NXT-G Programming

Workshop for FLL Coaches

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Outline

- Purpose:
  - This workshop is intended for *FIRST*® LEGO® League (FLL®) coaches who are interested in learning about LEGO® MINDSTORMS® NXT and the NXT-G programming language.

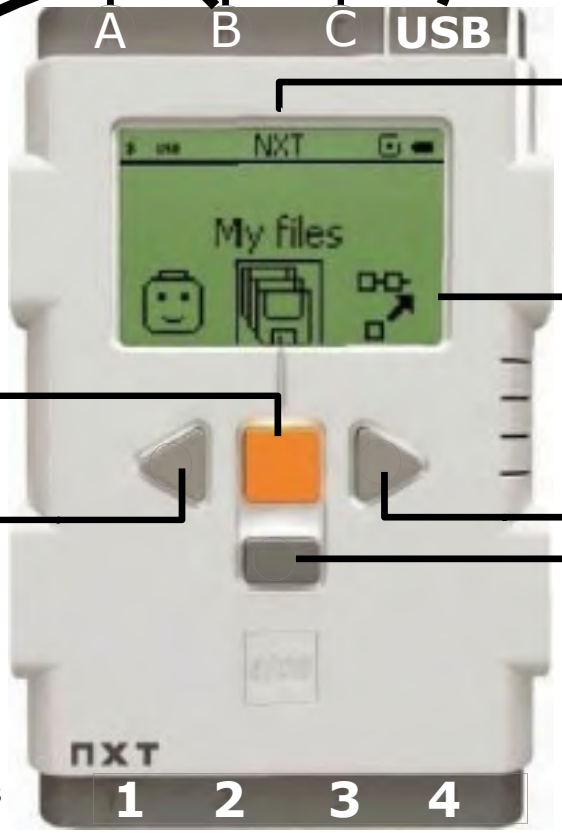
- Basic Programming Agenda (Introductory Workshop)
  - NXT Controller (aka: the "brick")
  - Blocks
  - The NXT-G Interface
  - The **MOVE**, **MOTOR** & **RESET** Blocks
  - Turns - there is more than one way to turn
  - Geometry and Math for the Robot
  - Resources

- Advanced Programming (for Advanced Workshop)
  - Light Sensors
  - Program Control (**WAIT**, **LOOP**, **SWITCH** Blocks)
  - Math (**VARIABLES**, **MATH** and **COMPARE** Blocks)
  - **My Block**
  - Touch Sensors

NXT Controller – The robot's "brain" aka: the "Brick"

The USB port is used to connect to The PC so you can download the Programs into NXT Controller

3 Output ports used for the motors



Name

Icons representing menu options

Use this button to turn on the NXT and select the shown option

SELECT menu option (left)

SELECT menu option (right)

Menu Level Back (off)

4 sensor Input ports used to attach sensors

Light Sensor

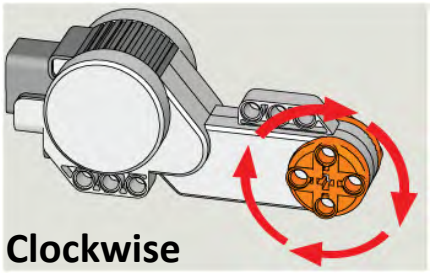
Touch Sensor

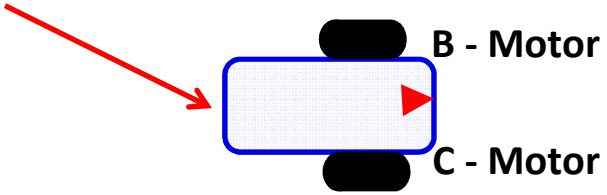
FLL Robot Configuration

- For FLL Competition you are allowed:
  - 1 NXT Brick [or the discontinued RCX yellow Brick]
  - Up to 3 motors; two for moving; the third is for the arm
  - Any number of LEGO-manufactured MINDSTORMS type sensors: touch, light, color, rotation or ultrasonic
    [However, you only have 4 sensor ports on the NXT!]
  - You can use as many non-electric LEGO pieces as you need
  - You may NOT use ANYTHING that is not made by LEGO

- Instructing the robot to move and turn is accomplished by the NXT Motors, which rotate in a predetermined direction.

- **All examples used in this document assume the robot configuration with motors mounted as shown.**





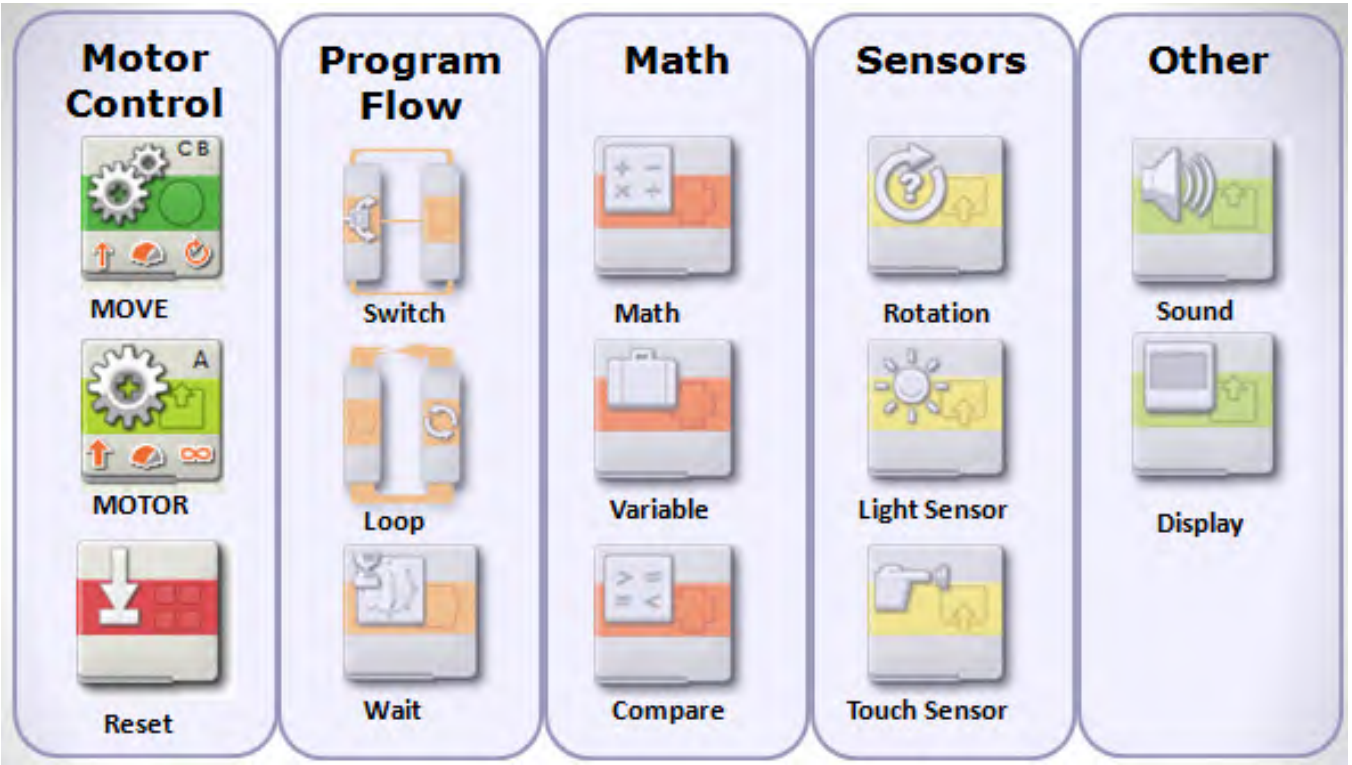
LEGO® MINDSTORMS ® Education NXT Software

- The FLL Robot Set includes the LEGO MINDSTORMS Education NXT Software
  - The current NXT-G software version is V.2.1.6
  - This icon-based easy-to-use software is based on LabVIEW®
    - LabVIEW is powerful system design software for engineering and science
  - The Education version includes Robot Educator step-by-step guide
    - 46 tutorials from beginner to advanced levels
  - The Education version also includes data logging functionality
    - Collect and analyze data from sensors
- Includes comprehensive *digital user manual*
- Includes team license

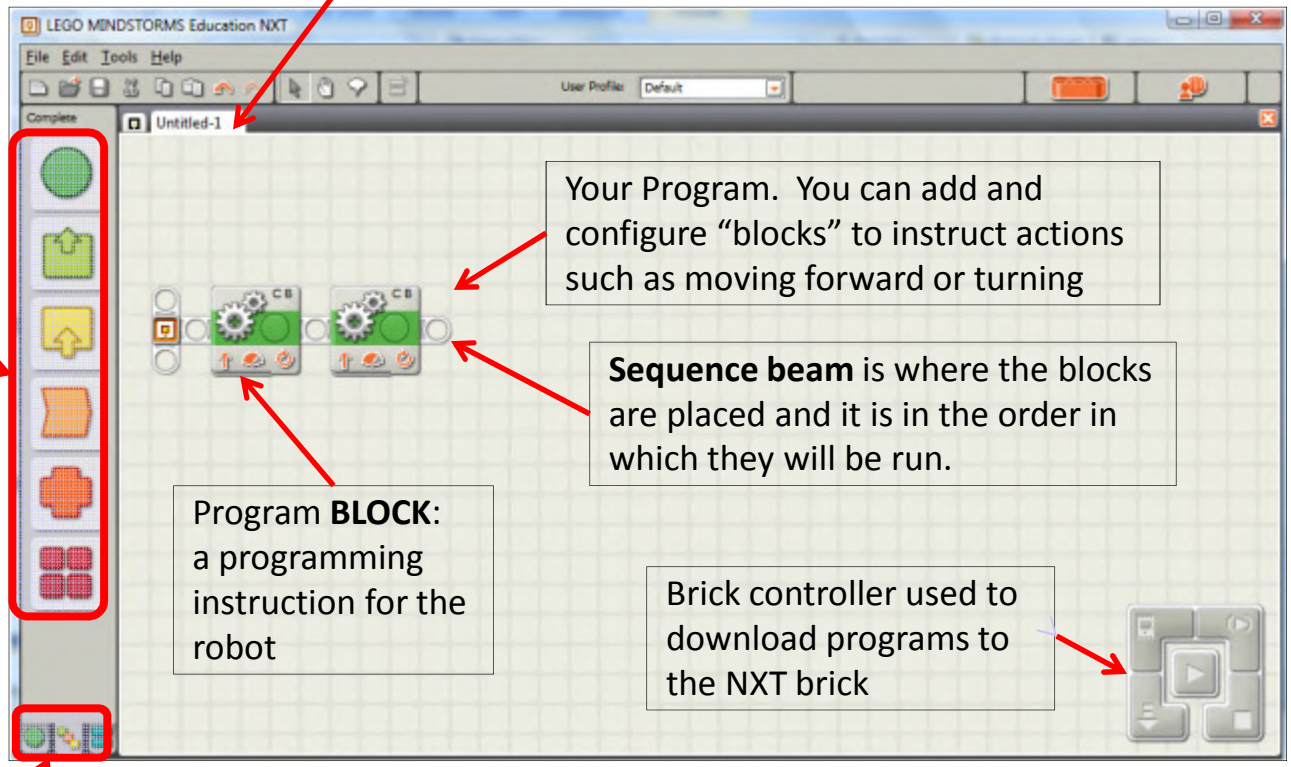
Programming the NXT Robot

- NXT software uses different programming "BLOCKS". Here are some of the most commonly used blocks.

