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The Advantages of Using Raspberry Pi 3 Compared to Raspberry Pi 2 SoC Computers for Sensor System Support

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Abstract. This paper shows the comparison between two generations of Raspberry Pi SoC computers, which can be marked as the first stage of nano revolution of ubiquitous computing and the Internet of Things.

Keywords: Information systems, Raspberry Pi SoC system, sensor systems, computer infrastructure, IoT.

1. Introduction

The evolution of the Internet, network technologies and Web application solutions have brought upon the marginalization of computer hardware and system programming. Virtualization of hardware and software platforms and introducing of large number of abstraction tiers have eased the development of application solutions for supporting work with Internet technologies. The application software development has become independent from the platform, and by its form more concise and closer to the natural language, when compared to standard high-level programming languages.
The idea of a general-use computer, minute by its size and affordable by the price, has been developed in 2006 by a group of Cambridge University professors. The reason lay in the concern about the IT students' foreknowledge. On the contrary to the students from the '80s and the '90s, whose foreknowledge about computer hardware and system programming was solid, the 21st century students know the world of IT only through Web applications, PC and game consoles. The initial idea was to develop *something* to stimulate interest for computer hardware and raise the level of software skills.
The first concept of Raspberry Pi system was based on Atmel Atmega644 microcontroller, but this solution was soon abandoned since the use of microcontrollers was excessively hardware-oriented, which made the PC architecture simulation harder. The alternative was found in SoC microprocessors aimed for Smart telephones and multimedia DVB TV BOX appliances. The use of Broadcom media processor (ARM 1176JZF – S) led to the creation of the first Raspberry Pi SoC computer, with the following dimensions: 8,6 x 5,4 x 1,7cm. Until this moment, Raspberry Pi reached its third generation, and according to the latest estimations, over six million copies have been sold. The key advantage of this SoC platform, when compared to usual PC

computers, is the existence of GPIO (general-purpose input/output) ports, by which it is possible for software applications to directly communicate and control hardware components and microcontrollers via serial USART, I^2C and I^2S protocols, as well as through the parallel connection via free GPIO ports.

2. Presenting Raspberry Pi 2 and Raspberry Pi 3 systems

Before directly comparing the hardware features of these two systems, we should point out that the two systems are mutually compatible by software. Although different versions and generations of ARM CPU architecture are found in Raspberry Pi 2 and Pi 3, Raspberry Pi foundation delivers the identical version of NOOBS and Raspbian Jessie image of Linux Debian operating system (current version 1.9.0 and 4.1, since 18th March 2016), with all the related software libraries. In this way, full compatibility of Raspberry Pi 3 with the new 64bit ARM Cortex-A53 processor ARM v8 and Raspberry Pi 2 with ARM v7 generation ARM Cortex-A7 32bit processor has been achieved.

Apart from ARM CPU and increase of clock frequency, Broadcom BCM2837 SoC CPU in Raspberry Pi 3 contains almost all the same components as its second-generation predecessor, Broadcom BCM2836 SoC CPU.
Table 1 shows the comparative review of the second and third generation of Raspberry Pi system, where improvements regarding network adapters and CPU performance are seen.

System	*Raspberry Pi 2*	*Raspberry Pi 3*
Release date	6th February 2015	29th February 2016
SoC IC	Broadcom BCM2836	Broadcom BCM2837
CPU	900MHz quad-core ARM Cortex-A7, ARM v7 generation	1.2GHz 64-bit quad-core ARM Cortex-A53, ARM v8 generation
GPU	Broadcom VideoCore IV on 250 MHz (BCM2837 GPU: 3D on 300 MHz, video part of on 400 MHz)	
Memory (SDRAM)	1GB LDDR2 400MHz (shared with GPU)	1GB LDDR3 900MHz (shared with GPU)
USB 2.0 ports	4 (via the on-board 5-port USB hub)	
Video input	15-pin MIPI camera interface (CSI) connector, used with the Raspberry Pi camera or Raspberry Pi NoIR camera	
Video outputs	HDMI (rev 1.3 & 1.4), composite video (3.5 mm jack)	
Audio inputs	As of revision 2 boards via I^2S	
Audio outputs	Analog via 3.5mm phone jack; digital via HDMI and, as of revision 2 boards, I^2S	
Storage	MicroSDHC slot	
On-board network	100Mbit/s 802.3 Ethernet (WiFi using USB adapter)	100Mbit/s 802.3 Ethernet; 802.11n 150Mbit/s WiFi; Bluetooth 4.1
Low-level peripherals	17× GPIO plus the same specific functions, and HAT ID bus	
Power ratings	600 mA	800mA
Power source	5 V via MicroUSB or GPIO header	

