

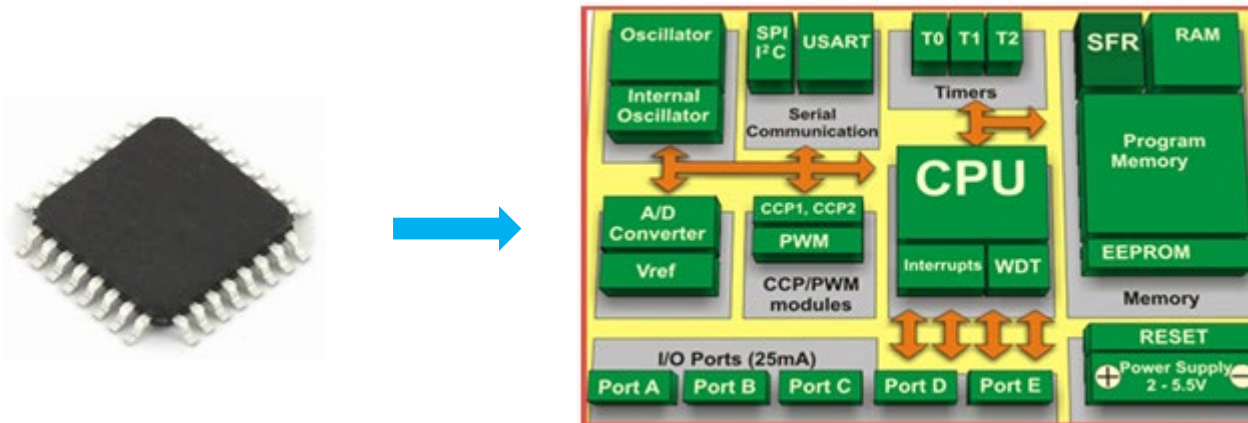
ESET 269 - Embedded Systems Development in C

MSP432 Overview

Dr. Garth V. Crosby

What is a Microcontroller?

- ❑ An **IC** which contains a CPU, ROM, RAM, I/O ports, communication peripherals, etc.
 - A microprocessor is only a CPU on an IC
- ❑ Serves as an **interface** between a **system** and **physical world**
 - Control motors, read voltages, communicate to PC, turn on relays, etc.
- ❑ Key component in embedded systems
 - **Microcontroller** (or processor) with external devices attached programmed for a specific dedicated purpose



What is a Microprocessor?

- ❑ Microprocessor is a very **large-scale integrated circuit (VLSI)** that uses the architecture of the general-purpose digital computer.
- ❑ Microprocessors are based on the **von Neumann** model of a stored program computer
- ❑ The stored program computer, a microprocessor's **program** is stored in **memory** along with its **data**



What is the difference - MPU, MCU

- ❑ **Microprocessor Units (MPU)** tend to be aimed at computer applications; they tend to have minimal "extras" on-chip.
 - Intel Pentium
 - AMD Opteron

- ❑ **Microcontroller Units (MCU)** tend to be aimed at embedded control applications; they tend to consist of a **processor** plus a number of useful **peripherals** (internal I/O modules, memory, etc).
 - 8051
 - PIC
 - **ARM**

Microcontroller Characteristics

- ❑ Not all microcontrollers are the same
- ❑ Common characteristics include
 - Speed
 - Memory
 - Peripherals
 - Number of inputs and outputs
 - Price
 - Footprint

Speed

- ❑ How **fast** the CPU can execute code, or instructions.
- ❑ Comes from a **clocking** source (internal or external).
 - Clock operates on rising edge
 - External clock is known as an oscillator (connects to controller)
- ❑ Speeds range from a few **MHz** to **GHz**.

