Design of DTMF Chip using VHDL and FPGA Synthesis

[1]Himani, [2]Dr A. K Gautam

[1]M.Tech Scholar, [2]Principal
Department of Electronic and Communication Engineering
S. D College of Engineering and Technology, Muzaffarnagar, U.P. India (251001)

***Abstract*: The DTMF keypad is widely used input peripheral in many embedded devices and different electronics circuits. The device considers the inputs as the alphabets and numbers and gives to the system for next level of processing. In DTMF dial telephone, a key is presented with a grouping of two sine waves. The dual tones of DTMF are referred as row and column frequencies of keypad. DTMF is the global standard for audible tones that represents the digits on a phone keypad. In the research paper, the DTMF chip is designed and synthesized on SPARTAN-3E FPGA and programmed with the help of VHDL code to display the digits 1, 2, 3, A, 4, 5, 6, B, 7, 8, 9, C, *, 0, #, D. The programming is done in Xilinx ISE 14.2 software and simulated in Modelsim 10.0 software.**

***Keywords*: DTMF Keypad, VHDL Programming, FPGA Synthesis**

1. Introduction

The DTMF system [1, 2] is a multifrequency based touch tone dialing system in which push buttons or the keypads in telephone [3, 4] and mobile sets are used to take the numbers against the pressed key or dialed number by the caller. DTMF is allowing the long-distance communication [5] over telephone lines of dialed numbers in voice frequency series. The signaling system has prevented the need of telecommunication operators between the called party and caller party, proceeded with automatic dialing in the telephone exchanges.

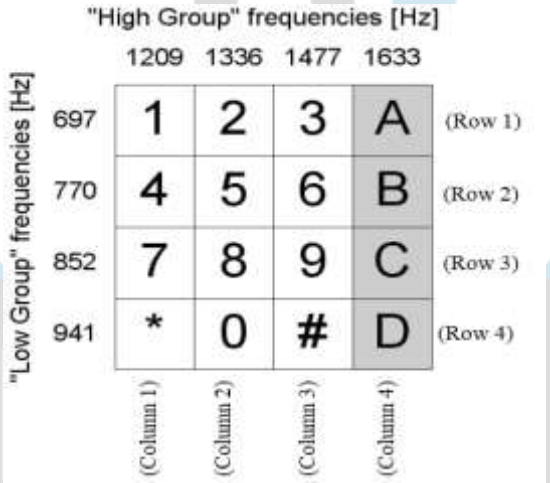

Fig.1 DTMF signaling

In DTMF dial telephone [6, 7], a key is presented with a grouping of two sine waves. The dual tones of DTMF are referred as row and column frequencies of keypad. DTMF is the global standard for audible tones that represents the digits on a phone keypad. The landline phones which are based on touch tone pad generate the corresponding DTMF tone for a key of dial pad. The landline phone systems can then listen and decode that tone to determine which key was pressed, and thus enables dialing. It is known as "Touchtone" phone previously a recorded trademark of AT&T.

2. DTMF Working

The Telephony Application Program Interface (TAPI) offers the platform to program the keypad and detect DTMF signals. The DTMF signaling [8, 9] altered individual digit into couple of tones. The system is associated with the four frequencies in four rows, called high tone group. Another four frequencies are linked with four columns as low tone group. The individual pressed key stipulates two frequencies as a result of DTMF signal as the summation of two sinusoidal signals, one for each frequency. The touchphone keypad [10] is shown in fig.2. The table 1 presents the key generation scheme at lower and higher frequency bands. For an example, the digit '5' translates into a sound with two frequencies, one at 770 Hz. and the other at 1336 Hz. In the same way, all the input digits are associated with the low and frequency band groups.

