低功耗微控制器應用設計探討

MICROCHIP

A Leading Provider of Smart, Connected and Secure Embedded Control Solutions

SMART | CONNECTED | SECURE

May 2023

Agenda

- Low Power MCU’s contribution for sustainability
- MCU Power Consumption Fundamentals
- MCU Power Management
- Intelligent Peripherals
- Application System Level Considerations
- Power Debugger Tools

Low Power MCU's contribution for sustainability

- **Help reduce energy usage**
  - Reduce the need for non-renewable energy sources such as fossil fuels, and reduces air pollution
- **Battery life**
  - Reduces the negative impact of waste batteries on the environment
- **IoT can help monitor and control energy usage**
  - Reduce the need for non-renewable energy sources and promotes sustainable energy use

Green Design to Save the Planet

M

請問電子產品設計時, 如果減少1mW耗電時, 可以降低多少的二氧化碳排放量? 相當於要種幾棵樹才能消耗? 假設該電子產品生產了1萬個, 每日約使用8小時, 然後產品壽命為3年.

要回答這個問題需要考慮多個因素，如產品的使用壽命、使用頻率、產品使用對象、產品生產方式、產品使用時的能源來源等等。以下提供一些大致的估算，但請注意這些數字僅供參考。

減少1mW耗電對應的碳排放減少量：

根據美國能源信息署 (EIA) 提供的資料，每千瓦時的發電在美國平均會釋放約1.22磅的二氧化碳。因此，如果減少1mW的耗電量，每個產品每天使用8小時，壽命為3年，可以減少的碳排放量約為：

1mW × 8小時 × 365天 × 3年 × 1萬個 × 1.22磅/千瓦時 ÷ 1000瓦/千瓦 ≈ 84.2磅二氧化碳

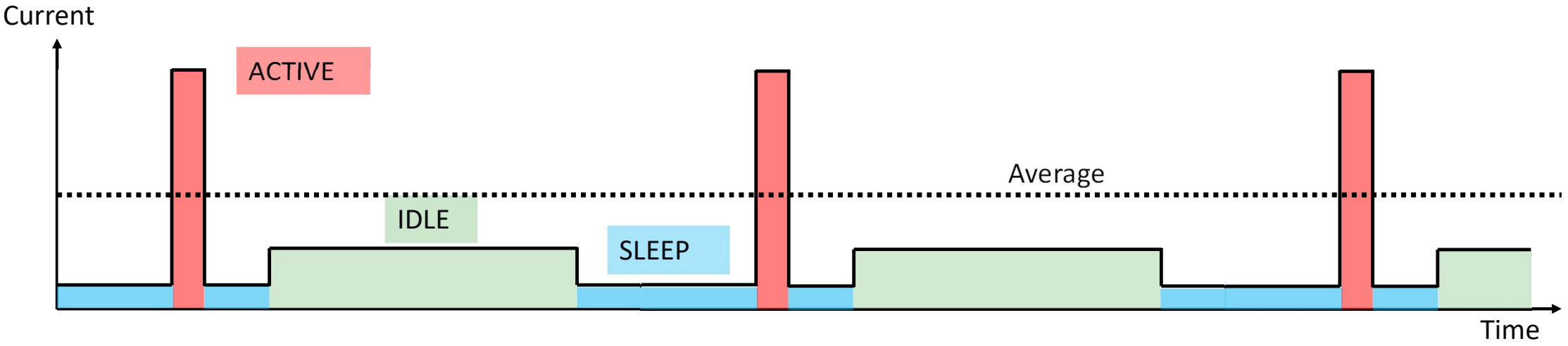
種植一棵樹可以抵銷的碳排放量因樹種、生長地點、生長年限等因素而異。一般認為，在20年左右的生長期內，一棵成年的樹可以抵銷約50磅的二氧化碳排放量。因此，減少1mW的耗電量相當於種植：

84.2磅二氧化碳 ÷ 50磅二氧化碳/棵 ≈ 1.68棵樹

MCU Power Consumption Fundamentals

Instantaneous & Average Currents

- **Device current is a function of both static and dynamic current**
- **Instantaneous – current being drawn by the MCU**
- **Average – <u>weighted</u> average of instantaneous currents**
  - Weighting is based on the duty cycle of the mode of operation
  - Required quantity for calculations like “estimated battery life”



Instantaneous & Average Current cont…

- How do different currents levels affect average current?

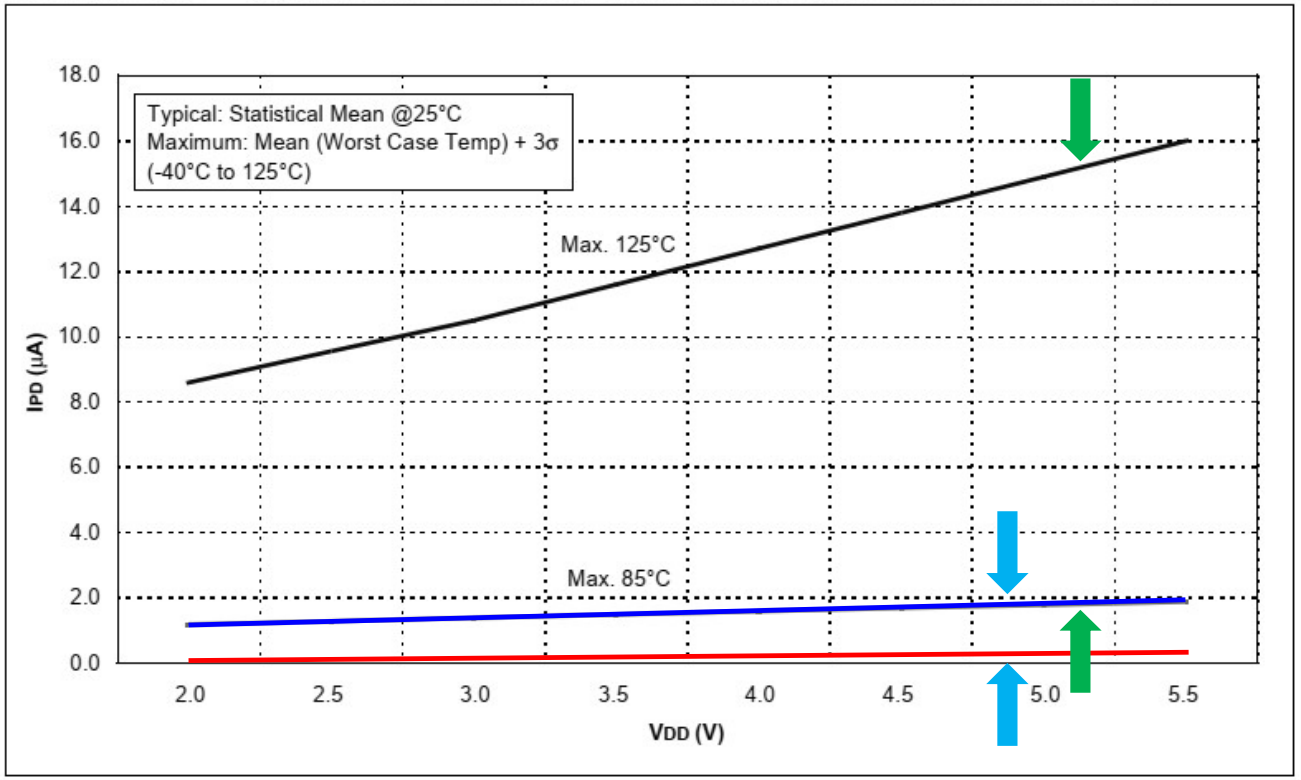
Active Current	Active Duty Cycle	Static Current	Static Duty Cycle	Average Current
5 mA	1%	10 uA	99%	59.9 uA
2.5 mA	**1%**	**10 uA**	**99%**	**34.9 uA**
50% reduction in active current; 47% reduction in average current				
2.5 mA	**1%**	**5 uA**	**99%**	**29.95 uA**
50% reduction in static current, 14% reduction in average current				

