Design and Implementation of PIR-Array to Reduce Power Consumption for Iraq's Households

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Abstract

The purpose of this study is to design and implement a model using PIR-sensors for motion detection to reduce the electrical power for designing smart home requirements for Iraq households. Reducing energy consumption of home appliances plays an important role in modern designs of smart homes. The PIR (passive infrared) sensor has been designed to detect human motion and has many applications especially in security fields. The main concept of the proposed work in this paper has focused on controlling the electrical devices (appliances), based on the location of a person movement inside the home. The design of the circuit control has also been designed to run specific devices located closed to person position in a room by designing PIR sensor array mounted in different angles. The proposed work has been compared with normal state by finding consumption in power (kWh) and tariffs belong to MoE-Iraq.

Keywords: Smart Home, Power Consumption, PIR, Degree Days**,** Arduino UNO, ATMEGA328,

الخلاصة

أن الغرض من هذه الدراسة هو تصميم وتطبيق نموذج لتقليل استهلاك الطاقة الكهربائية باستخدام متحسسات استشعار التغيرات في مستويات الاشعة تحت الحمراء من خلال كشف حركة الاشخاص لمتطلبات تصميم البيوت الذكية وتوظيفها في المنازل العراقية. أن تقليل استهلاك الطاقة الكهربائية في الاجهزة المنزلية تلعب دوراً مهما في التصاميم الحديثة للبيوت الذكية، وتم استخدام المتحسسات الاشعة تحت الحمراء للكشف عن حركة الاشخاص والتي تستخدم في الكثير من التطبيقات وبالاخص في حقل الحماية. الفكرة الاساسية من مقترح العمل يتركز على التحكم للاجهزة المنزلية بالأعتماد على الموقع لحركة الشخص في داخل المنزل. بالاضافة الى ذلك، تم تصميم دائرة الكترونية لتشغيل الاجهزة القريبة من حركة الشخص حيثما تم ربط المتحسس في زوايا مختلفة. وتم مقارنة العمل المقترح مع الحالة الاعتيادية لاستهلاك الطاقة وذلك بأيجاد كمية الطاقة المستهلكة (كيلوواط ساعة) والتعريفة المخصصة لوزارة الكهرباء في العراق.

الكلمات المفتاحية: البيت الذكي، استهلاك القدرة، متحسس الاستشعار للاشعة تحت الحمراء، درجة اليوم، أردوينو، ATMEGA328

Introduction

The modern design of smart homes has focused on smart controls and on converting the conventional switches to the centralize control system [Mustafijur 2015].The smart home technologies have focused on networking (wiring and wireless systems), controlling (remote control, smart phones, and web browsers), and smart devices (green, energy consumption, security, environment, and entertainment) [Rohit, 2015; Nazrul, 2014; Jayashri, 2013].

This study focuses on consuming energy by running many appliances (cooling, heating, lighting, and more) and which are interesting issues in modern smart home's design [Liyanage, 2013]. There are many approaches that show interest in reducing energy consumption in smart homes [Inji,2011;Alexandra,2011; Zipperer, 2013; Khan, 2012; Sophie, 2011; and ArtiKedar,2015], some of these approaches have focused on reducing the energy consumption based on movement detection of a person using PIR (Passive Infrared) sensor. The operation of saving energy by using PIR sensor is illustrated in figure (1) below.

