DESIGN AND IMPLEMENTATION OF FPGA BASED MOBILE PHONE CONTROLLER[+]

تصميم وتنفيذ الهاتف المتنقل كمسيطر بأستخدام مصفوفة البوابات القابلة للبرمجة موقعيا

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Abstract:

The work presented in this paper concerned with the design of a new remote control system, which can be used for controlling the on/off of home/office devices using mobile phone. The design consist of two main parts, the first part is a remote mobile phone used to select the home/office mobile and choose the selected tone code (0-9, *, #) from the user according to the selected device. The second part consist of a practical design which contains the fixed mobile phone connected with Dual Tone Multiple Frequency (DTMF) detector, delay and answer circuit and decoder to complete the function of responding the calling and analyze the tone code for control the selected device depending on tone analyzer of DTMF. The practical design which consists of DTMF, decoder and flip flops was implemented using Field Programming Gate Array (FPGA). The system has been worked in high speed action when implemented in Spartan FPGA package and good results have been recorded.
Keywords: **mobile phone, DTMF, Delay and answer circuit and FPGA.**

المستخلص:

العمل المقدم في هذا البحث يهتم بتصميم نظام حديث للسيطرة والتحكم عن بعد، ويستخدم للسيطرة على اجهزة الاشتغال والاطفاء للبيت او المكتب بأستخدام الهاتف الجوال. التصميم يتألف من جزئيين رئيسين: الاول يشمل هاتف جوال بعيد يستخدم لأختيار جهاز البيت\ المكتب واختيار رمز النغمة (٠-٩، *، #) من المستخدم طبقا للجهاز المختار. الجزء الثاني يشمل الجزء العملي ويحتوي على هاتف جوال ثابت مرتبط بكاشف تردد النغمة الثنائية المتعدد) ، دائرة التأخير والجواب وجهاز فك الرموز لأكمال وضيفة الاستجابة للأتصال وتحليل رمز النغمة الثنائية DTMF(المتعدد. التصميم العملي الذي يشمل كاشف تردد النغمة، جهاز فك الشفرة تم تنفيذه بأستخدام مصفوفة البوابة). عند تشغيل النظام تم الحصول على السرعة العالية بأستخدام مصفوفة البوابة المبرمجة وتم (Spartanالمبرمجة تسجيل النتائج الجيدة.

Introduction:

Mobile devices, such as mobile phones, are becoming multipurpose devices. These devices are capable of storing data as well as running custom application. As more people adopt these devices and begin to use them for personal or business tasks, the need for controlling access to the data stored within the devices will become vital especially in smart home [1].

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Smart home is a home equipped with special facilities to enable occupants to control or program an array of automated home electronic devices. For example, a homeowner on vacation can arm a home security system, control temperature gauges, switch appliances on or off, control lighting, program a home theater or entertainment system, and perform many other tasks. Smart home became smarter if the controlling can be done from any remote place. Our main focus is to control the home appliances from remote place [2].

The motivations behind the goal to remote control of home appliances are simple. It's not always feasible to be physically near to the home still sometimes it's very important to control the appliances for many purposes. So the remote controlling takes the control of the home beyond the home and to the hands of the people. If a simple mobile phone takes the added responsibility to control the smart home then the control is reachable from almost everywhere people travels and lives on earth [3].

Design a wireless control system using mobile phone has been an important research topic for a long time, in order to implement large-scale remote monitoring, networking techniques. When comparing with the previous researchers, many researches were introduced for design a system for controlling the home appliances, using PC and microcontroller.

[F. Aula] Present a system of the Personal Computer (PC) remote controlling with the mobile telephone through accessing the main PC parts; serial and parallel. The system implemented by using SMS (Short Message Service) as associated with all modern mobile phone devices and mobile telecommunication networks [4]. [R. Shariyar, et al and C. K. Das, et al] demonstrates a prototype which enables users to control their home appliances and systems from remote using a cell phone-based interface. This method was implemented by using microcontroller which is connected with the home mobile to make control the home appliances [5, 6].

This paper has been implemented by connecting the remote mobile phone with home mobile directly without using personal computer (PC) but connecting with delay and answer circuit, DTMF, decoder to complete the function of controlling system and using FPGA to implement this work with high speed action.

Dual Tone Multiple Frequency (DTMF):

*A much more efficient means of providing the dialing function of the telephone set is through the use of the dual tone multi frequency (DTMF). DTMF is also known as Touch Tone. Most central office is equipped to handle both Touch Tone and dial pulses. The arrangement of the keypad is shown in fig (1). There are 12 keys corresponding to the number between 0 to 9 and the characters * and #. Some keypads include four additional keys, A through D, for special control functions [7].*

*Each number (as well as the # and *) is represented by a pair of tones. For instance, the number "1" is represented by the frequencies 1209 Hz and 697 Hz.*

		Upper Band			
		1209 Hz	1336 Hz	1477 Hz	1633 Hz
Lower Band	697 Hz	1	2	3	A
	770 Hz	4	5	6	B
	852 Hz	7	8	9	C
	941 Hz	*	0	#	D

Fig. (1): Frequency/Key Matrix for DTMF Key Pads.

For example, in order to generate the DTMF tone for "1", you mix a pure 697 Hz signal with a pure 1209 Hz signal, as shown in fig (2):

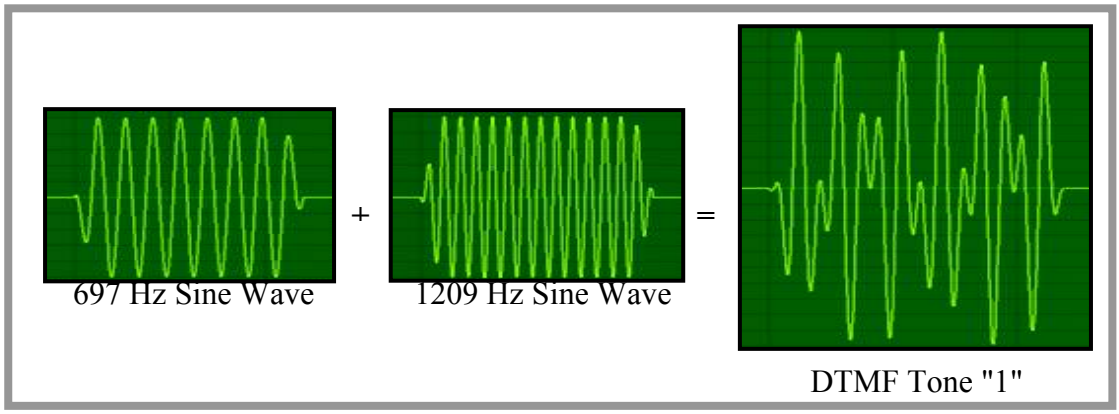

Fig. (2): Two Pure Sine Waves combine for form the DTMF Tone for "1".

These tones are used for the remote control of answering machines, also used for dialing in traditional analog telephone system.