Understanding the different contributors to power consumption is key to managing power

Temperature - Static Current

- **Temperature as a large effect on the static current**
- **PIC16F684 Quiescent current (Ipd) shown**
  - 1st current delta is ~2uA over 60C
  - 2nd current delta is ~13uA over 40C

FIGURE 16-14: MAXIMUM IPD vs. VDD (SLEEP MODE, ALL PERIPHERALS DISABLED)



MCU Power Management

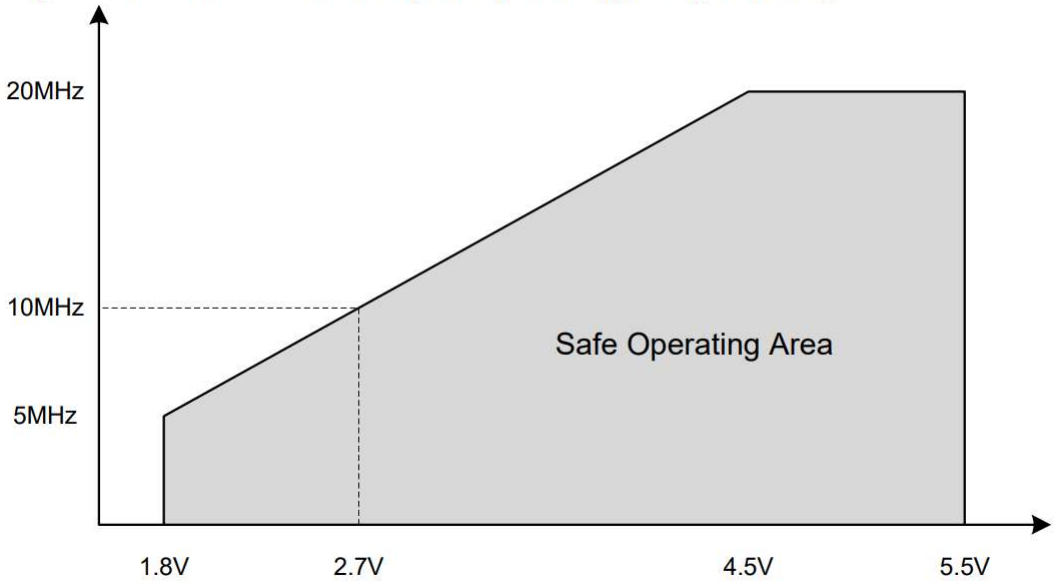
Voltage

Voltage Considerations

- **Performance can scale with supply voltage**

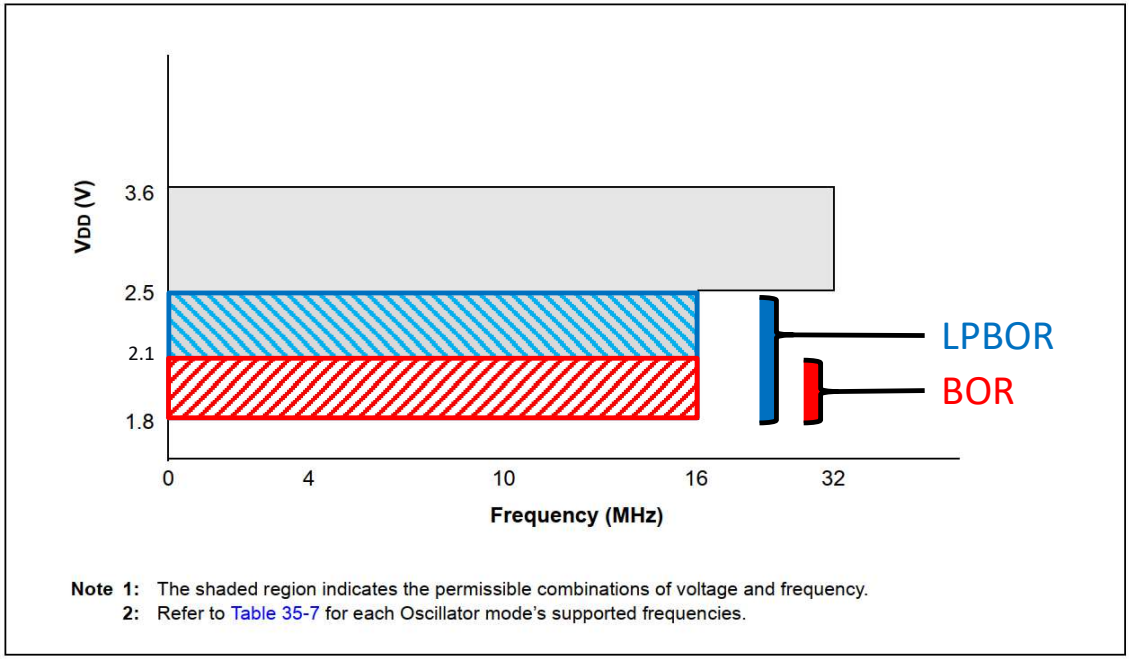
ATmega4809

Figure 4-1. Maximum Frequency vs. V_{DD} for [-40, 105]°C



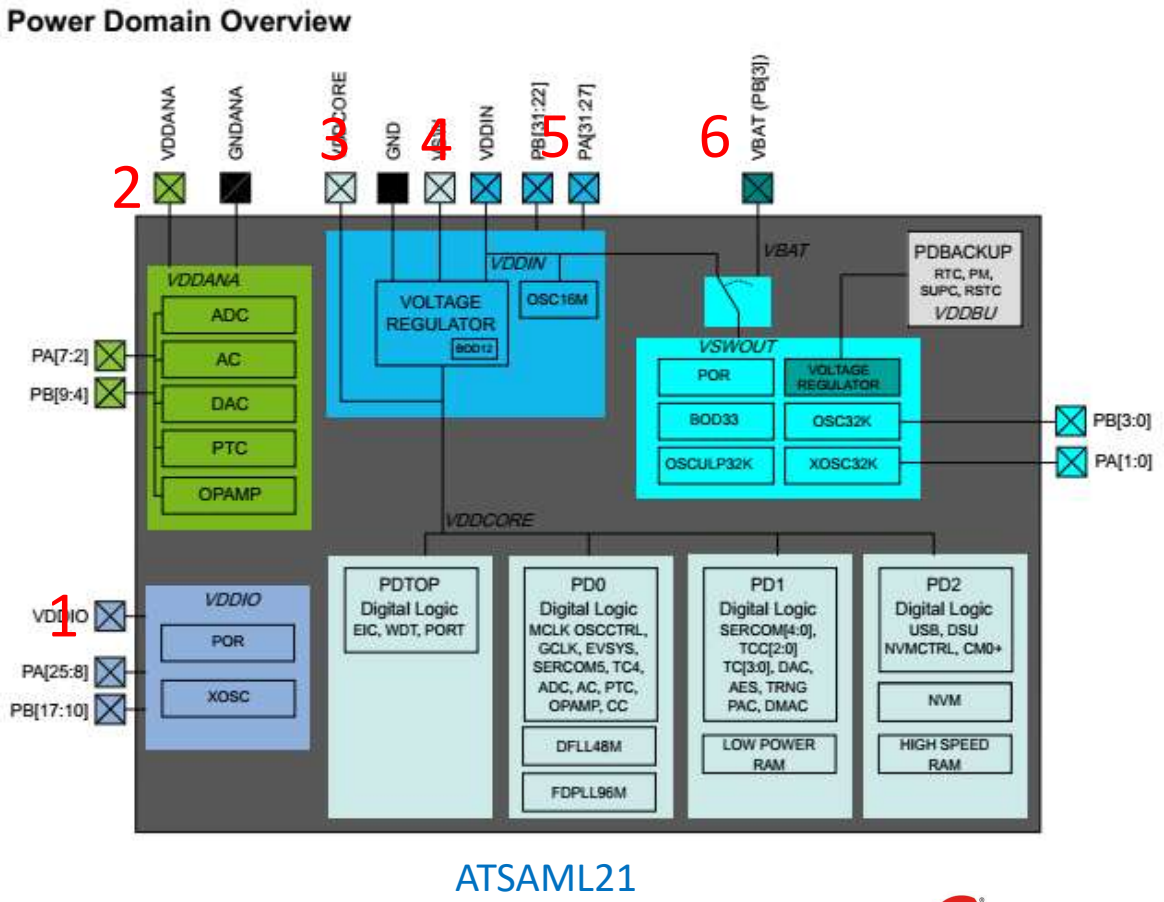
- **Supervisors can affect minimum voltage requirements**

