Visible Light Communication

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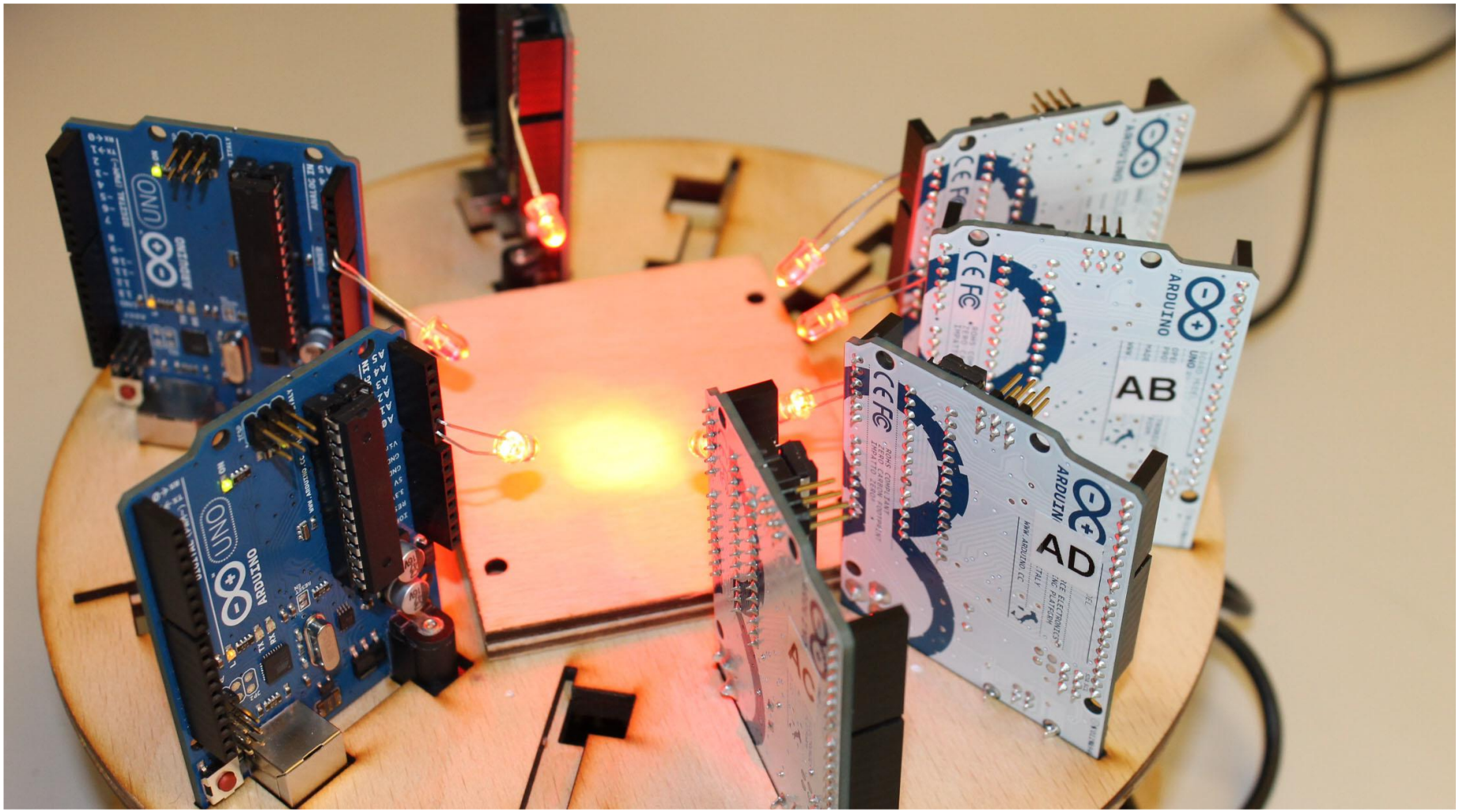
Motivation

- **Visible Light Communication**
  - Communication with visible light (380nm – 780nm)
- **Advantages**
  - No restrictions to radio bands
  - Cheap hardware
  - No known health issues
- **Disadvantages**
  - Heavy environmental noise
  - High absorption rates

Motivation – Related Work



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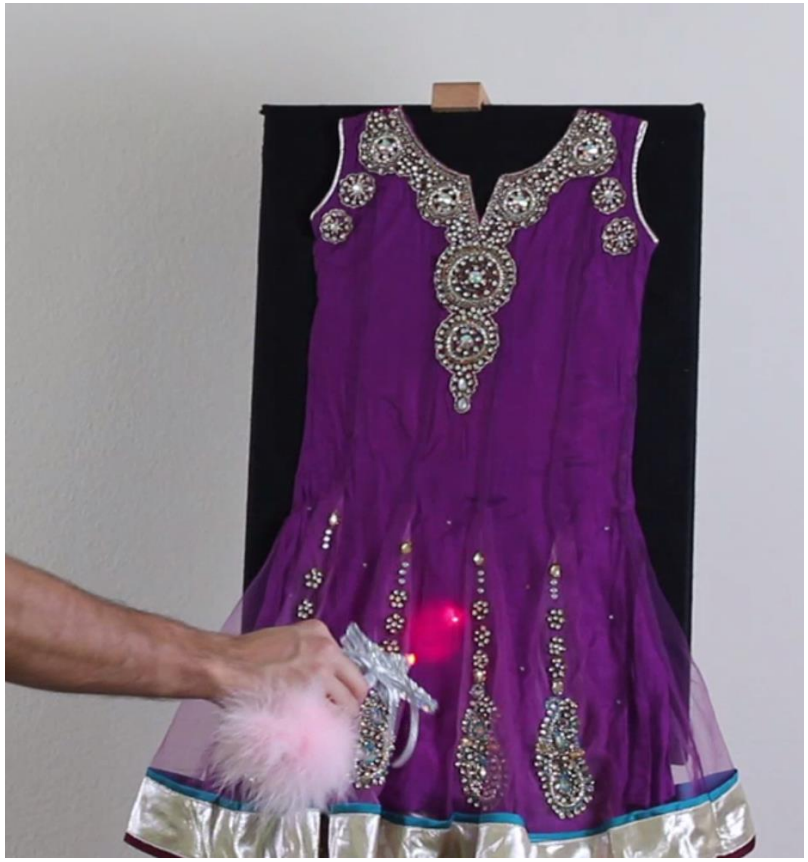
Motivation – Related Work



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Initial Goals

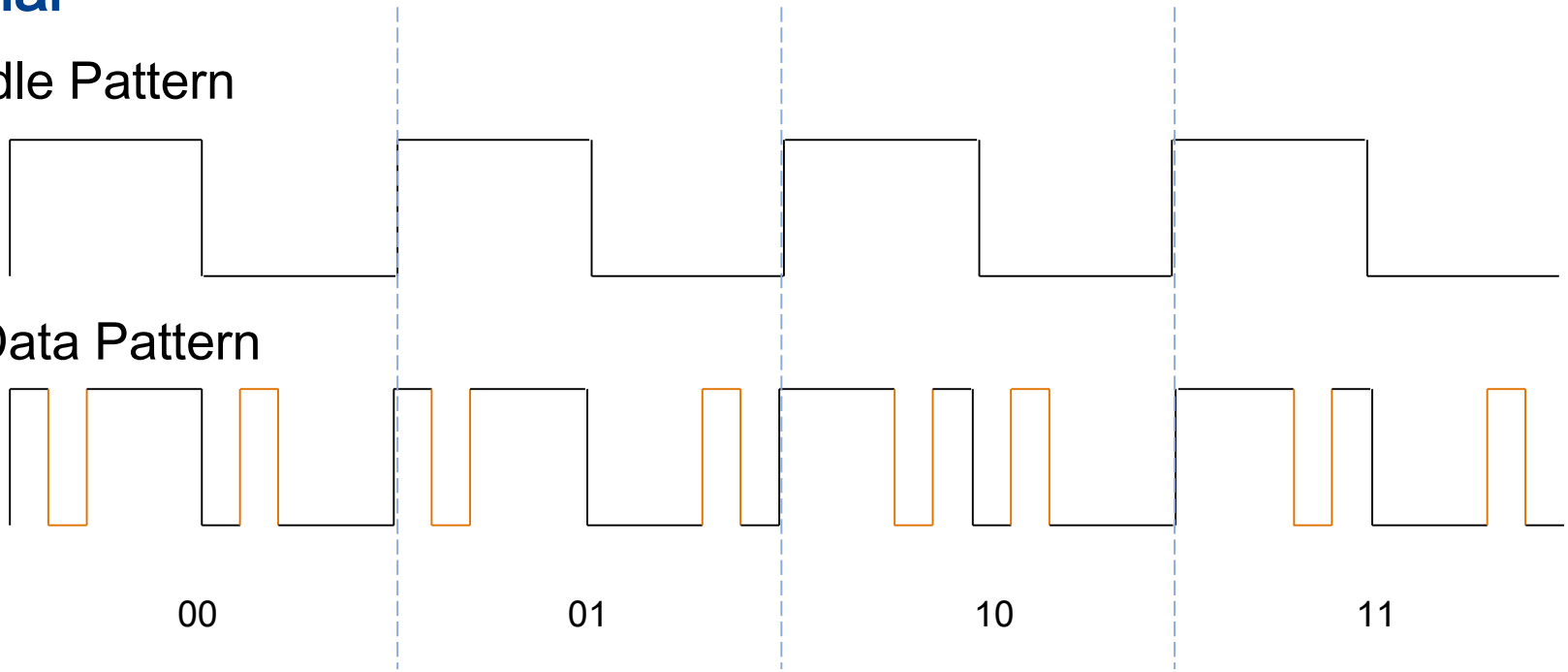
- **Basic Communication**
  - End-to-end
  - From Arduino to Arduino
  - From Smartphone to Arduino
- **Practical Use Case**
  - Possibly anything
  - Decided for moving toy train
    - Controlled by Smartphone via Bluetooth and VLC

