Capsense techniques

Eindhoven University of Technology
Industrial Design – Wearable Senses

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- RC method
- CVD method
- Noise reduction
- Digital filtering
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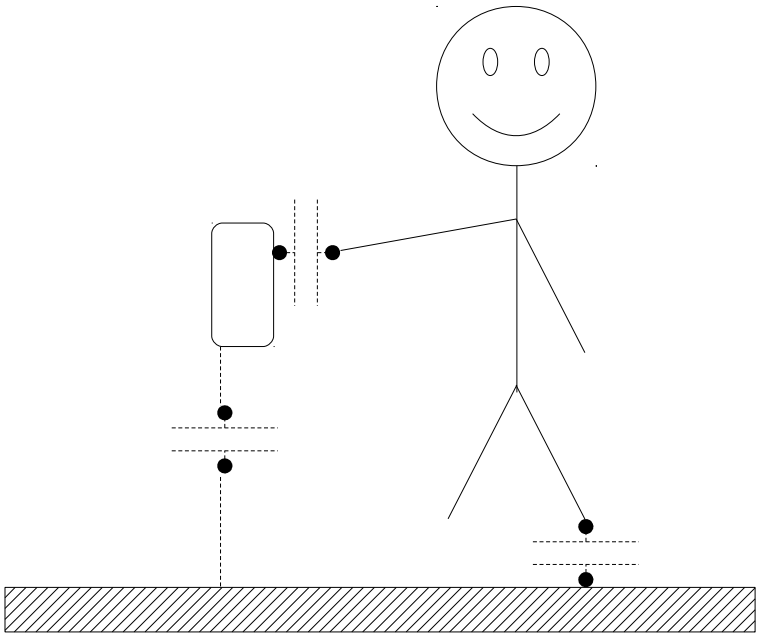
Capsense model

Capacitive connections:

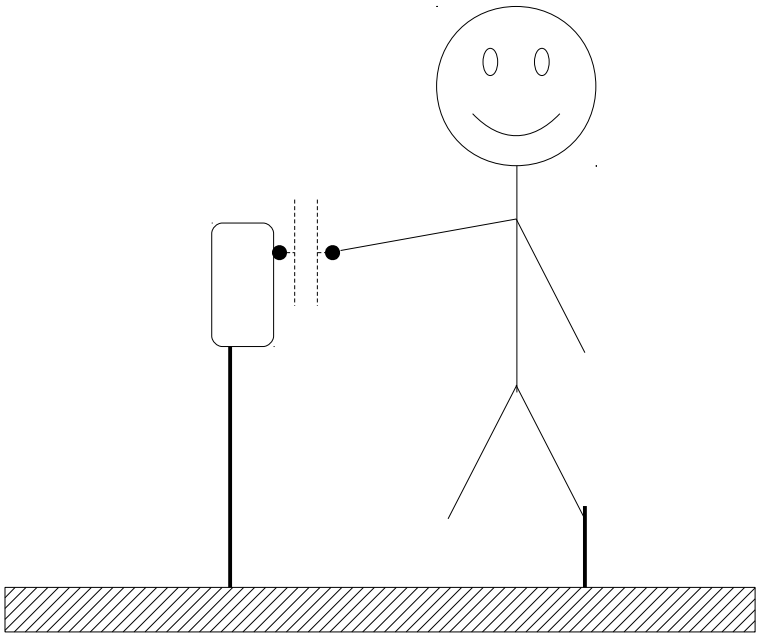
- From sensor to user
- From user to earth
- From earth to sensor



Capsense model

Improve signal strength:

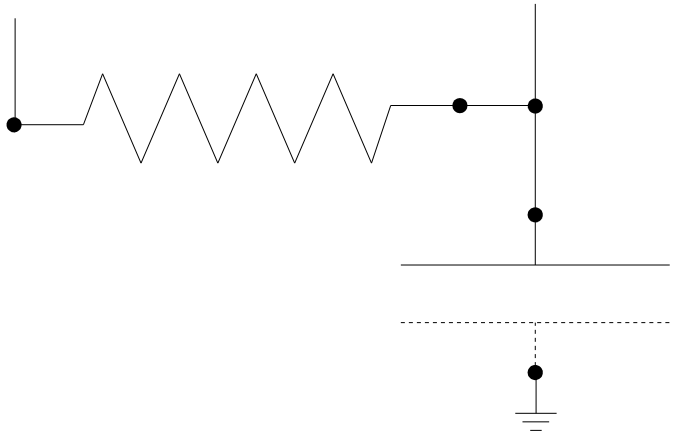
- Connect ground from device to earth
- Connect user to earth

