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Design and Development of an Automated Home Control System Using Mobile Phone

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Abstract This paper presents design and development of an Automated Home Control System (AHCS) using mobile phone. A cell (mobile) phone acts as a modem for the control of electrical home appliances. This is achieved when the mobile phone number is dialed and an appropriate command button is pressed. The paper demonstrates how to develop a system that aids the control of remote devices using mobile phones to enable devices without infrared though connected to power sources to be controlled and considering the possibility of users to monitor the status and usage of these devices. It makes use of a programmable interface controller (PIC) to control the switching of the output. This design is customized as a central device for four pieces of home appliances using relay to activate each of the respective electronic gadgets.

Keywords: *Automated home control system, mobile phone, modem, programmable interface controller (PIC), relay, Microcontroller, Dual Multi-Tone frequency (DMTF)*

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1. Introduction

Initially communication was done by travelling from kilometre to kilometre to deliver messages but now the trend involves talking to people even when they are far away around the globe even to the extent of seeing them using the present day 3G technologies. Now mobile phones can be used to trigger their greatest revolution: by allowing us to run our homes remotely. If you are heading home early on a sunny day to your house driving through traffic in Lagos, your mobile phone can be used to switch on your central air conditioner at the touch of a keypad or even turn on your water heater system on a cold night preparing yourself for a warm shower. Fitted to a kitchen wall, the unit will communicate with tiny transponders attached to air conditioners, fridges, washing machines, microwave ovens and household appliances. Computer chips and digital networks are now so cheap, we can use them where we want, and kitchens and utility rooms are just perfect for "intelligent" improvements. Japan is already transforming domestic life through its new I-mode mobile phone that can take and transmit pictures. One unexpected use includes the ability to buy Coca-Cola cans without handing over cash. Just pass your phone in front of a scanner on one of several hundred I-mode automated vendors in Japan and your credit card account will be debited in exchange for a chilled can of Coke [4].

Controlling device using switches are common. From a few decades, controlling devices using remote control switches like infrared remote control switch, wireless remote control switch, light activated switches are becoming popular. But these technologies have their own limitations. Laser beams are harmful to mankind. Some technologies like infra-red (IR) remote control are used for short distance applications. In such case, if we have system which does not require any radiations or which is not harmful, and cannot travel for a long distance. Hence the need to design and construct a project circuit that does not require any radiations, any laser beam which has no limitation of range, therefore it can be used from any distance ranging from metres to thousands of kilometres using a simple telephone line or mobile phone. This justifies the need to automate and control the home appliances via the use of mobile phone.

Home automation is a modern technology that gives home owners the ability to take charge and control of the devices placing security and convenience in their homes even when they are not physically at home. Imagine a situation where one is not sure if one turns off an electrical appliance on rushing out of home. One can use an enabled home automation system to confirm the suspicion and turns off the appliance from one's present location [1,4]. The simplified block diagram for the Automated home control system using phone is shown below.

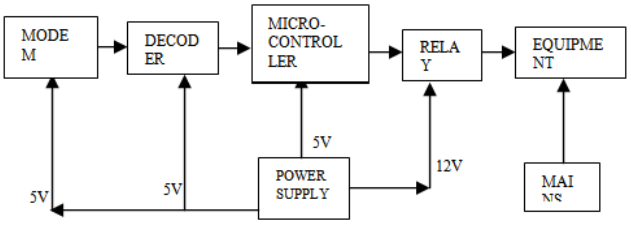

Figure 1. The Simplified Block Diagram of the System

2. Literature Review

By the early 1980s, the industry moved to infrared, or IR, remote technology. The IR remote works by using a low frequency light beam, so low that the human eye cannot see it, but which can be detected by a receiver in the TV. Zenith's development of cable-compatible tuning and teletext technologies in the 1980s greatly enhanced the capabilities and uses for infrared television (TV) remotes. Today, remote control is a standard feature on other consumer electronics products, including video cassette recorders (VCRs), cable and satellite boxes, digital video disc players and home audio receivers. And the most sophisticated TV sets have remotes with as many as 50 buttons.

Zenith developed the world's first wireless trackball TV remote control, called Z-Trak. The remote works like a computer mouse - click the ball and a cursor appears on the TV screen. Roll the ball and the cursor activates control menus hidden in different corners of the screen. Then, activate something from those menu bass, treble, contrast, colour temperature, and channel [5,6,8].

