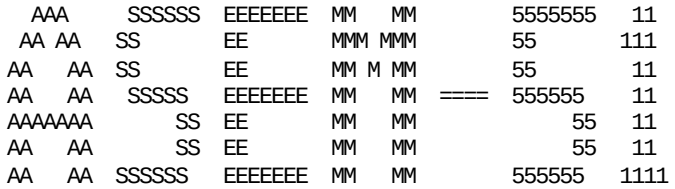
MCS-51 Microcontroller Family Macro Assembler



U S E R ' S M A N U A L

Version 1.3

June 25, 2002

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Foreword to Version 1.0

Today microcontrollers are used in a wide range of applications from simple consumer electronic products to complex avionic components. Thus I was not very surprised to find an 80C31 on the videotext decoder board, I purchased some time ago. Since it had a poor user interface and many bugs, I thought I could do it better and so I began to look for an 8051 cross assembler.
But in contrast to the huge number of hardware components sold, the number of people developing microcontroller software seemed to be remarkable small, and so was the number of development tools on the market.
There was a very small number of good professional cross assemblers for $250 and up - too expensive for hobby purposes. Aside of useless demos, there were no restricted starter kits or school versions available.
I found also a few shareware and public domain assemblers. But either they were poor and not very reliable, or not very 8051-specific, or they used some kind of fantasy syntax that was 100 % compatible to itself, but far away from the Intel standard. I didn't like them all!
There seems to be a general lack of useful and affordable microcontroller development software. This is a pity, because their universality, simple architectures and low prices make microcontrollers so interesting especially for hobby and education.
So I decided to write a handy 8051 cross assembler for the PC.

And here it is: ASEM-51 V1.0

I hope it will help to discover the wonderful world of microcontrollers.

Have fun!

Deisenhofen, July 19, 1994

W.W. Heinz

Foreword to Version 1.2

More than one year has passed, since I had released ASEM-51 V1.1 in October 1994. Although I didn't spend all the time on ASEM-51, V1.2 comes with several extensions, bug fixes, and numerous functional or internal improvements!
Highlights of the new version are a nearly perfectly featured list file with cross-reference and some new printing options, a bootstrap program for MCS-51 evaluation boards, and plenty of new *.MCU files. For detailed information see the ASEM-51 V1.2 Release Notes.

What I have learned through the last two years is that freeware is not free, neither for the author nor for the users.
ASEM-51 could not be made with nothing but numberless free hours, spent on pure software development. I also had to purchase a PASCAL development system, lots of microcontroller literature, and an 80C535 evaluation board.
The distribution of freeware seems to be a bigger problem than its development. First of all, one has to buy a modem. After that, it costs a lot of time, fees, trouble, and "interesting" discussions with the particular sysops, until the stuff is posted (or not) on several BBS and ftp sites.
To publish a program on shareware CD-ROMs, one has only to find out, which are the most suitable. For this, it is best to buy a dozen or two (and a CD-ROM drive), and to send the software to the publishers of those that seem to be the most popular.
The interested users finally have to purchase modems or CD-ROM drives, and pay the same fees, or buy the same CD-ROMs, to get the "freeware" again from these public sources.
After all, it may be cheaper, faster, and more convenient, to simply buy a professional software solution (if any) in the PC shop at the corner.
But it's not half the fun!

ASEM-51 V1.1 had been distributed (and mirrored) to more than 60 ftp sites all over the world, uploaded to so many BBS, and published on at least two shareware CD-ROMs.
But I only received mails from 9 users, a local cockroach, and an international monster. The latter two asked me for permission, to sell ASEM-51 for (their) profit, and failed miserably.
Most of the user mails started with "I have copied your assembler from an ftp site, which I don't remember. It is looking fine on the first glance! By the way, have you got a data sheet of the 80Cxyz?", or something like that.
During all the time, I have received one single error report only. Since it had been reported by phone, I couldn't reproduce it.
Nevertheless two serious bugs have been fixed since version 1.1, but I have found them by myself in November 1995 both.
Sure ASEM-51 is no mainstream software, but to be honest, I am a little disappointed of the poor user feedback!

Finally, I should thank the persons, who helped me to release ASEM-51:
Andreas Kies has tested all previous beta versions of the assembler. He has distributed the first releases, and maintained a free ASEM-51 support account right from the beginning.
Gabriele Novak has checked the orthography of all the documentation files.
Werner Allinger has tested the latest beta version and the bootstrap program.
Last but not least, I want to thank all interested users for their comments and suggestions.

Deisenhofen, January 22, 1996

W.W. Heinz

I. Introduction

ASEM-51 is a two-pass macro assembler for the Intel MCS-51 family of microcontrollers.
It is running on IBM-PC/XT/AT computers and all true compatibles under MS-DOS, Windows, and Linux.
The DOS real-mode assembler ASEM.EXE requires only 256 kB of free DOS memory and MS-DOS 3.0 (or higher).
The new protected-mode assembler ASEMX.EXE requires a 286 CPU (or better), and at least 512 kB of free XMS memory.
The new Win32 console-mode assembler ASEMW.EXE requires a 386 CPU (or better) and Windows 9x, NT, 2000 or XP.
The new Linux assembler asem requires a 386-based Linux system.
The new HTML documentation set requires a 90 MHz Pentium (or better) and a web browser.

The ASEM-51 assembly language is a rich subset of the Intel standard that guarantees maximum compatibility with existing 8051 assembler sources.
ASEM-51 can generate two sorts of object files: Intel-HEX format, which is directly accepted by most EPROM programmers, and absolute OMF-51 format, which is required for many simulators, emulators and target debuggers.
Thus ASEM-51 is suitable for small and medium MCS-51-based microcontroller projects in hobby, education and business. However, ASEM-51 has been designed to process also very large programs! Its most important features are:

- fast, compact, reliable, easy to use, and well-documented
- easy installation, almost no configuration required
- command line operation, batch and networking capability
- fully year 2000 compliant
- DOS (RM and PM), Win32 and Linux binaries included
- Intel-compatible syntax
- five location counters, one for each of the MCS-51 address spaces
- assembly-time evaluation of arithmetic and logical expressions
- segment type checking for instruction operands
- automatic code optimization of generic jumps and calls
- macro processing (that _really_ works)
- nested include file processing
- nested conditional assembly
- absolute OMF-51 module output (with debug information)
- Intel-HEX file output
- hex-to-binary conversion utility
- built-in symbols for 8051 special function registers (can be disabled)
- direct support of more than seventy 8051 derivatives
- support of user-defined 8051 derivatives
- special support of the Philips 83C75x family
- 8051 register bank support
- detailed assembler listing with symbol table or cross reference
- further fancy printing facilities ;-)
- documentation in ASCII and HTML format
- bootstrap program for testing on the MCS-51 target board
- support for easy integration into the popular Borland IDE
- limited update service by the author

The ASEM-51 software package has been developed with:

Borland-Pascal mit Objekten 7.0 (c) Borland International 1992
Delphi 2.0 Client/Server Suite (c) Borland International 1996
FreePascal 1.00 (c) Florian Klaempfl 2000

II. Getting started

This chapter describes the ASEM-51 distributions, their installation on the supported host platforms, and how to use them in daily work.

II.1 DOS and Windows Implementation

Until version 1.2, ASEM-51 was available in a real-mode implementation for plain MS-DOS only. Meanwhile a DOS protected-mode version and a Win32 console mode version have been added to the package.
In contrast to the new Linux implementation, all the DOS and Windows flavours are functionally identical and their basic operation can therefore be described together. Only a few minor differences and special features have to be discussed separately.
Since it should be possible to share program sources with the Linux version, all DOS and Windows executables are able to read ASCII files in both DOS and UNIX format, but write ASCII files in their native (DOS) format only.

II.1.1 Files

Your ASEM-51 distribution archive for DOS/Windows should contain the following groups of files:

1.)	ASEM_51.DOC	ASEM-51 User's Manual, ASCII format
	DOCS.HTM	index file of the ASEM-51 documentation, HTML format
	*.HTM	further pages of the HTML documentation
	*.GIF	GIF images referenced by HTML pages
	*.JPG	JPEG images referenced by HTML pages
	ASEM.EXE	assembler (DOS real-mode)
	ASEM.PIF	ASEM program information file for Windows 3.1x
	ASEM.ICO	ASEM icon file for Windows 3.1x
	ASEM2MSG.EXE	ASEM-51 message filter for Borland-IDE
	ASEM2MSG.PAS	Turbo-Pascal source of ASEM2MSG.EXE
	ASEMX.EXE	assembler (DOS protected-mode)
	ASEMX.PIF	ASEMX program information file for Windows 3.1x
	ASEMX.ICO	ASEMX icon file for Windows 3.1x
	DPMI16BI.OVL	Borland's 16-bit DPMI server (for ASEMX.EXE)
	RTM.EXE	Borland's 16-bit DPMI runtime manager
	ASEM32.BAT	runs ASEMX with Borland's 32-bit DPMI server
	ASEMW.EXE	assembler (Win32 console-mode)
	HEXBIN.EXE	hex-to-binary conversion utility (DOS)
	HEXBINW.EXE	hex-to-binary conversion utility (Win32)
	DEMO.A51	a sample 8051 assembler program
	*.MCU	processor definition files of 8051 derivatives (for a detailed list of MCU files see chapter "VI. Support of 8051 Derivatives")
2.)	BOOT51.DOC	BOOT-51 User's Manual, ASCII format
	BOOT51.HTM	index file of the BOOT-51 documentation, HTML format
	BOOT51.A51	BOOT-51 assembler source (requires ASEM-51 V1.3)
	CUSTOMIZ.EXE	BOOT-51 customization utility
	BOOT.BAT	batch file for application program upload
	UPLOAD.BAT	called by BOOT.BAT only
	COMPORT.EXE	setup utility for PC serial ports
	RESET51.EXE	program to reset target system via PC ports
	SLEEP.EXE	program to wait for the reset recovery time
	BLINK.A51	sample test program for BOOT-51
3.)	README.1ST	quick information, ASCII format
	LICENSE.DOC	ASEM-51 License Agreement, ASCII format
	RELEASE.130	ASEM-51 Release Notes, ASCII format
	SUPPORT.DOC	ASEM-51 Support Guide, ASCII format
	INSTALL.BAT	creates a proper ASEM-51 installation under MS-DOS
	KILLASEM.BAT	deletes all files of the ASEM-51 package (DOS)

The first group contains all files directly associated with the assembler. The second group contains all files directly associated with the bootstrap program. The third group contains general support and documentation files

that apply to the whole package.

II.1.2 Installation under MS-DOS or Windows

In principle ASEM-51 doesn't require a fuzzy software installation or configuration. In the simplest case you can copy all files of the package to your working directory, and enjoy the benefits of true plug-and-play compatibility!
On the other hand, an installation of ASEM-51 under MS-DOS is very simple:

- Create a new, empty scratch directory on your harddisk.

- Unpack your ASEM-51 distribution archive into this directory, or copy all files of the ASEM-51 package into it.

- Make the scratch directory default, run the batch file INSTALL.BAT provided, and follow the instructions.

If you don't like anything that is running automatically, or things are not quite clear, ASEM-51 can also be installed manually as follows:

- Create a new directory on your harddisk, e.g. C:\ASEM51.

- Copy all files of the ASEM-51 package into this directory.

- Append it to your PATH statement in file AUTOEXEC.BAT, e.g.

```
PATH C:\DOS;C:\UTIL;C:\ASEM51
```

- If this has not already been done while unpacking the distribution archive, create a subdirectory, e.g. C:\ASEM51\MCU, and move all the *.MCU files provided to this subdirectory, for better survey.

- Create another subdirectory, e.g. C:\ASEM51\HTML, and move all the *.HTM, *.GIF and *.JPG files to this subdirectory, respectively. (To read that HTML manual, invoke your web browser and start with file C:\ASEM51\HTML\DOCS.HTM!)

- Optionally define a DOS environment variable ASEM51INC in AUTOEXEC.BAT, to specify a search path for include files, e.g.

```
SET ASEM51INC=C:\ASEM51\MCU;D:\MICROS\MCS51\INCL
```

- For a proper operation of the Borland 16-bit DPMI server on computers with more than 16 MB RAM, be sure that EMM386.EXE (included in DOS 5.0 or later) is loaded, and define the environment variable DPMIMEM in AUTOEXEC.BAT as follows:

```
SET DPMIMEM=MAXMEM 16383
```

- Reboot your PC.

II.1.3 DOS Command Line Operation

ASEM-51 provides full support of command line operation and batch capability as the best commercial development tools. ;-)
Nevertheless, it can be integrated into foreign development environments, if desired. The assembler is invoked by typing:

```
ASEM <source> [<object> [<listing>]] [<options>]
```

where <source> is the 8051 assembler source, <object> is the output file, and <listing> is the assembler list file. The parameters <object> and <listing> are optional. When omitted, the file names are derived from the <source> file name, but with extensions HEX (or OMF) and LST. All file names may be specified without extensions. In these cases, the assembler adds default extensions as shown below:

file	extension

```
<source>        .A51
<object>        .HEX      (with /OMF-51 option: .OMF)
<listing>       .LST
```

If you want a file name to have no extension, terminate it with a '.'!
Instead of file names you may also specify device names to redirect the output to character I/O ports. Device names may be terminated with a ':'! It is not checked, whether the device is existing or suitable for the task. Although it is possible to read the source file from a character device (e.g. CON:) instead of a file, this cannot be recommended: Since ASEM-51 is a two-pass assembler, it always reads the source file twice!

ASEM recognizes the following options:

```
/INCLUDES:path1[;path2[; ... ;pathn]]
/DEFINE:symbol[:value[:type]]
/OMF-51
/COLUMNS
/QUIET
```

When the /INCLUDES option is used, the assembler searches the specified path for include files that cannot be found in the working directory. The path may be any number of directories separated by ';' characters. The directories will be searched from left to right. The path, specified with the /INCLUDES option, is searched before the path, defined with the (optional) DOS environment variable ASEM51INC!

The /DEFINE option is useful for selecting particular program variants from the command line that have been implemented with conditional assembly. It allows to define a symbol with a value and a segment type in the command line. Value and type are optional. The segment type of the symbol defaults to NUMBER, if omitted. The symbol value defaults to 0, if omitted. The symbol value may be any numerical constant. The symbol type must be one of the following characters:

```
C   =   CODE
D   =   DATA
I   =   IDATA
X   =   XDATA
B   =   BIT
N   =   NUMBER    (default)
```

By default, ASEM-51 generates an object file in Intel-HEX format.
When the /OMF-51 option is specified, an absolute OMF-51 module is generated.

Options may be abbreviated as long as they remain unique!

Examples:

0.) ASEM

When invoked without parameters, the assembler displays a help screen:

```
MCS-51 Family Macro Assembler ASEM-51 V1.3

usage:     ASEM <source> [<object> [<listing>]] [options]

options:        /INCLUDES:path1;path2;path3
                /DEFINE:symbol[:value[:type]]
                /OMF-51
                /COLUMNS
                /QUIET
```

1.) ASEM PROGRAM

will assemble the 8051 assembly language program PROGRAM.A51 and produce an Intel-HEX file PROGRAM.HEX and a listing PROGRAM.LST.

2.) ASEM TARZAN.ASM JANE JUNGLE.PRN

will assemble the 8051 assembly language program TARZAN.ASM and produce an Intel-HEX file JANE.HEX and a listing JUNGLE.PRN.

3.) ASEM PROJECT EPROM.

will assemble the 8051 assembly language program PROJECT.A51 and produce an Intel-HEX file EPROM and a listing PROJECT.LST.

4.) ASEM ROVER /OMF

will assemble the 8051 assembly language program ROVER.A51 and produce an absolute OMF-51 object module ROVER.OMF and a listing ROVER.LST.

5.) ASEM sample COM2: NUL

will assemble the 8051 assembly language program SAMPLE.A51, send the HEX file output to the serial interface COM2 and suppress the list file output by sending it to the NUL device.

6.) ASEM APPLICAT /INC:C:\ASEM51\MCU;D:\MICROS\8051\HEADERS

will assemble the program APPLICAT.A51, while all required include files will be searched first in the default directory, then in C:\ASEM51\MCU, and finally in D:\MICROS\8051\HEADERS.

7.) ASEM UNIVERSL /D:Eva_Board:8000H:C

will assemble the program UNIVERSL.A51, while the CODE symbol EVA_BOARD will be predefined with value 8000H during assembly.

When program errors are detected, they are flagged on the console. This may look as follows:

```
MCS-51 Family Macro Assembler ASEM-51 V1.3

APPLICAT.A51(14): must be known on first pass
USERBITS.INC(6): attempt to divide by zero
DEFINES.INC(37): symbol not defined
APPLICAT.A51(20): symbol not defined
APPLICAT.A51(27): no END statement found

     5 errors detected
```

Every error is flagged with the name of the source or include file, the local line number where it was found, and the error message itself. This output format makes it easy to integrate ASEM-51 into existing foreign development environments or workbenches.
A perfect fit for the Turbo C++ IDE (and perhaps others) can be reached with the /COLUMNS option. When specified, the column numbers of program errors are output additionally after the line numbers:

```
MCS-51 Family Macro Assembler ASEM-51 V1.3

APPLICAT.A51(14,12): must be known on first pass
USERBITS.INC(6,27): attempt to divide by zero
DEFINES.INC(37,18): symbol not defined
APPLICAT.A51(20,18): symbol not defined
APPLICAT.A51(27,1): no END statement found

     5 errors detected
```

If errors are detected in macro expansion lines, there is no corresponding location in the source file. Therefore, the error is flagged with the name of the source or include file, and the local line number from where the macro expansion has been invoked. (For callable macros this is the line with the macro call, and for repeat blocks this is the ENDM line.)
To give the user a hint, the macro name and expansion line (and optionally column) number are inserted before the actual error message:

```
        MCS-51 Family Macro Assembler ASEM-51 V1.3

        UARTIO.A51(44,1): RECEIVE(3,22): segment type mismatch
        UARTIO.A51(87,1): REPT(4,19): symbol not defined
        UARTIO.A51(87,1): REPT(8,19): symbol not defined
        UARTIO.A51(87,1): REPT(12,19): symbol not defined

             4 errors detected
```

The expansion line number is the number of the expansion line within the corresponding macro expansion, starting with 1. If the error occurs during expansion of a repeat block, the keyword REPT replaces the macro name.

The /QUIET option suppresses all console output except error messages.

When terminating, ASEM-51 returns an exit code to the operating system:

situation	ERRORLEVEL
no errors	0
program errors detected	1
fatal runtime error	2

Note: Warnings do not influence the exit code!

II.1.4 DOS Environment

To specify a search path for include files, an optional environment variable ASEM51INC can be defined:

```
SET ASEM51INC=<path>
```

<path> may be any number of directories separated by ';' characters.
Be sure that the whole definition doesn't contain any blanks or tabs!
If ASEM51INC is defined, the assembler searches the specified <path> for include files that can neither be found in the working directory, nor in the search path specified with the /INCLUDES option.
The <path> directories will be searched from left to right.