Basic Communication

- Orientated on OSI model
- Bit layer
  - Hardware control to transceive signals
  - Responsible for sending single bits
  - Synchronization
- MAC layer
  - Error detection
  - Frame separation
  - Delivery control

Bit Layer

- **Signal**
  - Idle Pattern
  - Data Pattern



- **Equal up- and downtime**
  - Constant level of perceived brightness
- **Slower than e.g. Manchester coding**

Bit Layer - Synchronization

- **Biggest problem in our project!**
- **First variant**
  - Continuous AD conversions of the sensor input
  - Moving average to remove background noise and to detect edges
  - Analyzation of each edge on detection
  - Problems:
    - conversions caused delays
    - High number of interrupts blocked program flow
- **Final variant**
  - With hardware edge detection
  - Edge triggered interrupt
  - All edges of a period are stored and analysed afterwards

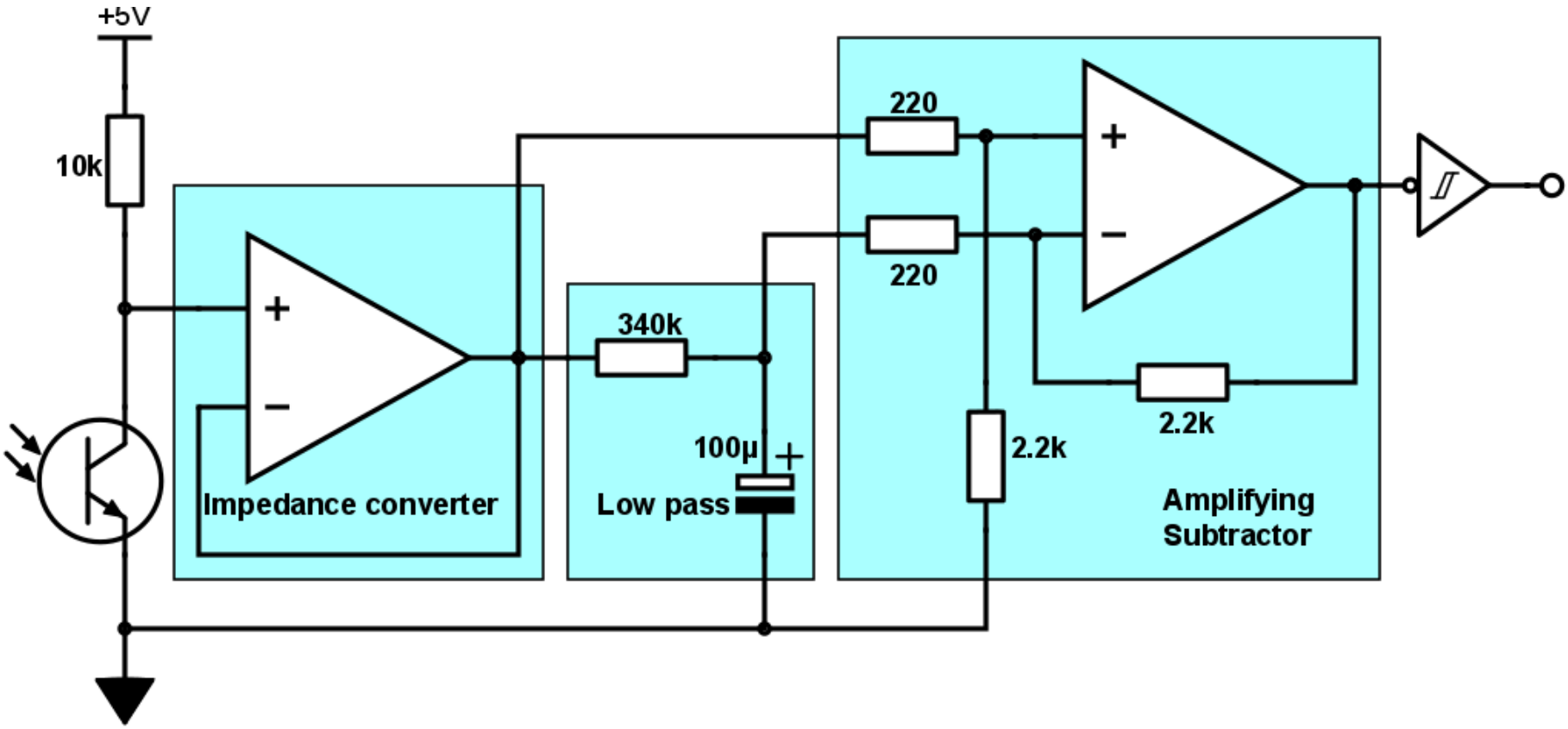
MAC Layer

16	8	8	0-248	8
0xBEEF	Flags + Length	Header CRC	Payload	Payload CRC

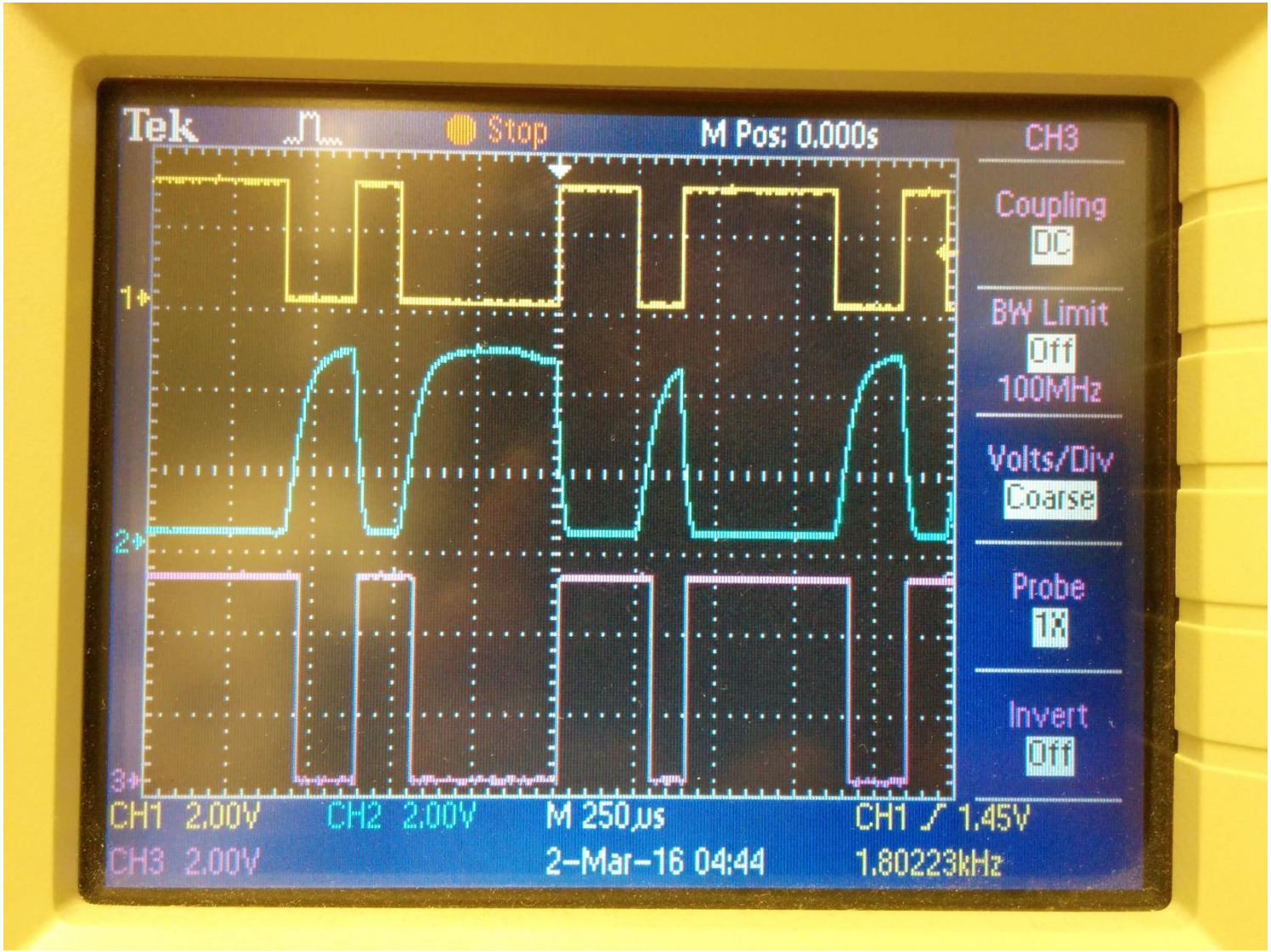
- Synchronization sequence to delimit frames
- Up to 31 byte per frame
- Header CRC to validate length

