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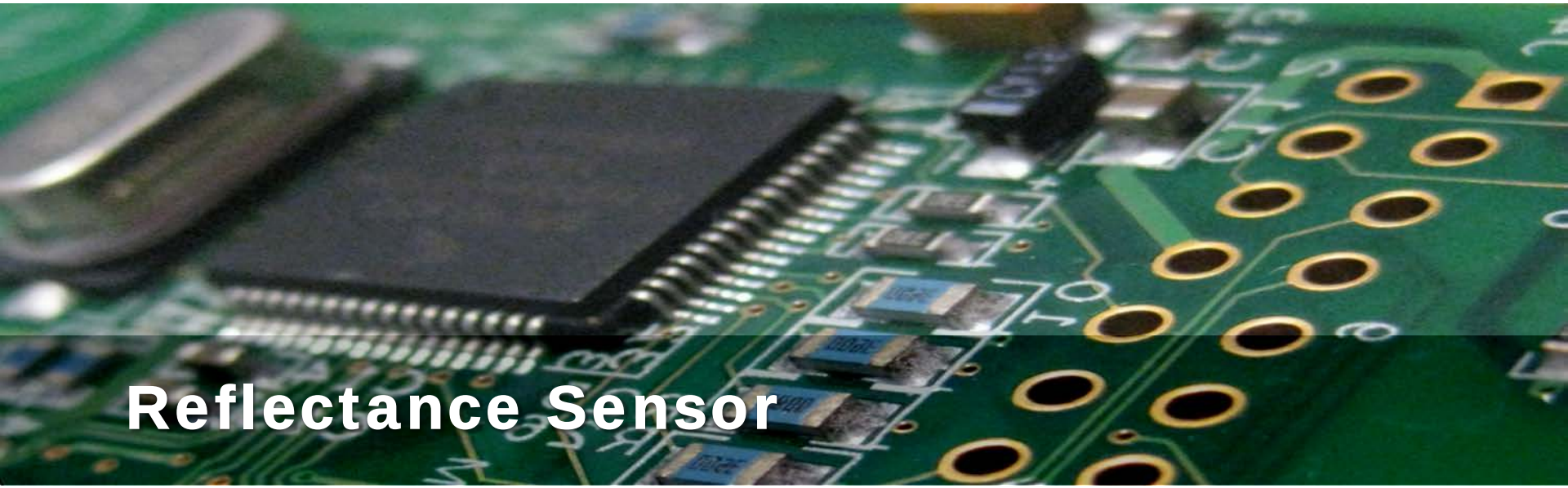

Reflectance Sensor

“Let's find that shiny place…”

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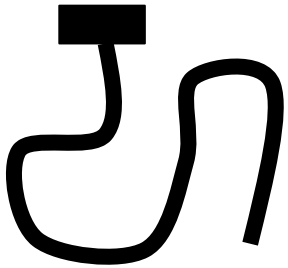
Line Following

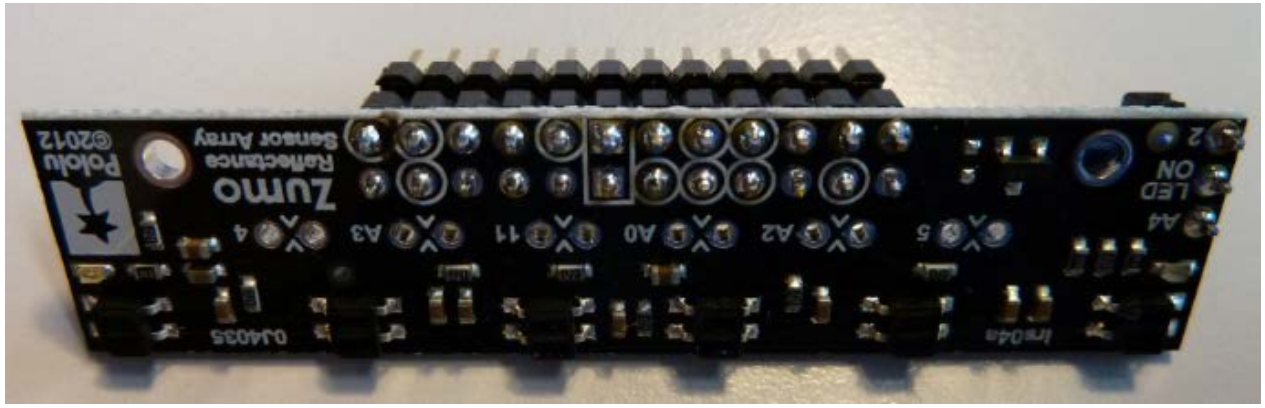
- Line Sensor: «what is my position on the line»
  - IR Reflectance Sensor
- Motors: «Move the robot»
  - Motor signals, H-Bridge
- Follow the Line: «stay on the line»
  - Closed Loop Control, PID
- Driving and Turning: «Turn left 90°»
  - Quadrature Sensor
  - Speed/Position estimation
- Wireless Control: «Move forward»
  - Radio Transceiver
  - Network stack



