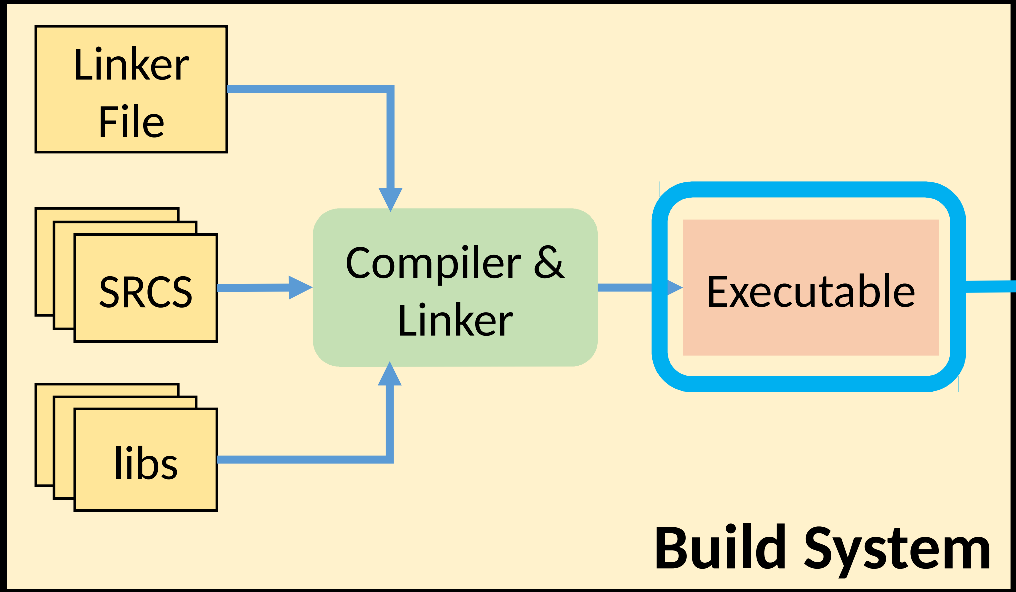
Attributes and Pragmas

Embedded Software Essentials

C2 M1 V7

Optimizations [S1]

- Optimizations will alter the implementation of code



Linker File

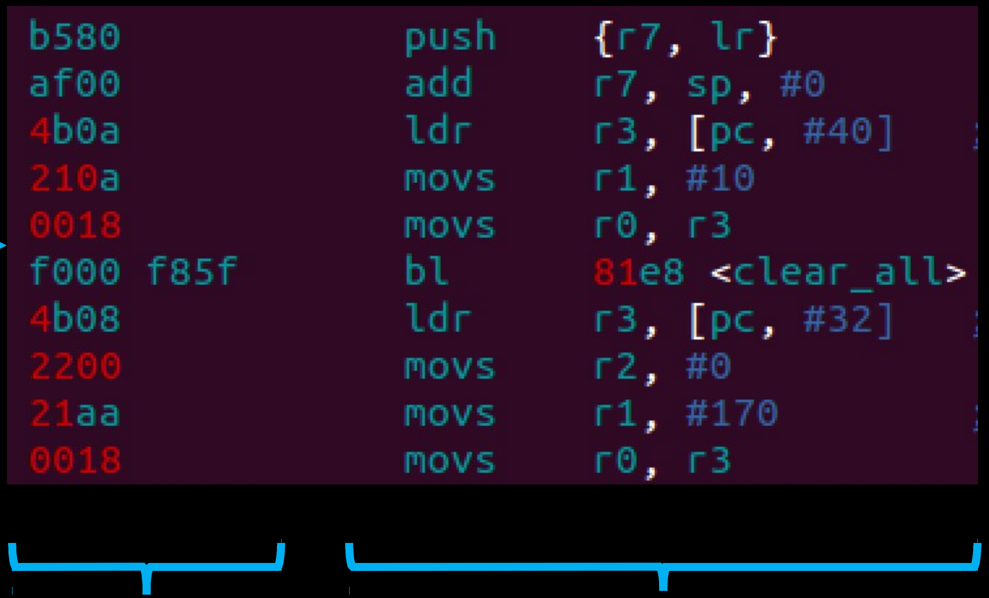
SRCS

libs

Compiler & Linker

Executable

Build System



```
b580          push   {r7, lr}
af00          add    r7, sp, #0
4b0a          ldr    r3, [pc, #40]
210a          movs   r1, #10
0018          movs   r0, r3
f000 f85f     bl     81e8 <clear_all>
4b08          ldr    r3, [pc, #32]
2200          movs   r2, #0
21aa          movs   r1, #170
0018          movs   r0, r3
```