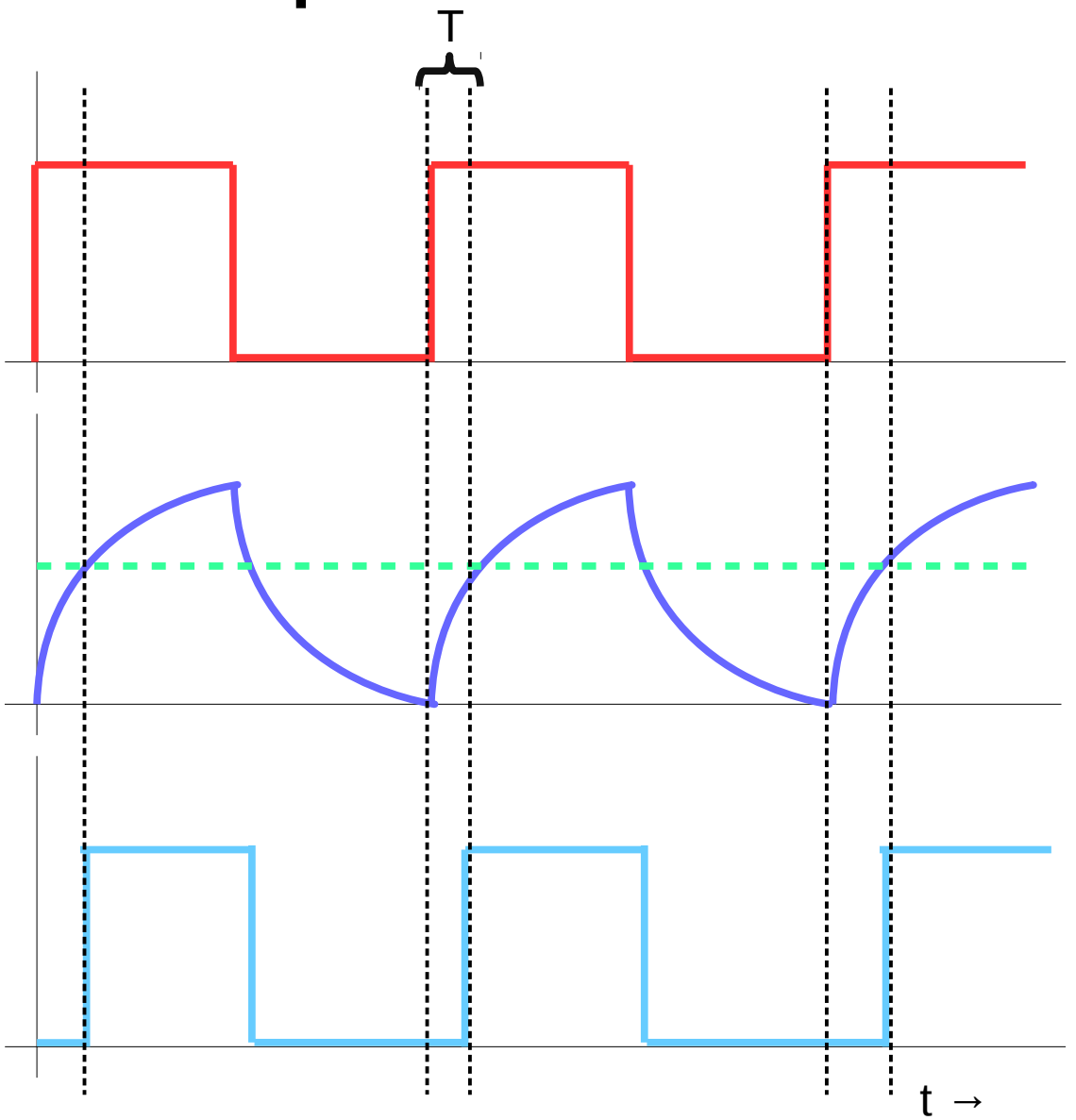


RC method: operation

To Arduino transmit pin

To Arduino receive pin



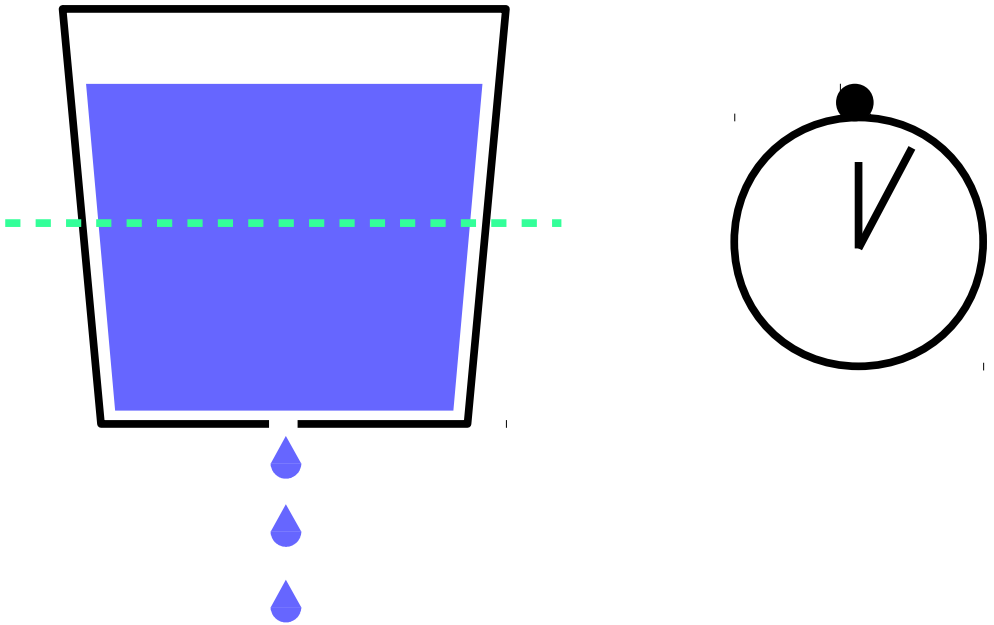


Reference voltage (~ 2.5V): above this level, signal is high (“1”), below it is low (“0”)

