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ANALYTICAL DESIGN AND CONSTRUCTION OF GSM BASED REMOTE CONTROLLER FOR SMART HOME APPLICATION

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ABSTRACT

Remote management of home and office appliances is a subject of growing interest in recent times. Similarly, this work demostrates a means which enables the users to control home and office appliances from remote, using Dual Tone Multifrequency (DTMF) of a cell-phone based circuit which can be interfaced with Central Control Unit of a residential

Introduction

Information communication was carried out at the primitive age by travelling from kilometres to miles and this was, of course, characterised with untimely feedback, if any at all. It was against this backdrop that tireless effort was made by the concerned minds to develop the information technology up to the current advanced Information and Communication Technology (ICT). In fact, the present day 3G technologies make the information processing and communication technology more effective, efficient, less costly, and interesting than imagined. For instance, it is now possible to use mobile phone to switch on central A.C at home while still in the traffic on one's way home on the sunny day or even turn

house to automate the building, it also keeps the users informed on the status of electricity by aids of monostable multivibrator incoporated without employing any microcontroller. The signal is triggerred through auto-redial of ordinary cell phone. In other to improve design efficiency and provide insight into the behaviour of this circuit, a simulating tool was effectively used and results obtained were recorded and compared with the respective theoretical values and that of built cicuit, making the implemented system to be of good quality with affordable cost and performs the desired functions.

Keywords: *Automation, GSM, DTMF, Remote, Interface, Signal.*

on water heater system on a cold night preparing oneself for a warm shower, and so on, just at the touch of one or two buttons on phone. In spite of these great benefits, the cost implication is affordable as computer chips and digital networks are now so cheap that one can use them at any preferred location such as kitchens and utility rooms.

As observed,[1]with advancement of technology things are becoming simpler and easier for us. Automation is the use of control systems and information technologies to reduce the need for human work in the production of goods and services. In the scope of industrialisation, automation is a step beyond mechanization, where mechanization provides human operators with machinery to assist them with the muscular requirements of work, automation greatly decreases the need for human sensory and mental requirements as well. Automation plays an increasingly important role in the world economy and daily experience. Home automation (also called domotics) is the residential extension of "building automation" [1]. It is automation of the home, housework or household activity. Home automation may include centralisation control of lighting, HVAC (heating, ventilation and air conditioning), appliances, and other systems to provide improved convenience, comfort, energy efficiency and security. Disabled can

provide increased quality of life for persons who might otherwise require caregivers or institutional care.

Also, [2] electrical energy is one of the main sources of power of energy to operate any electrical device or appliance. Most of the people turn on the light for 24 hours per day when they are away from home. Light turned on continuously leads to energy waste. Thus, this work is to provide a mechanism through the development of a device to provide a service to the home owner, to optimise the usage of electricity through remote control using a cell phone. Many existing method had been explored for control and monitoring home appliances, and the commonest of all was an infrared technology because of affordability, but it was characterised by requiring "live of sight' style of remote control, we have to point the remote at the application, appliance or device to make any changes happen. This work proposed the use of DTMF (Dual Tone Multi frequency) generated on a keypad of a mobile phone when pressed by the user [3], to control the system by sending the DTMF tone to the access point. DTMF is a generic communication term for touch tone (a Registered Trademark of AT and T), the tones produced when dialling on the keypad on the phone could be used to represent the digits, and a separate tone is used for each digit.

Review of related works

Several smart home projects such as Home Security with Messaging System [4], Security & Control System [5]and Remote and Security Control via SMS [6] were among the three alarm system that were designed using SMS application to securely monitor the home condition when the owners are away or at night. A system as established by [4] triggered by SMS to the home owner to notify the owner of any incident happened around the house such as robbery or fire. The security system used mobile phone with a combination of microcontroller circuit PIC16F877A which interfaced with the computer. The system responded when the sensor actively triggered by any abnormal activity, the PIC circuit also automatically activated the computer to send SMS to the owner using mobile phone as modem.

