

Joe Monitor Instructions

Version 1.0

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Over View

This is a 65C02 monitor developed for my 65C02 board. It contains a 65C02, 6551(ACIA), 6522(VIA) and the usual ROM (27C256), RAM decoding etc. It can be ported onto any 65C02 based computer with some minor modifications eg: KIM-1, Apple, C64, ViC20.

After searching the net I didn't like many if not all the 6502 OS/Monitors. In my opinion I liked bits of them. So I decided to create my own. I began with little care about space, more functionality, but in the end, i was forced to keep it real tight.

My goal was for it to be a development machine/ bench top computer. Able to paste code to the terminal, compile it, dump, decode it, edit it etc. Some of this code had been inspired by many before me - the A1 Assembler by San Bergmans

<https://www.sbprojects.net/whoami/index.php>.

I liked the front editor but didn't come with a disassembler. It's 2 pass assembler and felt solid - but mostly written for an Apple.

With his permission i used his front end, but i ended up re-writing allot of it and certainly went over every line.

On the other hand The KRUSADER by Ken Wessen had the super-efficient disassembler that I've seen before (probably created by MOS and used by Apple) and it was tackling the additional 65C02 instructions. Didn't like the editor no offence..

The old DOS debug command is how i wanted the console to feel, in other words, mistyping something means hitting the backspace not having to retype the whole line again as many of these monitors have you do - nuts.

So this is a full 2 pass assembler, with local and global labels, directives, the lot. I've also added a 65C02 disassembler, step by step debugging aka tracing, memory dump, ascii dump, fill, delete, block move, intel hex loader.

I've tested this on a real N65C02 computer. I've also included LCD 16x2 code - again also tested on real hardware.

Its currently takes just over 3.2KB

By Joe DiMeglio

Monitor Prerequisites

This has been designed for the Rockwell 65C02 CPU and a terminal running ANSI screen codes, with serial 19200 baud N81

I've used RealTerm found here <https://sourceforge.net/projects/realterm/> to work best.

This was programmed in Michael Kowalski min version 1.3.2

Intel Hex Loader

Build in.

The command line will look for ":" as the first character and will auto download file. Just paste the intelhex file to the command line.

Example Code

The monitor is designed to be able to be copied & pasted from an external text application such as notepad and pasted, followed by compiling it (S key).

Copy & paste below {every between the lines}

```
AUTO

WRBYTE      .EQ  $FFDC
ECHO        .EQ  $FFEF
CR          .EQ  $0D
SP          .EQ  $20
;-----
START       JSR  HELLO  ;output to screen
            JSR  COUNT
            RTS
;-----
HELLO       LDX  #0
.1          LDA  .3,X
            BPL  .2
            JSR  ECHO
            INX
            BNE  .1
.2          ORA  #1000.0000
            JMP  ECHO
.3
;-----
            .AT  -/HELLO WORLD/
;-----
COUNT     JSR  .2
            LDX  #0
.1          TXA
            JSR  WRBYTE
            LDA  #" "
            JSR  ECHO
            INX
            CPX  #10
            BCC  .1
.2          LDA  #CR
            JMP  ECHO
```

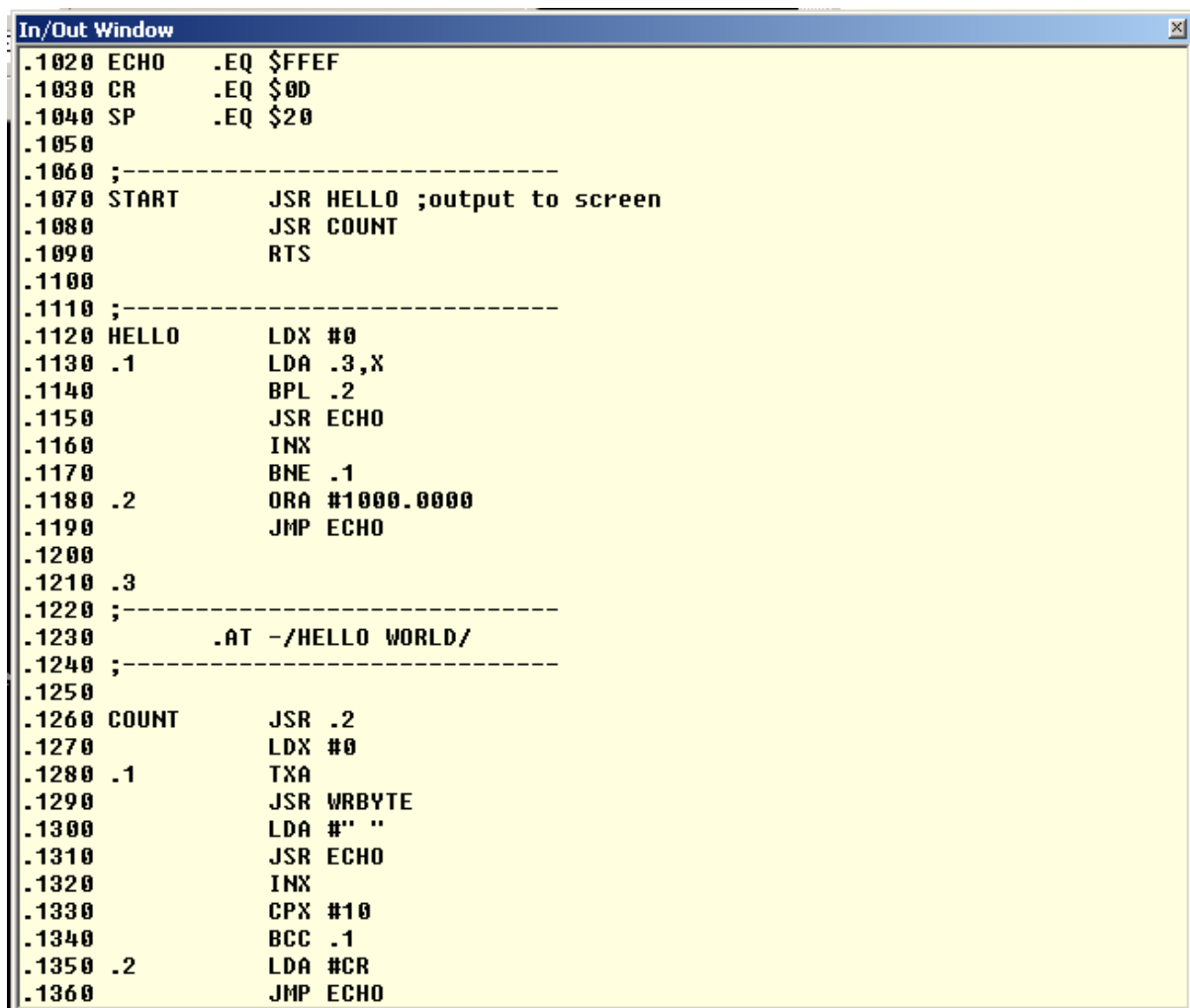
Command AUTO (A)

