Embedded Applications

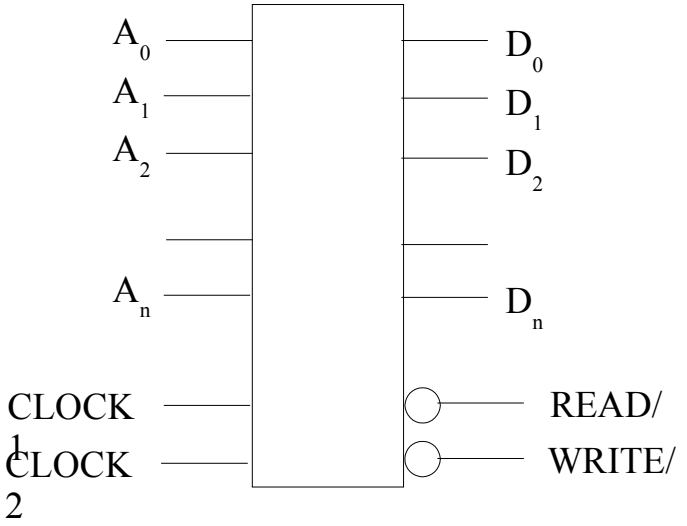
COMP595EA
Lecture03
Hardware Architecture

Microcontroller vs Microprocessor

- Microprocessor is a term used to describe all programmed computational devices.
- Microcontroller is a term often used to describe the subset of microprocessor that generally have the following characteristics:
    - Small
    - Slow
    - contains built-in RAM or ROM
    - Limited or no capability for external RAM/ROM
    - A collection of general purpose I/O signal pins

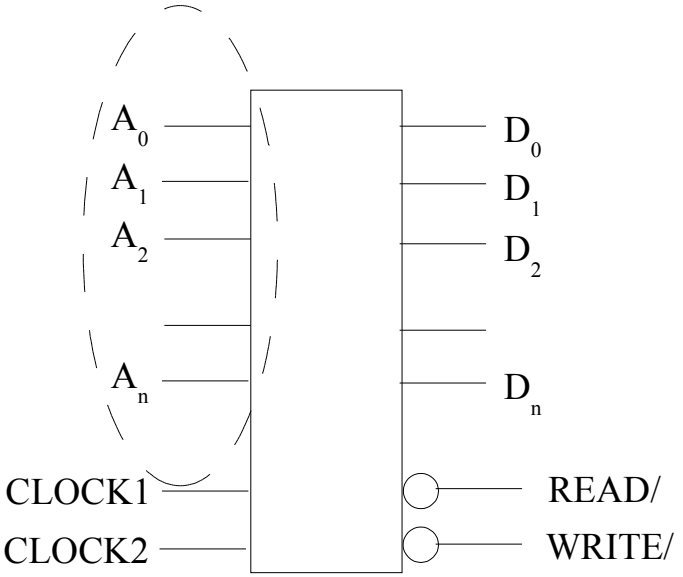
Microprocessor

- A simplified microprocessor
  - Address lines
  - Data lines
  - Read/Write control signals
  - clock inputs



Address Lines

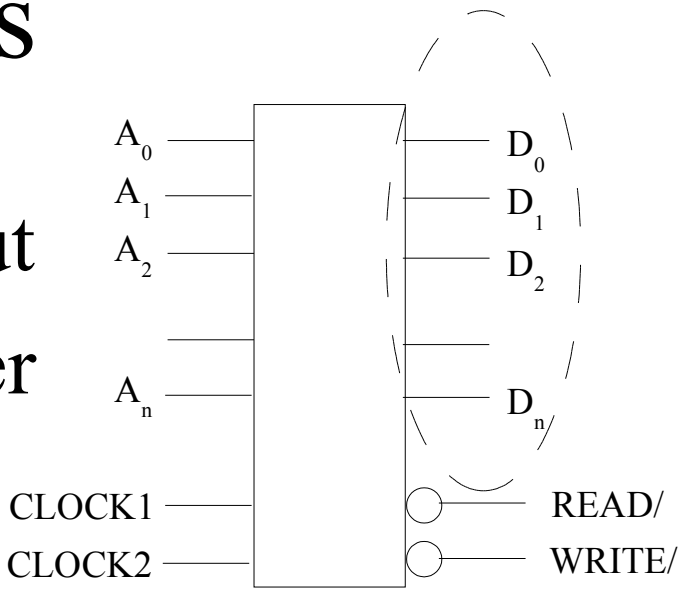
- A_0 through A_n are output signals used to specify desired address locations to other components of the overall circuit.