Machine Code

Assembly Code

Compile and Link with Optimizations

```
$ gcc main.c –o main.o –O2
```

Compiler Attributes [S2]

- **Attributes** can give specific details on how to compile code for
  - Variables
  - Structures & Structure Members
  - Functions

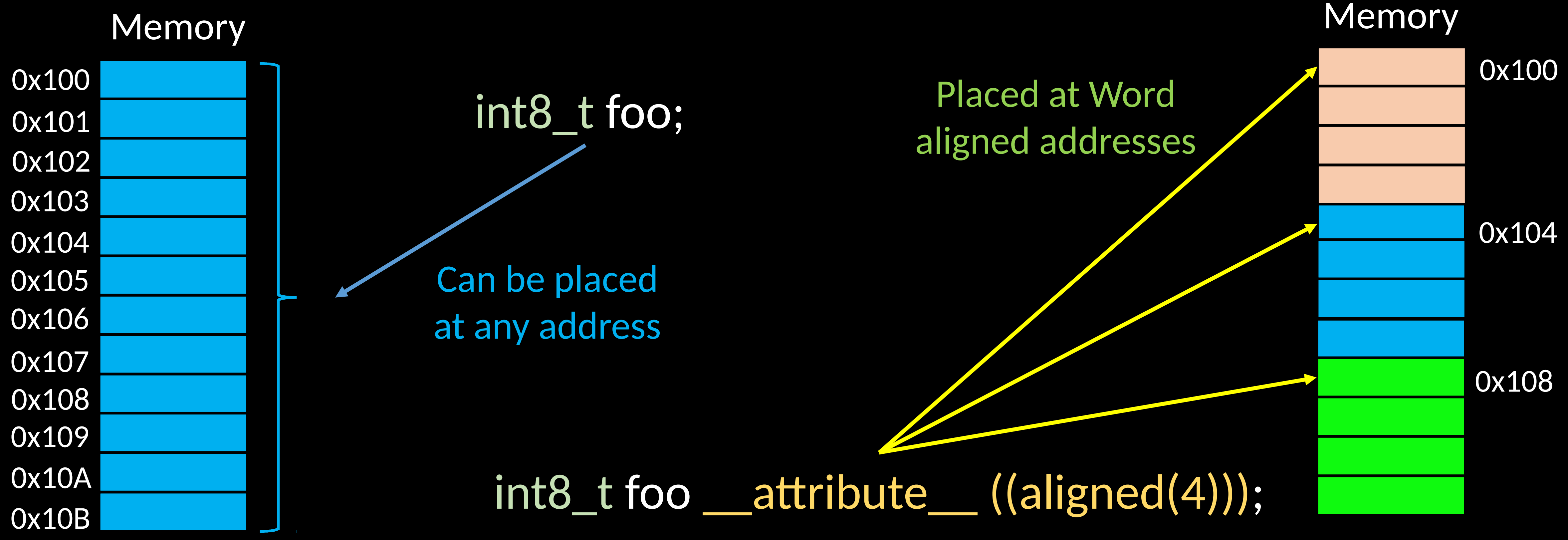
Attributes are **NOT** part of the C-standard

→ Not Portable Across Compilers

```
struct struct_name {
   int8_t   var1;
   int32_t var2;
   int8_t   var3;
} __attribute__ ((packed));
```

Alignment Attributes [S3]

- Alignment attributes specify memory alignment for data
  - Power of two: 2, 4, 8, 16



```
int8_t foo;
```

Can be placed at any address

Placed at Word aligned addresses

```
int8_t foo __attribute__ ((aligned(4)));
```

Alignment on a Structure [S4]

- Structures and structure members can be aligned

At a minimum, structure requires 6 Bytes

```
typedef struct  {
  int8_t   var1;
  int32_t var2;
  int8_t   var3;
} str1;
```

sizeof(str2) ▭ 12 Bytes

```
typedef struct {
  int8_t   var1 __attribute__ ((aligned(4)));
  int32_t var2 __attribute__ ((aligned(4)));
  int8_t   var3 __attribute__ ((aligned(4)));
} str2;
```

