EEL3744

Menu

- Big Picture
- Assembler Directives
- Examples using:
  > Debugging/Simulating in Atmel Studio
  > Downloading and Debugging/Emulating
    with the UF-board
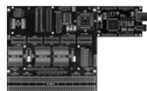
Look into my ...

> See on
> web-site: **GCPU_to_XMEGA.pdf,**
> **Examples: Table_Load_Example.asm,**
> **GPIO_Output.asm,**
> **doc0856_AVR_Instruction_Set.pdf**

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EEL3744

The Big Picture

Text Editor
{NOTEPAD}

Instruction
Mnemonics

6811 or GCPU:
LDAA #10

Source
"ASM" File

Machine
Codes

Assembler

List
File

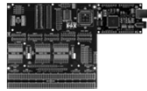6811: $86 $0A

GCPU: $02 $0A

Object
File

μP

Binary(Hex)

μP Simulator
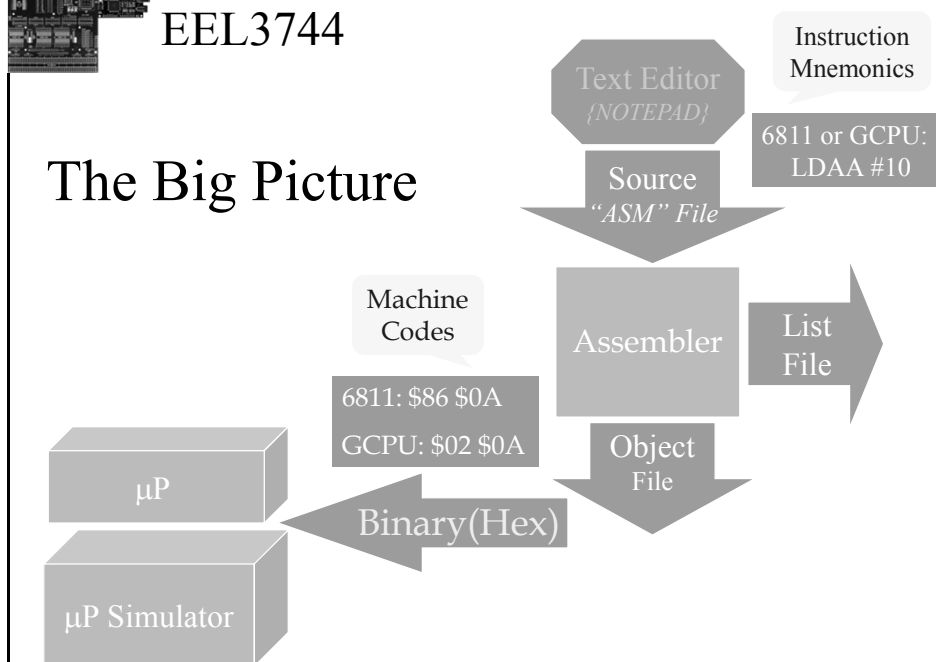
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EEL3744 Common Assembler Directives (Pseudo-instruction, GCPU)

- Assembly Control
  - >ORG   Origin program counter
- Symbol Definition
  - >EQU   Assign permanent value
- Data Definition/Storage Allocation
  - >DC.B   Define constant byte
  - >DC.W   Define constant word
  - >DS.B   Define storage bytes
  - >DS.W   Define storage word
  - > Old (alternate) form of above
    - – FCB   Form constant byte (similar to DC.B)
    - – FCC   Form constant character string (similar to DC.B)
    - – FDB   Form constant double byte (similar to DC.W)
    - – RMB   Reserve memory; single bytes (similar to DS.B)
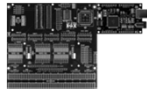
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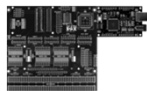
EEL3744   Atmel Assembler Directives

In Atmel Studio, see *Help*, then *AVR Assembler*, and then *Assembler directives*

