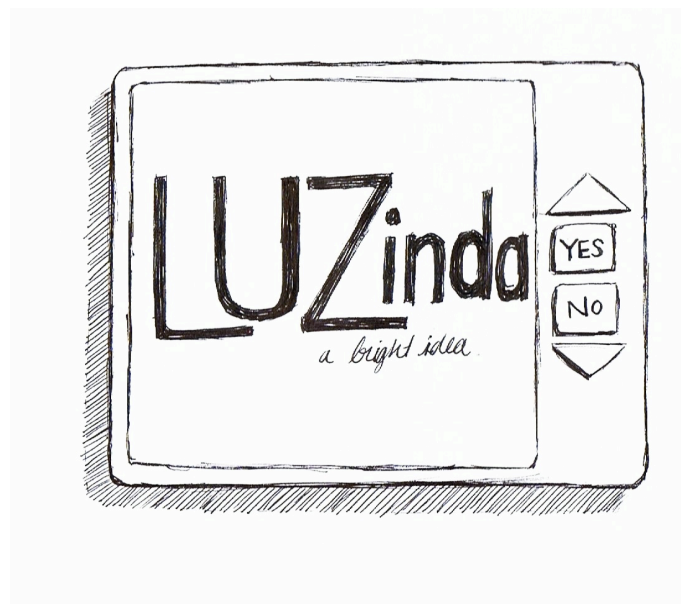


# LUZinda: A SMART LIGHTING SYSTEM FOR THE HOME



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## Executive Summary

Tasked with designing a system to conserve energy in the home, a smart and autonomous lighting system known as LUZinda (luz is the Spanish word for light) was developed. The design for LUZinda incorporates motion sensors and ambient light sensors that communicate wirelessly via XBee with an Arduino. This Arduino analyzes the information received from these sensors and signals to adjust the lighting environment. The Arduino communicates with the artificial lighting sources in the room through the X10 protocol. This is achieved by using an X10 two-way interface that communicates with other X10 modules attached to all of the artificial lighting sources. Commands sent from the Arduino to the X10 modules via the two-way interface are able to dim, brighten, turn on, and turn off the lights independently.

A simple user interface was also designed. This interface allows the user to tell LUZinda when they are satisfied with the lighting environment in the space. LUZinda is then able to “learn” and predict the user’s lighting preference, so it can adjust the lighting output automatically to ensure that the user is always satisfied with their environment.

After testing, it was found that the LUZinda system adds between 3 and 3.5-Watts to the overall lighting load. However, given a room with two or more lights, this extra load is generally accounted for with the energy savings through dimming. The more artificial lighting sources there are in a room, the more energy savings LUZinda provides.

Several recommendations have been made to further the flexibility and utility of LUZinda: the incorporation of zoning, the ability to distinguish between users and their varied tasks, creating a portable user interface for ease of use, designing and implementing an aesthetically appealing housing for sensor circuits and user interface, and improving the accuracy of motion detection.

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## Introduction

Energy conservation has been recognized as a major factor contributing to our impact on the environment. As our global population surged to 7 billion in 2011, our planet's natural resources are at the greatest risk of peril ever experienced. With the increasing number of people the earth needs to sustain, our draw on its dwindling natural resources is climbing. This is forcing us to use riskier and riskier technologies, those that require greater damage to the surrounding environment, to meet our energy demand.

By using less energy to complete tasks that once consumed an excess of energy, there is potential to reduce the population's environmental footprint. An area where there is considerable potential for this to be achieved is in the home. More than one-third of the energy consumed in the United States is in buildings, and nearly two-thirds is in the form of electricity [3]. Furthermore, it has recently been shown that large energy savings, up to 40 percent, can be made with smarter lighting solutions [3]; whether it is an increase in the use of day lighting, load shedding or simply smart scheduling, there are numerous options for increased energy efficiency.

Lights are often left on in a room after the occupant leaves or are turned on during bright, sunny days when ample light is already available. In addition, oftentimes lights are turned on because, while there may be a significant amount of natural light in a room, there is not quite enough light for a certain application, and a lot of energy may be wasted when a light could be turned on at a very dim setting rather than at full power. By creating a smart lighting system called LUZinda (luz is the Spanish word for light) that can sense occupancy, current ambient light levels (natural and artificial), and perhaps even learn and predict movement and lighting needs, the potential for energy savings is significant. It could also create a more efficient lifestyle where one wouldn't have to worry about lighting levels.

Lighting efficiency is a well-known and studied problem. There are many attempted solutions already in existence, however these tend to focus more on large-scale industrial and commercial settings rather than smaller-scale residential applications. LUZinda has combined several lighting control methods and technologies currently used in these industrial/commercial settings—such as occupancy sensors and ambient light sensors—into one simple module intended for the home. This module consists of a wireless sensor network that

communicates with a central control unit connected to the existing power lines of a house. LUZinda is a smart, easy-to-install system and it aims to maintain user-specified lighting levels for occupant satisfaction.

Dr. Cyril Leung of the Electrical and Computer Engineering Department at the University of British Columbia has sponsored the project. The aim of this project is to reduce the energy consumption in the home by focusing on lighting management. This has been attempted by creating a smart lighting network consisting of several fixtures that can cooperate to achieve the desired lighting conditions while maintaining lighting quality and efficiency. It will be designed with the user in mind, ensuring that it is easy to install and use. It will also follow the rules and guidelines of the Canadian Electrical Code.

The following assumptions have been made in order to achieve a complete system that has the main functions of the original, ideal system:

1. The analog output signal of the light sensor can be wirelessly transmitted
2. Product design completed
3. Central control unit wirelessly commands interface to the power lines

This report describes the design and technical background of LUZinda, and the conclusions drawn from testing. The deliverables will be summarized, and recommendations will be made for future work and improvements to the system.

## Discussion

### *METHODS AND THEORY*

The main objectives and guiding factors in the design of LUZinda were as follows:

1. Design a system able to determine and predict a user's lighting environment preference
2. Design a system able to adjust to a user's preferred lighting environment autonomously
3. Provide an easy-to-install lighting system
4. Provide an easy-to-use lighting system
5. Reduce overall energy consumption of lighting by adjusting lighting output to suit a user's needs

Several technologies available on the market were altered and adapted to achieve these parameters.

For the purposes of the system, it is essential to be able to detect the amount of ambient light in a space. This allows LUZinda to know the current state of the lighting environment at all times, and provides the opportunity to determine if this amount is too much, too little, or just enough. The space may have an abundance of natural light, reducing the need for artificial lighting. As the ambient lighting changes throughout the day, so too does the amount of dimming in artificial lighting. Thus, to achieve the greatest energy efficiency with the maximum amount of dimming while still providing a sufficient amount of light, a method of measuring the amount of ambient light in a space was needed.

This was done using photoresistors, although any standard photosynthetically active radiation (PAR) photodiode would suffice. These analog devices are able to detect visible light, outputting a variable between 0 and 1023 depending on the amount of light detected.

Another useful piece of information about the environment is whether or not it is occupied. An occupancy sensor is a device that detects whether or not a room is in use. This provides the option of turning lights off automatically to save energy if someone leaves a room. This helps avoid lights being left on in an unoccupied room, using electricity, and wasting energy.



There are currently two types of occupancy sensors available: Ultrasonic sensors and Infrared sensors.

Passive Infrared (PIR) sensors detect heat and movement; they respond to sudden changes in background heat energy. This requires that the sensor be placed very carefully so as to allow a “line of sight”, because they cannot see around objects. The sensitivity of these sensors also decreases with distance, which makes tuning them slightly more difficult.

Ultrasonic sensors use sound waves to detect occupants. A quartz crystal radiates high frequency (25-40kHz) sound waves whose reflected frequency is measured. Movement within the room is detected from a shift in reflected frequency. These sensors provide the ability to sense around objects given the surface of the object is hard enough.

A comparison of these two technologies can be seen in Table 1.

Table 1: PIR and Ultrasound Detection Comparison

PIR Sensors	Ultrasonic Sensors
<p><b>Sensitivity:</b>  Hand movement up to 10 ft.  Upper body movement up to 20 ft.  Full body movement up to 40 ft.</p> <p>Totally restricted to detecting occupancy within “line of sight”</p> <p>More sensitive than ultrasonic in situations where the occupant is moving laterally in front of the sensor rather than towards or away from the sensor</p> <p>Not sensitive to small changes in the space, resulting in fewer false triggers unless a sudden heat change occurs in the same wavelength range as that emitted by humans</p>	<p><b>Sensitivity:</b>  Hand movement up to 25 ft.  Upper body movement up to 30 ft.  Full body movement up to 40+ ft. (In general, can cover a larger area than PIR sensors)</p> <p>Less dependent on “line of sight” for occupancy; may detect occupancy behind objects/around corners if in enclosed space with hard surfaces</p> <p>More sensitive than PIR in situations where the occupant is moving towards or away from the sensor rather than laterally</p> <p>Ultrasonic sensors are more sensitive to small changes in the space, such as breezes from HVAC system or windows, resulting in more false triggers unless carefully calibrated</p>

<p>More effective for restricted-coverage areas such as aisles, outdoor and high-bay applications</p> <p>Costs a little less to purchase</p>	<p>May result in false triggers in restricted-coverage areas, outdoor and high-bay applications due to “leakage” of waves</p> <p>Costs a little more to purchase</p>
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Source: [9]

The characteristics of PIR sensors seem to suit applications such as those similar to LUZinda. A Panasonic AMN41121 standard detection PIR sensor was chosen. More information on this product can be found in Appendix C.

In addition, the information recorded by these sensors, the motion sensor and the ambient light sensor, needs to be analysed. This requires the use of some sort of microprocessor. For this, an Arduino Diecimilia was used. This small and powerful microcontroller was readily available and its open-source platform made it very easy to use. This acts as the “brain” of LUZinda. It receives as input the information provided by the sensors, analyses it, and determines which actions should be taken.

To perform these actions, however, the Arduino needed a method of communicating with light sources in a space. To create a system that was easy to install, it made sense to look at wireless solutions or at those that did not require electrical rewiring of the existing space. This means that a system could theoretically be installed by the user—without the aide of a certified electrician—saving time and money.

A method of home automation already available on the market is called X10. This protocol uses existing household wiring to transmit data between X10 devices. Digital data is encoded in 120kHz signals and transmitted in bursts during AC zero crossings (see FIG. 1). The data consists of an address (house code and unit code) and a command code.

Two different types of X10 modules are needed in the LUZinda design: an X10 transmitter and an X10 receiver.

A single X10 transmitter is required to send X10 signals to all light sources in the room. Known as an X10 two-way interface, the PSC05 transmitter is told what signals to send by Arduino. An RJ11 cable, commonly used as a telephone jack, connects the two-way interface to the Arduino. This interface is able to both send

and receive X10 commands, and it can transmit/receive to/from multiple light sources in a room.

All lights being controlled by the interface, or transmitter, must be attached to a receiver. This receiver, known as an X10 module, decodes the X10 commands sent by the interface and performs the commands on the light source it is controlling. Both table and floor lamps are attached to an X10 lamp module, while the overhead light uses an X10 dimmer switch, replacing the standard light switch. These modules receive the X10 command sent from the interface and control the lamp accordingly. Lamps may be dimmed, brightened, turned off, or turned on. Modules are necessary in decoding X10 signals sent from the interface.

