Hasso Plattner Institut

IT Systems Engineering | Universität Potsdam

Embedded Operating Systems

Distributed Control Lab

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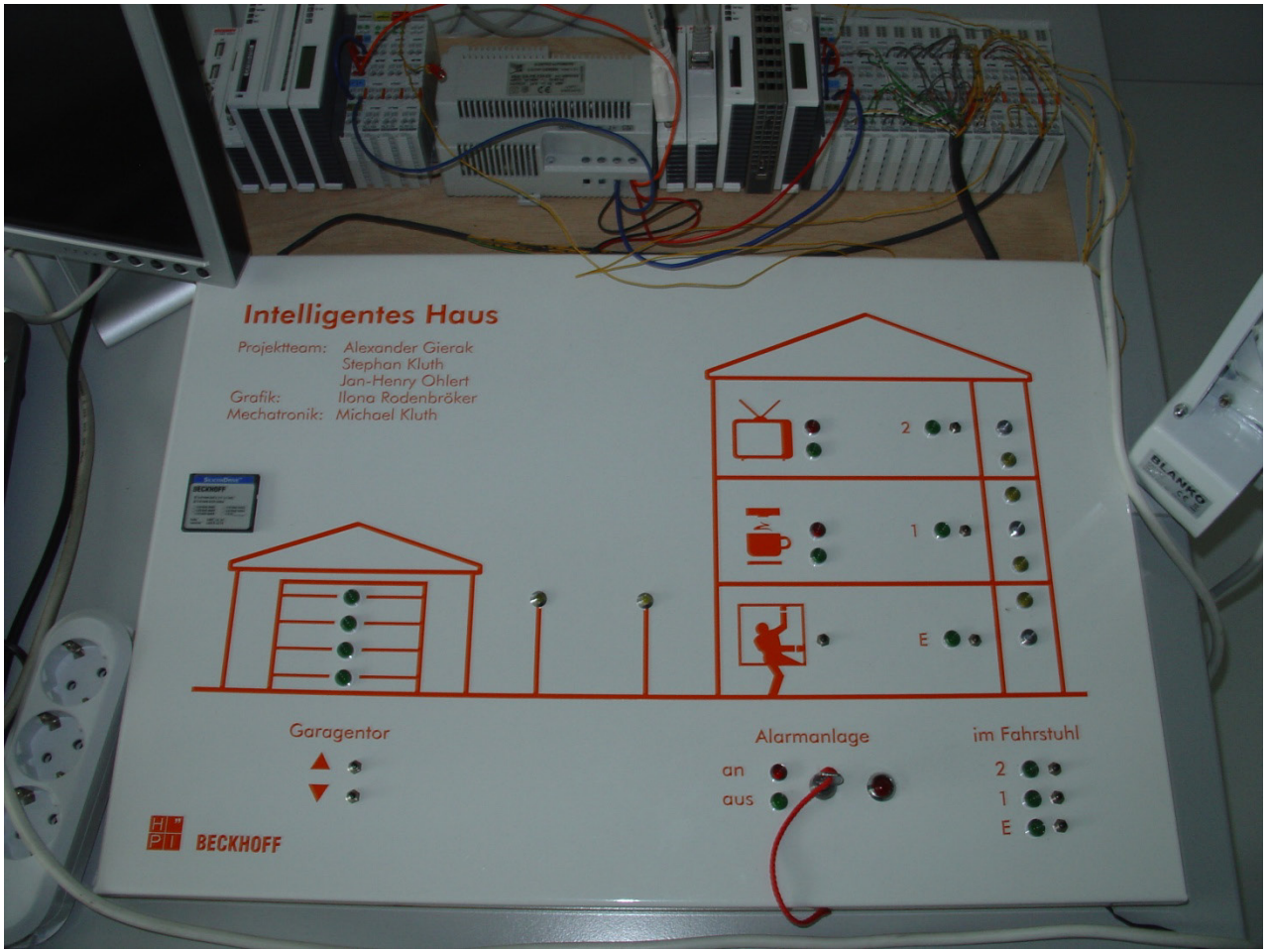
Operating Systems and Middleware

