



# Computer Science

## **Spring 2025: CSCI 181RT** Real-Time Systems in the Real World

### **Lecture 5**

Tuesday, February 4, 2025  
Edmunds Hall 105  
2:45 PM - 4:00 PM

Professor Jennifer DesCombes

# Agenda

- Go Backs
- Discussion on Reading
- Interrupt Based Real-Time Systems
- Basic Computer Architecture
- Preview of Lab
- Assignment
- Look Ahead
- Action Items

## Go Backs

- General?
- Mentor Session?
- Action Item Status
  - AI250130-1: David awarded 1% for missed update on “Jan 21” in Lecture Charts. - OK to Close?

# Discussion on Reading

- Stacks and Frames Demystified
- K&R

# Interrupt Based Real-Time Systems

- Respond to *Internal* or *External* Events
  - Internal - Timers, Fault Conditions
  - External - Logic Inputs, Ports, Input Compare, Input Count
- Hardware and Toolset Awareness
- Computer Architecture

# Basic Computer Architecture

- Simple Harvard Processing Core
- Harvard vs Von Neumann - The Same?
- Processors vs Micro-controllers
- Examples
  - Motorola 68000
  - PIC32 Series



**M68000**  
**8-/16-/32-Bit**  
**Microprocessors User's Manual**

Ninth Edition



**PIC32MZ Embedded Connectivity  
with Floating Point Unit (EF) Family**

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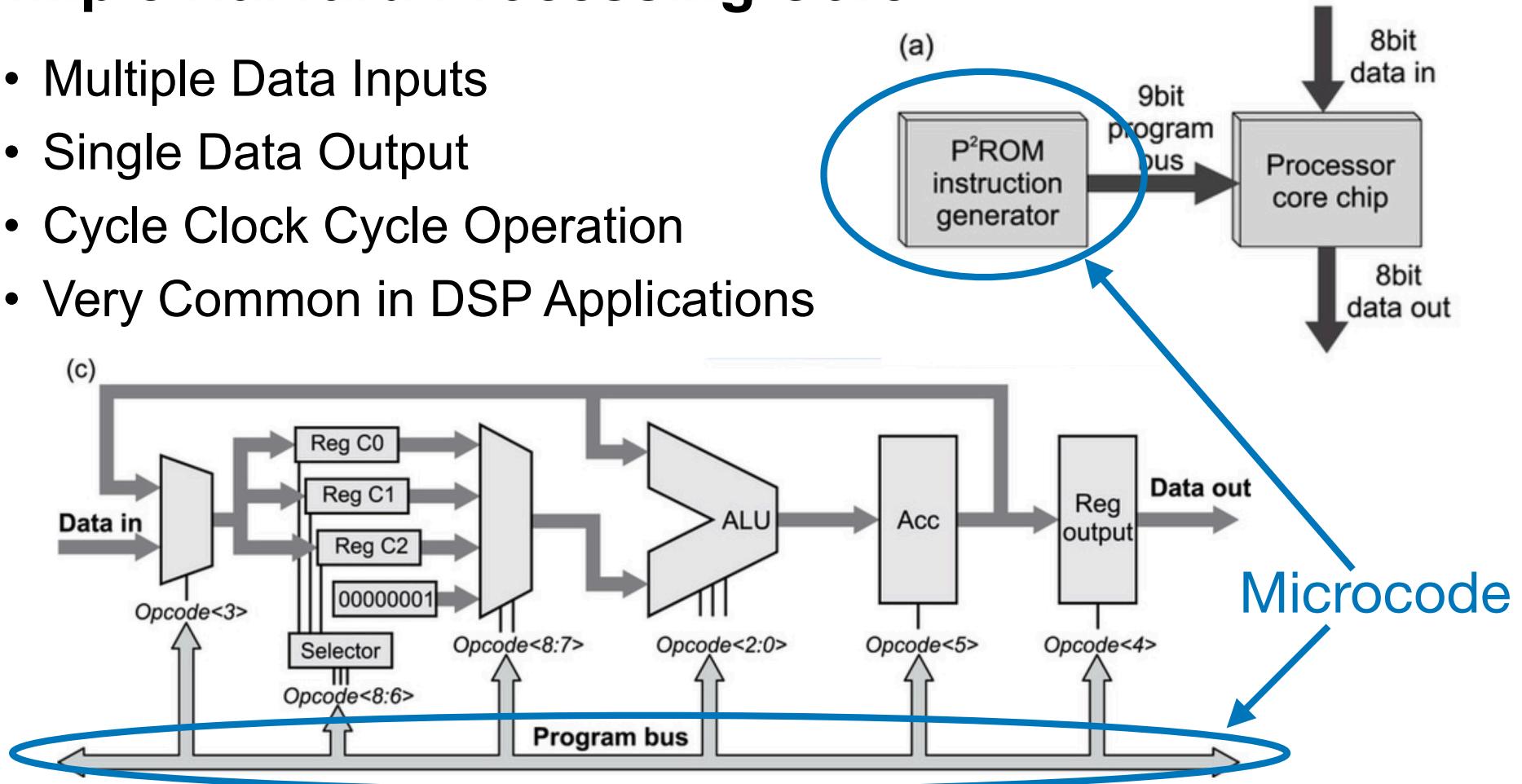
**32-bit MCUs (up to 2 MB Live-Update Flash and 512 KB SRAM) with FPU,  
Audio and Graphics Interfaces, HS USB, Ethernet, and Advanced Analog**

