RobotC-I2C Interface Packet

Scope: This tutorial will show steps to interface with I2C sensors.

Before we go into programming to I2C interfaces, there are a few things you should have a fair amount of knowledge, or at least know what they represent:

- Data structure – "struct" and "array" (this should been introduced in the Programming Packet II)
- Bits / hexadecimal representation. (in this document)
- What is a Memory Address? What is a bus? (in this document)

Table of Contents

CH1 – LEARNING ABOUT BITS & BYTES

CH1 – 1 BINARY & HEXADECIMAL BASED

Decimal number is base-10.

e.g.

valid digit: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9

number $2049_{10} = 10^3 * 2 + 10^2 * 0 + 10^1 * 4 + 10^0 * 9$

Binary number is base-2.

e.g. valid digit: 0, 1

$1010_2 = 2^3 * 2 + 2^2 * 0 + 2^1 * 1 + 10^0 * 0$

$= 10_{10}$

100010010

← most least →

significant bit significant bit

Hexadecimal number is base-16.

e.g. valid digit: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F

$10000_{16} = 16^4 * 1 + 16^3 * 0 + 16^3 * 0 + 16^3 * 0 + 16^0 * 0$

$= 65536_{10}$

$FFFF_{16} = 16^3 * 15 + 16^2 * 15 + 16^2 * 15 + 16^1 * 15 + 16^0 * 15$

$= 65535_{10}$

CH1 – 2 CONVERSION

From Decimal to Binary	2) 18 $18_{10} = 10010_2$ 2) 9 ---0 2) 4 ---1 2) 2 ---0 1 ---0	2) 15 $15_{10} = 1111_2$ 2) 7 ---1 2) 3 ---1 1 ---1
From Decimal to Hexadecimal	16) 18 $18_{10} = 12_{16}$ 1 ---2	16) 15 $15_{10} = 0F_{16}$ 0 ---F
From Binary to Decimal	10010_2 $= 2^4 * 1 + 2^1 * 1$ $= 18_{10}$	1111_{10} $= 2^3 * 1 + 2^2 * 1 + 2^1 * 1 + 2^0 * 1 = 15_{10}$
From Hex to Bin	0x0149AF $0_{16} = 0_{10} = 0_2$ $4_{16} = 4_{10} = 0100_2$ $9_{16} = 9_{10} = 1001_2$ $A_{16} = 10_{10} = 1010_2$ $F_{16} = 15_{10} = 1111_2$	0x0149AF $0_{16} = 0_{10} = 0_2$ $4_{16} = 4_{10} = 0100_2$ $9_{16} = 9_{10} = 1001_2$ $A_{16} = 10_{10} = 1010_2$ $F_{16} = 15_{10} = 1111_2$
From Bin to Hex	0111001010101011_2 7 2 5 11 $= 725B_{16}$ $= 16^3 * 7 + 16^2 * 2 + 16^1 * 5 + 16^0 * 11$ $= 29275_{10}$	0001100010001000_2 1 8 8 8 $= 1888_{16}$ $= 16^3 * 1 + 16^2 * 8 + 16^1 * 8 + 16^0 * 8$ $= 6280_{10}$

CH1 – 3 SIGNED BIT

1 byte = 8 bits   4 bytes = 1 Word, ie 32 bits

Data type: byte or char

- Contains 1 byte
- Can only hold 7 bits number representation, instead of 8 bits, because the highest significant bit is reserved as a signed bit.
- Signed byte: signed bit 0/1 0/1 0/1 0/1 0/1 0/1 0/1

  7^{th} 6^{th} 5^{th} 4^{th} 3^{rd} 2^{nd} 1^{st} 0^{th}

  If "signed bit" == 1, this is a negative

  If "signed bit" == 0, this is a positive

e.g.

byte x = $0100\ 0001_2$ = 0x41 = 65

byte x = $1011\ 1111_2$ = 0xbF = -65. You may ask why not $1100\ 0001_2$.

To make 65 → -65 :

1. Take ~0100 0001 = $1011\ 1110_2$
2. + 1 = $1011\ 1111_2$

Just for fun:

For byte x = $1100\ 0001_2$ = -63

1. $1100\ 0001_2$ - 1
2. ~$1100\ 0000_2$ = $0011\ 1111_2$ = 0x3F = 63

Data type: unsigned byte or char

- Contains 1 byte
- Can hold 8 bits number representation.
- Unsigned byte: 0/1 0/1 0/1 0/1 0/1 0/1 0/1 0/1

  7^{th} 6^{th} 5^{th} 4^{th} 3^{rd} 2^{nd} 1^{st} 0^{th}

e.g.

unsigned byte x = 1000001_2 = 65

unsigned byte x = 11000001_2 = 193

Question: int x = 64 (2 bytes integer)

Negative of x = ____________________________ (Fill in the blank)

CH1 – 4 BITWISE MATH OPERATION

A bitwise operation operates at the level of individual bits between two binary numbers. This is indispensable knowledge in electronic as you will see how these are used in sensors data operation in later exercises.

