DESN2000 (Computer Engineering) 2025 T2

Volatile Qualifier in C

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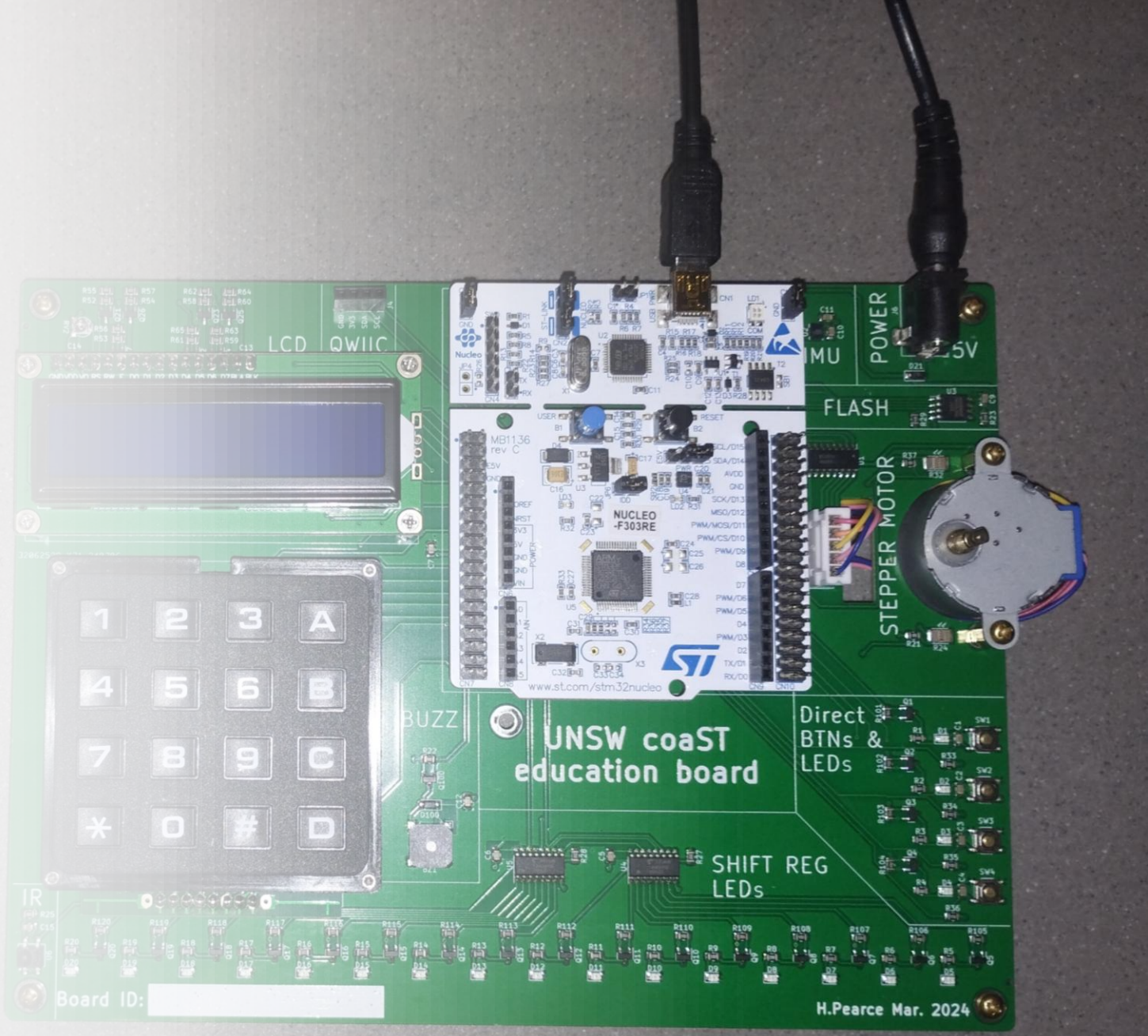
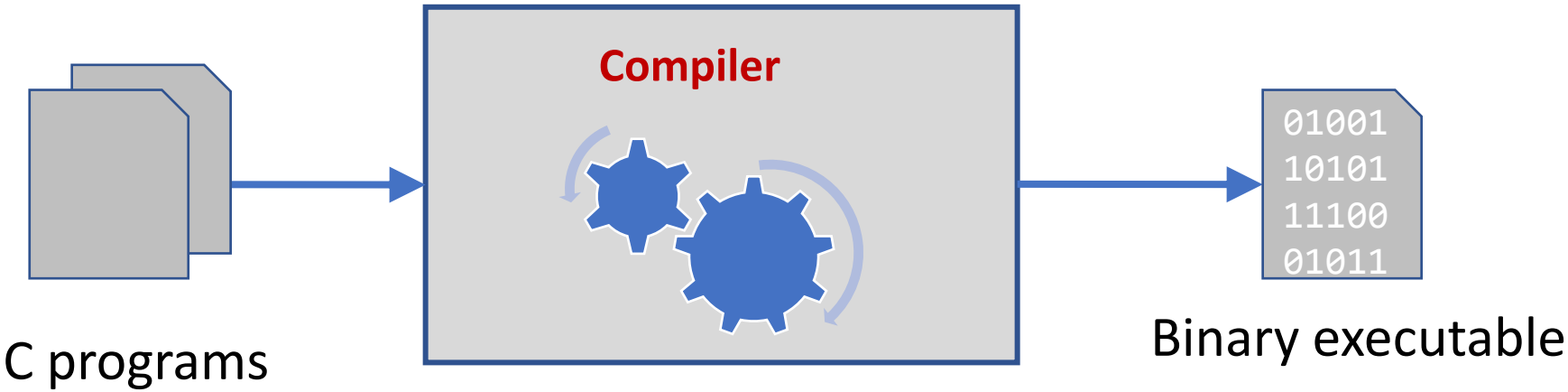