Learning Goals

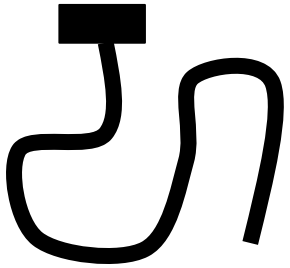
- Goal:
  - Differentiate between 'black' and 'white'
  - Line Position for PID
  - ‘Goal’ area detection

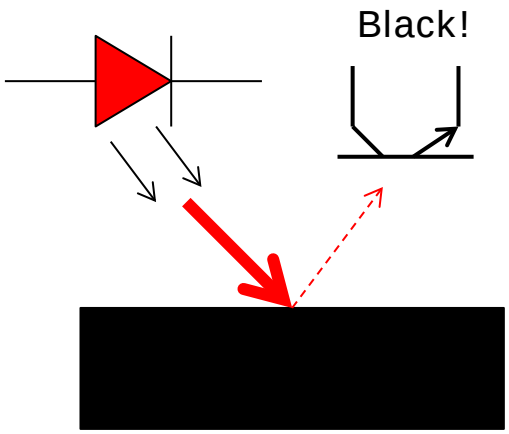
- Reflectance Sensor
- Capacitive Discharge
- Calibration/Normalization
- Black Line Detection

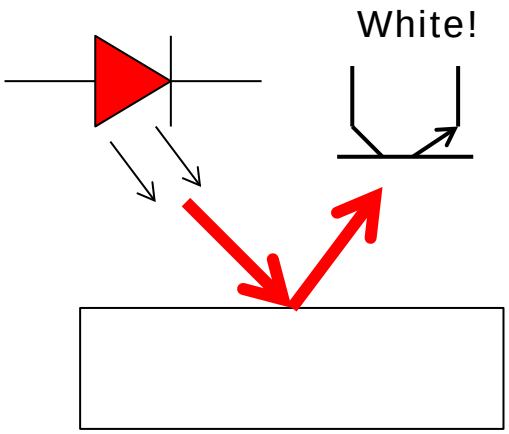


Sensing the Border (Line)

- Need to sense black lines
- Difference between 'black' and 'white'
- Really: low/high IR Reflectance!
- Idea
  - Measure reflectance of floor
  - IR LED with Phototransistor

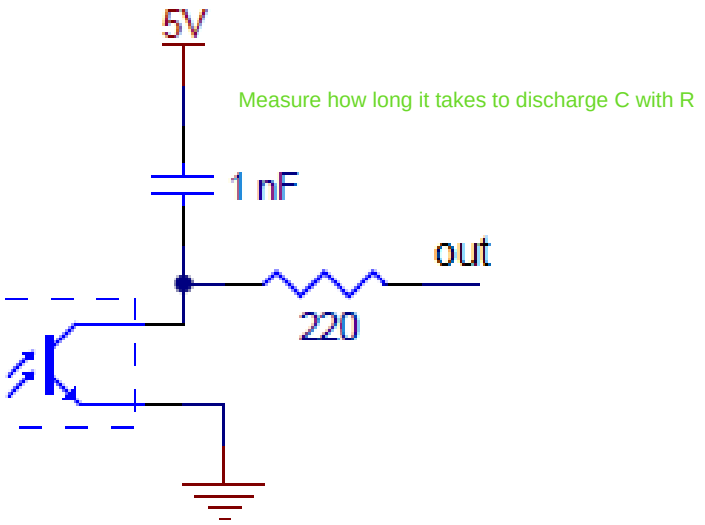






QTR Reflectance Sensor

- Analog or digital?
- Phototransistor with capacitor discharge circuit
- Shorter discharge ➔ more light (greater reflection)
- Measure discharge time with digital I/O pin