Also, see
http://www.avr-asm-tutorial.net/avr_en/beginner/DIREXP.html

Directive	Description
BYTE	**Reserve byte(s) to a variable.**
CSEG	**Code Segment**
CSEGSIZE	Program memory size
DB	**Define constant byte(s)**
DEF	**Define a symbolic name on a register**
DSEG	**Data Segment**
DW	**Define Constant word(s)**
ENDM, ENDMACRO	EndMacro
EQU	**Set a symbol equal to an expression**
ESEG	EEPROM Segment
EXIT	Exit from file
INCLUDE	**Read source from another file**
LIST	**Turn listfile generation on**
LISTMAC	Turn Macro expansion in list file on

EEL3744 — Atmel Assembler Directives

See doc1022 AVR Assembler User Guide

In Atmel Studio, see *Help*, then *AVR Assembler*, and then *Assembler directives*

Also, see http://www.avr-asm-tutorial.net/avr_en/beginner/DIREXP.html

Directive	Description
MACRO	Begin Macro
NOLIST	**Turn listfile generation off**
ORG	**Set program origin**
SET	**Set a symbol to an expression**
ELSE,ELIF	Conditional assembly
ENDIF	Conditional assembly
ERROR	Outputs an error message
IF,IFDEF,IFNDEF	Conditional assembly
MESSAGE	Outputs a message string
DD	Define Doubleword
DQ	Define Quadword
UNDEF	Undefine register symbol
WARNING	Outputs a warning message
OVERLAP/NOOVERLAP	Set up overlapping section
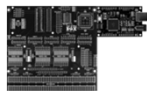
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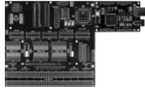# EEL3744 — **ORG**: Assembler Directive (Pseudo-instruction, **Atmel**)

- **ORG (Origin)**: It can be used to alter the location counter by setting it to any memory location in memory.
    > The ORG directive sets the location counter to an absolute value.
        – The value to set is given as a parameter
        – If an ORG directive is given within a **Data Segment**, then it is the **SRAM** location counter which is set
        – If the directive is given within a **Code Segment**, then it is the **Program Memory** counter which is set and if the directive is given within an EEPROM Segment, it is the **EEPROM** location counter which is set
    > The default values of the Code and the EEPROM location counters are zero, and the default value of the SRAM location counter is the address immediately following the end of I/O address space (0x60 for devices without extended I/O, 0x100 or more for devices with extended I/O) when the assembling is started.
    > Note that the **SRAM and EEPROM location counters count <u>bytes</u>.**
    > Note that the **Program Memory location counter counts <u>words</u>**.

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Assembly, Simulation, Demos

EEL3744   **ORG**: Assembler Directive (Pseudo-instruction, **Atmel**)

- **ORG (Origin)**: It can be used to alter the location counter by setting it to any location in memory.

Syntax:

    .ORG expression   ; where operand is a 16-bit address or an
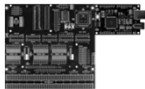   ; expression that evaluates to a 16-bit address

Example:

    .DSEG ; Start data segment
    .ORG 0x2000   ; Set SRAM address to 0x2000
    Total: .BYTE 1   ; Reserve a byte at SRAM address 0x2000

    .CSEG
    .ORG 0x0200   ; Set Program Counter to 0x200
    MAIN: ldi r16, 0xF   ; Do something

EEL3744   **EQU**: Assembler Directive (Pseudo-instruction, **Atmel**)

- **EQU (Equate)**: Set a symbol equal to an expression
    - > The EQU directive assigns a value to a label. This label can then be used in later expressions. A label assigned to a value by the EQU directive is a constant and can not be changed or redefined.
    - > EQU informs the assembler to equate the specified symbol name to the value of the operand.
    - > When the symbolic name is subsequently encountered in the assembly process, the assembler replaces it with the binary value of the corresponding operand.
    - > The operand can be either a value or an expression that can be evaluated. It should be used to improve the clarity and readability of the assembly program.
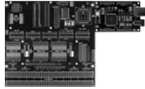
Syntax:

