Multimedia Technieken

2015 – 2016

Controlling an I2C Slave Device from User Space

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Controlling an I2C Slave Device from User Space

I2C in a Nutshell

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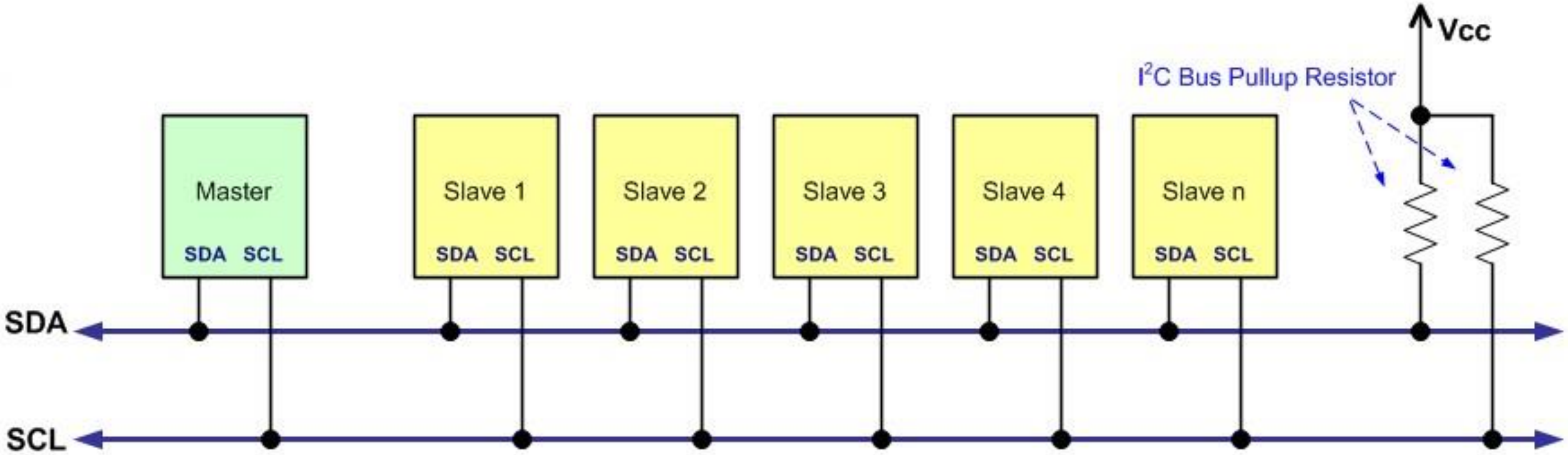
I2C in a Nutshell

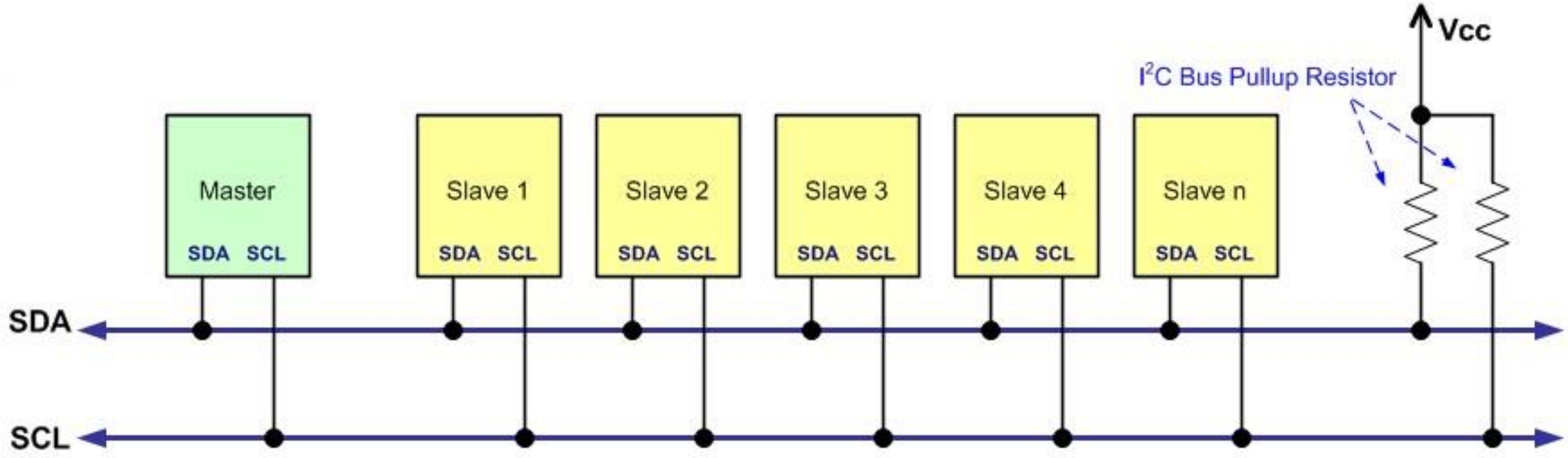
- Why I2C is commonly used to control external devices
  - Its a common standard
  - Its "fast" for low-speed devices
  - Bus architecture (multiple devices can be connected)
  - Easy to use
  - Wide support (most uC’s and processors have build in I2C peripheral)
  - Only 2 communication lines needed (SDA and SCL)