Learning Resources

The upcoming slides are adapted from “Embedded Systems with ARM Cortex-M Microcontrollers in Assembly Language and C (Fourth Edition)” – Yifeng Zhu

- Mixing C and Assembly - chapter 10

Compiler



Performance, Performance, Performance!

- Compiler can make aggressive optimization
  - Cache results in register to reduce memory accesses
  - Reorder computations
  - Eliminate useless and redundant computations

```
int flag = 0;

void SysTick_Handler(void){
    flag = 1;
    // Turn on the green LED
    GPIOE->ODR |= GPIO_ODR_ODR_8;
}

int main(void){
    GPIO_init();
    SysTick_init();

    while(flag == 0);

    // Turn on the red LED
    GPIOB->ODR |= GPIO_ODR_ODR_2;

    while(1);
}
```

Without optimization

```
        ...
        LDR r0, =flag  ; Get memory address
loop    LDR r1, [r0]   ; Read memory
        CMP r1, #0
        BEQ loop
        ...
```

With optimization

```
        ...
        LDR r0, =flag  ; Get memory address
        LDR r1, [r0]   ; Read memory
loop    CMP r1, #0
        BEQ loop
        ...
```

A dead loop since flag was 0. Thus, the program is blocked here and failed to turn on the red LED.

Solution

```
volatile int flag = 0;

void SysTick_Handler(void){
    flag = 1;
    // Turn on the green LED
    GPIOE->ODR |= GPIO_ODR_ODR_8;
}

int main(void){
    GPIO_init();
    SysTick_init();

    while(flag == 0);

    // Turn on the red LED
    GPIOB->ODR |= GPIO_ODR_ODR_2;

    while(1);
}
```

With/without optimization

```
        ...
        LDR r0, =flag  ; Get memory address
loop    LDR r1, [r0]   ; Read memory
        CMP r1, #0
        BEQ loop
        ...
```

Volatile variables

- Qualifier `volatile` tells the compiler that this value may change at any time
  - Do not apply any optimizations to remove reads or writes to these variables