You can do Binary Addition, Subtraction, Multiplication, and Division, like more other basic arithmetic. What we will focus on here is "bit shifting", and "bit masking" operations.

Bitwise operation is far faster than multiplication and division in computer.

Ch1 – 4.1 Bit Masking : OR (inclusive OR)

Operator: |

Function: set bits on

e.g. $x = 010_2$; $y = 111_2$, x = x | y, i.e. $x == 111_2$

Ch1 – 4.2 Bit Masking : AND

Operator: &

Function : find out which particular bit(s) is/are set.

e.g. $x = 010_2$; $y = 111_2$, x = x & y, i.e. $x == 010_2$
e.g. $x = 111_2$; $y = 101_2$, x = x & y, i.e. $x == 101_2$

Ch1 – 4.3 Bit Masking : XOR (exclusive OR)

Operator: ^

Function: set bits off or switch bit on& off

e.g. $x = 010_2$; $y = 111_2$, x = x ^ y, i.e. $x == 101_2$
e.g. $x = 101_2$; $y = 101_2$, x = x ^ y, i.e. $x == 0_2$

```
e.g. x = 1;  y = 1;  x = x^y; i.e.  x==0  // great to be used as an on/off switch
e.g. x = 0;  y = 1;  x = x^y; i.e.  x==1
```

Ch1 – 4.4 Bit Masking : NOT (complement)

Operator: ~

Function:, is a unary operation that performs logical negation on each bit

e.g. $x = 010_2$; ~x == 101_2

```
e.g. x = 1;  ~x == 0  // great to be used to alternate on/off state
e.g. x = 0;  ~x == 1
```

Quickly recapture the bitwise operations:

		Bit 3	Bit 2	Bit 1	Bit 0
	X	1	1	0	0
	Y	1	0	1	0
Bit-And	Z = X & Y	1	0	0	0
Bit-OR (inclusive)	Z = X | Y	1	1	1	0
Bit-XOR (exclusive)	Z = X ^ Y	0	1	1	0
Bit-NOT	Z = ~X	0	0	1	1

Caution! Do not use bit shift unless you FULLY aware of the signed and unsigned relationship, as well as binary math operation. If you have to use it, you should write a separate program to test out all signed and signed situation to ensure you will not have shifting errors.

CH1 – 5 BIT-SHIFT OPERATION

Ch1 – 5.1 Shift left

Operator : <<

Function: multiple by 2^n

e.g. x = $10_{10} * 2^{1}$; i.e. 1010_2 << 1
then x contains 20 , i.e 10100_2

e.g. x = $10_{10} * 2^{2}$; i.e. 1010_2 << 2
then x contains 40 , i.e 101000_2

Ch1 – 5.2 Shift right

Operator : >>

Function: divided by 2^n

e.g. x = $10_{10} / 2^{1}$; i.e. 1010_2 >> 1
then x contains 5, i.e 101_2

e.g. x = $10_{10} / 2^{2}$; i.e. 1010_2 >> 2
then x contains 2, i.e 10_2
(note that not 2.5 because this is supposed to deal with "int" data type, not float)

CH1 – 6 MORE ON BITS MATH FOR PERFORMANCE

In modern computer architecture, multiplication and division have been optimized to the point that it performs just as good as bits operation. The only one which will still be faster with bit math is calculating X^n, instead of using power(X, n).

Pseudo code for doing your power X^n:

Calculate X^n

Put bits math above in good use, let's try to calculate X^N, e.g. 9^3.

```
Let n1 , n2 = X
for I from 1 to exponent N
{   while n2 != 0
    {   If   last bit of n2 != 0
                 sum = sum + n1
          n1 << 1
          n2 >> 1
     }
    Set n1 to sum
    Reset n2 = operand
```

```
9x9=81

     *   1001  (n2)
         1001
        0000
       0000
      1001
      1010001
```

```
81x9=729
        1010001

        1010001
       0000000
      0000000
       1011011001
```

```
}
```

CH1 – 7 EXERCISE:

Ex 1: Complete all the conversions below

A) Conversion: base2(binary) vs. base10(decimal) vs. base16(hexadecimal)

Binary	Dec.	Hex.	Binary	Dec.	Hex.
1	1				0x17
11	3				0x1F
10001					0x88
10010					0x100
10100					0x10F
11000					0x00F
11011					0xF0

B) Calculate the following, and provide answer in hexadecimal format:

i. 16_{10} & 15_{10} ? Ans: ____________________
ii. 16_{10} | 15_{10} ? Ans: ____________________
iii. $1C_{16}$ | 11_2 ? Ans: ____________________
iv. $1C_{16}$ | 11000000_2. ? Ans: ____________________
v. 16_{10} ^ 15_{10} ? Ans: ____________________
vi. 16_{16} ^ 15_{16}? Ans: ____________________
vii. byte x = 3_{10}; What is ~x? Ans: ____________________
viii. ubyte x = 3_{10}; What is ~x? Ans: ____________________
ix. byte x = 0. Use a single bit masking method to get value of 0xF. Ans: ____________________
x. byte x = 101. Use a single bit masking method to get value of 0x3. Ans: ____________________

C) Use Bit-math to do the following (the first is done for you):

i. X = 0x1C. Write the binary representation. Ans: 0001 1100
ii. Calculate 20 / 4 using binary math. Ans: ____________________
iii. X = 0x1C. Get only the least (lowest) significant 2 bits. Ans: ____________________
iv. X = 0x1C. Get only the most (highest) significant 2 bits. Ans: ____________________

D) Write a program to extract data from two separate data fields and reassemble it to form an new data field.