- Continuous repetition until the message is acknowledged
- Message buffer

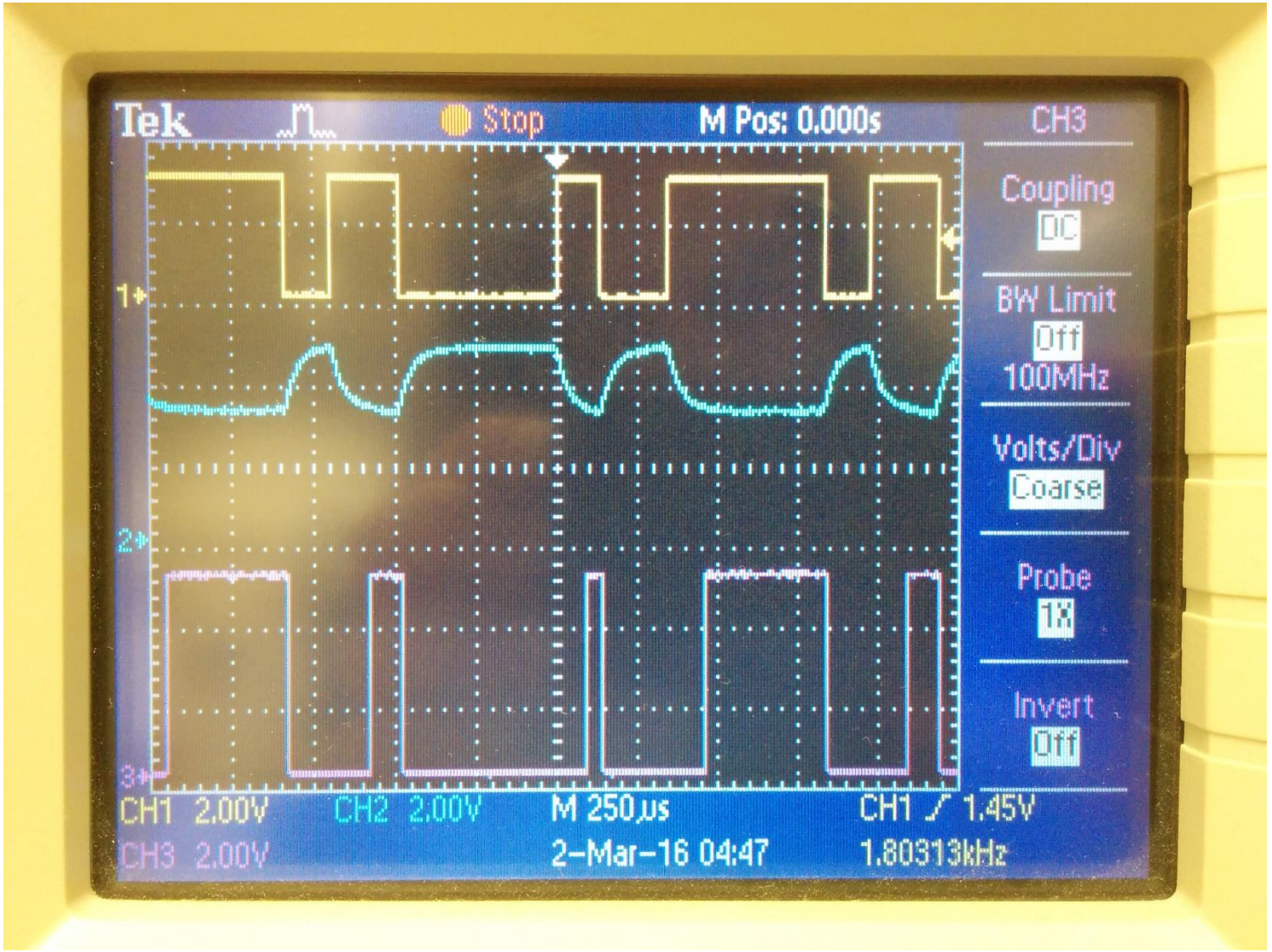
Hardware Edge Detector



Hardware Edge Detector

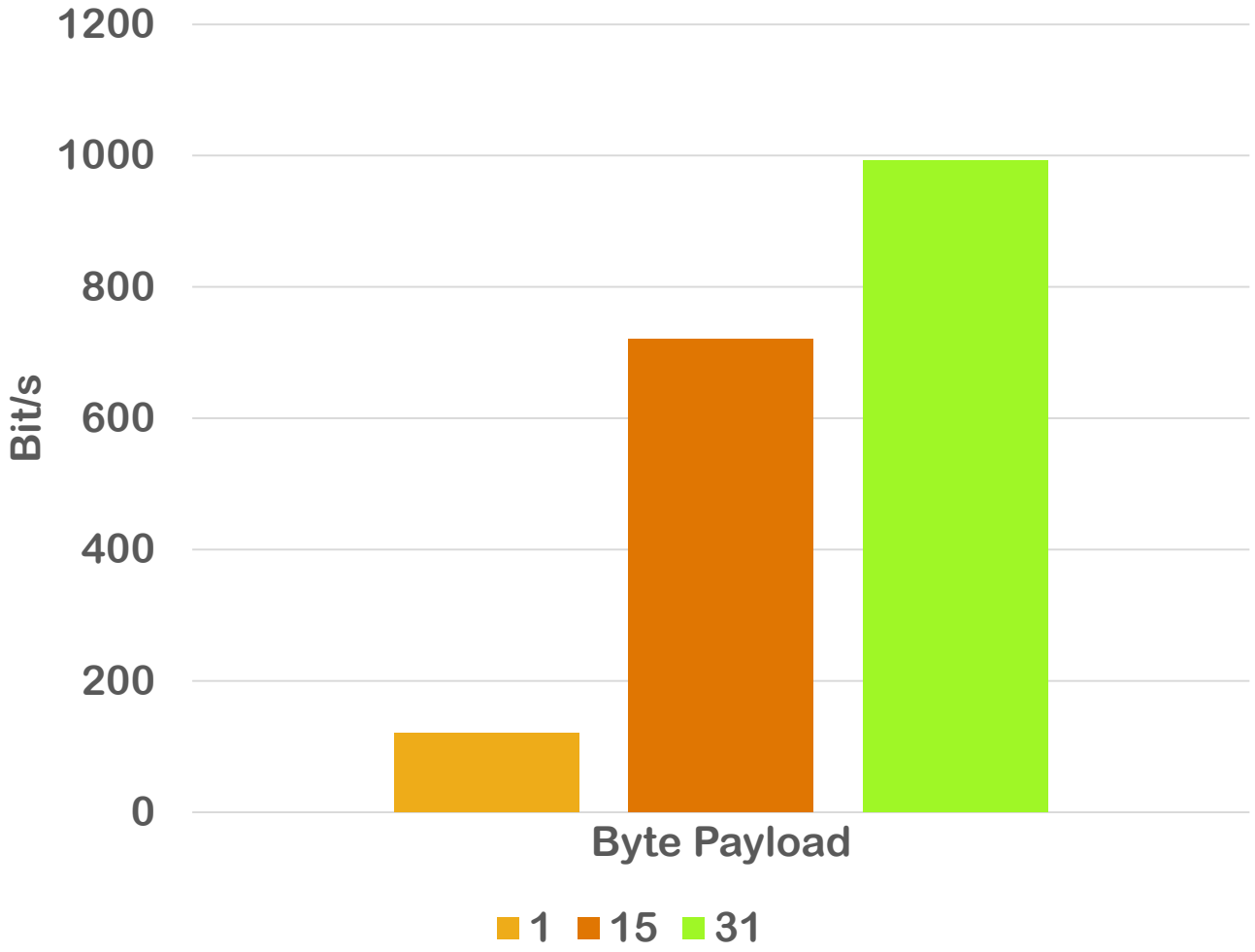


Hardware Edge Detector

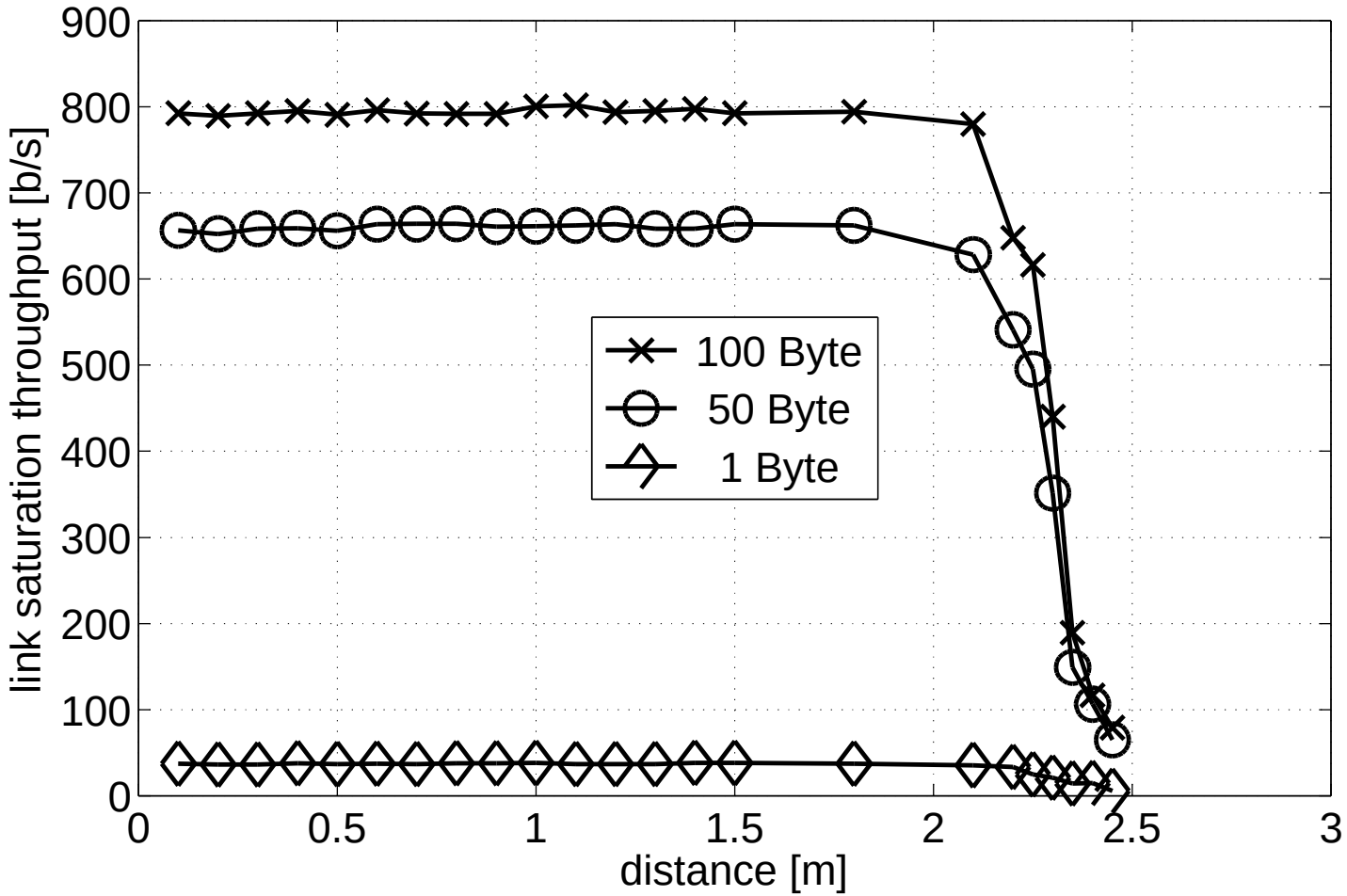


Evaluation

- Distance: 12 cm



Comparison: DisneyResearch vs. Our VLC



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Comparison: DisneyResearch vs. Our VLC

DisneyResearch

- Communication between several devices (CSMA)