Memory

- ❑ ROM (read only memory) - used for **program** storage and saving non-volatile data to microcontroller
- ❑ RAM (random access memory) - used for **variable** & **data storage** during operation. Volatile memory

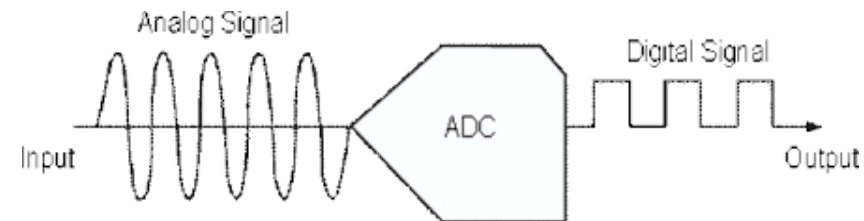
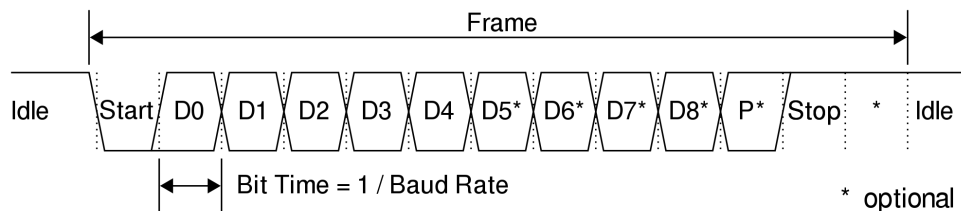
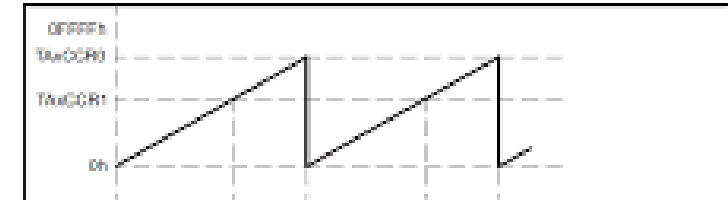
Volatile Memory	Non-Volatile Memory
Memory loses all of its data when power source is turned off	Memory will retain all data when power source is turned off

Input / Output Pins

- ❑ **Microcontrollers** typically do not have one pin per function
 - Exception is Vcc and GND connections
- ❑ A pin can serve as **input** or **output** for **digital**, **analog**, or any **peripheral** function
 - Program specifies use of pin on microcontroller
- ❑ Pin counts can range from several to 100+

