TED ÜNİVERSİTESİ

CMPE361 Computer Organization

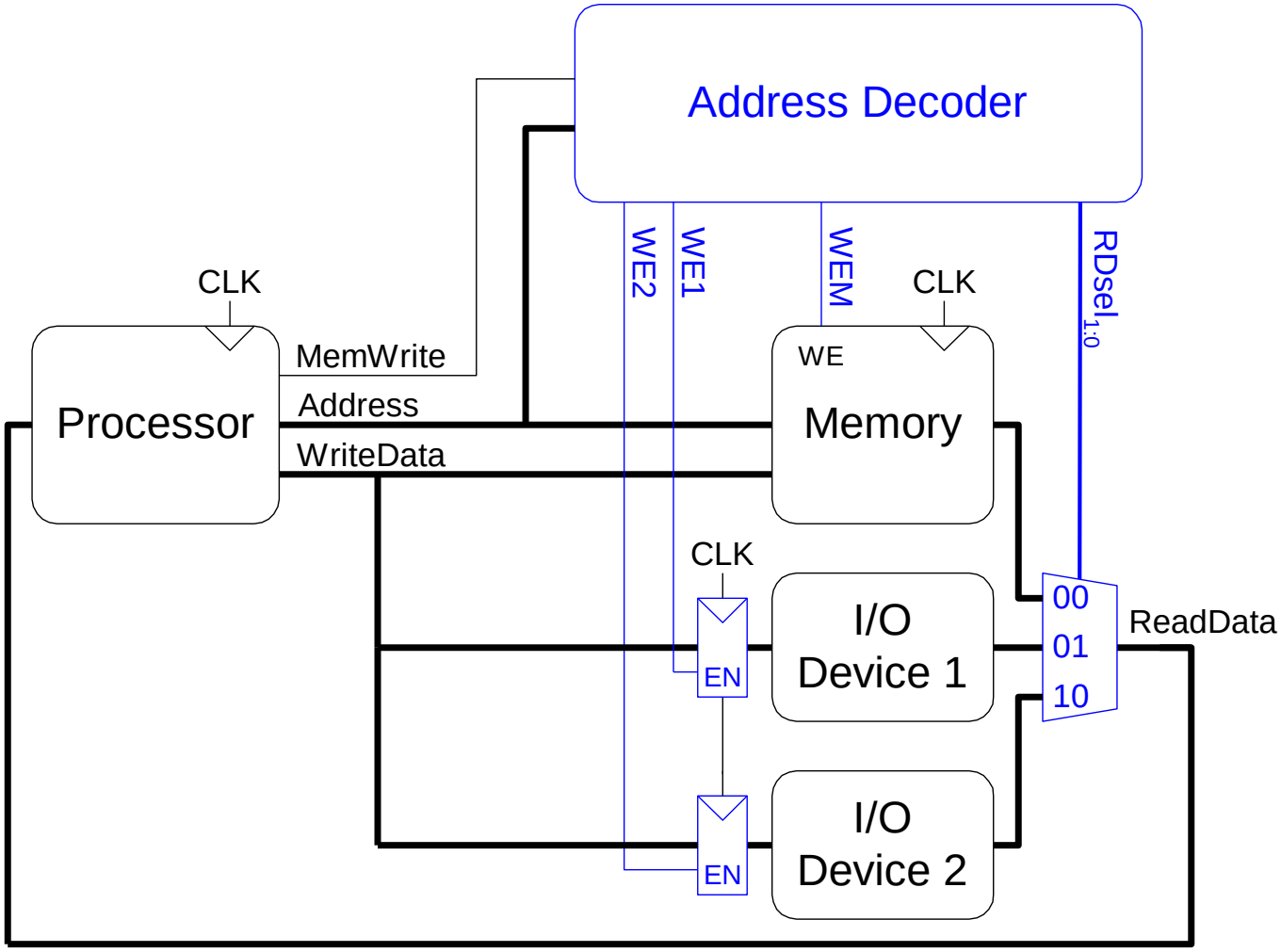
Department of Computer Engineering
TED University- Fall 2023

