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# Efficient DTMF Detection based on Zynq 7000 Series of FPGA

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## ABSTRACT:

Dual-tone multi-frequency (DTMF) is a signaling standard in telecom applications that produces two tones simultaneously for each key press. By using efficient DTMF, this project divided into three phase's i.e. FFT, Split Goertzel Algorthim without Resource Sharing Approach, Split Goertzel Algorthim with Resource Sharing Approach. In these three phases we analyze area, timing & power. First phase is Fast Fourier Transform (FFT). In FFT, recursive operation is repeated N times. So that in FFT it requires more hardware, power & time. Second phase is spilt Goertzel Algorthim without Resource Sharing Approach. For high speed tone detection third technique i.e, Split Goertzel Algorthim with Resource Sharing Approach is used. Here, it uses predetermined frequencies& very minimal set of hardware,scheduled inputs & outputs are used at appropriate clock edges. So that it consumes less area & power. To detect DTMF detection a new type of ZYBO board ZYNQ 7000 series FPGA is used. Zynq is the combination of software &hardware systems. For functional verification Mentor Graphics Modelsim is used and for synthesis Xilinx ISE is used.

Keywords: DTMF, FFT, spilt Goertzel Algorthim without Resource Sharing Approach, spilt Goertzel Algorthim with Resource Sharing Approach., Xilinx ISE, FPGA, ZYNQ Platform.

## I.INTRODUCTION:

DTMF telephone keypad generates a sinusoidal tone and it is a mixture of two frequencies i.e., row and column frequencies. The below figure shows that, how the frequencies are organized:

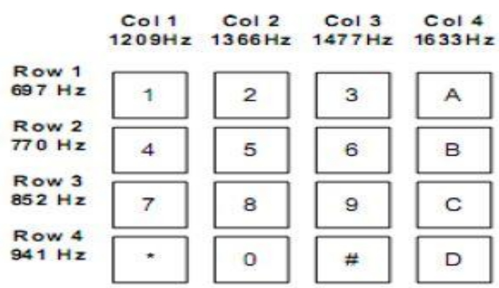


**Fig.1 Keypad represents high &low frequencies:**

The DTMF keypad represents like a 4×4 matrix, with each column & each row represents as high & low frequencies. EX: If we press a single key (as '2') will gives a sinusoidal tone for each of the two frequencies (1336 hertz (Hz) and 697 Hz). DTMF is mainly used to develop for telecommunication equipment. DTMF is a standard where keystrokes from the telephone keypad are translated into dual tone signals over the audio link. FPGA'S are parallel processing devices and it is used to improve the performance of systems.

In this paper, Zynq platform plays vital role. It is the combination of both processing system and programmable logic. Here processing system is software, programmable logic is hardware. Zynq

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is a platform; it combines a dual core ARM cortex_A9 processor with traditional FPGA logic fabric. Zynq devices are more flexible. Processing system (PS) & Programmable logic (PL) are used independently or together, & separate power circuitry is configured for both PS and PL.

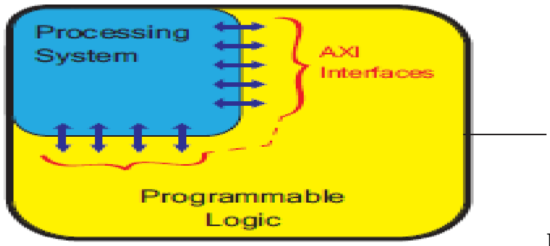


Fig.2

Zynq Architecture

Processing System is a hard processor. It exists as a dedicated and optimized silicon element on the device. Hard processors can achieve higher performance, for Zynq's ARM processor. Programmable logic is a soft processor like the Xilinx Micro Blaze, which is formed by combining elements of the programmable logic fabric. The implementation of a soft processor is therefore the equivalent of any other IP block deployed in the logic fabric of an FPGA. In general, the advantage of soft processors is that the number and precise implementation of processor instances is flexible. One or more Micro Blaze soft processors can be used within the PL portion of the Zynq, to operate in conjunction with the ARM processor.