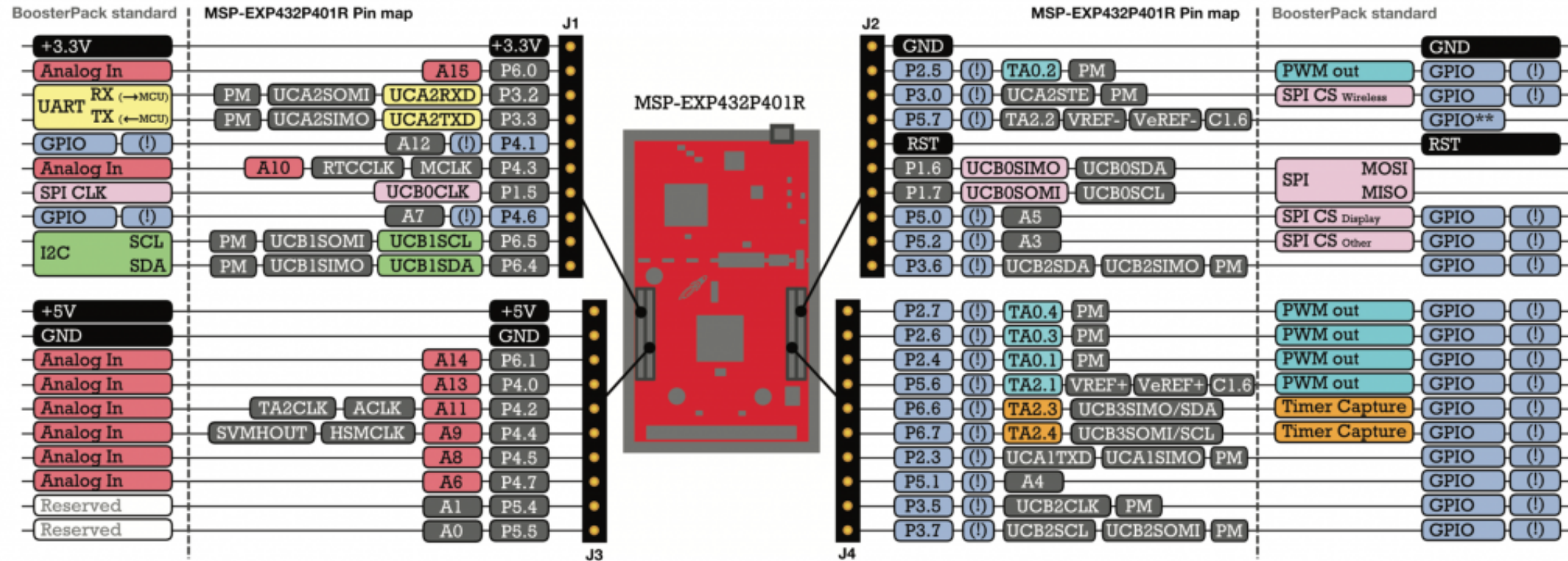
Peripherals

- ❑ Anything other than digital input/output
- ❑ **Timers** - controls timing operations
- ❑ **ADC** - converts analog signal to digital
- ❑ **Serial interface** - communication to other devices or sensors
- ❑ **Interrupts** - allows hardware to “interrupt” software execution



Also shown are functions that map with the BoosterPack pinout standard. Refer to the MSP432P401R Datasheet for additional details.
 NOTE: Some LaunchPads & BoosterPacks do not 100% comply with the standard, so please check your specific LaunchPad to ensure pin compatibility.

(!) Denotes I/O pins that are interrupt-capable
 ** Some LaunchPads do not have a GPIO here



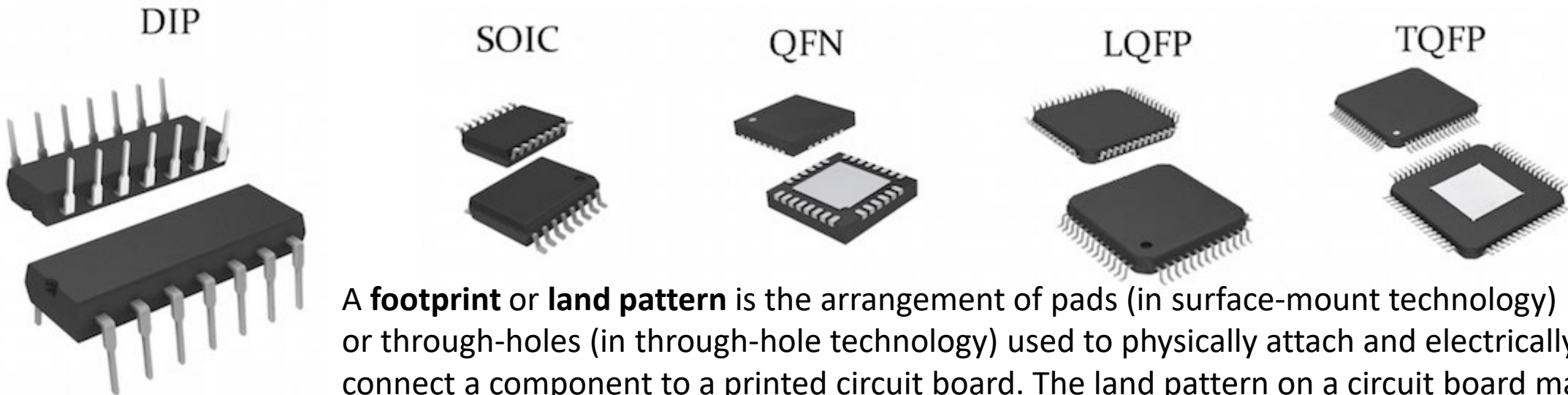
Footprint

- ❑ The same microcontroller can have different footprints
 - How it fits on the printed circuit board
- ❑ **Footprint** affects size, cost, and complexity

Dual in-line package (DIP)

Small Outline Integrated Circuit(SOIC); Quad Flat No-lead (QQN) package;

Low-profile Quad Flat package(LQFP); Thin Quad Flat Pack (TQFP)



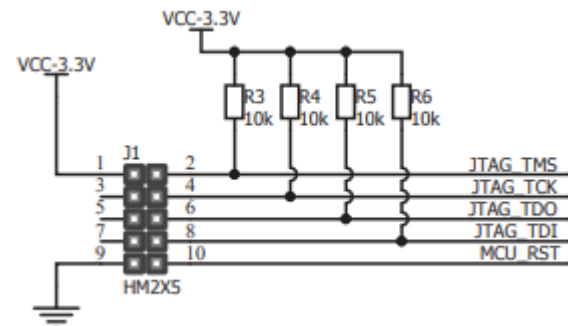
A **footprint** or **land pattern** is the arrangement of pads (in surface-mount technology) or through-holes (in through-hole technology) used to physically attach and electrically connect a component to a printed circuit board. The land pattern on a circuit board matches the arrangement of leads on a component.

