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A New Cash Register for Fuel Stations with Resistant Outdoor Conditions: Design Considerations

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Abstract – The Head of Revenue Administration (HRA) in Turkey imposes the obligation to use new generation payment recording devices (NG PRDs) at fuel stations. The pump and the cash register were separate units in old payment systems, and communication was provided via an interface. However, there are some security vulnerabilities in these systems due to the interface being separate from the cash register. In addition, it is known that due to the high fuel tax rates, significant losses occur due to tax evasion. Although the use of NG PRD has been made compulsory, no product in the market complies with the current legislation. Therefore, there is a need for these products to be developed for secure data communication in fuel pump cash registers, prevention of tax evasion, and monitoring of the informal economy in the fuel sector. This study aims to design and manufacture prototypes of NG PRDs and components for fuel stations in accordance with the technical guide of the HRA legislation. The main feature sought for NG PRDs is to ensure the continuity of communication between the pump and the cash register.

Keywords – New Generation Payment Recorder Device, Trusted Service Manager, Fuel Pump Cash Register

I. INTRODUCTION

The main field of activity performed by the Hugin company is the development of cash registers and POS devices and their complementary equipment. These products, developed with R&D activities, are offered to the sector in accordance with current legislation, providing ease of use and upgraded technical features. Our products are cash registers and equipment, POS, printers, touch screens, and additional software developed for these products.

The Head of Revenue Administration (HRA) in Turkey imposes the obligation to use new generation payment recording devices (NG PRDs) at fuel stations. The pump and the cash register were separate units in old payment systems, and communication was provided via an interface. However, there are some security vulnerabilities in these systems, and the leaks are due to the interface being separate from the cash register. In addition, it is known that due to the high fuel tax rates [1], [2], significant losses occur due to tax evasion. Although the use of NG PRD has been made compulsory, no product in the market complies with the current legislation. There is a need for these products to be developed for secure data communication in fuel pump cash registers, prevent tax evasion, and monitor the informal economy in the fuel sector. Hugin wants to develop new products and expand its product portfolio for the sector's needs expected to occur in a short time. With this project, the company started for the first time on the grounds of developing a product that will work outdoors, integrated with another automation system.

The study's main purpose is to design and manufacture prototypes of NG PRDs and components for fuel stations in accordance with the technical guide of the HRA legislation. The main feature sought for NG PRDs is to ensure the continuity of communication between the pump and the cash register. The proposed cash register

- is protected by an electronic and physical seal against external interventions.
- works on a multiprocess processor with at least 32 bits or higher data processing capacity.
- has daily memory protected by mesh cover supporting IPv4 and IPv6 protocols.
- contains a financial memory protected by a mesh cover and can record at least 1.000.000 receipts and a minimum 8 GB electronic recording unit.
- has Ethernet, 4G mobile communication serial port, and USB interfaces.
- can provide wireless or wired communication with EFT-POS devices.
- can work integrated with station automation systems, supports different payment types, contains an interface unit that enables communication with the EMRA automation system.
- has a printer of at least 58 mm.

There are some indirectly related studies that also designed or improved some types of cash register systems. For example,

Gücüyener and Erdan [3] proposed a new counterfeit money detection system applicable to all cash register devices. The system is based on recognizing the appearing characters above money, which is illuminated with ultraviolet light. He et al. [4] introduced hardware components of embedded systems for fiscal cash registers. They discussed the functions and characteristics of the board support package in developing the embedded system. In addition, Prokin [5] described turnover control devices based on GPRS terminals for sending data from fiscal electronic cash registers and fiscal printers to the server of the Tax Administration to prevent tax evasion, diversion of original goods from the distribution system, and infiltration of counterfeited or original goods into the distribution system without payment of customs, tax, and excise duties. Fawzi and Mohannad [6] developed a fuel dispensing system based on RFID technology. The system can improve the fueling process to make it much easier, secure, and reliable. It prevents unauthorized fueling by assigning a specified amount of fuel for registered vehicles. Hasan and Al-Naima [7] proposed a control system based on RFID technology to monitor the supply and dispense of vehicle fuel in Baghdad. The system consists of RFID readers attached to fuel dispensers and pumps and RFID tags assigned to the vehicles and the trucks used for delivering fuel to the fuel stations. Rachman [8] proposed a new cash register system that used inventory data and sales transaction data to produce information such as inventory report and sales report consisting of daily sales report, monthly sales report, and annual sales report to be given to the General Manager and evidence of payment to be given to the customers. Forostyanova1et al. [9] applied test derivation methods for finite state machines to test the communication protocol's functionality between the cash register software and the Loymax service when conducting cash transactions. The protocol was provided by Loymax, which is the company involved in the development and support of loyalty programs. Yu [10] proposed a new way of testing a fiscal cash register embedded system with a scenario pattern-based method. It also introduces some concepts of scenario and scenario patterns. The study introduced the whole process of verifying the fiscal cash register embedded system with scenario patterns.

