



CONTINUING  
EDUCATION **CENTER**

# MCU-based IoT Designs: Analog and Linear Peripherals

## Class 1: An Introduction to MCU-Based IoT Designs

3/13/2017

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# This Week's Agenda

- 3/13/17 An Introduction to MCU IoT Designs
- 3/14/17 A to D Conversion for MCU IoT Designs
- 3/15/17 D to A Conversion for MCU IoT Designs
- 3/16/17 Analog Support for MCU IoT Designs
- 3/17/17 Analog Front Ends (AFEs)

# Course Description

- MCUs provide the foundation on which the IoT is being created and at some point the digital Microcontroller world needs to meet the real analog world.
- Whether with analog sensors, coils for mechanical actuators or motors, high temperature thermocouples or simple battery level detectors connecting to the analog world is required.
- This course is an overview of the many types of analog and linear peripherals available for IoT applications, and quick description of the most common peripherals.
- Some specialized analog elements will also be included. Some example implementations will provide a 'hands-on' element for the course.

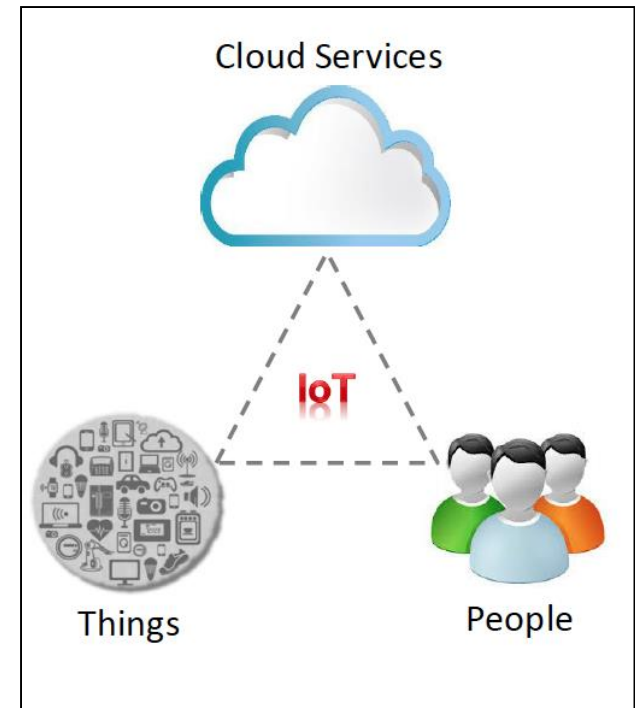
# Today's Topics

MCUs are the bricks on which the IoT is being built. This class will provide the background needed to understand why MCUs are used and how common IoT functions are implemented.

- What is the IoT?
- Review of MCU peripherals (Context)
- Types of analog and Linear peripherals
- What are analog and Linear peripherals used for in the IoT?
- What types of applications are important to you?

