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Remote Control of Electrical Appliances Using GSM Networks

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Abstract— *For over two decades the need for an improved method for transferring dialing information for control purpose through the telephone network was recognized. The traditional method of Dial Pulse signaling was not only slow and susceptible to distortion over long wire loops but also requires a direct current (DC) path through the communication channel. This paper presents a Global System for Mobile Telecommunication (GSM) network based system which can be used to remotely send streams of 8 bit data for control of electrical appliances. Furthermore, this paper used the Dual Tone Multi-Frequency (DTMF) function of the phone, and builds a microcontroller based circuit for appliances control to demonstrate wireless data communication. Practical result obtained showed an appreciable degree of accuracy, repeatability of the system and friendliness through the use of a microcontroller.*

Keywords— *Communication, DTMF, GSM, Networks, Microcontroller.*

I. INTRODUCTION

Many electrical appliances such as the television set, radio, audio player, air conditional, heater, microwave oven are equipped with controllers that allow the user to turn them on or off from a remote site over some distance within the region that can be covered by the transmitter. Some of the existing techniques include the Radio Frequency (RF) remotes, and Infra Red (IR) remotes (Li-jun, 2007) and (Mohammed, 2005). Both working independently on RF investigated different ways of wireless communication and adopted an appropriate system to send streams of data to control any electronic instrument. Brian Millier (http//www.google/Embedtronics) in the Atmel's application journal described how he designed an RF controlled irrigation system for his house. He used the HT12E and HT12D ICs with Abacom's transmitter/receiver pair and Atmel's AVR controller chip. Simlarly, John et al. (1989) used similar technology in the journal parasitic Harvesting in Shoes. The HT12E encoder and a Ming transmitter were used to provide RF signal in a Radio Frequency Identification (RFID) system. The IR system follows the line of site approach of actually pointing the remote at the device being controlled; this makes communication to be impossible over obstacles and barriers.

To overcome this, a signaling scheme utilizing voice frequency tones is employed. This scheme is known as Dual Tone Multi-Frequency (DTMF), Touch-Tone or simply tone dialing. As its acronym suggests, a valid DTMF signal is the sum of two tones, one from a low group (697-941Hz) and the other from a high group (1209-1633Hz) with each group containing four individual tones.

DTMF signaling plays an important role in distributed communication systems such as multiuser mobile radio (Zarlink, 1983). It is natural in the two way radio environment since it slips nearly into the center of the voice spectrum, has excellent noise immunity and it has a highly integrated method of implementation currently available. It is directly compactable with telephone signals simplifying automatic phone batch system.

The development of silicon implemented switch capacitors, sample-1 filters, marks the current generation of DTMF receiver technology. Initially single chip band Pass Filters were combined with currently available decoders enabling a two chip receiver design. A further advance in integration has merged both functions onto a single chip allowing DTMF receivers to be realized in minimal space of a low cost. Most Nokia phones have F-Bus and M-Bus connections that can be used to connect a phone to Personal Computers (PC) or in this case, a microcontroller. The connection can be used for controlling just about all functions of the phone.

In this paper, phones using GSM network interfaced with microcontroller is used to remotely control electrical appliances thus overcoming distance barrier problem and communication over obstacles with very minimal or no interference but is solely network dependent.