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# Simple Harvard Processing Core

- Multiple Data Inputs
- Single Data Output
- Cycle Clock Cycle Operation
- Very Common in DSP Applications



## Difference between Von Neumann and Harvard Architecture

# Harvard vs Von Neumann - The Same?

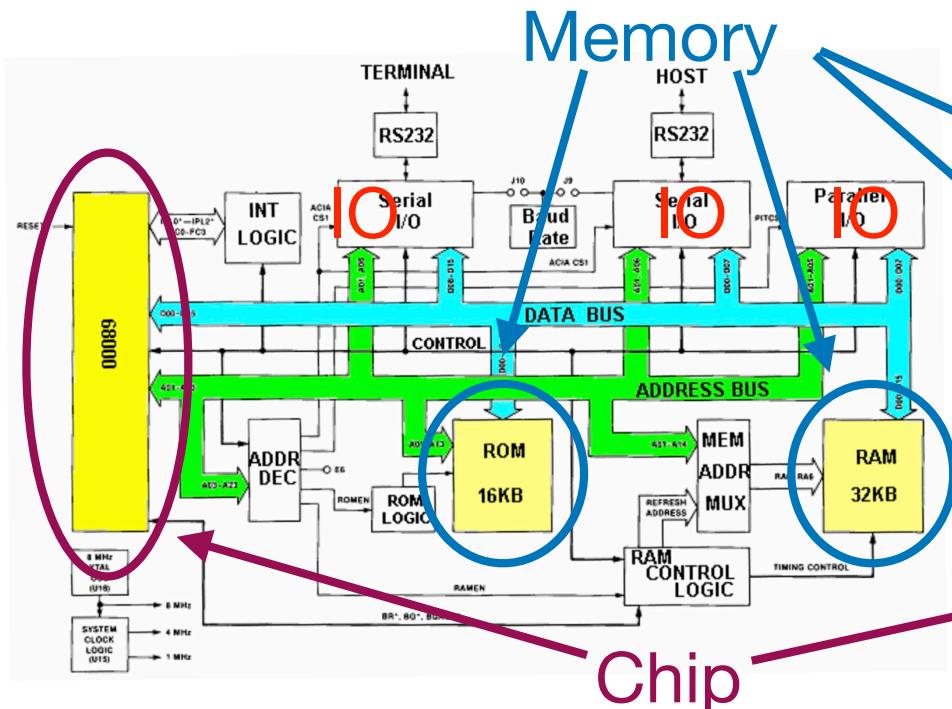
- Both Architectures Exist In Most Modern Processors

VON NEUMANN ARCHITECTURE	HARVARD ARCHITECTURE
It is ancient computer architecture based on stored program computer concept.	It is modern computer architecture based on Harvard Mark I relay based model.
Same physical memory address is used for instructions and data.	Separate physical memory address is used for instructions and data.
There is common bus for data and instruction transfer.	Separate buses are used for transferring data and instruction.
Two clock cycles are required to execute single instruction.	An instruction is executed in a single cycle.
It is cheaper in cost.	It is costly than Von Neumann Architecture.
<u>CPU</u> can not access instructions and read/write at the same time.	CPU can access instructions and read/write at the same time.
It is used in personal computers and small computers.	It is used in <u>micro controllers</u> and signal processing.