According to Sajidullah S. Khan, Anuja Khodustar and Koli, N.A who worked on Home automation appliance (2011) and striking results were obtained in terms of reduction in delay time between the transitions of streams from client to server using Java enabled program.

More so, Kai-Hung Liang, Kuo-Han Kan, and Szu-Chi Tien (2013) who carried out work on the precision positioning with shape-memory-alloy actuators. The result obtained using the inversion of non-linear model with model-reference-adaptive system (MRAS) was robust as regards to external disturbances and the positioning performance [13].

3. Design Procedure / Methodology

In this segment, there will be general overview of the design of some of the circuits, which are used in the realization of this work. These circuits consist of the modem stage, DTMF Decoder stage, PIC Microcontroller stage, switching stage and power supply stage.

3.1. The Modem

The modem receives the signal sent from the user's phone and sends it to the DTMF decoder which decodes the signal. A regular mobile phone will be used as a modern because of its lower cost and availability. The SIM card of the desired network will be inserted in the phone and its number becomes the access number of the device. The phone is configured such that it automatically answers incoming calls; this is to reduce the need for extra circuitry thereby minimizing the power consumption.

Figure 2. Nokia 1200 which is used as a modem

A NOKIA 1200 mobile phone is used as the modem because of its affordability and availability, the audio output of the phone will be connected to the DTMF decoder and its charging port will be connected to a 5v from the power supply which keeps the battery from discharging.

3.2. DTMF Decoder

This system uses Dual Tone Multi Frequency (DTMF) technology of telephone set. Every telephone set has this facility. There are two types of dialing facilities in a telephone system; pulse dialing mode and tone dialing mode. Here this system works on tone dialing mode. The DTMF mode is shortly called as tone dialing mode.

This system is divided into two sections.

1: Remote section

2: Local control section.

When a button is pressed in the telephone set keypad, a connection is made that generates a resultant signal of two tones at the same time. The two tones are taken from a row frequency and a column frequency. Its resultant frequency signal is called a "Dual Tone Multiple Frequency ". These tones are identical and unique.

A DTMF signal is the algebraic sum of two different audio frequencies which are chosen such that they are not the harmonics of each other.

By sending DTMF signals to the telephone exchange through cables or wireless, the server in the telephone exchange identifies these signals and makes the connection to the the intended receiver of the call.

Each of the low and high frequency groups comprise four frequencies from the various keys present on the telephone keypad; two different frequencies, one from the high frequency group and another from the low frequency group are used to produce a DTMF signal to represent the pressed key.

The frequencies are chosen such that they are not the harmonics of each other. The DMTF decoder circuit diagram is depicted in figure below.

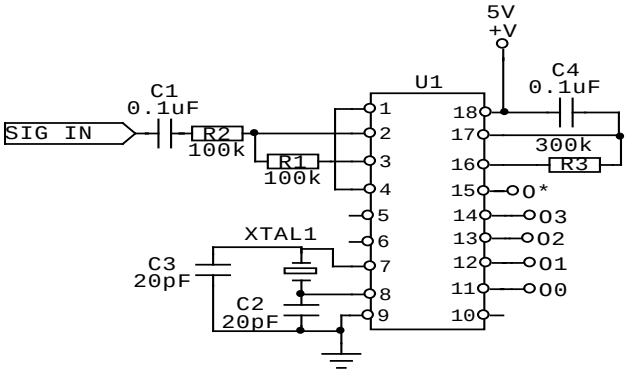

Figure 3. Circuit diagram of DTMF decoder

When the system number is dialed the modem automatically answers and waits for the user to press a button. When a one (1) is pressed, the DTMF tone flows into U1 through C1 which filters it and R1, R2 which divide the signal. XTAL1 is a crystal which generates the operating frequency of the decoder, C2, C3 filter the oscillation. C4 and R3 determine the response time of the tone.. U1 is the DTMF decoder IC which is a HT8870 chip. It operates on a maximum of 5v DC.

3.3. Microcontroller Stage

The microcontroller controls the entire operation of the circuit, its receives the decoded signals from the DTMF decoder then processes it and activates or deactivates the corresponding device by sending a logic to enable or disable the relay connected to the load. A microcontroller is used because of its low power consumption and flexibility of its functions [6].

