# I2C & USB 2.0

Lecture 7

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# I2C & USB 2.0

used by RP2040

- Buses
  - Inter-Integrated Circuit
  - Universal Serial Bus v2.0

# I2C

Inter-Integrated Circuit

# Bibliography

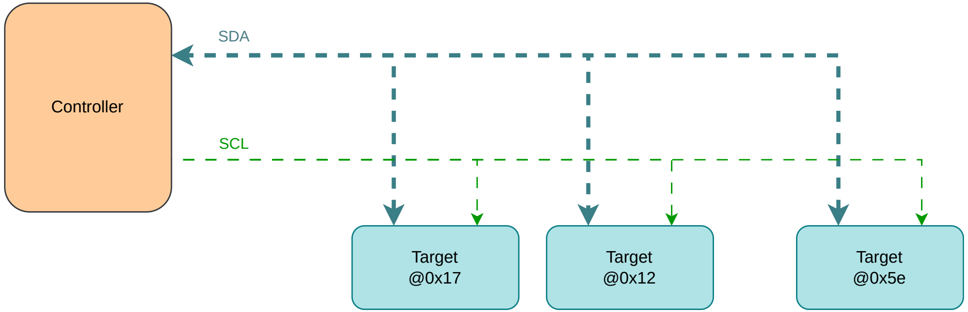
for this section


1. **Raspberry Pi Ltd**, *RP2350 Datasheet*
   - Chapter 12 - *Peripherals*
     - Chapter 12.2 - *I2C*
2. **Paul Denisowski**, *Understanding I2C*

# I2C

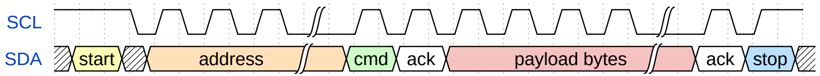
a.k.a *I square C*

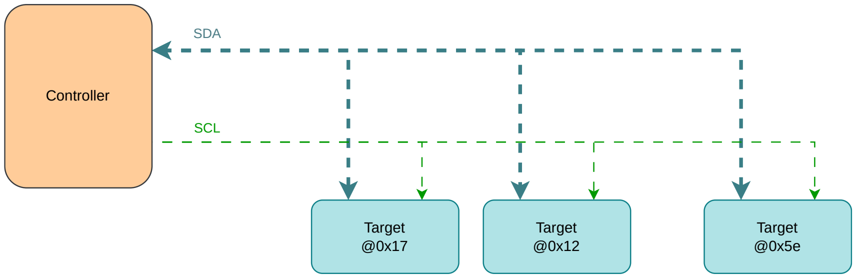
- Used for communication between integrated circuits
- Sensors usually expose an *SPI* and an *I2C* interface
- Two device types:
  - *controller* (master) - initiates the communication (usually MCU)
  - *target* (slave) - receive and transmit data when the *controller* requests (usually the sensor)



# Wires & Addresses

- *SDA* - **S**erial **DA**ta line - carries data from the **controller** to the **target** or from the **target** to the **controller**
- *SCL* - **S**erial **CL**ock line - the clock signal generated by the **controller**, **targets**
  - *sample* data when the clock is *low*
  - *write* data to the bus only when the clock is *high*
- each *target* has a unique address of **7 bits** or **10 bits**
- wires are never driven with `LOW` or `HIGH`
  - are always *pull-up*, which is `HIGH`
  - devices *pull down* the lines to *write* `LOW`



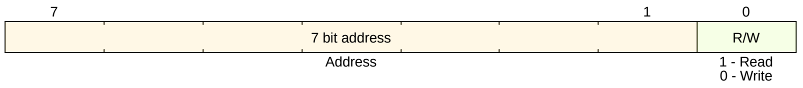



# Transmission Example

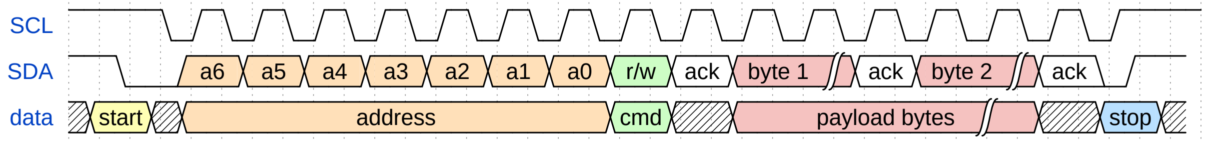
7 bit address

1. **controller** issues a `START` condition
   - pulls the `SDA` line `LOW`
   - waits for ~ 1/2 clock periods and starts the clock
2. **controller** sends the address of the **target**
3. **controller** sends the command bit ( `R/W` )
4. **target** sends `ACK` / `NACK` to **controller**
5. **controller** or **target** sends data (depends on `R/W` )
   - receives `ACK` / `NACK` after every byte
6. **controller** issues a `STOP` condition
   - stops the clock
   - pulls the `SDA` line `HIGH` while `CLK` is `HIGH`

## Address Format




## Transmission

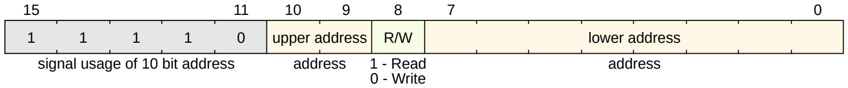


# Transmission Example

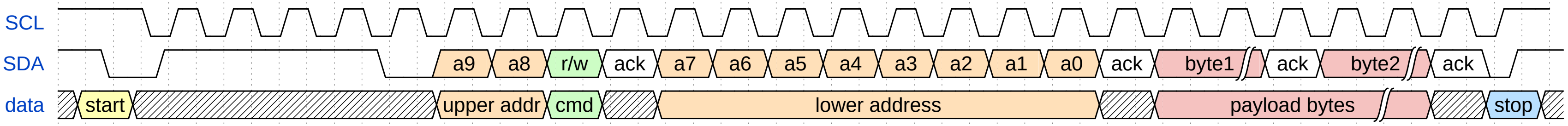
10 bit address

1. **controller** issues a `START` condition
2. **controller** sends `11110` followed by the *upper address* of the **target**
3. **controller** sends the command bit ( `R/W` )
4. **target** sends `ACK` / `NACK` to **controller**
5. **controller** sends the *lower address* of the **target**
6. **target** sends `ACK` / `NACK` to **controller**
7. **controller** or **target** sends data (depends on `R/W` )
   - receives `ACK` / `NACK` after every byte
8. **controller** issues a `STOP` condition

