Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

System Construction Course 2019,

Assignment 1

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Introduction

At the beginning of systems programming stands the communication with hardware. Very often no diagnostic device such as a debugger connected via JTAG is accessible. Therefore the first that we need is a sign of life of the hardware we are working with. The simplest you can do is let some lights blink in order to see that your code is actually running. In this exercise we will execute just this: with a very simple program written in assembly language we will let an LED light up. In the second part of the exercise we will learn more about linking and will experience the advantages of high level (systems) programming.

Lessons to Learn

- Learn to know ARM assembly language basics, understand the limits
- Understand GPIO control on BCM 2835/6, learn to read technical manuals
- Understand basics of linking and bootloading

1 Sign of Life

In this part of the exercise we illuminate an LED using low level assembler code.

Preliminary remarks

We have already prepared the boot media (SD card) for the Raspberry Pi such that it can load and boot a file called `kernel.img` from the first FAT partition. This is the standard procedure for the RPI. Parts of the bootloader image stems from http://openelec.tv/get-openelec.

All other resources can be found in our subversion repository located at
https://svn.inf.ethz.ch/svn/lecturers/vorlesungen/trunk/syscon/2019/shared
referred to as `shared` in the following. Use your ETH account credentials.

Preparation

1. Download the exercise material from shared/assignments/assignment1
   for example using `svn checkout ...`
2. Windows Users: copy `oberon32.exe` or `oberon64.exe` to file `oberon.exe`
3. Linux Users: copy `oberon32` or `oberon64` to file `oberon`. Make the file executable: `chmod +x oberon`.

   If you (later) want to see the history of commands within the Linux oberon shell, you can use the `rlwrap` tool: `rlwrap ./oberon ....`

Tasks

1. Connect an LED to ground and GPIO pin number 21 on the RPI2 expansion slot. The RPI2 expansion slot has the pinout displayed in Figure 1 below. Note that the GPIO pin number does **not** coincide with the expansion slot pin number!
2. Open file RPI.MinimalLED.Mos in your favourite editor.
3. Using ARM assembler language, program the GPIO pin 21 as output pin and set the pin accordingly.
4. Compile and link the kernel. You can either execute the following commands in the oberon shell

   ```
   Compiler.Compile -p=ARM RPI.MinimalLED.Mos
   Linker.Link -p=RPI MinimalLED
   FoxARMInstructionSet.Disassemble kernel.img
   exit
   ```

   or, equivalently, call

   ```
   ./oberon execute MakeMinimalLED.txt
   ```

5. Copy `kernel.img` to the FAT partition on the SD card and insert the SD card into the (powered off) RPI.
6. Power on the RPI and check if the LED lights up upon start.

