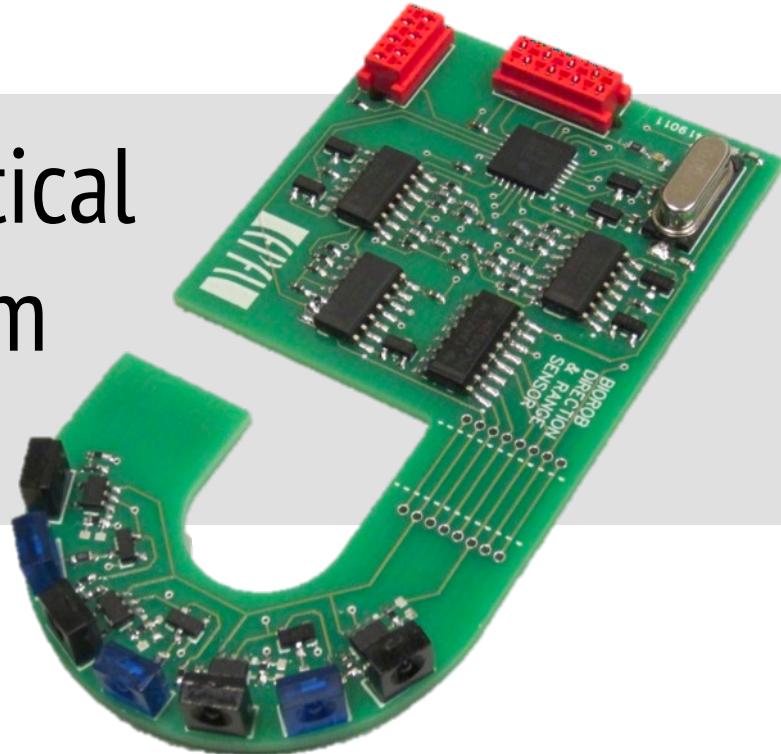


# Design of an Infrared / Optical Relative Positioning System for Mobile Robots

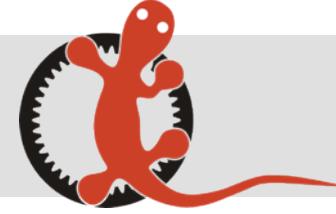
Semester Project

Raphael Cherney



ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE

# 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)

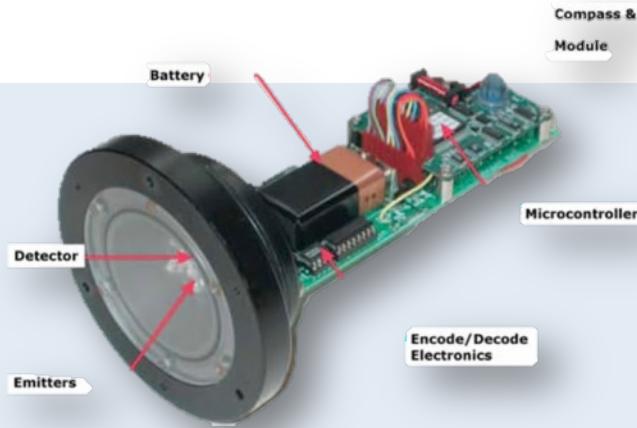


Photograph by A. Crespi

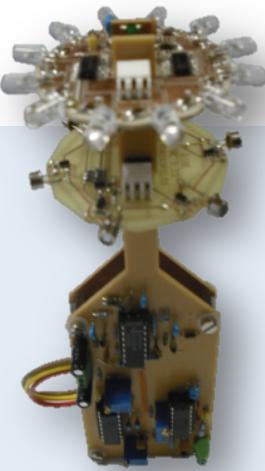


# STATE OF THE ART

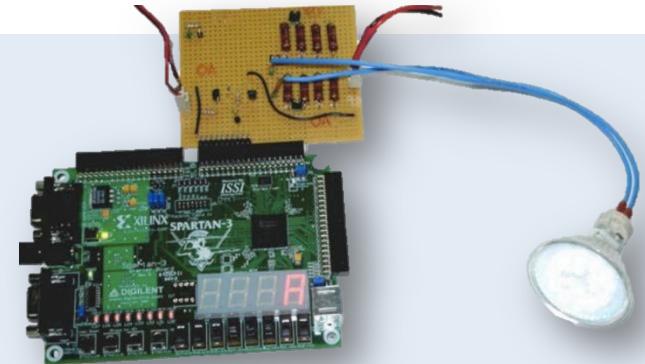
UNDERWATER



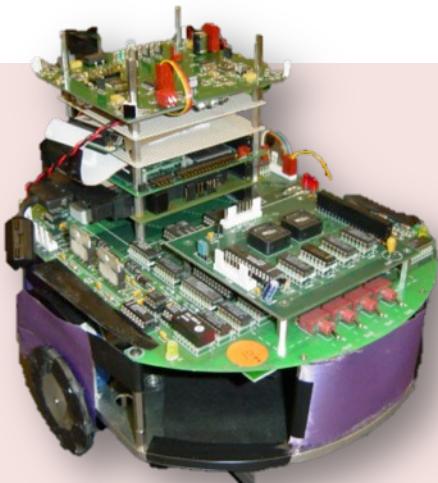
Tivey, 2004; WHOI



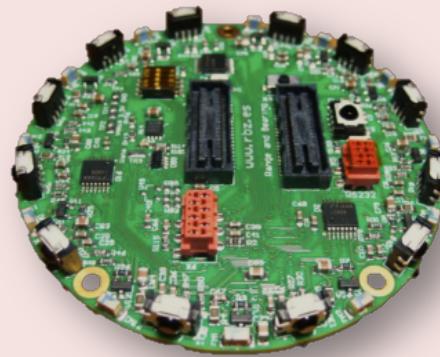
Anguita, 2010; Genova



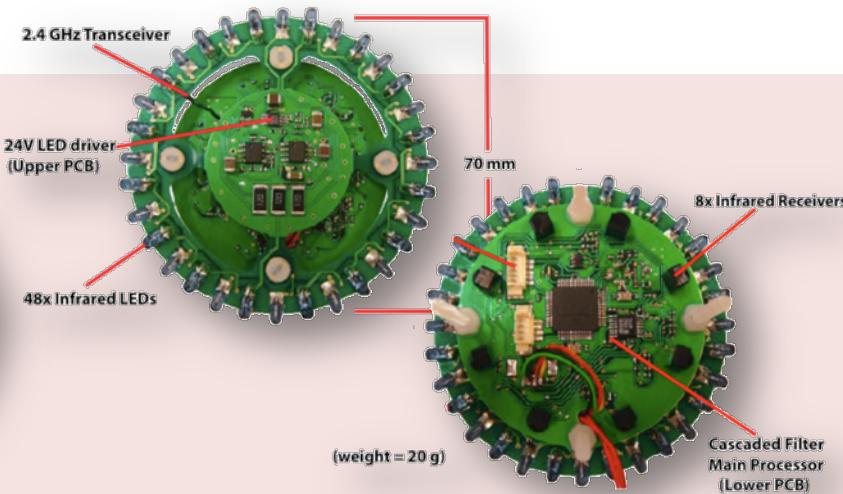
Hernandez, 2006; CEDINT



Kelly, 2004; USC



Gutiérrez, 2008; ETSI

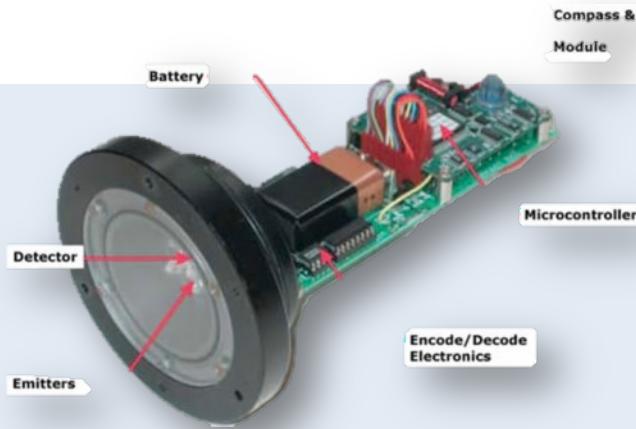


Roberts, 2009; EPFL

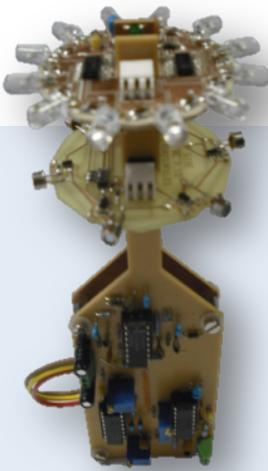


# STATE OF THE ART

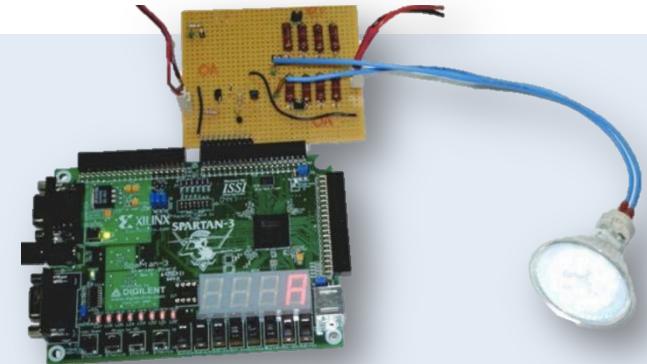
UNDERWATER



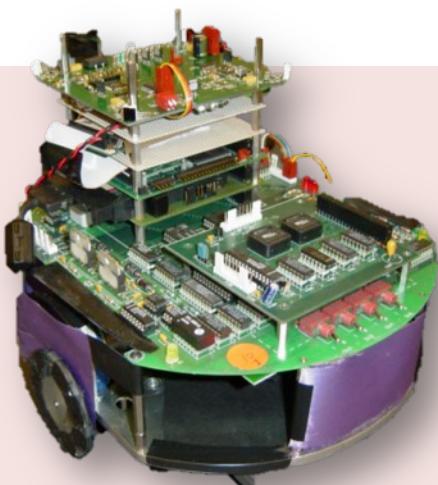
Tivey, 2004; WHOI



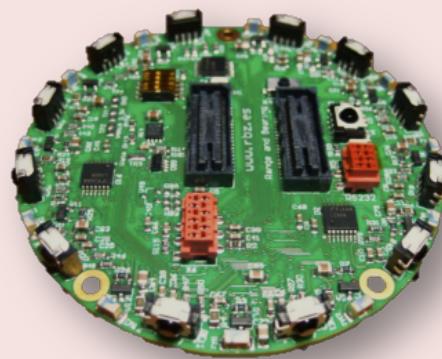
Anguita, 2010; Genova



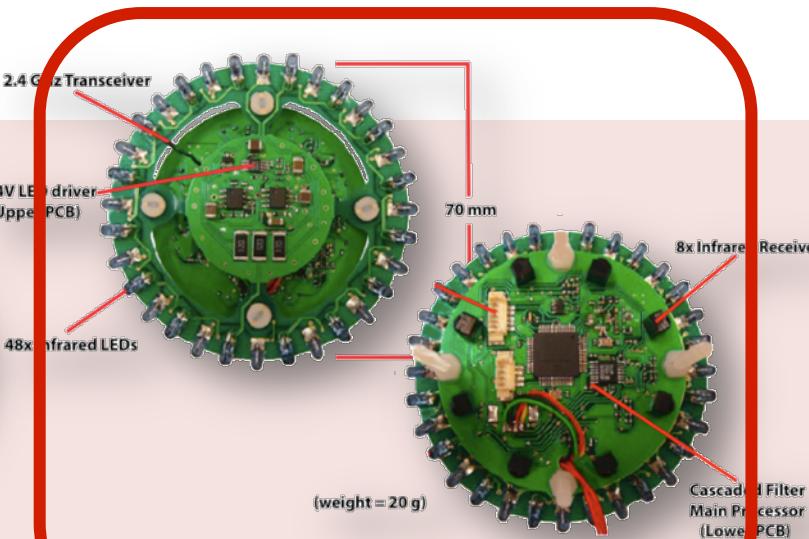
Hernandez, 2006; CEDINT



Kelly, 2004; USC



Gutiérrez, 2008; ETSI

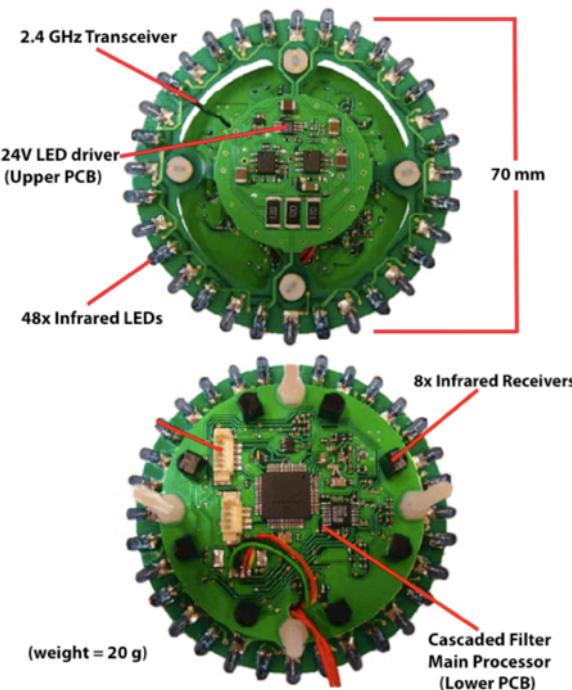


Roberts, 2009; EPFL

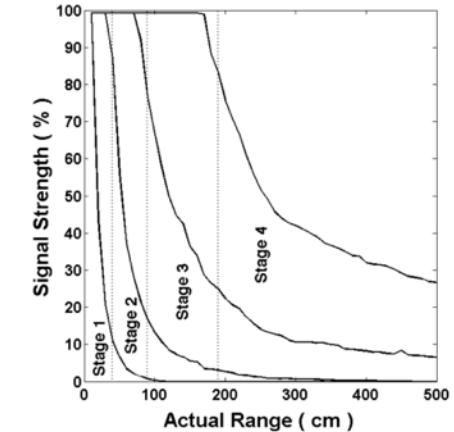
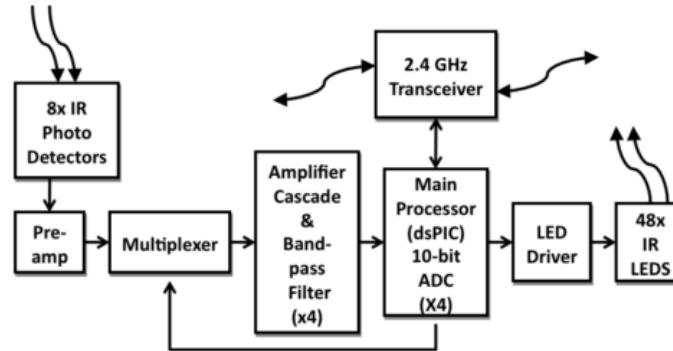
# STATE OF THE ART