Digital input as seen by Arduino

Time T between transmit pin going up and digital input going up is measure of capacitance

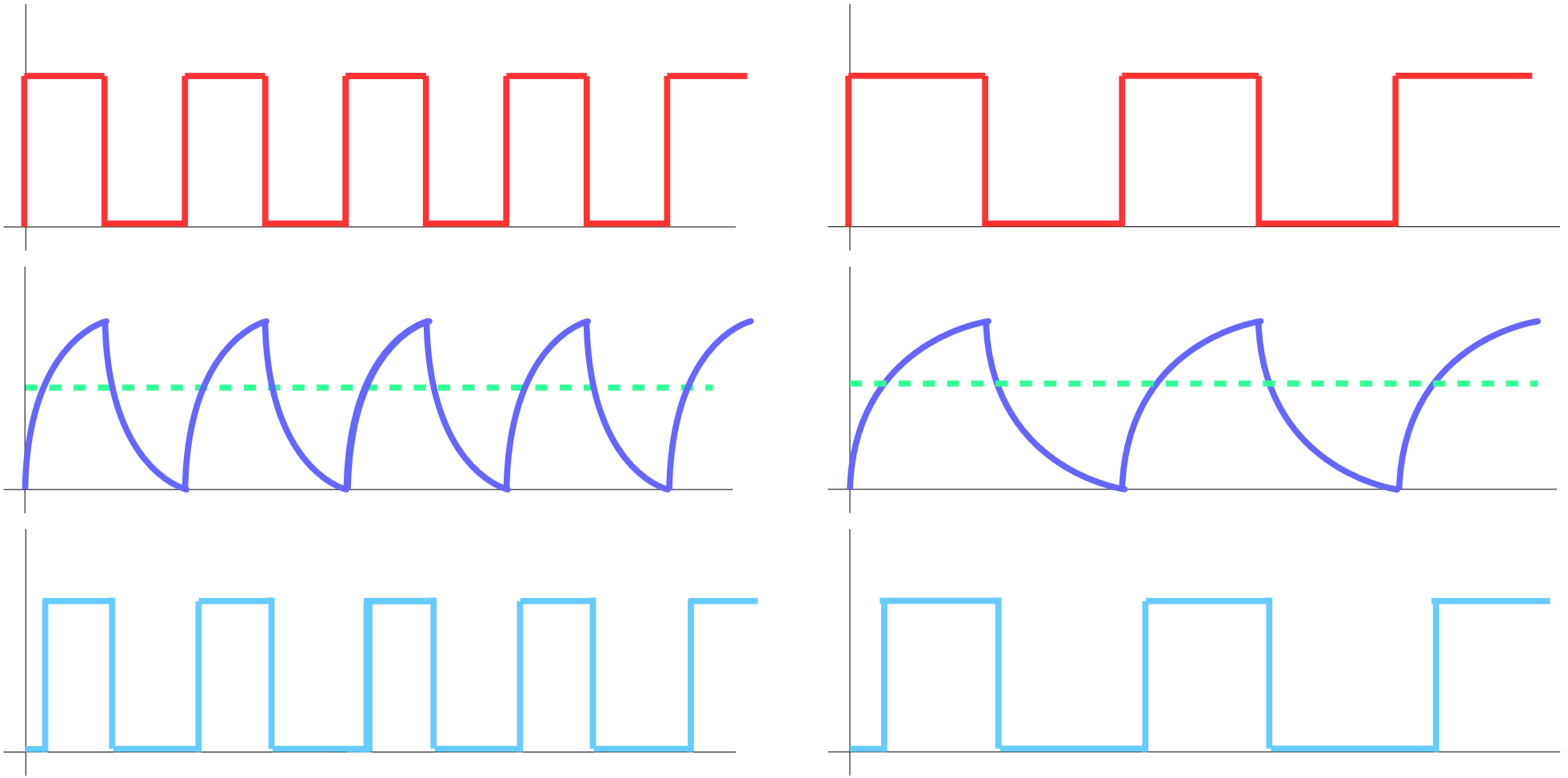
RC method: water bucket analogy



RC method: signals

No hand present (C is small)

