# Connecting Lego Mindstorms NXT and RP6v2 Robot

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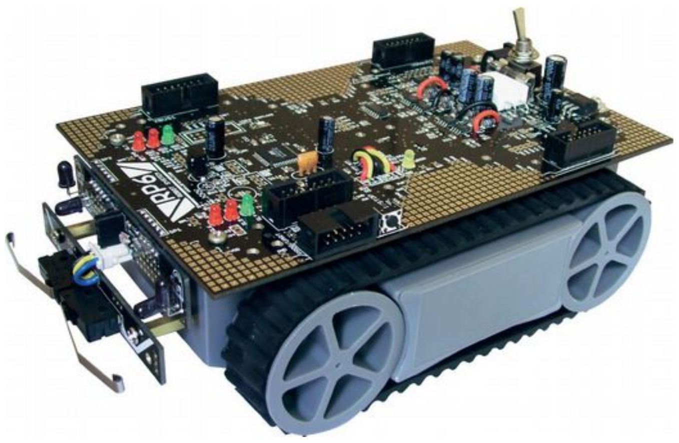

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## Motivation

The famous Lego Mindstorms NXT[i] brick controls its “smart” sensors, e.g. ultra-sound, via an I2C bus[ii]. After a small modification this bus can also be used for communicating with an Arexx RP6v2 robot[iii] (or other I2C gadgets). Below please find a collection of NXT blocks and corresponding RP6v2 software, which allow controlling a RP6v2 robot via a LEGO Mindstorm NXT.

In the future I hope to add more NXT+RP6v2 projects to the repository. For now I start with a simple crane. But the sky is the limit – let your imagination go wild!

## Requirements

The following hardware and software are required for our NXT+RP6v2 creations:

- LEGO Mindstorms NTX (e.g. set 8527) with NXT-G programming language
- custom RP6v2 blocks “NXT-RP6v2_Blocks.zip” installed (see Step 3: Install NXT Blocks)
- Arexx RP6v2 robot with WinAVR toolchain (download from http://www.arexx.com). Robot programmed with I2C slave software (see Step 2: Program the RP6v2)
- these NXT-G blocks from http://www.teamhassenplug.org/NXT/NXTGAdditions.html. Import via “Block Import and Export Wizard...” from the NXT-G “Tools” menu.
  - “Bit Logic“
  - “Display Number“
  - “IIC Read“
  - “IIC Write“
  - “IIC Read – multi“
- I2C hardware modification (see 1b: Pull-Up)
- I2C cable to connect NXT to RP6v2 (see 1a: Cable)

## Step 1: Connect NXT ↔ RP6v2

### *1a: Cable*

The cable for NXT has a proprietary RJ12 plug, while the RP6v2 has a standard multi-pin connector. To connect the two you can either assemble a new cable as described in http://www.philohome.com/nxtplug/nxtplug.htm, or modify an original NXT cables to make a Y-type adapter (see figure 1).

I have chosen the second option to allow connecting a smart sensor and the RP6v2 to the same port (only 4 ports on NXT!). Note that RP6V2 and non-I2C sensors cannot share the same port, and that not all NXT sensors communicate via I2C (touch sensor is a switch). I am not sure about all sensors, but the RP6v2 and the NXT ultra-sound sensor apparently can share one port.

On the RP6v2 side of the cable, I used a 5-pin connector to fit pin-head “I2C”, which can be found on the top, near the rear-left corner of the RP6v2 (see figure 2). For the connector pinning, see the schematic shown in figure 3.

