Embedded Systems Applications in Household Appliances' Performance – an Assay

By
PHIBANRILIN PYNGROPE
(13PIR010)

A THESIS SUBMITTED TO
AVINASHILINGAM INSTITUTE FOR HOME SCIENCE
AND HIGHER EDUCATION FOR WOMEN,
COIMBATORE – 641 043.

In partial fulfillment of the requirements for the Degree of

MASTER OF SCIENCE
IN
INTERIOR DESIGN AND RESOURCE MANAGEMENT

MARCH 2015

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GUIDE

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“A thankful heart is not only the greater virtue, but the parent of all other virtues”.

- Cicero

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INTRODUCTION

The emergence of electrical home appliances began between 1915 and 1920. The decline in domestic servants meant that households needed cheap, mechanical replacements. Domestic electricity supply, however, was still in its infancy — meaning this luxury was afforded only the more affluent households (Harper et al., 2003). The domestic application attached to "**home appliance**" is tied to the definition of appliance as **"An instrument or device designed for a particular use or function"** (Webster, 2013). More specifically, Collins dictionary defines "Home appliance" as: **"devices or machines, usually electrical, that are in the home and which use to do jobs such as cleaning or cooking".** The broad usage, afforded to the definition allows for nearly any device intended for domestic use to be a home appliance, including consumer electronics as well as stoves, refrigerators, toasters, air conditioners, and well pumps (Collins Dictionary, 2013).

With the invention of the microcontroller, the cost of electronic control fell rapidly. Remote and intelligent control technologies were adopted by the building services industry and appliance manufacturers. By the end of the 1990s, "domotics" was commonly used to describe any system in which informatics and telematics were combined to support activities in the home. The phrase is a neologism formed from domus (Latin, meaning house) and informatics, and refers to the application of computer and robot technologies to domestic appliances (George, 1997).

Today's kitchen appliances and home automation solutions are smarter, faster and more efficient than ever before, and they have to function that way in order to keep up with consumers' ever changing and increasing demands. The use of touch controls via Human Machine Interfaces (HMI) in appliances has moved beyond the niche high-end market to a wide range of applications to help consumers interact with their appliances in fresh and innovative ways. Modern-day home appliances are built with the user experience in mind. These once solely mechanical products now integrate a host of electronics and connectivity options to provide the newest features, reliability, energy efficiency, performance, and ease-of-use, consumers have come to expect.

Home automation refers to the use of computer and information technology to control home appliances and features (such as windows or lighting). It is adopted for reasons of ease, security and energy efficiency (Gerhart, 1999 and Harper et al., 2003). Systems can range from simple remote control of lighting through to complex computer/micro-controller based networks with varying degrees of intelligence and automation.

In today's digital world the life totally depends on at least one piece of equipment which contains processor like a phone, television, washing machine etc. (Figueiredo, 2014) Household appliances, such as microwave ovens, washing machines and dishwashers, include **embedded systems** to provide flexibility, efficiency and features.

(http://www.nxp.com/products/microcontrollers/application/home_appliances).

An embedded system is one that has computer-hardware with software embedded in it as one of its most important component. It is a dedicated computer based system for an application(s) or product. It may be an independent system or a part of large systems. Its software usually embeds into a ROM or flash (www.secab.org/siet/7thsem/embeddedsystems_and www.revastudents.info.pdf). According to Wilmshurst, (2010) "an embedded system is a system whose principal function is not computational but which is controlled by a computer embedded within it. The computer is likely to be microprocessor or microcontroller. The word embedded implies that it lies inside the overall system, hidden from view, forming an integral part of greater whole".

Mass production, such as **white goods** manufacturing, is traditionally bound to hierarchical factory floor procedures and accepts only gradual changes in technology and product architecture. White goods are conventionally white in colour, states, Vinod (2006) and include refrigerators, air conditioners, washing machines etc, which undergo periodical modifications in technology. The new type of appliances must behave rationally to facilitate the most frequently performed household activities, such as washing the laundry, cooking, baking, refrigeration, etc. It has to show a certain degree of intelligence, act autonomously, plan and induce actions in order to achieve the requested goals, and even learn. Communication with these appliances has to be user-friendly (Steblovnik, 2011).

Electronic Household appliances are classified under three types: Major, Small and Consumer electronics.

- **A major appliance, or domestic appliance, is a large machine used for routine housekeeping tasks such as cooking, washing laundry, or food preservation (http://en.wikipedia.org/wiki/Major_appliance).**
- **A small appliance or small domestic appliance is a portable or semi-portable machine, generally used on table-tops, counter-tops, or other platforms, to accomplish a household task. Examples include toasters, humidifiers, and coffee makers.**
- **Consumer electronics are electronic equipment intended for everyday use, most often in entertainment, communications and office productivity.**

Washing laundry is one of the most widespread forms of housework in the world. Refrigeration and air-conditioning are indispensable in everyday life for modern society. Cooking and cleaning also join the list as purely domestic activities, which are not assumed to involve any technology. The trend has changed now. Domestic technology is the incorporation of applied science into the home. There are many aspects of domestic technology. On one level, there are home appliances, home automation and other devices commonly used in the home, such as clothes dryers and washing machines. On another level, domestic technology recognizes the use of applied science to construct smart homes. It has been claimed that domestic technology has led to decreases in the time people spend on household work, states Bitman et al. (2004), although the factual basis of this claim is disputed.

Many household tasks were automated by the development of specialized automated appliances. For instance, automatic washing machines were developed to reduce the manual labor of cleaning clothes, and water heaters reduced the labor necessary for bathing (Collins English Dictionary, 2014).

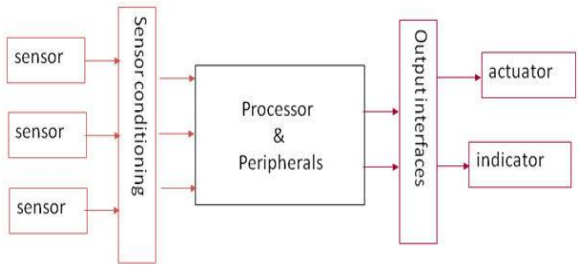
An embedded system has three main components: hardware, main application software, and a real time operating system (RTOS) that supervises the application software and provides a mechanism to let the processor run a process as per scheduling and do the context-switch between the various processes

(tasks). RTOS defines the way the system works. It organizes access to a resource in sequence of the series of tasks of the system. it schedules their working and execution by following a plan to control the latencies and to meet the deadlines. [Latency refers to the waiting period between running the codes of a task and the instance at which the need for the task arises.] It sets the rules during the execution of the application software. A small-scale embedded system may not need an RTOS. An embedded system has software designed to keep in view three constraints: Available system memory, available processor speed and the need to limit power dissipation when running the system continuously in cycles of wait for events, run, stop and wake-up. (*highered.mheducation.com/sites/dl/free/007340456x/167481/sample1.pdf*)

The embedded systems are basically application specific or domain specific. Application specific means the particular system is designed for some specific application only like cell phones, washing machine, camera etc (Chopra, 2013).

Application Areas of Embedded Systems: The embedded system have a huge variety of application domains which varies from very low cost to very high cost and from daily life consumer electronics to industry automation equipments, from entertainment devices to academic equipments, and from medical instruments to aerospace and weapon control systems. Right from waking up in morning to sleeping at night human beings keep using many systems, gadgets and devices which are embedded with vast variety of chips that control one's day to day life state, Bhatia, (2013).

Figure: 1. A typical embedded system



Source: http://www.slideshare.net/yayavaram/unit-1-embedded-systems-and-applications?

The embedded systems take electrical signal as input. Generally sensors or transducers convert physical entity into an electrical signal. These electrical signals are converted to Digital ones,

as processors are designed to handle digital signals.

The processor processes these signals using codes that reside in memory chip. RAMs are used to store volatile data. Most of the times ES are controlling the other systems which depends on the outputs from ES. For such systems Digital to analog converters are used. While designing, reliability, performance, and cost need to be kept in mind (Bhatia, 2013).

Many of the electronic devices in a kitchen (bread machines, food processor, dishwasher and microwave oven), living rooms (television, stereo and remote controls), workplace (fax machines, pagers, laser printers, cash registers, and credit card readers) are embedded systems.

Modern day households have thus become the hub of electronic and embedded system appliances. Ultimately the homemaker, the consumer of household appliances has to be on toes to comprehend such scientific advancements to effectively use them for common good.

With the advent of such systems thronging the local markets, it is inevitable that the market trends, competitive market structures, consumer behavior and the products as such be studied in detail as all these parameters indirectly affect one another. They have transformed both the elements of production and consumption. Evidence of research on these lines, especially the modern household appliances with embedded systems and their performances is also a felt lacuna. The need for and development of scientific research inputs to enhance their performance not only to simplify household activities, but also to enhance the well being of the homemakers has become the order of the day. All these factors reiterate the onus on the manufacturers, the firms, to innovate products which have functional, ergonomic, aesthetic, and socially responsive roles to sustain their product positions in the market as well as in the minds of the consumer.

Technology has penetrated every fibre of day to day living. Yet basic knowledge on the components that firms innovate, introduce and incorporate as a measure of value addition, for product flanking, brand building or brand extension strategy to sustain their presence in the market and to put up stiff competition with their prospective competitors remain in the silhouettes. None of the end-users,

the consumers are aware of such value additions or their promotional strategies the firm's pursue to make the products reach the end-users. Though relevant data are uploaded in space in their respective websites, consumers do not show interest to get to know about the gadgets they use in everyday life, which have decided their living style and status in the society.

Above all this is an untouched arena in household Physics and Consumerism, two divine disciplines in Home Science.

With this backdrop, the investigator, a scholar in Resource Management and an ardent advocate of consumerism, developed an interest to launch on the study on **''Embedded System Applications in Household Appliances' Performance – An Assay''** with the following objectives to:

1. Study trends in Consumer Behavior Regarding Household Appliances
2. Examine the Market Waves for Household Appliances with Embedded Systems (ES).
3. Analyse Performance Characteristics of Embedded System (ES) Applications in Select Household Appliances.
4. Count on the **'Product Benefits'** offered by the Firms (manufacturers) to Ensure **'Product Position'**.
5. Envisage the Benefits Accrued by Potential Consumers from use of Household Appliances with Embedded Systems - the Value Added Options.

The study analyses the status quo of both the consumers and the producers. It is hoped that the study would unfold a new leaf in the arena of household appliances - their components (ES), performance characteristics, use, popularity and ultimately consumer satisfaction.

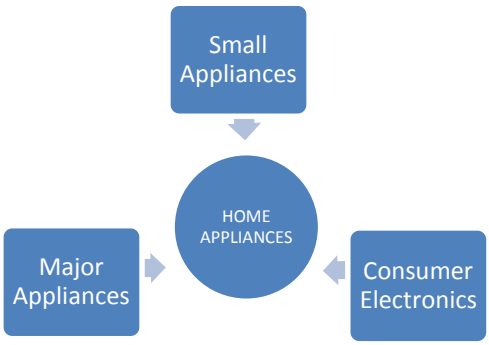
II. REVIEW OF LITERATURE

The literature pertaining to the study on **"Embedded Systems Applications in Household Appliances' Performance - An Assay"** are reviewed under the following broad headings:

A. Household Appliances – an Overview
B. Major Household Appliances
C. What are Embedded Systems?
D. How do Major Electronic Household Appliances Operate?
E. Types and Functions of Embedded Systems in Household Appliances

A. Household Appliances – an Overview

A home appliance is an electrical/mechanical machine which accomplishes some household functions, such as cooking or cleaning. Home appliances can be classified into:



Major appliances differ from small appliances because they are bigger and not portable. They may have special electrical connections, connections to gas supplies, or special plumbing and ventilation arrangements that may be permanently connected to the appliance. This limits where they can be placed in a home (Prasad, 2011).

Small appliances contrast with major appliances (British "white goods"), such as the refrigerator and washing machine, which cannot be easily moved and are generally placed on the floor. Another type of small appliances relate to heating and cooling such as: fans and window mounted air conditioners. Small appliances also contrast with consumer electronics (British "brown goods") which are for

leisure and entertainment rather than purely practical tasks (Ted, 1995). Brown goods are contrasted with major appliances, which are typically fixtures that cannot be easily moved. Many small appliances are powered by electricity (Peet et al. 1979).

Consumer electronics are often called brown goods by producers and sellers (Collins English Dictionary, 2014.). Main consumer electronics products include all major entertainment gadgets (Hoover, 2014).

B. Major Household Appliances

Major appliances may be roughly divided as follows:

Table 1: TYPES OF MAJOR APPLIANCES

Refrigeration equipment	Stoves	Washing equipment	Miscellaneous
Refrigerator	Microwave oven	-Dishwasher -Washing machine	Air conditioner

1. Washing machine

Three types of automatic washing machines dominate the market and offer large energy and water savings The three major types of ‘domestic washing machines’ can be assigned in two categories: Horizontal axis machines and Vertical axis machines. Appliances vary greatly in their configurations and the range of options. The most common types of automatic washing machines worldwide are:

- Vertical axis, top loading agitator washing machine
- Horizontal axis, front- or top loading washing machine
- Vertical axis, top loading impeller washing machine

The main task of all types of washing machines, also known as ‘clothes washers’, is to provide hygienically clean laundry and to preserve its value. They use energy to heat the washing water, to run the motor and the (electronic) control system (Pakula and Stamminger 2010). A ‘semi-automatic’ washing machine requires user intervention at one or more points during the programme to enable

the machine to proceed to its next operation. Examples of user intervention could include manual filling (water and detergents), non-automatic water leveling, transfer of the load between a washing drum and a spin extractor drum or manual draining at single and twin-tub semiautomatic washing machines (Faberi et al. 2007).

The most recent vertical axis machines use advanced electronic controls to adjust the water level automatically (depending on the load size) as well as higher spin speeds. Nevertheless, horizontal axis front- and top-loading washers are generally more efficient than top loading vertical axis models. Horizontal-axis machines don't completely submerge clothes, so they use on average 30 to 50 % less water than vertical-axis models. The less water a washing machine uses, the less energy is needed to heat it up for the washing process or to remove the water after rinsing and during spinning (toptenusa.org 2011).

In horizontal axis machines, only the bottom of the washtub is filled with water. Compared to vertical axis machines, significantly less water per wash cycle is used. Horizontal axis machines are commonly equipped with an internal electric water heating system. Hence, the energy consumption heavily depends on the chosen washing temperature. Modern washing machines with horizontal axis technology have an automatic load sensing function in order to reduce water and electricity consumption in response to consumer loads that are smaller than the rated capacity. (Pakula and Stamminger 2010)

2. Microwave oven

Control System in a Microwave oven: A microwave oven is made of two separate and interworking parts: the control section and the high-voltage section. The control section channels the electricity from the house grid to the microwave itself in a safe manner. The high-voltage section then does most of the work, taking the electricity and changing it into microwave rays that are then emitted into the cooking chamber. Both sections have security devices to ensure that microwaves do not dangerously malfunction or operate incorrectly. The triac is a device in the control section that helps channel electricity. This electromechanical relay normally seals the circuits of the microwave away from the electricity flowing through the outlet. When the microwave is turned on, sensors indicate that all the

devices are working and ready to produce the microwaves themselves. The triac then switches into an "on" position, allowing the electrical current to flow to the high voltage transformer.

- High Voltage Transformer: The microwave takes more power to work than the normal voltage of the household current produces. Fortunately, a device called the high voltage transformer takes care of this problem. Essentially, the high voltage transformer is a series of capacitors that spreads and loops the current to make it much more powerful, usually around 3000 volts from the normal 115 -120 volts supply.
- Magnetron Tube: With the voltage high enough, the current is then passed on to the magnetron tube, which turns the current into microwave energy. This specially made diode uses magnetic fields to control electrons so that as they pass through the diode they heat up the filament/cathode, which causes many of the electrons to split off in the form of microwave energy.
- Wave Guide: Once the microwave energy is created, it is channeled into the cooking chamber by the wave guide. There is usually another device that helps scatter or spread the microwaves so they fill the chamber effectively; sometimes a stirrer blade is used to "stir" the microwaves so they spread out or the tray on which the food is placed rotates itself.
- Frame: The microwave energy produced by microwave ovens can be very dangerous to humans, which is why the cooking chamber is carefully protected by a sealed frame that keeps any microwaves from escaping. The door to microwaves is covered by a thin metal grid with spaced holes that are too small for any microwaves to pass through, but allow the user to see into the chamber.

3. Dishwasher

The dishwasher has become an essential part of the appliance package in the modern kitchen. Some designers have considered it part of an ecological package along with the trash compactor and the garbage disposer. Each has had a significant role in creating a safer environment within the home. Present-day machines feature a drop-down front panel door, allowing access to the interior. The inside of a dishwasher are either stainless steel or plastic.

- Function of a Dishwasher

A dishwasher is a mechanical device for cleaning dishes and eating utensils. Unlike manual dishwashing, which relies largely on physical scrubbing to remove soiling, the mechanical dishwasher cleans by spraying hot water, typically between 55 and 75 °C (130 and 170 °F) at the dishes, with lower temperatures used for delicate items. A mix of water and detergent is circulated by a pump. Water is pumped to one or more rotating spray arms, which blast the dishes with the cleaning mixture. Once the wash is finished, the water is drained, more hot water is pumped in and a rinse cycle begins. After the rinse cycle finishes and the water is drained, the dishes are dried using one of different drying methods (e.g. a heating element at the bottom of the tub, fans, Zeolites based drying, etc.). Typically a rinse aid is used to eliminate water spots for streak-free dishes and glassware.

4. Air conditioner

In the most general sense, air conditioning can refer to any form of technology that modifies the condition of air (heating, cooling, (de-)humidification, cleaning, ventilation, or air movement). However, in construction, such a complete system of heating, ventilation, and air conditioning is referred to as HVAC (as opposed to *AC*) (Robert, 2006). The basic concept behind air conditioning is said to have been applied in ancient Egypt, where reeds were hung in windows and were moistened with trickling water. The evaporation of water cooled the air blowing through the window. This process also made the air more humid, which can be beneficial in a dry desert climate. In Ancient Rome, water

from aqueducts was circulated through the walls of certain houses to cool them. Other techniques in medieval Persia involved the use of cisterns and wind towers to cool buildings during the hot season (Bahadori, 1978).