Result = move the least significant 2 bits of field2 into the most significant position of result.

Move the most significant 2bits of field1 into the least significant position of result.

```
e.g.
If    int field1 =  0xdb02
      int field2 =  0x1f06
then  int result should be = 0x1011
```

Ex2: Write a display function to display an integer and/or char field in binary and hex value:

- Specification of this function can be : *void displaybits(char x)*
  - Return: none
  - Parameter : char x : is one byte integer. Your function will display its binary representation.
  - E.g. char abc = 254;
  - displayBits(abc);
  -
  - Your nxt should display : FE 11111110
  -
  - E.g. char abc = 16;
  - displayBits(abc);
  -
  - Your nxt should display : 10 10000

Hint:

For the hex display, it is easy… just use %x in your display

For binary display, use:

- binary shift
- Put each bit in a character array and a string, e.g char arr[9]; string str;
- Shift the bit : LSB to arr[7] … MSB to arr[0];
- Use StringFromChars(str, arr)…well. You need to do this because RobotC cannot do display a character array. It must be in string format.

CH2 – SET AND ACCESS I2C PORTS

CH2 – 1 BASIC TERMS

What is Memory Address ?

Computers only understand binary. Any hardware must have way to store its request and data, ie. the Memory Address.

Do not confuse this with the term Memory Register, although it is often referenced as such online by people using I2C code. A *register* is a bit placeholder for bits information stored in very fast memory/storage access area. This is built into the CPU (central processing unit) in order to speed up its operations by providing quick access to commonly used values. For this I2C reference, they use the term Register loosely as it means the memory address storing either instruction or data. Note: as far as memory is concerned, a memory address is memory address; it does not matter what you store it.

In short, it represents bits and bytes of request. Registers are the top of the *memory hierarchy* and are the fastest way for the system to manipulate request.

Typical uses of hardware registers include configuration and start-up of certain features, especially during initialization, storage configuration for hardware devices, such as central processing unit, I/O devices like sensors. etc.

Before you operate on the register request from a device, you need to know the "memory address layout". In short, it is a request map where you can get important request from the device like the tilt sensor.

```
e.g.
    nDeviceAddress = 0x02;  // the unique address of a I2C device
    nLocationPtr = 0x42;        // the address referring to a certain command for actiion
```

What is a Bus ?

A bus, as a computer term, may represent two things.

1. It can mean the physical electrical wires with multiples connections for hardware devices.
2. It can also mean any subsystem that provides a specific set of functionality as an electrical bus.

<u>Internal and external buses:</u>

Internal buses all the internal components of a computer to the motherboard, e.g. CPU, math processor, internal memory modules, etc. They are also called local bus. There are motherboard specific.

External buses connect external peripherals to the motherboard, such as the USB.

CH2 – 2 INTRODUCTION TO I2C PORTS

I²C means **Inter-Integrated Circuit**. It generically is referred as "two-wire interface". This is standardized bus design that has become very popular because

- low manufacturing cost
- its small size
- low weight,
- low power consumption.

I²C system design was created in the early 1980s, and standardized in early 1990s. It is have widely used in implementing peripheral devices. Ever since then, the physical size has been decreasing drastically. The speed has increased as well, ranging from 10 to 400 kbits/sec :

- 10kbits/s as low speed mode
- 100kbits/s classified as standard speed
- 400kbits/s as high speed mode

CH2 – 3 I2C PORTS TEST UTILITY IN ROBOTC

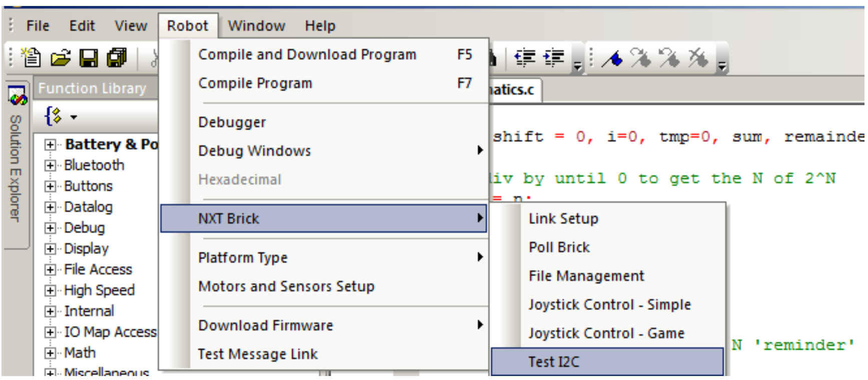
ROBOTC provides a tool for testing digital sensors on the NXT.

