Lego Interface Board 0.3

General Interface to Lego NXT Motors & Sensors

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Lego Interface Breadboard (LIB)
Best viewing with =>Office 2007

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WARNING

- Vc must be $> 6 < 9.5 \text{ Vdc}$

- Set proper power supply voltage BEFORE connecting the Lego Interface Board.

- To avoid damage to Lego products to not change or disturb circuits or operate without proper instruction, supervision, or EE knowhow.

- If a wire or component has come loose please have a supervisor repair before connecting power.
Lego Interface Breadboard

1. Lego Interface Board Formats of Use

The Lego Interface Board (LIB) provides an easy interface to motors, touch sensors, light sensor, breadboard sound sensor and a piezo speaker. Extended cable lengths are also available for tethered applications.

Altera, Xilinx, or other development kits

Microcontrollers or other Breadboard Circuits

Robot Applications

Example Youtube Robot Apps
2. Lego Interface Breadboard Proto 1.

Optional Power Switch
Banana jack Va to Vb (useful for testing)

Vc 6 - 9.5VDC
GND

Light Sensor Adjust
Sound Sensor Adjust
Microphone

Light Sensor Detect LED
Sound Sensor Detect LED

Lego Light Sensor Port
Lego Touch Sensor Port 1
Lego Touch Sensor Port 2

Motor Test DIP Switches
For normal operation all switches must be set to OFF (Open) position

Header 1
Use this header cable to interface to microcontrollers or Altera/Xilinx boards
### 3. Altera Expansion Header to Lego Interface Board Header

<table>
<thead>
<tr>
<th>Altera Expansion Header JP2 (GPIO_1)</th>
<th>Lego Interface Board Header1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Signal Name</strong></td>
<td><strong>FPGA Pin No.</strong></td>
</tr>
<tr>
<td>-----------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>GPIO_1[0]</td>
<td>PIN_K25</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>GPIO_1[2]</td>
<td>PIN_M22</td>
</tr>
<tr>
<td>GPIO_1[4]</td>
<td>PIN_M19</td>
</tr>
<tr>
<td>GPIO_1[6]</td>
<td>PIN_N20</td>
</tr>
<tr>
<td>GPIO_1[8]</td>
<td>PIN_M24</td>
</tr>
<tr>
<td>VCC5</td>
<td></td>
</tr>
<tr>
<td>GPIO_1[10]</td>
<td>PIN_N24</td>
</tr>
<tr>
<td>GPIO_1[12]</td>
<td>PIN_R25</td>
</tr>
<tr>
<td>GPIO_1[14]</td>
<td>PIN_R20</td>
</tr>
<tr>
<td>GPIO_1[16]</td>
<td>PIN_T23</td>
</tr>
<tr>
<td>GPIO_1[18]</td>
<td>PIN_T25</td>
</tr>
<tr>
<td>GPIO_1[20]</td>
<td>PIN_T21</td>
</tr>
<tr>
<td>GPIO_1[22]</td>
<td>PIN_U26</td>
</tr>
<tr>
<td>GPIO_1[24]</td>
<td>PIN_U23</td>
</tr>
<tr>
<td>VCC33</td>
<td></td>
</tr>
<tr>
<td>GPIO_1[26]</td>
<td>PIN_R19</td>
</tr>
<tr>
<td>GPIO_1[28]</td>
<td>PIN_U20</td>
</tr>
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<td>GPIO_1[30]</td>
<td>PIN_V26</td>
</tr>
<tr>
<td>GPIO_1[32]</td>
<td>PIN_V24</td>
</tr>
<tr>
<td>GPIO_1[34]</td>
<td>PIN_W25</td>
</tr>
<tr>
<td>Port</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>-------------------</td>
</tr>
<tr>
<td>2</td>
<td>GPIO_1[1]</td>
</tr>
<tr>
<td>4</td>
<td>GPIO_1[3]</td>
</tr>
<tr>
<td>8</td>
<td>GPIO_1[7]</td>
</tr>
<tr>
<td>12</td>
<td>GND</td>
</tr>
<tr>
<td>22</td>
<td>GPIO_1[19]</td>
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</table>
### Lego Interface Breadboard

