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Raspberry Pi Based Energy Efficient Industrial Automation System

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***Abstract*—This project proposes a secured and energy efficient wireless industrial automation system via credit card sized single board computer called raspberry pi. The aim of this work is to control the industrial devices, managing the power utilities and also monitoring the employee works. These are all done through Wi-Fi network with help of server pc. This server pc is password protected and it can be opened only by the authorized person. The main focus of this project is to reduce the power usage and to alert the people about the critical situations in the industry. This can be done by solar panel and also detecting the gas leakage and boiler temperature using the corresponding sensors. The system will activate the alarm interfaced with the raspberry pi during the critical situations. The proposed industrial security solution hinges on our novel integration of cameras and motion detectors into web application. Raspberry Pi operates and controls motion detectors and video cameras for remote sensing and surveillance, streams live video and records it for future playback. For instance, when motion is detected, the cameras automatically initiate recording and the Raspberry Pi device send it to the server pc through Wi-Fi network and alerts possible intrusion. There are two sections in server, one is control unit section and other one is video streaming section. Through control unit section, we can activate or deactivate the device. This is an embedded Linux based system implemented in System on chip and also increases the efficiency of the process by raspberry pi.**

***Keywords*—Camera, Gas Sensor, Raspberry pi, Solar Panel, Temperature Sensor, Wi-Fi.**

I. INTRODUCTION

Fast growing industrial age, needs speed in manufacturing in every industrial unit. Automation provides far better service to customers eliminating the monotonous work by human, achieving accuracy and speed in work. They are high in demand and are used to carry out most of the work which saves time and is more efficient. The use of Open-Source environment make it cost effective, Linux based Operating system used in Raspberry Pi (Raspbian OS), and Python are freely available for users to use and also to develop [1].Security will be critical for many next-generation applications and devices, especially well these applications and devices are applied into specific domain of our everyday life like industry, education and in hospitals. Security is very much essential in all kind of application activities. Illegal activities are happening in every place today. So governments are concentrating mainly on the security levels with their every invention. This will bring privacy all over the world, so in a thought of bringing privacy through security with the development and applications, like providing security in the industrial door control. The door control based automation system is an integrated system that facilitates user with an easy to use industrial automation system that can be fully operated based on username and password commands. This system is handled by particular user only, and hence the system is more secured.

II. SYSTEM DESIGN

A. Overview of the System Design

The temperature sensor, gas sensor and LAN cable are connected to the Raspberry pi and the industrial appliances, current and voltage measure are connected to the relay circuitry and that relay circuitry is interfaced with the Raspberry pi.

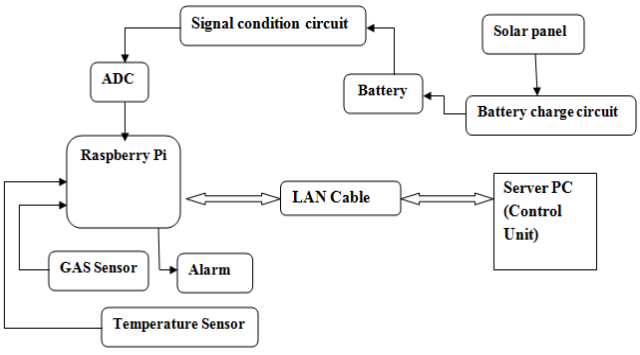

Fig. 1.Block Diagram of the Proposed System

B. *Embedded Main Board Module*

The industrial automation system consists of two modules, embedded main board and the base station. The embedded main board module (fig 2) designed with the help of ARM microcontroller and the processor is programmed with the embedded c language. The embedded main board module consists of Raspberry pi which is interfaced with the gas and temperature sensors, solar panel, buzzer, ADC circuit and current measurement unit. Basically this module be kept at the industrial site which measures the boiler temperature and senses the presence of hazardous gases. The system provokes alarm during the critical situations.

