

ECE 480
Design Team 2

Using I²C Peripherals with LEGO NXT

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Application Note
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Executive Summary

One weakness of the LEGO NXT brick is the small number of inputs and outputs available. This I/O limitation can be overcome by using a serial communication protocol such as I²C. Using serial communication, data is sent one bit at a time sequentially, requiring fewer wires and I/O ports than if the data is sent in parallel over several interconnects. The parallel output capacity of the LEGO NXT can also be extended by using a I²C compatible I/O expander IC such as the PCF8574 made by TI.

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Introduction

The LEGO NXT brick has only three motor control outputs and four sensor I/O ports. While this is enough for the simplest of projects most users wanting to build a more complex LEGO robot or accessible industrial manufacturing device will require more than seven peripheral devices. Multiplexing is the most commonly used tool for adding a few more buttons or motors to the LEGO NXT brick but the number of peripherals you can add with a multiplexer is still quite limited. With Inter-Integrated Circuit (I²C) communication we can add up to 112 devices per input line.

Objective

This application note will explain how to add more peripheral devices to the LEGO NXT brick than can be added using parallel communication. While the focus will be on two specific I²C compatible ICs the methods used are fairly general and can be applied to any I²C compatible IC. The concepts covered here could also be used with a different microcontroller with a different programming language. The I²C portion would work the same in any environment, requiring only a change in the programming language used.

Resources

The following resources are referenced in this document and having them on hand would help clarify some of the operation details of ICs mentioned.

TI PCF8574n Data Sheet

PCF8574 Remote 8-Bit I/O Expander for I²C Bus Datasheet

Basic I²C Communication

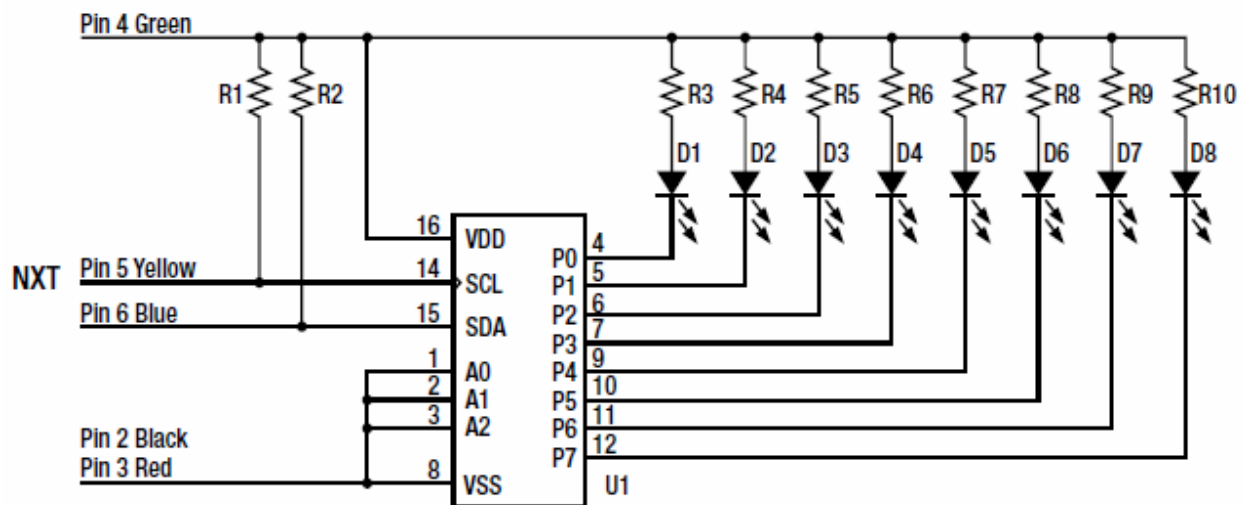
I²C communication requires two lines, one for data one for the clock signal. These lines are usually called SDA and SCL the former being for data and the latter for the clock signal. SDA is sampled when SCL is high and both lines are pulled high with a large resistor. Each node on the I²C bus has a unique address. Each message sent contains that address, directing only the correct peripheral to receive the data. In practice adding the full 112 possible devices is sometimes not feasible because many I²C compatible circuits use an address that is only adjustable within a small range, allowing us only 7 or 32 of each device. Fortunately most of these devices have a different base address allowing us to have both 7 of one chip and 32 of another. Nodes on an I²C bus are either master or slave nodes. Master nodes can initiate the exchange of data and slaves cannot.