Hand present (C is large)



RC method: issues

- Time between pulses can vary a lot depending on presence of hand (can vary from ~ 1us to ~ 500 us)
- Update rate at 500 us is very slow → limited filtering possible
- Variable update rate makes filtering difficult

RC method: pros & cons

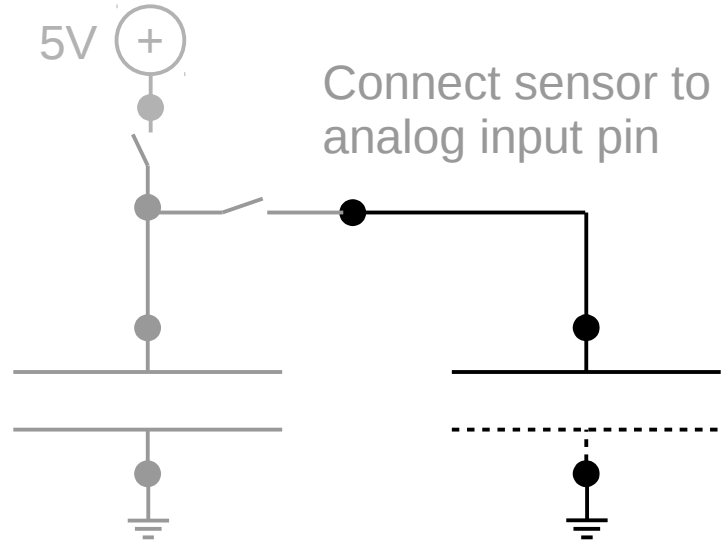
Pros:

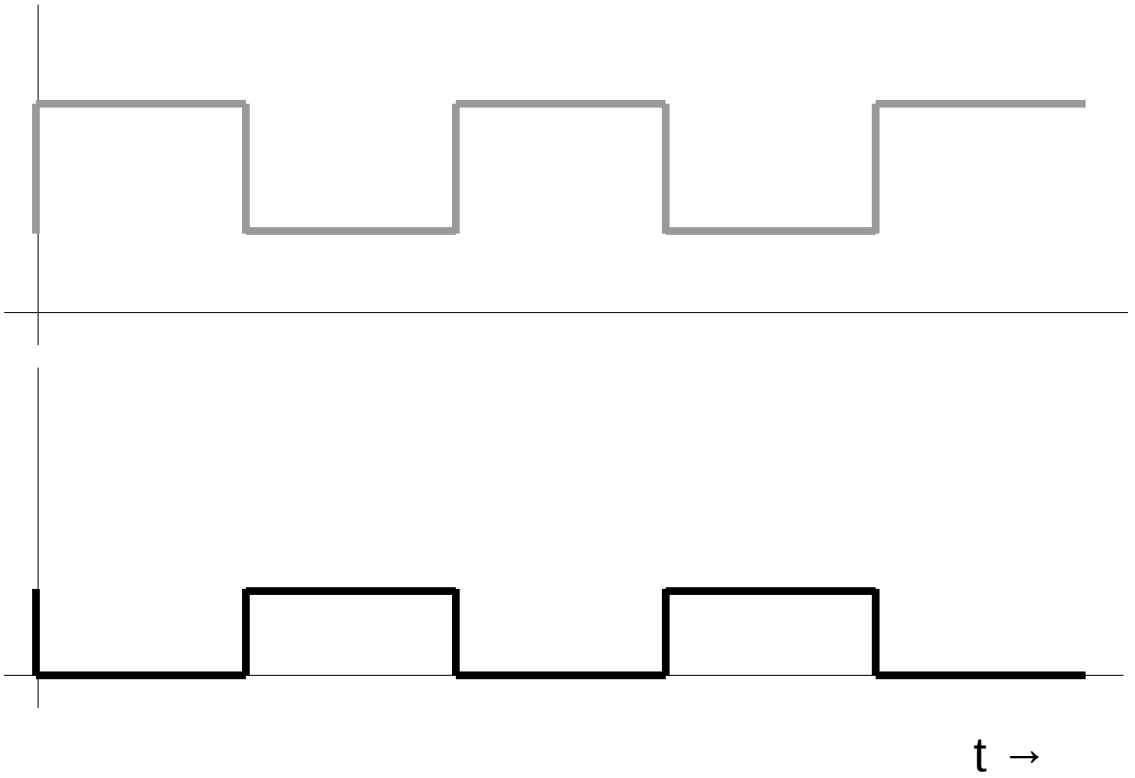
- Works on any 2 digital pins
- Simple
- Low cost
- Open source

Cons:

