# Embedded Coder Robot NXT Instruction Manual

![Image of Embedded Coder Robot NXT](image)

## Table 1: OSEK ISR/Task vs. Embedded Coder Robot Interface

<table>
<thead>
<tr>
<th>OSEK ISR/Task</th>
<th>Embedded Coder Robot Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOPPERS OSEK</td>
<td>I/O driver (GPT, DIO, I2C, SPI, UART, UDP...)</td>
</tr>
<tr>
<td>NXT BIOS</td>
<td>ARM7</td>
</tr>
<tr>
<td>NXT Hardware</td>
<td>Bluecore</td>
</tr>
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</table>

- ![](image1)
- ![](image2)
- ![](image3)
- ![](image4)
- ![](image5)
## Revision history

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Contents</th>
<th>Author</th>
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<tr>
<td>1.0</td>
<td>March 2008</td>
<td>Initial release</td>
<td>Takashi Chikamasa</td>
</tr>
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<td></td>
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<td><a href="mailto:takashic@cybernet.co.jp">takashic@cybernet.co.jp</a></td>
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<tr>
<td>1.1</td>
<td>April 2008</td>
<td>Updated to V3.10</td>
<td>Takashi Chikamasa</td>
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<td>Takashi Chikamasa</td>
</tr>
<tr>
<td></td>
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<td><a href="mailto:takashic@cybernet.co.jp">takashic@cybernet.co.jp</a></td>
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MATLAB version

Embedded Coder Robot NXT has been tested in MATLAB 7.2.0 (R2006a) to MATLAB 7.7.0 (R2008b) under Windows XP SP2. The below figure describes the MATLAB R2008b tools which are used for Embedded Coder Robot NXT. The bold font products are minimum required products for target deployment.

<table>
<thead>
<tr>
<th>Products</th>
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<th>Release</th>
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<tr>
<td>MATLAB</td>
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<td>R2008b</td>
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<td>Simulink</td>
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<td>Fixed-Point Toolbox</td>
<td>2.3</td>
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<tr>
<td>MATLAB Report Generator</td>
<td>3.4</td>
<td>R2008b</td>
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<td><strong>Real-Time Workshop</strong></td>
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<td>R2008b</td>
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<td><strong>Real-Time Workshop Embedded Coder</strong></td>
<td>5.2</td>
<td>R2008b</td>
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<td>Simulink Design Verifier</td>
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<td>Simulink Report Generator</td>
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<td>Simulink Verification and Validation</td>
<td>2.4</td>
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<td>R2008b</td>
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<td>Stateflow Coder</td>
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<tr>
<td>Virtual Reality Toolbox</td>
<td>4.8</td>
<td>R2008b</td>
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**Introduction**

This document describes a MATLAB® and Simulink® based development environment for LEGO® Mindstorms® NXT (hereafter, NXT). The environment is called “Embedded Coder Robot for LEGO Mindstorms NXT (ECRobot NXT)” and it provides a modeling capability for NXT control strategy, plant dynamics, and the ability to simulate and visualize these model components in a 3-D virtual reality graphical environment. ERobot NXT also provides for Real-Time Workshop® Embedded Coder based target deployment with an open source OSEK RTOS to the real NXT hardware. This means that you can fully experience Model-Based Design including modeling, simulation, code generation, target build, and testing on a real NXT for the LEGO Mindstorms NXT.

**Disclaimer**

LEGO® is a trademark of the LEGO Group of companies which do not sponsor, authorize or endorse this project. LEGO® and Mindstorms® are registered trademarks of The LEGO Group.

According to LEGO Mindstorms NXT Hardware Developer Kit,

> **Important note: When the NXT is disassembled or when third party firmware is used with the NXT, all warranties are rendered invalid**.

It means that if you uploaded an ERobot NXT generated binary executable to your NXT, your NXT may be out of any warranties provided from LEGO. Therefore, please be sure that the author of this document does not take any responsibility for any loss or damage of any kind incurred as a result of the use or the download of ERobot NXT and related third party tools.