    .EQU label = expression   ; where operand is a value or an expression
                                ; that evaluates to a value

Example:

    .EQU BestNo = $37   ; BestNo will be replaced by $37
    .EQU Table_Size = 10*BestNo ; Set the table size here
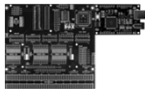
EEL3744   **DB**: Assembler Directive
(Pseudo-instruction, **Atmel**)

- **DB (Define Constant Byte) in program memory and EEPROM)**:
  It allocates space in memory and also initializes memory locations to
  specified values at the time of assembly
  - > The DB directive reserves memory resources in the program
    memory or the EEPROM memory
    - – **NOT for data memory and SRAM**
  - > To refer to the reserved locations, the DB directive must be
    preceded by a label
  - > The DB directive takes a list of expressions, and must contain at
    least one expression
  - > The DB directive must be placed in a **Code Segment** or an
    EEPROM Segment
- The expression list is a sequence of expressions, delimited by commas
- Each expression must evaluate to a number between -128 and 255

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EEL3744   **DB**: Assembler Directive
(Pseudo-instruction, **Atmel**)

- If the DB directive is given in a Code Segment
  and the expression list contains more than one
  expression, the expressions are packed so that
  **TWO BYTES are placed in each PROGRAM
  MEMORY WORD**
  - > If the expression list contains an odd number of
    expressions, the last expression will be placed in a
    program memory word of its own, even if the next
    line in the assembly code contains a DB directive
    - – The unused half of the program word is set to zero
    - – A warning is given, in order to notify the user that an extra
      zero byte is added to the .DB statement

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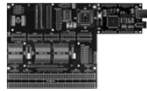
EEL3744   **DB**: Assembler Directive
(Pseudo-instruction, **Atmel**)

Syntax:

(label:) .DB operand   ; where operand is an 8-bit value, a list of
                       ;   bytes, or an expression that evaluates to an 8-bit value

Examples (see .lss file):

.ORG 0x100 ; This is in the Code Segment (Program Memory)
.DB   37, 0x73, 0xF1, 0 ; (0x200) = 37 = 0x25, (0x201) = 0x73
                        ; (0x202) = 0xF1, (0x203) = 0

GSmrt: .DB   0x99   ; (GSmrt) = (0x204) = 0x99

; Note that since there is only one byte above, (0x205) = 0
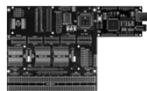
Tab2:   .DB   3, 9, 44, 0x2E, 244, 0xCD   ; Tab2 = 0x206
EOT: .DB   0xFF   ; EOT = End of Table
Mesg: .DB   "3744 is the 'best class' ever!" ; Text strings ok too

```
This is a        0x200   25 73 f1 00 99 00 03 09   %sñ.™…
memory           0x208   2c 2e f4 cd ff 00 33 37   ,.ôÏÿ.37
snapshot         0x210   34 34 20 69 73 20 74 68   44 is th
                 0x218   65 20 27 62 65 73 74 20   e 'best
                 0x220   63 6c 61 73 73 27 20 65   class' e
                 0x228   76 65 72 21 ff ff ff ff   ver!ÿÿÿÿ
```
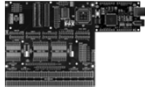
EEL3744   doc0856_AVR_Instruction_Set.pdf

Atmel Instructions

- Instruction Set Nomenclature
- I/O Registers (later)
- The Program and Data Addressing Modes
- Conditional Branch Summary
- Complete Instruction Set Summary
  - Explore instructions
- See LD, for example, in instruction manual:
  - Find "LD – Load Indirect from Data Space to Register"