Typical I²C Device Connection

The Physical Bus

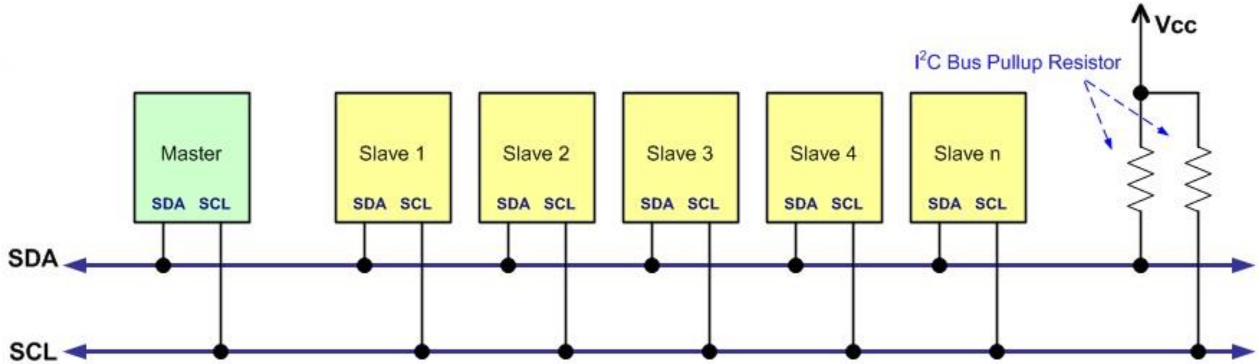
- The bus consists of just two wires, called SCL and SDA, and a ground
  - SCL is the clock line.
    - It is used to synchronize all data transfers over the I2C bus.
  - SDA is the data line.
  - The SCL and SDA lines are connected to all devices on the I2C bus.
- There does need to be a third wire which is the ground



Typical I^{2}C Device Connection

The Physical Bus

- Both SCL and SDA lines are "open drain" drivers.
  - What this means is that the chip can drive its output low, but it cannot drive it high.
  - For the line to be able to go high you must provide pull-up resistors to Vcc
  - There should be a resistor from the SCL line to Vcc and another from the SDA line to Vcc.
  - You only need one set of pull-up resistors for the whole I2C bus, not for each device.
- Vcc depends on the devices used. Typically 5V or 3V3



Typical I²C Device Connection

Masters and Slaves

- The devices on the I2C bus are either masters or slaves.
- The master is always the device that drives the SCL clock line
- The slaves are the devices that respond to the master.
- A slave cannot initiate a transfer over the I2C bus, only a master can do that.
- There can be, and usually are, multiple slaves on the I2C bus, however there is normally only one master.
  - It is possible to have multiple masters, but it is unusual.
- Slaves will never initiate a transfer.
  - Both master and slave can transfer data over the I2C bus, but that transfer is always controlled by the master.