These tones cannot be sent directly over the voice codec of a GSM MS (Group Special Mobile Mobile Station), as the codec would distort the tones. They are transferred as signals and then converted into tones in the fixed network part of the GSM system [8].

The standard defines the DTMF tones for 16 keys, but telephones only use 12 of these 16 keys. The remaining 4 tones are sometimes used within the telephone networks, but unless you are a telecommunication geek working for a telephone company or the military, you will probably never get to hear one of these tones.

Operational amplifier:

An operational amplifier is designed so that it performs some mathematical operations when external components, such as resistors and capacitors are connected to it terminals [9].

RC Circuit:

As shown in fig. (3), circuit containing both resistors and capacitors have many important applications. RC circuits are commonly used to control timing. When windshield wipers are set to operate intermittently, the charging of the capacitor to a certain voltage is the trigger that turns them on. The time delay between wipes is determined by the resistance and the capacitors in the circuit; adjusting a variable resistor changes the length of the time delay [10].

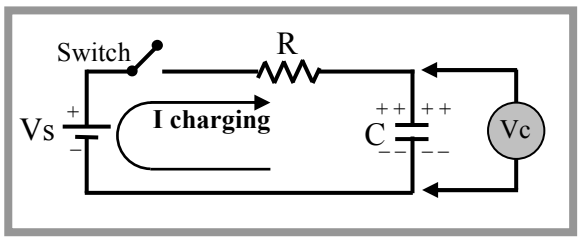

Fig. (3): shown RC circuit.

Time Constant:

As shown in fig. (4) When t=RC the instantaneous capacitor voltage level is always 63.3% of Vs. After a time period of (5 RC), the capacitor voltage is 99.3% of its maximum level [10].

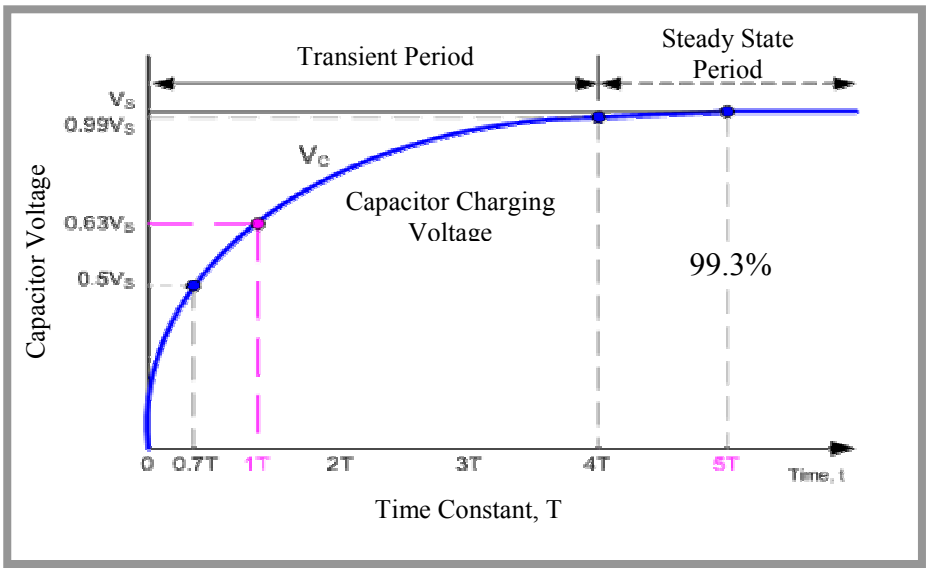

Fig. (4): Shown charging curve.

Particular Parts of the Proposal Design:

1- Main idea:

The idea of this work is control of home/office devices remotely. When the home owner call from any mobile to the mobile present in the home which is part of the electronic circuit control the selected as shown in fig. (5).

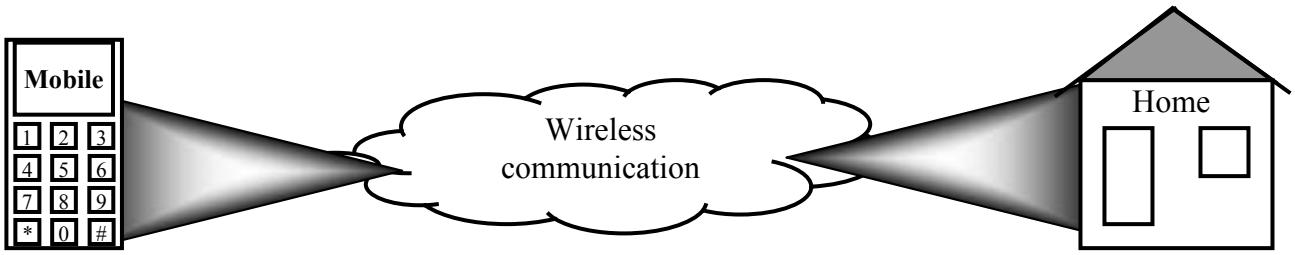

Fig. (5): The general block diagram of wireless control system.

Fig. (6) Illustrate the block diagram of the control circuit that used in home or office, which are consisting from the following part:

a) Delay and answer circuit
b) Tone analyzer
c) Decoder and flip-flops circuit
} Implemented by FPGA
d) Devices switching and switching off circuit.

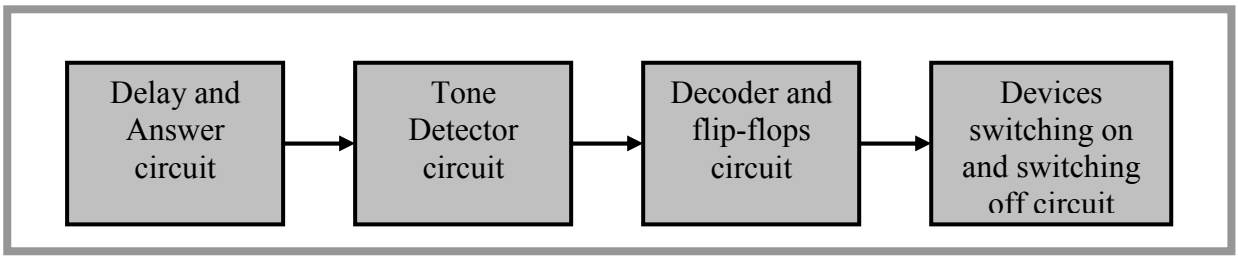

Fig. (6): The Control Circuit at home or office.

