

Introduction to Embedded System Design

Lecture - 3: Microcontroller Features, Essential Elements of Microcontroller Ecosystem

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Salient Features of Modern Microcontrollers

Expected Functions from a Microcontroller

- Read Digital Inputs
- Provide Digital Outputs
- Measure or maintain a record of Time (relative or absolute)
- Measure time between two events
- Measure Duration of an event
- Generate random numbers

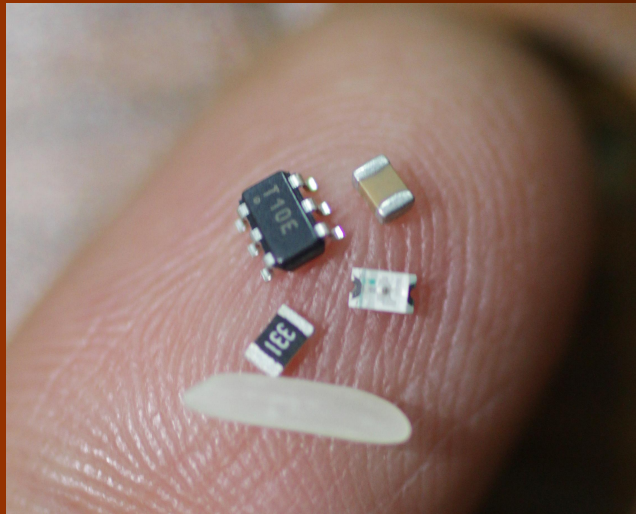
Expected Functions from a Microcontroller

- Respond to asynchronous events (Interrupts)
- Measure Voltage/Current/Resistance
- Provide analog voltage/current
- Store data
- Visualize data/information
- Print data
- Control motion

Microcontrollers

- CPU– 4/8 /16 /32/64 bit microprocessor (CISC / RISC, VN/Harvard)
- Memory
 - ROM / EEPROM / Flash memory – Program storage
 - Volatile Memory (RAM) – Data Storage
- Digital Input / Output pins
- Communication Interfaces
- In System Programming & Debugging
 - SPI Bus/JTAG Interface
- Peripherals
 - Timers, Counters, PWM Generators
 - Watchdog Timer with independent oscillator
 - Analog to Digital Converter, Digital to Analog Converter (explicit or implicit)
- 6 Pin to 200+ pin Devices!