AUTO linenum,increment

The command auto will auto number each line. The assembler uses line numbers to allow you to identify which line you like to delete, insert, renumber etc. Pressing **escape** on the last line will exit assembler editor.

Note: the default origin for source to is defined by the variable `DEF_ORG` which is \$1000 and the incremental steps are `DEF_INC` defaulted to 10. Also the count is set by `DEF_AUTO` – which is 1000

See constants.65s



```
In/Out Window
.1020 ECHO      .EQ $FFEF
.1030 CR        .EQ $0D
.1040 SP        .EQ $20
.1050
.1060 ;-----
.1070 START      JSR HELLO ;output to screen
.1080              JSR COUNT
.1090              RTS
.1100
.1110 ;-----
.1120 HELLO      LDX #0
.1130 .1         LDA .3,X
.1140              BPL .2
.1150              JSR ECHO
.1160              INX
.1170              BNE .1
.1180 .2         ORA #1000.0000
.1190              JMP ECHO
.1200
.1210 .3
.1220 ;-----
.1230              .AT -/HELLO WORLD/
.1240 ;-----
.1250
.1260 COUNT      JSR .2
.1270              LDX #0
.1280 .1         TXA
.1290              JSR WRBYTE
.1300              LDA #" "
.1310              JSR ECHO
.1320              INX
.1330              CPX #10
.1340              BCC .1
.1350 .2         LDA #CR
.1360              JMP ECHO
```

If no operands are given auto line numbering will start from the last entered line number + current increment. Or if no line has been entered before it will start from line number 1000, with an increment of 10.

You may use *linenum* to start the auto line numbering from any specified number.

You may use *increment* to change the default increment of 10.

AUTO	Start numbering from last entered line number + increment
AUTO 2000	Start numbering from 2000 with unchanged increment
AUTO 4000,5	Start numbering from 4000 with 5 as increment
AUTO ,10	Start numbering from last entered line number + 5 as new increment

Pressing ESC will cancel auto line numbering and the current unfinished line. Simply hit ESC when you're done entering your source code or when you make some typing errors which you can't correct with the back space key. Typing AUTO again will generate the same line number you have just cancelled to allow you to start from scratch with this line.

It goes without saying that you do not have to use AUTO line numbering if you just want to enter one or two lines somewhere in your program. Simply type the appropriate line number after the prompt, followed by your source text.

The value of *increment* is limited to the range of 1 to 255. Higher values are truncated to the LSB value only, which could cause some unexpected increments. An *increment* of 0 will result in an increment of 1.

Command Copy (C)

COPY source,destination,length

This command can be used to copy a part of memory to another destination. All three parameters are mandatory, you can't skip any of them.

It is possible that the destination block will eventually overwrite the source block. This means that the original block can be partially destroyed after the copy. However the copy will always be an exact copy of the original contents of the source block.

Warning! Be careful when the destination is in page 0. The COPY command uses 6 bytes there as temporary storage

Overwriting these values by random values will very likely crash your system. You should also be aware of the fact that the input buffer may partially overwrite your copied code if the destination is in the zero page.

There is absolutely no safeguard built into this command. You can make a copy anywhere in RAM, effectively destroying the data which is overwritten. This might even be your precious source text!

This command can be useful if you assembled a program with a different target address (See .TA directive). After assembling your code you can move the code to the desired destination.

Command LIST (L)

LIST begin,end

This command lists your source to the screen. If no parameters are given the entire program is listed. The *begin* and *end* parameters can be used in the usual manner to control the range to be listed.

