Firmware System Design: Selection of Hardware Platform

1. Chipset Architecture Selection
2. Effect of Word Size on Program Execution
3. Memory Considerations

Steven Dirven, Massey University, 2015

Selecting Hardware for Firmware - Reflection

Firmware Systems Design will be used as an example.

Self-Reflection

What is the difference between a microcontroller and a microprocessor?

How would I currently select a chipset hardware architecture?

What types of memory exist in embedded systems, and how are they used?

What do I currently know about "word size" and how it affects program execution?

Systems Design - Selecting Hardware for Firmware

1. Chipset Architecture Selection
   - Microprocessors
   - Microcontrollers - Harvard/Princeton Architecture
   - Digital Signal Processors
2. Effect of Word Size on Program Execution
   - Word Size - Meaning
   - Arithmetic Logic Unit
   - Word Size and Communications
3. Memory Considerations
   - ROM (Program Memory)
   - RAM (Processing Memory)
   - EEPROM (Persistent Memory)

Chipset Architecture Selection

Arduino and Raspberry Pi Comparison

Other than the peripheral features, what are the similarities and differences between an Arduino and a Raspberry Pi?

Are the differences at the hardware / firmware / software levels?

When is one more suitable than the other?

Chipset Architecture Selection

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Architectural Differences

- Arduino is microcontroller-based (ATmega family)
- Raspberry Pi is System-on-a-chip based

Chipset Architecture Selection - Microprocessors

Microprocessor Architecture

What does a micro<u>processor</u> consist of, and how does this make it different from a microcontroller?

What are the advantages and limitations of microprocessors, and when would you use one?

Chipset Architecture Selection - Microprocessors

Microprocessor Architecture

What does a microprocessor consist of, and how does this make it different from a microcontroller?

What are the advantages and limitations of microprocessors, and when would you use one?

Architectural Differences

- A microprocessor is literally a CPU that has no peripherals attached
- For a microprocessor to do anything it needs to be supported by memory modules and peripheral interfaces. The modular components allow for flexibility, though are overall more expensive than μCs

Chipset Architecture Selection - Microcontrollers

Microcontroller Architecture

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Chipset Architecture Selection - Microcontrollers

Microcontroller Architecture

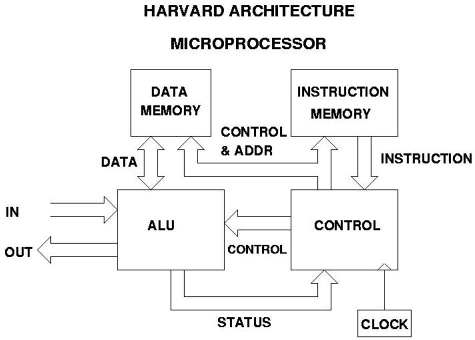
What does a microcontroller consist of, and how does this make it different from a microprocessor?

Microcontroller Components

A microcontroller has integrated peripherals such as:

- Memories (volatile and persistent)
- Timers
- Communication transciever modules
- Reserved Special Function Registers
- Analog and Digital pin features

Chipset Architecture Selection - Memory Management



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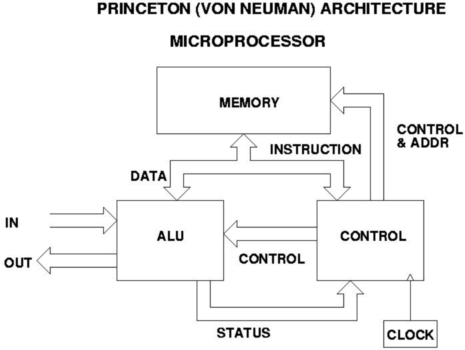
Chipset Architecture Selection - Memory Management



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Chipset Architecture Selection - Memory Management

There are advantages and limitations to each of the Princeton and Harvard Memory architectures. This is true for both microcontrollers and microprocessors.

Princeton architecture allows a program to modify itself whilst running but has both data and instructions travelling on the same bus which leads to a data transfer bottleneck.

Harvard architecture facilitates "pipelining" where instructions and data can be fetched simultaneously. However, program and data memory are fixed in size and cannot be used interchangably.

Chipset Architecture Selection - Digital Signal Processors

Digital Signal Processors have specialist architectures for performing repetitious or heavy duty mathematical operations in a time and power efficient manner.

Used in mobile phones for image and audio processing

Features may include functionality for various signal processing algorithms such as Fast Fourier Transforms (FFT), matrix mathematics, filtering, or convolution.

Microprocessors can generally perform the same tasks, though are less time and energy efficient.

Chipset Architecture Selection - Reflection

Chipset Architecture Selection

Microprocessors, microcontrollers, and digital signal processors each have different processing system architectures making them suitable for different applications.

Consider:

- If working with microprocessors determine which memory architecture is more suitable. Microcontrollers are typically a Harvard variant.
- That memory architecture has significant ramifications at the computational level

Introduction to "Word Size"

A "word" size/length/width is a term for the natural unit of data used in a particular processor design.

The majority of registers in a processor are usually word-sized. It represents the largest amount of data that can be fetched or stored in the working memory in a single operation.

Common word-sizes in current processors are 8,12,16,32,64 bits long

Data Busses are typically as wide, or half the width of, the word size. Data memory is typically addressed in words.

Arithmetic Logic Unit (ALU)

Consider multiplication of two numbers 8 bits in length.

The range of possible solutions is 2^8 *x* $2^8 = 2^{16}$.

This requires a register that is twice as long (16 bits), or the multiplication problem needs to be broken into seperate parts. If it has to be broken down the processor will have to perform multiple operations and fetch/store data multiple times which is undesirable.

Multiplication is much less processor intensive than division. If dividing by a constant that is not a power of 2 frequently the compiler should calculate the floating point reciprocal once and store it for future "divisions"

Word Size and Communication

Word size also affects communication buffers for peripherals. Consider how data is moved between its registers and program memory whether through Direct Memory Access, or moved by the processor on demand.

Some chips require communications with specific packet widths which may require data to be split and combined, or vice-versa unless the protocols at each end match.

Read-Only Memory (ROM)

Program Memory is typically manufactured as Read-Only Memory, where the CPU reads the instructions and performs operations on variables stored in Data Memory (More on that later).

This type of memory is slow to clear or write, and is written over by using a specialist programmer, or during bootloading to change the program. It is not altered during program execution.

As the name suggests, it is not designed to be frequently written, though it is quick to read during operation. This is persistent memory and does not require power to store the program.

Random Access Memory (RAM)

Random Access Memory is used to store variables and data that are ready to be manipulated.

It is a volatile memory that is both fast to read and write, though it requires power to store the information. When it loses power, it loses the information it was holding.

RAM is advantageous for data storage as it can be fetched, processed and overwritten in an efficient manner. It can also be used to record intermediary steps of calculations if required.

Electrically Erasable Programmable Read-Only Memory (EEPROM)

Electrically Erasable Programmable Read-Only Memory is used to store constants, calibration data, and system logs.

EEPROM is slow to write, though can be written at run time and persistently store data without power. It is typically read more often than written.

It can be used to store things that do not change often, or may need to be read back when the system is booted up in future. Additional examples of applications include state variables, error codes, or serial / firmware version numbers.

What to take away from this lecture

The Main Points

- Microprocessors are just a processing unit.
- Microcontrollers have memory and peripherals / features attached.
- The word length and bus architecture inside a chip play a significant role in its processing capability and applications
- RAM, ROM, and EEPROM memories each have advangates and disadvantages. The first is volatile, whilst the other two are persistent
- Understanding the underlying hardware is vitally important when developing firmware on these platforms.