nRF52832 Introduction

Introduction to the nRF52832 System-on-chip(SoC) and the nRF52 Development Kit

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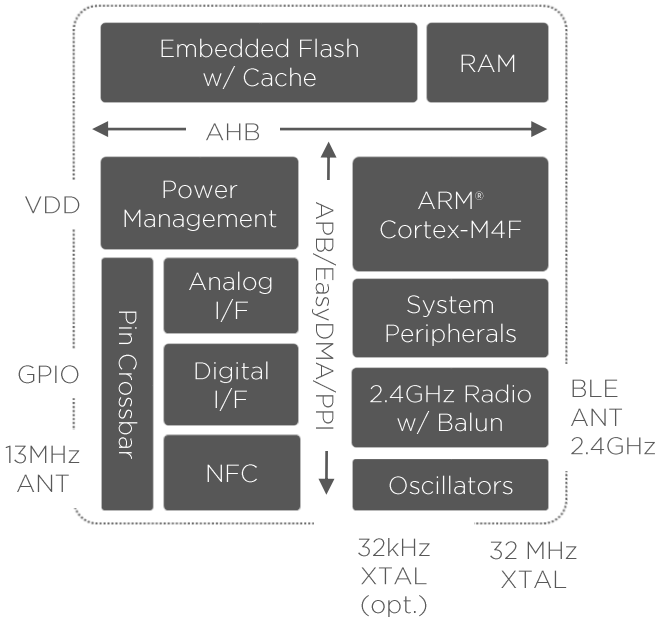
February 2018

nRF52 System-on-Chip(SoC) Architecture



ARM Cortex-M4F Processor

Internal Flash

Multi-Segmented RAM

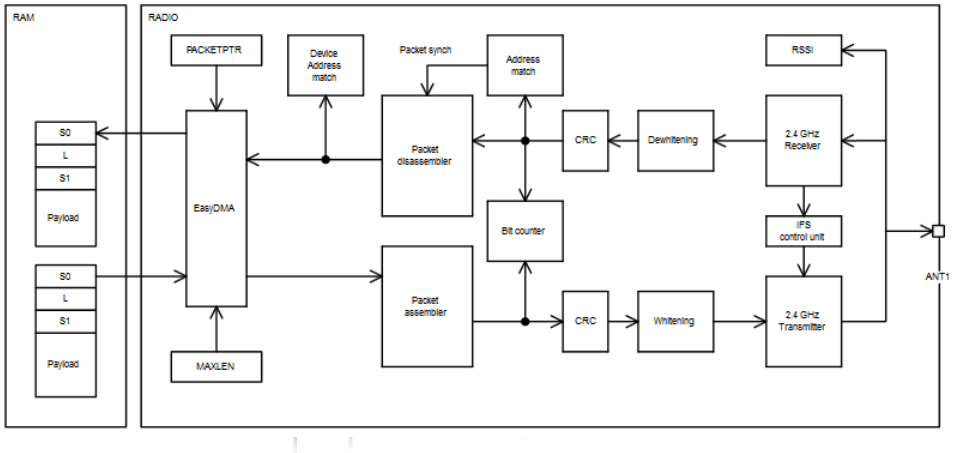
Flexible GPIO Mapping

PPI - Task and Event System

nRF52832 Overview

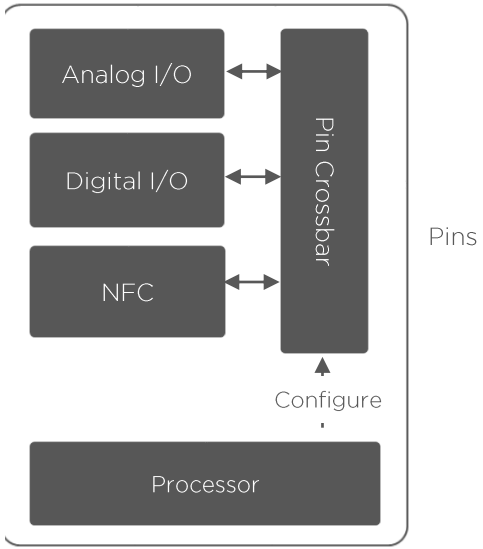
Radio	▪ BLE / ANT / 2.4 GHz ▪ 2 Mbps ▪ +4 dBm
Processor	▪ Cortex M4F ▪ 64 MHz
Memory	▪ 512/256 kB Flash w/cache ▪ 64/32 kB RAM with EasyDMA
Power management	▪ 1.7 to 3.6V supply voltage ▪ LDO and Buck DC/DC
Digital Interfaces	▪ 3x SPI Master or Slave ▪ 2x TWI Master or Slave ▪ 1x UART ▪ 3x PWM ▪ QDEC ▪ PDM ▪ I2S ▪ NFC
Analog interfaces	▪ 8-channel 10/12-bit ADC ▪ 15-level LP Comparator ▪ 64-level GP Comparator
GPIO	▪ 32 pins
System peripherals	▪ 5 x 32-bit Timers (2 with 6 CC Regs) ▪ 3 x Real-Time Counters(RTC) ▪ Programmable Peripheral Interconnect(PPI)

Powerful Ultra-Low Power Radio



Multi-Protocol Support	Bluetooth 5 ANT 2.4GHz RF
Performance (1MBps BLE)	- 96 dB RX Sensitivity Up to +4 dBm TX output Power
Power Efficiency (3V, DC/DC On)	5.4 mA RX Active Current 5.3 mA TX Active Current at 0 dBm 7.5 mA TX Active Current at +4 dBm
Features	EasyDMA / Register Interface / Soft FIFO in RAM RSSI On-chip Balun, Single ended RF pin

Flexible GPIO mapping



Configurable I/O - Pin Mapping

Dynamic Mapping with Software

Most Pins Support Analog and Digital

Simplifies PCB Design

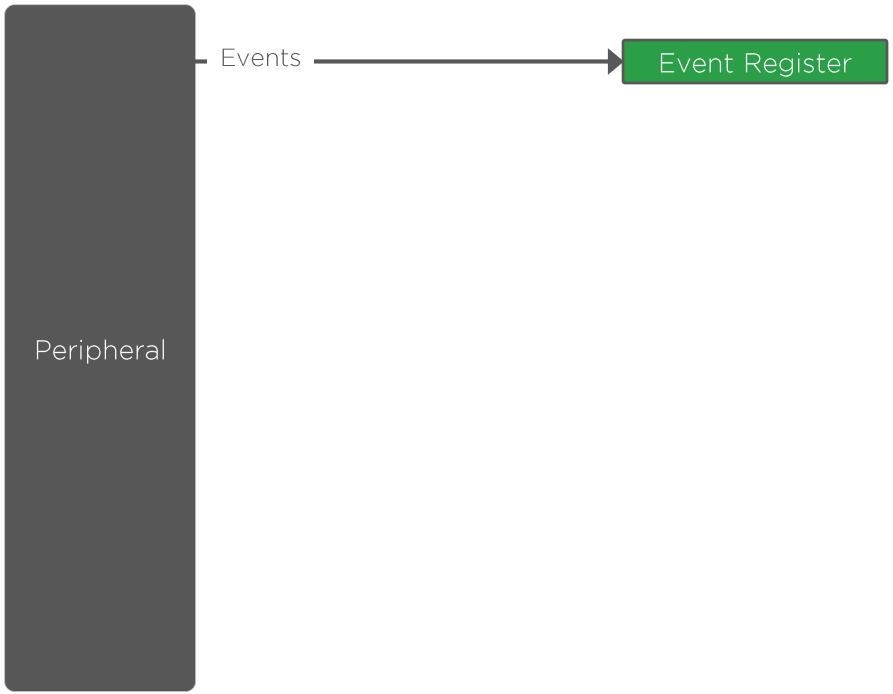
Enabling lower Cost PCB

Enabling more Compact Layout

NFC Tag

Software Stack	Card Emulation NFC-A Type 2 and Type 4 Read and write Support for Bluetooth low energy Touch-to-Pair
Current Consumption	400uA in Active Mode 100nA in Wake on Field Mode
Supported Antennas	NFC Forum Listener 6 (25x20mm 4-turn PCB antenna) Abracom 32 x 25mm flex Antenna
Range	Up to 40mm (depending on antenna and field strength)

