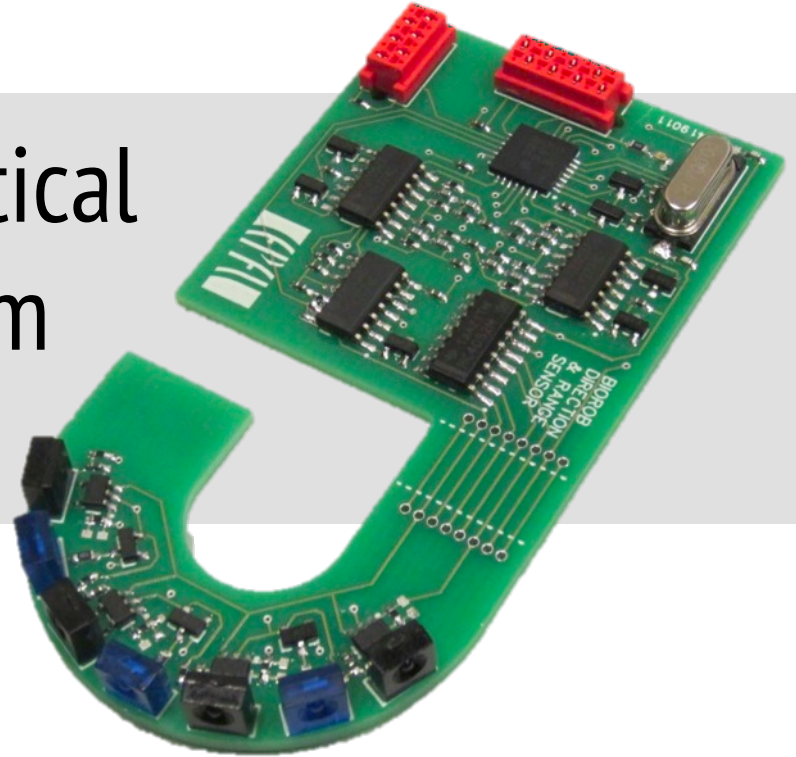


Design of an Infrared / Optical Relative Positioning System for Mobile Robots

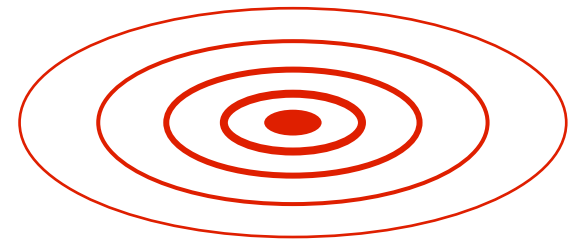
Semester Project
Raphael Cherney



GOALS



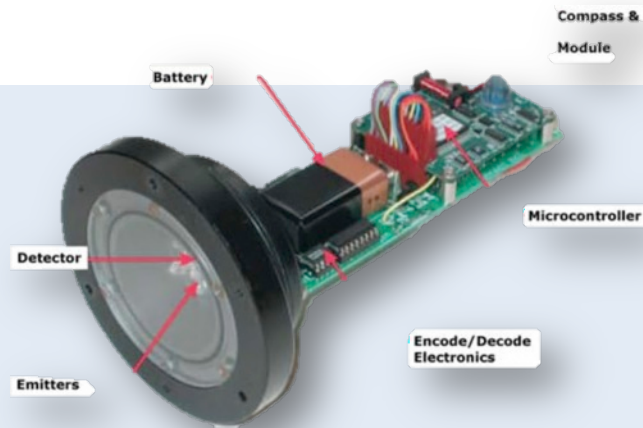
- Design a system that uses **modulated IR or optical signals** to determine the distance and direction to a modulated transmitter
 - Works in different lighting conditions
 - Visible light could provide better performance in water
- Decode low bandwidth data sent over the optical channel (e.g. 8 bit ID)
- Study the possibility of using the same sensor for obstacle sensing (by adding some transmitter at its side)



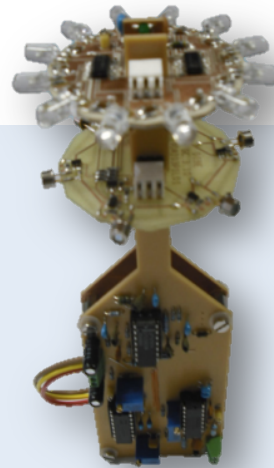
Photograph by A. Crespi



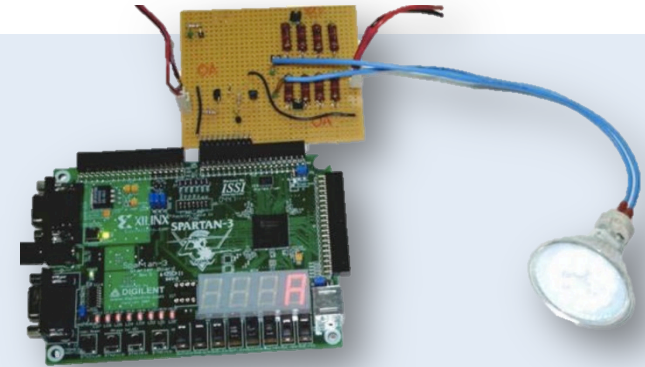
STATE OF THE ART



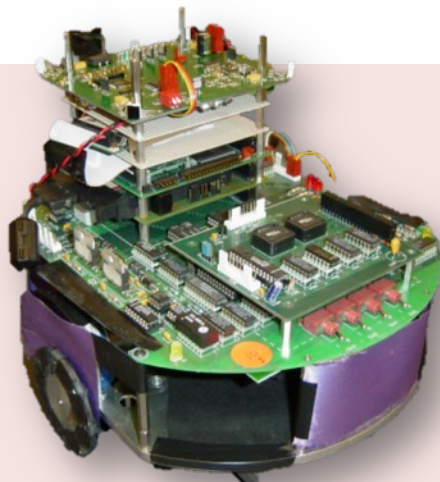
Tivey, 2004; WHOI



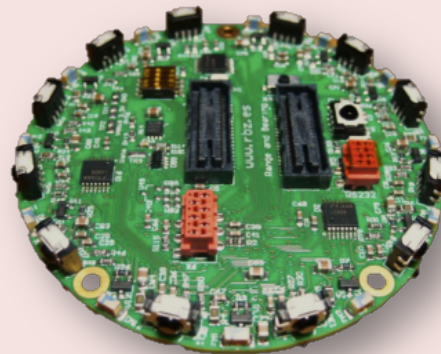
Anguita, 2010; Genova



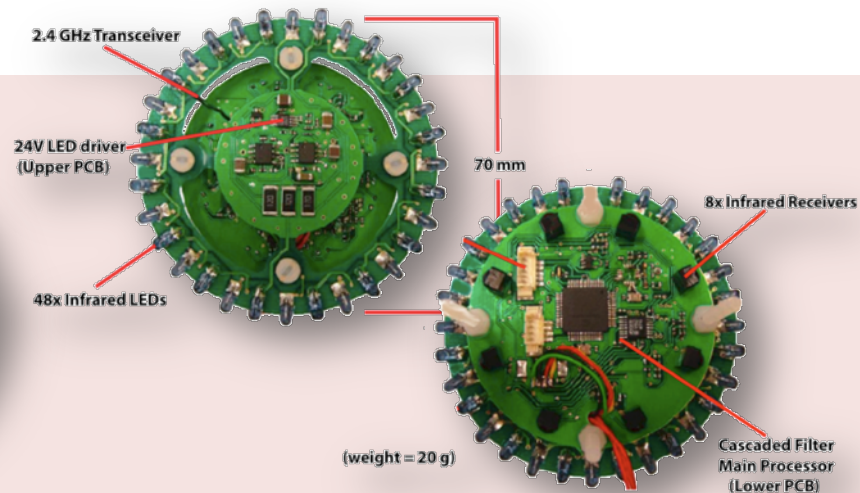
Hernandez, 2006; CEDINT



Kelly, 2004; USC



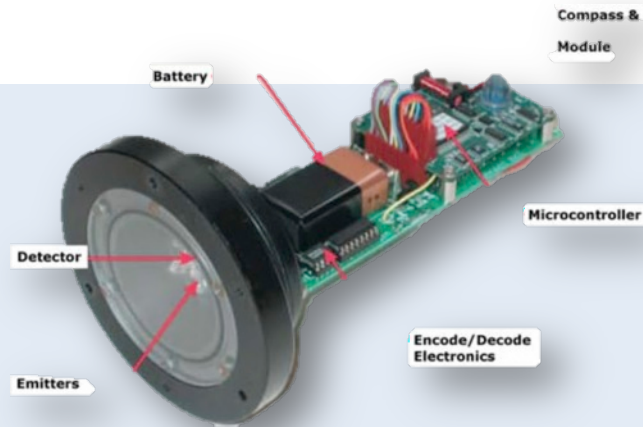
Gutiérrez, 2008; ETSI



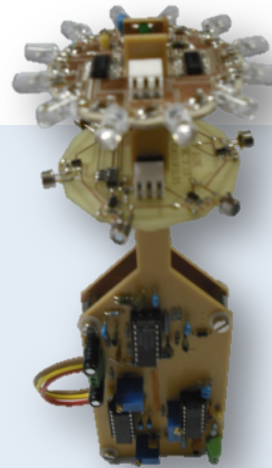
Roberts, 2009; EPFL



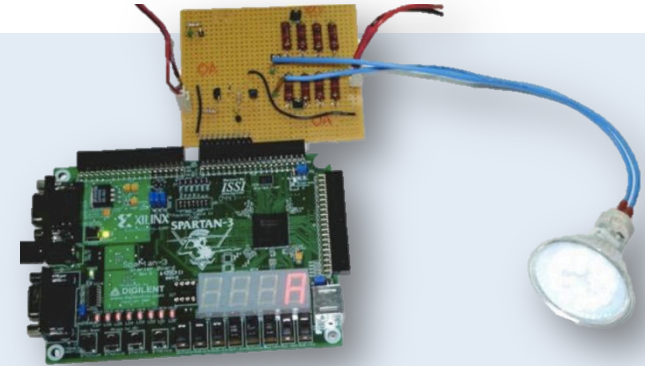
STATE OF THE ART



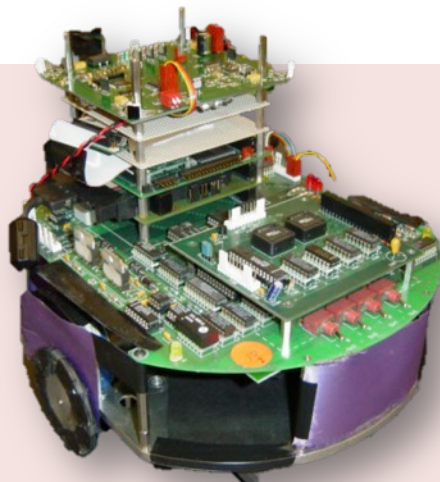
Tivey, 2004; WHOI



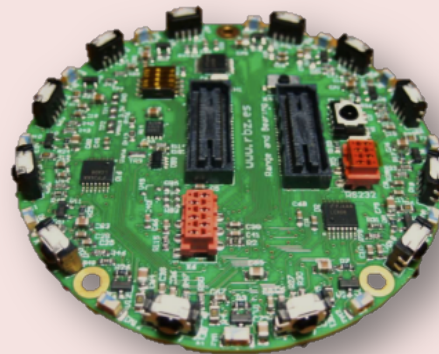
Anguita, 2010; Genova



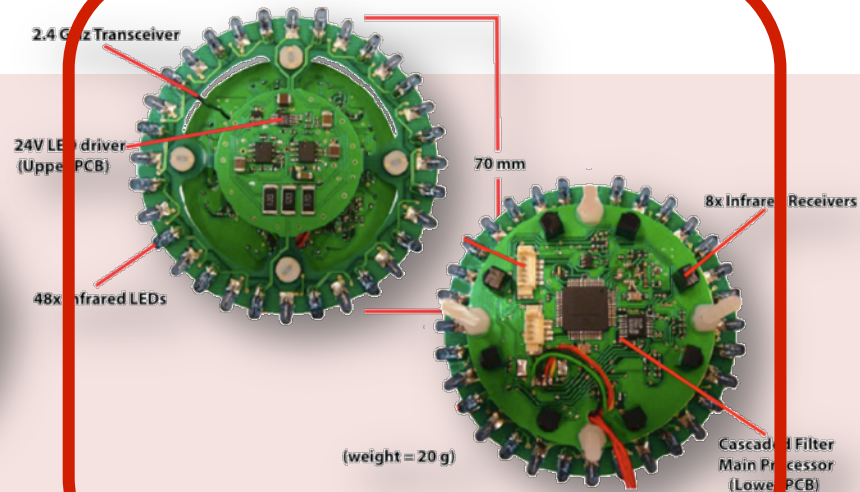
Hernandez, 2006; CEDINT



Kelly, 2004; USC



Gutiérrez, 2008; ETSI



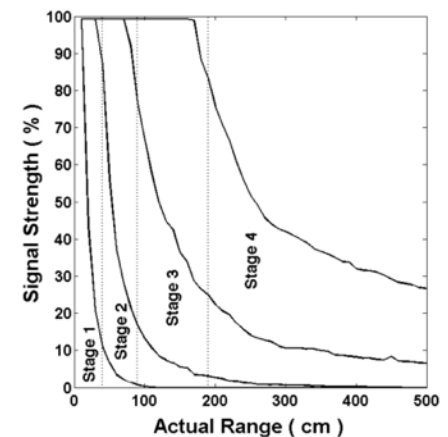
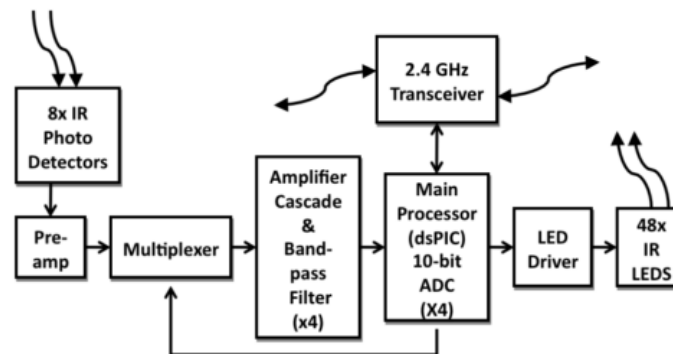
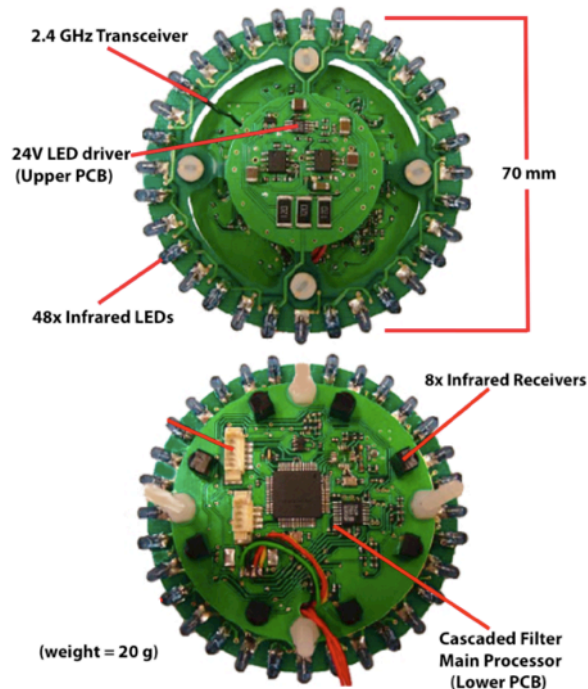
Roberts, 2009; EPFL



STATE OF THE ART

Range and Bearing Infrared Transceiver (RABIT)