Source: Pololu.com

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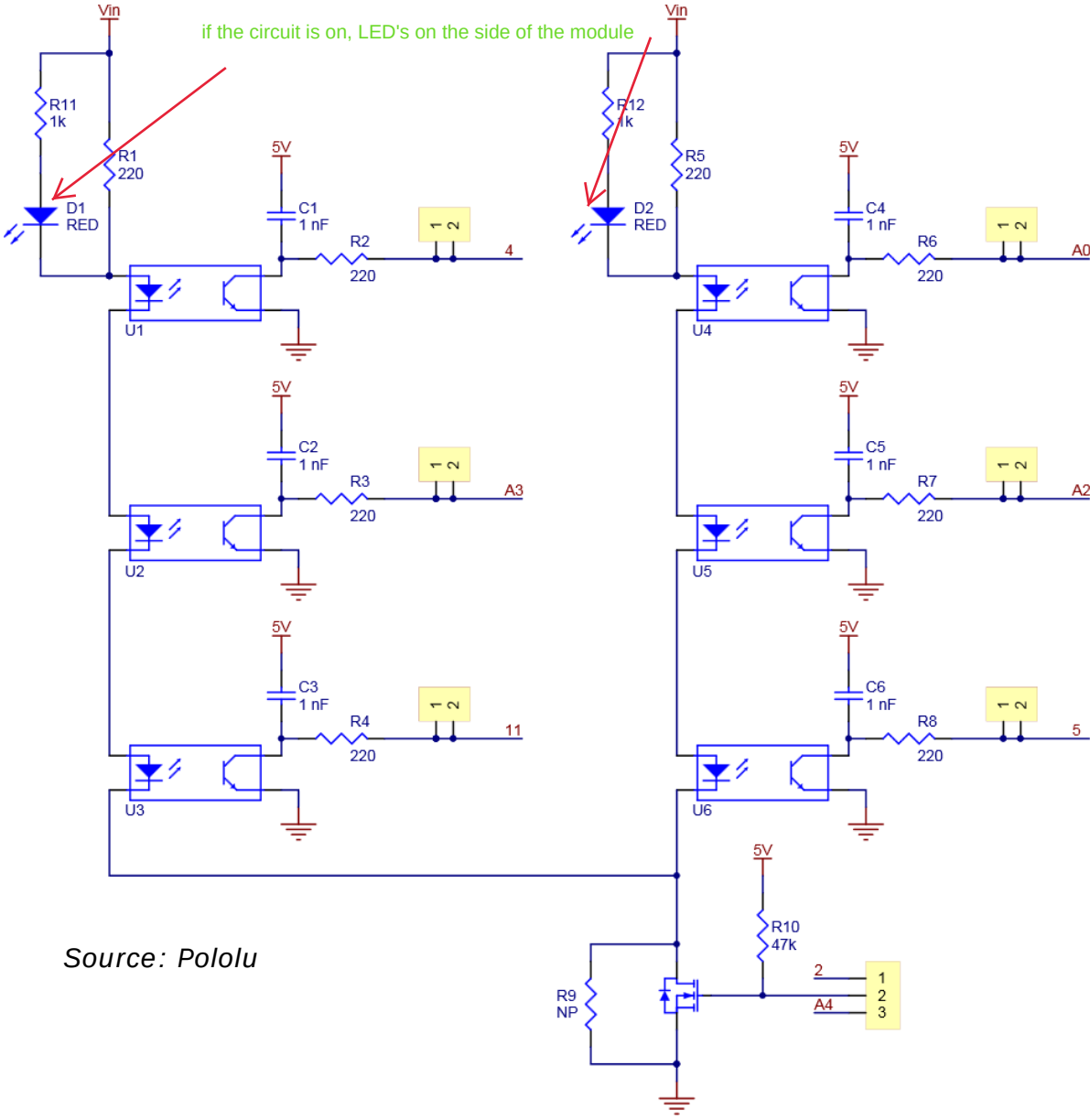
Zumo Reflectance Array

