



IO in Embedded Systems

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Overview

- Input/Output
- Digital, Analog
- Translation
- Heater control example



Input

- Usually simple
- No or minimal UI
- Examples
 - Buttons
 - Sensors (e.g. temperature)
 - Camera



Output

- Again simple (UI)
- Output signal needs *amplification*
 - (Solid-state) relays (On/Off)
 - Pulse-Width Modulation (PWM)
- Failure on output?
 - Broken wire
 - Read back with an input



Digital IO

- 1/0 – On/Off
- Represented as electrical value
 - E.g. 0=0V, 1=5V
- Translation to the *real* world
 - Contact switches
 - Relay
- Several IO bits/pins in one register



Analog IO

- Value range
 - E.g. $-20^{\circ}\text{C} \dots 100^{\circ}\text{C}$
- Representation as electrical signal
 - Voltage e.g. 0-20V
 - Resistance issue
 - Current 0-20mA
 - Industry standard
 - 4-20mA Value, $<4\text{mA}$ broken wire



Analog/Digital Conversion

- Electrical signal to digital information
 - Input: Analog/Digital Converter (ADC)
 - Output: Digital/Analog Converter (DAC)
- Resolution in bits
 - E.g. 8 bits => 0...255



Translation Example

- $-20^{\circ}\text{C} \dots 100^{\circ}\text{C} \Rightarrow 4\text{mA} \dots 20\text{mA}$
- $0\text{mA} \dots 20\text{mA} \Rightarrow 0 \dots 255$
- What value is read at 27°C ?
- Is the temperature sensor linear?



Control

- Read input
- Calculate output
- Write output
- Continue this loop *forever*



Example: Temperature control

```
For (;;) {  
    int temp = readTemp();  
    if (temp < 27) {  
        heaterOn = true;  
    } else {  
        heaterOn = false;  
    }  
    setHeater(heaterOn);  
    waitForNextPeriod();  
}
```



Heater Example cont.

- What happens around 27°C?
- On – Off – On – Off
- Not so good
 - Heater does not like this
 - Relay does not like this
- Solution
 - Hysteresis (two thresholds)



Example: Heater revised

```
for (;;) {
    int temp = readTemp();
    if (temp < 27) {
        heaterOn = true;
    } else if (temp > 30) {
        heaterOn = false;
    } else {
        // we keep the heater state
    }
    setHeater(heaterOn);
    waitForNextPeriod();
}
```



Summary

- IO is very simple
- Translation
 - Physical world to electrical signals
 - Electrical signals to digital information
- Almost no UI
- Control runs in a loop
 - The *control loop*