

# LabVIEW™ Toolkit for LEGO® MINDSTORMS® NXT Programming Guide

January 2009  
372574B-01



## **Worldwide Technical Support and Product Information**

ni.com

### **National Instruments Corporate Headquarters**

11500 North Mopac Expressway Austin, Texas 78759-3504 USA Tel: 512 683 0100

### **Worldwide Offices**

Australia 1800 300 800, Austria 43 662 457990-0, Belgium 32 (0) 2 757 0020, Brazil 55 11 3262 3599,  
Canada 800 433 3488, China 86 21 5050 9800, Czech Republic 420 224 235 774, Denmark 45 45 76 26 00,  
Finland 358 (0) 9 725 72511, France 01 57 66 24 24, Germany 49 89 7413130, India 91 80 41190000,  
Israel 972 3 6393737, Italy 39 02 41309277, Japan 0120-527196, Korea 82 02 3451 3400,  
Lebanon 961 (0) 1 33 28 28, Malaysia 1800 887710, Mexico 01 800 010 0793, Netherlands 31 (0) 348 433 466,  
New Zealand 0800 553 322, Norway 47 (0) 66 90 76 60, Poland 48 22 328 90 10, Portugal 351 210 311 210,  
Russia 7 495 783 6851, Singapore 1800 226 5886, Slovenia 386 3 425 42 00, South Africa 27 0 11 805 8197,  
Spain 34 91 640 0085, Sweden 46 (0) 8 587 895 00, Switzerland 41 56 2005151, Taiwan 886 02 2377 2222,  
Thailand 662 278 6777, Turkey 90 212 279 3031, United Kingdom 44 (0) 1635 523545

For further support information, refer to the *Technical Support and Professional Services* appendix. To comment on National Instruments documentation, refer to the National Instruments Web site at [ni.com/info](http://ni.com/info) and enter the info code `feedback`.

# Important Information

---

## Warranty

The media on which you receive National Instruments software are warranted not to fail to execute programming instructions, due to defects in materials and workmanship, for a period of 90 days from date of shipment, as evidenced by receipts or other documentation. National Instruments will, at its option, repair or replace software media that do not execute programming instructions if National Instruments receives notice of such defects during the warranty period. National Instruments does not warrant that the operation of the software shall be uninterrupted or error free.

A Return Material Authorization (RMA) number must be obtained from the factory and clearly marked on the outside of the package before any equipment will be accepted for warranty work. National Instruments will pay the shipping costs of returning to the owner parts which are covered by warranty.

National Instruments believes that the information in this document is accurate. The document has been carefully reviewed for technical accuracy. In the event that technical or typographical errors exist, National Instruments reserves the right to make changes to subsequent editions of this document without prior notice to holders of this edition. The reader should consult National Instruments if errors are suspected. In no event shall National Instruments be liable for any damages arising out of or related to this document or the information contained in it.

EXCEPT AS SPECIFIED HEREIN, NATIONAL INSTRUMENTS MAKES NO WARRANTIES, EXPRESS OR IMPLIED, AND SPECIFICALLY DISCLAIMS ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. CUSTOMER'S RIGHT TO RECOVER DAMAGES CAUSED BY FAULT OR NEGLIGENCE ON THE PART OF NATIONAL INSTRUMENTS SHALL BE LIMITED TO THE AMOUNT THEREFORE PAID BY THE CUSTOMER. NATIONAL INSTRUMENTS WILL NOT BE LIABLE FOR DAMAGES RESULTING FROM LOSS OF DATA, PROFITS, USE OF PRODUCTS, OR INCIDENTAL OR CONSEQUENTIAL DAMAGES, EVEN IF ADVISED OF THE POSSIBILITY THEREOF. This limitation of the liability of National Instruments will apply regardless of the form of action, whether in contract or tort, including negligence. Any action against National Instruments must be brought within one year after the cause of action accrues. National Instruments shall not be liable for any delay in performance due to causes beyond its reasonable control. The warranty provided herein does not cover damages, defects, malfunctions, or service failures caused by owner's failure to follow the National Instruments installation, operation, or maintenance instructions; owner's modification of the product; owner's abuse, misuse, or negligent acts; and power failure or surges, fire, flood, accident, actions of third parties, or other events outside reasonable control.

## Copyright

Under the copyright laws, this publication may not be reproduced or transmitted in any form, electronic or mechanical, including photocopying, recording, storing in an information retrieval system, or translating, in whole or in part, without the prior written consent of National Instruments Corporation.

National Instruments respects the intellectual property of others, and we ask our users to do the same. NI software is protected by copyright and other intellectual property laws. Where NI software may be used to reproduce software or other materials belonging to others, you may use NI software only to reproduce materials that you may reproduce in accordance with the terms of any applicable license or other legal restriction.

## Trademarks

National Instruments, NI, ni.com, and LabVIEW are trademarks of National Instruments Corporation. Refer to the *Terms of Use* section on [ni.com/legal](http://ni.com/legal) for more information about National Instruments trademarks.

LEGO and MINDSTORMS are trademarks of the LEGO Group. Other product and company names mentioned herein are trademarks or trade names of their respective companies.

Members of the National Instruments Alliance Partner Program are business entities independent from National Instruments and have no agency, partnership, or joint-venture relationship with National Instruments.

## Patents

For patents covering National Instruments products/technology, refer to the appropriate location: **Help»Patents** in your software, the `patents.txt` file on your media, or the *National Instruments Patent Notice* at [ni.com/patents](http://ni.com/patents).

## WARNING REGARDING USE OF NATIONAL INSTRUMENTS PRODUCTS

(1) NATIONAL INSTRUMENTS PRODUCTS ARE NOT DESIGNED WITH COMPONENTS AND TESTING FOR A LEVEL OF RELIABILITY SUITABLE FOR USE IN OR IN CONNECTION WITH SURGICAL IMPLANTS OR AS CRITICAL COMPONENTS IN ANY LIFE SUPPORT SYSTEMS WHOSE FAILURE TO PERFORM CAN REASONABLY BE EXPECTED TO CAUSE SIGNIFICANT INJURY TO A HUMAN.

(2) IN ANY APPLICATION, INCLUDING THE ABOVE, RELIABILITY OF OPERATION OF THE SOFTWARE PRODUCTS CAN BE IMPAIRED BY ADVERSE FACTORS, INCLUDING BUT NOT LIMITED TO FLUCTUATIONS IN ELECTRICAL POWER SUPPLY, COMPUTER HARDWARE MALFUNCTIONS, COMPUTER OPERATING SYSTEM SOFTWARE FITNESS, FITNESS OF COMPILERS AND DEVELOPMENT SOFTWARE USED TO DEVELOP AN APPLICATION, INSTALLATION ERRORS, SOFTWARE AND HARDWARE COMPATIBILITY PROBLEMS, MALFUNCTIONS OR FAILURES OF ELECTRONIC MONITORING OR CONTROL DEVICES, TRANSIENT FAILURES OF ELECTRONIC SYSTEMS (HARDWARE AND/OR SOFTWARE), UNANTICIPATED USES OR MISUSES, OR ERRORS ON THE PART OF THE USER OR APPLICATIONS DESIGNER (ADVERSE FACTORS SUCH AS THESE ARE HEREAFTER COLLECTIVELY TERMED "SYSTEM FAILURES"). ANY APPLICATION WHERE A SYSTEM FAILURE WOULD CREATE A RISK OF HARM TO PROPERTY OR PERSONS (INCLUDING THE RISK OF BODILY INJURY AND DEATH) SHOULD NOT BE RELIANT SOLELY UPON ONE FORM OF ELECTRONIC SYSTEM DUE TO THE RISK OF SYSTEM FAILURE. TO AVOID DAMAGE, INJURY, OR DEATH, THE USER OR APPLICATION DESIGNER MUST TAKE REASONABLY PRUDENT STEPS TO PROTECT AGAINST SYSTEM FAILURES, INCLUDING BUT NOT LIMITED TO BACK-UP OR SHUT DOWN MECHANISMS. BECAUSE EACH END-USER SYSTEM IS CUSTOMIZED AND DIFFERS FROM NATIONAL INSTRUMENTS' TESTING PLATFORMS AND BECAUSE A USER OR APPLICATION DESIGNER MAY USE NATIONAL INSTRUMENTS PRODUCTS IN COMBINATION WITH OTHER PRODUCTS IN A MANNER NOT EVALUATED OR CONTEMPLATED BY NATIONAL INSTRUMENTS, THE USER OR APPLICATION DESIGNER IS ULTIMATELY RESPONSIBLE FOR VERIFYING AND VALIDATING THE SUITABILITY OF NATIONAL INSTRUMENTS PRODUCTS WHENEVER NATIONAL INSTRUMENTS PRODUCTS ARE INCORPORATED IN A SYSTEM OR APPLICATION, INCLUDING, WITHOUT LIMITATION, THE APPROPRIATE DESIGN, PROCESS AND SAFETY LEVEL OF SUCH SYSTEM OR APPLICATION.

# Conventions

---

The following conventions are used in this manual:

» The » symbol leads you through nested menu items and dialog box options to a final action. The sequence **File»Page Setup»Options** directs you to pull down the **File** menu, select the **Page Setup** item, and select **Options** from the last dialog box.



This icon denotes a note, which alerts you to important information.

**bold**

**Bold text** denotes items that you must select or click in the software, such as menu items and dialog box options. **Bold text** also denotes parameter names front panel controls and indicators, dialog boxes, sections of dialog boxes, menu names, and palette names

*italic*

*Italic text* denotes variables, emphasis, a cross-reference, or an introduction to a key concept. *Italic text* also denotes text that is a placeholder for a word or value that you must supply.

monospace

Text in this font denotes text or characters that you should enter from the keyboard, sections of code, programming examples, and syntax examples. This font is also used for the proper names of disk drives, paths, directories, programs, subprograms, subroutines, device names, functions, operations, variables, filenames, and extensions.