## Range and Bearing Infrared Transceiver (RABIT)



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

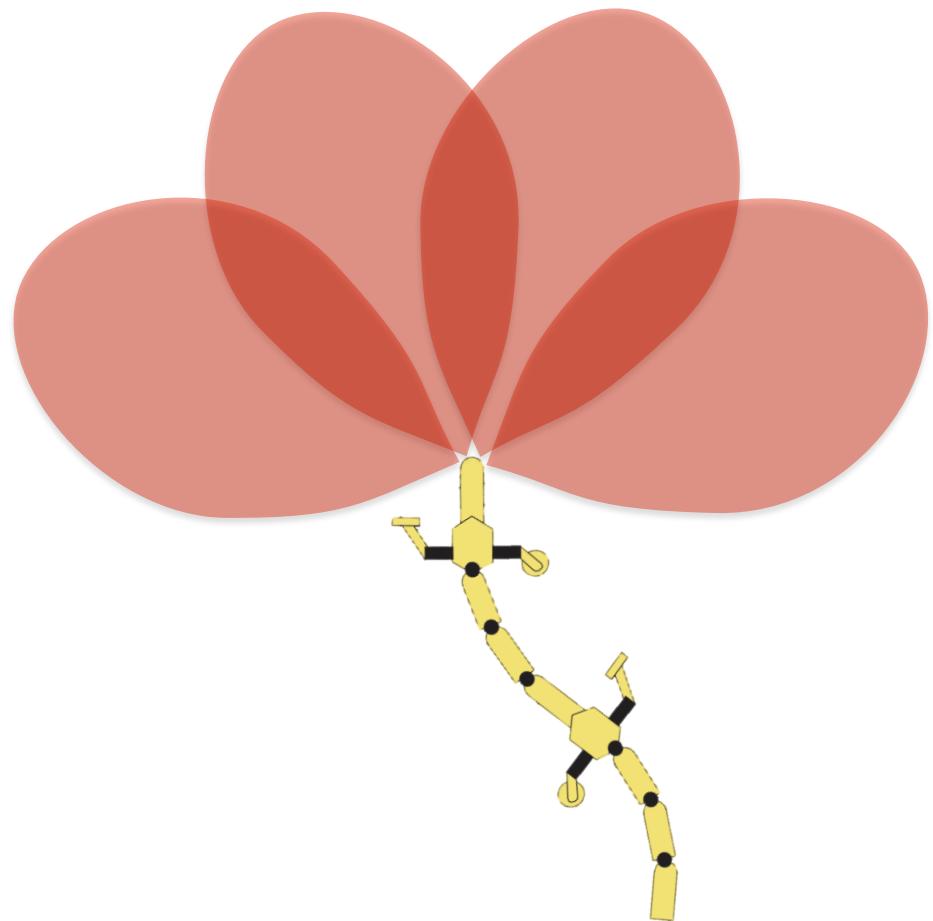


- Too large
- Communication done through radio

# DESIGN



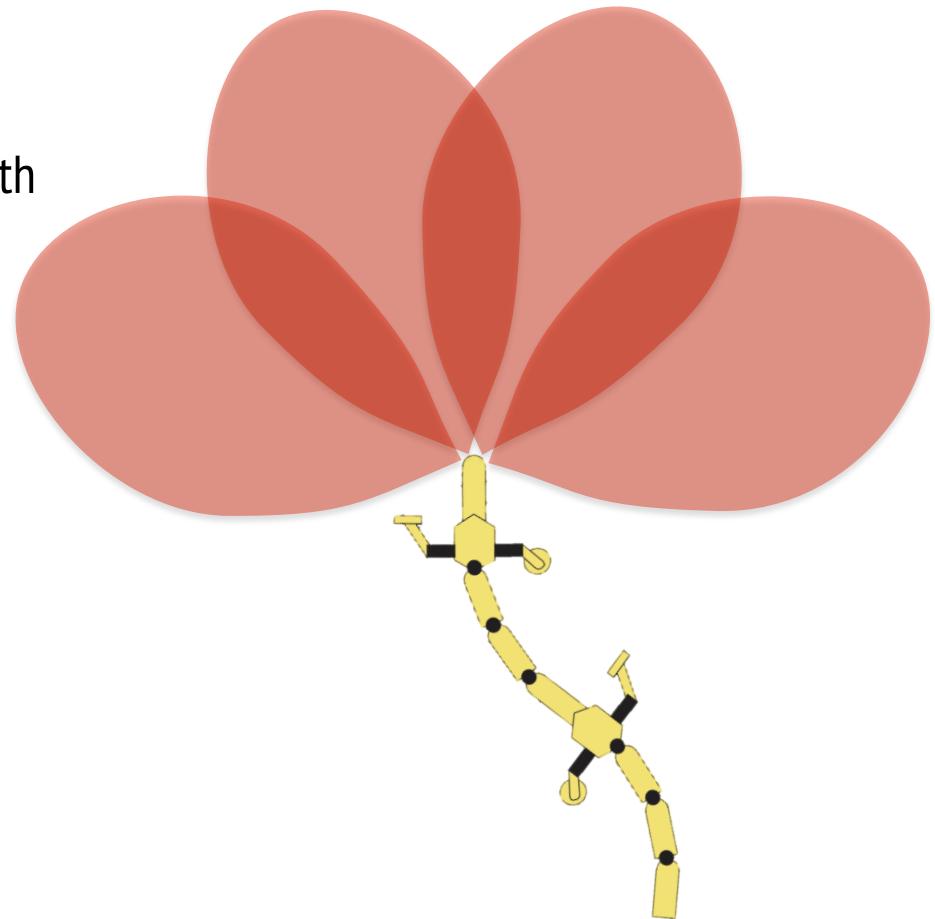
- Detector array



# DESIGN



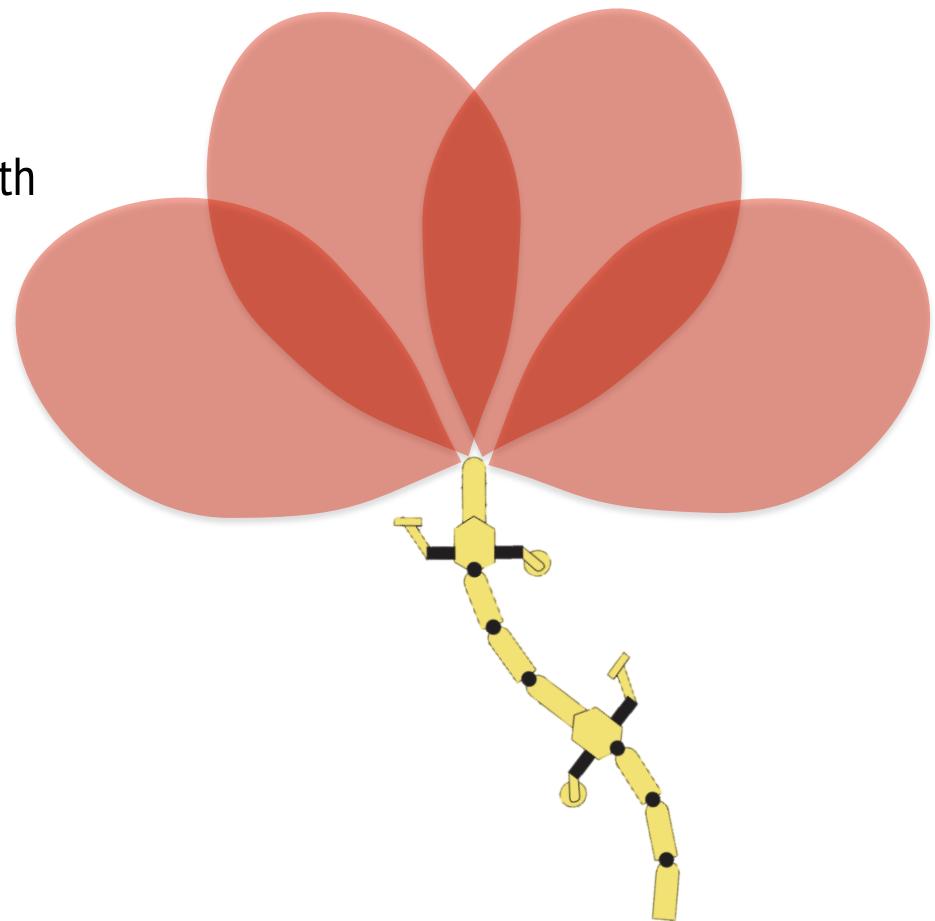
- Detector array
  - Direction determined based on sensor positions with strong signals
  - Distance estimated from signal strength



# DESIGN



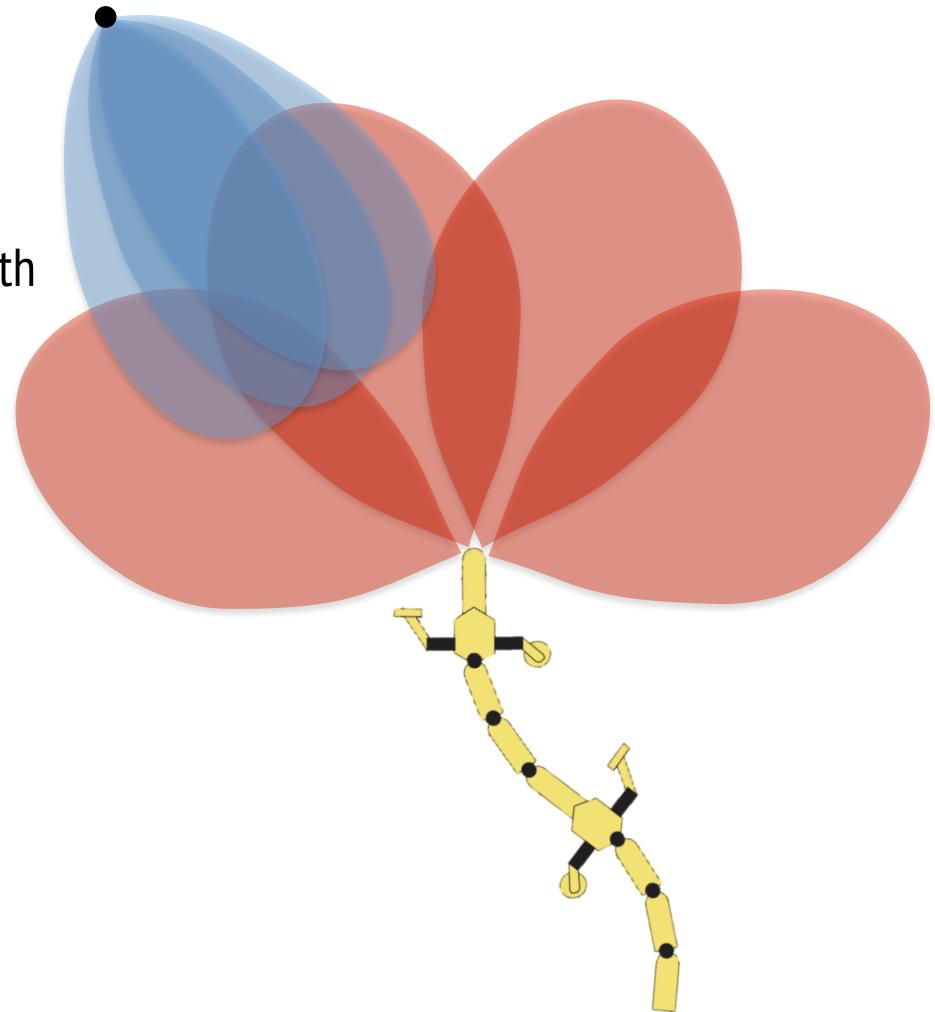
- Detector array
  - Direction determined based on sensor positions with strong signals
  - Distance estimated from signal strength
- Modulated signals (10 kHz carrier)



# DESIGN



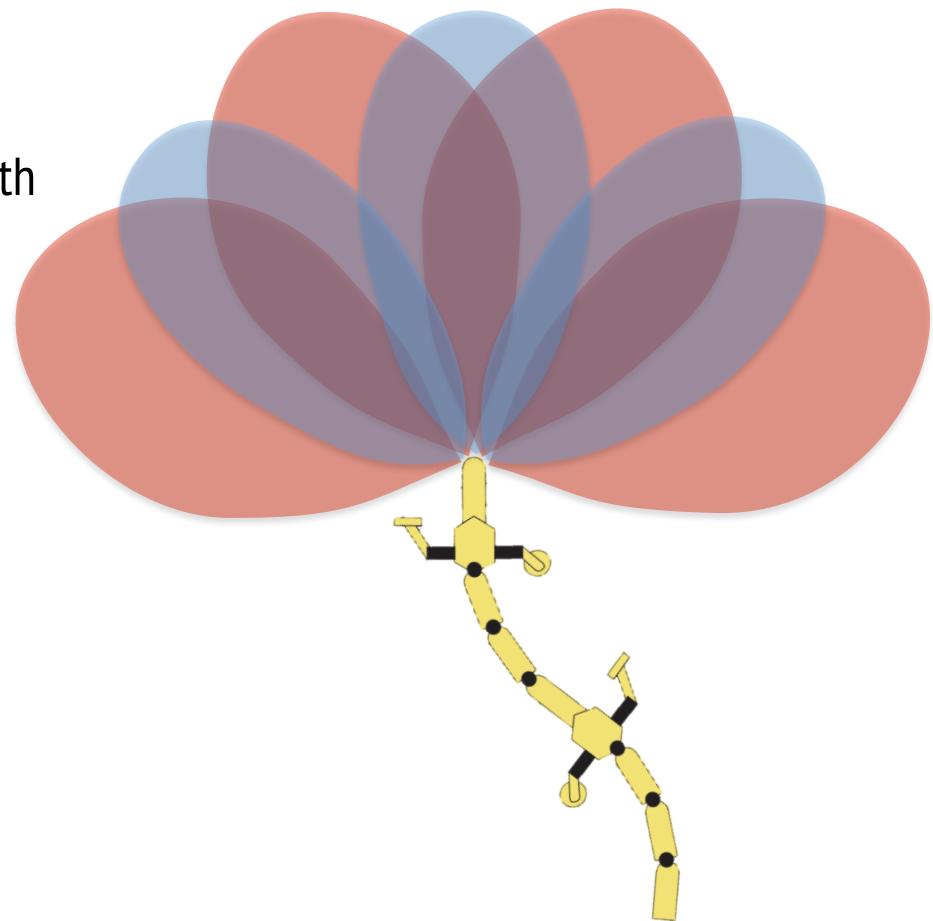
- Detector array
  - Direction determined based on sensor positions with strong signals
  - Distance estimated from signal strength
- Modulated signals (10 kHz carrier)
  - Active beacon



# DESIGN



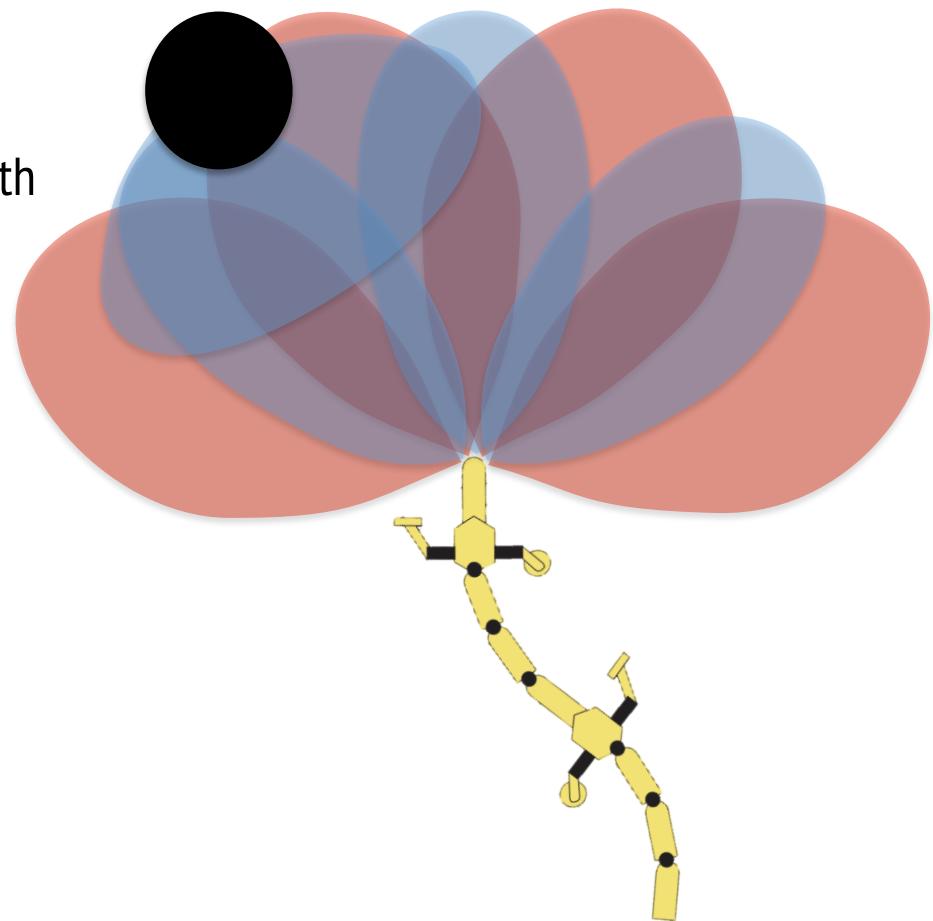
- Detector array
  - Direction determined based on sensor positions with strong signals
  - Distance estimated from signal strength
- Modulated signals (10 kHz carrier)
  - Active beacon
  - Onboard transmitter