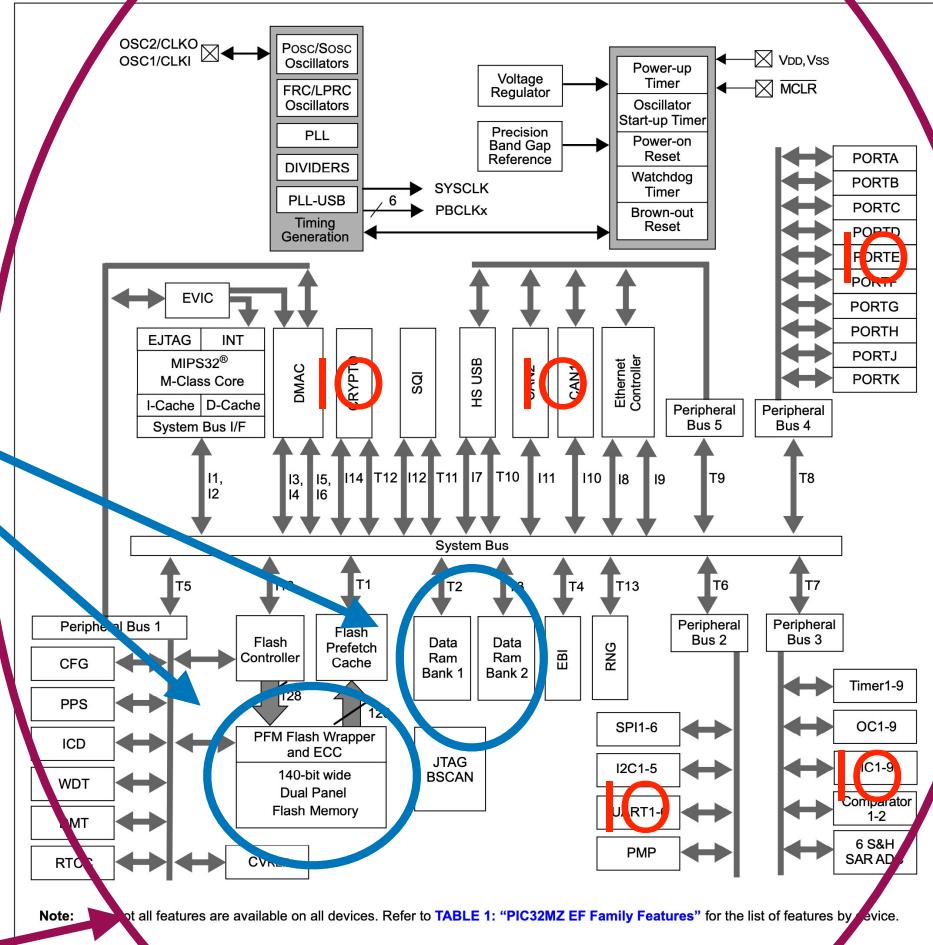
# Processors vs Micro-controllers

- Processors are Just Processors
  - Require Memory and IO
- Micro-controllers - Single Chip Solution



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FIGURE 1-1: PIC32MZ EF FAMILY BLOCK DIAGRAM



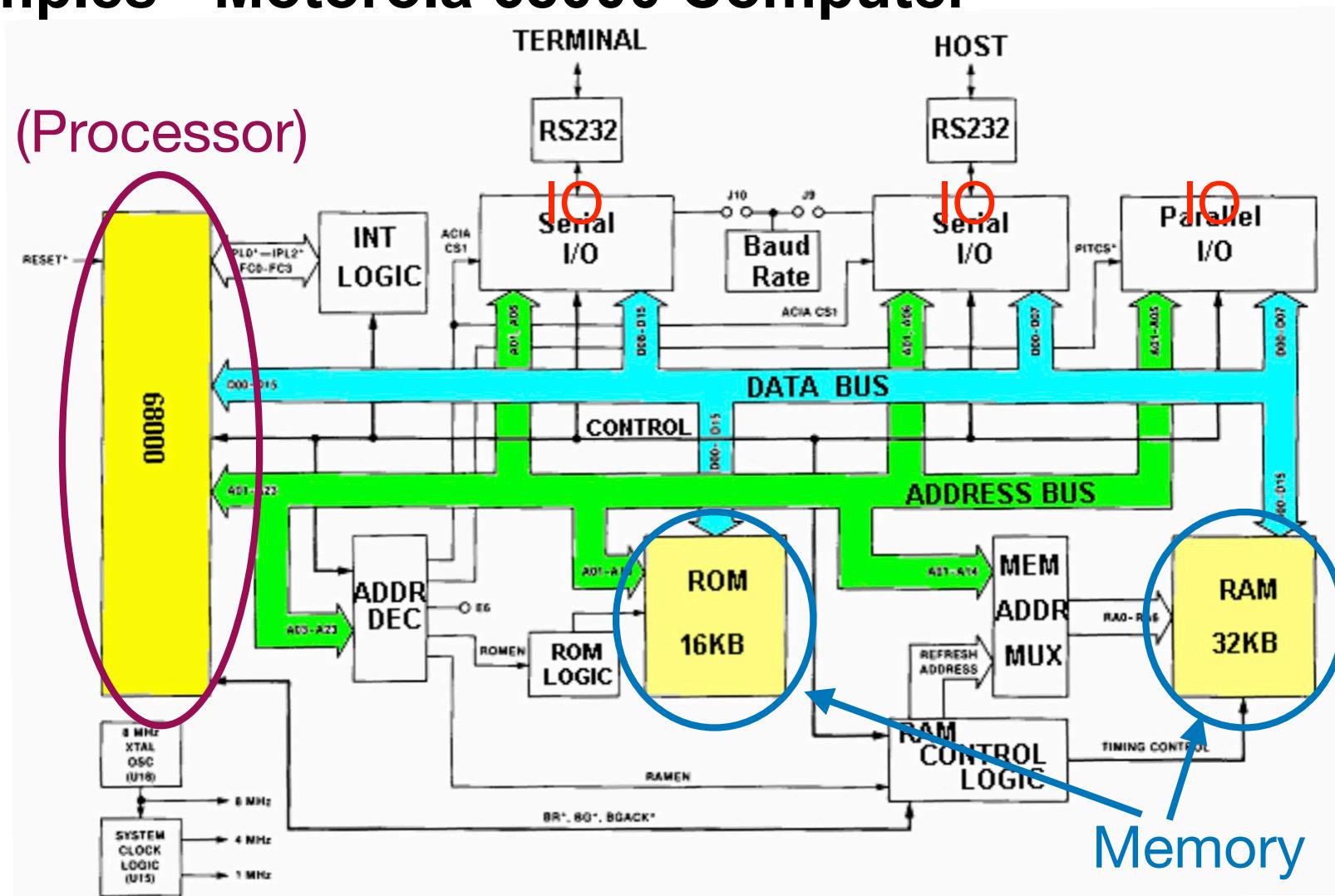
Tuesday, February 4, 2025

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## Examples - Motorola 68000 Computer