Size, Weight	85.60 mm × 56.5 mm, 45g

Table 1. Comparative review of the second and third generation of Raspberry Pi system characteristics

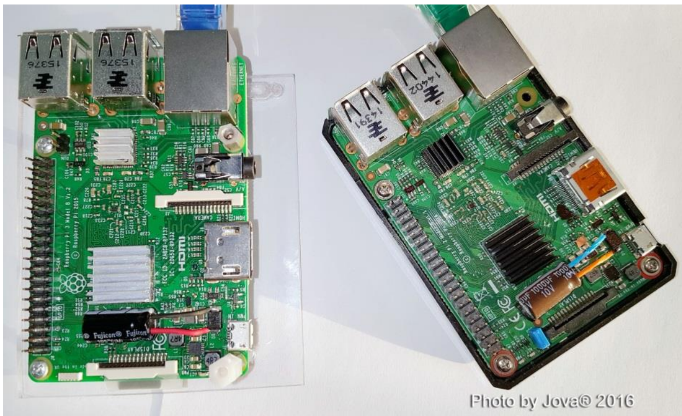

Figure 1. Raspberry Pi 3 and Pi 2 with the installed coolers and modified voltage level regulator

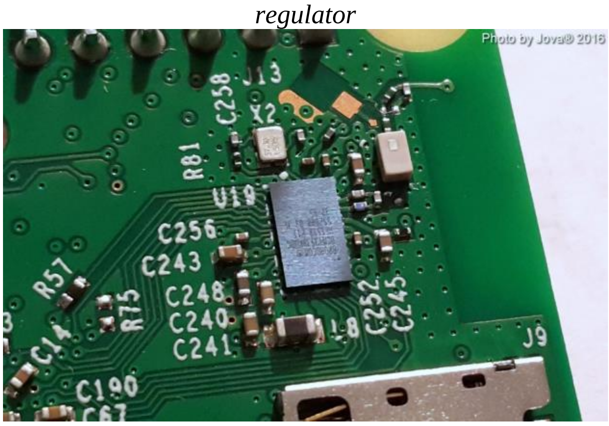

Figure 2. Broadcom BCM43438 chip with the Bluetooth 4.1/Low Energy (LE) support and 802.11n 2.4GHz WiFi, size ~5 x 3 mm

Apart from the new SoC CPU, another novelty from Raspberry Pi 3 is the board-integrated Broadcom BCM43438 chip, enabling support for Bluetooth 4.1 HS/Low Energy (LE), 802.11n dual band 2.4 and 5.6GHz WiFi and FM radio reception[1]. This frees 2 USB ports in comparison to the previous model, and enables lower investment

[1] Broadcom co. “Single-Chip Dual-Band Combo Device Supporting 802.11n, Bluetooth 4.0+HS & FM Receiver”, https://www.broadcom.com/products/Wireless-LAN/802.11-Wireless-LAN-Solutions/BCM4334; last visited on 22-03-2016

in preparing the system for wireless sensor system support, which would use the aforementioned communication standards.