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LDI – Load Immediate

Examples:

```
ldi   r16, 27     ; Load 27 (0x1B) into register r16, r16 ←$1B
ldi   r17, 0x34   ; Load 0x34 into register r17, r17←$34

clr   r31         ; Clear Z high byte, r31 ← 0
ldi   r30,$F0     ; Set Z low byte to $F0 (0x and $ are hex prefixes)
                  ;   r30←$F0
lpm r17, Z        ; Load constant from Program memory pointed
                  ;   to by Z, r17 ← (Z)
lpm               ; Load constant from Program memory pointed
                  ;   to by Z (notice with no operand, the default is r0),
                  ;   r0 ← (Z)
lpm r18, Z+       ; r18 ← (Z), Z++ [Z++ means Z←Z+1]

ldi   ZL, low(Table<<1)    ; Load ZL with low address of Table
ldi   ZH, high(Table<<1)   ; Load ZH with high address of Table
```
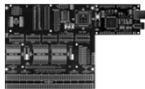
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LD – Load Indirect from Data Space to Register

Examples:

```
clr   r29         ; Clear high byte of Y (Y = r29 | r28), r29←0
ldi   r28,$37     ; Set low byte of Y to $37 (0x and $ are hex prefixes), r28 ← $37
ld    r0,Y+       ; Load r0 with data at address $37 (Y post increment),
                  ;   r0 ← (Y), Y++
ld    r1,Y        ; Load r1 with data at address $38, r1← (Y)
ldi   r28,$42     ; Set low byte of Y to $42, r28 ← $42
ld    r2,Y        ; Load r2 with data at address $42 (since r29 = 0), r2 ← (Y)
ld    r3,-Y       ; Load r3 with data at address $41 (Y pre decrement)
                  ;   Y--, r3 ← (Y) [Y-- means Y←Y-1]
ldd   r4,Y+2      ; Load r4 with data at address $43, r4 ← (Y+2)
```
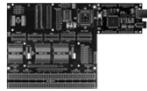
- Note that for loading with Y and Z, the **ldd** instruction lets you add up to 63 to Y or Z (%11 1111 = 63, i.e., a 6-bit post increment)
- There is **NO ldd** with X

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LPM – Load Program Memory

Examples:
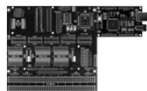
```
.org 0x100
Table_1:  .dw 0x4744       ; 0x44 is addresses when ZLSB = 0
                           ; 0x47 is addresses when ZLSB = 1

• • •

ldi ZH, high(Table_1<<1)   ; Initialize Z-pointer
ldi ZL, low(Table_1<<1)

lpm r17, Z     ; Load constant from Program memory pointed
               ;   to by Z (r31:r30), r17 ← (Z)
lpm            ; Load constant from Program memory pointed
               ;   to by Z (notice with no operand, the default is r0),
               ;   r0 ← (Z)
lpm r18, Z+    ; r18 ← (Z), Z++
```

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See spru513, Table 4-1, Table 4-2

Common Assembler Directives
(Pseudo-instruction, **DSC**)

- **Define Sections**   .bss = better save space ;)
  - > **.bss**   Reserves size words in the .bss (uninitialized data) section
  - > **.data**   Assembles into the .data (initialized data) section
  - > .sect   Assembles into a named (initialized) section
  - > **.text**   Assembles into the .text (executable code) section
  - > symbol .usect "section name", size in words

- **Define Constants (Data and Memory)**
  - > **.byte**   Initializes 1 or more successive bytes in current section
  - > **.char**   Initializes 1 or more successive bytes in current section
  - > **.word**   Initializes one or more 16-bit integers
  - > **.int**   Initializes one or more 16-bit integers
 - > **.long**   Initializes one or more 32-bit integers

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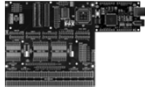
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Machine Language and Program Assembly