# DESIGN



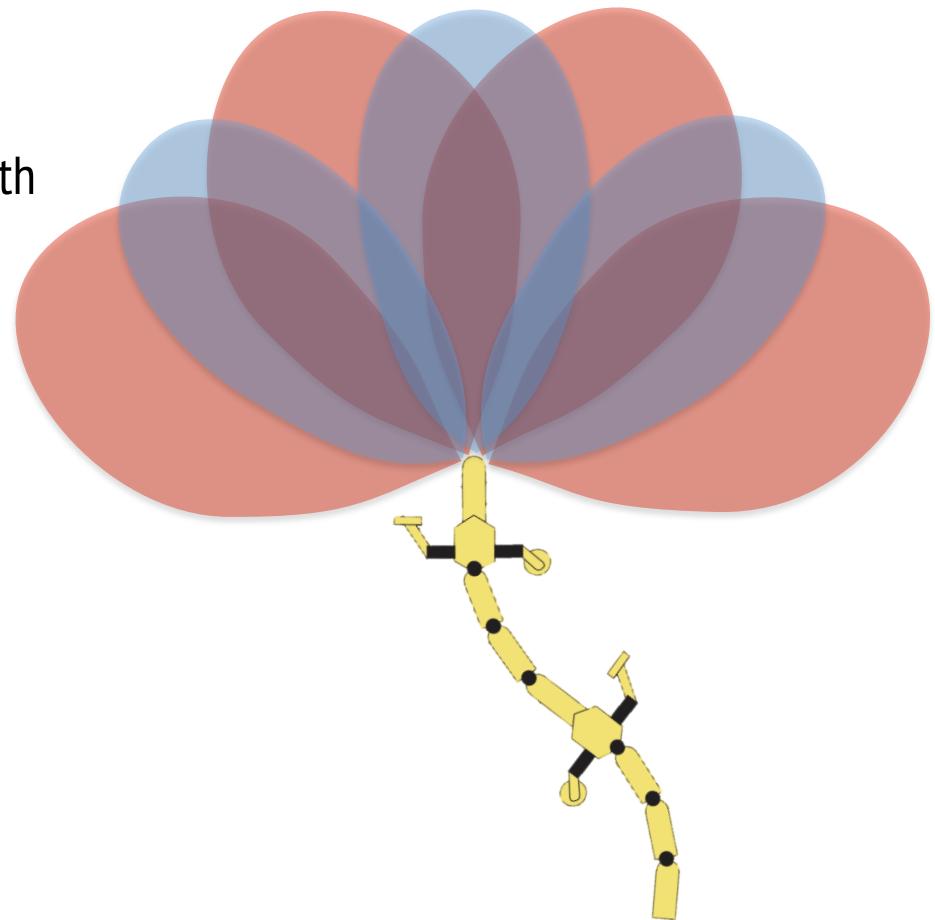
- Detector array
  - Direction determined based on sensor positions with strong signals
  - Distance estimated from signal strength
- Modulated signals (10 kHz carrier)
  - Active beacon
  - Onboard transmitter



# DESIGN



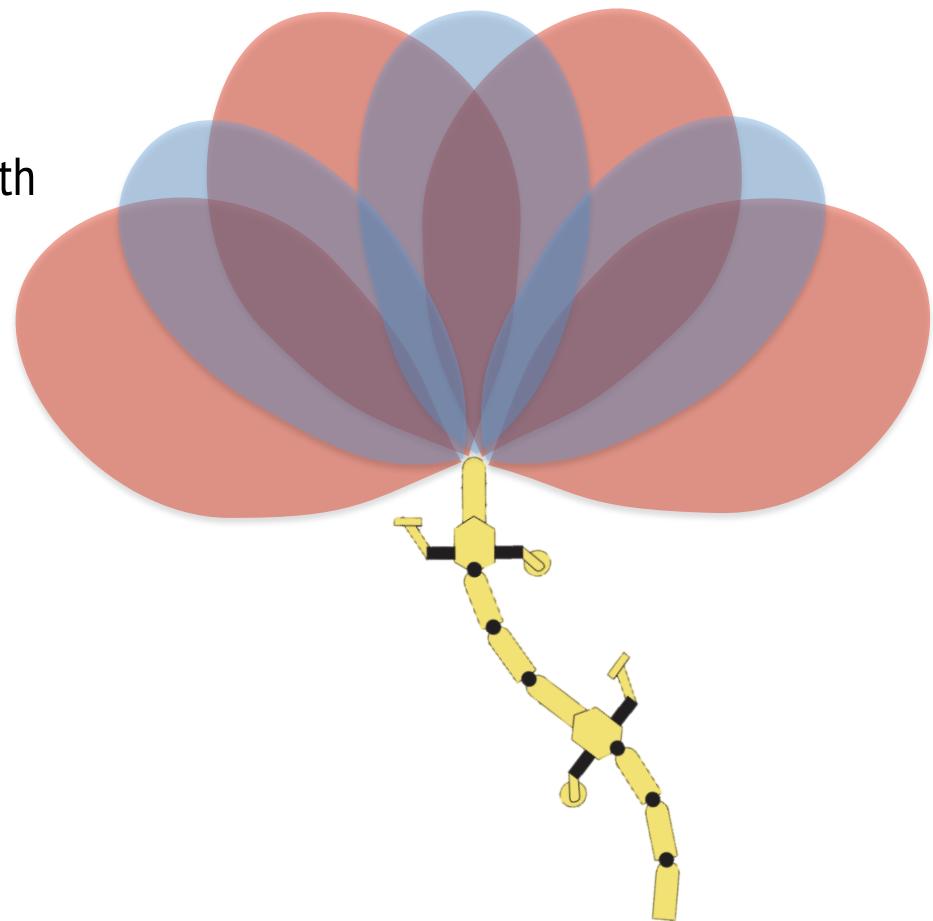
- Detector array
  - Direction determined based on sensor positions with strong signals
  - Distance estimated from signal strength
- Modulated signals (10 kHz carrier)
  - Active beacon
  - Onboard transmitter
- Transmit data over optical channel (PWM, PPM, OOK)



# 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)

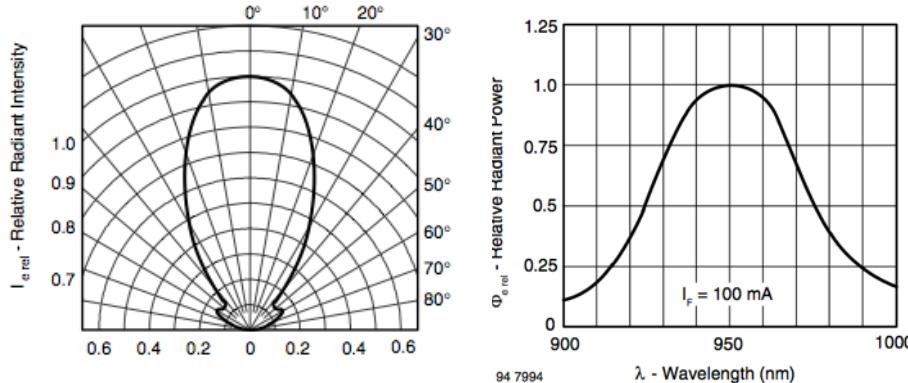


# TRANSMITTER

(onboard)

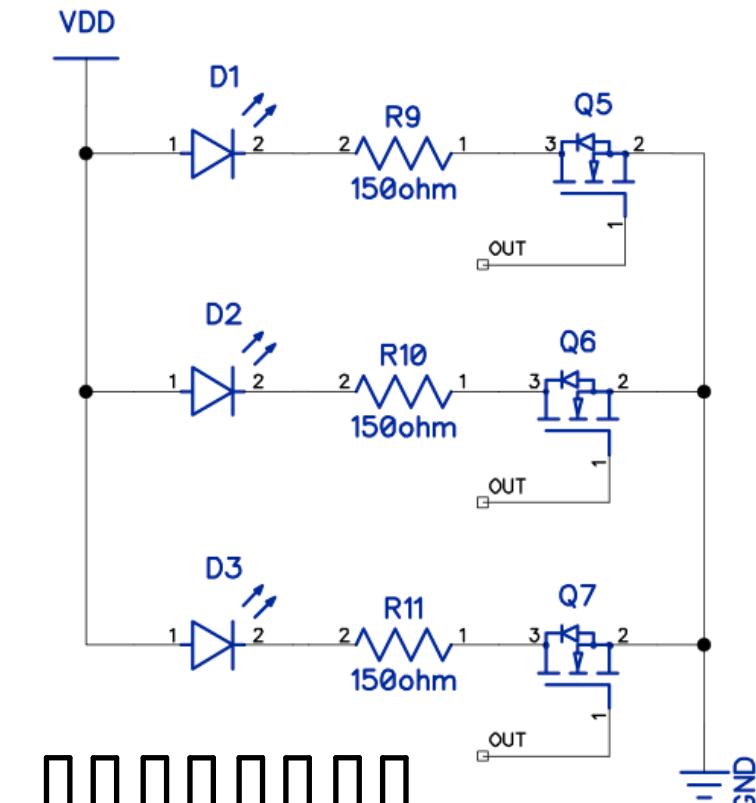


- Modulated 10 kHz carrier
- Uses TSKS5400 infrared emitting diode:



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

Transmitter Array

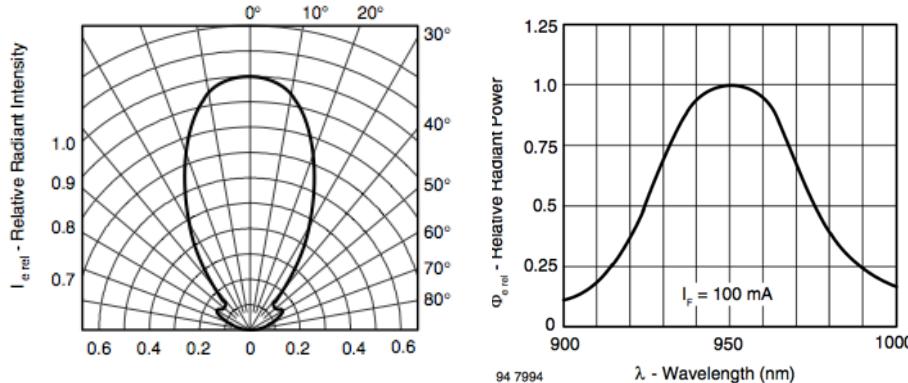


# TRANSMITTER

(onboard)

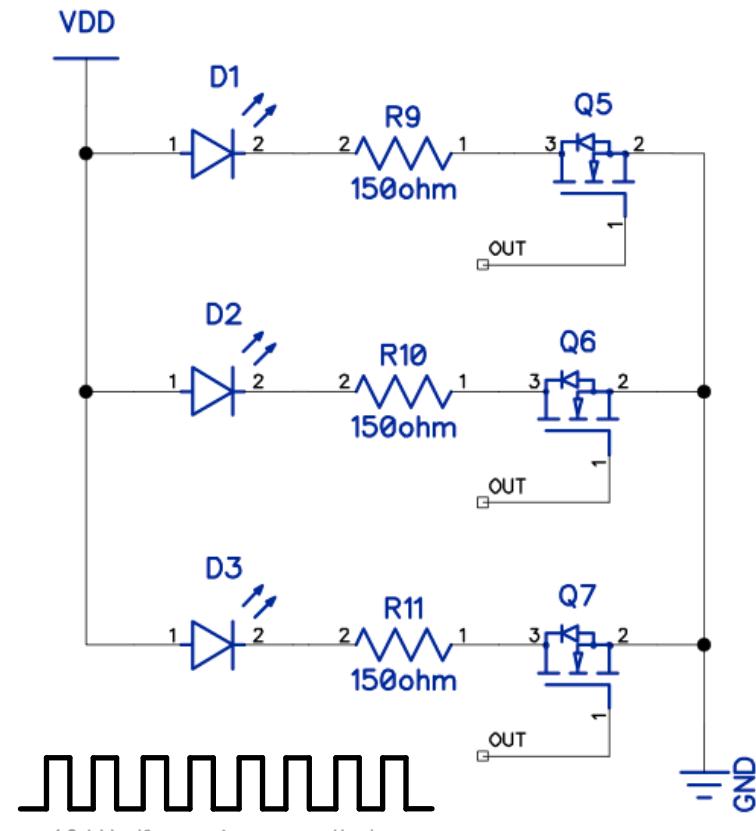


- Modulated 10 kHz carrier
- Uses TSKS5400 infrared emitting diode:



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

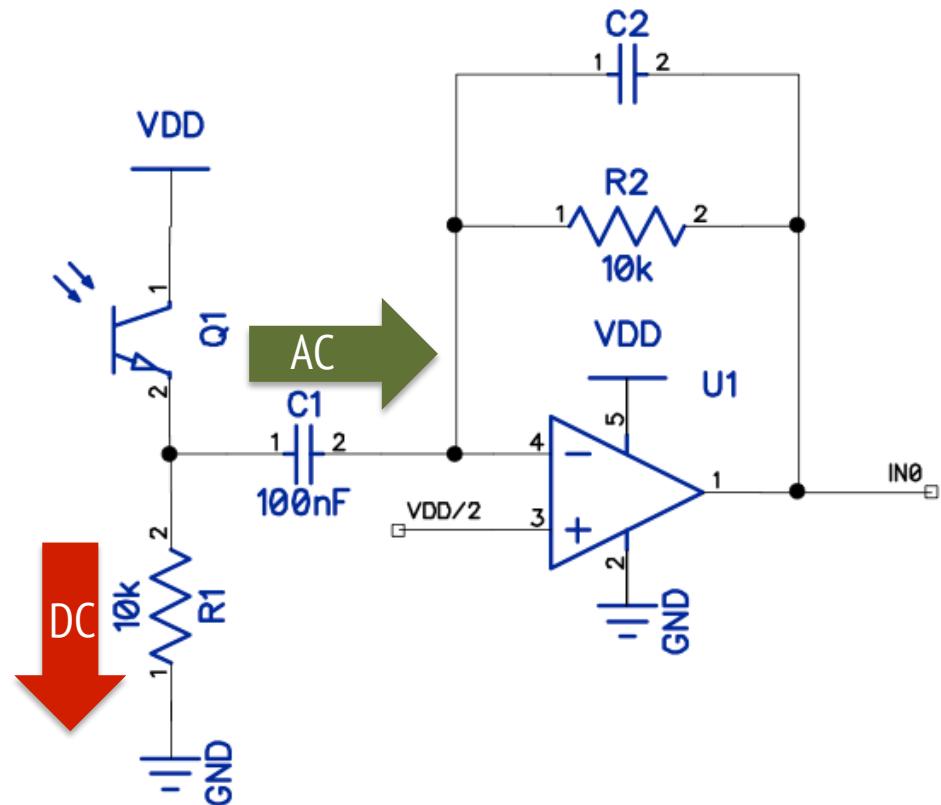
## Transmitter Array



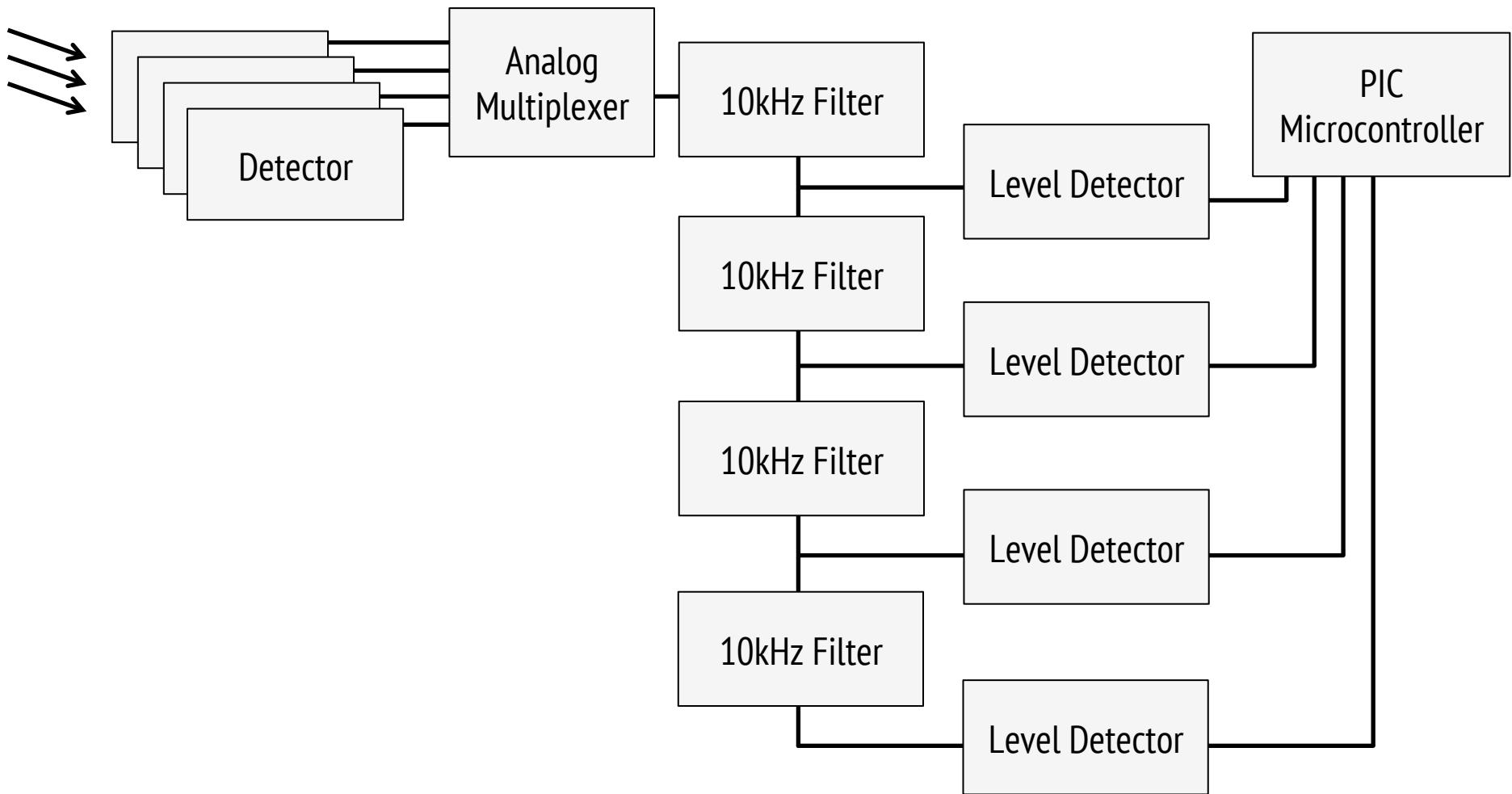
# DETECTOR



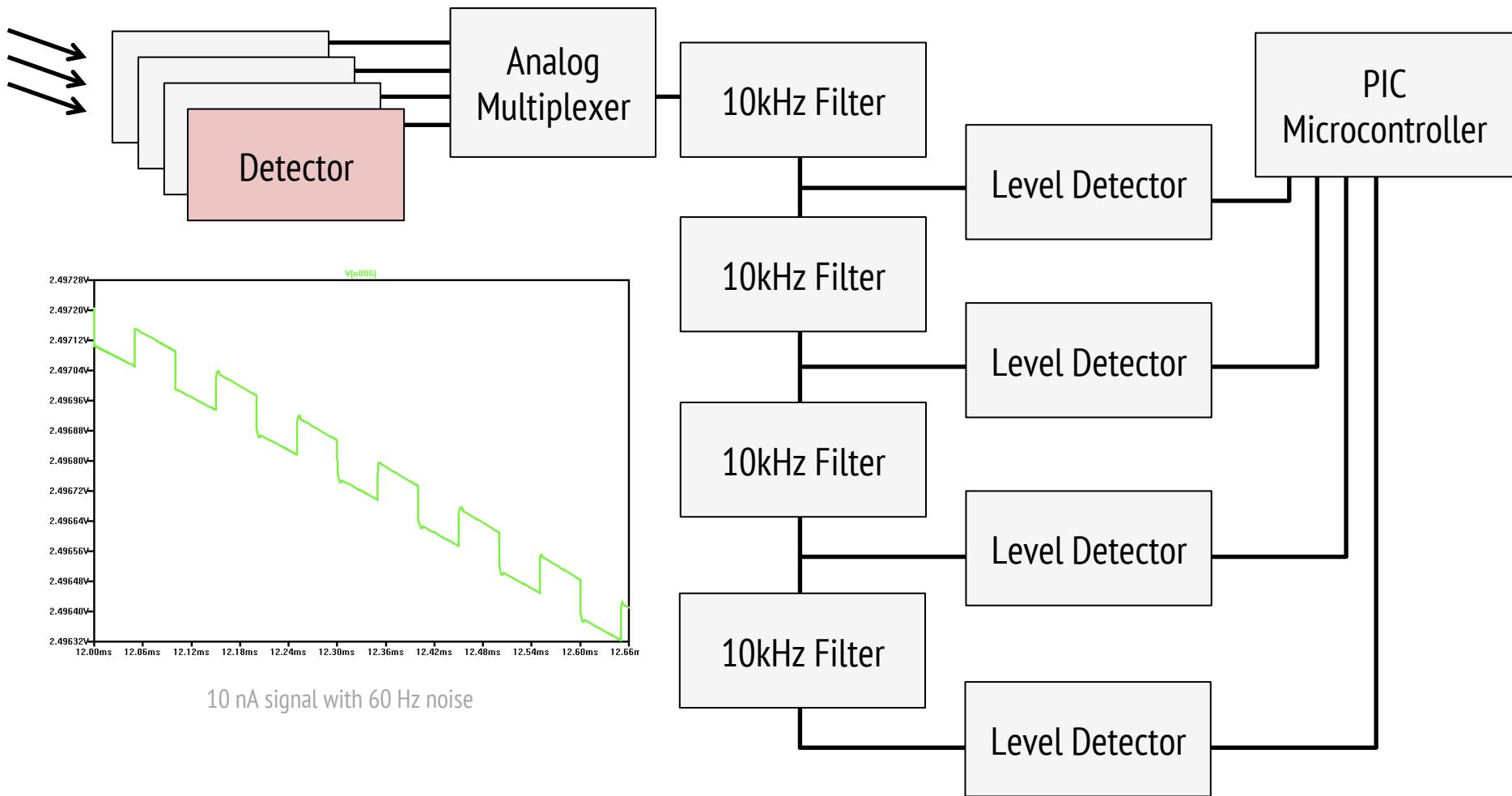
- AC-coupled transimpedance amplifier
- DC current (ambient light signal) passes through the resistor while the AC signal is passed to the amplifier



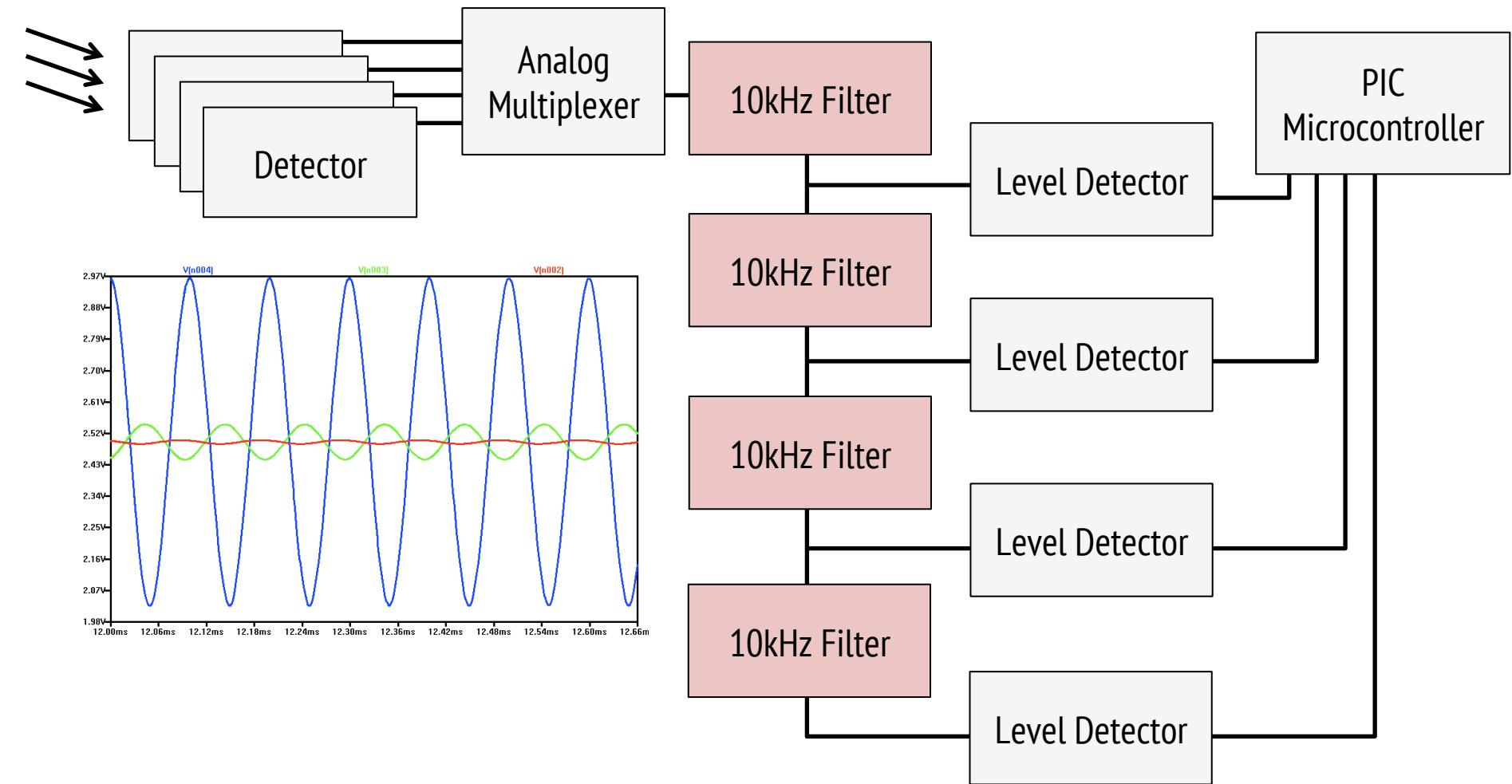
# RECEIVER



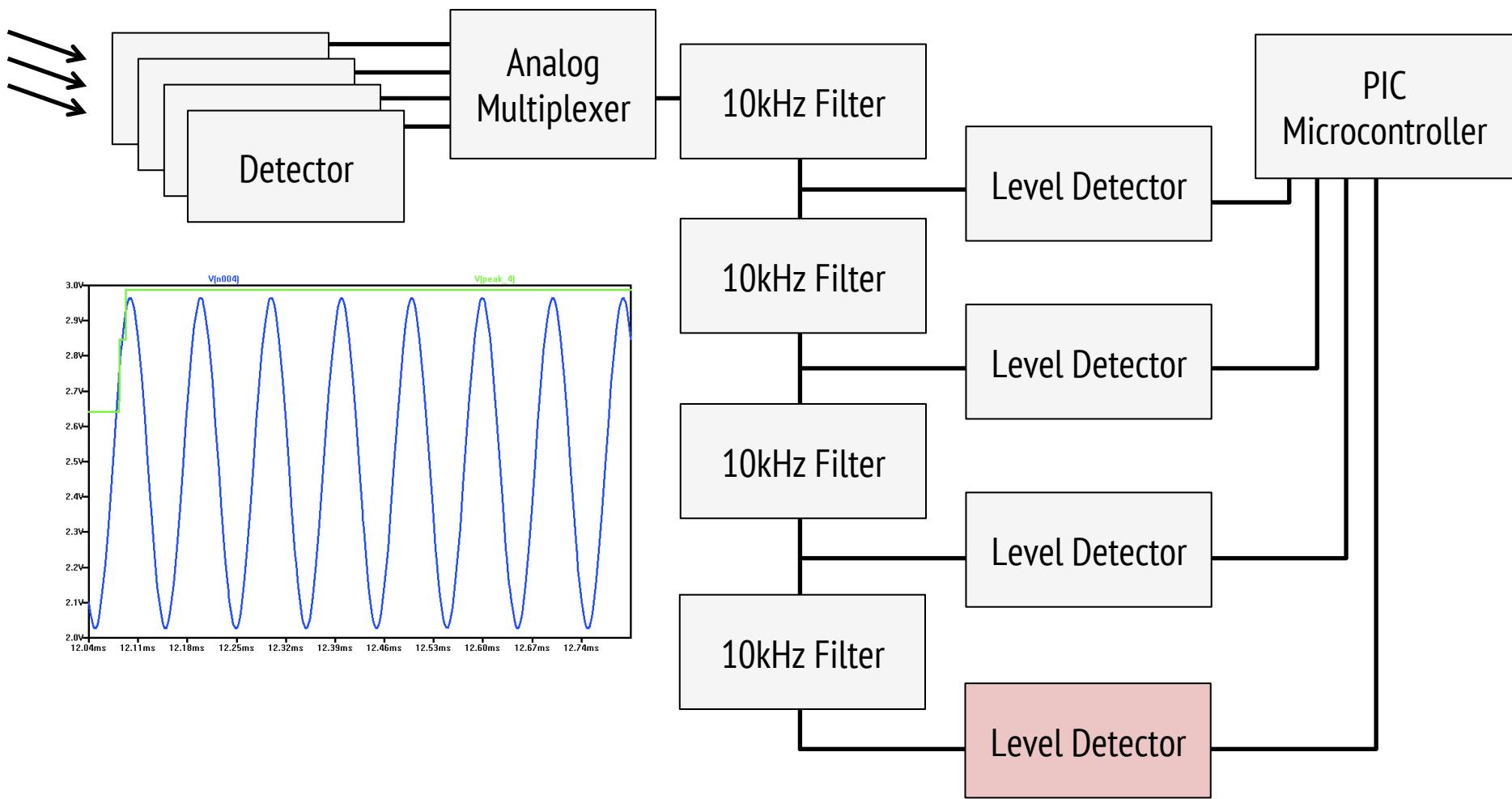
# RECEIVER



# RECEIVER



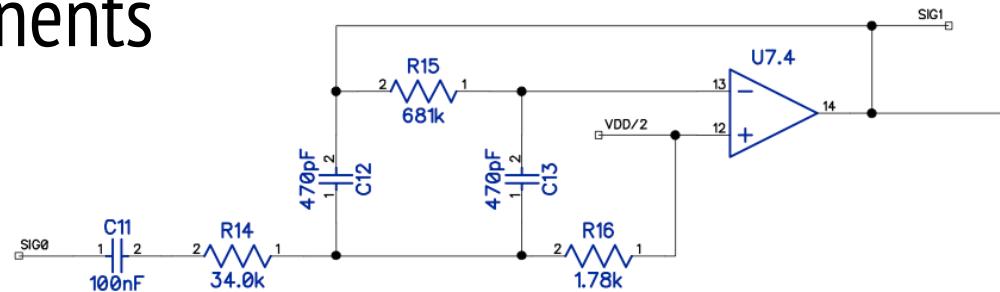
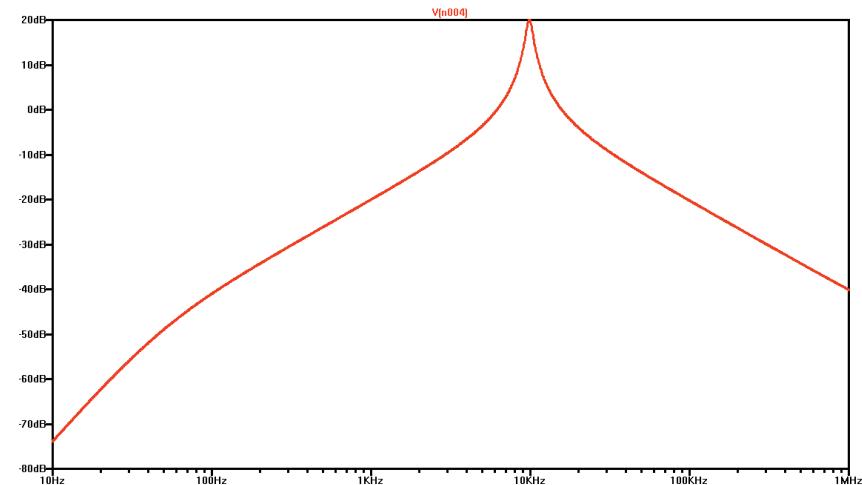
# RECEIVER



