Processors

- Execute programs
  - Serial execution of instructions
  - Simple, Universal
- Instruction execution engine: fetch/execute cycle
  - flow of control determined by modifications to program counter
  - instruction classes:
    - data: move, arithmetic and logical operations
    - control: branch, loop, subroutine call
    - interface: load, store from external memory
- Traditional architecture goal: Performance
  - Caches
  - Branch prediction
  - Multiple/OOO issue

Embedded Processors

- Processor is a Universal computing engine
  - Program can compute arbitrary functions
  - Use a processor for simple/specific tasks
- Advantages:
  - High-level language
  - Compilers/Debuggers
  - arbitrary control structures
  - arbitrary data structures
- Disadvantages:
  - Cost/Size

Embedded Processor (Microcontroller)

- Processor optimized for low cost
  - No cache
  - Small memory
  - No disks
  - 4 bit/8 bit/16 bit
  - No FP
  - No complicated datapath
  - Multicycle instruction interpretation
  - Simple/no operating system
  - Programs are static
- Low performance
  - 1 MIPS is enough if 1 ms is the time scale
- Integrate on a single chip

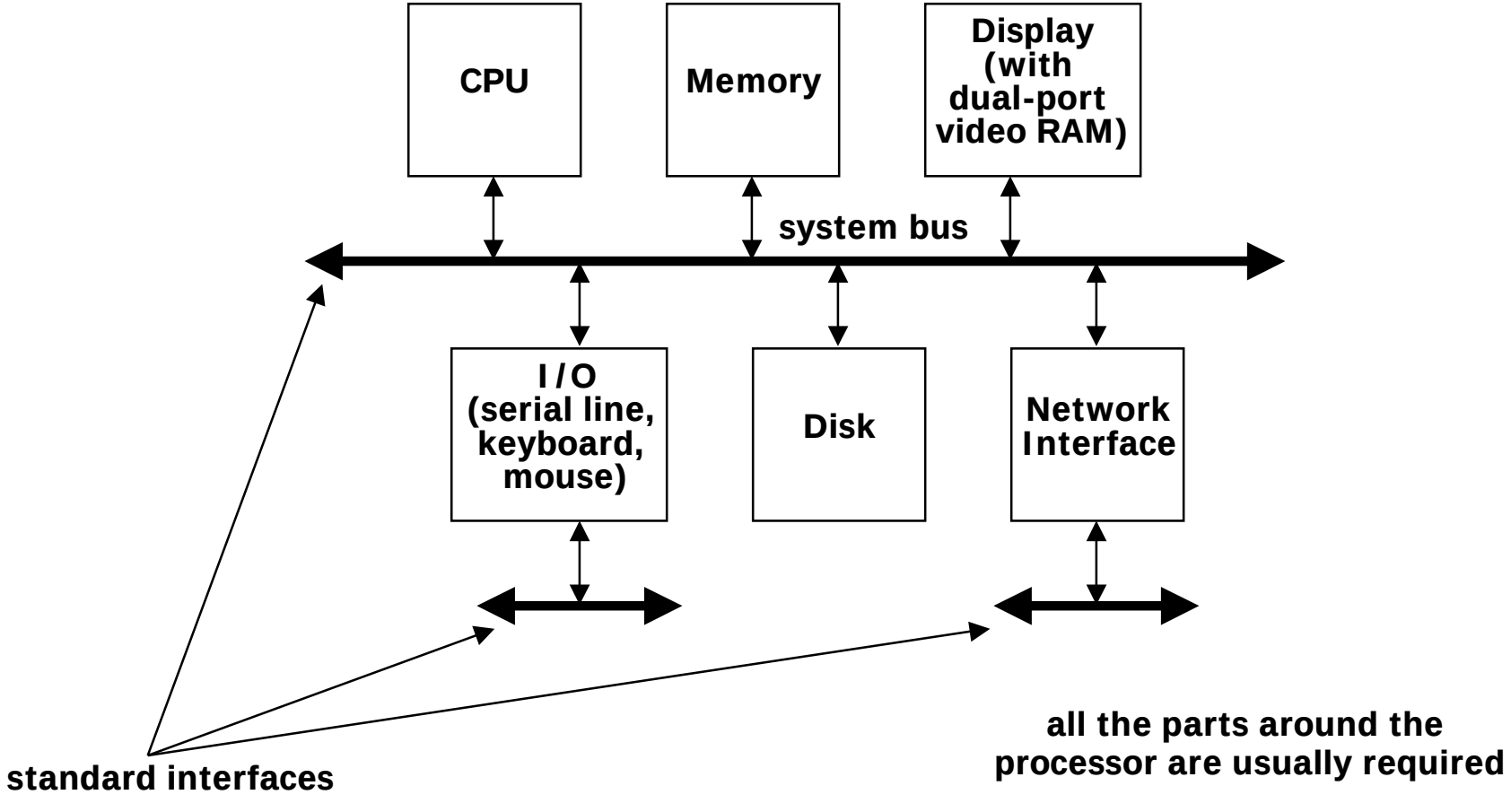
General-purpose processor

- Programmed by user
- New applications are developed routinely
- General-purpose
  - must handle a wide ranging variety of applications
- Interacts with environment through memory
  - all devices communicate through memory
  - DMA operations between disk and I/O devices
  - dual-ported memory (as for display screen)
  - oblivious to passage of time (takes all the time it needs)