# Contents

---

## Chapter 1

### Introduction

Related Documentation.....	1-2
Assumptions.....	1-2
NXT Firmware Concepts.....	1-3
NXT Programs and LabVIEW VIs .....	1-3
NXT Bytecode Instructions and LabVIEW Functions.....	1-3
NXT Program Data Space .....	1-4
Parallel Execution on the NXT Brick.....	1-4
LabVIEW Basics .....	1-5
Data Types.....	1-5
Supported Data Types .....	1-5
Unsupported Data Types.....	1-5
Controls, Indicators, and Constants.....	1-6
Sequence Flow Boolean Controls .....	1-6
NXT Refnum Controls.....	1-6
Functions .....	1-7
Numeric.....	1-7
Conversion .....	1-7
Logic .....	1-7
Strings .....	1-8
Arrays.....	1-8
Comparison .....	1-8
Miscellaneous.....	1-9
Structures .....	1-9
SubVIs .....	1-10

## Chapter 2

### Extensions to LabVIEW

Analog Input Devices (Touch, Light, and Sound Sensors) .....	2-2
Input Port Properties.....	2-2
Port.....	2-4
SensorType.....	2-5
SensorMode .....	2-6
Raw .....	2-7
Normalized.....	2-8
Scaled.....	2-9
InvalidData.....	2-10

Digital I/O Devices (Ultrasonic Sensors) .....	2-11
Digital I/O Port Setup .....	2-11
Low Speed Communication Methods .....	2-11
NXTCommLSCheckStatus .....	2-13
NXTCommLSWrite .....	2-14
NXTCommLSRead .....	2-15
Output Devices: Motors and Lamps .....	2-16
Output Port Properties .....	2-16
Port .....	2-18
PortList .....	2-19
UpdateFlags .....	2-20
Mode .....	2-22
RegMode .....	2-23
TurnRatio .....	2-24
RunState .....	2-25
Power .....	2-26
ActualSpeed .....	2-27
TachoLimit .....	2-28
TachoCount .....	2-29
BlockTachoCount .....	2-30
RotationCount .....	2-31
Overloaded .....	2-32
RegPValue .....	2-33
RegIValue .....	2-34
RegDValue .....	2-35
Built-In I/O .....	2-36
File Access Methods .....	2-36
File Handles .....	2-38
File Access Status Codes .....	2-39
File Access Performance Issues .....	2-40
NXTFileOpenRead .....	2-41
NXTFileOpenWrite .....	2-42
NXTFileOpenAppend .....	2-43
NXTFileResolveHandle .....	2-44
NXTFileClose .....	2-45
NXTFileRead .....	2-46
NXTFileWrite .....	2-47
NXTFileDelete .....	2-48
NXTFileRename .....	2-49
NXTListFiles .....	2-50
NXT Display Methods .....	2-51
NXTDrawText .....	2-51
NXTDrawPoint .....	2-52
NXTDrawLine .....	2-53

NXTDrawCircle .....	2-54
NXTDrawRect .....	2-55
NXTDrawGraphic.....	2-56
NXTSetScreenMode .....	2-57
NXT Button Method.....	2-58
NXTReadButton .....	2-58
Sound Playback Methods .....	2-59
NXTSoundPlayFile.....	2-59
NXTSoundPlayTone.....	2-60
NXTSoundGetState .....	2-61
NXTSoundSetState .....	2-62
Bluetooth Communication Methods.....	2-63
NXTCommBTCheckStatus .....	2-64
NXTCommBTWrite .....	2-65
NXTMessageRead .....	2-66
NXTMessageWrite .....	2-67
Low-Level System Methods.....	2-68
NXTGetStartTick.....	2-68
NXTKeepAlive .....	2-69
NXTRandomNumber.....	2-70
NXTIOMapRead.....	2-71
NXTIOMapWrite.....	2-72
Using Dynamic System Calls .....	2-73
Creating Access to a Dynamic System Call .....	2-73
Using the NXTDynamicSyscall Refnum .....	2-73

## Appendix A

### Technical Support and Professional Services

---

# Introduction

The LEGO® MINDSTORMS® NXT software uses a graphical programming language called NXT-G that is based on National Instruments LabVIEW 7.1. The high-level programming blocks in NXT-G block diagrams are built out of lower-level LabVIEW block diagrams. Ultimately, NXT-G blocks are just a special kind of VI developed for use with LEGO MINDSTORMS.



**Note** The LabVIEW Toolkit for LEGO MINDSTORMS NXT is based on LabVIEW 7.1, and you must have LabVIEW 7.1 or later to use the toolkit. You must use LabVIEW 7.1 to create blocks that you can import into the LEGO MINDSTORMS NXT software. If you are developing for *FIRST* Tech Challenge (FTC), you must use LabVIEW 8.5.1.

Using the LabVIEW Toolkit for LEGO MINDSTORMS NXT with LabVIEW 7.1 or later allows you to bypass the high-level limitations imposed by NXT-G. The toolkit enables you to create advanced programs using VIs and download them to the NXT Intelligent Brick. You can even extend the NXT-G programming language with new high-level blocks built out of LabVIEW VIs. Furthermore, LabVIEW provides a more advanced editing environment than the LEGO MINDSTORMS NXT software.

This document details the NXT-specific modifications and extensions to LabVIEW provided by the toolkit. Note that the toolkit does not support all LabVIEW features. Therefore, you should carefully review all notes and warnings listed in this document when programming with the toolkit.

Refer to the National Instruments Web site at [ni.com/mindstorms](http://ni.com/mindstorms) for more information about the LabVIEW Toolkit for LEGO MINDSTORMS NXT.



## Related Documentation

---

The following documents contain information that you may find helpful as you read this manual:

- *Getting Started with the LabVIEW Toolkit for LEGO® MINDSTORMS® NXT*
- *Creating LEGO® MINDSTORMS® NXT Software Blocks*

## Assumptions

---

This document assumes that you are using the LabVIEW Toolkit for LEGO MINDSTORMS NXT with LabVIEW 7.1 or later. This document also assumes that you are familiar with the following LabVIEW programming concepts:

- Data types: integers, Booleans, strings, arrays, and clusters
- Basic VIs and functions used with the listed data types
- Case, loop, and sequence structures
- Usage of subVIs
- Properties and methods

Refer to the *LabVIEW Help*, available in LabVIEW by selecting **Help»Search the LabVIEW Help**, for more information about these concepts.

The toolkit provides special palettes for working with both front panels and block diagrams. These palettes contain only supported LabVIEW features. You are not required to use these palettes, but using them will help you remember which features the toolkit supports.

This document assumes that you are using official LEGO or NI NXT firmware. Refer to the LEGO MINDSTORMS Web site at [mindstorms.lego.com](http://mindstorms.lego.com) for more information about firmware updates.

# NXT Firmware Concepts

---

The following sections provide a brief summary of how LabVIEW concepts correspond to NXT firmware concepts. Refer to the LEGO MINDSTORMS Web site at [mindstorms.lego.com](http://mindstorms.lego.com) for the NXT SDK and HDK documents describing the NXT hardware and firmware platform.

## NXT Programs and LabVIEW VIs

When you choose a VI to compile and download to an NXT brick using the toolkit, that VI becomes the *top-level VI* of the corresponding program file on the NXT brick. The toolkit compiles the top-level VI and all of its subVIs into one program file, and then downloads the program file to the NXT brick using the same name as the top-level VI. You can think of the top-level VI and its subVIs as the complete source code for the resulting binary program file.

Note the implication that subVIs have no analogous feature on the file system of the NXT brick. Inside the program file, subVIs become shared subroutines. Refer to the [SubVIs](#) section of this document for more information about using subVIs.

## NXT Bytecode Instructions and LabVIEW Functions

The NXT firmware executes a program file by interpreting its contents as bytecode instructions. You can think of many of the bytecode instructions as loosely analogous to LabVIEW functions. For example, the NXT firmware has an ADD bytecode that shares its semantics with the Add function in LabVIEW. In other words, the ADD bytecode behaves similarly to the Add function for a given set of input data types and values.

The *LabVIEW Help* documentation describes how all of the supported functions operate in general. Refer to the [Functions](#) section of this document for a list of NXT-specific exceptions and behavior changes.

## NXT Program Data Space

NXT programs maintain a data space for run-time data similarly to how LabVIEW maintains VI data spaces. You do not need to manage the data space because the toolkit compiler automatically organizes the data space of NXT programs and the NXT firmware manages the data space at run time.



**Note** This automatic management of the data space includes resizing arrays and strings as needed, much like LabVIEW. However, using arrays and strings requires a relatively large amount of memory and execution time on the NXT brick, so avoid overusing arrays and strings in the programs you write. If you extensively use dynamic array and string resizing while the program runs, such as placing Build Array functions in a loop, the program might intermittently run more slowly than normal.

Additionally, extensive use of dynamic array and string resizing can cause the NXT firmware to run out of memory during program execution. If the total size of the data space, including the array and string data, exceeds the size of the allotted RAM pool in the NXT firmware, the program immediately aborts and prints an error message on the display of the NXT brick.

## Parallel Execution on the NXT Brick

NXT firmware supports parallel execution of VI code in a similar sense to the way that LabVIEW executes parallel code on a single-processor PC. Parallel streams of functions or subVI calls share the CPU using an automatically managed cooperative multitasking system.

You do not need to perform any special steps to enable parallel execution. Write parallel code the same way you write parallel code for VIs that run on a PC.

# LabVIEW Basics

---

## Data Types

The toolkit only supports a limited subset of the data types that LabVIEW supports.

### Supported Data Types

The toolkit supports the following data types:

- 8-bit signed and unsigned integer numerics
- 16-bit signed and unsigned integer numerics
- 32-bit signed and unsigned integer numerics
- Booleans
- Strings
- Arrays containing integers, Booleans, strings, or clusters
  - Only one-dimensional (1D) arrays are supported
- Clusters containing integers, Booleans, strings, 1D arrays, or other clusters

### Unsupported Data Types

The toolkit does not support any data types not listed above. The following list includes some examples of unsupported data types:

- Single-precision floating point numbers
- Enumerations
- Arrays of two or more dimensions (including tables)
- Reference numbers (refnums) of any type other than those the toolkit provides
- Paths
- Waveform, digital waveform, or digital data tables
- Variant or ActiveX data

## Controls, Indicators, and Constants

When you compile and download VIs to an NXT brick, the layout and appearance of their front panels do not directly influence the compiled code. Thus, you can use any front panel control or indicator style as long as the NXT firmware supports the data type. For example, you can use numeric ring, slide, knob, chart, and graph controls and indicators as long as they do not rely on floating-point numbers or multi-dimensional arrays.

The same principle is true for custom controls, type definitions, and block diagram constants. As long as the NXT firmware supports the data type of the wire connected to a particular block diagram terminal, you can use any style or type definition.

## Sequence Flow Boolean Controls

The toolkit provides a special kind of Boolean control, Sequence Flow. Use the following tips when working with the Sequence Flow control:

- The toolkit identifies Sequence Flow controls by name. If the name of your Boolean control or indicator begins with Sequence Flow, the toolkit compiler classifies that control or indicator as a Sequence Flow control.
- The toolkit classifies wires connected to Sequence Flow controls as Sequence Flow wires. These wires are directly analogous to the white LEGO TECHNIC beams on NXT-G diagrams.
- No Sequence Flow controls, indicators, or wires generate corresponding data space items in the compiled NXT program.

## NXT Refnum Controls

The toolkit provides some special classes of generic refnum controls in order to expose NXT-specific features.

Refer to Chapter 2, *Extensions to LabVIEW*, for specific information on how to use each new class of refnum. Use the following tips when working with the NXT refnums:

- The toolkit identifies NXT refnum controls by name. If the name of your generic refnum control or indicator begins with Generic Refnum Name, the toolkit compiler classifies that control or indicator as an NXT refnum.
- NXT refnum controls, indicators, or wires do not generate corresponding data space items in the compiled NXT program. NXT refnum controls enable you to access the new properties and methods that the toolkit provides.

- Only wire these controls directly to the reference inputs of Property and Invoke Nodes. Do not assign NXT refnum controls to subVI connector pane terminals.

## Functions

The toolkit does not support all LabVIEW functions, and some supported functions exhibit special behavior or limitations when you use them with the toolkit. In general, any function that relies on one or more unsupported data types is itself unsupported.

The following lists the functions that the toolkit supports, along with any special usage notes.

### Numeric

- Add
- Subtract
- Multiply
- Quotient and Remainder (integer division)
- Increment
- Decrement
- Negate

### Conversion

- Numeric Conversions
  - Only conversions to integer data types are supported.
- Boolean to (0,1)
- String to Byte Array
- Byte Array to String
  - Only true byte array inputs are supported. LabVIEW automatically coerces any integer array to bytes, but the toolkit does not support this feature.

### Logic

- And
- Or

- Exclusive Or
- Not
  - The Not function only supports Boolean inputs.

## Strings

- String Length
- Concatenate Strings
  - String array inputs are not supported.
- String Subset
- Number to Decimal String
  - The width input is ignored.
- Decimal String to Number

## Arrays

The toolkit supports several basic array functions, but you cannot resize most of them to accept arbitrary numbers of inputs. Remember that you can only use 1D arrays.