Window unit air conditioners are installed in an open window. The interior air is cooled as a fan blows it over the evaporator. On the exterior the heat drawn from the interior is dissipated into the environment as a second fan blows outside air over the condenser. A large house or building may have several such units, permitting each room to be cooled separately. Packaged terminal air conditioner (PTAC) systems are also known as wall-split air conditioning systems. They are ductless systems. PTACs, which are frequently used in hotels, have two separate units (terminal packages), the evaporative unit on the interior and the condensing unit on the exterior, with an opening passing through the wall and connecting them. This minimizes the interior system footprint and allows each room to be adjusted independently. While room air conditioning provides maximum flexibility, when used to cool many rooms at a time it is generally more expensive than central air conditioning. (Hearst Magazines, June 1935)

Split systems: Split-system air conditioners come in two forms: mini-split and central systems. In both types, the inside-environment (evaporative) heat exchanger is separated by some distance from the outside-environment (condensing unit) heat exchanger. Other types are:

- Mini-split (ductless) system: A mini-split system typically supplies chilled air to a single or a few rooms of a building. Mini-split systems typically produce 9,000 to 36,000 Btu (9,500–38,000 kJ) per hour of cooling.
- Central (ducted) air conditioning: Central (ducted) air conditioning offers whole-house or large-commercial-space cooling, and often offers moderate multi-zone temperature control capability by the addition of air-louver-control boxes. In central air conditioning, the inside heat-exchanger is typically placed inside the central furnace/AC unit of the forced air heating system which is then used in the summer to distribute chilled air throughout a residence or commercial building.
- Portable units: Portable air conditioners are either evaporative or refrigerative.

- Portable split system: A portable split system has an indoor unit on wheels connected to an outdoor unit via flexible pipes, similar to a permanently fixed installed unit.
- Portable hose system: Hose systems, which can be monoblock or air-to-air, are vented to the outside via air ducts. The monoblock type collects the water in a bucket or tray and stops when full. The air-to-air type re-evaporates the water and discharges it through the ducted hose and can run continuously. A single-hose unit uses air from within the room to cool its condenser, and then vents it outside. This air is replaced by hot air from outside or other rooms (due to the negative pressure inside the room), thus reducing the unit's effectiveness (http://www.mitsubishipro.com/en/professional/products/heat-pump-systems/m--p-single-zone/m-series-heat-pump-systems/msz-fhmuz-fh).

C. What are Embedded Systems (ES)?

"An embedded system is a microcontroller-based, software-driven, reliable, real time control system, autonomous, or human-or network-interactive, operating on diverse physical variables and in diverse environments, and sold into a competitive and cost-conscious market" (Wilmshurst, 2010). An embedded system is the one that has computer hardware with software embedded in it as one of its most important components. It is a device that includes a programmable computer but is not itself intended to be a general purpose computer.

Embedded Systems (ES) are a combination of hardware and software, specially designed for a particular purpose to perform single or a very small task in the most efficient way states Figueiredo (2014). They are computing systems with tightly coupled hardware and software integration, which are designed to perform a dedicated function. An embedded system is a combination of computer hardware along with the mechanical or electrical parts, and system software to perform some specific task (Figueiredo, 2014).

The ES is a sophisticated system consisting of several hardware and software components, and its design may be several times more complex than that of a PC and the programs running on a PC. The ES processor can be a

general-purpose processor chosen from number of families of processors, microcontrollers, embedded processors and digital signal processors (DSPs). Alternatively, an application specific instruction processor (ASIP) may be designed for specific application on a VLSI chip. (http://www.newpagepublishers.com/samplechapter/002081.pdf)

"A general-purpose definition of ES is that they are devices used to control, monitor or assist the operation of equipment, machinery or plant. "Embedded" reflects the fact that they are an integral part of the system. In many cases, their "embeddedness" may be such that their presence is far from obvious to the casual observer". "An embedded system is one that has dedicated purpose software embedded in computer hardware". (www.bookspar.com/wp-content/.../Unit-1-Embedded-Systems.)

WHAT DO EMBEDDED SYSTEMS INCLUDE?

Embedded system embeds (locates) a software image in the ROM. The image mostly consists of the following:

-Boot up program

-Initialization data

-Strings for an initial screen display or system state.

-Programs for the multiple tasks that the system performs.

-RTOS kernel.

POINTS TO REMEMBER

1. An Embedded System is single functioned and AC can be remembered as a simple example.
2. Embedded Systems are Real time systems which is reactive in nature.
3. Many design challenges are associated with making an embedded system, including cost, power etc.
4. Embedded systems are classified into three major divisions: Small scale, Medium scale and Large scale.

REQUIREMENTS FOR OPERATION

The embedded system needs a power source and controlled and optimized power-dissipation from the total energy requirement for given hardware and software.

Clock and reset circuits

Use of the clock manager is a recent innovation.

Needs interfaces: Input Output (IO) ports, serial UART and other ports to accept inputs and to send outputs by interacting with the peripherals, display units, keypad or keyboard.

Bus controllers for networking its buses with other systems.

Timers and a watchdog timer for the system clock and for real time program scheduling and control.

An interrupt controlling unit.

ADC for taking analog input from one or multiple sources.

DAC using PWM for sending analog output to motors, speakers, sound systems, etc.

An LED or LCD display units, keypad and keyboard, pulse dialer, modern, transmitter. multiplexers and demultiplexers.

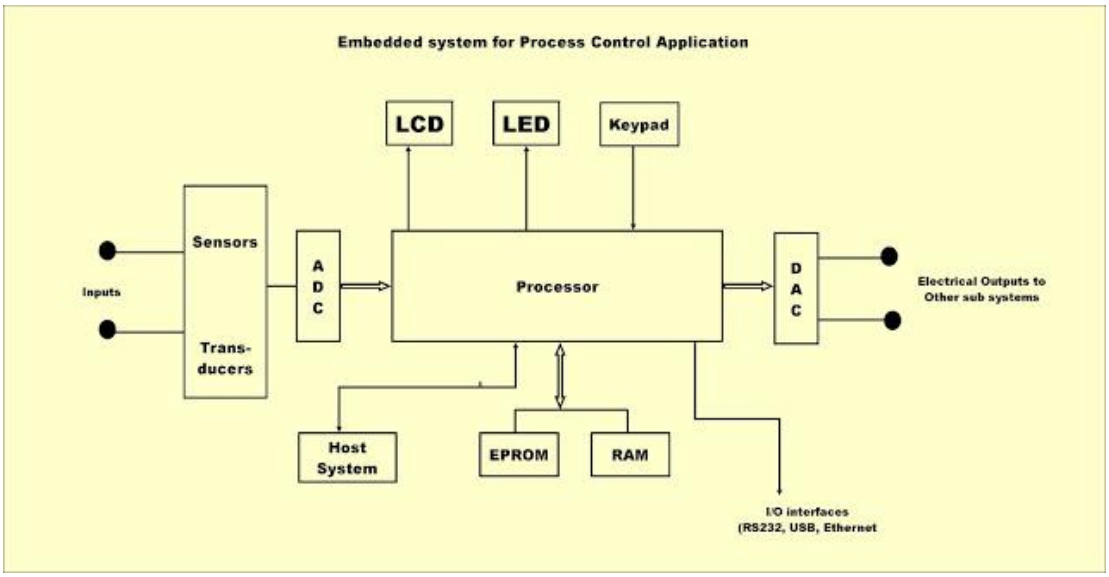


EXHIBIT: 1. Embedded System – an Introduction

ES are the electronic system that contains a microprocessor or micro-controller but people do not think of them as computers- the computer is hidden or embedded inside the system (en.wikipedia.org/wiki/Embedded_system). ES, an emerging area of computer technology, combine multiple technologies, such as computers, semiconductors, microelectronics, and the Internet, and as a result, are finding ever-increasing application in the modern world. These systems have been touching and changing modern lives like never before. ES is a combination of computer hardware, software, and additional mechanical or other technical components, designed to perform a dedicated function.

Most of such systems need to meet real time computing requirements. (https://software.intel.com/.../ AADIP_Chapter%201%20Embedded_System)

Categorization of embedded systems:

1) Broadly one can classify embedded system into any of these based on the performance of the microcontroller.
    - Small Scaled Embedded Systems
    - Medium Scaled Embedded Systems and
    - Sophisticated Embedded Systems.

- **Small scaled embedded system**: An embedded system supported by a single 8-16 bit Microcontroller with on-chip RAM and ROM designed to perform simple tasks is a Small scale embedded system.
- **Medium scaled embedded system**: An embedded system supported by 16-32 bit Microcontroller/Microprocessor with external RAM and ROM that can perform more complex operations is a Medium scale embedded system.
- **Large scaled embedded system**: Embedded system supported by 32-64 bit multiple chips which can perform distributed jobs is considered as a Large scale embedded system.

2) Embedded Systems can be categorized based on the complexity in building, cost factors, purpose of the system, tools and other related environment, availability, etc. as given below

Table 2: Categorization of Embedded Systems

Specifications	Small Scale Embedded System	Medium Scale Embedded System	Sophisticated Embedded System
Processor	**Here it may include 8 bit or 16 bit processor (it can't do computationally intensive process)**	**It may include a 16 bit or 32 bit processor. (It can think of little complex with this processor)**	**PLA, PAL, FPGA, and ASIC will fall in this category. (These are high end design elements that can be used to do wonders)**
Hardware Complexity	**Very little complexity will be visualized here.**	**Will have to face more complexity in terms of peripheral additions, interfaces etc.,**	**Highly Complex. (designers need enormous expertise to do and proceed with this)**
Software Complexity	**No complexity will be there in this coding. Because the device is not meant for performing complex functionalities.**	**There will be complexity added up. This will have few functions and code might be lengthy.**	**Most Complex. Designer needs to be a master to work on the code.**
Power	**Battery operated**	**Battery operated or live source based**	**Can be Battery or Live Source based on the application.**
Tools Availability	**Can be programmed in simple environment. So no much research on tools is required here.**	**Here one will have to use Debugger, Compiler, IDE etc., as the task goes slightly cumbersome.**	**Designer needs sophisticated environment here.**
Examples	**Calculator can be the simplest example. Stepper motor controller can be added to the list.**	**Washing Machine, Microwave Oven, and Vending machine.**	**Flight Landing Gear Systems, Car Braking Systems, Military Applications, Robots.**

3) Embedded systems can be classified into the following 4 categories based on their functional and performance requirements.
    - Stand-alone embedded systems
    - Real-time embedded systems- Hard real-time systems and Soft real- time systems
    - Networked embedded systems and
    - Mobile embedded systems

    Embedded systems span all aspects of our modern life. The Table overleaf gives the various applications of embedded systems.

Table 3: Applications of Embedded Systems

S. No	Embedded System	Application
1	Home Application	Dishwasher, washing machine, microwave, Top-set box, security system, HVAC system, DVD, answering machine, garden sprinkler systems etc.
2	Office Automation	Fax, copy machine, smart phone system, modem, scanner, printers.
3	Security	Face recognition, finger recognition, eye recognition, building security system, airport security, alarm system.
4	Academia	Smart board, smart room, OCR, calculator, smart cord.
5	Instrumentation	Signal generator, signal processor, power supplier, and Process instrumentation.
6	Telecommunication	Router, hub, cellular phone, IP phone, web camera.
7	Automobile	Fuel injection controller, anti-locking brake system, air bag system, GPS, cruise control.
8	Entertainment	MP3, video game, Mind Storm, smart toy.
9	Aerospace	Navigation system, automatic landing system, flight attitude controller, space explorer, space robotics.
10	Industrial	Assembly line, data collection system, monitoring system on pressure, voltage, current, temperature, hazard detecting system, industrial robot.
11	Personal	PDA, iPhone, palmtop, data organizer.
12	Medical	CT scanner, ECG, EEG, EMG, MRI, Glucose monitor, blood pressure number, medical diagnostic device.
13	Banking and Finance	ATM, smart vendor machine, cash register, share market.
14	Miscellaneous	Elevators, tread mill, smart card, security door etc.

D. How do Major Electronic Household Appliances Operate

a) **Operation mechanism in a Washing Machine:** Washing machine comes in two models i.e. – Top loading and Front loading machines.

Top loading machine –In top loading models the agitator of the machine twists back and forth and pulls the cloth down to the bottom of the tub. On

reaching the bottom of the tub the clothes work their way back up to the top of the tub where the agitator grabs them again and repeats the mechanism.

Front loading –In front loading machines the clothes are tumbled and plunged into the water over and over again. This is the first phase of washing. In the second phase of washing, water is pumped out from the tub and the inner tub uses centrifugal force to wring out more water from the clothes by spinning at several hundred rotations per minute(RPM) . This phase is called as “Spin Phase”. In the keyboard panel of the washing machine one can see three buttons like wash, spin and rinse. These buttons can be used to configure the washing stages. The inner tub of the machine contains a number of holes and during the spin cycle the inner tub spins, and forces the water out through these holes to the stationary outer tub from which it is drained off through the outlet pipe.

b) How Microwaves Work?

Microwave oven designers take advantage of the physical properties of food and electromagnetic waves. Basically, microwave ovens use electromagnetic waves to generate heat by moving water molecules. When caught in electromagnetic waves, water molecules move very quickly in a counterclockwise then clockwise motion, alternating back and forth at extreme speeds. This movement generates heat energy. When food is placed in a microwave oven, the movement of water molecules within the food generates heat energy that causes the food to warm rapidly. The two operating systems within a microwave oven connect directly to one another through the path of electricity that flows through the oven. Power enters a microwave oven through a power cord in the form of electricity. A series of fuses within the oven moves this electricity from the power cord to the computer system. The computer system relays information through a switch called a triac, which works only if all of the fuses and switches translating electricity throughout the oven operate properly. The triac helps to protect a microwave oven's electrical problems. If everything works properly, the triac turns on the oven's high-voltage transformer, which generates the electromagnetic, or microwaves that cook food. (http://www.ehow.com/info_12177413_operating-systems-microwave-ovens.html)

c) Principle of operation of Dishwasher

The principle of operation of the automatic dishwasher is to direct hot water and detergent at high speeds over dirty dishes. The mechanical action is provided by a motor-driven impeller or rotating spray arm plus other auxiliary water distributing devices. When the washes and rinses are completed, air warmed by a heating element is directed over the dishes for drying. The impeller dishwasher, in which a motor-driven impeller distributes water in all directions inside the tub, is one of two general systems in current use.

The other is the spray arm dishwasher, in which water is re-circulated by a separate pump, emerging from the nozzles of the spray arm, which rotates by recoil and sends water onto the dishes. In both types of dishwashers, the washing is accomplished by the combination of the mechanical force of the water striking the dish and removing the soil, and the chemical action of the hot, detergent water on grease and other food soils. To accomplish both functions, the dishes must be arranged in the tub so they will drain properly and water will not be trapped. Cold water is piped into the machine from home water supply.

The heating element at the bottom of the machine, powered by electricity, warms the water to a temperature of 30–60°C (86–140°F). That's far hotter than the water most people would use to wash by hand, which is why dishwashers are more hygienic (remove more bacteria) than ordinary hand-washing. An electric pump at the bottom of the machine pumps the water up through the side walls. The water squirts up through holes in the bottom, metal paddle, making it spin around. The bottom paddle is made of metal because it needs to withstand hotter temperatures at the base of the machine. After the water has bounced off the plates, it falls back to the bottom of the machine, where it is heated and pumped around the circuit again. After it flips out of the automatic dispenser on the door, the dishwasher tablet falls into the bottom of the machine and dissolves in the hot water there.

Wash action

Wash action in the dishwasher may be provided by water coming from as any as five different positions. Same levels are especially located for cleaning certain items such as the silverware. In each design, the water should be able to

move freely over and around the items in the load. The wash action may vary from one cycle to another. Regular and normal speed will be used for all cycles except the china-crystal cycle.

For this cycle, a second slower speed is accomplished by opening an air valve to give an effect similar to the aerator on a sink faucet. Such action reduces the force of the water and thus helps to prevent damage to fine china and crystal and light articles by their being forced out of position. Filtering action in the dishwasher may vary from one design to another. One design traps the food in a filter as it is washed from the dishes. This prevents the soil from returning through the spray arms to be re-circulated. The reverse flow of water sweeps the soil from the filter down the drain during the drain period.

d) Energy transfer in Air conditioner

In a thermodynamically closed system, any power dissipated into the system that is being maintained at a set temperature (which is a standard mode of operation for modern air conditioners) requires that the rate of energy removal by the air conditioner increase. This increase has the effect that, for each unit of energy input into the system (say to power a light bulb in the closed system), the air conditioner removes that energy. It is typical for air conditioners to operate at "efficiencies" of significantly greater than 100% (Winnick, 1996).

Thermal comfort within air-conditioned spaces affects occupants' productivity and health, state Leephakpreeda, et al (2012) A new conceptual development in designing air-conditioning systems has indicated that the indoor comfort temperature strongly depends upon changes of the outdoor air temperature rather than to be a conventional fixed temperature set-point (Leephakpreeda, et al, 2001).

In both comfort and process applications, the objective may be to not only control temperature, but also humidity, air quality, and air movement from space to space (http://www.mitsubishipro.com/en/professional/products/heat-pump-systems/m--p-single-zone/m-series-heat-pump-systems/msz-fhmuz-fh).A "regular" air conditioner transfers heat.

e) Refrigeration cycle

In the refrigeration cycle, heat is transported from a colder location to a hotter area. As heat would naturally flow in the opposite direction, work is required to achieve this. A refrigerator is an example of such a system, as it transports the heat out of the interior and into its environment (i.e. the room). The refrigerant is used as the medium which absorbs and removes heat from the space to be cooled and subsequently rejects that heat elsewhere. Circulating refrigerant vapor enters the compressor and is compressed to a higher pressure, resulting in a higher temperature as well.