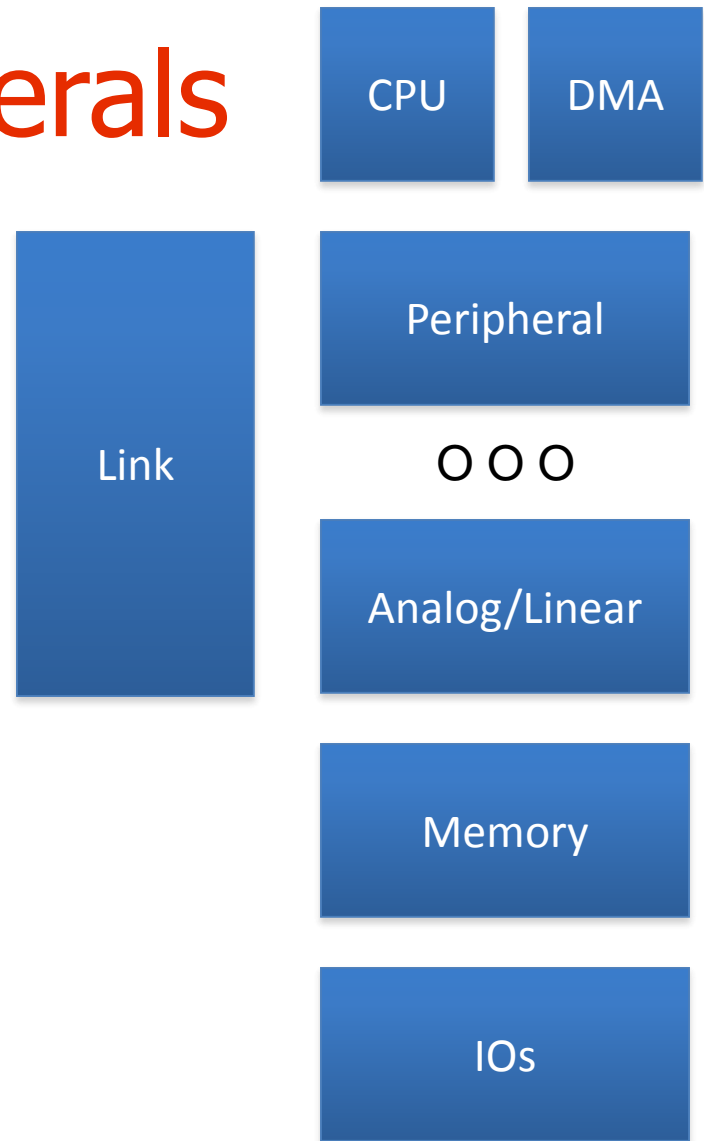
# What is the IoT?

- Things, people and cloud services getting connected via the Internet to enable new applications and business models
- Different from M2M
- Enabling technology- not a market



# MCU Peripherals

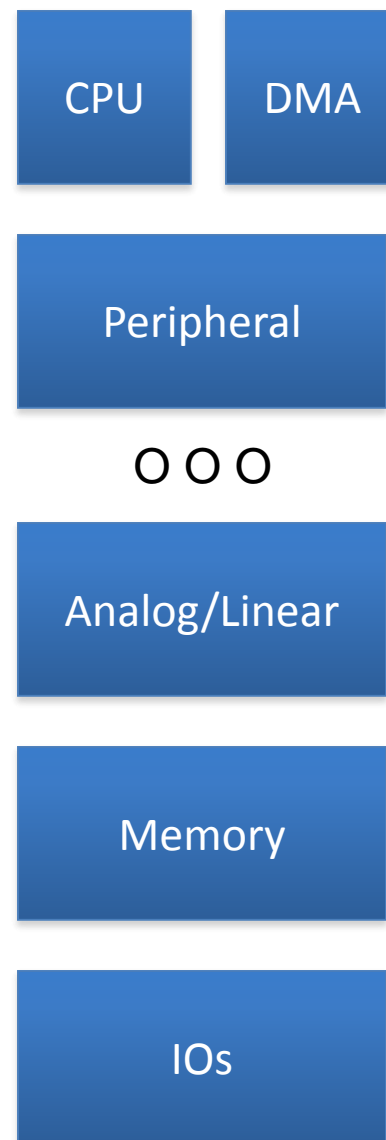
- What do they do and how do they work with other MCU modules?
- Peripherals- specialized functions for digital and analog
- CPU
  - Interrupts, Direct control
- Memory
  - General purpose DMA
  - Peripheral specific DMA
  - Internal FIFO or buffers
- Peripheral linking
- IOs



# CPU and Peripherals

How does the CPU Interact with the peripheral?

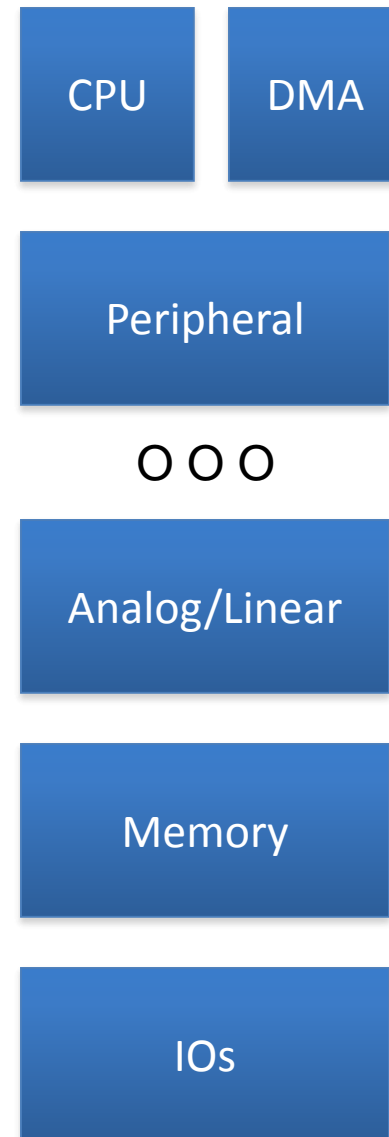
- Configuration
- Initialization
- Status and Control
- Interrupts
- DMA configuration/Initialization
- Low Power Modes
- IOs
  - Special output signals (CS Enables, CTS, RTS, etc.)



