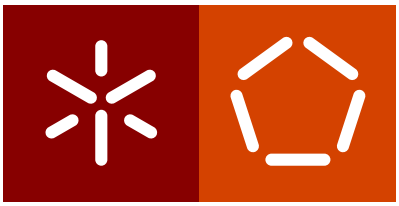

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Embedded systems

Assignment 1: Report

Development of a 3 button TV remote control — Analysis & Design

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List of Abbreviations

Notation	Description	Page List
IR	infrared	5
LED	Light Emitting Diode	4
LIRC	Linux Infrared Remote Control	5
TV	Television	1

1 Introduction

The present work illustrates the application of the two first stages of the Waterfall methodology — Analysis and Design — to develop a Television (TV) remote control. This type of project begins with the establishment of a contract between the client (Samsung company) and the project team, clearly defining the problem statement and deriving the product requirements and constraints associated to the project. It should be noted, however, that both roles are played out by the authors. A market research is performed to gain more insight over this market and the product placement, and the product overall characteristics.

In the analysis phase, the product requirements are derived — defining the client expectations for the product — as well as the project constraints — what the environments limits about the product. Finally, the theoretical foundations are outlined, providing the basic technical knowledge to undertake the project.

In the design phase, the product development starts, specifying the system in terms of hardware and software and its associated interfaces, the error handling required, and the design verification.

1.1 Problem statement

The first step of the project is to clearly define the problem, as a result of the contract established between the client and the project team, yielding, in this case, the following project statement:

"Design a remote control with three buttons that can remotely control the television (TV). It should be very light, powered by batteries and controls your TV via an infrared emitter. The TV has a built-in infrared receiver. A button on the remote control switches the TV on/off and will be labeled with the word "Power". The other two buttons are used to scroll up/down and select the available channels and they are labeled with the arrows up/down."

1.2 Market research

A TV remote is a device which is used to operate a television from distance in a wireless mode. It also makes the TV usage simpler, more user friendly with its suggestive buttons. These buttons control functions such as power, volume, channel switch and various other features.

TV remotes are composed by the TV remote Shell, the TV remote membrane, one LED and a data acquisition & Infrared emitter PCB, as illustrated in Fig. 1.1. The unit cost of universal TV remotes is about 3 to 5 EUR.

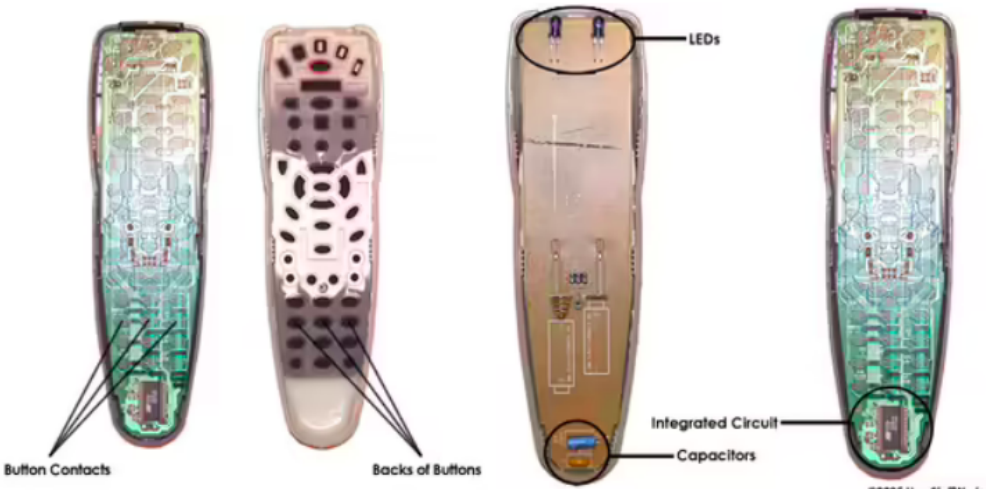

Figure 1.1: TV Remote control bill of materials, withdrawn from [1]

As can be seen in Fig. 1.2, the amount of televisions sold per year is about 200 million per year, with a tendency to increase over the next years. Thus, at least the same amount of TV remotes sells is expected, as each new TV requires one remote control, but it is expected to be exceeded due to TV remote replacement arising from its malfunctioning or bad usage.

