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Implementation of Golay Code in VLSI

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Abstract: ***The ability of the receiver to detect and correct the error from the received information is becoming major issues in wireless communication systems, so as to provide the processor with the correct information. There are numbers of methods available for implementing the hardware and software to achieve this. But, length of the communication link plays an important role because the distance of the transmitter and the receiver depends on the length, and multiple bits of the transmitted information may change due to the effect of noise on the transmitted signal. In many cases, that can cause extreme loss. In this project, using simple Golay code generated polynomial equation, we develop Golay code encoder and decoder for the ultrasound imaging.***

Keywords: Golay code; Encoding; CRC method: Decoding; FPGA

I. INTRODUCTION

Golay Code, proposed 1949 by M.J.E Golay. It's a linear code correction error and a component of ideal nontrivial codes. The communication device transmits data through a channel or medium such as wired or wireless, from source to destination. The reliability of the received data depends on the medium and external noise of the channel and this noise causes interference in the signal and introduces errors in the data transmitted. Through its coding theorem, Shannon showed that reliable transmission can only be achieved if the data rate is lower than that of channel capacity.

The detection and correction of errors can be achieved by adding redundant symbols to the Original data which is called ECC. ECCs are truly useful for one way long distance communications such as deep space communication or satellite communication. They also have application in wireless devices for communication and storage. Error detection and different errors correcting codes are there and can be used depending on the properties of the system and the application in which the error correcting is to be introduced. Generally, error correcting codes have been classified into Block Codes, Convolutional Codes, Low Density Parity Check Code (LDPC) and Golay Code. ECCs is really helpful for long-distance one-way communications such as deep space communication or satellite communication. They also have application in wireless communication and storage devices. In a noisy channel Error detection and correction helps while transmitting errorless data. Error detection refers to detect errors if any received by the receiver and correction is to correct errors received by the receiver.

The Binary Golay code(G23) is represented as (23, 12, 7), and the extended binary Golay code (G24) can be represented as (24, 12, 8). Golay code plays a vital role in different applications like laser application in coded excitation and ultrasound imaging. Golay code (24, 12) is a one type of block code. The minimum Hamming distance of general Golay code (23, 12) can be referred as dmin= 7, number of corrected error bits can be referred as t = 3. Therefore, all the 3-bit errors can be corrected, and it is also called as perfect code. The binary Golay code (G23) is a perfect linear error correcting code that can correct any combination of three or fewer random errors over 23 digits block. The Golay code can be extended by appending a parity check bit to each codeword. Binary Golay code (G23) is shown as (23,12,7), which means the code word length is 2.

II. LITERATURE SURVEY

A. Application of Golay Codes to Biomedical Transducers for Non-Invasive Transducer for Non-Invasive Measurement (2014)

In this [1] paper by combining the products of two separate codes cause self-induced noise to cancel. Here Signal-to-Noise Ratio (SNR) systems by mainly codes useful in bio-medical applications. The SNR improvement are greater because when input SNR is greater than unity. This [1] is mainly used to send multiple codes, by identify

and detect to extend velocity limits. Pulse shape integrity is important, but it requires large bandwidth.

B. DNA Barcoding through LDPC Codes (2015)

In this [2] paper barcoding system it is built from random error correcting codes, which limits multiplying accuracy and experimental and scalability. To avoid this binary BCH and pseudo-quaternary Hamming codes has been implemented. To design barcodes binary BCH and Low density parity check (LDPC) codes invented. Advantages of this [1] is low rate of read losses and undetected sample mis- identification errors rate. Simulation result accurate barcoding system with high multiplexing capacity, which is obtained by LDPC codes.

C. Application of Golay Coded Pulse Compression in Air Couples Ultrasonic Testing of Flexible Package Scale Defect (2016)

In this [3] paper flexible package is widely applied in industries such as food, medical products and daily chemical. There are different types of scale defect are there as bubble, contamination and channel leak, impact on product quality, mainly channel leak defects. Here by using [2] these defects can be detected in scale region through visual inspection or through destructive testing. But it consumes more time and enable to achieve online detection in manufacturing process. Air coupled ultrasound testing material is non-contact manner. Signal-to- Noise Ratio (SNR) is the main problem which limits the applications of air coupled ultrasonic testing.

D. High Speed Design of FPGA Based Golay Encodes And Decodes (2016)

Here [4] Field Programmable gate Array (FPGA) and simulation of Golay code and extended Golay code encode is represented. Here [4] the work is mainly to encoded data packet using the Golay encoder. The receiver is used to detect the errors and also correct them from received information. To give correct information data to the processor. Length of communication become very long because of the distance between transmitter and receiver is very large. Noise effects the transmitted signal by changing multiple bits of information. By this which cause loss in many cases. This [4] is based on optimization of time delay.