PIC16LF18325



Regulated Devices

- **How many voltage domains of the device?**
  - May have unregulated (HV) and regulated sections (LV)
  - May have multiple domains for analog,
    USB regulator and xcvr
- **Which modules are on which domain?**
- **What is the power supply for each domain?**

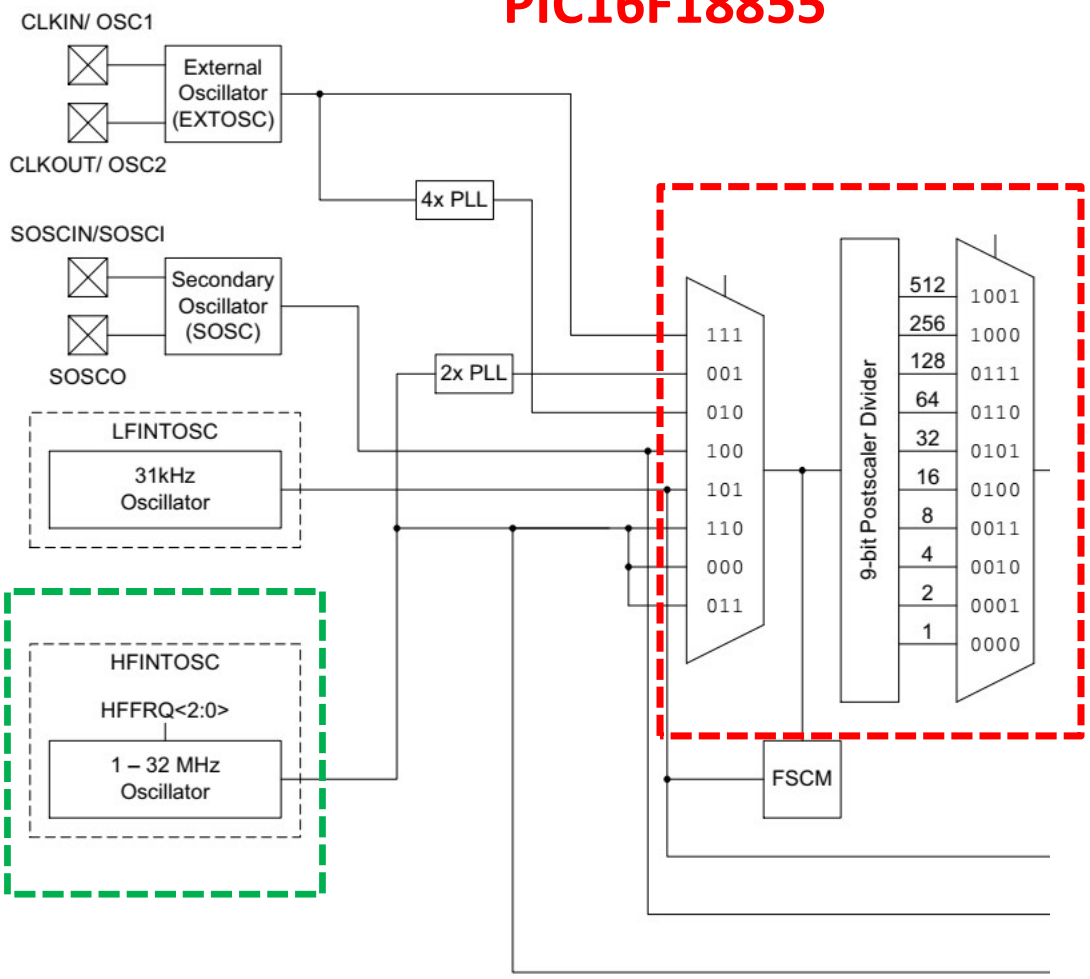


ATSAML21

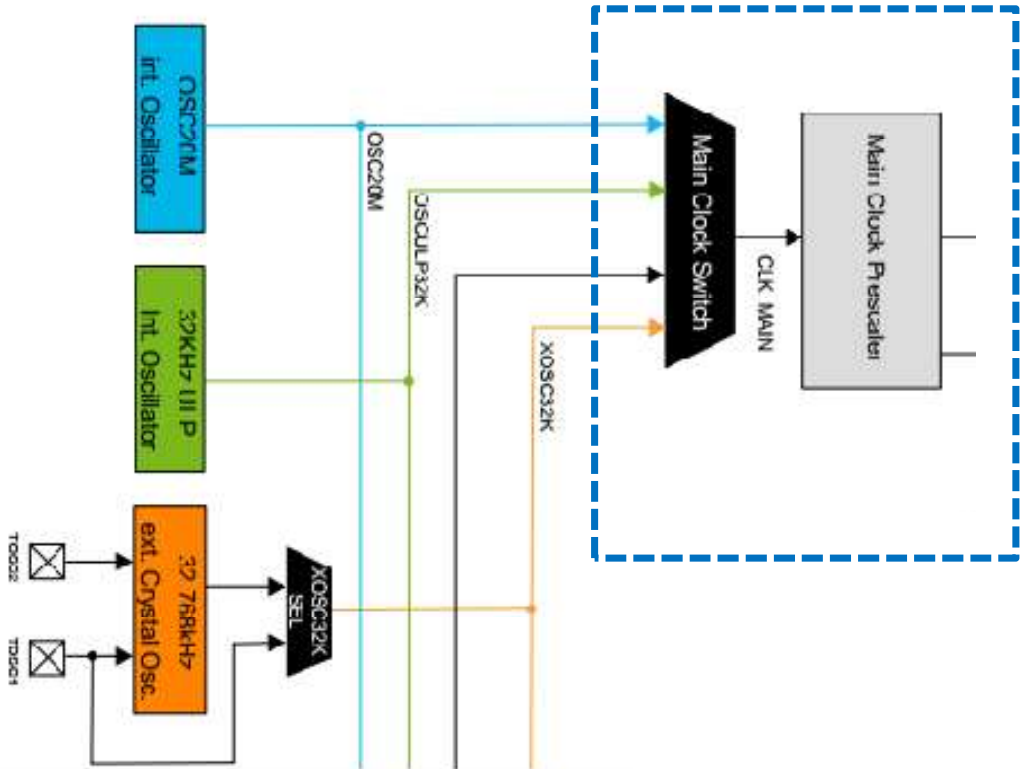
Clocks

Clock Generation - PIC and AVR devices

PIC16F18855



ATTiny817



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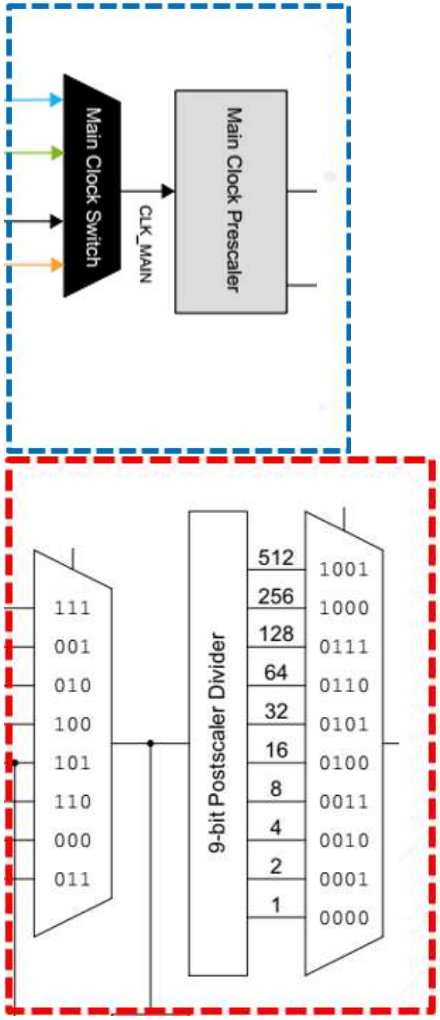
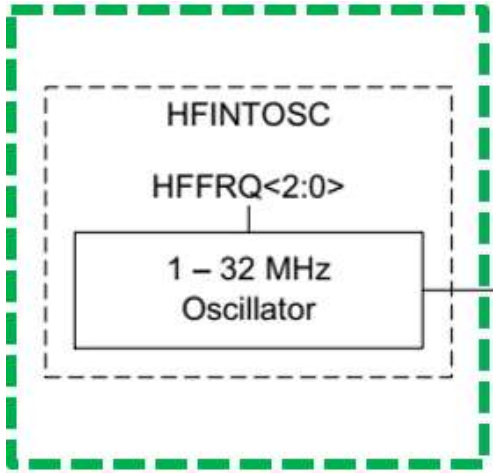
Clock Switching - PIC and AVR devices



