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Design of a Supervisory Control and Data Acquisition System for Monitoring Temperature and Light Intensity of a Workstation

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Abstract: *In this Project the design of a Supervisor Control and Data Acquisition (SCADA) system to monitor temperature and light intensity and voltage regulation was carried out. The system when implemented had the ability to control the environmental temperature and ambient light intensity of a workstation and transmit the data of these controlled parameters, wirelessly, between the site and base station. The base station was designed with an LCD display that would enable the user to view these parameters and also have input keypads that the user can use to alter the light intensity and temperature wirelessly. The system carries the voltage regulation on a fan and incandescent bulb as loads. To achieve this feat, an embedded system was used which involves the programming of a PIC microcontroller using assembly language. Other discreet components were also utilized such as resistor, capacitor and transistors. The wireless communication system used is radio frequency. This is possible because RF transceivers were mounted on the site base station. After the design, construction and testing, the project was able to function satisfactorily, as the SCADA system could alter environmental temperature and ambient light intensity of a site and transmit the information wirelessly to the base station from 10^{o}C to 100^{o}C and 1% to 100% light intensity and vice versa in reduction mode.*

Keywords*: SCADA, sensors, Micro Controllers, temperature, transceivers*

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I. INTRODUCTION

SCADA system is an acronym for Supervisory Control and Data Acquisition system. It is basically a system for remote monitoring and control that operates with coded signals over communication channels [1]. The system may be combined with a data acquisition system by adding the coded signals over communication channels to acquire information about the status of the remote equipment for display or for recorded functions. It is a type of industrial control system **[**1]. Typically, SCADA systems are used to automate complex industrial processes where human control is impractical, systems where there are more control factors, and more fast-moving control factors, than humans can comfortably manage. [2]. Control according to [3-4] consists of monitoring the state of a critical parameter, detecting when it varies from the desired state, and taking action to restore it. Control can be discrete or analog, manual or automatic, and periodic or continuous.

It is impossible to keep control and supervision on all industrial activities manually, hence some automated tool is required which can control, supervise, collect data, analyze data and generate reports[1]. In control processes where by environmental conditions are desired to be set, conditions such as the temperature, light intensity, pressure, humidity, environments conditional altering equipment would be employed.This is sometimes referred to as a secondary control process because it involves the use of a device or process to control another process. For instance, in the temperature regulation of an environment, the use of an air-condition unit or a simple domestic fan would be employed.

In all the above mentioned control process, the acquisition of data becomes necessary. Personnel would need to know the status of a particular machine to ensure that the total process would not be flawed. According to [5] processes usually employ handshake ability in its structure. Which means that the synchronous working of all machines and equipment in the total process is extremely important for the process to be successful. The accumulated data from the controlled parameters could be analyzed, stored or just displayed on a screen [6]. SCADA systems around the world, find use in a wide variety of applications, electric power generation, transmission and distribution. Electric utilities use SCADA systems to detect current flow and line voltage [6] and [7] to monitor the operation of circuit breakers, and to take sections of the power grid online or offline.There are no simple SCADA units in the market as these systems are used in industries and as such are not cheap or cost-effective for small scale usage hence this work is aimed at designing a small scale SCADA control system that can control and monitor two inputs and outputs with keypad user input and LCD display as a cost effective design for small scale use and implementation.

The SCADA design to be implemented in this work would be able to control two distinct physical parameters from a remote location and view obtained data from the site, on a screen placed several meters away. The two parameters that would be monitored and controlled are light intensity and temperature.

Various other studies has implemented the design of a SCADA system.[8] Designed an industry scale fitting SCADA work. The design was basically a power distribution SCADA system based on Programmable logic controller (PLC) and configuration software, and SCADA power distribution monitoring system for monitoring low-voltage and medium-voltage switchgears.[9] In their earlier research designed a simple SCADA system for filling process.

II. AIM

The aim of the project is to monitor and control the temperature and light intensity of a workstation using supervisory control and data acquisition (SCADA) system. This is majorly an academic prototype to demonstrate the basis of a SCADA system.