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Furthermore, the system developed by [7] used to control the switch for lamp, door and alarm system using Visual Basic 6.0 software and it employed computer and mobile phone to send and receive the text messages. Vehicle Speed Detection using SMS presented by [8] comprising the black box for warning system to control the exceeding speed of express bus via SMS and its of three main parts; microcontroller circuit, relay driving circuit and mobile phone. This work used PIC 16F873A, Nokia 3310 mobile phone and using JAL (Just another Language) software for the programming. Similar project was also implemented by Serasidis Vasilis [9], who developed a device that can control variety of electrical home appliance using SMS. The system worked based on the order message from user through mobile phone which was ON or OFF. This system also utilised mobile phone as a receiver which connected to the microcontroller and could control 8 electrical home appliances at any time. It made use of AT 9052313 microcontroller and Ericsson T10s mobile phone as a receiver at home, with MPLAB IDE as software.

System Development

Remote section, a DTMF encoder (chip Um 9124B) embedded in the mobile phone of the remote section

detects sinusoidal signals in the presence of noise,which is[13]the algebraic sum of two different audio frequencies and can be expressed as:

$$F(t) = Ao\ Sin(2\pi ft) + Bo\ Sin(2\pi ft)$$

$$\text{i.e DFT} = \sum[\text{Sin}(f_i t)\text{Sin}(f_2 t)] \qquad (1)$$

Where F_1 and F_2 are two audio frequencies which belong to low and high frequency respectively while A and B are peak amplitudes. Each of the low and high frequencies comprise four frequencies from the various keys present on the mobile phone keypads. DTMF assigns a specific frequency (consisting of two separate tones) to each key so that it can easily be identified by a microprocessor.

Table 1:Row and Column Correspondence Frequency

1	2	3	697
4	5	6	770
7	8	9	852
*	0	#	941
1209	1336	1477	Frequency(Hz)

[11] It is clear from eqn (1) that we will get the result as a "large" number if the two frequencies are the same and a "small" number or zero if they are different.The exact values of the frequencies are listed in table1. Each key is specified by its row and column locations. For example,[11] the"2" key is row 0 (R_1) and Column 1 (C_2). Thus using the above table "2" has a frequency of 2033Hz and "9" has a frequency of 852 + 1477 = 2329Hz

Received Mobile Phone and its Interface Circuit

[12]An incoming signal is received by mobile phone by generating a superimposed ring voltage of
approximately 90V AC at frequency of 20Hz over DC voltage **48V** by the aids of inner capacitor and[13] a resistor at the input of the DTMF decoder with a resistance of 100kΩ.[14]Since the standard voltage for the phone system is 48volts D.C while the ringing voltage is around 90 volts A.C**,** also,[12] telephone has a Tip-To-Ring impedance of 600 ohms, this is also specified in IEEE standard 661-1979. In order to reach the safe small current value for DTMF decoder, a very big input impedance of approximately 1MΩ was connected with 100kΩ, based on this; the current that reached the DTMF was calculated as below

$$R_T = \frac{10^6 \times 10^5}{10^6 + 10^5} = 9.9K\Omega,$$

$$X_C = \frac{1}{2\pi f C}$$

$$= \frac{1}{2\pi \times 20 \times 0.1 \times 10^{-6}} = 79.58k\Omega$$

$$Z = \sqrt{R_T^2 + X_C^2}$$

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$$= \sqrt{[(9.9)^2 + (79.58)^2]10^6} = 80.2K\Omega$$

$$I = \frac{V}{Z}$$

$$= \frac{90}{80.2 \times 10^3} = 1.12mA$$

Signal Decoding Unit

[13]A 5V chosen satisfied the power voltage that reached the DTMF which is $V_R = V_{DD} - V_D = 5 - 0.7 = 4.3V$. For the interfacing, character recognition check was performed by RC time constant driven by EST [Early Steering Flag]. This was deducted time for Gain Tone Access [13]

$$T_{GTA} = RC\ In\ \left[\frac{V_{DD}}{V_{Tst}}\right] \qquad (2)$$

Since independent selection of signal duration and interdigit pause were required, maximum interdigit pause reject had to be set before the component chosen[13]. As stated[13] Minimum V_{Tst} = 2.2ms, t_{DD} = 20ms (Minimum inter-digit pause reject), V_R = 4.3V (calculated), C = 100µF (chosen) and using these, the required resistor could be found.

$$20 \times 10^{-3} = R \times 0.1 \times 10^{-6}\ In\ \left[\frac{4.3}{2.2}\right],$$

R = 298.43kΩ , while chosen value was 300 kΩ

DTMF signal was tapped from the microphone pin of cell phone device through the red wire pins with crystal oscillator of frequency 3.58MHz which was decoded and inverted into 4-16 digital binary sequence by IC 74154 and hex inverters IC 7404 respectively .