- Array Size
- Index Array
  - You cannot resize this function.
- Array Subset
  - You cannot resize this function.
- Replace Array Subset
  - You cannot resize this function.
- Initialize Array
  - You cannot resize this function.
- Build Array
  - You must enable the **Concatenate Inputs** option with array inputs.

## Comparison

The following comparison functions support all compatible data types and the Compare Aggregates mode, where applicable.

- Equal?
- Not Equal?

- Equal to 0?
- Not Equal to 0?
- Greater?
- Less?
- Greater or Equal?
- Less or Equal?
- Greater than 0?
- Less than 0?
- Greater or Equal to 0?
- Less or Equal to 0?

## Miscellaneous

- Bundle
  - The toolkit does not support Bundle by Name.
- Unbundle
  - The toolkit does not support Unbundle by Name.
- Select
- Tick Count
- Flatten to String
  - The toolkit does not support the output type string value.
- Unflatten from String
  - You must wire a fully constructed template for value into the type input. The size of data in type input must match the flattened data in binary string exactly, including array sizes.
- Stop

## Structures

The toolkit supports the following structures.

### While Loops

- Stacked shift registers are not supported.
- Feedback nodes within while loops are not supported.
- Auto-indexing on array tunnels is not supported.



### Case Structures

- Only one specific value, or Default, is allowed in the case selector label for each subdiagram. You cannot use ranges (the “..” notation) or comma-separated lists of values.
- Usage of error cluster wires with the selector terminal is not supported.
- Sequence
- Only one frame per sequence structure is allowed.

## SubVIs

The NXT firmware run-time system is simpler than the LabVIEW run-time system. Remember the following limitations when using subVIs:

- You can pass only supported data types through subVI connector panes.
- The toolkit does not support VI refnums, so you cannot call subVIs by reference.
- Most settings on the **VI Properties** page do not affect the execution of VIs on the NXT brick. For example, the NXT firmware does not support the concepts of priority or a preferred execution system.



**Note** The **Reentrant execution** option in the **VI Properties** dialog box is a special exception. Reentrant execution enables a VI to be called by more than one caller. Normally, a VI can only be called by one caller at a time. However, if you want two callers to be able to call the same VI simultaneously, place a checkmark in the **Reentrant execution** checkbox. The toolkit makes a complete copy of reentrant VIs for each subVI call. In other words, every call to a reentrant subVI is completely independent in the NXT program and increases the overall size of the compiled program.

Remember that only one caller can have access to a non-reentrant subVI at any given time. The same issue exists here as with using non-reentrant subVIs in LabVIEW; parallel callers might have to wait (block) for access while another caller is running a given subVI.

Also remember that the toolkit compiler combines top-level VIs and all subVIs into a single program file on the NXT brick. This behavior is similar to using the LabVIEW Application Builder to compile all VIs into a single PC executable file—subVIs become components inside the executable file.

---

## Extensions to LabVIEW

The NXT firmware supports various I/O devices for which LabVIEW has no built-in interfaces. Examples include motor outputs, sensor inputs, and the NXT display. To support these devices, the toolkit provides extensions to LabVIEW in the form of five classes of *generic reference numbers*, or *refnums*, and an associated set of properties and/or methods with each class of refnums. Each property or method loosely corresponds to a particular piece of the I/O interface provided by the NXT bytecode interpreter.

The toolkit provides the following five classes of generic refnums:

- NXTInput
- NXTOutput
- NXTOutputMulti
- NXTSyscall
- NXTDynamicSyscall

The toolkit palettes provide type definition controls of each new refnum class.

You can use the NXTInput, NXTOutput, and NXTOutputMulti refnums with Property Nodes to expose the interfaces to input and output devices. Connect any of these refnums to a Property Node, and then resize the Property Node to expose as many properties as you need to read or write.

Each Property Node must include an input to specify the physical port(s) to access. Refer to the specific Port or PortList property descriptions for more information on each port. Each additional Property Node line corresponds to some configuration field, such as device mode or measured value, for the specified port(s).

You use the NXTSyscall and NXTDynamicSyscall refnums with Invoke Nodes to expose system-level methods for access to various other features of the NXT firmware. Use the NXTSyscall refnum with methods that the LabVIEW Toolkit for LEGO MINDSTORMS NXT provides. Use the NXTDynamicSyscall refnum with custom methods that you create.



**Note** Refer to the *Using Dynamic System Calls* section of this document for more information about using the NXTDynamicSyscall refnum.

Each method you use corresponds to a call to an internal system function matching the name of the method, or the *system call*. Most system call methods provide status codes as their return values. In general, status code values indicate one of the following three results:

- A status code of zero indicates a status of OK; no special action is required.
- A negative status code indicates an error.
- A positive status code indicates a warning.

System call methods might have more parameters listed below the return value. These parameters can be inputs, outputs, or both.



**Note** The toolkit does not support using error cluster inputs or outputs on Property Nodes or Invoke Nodes.

The following sections describe how to program various device types in more detail.

## Analog Input Devices (Touch, Light, and Sound Sensors)

The NXT brick features four input (sensor) ports, which you can connect interchangeably to both analog inputs, such as light sensors, and digital inputs, such as the NXT ultrasonic sensor. This section describes the interface provided to program analog input devices.

### Input Port Properties

To configure or read values from analog I/O devices, use the NXTInput interface. Connect an NXTInput refnum wire to the reference input of a Property Node. Then resize the Property Node to add more terminals. Adding more terminals enables you to display the properties you want to access. This section describes each property that this toolkit supports.

The Port property has the following considerations:

- Every NXTInput Property Node must include one and only one Port property.
- For a given Property Node, the value on the wire connected to Port specifies the physical input port to which all other properties apply.

Given the special nature of Port, National Instruments recommends always specifying the Port property as the first property in each NXTInput Property Node. This convention enhances the clarity of the code.

With the exception of the Port property, each NXTInput property corresponds to a configuration field in the input module of the NXT firmware. The toolkit compiler guarantees that all write operations execute before all read operations, and all operations execute in the order they appear in the Property Node, from top to bottom.

## Port

---

U8

Write-only

Required

Legal value range: [0, 3]

This property specifies the physical input port to which all other property reads and writes apply. Note that legal values are zero-based, such that the values 0, 1, 2, and 3 correspond to the physical port labels 1, 2, 3, and 4, respectively.

Every NXTInput Property Node must include only one wired Port property.

## SensorType

---

U8

Read-write

Optional

Legal values:

Value	Enum	Description
0x00	NO_SENSOR	No sensor configured
0x01	SWITCH	NXT or Legacy <sup>1</sup> touch sensor
0x02	TEMPERATURE	Legacy temperature sensor
0x03	REFLECTION	Legacylight sensor
0x04	ANGLE	Legacy rotation sensor
0x05	LIGHT_ACTIVE	NXT light sensor with floodlight enabled
0x06	LIGHT_INACTIVE	NXT light sensor with floodlight disabled
0x07	SOUND_DB	NXT sound sensor; dB scaling
0x08	SOUND_DBA	NXT sound sensor; dBA scaling
0x09	CUSTOM	Unused
0x0A	LOWSPEED	I2C digital sensor
0x0B	LOWSPEED_9V	I2C digital sensor; 9V power
0x0C	HIGHSPEED	Unused

This property specifies the sensor type for this port. The sensor type primarily affects scaling factors used to calculate the normalized sensor value, but some values have other side effects.

If you write to this property, also write a value of TRUE to the InvalidData property.

Unlike the Legacy firmware, no default sensor modes are associated with each sensor type.<sup>1</sup>

---

<sup>1</sup> Legacy refers to the RCX programmable controller used in previous versions of LEGO MINDSTORMS.

## SensorMode

U8

Read-write

Optional

Legal values:

Value	Enum	Description
0x00	RAWMODE	Report scaled value equal to raw value.
0x20	BOOLEANMODE	Report scaled value as one (TRUE) or zero (FALSE). Readings are FALSE if raw value exceeds 55% of total range; readings are TRUE if raw value is less than 45% of total range (inverse Boolean logic).
0x40	TRANSITIONCNTMODE	Report scaled value as number of transitions between TRUE and FALSE.
0x60	PERIODCOUNTERMODE	Report scaled value as number of transitions from FALSE to TRUE, then back to FALSE.
0x80	PCTFULLSCALEMODE	Report scaled value as percentage of full scale reading for configured sensor type.
0xA0	CELSIUSMODE	Scale TEMPERATURE reading to degrees Celsius.
0xC0	FAHRENHEITMODE	Scale TEMPERATURE reading to degrees Fahrenheit.
0xE0	ANGLESTEPMODE	Report scaled value as count of ticks on Legacy rotation sensor.

This property specifies the sensor mode for this port. The sensor mode affects the scaled value, which the NXT firmware calculates depending on the sensor type and sensor mode.

If you write to this property, also write a value of TRUE to the InvalidData property.

## Raw

---

U16

Read-only

Optional

Legal value range: [0, 1023]

This property specifies the raw 10-bit value last read from the analog to digital converter on this port. Raw values produced by sensors typically cover some subset of the full 10-bit range.



## Normalized

---

U16

Read-only

Optional

Legal value range: [0, 1023]

This property specifies a 10-bit sensor reading, scaled according to the current value of the `SensorType` property on this port. The NXT firmware automatically applies internal scaling factors such that the physical range of raw values produced by the sensor is mapped (normalized) to the full 10-bit range.

`SensorMode` is ignored when calculating the Normalized value.

You should use `Normalized` in conjunction with the `InvalidData` property. The `Normalized` value is only valid if `InvalidData` is `FALSE`.

## Scaled

---

U16

Read-write

Optional

Legal value range depends on SensorMode, as listed in the following table:

Mode	Value Range
RAWMODE	[0, 1023]
BOOLEANMODE	[0, 1]
TRANSITIONCNTMODE	[0, 65535]
PERIODCOUNTERMODE	[0, 65535]
PCTFULLSCALEMODE	[0, 100]
CELSIUSMODE	[-200, 700] (readings in 10 <sup>th</sup> of a degree Celsius)
FAHRENHEITMODE	[-400, 1580] (readings in 10 <sup>th</sup> of a degree Fahrenheit)
ANGLESTEPMODE	[0, 65535]

This property specifies a sensor reading, scaled according to the current sensor type and mode on this port.

You should read the Scaled property in conjunction with the InvalidData property. The Scaled value is only valid if InvalidData is FALSE.

Because some combinations of sensor types and modes might lead to accumulation of count values in the Scaled value field, you can reset this count by writing zero to the Scaled property at any time.

Note that you can write any value to this property at any time, but doing so is not generally very useful because outside of counter modes, the value is usually overwritten very quickly.

## InvalidData

---

Boolean

Read-write

Optional

Legal values: TRUE, FALSE

This property signifies that the values of Raw, Normalized, and Scaled might be invalid due to sensor configuration changes that the NXT firmware has not processed yet. For example, the NXT firmware might not have processed the sensor type or mode changes immediately due to hardware limitations.

In all cases where you change `SensorType` or `SensorMode`, use the `InvalidData` property to ensure that the next value you read back has been properly processed. Set `InvalidData` to `TRUE` in the same Property Node as you use to set `SensorType` and `SensorMode`, and then write a while loop that does not exit until `InvalidData` becomes `FALSE`. At that point, the `Normalized` and `Scaled` properties will return valid values for the new configuration.