III. COMPONENTSAND SPECIFICATIONS

+5V Power Supply

3.1 Temperature sensor

The temperature sensor chosen for the design is the LM35 IC temperature sensor. LM35 is a three terminal integrated circuit temperature sensor giving a linear voltage output of 10mV per degree Celsius. Available in two versions, one operating from ^{o}C to 100^{o}C (DZ version),and the other is from -40^{o}C to +100^{o}C (CZ version). The DZ version was used in this work. These devices are housed in TO-92 plastic packages and provide a low cost solution to temperature measurement. Ideally suited for ambient temperature measurement such as providing cold junction compensation for thermocouples. Below are the technical specifications.

LM35DZ	0 ^{o}C to 100 ^{o}C
Absolute Voltage (max)	+35V to -0.2V
Operating voltage range	+30V to +4V
Quiescent current @5V	91µA typical
Accuracy @ 25 ^{o}C	
LM35DZ	±0.9 ^{o}C

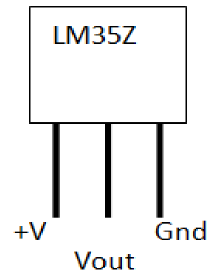


Figure 1: Temperature Sensor LM35

3.2 Light Intensity Sensor: This consists of the light dependent resistor (LDR) sensor for detecting light intensity changes. The light detector device used for the light detector is the light dependent resistor (LDR). From test and observation, the following was detected;

Dark resistance = 2.3MΩ
Light resistance = 380Ω at full day light
LDR Type = Plastic case ORP12
The LDR resistance changes with the light intensity such that the more light rays falls on it, the lower the resistance. This change must be converted to voltage change. This is achieved by connecting a fix resistance in series with the LDR to form voltage divider. The voltage output is now light dependent.
Using Voltage Divider Rule; [10]

$$Vout = \frac{R_s}{R_s + R} V_{cc} \dots\dots\dots\dots\dots\dots\dots\dots [1]$$

Where V_s = Sensor Voltage
V_c = Voltage across series resistance.
Using daylight resistance of 380Ω and current of 1.2mA.

Resistance $= \frac{V_{cc} - V_s}{I} = V_{cc} - \frac{(IR_{LDR})}{I} = 12 - \frac{(1.2 \times 10^{-3} \times 380)}{1.2 \times 10^{-3}}$ ……………..[2]

R = 9620Ω
Choose 10kΩ for R as the closest standard.
Thus, Vout (at full daylight) = 380 × 12 = 0.439V
This voltage shows that the LDR changes to light can result in output voltage change from a minimum of 0.4V to approximately 12V.

The microcontroller Unit used Microchip PIC16F88 model. It has onboard analog to digital converter (ADC) which is needed to convert the analog voltages of the temperatures to digital data. The features of interest of the microcontroller is listed thus;
• Timer1 Oscillator: 1.8 µA, 32 kHz, 2V
• Three Crystal modes:
- LP, XT, HS: up to 20 MHz
• Two External RC modes
• One External Clock mode:
- ECIO: up to 20 MHz
• Internal oscillator block:
- 8 user selectable frequencies: 31 kHz,
125 kHz, 250 kHz, 500 kHz, 1 MHz, 2 MHz,
4 MHz, 8 MHz

Peripheral Features:
• 10-bit, 7-channel Analog-to-Digital Converter
• Synchronous Serial Port (SSP) with SPI™
(Master/Slave) and I2C™ (Slave)
• Addressable Universal Synchronous
Asynchronous Receiver Transmitter
(AUSART/SCI) with 9-bit address detection:
- RS-232 operation using internal oscillator
(No external crystal required)

Special Microcontroller Features:
• 100,000 erase/write cycles Enhanced Flash
Program memory typical
• 1,000,000 typical erase/write cycles EEPROM
Data memory typical
• Wide operating voltage range: 2.0V to 5.5V