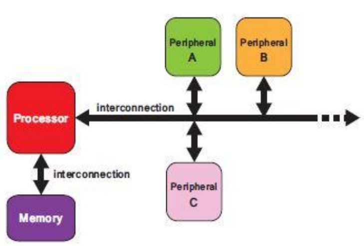


Fig.3 Hardware Architecture of Zynq

Processor works as the central element for hardware system. Software system runs through processor. Peripherals are functional components away from the processor

To achieve less area, low power, hardware optimized solution we use Spilt Goertzel Algorthim without RSA & Spilt Goertzel Algorthim with Resource Sharing Approach (RSA).

Mainly this paper divided into three phases.

Phase-I: In the first phase, by using Xilinx FFT core we can detect DTMF detection. The area, timing and power results are analyzed.

Phase-II: In the second phase spilt Goertzel Algorthim without Resource Sharing Approach is implemented. The area, timing and power results are analyzed.

Phase-III: In the third phase, spilt Goertzel Algorthim with Resource Sharing Approach is studied and suitable state machine based scheduling will be carried with limited resources to implement split Goertzel algorithm without RSA. The novel resource sharing based approach consumes less power and still it can detect efficient DTMF tones.

## II.IMPLEMENATION&DESIGN:

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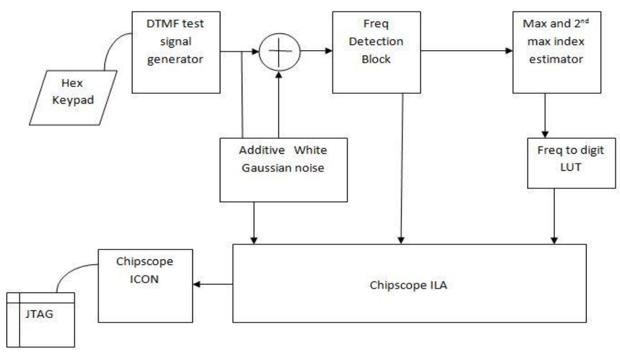


**Fig.4 General Module DTMF Detection**

The above figure represents General module DTMF Detection. It consists of six modules such as:

4x4 Hex key pad (input), Dual Tone Multi Frequency test signal generator, Additive white Gaussian noise, Frequency Detection block, Magnitude or index estimator and Frequency to digit look-up table.

Hex keypad is an external component and it act as input to DTMF module.

Frequency Test Signal Generator block generates necessary carrier frequencies. FTSG is again divided into two type's i.e, Frequency Word Selector & Direct Digital Synthesizer. FWS means, it selects frequency according to key pressed.

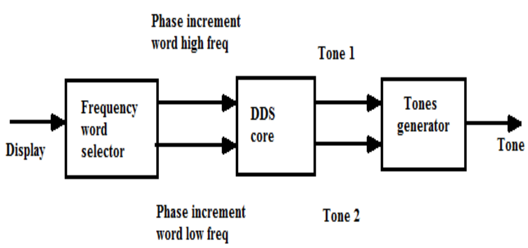


**Fig. 5 Frequency Word Selector**

DDS perform digital to analog conversation so that output will be in the form of analog usually a sine wave and this analog waveform combines with additive Gaussian noise then the output will be in the form of noise bits. This output gives as input to FDM i.e., Frequency Detection Module. Output will be in the form of magnitude indices. So that we can calculate 1st & 2nd max indices.

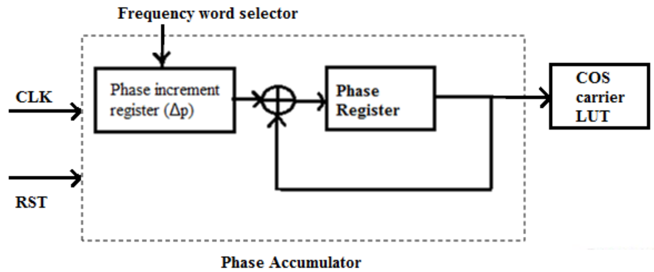


**Fig. 6 Direct Digital Synthesizer**

Chipscope ILA is used to monitor any internal signal of design. Chipscope ICON provides a communication path between Chipscope ILA & JTAG.