## Address Format




## Transmission




**controller** writes each bit when `CLK` is `LOW`, **target** samples every bit when `CLK` is `HIGH`

# I2C Modes

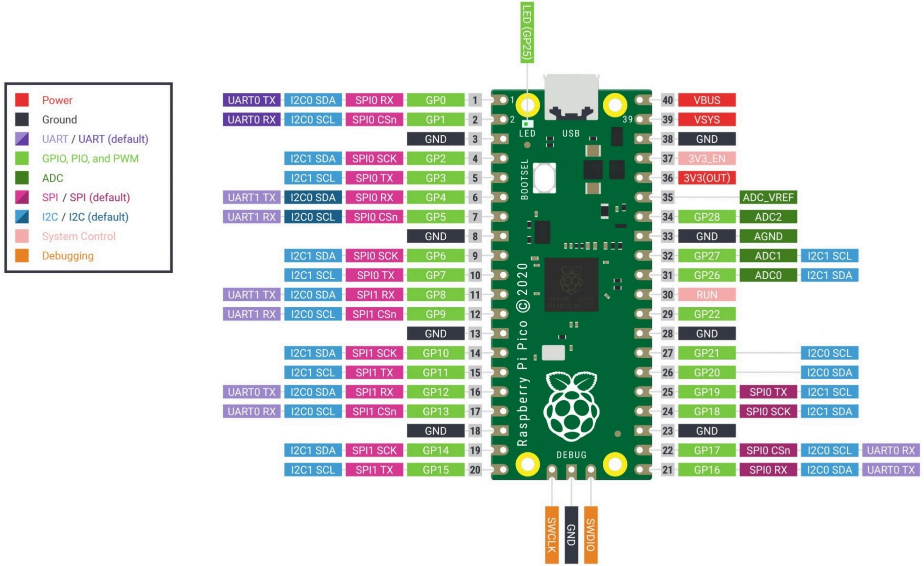
| Mode | Speed | Capacity | Drive | Direction |
|---|---|---|---|---|
| Standard mode (Sm) | 100 kbit/s | 400 pF | Open drain | Bidirectional |
| Fast mode (Fm) | 400 kbit/s | 400 pF | Open drain | Bidirectional |
| Fast mode plus (Fm+) | 1 Mbit/s | 550 pF | Open drain | Bidirectional |
| High-speed mode (Hs) | 1.7 Mbit/s | 400 pF | Open drain | Bidirectional |
| High-speed mode (Hs) | 3.4 Mbit/s | 100 pF | Open drain | Bidirectional |
| Ultra-fast mode (UFm) | 5 Mbit/s | ? | Push–pull | Unidirectional |

# Facts

| | | |
|---|---|---|
| Transmission | *half duplex* | data must be sent in one direction at one time |
| Clock | *synchronized* | the **controller** and **target** use the same clock, there is no need for clock synchronization |
| Wires | *SDA / SCL* | the same read and write wire and a clock wire |
| Devices | *1 controller several targets* | a receiver and a transmitter |
| Speed | *5 Mbit/s* | usually 100 Kbit/s, 400 Kbit/s and 1 Mbit/s |

# Usage

- sensors
- small displays
- RP2350 has two I2C devices



# Embassy API

for RP2350, synchronous

```rust
pub struct Config {
    /// Frequency.
    pub frequency: u32,
}
```

```rust
pub enum ConfigError {
    /// Max i2c speed is 1MHz
    FrequencyTooHigh,
    ClockTooSlow,
    ClockTooFast,
}
```

```rust
pub enum Error {
    Abort(AbortReason),
    InvalidReadBufferLength,
    InvalidWriteBufferLength,
    AddressOutOfRange(u16),
    AddressReserved(u16),
}
```

```rust
use embassy_rp::i2c::Config as I2cConfig;

let sda = p.PIN_14;
let scl = p.PIN_15;
let mut i2c = i2c::I2c::new_blocking(p.I2C1, scl, sda, I2cConfig::default());

let tx_buf = [0x90];
i2c.write(0x5e, &tx_buf).unwrap();

let mut rx_buf = [0x00u8; 7];
i2c.read(0x5e, &mut rx_buf).unwrap();

i2c.write_read(0x5e, &tx_buf, &mut rx_buf).unwrap();
```

# Embassy API

for RP2350, asynchronous

```rust
use embassy_rp::i2c::Config as I2cConfig;

bind_interrupts!(struct Irqs {
    I2C1_IRQ => InterruptHandler<I2C1>;
});

let sda = p.PIN_14;
let scl = p.PIN_15;
let mut i2c = i2c::I2c::new_async(p.I2C1, scl, sda, Irqs, I2cConfig::default());

let tx_buf = [0x90];
i2c.write(0x5e, &tx_buf).await.unwrap();

let mut rx_buf = [0x00u8; 7];
i2c.read(0x5e, &mut rx_buf).await.unwrap();

i2c.write_read(0x5e, &tx_buf, &mut rx_buf).await.unwrap();
```

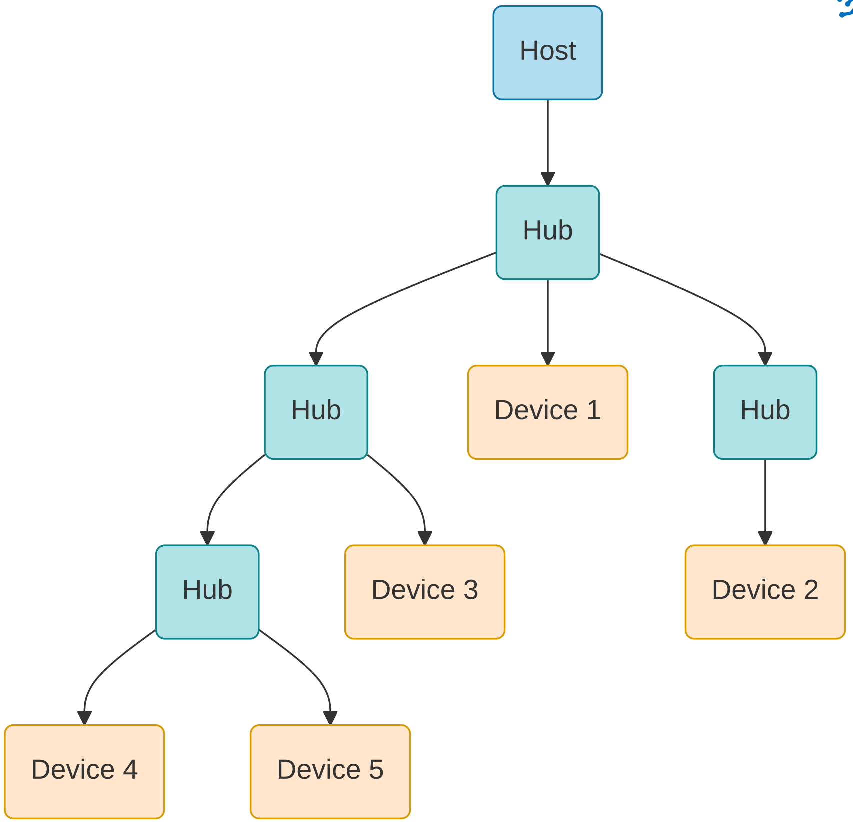
# USB 2.0

Universal Serial Bus

# Universal Serial Bus

2.0

- Used for communication between a host and several devices that each provide functions
- Two modes:
  - *host* - initiates the communication (usually a computer)
  - *device* - receives and transmits data when the *host* requests it
- each device has a 7 bit address assigned upon connect
  - maximum 127 devices connected to a USB host
- devices are interconnected using *hubs*
- USB devices tree