Prof. Dr. rer. nat. Andreas Polze

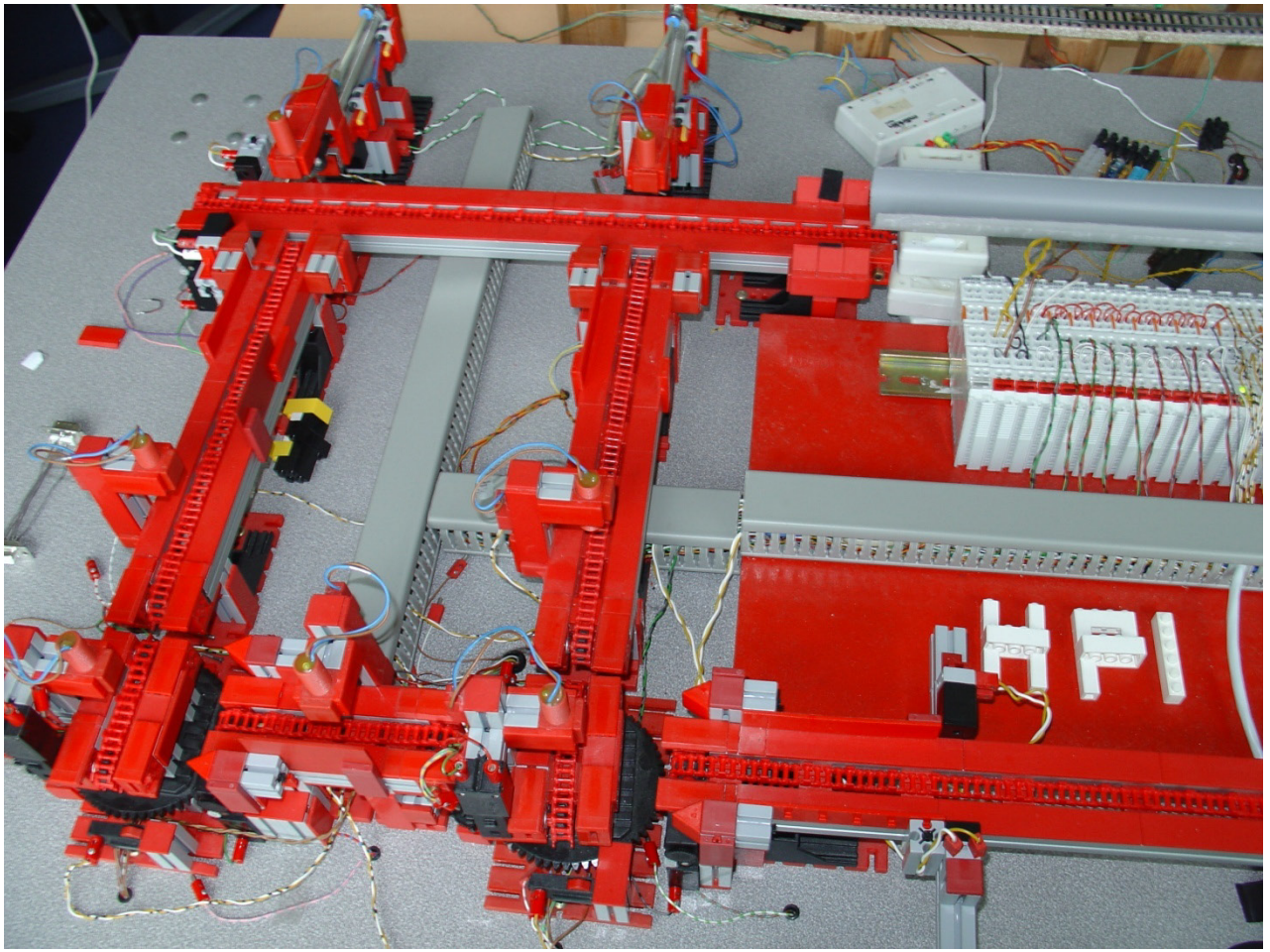
Agenda

- PLC – Programmable Logic Control (Beckhoff)
- Railroad
- Lego/NXT

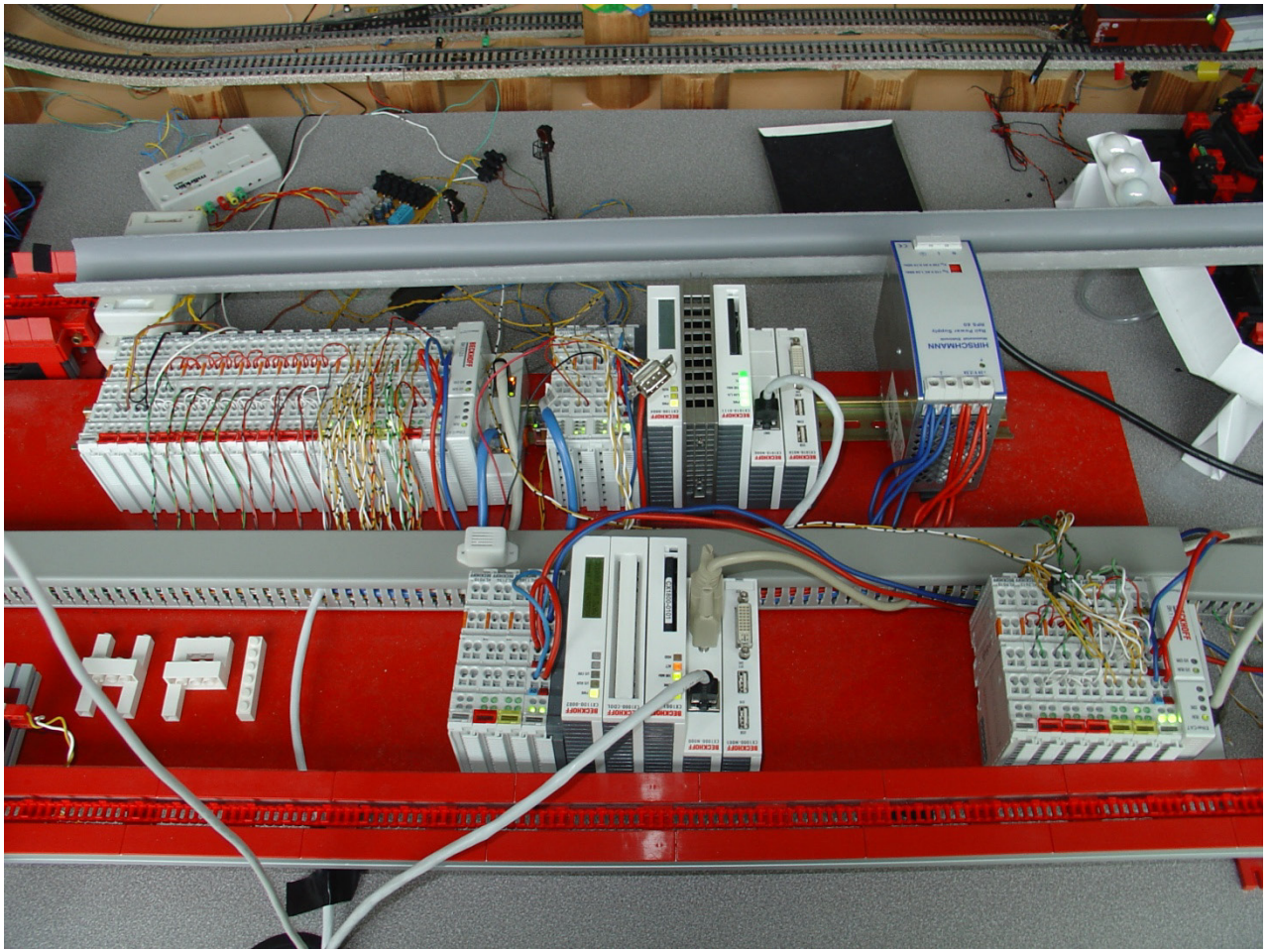
Intelligent House



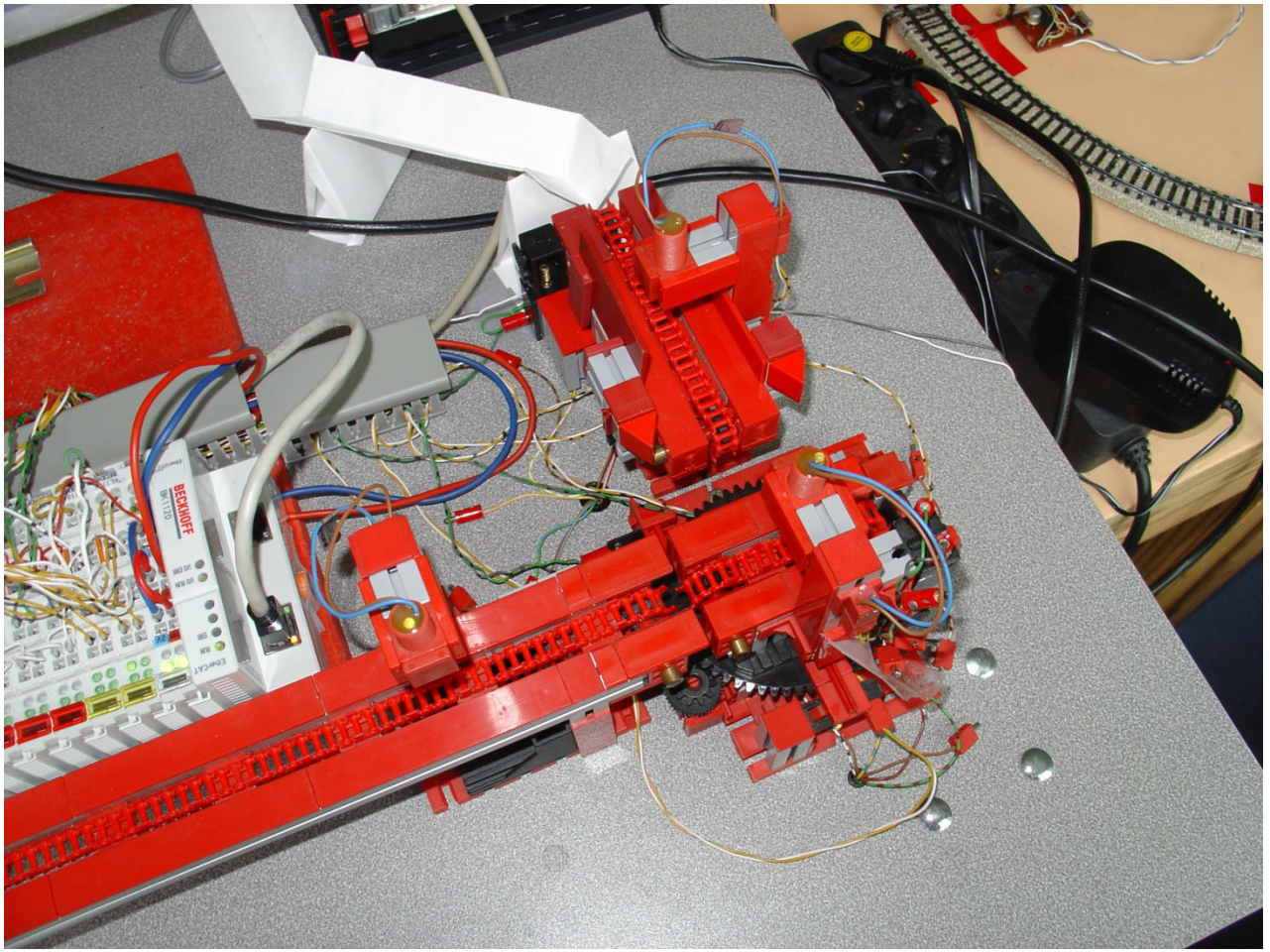
Fischertechnik – Assembly Line



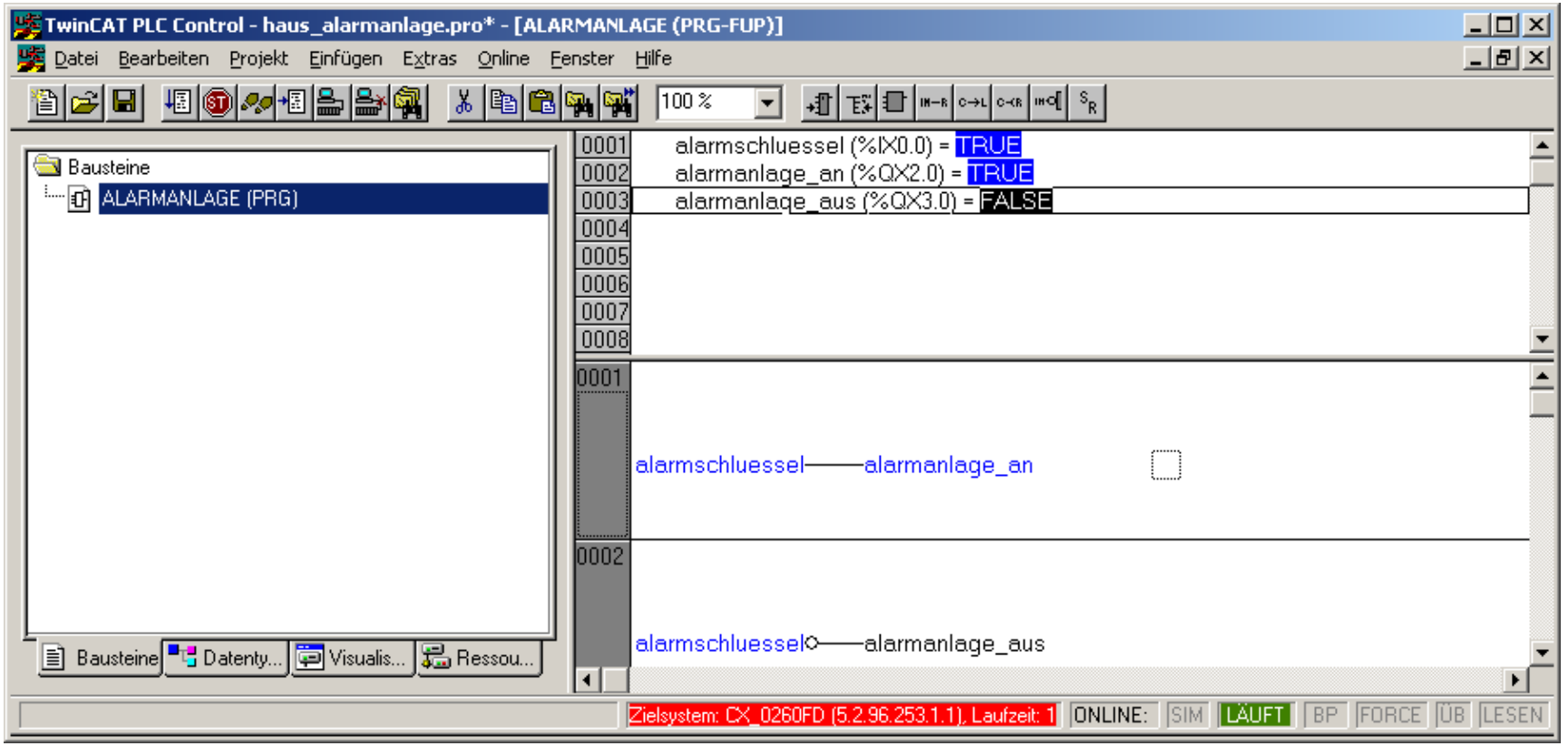
Fischertechnik – Assembly Line



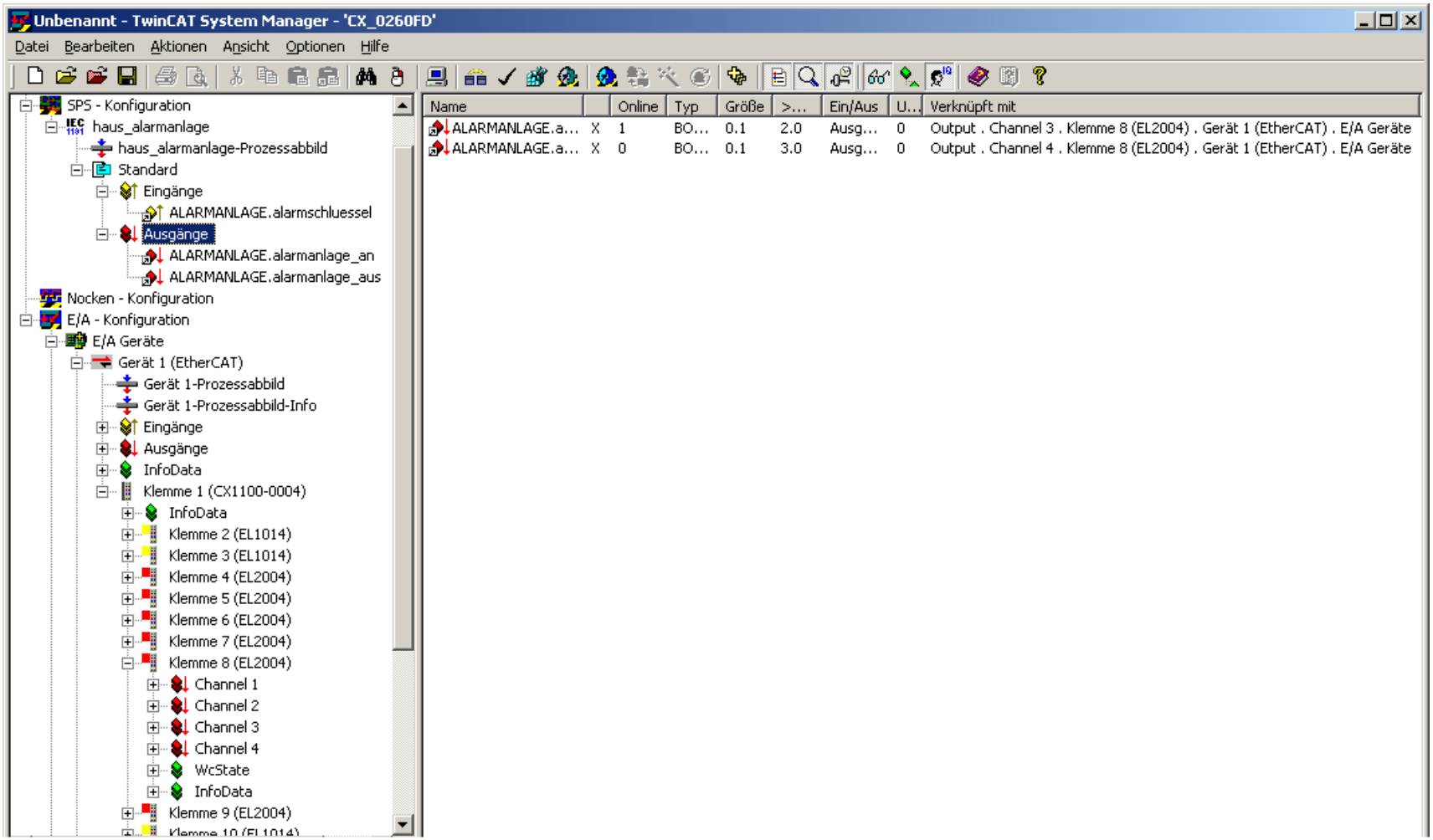
Fischertechnik – Assembly Line



TwinCAT PLC

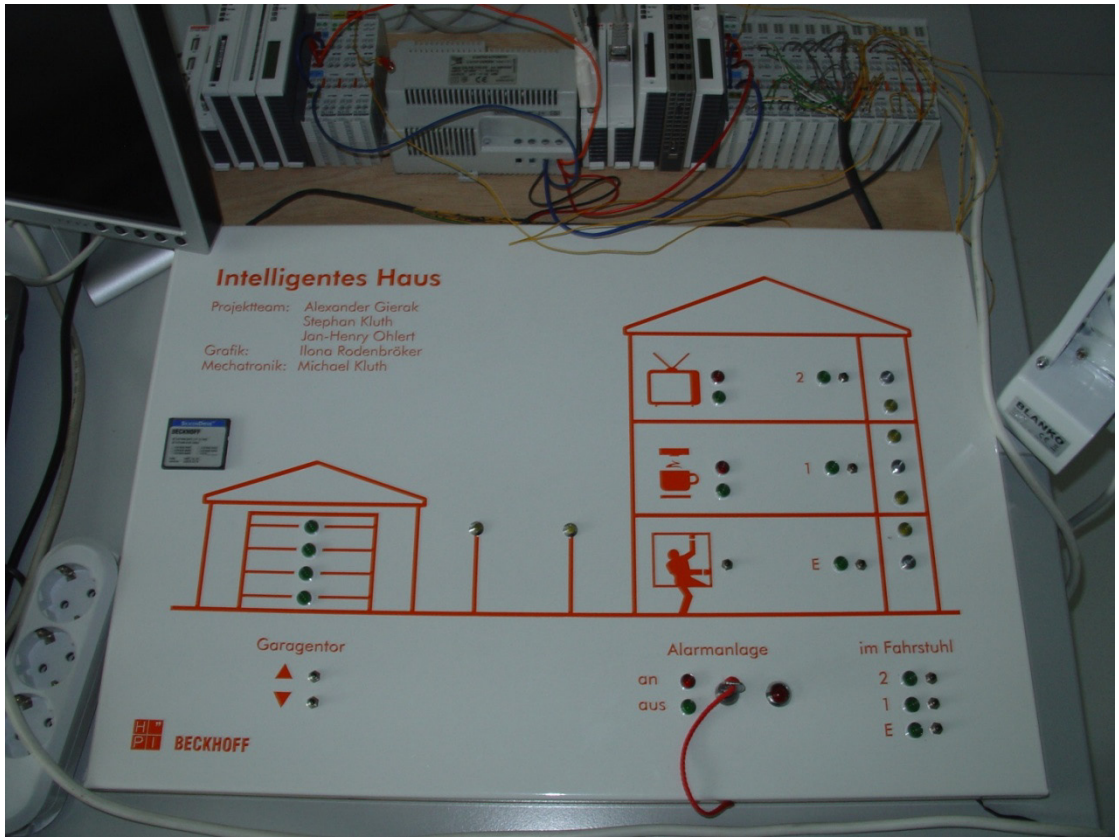

TwinCAT PLC Control - haus_alarmanlage.pro* - [ALARMANLAGE (PRG-FUP)]
Datei Bearbeiten Projekt Einfügen Extras Online Fenster Hilfe
100 %
Bausteine