Disclaimer about the MathWorks and the products which are used for this demo, please check the following URL: [http://www.mathworks.com/matlabcentral/disclaimer.html](http://www.mathworks.com/matlabcentral/disclaimer.html)

ECRobot NXT is just an example to present features of MATLAB products. Therefore, please be sure that ERobot NXT is not an official software development environment of LEGO Mindstorms NXT.

**Prerequisites**

This document assumes readers are experienced with MATLAB, Simulink, Stateflow®, Real-Time Workshop®, and Real-Time Workshop Embedded Coder in general.
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1 How to set up Embedded Coder Robot NXT

Embedded Coder Robot NXT uses third party software to set up the development environment. Most of them (except for MATLAB products) are available as free (or open source). As a precondition, MATLAB should be installed into the directory which does not spaces and multi-byte character due to GNU make.

1.1 How to install Cygwin / GNU Make

To set up a cross compilation environment, it needs to install Cygwin and GNU Make.

1. Download Cygwin 1.5.x or newer version (we use 1.5.24) from Cygwin website: [http://www.cygwin.com/](http://www.cygwin.com/)

2. Execute setup.exe of Cygwin.

![Cygwin Setup - Choose Installation Type](image)

Fig. 1-1 Cygwin installer(1)
3. Install Cygwin into the directory which does not include space or multi-byte character. (E.g. C:/cygwin)

![Cygwin Setup - Choose Installation Directory](image)

Fig. 1-2 Cygwin installer(2)

4. Select make 3-81-1 under Devel tree node. (SED is also need, but it is included by default)
1.2 How to install GNU ARM

GNU ARM is a GCC distribution for ARM7 CPU (ATMEL AT91SAM7S256) which is located in the NXT.

1. Download GCC-4.0.2 binary installer from FILES section of GNU ARM website: [http://www.gnuarm.com/](http://www.gnuarm.com/)


2. Execute installer and install GNU ARM into the directory which does not include space or multi-byte character (e.g. C:/cygwin/GNUARM)

3. ATMEL AT91SAM7S256 does not have FPU, therefore configure the installation dialog as follows.

![Setup - GNUARM](image)

Fig. 1-3 GNU ARM installer(1)
4. Check off Install Cygwin DLLs because of Cygwin was already installed

![GNU ARM installer](image)

Fig. 1-4  GNU ARM installer(2)

5. At the end of installation, it is asked to add the installation directory to Windows Environment Path, but it is NOT needed.
1.3 How to install NXT program upload tools

Since Embedded Coder Robot NXT v3.06 (and LEJOS OSEK v1.09), LEGO standard USB driver has been
used instead of ATMELO SAM-BA to upload a program to the NXT. This change provides the following benefits:
- LEGO standard programming software (NXT-G) and Embedded Coder Robot NXT can be used in a PC
- Better USB connectivity during program upload
- Easier to set up

Caution
If ATMELO SAM-BA was already installed, it needs to completely uninstall SAM-BA before install LEGO
standard USB driver.

How to install LEGO standard USB driver
If LEGO standard programming software was already installed in the PC, LEGO standard USB driver is also
installed, so you can skip this section.
Download MINDSTORMS NXT Driver v1.02 from LEGO software update website:
http://mindstorms.lego.com/Support/Updates/

Fig. 1-5 MINDSTORMS NXT Driver v1.02
Install enhanced NXT standard firmware + NeXTTool or LibUsb driver

Since nxtOSEK 2.02, nxtOSEK has supported an enhanced NXT standard firmware which is developed by John Hansen. The enhanced NXT standard firmware can handle both of application programs which are supported by NXT standard firmware (e.g. NXT-G, NXC/NBC...) and ARM7 native applications. Therefore, Embedded Coder Robot NXT 3.12 or later versions also supports the enhanced NXT standard firmware besides with nxtOSEK original application Flash using NXT BIOS and direct boot from RAM. User can select one of three approaches to upload an Embedded Coder Robot NXT generated C code to the NXT.
If you wanted to use Embedded Coder Robot NXT with other programming languages (e.g. NXT-G, NXC/NBC...), install enhanced NXT standard firmware and NeXTTool
If you wanted to use only Embedded Coder Robot NXT or wanted to write larger application over 64Kbytes, install LibUsb.