Example:

```
volatile int x;
y = x + x + x + x;
```

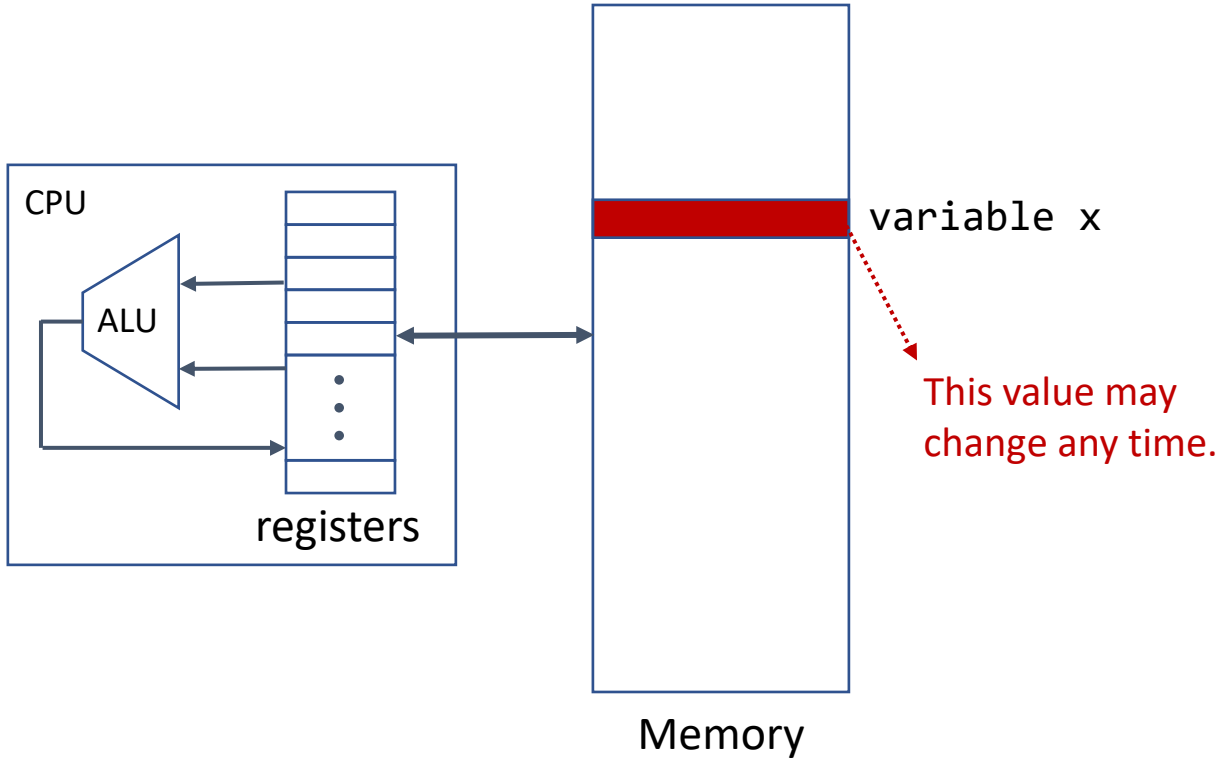
The computation cannot complete within a single clock cycle and x can change any time.

Compiler cannot optimize it as:

```
y = 4 * x;
```

or

```
y = x << 2;
```



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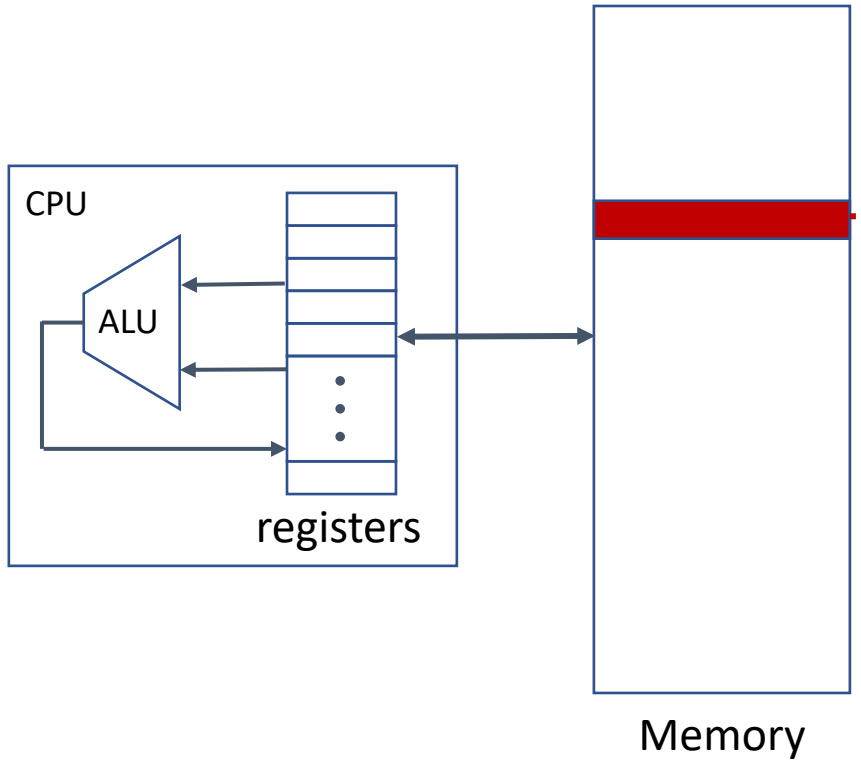

A memory value may be changed anytime by hardware.

