IO in Embedded Systems

Martin Schöberl
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 I/O

- Value range
  - E.g. -20°C ... 100°C

- Representation as electrical signal
  - Voltage e.g. 0-20V
    - Resistance issue
  - Current 0-20mA
    - Industry standard
    - 4-20mA Value, <4mA 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°C … 100°C => 4mA … 20mA
0mA … 20mA => 0 … 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

```c
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