

DEVELOPMENT OF A PC BASED HOUSEHOLD ELECTRICITY MANAGEMENT SYSTEM

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Abstract

It is a statement of fact that electricity is a necessity in every household of a civic society. However, the problem has been the inability to effectively control and manage electric power within the households, especially in a developing country such as ours. This paper presents a prototype computer controlled household electricity power management system. The system is interfaced for control purposes to the computer through the parallel port. The developed system consist of a two bed bedroom flat architectural model with electrical connection points, an interface circuit and a controlled software written in visual C# programming language. The prototype model is electrically wired to depict a typical household while the control software allows users to access and control electrical points through the hardware interface box. It effects power management by keeping the instantaneous total power consumption within the household under a specified wattage (set point), using a preset priority scheme for various electrical points in the model household.

Keywords: *HelpMan, Centronics, Microcontrollers, Application software*

1. Introduction

The control of process by automatic rather than manual means is called automation [1]. It is the use of computers to control machinery and processes, replacing human operators. This is a step beyond mechanization, where human operators are provided with machinery to help them in their jobs. Some advantages are repeatability, tighter quality control, and waste reduction, integration with business systems, increased productivity and reduction of labour. Some disadvantages are high initial costs and increased dependence on maintenance, [1]. The concept of automation became truly practical with the addition of the computer, whose flexibility allowed it to drive almost any sort of task, [2].

Home automation is an idea to bring into play the recent technology in the fields of computing and electronics; it seeks a solution to the problem of inaccuracy and inefficiency of men at controlling and monitoring different functions within the home. Since the mid 1980's, several major researchers in housing and electrical control industries have pursued the idea of an integrated home automation system, [3]. Ideally, such systems enable functions like lightening, heating, cooling, ventilation appliances, entertainment and security to be operated automatically. The homeowner programs controls or monitors the house by the home computer, remote controls or even over telephone and the Internet. These systems have many similarities with building automation systems used in commercial buildings. The electricity power consumption billing system has been a major source of disagreement between the electric power distributors and consumers especially in the developing countries like Nigeria. This is

because there seems to be no robust, low cost, software driven automated system that places an appreciable level of control, regulation and management on the total power consumption of home electrical appliances. Thus the development of a Personal Computer (PC) based Household Electricity Power Management system, (**HelpMan**).

This paper practically presents a PC enabled interactive system that will allow users to control household appliances within a stipulated range of electrical circuit. Users will be able to monitor electric power consumption of the appliances such that the total power usage will not exceed a preset value of a digital wattmeter at any given time. The system will also enable users to switch on and off appliances directly from the PC and also at any preset time.

2 The Paralel Port

Parallel port is a simple and inexpensive tool for building computer controlled devices and projects, [4] and [5]. The simplicity and ease of programming makes parallel port popular in electronics world. Parallel ports were originally developed by IBM as a way to connect a printer to the PC. When IBM was in the process of designing the PC, the company wanted the computer to work with printers offered by *Centronics*, a top printer manufacturer at the time. IBM decided not to use the same port interface on the computer that *Centronics* used on the printer. Instead, IBM engineers coupled a 25-pin connector, DB-25, with a 36-pin *Centronics* connector to create a special cable to connect the printer to the computer, [6].

When a PC sends data to a printer or other device using a parallel port, it sends 8 bits of data (1

byte) at a time. These 8 bits are transmitted parallel to each other; as opposed to the same eight bits being transmitted serially (all in a single row) through a serial port. The standard parallel port is capable of sending 50 to 100 kilobytes of data per second, [7] and [8]. Figure 1 describes a typical DB25 connector for parallel port interface and associated lines. The lines in DB25 connector for parallel port are divided into three groups, they are:

- Data lines (data bus)
- Control lines
- Status lines

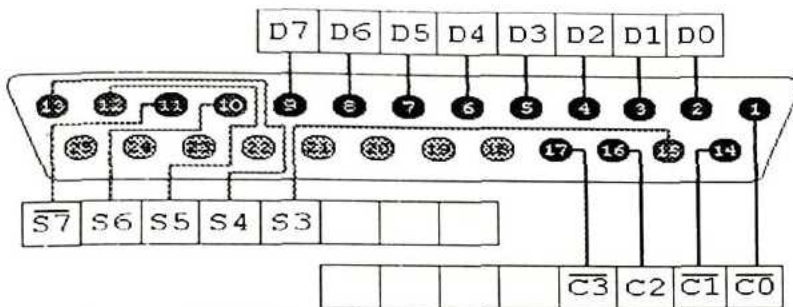


Figure 1: DB25 Connector for Parallel Port

Actual data is transferred over data lines. Control lines are used to control the peripheral, and of course, the peripheral returns status signals back to the computer through Status lines. These lines are connected to Data, Control and Status registers internally. The word connection does not mean that there is some physical connection between data, control and status lines. The registers are virtually connected to the corresponding lines such that whatever is written to these registers through program codes will appear in the corresponding lines as voltages. This can be measured with a multi-meter, and whatever is given to Parallel port as voltages can be read from these registers. For example, if '1' is written to Data register, the line Data0 (D0) will be driven to +5v and other data lines to 0V. The Data lines and Control lines can be programmatically turn on and off in the same way.

In PCs, these registers are memory mapped input/output interface units and hence they have unique addresses. These addresses must be known in order to work with the parallel port. In Windows 2000 operating system and above, the address can be seen by navigating through: Settings > Control Panel > System > Hardware > Device Manager > Ports (COM & LPT) > Printer Port (LPT1) > Properties = in Resources > Resource Setting. It is usually '0x378-0x37F' in hexadecimal number system format. For a typical PC, the base address of Line Printer 1 (LPT1) is 0x378 and of LPT2 is 0x278. The Data register resides at this base address, Status register at

base address + 1 and the control register is at base address + 2. So, the base address is known, addresses of other registers can be calculated.

3 The System Design

This system aims to control high voltage appliances with a digital computer, the output of the computer will be used to switch on and off 240V ac appliances. In a bid to achieve this, two questions readily comes to mind;

1. How will the output of a digital computer be made adequate enough to drive the high voltage circuit?
2. How will the computer be protected from transients and surges which normally occur in high voltage circuit?

Figure 2 shows the Power Flow Diagram of the system. Power flows from the computer through the opto-isolators to the interface circuit and to the appliances through the electromechanical relay. The optoisolator and relay electrically isolates the appliances from the computer thereby providing a solution to question 2 above, while the interface circuit answers question 1.

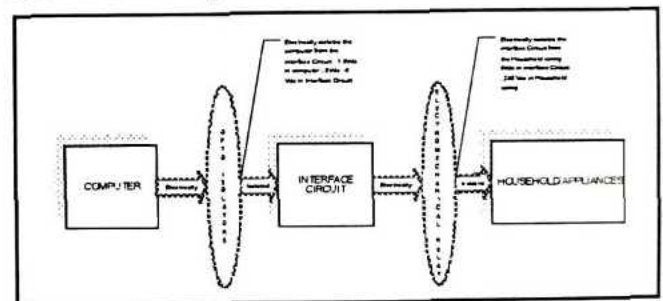


Figure 2: HelpMan Power Flow Diagram

The parallel port has 8 data lines; this makes it very essential to multiplex the 8bit data in order to control more than 8 electrical points. For this prototyped the 8 bit data lines were multiplexed to 16 data lines so as to control 16 electrical points and to demonstrate the process of multiplexing. The first 2 bits of the parallel port control lines were used for the multiplexing (data selector).