- Good range (similar constraints)
- Novel cascaded filter/amplifier chain

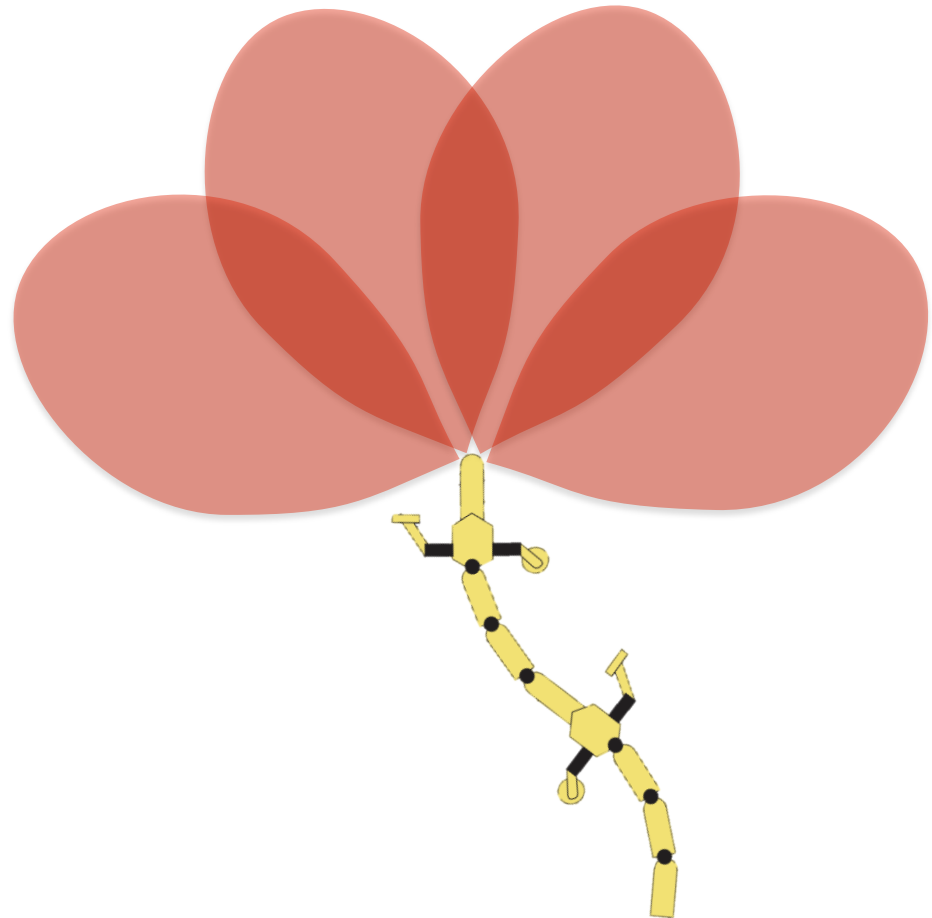


- Too large
- Communication done through radio

DESIGN



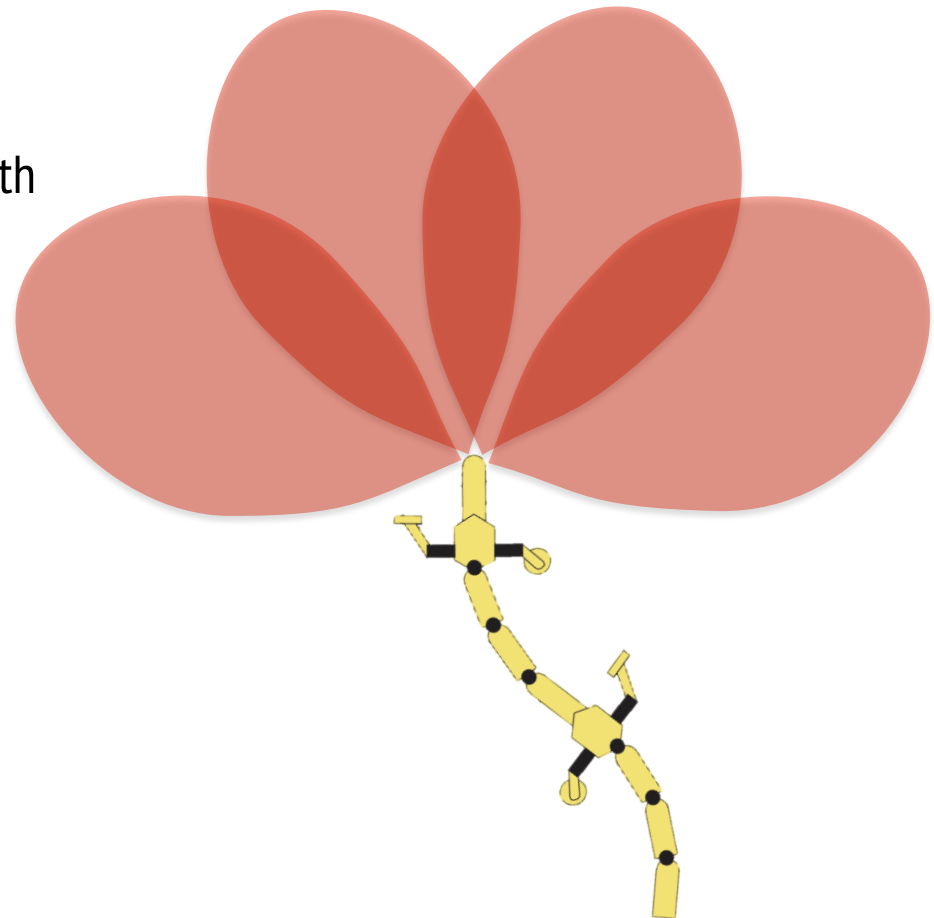
- Detector array



DESIGN



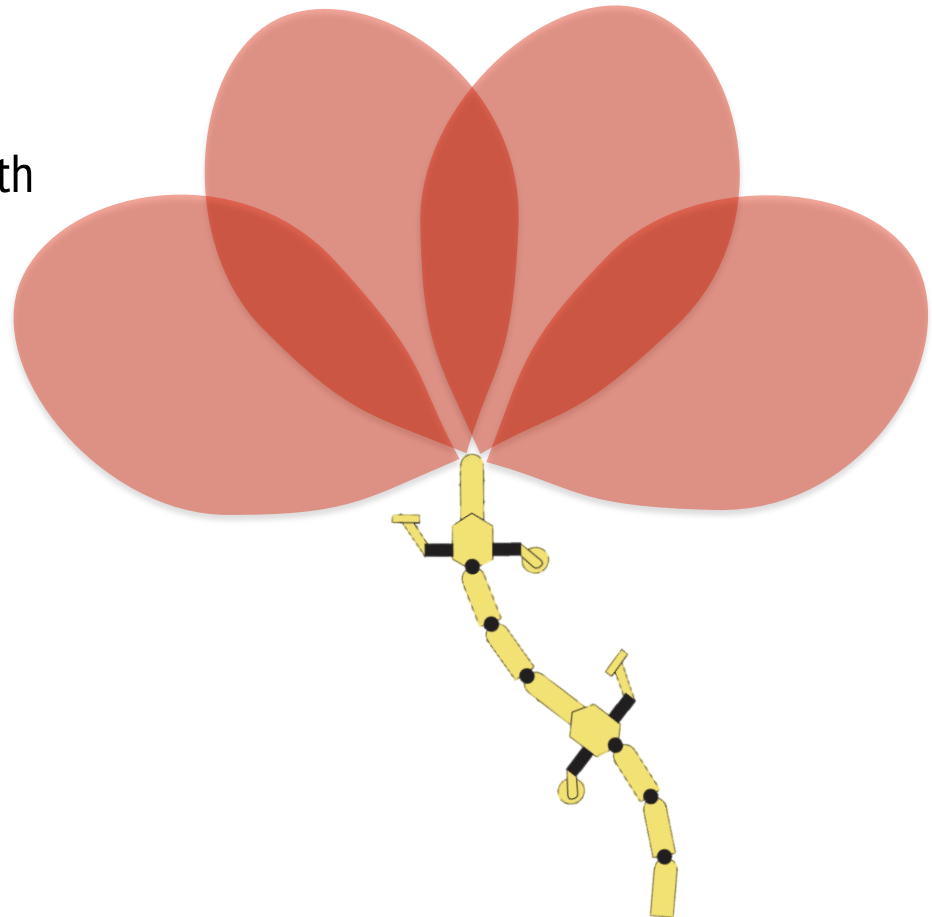
- Detector array
 - Direction determined based on sensor positions with strong signals
 - Distance estimated from signal strength



DESIGN



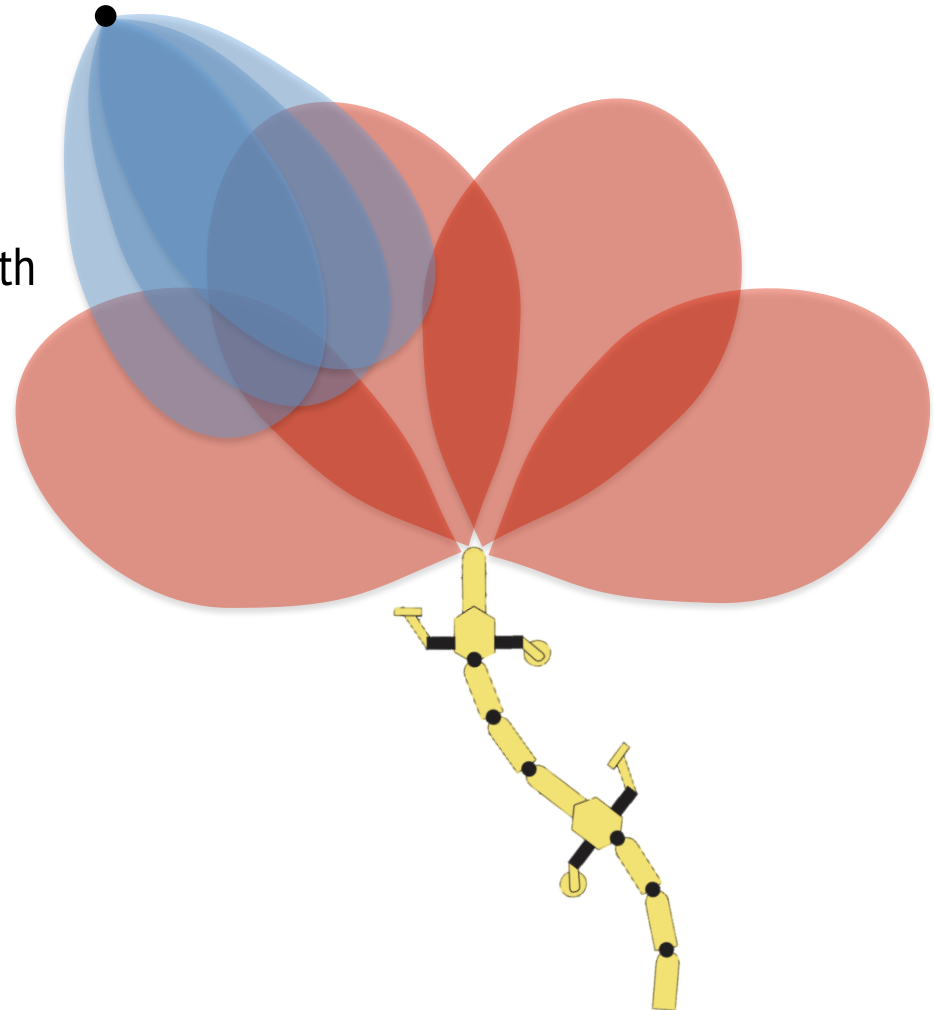
- Detector array
 - Direction determined based on sensor positions with strong signals
 - Distance estimated from signal strength
- Modulated signals (10 kHz carrier)



DESIGN



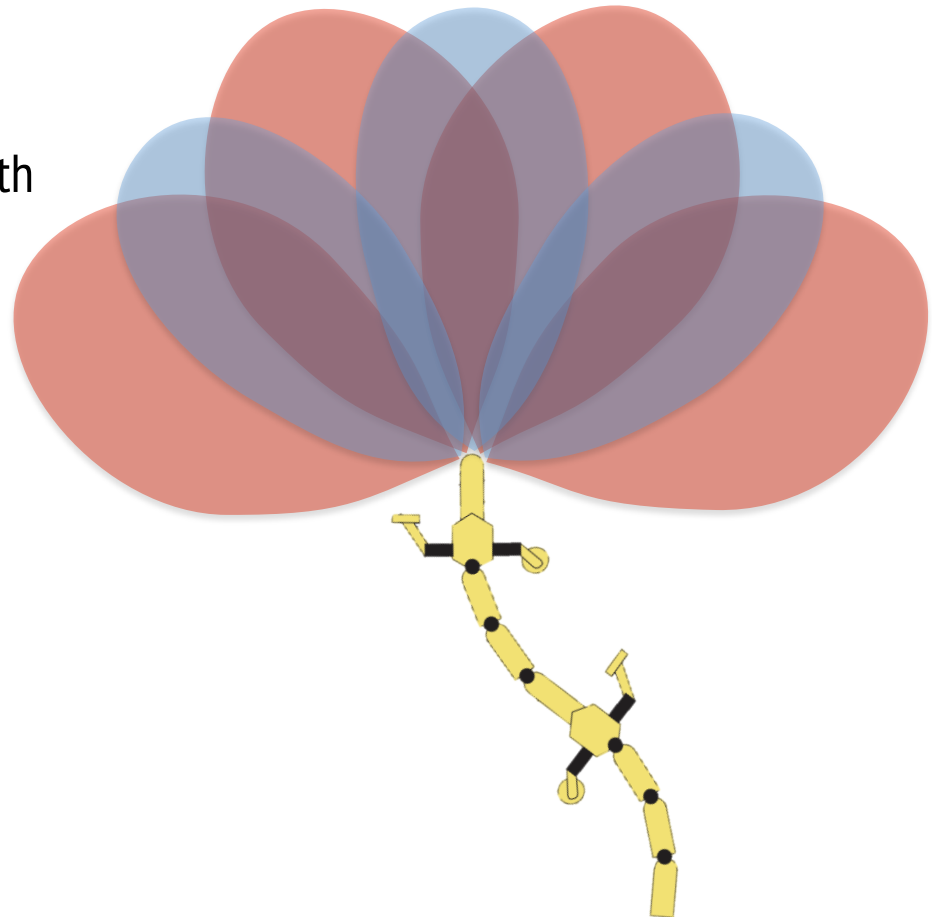
- Detector array
 - Direction determined based on sensor positions with strong signals
 - Distance estimated from signal strength
- Modulated signals (10 kHz carrier)
 - Active beacon



DESIGN



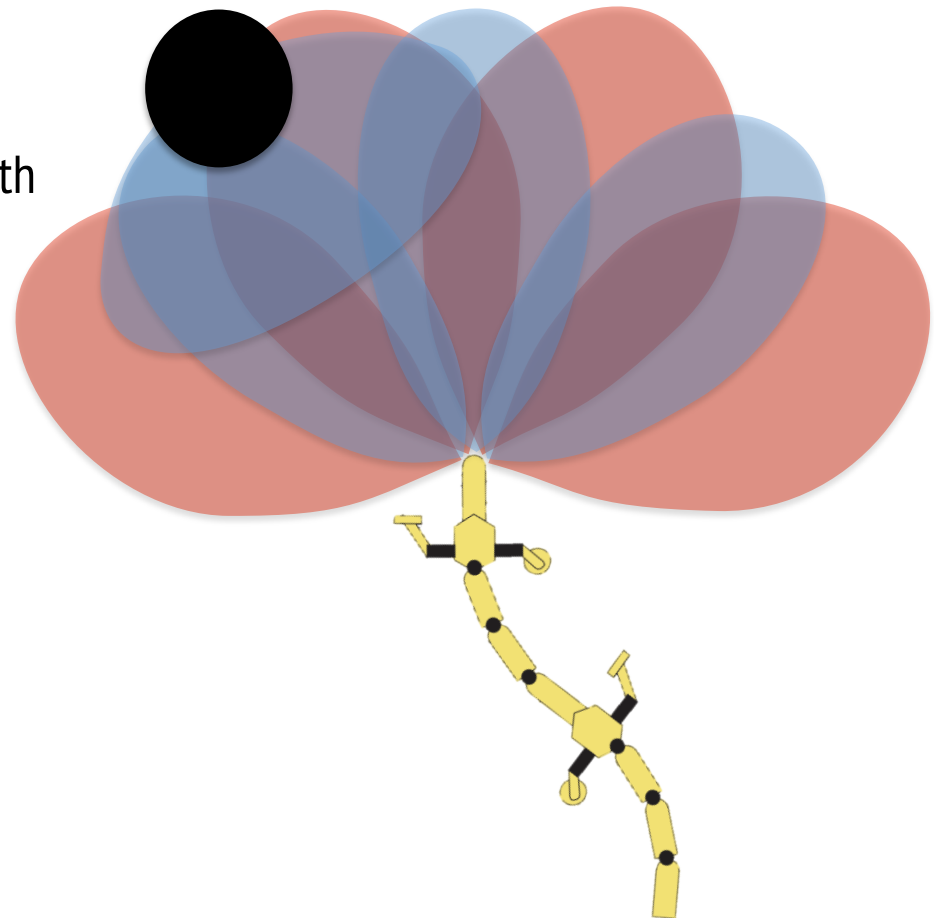
- Detector array
 - Direction determined based on sensor positions with strong signals
 - Distance estimated from signal strength
- Modulated signals (10 kHz carrier)
 - Active beacon
 - Onboard transmitter