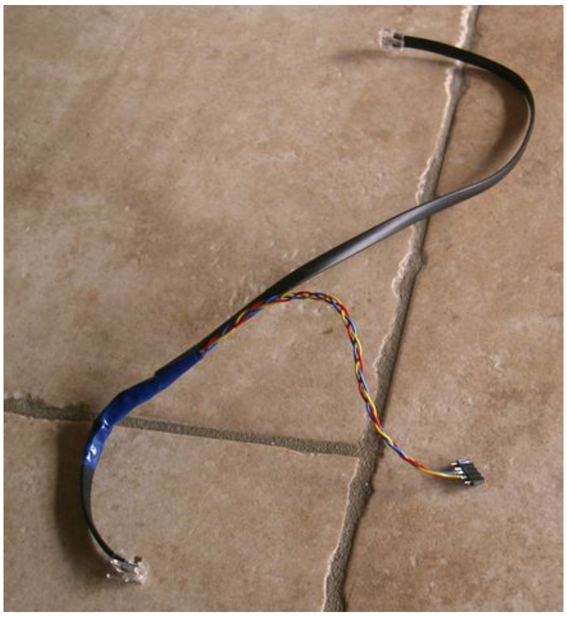


***figure 1:*** *Y-shape NXT adapter cable for RP6v2*

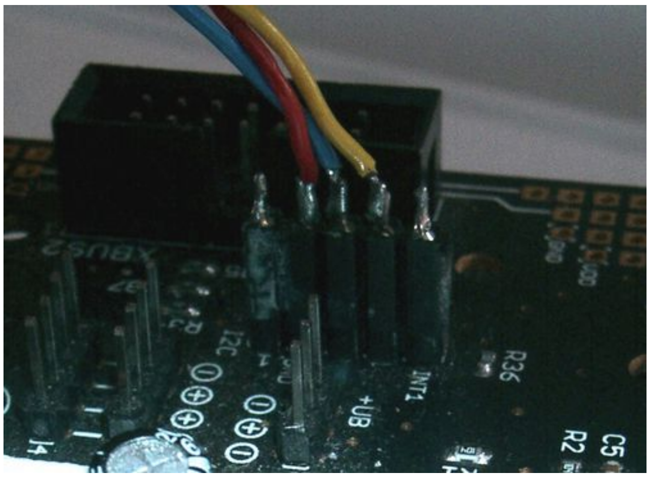


***figure 2:*** *I2C connector on RP6v2 side*

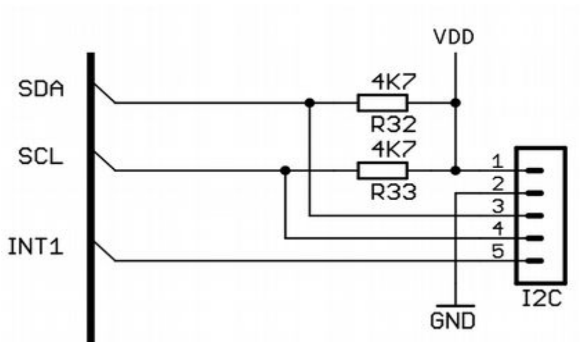


***figure 3:*** *schematics of the RP6v2 I2C connector*

| Number | NXT brick | RP6v2 |
|---|---|---|
| 1 | Analog (white) | - |
| 2 | GND (black) | GND (red) |
| 3 | GND (red) | SDA (blue) |
| 4 | Vdd=4.3V (green) | SCL (yellow) |
| 5 | SCL (yellow) | - |
| 6 | SDA (blue) | |

***figure 4:** NXT color coding and RP6v2 connector in figure 2*

### 1b: Pull-Up

The I2C bus was developed by Philips Semiconductors (now NXP) in the 1980s for on-PCB communication between ICs, e.g. microcontroller and sensors. On an I2C bus, the I2C master communicates with one or several I2C slaves, which are addressed by unique identifiers.

Other than intended by NXP, the Mindstorms NXT uses the I2C bus between separate units (i.e. brick and sensors) – and in the most difficult environment imaginable, namely children's playrooms. To improve robustness against ESD[iv], Lego therefore deviated from the I2C standard. Specifically, they implemented a 4.7kΩ series resistor for the SDA and SCL lines[v], which are missing in standard systems. As a consequence, the standard I2C 4.7kΩ pull-up resistor between SDA/SCL and Vdd is too low-ohmic and has to be replaced with a much higher value. Lego specifies a value of 82kΩ, but seemingly 47kΩ also works.