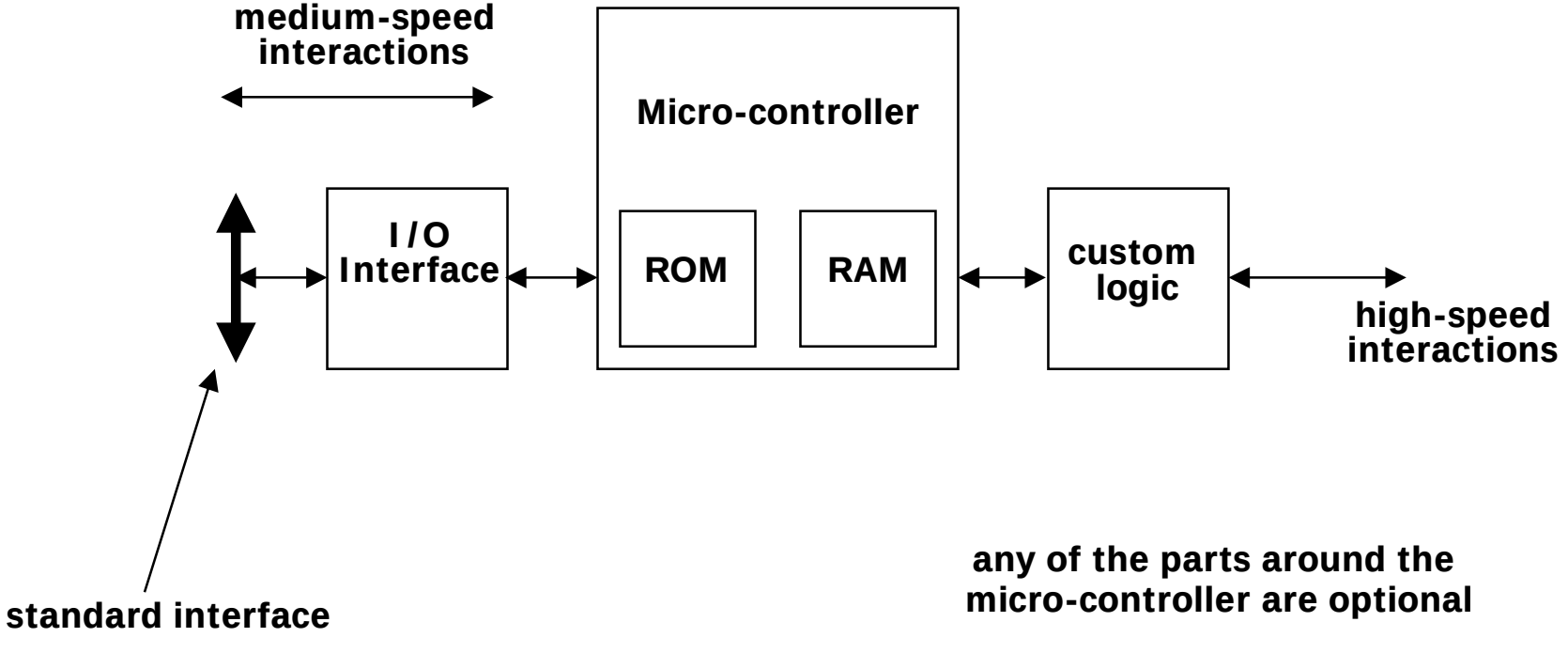
Embedded processors

- Programmed once by manufacturer of system
- Executes a single program (or a limited suite) with few parameters
- Task-specific
  - can be optimized for specific application
- Interacts with environment in many ways
  - direct sensing and control of signal wires
  - communication protocols to environment and other devices
  - real-time interactions and constraints

Typical general-purpose architecture



Typical task-specific architecture



How does this change things?

- Sense and control of environment
  - processor must be able to “read” and “write” individual signal wires
  - controls I/O devices directly
- Program has to do everything