## III.EXISTING PROBLEM:

### 1. FFT- 128 core:

FFT_128 CORE is used instead of FDB. The Fast Fourier Transform (FFT) implements the Cooley-Tukey FFT algorithm, & FFT is an efficient algorithm to compute the discrete Fourier transform (DFT) and it's inverse. DFT decomposes a sequence of values into components of the different frequincies.DFT often too slow compare to FFT. FFT Algorithms mainly used in wide range of mathematics from complex number arithmetic to group theory and number theory. Input data presents in natural order and the output data can be in either natural or bit/digit reversed order. In FFT it consumes more power, area,

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timing, & hardware. The below figure represents the FFT_128 Core as Frequency Detection Module

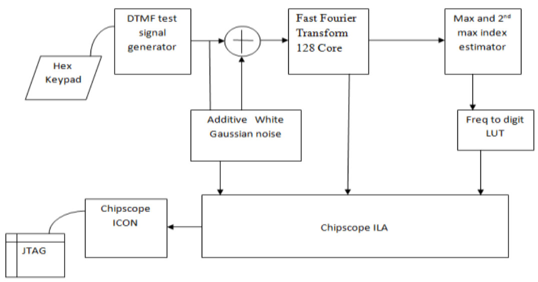


**Fig.7 Block Diagram with FFT-128 Core as Frequency Detection Module**

## IV.PROPOSED SOLUTION:

### 1.spilt Goertzel Algorthim without Resource Sharing Approach.

The spilt Goertzel Algorthim without Resource Sharing Approach is a DSP technique; it is used to identify the frequency components of a signal, and published by Dr. Gerald Goertzel in 1958. Here spilt Goertzel Algorthim without Resource Sharing Approach module is added instead of FDB in DTMF Detection General Module.

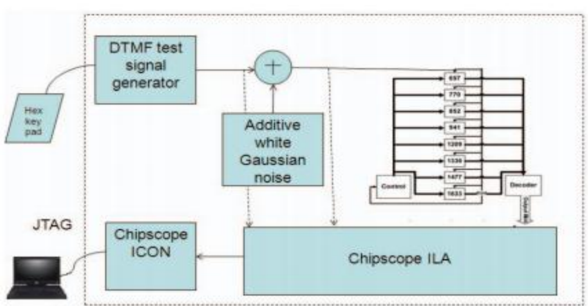


**Fig.8 Spilt Goertzel Algorthim without Resource Sharing Approach as Frequency Detection Module**

Spilt Goertzel Algorthim without Resource Sharing Approach is used to reduce the no. of real value multiplications compare to DFT. In spilt Goertzel Algorthim without Resource Sharing Approach specific &predetermined frequencies will use. So that it consumes less area, low power. The Goertzel Algorthim performs tone detection using much less CPU horse power than the Fast Fourier Transform. Spilt Goertzel Algorthim without Resource Sharing Approach series for a length of N is:

$$H_k\,(Z) = \frac{1 - e^{J\frac{2\pi K}{N}} z^{-1}}{\left(1 - e^{J\frac{2\pi K}{N}} z^{-1}\right)\left(1 - e^{J\frac{2\pi K}{N}} z^{-1}\right)}$$

K= 0, 1 ……. N_1

### 2. Spilt Goertzel Algorthim with Resource Sharing Approach.

Spilt Goertzel Algorthim with Resource Sharing Approach is an approach that, similar block of operations can assign.For example, +, to a common net list cell. Net list cells are be the resources; here net lists will be shared, so that it consumes less hardware. By using spilt Goertzel Algorthim without RSA we can implement spilt Goertzel Algorthim with RSA. In Goertzel algorithm all eight determined frequencies are appear, In spilt Goertzel Algorthim with RSA only 2 frequencies will used so that in spilt Goertzel Algorthim RSA consumes less hardware. The below figure shows spilt Goertzel Algorthim with Resource Sharing Approach.

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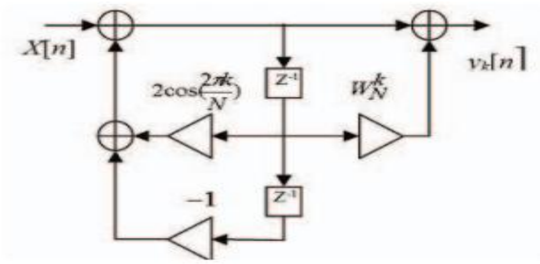


**Fig.9 Spilt Goertzel Algorithm with Resource Sharing Approach**

## V.SIMULATION AND SYNHESIS RESULTS:

The below Figures represent the Simulation results for FFT, Spilt Goertzel Algorthim without Resource Sharing Approach, Spilt Goertzel Algorthim with Resource Sharing Approach.

