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Title : Burst Error Correcting Bose-Chaudhuri-Hoquenghem (BCH) Coding for the p*64Kbit H261 Video Codec

Source : UK

1.0 Introduction

Several BCH codes are suitable for practical use for video conferencing applications. This document discusses the possible use of BCH(511,484).

BCH(511,484)

Generator Polynomial

$$g(x) = X^{27}+X^{26}+X^{24}+X^{22}+X^{21}+X^{16}+X^{13}+X^{11}+X^{9}+X^{8}+X^{6}+X^{5}+X^{4}+X^{3}+1$$

Block Length	= 511
No Error correction bits	= 27
Coding/Decoding Delay	= 8mS at 64Kbits/S
Redundancy	= 5.28%
Random Error Correction	= 3 random errors per block potentially.
Burst Error Correction	= Max burst length of 11 bits

BCH codes decoded to correct multiple random errors and Reed-Solomon codes both have powerful error correcting abilities. This is, however, at the expense of complex hardware. The decoding process involves the calculation of multiple syndromes, their translation to error positions and calculation of error magnitudes (for RS codes). Each stage comsumes a considerable amount of hardware.

BCH codes may also be decoded to correct burst errors. This may be achieved in a single stage process with comparitively small hardware overheads, and still provide a good error correcting performance.

FIG 1 shows the BCH(511,484) Encoder. It consists of a 27-stage linear feedback shift registers and a 9-bit counter for timing.

FIG 2 and FIG 3 shows the BCH(511,484) Decoder. This consists of two 27-bit linear feedback shift registers, a 511 stage delay shift register, and a 10-bit counter for timing. for burst only

Thus an Encoder/Decoder pair may be implemented in a single gate array (3000 gates) and a delay shift register.

2.0 Random Error Correcting Performance

Table 1 Shows the probabilities of the occurance of errors within a block of length 511 for various line error rates.

Table 2 Shows the random error correcting performance of the BCH(511,484) burst corrector, allong with results for some other codes. From simulation results it was found that :-

Number of Non-Consecutive Errors per Block In	Number of Errors per Block Out
0	0
1	0
2	1.95
3	3
4	4
.	.
.	.
.	.

From earlier work on the H261 algorithm it was found that

Error Rate	Effect on picture quality
10^{-6}	Very few perceivable errors
10^{-5}	Noticeable distortion
10^{-4}	Bad distortion
10^{-3}	Total distortion
10^{-2}	Frame breakdown

kbit/s
64 → 2 Mbit/s
tolerable

3.0 Burst Error Correcting Performance

BCH(511,484) can correct all single bursts up to length 11-bits.

Table 3 shows the codes performance to burst errors. For this the assumption that all errors occur in bursts of 8-bits. It was found from simulation results that when faced with multiple bursts the code produced on average no extra errors by mis-correction.

Table 4 shows the probabilities of 0,1,2,3,4 bursts occurring in a block of length 511 for various error rates.

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4.0 Conclusions

BCH(511,484) provides good error correction to random errors. At low error rates ($< 10^{-7}$) the probability of a block containing 2 or more errors is very small, and the large hardware overhead required to correct 2 or more random errors per block is probably not worthwhile. At high error rates (10^{-4}) double random error correction is more effective. However, BCH(511,484) gives output error rates of better than $5x10^{-6}$.

The single burst correcting ability of the code is very good. The code also copes well with multiply bursts, even though the coding can only correct 1 burst per block. From Table 3 it can be seen that for burst errors with a BER of 10-4 the code gives an output error rate of $1.2x10^{-6}$.

The hardware requirements for the BCH(511,484) burst corrector are very small, especially when compared to Reed-Solomon coding and BCH random error correction.

In summary, BCH(511,484) coding gives a good error correcting peformance with approximately one tenth of the hardware required for double random error correcting BCH and Reed-solomon codes.

5.0 Proposal

Adopt BCH(511,484) coding for error correction in the p*64Kbits H261 video codec.