To achieve this, resistors R32 and R33 (both 4.7kΩ) on the RP6v2 have to be replaced with 82kΩ SMD resistors. Alternatively, if you have no SMD parts available, you can also remove R32 and R33, and implement the pull-up resistors in the above described cable (which I did).

## Step 2: Program the RP6v2

Since the NXT is configured as I2C master the RP6v2 has to act as an I2C slave. The provided firmware "RP6_Firmware.zip" is almost identical to the original "I2C slave" example program provided by Arexx. Specifically, only debug options have been added and unused commands disabled. In the software the I2C identifier is set by macro RP6BASE_I2C_SLAVE_ADR = 10 (line 37 in source file). If a different ID is needed the below NXT blocks have to be adapted correspondingly.

Reading a variable is simply by reading the respective I2C register on the RP6v2.

Sending a command to the RP6v6 requires the following steps:

1. if required, write parameters to 1B registers 1..6
2. write command identifier to register 0

For a full list of implemented I2C commands, please refer to Appendix: RP6v2 Commands. For NXT-G some read blocks (e.g. get bumper status) and command blocks (e.g. start motor) are provided as templates.

For support on how to compile and upload "RP6_Firmware.zip", please refer to the Arexx homepage[iii] and RP6v2 forums on the internet.

## Step 3: Install NXT Blocks

File "NXT-RP6v2_Blocks.zip" contains some blocks to control the RP6v2 via I2C and also some generic blocks. Copy all provided blocks to "~/Documents/LEGO Creations/MINDSTORMS Projects/Profiles/Standardvorgabe/Blocks/Eigene Blöcke" (on a German MacOSX system). The provided blocks for RP6v2 control are shown in figure 5.

Other functions can be added easily by modifying a read (r) or write (w) block. Section Appendix: RP6v2 Commands gives you a full list of I2C commands implemented on the RP6v2.