<table>
<thead>
<tr>
<th>GPIO_1[21]</th>
<th>PIN_T20</th>
<th>24</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>GPIO_1[23]</td>
<td>PIN_U25</td>
<td>26</td>
<td>Input→</td>
<td>BUZZ1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPIO_1[25]</td>
<td>PIN_U24</td>
<td>28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GND</td>
<td>--</td>
<td>30</td>
<td>GND</td>
<td>GND</td>
<td>Digital GND</td>
<td></td>
</tr>
<tr>
<td>GPIO_1[27]</td>
<td>PIN_T19</td>
<td>32</td>
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<td>GPIO_1[29]</td>
<td>PIN_U21</td>
<td>34</td>
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<tr>
<td>GPIO_1[31]</td>
<td>PIN_V25</td>
<td>36</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>GPIO_1[33]</td>
<td>PIN_V23</td>
<td>38</td>
<td></td>
<td></td>
<td></td>
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<td>GPIO_1[35]</td>
<td>PIN_W23</td>
<td>40</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Signal BUZZ1 is connected to a terminal 1 on a piezo element. Terminal 2 is tied to Vc.**

### 4. Xilinx Expansion Header to Lego Interface Board Header

No information.

### 5. PIC Board to Lego Interface Board Header

No information.
## 6. Code Examples and Tutorials Download Links

<table>
<thead>
<tr>
<th>Altera DE2</th>
<th>Name of Code/Tutorial</th>
<th>Download Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interface</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Projects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lego Touch Sensor</td>
<td></td>
<td><a href="http://www.seattleu.edu/scieng/ece/projects.html">http://www.seattleu.edu/scieng/ece/projects.html</a></td>
</tr>
<tr>
<td>Lego Light Sensor</td>
<td></td>
<td><a href="http://www.seattleu.edu/scieng/ece/projects.html">http://www.seattleu.edu/scieng/ece/projects.html</a></td>
</tr>
<tr>
<td>Sound Sensor</td>
<td></td>
<td><a href="http://www.seattleu.edu/scieng/ece/projects.html">http://www.seattleu.edu/scieng/ece/projects.html</a></td>
</tr>
<tr>
<td>Piezo Speaker</td>
<td></td>
<td><a href="http://www.seattleu.edu/scieng/ece/projects.html">http://www.seattleu.edu/scieng/ece/projects.html</a></td>
</tr>
<tr>
<td>SN754410 Motor Driver</td>
<td></td>
<td><a href="http://www.seattleu.edu/scieng/ece/projects.html">http://www.seattleu.edu/scieng/ece/projects.html</a></td>
</tr>
<tr>
<td>General Projects</td>
<td></td>
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<tr>
<td>Interface</td>
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<tr>
<td>Projects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bug Pen</td>
<td></td>
<td><a href="http://www.seattleu.edu/scieng/ece/projects.html">http://www.seattleu.edu/scieng/ece/projects.html</a></td>
</tr>
</tbody>
</table>
7. Lego Interface Board Details

**Motor Driver - TI SN754410 Driver**


---

### MOTOR 1 CONTROL

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Signal Type</th>
<th>SN754410 PIN NAME</th>
<th>SN754410 Pin No.</th>
<th>PIN FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Input→</td>
<td>1,2EN</td>
<td>1</td>
<td>ENABLE MOTOR DRIVER OUTPUTS 1 &amp; 2</td>
</tr>
<tr>
<td>3</td>
<td>Input→</td>
<td>1A</td>
<td>2</td>
<td>INPUT 1</td>
</tr>
<tr>
<td>5</td>
<td>Input→</td>
<td>2A</td>
<td>7</td>
<td>INPUT 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2Y</td>
<td>DC MOTOR OUTPUT 2</td>
</tr>
</tbody>
</table>

Breadboard motor driver circuit includes 10K pulldown resistor on all SN754410 inputs

#### Function Table Motor 1

<table>
<thead>
<tr>
<th>INPUTS</th>
<th>OUTPUTS</th>
<th>MOTOR FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,2EN</td>
<td>1A</td>
<td>2</td>
</tr>
<tr>
<td>0</td>
<td>-</td>
<td>OFF</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>LOW</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>HIGH</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>HIGH</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>LOW</td>
</tr>
</tbody>
</table>

**PULSE WIDE MODULATION (PWM)** Try using a frequency of 100Hz with chip SN754410

<table>
<thead>
<tr>
<th>INPUTS</th>
<th>OUTPUTS</th>
<th>MOTOR FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PWM</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>PWM</td>
</tr>
<tr>
<td>1</td>
<td>PWM</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>PWM</td>
</tr>
</tbody>
</table>

