



TE2023 Microcontrollers Computer Architecture

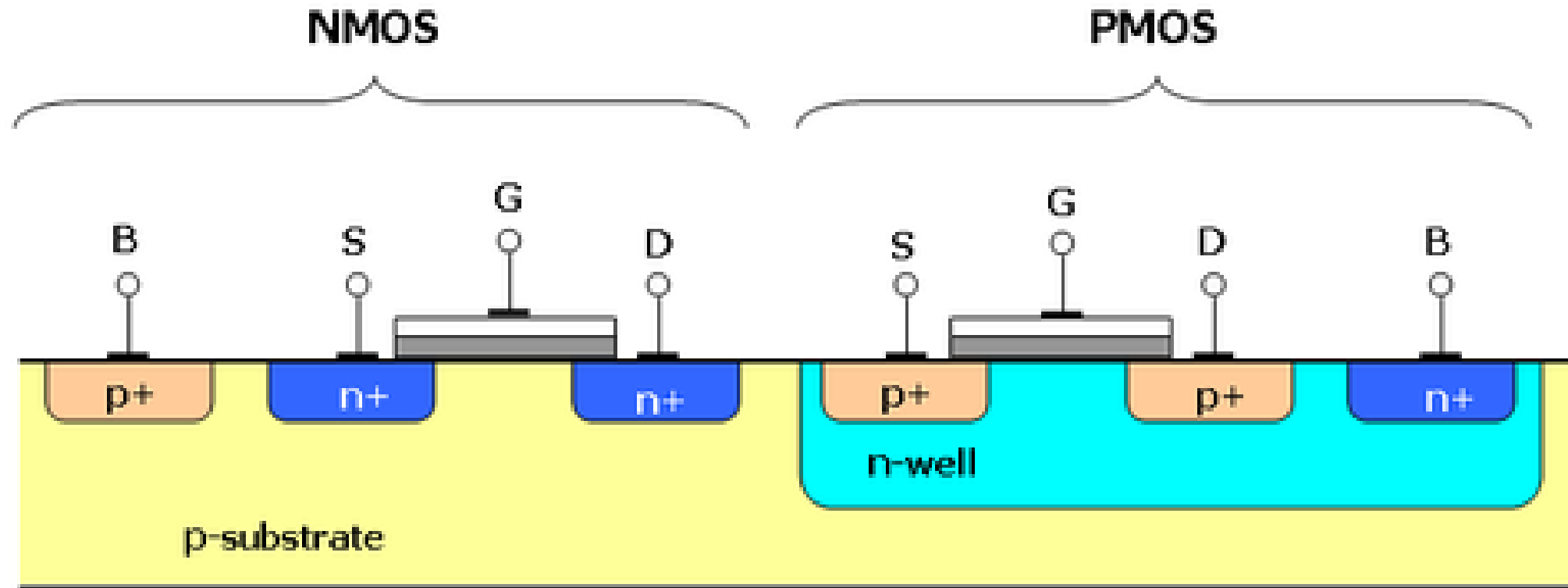
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Professor

Contents

- ▶ Brief history of computers and Moore's Law
- ▶ The computer
- ▶ Memory
- ▶ I/O ports
- ▶ System bus
- ▶ Software