  - sense input bits
  - change output bits
  - do computation
  - measure time
    - many applications require precise spacing of events
- Problems with this
  - Precise timing?
  - Too slow?

Connecting to inputs/outputs

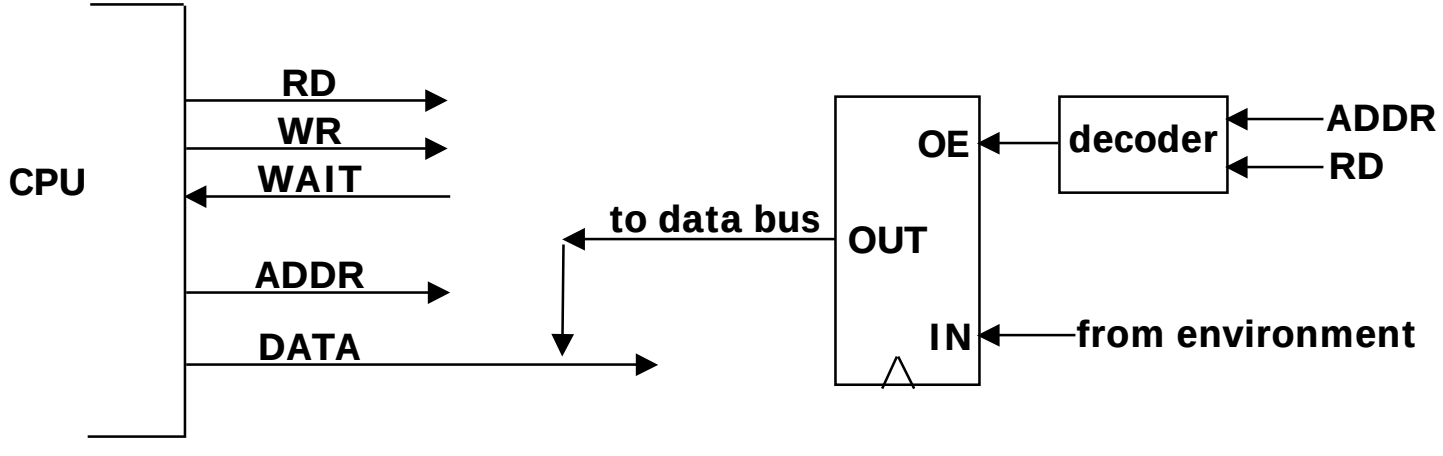
- Map external wire to a bit of a variable (memory or register)
  - if (a & 1) . . .
  - X = 2;

Example Problem: Accelerometer Interface

- Accelerometer output has one wire!
  - Acceleration coded as the duty cycle
    - pulse-width/cycle-length
      - 20% = -128
      - 80% = +127
    - cycle time = 10ms
- Write a C program that measures the acceleration
  - Input is low-order bit of variable X
  - Assign result to variable Z
  - Make up whatever you need