The hot, compressed refrigerant vapor is now at a temperature and pressure at which it can be condensed and is routed through a condenser. Here it is cooled by air flowing across the condenser coils and condensed into a liquid. Thus, the circulating refrigerant moves heat from the system and the heat is carried away by the air. The condensed and pressurized liquid refrigerant is next routed through an expansion valve where it undergoes an abrupt reduction in pressure. That pressure reduction results in flash evaporation of a part of the liquid refrigerant, lowering its temperature. The cold refrigerant is then routed through the evaporator. A fan blows the warm air (which is to be cooled) across the evaporator, causing the liquid part of the cold refrigerant mixture to evaporate as well, further lowering the temperature. The warm air is therefore cooled. To complete the refrigeration cycle, the refrigerant vapor is routed back into the compressor.

E. Types and Functions of Embedded Systems

The embedded system most often needs a real-time operating system for real-time programming and scheduling, device drivers, device management and multitasking. There are a large number of applications and products that employ embedded systems. A VLSI chip can embed IPs for the specific applications, besides the ASIP or a GPP core. A system-on-chip is the largest concept in embedded systems, for example, a mobile phone Embedded systems exist in other simple computerized mechanisms, such as remote controls and washing machines (Sanchez and Maria, 2007)

A system is also an arrangement in which all its units assemble and work together according to the plan or program. An embedded system is a sophisticated system that has a computer (hardware with application software and RTOS embedded in it) as one of its components. A processor has two essential units: Program Flow Control Unit (CU) and Execution Unit (EU). The CU includes a fetch unit for fetching instructions from the memory. The EU has circuits that implement the instructions pertaining to data transfer operations and data conversion from one form to another. The instructions, defined in the process instructions set, are executed in the sequence, that they are fetched from the memory. A processor is mostly in the form of an IC chip; alternatively, it could be in core in an ASIC or at a SOC. Core means a part of the functional circuit on the VLSI chip. An embedded system is a dedicated computer-based system for an application or product. Memory, timer, watchdog timer, interrupt controller, ADC or PWM, etc. are provided as required by the application.

- **Processor: A processor implements a process or processes as per the command (instruction) given to it.**
- **Process: A program or task or thread that has a distinct memory allocation of its own and has one or more functions or procedures for specific job. The process may share the memory (data) with other tasks.**
- **A processor may run multiple processes separately or concurrently.**
- **Microcontroller: A unit with a processor. (*highered.mheducation.com/sites/dl/free/007340456x/.../sample1.pdf*)**

How do these technologies operate in household appliances?

- **Washing machines:**

It is an automatic clothes-washing system. The important hardware parts include its status displays panel, the switches and dials for users-defined programming, a motor to rotate or spin, its power supply and control unit, an inner water-level sensor, a solenoid valve for letting water in and another valve for letting water drain out. These parts organize to wash clothes automatically

according to a program present by a user. The system-program is to wash the dirty clothes placed in a tank, which rotates or spins in pre-programmed steps and stages. It follows a set of rules. Rules pertain to following

- ✓ *Step 1. Wash by spinning the motor according to a programmed period.*
- ✓ *Step 2. Rinse in fresh water after draining out the dirty water, and rinse a second time if the system is not programmed in water-saving mode.*
- ✓ *Step 3. After draining out the water completely, spin fast the motor for a programmed period for drying by centrifuging out water from clothes.*
- ✓ *Step 4. Show the wash-over status by a blinking display.*
- ✓ *Step 5. Sound the alarm for a minute to signal that the wash cycle is complete. At each step, display the process stage of the system.*

In case of an interruption, the system executes only the remaining part of the program, starting from the position when the process was interrupted. There can be no repetition from Step 1 unless the user resets the system by inserting another set of clothes and resets the program.

- **Embedded System Application in Washing machine**

A washing machine has built-in basic washing programs that can be selected and started by Push-buttons.

Application Specific E.S: One of the examples of application specific E.S is a washing machine. Washing machine contains sensors, actuators, control unit and application –specific user interfaces like keyboards, display units etc. The actuator part of the washing machine consists of motorized agitator, tumble tub, water drawing pump and inlet valve to control the flow of water into the unit. The sensor part consists of the water temperature sensor, level sensor etc. The control part contains a microprocessor/ controller based board with interfaces to the sensors and actuators. The sensor data is fed back to the control unit and the control unit generates the necessary actuator outputs. The control unit also provides connectivity to user interfaces like keypad for setting the washing time, selecting the type of material to be washed like light, medium, heavy duty etc.•

User feedback is reflected through the display unit and LEDs connected to the control board. (Chopra, 2013)

The design of washing machines may vary from manufacturer to manufacturer but the general principle underlying in the working of the washing machine remains the same. The basic controls consist of a timer, cycle selector mechanism, water temperature selector, load size selector and start button. The mechanism includes the motor, transmission, clutch, pump, agitator, inner tub, outer tub and water inlet valve. Water inlet valve connects to the water supply line using at home and regulates the flow of water into the tub. The integrated control panel consists of a microprocessor/controller based board with I/O interfaces and a control algorithm running in it.

Input interface includes the keyboard which consists of wash type selector namely wash, spin and rinse, cloth type selector namely Light, Medium, Heavy duty and Washing time setting etc. The output interface consists of LED/LCD displays, status indication LEDs etc. connected to the I/O bus of the controller. This interface may vary from manufacturer to manufacturer and model to model. The other types of I/O interfaces which are invisible to the end user are different kinds of sensor interfaces like water temperature sensor, water level sensor, etc and actuator interface including motor control for agitator and tub movement control, inlet water flow control etc. (Chopra, 2013)

- **Embedded System Application in a Microwave oven**

Technically regarding computer technology, microwave ovens contain embedded systems, not operating systems. An operating system handles a large framework of commands and functions, such as those required by a computer with multiple programs. An embedded system, on the other hand, performs a very specific function. These systems contain a single program that executes all the functions required. While there are many different styles of microwaves, several primary devices remain the same throughout different models. Microwaves have become very automated and the addition of sensors have made them much more effective and safe to use, but the original design still holds true. (Sanchez and Maria, 2007).

The embedded system in a microwave oven works as a command device. It is designed to take directions from the keypad and turn them into commands. If, for instance, when a user programs a microwave oven to operate on high for two minutes, the embedded system triggers the high voltage transformer to operate on full blast for two minutes. When the two minutes expire, the embedded system commands the transformer to turn off. Because the embedded system does nothing more than translate simple commands, it contains relatively simple programming. (http://www.ehow.com/info_12177413_operating-systems-microwave-ovens.html)

- **Embedded system application in Dishwasher**

The dishwasher should have safety features such as a motor overload protector, water overflow protector, and a safety switch. The motor overload protector prevents the motor from burning out if it becomes overheated. The water overflow protector prevents overflow of water should the fill valve become defective. A safety switch stops the flow of water when the dishwasher door is opened

Many new dishwashers feature microprocessor-controlled, sensor-assisted wash cycles that adjust the wash duration to the quantity of dirty dishes (sensed by changes in water temperature) or the amount of dirt in the rinse water (sensed chemically/optically). This can save water and energy if the user runs a partial load. In such dishwashers the electromechanical rotary switch often used to control the washing cycle is replaced by a microprocessor but most sensors and valves are still required to be present. However, pressure switches (some dishwashers use a pressure switch and flow meter) are not required in most microprocessor controlled dishwashers as they use the motor and sometimes a rotational position sensor to sense the resistance of water. When it senses there is no cavitation it knows it has the optimal amount of water. A bimetal switch or wax motor opens the detergent door during the wash cycle. Some dishwashers include a child-lockout feature to prevent accidental starting or stopping of the wash cycle by children. A child lock can sometimes be included to prevent young children opening the door during a wash cycle. This prevents accidents with hot water and strong detergents used during the wash cycle.

A dishwasher should never be emptied before a complete process has been signified to be finished by the control system, as this will often leave the contents unwashed or still in a saturated state. It is a common misconception that to empty a dishwasher before the end of a cycle will save energy, as many of the contents may need to be re-run, hence almost doubling running costs. (http://en.wikipedia.org/wiki/dishwasher)

- **Embedded System Application in an Air conditioner**

The temperature is set as per requirement, say 20 °C. There may be variations in external temperature and that will also reflect in the room where air conditioner is fitted. But however the external temperature varies, the AC machine facilitates user with cool atmosphere (i.e., 20 °C) inside the room as per requirement. (www.newagepublishers.com/samplechapter/002081.pdf)

An electronic controller built into the application, continuously monitors the process variables and ensures that the Process Variable (PV) does not change; in the event of a change the controller generates a counteracting signal applied to the application so that the deviated PV is brought to its normal operating value. This could define embedded systems clearly**! In air conditioner, temperature is the process variable.** A controller inside will keep on monitoring the process variable. If at all the room temperature changes due to variation in external temperature, controller will take a counter acting signal and PV (temperature) will be brought to required range. (www.newacademicscience.co.uk/ *samplechapter/000082.pdf)*

MICRO PROCESSOR ???

- *It is a programmable digital electronic component that incorporates the functions of a central processing unit (CPU) on a single semi conducting integrated circuit (IC)*
- *Microprocessor is the integration of a number of useful functions into a single IC package that has,*
  - ✓ *The ability to execute a stored set of instructions to carry out user defined tasks.*
  - ✓ *The ability to access external memory chips to both read and write data from and to the memory.*

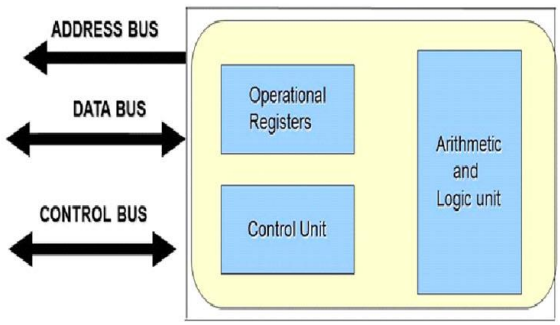
It is small (micro) and will do any computation (Processor)

Hence the name MICRO PROCESSOR

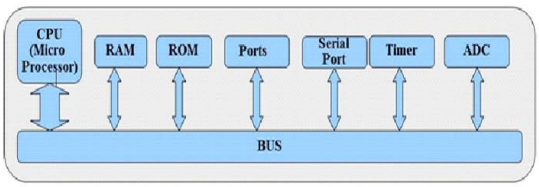
MICRO CONTROLLER ???

- *Microcontroller is a small (micro) single-chip computer designed to perform a specific function, and the specific function is to control (controller) objects, processes or events.*
- *It is dedicated to one task, or a set of closely related task. It is similar to a personal computer, it has similar components built on to a single chip:*
  - ✓ *CPU, Memory (ROM and RAM)*
  - ✓ *I/O ports, Serial ports*
  - ✓ *Timer*

FUNCTIONAL BLOCKS



MICRO CONTROLLER HAS...



CPU	*:Processing Module*
RAM	*:For storing DATA*
ROM	*:For storing the application program*
Ports	*:For interfacing with the outside world*
Timer	*:Allows the MCU to perform tasks for certain time periods*
ADC	*:Allows the MCU to accept analogue input data for processing*

MICROPROCESSOR will have....

ALU -Arithmetic and logic Unit
Accumulator Register
General Purpose Register (A,B,C,D,E,H AND L)
Instruction Register
Flags (Z,S,P,CY and AC)
Program Counter
Stack pointer
Data Pointer

Data and Address Buses (8 , 16 32 bit and more)

MICROPROCESSOR ,BY-ITSELF, is Incomplete

- ♦Add computer power to a device to enable to perform more, better at a low cost
- ♦ Ideal for applications in which cost, power and space are crucial.
- ♦ Easy integration with circuits
- ♦ Programmable and re programmable.
- ♦ Lots of inbuilt I/O capabilities.

A Microcontroller is a single chip device:

Analogous to a computer system with

A processor
Program storage
Data storage
Timers
Input/Output Ports
Interrupt service capability

This versatile chip provides us the the capability for developing simple to complex applications

Exhibit: 2

III. PLAN AND PROCEDURE

The plan and procedure pertaining to the study on **"Embedded Systems Applications in Household Appliances' Performance- an Assay"** are streamlined under the following broad headings:

A. Consumer Survey
B. Field Research
C. ES Incorporated Appliances- A Portfolio

A. Consumer Survey: According to Agarwal (2009)a survey is a process of collecting data from the existing source about a problem under study with no particular control over the factor that affect the characteristics of interest in the study. As the sample chosen were consumers, the plan included a consumer research, which involves the study of demographic features of consumers, their needs and expectations about products, factors influencing purchase decisions, level of consumer satisfaction etc. (Vinod, 2006). The survey was mainly drafted to draw information on the buying habits of the consumers on electrical/electronic household appliances (gadgets). Hence, the methodology pertaining to this part of the study is channelised to include the following :

1. **Selection of Locale:** Coimbatore city being the hub of commercial activity, this locale was selected for conduct of the study using convenience sampling. Sampling is the process of learning about a population on the basis of a sample drawn from it states, Gupta (2010), while convenience sampling refers to the collection of information from members of the population who are conveniently available to provide it (Sekaran, 2006). Ease in access as the investigator resides in the city and availability of the required sample was the factors considered in the selection of the locale.
2. **Selection of Sample:** The topic under consideration being details on household appliances, the sample selected was evidently homemakers with rich experience in homemaking. To facilitate collection of reliable data 50 consumers, all women who were gainfully employed were selected adopting purposive sampling. Purposive sampling is the method used for relating, the targeted particular group when the desired population for the study is rare or very difficult to locate and recruit for the study (Saravanavel, 2005).

   Household appliances assume a major role in effective homemaking while the productivity and efficiency of the homemaker gets reflected through her

prudent choice of such labour saving gadgets. Such appliances are floated in the market with high sophistication. These are electrical / electronic gadgets available for almost all household activities. Perhaps, all modern households are saturated with various such gadgets which have a major role to play in assisting the homemaker-the ultimate consumer. Hence 50 consumers who were end-users of such gadgets were selected for conduct of the study. Ease in approachability, minimum ten years of homemaking experience, affordability and willingness to participate were the criteria considered in selection of the samples.

3. **Selection of Method and Tool**: The method decided upon was face-to-face interview, a system in which both the investigator as well as the informants discusses the problem under research, the former usually taking the initiative with the object of extracting information from the latter (Sharma, 2007). No other approach enables ones to glean much information and yet remain so flexible states, Misra(2001). The method used was a semi-structured interview. This kind of interview begins with a streamlined set of questions, but has the flexibility to add additional questions based on the interviewee's responses (http://www.geo.mtu.edu). The tool used was an interview schedule. According to John (2004) an interview schedule is a performa containing a set of questions and is very useful in gathering information. It elicit d details on sample's family background, possession of electrical/electronic gadgets, purpose, and motivation for purchase, use, reasons for purchase and the like. A model schedule was tested on three samples. Necessary modifications were effected based on the light of the study and finalised. A sample of the schedule is presented under Appendix I. The inquiry basically was to derive information about the popularity of manufacturer's brand of applicants with embedded system in the household level.

   The interview was coupled with observation so as to enable the interviewer to collect more reliable data. Observation, in Kothari's (2007) words in the basic method of obtaining information about the world around. This method helped the investigator to observe the gadgets used in the selected households, a few particularly when they were in use. Hence both the methods facilitated in gathering primary data, proving this as a **'primary research'**, as it is based on data from primary sources (Vinod, 2006).

4. **Conduct of the study:** The samples were approached during leisure to collect details as per the schedule. The findings are analysed and are presented under Chapter IV.

B. Field research: When data collection is based on primary data, it is also referred to as field research (Vinod, 2006). If the home makers have to be enjoying electrical/electronic gadgets in the houses, there has to be good many companies/agencies selling them. To comprehend details on this score this part of the study was channelised to include the following steps:

1. **Selection of Locale:** Coimbatore City which is famous as a 'business-hub' was the locale selected for the study. Specific areas within the City like Gandhipuram, Race Course, Saibaba colony, Vadakovai and Townhall which house many showrooms dealing with sale of sophisticated household appliances was chosen adopting purposive sampling.
2. **Selection of Sample:** The consumer survey brought to light five electrical/electronic appliances, one each for cooking, storing, washing clothes, washing dishes and for comfort to have conquered the minds of the consumers. Their presence was highly felt in the selected households. Hence, dealers who dealt with the sale of these gadgets were picked and chosen for further study. Hence, the sampling method chosen was purposive, which advocate deliberate selection of sample units that confirm to some predetermined criteria, also known as judgment sampling (Kothari, 2005). Thus the popular showrooms spread across the City were chosen for the study.
3. **Selection of Method and Tool:** Personal interview was the chosen method which also enabled side-by-side observation. Personal interview requires a person(the interviewee) asking questions generally in a face-to-face contact to the other person or persons, while collecting data (Kothari, 2007)

   To facilitate in the process an interview guide was used. An interview guide is a list of topic questions as areas which the interviewer uses merely as a prompter during the interview(Saravanavel, 2008). Observation was tied up with interview as it affords accurate watching and noting of phenomena as they occur in nature with regard to cause and effect or mutual relation (Cauvery, et al, 2010).

   The tool requested details on the specific five appliances- nature of embedded systems (ES), their function in appliances, popular brands/firms, value addition affected through ES, special features added, models floated, product differentiation and diversification entertained by the firms (the manufacturers) contributions to social-cost benefits and environmental

protection, star rating and many such factors which have become the functional criteria based on which sales volume increases on the one hand and the customers decide on their **'product positioning'** on the other.

4. **Conduct of the Study:** The floor managers of the shops were visited during their leisure, necessary rapport was created, purpose of the study was explained and the needed information was collected. Hence both the surveys facilitated collection of primary data from the concerned samples. The data obtained was consolidated, analysed and is presented under Chapter IV.