- Slow or variable update rate
- Filtering is limited or difficult

CVD method: operation

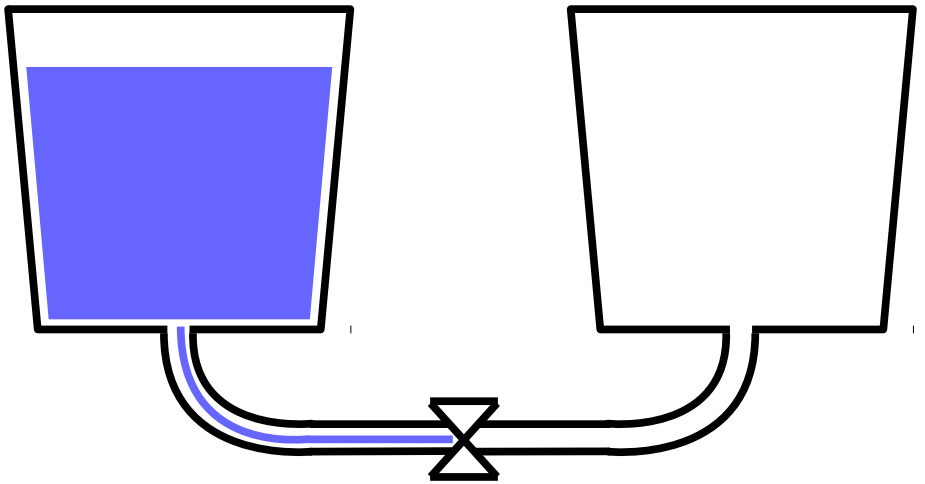




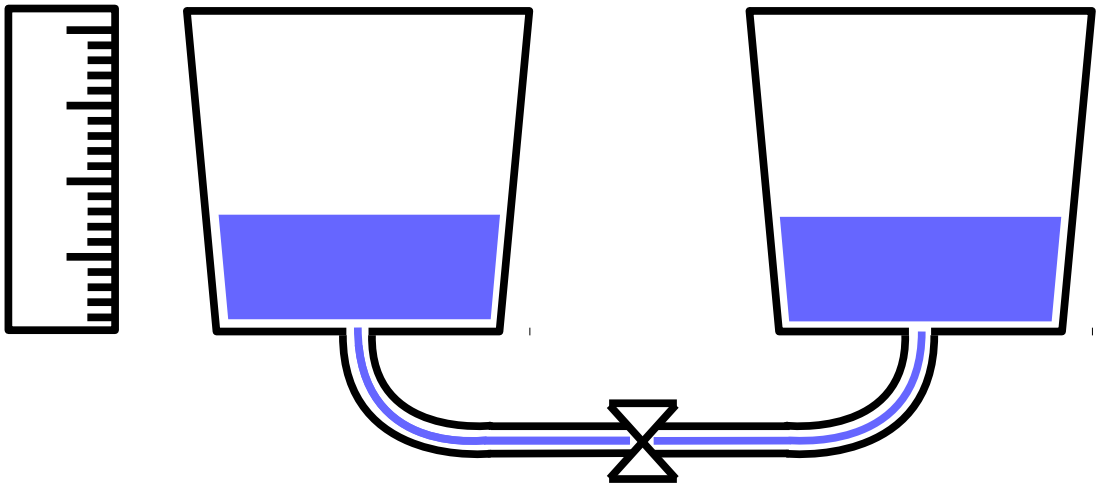
Use internal sample & hold capacitor of ADC as reference capacitor. Charge internal C&H, then spread charge over C&H and sensor and finally measure voltage.

CVD method: water bucket analogy

- Close valve
- Fill reference bucket (charge S&H capacitor)

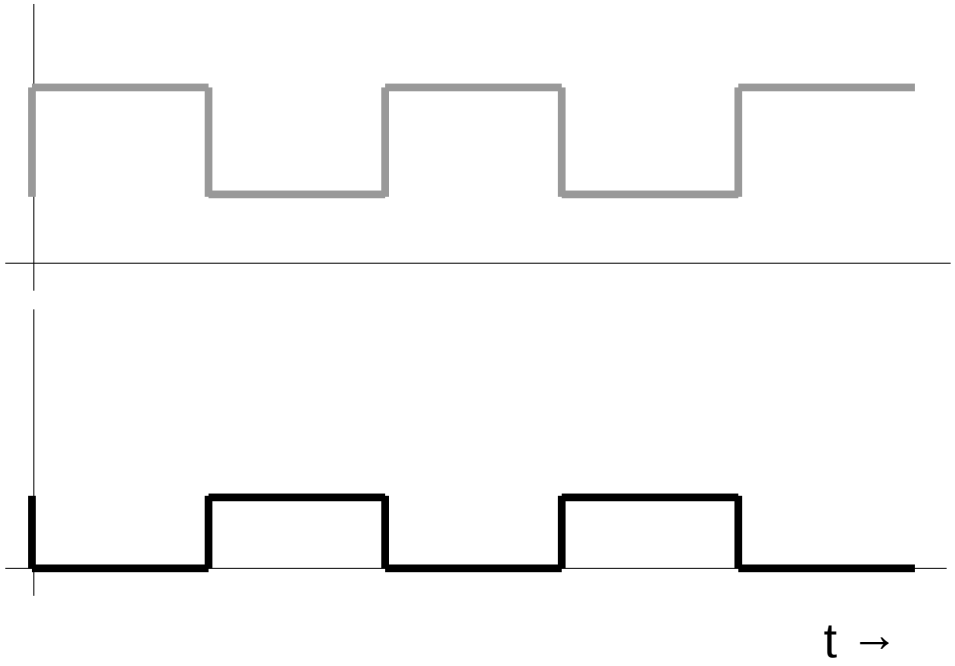


- Open valve: water will distribute over both buckets (charge distributes over S&H and sensor)
- Measure water level