- LED for sending/receiving
- Continuous AD conversion

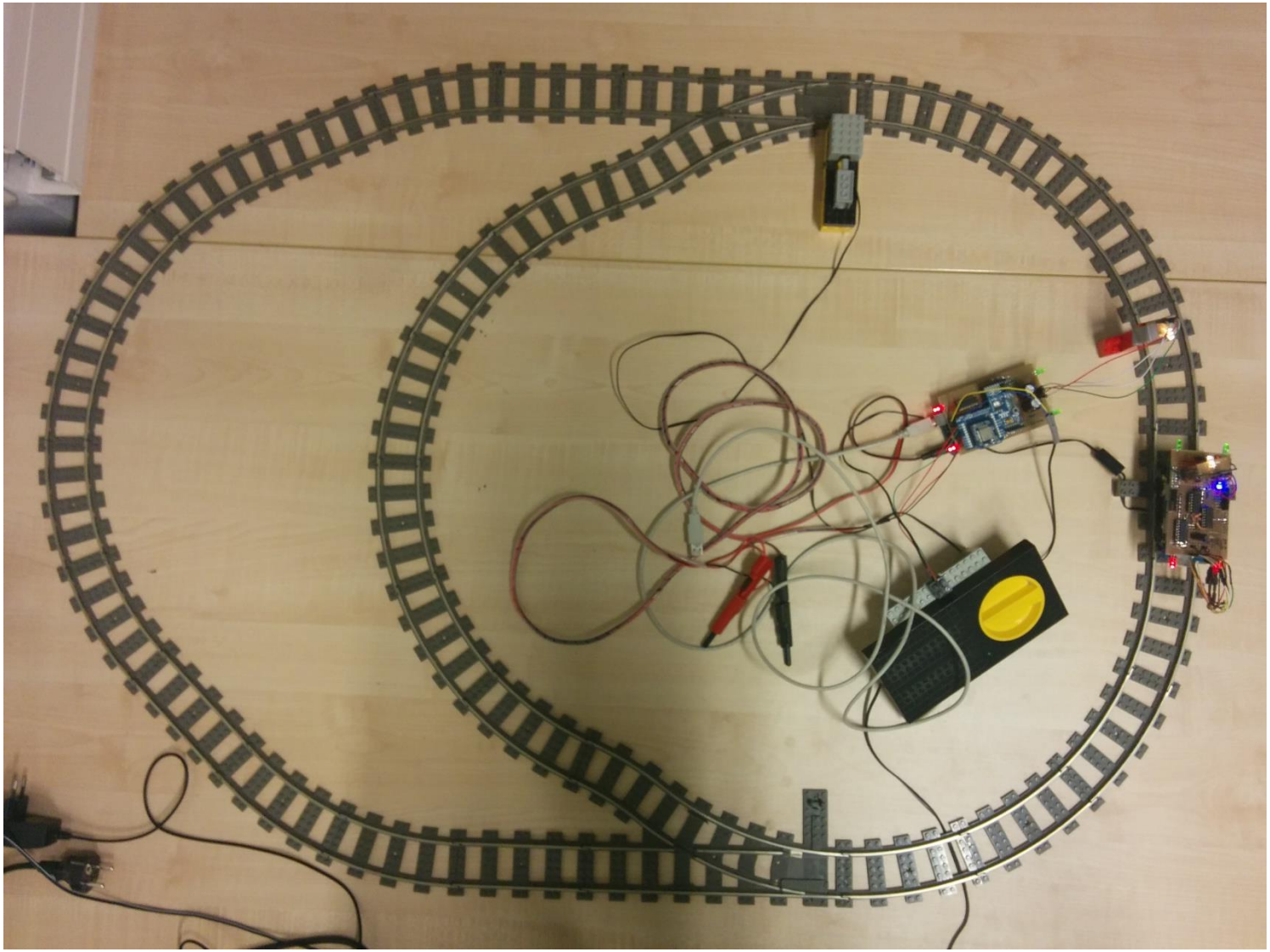
Our VLC

- Communication between 2 Arduinos
- LED for sending, phototransistors for receiving
- Hardware edge detector

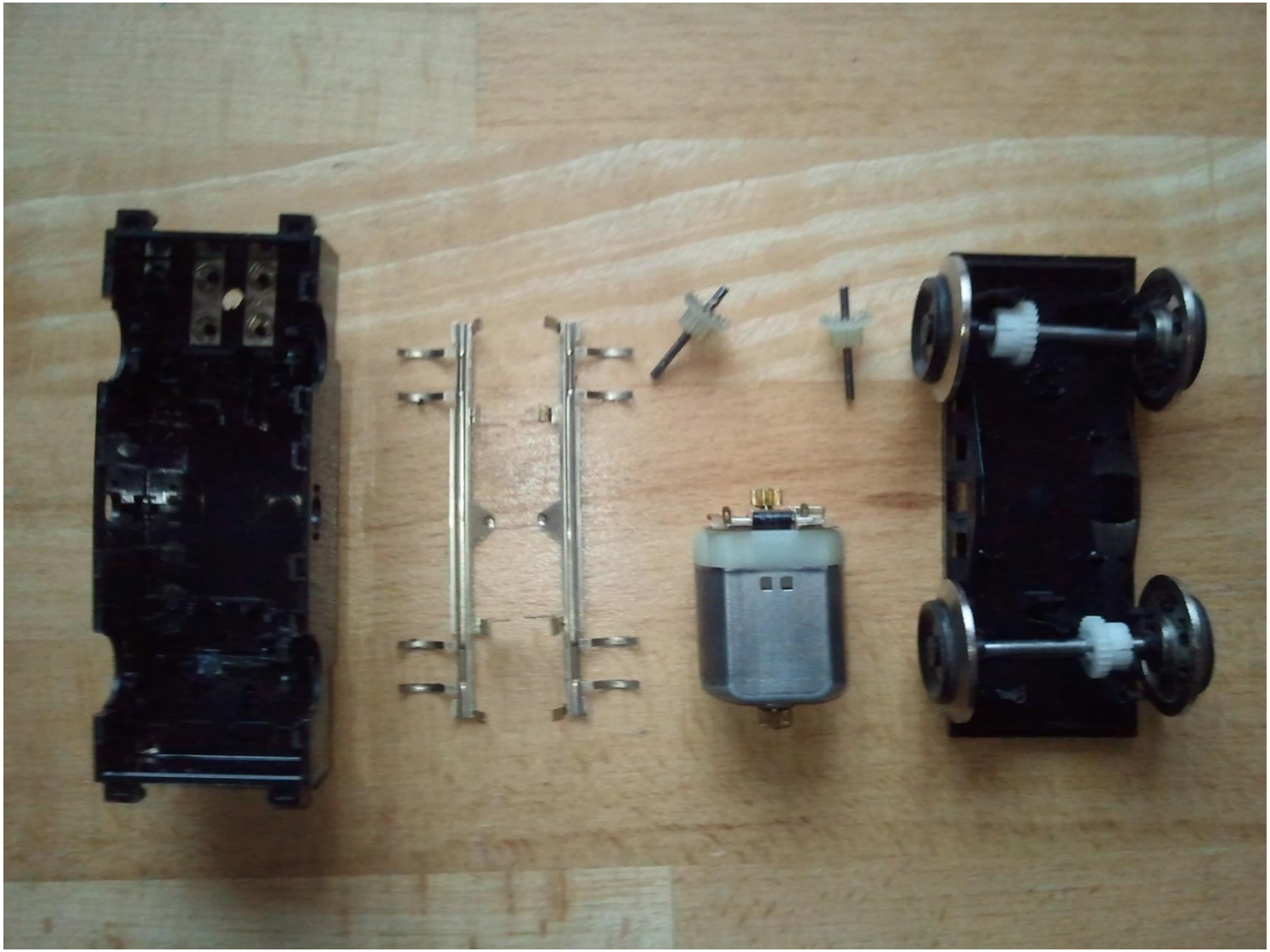
Use Case

- Control a LEGO train with VLC
- App communicates with a track controller via Bluetooth
  - Control turnout, speed, direction, headlights and taillights
- Track controller communicates with train via VLC
  - Signal along the track transmits data