The rest of the paper is organized as follows. In Section II, the details of the basic hardware modules are given as conceptual design studies. Drivers and application layer components are detailed in Section III. Section IV presents details related to mechanical design and prototype development. Finally, section V concludes the paper with possible future research directions.

II. Hardware Modules and Conceptual Design

The basic hardware modules and a block diagram that will enable the device to perform its functions are shown in Figure 1.

The features of the basic hardware modules can be listed as follows:

- Pump: A device with one or more fuel (unleaded, normal gasoline, diesel, etc.) guns that fill the vehicle from the fuel tank.

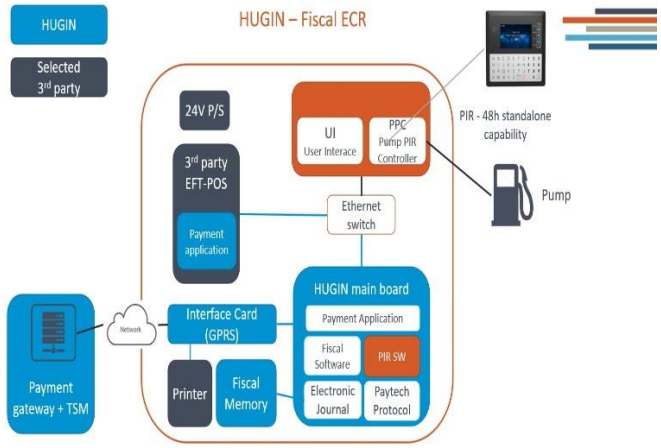

Figure 1. Fiscal electronic cash register

- Teosis I/F Board: It is used to communicate between the pump (20 different protocols), the automation system (4 different protocols including Asis and Turpak), and the cash register. A cash register connection can be used in RS232, SPI, or I2C.
- EKU Board: Standard SD card 1 GB. Capacity can be increased according to the communique.
- FM Board (HG9 202/300)
  - NAND Flash Memory (MT29F1G08ABADAH4-IT 1Gbit (128M*8bit))
  - 32-bit ARM Cortex-M0 microcontroller (LPC1114FBD48/302)
  - Tamper FF
- HG20 Main Board
  - MAX32590-LNS+ (ARM926EJ-S processor core secure microcontroller)
  - LDDR SDRAM
  - NAND Flash
  - UART (Printer, GPRS, EFT-Pos)
  - SPI (FM, Teosis I/F)
  - USB (host)x2
  - NTC (ADS1018IDGST Texas)
  - USB Device (optional)
  - DS Sensors
  - Buzzer
  - Rubber dome cover x2
  - FM connector (FPC 12p)
  - LCD connector (16 pins)
  - Printer driver board connector (5p)
  - Keyboard connector (FPC 16pin)
  - Heater connector (2P)
  - Fan connector (2p)
  - Pinpad connector (RJ45)
  - GPRS connector (20p)
  - Power connector (AC 3pin)
  - NTC connector (2p)
  - USB connector
  - UART connector
  - IF connector (Teosis)
- LCD Module: LCD 20x4 (20 characters, 4 lines)
- Keyboard: Membrane keyboard in outdoor waterproof and dustproof type.

- Printer Board: (CAPD247) 2.0″ (-10°C ~ -50°C) driver board
- Fan-Heater
  - Panel type heater 50W – 60W 220V 50Hz
  - DC fan (5cm x 5cm)
- GPRS Board (HG7)
  - GPRS SAR-G300 (U-blox)+ GPRS PCB antenna
  - GPRS antenna connector (734120110)
  - SIM
- PSU: Internal 24Vdc 6.3A adapter (open case)
  - AC cable (3p from mains) input will be without a connector, and AC cable will be directly connected to PSU.
  - DC cable 8p (24v 4p, GND 4p)

III. Drivers and Application Layer Components

As part of the design studies, the Teosis interface and modules of the application layers were implemented. The development of middleware modules that associate the application layer software with the driver layer was completed. In addition, application-layer integration was provided, and Terminal Management System (TSM) integration studies were carried out. The following modules have been developed for the driver layer as part of the software design:

- Microprocessor integration: Program loading to the microprocessor, making peripherals usable.
- USB host: Codes required for keyboard, barcode, and mouse devices have been created.
- Memory Interface: Static RAM and NAND Flash access are provided.
- Ethernet: Set to 10/100 Mbps.
- GPIO Control: Drawer, Buzzer, Keyboard, LCD, Printer Step Motor accesses are provided.
- Interrupt Management: Key functions and timers are arranged.
- Fiscal Memory Protocol: It is designed to provide the operations of writing and reading information to the financial memory with the password mechanism.
- ADC: Printer temperature control is required for NTC sensor ambient temperature control.
- LCD Character: The driver program of the 4x20 character LCD module has been written.
- Ethernet: Ethernet driver program has been written according to the IC used.
- GPRS: The driver has been prepared according to the protocol of the U-Blox module we use.
- UART: The driver has been prepared for connection with Teosis interface and printer driver board.

The following studies were carried out within the scope of developing driver sub-components.

- Development of low-level security drivers to provide tamper status detection from mesh and switch mechanisms through the dynamic sensors of the processor.
- Thermal Printer has been developed to control and use 36 character/line driver and ESC POS commands for the thermal print head with a 56 mm paper cutter.

Driver tests and integration studies have been completed. All drivers have been run and found to work without any problems. Application layer components have been identified. These include

- IPv6 control,
- Financial certificate management,
- Financial memory manager,
- Electronic recording unit manager,
- Database administrator,
- Financial report,
- Event log manager,
- User layer interface.

Middleware modules have been created that associate the application layer software with the driver layer. The following modules, developed in the application layer, are integrated into the pump cash register hardware (i.e., driver layer).

- IPv6 control,
- Financial memory manager,
- Financial report,
- User layer interface.

The modules of the following application layers have been developed:

- Communication software of the HRA
- Database administrator
- Financial report
- Event log manager
- A simulator is used for data communication sublayers. The data security layers have been implemented.
- The development of middleware modules (i.e., financial certificate management, electronic recording unit manager, database manager, event recording manager) that associate the application layer software with the driver layer has been completed.

TSM integration studies have been carried out. Correct operation is ensured by using the simulator for TSM data communication sublayers. TSM provides tracking of NG PRD information (i.e., production, activation, scrapping, transfer, maintenance, etc.). In addition, the terminal service center performs the services of collecting, storing, processing, and reporting the receipt or report information to be produced by these devices in accordance with the technical standards determined by the Presidency while ensuring confidentiality and security.

IV. Mechanical Design and Prototype Development

All studies up to prototype manufacturing have been completed within the scope of mechanical design and prototype development studies. Test studies and official approval process activities have been carried out.

Due to the necessity of protecting the main processor, financial memory, and interface unit with an electronic seal in NG PRDs described in the technical manual of the new generation fuel pump payment recorder devices. Afterward, 3D drawings were made (Solid Works). When the 3D data drawings were completed, prototype printouts were taken with 3D printing, and necessary corrections were performed before the mold. After all the corrections, the mold-making phase was started. These stages are shown in Figure 2.

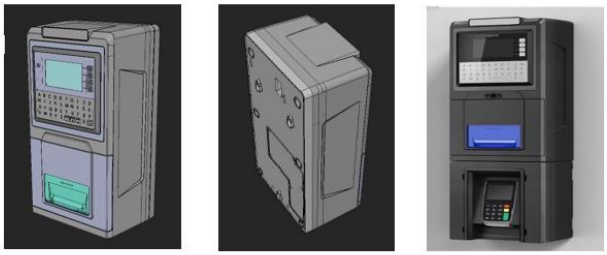

Figure 2. The 3D data drawings of the prototype printouts

V. Conclusion and Future Work

This study designed and manufactured prototypes of NG PRDs and components for fuel stations in accordance with the technical guide of the HRA legislation. The main feature of NG PRDs is to ensure the continuity of communication between the pump and the cash register. Significant experience has been gained in research on outdoor product design. Within the scope of the project work, for the first time, new standards for product design suitable for the external environment (ATEX and IP54) were learned. It is thought that this acquisition will have a triggering effect on the design and development of new products that can work in the external environment. By examining the literature, market research, and related technical documents, theoretical knowledge has been increased, the requirements have been thoroughly investigated, and input has been provided to the project. Additional R&D achievements include the continuity of pump-cash register communication, the automation system to run all commands at an optimum level and continuously, the development of a protocol for the compatibility and integration of the interface with all pumps in the market, and the implementation of algorithms for communication and continuous connection.

Currently, the final product can only be fixed on the wall. In the upcoming processes, it will be possible to use it in places with no walls, by making a design work for the lower leg. In addition, the EFT-POS part of the product has been designed modularly, and only the relevant part will be adjusted according to the desired EFT-POS.

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