A standardized 40-pin GPIO connector was introduced with Raspberry Pi B+ series[2], enabling I^2C, I^2S, SPI, UART, EEPROM communication protocols on the remaining 26+2 ports, next to the power outlets (+3,3V i 5V), leaving 17 unallocated GPIOs for the user to program them.

Figure 3 shows the scheme and architecture of GPIO prots, introduced with Raspberry Pi B+ system, which is still a valid format standard, used with Raspberry Pi 2 and Pi 3 SoC systems.

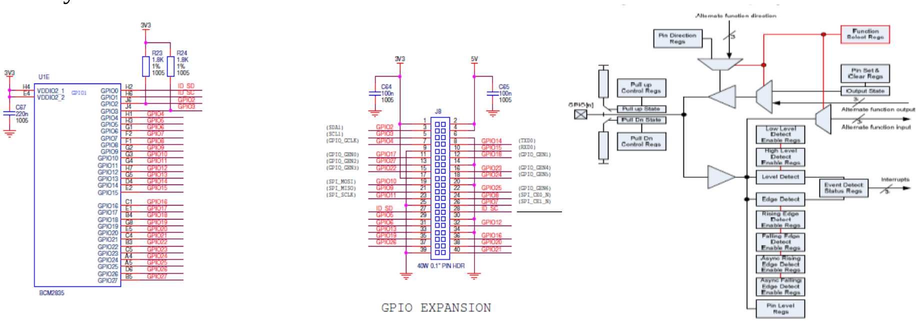

Figure 3. An extract from the electronic scheme of Raspberry Pi B+ system, with the emphasis on GPIO connectors and their connection to the CPU (left), an individual GPIO port[3]scheme, within Broadcom BCM2835 CPU.

As it can be seen in Figure 3, all ports are directly connected to SoC CPU, which enables an extremely fast access. What should be noted are the limits related to work conditions, i.e. the allowed electricity unit value. The input voltage of any GPIO port cannot exceed 3.3V (absolute maximum 3.6V), nor be lower than GND level which powers the CPU (regardless of the fact that each port has the rudimentary overvoltage protection). On the other hand, the electric current per one GPIO port can vary from 2mA to the maximum of 16mA, and the total current in all GPIO ports must not exceed 50mA. The direct link with CPU and its system bus enables really small latencies and extremely fast bus operation. The documentation accompanying Broadcom BCM2835 SoC[3] notes that the standardized protocols UART, SPI and I^2C are limited only to the speed of system bus, therefore the SPI_clock=125MHz is possible for the system bus clock speed of the CPU of 250 MHz. On the contrary to the aforementioned standard protocols, free GPIO ports are not predefined by the clock speed and are approachable

[2] https://www.raspberrypi.org/documentation/hardware/raspberrypi/schematics/Raspberry-Pi-B-Plus-V1.2-Schematics.pdf

[3] https://www.raspberrypi.org/documentation/hardware/raspberrypi/bcm2835/BCM2835-ARM-Peripherals.pdf

from the program code, directly reading, setting up, monitoring or triggering events by their states or changes.

Given that after the mentioned BCM2835, new BCM2836 and BCM2837 SoC CPU have not been released with the publically available documents regarding speed and parameters of input/output ports, it can be assumed that all of the above is valid for them as well. The subject of our study will be exactly the aspect of access speed, i.e. the free GPIO ping from program code of various program languages and driver libraries. Our interest lies in the fact that Raspberry Pi has been increasingly used (directly or indirectly) for controlling and monitoring of work of microcontrollers, analog-digital converters and other electronic sets, related to the use in sensor systems.
In operation theory, the maximum speed at which the processor can handle these ports is:

$$FGPIO(max) = Periferial\_Clock\_Source/(Clock\ Divisors+1) \qquad (\mathbf{1})$$

Where Clock Divisors, i.e. DIVI is an integer, aligned with the applied MASH (Multi-stAge noise SHaping) degree of filtering order. As of BCM2835, the producer recommends not to set the values which would exceed the frequency of 25MHz, although the maximum clock speed frequency of GPIO ports is around 125 MHz at 1.2V. This frequency can drop significantly, depending on GPIO port capacitance and usage.