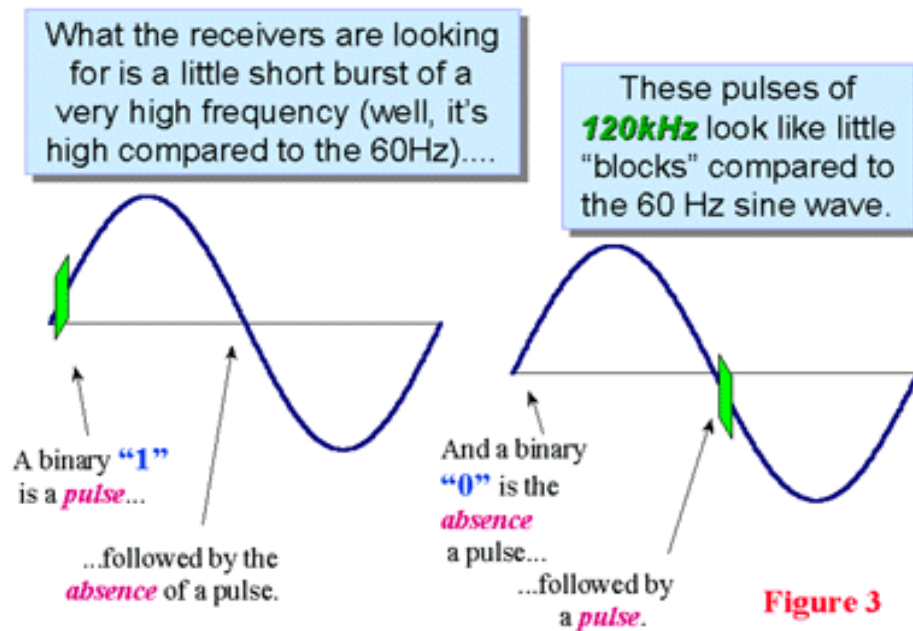


FIG. 1: Description of X10 Signal Communication Using Existing Electrical Wiring  
Source: <http://hometoys.com/emagazine.php?url=/htinews/feb99/articles/kingery/kingery13.html>

Another aspect of wireless communication that improves the ease of use of LUZinda is having the sensors transmit wirelessly. This allows for sensors to be placed discretely and strategically throughout a space to provide accurate and useful data collection.



FIG. 2: XBee Device

Source: <http://www.trossenrobotics.com/store/p/5977-XBee-Explorer-Regulated.aspx>

A relatively simple device that was readily available, met all of our criteria, and that interfaced well with the Arduino was the XBee (as seen in FIG. 2), which uses the ZigBee protocol. They are able to communicate both analog and digital signals, a necessary function for use with our ambient light sensors and occupancy sensors, respectively. They use little power (up to 50mW) and can send and receive data.

Each sensor is attached to an XBee that will read its output. This XBee will communicate with another XBee attached to the Arduino. Analog signals cannot be sent directly, but they can be converted to PWM and this can then be sent. These PWM signals need to be analyzed and converted back into analog signals by the Arduino.

Due to time restrictions, the analog abilities of XBee were never realized for this stage of the design. Thus, only motion sensors are able to communicate wirelessly while the photosensors must be hardwired to the Arduino.

Finally, after this system had been designed, adjustments had to be made to make LUZinda easy to use. A simple user interface was designed for this purpose.

In many homes where automatic lighting exists, it is not used effectively because the method of control is complicated and unclear to anyone not trained in its operation. For example, many porch lights can be controlled by a motion sensor, but if this is overridden, it can be difficult to return it to automatic mode again. In this case, the light may be left on longer than is necessary, wasting power.

While energy conservation and management is important, so is lighting quality. Lighting preferences can vary widely and there is a correlation between lighting satisfaction and occupant productivity [3]. This introduces the need for a system

that can “learn” to supply the perfect amount of light for individuals, for various activities. In fact, it has been recently shown that it could be energy efficient on average, if occupants were allowed to work under their ideal lighting conditions [3].

For these reasons, LUZinda must be able to determine what the optimal lighting environment is based on a user’s preference. This means that there must be some form of user input for LUZinda to decipher and interpret, in order to gain an understanding of the user’s needs. Thus, LUZinda has two modes of operation: a “learning” mode and standard mode.

During the first few days after install, LUZinda is under “learning” status. This means that LUZinda is trying to determine the user’s preferred lighting output. This is achieved by having the user answer a simple question several times throughout the day for the entirety of the learning period (about 10 days). The questions are displayed and answered using an LCD screen attached to the Arduino. The screen has four buttons as input: Up, Down, Yes, and No. The learning period interface is designed as follows in FIG. 3:

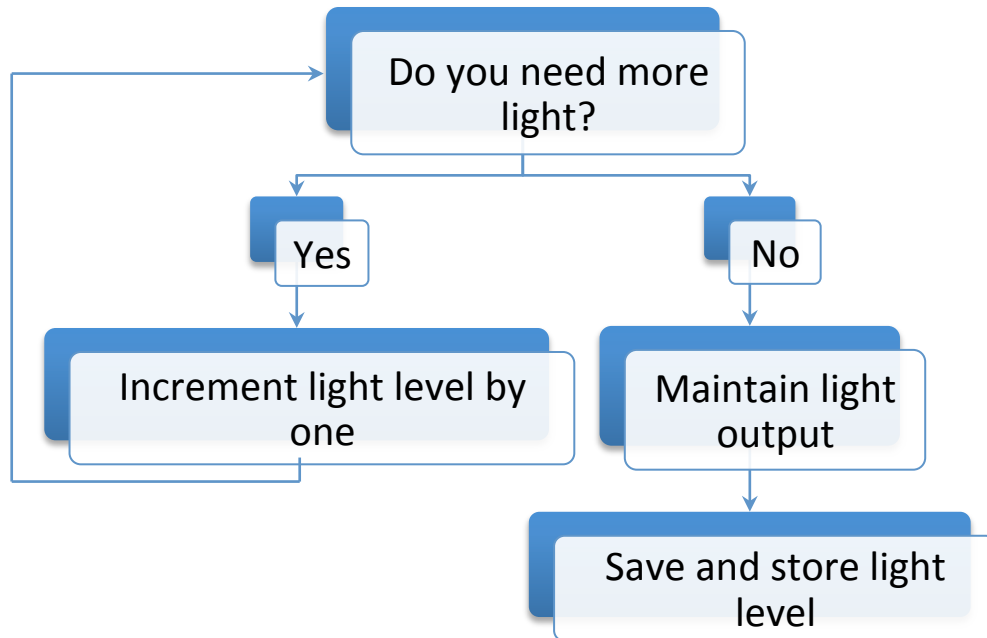


FIG. 3: User Interface Flow Diagram During Learning Operation

After LUZinda has completed the learning period and has determined the user's lighting threshold, standard operation starts. In this setting, the user can either choose to accept the lighting environment provided automatically by LUZinda, determined from the sensor inputs and thresholds, or they may adjust the settings manually. When in automatic mode, inputs from both motion and ambient light sensors are taken, and lights are turned on and adjusted according to the input from these sensors. If and when the user decides they need a more specific lighting environment, whether due to a specialized task or for another reason, they can adjust the light output using the push buttons on the LCD screen. Doing so enters manual mode. If there is not enough light in the room, the user simply has to adjust the brightness using the buttons on the interface and the network will adjust the lighting output accordingly. They may also choose to have LUZinda remember these changes. This will adjust the light threshold to include the settings just changed by the user. It is explained as follows in FIG. 4:

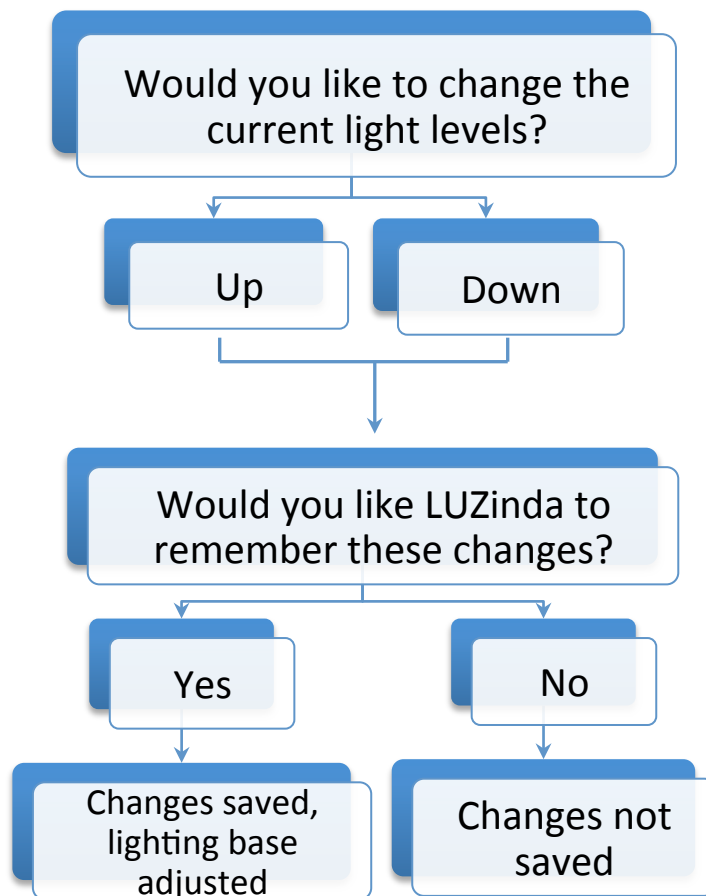


FIG. 4: User Interface Flow Diagram During Standard Operation

In order for LUZinda to determine the threshold light level, the analog signal from the light sensor is saved when the user has answered “No” during the learning phase. This value is saved to the Arduino’s EEPROM memory. EEPROM consists of 1024 bytes, and each byte stores an integer value from zero to 255. LUZinda initializes all of the values to zero at the beginning of the learning phase. Throughout the entirety of the learning, when the user is satisfied with a certain light level, the EEPROM byte value corresponding to the ambient light level (0-1023) is incremented by one. At the end of the learning phase the mean value of the user’s preferred light levels is calculated, and a range of  $\pm 15$  is set around the mean value (to allow for slight variances in the analog information from the photosensor). This mean value is set as LUZinda’s threshold light level.

Finally, in the standard operating setting, the user has the ability to manually override the automatic controls by increasing or decreasing the light levels. When the override occurs, the user is asked if they would like LUZinda to remember the changes. If the answer is “Yes”, the EEPROM byte value corresponding to the ambient light level (0-1023) is incremented by one and a new mean value is calculated. Again, this new mean value is set as LUZinda’s new threshold light level.

### SYSTEM FLOW DIAGRAM

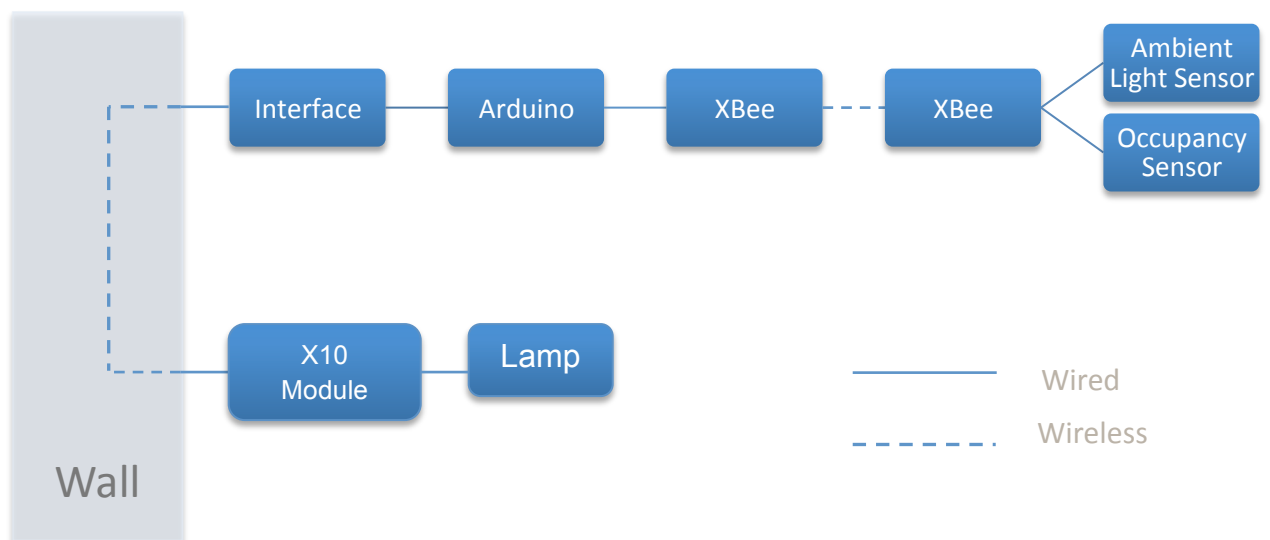


FIG. 5: LUZinda System Flow Diagram

## TESTING AND RESULTS

LUZinda was installed in a 3-meter x 3-meter test room to imitate real-life conditions. This room contains a desk lamp, an overhead ceiling lamp, and a 1-meter x 2-meter window. This provided a variety of light sources within the room.