DESIGN



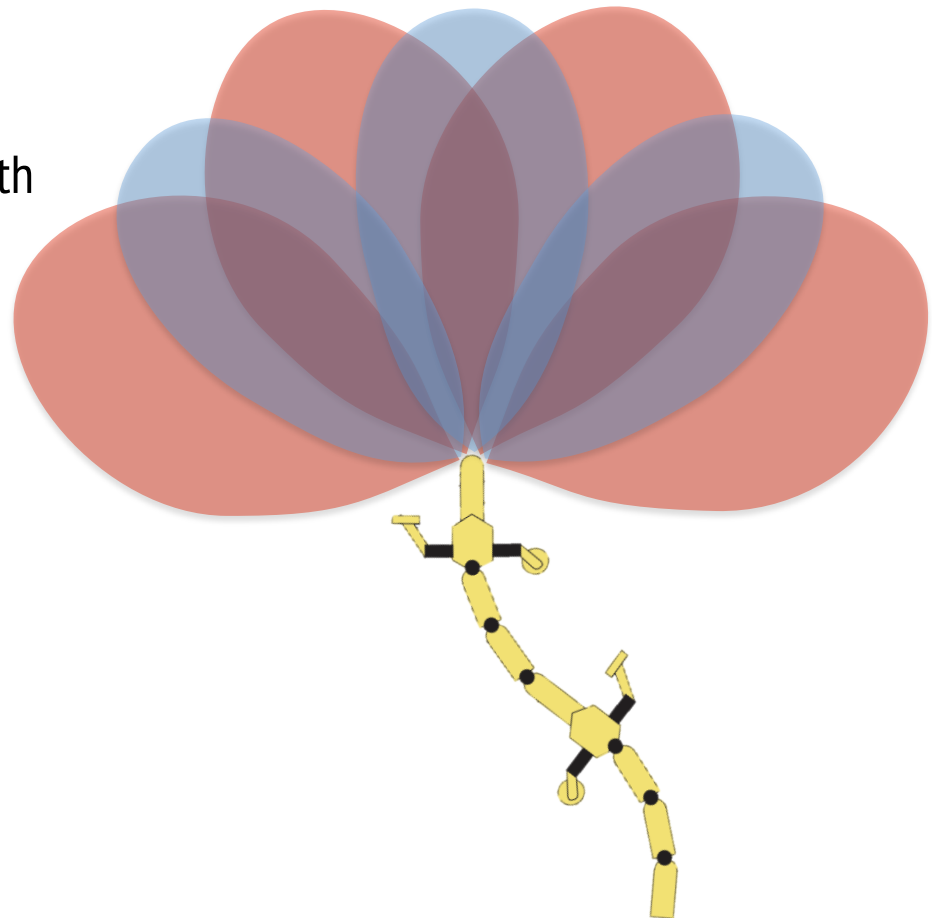
- Detector array
 - Direction determined based on sensor positions with strong signals
 - Distance estimated from signal strength
- Modulated signals (10 kHz carrier)
 - Active beacon
 - Onboard transmitter



DESIGN



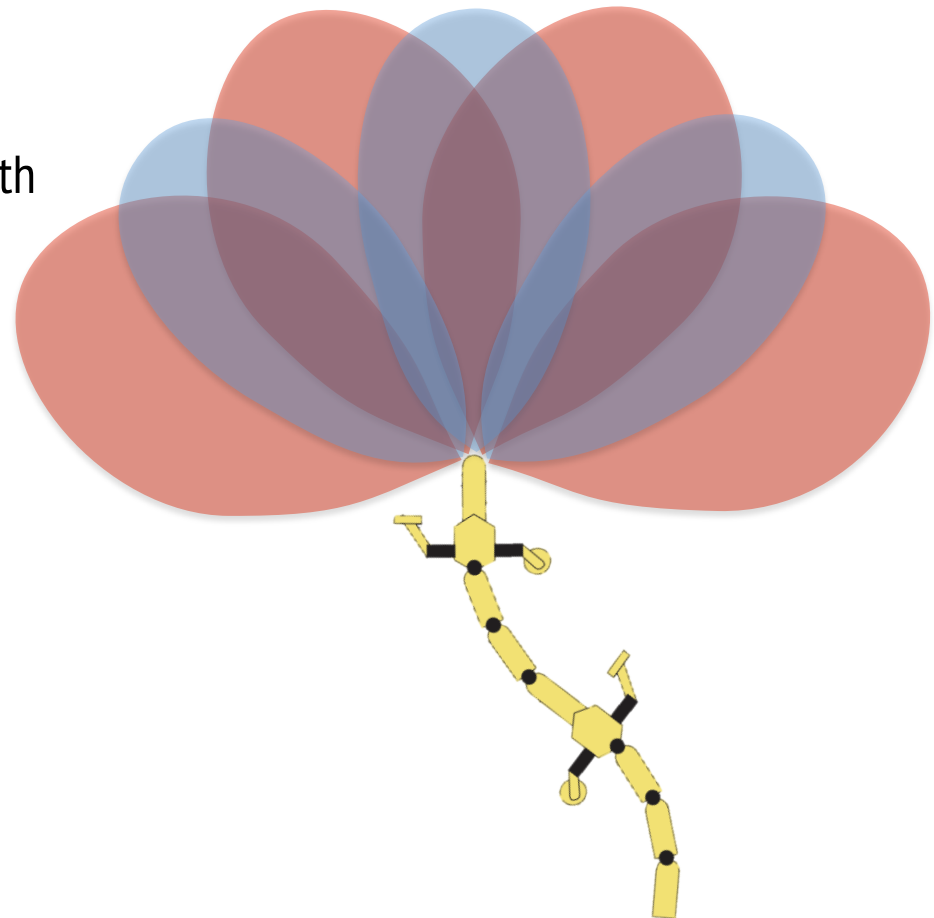
- Detector array
 - Direction determined based on sensor positions with strong signals
 - Distance estimated from signal strength
- Modulated signals (10 kHz carrier)
 - Active beacon
 - Onboard transmitter
- Transmit data over optical channel (PWM, PPM, OOK)



DESIGN



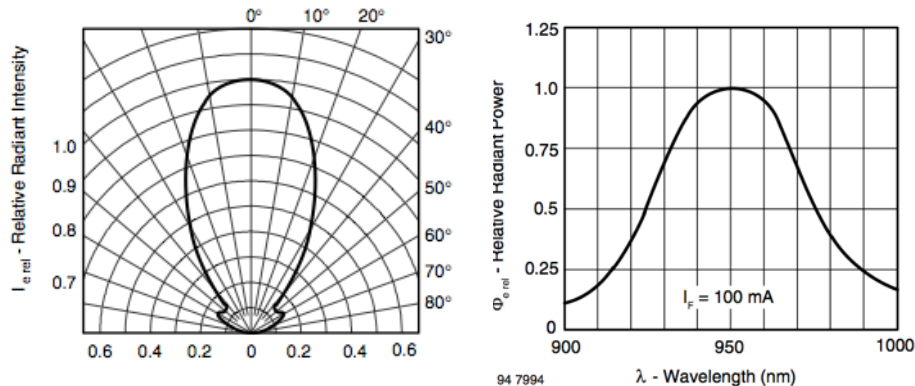
- Detector array
 - Direction determined based on sensor positions with strong signals
 - Distance estimated from signal strength
- Modulated signals (10 kHz carrier)
 - Active beacon
 - Onboard transmitter
- Transmit data over optical channel (PWM, PPM, OOK)
- Works with visible or infrared light (depending on transmitter and detector choice)





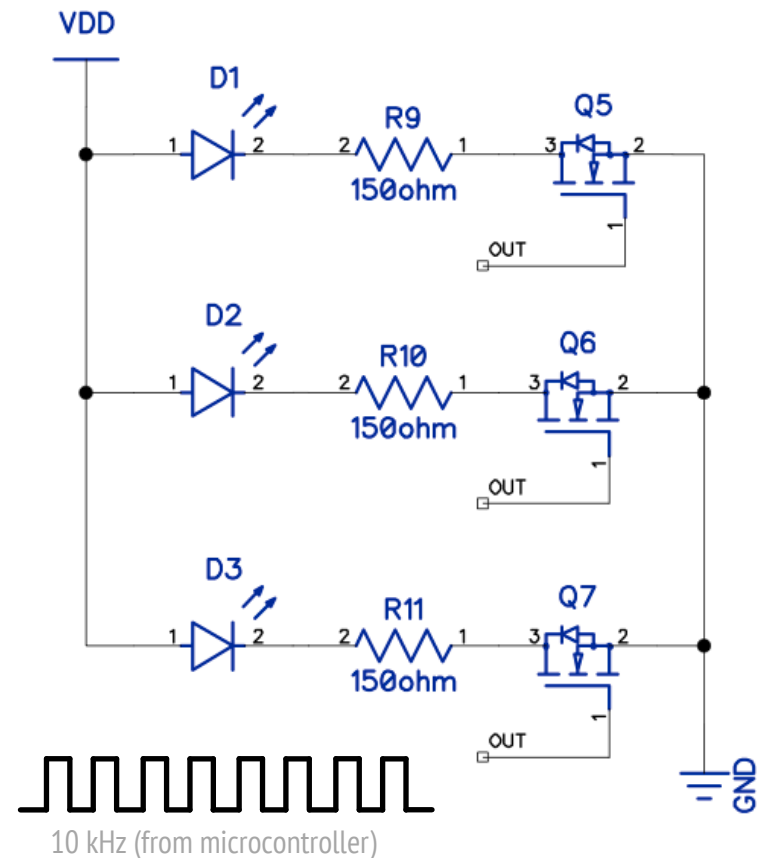
TRANSMITTER (onboard)

- Modulated 10 kHz carrier
- Uses TSKS5400 infrared emitting diode:



- Can be easily modified to allow for other transmitters (including visible LEDs)

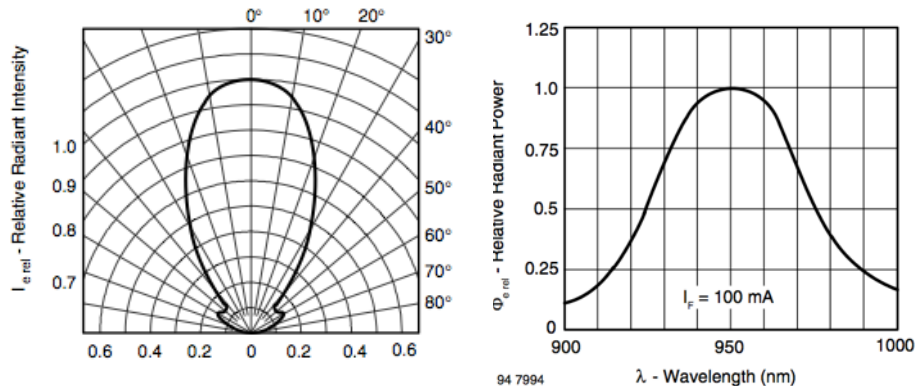
Transmitter Array





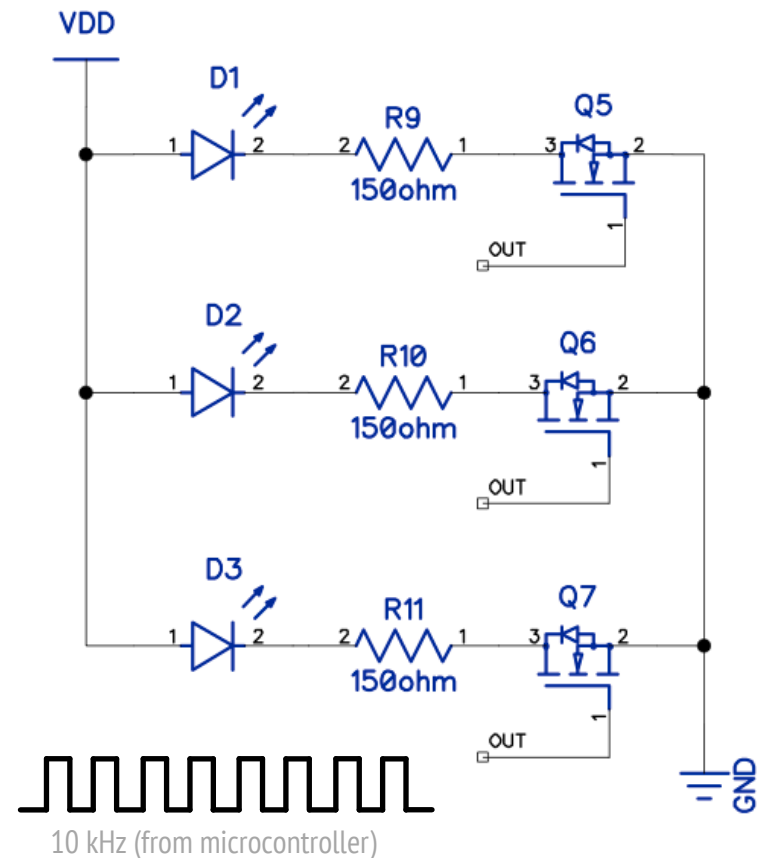
TRANSMITTER (onboard)

- Modulated 10 kHz carrier
- Uses TSKS5400 infrared emitting diode:



- Can be easily modified to allow for other transmitters (including visible LEDs)