In this design a PIC16F84A is used because it consumes lower power compared to other available microcontrollers. Its program memory contains a 1Kilobyte word which translates to 1024 instructions. Since each 14-bit program memory word is the same width as each device instruction. The data memory (RAM) contains 68 bytes. Data electronically erasable programmable read only memory (EEPROM) is 64 bytes. There are also 13 input/ output (I/O) pins that are user-configured on a pin-to-pin basis. Some pins are multiplexed with other device functions.

The microcontroller receives the signal from the Decoder in form of binary numbers then activates the corresponding device by sending a high logic to the transistor that controls the relay or if a deactivating data is received from the decoder, it sends a low logic to the transistor of the corresponding relay. Crystal XTAL2 generates the frequency needed for the operation of the microcontroller; it is a 4 MHz crystal. The microcontroller operates on a 5vdirect current (DC) supply. The data from the decoder is connected to PORTA while the transistors are connected to PORTB of the microcontroller.

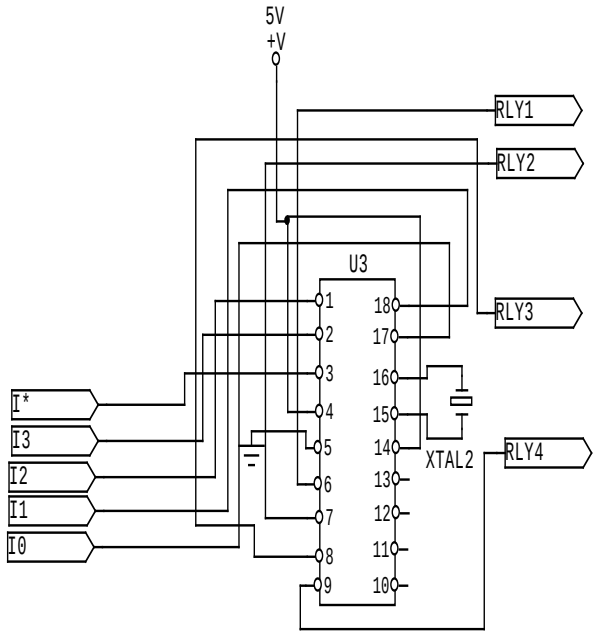

Figure 4. Circuit diagram of microcontroller section

3.4. Switching Transistor Stage

This is a simple electromechanical switch made up of an electromagnet and a set of contacts. The electromagnet is used to operate a switching mechanism, but other operating principles are also used. Relays find applications where it is necessary to control a circuit by a low-power signal, or where several circuits must be controlled by one signal.

The switching transistor switches the relay which powers the Load. The transistor as a switch operates in class A mode. The relay is switched on when the microcontroller (PIC16F84) gives a HIGH output. A base resistor is required to ensure perfect switching of the transistor in saturation. The diode connected across the relay is to protect the transistor from back electromotive force (EMF) that might be generated since the relay coil present is an inductive load [9].

In this paper, Rc is the collector resistance that serves as the resistance of the relay coil, which is 400Ω for the relay type adopted in this paper.

Hence, Parameters used in this paper are as follows:

Rc is Relay coil resistance.