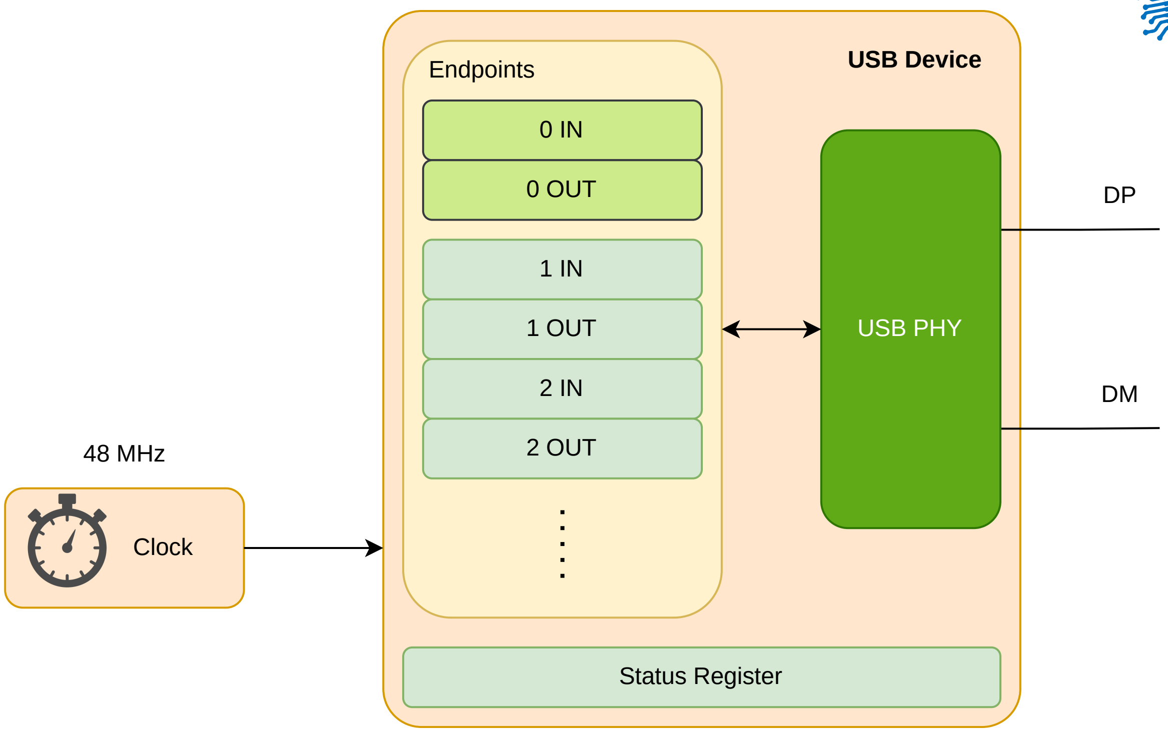
# Bibliography

for this section


1. **Raspberry Pi Ltd**, *RP2350 Datasheet*
   - Chapter 12 - *Peripherals*
     - Chapter 12.7 - *USB*
2. *USB Made Simple*

# USB

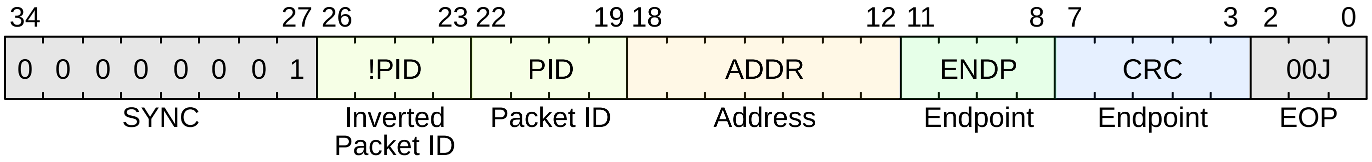
- can work as **host** or **device**, but not at the same time
- uses a differential line for transmission
- uses a 48 MHz clock
- maximum 16 endpoints (buffers)
  - *IN* - from **device** to **host**
  - *OUT* - from **host** to **device**
- endpoints 0 IN and OUT are used for control



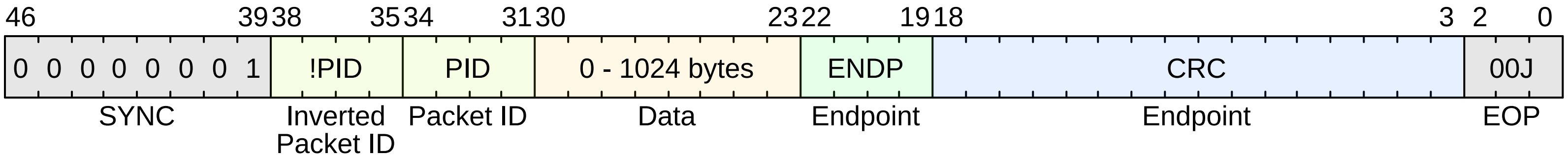
# USB Packet

the smallest element of data transmission

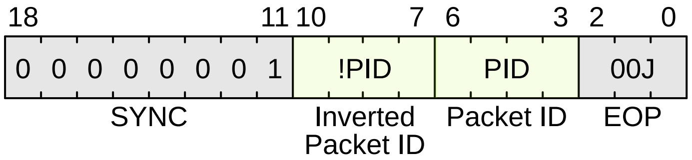
## Token




## Data




## Handshake

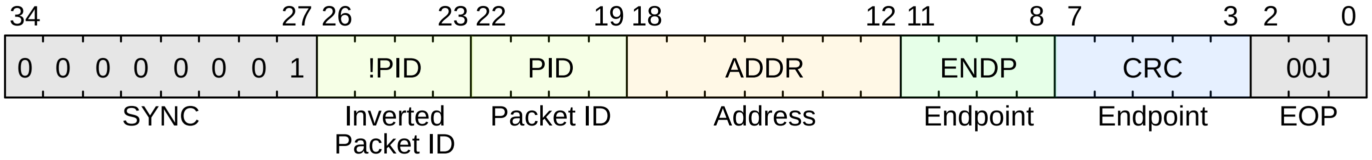


# Token Packet

usually asks for a data transmission

| Type | PID | Description |
| --- | --- | --- |
| *OUT* | `0001` | **host** wants to transmit data to the **device** |
| *IN* | `1001` | **host** wants to receive data from the **device** |
| *SETUP* | `1101` | **host** wants to setup the **device** |

Address: `ADDR`:`ENDP`

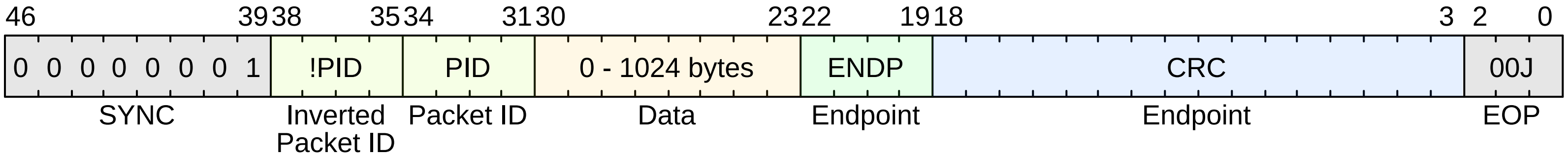


# Data Packet

transmits data

| Type | PID | Description |
| --- | --- | --- |
| *DATA0* | `0011` | the data packet is the first one or follows after a `DATA1` packet |
| *DATA1* | `1011` | the data packet follows after a `DATA0` packet |