The system was able to respond to different stimuli appropriately. It was able to vary the output of each light source independently. It provided a smooth transition between dimming and brightening, and was able to maintain a constant light output as per the user's preference.

Tasked with saving energy in the home, this was the main focus of testing. Data was needed to verify that the system was not using more energy than it was saving.

Dimming lights, a feature of our system, reduces the power used. A lamp with X10 lamp module was plugged into a power meter; X10 commands were sent to this light to dim and brighten it. The energy versus dim setting was recorded, and the process was repeated several times. The data can be seen in FIG. 6 below.

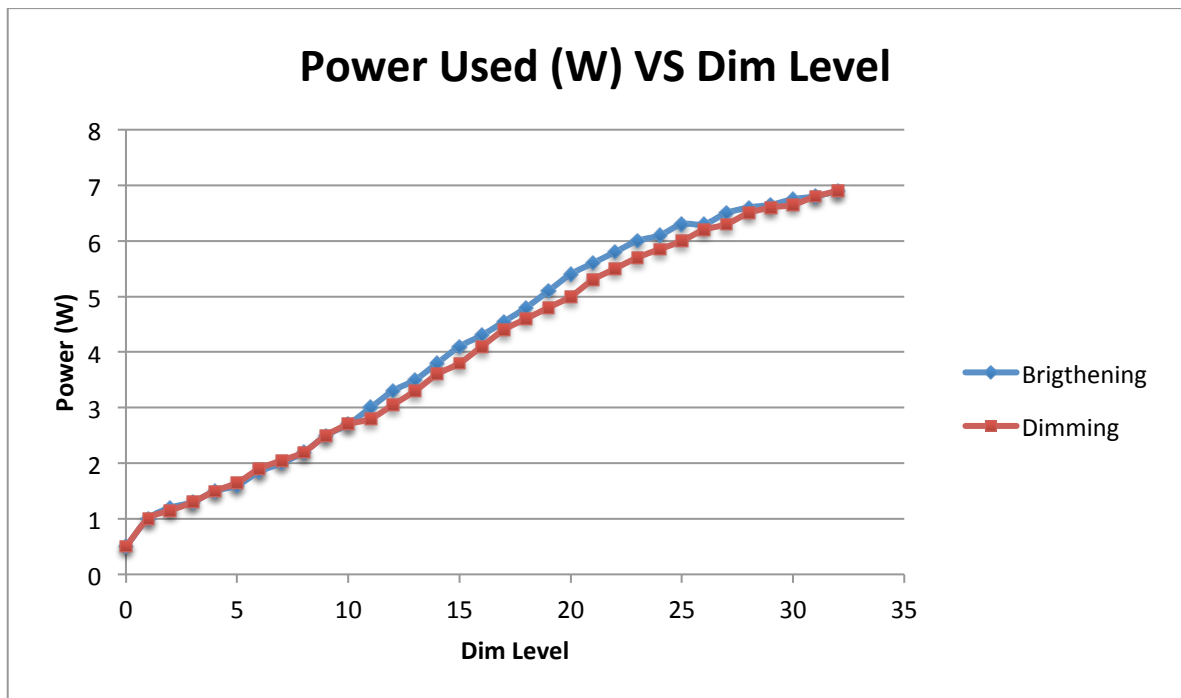


FIG. 6: Power Used VS Dim Level of a Standard Desk Lamp Taken Using LUZinda

The power used by different components of the system was also recorded using the power meter. The values taken are as follows in Table 2:



Table 2: Power Used by LUZinda Components

<b>PSC05 Two-Way X10 Interface</b>	
Standby	1.9 W
Sending Commands	1.9 W
<b>Table Lamp</b>	
6.85 W	
<b>Arduino with LCD Screen</b>	
Standby	1.15 W
Sending Commands	1.15 W
<b>Interface + Lamp Module + Arduino</b>	
3.35 W	

## DISCUSSION OF RESULTS

It is clear from FIG. 6 that the power used by a lamp decreased as it dims. This is true for any incandescent light. This means that the more LUZinda is able to dim a light, the greater the energy savings will be.

It was also imperative to determine the amount of power LUZinda needs to operate. If this amount is greater than the savings the system generates, then it is clear that it is of no benefit to install.

Any installation of LUZinda, whether with one sensor or ten, only needs a single interface. This interface requires the greatest draw on power at 1.9-Watts constant (it doesn't vary with sending or receiving a command, or with standby operation). Each additional module or switch, needed for each separate light fixture in the space, only draws 50-miliWatts (or 0.05-Watts).

With a single desk lamp (such as the one used during testing), it requires a dim setting of nearly 15 out of 32 to achieve a net-energy use of zero—that is, the dimmed lamp's energy use with the system's energy use is equal to the the energy use of just the lamp at full power. This translates to a very dim and rather impractical light output. However, if two lights are installed in the system, a net-energy use of zero is achieved with a much more practical and realistic dim setting.

Therefore, since the main energy draw of the system is due to a single interface, with low-power modules and switches affording energy savings due to dimming, a system with multiple light sources provides the most energy savings. The more

lights that are able to be dimmed, the more energy is saved to offset the high power usage of the interface. Thus, a room with many light sources provides the greatest energy savings.

## Conclusions

In creating a system to increase energy efficiency in the home, a smart lighting system named LUZinda was designed. LUZinda combines a wireless sensor network and the X10 protocol to provide an easy-to-install system, requiring little to no costly electrical rewiring. By creating a simple user interface, LUZinda focuses on user satisfaction in a lighting environment to provide consistent and efficient conditions.

While installing the LUZinda system adds to the overall electrical energy draw in a space, the total savings in decreased lighting output negates this added draw of power. In spaces where there are two or more lights, the system is able to reduce the net amount of power required to light a room to a satisfactory (or preferred) level for the user.

LUZinda, when used in a space with more than two artificial lighting sources, has achieved the guidelines of increasing the energy efficiency in the home. It is easy to use, easy to install, able to predict a user's preferred lighting environment, and able to autonomously adjust to these preferred settings.

## Project Deliverables

### *DELIVERABLES*

As discussed in the proposal for this system, the deliverables for this project are a working prototype with documentation provided in this report. The final prototype has remained true to the original plan with the exception of the analog photosensors not being wireless. The final design is as discussed previously in this report.

### *FINANCIAL SUMMARY*

As can be seen from Table 3 below, this project has remained under the initial budget of \$200.

Table 3: LUZinda Financial Summary

#	Description	Quantity	Vendors	Cost/ea	Purchased by:	To be funded by:
1	X10 Two-way interface	1	Ebay	~\$5	Jon Nakane	Project Lab
2	RJ11 – phone jack	1	n/a		Project Lab	Project Lab
3	X10 Lamp Module	2	AARTech Canada	\$19.99	Jon Nakane	Project Lab
4	X10 Dimmer Switch	1	AARTech Canada	\$24.99	Jon Nakane	Project Lab
5	MP Motion Sensor	1	Digikey	\$15.44	Jon Nakane	Project Lab
6	Arduino Diecimila	1		\$10	Project Lab	Project Lab
7	Arduino LCD and KeyPad Shield	1		\$12	Project Lab	Project Lab
8	Belkin Smart Meter	1	Craig R.	\$0	n/a	n/a
9	Photocell	2	Digikey	\$0.80	Project Lab	Project Lab
10	Comparator LM311	2	Digikey	\$0.56	Project Lab	Project Lab
11	9V batteries	2	Digikey	\$2.38	Project Lab	Project Lab
12	Miscellaneous (i.e. breadboards,	n/a	n/a	~\$10	Project Lab	Project Lab

	circuit components, wire, etc.)					
Total Cost				~\$101.16	Project Lab	Project Lab

### *ONGOING COMMITMENTS BY TEAM MEMBERS*

While there are a few small design features that have not been completed (mainly the wireless communication ability of the photosensors), a functioning system has been implemented in the test-room. The team will ensure that this prototype is functioning as expected, testing each component of the design, before submission, as follows:

1. Automatic control of lights through receiving and analyzing signals from one motion sensor and one ambient light sensor
2. User interface goes through learning phase and correctly stores user's preferred light levels.
3. User interface smoothly enters standard operating phase, and correctly allows manual override, as well as, any changes made to the threshold light level.

Once this has been accomplished, the project is deemed successful and all future design alterations may be attempted by whoever pleases. The team will remain available for contact if questions or further clarification are desired.

## Recommendations

For this system to reach its full potential, a list of recommended improvements and alterations has been compiled. They are detailed below.

### 1. *Wireless Photosensors using XBee*

According to several sources online, XBee's have the ability to simply send analog signals via PWM. After many hours of debugging, it was decided that this feature was not going to be incorporated into this design phase. Using the XBee's to send analog data from the photosensors wirelessly proved to be too time consuming for this stage of the design, but its incorporation would provide much more flexibility as to the placement of the light sensors. This would also enable zoning (discussed below).

### 2. *Zoning*

The state and usage of a lighting environment change with the available daylight and the tasks being performed in the space. By dividing the floor plan of a space into several zones, each having separate lighting controls, one can adjust the lighting in each zone to accommodate how it's being used [8]. Individual dimming of each light source is necessary to deliver the appropriate light outputs for energy savings and user satisfaction [3]. A coordinated illumination approach exploiting zoning can be used to optimize the effects of meeting an occupants lighting preference while reducing the net energy usage [6].

Due to the limited amount of time in designing this system, only a single motion sensor and a single photosensor were implemented. To fully take advantage of the capabilities of X10 control, of being able to control separate light sources differently using a single interface, it is recommended to install multiple sensors at different locations in the space. This provides the opportunity for *zoning*—having different zones within a space that have different lighting environments for different requirements or tasks. For instance, if a certain portion of a room is darker than others, this zone requires a greater lighting output. This situation requires that this zone have a separate photosensor to determine the output of light needed to attain a satisfactory level.

By increasing the number of sensors in a space, one can incorporate zoning to achieve greater flexibility and function with LUZinda.

### 3. *Task-Specific Lighting*

Providing the possibility of predictive lighting, in all senses, would create a truly smart lighting system. By incorporating a more detailed and planned approach to motion sensors, it is conceivable that LUZinda could one day determine a lighting environment based not only on a user's lighting preference, but also on their preference *according to the task being performed*. If the user were writing or reading, brighter task lighting would normally be preferred over softer, ambient light. Having the ability to discern between different events, either through motion detected or by some other means, would provide a wealth of opportunity for LUZinda.

### 4. *Energy Savings*

Since installing LUZinda in the home adds roughly 3-Watts of power usage regardless of the number of lights being controlled, using the system with more lights will only increase energy savings. Using this system with a single light may not provide savings, but using it with two or more lights will demonstrate energy savings. For this reason, it is recommended that LUZinda be installed in larger, open spaces using several different artificial lighting sources.

### 5. *Distinguishing Between Users*

Different users often have different lighting preferences. The current design of the system takes the average of these stored preferences to determine the lighting environment. If LUZinda were able to distinguish one user from another, to discern a particular user's preference from another's, then the satisfaction with the produced lighting environment should only be increased. Distinguishing the presence of different users may be achieved through RFID tags, cameras, or by other means.

### 6. *Accuracy of Motion Detection*

It seems common for complaints about the accuracy of motion detection to arise. Implementing a method of achieving motion detection while reducing the number of false triggers would ease these worries. It would also further

increase electricity savings by decreasing the amount of time lights are wrongly turned on or left on.