Peripheral Tasks and Events

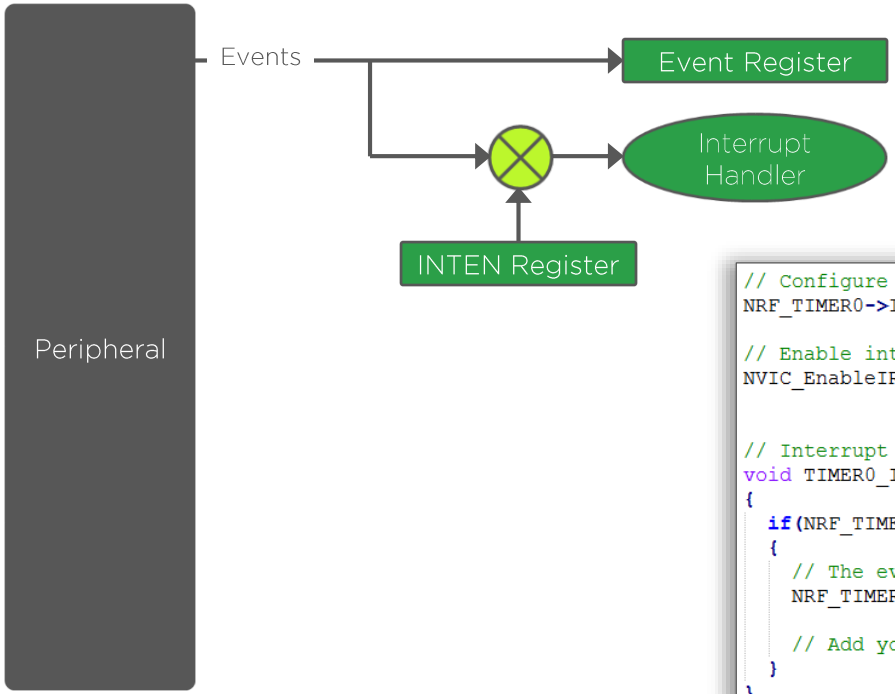



```c
if (NRF_TIMER0->EVENTS_COMPARE[0] == 1)
{
  // The event has occured
}
else
{
  // The event has not occured
}
```

```c
// Clear the event
NRF_TIMER0->EVENTS_COMPARE[0] = 0;

// Wait for the event to occur again
while(NRF_TIMER0->EVENTS_COMPARE[0] == 0);
```

Peripheral Tasks and Events



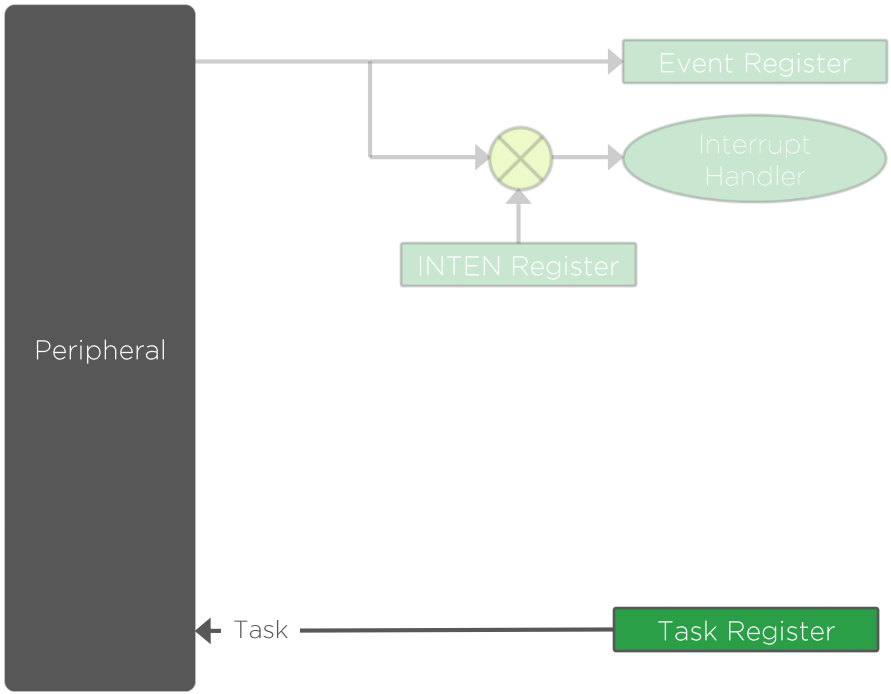

```
// Configure which event(s) should generate interrupts
NRF_TIMER0->INTENSET = TIMER_INTENSET_COMPARE0_Enabled << TIMER_INTENSET_COMPARE0_Pos;

// Enable interrupts globally for the peripheral
NVIC_EnableIRQ(TIMER0_IRQn);


// Interrupt handler
void TIMER0_IRQHandler(void)
{
  if(NRF_TIMER0->EVENTS_COMPARE[0])
  {
    // The event must be manually cleared
    NRF_TIMER0->EVENTS_COMPARE[0] = 0;

    // Add your own code here
  }
}
```

Peripheral Tasks and Events



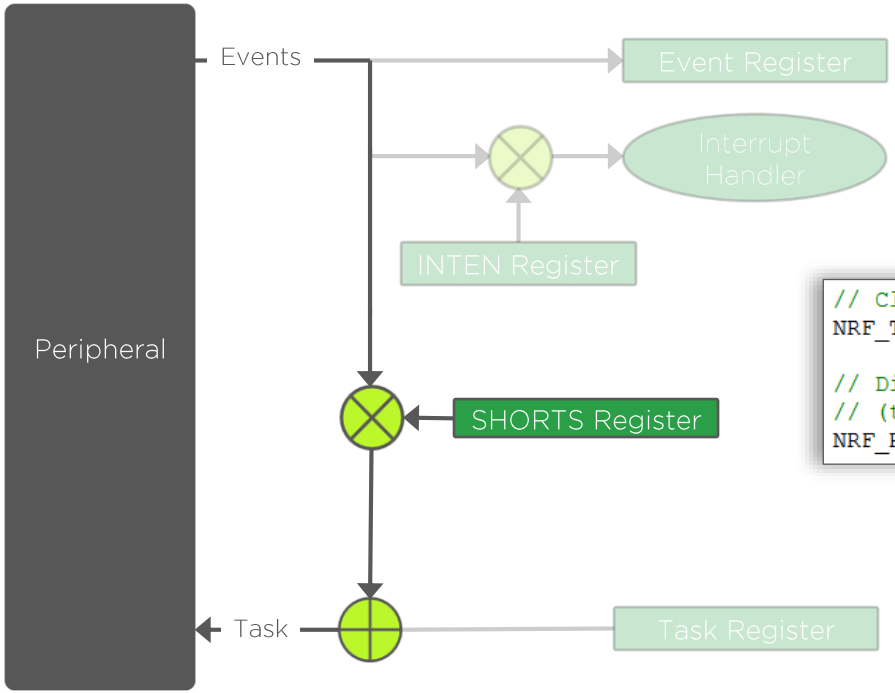

```
// Start the timer
NRF_TIMER0->TASKS_START = 1;

// Stop the timer
NRF_TIMER0->TASKS_STOP = 1;
```

```
// Enable the radio in RX mode
NRF_RADIO->TASKS_RXEN = 1;

// Disable the radio
NRF_RADIO->TASKS_DISABLE = 1;
```

Peripheral Tasks and Events




```
// Clear the timer automatically when the COMPARE2 event occurs
NRF_TIMER0->SHORTS = TIMER_SHORTS_COMPARE2_CLEAR_Msk;

// Disable the radio automatically after sending or receiving a packet
// (the END event occurs after a complete packet is sent or received)
NRF_RADIO->SHORTS = RADIO_SHORTS_END_DISABLE_Msk;
```