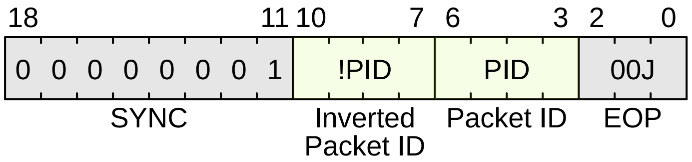
Data can be between 0 and 1024 bytes



# Handshake Packet

acknowledges data

| Type | PID | Description |
|---|---|---|
| *ACK* | `0010` | data has been **successfully received** |
| *NACK* | `1010` | data has **not** been **successfully received** |
| *STALL* | `1110` | the device has an **error** |



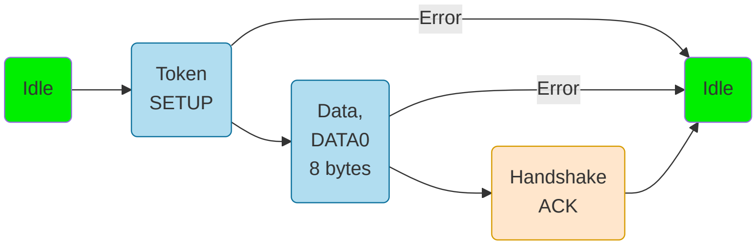
# Transmission Modes

- *Control* - used for configuration
- *Isochronous* - used for high bandwidth, best effort
- *Bulk* - used for low bandwidth, stream
- *Interrupt* - used for low bandwidth, guaranteed latency

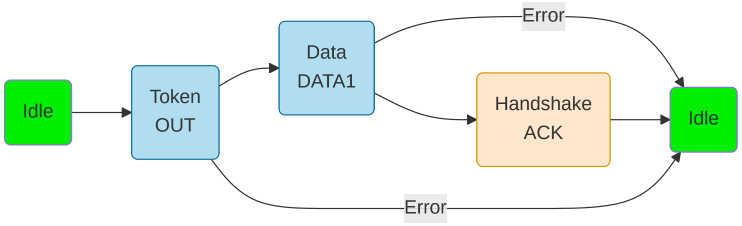
# Control

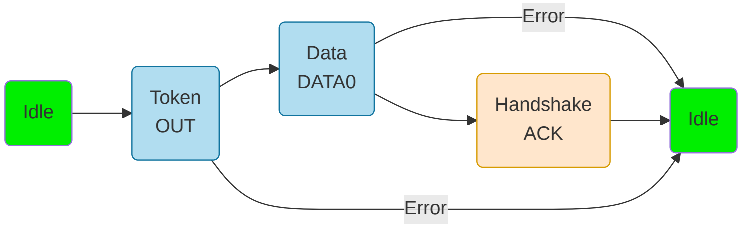
used to control a device - ask for data

**Setup** - send a command (*GET_DESCRIPTOR, ...*)



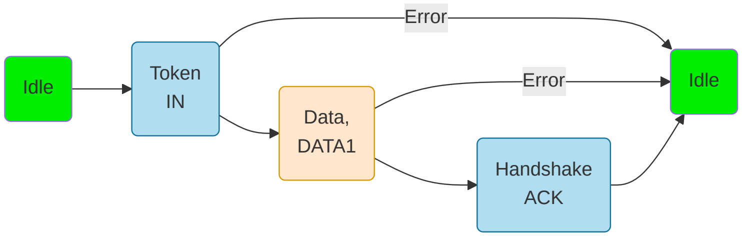

**Data** - *optional* several transfers, host transfers data




...

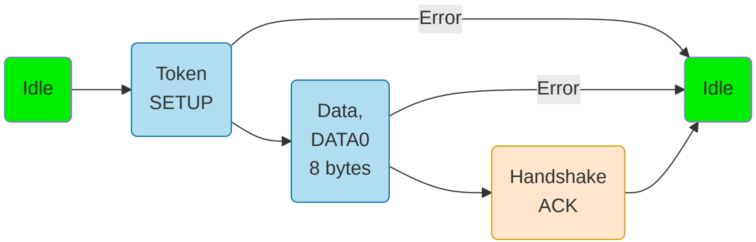
**Status** - report the status to the host



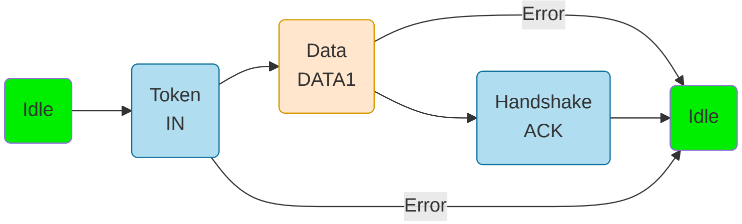
# Control

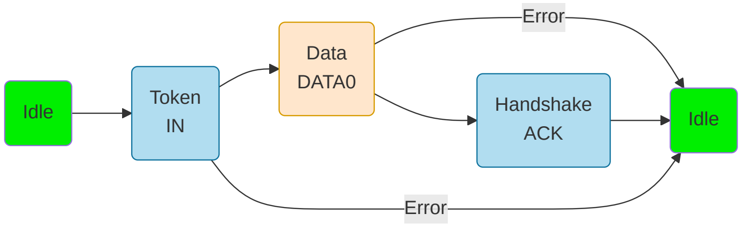
used to control a device - send data

**Setup** - send a command (*SET_ADDRESS*, ...)



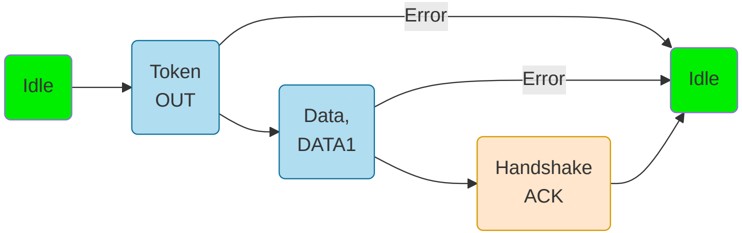

**Data** - *optional* several transfers, device transfers the requested data




...