Programming Block?
It is a specific step or action the robot will perform.



LEGO MINDSTORMS NXT Interface



Program name

Programming Palette menu. Each option has a set of program blocks; move the mouse over it to see the available blocks

Your Program. You can add and configure "blocks" to instruct actions such as moving forward or turning

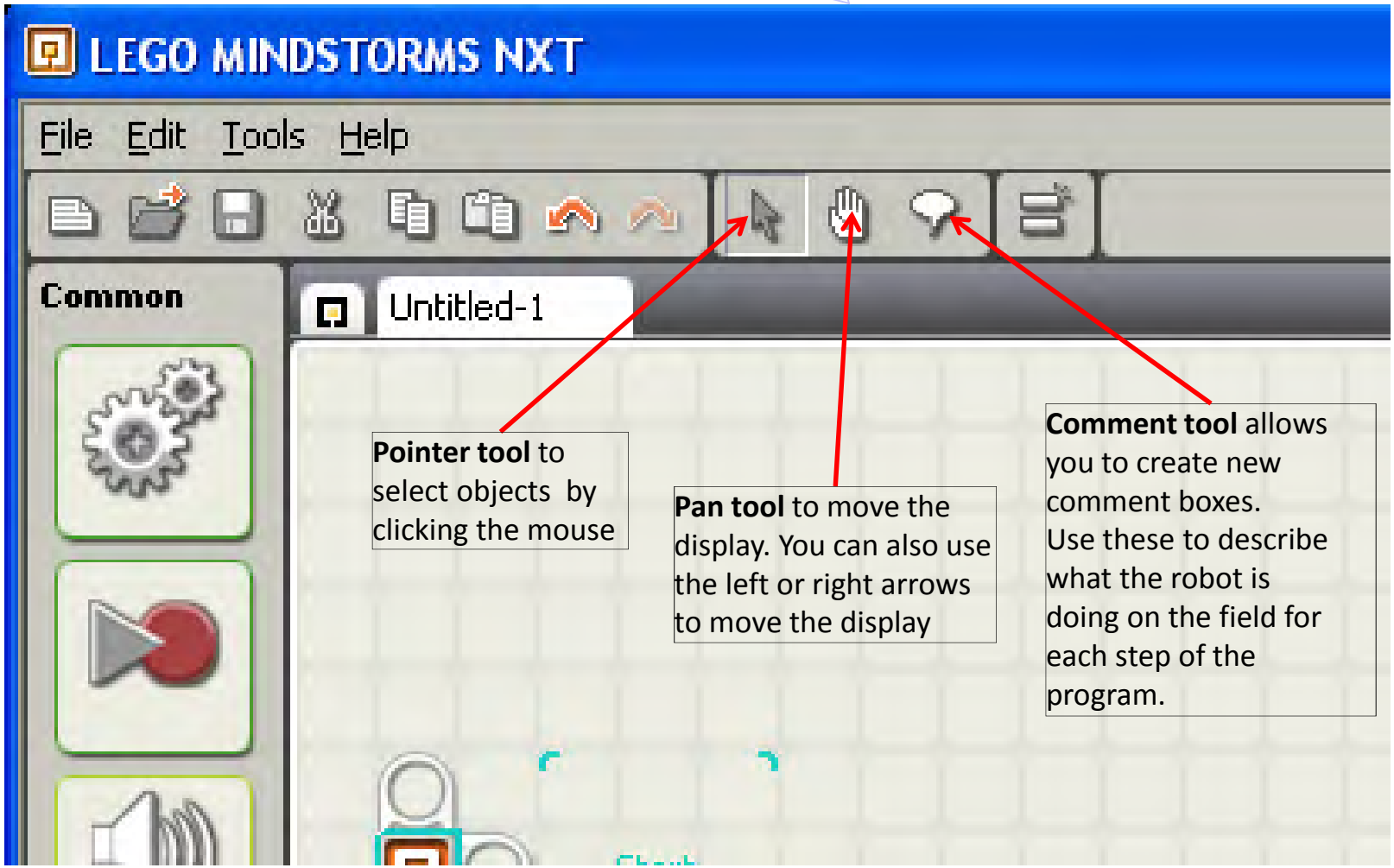
Sequence beam is where the blocks are placed and it is in the order in which they will be run.

Program **BLOCK**: a programming instruction for the robot

Brick controller used to download programs to the NXT brick

Palette selector

LEGO MINDSTORMS NXT Interface

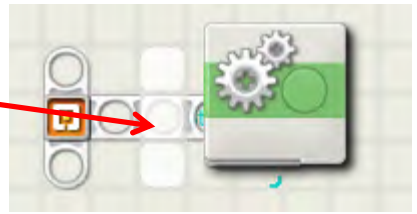


Steps to add a Programming Block

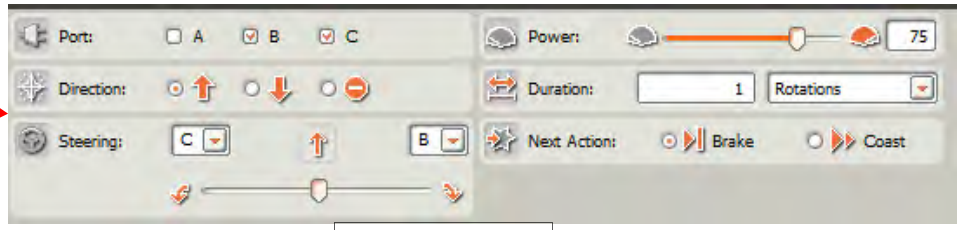
1. Click and hold block with left mouse button to drag it

2. Drag the block to place it on the sequence beam

3. When you see the white bar, release the mouse (this is the location for placing the block)

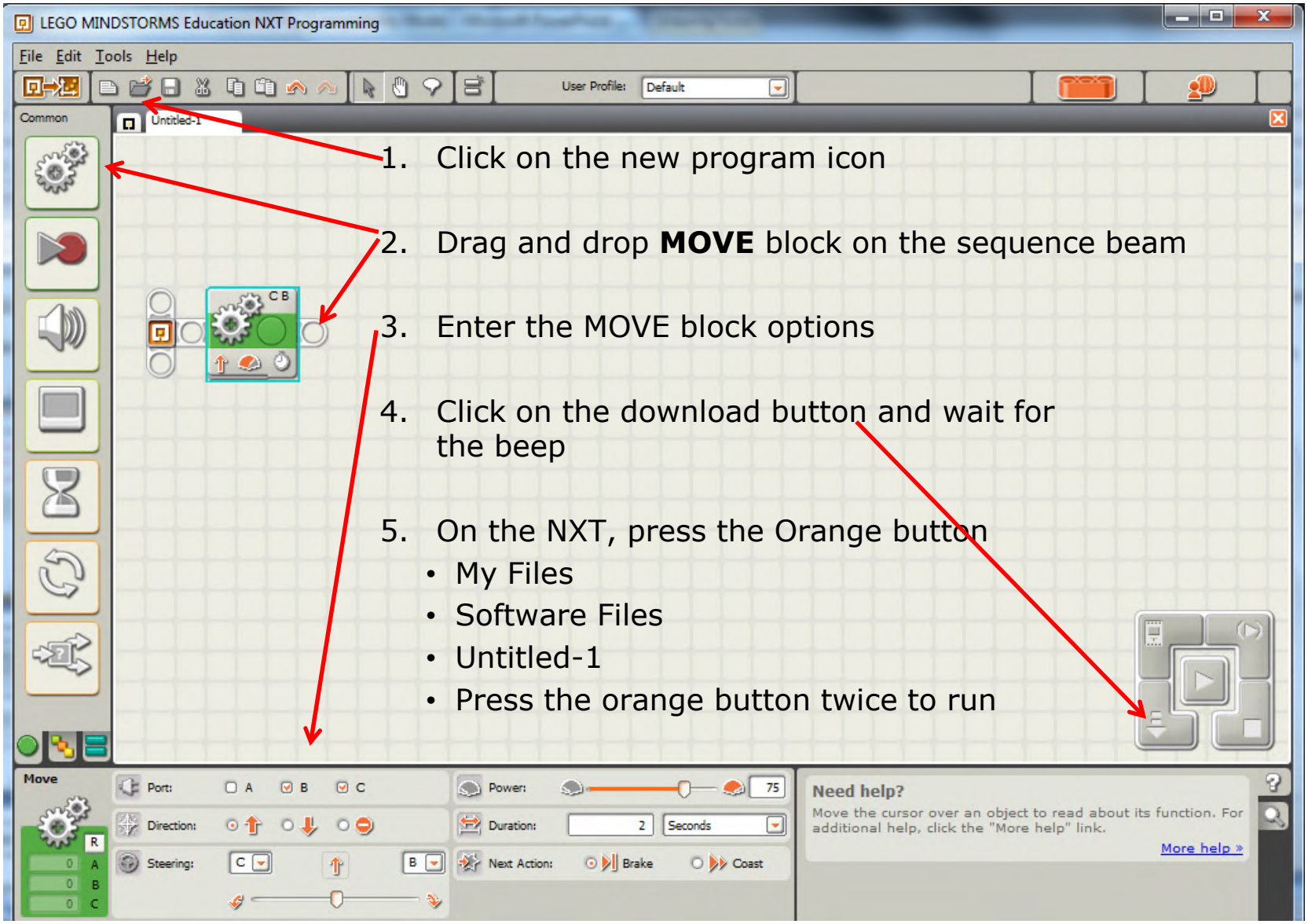


4. Update the options of the selected block in its control panel



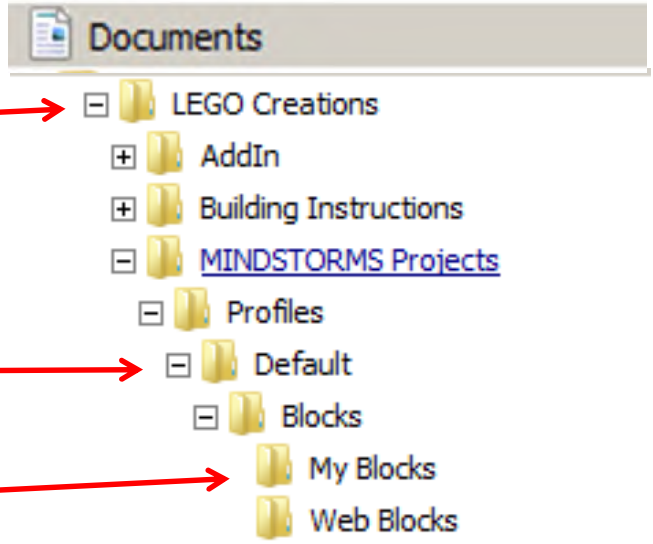
Control Panel

Your First Program



Where are the programs stored?