Use Case



Hardware



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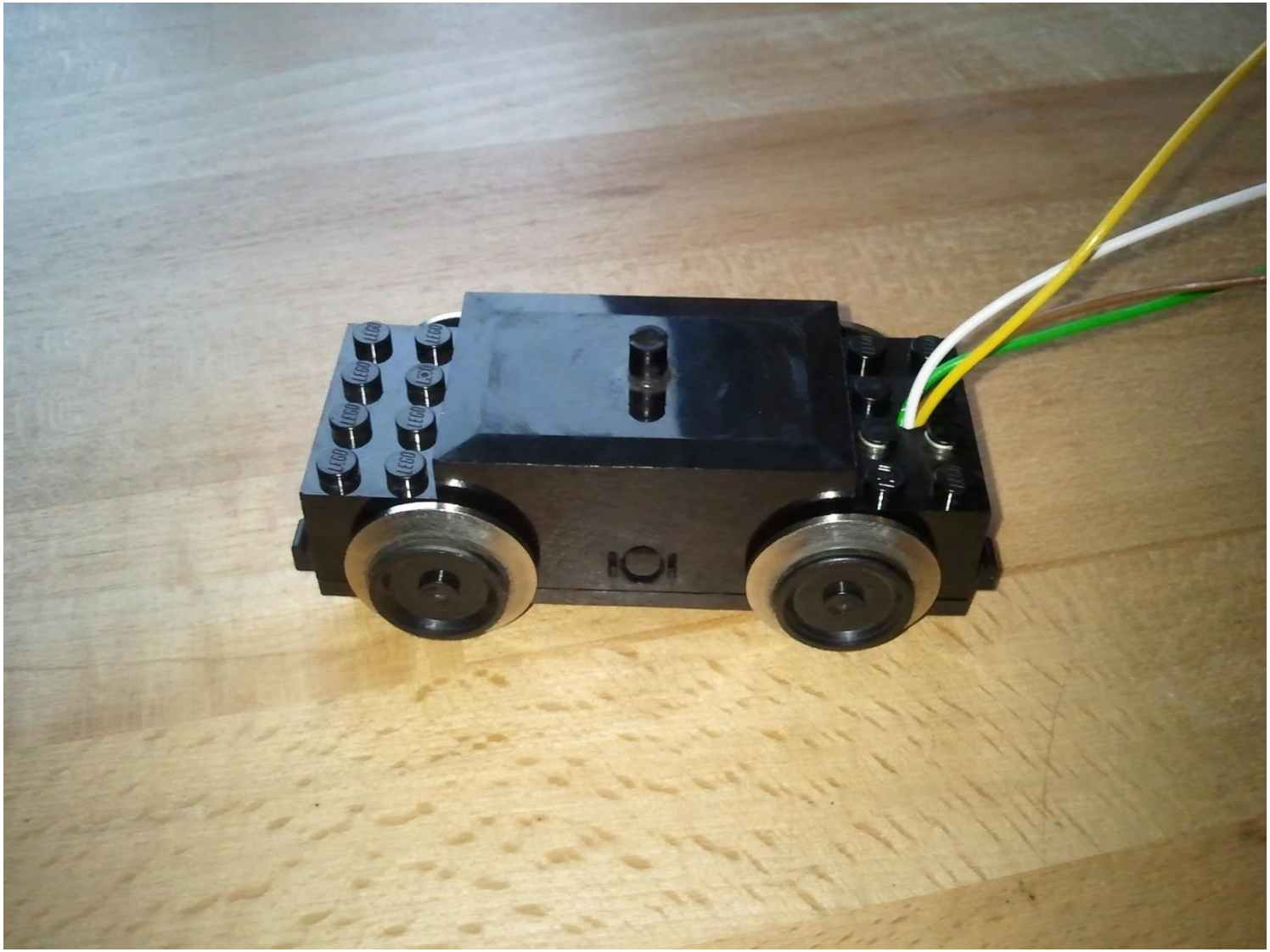

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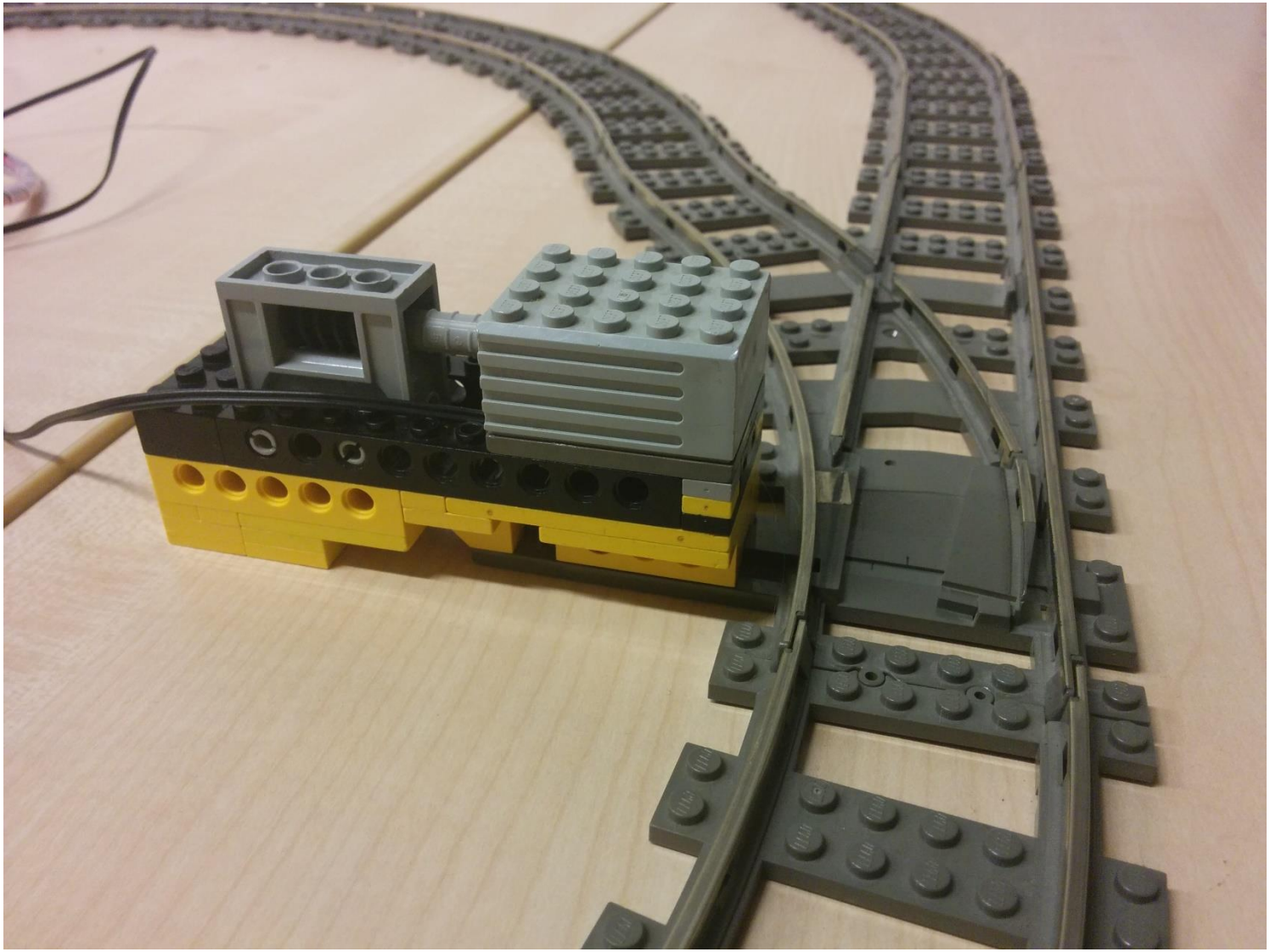
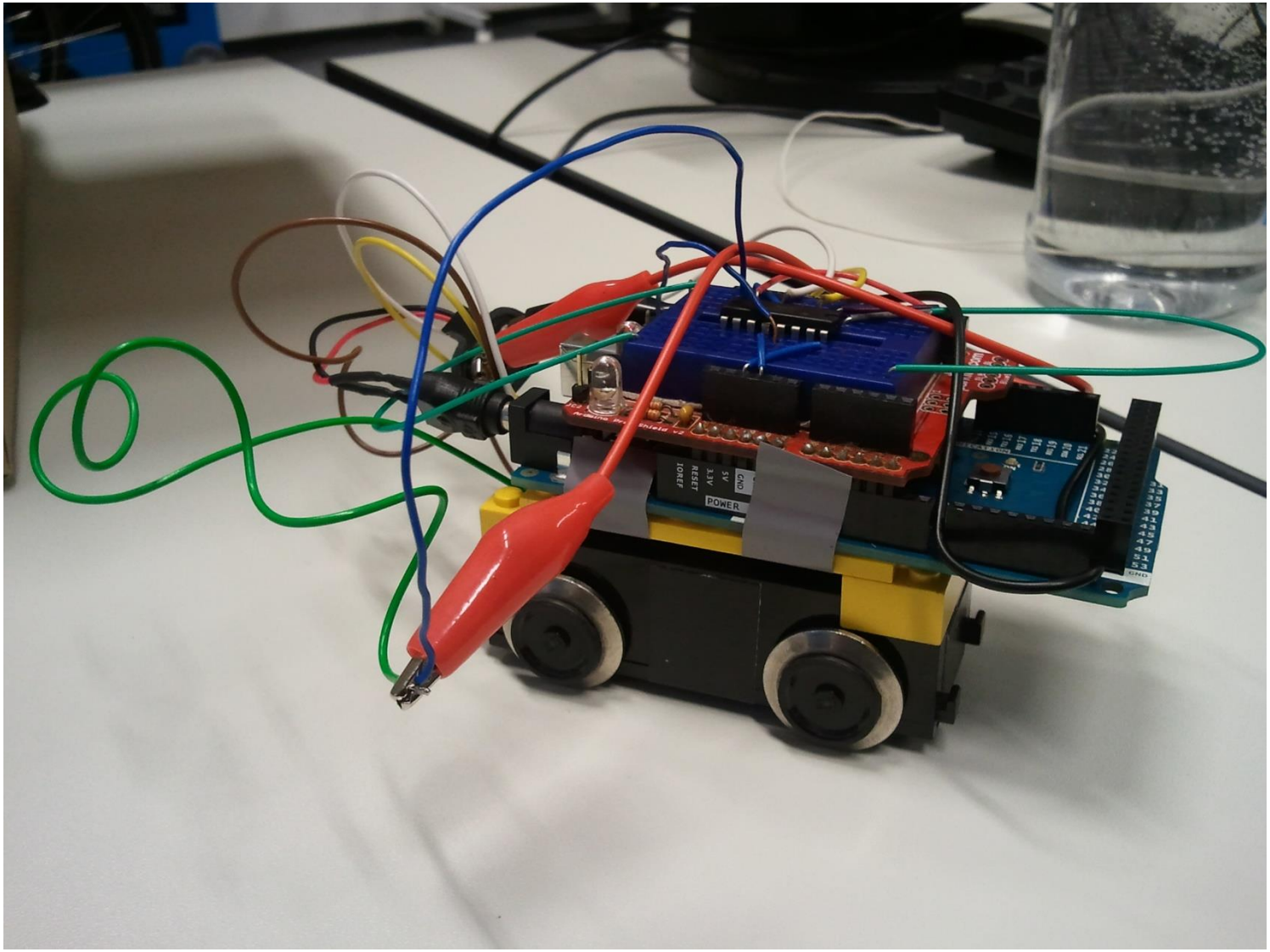