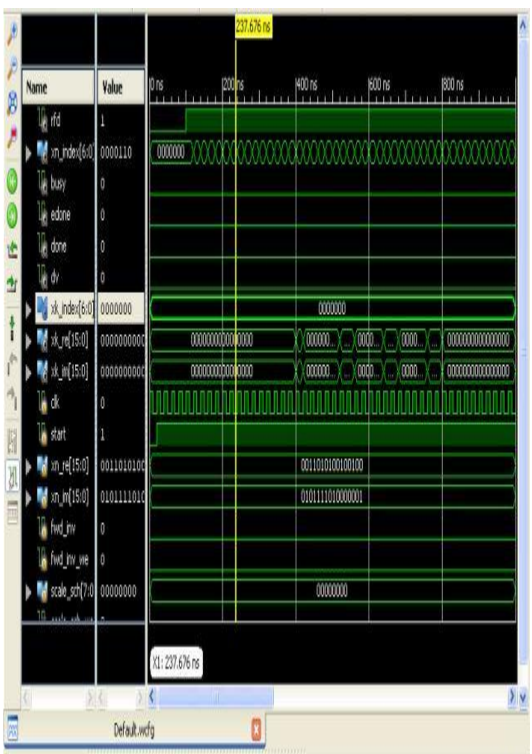

**Fig.10 simulation Results of FFT**

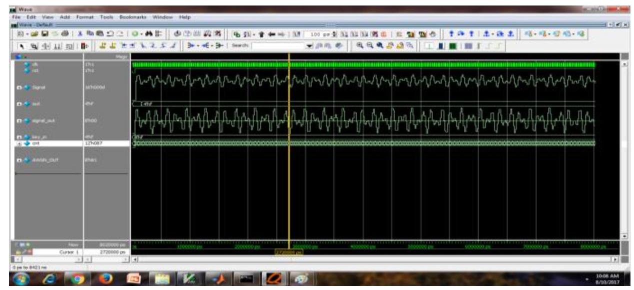

**Fig. 11 Simulation Results of Spilt Goertzel Algorithm without Resource Sharing Approach**

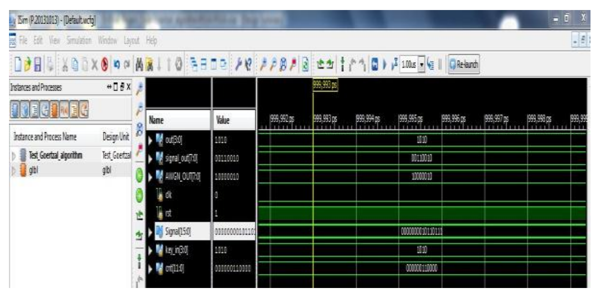

**Fig.12 Simulation Results of Spilt Goertzel Algorithm with Resource Sharing Approach**.

The Module, RTL Schematic, Device Utilization Summary are shown below by screenshots for FFT

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**Fig.13 Module of FFT**

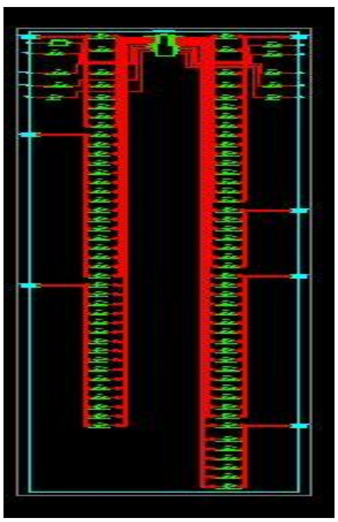

**Fig.14 RTL Schematic of FFT**

**Table_1: Device utilization Summary of FFT**

| Device Utilization Summary(estimated values) | | | |
|---|---|---|---|
| Logic Utilization | Used | Available | Utilization |
| Number Of Slice Registers | 1991 | 35200 | 5% |
| Number Of Slice LUTs | 1727 | 17600 | 9% |
| Number Of fully used LUT-FF pairs | 1527 | 2191 | 69% |
| Number Of bonded IOBS | 96 | 100 | 96% |
| Number Of Block RAM/FIFO | 4 | 60 | 6% |
| Number Of BUFG/BUFG CTRLS | 1 | 32 | 3% |
| Number Of DSP 48E1S | 9 | 80 | 11% |

The below figures represent Module, RTL Schematic, Device Utilization Summary for Spilt Goertzel Algorthim without Resource Sharing Approach.

