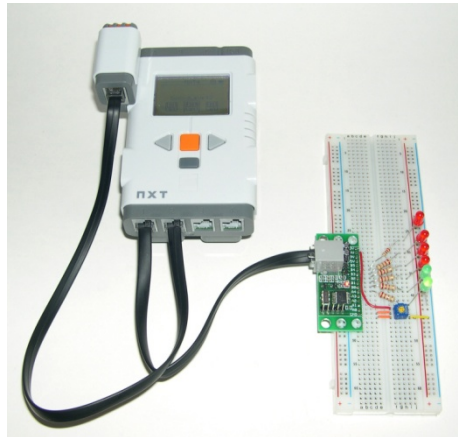




# HiTechnic Experimenter's Kit Handbook

**Electronic designs and experiments for LEGO® NXT  
and the HiTechnic Prototype Board**



**Experimenter's Kit A**

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# HiTechnic Experimenter's Kit Handbook

Experimenter's Kit A

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# Introduction

This HiTechnic Experimenter's Kit Handbook A is a guide to the HiTechnic Experimenter's Kit and guides the reader through the steps necessary to assemble electronic circuits and write companion programs for the LEGO MINDSTORMS NXT. The Experimenter's Kit is a great way to learn more about the exciting world of electronics and how to use NXT in conjunction with the circuits created.

This handbook will guide you through the process of

- identifying electronic components
- circuit diagram basics
- step by step instructions to use components to build circuits
- create NXT programs to control and interact with the electronic circuits you build.

The HiTechnic Experimenter's Kit contains all the parts needed to build the electronic circuits for each experiment plus many other circuits you may wish to design.

HiTechnic thanks Xander Soldaat and Jason Kremer for their contributions during the development of this handbook and the experiments.


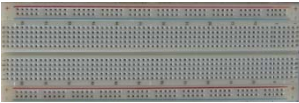






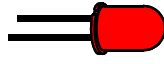
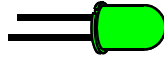
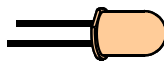


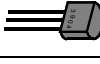
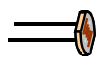
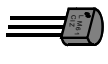
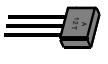

## Handling Warning

The Prototype sensor and electronic parts used to create circuits may be damaged by static discharge so care must be taken when handling the sensor and components to avoid static.

The components and the HiTechnic Prototype board are packaged in antistatic packaging. It is recommended you store the items in the original packaging when not in use.

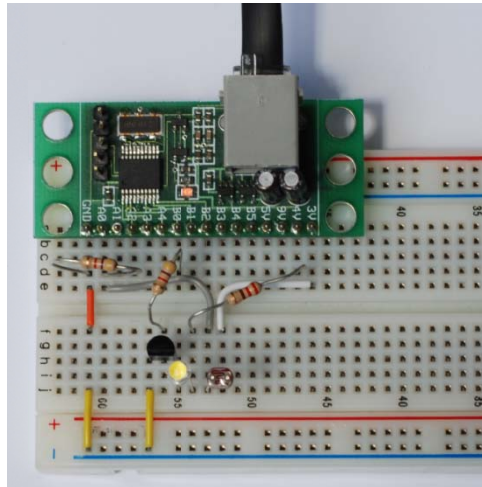


# Experimenters Kit A Contents

Qty	Description	Image
1	HiTechnic Solderless Prototype board for MINDSTORMS NXT	
1	Solderless breadboard	
1	Jumper wire set	
6	220 ohm resistor	
2	4,700 ohm resistor	
2	10,000 ohm resistor	
1	10K ohm potentiometer	
1	1.0 microfarad capacitor	
4	Red Light Emitting Diode	
2	Green Light Emitting Diode	
1	High Brightness Light Emitting Diode (clear dome)	
1	Red push button	
1	Green push button	
1	2N3904 transistor	
1	Photo-sensor	
1	Temperature sensor	
1	Magnetic sensor	
1	Magnet	

# Getting Started

The HiTechnic NXT Solderless Prototype board is designed to be plugged into a solderless breadboard. Circuits can be built up on the breadboard as shown below.

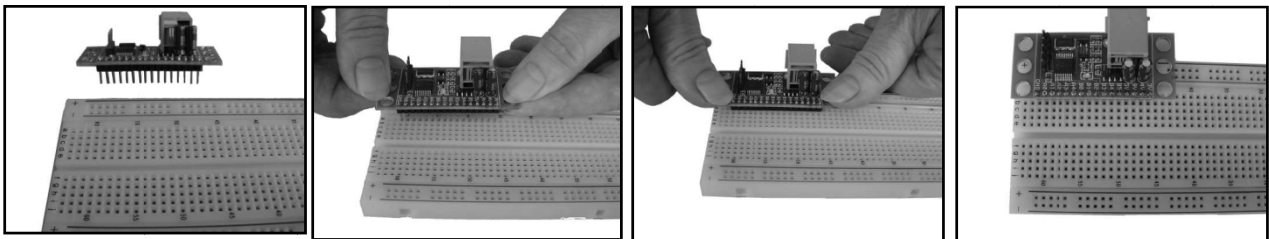


It is recommended that you attach it as described so its placement will match the instructions for each experiment.

The Solderless breadboard is the perfect platform for experimenting with electronics. The breadboard has rows of holes, into which you push the components and jumper wires to make up your circuit. When a component is pushed into a hole in the breadboard it makes contact with a contact grid. The connections within the breadboard kit will be covered later.

The board has 16 pins on the bottom which must be pushed into holes *a61* - *a46* of the solderless breadboard.

1. Take the board and hold it so the pins are straight and above the target holes.
2. Press straight down applying even pressure.

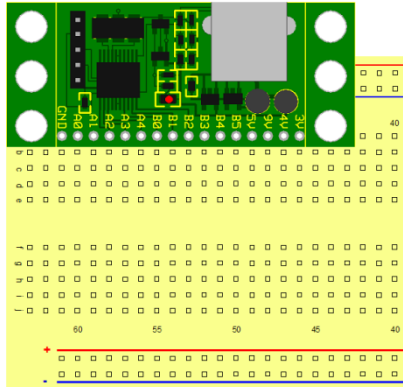


All the experiments in this handbook illustrate the prototype board installed in this position and this matches the layout drawings.

## NXT Programs

Example NXT programs for each experiment can be downloaded from [www.hitechnic.com/downloads](http://www.hitechnic.com/downloads). Programs are available for NXT-G, NXC, LabVIEW and RobotC. A full list of example programs for each of the programming languages is shown in Appendix 1.

## The layout diagram

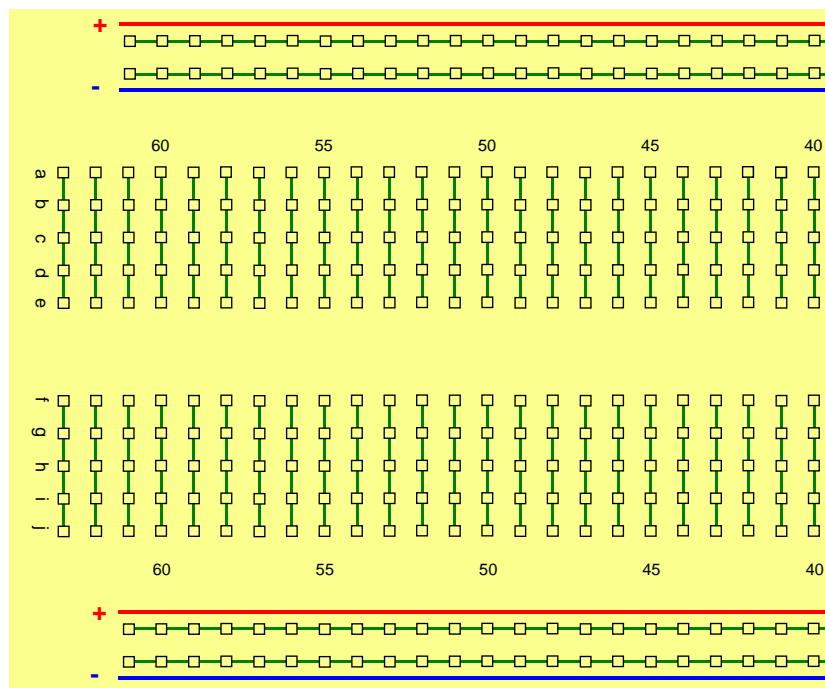


The solderless version of the Prototype board has 16 pins on the underside of the board with the intention of making it easy to attach to a solderless bread-board.

The holes in the board can be used to attach the board to LEGO brick studs if required.

## The solderless breadboard

The solderless breadboard connects the holes both horizontally for the power busses that are along the top and the bottom of the breadboard and vertically for the signals as shown by the lines superimposed on the diagram below.