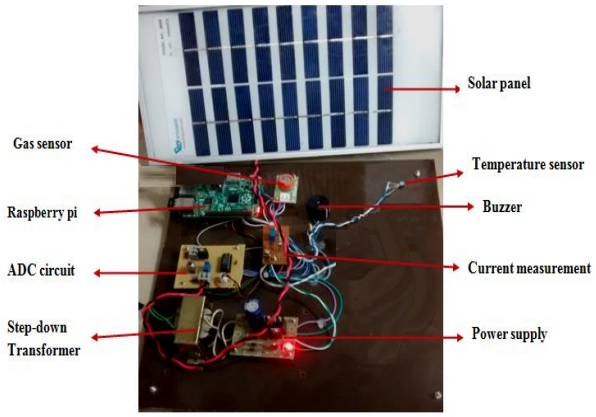

Fig. 2. Prototype of Embedded Controller Unit

C. *Base Station Module*

The industrial activity is monitored from the base station. The sensor information from raspberry pi is sent to the base station pc, through LAN. At the base station a web page is created and the page is updated with the current information about the industrial site. From the base station itself, the amount of energy conservation at the industry is monitored. The base station pc is shown in fig3.

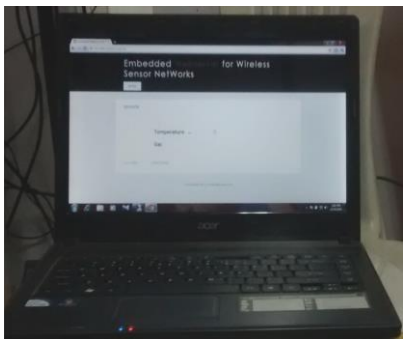

Fig. 3. Base Station PC

III. HARDWARE REQUIREMENTS

A. *ARM Processor*

1) *General description of LPC2148*

The LPC2141/42/44/46/48 microcontrollers are based on a 16-bit/32-bit ARM7TDMI-S CPU with real-time emulation and embedded trace support, that combine microcontrollers with embedded high-speed flash memory ranging from 32 kb to 512 kb. A 128-bit wide memory interface and a unique accelerator architecture enable 32-bit code execution at the maximum clock rate. For critical code size applications, the alternative 16-bit Thumb mode reduces code by more than 30 % with minimal performance penalty. Due to their tiny size and low power consumption, LPC2141/42/44/46/48 are ideal for applications where miniaturization is a key requirement, such as access control and point-of-sale [2]. Serial communications interfaces ranging from a USB 2.0 Full-speed device, multiple UARTs, SPI, SSP to I2C-bus and on-chip SRAM of 8 kb up to 40 kb, make these devices very well suited for communication gateways and protocol converters, soft modems, voice recognition and low end imaging, providing both large buffer size and high processing power. Various 32-bit timers, single or dual 10-bit ADCs, 10-bit DAC, PWM channels and 45 fast GPIO lines with up to nine edge or level sensitive external interrupt pins make these microcontrollers suitable for industrial control and medical systems.

B. *Temperature Sensor(LM35)*

LM35 is a precision IC temperature sensor with its output proportional to the temperature (in ºC). The sensor circuitry is sealed and therefore it is not subjected to oxidation and other processes. Temperature can be measured more accurately than with a thermistor. It also possess low self-heating and does not cause more than 0.1ºC temperature rise in still air [3]. The operating temperature range is from -55°C to 150°C. The output voltage varies by 10mV in response to every ºC rise/fall in ambient temperature, i.e., its scale factor is 0.01V/ ºC. The LM35 (fig 4) series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±1⁄4°Cat room temperature and ±3⁄4°cover a full −55 to +150°Ctemperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 µA from its supply, it has very low self-heating, less than 0.1°C in still air.