Figure 3 shows the hardware circuit diagram of the entire HELPMAN system. The control software detects the point(s) to be switched ON/OFF, generate and send the required signal through the control lines and data lines to the Chip Select of 74LS574 octal D latch and 74LS04 NOT gate respectively; this allows the 8bit data line to be exclusively used by the activated 74LS574. The infrared LED in the 4N32 opto-isolator of the electrical points to be controlled is forward biased (in case of ON), it emits infrared rays internally, (Vishay Semiconductor, 2004). This ray energizes the base of the photo transistor (Note that there is a pair of

Transistor in the 4N32 coupled in the photo-Darlington configuration), the transistor conducts and allow the magnified current to energize the relay coil, the plate in the coil becomes magnetized and the relay switch is closed, which in turn allows the ac Voltage to power the specific Appliance (A bulb in this case).

The power supply section supplies the required regulated DC voltage of 5V and 6V to the Vcc of the ICs and the collector of the phototransistors respectively.

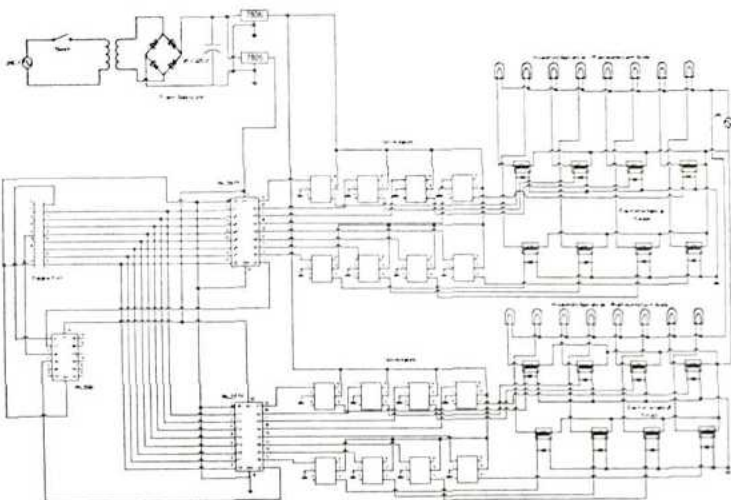


Figure 3: HelpMan Interface Circuit Diagram

4 The System Hardware

In the actual construction of *HelpMan*, circuit in figure 3 is separated into two, the *modeled household electrical wiring* and the *interface box*; The 16 AC bulbs represent the 16 electrical points within the two bedroom flat modeled building, while all power and switching circuits is packed in the Interface Box. However, there is a provision for 16 terminals that enable user to connect the two separated circuits together. It is good to note that 240V AC is the mains power within the household while 5-6V dc is the power in the *Interface box*.

Figure 4 shows the **HelpMan** Interface Circuit Board with the multiplexing and isolating components electrically connected together, while figures 5 and 6 are the views of the household model.



Figure 4: HelpMan Interface Circuit Board



Figure 5: Approach View of the Household

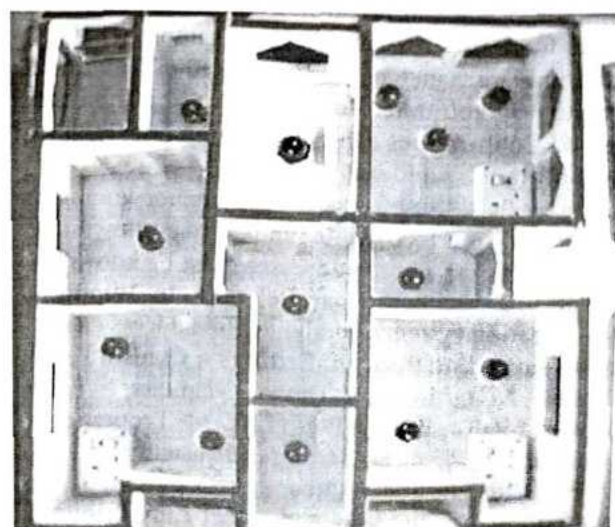


Figure 6: Household Model when the roof is detached showing the electrical points within the entire household

5 The System Application Software

The application software drives the designed and constructed control hardware. The software was developed with C# (an object oriented programming language) of Microsoft Visual studio.NET, [9]. It helps Home electric power users to effectively control and monitor household electric power consumption and usage. It enables users to keep the total power consumption at any given time within the household, under a preset power value, such that any attempt to use more than the preset power consumption value will lead to a "prioritized" load shedding. *Prioritized* in the sense that all electrical points and rooms within the household are already given a particular priority that is commensurate with their level of importance. This is left to the discretion of the user during point configuration set-up. The important modules that were combined together to build the application includes:

User authentication Module: The authentication module verifies the user and grant privileges according to the user account; verification can be through the windows operating system user accounts or through the username /password.