LIST	list entire program
LIST 1000	list only line 1000
LIST 1000,2000	list lines 1000 until 2000
LIST 1000,	list from line 1000 until the end of source
LIST ,2000	list from begin of source to line 2000
LIST D	list dump the entire program

The ESC key aborts the listing.

The LIST command has one extra option. Typing LIST D will dump the entire program to the output without line numbers. This option can be used to transfer your source file to the PC over the RS232 connection. The resulting file on the PC can then be saved


```
In/Out Window
0 COMPILE ERROR(s)
.1
1010 WRBYTE .EQ $FFDC
1020 ECHO .EQ $FFEF
1030 CR .EQ $0D
1040 SP .EQ $20
1060 ;-----
1070 START      JSR HELLO ;OUTPUT TO SCREEN
1080           JSR COUNT
1090           RTS
1110 ;-----
1120 HELLO      LDX #0
1130 .1         LDA .3,X
1140           BPL .2
1150           JSR ECHO
1160           INX
1170           BNE .1
1180 .2         ORA #1000.0000
1190           JMP ECHO
1210 .3
1220 ;-----
1230           .AT -/HELLO WORLD/
1240 ;-----
1260 COUNT      JSR .2
1270           LDX #0
1280 .1         TXA
1290           JSR WRBYTE
1300           LDA #" "
1310           JSR ECHO
1320           INX
1330           CPX #10
1340           BCC .1
1350 .2         LDA #CR
1360           JMP ECHO
.
```

Command Memory (Y)

Ylomem,himem

This command can be used to examine or change the memory configuration.

With no parameters this command will show you the current **Lower Limit**(LOMEM), **Total RAM** and end of source address. Your source file starts at address Lower Limit and may extend almost to address **UPPER Spent**(HIMEM). The end of your source file is at the same time the beginning of the symbol table which is built during pass 1 of the assembler. The symbol table will hold all your label declarations and may grow from the end of the source text all the way up to UPPER Spent.

Each global label will occupy 6 bytes in the symbol table, while each local label will occupy 2 bytes. This should give you a rough idea about the required amount of memory for the symbol table.

You can use the MEMORY (Y) command to find out what part of memory to save to file/cassette in order to store your source text. Lower Limit will be the start address and end of source will be the end address to write.

Generated code can be stored from address \$0200 up to LOMEM, unless you have set the user safe area which can be set with the zero page addresses [USR_OBJLO](#) and [USR_OBJHI](#).

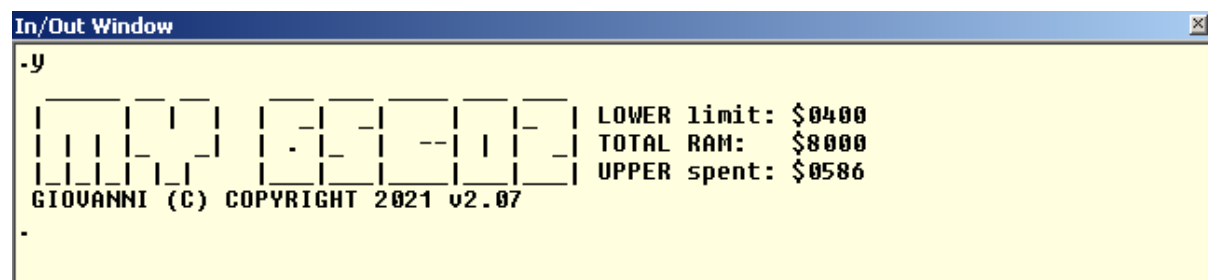
```
Y
0600.$8000      lomem,himem
0F14           end of source text
```

At start up LOMEM will be set to \$0600 and HIMEM to the highest available RAM address (max \$8000). You may change LOMEM and HIMEM to your own liking, and I mean that!

Sensible values are from address \$0200 up to the last available RAM .Any other values will probably crash your computer sooner or later!

Changing LOMEM and/or HIMEM will delete your current source text!

```
Y $1000,$8000
$1000.$8000
$1000
```



Command NEW (N)

With this command you simply delete your current source text so you can start from scratch.

Command OLD (O)

If you accidentally typed the NEW command you may restore your program. This will only work if you haven't entered any new source lines after executed the NEW command!

Command Assemble Code (S)

This command effectively starts the 2 pass assembler. If no errors are found this command will inform you about the memory locations which are used to store the generated code.

The first column starts after the first space behind the line number. This column may contain a label or may be blank. A global label always starts with a character from A to Z and may contain any number of characters from A to Z, 0 to 9, or dots. Global label definitions may be followed by a colon, which is customary in some assemblers. Local labels always start with a dot, followed by a decimal number from 0 to 99.

If the first column does not contain a label it must start with a space. Or a line can start with a semi-colon in the first column, which indicates that the rest of the line is a comment. Comments are ignored by the assembler and are only there for us humans.

```
1000 LABEL
1010 ECHO:
1020 .59
1030 LABEL.WITH.A.VERY.LONG.NAME
1040 ; THIS LINE CONTAINS A COMMENT
1050 ; COMMENT LINES ARE IGNORED BY
1060 ; THE ASSEMBLER
1070 NOP          NO LABEL ON THIS LINE
```

If the first character is a space the first column is considered empty, and thus contains no label (See line 1070). Please note that would make 2 spaces if you also count the space which always follows the line number!