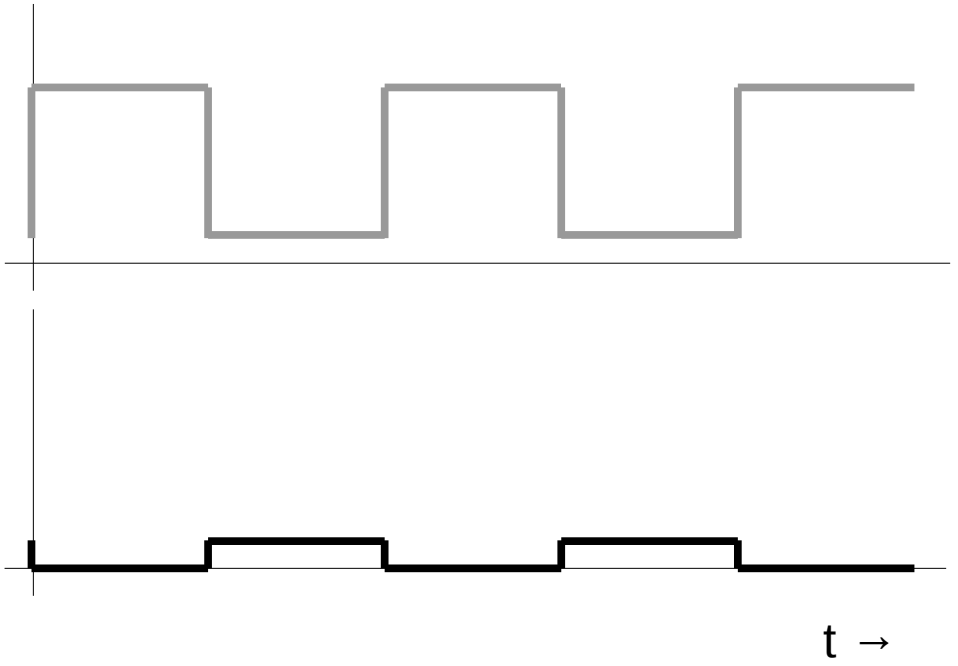


CVD method: signals

No hand present (C is small)



Hand present (C is large)



CVD method: issues

- Requires an internal ADC that is connected to a GPIO
- MCU should be able to switch pin between digital output and analog input while ADC is connected
- Works with most MCUs that have an ADC connected to GPIO through a multiplexer
  - Including Arduino
  - Does not work with ESP8266 (?)

RC method: pros & cons

Pros:

- Works on any analog input
- Fast and predictable timing
- Allows diverse filtering
- Ultra low cost

Cons:

- Does not work if MCU does not have analog multiplexer / GPIO combination
- Patent by Microchip (but Arduino uses Atmel and Microchip recently bought Atmel)

Reduce periodic noise

Often periodic noise is present in actual systems. Can be caused by:

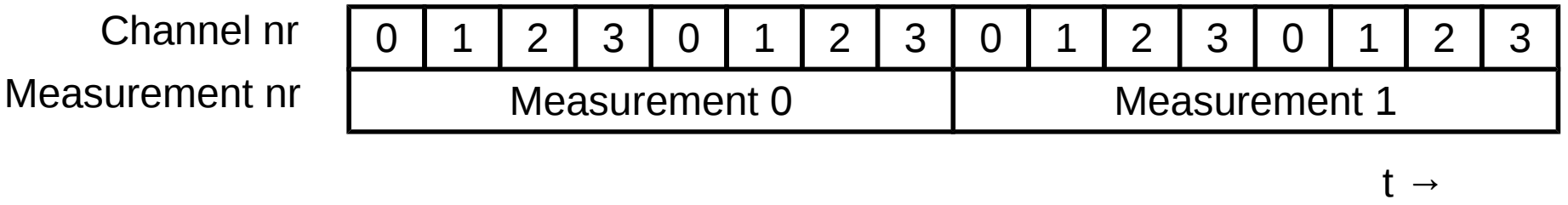
- Power supply
- Motors
- LEDs (PWM signals)
- ...

Channel nr	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3

In this example, channel 1 always measures a value that is too high.