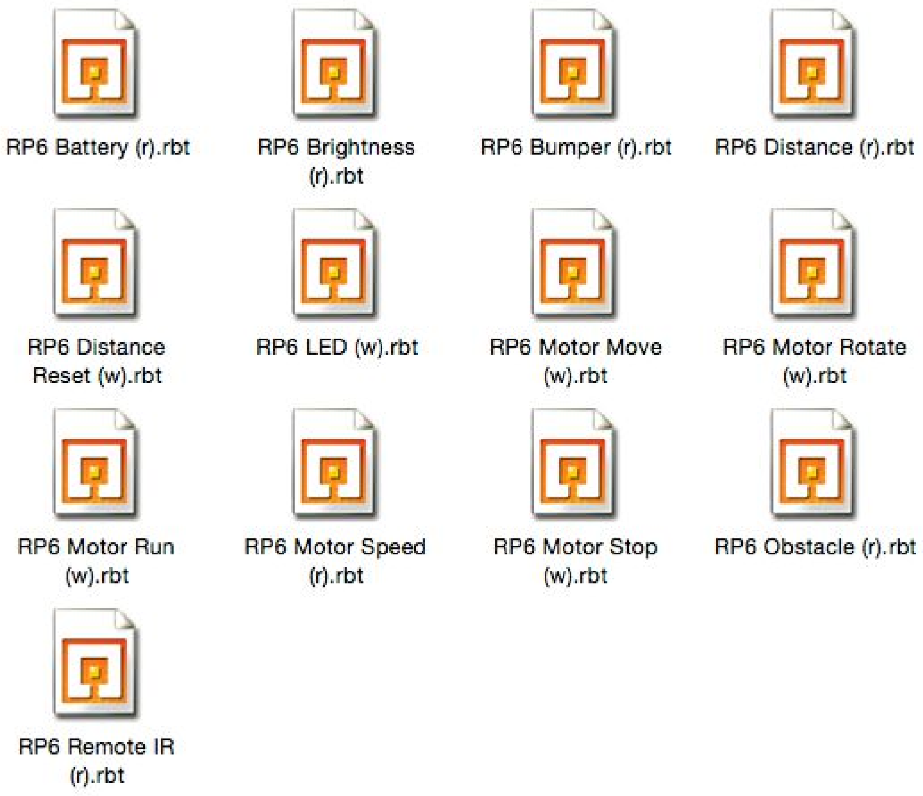
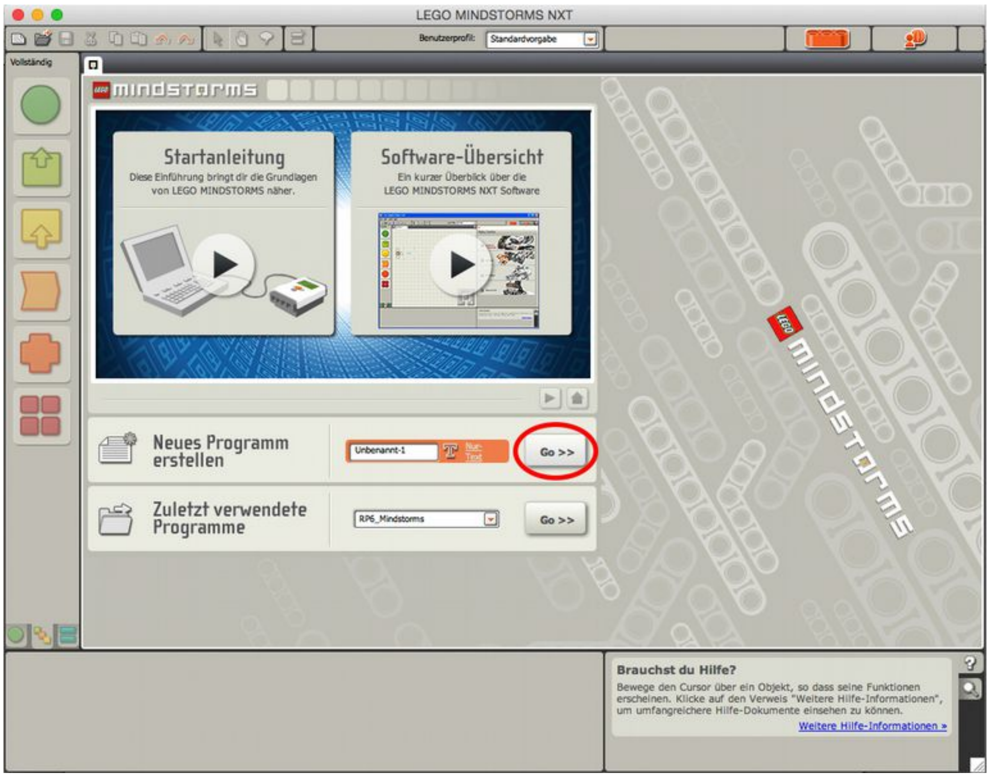


***figure 5:*** *provided NXT blocks for remote control of RP6v2 via I2C*

## Step 4: Program the NXT

Below I give a step-by-step introduction for a small NXT/RP6v2 project. The target of the project is simply move the RP6v2 forward (→ control motors) and play a sound on the NXT when the RP6v2 hits an obstacle (→ read sensor). Before we begin please make sure that the RP6v2 is connected to NXT port 3 and is programmed as I2C slave (see Step 2: Program the RP6v2). No other motor or sensor is required on the NXT.