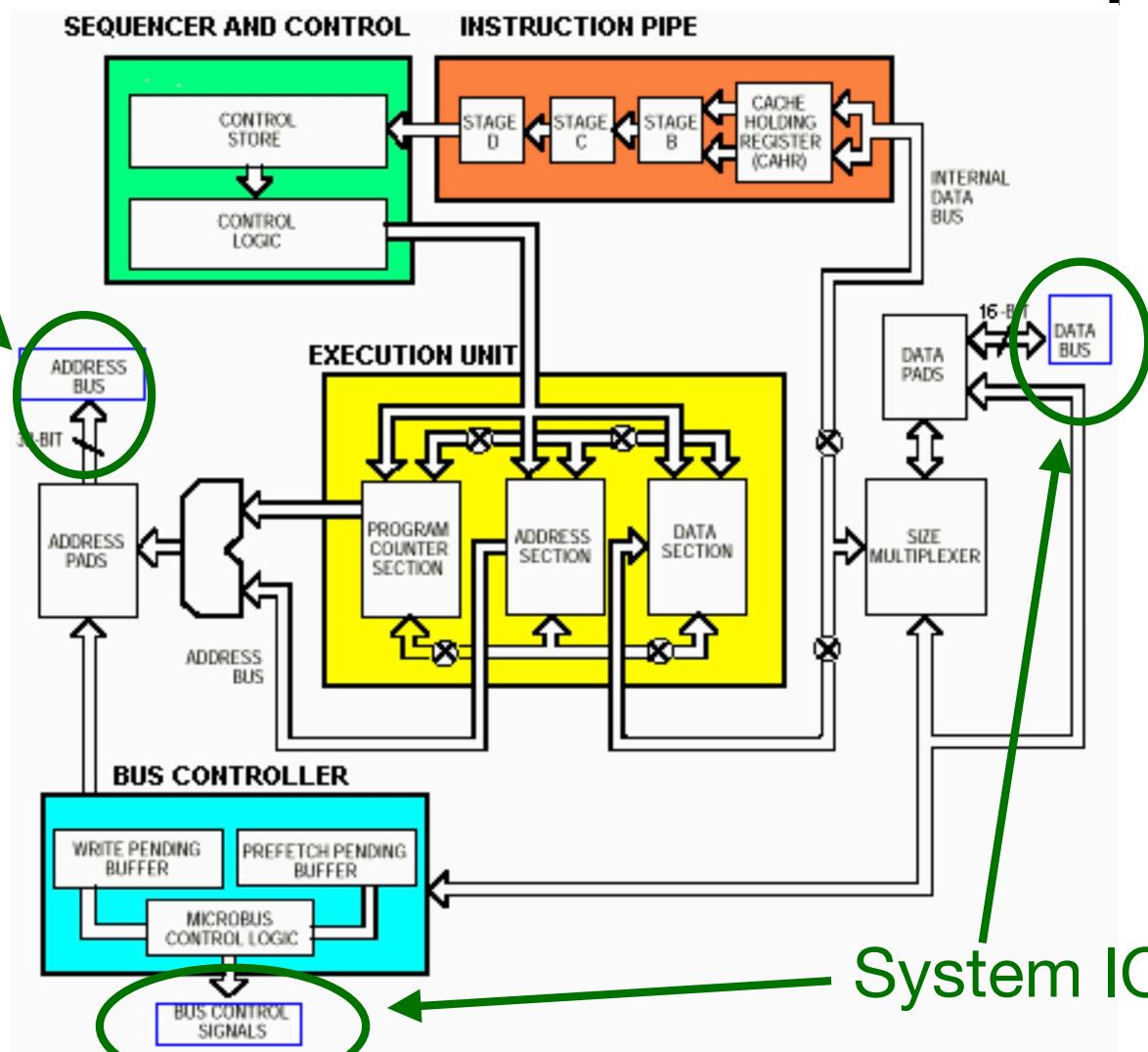
Chip (Processor)