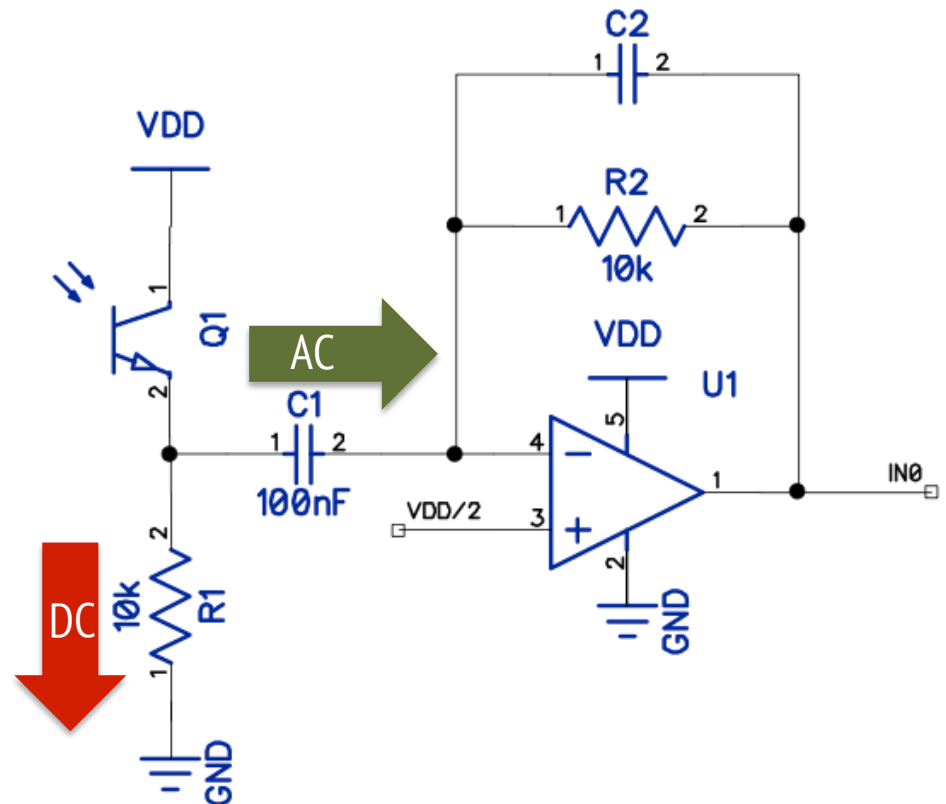
Transmitter Array



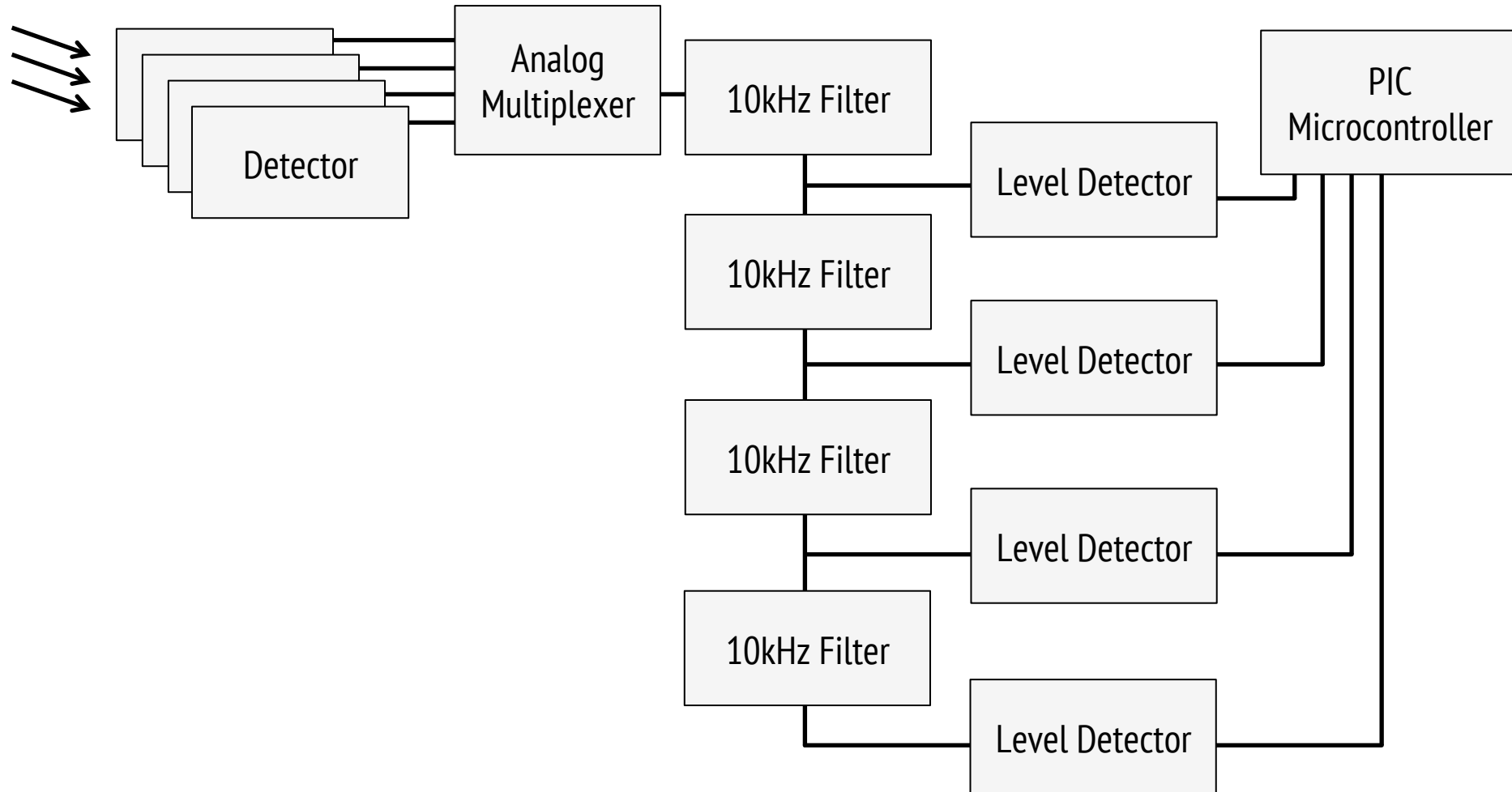


DETECTOR

- AC-coupled transimpedance amplifier
- DC current (ambient light signal) passes through the resistor while the AC signal is passed to the amplifier

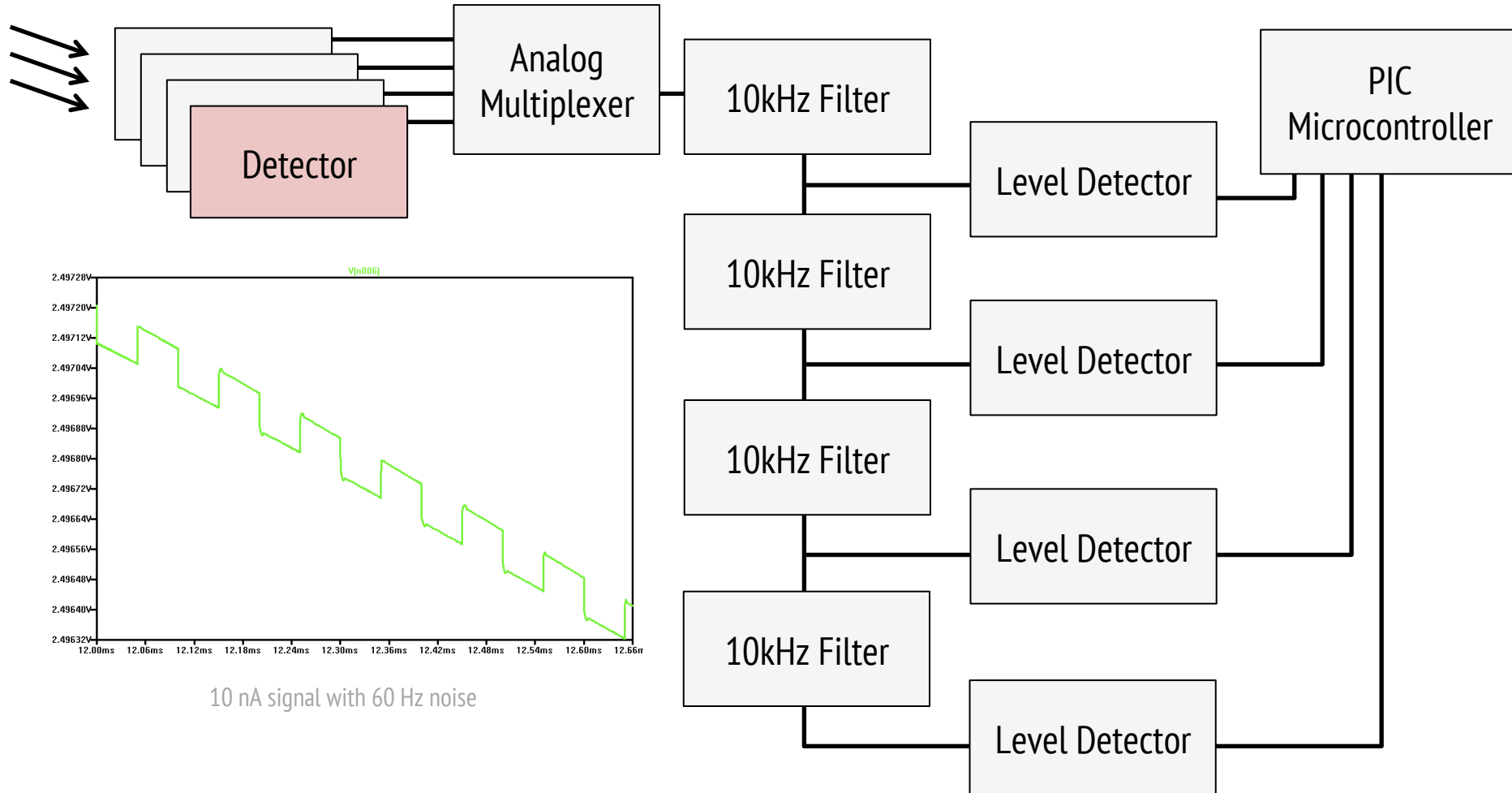


RECEIVER



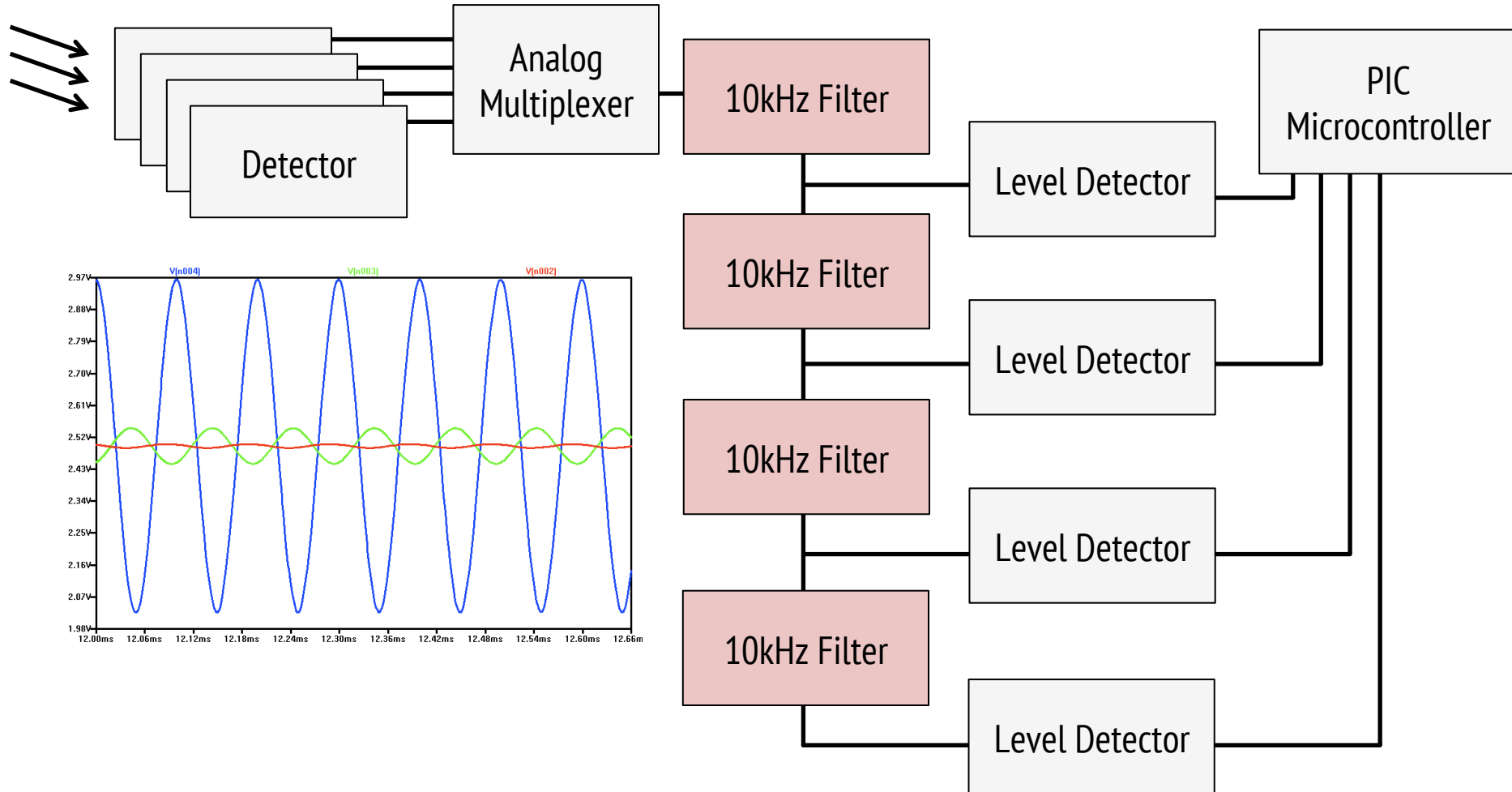


RECEIVER



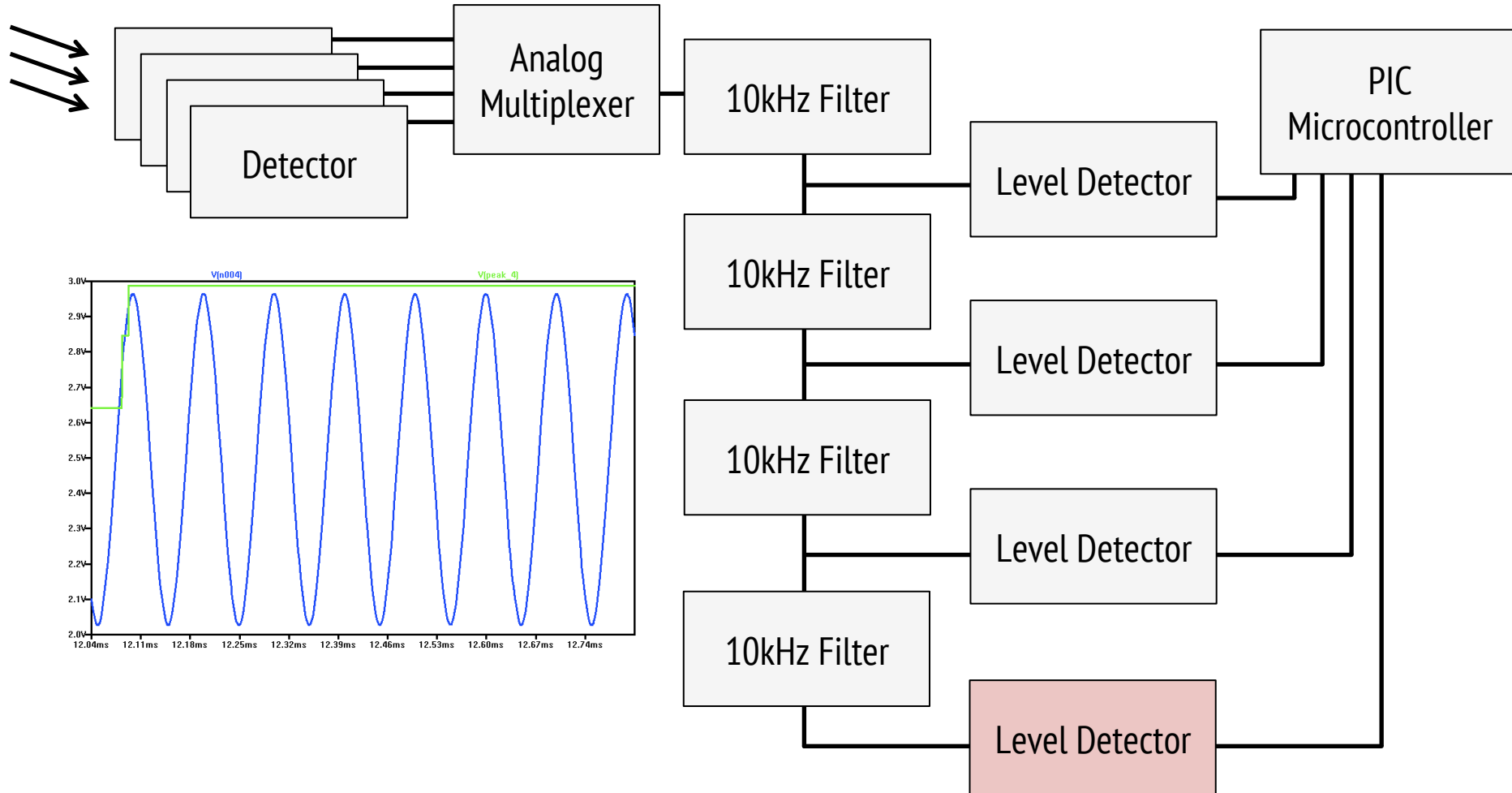


RECEIVER





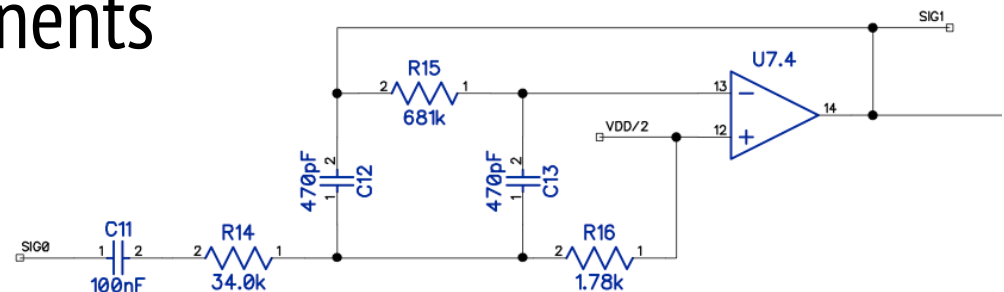
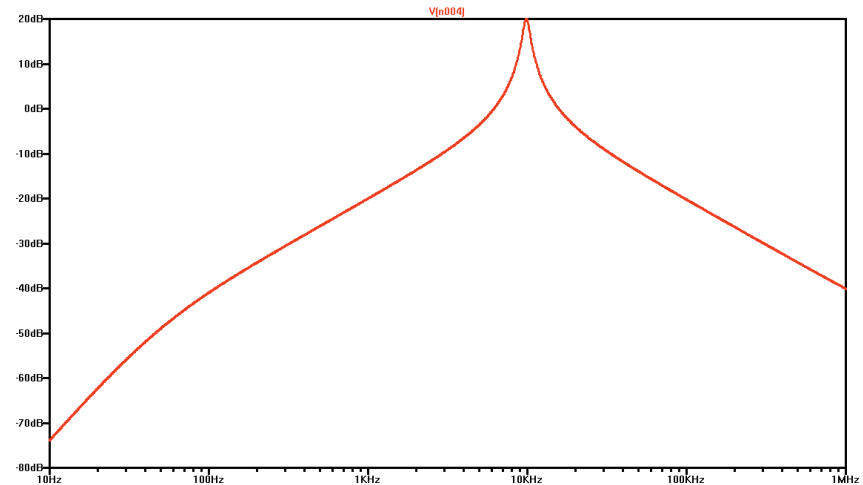
RECEIVER