Moore's Law



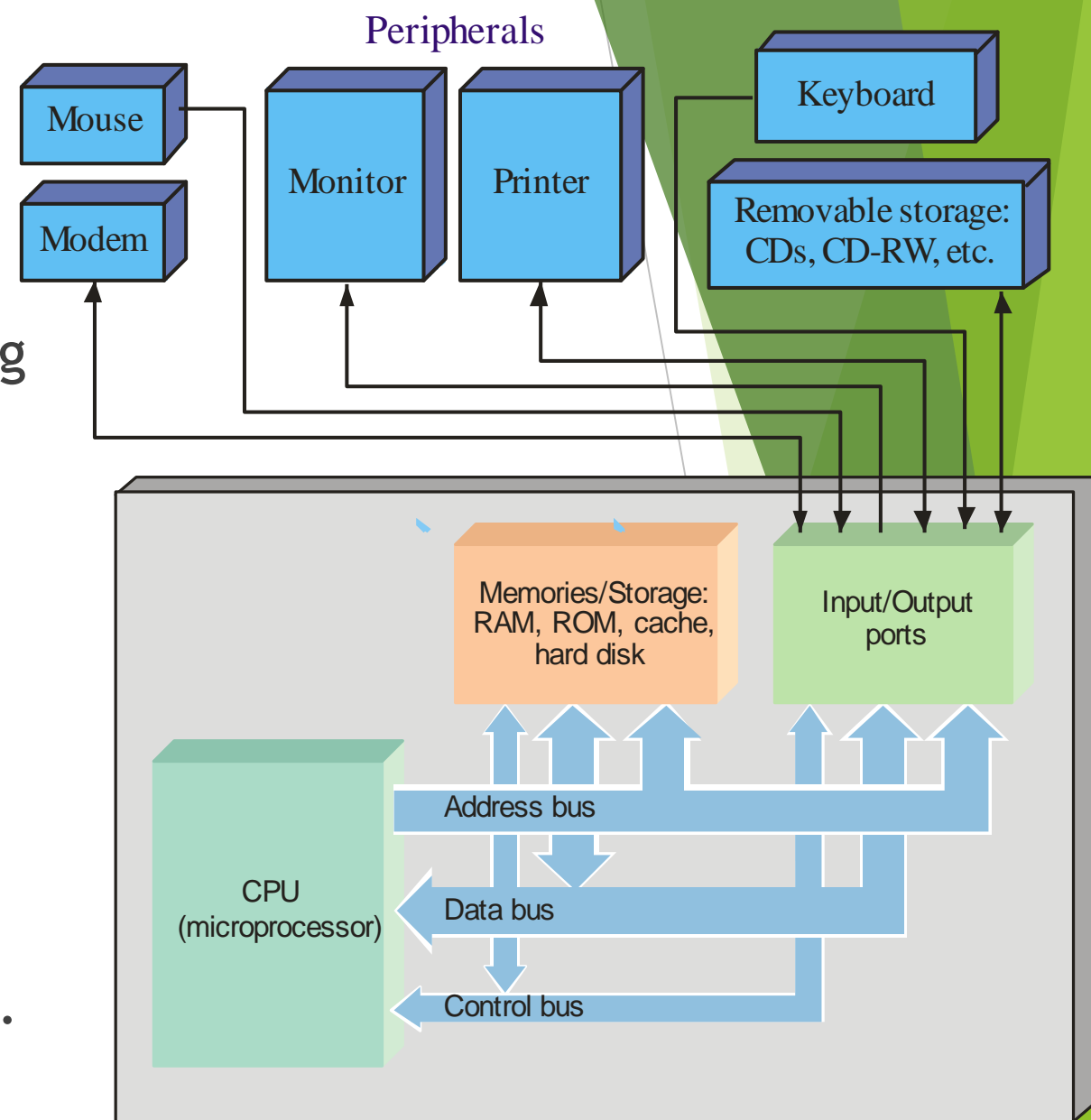
History of the microprocessor

- ▶ Transistor invented in Bell Labs (AT&T) in 1948 by Bardeen and Brattain
- ▶ In the 50s the first “computers” were made with vacuum tubes
 - ▶ Logic gates and flip-flops
- ▶ In 1959 Jack Kilby (Texas Instruments) invented the Integrated Circuit. Robert Noyce develops his own 6 months later
- ▶ In 1971 Intel introduces the 4004, the first microprocessor
 - ▶ 4-bits, 740kHz
 - ▶ 2300 transistors
 - ▶ 4 bit bus multiplexed*
 - ▶ Harvard Architecture *
 - ▶ 46 instructions*
 - ▶ Stack of 3 subroutine calls*