1.1 System Description

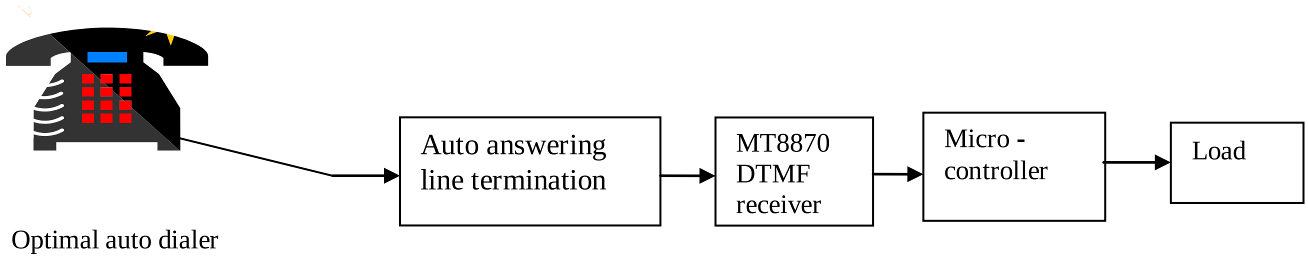

Figure 1: **DTMF Data Communication Architecture**

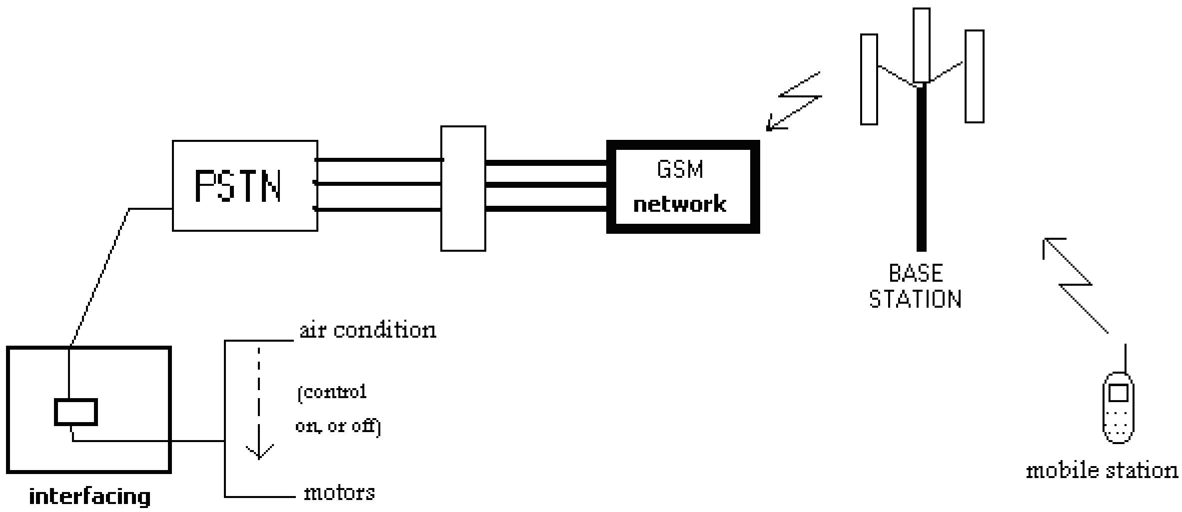

Figure 2: **Functional Block of the System**

The diagrams in figure 1 and figure 2 describe the overall system. A ringing voltage detector signals the microcontroller of an incoming call. The microprocessor after the prescribed number of rings closes the answer relay engaging the proper terminating impedance. A two to four wire converter splits bidirectional audio signal from the balanced telephone line into separate single ended transmit and receive paths.

Received audio signal is switched to the DTMF receiver through the cross point switch. Upon receiving a valid DTMF signal, the microcontroller is alerted by the rising edge of Delayed Steering Output **(S_{Td})**. The microcontroller then checks for a valid password sequence and decode subsequent commands. A command can be entered to put the system into remote control mode, subsequent data is transmitted to a selected device until a reset command is entered. The state indicators represent the binary equivalent of the hexadecimal.

An infinite variety of devices could be controlled by such a system, the spectrum of which is limited only by the ability to provide appropriate interfacing. This system can also be the heart of a DTMF intercom system allowing communication, phone batching and remote control from various household locations.

II. DESIGN FRAMEWORK

2.1 System Design

The design process is divided into two; Hardware and Software designs.