AMPLIFYING FILTERS



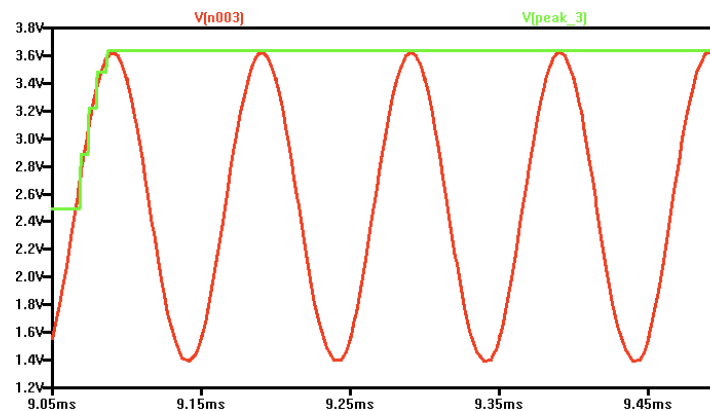
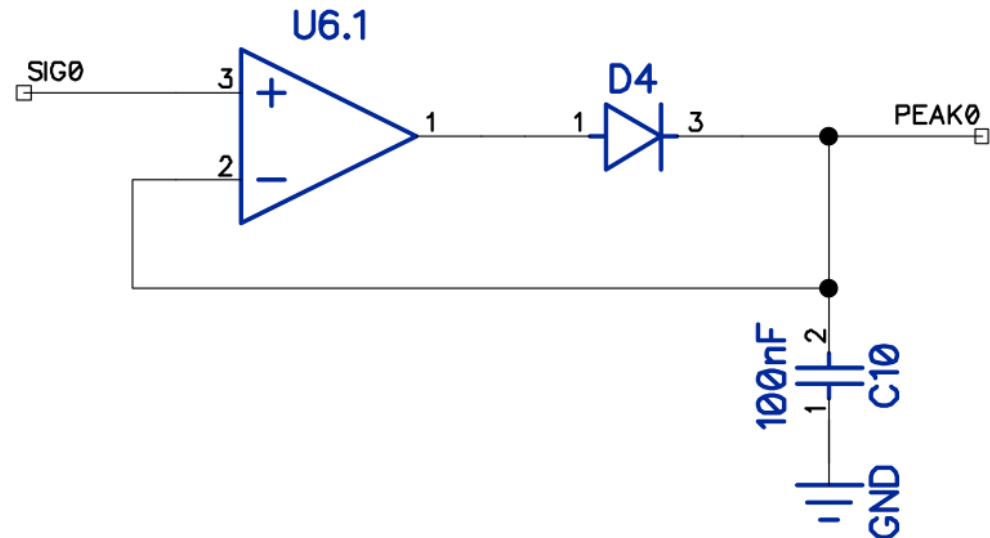
- Active, narrow band pass filters
 - modified Deliyannis filter
- Gain of 10 for selected frequency
- Relatively few components
- 4 cascaded stages
 - danger of ringing





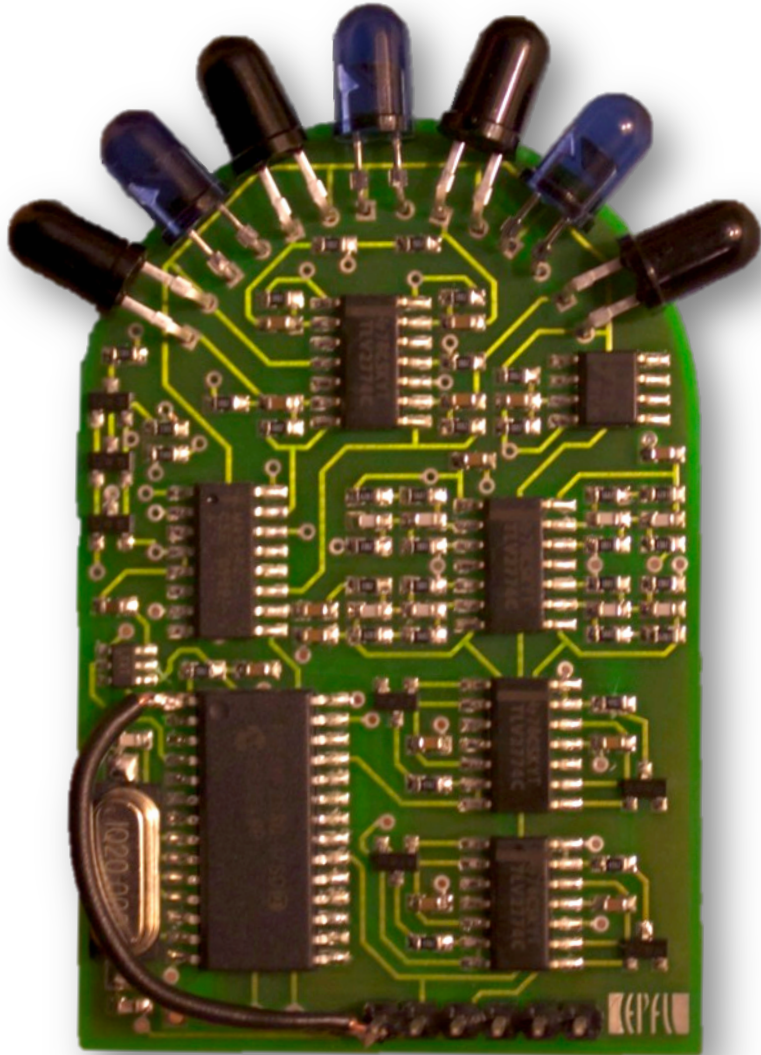
LEVEL DETECTOR

- Simple, few components
- Can be reset by microcontroller (switch pin to output)
- Maximum level is one diode drop below VDD





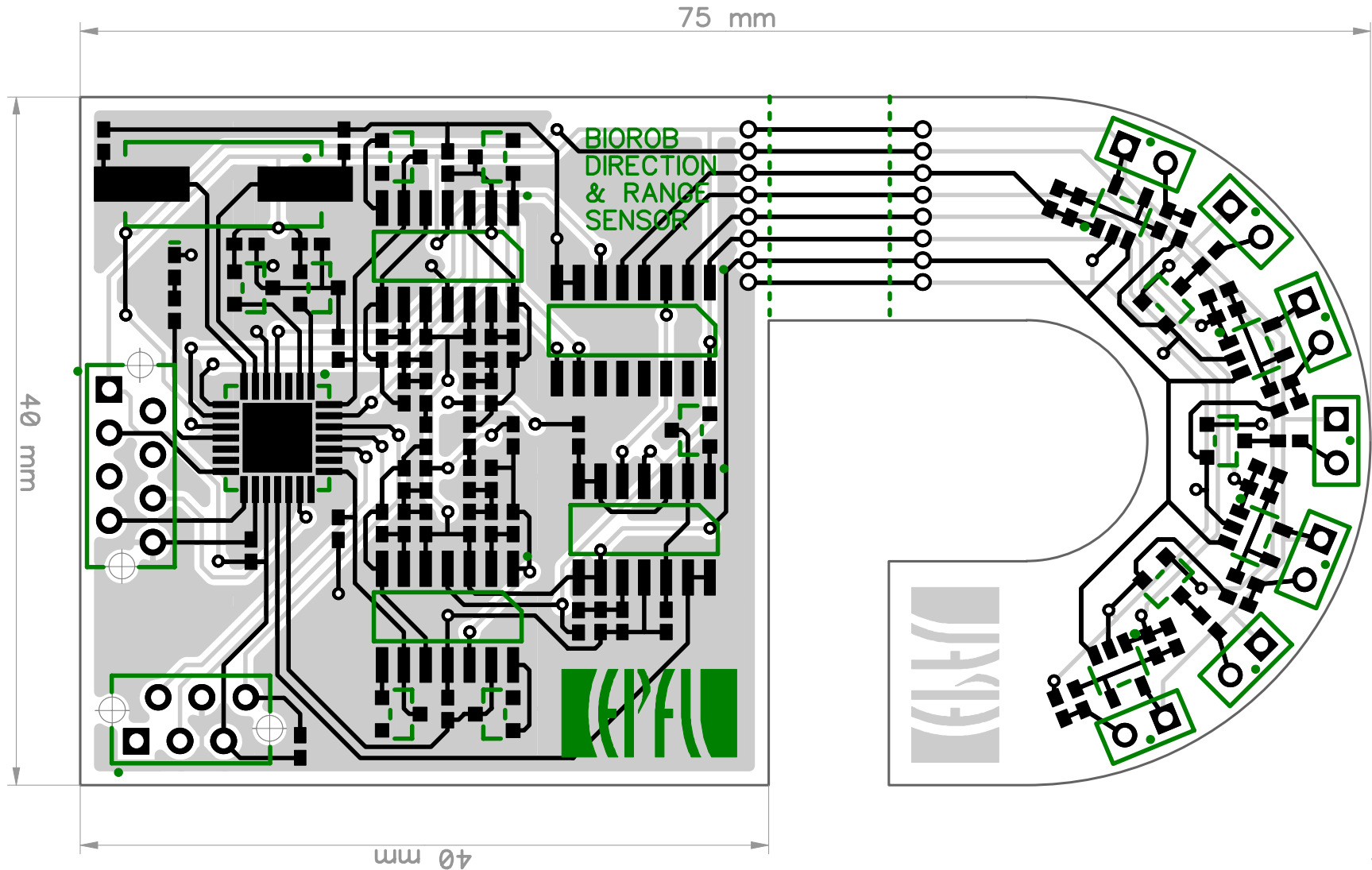
FIRST PROTOTYPE



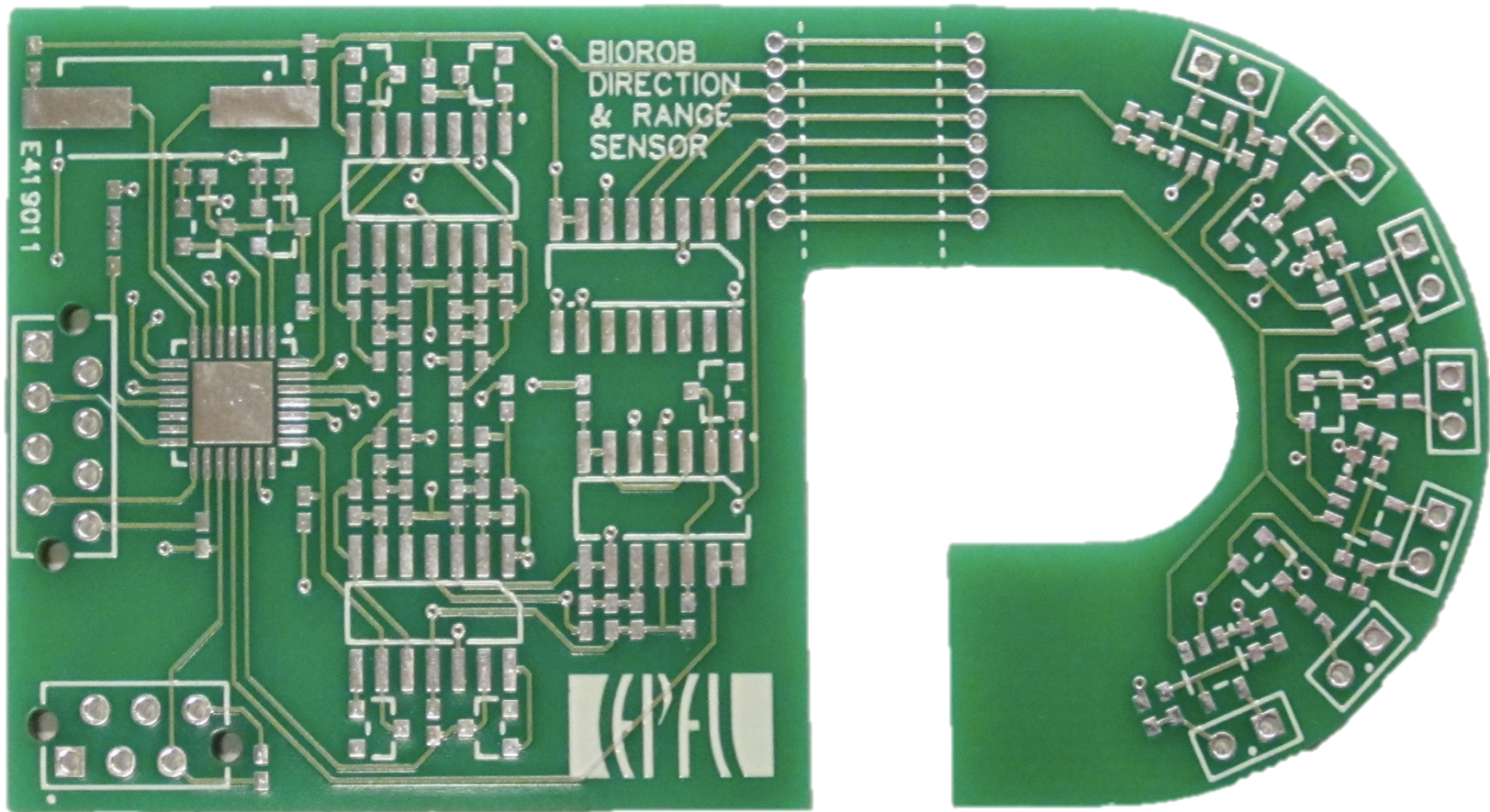
- Test analog circuit
- Prototype firmware
- Catch design errors