# AMPLIFYING FILTERS



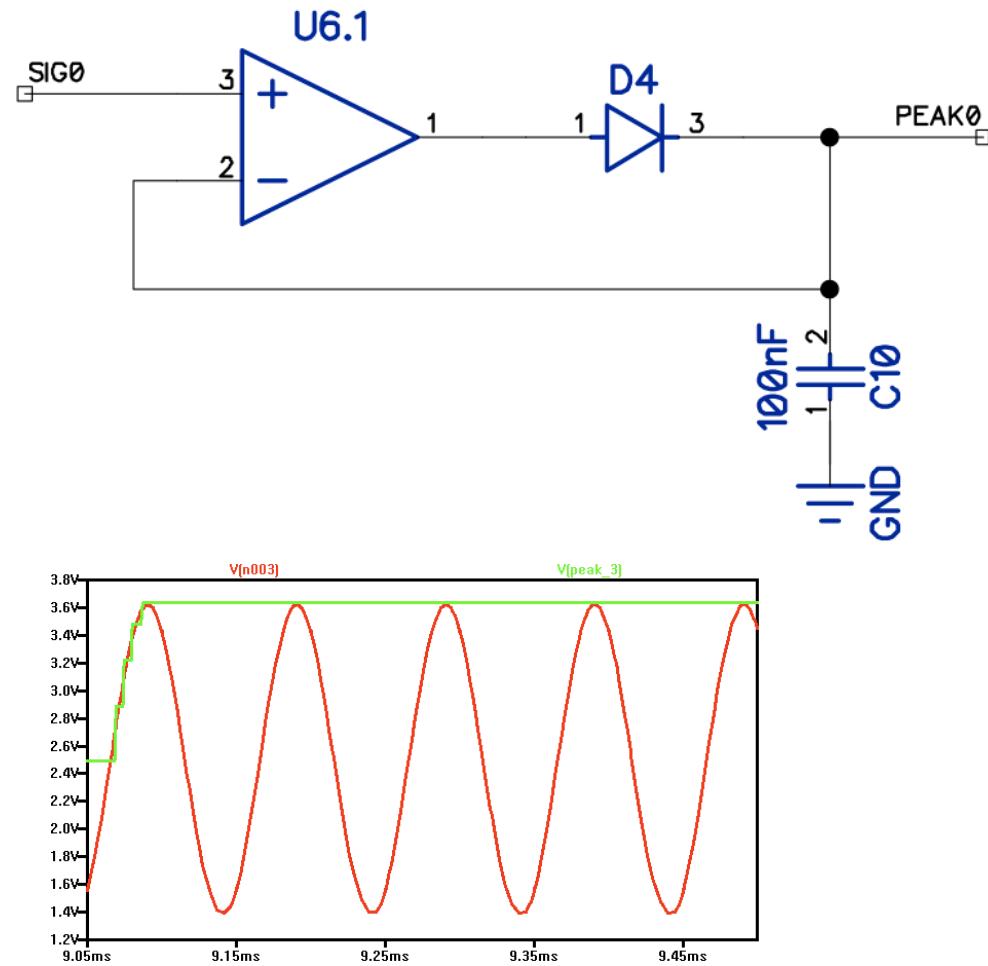
- Active, narrow band pass filters
  - modified Deliyannis filter
- Gain of 10 for selected frequency
- Relatively few components
- 4 cascaded stages
  - danger of ringing



