

Design of Reed Solomon Encoder and Decoder

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Abstract: Reed-Solomon codes are used for error detection and correction for reliable communication on noisy channel. The implementation of Reed-Solomon encoder and decoder for RS (255,239) is proposed. Error correction codes are also known as forward error correction codes because it avoids the back-channel or retransmission of data. So, Reed-Solomon codes are preferred for error checking. The main part of reed-Solomon encoder is the linear feedback shift register that is implemented using VHDL and in decoder, syndrome calculator, Berlekamp-Massey Algorithm are the main components. Reed Solomon encoder and decoder have input and output pipelined buffer in order to improve the speed and reduce the error in the system. This pipelined arrangement will improve the throughput of the system with a minimum overhead of area and power. Here Reed-Solomon code will be synthesized using VHDL on Xilinx and implemented on FPGA.

Key Words: Reed Solomon (RS) codes, Error Correcting Code (ECC), Linear feedback shift register (LFSR), Berlekamp-Massey algorithm, Chien search algorithm.

I. Introduction:

Digital communication is immune to errors but still there exists some errors due to change in the bits. To overcome this problem error correcting codes are widely used in digital communication. The most commonly used error correcting code is Forward error correction code (FEC) and it is one of the important part of digital communication systems.[1] Wireless technology is fast becoming a trend in present communication systems, as the demand for greater bandwidth allocation is being addressed by fixed wireless broadband access. However, the use of free space, as a medium, introduces many sources of error in the transmission of data across the channel. Burst Error (contiguous errors in the bit stream) is a common occurrence in digital communication systems, broadcasting systems and digital storage devices. Forward error correction is a technique in which redundant information is added to the original message, so that some errors can be corrected at the receiver, using the added redundant information. Reed Solomon Encoder and Decoder comes under the category of forward error correction codes [3]

Reed Solomon is the most reliable forward error correcting code. It is called as FEC as it avoids back channel interference. Reed Solomon codes are non-binary BCH error correcting codes. In 1959, Irving Reed and Gus Solomon described a new class of error correcting codes called Reed-Solomon codes [2]. RS codes are based on arithmetic of finite fields and Galois fields. The digital audio disk or compact disk uses Reed Solomon codes for error detection and error concealment [1] Reed-Solomon codes were constructed and decoded through the use of finite field arithmetic. Reed Solomon codes are burst error correcting codes. RS codes detect and correct errors on symbol level i.e. if there is any error of 1-bit or 2-bit or m bit in symbol of m bit then these error correcting codes will correct the complete symbol. Before the transmission of data, RS encoder appends some parity bits to the data so that at decoder these bits can be used for error detection and correction. Algorithm used for encoding RS codes is very complex as calculations are done

over Galois field. [4]. The structure of RS codeword shown in figure below. [5]

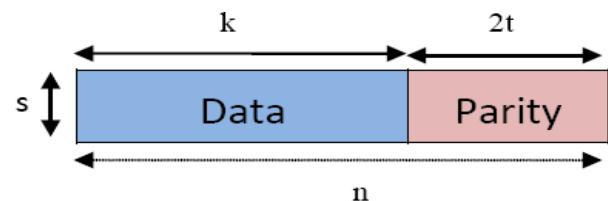


Fig. 1 The Structure of a RS Codeword

Where, k = message length
 n = block length
 $2t$ = parity length
 s = symbol length

II. Reed Solomon encoder and Decoder

A Reed-Solomon code is a q^m -ary BCH code of length $q^m - 1$. The coded symbols are elements of the corresponding Galois field $GF(q^m)$. In this paper, we will be dealing with extensions of binary codes, i.e., $q=2$. This field is generated by a primitive irreducible polynomial of degree m . The message of $k \cdot m$ bits is divided into k symbols, each symbol being an m -bit element from $GF(2^m)$. Each symbol is regarded as a coefficient of $k-1$ degree polynomial, $m(x)$. A total of $2t$ parity symbols are appended to the message, thus making a systematic encoding format. Such an RS code is denoted by 2 parameters, n and k , and is written as $RS(n, k)$. The distance of RS codes is: Distance = $n - k + 1 = 2t + 1$. Here there are k message symbols, and $n - k = 2t$ parity symbols, for a total of n symbols. RS codes may be shortened to $RS(n', k')$, where $n' = n -$ and $k' = k - 1$. In this case, the distance property $d = 2t + 1$ still holds. The encoded message, $c(x)$, is formed as follows: 1. Multiply the message $m(x)$ by x^{2t} . 2. From the parity symbols, $b(x)$, by dividing the above result by the generator polynomial. 3. $c(x) = m(x) \cdot x^{2t} + b(x)$. Thus, in order to specify a Reed-Solomon code completely, the following items must be described. 1. The degree of the field generator polynomial, m , and its coefficients. 2. The error-correcting capability, t , of the code. 3. The number of message

symbols, k. 4. The log of the initial root of the code generator polynomial, m_0 . [7]