## Digital I/O Devices (Ultrasonic Sensors)

---

To program digital I/O devices, you need to use both the NXTInput and NXTSyscall interfaces. You need both interfaces because digital and analog devices share the same physical ports.

### Digital I/O Port Setup

First, use an NXTInput Property Node, to set the SensorType property of the port to a value compatible with the sensor. The NXT firmware supports the following two SensorType values for use with digital devices:

- **LOWSPEED**—Use this type if the sensor does not require 9V power.
- **LOWSPEED\_9V**—Use this type if the sensor requires 9V power.

These low-speed sensor types are for use with sensors using the I2C protocol to communicate with the NXT brick. The ultrasonic sensor included with NXT bricks requires 9V power, so use LOWSPEED\_9V when you connect to this sensor.

Remember that you also need to set the InvalidData property to TRUE after setting a new SensorType, then wait, using a While Loop, for the NXT firmware to set it back to FALSE. This process ensures that the firmware has time to initialize the port properly, including the 9V power lines, if applicable. Some digital devices might need additional time to initialize after power up.

### Low Speed Communication Methods

After the port is initialized, you need to access the I2C communication subsystem of the NXT firmware to communicate with the device.

Use NXTSyscall refnums with invoke nodes to expose the interface to this communication system. The toolkit provides the following three methods for low speed digital communication: NXTCommLSWrite, NXTCommLSCheckStatus, and NXTCommLSRead.

The firmware uses a *master/slave* setup in which the NXT brick is always the master device. That is, the NXT firmware is responsible for controlling the write and read operations. The firmware maintains write and read buffers for each port, and the three system call methods provided enable you to access these buffers.

A call to `NXTCommLSWrite` constitutes the start of an asynchronous *transaction* between the NXT brick and a digital device, such that the program continues to run while the firmware manages sending bytes from the write buffer and reading the response bytes from the device. Because the NXT is the master device, you must also specify the number of bytes to expect from the device in response to each write operation. You can exchange up to 16 bytes in each direction per transaction.

After you start a write transaction with `NXTCommLSWrite`, use `NXTCommLSCheckStatus` in a While Loop to check the status of the port. If `NXTCommLSCheckStatus` returns a status code of zero and a count of bytes available in the read buffer, the system is ready for you to use `NXTCommLSRead` to copy the data from the read buffer into your own buffer.

Note that any of these calls might return various status codes at any time. A status code of zero means the port is idle and the last transaction, (if any), did not result in any errors. Negative status codes indicate errors, while the positive status code `STAT_COMM_PENDING` indicates that a transaction is in progress on the specified port.

The following sections provide more information about each low-speed communication method.

## NXTCommLSCheckStatus

Parameters:

Parameter	Data Type	I/O Direction	Description
Status Code	I8	output	Refer to the following status codes.
Port	U8	input	Port, [0, 3]
BytesReady	U8	input	Number of bytes ready for reading, if any

This system call method checks the status of the I2C communication on the specified port. If the last operation on this port was a successful NXTCommLSWrite operation that requested response data from a device, BytesReady indicates the number of bytes in the internal read buffer. You can access this information using NXTCommLSRead.

If the return value is zero, the port is idle and the last operation (if any) did not cause any errors.

This method can return the following non-zero status codes:

Status Code	Enum	Description	
32	0x20	STAT_COMM_PENDING	Port is busy performing a transaction.
-35	0xDD	ERR_COMM_BUS_ERR	Last transaction failed (possible device failure).
-33	0xDF	ERR_COMM_CHAN_INVALID	Specified port is out of range.
-32	0xE0	ERR_COMM_CHAN_NOT_READY	Specified port is not properly configured.

Commonly, ERR\_COMM\_BUS\_ERR means that either no digital device is connected to the specified port or the connected device is configured incorrectly. Attempt to write new data to the device to clear the error condition.

If you see ERR\_COMM\_CHAN\_NOT\_READY, make sure SensorType is set properly and InvalidData is FALSE for this port before attempting further transactions.

If you see STAT\_COMM\_PENDING, an operation is in progress and you should not interrupt it. Avoid calls to NXTCommLSRead or NXTCommLSWrite until NXTCommLSCheckStatus returns zero or a negative error code.

## NXTCommLSWrite

Parameters:

Parameter	Data Type	I/O Direction	Description
Status Code	I8	output	Refer to the following status codes.
Port	U8	input	Port, [0–3]
Buffer	U8 array	input	Up to 16 bytes for writing to device
ReturnLength	U8	input	Number of bytes expected from device in response to writing data in Buffer; maximum 16

This system call method copies data from the buffer input to an internal write buffer and instructs the NXT firmware to perform a transaction by sending the write buffer to the device and reading ReturnLength bytes back into the internal read buffer.

If the return value is zero, the method successfully started a communication transaction. Use NXTCommLSCheckStatus to monitor the status of the transaction.

This method can return the following non-zero status codes:

Status Code	Enum	Description	
-33	0xDF	ERR_COMM_CHAN_INVALID	Specified port is out of range.
-32	0xE0	ERR_COMM_CHAN_NOT_READY	Specified port is busy or not properly configured.
-19	0xED	ERR_INVALID_SIZE	Either buffer size or ReturnLength exceeded 16-byte maximum.

## NXTCommLSRead

Parameters:

Parameter	Data Type	I/O Direction	Description
Status Code	I8	output	Refer to the following status codes.
Port	U8	input	Port, [0–3]
Buffer	U8 array	output	Bytes read from device, if any
BufferLength	U8	input	Upper bound on number of bytes to read into Buffer; actual number returned limited to bytes available in the internal read buffer

This system call method attempts to copy BufferLength bytes from the internal read buffer to your buffer.

If the return value is zero, the read operation succeeded and Buffer contains all bytes available in the internal buffer. Successive NXTCommLSRead method calls will read new data each time.

This method can return the following non-zero status codes:

Status Code	Enum	Description	
32	0x20	STAT_COMM_PENDING	Port is busy performing a transaction.
-35	0xDD	ERR_COMM_BUS_ERR	Last transaction failed (possible device failure).
-33	0xDF	ERR_COMM_CHAN_INVALID	Specified port is out of range.
-32	0xE0	ERR_COMM_CHAN_NOT_READY	Specified port is not configured properly.

If any negative status code error is returned, Buffer is an empty array.



## Output Devices: Motors and Lamps

---

Two different kinds of output devices are compatible with the NXT brick: interactive motors, NXT motors with integrated position encoders, and non-interactive motors or lamps, Legacy-compatible outputs. All of these devices are programmed using a common set of Property Nodes in LabVIEW. The only difference is that non-interactive devices ignore the properties that do not affect them. For example, instructing a lamp to rotate counter-clockwise for 360 degrees is invalid because the lamp only responds to power levels. Furthermore, VIs written to use interactive device features might not operate correctly when used with non-interactive devices. For example, you might write a VI to instruct an interactive motor to rotate 360 degrees, and then wait in a While Loop for the NXT firmware to complete the action. Non-interactive devices, such as lamps, do not include position encoders, so such a loop never receives the necessary feedback to finish executing.

You can access output ports using one of the following two classes of Property Nodes: `NXTOutput` and `NXTOutputMulti`. `NXTOutput` only allows accessing parameters of one port at a time, while `NXTOutputMulti` accepts an array of port numbers so you can configure multiple ports in a single operation. This ability of `NXTOutputMulti` is useful to ensure that the firmware synchronizes multiple motors tightly. Conversely, you can only read properties from one output at a time, so `NXTOutput` is useful for inspecting the state, such as power level or motor position, of an output port.

Use `NXTOutputMulti` to synchronize the behavior of two or more motors, and use `NXTOutput` to read properties of an output or to configure only one output at a time.

### Output Port Properties

To configure or read values from output devices, connect an `NXTOutput` or `NXTOutputMulti` `refnum` wire to any reference input of the Property Node, and then resize the Property Node to add more terminals. Adding more terminals enables you to display the properties you want to access.

This section describes each property that this toolkit supports. Because `NXTOutput` and `NXTOutputMulti` Property Nodes share many properties, this section describes the properties only once. Each property description specifies the access rules, read-only, write-only, or read-write, provided by each interface.

Use the following tips when working with the Port and PortList properties:

- Every NXTOutput or NXTOutputMulti Property Node must include one and only one Port of the PortList property, respectively.
- For a given Property Node, the value(s) on the wire connected to Port/PortList specify the physical output port to which all other properties apply.



**Note** Given the special nature of Port/PortList, National Instruments recommends always specifying Port/PortList as the top property in each NXTOutput/NXTOutputMulti node. This coding convention enhances code clarity.

With the exception of Port/PortList, each property corresponds to a write or read of the associated field in the output module of the NXT firmware. All write operations are guaranteed to execute before all read operations, and all operations execute in the order they occur on the Property Node, from top to bottom. Furthermore, the toolkit compiler combines all write operations in each Property Node into a single bytecode instruction, such that all write operations in a Property Node occur simultaneously.

Some property write operations also require an additional step to commit a new value to the internal configuration data of the NXT firmware. You must also set the appropriate bit on the UpdateFlags property. The flags are defined in the description of the UpdateFlags property and the descriptions of properties that require flags to be set specify which flags are applicable.

## Port

---

U8

NXTOutput: write-only

NXTOutputMulti: unsupported

Required

Legal value range: [0, 2]

This property specifies the physical port to which all other property read/writes apply. Note that legal values are zero-based, such that the values 0, 1, 2, and 3 correspond to the physical port labels 1, 2, 3, and 4, respectively.

Every NXTOutput Property Node must include only one Port property.

## PortList

---

U8 array

NXTOutput: unsupported

NXTOutputMulti: write-only

Required

Legal value range: [0, 2] (arrays of 1, 2, or 3 elements in this range)

This property specifies a list of physical ports to which all other property writes apply. Note that the values 0, 1, and 2 correspond to the physical port labels A, B, and C, respectively.

Every NXTOutputMulti Property Node must include one and only one PortList property.

## UpdateFlags

U8

NXTOutput: read-write

NXTOutputMulti: write-only

Optional

Bitfield including any combination of the following flag bits:

Value	Enum	Description
0x01	UPDATE_MODE	Commits changes to the Mode property
0x02	UPDATE_SPEED	Commits changes to the Power property
0x04	UPDATE_TACHO_LIMIT	Commits changes to the TachoLimit property (interactive motors only)
0x08	UPDATE_RESET_COUNT	Resets internal movement counters and cancels current goal (interactive motors only)
0x10	UPDATE_PID_VALUES	Commits changes to PID regulation parameters RegPValue, RegIValue, and/or RegDValue (interactive motors only)
0x20	UPDATE_RESET_BLOCK_COUNT	Resets block-relative position counter (interactive motors only)
0x40	UPDATE_RESET_ROTATION_COUNT	Resets program-relative position counter (interactive motors only)

This property is an unsigned byte bitfield with zero or more of the bit values above set.

You can use UPDATE\_MODE, UPDATE\_SPEED, UPDATE\_TACHO\_LIMIT, and UPDATE\_PID\_VALUES in conjunction with other properties to commit changes to the internal state of the NXT firmware module. You must set the appropriate flags after setting one or more of these properties before the changes actually take affect. For example, write a value of 0x03 (UPDATE\_MODE | UPDATE\_SPEED) to UpdateFlags immediately after you write new values to the Mode and Power properties.

The reset flags are independent of other properties and automatically reset the rotation value to zero when used.