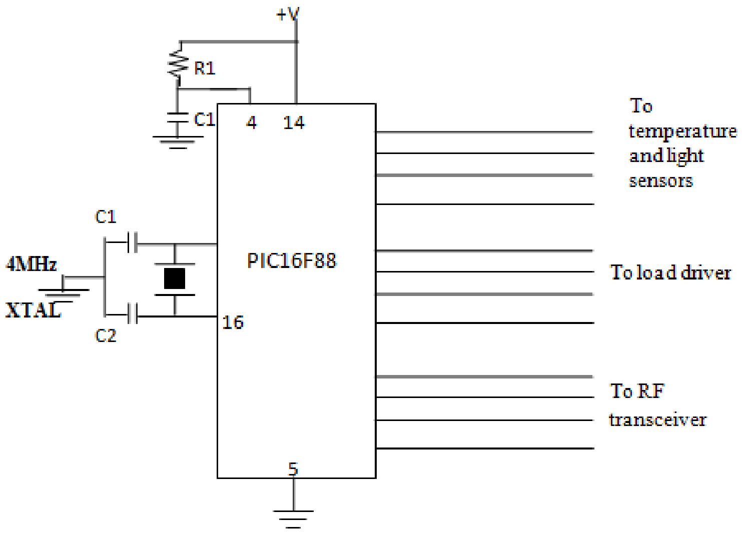


Figure 2: Microcontroller circuit

RF Transceiver the RF transceiver module used is the KYL-500S mini transceiver module, RS232 based.
Power output = 50mW default (range 10mW to approx. 80mW)
RF Line-of-sight Range: = 1000m@1200bps; 600m@9600bps
RF Effective Rate: = 1200/2400/4800/9600/19200bps
Frequency Band: = 433MHz (400/450MHz/470MHz)
Channel = 8(default), 16/32/64(optional)
The unit used in this work was already configured for 9600bps data speed rate.

Load Controller

It consists of an Optocoupler and a power TRIAC driver stage. The Optocoupler serves as an isolator between the power drive circuit and the sensor stage. They are simple and effective solution to interfacing, hence the use of it here. It is used to trigger the power Triac circuit. Fig 3 shows the diagram of MOC3021 Optocoupler.

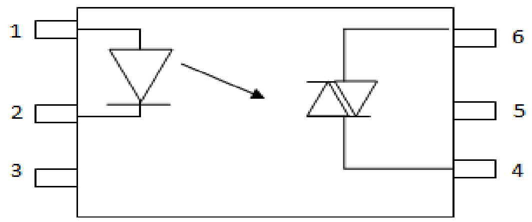


Figure 3: MOC3021 Optocoupler

MOC3021 specifications

LED drive current, I_{FT} = 15mA max
LED voltage, V_d = 2V
Triac drive current = 300mA max.
The limiting resistor value can be obtained thus,

$$R = \frac{V_{CC} - V_d}{I_{FT}} = \frac{12-2}{15 \times 10^{-3}}$$

R = 667Ω
A value of 680Ω was chosen as the practical available value.

The power drive consists of the power Triac connected to control power to the fan and light bulbs serving as the load. The Optocoupler stage drives it, and it in turn switches power to the bulbs. It does full wave switching to ensure positive and negative variation of the ac voltage. The circuit is as shown in fig 4.

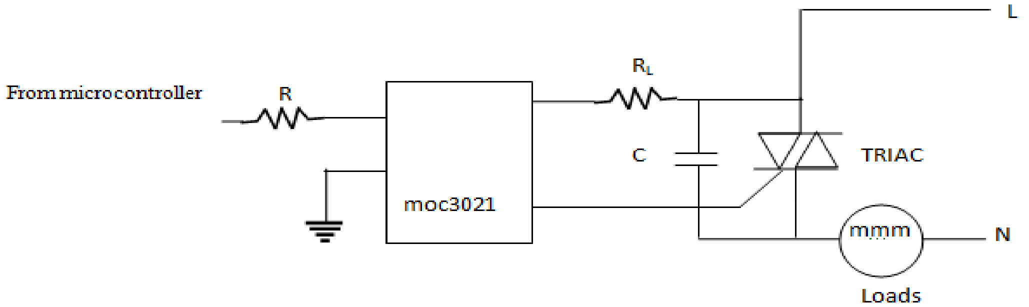


Figure 4: Power Triac Driver Circuit

Resistor R_L and C is serving as limiting resistor and transient suppression respectively in the circuit.
R_L = max load voltage / max. Trigger current
Max load voltage = 240V
Max trigger current = 360mA
$R_L = 240 / 360 \times 10^{-3}$
R_L = 666.7Ω
The chosen value is 680Ω as the closest value in the market.
The capacitor C value is not too critical, it is to reduce transients. The chosen value is 100nF.