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Fig. 4. Temperature Sensor (LM35)

C. Gas Sensor(MQ3)

MQ-3 gas sensor is shown in Figure.4.3. The sensor composed by micro AL2O3 ceramic tube, Tin Dioxide (SnO2) sensitive layer, measuring electrode and heater are fixed into a crust made by plastic and stainless steel net. The heater provides necessary working conditions for work of sensitive components. The enveloped MQ-3 have 6 pin, 4 of them are used to fetch signals and other 2 are used for providing heating current. MQ3 flammable gas and smoke sensor detects the concentrations of combustible gas in the air and outputs its reading as an analog voltage. The sensor (fig 5) can measure concentrations of flammable gas of 300 to 10,000 ppm. The sensor can operate at temperatures from -20 to 50°C and consumes less than 150 mA at 5 V. Connecting five volts across the heating (H) pins keeps the sensor hot enough to function correctly [4]. Connecting five volts at either the A or B pins causes the sensor to emit an analog voltage on the other pins. A resistive load between the output pins and ground sets the sensitivity of the detector. The resistive load should be calibrated for the particular application but a good starting value for the resistor is 20 kΩ.

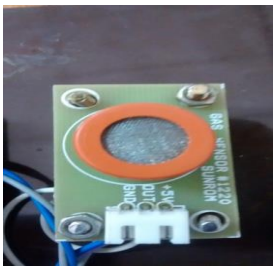

Fig. 5. Gas Sensor

D. Buzzer

The buzzer (Fig 6) is interfaced with the Raspberry pi, which provokes an alarm during hike in boiler temperature and also during the detection of presence of hazardous gases. The Fig 7 shows the circuit diagram of the buzzer.

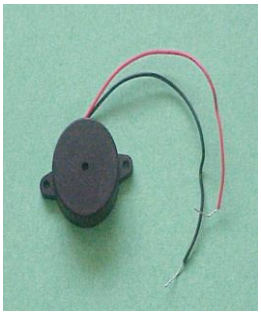

Fig. 6. Buzzer

E. Solar Panel

A solar panel contains a set of solar photovoltaic modules electrically connected and mounted on a supporting structure. A photovoltaic module is a packaged, connected assembly of solar cells. The solar panel can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications. Each module is rated by its DC output power under standard test conditions (STC), and typically ranges from 100 to 320 watts. A single solar module can produce only a limited amount of power; most installations may produce larger amount of electric power. A photovoltaic system typically includes a panel or an array of solar modules, an inverter, and sometimes a battery and/or solar tracker and interconnection wiring.

Solar modules use light energy (photons) from the sun to generate electricity through the photovoltaic effect. The majority of modules use wafer-based crystalline silicon cells or thin-film cells based on cadmium telluride or silicon. The structural (load carrying) member of a module can either be the top layer or the back layer. Cells must also be protected from mechanical damage and moisture [5]. Most solar modules are rigid, but semi-flexible ones are available, based on thin-film cells. This solar panel stores the energy source in the 12v battery and it accommodates and also segregates the power supply to the Transmitter side. The solar panel is shown in the Fig 7. The embedded main board module is provided with the switch, through which we can opt for solar energy or AC supply.

Fig. 7. Solar Panel

F. ADC PCF8591

An analog-to-digital converter is a device that converts a continuous physical quantity (usually voltage) to a digital number that represents the quantity's amplitude. The PCF8591 is a single-chip, single-supply low-power 8-bit CMOS data acquisition device with four analog inputs, one analog output and a serial I2C-bus interface [6]. Three address pins A0, A1 and A2 are used for programming the hardware address, allowing the use of up to eight devices connected to the I2C-bus without additional hardware. Address, control and data to and from the device are transferred serially via the two-line bidirectional I2C-bus. The functions of the device include analog input multiplexing, on-chip track and hold function, 8-bit analog-to-digital conversion and an 8-bit digital-to-analog conversion. The maximum conversion rate is given by the maximum speed of the I2C-bus.

