Chapter 2

Overview of Architecture and Microcontroller-Resources

Lesson 3

- **DAC (Digital to Analog Conversion)**
- PWM (Pulse-width modulation)
- ADC (Analog to Digital Conversion)
- Multi channel PWMs
- Multichannel ADC

Microcontroller-resources

Port P1

Port P0

Port P2

Port P3

ADC

Timers RTC WDT

Synchronous SI

UART mode SI

Internal Program Memory

Internal Data Memory

PWM

PWM for DAC Function after an Integrator

Digital to Analog Conversion (DAC)

- A digital output needs to be converted into analog signals in many applications
- A DAC analog output proportional to digital input bits.
- A reference input (Vref+) defines the maximum output (when input bits= all 1s) and Vref- the minimum output (when input bits= all 0s).

DAC Analog output

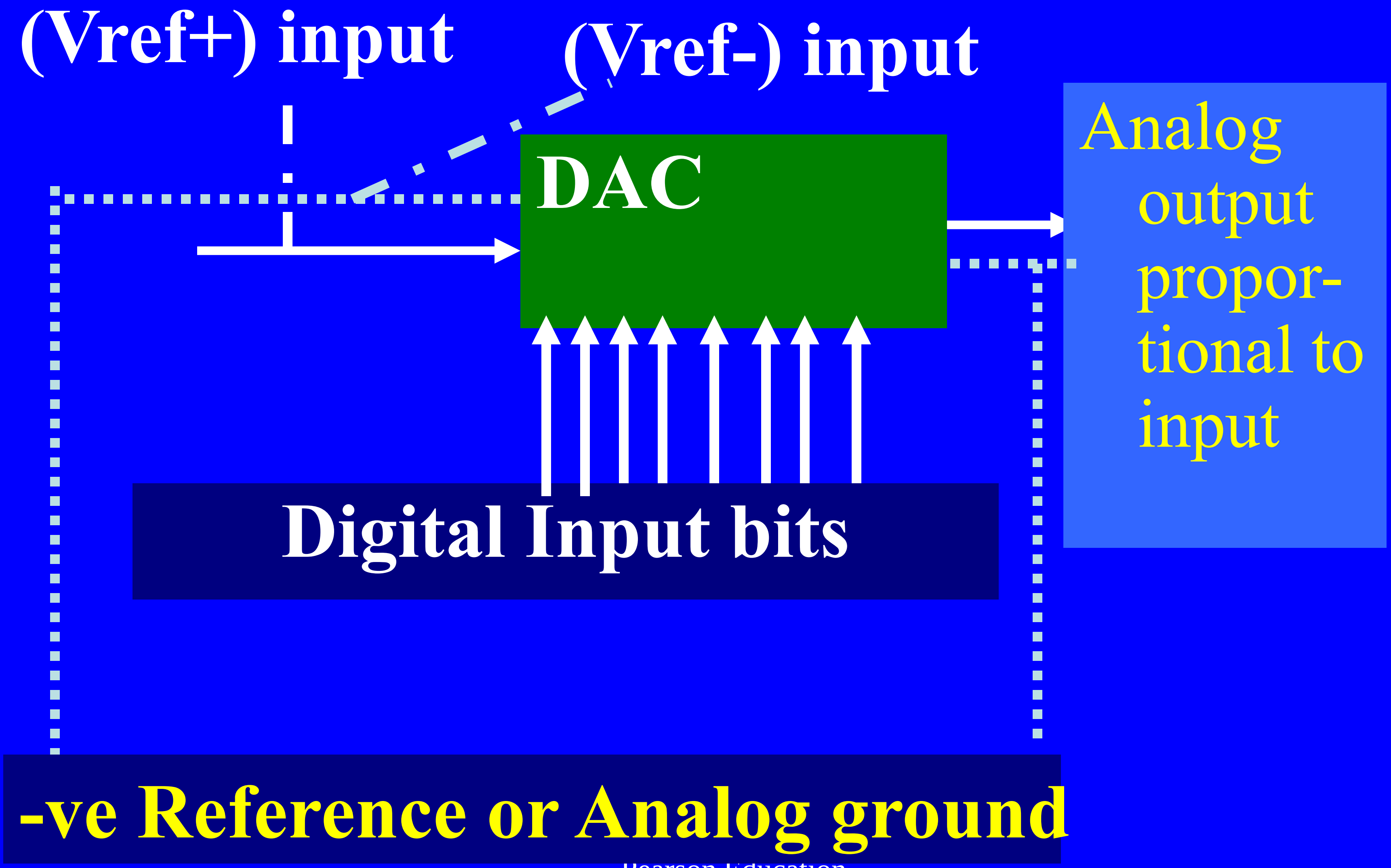
- Analog output of n-bit DAC =

$$\frac{(\text{n-bit input})\,(\text{Vref+} - \text{Vref-})}{\{(2^{n}) - 1\}}$$

8-bit DAC example

- **8-bit DAC functions as follows.**
- **Let (Vref+) = 1.275 V and (Vref-) = 0 V.**
- **When input bits= all 0s = 00000000 (=0d) generate output = 0V,**
- **= 10000000 (= 128d) generate output = 0.64V and**
- **= 11111111 (= 255d) generate output = 1.275V**

8-bit DAC example



Pearson Education

PWM (Pulse-width modulation)

PWM

- An MCU implements DAC function by sending a PWM output at an external pin and an integrator circuit integrates PWM signal for one pulse duration and then gives analog output.
- PWM width is proportional to desired analog output and is controlled by a value x loaded into PWM register.