Examples:

1.) `SET ASEM51INC=C:\ASEM51\MCU;D:\MICROS\MCS51\INCL`

   If include files can neither be found in the working directory, nor in the /INCLUDES path (if specified), the assembler searches next C:\ASEM51\MCU and finally D:\MICROS\MCS51\INCL.

2.) `SET ASEM51INC=C:\ASEM51\MCU;%PATH%`

   If ASEM51INC is defined as above in AUTOEXEC.BAT after the PATH statement, the assembler finally searches the directory C:\ASEM51\MCU and then all the directories, contained in the DOS program search path, from left to right!

The maximum length of <path> is limited to 255 characters. This cannot be exceeded with the SET command of the DOS command interpreter COMMAND.COM, but with third party command interpreters like 4DOS (max. 512 characters)!

Note that trailing blanks and tabs behind the names of environment variables seem to be considered significant under MS-DOS! If one subsequently defines

```
SET ASEM51INC =C:\ASEM51\MCU
```
and
```
SET ASEM51INC=C:\8051\MCU
```

there will be two (!) entries concurrently in the DOS environment! However, the assembler will recognize the second one only. Since DOS doesn't truncate trailing blanks and tabs from variable names, the assembler can't do this either! That is why you should be sure, to always define the environment variable without blanks and tabs.

II.1.5 Running ASEM-51 in the Borland-IDE

Turbo C++ (1.0 thru 3.0) users will appreciate the possibility to invoke ASEM-51 as a transfer program from the Borland IDE.
For this, the filter program ASEM2MSG for the ASEM-51 error messages has been provided. To integrate ASEM-51 into the Borland IDE, perform the following steps:

- Be sure that ASEM-51 has been installed properly as described before, or that ASEM.EXE and ASEM2MSG.EXE are somewhere in your PATH.

- Start the Turbo C++ (or Borland C++) IDE for DOS.

- For Turbo C++ 1.0, first click: Options | Full menus | ON

- Click from the menu bar: Options | Transfer

- When the "Transfer" dialog box is active, press the Edit button.

- Now the "Modify/New Transfer Item" dialog box should be active. Fill in the following items:

```
Program Title:   ASEM-~51
Program Path:    ASEM
Command Line:    $NOSWAP $SAVE CUR $CAP MSG(ASEM2MSG) $EDNAME /C
Translator:      [X]
Hot key:         Shift F8
```

  Then press the New button.

- When returned to the "Transfer" dialog box, press the OK button.

- Click from the menu bar: Options | Save | OK

Now it should be possible, to assemble the file in the active edit window with ASEM-51, when pressing Shift-F8. The error messages (if any) should appear in the "Message" window. You can browse through the errors, and jump into the source text by simply pressing <Enter>. This even works, if the error is not in the program itself, but in an include file!

Turbo-Pascal 7.0 users can also employ their Borland IDE for assembly.
To integrate ASEM-51 into the Turbo-Pascal IDE, perform the following steps:

- Be sure that ASEM-51 has been installed properly as described before, or that ASEM.EXE and ASEM2MSG.EXE are somewhere in your PATH.

- Start the Turbo-Pascal 7.0 (or Borland-Pascal 7.0) IDE for DOS.

- Click from the menu bar: Options | Tools

- When the "Tools" dialog box is active, press the New button.

- Now the "Modify/New Tool" dialog box should be active. Fill in the following items:

```
Title:           ASEM-~5~1
Program path:    ASEM
Command line:    $NOSWAP $SAVE CUR $CAP MSG(ASEM2MSG) $EDNAME
Hot keys:        Shift+F8
```

  Then press the OK button.

- When returned to the "Tools" dialog box, press the OK button.

- Click from the menu bar: Options | Environment | Preferences

- When the "Preferences" dialog box is active, disable the "Close on go to source" item in the "Options" checkbox. Then press the OK button.

- Finally click from the menu bar: Options | Save

Now ASEM-51 can be invoked with Shift-F8, to assemble the program in the active edit window, while error messages (if any) appear in the "Messages" window.

Users of both Turbo C++ and Turbo-Pascal should prefer the Turbo C++ IDE. In the Turbo-Pascal 7.0 IDE, the /COLUMNS (or /C) option has no effect! Turbo-Pascal versions prior to 7.0 didn't implement the Tools menu.

Note that the transfer macro $SAVE CUR saves the contents of the active edit window (if modified), before ASEM.EXE is invoked! If your assembler program includes further source files (which may be currently loaded into other edit windows), better specify $SAVE ALL. This will save the contents of all (modified) edit windows to disk files, before invoking ASEM.EXE! If you are not sure, specify $SAVE PROMPT. This will prompt you for every (modified) edit window to save the contents before running ASEM.EXE. For further information on transfer macros, refer to the Borland online help!

II.1.6 Running ASEM-51 from Windows 3.1x

Of course ASEM and ASEMX are running fine in the Windows 3.1x DOS-Box! But for integration into the Windows 3.1x desktop, the files ASEM.PIF and ASEM.ICO have been provided. To insert ASEM-51 into a group of the Program Manager, perform the following steps:

- Be sure that ASEM-51 has been installed properly for MS-DOS as described before.

- Start Windows 3.1x and expand the Program Manager window to its full screen size representation, if necessary.

- Focus the program group in which ASEM-51 is to be inserted, e.g. "Applications".

- Click from the Program Manager menu bar: File | New

- When the "New Program Object" dialog box is active, choose the option "Program Item", and click the OK button.

- Now the "Program Item Properties" dialog box should be active. Fill in the following items:

```
Description:          ASEM-51
Command Line:         ASEM.PIF
Working Directory:                (whatever you want)
Shortcut Key:                     (whatever you want)
Run Minimized:        [ ]
```

  Then press the [Change Icon] button.

- Now a message box appears with the error message "There are no icons available for the specified file". Simply press the OK button.

- The "Change Icon" dialog box should be displayed now. Fill in

```
File Name:      ASEM.ICO
```

  and press the OK button. Now the ASEM-51 icon should be displayed in the icon field. Press the OK button again.

- When returned to the "Program Item Properties" dialog box, press the OK button.

(In national Windows versions, things may look slightly different.)

Now ASEM.EXE can be invoked by simply double-clicking the ASEM-51 icon. After entering the program parameters in a corresponding dialog box, ASEM is running in a DOS window, which remains open after program termination, to let you have a look on the error messages.

In principle, the installation of the protected-mode assembler ASEMX.EXE can also be done as described above. However, the <Description> field should be filled with "ASEM-51 XMS", the <Command Line> should be "ASEMX.PIF", and the icon <File Name> should be ASEMX.ICO instead.

II.1.7 Running ASEM-51 from BRIEF

BRIEF 3.x users can integrate ASEM-51 into their editor by simply defining another DOS environment variable in their AUTOEXEC.BAT with

```
SET BCA51="ASEM %%s"
```

This specifies the command for compiling files with extension *.A51. After that, ASEM-51 can be invoked from BRIEF with Alt-F10.

II.1.8 The DOS Protected-Mode Assembler ASEMX

In general, the proven real-mode assembler ASEM.EXE is sufficient also for very large programs. Nevertheless, it may be running out of memory, if a program contains a huge number of long user-defined symbols, or lots of large macro definitions.
To close the gap, the ASEM-51 package includes the new protected-mode assembler ASEMX.EXE. ASEMX is functionally identical to ASEM, but it can use extended memory, to meet extreme workspace requirements.
ASEMX is accompanied by Borland's 16-bit DPMI server DPMI16BI.OVL and runtime manager RTM.EXE. It requires a 286 CPU (or better), and at least 512 kB of free XMS memory (1 MB recommended)!
When ASEMX is invoked, DPMI16BI.OVL and RTM.EXE must be either

- in your default directory,
- where ASEMX.EXE is, or
- somewhere in your PATH

During startup, the DPMI server tries to allocate all the remaining free XMS memory for use by ASEMX. If you don't want this, you can restrict the amount of allocated memory with the DOS environment variable DPMIMEM:

```
SET DPMIMEM=MAXMEM n
```

will restrict the XMS memory space, used for the DPMI interface, to n kB. Never set n to a value greater than 16383!!!

In general, the Borland DPMI interface is very reliable and does normally not conflict with other memory managers. ASEMX will also run with other versions of DPMI16BI.OVL and RTM.EXE provided with various Borland software packages (except TC++ 3.0 and BC++ 3.1).

However, there is trouble ahead on systems with more than 16 MB RAM! Without specific installation, there is a fatal tendency to crash, hang, or even boot, whenever a DPMI program like ASEMX is invoked.
For proper operation of the DPMI interface, MS-DOS 5.0 (or later) is required, and EMM386.EXE must be loaded!
If EMM386.EXE has been loaded with parameters (e.g. NOEMS), the Borland 16-bit DPMI server cannot handle more than 16 MB! However, without parameters (i=nnnn, x=nnnn are o.k.) or with other DPMI servers there may be more. In these cases, ASEMX can use up to 64 MB of extended memory!

If ASEMX is running in a system environment with an own DPMI server, e.g. the Windows DOS-Box, RTM.EXE will detect this and use the active DPMI server instead of DPMI16BI.OVL. In this case, the environment variable DPMIMEM has no effect.
To restrict (or increase) the available XMS memory for the Windows 3.1x DOS prompt, change file DOSPRMPT.PIF in your WINDOWS directory with the Windows PIF file editor.
For further information on how to make more or less XMS memory available to application programs in other system environments, see the corresponding user manuals.

Another interesting alternative is the Borland 32-bit DPMI server with virtual memory management. It cannot be provided with the ASEM-51 package

for license reasons, but is contained in Borland's Turbo-Assembler 4.0 and 5.0, Borland C++ 4.5x and 5.0x, and maybe others. It has originally been developed for the Borland command line tools, but it also works with ASEMX. It requires a 386 CPU (or better), and allows to extend the free physical memory with a swap file that can be created with the program MAKESWAP.EXE. Apart of that, the 32-bit DPMI server DPMI32VM.OVL and the runtime manager 32RTM.EXE are required.
The batch file ASEM32.BAT, provided with the ASEM-51 package, shows how to run ASEMX with 64 MB of virtual memory, using Borland's 32-bit DPMI server.

II.1.9 The Win32 Console-Mode Assembler ASEMW

In principle, the DOS assemblers ASEM and ASEMX are also running in the Windows 9x/NT/2000/XP DOS-Box, but with some typical DOS-specific limitations: file names are restricted to the 8.3 format, path strings are limited to 64 characters, the real-mode assembler cannot access more than 640 kB RAM, and so on.
To overcome these disadvantages, the ASEM-51 package comes with the new Win32 console-mode assembler ASEMW.EXE. ASEMW is functionally identical to ASEM, but it can handle long file names and benefits of the Win32 memory management, which allows to assemble astronomically large programs!

Hint: If you love file names with blanks in the middle, you have to enclose them in double quotes, e.g.

```
ASEMW "Test-Program for my 80C32 Evaluation-Board.a51"
```

II.1.10 The HEXBIN Utility

Most EPROM programmers are accepting the Intel-HEX object file format that is output by ASEM-51. However, for dumb EPROM burners and special purposes it might be useful to convert the HEX file to a pure binary image file. For this the conversion utility HEXBIN is provided.
It is invoked as follows:

```
HEXBIN <hex> [<bin>] [/OFFSET:o] [/LENGTH:l] [/FILL:f] [/QUIET]
```

where <hex> is the input file in Intel-HEX format, and <bin> is the binary output file. The parameter <bin> is optional. When omitted, the file name is derived from the <hex> file name, but with the extension BIN. All file names may be specified without extensions. In these cases, the program adds default extensions as shown below:

file	extension
<hex>	.HEX
<bin>	.BIN

If you want a file name to have no extension, terminate it with a '.'! Instead of file names you may also specify device names to redirect the output to character I/O ports. Device names may be terminated with a ':'! It is not checked, whether the device is existing or suitable for the task.

The binary file output can also be controlled with the options /OFFSET, /FILL and /LENGTH.
Normally the first byte in the binary file is the first byte of the HEX record with the lowest load address. If a number of dummy bytes is to be inserted on top of the file (e.g. for alignment in an EPROM image), this can be performed with the /OFFSET option:

```
/OFFSET:1000
```

would insert 4096 dummy bytes before the first byte of the first HEX record loaded. The offset must always be specified as a hex number. The default offset is 0.
Since there may be peepholes between the HEX records, a fill byte value can be defined with the /FILL option:

```
/FILL:0
```

would fill all peepholes between the HEX records with zero bytes as well as all the dummy bytes that might have been inserted with the /OFFSET or /LENGTH option. The fill byte value must always be specified as a hex number.
The default fill byte is the EPROM-friendly FFH.
By default the last byte in the binary file is the last byte of the HEX record with the highest load address. If the binary file should have a well defined length, then a number of dummy bytes can be appended to the file (e.g. for exactly matching an EPROM length), this can be performed with the /LENGTH option:

```
/LENGTH:8000
```

would append as many dummy bytes behind the last byte of the file, that the total file length becomes exactly 32768 bytes. The file length must always be specified as a hex number.
When HEXBIN has been invoked with all the above options, it may display a file conversion report like this:

```
Hex File Converter HEXBIN V2.3

             offset:     1000H bytes
      first address:     9000H
       last address:     A255H
fill peepholes with:       00H
binary image length:     8000H bytes
```

The /QUIET option suppresses this console output, while error messages are displayed regardless.

Options may be abbreviated as long as they remain unique!

Examples:

0.) HEXBIN

When invoked without parameters, HEXBIN displays a help screen:

```
Hex File Converter HEXBIN V2.3

usage:       HEXBIN <hexfile> [<binary>] [options]

options:     /OFFSET:offset
             /LENGTH:length
             /FILL:fillbyte
             /QUIET
```

1.) HEXBIN PROGRAM

will convert the Intel-HEX file PROGRAM.HEX to a pure binary image file PROGRAM.BIN.

2.) HEXBIN TARZAN.OBJ JUNGLE/FILL:E5

will convert the Intel-HEX file TARZAN.OBJ to a binary image file JUNGLE.BIN and fill all peepholes between the HEX file records with the binary value E5H.

3.) HEXBIN PROJECT EPROM. /off:8000 /length:10000 /f:0

will convert the Intel-HEX file PROJECT.HEX to a binary image file EPROM, insert 32K dummy bytes on top of file, fill all peepholes and the dummy bytes with nulls, and extend the file to exactly 64K.

When terminating HEXBIN returns an exit code to the operating system:

situation	ERRORLEVEL
no errors	0
conversion errors detected	1
fatal runtime error	2

There is also a Win32 console-mode version of HEXBIN: HEXBINW.EXE!
HEXBINW is functionally identical to HEXBIN, but can handle long file names.

II.2 Linux Implementation

Until version 1.2, ASEM-51 was available for MS-DOS only.
To get rid of the original DOS "look and feel", many interfaces to the operating system had to be modified or rewritten, e.g. command line processing, console I/O, file handling, UNIX environment, and memory management. Furthermore, the general behaviour of the programs had to be adapted to UNIX conventions.
A certain rest of DOS flavour may still be remaining though.
On the other hand, the Linux binaries are able to read ASCII files in both DOS and UNIX format. However, ASCII files are always written in UNIX format.
All these differences make it necessary to describe the Linux implementation in a separate section!

II.2.1 Files

Your ASEM-51 distribution archive for Linux should contain the following groups of files:

1.)	asem_51.doc	ASEM-51 User's Manual, ASCII format
	docs.htm	index file of the ASEM-51 documentation, HTML format
	*.htm	further pages of the HTML documentation
	*.gif	GIF images referenced by HTML pages
	*.jpg	JPEG images referenced by HTML pages
	asem	assembler (Linux 386)
	asem.1	man-page for asem
	hexbin	hex-to-binary conversion utility (Linux 386)
	hexbin.1	man-page for hexbin
	demo.a51	a sample 8051 assembler program
	*.mcu	processor definition files of 8051 derivatives (for a detailed list of MCU files see chapter "VI. Support of 8051 Derivatives")
2.)	boot51.doc	BOOT-51 User's Manual, ASCII format
	boot51.htm	index file of the BOOT-51 documentation, HTML format
	boot51.a51	BOOT-51 assembler source (for ASEM-51 V1.3 and up)
	customiz	BOOT-51 customization utility (Linux 386)
	customiz.1	man-page for customiz
	boot	shell script for application program upload
	boot.1	man-page for boot
	upload	called by boot only (generic version)
	upload.new	"new" upload (optimized for stty 2.0 or later)
	reset51	program to reset the target system via PC ports
	reset51.1	man-page for reset51
	blink.a51	sample test program for BOOT-51
3.)	README.1ST	quick information, ASCII format
	license.doc	ASEM-51 License Agreement, ASCII format
	release.130	ASEM-51 Release Notes, ASCII format
	support.doc	ASEM-51 Support Guide, ASCII format
	install.sh	creates a proper ASEM-51 installation under Linux
	uninst51.sh	deletes all files of the ASEM-51 package (Linux)

II.2.2 Installation under Linux

ASEM-51 for Linux is available as a tar archive and an rpm package.
If you have got the rpm package, login as root and simply type

```
rpm -i asem51-1.3-1.i386.rpm
```

The rpm package has been tested on S.u.S.E.-Linux only, but should also work on other Linux distributions that meet the FHS directory standard.
If you have got the tar archive, perform the following steps:

```
gzip -d asem51-1.3-ELF.tar.gz
```

```
   tar xvf asem51-1.3-ELF.tar
   cd asem51
   sh install.sh
```

If you are installing ASEM-51 as root (preferred), the installation script
install.sh will install the whole package in /usr/local/share/asem-51/1.3,
and establish some symbolic links in /usr/local/bin and /usr/local/man/man1.

If you are installing ASEM-51 under another user-id, install.sh tries to
install the software in your home directory under ~/asem-51/1.3, and
establish some symbolic links in ~/bin and ~/man/man1.

For details see the messages, install.sh is displaying on the console,
and do some fine-tuning accordingly:

If you haven't installed ASEM-51 as root, it may be necessary to add
~/bin to your PATH, and ~/man to your MANPATH.

To specify a search path for the include files *.mcu provided, you can
define an optional environment variable ASEM51INC.
For this, bash, ksh, and sh users should insert the following lines into
their .profile file:

```
    ASEM51INC=/usr/local/share/asem-51/1.3/mcu
    export ASEM51INC
```

csh, tcsh, and zsh users should insert the following line into their
.login file respectively:

```
    setenv ASEM51INC /usr/local/share/asem-51/1.3/mcu
```

If you have installed ASEM-51 in your home directory, ASEM51INC should
point to ~/asem-51/1.3/mcu of course.

