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”
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

<table>
<thead>
<tr>
<th>0x32</th>
<th>0xF1</th>
<th>0x11</th>
<th>0x67</th>
<th>......</th>
<th>0x7B</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>......</td>
<td>2^{M-1}</td>
</tr>
</tbody>
</table>
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).

\[
\begin{array}{cccccc}
0x32 & 0xF1 & 0x11 & 0x67 & \ldots & 0x7B \\
0 & 1 & 2 & 3 & 2^{M-1} & \\
\end{array}
\]
Memory Operations

Read

\texttt{\texttt{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 \texttt{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

• 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

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
Components of a Microprocessor

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

• For the Teensies (Arm Cortex M4 processor): the data bus is 32 bits wide (4 bytes)
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 instruction decoder
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)