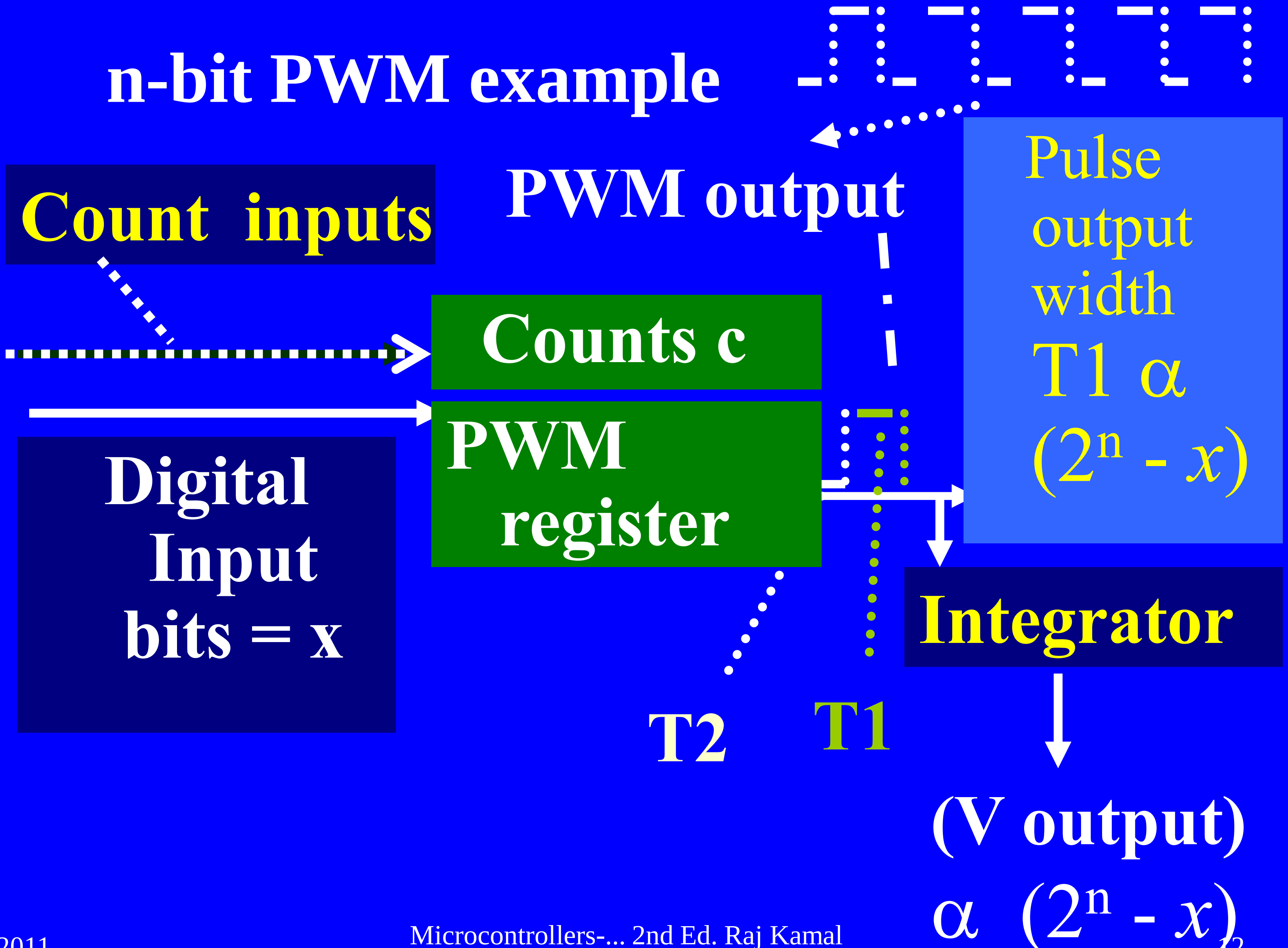
PWM output

- x = digital bits in an n-bit PWM register
- PWM output bit = 1 for period T1
- PWM output bit = 0 for period T2
- T1 α $(2^n - x)$;
- T2 α (x);
- (T1 + T2) α (2^n). Frequency = 1/ (T1 + T2)
- V Output of integrator α (T1)/ (T1+T2)
- Duty Cycle = 100. (T1)/ (T1+T2) %

8-bit PWM example

- When x in PWM register = all 0s = 00000000 (=0d). Let pulse-width T1= 0 ms, and T1+T2 = 256 *5 μs = 1.28 ms
- x= 10000000 (= 128d) generate output width T1 = 0.64 ms, when register count-input pulse periods equal (0.64/128) ms = 5 μs
- x = 11111111 (= 255d) generate width T1 = 1.275 ms.

n-bit PWM example



Integrator Outputs

PWM output

Analog output V α $(2^n - x)$

Integrator 1

Integrator 2

Integrator 3

(V output) α $[-(2^n - 1) + (2^n - x)]$

T2 **T1**

Analog output V α $-(2^n - x)$

PWM Applications

- PWM generates analog outputs and signals
- PWM controls a DC motor
- PWM control a servomotor in a robot

ADC (Analog to Digital Conversion)

Analog to Digital Conversion (ADC)

- Analog input needs to be converted into bits in many applications
- Digital output bits proportional to ADC analog input
- A reference input (Vref+) defines the maximum input (when output bits= all 1s) and Vref- the minimum input (when output bits= all 0s).