V_+ *is Regulated voltage from the power supply stage.*

V_{BE} *is Silicon.*

V_{CE} *is when transistor is switched off.*

V_{IN} *is from multivibrator.*

H_{FE} *is from data sheet for C9103.*

$$R_C = 400$$

$$V_+ = 12V$$

$$V_{BE} = 0.6V$$

$$V_{CE} = 0V$$

$$V_{IN} = 5V$$

$$H_{FE} = 300$$

$$V^+ = 12V$$

$$V^+ = I_C R_C + V_{CE} \quad (1)$$

$$V_{CE} = 0V \quad (2)$$

$$V^+ = I_C R_C$$

$$12 = 400 I_C$$

$$I_C = \frac{12}{400}$$

$$I_C = 3A$$

$$V_{IN} = I_B R_B + V_{BE} \quad (3)$$

$$4 - 0.6\text{V} = \text{I}_\text{B}\text{R}_\text{B} \quad (4)$$

$$\text{Hfe} = \frac{I_C}{I_B} \quad (5)$$

$$300 = \frac{3}{I_B}$$

$$I_B = \frac{3}{300}$$

$$I_B = 0.01A$$

$$3.4 = I_B R_B \quad (6)$$

$$R_B = \frac{3.4}{0.01}$$

$$R_B = 340\Omega \quad (7)$$

The output of the PIC16F84 triggers the transistor switching stage, which switches ON and OFF the load circuit. The switching circuit is used since the microcontroller (PIC16F84) output may not give enough current to drive the relay directly [6]. The figure below shows the schematic transistor switching based circuit of the system.

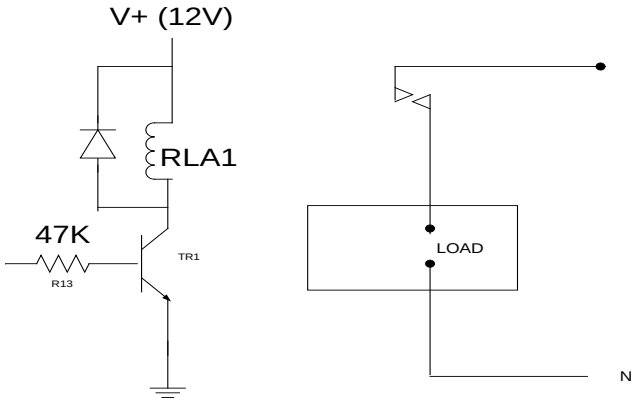

Figure 5. Schematic diagram of a transistor switching with relay

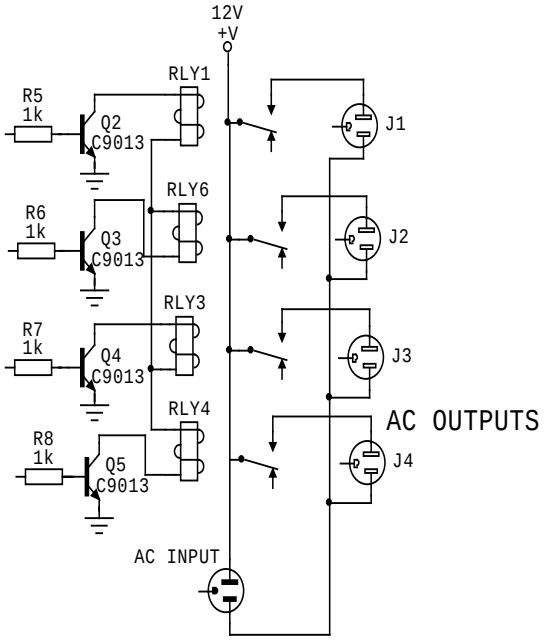

Figure 6. Circuit Diagram of the Switching Stage

3.5. Power Supply Stage

The relay uses 12V while the other sources use 5V DC. The power supply stage is a linear power supply type and involves a step down transformer, filtering capacitor, and a voltage regulator to give the various voltage levels. The circuit diagram is shown in figure 7 below.

The 220v supply mains is stepped down to 12v AC by transformer T1 then converted to DC by D1, the voltage is filtered by C5 and regulated to 5v by U2.

$$Output\ current\ I_O = 0.5A\ with\ load$$

$$Output\ voltage\ V_O = 12V$$

$$Input\ current\ I_I = ?$$

$$Input\ voltage\ V_I = 220V$$

$$Power = VI \quad (8)$$

$$I_I = V_O I_O \quad (9)$$

$$I_I = \frac{12 \times 0.5}{220} = 0.027A$$

$$Power = 1.2VAPeak\ voltage V_P = V_O \times \sqrt{2} = 12 \times \sqrt{2} = 16.97V \quad (10)$$