2 Blinkenlights

Introduction

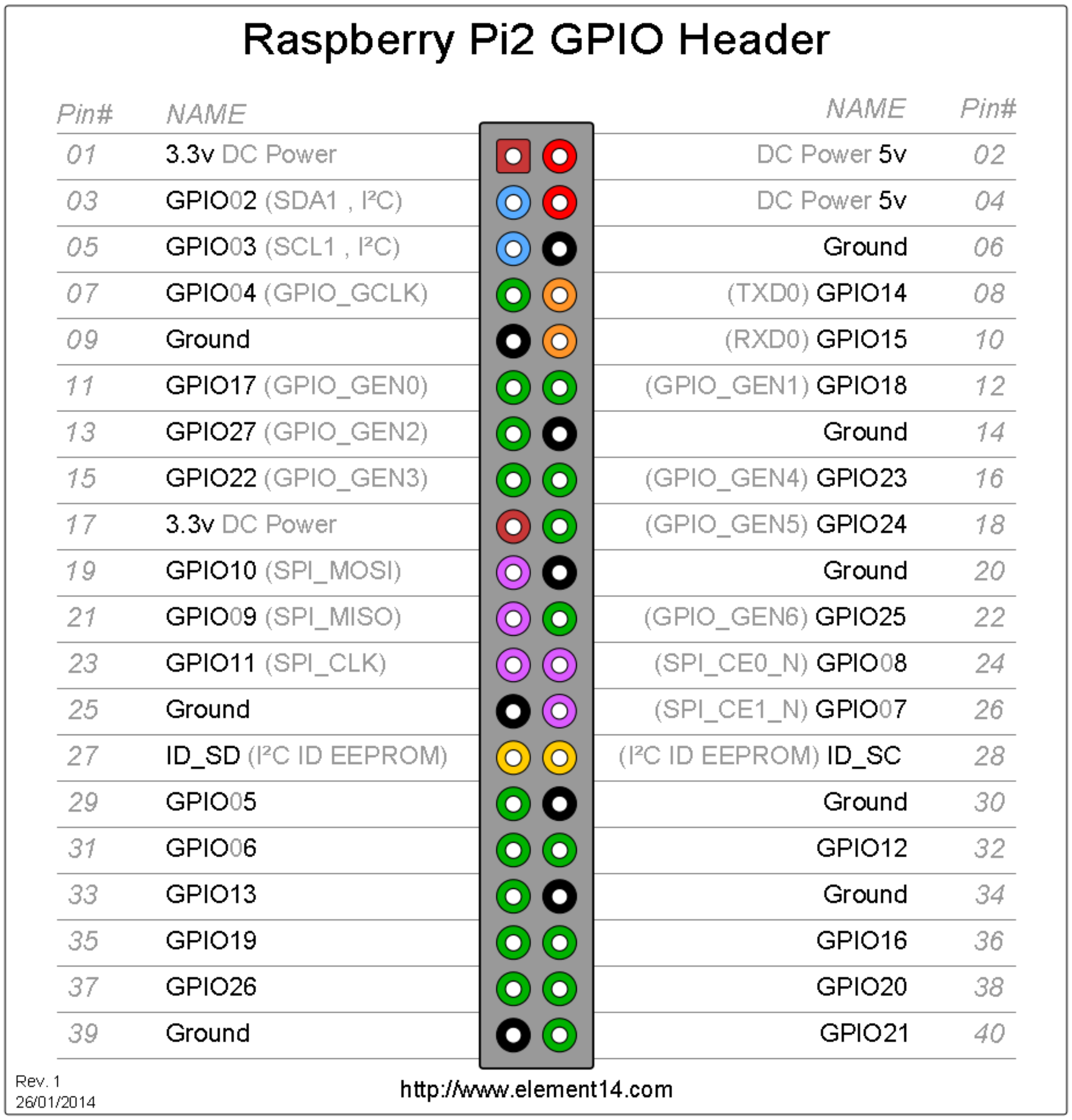
In this part of the exercise, we will use some high level language code in order to let the LED blink. Do not start with this second part before having solved the first part.

Tasks

1. Open file RPI.BlinkLED.Mos in your favourite editor.
2. Read the file. On a first sight, the code should light up the LED. But it does not work (try, if you like). Why? Compile and link it. Look at the linked image and understand how things are organized. Understand what is missing in order to run the program and patch the program. Check that the LED lights up when booting.
3. Now, using high-level language features, implement a blinking LED: Compile and link the kernel. Copy `kernel.img` to the SD card and insert the SD card into the (powered off) RPI.
4. Power on the RPI and check if the LED blinks up upon start. Look at the frequency of the LED and try to estimate the rate of executed instructions per second. What is your observation? Try to explain what you find.

   (Of course, if you like, you can now also add other LED colors and play with the hardware.)

Have fun!



Raspberry Pi2 GPIO Header

Pin#	NAME	NAME	Pin#
01	3.3v DC Power	DC Power 5v	02
03	GPIO02 (SDA1 , I²C)	DC Power 5v	04
05	GPIO03 (SCL1 , I²C)	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 (I²C ID EEPROM)	(I²C 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

Figure 1: Raspberry Pi 2 Pinout

Documents

- BCM2835 ARM Peripherals Technical Manual:
  shared/documents/rpi/BCM2835-ARM-Peripherals.pdf
- Lecture Slides System Construction Lecture 1 from the course-homepage
  `http://lec.inf.ethz.ch/syscon`
- Oberon Language Report (Draft 2019)
  shared/documents/oberon/ActiveOberonLanguageReport.pdf