2- Delay and answer circuit:

When the home owner call the home, the following circuit delay the opening of calling between these two mobiles for 3 seconds to enable the caller from hearing the tone and knowing that the call is done, then this circuit after that open the connection between the two mobiles by generation a signal for 0.3 second which is needed for pressing on the open key as shown in the fig. (7)**.**

V_{fib}=signal from mobile motor

V_{cc}=6v, V_{ref1}=5v, V_{ref2}=2v

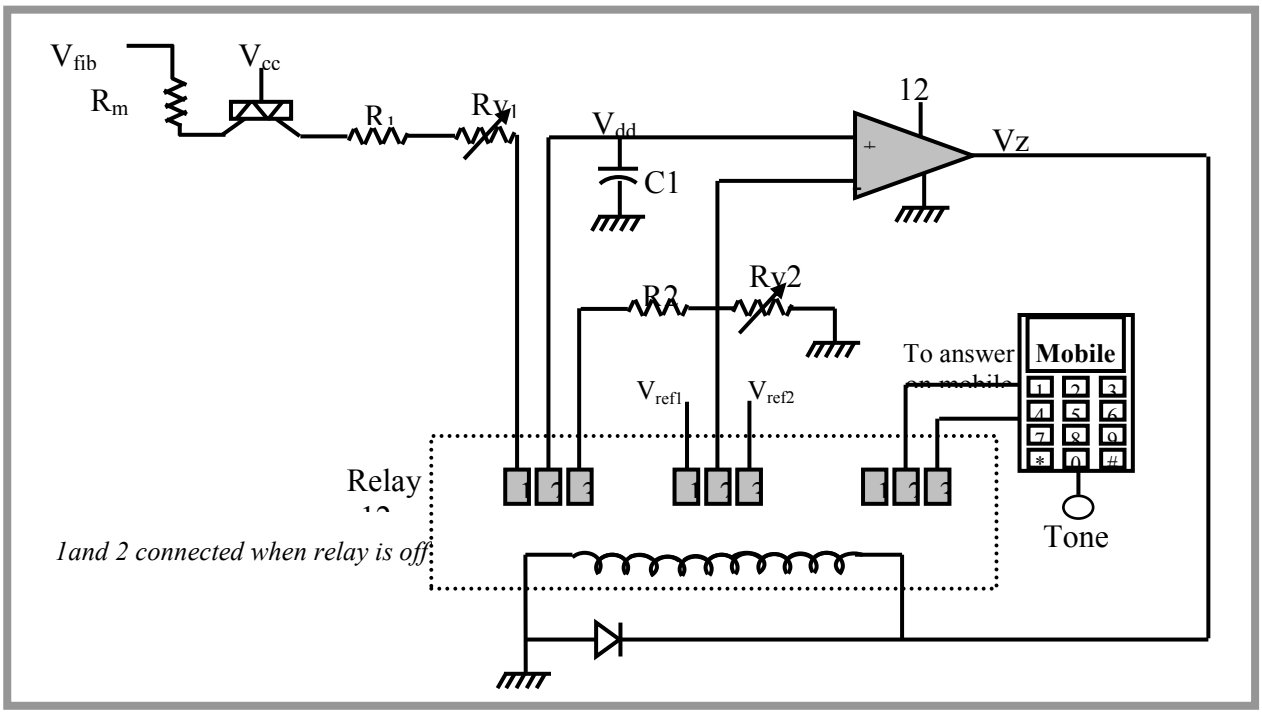

Fig. (7): The delay and answer circuit.

$T_1 = (R_1+R_{v1})*C_1$ …… *(1)*

Where: $T_1=5t$. *t= must be 3 second.*

Assume that $C_1=100\ \mu f$, *therefore* $(R_1+R_{v1}) = 150k\Omega$.

We used $R_1=100k\Omega$ & $R_{v2}=100k\Omega$ *to make facility to change in the charging time* (T_1).

$T_2 = (R_2+R_{v2})*C_1$ …… *(2)*

Where: $T_2=5t$. *t= must be 0.3 second.*

$C_1=100\ \mu f$, *therefore* $(R_2+R_{v2}) = 15k\Omega$.

We used $R_1=10k\Omega$ & $R_{v2}=10k\Omega$ *to make facility to change in the discharging time* (T_2).

Tone detector circuit (DTMF detector):

This circuit receive the sounds from caller mobile and according to the received tone (0-9,*, #) will generate four output bits as shown in fig. (8). actually this integrates in fig.8 replaced in our circuit by FPGA (Xilinx's SPARTAN) in order to optimize operation and increase the system speed action; the data output for tone detector circuit are described in table (1).

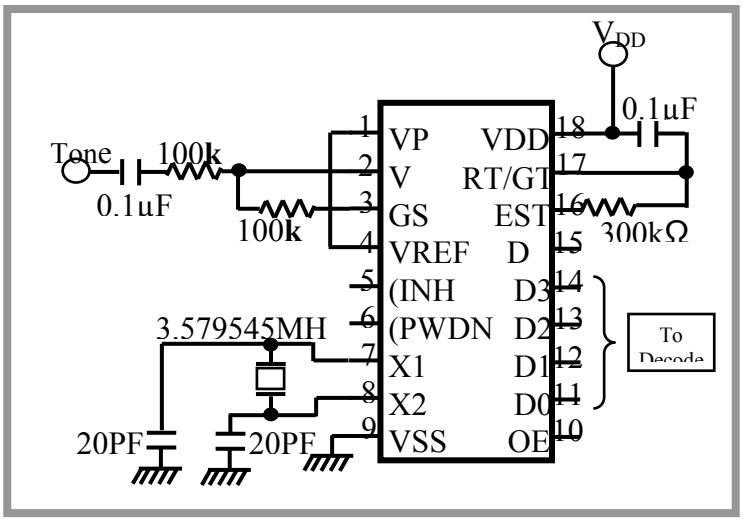

Fig. (8): Tone detector Circuit.

Table (1): The data output for tone detector circuit.

Lower Band (Hz)	Upper Band (Hz)	Digit	OE	D3	D2	D1	D0	Comment
697	1209	1	H	L	L	L	H	Used
697	1336	2	H	L	L	H	L	Used
697	1477	3	H	L	L	H	H	Used
770	1209	4	H	L	H	L	L	Used
770	1336	5	H	L	H	L	H	Used
770	1477	6	H	L	H	H	L	Used
852	1209	7	H	L	H	H	H	Used
852	1336	8	H	H	L	L	L	Used
852	1477	9	H	H	L	L	H	Used
941	1209	0	H	H	L	H	L	Used
941	1336	*	H	H	L	H	H	Used
941	1477	#	H	H	H	L	L	Used
697	1633	A	H	H	H	L	H	Unused
770	1633	B	H	H	H	H	L	Unused
852	1633	C	H	H	H	H	H	Unused
941	1633	D	H	L	L	L	L	Unused
-----	-----	ANY	L	Z	Z	Z	Z	

H: High (Logic one)
L: Low (Logic zero)
The data outputs (D0~D3) are quadruple state outputs. When OE input becomes low, the data outputs (D0~D3) are high impedance.
The overall system of the control system was illustrated in fig. (9).