$$Ripple\ voltage V_R = V_P - V_O = 16.97 - 12 = 4.97V \quad (11)$$

$$C = Capacitance\ of\ filter\ see\ diagram)$$

$$C = \frac{I_O}{(2 \times F \times V_R)} \quad (12)$$

$$f = 50Hz, I_O = 0.1A, V_R = 4.97V\ from\ above$$

$$C = \frac{0.5}{(2 \times 50 \times 4.97)} = 0.001f = 1000\mu f \quad (13)$$

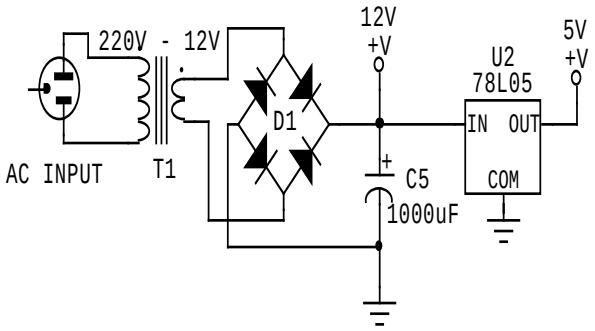

Figure 7. Power soupply stage

3.6. Principle of Operation

When the circuit is connected to the mains, 220V alternating current flows into the transformer T1 which steps it down from 220v to 12v. It is converted to direct current (DC) by a Bridge rectifying diode and filtered by C5. The voltage regulator regulates the voltage to 5v which is used to power the DTMF decoder and the microcontroller.

When the subscriber identification module (SIM) number of the mobile phone in the circuit is dialled by another phone, it automatically answers, if 1 is pressed by the caller, a DTMF tone is sent from the caller phone to the phone connected to the circuit. When a one (1) is pressed, the signal flows to the DTMF decoder through capacitor which filters it, and resistors R2, R1 act as voltage divider. The signal is decoded and a digital output is sent to the microcontroller which activates the first output by sending a high logic to the transistor connected to pin 6 of the microcontroller through the 1kΩ resistor, therefore activating the transistor. The transistor then activates the Relay RLY1 and its normally open contacts become closed, causing the 220v supply to flow to the load.

If a zero (0) is pressed, it is decoded by HT8870, then the microcontroller which sends a low logic to Q2 and deactivates the transistor therefore the relay becomes deactivated. Its normally open contacts become open

causing the voltage not to flow to the load. This switches off the load.

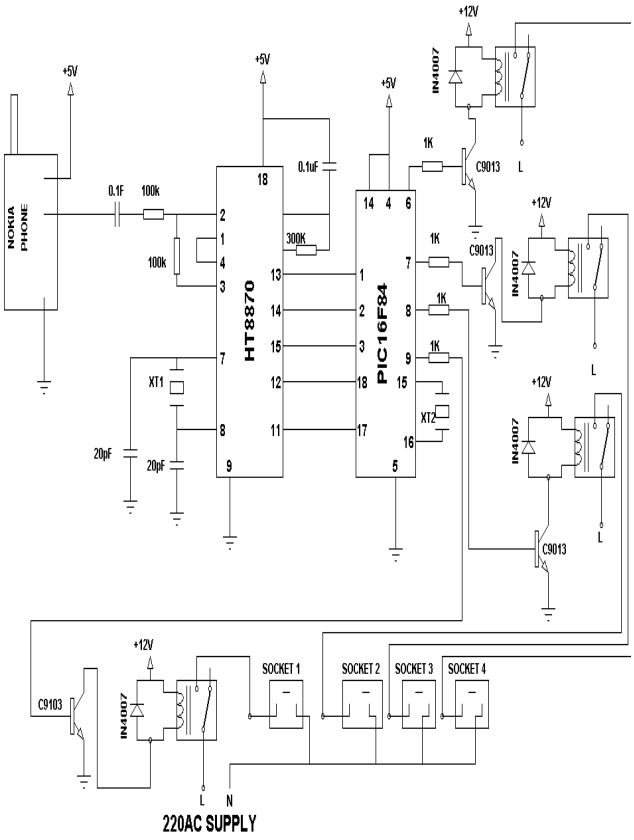

Figure 8. Comprehensive circuit diagram of the system

3.7. Operation of Automatic Home Control System (AHCS)

The AHCS has a SIM card installed in its modem, when a user dials the number of the modem, the system automatically answers the call then waits for the user to press the command button; if zero is pressed the first equipment goes off but if one is pressed it automatically powers on. If two (2) is pressed, the second equipment powers on but if three (3) is pressed it goes off. However, if four(4) is pressed, the third equipment powers on and if five(5) is pressed, it goes off. Six and Seven switch on and off the equipment respectively. If eight is pressed, all the pieces of equipment power on and if nine is pressed, all will be powered off.

