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Remote Light Intensity Monitoring System Using BPW21r, ARM, Arduino and ZigBee

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Abstract: Measurement of light intensity is a prime necessity in several occasions. The diversity of such needs make their way to various branches of physics and engineering as well as in media. For instance, design optimum lighting conditions of a room, good quality pictures by determining the right exposure, streets and parking must be well lit at night, optimizing light levels in museums and art galleries etc. Lux meter is used for the light intensity measurement. The light intensity measurement is needed especially in remote areas, where mobile network is unavailable. So, there is an requirement to do the remote place light intensity monitoring system which is to be accurate, easily operated, simple in working, cost-effective and light weight. This paper represents the wireless light sensor data communication using photodiode BPW21r, ARM microcontroller, ZigBee module, Arduino, Graphics LCD and PC. The calibration of BFW21r was performed using lux meter, dimmer and lamp arrangement. The transmitter section includes the light sensor photodiode, microcontroller and ZigBee. Receiver section receives the data using ZigBee and displays it on GLCD and stores the same in PC for further processing.

Keywords: Arduino, Wireless communication, Light sensor, Graphic LCD, ZigBee.

I. INTRODUCTION

Measurement of light intensity is a prime necessity in several applications. The diversity of such needs make their way to various branches of physics and engineering as well as in media. For instance, in engineering, such kinds of measurements are needed to design optimum lighting conditions of a room. In photography, light intensity measurements ensure good quality pictures by determining the right exposure. Optimizing light levels in museums and art galleries. Artwork and paintings are often exhibited to a large number of people and lighting can make or break the exhibit. If the light levels are too low then details can be missed by viewers. On the other hand, having too much light will wash out the colours and the artwork may not have the same impact intended by the artist. Museum lighting designers rely on light meters to help them to set the correct levels of lighting in order to properly exhibit precious works of art. More light can waste money on energy bills. Designers can test the performance of their lighting systems and adjust them to produce the best amount of light.

To perform these measurements, technicians often make use of lux meters which are specialized devices that measure the intensity of light falling on a surface. The lux is the SI unit of luminance and measures lumens per square meter (lm/m^2). It effectively measures the amount of power from the light falling on a given unit of area, except that the power measurement is weighted to reflect the sensitivity of the human eye to varying wavelengths of light. A simpler way to describe a lux meter is to say that it measures how bright the light falling on the sensor is [1].

The different types of light sensor for a lux meter can include photo-resistor or light dependent resistor (LDR), photodiode, phototransistor etc. The LDR light meter is good enough in a normal applications when just measurement of the lighting levels. Different type of sensors is to be used, if precise and accurate measurements are needed. Photodiodes can be used in either zero bias or reverse bias. Diodes have extremely high resistance when reverse biased. This resistance is reduced when light of an appropriate frequency shines on the junction. Hence, a reverse biased diode can be used as a light detector by monitoring the current flowing through it coupled to a 10KOhm resistor.

There is requirement of light intensity monitoring especially in remote areas where mobile network is not available. For example, the thermometer is used to note the light intensity which contains LDR whose resistance indicates the light intensity. It is quite inefficient because it fails to provide precise values of light intensity, also it takes a lot of time to reach a constant value So, there is an requirement light intensity monitoring system which is accurate, easily operated, simple in working, simple construction, cost-effective, comfortable to carry and light weight [2].

The aim is to design and develop a system which fulfils all these requirements. Light intensity sensor BPW21r was used to sense the light intensity. ARM microcontroller is used to transmit the data wirelessly by using ZigBee. In ARM microcontroller, there are inbuilt 12-bit ADC which is used for analog to digital conversion (ADC) of data and then using ZigBee serial data transferred from a remote location/station [3].

At the receiver section, Arduino microcontroller was used to decode the serial data, which is transmitted, by ZigBee and it was displayed on graphics LCD as well as the light

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intensity data are stored in PC. Transmitter and receiver block diagrams are shown in Figure 1(a) and 1(b) respectively.