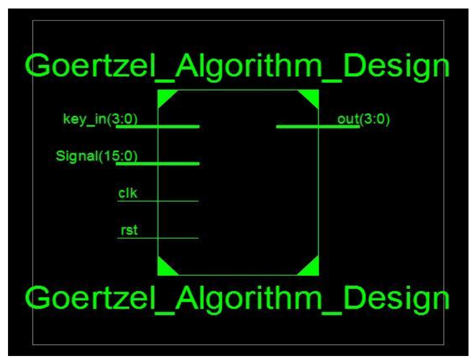


**Fig. 15 Spilt Goertzel Algorthim without Resource Sharing Approach. Module**

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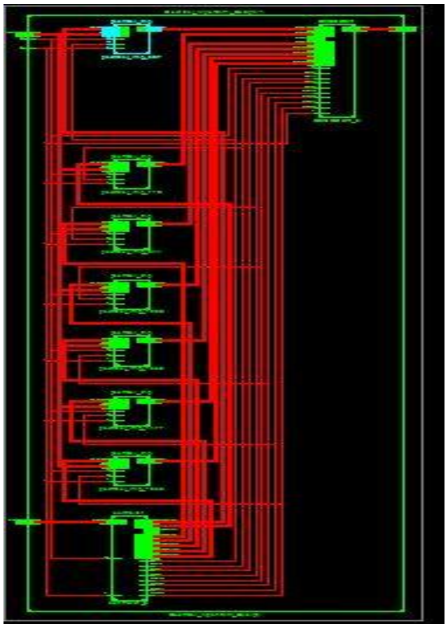

**Fig.16 RTL Schematic of Spilt Goertzel Algorthim without Resource Sharing Approach.**

**Table_2: Device Utilization Summary of Spilt Goertzel Algorthim without Resource Sharing Approach.**

| Device Utilization Summary(estimated values) | | | |
|---|---|---|---|
| Logic Utilization | Used | Available | Utilization |
| Number Of Slice Registers | 1991 | 35200 | 5% |
| Number Of Slice LUTs | 1727 | 17600 | 9% |
| Number Of fully used LUT-FF pairs | 1527 | 2191 | 69% |
| Number Of bonded IOBS | 96 | 100 | 96% |
| Number Of Block RAM/FIFO | 4 | 60 | 6% |
| Number Of BUFG/BUFGCTRLS | 1 | 32 | 3% |
| Number Of DSP 48E1S | 9 | 80 | 11% |

The below figures represent Module, RTL Schematic, Device Utilization Summary for Spilt Goertzel Algorthim with Resource Sharing Approach.

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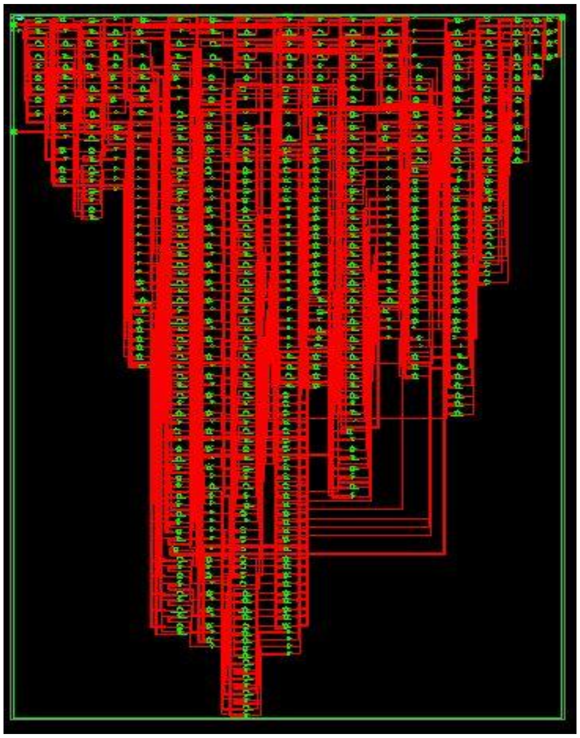