Input data registers:

- `GPIOB->IDR`
- `SPI1->DR`
- `USART1->DR`

Status registers:

- `USART1->SR`

Volatile variables

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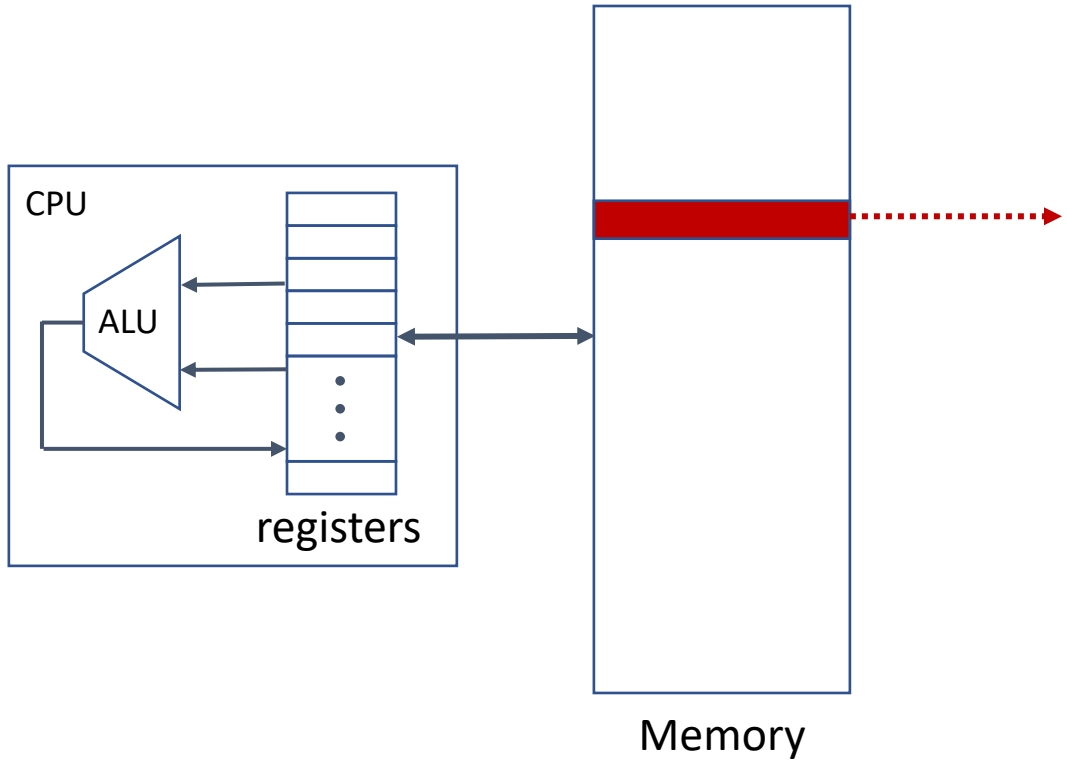


This value may be changed anytime by software.

- Interrupt handlers
- Another thread (with OS or RTOS)

Three Common Usages of volatile

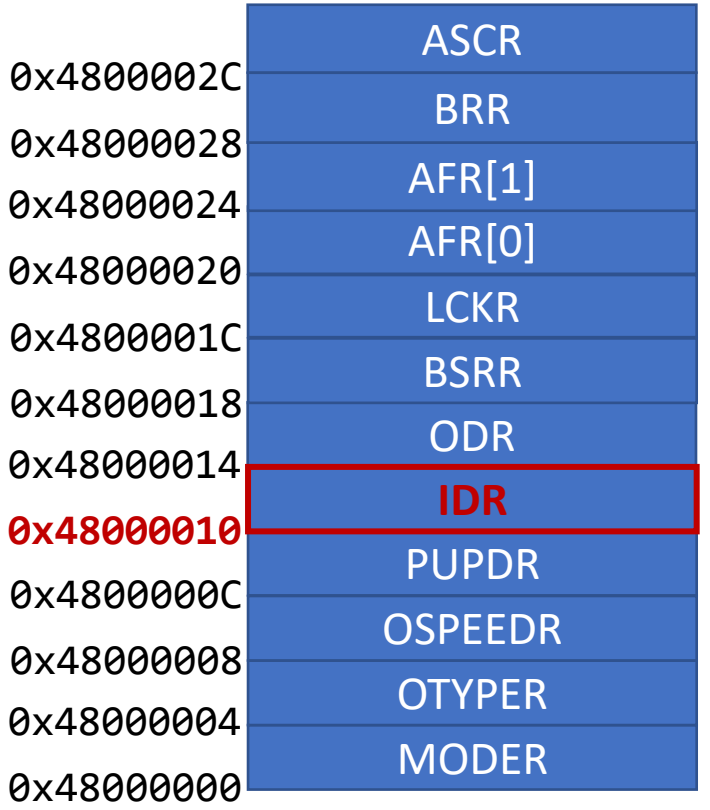
- Use volatile on accessing memory-mapped I/O registers

```
#define GPIOA_IDR (*((uint32_t volatile *) 0x48000010))

void main(void){
    ...

    // Read the input on pin 2
    Pin2 = GPIOA_IDR >> 2;

    ...
}
```



