DESN2000 (Computer Engineering) 2026 T2

Pulse Width Modulation (PWM)

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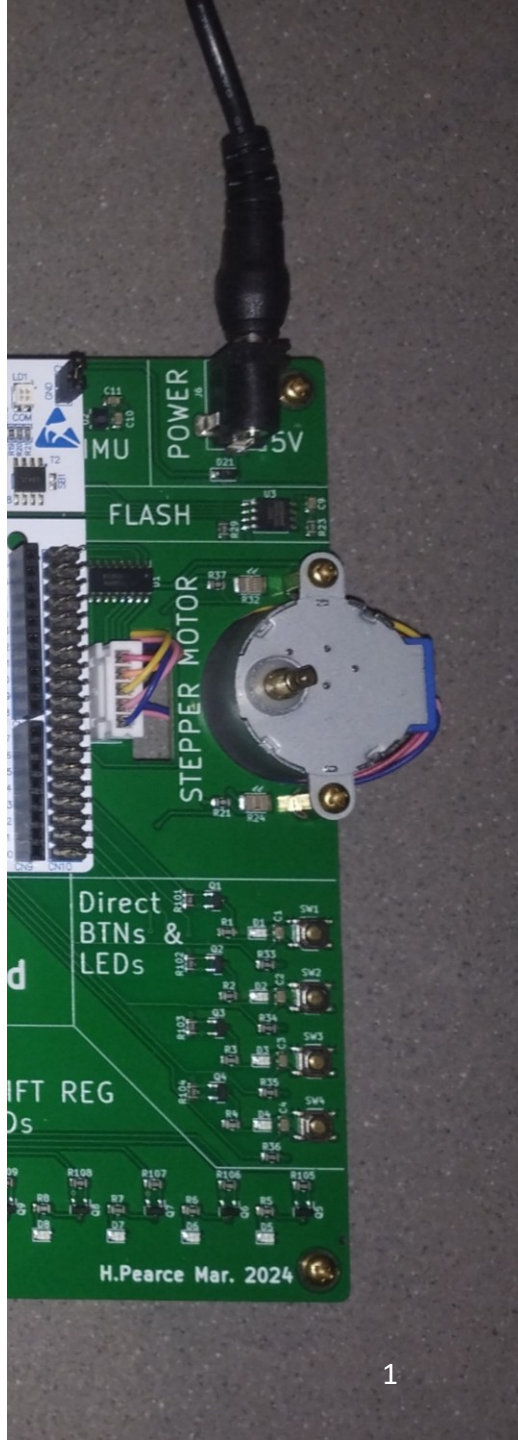
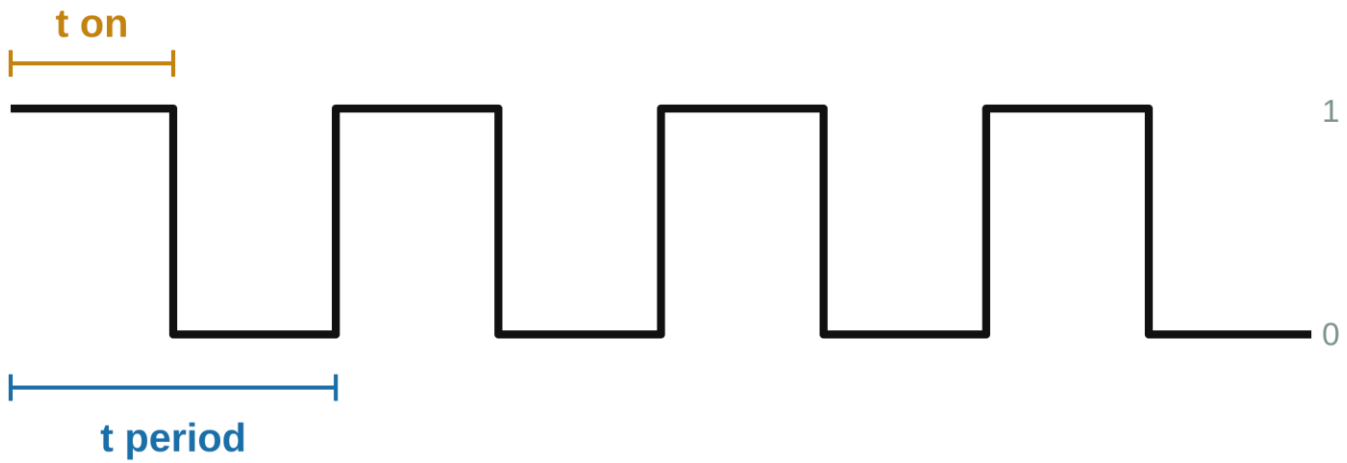