Digital sensors are those that support the industry standard I2C protocol for communications between the NXT and the sensor. The utility allows you to easily test an I2C sensor on the NXT.

To do this, you should find out the I2C address map from the sensor that you are interested in. For simplicity, we are going to use the NXT ultrasonic sensor as an example. Steps :

This section of information is largely extracted from the RobotC-I2C document.

Invoke the I2C ports test utility

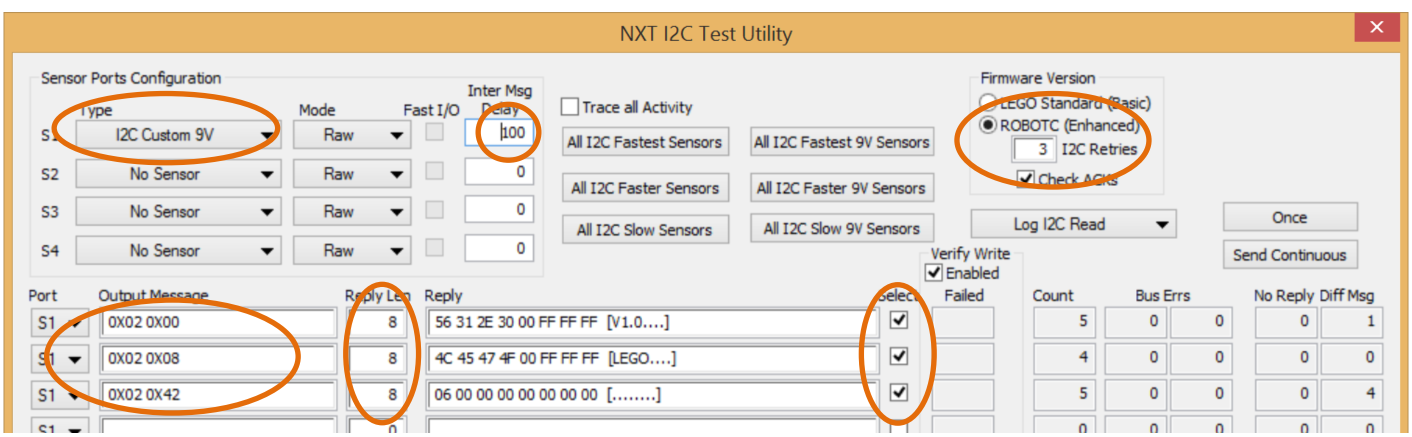


Manual test out the responses from I2C Test Utility

The following window shows up. When this utility is first opened, it will interrogate the NXT to get the current settings of these values.

Sample steps:

- Hook up an ultrasonic sensor which is an I2C custom sensor as well.
- Run the utility.
- Type the entries shown below:



Port
I2C sensors port

The hexadecimal bytes of the message to be sent to the sensor

Output Message

Reply Len (Length)

The length of the reply expected from the sensor in bytes

Reply
The reply returned from the sensor in hexadecimal (and converted to ASCII)

Select
A checkbox to determine if the selected message should be included or excluded from the test cycle.

Once/Continuous Buttons
These buttons select whether a single test cycle or continuous testing should be performed.

Verify Write
If checked, the NXT will send an ACK message to check if the I2C message was successfully sent to the NXT. The "Failed" text box will return a count of the number of failed messages.

Count
A text box containing the number of messages sent in total.

Bus Errors
Number of bus errors encountered during error transmission. Bus error is detected by the I2C firmware and usually indicates an attempt to send an I2C message to a sensor that does not support I2C messaging.

No Reply
Number of messages sent to the I2C message that did not recieve a reply from the sensor.

Diff Msg (Different Message)
Number of different messages recieved from the I2C sensor... this counter will not increment when the same message is recieved from the I2C sensor in succession

Exercise: Download the utility file called **ic2Scanner** from http://robotc.stormingrobots.com to detect i2c devices address.

I2C Fast Sensor vs. I2C Slow Sensors

Use either of these two buttons to quickly configure all four sensor ports as a custom I2C sensor. “Fast” sensors will use the ROBOTC firmware capability to transmit I2C messages at five times the speed found in the standard LEGO supplied firmware. Fast mode generally works with all third party sensors, slow mode is required for the LEGO ultrasonic sensor. The difference is that most 3rd party sensors include a microprocessor that has I2C messaging support in hardware and can keep up with the faster ROBOTC messaging rate. Slow sensors have a “bit-banged’ implementation and cannot keep up.

Firmware Version

Configure these parameters for either standard LEGO firmware or ROBOTC firmware. Standard firmware does not support fast mode signaling and will always try to send a I2C message three times before reporting failures. Trying three times can easily mask intermittent transient errors. The number of total tries can be user configured in the ROBOTC firmware. The default value is a total of three tries. Setting the number of retries to zero is useful to ensure transient errors are not masked.