1. launch the NXT-G IDE and start a new project

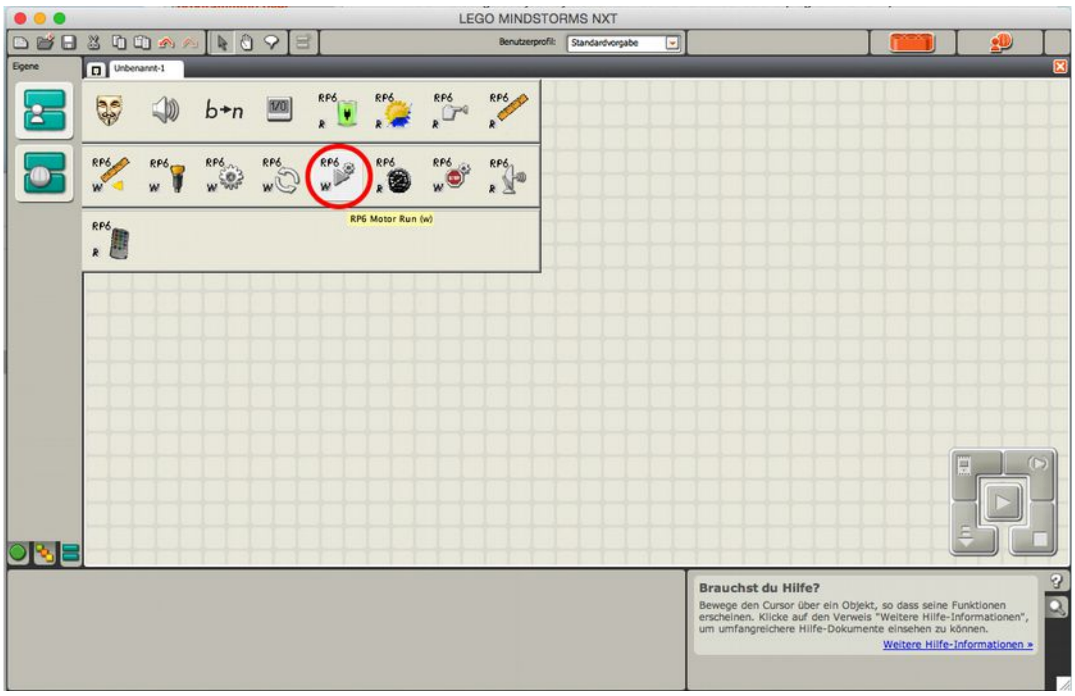


Diese Einführung bringt dir die Grundlagen von LEGO MINDSTORMS näher.

Ein kurzer Überblick über die LEGO MINDSTORMS NXT Software

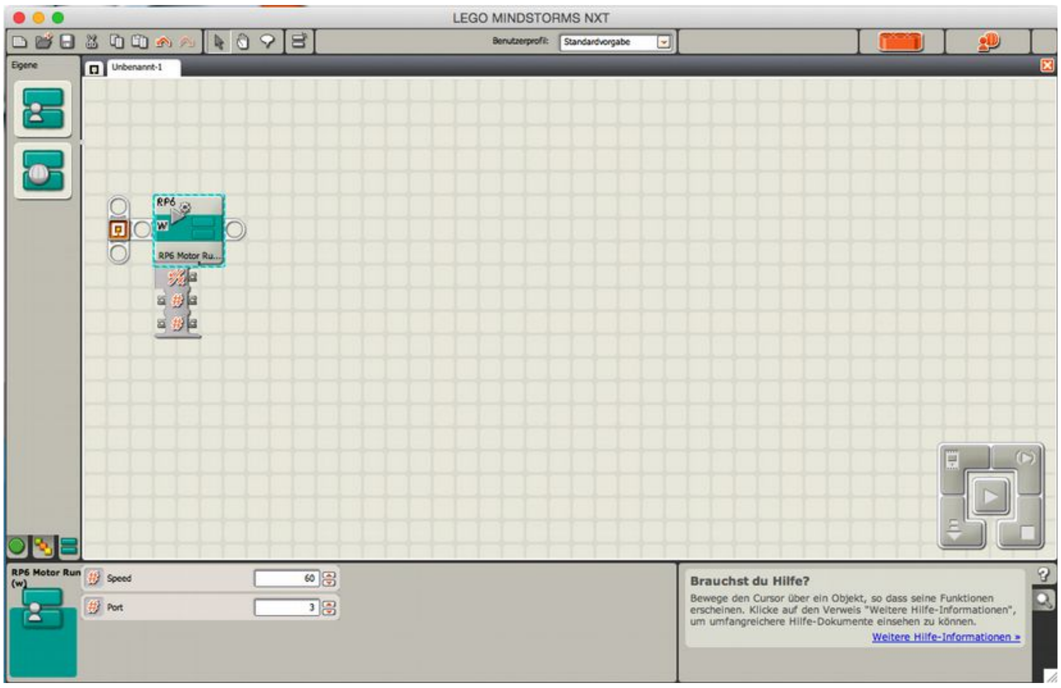
**Brauchst du Hilfe?**
Bewege den Cursor über ein Objekt, so dass seine Funktionen erscheinen. Klicke auf den Verweis "Weitere Hilfe-Informationen", um umfangreichere Hilfe-Dokumente einsehen zu können.
Weitere Hilfe-Informationen »