# Interrupts

## Peripherals and Interrupts

- Let the CPU do something else
  - Low Power Mode (Sleep)
  - Computation, staged processing
- Types of Interrupts
  - Exception handling
  - Buffer management
  - Task complete, Task needed
  - Wake-up
  - Non-CPU Interrupts
- Interrupt Identification

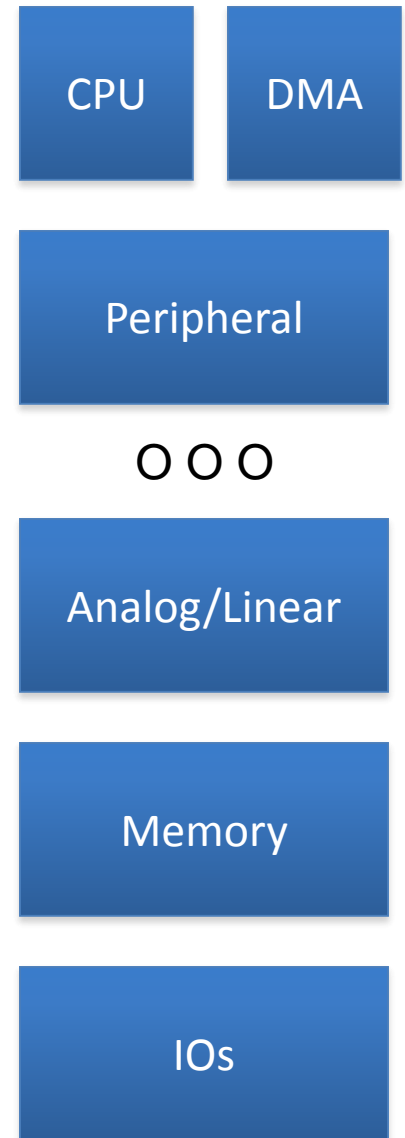