Reduce periodic noise

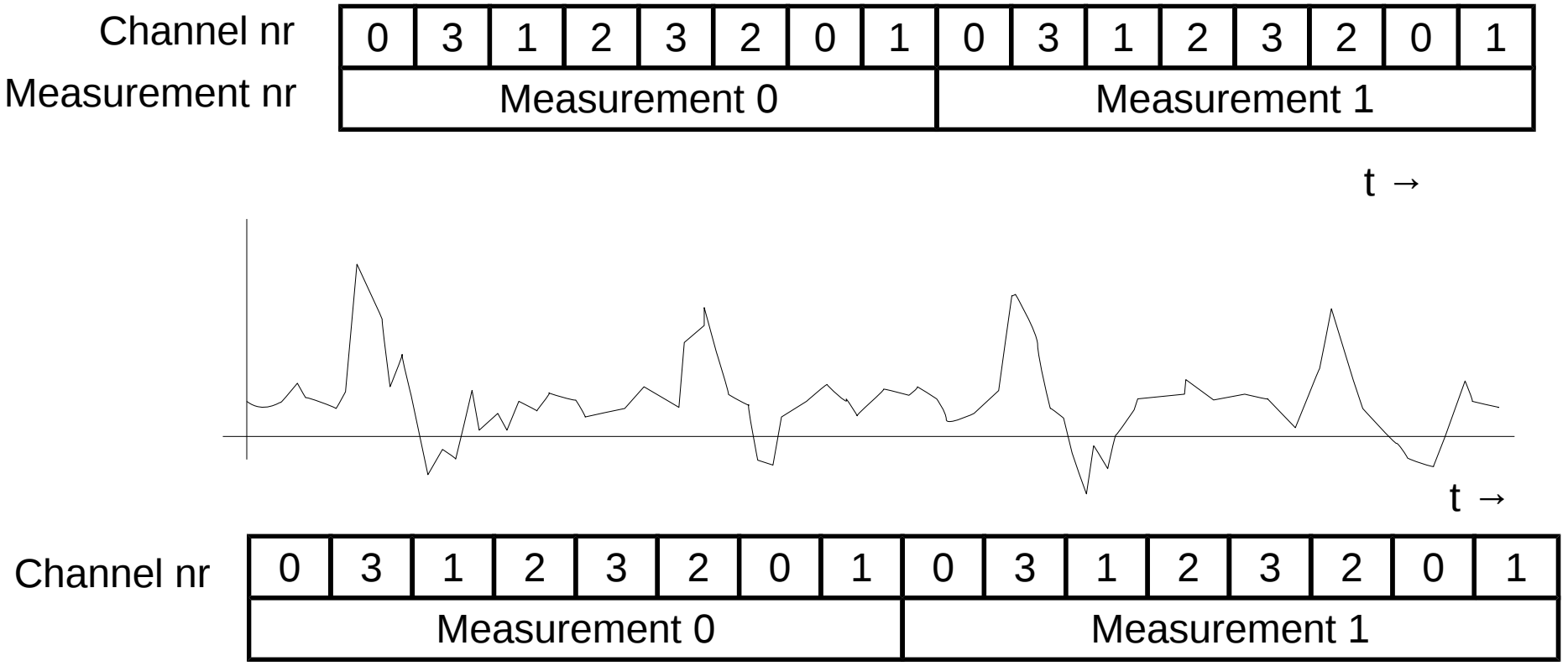
CVD is very fast. This allows to take sum acquisitions and use as one measurement. Example for 4 sensors, using 2 acquisitions per measurement:



This can be used to spread out noise (see next slide)

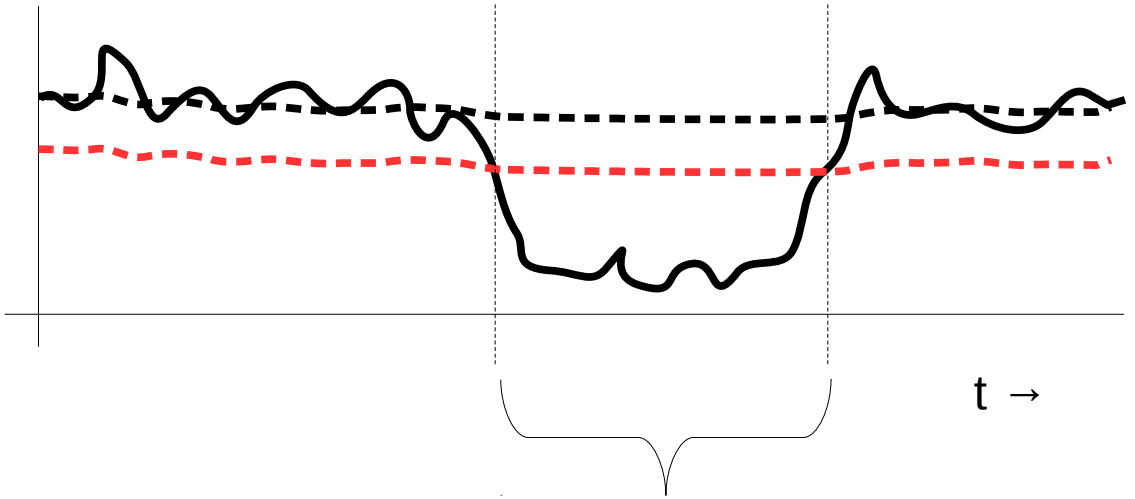
Reduce periodic noise

Use a (pseudo-)random acquisition order to spread out the noise over all channels:



Works very well when combining large number of acquisitions (16 or more).