CH2 – 4 WHAT IS I2C ADDRESS, MEMORY ADDRESS & BUS

Memory Address Map

Computers only understand binary. Any hardware must have way to store its data, i.e. memory address.

Memory Address (sometimes they may refer to as *register)* is a bit placeholder for bits information stored in very fast memory/storage access area. This is built into the CPU (central processing unit) in order to speed up its operations by providing quick access to commonly used values.

In short, it represents bits and bytes of data. True Registers are the top of the *memory hierarchy* and are the fastest way for the system to manipulate data.

Typical uses of hardware registers include configuration and start-up of certain features, especially during initialization, storage configuration for hardware devices, such as central processing unit, I/O devices like sensors. etc.

Before you operate on the register data from a device, you need to know the "register layout". In short, it is a data map where you can get important data from the device like the tilt sensor.

```
e.g.
    nDeviceAddress = 0x02;
    nLocationPtr = 0x42;
```

IMPORTANT: This I2C memory address MUST be even … You will see why when you work with the I2C code on the Arduino side.

I2C Address vs other Memory Address Commands

In essence, I2C address is memory address. Distinction should be mentioned:

I2C address : an unique memory address to identify a specific I2C device. In the case when you connect to multiple I2C devices, you must have an unique memory address to address each single device.

Other Memory addresses are used for certain commands determined by the manufacturer. If you are the one who create the I2C device, you will be the one who create the I2C unique address, and all other command addresses.

Bus

A bus, as a computer term, may represent two things.

It can mean the physical electrical wires with multiples connections for hardware devices.

It can also mean any subsystem that provides the a specific set of functionality as an electrical bus.

The arrangement may use both parallel (multidrop) and bit-serial (daisy chain) connections. One example is a USB hub.

In essence, a design of bus forms a standard interconnection points for which multiple manufacturers build compatible and interchangeable interfaces.

Internal and external buses:

Internal buses all the internal components of a computer to the motherboard, e.g. CPU, math processor, internal memory modules, etc. They are also called local bus. There are motherboard specific.

External buses connect external peripherals to the motherboard, such as the USB.

NXT Sample Memory map model

HiTechnic I2C Sensor memory model:

Address	Type	Contents
00-07H	byte	Reserved
08-0FH	byte	Manufacturer
10-17H	byte	Sensor type
18-3DH	byte	Not used
3E, 3FH	byte	Reserved
40H	byte	Not used
41H	Byte	Reserved
42H	Memory Address 42H and higher will contain layout specific for different device.	

CH2 – 5 BASIC PROGRAMMING OPERATIONS ON I2C DEVICES

Steps to do for interfacing with an I2C sensor:

1) Create a sample data structure to represent the standardized protocol for I2C communication. This sample shows 3 bytes message size.

```
typedef struct{
    byte nMsgSize;
    byte nDeviceAddress;
    byte nLocationPtr;
  } TI2C_Output;
```

OR

```
Byte msg[3];
// whatever # of bytes that
you will need for your message
size.
```

2) Initialize I2C sensor port and check the port for communication readiness

```
SensorType[S1] = sensorI2CCustom;
```

3) Check the communication status

```
while (nI2CStatus[S1] == STAT_COMM_PENDING)
       wait1Msec(2);
```

4) Setup device's internal location, memory address, a "read" command.

```
sOutput.nMsgSize = 2;
sOutput.nDeviceAddress = 0x02;
sOutput.nLocationPtr = 0x42;
// 0x42 is the address used for a
certain i2c command
sendI2CMsg(S1, &sOutput, 0);
```

or

```
Byte msg[3];

sendI2CMsg(S1, msg, 0);
```

5) Check the communication status

```
while (nI2CStatus[S1] == STAT_COMM_PENDING)
     wait1Msec(2);
```

6) Read the message:

```
// prepare the message space.
// N is the # of bytes. Refer to the I2C sensor specification
byte replyMessage[N];

// get the message
readI2CReply(S1, replyMessage, N);
```

7) Normalize the read value from the Memory Address:

   "replyMessage[…]" only returns the raw value.

   You may have to do some work to get the normalized (or cooked) value.

   This is specific to individual I2C device manufacturer. You must obtain the memory map model from the I2C sensors manufacturer.

This section shows the basic steps to interface with any I2C devices with NXT. In the later chapters, samples are given to interface with specific I2C devices.

More Effective ways to communicate with an I2C sensor

Send a command over to I2C device, but not expecting any value back, such as telling the I2C sensor to do some configuration, or turning on internal LED, etc.

```
Msg[0] = 3;    //there are 3 bytes in the message stream
Msg[1] = 0x02;
Msg[2] = 0x42;
Msg[3] = 5;
sendI2CMsg(port, Msg, 4);

//where the value  5  may mean some configuration value to the sensor.
// e.g. it may mean to tell the sensor turning on its LED, or blink its LED 5 times, or
//      something more useful - telling it to do data filtering with 5 data points.
// The third parameter tells the I2C sensor that it expects it to return a 4 bytes value.

Then, your code should do this in order to get 4 bytes back from the I2C sensor :

   readI2CReply(S1, replyMessage, 4);
```

Caution !!!