# Memory and Peripherals

## DMA

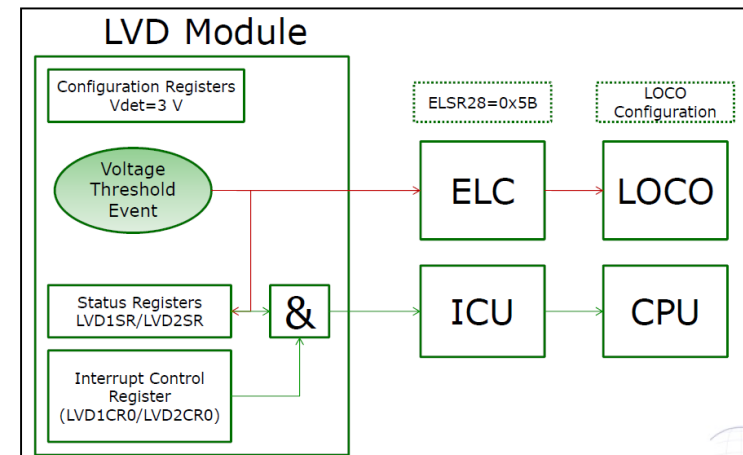
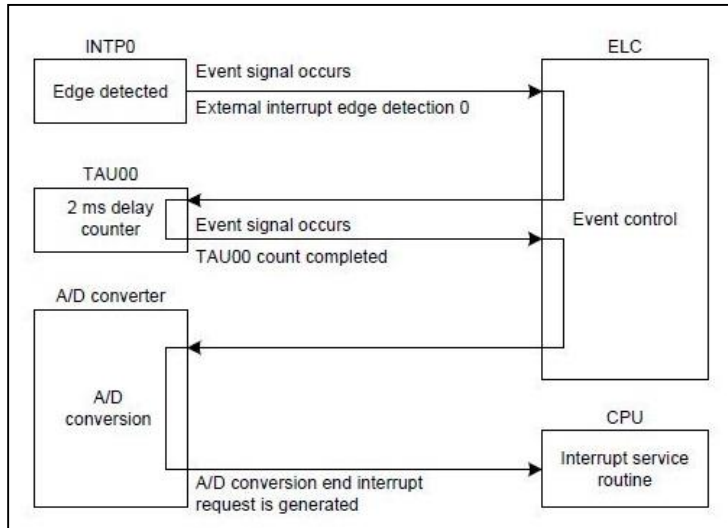
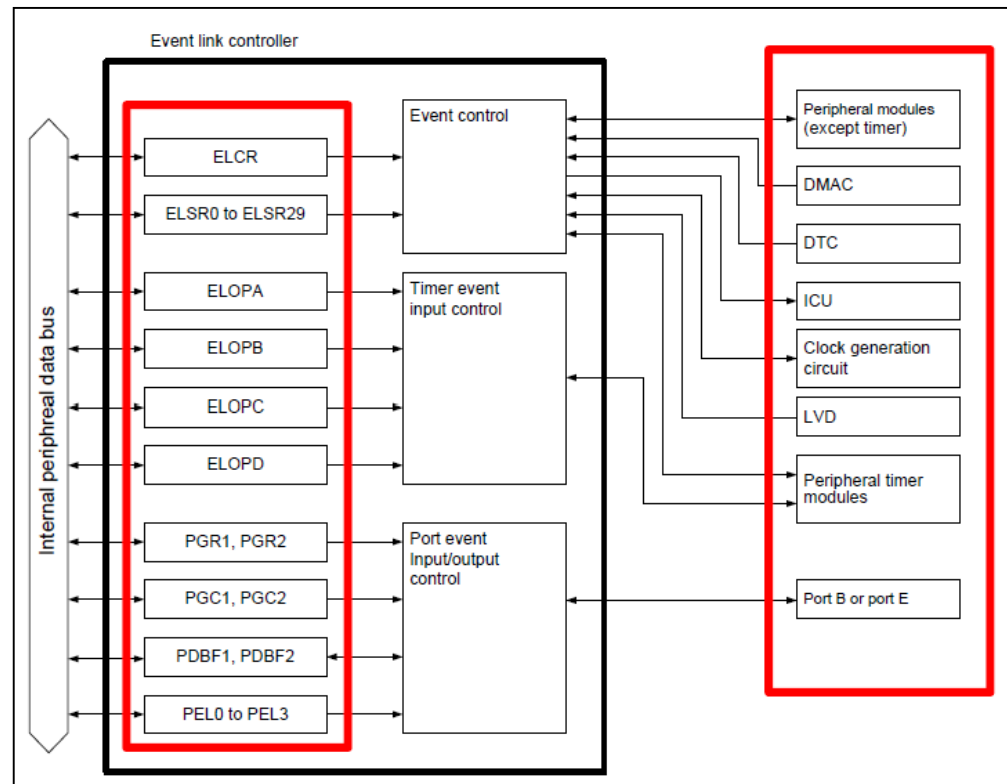
- Transfer data to/from Memory
- Complex buffer organization
- Priority of transfer
- Error Handling
- Power efficiency
- When not to use?
- General DMA vs Peripheral DMA
- Peripheral to Peripheral transfers?
- Bus architecture and bandwidth