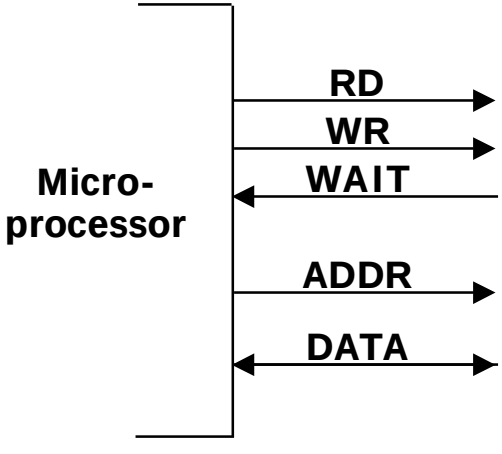
Memory-mapped inputs

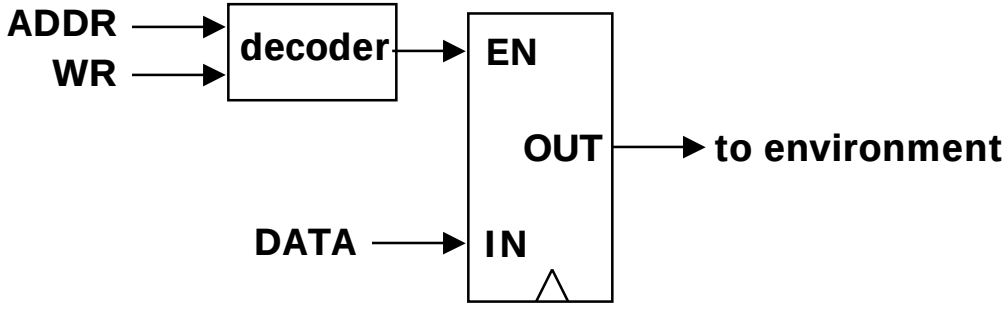
- Map external wire to a bit in the address space of the processor
- External register buffers values coming from environment
  - map register into address space
  - decoder needed to select register for reading
  - output enable (OE) so that many registers can use the same data bus



Memory-mapped outputs

- Map external wire to a bit in the address space of the processor
- Connect output of memory-mapped register to environment
  - map register into address space
  - decoder need to select register for writing (holds value indefinitely)
  - input enable (EN) so that many registers can use the same data bus





On-chip support for communication

- Processor may not be fast enough
- Offload standard protocols
- Built-in device drivers
  - for common communication protocols
  - serial-line protocols most common as they require few pins
- e.g. RS-232 serial interface
  - special registers in memory space for interaction
- Increases level of integration
  - pull external devices on-chip
    - must be standard
  - eliminate need for shared memory or system bus

Measuring Time

- Keep track of detailed timing of each instruction's execution
  - highly dependent on code
  - hard to use with compilers
  - not enough control over code generation
  - interactions with caches/instruction-buffers
- Loops to implement delays
  - keep track of time in counters
  - keeps processor busy counting and not doing other useful things
- Real-time clock
  - sample at different points in the program
  - simple difference to measure time delay

Timers

- Separate and parallel counting unit(s)
  - co-processor to microprocessor
  - does not require microprocessor intervention
  - in simple case, like a real-time clock
    - set timer/read timer
  - interrupt generated when expired
- More interesting timer units
  - self reloading timers for regular interrupts
  - pre-scaling for measuring larger times
  - started by external events

Input/output events

- Input capture
  - record precise time when input event occurred
  - to be used in later handling of event
- Output compare
  - set output to happen at a point in the future
  - reactive outputs – set output to happen a pre-defined time after some input
  - processor can go on to do other things in the meantime

Example Microcontroller: 8051

- Very old, very common and very cheap microcontroller
  - Lots of variants
- Review online documentation
  - learn how to read documentation
- Instruction set
  - instruction capabilities
  - timing
- Special registers and integrated I/O devices
  - I/O ports
  - serial interface
- Interrupt organization
- Memory space and its allocation
- Timers

Why the 8051?

- We have a synthesizable core that works
- We have a good compiler/debugger
  - very common microcontroller with simple instruction set
  - lots of features
  - lots of alternatives
  - lots of support and resources
  - good tools available: we will use the Keil software
    - Assembler
    - C compiler
    - Debugger
  - we will use the C compiler mostly
    - requires a good understanding of the 8051 architecture