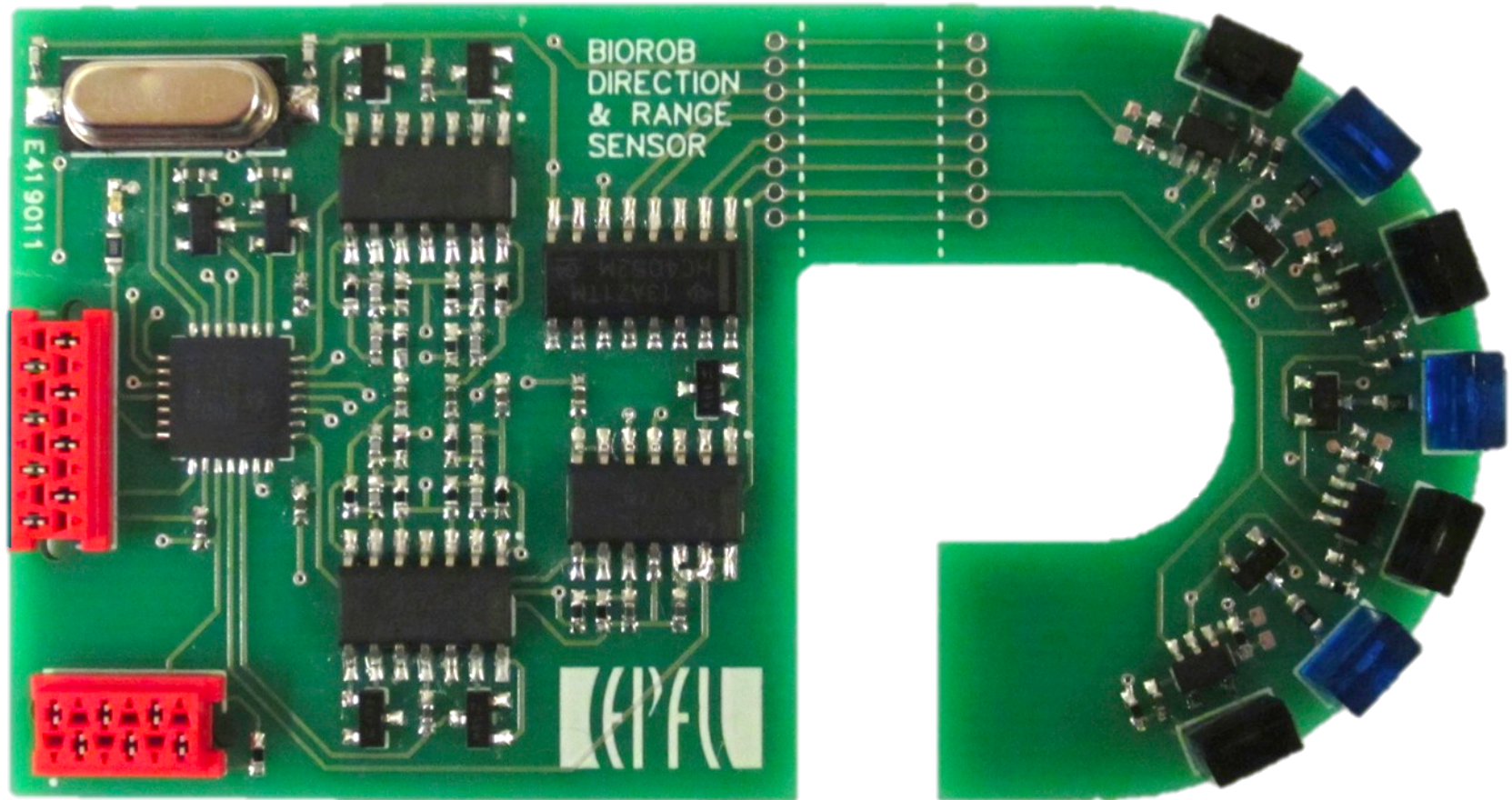
SECOND PROTOTYPE



SECOND PROTOTYPE

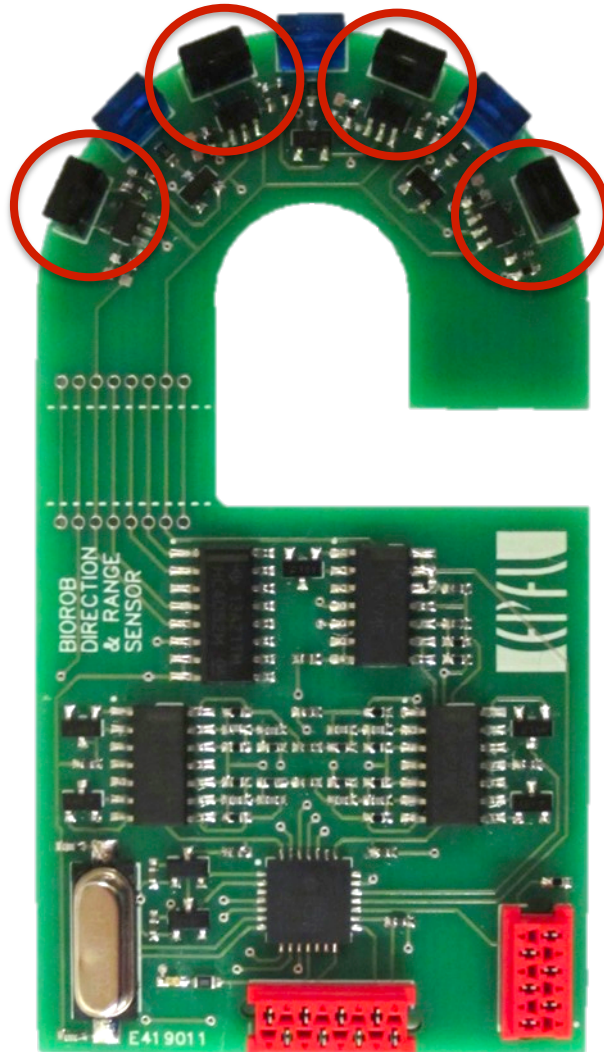


SECOND PROTOTYPE





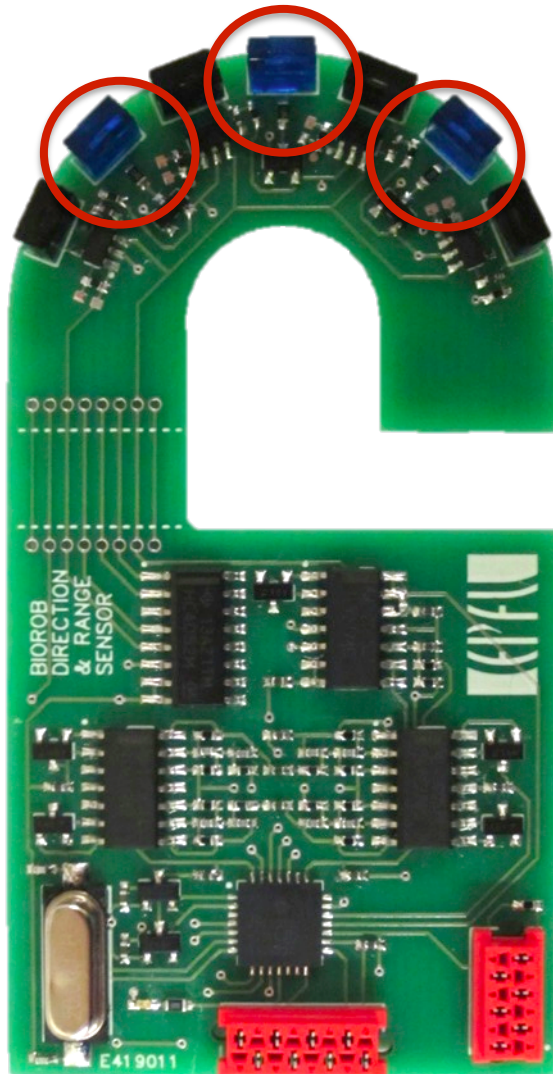
SECOND PROTOTYPE



- Detector array

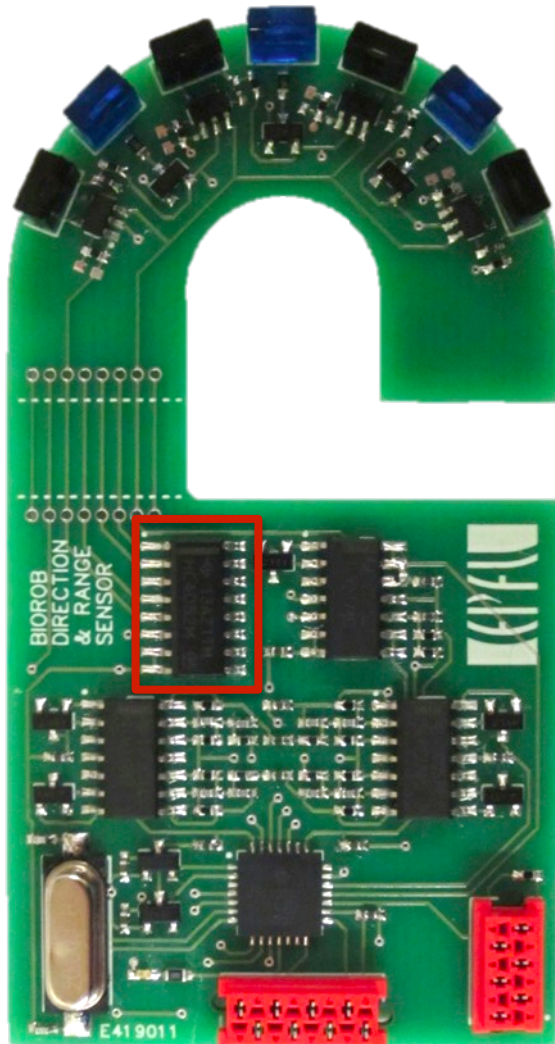


SECOND PROTOTYPE



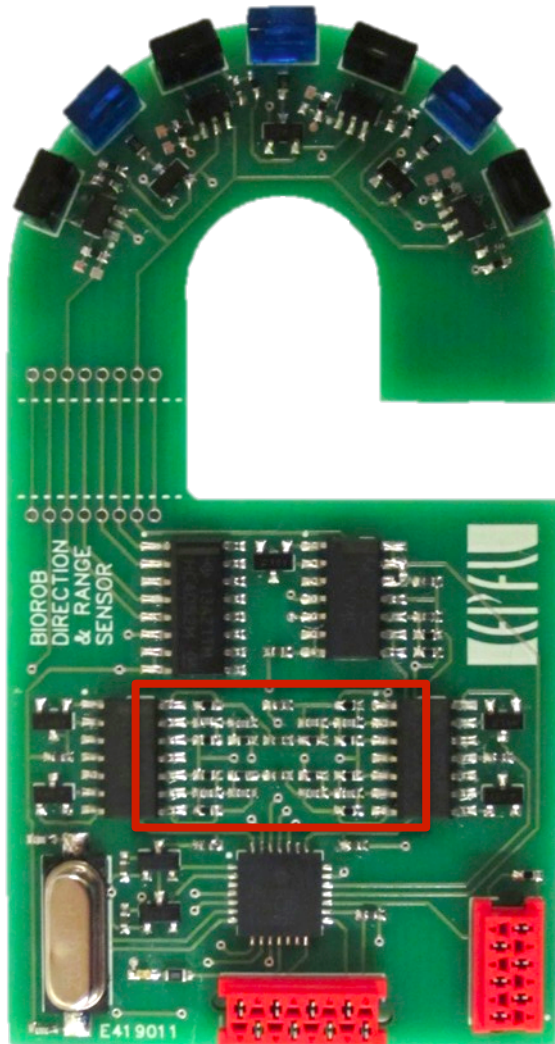
- Detector array
- Transmitter array

SECOND PROTOTYPE



- Detector array
- Transmitter array
- Analog multiplexer

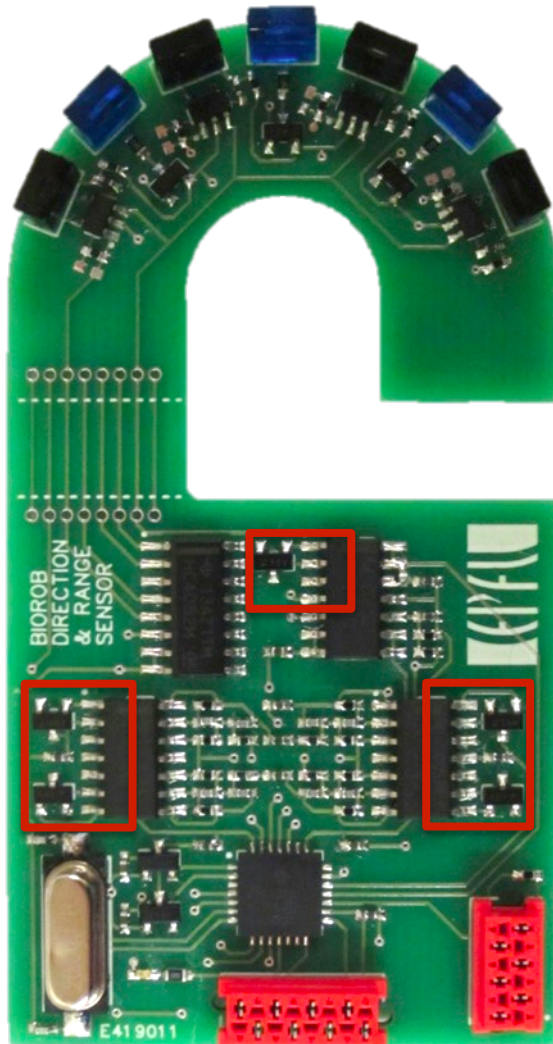
SECOND PROTOTYPE



- Detector array
- Transmitter array
- Analog multiplexer
- Cascaded 10 kHz filters



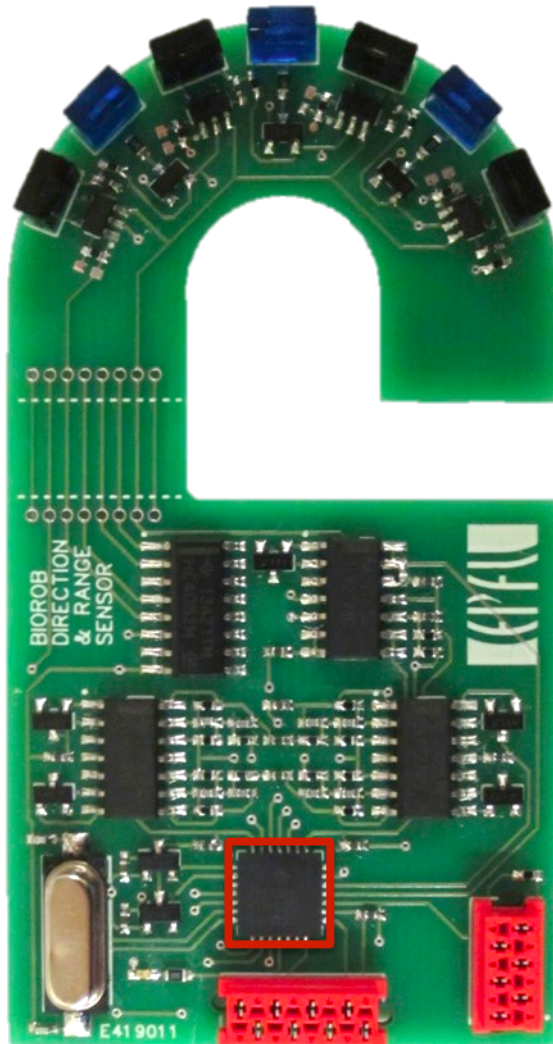
SECOND PROTOTYPE



- Detector array
- Transmitter array
- Analog multiplexer
- Cascaded 10 kHz filters
- Peak detectors



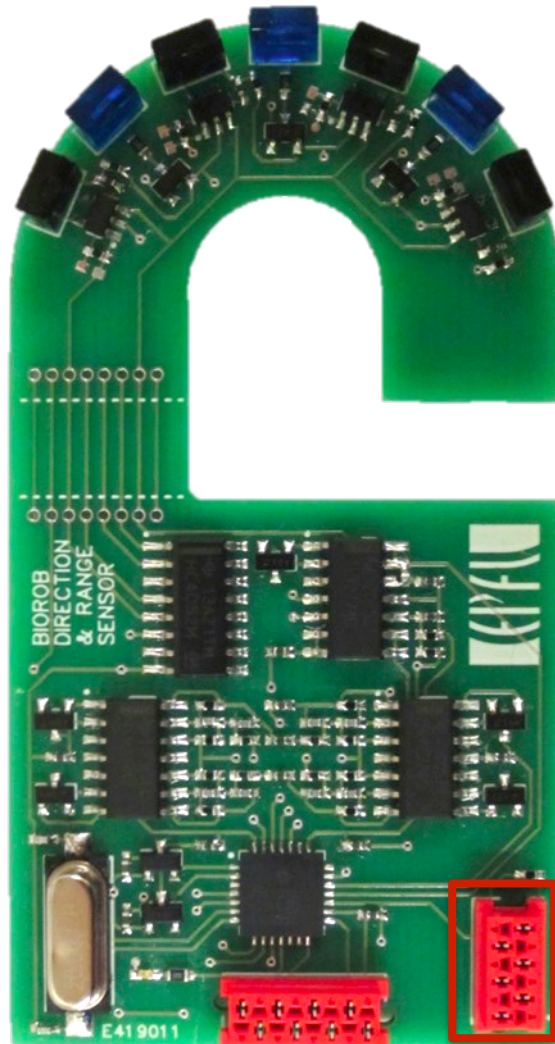
SECOND PROTOTYPE



- Detector array
- Transmitter array
- Analog multiplexer
- Cascaded 10 kHz filters
- Peak detectors
- Microcontroller

