as commands to the assembler to define properties of the code. These properties include items such as:
 - Addresses to start code or data segments
 - Allocation of memory space
 - Constant or symbol definitions
- Beware ! Assembler directives vary from one software vendor to another.

Typical Assembler Directives

Mnemonic	Function
ORG	This command sets the starting address for the code or data to follow. It let you put code and data anywhere in program memory you wish.
EQU	This command equates the value to a label. The label can then be used as a constant throughout the rest of the code.
DS/DB/DW	DS(define storage) simply allocates memory whereas DB (define single byte) and DW (define word: 2 bytes) to allocate memory space and store an initial value
END	Tells the assembler to stop assembling. Anything after END will be ignored.

Some Examples of Directives

```
                ORG 800H           ;set PC to address 800H
                TEN EQU 10         ;Symbol TEN equated to 10
IO_BUFFER:      DS 8              ;Reserve a buffer (8 bytes)
                                ;for the I/O
                DB 'Hello'        ;ASCII literal
RADIX:          DW 'H',1000H      ;1st byte contains 0
                                ;2nd byte contains 48H
                                ;3rd byte contains 10H
                                ;4th byte contains 0
                                ;"Always high byte first !"
ALSO_TEN        EQU TEN          ;Symbol equated to a
                                ;previously defined symbol.
```

Segment Selection Directives

- Two Types of segments: absolute and relocatable
- Absolute: located at specific location
 - Ex: CSEG at 0000H
 - Types are:
 - CSEG code space
 - DSEG directly addressable internal data space
 - ISEG indirectly addressable internal data space
 - BSEG bit-addressable space
 - XSEG external data space

Relocatable Segments

- Assembler decides location of segment.
 - generally best choice
 - Ex: RSEG segment_name
 - segment_name needs to be previously defined with the SEGMENT directive
 - Ex: mydata SEGMENT data
 - RSEG mydata
 - first directive only defines mydata to be a data segment
 - don't actually use the segment until RSEG directive is issued

Syntax of SEGMENT directive

- symbol SEGMENT segment_type
- segment type can be one of:
 - CODE code
 - DATA directly addressable internal data
 - IDATA indirectly addressable internal data
 - BIT bit
 - XDATA external data
 - CONST constant, typically stored in code space

Example – hardware ports

- C

```
code char x;
xdata PORTA _at_ 0x4000;
```
- Assembly

```
myrom SEGMENT CODE
      RSEG myrom      ;relocatable cseg
x:    DS 1             ;define one byte
XSEG  AT 4000h         ;absolute segment
PORTA: DS 1           ;1 byte port at 4000
```

Usage of Segments

```
<name segment and declare type>
<declare beginning of segment>
  <segment contents (code, vars, consts)>
<next segment>
```

Labels (includes variables)

- Variable are declared in segment.
- Ex:

mybyte:	DS	1
↑	↑	↙
name	define storage	# of bytes
- In program: _____
- Assembler codes as: _____
- ____ is the location chosen by assembler.

Storage Definition Directives

- DS define storage byte
- DSB define storage byte
- DSW define storage word
- DSD define storage double
- DBIT define storage bit

Variables declared outside of segments

- Can be of types: DATA, IDATA, CODE, XDATA and BIT
- Ex:

another	DATA	7FH
↗	↑	↙
name	type	location

Constants in Code Space

- Example:

CSEG	AT	0100H
lookup:	DB	1,2,3,4,5,42
↑	↙	↙
name	define storage	values
- Storage definition could also be of type DW or DD.

More Assembler Directives

- **EXTERN**: declare variables from other modules (ASM files)
- **PUBLIC**: declare variable to be used in other module
- **USING**: tell compiler current register bank
 - Ex:
- **EQU**: create “assembler” constant
 - Ex:
- **END**: last statement in source file

Immediate Data

Example:

- **MOV A, #2AH** ; hex
- **MOV A, _____** ; decimal
- **MOV A, _____** ; binary
- **MOV A, _____** ; _____ is default
- **MOV A, _____**

SFRs

- Example:
 - **SETB D7H**
 - **SETB _____**
- Example:
 - **SETB D0H**
 - **SETB _____**
- SFRs can generally be referenced by name.

General Program Layout

- **Data Segments**
 - declare segments
 - declare variables
- **Code segments**
 - declare segments
 - declare constants