The system is designed for four pieces of equipment but more equipment can be used by adding more relays and changing the coding sequence of the equipment control. A password can also be added to secure the system from intruders.

The underlying principle mainly relies on the ability of DTMF (Dual Tone Multi Frequency) integrated circuits (ICs) to generate DTMF corresponding to a number or code in the number pad and to detect the same number or code from its corresponding DTMF. In detail, a DTMF generator generates two frequencies corresponding to a number or code in the number pad which will be transmitted through the communication networks, constituting the transmitter section which is simply equivalent to a mobile set. In the receiver part, the DTMF detector IC, for example IC MT 8870 detects the number or code sent by the transmitter or mobile phone then through the inspection of the two transmitted frequencies. It detects which button is pressed and sends a digital equivalent to the DTMF.

3.8. The Software

The program of the AHCS controls the entire operation of the circuit. It is written in assembly language and compiled using MPLAB. The compiled program is transferred into the microcontroller with a programmer called PICSTART PROGRAMMER. The function of the device can easily be modified by adjusting the program in the microcontroller.

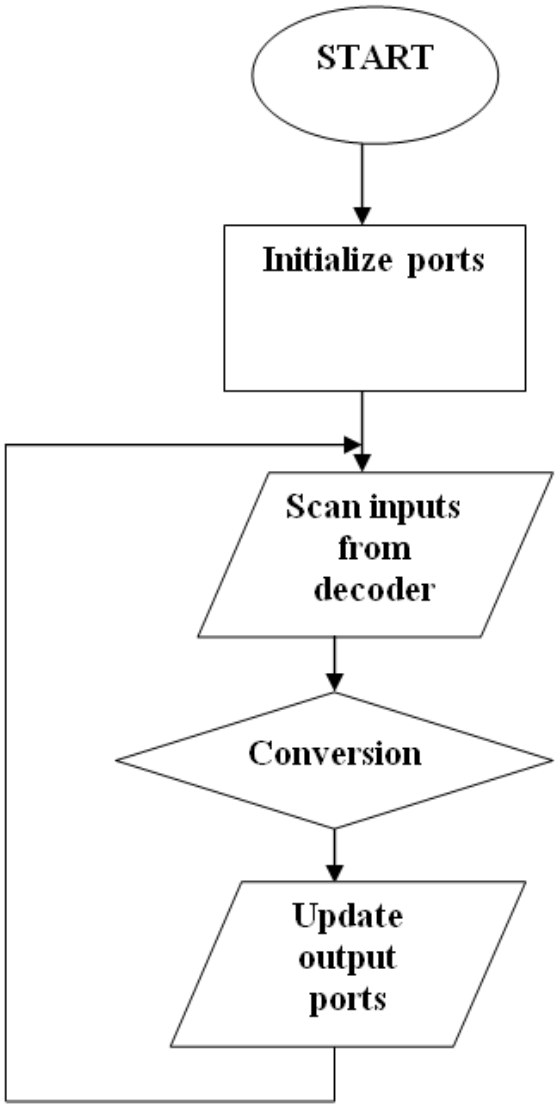

Figure 9. Flow chart of program

3.9. Construction

The circuit was first implemented on a breadboard and was certified working before it was soldered on a Vero board. The power supply was first soldered before other stages. The stages were soldered sequentially and at each stage, they were tested to ascertain its operability. The decoder, HT8870 and microcontroller PIC16F84 were not soldered directly on the Vero board, an IC socket of 14 pin and 16 pin were first soldered and the Decoder IC and Microcontroller IC were now inserted into the IC socket.

4. Testing and Expected Result

The various tests were carried out on different modules and striking results were obtained for each circuit diagram that makes the whole system.

Special features of the system allow end-users to use a mobile phone to carry out control activities isolatedly by pressing some certain buttons depending on the task to be carried out.

5. Conclusion

The various methods of designing automated home appliances were adopted in this paper. However, various components were designed and tested separately and collectively to ensure it does meet the specification of the end-users by avoiding the incident of fire outbreak as a result of failure to switch off the electronic gadgets which may get burnt when there is slight power surge. This makes the control of all home appliances to be easy to deal with as against the manual way.

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