2.1.1 Hardware Design

2.1.1.1 The Microcontroller

The microcontroller is actually a computer on chip. It is a member of the 8051 family of microcontrollers and is 8 bit wide. It has 256 bytes of RAM, 8K of on chip ROM, three timers, 32 inputs and output pins making a total of four ports, each 8 bit wide. 1 serial pin and 8 interrupt sources all on a single chip. In all is a forty pin IC (Integrated Circuit). The AT89C51 microcontroller is an 8 bit processor meaning that the central processing unit (CPU) can work only on 8 bit. Data larger than 8 bit must be broken down into 8 bit pieces to be processed by the CPU, it is a programmable chip: the availability of software development tools such as compilers, assemblers and debuggers so that it behave exactly as the designer program it. This makes it more effective and reliable in carrying out task especially in a design that involves logic decision, control and possible to be interfaced with the MT8870D DTMF chip.

2.1.1.2 The MT8870 DTMF Chip

The MT8870 is a complete DTMF receiver, integrating both the band split filter and digital decoder functions. The filter section uses switch capacitor techniques for high and low group filters; the decoder uses digital counting techniques to detect and decode all 16 DTMF tone pairs into a 4 bit code. External component count is minimized by on chip provision of a differential input amplifier clock oscillator and latched three state bus interfaces.

2.1.1.2.1 Functional Description of MT8870

Filter Section: Separation of the low group and high group tones is achieved by applying the DTMF signal to the input of the two sixth order switched capacitor band pass filter, the band width of which correspond to the low and high group frequencies.

Each filter output is followed by a single order switched capacitor filter section which smoothens the signal prior to limiting; limiting is performed by high gain comparators which are provided with hysteresis to prevent detection of unwanted low level signals. The output of the comparators provides full rail logic swing at the frequency of the incoming DTMF signals.

Decoder Section: Following the filter section is a decoder employing digital counting techniques to determine the frequencies of the incoming tones and to verify that they correspond to standard DTMF Frequencies. A complex averaging algorithm protects against tone simulation by extraneous signals such as voice while providing tolerance to small frequency deviations and variations. This averaging variation algorithm has been developed to ensure an optimum combination of immunity to talk off and tolerance to the presence of interfering frequencies (third tone) and noise. When the detector recognizes the presence of two valid tones (this is referred to as the signal condition, in some industry specifications) the early steering ($\mathbf{E_{St}}$) output will go to an active state. Any subsequent loss of signal condition will course $\mathbf{E_{ST}}$ to assume an inactive state.

Steering Circuit: Before registration of a decoded tone pair, the receiver checks for a valid signal duration (referred to as character recognition condition) this check is performed by an external Resistance Capacitance (RC) time constant $\mathbf{E_{ST}}$. Logic high on $\mathbf{E_{ST}}$ causes collector voltage ($\mathbf{v_c}$) to rise as the capacitor discharges. The time required to detect the presence of two valid tones top is function of the decode algorithm, the tone frequency and the previous state of the decode logic. $\mathbf{E_{ST}}$ indicates and initiates an RC timing circuit. If both tones are present for the minimum guide time ($\mathbf{t_{CTP}}$) which is determine by the external RC network, the DTMF signal is decoded and the resulting data is latched in the output register. The delay steering ($\mathbf{S_{tD}}$) output is raised and indicates that new data is available. The time required to receive a valid DTMF signal ($\mathbf{T_{rec}}$) is equal to the sum of time to detect the presence of valid DTMF signals ($\mathbf{t_{DP}}$) and guard time, tone present.
($\mathbf{t_{GTP}}$).

F-low(Hz)	F-high(Hz)	Key	TOE	Q4	Q3	Q2	Q1
697	1209	1	1	0	0	0	1
697	1336	2	1	0	0	1	0
697	1447	3	1	0	0	1	1
770	1209	4	1	0	1	0	0
770	1336	5	1	0	1	0	1
770	1477	6	1	0	1	1	0
852	1209	7	1	0	1	1	1
852	1336	8	1	1	0	0	0
852	1477	9	X	1	0	0	1
941	1209	0	X	1	0	1	0

Table 1: **MT8870 Output Truth Table**

2.2 Software Design

The control program is developed in assembly language using the 8051 instruction set. The flowchart for the program is given figure 3.