## *7. Product Design*

While a functioning system has been built and a conceptual design for the system housing has been provided, building this housing has not been attempted. By doing this, the system would appear more complete and its aesthetics would be less obtrusive for a user to install. This would increase its appeal to the masses.

## *8. Portable Interface*

It is well understood that a user may not enjoy constantly entering their lighting preference during the system's "learning" period, especially if this involves crawling to a narrow area near the wall receptacle. For this reason, having a wireless, portable user interface would be ideal. Somewhat like a TV remote, this interface allows the user to control LUZinda from afar if needed. It may also be able to be mounted on a wall for storage and increased accessibility.

Another option is to have a smart phone app that performs as this interface. With the increasing popularity of this technology, this idea could be attractive to users today.



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- [9] Introduction to Occupancy Sensors. (n.d.). Retrieved November 12, 2011, from [http://www.lightingdesignlab.com/articles/occ\\_sensor/intro\\_occens.htm](http://www.lightingdesignlab.com/articles/occ_sensor/intro_occens.htm)
- [10] How Dimmer Switches Work. (n.d.). Retrieved November 12, 2011, from <http://home.howstuffworks.com/dimmer-switch2.htm>

## Appendix A: LUZinda Code

```
/*
This sketch incorporates UserInterface_Learning.pde and
UserInterface_Standard.pde into lightsensor.pde
Combined by Megan Cramb on 25 Mar 2012 using code from Keara
Marshall and Sofia Moreno
Modified by Megan Cramb on 28 Mar 2012
-added UserInterface_Standard components
Modified by Megan Cramb on 29 Mar 2012
-removed software reset (commented out)
-added unit code before every command so program doesn't
forget which light it's writing to
--> should we remove the unit code from setup()??
-added proportional gain to lightsensing ("calc_p()")
-added saving data to EEPROM ("save_data()")
-added calculate mean ("calc_base()")
--> still need to analyze data to find range
Modified by Sofia Moreno on 01 Apr 2012
-changed sequence of some events and functions
-removed test_phase() function
-added transition from learning to standard phase
-added occupancy LOW timer (i.e. when to turn off lights)
-added variables that will stand in as new ranges--depending
on current phase

*/

#include <psc05.h>
#include "Arduino.h"
#include <x10.h>
#include <x10constants.h>
#include <LiquidCrystal.h>
#include <EEPROM.h>
#include <WProgram.h>

//constants/variables
//x10
#define zcPin 2 //yellow
#define dataPin 3 //blk

int lightSense = 1; //analog pin1 on arduino
int occupancySense = 11; //digital pin11 on arduino
int light = 0; //initialize analog value read
from lightsensor
int occupancy = 0; //initialize LOW occupancy
int base;
```

```

int p = 2;                                // # times to write dim/bright
command to light -- initial, later calculated proportional
to diff b/w current & base light
int range;

x10 myHouse = x10(zcPin, dataPin);

unsigned long time;
unsigned long startTime;

//lcd screen
int lcd_key      = 0;
int lcd_but      = 0;
int lcd_but2     = 0;
int adc_key_in   = 0;
boolean YES      = true;
boolean NO       = true;
boolean UP       = true;
boolean DOWN     = true;
#define btnNO     0
#define btnRIGHT  0
#define btnUP     1
#define btnDOWN   2
#define btnYES    3
#define btnLEFT   3
#define btnSELECT 4
#define btnNONE   5
boolean learning = true;
boolean standard = false;
boolean testing  = false;

LiquidCrystal lcd(8, 9, 4, 5, 6, 7);

//function declarations
int read_LCD_buttons();
void learning_phase();
void standard_phase();
int calc_p();
void save_data();
int calc_base();

void setup()
{
  Serial.begin(9600);
  pinMode(occupancySense, INPUT);

  time = 0.0;
  startTime = 0.0;

```

```

base = 150;           //can range from 0-1023
range = 30;           //initial range around low base level

myHouse.write(HOUSE_A, UNIT_1, 3);
myHouse.write(HOUSE_A, UNIT_3, 3);

////EEPROM initialization --
////can only write to EEPROM a limited number of times
(100,000), commented out unless testing the data saving
/*
// write a 0 to all 512 bytes of the EEPROM
for (int i = 0; i < 1024; i++)
    EEPROM.write(i, 0);
*/
}

void loop()
{
    occupancy = digitalRead(occupancySense);
    delay(100);

    while (occupancy == LOW)
    {
        time = millis();

        if (time-startTime >= 180000)    //if more than 3
minutes has passed while occupancy=LOW
        //turn all lights off
        myHouse.write(HOUSE_A, ALL_UNITS_OFF, 3);

        occupancy = digitalRead(occupancySense);
    }

    while (occupancy == HIGH)
    {
        light = analogRead(lightSense);

        startTime = millis();
        Serial.println(startTime);
        Serial.println(light);
        delay(100);

        if ( startTime >= 864000000)    // when 10 days have
passed, enter standard phase
            standard = true;

        while (light > base + range)    //decrease light

```

```

level
{
    p = calc_p();
    //send DIM command
    myHouse.write(HOUSE_A, UNIT_1, 3);
    myHouse.write(HOUSE_A, DIM, p);
    delay(200);
    myHouse.write(HOUSE_A, UNIT_3, 3);
    myHouse.write(HOUSE_A, DIM, p);
    delay(600);
    light = analogRead(lightSense);
    Serial.println(light);
    Serial.println(p);
}
while (light < base - range)    //increase light level
{
    p = calc_p();
    //send BRIGHT command
    myHouse.write(HOUSE_A, UNIT_1, 3);
    myHouse.write(HOUSE_A, BRIGHT, p);
    delay(200);
    myHouse.write(HOUSE_A, UNIT_3, 3);
    myHouse.write(HOUSE_A, BRIGHT, p);
    delay(600);
    light = analogRead(lightSense);
    Serial.println(light);
    Serial.println(p);
}

if (learning == true)
{
    range = 300;                //so as not to reverse any
changes user made
    learning_phase();
}

else if(standard == true)
{
    if (learning == true)    //transition from learning to
standard -- only once! when both are true
    {
        base = calc_base();
        range = 15;          //narrow the range so during
std op. light levels are as close to user's preference
        learning = false;
    }
    standard_phase();
}
}

```

```

        //check for occupancy
        occupancy = digitalRead(occupancySense);
    }
}

////////////////////////////////////
////////////////////////////////////
////////////////////////////////////
FUNCTIONS
////////////////////////////////////
////////////////////////////////////
////////////////////////////////////

////////////////////////////////////
////////////////////////////////////
////////////////////////////////////
// Read LCD Buttons
// returns which button was pressed
////////////////////////////////////
////////////////////////////////////

int read_LCD_buttons()
{
    adc_key_in = analogRead(0);
    if (adc_key_in > 1000) return btnNONE; // We make this the
1st option for speed reasons since it will be the most
likely result
    if (adc_key_in < 50)    return btnRIGHT;
    if (adc_key_in < 195)   return btnUP;
    if (adc_key_in < 380)   return btnDOWN;
    if (adc_key_in < 555)   return btnLEFT;
    if (adc_key_in < 790)   return btnSELECT;
    return btnNONE; //when no button pressed
}

////////////////////////////////////
////////////////////////////////////
////////////////////////////////////
// Learning Phase
// asks the user if they need more light and saves data when
// user is satisfied
////////////////////////////////////
////////////////////////////////////

void learning_phase()
{
    lcd.setCursor(0,0);

```

```

    lcd.print("Do you need more");
    lcd.setCursor(0,1);
    lcd.print("light?");

    lcd.setCursor(10,1);
    lcd_key = read_LCD_buttons();

    if(lcd_key == btnLEFT)          //User needs more light
    {
        lcd.setCursor(10,1);
        lcd.print("YES");
        //increase light level
        //send BRIGHT command
        myHouse.write(HOUSE_A, UNIT_1, 2);
        myHouse.write(HOUSE_A, BRIGHT, 2);
        delay(200);
        myHouse.write(HOUSE_A, UNIT_3, 2);
        myHouse.write(HOUSE_A, BRIGHT, 2);
        delay(500);
        lcd.clear();                //clears screen until it
is ready to receive an answer again
    }

    else if(lcd_key == btnRIGHT)    //Current light
level is adequate
    {
        lcd.setCursor(10,1);
        lcd.print("NO");
        //////////////////////////////////////add in code here to
save data (EEPROM)////////////////////////////////////
        //save_data();

        delay(500);
        lcd.clear();
    }

    lcd.setCursor(10,1);
    lcd.print("  ");
}

////////////////////////////////////
////////////////////////////////////
// Standard Phase
// Set after learning phase, regular operation, manual
// override
////////////////////////////////////
////////////////////////////////////

```

```

void standard_phase()
{
    lcd_key = read_LCD_buttons();

    YES = true;
    NO = true;
    UP = true;
    DOWN = true;

    lcd.setCursor(0,0);
    lcd.print("Would you like to change the current light
levels?");

    switch(lcd_key)
    {
    case btnYES:
        {
            while(YES == true)
            {
                lcd.clear();
                lcd.print("Use UP or DOWN,"); //to adjust light
levels
                lcd.setCursor(0,1);
                lcd.print("then press YES");

                delay(300);

                lcd_but = read_LCD_buttons();

                switch(lcd_but)
                {
                case btnSELECT:
                    {
                        YES = false;
                        break;
                    }
                case btnYES:
                    {
                        while(UP == true)
                        {
                            lcd.clear();
                            lcd.print("Would you like Luzinda to remember
these changes?");

                            delay(500);

                            lcd_but2 = read_LCD_buttons();

```



```

switch(lcd_but2)
{
case btnYES:
{
while(YES == true)
{
lcd.clear();
lcd.setCursor(6,0);
lcd.print("YES");
////////////////////////////////////
add code to save data (EEPROM)
////////////////////////////////////
//save_data();
//base = calc_base();
lcd.setCursor(0,1);
lcd.print("Changes saved");
delay(1000);
YES = false;
NO = false;
UP = false;
lcd.clear();
break;
}
break;
}
case btnNO:
{
while(NO == true)
{
lcd.clear();
lcd.setCursor(6,0);
lcd.print("NO");
lcd.setCursor(0,1);
lcd.print("Changes not saved");
delay(1000);
UP = false;
NO = false;
YES = false;
lcd.clear();
break;
}
break;
}
case btnSELECT:
{
lcd.clear();
lcd.print("Changes not saved");
delay(1500);

```

```

        UP = false;
        YES = false;
        NO = false;
        lcd.clear();
        break;
    }
}
}
}
case btnUP:
{
    //increase light output
    myHouse.write(HOUSE_A, UNIT_1, 3);
    myHouse.write(HOUSE_A, BRIGHT, 2);
    delay(200);
    myHouse.write(HOUSE_A, UNIT_3, 3);
    myHouse.write(HOUSE_A, BRIGHT, 2);
}
case btnDOWN:
{
    //decrease light output
    myHouse.write(HOUSE_A, UNIT_1, 3);
    myHouse.write(HOUSE_A, DIM, 2);
    delay(200);
    myHouse.write(HOUSE_A, UNIT_3, 3);
    myHouse.write(HOUSE_A, DIM, 2);
}
}
break;
}
case btnNO:
{
    lcd.clear();
    lcd.setCursor(6,0);
    lcd.print("NO");
    delay(1000);
    break;
}
default:
    break;
}
}

////////////////////////////////////
////////////////////////////////////
// Calculating P
// returns a value=p that is proportional to the difference