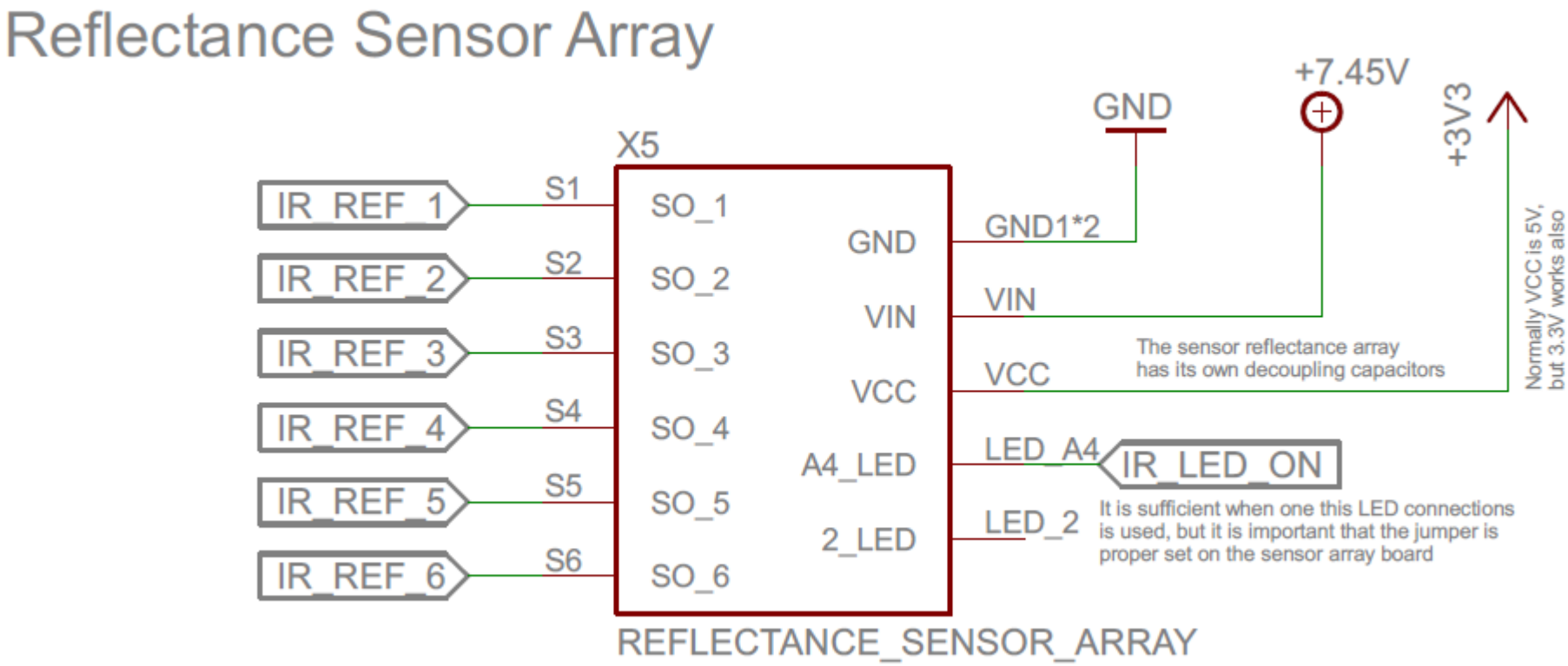
- 5V ➔ 3.3V!
- 2 Red LED's
- 2x3 Series IR LED's
- MOSFET
  - IR_LED_ON
  - ~40 mA