ELSEVIER

Input/Output (I/O) Systems

- Processor accesses I/O devices (like keyboards, monitors, printers) just like memory
- Each I/O device assigned one or more address
- When that address is detected, data read/written to I/O device instead of memory
- A portion of the address space dedicated to I/O devices

Memory-Mapped I/O Hardware



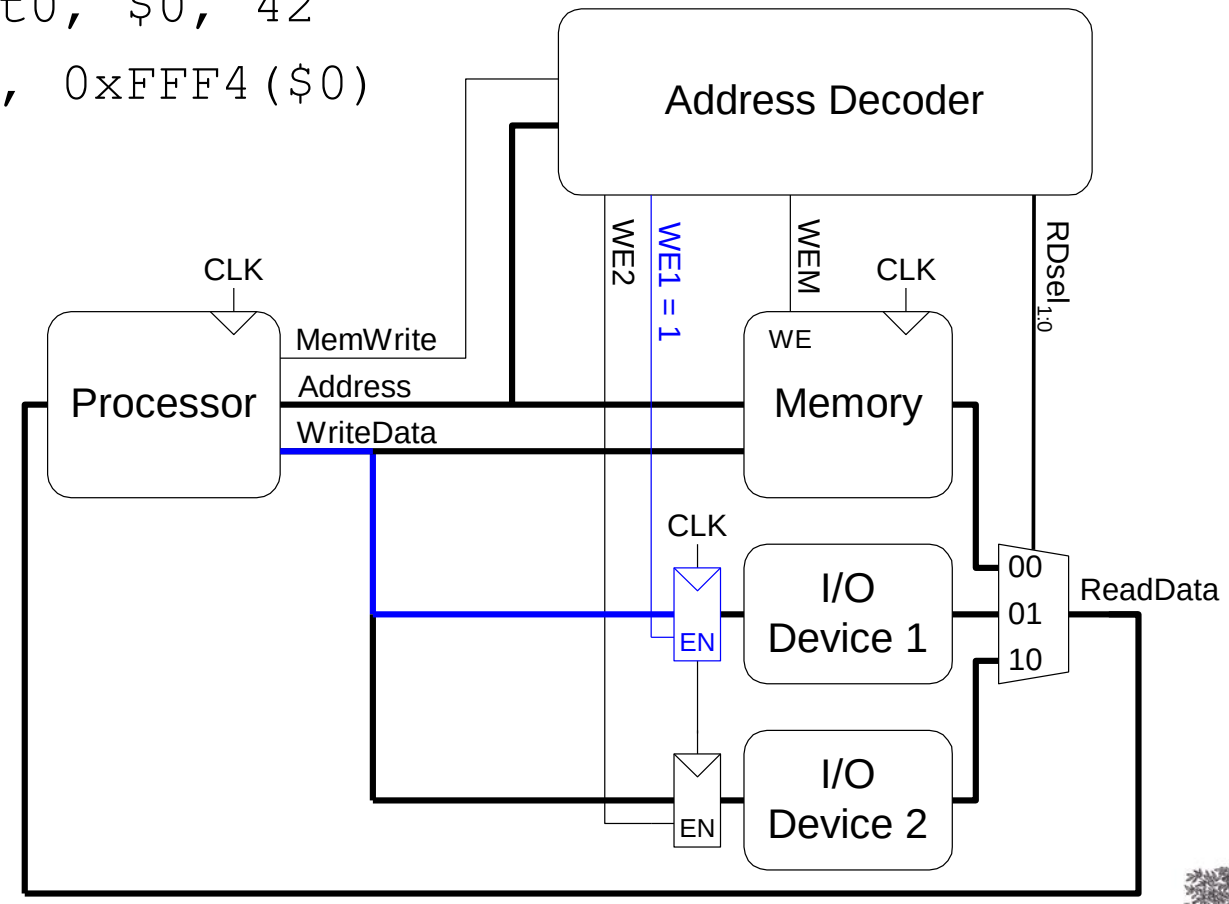
Memory-Mapped I/O Code

- Suppose I/O Device 1 is assigned the address 0xFFFFFFF4
  - **Write the value 42 to I/O Device 1**
  - **Read value from I/O Device 1 and place in `$t3`**