C. ES Incorporated Appliances – a Portfolio: While the first two sections of the study stressed on primary data and use of appliances with ES in real time situations, this part of the study earmarked its venture to collect data from **secondary sources**. Therefore this part of the study is dependent on **'secondary research'** in its totality.

Rationale: The floor managers / proprietors met in the showrooms could enlighten the investigator only on the functional components of the five selected appliances, namely, microwave oven (cooking), refrigerator (storing), washing machine (washing), dishwasher (cleaning), and air conditioner (comfort giving / luxury) appliances. ***Details regarding the inputs to value addition in these appliances by different firms were not in their purview***.

State - of - the - art microcontroller / microprocessor based advances in technology have created a boom in the appliances' industry, especially with the advent of electronics and embedded systems. Majority of the appliances have become sleek, robust, intelligent, efficient, high – performers. Their ***'brain – child'***, the ***'sookshmakartha'*** lies hidden in a chip (an integrated circuit) and are invisible to the user's eye. It is high time the end – users, the consumers, gained knowledge on at least the basics of these technologies which have transformed their day to day living. Such invisible chips and their role in enhancing the performance thresholds of appliances have to be made known to the end – users. Being ubiquitous, consumers' dependence on them can never be shaken.

Proliferation of HMI (Human Machine Interfaces) oriented gadgets and touch controls, all the more have made it indispensible that the end – users have to have minimal knowledge about them. Perhaps details on the microcontroller or microprocessor (software used) used to performance – empower these gadgets are not within the purview of the study; it aims only to locate the functional components. Therefore the impetus on

knowledge about such inputs that the firms manufacturing household appliances have incorporated in their gadgets.

Though details are readily available on their respective websites, access to and by consumers are felt lacunas. Hence the details were downloaded and the inputs incorporated by individual Firms categorized and presented as individual case studies under Results and Discussion.

1. **USP Strategies Adopted by the Firms**: 'Secondary research', a study depending on secondary sources of data was the method adopted. The data was downloaded from individual, respective websites of the most popular Brands and analyzed for unique features offered. Findings of this part of the study portray the "Unique Selling Propositions" (USP) innovate and introduces in their various models of appliances, product differentiation and product flanking strategies adopted by select Firms (maximum represented in the consumer survey) and the price differentials accrued due to such value additions. These facts are delineated under Chapter IV.
2. **Basic Circuit Diagrams for Household Appliances with ES**: Basic circuit diagrams for individual appliances, components of the appliances, operational features for successful performance and the like were collected from secondary sources and the details are presented as a portfolio in Results and Discussion.

IV. RESULTS AND DISCUSSION

The findings pertaining to the study on **'Embedded System Applications in Household Appliances' Performance – An Assay'** are analysed under the following broad headings:

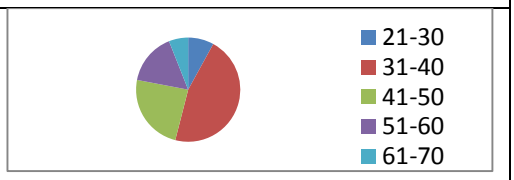
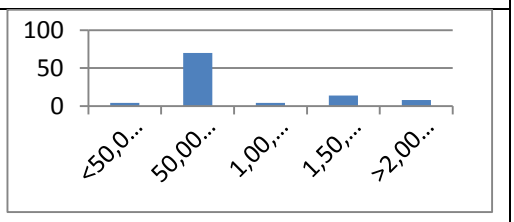
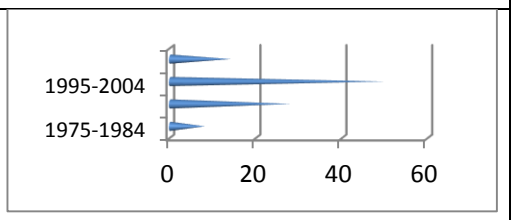
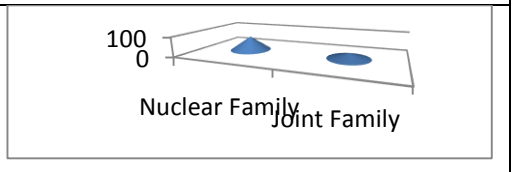
A. Outcomes of Motivation Research
B. Profile of the Appliances Market
C. Unique Selling Proposition via ES Strategies Adopted.
D. Portfolio of Circuit Diagrams for Household Appliances with ES

A. Outcomes of Motivation Research: This part of the findings is analysed under:

1. Family Profile
2. Psychographic Segmentation- Preference for Appliance

1. Family Profile: The family profile of the selected samples is presented under Table

Table: 4. Family Profile of the Consumer

Personal Information	Details	Percentage reporting (N=50)	
Age(range in years)	21-30	**8**	
	31-40	**46**	
	41-50	**24**	
	51-60	**16**	
	61-70	**6**	
Monthly family income (Range in Rs.)	<50,000	**4**	
	50,000-1,00,000	**70**	
	1,00,000-1,50,000	**4**	
	1,50,000-2,00,000	**14**	
	>2,00,000	**8**	
Year of marriage (Range in years)	1975-1984	**8**	
	1985-1994	**28**	
	1995-2004	**50**	
	2005-2014	**14**	
Type of family	Nuclear Family	**72**	
	Joint Family	**28**	

Almost 86 percent of the samples were found to be in their productive ages between 31-60 years while a merge six percent were found to be senior citizens. It is found to be a good selection as they belong to a heterogeneous mix of age groups. Their attitudes, interests and lifestyles can show difference reflecting their individual lifestyles.

For a majority of 70 percent of the samples monthly income earned fell below `one lakhs, while for 14 percent it was between `1.5to 2 lakhs. Likewise for a negligible four percent the income earned was only below `.50,000/- while eight percent of their counterparts earned above `two lakhs. Disparity in income range was thus found to be prominent.

As if to prove the disappearance of joint families in the Indian societies, 72 percent of the. samples stated to have established nuclear families.

A majority of 78 percent have been in marital life for almost two decades while the rest had put up much more experience in family living. Only 14 percent stated to have been married in the last one decade. These are evidences to prove that their behaviour as consumers of electrical/electronic gadgets for household use is quite rich with experience in selection and use of them. Moreover such an experience would have come handy in the choice of brands and in expressing brand loyalty. Nair and Nair (2002) address this issue among consumers stating that consumers buy what is expressed economically as ***'want satisfaction'***. From their point of view, what they desire are not the products but ***satisfying experiences***.

2. Psychographic Segmentation- Preference for Appliances

Psychographic segmentation is the analysis of people from the inside states, Vinod (2006), focusing on consumer's psychological makeup including social roles, activities, attitudes, interests, opinion and lifestyle-the pattern in which people live and spend money. Hence this aspect of the findings are analysed under:

a. **Appliances Possessed.**
b. **Reasons for Possessing Appliances**
c. **Models Preferred.**
d. **Brands Preference Exhibited.**
e. **Product Positioning**
f. **Awareness on Embedded Systems Applications in Appliances.**

a) Appliances Possessed: Table presents the data on appliances possessed by the selected sample.

Table: 5. Appliances Possessed

Purpose	Appliances possessed	Percent reporting (N=50)
Storing	Refrigerator	**100**
Laundry	Washing machine	**92**
Cooking	Microwave oven	**72**
	Toaster	**68**
Maintenance	Vacuum cleaner	**70**
Luxury	Air conditioner	**70**
Cleaning	Dishwasher	**20**

The survey revealed seven appliances serving six varied purposes to be possessed by the samples. While appliances for storing (refrigerator), laundry (washing machine), and cooking (microwave oven/toaster) ranked high in possession as revealed by 100, 92, 72 and 68 percent of the samples respectively, vacuum cleaners which aided in household maintenance followed next. Air conditioners, a luxury item and dishwashers were owned by 54 and 20 percent of the samples. Among the appliances possessed except toasters and vacuum cleaners, the others were electronic-the modern day gadgets. The reasons for which they were possessed are expressed in the following aspects.

b) Reasons for Possessing Appliances: Need based selection, luxury, availability, simplifying work, saving time and energy, avoiding peak loads, status symbol and affordability were cited as reasons for possessing such appliances. They declare the fast moving trend among consumers to go in for many electronic goods, especially **'white goods'**.

c) Models preferred: This part of the findings is analysed under the following headings:

i. ***Preference for Washing Machines***
ii. ***Type of Refrigerators Purchased***
iii. ***Microwave Ovens Chosen***
iv. ***Vacuum CleanersBought***
v. ***Air Conditioners Sought***
vi. ***Toasters Preferred***

i. **Preference for Washing machines:** Details on this score as presented under Table

Table: 6. Preference for Washing Machines

Brand	Percent reporting (N=46)		
	Model preferred		
	Semi-Automatic	Fully-Automatic (top loading)	Fully-Automatic(front loading)
SAMSUNG	4.3	26.2	8.7
IFB	-	6.5	17.4
LG	4.3	13.0	-
Whirlpool	2.2	13.0	-
BOSCH	-	-	2.2
BPL	-	2.2	-
Total	10.8	60.9	28.3

Fully automatic top loading models were found to be popular among washing machines irrespective of brand preference. Yet fully automatic front loading models also found a place in the consumers' preference.

ii. **Type of Refrigerators Preferred:** Table presents the model variations in refrigerators preferred by the selected consumers.

Table: 7.Types of Refrigerators Preferred

Brand	Percent reporting (N=50)	
	Model preferred	
	Direct cool	Frost free
LG	6	26
Whirlpool	2	22
SAMSUNG	10	20
Godrej	2	-
Haier	8	4
Total	28	72

The two model variations in refrigerators were direct cool and frost free models; between them the latter was much preferred by the samples- as is evident from the 72 per cent who reported so.

iii. **Microwave Ovens Chosen:** The following Table illustrates details on the same.

Table: 8. Microwave Ovens Chosen

Brand	Percent reporting (N=36)		
	Model preferred		
	Solo	Grill	Convection
LG	11.1	16.7	8.33
SAMSUNG	5.6	8.33	13.9
IFB	-	2.8	5.6
Godrej	-	2,8	-
Panasonic	2.8	5.6	2.8
USHA	-	-	2.8
BAJAJ	5.6	-	-
Electrolux	2.8	-	-
SHARP	-	2.8	-
Total	17.9	39.03	33.43

Microwaves were available in the market in three distinct models namely, Solo, Grill and Convection. LG was found to be the most preferred followed by Samsung especially for convection models. Others in the market (seven more firms) were found to be patronised only by a negligible proportion of the customers who owned them.

iv. **Vacuum Cleaners Bought:** Table gives details on the same

Table: 9. Vacuum Cleaners Bought

Brand	Percent reporting (N= 35)	
	Model preferred	
	Wet and dry	Dry
EUREKA FORBES Your friend for life	31.4	48.6
Panasonic	5.7	-
LG	2.9	2.9
PHILIPS sense and simplicity	8.6	-
Total	48.5	51.5

There were two models in vacuum cleaners. Both the models offered by Eureka Forbes were preferred by the samples. It is clear that regarding these products the customers were shrewd enough to choose those brands which had gained reputation and goodwill in the market.

v. **Air Conditioners Sought:** Table illustrates the details pertaining to this data

Table: 10. Air Conditioners Sought

Brand	Percent reporting (N= 35)	
	Model preferred	
	Split AC	Window AC
SAMSUNG	33.3	-
LG	18.5	11.1
VOLTAS	26	-
GENERAL	7.4	-
Carrier	3.7	-
Total	88.9	11.1

Window AC offered by LG alone found a place in the purchases made by the selected sample. Otherwise all others showed preference for split AC (88.9%). Samsung and Voltas topped the list on brand preference as represented by 33.3 and 26 per cent respectively.

vi. **Toaster Preferred:** Details regarding preference exhibited for toasters is presented in the following Table

Table: 11. Toasters Preferred

Brand	Percent reporting (N=34)		
	Model preferred		
	Bread toaster	Sandwich maker	Pop-up toaster
PHILIPS	11.8	11.8	11.8
Premier	-	2.9	-
BAJAJ	11.8	5.9	5.9
Prestige	5.9	26.5	-
USHA	2.9	2.9	-
Total	32.4	50	17.7

All models offered by Phillips had a patronage among the customers, though sandwich toaster of Prestige ranked high in preference.

However these facts are reflective of the customer's behavioural patterns regarding such appliances in the home. These facts project one more aspect. All the consumers, irrespective of brand preference evinced interest in possessing mainly the top-of-the-line models which stand testimony to the advanced technology era. Choice for appliances of lesser technology can be attributed to their affordability.

d) Brand Preference Exhibited: The word 'Brand' is derived from an old Norse word **'brandir'**. It means 'to burn'- meaning imprinting an idea or symbol on a product. The following analysis indicates the brands preferred in household appliances on the following lines:

i. **Brands Preferred in Cooking and Storing Appliances**
ii. **Brand name Popular in Laundry and Cleaning Appliances**
iii. **Preference for Appliances Owned for Luxury and Maintenance**

i. Brands Preferred in Cooking and Storing Appliances:

Brand is the name, term, symbol, mark or design or a combination of them which is intended to identify goods or services of the sellers or a group of sellers and to differentiate them from those of competitors. Table presents the brands preferred among cooking and storing appliances

.

Table: 12. Brands Preferred in Cooking and Storing Appliances

Purpose	Appliances	Percent reporting											
		Brand preference											
		LG	Samsung	IFB	Godrej	Panasonic	Usha	Bajaj	Electrolux	Sharps	Philips	Premier	Prestig
Cooking	Microwave Oven (N=36)	36	28	8	3	11	3	6	3	3	-	-	-
	Toaster (N=34)	-	-	-	-	-	6	24	-	-	35	3	32

The findings revealed two aspects. One, there exists stiff competition among manufacturers of microwave ovens and toasters in the market. Secondly, the consumers or samples were found to successfully capitalise on the market structure and had opted for various brands in purchase of these two items. Though LG and Samsung were the top brands preferred for microwave ovens, Philips, Prestige or Bajaj were the ones preferred for toasters. This has also made clear that as far as small heating appliances are concerned; those three brands had really stolen the show.

ii. Brand name Popular in Laundry and Cleaning Appliances: Washing clothes and cleaning utensils are cumbersome activities for any homemaker. Deciding on purchase of a device that could save their labour in these two activities is a welcome change. Table illustrates the trendsetters in purchase of appliances for these two activities.

Table: 13. Brand name Popular in Laundry and Cleaning Appliances

Purpose	Details	Percent reporting						
		Brand preference						
		IFB	Samsung	LG	Whirlpool	Bosch	BPL	Siemens
Laundry	Washing machine (N=46)	24	39	17	15	2	2	-
Cleaning	Dish-washer (N=10)	10	20	20	-	-	-	50

Vinod (2006) comments on brands as perceptual entity that lives in the consumer's mind. It is no wonder that Samsung, IFB and LG again have emerged as popular brands among consumers who owned washing machines. Though use of dishwashers is yet to have a brilliant take off in India, its presence could be felt in 20 percent of the households surveyed. Brand preference was maximum for Siemens followed by the same three brands. It is evident that these brands have registered in the minds of the consumers and they have achieved a **'product position'**. Product position refers to the place the product occupies in consumer's mind in relation to competing products. (Vinod, 2006)

iii. Preference for Appliances Owned for Luxury and Maintenance: Purchasing appliances that may aid in maintenance of a house and to enhance one's comfort and convenience as luxury good shows the emerging trends in modern consumerism. Table gives details on the appliances possessed for these two purposes.

Table: 14. Appliances owned for Luxury and Maintenance

Purpose	Details	Percent reporting							
		Brand preference							
		Samsung	LG	Voltas	OGene-ral	Carrier	Eureka Forbes	Panasonic	Philips
Luxury	Air conditioner (N=35)	33	30	26	7	4	-	-	-
Maintenance	Vacuum Cleaner (N=35)	-	6	-	-	-	80	6	8

The findings revealed entry of new companies in the market for vacuum cleaners. Yet Eureka Forbes topped the list as they are appliances specific. It was also evident that

these companies were found to show outstanding performance as far as these two purposes were concerned. Further Samsung and LG again emerged as popular brands among air conditioner users. These findings also enabled locating '***Brand Cohorts'***. They are a segment of loyal customers whose usage of that particular brand can be used to understand their reactions to other brands.

e) Product Positioning:

Kotler (1994) opines a product to exist only when it finds a place in the consumer's mind through some distinguishing features in relation to other products in the market based on which they will position a product in their mind. Ultimate aim of product policy is to create a place for the product in the consumer's mind. Therefore it becomes necessary to study consumer behaviour (an element of product positioning) towards the products analysed against the other three product positioning elements namely Product position (design, special features, attributes, quality, price, durability, brand, neutral etc), company positions (goodwill or reputation) and competition (number of competitors and their status). In this connection an enquiry on the brands patronised for all the appliances possessed by them revealed the following data.

Table: 15. Product Positioning-Consumers' View

Appliances	**Brand (top 2 preferred)**	**Models (top 1 or 2 preferred)**
Washing machines	Samsung, IFB	Fully automatic (top loading) Fully automatic (front loading)
Refrigerators	LG, Samsung	Frost free
Microwave ovens	LG, Samsung/IFB	Grill; Convection
Dishwashers	Siemens, LG/Samsung	Front loading
Vacuum Cleaners	Eureka Forbes, Philips	Dry; Wet and Dry
Air conditioners	Samsung, LG	Split AC
Toasters	Prestige, Philips	Sandwich; Pop-up toaster

Samsung, LG and IFB were the brands that had found a place in the minds of the consumers as far as these appliances are concerned. The first five appliances are electronic devices functional with embedded systems. The last two are electrical (motor driven and heating) appliances. These factors point out:

- ***The proliferation of electronic appliances with embedded systems among a selected population.***
- ***Existence of three major companies (Brands) manufacturing appliances with embedded systems.***

- ***Choice of the three popular brands by the selected sample highlighting their product positioning.***

f) Awareness on Embedded Systems Applications in Appliances:

An enquiry on this issue revealed only 35 percent of the samples to be aware of the concept of embedded systems. Ironically none of the samples had knowledge on the existence of embedded systems and their role in performance of household appliances which they used in their everyday life.

