Microprocessors

Components of a Microprocessor

What are the key components of (and/or around) a microprocessor?

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: temporarily store arbitrary data
  - Special purpose: used to control the processor

Memory

What is the fundamental unit of memory?

Memory

What is the fundamental unit of memory?

- The bit!

Collections of Bits

Individual bits are inconvenient to write/interpret

- At minimum, we collect bits into groups of 8 bits (a byte)
  - Common for this to be the standard unit of memory in small microcontrollers
  - This means that all operations involve the simultaneous communication/processing of the 8 bits
- For older laptops/desktops, and our Teensy 3.5 microcontrollers, the unit is 4 bytes
  - Common term for this unit: 1 “word”

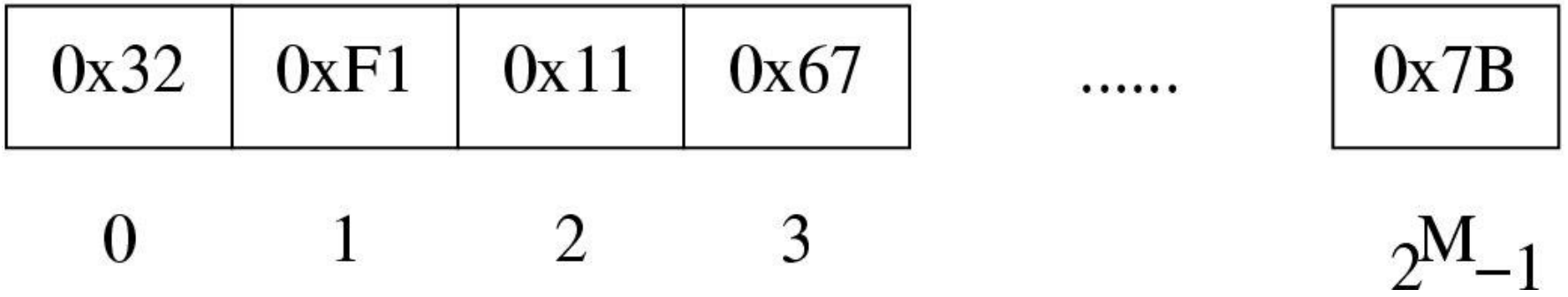
Binary vs Decimal vs Hexadecimal

Memory

What are the essential components of a memory?

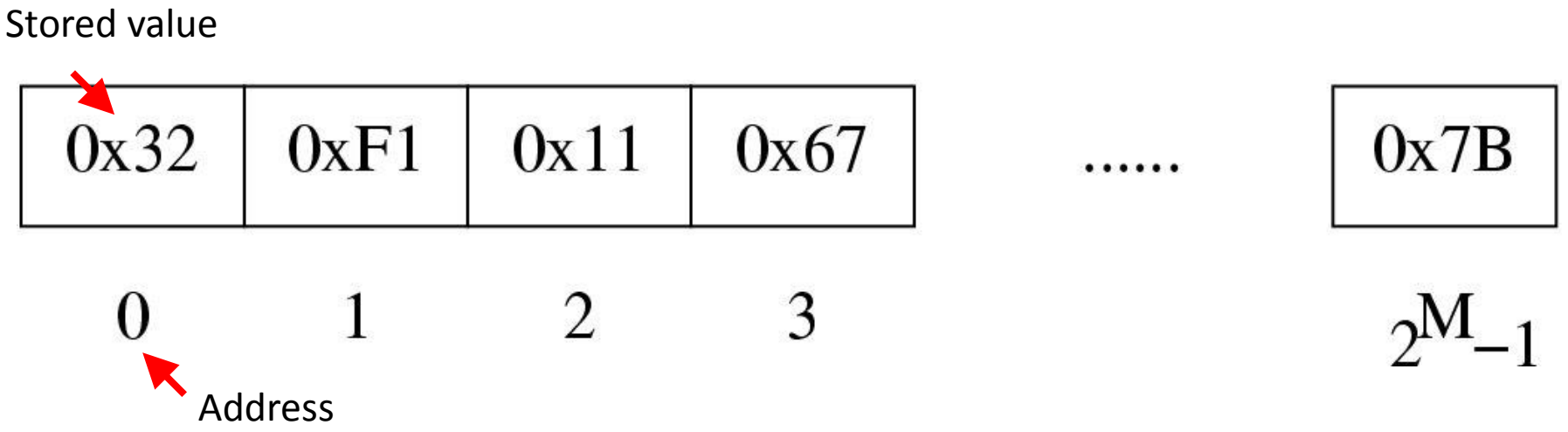
A Memory Abstraction

- We think of memory as an array of bytes – each with its own address
- Each element contains a value



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)



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

Random Access Memory (RAM)

- Computer can change state of this memory at any time
- Once power is lost, we lose the contents of the memory

- This will be our data storage on our microcontrollers

Types of Memory

Read Only Memory (ROM)