To read the HTML manuals, invoke your web browser and bookmark the index page

```
    /usr/local/share/asem-51/1.3/html/docs.htm    (installation as root)
    ~/asem-51/1.3/html/docs.htm                   (local installation)
```

Note that you cannot reset your 8051 target system with a PC printer port,
if you haven't installed ASEM-51 as root!
(For details see the BOOT-51 documentation provided.)

If you have installed ASEM-51, but you don't like it, you can easily
uninstall it. If you have installed the rpm package, simply type

```
    rpm -e asem51
```

If you have installed the generic tar archive, be sure to uninstall
ASEM-51 under the same user-id you previously used for installation! Run

```
    uninst51.sh
```

and that's it.

II.2.3 Linux Command Line Operation

Under Linux, the assembler is invoked by typing:

```
asem [<options>] <source> [<object> [<listing>]]
```

where <source> is the 8051 assembler source, <object> is the output
file, and <listing> is the assembler list file.
All file names that are specified explicitly, are left unchanged.
The parameters <object> and <listing> are optional. When omitted, the
<object> file name is derived from the <source> file name, but with
extension ".hex" (or ".omf"). When the <listing> file name is omitted,
it is derived from the <object> file name, but with extension ".lst":

```
        file            extension
        ------------------------------------------------
```

```
        <object>         .hex    (with -o option: .omf)
        <listing>        .lst
```

Instead of file names you may also specify device names to redirect the output to I/O devices. Device names are assumed to start with "/dev/". Of course no extensions will be added to device names!
It is not checked, whether the device is existing or suitable for the task. Although it is possible to read the source file from a character device instead of a file, this cannot be recommended: Since ASEM-51 is a two-pass assembler, it always reads the source file twice!
The maximum length of a file parameter is limited to 255 characters!

asem recognizes the following options:

short options	long options
-i path1:path2:path3	--includes=path1:path2:path3
-d symbol[:value[:type]]	--define=symbol[:value[:type]]
-o	--omf-51
-c	--columns
-v	--verbose

The short and long options in the same row are equivalent.
Long options may be abbreviated as long as they remain unique.
All option names are case-sensitive!

When the --includes option is used, the assembler searches the specified path for include files that cannot be found in the working directory. The path may be any number of directories separated by ':' characters. The directories will be searched from left to right.
The path, specified with the --includes option, is searched before the path, defined with the (optional) environment variable ASEM51INC!
The maximum path length is limited to 255 characters.

The --define option is useful for selecting particular program variants from the command line that have been implemented with conditional assembly. It allows to define a symbol with a value and a segment type in the command line. Value and type are optional. The segment type of the symbol defaults to NUMBER, if omitted. The symbol value defaults to 0, if omitted. The symbol value may be any numerical constant. The symbol type must be one of the following characters:

```
            C   =   CODE
            D   =   DATA
            I   =   IDATA
            X   =   XDATA
            B   =   BIT
            N   =   NUMBER    (default)
```

By default, ASEM-51 generates an object file in Intel-HEX format. When the --omf-51 option is specified, an absolute OMF-51 module is generated.

Examples:

0.) asem

When invoked without parameters, the assembler displays a help screen:

```
        MCS-51 Family Macro Assembler ASEM-51 V1.3

        usage:     asem [options] <source> [<object> [<listing>]]

        options:   -i   --includes=path1:path2:path3
                   -d   --define=symbol[:value[:type]]
                   -o   --omf-51
                   -c   --columns
                   -v   --verbose
```

1.) asem program.a51

will assemble the 8051 assembly language program program.a51 and produce an Intel-HEX file program.hex and a listing program.lst.

2.) asem tarzan.asm jane jungle.prn

will assemble the 8051 assembly language program tarzan.asm and produce an Intel-HEX file jane and a listing jungle.prn.

3.) asem project eprom

will assemble the 8051 assembly language program project and produce an Intel-HEX file eprom and a listing eprom.lst.

4.) asem -o rover.a51

will assemble the 8051 assembly language program rover.a51 and produce an absolute OMF-51 object module rover.omf and a listing rover.lst.

5.) asem sample.a51 /dev/ttyS0 /dev/null

will assemble the 8051 assembly language program sample.a51, send the HEX file output to the serial interface /dev/ttyS0 and suppress the list file output by sending it to the /dev/null device.

6.) asem -i /usr/local/include/asem-51:~/8051/inc app.a51

will assemble the program app.a51, while all required include files will be searched first in the default directory, then in /usr/local/include/asem-51, and finally in ~/8051/inc.

7.) asem --define=Eva_Board:8000H:C universal.a51

will assemble the program universal.a51, while the CODE symbol EVA_BOARD will be predefined with value 8000H during assembly.

When program errors are detected, corresponding error messages are output to standard error. This may look as follows:

```
applicat.a51(14): must be known on first pass
userbits.inc(6): attempt to divide by zero
defines.inc(37): symbol not defined
applicat.a51(20): symbol not defined
applicat.a51(27): no END statement found
```

Every error is flagged with the name of the source or include file, the local line number where it was found, and the error message itself. This output format provides a hook to run ASEM-51 from third-party IDEs. A perfect fit may be reached with the --columns option. When specified, the column numbers of program errors are output additionally after the line numbers:

```
applicat.a51(14,12): must be known on first pass
userbits.inc(6,27): attempt to divide by zero
defines.inc(37,18): symbol not defined
applicat.a51(20,18): symbol not defined
applicat.a51(27,1): no END statement found
```

If errors are detected in macro expansion lines, there is no corresponding location in the source file. Therefore, the error is flagged with the name of the source or include file, and the local line number from where the macro expansion has been invoked. (For callable macros this is the line with the macro call, and for repeat blocks this is the ENDM line.) To give the user a hint, the macro name and expansion line (and optionally column) number are inserted before the actual error message:

```
uartio.a51(44,1): RECEIVE(3,22): segment type mismatch
uartio.a51(87,1): REPT(4,19): symbol not defined
uartio.a51(87,1): REPT(8,19): symbol not defined
uartio.a51(87,1): REPT(12,19): symbol not defined
```

The expansion line number is the number of the expansion line within the corresponding macro expansion, starting with 1. If the error occurs during expansion of a repeat block, the keyword REPT replaces the macro name.

By default, ASEM-51 is totally "quiet", if no errors are detected.
If the --verbose option is specified, additional product, version, and error summary information is written to standard output:

```
        MCS-51 Family Macro Assembler ASEM-51 V1.3

        uartio.a51(44,1): RECEIVE(3,22): segment type mismatch
        uartio.a51(87,1): REPT(4,19): symbol not defined
        uartio.a51(87,1): REPT(8,19): symbol not defined
        uartio.a51(87,1): REPT(12,19): symbol not defined

             4 errors detected
```

When terminating, ASEM-51 returns an exit code to the calling process:

situation	exit code
no errors	0
program errors detected	1
fatal runtime error	2

Note: Warnings are also output on standard error,
but do not influence the exit code!

II.2.4 Linux Environment

To specify a search path for include files, an optional environment variable ASEM51INC can be defined:

1.) For bash, ksh, and sh:

```
ASEM51INC=<path>
export ASEM51INC
```

2.) For csh, tcsh, and zsh:

```
setenv ASEM51INC <path>
```

<path> may be any number of directories separated by ':' characters.
Be sure that the whole definition doesn't contain any blanks or tabs!
If ASEM51INC is defined, the assembler searches the specified <path> for include files that can neither be found in the working directory, nor in the search path specified with the --includes option.
The <path> directories will be searched from left to right.

Examples:

1.) bash:

```
ASEM51INC=/usr/local/include/asem-51:~/micros/mcs51/inc
export ASEM51INC
```

If include files can neither be found in the working directory, nor in the --includes path (if specified), the assembler searches next /usr/local/include/asem-51 and finally ~/micros/mcs51/inc.

2.) csh:

```
setenv ASEM51INC /usr/local/include/asem-51
```

If ASEM51INC is defined as above in .login, the assembler finally searches the directory /usr/local/include/asem-51 for include files.

The maximum length of <path> is limited to 255 characters.

II.2.5 The HEXBIN Utility

Most EPROM programmers are accepting the Intel-HEX object file format that is output by ASEM-51. However, for dumb EPROM burners and special purposes it might be useful to convert the HEX file to a pure binary image file. For this the conversion utility hexbin is provided.
It is invoked as follows:

```
hexbin [<options>] <hexfile> [<binary>]
```

where <hexfile> is the input file in Intel-HEX format, and <binary> is the binary output file. All file names that are specified explicitly, are left unchanged. The parameter <binary> is optional. When omitted, the file name is derived from the <hexfile>, but with the extension ".bin".
The maximum length of a file parameter is limited to 255 characters!

Instead of file names you may also specify device names to redirect the input or output to I/O devices. Device names are assumed to start with "/dev/".
Of course no extensions will be added to device names!
It is not checked, whether the device is existing or suitable for the task.

hexbin recognizes the following options:

short options	long options
-o <offset>	--offset=<offset>
-l <length>	--length=<length>
-f <fillbyte>	--fill=<fillbyte>
-v	--verbose

The short and long options in the same row are equivalent.
Long options may be abbreviated as long as they remain unique.
All option names are case-sensitive!

The binary file output can be controlled with the options --offset, --fill and --length.
Normally the first byte in the binary file is the first byte of the HEX record with the lowest load address. If a number of dummy bytes is to be inserted on top of the file (e.g. for alignment in an EPROM image), this can be performed with the --offset option:

```
--offset=1000
```

would insert 4096 dummy bytes before the first byte of the first HEX record loaded. The offset must always be specified as a hex number. The default offset is 0.
Since there may be peepholes between the HEX records, a fill byte value can be defined with the --fill option:

```
--fill=0
```

would fill all peepholes between the HEX records with zero bytes as well as all the dummy bytes that might have been inserted with the --offset or --length option. The fill byte value must always be specified as a hex number. The default fill byte is the EPROM-friendly FFH.
By default the last byte in the binary file is the last byte of the HEX record with the highest load address. If the binary file should have a well defined length, then a number of dummy bytes can be appended to the file (e.g. for exactly matching an EPROM length), this can be performed with the --length option:

```
--length=8000
```

would append as many dummy bytes behind the last byte of the file, that the total file length becomes exactly 32768 bytes. The file length must always be specified as a hex number.

By default, hexbin is totally "quiet", if no errors are detected.
If the --verbose option is specified, additional product and version information, and a file conversion report is written to standard output:

```
        Hex File Converter HEXBIN V2.3

                     offset:      FF0H bytes
               first address:     7FF0H
                last address:     8255H
        fill peepholes with:       A5H
        binary image length:     2000H bytes
```

Examples:

0.) hexbin

When invoked without parameters, hexbin displays a help screen:

```
      Hex File Converter HEXBIN V2.3

      usage:      hexbin [options] <hexfile> [<binary>]

      options:   -o   --offset=<offset>
                 -l   --length=<length>
                 -f   --fill=<fillbyte>
                 -v   --verbose
```

1.) hexbin program.hex

will convert the Intel-HEX file program.hex to a pure binary image file program.bin.

2.) hexbin -f E5 tarzan.obj jungle.bin

will convert the Intel-HEX file tarzan.obj to a binary image file jungle.bin and fill all peepholes between the HEX file records with the binary value E5H.

3.) hexbin --off=8000 -l10000 --fill=0 project.hex eprom

will convert the Intel-HEX file project.hex to a binary image file eprom, insert 32K dummy bytes on top of file, fill all peepholes and the dummy bytes with nulls, and extend the file to exactly 64K.

When terminating hexbin returns an exit code to the calling process:

situation	exit code
no errors	0
conversion errors detected	1
fatal runtime error	2

II.3 The DEMO Program

For getting started with a new assembler, it is always helpful to have a program that can be assembled with it. For this purpose, the 8051 assembler program DEMO.A51 is provided, which can be used for a first test of the ASEM-51 installation. For this, you should either have installed ASEM-51 as described above, or keep all files of the ASEM-51 package directly in your working directory!

Under MS-DOS or in a Windows DOS-Box simply type

```
ASEM DEMO
HEXBIN DEMO
```

at the DOS prompt. ASEM and HEXBIN should finish without errors and you should have the following new files on your disk:

```
DEMO.HEX          Intel-HEX file
DEMO.LST          assembler list file of DEMO.A51
DEMO.BIN          binary image file of DEMO.HEX
```

Under Linux type

```
asem demo.a51
hexbin demo.hex
```

Again asem and hexbin should finish without errors and you should have the following new files on your disk:

```
demo.hex          Intel-HEX file
demo.lst          assembler list file of demo.a51
demo.bin          binary image file of demo.hex
```

If something goes wrong, either ASEM-51 is not properly installed, there may be files missing in your distribution, or the assembler simply cannot find the include file 8052.mcu!
demo.a51 may also serve as a sample assembler program that includes examples for (nearly) all machine instructions, pseudo instructions, assembler controls, and meta instructions that have been implemented in ASEM-51. Whenever in doubt how to use a particular command, demo.a51 may be a valuable help.
Unlike other assemblers, the ASEM-51 list file is no alibi feature! It is really instructive to compare the original source to the generated code in the listing.

III. The ASEM-51 Assembly Language

The user should be familiar with 8051 microcontrollers and assembly language programming. This manual will not explain the architecture of the MCS-51 microcontroller family nor will it discuss the basic concepts of assembly language programming. It only describes the general syntax of assembler statements and the assembler instructions that have been implemented in ASEM-51.

III.1 Statements

Source files consist of a sequence of statements of one of the forms:

```
          [symbol:]  [instruction [arguments]]     [;comment]

           symbol     instruction  argument        [;comment]

          $control   [(argument)]                 [;comment]
```

Everything that is written in brackets is optional.
The maximum length of source code lines is 255 characters.
Everything from the ';' character to the end of line is assumed to be commentary. Blank lines are considered to be commentary, too.
The lexical elements of a statement may be separated by blanks and tabs.
Aside of character string constants, upper and lower case letters are equivalent.

```
Examples:     HERE:   MOV A,#0FFH     ;define label HERE and load A with FFH

                      YEAR EQU 1999   ;define symbol for current year

              $INCLUDE (80C517.MCU)   ;include SAB80C517 register definitions
```

III.2 Symbols

Symbols are user-defined names for addresses, numbers or macros.
Their maximum significant length is 31 characters. They can be even longer, but everything behind the first 31 characters is ignored.
Symbols may consist of letters, digits, '_' and '?' characters.
A symbol name must not start with a digit!
Upper and lower case letters are considered to be equivalent.
Note: Assembly language keywords must not be redefined as user symbols!

```
Example:     Is_this_really_a_SYMBOL_?       is a legal symbol name!
```

III.3 Constants

Numeric constants consist of a sequence of digits, followed by a radix specifier. The first character must always be a decimal digit. The legal digits and radix specifiers are:

constant	digits	radix
binary	0 ... 1	B
octal	0 ... 7	Q or O
decimal	0 ... 9	D or none
hex	0 ... F	H

Thus, for example, the following constants are equivalent:

```
1111111B      binary
    177Q      octal
    177o      octal
     127      decimal
    127d      decimal
    07FH      hex
```

Character constants may be used wherever a numeric value is allowed. A character constant consists of one or two printing characters enclosed in single or double quotes. The quote character itself can be represented by two subsequent quotes. For example:

```
 'X'       8 bit constant:       58H
"a@"      16 bit constant:     6140H
''''       8 bit constant:       27H
```

In DB statements, character constants may have any length. In this case, we call it a character string. For example:

```
'This is only text!'
```

III.4 Expressions

Arithmetic expressions are composed of operands, operators and parentheses.
Operands may be user-defined symbols, constants or special assembler symbols.
All operands are treated as unsigned 16-bit numbers.
Special assembler symbols, that can be used as operands are:

AR0, ... , AR7	direct addresses of registers R0 thru R7
$	the location counter of the currently active segment (start address of the current assembler statement)

The following operators are implemented:

Unary operators:	+	identity:	+x = x
	-	two's complement:	-x = 0-x
	NOT	one's complement:	NOT x = FFFFH-x
	HIGH	high order byte	
	LOW	low order byte	

Binary operators:	+	unsigned addition	
	-	unsigned subtraction	
	*	unsigned multiplication	
	/	unsigned division	
	MOD	unsigned remainder	
	SHL	logical shift left	
	SHR	logical shift right	
	AND	logical and	
	OR	logical or	
	XOR	exclusive or	
	.	bit operator used for bit-adressable locations	
	EQ or =	equal to	results are:
	NE or <>	not equal to	
	LT or <	less than	0 if FALSE
	LE or <=	less or equal than	FFFFH if TRUE
	GT or >	greater than	
	GE or >=	greater or equal than	

Operators that are no special characters but keywords as SHR or AND must
be separated from their operands by at least one blank or tab.
In general expressions are evaluated from left to right according to
operator precedence, which may be overridden by parentheses.
Parentheses may be nested to any level.
Expressions always evaluate to unsigned 16-bit numbers, while overflows
are ignored. When an expression result is to be assigned to an 8-bit
quantity, the high byte must be either 00 or FF.

Operator precedence:

( )		highest
+ - NOT HIGH LOW	(unary)	
.		
* / MOD		
SHL SHR		
+ -	(binary)	
EQ = NE <> LT < LE <= GT > GE >=		
AND		
OR XOR		lowest

Example: The expression P1.((87+3)/10 AND -1 SHR 0DH) will evaluate to 91H.

III.5 The 8051 Instruction Set

ASEM-51 implements all 8051 machine instructions including generic jumps and calls. The assembler implements two instructions

```
JMP  <address>
CALL <address>
```

that do not represent a specific opcode: generic jump and call.
These instructions will always evaluate to a jump or call, not necessarily the shortest, that will reach the specified address.
JMP may assemble to SJMP, AJMP or LJMP, while CALL can only evaluate to ACALL or LCALL. Note that the assembler decision may not be optimal. For code addresses that are forward references, the assembler always generates LJMP or LCALL respectively. However, for backward references this is a powerful tool to reduce code size without extra trouble.

With the $PHILIPS control, ASEM-51 can be switched to the reduced instruction set of the Philips 83C75x family of microcontrollers. This disables the LJMP, LCALL, and MOVX instructions as well as the XDATA and XSEG pseudo instructions, and generic jumps and calls will always assemble to absolute addressing.

The rest of the 8051 instruction mnemonics is listed in Appendix D.
Appendices I and J are containing tables of all 8051 instructions with their opcodes, mnemonics, arguments, lengths, affected flags and durations.
The comprehensive example program DEMO.A51 provided shows all the 8051 instructions in a syntactical context.

For detailed information on the Intel MCS-51 architecture and instruction set refer to the HTML documentation file MCS51MAN.HTM provided.
(Requires a web-browser and full Internet access!)

III.6 Pseudo Instructions

In the subsequent paragraphs, all ASEM-51 pseudo instructions are described.
Lexical symbols are written in lower case letters, while assembler keywords are written in upper case.
Instruction arguments are represented by <arg>, <arg1> or something like that. Numeric expressions are represented by <expr>, <expr1> and so on.
Syntax elements enclosed in brackets are optional.
The ellipsis "..." means always "a list with any number of elements".