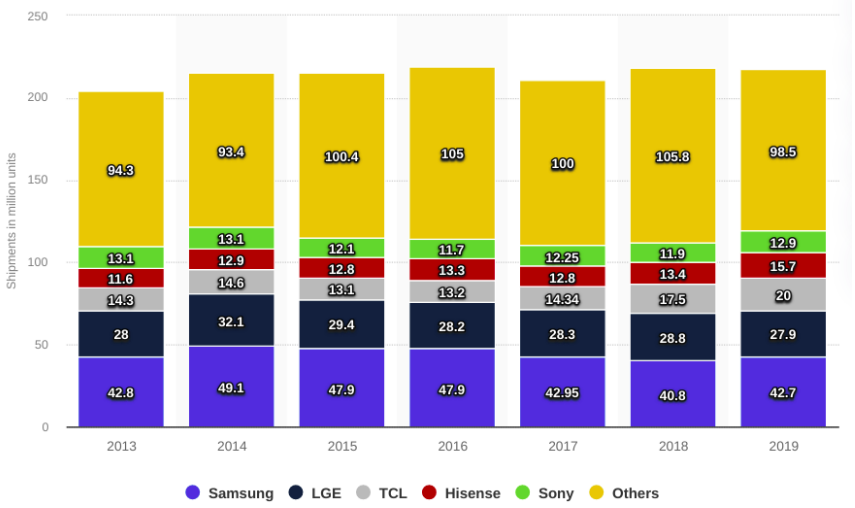

Figure 1.2: Global LCD TV unit shipments from 2015 to 2019, by vendor (in millions), withdrawn from [2]

2 Analysis

In the analysis phase, the product requirements are derived — defining the client expectations for the product — as well as the project constraints — what the environments limits about the product. Finally, the theoretical foundations are outlined, providing the basic technical knowledge to undertake the project.

2.1 Requirements

The requirements defined the client expectations for the TV remote control, namely:

- Remotely operated
- Low weight
- Powered by batteries
- 3 buttons: Power (Off/On); Up and Down for channel selection.
- Infrared emitter response time (system output response time): 100 ms
- The TV remote may be upgraded in the future to use more buttons

2.2 Constraints

The project constraints are the limitations the environment imposes on it, namely:

- the TV remote must contain an infrared emitter (the TV already has an infrared receiver)
- The TV remote control must supply the required data frames imposed by the TV manufacturer
- Data frames may not be provided by the client
- Security concerns are defined by the data frames and the specific communication frequency imposed by the TV manufacturer
- 1 week deadline: 14 h
- Manpower: 2 people
- Budget:
    - HW (parts acquisition and assembly): fixed costs — 1 EUR/unit (1000 batch production)
        - TV remote Shell

  - TV remote membrane
  - Data acquisition & Infrared emitter PCB
- Development: project — 20 EUR per hour per person, totalling 560 EUR + IVA

2.3 Theoretical foundations

The theoretical foundations provide the basic technical knowledge for project undertaking. In that sense, it is important to understand the principle of operation and the related technologies, namely the infrared communication protocol consisting of well-established data frames, specific to each manufacturer and at specific bandwith. It should be highlighted that the communication protocol information is critical for the correct behavior of the TV remote control, as the latter must stimulate the TV, complying to this protocol.

Pushing a button on a remote control sets in motion a series of events that causes the controlled device to carry out a command. The process can be generally described as:

1. pushing the button on the remote control causes a touch to the contact beneath it and complete the button circuit on the circuit board. The integrated circuit detects this.
2. The integrated circuit sends the binary of the button function command to the infrared Light Emitting Diode (LED) at the front of the remote.
3. The LED emits a series of light pulses that corresponds to the binary the button command.