Source: Pololu

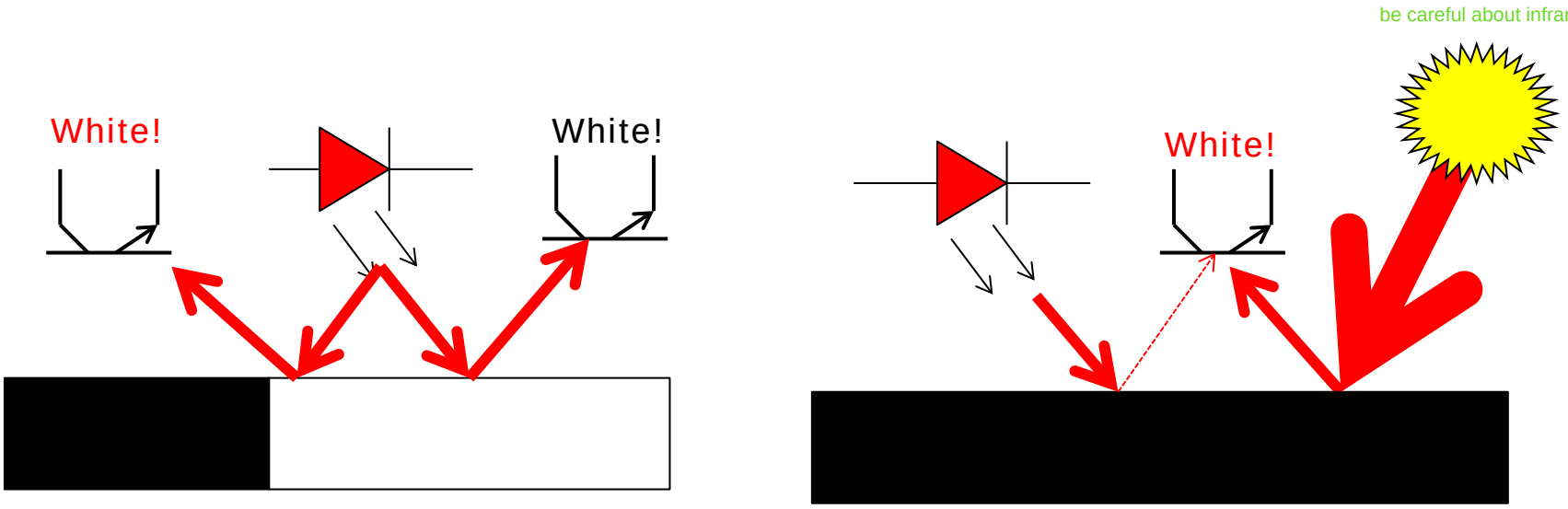
Reflectance Sensor Connector

- IR_LED_ON to turn on FET/Transistor



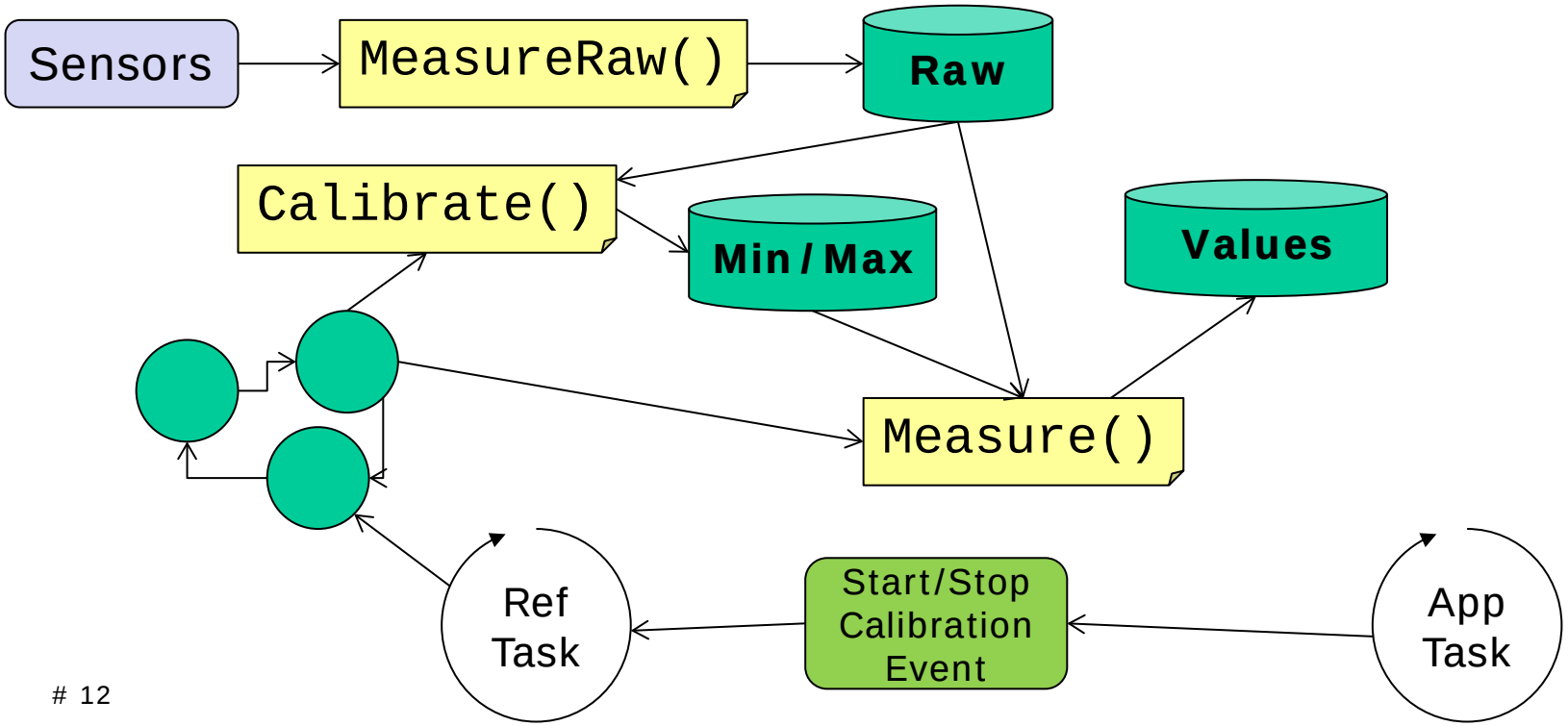
Problems

- Reflections to other sensors/crosstalk
- 'External' Ambient Light
- Distance to ground
- 'Shielding'



Reflectance Control and Data Flow

- External calibration start/stop (e.g. push button)
- Calibration: raw min/max values scaled to 0-1000
- Reference Task processes state machine
- But: do not create too many tasks!

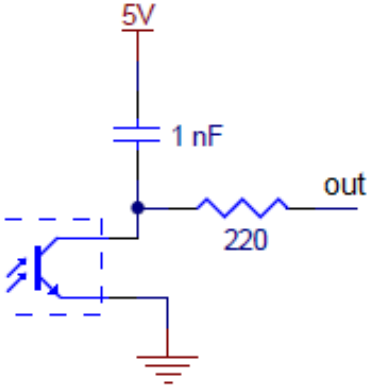


Raw Sensor Value Acquisition

- Turn IR LED on with the FET