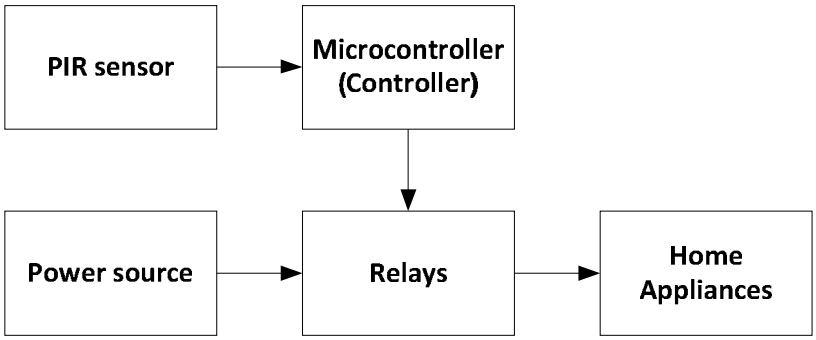

Figure (1) General concept of controlling energy consumption in smart home

The PIR sensors are mounted to wall of room, one sensor in each room or walk-through [Rashmi,2015], if the PIR sensor is detected any motion; the controller circuit takes a decision to turn on/off home appliances by switching relays on/off.

Passive Infra-Red Sensor Technology

The PIR detector sensor is designed to response to components which have self-generated and reflection of infrared radiation. Any object emitting a temperature in infrared is considered as part of electromagnetic spectrum [Thankuriah 2013]. Animals and human body generate heat and infrared radiation [Paul R 2013].The temperature emitted from human body can be derived from Wien's displacement equation as below:

$$\lambda_{peak} = \frac{2898}{T} \ldots\ldots (1)$$

Where λ_{peak} the peak in micrometers, T in Kelvin, and 2898 is Wien's constant [Pavanello,2010]. By considering human body temperature is (35^{o}C) (308Kelvin), the emitting started at 9.4μ m as derived from equation (1).

$$\lambda_{peak} = \frac{2898}{308} = 9.4\mu\text{m}$$

For that, the PIR sensor wavelength operations range is (8-14μ m)[Sauro, 2013].

The PIR operation concept depends on the differences of IR energy for intruder and background. In addition to that, the PIR detects an object when the object locates in-site of sensor and has different temperature than the background. Besides that, PIR sensor is passive device which means doesn't transmit signal [James, 2013; Mary, 2006].

The PIR detector has been designed with two pyroelectric material to filter an incoming radiation and generate low levels of thermal energy,for that, the pyroelectric current flow is small and need to convert this small signal to convenient signal. Circuit design illustrated in figure (2) describes the electronic component of PIR module.

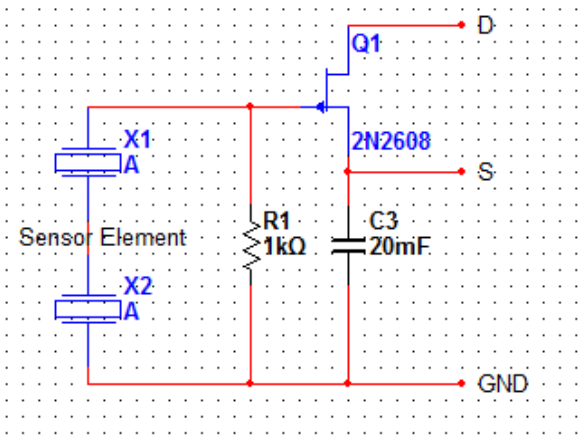

Figure (2) PIR circuit design

The module used is LHi778 pyroelectric infrared detector and it has dual element ceramic with FET transistor. The operation of circuit in figure (2) started when element (X1) detects temperature (human body), and is compared with element (X2) value, and sends a signal to operate the FET.

Energy Consumption in Smart Home (Proposed Method)

The energy consumption quantitatively assessing method in the proposed work is related to outdoor temperatures concept based on the "degree days". This method is developed by the specialist engineers in heating, ventilation, and air conditioning, and is used to assess the energy in buildings and private homes [John,2005]. The measuring of energy consumption using Degree Days (DD) has reference temperature which is ($65^{o}F=18^{o}C$),if the mean daily temperature is below the reference temperature and is considered as heating degree days (HDD),otherwise, it's considered as cooling degree days (CDD) as determined in equations (2 and 3) below[John, 2013].

$$HDD = \sum [(T]_i - A) \ldots . (2)$$

$$CDD = \sum (65 - T_i) \ldots . (3)$$

Where, T_i is the mean of daily temperature for the day i, and A is the threshold temperature. The degree day measuring method is illustrated in figure (3).