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Probability of Block (511-bits) containing Errors

Error Rate In (BER)	0 errors	1 error	2 errors	3 errors	4 errors
10^{-8}	? 1.00000	$5.110E^{-6}$	$1.303E^{-11}$	$2.210E^{-17}$	$1.123E^{-22}$
10^{-6}	$9.995E^{-1}$	$5.107E^{-4}$	$1.302E^{-7}$	$2.210E^{-11}$	$1.123E^{-14}$
10^{-5}	$9.949E^{-1}$	$5.084E^{-3}$	$1.296E^{-5}$	$2.200E^{-8}$	$1.117E^{-10}$
10^{-4}	$9.502E^{-1}$	$4.856E^{-2}$	$1.238E^{-3}$	$2.101E^{-5}$	$1.067E^{-6}$
10^{-3}	$5.997E^{-1}$	$3.068E^{-1}$	$7.831E^{-2}$	$1.330E^{-2}$	$6.763E^{-3}$
10^{-2}	$5.883E^{-3}$	$3.036E^{-2}$	$7.821E^{-2}$	$1.340E^{-1}$	$6.878E^{-1}$

Notes :

1. Error Rate assumes Gaussian distribution.

2. Probabilities show probability that block of length 511 contains 0,1,2,3,4 single random errors.

$$P(n) = P_e^{n}(1-P_e)^{511-n} * {}^{511}C_n$$

Where n is number of errors in block.
P_e is error rate.
P(n) is probability of n errors in block.

<u>TABLE 1: Probabilities of Errors Occuring in Block</u>

Error Rate In (BER)	Error Rate Out BCH(511,484) Burst Corr.	BCH(511,493) 2-Random	2-random Perfect Rand	3-random perfect Rand	RS(255,251)
10^{-8}	$1.36E^{-20}$	$< E^{-20}$	$< E^{-20}$	$< E^{-20}$	$< E^{-20}$
10^{-6}	$5.10E^{-10}$	$1.72E^{-13}$	$1.29E^{-13}$	$< E^{-20}$	E^{-12}
10^{-5}	$5.09E^{-8}$	$1.73E^{-10}$	$1.29E^{-10}$	$2.22E^{-13}$	E^{-9}
10^{-4}	$4.97E^{-6}$	$1.69E^{-7}$	$1.25E^{-7}$	$2.12E^{-9}$	E^{-6}
10^{-3}	$4.00E^{-4}$	$1.32E^{-4}$	$9.32E^{-5}$	$1.51E^{-5}$	E^{-3}
10^{-2}	$9.94E^{-3}$	$1.12E^{-2}$	$9.63E^{-3}$	$8.85E^{-3}$	E^{-2}

Notes :

1. Error Rate in is BER assuming Gaussian distribution of single random errors
2. BCH(511,484) column gives error rate out after correction using burst correction only.
3. BCH(511,493) Column gives error rate out after correction using 2-rand error correction.
4. 2-Random (Perfect) gives error rate out after perfect 2-random error correction, ie corrector makes no mis-corrections.
5. 3-Random (Perfect) gives error rate after perfect 3-random error correction, ie corrector makes no mis-corrections.

<u>TABLE 2 : Random Error Correcting Performance</u>

Error Rate In (BER)	Error Rate Out BCH(511,484)
10^{-8}	$1.36E^{-20}$
10^{-6}	$1.27E^{-10}$
10^{-5}	$1.27E^{-8}$
10^{-4}	$1.27E^{-6}$
10^{-3}	$1.20E^{-3}$
10^{-2}	$7.21E^{-3}$

15.625 μs
156 ms

MTBF

	1	6	24	30
	64	384	1536	1920
10^{-4}	156 ms	26 ms	6.5 ms	5.2 ms
10^{-5}	1.56 s	260 ms	65 ms	52 ms
10^{-6}	15.6 s	2.6 s	650 ms	520 ms
10^{-7}	156 s	26 s	6.5 s	5.2 s
10^{-8}	1560 s	260 s	65 s	52 s
10^{-9}	15600 s	2600 s	650 s	520 s

Notes :

1. All errors occuring in bursts of 8-bits.

   On average each burst will corrupt 4-bits

   Thus Burst Rate = BER/4.