Per default a label gets the value of the current program counter. Only global labels may get a different value if the source line contains an .EQ directive.

Please note that global labels may contain virtually any number of characters (from 1, up to the maximum line length). All these characters are significant!

However in order to preserve memory keep your labels as short as possible but keep them meaningful. Every character is one byte of your valuable memory, for every reference to that label!

If your source text contains errors the line numbers of the offending lines are listed, followed by a short description of the error which occurred. No code will be generated if errors occur during pass 1. Code generated in pass 2 will not be reliable if any errors occur during assembly.

```

.S
-----
.ORG ->$1000.$103A
-----
0 COMPILE ERROR(s)
.
```

Compiling Errors will show you will which lines have errored on.

```

.S
-----
1130 ERROR
1150 ERROR
-----
2 COMPILE ERROR(s)
.
```

The second column starts at least one space behind the first column. It contains an assembler directive or a mnemonic.

An assembler directive always starts with a dot, followed by 2 characters. See the description of the available directives further down this page. A mnemonic always consists of 3 characters

The second column may also start with a semicolon, which means that the rest of the line contains comments only.

If the second column is left empty, the entire rest of the line must remain empty. This is not a problem for the assembler. It is perfectly legal to place only a single label on a separate source line.

```

1000 START ; THE PROGRAM STARTS HERE
1010      INX
1020 .1    RTS
1030 TEXT
1040      .AS -/HELLO/
```

The third column starts at least one space behind the second column. It contains the operand of the previous mnemonic or assembler directive, if one is required. If the previous mnemonic or assembler directive did not need an operand this column is simply regarded as comment.

Some mnemonics have an optional operand. One such an example is the ROL instruction. Without operand it Rolls the contents of the Accumulator. With an operand it Rolls the contents of the address indicated by the operand.

In such cases you will have to use a semi-colon as a comment delimiter.

```
1000      ROL
1010      ROL MEMORY
1020      ROL      ;THIS IS A COMMENT
1030      ROL ; OR COMMENT LIKE THIS
```

Command Clear Sceen (z)

Clear screen via ANSI Screen codes to the terminal.

Command Help (?)

Shows help screen

Command Go (G)

G address or label

Execute the code from address or from label

Command Erase Line (E)

Erase begin,end

Use this command to delete multiple lines at a time. Be careful though, undo is not possible. Once deleted the lines are gone forever!

Both the *begin* and *end* parameters are optional. However you'll have to enter at least one parameter for safety reasons.

ERASE 2000	delete only line 2000
ERASE 2000,2300	delete lines from line 2000 to 2300
ERASE 2000,	delete from line 2000 until the end of source
ERASE,2300	delete from begin of source to line 2300

Command Value (V)

VALUE expression,expression

This command can be used to view the value of labels, convert numbers from one radix to another, or even to do some simple calculations. Label values are only valid after a successful assembly run.

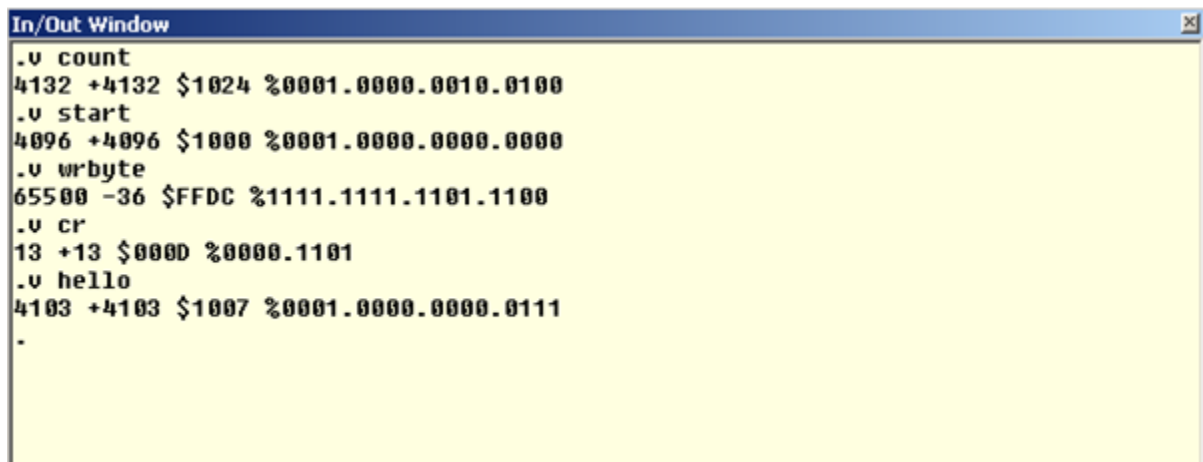
```
VALUE $1234
4660 +4660 $1234 %0001.0010.0011.0100
```

```
VALUE -1
65535 -1 $FFFF %1111.1111.1111.1111
```

```
VALUE $1234+135
4795 +4795 $12BB %0001.0010.1011.1011
```

```
VALUE ECHO
65519 -17 $FFEF %1111.1111.1110.1111
```

```
VALUE $1234,1234,%0101.1010
4660 +4660 $1234 %0001.0010.0011.0100
1234 +1234 $04D2 %0000.0100.1101.0010
90 +90 $005A %0101.1010
```