Number Display Unit(NDU) and Device Control Unit(DCU)

For NDU, [15][16]Since microcontroller was not used , common anode seven-segment with seven segment decoder TTL IC 7447 was interfaced with a BCD, initialised by D flip flop of asynchronously clocked period (T) greater or equal to the sum of worst–case Clk-Q delay(tclk-Q) i.e. satisfy maximum delay restriction given by:

$$d = 1.05\ t_{clk} + t_{setup} \leq T - t_{logic} - t_{skew} \qquad (3)$$

with specified interdigit pause accept given was 40ms (Mux) to clock the multiplexer.

$$T \geq \text{time (D)} + \text{time (Inv)} + \text{time (Mux)} \quad (4)$$

Switching characteristics of Mux for 5V[18] are t_{PLH} =36ns,t_{PHL} = 33ns,t_{PLH} (stobe output) = 30ns, and t_{PHL} (strobe output) = 27ns.

hence, time (Mux) = (36 + 33 + 30 + 27) ns = 126ns

Switching characteristic of inverter for 5V[19] t_{PHL} = 300ns, t_{PLH} = 200ns and t_{TLH} = 300ns

time (Inv) = (200 + 300 + 300) ns = 800ns ,

time (D) = 40ms – 0.926 ≈ 40ms

For D flip flop at 5V [20] $t_{clk} = t_{RCL} + L_{FCL}$ = (15 + 15) ms = 30ms

max t_{setup} = 40ns ,t_{logic} = 350ns and t_{skew} = 0

$D = 1.05\,(30 \times 10^{-6}) + (400 \times 10^{-9}) + 350 \times 10^{-9} \leq T$

D = 3.22ms ≤ 40ms

For the driving circuit, a transistor maximum collector current should be greater than the load current I_c. With relay Voltage rating = 12V, relay Resistance = 150 Ohms,then $I_C = 80mA$

The transistor minimum current gain h_{FE} should be [20].

$$h_{FE} > \frac{5 \times Load\ Current}{drive\ Current} \quad (5)$$

Drive current = Output current of the CMOS D Flip Flop = 5mA

$$\therefore\ h_{FE} = \frac{5 \times 80mA}{5mA} = 80$$

2N222 transistor that had a maximum collector I_C = 0.8A and h_{FE} 300 [21] satisfied these conditions ,so ,base ressistor calculated as[20]

$$Base\ resistor = \frac{Drive \times Current\ gain}{5 \times Maximum\ Collector\ Current} = \frac{V_C \times h_{FE}}{5 \times 0.8} = \frac{12 \times 300}{5 \times 0.8} = 900\Omega$$

Hence, a resistor whose resistance greater than 900Ω was used as a base resistor. For the other two 10amps, they shared the same power with ICs, it was preferred to use[20]

$$R_B = 0.2 \times R_L \times h_{FE} \quad (6)$$

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$$I_C = \frac{5}{100} = 50mA$$

$$Since\ R_L = 10\ ,\ h_{FE} = \frac{5 \times 50 \times 10^{-3}}{5 \times 10^{-3}} = 50$$

2N222 employed had base resistor $R_B = 0.2 \times 100 \times 3$ = 6kΩ

Ring Feedback Detector Circuit was used to re-affirm the status of electricity , this was built around a monostable multivibrator and set for a period of 3 seconds.