PWM

- Digital output
  - 1 or 0 -> LED on or off
  - We used GPIO for this
- Analog output
  - Control the brightness of the LED
  - PWM allows us to use a GPIO pin for this

Duty Cycle

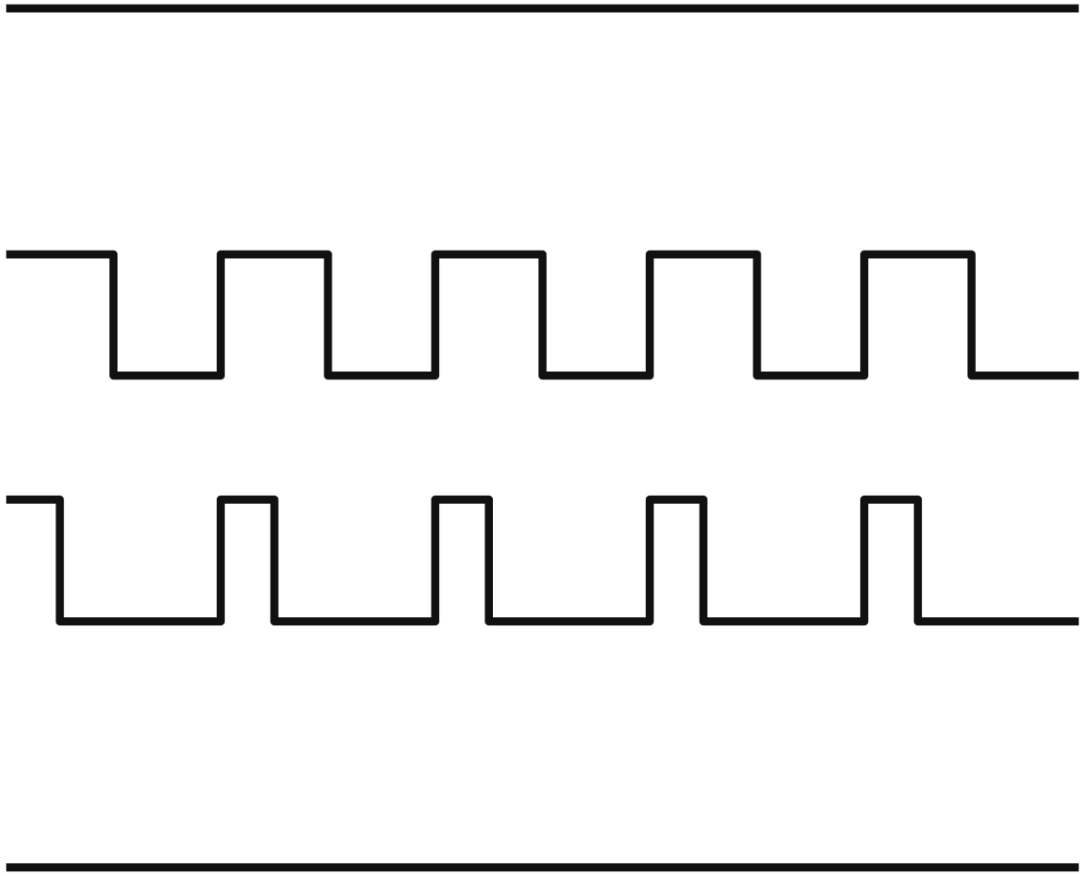


$$\text{duty cycle (as a percentage)} = \frac{t_{on}}{t_{period}} \times 100$$

$$\text{duty cycle (as a fraction)} = \frac{t_{on}}{t_{period}}$$

Duty Cycle

100%



Always high
LED at full brightness

50%

High half the time
half brightness

25%

High a quarter of the time
quarter brightness

0%

Always low
LED off

LED Brightness

- Very fast change so the eye cannot see
  - Say we do a pulse frequency of 60Hz
  - $t_{period} = 1/60 = 0.016s = 16$ ms
- The average voltage to the LED is proportional to the duty cycle
  - Say we want 25% brightness
  - 25% duty cycle means: $t_{on} = 4$ ms