```

```

// between ambient light levels and the base light level
//
//

int calc_p()
{
    int diff = base - light;
    int new_diff = abs(diff);
    if (new_diff > 200)
    {
        p = 4;
    }
    else if (200 > new_diff > 100)
    {
        p = 3;
    }
    else if (new_diff < 100)
    {
        p = 2;
    }
    return p;
}

//
// Save Data
// saves the number of times the user is satisfied with a
// current light level to the Arduino's EEPROM memory
//
//

/*
void save_data()
{
    int address = light;
    byte value = EEPROM.read(address); //current number of
times this light setting was saved
    if (value == 254)
    {
        Serial.print("max value reached"); //so that
value stored will not go above 255 or reset to 0
    }
    else if (value < 254)
    {
        value = value + 1; //increment the
number of times this light setting was saved
        EEPROM.write(address, value); //store this value in
the corresponding light level address in memory
    }
}

```

```

    }

    Serial.print(address);
    Serial.print("\t");
    Serial.print(value, DEC);
    Serial.println();
}
*/

////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////
////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////
// Calculate the Base
// returns the mean value of the light levels the user has
// been satisfied with over the learning period
////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////
////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////

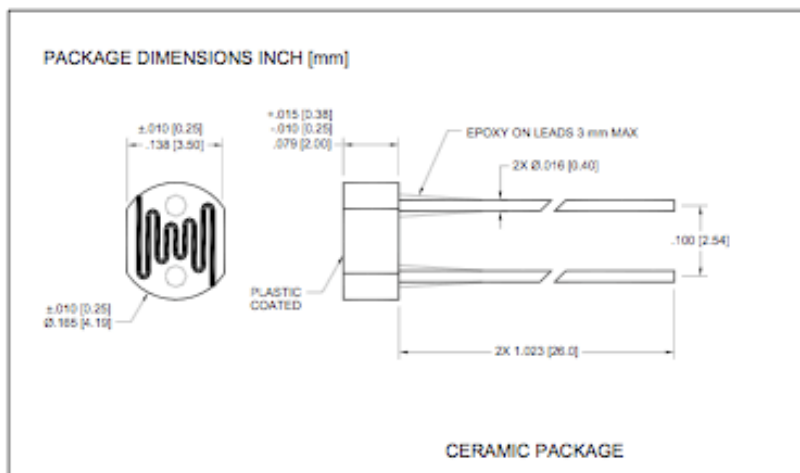
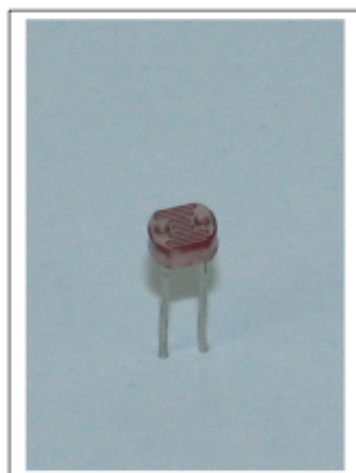
/*
int calc_base()
{
    int value = 0;          //number of times corresponding light
value was saved
    int sum = 0;
    int n = 0;              //number of times data was stored
    int mean = 0;
    //read current values from memory, add up all light
sensing values,
    //find mean
    for(int i=0; i<1023; i++)
    {
        value = EEPROM.read(i);
        sum = sum + value*i;
        n = n + value;
    }
    mean = sum / n;
    return mean;
}
*/

```

## Appendix B: Photosensor Datasheet



### CdS Photoconductive Photocells PDV-P9200



#### FEATURES

- Visible light response
- Sintered construction
- Low cost

#### DESCRIPTION

The **PDV-P9200** are (CdS), Photoconductive photocells designed to sense light from 400 to 700 nm. These light dependent resistors are available in a wide range of resistance values. They're packaged in a two leaded plastic-coated ceramic header.

#### APPLICATIONS

- Camera exposure
- Shutter controls
- Night light Controls

#### ABSOLUTE MAXIMUM RATING (TA= 23°C UNLESS OTHERWISE NOTED)

SYMBOL	PARAMETER	MIN	MAX	UNITS
$V_{pk}$	Applied Voltage		150	V
$P_{d \Delta po/5t}$	Continuous Power Dissipation		90	mW/°C
$T_O$	Operating and Storage Temperature	-30	+75	°C
$T_S$	Soldering Temperature*		+260	°C

\* 0.200 inch from base for 3 seconds with heat sink.

#### ELECTRO-OPTICAL CHARACTERISTICS RATING (TA= 23°C UNLESS OTHERWISE NOTED)

SYMBOL	CHARACTERISTIC	TEST CONDITIONS	MIN	TYP	MAX	UNITS
$R_D$	Dark Resistance	After 10 sec. @ 10 Lux @ 2856 °K	5			MΩ
$R_L$	Illuminated Resistance	10 Lux @ 2856 °K	10		50	KΩ
S	Sensitivity	$\frac{\log(R_{100}) - \log(R_{10})}{\log(E_{100}) - \log(E_{10})}$		0.9		Ω/Lux
$\lambda_{range}$	Spectral Application Range	Flooded	400		700	nm
$\lambda_{peak}$	Spectral Application Range	Flooded		520		nm
$t_r$	Rise Time	10 Lux @ 2856 °K		70		ms
$T_f$	Fall Time	After 10 Lux @ 2856 °K		15		ms

\*\*R100, R10: cell resistances at 100 Lux and 10 Lux at 2856 °K respectively.

\*\*\*E100, E10: luminances at 100 Lux and 10 Lux at 2856 °K respectively.

Information in this technical datasheet is believed to be correct and reliable. However, no responsibility is assumed for possible inaccuracies or omission. Specifications are subject to change without notice.

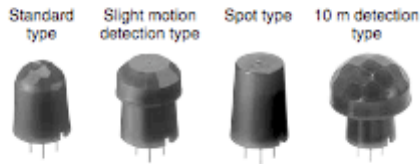
REV 3/30/06

## Appendix C: Motion Sensor Datasheet

**Panasonic**  
ideas for life

Passive infrared  
human detection sensor  
with built-in amp.

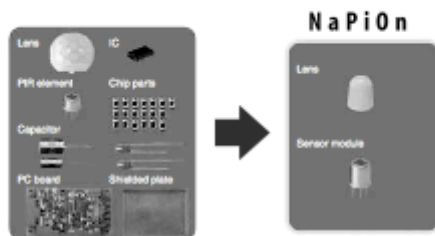
**MP MOTION SENSOR**  
**'N a P i o n'**



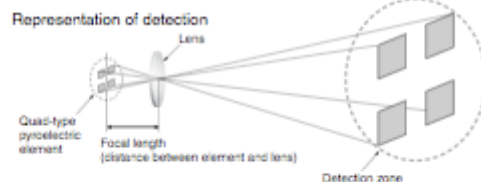
Compliance with RoHS Directive

### FEATURES

1. **N a P i o n** pyroelectric sensor modules contain the necessary functions in a small package (TO-5). These miniature, high-performance infrared human detection sensors take the trouble out of circuit design and mounting.

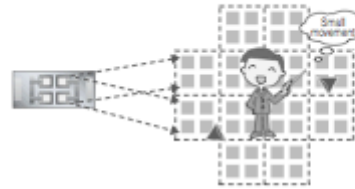


2. Ideal for small-movement detection thanks to quad-type pyroelectric element.  
The quad-type pyroelectric element contained in **N a P i o n** has four receptors. Since the detection zone within the detection range is so precise, even small movements can be detected.



3. Lenses can be miniaturized because the pyroelectric element is small

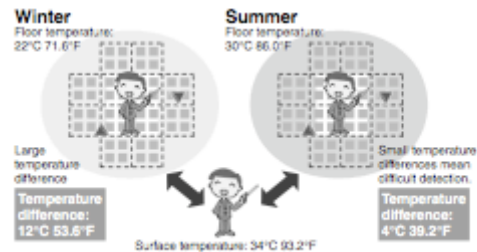
A short focal length is all that's required even when detecting at the same distance, because the size of the **N a P i o n** pyroelectric element is so small. This means that high precision is maintained even though the lens is small and the sensor itself has been miniaturized.



4. Small temperature differences also detected.

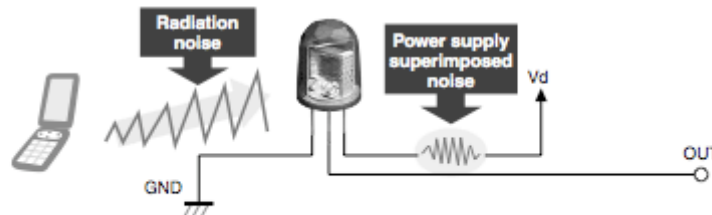
**N a P i o n** detects the temperature difference between the detection target and its surroundings, and the lowest required temperature difference to the background is 4°C 39.2°F.

This means that temperature differences can be accurately detected not only in winter, when the temperature differences are large, but also in summer, when temperature differences are slight.



5. Excellent noise resistance (radiation noise, power supply noise)

The entire **N a P i o n** circuitry is enclosed in a metal package, which means it has extremely high electromagnetic shielding capabilities. With proven resistance against power supply noise, it is also resistant against power supply superimposed noise.



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## MP Motion Sensor (AMN2, 3, 4)

### TYPICAL APPLICATIONS

- Home appliance market: Air conditioner, air purifier and fan heater
- Construction equipment: lighting, automatic switches
- Commercial equipment: vending machines, facilities for designated smoking areas
- Anti-crime device market: crime prevention sensor, simple anti-crime devices, surveillance cameras

### ORDERING INFORMATION

Output type	AMN			1		
2: Analog output						
3: Digital output						
Detection performance						
1: Standard detection type						
2: Slight motion detection type						
3: Spot detection type						
4: 10m detection type						
Feature						
1: PC board mounting type						
Operating voltage						
1: 5V DC						
2: 3V DC						
Lens color						
1: Black						
2: White						

### PRODUCT TYPES

Detection performance	Output type	Digital output	Low current consumption type Digital output	Analog output
	Lens color			
Standard detection type	Black	AMN31111	AMN41121	AMN21111
	White	AMN31112	AMN41122	AMN21112
Slight motion detection type	Black	AMN32111	AMN42121	AMN22111
	White	AMN32112	AMN42122	AMN22112
Spot detection type	Black	AMN33111	AMN43121	AMN23111
	White	AMN33112	AMN43122	AMN23112
10m detection type	Black	AMN34111	AMN44121	AMN24111
	White	AMN34112	AMN44122	AMN24112

Standard packing: Carton: 50 pcs.; Case: 1,000 pcs.

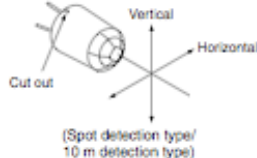
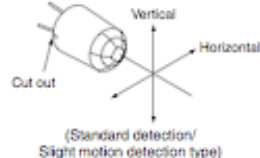
### RATING

#### 1. Detection performance

Items	Standard detection type	Slight motion detection type	Spot detection type	10m detection type	Conditions of objects to be detected
Rated detection distance Note 1)	Max. 5m 16.404ft	Max. 2m 6.562ft	Max. 5m 16.404ft	Max. 10m 32.808ft	1. Detectable difference in temperature between the target and background is more than 4°C 7.2°F. 2. Movement speed 1) Digital output type • Standard detection type/Spot detection type/ 10m detection type: 0.8 to 1.2 m/s • Slight motion detection type: 0.5 m/s 2) Analog output and low current consumption types • Standard detection type/Spot detection type/ 10m detection type: 0.5 to 1.5 m/s • Slight motion detection type: 0.3 to 1.0 m/s 3. Detection object = human body (size is 700mm × 250mm 27.559inch × 9.843inch, but for the slight motion detection type the size is 200mm × 200mm 7.874inch × 7.874inch)
Detection range	Horizontal Note 2)	100°	91°	38°	110°
	Vertical Note 2)	82°	91°	22°	93°
	Detection zone Note 3)	64 zones	104 zones	24 zones	80 zones

Notes: 1. Depending on the difference in temperature between the background and detection target and the speed at which the target moves, these sensors may be capable of detection beyond the detection distances stated above. Nevertheless, they should be used within the prescribed detection distances. For further details, refer to the detection range diagram on page 24.

2.



This angle represents the center point of the detection zone created by the outermost lens.