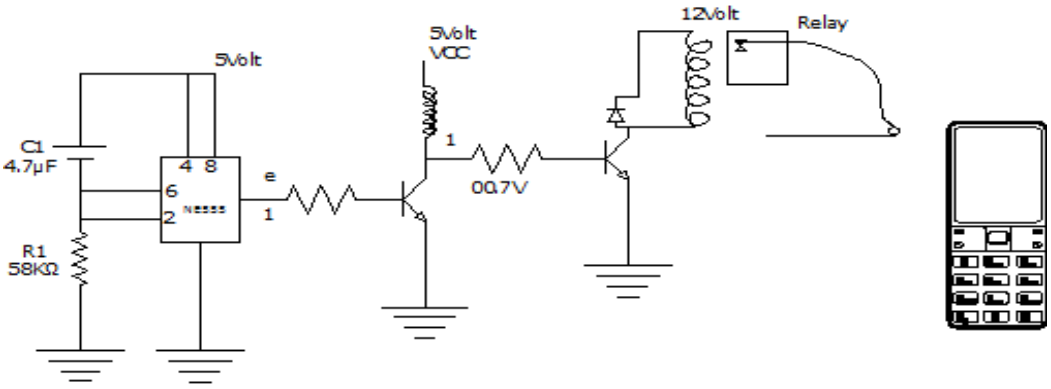

Fig1:Feed Back Unit of the GSM Home Automation

$$T_d = 1.1R_bC_b \qquad (7)$$

$$Choosing\ C = 4.7\mu F, R_b = 58k\Omega$$

Power Supply Section

Total generating current in the circuit was7.1Amps, a permanent back up of two 4.7 amp hour batteries were employed as a back up charging unit which resulted into power supply of the following parameters;162 Watt, 230/15.5 Volts, 0.7/10.44amps and 450/30 turns with $1900\mu F$(fig2)

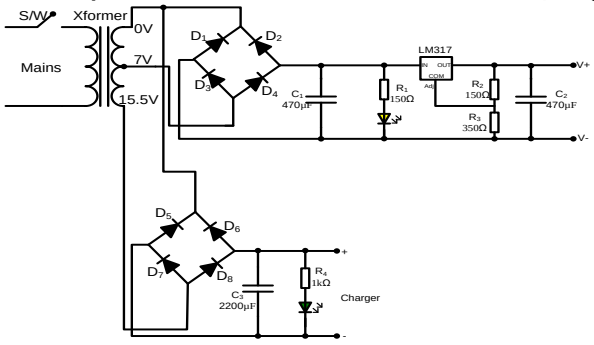

Fig2:-Power Supply Section for the Charging and Feed Back Unit

With $E_S = 13.8$, $V_L = 2V$ and $I_L = 20mA$ (recommend Values) LED charging alert and power alert resistors were calculated as 590Ω and $150\ Ohms$ using

$$R = \frac{V_S - V_L}{I} \qquad (8)$$

rectified and filtered with IN4001 and 470µF capacitor while the feedback unit was powered with 5V (E_{dc} Value), using diode forward voltage i.e.

$$E_{dc} = E_{rms} - E_f \text{[22]}$$

$$E_{rms} = (5 + 1.8)V = 6.8V = Es$$

$$E_{max} = E_{rms} \times \sqrt{2} = 6.8 \times \sqrt{2} = 9.6 Volts$$

For the two diodes[23] $C_4 = \frac{I_{dc}}{4\pi f(E_m - E_{dc})}$ (9)

$$I_{dc} = 470 \times 10^{-6} \times 4\pi \times 50\ (9.6 - 5) = 1.35 Amps,$$

$$then, \quad I_m = \frac{I_{dc} \times \pi}{2}$$

$$= \frac{1.35 \times \pi}{2} = 2.13\ Amps$$

$$I_{rms} = \frac{2.13}{\sqrt{2}} = 1.51\ Amps$$

Minimising resistant leakage 7V was chosen which made $N_s \approx 14\ turn$

$$I_P = 40mA$$

For regulator (LM 317), [24] the voltage across R_2 is 1.25Volts, while R_1 is normally chosen between 100 and 470 Ohms.V_{R1} = 1.25 Volts, R_1 = 150 Ohms (Chosen)