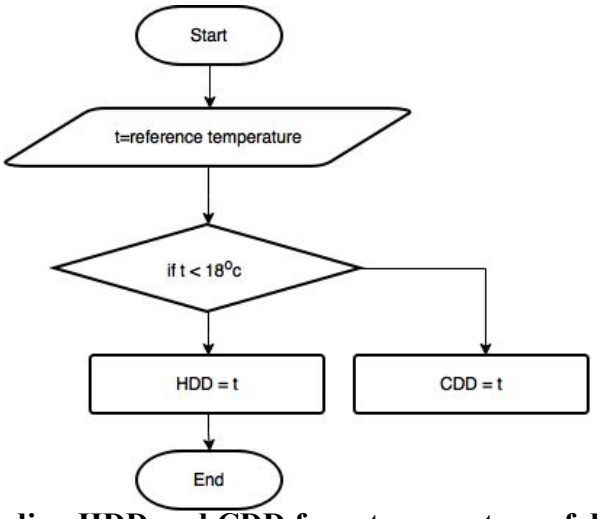

Figure (3) finding HDD and CDD form temperature of degree day

Temperature data for Baghdad city during 12 months of the 2015 is presented in table (1). The temperature values in this table have been calculated by finding the mean of the temperature of each month. Moreover, both the degree days (heating and cooling degree days) have been calculated and included in this table.

Table (1) Temperature data for Baghdad city during 12 months of the 2015

CDD	HDD	Low	High	Month
3.6	-3.6	3.3	14.4	Jan.
0.2	-0.2	6.1	17.8	Feb.
-4.8	4.8	10	22.8	Mar.
-10.9	10.9	15	28.9	Apr.
-17.6	17.6	20	35.6	May
-22.6	22.6	23.3	40.6	Jun.
-25.3	25.3	25.6	43.3	Jul
-24.2	24.2	23.9	42.2	Aug
-21.4	21.4	20.6	39.4	Sep.
-14.8	14.8	15.6	32.8	Oct.
-5.3	5.3	8.3	23.3	Nov.
1.3	-1.3	5.6	16.7	Dec.

- **Electricity Tariffs for Baghdad's Residential Sectors**

The electricity tariff for residential sectors of Iraqi's MoE for year 2015 is presented in table (2) below [IMF 2015].

Table (2) Iraqi's MoE electricity tariffs for mid of the year 2015 and new structure

Old structure		New structure	
Consumption bracket	Tariffs (ID/kWh)	Consumption bracket	Tariffs (ID/kWh)
1-1000	10	1-500	10
1001-2000	20	501-1000	10
2001-4000	30	1001-1500	20
4000-	50	1501-2000	40
		2001-3000	80
		3001-4000	120
		4001-	200

- **Calculating Electricity Energy and Cost**

PThe power consumption is usually measured by kilowatt-hours (kWh); which means one kilowatt (1000 watt) of power per hour. Equation (4) determines the calculation of kWh depending on voltage and ampere of main power source.

$$E_{kWh} = \left(V \times \frac{I}{1000}\right) \times hours \ldots . (4)$$

Where, (VxI) /1000 is the power, and E is the energy represented in kWh.

Proposed Design

The proposal design reduces power consumption by detecting the motion of human to control the electric appliances by turning these appliances (ON and OFF). The procedure of whole proposed design has been illustrated in figure (4).