Functional aspects, ease in use, economical (suits to budget), ergonomically designed, aesthetic appeal, USP, occupying less space, simple Human-Machine Interface (HMI) and the like were the unique features identified by the sample in positioning the products for their brands. Evidently these have emerged as motivational aspects for the concerned sample for purchase and use of these appliances.

B. Profile of the Appliances' Market

The term 'market' has come to signify a public place in which goods and services are bought and sold. In an economic sense, a market has no reference to a place, but to a commodity which is being bought or sold (Sankaran, 2004). To this effect, selected firms dealing with the appliances with embedded systems (ES) manufactured by those 'Brand-owners' highlighted through the consumer survey were visited and the findings of the survey are presented under:

1. **Product line of Appliances with ES**
2. **Categorization of Appliances with ES**
3. **Appliances Profile**
4. **Innovative endeavours**
5. **Price range of Products**
6. **Energy Rating**

1. **Product Line of Appliances with ES:** A product mix (portfolio or range) is the total list of products which a firm offers to its buyers, states, Vinod (2006). They may have several product lines comprising the product mix. Hence the product line of the selected firms with regard to appliances with ES alone was enquired of and the details are presented under the following Table.

Table: 16. Product Line of Appliances with ES

Appliances with ES	Product flanking strategies adopted	Firms with product line						
		IFB	SAMSUNG	LG	Whirlpool	Panasonic	Voltas	Siemens
Washing machine	Semi automatic	-	✓	✓				
	Fully automatic(top loading)	✓	✓	✓				
	Fully automatic (front loading)	✓	✓	✓				
Refrigerator	Direct cool		✓	✓	✓			
	Frost free		✓	✓	✓			
Microwave oven	Solo		✓	✓		✓		
	Grill		✓	✓		✓		
	Convection		✓	✓		✓		
Air conditioner	Split AC		✓	✓			✓	
	Window AC		✓	✓			✓	
Dishwasher	Front loading	✓		✓				✓

The findings revealed two firms to have set admirable**'product line'** for household appliances with ES in the local market. A 'firm' refers to a unit of business control (Sankaran, 2004). They produce the same commodity and are competing in the field. The findings of the study therefore are in-situ examples of **'product differentiation'** adopted by the sample firms as expressed through the **'product flanking'** styles adopted. ***Differentiation*** means adding a new quality, design or colour to an existing product. By bringing out various flanking strategies the selected firms have proved that.

2. **Categorization of Appliances with ES:** Embedded systems are categorised based on the complexity in building, cost factors, purpose of the system, tools and other related

environment, availability etc(http://www.newpagepublishers.com/samplechapter/002081.pdf). Based on the categorisation prescribed, the five selected appliances with ES can be classified under **Medium scale embedded systems.**

3. **Appliances' Profile:** This aspect of the findings analyses the appliances available in the market for their unique features.
    a) **Washing machines with ES**
    b) **Refrigerators with ES**
    c) **Microwave ovens with ES**
    d) **Air conditioners with ES**
    e) **Dishwashers with ES**

a) Washing Machines with ES: Table pictures the details of the popular washing machines with ES available in the market.

Table: 17. Washing Machines with ES

Company Models	Firm company represented	Materials used for Drums	Features/technology used	Wash action
Semi automatic	Samsung	Fibre	Scrubber	Scrub wash
	LG	Fibre	3 pulster	Scrub wash
Fully automatic (top loading)	Samsung	Metal	Diamond drum Wobble technology	Scrub wash
	IFB	Metal	Auto sensor	Scrub wash and aqua energie
	LG	Metal	3 pulster Turbo drum technology	Jet spring technology Aqua energie
Fully automatic (front loading)	Samsung	Stainless steel	Aqua bubble wash Baby care	Tumble wash
	IFB	Stainless steel	Digital inverter motor Smart diagnosis	Tumble wash
	LG	Stainless steel	-	Tumble wash 6 motion wash

It was evident that through product differentiation the firms were able to bring in and introduce various technologies such that one was different from the other. Similarly, introduction of fascinating technologies in ways that one firm competed with the other in a silent way was also very obvious. From top loading models all had incorporated only scrub wash while tumble wash was the dictum for all front loading machines.

b) Refrigerator with ES: The findings regarding this aspect are presented under Table

Table: 18. Refrigerators with ES

Firms (company) represented	Materials used for interior	Features	Operation
LG	Stainless steel	Moist balance crisper	Direct cool
	Metal and fibre	Durachill Smart invertor Tower LCD Ion door cooling	Frost free Multi air flow technology
Whirlpool	Stainless steel	Power cool zone Super quick ice maker Twin crisper	Direct cool Advanced air flow technology
	Metal and fibre	Chilling gel Flexi-cool Stabilizers free operation	Frost free 6th sense deep freeze technology
Samsung	Stainless steel	Stabilizer free operation	Direct cool
	Metal and fibre	Moist free zone Cool pack Stabilizer free operation LED light	Frost free

Here again through product differentiation the firms had introduced unique features in the frost free models, while the direct cool models retained their status quo with minimal modifications.

Durachill, quick ice, chilling gel, flexi-cool, cool pack, moist free zone and the like were the jargons used to explain the advanced technologies incorporated by companies. LED light options and in built stabilizers were the common features included.

c) **Microwave Ovens with ES:** The findings regarding this aspect are presented under the following Table.

Table: 19. Microwave Ovens with ES

Firms represented	Materials used	Features	Operation
LG	Metal	Preheating and boiling	Solo microwave
	Metal	52 auto cook menu	i wave technology grill microwave
	Stainless steel	301 auto cook menu Charcoal light heater	Light wave Convection
Samsung	Metal	Reheating and boiling	Solo microwave
	Metal	67 auto cook menu Rapid defrost	Trio wave technology Grill microwave
	Metal	220 auto cook menu	Convection
	Metal	Reheating and boiling	Solo microwave
	Metal	Grilling and reheating	Intelo wave Grill microwave
	Stainless steel	Vapour clean defrost 101 auto cook menu	100-200°C Convection

With regard to microwave ovens too, it could be seen evidently that the concerned firms had introduced new features both to differentiate their own products (in the product line) and those offeredby competing companies. Quality value additions have become the benchmark fora successful market.

Air conditioners with ES: Table presents details on the same

Table: 20. Air Conditioners with ES

Firms represented	Material used	Features	Operation
Samsung	Aluminium alloy Stainless steel	Cooling capacity 500 watt	Split Multiplus technology
	Fully copper	Instant cooling	Window AC
LG	Aluminium alloy fiber body	Instant cooling	Split
	Aluminium alloy	Instant cooling	Window AC
Voltas	Fully copper	Silver ion filter Catechin filter	Split
	Fully copper	Air flow 850 cmh Silver ion filter, Catechin filter	Window AC

Differences among products was observed in materials used and the technology introduced. Instant cooling was their common ‘mantra’.Changes were observed in the filters used and air flow volumes.

d. Dishwashers with ES: Table presents details on the same

Table: 21. Dishwashers with ES

Firms represented	Material used	Features	Operation
Siemens	Metal	Shower system dry 12 place setting	Spray and Impeller Shower system coupled with steam dry
LG	Metal	Powerful Flexible and Oh-so quite Easy rack plus system	Spray and Impeller Shower system coupled with steam dry
IFB	Metal Plastic (front door)	Automatic sensor wash 3D shower Internal fan	Spray and Impeller Shower system coupled with steam dry

All the three firms had used metal for the drums. Shower system with steam dry was the technology used in all. IFB alone had introduced automatic sensor wash system.

Economists, from day one, had called for only '**survival of the fittest'**. The findings of the study but prove the factor. All the firms were found to vie with each other in embedding multiple components enabling multifarious functions.

Every company tries to capture a major share in the market, and hence adopt various marketing strategies. On the basis of market share they enjoy, they can be classified as a **'market leaders'**. Those firms which have the maximum share in the market for a particular product or products are included in this category. Having said so, all the firms that have floated, various appliances in the market qualify to be called as market leaders. These firms evidently are financially strong and have a good distribution network. One of the strategies they adopt according to Vinod (2006) is '***strategy of innovation'***, followed by ***product flanking***, ***multi brand strategy*** and or ***brand extension strategy***. This has paved way for the next part of the analysis.

4. **Innovative Endeavours:**Innovations means and creating new ideas or introducing changes states,Vinod (2006). Hence the details on innovative endeavours adopted by the sample firms in their products are analysed and tabulated below.

Table: 22. Innovative Aspects Introduced in Home Appliances

Appliances		Innovations Introduced						
		Firms Represented						
	Models	**Samsung**	**IFB**	**LG**	**Whirlpool**	**Panasonic**	**Voltas**	**Siemens**
Washing Machine	Semi automatic	New designs	-	New design	-	-	-	-
	Fully automatic (top)	Diamond drum	Power and water conservation	Diamond drum 6 motion wash	-	-	-	-
	Fully automatic (front)	-Bubble wash technology -Diamond drum -Ceramic heater	Crescent moon drum 3D wash Laundry add option	Turbo drum	-	-	-	-
Refrigerator	Direct cool	Anti fungal gasket	-	Cool pack Star rating	Cool pack Star rating	-	-	-
	Frost free	Convertible freezer Digital inverter compressor	-	Digital inverter motor compressor	Cool pack Freshnizer	-	-	-
Microwave oven	Solo microwave	Digital operation	-	Automatic	-	Digital operation	-	-
	Grill microwave	Trio wave	-	Intelo wave	-	Intelo wave	-	-
	Convection microwave	Ceramic coat Slim fry	-	Charcoal heat	-	Zero oil	-	-
Air conditioner	Split AC	Digital inverter compressor	-	Digital inverter compressor	-	-	6-in-1 filter	-
	Window AC	-	-	5 filter	-	-	Sleek and compact	-
Dishwasher	Front loading	Automatic sensor wash Less power and water	-	Korean technology	-	-	-	German technology

In matters of quality, the manufacturers of consumer goods, particularly speciality goods and convenience goods, face the problem of changing the quality often to suit the market. The process of changing the quality according to Nair and Nair (2002) fall under two heads: **trading up** and **trading down**. The process of introducing higher quality products by a manufacturer, whose low quality products are famous, is termed as **trading up**. This study has proved the fact. All the firms had introduced some quality input to their existing products. Though not all can be called as innovations in the real sense they **tantamount to real trading up** as they point to **value addition** in all products.

It was blatantly visible that two firms (Samsung and LG) to run 'head over heels' in practicing 'trading up', very well by adopting 'product differentiation' as a viable strategy.

Nair and Nair (2002) state that such trading up invariably demands a higher price too. The firms having earned a reputation for their lower quality products ensure that it is practicable.

5. Price range of Products

Having analysed the recent inputs to enhance the quality of the products produced by the firms their saleable price in the market was found out and is tabulated under the following heads:

a. Selling Price of Washing Machines
b. Cost of Refrigerators
c. Monetary value of Microwave ovens
d. Access to Air-conditioners
e. Price tag on Dishwashers

a. Selling Price of Washing Machines: Price tag attached to different brands of washing machines is portrayed through Table.

Table: 23. Selling Price of Washing Machines

Model	Selling price in `							
	Firms requested	**10,000-15, 000**	**10,000-16,000**	**15,000-35,000**	**15,000-40,000**	**22,000-1,00,000**	**15,000-1,00,000**	**25,000-1,00,000**
Semi automatic	Samsung	✓						
	LG		✓					
Fully automatic (top)	Samsung				✓			
	IFB			✓				
	LG				✓			
Fully automatic (front)	Samsung							✓
	IFB					✓		
	LG						✓	

The study revealed that with improvement in features, especially in terms of increase in the number of programmes embedded in the systems, the cost of washing machines was found to fly high. While the semi automatics with minimal programmes cost a minimum of `10,000/- the high-end versions cost cent per cent more.

b. Cost of Refrigerators: Refrigerators basically belong to the most important appliances in modern households. Firms producing them had introduced very many innovative inputs to make them highly effective for storing products at home. The following Table indicates the cost of the products available for sale in the market.

Table: 24. Cost of Refrigerators

Model	**Firms represented**	**Cost (range in `)**					
		13,000-20,000	**13,000-22,000**	**13,000-24,000**	**20,000-2,50,000**	**22,000-2,00,000**	**23,000-2,50,000**
Direct cool	LG	✓					
	Whirlpool		✓				
	Samsung			✓			
Frost free	LG				✓		
	Whirlpool					✓	
	Samsung						✓

Among the firms represented LG emerged a little economical, while Samsung sold both the models at a high price; especially the frost free high end model cost a fortune. When the cost range extends from mere ` 20,000/- to ` 2, 50,000/- one can imagine the value addition made to all high end versions of frost free models. Definitely refrigerators are found to emerge with **high-tech** embedded systems involving innumerable programs.

c. Monetary Value of Microwave ovens: This part of the study is presented under Table

Table: 25. Monetary value of Microwave ovens

Model	Firms represented	Cost (range in `)					
		5,000-7,000	5,500-8,000	6,500-9,000	7,000-9,000	8,000-50,000	9,500-50,000
Solo microwave	LG	✓					
	Samsung		✓				
	Panasonic	✓					
Grill microwave	LG			✓			
	Samsung				✓	✓	✓
	Panasonic			✓			
Convection microwave	LG						✓
	Samsung						✓
	Panasonic						✓

Here again with enhanced features and the firms producing it, the cost of the product varied and increased. The high-end models of LG and Samsung were found to fetch a good market value. Extraordinary features, multiple options and HMI provisions have set their products/models on high pedestal.

d. Access to Air conditioners: The three gadgets discussed above belong to the category of appliances which have a functioned value in the household, but ACs is comfort-providers. Evidently they also need to be priced high. Hence, this part of the study analyses how far consumers have access to them.

Table: 26. Access to Air conditioners

Model	Firms represented	Cost (range in `)					
		20,000-27,000	22,000-27,000	22,000-34,000	23,000-70,000	25,000-60,000	25,000-70,000
Window AC	Samsung	✓					
	LG		✓				
	Voltas			✓			
Split A/C	Samsung					✓	
	LG				✓		
	Voltas						✓

Voltas, a company of high repute with a prolonged product positioning in the market had emerged as the firm, marketing the top-of-the-line air conditioners with extra features in the market. An important finding was that between the low-featured ones in the two models available (window and split), there was not much of a price difference making both affordable even for families in the middle income.

e. Price tag on dishwashers: Table presents details on the same

Table: 27. Price tag on dishwashers

Firm represented	Cost (range in `)		
	40,000-60,000	36,000-1,50,000	34,000-2,00,000
LG	✓		
Siemens		✓	
IFB			✓

Among the three, IFB emerged as the most expensive model, though all of them floated one at a cost less than or equal to ` 40,000/-

These findings prove that the firms had ventured well in '**product differentiation'**. According to Kotler (1994), it is the act of designing a set of meaningful differences to distinguish the company's offer from competitor's offers; by which the firm establishes that its product is different from other products and better than other products in the market. It is evident that all the firms studied had successfully excelled on this marketing issue. The findings further highlighted that the firms were producing and marketing state-of-the-art appliances with unique features on the one hand and simultaneously showing off their concern for the families belonging to varied income groups, by providing ranges affordable by all-least expensive to the most expensive models.

f. Energy Ratings on Appliances

Table: 28. Energy Rating on Appliances

Firms represented	Star rating	Models in appliances										
		Washing machine			Refrigerators		Microwave Oven			Air conditioner		Dish washer
		a	b	c	a	b	a	b	C	a (Window)	b (Split)	
Samsung	1 or 2									✓		
	3	✓	✓									
	4			✓		✓	✓	✓	✓		✓	
	5				✓							
LG	1 or 2									✓		
	3											
	4	✓	✓			✓					✓	✓
	5			✓	✓		✓	✓	✓			
IFB	2		✓	✓								
	3											
	4											✓
	5											
Whirlpool	2											
	3											
	4					✓						
	5				✓							
Panasonic	2											
	3											
	4						✓	✓	✓			
	5											
Voltas	2									✓		
	3											
	4										✓	
	5											
Siemens	4											✓

LG was found to be the firm having a long product line in the product mix of household appliances. They had embarked on manufacturing all the five appliances. Samsung had followed suit laying their indelible imprints on four varied appliances. Both the firms were found to be environment-conscious as their products were rated with 4 or 5 star rating, proving that their products consumed less power and other resources as well. The

four firms which floated only one each of the five selected appliances even were found to be marketing quality products with high star rating.

Star rating being an important factor which analyses the embedded systems in the appliances also prove that the appliances' perform well with their respective embedded systems.

C. **Unique Selling Propositions (USP) Strategies Adopted:**Consumers generally choose products and services which give them greatest value. Therefore the key to winning and keeping customers is to understand their needs and buying processes before their competitors do and deliver more value. It is therefore necessary that the company should ensure **Unique Selling Propositions (USP)**, state, Vinod (2006) so as to induce the customers to buy the product of the company. Naturally the firms (companies) have to indulge in **'positioning by corporate identity'** and **'Brand endorsement'**. The findings of the case studies are analysed for their inputs on these linesand are delineated under the following Tables.(The most popular firms for each appliance alone are discussed in detail).

i. **USP Floated for Refrigerators**

Refrigerator models varied in the capacity. Tables 29 and 30 portray the USP offered for direct cool and frost free models by the selected firms.