Evolution of the Train



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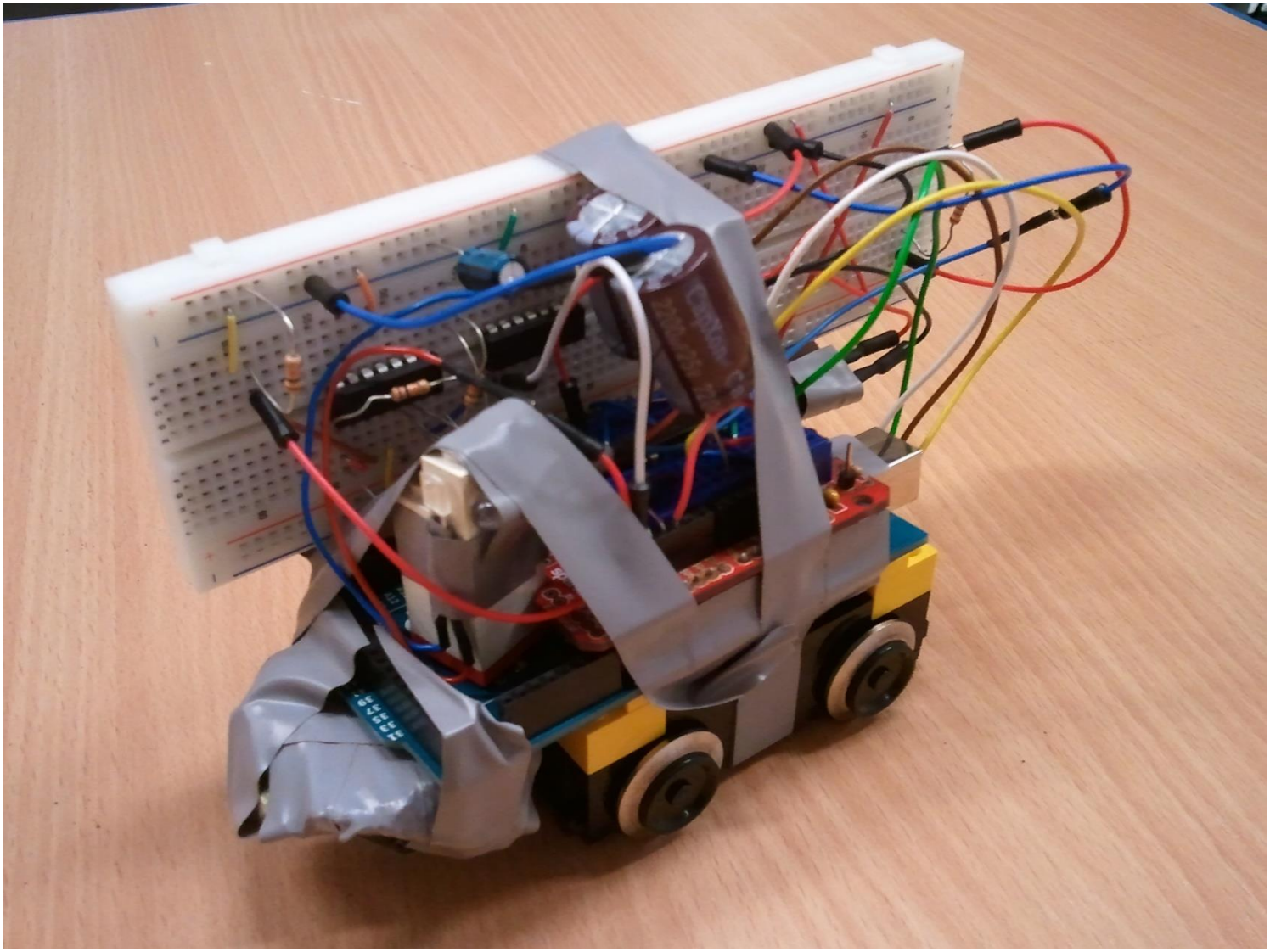

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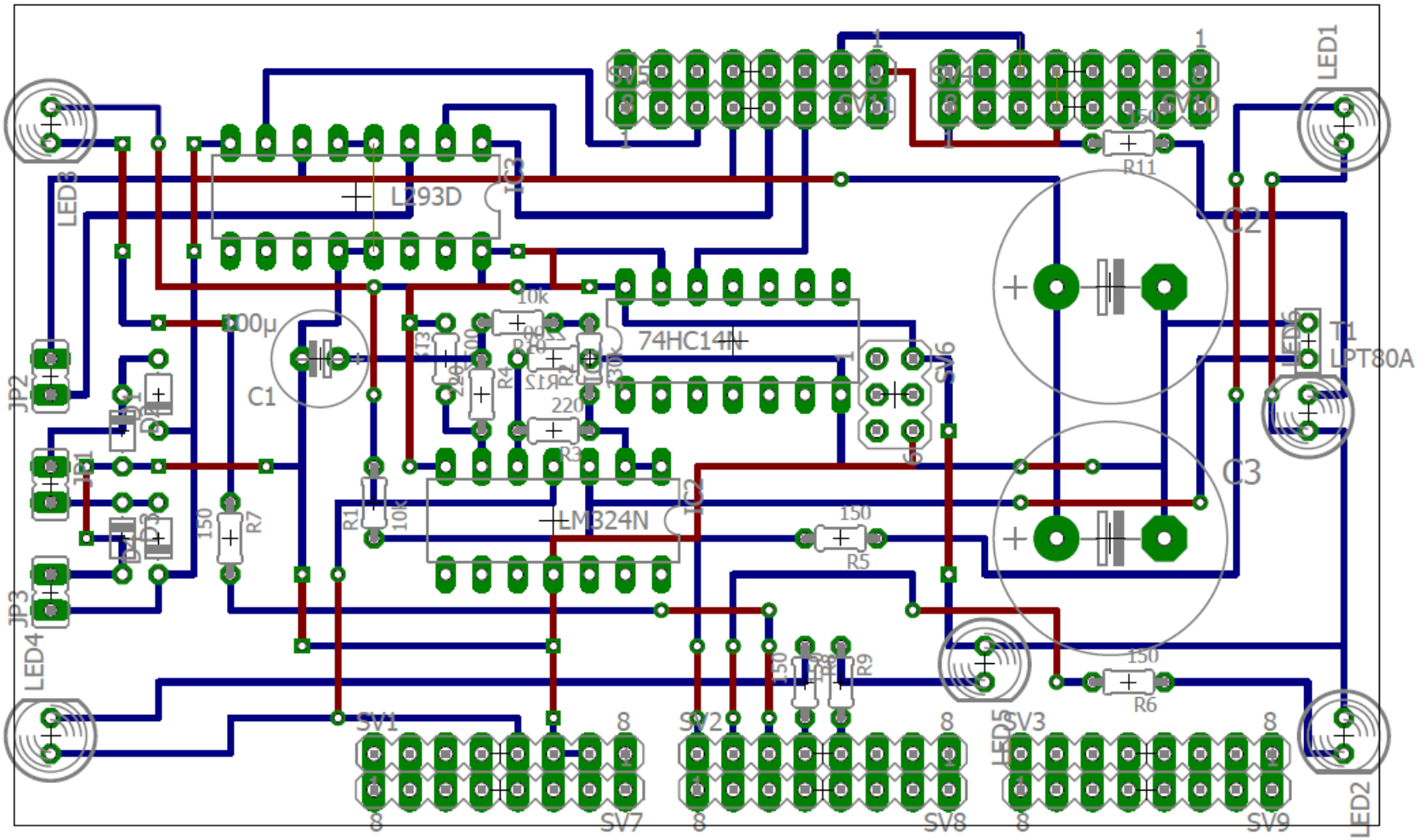