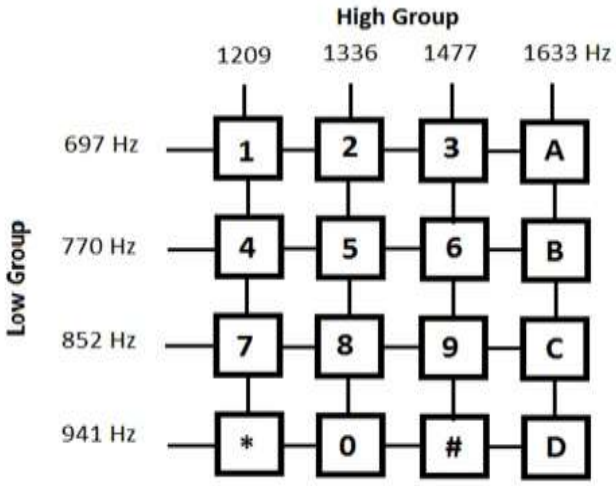

Fig. 2 Touch tome DTMF Keypad

Table 1 Frequency generation of touch keypad

Digit	Low Frequency (f_{Low})	High Frequency (f_{HIGH})
1	697 Hz	1209 Hz
2	697 Hz	1336 Hz
3	697 Hz	1477 Hz
A	697 Hz	1633Hz
4	770 Hz	1209 Hz
5	770 Hz	1336 Hz
6	770 Hz	1477 Hz
B	770 Hz	1633Hz
7	852 Hz	1209 Hz
8	852 Hz	1336 Hz
9	852 Hz	1477 Hz
C	852 Hz	1633Hz
*	941 Hz	1209 Hz
0	941 Hz	1336 Hz
#	941 Hz	1477 Hz
D	941 Hz	1633Hz

3. Results & Discussions

The Modelsim simulation waveform of the DTMF decoder chip is shown in fig. 3. It shows the simulation of the test inputs for the dialed number 9796321275 (hexadecimal).

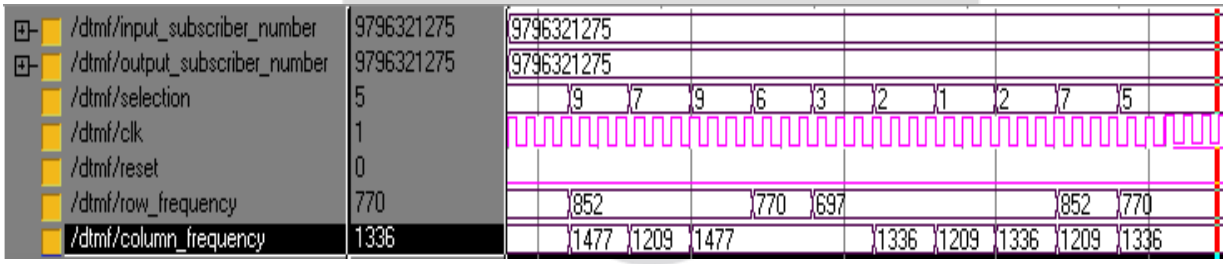

Fig.3 Modelsim simulation waveform

Test- Case: clk = clk signal, reset = reset, Input_subscriber_number<39:0> = 9796321275 (hexadecimal) = "1001 0111 1001 0110 0011 0010 0001 0010 0111 0101" (binary), Then output_subscriber_number<39:0> = 9796321275 (hexadecimal) = "1001 0111 1001 0110 0011 0010 0001 0010 0111 0101" (binary).

When, selection <3:0> = "1001", then row_frequency = 852 Hz , column_frequency = 1477 Hz.

When, selection <3:0> = "0111", then row_frequency = 852 Hz , column_frequency = 1209 Hz.

When, selection <3:0> = "1001", then row_frequency = 852 Hz , column_frequency = 1477 Hz.

When, selection <3:0> = “0110”, then row_frequency = 770 Hz , column_frequency = 1477 Hz.

When, selection <3:0> = “0011”, then row_frequency = 697 Hz , column_frequency = 1477 Hz.

When, selection <3:0> = “0010”, then row_frequency = 697 Hz , column_frequency = 1336 Hz.

When, selection <3:0> = “0001”, then row_frequency = 697 Hz , column_frequency = 1209 Hz.

When, selection <3:0> = “0010”, then row_frequency = 697 Hz , column_frequency = 1336 Hz.

When, selection <3:0> = “0111”, then row_frequency = 852 Hz , column_frequency = 1209 Hz.

When, selection <3:0> = “0101”, then row_frequency = 770 Hz , column_frequency = 1336 Hz.

