Guidelines of Embedded System and Proposed Universal Vending Machine Control System

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Abstract: *Embedded systems are rising as a necessary part of modern products. It design problems are posing challenges that engage entirely new skills for engineers. This paper presents the extracted knowledge about embedded hardware and its structure. ARM processor is one of the popular embedded hardware. Vending Machines used to provide unmanned products selling services. It operates via embedded systems which drive motors, dispensers and payments mechanism and list goes on. There are several vending control systems running around the world, but all those related to its category. There are also limitations in dispensers, payments mechanism and vandal resistance. Finally, this paper proposed the universal vending machine control system by which it can develop any of the vending products with unlimited dispensers, payment modes and vandal resistance from single control system.*

Keywords: *Embedded system, Hardware architecture, ARM, Vending machine, control system.*

1. EMBEDDED SYSTEM

Embedded system is a grouping of computer hardware and software. Possibly further mechanical or other parts are designed to perform a specific function [1]. These devices are application specific circuit which combines with the application specific programming whose whole aim is to focus on one work but it perform one task with the best possible efficiency. "About 79% of all the processors are used in embedded systems". In addition, it is reported that "for many products in the area of consumer electronics the amount of code is doubling every two years" [3]. Digital Signal Processors are special-purpose processors designed for executing mathematically intensive algorithms.

RISC processor has simple format instructions with fast instruction execution. This also reduces the size and power consumption of the processing unit [4]. CISC processor has a complex format instruction with slow instruction execution. CISC processors have a single processing unit, external memory, a relatively small register set, and many hundreds of different instructions. Early computer mathematician and scientist John von Neumann invented simple control flow architecture [4]. One shared memory for instructions and data with one data bus and one address bus between processor and memory. The Harvard architecture uses physically separate memories for their instructions and data, requiring dedicated buses for each of them [4].

1.1. Embedded System Needs

Embedded system facilitates small and dedicated task with the cost and effectiveness. It is most reliable and efficient in its work. In addition, its low power and accurate performance open wide area of solutions [6].

1.2. Challenges and Issues

Every system has its own problem and resistive area which make trouble to accelerate it. Embedded systems also have some challenges and issues which make its acceleration slow. Those are Co-design, operating system, Code optimization, Efficient input/output, Testing and debugging [7].

1.3. Development Process

Like software development process, embedded systems also have some processes to develop it in a manner [5]:

- Determine the requirements of the embedded system.
- Design the system architecture.
- Select the operating system.
- Choose the processor and the associated peripherals.
- Choose the development platform.
- Code the application and optimize the code according to code optimization guidelines.
- Verify the software on the host system.
- Verify the software on the target system

2. EMBEDDED SYSTEM GUIDELINES

Embedded systems are the base of today's emerging technologies. It is continuously providing help in revolutionary change [8]. Embedded system has limited input outputs, memories. So, system should design and develop with best hardware and software guidelines to meet the requirements and best way.

2.1. Chip Selection Guidelines

Chip selection is an art, because it needs lots of the considerations to cope up the system requirement and scalability [9]. Followings are the guidelines to select chip:

- Code Memory
- Memory limitations

- Storage memory
- Speed
- Power
- Size
- Compiler
- Language
- Peripheral
- Interface
- Update requirement
- Cost and Licensing

2.2. Compiler Selection Guidelines

Compiler selection is also a keen decision which should take as early as possible. Followings are the guidelines to select a compiler:

- Required Language support.
- Support wide variety of processor.
- Good and Optimized compiler.
- Easily Reconfigurable and full tool.
- Simulation support Emulation debugging support.
- Tool chain support and Inexpensive.

2.3. Programming Guidelines

Programmer can also make the system fast with the help of best memory and utilization. Following are the guidelines to make CPU faster with the help of code management:

- Make each instruction use as few clock cycles as possible.
- Keep as much data inside the CPU as possible.
- Make each clock cycle as short as possible.
- Get each instruction to do as much as possible

2.4. Code Maintenance Guidelines

Programmers often ignore code maintenance which is a key aspect of application development. For applications with short lives, may not pose a significant problem because once deployed, no one will touch the code again. Embedded systems applications may have lives that span decades and early coding mistakes can result in significant bug-fix and update costs later on [10]. Developer must consider code maintenance during design and implementation of software for an embedded application that will have a long life. The following tips provide help in maintains application [4]:

- Avoid assembly code.
- Avoid comment creep.
- Do not optimize prematurely.
- Keep ISRs simple.
- Leave debugging code in source files.
- Separate low-level I/O routines from the higher-level program logic.
- Break up functionality as needed.
- Keep all documentation with the code.
- Avoid clever techniques.
- Put all definitions in one place