The LEGO NXT brick has the hardware necessary to communicate using I²C but does not come with the software blocks necessary to use this hardware. However third party software blocks can be downloaded that does allow I²C. These software blocks can be added to any LEGO program. There are two LEGO I²C programming blocks, the I²C write block, and the I²C read block. The write Block has three data fields that can be filled out: address, register, and data. The address register refers the I²C address of the peripheral you are writing to. The register field sets which of the devices registers you are writing the data to, and the data field is the

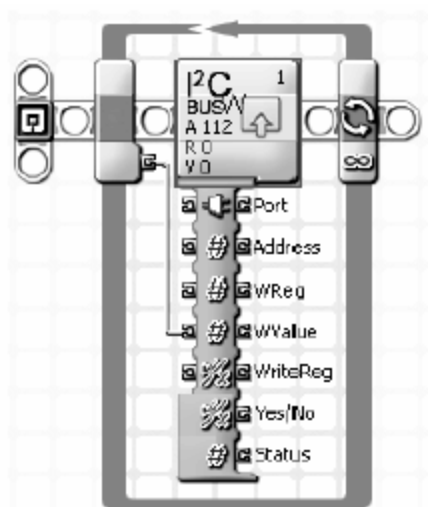
information being sent to the peripheral. The I²C read block has an address field and a registry field, allowing you to select the registry to read from if your IC has multiple registries.

TI PCF8574 I/O Expander

The PCF8574 I/O Expander translates serial data from the I²C and outputs in parallel from its eight I/O ports. An example using the PCF8574 is drawn below. The colored pins 2-6 refer to the colors of the wires inside a LEGO wire, you will have to cut open the LEGO wire to attach these wires. Pins A0, A1, and A2 are used to set the I²C address. With all three address ports grounded through the red LEGO wire the address of the I/O expander will be 64. If you wish to add more I/O expanders set some of the address pins high.



The value of resistors R1 and R2 should be around 82K Ω . They pull the I²C communication pins high. The value of R3 - R10 depends on the voltage requirements of the LEDs you use. The LEGO NXT brick supplies 4.75V on the green wire so 100 Ω is a common choice. To program the NXT brick to light the LEDs in the NXT environment create a counting loop and place a I²C write block in the center of it as shown below.



The loop counter will feed numbers into the write value of the I²C write block. set the address value to 64 and leave the registry field blank and the I/O Expander has no registries. While the program is running the LED powered by the least significant bit will flash so rapidly it will appear to just be on. only the top few LEDs will be easily countable. The counting direction may appear backwards to you because an on LED represents zero. This circuit is powered through the LEGO NXT brick. The LEGO NXT can only supply about 175mA through all of its ports combined.

Because of this limitation if you want to implement more than one or two I²C circuits it may become necessary to attach an external power supply. In that case simply replace the Red wire connections with a ground and the green wire connections with a 4.5V to 5.25V power supply

The I²C read block can be used to read logical highs or lows off of the I/O expanders pins. To set the I/O expander to read the most significant bit sent in the data field must be high. Addressing is done the same as when writing.

SAA1064 4-Digit LED Driver with I²C Bus Interface

Seven segment displays are a common peripheral. Rather than use multiple I/O expanders to implement a multi-digit LED display through I²C we can use an IC design for the task. This reduces the number of ICs required for a design and frees up some addressing space. The SAA1064 is designed to drive four seven segment decimal displays with common anodes using multiplexing. Different seven segment LEDs have different pin configurations so look at the data sheets for the LED display you have as well as the SAA1064 datasheet for a wiring diagram. The most significant difference between controlling the I/O expander and the LED driver is the LED driver has registers. These registers are used to choose which of the four digits the LED driver can control is being written to whenever data is sent to the LED drivers' I²C address. To send data to the first digit set the data register to one. To send to the second digit set the register to 2 and so forth. The SAA1064's default address is 113, different than the I/O expanders default address.

References:

Extreme NXT: Extending the LEGO MINDSTORMS NXT to the Next Level. 2009

Michael Gasperi, Philippe E. Hurbain, Isabelle L Hurbain

PCF8574 Remote 8-Bit I/O Expander For I²C Bus Datasheet. July, 2001. TI

SAA1064 4-digit LED-driver with I²C-Bus interface. Feb, 1991. Philips Semiconductors