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C/Assembler Tutorial

# *Accessing C Structs in Assembler*

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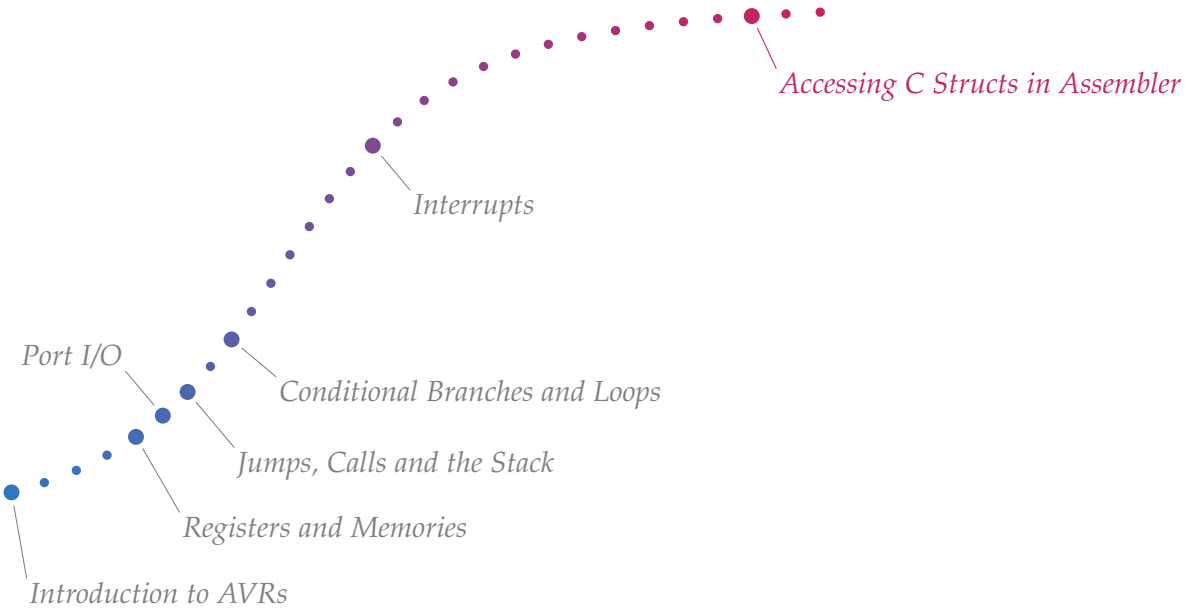

Accessing C structs in assembler programs is not an AVR issue, but a generic programming problem. However, knowing how to do it is especially useful when an ISR (or any other function) must be "hand–coded". This tutorial outlines the steps necessary for making C structs and their members' offsets visible to assembler code and how to use them.

The procedure of making C structs usable in assembler code is, as it is presented here, neither system– nor compiler–independent. Nonetheless, it is very easy to port between systems — I'm not sure about compilers. Furthermore, a text–processing tool such as `gawk` is needed. For this tutorial it is assumed that `gcc` is used.

`gawk` is available at `http://www.gnu.org/s/gawk/`; a windows port is available at `http://gnuwin32.sourceforge.net/packages/gawk.htm`.

## *Initial Situation*

The first thing we need when assembler code must access a C struct is the C struct itself, including a type definition. These are in `myStruct.h`:

```
#include <stdint.h>

struct SMyStruct_impl
{
  uint8_t first;
  uint8_t second;
};
typedef struct SMyStruct_impl TMyStruct;
```

The defined type has two members, `first` and `second`, both are an unsigned 8–bit integer. `first` starts at offset 0 and `second` starts at offset 1. This file is included by our main file, `main.c`:

```
#include "myStruct.h"

volatile TMyStruct tMyStruct;

void asm_out(void); /* prototype */

int main(void)
{
  tMyStruct.first = 0xAA;
  tMyStruct.second = 0x55;
  /* here we call the asm function */
  asm_out();
  while(1);
  return 0;
}
```

Two things must be considered here: the compiler has no control over the code behind `asm_out()`. It only knows the prototype of this function, but not what variables it might touch. This is why `tMyStruct` is declared volatile — it prevents the compiler from optimizing away the two assignments to the struct in `main()`. `asm_out()` will later use the values assigned to the struct members. This code is written as if there was no interface between C and Assembler; in fact, one could know write `asm_out()` in C.

### *Extracting the Structure Offsets*

The structure offsets are known when `TMyStruct` is typedef'ed, so `myStruct.h` will be needed for this process. Only the compiler can turn the type definition into offsets, so compiler call is necessary in which the compiler is used to calculate the offsets and write them into a seperate file. The following is the file `myStruct_offsets.c`:

```
#include <stddef.h>
#include "myStruct.h"

#define _ASMDEFINE(sym, val) asm volatile \
  ("\n-> " #sym " %0 \n" : : "i" (val))
#define ASMDEFINE(s, m) \
  _ASMDEFINE(offsetof_##s##_##m, offsetof(s, m));

myStruct_defineOffsets() {
  ASMDEFINE(TMyStruct, first);
  ASMDEFINE(TMyStruct, second);
}
```

These macros, as well as the following procedures, are based on those presented at `http://docs.blackfin.uclinux.org/doku.php?id=toolchain:gas:structs`

Two macros are defined: `_ASMDEFINE(sym, val)` and `ASMDEFINE(s, m)`.