These APIs preform the bare minimum in a communication mechanism. However, it is far from robust. You must perform your own error checking, retries, etc., to ensure integrity of a message route. Additional library layer which comes with RobotC to perform many more detailed tasks to help making your code more robust.

In common.h, you will find two functions in lieu of these two functions. They are **writeI2C(…)** and **readI2C(…).** They did a lot of error checking for you.

With pre-version 3.5, pointers were not supported by RobotC. Depending which version you have with RobotC, you may need to modify the writeI2C like the following:

bool writeI2C2(tSensors link, char *request, char *reply) ;

bool writeI2C2(tSensors link, char *request, char *reply, int replylen) ;

Before you decide to definitely write a robust I2C communication layer, you should always use "writeI2C(…)" API instead of the native sendI2Cmsg(…) ,etc.

CH2 – 6 INTERFACE WITH NON-NXT I2C DEVICES

2 Big Gotcha-you points to watch out for:

- Proprietary libraries
- Pull-up resistors

NXT can interface with I2C devices which are not sensors. You should review the devices' specification, and best to at least get a logic analyzer to observe the device's signaling behavior. More examples will be included here:

But in general, you are pretty much on your own!

<…Under construction …>

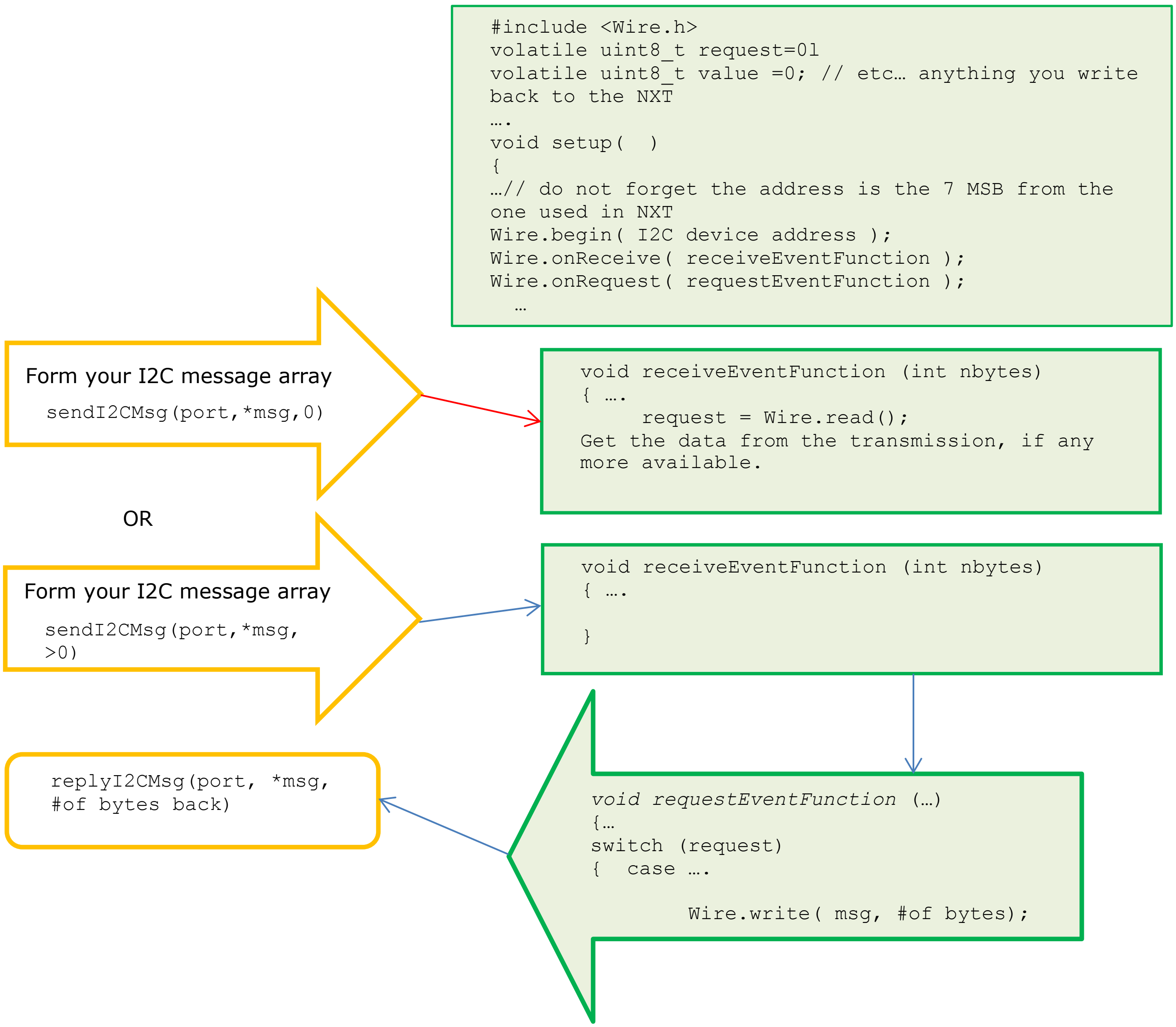
CH2 – 7 I2C COMMUNICATION BETWEEN NXT & ARDUINO FLOW DIAGRAM

Note: Create a shared header file which contains the I2C address for the slave device, as well as all the command addresses.