- **Main Clock Switch Mux**
  - Allows software control over desired clock source
  - Choose lowest power clock source needed
- **Clock Post-scaler**
  - Allows clock source to be divided up to 1:512
  - Select lowest available frequency needed
  - Does not alter power consumption of the clock source, only the clock consumers
- **Issues to be aware of:**
  - Changing CPU clock frequency also changes peripheral frequency for those on the same clock
    - Baud rate generator
    - PWM output

Clock Switching - PIC and AVR devices cont…



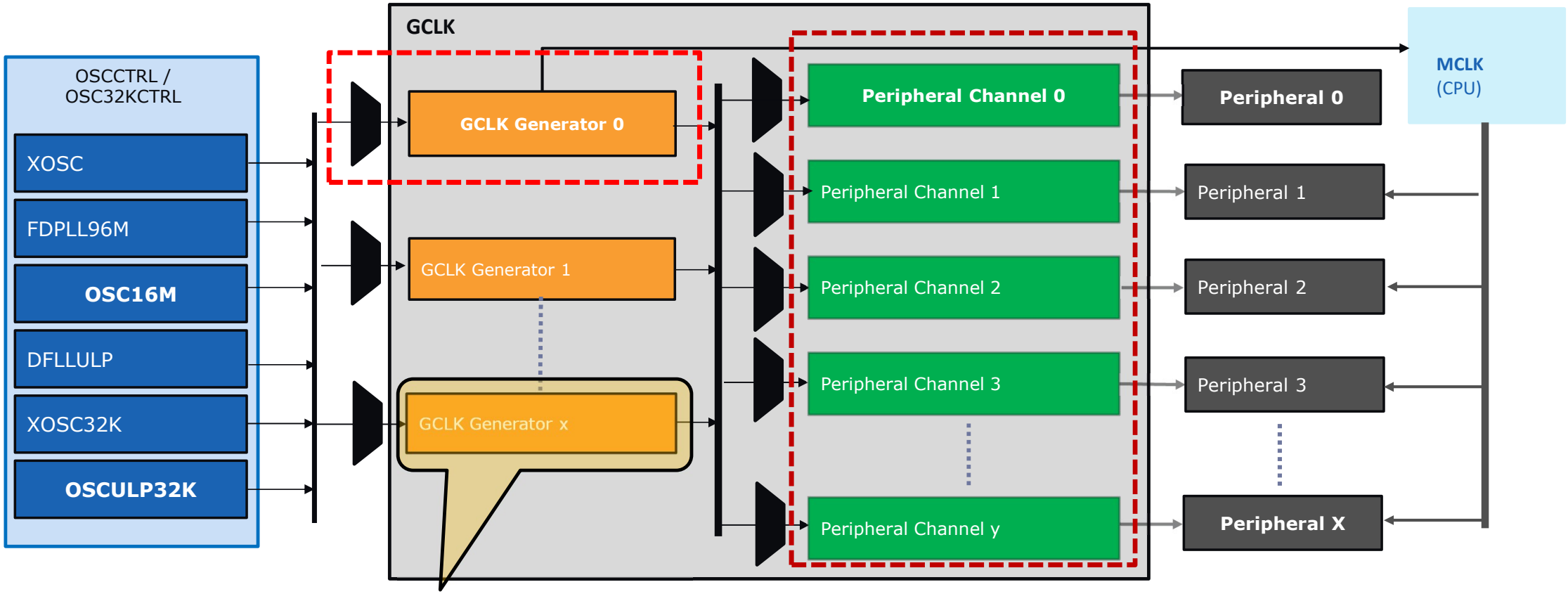
Oscillator Frequency Selection

- Allows the base frequency of the oscillator to be altered.
  - Changes the current consumption of the clock source
- E.g. on the PIC16F18855, frequency options are:
  - 1, 2, 4, 8, 12, 16, 32 MHz

Issues to be aware of:

- Frequency accuracy can degrade at lower frequencies
- Same warning as clock switching about new target frequency
  - Now affects modules that have selected the internal oscillator as a clock source

Clock Generation - SAM devices



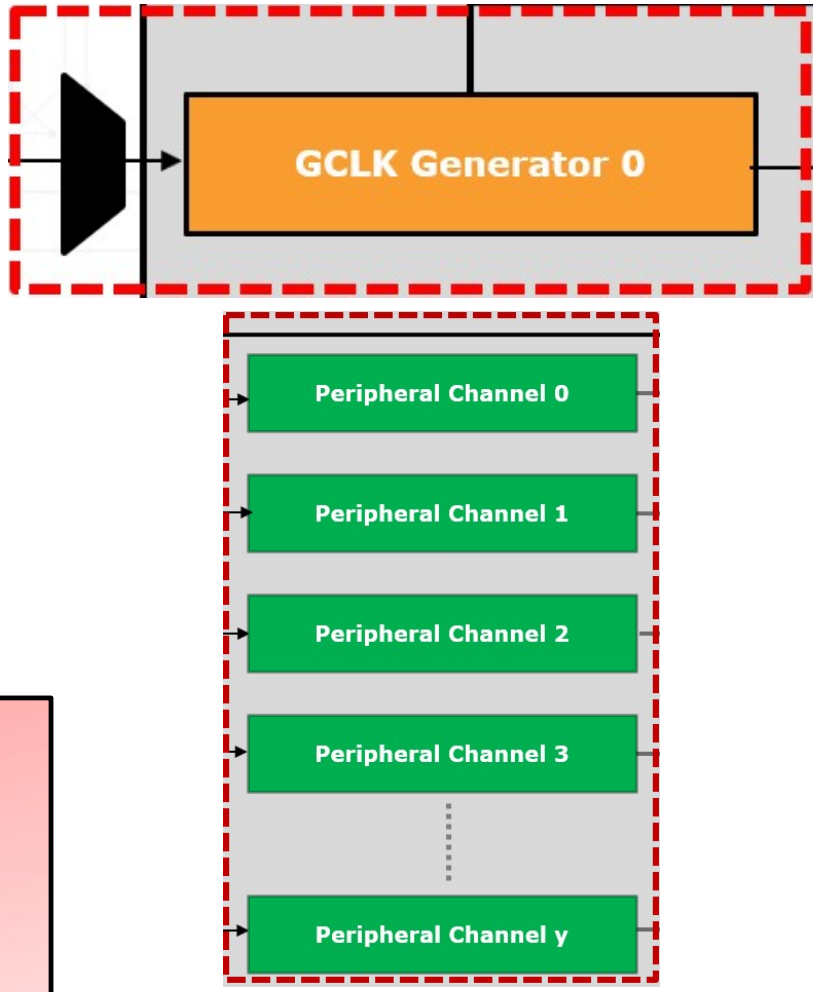
Clock Generator isolates peripherals from their sources for frequency generation

SAM Clock Control

- **Clock Generator (GCLK)**
  - Input Mux provides clock switching
  - Clock Generator provide clock divider