TRIAC DATA of BT137

Gate trigger current $I_{GT} =$ 80mA
Gate trigger Voltage $V_{GT} =$ 2.5V
Max. Surge Current I_{surge} = 100A
Hold current I_{HOLD} = 50mA
Max. Forward current I_T rms = 10A

IV. DESIGN METHODS

The design of the SCADA system is divided into three sections which are the SITE, the Base Station and the Android GUI. The site refers to the stage that has the control elements and the sensors through which it monitors the environmental parameters. The base station refers to the receiver end where the control commands are sent to the site remotely and the user display and GUI are located.

THE POWER SUPPLY UNIT: The PSU converts the 220V from the Mains voltage to approximately 12V and 5V dealing with digital integrated circuit. Figure 5 shows the circuit diagram of the power supply unit.

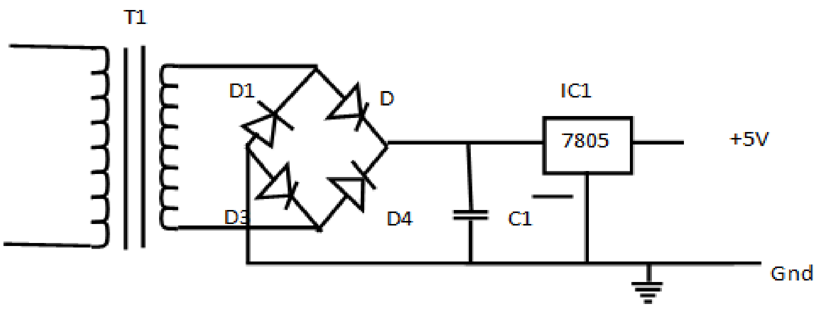


Figure 5: The power supply unit

THE SITE: The Site consists of the temperature sensor stage, temperature sensor LM35 IC (DZ version) operating from ^{o}C to 100^{o}C, light intensity control sensor, microcontroller unit PC16F88, RF transceiver KYL-500S and load driver MOC3021 Optocoupler and Power Triac methods used for the setup of the site as shown in figure 6 is explained below:

- The temperature and the light sensors are connected to the microcontroller which feeds the light and temperature control circuit.
- The transceiver Unit connected to the Microcontroller to transmit and receive data to and from the temperature and light control circuits as a single package from site to the base station.

The site has the temperature sensor LM35 and LDR light sensors. When the system is powered, the microcontroller checks the sensor outputs get their voltage and convert to the digital equivalent. The data is then processed and transmitted to the receiver through the RF transceiver. The microcontroller through the Optocoupler and Triac serving as power drivers regulates the voltage supply the loads (bulb and fan) with train of pulse width determine/set by the user from the base station.