Table: 29. USP Floated for Refrigerators (Direct cool)

Firms represented	**Model 1**	**Model 2**	**Model 3**
LG	5 star rating Door-single **Power cut ever cool technology** Stabilizer free operation	5 star rating Door-single **Power cut ever cool technological** **Fastest ice making technology** Stabilizer free	5 star rating Door-single **Open door alarm** **Moisture Humidity Control** Locking mechanism
Whirlpool	4 star rating Door lock Door- single **6th sense fast forward ice technology** **6th sense door alarm** Built-in stabilizer	5 star rating Door lock Door- single **Power cool zone** **Moisture or humidity control**	4 star rating Door lock Door- single **Roll-Bond Freezer** Stabilizer free **Large voltage range (130-300 V) operation**
Samsung	5 star rating Single door Stabilizer free **Cool pack**	5 star rating Single door Stabilizer free **Cool pack** **Chilled room**	**Higher humidity with fresh technology** Stabilizer free

Factors like door provision, star rating, stabilizer free operation etc were found to be common factors for all models irrespective of the brand name held. Features unique to each model are highlighted. They refer mainly to the performance efficiency of the models.

Table: 30. USP floated for Refrigerators (Frost free)

Firm represented	Model 1	Model 2	Model 3
LG	4 star rating Door-double **Power cut ever cool technology** Stabilizer free operation **Humidity controller** **Tower LED** Anti-bacteria gasket	2 star rating Door-double **4-way cooling technology** Anti-bacteria gasket Stabilizer free **TFR Chiller zone** **Humidity controller** **Freshnizer** **Ag Ion deodorizer** **Reciprocatory**	4 star rating Door-double **Green Ion door cooling technology** **Smart inverter compressor** **Door alarm** **Ever fresh zone** **Eco- friendly refrigerant** **Z Deodorizer** **External Micom**
Whirlpool	3 door type 4 star rating **6th sense Active Fresh technology** **Modern air booster system** **Moisture retention technology** **MicroBlock** **Bulb RC lamp** **Controls cold air circulation** **Quick chill bottle zone**	4 star rating 2 door **6th sense Freeze technology** **Flexi cool mechanism** **Freshonizer (minimise oxidation)** **Chilling gel** **Twin cooling tower**	3 star rating 2 door Stabilizer free operation **High-speed cold air inflow** **Flexi cool technology** **Power efficient Refrigeration** **Ice twister**
Samsung	3 star rating 2 door **Digital inverter compressor** **Digital display** **Water dispenser** **Multi flow** **Ice max** **LED Light** **Moist, fresh zone** **Twister ice maker** **Chiller tray** **Moisture or humidity control**	4 star rating 2 door **Digital inverter compressor (with 7 adjustable speeds)** **Moist fresh zone** **LED Lighting** **87 litres freezer cooling** **8 hrs backup cooling capability** **Power cool function** **Integrated door alarm systems**	3 star rating 2 door **Digital inverter compressor(with 7 adjustable speeds)** **Cool pack** **Multi flow and no frost** **Twist ice maker** **Stabilizer free** **Moist fresh zone**

The frost free models had multiple opportunities for introducing unique features. All the three popular brands had given competitive inputs to raise their models to peaks of performance. Evidently all these are possible only because of the incorporation of embedded

systems, where the programs set could perform various gimmics invisible to the human eye. It is no wonder majority of consumers had opted for these models.

ii. USP floated for Microwave Ovens: The following Tables 31, 32 and 33 detail on the issue

Table: 31. USP floated for Microwave oven (Solo)

Firms represented	Model 1	Model 2
LG	**Next step guide functionality** **Cooking completion alarm** **Five different power levels** **Intello wave technology**	**5 power levels** **Cooking completion indicator**
Samsung	**Triple Distribution System** **Child safety lock** **LED display** **Touch keypad (membrane)** **Reminder End Signal** **Power saving** **Clock**	**6 power levels** **Reminder End signal** **Triple distribution system** **Child lock** **CMO (mount)** **30 sec Plus control features** **Tact (buttons)control** **Clock setting**

Multiple power levels child safety lock, LED display and technology used differed among the studied.

Table: 32. USP floated for Microwave oven (Grill)

Firms represented	Model 1	Model 2
LG	**Preset menus-52** **Indian menus-35** **5 power levels** **Child lock** **Intellowave technology**	**Preset menus- 52** **iwave technology** **Child lock** **Programme panel- keypad control** **Type-microwave**
Samsung	**Anti-bacteria protection** **40percent power** **5 Power Levels** **Child lock** • **Type : Grill**	**7 stages of power levels** • **44 Preset Cooking Menus** • **6 Power Levels** **Child lock** **Type-Grill Microwave**

Only one Firm offered grill type microwave ovens. There were two models for sale. Technology used, menu options decided the model variations.

Table: 33. USP floated for Microwave oven (Convection)

Firm represented	Model 1	Model 2 or 3
LG	**Touch keypads(membrane) control** **4 mode cooking** **Auto cook menu-101** **Auto Indian cook menu-61** **Two stage cooking** **Cooking completion alarm** **Child lock** **5 power levels** **Intello wave technology**	**Auto cook 151** **Auto Indian cook- 101** **Tact dial control** **Intello wave technology** **5 microwave power levels** **Child lock cooking completion alarm** **Next step guide** **LED display** **Auto defrost**
Samsung	• **67 Number of Preset Menus** • **21 Litres Capacity** • **Type- Convection Microwave** **1200 W Power Consumption** **6 power levels** **Auto Defrost** **Child lock** **Triple Distribution System wave** **Bubble Switch**	**121 Auto Cook menus** **LED display-Bar** **Power Level 6** **Child lock** **Deodorizer** **Type-convection**

iii. USP Factors Incorporated in Washing Machines

Major factor, apart from loading options, differentiating washing machines is their capacity for washing clothes. Hence models also emerge with this as major criteria. Tables 34 and 35portray the distinguishing features afforded by each in easing the drudgery of end-users.

Table: 34. USP Floated for Washing machines (Fully automatic top loading)

Firms	Model 1 (High-end	Model 2	Model 3

represented	models)		
Samsung	***Key factors*** ***In-built memory*** ***Fuzzy logic option*** ***6 washing programmes*** ***Function switch(for selective options)*** ***LED (glows for selected program and blinks for current running process)*** ***Optional air turbo*** ***LCD display (optional)-see the functions going on, remaining time etc***	6.5kg 4 water level 4 washing cycle Centre jet pulsator Fuzzy logic technology	6.2kg Auto restart Child lock 5 different water levels Pulsator 7 wash programmes Wobble technology 3D dynamic water currents Tangle free washing Air turbo designing LED display
IFB	7.2kg Pulsator Punch swirling tornado 8 wash cycle systems Digital display (7 segment LED display) End of the program beep 3D waterfall Auto imbalance sensing plus control Electronic controls Programme follower with light indicators	6.5kg Agitator Multiple wash programmes Digital display	6kg Agitator Multiple wash programmes Digital display
LG	6.2kg Fuzzy logic Turbo drum Punch+3 pulsator Auto restart Child lock Auto balance Digital display	i-sensor fuzzy logic control microprocessor air dry 3 stages wash Punch+3 pulsator Digital display Water level selection Memory display Delay start	i-sensor fuzzy logic control child lock guide by hitech voice module(in 2 languages) 2 optional program

Presence of high-tech sensors and embedded programmes is well documented through the Table. The firms had put in all efforts to ease the activity at home.

Table: 35. USP Floated for Washing machine (Fully automatic front loading)

Firms represented	Model 1	Model 2	Model 3
Samsung	6kg 8 wash/4 options programmes Anti- limescale heater Delay end function(19 hrs) Fuzzy logic control Over heating control Over volt control Baby care	6.5kg Eco-bubble technology Energy efficient Anti-limescale heater Dot LED + time display Door lock display Time lap display Progress indicator Jog dial Eco drum clean Fault check display Self diagnostic systems Fuzzy logic control Anti-foam control Delay end function (19 hrs)	12kg Eco bubble wash Digital inverter motor VRT Plus sensor Consistent power Anti- limescale heater Quick timed wash (15 ms) Eco drum Energy efficient Auto restart Optimal water use Time left display Anti foam control Overheating control
IFB	5.5kg 14 wash program Auto imbalance sensing and control Auto restart Foam control Memory backup Self diagnosis LED display	6.5kg Electronic control 7 segment LED display Smart jog dial Audio visual induction No. of program-100 Program time and progress indicator	6kg Electro mechanical control Barrier free program console Program progress indicator No. of program- 15 Auto restart Memory backup Self diagnosis Auto imbalance sensing and control.
LG	6.5kg 6 motion direct drive technology Smart diagnosis Child lock Digital display	8/4kg 6 motion Inverter direct drive technology Smart diagnosis Fuzzy logic Fault diagnosis(digital display) Remaining time display	8/6kg Baby care LED touch panel Fuzzy logic 5 spin speed options Remaining time display Fault diagnosis

The programs embedded with advance models were found to be over and above those provided in the preceding models. It is evident that the Research and Development wings in all these firms had done extensive research on every minute detail of activity that goes with washing of clothes and had found solutions to make them as smooth as possible-

for e.g.: tangle free clothes wash, baby care, auto restart, ergonomic designs and drudgery reduction. They had left no leaf unturned to bring in the new wave technologies to every Indian door step. They have thus capitalised very well on the '***versatility of embedded systems'*** to turn washing clothes – from a drudgeryto an enjoyable experience.

iv. **USP Floated for Dishwasher:** Details on USP offered for dishwashers are presented through Table

Table: 36. USP Floated for Dishwasher

Firms represented	**Model 1**	**Model 2**	**Model3**
IFB	Program for extra heavily soiled wash Steam drying Express programs Energy saver Water softener (upto60 DH) Static heat drying Delay start Error display Child lock	Smart deign Jet wash Super energy efficient Steam drying Water softener Hi-tech control panel Child lock Error display 9 wash progress Start delay	5 wash programs Digital display Child lock Eco wash LED display(on control panel for error detection)
Siemens	5 wash programs Digital display Self cleaning filter system Aqua stop(sensor) with 24 hr anti-leak system iQ drive 48 db noise level Time indicator Load sensor LED(red) indicators Hydromix glass care protection technology Servo lock	5 wash programs Digital display Self cleaning filter system LED(red) indicators Time indicator iQ drive Glass care protection technology Servo lock 48 db noise level Aqua sensor Load sensor SpeedMatic hydraulic system Time delay(electronic)	5 wash program Heat system for drying Self cleaning filter 52 db noise level LED displays, salt levels and rinse and end of cycle.

Wash programs, water and energy saving, digital displays, water softeners, delay start, error displays, LED displays, and noise level controls were the common factors highlighted in dishwashers. In Siemens's products self-cleaning filters and load sensors were additional features.

v. USP floated for Air conditioner: Takes 37 and 38 present details on the USP floated for Split and Window model air conditioners

Table: 37. USP Floated for Air conditioner (Split AC)

Firms represented	Model 1	Model 2	Model 3
LG	1.5 ton E saver mode Remote control 36 db Timer Auto restart Sleep mode Air swing	1 ton E saver mode 35 db Timer Auto restart Sleep mode Remote control Air swing	1.5 db 36 db E saver mode Timer Auto restart Sleep mode Remote control Air swing
Voltas	1.0 Ton LED display Self diagnosis Auto restart Anti fungal clean air technology Air saving LCD display Timer Cross flow Dual temperature Air flow volume-indoor-500cmh Noise-35/38/40 db LCD remote R-22 sleep mode turbo mode Auto restart 3D air flow Ionizer	1.5 ton R-22 Air flow 850 cmh Auto restart Front panel display Turbo mode Power saving mode Glow button remote Night mode	1.2 ton LCD remote Glow buttons Dual temperature display Lock Auto restart Front panel display Self diagnosis 42 db Air flow volume-850 cmh
Samsung	1.5 ton 4 way air flow director R-22 Air circulation-14 CMM 32-43 db indoor sound Moisture removal Turbo mode Dehumidification mode Auto restart Digital display Auto clean	4 way air flow direction R-22 Air circulation-14CMM Moisture removal-1.8L/h Indoor sound level-32-43 db Turbo mode Dehumidification mode Digital display Auto clean Timer	1.5 ton R-22 Air circulation-16 CMM Moisture level-1.8L/h 32-43 db Fast cool Single user mode Smart saver Turbo mode Dehumidification mode Indoor temperature

	Timer Indoor temperature display Auto air direction control Energy save	Indoor temperature display Auto air direction control Energy save	display

Distinguishing factors in components which were common to all were incorporated in capacity, air circulation, temperature control modes, noise level controls, dehumidification set-up etc. Auto restart, sleep mode, timers, digital display were common features irrespective of the brands, but were programmed in their respective unique ways.

Table: 38. USP Floated for Air conditioner (Window AC)

Firms represented	**Model 1**	**Model 2**	**Model 3**
LG	1.5 ton Dehumidification mode R-22 High air circulation(500CFM) 52 db noise level 3fan speeds Timer Auto restart Sleep mode Air swing	1.5 ton Microprocessor(adjust room temperature to match body metabolism rate) Timer Auto restart Sleep mode Air swing R-22 52 db 3 fan speeds Air circulation 580CFM	1.5 ton Mosquito away technology 3 fan speeds Air circulation-500CFM R-22 Timer Auto restart Sleep mode Air swing
Voltas	1.5 ton R-22 Air circulation-700CMF 56 db Timer Auto restart Sleep mode Self diagnosis Memory function Large LED display	1.5 ton R-22 Air circulation 700CFM 58 db Timer Auto restart Sleep mode Air swing Self diagnosis Memory function Large LED display	1.0 ton R-22 Air circulation 450CFM 54 db Timer Auto restart Sleep mode Air swing

Samsung	1.5 ton 54 db Digital temperature control 3 fan speeds Timer Auto restart Remote control Indoor temperature display Dehumidification Smart saver	1.5 ton R-22 52 db Digital temperature control 3 fan speeds Auto restart Remote control Air swing Ventilation control	2 ton 55 db Digital temperature control 3 fan speeds Timer Auto restart Remote control Indoor temperature display Smart saver

Many of the features given in split models, though were missing in window models, timers, auto restart, sleep mode and air swing aspects were programmed in these too.

USP offered in a nutshell

USP offered by all the firms in all their products have emerged in fulfilling these promises

- **Extraordinary features (brand wise) excelling one another.**
- **Access to all to own all appliances – varied models, range of prices.**
- **Bringing embedded systems to Indian door steps.**
- **Eco- friendly Appliances.**
- **Appliances with default stabilizers to suit Indian electricity distribution systems.**
- **Incorporation of embedded systems in all appliances to improve their performance capabilities – to fulfil their functions in the most efficient manner.**
- **Appliances to free consumers (homemakers) from household drudgery.**
- **Enhancement in quality of life and studied of living.**
- **Ergonomic designs.**
- **Perfection- Oriented Programs and Circuitry.**

- **Capitalise on the intelligence of embedded systems.**
- **Make sophisticated appliances use-friendly- HMI (touch panels, etc.)**

D. Portfolio of Circuit Diagrams for Household Appliances with ES: An introduction to the technology is given below for ease in comprehension.

Classic ES have been considered dedicated solutions to a single application. In these classic systems, the hardware is custom designed to solve a specific application and the operating system is developed internally. All the software is self-contained in non-volatile RAM and there is limited user interface.

In the case of embedded systems with operating systems (OS), once the application software is loaded into memory it will run the application without any host system. Coming to the hardware details of the embedded system, it consists of the following important blocks.

- ***CPU(Central Processing Unit)***
- ***RAM or ROM***
- ***I.Q Devices***
- ***Communication Interface***
- ***Sensors etc. (Application specific circuitry)***

Central Processing Unit: A CPU is composed of an Arithmetic Logic Unit (ALU), a Control Unit (CU), and many internal register that are connected by buses. The ALU performs all the mathematical operations (Add, Sub, Mul, Div), logical operations (AND, OR), and shifting operations within.The CPU works in a cycle of fetching an instruction, decoding it, and executing it, known as the fetch-decode-execute cycle. The cycle begins when an instruction is fetched from a memory location pointed to by the PC to the IR via the data bus. For embedded system design, many factors impact the CPU selection, e.g., the maximum size (number of bits) in a single operand for ALU (8, 16, 32, 64 bits), and CPU clock frequency for timing tick control, i.e. the number of ticks (clock cycle) per second in measures of MHz.

Memory: ES memory can be either on-chip or off-chip. On chip memory access is much fast than off-chip memory, but the size of on-chip memory is much smaller than the size of off-chip memory. Usually, it takes at least two I/Q ports as external address lines plus few control lines such as R/W and ALE controls lines to enable the extended memory. Generally the data is stored in RAM and the program is stored in ROM.

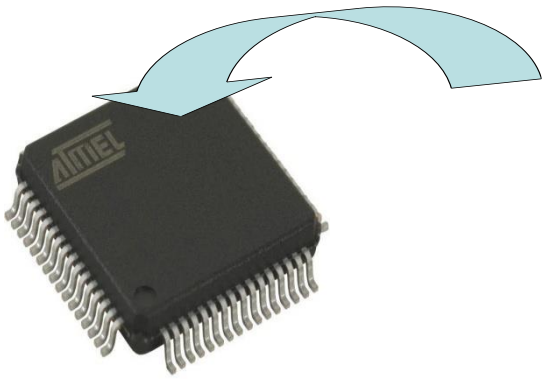
Definition: An Embedded System is one that has computer hardware with software embedded in it as one of its important components.

Systems to control, monitor or assist the operation of equipment, machinery or plant.

◆Embedded System has a computer as one of its components but itself is not a general purpose computer.
◆Embedded System is task specific hardware and software are optimized and is a part of larger system
◆ Embedded System respond to environment by using sensors, monitor and control external environment without human intervention

The term "Embedded" reflects the fact that they are an integral part of the system they control.

They are not separate entity Most often they are physically built-in to the devices they control.