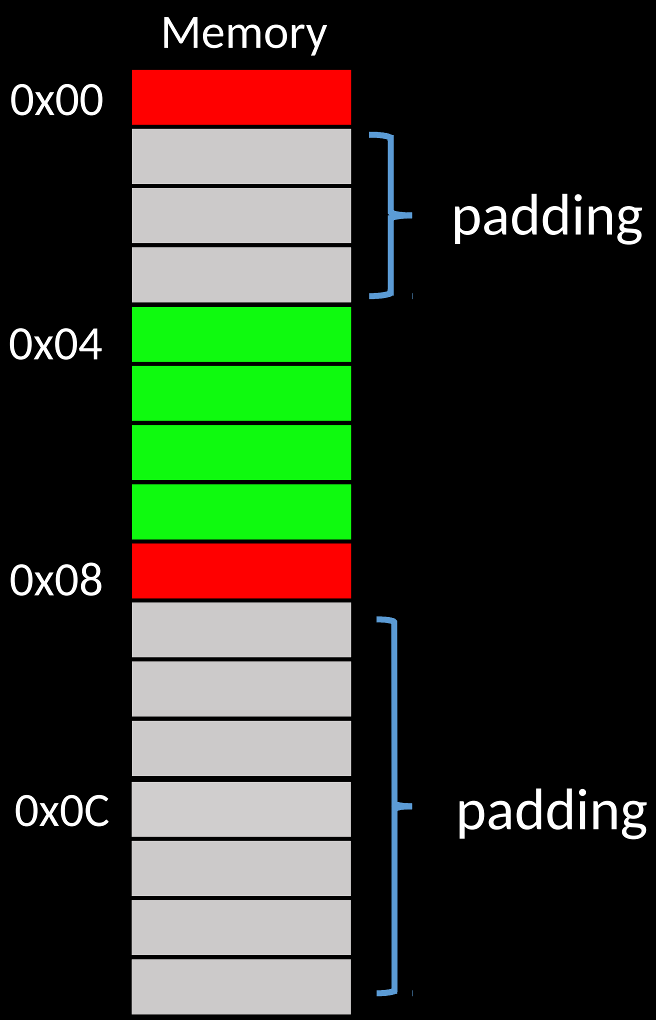
Alignment on a Structure [S5]

- Structure is aligned, all members aligned

```
typedef struct  {
   int8_t   var1;
   int32_t var2;
   int8_t   var3;
} str3 __attribute__ ((aligned));
```

sizeof(str3) ▭ 16 Bytes

Aligned structure members size would require 12 bytes, Not a power of 2!

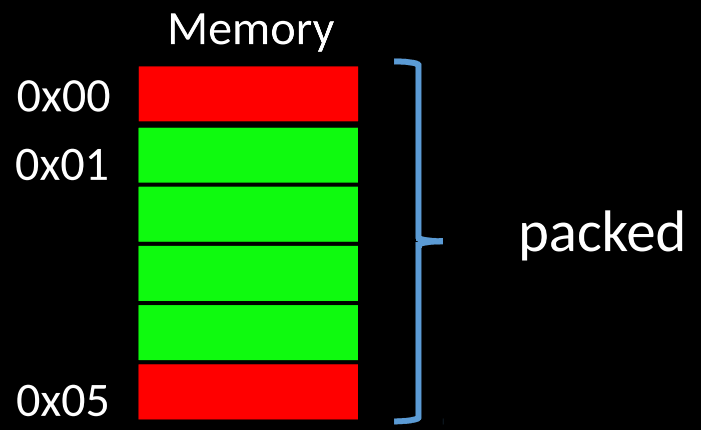


Alignment on a Structure [S6]

- Structure is packed, alignment ignored

```
typedef struct  {
   int8_t   var1;
   int32_t var2;
   int8_t   var3;
} str4 __attribute__ ((packed));
```

sizeof(str4) □ 6 Bytes



When structure is packed,
members will be unaligned!!!