For UPDATE\_RESET\_BLOCK\_COUNT, block-relative refers to the way this flag is used in the LEGO MINDSTORMS NXT software. By convention, this flag is set every time an NXT-G motor control block starts execution. This convention means that the BlockTachoCount property always provides a position measurement relative to the last NXT-G motor control block to execute. The VIs included with the toolkit follow the same convention, but you do not need to follow this convention.

For UPDATE\_RESET\_ROTATION\_COUNT, program-relative refers to the fact that this position counter is reset automatically at the beginning of every program. Set UPDATE\_RESET\_ROTATION\_COUNT to reset this counter manually during program execution.

## Mode

---

U8

NXTOutput: read-write

NXTOutputMulti: write-only

Optional

Bitfield including any combination of the following flag bits:

Value	Enum	Description
0x01	MOTORON	Enables PWM power to port(s) according to value of the Power property
0x02	BRAKE	Applies electronic braking to port(s)
0x04	REGULATED	Enables active power regulation according to value of RegMode (interactive motors only)

This property is an unsigned byte bitfield with zero or more mode bits set. Clearing all bits with a Mode value of 0x00 is considered COAST mode; motors connected to the specified port(s) will rotate freely.

You must set the MOTORON bit for the NXT firmware to provide any power to the specified output port(s). Power is provided as a PWM waveform modulated by the Power property.

The BRAKE bit enables application of electronic braking to the circuit. Braking in this sense means that the output voltage is not allowed to float between active PWM pulses. Electronic braking improves the accuracy of motor output, but uses slightly more battery power.

You must use the REGULATED bit in conjunction with the RegMode property. Refer to the [RegMode](#) section for more information about using the REGULATED bit with the RegMode property.

You must set the UPDATE\_MODE bit in the UpdateFlags bitfield to commit changes to the Mode property.

## RegMode

---

U8

NXTOutput: read-write

NXTOutputMulti: write-only

Optional

Interactive motors only

Legal Values:

Value	Enum	Description
0x00	REG_IDLE	Disables regulation
0x01	REG_SPEED	Enables speed regulation
0x02	REG_SYNC	Enables synchronization between any two motors

This property specifies the regulation mode to use with the specified port(s).

This property is ignored if you do not set the REGULATED bit in the Mode property. Unlike the Mode property, RegMode is not a bitfield. You can set only one RegMode value at a time.

*Speed regulation* means that the NXT firmware attempts to maintain a certain speed according to the Power set-point. To accomplish this, the NXT firmware automatically adjusts the actual PWM duty cycle if the motor is affected by a physical load. This automatic adjustment is reflected by the value of the ActualSpeed property.

*Synchronization* means that the firmware attempts keep any two motors in synch regardless of varying physical loads. A common usage of this mode is to maintain a straight path for a vehicle robot automatically, but you also can use this mode with the TurnRatio property to provide proportional turning. You must set REG\_SYNC on at least two motor ports to have the desired affect. If REG\_SYNC is set on all three motor ports, only the first two, A and B, are synchronized.



## TurnRatio

---

I8

NXTOutput: read-write

NXTOutputMulti: write-only

Optional

Interactive motors only

Legal value range: [-100, 100]

This property specifies the proportional turning ratio for synchronized turning using two motors.

You must set other properties appropriately on at least two motor ports for TurnRatio to have the desired effect. Use the following guidelines when setting this property:

- Mode bitfield must include MOTORON and REGULATED bits. BRAKE bit is optional.
- RegMode must be set to REG\_SYNC.
- RunState must be set to a non-IDLE value.
- Power must be set to a non-zero value.

After you set these property values, the NXT firmware uses the TurnRatio value to adjust relative power settings for the left and right motors automatically.

Left and right refer to the physical arrangement of the output plugs on an NXT brick when facing the display screen. The following table includes the only three valid combinations of left and right motors that you can use with TurnRatio:

Left	Right
Output Port A	Output Port B
Output Port B	Output Port C
Output Port A	Output Port C

Note that this definition of left and right is independent of the LEGO model you are using.

Negative TurnRatio values shift power towards the left motor, while positive TurnRatio values shift power towards the right motor. In both cases, the actual power applied is proportional to the Power set-point, such that an absolute value of 50% for TurnRatio normally results in one motor stopping, and an absolute value of 100% for TurnRatio normally results in the two motors turning in opposite directions at equal power.

## RunState

---

U8

NXTOutput: read-write

NXTOutputMulti: write-only

Optional

Legal Values:

Value	Enum	Description
0x00	RUN_STATE_IDLE	Disables power to specified port(s)
0x10	RUN_STATE_RAMPUP	Enables automatic ramp-up to the Power set-point (interactive motors only)
0x20	RUN_STATE_RUNNING	Enables power to specified port(s) at the Power set-point
0x40	RUN_STATE_RAMPDOWN	Enables automatic ramp-down to the Power set-point (interactive motors only)

This property specifies an auxiliary state to use with Mode, RegMode, and Power on the specified port(s). Set only one of the legal values at a given time.

RUN\_STATE\_RUNNING is the most common setting. Use RUN\_STATE\_RUNNING to enable power to any output device connected to the specified port(s).

RUN\_STATE\_RAMPUP enables automatic ramping to a new Power set-point that is greater than the current Power set-point. When you use RUN\_STATE\_RAMPUP in conjunction with appropriate TachoLimit and Power values, the NXT firmware attempts to increase the actual power smoothly to the new Power set-point over the number of degrees specified by TachoLimit.

RUN\_STATE\_RAMPDOWN enables automatic ramping to a new Power set-point that is less than the current Power set-point. When you use RUN\_STATE\_RAMPDOWN in conjunction with appropriate TachoLimit and Power values, the NXT firmware attempts to smoothly decrease the actual power to the new Power set-point over the number of degrees specified by TachoLimit.

## Power

---

I8

NXTOutput: read-write

NXTOutputMulti: write-only

Optional

Legal value range: [-100, 100]

This property specifies the power level set-point for the specified port(s).

The absolute value of Power is used as a percentage of the full power capabilities of the motor.

The sign of Power specifies rotation direction. Positive values for Power instruct the firmware to turn the motor forward, while negative values instruct the firmware to turn the motor backward. Forward and backward are relative to a standard orientation for a particular type of motor.



**Note** Direction is not a meaningful concept for outputs like lamps. Lamps are only affected by the absolute value of Power.

You must set some other properties appropriately for the Power setpoint to have the desired effect. Use the following guidelines when setting this property:

- Mode bitfield must include MOTORON bit. BRAKE bit is optional.
- RunState must be set to a non-IDLE value.

You must set the UPDATE\_SPEED bit in the UpdateFlags bitfield to commit changes to the Power property.

## ActualSpeed

---

I8

NXTOutput: read-only

NXTOutputMulti: unsupported

Optional

Interactive motors only

Legal value range: [-100, 100]

This read-only property returns the actual percentage of full power that the NXT firmware is applying to the output currently. This value can vary from the current Power set-point when the internal auto-regulation code of the NXT firmware responds to drag on the output axle.

## TachoLimit

---

U32

NXTOutput: read-write

NXTOutputMulti: write-only

Optional

Interactive motors only

Legal value range: [0, 4294967295]

This property specifies the rotational distance in degrees that you want to turn the motor.

Set the UPDATE\_TACHO\_LIMIT flag to commit changes to TachoLimit. The NXT firmware treats the new TachoLimit value as a relative distance from the motor position at the moment that the UPDATE\_TACHO\_LIMIT flag is processed. Remember that the sign of the Power property specifies the direction of rotation.

## TachoCount

---

I32

NXTOutput: read-only

NXTOutputMulti: unsupported

Optional

Interactive motors only

Legal value range: [-2147483648, 2147483647]

This read-only property reports the internal position counter value for the specified port. This internal count is reset automatically when a new goal is set using the TachoLimit and the UPDATE\_TACHO\_LIMIT flag.

Set the UPDATE\_RESET\_COUNT flag in UpdateFlags to request that the NXT firmware resets TachoCount and cancels any current programmed goals.

The sign of TachoCount specifies rotation direction. Positive values correspond to forward rotation while negative values correspond to backward rotation. Forward and backward are relative to a standard orientation for a particular type of motor.

## BlockTachoCount

---

I32

NXTOutput: read-only

NXTOutputMulti: unsupported

Optional

Interactive motors only

Legal value range: [-2147483648, 2147483647]

This read-only property reports the block-relative position counter value for the specified port.

Refer to the [UpdateFlags](#) section for more information about using block-relative position counts.

Set the UPDATE\_RESET\_BLOCK\_COUNT flag in UpdateFlags to request that the firmware resets BlockTachoCount.

The sign of BlockTachoCount specifies the rotation direction. Positive values correspond to forward rotation while negative values correspond to backward rotation. Forward and backward are relative to a standard orientation for a particular type of motor.

## RotationCount

---

I32

NXTOutput: read-only

NXTOutputMulti: unsupported

Optional

Interactive motors only

Legal value range: [-2147483648, 2147483647]

This read-only property reports the program-relative position counter value for the specified port.

Refer to the [UpdateFlags](#) section for more information about using program-relative position counts.

Set the UPDATE\_RESET\_ROTATION\_COUNT flag in UpdateFlags to request that the NXT firmware resets the RotationCount property.

The sign of RotationCount specifies rotation direction. Positive values correspond to forward rotation while negative values correspond to backward rotation. Forward and backward are relative to a standard orientation for a particular type of motor.



## Overloaded

---

Boolean

NXTOutput: read-only

NXTOutputMulti: unsupported

Optional

Interactive motors only

Legal values: TRUE, FALSE

This read-only property returns TRUE if the speed regulation functionality of the NXT firmware is unable to overcome physical load on the motor, such as the motor is turning more slowly than expected. Otherwise, this property returns FALSE.

You must set other properties appropriately for the value of Overloaded to be meaningful. Use the following guidelines when setting this property:

- Mode bitfield must include MOTORON and REGULATED bits.
- RegMode must be set to REG\_SPEED.
- RunState must be set to a non-IDLE value.

## RegPValue

---

U8

NXTOutput: read-write

NXTOutputMulti: write-only

Optional

Interactive motors only

Legal value range: [0, 255]

This property specifies the proportional term used in the internal PID control algorithm. Refer to the *Proportional-Integral-Derivative (PID)* topic in the *LabVIEW Help* for more information.

Set the UPDATE\_PID\_VALUES to commit changes to RegPValue, RegIValue, or RegDValue.

## RegIValue

---

U8

NXTOutput: read-write

NXTOutputMulti: write-only

Optional

Interactive motors only

Legal value range: [0, 255]

This property specifies the integral term used in the internal PID control algorithm.

Set the UPDATE\_PID\_VALUES to commit changes to RegPValue, RegIValue, or RegDValue.

## RegDValue

---

U8

NXTOutput: read-write

NXTOutputMulti: write-only

Optional

Interactive motors only

Legal value range: [0, 255]

This property specifies the derivative term used in the internal PID control algorithm.

Set the UPDATE\_PID\_VALUES to commit changes to RegPValue, RegIValue, or RegDValue.

## Built-In I/O

---

The toolkit provides access to several kinds of built-in I/O, including the following:

- Manipulating files in a simple flash file system using the **File Access Methods**
- Drawing to the NXT display using the **NXT Display Methods**
- Reading the built-in buttons on the NXT brick using the **NXT Button Method**
- Playing back recorded or synthesized sound using the **Sound Playback Methods**
- Communication with connected Bluetooth peers using the **Bluetooth Communications Methods**

To use any of these built-in I/O features in a program, connect an NXTSyscall refnum to the reference input of any Invoke Node and select the appropriate method.

### File Access Methods

Use the file access methods to create, modify, rename, or delete files stored on the NXT brick.