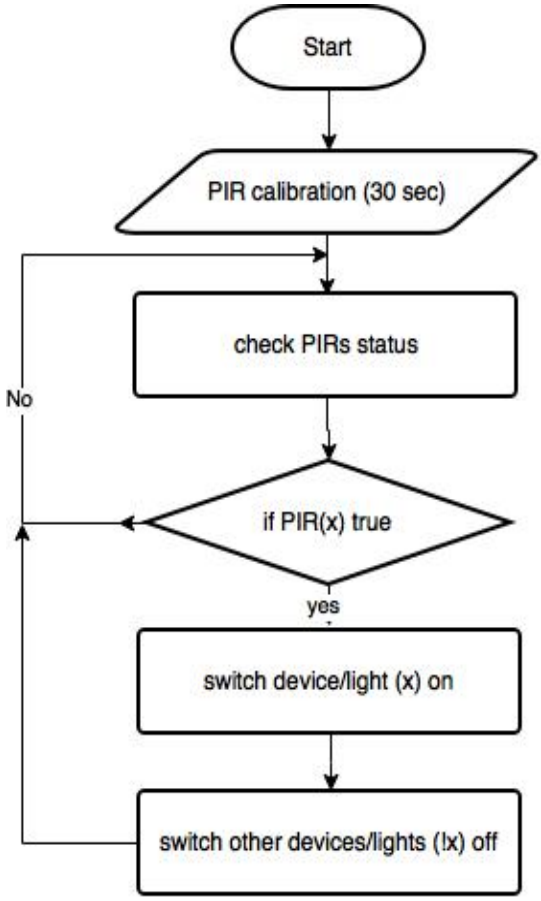

Figure (4) Procedure of proposed design

There has been an electronic hardware design using Arduino Uno Kit which is considered as the main controller and programmed to watch and get states the PIRs then operates the output (relays) where the appliances connected to, as shown in figure (5).

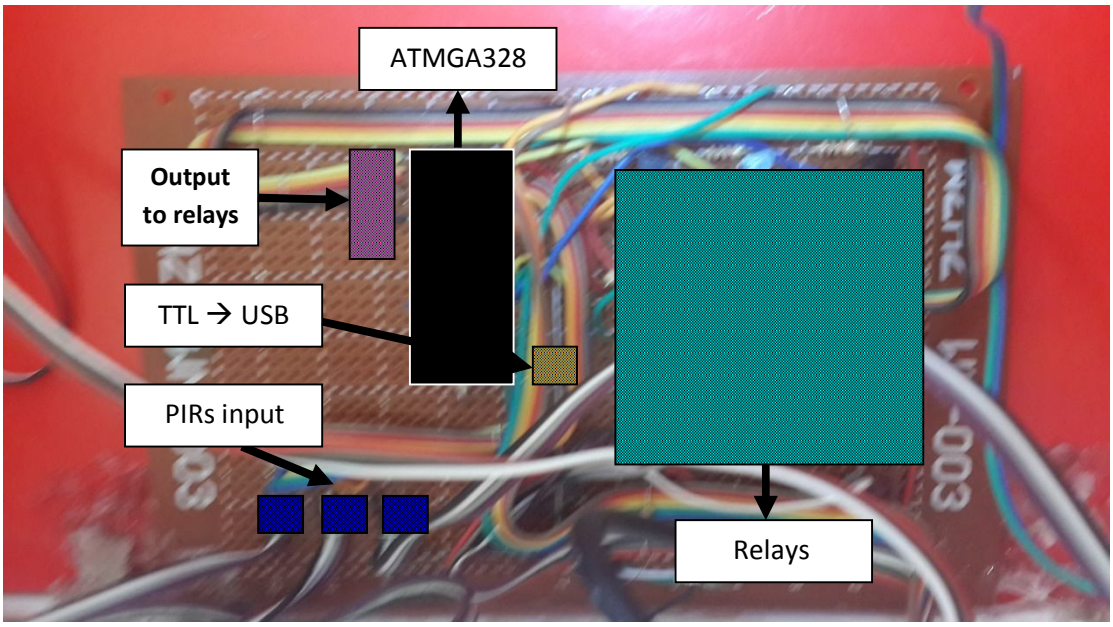

Figure (5) Electronic hardware design

An interface program has also been designed using Microsoft Visual Basic.NET (2012).This program collects and records the data from electronic hardware (controller) via serial port and displays the states of PIRs and operations of the appliances visually as shown in figure (6).