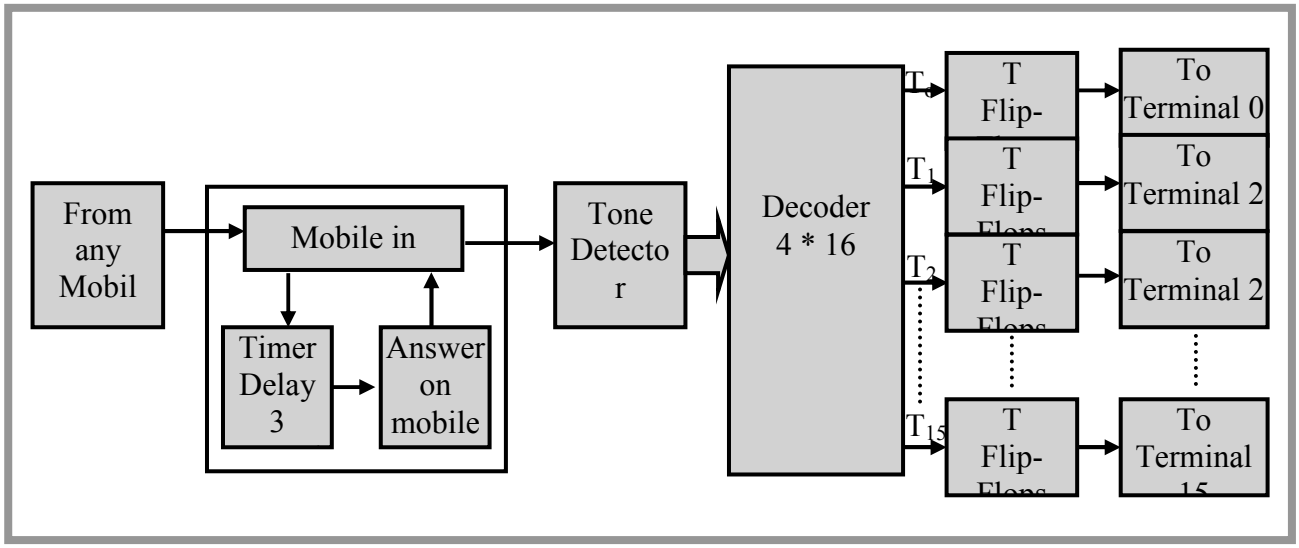

Fig. (9): Block diagram of wireless control system.

Circuit structure in FPGA:

Xilinx launched the industry's first FPGA (Field Programmable Gates Array) that could implement few thousands of gates. Today, an FPGA (Xilinx's **SPARTAN**) is capable of implementing one million gates. The reasons for such a quantum leap are simple.

- Technological improvements.
- Quick prototyping demands for complex digital systems targeting Application Specific Integrated Circuits (ASICs).
- Suitable for low volume, high – density and quick turnaround of complex digital systems.
- In-system reprograms ability.

The FPGA package works in this system of wireless control system as the part specialist for (tone detector and transform to digital output data) which gives instruction to operate the home equipments. After implement and build this part in **(software and hardware)** by using FPGA technology **Xilinx's SPARTAN** model as shown in fig. (10), we got high speed frequency its more than the speed frequency if we use another item different from FPGA package.

We get our result by using FPGA that profit very high speed about **1.613 MHZ** as explain in FPGA simulation waveform, FPGA package circuit consist from the following components:-

1. A/D convertor 2.shift register 3.control 4.Decoder 5.Cascaded of T-flip flop 6.sixteen output terminals.

The above items can be descripting down as the following:

1- A/D Convertor:

The A/D convertor (Analog to digital convertor) is the first item in FPGA package in this system, the function of this item use to convert the analog input signal to its equivalent input digital signal. This analog input signal loaded to FPGA package from the tone mobile phone. The input analog signal represent the signal have the same frequency of The number pressed from the mobile key at home the output of IC A/D convertor is the digital signal which is loaded to parallel in /parallel out shift register.

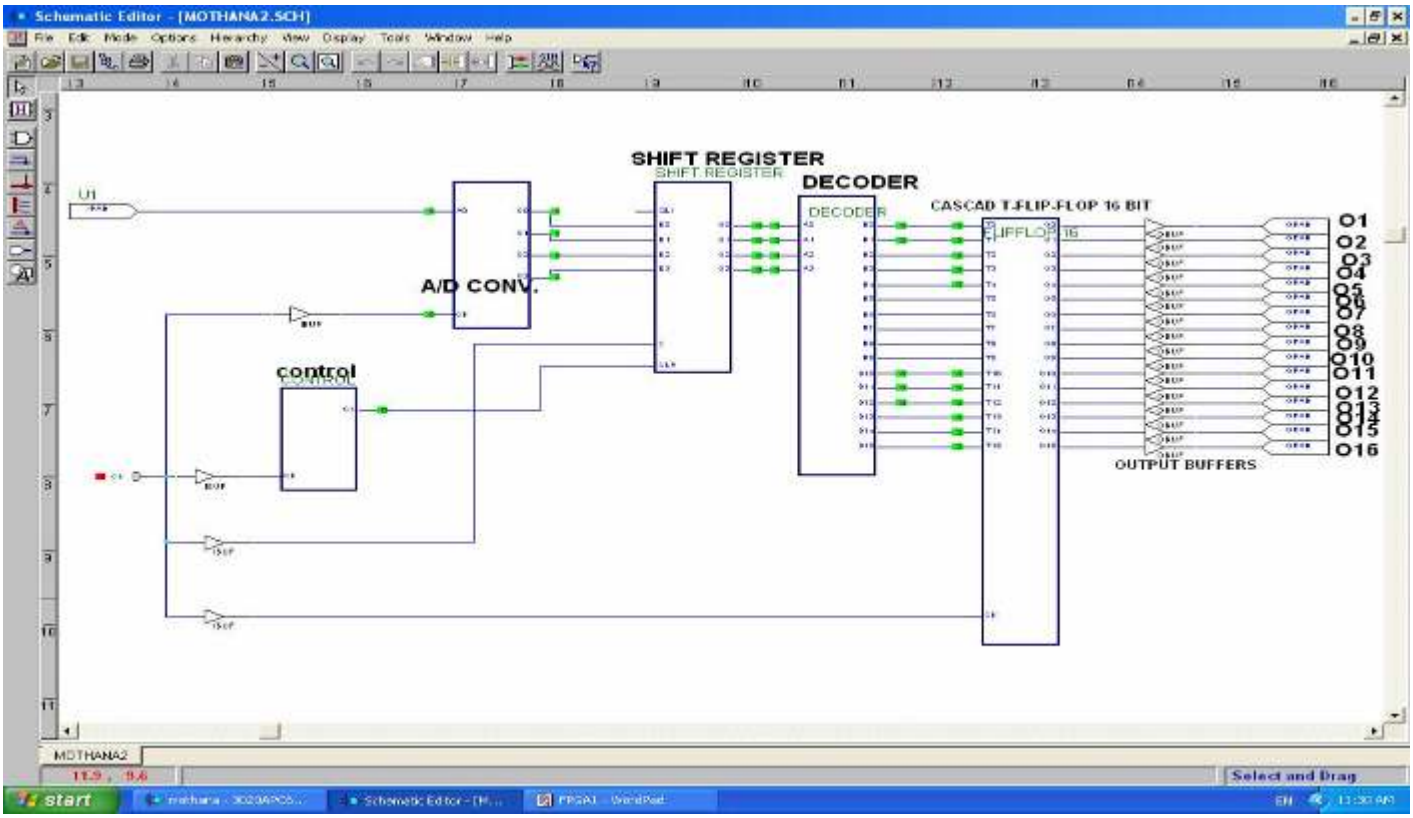

Fig. (10): FPGA XILINX SPARTAN model structural circuit.

