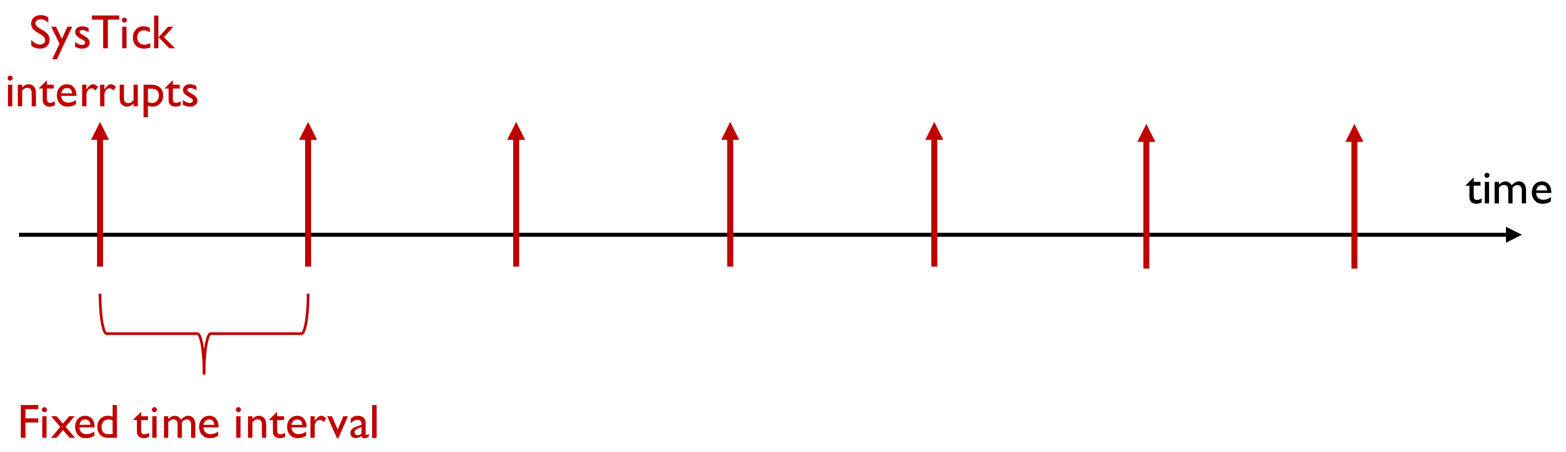
ARM Cortex-M
System Timer (SysTick)

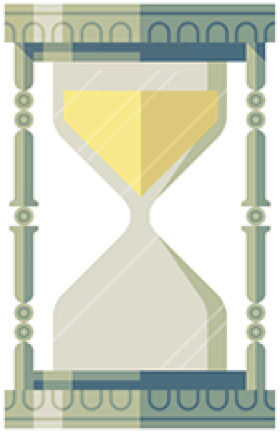
CSE 4219
Principles of Embedded System Design

Taken from Dr. Yifeng Zhu's Lecture Notes
Embedded Systems with ARM Cortex-M Microcontrollers in Assembly Language and C – Chapter 11

System Timer (SysTick)