# Organizing the Electronic Components

The electronic components in the Experimenter kit are easily identified and can be organized into component types and value.

## Component list

Part type	Quantity
Resistor, 220 ohm	6
Resistor, 4,700 ohm	2
Resistor, 10,000 ohm	2
Potentiometer, 10,000 ohm	1
Capacitor, 1.0uF	1
LED, red, display	4
LED, green, display	2
LED, high brightness, clear dome	1
Transistor, 2N3904	1
Photosensor	1
Magnetic sensor	1
Temperature sensor	1
Pushbutton, red	1
Pushbutton, green	1
Magnet	1

The parts can be divided into five categories,

- Resistors
- Capacitors
- Opto-electronic devices
- Semiconductors
- Electro-mechanical devices.

## Resistors

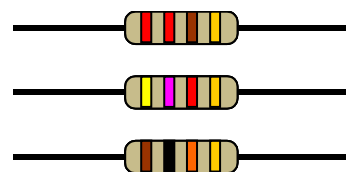
The resistors are the small tubular items with colored bands printed around them. Each resistor has four bands which are used to encode the value of the resistor as measured in ohms.











The first two bands define the first two digits of the value.

The third band is the multiplier used to show how many zeros follow the first two digits.

The fourth band is gold colored indicating that the resistance value is accurate to 5%.

The following table shows the colors used in the bands and the value. Using this chart you can determine the value of each of the resistors.

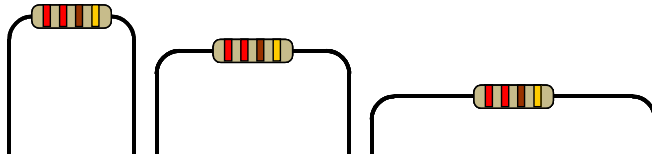


Color	Value	Multiplier
	0	
	1	0
	2	00
	3	000
	4	0000
	5	00000
	6	000000
	7	
	8	
	9	

For the 3 different values of resistor supplied in this kit, 220 ohms is red – red – brown. 4,700 ohms is yellow – violet – red and 10,000 ohms is brown – black – orange.

Hint:

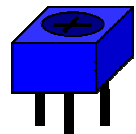
We recommend that you do not cut the resistor leads, instead bend the leads to make the resistor span the number of holes in the breadboard needed for each experiment.



Resistor Symbol

## Potentiometer

A potentiometer is a resistor with a sliding contact that adjusts the resistance. The resistance value will vary from 0 to the maximum value of the potentiometer.



Potentiometer Symbol

## Capacitors

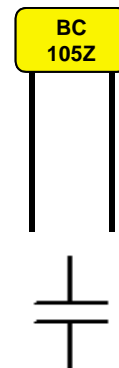
There is one capacitor included with this kit. Capacitors usually have their value printed on the part and in this kit, the value is 105.

Much like resistors, the first two digits are the value while the third is the multiplier. The multiplier states how many zeros have to be added to the value digits, so in the case of this capacitor, the value is 10 followed by 5 zeros, thus 1000000.

The units in this case are pico-Farads (pF) or  $10^{-12}$  of a Farad. The Farad as a unit of measurement is excessively large. Since this capacitor is 1,000,000 pico-Farads, it can also be referred to as 1.0 micro-Farads ( $\mu\text{F}$ ).

The micro-Farads ( $\mu\text{F}$ ) units in this case are  $10^{-6}$  of a Farad.

Note: The appearance of the capacitor may vary.



Capacitor Symbol

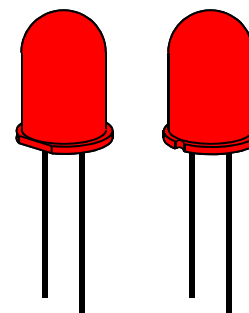
## Opto-Electronic devices

The opto-electronic devices included in this kit are LEDs and a photocell.

### LED

LEDs, or Light Emitting Diodes, can be switched on and off like other lights but are smaller and use much less current. Each LED is polarity sensitive, meaning it will only operate if connected the right way around. The lead, referred to as the cathode, which must be connected to the negative side of the power source, is usually signified by the shorter of the two leads and can be often further identified as on the side with a flat section or notch in the rim around the bottom of the LED body.

The other lead, which is referred to as the anode, must be connected to the positive side of the power source and is usually the longer of the two leads.

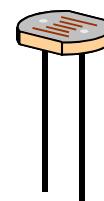


LED Symbol

### Photo Cell

The photo-cell is a resistive cadmium-sulfide type which is not polarity sensitive so, unlike the LED, will work either way around in the circuit.

This component works by decreasing its resistance as the level of light increases. Its spectral response is very similar to the human eye, peaking between green and red.



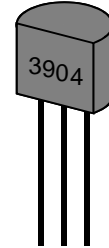
Photocell Symbol

## Semiconductors

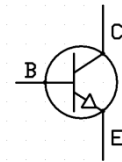
The semiconductor devices include a transistor, a magnetic Hall effect sensor chip and a temperature sensor chip.

### Transistor

The transistor is an NPN type 2N3904. This device operates with a positive supply. The negative supply is applied to the emitter (E) pin. The control input, the base (B) pin, requires a small current to flow into it to control the much larger output current which will flow from the load connected to the positive supply into the collector (C) pin.



The standard schematic symbol for the transistor is shown with the three leads identified.

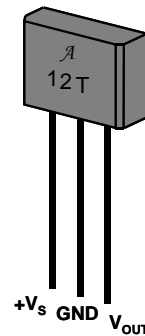


Transistor Symbol

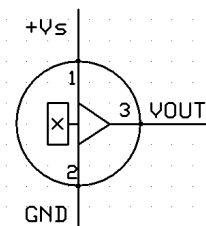
### Magnetic Hall-effect Switch

The magnetic Hall effect sensor chip detects either north or south poles of a magnet.

The chip contains a Hall effect sensor and electronics to amplify and condition the signals produced.

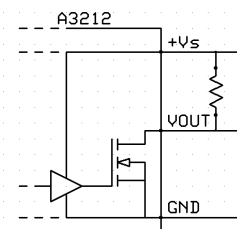


The center ground (GND) pin should be connected to the system ground. The power pin (+Vs) should be connected to the 3.3v supply.



Hall-effect detector symbol

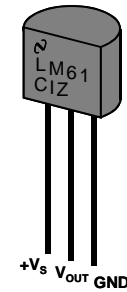
The output pin (VOUT) is unusual in that it is set up in an “open drain” configuration. This means it behaves like a switch connected to ground. In order to obtain a signal voltage from this device, it is necessary to provide a “pull-up resistor”.



## Temperature Sensor Chip

The temperature sensor chip measures the temperature of its package and thus the air or other object that is touching the sensor.

The chip contains a temperature sensor and electronics to amplify and condition the signal produced.

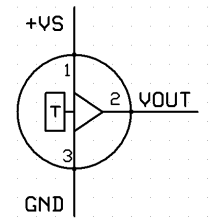


The ground (GND) pin should be connected to the system ground. The power pin (+Vs) should be connected to the 3.3v supply. The output pin (VOUT) provides a voltage that is proportional to temperature, thus;

$$V_{out} = 10 \times T + 600$$

where T is the package temperature in °C and VOUT is the output voltage in milli-volts.

The temperature sensor is able to measure temperatures over the range -30°C to 100°C.



## Other Components

### Magnet

The magnet included in the kit can be used to activate the Hall Effect sensor. Just place the magnet close to the sensor to trigger a change in the sensor's output.

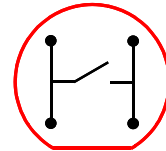
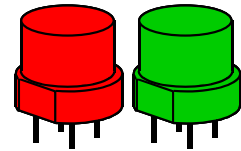


Just

### Switch

The two switches included in the kit are push button switches so the switch is closed (makes an electrical connection) when it is pushed.

These buttons have four leads organized as two pairs as shown. It is therefore important to mount the button correctly in the solderless breadboard to ensure the switch doesn't appear to be permanently closed.



## Component Specifications

Appendix 1 has a list of manufacturers of the opto-electronic, semiconductors and electro-mechanical devices with links to manufacturers web sites where you will find complete specifications.

# Experiment - 1 Introduction to the Prototype Board

This experiment will introduce you to the HiTechnic NXT Solderless Prototype Board and techniques to create circuits.

With this experiment you will build a simple circuit with a switch and one LED. The NXT program for this circuit reads the status of the switch and when it is closed (the switch is pressed), the program will power the LED.

## Parts

The parts needed for this circuit are;

Part	Quantity	Notes
220 Ohm resistor	1	red – red –brown - gold
10K Ohm resistor	1	brown – black – orange – gold
LED	1	red
Switch	1	red button switch

Make sure the Prototype board is installed in the breadboard as described in section 1.