Two Global Power Modes

ON

All blocks Idle and ready to start
Configurable RAM retention
All wake-up sources
Clock and power management running

CPU Running

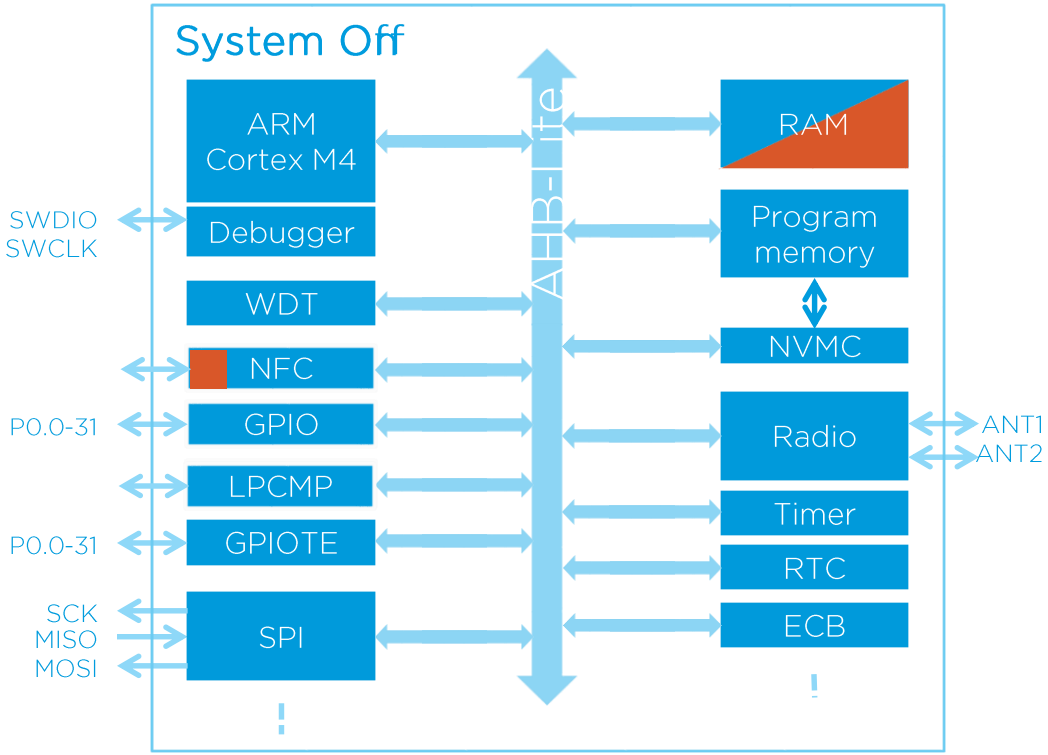
ON Idle with RTC

OFF

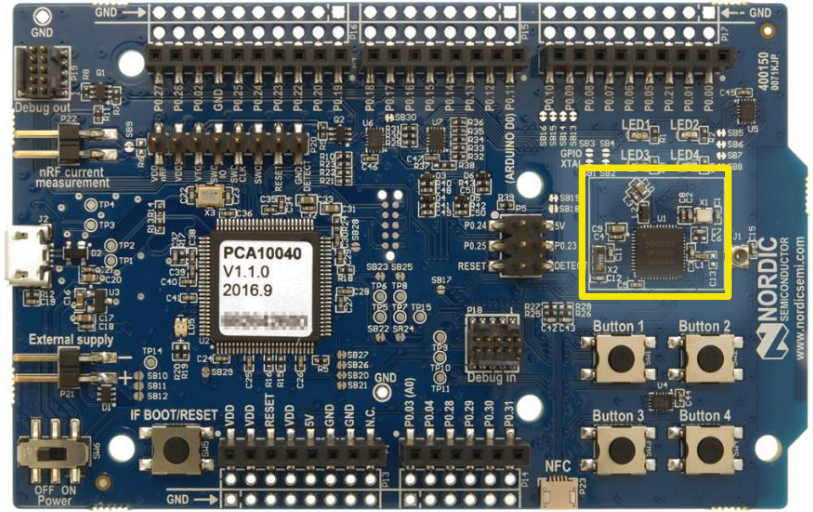
All blocks turned Off
Configurable RAM retention
Wake-on Reset, Pin, Comparator and NFC
I/O pin state retained

OFF

Power Management



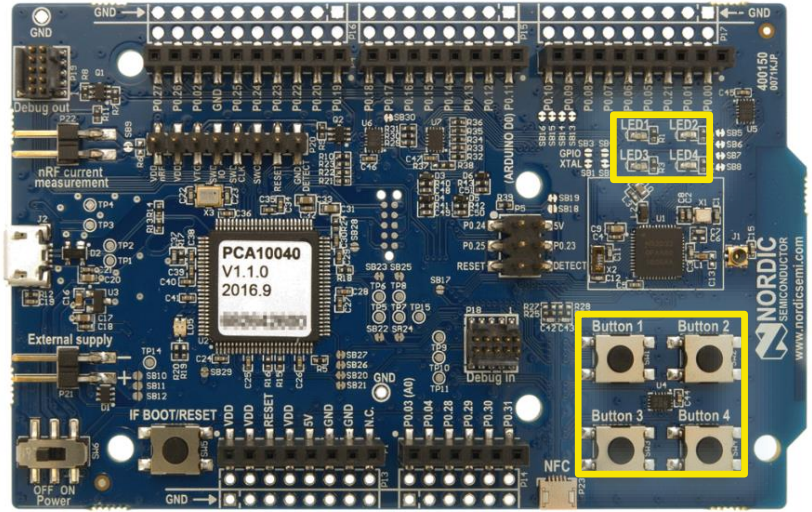
nRF52 Development Kit



Key Features

- nRF52832 SoC

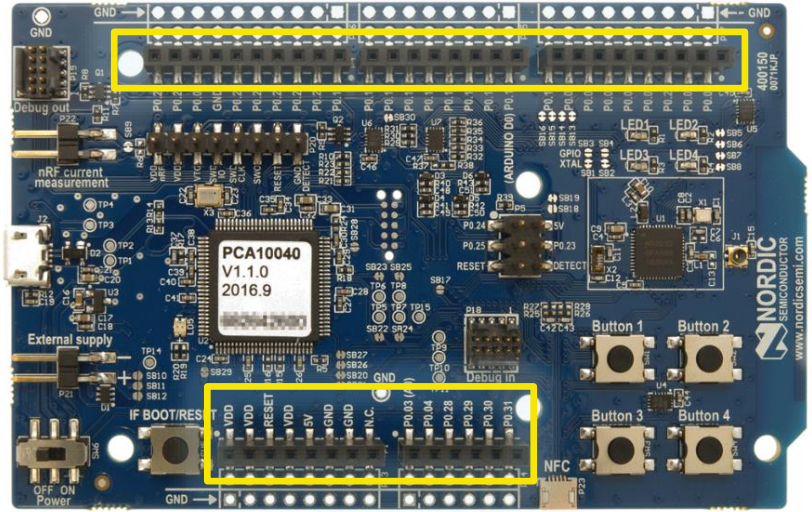
nRF52 Development Kit



Key Features

- nRF52832 SoC
- Buttons and LEDs for user interaction

nRF52 Development Kit



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- nRF52832 SoC
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- I/O interface for Arduino form factor plug-in modules

