



Directives

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Instruction format

- A general source line is:

`{label} {operation} {;comment}`

- operation may be:

- an instruction
- a directive
- a pseudo-instruction

labels must start at the beginning of the line

The instructions, directives, and pseudo-instructions must be preceded by a white space, either a tab or any number of spaces

Common directives

AREA	Defines a block of code or data
RN	Can be used to associate a register with a name
EQU	Equates a symbol to a numeric constant
ENTRY	Declares an entry point to your program
DCB, DCW, DCD	Allocates memory and specifies initial runtime contents
ALIGN	Aligns data or code to a particular memory boundary
SPACE	Reserves a zeroed block of memory of a particular size
LTORG	Assigns the starting point of a literal pool
END:	Designates the end of a source file

Sections of data and code

- The IDE tools need to be told how to treat all the different parts of a program
 - Data sections,
 - Program sections,
 - Blocks of coefficients, etc.
- These sections, which are indivisible and named, then get manipulated by the linker and ultimately end up in the correct type of memory in a system.
 - The data, which could be read-write information, could get stored in RAM,
 - The program code which might end up in Flash memory.

Sections of data and code (II)

- Normally you will have separate sections for your program and your data, especially in larger programs.
 - The code must have at least one AREA directive in it, which is usually found in the first few lines of a program
 - Blocks of coefficients or tables can be placed in a section of their own.

Sections of data and code (III)

- `AREA sectionName {, attr} {, attr}...`
- If *sectionName* starts with a number, it must be enclosed in bars
e.g. `|1_DataArea|`
- `|.text|` is used by the C compiler
- At least one AREA directive is mandatory
- Example: `AREA Example, CODE, READONLY`

Section attributes

- `CODE`: the section contains machine code
- `DATA`: the section contains data
- `READONLY`: the section can be placed in read-only memory
- `READWRITE`: the section can be placed in read-write memory
- `ALIGN = expr`: the section is aligned on a 2^{*expr*} -byte boundary

Register names

- r0-r15 or R0-R15
- a1-a4 or r0-r3
- r13, R13, sp, SP
- r14, R14, lr, LR
- r15, R15, pc, PC
- You can assign other names with RN:

name RN registerIndex

- E.g. `coeff1 RN 8`

Declaring constants

- The `EQU` directive gives a symbolic name to a numeric constant:

name EQU expression

- Advantages:
 - readability
 - easiness in updating the value through the code

Numbers

- You can express numbers in any base:
 - decimal: e.g. 123
 - hexadecimal: e.g. 0x3F
 - other bases in the format n_xxx where
 - n is the base
 - xxx is the number in that base

Constant allocation in code memory

`{label} DCxx expr{,expr}...`

- The available directives are:
 - DCB: define constant byte
 - DCW: define constant half-word
 - DCWU: define constant half-word unaligned
 - DCD: define constant word
 - DCDU: define constant word unaligned
- *expr* is:
 - a numeric expression in the proper range
 - a string (with DCB only)

DCB

```
myData    DCB 65, 0x73, 8_163  
          DCB "embly"
```

Address	Value	Octal	Hex	ASCII
0x000000D2	65	101	41	A
0x000000D3	115	163	73	s
0x000000D4	115	163	73	s
0x000000D5	101	145	65	e
0x000000D6	109	155	6D	m
0x000000D7	98	142	62	b
0x000000D8	108	154	6C	l
0x000000D9	121	171	79	y

DCW

myData DCB 65, 0x73, 8_163
 DCW 0x626D, 0x796C

Address	Value	Octal	Hex	ASCII
0x000000D2	65	101	41	A
0x000000D3	115	163	73	s
0x000000D4	115	163	73	s
0x000000D5	0	0	0	NUL
0x000000D6	109	155	6D	m
0x000000D7	98	142	62	b
0x000000D8	108	154	6C	l
0x000000D9	121	171	79	y

DCWU

myData DCB 65, 0x73, 8_163
 DCWU 0x626D, 0x796C

Address	Value	Octal	Hex	ASCII
0x000000D2	65	101	41	A
0x000000D3	115	163	73	s
0x000000D4	115	163	73	s
0x000000D5	109	155	6D	m
0x000000D6	98	142	62	b
0x000000D7	108	154	6C	l
0x000000D8	121	171	79	y

DCD

```
myData    DCB  65, 0x73, 8_163  
          DCD  0x796C626D
```

Address	Value	Octal	Hex	ASCII
0x000000D2	65	101	41	A
0x000000D3	115	163	73	s
0x000000D4	115	163	73	s
0x000000D5	0	0	0	NUL
0x000000D6	0	0	0	NUL
0x000000D7	0	0	0	NUL
0x000000D8	109	155	6D	m
0x000000D9	98	142	62	b
0x000000DA	108	154	6C	l
0x000000DB	121	171	79	y

DCDU

```
myData    DCB  65, 0x73, 8_163
          DCDU 0x796C626D
```

Address	Value	Octal	Hex	ASCII
0x000000D2	65	101	41	A
0x000000D3	115	163	73	s
0x000000D4	115	163	73	s
0x000000D5	109	155	6D	m
0x000000D6	98	142	62	b
0x000000D7	108	154	6C	l
0x000000D8	121	171	79	y

Align

- The `ALIGN` directive aligns the current location to a specified boundary by padding with zeros:

`ALIGN {expr{, offset}}`

- The current location is aligned to the next address of the form

$$n * \textit{expr} + \textit{offset}$$

- If *expr* is not specified, `ALIGN` sets the current location to the next word boundary.
- Example: The `ADR` Thumb pseudo-instruction can only load addresses that are word aligned, but a label within Thumb code might not be word aligned. Use `ALIGN 4` to ensure four-byte alignment of an address within Thumb code.

Align expr

```
myData    DCB 65  
          ALIGN 2  
          DCB 115
```

Address	Value	Octal	Hex	ASCII
0x000000D4	65	101	41	A
0x000000D5	0	0	0	NUL
0x000000D6	115	163	73	s

Align expr

```
myData    DCB  65  
          ALIGN 4  
          DCB 115
```

Address	Value	Octal	Hex	ASCII
0x000000D4	65	101	41	A
0x000000D5	0	0	0	NUL
0x000000D6	0	0	0	NUL
0x000000D7	0	0	0	NUL
0x000000D8	115	163	73	s

Align expr, offset

```
myData    DCB 65  
          ALIGN 4, 3  
          DCB 115
```

Address	Value	Octal	Hex	ASCII
0x000000D4	65	101	41	A
0x000000D5	0	0	0	NUL
0x000000D6	0	0	0	NUL
0x000000D7	115	163	73	s

Reserving a block of memory

- The SPACE directive reserves a zeroed block of memory:

`{label} SPACE expr`

- `expr` is the number of bytes to reserve

- Example:

```
long_var SPACE 8
```

Ending the source file

- The `END` directive tells the assembler that the current location is the end of the source file:

`END`