---

### MOTOR 2 CONTROL

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Signal Type</th>
<th>SN754410 PIN NAME</th>
<th>SN754410 Pin No.</th>
<th>PIN FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Input→</td>
<td>3,4EN</td>
<td>9</td>
<td>ENABLE MOTOR DRIVER OUTPUTS 3 &amp; 4</td>
</tr>
<tr>
<td>9</td>
<td>Input→</td>
<td>3A</td>
<td>10</td>
<td>INPUT 3</td>
</tr>
<tr>
<td>13</td>
<td>Input→</td>
<td>4A</td>
<td>15</td>
<td>INPUT 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4Y</td>
<td>DC MOTOR OUTPUT 4</td>
</tr>
</tbody>
</table>

Breadboard motor driver circuit includes 10K pulldown resistor on all SN754410 inputs

#### Function Table Motor 2

<table>
<thead>
<tr>
<th>INPUTS</th>
<th>OUTPUTS</th>
<th>MOTOR FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,4EN</td>
<td>3A</td>
<td>4A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3Y</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4Y</td>
</tr>
</tbody>
</table>

Same as Function Table Motor 1 respectively
The SN754410 is a favorite hobby chip used, probable because it is one of the rare chips still in production that come in a thru-hole package. Only good for hobby stuff. Very inefficient when used as a motor driver.

The Lego Interface board includes a DIP switch for testing motors. Be sure all switches are in the OFF (OPEN) position when interfacing with other boards.
**Pulse Width Modulation Introduction**

Figure 2a shows a PWM signal at a 10% duty cycle. That is, the signal is ON for 10% of the period and OFF the other 90%. Figures 2b and 2c show PWM outputs at 50% and 90% duty cycles, respectively. The longer the signal is ON compared to the OFF periods, results in higher power supplied to the motor.

![Figure 2a](image1.png)

![Figure 2b](image2.png)
The duty cycle is defined as the percentage of digital ‘high’ to digital ‘low’ signals present during a PWM period.

Common modulating frequencies range from 1 kHz to 200 kHz with real motor drivers.

PWM can be produced by common microcontrollers or even a 555 timer circuit.

http://www.eetimes.com/discussion/beginner-s-corner/4023833/Introduction-to-Pulse-Width-Modulation
Sound Sensor Circuit

Board circuit consists of a LM324 comparator and MIC.


<table>
<thead>
<tr>
<th>Header1 Pin No.</th>
<th>Signal Type</th>
<th>LM324 Signal Name</th>
<th>LM324 Pin No.</th>
<th>Description</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>←Output</td>
<td>SDETECT</td>
<td>1</td>
<td>Non-debounced comparator output. When a sound is detected output goes HIGH.</td>
<td>Comparator Output, Normal LOW</td>
</tr>
<tr>
<td>4</td>
<td>←Output</td>
<td>DEBSDETECT</td>
<td>7</td>
<td>Debounced comparator output signal. When a sound is detected output goes HIGH for 5-20 ms</td>
<td>Comparator Output, Normal LOW</td>
</tr>
</tbody>
</table>

- POT 1 allows for sensitivity adjustment
- LED 1 flashes ON when a sound is detected
- This circuit is meant for simple clap trigger event applications
**Touch Sensor (TS) 1**

Circuit uses a 74HC14 [Schmitt Inverter](#) to debounce signal from sensor. [See circuit](#).

<table>
<thead>
<tr>
<th>Header1 Pin No.</th>
<th>Signal Type</th>
<th>TS Signal Name</th>
<th>74HC14 Pin No.</th>
<th>Description</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>←Output</td>
<td>TOUCHSEN1</td>
<td></td>
<td>Direct from Sensor</td>
<td>Non-debounced Signal. HIGH = Sensor Switch Open. LOW = Sensor Switch Closed.</td>
</tr>
<tr>
<td>16</td>
<td>←Output</td>
<td>DEBTOUCHSEN1</td>
<td>6</td>
<td></td>
<td>Debounced Signal. LOW = Sensor Switch Open. HIGH = Sensor Switch Closed. Schmitt Inverter Output. Normal LOW</td>
</tr>
</tbody>
</table>

**Touch Sensor (TS) 2**

<table>
<thead>
<tr>
<th>Header1 Pin No.</th>
<th>Signal Type</th>
<th>TS Signal Name</th>
<th>74HC14 Pin No.</th>
<th>Description</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>←Output</td>
<td>TOUCHSEN2</td>
<td></td>
<td>Direct from Sensor</td>
<td>Non-debounced Signal. HIGH = Sensor Switch Open. LOW = Sensor Switch Closed.</td>
</tr>
<tr>
<td>20</td>
<td>←Output</td>
<td>DEBTOUCHSEN2</td>
<td>4</td>
<td></td>
<td>Debounced Signal. LOW = Sensor Switch Open. HIGH = Sensor Switch Closed. Schmitt Inverter Output. Normal LOW</td>
</tr>
</tbody>
</table>