Insert the 10K ohm resistor so it connects between GND and A0 connections on the Prototype board. Remember that breadboard connections run across the width of the breadboard so you will insert the resistor leads as shown in Figure 1. Bend the leads so the can be inserted as shown.

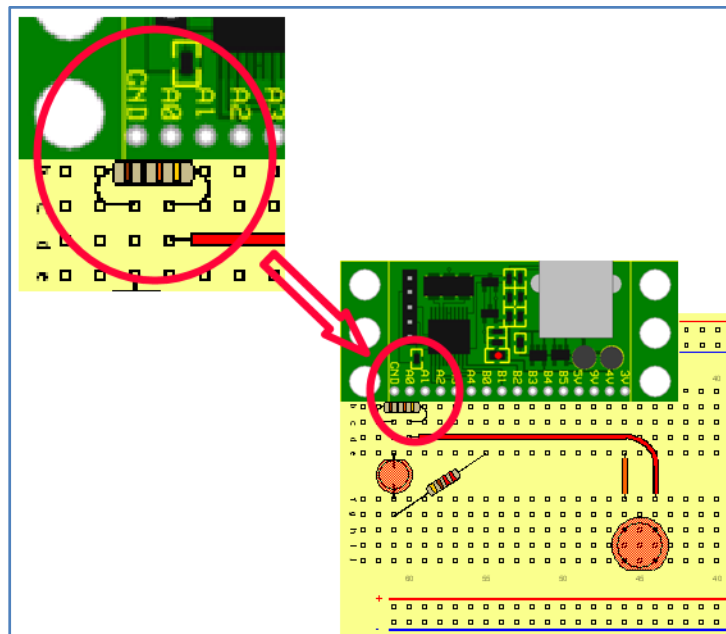


Figure 1

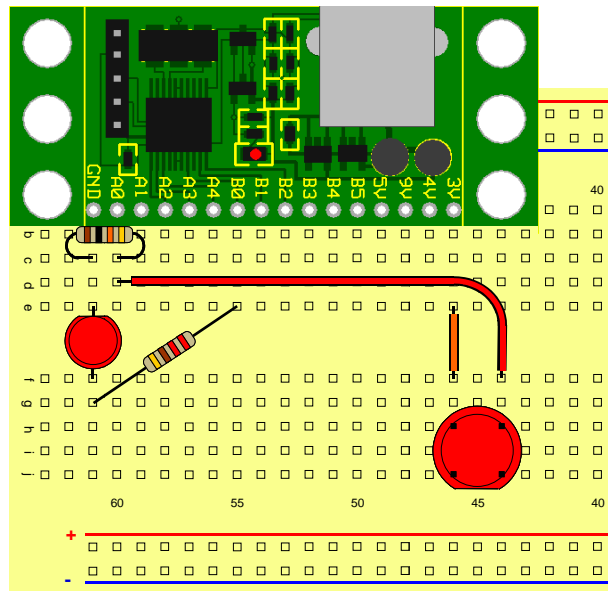
Insert the LED as shown. Note that the LED has a flat or notch on one side and this must face towards the prototype board.

Insert the 220 Ohm resistor as shown between B0 and the LED.

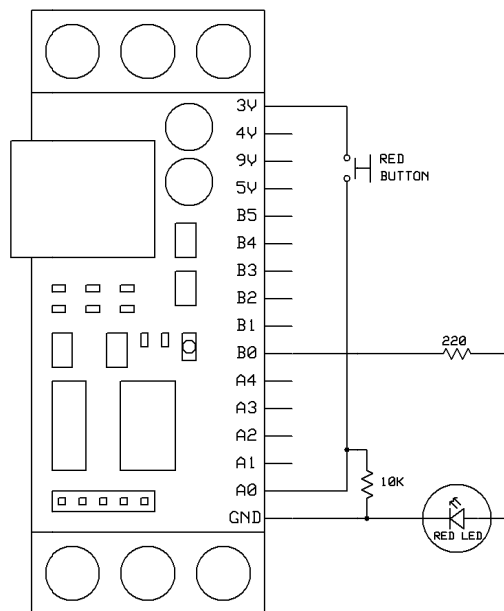
Insert the switch with the flat side is facing away from the prototype board and the left 2 leads line up with the 3V connection.

NOTE: The jumper wires are different colors, based on their length. For this circuit we will use one red and one orange wire. These can be installed as shown.

The circuit is now complete



## Circuit Diagram



## Programming

Each experiment has test programs in different programming languages. Download the programs from the HiTechnic web site [www.hitechnic.com](http://www.hitechnic.com). For this circuit use the program Exp1.rbt for

MINDSTORMS NXT-G or the appropriate program type if using another programming environment.

This test program will read the voltage across the 10K ohm resistor and turns the LED on if this voltage is greater than half the maximum possible voltage. When you press the switch, the NXT program will turn the LED on by writing a 1 to the digital output port.

Now you have successfully built your first circuit, move onto the more complicated experiments.

## Experiment - 2      Six LEDs and a potentiometer

This experiment demonstrates how to read an analog device, in this case a variable potentiometer, and output a digital value that is used to drive 6 LEDs.

Parts

The parts needed for this circuit are;

Part	Quantity	Notes
220 Ohm resistor	6	Red – red –brown - gold
10k potentiometer	1	
LED	6	2 green, 4 red

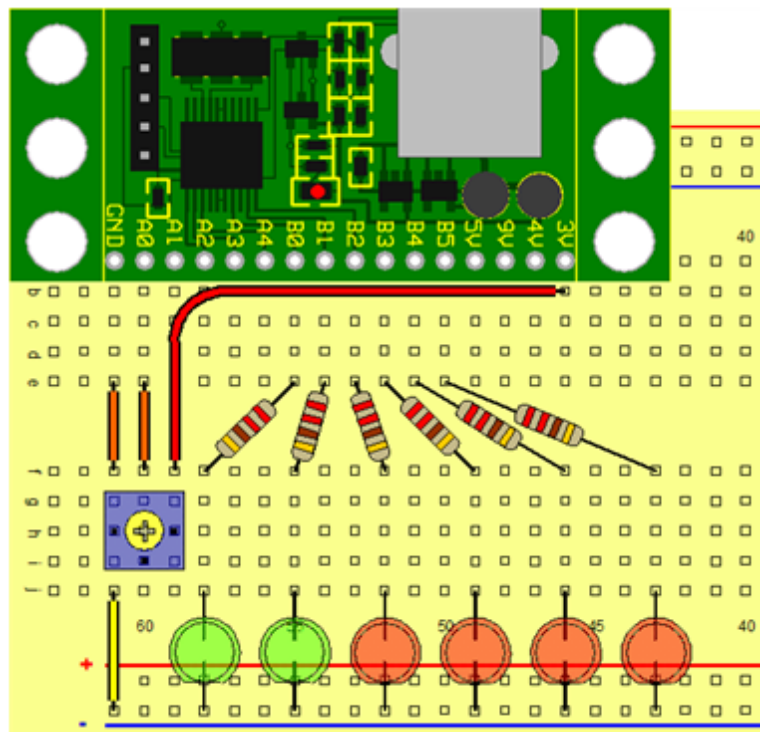
Make sure the prototype board is installed in the breadboard as described in section 1.

Install the components starting with the resistors. It does not matter which way around resistors go. Install the first resistor to line up with port B0 as shown. Then connect the other five resistors to port B1 through B5.

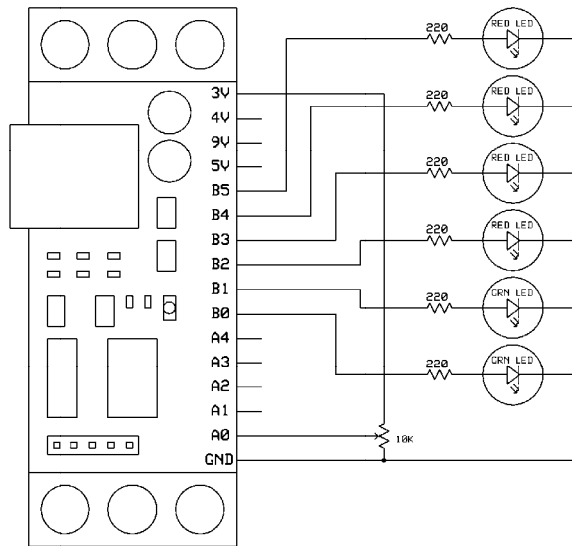
Install the LEDs making sure the cathode lead (next to the flat or notch on the LED case) is connected to the negative power bus (outer row of holes). The other LED lead is connected to each of the resistors.

Install the potentiometer as shown so the three leads line up with GND, A0 and A1.

Use jumper wires to complete the circuit as shown. The wires are color coded based on their length. This circuit can be completed with two orange, one yellow and one red wire.