DB <arg1> [,<arg2> [,<arg3> ...]] — define bytes

The DB instruction reserves and initializes a number of bytes with the values defined by the arguments. The arguments may either be expressions (which must evaluate to 8-bit values) or character strings of any length. DB is only allowed in the CODE segment!

Example: DB 19,'January',98,(3*7+12)/11

DW <expr1> [,<expr2> [,<expr3> ...]] — define words

The DW instruction reserves and initializes a number of words with the values defined by the arguments. Every argument may be an arbitrary expression and requires two bytes of space.
DW is only allowed in the CODE segment!

Example: DW 0,0C800H,1999,4711

DS <expr> — define space

Reserves a number of uninitialized bytes in the current segment.
The value of <expr> must be known on pass 1!
DS is allowed in every segment, except in the BIT segment!

Example: DS 200H

DBIT <expr> — define bits

Reserves a number of uninitialized bits.
The value of <expr> must be known on pass 1!
DBIT is only allowed in the BIT segment!

Example: DBIT 16

NAME <symbol> — define module name

Defines a module name for the OMF-51 object file. If no module name is defined, the module name is derived from the source file name.
When generating Intel-HEX file output, the NAME instruction has no effect. The module name must be a legal assembler symbol.
Only one NAME instruction is allowed within the program. The symbol however, may be redefined in the subsequent program.

Example: NAME My_1st_Program

ORG <expr> — origin of segment location

Sets the location counter of the current segment to the value <expr>.
The value of <expr> must be known on pass 1!
It must be greater or equal to the segment base address.
The default value of all location counters at program start is 0.

Example: ORG 08000H

USING <expr> using register bank

Sets the register bank used to <expr>, which must be in the range of 0...3. The USING instruction only affects the values of the special assembler symbols AR0, ... , AR7 representing the direct addresses of registers R0, ... , R7 in the current register bank.
The value of <expr> must be known on pass 1!
The default value for the register bank is 0.

Example: USING 1

END end of program

This must be the last statement in the source file. After the END statement only commentary and blank lines are allowed!

Example: END ;end of program

<symbol> EQU <expr> define numeric constant
<symbol> EQU <reg> define invariant register
<symbol> SET <expr> define numeric variable
<symbol> SET <reg> define variable register

The EQU instruction defines a symbol for a numeric constant or a register. If a numeric expression <expr> is assigned to the symbol, it will be of the type NUMBER. If a register <reg> is assigned to the symbol, it will be of the type REGISTER. <reg> may be one of the special assembler symbols A, R0, R1, R2, R3, R3, R4, R5, R6, or R7.
A symbol once defined with EQU can never be changed!
The SET instruction is working quite similar to EQU. However, symbols defined with SET can be redefined with subsequent SET instructions!
The values of <expr> and <reg> must be known on pass 1!
A symbol that has been SET, cannot be redefined with EQU!
A symbol that has been EQU'd cannot be reSET!
On pass 2, forward references to a SET symbol always evaluate to the last value, the symbol has been SET to on pass 1.
Register symbols can be used as instruction operands within the whole program instead of the corresponding registers.
Forward references to register symbols are not allowed!

Examples:
```
MAXMONTH  EQU 12
OCTOBER   EQU MAXMONTH-2
COUNTREG  EQU R5

CHAPTER   SET  1
CHAPTER   SET  CHAPTER+1
CHAPTER   SET  A
```

<symbol> CODE <expr> define ROM address
<symbol> DATA <expr> define direct RAM address
<symbol> IDATA <expr> define indirect RAM address
<symbol> BIT <expr> define bit address
<symbol> XDATA <expr> define external RAM address

These instructions define symbolic addresses for the five 8051 memory segments (address spaces). For DATA, IDATA and BIT type symbols, the value of <expr> must not exceed 0FFH!
The value of <expr> must be known on pass 1!
Once defined with one of the above instructions, the symbols cannot be redefined.

Examples:
```
EPROM    CODE  08000H
STACK    DATA       7
V24BUF   IDATA   080H
REDLED   BIT     P1.5
SAMPLER  XDATA  0100H
```

```
CSEG [AT <expr>]                        switch to CODE  segment [at address]
DSEG [AT <expr>]                        switch to DATA  segment [at address]
ISEG [AT <expr>]                        switch to IDATA segment [at address]
BSEG [AT <expr>]                        switch to BIT   segment [at address]
XSEG [AT <expr>]                        switch to XDATA segment [at address]
```

These instructions switch to one of the five 8051 address spaces. If a segment base address is specified with "AT <expr>", a new absolute segment is started, and the location counter is set to <expr>. If "AT <expr>" is omitted, the location counter keeps the previous value of the particular segment.
The value of <expr> must be known on pass 1!
At program start, the default segment is CODE and the base addresses and location counters of all segments are set to zero.

Examples:

```
DSEG            ;switch to previous DATA segment

CSEG AT 8000h   ;start a new CODE segment at address 8000H

XSEG at 0       ;start a new XDATA segment at address 0
```

III.7 Segment Type

Every assembly time expression is assigned a segment type, depending on its operands and operators. The segment type indicates the address space, the expression result might belong to, if it were used as an address. There are six possible segment types:

```
CODE
DATA
IDATA
XDATA
BIT
NUMBER    (typeless)
```

Most expression results have the segment type NUMBER. That means they are assumed to be typeless. However, in some cases it may be useful to assign a particular segment type!
The following six rules apply when the segment type is evaluated:

1. Numerical constants are always typeless.
   Consequently their segment type is NUMBER.

2. Symbols are assigned a segment type during definition. Symbols that are defined with EQU or SET have no segment type.
   Labels get the segment type of the currently active segment.

3. The result of a unary operation (+, -, NOT, HIGH, LOW) will have the segment type of its operand.

4. The results of all binary operations (except "+", "-" and ".") will have no segment type.

5. If only one operand in a binary "+" or "-" operation has a segment type, then the result will have that segment type, too. In all other cases, the result will have no segment type.

6. The result of the bit operation "." will always have the segment type BIT.

Examples:

The following symbols have been defined in a program:

```
OFFSET  EQU   16
START   CODE  30H
DOIT    CODE  0100H
REDLED  BIT   P1.3
VARIAB4 DATA  20H
PORT    DATA  0C8H
RELAY   EQU   5
```

1.) The expression START+OFFSET+3 will have the segment type CODE.
2.) The expression START+DOIT will be typeless.
3.) The expression DOIT-REDLED will be typeless.
4.) The expression 2*VARIAB4 will be typeless.
5.) The expression PORT.RELAY will have the segment type BIT.

The segment type is checked, when expressions appear as addresses. If the expression result is not typeless and does not have the segment type of the corresponding segment, the instruction is flagged with an error message. The only exceptions are the segment types DATA and IDATA, which are assumed to be compatible in the address range of 0 to 7FH. Since ASEM-51 does only support absolute segments, those addresses are really always pointing to the same physical location in the internal memory.

Example:

```
 Line  I  Addr  Code            Source

    1:          N        30             DSEG AT 030H     ;internal RAM
```

```
2:      30  N       01     COUNT:  DS 1            ;counter variable
3:
4:                             CSEG             ;ROM
5:    0000  C2 30              START:  CLR COUNT
                                                 ^
                        @@@@@ segment type mismatch @@@@@
```

The CLR instruction is flagged with the error message "segment type mismatch" in the assembler list file, because only a BIT type address is allowed here. However, COUNT is a label with the segment type DATA!

III.8 Assembler Controls

ASEM-51 implements a number of assembler controls that influence the assembly process and list file generation. There are two groups of controls: primary and general controls.
Primary controls can only be used at the beginning of the program and remain in effect throughout the assembly. They may be preceded only by control statements, blank and commentary lines. If the same primary control is used multiple times with different parameters, the last one counts.
General controls may be used everywhere in the program. They perform a single action, or remain in effect until they are cancelled or changed by a subsequent control statement.
A control statement starts always with a '$' character, followed by one or more assembler controls.
Assembler controls may have a number or string type operand, which must always be enclosed in parentheses.
Number type operands are arithmetic expressions that must be known on pass 1.
String type operands are character strings which are enclosed in parentheses instead of quotes. In analogy to quoted strings, no control characters (including tabs) are allowed within these strings! The string delimiter ')' can be represented by two subsequent ')' characters.
If a control statement changes the listing mode, the control statement itself is always listed in the previous listing mode!
The following table lists all the implemented controls and their abbreviations:

Control	Type	Default	Abbreviation	Meaning
$COND	G	$COND	---	list full IFxx .. ENDIF constructions
$NOCOND	G		---	don't list lines in false branches
$CONDONLY	G		---	list assembled lines only
$DATE(string)	P	''	$DA	inserts date string into page header
$DEBUG	P	$NODEBUG	$DB	include debug information into object
$NODEBUG	P		$NODB	don't include debug information
$EJECT	G		$EJ	start a new page in list file
$ERROR(string)	G		---	force a user-defined error
$WARNING(string)	G		---	output a warning message to console
$GEN	G	$GEN	$GE	list macro calls and expansion lines
$NOGEN	G		$NOGE	list macro calls only
$GENONLY	G		$GO	list expansion lines only
$INCLUDE(file)	G		$IC	include a source file
$LIST	G	$LIST	$LI	list subsequent source lines
$NOLIST	G		$NOLI	don't list subsequent source lines
$MACRO(n)	P	$MACRO(50)	$MR	reserve n % of free memory for macros
$NOMACRO	P		$NOMR	reserve all for the symbol table
$MOD51	P	$MOD51	$MO	enable predefined SFR symbols
$NOMOD51	P		$NOMO	disable predefined SFR symbols
$NOBUILTIN	P	list SFR	---	don't list predefined symbols
$NOTABS	P	use tabs	---	don't use tabs in list file
$PAGING	P	$PAGING	$PI	enable listing page formatting
$NOPAGING	P		$NOPI	disable listing page formatting
$PAGELENGTH(n)	P	n=64	$PL	set lines per page for listing
$PAGEWIDTH(n)	P	n=132	$PW	set columns per line for listing
$PHILIPS	P	MCS-51	---	switch on 83C75x family support

$SAVE	G		$SA	save current $LIST/$GEN/$COND state
$RESTORE	G		$RS	restore old $LIST/$GEN/$COND state
$SYMBOLS	P	$SYMBOLS	$SB	create symbol table
$NOSYMBOLS	P		$NOSB	don't create symbol table
$TITLE(string)	G	copyright	$TT	inserts title string into page header
$XREF	P	$NOXREF	$XR	create cross reference
$NOXREF	P		$NOXR	don't create cross reference

The subsequent paragraphs contain detailed explanations of the implemented controls.

III.8.1 Primary Controls

$DATE (string)	Inserts a date string into the list file page header. If $DATE() is specified, the actual date is inserted. Date strings will be truncated to a maximum length of 11 characters. Default is: no date string. The control has no effect, when the $NOPAGING control has been specified.
$DEBUG	Includes debug information into the OMF-51 module. When generating Intel-HEX file output, $DEBUG has no effect.
$NODEBUG	Don't include debug information. (Default!)
$MACRO (n)	Save macro definitions and expand macro calls. (Default!) Optionally reserve n % of free memory for macro definitions. (0 <= n <= 100) Default is n=50. The control has been implemented for compatibility purposes only. In ASEM-51 it has no effect except that it cancels the $NOMACRO control.
$NOMACRO	Don't save macro definitions and don't expand macro calls. Reserve all free memory for the symbol table. The control has been implemented for compatibility purposes only. In ASEM-51, it only suppresses the macro expansion.
$MOD51	Switches on the built-in 8051 special function register and interrupt symbol definitions. (Default!)
$NOMOD51	Switches off the built-in 8051 special function register and interrupt symbol definitions. The predefined symbols ??ASEM_51 and ??VERSION cannot be switched off!
$PAGING	Switches on the page formatting in the list file. (Default!)
$NOPAGING	Switches off the page formatting in the list file.
$PAGELENGTH (n)	Sets the list file page length to n lines. (12 <= n <= 65535) Default is n=64. The control has no effect, when the $NOPAGING control has been specified.
$PAGEWIDTH (n)	Sets the list file page width to n columns. (72 <= n <= 255) Default is n=132.
$PHILIPS	Switches on the Philips 83C75x family support option. This disables the LJMP, LCALL, and MOVX instructions as well as the XDATA and XSEG pseudo instructions. Generic jumps and calls will always assemble to absolute addressing.
$SYMBOLS	Generates the symbol table at the end of the list file. (Default!) When the $XREF control is active, $SYMBOLS has no effect!
$NOSYMBOLS	Suppresses the symbol table at the end of the list file. When the $XREF control is active, $NOSYMBOLS has no effect!
$NOBUILTIN	Suppresses the predefined (built-in) symbols in the symbol table or cross-reference listing for a better survey. Only the user-defined symbols are listed.
$NOTABS	Expands all tab characters in the list file output to blanks.

$XREF Generates a cross-reference listing instead of a symbol table. Note that this slightly slows down assembly, and consumes about 67 % more memory space!

$NOXREF Generates a symbol table instead of a cross-reference listing. (Default!)

```
Examples:   $NOMOD51              ;switch off 8051 SFR symbol definitions
            $PAGELENGTH(60)       ;set page length to 60 lines per page
            $PW(80)               ;set page width to 80 characters per line
            $NOSYMBOLS            ;no symbol table required
            $NOTABS               ;printer doesn't support tab characters
            $DATE(2. 8. 95)       ;date of latest version
            $XREF                 ;generate a cross-reference listing
            $ DEBUG NOPAGING      ;include debugging information into OMF-51
                                  ;modules, and suppress page formatting
```

III.8.2 General Controls

$COND List full IFxx .. ELSEIFxx .. ELSE .. ENDIF constructions. (Default!) The Control is overridden by $NOLIST.

$NOCOND Don't list lines in false IFxx .. ELSEIFxx .. ELSE .. ENDIF branches. The Control is overridden by $NOLIST.

$CONDONLY List lines in true IFxx .. ELSEIFxx .. ELSE .. ENDIF branches only, without the IFxx, ELSEIFxx, ELSE and ENDIF statements itself. The Control is overridden by $NOLIST.

$EJECT Starts a new page in the list file.
The control has no effect, when the $NOPAGING control has been specified.

$ERROR (string) Forces an assembly error with a user-defined error message. This is intended to support configuration management and can be applied sensefully with conditional assembly only.

$WARNING (string) Outputs a user-defined warning message to the console, and increments the warning count. This is also intended to ease configuration management.

$GEN List macro calls and expanded macros. (Default!)
The listing fully shows the nesting of macro calls.
The Control is overridden by $NOLIST.

$NOGEN List macro calls only. The expanded macros are not listed.
The Control is overridden by $NOLIST.

$GENONLY List the expanded macro bodies only. Macro calls and EXITM statements are not listed.
The Control is overridden by $NOLIST.

$INCLUDE (file) Includes an external source file into the assembler program just behind the $INCLUDE statement. If the include file has not been specified with an absolute path, and it cannot be found in the default directory, the path specified with the /INCLUDES command line option (if present) is searched from left to right, and if it cannot be found there either, the path specified with the environment variable ASEM51INC (if defined) is searched from left to right as well.
Include files may be nested to any depth.

$LIST List source code lines. (Default!)

$NOLIST Do not list source code lines, provided they do not contain errors, until the next $LIST statement occurs.

$SAVE Saves the current $LIST/$GEN/$COND state on a $SAVE-stack.
$SAVE statements can be nested to any depth.

```
$RESTORE          Restores a previously saved $LIST/$GEN/$COND state.

$TITLE (string)   Inserts a title string into the list file page header.
                  Titles may be truncated according to the specified (or
                  default) page width.
                  Default: ASEM-51 copyright information.
                  The control has no effect, when the $NOPAGING control has
                  been specified.


Examples:   $NOLIST                ;switch off listing
            $INCLUDE (8052.MCU)    ;include 8052 SFR symbol definition file
            $LIST                  ;switch on listing
            $TITLE (Computer-Controlled Combustion Unit for Motorcycles)
            $EJ                    ;new page with new title
            $ERROR(invalid configuration: buffer size > external RAM size)
            $WARNING(int. RAM doesn't meet minimum stack size requirements)
            $SAVE GENONLY CONDONLY ;save old $LIST/$GEN/$COND status, and list
                                   ;only source lines that are really assembled
            $RESTORE               ;restore previous listing mode
```

III.9 Predefined Symbols

For easy access to the 8051 special function register and interrupt addresses, ASEM-51 has a number of predefined (built-in) DATA, BIT and CODE symbols.
These predefined symbols can be switched off with the $NOMOD51 control.
For detailed information on symbols and addresses refer to Appendix C.
For identification of the assembler and its version number, the following NUMBER type symbols are predefined:

```
       ??ASEM_51  =  8051H        ASEM-51
       ??VERSION  =  0130H        version 1.3
```

These two symbols can not be switched off!

III.10 Conditional Assembly

Conditional assembly allows to assemble or ignore selected parts of code. This can be used to keep the code for various program variants in a single source, to ease configuration control and maintenance. Conditional assembly is also useful to write fancy macros.
The following fourteen meta instructions have been implemented:

```
IF     <expr>           ELSEIF     <expr>
IFN    <expr>           ELSEIFN    <expr>
IFDEF  <symbol>         ELSEIFDEF  <symbol>
IFNDEF <symbol>         ELSEIFNDEF <symbol>
IFB    <literal>        ELSEIFB    <literal>
IFNB   <literal>        ELSEIFNB   <literal>
ENDIF                   ELSE
```

Meta instructions overlay the Intel MCS-51 assembly language, but are not part of it! C programmers may compare them to C preprocessor commands.
In the subsequent text, IFxx is used as a collective name for the IF/IFN/IFDEF/IFNDEF/IFB/IFNB instructions. In analogy ELSEIFxx is used as a collective name for the ELSEIF/ELSEIFN/ELSEIFDEF/ELSEIFNDEF/ELSEIFB/ELSEIFNB instructions (not including ELSE).

III.10.1 General IFxx Construction

Simple IFxx ... ENDIF constructions can be used to assemble a number of enclosed statements only, if a particluar condition is met:

```
IFxx <condition>
  <statement 1>
  <statement 2>
      .              ;assembled if <condition> is TRUE
      .
  <statement n>
ENDIF
```

The statements 1 through n are assembled if <condition> is TRUE, otherwise they are ignored.