How to install enhanced NXT standard firmware and NeXTTool

  (any version numbered 106 or later includes the native-invocation feature) and install the enhanced NXT standard firmware to the NXT using NXT-G firmware update feature or below NeXTTool.

  and install it to the directory which does not contain space and multi-byte characters. NeXTTool is a PC console program and it enables uploading .rxe file to the NXT.

How to install LibUsb

LibUsb is an open source C library for accessing USB devices. LibUsb installer for Windows is included in the nxtOSEK distribution package (lejos_osek/lejos_nxj/3rdparty/lib).
Execute libusb-win32-filter-bin-0.1.12.1.exe to install LibUsb to the directory which does not contain space and multi-byte characters.
Fig. 1-6  libush-win32-filter-bin-0.1.12.1.exe
1.4 How to install Embedded Coder Robot NXT

Extracted ecrobotNXT directory should be stored into the directory which does not include space and multi-byte character (e.g. Japanese) due to GNU Make.

```
docs
environment
nxt2nxt
nxtmouse
nxtracer
nxtremocon
nxtway
samples
ecrobotnxtsetup.m
```

Fig. 1-7 ecrobotNXT directory

Since Embedded Coder Robot NXT V3.10, ecrobotnxtsetup.m file is added to be easier to set up all necessity configurations for target deployment. ecrobotnxtsetup.m provides GUI to specify directory path to Cygwin/bin and GNUARM root. To use Embedded Coder Robot NXT for target deployment, it has to execute ecrobotnxtsetup.m file. If you use Embedded Coder Robot NXT for only simulation, it just needs to set MATLAB path to ecrobotNXT/environment directory.

**Caution**

If GNUARM_ROOT was defined as a Windows Environment Variable, please remove GNUARM_ROOT variable. It makes a confliction against the new build process in NXTOSEK 2.00 or later versions.
1.5 How to install nxtOSEK / NXT GamePad

nxtOSEK is an open source firmware replacement for NXT and it includes TOPPERS OSEK RTOS which is complied with OSEK ECC2. nxtOSEK is available at:

http://lejos-osek.sourceforge.net/index.htm

How to install nxtOSEK

Extracted nxtOSEK (v2.00 or later version) consists of nxtOSEK directory. It needs to store nxtOSEK folder into the environment directory of Embedded Coder Robot NXT.

![Fig. 1-8 nxtOSEK directory](image)

After all installation is completed, please re-start the PC.
2 Embedded Coder Robot NXT sample programs

Several sample programs are available in ecrobotNXT/samples directory. These sample programs are useful to confirm the basic features of Embedded Coder Robot NXT.

<table>
<thead>
<tr>
<th>File</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BluetoothRead.m</td>
<td>M script for Bluetooth receive in MATLAB (used with TestBluetoothTx.mdl)</td>
</tr>
<tr>
<td>BluetoothWrite.m</td>
<td>M script for Bluetooth send in MATLAB (used with TestBluetoothRx.mdl)</td>
</tr>
<tr>
<td>FrequencyList.m</td>
<td>M script for TestSoundTone.mdl</td>
</tr>
<tr>
<td>TestBluetoothRx.mdl</td>
<td>Simulink model for Bluetooth receive</td>
</tr>
<tr>
<td>TestBluetoothTx.mdl</td>
<td>Simulink model for Bluetooth send</td>
</tr>
<tr>
<td>TestFloatingPoint.mdl</td>
<td>Simulink model for floating-point calculation</td>
</tr>
<tr>
<td>TestHiTechnicSensors.mdl</td>
<td>Simulink model for HiTechnic Sensors</td>
</tr>
<tr>
<td>TestMotor.mdl</td>
<td>Simulink model for Servo Motors and program upload to RAM</td>
</tr>
<tr>
<td>TestMotorFlash.mdl</td>
<td>Simulink model for Servo Motors and program upload to Flash</td>
</tr>
<tr>
<td>TestMotorRXE.mdl</td>
<td>Simulink model for Servo Motor and program upload to the enhanced NXT firmware</td>
</tr>
<tr>
<td>TestNXTGamePad.mdl</td>
<td>Simulink model for NXT GamePad</td>
</tr>
<tr>
<td>TestSoundTone.mdl</td>
<td>Simulink model for Sound Tone output</td>
</tr>
<tr>
<td>TestSoundWAV.mdl</td>
<td>Simulink model for WAV sound output</td>
</tr>
<tr>
<td>TestUltrasonicSensor.mdl</td>
<td>Simulink model for Ultrasonic Sensor</td>
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2.1 TestMotor.mdl

