DESIGN OF AN ETHERNET BASED RESIDENTIAL SECURITY SYSTEM

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Abstract

Current home alarm systems are quite complicated in that they require the installer to spend large amounts of time for installation or have prior professional installation experience. In addition, programming the system is a non-trivial task and usually requires prior alarm system programming knowledge.

This paper explains the design of an ethernet based residential security system that is controlled by a micro-controller and has LabVIEW for user interface. The system is easy to configure and install. The security system offers the same general features of currently available home alarm systems but with potential expandability.

Introduction

According to the FBI, there were more than 2.3 million burglary offenses nationwide in 1998. An estimated $3.1 billion in losses was a result of burglaries in 1998 [1]. In the USA, a burglary occurs every 8 seconds and, on average, 1 out of every 6 homes will be burglarized this year [2]. Homes without security systems are about 3 times more likely to be broken into than homes with security systems [2]. Burglar alarms have become standard equipment in stores and other businesses, and they're becoming increasingly common in residences as well.

Home based alarm systems are increasingly offered, as a built-in feature, in newly constructed homes. Typically, in currently available alarm systems, the security systems are installed and managed by third party companies. In case of a break-in, the company managing that particular home security system informs the homeowner of it. Today, when people are building homes and electricians are wiring them, there are many more types of cable that need to be used [3]. The electrical contractor will still be installing pretty much the same type of wire for electricity service that was used decades ago but other decisions need to be made. Installers now use the CAT 5 cable for telephone service as its electrical properties lead to better signals and less cross-talk between telephone lines. The prices on these cables have come down dramatically in recent years so that the cost differential between ordinary telephone cable and Cat 5 is negligible. It's a big selling point in many newly built homes [3].

If one is building or remodeling a home, a second Cat 5 cable to each location where a telephone jack will be installed is not far fetched. Ethernet, the most popular networking technology, can send data up to 100 megabits per second over Cat 5 cables.

With the advent of the Ethernet and great progress made in wireless systems over the last decade, many mobile devices and buildings-both commercial and residential are already equipped with off-the-shelf IEEE 802.11b wireless Ethernet technology [4]. Thus, there is a need to integrate the Ethernet with an easily configurable, adaptable security system that can be installed in a wide variety of locations.

Methods

The system presented in this paper is completely controllable from the PC, thus creating an easily adaptable system. The system also has the ability to send multiple e-mails to warn the home or business owner of vandalism or possible break in. To discourage the intruder, an audio siren will also sound as in traditional alarm systems to alert neighbors of a possible problem in the neighborhood.

The PC communicates to sensor modules via a micro-controller over Ethernet cable instead of proprietary cable. Each module possesses its own IP address informing the central computer about stable and unstable areas. The central computer contains control software with a graphical user interface. The following criteria were identified in the selection of the control software:

a. TCP/IP communications compatible
b. Windows Graphical User Interface (GUI)
c. High level Windows programming
d. Easy installation on any Windows based PC

LabVIEW (Laboratory Virtual Instrument Engineering Workbench) was found to satisfy the listed criteria and hence chosen as the control software. It is a powerful and flexible instrumentation and analysis software development application that uses a graphical programming language to create programs relying on graphic symbols to describe programming actions [5]. LabVIEW programs called VIs (Virtual Instruments) are available for data acquisition, instrument control and data analysis. In addition, LabVIEW has a good set of VIs for data presentation on various types of charts and graphs and is capable of accepting a C++ code as input [5].

A) Design Criteria

Input

Eighteen buffered input lines capable of monitoring alarm sensors (normally closed switches, open when tripped or wire is cut) were required for the project. The inputs to the micro-controller must be low when the sensor switch is closed and high when the switch is open (the switch output will be floating when open). The input to the buffer will be a logic low or logic high (0V or VCC=5V). The input pins on the micro-controller to be used are: Port A0 – Port A7; Port B0 – Port B5; Port C1, Port C3, Port C5, Port C7; Port C1, C3, C5, and C7 are designated as door inputs. All others are generic sensor inputs.

Output

There need to be 2 output lines, one of which needs to be buffered. The buffered output line must sink no more than the micro-controller can supply. Given logic high (VCC=5V) the buffer needs to be able to switch a standard piezoelectric alarm siren on and off. The second output line needs to be accessible but not connected because it is for expansion purposes.

B) Software

Input

The software needs to continuously monitor the input pins and send the pin status to the control PC when an update request is received. The input pin status code to be sent to the Control PC is as follows: Ready / No Trip = 1000; Door Open = 2000; Any Other Trip = 3000.

Output

The software needs to input the system status from the Control PC and control the output pins accordingly. The system status to be input from the Control PC is as follows: Ready / No

Alarm = 1000; Not Ready / No Alarm = 2000; 20 Second Warning = 3000; Armed / No Alarm = 4000; Alarm = 5000; The output pins will only go high when a system status of 5000 is received and will be low in all other cases.

C) Power

The module needs to power the micro-controller, the inverters, the pull up resistors for the inverters, the siren relay, the siren, the transistor to drive the relay, and all active sensors connected.