E. A Review on Design and Simulation of Extended Golay Decoder (2016)

Field Programmable Gate Array (FPGA) use both binary Golay codes and extended Golay codes. The encoding scheme such as hamming codes, block codes, turbo codes, Cyclic Redundancy Check (CRC) codes are contained. Main use of Field Programmable Gate Array (FPGA) is that it is of high speed and low latency and less complexity architecture. This paper [5] proceed error correcting codes that is Golay codes and extended Golay codes.

F. The Golay Code Outperforms the Extended Golay Code under Hard Decision Decoding (2016)

The Golay code is used in many applications. The extended Golay code used for NASA's voyage mission. It is used to protect data handling capabilities of NASA's mission. Extended Golay code is used as automatic link establishment protocol. Also, it is used in paging protocols. In extended binary Golay code power efficiency is slightly worse.

G. Design of Efficient Golay Encoder for Deep Space Missions (2017)

Error detection and its correction plays are important role in digital data over using communication channel. Here binary Golay is called as superior block code (23, 12, 7). It is used in many applications such as ultrasound imaging, coded excitation imaging for laser, voyager mission of NASA. Notation for block code is (n, k, d). Where, m2 length, message with length as k, minimize hamming distance between two code words. C is the code word which is used to detect and correct an error.

H. Implementation of Designed Encoder and Decoder for Golay code (2017)

To detect and correct the errors from the received information wireless communication system is used. This process is used to correct the errors in obtained information. Transmission of data between transmitter and receiver depends on the length of communication. Field Programmable Gate Array (FPGA) based Golay code and extended Golay code is used.

*I. Decoding of the se*ven Error Correcting Binary Quadratic Residue Codes *(2017)*

Fast syndrome weight decoding algorithm (FSWDA) is used to decode up to seven possible errors in quadratic residue code (70, 40, 15) and (97, 49, 15). In QR code error- locator is complicated and it is time consuming. FSWDA evaluate error locator polynomial. It generates the table which store syndrome and corresponding errors in memory. It is an efficient and high speed decoder.

J. High Speed Encoder and Decoder of Binary Golay Code *(2017)*

Binary Golay code is represented as given (23, 12, 7) and extended binary Golay code is represented as (24, 12, 8). Golay codes are used in different applications like coded excitation in laser and imaginary ultrasound imaging. Golay code is a type of block code extended binary Golay code (24, 12) optimized the Golay code (20, 12) derived from LDPC error correction method.

K. Novel and Fast Hardware Implementation for Golay Code Encoder(2018)

In this [11] paper error correction code (ECC) is used to minimize the errors caused in digital systems. Binary Golay code is 'ECC' code that can correct combination of 3 or random errors over a block of 23 digits. This code can extend parity check bits. In this [11] paper, encoding of

both binary Golay and extended Golay code based on the CRC. By using data path & control unit and conversion unit is constructed in this Golay code encoder. Xilinx ISE is used. It is used because it has low latency, high throughput, low area and less complexity.

L. Chain Successive Cancellation Decoding of the Extended Golay Code (2018)

In this [12] paper (24, 12, 8) is the extended Golay code and it is a query-perfect self-dual code. The algebraic structure of Golay code is efficient decoding. These algorithms are only to the extended Golay code is represented in the chained polar sub code, which explore decoding techniques for error codes and error correcting codes. Low complexity decoding algorithm is based on this representation.

M. Functional Ultrasound Imaging of the Brain Reveal Propagation of Task Related Brain Activity in Behaving Primates (2019)

Here in [13] micro imaging modalities like MRI and EEG are able to recode the brain, but the price of limited spatiotemporal resolution is limited. Functional ultrasound imaging (FUI) of brain is used to access change in blood volume while performing tasks.

III. METHODOLOGY

A. Golay Encoder

To reduce the probability of error the digital systems, the error correction code is used. The binary Golay code is an error correction code that can rectify any combination of three or fewer random errors over a 23-digit block. This code can be extended to each codeword by appending a parity check bit.

a) Proposed Algorithm for Encoder

The steps needed to perform the encoding procedure are listed below.

1) A characteristic polynomial G(x) is chosen for the generation of check bits .
2) To the right hand side of the message M(x) 11 Zeros are attached. P(x) takes part in the long division process with G(x) to the resulting polynomial.
3) The remaining bits are the check bits for G23 except the most significant bit (MSB) that resulted at the end of the division operation. The encoded Golay (23, 12, 7) codeword is given to us by appending check bits with the message.
4) Added parity bit to transform binary Golay code into extended Golay code (24, 12, 8). If there is also the weight of binary Golay code, then parity bit 0 is appended, otherwise 1 is appended. The proposed encoder algorithm clearly follows the basic process of generating the CRC and includes a method for binary conversion.
5) An example of generating Golay word code based on the above algorithm is shown in the Fig. 1. Let us say, the encoded message is A27h. In binary format, therefore, M(x) = A27h and P(x) is represented as 1010 0010 0111 0000 0000 000. Finally, in hexadecimal format the generated check bits are 435h. For the message bits (A27h) the encoded codeword is therefore A27435h.