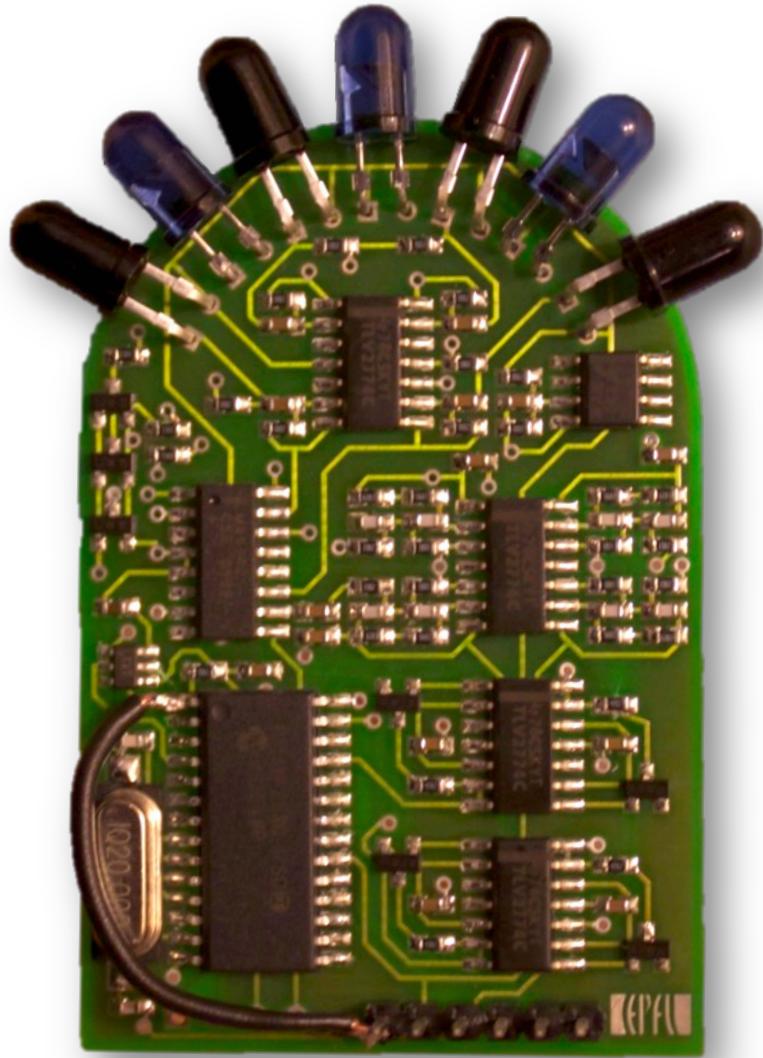
# LEVEL DETECTOR



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

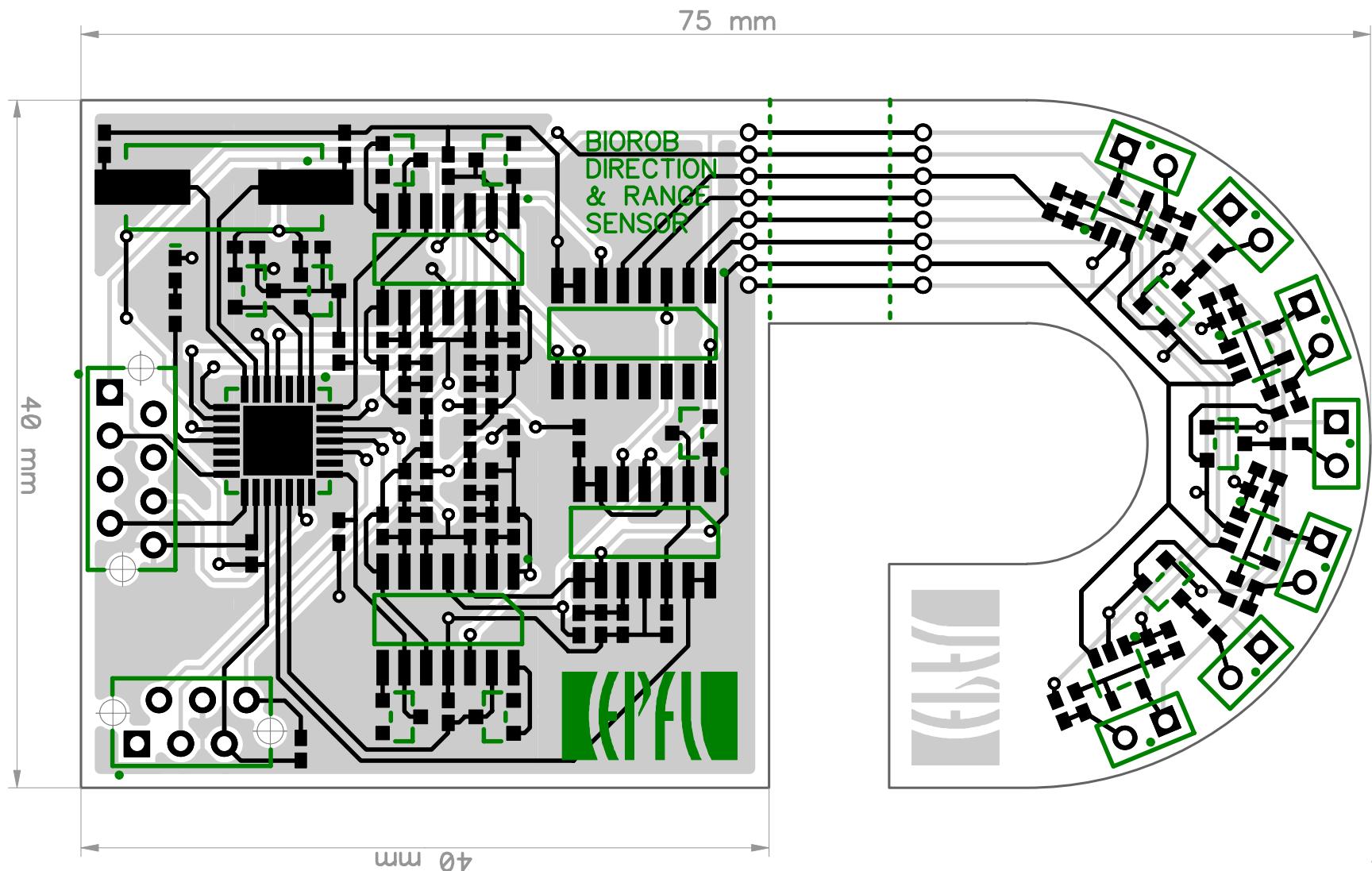


# FIRST PROTOTYPE

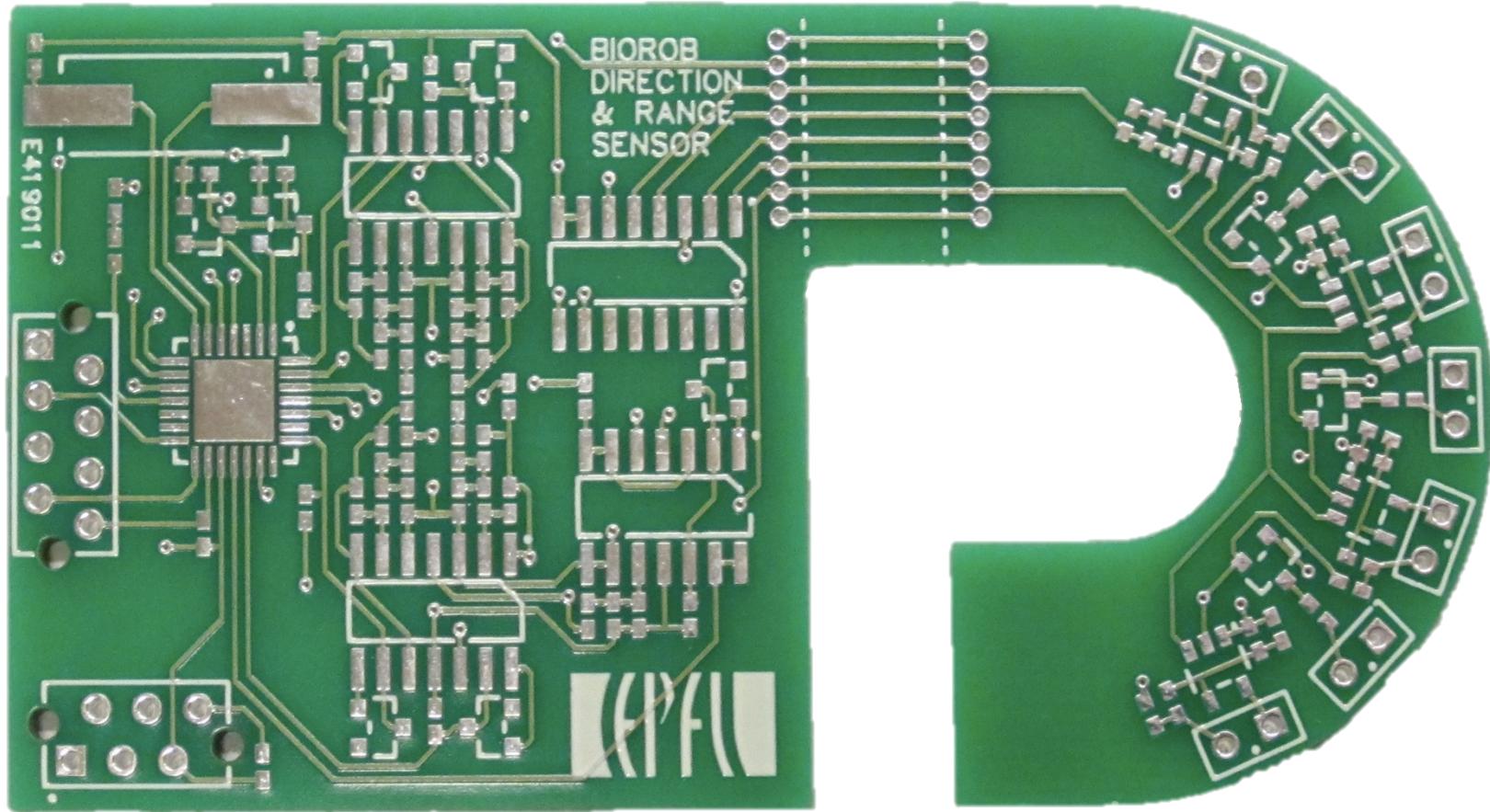


- Test analog circuit
- Prototype firmware
- Catch design errors

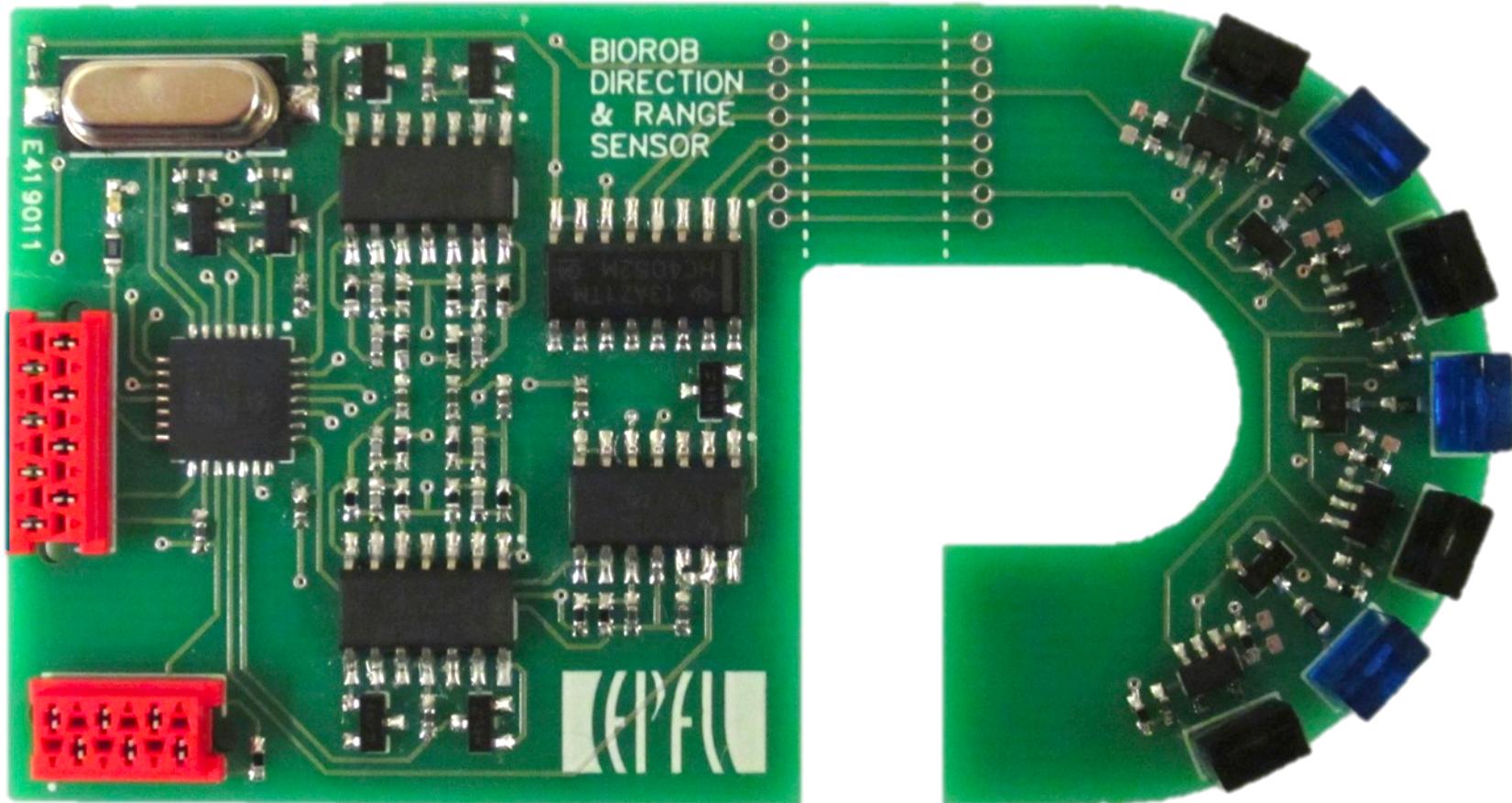
# SECOND PROTOTYPE



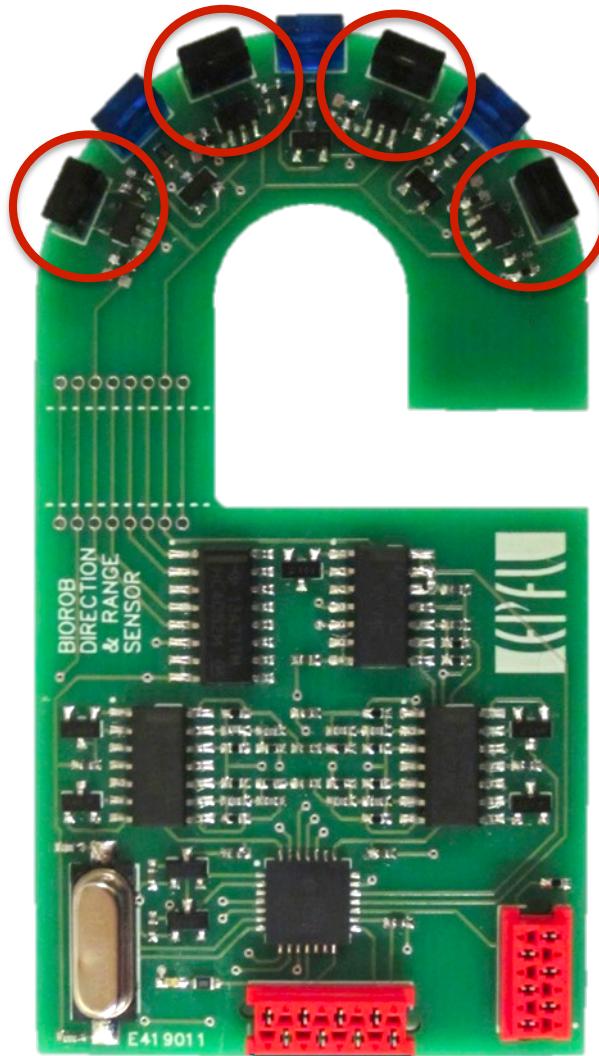
# SECOND PROTOTYPE



# SECOND PROTOTYPE

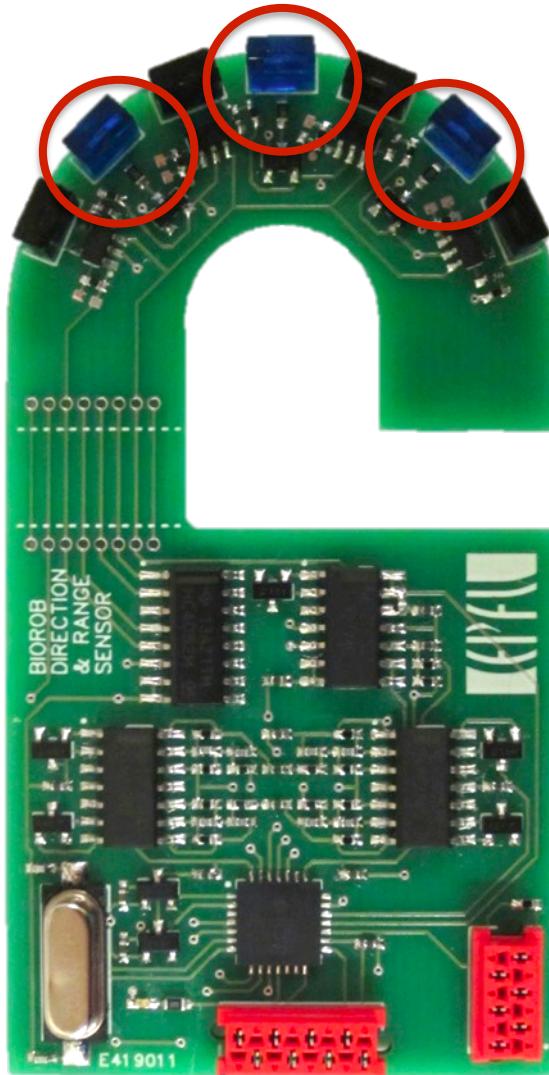


# SECOND PROTOTYPE



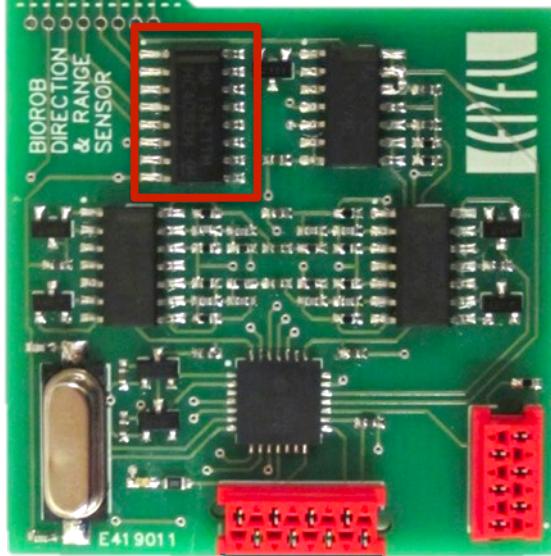
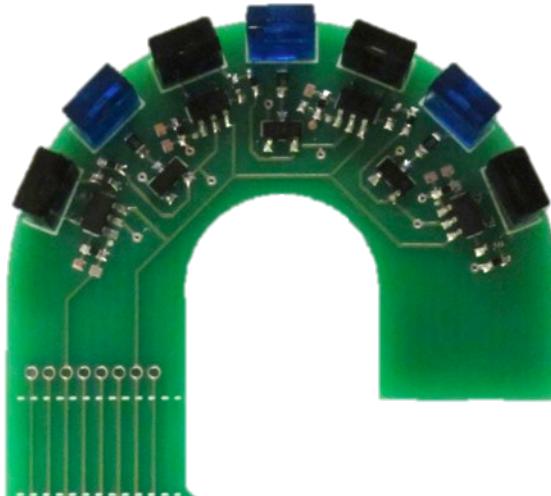
- Detector array

# SECOND PROTOTYPE



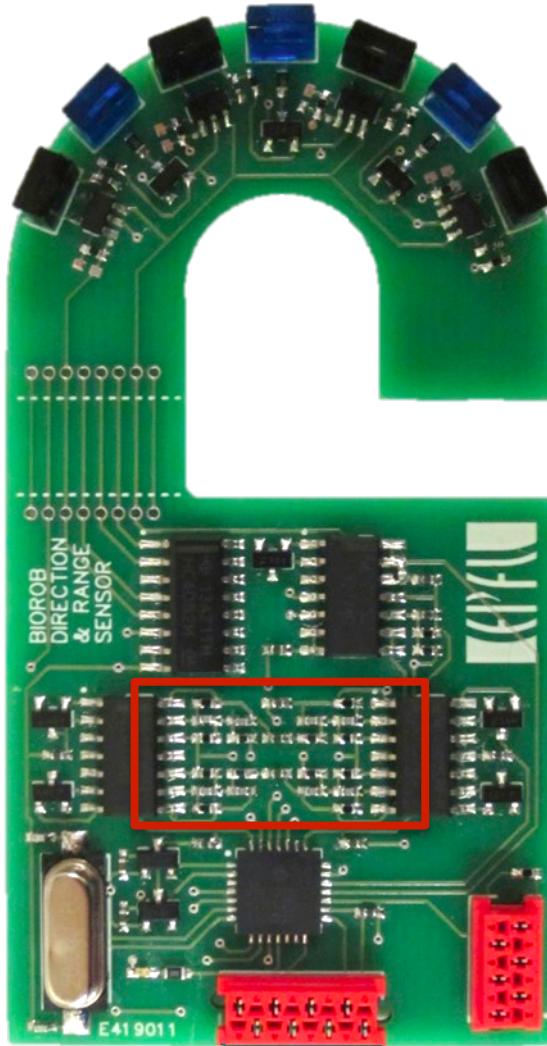
- Detector array
- Transmitter array

# SECOND PROTOTYPE



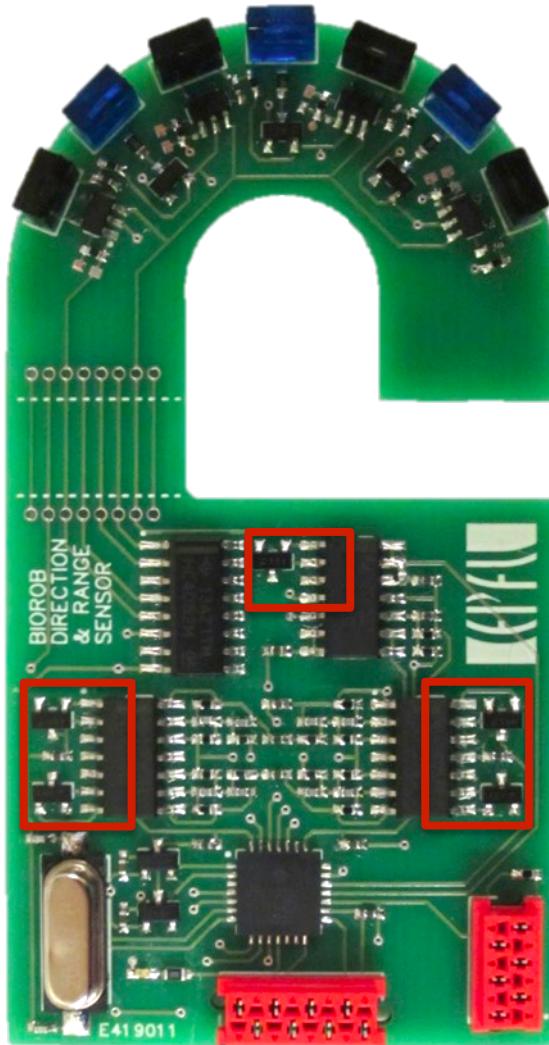
- Detector array
- Transmitter array
- Analog multiplexer

# SECOND PROTOTYPE



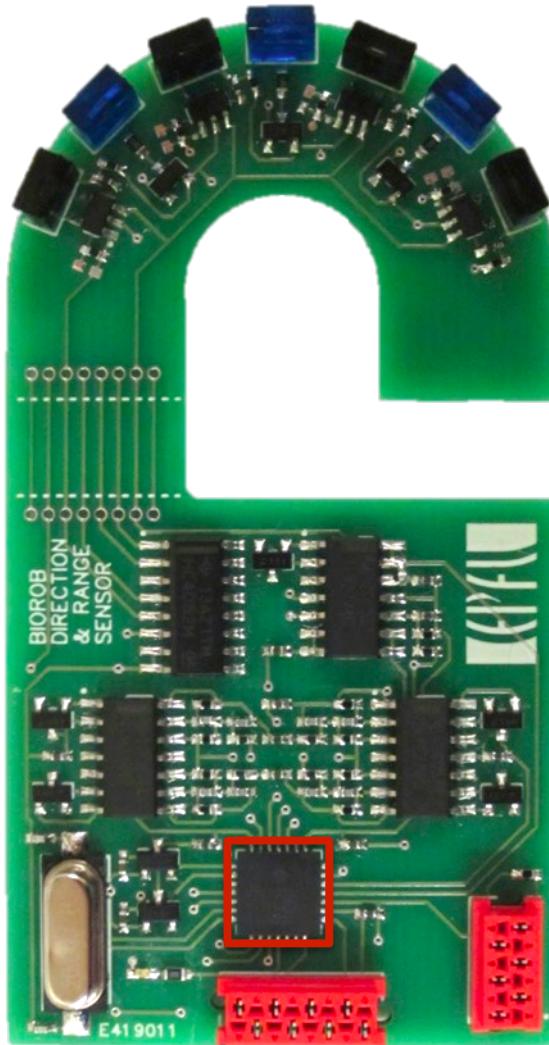
- Detector array
- Transmitter array
- Analog multiplexer
- Cascaded 10 kHz filters

# SECOND PROTOTYPE



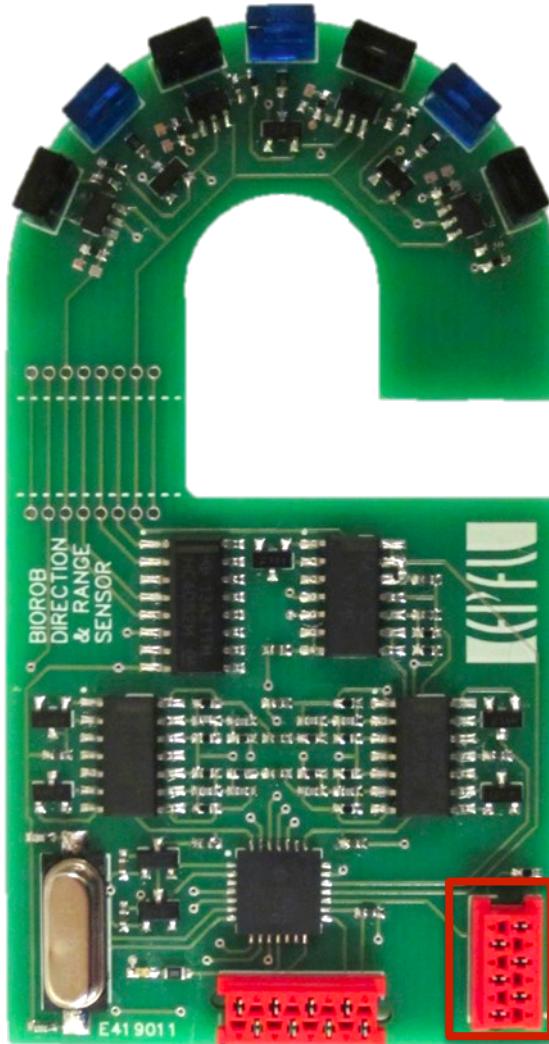
- Detector array
- Transmitter array
- Analog multiplexer
- Cascaded 10 kHz filters
- Peak detectors