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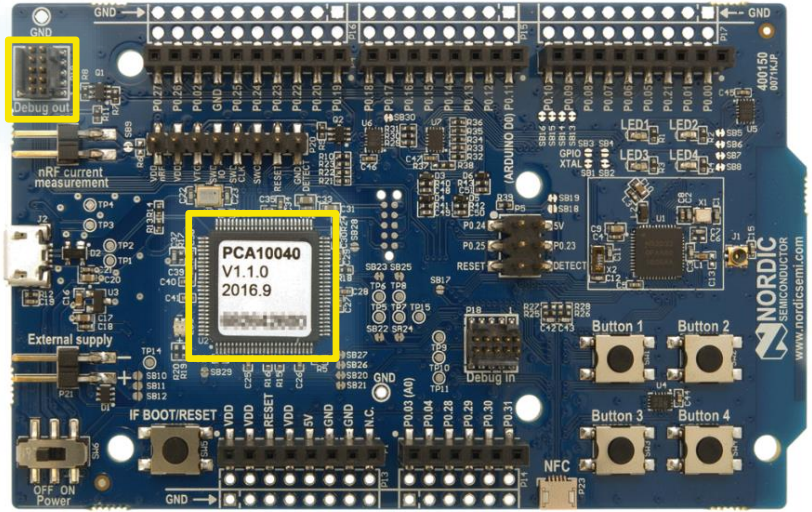

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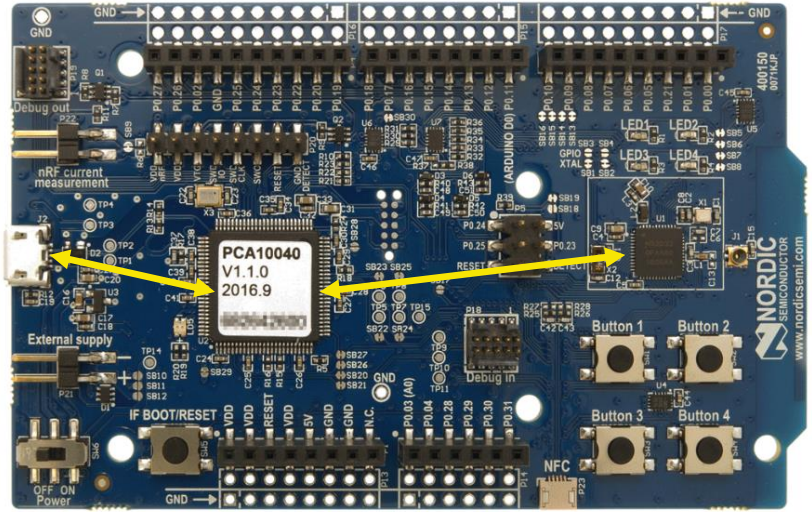
- Segger J-link OB Debugger with debug out functionality

nRF52 Development Kit



Key Features

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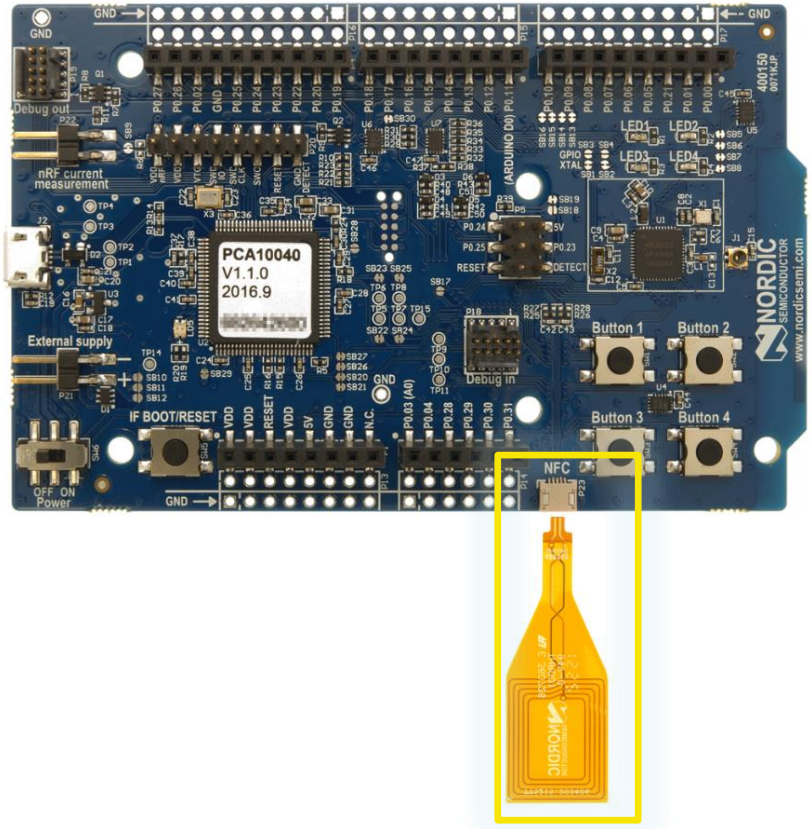
- Buttons and LEDs for user interaction
- I/O interface for Arduino form factor plug-in modules
- Segger J-link OB Debugger with debug out functionality
- Virtual COM Port interface via UART
- Drag-and-drop Mass Storage Device programming

nRF52 Development Kit



Key Features

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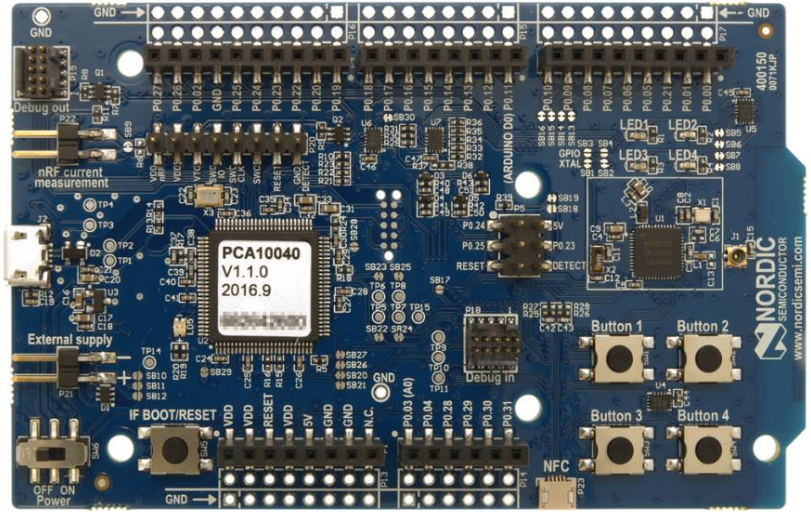
- Drag-and-drop Mass Storage Device programming
- NFC-A Support

nRF52 Development Kit

- SDK examples are tailored to our Development Kits
- UART or Segger Real-Time Terminal (RTT) allows for easy debugging
- Measure the current consumption of your application



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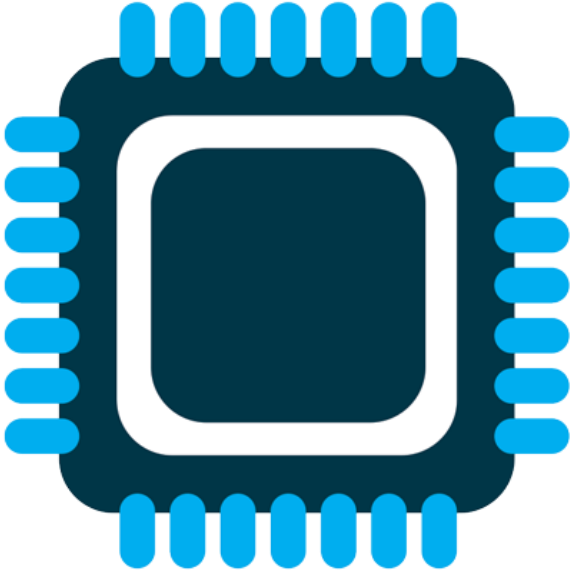

Microcontroller Introduction

A short introduction to the wonderful world of microcontrollers!