If it should be possible to select two variants of code depending on a particular condition, this can be done with an IFxx .. ELSE .. ENDIF construction. If the <condition> in the IFxx statement is TRUE, then statements 1 to n are assembled and the statements n+1 to n+m are ignored.

```
IFxx <condition>
  <statement 1>
      .              ;assembled if <condition> is TRUE
  <statement n>
ELSE
  <statement n+1>
      .              ;assembled if <condition> is FALSE
  <statement n+m>
ENDIF
```

Should <condition> be FALSE, it is exactly vice versa! That means the statements 1 to n are ignored and the statements n+1 to n+m are assembled. This works also, if the IFxx or ELSE branches contain no statements at all.

Whenever more than two cases have to be distinguished, a corresponding number of ELSEIFxx branches can be inserted between the IFxx and the ELSE branch. In such an IFxx .. ELSEIFxx .. ELSE .. ENDIF construction, only the statements in the branch with the first TRUE condition are assembled. The statements in all other branches are ignored.
If none of the conditions is TRUE, only the statements in the ELSE branch (if any) are assembled.

```
IFxx <condition 1>
      .               ;assembled if <condition 1> is TRUE
      .
```

```
      ELSEIFxx <condition 2>
            .               ;assembled if <condition 1> is FALSE,
            .               ;and <condition 2> is TRUE
      ELSEIFxx <condition 3>
            .               ;assembled if <condition 1> and
            .               ;<condition 2> are FALSE, and
            .               ;<condition 3> is TRUE
            .
            .
      ELSEIFxx <condition n>
            .               ;assembled if <condition 1> thru
            .               ;<condition n-1> are FALSE and
            .               ;<condition n> is TRUE
      ELSE
            .               ;assembled if <condition 1> thru
            .               ;<condition n> are FALSE
      ENDIF
```

IFxx ... ELSEIFxx ... ELSE ... ENDIF constructions may be nested to any depth! The listing mode of those constructions can be set with the $COND, $NOCOND and $CONDONLY controls.

III.10.2 IFxx and ELSEIFxx Instructions

The particular IFxx instructions are working as follows:

IF <expr> The IF condition is TRUE, if the expression <expr> is not equal to 0. The value of <expr> must be known on pass 1!

IFN <expr> The IFN condition is TRUE, if the expression <expr> is equal to 0. The value of <expr> must be known on pass 1!

IFDEF <symbol> The IFDEF condition is TRUE, if the <symbol> is defined in the program. Forward references to <symbol> are not allowed!

IFNDEF <symbol> The IFNDEF condition is TRUE, if the <symbol> is not defined in the program. Forward references to <symbol> are not allowed!

IFB <literal> The IFB (if blank) condition is TRUE, if the <literal> is empty. <literal> is a string, enclosed in angle brackets.

IFNB <literal> The IFNB (if not blank) condition is TRUE, if the <literal> is not empty. <literal> is a string, enclosed in angle brackets.

Although the IFB and IFNB statements are valid also outside of macros, they can be applied sensefully in macro bodies only. Usually they are used to decide, whether macro arguments have been left blank, or not.

The corresponding ELSEIFxx instructions are working respectively.

Example 1: IF .. ELSE .. ENDIF construction

```
TARGET EQU 0    ;configuration:  1 for application board
                ;--------------  0 for evaluation board
IF TARGET
  ORG 0         ;program start address of application board
ELSE
  ORG 8000H     ;program start address of evaluation board
ENDIF
```

Currently the program is configured for the evaluation board version.

Example 2: IFNDEF .. ELSE .. ENDIF construction

```
;EVA_537 EQU 0      ;symbol undefined: 80C537 application board
                    ;symbol defined:   80C537 evaluation board
 IFNDEF EVA_537
```

```
  CLOCK EQU 16     ;clock frequency of application board
  CSEG  AT  0      ;program start address of application board
ELSE
  CLOCK EQU 12     ;clock frequency of evaluation board
  CSEG  AT  8000H  ;program start address of evaluation board
ENDIF
```

Currently the program is configured for the application board version.

Example 3: IFB .. ELSE .. ENDIF construction

```
DECIDE MACRO X, Y
  IFB <X&Y>
    NOP
    NOP
  ELSE
    DB '&X,&Y'
  ENDIF
ENDM
```

If the above macro is invoked as follows,

```
DECIDE Nonsense
```

the parameter X will be replaced by "Nonsense" and the parameter Y by a zero length string. Thus the IFB literal becomes <Nonsense>, and the macro will be expanded to:

```
    DB 'Nonsense,'
```

If the macro will be invoked without arguments,

```
DECIDE
```

the parameters X and Y will be replaced by zero length strings both, and the IFB literal becomes <>. Thus the macro will be expanded to:

```
    NOP
    NOP
```

Macros are explained in detail in chapter "III.11 Macro Processing".

Example 4: IFNDEF .. ELSEIF .. ELSEIF .. ELSE .. ENDIF construction

The symbol BAUDRATE serves to define the UART baudrate:

```
IFNDEF BAUDRATE
  LJMP AUTOBAUD            ;automatic baudrate detection
ELSEIF BAUDRATE EQ 9600
  MOV TH1, #0FDH           ;9600 baud
ELSEIF BAUDRATE EQ 1200
  MOV TH1, #0E8H           ;1200 baud
ELSE
  $ERROR(baudrate not implemented)
ENDIF
```

If the symbol BAUDRATE is not defined at all, a jump to the label AUTOBAUD is performed.
If the symbol BAUDRATE is defined with one of the legal values 9600 or 1200, timer 1 is initialized accordingly.
If the symbol BAUDRATE is defined with another value, a corresponding user-defined error message is generated.

III.11 Macro Processing

Macros allow to combine basic assembler instructions to "super commands". For this, macros are defined as blocks of code, which can be used in a program, wherever it is desired.
However, an advanced macro design with parameters, local symbols and macro operators, combined with conditional assembly, goes far beyond this basic functionality!
With only five keywords (MACRO, REPT, ENDM, EXITM, LOCAL) and some control characters the ASEM-51 macro processor provides a variety of powerful tools. These five meta instructions are not part of the Intel MCS-51 assembly language, but overlay it, as already known from conditional assembly.
There are two sorts of macros: callable macros and repeat blocks.

III.11.1 Simple Callable Macros

Macros must first be defined, before they can be called in a program.
A simple macro definition consists of the macro name, which can be defined with the keyword MACRO, the macro body, and a final ENDM (end macro) instruction.

```
<macro name> MACRO
<body line 1>
<body line 2>
    .
    .
<body line m>
ENDM
```

The macro name must be a valid, unique symbol. It cannot be redefined later. Keywords cannot be used as macro names.
The macro body may comprise any number of lines. Body lines may be all kinds of assembler instructions, pseudo instructions, controls, meta instructions, macro calls and even further macro definitions.
The macro body and the whole macro definition is terminated with the ENDM instruction.
Macros must be defined, before they can be called. Forward references to macros are not allowed. Once defined, a macro can be called by its name in the subsequent program as often as desired. Whenever a macro is called, the macro body will be "inserted" into the program and then assembled as normal source lines. This process is called macro expansion.

```
Example:        MY_FIRST MACRO  ;definition
--------        MOV A,#42
                ADD A,R5
                ENDM

                MY_FIRST        ;call

                After the call of the macro MY_FIRST, the body lines

                MOV A,#42
                ADD A,R5

                are inserted into the program and assembled.
```

III.11.2 Macro Parameters

Callable macros may have parameters, to allow more flexible use.
The names of the formal parameters are specified in the macro definition behind the keyword MACRO, separated by commas. All parameter names of a macro must be different, valid symbols. Keywords cannot be used as parameter names. Macros may have any number of parameters, as long as they fit on one line. Parameter names are local symbols, which are known within the macro only. Outside the macro they have no meaning!

```
<macro name> MACRO <parameter 1>, <parameter 2>, ... ,<parameter n>
<body line 1>
```

```
   <body line 2>
       .
       .
   <body line m>
   ENDM
```

When called, actual arguments can be passed to the macro. The arguments must be separated by commas. Valid macro arguments are

1. arbitrary sequences of printable characters, not containing blanks, tabs, commas, or semicolons

2. quoted strings (in single or double quotes)

3. single printable characters, preceded by '!' as an escape character

4. character sequences, enclosed in literal brackets < ... >, which may be arbitrary sequences of valid macro arguments (types 1. - 4.), blanks, commas and semicolons

5. arbitrary sequences of valid macro arguments (types 1. - 4.)

6. expressions preceded by a '%' character

Note: The keywords MACRO, EQU, SET, CODE, DATA, IDATA, XDATA, BIT, and the ':' character cannot be passed as the first macro argument, because they always start a symbol definition!
Therefore they must be enclosed in literal brackets < ... >.

During macro expansion, these actual arguments replace the symbols of the corresponding formal parameters, wherever they are recognized in the macro body. The first argument replaces the symbol of the first parameter, the second argument replaces the symbol of the second parameter, and so forth. This is called substitution.
Without special assistance, the assembler will not recognize a parameter symbol if it

- is part of another symbol

- is contained in a quoted string

- appears in commentary

Example 1:

```
MY_SECOND MACRO CONSTANT, REGISTER
MOV A,#CONSTANT
ADD A,REGISTER
ENDM

MY_SECOND 42, R5
```

After calling the macro MY_SECOND, the body lines

```
MOV A,#42
ADD A,R5
```

are inserted into the program, and assembled.
The parameter names CONSTANT and REGISTER have been replaced by the macro arguments "42" and "R5".

The number of arguments, passed to a macro, can be less (but not greater) than the number of its formal parameters. If an argument is omitted, the corresponding formal parameter is replaced by an empty string.
If other arguments than the last ones are to be omitted, they can be represented by commas.

Example 2:

The macro OPTIONAL has eight formal parameters:

```
OPTIONAL MACRO P1,P2,P3,P4,P5,P6,P7,P8
  .
  .
<macro body>
```

```
                .
                .
              ENDM

              If it is called as follows,

              OPTIONAL 1,2,,,5,6

              the formal parameters P1, P2, P5 and P6 are replaced by the
              arguments 1, 2, 5 and 6 during substitution. The parameters
              P3, P4, P7 and P8 are replaced by a zero length string.
```

For more flexible macro design, there must be a possibility to recognize empty macro arguments, and to branch the macro expansion accordingly. This can be performed with conditional assembly, using the IFB and IFNB meta instructions. (See chapter "III.10.2 IFxx and ELSEIFxx Instructions".)

III.11.3 Repeat Macros

Repeat macros don't have a macro name, and therefore cannot be called multiple times. They are always expanded immediately after their definition. During expansion, their macro body is repeated n times (0 <= n <= 65535). Repeat macros start with the keyword REPT, followed by an expression, which must be known on pass 1. In analogy to callable macros, there is a macro body, which must be terminated with an ENDM instruction:

```
   REPT <expression>
   <body line 1>
   <body line 2>
       .
       .
   <body line m>
   ENDM
```

The expression value specifies how many times the macro body is to be repeated. Since repeat macros start with the keyword REPT, they are sometimes also called "REPT blocks".

Example:

```
              REPT 5
              NOP
              ENDM
```

This REPT block will expand to five NOP instructions immediately after its definition:

```
              NOP
              NOP
              NOP
              NOP
              NOP
```

III.11.4 Local Symbols

Local symbols are symbols, which are only known within a macro body, but not outside the macro. Symbols that are defined for the whole program, will subsequently be called "global symbols" for better understanding.
We are already familiar with a special case of local symbols: formal macro parameters. They appear in the macro definition only. Since they are substituted during macro expansion, we don't have further problems with them. But what happens with symbols that are defined in a macro body?

Example 1:

The following simple macro is intended to read a character from the 8051 UART, and to return it in A:

```
              RECEIVE MACRO
       UARTIN: JNB RI,UARTIN
              MOV A,SBUF
              CLR RI
              ENDM
```

```
                This will work only once! If the macro RECEIVE is called
                multiple times, the label UARTIN will be multiply defined.
```

This can be solved by simply declaring the symbol UARTIN local.
For this, the LOCAL statement has been introduced. After the keyword LOCAL, a list of local symbols can be specified, separated by commas. These symbols will only be valid inside the macro that contains the LOCAL statement. LOCAL statements may only be placed directly after the MACRO or REPT statement, preceding the first body line. They may contain any number of local symbols. The macro body may be preceded by an arbitrary number of LOCAL statements.
Local symbols must be valid symbols, unique within the macro, and different from the formal parameters (if any). Keywords cannot be used as local symbol names. If a local symbol has the same name as a global symbol, the local scope takes precedance during substitution.
When a macro is expanded, its local symbols are always substituted: the formal parameters are replaced by the macro arguments, and the local symbols that have been declared in a LOCAL statement are replaced by unique, global symbol names, which the assembler generates during every expansion. These have always the format ??xxxx, where xxxx is a unique symbol number.

Example 2: ----------

After a redesign of our previous macro RECEIVE using local symbols, it is looking as follows:

```
                RECEIVE MACRO
                LOCAL UARTIN
        UARTIN: JNB RI,UARTIN
                MOV A,SBUF
                CLR RI
                ENDM
```

Enhanced as shown above, the macro will work correctly, as often as desired. When RECEIVE is called for the first time, the local symbol UARTIN will be replaced by ??0000,

```
        ??0000: JNB RI,??0000
                MOV A,SBUF
                CLR RI
```

when it is called for the second time, UARTIN will be replaced by ??0001, and so on:

```
        ??0001: JNB RI,??0001
                MOV A,SBUF
                CLR RI
```

However, it is recommended not to define global symbols in the format ??xxxx, to avoid name conflicts with substituted local symbols from expanded macros.

III.11.5 Macro Operators

There are some special control characters, which are very useful for macro definition, call and expansion:

;; Macro commentary:
Normally, comments in body lines are also contained in the expanded lines. If a commentary begins with ';;' however, it is not stored during macro definition. Therefore, it doesn't consume memory space, and appears in the list file in the macro definition only, but not in the expanded lines.

! Literal operator:
If the escape character '!' precedes another printable character in a macro argument, the assembler is forced to treat that character literally. This means it will be passed to the macro, even if it is a control character, while the literal operator itself is removed.

< > Literal brackets:
If a macro argument is intended to contain separation or control characters, it must be enclosed in literal brackets < ... > to pass it to the macro as one argument string, while the outermost pair of

brackets is removed. Literal brackets can be nested to any depth.

% Evaluation:
If a macro argument is preceded by the evaluation operator '%', it is interpreted as an expression, which will be evaluated before it is passed to the macro. The actual argument string will not be the expression itself, but a decimal ASCII representation of its value. The expression must be known on pass 1.

& Substitution:
The '&' character separates parameter names (local symbols) from surrounding text. Outside quoted strings and commentary it serves only as a general separation character. This applies always when a local symbol directly precedes or follows another alphanumeric string. Inside quoted strings and commentary, a local symbol must be preceded by '&' if it is to be substituted there.
During every macro expansion, the assembler removes exactly one '&' from every sequence of '&' characters. This allows for example, to define a nested macro inside a macro body, which also uses the substitution operator '&': one writes simply '&&'!

Example 1: ----------
The commentary should only be visible in the definition of the macro LICENSE:

```
LICENSE MACRO
DB 'Copyright'  ;;legal stuff
ENDM
```

When called, the expanded macro body is looking like this in the list file:

```
DB 'Copyright'
```

Example 2: ----------

```
SPECIAL !;
```

passes a semicolon to the macro SPECIAL as a literal argument. This could also be done with

```
SPECIAL <;>
```

Example 3: ----------
The macro CONST defines a 16-bit constant in ROM:

```
CONST MACRO NUMB
DW NUMB
ENDM
```

If it is called as shown below,

```
CONST 0815H+4711-42
```

the parameter NUMB would be substituted as follows:

```
DW 0815H+4711-42
```

If the same macro argument is preceded by a '%' however,

```
CONST %0815H+4711-42
```

the substitution will result in:

```
DW 6738
```

Example 4: ----------
During substitution, both arguments of the macro CONCAT should form a seamless symbol name:

```
CONCAT MACRO NAM, NUM
MOV R3,#0
NAM&NUM: DJNZ R3,NAM&NUM
ENDM
```

When CONCAT is called as follows,

```
                CONCAT LABEL, 08

                the parameters NAM and NUM are substituted during macro
                expansion as shown below:

                MOV R3,#0
        LABEL08: DJNZ R3,LABEL08
```

III.11.6 Premature End of a Macro Expansion

Sometimes it is useful, if a macro expansion can be terminated, before the end of the macro body is reached. This can be forced with the EXITM (exit macro) instruction. However, this makes sense in conjunction with conditional assembly only.

```
Example:        FLEXIBLE MACRO QUANTITY
--------        DB 'Text'
                IF QUANTITY LE 255
                EXITM
                ENDIF
                DW QUANTITY
                ENDM

                The macro FLEXIBLE always has to insert the string 'Text'
                into the CODE space. After that, it should insert a 16-bit
                constant only, if the numerical value of the parameter
                QUANTITY is greater than 255.
                Otherwise the macro expansion should be terminated with
                EXITM before. If the macro is called as follows,

                FLEXIBLE 42

                it will be expanded to

                DB 'Text'

                in list mode $GENONLY/$CONDONLY.
                However, if it is called like this,

                FLEXIBLE 4711

                it will be expanded to:

                DB 'Text'
                DW 4711
```

When a macro expansion is terminated with EXITM, all IFxx constructions that have been opened within the macro body so far, are closed.
Of course macro bodies may also contain control statements. If an include file is inserted into a macro body with a $INCLUDE control, and this include file, or a nested include file, contains an EXITM instruction, all include file levels up to the next macro level are closed at this point, and the expansion of that macro is terminated immediately.

III.11.7 Nested and Recursive Macro Calls

Macro bodies may also contain macro calls, and so may the bodies of those called macros, and so forth.
If a macro call is seen throughout the expansion of a macro, the assembler starts immediately with the expansion of the called macro. For this, its its expanded body lines are simply inserted into the expanded macro body of the calling macro, until the called macro is completely expanded. Then the expansion of the calling macro is continued with the body line following the nested macro call.

```
Example 1:      INSIDE MACRO
----------      SUBB A,R3
                ENDM

                OUTSIDE MACRO
```

```
MOV A,#42
INSIDE
MOV R7,A
ENDM
```

In the body of the macro OUTSIDE, the macro ISIDE is called. If OUTSIDE is called (and the list mode is set to $GENONLY), one gets something like the following expansion:

```
Line  I  Addr  Code            Source

  15+ 1  0000  74 2A           MOV A,#42
  17+ 2  0002  9B              SUBB A,R3
  18+ 1  0003  FF              MOV R7,A
```

Since macro calls can be nested to any depth (while there is free memory), the macro expansion level is shown in the I-column of the list file. Since macro and include file levels can be nested in arbitrary sequence and depth, the nesting level is counted through all macro and include file levels regardless. For better distinction, the character following the global line number is ':' for include file levels, and '+' for macro levels.