TABLE 3 : Burst Error Correcting Performance Of BCH(511,484)

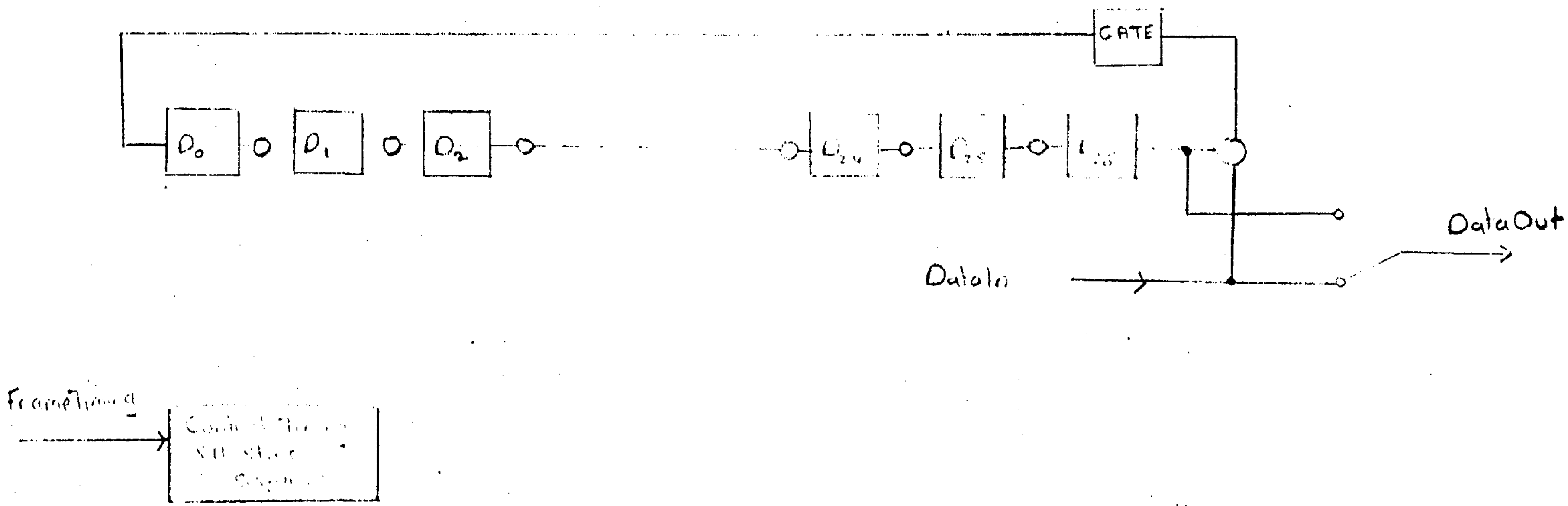
Error Rate In (BER)	Probability of Block (511-bits) containing Bursts				
	0 bursts	1 burst	2 burst	3 bursts	4 bursts
10^{-8}	1.00000	$1.278E^{-6}$	$8.144E^{-13}$	$3.454E^{-19}$	$4.387E^{-25}$
10^{-6}	$9.999E^{-1}$	$1.277E^{-4}$	$8.143E^{-9}$	$3.454E^{-13}$	$4.387E^{-17}$
10^{-5}	$9.987E^{-1}$	$1.276E^{-3}$	$8.134E^{-7}$	$3.450E^{-10}$	$4.382E^{-13}$
10^{-4}	$9.873E^{-1}$	$1.261E^{-2}$	$8.041E^{-5}$	$3.411E^{-7}$	$4.332E^{-9}$
10^{-3}	$8.801E^{-1}$	$1.125E^{-1}$	$7.171E^{-3}$	$3.042E^{-4}$	$3.865E^{-5}$
10^{-2}	$2.783E^{-1}$	$3.564E^{-1}$	$2.278E^{-1}$	$9.686E^{-2}$	$1.233E^{-1}$

Notes :