D) Design Solution

Hardware – Input

The sensor interface module comprises18 input lines that need to be buffered – 14 general sensor inputs (immediate trip) and 4 door sensor inputs (delayed trip). For an embedded Ethernet micro-controller, the RabbitCore 2100 was chosen. The Rabbit RCM2100 micro-controller has 512K Flash, 512K of SRAM and 34 parallel I/O lines. The 74hc04 hex inverters have low power consumption (40uA + total output current), can sink up to 25mA output, and do not require external output pull-up resistors that the 74hc07 buffers do. The nominal input current of the input pins on the RabbitCore 2100 is 10uA, so the buffers will draw a total of .3mA (DC1). The input of the buffer is a logic low or logic high (0 or VCC=5V), depending on the sensor switch being open or closed. When the switch is closed, the input of the inverter will be logic high, creating a logic low output. When the switch is open, the input pin would be floating. The output must be logic high when the switch is open for the code to operate correctly, so we had to add pull down resistors to each input pin. We chose 4.7k Ohm resistors to minimize current draw and provide a logic low to the inverter (DC2). The inverter requires 1mA of input current to switch to a logic low or logic high. Using a supply of 5V, the pull down resistors will draw a maximum of 1.06mA (DC2). This current is adequate to provide the input pins with logic low.

Output

Two buffered siren outputs were required – one for driving the siren circuitry and the other for future expansions. The RabbitCore 2100 can provide a maximum of 8mA on the output pins. The standard piezo alarm siren running at 12 volts draws a maximum of 300mA. An Aromat JE1 series 5V relay capable of switching up to 30VDC at 5A was used to switch the siren on and off. This is well above the desired 300mA current. To drive the relay coil, and act as a buffer between the RabbitCore 2100 and the coil, a 2n2222 transistor was used. The relay coil requires 80mA at 5VDC, so this fell well within the 800mA collector current maximum of the transistor. The transistor with an 80mA collector current has a gain of at least 190 (2). The board is capable of supplying up to 8mA; therefore the transistor will saturate and turn on the relay, and the buffer will work correctly (DC3). The measured base current of the transistor is 1.2mA.

The inputs and outputs for the Interface Module through hex inverter buffers from the micro-controller are shown in Figure 1. The communication to and from the Control PC is done over Ethernet cable and this is the only cable that is run between the two. Power is also transmitted to the module over this cable. Therefore, a power supply may be located a distance away from the module.

The inputs and outputs for the entryway module, as well as the basic communication between itself and the control PC, is shown in Figure 2. The communication to and from the Control PC is done over Ethernet cable and this is the only cable that is run between the two.

E) Interface Module

The entryway module is comprised of 16 keys and a 4x4 matrix keypad with a 2x20 character LCD display. The module also has red and green LEDS to indicate arming/disarming of the system and houses a piezo buzzer for audio. The entryway module was powered by power

Figure 1: Block diagram of the hardware system and itconnections.

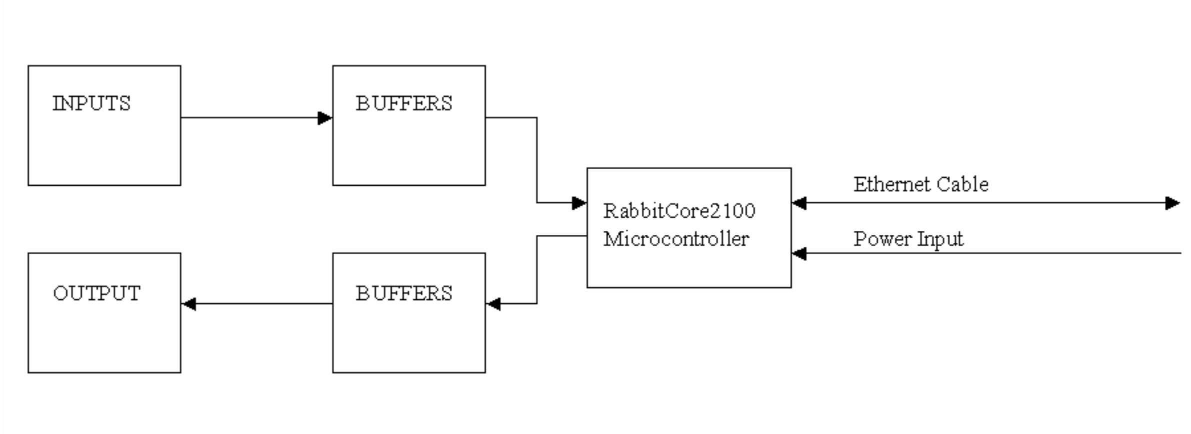
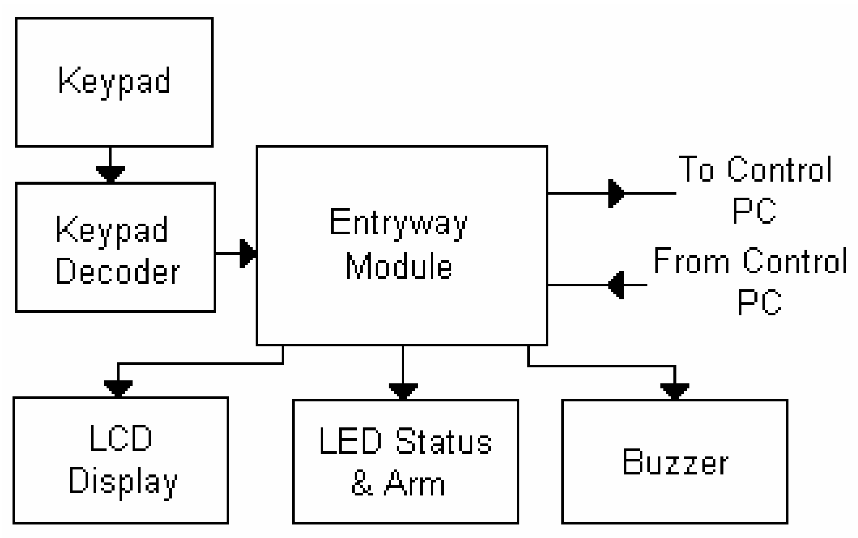


Figure 2: Block diagram of the complete system



over Ethernet, which will be discussed in the following sections.