If macros are calling themselves, one speaks of recursive macro calls. In this case, there must be some stop criterion, to prevent the macro of calling itself over and over until the assembler is running out of memory! Here again, conditional assembly is the solution:

Example 2: ----------

The macro COUNTDOWN is to define 16-bit constants from 1 thru n in descending order in ROM. n can be passed to the macro as a parameter:

```
COUNTDOWN MACRO DEPTH
IF DEPTH GT 0
DW DEPTH
COUNTDOWN %DEPTH-1
ENDIF
ENDM
```

If COUNTDOWN is called like this,

```
COUNTDOWN 7
```

something like the following macro expansion results (in list mode $GENONLY/$CONDONLY):

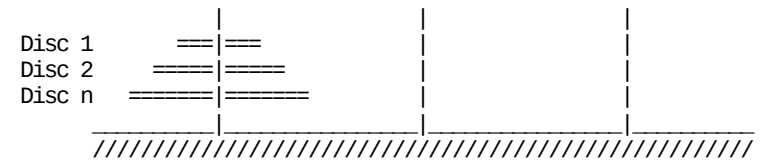
```
Line  I  Addr  Code            Source

  16+ 1  0000  00 07           DW 7
  19+ 2  0002  00 06           DW 6
  22+ 3  0004  00 05           DW 5
  25+ 4  0006  00 04           DW 4
  28+ 5  0008  00 03           DW 3
  31+ 6  000A  00 02           DW 2
  34+ 7  000C  00 01           DW 1
```

After the Dark Ages, when the dust was settling and the sun broke through the gloom, computer science discovered the method of recursive programming. There was no doubt that this was the SOLUTION!
And the computer scientists started to explain this to the students. But it seemed that the students didn't get it. They always complained that recursive calculation of n! is a silly example indeed.
All the scientists felt stronly that there was still something missing. After 10 more years of hard research work, they also found the PROBLEM:

Example 3: ----------

The Towers of Hanoi

There are three vertical sticks on the table. On stick 1 there are n discs with different diameters and a hole in the middle, the smallest disc on top, the biggest on the bottom.



The PROBLEM is to transfer the tower of discs from stick 1 to stick 2 with a minimum of moves. But only the topmost disc on a tower may be moved at one time, and no disc may be layed on a smaller disc. Stick 3 may be used for scratch purposes. This is a SOLUTION with ASEM-51 macros:

```
;The Towers of Hanoi

$GENONLY CONDONLY

DISCS EQU 3     ;number of discs

HANOI MACRO n, SOURCE, DESTINATION, SCRATCH
  IF n > 0
    HANOI %(n-1), SOURCE, SCRATCH, DESTINATION
;   move topmost disc from stick &SOURCE to stick &DESTINATION
    HANOI %(n-1), SCRATCH, DESTINATION, SOURCE
  ENDIF
ENDM

HANOI DISCS, 1, 2, 3

END
```

The recursive macro HANOI generates an instruction manual for the PROBLEM, where the instructions appear as comment lines in the list file. The symbol DISCS must be set to the desired number of discs. If HANOI is called like this,

```
HANOI 3, 1, 2, 3
```

the following "instruction manual" is generated:

```
27+ 3       ;   move topmost disc from stick 1 to stick 2
35+ 2       ;   move topmost disc from stick 1 to stick 3
44+ 3       ;   move topmost disc from stick 2 to stick 3
53+ 1       ;   move topmost disc from stick 1 to stick 2
64+ 3       ;   move topmost disc from stick 3 to stick 1
72+ 2       ;   move topmost disc from stick 3 to stick 2
81+ 3       ;   move topmost disc from stick 1 to stick 2
```

The GENONLY and CONDONLY controls ensure that the table doesn't contain all the macro calls and IF constructions.

Exercise 1: Modify the macro HANOI so that it is generating a move table in ROM, which could directly be used as an input for an 8051-controlled robot-arm that really plays the game with 3 real sticks and n real discs.

Exercise 2: Prove that the minimum number of moves is $2^n - 1$. ;-)

III.11.8 Nested Macro Definitions

A macro body may also contain further macro definitions. However, these nested macro definitions aren't valid until the enclosing macro has been expanded! That means, the enclosing macro must have been called, before the nested macros can be called.

Example 1: A macro, which can be used to define macros with arbitrary names, may look as follows:

```
DEFINE MACRO MACNAME
MACNAME MACRO
```

```
DB 'I am the macro &MACNAME.'
ENDM
ENDM
```

In order not to overload the example with "knowhow", :-)
the nested macro only introduces itself kindly with
a suitable character string in ROM. The call

```
DEFINE Obiwan
```

would define the macro

```
Obiwan MACRO
DB 'I am the macro Obiwan.'
ENDM
```

and the call

```
DEFINE Skywalker
```

would define the following macro:

```
Skywalker MACRO
DB 'I am the macro Skywalker.'
ENDM
```

Example 2: ---------- A macro is to insert a variable number of NOPs into the program. For this, a macro with a nested REPT block seems to be best-suited:

```
REPEAT MACRO NOPS
REPT NOPS
NOP
ENDM
ENDM
```

The macro call

```
REPEAT 4
```

results in something like that:

```
Line  I  Addr  Code            Source

   9+ 1        N      0004     REPT 4
  10+ 1                       NOP
  11+ 1                       ENDM
  12+ 2  0000  00              NOP
  13+ 2  0001  00              NOP
  14+ 2  0002  00              NOP
  15+ 2  0003  00              NOP
```

III.11.9 Representation in the List File

Sometimes macro expansions tend to produce much more listing lines than resulting code. To list or not to list - that is the question!
The requirements to either get a better overall view or more detailed information may vary in different development phases or program sections.
To always get the best results, a number of general controls has been introduced, which influence the representation of macro expansions and IFxx constructions in the list file (see chapter "III.8 Assembler Controls"):

Control	Type	Default	Abbreviation	Meaning
$GEN	G	$GEN	$GE	list macro calls and expansion lines
$NOGEN	G		$NOGE	list macro calls only
$GENONLY	G		$GO	list expansion lines only
$COND	G	$COND	---	list full IFxx .. ENDIF constructions
$NOCOND	G		---	don't list lines in false branches
$CONDONLY	G		---	list assembled lines only

$SAVE	G	$SA	save current $LIST/$GEN/$COND state
$RESTORE	G	$RS	restore old $LIST/$GEN/$COND state

IV. Compatibility with the Intel Assembler

With their cross assembler ASM51, Intel has defined and implemented a suitable assembly language for the MCS-51 family, which has always been the only real standard in the 8051 world.
Unfortunately, Intel has announced the "end of life" of ASM51 (final version 2.3) and all the other Intel MCS-51 development tools to the end of 1993.
The ASEM-51 assembly language is a subset of the Intel standard that guarantees maximum compatibility with existing 8051 assembler sources.
It implements all 8051 instruction mnemonics as well as a rich and useful subset of the Intel pseudo instructions and assembler controls.

IV.1 Restrictions

Since ASEM-51 generates an Intel-HEX file (or absolute OMF-51) output instead of relocatable object modules, the whole source code of an 8051 application program has to reside in one single file. Consequently all pseudo instructions that deal with relocatable segments or external or public symbols, have not been implemented:

```
PUBLIC
EXTRN
SEGMENT
RSEG
```

Intel-style macros are not supported! (Thus the '%' character can be used in comments.)
Up to now only the following assembler controls and their abbreviations have been implemented:

	primary controls	abbrev.	general controls	abbrev.
Intel-controls	$DATE (<string>)	$DA	$EJECT	$EJ
	$DEBUG	$DB	$GEN	$GE
	$NODEBUG	$NODB	$NOGEN	$NOGE
	$MACRO (<percent>)	$MR	$GENONLY	$GO
	$NOMACRO	$NOMR	$INCLUDE (<file>)	$IC
	$MOD51	$MO	$LIST	$LI
	$NOMOD51	$NOMO	$NOLIST	$NOLI
	$PAGING	$PI	$SAVE	$SA
	$NOPAGING	$NOPI	$RESTORE	$RS
	$SYMBOLS	$SB	$TITLE (<string>)	$TT
	$NOSYMBOLS	$NOSB		
	$PAGELENGTH (<lines>)	$PL		
	$PAGEWIDTH (<columns>)	$PW		
ASEM-51 controls	$NOBUILTIN	-----	$COND	-----
	$NOTABS	-----	$NOCOND	-----
	$PHILIPS	-----	$CONDONLY	-----
			$ERROR (<string>)	-----
			$WARNING (<string>)	-----

IV.2 Extensions

Assembler controls need not start in column 1, but may be preceded by any number of blanks and tabs. Primary controls may also be preceded by comment lines and $INCLUDE statements, provided the corresponding include files are only containing other control statements and commentary.
The source file may contain blank and comment lines behind the END statement.
Character strings may also be enclosed in double quotes.
The DATA symbol for the special function register PCON is predefined.
The bit operator '.' is legal in all expressions, not only in those that have to match the segment type BIT.

ASEM-51 introduces a set of meta instructions, which overlay the Intel MCS-51 assembly language, but are not part of it!
The meta instructions IFxx, ELSEIFxx, ELSE, and ENDIF allow conditional

assembly, while the meta instructions MACRO, REPT, ENDM, EXITM, and LOCAL (and some control characters) form a powerful macro processing language. For detailed information on meta instructions see chapters "III.10 Conditional Assembly" and "III.11 Macro Processing".

IV.3 Further Differences

To make semantics unique, especially the precedence of unary operators in expressions is slightly different. Furthermore, expressions with a bit operation "." evaluate to a BIT type result, not to NUMBER. The segment type of symbols that are defined with EQU or SET evaluates always to NUMBER. Otherwise it might be difficult in some cases, to force the definition of typeless symbols. This is described in detail in chapters "III.4 Expressions" and "III.7 Segment Type".
Except in DB instructions, the zero length string constant '' is illegal.
The $NOMOD51 control disables also the predefined CODE addresses.
The special assembler symbols AR0...AR7 are predefined for bank 0 before the first USING statement occurs.

V. List File Format

The ASEM-51 list file format has been designed to give the user as much information about the generated code as possible.
Besides the source code listed, there are five basic layout structures in the listing:

- the page header
- the file header
- the line headings
- the error diagnosis
- the symbol table or cross-reference listing

Normally, every page of the listing starts with a page header as shown below:

```
ASEM-51 V1.3              Copyright (c) 2001 by W.W. Heinz              PAGE 1
```

It identifies the assembler, contains the copyright information and shows the actual page number at the right margin. After the page header, source lines are output in the list file format. When the maximum number of lines per page is reached, another page header is output after a form feed character.
If your printer doesn't support form feeds, the page header can be suppressed with the $NOPAGING control. The number of lines per page can be adjusted to the paper format with the $PAGELENGTH control. The width of the page header (and all other lines) can be set with the $PAGEWIDTH control.

The file header appears only on the first page. It identifies the assembler, lists all input and output files and marks the columns for the line headings. A typical file header is looking as shown below:

```
       MCS-51 Family Macro Assembler   A S E M - 5 1   V 1.3
       ================================================


        Source File:    demo.a51
        Object File:    demo.hex
        List File:      demo.lst


 Line  I  Addr  Code            Source
```

Directly after the file header starts the listing of the source code lines. Every source code line is preceded by a line heading. The line heading consists of four columns: line number, include file or macro level, line address, and generated code.
By default the line headings contain tab characters to save disk space. If your printer or file browser doesn't support tabs, they can be expanded to blanks with the $NOTABS control.

The column "Line" contains the global line number. It is not necessarily the local line number within the particular source file, but a global line number that is counted over the main source, all include files, and all macro expansion lines.
Since include files and macros can be nested arbitrarily, the global line number is terminated by a ':' character for the main source and all include file levels, and with a '+' character for macro expansion levels.

The column "I" flags the level of include file or macro nesting. In the main source, this column is empty. The first include file gets level 1. If this include file includes another include file, this one gets level 2, and so on. This is also valid for nested macro calls. If a macro is called in the main source, its expansion lines get level 1. If this macro calls another one, it gets level 2, and so forth.
Include file and macro levels can be nested in any sequence and to any depth!

The column "Addr" shows the start address of the listed line in the currently active segment (8051 address space). All addresses are represented as hex numbers. The addresses in the CODE and XDATA segments are four-digit numbers. Addresses in all other segments are two-digit numbers. For lines that cannot be assigned to a particular segment, the "Addr" field is left blank.

The "Code" column may contain up to four bytes of generated code, which is sufficient for all 8051 instructions. The code is listed in hex byte quantities starting from the left margin of the "Code" column.
However, the code generated for DB and DW instructions may be longer than four bytes. In these cases, the source code line is followed by additional line headings until the whole code of the line is listed.
The "Code" column does not always contain code that consumes space in the 8051 CODE segment. In contrast to many other assemblers, ASEM-51 lists the evaluation results of all expressions that may appear in pseudo instructions or assembler controls. These values are listed in hex representation at the right margin of the "Code" column. The segment type of those expressions is flagged with one single character at the left margin of the "Code" column:

C	CODE
D	DATA
I	IDATA
X	XDATA
B	BIT
N	typeless number
R	register

The "Source" column finally contains the original source code line.
A typical source code listing is looking as follows:

```
 Line  I  Addr  Code           Source

    1:                              ;A sample List File Demo Program
    2:                              ;------------------------------
    3:                        $NOMOD51                ;no 8051 SFR
    4:          N     004F    $PAGEWIDTH (79)         ;79 columns per line
    5:                        $NOTABS                 ;expand tabs
    6:          N       90            P1    DATA 090H  ;port 1 address
    7:          B       93            INPUT BIT  P1.3  ;pulse input
    8:
    9:          N     8000            ORG  08000H      ;set location counter
   10:    8000  80 20                  SJMP START       ;jump to start address
   11:
   12:    8002  01 07                  DB  1,7          ;define bytes
   13:    8004  00 02 00 0C            DW  2,12,9       ;define words
          8008  00 09
   14:    800A  63 6F 66 66            DB  'coffeeright (c) 1999',0    ;string
          800E  65 65 72 69
          8012  67 68 74 20
          8016  28 63 29 20
          801A  31 39 39 39
          801E  00
   15:    801F  N     0003             DS  3            ;define space
   16:
   17:    8022  75 30 00       START:  MOV COUNT,#0     ;reset counter
   18:    8025  30 93 FD       LLEVEL: JNB INPUT,LLEVEL ;wait for high
   19:    8028  20 93 FD       HLEVEL: JB  INPUT,HLEVEL ;wait for low
   20:    802B  05 30                  INC COUNT        ;count pulse
   21:    802D  80 F6                  JMP LLEVEL       ;next pulse
   22:
   23:          N       30            DSEG AT 030H     ;internal RAM
   24:      30  N       01     COUNT:  DS 1             ;counter variable
   25:
   26:                              END
```

If an error is detected in a source line, its position is flagged with a ^ character as good as possible, and a comprehensive error message is inserted. This is looking as shown below:

```
  17:    8022  75 30 00        START:  MOV COUNT,#0     ;reset counter
  18:    8025  30 93 FD        LLEVEL: JNB INPUT,LLEVEL ;wait for high
  19:    8028  20 93 00        HLEVEL: JB  INPUT,HLEUEL ;wait for low
                                                 ^
                          @@@@@ symbol not defined @@@@@

  20:    802B  05 30                   INC COUNT        ;count pulse
  21:    802D  80 F6                   JMP LLEVEL       ;next pulse
```

The error diagnosis at the end of program lists the register banks used, and the total number of errors detected throughout the assembly:

```
                    register banks used:  0, 1, 3

                    187 errors detected
```

A register bank counts as "used", if the program had switched to that bank with a USING instruction, or one of the special assembler symbols AR0 ... AR7 has been used, while the bank was active. The message

```
                    register banks used:  ---
```

means, that no bank has been used explicitly, and that the program code may, but need not, be register bank independent.

After the source code listing and error diagnosis, the symbol table or cross-reference listing starts. By default, a symbol table is generated. The symbol table lists all the symbols of a program in alphabetical order with their symbol name, segment type, hex value and first definition line. Predefined symbols are listed without a definition line number. The symbol table listing can be suppressed with the $NOSYMBOLS control. A typical symbol table listing is looking as shown below:

```
              L I S T   O F   S Y M B O L S
              ==============================


SYMBOL                            TYPE     VALUE        LINE
------------------------------------------------------------
AKKUM                             REGISTER     A          38
COUNT                             DATA        30          47
HLEVEL                            CODE      802E          35
INPUT                             BIT         93          12
LLEVEL                            CODE      802B          34
MY_PROGRAM                        MODULE                  14
P1                                DATA        90
QUANT                             NUMBER    0013          22
RECEIVE                           MACRO                    5
SP                                DATA        81
STACK                             IDATA       80          17
START                             CODE      8022          31
VOLTDC                            XDATA     D785          50
```

If the $XREF control is specified, a cross-reference listing is generated instead of a symbol table. The corresponding cross-reference listing for the symbol table above is looking as follows:

```
              C R O S S - R E F E R E N C E - L I S T I N G
              ============================================


SYMBOL                            TYPE     VALUE     DEFINED  REFERENCED
------------------------------------------------------------------------------
AKKUM                             REGISTER     A          38          42      43
COUNT                             DATA        30          47          32      40
```

				43	44
HLEVEL	CODE	802E	35	35	
INPUT	BIT	93	12	34	35
LLEVEL	CODE	802B	34	34	41
MY_PROGRAM	MODULE		14		
P1	DATA	90		12	
QUANT	NUMBER	0007	22	44	
	NUMBER	0013	37		
RECEIVE	MACRO		5		
SP	DATA	81		31	
STACK	IDATA	80	17	31	
START	CODE	8022	31	24	
TRASH	undef.	----		42	
VOLTDC	XDATA	D785	50	33	

It lists all the symbols of the program in alphabetical order, with their symbol name, all definitions including definition lines, segment types, and numerical values. Furthermore, all symbol references are listed as well.
The SYMBOL column contains the symbol name, while the columns TYPE, VALUE, and DEFINED may contain the segment types, numerical values, and definition lines of one, more, or no symbol defintions.
Register symbols have the symbol type "REGISTER", module names have the symbol type "MODULE", macro names have the symbol type "MACRO", and symbols that have been referenced but not defined, are flagged with "undef." in the TYPE column.
Starting from column REFERENCED up to the right margin, there is a number of columns (depending on the page width), containing all line numbers of symbol references (if any).
The cross-reference listing does not distinguish, whether multiple definitions of, or references to a particular symbol are legal or not. For this, refer to the error messages in the source listing.