Its software embeds in ROM (Read Only Memory). It does not need secondary memories as in a computer

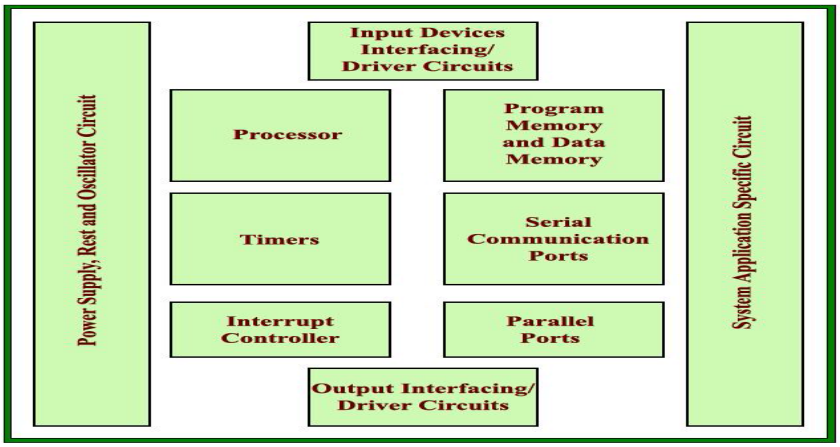


Exhibit: 3. Embedded Systems

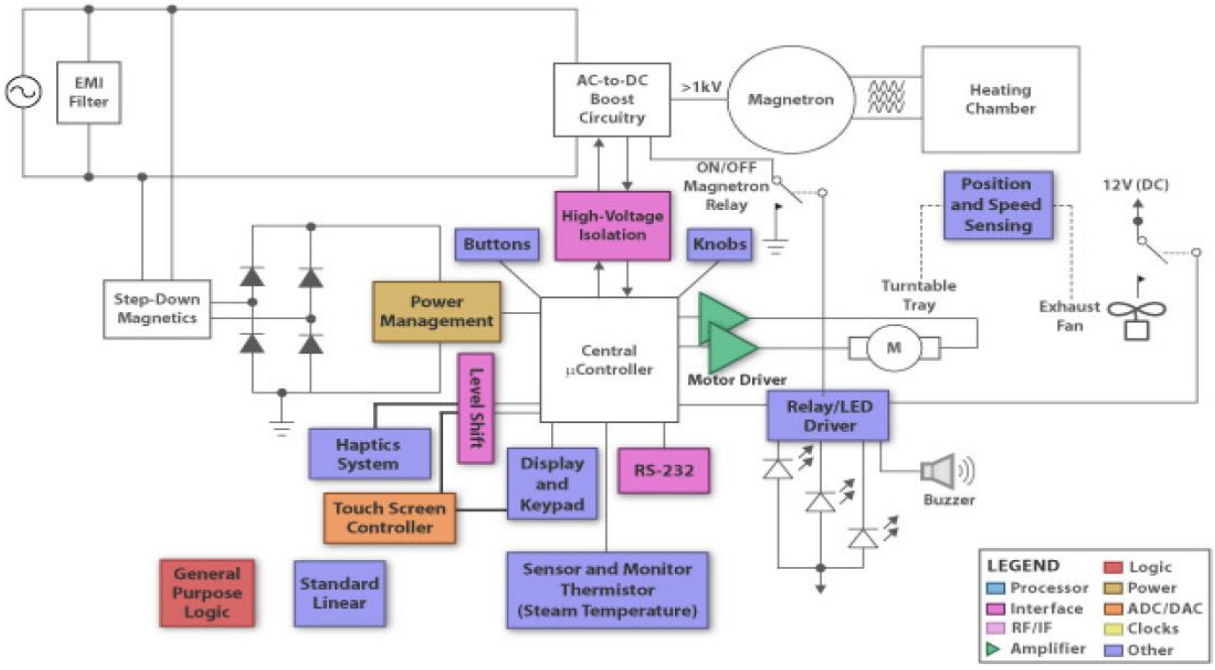
I/Q Ports: The I/Q ports are used to connect input and output devices. The common input devices for an ES include keypads, switches, buttons, knobs, and all kinds of sensors (light, temperature, pressure, etc).The output devices include Light Emitting Diodes (LED), Liquid Crystal Displays (LCD), printers, alarms, actuators, etc. Some devices support both input and output, such as communication interfaces including Network Interface Cards (NIC), modems, and mobile phones.

Communication Interfaces: To transfer the data or to interact with other devices, the embedded devices are provided the various communication interfaces like RS232, RS422, RS485, USB, SPI (Serial Peripheral Interface), SCI (Serial Communication Interface), Ethernet etc.

Application Specific Circuitry: The ES sometimes receives the input from a sensor or actuator. In such situations certain signal conditioning circuitry is needed. This hardware circuitry may contain ADC, Op-amps, DAC etc. such circuitry will interact with the embedded system to give correct output.

Power supply: Most of the embedded systems now a days' work on battery operated supplies because low power dissipation is always required. Hence the systems are designed to work with batteries. (http://www.slideshare.net/yayavaram/unit-1-embedded-system-and-applications?related=3)

The following plates depict the basic configuration for all the selected five appliances with ES. All the appliances are delineated with their individual configuration and the unique features operational by the embedded system application 'embedded' in them.



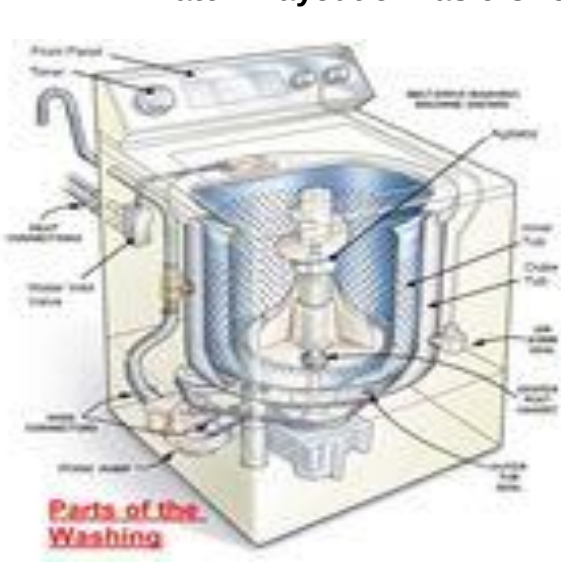
A microwave oven consists of

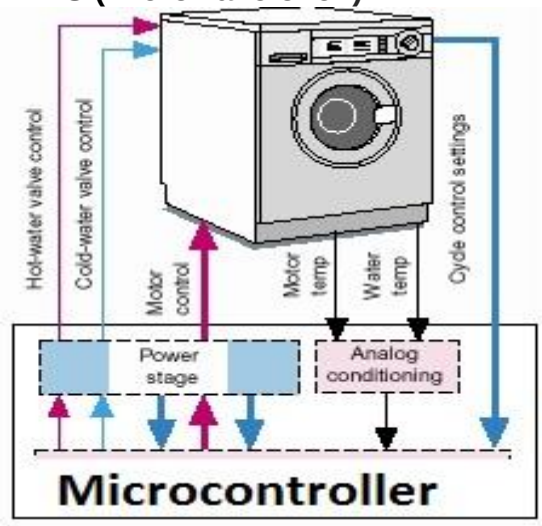
- a high voltage power source, commonly a simple transformer or an electronic power converter, which passes energy to the magnetron
- a high voltage capacitor connected to the magnetron, transformer and via a diode to the chassis
- a cavity magnetron, which converts high-voltage electric energy to microwave radiation
- a magnetron control circuit microcontroller
- a short waveguide (to couple microwave power from the magnetron into the cooking chamber)
- a metal cooking chamber
- a turntable or metal fan

In all types, the basic operation is same but features may varied based on

- **Microcontroller type**
- **Displays (LEDs, LCDs, Crystal glass Displays etc)**
- **Push Buttons (Press buttons, dials, Touch screens etc)**
- **Additional features (grill, Heaters, Toaster etc..)**

Plate: I Layout of Basic Circuitry in ES (Microwave oven)





Control Board (Microcontroller): **The PCB comprises of the various electronic components, microcontroller and circuits, which are programmed to perform in unique ways depending on the load conditions (the condition and the amount of clothes loaded in the washing machine). They are sort of artificial intelligence devices that sense the various external conditions and take the decisions accordingly. These are also called as fuzzy logic systems. Thus the PCB will calculate the total weight of the clothes, and find out the quantity of water and detergent required, and the total time required for washing the clothes. Then they will decide the time required for washing and rinsing.**

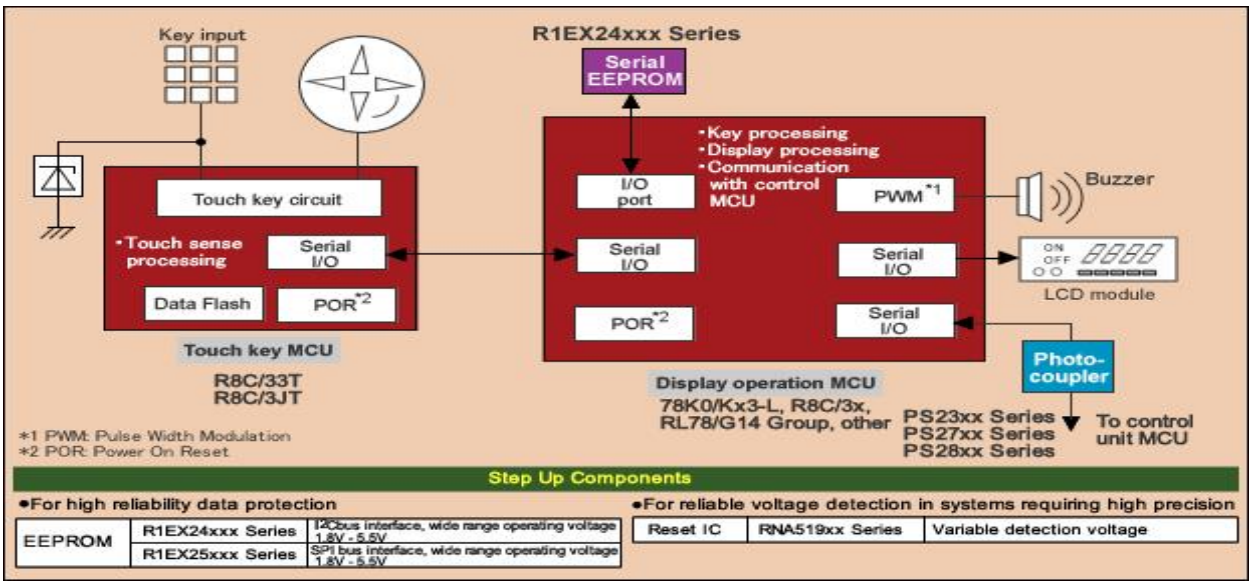
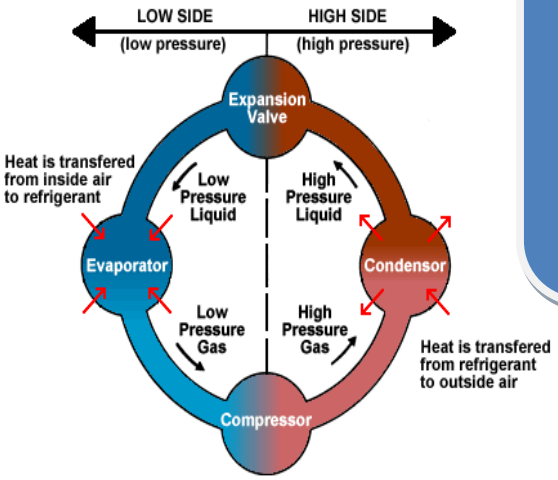


Plate: II Layout of Basic Circuitry in ES (Washing Machine)

Basic Refrigeration Cycle



Air conditioning (AC) is the process of altering the properties of air (primarily temperature and humidity) to more comfortable conditions, typically with the aim of distributing the conditioned air to an occupied space to improve thermal comfort and indoor air quality. In common use, an air conditioner is a device that lowers the air temperature. The cooling is typically achieved through a refrigeration cycle, but sometimes evaporation or free cooling is used. Air conditioning systems can also be made based on desiccants.

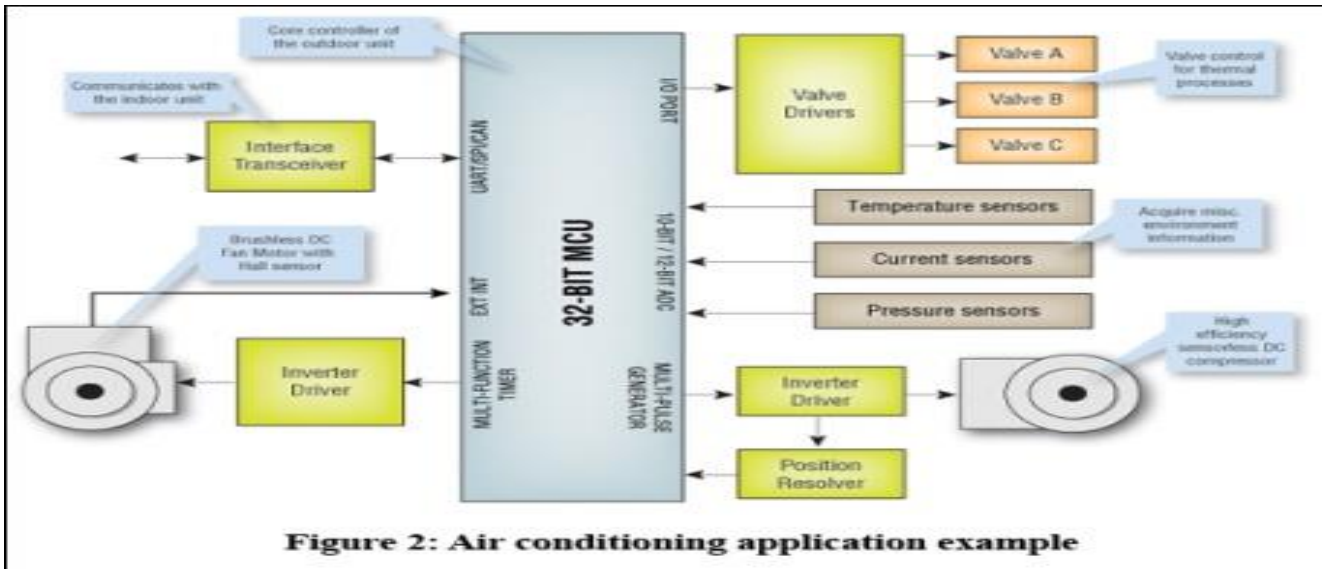
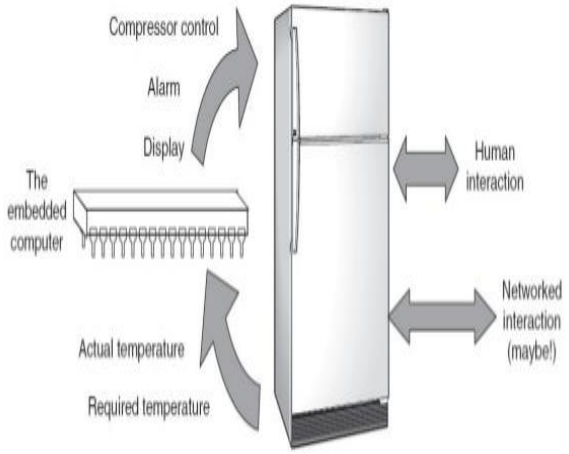


Figure 2: Air conditioning application example

Principles of Refrigeration

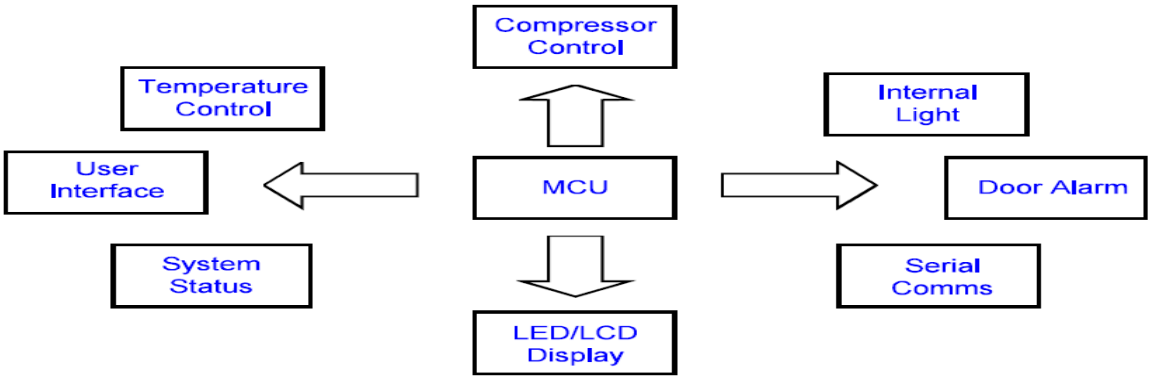
In the most general sense, air conditioning can refer to any form of technology that modifies the condition of air (heating, cooling, (de-)humidification, cleaning, air conditioners were the first to use inverter control. For inverter control of a compressor motor, several types of semiconductor devices are required, such as microcontrollers for overall system control, PWM generation and various protection features; an IGBT for the inverter driver section; and Photo couplers in the interface section. Recently, many room air conditioners come with an automatic filter cleaner and a voice recognition remote control. Power factor correction (PFC) ICs or IGBTs are used in the power supply circuit to keep harmonics in the input current below the IEC limit.

Plate: III Layout of Basic Circuitry in ES (Air Conditioner)



The main electrical components required for a domestic refrigeration system are some means of temperature control and a Refrigerant Compressor.

Embedded within a domestic Fridge compartment is an Evaporator, a on the outside a Condenser, heat exchanging coils and the refrigera compressor. The compressor is driven by an electrical motor. When power is applied to the compressor the pressure of the refrigerant is increased. This increase in pressure causes an increase in refrigera temperature and the heat produced by this action is dissipated throu the heat exchanging coils at the rear of the appliance. This action is illustrated in the following diagram.