---

[Lego Touch Sensor Schematic](#)
Example 1: Touch Sensor Switch Bounce When Pressed
(1 ms per division zoom-in capture) Yellow = TOUCHSE nx

Example 2: Switch Bounce When Pressed. Yellow = TOUCHSE nx
Example 1: Switch Bounce When Released. Yellow = TOUCHSENx

Example 2: Switch Bounce When Released. Yellow = TOUCHSENx
Touch Sensor Debounce Circuit

Non-debounced signal TOUCHSENX (Yellow) and debounced signal DEBTOUCHSENX (Green)
(5 ms per division zoom-out capture)

This is typically what you should expect.
Switch Pressed & Released: No Capacitor C1: Yellow = TOUCHSENx, Green = DEBTOUCHSENx

Switch Pressed: No Capacitor C1: Yellow = TOUCHSENx, Green = DEBTOUCHSENx
Lego Interface Breadboard

Switch Released: No Capacitor C1: Yellow = TOUCHSENx, Green = DEBTOUCHSENx

Switch Pressed: With Capacitor C1: Yellow = TOUCHSENx, Green = DEBTOUCHSENx
Lego Interface Breadboard

Switch Released: With Capacitor C1: Yellow = TOUCHSENx, Green = DEBTOUCHSENx

Switch Pressed & Released

This is what to expect on TOUCHSENx (Yellow) & DEBTOUCHSENx (Green)
Light Sensor

Circuit consists of a LM324 comparator to convert the Lego light sensor’s analog signal to digital bit.

<table>
<thead>
<tr>
<th>Header1 Pin No.</th>
<th>Signal Type</th>
<th>Signal Name</th>
<th>Description</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Input→</td>
<td>DIGIC10</td>
<td>Input to Lego Light Sensor. LOW = Disable Lego Light Sensor (Turns Output LED OFF) HIGH = Enable Lego Light Sensor (Turns Output LED ON)</td>
<td>10K Pulldown</td>
</tr>
<tr>
<td>8</td>
<td>←Output</td>
<td>LDETECT</td>
<td>Debounced Signal. When reflected light is detected LDETECT goes LOW. Normal HIGH. • Sensitivity is adjustable by POT2. You may need to adjust POT2 for different colors and glossy-flat finishes. • LED 2 is ON when light has crossed threshold</td>
<td>Output from Comparator</td>
</tr>
</tbody>
</table>

Light Sensor Function Table

<table>
<thead>
<tr>
<th>INPUTS</th>
<th>CONDITION</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIGIC10</td>
<td>REFLECTION</td>
<td>LDETECT</td>
</tr>
<tr>
<td>LOW</td>
<td>DON’T CARE</td>
<td>HIGH</td>
</tr>
<tr>
<td>HIGH</td>
<td>NO</td>
<td>HIGH</td>
</tr>
<tr>
<td>HIGH</td>
<td>YES</td>
<td>LOW</td>
</tr>
</tbody>
</table>

Lego Light Sensor Schematic
<table>
<thead>
<tr>
<th>Header1 Pin No.</th>
<th>Signal Type</th>
<th>Signal Name</th>
<th>Description</th>
<th>LIB Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>Input→</td>
<td>BUZZ1</td>
<td>Signal BUZZ1 is connected to the negative terminal on the LIB piezo element. The positive terminal is tied to Vc.</td>
<td>Piezo buzzers require an oscillating frequency in the audible range in order to generate sound similar to a speaker but with much higher impedance, hence does not require much current.</td>
</tr>
</tbody>
</table>

Continued below...
8. Robot Applications

Controlled by breadboard microcontroller or Altera Board.

Six D size batteries provide power to both the Altera DE2 and motors-sensors.

Best to use NiMH batteries. Always monitor battery voltage before use under load condition.
Lego Interface Breadboard

- Extended cable lengths are also available for tethered applications.

Altera DE2 interfaced to Lego products: [http://www.youtube.com/watch?v=sIWRuqNM3Xc](http://www.youtube.com/watch?v=sIWRuqNM3Xc)

Iphone controlled Lego: [http://www.youtube.com/watch?v=7pIS69teEvw&feature=related](http://www.youtube.com/watch?v=7pIS69teEvw&feature=related)