A screenshot of a terminal window titled "In/Out Window". The window has a blue title bar and a yellow background. It displays the output of an assembly process, showing labels and their corresponding values in decimal, hexadecimal, and binary formats. The output is as follows:

```
.v count
4132 +4132 $1024 %0001.0000.0010.0100
.v start
4096 +4096 $1000 %0001.0000.0000.0000
.v wrbyte
65500 -36 $FFDC %1111.1111.1101.1100
.v cr
13 +13 $000D %0000.1101
.v hello
4103 +4103 $1007 %0001.0000.0000.0111
-
```

Command Ascii (I)

i address

Ascii dump address. Address with \$ is considered hex value.

```
In/Out Window
.i $1000
.: 1000 / .. $.` .....L..HELLO WORL..6... .....L.....
.: 102A / .....L.....
.: 1054 / .....
.: 107E / .....
.: 10A8 / .....
.: 10D2 / .....
.: 10FC / .....
.: 1126 / .....
.: 1150 / .....
.: 117A / .....
.: 11A4 / .....
.: 11CE / .....
.: 11F8 / .....
.: 1222 / .....
.: 124C / .....
.: 1276 / .....
.: 12A0 / .....
.: 12CA / .....
.: 12F4 / .....
.: 131E / .....
-█
```


Command User Command (@)

@ command

The @ command allows users to extend the commands to the monitor. Changing the [USERKEYDEF](#) vector, will mean that you can then add commands to the keyboard input. I.e; @ command will jump to [USERKEYDEF](#) where the user then needs to parse the IN keyboard buffer for addition keys/commands.

For example @S would jump to USERKEYDEF {aka *JMP (USERKEYDEF)*} where your routine would parse the IN for S and then act accordingly if found. See routine KEYDEF for example of how current commands are parsed.

Command Renumber (R)

RENUMBER from,first,increment

From time to time you may want to renumber your source, or part of your source. Usually you want to do that to tidy up a bit, or to make room for more than a few new source lines between two other lines. For that purpose you can use the RENUMBER command.

The *from* parameter determines the line from which to start renumbering. If you omit it you will renumber your entire program.

first will be the first new line number to be used for the renumbered part of your source. If this line number is omitted the default AUTO line number will be used (1000). Finally the *increment* parameter will determine the increment of the renumbered part of your source. If it is omitted the default increment of 10 will be used. The valid range for *increment* is from 1 to 255.

You can't set *from* higher than *first*, otherwise you may get duplicate line numbers which would definitely confuse the editor.

After renumbering the next auto line number will be the last renumbered line number + increment. The new increment will also be set according to the renumbered increment.

RENUMBER	renumbers entire source, same as RENUMBER 0,1000,10
RENUMBER 2000,3000	renumbers source from 2000 until end, increment 10
RENUMBER ,4000	renumbers entire source, new source starts at 4000
RENUMBER 1000,2000,5	renumbers from line 2000, new line 2000, increment 5

Command Disassembler (D)

D address (or label)

This will disassemble code from start address or from label. When just press d will continue down one page.

```
In/Out Window
.d $1000
.. 1000 20 07 10 JSR $1007 / ..
.. 1003 20 24 10 JSR $1024 / $.
.. 1006 60 RTS /`
.. 1007 A2 00 LDX #$00 /..
.. 1009 80 19 10 LDA $1019,X /...
.. 100C 10 06 BPL $1014 /..
.. 100E 20 EF FF JSR $FFEF / ..
.. 1011 E8 INX /.
.. 1012 D0 F5 BNE $1009 /..
.. 1014 09 E8 ORA #$E8 /..
.. 1016 4C EF FF JMP $FFEF /L..
.. 1019 48 PHA /H
.. 101A 45 4C EOR $4C /EL
.. 101C 4C 4F 20 JMP $204F /LO
.. 101F 57 CPX /W
.. 1020 4F CPX /O
.d
.. 1021 52 4C EOR ($4C) /RL
.. 1023 C4 18 CPY $18 /..
.. 1025 36 A2 ROL $A2,X /6.
.. 1027 00 BRK /.
.. 1028 8A TXA /.
.. 1029 20 DC FF JSR $FFDC / ..
.. 102C A9 00 LDA #$00 /..
.. 102E 20 EF FF JSR $FFEF / ..
.. 1031 E8 INX /.
.. 1032 E0 0A CPX #$0A /..
.. 1034 90 F2 BCC $1028 /..
.. 1036 A9 0D LDA #$0D /..
.. 1038 4C EF FF JMP $FFEF /L..
.. 103B 00 BRK /.
.. 103C 00 BRK /.
.. 103D 00 BRK /.
```

Command Mem Dump (M)