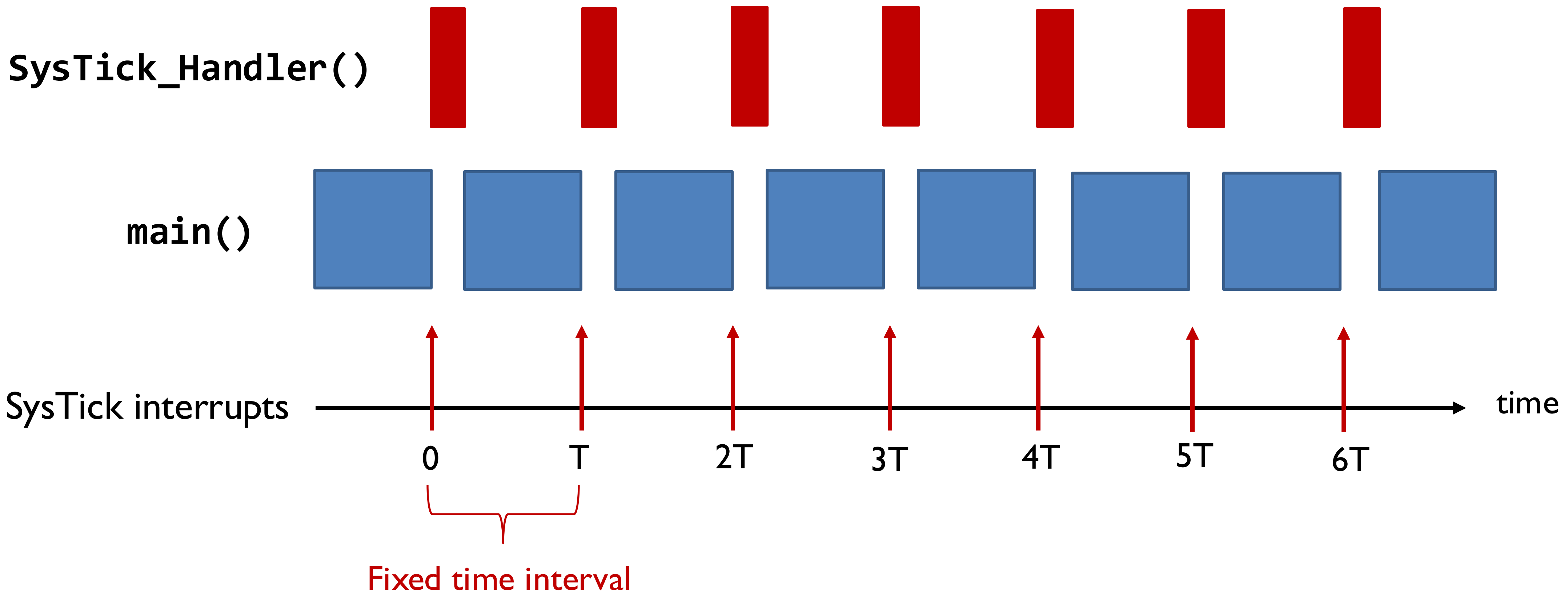
- Generate SysTick interrupts at a fixed time interval





- Example Usages:
  - Measuring time elapsed, such as time delay function
  - Executing tasks periodically, such as periodic polling, and OS CPU scheduling

System Timer (SysTick)



System Timer (SysTick)

- System timer is a standard hardware component built into ARM Cortex-M.
- This hardware periodically forces the processor to execute the following ISR:

```
void SysTick_Handler(void){
   ...
}
```