ADC output

- n-bit ADC (output) =

$$\frac{\text{Analog input} \times \{(2^n)-1\}}{(\text{Vref+} - \text{Vref-})}$$

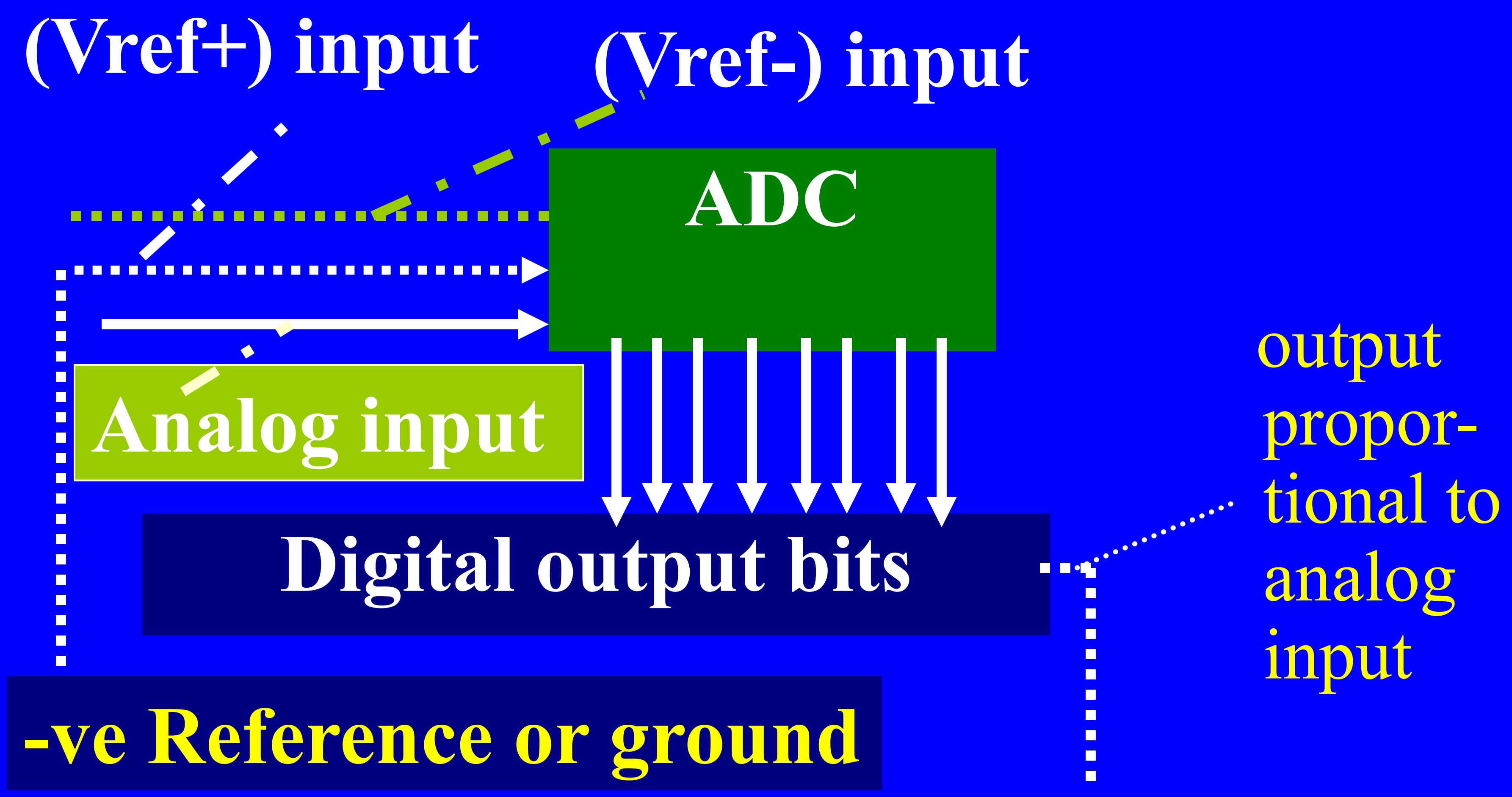
8-bit ADC example

- **8-bit ADC functions as follows.**

Let (Vref+) = 1.275 V and (Vref-) = 0 V.

- **Output bits = all 0s = 00000000 (=0d) when input = 0V,**
- **Output bits = 10000000 (= 128d) when input = 0.64V and**
- **Output bits = 11111111 (= 255d) when input = 1.275V**