G. Raspberry Pi

The Raspberry Pi(Fig 8)is a small computer about the size of a credit card and costs approximately £25. It was developed in the UK by the Raspberry Pi Foundation with the hope of inspiring a generation of learners to be creative and to discover how computers are programmed and how they function. This small computer features amazing HD (high-definition) quality video playback, sports high quality audio and has the ability to play 3D games. The device uses the ARM processor which does most of the hard work in order to run the Raspberry Pi.ARM processors can be thought of as the brains of the device. These processors are mainly used in small devices such as mobile phones, handheld mobile gaming devices and other small digital devices. The reason for this is that ARM processors are extremely efficient and fast when used in small devices [7]. This makes the ARM processor the obvious choice for the Raspberry Pi. Even though the Raspberry Pi is a computer it does not have a hard drive like traditional computers, instead it relies on the SD card for the starting up and storing of information. For the Raspberry Pi the SD card does the same job as a hard drive does in a traditional computer. The SD card must contain the operating system, programs and the data needed to run the Raspberry Pi. The operating system tells the Raspberry Pi how to function, how to handle any input from the user and how to manage programs when they are running. Fig 9 shows the architecture of raspberry pi. Operating System that can run withRaspberrypiare:Linux(Raspbian,DebianGNU/Linux,Open ELEC, Fedora,ArchLinuxARM,Gentoo,RISCFreeBS,NetBSD ,Plan9, Openwrt, Android, Firefox OS).

Fig.8. Raspberry pi

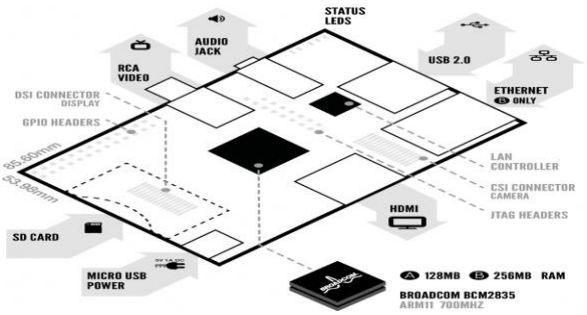

Fig. 9. Raspberry Pi Architecture

IV. SOFTWARE REQUIREMENTS

A. Web Server

The template is designed so that author affiliations are not repeated each time for multiple authors of the same affiliation. Please keep your affiliations as succinct as possible (for example, do not differentiate among departments of the same organization). This template was designed for two affiliations. The embedded web server is the combination of embedded device and Internet technology, which provides a flexible remote device monitoring and management function based on Internet browser and it has become an advanced development trend of embedded technology [8]. The implementation of embedded Internet technology is achieved by means of the embedded web server. It runs on embedded system with limiting computing resources to serve web documents including static and dynamic information about embedded system to web browser. We can connect any electronic device/equipment to web server and can obtain the real-time status information and control remote equipment without time and space restriction through web page released by embedded web server. Embedded server is a single chip implementation of the Ethernet networking standard.

It consists of two primary elements communicating with each other:

i) A server consisting of an ARM processor with an Ethernet controller.
ii) A client computer which is connected to controller through this RJ45 interface.

B. Process between PC with Main Board

The client computer sends/receives data to/from the ARM microcontroller using TCP packets. The client has to enter IP address to access this server. This request is taken by the operating system of the client and given to the LAN controller of the client system. The LAN controller sends the request to the router that processes and checks for the system connected to the network with the particular IP address. If the IP address entered is correct and matches to that of the server, a request is sent to the LAN controller of the server and a session is established and a TCP/IP connection is establishes and the

server starts sending the web pages to the client through which we can remotely monitor and control the sensor and device status respectively.

C. Ethernet Interface Design

Ethernet provides services corresponding to Layers 1 and 2 of the OSI reference model. It is standardized as IEEE 802.3 It specifies bus topology with connecting cable with both station and the actual network medium. Ethernet interface consists of MAC controller and PHY interface. MAC layer is responsible for data packaging, closing, sending and receiving. Its highly integrated design eliminates the need for costly external components required by other Ethernet controllers. Fig.10 shows ARM interfaced with Ethernet controller.