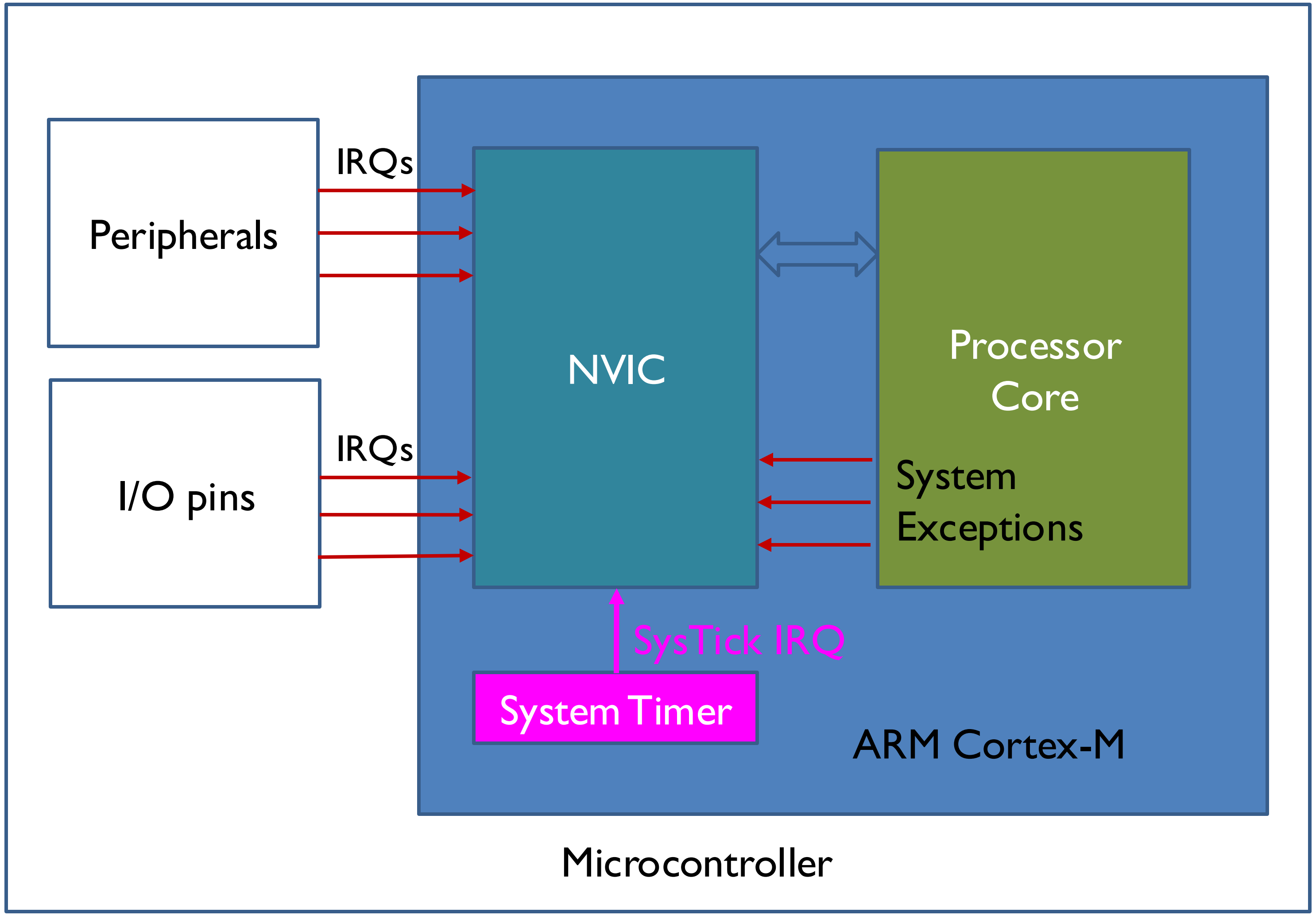
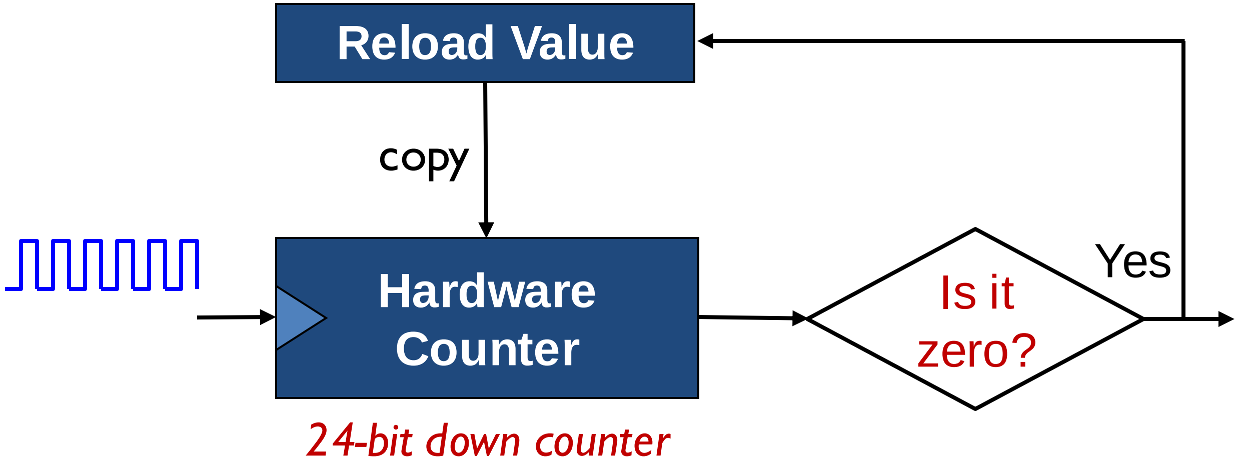