The Refrigerant then condenses and passes through from the high – pressure environment of the condenser through an expansion valve to the low –pressure evaporation system inside the Fridge compartment on evaporating, the Refrigerant absorbs heat and subsequently reduces the enclose temperature. The warmer Refrigerant a circulated to the outside of the compartment where the cycle repeats under thermal control

Plate: IV Layout of Basic

Basically, a dishwasher is a robot that cleans and rinses dirty dishes. Humans have to load the dishes, add detergent, set the proper washing cycles and turn it on, but the dishwasher accomplishes a whole series of functions by itself. A dishwasher

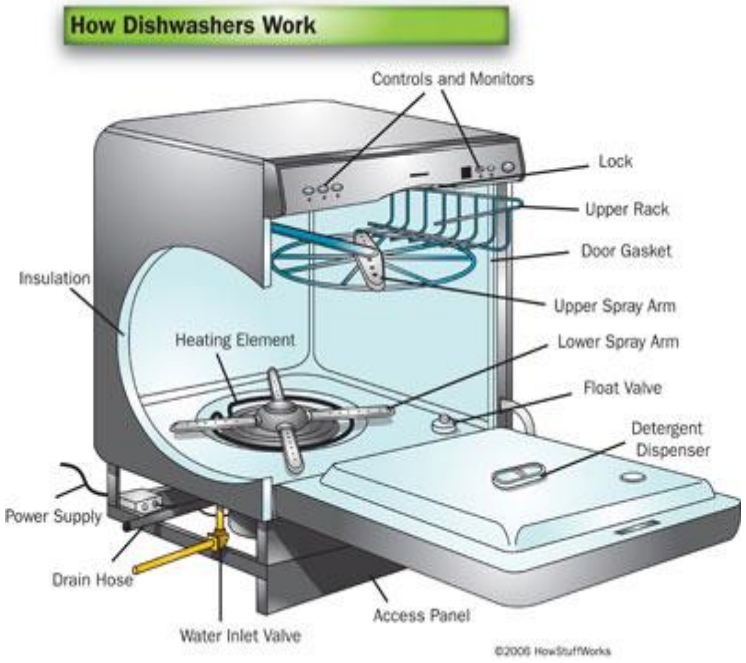
Adds water

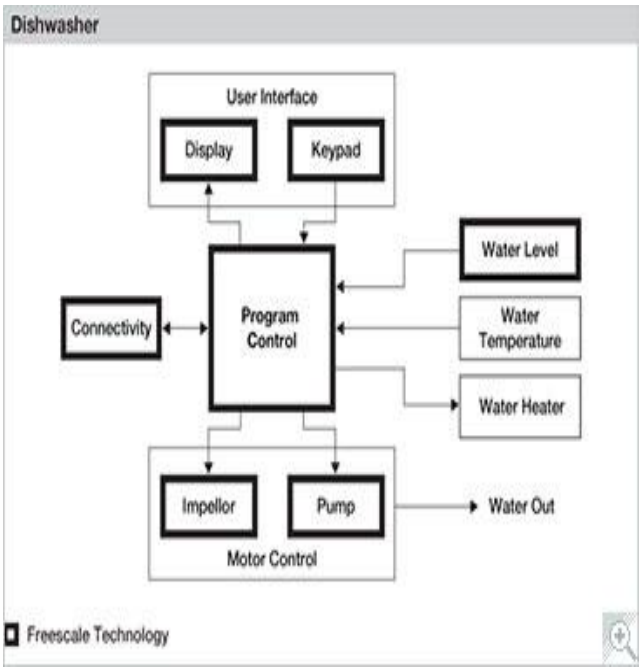
- Heats the water to the appropriate temperature

Automatically opens the detergent dispenser at the right time

- Shoots the water through jets to get the dishes clean
- Drains the dirty water
- Sprays more water on the dishes to rinse them
- Drains itself again

Heats the air to dry the dishes off, if the user has selected that setting





The microcontroller is used in this unit, can manage various functions to fulfill coherent operation of the dishwasher.

For example, in a dishwasher system, the following tasks may exist:

1. Water Manager: This task manages the water intake and drain
2. Motor Manager: This task manages the direction and speed of a motor according to the selected wash cycle
3. Door Manager: This task tracks the status of the dishwasher door and informs other tasks of the current status or any change in the status
4. Display Manager: This task tracks the status of various functions of the dishwasher and displays it on the LCD mounted on the front panel

Likewise, in the dishwasher system, the microcontroller may be concurrently managing a variety of tasks such as Water Manager, Motor Manager, Door Manager, Display Manager, etc. Each task individually "thinks" that it has the full attention of the microcontroller; however, in reality, the microcontroller is attending each one of them according to a pre-determined scheme or Program loaded in microcontroller

Plate: V Layout of Basic Circuitry in ES (Dishwasher)

Speed of performance, perfection, silent mechanism, troubleshooting by selves, in-built stabilizer, star rating, and energy rating were preferred features in such appliances with ES which distinguish them from conventional ones. Aesthetics and ergonomics were also other considerations.

It is evident therefore that all these household appliances proudly owned by the selected consumers efficiently perform their functions through the embedded system applications installed in each. Their uniqueness evidently 'vested' in the programs written and embedded in each which are highly confidential and which have their copyrights. All of them had their own tricks-of-the-trade. Salutations to Research and Development team in all the firms. **Their contribution to 'household physics', which consumers and even 'Home Scientists' who study Household Equipment has forgotten is highly laudable.** They have made household activities very sophisticated yet a child play – ***good start in smarter homemaking.***

V. SUMMARY AND CONCLUSION

A home, household activity and its appliances are inseparable entities from by gone days and their significance is much more advanced with the advent of sophisticated gadgetry playing vital roles in modern days. Presence of appliances with advanced technologies (electrical/electronic/embedded systems) leaves tell tale marks on both the production side (manufacturers) and consumption side (homemaker/end-user) and reiterate the need for both the groups to be alert about current changes. While it is a matter of survival and product positioning for manufacturers (firms/companies) it is values of saving labour, status and prestige for the consumers. With mushrooming household appliances, especially those with embedded systems (ES) thronging the market, the psychology of consumers and the firms in accepting the changes warrants in-depth analysis. With this back drop the study on **'Embedded Systems Applications on Household Appliances' Performance- an Assay'** was launched by the investigator, an ardent 'Resource Management' student with real concern for management of resources at all levels.

To comprehend the concepts, 50 gainfully employed homemakers (consumers),and ten dealers of the specific five household appliances with ES (found in all households selected for the survey) were selected for the study adopting purposive sampling. Primary data was collected using a semi-structured interview schedule and an interview guide respectively. Details on performance credentials of all the five appliances with ES were obtained through secondary data. The major objectives addressed were to:

- ***Identify prospective end-users of Appliances with ES***
- ***Locate Market trend for Appliances with ES***
- ***Firm/Brand Vs USP measures operational in Appliances with ES***

The findings of the study are summarised under:

A. Appliances with ES Vs Consumer Acceptance: This part of the findings are summarised under:

1. Consumer Profile

- The sample belonged to a heterogeneous mix of age groups with a majority of 86 per cent to be in their productive ages between 31-60 years.
- Income (monthly) representation showed 70 per cent to be earning below

₹1, 00,000/-, while for 14 per cent it was between₹ 1.5 to 2.0 lakhs. Those earning below₹ 50,000 (4%) and above₹ 2.0 lakhs (8%) also featured.

- Nuclear families (72%) predominated.
- Except 14 per cent who had been married only for the last one decade, all others had put on two or more decades of marital life.
- All these are indicative of the rich experience the samples had in homemaking and in the use of household appliances.

2. Psychographic Segmentation based on Possession of Appliances

This part of the study analysed the psychological state of mind, which reflected the consumer's interests, attitudes, opinion and life style and projects their living pattern and spending habits. The findings are summarised as under:

- The samples possessed seven appliances serving six varied purposes-storing, laundry, cooking, maintenance, cleaning and luxury.
- Refrigerators (100%), washing machines (92 %), microwave ovens (72%), air conditioners (70%), and dishwashers (20%)- all modern electronic gadgets (with embedded system) adorned the list.
- The other two appliances-vacuum cleaners (70%) and toasters (68%) were electrical appliances.
- Need based selection, luxury, availability, simplifying work; saving time and energy, status symbol and affordability were attributed as reasons.
- Fully automatic top loading models (64%) followed by front loading models (28%) predominated among washing machines.
- A majority of 72 per cent preferred frost free refrigerators.
- Grill (39%) followed by solo microwaves (28%) were possessed by those who owned microwave ovens.
- Among consumers who enjoyed Air conditioners split AC was preferred by almost 90 per cent.
- An equal population of samples (48%) among those who owned vacuum cleaners had wet + dry or dry vacuum cleaner.
- Among those who used toasters, sandwich (50%) and bread toasters (32%) were popular.
- Microwave ovens possessed showed representation by nine companies/brand/firms in the households among which LG (36%), Samsung (28%) and Panasonic (11%) stole the show.

- Choice of toasters was from five brands, where Philips (35%) Prestige (32%) and Bajaj (24%) topped the list.
- From among six companies represented for washing machines Samsung (39%), IFB (24%), LG (15%) and Whirlpool (15%) showed good sweep.
- Among a negligible proportion who used a dishwasher 50 per cent had opted for Siemens.
- Samsung (33%), LG (30%) and Voltas (26%) were the company brands patronised for air conditioners.
- Eureka Forbes made a clean sweep for vacuum cleaning as 80 per cent of those who had it owned only that brand.
- Samsung (four appliances), LG (four appliances), IFB (three appliances), Siemens (1) and Eureka Forbes (one appliance) were found to have gained strong **'product positioning'** among the consuming public, especially for household appliances.
- It was pathetic to record that none of the samples, though aware of embedded systems, were not aware of their presence in the appliances they used, nor did they know the significant role they played in fulfilling the **'want satisfaction'**, the consumers much desired whenever they spent money on purchase of such appliances.

B. The Market Panorama for the Appliances

- Market trend was channelised to find details only about the five major appliances with ES, reported as used by the sample consumers.
- Two famous firms (LG and Samsung) had set admirable **'products mix'** for household appliances with ES.
- While LG had set **product lines** for all the five specific appliances, Samsung had set product lines for four appliances.
- **Product flanking strategies** were adopted for four appliances except dishwashers.
- Thus washing machine came with three options (semi automatic, fully automatic-top and front loading), refrigerators with two (direct cool and frost free), microwave with three (solo, grill and convection) and air conditioners with two (split and window) options
- IFB floated-two appliances (washing machine and dishwasher), whirlpool-one (refrigerator), Panasonic-one (microwave oven), Voltas-one (air conditioner) and Siemens-one (dishwasher).

- Based on the embedded system used as an inbuilt component in the appliances, all, the five appliances can be classified as **Medium scaled**.
- For their depth study the major three brands/firms of appliances with ES alone were chosen. The choice varied with the appliances, complying with the findings of the household survey.
- For washing machines among the three popular brands, wash action used was almost the same. Scrub mode for semi automatic and fully automatic (top loading) modes and tumble wash for fully automatic (front loading) machines. LG alone used jet spray technology, and 6 motion wash for their top and front loading machines respectively.
- All of them had introduced different features in their inbuilt components.
- Almost all the refrigerators came with inbuilt stabilizer and LED lights.
- All the firms had introduced different technologies to enhance the efficiency of their models. Durachill, power cool zone, chilling gel, flexi-cool, cool pack etc were some such features introduced by different firms.
- In microwave ovens, the technologies introduced were i wave (LG) trio wave (Samsung) and intelo wave (Panasonic).
- Several auto cook menus (multicuisine and Indian) have been inbuilt in the Grill and Convection models by all the three firms.
- All the brands selected boasted of instant cooling in their air conditioners.Changes effected were in their cooling capacity, air flow volume or in filters used.
- Shower system coupled with steam dry was the technology used in all dishwashers. IFB alone had introduced automatic sensor wash system.
- All the firms thus have emerged as **Market leaders**.
- The firms had successfully introduced several innovative ideas in all their appliances to face the challenges put forth by their competitors.
- Change in drum used, wash technologies (bubble, turbo, 3D), convertible freezers, digital operations, star rating, cook technologies(trio wave, intello), filters used, compactness, sleek designs, sensors and the like were the arenas where innovative ideas had been introduced projecting their products as efficient ones.
- Washing machines came with price tags affordable by all ranging from ₹20,000/- for semi automatics to `1,00,000/- for the high end models of the top brass companies.

- Refrigerators, especially direct cool models were priced ` 24,000/- as maximum. But frost free models were quoted upto ` 2,50,000/- highlighting the sophistication and superior inputs embedded in them. Evidently refrigerators are a premium product in the market.
- Single function microwaves came in affordable prices (` 2,500-8,000/-) irrespective of the firms producing it, but converter models showed high differential in price ranges (`8,000-50,000/-). Probably the features incorporated have direct relationship to the price quotes.
- Though air conditioners are designated as luxury appliances, they were sold in comparatively affordable prices from `. 20 to 34,000/- for window and from `. 23 to 70,000/- for split ACs.
- Bottom – of – the – line models in dishwashers were priced less costing only between `. 30 to 60,000/- while top – of – the – line models cost up to `. 2,00,000/-.
- Except for a few low end versions, all appliances also were found to be rated from 3 – 5 star, proclaiming their commitment to social and environmental concerns.
- The study has thus proved that the firms had ventured well in '***product differentiation'***. All have projected features which are unique to their own brands and have established their '***Brand endorsements'***.
- It is also evident that the market studied is afresh with household appliances with ES belonging to new – generation technologies.

C. USP – the Magnetic Field of Modern Consumerism

- The consuming public is drawn to indulge in purchases by the Unique Selling Propositions (USP) offered by the Firms. The field of household appliances is in no way different.
- The three giant Firms in the refrigeration industry individually had effected changes in their models through refrigeration technology, chill zones, ice making speed, star rating, various controls, aesthetics, storage provisions and the like.
- Among the two main manufacturers of microwave ovens, the models, control options, timers, power levels, auto cook menu options, child lock etc. were the attractive features.
- Regarding washing machines, washing options, water and energy use, controls, type of drum, other innovative programs (auto restart, memory back up, self-diagnosis, auto imbalance sensing), LED displays, program time and progress indicators guided in purchase.

- Method of wash and dry, energy and water saving, child lock, load sensors and LED displays were put forth as unique features for dishwashers.
- Capacity, noise levels, air flow volume, temperature display, air swing and auto restart were the inputs highlighted in air conditioners.
- Sleek look, ruggedness, finish, aesthetics, ergonomic designs, an eye for perfection and speed of operation apart from budget were the other factors looked into by consumers.
- To sum up the following are the USP offered by the Firms
  - ***Extraordinary features (brand wise) excelling one another***
  - ***Access to all to own all appliances – varied models, range of price***
  - ***Bringing fuzzy logic and embedded system operated systems to Indian doorsteps***
  - ***Ecofriendly appliances***
  - ***Appliances with default stabilizers to tackle Indian electricity distribution system***
  - ***Appliances with default self-diagnosis***
  - ***Appliances to free consumers from household drudgery***
  - ***Enhancement in quality of life and standard of living***
  - ***Ergonomic designs***
  - ***Perfection-oriented programs and circuitry***
  - ***Capitalize on the intelligence of embedded systems***
  - ***Incorporation of ES in all appliances to improve their performance capabilities – to fulfill functions in the most effective manner***
  - ***Make sophisticated appliances user friendly – HMI (touch panels etc.)***

D. Evidence of Advancement in Household Physics and Instrumentation Engineering

- The basic circuitry of the programs embedded in the selected five appliances which portray tremendous display of precision – oriented, user – friendly, appliance – specific. Techno – perfect applications given in the previous Chapter offer telltale proof of their **versatility** and opportunities for further improvement.
- **Communication and interaction** between the user and appliance has been made easy and feasible

- Further refinement and research in household physics may end up in engineering more sophisticated instruments making performance of household activities much smoother and the sail more **quality – laden**.
- Now they call the '**dishwasher**' alone as a **'mini robot'**. A time may come in the near future when all the said appliances will emerge as small 'robots'.

Conclusion

Incorporation of programs as ES in household appliances have advertently or inadvertently benefited the nation (ecofriendly designs, stabilizer –free operation, energy and water conservation, techno –transfer), consumers (completion of household activities, perfection in activity, value for money, drudgery reduction, appreciable quality of life, HMI, prestige etc.,) and the industry (new wave, next – gen technologies, widened scope for entrepreneurship, ergonomic designs, enlarging product line and mix, healthy competition).

Above all the appliances definitely contribute to the consumer's desire for ***"want satisfaction"*** and ***"satisfying experiences"*** whenever they purchase such appliances. Likewise the Firms also have the satisfaction, that they are not selling products, but ***"product benefits"***. Thus both the producers and consumers obtain '***mutual benefits'***. With these in mind the following recommendations are put forth for future action.

Recommendations

- ***Strengthen the discipline of "Household Equipment" and offer the same as compulsory subject for all Home Science (Family and Community Science) students***
- ***Enlarge scope for research on all electronic home appliances***
- ***Enhance industry – academia linkages to design more efficient, need based appliances***
- ***Create awareness among consumers on new – generation home appliances and their operation***
- ***Study market trends for other household appliances with ES***

It is rightly said

Where there are changes, there are always business opportunities

- Makihara

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APPENDIX I

Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore

A semi-structured Interview Schedule to Elicit Information on Household Appliances Possessed

- Name of Interviewee:
  Interviewer:

- Personal Details
  Age (in years)
  Occupation
  Monthly Family Income
  Year of Marriage
  Type of Family

- Details of Household Appliances Possessed

Appliances Possessed	Brand	Model	Details	Cost Incurred in (Rs)	Year of purchase

- State the reasons for possessing these appliances
- Motivating factors for purchase of appliances
- Are you aware of Appliances with Embedded Systems

APPENDIX II

Interview guide to elicit information on Market trend for household appliances

Interviewee:

Interviewer:

Address:

- Household Appliances dealt with
- Details of the Appliances dealt with
- Unique features of individual appliances
- Appliances with ES
- Brands/Firms manufacturing them
- Operational systems in Appliances with ES
- Market trend for Appliances with ES
- Benefits
- Distinguishing features