Microprocessors

Questions?

- Project 6: still need demos
- Project 7: due Thursday

Quiz

Components of a Microprocessor

- Memory:
  - Storage of data
  - Storage of a program
  - Either can be temporary or “permanent” storage
- Registers: small, fast memories
  - General purpose: store arbitrary data
  - Special purpose: used to control the processor

Components of a Microprocessor

- Instruction decoder:
  - Translates current program instruction into a set of control signals
- Arithmetic logical unit:
  - Performs both arithmetic and logical operations on data: add, subtract, multiply, AND, OR …
- Input/output control modules

Components of a Microprocessor

- Many of these components must exchange data with one-another
- It is common to use a ‘bus’ for this exchange

Collections of Bits

- 8 bits: a “byte”
- 4 bits: a “nybble”

- “words”: can be 8, 16, or 32 bits (depending on the processor)

Collections of Bits

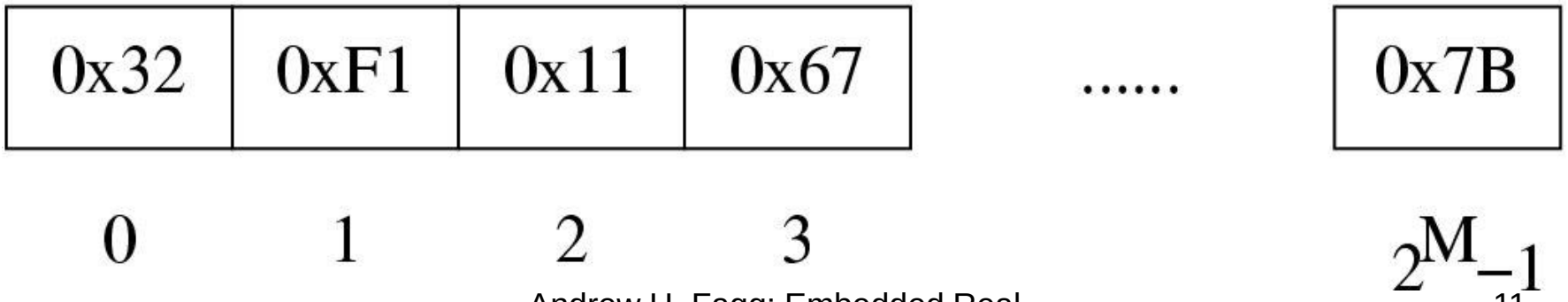
- A data bus typically captures a set of bits simultaneously
- Need one wire for each of these bits
- In the Atmel Mega2560: the data bus is 8-bits “wide”
- In your laptops: 32 or 64 bits

Memory

What are the essential components of a memory?

A Memory Abstraction

- We think of memory as an array of elements – each with its own address
- Each element contains a value
  - It is most common for the values to be 8-bits wide (so a byte)



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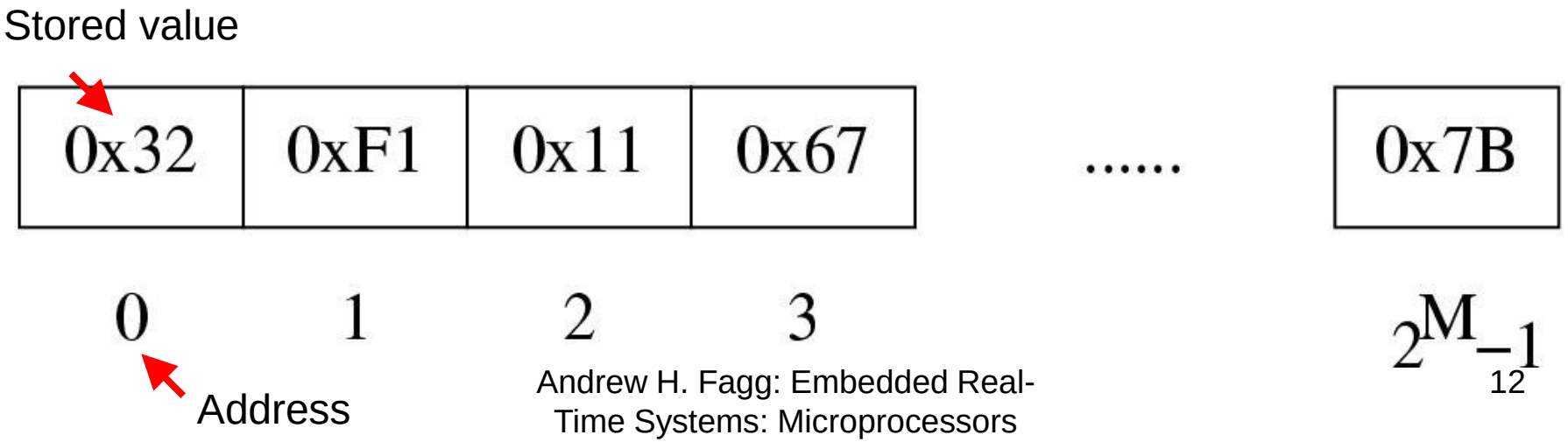