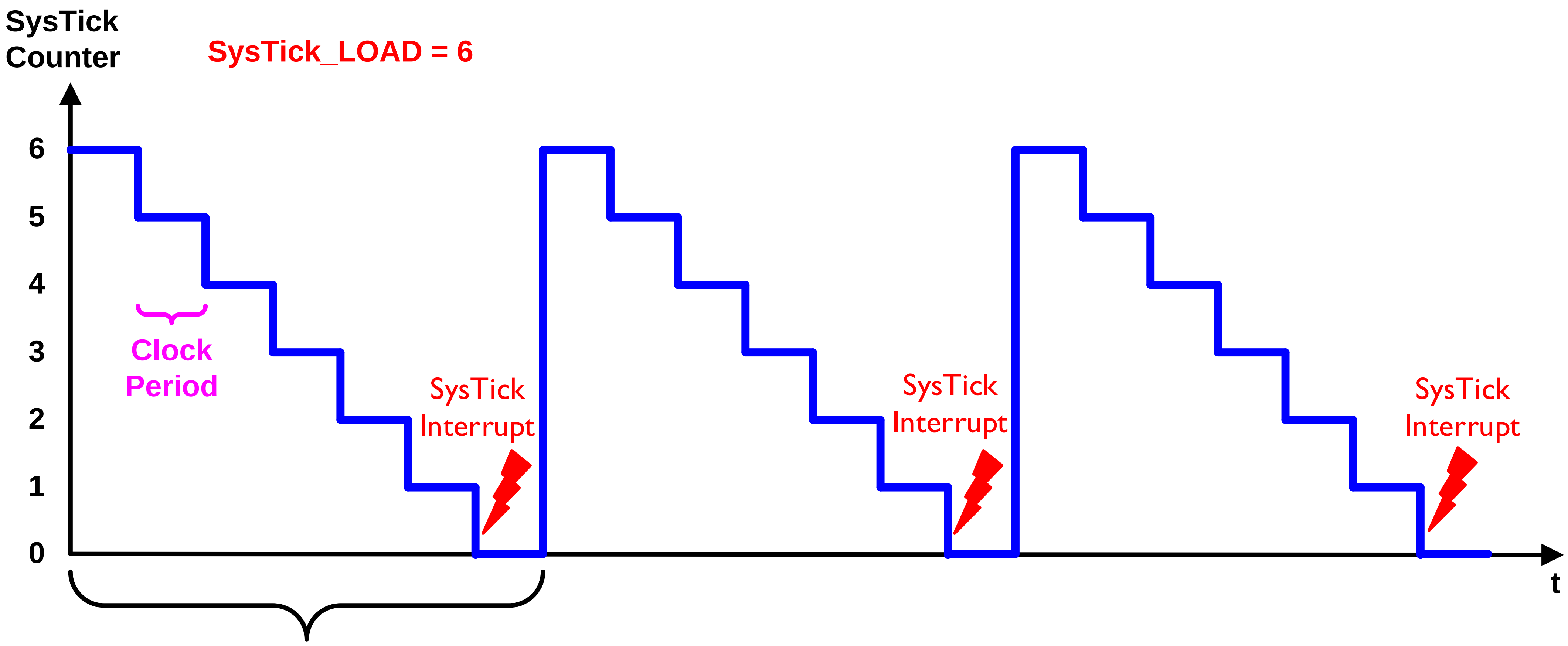