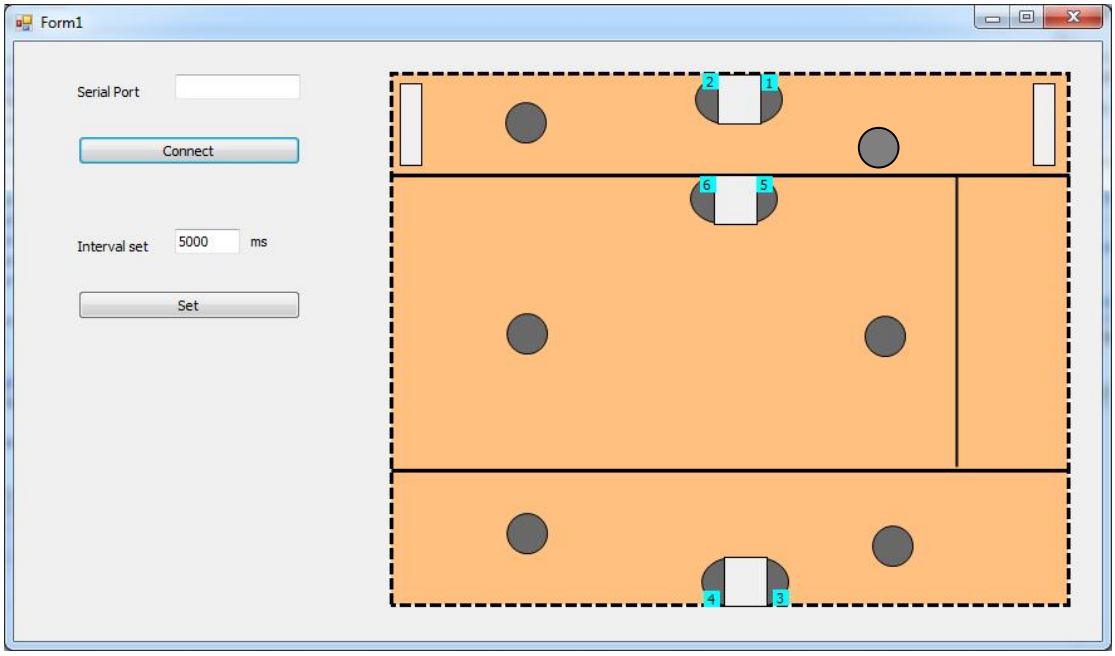

Figure (6) Interface program display the PIRs states and operation of appliances

Results

In this proposed work, a basic sensor array of PIR sensors has been designed to reduce the power consumption for households in Iraq country. The design has also focused on controlling lights, air condition, and TV which are considered as the main appliances and the most consumed of power. The power consumption of proposed work has been compared with the normal state of power consumption for households by calculating value of electricity in kWh. Table (3) explains the normal state of average household use of electricity during one month.

Table (3) Power consumption in normal state for average electricity used in household during one month

Tariff (ID)	total/month	Days	kWh	number	hours	voltage	ampere	appliance
1501-2000 40 ID	1188	30	39.6	1	18	220	10	Air condition
	213.84	30	7.128	6	18	220	0.3	light
	154.44	30	5.148	1	18	220	1.3	TV
62251.2	1556.28							

The setting rules describe the relationship between the input and output variables. Setting rules are based on IF and THEN portions. If any of the rules meets the conditions, it will control the output and gives the action based on the input variable. The rules set of our work is described in table (4) below.

Table (4) Rule sets of proposed work

Control	PIR(1)	PIR(2)	PIR(3)	PIR(4)	PIR(5)	PIR(6)
Air condition turn on	1	X	X	X	X	X
Light 1	X	1	X	X	X	X
Light 2	X	1	X	X	X	X
Light 3	X	X	1	X	X	X
Light 4	X	X	X	1	X	X
Light 5	X	X	X	X	1	X
Light 6	X	X	X	X	X	1
TV on	X	X	X	X	X	1

During the test phase of hardware operations in real-time, we've collected some of the results as represented in figure (7) below.