The connections and components used to construct the sensor interface module are illustrated in Figure 3. The Rabbit MC inputs and outputs are the actual pins used to monitor the alarm sensors and system status. Screw terminals to allow for ease of connection connect the sensors and siren.

Bandwidth Considerations

The control PC sends system status (4 bytes) to the interface and entryway module every 1.5 seconds. During this period the control PC receives 4 bytes of information from each module as described in Table I below.

Every 1.5 seconds the system transfers a total of 16 bytes or 128 bits over the Ethernet connection. This is a light load over a standard 100BaseT Ethernet network, which is capable of 100 MBPS.

Figure 3: Functional Schematic of the interface module.

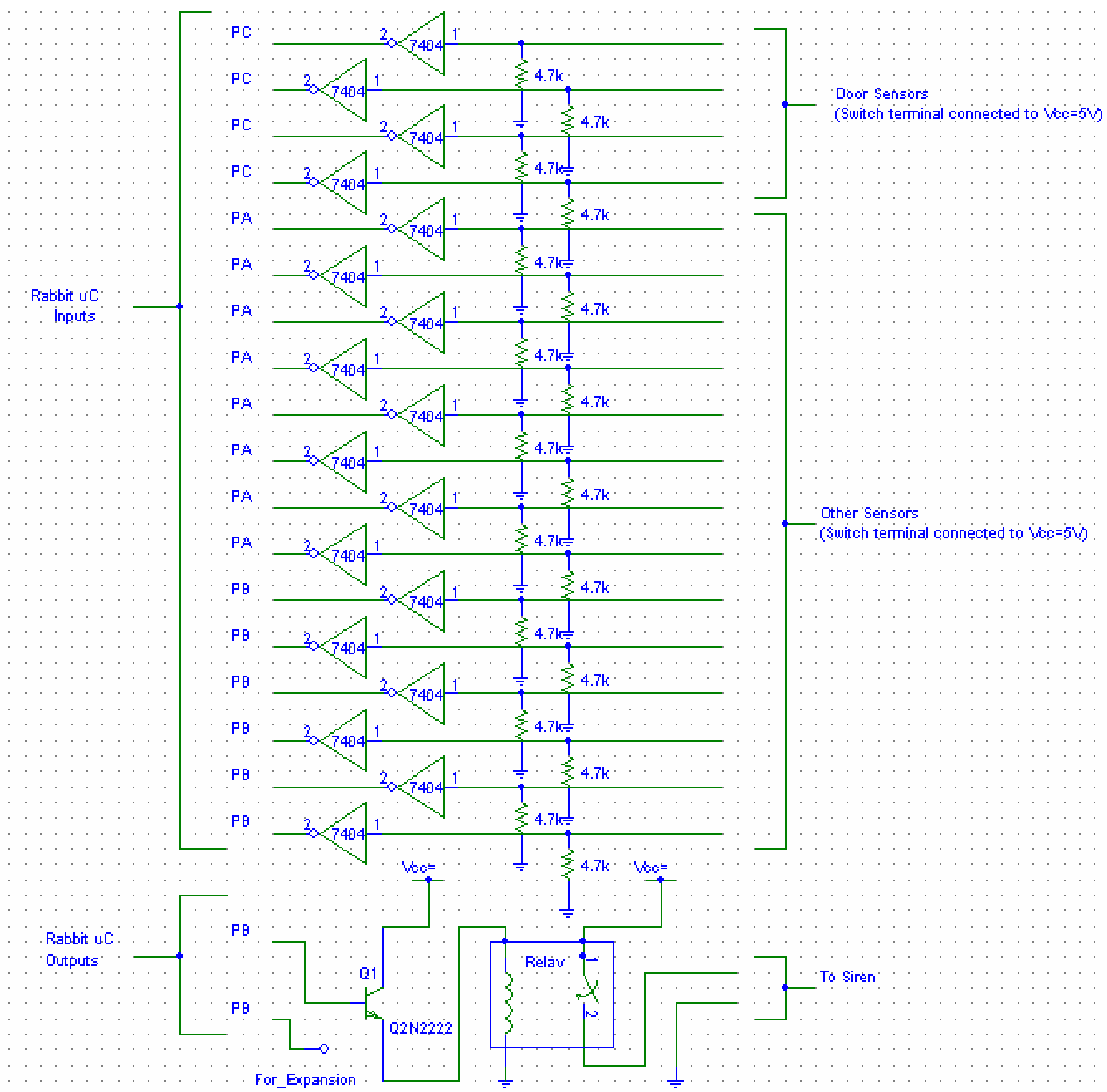


Table I – Requirements for communication

Interface Module	Bytes
Send	4
Receive	4
Entryway Module	
Send	4
Receive	4
Total	**16**