Bit Size

- ❑ Refers to size of **instructions**, **data bus width**, **memory address size**, **register size**, etc.
 - **Registers** are **memory** elements that store variables, program memory, and pin functionality information
- ❑ More **bits** means more **features** and **memory**.
 - 32 - bit register can define more functionality than 8-bit
 - Multiple 8 - bit instructions are needed compared to a single 16 or 32 - bit instruction
- ❑ **Higher bit** processors are useful for more demanding applications

Using a Microcontroller

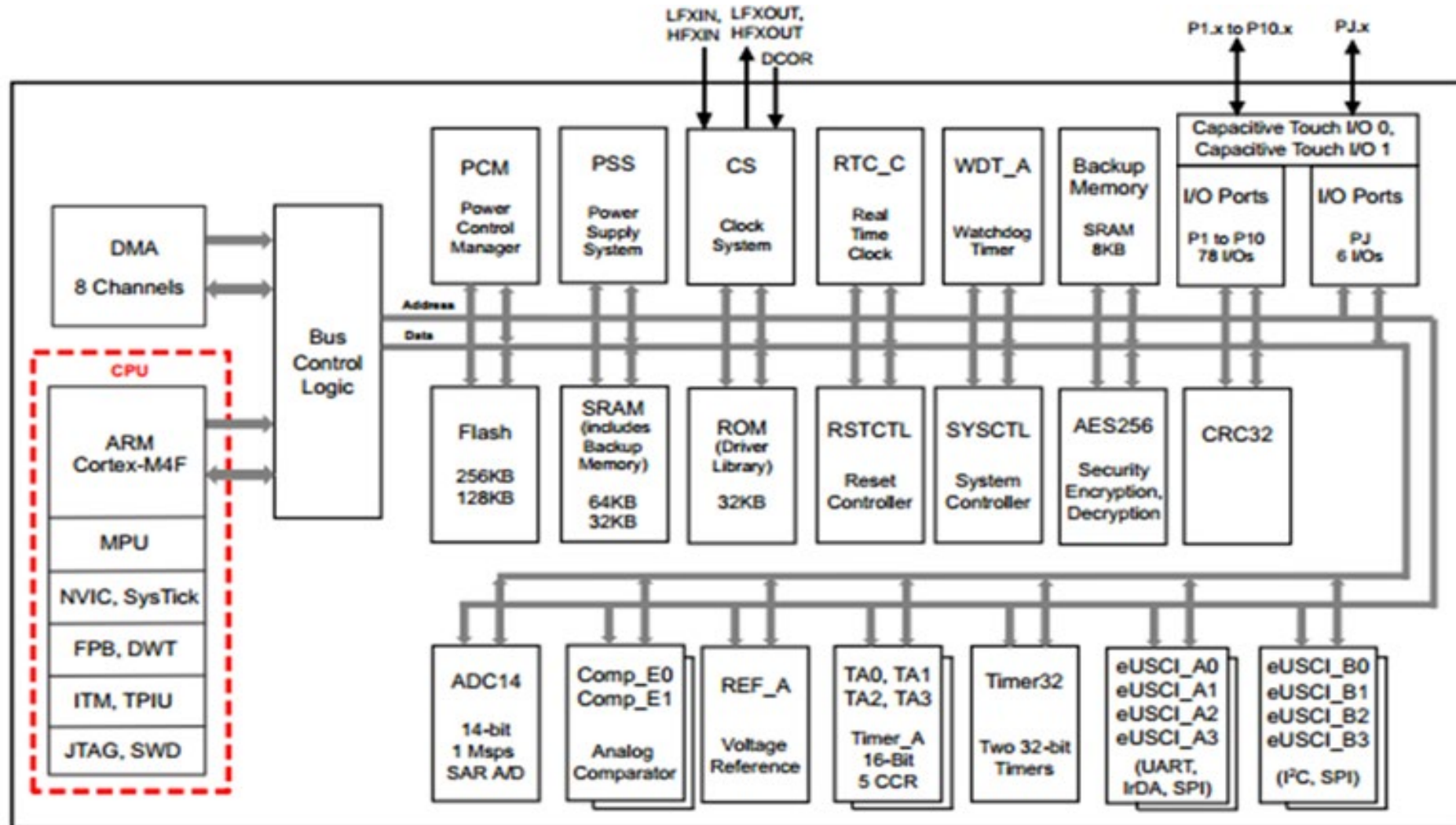
- ❑ Does nothing unless it's programmed. Most common language is **C** & **assembly**.
- ❑ Uses an **Integrated Design Environment (IDE)** to program controller
 - IDE varies by vendor of the microcontroller
 - Need a special device called a programmer to program controller
- ❑ Program instructs how the microcontroller behaves by setting **registers** for functionality, and executing C code statements to act on