## Circuit Diagram



## Programming

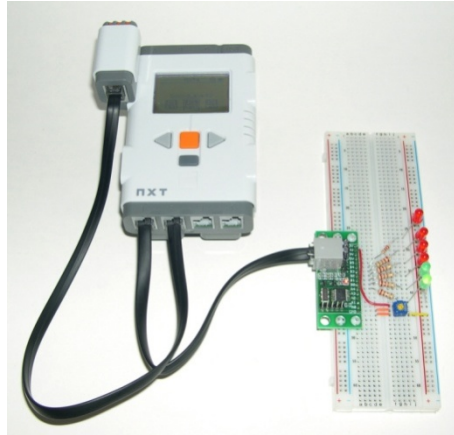
The NXT-G program Exp2\_6LED.rpt can be loaded using the Mindstorms software. Make sure the Prototype board is connected to sensor port 1 of your NXT.

The program reads the analog port A0 to read the voltage from the potentiometer and uses this value to decide which LED to turn on. The LEDs are turned on by writing the correct value to the digital port.

As you turn the potentiometer clockwise, you'll notice that the LEDs turn on in sequence. This sequence has been made deliberately *non-linear*. Non-linear means that the voltage levels at which each LED turns on are not equally spaced.

## Experiment - 3      Six LEDs and a microphone

This experiment will use the same layout as Experiment 2 plus the NXT sound sensor instead of the potentiometer.



Use the assembly from Experiment 2, *Six LEDs and a potentiometer*.

Ensure the Prototype board is connected to sensor port 1 and the LEGO NXT sound sensor is connected to port 2 of your NXT.

### Programming

Load the program EXP3 LED-sound.rbt and load it into your NXT.

The program reads the sound level from the sound sensor and decides which LED to turn on based on the measurement from the sound sensor.

As you increase the sound level, you'll notice that the LEDs turn on in sequence. This sequence has again been made deliberately *non-linear*. This time, the non-linearity approximates the apparent loudness your ear perceives.

## Experiment - 4      Light Level

This experiment shows you how to build a working light sensor.

### Parts

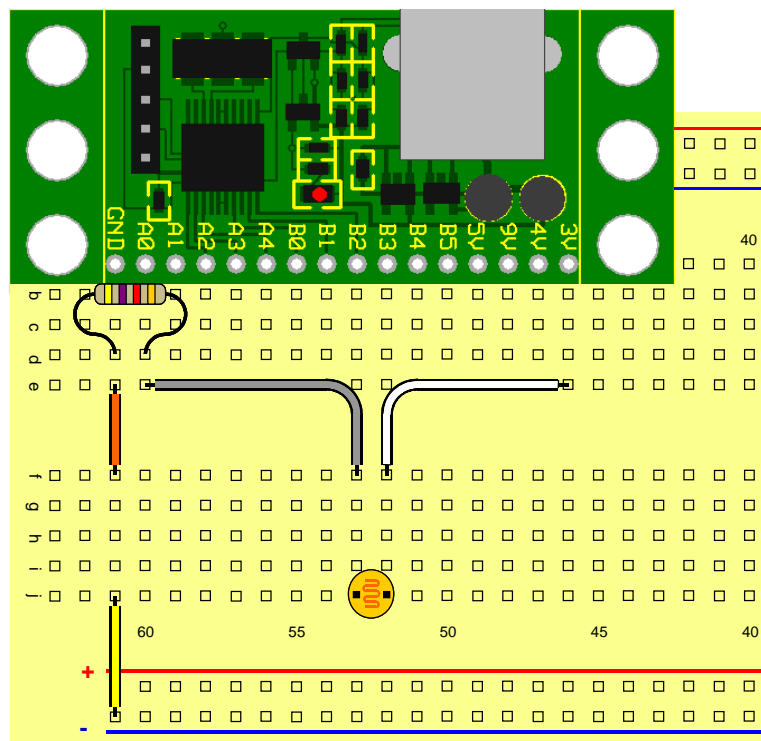
The parts needed for this circuit are;

Part	Quantity	Notes
4.7K Ohm resistor	1	yellow – violet – red – gold
Photo cell	1	

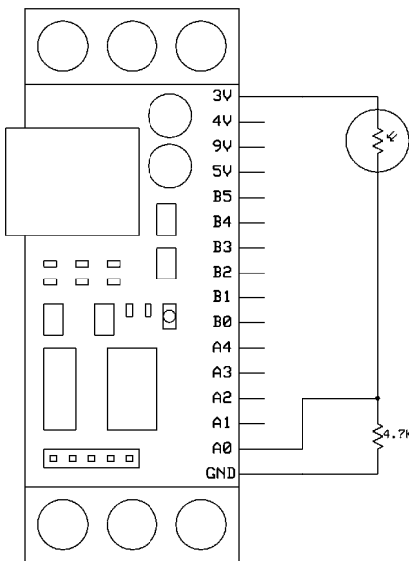
Insert the leads of the resistor to connect with the GND and A0. The leads on the resistor can be bent to permit them to span the distance between the holes as shown.

Insert the photocell leads into adjacent holes in section f - j. The photocell leads need not be spread to permit them to fit. Note that the photocell leads should be used full length so do not cut the leads. The photocell is not polarized, so; it does not matter which way around it is installed.

The wires are color coded based on their length. There is an orange one, a yellow one, a gray one and a white one to install. Note the orange and yellow wires are not needed for this circuit but will be used in the extended version of this circuit.



## Circuit Diagram



## Programming

Load the program Exp4 Light Level.rbt using MINDSTORMS software. Ensure the Prototype Board is connected to sensor port 1 of your NXT.

The program reads the voltage from the photocell and displays it on the NXT screen.

As you allow more light to shine on the photocell, the higher the reading will be.

## Experiment - 5 Ambient Canceling Light Sensor

This experiment uses the layout built in Experiment 4 and adds to the design by creating a light sensor that measures and cancels out the background light level.

### Additional Parts

Part	Quantity	Notes
220 Ohm resistor	1	Red – red –brown – gold
4.7K Ohm resistor	2	Yellow – violet – red – gold
LED	1	high brightness (clear dome)
Transistor	1	2N3904

Insert the 220 Ohm resistor to connect to 4V and the lower breadboard section as shown.

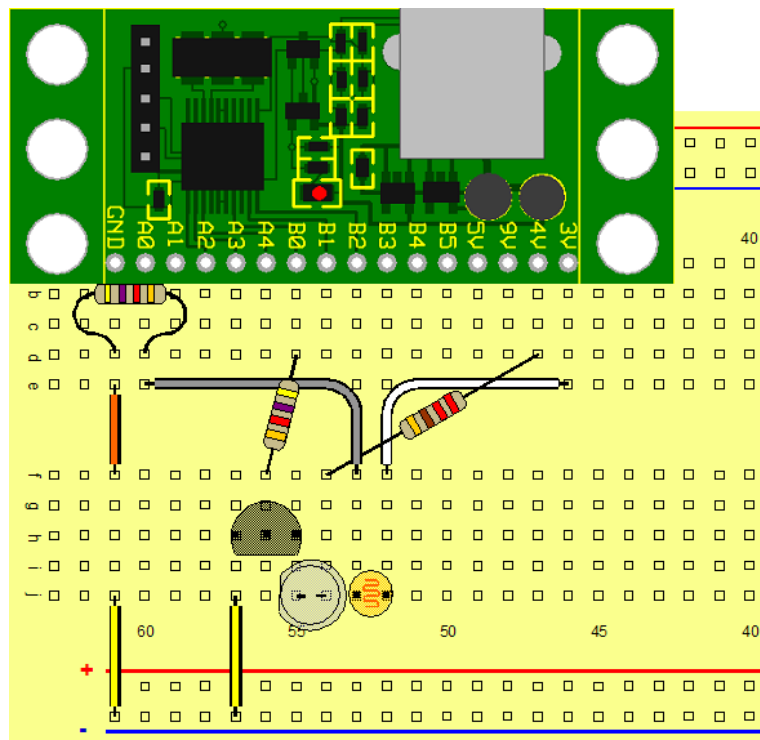
Insert one 4.7K Ohm resistor to connect B0 and the lower section of the breadboard and the other between GND and A0.

Insert the high brightness LED making sure the LED body flat or notch faces toward the left of the layout diagram. Note that the LED leads should be used full length.

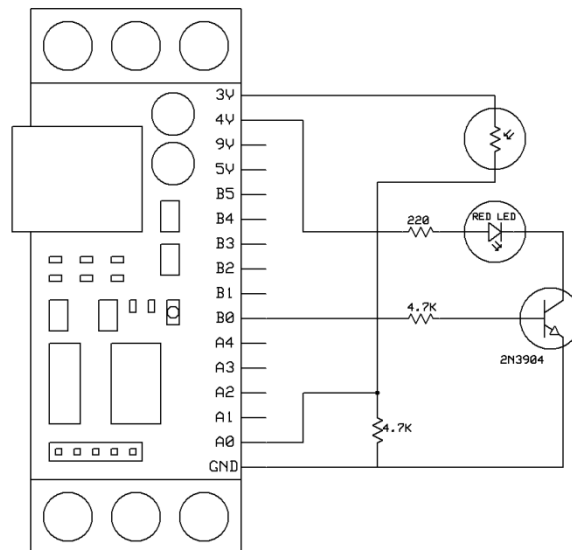
Insert the transistor making sure it is around the right way, with the flat side facing toward the bottom of the diagram.