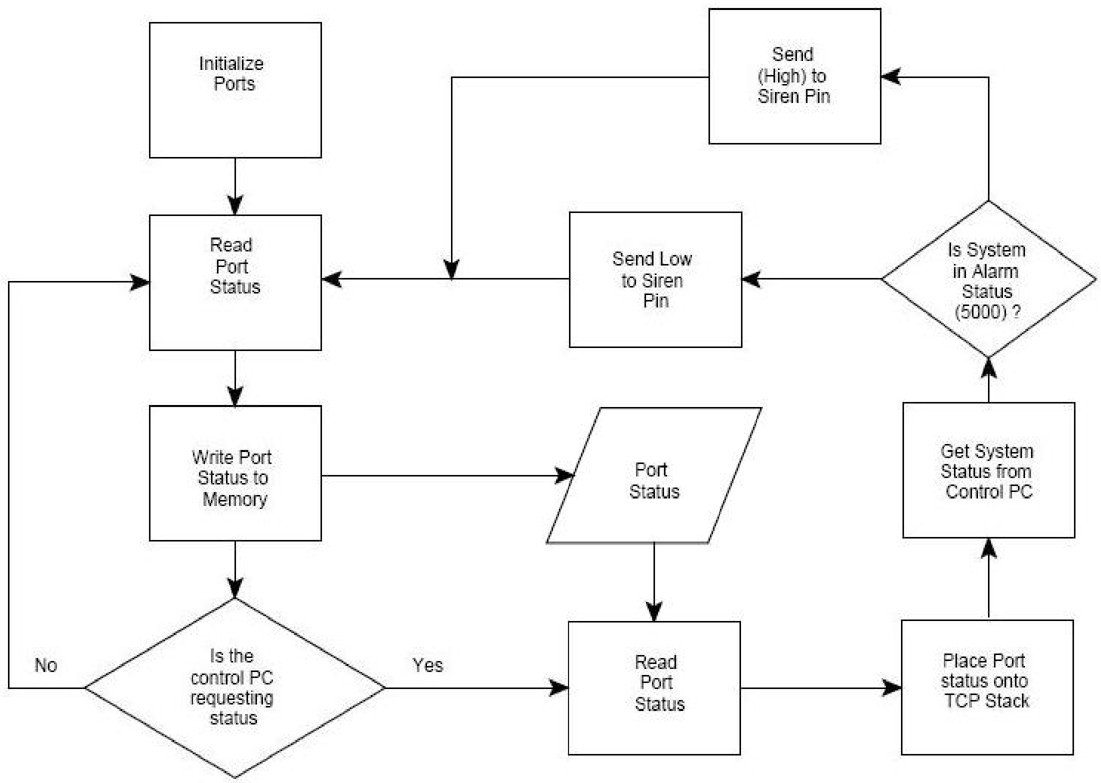
F) The C code

The Dynamic C code (Figure 4) consists of 5 main operations. These operations are:

1) Ports are initialized and set correctly for inputs/outputs as needed

2) The relay port is set to off so no false alarm will be given at startup

Figure 4: Flow-chart of the dynamic C code.



3) The code first runs through to check the ports and then establishes communication with the Control PC over TCP/IP protocol

4) The module waits for system status back from the Control PC

5) Depending on system status, the boards makes the necessary changes through code to alert any change in status.

Steps 1 and 2 are performed the first time through the code while steps 3 through 5 are in a while loop which runs forever. In short, steps 3 through 5 continue communication between the interface board and the control PC where the interface module sends the port status of the sensors, and the Control PC sends the system status for the entire alarm system.

The PC does the actual control and monitoring of the entire system. The control PC runs a LabVIEW program, which retrieves the status of the sensors from the sensor interface module and the entryway identification device information from the entryway module. It then compares the pin status against the predefined port status stated in the Interface Module Specifications. If the system is armed and the port status shows a trip, the software then activates the siren and sends an e-mail to the recipient specified in the software.

The information retrieved from the entryway module is used to arm and disarm the system. When a PIN number is entered on the keypad it is stored in memory for the control software to retrieve. When the software retrieves the PIN number it will decide to arm or disarm depending on the current system status. If the system is disarmed and a PIN number is entered from the module, the software retrieves it and compares it to the PIN numbers on file; if it matches the numbers stored in the setup file, the system will arm. If the system is armed and a PIN number is entered from the module, the software retrieves it and compares it to the PIN numbers on file, if it matches the numbers stored in the setup file, the system will disarm.

The system will also have the capability to send e-mail messages out to various recipients. Most major cellular phone companies support text e-mail messages, so the message can be sent to the owner's cell phone, alerting them to the status of their alarm. The message may also be sent to other e-mail servers, such as a basic e-mail address used for work or home.

G) LABVIEW SOFTWARE DECISION FLOW

The Virtual Instruments designed in the LabVIEW program to perform various control functions are shown in Figure 6.