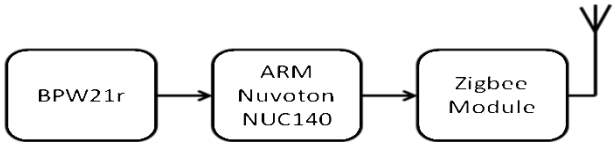

Fig. 1(a).Block diagram of transmitter

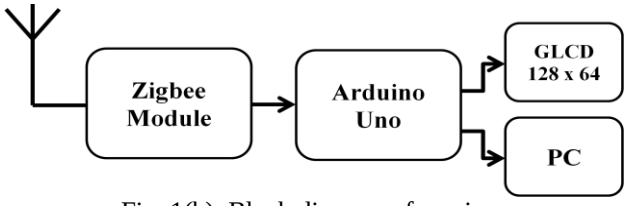

Fig. 1(b). Block diagram of receiver

II. MODULE INFORMATION

A. ARM microcontroller

The ARM architecture was originally developed by Acorn Computers in the 1980s. An ARM is Advanced RISC Machines (ARM) 32-bit and 64-bit processor. ARM controller operates at a higher speed, performing more millions of instructions per second (MIPS). ARM processors are extensively used in consumer electronic devices such as smart phones, tablets, multimedia players and other mobile devices. The ARM® Cortex®-M0 processor is the smallest ARM processor available in the market [4]. NUC140 Series is 32-bit microcontrollers with embedded ARM®Cortex-M0 core for industrial control and applications which need rich communication interfaces. The Cortex-M0 is the newest ARM® embedded processor with 32-bit performance and at a cost equivalent to traditional 8-bit microcontroller. The NuMicro NUC140 Connectivity Line with USB 2.0 full-speed and CAN functions embeds Cortex-M0 core running up to 50 MHz with 32K/64K/128K-byte embedded flash, 4K/8K/16K-byte embedded SRAM, and 4K-byte loader ROM for the ISP. It also equips with plenty of peripheral devices, such as Timers, Watchdog Timer, RTC, PDMA, UART, SPI, I2C, I2S, PWM Timer, GPIO, LIN, CAN, PS/2, USB 2.0 FS Device, 12-bit ADC, Analog Comparator, Low Voltage Reset Controller and Brown-out Detector [5]. The block diagram of NuMicro NUC140 is shown in Figure 2.

Specification of Cortex M0: Runs up to 50 MHz, operating voltage ranges from 2.5 V to 5.5 V, 32K/64K/128K bytes Flash for program code, 4KB flash for ISP loader, 4K/8K/16K bytes embedded SRAM, Support 4 sets of 32-bit timers with 24-bit up-timer and one 8-bit pre-scale counter, Independent clock source for each timer, RTC, PWM/Capture, four 16-bit PWM generators provide eight PWM outputs, UART ports with flow control (TXD, RXD, CTS and RTS), Up to four sets of SPI controller, Support SPI master/slave mode, Variable length of transfer data from 1 to 32 bit [5].