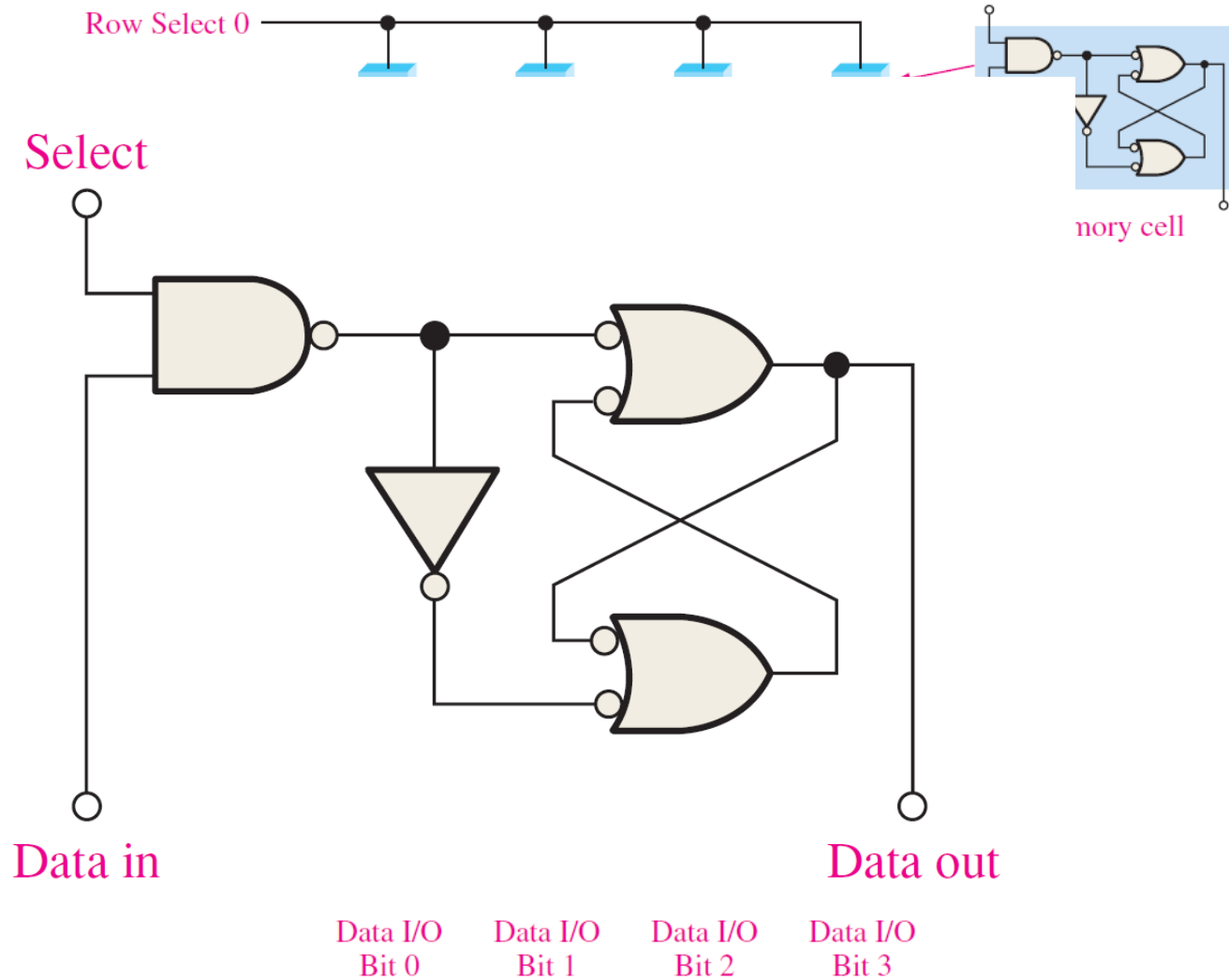


The Computer

- ▶ **CPU** performs operations requesting instructions from memory and executing them
- ▶ **Memory** stores instructions and data required by the CPU
- ▶ **I/O ports** connect the system with the peripherals
- ▶ **Buses** are groups of wires with a common purpose
- ▶ **Peripherals** are the performing devices. They have inputs and outputs