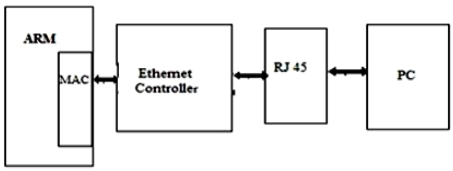

Fig. 10. ARM interfaced with Ethernet Controller

D. Software Development

When the system is powered up the initialization part of the system software configures various on chip peripherals such as timers, interrupts etc. It also initializes the external interfaces viz. Ethernet, ADC, etc. Once the system hardware is initialized, the system loads the TCP/IP stack and enables the network communication via Ethernet. The HTTP server application is started and the web server can now be reached from the remote node. At this point the system keeps polling for the HTTP request [9]. When the HTTP request arrives from any of the remote hosts, the embedded web server responds it with the acknowledgement, and checks for the authentication. The requests with proper authentication are accepted by the Embedded Web Server, in response of which it reads the ambient parameters, embed them in the preformatted web page and sends the HTML webpage to the requestor node.

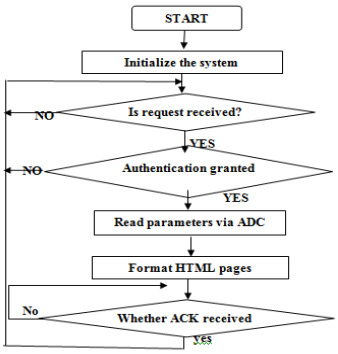

Fig. 11. Flow Chart of System Design

E. Raspbian OS

Raspbian is an unofficial port of Debian Wheezy arm with compilation settings adjusted to produce code that uses "hardware floating point", the "hard float" ABI and will run on the Raspberry Pi. The port is necessary because the official Debian Wheezy arm release is compatible only with versions of the ARM architecture later than the one used on the Raspberry Pi (ARMv7-A CPUs and higher vs the Raspberry Pi's ARMv6 CPU).Software development process based OS includes: the establishment of cross-compiler, the creation of root file system, the transplant of Boot loader, the porting of embedded Linux, and the development embedded Web server. ARM Linux gcc is the cross compiler used. Boot loader vi is used here [10]. The function of Boot loader is to initialize the hardware devices, establish memory mapping tables, thus establish appropriate hardware and software environment, provides interface to send commands to target board and prepare for the final call to the operating system kernel. Linux is used as operating system because Linux system is having a hierarchical structure and completely opens its kernel source. Linux can port to a wide range of hardware platforms, and can run in most of the architecture. Linux has a comprehensive set of editing, debugging and other development tools, graphical interface, a powerful network supporting and rich applications. In addition, the kernel can be reduced by configuring it.

F. Embedded C

The term “computer” usually conjures up in the minds of many people the image of a mainframe, a minicomputer, a PC, a workstation or a laptop computer. However, computers have always been embedded into all sorts of everyday items from automobiles and planes to TVs, in-house entertainment centers and toasters. These are usually called embedded computers or embedded systems, and actually account for more than 90% of all the world’s manufactured processors. Such embedded computers are gaining importance as an increasing number of systems use embedded processors, RAM, disk drives, and networks An embedded system is some combination of computer hardware and software, either fixed in capability or programmable, that is specifically designed for a particular function. Embedded systems that are programmable are provided with programming interfaces, and embedded systems programming is a specialized occupation. Certain operating systems or language platforms are tailored for the embedded market, such as Embedded Java and Windows XP Embedded. However, some low-end consumer products use very inexpensive microprocessors and limited storage, with the application and operating system both part of a single program. The program is written permanently into the system's memory in this case, rather than being loaded into RAM (random access memory) like programs on a personal computer. The software is installed on the controller, the brains of the electronic device. Each embedded system is used for one specific function. Extensions for the programming language C to support embedded processors, enabling portable

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and efficient application programming for embedded systems is Embedded C.