$$I_{R1} = \frac{V_{R2}}{R_2} = \frac{1.25}{150} = 8.3\ mA$$

$$V_{R3} = V_{out} - V_{R2} \qquad (10)$$

$$Then[22], \quad R_3 = R_3\left[\frac{V_{out}}{V_{R2}} - 1\right] \qquad (11)$$

$$R_3 = 150\left[\frac{5}{1.5} - 1\right] = 350\ Ohms$$

Six 30 amp connectors (two inputs and four outputs) were finally connected to the relays,with 1.5 and 2.5 single core cables. And the whole was assembled in a PCB (fig3) and could be assembled in a single cabinet in which the board gets fairly fitted along with CCU (Central Control

Unit). Samsung CE 0168 with model number GT - E 1105F was used for interfacing and configured in the following mode; auto – redial, auto – answer and voice server mode.

In order to actualise the workability of the circuit and behavioural nature under various conditions for better construction, a simulating software proteus was employed, however the whole circuit could not be implemented on proteus because of un-availability of DTMF to BCD (MT8870) on proteus library. This was replaced with
thumb switched – BCD. Besides, a multimeter was used to measure voltages at different terminal in the circuit. The result obtained was recorded and compared with the respective theoretical values to meet the level required. Followed by appliance interface test, a bulb was connected to one of the relays and the power supply was switched on. Successful authentication with GSM network, automation and consistency of the connection were conducted to actuate that the mobile phone dialed the GSM receiver's number, the DTMF received was observed at both ends to verify its consistency.

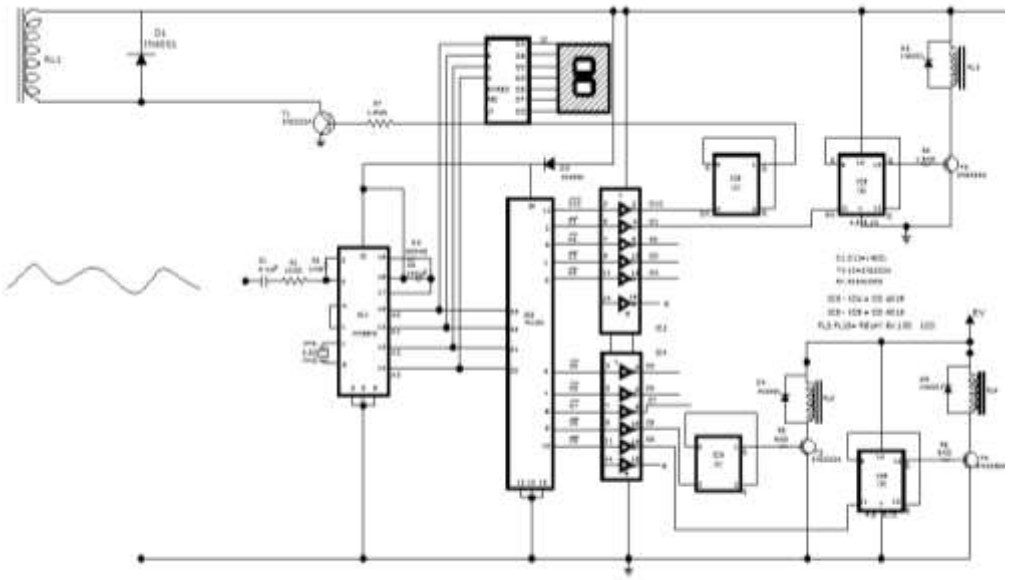

FIG. 3: Circuit Diagram of the Local Control Section OF GSM Based Remote Controller

Lastly, proper decoding of the remote user's command and issuance of the equivalent command to the controlled device were also performed, so as to observe the output command at the input/output interface with

the corresponding controlled device. Bulbs were connected to the appliance interface connectors of the circuit and the power was switched on. A phone was used to activate the bulbs.

EXPERIMENTAL RESULTS AND DISCUSSION

The workability of the designed circuit was easily confirmed through the proteus software during simulation, with the aid of stub switch, varied displaying codes representing each of the relays was viewed correspondinly. Also, the low and high state of digital components were represented by blue and red colour respectively. While yellow dot represent the grounding wire. The light blue colour shown that the relays are at ON stage [fig4].