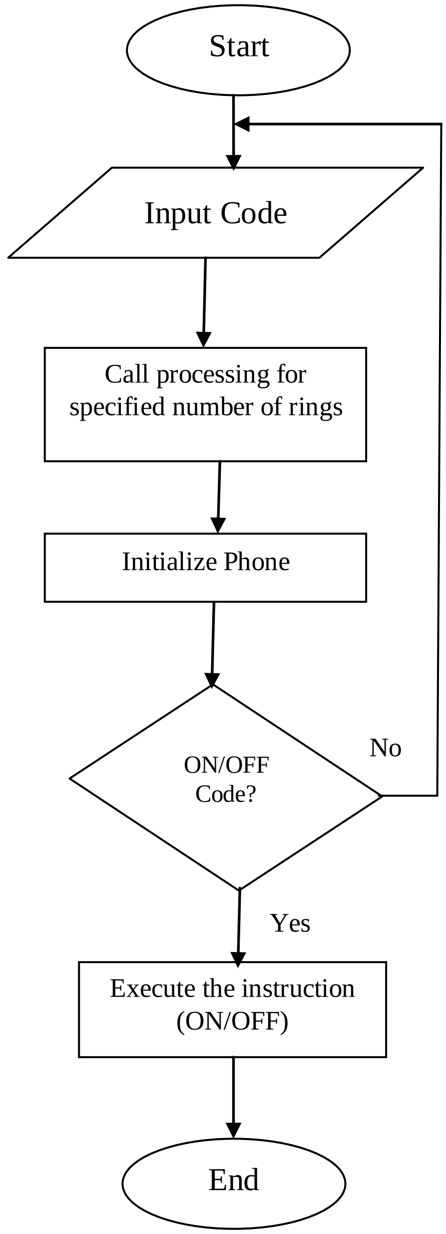

Figure 3: **Control Program Flowchart**

III. DESIGN CALCULATION

3.1 Steering and Guard Time Circuit Operation for Decoder Section

$\mathbf{t_{GTP} < t_{GTA}}$

$t_{GTA} = (R_p C) \ln(\frac{V_{DD}}{V_{TST}})$ -- eqn. 3.1

$\mathbf{R_P = R_1R_2(R_1+R_2)}$ -- eqn. 3.2

Operating at $\mathbf{t_{GTP} > t_{GTA}}$

$t_{GTA} = (R_1 C) \ln(\frac{V_{DD}}{V_{TST}})$ -- eqn. 3.3

Typically, $\mathbf{V_{Tst} = 0.5V_{DD}} = \frac{5V}{2} = 2.5V$ --- eqn. 3.4

$t_{GTA}= \left(390\times 10^{3}\times 100\times 10^{-9}\right)\ln 2$ -- eqn. 3.5

given $\ln 2 = 0.693,$

$\simeq 390\times 100\times 10^{-6}\times 0.693 = 0.027027 \cong 0.03sec \approx 3mSec$

$t_{GTP}= RC\ \mathrm{In}\left(\frac{V_{DD}}{(V_{DD}-V_{TST})}\right)$ -- eqn. 3.6

$t = \left(100\times 10^{-9}\times 390\times 10^{3}\right)\ \mathrm{In}\left(\frac{5}{2.5}\right) = 0.03sec \approx 3mSec.$ This is typical for DTMF.

The actual value of V_{DD} as measured with digital multi-meter is 4.9V compared to the 5V of the Microcontroller. The drop of 0.1V may be as a result of the drop across load resistances.

3.2 Differential Input Configuration of MT8870

The input arrangement of the MT8870 provides a differential input operational amplifier as well as a bias source (V_{ref}) which is used to bias the input at mid rail. Provision is made for connection of a feedback resistor to the op-amp output (GS) for adjustment of gain.

$C_1=C_2= 10nF$

$R_1=R_4=R_5= 100K\Omega$

$R_3 = 56K\Omega$

$R_2= 37K\Omega$

$R_3= 2\left(\frac{R_2R_5}{R_2+R_5}\right) = 2\left(\frac{39\times 100}{39+100}\right) = 28.052K\Omega$

$2R_3=56K$

$\text{Voltage Gain} = \frac{R_5}{R_1} = \frac{100K\Omega}{100K\Omega} = 1$

Therefore the op-amp has unity voltage gain.