Function Attributes [S7]

- Compiler Attributes can apply to Functions
  - Inline – Skips calling convention, copies function body into calling code

Compiler will NOT ignore this

Compiler might ignore this

```
__attribute__ ((always_inline)) inline int32_t add( int32_t x, int32_t y ) {
    return (x + y);
}
```

Inline keyword is a c99 Feature ▭ Not supported in c89

always_inline is a GCC attribute ▭ Not supported on other compilers

Function Pragmas [S8]

- Pragmas provide special instructions to the compiler
  - Push/Pop – Add extra option for compilation
  - Optimize – Specify a certain level of optimization block of code

```
#pragma GCC push
#pragma GCC optimize (“O0”)
int32_t add( int32_t x, int32_t y )
{
    return (x + y);
}
#pragma GCC pop
```

Only this code will have Zero Optimizations applied

GNUC Support [S9]

- Embedded teams can support multiple chipset platforms and multiple architectures
  - Different architecture ***may*** require different compiler

__attribute__(x) is only a GCC compiler keyword, Throws errors for other compilers

```
#ifndef (__GNUC__)
#define __attribute__ (x)
#endif
```

Define as nothing for Non-GNU C compilers

Ignore all slides after this

Unused slide material

Introduction [S1.3.6.a]

Attributes and pragmas are compiler directives (i.e. not part of C)

Can use them on functions and variables to convey special information to compiler.

```
/* Use #pragma to specify compiler directives  */
#pragma Otime                    /* Optimize for execution time */

/* Using attributes on functions */
void Mandelbrot16(uint16_t n, uint16_t c);  __attribute__
((noreturn));
                         __attribute__ ((always_inline));
#pragma Ospace                             /* Optimize for code space */
struct __attribute__ ((packed)) PackedStruct {      /* sizeof(PackedStruct) = 5 bytes
*/
    uint8_t varx   __attribute__ ((mode (__pointer__)));
    uint32_t vary __attribute__ ((aligned (16)));              /* allocate ’vary’ on 16-bit
boundary */
};
```

Compiler Specific [S1.3.6.b]

Function attributes and pragmas are compiler-dependent, though some common ones may be shared between them.

```
/* Only valid for MIPS */
void __attribute__ ((interrupt, use_shadow_register_set)) v1
();

/* Gives error unless using GCC Solaris compiler */
#pragma fini (fnc1, fnc2, fnc3, fnc4);

/* Works for GCC ARM compiler */
#pragma thumb
void __attribute__ ((interrupt, use_shadow_register_set)) v1
();
static int max(int x, int y) __attribute__((always_inline));
```

Attributes at Compile Time [S1.3.6.c]

Attributes can be turned on/off using compile time switches

```
/* If compiler is not GNU C, then omit ‘__attribute__’ */
#ifndef __GNUC__
#define __attribute_(x)  /* Nothing */
#endif

/* Can also use pragmas to enable/disable optimization at
certain parts */
#pragma GCC push_options
#pragma GCC optimize (“O0”)
     // code section here
#pragma GCC pop_options
```

Aligned [S1.3.6.d]

By default, strongly declared symbols have definitions.
Symbols declared *weak* don’t need definitions – i.e. can have multiple definitions.

```
/
*****************************************************************************
*****
 * Forces compiler to ensure ‘S’ or ‘some_int_var’
 * will be allocated and aligned at least on a 8-bit boundary.

*****************************************************************************
*****/
struct S {short f[3]; } __attribute__ ((aligned (8)));
typedef int some_int_var __attribute__ ((aligned (8)));
```

Packed [S1.3.6.e]

Using the *packed* attribute on a **struct** or **union** makes each its members also *packed*.

```
/* Members of packed_struct are packed, but internal layout of
ustruct is not packed. The unpacked_struct must be packed
separately. */
struct unpacked_struct{
    uint8_t c1;
    uint32_t c2;
};

struct __attribute__ ((__packed__)) packed_struct {
    uint8_t d1;
    uint32_t d2;
    struct unpacked_struct ustruct;
};
```

Target [S1.3.6.f]

Target attribute allows user to specify target-specific compilation options.

```
/* Equivalent to compiling somefunc with ‘–march=core2’ and ‘-sse4a’ target
options. */

uint32_t somefunc (void) __attribute__ ((__target__ (“march=core2", "sse4a")));
```

Pragma Optimizations [S1.3.6.g]

Use pragma to specify optimization levels and types

```
#pragma Otime
void function1(){ … }      /* Optimize function1 for execution
time */

#pragma push           /* Save current pragma state */

#pragma O2             /* Optimize at level 3 */
uint32_t function2(){ … }     /* Optimize function2 at O3*/

#pragma Ospace
uint8_t function3(){ … } /* Optimize function3 for code size */

#pragma pop            /* Restores previously saved pragma
state */
```