2- Control:

This item consist of one in -one out use to control the shift register the fundamental work of this item in order not mix between two tones ,the control IC contains of D-flip flop connected to work as counter calculate 4 digit clock in order to complete one tone cycle after make reset.

3- Shift register:

This item contained from 4in-4out parallel in/parallel out shift register use to make shift between instantaneous tone and another tone in order to not make over lab between them, the item internal design as in fig. (11), the input by each clock 4 bit under control which is loaded from previous circuit A/D convertor. The output of the shift registers loaded to (4x16) Decoder.

4- (4 X 16) Decoder:

This item contained from 4in-16out it use to decode the input data which loaded from output shift register and get the digital digit number which pressed 1st time from mobile key at home. The output of Decoder loaded to cascaded T-flip flop, the internal structure of this item as shown in fig. (12). each output represents devise or equipment want to operate.

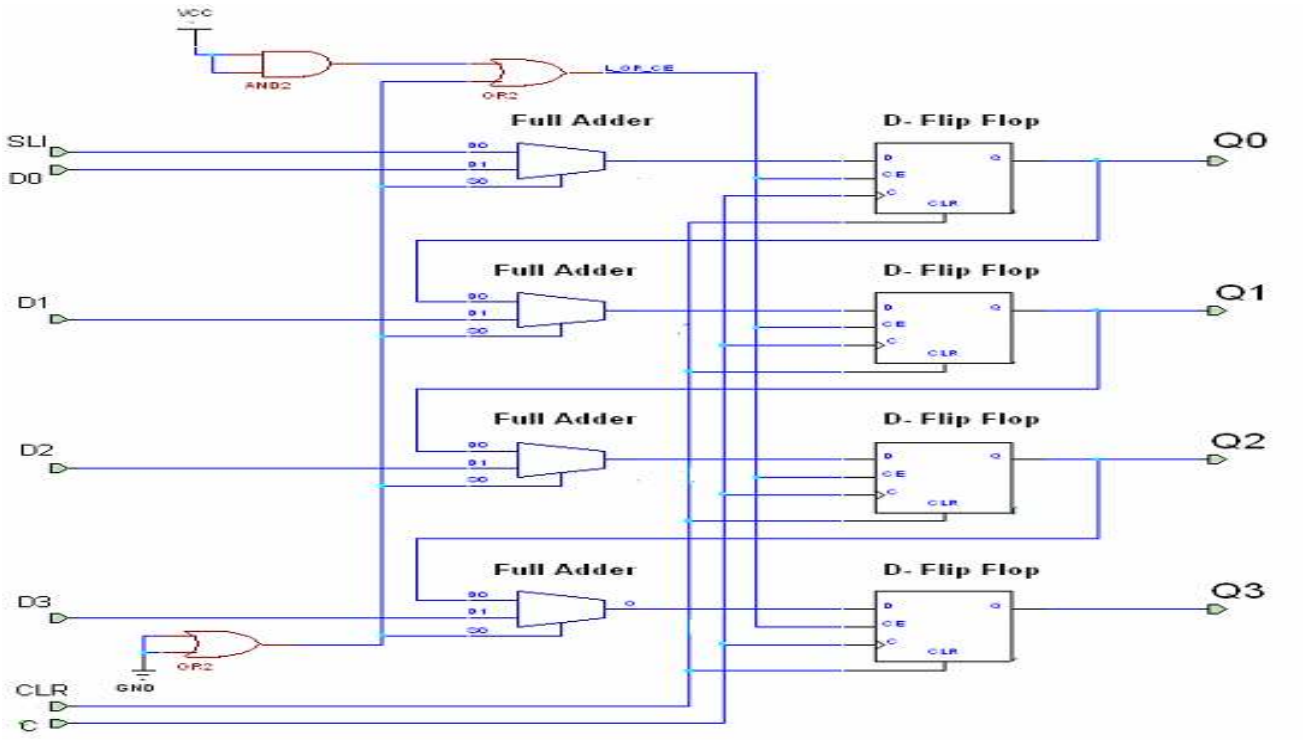

Fig. (11): Shift Register internal design.

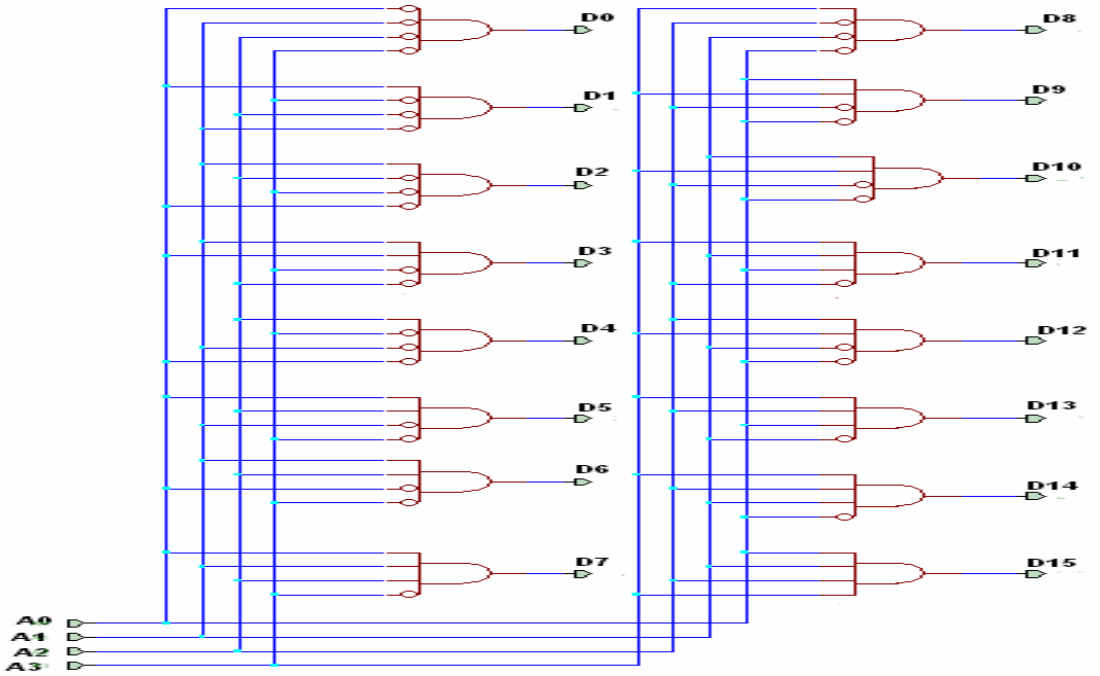

Fig. (12): Decoder internal design.