3.3 Input Impedance

$z_{indiff} = \sqrt[2]{R_1{}^2 + \left(\frac{1}{\omega c}\right)^2}$ -- eqn. 3.7

$= \sqrt[2]{(100\times 10^{3})^2 + (\frac{1}{2\pi\times 685\times 10\times 10^{-9}})^2} = 100K$

The design of DTMF receiving system can generally be broken down into three functional blocks. The first consideration is the interface to the transmission medium. This consists of few simple components to adequately configure the MT8870 Input stage or may be as complex as some form of demodulation, multiplexing or analogue switching system.

The second functional block is the DTMF receiver itself. This is the receiving system's interface parameter can be optimized for specific signal condition delivered from the front end interface.

The third and most widely varying function is the output control logic. This control is responsible for handling system protocols and adaptively varying the tone receiver's parameter to adjust for changing signal conditions.

From the calculation above, the input voltage gain is unity. With the unity gain the MT8870 will accept maximum signal level of 1dBm into 600Ω. The lowest DTMF frequency that must be detected is approximately 685Hz.

Allowing 0.1dB of attenuation at 685Hz, the required input time constant is derived from:

$M(\omega)dB = 20\log_{10}\frac{R_f}{R} + 20\log_{10}\frac{\omega\tau}{((\omega\tau)^2+1)^{1/2}}$ ------------------------------------ eqn. 3.8

Where **$M(\omega)$ dB** = Amplifier gain in decibel

ω= radian frequency

τ = input time constant

Therefore;

$$-0.1 = 20\log_{10}\frac{(2\pi)685\tau}{((2\pi*685\tau)^2+1)^{\frac{1}{2}}}$$

$$\tau = 1.52ms$$

Choosing **R = 220KΩ** gives a high input impedance (440 less in the pass band) and $C = \frac{\tau}{R} = 6.9nF$. Using a standard value, C is chosen to be 10nF to achieve a unity gain in the pass band. $\mathbf{R_f}$ is chosen to be equal to R that is; $\mathbf{R_f = R}$, $\mathbf{R_a}$ and $\mathbf{R_b}$ are biasing resistors. The choice of $\mathbf{R_a}$ is not critical and could be set at 68K say. Bias resistor $\mathbf{R_a}$ adds a zero to the non-inverting path through the differential amplifier but has no effect on the inverting path. The zero can be exactly cancelled by the added pole due to $\mathbf{R_b}$, if $\mathbf{R_b}$ is chosen as

$$R_b = \frac{R_a R_f}{R_a + R_f}$$

3.4 Interfacing the System to Loads

A valid DTMF is received via connections with the HF–connector of the phone, this signal is being decoded and the output is feed into the port of the microcontroller. Software developed takes over control of loads through the use of electromechanical switch (relays). The relay is connected to the controller through an NPN transistor (BC337) low power transistor acting as a switch and current driver to the relay with diodes across the relay terminals to prevent backward current flow.

$$R_b = \frac{V_{cc} - V_{BE}}{I_\beta}$$ --- eqn. 3.9

$$I_B = \frac{I_C}{\beta}$$

$\beta = 200$ and $I_C = 500mA$ for BC337 NPN Transistor

$$I_B = \frac{500mA}{200} = 2.5mA$$

$$R_B = \frac{500mA \times 0.7}{2.5mA} = 1.72K\Omega$$

Hence a standard 1K resistor was used.

