**System on chip with RISC-V microprocessor and Linux operating system**

In this project, RISC-V microprocessor and Linux (xv6) will be the core parts. It aims to construct a system on chip (SoC) to run the transplanted operating system and enable it to act as a minicomputer such as getting input from keyboard. This project will improve the understanding of OS and microprocessor and programming skills.

**1. Regulatory considerations**

**1.1 RoHS regulation**

In this project, the only physical material is *Digilent 410-292 Nexys 4 DDR Artix-7 Development Board.* Its serial number is 410-292, type is Nexys 4, and manufacturer is Digilent. According to EU Directives 2011/65/EU and 2015/863, 10 kinds of hazardous substances in electrical and electronic equipment are restricted. In the specification given by manufacturer, the concentration of Cadmium is 0.01% and the others’ concentration are 0.1%. Since the device will be connected to computer and provided with voltage, it must be capable of being worked in higher temperature required by lead-free soldering. The manufacturer and retailers also provide a Declaration of Conformity illustrates this electrostatic discharge sensitive device has been handled and packed under conditions that meet the administrative and technical requirements of the ANSI/ESD S20.20:2014 and BS EN 61340-5-1:2007 Electrostatic Control Standards. Therefore, when testing the program on this board, the risk of hardware will be minimized. Each module of this board is available from RS components, which means they have met RoHS regulation.

**1.2 WEEE regulation**

WEEE is a complex mixture of materials and components. Such kind of component id quite dangerous because of their hazardous elements which may cause some environmental and health problems. Therefore, how to recycle these equipment are quite essential. The specification of *Digilent 410-292 Nexys 4 DDR Artix-7 Development Board* shows that the concentration of harmful elements are less or equal than 0.1%. Moreover, the manufacturer has joined the producer compliance scheme (PCS) so that its sales are under supervision. Since it does not contain any batteries, it is not necessary to subtract and report separately. In UK, there are three retailers selling this product, Farnell UK, Rapid Electronics and RS Components Ltd. On their website, all of them have sale areas larger than 400 square meters and accept small WEEE for free from private household customer services or not need to purchase new equipment. Therefore, this development board meets WEEE regulation.

**2. SD/Ethical Implications of large-scale manufacture and sale**

In this project, only FPGA and computers are utilized. FPGA is responsible for constructing the system on chip to execute the operating system while the computer has duty on designing all the components. There is no immediate benefit to sustainability and otherwise, SoC on FPGA does worse on sustainability. Compared with ASIC, FPGA consumes more resources because it needs to support program and has more usability; thus, it does not have perfect performance on sustainability when largely being manufactured. In addition, the CPU in this project doesn’t take security into consideration, and someone who knows the computer architecture can easily know what is doing in this system. The DDR2 SDRAM may also be affected by the RowHammer problem, which is that is the malicious program repeatedly open and close some cells of memory, it will cause data loss. Moreover, some IP core in the project are provided by Xilinx and users should obey its licenses. If the potential customers who use IP core in the way of violating these licenses, they will be sued for charge. Hence, the only restriction is that licenses of Xilinx should be obeyed when using IP core. However, the rest part is open-sourced and customers need only to obey MIT license. Furthermore, the design of SoC isn’t energy-efficient, which means that it wastes too much power than what existed in the market now. This part can be the improvement on the sustainability in the future.

In conclusion, for large manufacture, this project should improve on power consumption and resources usage because it does worse in those two parts. On the other hand, for sale, licenses of Xilinx and MIT should be emphasized and also security will also be a significant problem in the future.

**3. SD/Ethical Implications of follow-on products/markets**

RISC-V is a new, simple, open, and free instruction set architecture that can be freely used by any academic institution or business organization. With RISC-V, many new products can be produced, for example, using the RISC-V architecture to develop artificial intelligence chips for low-power devices, and providing lower-cost chips for intelligent driving.

RISC-V meets the Sustainable Development regulations, because it meets the Technocentric concerns, Eco-centric concerns and Sociocentric concern.

RISC-V is aimed at the Internet of Things market. With a budding market, RISC-V has its market opportunities. At this time, RISC-V is defined as a national standard instruction set by many countries, such as India. Furthermore, it has also attracted the attention of many chip manufacturers in the industry, many companies have joined the RISC-V Foundation and expressed support for it, including Samsung, Google, Huawei. This shows that RISC-V has good Eco-centric concerns.

The reason why RISC-V has become popular is that it has five advantages. These advantages indicate that RISC-V meets the technical needs of users and has great Technocentric concerns.

1) Minimalist. With its technical advantages, RISC-V has a streamlined length. Compared with traditional commercial architectures that are long, numerous instructions, and incompatible with each other, the advantages are obvious.

2) Clean. RISC-V clearly distinguishes between user and privileged instruction subsets, it avoids the requirements for special micro-architectures and special processes. Therefore, it is universal and could reduce costs significantly.

3) Modular. RISC-V instructions are divided into a core basic instruction set and a standard extensible instruction subset. The basic instruction set is small, but the extension set can be loaded according to user needs, which ensures that the instructions can be applied to different scenarios.

4) Scalable. Because RISC-V fully considers the scalability and specificity requirements of the chip design, it has variable-length instruction encoding, and reserves a large amount of available encoding space, making future instruction extensions convenient and feasible.

5) Stability. After several years of iteration, the benchmark instructions and some standard extensible instructions have been determined, and the implementation of new functions only needs to increase the extended subset without the need to release a new version of the entire instruction set.

In addition, because RISC-V uses the BSD License open source protocol, the instruction set of it is completely open. RISC-V gives users a lot of freedom and allows users to modify and redistribute open source code, it also allows commercial software release and sales based on open source code. Due to the monopoly status, patent restrictions, and high patent fees of the two giants, ARM's RISC architecture and Intel's CISC architecture, industry users are becoming increasingly overwhelmed. In this situation, RISC-V gives users the opportunity to avoid ARM's high chip royalties and Intel x86 intellectual property system lock-up, so it greatly attracts those countries that promote an innovative economy and companies in the global chip industry. This shows that it has great Sociocentric concern.