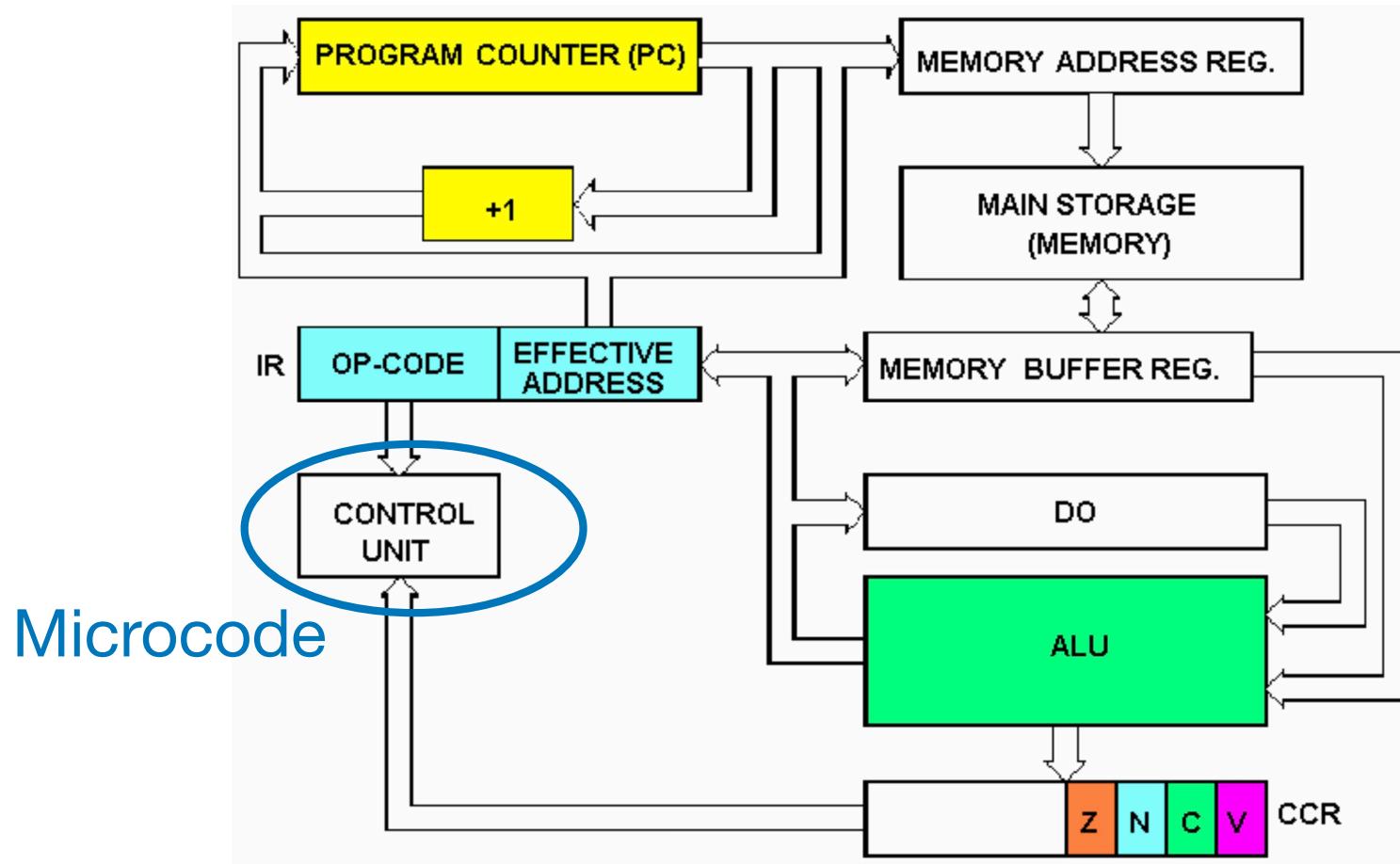
## Examples - Motorola 68000 Processor - Chip

System IO



System IO

## Examples - Motorola 68000 Processor - Core



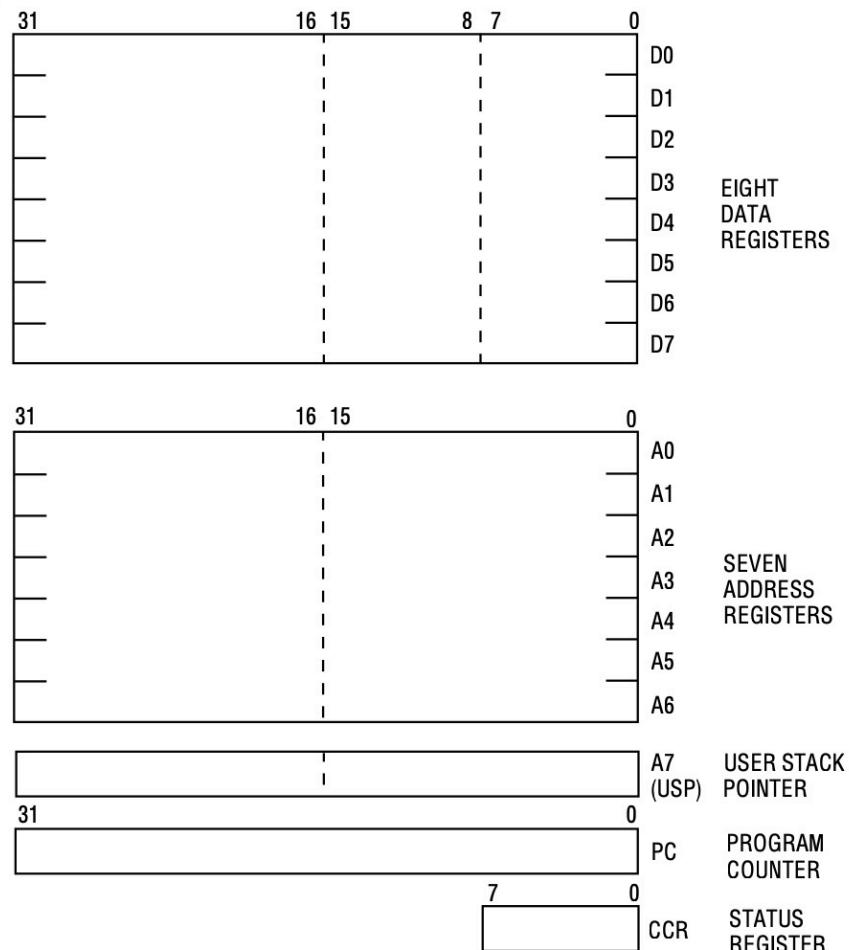
# Examples - Motorola 68000 Processor - Registers