VI. Support of 8051 Derivatives

Today a large number of 8051 derivatives is available that grows almost monthly! They all use the same instruction set of the MCS-51 processor core, but are different in peripheral components, to cover a wide range of applications. The difference for the assembly language programmer is mainly the varying set of special function registers and interrupt addresses.
It is always good practice to use the same SFR names in a microcontroller application program that the manufacturer of the derivative used has defined. For this the processor definition files *.MCU are provided. They all are include files with the special function register definitions of a particular 8051 derivative. However, the predefined symbols of ASEM-51 must be switched off prior to including the SFR definitions of another derivative as shown below:

```
$NOMOD51
$INCLUDE (80C515.MCU)
```

This would switch off the predefined symbols of the 8051 and include the register definitions of the 80C515 or 80C535 respectively.
Hence it is easy for the user to adapt ASEM-51 to a brandnew 8051 derivative! All what he has to do is to write a corresponding include file with the SFR definitions derived from the manufacturer's data sheet.
The name of every processor definition file is corresponding to the ROM version of a particular derivative. Of course it also applies to the EPROM, EEPROM, flash, and ROM-less versions (if any) of that derivative.
By the way, the file 8051.MCU provided contains exactly the predefined symbols of ASEM-51, because its internal symbol table has been generated from it!
To switch ASEM-51 to the reduced instruction set of the Philips 83C75x family of microcontrollers, the $PHILIPS control can be used.

Currently the following processor definition files are provided with ASEM-51:

Name	Manufacturer	Versions
8051.MCU	Intel	8051, 8031, 8751BH
	(and others)	8051AH, 8031AH, 8751H, 8051AHP, 8751H-8
		80C51BH, 80C31BH, 87C51, 80C51BHP
	Atmel	89C51, 89LV51, 87LV51, 80F51, 87F51
8052.MCU	Intel	8052AH, 8032AH, 8752BH
	SIEMENS	80513, 8352-5
80C52.MCU	Intel	80C52, 80C32, 87C52,
		80C54, 87C54, 80C58, 87C58
83C51FX.MCU	Intel	83C51FA, 80C51FA, 87C51FA
		83C51FB, 87C51FB, 83C51FC, 87C51FC
83C51R.MCU	Intel	83C51RA, 80C51RA, 87C51RA,
		83C51RB, 87C51RB, 83C51RC, 87C51RC
83C51KB.MCU	Intel	83C51KB
83C51GB.MCU	Intel	83C51GB, 80C51GB, 87C51GB
83C151.MCU	Intel	83C151SB, 87C151SB, 80C151SB
		83C151SA, 87C151SA
83C152.MCU	Intel	80C152JA, 83C152JA, 80C152JB
		80C152JC, 83C152JC, 80C152JD
83C452.MCU	Intel	83C452, 80C452
8044.MCU	Intel	8044AH, 8344AH, 8744AH
83931HA.MCU	Intel	83931HA, 80931HA
83931AA.MCU	Intel	83931AA, 80931AA
80512.MCU	SIEMENS	80512, 80532
80515.MCU	SIEMENS	80515, 80535, 80515K, 83515-4
80C515.MCU	SIEMENS	80C515, 80C535, 83C515H
83C515A.MCU	SIEMENS	83C515A-5, 80C515A
80C517.MCU	SIEMENS	80C517, 80C537
C501.MCU	SIEMENS	C501-1R, C501-L
C502.MCU	SIEMENS	C502-2R, C502-L
C503.MCU	SIEMENS	C503-1R, C503-L
C504.MCU	SIEMENS	C504-2R, C504-L
C509.MCU	SIEMENS	C509-L
C511.MCU	SIEMENS	C511, C511A
C513.MCU	SIEMENS	C513, C513A, C513A-H

C513AO.MCU	SIEMENS	C513AO
C515.MCU	SIEMENS	C515-L, C515-1R
C515A.MCU	SIEMENS	C515A-L, C515A-4R
C515C.MCU	SIEMENS	C515C-8R
C517A.MCU	SIEMENS	C517A-L, C517A-4R, 83C517A-5, 80C517A
C540U.MCU	SIEMENS	C540U
C541U.MCU	SIEMENS	C541U
83C451.MCU	Philips	83C451, 80C451, 87C451
83C528.MCU	Philips	83C528, 80C528, 87C528, 83C524, 87C524 83CE528, 80CE528, 89CE528
83C550.MCU	Philips	83C550, 80C550, 87C550
83C552.MCU	Philips	83C552, 80C552, 87C552
83C562.MCU	Philips	83C562, 80C562
83C652.MCU	Philips	83C652, 80C652, 87C652 83C654, 87C654, 83CE654, 80CE654
83C750.MCU	Philips	83C750, 87C750
83C751.MCU	Philips	83C751, 87C751
83C752.MCU	Philips	83C752, 87C752
83C754.MCU	Philips	83C754, 87C754
83C851.MCU	Philips	83C851, 80C851
83C852.MCU	Philips	83C852
87LPC762.MCU	Philips	87LPC762
87LPC768.MCU	Philips	87LPC768
80C521.MCU	AMD	80C521, 80C541, 87C521, 87C541, 80C321
80C324.MCU	AMD	80C324
83C154.MCU	OKI	83C154, 80C154, 85C154VS
83C154S.MCU	OKI	83C154S, 80C154S, 85C154HVS
80C310.MCU	DALLAS	80C310
80C320.MCU	DALLAS	80C320, 87C320, 80C323, 87C323
80C390.MCU	DALLAS	80C390
87C520.MCU	DALLAS	87C520, 83C520
87C530.MCU	DALLAS	87C530, 83C530
87C550.MCU	DALLAS	87C550
89C420.MCU	DALLAS	89C420
DS5000.MCU	DALLAS	5000FP, 5000, 5000T, 2250, 2250T
DS5001.MCU	DALLAS	5001FP, 5002FP, 5002FPM, 2251T, 2252T
MAX7651.MCU	Maxim	MAX7651, MAX7652
COM20051.MCU	SMC	COM20051
89C52.MCU	Atmel	89C52, 89C55, 89LV52, 89LV55, 87LV52, 80F52, 87F52
87F51RC.MCU	Atmel	87F51RC, 87F55, 87LV55
89C1051.MCU	Atmel	89C1051
89C2051.MCU	Atmel	89C2051, 89C4051, 89C1051U
89S8252.MCU	Atmel	89S8252, 89LS8252
89S51.MCU	Atmel	89S51
89S52.MCU	Atmel	89S52, 89LS52
89S53.MCU	Atmel	89S53, 89LS53
89S4D12.MCU	Atmel	89S4D12
73M2910.MCU	TDK	73M2910, 73M2910A
AN2131.MCU	Cypress	AN2121, AN2122, AN2125, AN2126, AN2131, AN2135, AN2136

All SIEMENS derivatives are now manufactured and sold by Infineon!

Appendix A

ASEM-51 Error Messages

A.1 Assembly Errors:

Assembly errors apply to the consistency of the assembly language program in syntax and semantics. If one of these errors is detected, it is flagged in the list file, and program execution continues. When assembly is finished, ASEM terminates with exit code 1:

Error Message	Meaning
address below segment base	Attempt to set the location counter of the current segment below the segment base address.
address out of range	The address of a jump or call instruction cannot be reached with the selected addressing mode.
already a macro parameter	In a macro definition, a local symbol is equal to a previously defined parameter name.
argument exceeds end of line	A macro argument contains more opening than closing angle brackets.
attempt to divide by zero	During evaluation of an assembly time expression, the assembler has to divide by zero.
binary operator expected	In this position of an expression, only binary operators are allowed.
comma expected	There should be a ',' character in the marked position.
commands after END statement	The END statement is followed by further assembler statements.
constant out of range	A numerical constant is greater than 65535.
duplicate local symbol	In a macro definition, a local symbol is defined multiple times or equal to a previously defined parameter name.
duplicate parameter name	The parameter names of a macro are not all different.
ENDIF statement expected	There are pending IFxx constructions, which are not terminated with an ENDIF meta instruction.
ENDM statement expected	There are macro definitions, which are not terminated with an ENDM instruction.
expression out of range	The result of an expression is too big or too small for that purpose.
file name expected	There should be a valid file name in this position.
forward reference to macro	A macro has been called, before it has been defined.

forward reference to register	A register type symbol has been used, before it has been EQU'd or SET.
illegal character	A statement contains characters, which are not allowed in MCS-51 assembly language.
illegal constant	There are syntax errors in a numeric constant.
illegal control statement	A statement is starting with an unknown keyword beginning with a $.
illegal operand	In this position of an expression, a valid operand had been expected.
illegal statement syntax	A statement contains a syntax element, which is not allowed in this context.
invalid base address	A DATA address that is not bit-addressable has been used on the left side of a '.' operator.
invalid bit number	A number greater than 7 has been used on the right side of a '.' operator.
invalid instruction	The instruction has previously been disabled with the $PHILIPS control.
macro type operand	A macro type symbol is used as an operand in a numeric expression.
maximum line length exceeded	During macro expansion, the replacement of parameters and/or local symbols increases the resulting line length to more than 255 characters.
misplaced LOCAL instruction	In a macro definition, a LOCAL instruction is preceded by body lines.
misplaced macro instruction	A macro instruction is used outside of a macro definition, or otherwise misplaced in the program structure.
misplaced macro operator	A macro operator (<, >, !, %, &) has been used in a wrong position.
module name already defined	There are more than one NAME statements in the program.
must be known on first pass	The result of an expression must fully evaluate on pass 1 of assembly.
must be preceded by $SAVE	A $RESTORE control occurs without a preceding $SAVE control.
must be preceded by IFxx	An ELSEIFxx, ELSE or ENDIF meta instruction occurs without a preceding IFxx meta instruction.
no END statement found	The program ends without an END statement.
not allowed in BIT segment	Instruction is not allowed in a BIT segment.
only allowed in BIT segment	Instruction is only allowed in a BIT segment.
only allowed in CODE segment	Instruction is only allowed in a

	CODE segment.
operand expected	An instruction ends, before it is syntactically complete.
phase error	A symbol is evaluating to different values on pass 1 and pass 2, or a macro has been defined different on pass 1 and pass 2.
Note: -----	This is a serious, internal assembler error, and should be reported to the author immediately!
preceded by non-control lines	A primary control occurs after statements that are no assembler controls.
register type operand	A register type symbol is used as an operand in a numeric expression.
segment limit exceeded	The location counter exceeds the boundaries of the current segment.
segment type mismatch	The segment type of an operand does not match the type of the instruction.
string exceeds end of line	A character string is not properly terminated with a quote.
symbol already defined	Attempt to redefine a symbol, which is already defined.
symbol name expected	There should be a valid symbol name in this position.
symbol not defined	A symbol is referenced, which has never been defined.
too many closing parentheses	An expression contains more closing than opening parentheses.
too many opening parentheses	An expression contains more opening than closing parentheses.
too many operands	An instruction contains more operands than expected.
unary operator expected	In this position of an expression, only unary operators are allowed.
user-defined error	A user-defined error message has been forced with the $ERROR control.

A.2 Runtime Errors:

Runtime errors are operational errors, or I/O errors.
If one of these errors is detected, it is flagged on the console,
and ASEM is aborting with exit code 2:

Error Message	Meaning
access denied	No privilege for attempted operation.
ambiguous option name	Not enough characters specified.
argument missing	Option requires an argument.
disk full	No more free disk space.
disk write-protected	Attempt to write to a write-protected disk.
drive not ready	Disk drive is off, or no media mounted.
duplicate file name	Attempt to overwrite an input or output file.
fatal I/O error	General (unknown) disk or device I/O error.
file not found	Source or include file not found. (DOS/Windows)

illegal option syntax	Option is not correctly specified.
invalid argument	Option has an illegal argument.
no input file	There is no file name in the command line.
no such file or directory	Source or include file not found. (Linux)
not a directory	Path contains a non-directory name. (Linux)
out of memory	Heap overflow!
path not found	Disk or directory not found. (DOS/Windows)
symbol is predefined	A /DEFINE option specifies a predefined symbol.
too many open files	No more free file handles.
too many parameters	More than three file names have been specified.
unknown option	Option is not implemented.

Appendix B

HEXBIN Error Messages

B.1 Conversion Errors:

Conversion errors apply to the consistency of Intel-HEX file and program options. If one of these errors is detected, it is flagged on the console, and HEXBIN is aborting with exit code 1:

Error Message	Meaning
checksum error	Checksum is not correct.
data after EOF record	Type 0 records after type 1 record.
file length out of range	/LENGTH option makes file too large.
fill-byte out of range	/FILL option defines byte value > 255.
hex file format error	Certainly no Intel-HEX file.
illegal hex digit	Character is no valid hex digit.
illegal record type	Record type is none of 0 or 1.
invalid record length	Record length doesn't match the record.
multiple EOF records	More than one type 1 record.
no data records found	File doesn't contain any type 0 records.
no EOF record found	File ends without a type 1 record.
offset out of range	/OFFSET option makes file too large.
record exceeds FFFFH	Address space wrap around in record.
record exceeds file length	/LENGTH option made file too short.

B.2 Runtime Errors:

Runtime errors are operational errors, or I/O errors. If one of these errors is detected, it is flagged on the console, and HEXBIN is aborting with exit code 2:

Error Message	Meaning
access denied	No privilege for attempted operation.
ambiguous option name	Not enough characters specified.
argument missing	Option requires an argument.
disk full	No more free disk space.
disk write-protected	Attempt to write to a write-protected disk.
drive not ready	Disk drive is off, or no media mounted.
duplicate file name	Attempt to overwrite an input or output file.
fatal I/O error	General (unknown) disk or device I/O error.
file not found	Intel-HEX file not found. (DOS/Windows)
illegal option syntax	Option is not correctly specified.
invalid argument	Option has an illegal argument.
no input file	There is no file name in the command line.
no such file or directory	Intel-HEX file not found. (Linux)
not a directory	Path contains a non-directory name. (Linux)
path not found	Disk or directory not found. (DOS/Windows)
too many open files	No more free file handles.
too many parameters	More than two file names have been specified.
unknown option	Option is not implemented.

Appendix C

Predefined Symbols

DATA Addresses:

P0	080H	P1	090H
SP	081H	SCON	098H
DPL	082H	SBUF	099H
DPH	083H	P2	0A0H
PCON	087H	IE	0A8H
TCON	088H	P3	0B0H
TMOD	089H	IP	0B8H
TL0	08AH	PSW	0D0H
TL1	08BH	ACC	0E0H
TH0	08CH	B	0F0H
TH1	08DH		

BIT Addresses:

IT0	088H	EA	0AFH
IE0	089H	RXD	0B0H
IT1	08AH	TXD	0B1H
IE1	08BH	INT0	0B2H
TR0	08CH	INT1	0B3H
TF0	08DH	T0	0B4H
TR1	08EH	T1	0B5H
TF1	08FH	WR	0B6H
RI	098H	RD	0B7H
TI	099H	PX0	0B8H
RB8	09AH	PT0	0B9H
TB8	09BH	PX1	0BAH
REN	09CH	PT1	0BBH
SM2	09DH	PS	0BCH
SM1	09EH	P	0D0H
SM0	09FH	OV	0D2H
EX0	0A8H	RS0	0D3H
ET0	0A9H	RS1	0D4H
EX1	0AAH	F0	0D5H
ET1	0ABH	AC	0D6H
ES	0ACH	CY	0D7H

CODE Addresses:

RESET	0000H	EXTI1	0013H
EXTI0	0003H	TIMER1	001BH
TIMER0	000BH	SINT	0023H

Plain Numbers:

??ASEM_51	8051H	??VERSION	0130H

Appendix D

Reserved Keywords

Special Assembler Symbols:

$	location counter
A	accumulator
AB	A/B register pair
AR0,AR1,AR2,AR3,AR4,AR5,AR6,AR7	direct register addresses
C	carry flag
DPTR	data pointer
PC	program counter
R0, R1, R2, R3, R4, R5, R6, R7	registers

Instruction Mnemonics

ACALL	DA	JNB	MUL	RR
ADD	DEC	JNC	NOP	RRC
ADDC	DIV	JNZ	ORL	SETB
AJMP	DJNZ	JZ	POP	SJMP
ANL	INC	LCALL	PUSH	SUBB
CALL	JB	LJMP	RET	SWAP
CJNE	JBC	MOV	RETI	XCH
CLR	JC	MOVC	RL	XCHD
CPL	JMP	MOVX	RLC	XRL

Pseudo Instructions

AT	DATA	DSEG	IDATA	SET
BIT	DB	DW	ISEG	USING
BSEG	DBIT	END	NAME	XDATA
CODE	DS	EQU	ORG	XSEG
CSEG				

Operators

AND	GT	LOW	NE	SHL
EQ	HIGH	LT	NOT	SHR
GE	LE	MOD	OR	XOR

Assembler Controls

$COND	$GO	$NODEBUG	$NOSYMBOLS	$RS
$CONDONLY	$IC	$NOGE	$NOTABS	$SA
$DA	$INCLUDE	$NOGEN	$NOXR	$SAVE
$DATE	$LI	$NOLI	$NOXREF	$SB
$DB	$LIST	$NOLIST	$PAGELENGTH	$SYMBOLS
$DEBUG	$MACRO	$NOMACRO	$PAGEWIDTH	$TITLE
$EJ	$MO	$NOMO	$PAGING	$TT
$EJECT	$MOD51	$NOMOD51	$PHILIPS	$WARNING
$ERROR	$MR	$NOMR	$PI	$XR
$GE	$NOBUILTIN	$NOPAGING	$PL	$XREF
$GEN	$NOCOND	$NOPI	$PW	
$GENONLY	$NODB	$NOSB	$RESTORE	

Meta Instructions

ELSE	ELSEIFN	ENDM	IFDEF	LOCAL
ELSEIF	ELSEIFNB	EXITM	IFN	MACRO
ELSEIFB	ELSEIFNDEF	IF	IFNB	REPT
ELSEIFDEF	ENDIF	IFB	IFNDEF	

Appendix E

Specification of the Intel-HEX Format

This object file format is supported by many cross assemblers, utilities, and most EPROM programmers.
An Intel-HEX file is a 7-bit ASCII text file, that contains a sequence of data records and an end record. Every record is a line of text that starts with a colon and ends with CR and LF.
Data records contain up to 16 data bytes, a 16-bit load address, a record type byte and an 8-bit checksum. All numbers are represented by upper case ASCII-hex characters.

DATA RECORD:

Byte 1	colon (:)
2 and 3	number of binary data bytes for this record
4 and 5	load address for this record, high byte
6 and 7	load address " " " low byte
8 and 9	record type: 00 (data record)
10 to x	data bytes, two characters each
x+1 to x+2	checksum (two characters)
x+3 to x+4	CR and LF

A typical data record looks like

```
:10E0000002E003E4F588758910F58DF58BD28E302A
```

The end record is the last line of the file.
In principle it is structured like a data record, but the number of data bytes is 00, the record type is 01 and the load-address field is 0000.

END RECORD:

Byte 1	colon (:)
2 and 3	00 (number of data bytes)
4 and 5	00 (load address, high byte)
6 and 7	00 (load address, low byte)
8 and 9	record type: 01 (end record)
10 and 11	checksum (two characters)
12 and 13	CR and LF

The typical END record looks like

```
:00000001FF
```

The checksum is the two's complement of the 8-bit sum, without carry, of the byte count, the two load address bytes, the record type byte and all data bytes.