The flexibility offered by Raspberry Pi and other similar SoC computers can be followed by the advanced 32bit microcontroller systems in certain way, but only in the narrow field of process control and analog electrical values. On the other hand, SoC systems have several times better performances in the terms of classical computing, multimedia etc.

3. Measuring and System Performances

If we begin with the model by which it is expected that Raspberry Pi 2 or Pi 3 systems are able to do successive and parallel reading of 8bit fast industrial sensor AD converter AD7821/22 with 1.6-2MSPS or to set the 8bit states on 5.6MSPS DA-converter like AD7528JN, a question arises – at which software environment and under which conditions Raspberry Pi 2 or Pi 3 can enable it?
By using a simple sequence which directly sets the GPIO port state 11 to 1 in program code, and then erases it, i.e. sets it to the zero value using the SainSmart DDS140 osciloscope and the UNI-T UT61E frequency meter, we have been monitoring the generated sequence clock speed, and the measurement results have been summarized in Table 2.

The key part of the code sequence executed in C is:

```
// To set GPIO pin 11 to output
// we must use INP_GPIO before we can use OUT_GPIO
INP_GPIO(11);
```

```
OUT_GPIO(11);

  while(1) {
    GPIO_SET = 1<<11;
    GPIO_CLR = 1<<11;
  }
```

A similar code is executed in Pyton:

```
import RPi.GPIO as GPIO
import time

GPIO.setmode(GPIO.BCM)
GPIO.setup(11, GPIO.OUT)
while True:
    GPIO.output(11, True)
    GPIO.output(11, False)
```

Language	***Used Library***	***Rasberry Pi 1 B+***	***Pi 2***	***Pi 3***
Shell	/proc/mem access	2.8 kHz	6.2 kHz	12.92 kHz
Shell / wiringPi	WiringPi gpio utility	40 Hz	92 Hz	183 Hz
Python	RPi.GPIO	70 kHz	190.23 kHz	322.5 kHz
Python	wiringpi2 bindings	28 kHz	105 kHz	168.9 kHz
C	Native library	22 MHz	42.16 MHz	55.8-57 Mhz
C	BCM2835	5.4 MHz	6.97 MHz	9.3-11 MHz
C	WiringPi normal GPIO wiringPiSetup()	4.1 MHz	9.76 MHz	13.83 MHz

Table 2. A comparative review of speed.-frequency, code generated clock speed of GPIO port in various programming languages on the Raspberry Pi, Pi2 and Pi3 platform.

4. Conclusion

Given that, according to the results of measurements presented in Table 2, Raspberry Pi 3 has generated the clock speed greater by 67,5% (between 35.2 and 108.4%) in average, compared to Raspberry Pi 2 and has managed to enable over 9MHz more by maximum CPU usage of 25% (1x core tread) in all tests written in C, we can say that Raspberry Pi 3 is a far better and faster platform, compared to its predecessor. Despite the acceleration brought by Raspberry Pi 3 program library and the speed of access to GPIO port from script and interpreter languages, it still cannot meet the more serious and demanding application requirements. In both cases, the speed of port state change higher than 150 kHz has been achieved in Python, which can enable successful value reading for the majority of commercial 50-100KSPS analog-digital converters. All the mentioned facts enable for Raspberry Pi 3 to provide better performance in its domain than the popular Atmel ATMega328 microcontroller with Arduino development platform.

According to our measuring in Whitestone test, Raspberry Pi 3 achieves 727,85MIPS, in comparison to 497MIPS with Raspberry Pi 2. Moreover, according to the arithmetic tests with floating point - Linpack and Livermore Loops Benchmark, Raspberry Pi 3 achieves 194MFLOPS (max 422) compared with 150MFLOPS (max 247), which in total present the values which are one step away from the PC world, but far beyond the reach of microcontroller platform possibilities.

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