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A Litrature Survey on Golay Codes

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***Abstract*— The current world of digital communication secure data communication prime task. Data coding decoding explore a variety of applications of the theory of arithmetic and computation. In the fields of cryptography and cryptanalysis as well as in the field of digital communication. For the improvement of security of the codes using the Galious field (G.F.). Computation over finite fields (also called Galois fields) is an active area of research in number theory and algebra, and finds many applications in cryptography, error control coding and combinatorial design. In this survey paper shows the literature review of golay code in digital communication. A bird eye review for Golay code is presented in this research work. A Golay code is presented addressing the error correcting phenomena. This is used in field programmable gate array (FPGA). There are various researchers presents there techniques for correcting the error check. This research work reviews that work.**

Keywords—Architecture, decoder, encoder, field programmable gate array (FPGA), Golay code.

I. Introduction

The Golay code was presented in [2] to address error correcting phenomena. The binary Golay code (G23) is represented as (23, 12, 7), while the extended binary Golay code (G24) is as (24, 12, 8). The extended Golay code has been used extensively in deep space network of JPL-NASA as well as in the Voyager imaging system [6]. In addition, Golay code plays a vital role in different applications like coded excitation for a laser [7] and ultrasound imaging due to the complete sidelobe nullification property of complementary Golay pair. All these applications need generation of Golay sequence, which is fed as trigger to the laser modules. However, for generating Golay code an automatic pattern generator is used, which is of very high cost. To combat this problem, a hardware module programmed to yield a Golay encoded codeword may be used. Golay decoder is used extensively in communication links for forward error correction. Therefore, a high speed and high throughput hardware for decoder could be useful in communication links for forward error correction.

II. Back Ground

Communication is important in our daily lives. We use phones, satellites, computers and other devices to send messages via a channel to a receiver. Unfortunately, most types of communication are subject to noise, which can cause errors in the messages that are sent. Especially when sending messages is a difficult or expensive task, for example in satellite communication, it is important to find ways of minimizing the occurrence of errors. This is the central idea in coding theory: what message was sent given what we received? To make this problem as simple as possible, we use error correction codes. The main idea is to add redundancy to messages that allows us to identify and correct errors that may occur. This thesis deals with a specific type of error-correcting code, the extended Golay code G24, named after the Swiss mathematician Marcel J.E. Golay (1902-1989). He used mathematics to solve real problems, one of which was the question of how to send messages from satellites through space. Golay Extended Code was used to send Voyager 1 and 2 images of Jupiter and Saturn. With the extended Golay code we are talking about a specific group of Mathieu, M24, as it is strongly related to the code. This group bears the name of the French mathematician Emile Léonard Mathieu (1835-1890). The last part of this thesis describes four geometrical figures with which we can visualize the properties of G24 and M24.

III. Back Ground

There are two closely related binary Golay codes. The **extended binary Golay code**, G_{24} (sometimes just called the "Golay code" in finite group theory) encodes 12 bits of data in a 24-bit word in such a way that any 3-bit errors can be corrected or any 7-bit errors can be detected. The other, the **perfect binary Golay code**, G_{23}, has code words of length 23 and is obtained from the extended binary Golay code by deleting one coordinate position (conversely, the extended binary Golay code is obtained from the perfect binary Golay code by adding a parity bit). In standard code notation the codes have parameters [24, 12, 8] and [23, 12, 7], corresponding to the length of the code words, the dimension of the code, and the minimum Hamming distance between two code words, respectively.

In mathematical terms, the extended binary Golay code G_{24} consists of a 12-dimensional linear subspace W of the space $V=\mathbf{F}_2^{24}$ of 24-bit words such that any two distinct elements of W differ in at least 8 coordinates. W is called a linear code because it is a vector space. In all, W comprises $4096 = 2^{12}$ elements.

- The elements of W are called *code words*. They can also be described as subsets of a set of 24 elements, where addition is defined as taking the symmetric difference of the subsets.
- In the extended binary Golay code, all code words have Hamming weights of 0, 8, 12, 16, or 24. Code words of weight 8 are called **octade** and code words of weight 12 are called **do decads**.
- Octads of the code G_{24} are elements of the S(5,8,24) Steiner system. There are 759 = 3*11*23 octads and 759 complements thereof. It follows that there are $2576 = 2^4*7*23$ dodecads.
- Two octads intersect (have 1's in common) in 0, 2, or 4 coordinates in the binary vector representation (these are the possible intersection sizes in the subset representation). An octad and a dodecad intersect at 2, 4, or 6 coordinates.
- Up to relabeling coordinates, W is unique.

The binary Golay code, G_{23} is a perfect code. That is, the spheres of radius three around code words form a partition of the vector space. G_{23} is a 12-dimensional subspace of the space $\mathbf{F}_2^{23}$.