2. use "RP6v2 Motor Run (w)" from "Custom Palette" to start motors



**Brauchst du Hilfe?**
Bewege den Cursor über ein Objekt, so dass seine Funktionen erscheinen. Klicke auf den Verweis "Weitere Hilfe-Informationen", um umfangreichere Hilfe-Dokumente einsehen zu können.
Weitere Hilfe-Informationen »

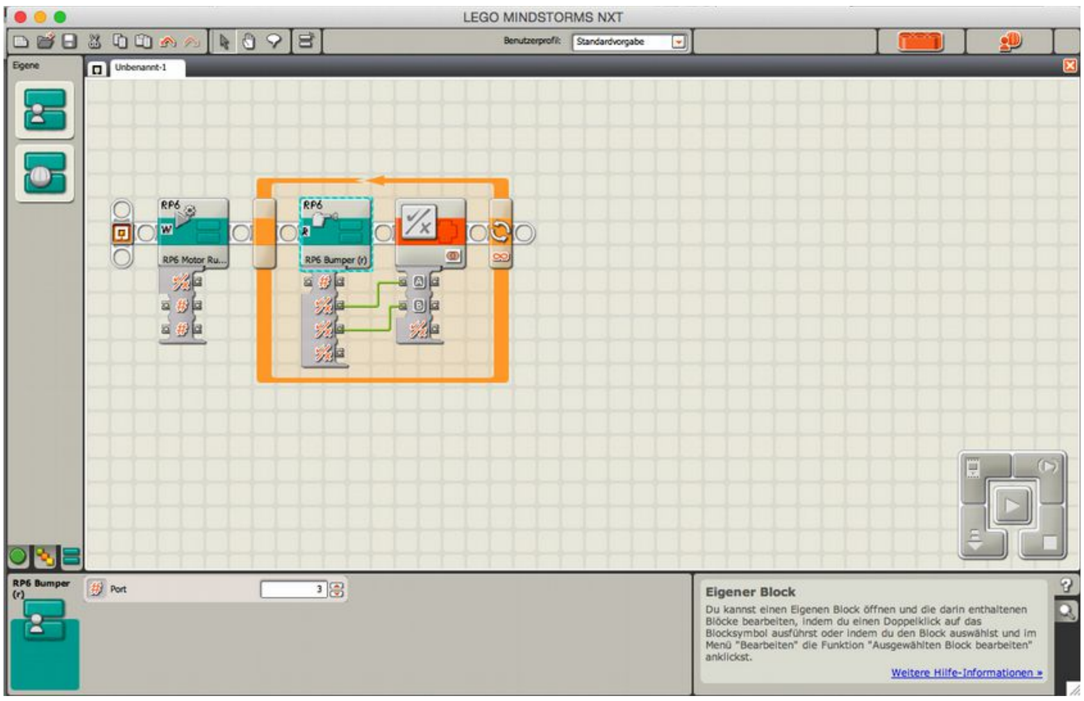
3. set port to 3 (connected to RP6v2) and motor speed e.g. to 60



Speed 60
Port 3

**Brauchst du Hilfe?**
Bewege den Cursor über ein Objekt, so dass seine Funktionen erscheinen. Klicke auf den Verweis "Weitere Hilfe-Informationen", um umfangreichere Hilfe-Dokumente einsehen zu können.
Weitere Hilfe-Informationen »