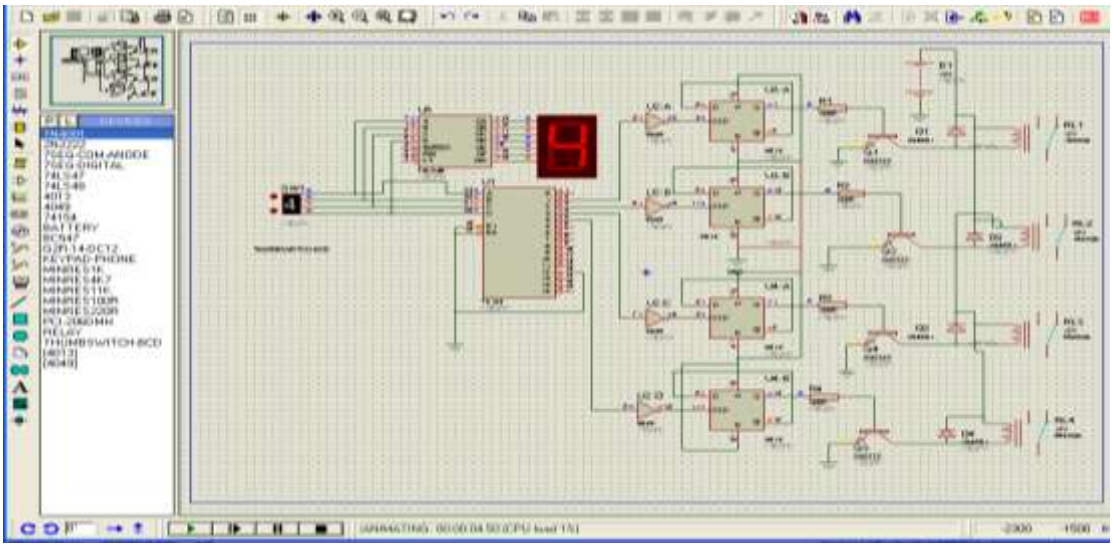

Fig 4: GSM Controller Simulating Circuit Diagram on Proteus

When test was carried out the experimental results were slightly different from theoretical values, perhaps it could be attributed to percentage error or low battery of the measuring instrument used, beside human error cannot be totally eliminated. Apart from the aforementioned, it was fully established that the GSM network and DTMF were properly decoded, also proper voltage was observed at the desired device control interface.

However, the time between calling and receiving of call depended solely on GSM network and for documentation it took 4-7seconds when the network was good and about 3-6 minutes when the network was bad. Also the feedback alert took 4-10 seconds and the auto-dialling continued until there was a response from the user.

As a result of this, home and office appliances can be effectively controlled using a cell phone, ,user can remote access to the system ,which ensures proper controlling of the device thereby serving as a security measure for the residents when they are not at home .Moreover ,users are comprised of owners who own the system , administrators who are responsible for managing and configuring the system ,also the police or fire department personnel who are contacted in case of an emergency can utilize this system as an effective method.

With approximate cost estimation, which amounted to 16,380 naira, the price is very reasonable and the device is affordable for an average consumer. However, some factors have to be considered for proper implementation of the system; the receiver must reside in a location where there is sufficient strength signal,the only person who can communicate with the control module is the person who will be successfully authenticated. Acessing the controlling unit is only possible through a cell phone with DTMF capabilities, voice server mode and auto answer facilities.

Conclusion and Recommendations

Mobile phones have become invaluable part of life, the implemented system used GSM technology to communicate which reduces cost and creates user friendly system of remote device. Thus, systems can be used as a test bed for any application that requires on-off switching base applications. Lastly, the potential for practical applications of this system cannot be quantified, it can be used to implement intelligent homes, control of devices in offices and industries.

The system designed can be further expanded to provide such control over the GPRS,in this way the capabilities of the internet can be combined with our physical line free communication system. Also, audio

or once based approach can also be developed which is beneficial for physically handicapped persons, with the help of speech we can control home or office appliances.

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