- Wait ~200 µs needs some time until they're on
- For all sensors
  - I/O pin as output
  - Set it to HIGH
- ~20-50 µs charge time
- Start/Reset time counter
- Set all pins as I/O change the pins as input pins
- Measure time pin gets LOW
- Turn IR LED off

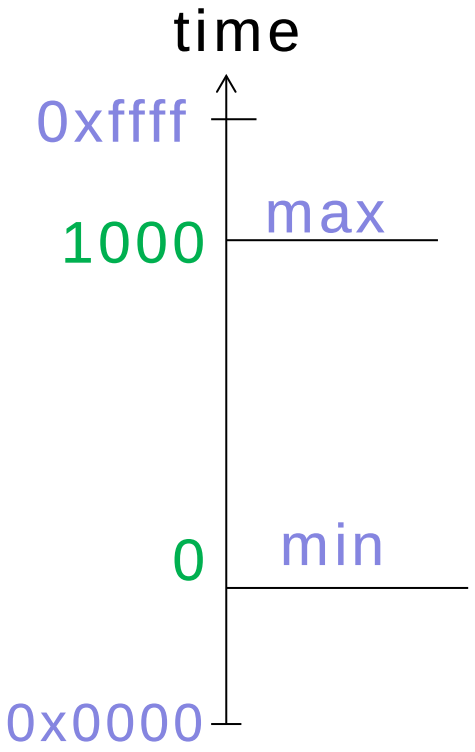
we can't allow context switch! because the measurement can't be interrupted

Source: Pololu.com



Min / Max and Value Scaling

- Values scaled to 0-1000
- Offset compensation
- Normalized Sensor values
- Overflow prevention (16bit)
- Interested in 'dark/white', not in the exact gray value