Bjørn Spockeli

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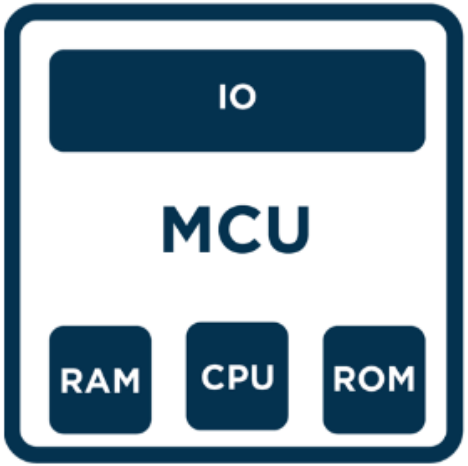
October 2018

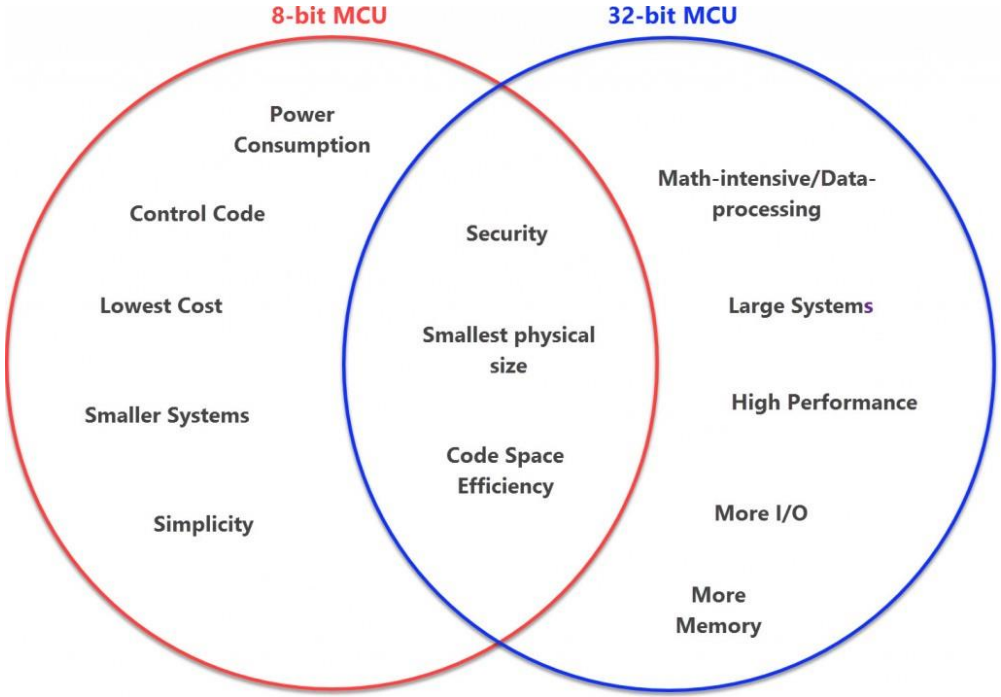
What is a microcontroller?

"A microcontroller is a self-contained system with peripherals, memory and a processor that can be used as an embedded system."



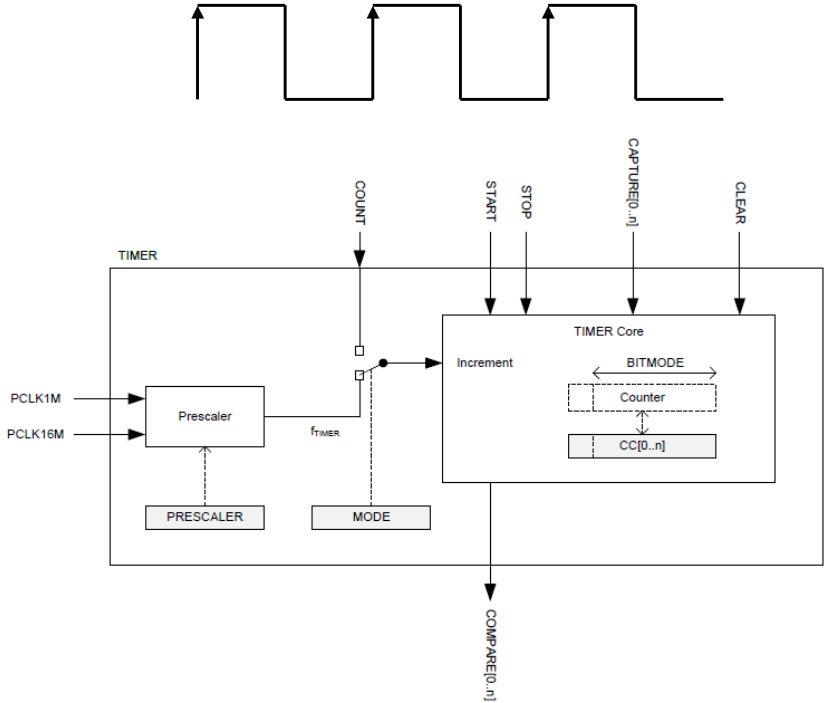
- Comes in many shapes and sizes
  - *8-bit, e.g. AVR 328P*
  - *32-bit, e.g. STM32 (ARM Cortex M3)*

8-bit vs 32-bit?



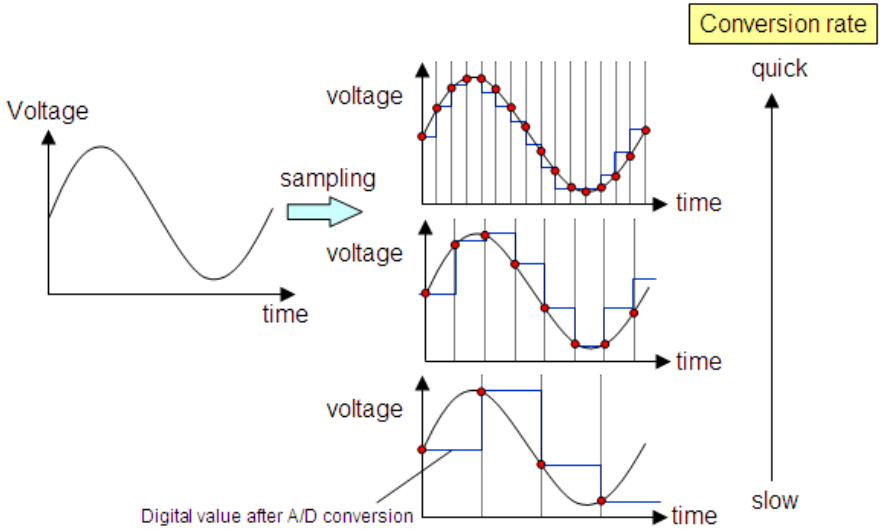
Timers/Counters

- Counts the clock cycles of the system clock
- Comes in 8-bit, 16-bit, 24-bit or 32-bit configurations(usually configurable)
- COUNTER register keeps track of the number of clock cycles
- Compares Counter with Capture/Compare(CC) registers.
- Prescaler determine how often the Counter is updated, e.g prescaler of 8 will result in the counter incrementing every 8th clock cycle



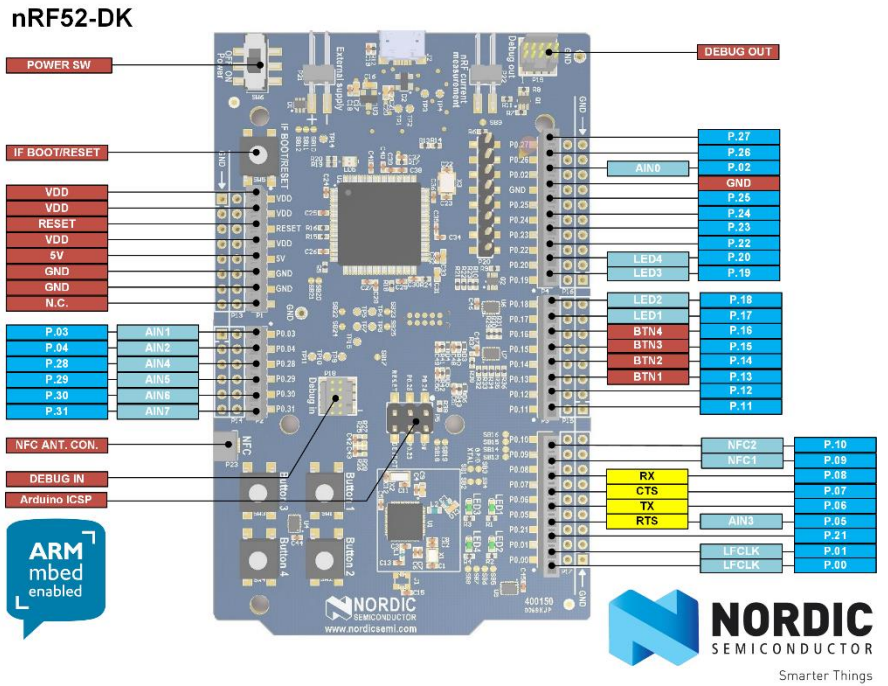
Analog-Digital Converter(ADC)