3. Regarding of detection zone, please refer to "DETECTION PERFORMANCE" on page 24.

## MP Motion Sensor (AMN2, 3, 4)

### 2. Absolute maximum ratings (Measuring condition: ambient temperature = 25°C 77°F) (Common to All types)

Items	Absolute maximum ratings
Power supply voltage	-0.3 to 7 V DC
Usable ambient temperature	-20 to 60°C -4 to +140°F (No freezing and condensing at low temperature.)
Storage temperature	-20 to 70°C -4 to +158°F

### 3. Electrical characteristics (Common to All types)

#### 1) Digital output

Items		Symbol	Electrical characteristics *( ) is low current consumption type	Measured conditions *( ) is low current consumption type
Rated operating voltage	Minimum	Vdd	3.0 V DC (2.2 V DC)	
	Maximum		6.0 V DC (3.0 V DC)	
Rated consumption current (Standby) Note	Typical	Iw	170 μA (46 μA)	Ambient temperature = 25°C 77°F Operating voltage = 5V (3V) Iout = 0
	Maximum		300 μA (60 μA)	
Output current (when detecting)	Maximum	Iout	100 μA	Ambient temperature = 25°C 77°F Operating voltage = 5V (3V) Vout ≤ Vdd-0.5
Output voltage (when detecting)	Minimum	Vout	Vdd -0.5	Ambient temperature = 25°C 77°F Operating voltage = 5V (3V) Open when not detecting
Circuit stability time	Typical	Ttw	7 s	Ambient temperature = 25°C 77°F Operating voltage = 5V (3V)
	Maximum		30 s	

Note: The current which is consumed during detection consists of the standby consumed current plus the output current.

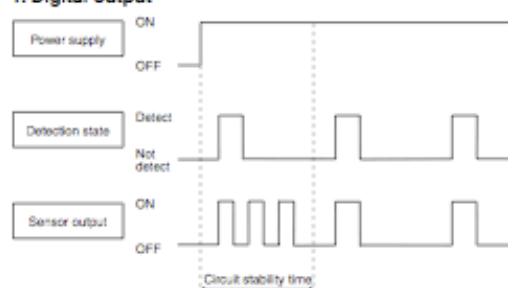
#### 2) Analog output

Items	Symbol	Specified value	Measured conditions
Operating voltage	Minimum	Vdd	4.5 V DC
	Maximum		5.5 V DC
Consumption current	Typical	Iw	170 µA
	Maximum		300 µA
Output current	Maximum	Iout	50 µA
Output voltage range	Minimum	Vout	0 V
	Maximum		Vdd
Output offset average voltage	Minimum	Voff	2.3 V
	Typical		2.5 V
	Maximum		2.7 V
Steady-state noise	Typical	Vn	155 mV p-p
	Maximum		300 mV p-p
Detection sensitivity	Minimum	Vh or Vl	0.45 V
Circuit stability time	Maximum	Ttw	45 s

Note: To set to the same detection performance as the digital output type, set the output voltage to the offset voltage (2.5V) ± 0.45V (i.e. 2.95V or more and 2.05V or less).

## TIMING CHART

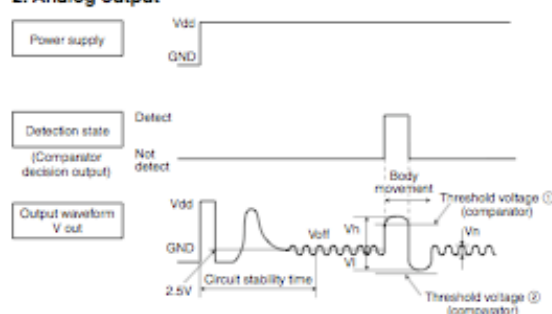
### 1. Digital output



Note: Circuit stability time: 30s max.

While the circuitry is stabilizing after the power is turned on, the sensor output is not fixed in the "on" state or "off" state. This is true regardless of whether or not the sensor has detected anything.

### 2. Analog output

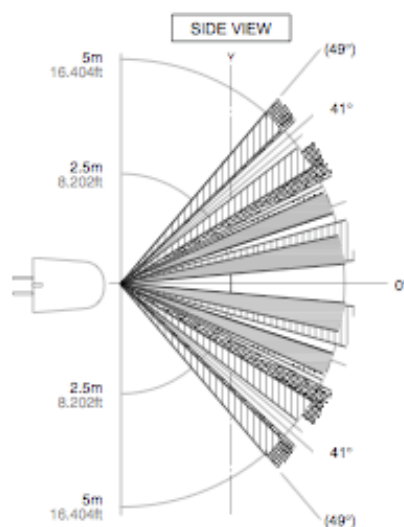
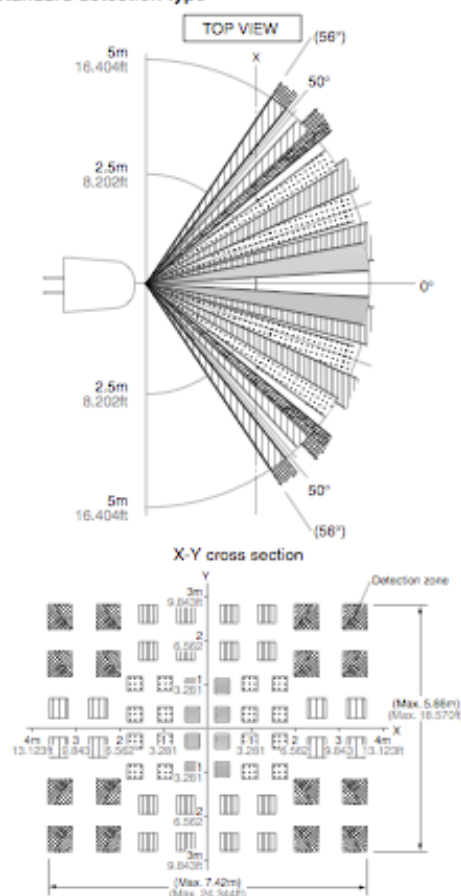


Note: Circuit stability time: 45s max.

While the circuitry is stabilizing after the power is turned on, the sensor output is not fixed in the "on" state or "off" state. This is true regardless of whether or not the sensor has detected anything.

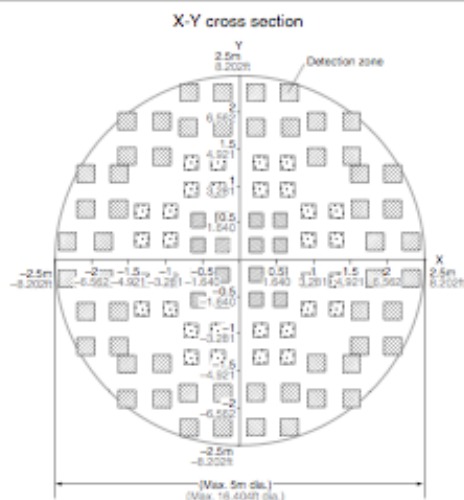
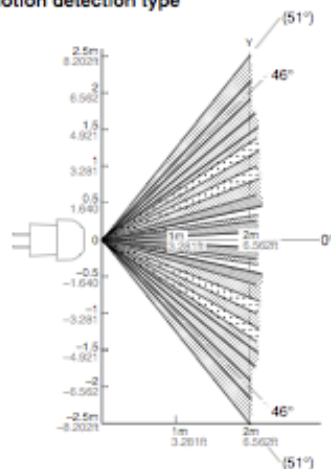


### 1. Standard detection type



Notes: 1. The X-Y cross-sectional diagram shows the detection area.  
2. The differences in the detection zone patterns are indicative of the projections of the 16 lenses with single focal point and with five optical axes.  
An object whose temperature differs from the background temperature and which crosses inside the detection zone will be detected.

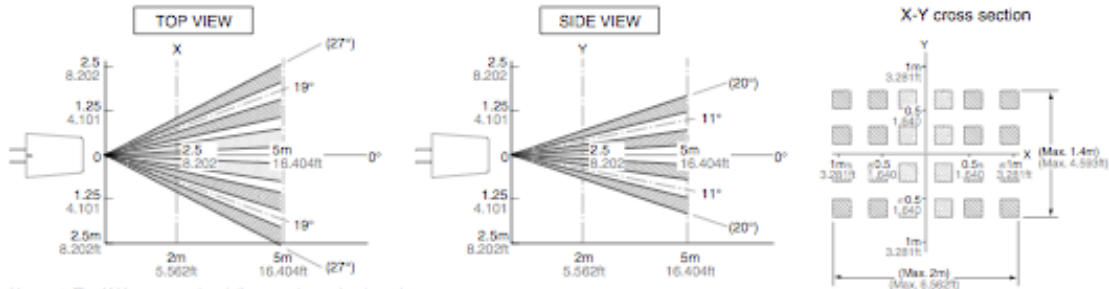
## 2. Slight motion detection type



Notes: 1. The X-Y cross-sectional diagram shows the detection area.  
2. The differences in the detection zone patterns are indicative of the projections of the 26 lenses with single focal point and with three optical axes.  
An object whose temperature differs from the background temperature and which crosses inside the detection zone will be detected.

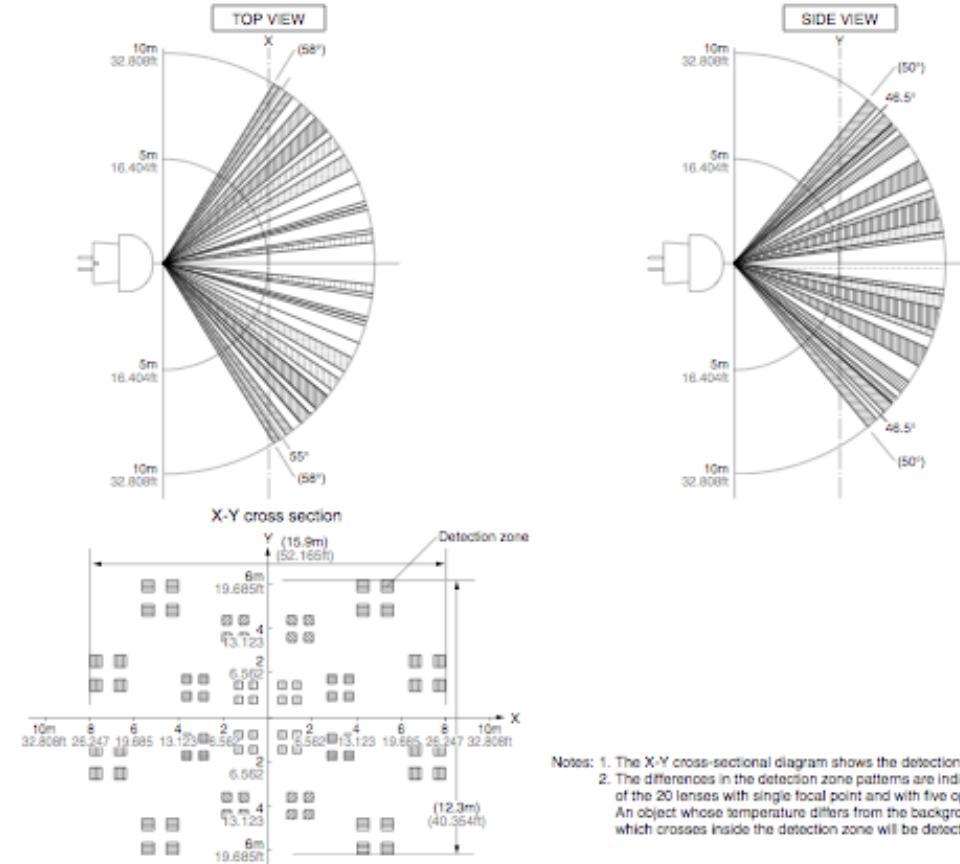
## MP Motion Sensor (AMN2, 3, 4)

### 3. Spot detection type



Notes: 1. The X-Y cross-sectional diagram shows the detection area.  
2. The differences in the detection zone patterns are indicative of the projections of the 5 lenses with single focal point and with two optical axes.  
An object whose temperature differs from the background temperature and which crosses inside the detection zone will be detected.