The Reed Solomon Encoder reads in k data symbols computes the n – k symbols, append the parity symbols to the k data symbols for a total of n symbols. Data symbol is represented in polynomial form with highest power of x representing MSB and lowest power of x representing LSB. Input data symbols will contain powers from 0 to k – 1 (LSB to MSB) and output symbols will contain powers from 0 to n-1 (LSB to MSB) [8].

Reed Solomon codes are constructed using a special type of polynomial called generator polynomial $g(x)$ having α as its one of root is given by (1) and (2).

$$g(x) = (x + \alpha^0)(x + \alpha^2)(x + \alpha^3) \dots (x + \alpha^{2t}) \quad (1)$$

$$g(x) = \quad (2)$$

Encoding is achieved by adding the remainder of a GF polynomial division into the message. For implementation of this division method, linear feedback Shift Register (LFSR) technique is used [9].

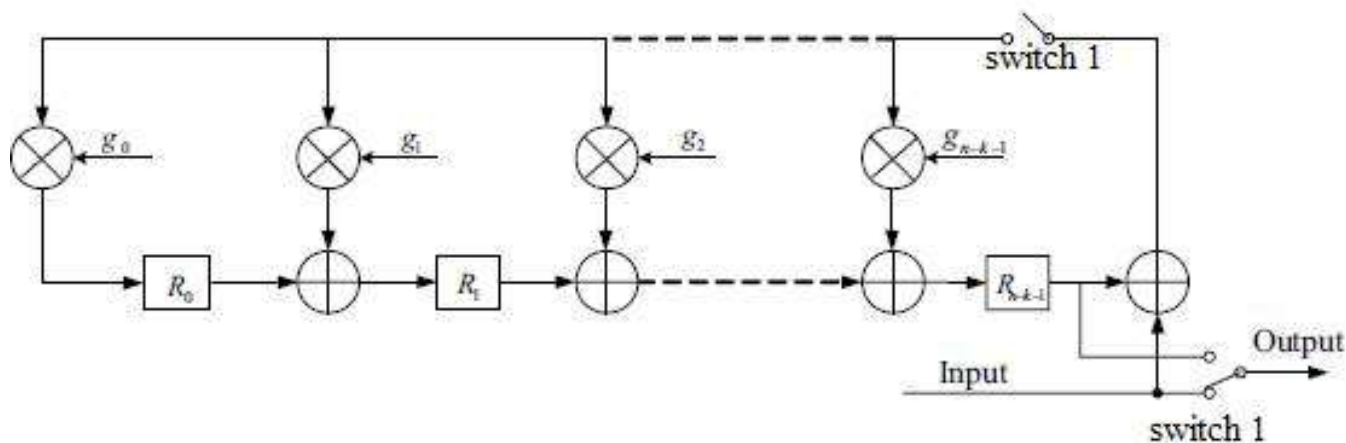


Fig.3. Block diagram of RS Encoder[6]

The decoding procedure for Reed- Solomon codes involves determining the locations and magnitudes of the errors in the received polynomial $R(x)$. Locations are those powers of x in the received polynomials whose coefficients are in error. Magnitudes of the errors are symbols that are added to the corrupted symbol to find the original encoded symbol.