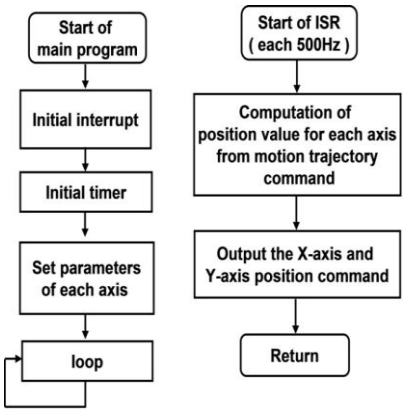

Fig. 12. Design Flow

G. HTML

HTML stands for hyper text markup language. It is used to create a webpage in web designing. It is not case sensitive and is error free language. It creates only static webpage. HTML(Hypertext Markup Language) is the language used by the web to define and display its files. These files can contain text, or multimedia. HTML files are ASCII text files that contain the text to be displayed and the markup tags that tell how to display them.

V. SOFTWARE IMPLEMENTATION

a. Downloading an Image

The operating system that will be installed onto the SD card must be downloaded from the Internet. This will usually be a zip file that then extracts to a file of type .img an image file. Whatever image file downloaded, the actual installation process is the same.

b. Choose your Operating System

To install linux, ‘distro’ or Distribution is needed. Being an Open Source operating system, anyone can take one of the existing distributions an add things to it or configure it in a certain way before packaging it up as another distribution option for anyone to use. This is how the most common Raspberry Pi distribution 'Raspbian' came into existence. The 'Debian' distribution was configured and kitted out with useful things like IDLE (a python-programming language development editor) and Scratch (a learn-to-program gaming system) to make it suitable for the Pi. Ada fruit have then taken Raspbian and configured it to make it as easy as possible to use the GPIO connector to attach DIY electronics to the Pi.

VI. RESULTS AND DISCUSSION

This embedded control unit is placed in the industrial site, which senses the presence of gas and about the boiler temperature. The system is designed in such as a way, to provoke alarm during critical situations. Fig. 13 shows the prototype of Embedded Industrial System. Base station is shown in the fig 14. And Webpage result is shown in the fig 15.

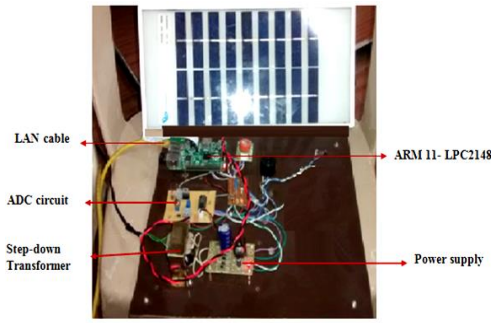

Fig. 13.Prototype of Embedded Industrial System

Fig. 14. Home Webpage

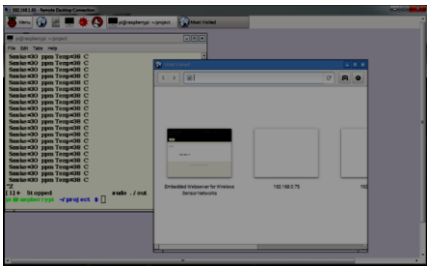

Fig. 15. Webpage Result

VII. CONCLUSION

This work has practically implemented the Raspberry pi wired sensor network in the industrial automation system to detect the temperature, gas, and consumption power of every electrical facility as the running parameters of the solar panel. The aim of this work is to control the industrial devices, managing the power utilities and also monitoring the employee works. These are all done through wired network with help of server pc. This server PC is password protected and it can be opened only by the authorized person. From the transmitter side, the sensor data sent to the server PC every 3 seconds. The whole energy-saving system functions successfully and the parameters monitored at the industrial side are displayed in the base station server pc.

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