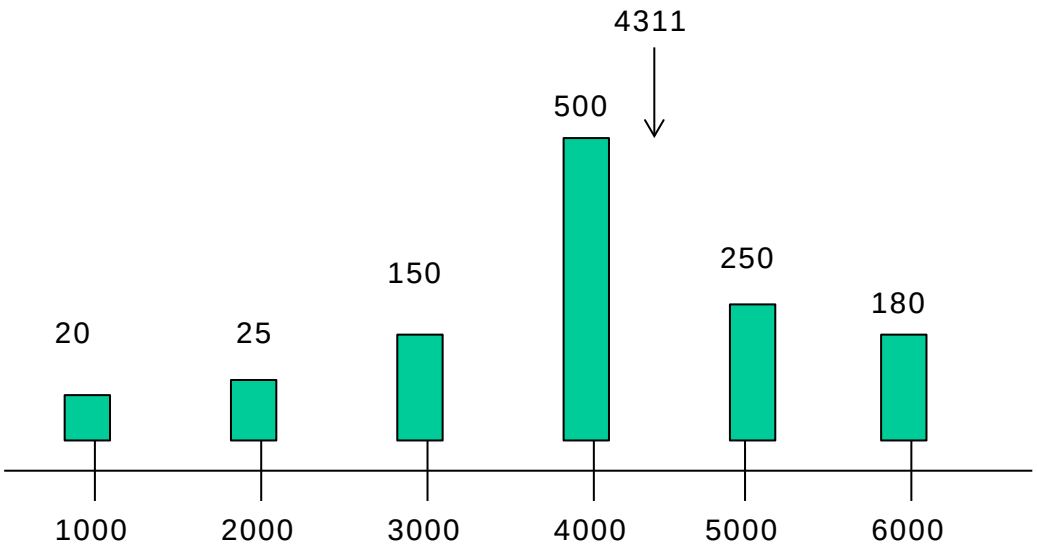


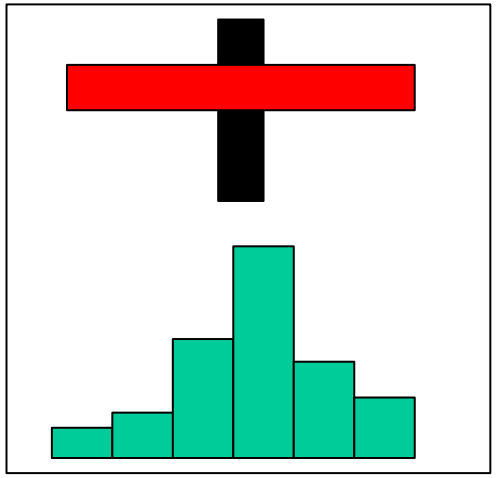

```
raw val     : 0x00CF 0x0092 0x02FD 0x085A 0x00B6 0x00A3
min val     : 0x00A4 0x007A 0x007E 0x009B 0x0087 0x0089
max val     : 0xD22B 0x08B6 0x081B 0x0A9F 0x08D0 0x0AFB
calib val   : 0x0000 0x000B 0x014C 0x0314 0x0012 0x0005
```

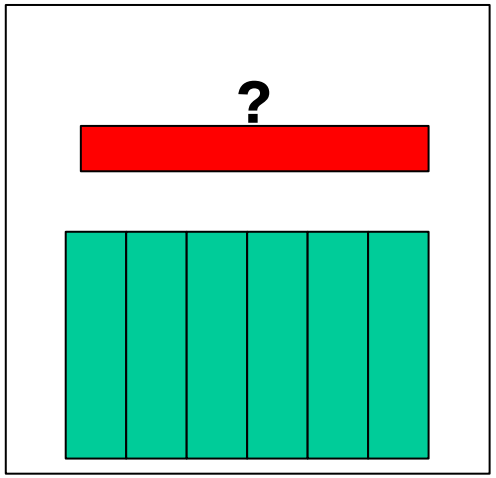
Line Position Algorithm

- White line: inverted 'black'
- Weighted value to represent 'line' position
- Val = SUM(S_i * i*1000) / SUM(S_i))