ALARMANLAGE (PRG)
Bausteine
Datenty...
Visualis...
Ressou...
0001 alarmschluessel (%IX0.0) = TRUE
0002 alarmanlage_an (%QX2.0) = TRUE
0003 alarmanlage_aus (%QX3.0) = FALSE
0004
0005
0006
0007
0008
0001
alarmschluessel
alarmanlage_an
0002
alarmschluessel
alarmanlage_aus
Zielsystem: CX_0260FD (5.2.96.253.1.1), Laufzeit: 1
ONLINE:
SIM
LÄUFT
BP
FORCE
ÜB
LESEN

TwinCAT System Manager



Project Idea

- PLC – Controlling a virtual intelligent house:
  - Elevator
  - Garage door
  - Lighting
  - Alarm system
  - Coffee maker
  - TV



Agenda

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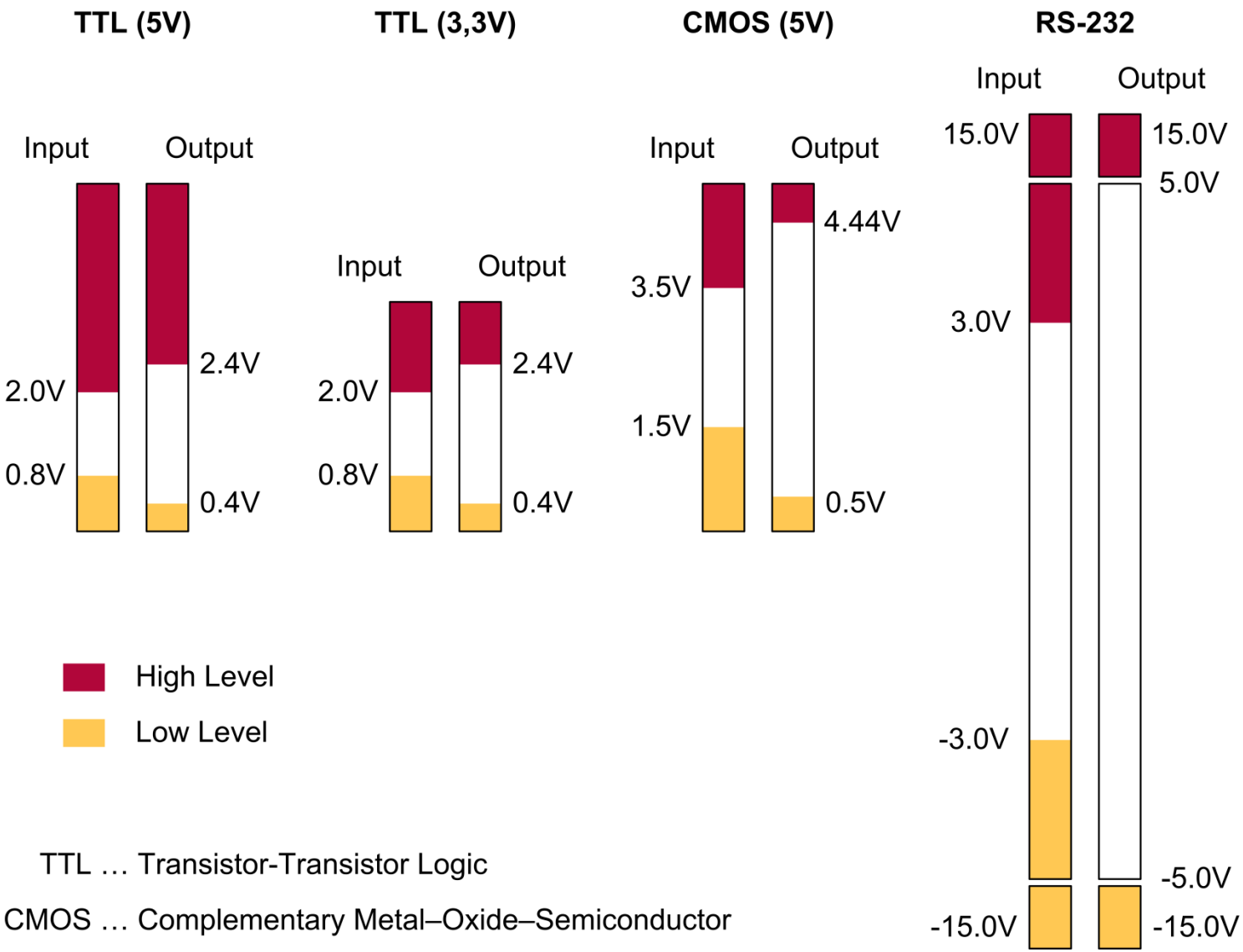
Logical Voltage Levels