### 4. 10m detection type

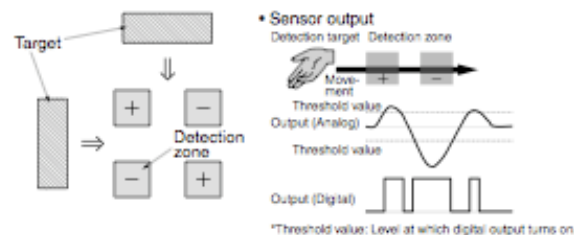


Notes: 1. The X-Y cross-sectional diagram shows the detection area.  
2. The differences in the detection zone patterns are indicative of the projections of the 20 lenses with single focal point and with five optical axes.  
An object whose temperature differs from the background temperature and which crosses inside the detection zone will be detected.

### 5. Notes regarding the detection zone

The detection zone has the polarity shown in the diagram on the right.

When targets enter both the + and - zones with the same timing, the signals are cancelled each other, thus in this case there is a possibility that the object cannot be detected at the maximum specified detection distance.



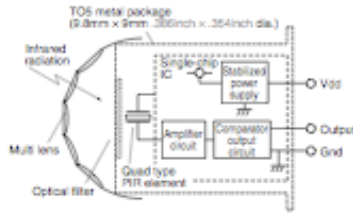
\*Threshold value: Level at which digital output turns on.

## MP Motion Sensor (AMN2, 3, 4)

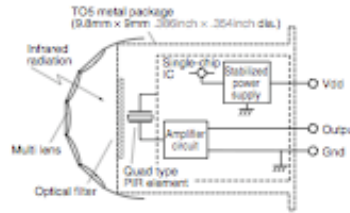
### HOW TO USE

#### 1. Block diagram output circuit

##### 1) Block diagram of the digital output circuit

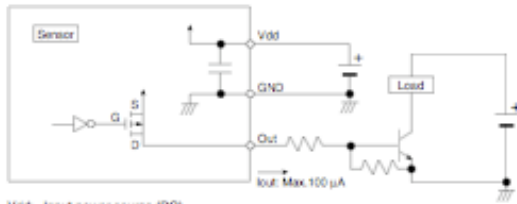


##### 2) Block diagram of the analog output circuit



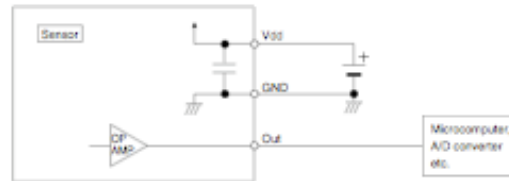
#### 2. Wiring diagram

##### 1) Digital output



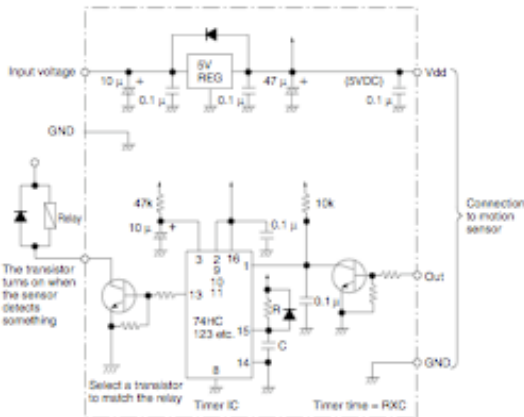
VDD: Input power source (DC)  
GND: GND  
Out: Output (Comparator)

##### 2) Analog output

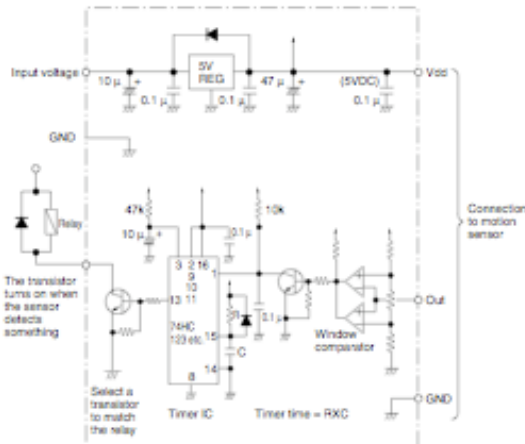


#### 3. Timer circuit example

##### 1) Digital output



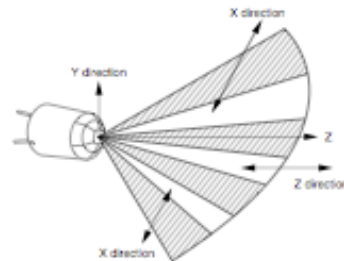
##### 2) Analog output



Note: This is the reference circuit which drives the MP motion sensor. Install a noise filter for applications requiring enhanced detection reliability and noise withstanding capability.  
Differences in the specifications of electronic components to which the units are connected sometimes affect their correct operation; please check the units' performance and reliability for each application.  
Panasonic Electric Works, Ltd. accepts no responsibility for damages resulting from the use of this circuit.

#### 4. Installation

Install the sensor so that people will be entering from the X direction shown below.  
(If persons approach the sensor from the Z direction, detection distance will be shortened.)



## MP Motion Sensor (AMN2, 3, 4)

### DIMENSIONS (mm/inch)

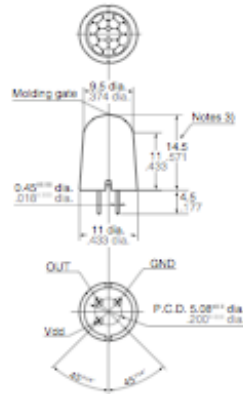
The CAD data of the products with a **CAD Data** mark can be downloaded from: <http://panasonic-electric-works.net/nc>

#### 1. Standard detection type

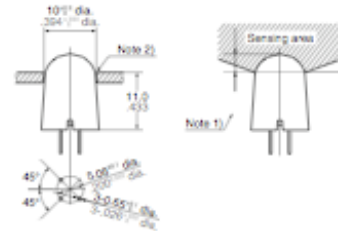
##### CAD Data



General tolerance  $\pm 0.5 \pm 0.20$



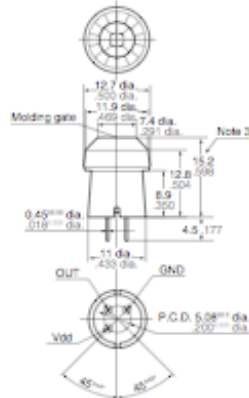
##### Recommended panel mounting hole



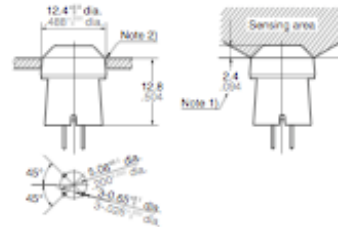
- Notes: 1. In order to ensure proper detection, install it with the lens exposed at least 3.5mm .138inch.  
2. As for panel mounting hole, tapering or making a large size hole should be done.  
3. The height dimension does not include the remaining molding gate.

#### 2. Slight motion detection type

##### CAD Data



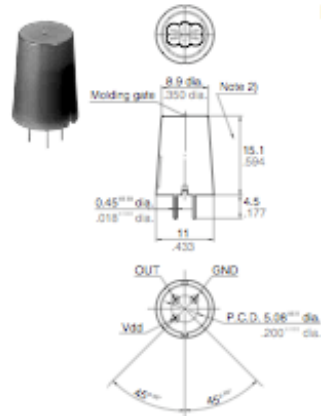
##### Recommended panel mounting hole



- Notes: 1. In order to ensure proper detection, install it with the lens exposed at least 2.4mm .094inch.  
2. As for panel mounting hole, tapering or making a large size hole should be done.  
3. The height dimension does not include the remaining molding gate.

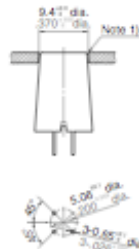
#### 3. Spot detection type

##### CAD Data



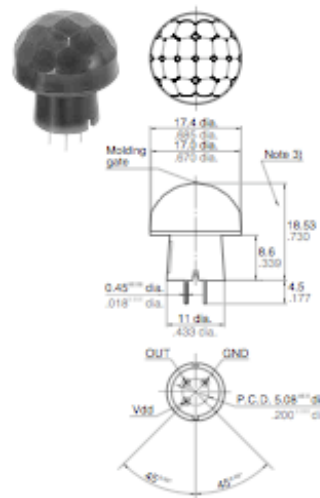
- Notes: 1. As for panel mounting hole, tapering or making a large size hole should be done.  
2. The height dimension does not include the remaining molding gate.

##### Recommended panel mounting hole



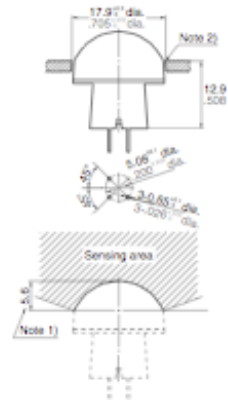
#### 4. 10m detection type

##### CAD Data



- Notes: 1. In order to ensure proper detection, install it with the lens exposed at least 5.6mm .220inch.  
2. As for panel mounting hole, tapering or making a large size hole should be done.  
3. The height dimension does not include the remaining molding gate.

##### Recommended panel mounting hole



## MP Motion Sensor (AMN2, 3, 4)

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### NOTES

#### 1. Checkpoints relating to principle of operation

MP motion sensors are passive infrared sensors which detect changes in the infrared rays. They may fail to detect successfully if a heat source other than a human being is detected or if there are no temperature changes in or movement of a heat source. Care must generally be taken in the following cases. The performance and reliability of the sensors must be checked out under conditions of actual use.

##### 1) Cases where a heat source other than a human being is detected.

- (1) When a small animal enters the detection range.
- (2) When the sensor is directly exposed to sunlight, a vehicle's headlights, an incandescent light or some other source of far infrared rays.
- (3) When the temperature inside the detection range has changed suddenly due to the entry of cold or warm air from an air-conditioning or heating unit, water vapor from a humidifier, etc.

##### 2) Cases where it is difficult to detect the heat source

- (1) When an object made of glass, acrylic or other subject which far infrared rays have difficulty passing through is located between the sensor and what is to be detected.
- (2) When the heat source inside the detection range hardly moves or when it moves at high speed; for details on the movement speed, refer to the section on the performance ratings.

##### 2. When the detection area becomes larger

When the difference between the ambient temperature and body temperature is large (more than 20°C/68°F), detection may occur in isolated areas outside the specified detection range.

#### 3. Other handling cautions

- 1) Be careful not to allow dust or dirt to accumulate on the lens as this will adversely affect the detection sensitivity.
- 2) The lens is made of a soft material (polyethylene).  
Avoid applying a load or impact since this will deform or scratch the lens, making proper operation impossible and causing a deterioration in its performance.
- 3) The sensor may be damaged if it is exposed to static with a voltage exceeding  $\pm 200\text{V}$ . Therefore, do not touch its terminals directly, and exercise adequate care in the handling of the sensor.
- 4) When the leads are to be soldered, solder them by hand for less than 3 seconds at a temperature of less than 350°C/662°F at the tip of the soldering iron. Avoid using a solder bath since this will cause a deterioration in the sensor's performance.
- 5) Do not attempt to clean the sensor. Cleaning fluid may enter inside the lens area causing a deterioration in performance.
- 6) When using the sensors with cables, it is recommended that cables which are shielded and as short as possible be used in order to safeguard against the effects of noise.

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### For Cautions for Use.



# NOTES FOR USING MOTION SENSOR (Common)

## SAFETY PRECAUTIONS

Head the following precautions to prevent injury or accidents.

- Do not use these sensors under any circumstances in which the range of their ratings, environment conditions or other specifications are exceeded. Using the sensors in any way which causes their specifications to be exceeded may generate abnormally high levels of heat, emit smoke, etc., resulting in damage to the circuitry and possibly causing an accident.