IV. Literature Survey

A. *2015, "Efficient Hardware Implementation of Encoder and Decoder for Golay Code", **Satyabrata Sarangi, Swapna Banerjee***

This brief lays out cyclic redundancy check-based encoding scheme and presents an efficient implementation of the encoding algorithm in field programmable gate array (FPGA) prototype for both the binary Golay code (*G*23) and extended binary Golay code (*G*24). High speed with low-latency architecture has been designed and implemented in Virtex-4 FPGA for Golay encoder without incorporating linear feedback shift register. This brief also presents an optimized and low-complexity decoding architecture for extended binary Golay code (24, 12, 8) based on an incomplete maximum likelihood decoding scheme. The proposed architecture for decoder occupies less area and has lower latency than some of the recent work published in this area. The encoder module runs at 238.575 MHz, while the proposed architecture for decoder has an operating clock frequency of 195.028 MHz. The proposed hardware modules may be a good candidate for forward error correction in communication link, which demands a high-speed system.

B. *2014. "FPGA-Based Bit Error Rate Performance Measurement of Wireless Systems" **Amirhossein Alimohammad and Saeed Fouladi Fard***

This article presents the validation of the performances of the digital baseband communication systems (BER) on a field-programmable gate array (FPGA). The proposed BER tester integrates fundamental baseband signal processing modules from a conventional wireless communication system with a realistic fading channel simulator and a precise Gaussian noise generator on a single FPGA to provide a test environment Accelerated and repetitive in the laboratory. Using a developed graphical user interface, the error rate performance of single antenna and multi-antenna systems over a wide range of parameters can be quickly assessed.

C. *Dec 2012, "A low-complexity soft-decision decoding architecture for the binary extended Golay code" [03]*

The extended binary Golay code (24, 12, 8) is a well-known short linear block frequency error correction code with remarkable properties. This research work studies the design of a low decision decoding architecture for this code. A dedicated algorithm is introduced which takes advantage of the properties of the code to simplify the decoding process. The results of the simulation show that the proposed algorithm achieves a performance close to the maximum likelihood with a low computational cost. The architecture of the decoder is described and the results of the VLSI synthesis are presented. The soft-resolution decoding of the Golay codes has been studied and the architecture of the decoder has been described.

D. *2010, Photoacoustic Signal Generation with Golay Coded Excitation Shin-Yuan Su, and Pai-Chi Li.*

Photoacoustic imaging (AP) has the potential to image soft tissue with high contrast and high spatial resolution. Conventionally, a Q-switching Nd: YAG laser providing ns pulse duration and pulse energy mJ is suitable for PA applications. However, such a laser is typically cumbersome and expensive. On the other hand, a small diode laser with a low relative cost is potentially useful for performing PA imaging because it provides a PRF up to kHz, but the pulse energy of such a laser is generally too low for one Generation of effective PA. In this study, we proposed an excitation encoded by Golay using a diode laser to generate a PA signal. A high frequency 20 MHz PA transducer integrated into an optical fiber has been proposed to allow retrograde ultrasound and PA detection. The signal-to-noise ratio (SNR) of the generated PA signals of different Golay code lengths (i.e., 2, 4, 16 and 256 bits) was evaluated and pulse durations 25, 50, 100 and 200 ns).

E. Dec.2009, High-Speed Low-Complexity Golay Decoder Based on Syndrome-Weight Determination Ming-Haw Jing, Yih-Ching Su, Jian-Hong Chen, Zih-Heng Chen, Yaotsu Chang,

In this research work, we present a hardware decoder of very high bit rate and efficient in the zone of the binary code (23, 12, 7) of Golay. The key feature of this proposed algorithm is the rapid determination of error positions by analyzing the weight of syndromes without large operations of finite fields. By comparing with the algorithm using a syndrome, the proposed algorithm is more suitable for designing parallel material using two syndromes. For a common FPGA technology, the complete system occupies only 666 logical elements and the delay is 25.9 ns; For a CMOS technology of 0.18 μm, the result is an area of 0.026 mm2 and a throughput of 2.58 Gbps. A very high speed decoder of the binary code (23, 12, 7) of Golay has been proposed. The key feature of this proposed algorithm is the rapid determination of the weight of the syndrome in a parallel architecture.

F. Aug. 2006 On Construction of the (24, 12, 8) Golay Codes, Xiao-Hong Peng, Paddy G. Farrell,

Two product matrix codes are used to construct the Golay binary code (25, 12, 8) by the direct sum operation. This construction provides a systematic way to find appropriate linear block component codes (8,4,4) to generate the Golay code, and it generates and extends existing methods that use a similar construction framework. The built code is simple to decode. The authors have shown that the Golay binary code (24, 12, 8) can be constructed as the direct sum of two matrix codes involving four component codes, two of which are simple linear block codes (a repetition code and An SPC code). The other two component codes are two different codes (8, 4, 4); One of them is a systematic code and the other is its modified version. There are eight different modified codes that meet the construction criteria or rules presented. It is not difficult to show that the eight corresponding codes (24, 12, 8) formed by our construction represent eight different, although partially overlapping, code subspaces, but they are all equivalent or areomorphic to (24, 12, 8).

V. Conclusion

This paper presents a review on Golay code. A binary Golay code is a type of linear error-correcting code used in digital communications. The binary Golay code, along with the ternary Golay code, has a particularly deep and interesting connection to the theory of finite sporadic groups in mathematics. There are various methods for representing Golay code which are defined by numerous researchers are present in this paper.

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