The NXT firmware organizes all files in a simple flat file system stored in the flash memory on the NXT brick. Files are listed and referred to by name, and files can have any size up to the amount of available flash. The file system is flat because the file system does not support organizing files into hierarchical folders. NXT firmware 1.05 allows you to create up to 63 files, assuming flash space is available.

NXT filenames include up to 15 characters for the main name, a dot, and 3 characters for the extension, which specifies the file type. This convention is referred to as *15.3 filenames*. A file extension serves as a cue to the NXT firmware as to how and where files are listed and treated.

The NXT firmware 1.05 and the LEGO MINDSTORMS NXT software use the following main file extensions:

- **RXE**—Executable files compiled from NXT-G, LabVIEW, or another compatible programming environment
- **RPG**—Simple 5-step programs created using the NXT Program UI on the NXT brick

- **RTM**—Built-in Try Me programs
- **RIC**—Image (graphic) files for use with the NXTDrawGraphic system call method in RXE programs
- **RSO**—Sound files
- **SYS**—Internal NXT firmware files
- **CAL**—Sensor calibration file
- **TXT**—ASCII text file using CR/LF (Windows) end-of-line convention

When manipulating files with a program, you can create, modify, rename, or delete any file in the system. Typical NXT programs use simple text files with the TXT extension. You then can upload these files easily to a PC, which then can read the files. You can use any extension or file encoding you choose, but make sure not to interfere with the various files that the NXT firmware and other programs use.

The default NXT firmware configuration includes several built-in files. You can delete any of these files to free up space, but you lose any associated functionality until you restore these files.

To manipulate files, wire an NXTSyscall refnum to any Invoke Node, then choose a method beginning with NXTFile. The following sections list these individual methods along with some method concepts.

## File Handles

You must open a handle to a file before you can use read or write methods on the file. The `NXTFileOpenRead`, `NXTFileOpenWrite`, or `NXTFileOpenAppend` methods return a unique handle value. The NXT firmware also automatically registers open handles in an internal table such that the `NXTResolveHandle` system call method can look up any open handle by filename.

You must close each file handle with the `NXTFileClose` method before using the file to which it refers for any other purpose. When a program ends, the NXT firmware automatically closes any handles left open by the program.

The NXT firmware restricts the maximum number of concurrently open file handles to 16. Note that running programs uses up one file handle, and any current sound playback or other background process can take up additional file handles. In practice, a program can generally open 10–12 handles, but opening that many handles is fairly rare.

## File Access Status Codes

File access system call methods return a different set of status codes from most other system call methods. File access status codes are unsigned 16-bit integers rather than signed 8-bit integers. In most cases, you only need to check if file access methods return status codes other than zero (SUCCESS), but the following table lists specific codes which you might see in your programs.

Value	Enum	Description
0x0000	SUCCESS	Operation succeeded.
0x8100	NO_HANDLES	The firmware is not able to allocate any more file handles for this operation.
0x8300	NO_FILES	The firmware is not able to create any more files.
0x8400	PARTIAL_WRITE	Write request exceeded space available in file; partial write performed.
0x8500	EOF	File operation reached end of file.
0x8700	FILE_NOT_FOUND	Specified file not found.
0x8800	FILE_CLOSED	Specified file or handle is already closed.
0x8900	NO_LINEAR_SPACE	The firmware is not able to allocate requested linear file system space for specified file.
0x8A00	GENERIC_ERROR	A generic (unspecified) error condition occurred.
0x8B00	FILE_BUSY	Cannot acquire file handle for specified file because some other operation has opened the file.
0x8C00	NO_WRITE_BUFFERS	Cannot open file for write operation because all write buffers are already in use. Only four files can be open for write simultaneously.
0x8D00	ILLEGAL_APPEND	Cannot open file for append.
0x8E00	FILE_FULL	Allocated space for specified file is full (no more write operations allowed).
0x8F00	FILE_EXISTS	Failure to create or rename file due to name collision.
0x9200	ILLEGAL_FILE_NAME	Illegal file name provided. Ensure file name consists of 15.3 (or fewer) printable characters.
0x9300	ILLEGAL_HANDLE	Allocated space for specified file is full.



## File Access Performance Issues

Writing to flash memory is very slow compared to RAM access on the NXT brick. Writing to flash memory also ties up the CPU. File write operations are buffered in RAM whenever possible, but the firmware is subject to pauses of 6–30 ms while these buffers are committed to flash. If you experience significant delays during program operations, consider minimizing the amount of flash writing you perform.

Most file access method calls are subject to delays averaging 6 ms or less, with `NXTFileOpenWrite` subject to the most delay per call. The following sections describe the methods and include specific notes about potential flash writing performance issues where applicable.

## NXTFileOpenRead

---

Parameters:

Parameter	Data Type	I/O Direction	Description
Status Code	U16	output	Refer to the <a href="#">File Access Status Codes</a> section.
File Handle	U8	output	Unique handle to identify open file
Filename	string	input	Maximum of 19 characters (15.3 filename)
Length	U32	output	Length of file in bytes

This system call method attempts to open the file specified by Filename for read operations.

If the return value is zero, the file open operation succeeded. File Handle is assigned a unique handle for use with NXTFileRead and NXTFileClose, and Length is assigned the current length of the file. Furthermore, this file is registered for use with NXTFileResolveHandle.

If the return value is non-zero, an error occurred attempting to open the file. You can ignore File Handle and Length. This file is not registered for use with NXTFileResolveHandle.

## NXTFileOpenWrite

Parameters:

Parameter	Data Type	I/O Direction	Description
Status Code	U16	output	Refer to the <a href="#">File Access Status Codes</a> section.
File Handle	U8	output	Unique handle to identify open file
Filename	string	input	Maximum of 19 characters (15.3 filename)
Length	U32	input-output	Length of file in bytes

This system call method attempts to create a file with the name specified by Filename and size in bytes specified by Length, then keep the file open for write operations. You must specify the total file size using the Length parameter when you create the file. If you do not use all of the memory allocated for a particular file before closing the file handle, you can open the file for further write operations using the NXTFileOpenAppend system call method.

If the return value is zero, the file creation operation was successful. The File Handle output is assigned a unique handle for use with NXTFileWrite and NXTFileClose and the Length output is assigned the current length of the file. Furthermore, this file is registered for use with NXTFileResolveHandle.

If the return value is non-zero, an error occurred attempting to open the file. You can ignore the File Handle. This file is not registered for use with NXTFileResolveHandle.

Only four files can be concurrently opened for write operations. This limit includes files opened with NXTFileOpenAppend.



**Note** File creation involves writing data to flash, so this system call method is subject to the performance issues previously described. NXTFileOpenWrite is potentially subject to the most flash writing delay of any method. Creating a very large file can result in a delay of up to 30 ms.

## NXTFileOpenAppend

---

Parameters:

Parameter	Data Type	I/O Direction	Description
Status Code	U16	output	Refer to the <a href="#">File Access Status Codes</a> section.
File Handle	U8	output	Unique handle to identify open file
Filename	string	input	Maximum of 19 characters (15.3 filename)
Length	U32	output	Number of bytes remaining in file

This system call method attempts to open the file specified by Filename for append (write) operations. This operation is useful only if a file already exists and has been closed before all of its allocated space has been filled.

If the return value is zero, the file open operation succeeded. The File Handle output contains a unique handle for use with NXTFileWrite and NXTFileClose and the Length output contains the number of unused bytes remaining in the file. The internal file cursor is set automatically to the end of existing data such that future calls to NXTFileWrite do not overwrite any data. Furthermore, this file is registered for use with NXTFileResolveHandle.

If the return value is non-zero, an error occurred attempting to open the file. You can ignore the File Handle. This file is not registered for use with NXTFileResolveHandle.

Only four files may be concurrently opened for write operations. This limit includes files opened with NXTFileOpenAppend.

## NXTFileResolveHandle

---

Parameters:

Parameter	Data Type	I/O Direction	Description
Status Code	U16	output	Refer to the <a href="#">File Access Status Codes</a> section.
File Handle	U8	output	Unique handle to identify open file
Write Handle?	Boolean	output	TRUE if returned handle is for write operations.
Filename	string	input	Maximum of 19 characters (15.3 filename)

The NXT firmware has a list of open file handles. This system call method searches the list of open file handles by Filename. To succeed, Filename must contain the exact filename of an already opened file.

If the return value is zero, the file is already open. The File Handle output is assigned a unique handle for use with NXTFileRead/NXTFileWrite and NXTFileClose. If the Boolean output Write Handle? is set to TRUE, the file is open for write operations. Otherwise, the file is open for read operations.

If the return value is non-zero, the file is not yet open. You can ignore File Handle and Write Handle?. If you intend to use the file, call the appropriate open method for the file.

## NXTFileClose

---

Parameters:

Parameter	Data Type	I/O Direction	Description
Status Code	U16	output	Refer to the <i>File Access Status Codes</i> section.
File Handle	U8	input	Unique handle to identify open file

This system call method closes the handle specified by File Handle.

If the return value is zero, the method successfully closed the file handle and removed the file from the list of open files that NXTResolveHandle uses.

If the return value is non-zero, the close operation failed. Either the specified file handle was invalid or no file was currently open using that file handle.

All files opened by an NXT program are automatically closed when the program finishes or is aborted.

Note that a successful NXTFileClose operation commits any pending file write buffers to flash memory, so this operation is subject to a 6–30 ms delay in performing the operation.

## NXTFileRead

---

Parameters:

Parameter	Data Type	I/O Direction	Description
Status Code	U16	output	Refer to the <a href="#">File Access Status Codes</a> section.
File Handle	U8	input-output	Unique handle to identify open file
Buffer	string	output	File data in string format
Length	U32	input-output	Length of file in bytes

This system call method attempts to read Length bytes of data from the file opened with the handle specified by File Handle.

If the return value is zero, the file read operation succeeded. Buffer contains Length bytes of file data in string format. If the file contains text data, use the string like a normal text string, such as the display to the screen. If the file contains flattened binary data, use the Unflatten from String function to unflatten it.

If the return value is non-zero, an error occurred attempting to read bytes from the file. Note that Buffer might still contain valid data if the method encountered the end of the file before reading Length bytes. In this case, the Length output contains the count of bytes that were actually read.

Successive calls to NXTFileRead with the same file handle reads new data each time. For example, each read operation advances the internal file read cursor.

## NXTFileWrite

Parameters:

Parameter	Data Code	I/O Direction	Description
Status Code	U16	output	Refer to the <i>File Access Status Codes</i> section.
File Handle	U8	input-output	Unique handle to identify open file
Buffer	string	input-output	File data in string format
Length	U32	input-output	Number of bytes to write (in); number of bytes written (out)

This system call method attempts to write Length bytes of data to the file opened with the handle specified by File Handle. If you use all of the memory allocated for the specified file, the NXTFileWrite method writes partial contents of the Buffer data to the file. The method sets Length to the number of bytes actually written, but does not modify the Buffer. If you intend to write more data, you need to close this file and use NXTOpenWrite to create a new file.

If the return value is zero, the file write operation succeeded.

If the return value is non-zero, an error occurred attempting to write bytes from the file.

Successive calls to NXTFileWrite with the same file handle write new data each time. Each write operation advances the internal file write cursor.



**Note** NXTFileWrite involves writing to flash memory, so this system call method is subject to the performance issues described above. Because NXTFileWrite often is called many times in quick succession to stream data to a file, the NXT firmware provides some buffering to help minimize the performance cost. This buffering means that a 4–6 ms delay might occur for every 256 bytes written.