# SECOND PROTOTYPE



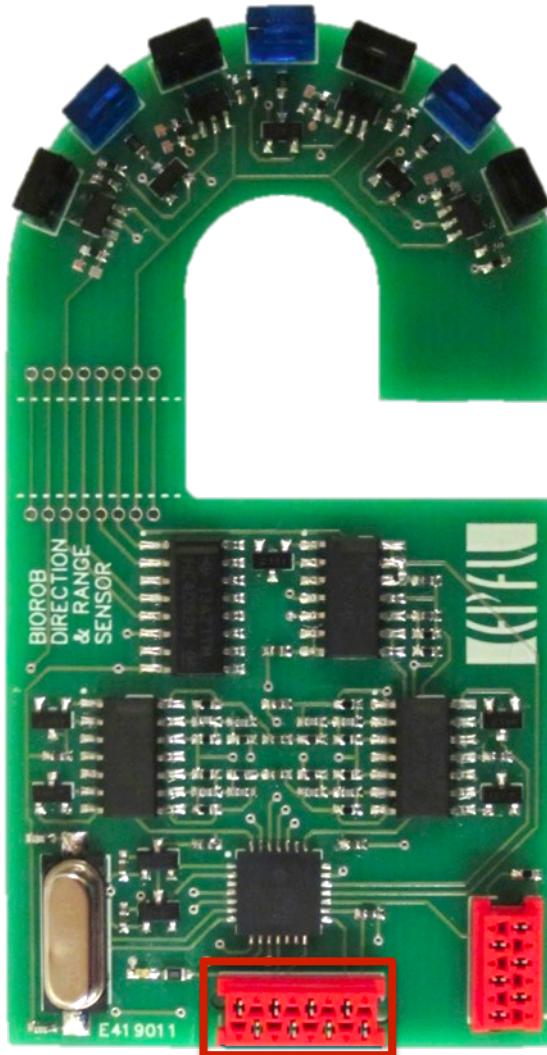
- Detector array
- Transmitter array
- Analog multiplexer
- Cascaded 10 kHz filters
- Peak detectors
- Microcontroller

# SECOND PROTOTYPE



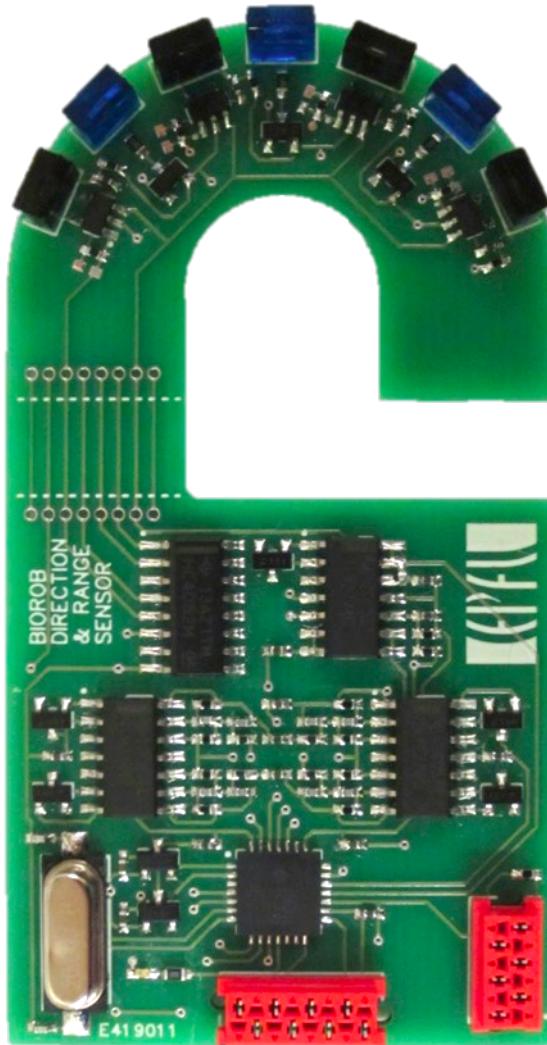
- Detector array
- Transmitter array
- Analog multiplexer
- Cascaded 10 kHz filters
- Peak detectors
- Microcontroller
- Programming port

# SECOND PROTOTYPE



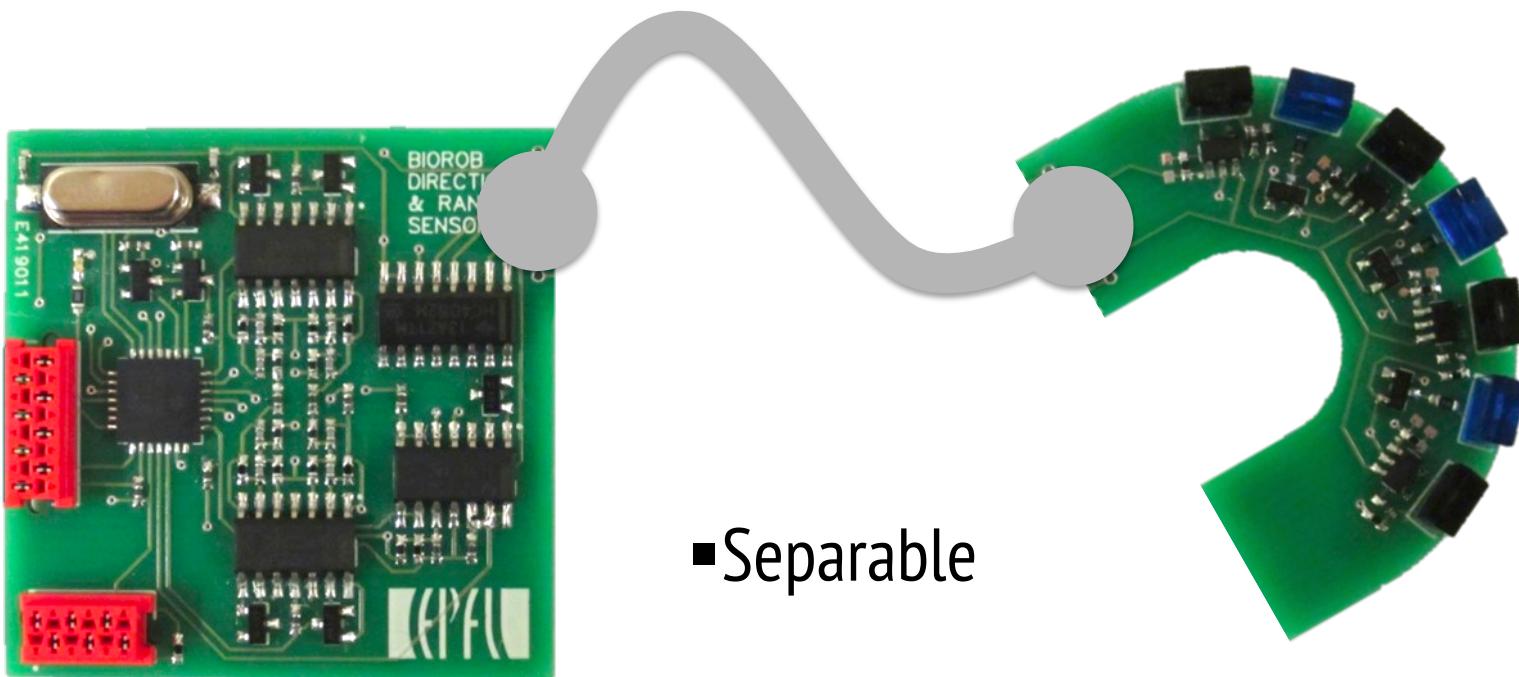
- Detector array
- Transmitter array
- Analog multiplexer
- Cascaded 10 kHz filters
- Peak detectors
- Microcontroller
- Programming port
- Interface port

# SECOND PROTOTYPE



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

# SECOND PROTOTYPE

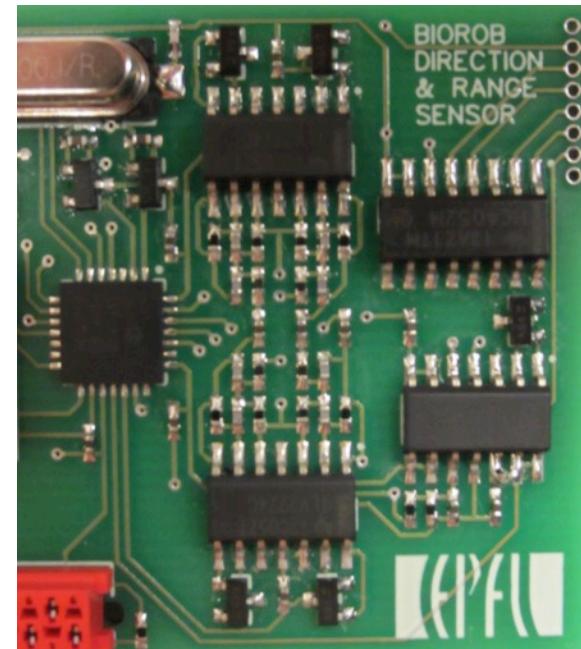
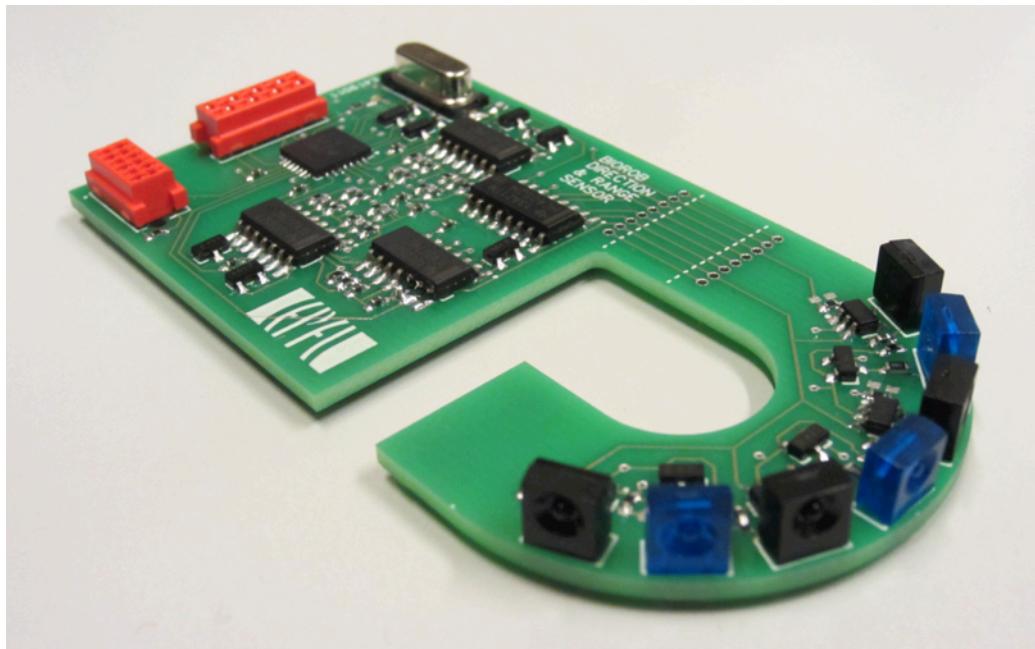