- Once you install the Mindstorms software, it will create a "**Lego Creations**" and other subdirectories in your Documents Folder as shown.
- All the programs will be created in the "**Default**" Folder
- All **My Blocks** will be created in the "**My Blocks**" folder



- Save programs with descriptive names
- Backup all your programs at the end of each session
- Use the Print command to print copies of your best programs to show the Judges at tournaments

Robot Actions

- For *FIRST* LEGO League, the NXT robot usually has **<u>two Motors</u>** to control the movement of the robot:
  - Move Forward or Backwards (mostly using the **MOVE** block)
  - Turn Left or Right, using either the left or right motors (always use the **MOTOR** block)
  - Spin Left or Right using both motors which are moving in opposite direction (always use the **MOTOR** block).

- The **Arm** is usually the third motor, which is used to manipulate mission models by scooping, pushing, pulling or turning actions.

The arm is used to manipulate objects (always use the A port)

NXT Motors and control BLOCKS

- NXT Motors have a built-in rotation sensors that continuously measure and monitor the number of degrees / rotations while it is moving forward or backwards.
- You can manipulate the motors using the **MOTOR**, **MOVE** and **ROTATION SENSOR** Blocks

MOTOR BLOCK

- Controls one motor
- No Synchronization
- No Acceleration

MOVE BLOCK

- Controls 2 motors
- Synchronize motor movement to ensure robot moves straight
- Automatically corrects errors
- Applies power gradually (accelerate)
- Slows down (decelerate)

ROTATION SENSOR BLOCK

- Counts the number of motor degrees (one full rotation is 360 degrees) that your motor turns.
- Used to reset the rotation counter to 0.

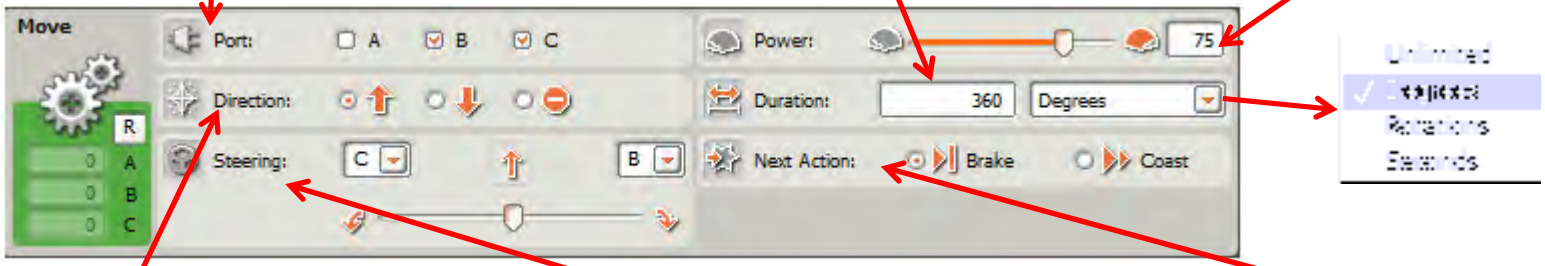
The MOVE Block – explained

Port: Select motors to move. These correspond to the ports on the NXT brick

Duration: used to specify the interval in: Degrees, time (seconds), or rotations (one rotation = 360 degrees).

Power: Amount of power to use to control the motor. The default is 75%.

Control Panel



Direction: the direction in which you want to turn the motor - forward (up) or backwards (down).

Steering: instructs the robot to apply more power to one of the motors to control turns.
NOTE: This is useful for rotating the robot in place, or when you wish to make "tight" turns.

BEWARE that using steering may not be consistent at low power!!!
IT IS UNRELIABLE, SO AVOID USING IT.

Next Action: instructs the motor to either brake or coast at the end of the action.
NOTE: "brake" will provide a more accurate travel distance, while coast will cause motor/robot to "roll" to a stop as the power is cut off and therefore overshoot the target.

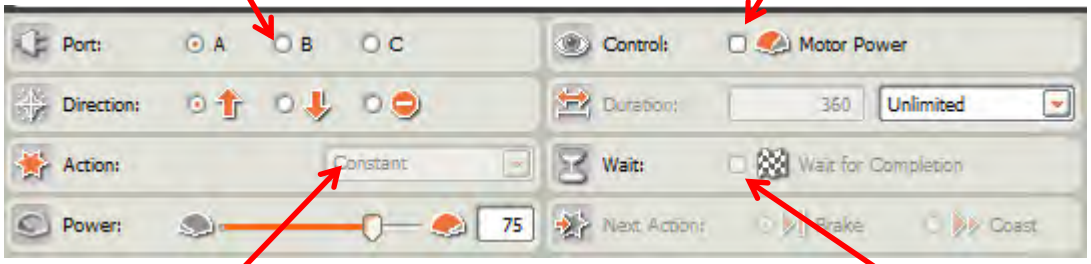
The MOTOR block

- The **MOTOR** block controls a single motor with slightly different configuration options than the **MOVE** block.

- The **MOTOR** block is ideal for controlling the robot's arm, and for controlled turns

Port: Select motor

Power: Increases power if resistance is met



Action: there are three options:
Constant: power is consistent for the duration
Ramp UP: slowly increase speed until desired power is reached
Ramp Down: slowly decrease speed until it reaches zero power.

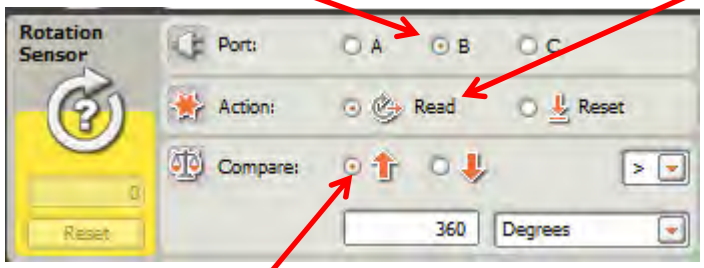
Wait: check the box so other blocks in the program can proceed while the motor completes its action

ROTATION SENSOR block

- The NXT's motor has a built-in ***rotation sensor counter*** that tracks the exact number of degrees as the motor spins. The information is available through the **ROTATION SENSOR** block. You can reset ***rotation sensor counter*** to zero, or read the information in the ***rotation sensor counter***.

Port: identify the NXT port where the motor is connected

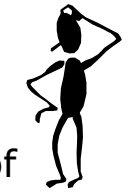
Action: you can either read the value of the sensor or reset it to zero



Compare: select arrow which identifies the direction that motor is spinning.

Note: There is an advanced feature with the rotation sensor that allows you to compare the degrees or rotation to a specified value and provide a "True" or "False" response. This will be covered in the advanced workshop.

More about Motors – Accumulated Errors



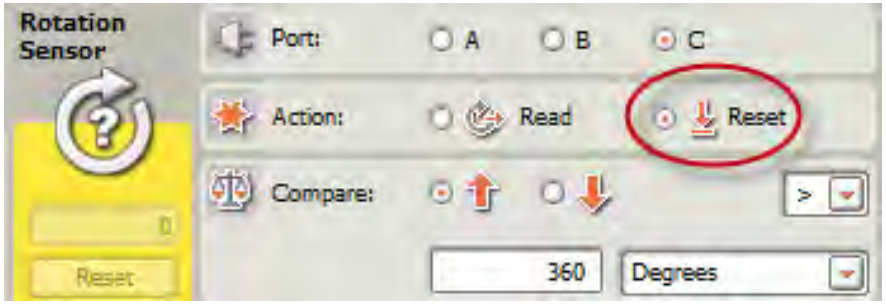
- As the motors move, the rotation sensors of the motors keeps tracks the number of degrees between moves and makes corrections to correct "accumulated error"
- Example:

Block	Specified Duration	Actual Duration	Accumulated error
Move #1, Coast	200 degrees	220 degrees	20 degrees
Wait, 1 second			
Move #2, Coast	200 degrees	230 degrees	50 degrees
Wait, 1 second			
Move #3, Coast	200 degrees	210 degrees	60 degrees
Wait, 1 second			
Move #4, Brake	200 degrees	**140 degrees**	0 degrees
TOTAL	**800 degrees**	**800 degrees**	

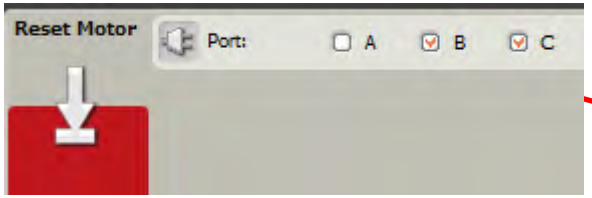
- Note that the fourth MOVE was adjusted by the NXT to correct the accumulated error
- While this might be a helpful feature, it often causes undesirable results in FLL programs

How to correct the accumulated error?

- First, the Rotation Sensor block allows you to set the rotation counters to zero

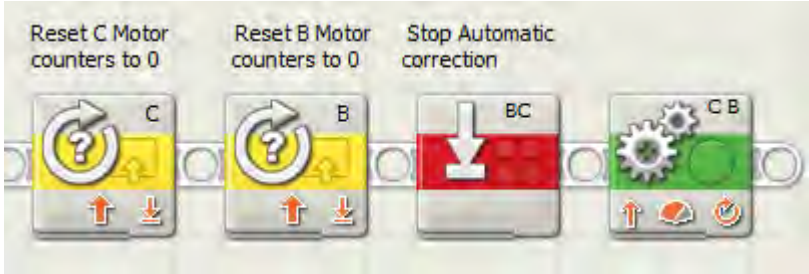


- To stop automatic error correction, use the **RESET** block



Port: select the ports for which you would like to turn off the auto error correction

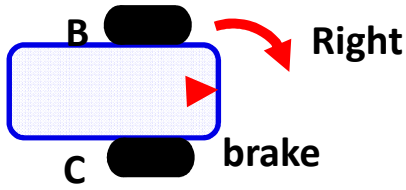
TIP: use the RESET block before each move or motor block!