# Event Linking

## Directly Link Peripherals

- Different names...
- CPU-less operation
- Low to medium complexity tasks



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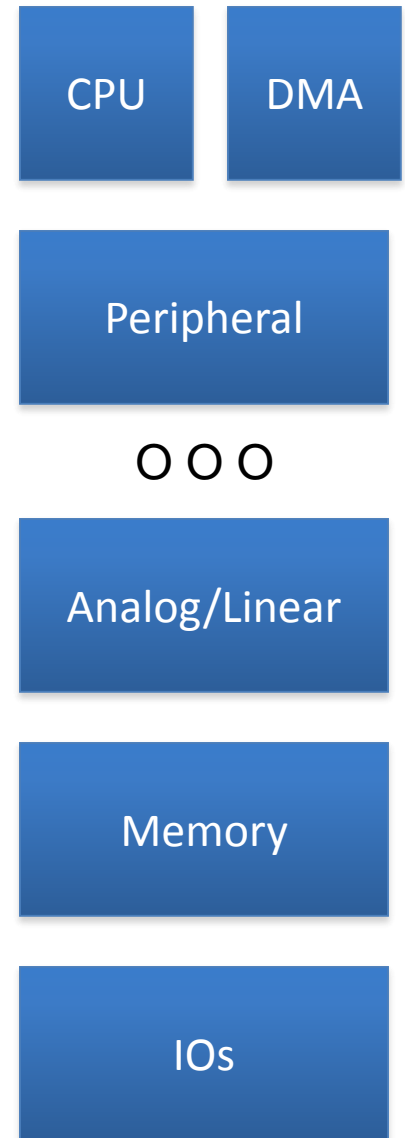
# Peripherals and IOs

## The I/O Resource Issue

- How many IOs do you need?
- How many do you have?
- How many peripheral IOs do you need?
- Are the IO locations in conflict?
- How do you figure this out?

## Peripheral Pin Select (many names)

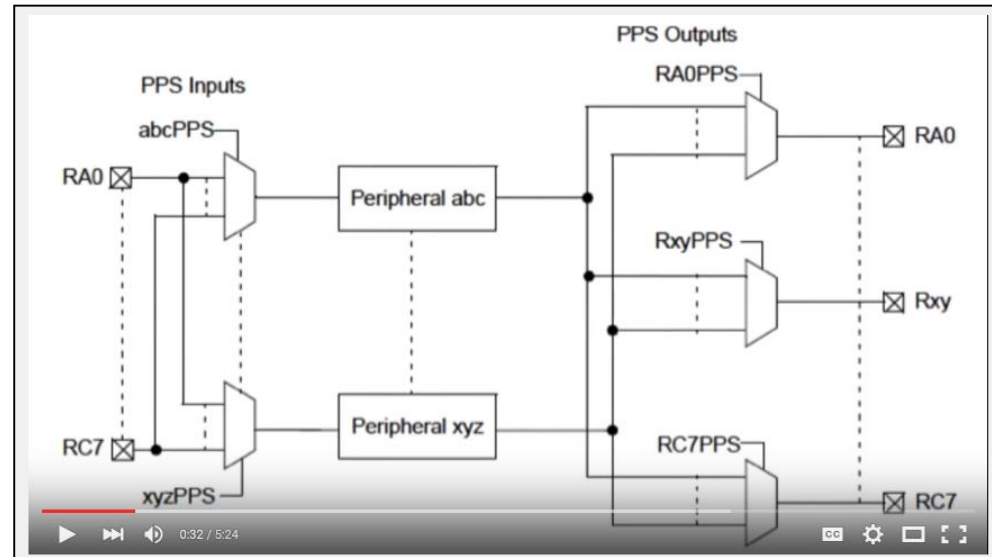
- Select the IO pin for peripheral IO signals



# PIC Pin Select

## Peripheral Pin Select

- Assign MCU pins to peripheral IO signals
- Inputs
- Outputs
- Easy for small pin count devices
- Too complex for large devices
- Other approaches
  - Pin muxing
  - Pin selection



xxxPPS: Peripheral xxx Input Selection Register

U-0	U-0	U-0	R/W-q/u	R/W-q/u	R/W-q/u	R/W-q/u	R/W-q/u
—	—	—	xxxPPS<4:0>				—
bit 7			1	0	1	0	1 bit 0

bit 4:0 xxxPPS<4:0>: Peripheral xxx Input Selection bits  
11xxx = Reserved. Do not use.