Power

The power for this module will be supplied using Power over Ethernet (PoE). The maximum voltage that will be received at the module from the PoE module is 30VDC, and the minimum is 14.5VDC. The nominal current capability of the PoE module is 1.1 Amps, with maximum of 1.8 Amps. The total maximum current this board will draw is 837.45 A, so this value is within the nominal capabilities of PoE. Alarm sensors and the siren will run off of 12VDC drawing 580mA (max), and all other devices run off of 5VDC drawing 247.45mA (max). Therefore, two regulators were used to step down the high input voltage to the two different supplies. These regulators had to be able to accept up to 30VDC. Linear regulators dissipate the voltage drop through heat. With a 30VDC, a linear regulator will run hot even with a large heat sink. A common switching regulator, the LM2575 series was chosen to perform this task. These regulators are commonly used to replace the LM78XX regulators when heat and efficiency are concerns. These regulators in many cases do not need a heat sink and run with up to 88% efficiency. They can accept up to 40VDC and have a guaranteed rated output of 1.0 Amps. A 12V, LM2575 regulator and a 5V LM2575 regulator were used. The same 30V maximum input was fed into both, so the current would be split up (the 12V regulator won't have to pass through the current for the 5V regulator). This

Figure 5: LabVIEW program flow-chart showing the decision making process for the control software.

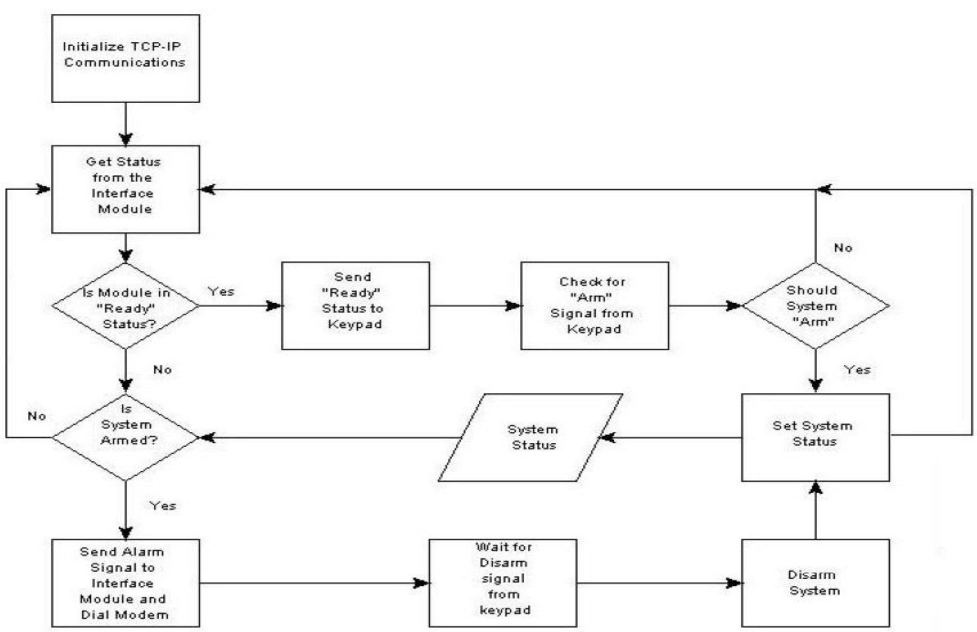
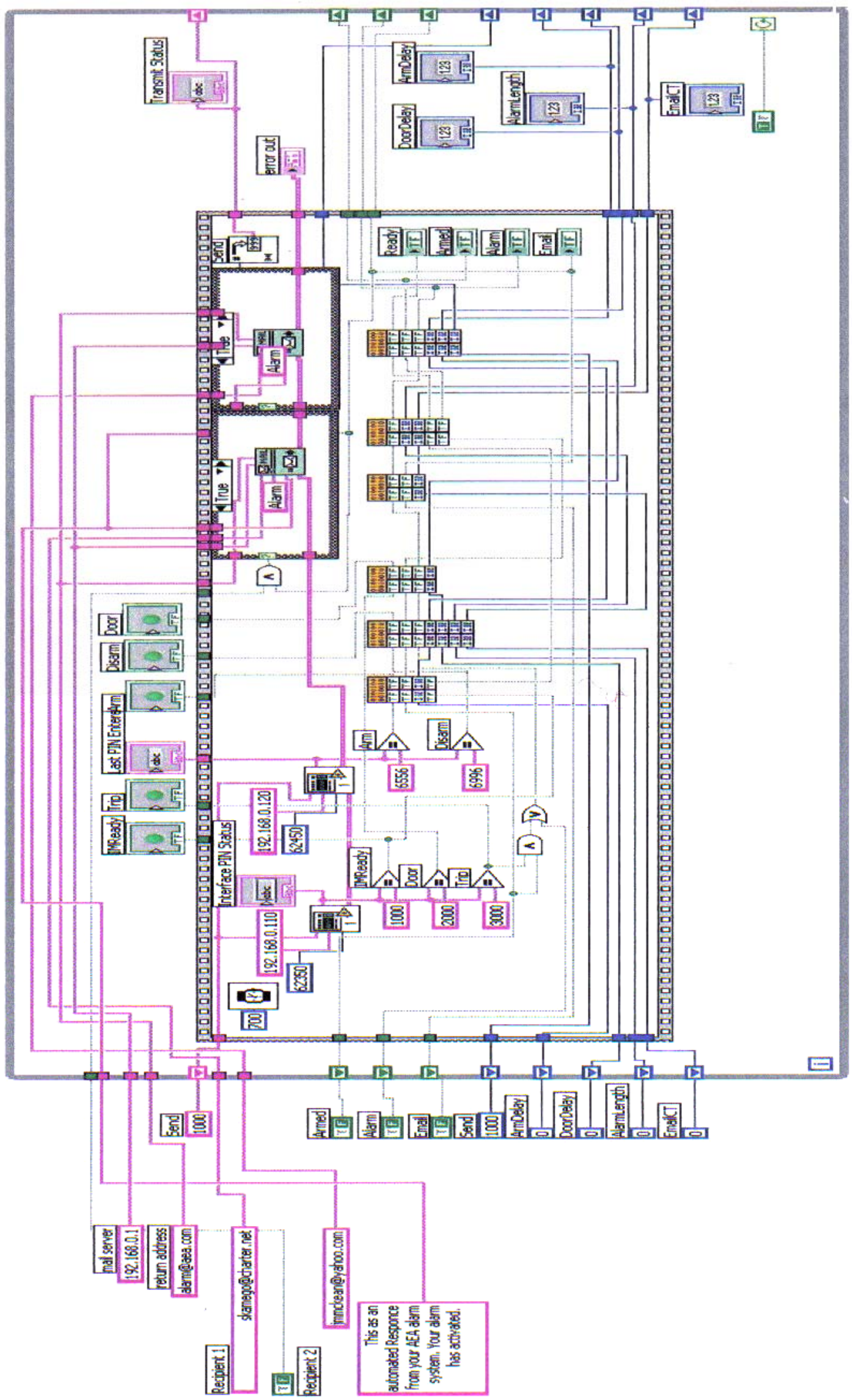