`ASMDEFINE` uses `s` (a structure name) and `m` (a structure member) to assemble a symbol string. Assuming that `s` is `TMyStruct` and `m` is `first`, the string is `offsetof_TMyStruct_first`.

Then `_ASMDEFINE` is used to insert a line of assembler into the compiler output, using `asm volatile`. This is a "fantasy" instruction, starting with `->`. Afterwards `val` is added as an integer value at the end of the line. `val` was supplied by the calling macro, `ASMDEFINE`, and is equal the the member's offset in the struct.

At the end of `myStruct_offsets.c`, the two offsets are actually created, by calling `ASMDEFINE` in a function. This is a dummy function and will not show up in the final binary!

The assembler, which is `gas` in this case, cannot assemble the lines starting with `->` — it would emit an error, because `->` is not a valid assembler instruction. The compiler needs to be

stopped *before* it calls the assembler. For `gcc`, this is done with the `-S` option. If you haven't done this before, create the files `myStruct.h` and `myStruct_offsets.c`, each with the content shown above, open a terminal and execute

```
avr-gcc -S myStruct_offsets.c -o -
```

The trailing `-` is important, as it tells the `-o` option to write the output to `stdout`. You should see the object file output, including two lines starting with `->`. Here is a sample:

```
myStruct_defineOffsets:
        push r29
        push r28
        rcall .
        in r28,__SP_L__
        in r29,__SP_H__
/* prologue: function */
/* frame size = 2 */
/* #APP */
 ;  53 "myStruct_offsets.c" 1


-> offsetof_TMyStruct_first 0
```

As you can see, the function `myStruct_defineOffsets` is created, and at the end of the above piece of object code the offset of the first member of `TMyStruct` is shown — we're almost there. The `->` lines now have to be extracted from the object code, which can be done using `gawk`:

```
avr-gcc -S myStruct_offsets.c -o - | gawk '($1 == "->")
  { print "#define " $2 " " $3 }' > myStruct_offsets.h
```

The compiler output is piped to `gawk`, which replaces `->` with `#define`, and writes the resulting line to its own output. `gawk`'s output is written to `myStruct_offsets.h`. That file now contains:

```
#define offsetof_TMyStruct_first 0
#define offsetof_TMyStruct_second 1
```

### *Using the Structure Offsets*

Now it's time to include this header file in an asm file called `asm_out.S`:

```
#include <avr/io.h>
#include "myStruct_offsets.h"
#define work 18 // our working register
```

```
.extern tMyStruct ; "import" tMyStruct from main.c
.section .text

.global asm_out ; "export" for the linker
asm_out:
  ; directly accessing the first struct member, as in
  ; PORTD = tMyStruct.first;
  lds work, tMyStruct + offsetof_TMyStruct_first
  out _SFR_IO_ADDR(PORTD), work

  ; directly accessing the second member
  lds work, tMyStruct + offsetof_TMyStruct_second
  out _SFR_IO_ADDR(PORTD), work

  ; indirect access: Z->tMyStruct as in
  ; TMyStruct* Z = &tMyStruct;
  ldi ZL, lo8(tMyStruct)
  ldi ZH, hi8(tMyStruct)

  ; indirectly accessing the first member as in
  ; PORTD = Z->first;
  ldd work, Z+offsetof_TMyStruct_first
  out _SFR_IO_ADDR(PORTD), work

  ; indirectly accessing the second member
  ldd work, Z+offsetof_TMyStruct_second
  out _SFR_IO_ADDR(PORTD), work
ret
```

The assembler file includes the headers, imports the symbol `tMyStruct` and places `asm_out` in the `text` section.

`asm_out` writes the values of each structure member to PORTD in two different ways (you should be familiar with them). It is "exported" as a global symbol so that the linker can find it. Finally, it is possible to call the asm function from C (`main.c`):

More about sections at `http://www.nongnu.org/avr-libc/user-manual/mem_sections.html`

```
#include "myStruct.h"

volatile TMyStruct tMyStruct;

void asm_out(void); /* prototype! */

int main(void)
{
  tMyStruct.first = 0xAA;
  tMyStruct.second = 0x55;
  asm_out();
```

```
    while(1);
    return 0;
}
```

One final note: the structure must be declared volatile, because the compiler could otherwise optimize the member assignments away – they are not used in any part of code *that the compiler is aware of*.

### *Putting it all Together*

After everything is more or less explained, we can put the whole thing together:

First, create a C file for each structure you need the offsets of. The macros defined above can be put into a header file, call it `asmDefine.h` for example. The newly created C files need to be compiled every time the structure definition changes, using the command line that first creates object code and then extracts the offsets. This can be done with an IDE that support pre–build steps, a batch file, or built into a makefile — your choice.

Second, include the generated header file in any assembler file that needs access to the offsets. Any structure that is used must be imported as an external symbol for the linker to find it.

Third, take into account that the compiler is not aware of the assembler code's functionality. Depending on optimisation settings, it might delete assignments in your main code if they are of no effect to the compiler.