## NXTFileDelete

---

Parameters:

Parameter	Data Code	I/O Direction	Description
Status Code	U16	output	Refer to the <i>File Access Status Codes</i> section.
Filename	string	input	Maximum of 19 characters (15.3 filename)

This system call method deletes the file specified by Filename.

If the return value is zero, the delete operation succeeded.

If the return value is non-zero, the delete operation failed. Either the specified file does not exist or an open handle is associated with the file.

Be careful to close any open handles associated with a file before deleting it.

Note that file deletion involves writing internal file system data to flash memory, so this system call method is subject to a 6–30 ms delay in performing the operation.

## NXTFileRename

---

Parameters:

Parameter	Data Code	I/O Direction	Description
Status Code	U16	output	Refer to the <i>File Access Status Codes</i> section.
Old Filename	String	input	Maximum of 19 characters (15.3 filename)
New Filename	String	input	Maximum of 19 characters (15.3 filename)

This system call method renames the file specified by Old Filename to New Filename.

If the return value is zero, the rename operation succeeded.

If the return value is non-zero, the rename operation failed. Either the specified file does not exist or an open handle is associated with the file.

Be careful to close any open handles associated with a file before renaming it.

Note that file renaming involves writing internal file system data to flash memory, so this system call method is subject to a 6–30 ms delay in performing the operation.

## NXTListFiles

---

Parameters:

Parameter	Data Code	I/O Direction	Description
Status Code	I8	output	
Pattern	String	input	File extension, such as *.exe.
File List	String array	input-output	List of files on the NXT device with the <b>Pattern</b> file extension.

This system call method lists the files on the NXT device that have the file extension, or **Pattern**, you specify. You must wire an array to the **File List** input. This system call method then populates that array and returns the results in the **File List** output.

If the status code is zero, the method successfully returned the list of files on the NXT device. If no files of the extension you specify exist on the NXT device, the method returns an empty **File List**.

If the status code is non-zero, the method failed due to a memory error and did not return the list of files on the NXT device.

## NXT Display Methods

Use the display methods to draw text, points, shapes, or graphic files to the built-in display on the NXT brick.

### NXTDrawText

Parameters:

Parameter	Data Code	I/O Direction	Description
Status Code	I8	output	Unused
Location	cluster I16 (X) I16 (Y)	input-output	Coordinates from lower left of screen
Text	string	input	Text string to draw
Options	U32	input	Bitfield of draw options

This system call method renders the string `Text` at the coordinates specified by `Location`. The method only renders printable characters—non-ASCII or non-printable characters are ignored. The method does not wrap text at the screen edges.

All draw coordinates are relative to the lower left corner of the screen on the NXT brick. The `NXTDrawText` method coerces y-coordinates to multiples of eight by rounding down such that text always appears on one of eight distinct lines on the display.

Set the least significant bit of `Options` to 1 to clear the entire screen before drawing. If you do not set this bit, the method overlays the text on top of any pixels already drawn by the program.

The first drawing system call method to execute in a program automatically clears the screen regardless of the value of `Options`.

The return value is always zero.

## NXTDrawPoint

---

Parameters:

Parameter	Data Code	I/O Direction	Description
Status Code	I8	output	Unused
Location	cluster I16 (X) I16 (Y)	input	Coordinates from lower left of screen
Options	U32	input	Bitfield of draw options

This system call method draws a single, black pixel at the coordinates that Location specifies.

All draw coordinates are relative to the lower left corner of the screen on the NXT brick.

Set the least significant bit of Options to 1 to clear the entire screen before drawing. If you do not set this bit, the method overlays the point on top of any pixels already drawn by the program.

The first drawing system call method to execute in a program automatically clears the screen regardless of the value of Options.

The return value is always zero.

## NXTDrawLine

Parameters:

Parameter	Date Code	I/O Direction	Description
Status	I8	output	Unused
StartLocation	cluster I16 (X) I16 (Y)	input-output	Coordinates from lower left of screen
EndLocation	cluster I16 (X) I16 (Y)	input-output	Coordinates from lower left of screen
Options	U32	input	Bitfield of draw options

This system call method draws a black line one pixel wide, from StartLocation to EndLocation.

All draw coordinates are relative to the lower left corner of the screen on the NXT brick.

Set the least significant bit of Options to 1 to clear the entire screen before drawing. If you do not set this bit, the method overlays the line on top of any pixels already drawn by the program.

The first drawing system call method to execute in a program automatically clears the screen regardless of the value of Options.

The return value is always zero.

## NXTDrawCircle

---

Parameters:

Parameter	Data Code	I/O Direction	Description
Status Code	I8	output	Unused
Center	cluster I16 (X) I16 (Y)	input-output	Coordinates from lower left of screen
Radius	U8	input	Radius, in pixels
Options	U32	input	Bitfield of draw options

This system call method draws a circle outline specified by Center coordinates and Radius in pixels.

All draw coordinates are relative to the lower left corner of the screen on the NXT brick.

Set the least significant bit of Options to 1 to clear the entire screen before drawing. If you do not set this bit, the method overlays the circle on top of any pixels already drawn by the program. The circle outline is transparent; the method never modifies pixels inside the circle.

The first drawing system call method to execute in a program automatically clears the screen regardless of the value of Options.

The return value is always zero.

## NXTDrawRect

Parameters:

Parameter	Data Type	I/O Direction	Description
Status Code	I8	output	Unused
Location	cluster I16 (X) I16 (Y)	input-output	Coordinates from lower left of screen
Size	cluster I16 (Width) I16 (Height)	input-output	Dimensions of rectangle, in pixels
Options	U32	input	Bitfield of draw options

This system call method draws a rectangle outline with one corner at the coordinates specified by Location. The Size cluster specifies relative coordinates of the corner opposite from Location.

Set the least significant bit of Options to 1 to clear the entire screen before drawing. If you do not set this bit, the method overlays the rectangle on top of any pixels already drawn by the program. The rectangle outline is transparent; the method never modifies pixels inside the rectangle.

The first drawing system call method to execute in a program automatically clears the screen regardless of the value of Options.

The return value is always zero.



## NXTDrawGraphic

---

Parameters:

Parameter	Data Code	I/O Direction	Description
Status Code	I8	output	Unused
Location	cluster I16 (X) I16 (Y)	input-output	Coordinates from lower left of screen
Filename	string	input	Maximum of 19 characters (15.3 filename)
Variables	I32 array	input	Optional parameters as defined by the RIC file.
Options	U32	input	Bitfield of draw options

This system call method renders the RIC-format graphic file (the LEGO standard image format) specified by Filename. Location specifies coordinates of the lower left corner of the rendered image.

All draw coordinates are relative to the lower left corner of the screen on the NXT brick.

The Variables argument specifies an array of arbitrary numeric parameters RIC files might use. Most files ignore these variables.

Set the least significant bit of Options to 1 to clear the entire screen before drawing. If you do not set this bit, the method overlays the graphic on top of any pixels already drawn by the program.

The first drawing system call method to execute in a program automatically clears the screen regardless of the value of Options.

If return value is non-zero, an error occurred while attempting to draw the file. Either the specified file does not exist or is not a valid RIC format file.

## NXTSetScreenMode

---

Parameters:

Parameter	Data Code	I/O Direction	Description
Status Code	I8	output	Unused
ScreenMode	U32	input	New screen mode

This system call method sets a new mode for the display screen on the NXT brick. The only valid mode for the NXT firmware 1.05 is `RESTORE_NXT_SCREEN` (value: 0). Use this screen mode to restore the default status screen after using any of the `NXTDraw` system call methods.

The return value is always zero.

## NXT Button Method

Use the NXT button method to read the status of the built-in buttons on the NXT brick. Note that you can read only the top three buttons. The bottom button always aborts the program.

## NXTReadButton

Parameters:

Parameter	Data Code	I/O Direction	Description
Status Code	I8	output	Unused
Index	U8	input	Button index: RIGHT, LEFT, or ENTER
Pressed	Boolean	output	TRUE if specified button is currently depressed
Count	U8	output	Number of times specified button has been pressed and released since last reset.
Reset?	Boolean	input	Set to TRUE to reset Count after reading state.

This system call method reads the state of the built-in NXT button specified by Index (RIGHT, LEFT, or ENTER).

Set Reset? to TRUE to reset Count after reading the state.

If the status code is zero, Pressed returns TRUE when the button is depressed, and Count returns the number of times button has been depressed and released since last reset.

If the status code is non-zero, you specified an invalid value for Index.

Legal values for Index:

Value	Enum	Description
0x01	RIGHT	Right arrow button
0x02	LEFT	Left arrow button
0x03	ENTER	Center square button

## Sound Playback Methods

Use the sound playback methods to control the sound module on the NXT brick.

### NXTSoundPlayFile

Parameters:

Parameter	Data Code	I/O Direction	Description
Status Code	I8	output	Unused
Filename	string	input	Maximum of 19 characters (15.3 filename)
Loop?	Boolean	input	Set to TRUE to enable automatic looping of sound file
Volume	U8	input	Volume of playback: [0, 4]

This system call method starts playback of the sound file specified by Filename. The file must be a valid RSO-format sound file (the LEGO standard sound file format).

Set Loop? to TRUE to loop playback automatically and indefinitely without further system call methods.

The integer values for Volume correspond to the following behaviors:

Integer Value	Value Description
0	Sound playback disabled
1	25% of full volume
2	50% of full volume
3	75% of full volume
4	100% of full volume

## NXTSoundPlayTone

Parameters:

Parameter	Data Code	I/O Direction	Description
Status Code	I8	output	Unused
Frequency	U16	input	Frequency of tone in Hertz
Duration	U16	input	Duration of tone in milliseconds
Loop?	Boolean	input	Set to TRUE to enable automatic looping of tone
Volume	U8	input	Volume of playback: [0, 4]

This system call method starts playback of a tone specified by Frequency (Hz) and Duration (ms).

Set Loop? to TRUE to loop playback automatically and indefinitely without further system call methods.

The integer values for Volume correspond to the following behaviors:

Integer Value	Value Description
0	Sound playback disabled
1	25% of full volume
2	50% of full volume
3	75% of full volume
4	100% of full volume

## NXTSoundGetState

---

Parameters:

Parameter	Data Code	I/O Direction	Direction
State	U8	output	Sound module state
Flags	U8	output	Bitfield of sound module flags

This system call method reads the internal state and flags of the sound module of the NXT brick. If Flags is non-zero, the sound module has playback operations pending or in progress. Normally, you can ignore the return value.

The return value might report the following values:

Value	Enum	Description
0x00	SOUND_IDLE	Sound module is idle, but there might be a pending request to playback sound
0x02	SOUND_FILE	Sound module is playing an RSO file
0x03	SOUND_TONE	Sound module is playing a tone
0x04	SOUND_STOP	Request to stop playback in progress

Flags might report the following values:

Value	Enum	Description
0x00	SOUND_FLAGS_IDLE	No flags set; sound module is completely idle
0x01	SOUND_FLAGS_UPDATE	A request for playback is pending
0x02	SOUND_FLAGS_RUNNING	Playback in progress

## NXTSoundSetState

Parameters:

Parameter	Data Code	I/O Direction	Description
State	U8	input	New state for sound module
Flags	U8	input	Bitfield of sound module flags

This system call method writes new State and Flags values to the sound module of the NXT brick.



**Note** Use this system call method with caution because it directly influences the internals of the sound module on the NXT brick. Use this method only for stopping current playback by writing a new State value of SOUND\_STOP.