Insert the photo cell as shown. It does not matter which way around the photo cell is inserted.

Using the color coded jumper wires, complete the circuit as shown.



## Circuit Diagram



## Programming

Load the program Exp5 AC Light.rbt. Ensure the Prototype board is connected to sensor port 1 of your NXT.

The program turns the LED on and off and measures the light level for both conditions. It then subtracts the reading obtained with the LED off from the reading obtained with the LED on and displays that value. If there is nothing placed above the LED – photocell *sensor head*, these readings will be very similar. However, if a white object or surface is placed a few centimeters above the sensor head, the two readings will start to differ because the white surface reflects the light from the LED when it is on. This provides a good way to detect the presence or absence of an object.

You can experiment to see how different colored and different sized objects affect the results.

## Experiment - 6 Reaction Time Measurement

This experiment will allow you to build a simple reaction timer to measure the time it takes you to press a button after a light has been turned on.

### Parts

Part	Quantity	Notes
220 Ohm resistor	2	Red – red –brown – gold
10K Ohm resistor	2	Brown – black – orange - gold
LED	2	Red and green
Button switch	2	Red and green

Insert the two 10K Ohm resistors to connect between GND - B0 and GND – B1 as shown.

Connect the four jumper wires from e – f as shown.

Insert a 220 Ohm resistor to connect B4 and the lower section of the breadboard.

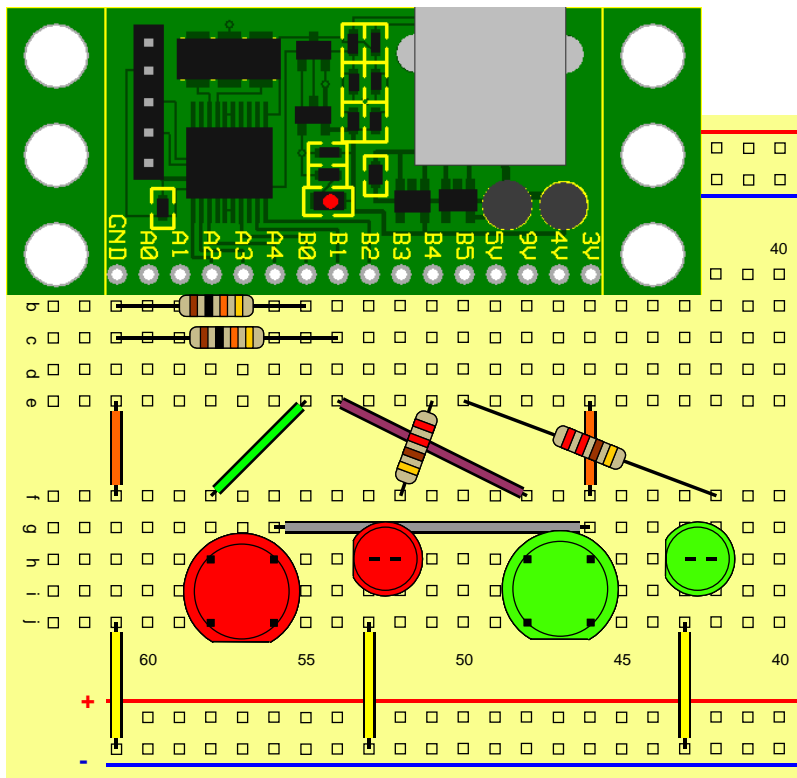
Insert a 200 Ohm resistor to connect B5 to the lower section as shown.

Insert the LEDs making sure the LED body flat or notch faces toward the left of the layout diagram. Note that the LED leads should be used full length.

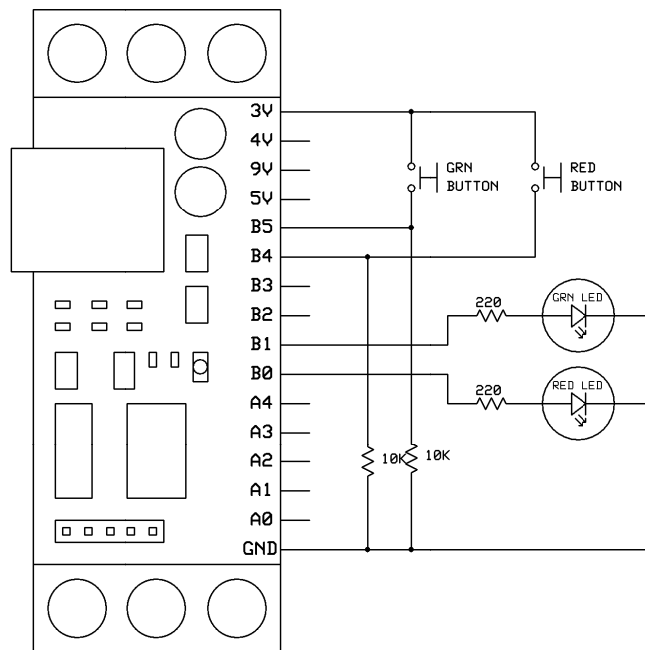
Insert the red and green switches making sure the flat on the body is facing away from the prototype board as shown.

The wires are color coded based on their length.

Insert the remaining wires as shown.



## Circuit Diagram



## Programming

Load the program Exp6 Reaction.rbt. Ensure the Prototype Board is connected to sensor port 1 of your NXT.

The program waits for a random amount of time and then turns on the red LED as well as starting a timer. When the red button is then pressed, the timer is stopped and the number of milliseconds it took to press the button is displayed in milliseconds (a millisecond is 1/1000 of a second).

To restart the test, press both the red and green buttons at the same time.

## Variant - More Complex Reaction Time Measurement

A variant of this experiment uses the same layout but will require a more complex response.

Load the program Exp6 Var.rbt. Ensure the Prototype Board is connected to sensor port 1 of your NXT.

The program waits for a random amount of time and then randomly turns on either the red or green LED as well as starting a timer. When the matching button is then pressed, the timer is stopped and output as the number of milliseconds it took for the subject to press it after seeing the LED turn on.

This test adds a decision to the reaction time measurement which for most subjects will add to their reaction time.

To restart the test, press both the red and green buttons at the same time.

## Experiment - 7      Magnetic Switch Sensor

This experiment shows you how to build a working magnetic switch sensor.

Parts

Part	Quantity	Notes
220 Ohm resistor	1	red – red –brown – gold
10K Ohm resistor	1	brown – black – orange - gold
LED	1	green
Magnetic Sensor	1	Hall effect sensor chip

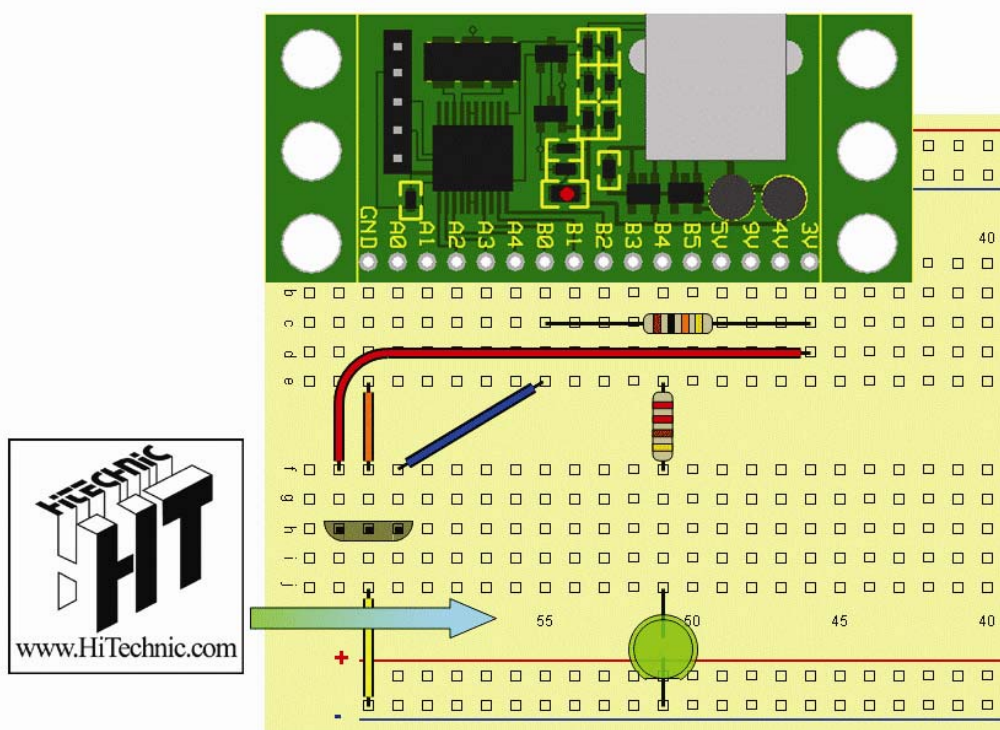
Insert the 10K Ohm resistor to connect B0 - 3V as shown.