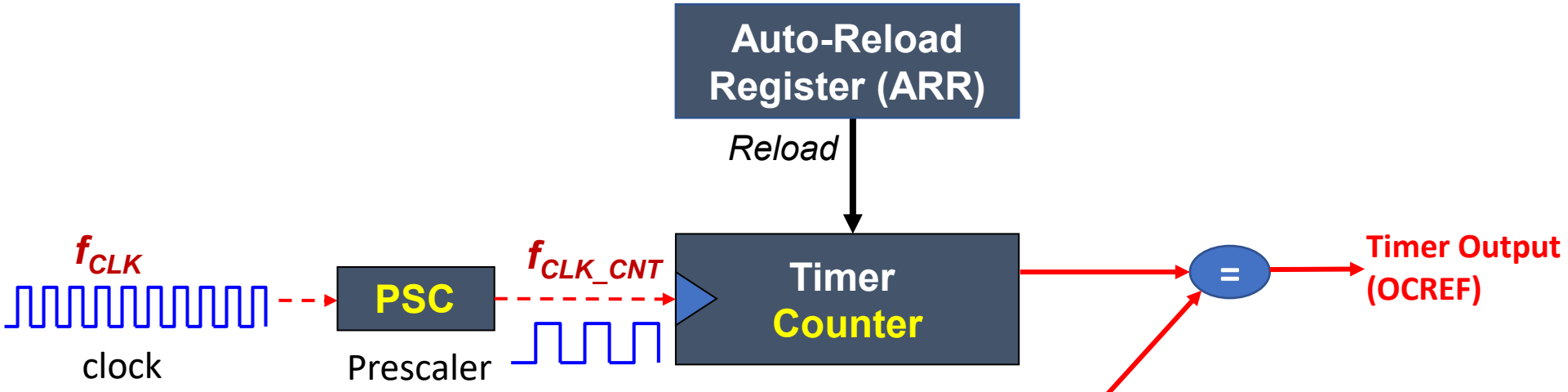
PWM Applications

- To control analog variables
  - LED dimming
  - Motor speed control
    - For DC motors (that are not stepper motors)
  - Communication

PWM in Software

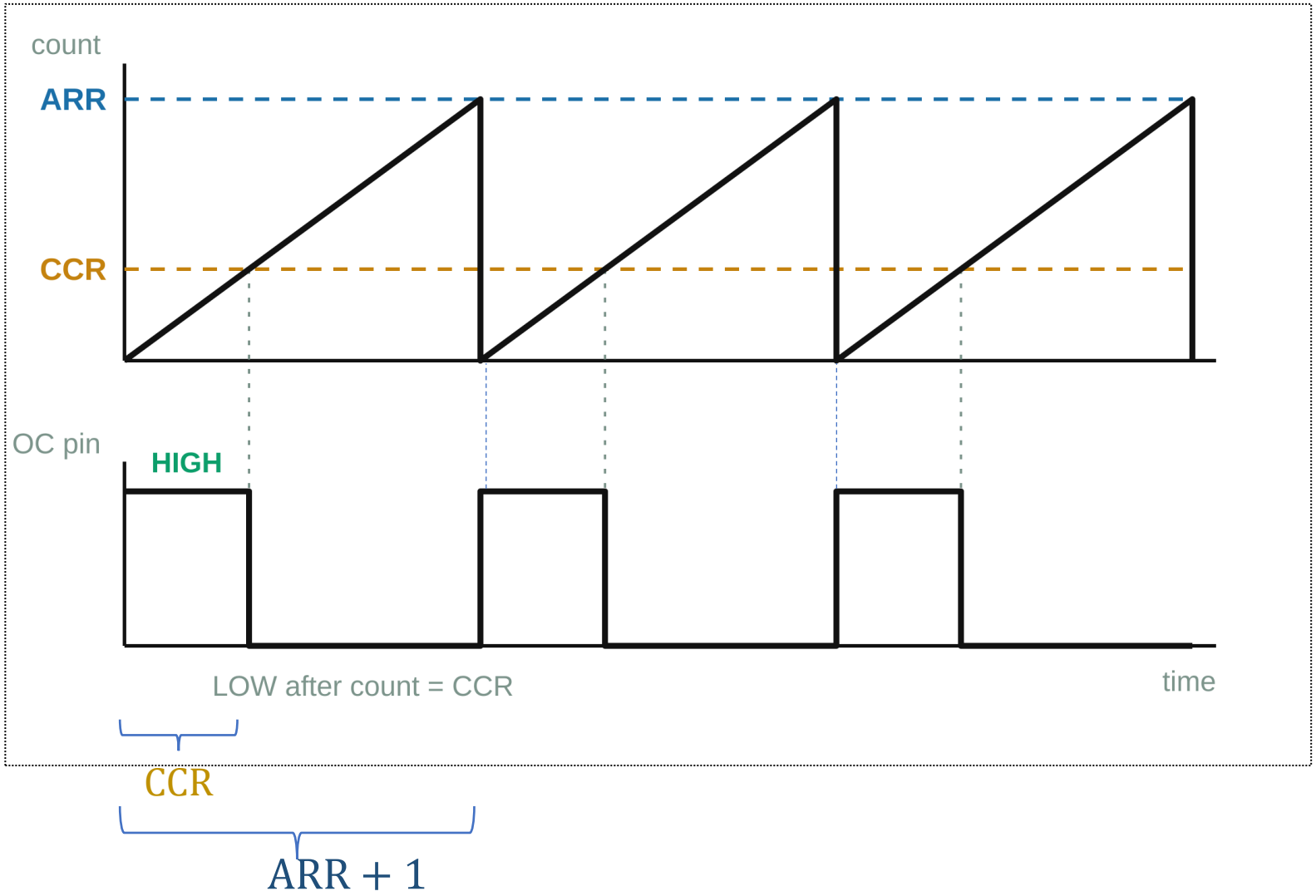
```
#define T_PERIOD 16
#define T_ON 4
#define T_OFF T_PERIOD-T_ON
while(1){
     HAL_GPIO_Write(LD2,1);
     HAL_Delay(T_ON);
     HAL_GPIO_Write(LD2,0);
     HAL_Delay(T_OFF);
}
```