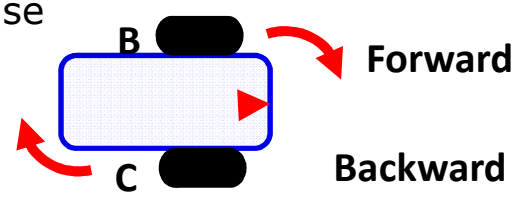
Turn vs. Spin

- There are two ways in which you can make the robot turn
  - Make ONLY one motor move, or
  - Using both motors moving in opposite direction, and this is referred to as "**spinning**"

- One Motor move:
  - Right Turn – Use motor block and select the "**B**" motor
  - In this case the robot's right wheel will be stationary and the left wheel will move.



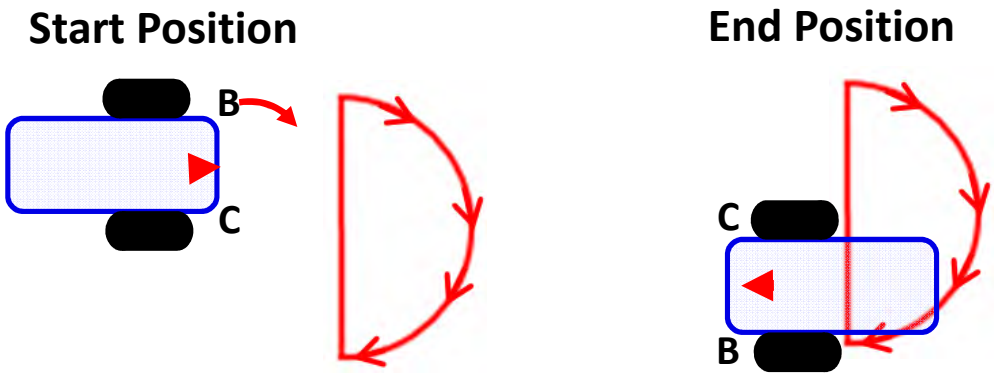
- Turning with two motors in opposite direction
  - To turn the robot right (spin clockwise), use the MOTOR blocks where the the "C" motor will turn counter clockwise and "B" motor will turn clockwise.



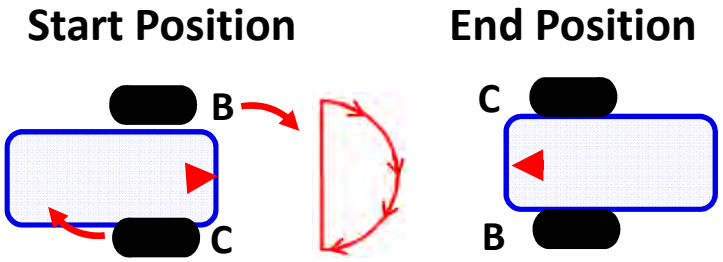
TIP: for turning in a tight spot, use the two motors.

Turns Continued

- To make 180 degree right turn using a single motor



- To make 180 degree right turn using two motors (spin in place)



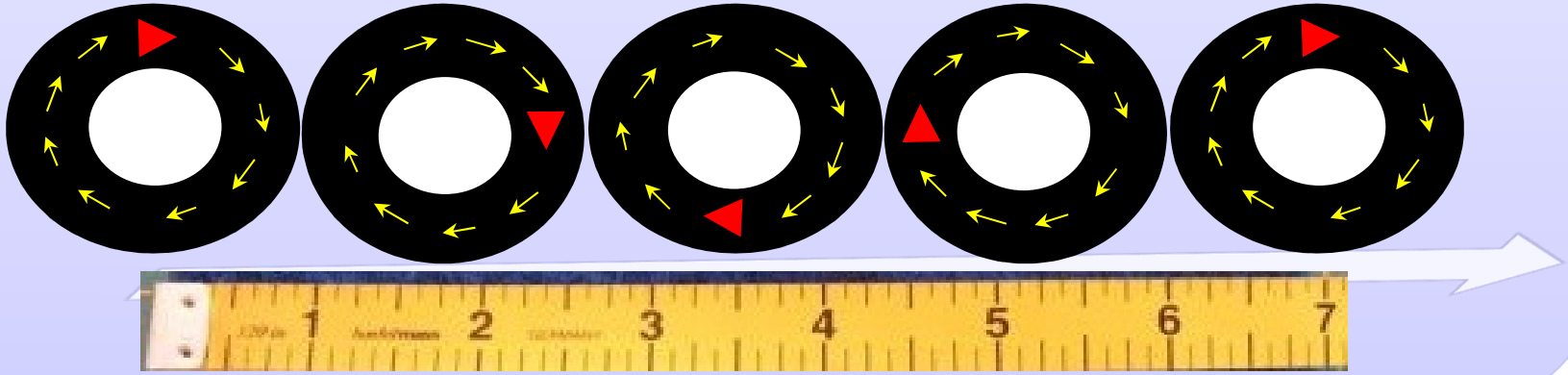
- Note that the distance travelled by the two wheels is shorter (exactly half) when using two motors.

Geometry and Math

Fun way to see that what is learned in school can be applied to the FIRST LEGO League's robots.

Note: it may be a stretch for younger teams that have not covered these concepts in school.

$$\text{Circumference} = \pi \times \text{Diameter}$$



Inches to Motor Degrees

- The Circumference of the robot's wheel determines the number of inches it will travel in 1 rotation
- Circumference of wheel = π x Diameter
- Degrees traveled per inch = 360 / circumference of wheel

3.2 inches

- Circumference of wheel = π x Diameter = 3.14 x 3.2 = 10.0 inches
- Degrees traveled per inch = 360 / 10.0 = 36 motor degrees

1 Rotation = 10 inches

2.2 inches

- Circumference of wheel = π x Diameter = 3.14 x 2.2 = 6.9 inches
- Degrees traveled per inch = 360 / 6.9 = 52 motor degrees

1 Rotation = 7 inches

1.2 inches

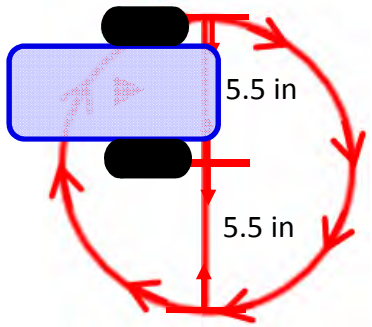
- Circumference of wheel = π x Diameter = 3.14 x 1.2 = 3.8 inches
- Degrees traveled per inch = 360 / 3.8 = 95 motor degrees

1 Rotation = 3.8 inches

You can *use a ruler or measuring tape to plan missions…*

Measuring turn travel distance – More Geometry!

- When the robot turns using one motor, it will make a circle whose Radius is the distance between the wheels



In this case, the radius is 5.5 inches

Circumference $= \pi \times C = 2 \times \pi \times R$
$= 2 \times 3.14 \times 5.5 = 34.5$ inches

2.2 inches

- If the robot is using the wheel whose diameter is 2.2 inches and therefore its circumference is 7 inches, how many **wheel rotations** will it take to make a complete robot turn rotation (34.5 inches)?

$$\frac{\text{Circumference of Robot Turn Circle}}{\text{Circumference of Robot's Wheel}} = \frac{\text{Diameter} \times \boldsymbol{\pi}}{\text{Diameter} \times \boldsymbol{\pi}} = \frac{11 \times \cancel{3.14}}{2.2 \times \cancel{3.14}} = 4.9$$

Note: it takes 4.9 wheel rotations to make a complete (360º turn)
(or *4.9 motor degrees to travel 1 degree of turn circle*)

- Example: to make a 90º robot turn
  - Motor Degrees = 90 X 4.9 = 441 Motor Degrees

Programming Process

- Analysis and Planning Steps
  - Define the problem
  - Brainstorm solutions and select one
  - KEEP IT SIMPLE!
  - Plan and create a flowchart and take measurements

- Programming suggestions
  - Divide the program into small steps
  - Program one step at a time
    - Example: Move the robot to black line
  - Once the step is consistently repeatable, go to the next step
  - Whenever possible, reuse repeatable combinations of blocks using MY BLOCK
  - Ask for help
    - http://forums.usfirst.org/forumdisplay.php?f=24
    - The questions should be generic and not specific to strategy

Tips

- For moving straight, the **MOVE** block has a built-in PID (Proportional, Integral, Derivative) controller to synchronize the movement of "B" & "C" motors. If one motor falls behind, the **MOVE** block compensates by applying more power to that motor. The **MOVE** block is ideal for moving the robot straight.
- For driving the robot, use the **B & C** motor ports; the **A** port should be used for the robot's arm.
- Using full motor power (100%) may cause erratic robot movement, use 75% or less.
- Conversely, too little power (below 25%) may cause the robot to stall.
- Brake at the end of each **MOVE** block to take advantage of the PID, which self corrects to achieve more precise moves.
- Using Degrees is a more accurate way to move motors; using time, will be inconsistent when the batteries become weak
- The **MOVE** block also keeps track of "errors" that accumulate in multiple blocks and adjusts itself.
- Use the ***brake*** option and also use the **RESET** block.
- REMEMBER: the tradeoff between speed and accuracy!

<u>Watch battery voltage</u>

- If you are using the rechargeable Lithium Ion battery, stop programming and recharge it when the it falls below 7.8 volts – the highest voltage is 8.3.
- If you use Alkaline batteries, replace them at 7.8 volts – their highest voltage is 9.4

Finally, the NXT Programming Resources

- The most popular NXT programming tutorial http://www.ortop.org/NXT_Tutorial/
- Several other excellent NXT Programming tutorials are available on FLL Team Resources http://www.firstlegoleague.org/challenge/teamresources
- Good books on NXT programming are available for beginners and more advanced:
  - Laurens Valk. *The LEGO MINDSTORMS NXT 2.0 Discovery Book: A Beginner's Guide to Building and Programming Robots*. San Francisco: No Starch Press, 2010.
  - James Floyd Kelly. *LEGO Mindstorms NXT-G Programming Guide*, 2nd ed. Berkeley CA: Apress, 2010.
- Download great worksheets for planning missions http://www.techbrick.com/
- FLL Forum where you can find answers to your questions from other coaches http://forums.usfirst.org/forumdisplay.php?f=24
- Update the NXT firmware to the latest version (currently 1.31) http://mindstorms.lego.com/en-us/support/files/Firmware.aspx
- Purchase or sell extra LEGO pieces www.bricklink.com

Advanced Programming

Why light sensors?