## 2.1.1 User' Programmer's Model

The user programmer's model (see Figure 2-1) is common to all M68000 MPUs. The user programmer's model, contains 16, 32-bit, general-purpose registers (D0–D7, A0–A7), a 32-bit program counter, and an 8-bit condition code register. The first eight registers (D0–D7) are used as data registers for byte (8-bit), word (16-bit), and long-word (32-bit) operations. The second set of seven registers (A0–A6) and the user stack pointer (USP) can be used as software stack pointers and base address registers. In addition, the address registers can be used for word and long-word operations. All of the 16 registers can be used as index registers.

# Examples - Motorola 68000 Processor - Registers

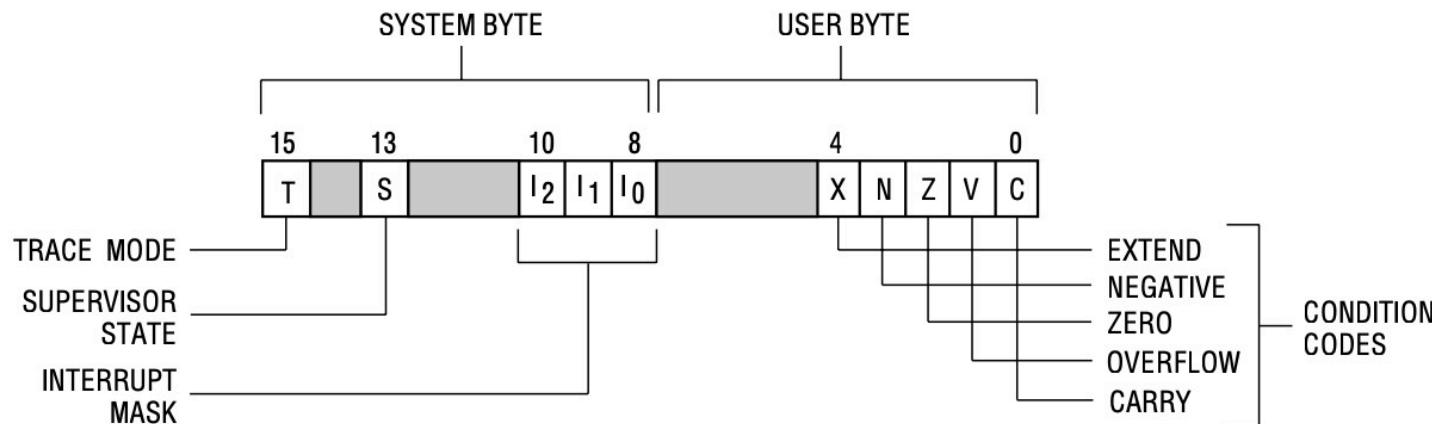
- 8 Data Registers
- 8 Address Registers
  - 7 General Purpose
  - 1 Dedicated to Stack Pointer
- Program Counter
- Status Register



# Examples - Motorola 68000 Processor - Registers

## 2.1.3 Status Register

The status register (SR), contains the interrupt mask (eight levels available) and the following condition codes: overflow (V), zero (Z), negative (N), carry (C), and extend (X). Additional status bits indicate that the processor is in the trace (T) mode and/or in the supervisor (S) state (see Figure 2-4). Bits 5, 6, 7, 11, 12, and 14 are undefined and reserved for future expansion