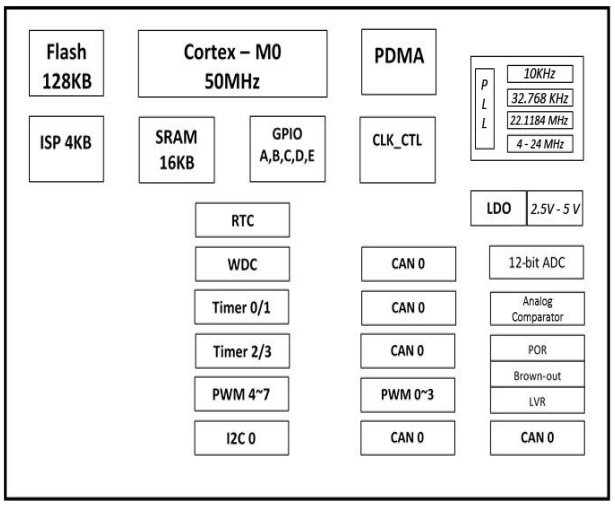

Fig. 2. Block Diagram NuMicroNUC140

B. Arduino Microcontroller

The Arduino ATmega328 is a programmable microcontroller for prototyping electromechanical devices is shown in Figure 3 (a). Figure 3(b) shows the pin-out of Atmega328. It has 14 digital Input / output pins (of which 6 can be used as PWM outputs), a 16 MHz ceramic Resonator, a USB connection, a power jack, an ICSP header and a reset button as shown in figure. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started.

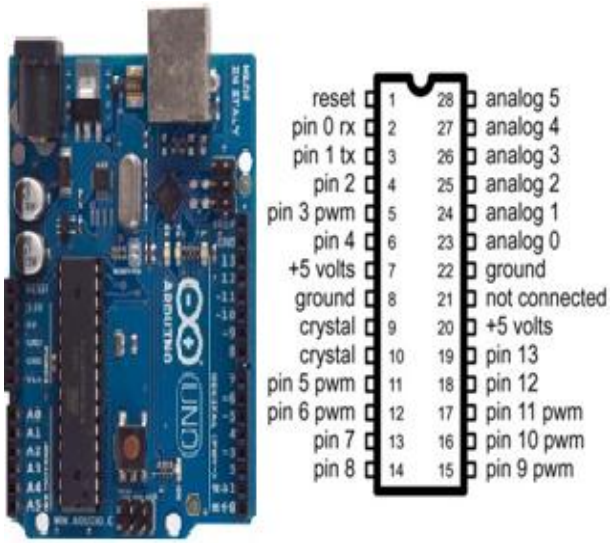

Fig. 3 (a) and (b) Arduino ATmega328 board and Pin-out of Atmega328

The Uno has 6 analog inputs, labelled A0 through A5, each of which provide 10 bits of resolution (i.e. 1024 different values). A software serial library allows for serial communication on any of the Uno's digital pins. The ATmega328 also supports I2C (TWI) and SPI communication. The Arduino software includes a wire library to simplify use of the I2C bus. For SPI communication, SPI library is available [6].

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Features of ATmega328: Operating Voltage 5V, Input Voltage (limits) 6-20V, Digital I/O Pins 14 of which 6 provide PWM output, 32 bit flash memory, 2KB SRAM, 1KB EEPROM and clock speed 16 MHz.

C. BPW21r

A photodiode is a type of photo resistor in which the incident light falls on a semi-conductor junction and the separation of electrons and holes caused by the action of light will allow the junction to conduct even when it is reverse biased. Photodiodes are constructed like any other diodes, without the opaque coating that is normally used on signal and rectifier diodes. In the absence of this opaque coating, the material is transparent enough to permit light to affect the junction conductivity and so alter the amount of reverse current, its amplitude is not large, and the sensitivity of photodiodes is quoted in terms of μA of current per mW/cm² of incident power. Photodiode BPW21r is shown in Figure 4.

Fig. 4 BPW21r photodiode

BPW21r a planar silicon PN photodiode in a hermetically sealed short TO-5 case, especially designed for high precision linear applications. Due to its extremely high dark resistance, the short circuit photocurrent is linear over seven decades of illumination level. On the other hand, there is a strictly logarithmic correlation between open circuit voltage and illumination over the same range. The device is equipped with a flat glass window with built in colour correction filter, giving an approximation to the spectral response of the human eye [7].