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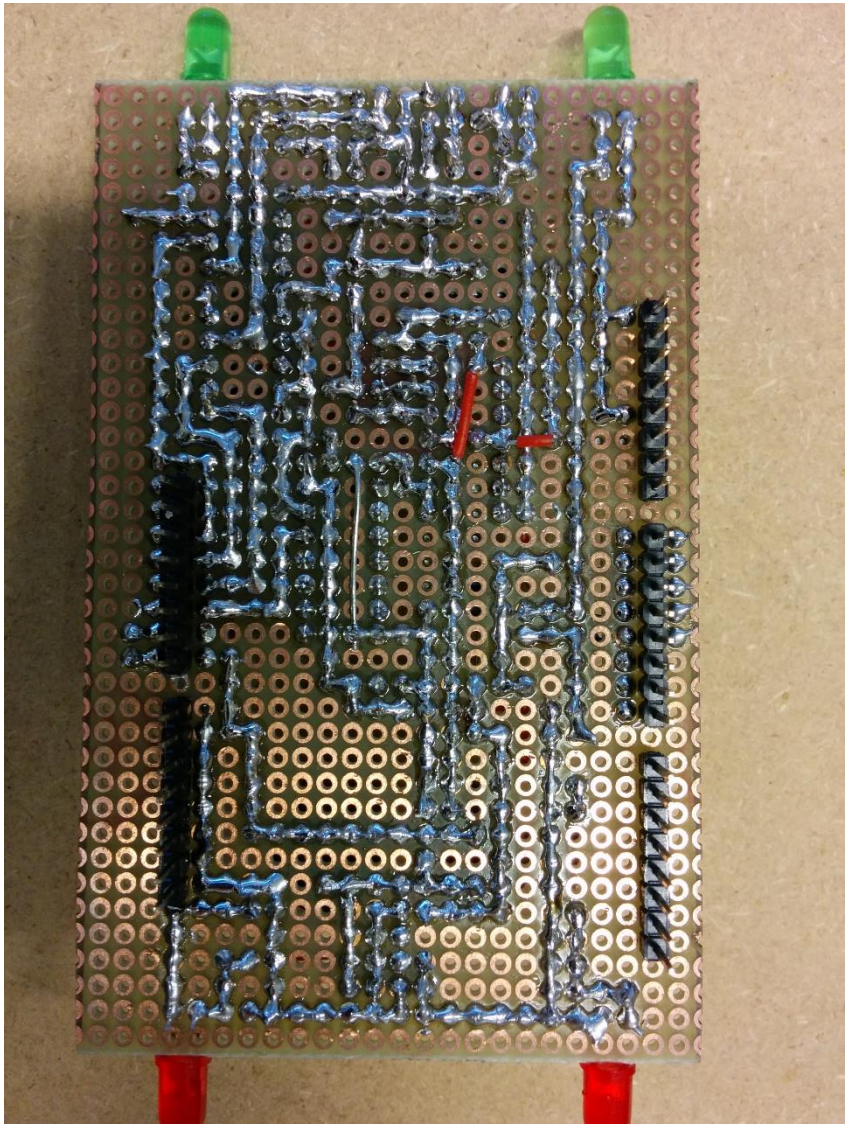