Controlling an I2C Slave Device from User Space

Our Goal

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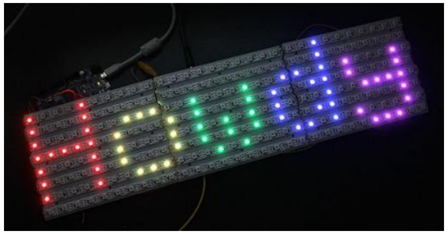
Our Goal

- Connect the Raspberry Pi 2 to the mBed i2c NeoPixel driver
- Write a user space application and let it communicate with the slave device
  - We will need to cross-compile the source to the ARM architecture
- In this setup the Raspberry Pi will act as a master while the mbed NeoPixel driver is the slave



Controlling an I2C Slave Device from User Space

Enabling I2C on the Raspberry Pi 2

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Step 1 - Enable i2c

- Use the raspi-config utility to enable i2c

```
pi@raspberrypi ~ $ sudo raspi-config
```

```
ââââââââââââââââââ¤ Raspberry Pi Software Configuration Tool (raspi-config) ââââââââââââââââââ
â Setup Options                                                                            â
â                                                                                          â
â     1 Expand Filesystem                     Ensures that all of the SD card storage      â
â     2 Change User Password                  Change password for the default user (p      â
â     3 Enable Boot to Desktop/Scratch        Choose whether to boot into a desktop e      â
â     4 Internationalisation Options          Set up language and regional settings t      â
â     5 Enable Camera                         Enable this Pi to work with the Raspber      â
â     6 Add to Rastrack                       Add this Pi to the online Raspberry Pi       â
â     7 Overclock                             Configure overclocking for your Pi           â
â     8 Advanced Options                      Configure advanced settings                  â
â     9 About raspi-config                    Information about this configuration to      â
â                                                                                          â
â                                                                                          â
â                          <Select>                          <Finish>                      â
â                                                                                          â
ââââââââââââââââââââââââââââââââââââââââââââââââââââââââââââââââââââââââââââââââââââââââââââ
```

- Select ‘Advanced Options’ => ‘I2C’ => ‘Enable’

Step 2 - Edit Module File

- Open the modules file

```
pi@raspberrypi ~ $ sudo nano /etc/modules
```

- And add the following to it

```
i2c-bcm2708
i2c-dev
```

- This will make sure the i2c device modules are loaded when the kernel is booted

Step 3 - Install Utilities

- Install i2c-tools which has a bus discovery tool which is really handy

```
pi@raspberrypi ~ $ sudo apt-get update
pi@raspberrypi ~ $ sudo apt-get install i2c-tools
```

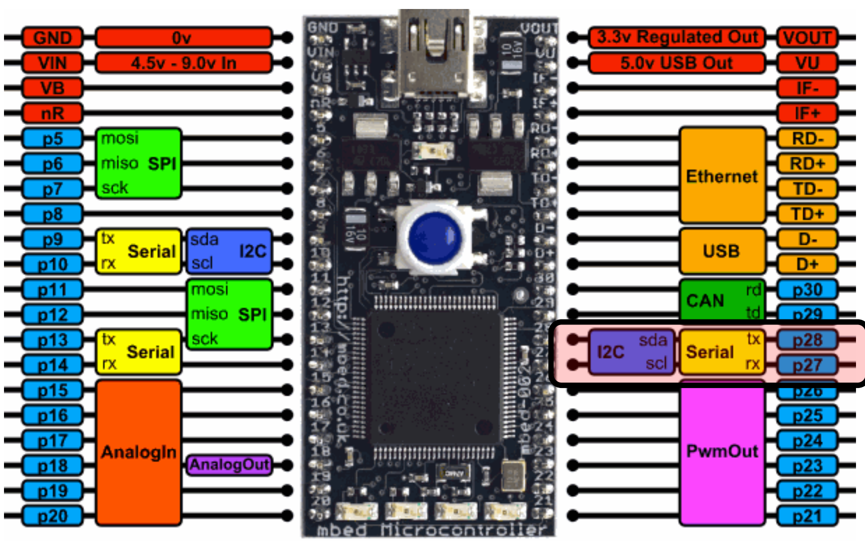
- Shutdown the Raspberry Pi

```
pi@raspberrypi ~ $ sudo halt
```