- Separable

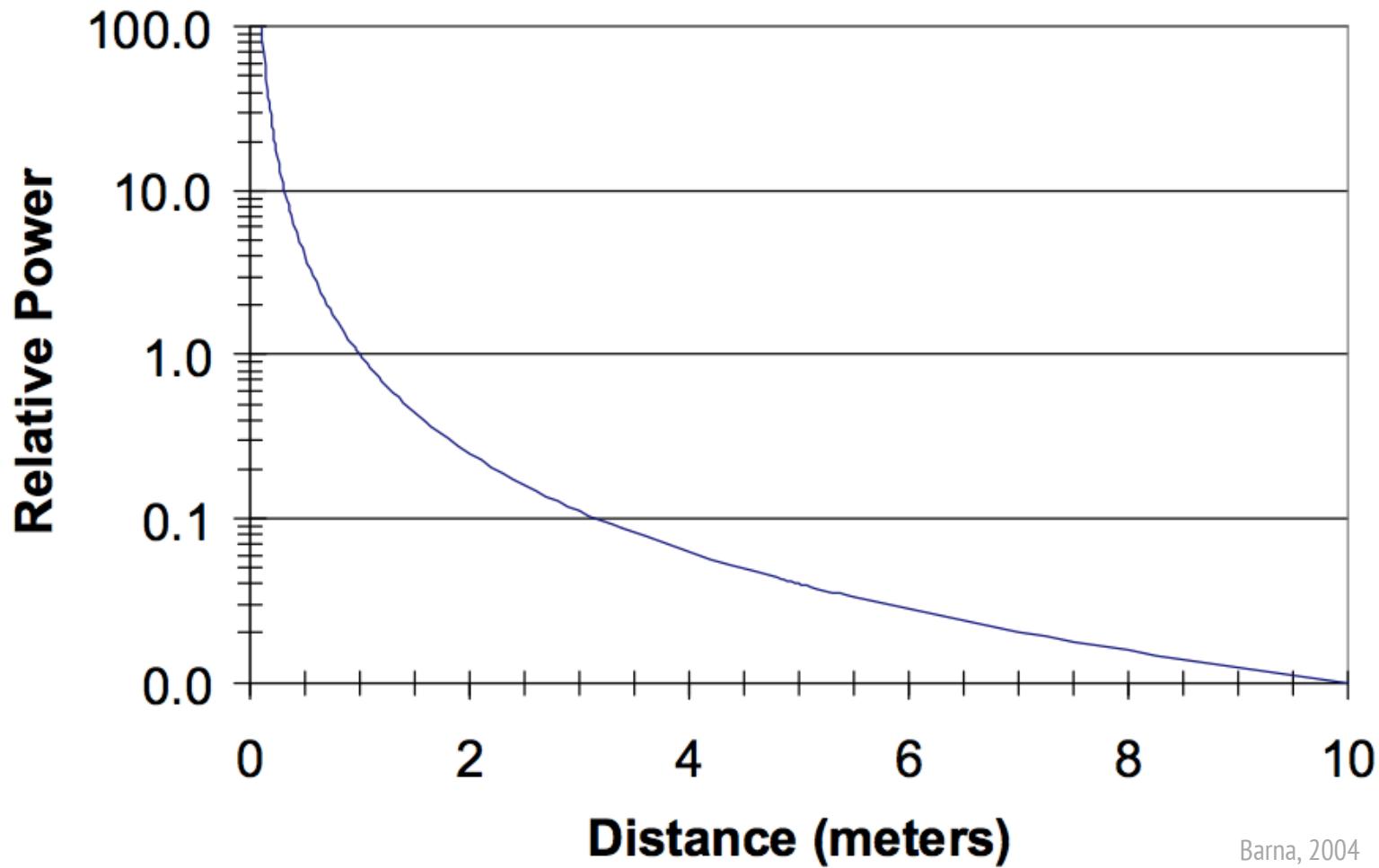
# SECOND PROTOTYPE



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



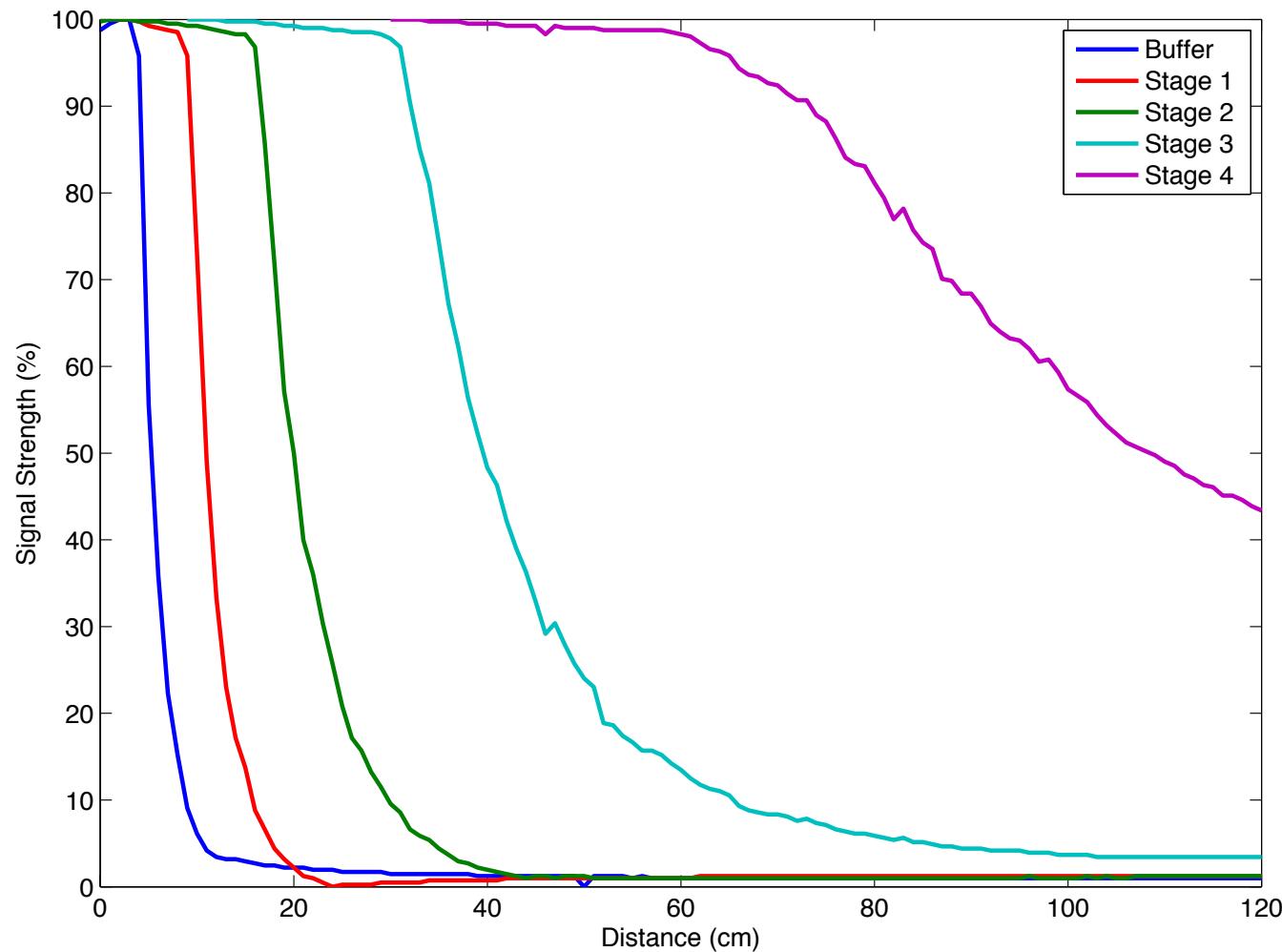
# DISTANCE



Barna, 2004

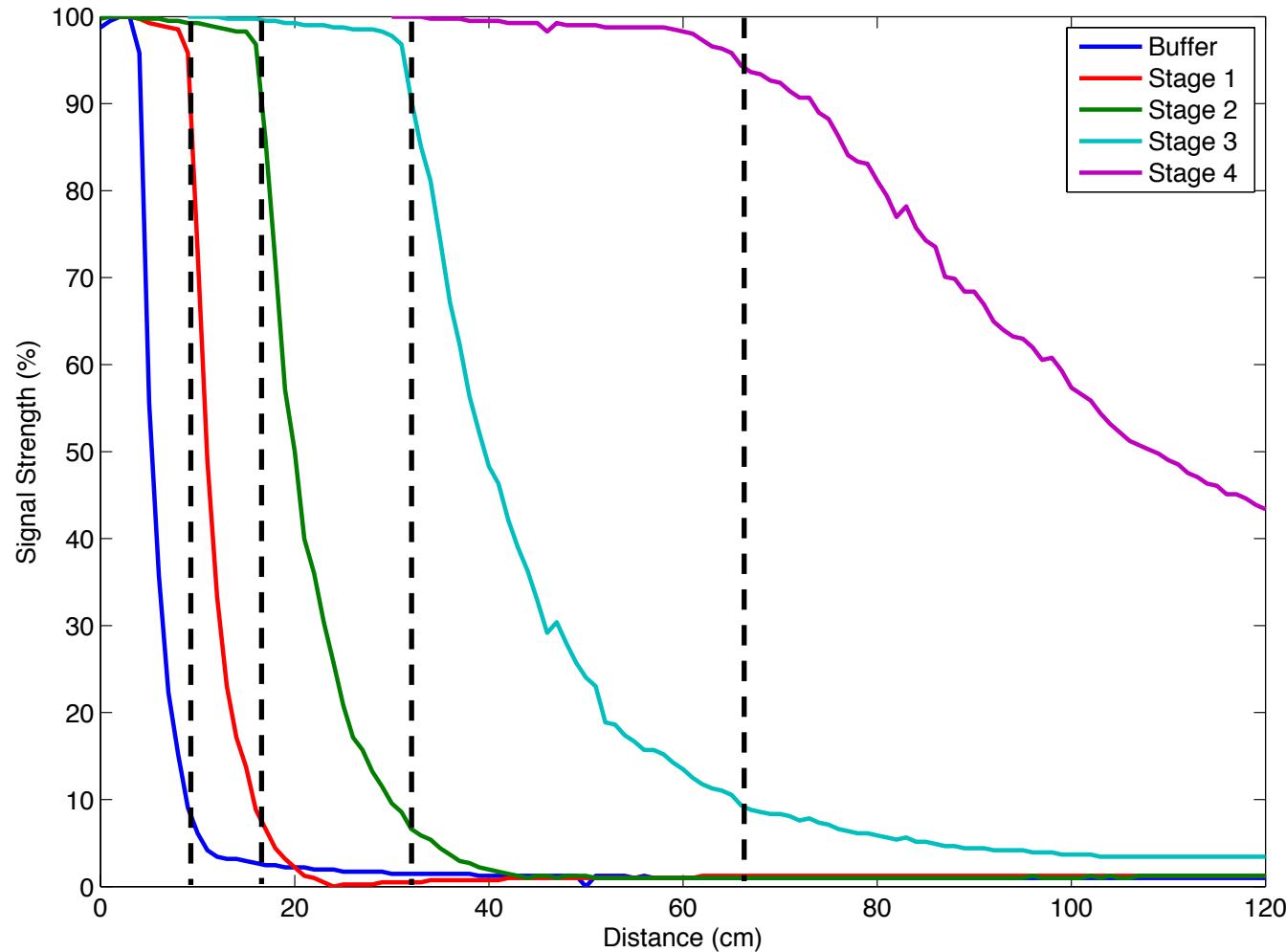
# DISTANCE

using low power transmitter



# DISTANCE

using low power transmitter

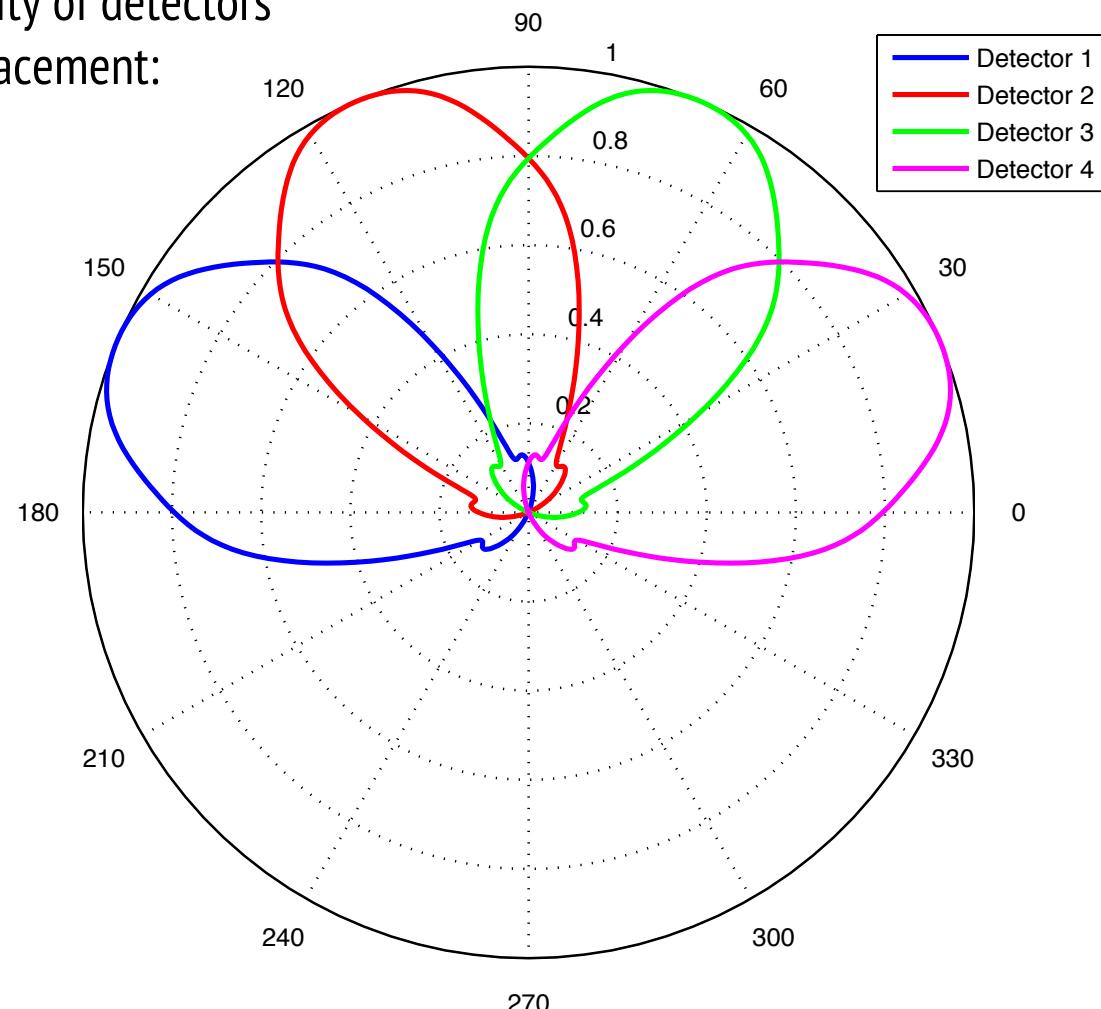


Note that the Buffer signal is noisier

# ANGLE DETERMINATION



Relative sensitivity of detectors  
vs. angular displacement:



# ANGLE DETERMINATION

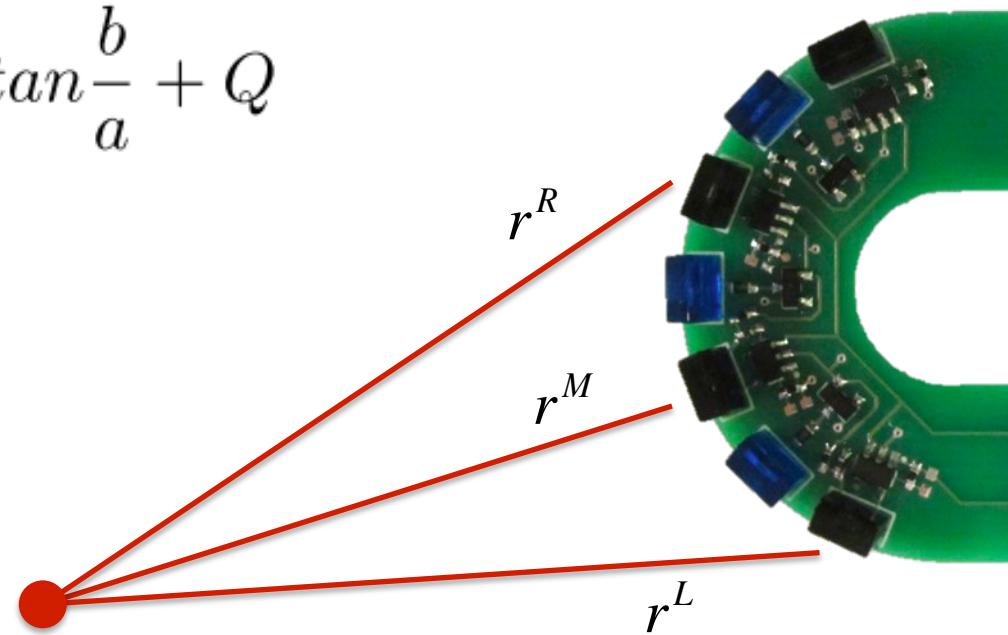


- If we assume that the angular sensitivity profile is given by  $r' = r \cdot \cos(\theta)$ , we can compute the following solution:

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

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

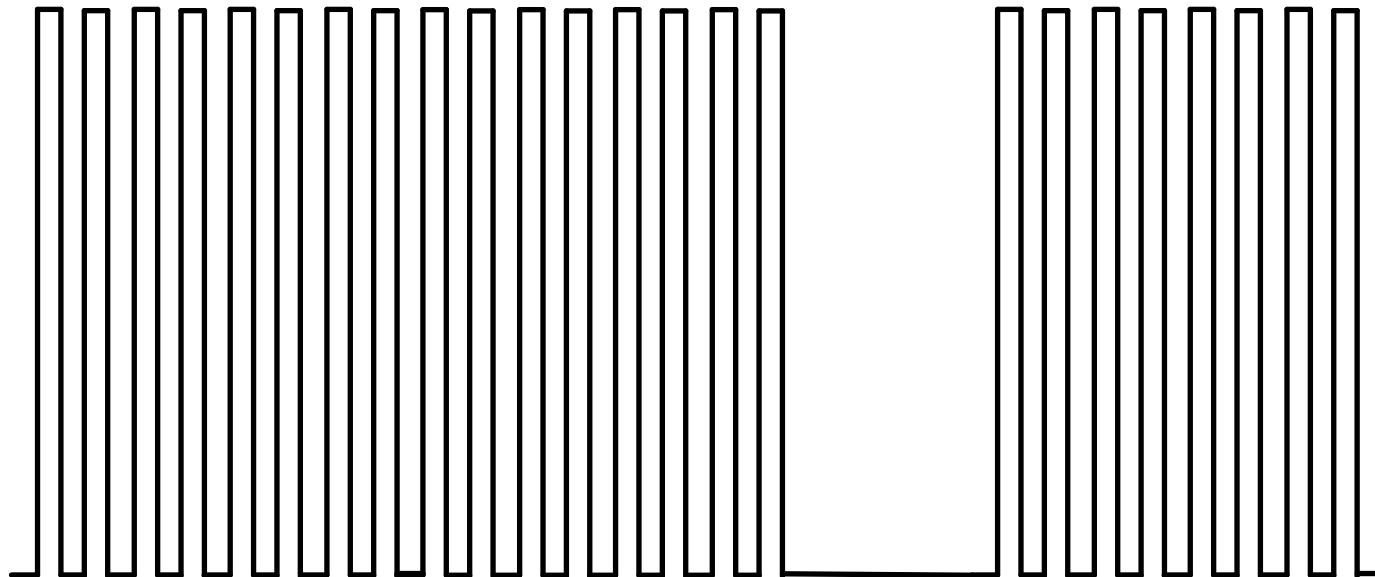
$$b = \frac{r^L - r^R}{2.\sin(\frac{\pi}{4})}$$



# DATA TRANSMISSION



- Pulse width modulation
  - very low data rate



# FUTURE WORK



- Integrate into salamander
- High power transmitter
- Efficient firmware

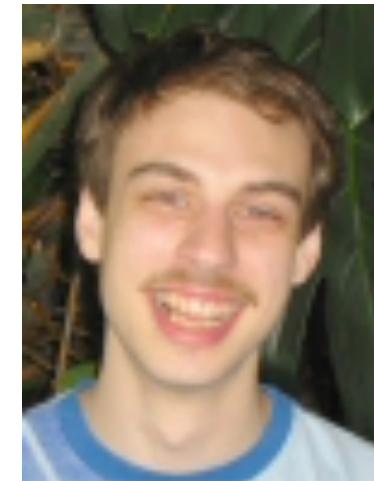


Photograph by A. Herzog

# THANK YOU



- Auke Jan Ijspeert
- Alessandro Crespi



# QUESTIONS