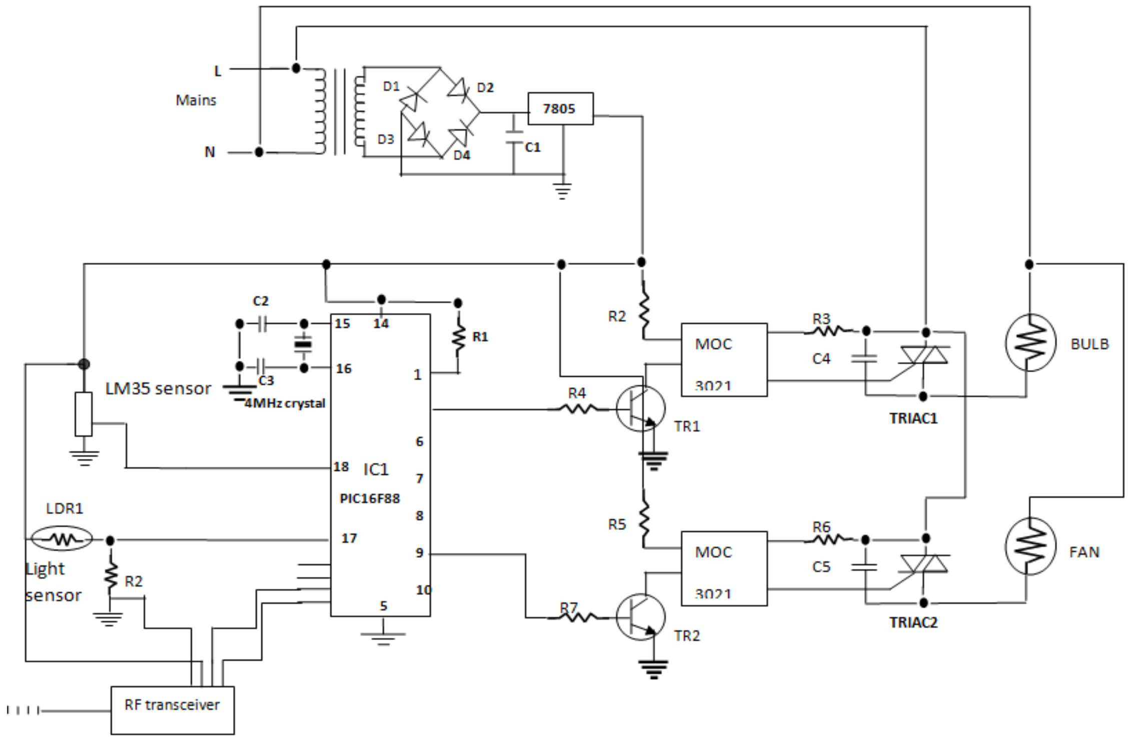


Figure 6: Complete circuit diagram of the SCADA SITE stage

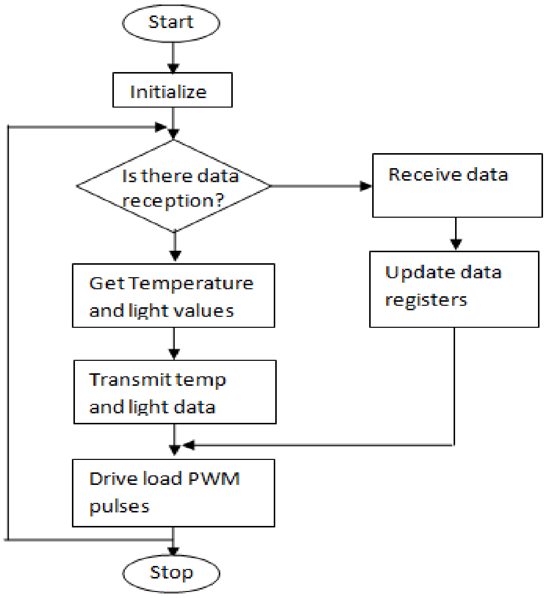


Figure 7: Flowchart diagram of the Site Microcontroller code development

THE BASE STATION: This is the control stage the user directly accesses to control the site. In this section the microcontroller checks the keypad for any parameter settings and if the user sets the parameters of temperature and light intensity levels, the microcontroller stores it and transmit these data to the site using the RF transceiver for the site to effect the new adjusted data. It consists of the RF transceiver circuit, LCD Display unit, Keypad input and Bluetooth Module connected through the RF Link.

The microcontroller also monitors the RF transceiver for new data and if there is, takes the new data, processes it and displays it on the LCD screen.

The system also monitors the serial line for incoming data from PC or from android application through Bluetooth, and if there is it will process it and transmit the data to the site.

Operation Methods used for the setup of the Base Station is explained thus:

- Data Reception: The Microcontroller receives data from the sensors through the RF transceiver. These data is processed and used to drive the LCD to display information on the screen.
- Command Transmission: The microcontroller monitors the keypad when the user keys in a command for light intensity and Temperature. Then transmits it to the site which responds accordingly.
- Serial Communication: The Bluetooth module and the serial link (USB) is constantly monitored for command data. The serial link consists of a serial converter IC2 and USB to Serial converter.