Application Initialization Module: After successful user authentication, the application initializes by retrieving the latest configuration settings from the Xml_configuration file and restores the application to its previous last state

Electrical Points and Power Configuration Module: This module simply allow user to attach an appliance to a specific switch and prioritize the appliance (the rooms are also prioritized). It also enable user to set the maximum instantaneous power consumption for the household. Figure 7 shows the user interface for this module.

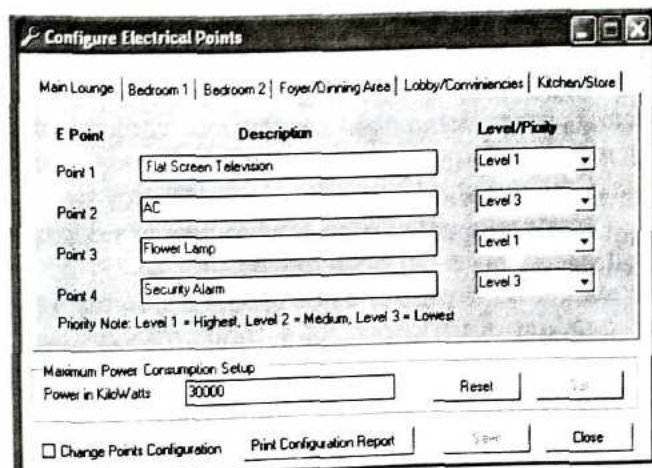


Figure 7: User Interface For The Configuration Module

Electrical Points Switching Module: The switching module allows users to switch ON/OFF the electrical points at will just by a click of the mouse. However a number of operations are performed whenever a switch is toggled. These operations are explained in the system operation. Figure 8 shows the user interface for this module

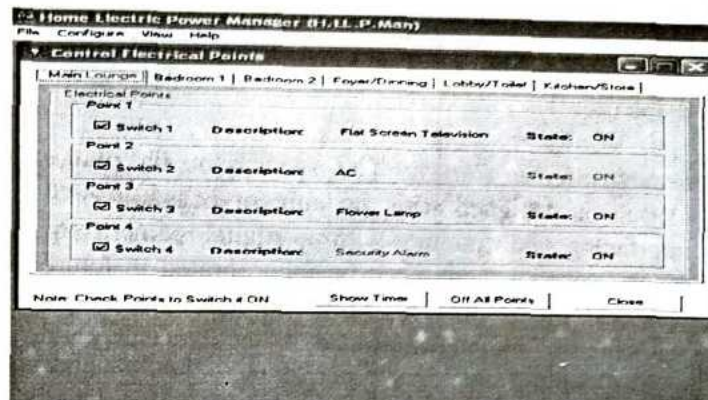


Figure 8: User Interface Diagram for the Switching Module.

Electrical Points Timing Module: The timing module allow user to specify time to ON/OFF a point.

Configurations Printing Module: The printing module simply reads the configuration settings from the xml_configuration file and sends it to the printer for printing.

Application User Manager: Application user manager module keeps tracks of all application users; it helps in creating, updating, deleting and displaying user information.

Power Graph Display Module: This module plots the instantaneous total power consumption within the household against time. Figure 9 depicts the user interface diagram for the power graph display module.