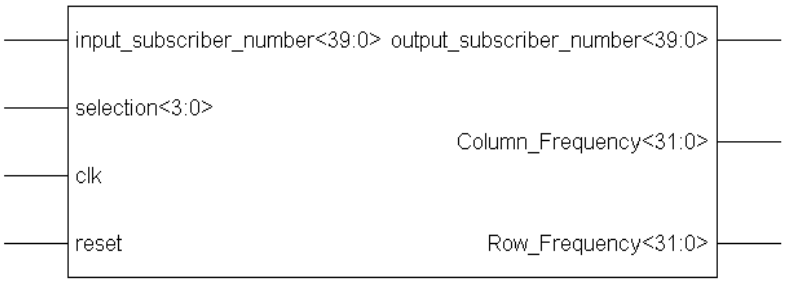

Fig. 4 RTL View of DTMF keypad

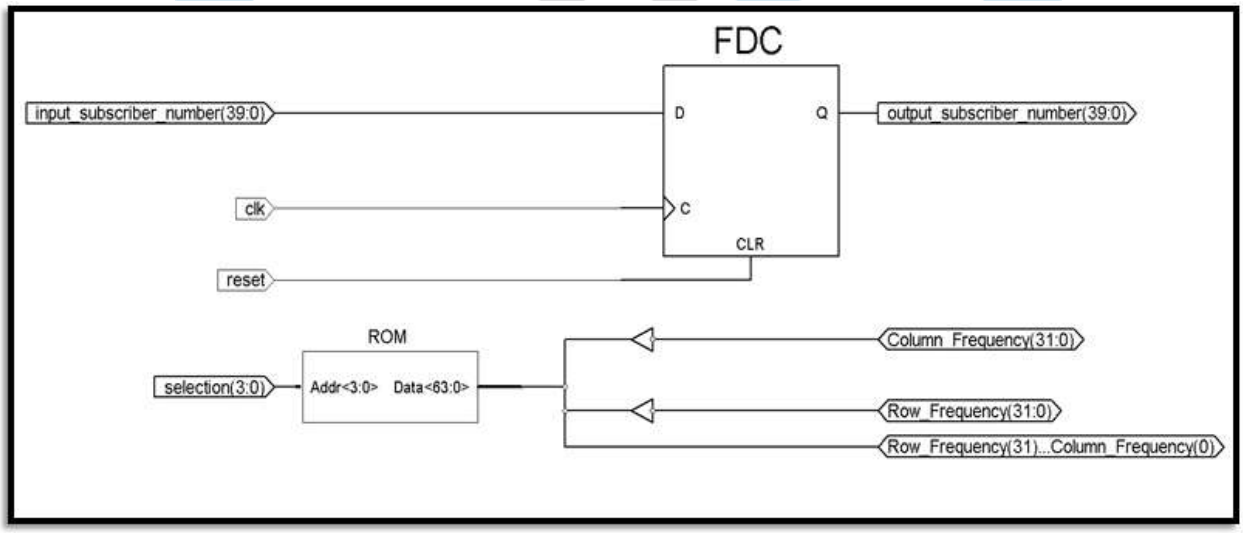

Fig. 5 Internal logic schematic of DTMF chip

The Fig.4 and Fig.5 detail about the RTL chip design and Internal logic schematic of DTMF chip. The chip has Input_subscriber_number<39:0> and Output_subscriber_number<39:0> as the input and output subscriber numbers. The column_frequency <31:0> and row_frequency <31:0> are the output and selection<3:0> presents the 4-bit logic input to presents the dialing or dialed digit selection from “0, 1, 2, 3, 4, 5, 6, 7, 8, 9, *, #, A, B, C, D” as the key inputs of DTMF decoder.

4. Hardware Utilization Summary

The FPGA synthesis is the process of program translation and optimization on specific FPGA. After translation, the same code is verified with respect to several inputs in terms of LUTs. In the coding of VHDL, it is possible to optimize the hardware resources, if the hardware usage is more than 100 % of the chosen FPGA. The percentage of hardware that is used by the device is given by device utilization report for the implementation of chip. Device hardware includes No. of slices. of input LUTs, No. of bounded IOBs and No. of gated clocks (GCLKs) used in design implementation. Timing details provides the knowledge of maximum frequency and combinational delay. The table 2 and table 3 detail about the hardware parameters and timing parameters .

Table 2 Xilinx software parameters for DTMF

Parameter	DTMF Chip
Number of Slices	31
Number of Slice flipflops	40
Number of LUTs Usage	18
Number of IoBs	149
GCLKs	1
Memory Usage	109524 kB

Table 3 Timing values for DTMF

Parameter	DTMF Chip
Frequency (MHz)	219.0 MHz
Min Period (ns)	1.291 ns
Min time before clock signal (ns)	2.520 ns
Max Time after clock signal(ns)	6.788 ns
Combinational Delay (ns)	9.728 ns

5. Conclusions

DTMF is the touch tome dial telephone technology and trademark of AT & T Company for the signaling system. As the user presses the key on the touch pad or keypad then two sinusoidal sine waves are generated in row wise and column wise and the number is detected. Several companies are working on DTMF technology to provide different embedded applications. The keypad is the essential part in embedded system-based applications. The hardware chip is designed using VHDL successfully and SPARTAN 3E FPGA is used for the synthesis on Xilinx ISE 14.2 software. The simulation of the test cases is applied for dialed digit selection from "0, 1, 2, 3, 4, 5, 6, 7, 8, 9, *, #, A, B, C, D" as the key inputs of DTMF decoder. The chip operation is tested with the number verification of the calling and called party against different tone frequencies. The designed DTMF can be used for multiple input multiple output configuration in which multiple users can perform intercommunication.

References

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