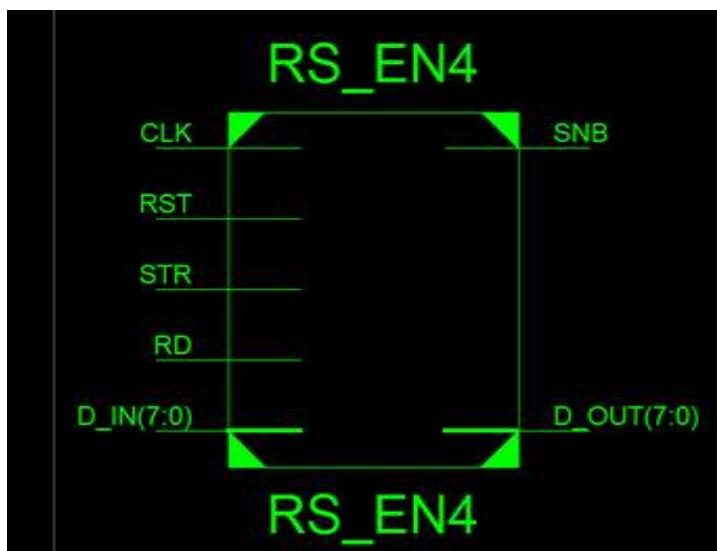


Fig. RTL schematic of Reed Solomon encoder

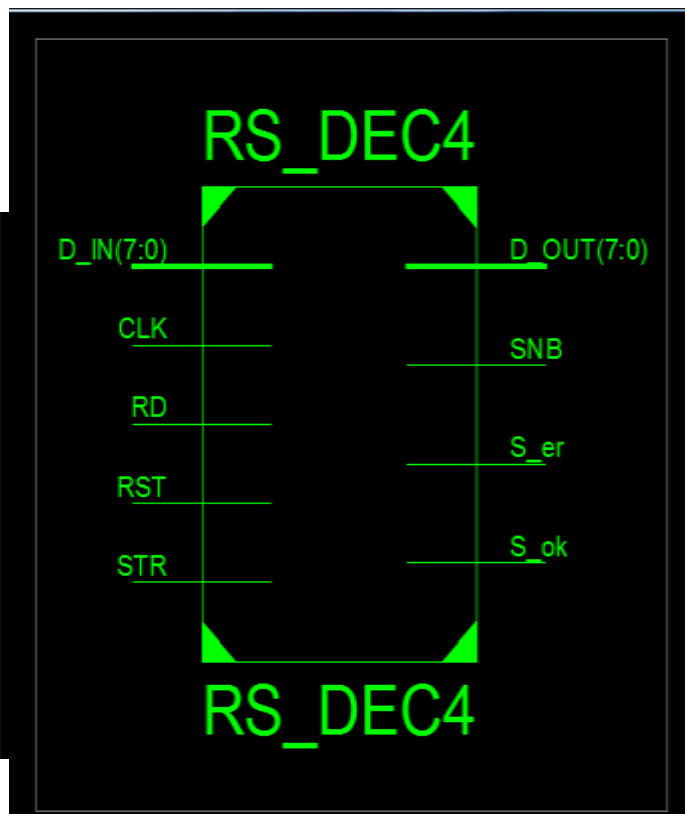


Fig. RTL view of Reed Solomon Decoder



Fig. Simulation waveform of Reed Solomon Encoder

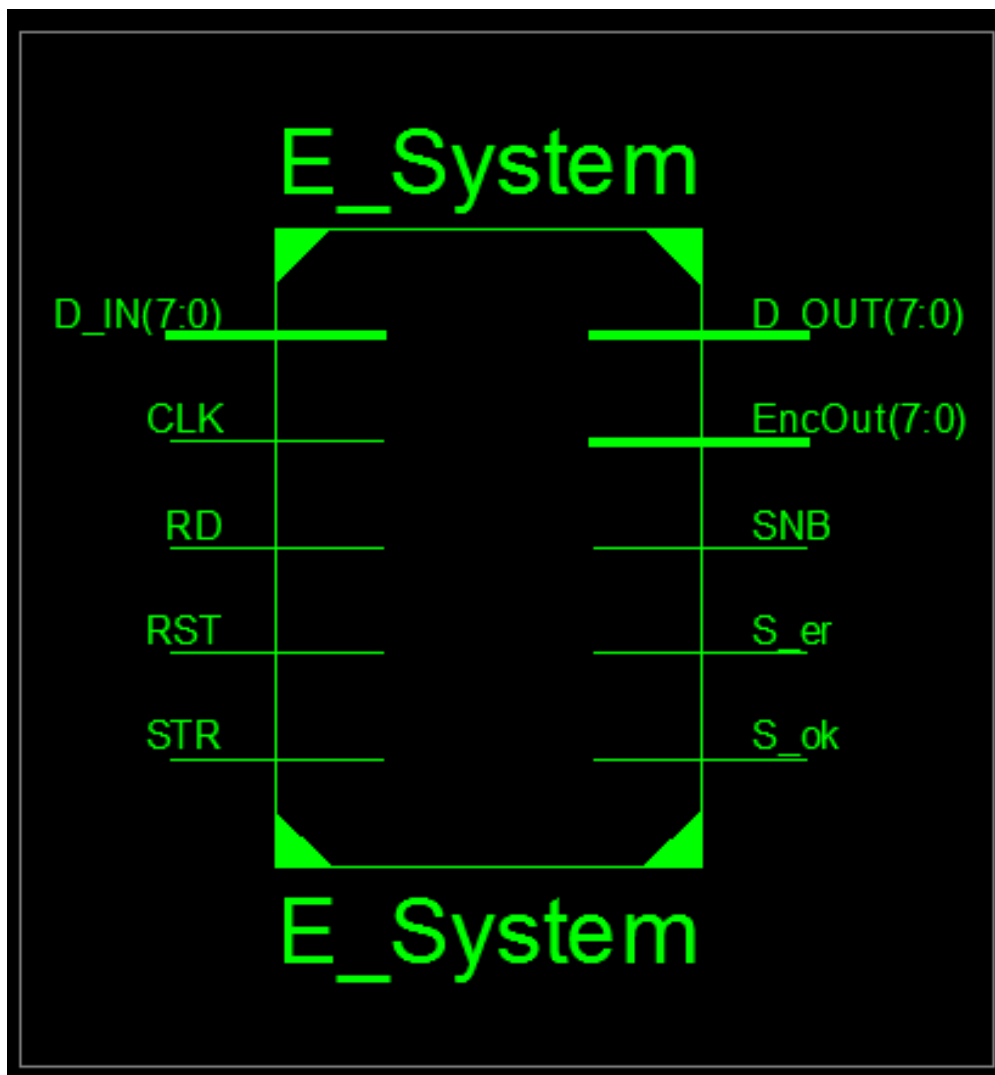


Fig. RTL view of Reed Solomon encoder and decoder

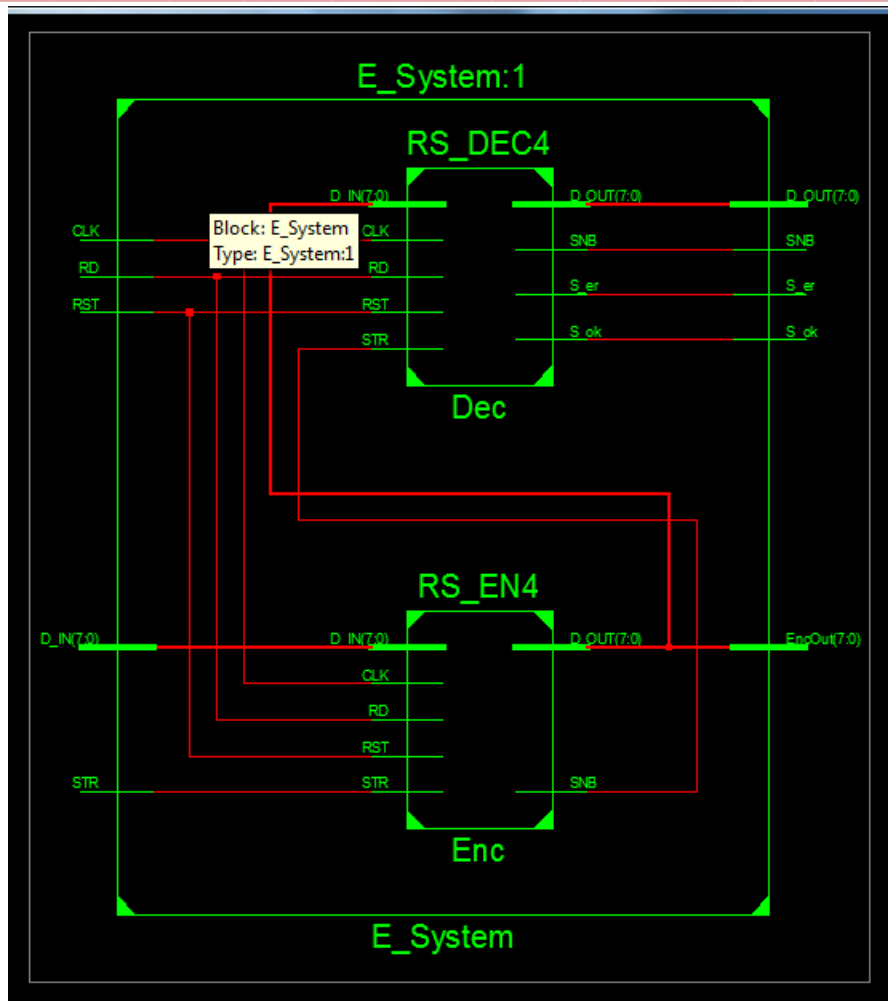