I2C Communication Flow Diagram

*** WITH THE ROBOTC NATIVE I2C CALLS

NXT (I2C Master Device) Arduino (I2C Slave Device)



*** WITH THE ROBOTC - XANDER'S I2C CALLS

```
volatile uint8_t receiveBuffer[18];

void setup() {
  clearReceiveBuffer();
  //shift i2c address by 1
  Wire.begin(I2CArduinoAddress >> 1);

  Wire.onReceive(receiveEvent);
  Wire.onRequest(requestEvent);
}

void receiveEvent(int bytesReceived){
  int i=0;
  clearReceiveBuffer();
  while(Wire.available()){
    receiveBuffer[i++] = Wire.read();
  }
  //requestEvent will not be called
  if (receiveBuffer[0] == 0x41){
    processCommand();
  }
}

void requestEvent(){
  int memoryAddress = receiveBuffer[0];
  if (memoryAddress == 0x00){
    Wire.write(sensorVersion, 8);
  }
  else if (memoryAddress == 0x08){
    Wire.write(sensorName, 8);
  }
```

```
int I2CArduino(tSensors link, byte add) {

  memset(I2CRequest, 0, 17);
  memset(I2CReply, 0, 17);

  I2CRequest[0] = 2;     // Message size
  I2CRequest[1] = 0x02;  // I2C Address
  I2CRequest[2] = 0x08;  // memory address
                         // for data
  if (!writeI2C(link,I2CRequest,I2CReply,8)){
    return -1;
  }
  return 0;
}
```

1

2

receiveEvent gets all items from I2CRequest[2] on.
In this case it is the just one value: 0x08.
Puts it in its receiveBuffer array.

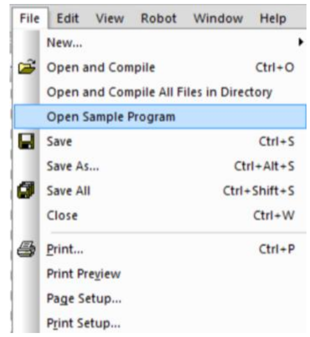
The first (and only) element in receiveBuffer is 0x08 so we send back the buffer (sensorName).

The I2CReply buffer will be set to sensorName and we can then display the information.

CH2 – 7 EXERCISES

Ex1: Learn from the I2C Sample from robotC

Copy the "common.h" from the <your robotC installation directory>\Sample Programs\NXT\3rd Party Sensor Drivers\drivers. (per up to RobotC version 3.6.x)



Look at various I2C sensors sample codes, such as:

- Accelerometer
- Compass
- Sharp IR distance sensor
- Light Array
- And many more.

Ex2: Write a program to display the distance from the ultrasonic sensor. However, you are supposed to obtain the distance data via I2C calls and treat it like a custom sensor, not the one from the default NXT firmware. To do this, you need to do the following:

a) You may verify it with the RobotC I2C utility to check out the command address like this:
- Type : I2C Custom 9V
- Output Message: 0x02 0x42

b) In your code :

SensorType[S1] = sensorCustom9V; // **do not set** it to sensorSONAR

Ex2: Your task is to write your layer of own communication APIs.

This layer is about robust networking interface practice with I2C protocol, so it is outside the scope of this document. However, you are encouraged to look into common.h to examine the proper error checking steps from Xander's writeI2C(…) to write more robust networking communication interface.

CH3 – HITECHNIC ACCELEROMETER INTERFACE

Accelerometer is used to measure acceleration. It is used to measure a variety of things that are used in large array of electronic equipment, and robots including Acceleration, Tilt angle, Vibration, or even Gravity.

Big thanks to MEMS, Micro-Electro-Mechanical-Systems under the category of NanoTechnology. It allows a single accelerometer along with other transmitters all into a single substrate. While we are entering the NanoTechnology era, accelerometers will permeate our lives as never before!

Applications:

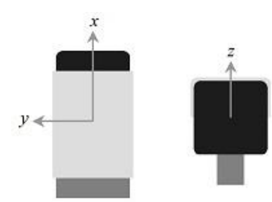
Wii Game Controller, Car airbag deployment, any system which involves human motion monitoring and many more.

Some educational videos:

- The Photolithography process used in M.E.M.S.
- Basic MEMS fabrication
- **Accelerometer measures RC car crash drop from 45ft. - Another Geek Moment**

CH3 – 1: FOR ACCELERATION MEASUREMENT:

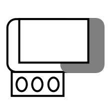
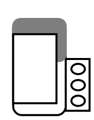
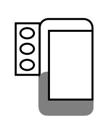
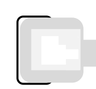
The NXT Acceleration Sensor contains a three axis accelerometer that measures acceleration in three axes, *x, y* and *z*. Acceleration is measured in the range of –2g to +2g with scaling of approximately 200 counts per g.