Insert the 220 Ohm resistor to connect B4 and the lower section of the breadboard.

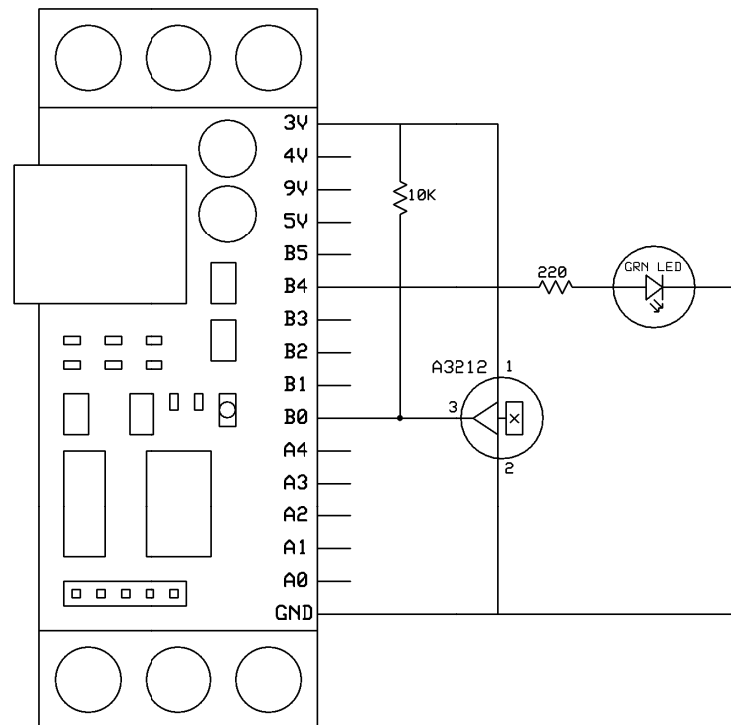
Insert the LED making sure the LED body flat or notch faces toward the left of the layout diagram. Note that the LED leads should be used full length.

Insert the magnetic sensor integrated circuit by gently spreading its leads and inserting it with the flat sided facing towards the prototype board as shown.

Insert the connecting wires to complete the circuit.



## Circuit Diagram



## Programming

Load the program Exp7 Magnetic Sw.rbt. Ensure the Prototype Board is connected to sensor port 1 of your NXT.

The program reads the output from the magnetic sensor and uses it to turn the LED on or off.

Use the supplied HiTechnic magnet to activate the magnetic sensor.

## Experiment - 8      Temperature Sensor

This experiment will allow you to build a working temperature sensor.

Parts

Part	Quantity	Notes
1.0 $\mu$ F capacitor	1	
220 Ohm resistor	1	Red – red –brown – gold
10K Ohm resistor	1	Brown – black – orange - gold
LED	1	red
Temperature Sensor	1	temperature sensor chip

Insert the 1.0  $\mu$ F capacitor between GND and A0.

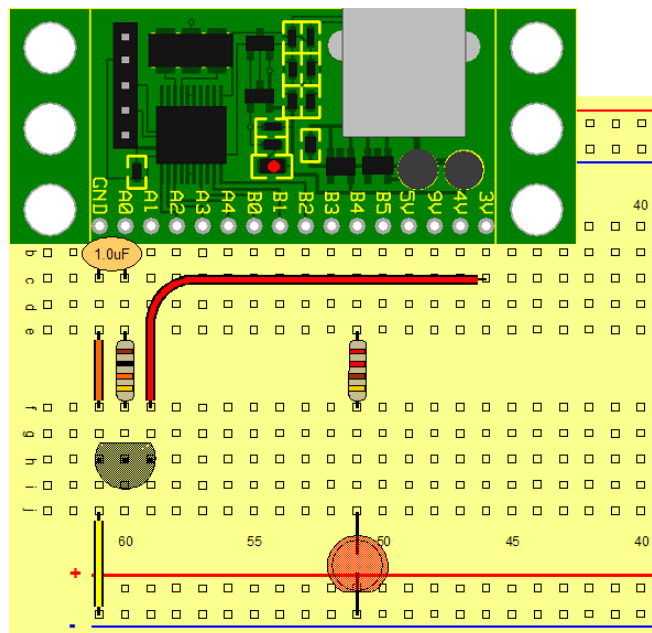
Insert the 10K Ohm resistor to connect to A0 and the next breadboard section as shown.

Insert the 220 Ohm resistor to connect to B4 and the next breadboard section.

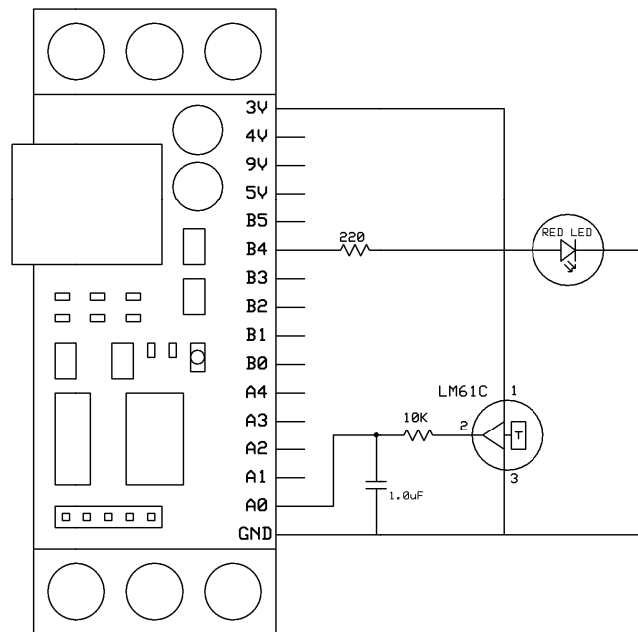
Insert the temperature sensor by gently spreading its leads and inserting it with the flat side facing towards the prototype board as shown.

Insert the LED leads as shown. Note that the LED body has a flat or notch which must face toward the bottom of the layout diagram.

The wires are color coded based on their length. Insert one orange, yellow and one red wire as shown.



## Circuit Diagram



## Programming

Exp8 Temp.rbt and load it into your NXT. Ensure the Prototype Board is connected to sensor port 1 of your NXT.

The program reads the voltage from the temperature sensor and displays it. It also decides if it is above a predefined threshold and if so turns the LED on.

# Appendix 1

## HiTechnic Experimenter's Kit Sample Programs

For each Experiment there is a sample program in four programming languages for the NXT.