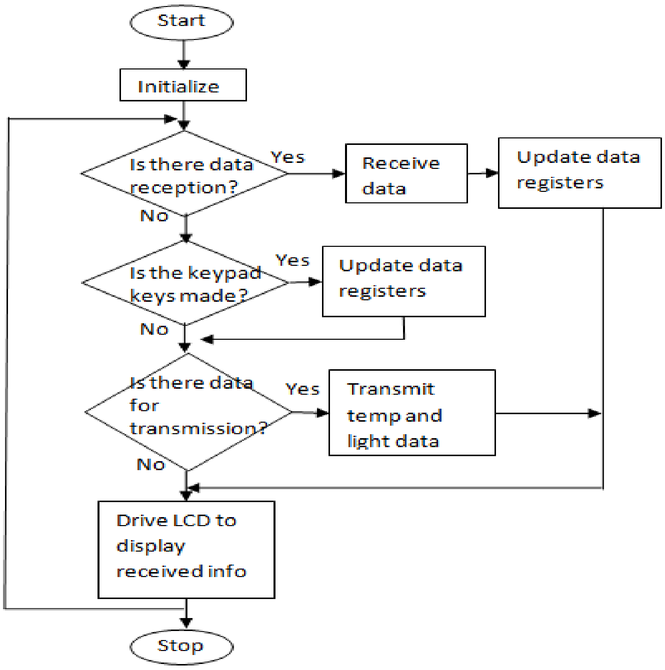
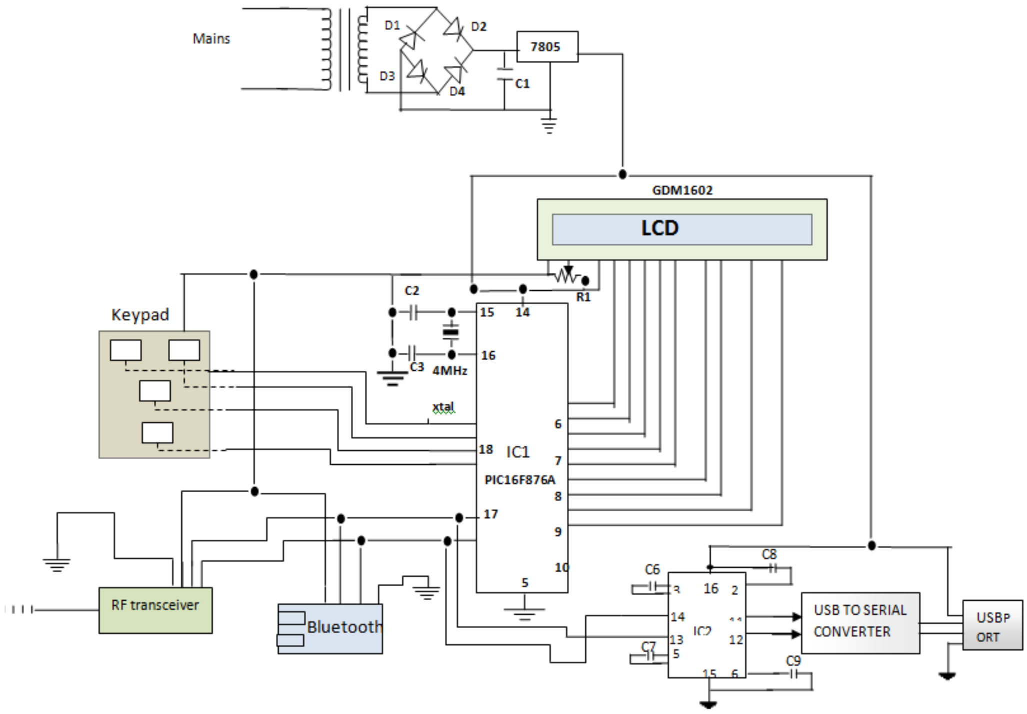


Figure 8: Flowchart diagram of the Base Station Microcontroller code development



IV. CONCLUSION

SCADA systems around the world, find use in a wide variety of applications. Electric power generation, transmission and distribution are examples of such industry. Electric utilities use SCADA systems to detect current flow and line voltage, to monitor the operation of circuit breakers, and to take sections of the power grid online or offline. Another is the water and sewage industry. The test resultof this research shows that everything involving concept and components worked as designed. It means increased efficiency and profitability in industrial control processes. The success of this work shows the beauty of a real SCADA in action and has built the appreciation for the reason why SCADA systems are invaluable to our industrial growth in Nigeria.

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