5- Cascaded T-flip flop 16 bit:

This item contained of 16in-16out ,it consist from 16 T-flip flop components connected in cascade in order to give digit number at output the item structure as shown in fig. (13). each output represents devise or equipment want to operate.

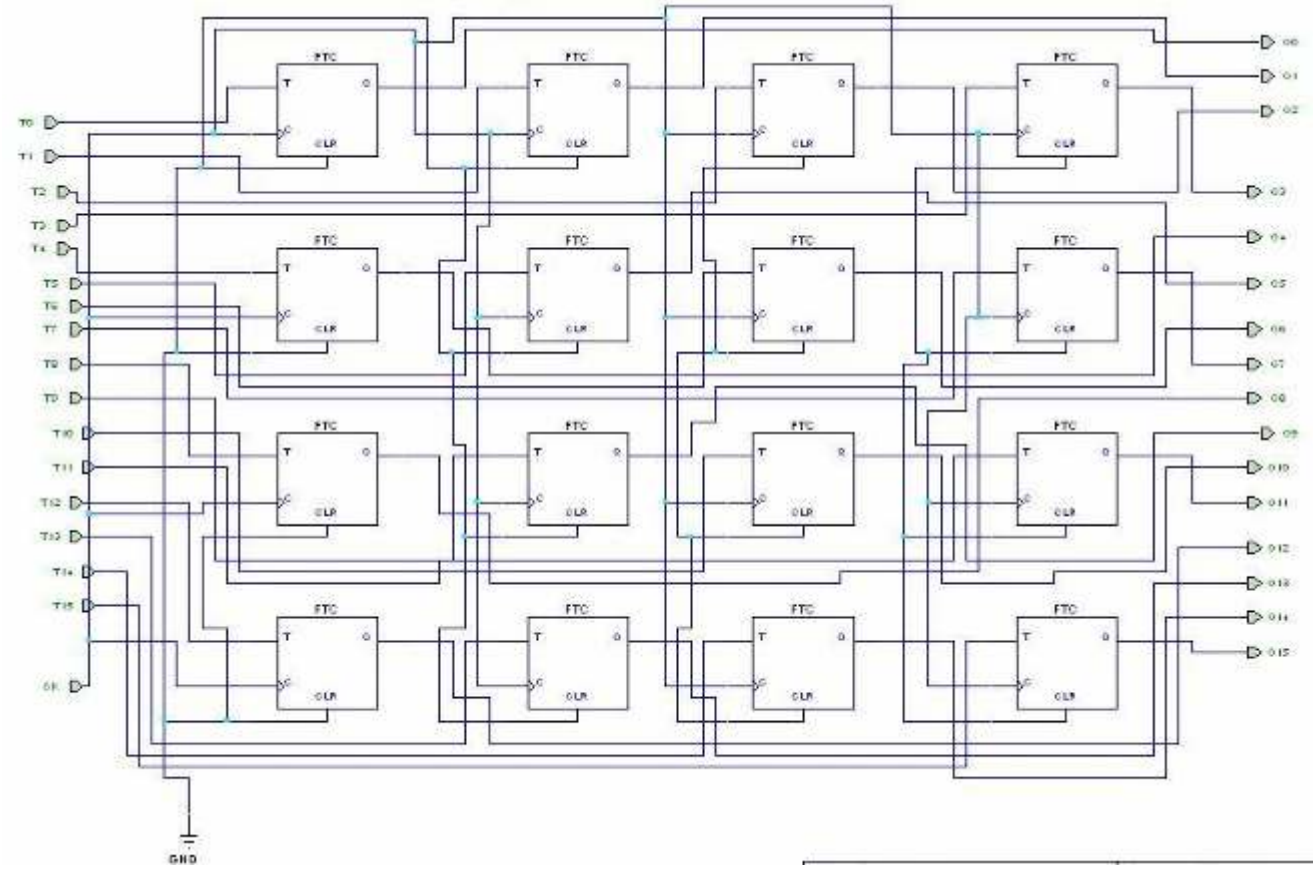

Fig. (13): cascade 16 T-flip flop internal designs.

Simulation waveforms:

After make simulation waveform for our circuit wireless block diagram fig.5 using FPGA Xilinx's XILINX SPARTAN model we get the waveform as shown in fig. 14. It explain for example the tone of number 7 (as it appear in the 1st tone) loaded to A/D convertor after complete the function of delay and answer analog circuit and press in the key of number 7 for mobile at home. After that it controlled by controller it shifted by parallel in/ parallel out shift register and we get the digit number after decoder and cascade T-flip flop in the output as shown in figure-6 and the digit no.7 which got in the output represent controlled for an devices in home. We got these results in standard time and in very high frequency about **1.613MHZ**.we repeat that in this simulation waveform for another tones represent no. 3,5 and 9 respectively and all of these no.3,5 and 9 represent controlled on devises in another location in home.

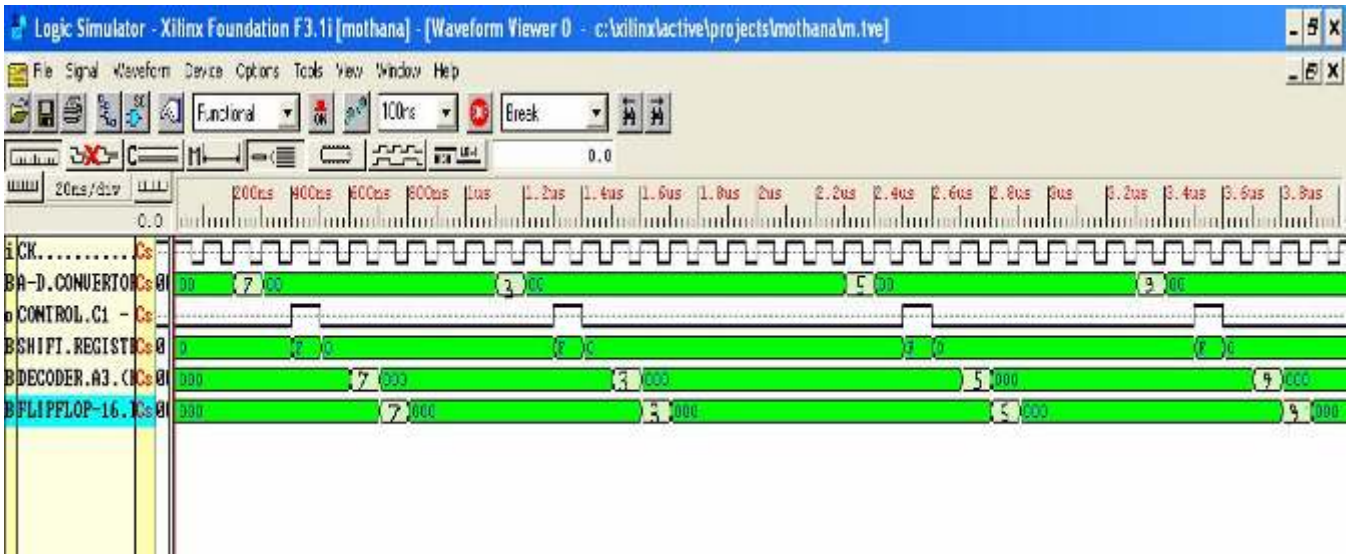

Fig. (14): Simulation waveform for data inters to package XILINX SPARTAN model.