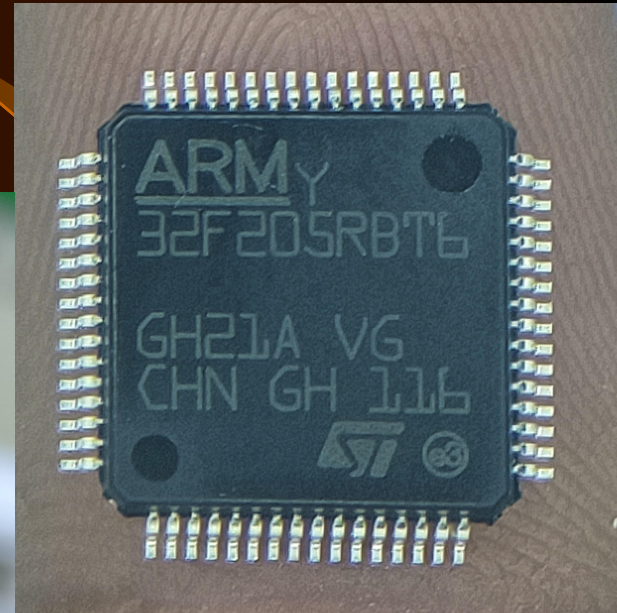
Size Diversity



AT Tiny10



TIVA TM4C1231
Cortex-M4



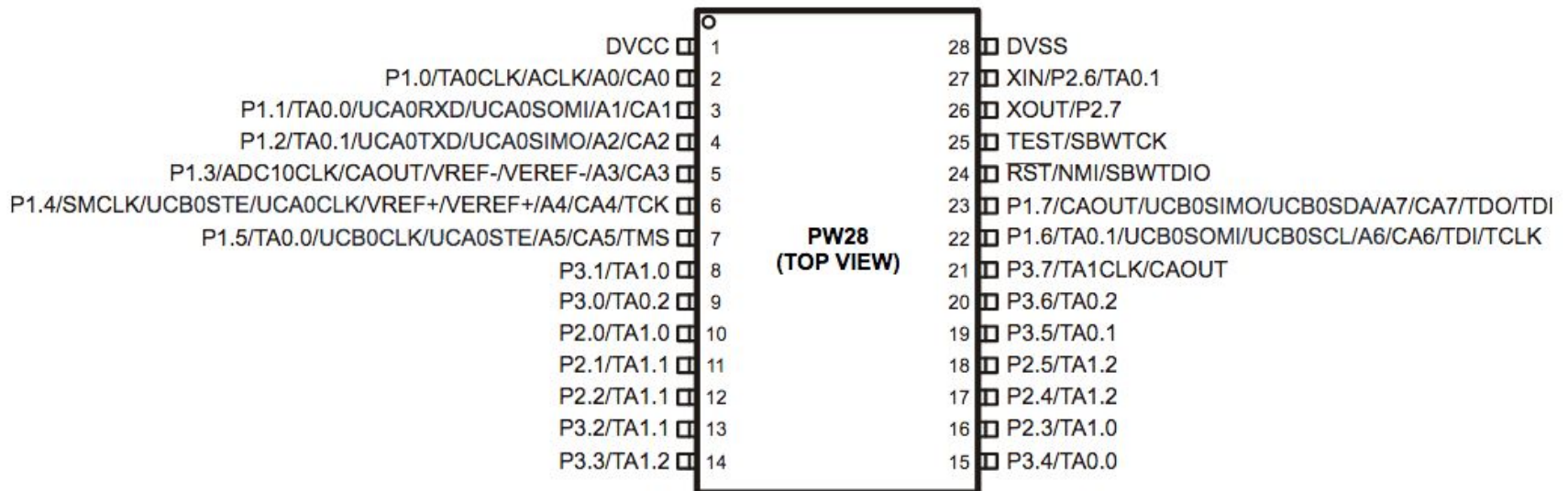
STM32F205
Cortex-M3

Features of Modern Microcontrollers

- Fully programmable pins – Input or Output
- Output pins with 30-40 mA Source/Sink current capability
- Input Pins with weak and strong pull up or tri-state capability
- Each pin offers multiple functions one of which can be selected

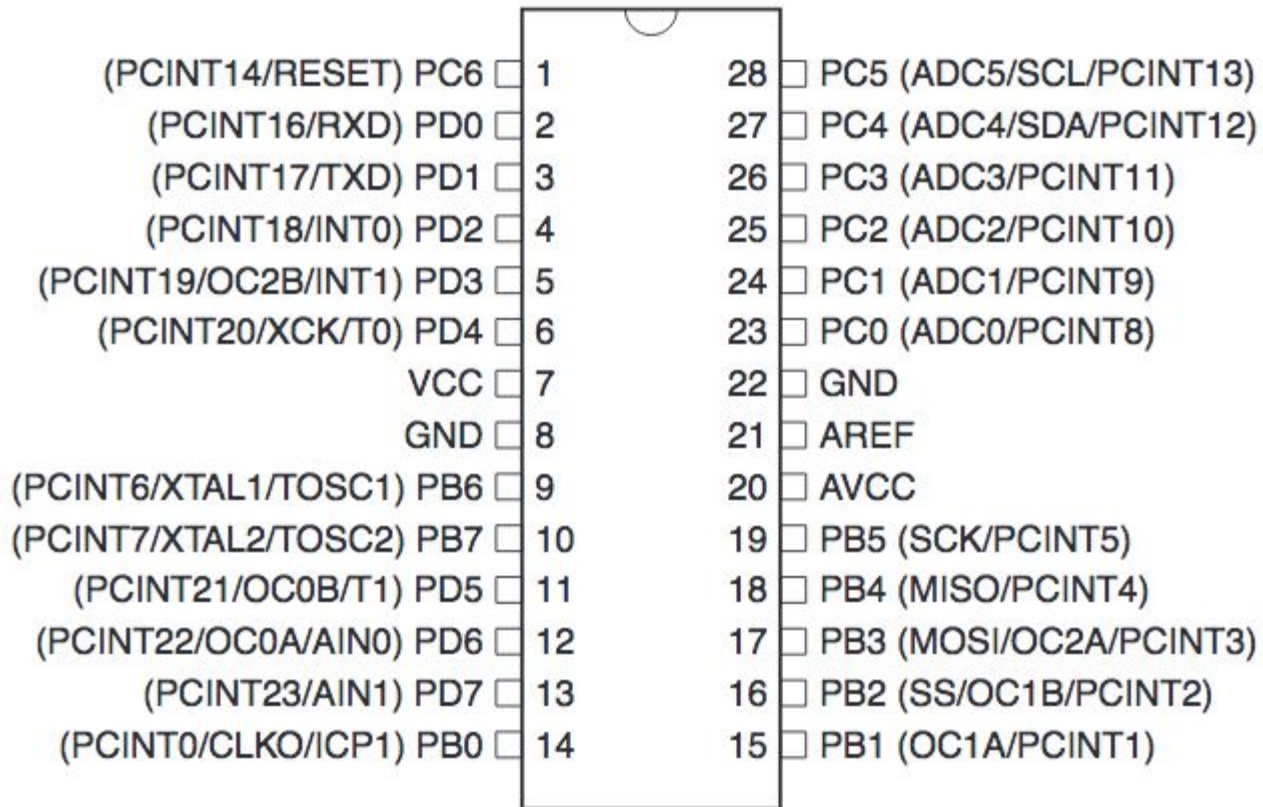
Multiple Functions on Each Pin

Device Pinout, MSP430G2x13 and MSP430G2x53, 28-Pin Devices, TSSOP



NOTE: ADC10 is available on MSP430G2x53 devices only.