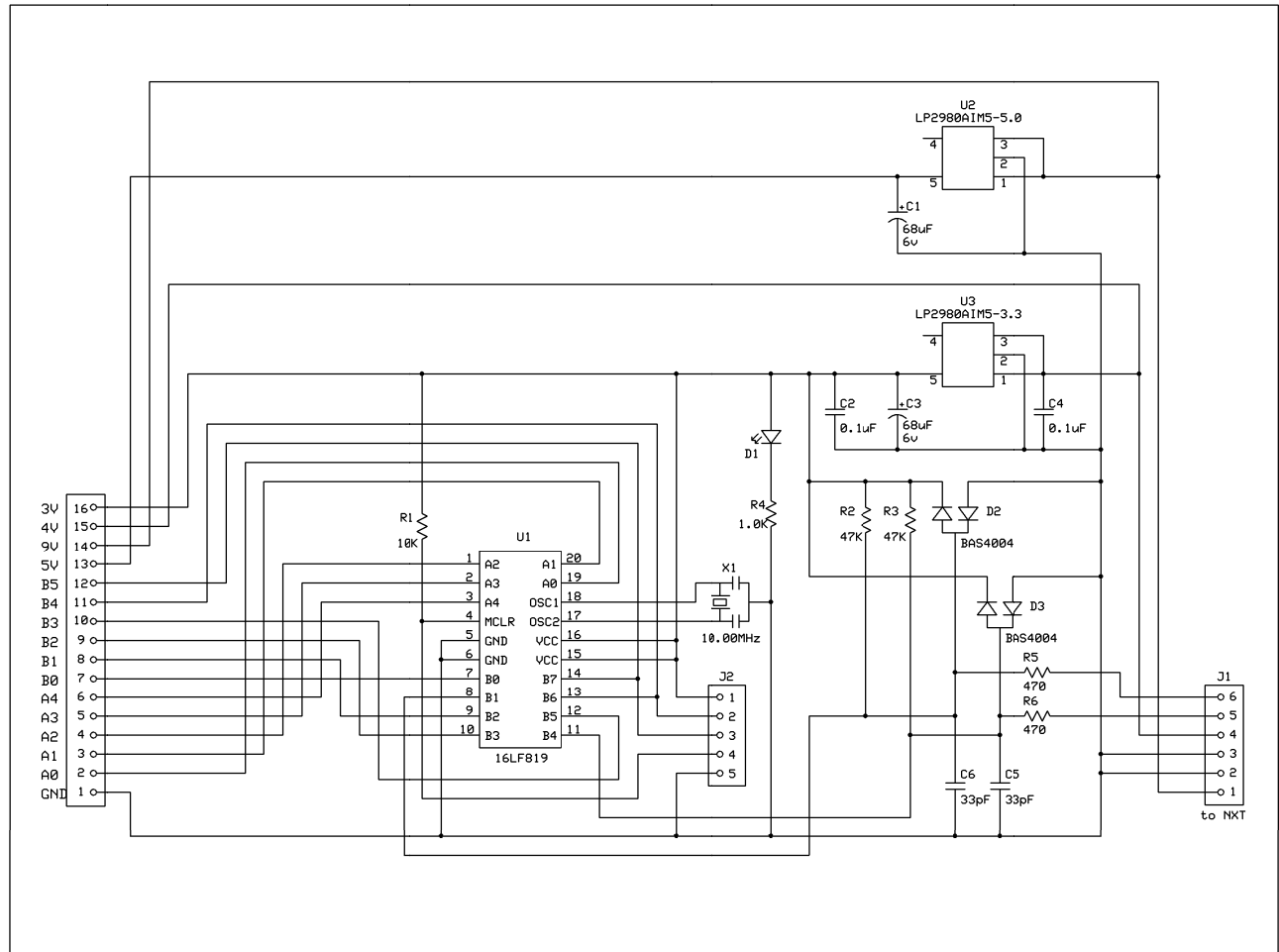
**Experiment Program Names**

<b>Experiment</b>	<b>NXT-G</b>	<b>NXC</b>	<b>RobotC</b>	<b>LabVIEW</b>
1 - Introduction to the Prototype Board	Exp1 Intro.rbt	NCX Exp1.nxc	RBC_Exp1.c	LV Exp1.vi
2 - Six LEDs and a potentiometer	Exp2 6LED.rpt	NCX Exp2.nxc	RBC_Exp2.c	LV Exp2.vi
3 - Six LEDs and a microphone	Exp3 LED-sound.rpt	NCX Exp3.nxc	RBC_Exp3.c	LV Exp3.vi
4 - Light Level	Exp4 Light Level.rpt	NCX Exp4.nxc	RBC_Exp4.c	LV Exp4.vi
5 - Ambient Canceling Light Sensor	Exp5 AC Light.rpt	NCX Exp5.nxc	RBC_Exp5.c	LV Exp5.vi
6 - Reaction Time Measurement	Exp6 Reaction.rpt	NCX Exp6.nxc	RBC_Exp6a.c	LV Exp6.vi
Complex Reaction Time Measurement	Exp6 Var.rpt	NCX Exp6 Var.nxc	RBC_Exp6b.c	LV Exp6b.vi
7 - Magnetic Switch Sensor	Exp7 Magnetic Sw.rpt	NCX Exp1.nxc	RBC_Exp7.c	LV Exp7.vi
8 - Temperature Sensor	Exp 8 Temp.rpt	NCX Exp1.nxc	RBC_Exp8.c	LV Exp8.vi

## Appendix 2

### The HiTechnic Prototype Board Schematic

The Prototype Board schematic shows the components that make up the prototype circuit and all the connections, both input and output. If you are new to electronics do not worry about the schematic.



There are 4 different power supplies available, 3.3 volts stabilized, 4.3 volts un-stabilized, 5 volts stabilized and 9 volts un-stabilized. The 4.3 volt and 9 volt supplies are obtained from the NXT. Two voltage regulator chips are used to derive the two stabilized supplies. The unregulated supplies are current limited, The 4.3 volt supply and thus the 3.3 volt supply is limited to 20 milli-amps while the 9 volt supply and thus the 5 volt supply is limited to 12 milli-amps.

The 5 analog inputs (A0 – A4) are connected to the analog to digital converter within the microcontroller (PIC16LF819) which provides 10 bit conversion accuracy with a voltage range of 0 – 3.3 volts.

The 6 digital signals (B0 – B5) can be individually controlled to be either an input or an output which can be set to 0 volts or 3.3 volts.

## Appendix 3

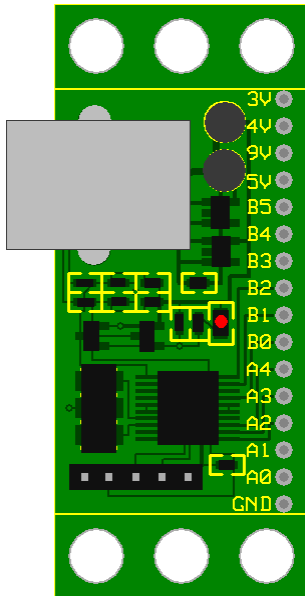
### Specifications and Datasheets

Part	Manufacturer	Part Number	Datasheet Link
Magnetic Hall Effect Sensor	Allegro MicroSystems Inc	A3212EUA-T	<a href="http://www.allegromicro.com/en/Products/Part_Numbers/3212/">http://www.allegromicro.com/en/Products/Part_Numbers/3212/</a>
Temperature Sensor	National Semiconductor Corporation	LM61CIZ	<a href="http://www.national.com/mpf/LM/LM61.html">http://www.national.com/mpf/LM/LM61.html</a>

## Appendix 4

### NXT-G Prototype Sensor Block

This block allows full control over the Prototype Board. You can read the values from any of the five analog inputs and read and write data to the six digital input/outputs. This allows you to safely connect your own electronics experiments to the NXT.

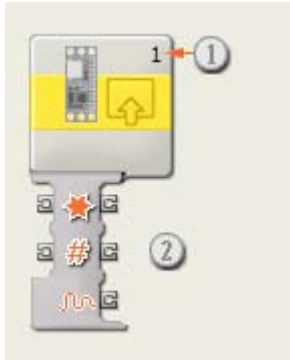


The five analog input channels are numbered A0 - A4. The six digital input/output bits are numbered B0 - B5. The board can also supply a range of voltages to help you power your experimental circuitry. There is a common GND (ground) which is the negative supply connection. There are four positive supply connections available, 5V, 9V, 4V and 3V. There is also an LED to warn you when power is being supplied to the board from the NXT. Commonly, you should disconnect the connection to the NXT while adjusting your experimental circuitry.

There are two versions of the Prototype Board, a solderless one as shown in the picture which is intended to be plugged into a solderless breadboard and a solderable one on which you can mount the components and wires you need permanently once you have your circuitry working correctly. Both boards work the same way as far as programming is concerned.

You must drag at least one output data wire from this block's data hub to another block for any information to be sent.

## Display Settings



1. The number shows which of your NXT's ports are connected to the prototype sensor. You can change this number in the configuration panel if you need to.

2. The block's data hub will open automatically when the block is placed in the work area. At least one data wire must be dragged from the block's output plug to another block's data hub. The analog channel and other features can be set dynamically by connecting an input data wire. (See the Data Hub section below for more information.)

## Configuring the Prototype Sensor Block



3. Choose the port where your Prototype sensor is plugged in. By default, the block will be set to port 1 for the prototype sensor. You can change this selection if you need to.
4. You can choose the Action the block will perform, Read Analog, Read Digital or Write Digital.

## Prototype Sensor block Data Hub plugs

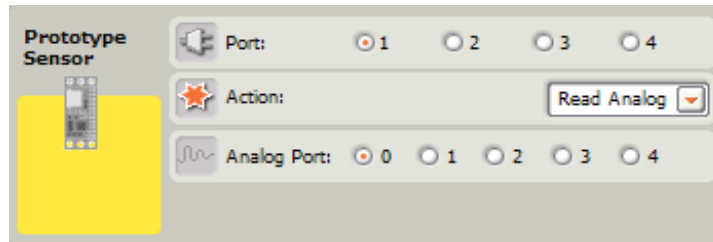
You must click on the Data Hub to open it as shown.



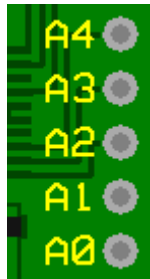
This plug wires the number for which of your NXT's ports are connected to the prototype sensor.