3. ADVANCE RISC MACHINE (ARM)

ARM basically designs the technology that lays at the heart of advanced digital products, from wireless, networking and consumer entertainment solutions to storage devices, imaging, automotive and security. ARM's offering 32-bit RISC microprocessors, graphics processors, enabling software, cell libraries, embedded memories, high-speed connectivity products, peripherals and development tools [11]. The ARM processor is a powerful low-cost, efficient, low-power RISC processor. Its design was originally for the Archimedes desktop computer, but somewhat ironically numerous factors about its design make it unsuitable for use in a desktop machine. ARM does not fabricate silicon itself, but instead just produces the designs that are an Intellectual Property (or IP) company.

3.1. Evaluator-7T Board

The evaluator-7t is an ARM7TDMI-based trainer board as shown in figure 1. It is a simple arm platform that includes a minimal set of core facilities. It is powerful and flexible enough to function as an evaluation platform for ARM technology. The board provides facility to download and debug software images. It also facilitates developer to attach additional input/output devices and peripherals for experimentation [11].

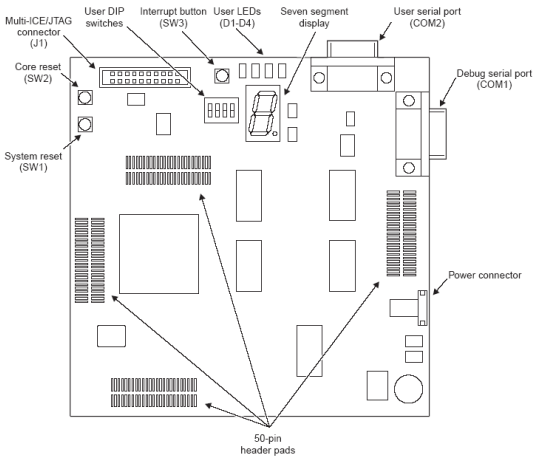

Fig. 1: Lay out of Evaluator board

3.2. Applications

- Personal digital assistants
- Cell phones

- Pagers
- Automotive
- Modems
- Personal audio products

3.3. Benefits

- Designed specifically for ASIC and ASSP integration.
- Supports the Thumb® instruction set to enable 32-bit performance at 16-bit, or even 8-bit cost and increased code density.
- High performance allows system designers to integrate more functionality into both price and power sensitive applications.
- Very low power consumption.
- Wide range of development tools from ARM and third party suppliers

3.4. IAR Embedded Workbench Compiler

IAR Embedded Workbench for ARM is an integrated development C/C++ environment for building and debugging embedded applications. It provides extensive support for a wide range of ARM devices, hardware debug systems and RTOSs and generates very compact and efficient code. Ready-made device configuration files, flash loaders and over 1000 example projects are included

3.5. Sample Program

Following program made in "IAR Embedded Workbench for ARM". It displays counting from 0 to 9 on seven segment display of evaluator-7T board with some delay with same iteration throughout its life [12].

```
#include <stdio.h>
#include <intrinsics.h>
#include <Samsung/ios3c4510b.h>

// LED 7-segment codes for digits 0-9.
unsigned int seg7table[] = {
  0x17c00, // 0
  0x01800, // 1
  0x0ec00, // 2
  0x0bc00, // 3
  0x19800, // 4
  0x1b400, // 5
  0x1f400, // 6
  0x01c00, // 7
  0x1fc00, // 8
  0x19c00, // 9
};

void delay()
{
  volatile int count = 1000000;
  while (--count) ;
}
main()
{
  int i;

  // Loop forever.
  for (;;)
  {
    // Count from 0 to 9 on 7-segment LED display.
    for (i = 0; i < 10; i++)
    {
      __IOPDATA &= ~0x1fc00; // Clear all segments.
      __IOPDATA |= seg7table[i]; // output current digit.
      delay(); // Wait a little before displaying next digit.
    }
  }
}
```

4. UNIVERSAL VENDING MACHINE CONTROL SYSTEM

4.1. Vending Machine

Vending means the sale of goods or services, not from a permanent structure, associated with recreation on the public lands or related waters, such as food, beverages, clothing, firewood, souvenirs, photographs or film (video or still), or equipment repairs [4].

4.2. Classification

Vending machines are classified mainly according to the products it carries. Below are just some of them:

- Newspaper vending machines.
- Candy vending machines.
- Soda snack/vending machines.
- Specialized Vending

4.3. Problem Domain

Vending machine commonly used to take payments and dispenses the required product. There are number of companies available, but no one provides universal control systems. There are some areas in which it has limits like Payments, products, dispensers, backups, configurations, online updates and securities.