One of the ways for the robot to know its location is to take advantage of the markings on the field mat. Every year, the Robot Game's mat has lines or dark markings that can be detected by the light sensor.

In this section, we will cover the following

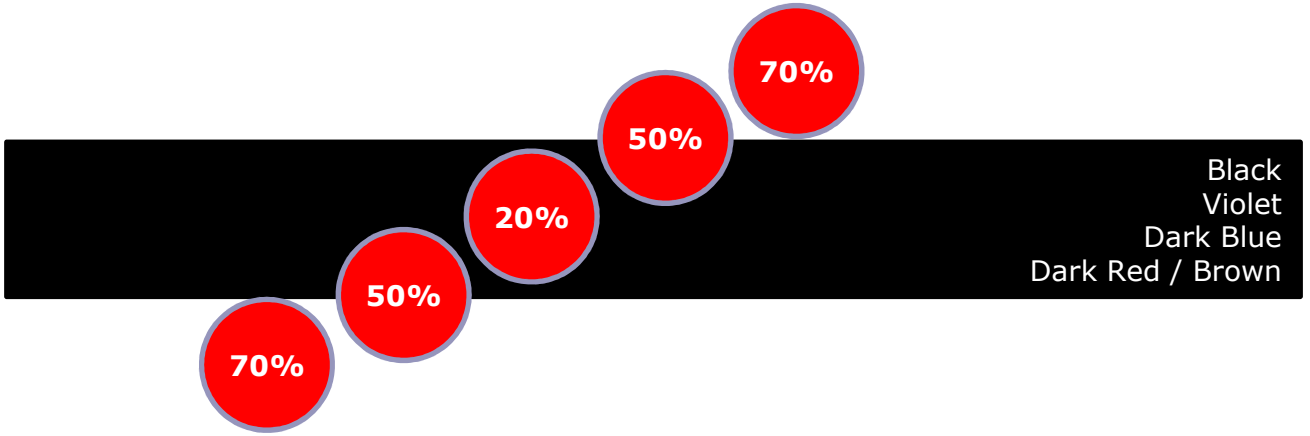
- *How do light sensors work?*
- *How to calibrate lights sensors?*
- *How to install the light sensor calibration program?*

Commonly used Programming Examples:

- *Move until a dark line is encountered by the robot,*
- *Align the robot with a black line*
- *Follow a line*

Light Sensors…

- The **LIGHT SENSOR** shines a light on the mat and reads the reflected brightness level (***intensity)*** level, i.e. dark or bright, to help the robot recognize its position and through programming take action.
- The light sensor doesn't see colors, it only sees "level of brightness" or ***intensity***
- Light ***intensity*** ranges from 0-100%
- On a bright (white) area of the mat the light ***intensity*** value will be above 50%
- On darker area (blue, black, green,…), the light ***intensity*** value will be below 50%



- To obtain more accurate readings, make sure the light sensor is close to the mat (less than ½ inch) and shielded from bright external light sources (like the sun)
- Calibrate the sensor whenever light conditions change (see next slide)

Calibrate Sensor

- The "***Calibrate***" program should be available on the NXT
- To use it:
  1. Select My Files, then Software Files
  2. Navigate back and forth using the left or right arrows until you encounter the ***Calibrate*** program
  3. Select the ***Calibrate*** program by pressing the orange button
  4. Run the ***Calibrate*** program by pressing the orange button and follow the instructions.

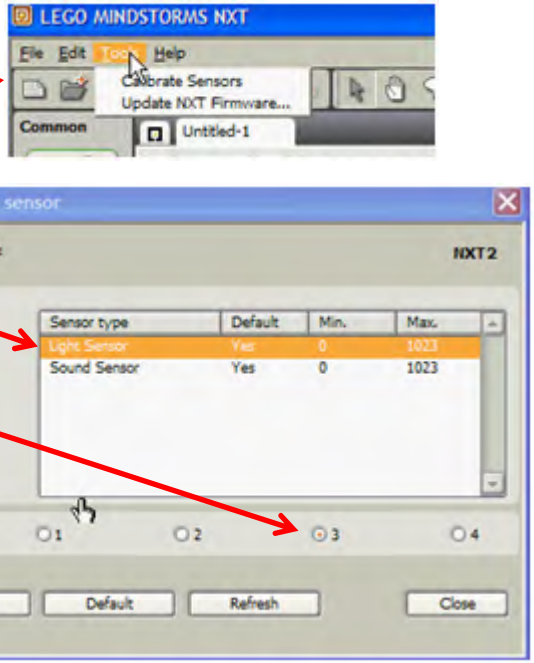
- Once you see the menu, move the sensor over the darkest spot on the mat (e.g., black line) and you'll notice the Min. Value changes. Press the enter key to select the "Min Value" which is the darkest spot on the mat.

- Then move the sensor over the brightest spot (white area) on the mat and press the enter button to capture the "Max Value" which is the brightest spot on the mat.

If you use 2 light sensors, you do not need to calibrate both. The calibration will apply to all light sensors attached to the NXT.

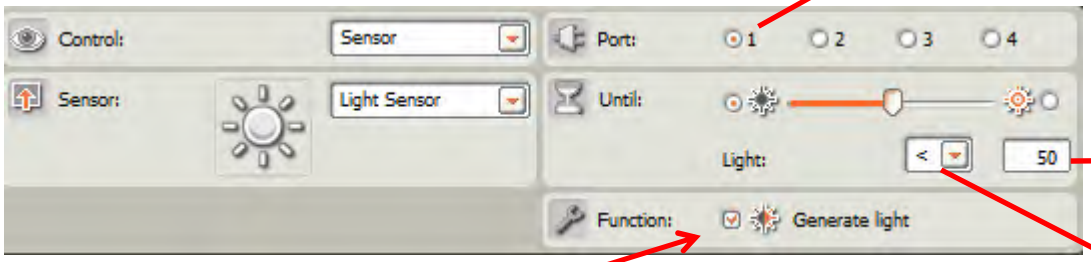
Installing the Light Sensor Calibration Program

- Ensure that the robot is connected to the PC
- In the Mindstorms Software, select "Tools", then "Calibrate Sensors"
- Select "Light Sensor" and choose the port number to which the light sensor is connected (in the example to the right, it is port 3)
- Press the Calibrate button to download the "Calibrate" program into the NXT brick.
- After the program is downloaded, it will run (see previous slide)



WAIT for light value block

- The WAIT block keeps checking for the specified light value and when the condition is met, the next step in the program continues.



Port: identify the NXT port where the light sensor is connected

Enter value you would like to test.

If you check the “Generate Light” checkbox, the light sensor will turn on its own small light source; use it always.

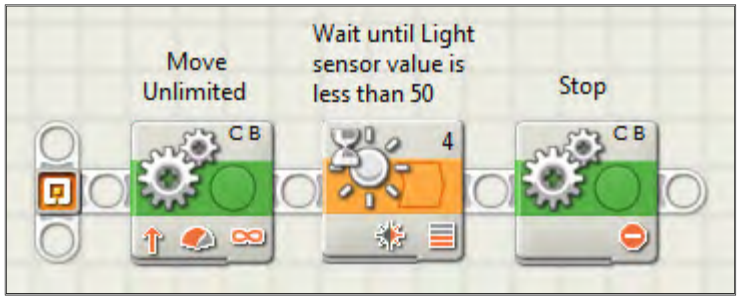
Select “>” greater than or “<“ less than. Example: if you select “<“ and entered 50, and the light sensor encounters a black block, the result will be the test is “True”

FLL teams sometimes design Robots with light sensors to detect dark blocks on the mat or for following a line.

Wait Block – Examples

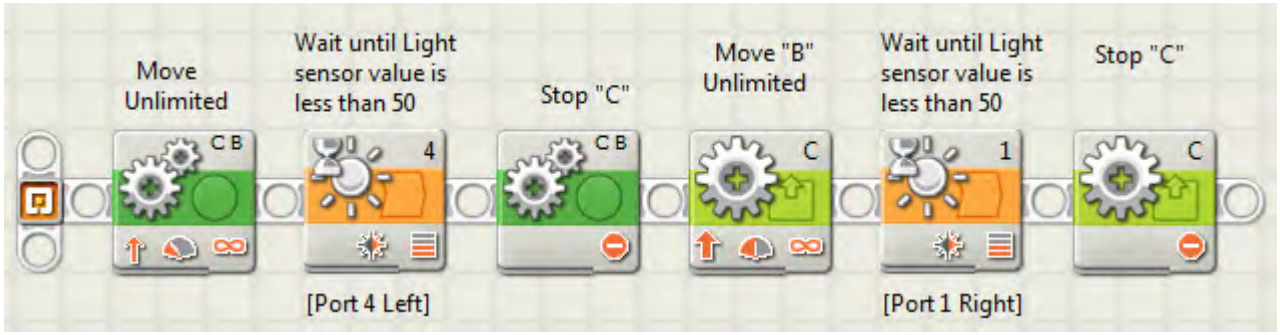
Example 1:

Move until the robot detects a (black) dark line and stop



Example 2:

Align the robot with a black line



This program assumes the left light sensor will reach the black line first. The comment for step 3 should say Stop “B” and “C”. The comment for step 4 should say Move “C” Unlimited. “C” is the right motor. Both light sensors should end up near the edge of the black line.

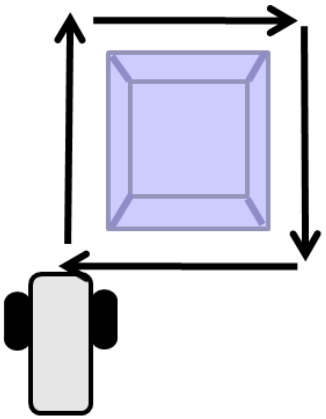
Advanced Blocks and Example

- *To create a line follower program you will need to use the light sensor and repeatedly check the light value and adjust the robot's position*
- *LOOP Block*
- *COMPARE Block – Line follower examples*
- *Additional Blocks*
  - *VARIABLE*
  - *MATH*
  - *COMPARE*
- *Data Hubs*

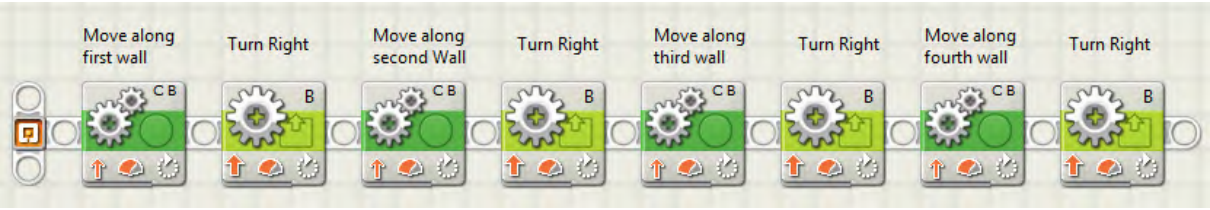
The LOOP Block

- Sometimes, there are actions that you want to repeat. The **LOOP** block allows you to repeat those actions until an end condition is met (or becomes TRUE).