Figure 6: LabVIEW VI diagram.



provided minimum power dissipation, again allowing them to run cooler. These regulators also implement overheat protection circuitry, so burning out is not an issue. Each regulator requires four components. They require two capacitors of standard values (100uF@75V, 330uF@25V). They also require a Schottky diode of standard value that one can select from a table. Based on availability and compatibility, a 1N5821 was chosen. This diode is rated over 52kHz, which is the switching frequency of the regulator. They are also rated for 30 Volts at 3 Amps. This is well below the maximum output value of 12 Volts at 580mA or 5 Volts at 247.45mA. Each regulator also requires an inductor in which the value can also be chosen from a chart.

UPS Battery Backup

Figure 8 shows how the battery backup will be set up. The UPS will feed a constant 120VAC into the Control PC as well as the PoE transformer. Therefore, in the event of a power failure, our entire system will be backed up and power will not be lost.

Power Over Ethernet

Power to the Interface and Entryway modules was supplied by Power over Ethernet (PoE). PoE allows both data and power to be delivered to a device by one CAT 5 Ethernet cable. This is similar to the way the telephone company powers telephones from the central office through the same twisted pair that carries the voice (10).

In a CAT 5 Ethernet cable two of the four twisted pair are used for data communications, thus leaving two spare pairs of wire in which to carry power. The current application requires a minimum end voltage of 14.5V with a current of .8A. According to the AWG Wire Table a 24-gauge wire can carry maximum amperage of 0.8081 A and has a resistance of 25.669 Ohms/ Kft.

Since the current application requires an end voltage of 14V, a power source of approximately 17V will be required.

Figure 7: Circuit diagram of voltage regulators used in conventional power supply circuit.