TestMotor.mdl is used to describe code generation and program upload into RAM in NXT.

![TestMotor.mdl diagram](image)

**Fig. 2-1** TestMotor.mdl

**Generate target executables**

1. Open TestMotor.mdl.
2. Single click `nxtdl('TestMotor_app', 'build')` annotation to build target executables. If Embedded Coder Robot NXT was set up properly, target executables are created in `nxprj` directory under the current directory.
Uploading program into RAM

1. NXT as out of the box has LEGO standard firmware. At first, it needs to do hardware reset the NXT. Hardware reset button is located in the hole at the most left side behind the USB port and use a paper clip to press and hold the hidden button for four seconds. The NXT will then play a soft pulsing sound that signals its readiness.

NOTE
Step1 is required only for the first time when you upload a program, from next time, it is not needed.

2. Connect PC and NXT via USB cable.
3. Press ENTR button (orange colored rectangle button) on the NXT.
4. Click nxtbuild('TestMotor_app', 'ul2ram') annotation in TestMotor.mdl to upload the program into RAM. nxtOSEK splash screen is displayed for 3 seconds and turned to main screen. If program is uploaded into RAM, [R] is displayed in the main screen.

Fig 2-2  nxtOSEK splash screen and main screen

NOTE
To upload a program to the NXT, PC user domain needs to have administrator access right.
5. Press RUN (right triangle button) to start the uploaded application. If STP button (left triangle button) is pressed, application program is stopped and back to main screen.

**NOTE**
If any buttons do not work at the step 5. It needs to remove the battery of the NXT for five seconds and attach it again, then perform step2 to step5 again.

6. Application program is stored in RAM, therefore if NXT is turned off by pressing EXIT button, it needs to upload the program again (perform step 2 to step5).
2.2 TestMotorFlash.mdl

TestMotorFlash.mdl is used to describe code generation and program upload into Flash in NXT.

![TestMotorFlash.mdl](image)

Fig. 2-3 TestMotorFlash.mdl

**Generate target executables**
1. Open TestMotorFlash.mdl.
2. Single click nxtnbuild('TestMotor_app', 'build') annotation to build target executables. If Embedded Coder Robot NXT was set up properly, target executables are created in nxtrpj directory under the current directory.
**Uploading NXT BIOS into Flash**

1. NXT as out of the box has LEGO standard firmware. At first, it needs to do hardware reset the NXT. Hardware reset button is located in the hole at the most left side behind the USB port and use a paper clip to press and hold the hidden button for four seconds. The NXT will then play a soft pulsing sound that signals its readiness.

2. Connect PC and NXT via USB cable.

3. Click nxtbuild('biosflash’) annotation in TestMotorFlash.mdl to upload NXT BIOS into Flash. NXT BIOS screen is displayed.

![NXT BIOS screen](image.png)

**Fig 2-4** NXT BIOS screen (UPLOAD: READY)

**NOTE**

NXT BIOS upload is required only when LEGO standard firmware was installed in the NXT.
Uploading application program into Flash

1. Make sure that NXT BIOS screen (UPLOAD: READY) is displayed.
2. Connect PC and NXT via USB cable.
3. Click nxtbuild('TestMotor_app', 'ul2flash') annotation in TestMotor.mdl to upload application program into Flash.
4. Program upload status can be monitored by progress bar in the LCD display. A few seconds later, upload is finished.