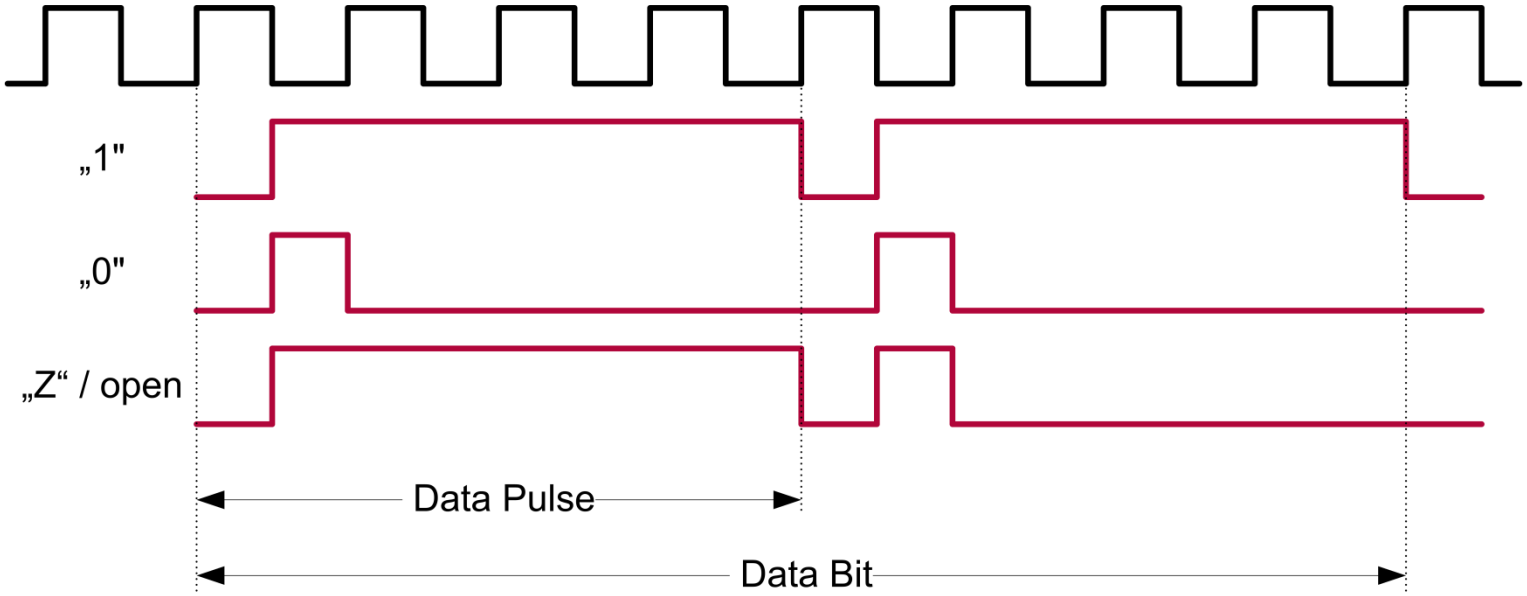


TTL … Transistor-Transistor Logic

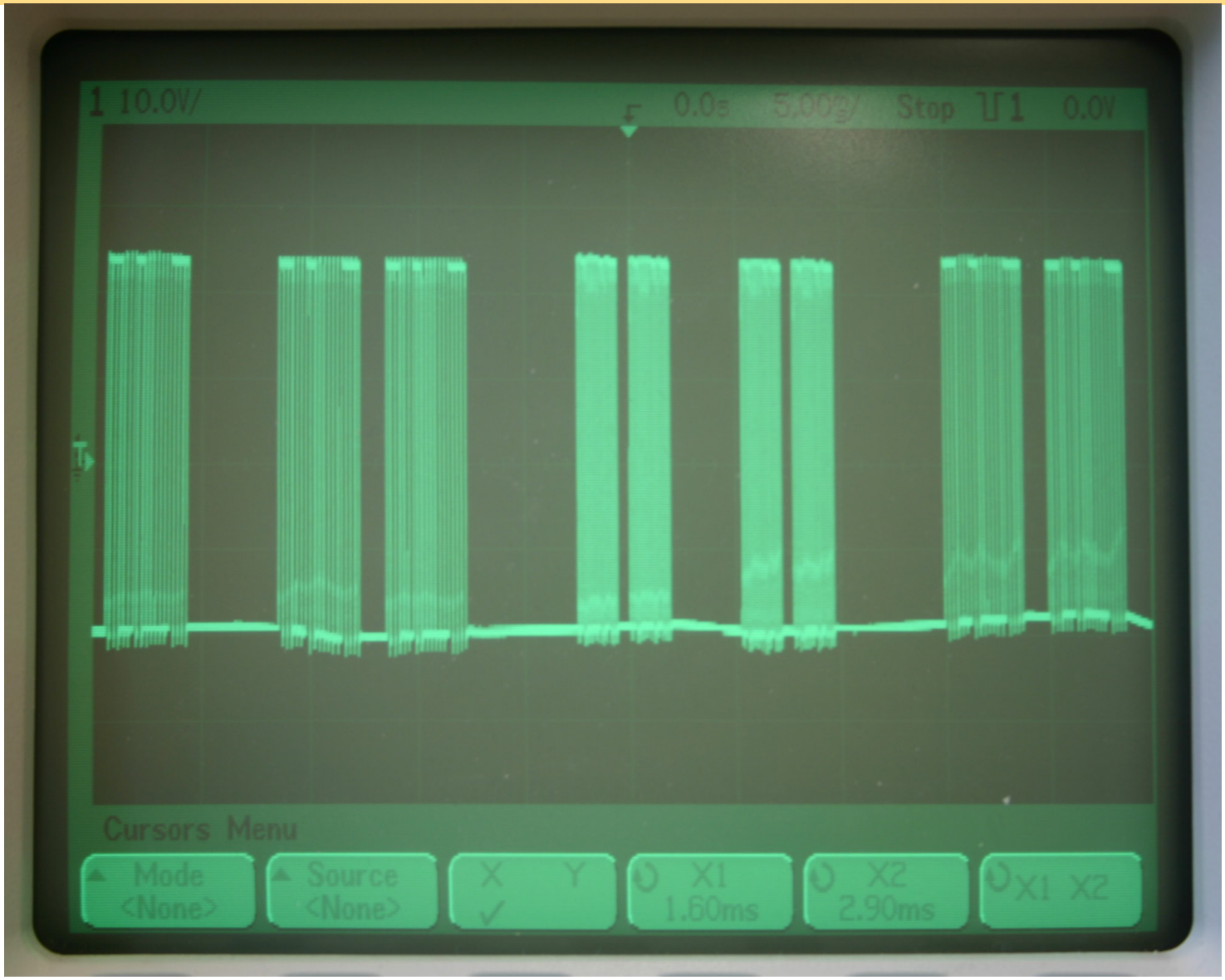
CMOS … Complementary Metal–Oxide–Semiconductor

Locomotive and Magnet Items Control

- Operating voltage for several components (Motor, Lamp, …)
- Digital control – Message transmissing using data packets
  - Binary and ternary data coding

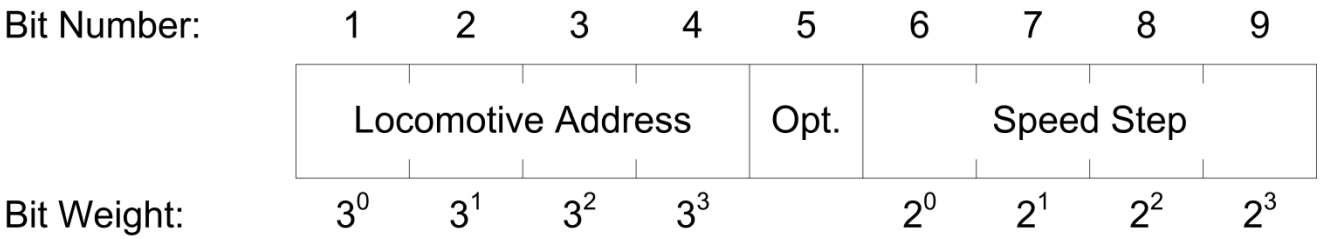


Control Information (Example)

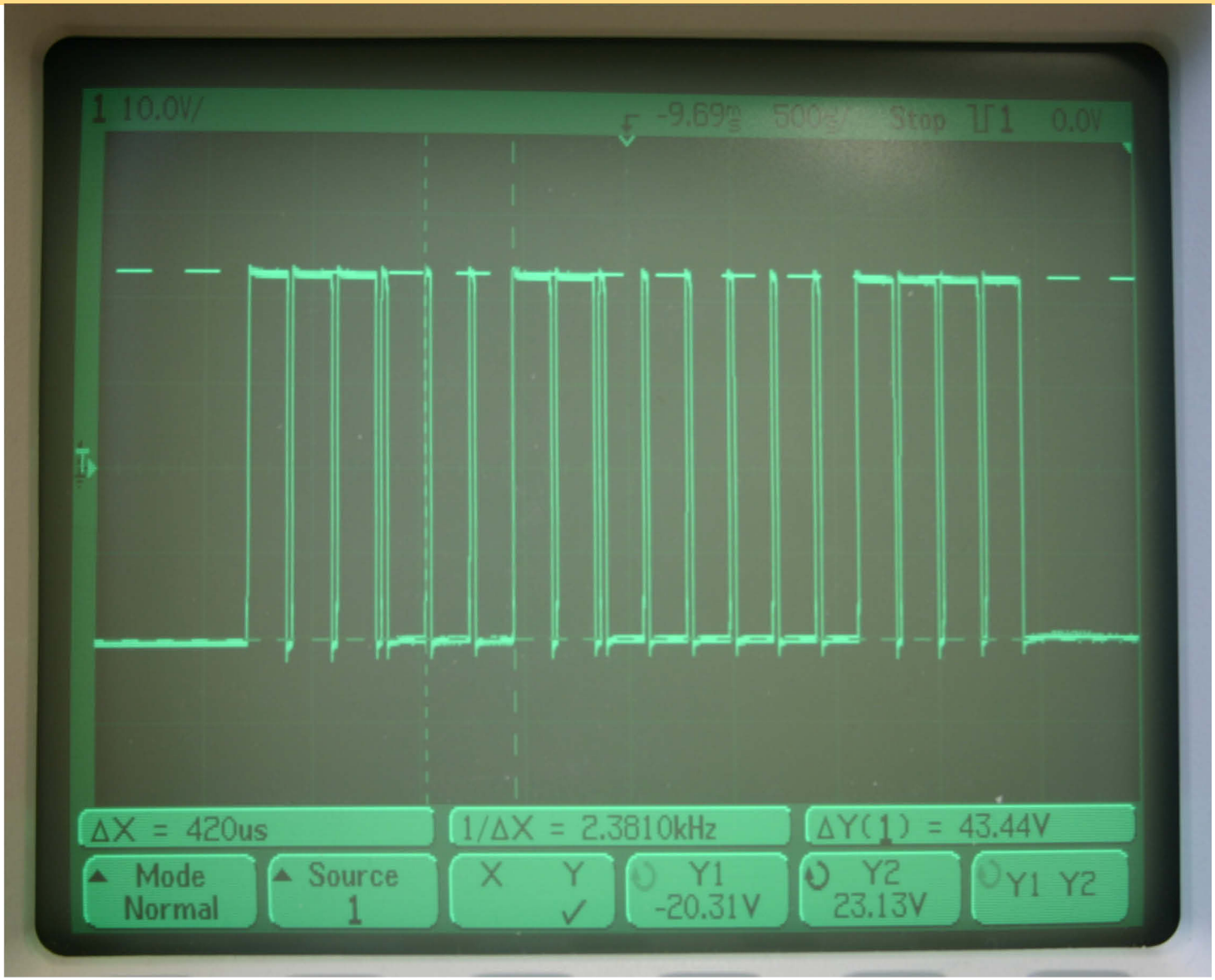


Locomotive Control

- Clock 19,2 kHz → Data pulse width about 208 µs
- Data format:
  - Loco address: 4 ternary digits (0 ... 79 / 80 – Idle)
  - Option: 1 binary digit (0 – Off / 1 – On)
  - Speed step: 4 binary digits
    (0 – Stop / 1 – Inversion of the direction /
    2 – Lowest speed step /
    15 – Highest speed step)