- Converts an analog voltage on a pin to a digital number.
- Ratiometric value
- $$\frac{ADC\ Resolution}{Reference\ Voltage \times ADC\ value} = V_{measured}$$
- Resolution:
  - 8-bit: 256(2^8) discrete levels
  - 10-bit: 1,024 (2^{10}) discrete levels
  - 16-bit: 65,536 (2^{16}) discrete levels
- ADCs are fairly complex!



General Purpose Input/Output(GPIO) pins

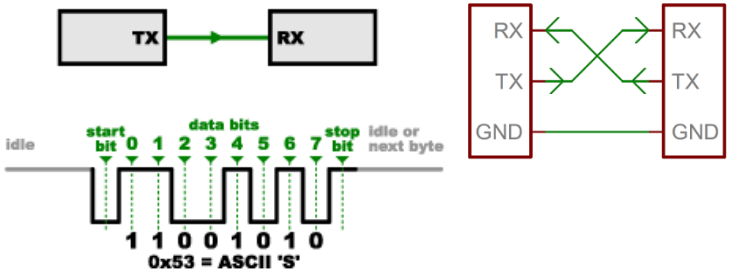
- Generic pin controllable by the user at run time.
- Arranged in ports, pins per port is determined by architechture, e.g. 8-bit -> 8 pins/port
- Configurable parameters:
  - Input/Output
  - Digital/Analog
  - Internal pull-up and/or pull-down resistor
  - Drive strength



Serial Communication

Universal asynchrounous receiver/transmitter(UART)

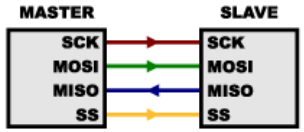
- Asynchronous = data is transfer without no clock signal.
- Can be simplex(1 line), half-duplex(1/2 lines) or full-duplex(2 lines)
- Data needs to be framed:
  - Data bits: Data that you want to sent
  - Synchronization bits: Start and stop bits
  - Parity bits: Used for error checking
- Both sides must agree Baudrate: Transfer speed

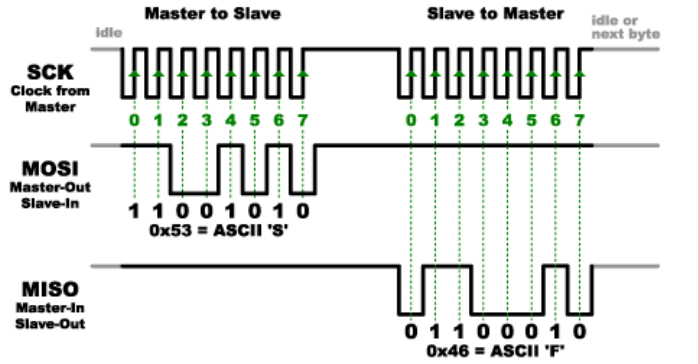


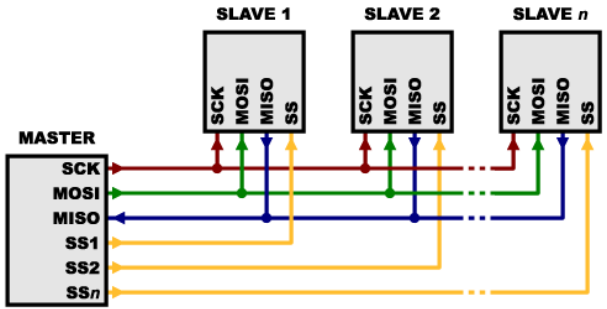
Serial Communication

Serial Peripheral Interface(SPI)

- Synchronous data transfer = clock signal
- Uses four lines
  - SCK – Clock signal
  - MOSI(Master-Output, Slave-Input)
  - MISO(Master-Input, Slave-Output)
  - SS – Slave Select
- Advantages
  - Full-duplex
  - Support clock rates upwards of 10MHz
  - Supports multiple slaves
- Disadvantages
  - Uses minimum 4 lines.
  - Each slave needs a separate SS line



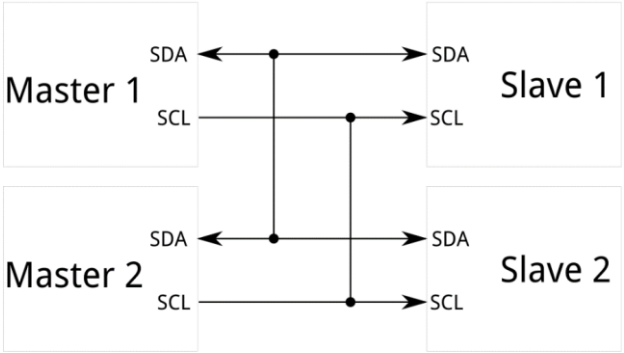


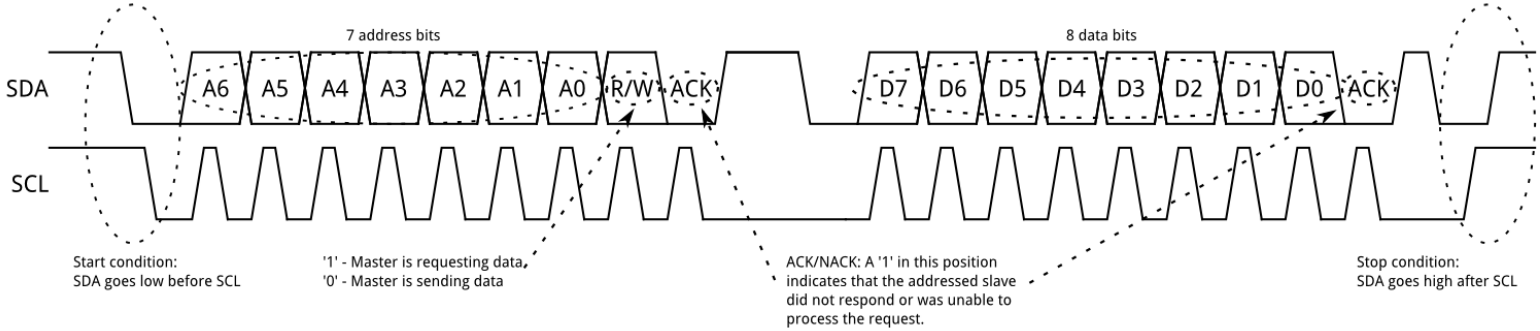


Serial Communication

Inter-integrated Circuit(I^2C)