8-bit DAC example



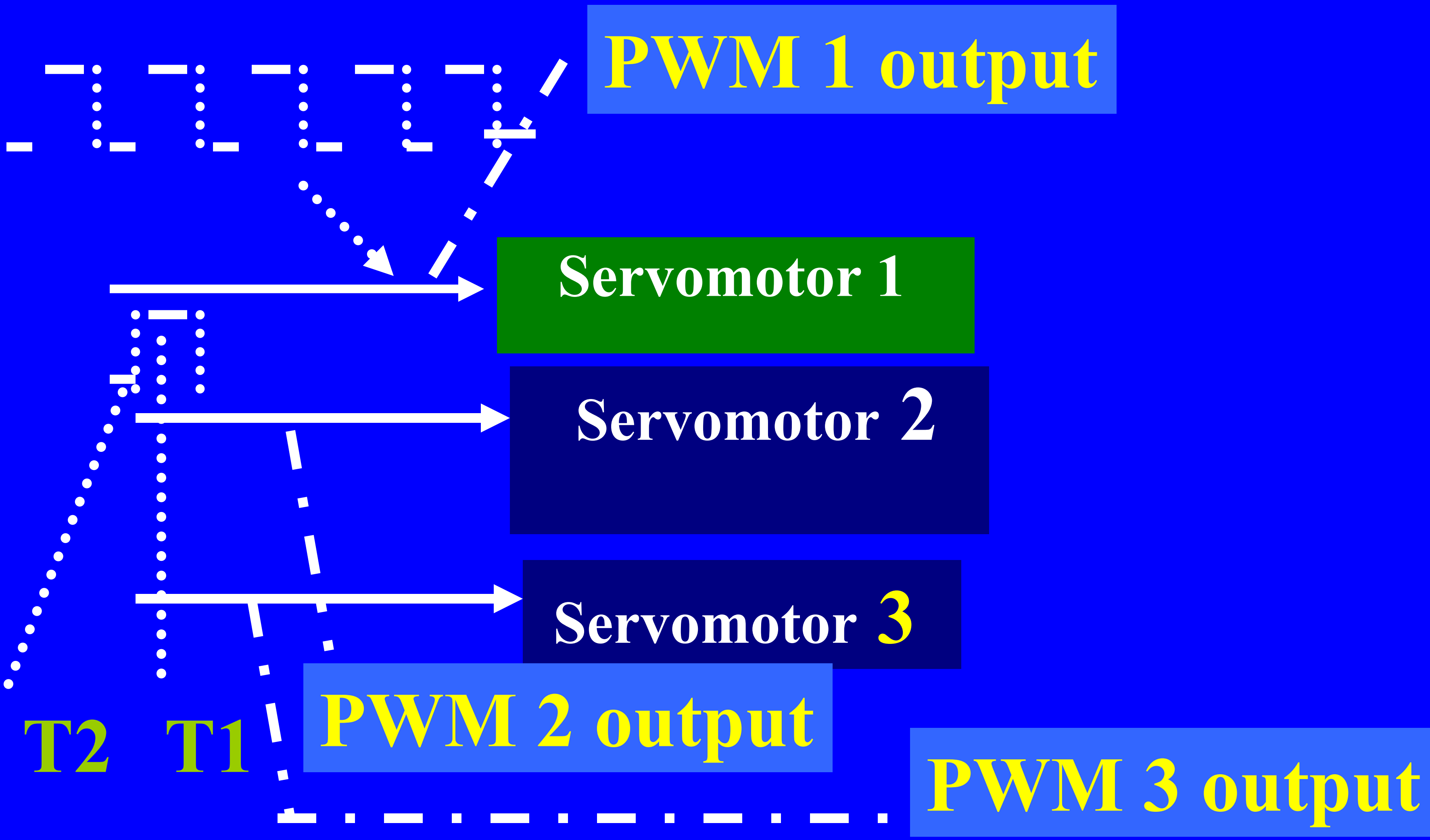
Multiple channels- PWMs

Multiple channels PWM Applications

- PWMs control the *n* servomotor in a *m*- degree of freedom robot

- PWMs control *n*-DC motors or *n* -systems in a plant

3-Channels PWMs

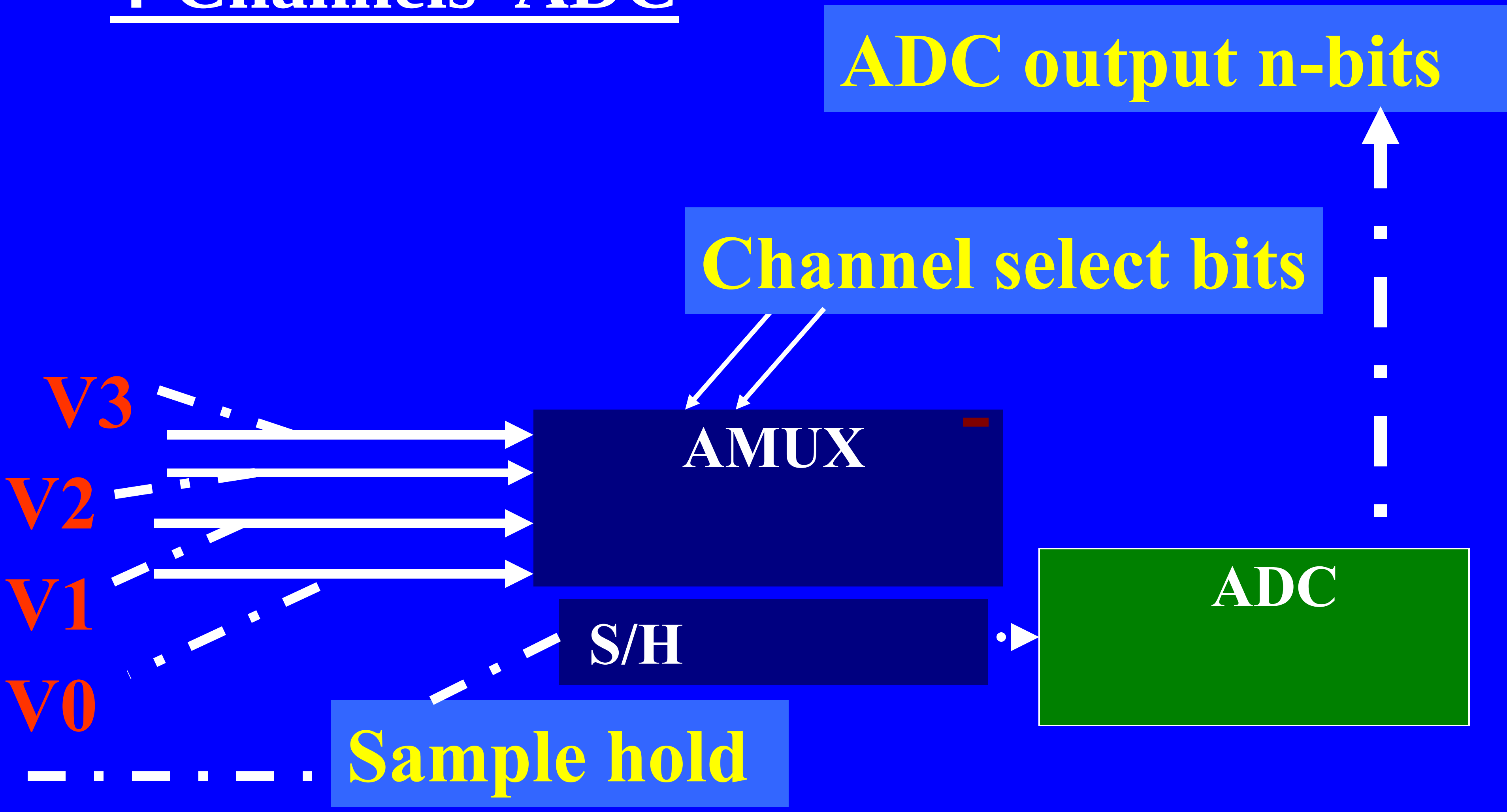


Multichannel ADC

Multiple channels ADC Applications

- An ADC with AMUX control the *n*-sensor-inputs from a system
- An ADC with AMUX controls n -physical parameters in a data acquisition system
- Analog multiplexer (AMUX) helps in multiple analog inputs

4-Channels ADC



Summary

We learnt

- PWM Devices Control motors and and servomotors
- Use integrators and PWMs For DAC functions
- DAC input bits α analog output

We learnt

ADC Device

- ADC output bits α analog input
- Senses multiple physical parameters
- Analog multiplexer (AMUX) helps in multiple analog inputs