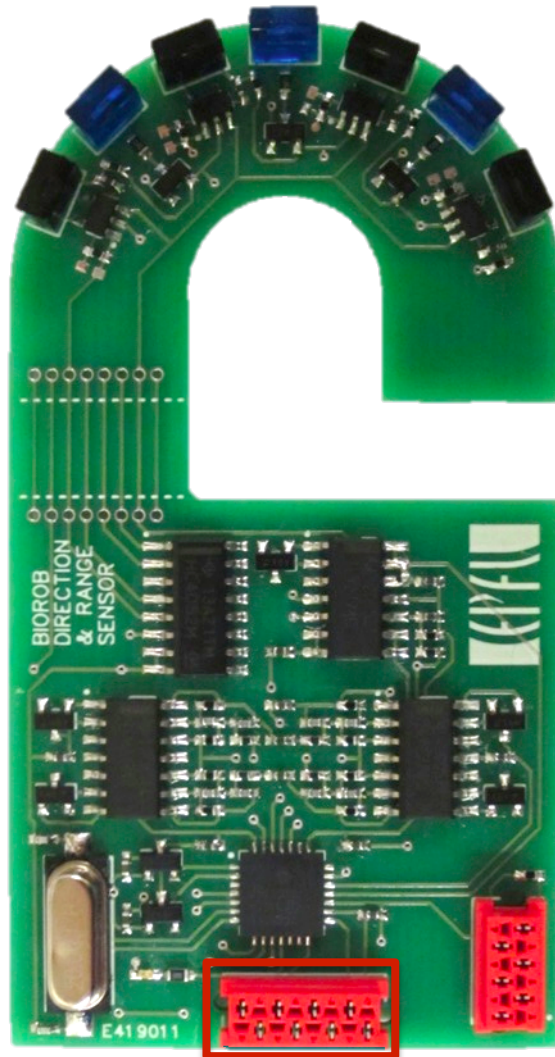


SECOND PROTOTYPE



- Detector array
- Transmitter array
- Analog multiplexer
- Cascaded 10 kHz filters
- Peak detectors
- Microcontroller
- Programming port

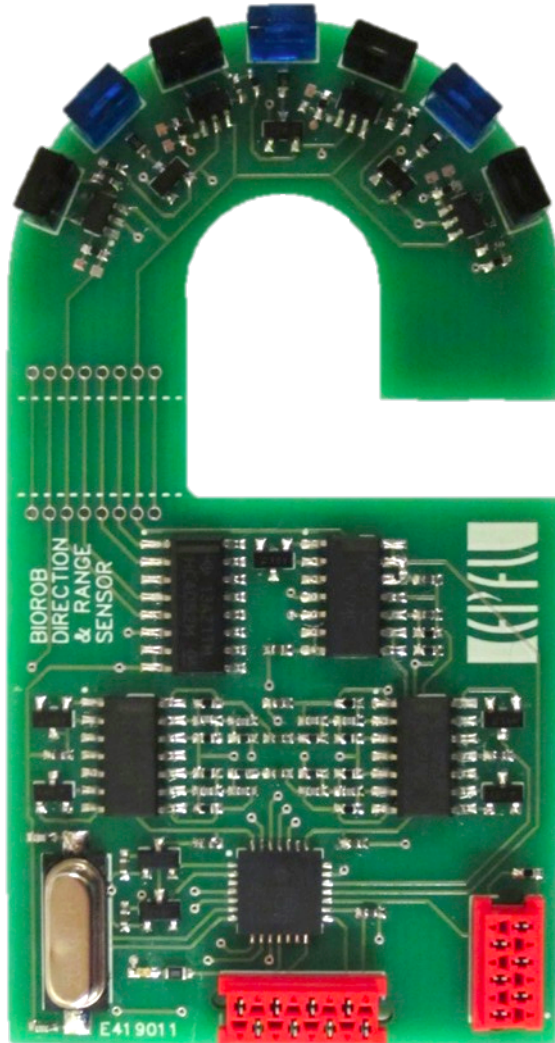
SECOND PROTOTYPE



- Detector array
- Transmitter array
- Analog multiplexer
- Cascaded 10 kHz filters
- Peak detectors
- Microcontroller
- Programming port
- Interface port

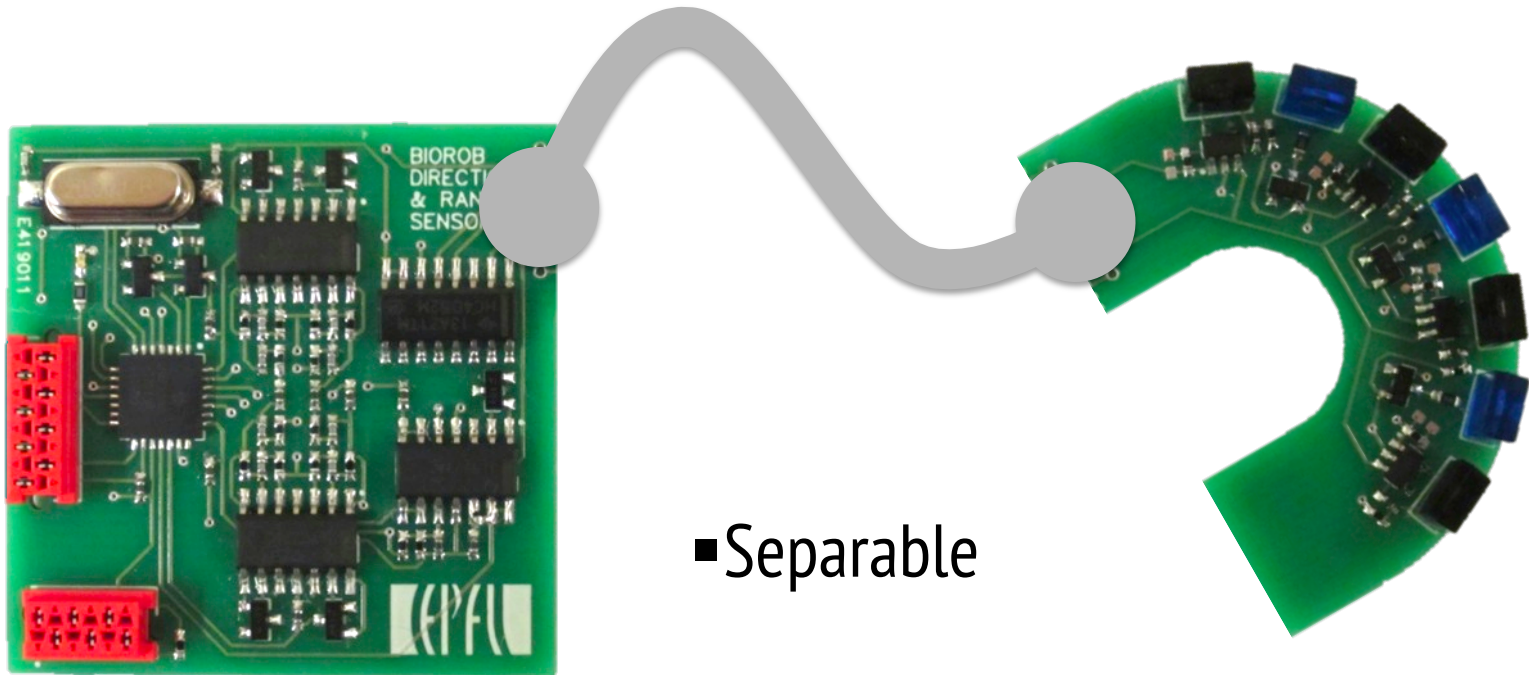


SECOND PROTOTYPE



- Detector array
- Transmitter array
- Analog multiplexer
- Cascaded 10 kHz filters
- Peak detectors
- Microcontroller
- Programming port
- Interface port
- And...

SECOND PROTOTYPE

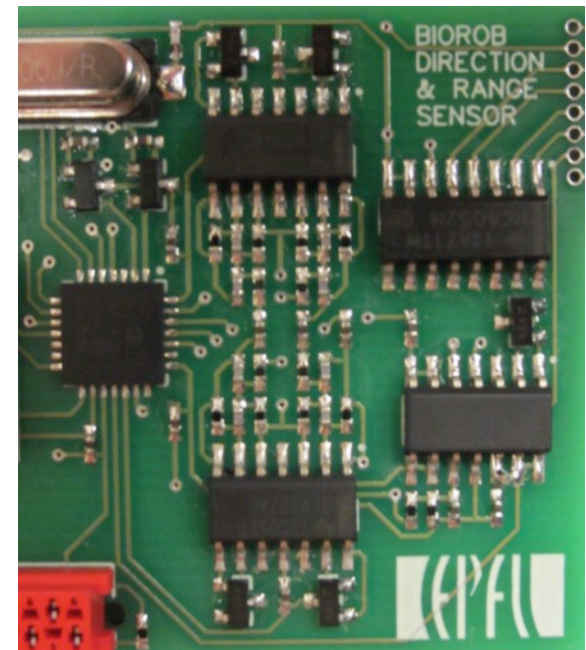
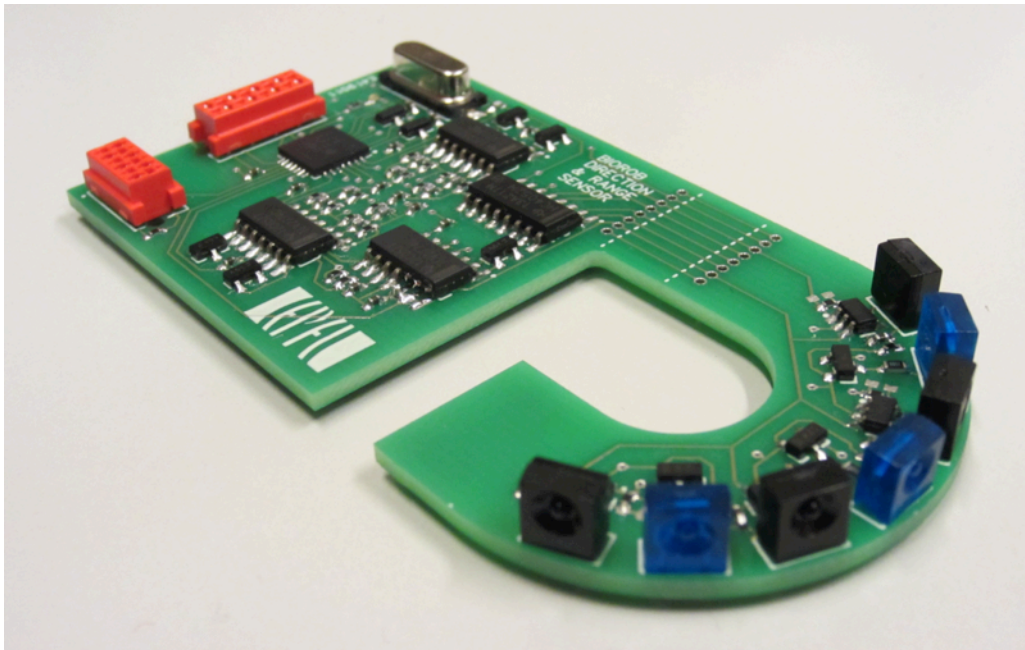