Fig. Internal structure of Reed Solomon Encoder and Decoder

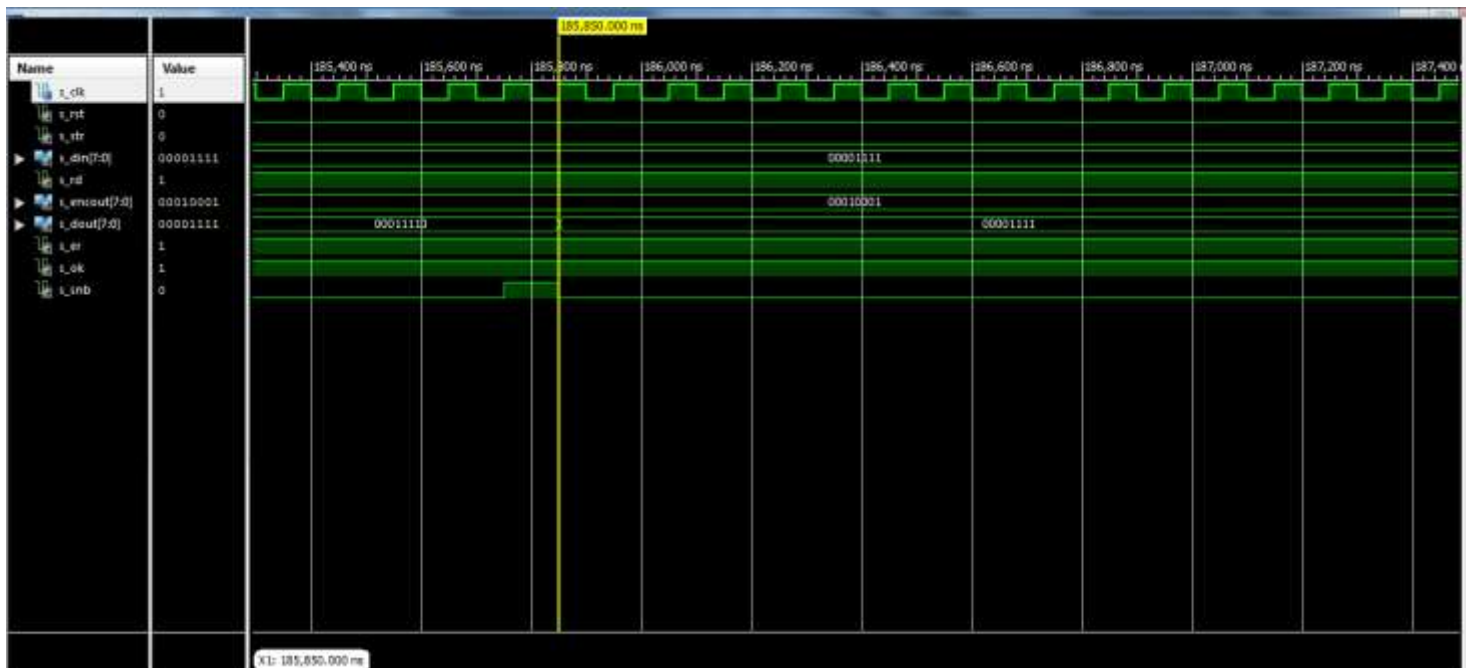


Fig. Simulation waveform of Reed Solomon Encoder and Decoder

Logic Utilization	Used	Available	Utilization
Number of Slice Registers	17076	28800	59%
Number of Slice LUTs	11601	28800	40%
Number of fully used LUT-FF pairs	6736	21941	30%
Number of bonded IOBs	31	480	6%
Number of Block RAM/FIFO	2	60	3%
Number of BUFG/BUFGCTRLs	2	32	6%

Fig. Device utilization summary

Conclusion:

We will work on pipelined Reed Solomon encoder and decoder. Our work will improve the speed of RS encoder and decoder. This work also improve the efficiency of entire system. This work will improve the delay and throughput of Reed Solomon system.

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