Features:

- Package leaded type
- Package TO-5form
- Dimensions 8.13 mm
- Radiant sensitive area 7.5 mm^2
- High photo sensitivity
- Hermetically sealed package
- Cathode connected to package
- Flat glass window
- Low dark current
- High shunt resistance
- High linearity

D. ZIGBEE Technology

ZigBee Alliance was established in August, 2001. The ZigBee specification officially named ZigBee in 2007 and is shown in Figure 5. It is a new wireless technology guided by the IEEE 802.15.4 Personal Area Networks (PAN) standard. It currently operates in the 868MHz band at a data rate of 20Kbps in Europe, 914MHz band at 40Kbps in the USA, and the 2.4GHz ISM bands Worldwide at a maximum data-rate of 250Kbps. It is capable of connecting 255 devices per network. The specification supports data transmission rates of up to 250 Kbps at a range of up to 30 meters. This technology allows users to set up a network quickly and allows them to set up networks where it is impossible or inconvenient to wire cables. Wireless networks are more cost-efficient than wired networks in general [7].

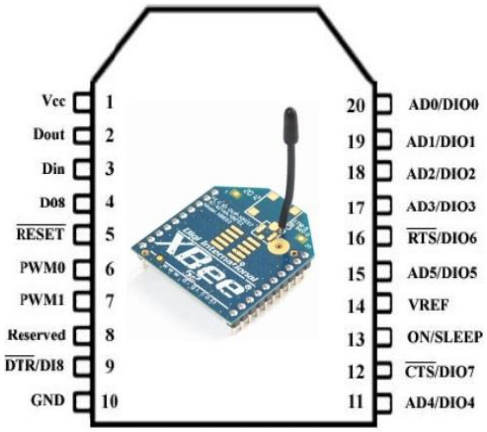

Fig. 5. Pin diagram of X-Bee Transceiver

ZigBee Module is a low-cost, low-power, wireless mesh networking standard. The low cost allows the technology to be widely deployed in wireless control and monitoring applications [8]. The low power usage allows longer life with smaller batteries and the mesh networking provides high reliability and larger range. Temco has developed a embedded antenna of wireless data communication module, which adopts standard ZigBee wireless technology. This module is in line with the Industry Standard applications of wireless data communication module. This module can achieve transparent data transmission between many devices, and it can form a MESH network. This device has the characteristics of small volume, ultra-low power consumption and low-cost. It can be either as an independent data transmission termination or be easily embedded into a variety of products to form a short-range wireless data transmission solution [9].

Wireless communication applications includes Sensor network, Automatic meter reading system of water, gas, heat, electricity meters, Intellectual traffic control, Signal lights control and Street lights control, Fire safety alarm, Building monitoring , Catering order, Canteen' s sale of food system, Access control, time and attendance system etc[10].

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E. Graphic liquid crystal display (GLCD)

The graphical LCD is made up of a grid of pixels is shown in figure 6. Common resolution is 128×64. That means that there are 64 horizontal lines and each line has 128 pixels. These displays are monochrome that means each pixel can either be ON or OFF. ON pixels looks dark while OFF pixels are nearly invisible. The GLCD has a graphic RAM where each bit in ram corresponds to one pixel on screen. You write to the graphic RAM to modify its contents and the screen will change accordingly. The LCD module offers just that much functionality

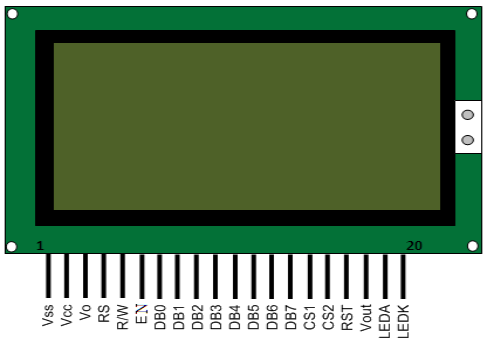

Fig. 6. Graphics LCD

Graphic primitives like line, circles, rectangle etc., text drawing, image/icon drawing, double buffering, 128x 64 dots/pixel, 8-bit Parallel Interface, Display is Split logically in half. LCD Control Lines: - RS: Select Data register or a Command/Status register, R/W#: Read/Write select control line, E: Latches information presented to its, CS1&CS2: Chip Select Signals, Reset: LCD Reset signal [11].