Memory-Mapped I/O Code

- **Write the value 42 to I/O Device 1 (0xFFFFFFF4)**

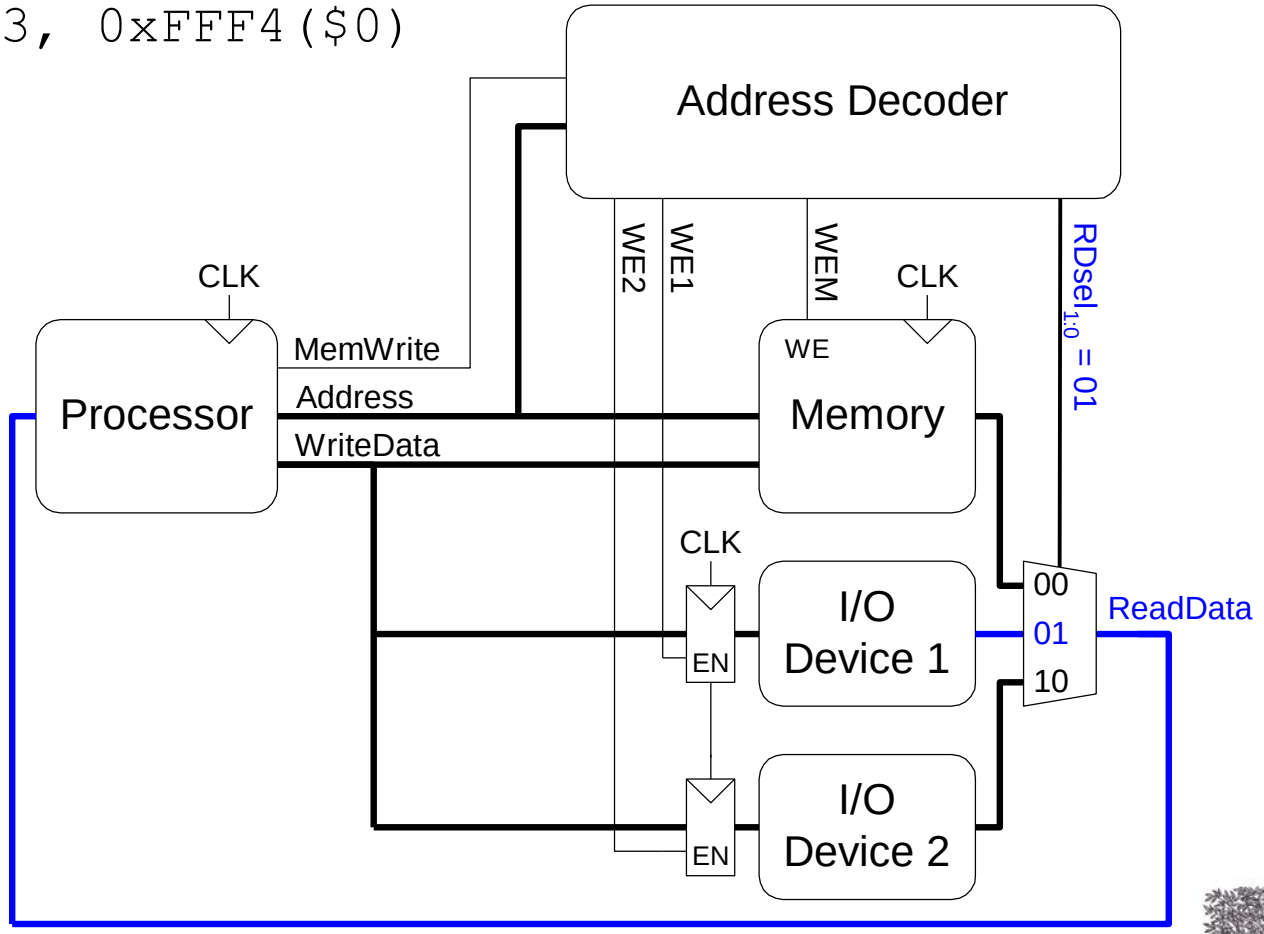
```
addi $t0, $0, 42
sw $t0, 0xFFF4($0)
```