- Normally the address values are set by the Instruction pointer or as the result of some instruction attempting to fetch required data.

Data Lines

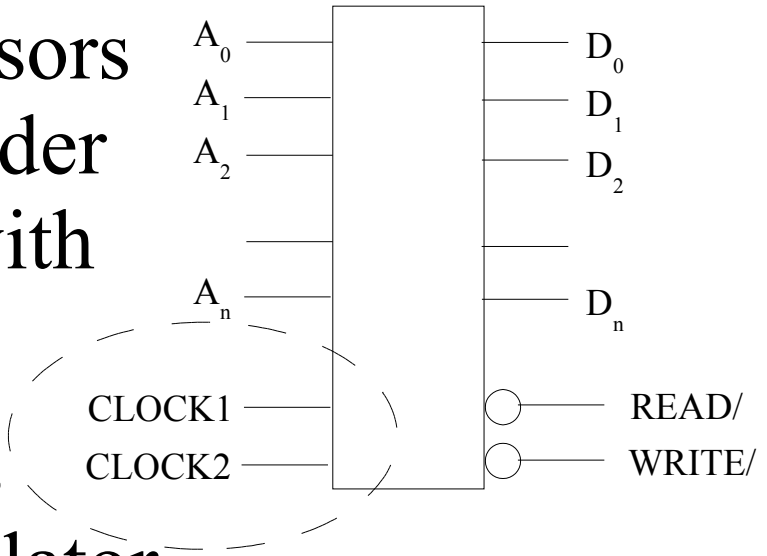
- D_0 through D_n are input/Output signals that come from/to other components (typically RAM or ROM chips) of the circuit.



- If the operation is a read from an address then the data signals are set by other components in response to the address line settings
- If the operation is a write then the microprocessor sets the data lines to the value it wants stored at the address.

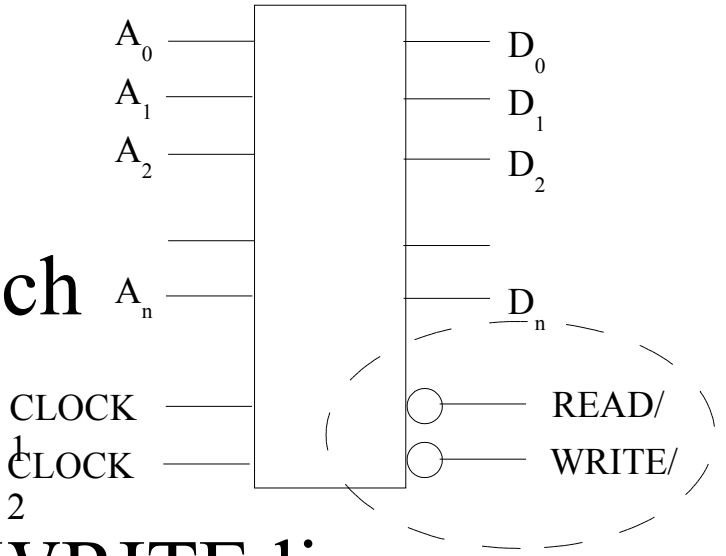
Clock inputs

- All Classical microprocessors require a clock input in order to synchronize and deal with gate and circuit delays
- Most will have two inputs to allow for a crystal oscillator circuit to be used instead of a more expensive clock generator.