M address

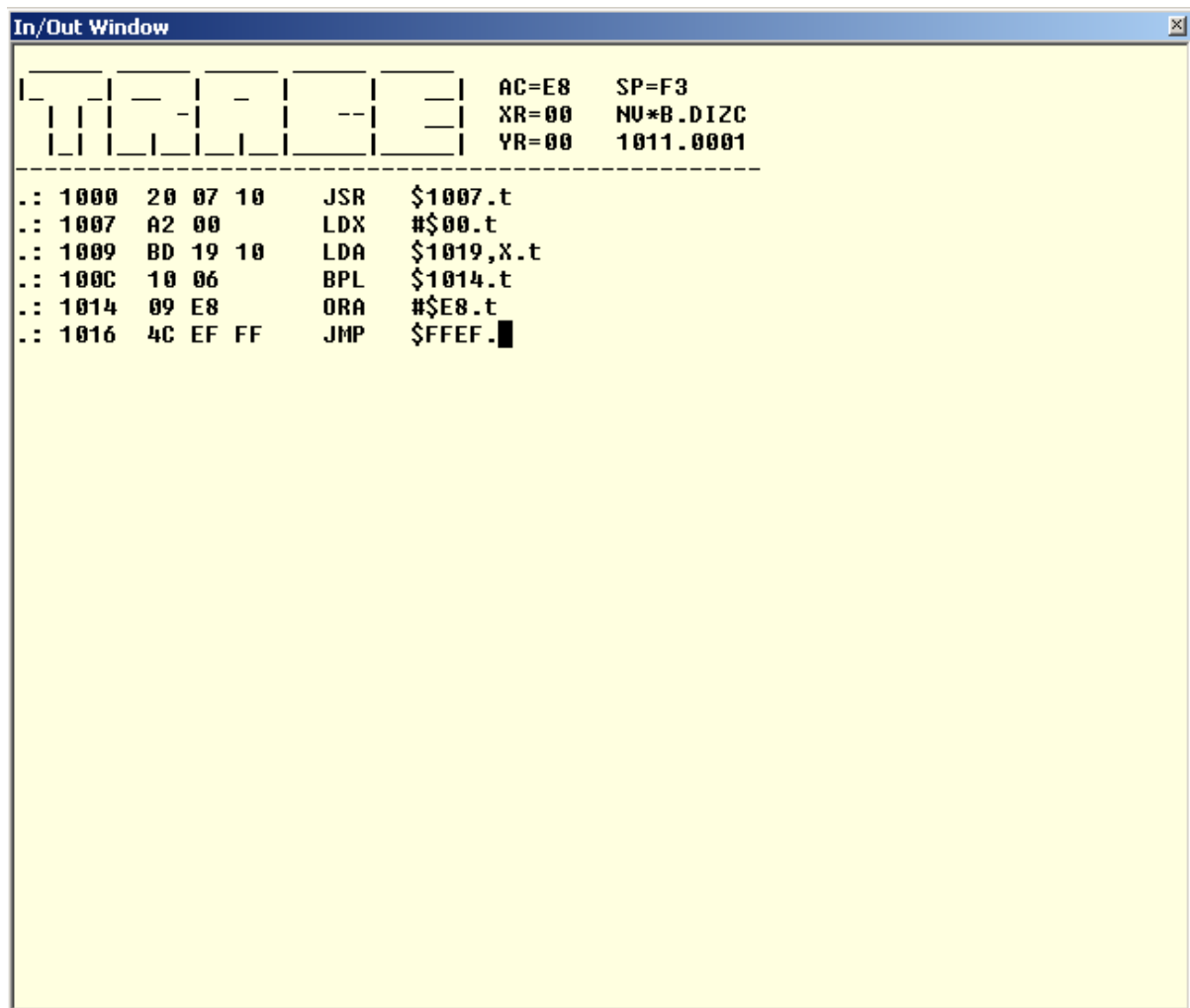
Byte and ascii dump of ram. Consecutive M, will continue page through the memory.

```
In/Out Window
.m $1000
.: 1000 20 07 10 20 24 10 60 A2 00 BD 19 10 10 06 20 EF / .. $.`.....
.: 1010 FF E8 D0 F5 09 E8 4C EF FF 48 45 4C 4C 4F 20 57 /.....L..HELLO W
.: 1020 4F 52 4C C4 18 36 A2 00 8A 20 DC FF A9 00 20 EF /ORL..6....
.: 1030 FF E8 E0 0A 90 F2 A9 0D 4C EF FF 00 00 00 00 /.....L.....
.: 1040 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 /.....
.: 1050 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 /.....
.: 1060 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 /.....
.: 1070 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 /.....
.: 1080 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 /.....
.: 1090 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 /.....
.: 10A0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 /.....
.: 10B0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 /.....
.: 10C0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 /.....
.: 10D0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 /.....
.: 10E0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 /.....
.: 10F0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 /.....
.: 1100 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 /.....
.: 1110 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 /.....
.: 1120 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 /.....
.: 1130 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 /.....
.
```

Command Trace (T)

T address

This is steps through the code one line at time. Pressing **t** will continue to step through each line. The flags, PC, registers show the values of the last actioned command.



The screenshot shows a window titled "In/Out Window" with a yellow background. At the top, there is a diagram of a 68000 processor with its registers and flags. Below this, a list of assembly instructions is shown, each preceded by a colon and a line number. The instructions are: JSR \$1007.t, LDX #\$00.t, LDA \$1019,X.t, BPL \$1014.t, ORA #\$E8.t, and JMP \$FFEF.t. To the right of the instructions, the current values of the registers and flags are displayed: AC=E8, SP=F3, XR=00, NU*B.DIZC, YR=00, and 1011.0001.