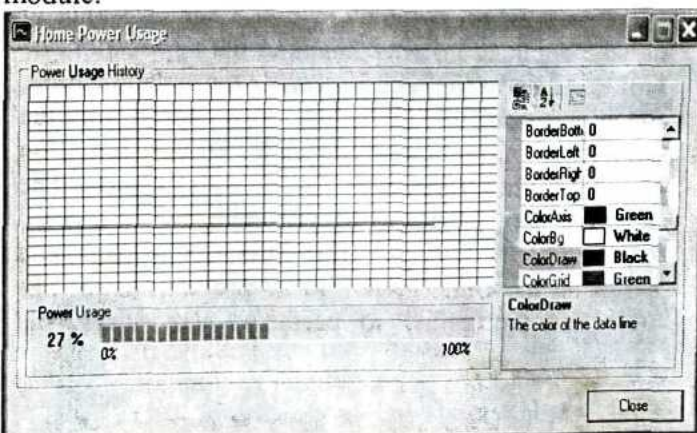


Figure 9: Power Graph Interface

Configuration Display Module: The configuration display module displays in tabular form the location of electrical points, the appliance that is plugged to each point, the priority of each points and the maximum power allowed within the household.

Electrical Wiring Plan Display Module: This module allow user to view the graphical location of electrical point that is being controlled on the computer, it presents the electrical wiring plan of the whole house to the user.

Security/Media Player: The security/media player module is designed with the aim (or possibility) of interfacing the module with a digital camera for security purposes, this can be incorporated in future versions of **HelpMan**, however users have the privileged of playing multimedia files like video and music (sound).

User Help Module: Putting in mind the level of computer literacy of potential users of the application, the User Help module provides handful help services for the user of the software. it explains and guide explicitly on how to use the application.

6 The System Operation

With reference to figure 10, HelpMan is simply a feedback control system in which digital signal flowing out from the PC will enable user to control electrical points, and simultaneously, the total instantaneous power consumption by all household appliances will flow into the PC in form of digital signal. It should be noted that all apartments (rooms) within the household has designated priorities and all electrical points within a given apartment equally has designated priorities. The system is very flexible in that any of the configuration settings or priorities can be changed at will by authorized user of the application or the system.

With an assumption that **User A** wants to use the application, after lunching the application, he will be taken to the security center for authentication, the application validate the user information from the datacenter and grants privileges to the user based on user account (Controller or Simple User). The software then initializes by retrieving the last saved configuration settings from the datacenter and restoring the entire system to its previous state. The user has the ability to perform many tasks, but

primarily he will want to switch ON or OFF an electrical appliance,

When a "Switch" (Checkbox) is clicked, the application calculates the binary value to be sent to the parallel port, detects the transparent latch that is controlling the switched point, sends the binary value to switch on the point through the data lines and the signal to select the transparent latch through the control lines. The application immediately changes the status of the electrical point to **ON** or **OFF** as the case may be. The total instantaneous power consumption is calculated and compared with the preset maximum power, if the calculated power is found to be greater than the preset maximum power consumption, the application calculates the excess loads, locate the room with minimum priority and the point with minimum priority in that room, such point is switched OFF. This load shedding will continue until the instantaneous power consumption is less than or equal to the preset power consumption. Thus the power consumption within a typical household is being monitored and put under control.

The operation of parallel port, when the computer boots varies somewhat between different computers and operating systems. In Microsoft XP, the parallel port data pins states are random in the beginning, but all pins are later set to logic 1 state after booting. On some computers the pin states can change few times during the boot process. This was discovered when Light Emitting Diodes (LEDs) were connected to parallel port pins during booting. For example many laptop computers like to send boot time diagnosing codes to the parallel port data pins. During the boot process the code sent to parallel port can change several times.

In view of this users should note the following instructions.

- Make sure that the interface circuit is not powered up (so it does not matter if PC data pins change state).
- Boot-up the PC normally
- Start your controlling software (this sets parallel port to right state)
- Power-up the interface circuit.

In this way the device will not get any control signal it is not design to get, no matter what happens during power-up.