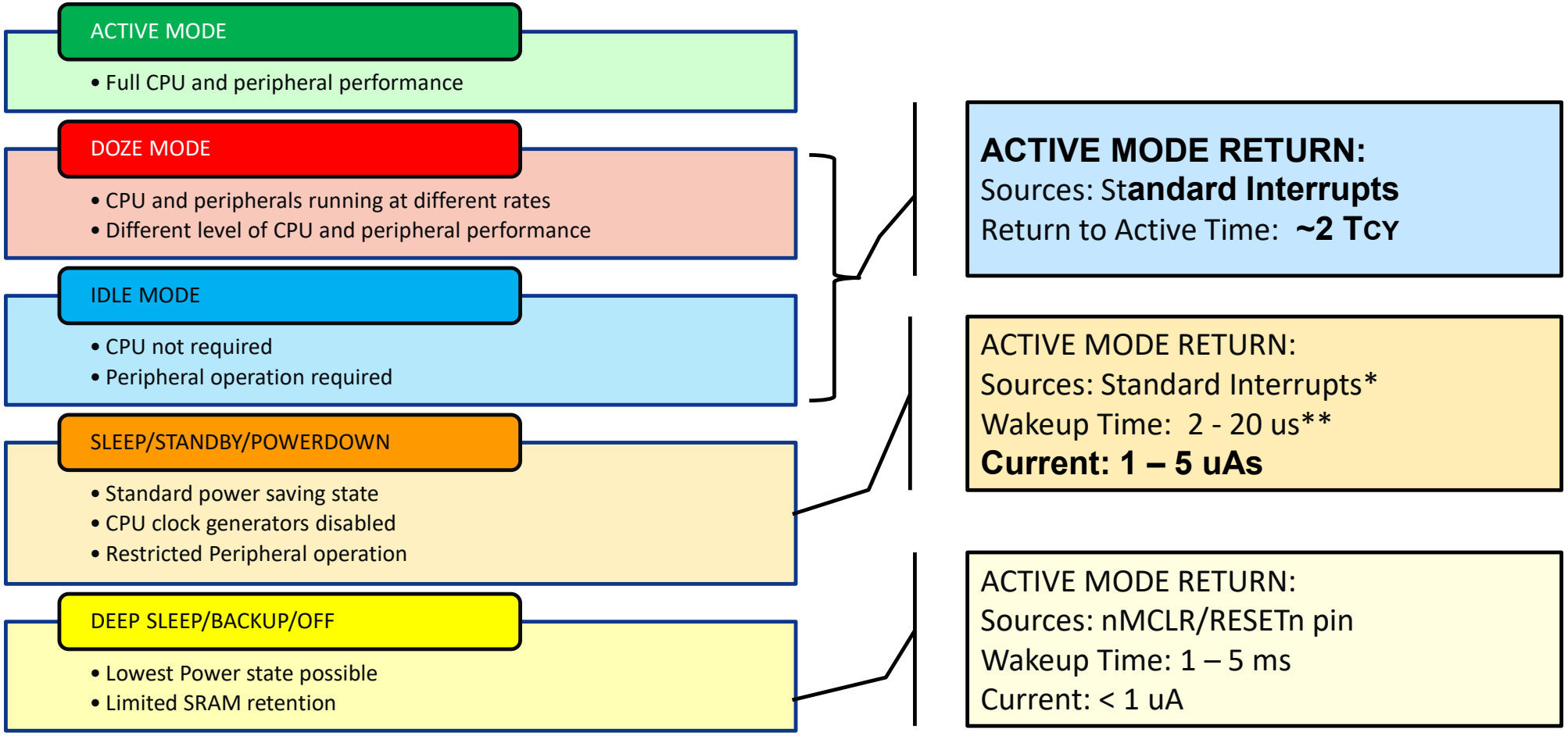
- **Peripheral Channel Enables**
  - Select GCLK source
  - Enables clocks to module

- **Peripheral Module Disable (PMD)**
  - PIC based peripheral clock management tool
  - PMD disables the clock interface to a peripheral module



Power Modes

Power Modes



Intelligent Peripherals

Intelligent Peripherals

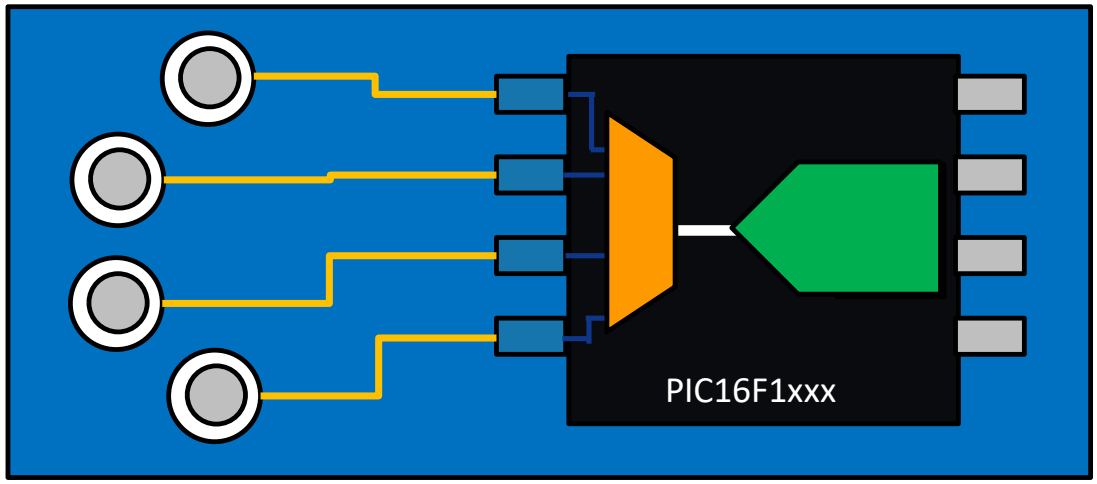
- **The less the CPU is required to manage the overall operation of an MCU, the lower the power consumption of that MCU.**

- **Intelligent Peripherals can reduce the CPU load in an application**
  - a.k.a. Core Independent Peripherals (C.I.P.s)
  - Classic example?

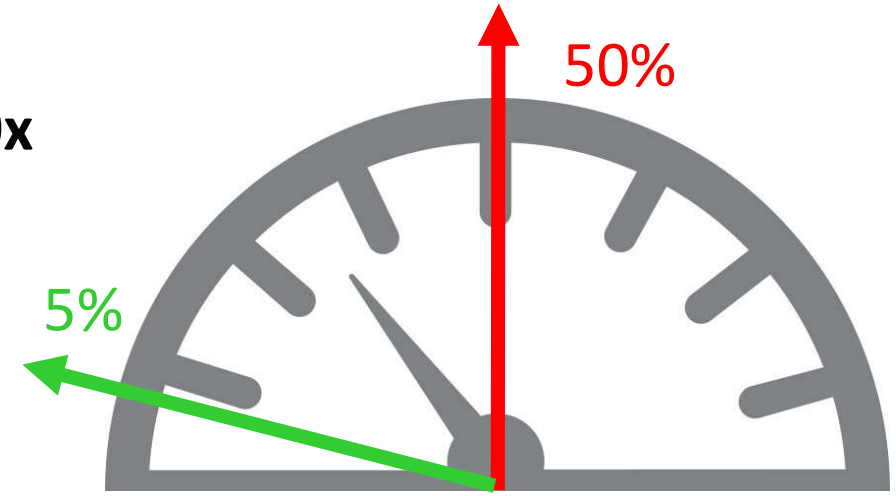
- **Principal can be extended to any peripheral**

C.I.P. Examples - Touch

- **Initial mTouch® algorithm**
  - 4 buttons
  - **ADC** only
    - No hardware acceleration
  - High frequency (8MHz) to make timing
  - Blocking operation