Line	Address	Hex	Instruction	Comment
1000	20 07 10		JSR	\$1007.t
1007	A2 00		LDX	#\$00.t
1009	BD 19 10		LDA	\$1019,X.t
100C	10 06		BPL	\$1014.t
1014	09 E8		ORA	#\$E8.t
1016	4C EF FF		JMP	\$FFEF.t

AC=E8 SP=F3
XR=00 NU*B.DIZC
YR=00 1011.0001

Directives

Directives are often called pseudo opcodes. They are always to be found in column 2, where you would also find processor opcodes (mnemonics). A directive is a command to the assembler, for instance to generate data bytes or change the current program counter.

.AS -/string/

This directive allows you to enter an entire string as data into your program. If the first character of the operand is — sign the entire string will be in negative ASCII (128 .. 256), the way the Apple 1 likes to get its ASCII characters. If the first character is not a — sign the string will be in positive ASCII (0 .. 127).

The string of characters must be surrounded by a so called delimiter. A delimiter can be virtually any ASCII character, which should be the same at the beginning and at the end of the string. Usually the characters / \ " or ' are used as delimiters, that is if you can type \ of course. The delimiter you use may not occur in the string, otherwise you'll get an error message.

```
1000    .AS /ABC/           generates 41 42 43
1010    .AS !123!          generates 31 32 33
1020    .AS -"ABC"         generates C1 C2 C3
1030    .AS -'1234567890'  generates B1 B2 ... B3 B0
```

Please note that the Assembler does not allow you to use more than one operand after

.AT -/string/

This directive is almost identical to the .AS directive. The only difference is the polarity of the last generated character, which is opposite from the rest of the string. This opposite polarity can be used by the software to signal the end of the string to be printed.

```
1000    .AT /ABC/           generates 41 42 C3
1010    .AT !123!          generates 31 32 B3
1020    .AT -"ABC"         generates C1 C2 43
1030    .AT -'1234567890'  generates B1 B2 ... B3 30
```

.BS expression

This directive skips the number of bytes indicated by the *expression*. Therefore the *expression* may not contain forward referenced labels, otherwise the assembler would not know how many bytes to skip.

Skipped bytes are not altered! The only thing that happens is that the current program counter is incremented by *expression*.

You can use .BS for instance to declare RAM addresses easily (like i.e. Zero Page locations).

```
1000          .OR $0080
1010 POINTER .BS 2      A 2 BYTE POINTER
1020 COUNT   .BS 1      A 1 BYTE COUNTER
1030 BUFFER  .BS 10     A 10 BYTE BUFFER
1040 FLAG    .BS 1      A 1 BYTE FLAG
```

You may use any value as *expression*, even quite silly values like \$FFFF, the A1-Assembler couldn't care less.

.DA expression

With this directive you can include data bytes and words into your program. You can include as many operands as you like (until the program line is full), all separated from the previous one by a comma. Any combination of word, LSB and MSB operands is possible. For byte data the *expression* must be preceded by a # or a / symbol. The # symbol will use only the LSB of the 16-bit *expression*, whereas the / symbol will use the MSB. Word data is generated with LSB first (little endian). This is the way the 6502 likes it best.

```
1000      .DA $1234                      generates 2 bytes, 34 12
1010      .DA #$1234                     generates 1 byte, 34
1020      .DA /$1234                     generates 1 byte, 12
1030      .DA $1234,$5678,$9ABC          multiple operands, 34 12, 78, 9A
```

.EQ expression

Normally a label will get the value of the Program Counter at the beginning of the line on which the label is assigned. This behaviour can only be changed by this directive. Column 1 must contain a global label when the second column contains the .EQ directive. You can't use the .EQ directive on local labels.

The label in column 1 gets the value which is represented by *expression*. This *expression* may not contain forward referenced labels!

```
PRBYTE .EQ $FFDC
ECHO   .EQ $FFEF
CR     .EQ $8D
SPACE  .EQ " "
CHOUT  .EQ ECHO      CHOUT will get the value $FFEF
```

It doesn't matter what type of data is assigned to a label. It may be an address, a constant value, an ASCII value, or whatever. You can however only assign values to labels. This means that you cannot assign a string of characters to a label.

.OR expression

This directive sets the starting address of your program, or parts of it. It also sets the target address to the same value (See .TA directive). If this directive is omitted the default starting address will be \$1000. See [DEF_ORG](#) in Constants.65s

You can set the starting address *expression* anywhere in memory. However you can not store code just about anywhere in memory. If you haven't set a user safe area you can only generate code to the range from \$0200 (DEF_OBLOW) to LOMEM, otherwise you'll get a memory error.

You may change the starting address of your program as often as you like. Every block of memory generated is reported by the assembler, which makes it easier for you to locate your code.

The *expression* may not contain forward referenced labels.

```
1000      .OR $0080      ;START ZP DEFINITION
1010 PNTR  .BS 2
1020 CNTR  .BS 1
1030 BFFR  .BS 10
1040      .OR $0300      ;START CODE HERE
1050      NOP
1060      NOP
1070      .OR $0400      ;MORE CODE HERE
1080      NOP
1090      NOP
1100      NOP
```

(.BS directive does not generate code)

```
.S
-----
.ORG ->$0080.$008C
.ORG ->$0300.$0301
.ORG ->$0400.$0402
-----
0 COMPILE ERROR(s)
-
```

.TA expression

You can't generate code in protected memory. Normally you can only generate code from address \$0200 until LOMEM, the rest of memory is protected.