**Status** - report the status to the device

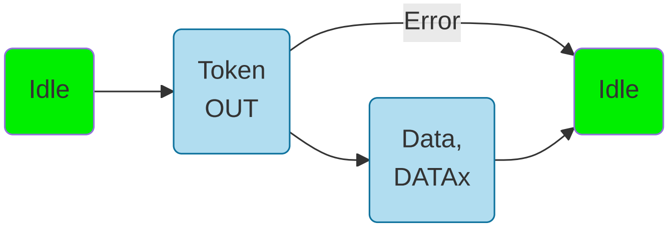


# Isochronous

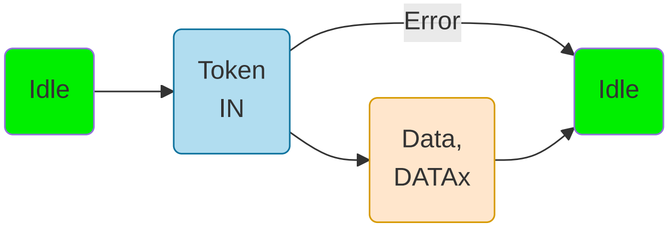
fast but not reliable transfer

- has a guaranteed bandwidth
- allows data loss
- used for functions like streaming where loosing a packet has a minimal impact

**OUT** - transfer data from the host to the device




**IN** - transfer data from the device to the host

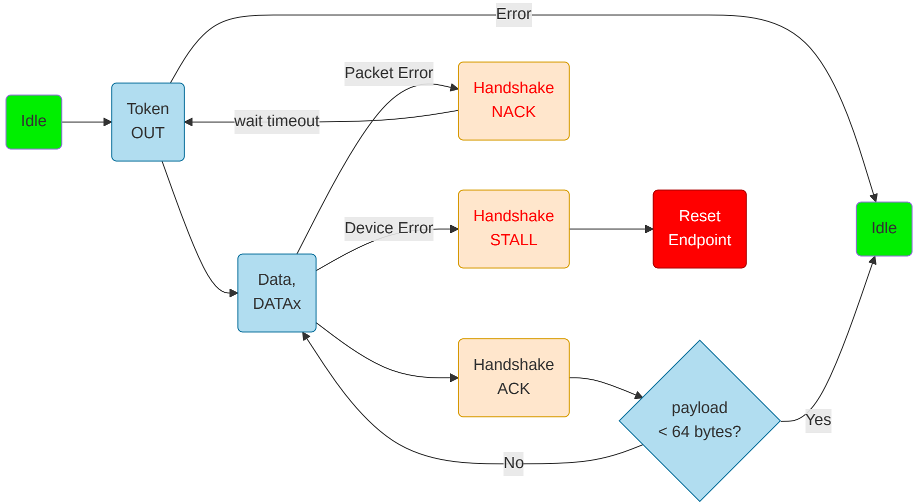


# Bulk

slow, but reliable transfer

- does not have a guaranteed bandwidth
- does not allow data loss
- used for large data transfers where loosing packets is not permitted

**OUT** - transfer data from the host to the device



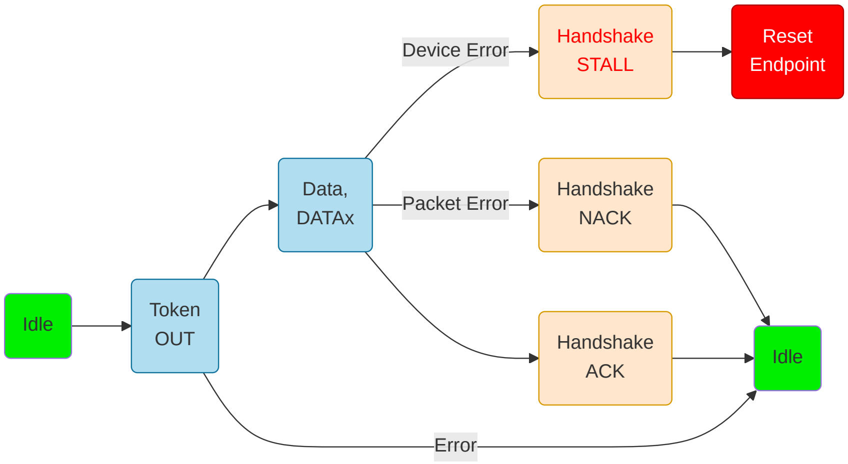

**IN** - transfer data from the device to the host

# Interrupt

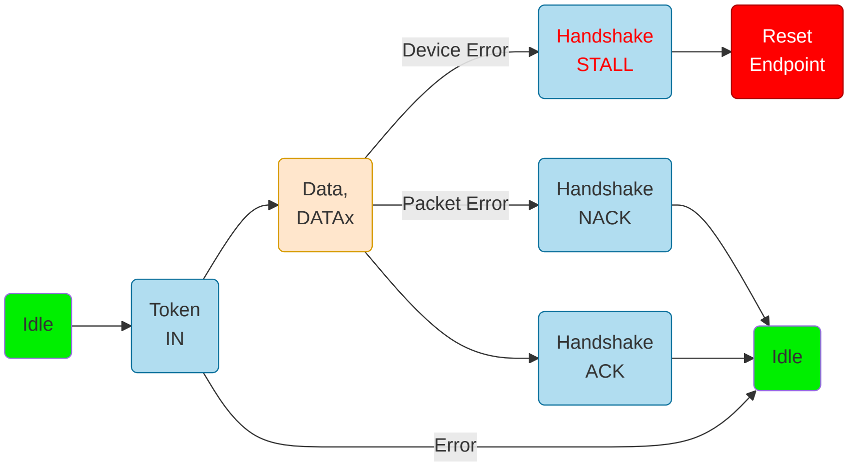
transfer data at a minimum time interval

- the endpoint descriptor asks the host start an interrupt transfer at a time interval
- used for sending and receiving data at certain intervals