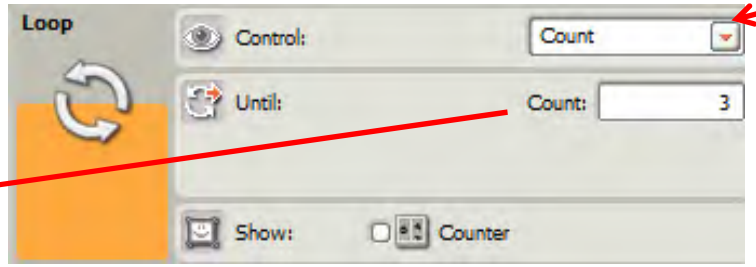
- Example: make the robot move around a box and return to its starting position

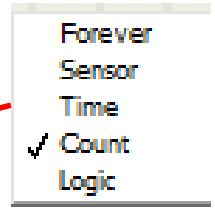


To move along the box sides, it takes 8 blocks as follows:



Using the **LOOP** block, only

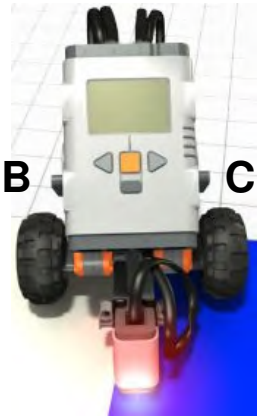


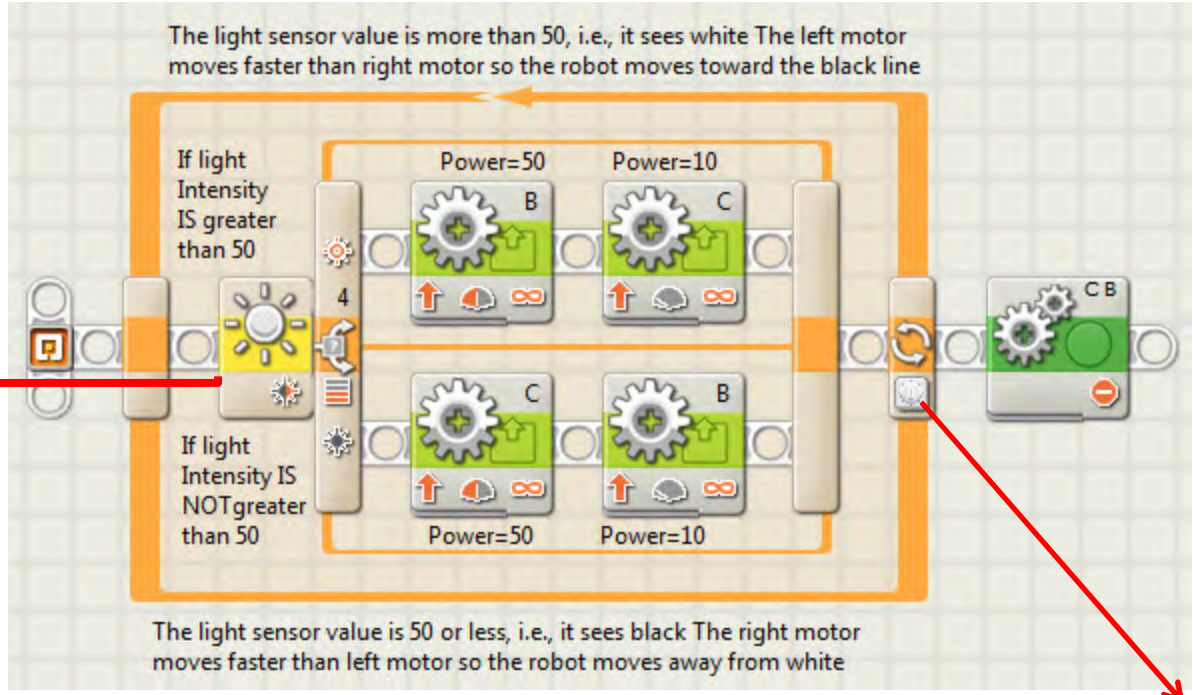


Warning: Deleting the LOOP block will also delete all the blocks within the loop. You can move the blocks out of the loop, then delete it.

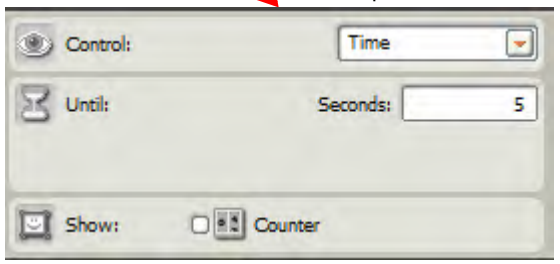
SWITCH block

- The **SWITCH** block will check for a condition and will take different action if the condition is true and another action if the condition is false





Loop for 5 seconds



Advanced Blocks

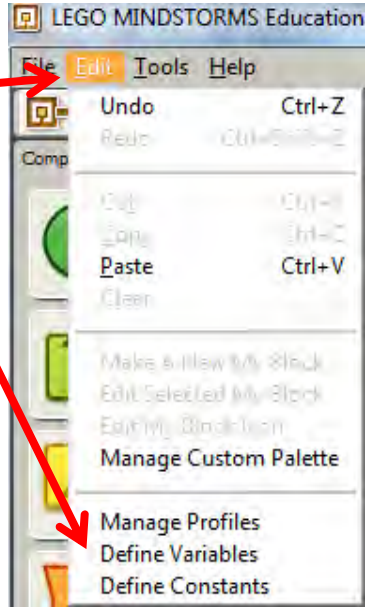
VARIABLE block
- The variable block is a "bucket" where you can store information and retrieve it at a later time.
- There are three types: Number, Text, and Logic

MATH block
- The math block allows the addition, subtraction, multiplication or division of two numbers.

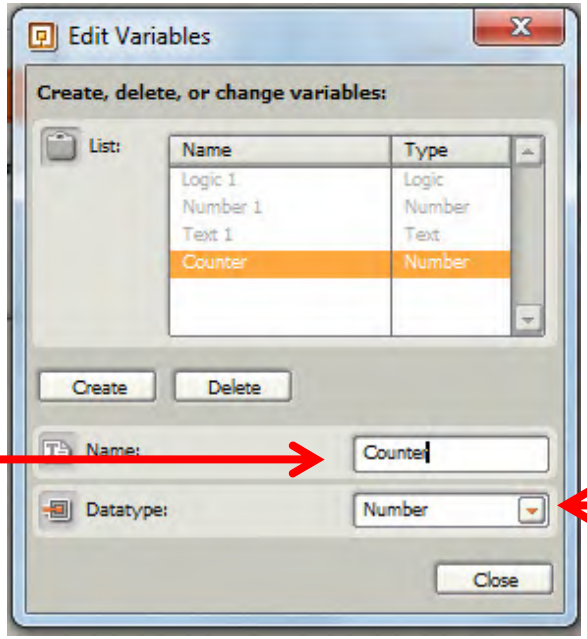
COMPARE block
- The compare block allows you to determine if one number is greater than, less than or equal to another number.

VARIABLES – how to create your own variables

- To create your own variables
  1. Select “Edit” Menu and "Define Variables" option



  2. Type the name of the variable, then select its type.



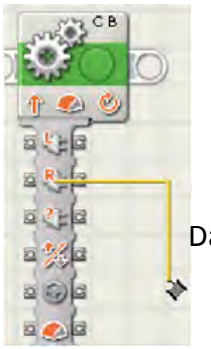
Data Hubs and Data Wires

- ***Data Hub*** is another way of providing input data into a Block.

- Most blocks have a tab at the bottom and when clicked the block expands to show its data "hubs"

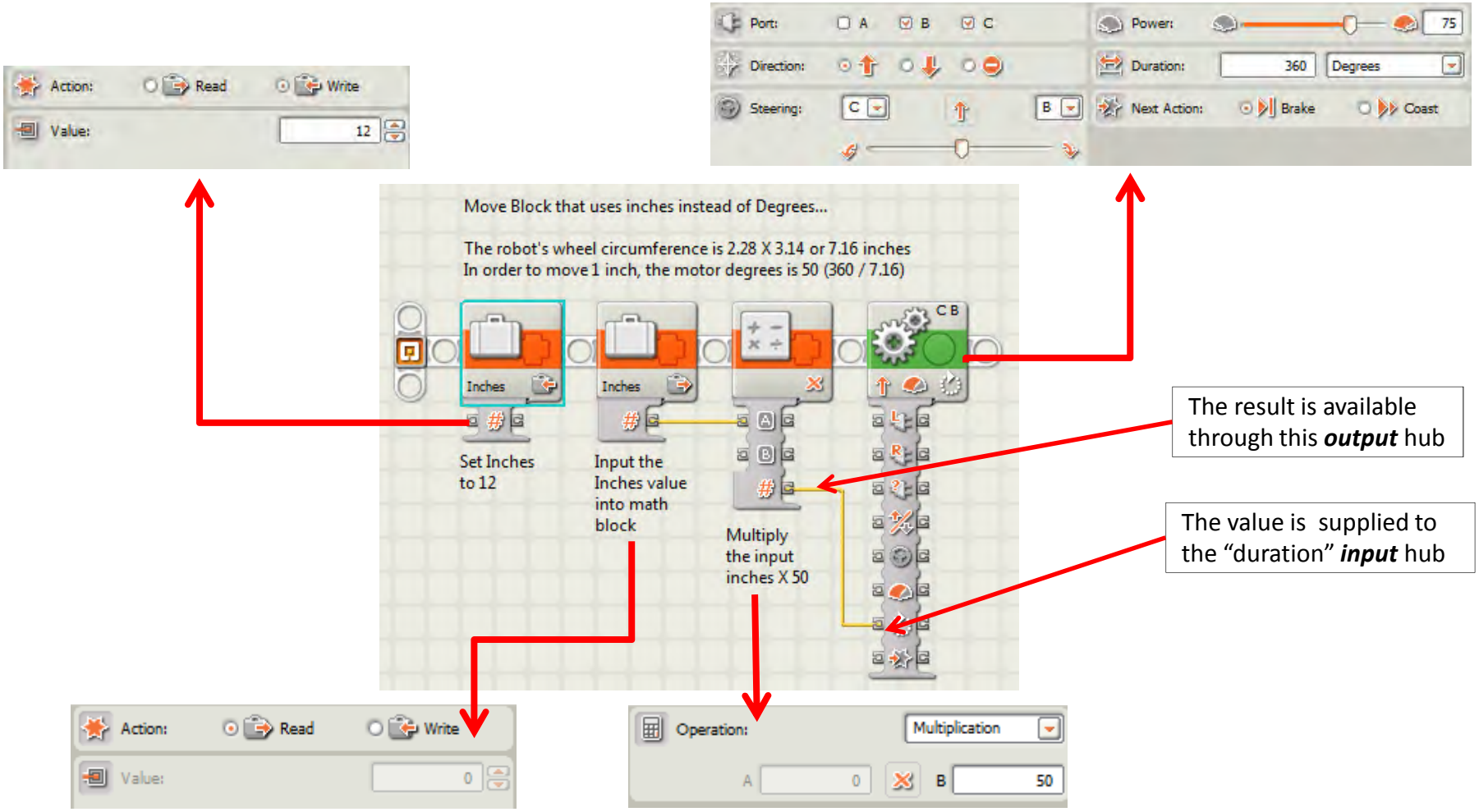
- The **MOVE** block has several data hubs that correspond to its input fields