Diagram of System Timer (SysTick)

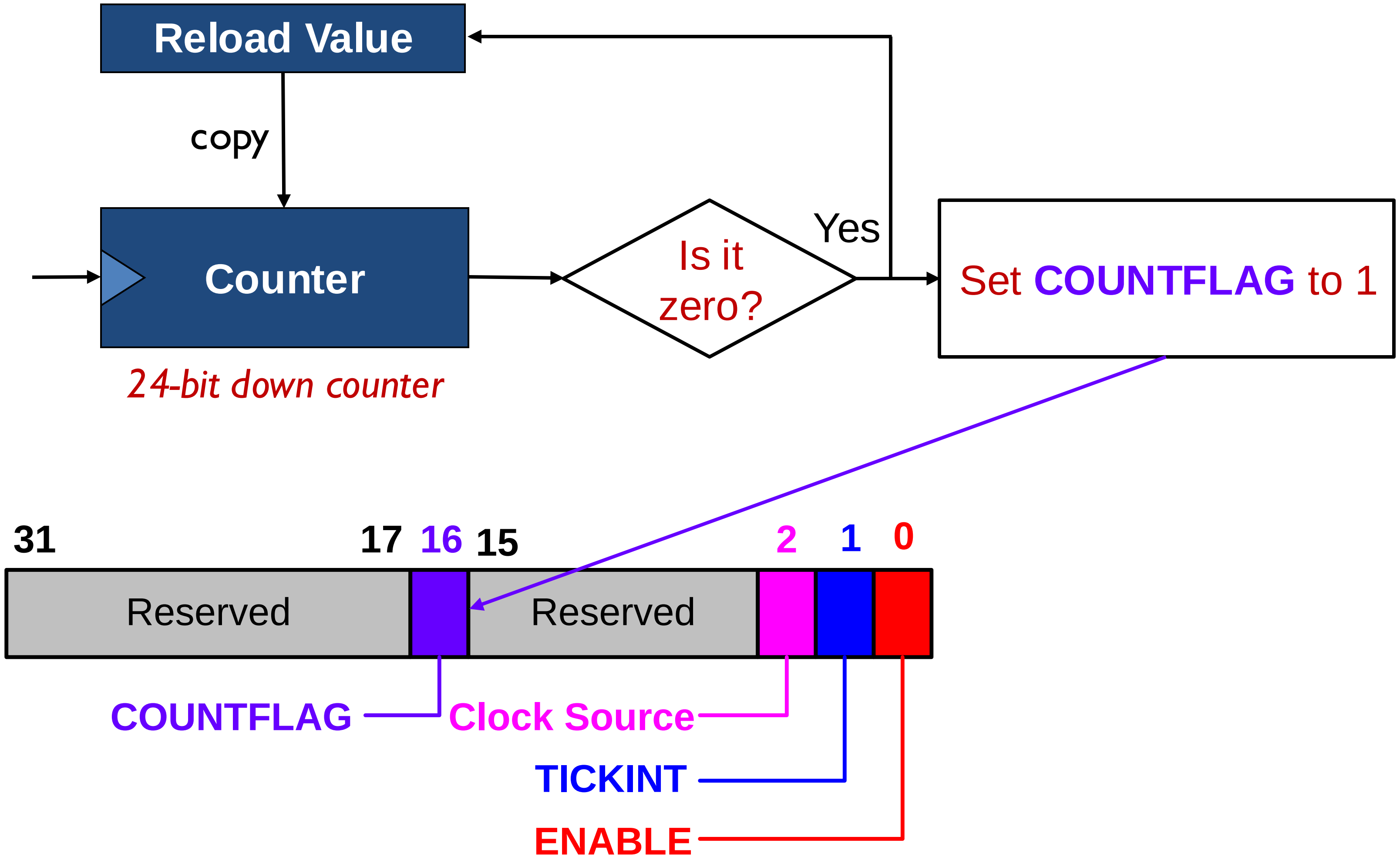


System Timer



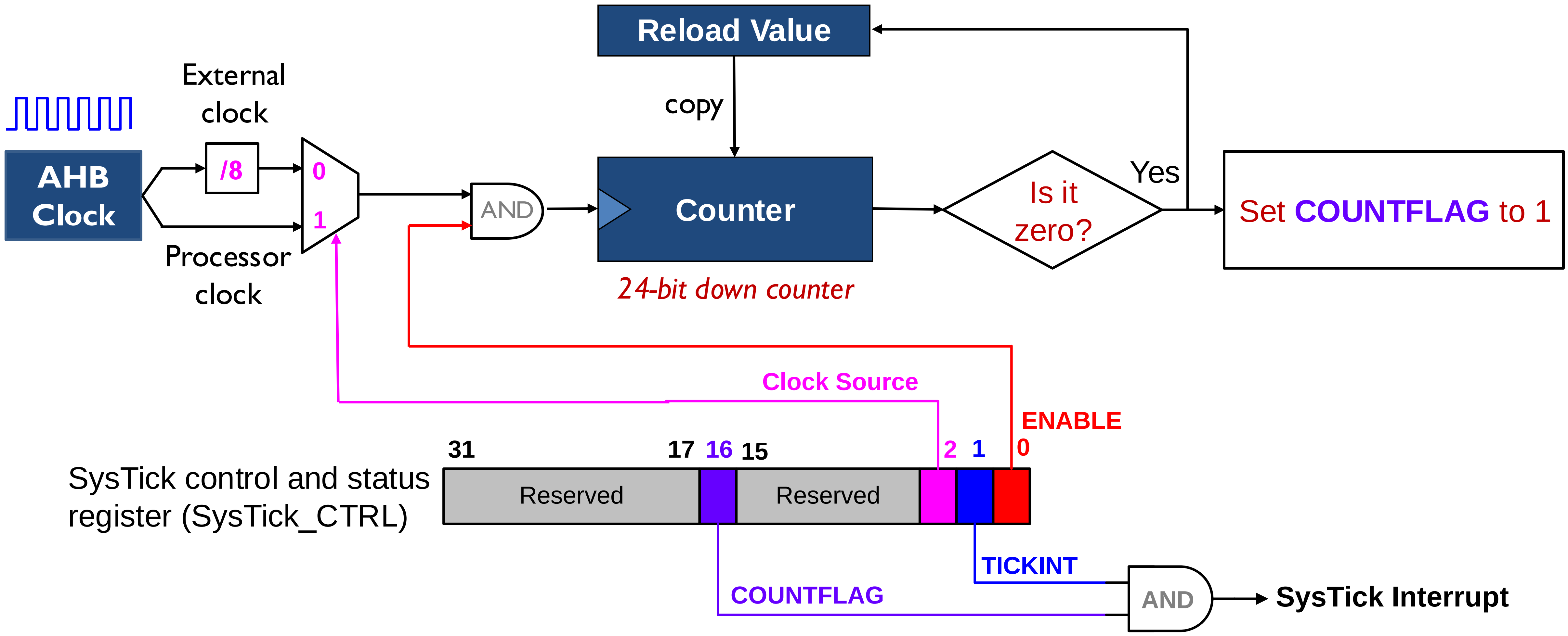
SysTick Interrupt Time Period = (SysTick_LOAD + 1) × Clock Period = 7 × Clock Period

Diagram of System Timer (SysTick)