**OUT** - transfer data from the host to the device



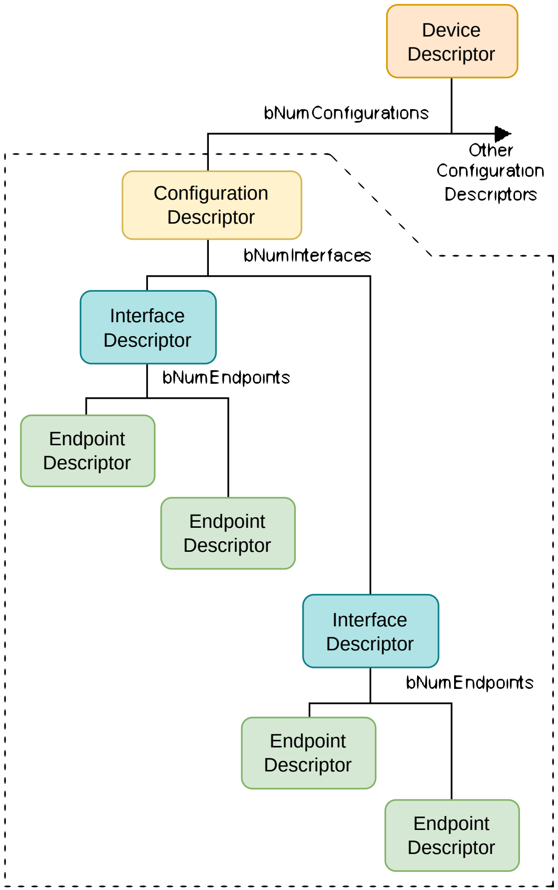

**IN** - transfer data from the device to the host



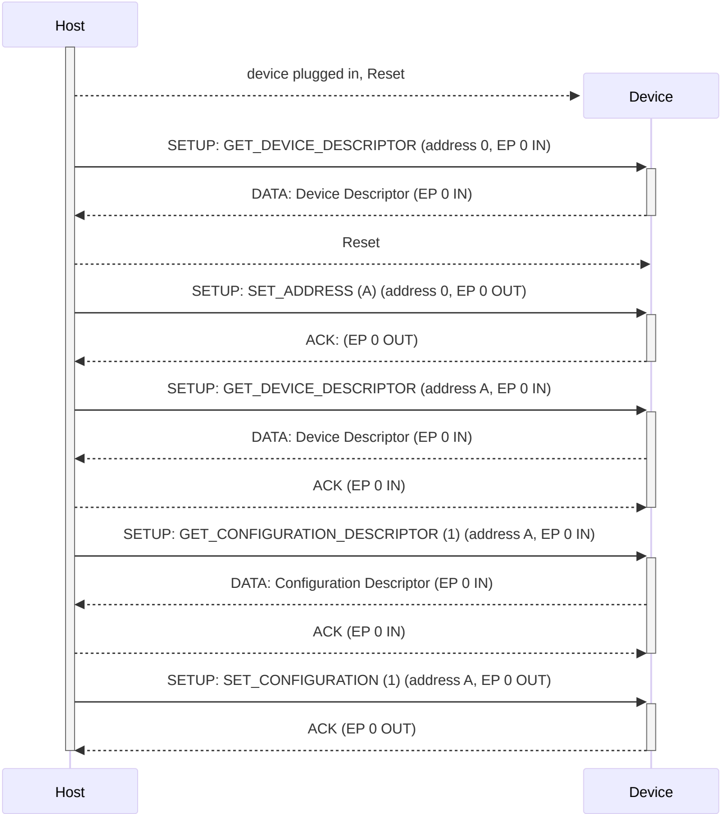
# Device Organization

configuration, interfaces, endpoints

- a *device* can have multiple *configurations*
  - for instance different functionality based on power consumption
- a *configuration* has multiple *interfaces*
  - a device can perform multiple functions
  - Debugger
  - Serial Port
- each *interface* has *alternate settings* with multiple *endpoints* attached
  - endpoints are used for data transfer
  - maximum 16 endpoints, can be configured IN and OUT
- the device reports the descriptors in this order

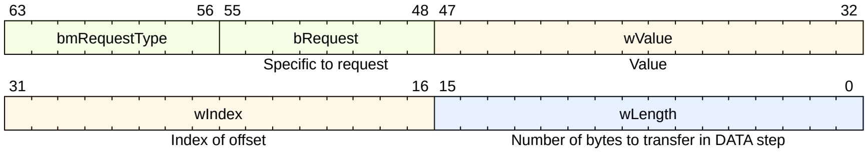


# Connection

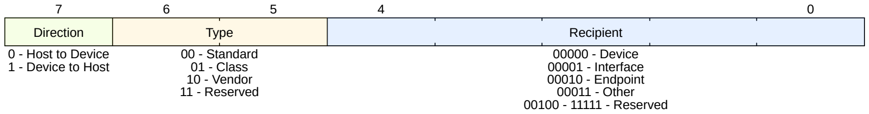



# Token SETUP Packet

## The DATA packet of the SETUP Control Transfer




## *bmRequestType* field



# Device Classes

predefined devices types

| Device Class Code | Class Name | Description |
|---|---|---|
| `0x00` | **Device Class** | Device class-specific; the class code is assigned by the device. |
| `0x01` | **Audio** | Audio devices (e.g., audio interfaces, speakers, microphones). |
| `0x02` | **Communications and CDC Control** | Devices related to communication (e.g., modems, network adapters). |
| `0x03` | **HID (Human Interface Device)** | Devices like keyboards, mice, and other human interface devices. |
| `0x05` | **Physical Interface Device (PID)** | Devices that require physical input/output (e.g., game controllers). |
| `0x06` | **Image** | Image devices such as digital cameras and scanners. |
| `0x07` | **Printer** | Devices for printing (e.g., printers). |
| `0x08` | **Mass Storage** | Mass storage devices (e.g., USB flash drives, external hard drives). |
| `0x0A` | **Still Image Capture Device** | Devices for still image capture (e.g., digital cameras). |
| `0x0B` | **Smart Card** | Smart card readers and related devices. |
| `0x0D` | **Content Security** | Devices for content protection (e.g., video players). |
| `0x0E` | **Video** | Video devices (e.g., webcams, video capture devices). |
| `0x0F` | **Personal Healthcare** | Healthcare devices (e.g., thermometers, blood pressure monitors). |
| `0x10` | **Audio/Video** | Devices with combined audio/video functions. |
| `0x11` | **Health Device** | Devices used in health-related monitoring. |
| `0x12` | **Diagnostic Device** | Devices for diagnostics or test instruments. |
| `0xFF` | **Vendor Specific** | Vendor-specific devices (class code not assigned by USB standard). |

# Device Descriptor

describes the whole device

| Field | Value | Description |
|---|---|---|
| *bLength* | `18` | Descriptor length in bytes. |
| *bDescriptorType* | `1` | Descriptor type (1 = Device Descriptor). |
| *bcdUSB* | `0x0200` | USB specification release number (2.0). |
| *bDeviceClass* | `0xFF` | Device class (0xFF = Vendor Specific). |
| *bDeviceSubClass* | `0` | Device subclass (0 = defined by the interface). |
| *bDeviceProtocol* | `0` | Device protocol (0 = defined by the interface). |
| *bMaxPacketSize0* | `64` | Maximum packet size for endpoint 0 (64 bytes). |
| *idVendor* | `0xC0DE` | Vendor ID (example: `0xC0DE` ). |
| *idProduct* | `0xCAFE` | Product ID (example: `0xCAFE` ). |
| *bcdDevice* | `0x0100` | Device release number (example: `1.0` ). |
| *iManufacturer* | `1` | Index of the string descriptor for the manufacturer. |
| *iProduct* | `2` | Index of the string descriptor for the product. |
| *iSerialNumber* | `3` | Index of the string descriptor for the serial number. |
| *bNumConfigurations* | `1` | Number of configurations supported by the device. |

# Configuration Descriptor

one of the configurations

| Field | Value | Description |
| --- | --- | --- |
| *bLength* | `9` | Descriptor length in bytes (always 9 for configuration descriptor). |
| *bDescriptorType* | `2` | Descriptor type (2 = Configuration Descriptor). |
| *wTotalLength* | `0x0022` | Total length of data returned for this configuration (including all descriptors). |
| *bNumInterfaces* | `1` | Number of interfaces supported by this configuration. |
| *bConfigurationValue* | `1` | Value to select this configuration. |
| *iConfiguration* | `4` | Index of the string descriptor describing the configuration. |
| *bmAttributes* | `0x80` | Configuration characteristics (bus-powered, no remote wake-up). |
| *bMaxPower* | `50` | Maximum power consumption (in 2mA units, so `50` means 100mA). |