GPIOA Peripheral Registers

Three Common Usages of volatile

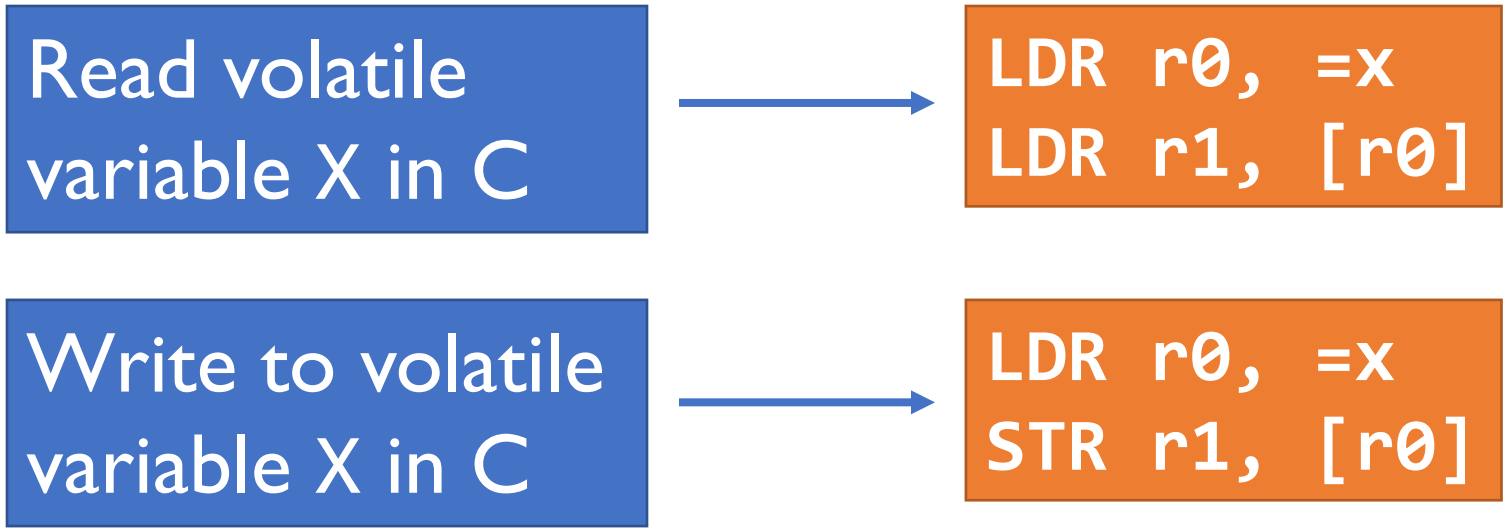
- Use volatile on accessing memory-mapped I/O registers
- Use volatile on global variables accessed in interrupt service routines
- Use volatile on global variables shared between multi-thread tasks

```
volatile uint32_t counter;

void SysTick_Handler(void){
    counter++;
}
```

Summary

Volatile forces compiler to generate executable that performs actual memory reads and writes, instead of caching values in registers!



Syntax of volatile keyword

- Declare a variable volatile

```
volatile int x;
int volatile y;
```

Pointers

```
int* pi;
int volatile* pvi;
int* volatile vpi;
int volatile* volatile vpvi;
```

Trick: Read from left to right

Pointers

- A pointer to an int
  ```
  int* pi;
  ```
- A pointer to a volatile int
  ```
  int volatile* pvi;
  ```
- A volatile pointer to an int
  ```
  int* volatile vpi;
  ```
- A volatile pointer to a volatile int
  ```
  int volatile* volatile vpvi;
  ```