Implementation:

After make implementation for our circuit by using programming software of fig. (14) In FPGA package Xilinx's SPARTAN model we get the following layout as shown in fig. (15) Which represent the over view the internal connections around the gates in FPGA package.

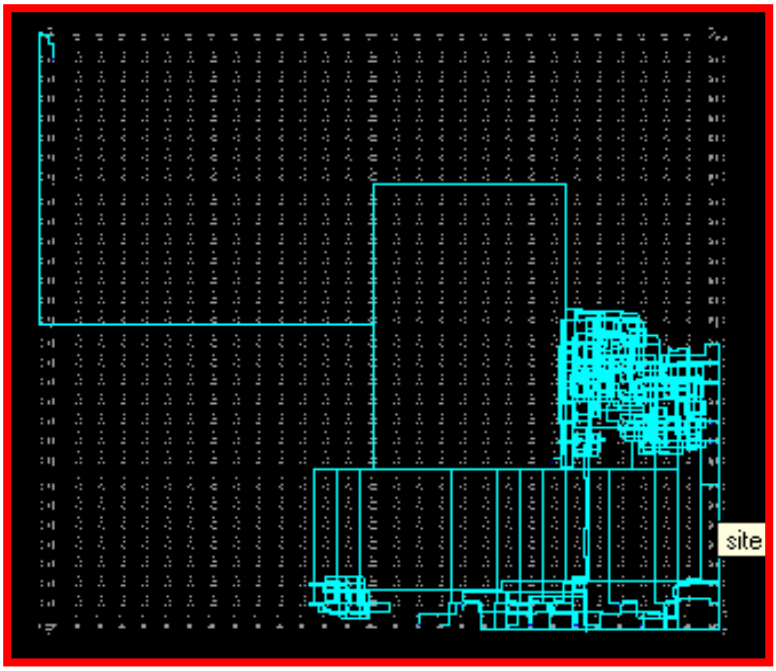

Fig. (15): layout for fig. (6) Internal connections when implement in FPGA package XILINX SPARTAN.

1- Implementation the Overall Design:

The internal schematic of mobile phone was shown in fig. (16), it illustrate how to connect the delay and answer circuit with mobile phone.

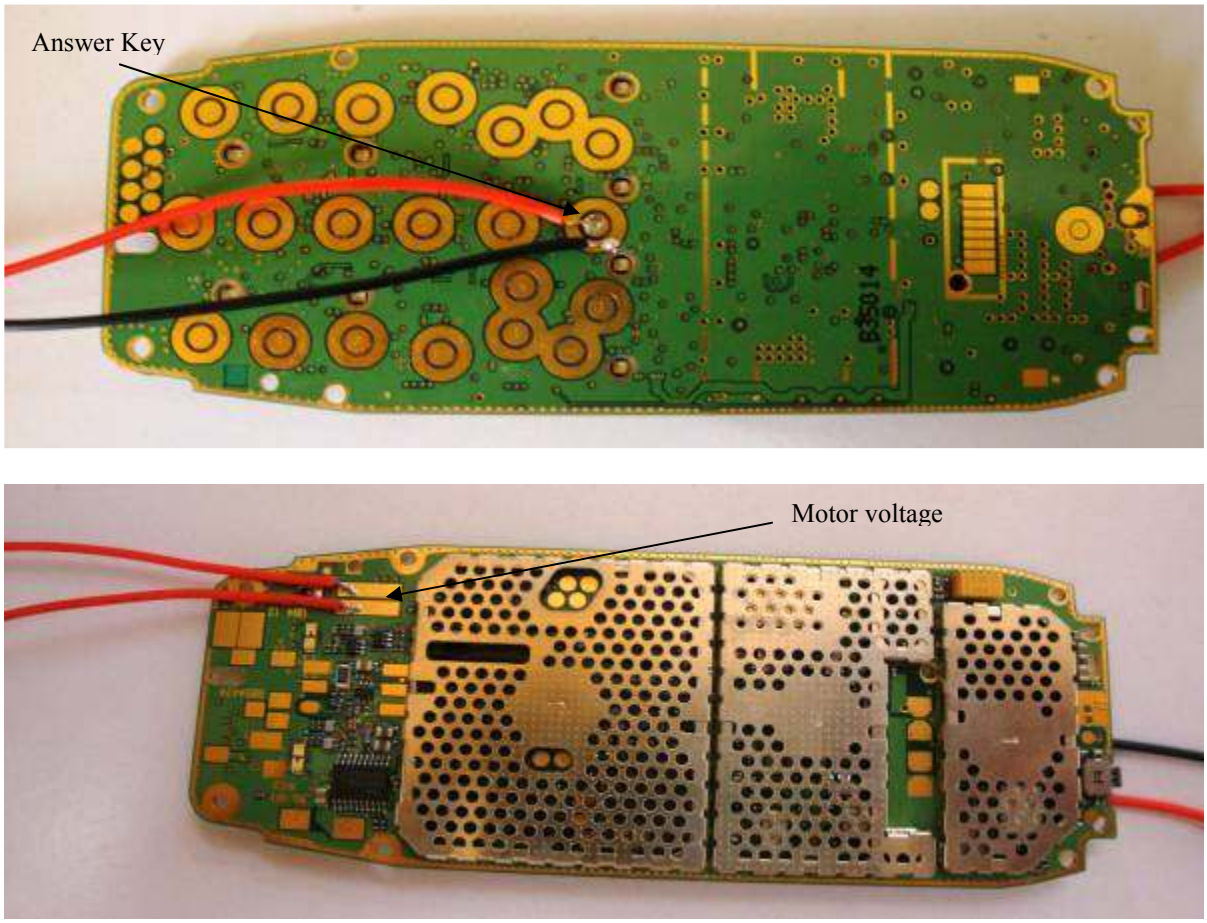

Fig. (16): shown the internal schematic of mobile phone.