# Interface Descriptor

| Field | Value | Description |
|---|---|---|
| *bLength* | `9` | Descriptor length in bytes (always 9 for interface descriptor). |
| *bDescriptorType* | `4` | Descriptor type (4 = Interface Descriptor). |
| *bInterfaceNumber* | `0` | Number of this interface (starting from 0). |
| *bAlternateSetting* | `0` | Alternate setting (0 = default setting). |
| *bNumEndpoints* | `1` | Number of endpoints used by this interface. |
| *bInterfaceClass* | `0xFF` | Interface class (0xFF = Vendor Specific). |
| *bInterfaceSubClass* | `0` | Interface subclass (0 = vendor specific). |
| *bInterfaceProtocol* | `0` | Interface protocol (0 = vendor specific). |
| *iInterface* | `5` | Index of the string descriptor describing this interface. |

# Endpoint Descriptor

| Field | Value | Description |
|---|---|---|
| *bLength* | `7` | Descriptor length in bytes (always 7 for endpoint descriptor). |
| *bDescriptorType* | `5` | Descriptor type (5 = Endpoint Descriptor). |
| *bEndpointAddress* | `0xb1_0000_001` | Endpoint address ( `0x81` ): **Bit 7** indicates **IN** direction (device to host), and **Bits 0-3** indicate the endpoint number ( `1` in this case). |
| *bmAttributes* | `0x02` | Endpoint attributes ( `0x02` = Bulk endpoint). |
| *wMaxPacketSize* | `64` | Maximum packet size the endpoint can handle (64 bytes). |
| *bInterval* | `0` | Interval for polling (relevant for interrupt endpoints; `0` for others). |

# Strings Descriptor

## String Descriptor for Configuration and Interface

| Field | Value | Description |
|---|---|---|
| *bLength* | `4` | Descriptor length in bytes (always 4 for string descriptor header). |
| *bDescriptorType* | `3` | Descriptor type (3 = String Descriptor). |
| *bString* | `0x09 0x55 0x53 0x42 0x20 0x43 0x6F 0x6E 0x66 0x69 0x67 0x20 0x31` | UTF-16LE string encoding: `"USB Config 1"`. |

Explanation: This string descriptor corresponds to **Configuration 1**. The string is encoded in **UTF-16LE** (little-endian). Each character is represented by two bytes.

# USB 1.0 and 2.0 Modes

| Mode | Speed | Version |
|---|---|---|
| Low Speed | 1.5 Mbit/s | 1.0 |
| Full Speed | 12 Mbit/s | 1.0 |
| High Speed | 480 Mbit/s | 2.0 |

# Facts

| | | |
|---|---|---|
| Transmission | *half duplex* | data must be sent in one direction at one time |
| Clock | *independent* | the **host** and the **device** must synchronize their clocks |
| Wires | *DP / DM* | data is sent in a differential way |
| Devices | *1 host*<br>*several devices* | a receiver and a transmitter |
| Speed | *480 MBbit/s* | |

# Embassy API

for RP2350, setup the device

```rust
use embassy_rp::usb::{Driver, InterruptHandler};
use embassy_usb::Config;

bind_interrupts!(struct Irqs {
    USBCTRL_IRQ => InterruptHandler<USB>;
});

let mut config = Config::new(0xc0de, 0xcafe);
config.manufacturer = Some("Embassy");
config.product = Some("USB sender receiver");
config.serial_number = Some("12345678");
config.max_power = 100;
config.max_packet_size_0 = 64;

let driver = Driver::new(p.USB, Irqs);
```

# Embassy API

for RP2350, setup the descriptors

```rust
use embassy_usb::msos::{self, windows_version};
use embassy_usb::Builder;

// It needs some buffers for building the descriptors.
let mut config_descriptor = [0; 256];
let mut bos_descriptor = [0; 256];
let mut msos_descriptor = [0; 256];
let mut control_buf = [0; 64];

let mut builder = Builder::new(driver, config,
  &mut config_descriptor, &mut bos_descriptor, &mut msos_descriptor, &mut control_buf,
);

// Required for Windows
const DEVICE_INTERFACE_GUIDS: &[&str] = &["{AFB9A6FB-30BA-44BC-9232-806CFC875321}"];
builder.msos_descriptor(windows_version::WIN8_1, 0);
builder.msos_feature(msos::CompatibleIdFeatureDescriptor::new("WINUSB", ""));
builder.msos_feature(msos::RegistryPropertyFeatureDescriptor::new(
  "DeviceInterfaceGUIDs",
  msos::PropertyData::RegMultiSz(DEVICE_INTERFACE_GUIDS),
));
```

# Embassy API

for RP2350, setup the device’s function and start

```rust
// Add a vendor-specific function (class 0xFF), and corresponding interface,
// that uses our custom handler.
let mut function = builder.function(0xFF, 0, 0);
let mut interface = function.interface();
let mut alt = interface.alt_setting(0xFF, 0, 0, None);
let mut read_ep = alt.endpoint_bulk_out(64);
let mut write_ep = alt.endpoint_bulk_in(64);
drop(function);

// Build the builder.
let mut usb = builder.build();

// Create the USB device handler
let usb_run = usb.run();
```

# Embassy API

for RP2350, use the USB device

```rust
let echo_run = async {
  loop {
    read_ep.wait_enabled().await;
    info!("Connected");
    loop {
      let mut data = [0; 64];
      match read_ep.read(&mut data).await {
        Ok(n) => {
          info!("Got bulk: {:a}", data[..n]);
          // Echo back to the host:
          write_ep.write(&data[..n]).await.ok();
        }
        Err(_) => break,
      }
    }
    info!("Disconnected");
  }
};

// Run everything concurrently.
// If we had made everything `'static` above instead, we could do this using separate tasks instead.
join(usb_run, echo_run).await;
```

# Host API

using `nusb`

```rust
use nusb::transfer::RequestBuffer;

const BULK_OUT_EP: u8 = 0x01;
const BULK_IN_EP: u8 = 0x81;

async fn main() {
    let di = nusb::list_devices()
        .unwrap()
        .find(|d| d.vendor_id() == 0xc0de && d.product_id() == 0xcafe)
        .expect("no device found");

    let device = di.open().expect("error opening device");
    let interface = device.claim_interface(0).expect("error claiming interface");

    let result = interface.bulk_out(BULK_OUT_EP, b"hello world".into()).await;
    println!("{result:?}");

    let result = interface.bulk_in(BULK_IN_EP, RequestBuffer::new(64)).await;
    println!("{result:?}");
}
```

# Host API

using Python

```python
import usb
import time

# Find the USB device
dev = usb.core.find(idVendor=0xc0de, idProduct=0xcafe)
if dev is None:
    raise ValueError('Device not found')

dev.set_configuration() # Set the active configuration (this is usually required after device detection)

OUT_ENDPOINT = 0x01  # Usually 0x01 for OUT endpoint
IN_ENDPOINT = 0x81  # Usually 0x81 for IN endpoint (Endpoint 1, Direction IN)

data_to_send = b"Hello, USB Device!"

dev.write(OUT_ENDPOINT, data_to_send)
time.sleep(1) # Wait for a short time to ensure data is transferred

data_received = dev.read(IN_ENDPOINT, 64)  # Read 64 bytes (adjust the size if needed)
print("Data received from device:", bytes(data_received))

usb.util.release_interface(dev, 0) # Release the device interface (optional, but good practice)
```