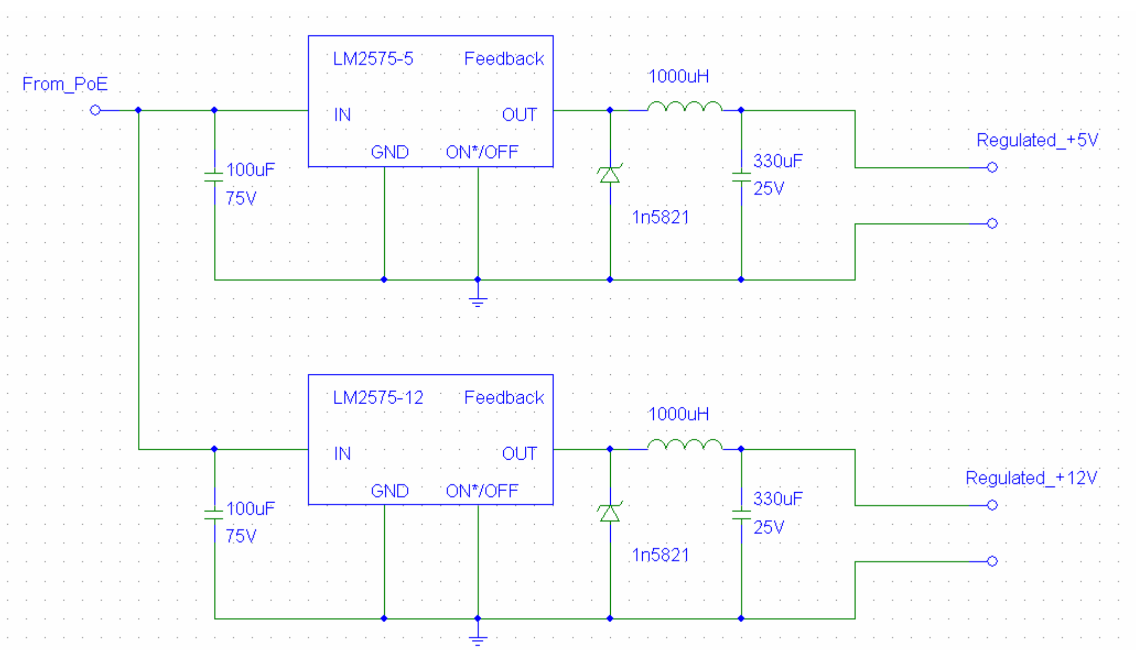


Figure 8: Block diagram of UPS Battery backup

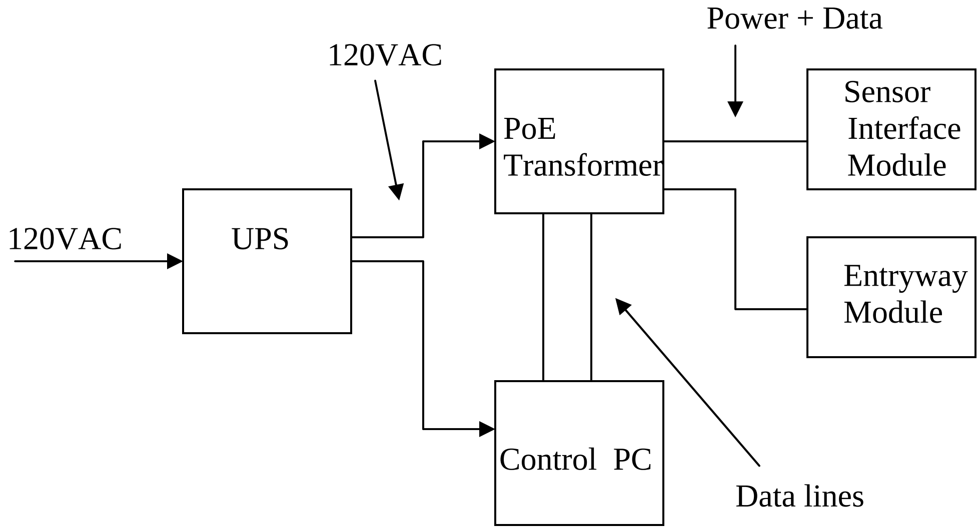
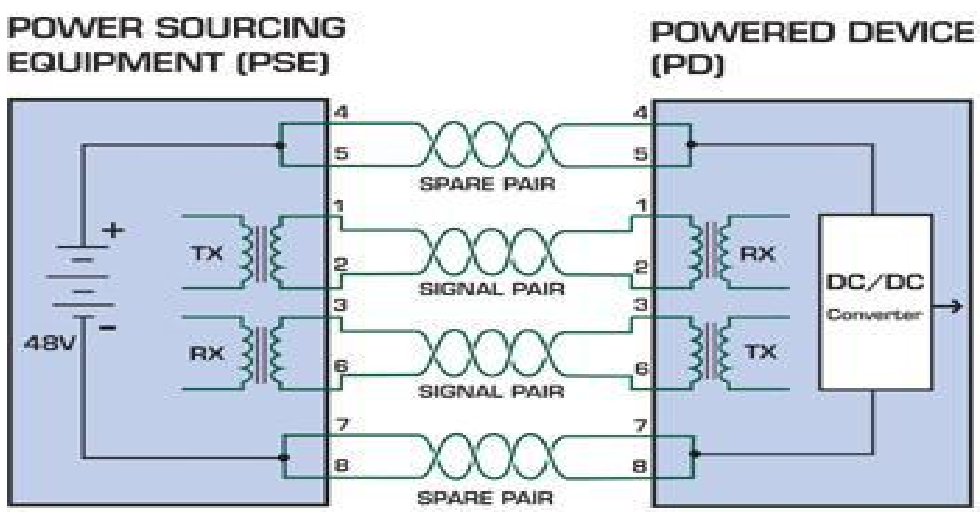


Figure 9: Functional schematic of power over Ethernet.



AWG = American Wire Gauge size from 0000 to 40
Ohms/Kft = Ohms Per 1,000 ft.
Ft/Ohm = Number of feet required for 1 Ohm of resistance
Ohms/Lb = Ohms Per Pound
Lb/Kft = Pounds Per 1,000 feet
*AMPS = Conservative Amp Rating based on 750 circulare mils per Amp
MaxAmps = Maximum allowable current based on 500 circular mils per Amp. Do NOT exceed this rating.

Results

The system was installed in an apartment and tested for reliable operation. Sensors were installed at the main door and the windows. It was subjected to normal routine activities such as leaving the apartment and arming the system, re-entering and disarming the system, testing the system. The system was tested for a period of 24 hours to ensure that all devices performed reliably. The LabVIEW interface – at the monitoring area did not show any anomalies during the tests. Simulating a ‘break-in’ also tested the system. The window of the apartment was opened from outside. The system’s audio alarm sounded within 10 seconds, alerting a neighbor. A screen capture of the LabVIEW interface is shown in Figure 10. The LabVIEW screen indicates that the alarm has been triggered. Also, the ‘resident’ of the apartment received a text message on his cell phone, informing him of the ‘break-in’. A snapshot of the cell phone with the message is shown in Figure 11. An e-mail was sent to the ‘owner’ at work, informing him of the ‘break-in’. A sample e-mail is shown in Figure 12.

Conclusions

To own a home is the American dream and to take care of it and its occupants is a necessity in these times. With advances in networking and wireless technology, many homebuilders are incorporating CAT 5 cables in newer homes.

Figure 11: Snapshot of cell phone message.

Figure 10: Screen capture of LabVIEW interface at monitoring area.