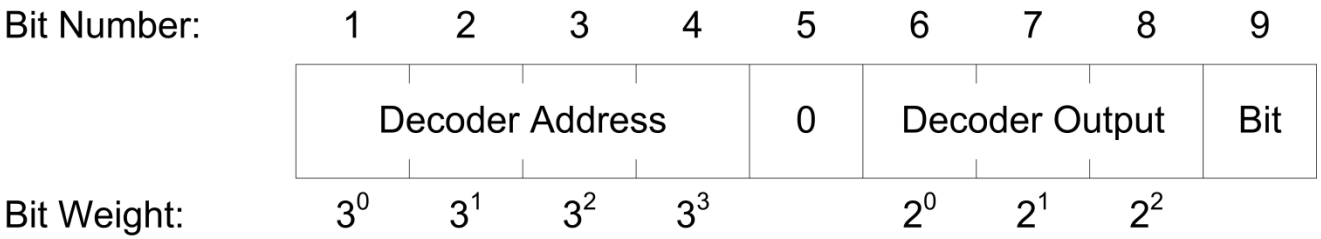


Locomotive Control (Example)

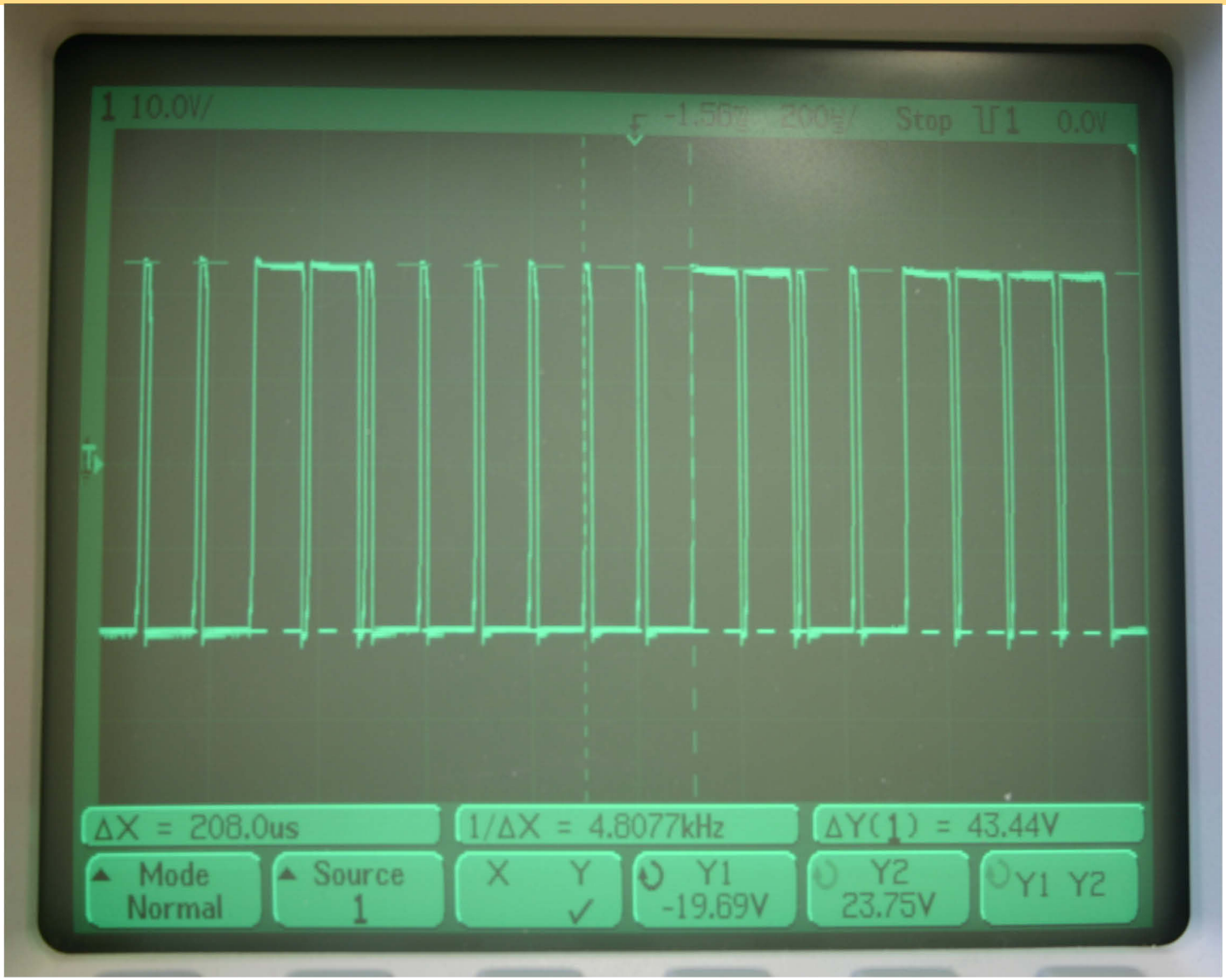


Magnet Items Control

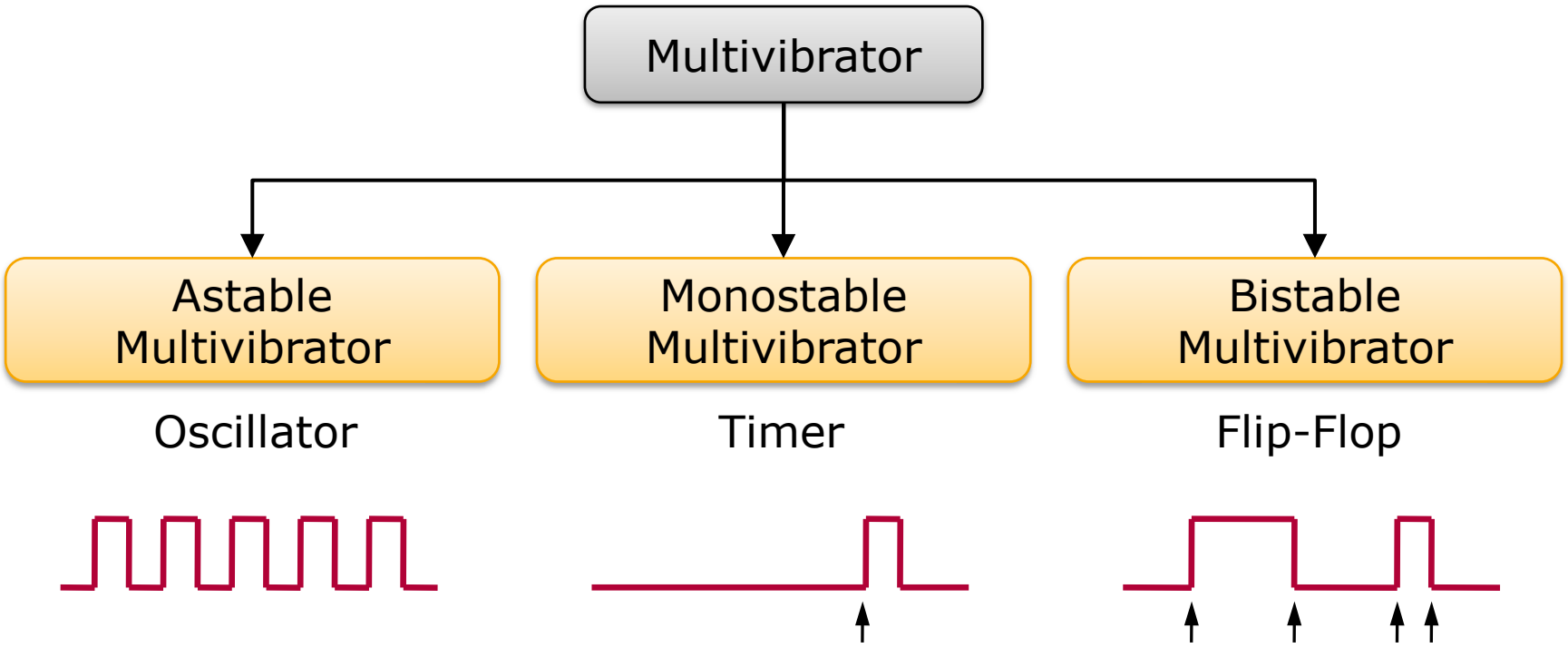
- Clock 38,4 kHz → Data pulse width about 104 µs
- Data format:
  - Decoder address: 4 ternary digits
  - Reserved: 1 binary digit (always 0)
  - Decoder output: 3 binary digits
  - Bit: 1 binary digit (0 – Off / 1 – On)



Magnet Items Control (Example)



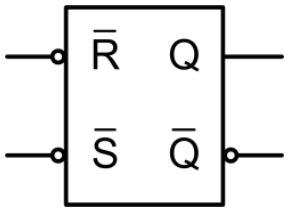
Multivibrator / Flip-Flop



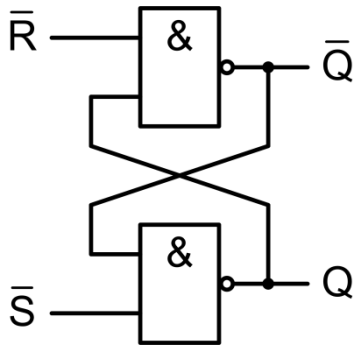
Flip-Flop (Examples)

RS Flip-Flop

Symbol:



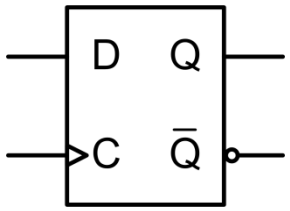
Implementation with NAND gates:



R	S	Q
L	L	- / H
L	H	L
H	L	H
H	H	x

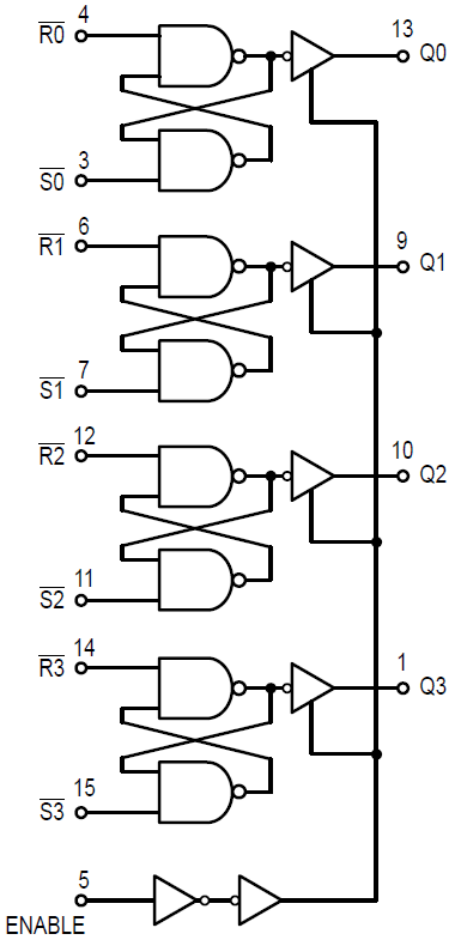
D Flip-Flop

Symbol:



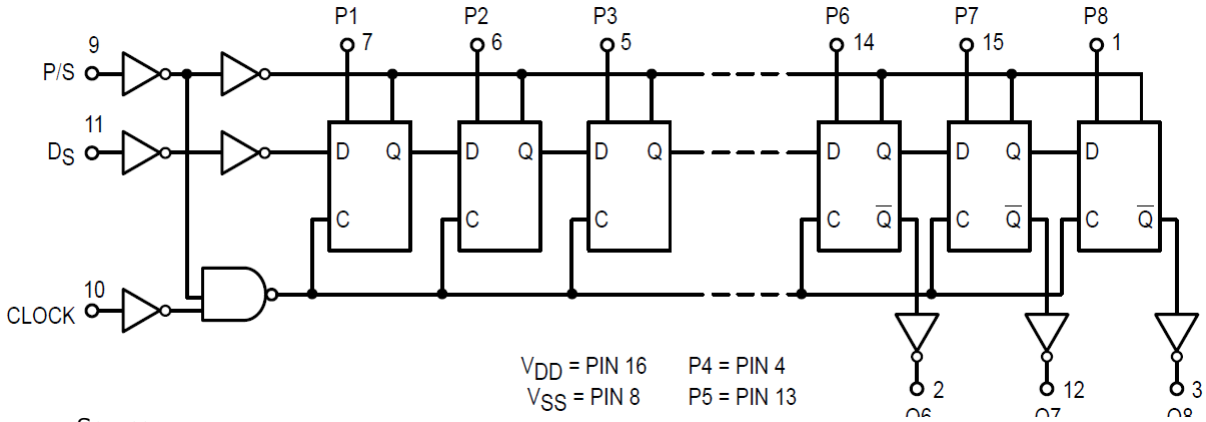
D	C	Q
x	L	x
X	H	x
L	↓	L
H	↓	H

Return Signal Information using the S88 Decoder



Source:

MOTOROLA Semiconductor Technical Data
MC14044B

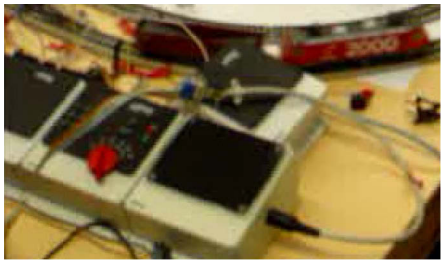


Source:

MOTOROLA Semiconductor Technical Data
MC14014B

Project Idea

- Railroad 1:
  - Controlling trains via PC and Märklin control unit (management of independent trains within the same rail segment)

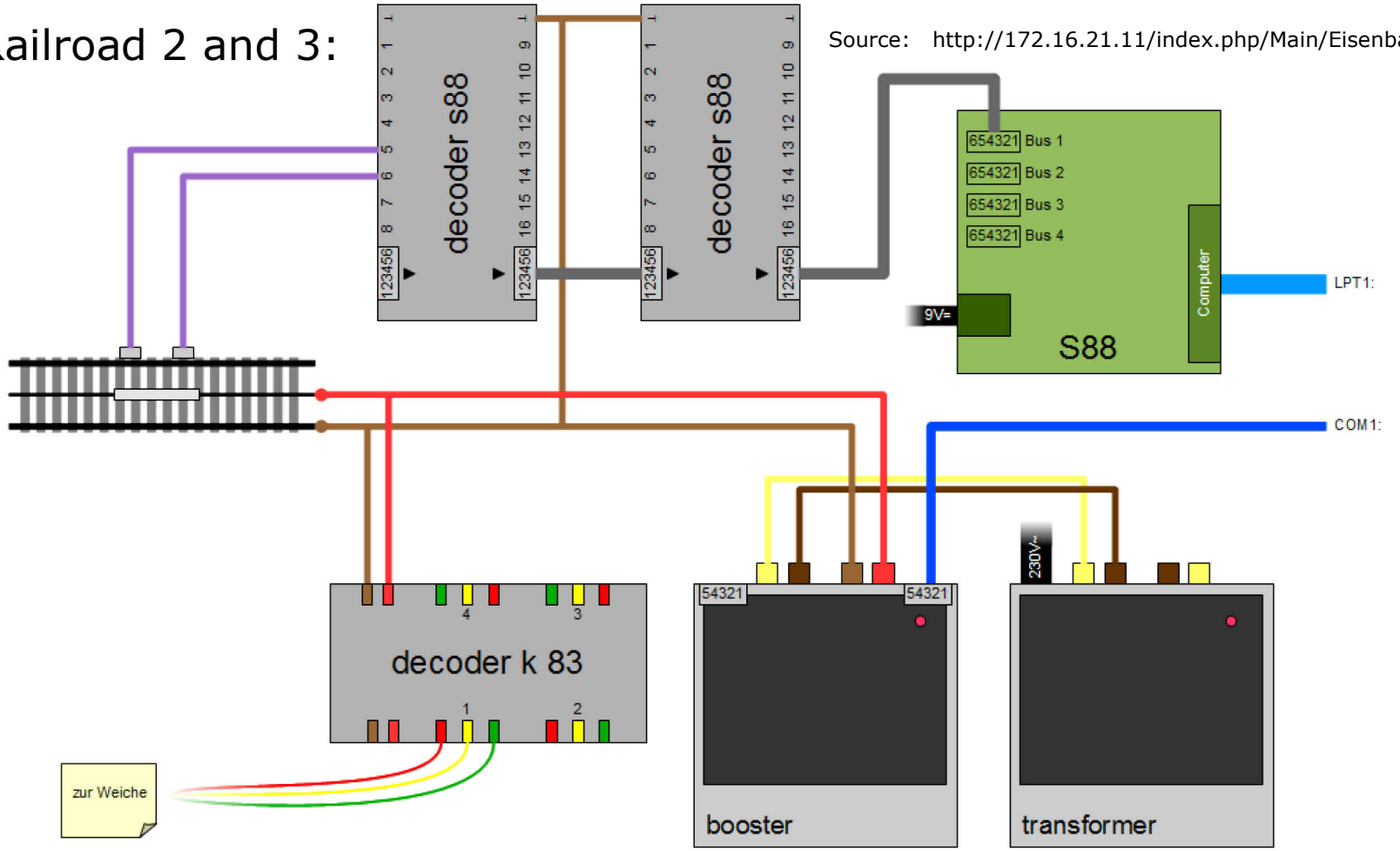


PC Interface Märklin 6015

- RS-232, 2400bps (~210 bytes per second)
- Challenges (a selection ☺):
  - Controlling locomotives (messages get lost if the time between consecutive messages is too short)
  - Controlling switches
    - Magnets need to be kept active for some time -> mechanical movement
    - Magnets must be deactivated explicitly -> otherwise, the coil may burn out
    - A deactivation command locks the interface for a certain time -> no further commands or S88 polling
  - Exact timing for reading information from the S88 decoder in polling mode

Project Idea

- Railroad 2 and 3:



Direct control (Booster)

- Messages for locomotives are sent directly to the Booster
  - µC or via PC (serial port) with special bit patterns
  - Unreliable transmission -> periodic repetition needed
- Where are the trains? (ideas welcome)
  - Detectors (light barriers, reed contacts, ...) connected to S88 decoders, read via µC or PC (parallel port)
    - Light barriers are bulky, but known to work (somehow)
    - Mechanical items (contact rail, switch rail) need regularly cleaned tracks, and are worn out...
  - Last seminar: optical recognition (laser pointers to ceiling, tracked using two WebCams)

Agenda

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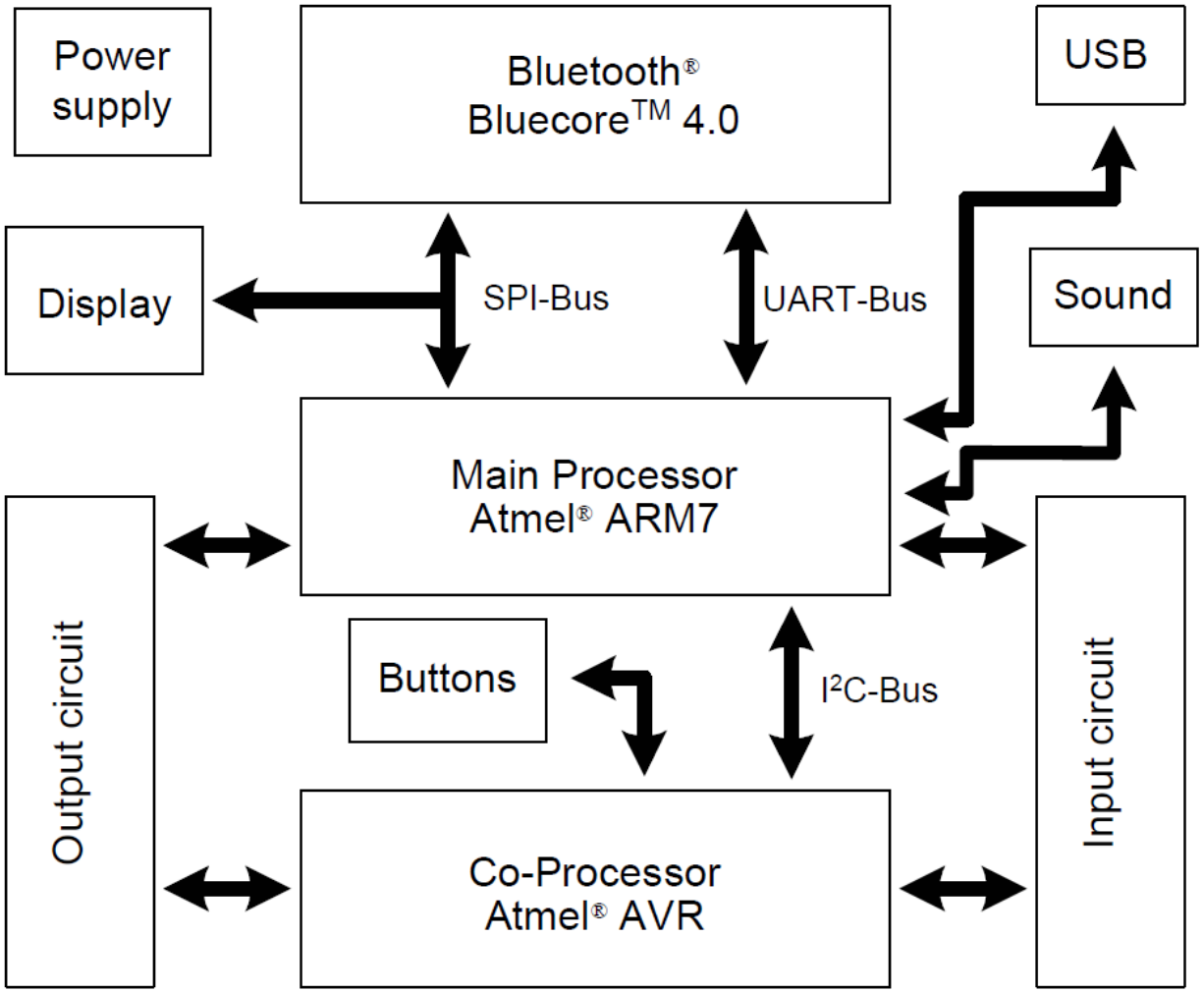
- Railroad
- Lego/NXT