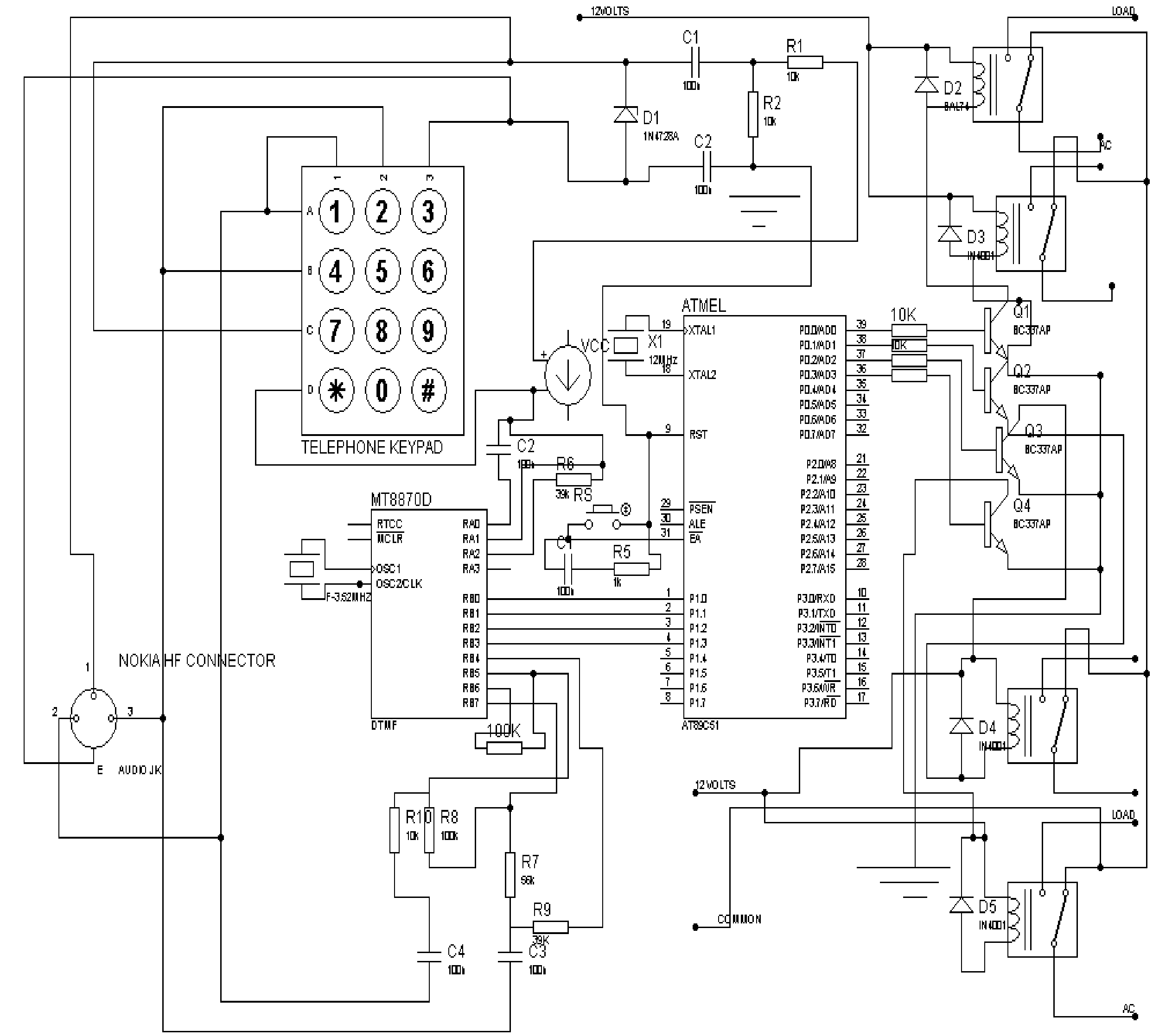

Figure 4: **Complete Circuit Diagram**

4.0 PERFORMANCE EVALUATION AND TESTING

The circuit design was simulated with Protus ISIS Professional to test the output of various stages for desired output which also gave almost the same performance after the construction and connected with different load specifically electric bulbs, fans, and kettle which were effectively controlled.

5.0 CONCLUSION

A robust, simple and low cost automatic control system for electrical appliances using GSM network which is not limited by distance barrier and obstacle has been successfully designed and constructed. Simple components which are cheap and readily available were used in this design. Though the project exhibits a satisfactory performance, there is need to improve on the design so as to obtain a better performance. That is, a more sophisticated system. This can be achieved by the use of high power switching components like thyristors, photo triac and SCRs for industrial heavy load switching that is dangerous for human-being also improvement can be made to achieve the feedback control.

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