Many of the vending control systems found with respect to machine and it is also most costly part. It just required one time cost to develop and production will be so cheap. It can save many through the universal control system.

4.4. Proposed Solution

The proposed idea is that, controller should have the capabilities of all the payment modes, unlimited number of

dispensers, product selections, backups the transaction logs, configuration of control system, online update, firmware update, product selections, General purpose Input Outputs, system and security control sensors as shown in Figure 2.

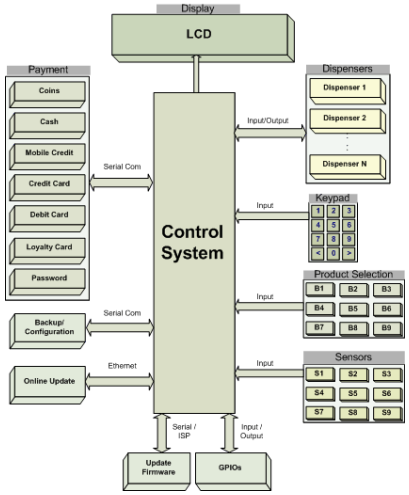

Fig. 2: Universal Vending Machine Control System Architecture

4.4.1. Control System

Control system is the brain of system which controls the input and outputs to perform desired task. It perform task to according to stored configuration. Whenever it starts the system it displays its status on LCD and works according to programmer routines.

4.4.2. LCD

Liquid Crystal Display (LCD) will provide user guidance that what is the next step to do. A 4* 20 character display commonly used in vending machines.

4.4.3. Payment

Payment modes are the main key to make the system demand. So the maximum payment mode, make the machine in use. The most common payment mode is coins based. The universal system has the capability to active one or more modes for the specified system. There are several payment modes available but for this system which mentioned as bellow:

4.4.4. Dispensers

The control system has the ability to drive unlimited numbers of dispensers. Just connect dispenser circuit to electronic board of control system and configure in the control system via firmware and/or Serial configuration via LAPTOP.

4.4.5. Keypad

Keypad is input device; use to provide instruction to system.

4.4.6. *Product Selections*

Vending machine product selection is basically used to select which product user required to purchase.

4.4.7. *Sensors*

Sensors are the inputs for the system which assures the system the work has been perform, indication of any fault occurrence, measures the specified situation, security information etc.

4.4.8. Backup

The transaction of vending machine can be extract via attaching Laptop with serial port and computer software will communicate with the control system to extract it.

4.4.9. *Configuration*

Universal control system is based on parameter based, which loads when system starts. So the system needs to configure according to requirement like, payment modes selection, dispensers quantities and its sensors, product selection enable/ disable, online update configuration, GPIO and sensors configurations.

4.4.10. *Online Updates*

Online feature provides the transaction logging at remote side and many system status and configuration can also do by Ethernet connection.

4.4.11. *Firmware Update*

System has the ability to update firmware via installed position.

4.4.12. *GPIOS*

General purpose Inputs Outputs (GPIOs) are extra connection, which can be use if required.

4.5. Advantages

- Easy to install
- Easy to configure
- Easy to update firmware
- Easy to monitor
- Secure
- Long term business
- Universal controller for all vending machine
- Cheap in production
- Not easy to found competitor
- Stable system
- Easy to upgrade

4.6. Disadvantages

- Required big architecture
- More research required
- More resource required
- More time required
- Initially costly system

CONCLUSION

This research concludes by imparting the information of embedded systems' hardware architecture, control flow architecture, issues and challenges. Embedded system is a grouping of computer hardware and software. Embedded architectures are RISC and CISC, RICS is now commonly used in embedded processor due to its significant features. Harvard control flow architecture is better and use in high end system as compare to Von Neumann architecture.

Embedded system guidelines will be beneficial for developing high end systems. Guidelines help in designing and development of hardware; selecting processor; language selection; choosing compiler and writing of codes with easy to maintain.

ARM is one of the most licensed processor cores in the world Used especially in portable devices due to low power consumption and reasonable performance. Code written for ARM7TDMI is binary-compatible with other members of the ARM7 Family and forwards compatible with the ARM9 and ARM9E families.

While many controllers available for vending machine with respect to its category, the universal vending control system concept will cover an extensive area for the vending machine. The architecture of proposed system have wide variety of payment modes, it covers almost all modes. The unlimited dispensers feature opens an area to develop vending shell as wide as required. Other features backup of transaction logs offline/online, system configuration, security sensors, firmware updates etc are also make this system valuable and capable to capture huge market.

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