Memory



5,



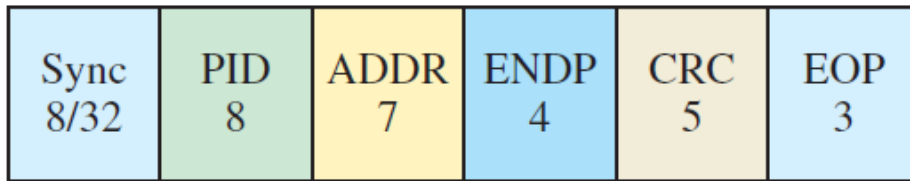
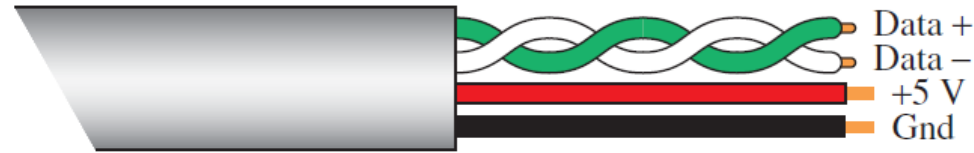
Non-volatile memory

- ▶ FLASH
- ▶ ROM, PROM, EPROM, UV PROM, EEPROM

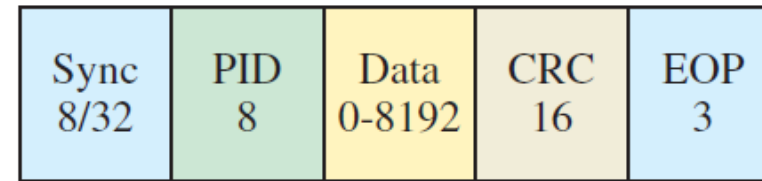


I/O pc

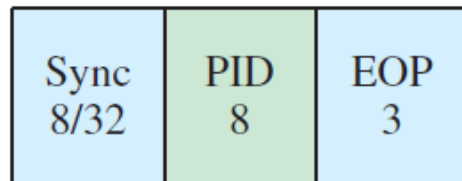
► Interfa



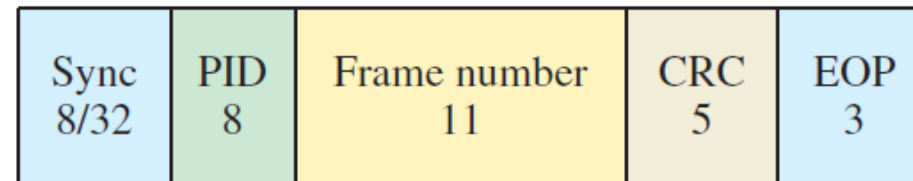
(a) Token packet



(b) Data packet



(c) Handshake packet



(d) Start-of-frame packet

► FUI CUI

(b) Type A connector

(c) Type B connector

► Mem **FIGURE 13-63** USB cable and connectors for USB standards through 2.0.

► Direct I/O



System bus

- ▶ The computer must be able to specify where to get data from, move data from source to destination, and to coordinate data movement. System bus is in charge of this
- ▶ Address bus
 - ▶ Where to read/write data from/to
- ▶ Data bus
 - ▶ Actual data transferred. Bidirectional
- ▶ Control bus
 - ▶ Control and operation of the system
 - ▶ Controls read, write, interrupts, sequencing



Software

- ▶ Refers to every instruction executed by the computer
- ▶ System software (Operating System)
 - ▶ BIOS - Basic Input Output System (firmware, stored in ROM)
 - ▶ Manages hardware and program runtime:
 - ▶ Peripheral connection
 - ▶ Memory distribution to load new programs
 - ▶ Manages programs for running concurrently (multitasking)
- ▶ Application Software (Programs)
 - ▶ Small programs (cmd, bash)
 - ▶ Large programs (Word, videogames, Google Chrome)



Core

System

Memory

Clocks

ARM® Cortex®-M0+ core up to 72 MHz
(up to 96 MHz for high-speed run)

Single Wire
Debug

Interrupt
Controller

Micro Trace Buffer

Power
Management
Controller

Bit Manipulation
Engine

DMA

Internal
Watchdogs

Low-Leakage Wakeup

Program Flash
32–512 KB

SRAM
4–128 KB

32-Byte
Register File

BOOTROM
16–32 KB

High Accuracy
60 M/48 MHz IRC

Low-Speed IRC
8 M/2 MHz or
4 M/32 kHz

PLL/FLL

Low-/High-Frequency
Oscillators

1 kHz LPO

Security and Integrity

Analog

Timers

Communication Interfaces

HMI

Cyclic
Redundancy
Check (CRC)