- Disconnect the power adapter and connect your i2c device

Step 4 - Connecting the i2c of mBed to the Raspberry Pi 2

- Raspberry Pi runs at 3.3V
- mBed runs at 3.3V
- So no level shifting is required
- We do not need to add pull-up resistors because the Raspberry Pi 2 already has pull-ups of 1k8 on each i2c line



Raspberry Pi2 GPIO Header

Pin#	NAME	NAME	Pin#
01	3.3v DC Power	DC Power 5v	02
03	GPIO02 (SDA1 , I^2C)	DC Power 5v	04
05	GPIO03 (SCL1 , I^2C)	Ground	06
07	GPIO04 (GPIO_GCLK)	(TXD0) GPIO14	08
09	Ground	(RXD0) GPIO15	10
11	GPIO17 (GPIO_GEN0)	(GPIO_GEN1) GPIO18	12
13	GPIO27 (GPIO_GEN2)	Ground	14
15	GPIO22 (GPIO_GEN3)	(GPIO_GEN4) GPIO23	16
17	3.3v DC Power	(GPIO_GEN5) GPIO24	18
19	GPIO10 (SPI_MOSI)	Ground	20
21	GPIO09 (SPI_MISO)	(GPIO_GEN6) GPIO25	22
23	GPIO11 (SPI_CLK)	(SPI_CE0_N) GPIO08	24
25	Ground	(SPI_CE1_N) GPIO07	26
27	ID_SD (I^2C ID EEPROM)	(I^2C ID EEPROM) ID_SC	28
29	GPIO05	Ground	30
31	GPIO06	GPIO12	32
33	GPIO13	Ground	34
35	GPIO19	GPIO16	36
37	GPIO26	GPIO20	38
39	Ground	GPIO21	40

Rev. 1
26/01/2014
http://www.element14.com

Step 5 - Scanning the bus using i2cdetect

- Once the two embedded boards are connected using i2c you can use the i2cdetect tool to scan the bus for slave devices
- For we need to check "/dev" for available i2c busses

```
pi@raspberrypi ~ $ cd /dev
pi@raspberrypi ~ $ ls i2c-*
```

- Look for "i2c-x" where x is a number

- Use the i2cdetect tool to scan the bus and replace x with the number of the actual device bus

```
pi@raspberrypi ~ $ i2cdetect -r x
```

Step 5 - Scanning the bus using i2cdetect

- Example

```
pi@raspberrypi ~ $ sudo i2cdetect -r 1
```

- You should get similar output when the mBed is connected

```
     0  1  2  3  4  5  6  7  8  9  a  b  c  d  e  f
00:          -- -- -- -- -- -- -- -- -- -- -- -- --
10: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
20: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
30: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
40: 40 -- -- -- -- -- -- -- 48 -- -- -- 4C -- -- --
50: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
60: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
70: -- -- -- -- -- -- -- --
```

- 0x40 is the NeoPixel slave. Can you explain the other two devices ?

7-bit or 8-bit address ?

- Also notice that the mBed uses the 8-bit address (R/W) LSB included while Linux uses the 7-bit address
  - You will need to use the 7-bit address in you C++ program !

```
     0  1  2  3  4  5  6  7  8  9  a  b  c  d  e  f
00:          -- -- -- -- -- -- -- -- -- -- -- -- --
10: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
20: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
30: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
40: 40 -- -- -- -- -- -- -- 48 -- -- -- 4C -- -- --
50: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
60: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
70: -- -- -- -- -- -- -- --
```

- Part from the mBed slave code:

```
I2cSettings settings;
settings.frequency = 100000;
settings.address = 0x80;
```

Controlling an I2C Slave Device from User Space

The mBed NeoPixel Driver Slave

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The mBed NeoPixel Driver Slave

- The mBed controls a NeoPixel string of RGB LED's
  - The size of a string and number of strings can be configured in the slave code
    - A string is a continuous connection of NeoPixel LED's