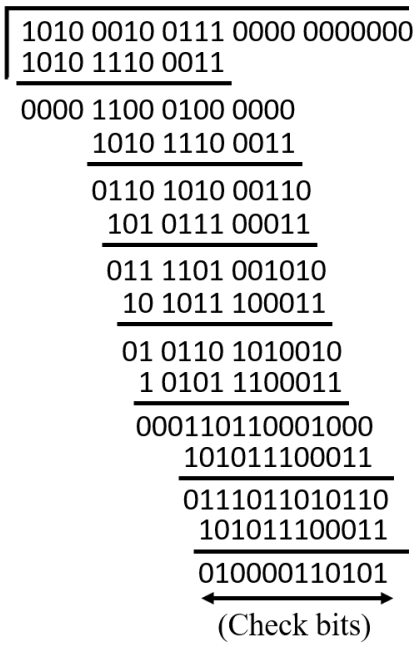

Fig 1. Encoding of Golay code

b) Encoding Output

Fig 2. Encoding Output

B. Golay Decoder

Golay decoder is used extensively in communication links for forward error correction. A high speed and high throughput hardware decoder could be useful in communication links for forward error correction.

a) Algorithm

- Set input clock as wire
- Set input reset as wire

- Set input cw_rec as wire which is of 24 bits.
- Set output as msg_word, parity bit as output register.
- Declare combination as local parameter
- Call syndrome program
- Compare syndrome with each local parameter

  If it is true, error=0

  else

  error=1

  end

b) Decoding Output

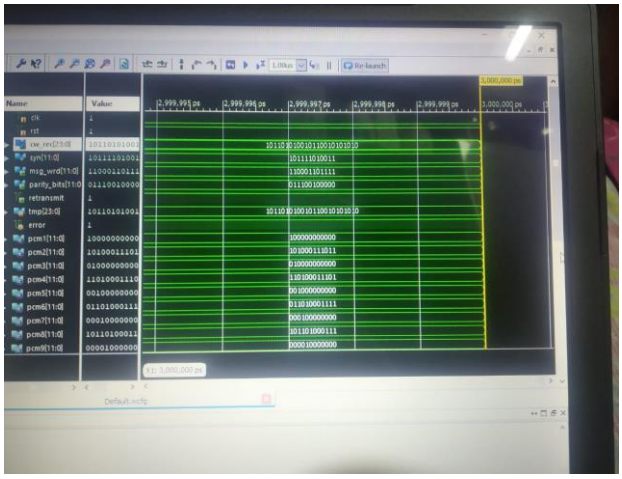

Fig 3. Decoding output

C. Power

- Here signal refers to wire or register and leakage is also FPGA power and in case if we don't dump our program into FPGA board also, it uses default power as 0.321W.
- The total power consumed here is 0.368W.
- Dynamic power is 0.047W and quiescent power is 0.321W.

D. Time

- Minimum period: 5.37ns (Maximum frequency: 186.114 MHz).
- Minimum input arrival time before clock: 2.795ns.
- Maximum output required time after clock: 2.826ns.

E. Area

- The FPGA family uses here is Vertex-5.
- Slice Register is like D flip flop.
- Available slice registers are 12480 and we have used 48 of that.
- LUT stands for lookup table. It is a memory, available are 12480 and we have used 144 out of that.
- Available fully used LUT-flip pairs are 157 and we have used 35.
- Available bonded input output blocks are 172, we have used 40.
- Available block RAM are 26, we have used 2.

Device	
Family	Virtex5
Part	xc5vlx20t
Package	ff323
Temp Grade	Commercial
Process	Typical
Speed Grade	-2

On-Chip	Power (W)	Used	Available	Utilization (%)
Clocks	0.004	1	--	--
Logic	0.002	143	12480	1
Signals	0.012	186	--	--
BRAMs	0.008	2	26	8
IOs	0.021	40	172	23
Leakage	0.321			
Total	0.368			

Supply Summary		Total	Dynamic	Quiescent
Source	Voltage	Current (A)	Current (A)	Current (A)
Vccint	1.000	0.263	0.027	0.236
Vccaux	2.500	0.032	0.000	0.032
Vcco25	2.500	0.010	0.008	0.002

	Total	Dynamic	Quiescent
Supply Power (W)	0.368	0.047	0.321

Fig 4. Power Values

Device Utilization Summary (estimated values)			[-]
Logic Utilization	**Used**	**Available**	**Utilization**
Number of Slice Registers	48	12480	0%
Number of Slice LUTs	144	12480	1%
Number of fully used LUT-FF pairs	35	157	22%
Number of bonded IOBs	40	172	23%
Number of Block RAM/FIFO	2	26	7%
Number of BUFG/BUFGCTRLs	1	32	3%

Fig 5. Area Values

IV. CONCLUSION

In this paper we discuss the Golay Code and the encoder and decoder process. These encoding and decoding algorithms been applied successfully in VLSI as Golay Code. Decoding algorithm consists of power, timing and location.

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