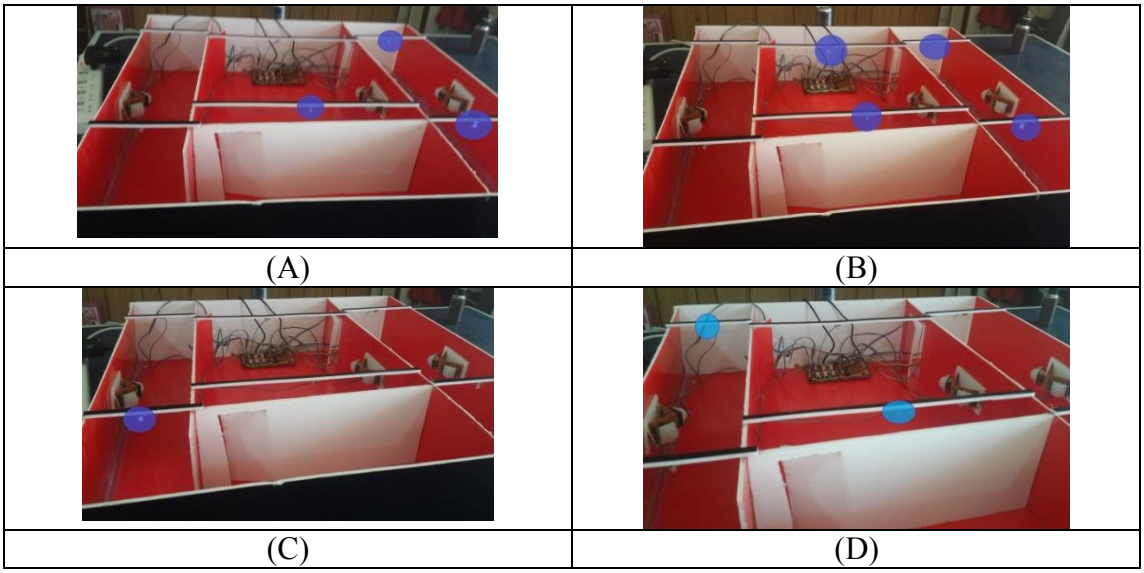

Figure (7) hardware operations results in real-time, (A) lights (3, 4, and 5) turn on, (B) lights (3, 4, 5, and 6), (C) light 3 turn on turn on, (D) light (4 and 5) turn on

Moreover we've calculated power consumption for households based on operation of the proposed hardware design during one month by finding the average of each appliances considered in this work and the results has been explained in table (5).

Table (5) Power consumption by proposed work for average electricity used in household during one month

tariff (ID)	total/month	Days	kWh	number	hours	voltage	ampere	appliance
501-1000 10 ID	792	30	26.4	1	12	220	10	air condition
	95.04	30	3.168	6	8	220	0.3	light
	85.8	30	2.86	1	10	220	1.3	TV
9728.4	972.84							

Conclusion

An important issue in smart home design focuses on reducing power consumption. The proposed work has focused on reducing power consumption in household depending on using PIR sensors mounted on wall. Besides that, the PIR sensors are connected to Arduino UNO Kit to digital port. In addition to that, monitor system has been designed using Visual Studio (Visual Basic.NET 2012) and interfaced to Arduino UNO for data acquisition.

During experimental work, we've designed controller circuit to turning on/off home appliances depending on a person motion in any part of home. These appliances do not need to be operated all time but only when a person is available. Then, we've found the monthly average for each device operation from the proposed design. Finally, we've compared results by calculating kWh for both the normal state and the proposed work of power consumption and finding the monthly tariffs. The electricity used in normal state was (1556.28 kWh) and tariff is (40 ID) and hence, the cost is (62,251 ID) according to MoE. Whereas the electricity consumed by using the proposed hardware design is (972.84 kWh) and tariff is (10 ID) and hence, the cost is (9,728 ID).

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