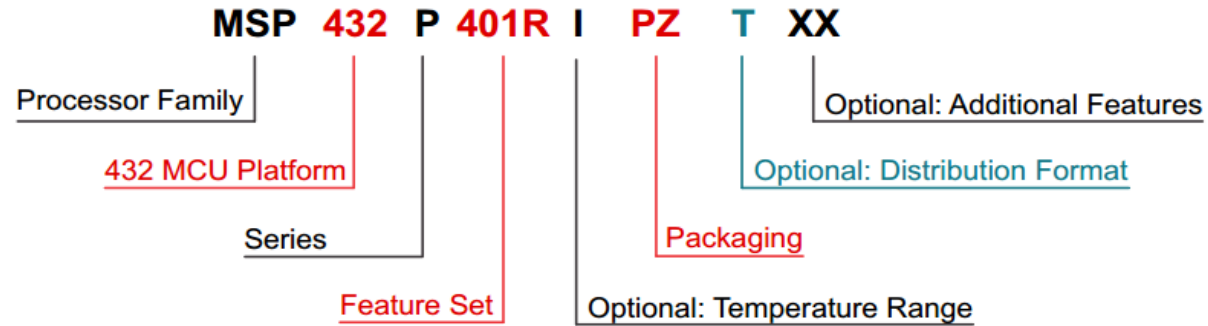
MSP432 Processor & Memory

- ❑ **ARM 32-bit** Cortex M4F Processor
 - ARM is an architecture for the CPU with several peripherals, instructions, and standards set by ARM Inc.
 - M4F denotes the CPU has a **floating point processor** to handle float operations
- ❑ **256 kB** Flash memory (ROM), of which **64 kB** is SRAM
- ❑ 3 MHz to 48 MHz CPU speeds
- ❑ Low power capable device at standard operation of 3.3 V
- ❑ <https://www.ti.com/lit/ds/slas826e/slas826e.pdf>