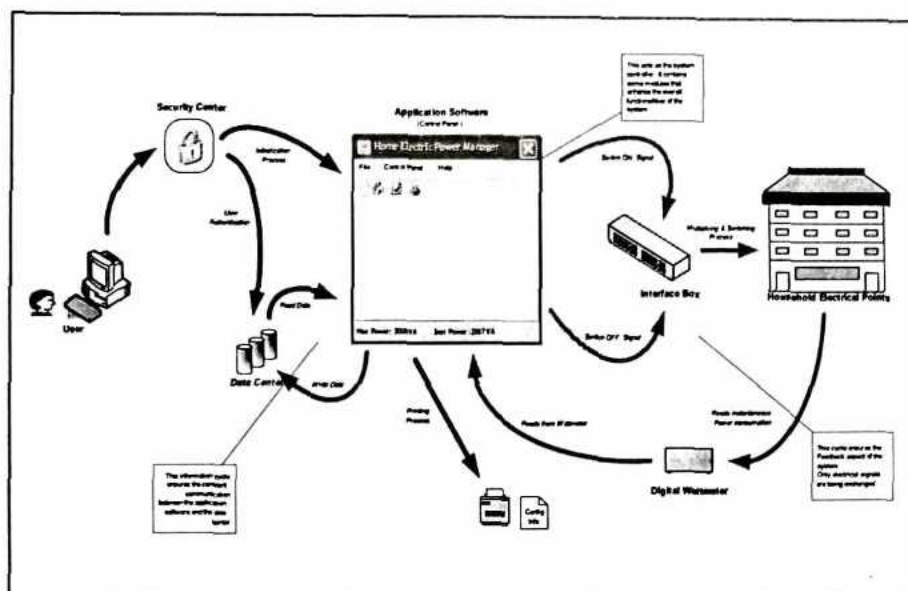


Figure 10: HelpMan Operation Diagram

7 Conclusion

This paper has successfully presented a functional low cost computer controlled system that controls and monitors electricity power consumption within a household. The system is not costly since its major components can be locally acquired. The major strength of the system lies in its flexibility and scalability. It is flexible in the sense that the user can easily change the configurations of the system and scalable in the sense that the electrical points to be controlled can be increased to accommodate at least 256 electrical points by simply multiplexing the parallel port data lines. The system is not eliminating the use of manual switches within the household but the Computer controlled switching mechanisms takes precedence over the manual switches. It is also good to note that the computer need not to be ON always, the electrical points can still maintain their status even when the computer is shut down.

The design and implementation of this system is a plus to the Nigerian electric power industries, however the participation and investment of the government and private sector to develop this technology can not be over emphasized. Examining the system carefully, it can be inferred that it will have a better application in the industrial buildings, power sub-stations rather than the household.

It will be far from the truth to say that this system did not pose some problems during the design and construction stage, one major problem is the inability of the PC to always communicate seamlessly with the hardware, sometimes there were fluctuations when switching the electrical points, this was due to the time delay when changing from one latch to another (i.e. changing data bus control).

Another problem was the high current requirements of the electromechanical relays used in constructing the system, there is need to always keep the supplied current at minimum requirement, once it is less than what is required, the relays vibrate and auto disconnect from the circuit. This can be reduced by connecting the interface circuit to a voltage stabilizer or current amplifier. The system is also "stationary"; it can only be operated from a point in the household where the point's terminals are located.

8 Recommendation

The functionalities of the system can be further enhanced through the following recommendations:

- Implementing the system with Microcontrollers, this will increase the portability of the interface circuit, and allow seamless communication between the PC and the Interface circuit although its flexibility might be impaired.
- Designing and implementing wireless communications between the PC and the electrical points, this can be done through Bluetooth, infrared or any other wireless communication technology. This will enable the control of Electrical points from any location within and outside the household depending on the strength of the wireless technology employed.
- USB interfacing will be faster and preferable than parallel port interfacing since new

models of PCs do not have the conventional printer port (Parallel Port).

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