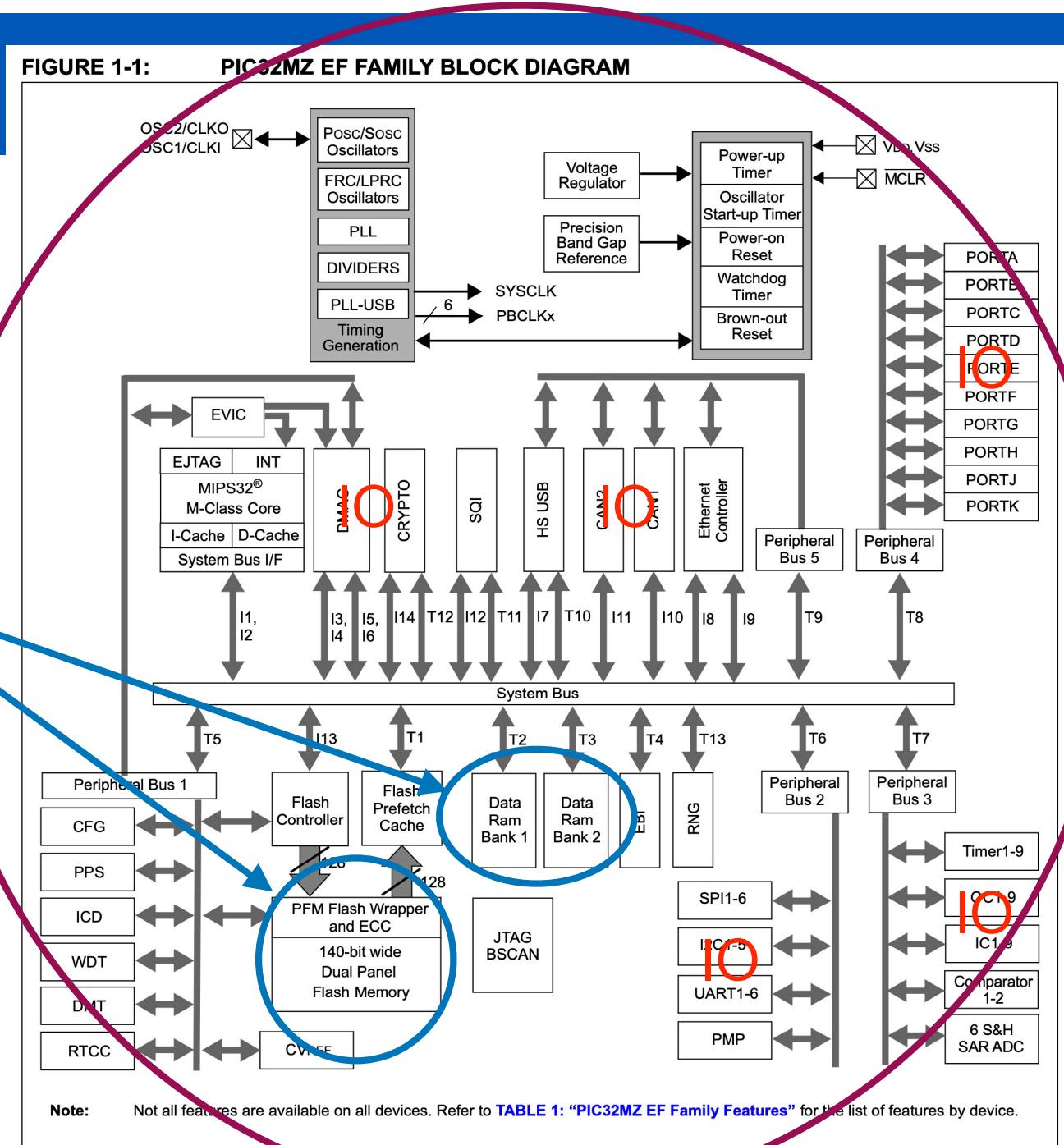




## Examples - PIC32 Series - Chip

Memory

Chip  
(Micro-  
controller)



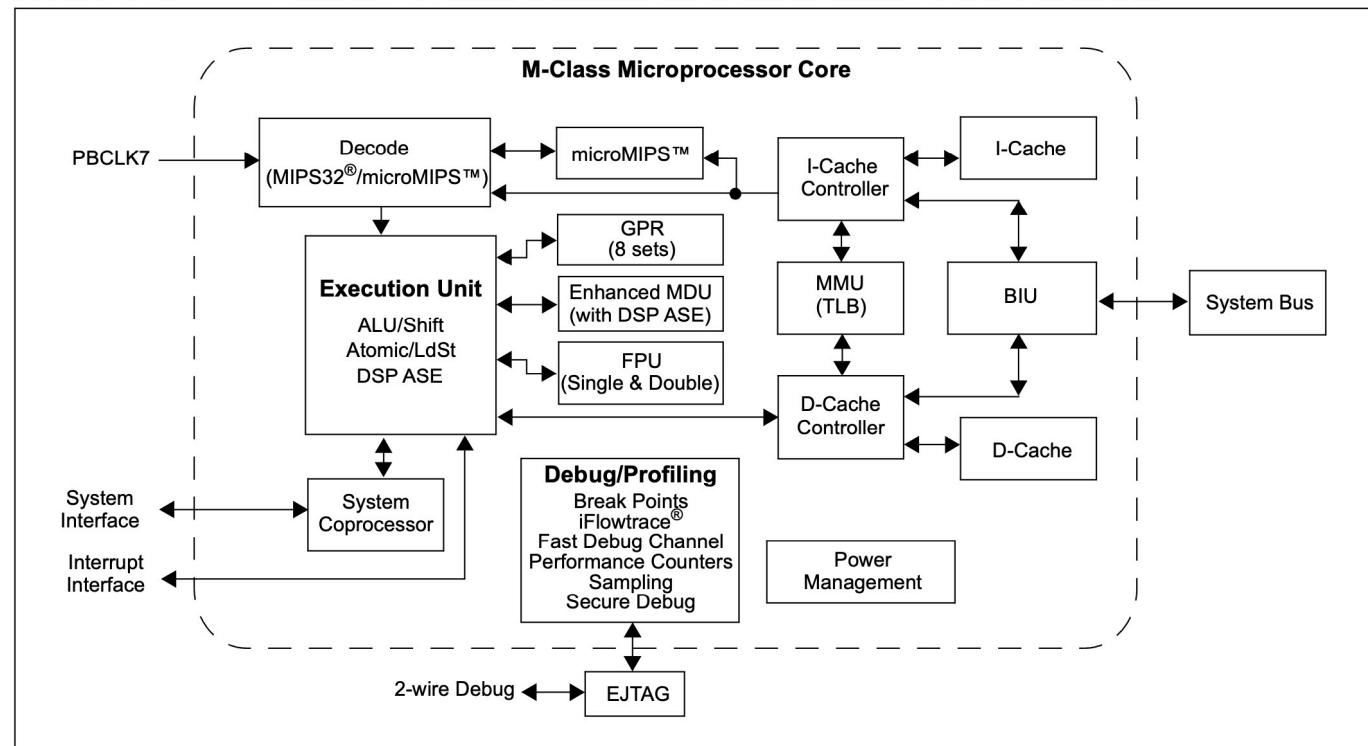
# Examples - PIC32 Series - Processing Core