Memory-Mapped I/O Code

- **Read the value from I/O Device 1 and place in `$t3`**

```
lw $t3, 0xFFF4($0)
```



I/O System Types

- Embedded I/O Systems
- PC I/O Systems

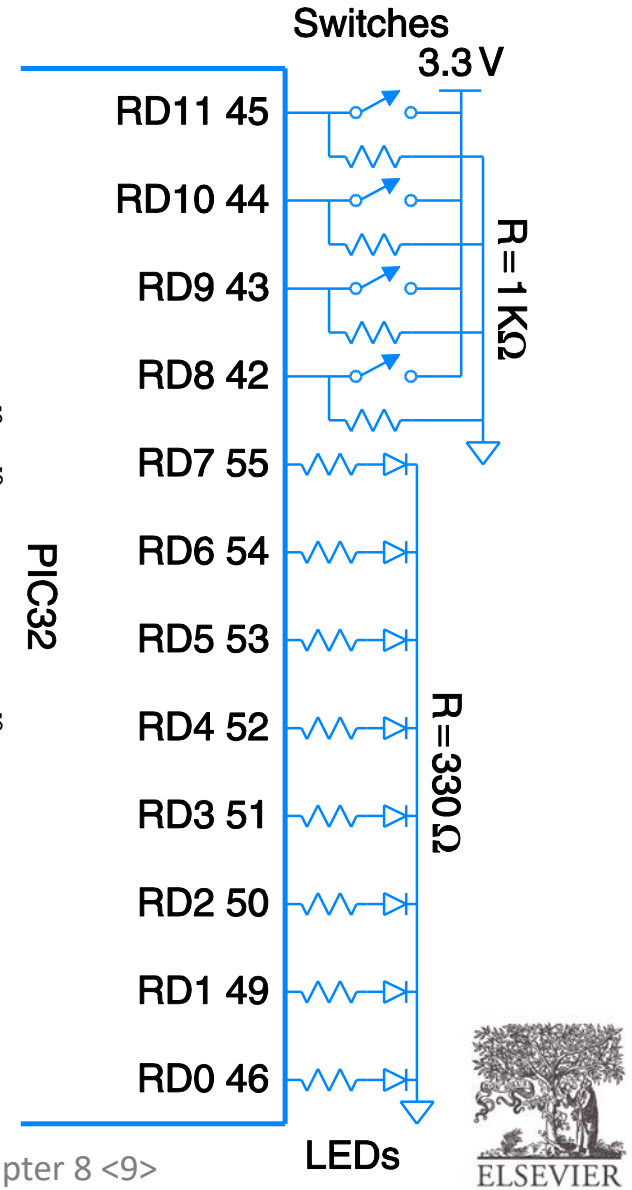
Embedded I/O Systems

- Example microcontroller: PIC32
  - microcontroller
  - 32-bit MIPS processor
  - low-level peripherals include:
    - serial ports
    - timers
    - A/D converters

Digital I/O

```
// C Code
#include <p3xxxx.h>

int main(void) {
  int switches;
  TRISD = 0xFF00;        // RD[7:0] outputs
                         // RD[11:8] inputs
  while (1) {
    // read & mask switches, RD[11:8]
    switches = (PORTD >> 8) & 0xF;
    PORTD = switches;  // display on LEDs
  }
}
```