**Fig. 17 RTL Schematic of Spilt Goertzel Algorthim with Resource Sharing Approach.**

**Table _3: Device Utilization Summary for Spilt Goertzel Algorthim with Resource Sharing Approach.**

The below figure represents the Power Distribution for Spilt Goertzel Algorthim without Resource Sharing Approach., Spilt Goertzel

| Logic Utilization | Used | Available | Utilization |
|---|---|---|---|
| Number Of Slice Registers | 1 | 35200 | 0% |
| Number Of Slice LUTs | 78 | 17600 | 0% |
| Number Of fully used LUT-FF pairs | 12 | 79 | 15% |
| Number Of bonded IOBS | 26 | 100 | 26% |
| Number Of BUFG/BUFGCTRLS | 1 | 32 | 3% |
| Number Of DSP 48E1S | 6 | 80 | 7% |

Algorthim with RSA.

**Table_5: Power results for Spilt Goertzel Algorthim with Resource Sharing Approach.**

| Device | |
|---|---|
| Family | Zynq - 7000 |
| Part | Xc7z010 |
| Package | Clg400 |
| Temp Grade | Commercial |
| process | Typical |
| Speed Grade | -3 |

| On-chip | Power(w) | Used | Available | Utilization (%) |
|---|---|---|---|---|
| Clocks | 0 | 1 | ---- | ------ |
| Logic | 0 | 63 | 17600 | 0 |
| Signals | 0 | 650 | ----- | ------ |
| DSPS | 0 | 21 | 80 | 26 |
| IOS | 0 | 26 | 230 | 11 |
| Leakage | 0.01 | | | |
| Total | 0.01 | | | |

| Thermal Properties | Effective TJA(c/w) | Max Ambient(c) | Junction Temp(c) |
|---|---|---|---|
| | 5.5 | 84.5 | 25.5 |

| Supply Power(w) | Total | Dynamic | Quiescent |
|---|---|---|---|
| | 0.100 | 0.00 | 0.100 |

**Table_4: Power results for Spilt Goertzel Algorthim without Resource Sharing Approach.**

| Device | |
|---|---|
| Family | Zynq - 7000 |
| Part | Xc7z010 |
| Package | Clg400 |
| Temp Grade | Commercial |
| process | Typical |
| Speed Grade | -3 |

| On-chip | Power(w) | Used | Available | Utilization (%) |
|---|---|---|---|---|
| Clocks | 0 | 1 | ---- | ------ |
| Logic | 0 | 61 | 17600 | 0 |
| Signals | 0 | 259 | ----- | ------ |
| DSPS | 0 | 6 | 80 | 8 |
| IOS | 0 | 26 | 230 | 11 |
| Leakage | 0.01 | | | |
| Total | 0.01 | | | |

| Thermal Properties | Effective TJA(c/w) | Max Ambient(c) | Junction Temp(c) |
|---|---|---|---|
| | 5.5 | 84.5 | 25.5 |

| Supply Power(w) | Total | Dynamic | Quiescent |
|---|---|---|---|
| | 0.100 | 0.00 | 0.100 |

## V. CONCLUSION

In this project, we detect DTMF based FPGA implementation using Spilt Goertzel Algorithm with optimized Resource Sharing Approach. In the first phase, by using Xilinx FFT core we detected DTMF detection. The area, timing and power results are analyzed. The disadvantage of the DFT technique is that it requires each harmonic to be calculated separately, which requires much more processing power, hardware& memory. In the second phase the split Goertzel algorithm without Resource Sharing Approach analysis is carried out. In the next phase the split Goertzel algorithm with Resource Sharing Approach is studied and suitable state Machine based scheduling will be carried with limited resources to implement split Goertzel algorithm without Resource Sharing Approach. To detect DTMF detection a new type of ZYBO board ZYNQ 7000 series FPGA is used. In FFT Total area consumed i.e; total gates used 2369, memory consumption 445818 kilo bytes & speed is 1.5ns. In FFT it consumes more area, power, speed. In Split Goertzel Algorthim without Resource Sharing Approach; Total area consumed i.e; total gates used 33, memory consumption 445818 kilo bytes & speed is 4.123ns. In Split Goertzel Algorthim with Resource Sharing Approach; Total area consumed i.e; total gates used 20, memory consumption 445818 kilo bytes & speed is 4.123ns.In Split Goertzel Algorthim with Resource sharing Approach can detect the incoming frequency within a ±1.5% offset range. This algorithm does not check for overflow problems. So that it consumes less area, power& memory.

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