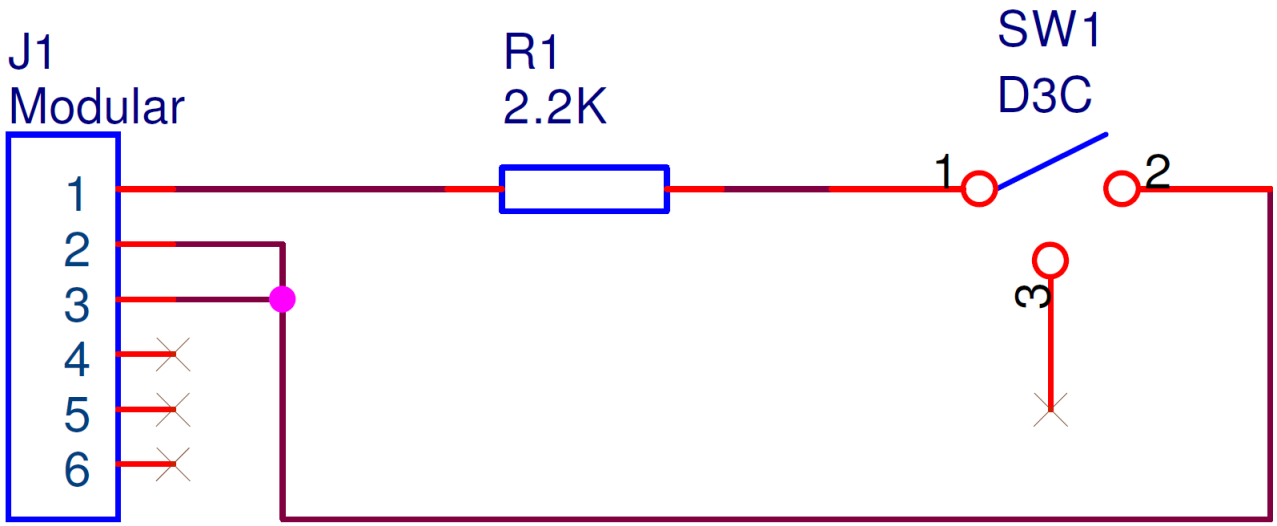
Lego – System Overview

Block Diagram NXT Brick



Source:
LEGO® MINDSTORMS® NXT Hardware Developer Kit

Touch Sensor (Switch)



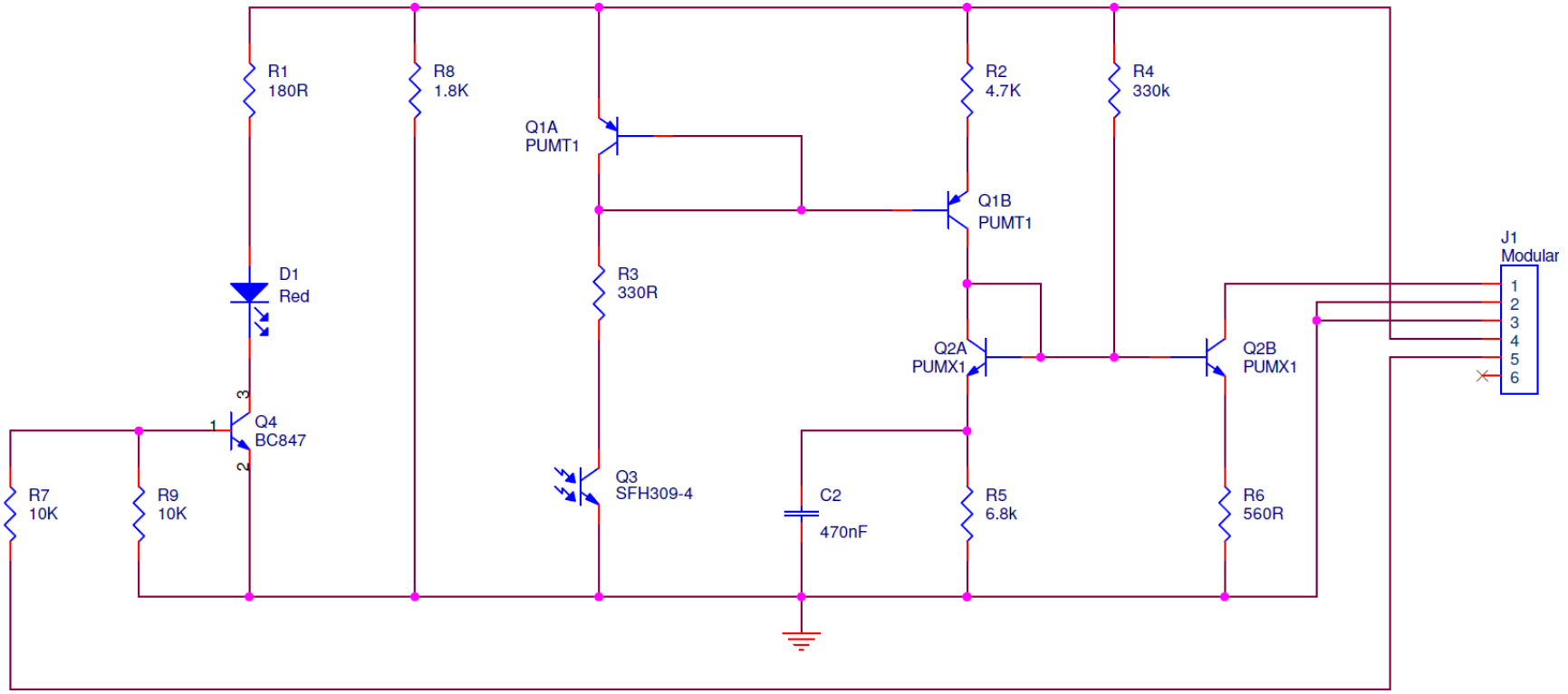
Source:

LEGO® MINDSTORMS® NXT
Touch Sensor
Hardware Schematic

Light Sensor (Reflected-Light Barrier)

Source:

LEGO® MINDSTORMS® NXT
Light Sensor
Hardware Schematic



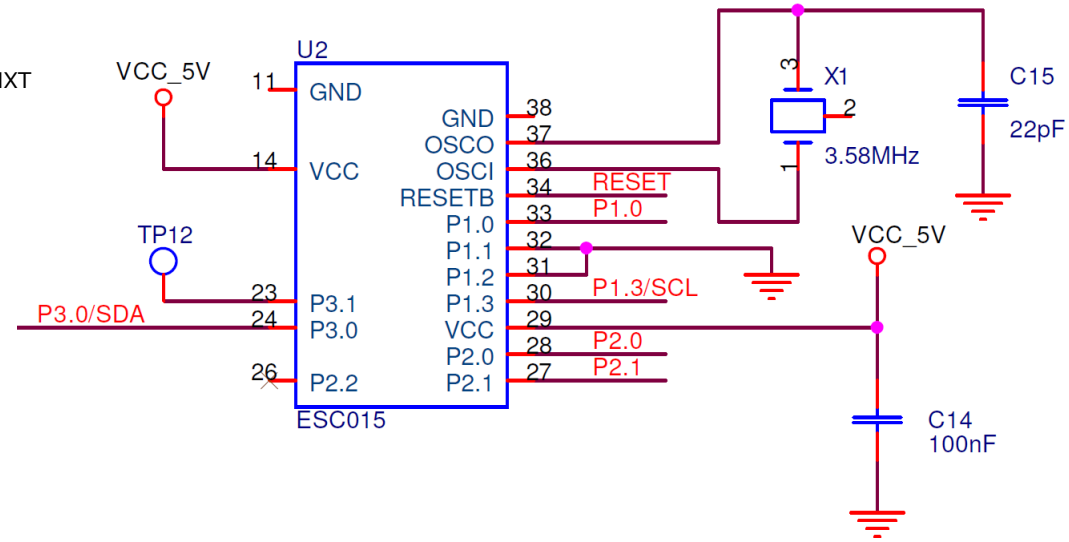
Ultrasonic Sensor (1/2)

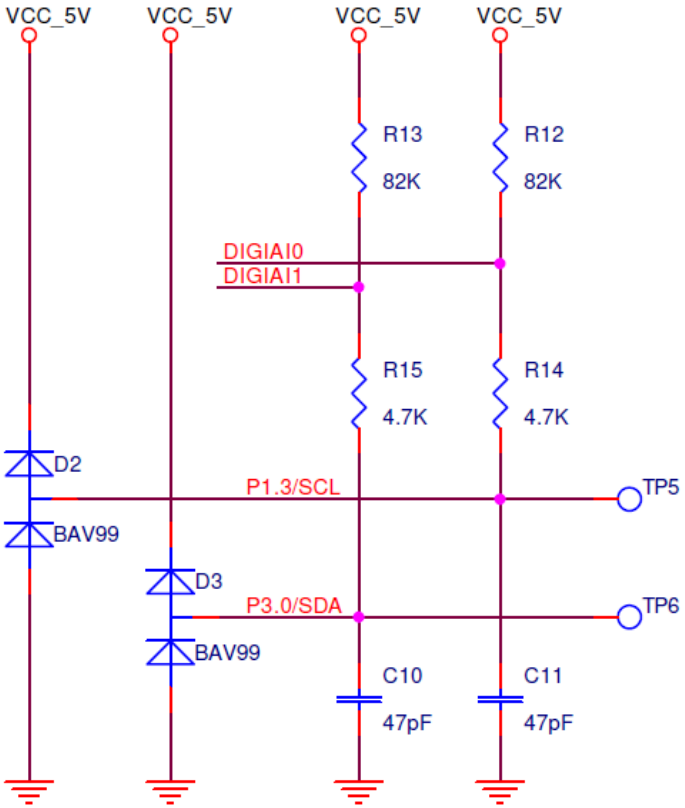
Source: LEGO® MINDSTORMS® NXT Ultrasonic Sensor Hardware Schematic