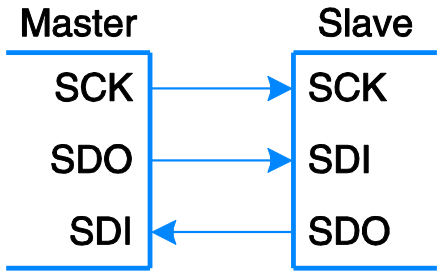


Serial I/O

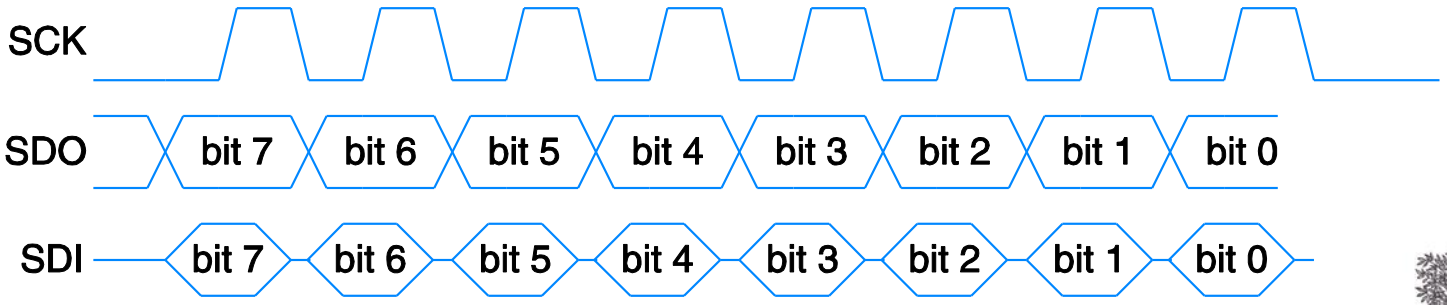
- Example serial protocols
  - **SPI:** Serial Peripheral Interface
  - **UART:** Universal Asynchronous Receiver/Transmitter
  - Also: USB, Ethernet, etc.

SPI: Serial Peripheral Interface

- Master initiates communication to slave by sending pulses on SCK
- Master sends SDO (Serial Data Out) to slave, msb first
- Slave may send data (SDI) to master, msb first



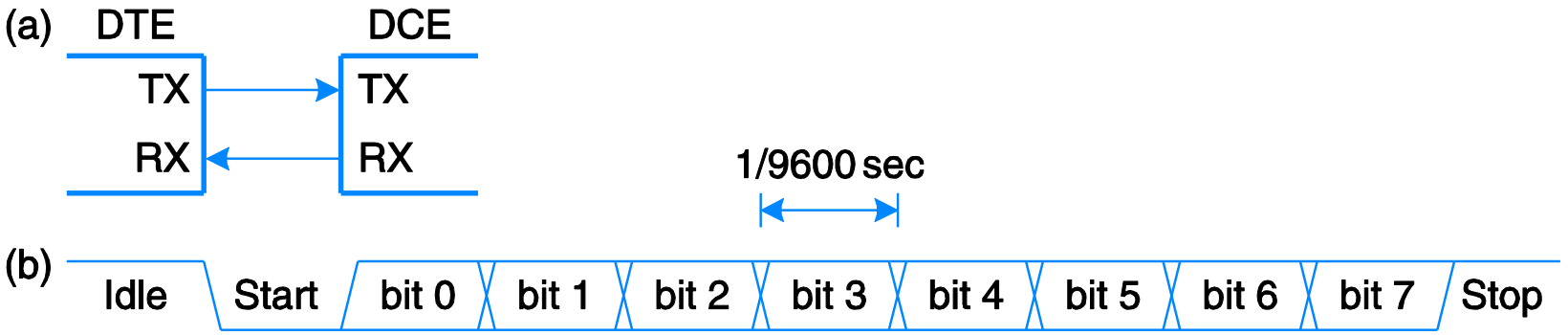
(a)



(b)

UART: Universal Asynchronous Rx/Tx

- Common configuration:



Analog I/O

- Needed to interface with outside world
- **Analog input:** Analog-to-digital (A/D) conversion
- **Analog output:**
  - Digital-to-analog (D/A) conversion