The acceleration measurement for each axis is refreshed approximately 100 times per second. This sensor provides 3-axes data.

To view: You may use the I2C Utility tool if you have RobotC version 2.0+. Otherwise, you can view this using the ultrasonic selection on the NXT. Only the x-axis value will.

CH3 – 2: FOR TILT MEASUREMENT:

X axis = 0 	X axis = 200 	X axis = -200 
Y axis = 0  (looking at the sensor from the back)	Y axis = -200  (counterclockwise)	Y axis = 200  (clockwise)

Z-axis: This becomes not useful as it should show ~200, as it indicates the gravity.

CH3 – 3: SENSOR MEMORY ADDRESS LAYOUT

You should write your own view functions to see how your movements are measured in each axis. Viewing the axis data to determine which axis or axes will best fit your work.

First of all, you need to know the Memory Address layout.

HiTechnic I2C Sensor memory model for the accelerometer (we call it tilt sensor)

Address	Type	Contents
42H	byte	*X* axis upper 8 bits
43H	byte	*Y* axis upper 8 bits
44H	byte	*Z* axis upper 8 bits
45H	byte	*X* axis lower 2 bits
46H	byte	*Y* axis lower 2 bits
47H	byte	*Z* axis lower 2 bits

Sample:

```
//
//  i.e.   200 units per 1 g. [where 'g' == acceleration due to gravity]

task main()
{
  // Local variables section
  int xUpper,xLower;
  int yUpper,yLower;
  int zUpper,zLower;
  int xVal,yVal,zVal;

  typedef struct{
    byte nMsgSize;
    byte nDeviceAddress;
    byte nLocationPtr;
  } TI2C_Output;
  byte replyMessage[6];
  long nLoops = 0;
  TI2C_Output sOutput;
// done creating local variables

// step 1 : initialize the sensor port
  SensorType[S1] = sensorI2CCustomFast;
  wait10Msec(5);  // give it some time to initialize.
  nI2CBytesReady[S1]=0;

// step 2 : wait until the port is ready for operation

  while(nI2CStatus[S1]== STAT_COMM_PENDING)
    wait1Msec(2);

// step 3 : set up the device's internal location Memory Address index to
//          indicate which of 256 (2^8)  different internal Memory Addresss
//          a "read" command should start at. This is manufacturer specific.
//          Need to look up the HiTechnic's memory address maplayout
  sOutput.nMsgSize = 2;
```

```
     sOutput.nDeviceAddress = 0x02;
     sOutput.nLocationPtr = 0x42;

     while(true)
     { ++nLoops;              // simple loop count for testing communication.
       nI2CBytesReady[S1] = 0;

   // step 4 : Send command to the sensor before read
       sendI2CMsg(S1, sOutput, 6);      // send 6 bytes of sOutput

       while (nI2CStatus[S1] == STAT_COMM_PENDING)
         wait1Msec(2);

       memset(replyMessage, 0, 6);

       if (nI2CStatus[S1] == NO_ERR)
       {

   // step 5 : read command to get 6 bytes of data and put them in replyMessage
         readI2CReply(S1, replyMessage[0], 6);

   // step 6 : normalize the data, i.e. extract and/or parse data
   //         from the replyMessage stream

         xUpper = replyMessage[0];  // addr:0x42
         yUpper = replyMessage[1];  // addr:0x43
         zUpper = replyMessage[2];  // addr:0x44

         xLower = 0x03 & replyMessage[3];// addr:0x45; only want the lowest 2 bits
         yLower = 0x03 & replyMessage[4];// addr:0x46; only want the lowest 2 bits
         zLower = 0x03 & replyMessage[5];// addr:0x47; only want the lowest 2 bits

         xVal = (xUpper << 2) | xLower;  //put xUpper to upper 8 bits + xLower
         yVal = (yUpper << 2) | yLower;  //
         zVal = (zUpper << 2) | zLower;  //

         nxtDisplayTextLine(4, "x-val %d", xVal);
         nxtDisplayTextLine(5, "y-val %d", yVal);
         nxtDisplayTextLine(6, "z-val %d", zVal);
       }
       Else
       { nxtDisplayTextLine(3, "i2c err %d", nI2CStatus[S1]);
       }
     }
   }
```

CH4 – OTHER I2C DEVICE INTERFACE

HiTechnic InfraRed Seeker

- Need the following 2 files from HiTechnic unless you will write your own I2C interfaces. They are at:
  - File > Open Sample Programs > 3rd Party Sensor Drivers >drivers
  - common.c, HTIRS2-driver.h

- I2C InfraRed Seeker - version sample

HiTechnic Sensors Mux

HiTechnic has an excellent document about programming interface with Sensors Mux.

More will be added in the future.