- 10111 = Peripheral input is RC7
- 10110 = Peripheral input is RC6
- 10101 = Peripheral input is RC5
- 10100 = Peripheral input is RC4
- 10011 = Peripheral input is RC3
- 10010 = Peripheral input is RC2
- 10001 = Peripheral input is RC1
- 10000 = Peripheral input is RC0

- 01111 = Peripheral input is RB7
- 01110 = Peripheral input is RB6
- 01101 = Peripheral input is RB5
- 01100 = Peripheral input is RB4

RxyPPS: Pin Rxy Output Source Selection Register

U-0	U-0	U-0	R/W-0/u	R/W-0/u	R/W-0/u	R/W-0/u	R/W-0/u
—	—	—	RxyPPS<4:0>				—
bit 7							bit 0

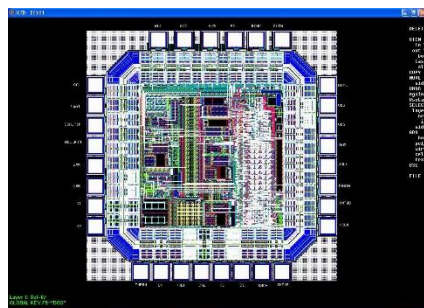
<https://www.youtube.com/watch?v=tf2SfSm6fQg>

Presented by:

# Types of Peripherals

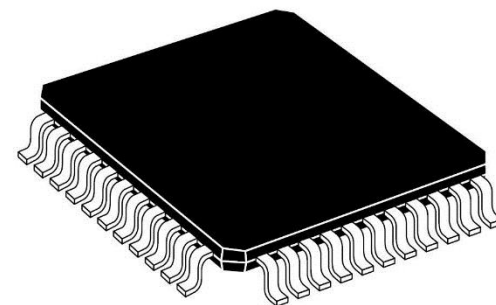
## Internal

- Timers (GPT, WDT, RTC, etc.)
- Accelerators (CRC, Crypto, etc.)
- Interrupt Controller
- Interconnect Matrix
- Power control
- Event Link
- Etc.



## External

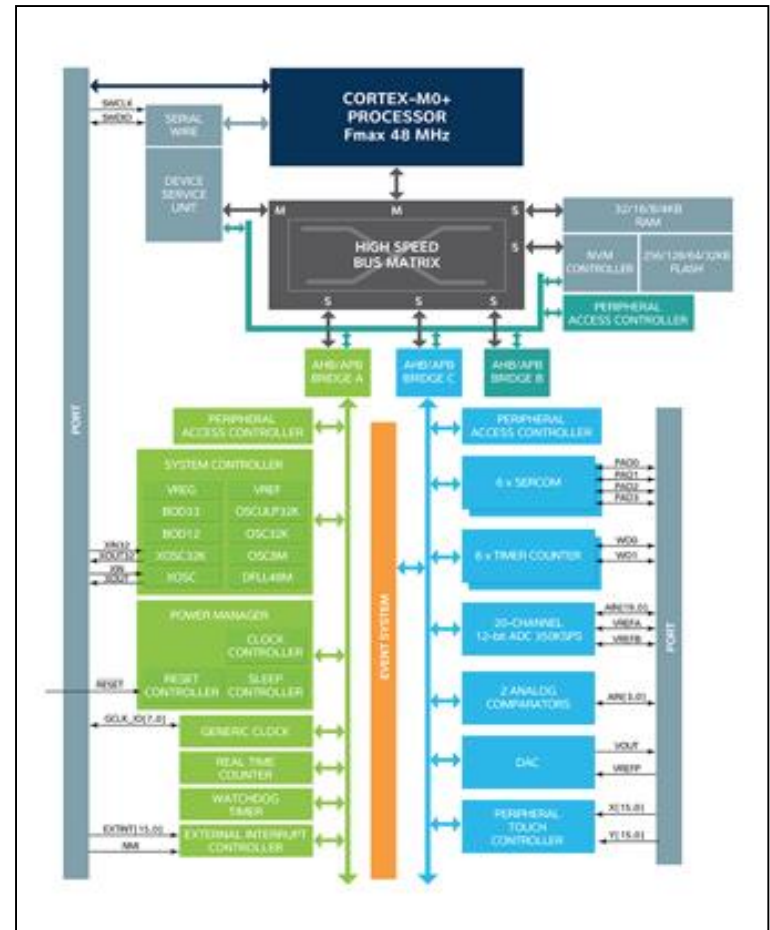
- Serial Interface (I2C, SPI, etc.)
- Analog (DAC, ADC, LVD, etc.)
- Memory Interface (SRAM, Flash, etc.)
- HMI (LCD, Touch, Keypad, etc.)
- Debug
- Etc.