- Slave code is available on mBed as library
  - Import the library 'NeoPixelI2cDriver'
  - Search for 'neopixel'

The mBed NeoPixel Driver Slave

- The NeoPixel data line needs to be connected to the SPI pin (pin 5) on the mBed
  - Everything can be tested without NeoPixel string (debug info is outputted to console)
- To get some console output from the slave device you can use a terminal program such as Putty to connect to the serial interface over USB at a speed of 115200 baud.
- The slave device also has an alive LED which will blink periodically as long as the device is operational and responsive.
- The I2C bus operates at 100kHz and the slave device address is 0x80 (0x40 7-bit).

The mBed NeoPixel Driver Slave - main.cpp

https://developer.mbed.org/users/dwini/code/NeoPixelI2cSlave/

```
#include "mbed.h"
#include "neopixel_string.h"
#include "i2c_device.h"
#include "neopixel_string_factory.h"
#include "neopixel_i2c_daemon.h"

// This must be an SPI MOSI pin.
#define DATA_PIN p5
#define STRING_SIZE 8

#define DEBUG_MODE 1
#include "log.h"

Serial pc(USBTX, USBRX); // tx, rx
```

The mBed NeoPixel Driver Slave - main.cpp

https://developer.mbed.org/users/dwini/code/NeoPixelI2cSlave/

```
int main() {
    pc.baud(115200);
    SimplyLog::Log::i("Neopixel driver loading\r\n");

    I2cSettings settings;
    settings.frequency = 100000;
    settings.address = 0x80;

    SimplyLog::Log::i("Slave is working @ %dHz\r\n", settings.frequency);
    SimplyLog::Log::i("Slave is working @ SLAVE_ADDRESS = 0x%x\r\n", settings.address);

    SimplyLog::Log::i("Creating NeoPixel String\r\n");
    NeoPixelString * first_string = NeoPixelStringFactory::createNeoPixelString(DATA_PIN, STRING_SIZE);

    SimplyLog::Log::i("Creating I2cDevice\r\n");
    I2cDevice i2c(p28, p27, &settings);

    SimplyLog::Log::i("Creating NeoPixel I2c Daemon\r\n");
    NeoPixelI2cDaemon neo(&i2c, LED1);
    neo.attachPixelString(first_string);

    SimplyLog::Log::i("Listening in blocking mode\r\n");
    neo.listen(true);

    while(1) { }
}
```

The mBed NeoPixel Driver Slave - Possible Transactions

- @ the moment there are three commands that can be send to the slave
  - OFF (0x01) which will turn off all the LED's
  - DIAGNOSTIC (0x02) which will run a pre-programmed diagnostic routine
  - SINGLE_COLOR (0x03) which allows all LED's to be programmed with a given color

- OFF and DIAGNOSTIC and single byte transactions
- SINGLE_COLOR is a four-byte transactions
  - First byte is the command (0x03)
  - Following three bytes are the RGB values (0 - 255 or 0x00 to 0xFF)

The mBed NeoPixel Driver Slave - Possible Transactions

- The master can also request some information from the slave by sending a read request
  - @ the moment the slave will answer with a single byte value, namely the number of strings attached to the mBed (which will be 1).

Controlling an I2C Slave Device from User Space

Raspberry Pi 2 User Space Master Program

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Start from the Base

- Some decent information can be found @ http://elinux.org/Interfacing_with_I2C_Devices

- You can start from the example program that I created
  - Not very OOP, that is YOUR task

- See GitHub:
  - https://github.com/BioBoost/pi_i2c_master_neopixel_driver.git

Controlling an I2C Slave Device from User Space

Assignment

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Assignment

- Create a C++ program to control the mBed slave device from User Space
  - Use OOP !!
    - No single class or 400 lines main function programs
      - This will get you flunked !
      - Prove what you have learned and what you are capable off !
- This needs to be incorporated in the final program of the group

- Requirements
  - Fading (from bright to dark and vice versa) or Stroboscope (with adjustable timings)
  - Set colors (per LED not just one color for the whole string)

- You can extend the slave program as you seem fit