Digital filtering



Touch detected: do not update baseline

Raw signal

Filtered signal (baseline)

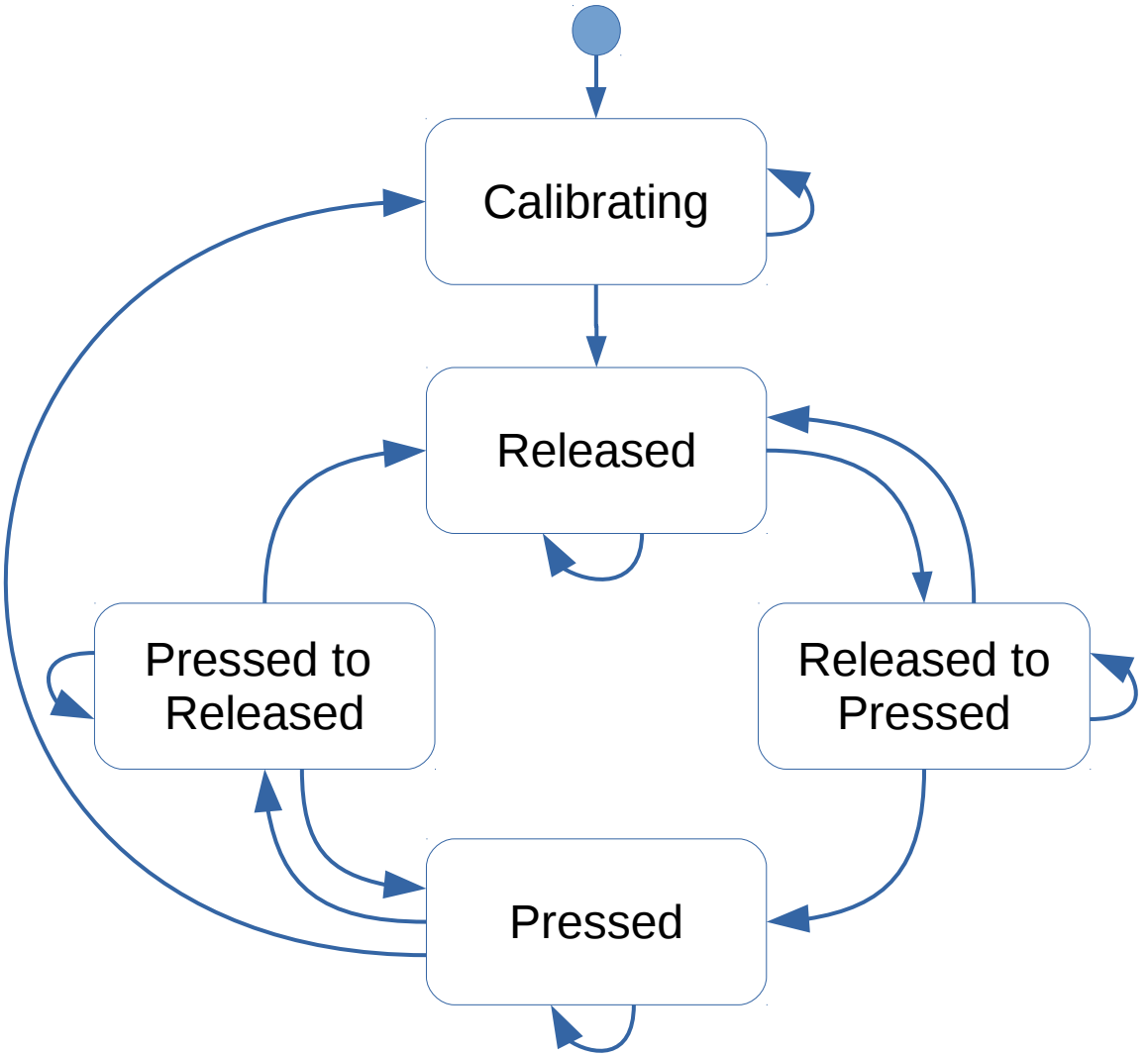
Threshold (baseline – fixed value)

Digital filtering

Possible filters:

- Simple single pole exponential decaying filter
  - This is what I usually use
  - This is also only filter available at my github
- FIR filter
- Median filter
- Rate limiting filter
  - Slow but very good against conducted noise

Button state machine



Summary

- Connnect device and/or user to earth for stronger signal
- CVD allows much faster sampling rate at higher resolutions than RC method
- Noise reduction can take place on several levels:
  - Combining acquisitions + pseudo random sequence
  - Filtering measurements
  - Button state machine