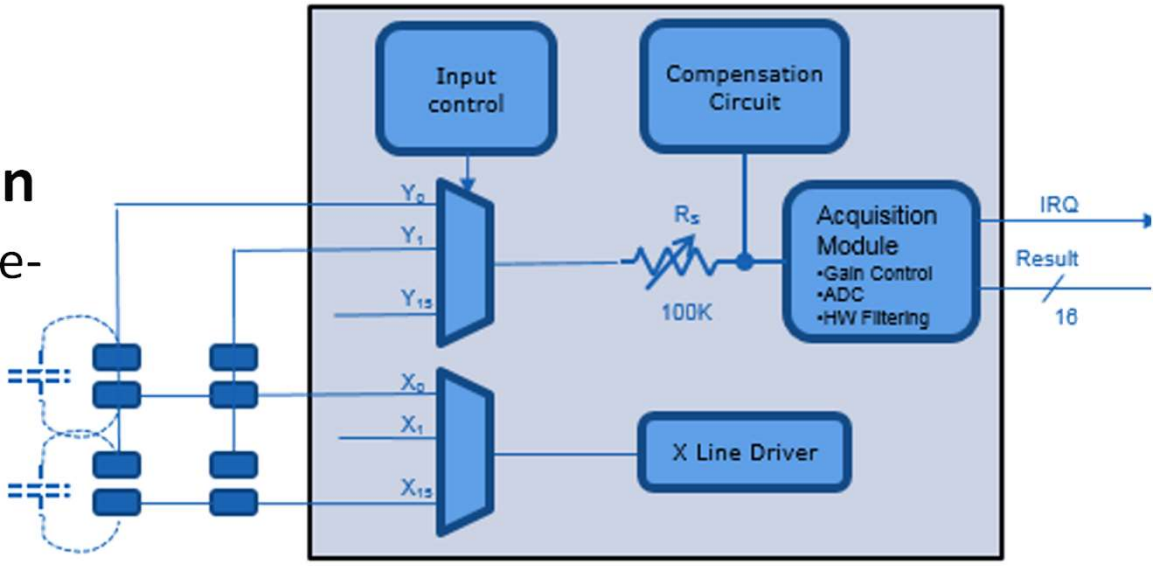
- **ADCC reduced CPU load by a factor of 10x**
  - Automated signal acquisition
  - Interrupt (non-blocking) behavior



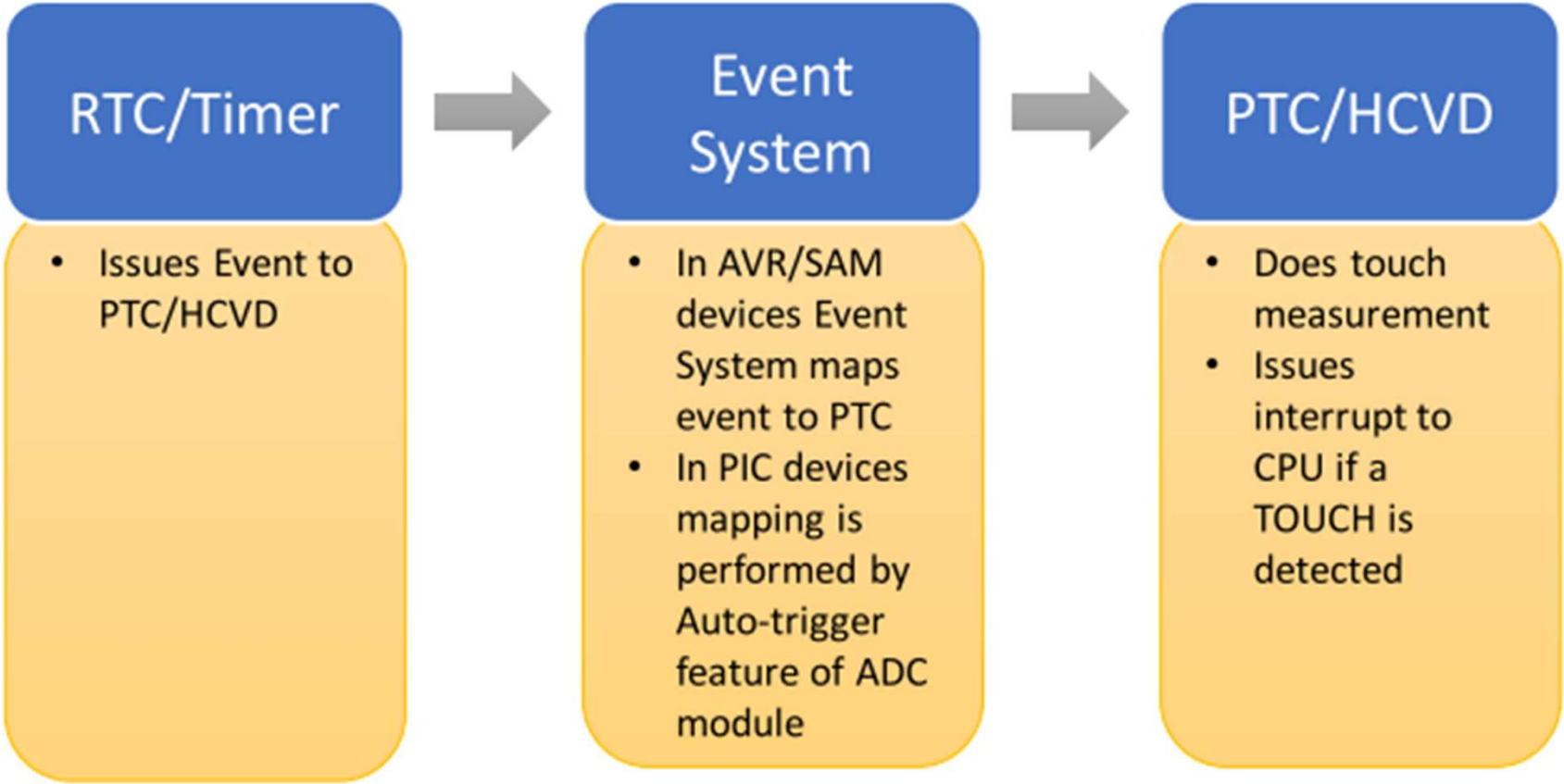
C.I.P. Examples - Touch cont…

Peripheral Touch Controller (PTC)

- **Mutual and Self-Capacitive Touch**
  - Can run both methods at the same time
  - No tuning needed
  - No external components needed
- **Lowest Standby Power Consumption**
  - 4µA standby with multi-button with wake-up on touch
- **Low CPU Utilization**
  - Autonomous operation
  - Non blocking interrupt behavior

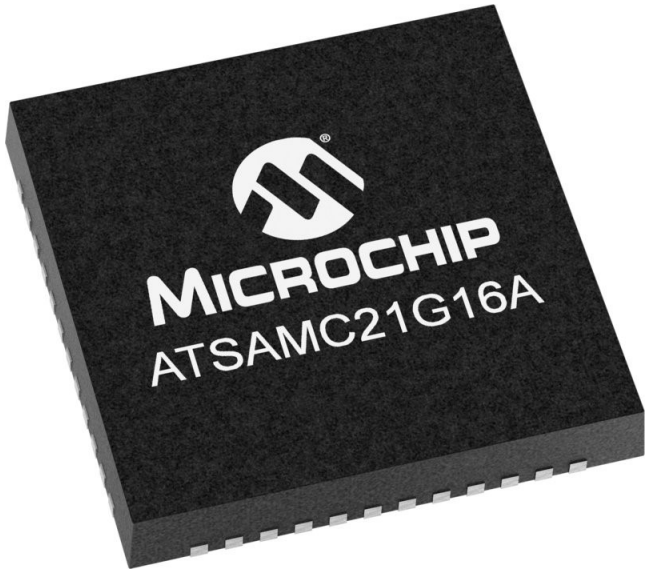


C.I.P. Examples - Touch cont…



C.I.P. Examples - Touch cont…

- **Without PTC**
  - ADC only
  - 7 or 8 cap buttons

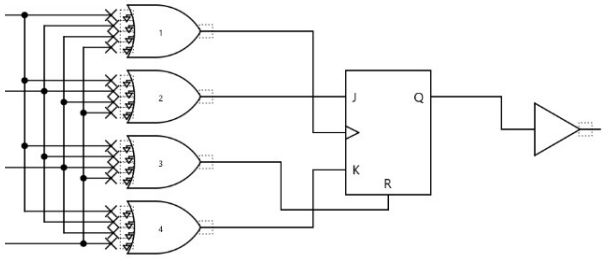


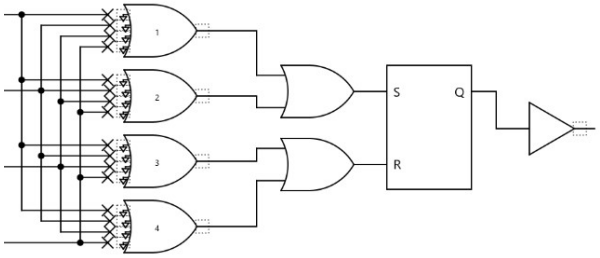
- **Cortex M0+**
- 48 MHz operation
- Lots of FLASH
- Lots of RAM