III. CIRCUIT DIAGRAM OF TRANSMITTER AND RECEIVER

Transmitter: Circuit diagram of transmitter is shown in figure 7. The BPW21r photodiode output is connected to the microcontroller. The microcontroller ADC output is given to ZigBee module to transmit. The transmitted signal is received by using ZigBee module. The light intensity is displayed on GLCD. The data can be stored in PC for further processing.

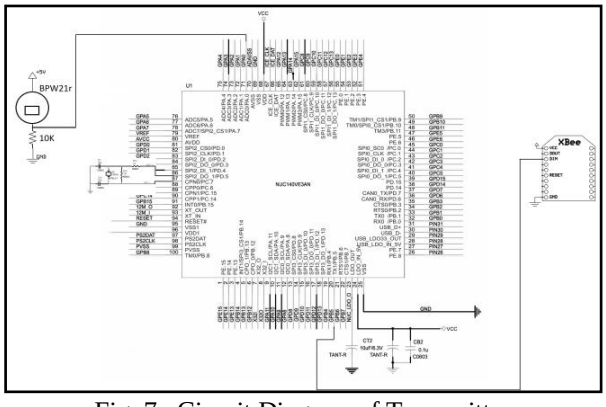

Fig. 7. Circuit Diagram of Transmitter

Receiver: Circuit diagram of receiver is shown in figure 8.

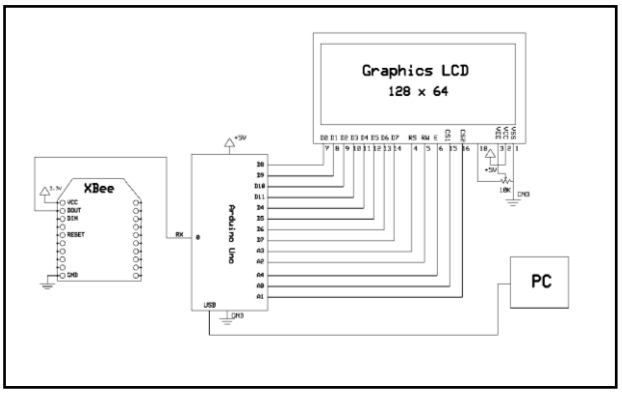

Fig. 8. Circuit Diagram of Receiver

IV. CIRCUIT DESCRIPTION

Now a day, an ARM advance microcontroller is used. An ARM processor is one of a family of CPUs based on the RISC (reduced instruction set computer) architecture developed by Advanced RISC Machines (ARM). The aim is to sense the light Intensity using BPW21r, convert the signal into digital using 12 bit inbuilt ADC of ARM and transmit digital information wirelessly through ZigBee. It is a new wireless technology guided by the IEEE 802.15.4 Personal Area Networks (PAN) standard. It is primarily designed for the wide ranging automation applications and to replace the existing non-standard technologies. It currently operates in the 868MHz band at a data rate of 20Kbps in Europe, 914MHz band at 40Kbps in the USA, and the 2.4GHz ISM bands worldwide at a maximum data-rate of 250Kbps Light intensity is sensed by sensor BPW21r. Output of the sensors is given to PA0 pin of ARM microcontroller. It is shown in figure 7. ARM having a inbuilt 12-bit ADC, hence its output vary from 0 to 4096. This output is calibrated in the form of percentage and sent to Rx pin of receiver Zigbee module. At receiver section, Arduino controller was used for driving the GLCD shown in figure 8. The Arduino Uno is a microcontroller board based on the ATmega328. It is a programmable microcontroller for prototyping electromechanical devices. The Arduino Uno has a number of facilities for communicating with a computer, to another Arduino, or other microcontrollers.

The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (Rx) and 1 (Tx). The GLCD is a special type LCD that is used to monitor the light intensity. The graphical LCD is made-up of a grid of pixels. There are 64 horizontal lines and each line has 128 pixels. These displays are monochrome.