- A consequence of the stored program concept is that the assembly language instructions must be transformed into a form that can be stored in memory locations, and also that can be processed by the microprocessor. In other words, an ***assembly language program***, also called ***source code***, has to be transformed into a ***machine language program***, also called ***object code***.
- This transformation process, called ***program assembly***, can be done automatically by a computer program called an ***assembler***
    > Usually built into the IDE (Integrated Development Environment), e.g., Atmel Studio
- The machine language program is simply a ***coded version*** of the assembly language program, with each machine language instruction corresponding to an assembly language instruction.
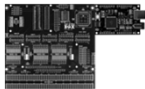
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XMEGA
Assembler Prefix, Suffix, Operators

- XMEGA assembler
  > By default, numbers are assumed to be **decimal**

Base	Prefix
Hex	0x (or $)
Octal	0 (leading zero only)
Binary	0b
Decimal	Nothing

| Operator Symbol	Operation
!	Logical Not
~	Bitwise Not
-	Unary Minus
*	Multiplication
/	Divide
%	Remainder after division
+	Addition
-	Subtraction
<<	Shift Left
>>	Shift right
<, <=	Less than (or equal to)
>, >=	Greater than (or equal to)
==, !=	Equal, not equal
&, |	Bitwise And (Bitwise OR)
^	Bitwise XOR
&&, ||	Logical AND (Logical OR)
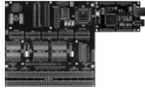
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XMEGA Assembler Functions

- LOW(expression) returns the low byte of an expression
- HIGH(expression) returns the second byte of an expression
- BYTE2(expression) is the same function as HIGH
- BYTE3(expression) returns the third byte of an expression
- BYTE4(expression) returns the 4th byte of an expression
- ABS() Returns the absolute value of a constant expression
- STRLEN(string) returns the length of a string constant, in bytes
- LWRD(expression) returns bits 0-15 of an expression
- HWRD(expression) returns bits 16-31 of an expression
- EXP2(expression) returns 2^expression
- LOG2(expression) returns the integer part of log2(expression)

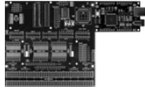University of Florida, EEL 3744 – File **04**
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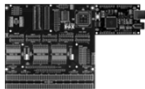
EEL3744   Using the ATMEL Studio Simulator

`Table_Load_Example.asm`

- Demo the simulator with ***Table_Load_Example.asm***
  > Assemble (F7)
  > Single step (F11), Continue [Run] (F5), Run to Cursor (Ctrl-F10)
  > Run with breakpoints
    – Add breakpoint by clicking on line number (in asm file) [creates a red dot]
      ☞ Select **Debug | Windows | Breakpoints** to be able to see and remove breakpoints
  > To see the address for the instructions (while simulating/emulating),
    Debug | Windows | Disassembly (or use Alt-8)
    – Go to address 0x100 (for program memory) and 0x200 for program
  > See **Solution Explorer** window
    – Look at **Dependencies | ATxmega128A1Udef.inc** (from .include in source)
    – Look at **File | Open | File** (or in **Solution Explorer** see **Output Files**)
      ☞ List file: **Debug/Table_Load_Example.*lss***
      ☞ Object file: **Debug/Table_Load_Example.*hex*** (human readable; compare to .*obj*)
      ☞ Map file: **Debug/Table_Load_Example.*map*** (see end of file)

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Using uPAD Board and
ATMEL Studio <u>Emulator</u>

- Find and select the Simulator menu on top right
  - > Select debugger/programmer | AVR **ICE**
- All controls for Emulator are the same as the Simulator
  - > Assemble (F7)
  - > Single step (F11), Continue [Run] (F5), Run to Cursor (Ctrl-F10)
  - > Run with breakpoints
- Just do it
  - > Demo single step, run, breakpoint?
  - > Show memory and registers
  - > Now run **GPIO_Output** (but do **NOT** look at too closely)
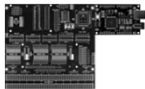   - – Will see this file again in Lecture 6: GPIO

`Table_Load_Example.asm`

`GPIO_Output.asm`

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The End!