Multiple Functions on Each Pin



Features of Modern Microcontrollers

- Some functions available on multiple pins.
- Flash memory for Program storage (1KB to few MB) with lock
- SRAM for data (0 to 10s of KB)
- EEPROM for semi-constants (0 to few KB)

Functions Available on Multiple Pins

Table 16-1. I2C Signals (100LQFP)

Pin Name	Pin Number	Pin Mux / Pin Assignment	Pin Type	Buffer Type ^a	Description
I2C0SCL	72	PB2 (3)	I/O	OD	I ² C module 0 clock. Note that this signal has an active pull-up. The corresponding port pin should not be configured as open drain.
I2C0SDA	73	PB3 (3)	I/O	OD	I ² C module 0 data.
<u>I2C1SCL</u>	34 74	PA6 (3) PG4 (3)	I/O	OD	I ² C module 1 clock. Note that this signal has an active pull-up. The corresponding port pin should not be configured as open drain.
<u>I2C1SDA</u>	35 75	PA7 (3) PG5 (3)	I/O	OD	I ² C module 1 data.
<u>I2C2SCL</u>	36 95	PF6 (3) PE4 (3)	I/O	OD	I ² C module 2 clock. Note that this signal has an active pull-up. The corresponding port pin should not be configured as open drain.
<u>I2C2SDA</u>	58 96	PF7 (3) PE5 (3)	I/O	OD	I ² C module 2 data.
I2C3SCL	1 62	PD0 (3) PG0 (3)	I/O	OD	I ² C module 3 clock. Note that this signal has an active pull-up. The corresponding port pin should not be configured as open drain.

Features of Modern Microcontrollers

- Interrupt on Pin Change on all/most pins
- Internal and external clock sources. Internal RC clock w/ trimming
- Clock scalability
- Multiple Vcc domains
- Low operating current (from 1mA/MHz to 0.1 mA/MHz)

Features of Modern Microcontrollers

- Operating modes: active, sleep, power down
- Wide V_{cc} range (0.9V to 6V)
- Multiple Reset sources: POR, User, BOD, Watchdog
- Watchdog timer with independent clock
- BOD with programmable threshold

Features of Modern Microcontrollers

- Mixed signal capability – SAR/Dual-slope/Delta-Sigma ADC with resolution of 8 to 16 bits
- Mixed signal capability – hardware DAC or through PWM
- Mixed signal requirement – Independent Analog & Digital Vcc
- Timer and Counter: 8, 16-bits.
- High frequency PWM with various options (dead zone etc.)

Features of Modern Microcontrollers

- General Purpose Communication: UART, SPI, I2C, 1-wire
- Specialized Communication: CAN, LIN, Ethernet, USB (device, OTG, Host), WiFi, Bluetooth, BLE, RF
- Special function: floating point unit, encryption unit, hardware accelerator
- In System Programming and In Application Programming
- On Chip Debug
- JTAG
- DMA capability on needed peripherals

Application Development Tools

- Development platform (usually a PC these days)
- Assembler (cross-assembler), Compiler (cross-compiler)
- Simulator/debugger
- Evaluation board
- Program Download tool (ISP, or Bootloader)
- Emulator and/or On Chip Debugger (OCD)

System Development Tools

- Circuit prototyping facility
- Schematic capture and PCB layout CAD tools
- Circuit Soldering (POC, final versions) facility
- Microscope/Magnifier
- Oscilloscope, Logic Analyzer, Mixed Signal Oscilloscope
- DMM, LCR bridge
- Bench power supply



Elements of Microcontroller Ecosystem

“Roti, Kapda, Makaan and Internet” for a Microcontroller! (Essential Elements for Survival)

- Clock
- Reset
- Power Supply
- Program Download Capability

The Clock Subsystem!

- Why do we need Clock?
- What Should be the Clock Frequency?
- Implications of Clock Frequency Value?
- What Topology for the Clock Generator?
- Desirable Features for the Clock Generator?
- RTC Clock?
- Clock Frequency Stabilization: TCXO, Temperature Sensor + Varactor diode in parallel to Crystal.

Lecture - 3 Summary

- Expected Functions From a Microcontroller
- Salient features of modern Microcontrollers
- Elements of Microcontroller ecosystem



Thank you!