- ***Data wires*** connect ***data hubs***; you create a data wire by "drawing it out" of a block's data hub.



Variable, Math Blocks Examples

- Earlier, we learned that for each inch of robot movement, 50 motor degrees are required. In this example, we will make the robot move 12 inches; convert the inches into motor degrees



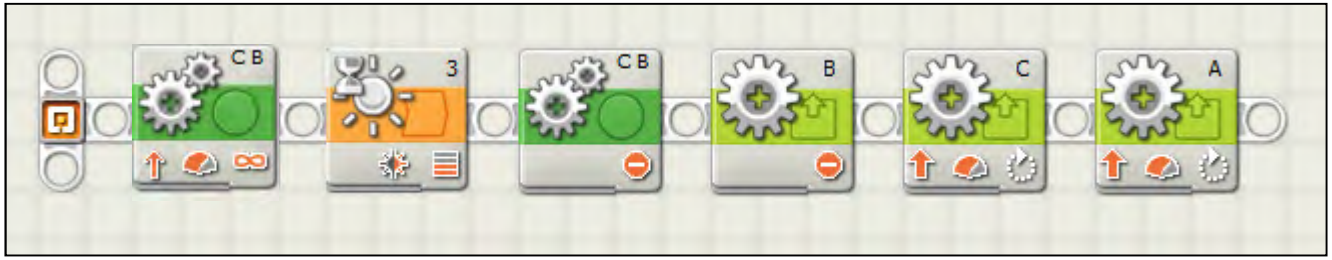
Now for the best part of NXT-G: My Block

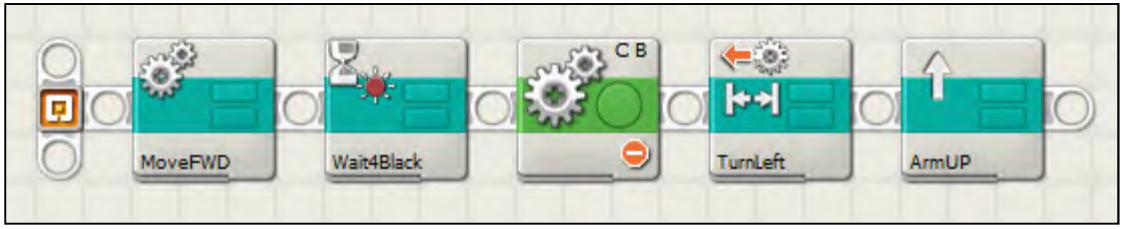
In the previous example, we programmed the robot to move forward 12 inches, what if we wanted to use this and specify different distances?

***NXT-G** allows you to create your own block and it is called **My Block**!*

What are the typical commands?

- NXT-G blocks are hardware-component focused (MOVE, MOTOR, SENSOR, etc.)
- MyBlock allows the creation of ***meaningful actions*** such as Turn Left, Spin Left, Move Forward, Arm Up, Follow Line, etc.
- Command names should be ***self explanatory*** so any team member can understand and debug programs
  - Which program is easier to read?





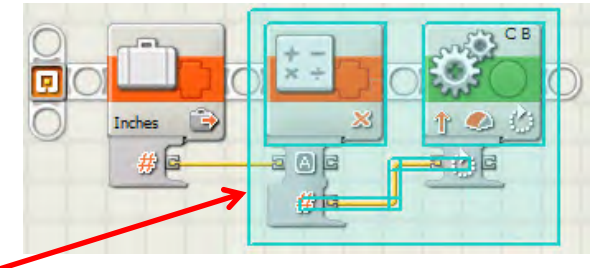
My Block

- **My Block** is a combination one or more blocks that are grouped into a single "Block". Once created, it can be used in many programs. **My Block** can be used in the following ways:
  1. Minimize the coding, if certain actions are repeated in multiple programs. Often, you need to repeat certain steps, for example, different programs may require the robot to back into the wall to re-orient itself. This process can be placed into a **My Block**
  2. Divide a program into smaller manageable pieces
  3. Reduce the amount of memory used
  4. Clarify the action taken in programs by creating self explanatory **My Blocks**

- Example 1: your program already includes 22 **MOVE**, **MOTOR**, **LOOP** blocks and you're not finished. It is time to consider breaking up the program into "chunks", i.e., **My Blocks**.
- Example 2: For turning left or right you use the **MOTOR** block. When someone is reviewing the program, they can't tell which way the robot is turning if you are only using **MOTOR** block. Solution: create a "Turn Left" **My Block** to make it easy to understand the program.
- Example 3: One you've fine-tuned a perfect 90 degree turn, you can create your own **My Blocks** for the perfect 90-degree left and right turns.

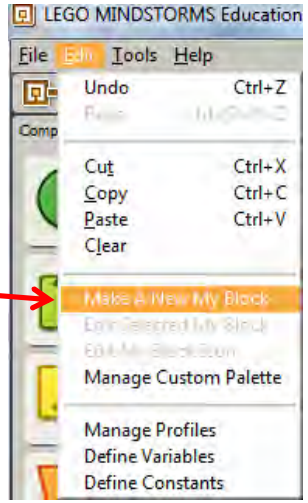
My Block Example – Moving Forward using inches

- Objective:
  - Build a move **My Block** that takes one input called duration which represents the number of inches

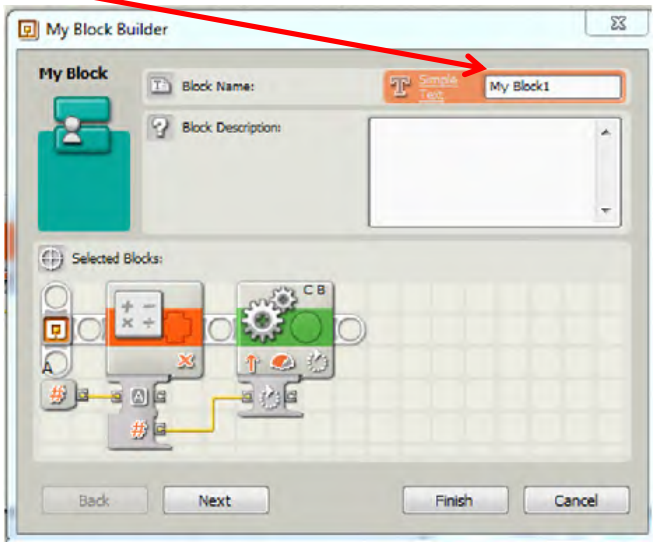


1. Select the Math & Move blocks

2. Select Edit and "Make A New **My Block**"



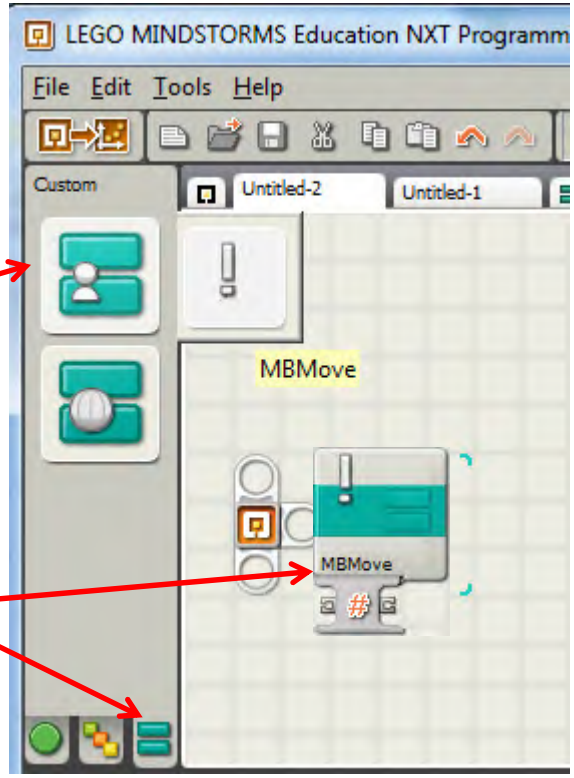
3. Type **My Block** Name "MBMove" and press finish button.



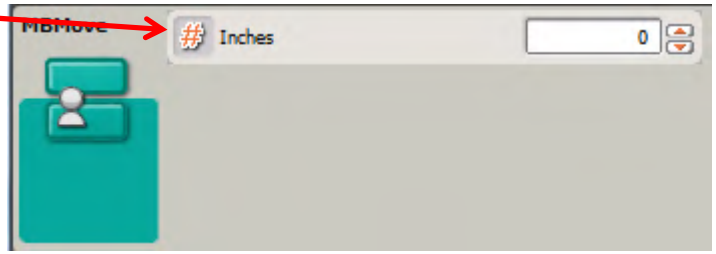
Using My Block

- Once you've created **My Block**, it will become available on the custom pallet

1. Select the custom pallet
2. Move the mouse over the top "**My Blocks**" icon
3. Drag and drop the **My Block** named "MBMove" into the program



- When you click on the **My Block** "MBMove" you'll see its control with the input value named inches. You can enter the value into this field.