You may indicate a user safe area by setting the memory addresses USR_OBJLO and USR_OBJHI to declare another part of memory to be safe. However you're in charge there, you're the one who should be absolutely sure that it IS safe! Setting these two values doesn't automatically make the area safe, it only allows the assembler to store generated code there.

But what if you want to create a program which should run in a protected area, let's say from address \$E000? Simple, you set the .OR to \$E000, and change the target address to a safe area, e.g. \$0300 (see example below).

The assembler will generate all addresses as if it was actually using address \$E000. However the code is stored at address \$0300. Obviously this will result in a program which does not work as is. You'll have to move the program to the intended destination before it can be run.

Moving the code to its final destination can be done with the COPY (C) command, or by saving it to file and loading it at a different address.

The *expression* may not contain forward referenced labels.

```
1000          .OR $E000
1010          .TA $0300
1020 START    NOP
1030          NOP

START
-----
ORG -> $0300.$0301      this proves that the right target address is used
-----
0 COMPILE ERRORS
```



```
VALUE START          here's some more proof
57344 -8192 $E000 %1110.0000.0000.0000
```

```
In/Out Window
```

```
|_| |_| |_| |_| |_| |_| |_| |_| |_| LOWER limit: $0400  
|_| |_| |_| |_| |_| |_| |_| |_| |_| TOTAL RAM:   $8000  
|_| |_| |_| |_| |_| |_| |_| |_| |_| UPPER spent:  $0400  
  
GIOVANNI (C) COPYRIGHT 2021 v2.07  
  
.1000      .OR $E000  
.1010      .TA $0300  
.1020 START NOP  
.1030      NOP  
.S  
  
-----  
.ORG ->$0300.$0301  
  
-----  
0 COMPILE ERROR(s)  
.v start  
57344 -7936 $E000 %1110.0000.0000.0000  
-█
```

.DB expression

Single byte definition.

Note: < WORD –returns lower byte

>WORD – returns upper byte

Numbers And Expressions

Many commands and operands accept numbers and expressions. An expression is simply a mathematical combination of several numbers.

Any number is limited to 16-bits only. Enter larger numbers than that and you'll be treated with a range error.

You may precede any number with a negative sign to make it negative (2's compliment).

Wherever the Assembler expects a number you can supply it in one of the following options:

Decimal numbers

Start with a digit from 0 to 9, and may only contain these numbers.

```
123
-500
```

Hexadecimal numbers

Start with a dollar symbol, and contains only normal digits 0 to 9 and extra digits A to F.

```
$10
$FFEF
-$100
```

Binary numbers

Start with a percent symbol and may contain only the digits 0 and 1. You may place dots anywhere in a binary number to make them easier to read. The assembler simply ignores the dots.

```
%1000.1101
%1111100101110101
%1111.1001.0111.0101    same value as above!
-%1000
```

Positive ASCII

Generates values between 0 and 127, depending on the character enclosed in single quotes.

```
'A'    TRANSLATES TO $41
'2'    TRANSLATES TO $32
```

Negative ASCII

Generates values between 128 and 255, depending on the character enclosed in double quotes. Please note that this is the native Apple 1 mode to represent ASCII characters!

```
"A"    TRANSLATES TO $C1
"3"    TRANSLATES TO $B3
```

Current PC

A single dollar symbol, not followed by a legal hexadecimal digit, will result in the current program counter value. The value used was the program counter at the start of the current source line.

\$

Labels

Simply the label's value is used. Only assembly pass 1 allows the use of labels which are not defined yet. In that case we speak of forward referenced labels.

An undefined label during pass 2 of the assembly will result in a definition error.

In case of forward referenced labels we can not know their actual value during pass 1 of the assembler. Therefore some instructions which can use shorter addressing modes will fall back on the worst case scenario and use long addressing mode instead.

Expressions can be used to combine 2 or more values to get a new final value. You can use one of the 4 basic operators in expressions:

- + Addition
- Subtraction
- * Multiplication
- / Division

All expressions are evaluated from left to right. No priority is given to multiplication and division over addition and subtraction unlike in normal math. Parentheses can not be used to change priority in expressions. Overflows in expressions are ignored and the result is always truncated to 16-bit integers.

You can mix any legal number form with any number of operations.

```
1234+$1200    RESULTS IN $16D2
$F000-123     RESULTS IN $EF85
%101*2        RESULTS IN $000A
$5678/4       RESULTS IN $159E
LABEL*2       RESULTS IN THE VALUE OF LABEL TIMES 2
```

All results are 16-bits long integers. No errors are reported if the result exceeds the limits of a 16-bit number, only the least significant 16-bits are used as result. This may sometimes give some strange results, especially if the expression contains multiple operations.

For example $7/8*100$ results in 0. This is because $7/8$ is 0.875, which is truncated to 0 caused by the integer division. You'll get a much better result by rewriting the expression to $100*7/8$, which is still an integer.

The data directive (.DA) and all immediate addressing mode instructions normally use the < symbol to identify the 8 least significant bits of the expression. If you need the most significant bits however you can substitute the <symbol by the >symbol.

.DA \$1234	16-Bit data result (\$34 \$12)
.DA <\$1234	8-Bit data result LSB (\$34)
.DA >\$1234	8-Bit data result MSB (\$12)
LDA <\$1234	Load Accu with LSB (\$34)
LDX >\$1234	Load X with MSB (\$12)