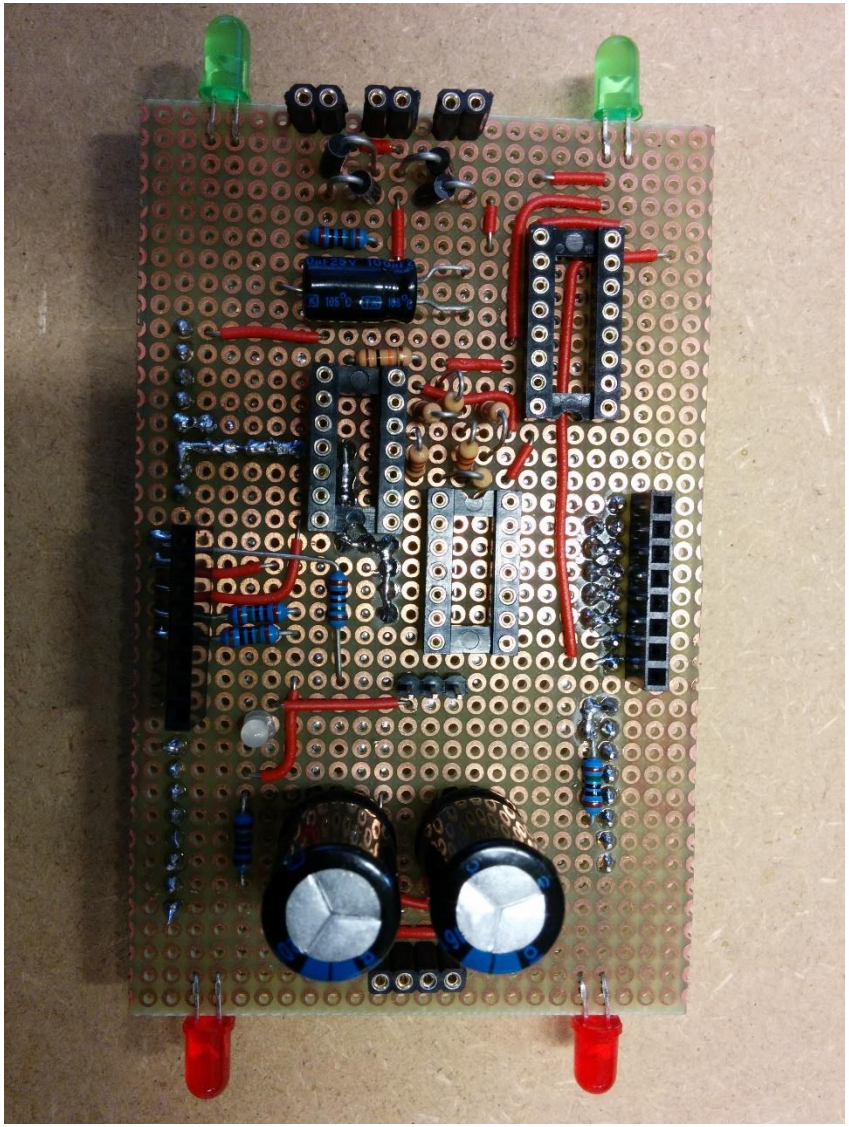

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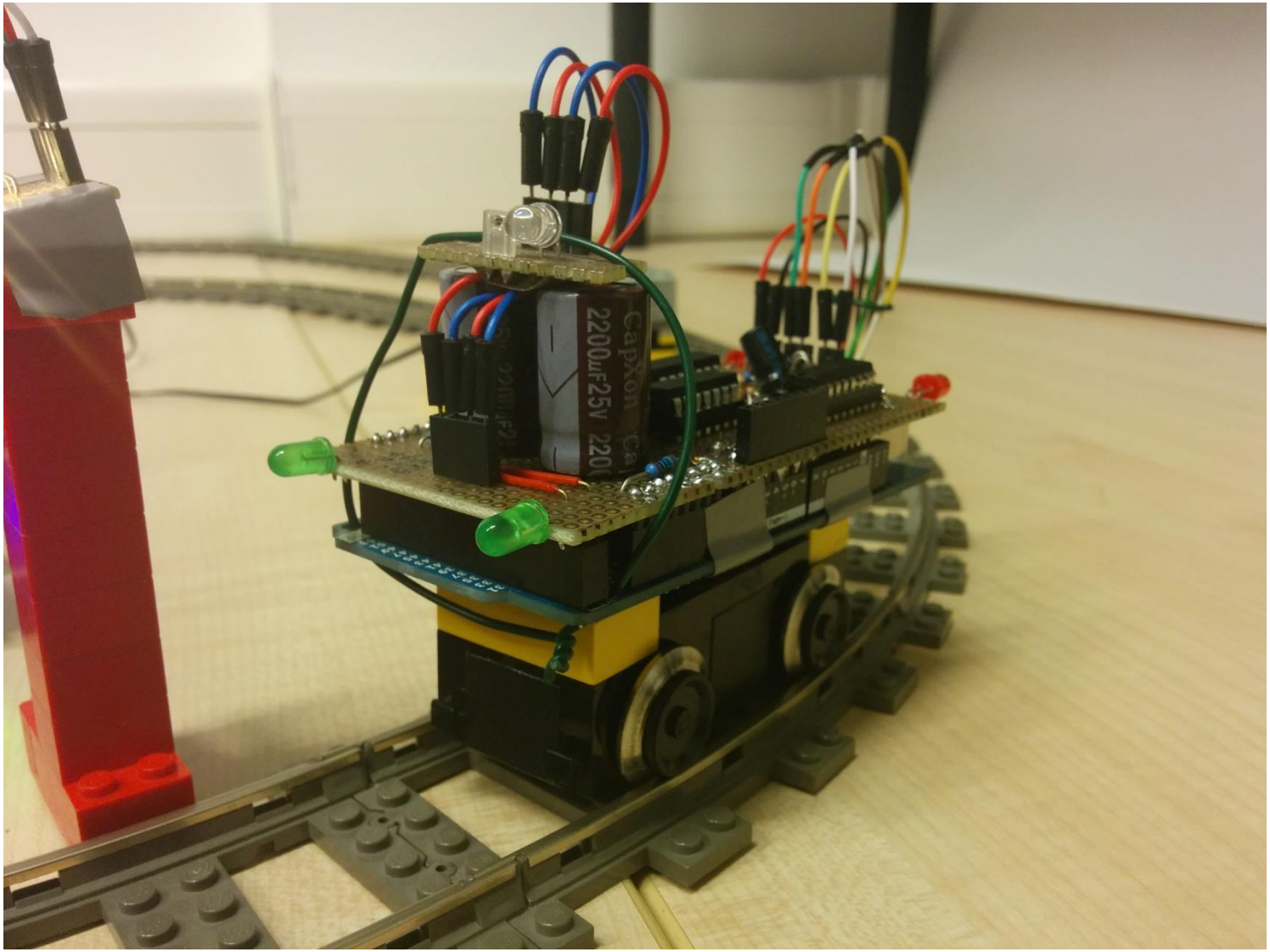
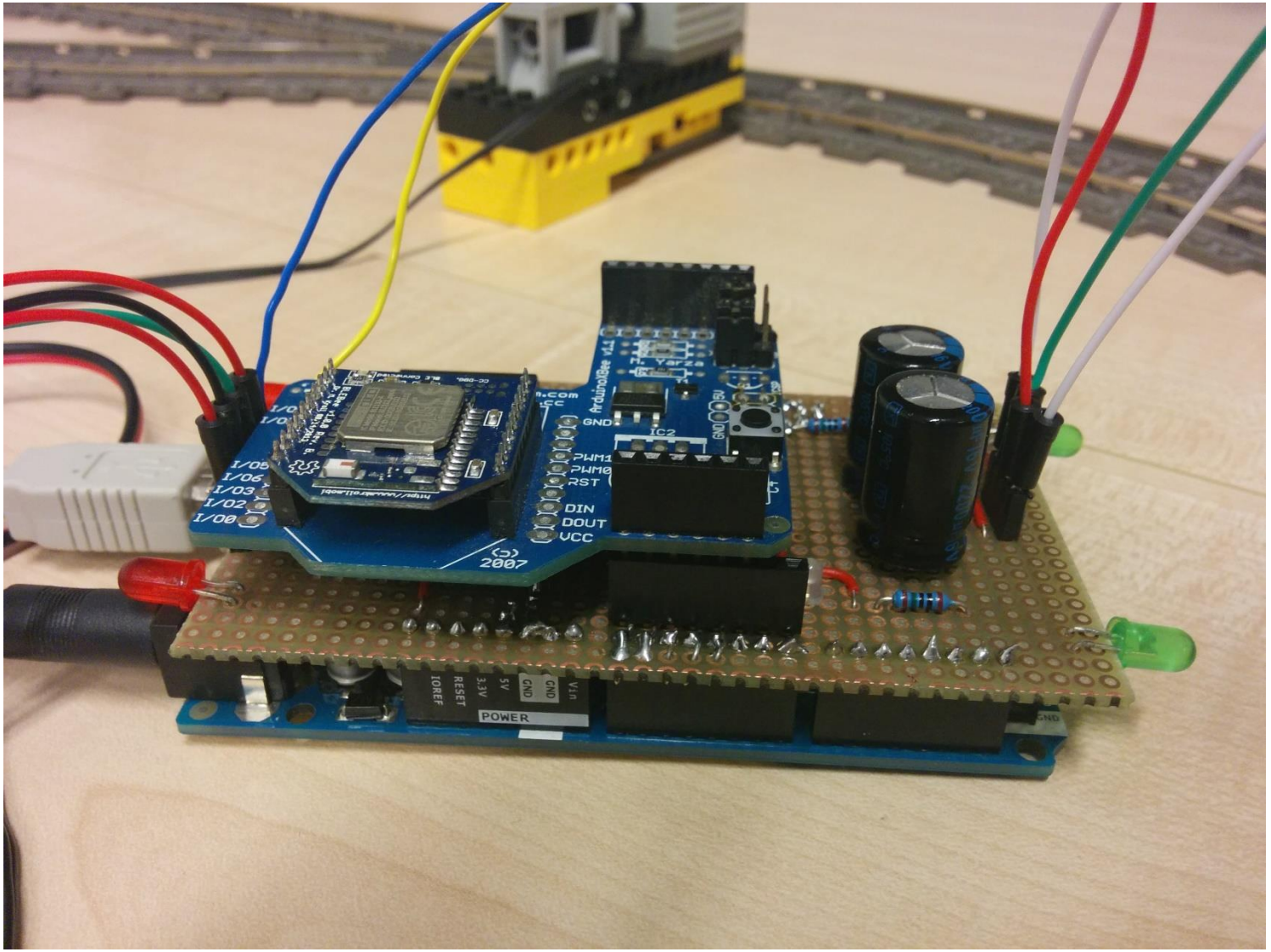
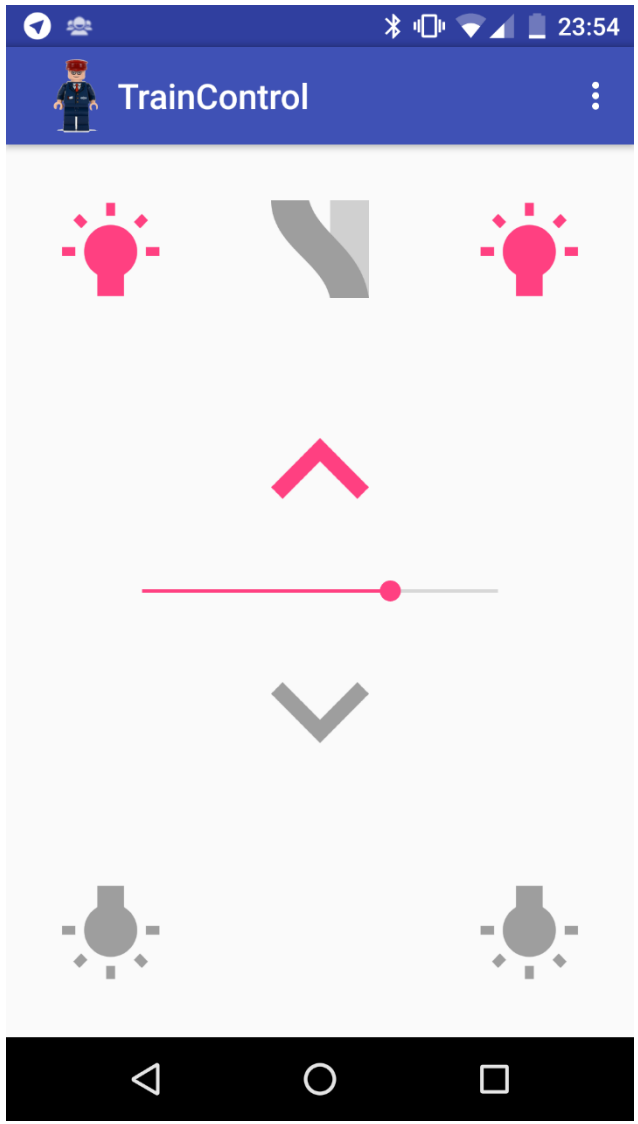


Final Track Controller



App - TrainControl



Demonstration

Sources

1. Subway Train Conductor. http://lego.wikia.com/wiki/Subway_Train_Conductor
2. Stefan Schmid, Giorgio Corbellini, Stefan Mangold, and Thomas R. Gross. 2013. LED-to-LED visible light communication networks. In *Proceedings of the fourteenth ACM international symposium on Mobile ad hoc networking and computing* (MobiHoc '13). ACM, New York, NY, USA, Pages 1-10.
3. Visible Light Communication. https://www.disneyresearch.com/project/visible-light-communication/