The following value is the only value you can write to State:

Value	Enum	Description
0x04	SOUND_STOP	Request to stop playback

The following value is the only value you can write to Flags:

Value	Enum	Description
0x00	SOUND_FLAGS_IDLE	No flags set

## Bluetooth Communication Methods

Use the Bluetooth communication methods to send packets of information to other devices connected to the NXT brick through Bluetooth. You also use these methods to access the messaging queue system of the NXT firmware.

The NXT firmware uses a master/slave serial port system for Bluetooth communication. You must designate one Bluetooth device as the master device before you run a program using Bluetooth. If the master device is the NXT brick, you can configure up to three slave devices using serial ports 1, 2, and 3 on the NXT brick. If the slave device is an NXT brick, port 0 on the NXT brick is reserved for the master device.

Programs running on the master NXT brick can send packets of data to any connected slave devices using the `NXTCommBTWrite` method. However, programs on slave devices cannot send packets to master devices. The firmware of slave NXT bricks automatically handles responses sent by programs on master devices.

Refer to the LEGO MINDSTORMS Web site at [mindstorms.lego.com](http://mindstorms.lego.com) for the communications protocol documentation for Bluetooth.

This section also includes descriptions of the system call methods for accessing the mailboxes, or message queues, on the NXT brick. By using the direct command protocol, a master device can send messages to slave NXT bricks in the form of text strings addressed to a particular mailbox. Each mailbox on the slave NXT brick is a circular message queue holding up to five messages. Each message can be up to 58 bytes long.

To send messages from a master NXT brick to a slave brick, use `NXTCommBTWrite` on the master brick to send a `MessageWrite` protocol packet to the slave. Then, use `NXTMessageRead` on the slave brick to read the message. The slave NXT brick must be running a program when an incoming message packet is received. If no program is running, the slave NXT brick ignores the message, and the message is lost.

To exchange numeric data using the message system, use the `OP_FLATTEN` and `OP_UNFLATTEN` instructions to convert data to and from text strings.



## NXTCommBTCheckStatus

---

Parameters:

Parameter	Data Code	I/O Direction	Description
Status Code	I8	output	Refer to the following status codes.
Connection	U8	input	Connection (port), [0, 3]

This system call method checks the status of the Bluetooth communication on the specified port.

If the return value is zero, the port is idle and the last operation, (if any, did not cause any errors.

This method can return the following non-zero status codes:

Status Code		Enum	Description
32	0x20	STAT_COMM_PENDING	Port is busy performing a transaction.
-35	0xDD	ERR_COMM_BUS_ERR	Last transaction failed
-33	0xDF	ERR_COMM_CHAN_INVALID	Specified port is out of range [0,3]
-32	0xE0	ERR_COMM_CHAN_NOT_READY	Specified port is not properly configured

If you see ERR\_COMM\_CHAN\_NOT\_READY, make sure a Bluetooth connection is configured on the specified port.

If you see STAT\_COMM\_PENDING, an operation is in progress and do not interrupt it. Avoid calls to NXTCommBTWrite until NXTCommBTCheckStatus returns zero or a negative error code.

## NXTCommBTWrite

Parameters:

Parameter	Data Code	I/O Direction	Description
Status Code	I8	output	Refer to the following status codes.
Connection	U8	input	Connection (port), [0, 3]
Buffer	U8 array	input	Up to 256 bytes for writing to specified port

This system call method copies data from the buffer input to an internal Bluetooth buffer and instructs the NXT firmware to send the data to the device configured on the specified port.

If the return value is zero, the method successfully started a communication transaction. Use NXTCommBTCheckStatus to monitor the status of the transaction.

This method can return the following non-zero status codes:

Status Code		Enum	Description
-33	0xDF	ERR_COMM_CHAN_INVALID	Specified port is out of range
-32	0xE0	ERR_COMM_CHAN_NOT_READY	Specified port is busy or not properly configured
-19	0xED	ERR_INVALID_SIZE	Buffer size exceeded maximum size

If you are sending data to another NXT brick, the buffer must contain a complete packet conforming to the NXT communication protocol.

Refer to the LEGO MINDSTORMS Web site at [mindstorms.lego.com](http://mindstorms.lego.com) for the communications protocol documentation for Bluetooth.

## NXTMessageRead

---

Parameters:

Parameter	Data Code	I/O Direction	Description
Status Code	I8	output	Refer to the following status codes.
QueueID	U8	input	Mailbox queue, [0, 9]
Remove (T)	Boolean	input	If TRUE, remove message from specified queue after reading data
Message	string	output	Message data

This system call method reads the oldest message available in the specified mailbox queue and optionally removes that message from the queue.

If the return value is zero, the specified message queue was not empty and the Message output contains the oldest message from the queue.

This method can return the following non-zero status codes:

Status Code	Enum	Description
64	0x40	STAT_MSG_EMPTY_MAILBOX
-18	0xEE	ERR_INVALID_QUEUE

If you are calling NXTMessageRead on a master NXT brick with slave devices connected, this method also periodically checks for outgoing messages on the slave devices by automatically exchanging Bluetooth protocol packets with slaves.

## NXTMessageWrite

---

Parameters:

Parameter	Data Code	I/O Direction	Description
Status Code	I8	output	Refer to the following status codes.
QueueID	U8	input	Mailbox queue, [0, 19]
Message	string	input	Message data

This system call method writes a new message to the specified mailbox queue. If there are already five messages in the specified queue, the oldest message is deleted.

If the return value is zero, the method succeeded in writing the message to the specified mailbox queue.

This method can return the following non-zero status codes:

Status Code	Enum	Description	
-18	0xEE	ERR_INVALID_QUEUE	Invalid mailbox queue specified
-19	0xED	ERR_INVALID_SIZE	Message too large

If you are calling NXTMessageWrite on a slave NXT brick, use mailbox queues 10 through 19 as outboxes. When the master NXT brick reads messages, the brick checks these upper 10 mailboxes for outgoing message on the slave device.

## Low-Level System Methods

Use the low-level system methods to access miscellaneous low-level features of the NXT firmware system.

### NXTGetStartTick

---

Return Value:

<b>Parameter</b>	<b>Data Code</b>	<b>I/O Direction</b>
Program Start Tick	U32	output

This system call method returns the value of the system millisecond timer corresponding to the start of execution of the current program. This system call method is useful for measuring the time difference relative to the start of program execution.

## NXTKeepAlive

---

Return Value:

Parameter	Data Code	I/O Direction
Sleep Time Limit	U32	output

This system call method resets the internal sleep timer in the NXT firmware and returns the current time limit in milliseconds until the next automatic sleep. Use this method to keep the NXT brick from automatically turning off. Use the UI menu on the NXT brick to configure the sleep time limit.

## NXTRandomNumber

---

Return Value:

<b>Parameter</b>	<b>Data Code</b>	<b>I/O Direction</b>
Random Number	I16	output

This system call method returns a signed 16-bit random number. Internally, the NXT firmware selects new random seeds after every twenty calls to this system call method.

## NXTIOMapRead

---

Parameters:

Parameter	Data Code	I/O Direction	Description
Status Code	I8	output	Unused
ModuleName	string	input	Name of the firmware module
Offset	U16	input	Offset from beginning of the firmware module I/O map
Count	U16	input	Number of bytes to read
Buffer	U8 array	output	I/O map data

This system call method reads internal firmware module state information. This method is reserved for internal use only.



## NXTIOMapWrite

---

Parameters:

<b>Parameter</b>	<b>Data Code</b>	<b>I/O Direction</b>	<b>Description</b>
Status Code	I8	output	Unused
ModuleName	string	input	Name of the firmware module
Offset	U16	input	Offset from beginning of the firmware module I/O map
Buffer	U8 array	input	I/O map data

This system call method writes internal firmware module state information. This method is reserved for internal use only.

# Using Dynamic System Calls

Dynamic system calls are custom functions that you create in the NXT firmware.



**Note** When you create a dynamic system call, ensure the ID of the system call is unique.

You can create system-level methods that access dynamic system calls from an NXT VI. You then can use the `NXTDynamicSyscall` refnum to expose these methods.

You must update the NXT firmware to support the dynamic system call and build a new firmware image before you can access the system call from an NXT VI.

## Creating Access to a Dynamic System Call

Complete the following steps to create access to a dynamic system call.

1. Create a `.rc` file that defines the system-level method with which you want to access the dynamic system call.
2. Save the `.rc` file in the `labview\resource\objmgr` directory. The name of the `.rc` file must begin with `NXT`.
3. Create a VI that outputs the data type and default return value of the dynamic system call as a LabVIEW variant data type. The toolkit compiler uses this VI to determine the data to send to the dynamic system call in the firmware.
4. Select the  $4 \times 2 \times 2 \times 4$  connector pane pattern for the VI. Refer to the *LabVIEW Help*, available by selecting **Help»Search the LabVIEW Help**, for information about building connector panes.
5. Assign the top-right terminal of the connector pane to the variant output, as shown at left.
6. Save the VI in the `labview\vi.lib\addons\NXTToolkit\DynamicSystemCalls` directory. The name of the VI must be the same as the name of the system-level method you created.



## Using the `NXTDynamicSyscall` Refnum

Complete the following steps to use the `NXTDynamicSyscall` refnum to access a dynamic system call you created.

1. Create a new NXT VI.
2. Place the `NXTDynamicSyscall` refnum on the front panel.

3. Press the <Ctrl-E> keys or select **Window»Show Block Diagram** to display the block diagram.
4. Place an Invoke Node on the block diagram.
5. Wire the NXTDynamicSyscall refnum to the **reference** input of the Invoke Node.
6. Click the **Method** element of the Invoke Node and select the system-level method you created from the shortcut menu.



---

# Technical Support and Professional Services

Visit the following sections of the award-winning National Instruments Web site at [ni.com](http://ni.com) for technical support and professional services:

- **Support**—Technical support at [ni.com/support](http://ni.com/support) includes the following resources:
  - **Self-Help Technical Resources**—For answers and solutions, visit [ni.com/support](http://ni.com/support) for software drivers and updates, a searchable KnowledgeBase, product manuals, step-by-step troubleshooting wizards, thousands of example programs, tutorials, application notes, instrument drivers, and so on. Registered users also receive access to the NI Discussion Forums at [ni.com/forums](http://ni.com/forums). NI Applications Engineers make sure every question submitted online receives an answer.
  - **Standard Service Program Membership**—This program entitles members to direct access to NI Applications Engineers via phone and email for one-to-one technical support as well as exclusive access to on demand training modules via the Services Resource Center. NI offers complementary membership for a full year after purchase, after which you may renew to continue your benefits.

For information about other technical support options in your area, visit [ni.com/services](http://ni.com/services), or contact your local office at [ni.com/contact](http://ni.com/contact).

- **Training and Certification**—Visit [ni.com/training](http://ni.com/training) for self-paced training, eLearning virtual classrooms, interactive CDs, and Certification program information. You also can register for instructor-led, hands-on courses at locations around the world.
- **System Integration**—If you have time constraints, limited in-house technical resources, or other project challenges, National Instruments Alliance Partner members can help. To learn more, call your local NI office or visit [ni.com/alliance](http://ni.com/alliance).

If you searched [ni.com](http://ni.com) and could not find the answers you need, contact your local office or NI corporate headquarters. Phone numbers for our worldwide offices are listed at the front of this manual. You also can visit the Worldwide Offices section of [ni.com/niglobal](http://ni.com/niglobal) to access the branch office Web sites, which provide up-to-date contact information, support phone numbers, email addresses, and current events.