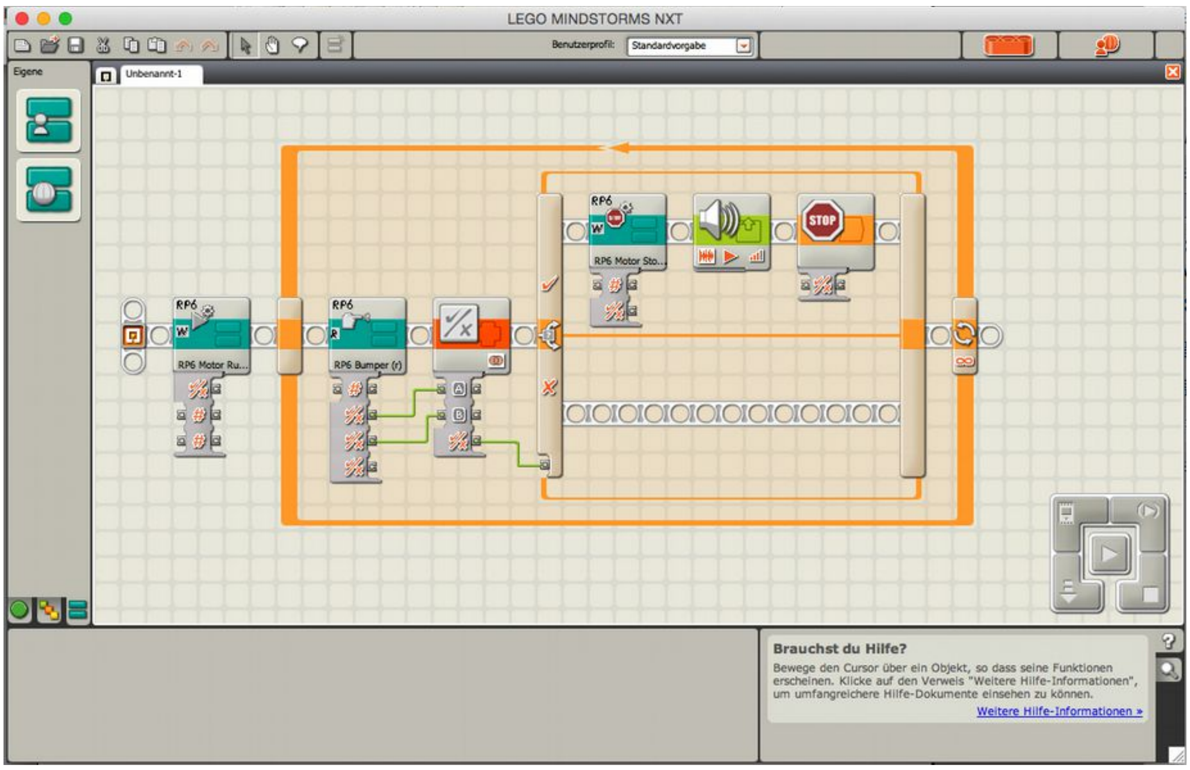
4. within endless loop, use “RP6 bumper (r)” block with port=3 to check for collisions. OR the result → TRUE if any bumper is hit.



Port 3

**Eigener Block**
Du kannst einen Eigenen Block öffnen und die darin enthaltenen Blöcke bearbeiten, indem du einen Doppelklick auf das Blocksymbol ausführst oder indem du den Block auswählst und im Menü "Bearbeiten" die Funktion "Ausgewählten Block bearbeiten" anklickst.
Weitere Hilfe-Informationen »

5. if bumper is hit, stop both RP6v2 motors using “RP6 stop motors (w)”, play a sound on the NXT and exit the program. The final project should look like this



Brauchst du Hilfe?

Bewege den Cursor über ein Objekt, so dass seine Funktionen erscheinen. Klicke auf den Verweis "Weitere Hilfe-Informationen", um umfangreichere Hilfe-Dokumente einsehen zu können.

Weitere Hilfe-Informationen »

6. upload above NXT-G project to the NXT and run. If you upload via USB disconnect cable before launching the program
7. there's no step 7. Now play and have fun!