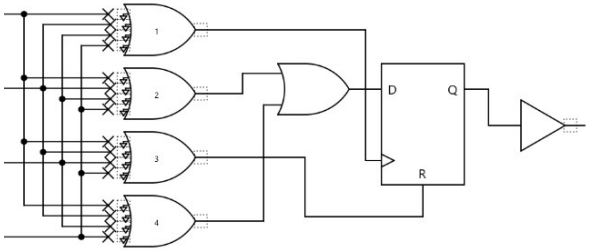
- **With PTC**
  - 4” PCAP Touch screen

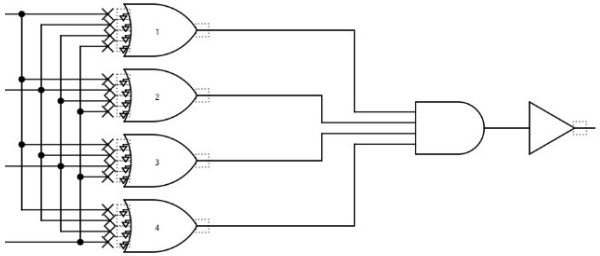
C.I.P. Examples - Logic

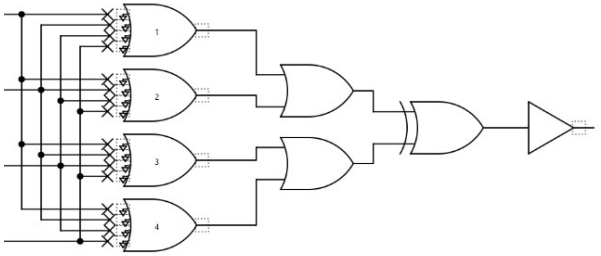
Configurable Logic Cell

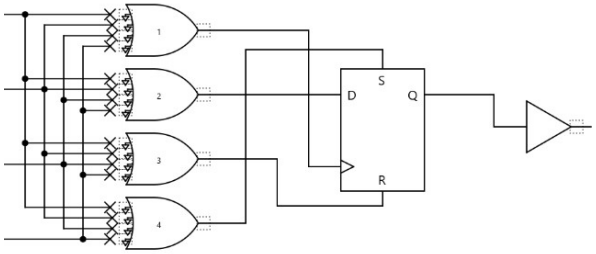


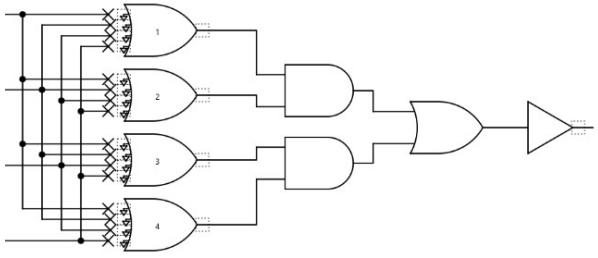


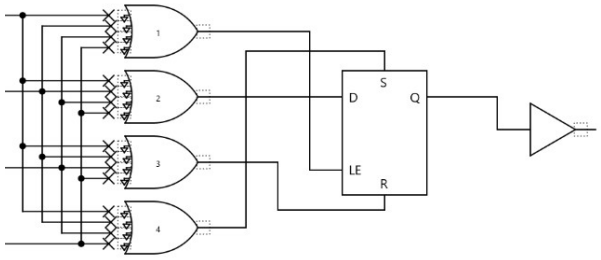






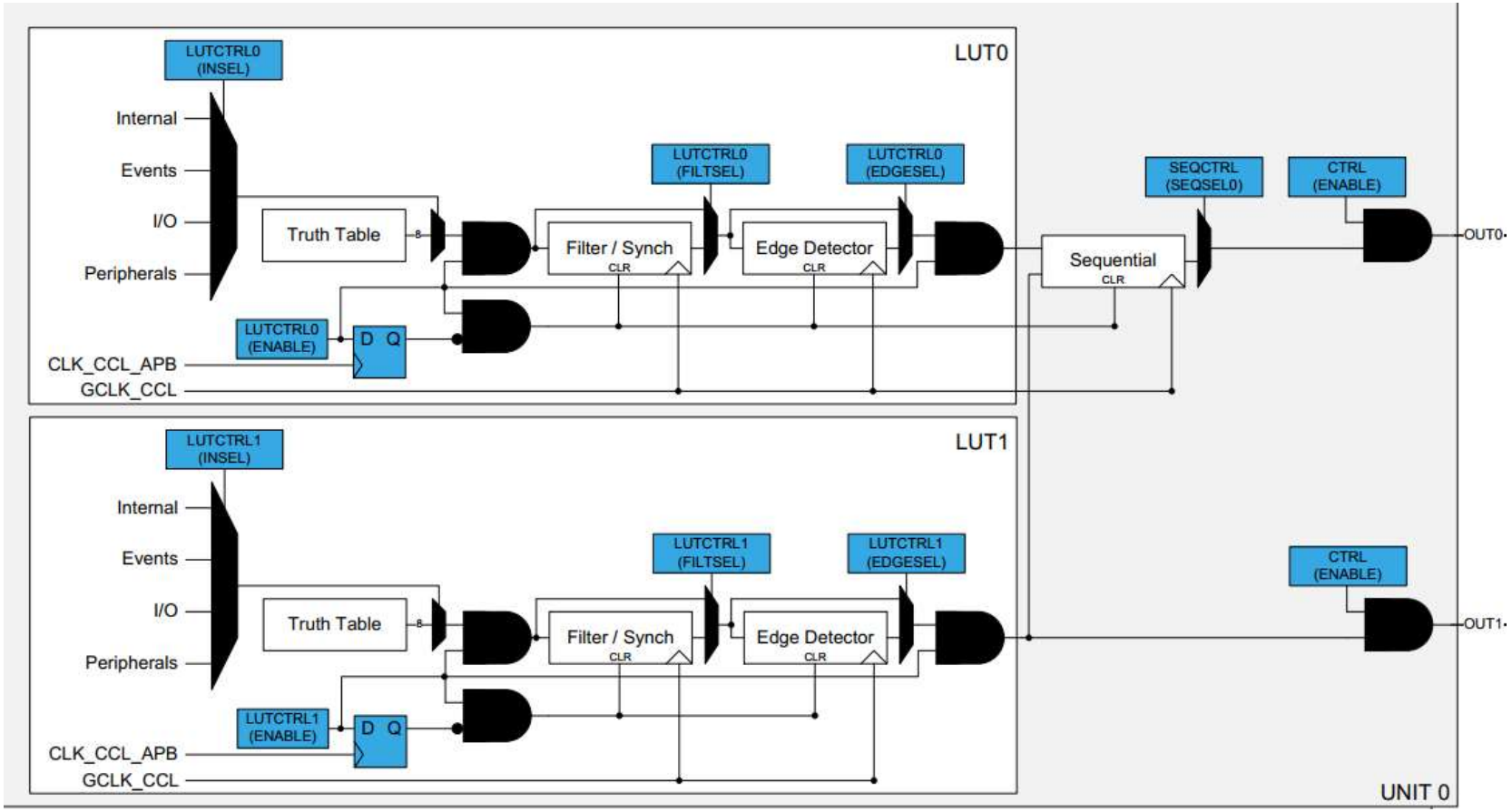






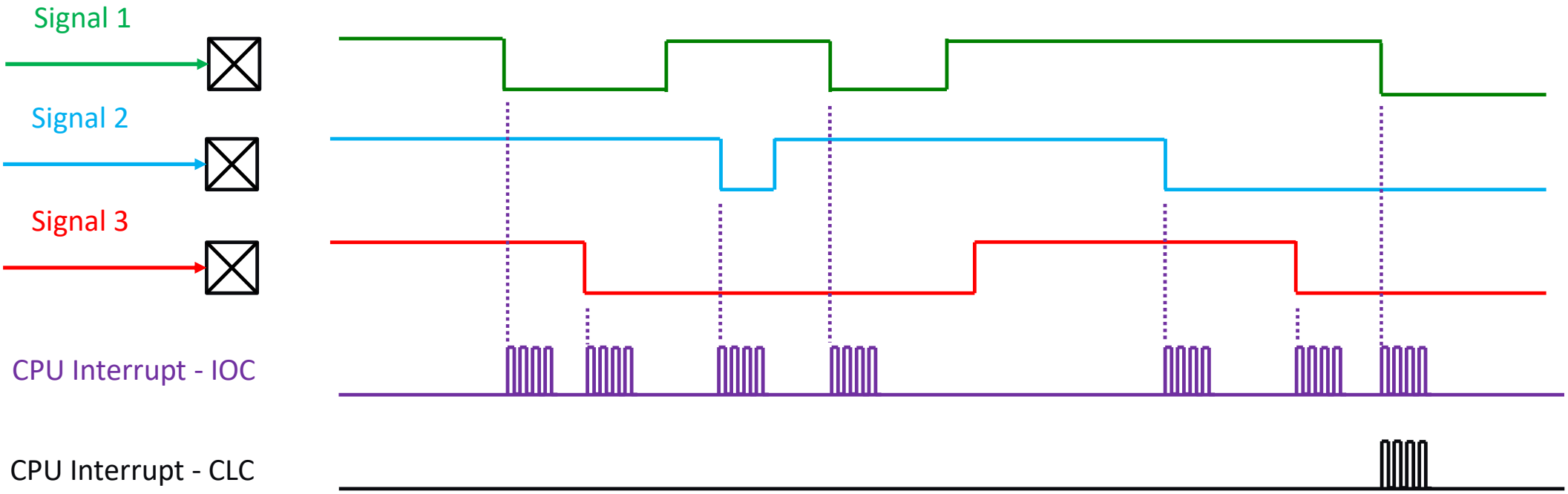
C.I.P. Examples - Logic cont…

Configurable Custom Logic



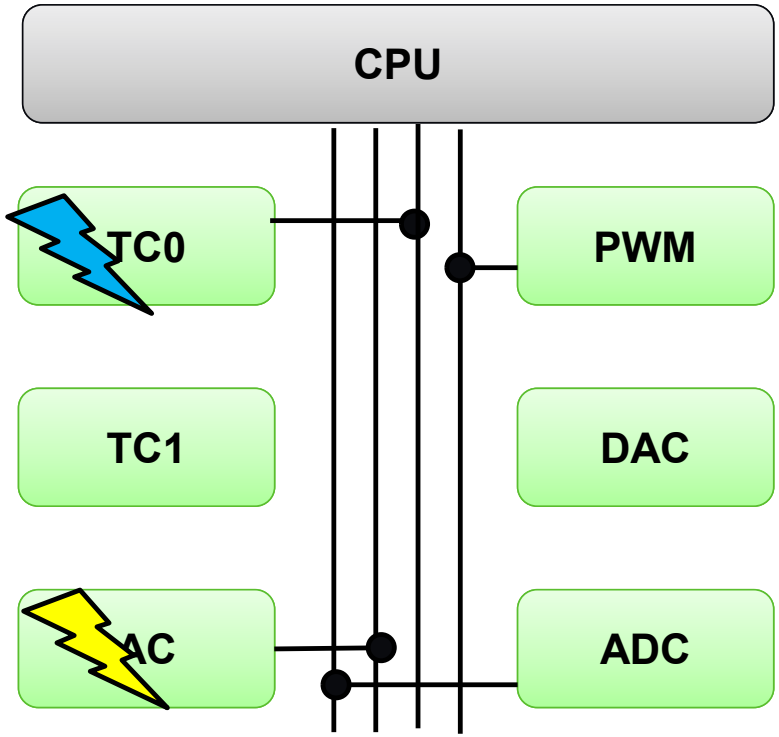
C.I.P. Examples - Logic cont…

- **Low Power Multi-signal detection**
  - Detect when 3 external pins have gone low at the same time



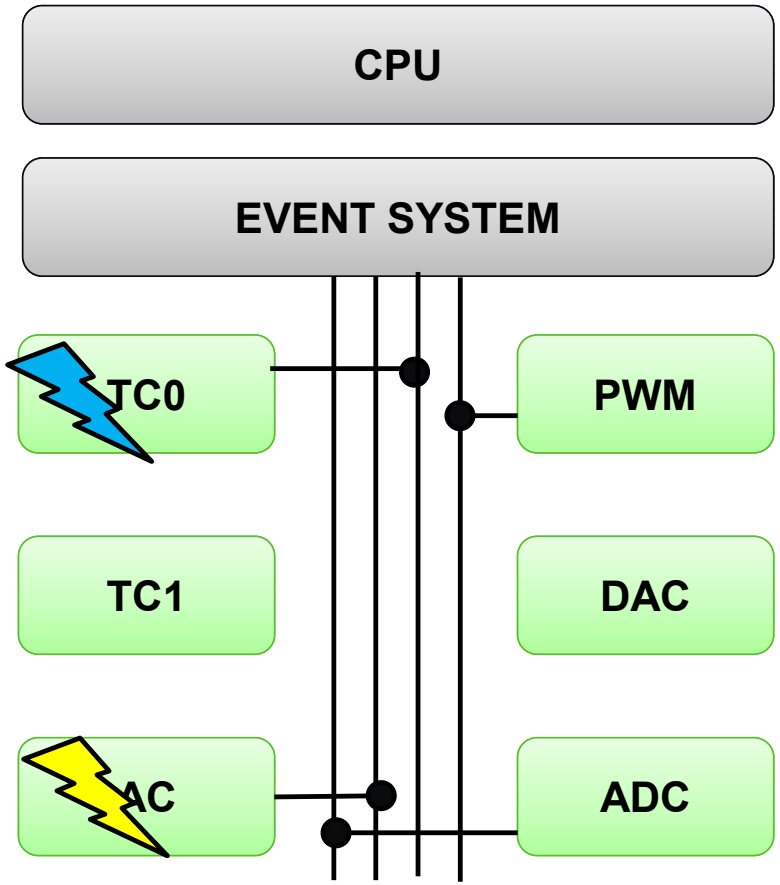
Peripheral Interconnect

- **Peripheral Events would need to be passed via the CPU**
  - Using Interrupts
- **Delayed event reaction time**
  - Interrupt latency becomes an issue
  - Non-deterministic reaction time
- **Disadvantages**
  - Increased CPU overhead
  - Increased Power Consumption



Interconnect - Event System

- **Event System allows communication between peripherals without CPU intervention**
- **Latency free event handling**
  - Safe fault protection
  - Deterministic reaction time
- **Advantages**
  - Reduced CPU overhead
  - Reduce Power Consumption



Peripheral Interconnect - PTG

- **Peripheral Trigger Generator**
  - Complex input sequencer that can coordinate operation of peripherals
- **Command based sequencer**
  - 8-bit commands
  - 32-byte command queue
  - Command queue is reprogrammable
- **Multiple Input and Output sources**
  - Safe fault protection
  - Predictable reaction time