MSP432 Block Diagram



MSP432 Naming Convention

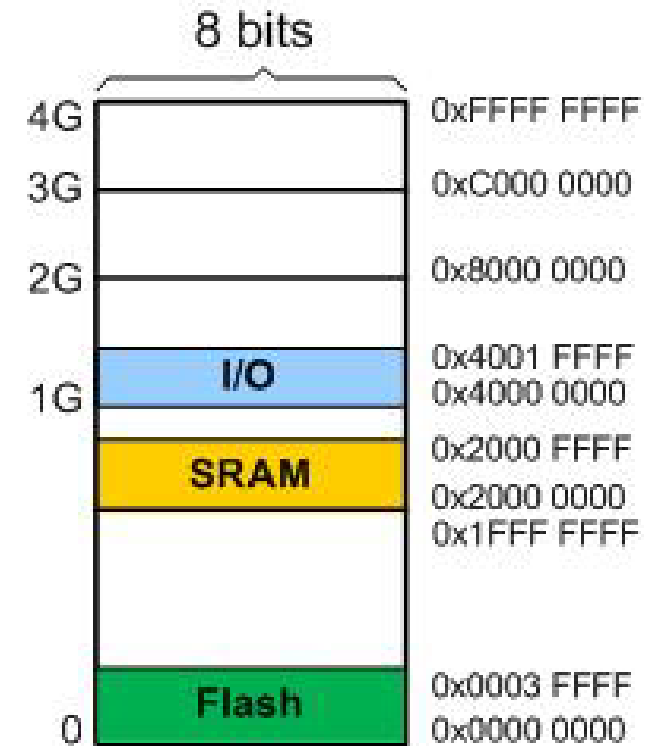


Processor Family	MSP = Mixed Signal Processor XMS = Experimental Silicon			
432 MCU Platform	TI's 32-bit Low-Power Microcontroller Platform			
Series	P = Performance and Low-Power Series			
Feature Set	First Digit 4 = Flash based devices up to 48 MHz	Second Digit 0 = General Purpose	Third Digit 1 = ADC14	Fourth Digit R = 256KB of Flash 64KB of SRAM M = 128KB of Flash 32KB of SRAM
Optional: Temperature Range	S = 0°C to 50 °C I = 40 °C to 85 °C T = -40 °C to 105 °C			
Packaging	PZ = LQFP			

Memory Map

- ❑ Usable **inputs/outputs (I/O)** are **mapped** in memory
 - Accessible by an **address**. Address is where **registers** reside

	Allocated size	Allocated address
Flash	256KB	0x0000 0000 to 0x0003 FFFF
SRAM	64KB	0x2000 0000 to 0x2000 FFFF
I/O	All the peripherals	0x4000 0000 to 0x4001 FFFF



MSP432 Peripheral Specs.

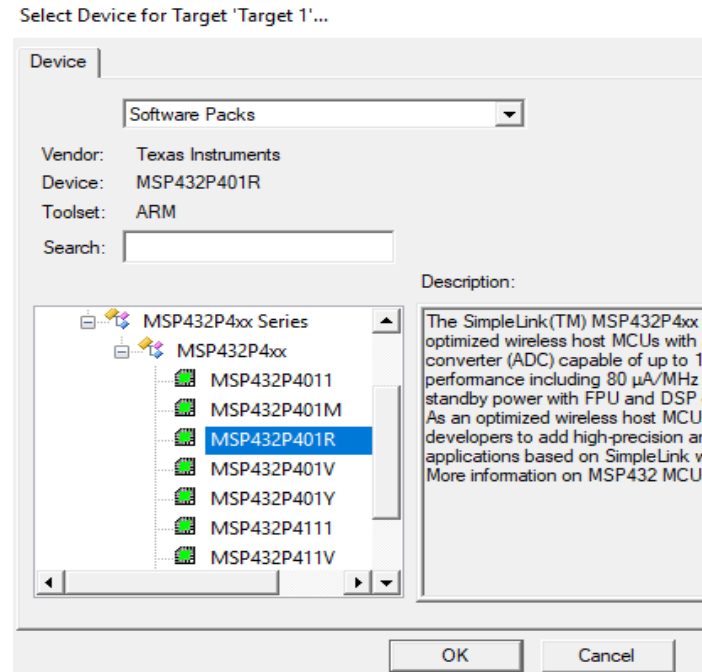
- ❑ Outside of **80+ digital I/O** MSP432 includes
- ❑ **1** analog to digital (ADC) converter, up to 24 channels at 1 MSPS and up to 14-bit resolution
- ❑ **2** analog comparators
- ❑ Multiple 16-bit, 32-bit, and 24-bit **timers**
- ❑ **8** communication channels using UART, SPI, and I2C protocols

How Does Coding Change?

- ❑ **Registers** have to be assigned **values** to allow peripherals to work on MSP432
- ❑ Use of bitwise **logic operations** to **read** and **write** register values
- ❑ **Registers** are **defined** & **declared** in **structs** with a specific .h and .c file
 - Created with project in Keil
- ❑ Using signed or unsigned datatypes
 - http://www.keil.com/support/man/docs/armcc/armcc_chr1359125009502.htm
- ❑ Printf, scanf, and Lab Template will no longer be used
- ❑ Online compiler will no longer be used