## 3.1 Architecture Overview

The MIPS32 M-Class Microprocessor core in PIC32MZ EF family devices contains several logic blocks working together in parallel, providing an efficient high-performance computing engine. The following blocks are included with the core:

- Execution unit
- General Purpose Register (GPR)
- Multiply/Divide Unit (MDU)
- System control coprocessor (CP0)
- Floating Point Unit (FPU)
- Memory Management Unit (MMU)
- Instruction/Data cache controllers
- Power Management
- Instructions and data caches
- microMIPS support
- Enhanced JTAG (EJTAG) controller

**FIGURE 3-1: PIC32MZ EF FAMILY MICROPROCESSOR CORE BLOCK DIAGRAM**



# Preparation for Lab

- Evaluation Boards
- USB-micro to USB-A Cables
- Software Installation - Mostly Achieved
- Compilation of Micro-controller Software
- Use of Virtual Comm Window

# Assignment - Lab Preparation

## Documentation

Title	Download	Star
Curiosity PIC32MZ EF 2.0 Development Board Users Guide	<a href="#"> Download</a>	
PIC32MZ_EF Curiosity Board 2.0 Design Documentation	<a href="#"> Download</a>	
Create a new MPLAB Harmony v3 project using MCC	<a href="#"> Link</a>	
Update and Configure an Existing MHC-based MPLAB Harmony v3 Project to MCC-based Project	<a href="#"> Link</a>	
Getting Started with Harmony v3 Peripheral Libraries on PIC32MZ EF MCUs	<a href="#"> Link</a>	
Getting Started with Harmony v3 Drivers and Middleware on PIC32MZ EF MCUs using FreeRTOS	<a href="#"> Link</a>	
Creating a Hello World Application on PIC32 Microcontrollers Using MPLAB Harmony v3 and the MPLAB Code Configurator (MCC)	<a href="#"> Download</a>	
How to Build an Application by Adding a New PLIB, Driver, or Middleware to an Existing MPLAB Harmony v3 Project	<a href="#"> Download</a>	
How to Use the DMA CRC Generator on PIC32MX/PIC32MZ/PIC32MM Devices	<a href="#"> Download</a>	

# Assignment - Lab Preparation

- Research Microchip Development Tools

## MPLAB Harmony 3

Embedded Software Development Framework for 32-bit  
Microcontrollers and Microprocessors

<https://www.microchip.com/en-us/tools-resources/configure/mplab-harmony>

# Assignment - Readings

**Assignment:** None for Next Thursday

## Google topic - computer microcode

Spend about 20 minutes on this - read about history and current implementations.

- Lecture Reading
  - K&R - Page 151 - 168
    - Chapter 6: Structures (Note - Very Useful)
- PIC32MZ Embedded Connectivity with FP Unit (EF) Family
  - <https://ww1.microchip.com/downloads/aemDocuments/documents/MCU32/ProductDocuments/DataSheets/PIC32MZ-Embedded-Connectivity-with-Floating-Point-Unit-Family-Data-Sheet-DS60001320H.pdf>

## Look Ahead

- Discuss of Lab
- More on Interrupt Based Real-time Systems

## References

### Difference between Von Neumann and Harvard Architecture

Last Updated : 30 Aug, 2024, More on Interrupt Based Real-time Systems

<https://www.geeksforgeeks.org/difference-between-von-neumann-and-harvard-architecture/>

### A thin-film microprocessor with inkjet print-programmable memory

December 2014 • Scientific Reports 4(1):7398 DOI: 10.1038/srep07398

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Authors: Kris Myny - IMEC; Steve Smout - IMEC; Maarten Rockelé VLAIO - Flemish Agency Innovation and Entrepreneurship; Ajay Bhoolokam

[https://www.researchgate.net/publication/269414890\\_A\\_thin-film\\_microprocessor\\_with\\_inkjet\\_print-programmable\\_memory](https://www.researchgate.net/publication/269414890_A_thin-film_microprocessor_with_inkjet_print-programmable_memory)

### EECE416 Microcomputer Fundamentals - 68000 Processor

Dr. Charles Kim Howard University

<https://www.mwftr.com/ucF08/LEC05-68K-1.pdf>

# Action Items and Discussion

AI#:	Owner	Slide #	Document	Action