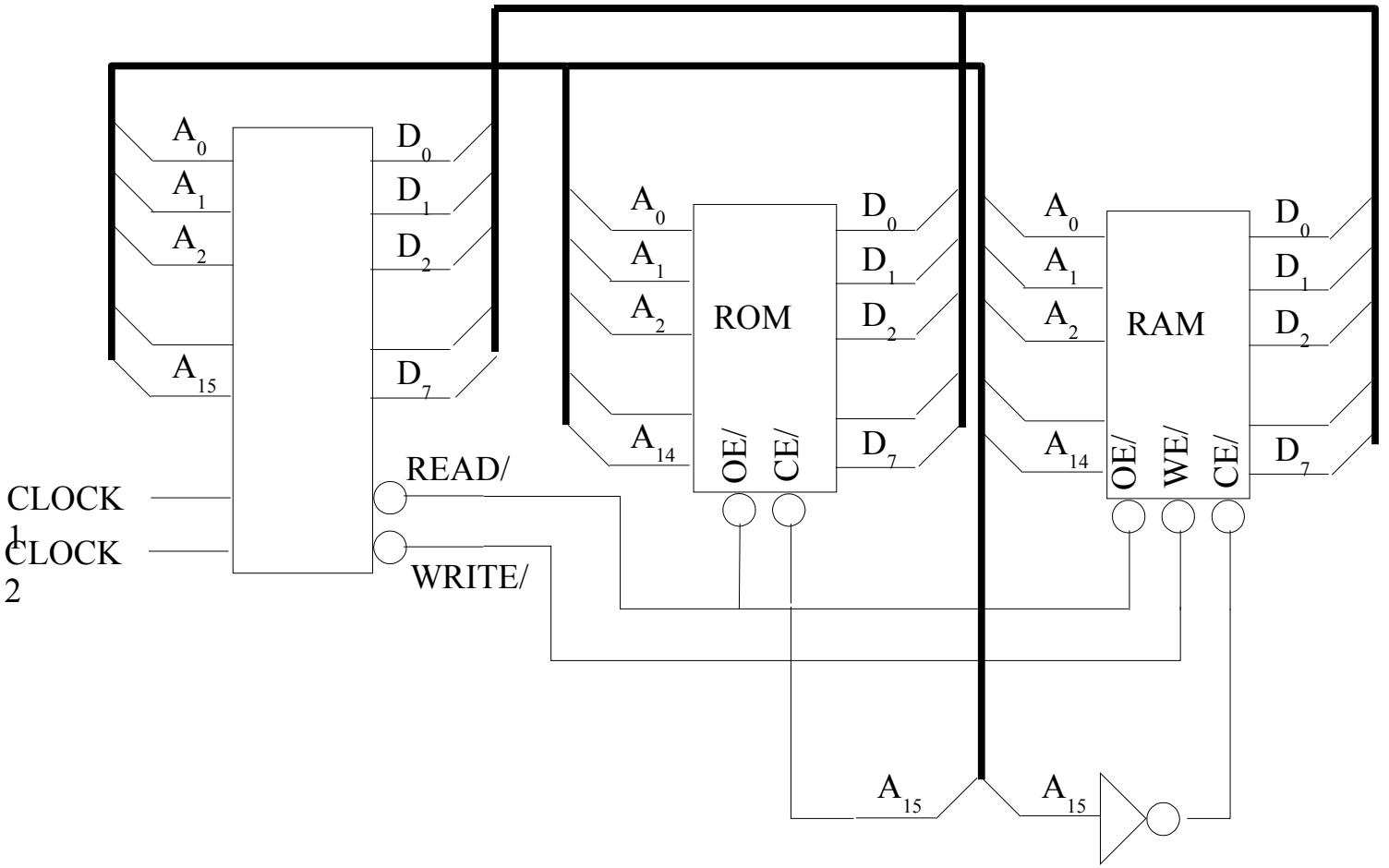
Read/Write Lines

- RAM can either be read or written to. To allow the microprocessor to select which operation to perform it is connected to the other components via READ and WRITE lines.



- These lines are output lines which are usually asserted low (thus the inverting bubble depicted on those lines).

Basic Microprocessor System



More than just memory

- Hardware devices other than memory can be connected in this manner.
- Sensor devices or other chips can be attached to the address/data busses as long as they are addressed at a different location than the memory.
  - If the microprocessor can address 1Megabyte, and
  - ROM and RAM take up the first 64Kbytes.
  - Then other devices can be allocated above this.
- Such devices are called “memory mapped”

Memory Mapping

- Very easy to use such devices.
- Good for polled devices. (eg. temp. sensors)
  - Can update asynchronously
- Can be very wasteful of memory space

I/O address space

- As an alternative to memory address space:
  - I/O address space
- requires support in the instruction set and additional hardware pins.
  - MOVE might de-assert the I/O address pin and access a memory location.
  - IN and OUT conversely would assert the I/O address pin and perform the data transfer.
- Still requires glue logic to control OE/ for all devices.