Appendix F

The ASCII Character Set

hex	00	10	20	30	40	50	60	70
0	NUL	DLE		0	@	P	`	p
1	SOH	DC1	!	1	A	Q	a	q
2	STX	DC2	"	2	B	R	b	r
3	ETX	DC3	#	3	C	S	c	s
4	EOT	DC4	$	4	D	T	d	t
5	ENQ	NAK	%	5	E	U	e	u
6	ACK	SYN	&	6	F	V	f	v
7	BEL	ETB	'	7	G	W	g	w
8	BS	CAN	(	8	H	X	h	x
9	HT	EM	)	9	I	Y	i	y
A	LF	SUB	*	:	J	Z	j	z
B	VT	ESC	+	;	K	[	k	{
C	FF	FS	,	<	L	\	l	|
D	CR	GS	-	=	M	]	m	}
E	SO	RS	.	>	N	^	n	~
F	SI	US	/	?	O	_	o	DEL

Appendix G

Literature

		Order Number
Intel:	MCS(R) 51 Microcontroller Family User's Manual	
	MCS-51 Macro Assembler User's Guide	
	8-Bit Embedded Controllers 1990	
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Appendix H

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Appendix I

8051 Instructions in numerical Order

Abbreviations:

direct	=	8-bit DATA address in internal memory
const8	=	8-bit constant in CODE memory
const16	=	16-bit constant in CODE memory
addr16	=	16-bit long CODE address
addr11	=	11-bit absolute CODE address
rel	=	signed 8-bit relative CODE address
bit	=	8-bit BIT address in internal memory

Opcode	Mnemonic	Operands	Bytes	Flags	Cycles
00	NOP		1		1
01	AJMP	addr11	2		2
02	LJMP	addr16	3		2
03	RR	A	1		1
04	INC	A	1	P	1
05	INC	direct	2		1
06	INC	@R0	1		1
07	INC	@R1	1		1
08	INC	R0	1		1
09	INC	R1	1		1
0A	INC	R2	1		1
0B	INC	R3	1		1
0C	INC	R4	1		1
0D	INC	R5	1		1
0E	INC	R6	1		1
0F	INC	R7	1		1
10	JBC	bit, rel	3		2
11	ACALL	addr11	2		2
12	LCALL	addr16	3		2
13	RRC	A	1	CY P	1
14	DEC	A	1	P	1
15	DEC	direct	2		1
16	DEC	@R0	1		1
17	DEC	@R1	1		1
18	DEC	R0	1		1
19	DEC	R1	1		1
1A	DEC	R2	1		1
1B	DEC	R3	1		1
1C	DEC	R4	1		1
1D	DEC	R5	1		1
1E	DEC	R6	1		1
1F	DEC	R7	1		1
20	JB	bit, rel	3		2
21	AJMP	addr11	2		2
22	RET		1		2
23	RL	A	1		1
24	ADD	A, #const8	2	CY AC OV P	1
25	ADD	A, direct	2	CY AC OV P	1
26	ADD	A, @R0	1	CY AC OV P	1
27	ADD	A, @R1	1	CY AC OV P	1

Opcode	Mnemonic	Operands	Bytes	Flags	Cycles
28	ADD	A, R0	1	CY AC OV P	1
29	ADD	A, R1	1	CY AC OV P	1
2A	ADD	A, R2	1	CY AC OV P	1
2B	ADD	A, R3	1	CY AC OV P	1
2C	ADD	A, R4	1	CY AC OV P	1
2D	ADD	A, R5	1	CY AC OV P	1
2E	ADD	A, R6	1	CY AC OV P	1
2F	ADD	A, R7	1	CY AC OV P	1
30	JNB	bit, rel	3		2
31	ACALL	addr11	2		2
32	RETI		1		2
33	RLC	A	1	CY P	1
34	ADDC	A, #const8	2	CY AC OV P	1
35	ADDC	A, direct	2	CY AC OV P	1
36	ADDC	A, @R0	1	CY AC OV P	1
37	ADDC	A, @R1	1	CY AC OV P	1
38	ADDC	A, R0	1	CY AC OV P	1
39	ADDC	A, R1	1	CY AC OV P	1
3A	ADDC	A, R2	1	CY AC OV P	1
3B	ADDC	A, R3	1	CY AC OV P	1
3C	ADDC	A, R4	1	CY AC OV P	1
3D	ADDC	A, R5	1	CY AC OV P	1
3E	ADDC	A, R6	1	CY AC OV P	1
3F	ADDC	A, R7	1	CY AC OV P	1
40	JC	rel	2		2
41	AJMP	addr11	2		2
42	ORL	direct, A	2		1
43	ORL	direct, #const8	3		2
44	ORL	A, #const8	2	P	1
45	ORL	A, direct	2	P	1
46	ORL	A, @R0	1	P	1
47	ORL	A, @R1	1	P	1
48	ORL	A, R0	1	P	1
49	ORL	A, R1	1	P	1
4A	ORL	A, R2	1	P	1
4B	ORL	A, R3	1	P	1
4C	ORL	A, R4	1	P	1
4D	ORL	A, R5	1	P	1
4E	ORL	A, R6	1	P	1
4F	ORL	A, R7	1	P	1
50	JNC	rel	2		2
51	ACALL	addr11	2		2
52	ANL	direct, A	2		1
53	ANL	direct, #const8	3		2
54	ANL	A, #const8	2	P	1
55	ANL	A, direct	2	P	1
56	ANL	A, @R0	1	P	1
57	ANL	A, @R1	1	P	1
58	ANL	A, R0	1	P	1
59	ANL	A, R1	1	P	1
5A	ANL	A, R2	1	P	1
5B	ANL	A, R3	1	P	1
5C	ANL	A, R4	1	P	1
5D	ANL	A, R5	1	P	1
5E	ANL	A, R6	1	P	1
5F	ANL	A, R7	1	P	1

Opcode	Mnemonic	Operands	Bytes	Flags	Cycles
60	JZ	rel	2		2
61	AJMP	addr11	2		2
62	XRL	direct, A	2		1
63	XRL	direct, #const8	3		2
64	XRL	A, #const8	2	P	1
65	XRL	A, direct	2	P	1
66	XRL	A, @R0	1	P	1
67	XRL	A, @R1	1	P	1
68	XRL	A, R0	1	P	1
69	XRL	A, R1	1	P	1
6A	XRL	A, R2	1	P	1
6B	XRL	A, R3	1	P	1
6C	XRL	A, R4	1	P	1
6D	XRL	A, R5	1	P	1
6E	XRL	A, R6	1	P	1
6F	XRL	A, R7	1	P	1
70	JNZ	rel	2		2
71	ACALL	addr11	2		2
72	ORL	C, bit	2	CY	2
73	JMP	@A+DPTR	1		2
74	MOV	A, #const8	2	P	1
75	MOV	direct, #const8	3		2
76	MOV	@R0, #const8	2		1
77	MOV	@R1, #const8	2		1
78	MOV	R0, #const8	2		1
79	MOV	R1, #const8	2		1
7A	MOV	R2, #const8	2		1
7B	MOV	R3, #const8	2		1
7C	MOV	R4, #const8	2		1
7D	MOV	R5, #const8	2		1
7E	MOV	R6, #const8	2		1
7F	MOV	R7, #const8	2		1
80	SJMP	rel	2		2
81	AJMP	addr11	2		2
82	ANL	C, bit	2	CY	2
83	MOVC	A, @A+PC	1	P	2
84	DIV	AB	1	CY OV P	4
85	MOV	direct, direct	3		2
86	MOV	direct, @R0	2		2
87	MOV	direct, @R1	2		2
88	MOV	direct, R0	2		2
89	MOV	direct, R1	2		2
8A	MOV	direct, R2	2		2
8B	MOV	direct, R3	2		2
8C	MOV	direct, R4	2		2
8D	MOV	direct, R5	2		2
8E	MOV	direct, R6	2		2
8F	MOV	direct, R7	2		2
90	MOV	DPTR, #const16	3		2
91	ACALL	addr11	2		2
92	MOV	bit, C	2		2
93	MOVC	A, @A+DPTR	1	P	2
94	SUBB	A, #const8	2	CY AC OV P	1
95	SUBB	A, direct	2	CY AC OV P	1
96	SUBB	A, @R0	1	CY AC OV P	1
97	SUBB	A, @R1	1	CY AC OV P	1

Opcode	Mnemonic	Operands	Bytes	Flags	Cycles
98	SUBB	A, R0	1	CY AC OV P	1
99	SUBB	A, R1	1	CY AC OV P	1
9A	SUBB	A, R2	1	CY AC OV P	1
9B	SUBB	A, R3	1	CY AC OV P	1
9C	SUBB	A, R4	1	CY AC OV P	1
9D	SUBB	A, R5	1	CY AC OV P	1
9E	SUBB	A, R6	1	CY AC OV P	1
9F	SUBB	A, R7	1	CY AC OV P	1
A0	ORL	C, /bit	2	CY	2
A1	AJMP	addr11	2		2
A2	MOV	C, bit	2	CY	1
A3	INC	DPTR	1		2
A4	MUL	AB	1	CY OV P	4
A5	illegal opcode				
A6	MOV	@R0, direct	2		2
A7	MOV	@R1, direct	2		2
A8	MOV	R0, direct	2		2
A9	MOV	R1, direct	2		2
AA	MOV	R2, direct	2		2
AB	MOV	R3, direct	2		2
AC	MOV	R4, direct	2		2
AD	MOV	R5, direct	2		2
AE	MOV	R6, direct	2		2
AF	MOV	R7, direct	2		2
B0	ANL	C, /bit	2	CY	2
B1	ACALL	addr11	2		2
B2	CPL	bit	2		1
B3	CPL	C	1	CY	1
B4	CJNE	A, #const8, rel	3	CY	2
B5	CJNE	A, direct, rel	3	CY	2
B6	CJNE	@R0, #const8, rel	3	CY	2
B7	CJNE	@R1, #const8, rel	3	CY	2
B8	CJNE	R0, #const8, rel	3	CY	2
B9	CJNE	R1, #const8, rel	3	CY	2
BA	CJNE	R2, #const8, rel	3	CY	2
BB	CJNE	R3, #const8, rel	3	CY	2
BC	CJNE	R4, #const8, rel	3	CY	2
BD	CJNE	R5, #const8, rel	3	CY	2
BE	CJNE	R6, #const8, rel	3	CY	2
BF	CJNE	R7, #const8, rel	3	CY	2
C0	PUSH	direct	2		2
C1	AJMP	addr11	2		2
C2	CLR	bit	2		1
C3	CLR	C	1	CY	1
C4	SWAP	A	1		1
C5	XCH	A, direct	2	P	1
C6	XCH	A, @R0	1	P	1
C7	XCH	A, @R1	1	P	1
C8	XCH	A, R0	1	P	1
C9	XCH	A, R1	1	P	1
CA	XCH	A, R2	1	P	1
CB	XCH	A, R3	1	P	1
CC	XCH	A, R4	1	P	1
CD	XCH	A, R5	1	P	1
CE	XCH	A, R6	1	P	1
CF	XCH	A, R7	1	P	1

Opcode	Mnemonic	Operands	Bytes	Flags		Cycles
D0	POP	direct	2			2
D1	ACALL	addr11	2			2
D2	SETB	bit	2			1
D3	SETB	C	1	CY		1
D4	DA	A	1	CY	P	1
D5	DJNZ	direct, rel	3			2
D6	XCHD	A, @R0	1		P	1
D7	XCHD	A, @R1	1		P	1
D8	DJNZ	R0, rel	2			2
D9	DJNZ	R1, rel	2			2
DA	DJNZ	R2, rel	2			2
DB	DJNZ	R3, rel	2			2
DC	DJNZ	R4, rel	2			2
DD	DJNZ	R5, rel	2			2
DE	DJNZ	R6, rel	2			2
DF	DJNZ	R7, rel	2			2
E0	MOVX	A, @DPTR	1		P	2
E1	AJMP	addr11	2			2
E2	MOVX	A, @R0	1		P	2
E3	MOVX	A, @R1	1		P	2
E4	CLR	A	1		P	1
E5	MOV	A, direct	2		P	1
E6	MOV	A, @R0	1		P	1
E7	MOV	A, @R1	1		P	1
E8	MOV	A, R0	1		P	1
E9	MOV	A, R1	1		P	1
EA	MOV	A, R2	1		P	1
EB	MOV	A, R3	1		P	1
EC	MOV	A, R4	1		P	1
ED	MOV	A, R5	1		P	1
EE	MOV	A, R6	1		P	1
EF	MOV	A, R7	1		P	1
F0	MOVX	@DPTR, A	1			2
F1	ACALL	addr11	2			2
F2	MOVX	@R0, A	1			2
F3	MOVX	@R1, A	1			2
F4	CPL	A	1		P	1
F5	MOV	direct, A	2			1
F6	MOV	@R0, A	1			1
F7	MOV	@R1, A	1			1
F8	MOV	R0, A	1			1
F9	MOV	R1, A	1			1
FA	MOV	R2, A	1			1
FB	MOV	R3, A	1			1
FC	MOV	R4, A	1			1
FD	MOV	R5, A	1			1
FE	MOV	R6, A	1			1
FF	MOV	R7, A	1			1

Appendix J

8051 Instructions in lexical Order

Abbreviations:

direct	=	8-bit DATA address in internal memory
const8	=	8-bit constant in CODE memory
const16	=	16-bit constant in CODE memory
addr16	=	16-bit long CODE address
addr11	=	11-bit absolute CODE address
rel	=	signed 8-bit relative CODE address
bit	=	8-bit BIT address in internal memory

i = register numbers 0 or 1
n = register numbers 0 thru 7
a = 32 * m
m = the 3 most significant bits of an absolute address

Opcode	Mnemonic	Operands	Bytes	Flags	Cycles
11+a	ACALL	addr11	2		2
24	ADD	A, #const8	2	CY AC OV P	1
26+i	ADD	A, @Ri	1	CY AC OV P	1
25	ADD	A, direct	2	CY AC OV P	1
28+n	ADD	A, Rn	1	CY AC OV P	1
34	ADDC	A, #const8	2	CY AC OV P	1
36+i	ADDC	A, @Ri	1	CY AC OV P	1
35	ADDC	A, direct	2	CY AC OV P	1
38+n	ADDC	A, Rn	1	CY AC OV P	1
01+a	AJMP	addr11	2		2
54	ANL	A, #const8	2	P	1
56+i	ANL	A, @Ri	1	P	1
55	ANL	A, direct	2	P	1
58+n	ANL	A, Rn	1	P	1
B0	ANL	C, /bit	2	CY	2
82	ANL	C, bit	2	CY	2
53	ANL	direct, #const8	3		2
52	ANL	direct, A	2		1
B6+i	CJNE	@Ri, #const8, rel	3	CY	2
B4	CJNE	A, #const8, rel	3	CY	2
B5	CJNE	A, direct, rel	3	CY	2
B8+n	CJNE	Rn, #const8, rel	3	CY	2
E4	CLR	A	1	P	1
C2	CLR	bit	2		1
C3	CLR	C	1	CY	1
F4	CPL	A	1	P	1
B2	CPL	bit	2		1
B3	CPL	C	1	CY	1
D4	DA	A	1	CY P	1
16+i	DEC	@Ri	1		1
14	DEC	A	1	P	1
15	DEC	direct	2		1
18+n	DEC	Rn	1		1
84	DIV	AB	1	CY OV P	4
D5	DJNZ	direct, rel	3		2

Opcode	Mnemonic	Operands	Bytes	Flags		Cycles
D8+n	DJNZ	Rn, rel	2			2
06+i	INC	@Ri	1			1
04	INC	A	1		P	1
05	INC	direct	2			1
A3	INC	DPTR	1			2
08+n	INC	Rn	1			1
20	JB	bit, rel	3			2
10	JBC	bit, rel	3			2
40	JC	rel	2			2
73	JMP	@A+DPTR	1			2
30	JNB	bit, rel	3			2
50	JNC	rel	2			2
70	JNZ	rel	2			2
60	JZ	rel	2			2
12	LCALL	addr16	3			2
02	LJMP	addr16	3			2
76+i	MOV	@Ri, #const8	2			1
F6+i	MOV	@Ri, A	1			1
A6+i	MOV	@Ri, direct	2			2
74	MOV	A, #const8	2		P	1
E6+i	MOV	A, @Ri	1		P	1
E5	MOV	A, direct	2		P	1
E8+n	MOV	A, Rn	1		P	1
92	MOV	bit, C	2			2
A2	MOV	C, bit	2	CY		1
75	MOV	direct, #const8	3			2
86+i	MOV	direct, @Ri	2			2
F5	MOV	direct, A	2			1
85	MOV	direct, direct	3			2
88+n	MOV	direct, Rn	2			2
90	MOV	DPTR, #const16	3			2
78+n	MOV	Rn, #const8	2			1
F8+n	MOV	Rn, A	1			1
A8+n	MOV	Rn, direct	2			2
93	MOVC	A, @A+DPTR	1		P	2
83	MOVC	A, @A+PC	1		P	2
F0	MOVX	@DPTR, A	1			2
F2+i	MOVX	@Ri, A	1			2
E0	MOVX	A, @DPTR	1		P	2
E2+i	MOVX	A, @Ri	1		P	2
A4	MUL	AB	1	CY	OV P	4
00	NOP		1			1
44	ORL	A, #const8	2		P	1
46+i	ORL	A, @Ri	1		P	1
45	ORL	A, direct	2		P	1
48+n	ORL	A, Rn	1		P	1
A0	ORL	C, /bit	2	CY		2
72	ORL	C, bit	2	CY		2
43	ORL	direct, #const8	3			2
42	ORL	direct, A	2			1
D0	POP	direct	2			2
C0	PUSH	direct	2			2
22	RET		1			2
32	RETI		1			2
23	RL	A	1			1
33	RLC	A	1	CY	P	1

Opcode	Mnemonic	Operands	Bytes	Flags	Cycles
03	RR	A	1		1
13	RRC	A	1	CY P	1
D2	SETB	bit	2		1
D3	SETB	C	1	CY	1
80	SJMP	rel	2		2
94	SUBB	A, #const8	2	CY AC OV P	1
96+i	SUBB	A, @Ri	1	CY AC OV P	1
95	SUBB	A, direct	2	CY AC OV P	1
98+n	SUBB	A, Rn	1	CY AC OV P	1
C4	SWAP	A	1		1
C6+i	XCH	A, @Ri	1	P	1
C5	XCH	A, direct	2	P	1
C8+n	XCH	A, Rn	1	P	1
D6+i	XCHD	A, @Ri	1	P	1
64	XRL	A, #const8	2	P	1
66+i	XRL	A, @Ri	1	P	1
65	XRL	A, direct	2	P	1
68+n	XRL	A, Rn	1	P	1
63	XRL	direct, #const8	3		2
62	XRL	direct, A	2		1