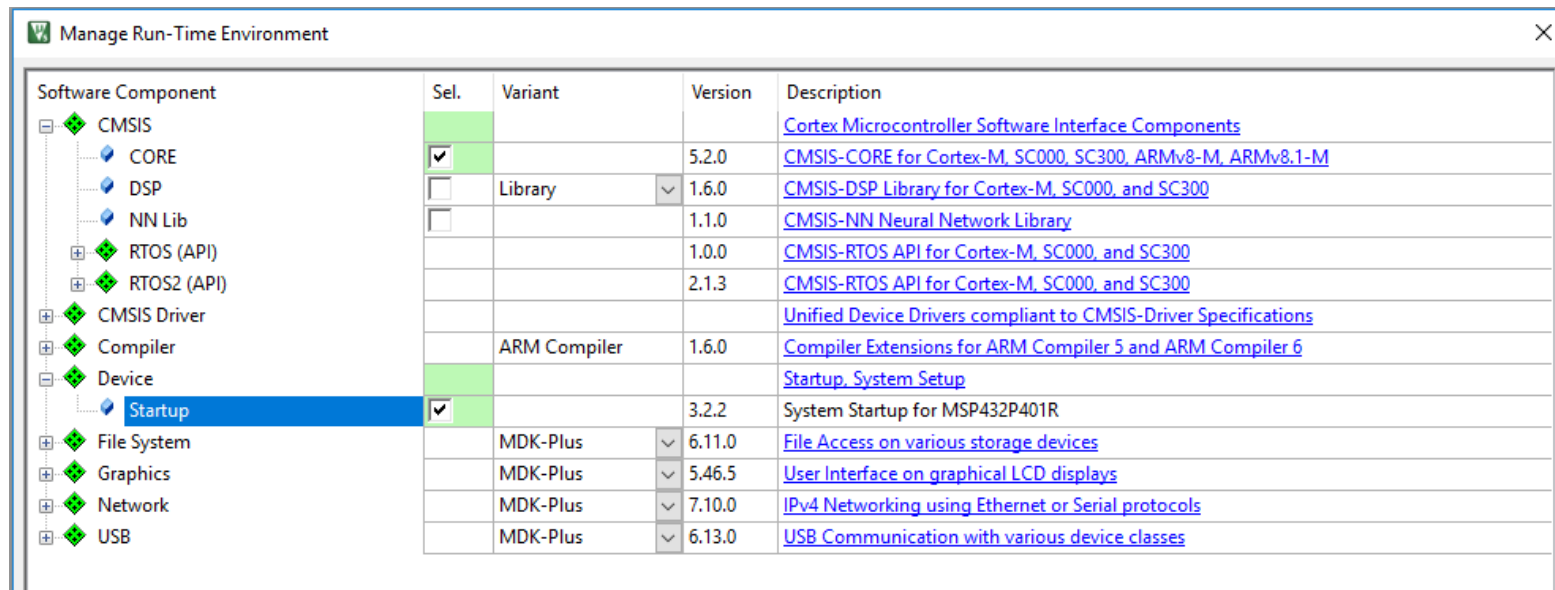
Setting Up Keil Project

- ❑ Create project to setup MSP432 with appropriate startup C and **header** files
 - Create a new uVision project and select a save destination
- ❑ Select the appropriate MSP432 device



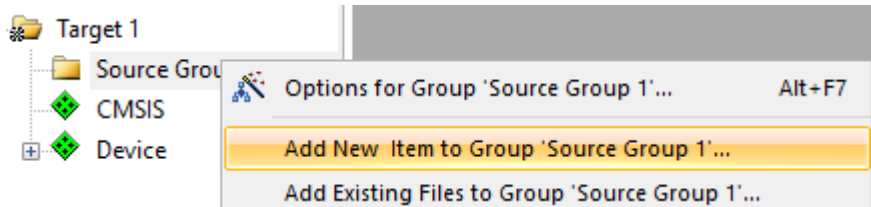
Setting Up Keil Project

- ❑ Expand CMSIS and Device, check the **CORE** and **Startup** boxes
 - Sets up C and header files to use in project. **CORE** allows access to device peripherals through a standard API. **Startup** sets many of the default values for the MSP432



Setting Up Keil Project

- ❑ Add the main.c file in the source groups folder
- ❑ Include the “MSP.h” file and add a while(1) loop



```
//place header files as needed
#include "MSP.h"

int main(void)
{
    //place code that runs once

    while(1)
    {
        //place code to execute repeatedly
    }
}
```

Basic C Template

Startup.C File

- ❑ Sets **default** values
 - Clock speed, floating point processor, watchdog, etc.
- ❑ Defaults
 - **Clock** speed is 3 MHz, can change the value in the startup file
 - **Floating point** processor enabled
 - Watchdog is turned halted
- ❑ Recommended to not modify when first programming

MSP432 Items Used For Class

- ☐ Digital I/O
- ☐ UART communication
- ☐ Timers for delay
- ☐ Interrupts
- ☐ Analog to digital conversation