Flash Access
Controller

MMCAU

True Random
Number
Generator

Unique ID

16-bit SAR ADC

2 x High-Speed ACMP

12-bit DAC

V_{REF}

1 x 6-ch. Timer/PWM

2 x 2-ch. Timer/PWM

2 x Low-Power Timer

Independent RCT

4-ch. Periodic
Interrupt Timers

3 x Low-Power
I²C

3 x LPUART

3 x Low-Power
SPI

ISO7816-E
VMSIM

Flex™ I/O

Crystal-less
USB FS
Device/OTG

USB Voltage
Regulator

Serial Audio
Interface/I2S

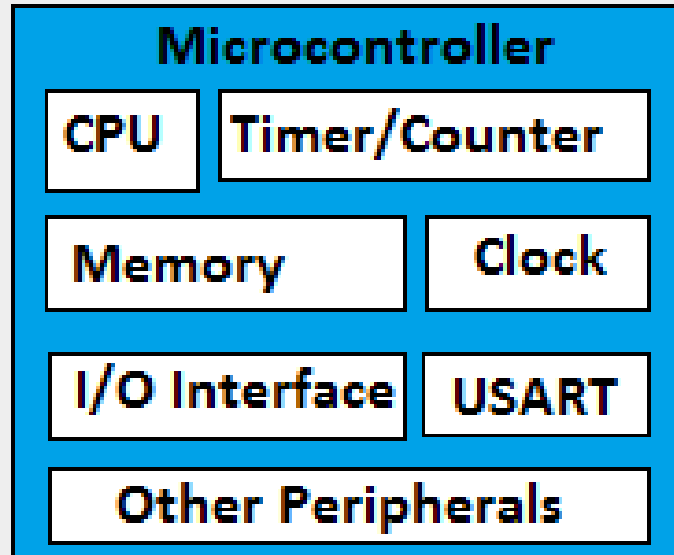
GPIOs
with Interrupts

16-ch. Touch
Sensor
Interface

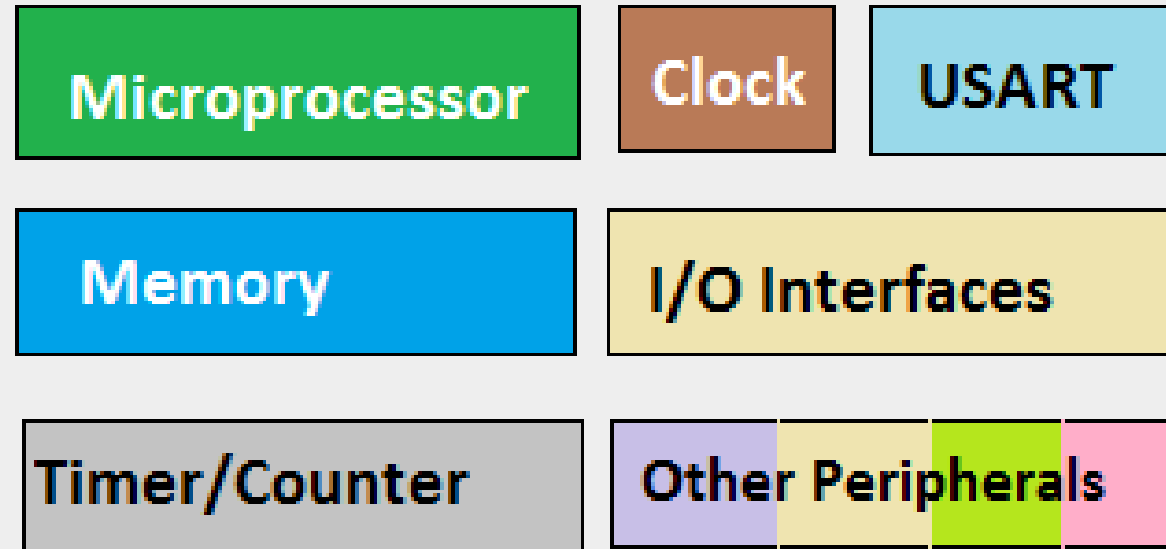
 Optional

Microcontrollers vs Microprocessors

One Chip



Many Different Chips



AVR Tutorials Diagrams
www.AVR-Tutorials.com

- SoCs blur the line between them