- Computer **cannot** arbitrarily change state of this memory
- When power is lost, the contents are maintained

Types of Memory

Erasable/Programmable ROM (EPROM)

- State can be changed under very specific conditions (usually not when connected to a computer)

- Our microcontrollers have an Electrically Erasable/Programmable ROM (EEPROM) for program storage
  - Also called *Flash Memory*

Back to: Components of a Microprocessor

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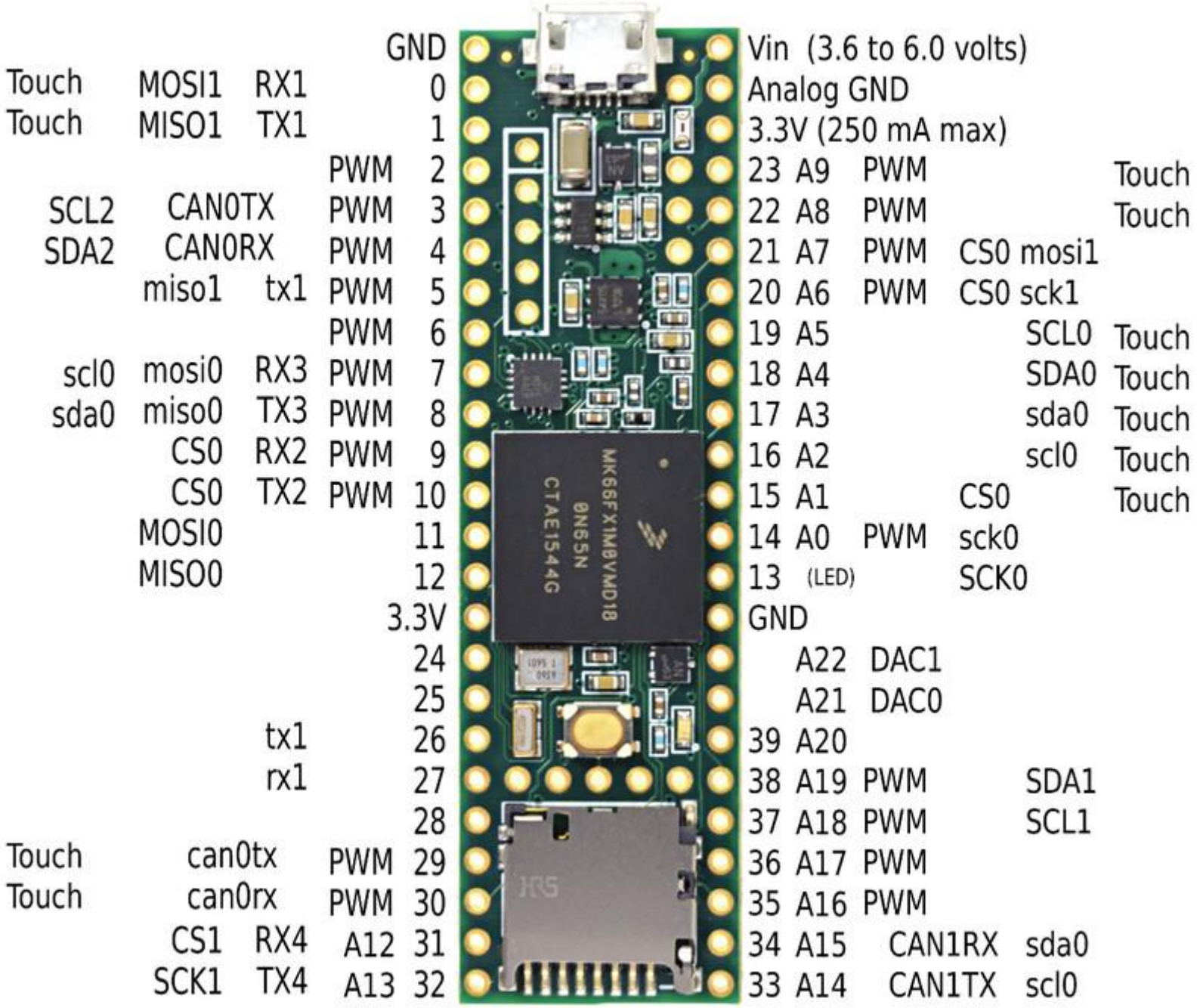
Typical architecture now: all of these memories are addressed in the same way

Components of a Microprocessor

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

Teensy 3.5

- Arm Cortex M4 microprocessor
  - 120 MHz clock
  - Can execute up to one instruction per clock cycle
- USB (both client and server)
- SDcard interface
- On-board LED
- Many I/O pins



Teensy 3.5

- Floating Point Unit (FPU): high-speed math
- Serial I/O: RS232, I2C, SPI, CAN, Ethernet
- Digital I/O
- Pulse Width Modulation (PWM)
- Multiple timers
- Digital-to-analog converter channels (2)
- Analog-to-digital converter channels (25)