- Before connecting a connector, check the pin layout by referring to the connector wiring diagram, specifications diagram, etc., and make sure that the connector is connected properly. Take note that mistakes made in connection may cause unforeseen problems in operation, generate abnormally high levels of heat, emit smoke, etc., resulting in damage to the circuitry.

- Do not use any motion sensor which has been disassembled or remodeled.

- Protection circuit recommended

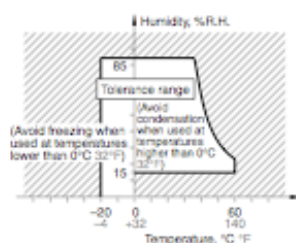
The possible failure mode is either open or short of the output transistor. An excess heat is the cause for short mode failure. For any important and serious application in terms of safety, add protection circuit or any other protection method.

## NOTES FOR MOTION SENSOR

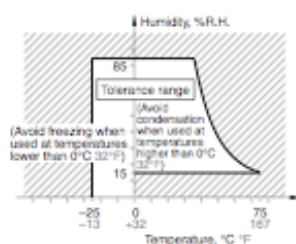
### 1. Ambient operating conditions

1) Temperature: Refer to the absolute maximum ratings for the temperature of each individual sensor.  
2) Humidity: 15% to 85% RH (No freezing nor condensation at low temperature)  
3) Atmospheric pressure: 86 to 106 kPa  
4) Because the humidity range differs depending on the ambient temperature, the humidity range indicated below should be used. Continuous operation of the switch is possible within this range, but continuous use near the limit of the range should be avoided.  
This humidity range does not guarantee permanent performance.

<MP Motion Sensor>



<MA Motion Sensor>



In general, degradation of electronic devices accelerates when they are operated under conditions of high temperature or high humidity. Before use, confirm the reliability of the sensors under the expected operating conditions.  
5) The sensors do not have a water-proof or dust-proof construction. Depending on the ambient operating conditions, some means of providing protection from water and dust and preventing the formation of ice and condensation must be provided prior to using the sensors. If a sensor is used with a cover installed, the initial detection performance specifications may not be able to be met. Confirm the operation under the actual operating conditions.

6) Take care to avoid exposing the sensors to heat, vibration or impact since malfunctioning may result.

### 2. Concerning external surge voltages

Since the internal circuitry may be destroyed if an external surge voltages is supplied, provide an element which will absorb the surges. The levels of the voltage surges which the sensor can withstand is given below.

MA motion sensors: 500 V ( $\pm 1.2 \times 50\mu\text{s}$  unipolar full-wave voltage)

MP motion sensors: Within the supply voltage given in the absolute maximum ratings.

### 3. Concerning power supply-superimposed noise

1) Use a regulated power supply as the power supply. Otherwise, power supply-superimposed noise may cause the sensors to malfunction. The levels of noise which the sensor can withstand is given below.

MA motion sensors:  $\pm 200$  V (50ns, 1 $\mu\text{s}$  wide square waves)

MP motion sensors:  $\pm 20$  V (50ns, 1 $\mu\text{s}$  wide square waves)

2) To maintain the power supply noise performance, be certain to connect a capacitor (33 $\mu\text{F}$  or more) to the sensor power supply input terminal in order to stabilize the power supply voltage.

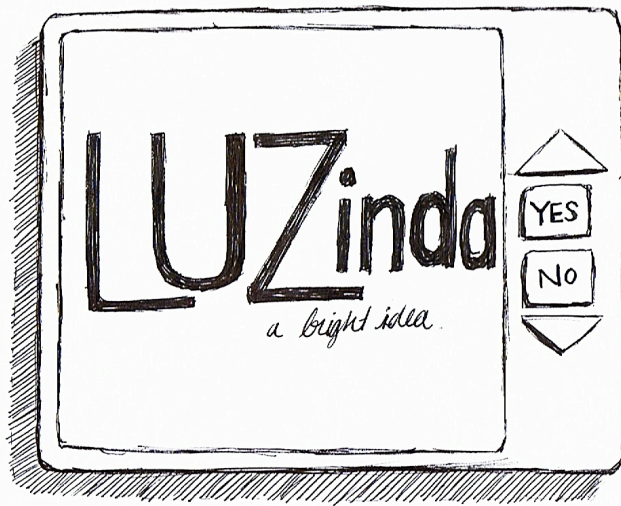
### 4. Drop damage

If the sensor is dropped, damage can occur resulting in incorrect operation. If dropped, be sure to do a visual check of the exterior for noticeable damage and check the operation characteristics for faulty operation.

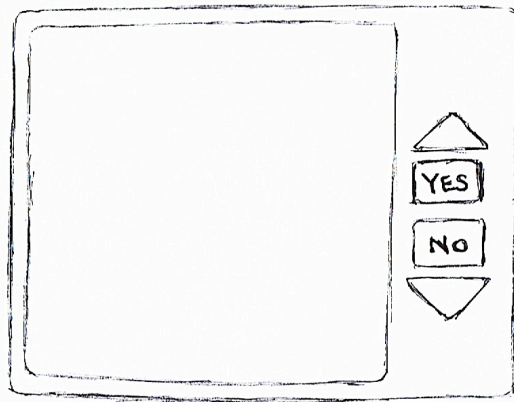
### 5. Concerning the circuit sides

Since the circuit sides given in this catalog are not protected in terms of circuit design, check out the performance and reliability of the circuits prior to using the sensors.

## Appendix D: System Design Sketches



PORTABLE USER INTERFACE



FRONT



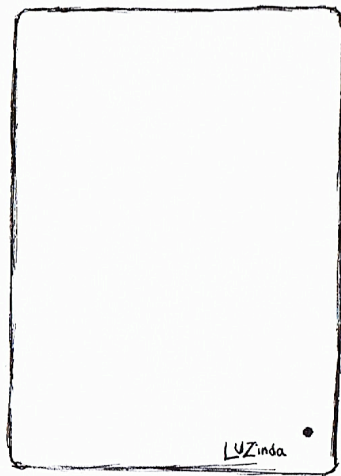
SIDE

PORTABLE USER INTERFACE.

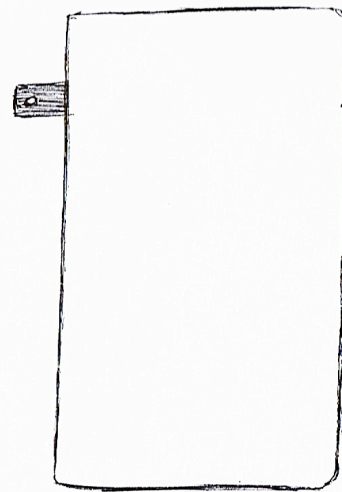
*Features:*

- *4 push buttons: Up, Down, Yes, No*
- *Large, backlit LCD screen*
- *Portability*
- *Wireless communication with LUZinda base station*
- *Finger grips on sides*





FRONT



SIDE

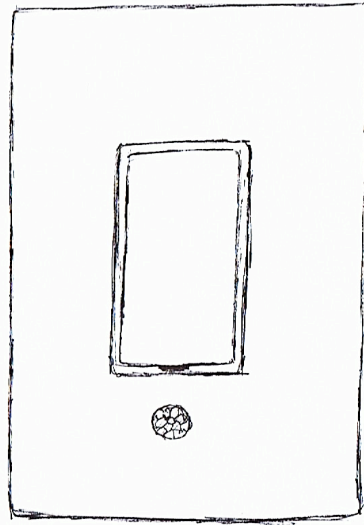
BASE STATION.

*Includes:*

- *X10 Two-Way Interface*
- *Arduino*

*Features:*

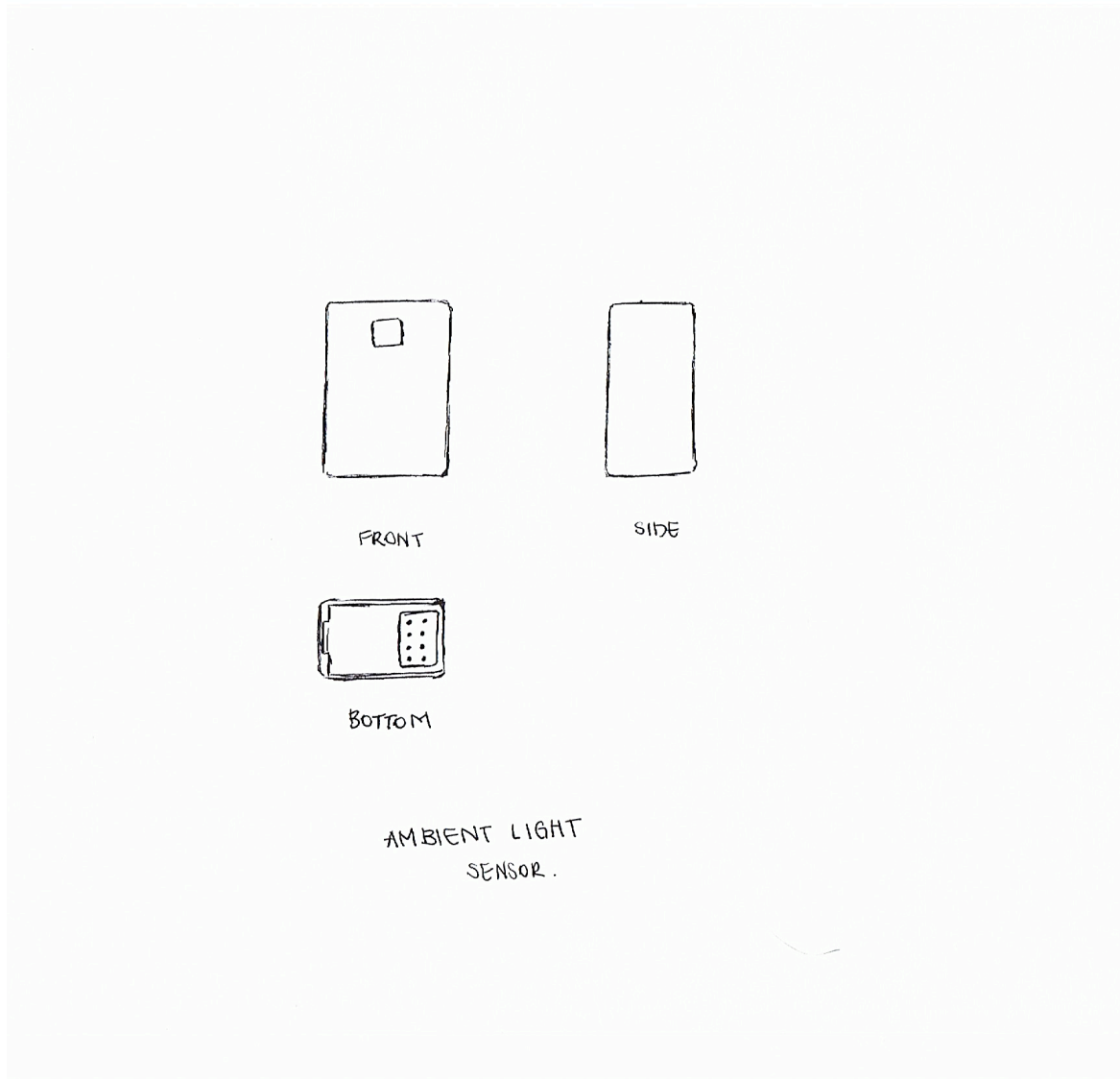
- *Simply plug-and-go*
- *Status LED on face*



LIGHT SWITCH WITH MOTION SENSOR.

*Includes:*

- *Dimmable switch*
- *Status LED*
- *Built-in motion sensor*
- *Touch/tap design*



*Includes:*

- *9-Volt battery*
- *XBee*
- *Photosensor*

*Features:*

- *Small design*
- *Wall mountable (with stick pad)*
- *Sensor window for protection (made of plastic)*
- *Latch to easily replace battery*