Notes:

- in case of I2C communication errors, provided NXT blocks sound a warning
- RP6v2 needs to be in user mode to respond to I2C (green LEDs blink alternating every 1s)

# Appendix: RP6v2 Commands

## *Read Registers*

| register | bits | description | type | NXT block |
|---|---|---|---|---|
| 0 | 0 | battery low warning | logic | I2C Multiple Read |
| | 1 | bumber left | logic | |
| | 2 | bumber right | logic | |
| | 3 | IR-RC5 received | logic | |
| | 4 | IR-RC5 ready to send | logic | |
| | 5 | ACS: obstacle left | logic | |
| | 6 | ACS: obstacle right | logic | |
| | 7 | motor state changed | logic | |
| 1 | 0 | power on | logic | I2C Multiple Read |
| | 1 | ACS active | logic | |
| | 2 | watchdog timer | logic | |
| | 3 | watchdog request | logic | |
| | 4 | watchdog active | logic | |
| 2 | 0 | motor activity completed | logic | I2C Multiple Read |
| | 1 | motor running | logic | |
| | 2 | motor over-current | logic | |
| | 3..4 | direction<br>(FWD=0, BWD=1, LEFT=2, RIGHT=3) | number | |
| 3 | 0..7 | motor power left (0..210) | number | I2C Multiple Read |
| 4 | 0..7 | motor power right (0..210) | number | |
| 5 | 0..7 | motor speed left | number | RP6 Motor Speed |
| 6 | 0..7 | motor speed right | number | |
| 7 | 0..7 | target speed left | number | I2C Multiple Read |
| 8 | 0..7 | target speed right | number | |
| 9+10 | 0..15 | distance left (L+H) | number | RP6 Distance |
| 11+12 | 0..15 | distance right (L+H) | number | |
| 13+14 | 0..15 | brightness left (L+H) | number | RP6 Brightness |
| 15+16 | 0..15 | brightness right (L+H) | number | |
| 17+18 | 0..15 | motor current left (L+H) | number | I2C Multiple Read |
| 19+20 | 0..15 | motor current right (L+H) | number | |
| 21+22 | 0..15 | battery voltage level (L+H) | number | RP6 Battery |
| 23+24 | 0..15 | ADC0 (L+H) → 0..1023 | number | I2C Multiple Read |
| 25+26 | 0..15 | ADC1 (L+H) → 0..1023 | number | I2C Multiple Read |
| 27 | 0..7 | IR-RC5 address | number | RP6 Remote IR |
| 28 | 0..7 | IR-RC5 data | number | |
| 29 | 0..7 | state LEDs | number | I2C Multiple Read |

## *Send Command*

| NXT block | description | command ID | parameter 1 | parameter 2 | parameter 3 | parameter 4 | parameter 5 |
|---|---|---|---|---|---|---|---|
| RP6 LED | set LED status | 3 | bit mask LEDs<br>(0x00=all off;<br>0x01=all on;<br>>=bit 2 → mask) | - | - | - | - |
| RP6 Motor Stop | stop motor | 4 | - | - | - | - | - |
| RP6 Motor Run | start motor | 5 | speed left (0..255) | speed right (0..255) | - | - | - |
| RP6 Motor Move | drive fixed distance | 7 | speed (0..255) | direction<br>(FWD 0, BWD 1,<br>LEFT 2, RIGHT 3) | distance (HB) in encode pulses | distance (LB) in encode pulses | wait until finished? |
| RP6 Motor Rotate | rotate on spot | 8 | speed (0..255) | direction<br>(FWD 0, BWD 1,<br>LEFT 2, RIGHT 3) | angle (HB) in deg | angle (LB) in deg | wait until finished? |
| RP6 Distance Reset | reset distance measurement | 13 | - | - | - | - | - |

i Lego Mindstorms, see http://en.wikipedia.org/wiki/Lego_Mindstorms_NXT
ii I2C bus, see http://en.wikipedia.org/wiki/I²C
iii RP6v2 robot, see http://www.arexx.com/rp6/
iv Electrostatic discharges, see http://en.wikipedia.org/wiki/Electrostatic_discharge
v Mindstorms NXT I2C, see http://mbed.org/users/aworsley/notebook/lego-mindstorms-nxt-brick-interface/