# Analog and Linear Peripherals

What are the common Analog and Linear Peripherals for IoT designs?

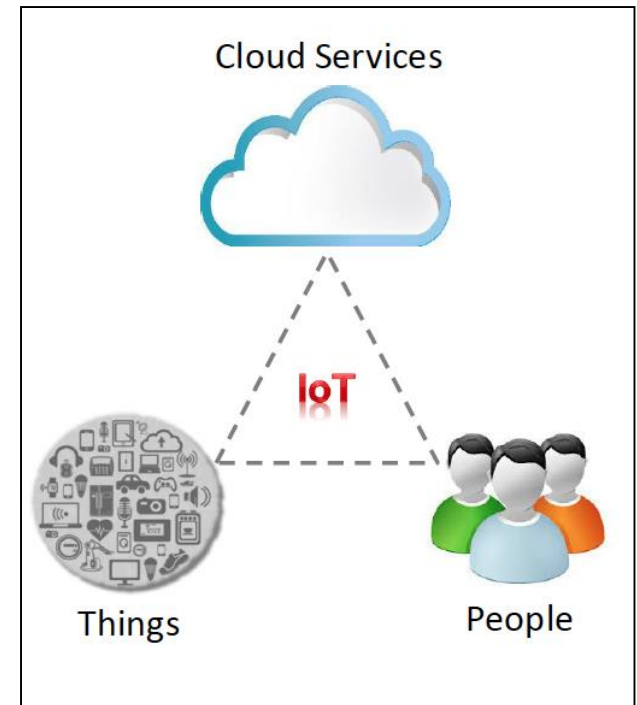
- D to A Conversion
- A to D Conversion
- Low Voltage Detection
- High Speed Analog Comparators
- Touch Controllers



# Analog and Linear For IoT Designs

## Key Applications

- Connecting to the 'real world'
  - A to D Conversion
  - D to A conversion
- Low power operation
- Battery operation
- High speed analog signal sensing
- Digital signal synthesis
- Energy Harvesting
- Etc...



# Course Resources (Product Training Modules)

Digital to Analog Converters:

- <http://www.digikey.com/en/ptm/r/renesas-electronics-america/digital-to-analog-converter-part-1>
- <http://www.digikey.com/en/ptm/r/renesas-electronics-america/digital-to-analog-converter-part-2>
- [Concerto Analog Sub-system: http://www.digikey.com/en/ptm/t/texas-instruments/microcontrollers-concerto-training-topic-5-the-analog-sub-system](http://www.digikey.com/en/ptm/t/texas-instruments/microcontrollers-concerto-training-topic-5-the-analog-sub-system)

PSoC Analog Co-processor:

- <http://www.digikey.com/en/ptm/c/cypress/psoc-analog-coprocessor>

Peripheral Devices:

- [Maxim ADC http://www.digikey.com/en/product-highlight/m/maxim-integrated/max11410-24-bit-multi-channel-low-power-adc](http://www.digikey.com/en/product-highlight/m/maxim-integrated/max11410-24-bit-multi-channel-low-power-adc)



# Course Resources (MCUs)

- Atmel <http://www.digikey.com/en/product-highlight/a/atmel/sam-v-microcontrollers>
- Microchip <http://www.digikey.com/en/product-highlight/m/microchip-technology/pic32mm-mcu-family>
- Renesas RL78 <http://www.digikey.com/product-detail/en/renesas-electronics-america/YRDKRL78G13/YRDKRL78G13-ND/2796058>
- Texas Instruments <http://www.digikey.com/product-detail/en/texas-instruments/MSP-EXP430G2/296-27570-ND/2331789>

# Course Resources (Development Kits)

- PIC32M <http://www.digikey.com/product-detail/en/microchip-technology/DM240001/DM240001-ND/957553>
- TI Launchpad <http://www.digikey.com/product-detail/en/texas-instruments/LAUNCHXL-CC1310/296-44201-ND/6050667>

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