V. EXPERIMENTAL SETUP

The photograph of the working system is shown in Figure 9 and Figure 10. First photograph includes the light sensor, ARM microcontroller and ZigBee.

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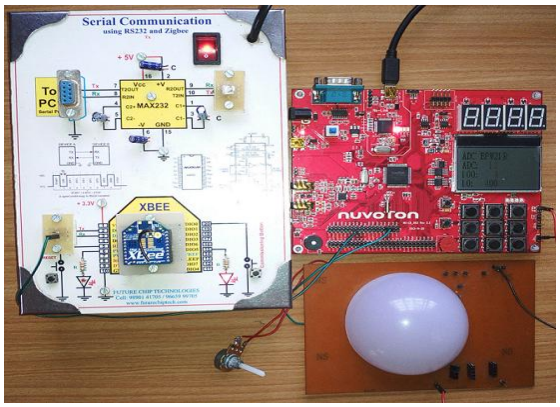

Fig. 9. Experimental setup of Transmitter

Receiver photograph includes the ZigBee, AtMega328 and GLCD.

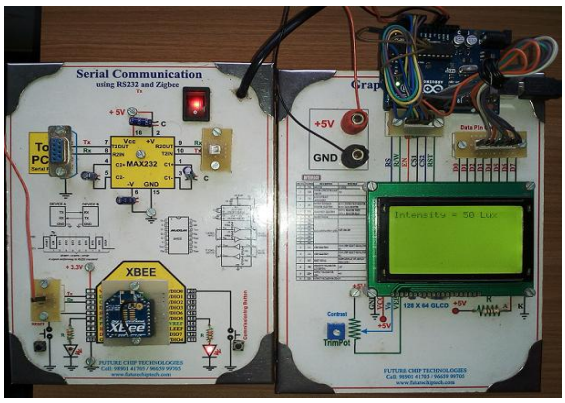

Fig. 10. Experimental setup of Receiver Section

VI. RESULT

Table 1: Values of lux meter and ADC of ARM

Sr.No	Lux meter lx	ADC values lx
1	50	49
2	100	95
3	150	148
4	200	198
5	250	248
6	300	295
7	350	345
8	400	403
9	450	454
10	500	490
11	550	555
12	600	601
13	650	653
14	700	705
15	750	745
16	800	802
17	850	856
18	900	910
19	950	958
20	1000	1010

Calibration of photodiode BPW21r was performed by using dimmer and lamp arrangement. Lamp intensity was varied by dimmer voltage. The light sensor signal was converted into digital by using inbuilt ADC of ARM microcontroller. The values of lux meter and ADC values are shown in Table 1.Receiver GLCD display the values of light intensity. These values are same as the ADC values transmitted by ZigBee.
The graph of light intensity and ADC values are shown in Figure 11. It has linear nature.

Figure 11: Graph of light intensity and ADC values

VII. CONCLUSION

The wireless light sensor data communication using photodiode BPW21r, ARM microcontroller, ZigBee module, Arduino, Graphics LCD and PC is presented. The calibration of BFW21r was performed using lux meter, dimmer and lamp arrangement. The transmitter section includes the light sensor photodiode, microcontroller and ZigBee. Receiver section receives the data using ZigBee and displays it on GLCD. The reading of lux meter and ADC values are approximately same. The graph of light intensity and ADC values is linear. The ADC values transmitted and the data received are same.

The presented wireless light intensity monitoring system is simple and accurate. ZigBee communication technology is used. ARM and Arduino Uno has mostly all the capabilities inbuilt and requires less hardware for its operation. The circuit complexity is less hence easy to understand by any one. Good lightning plays an important role to perform work comfortably and efficiently. Safeguarding health at the system can be effectively used to monitor light intensity.

ACKNOWLEDGMENT

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BIOGRAPHY

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