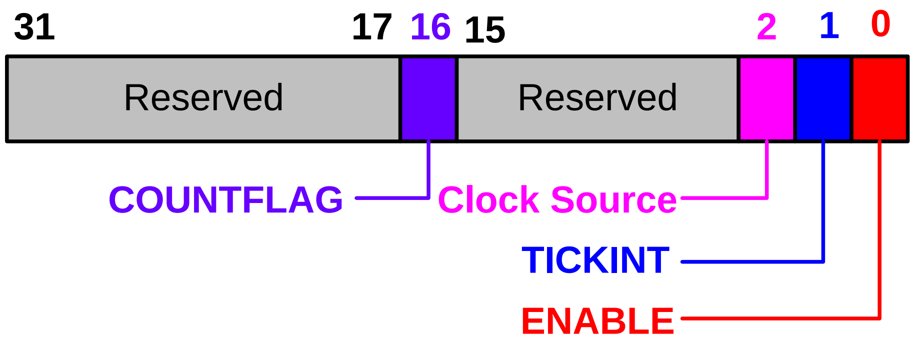
SysTick control and status register (SysTick_CTRL)

Diagram of System Timer (SysTick)



Registers of System Timer

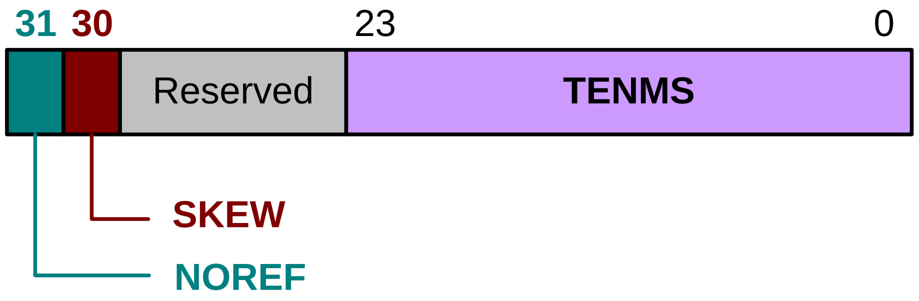
SysTick control and status register (SysTick_CTRL)