As an example, one can take a look at the clicking on the “volume up” button on a Sony TV remote (Fig. 2.1):

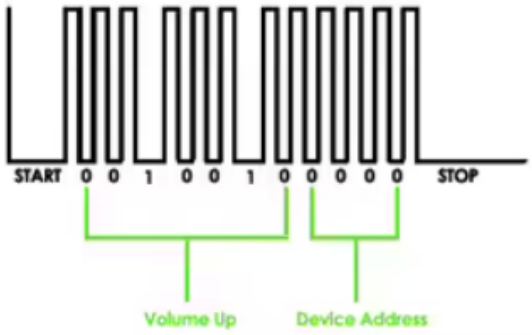

Figure 2.1: Example of wave generator for ”volume up” from [3]

The remote signal includes more than the command for “volume up”. It sends several bits of information to the receiving device, establishing a communication protocol, including:

- a “start” command
- the command code for “volume up”
- the device address (so the TV knows the data is intended for it)

- a “stop” command (triggered when you release the “volume up” button)

In this case, the buttons that are needed and its codes are:

- Power On = 001 0101
- Power Off = 010 1111
- Volume Up = 001 0010
- Volume Down = 001 0011

2.3.1 Reverse engineering

The contract established between the client (Samsung company) and the developer team (the authors) imposes the disclosement of the required information about the communication protocol. However, this is not always necessarily the case. As such, it is important to have a backup plan, which, in this case, corresponds to perform reverse engineering on the communication protocol.

For this endeavour, an “attack” can be performed on the TV, by stimulating it at varying frequencies and set of commands and observing its effect. Obviously, the complexity grows with the number of required commands, but as in this case there are only 3 commands, this can be feasible. Furthermore, this can be bootstrapped by using available TV remote control emulators. An example setup can be connecting an infrared (IR) receiver at a Raspberry Pi, as illustrated in Fig. 2.2 and loading a package, called Linux Infrared Remote Control (LIRC) that allows you to decode and send infrared signals of many (but not all) commonly used remote controls.

The most important part of LIRC is the lircd daemon which decodes IR signals received by the device drivers and provides the information on a socket. It also accepts commands for IR signals to be sent if the hardware supports this [4]. Additionally, the sent IR signals can be used to identify the emitter characteristics, if already present in the database, or simply recorded for later usage. For the present use case, the list of available commands for Samsung TVs can also be obtained for the database for actual TV “attack”.

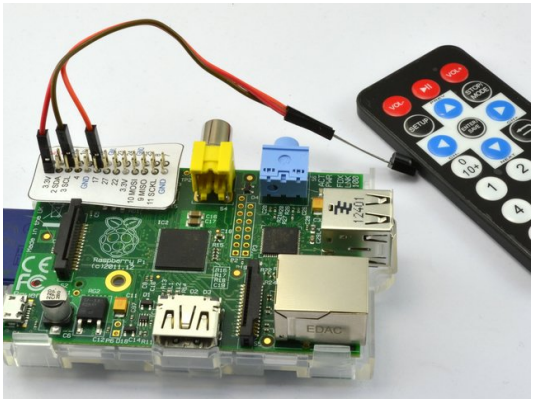

Figure 2.2: Example setup for reverse engineering of TV remote control commands using an emulator [5]

3 Design

In this section the theoretical foundations are used to design a viable solution, accordingly to the requirements and constraints listed. In the design phase, the product development starts, specifying the system in terms of hardware and software and its associated interfaces, the error handling required, and the design verification.

3.1 Hardware specification

- Block diagram with COTS components, if possible - List of constraints of functions to be implemented in HW or SW - Inclusion of a multiplexer may reduce SW burden - CPU peripherals: - PCA for wave generation

3.2 Hardware interfaces definition

- I/O ports - HW registers - Memory addresses for shared or I/O by memory mapping - HW interrupts

3.3 Software specification

Top-down methodology 1. Identify main subsystems 1. Signal input detector 2. Event handler 3. Output generator

3.4 Software interfaces definition

- Define the APIs in detail: - header files with: - functions prototypes - data structure declarations - class declarations

3.5 Start-up/shutdown process specification

3.6 Error handling specification

- Create error-handling routines - Watchdog timer can be used for system recovery

3.7 Design verification

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