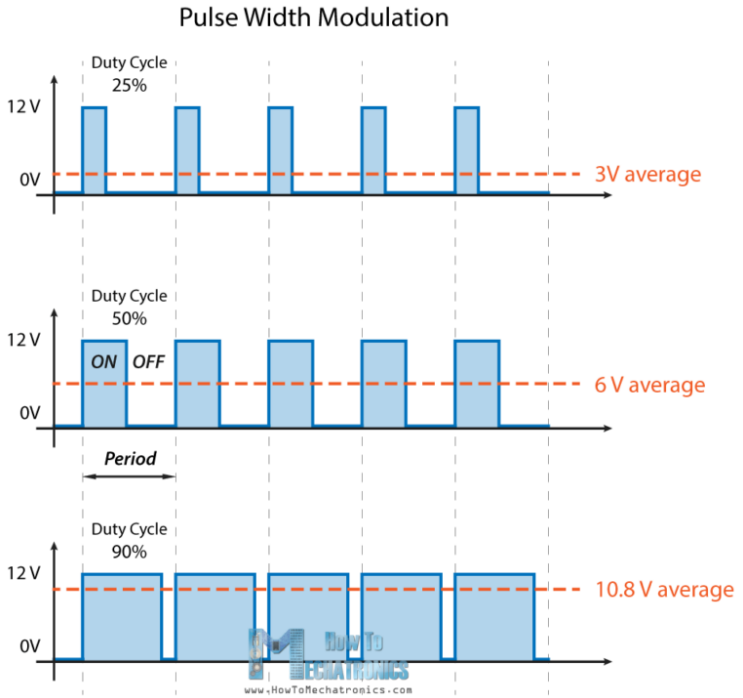
- I2C bus consists of two signals:
  - SCL is the clock signal
  - SDA is the data signal
- Half-duplex
- Clock speed at 100kHz or 400kHz





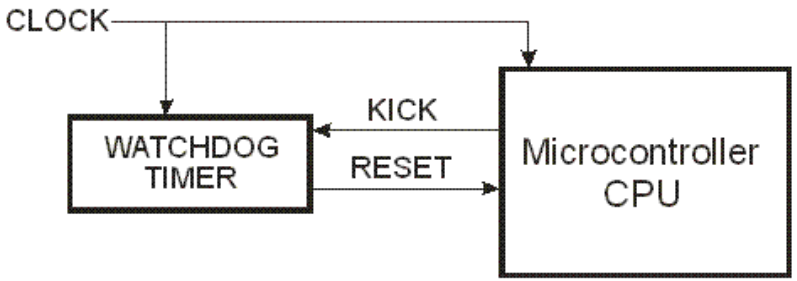
Pulse-Width Modulation(PWM)

- A method for generating an analog signal using a digital source.
- A digital signal is either **High** or **Low**, cannot be something in-between.
- A PWM signal is defined by its:
  - Frequency(Hz)
  - Duty cycle(percentage)



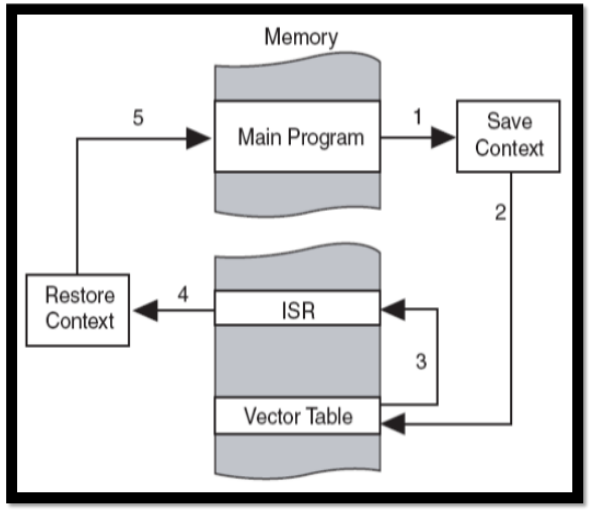
Watchdog Timer(WDT)

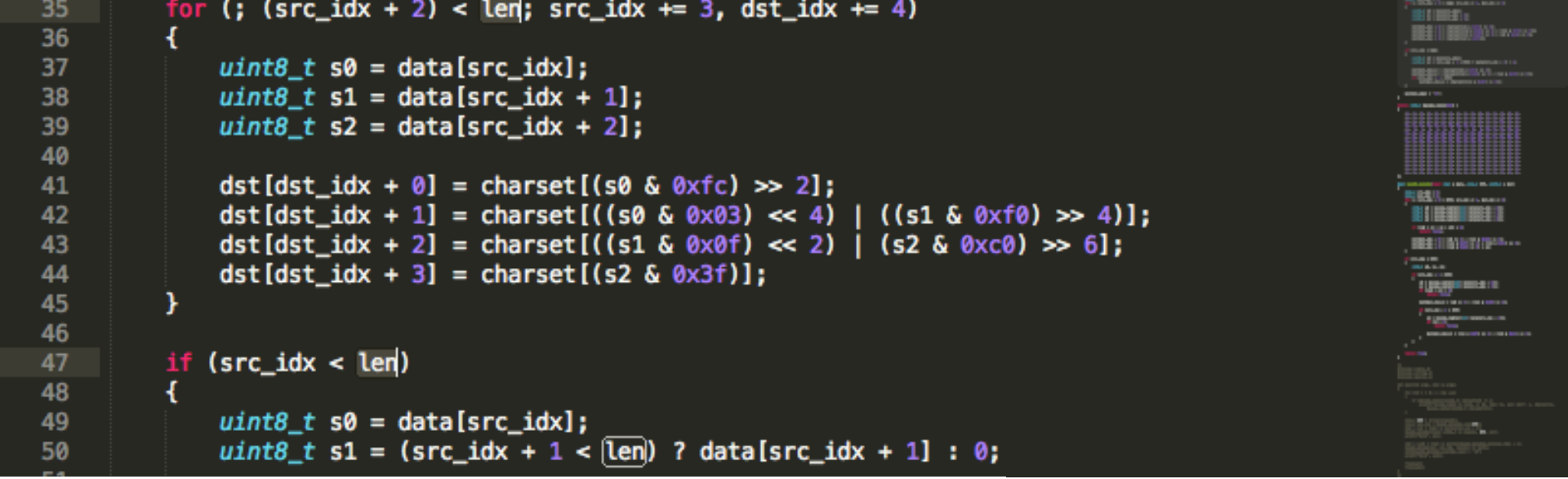
- Failsafe mechanism
- Counter starting at a predetermined value and counts down to zero.
- System will be reset if the watchdog counter reach zero.
- CPU must «feed» or «kick» the Watchdog to reset the counter.



Polling and Interrupts

- **Polling:** CPU continously monitors a variable/register to see if a specific task should be performed.
- **Interrupt:** CPU is free to execute its main code until an interrupt occurs, it will then branch to the Interrupt Service Routine or Interrupt Handler which contains code to do the task.
- Interrupts are more efficient than polling. (Mailbox anology)





```
for (; (src_idx + 2) < len; src_idx += 3, dst_idx += 4)
{
    uint8_t s0 = data[src_idx];
    uint8_t s1 = data[src_idx + 1];
    uint8_t s2 = data[src_idx + 2];

    dst[dst_idx + 0] = charset[(s0 & 0xfc) >> 2];
    dst[dst_idx + 1] = charset[((s0 & 0x03) << 4) | ((s1 & 0xf0) >> 4)];
    dst[dst_idx + 2] = charset[((s1 & 0x0f) << 2) | (s2 & 0xc0) >> 6];
    dst[dst_idx + 3] = charset[(s2 & 0x3f)];
}

if (src_idx < len)
{
    uint8_t s0 = data[src_idx];
    uint8_t s1 = (src_idx + 1 < len) ? data[src_idx + 1] : 0;
```