$$\frac{20*1000+25*2000+...180*6000}{20+25+150+500+250+180}$$



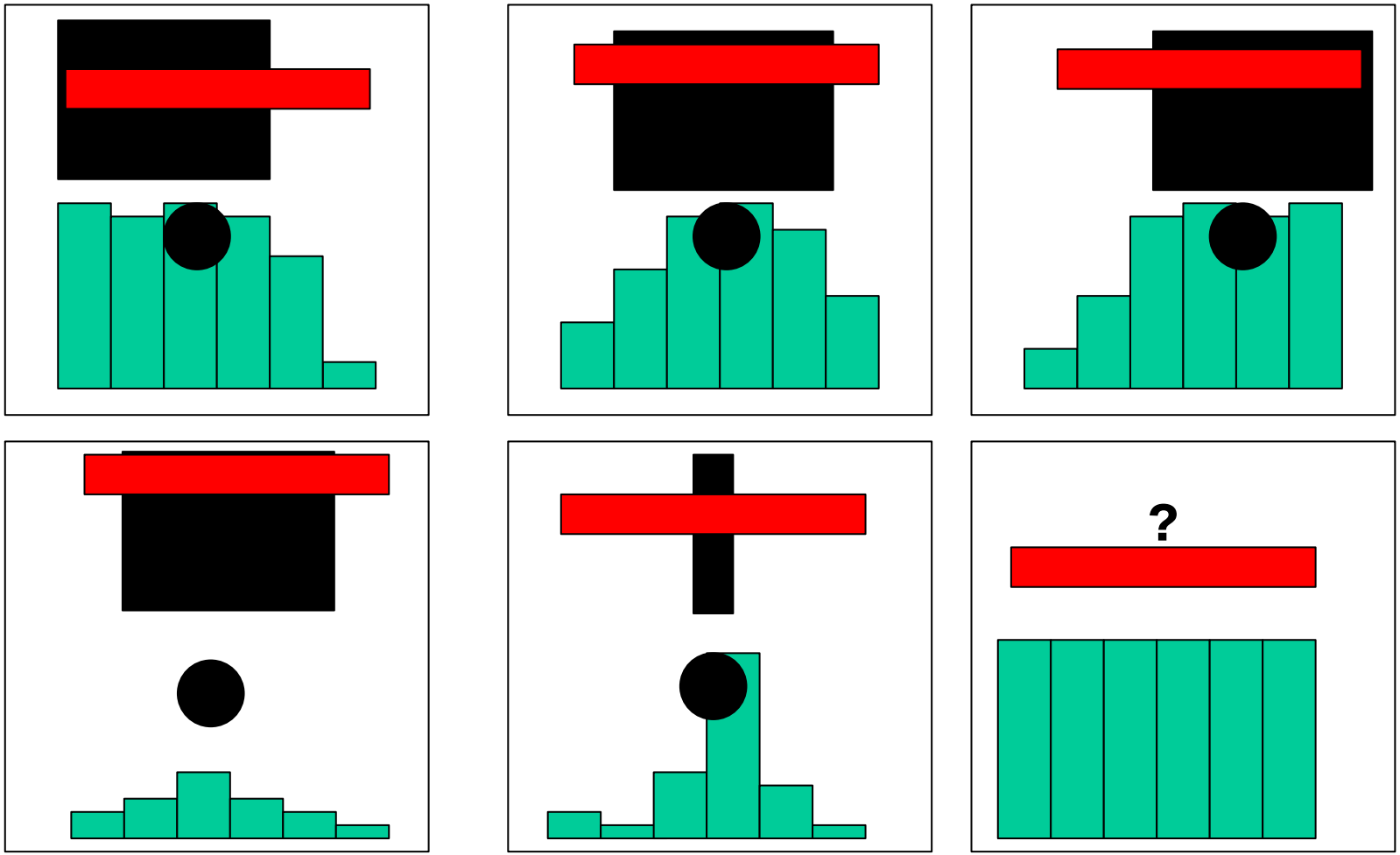




das vorgegebene Papier reflektiert auch Infrarotstrahlen!

Sensor Patterns

- Black 'Line' Detection

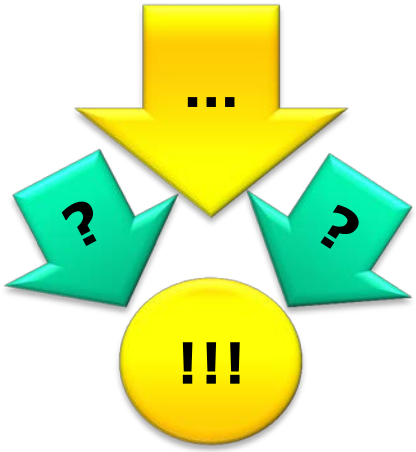


Implementation Consideration

- RTOS Task or Process() function for Sensor?
  - Task overhead (stack), but can be blocking
  - Function: non-blocking, frequently called
  - Periodic sampling vs. 'on demand'
- Events
  - Event to start/stop calibration
  - Event(s) for end of line?
- Application and Data?
  - Interruption (task?) during measurement?
  - Timeout during measurement? context switch during measurement? probably no!
  - What kind of data is needed for the Robot application?
  - State machine in main application loop
  - Drive forward and do not fall from the table ☺

Summary

- Line detection
- Capacitive Discharge
  - IR LED
  - Photo Transistor
- Timing
- Raw values
- Scaled/normalized values
- Line position calculation



Lab Task

- Integrate
  - Reflectance.c
  - Reflectance.h
- Reentrancy
- Timeout
- RTOS task or Process() function
- Extend
  - Ability to calibrate
    - Button?
    - Shell?