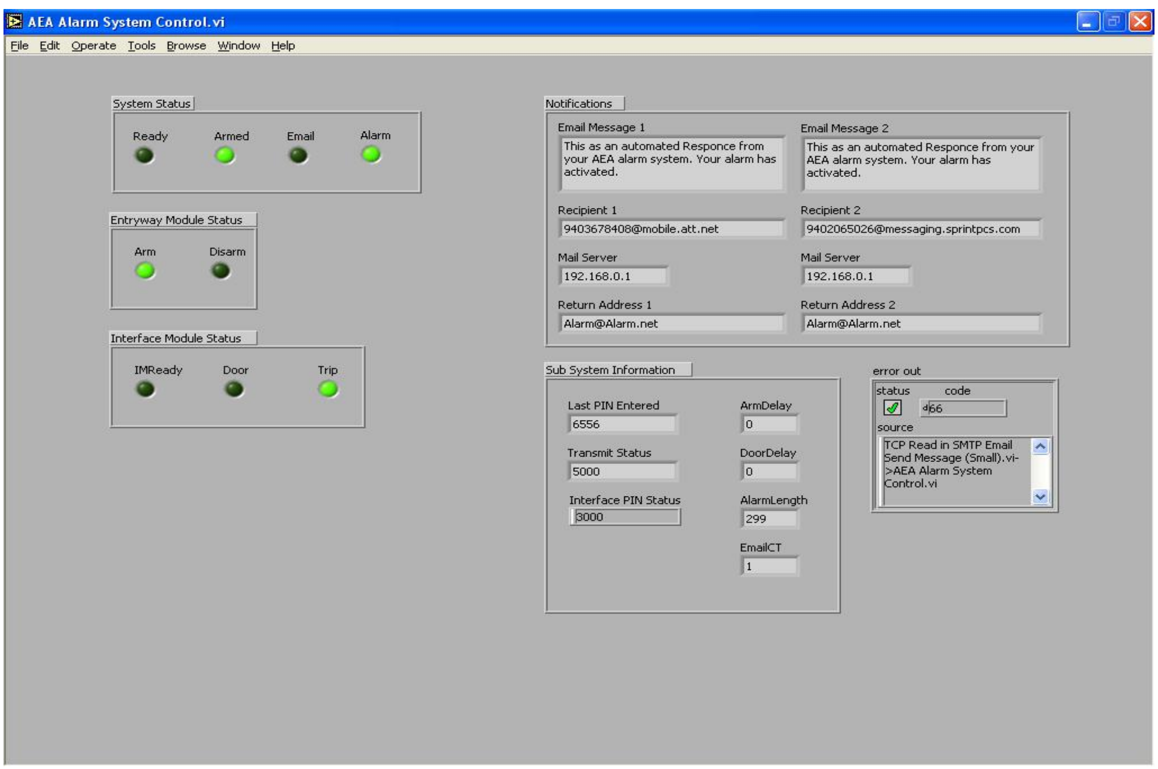
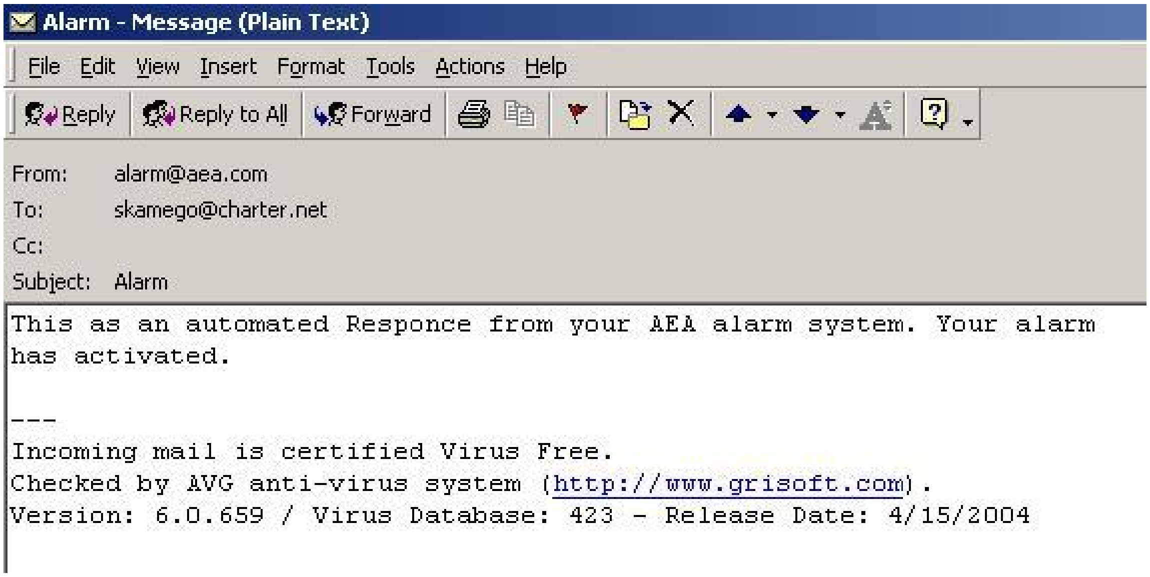


Figure 12: Example of email sent out after a ‘break-in’ occurred.



Thus, homes are becoming increasingly amenable to Ethernet based applications. With home-owners and law enforcement authorities spending a lot of money on false alarms and home owners also footing the bill on complicated installation of alarm systems, there is need for a newly designed security system that fits in well with the smart home concept. This paper presents such a design that is easy to install and monitor. The other advantage of the system is the use of power over Ethernet which reduces the number of cables, provides easy connection, and uses common CAT 5 cables.

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