Embedded C programming

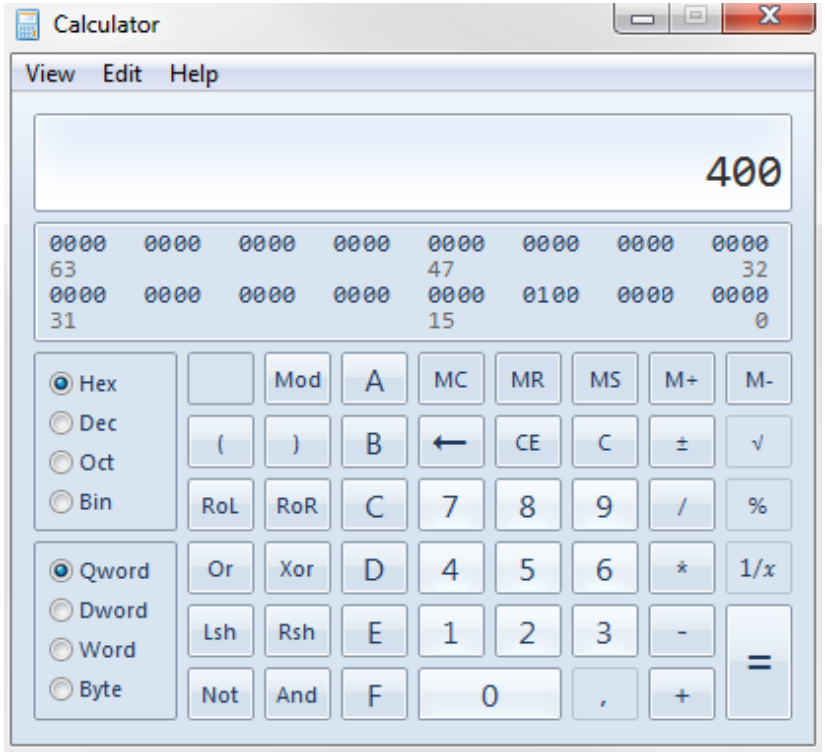
Short introduction to C programming on embedded devices

Data types

Data Type	Size (bytes)	Size (bits)	Value Range
unsigned char	1	8	0 to 255
signed char	1	8	-128 to 127
char	1	8	either
unsigned short	2	16	0 to 65,535
short	2	16	-32,768 to 32,767
unsigned int	4	32	0 to 4,294,967,295
int	4	32	-2,147,483,648 to 2,147,483,647
unsigned long	8	64	0 to 18,446,744,073,709,551,616
long	8	64	–9,223,372,036,854,775,808 to 9,223,372,036,854,775,807
unsigned long long	8	64	0 to 18,446,744,073,709,551,616
long long	8	64	–9,223,372,036,854,775,808 to 9,223,372,036,854,775,807
float	4	32	3.4E +/- 38 (7 digits)
double	8	64	1.7E +/- 308 (15 digits)
long double	8	64	1.7E +/- 308 (15 digits)
bool	1	8	false or true

Binary & Hexadecimal

- Binary is base 2
  - Uses only 0 and 1
- Hexadecimal is base 16
  - Uses digits 0-9 and letters A-F
- 4 binary digits can be represented by 1 hexadeximal digit. (16 = 2^4)
- Numbers take up less space and are easier to write.
  Ex. 10 = 0b1010 = 0xA



Endianess

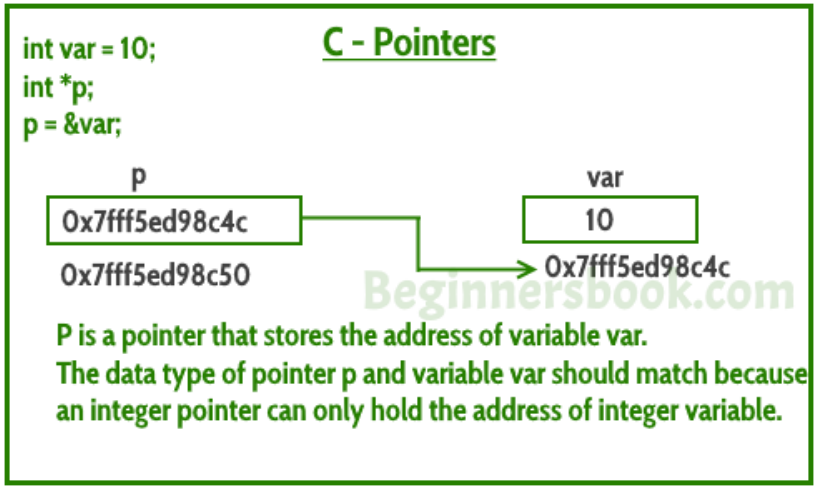
- Byte/bit order.
- **Big endian:** most significant bits (MSBs)occupy the lower address.
- **Little endian:** least significant bits (LSBs) occupy the lower address.
- nRF52832 uses **Little Endian.**

Big Endian

Little Endian

Pointers

- A pointer points to the memory address of a variable.
- The pointer itself has an memory address.
- The pointer can be dereferenced to access the value at the memory address.
- * is called the dereference operator
- & is the reference operator.



Keywords

- Keywords are predefined, reserved words that have special meanings to the C compiler.
- 40 keywords in C, we'll concentrate on:
  - typedef
  - const
  - static
  - struct
  - void
- Assume that **if**, **else**, **for** and **while** are known.

Keywords in C Language

auto	double	int	struct
break	else	long	switch
case	enum	register	typedef
char	extern	return	union
continue	for	signed	void
do	if	static	while
default	goto	sizeof	volatile
const	float	short	unsigned

Keywords - typedef

- The **typedef** keyword is used to explicitly associate a type with an identifier.
- More convenient to write *int8_t* than *signed char*
- Make the code more readable and understandable.

```
typedef signed    char      int8_t;
typedef unsigned  char      uint8_t;

typedef signed    short     int16_t;
typedef unsigned  short     uint16_t;

typedef signed    int       int32_t;
typedef unsigned  int       uint32_t;

typedef signed    long long int64_t;
typedef unsigned  long long uint64_t;
```

Keywords - struct

- The struct keyword is used for declaring a structure(often used in combination with typedef).
- A structure can hold member variables of different types under a single name.
- The . (dot) operator is used to access member variables
- The -> operator is used to access member variables from a structure pointer.

```c

typedef struct person_t {
    int age;
    double weight;
}

person_t person_1;      // structure of type person_t
person_1.age = 28;
person_1.weight = 75;

printf("Age:",person_1.age);
printf("Weigth:", person_1.weight);

person_t * p_person;  // pointer to a structure of person_t
p_person = &person_1;

printf("Age:", p_person->age);
printf("Weigth:", p_person->weight);

// p_person->weight is the same as (*p_person).weight

```

Keywords – const and static

- A constant is a value or an identifier whose value cannot be altered in a program.
- static has two different meanings:
  1. A static global variable/function or a function is "seen" only in the file it's declared in.
  2. A static variable inside a function keeps its value between function calls.

```
const double pi = 3.14;
static int value = 5;

void counter()
{
    static int32_t count = 0;
    count = count + 1;
    printf("Count", count);
}

int main()
{
    counter();
    counter();
    counter();
}
```

Keyword - void

- The **void** keyword indicates that a function doesn't return any value.
- The void keyword can also be passed as an argument to a function, indicating that this function has no parameters

```
/**@brief Function for putting the chip into sleep mode.
 *
 * @note This function will not return.
 */
static void sleep_mode_enter(void)
{
    ret_code_t err_code;

    /* Go to system-off mode (this function will not return;
    wakeup will cause a reset). */
    err_code = sd_power_system_off();
    APP_ERROR_CHECK(err_code);
}
```

Macros and Conditional directives

- A macro is a fragment of code which has been given a name. The name will be replaced by the code fragment.
- Two types of macros
  - Object-like macros
  - Function-like macros
- Conditional directives are used to decide which code chunks that should be compiled.

```
#define DEVICE_NAME          "Nordic_Template"

#define APP_ADV_INTERVAL     300

/**@brief Macro for converting milliseconds to ticks.
 *
 * @param[in] TIME           Number of milliseconds to convert.
 * @param[in] RESOLUTION     Unit to be converted to in [us/ticks].
 */
#define MSEC_TO_UNITS(TIME, RESOLUTION) (((TIME) * 1000) / (RESOLUTION))

#define MIN_CONN_INTERVAL     MSEC_TO_UNITS(100, UNIT_1_25_MS)

#ifdef SOFTDEVICE_PRESENT
#include "nrf_sdh.h"
#include "nrf_sdh_soc.h"
#endif
```