The overall system in fig. (9) Was built as a hardware design which contains delay and answer circuit, FPGA package, lamp with 220 V, mobile phone, relay with 220 V to supply the lamp with voltage in addition to power supplies (12, 5) DC voltage to supply the circuit. Fig. (17) Was illustrate the dialing operation and no connection between the remote mobile and fixed mobile phone and the lamp was off.

Fig. (18) Was illustrate the dialing was complete and the lamp became on after choice the tone of no.1.

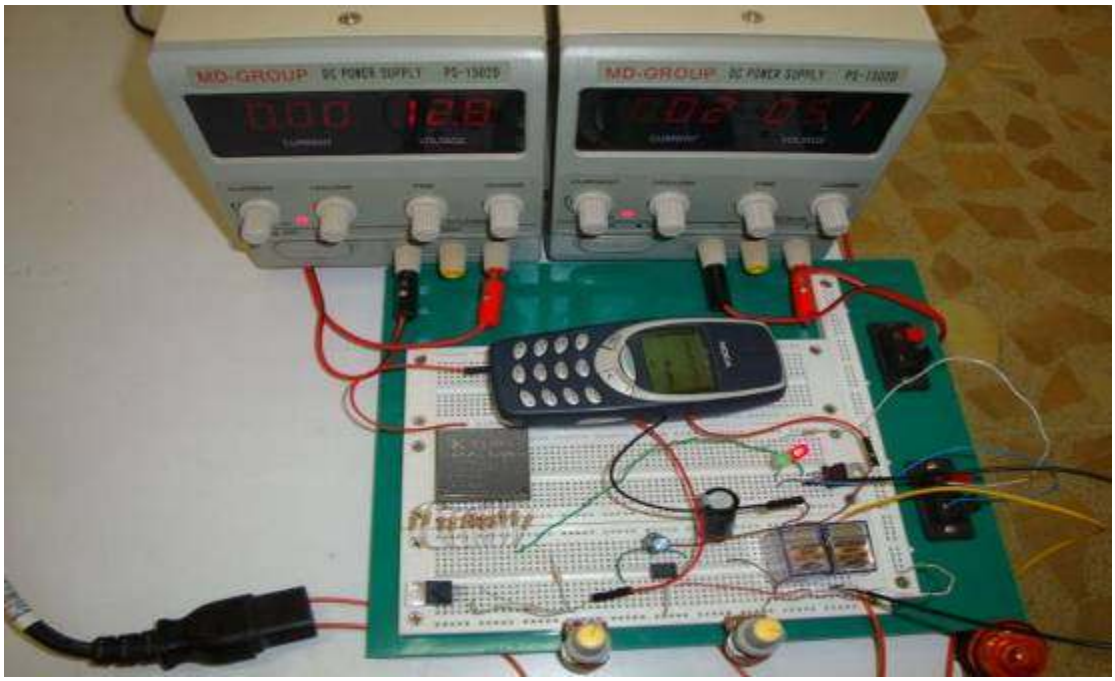

Fig. (17): The overall wireless control system with no connection and lamp off.

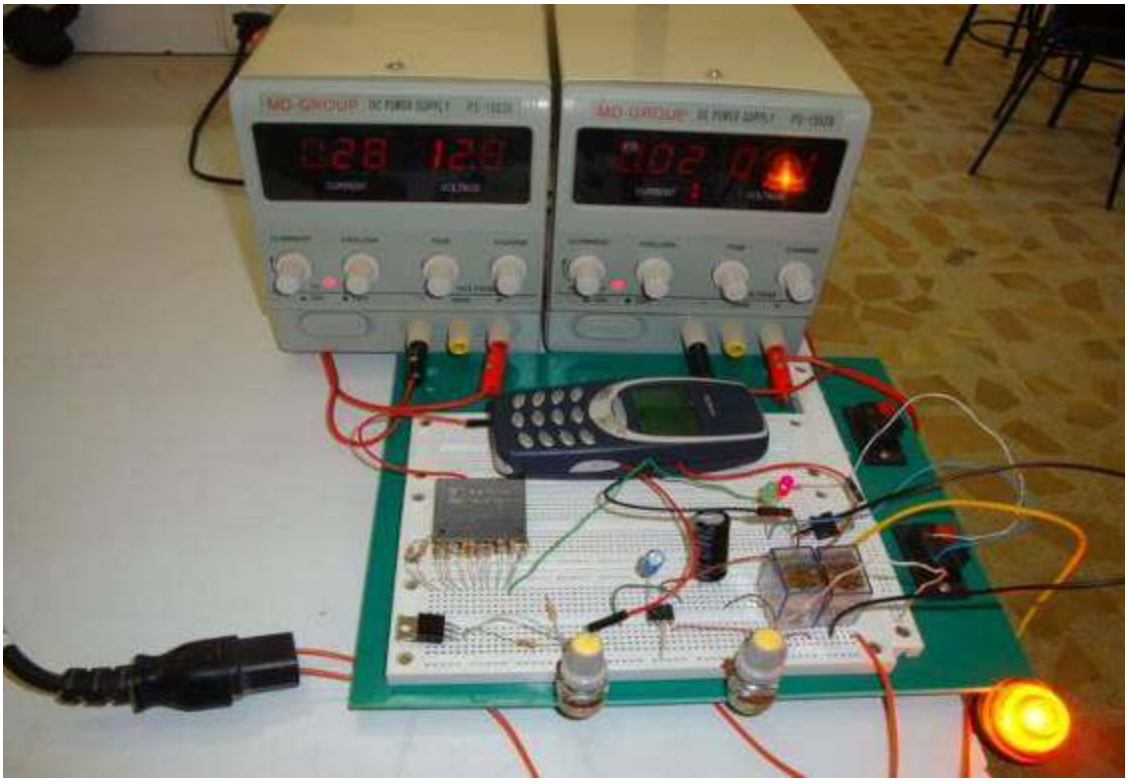

Fig. (18): The overall system with connection and lamp on.

Conclusions:

1. The wireless control system was built using two mobile phones. The first is a remote mobile and the second is a fixed mobile phone connected with many circuits for making the connection between them and executes the operations.
2. The system can be used as a test bed for any application that requires on-off switching based applications**.**
3. The system was dealing with 16 devices for switching on-off depended on (4x16) decoder and expanded it by choice another decoder.
4. The estimate time of delay circuit which used for delay the dialing between the two mobile before the answering is 3 second and can be decrease or increase it depended on the value of resistors and capacitor.
5. Connecting each output of the decoder with T-flip flop to make toggle the switching from on to off and vice versa at the same tone and then, using D-flip flop for storing the value of output.
6. The system is more reliable for connecting with any device of (220V or 110V) because it's depended on the relays which it connects.
7. The wireless control system was implemented by using FPGA package and its very high frequency about 1.613 MHZ.
8. Xilinx's SPARTAN of FPGA it's more suitable and demand for low volume, high density and programming for complex digital system. Therefore, has been used for implementation the system.

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