SysTick reload value register (SysTick_LOAD)

SysTick current value register (SysTick_VAL)

SysTick calibration register (SysTick_CALIB)



Registers of System Timer

SysTick reload value register (SysTick_LOAD)

- 24 bits, maximum value `0x00FF.FFFF` (16,777,215)
- Counter counts down from RELOAD value to 0.
- Writing RELOAD to 0 disables SysTick, independently of TICKINT
- Time interval between two SysTick interrupts

Interval = (RELOAD + 1) × Source_Clock_Period

- If `100` clock periods between two SysTick interrupts

RELOAD = 99

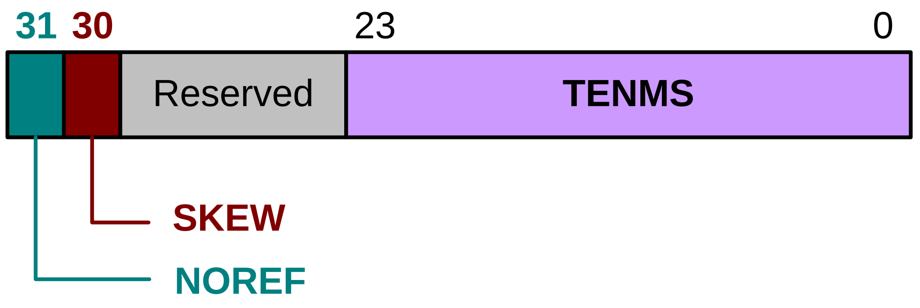
Registers of System Timer

SysTick current value register (SysTick_VAL)

- Reading it returns the current value of the counter
- When it transits from 1 to 0, it generates an interrupt
- Writing to SysTick_VAL clears the counter and COUNTFLAG to zero
  - Cause the counter to reload on the next timer clock
  - But, does not trigger an SysTick interrupt
- It has random value on reset.
  - Always clear it before enabling the timer

Registers of System Timer

SysTick calibration register (SysTick_CALIB)



- A read-only register
- TENMS (`10 ms`) holds the reload value, which will yield a 10ms period
- May not be implemented or may be defined differently by chip designers

Example Code

```
// Input: ticks = number of ticks between two interrupts
void SysTick_Initialize (uint32_t ticks) {

    SysTick->CTRL = 0;              // Disable SysTick

    SysTick->LOAD = ticks - 1;      // Set reload register

    // Set interrupt priority of SysTick to least urgency (i.e., largest priority value)
    NVIC_SetPriority (SysTick_IRQn, (1<<__NVIC_PRIO_BITS) - 1);

    SysTick->VAL = 0;               // Reset the SysTick counter value

    // Select processor clock: 1 = processor clock; 0 = external clock
    SysTick->CTRL |= SysTick_CTRL_CLKSOURCE;

    // Enables SysTick interrupt, 1 = Enable, 0 = Disable
    SysTick->CTRL |= SysTick_CTRL_TICKINT;

    // Enable SysTick
    SysTick->CTRL |= SysTick_CTRL_ENABLE;
}
```

Implementing Delay Function

```
volatile int32_t TimeDelay;

int main (void {
  SysTick_Initialize(1000);  // Interrupt period = 1000 cycles
  Delay(100);                // Delay 100 ticks
  ...
}

void SysTick_Handler (void) { // SysTick interrupt service routine
  if (TimeDelay > 0)     // Prevent it from being negative
    TimeDelay--;         // TimeDelay is a global volatile variable
}

void Delay (uint32_t nTime) {
  // nTime: specifies the delay time length
  TimeDelay = nTime;       // TimeDelay must be declared as volatile
  while(TimeDelay != 0);   // Busy wait
}
```

Calculating Reload Value

- Suppose clock source = 80MHz
- Goal: SysTick Interval = 10ms
- What is RELOAD value?

$$Reload = \frac{10\ ms}{Clock\ Period} - 1$$

$$= 10ms \times Clock\ Frequency\ - 1$$

$$= 10ms \times 80MHz - 1$$

$$= 10 \times 10^{-3} \times 80 \times 10^{6} - 1$$

$$= 800000 - 1$$

$$= 799999$$