■ Separable

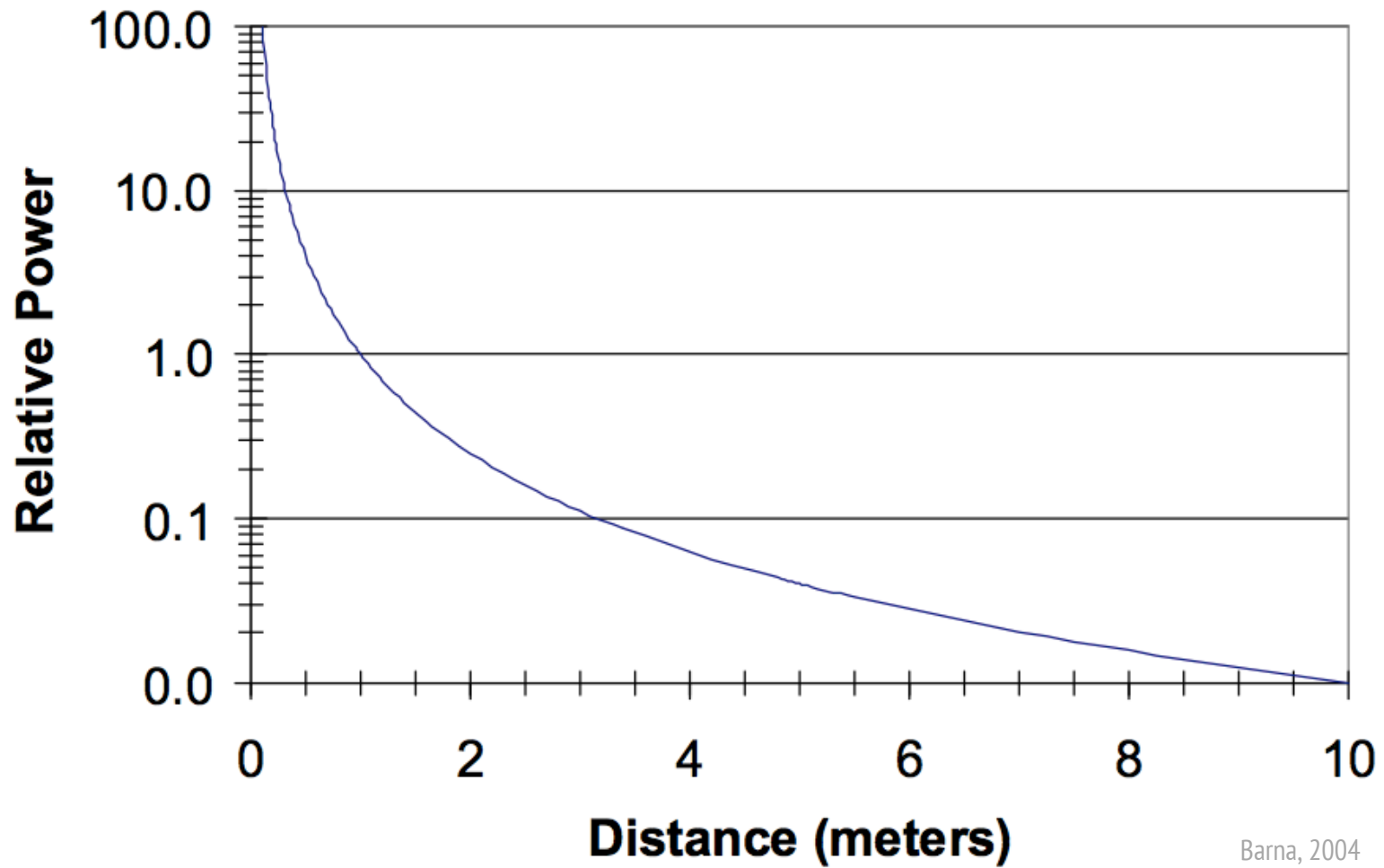


SECOND PROTOTYPE

- Small size (4 cm x 4 cm + detector)
- Few components
- Single 5V supply

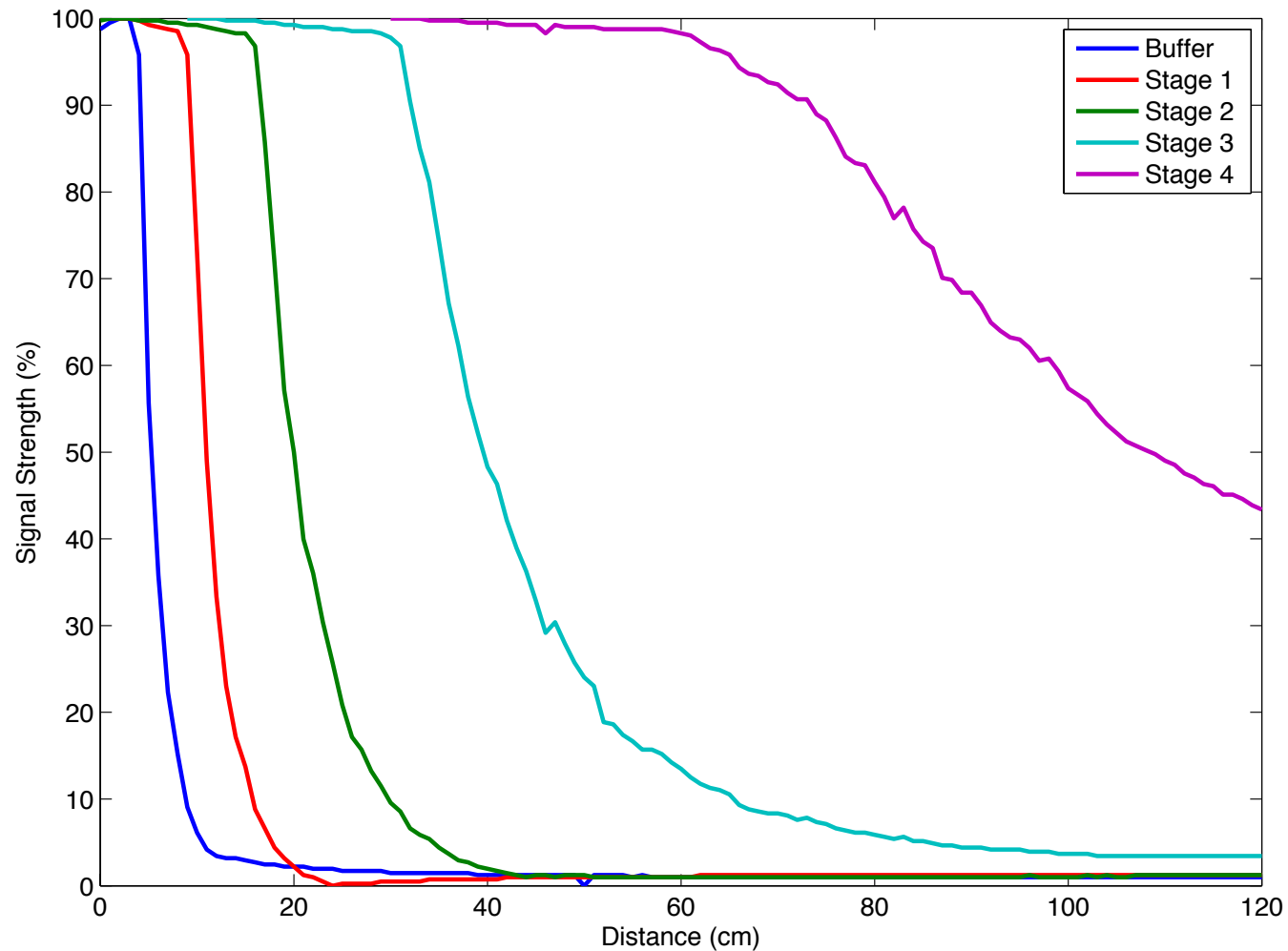


DISTANCE

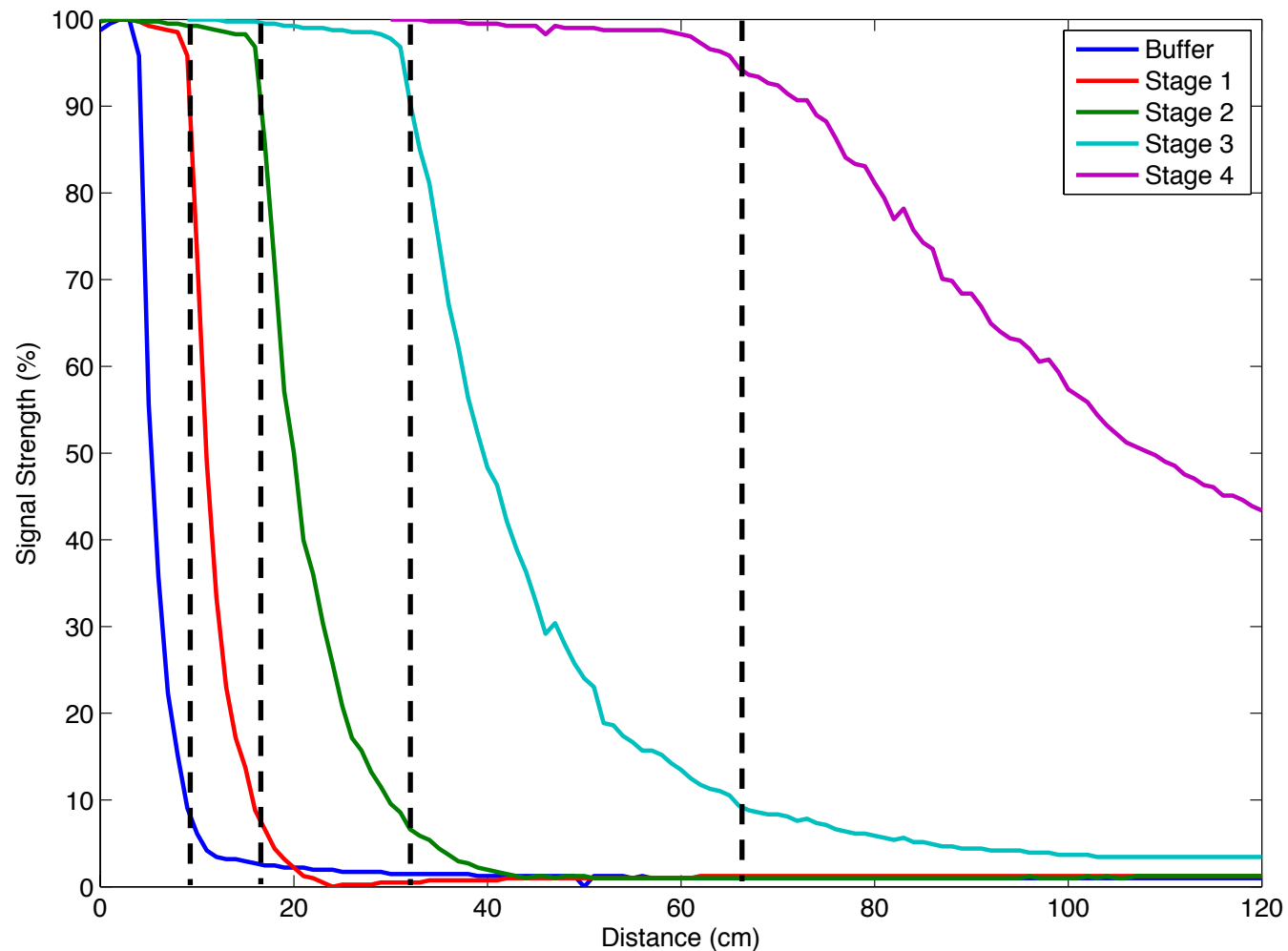


Barna, 2004

DISTANCE using low power transmitter



DISTANCE using low power transmitter

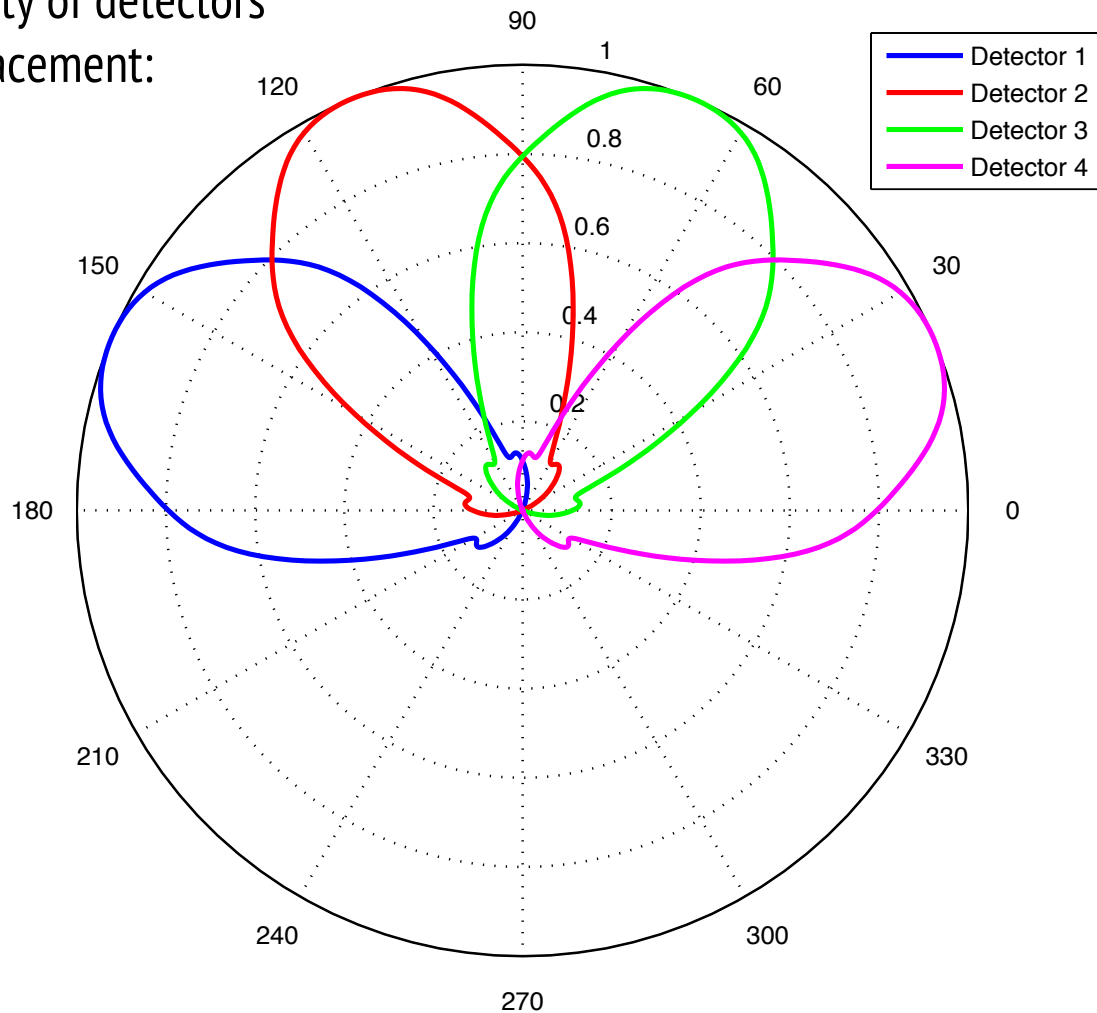


Note that the Buffer signal is noisier

ANGLE DETERMINATION



Relative sensitivity of detectors
vs. angular displacement:





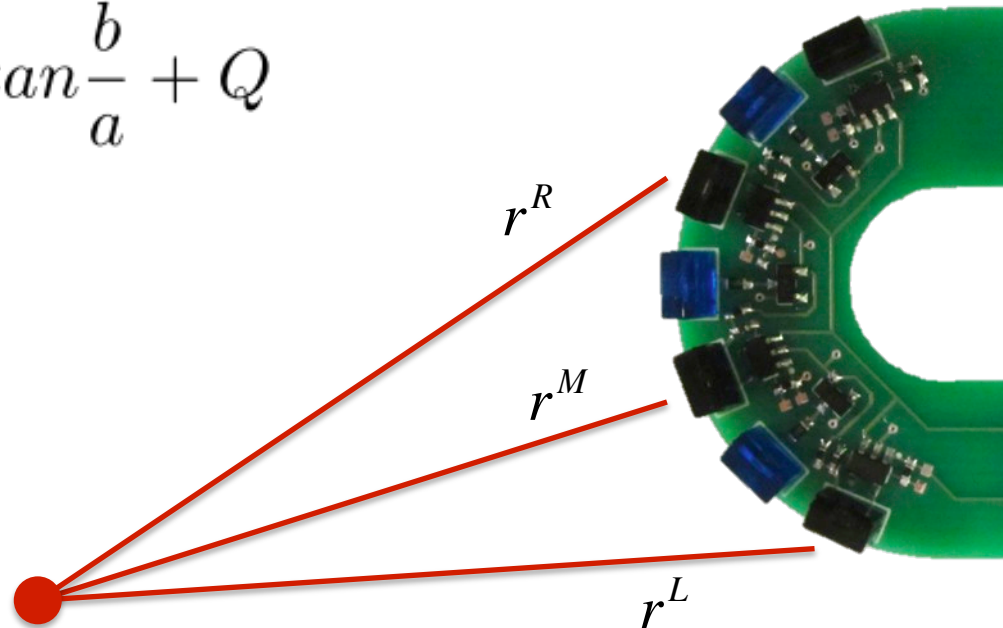
ANGLE DETERMINATION

- If we assume that the angular sensitivity profile is given by $r' = r \cdot \cos(\theta)$, we can compute the following solution:

$$r = \frac{1}{\sqrt{a^2 + b^2}} \quad \theta = \arctan \frac{b}{a} + Q$$

$$a = \frac{r^L + r^R + 2 \cdot r^M}{2 \cdot \cos\left(\frac{\pi}{4}\right) + 2}$$

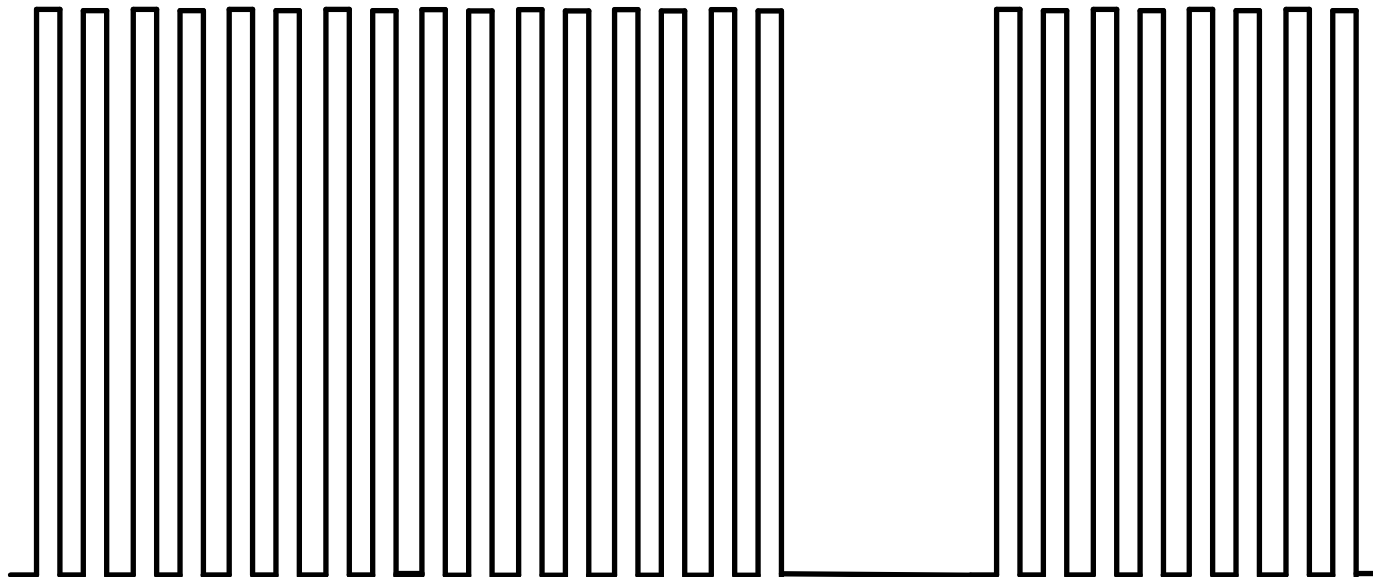
$$b = \frac{r^L - r^R}{2 \cdot \sin\left(\frac{\pi}{4}\right)}$$



DATA TRANSMISSION



- Pulse width modulation
 - very low data rate



FUTURE WORK



- Integrate into salamander
- High power transmitter
- Efficient firmware

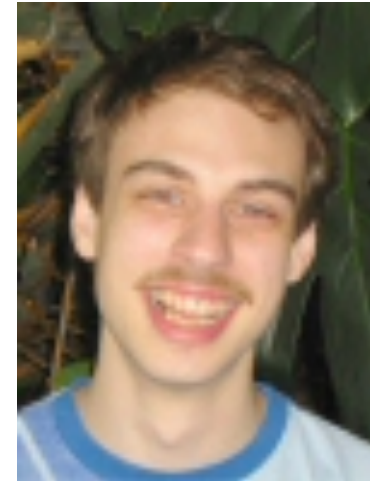


Photograph by A. Herzog

THANK YOU



- Auke Jan Ijspeert
- Alessandro Crespi



QUESTIONS

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