# Sensors

Analog and Digital Sensors

# Bibliography

for this section

**BOSCH**, *BMP280 Digital Pressure Sensor*

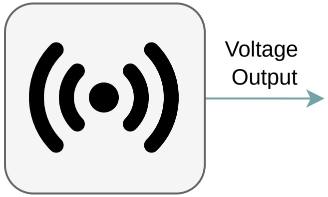
- Chapter 3 - *Functional Description*
- Chapter 4 - *Global memory map and register description*
- Chapter 5 - *Digital Interfaces*
    - Subchapter 5.2 - *I2C Interface*

# Sensors

analog and digital

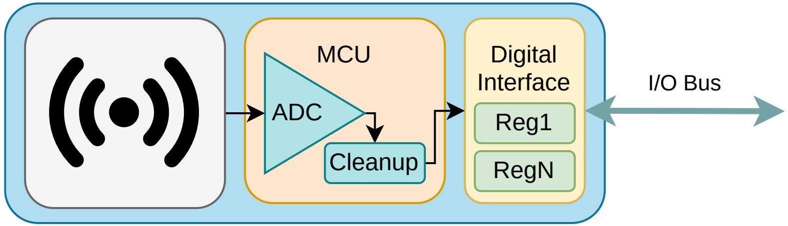
## Analog

- only the transducer (the analog sensor)
- outputs (usually) voltage
- requires:
  - an ADC to be read
  - cleaning up the noise



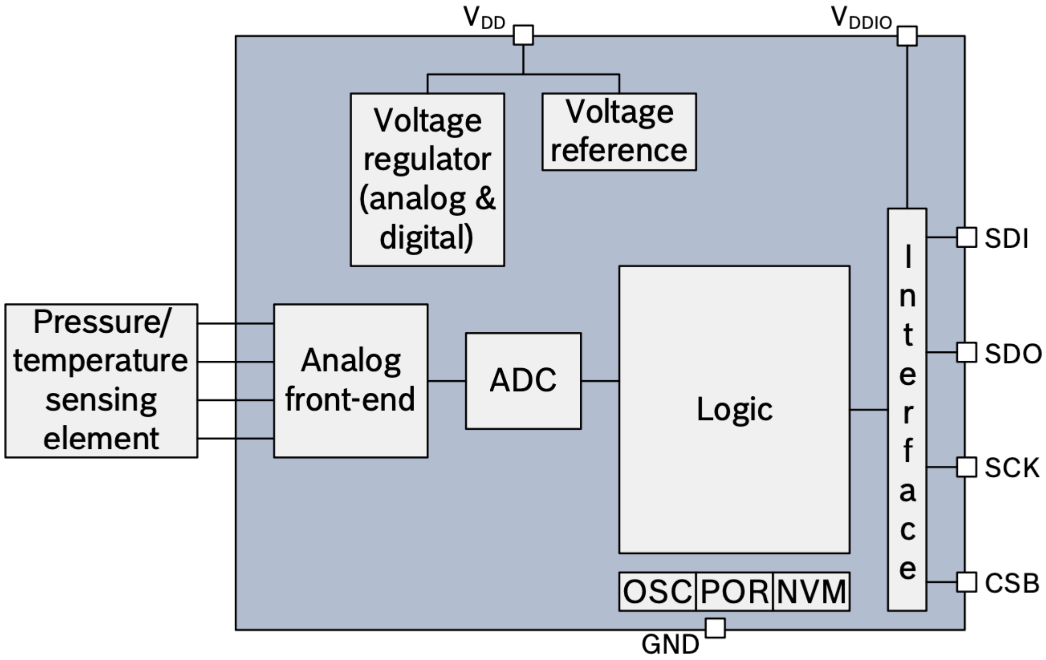

## Digital

- consists of:
  - a transducer (the analog sensor)
  - an ADC
  - an MCU for cleaning up the noise
- outputs data using a digital bus



# BMP280 Digital Pressure Sensor

schematics




Datasheet

# BMP280 Digital Pressure Sensor

registers map

| Register Name | Address | bit7 | bit6 | bit5 | bit4 | bit3 | bit2 | bit1 | bit0 | Reset state |
|---|---|---|---|---|---|---|---|---|---|---|
| temp_xlsb | 0xFC | temp_xlsb<7:4> | | | | 0 | 0 | 0 | 0 | 0x00 |
| temp_lsb | 0xFB | temp_lsb<7:0> | | | | | | | | 0x00 |
| temp_msb | 0xFA | temp_msb<7:0> | | | | | | | | 0x80 |
| press_xlsb | 0xF9 | press_xlsb<7:4> | | | | 0 | 0 | 0 | 0 | 0x00 |
| press_lsb | 0xF8 | press_lsb<7:0> | | | | | | | | 0x00 |
| press_msb | 0xF7 | press_msb<7:0> | | | | | | | | 0x80 |
| config | 0xF5 | t_sb[2:0] | | | filter[2:0] | | | | spi3w_en[0] | 0x00 |
| ctrl_meas | 0xF4 | osrs_t[2:0] | | | osrs_p[2:0] | | | mode[1:0] | | 0x00 |
| status | 0xF3 | | | | | measuring[0] | | | im_update[0] | 0x00 |
| reset | 0xE0 | reset[7:0] | | | | | | | | 0x00 |
| id | 0xD0 | chip_id[7:0] | | | | | | | | 0x58 |
| calib25...calib00 | 0xA1…0x88 | calibration data | | | | | | | | individual |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Registers:** | Reserved registers | Calibration data | Control registers | Data registers | Status registers | Revision | Reset |
| **Type:** | do not write | read only | read / write | read only | read only | read only | write only |

Datasheet

# Reading from a digital sensor

using synchronous/asynchronous I2C to read the `press_lsb` register of BMP280

```rust
const DEVICE_ADDR: u8 =  0x77;
const REG_ADDR: u8 = 0xf8;

let mut buf = [0x00u8];

i2c.write_read(
  DEVICE_ADDR, &[REG_ADDR], &mut buf
).unwrap();

// use the value
let pressure_lsb = buf[1];
```

```rust
const DEVICE_ADDR: u8 =  0x77;
const REG_ADDR: u8 = 0xf8;

let mut buf = [0x00u8];

i2c.write_read(
  DEVICE_ADDR, &[REG_ADDR], &mut buf
).await.unwrap();

// use the value
let pressure_lsb = buf[1];
```

# Writing to a digital sensor

using synchronous/asynchronous I2C to set up the `ctrl_meas` register of the BMP280 sensor

```rust
const DEVICE_ADDR: u8 =  0x77;
const REG_ADDR: u8 = 0xf4;

// see subchapters 3.3.2, 3.3.1 and 3.6
let value = 0b100_010_11;

let buf = [REG_ADDR, value];
i2c.write(DEVICE_ADDR, &buf).unwrap();
```

```rust
const DEVICE_ADDR: u8 =  0x77;
const REG_ADDR: u8 = 0xf4;

// see subchapters 3.3.2, 3.3.1 and 3.6
let value = 0b100_010_11;

let buf = [REG_ADDR, value];
i2c.write(DEVICE_ADDR, &buf).await.unwrap();
```

# Conclusion

we talked about

- Buses
  - Inter-Integrated Circuit
  - Universal Serial Bus v2.0