![NXT BIOS screen (UPLOAD: FINISHED)](image)

5. Press EXIT button (gray colored rectangle button) to turn off the NXT.

**NOTE**
If any buttons do not work at the step 4. It needs to remove the battery of the NXT for five seconds and attach it again.

6. Click nxtbuild('TestMotor_app', 'ul2flash') annotation in TestMotorFlash.mdl to upload the program into Flash. nxtOSEK splash screen is displayed for 3 seconds and turned to main screen. If program is uploaded into Flash, [F] is displayed in the main screen.
7. Press RUN (right triangle button) to start application program. If STP button (left triangle button) is pressed, application program is stopped and back to main screen.

**NOTE**
If any bottuns do not work at the step 7, It needs to remove the battery of the NXT for 5 seconds and insert it again, then perform from step1 again.

8. Press EXIT button to turn off the NXT. Application program remains in Flash, thus you can re-start the program by pressing ENTR button.

9. To upload a new nxtOSEK application to Flash:
Press ENTR + STP button for more than 1 seconds while nxtOSEK main screen is displayed, the NXT is turned off automatically. Press ENTR button to turn on the NXT again, NXT BIOS screen is displayed.

**NOTE**
Once NXT BIOS was uploaded, NXT BIOS upload is NOT required to upload a new application program into Flash.
2.3 TestMotorRXE.mdl

TestMotorRXE.mdl is used to describe code generation and program upload to the enhanced NXT standard firmware in the NXT.

![TestMotorRXE.mdl](image)

**Fig. 2-7 TestMotor.RXEmdl**

**Generate target executables**

1. Open TestMotorRXE.mdl.
2. Single click ntxtbuild('TestMotor_app', 'build') annotation to build target executables. If Embedded Coder Robot NXT was set up properly, target executables are created in nxtprj directory under the current directory.

**Uploading program to the enhanced NXT standard firmware**

3. Connect PC and NXT via USB cable.
4. Turn on the NXT which has the enhanced NXT standard firmware.
5. Click ntxtbuild('TestMotor_app', 'rxeflash') annotation in TestMotorRXE.mdl to upload the program to the NXT. nxtOSEK splash screen is displayed for 3 seconds and turned to main screen. If program is executed into RAM, [R] is displayed in the main screen.
NOTE
To upload a program to the NXT, PC user domain needs to have administrator access right.

6. Press RUN (right triangle button) to start the uploaded application. Once Embedded Coder Robot NXT
(nxtOSEK) application is started, the NXT is fully controlled by the Embedded Coder Robot NXT
application.
   If STP button (left triangle button) is pressed, application program is stopped and back to main screen.
   If EXIT button (gray colored rectangle button) is pressed, the NXT is turned off.

The enhanced NXT standard firmware provides a file system; hence, multiple nxtOSEK application programs
can be uploaded to the NXT. The maximum size of an nxtOSEK application is 64Kbytes.
3 Trouble shootings

Q1 Can’t build a target executable

A1. Confirm settings of the installed third party software.
    Make sure that installation directory does not contain spaces or multi-byte characters.
    Make sure that Windows Environment Variable and Path are set correctly.
A2. Confirm MATLAB current directory.
    Make sure that current directory path does not contain spaces or multi-byte characters.

Q2 Can’t upload a program to the NXT

A1. Remove the battery of the NXT for five seconds and insert it again, then try it again.
A2. Check Windows Control Panel->System->Hardware->Device Manager->LEGO Devices->LEGO
    MINDSTORMS NXT Firmware Update Mode->(right click on the LEGO MINDSTORMS NXT
    Firmware Update Mode) Property->Driver->Driver Details. libusb0.sys should be appeared besides with
    fantom.sys. If libusb0.sys does not exist, Re-install libUSB to the directory which do not contain spaces
    and multi-byte characters.
A3. Confirm log-in user account
    Make sure that user account has an administrator right.
A4. Change the USB port on PC for program upload.
A5. Hardware reset the NXT and then try it again.