1. This plug wires the port number the prototype board is plugged in (1 – 4)
2. This plug wires the action to be performed by the block, Read Analog, Read Digital or Write Digital.
3. This plug wires the channel number for the Read Analog action.
4. This plug wires the six bit value to be output for the Write Digital action.
5. This plug wires the six bit control to be used for the Write Digital action.
6. This plug outputs the analog value from a Read Analog action.
7. This plug outputs the digital value from a Read Digital action.

## Using the Read Analog Action



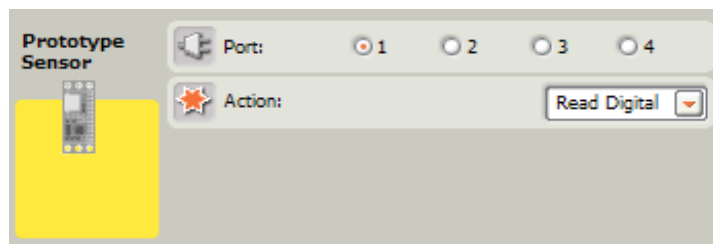
The prototype analog channels A0 - A4 convert the input voltage in the range of 0 - 3.3 volts into a value in the range 0 - 1023.



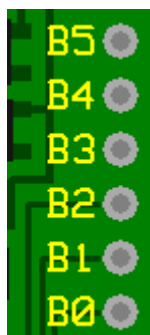
The selected channel's value will be placed on the block's Read Analog output. The simplest way to convert these values into a voltage in units of milli-volts (1/1000 of volts) is to multiply the number by 129 and divide the result by 40.  $V_{mv} = \text{Value} \times 129 / 40$

If an input which is not connected to anything is read, it will return an unpredictable reading.

## Using the Read Digital Action



The prototype digital bits will be read as a value in the range 0 - 63.



Each digital port bit has a binary value as follows;

Bit	Value
B0	1
B1	2
B2	4
B3	8
B4	16
B5	32

In order to make it easy to use the digital port's individual bits, it is necessary to use logical functions AND and OR. For example, if you wish to determine if bit B3 is a one or a zero, simply take the port value and AND it with 8 (the binary value for bit 3). If the bit was a one, the result will be non-zero, i.e.; 8. If the bit was a zero, the result will be zero.

The logic block can be downloaded from [www.hitechnic.com](http://www.hitechnic.com).

The voltage level ranges for the logic inputs are;

Logic 0          0v - 0.5v

Logic 1          2v - 3.3v

## Using the Write Digital Action



The prototype digital connections can be set as inputs or outputs. A Digital Control register can be set to any value between 0 - 63. For each bit B0 - B5, a control bit of zero will configure the connection as an input whereas a control bit of one will configure it as an output. So for example, if you wish to make B0 - B3 as outputs and B4 and B5 as inputs, you would output a control value of 15 (1 + 2 + 4 + 8).

The corresponding bits in the Digital Out value will then be used to set the state of the prototype digital connections which have corresponding one bits in the Digital Control register.

An output which is set to a zero has a connection to GND which can sink up to 12mA. An output which is set to a one has a connection to the 3.3v supply can source up to 12mA.

When a connection is configured as an output, its current state will be reflected when the digital port is read.

## Prototype Sensor power outputs

There are four power supply outputs available.



### 9V

The 9V output is basically the NXT battery voltage which is normally provided to sensors. This voltage may range from 6 - 9 volts and can supply about 12mA.

### 5V

The 5V supply is provided by a 5.0 volt regulator connected to the 9V supply. If no power is being drawn from the 9 volt supply, then about 12mA is available from this output.

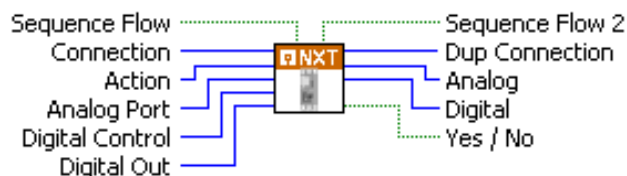
### 4V

The 4V output is basically the NXT 4.3 volt sensor supply voltage. The output can supply about 20mA.

### 3V

The 3V supply is provided by a 3.3 volt regulator connected to the 4V supply. If no power is being drawn from the 4 volt supply, then about 20mA is available from this output.

## LabVIEW VI



Connection: Port

Analog:

Analog port value 0 – 1023

Action: 0 = Read Analog port  
Analog port 0 - 4

Digital:

Digital port data

1 = Read Digital port  
2 = Write Digital port

Digital Control: Bit = 0 – Input port  
Bit = 1 – Output port

Digital Out: Data written to digital port

## Appendix 5

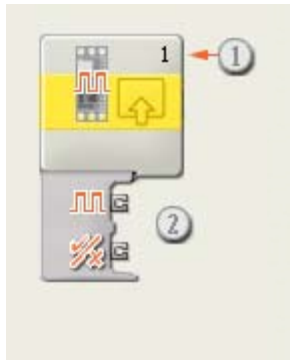
### NXT-G Prototype Digital Read Block



This block reads the Prototype Board Digital input port and allows testing of each bit and sets an output Boolean when the required state is read. The block configuration lets you test for any combination of the six digital inputs.

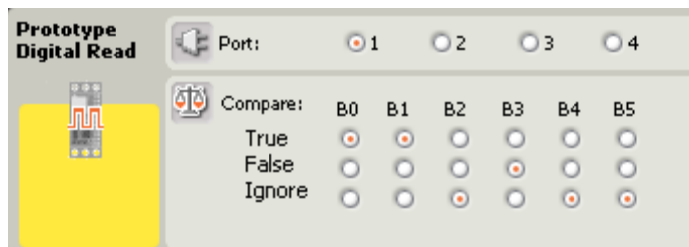
You must drag at least one output data wire from this block's data hub to another block for any information to be sent.

### Display Settings



1. The number shows which of your NXT's ports are connected to the prototype sensor. You can change this number in the configuration panel if you need to.
2. The block's data hub will open automatically when the block is placed in the work area. At least one data wire must be dragged from the block's output plug to another block's data hub. The analog channel and other features can be set dynamically by connecting an input data wire. (See the Data Hub section below for more information.)

### Configuring the Prototype Digital Read Block



1. **Port:** Choose the port where your Prototype sensor is plugged in. By default, the block will be set to port 1 for the prototype sensor. You can change this selection if you need to.
2. **Compare:** Select the desired combination of the Prototype Digital inputs that will be combined to create the overall required logic output. Each bit can be selected as True (1), False (0) or Ignore (don't care). When the state of all digital bits matches the combination set in the Compare Table, the block output logic state will be set to True, otherwise it will be False.;

For example, with the setting shown in the front panel above, the overall logic output will be set to True when

B0 is True  
and  
B1 is True  
and  
B3 is False  
All other bits are ignored

## Prototype Digital Read block Data Hub plugs

You must click on the Data Hub to open it as shown.



1. This plug wires the number for which of your NXT's ports are connected to the prototype sensor.
2. This plug wires the compare selection for B0, 0=True, 1=False. 2=Ignore.
3. This plug wires the compare selection for B1, 0=True, 1=False. 2=Ignore.
4. This plug wires the compare selection for B2, 0=True, 1=False. 2=Ignore.
5. This plug wires the compare selection for B3, 0=True, 1=False. 2=Ignore.
6. This plug wires the compare selection for B4, 0=True, 1=False. 2=Ignore.
7. This plug wires the compare selection for B5, 0=True, 1=False. 2=Ignore.
8. This plug wires the digital value from the read.
9. Boolean result of the overall compare table, True or False. (Yes / No)

The prototype digital bits will be read as a value in the range 0 - 63.

Each digital port bit has a binary value as follows;

Bit	Value
B0	1
B1	2
B2	4
B3	8
B4	16
B5	32

## Appendix 6

### Digital Port Control and Data Binary Values

In order to access the Prototype Sensor digital ports and to configure the port control, it is useful to express the values in binary. NXT-G does not support binary values directly so decimal values are used. The following table shows values in decimal and binary mapped to the digital ports.

Decimal Value	Ports					
	B5	B4	B3	B2	B1	B0
0	0	0	0	0	0	0
1	0	0	0	0	0	1
2	0	0	0	0	1	0
4	0	0	0	1	0	0
8	0	0	1	0	0	0
16	0	1	0	0	0	0
32	1	0	0	0	0	0

### Digital Control Port

The digital control port is used to configure each digital port (B0 – B5) to be either an input port (read) or an output port (write). To set a port to output, the control must be set to 1. For example, if port B4 has a connected LED, it must be set to Output before the LED can be set ON. To do this the B4 control must be set to 1 so the control value to enable this is 16. All other ports will be set to 0 in this case so they will be input ports.

If more than one port is to be set to output add the values for each port together to determine the decimal value to use. For example, if ports B2, B3 and B4 are to be outputs, the decimal control value will be

$$4 + 8 + 16 = 28$$