Bus Handshaking

- Rom and RAM devices are built using gates or other technology that introduces delays.
- Address and data lines must remain stable for a certain period and the read/write enable lines must be asserted for a minimum period of time.
- Microprocessor controls ll of these
- The proper sequence of timings is called a “Bus Cycle”

No Handshake

- Simplest method
  - Hardware engineer selects parts that are all “fast enough” (Or picks a slow enough microprocessor)
  - speed = $$$$

Wait signals

- Some microprocessors provide a wait signal input.
- Any device that wants the microprocessor to extend the bus cycle simply asserts the wait signal.
- No matching output is provided on RAM or ROM chips.
  - Hardware engineer has to design the proper logic to assert the signal.
  - time to design = $$$$

Wait States

- Some microprocessors provide for software controlled wait states to be inserted to bus cycles.
- These are effectively no-op instructions that just take up some time and cause the microprocessor to wait during a memory transaction.
- Some allow for variable wait states tailored to particular address ranges
  - RAM is faster than ROM which is faster than I/O devices. typically.

Wait States (Cont.)

- Be knowledgeable about your microprocessor!
  - They may start with all wait state tables or information defaulting to the maximum number of wait states.
  - If your hardware design buddy selected fast components or if clock cycles are precious then you need to know enough to insert the proper code just after startup to turn down the wait states.
- Too few wait states can cause unstable/unreliable systems (overclocking)

Direct Memory Access (DMA)

- In more complicated systems it is desirable to have I/O devices or devices other than the Microprocessor place data into RAM
- DMA is a system that some microprocessors support that allow other devices to request the address/data bus.
  - (They're always connected to these busses; they're just asking for control)
  - Dual ported memory can also provide similar functionality.

Interrupts

- Most microprocessors will allow interrupts
  - Provide for asynchronous interfacing with the real world.
    - When will the pressure rise?
    - Will the temperature get too high before the pressure; or vice versa?
    - Who knows?... asynchronous
  - Do you want to continuously poll devices or would you just rather be notified when something needs attention? Intuitively we perform the latter.

Interrupts

- Usually several are provided.
  - You may have heard of IRQ lines in your PC
    - Early PCs limited to 8 IRQ because the microprocessor had 8 interrupt pins.
    - Later moved to 16
    - Now being replaced by more scalable architectures such as APIC controllers.
  - Normally Open-Collector and asserted low.
- Software interrupts or timers are also available and very useful on many microprocessors (eg. Watchdog timers)

Other Devices / Features

- UART: serial port commonly available on most microprocessors (especially microcontrollers)
  - Often requires additional circuitry to match voltage levels.
  - Can be useful for communicating between devices
- PAL: Programming Array Logic
  - Little bits of glue circuitry are common. To invert signals, to select and enable chips...
  - PALs are programmable bits of glue. you can make them into just about any little collection of gates.

More Support Devices

- Application-Specific Integrated Circuits (ASICs)
  - Generally provide very complex processing in a very module fashion.
    - You want to decode a Dolby Digital 5.1 surround stream.
    - You could do it with a microprocessor but it's much more cost effective to buy the off the shelf module for it and hook it up in conjunction with a controller.
    - COTS: Commercially Available Off The Shelf

Watchdog Timers

- To improve reliability it is very useful to have a support circuit that helps detect when your microprocessor has stopped doing its job.
  - Microprocessor periodically and regularly asserts some RESET/ signal attached to a watchdog circuit.
  - watchdog circuit timer resets to some number upon a reset.
  - counts down every clock cycle.
  - watchdog asserts some restart signal to the microprocessor when timer reaches zero.

Fighting the good fight...

- Copies of software are free; copies of hardware eat up profits. Every additional part added to a design costs money. Revisions or addition of code are free.
- Every part takes up space. space is precious.
- Every part uses up a little power.
- Every part produces a little heat.
- Faster circuits cost more, use more power and generate more heat.

- Clever and competent software programmers are therefore valuable.