More My Block Examples

- Reset
- Move Forward
- Move Back
- Turn Left
- Turn Right
- Spin Left
- Spin Right
- Curve Forward
- Curve Back
- Line Follower
- Align Robot With Black Line
- Square to Wall

My Block Tips

- Use **My Block** to break down a large program into two or more **My Blocks**
- If you create a **My Block** with one input and decided later to add another input, you'll have to start over
- If you create a **My Block** with two inputs and decided later to remove one, you cannot delete the extra input; either start over, or ignore the extra input.
- You can rename a data port by double clicking its text label inside the **My Block**.
- The order of the inputs and outputs is unpredictable.
- **Do not use Save As to create new My Blocks, instead, use the file system to create a copy and edit that one**
- If you move a **My Block** between computers, the program that uses the **My Block** may not work!

Touch Sensor

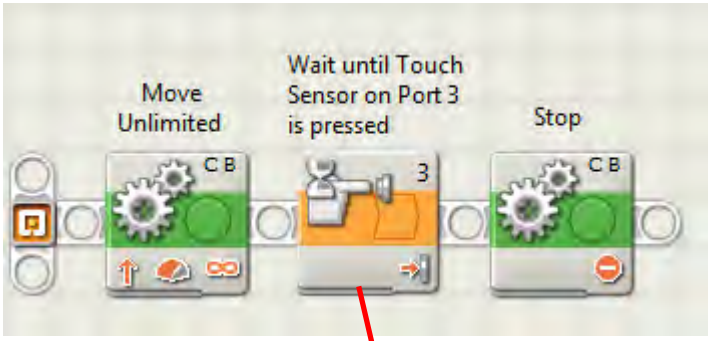
- *WAIT block for touch sensor and example*
- *TOUCH SENSOR block*
- *LIGHT SENSOR block*
- *ROTATION SENSOR block*

- *The difference between WAIT blocks (orange) and SENSOR blocks (yellow)*
- *Advance Line Follower **My Block** example using Rotation Sensor and compare block*

Wait Block - Touch Sensor example

Wait for Touch

Example: stop when the touch sensor is pressed



Sensors

Light Sensor Block

This sensor detects ambient (surrounding) light. For example, you might program your robot to move forward and stop whenever the light level falls below 50%.

Touch Sensor Block

This block checks a touch sensor's condition (pressed, released or bumped) at a specific point in the program. It sends out its finding as a logic signal (true or false) through a data wire.

Rotation Sensor Block

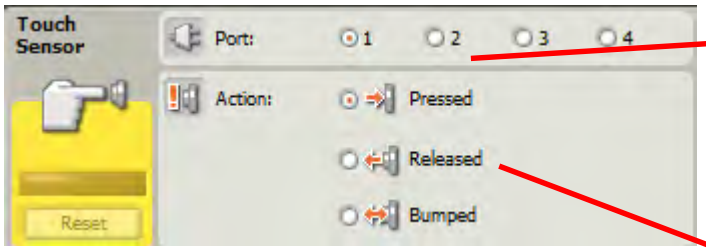
This block counts the number of degrees (one full rotation is 360 degrees) that your motor turns. Through data wires, this block can send out the current number of degrees to be used. The rotation sensor can also be used to reset the rotation counter to 0.

TOUCH SENSOR block

- The touch sensor is used to detect conditions to help the robot recognize its position and through programming take action. The touch sensor recognizes these three conditions:
  - ***Pressed*** = pushed in and stays pushed in
  - ***Released*** = not pushed in
  - ***Bumped*** = Pushed and then released

    Beware of using "bumped" condition within a loop; it may happen so fast that your program may not catch it!!!

- Note: Using this block, and "reading" whether the action is met (true or false) will be covered in detail later.



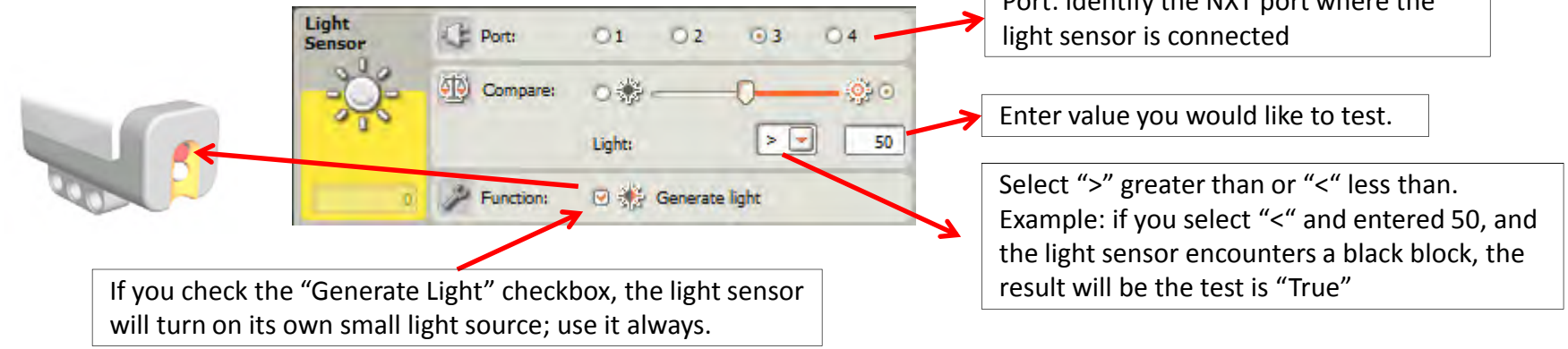
Port: identify the NXT port where the touch sensor is connected

Action: select the desired action (pressed, released or bumped).

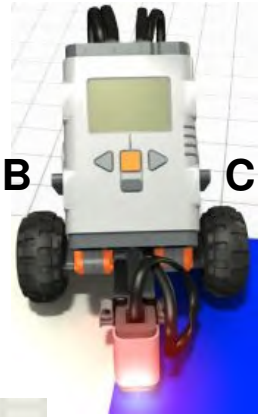
FLL teams sometimes design Robots with touch sensors to detect if the robot hits an object (e.g., wall) then stop. This is a common way to align the robot with one of the table's walls.

LIGHT SENSOR block

- The **LIGHT SENSOR** block is used to *READ* the detected light ***intensity*** level, i.e. dark or bright.

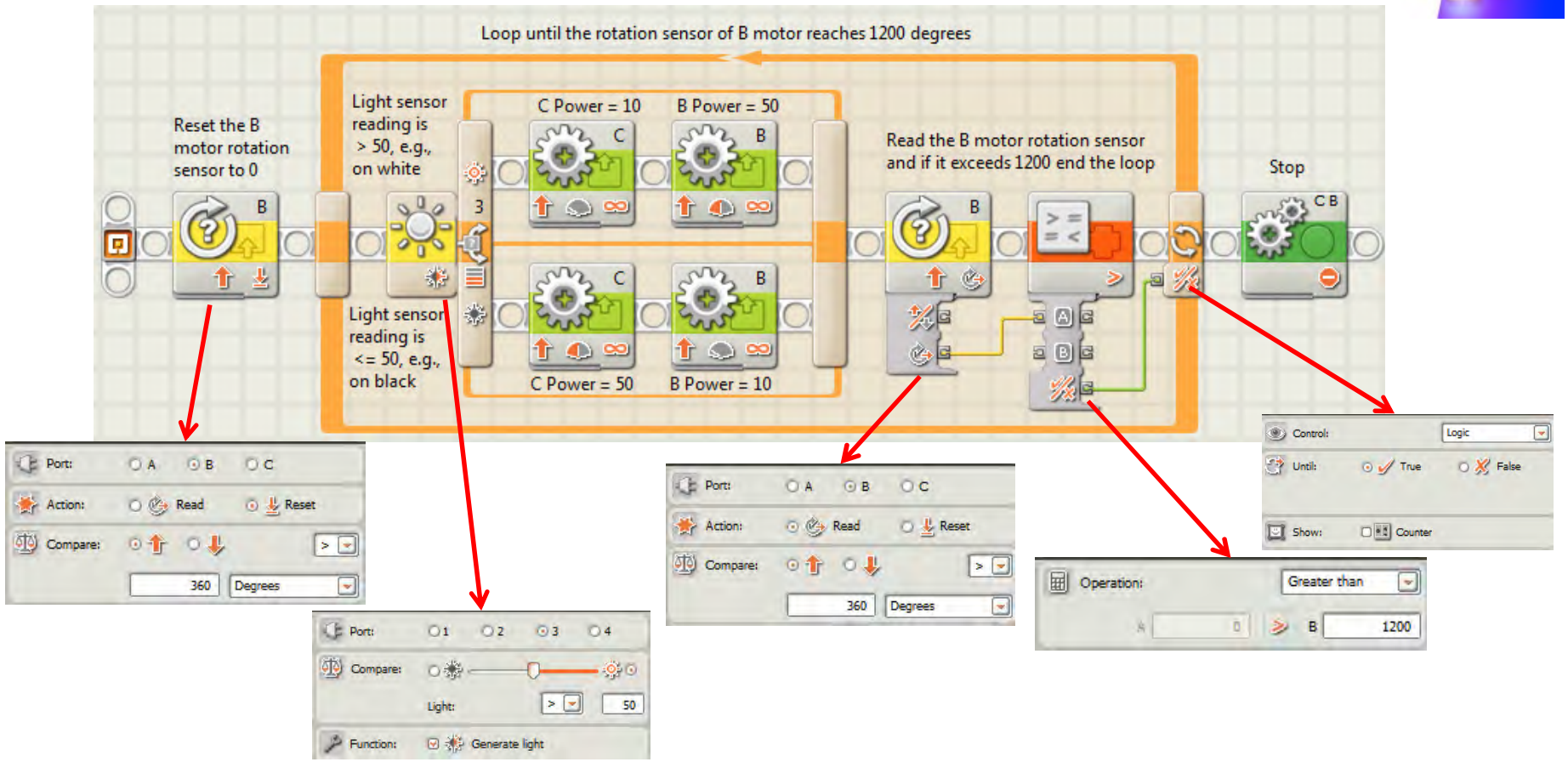


Advanced Line Follower Example



- The **COMPARE** block can determine if a number is greater than (>), less than (<) or equal to (=) another number. Similar to the MATH block, the input A and B values can be typed in or supplied by data wires.

- Example: You are using a light sensor, and want to follow a black line for 1200 degrees.



Challenges

- What is the fastest way to follow the line to the “T” end?
- A move **My Block** that can move forward or back at a different power level
- Simultaneously move and raise or lower the arm
- A **My Block** that moves a certain number of inches as input
- A **My Block** to turns left using turn angle degrees as input