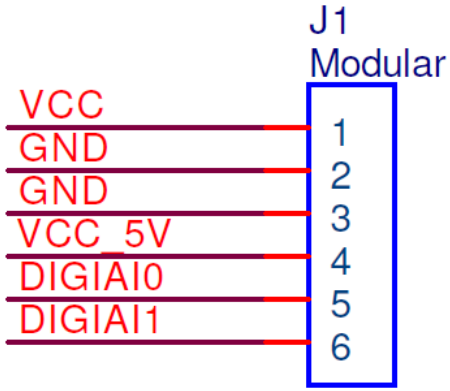
Ultrasonic Sensor (2/2)

Source:

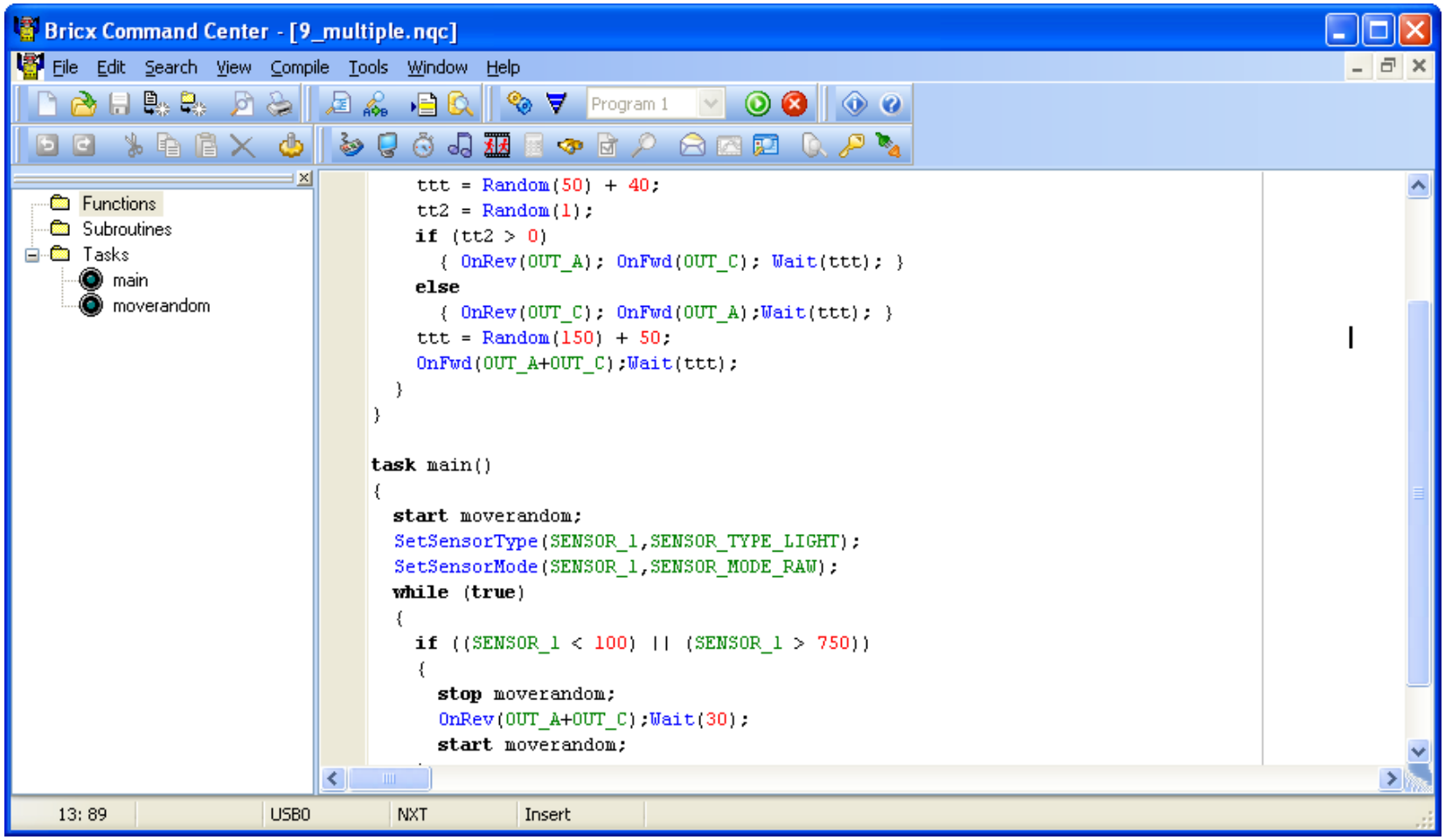
LEGO® MINDSTORMS® NXT
Ultrasonic Sensor
Hardware Schematic



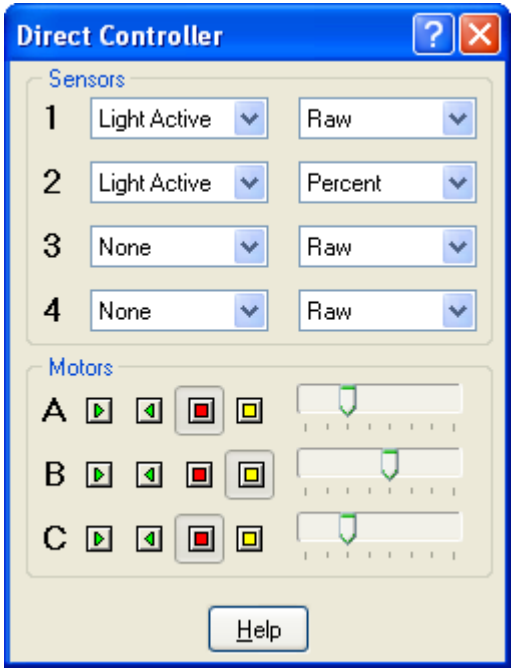


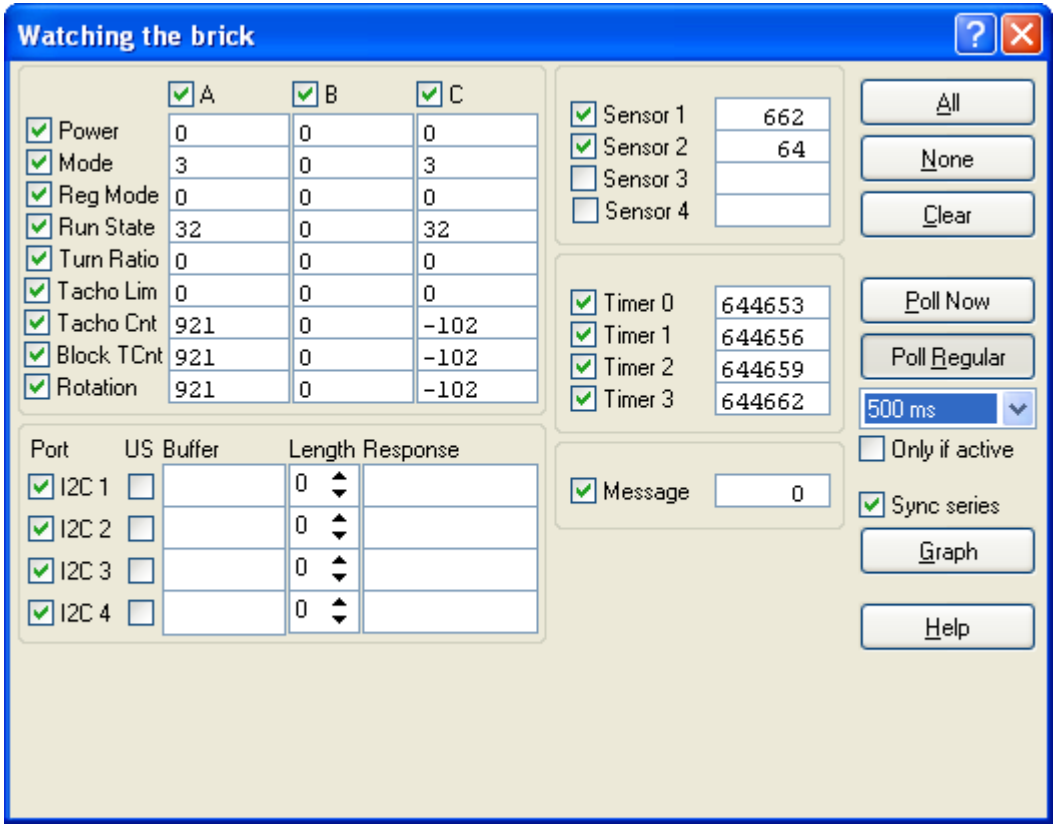


Bricx Command Center



Controller & Watcher





Project Idea

- LEGO Mindstorms NXT
  - Develop your own small operating system – thread management and scheduling

Source: http://shop.lego.com/en-DE/LEGO-MINDSTORMS-NXT-2-0-8547

Minimal
NXT Real-Time Operating System

You should implemented a minimal real-time operating system with the following features:

- Threads (minimal dispatcher + API)
- Minimal memory management (at least static stack memory management for threads)
- A static priority-based, FIFO scheduler
- A sleep function, which suspends the current thread for a specified amount of milliseconds

Minimum Set of Implemented Functions (1/2)

void create_thread (void* entry_point, int stack_size,
unsigned char priority, int* thread_id)

- Creates a new thread
- Starting with a call to entry_point
- With a stack as specified by stack_size (you are allowed to demand a fixed stack size – always 512 Byte ...)
- The thread with the highest priority runs
- Returns an ID for the thread

void terminate_thread ()

- Can only be called by a thread to terminate itself (destroy the thread control block)

Minimum Set of Implemented Functions (2/2)

- int get_thread_id ()
  - Returns the ID of the thread (just for printing/debugging)
- void sleep (int milliseconds)
  - Thread is suspended for the specified amount of milliseconds
- int tick_count ()
  - Returns the number of milliseconds since the start of the system

NXT Real-Time Operating System
Further Information

- Estimate for all functions of your operating system the worst case execution times. Is your operating system predictable? Also specify the time required for a context switch.
- Think of an example to demonstrate your operating system. Your demo application should have at least two parallel activities. For your demo application, please indicate the utilization of the threads. Also specify deadlines, periods and execution times of the parallel activities.
- As a starting point you can use an adapted version of the Lego NXT firmware. This start-kit already contains the configuration of the timer interrupt, which is necessary to implement pre-emptive scheduling.