PWM using Timers



$$t_{period} = \frac{(1 + ARR)(1 + PSC)}{f_{CLK}}$$

PWM using Timers



$$\textbf{Duty Cycle} = \frac{CCR}{ARR + 1}$$

PWM using Timers

- For 16ms PWM period and 25% duty cycle:

$$t_{period} = \frac{(1 + ARR)(1 + PSC)}{f_{CLK}}$$

$$16ms \times 72MHz = (1 + ARR)(1 + PSC)$$

$$1152 \times 1000 = (1 + ARR)(1 + PSC)$$

$$ARR = 1151 \qquad PSC = 999$$

$$Duty\ Cycle = \frac{CCR}{ARR + 1}$$

$$0.25 = \frac{CCR}{1151 + 1}$$

$$CCR = 288$$

- See example code for implementation

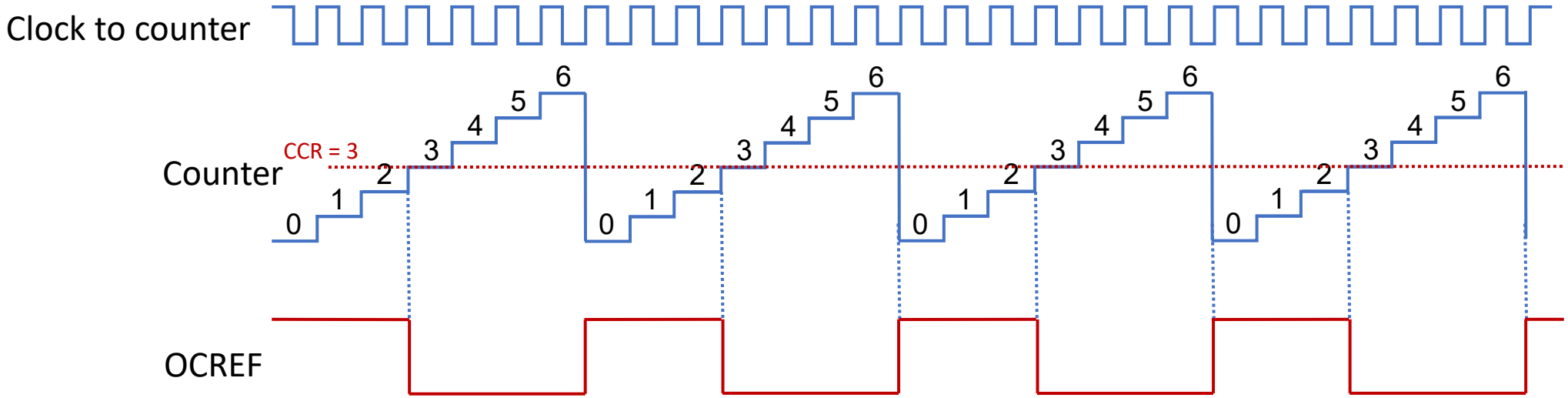
PWM using Timers

Figure adapted from: Yifeng Zhu, Embedded Systems with ARM Cortex-M Microcontrollers in Assembly Language and C

Mode 1

Timer Output (OCREF) =
- High if counter < CCR
- Low if counter ≥ CCR

Upcounting mode, ARR = 6, CCR = 3, RCR = 0



$$\text{Duty Cycle} = \frac{CCR}{ARR + 1} = \frac{3}{7}$$

$$\text{Period} = (1 + ARR) * \text{Clock Period} = 7 * \text{Clock Period}$$

Observe using Oscilloscope

- From STM32 Nucleo-64 boards user manual, find where the LD2 (PA5) is located