Memory Operations

Read

```
foo(A+5);
```

reads the value from the memory location referenced by the variable ‘A’ and adds the value to 5. The result is passed to a function called `foo();`

Memory Operations

Write

```
A = 5;
```

writes the value 5 into the memory location referenced by ‘A’

Types of Memory

Many types of memory exist, including:

- Random access memory (RAM)
- Read-only memory (ROM)
  - Erasable/Programmable ROM (EPROM)
  - Electrically Erasable/Programmable ROM (EEPROM) (of FLASH memory)

Buses

- In the simplest form, a bus is a single wire
- Many different components can be attached to the bus
- Any component can take input from the bus or place information on the bus

Buses

- At most one component may write to the bus at any one time
- In a microprocessor, which component is allowed to write is usually determined by the code that is currently executing

Connecting Assembly Language to C

- Our C compiler is responsible for translating our code into Assembly Language
- Today, we rarely program in Assembly Language
  - Embedded systems are a common exception
  - Also: it is useful in some cases to view the assembly code generated by the compiler

An Example

A C code snippet:

```
if(B < A) {
    D += A;
}
```

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```

The Assembly :

```
LDS R1 (A)
LDS R2 (B)
CP R2, R1
BRGE 3
LDS R3 (D)
ADD R3, R1
STS (D), R3
……..
```

An Example

A C code snippet:

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if(B < A) {
    D += A;
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The Assembly :

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LDS R1 (A)
LDS R2 (B)
CP R2, R1
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ADD R3, R1
STS (D), R3
……..
```

PC

Load the contents of memory location A into register 1

An Example

A C code snippet:

```
if(B < A) {
    D += A;
}
```

The Assembly :

```
LDS R1 (A)
LDS R2 (B)
CP R2, R1
BRGE 3
LDS R3 (D)
ADD R3, R1
STS (D), R3
……..
```

PC

Load the contents of memory location B into register 2

An Example

A C code snippet:

```
if(B < A) {
    D += A;
}
```

The Assembly :

```
LDS R1 (A)
LDS R2 (B)
CP R2, R1
BRGE 3
LDS R3 (D)
ADD R3, R1
STS (D), R3
……..
```

PC

Compare the contents of register 2 with those of register 1

This results in a change to the status register

An Example

A C code snippet:

```
if(B < A) {
    D += A;
}
```

The Assembly :

```
LDS R1 (A)
LDS R2 (B)
CP R2, R1
BRGE 3
LDS R3 (D)
ADD R3, R1
STS (D), R3
……..
```

PC

Branch If Greater Than or Equal To:
jump ahead 3 instructions if true

An Example

A C code snippet:

```
if(B < A) {
    D += A;
}
```

The Assembly :

```
LDS R1 (A)
LDS R2 (B)
CP R2, R1
BRGE 3
LDS R3 (D)
ADD R3, R1
STS (D), R3
……..
```

if true

PC

Branch if greater than or equal to will jump ahead 3 instructions if true

An Example

A C code snippet:

```
if(B < A) {
    D += A;
}
```

Not true: execute the next instruction

The Assembly :

```
LDS R1 (A)
LDS R2 (B)
CP R2, R1
BRGE 3
LDS R3 (D)
ADD R3, R1
STS (D), R3
……..
```

if not true

PC

An Example

A C code snippet:

```
if(B < A) {
    D += A;
}
```

The Assembly :

```
LDS R1 (A)
LDS R2 (B)
CP R2, R1
BRGE 3
LDS R3 (D)
ADD R3, R1
STS (D), R3
……..
```

PC

Load the contents of memory location D into register 3

An Example

A C code snippet:

```
if(B < A) {
    D += A;
}
```

The Assembly :

```
LDS R1 (A)
LDS R2 (B)
CP R2, R1
BRGE 3
LDS R3 (D)
ADD R3, R1
STS (D), R3
……..
```

PC

Add the values in registers 1 and 3 and store the result in register 3

An Example

A C code snippet:

```
if(B < A) {
    D += A;
}
```

Store the value in register 3 back to memory location D

The Assembly :

```
LDS R1 (A)
LDS R2 (B)
CP R2, R1
BRGE 3
LDS R3 (D)
ADD R3, R1
STS (D), R3
.....
```

PC

Take-Aways

Instructions are the “atomic” actions that are taken by the processor

- Many different component work together to execute a single instruction
- One line of C code typically translates into a sequence of several instructions
- In the mega 2560, most instructions are executed in a single clock cycle

The high-level view is important here: you won’t be compiling programs on exams