1. Error Rate assumes all errors occur in bursts of 8-bits.

2. On average aburst of 8-bits corrupts 4-bits, ie creates 4 errors.

<u>TABLE 4: Probabilities of Bursts Occuring in Block</u>



State 1 – 484 : Data Out = Data In
Gate = ON

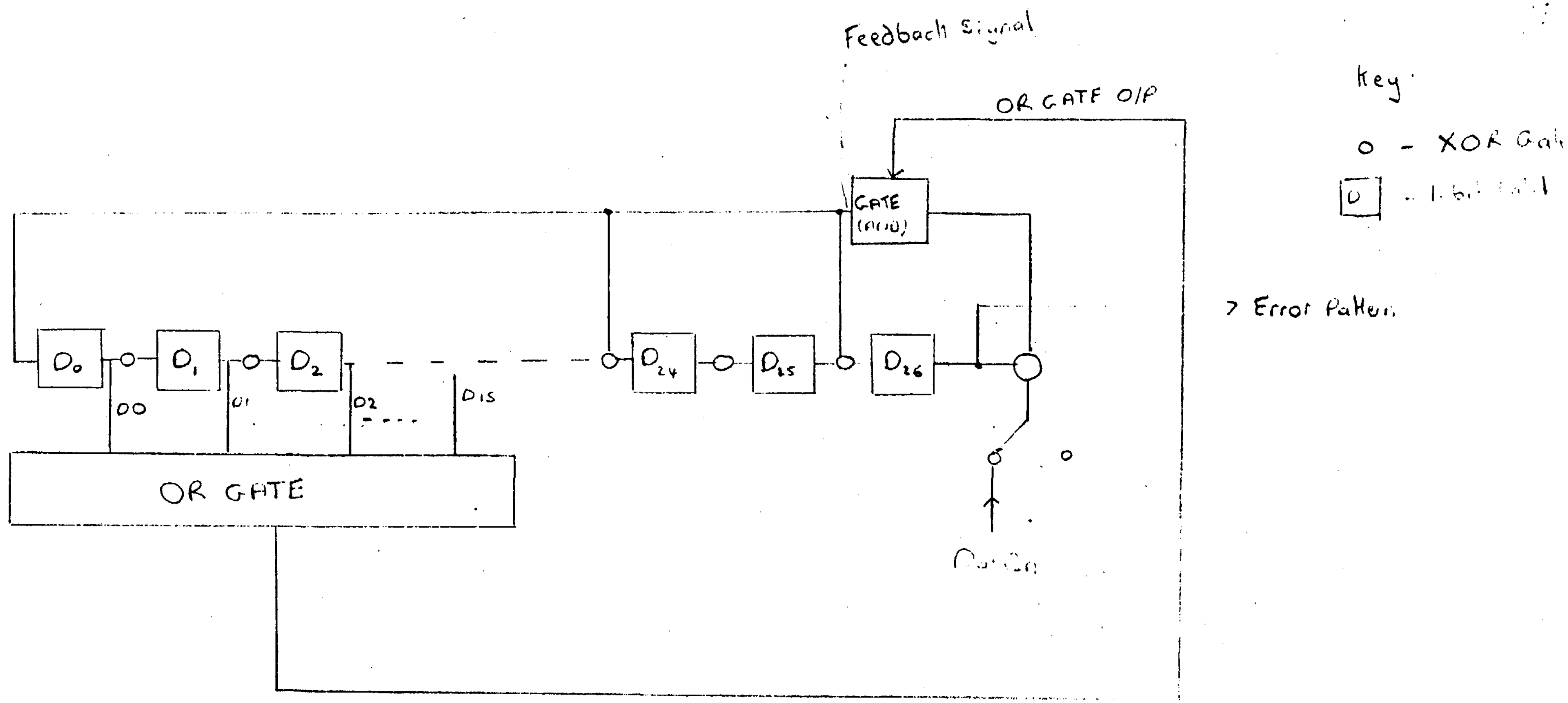
State 485 – 511 Data Out = Data Out [26]
Gate = OFF

⊕ – XOR

[D] – 1 bit Latch

Generator Polynomial $g(x) = X^{27} + X^{26} + X^{24} + X^{22} + X^{2}$ …

Fig 1 BCH (511, 484) Encoder



State 1 - 511 : Feedback = DataIn XOR DataOut[26]

State 512 - 1022 : Feedback = ORGate O/P AND DataOut[26]

generator Polynomial $g(x) = X^{27} + X^{26} + X^{24} + X^{22} + X^{21} + X^{16} + X^{13} + X^{11} + X^{9} + X^{8} + X^{6} + X^{5} + X^{1} + 1$

<u>Fig 2 Linear Feedback Shift Register For BCH (511, 484) Burst Corrector</u>

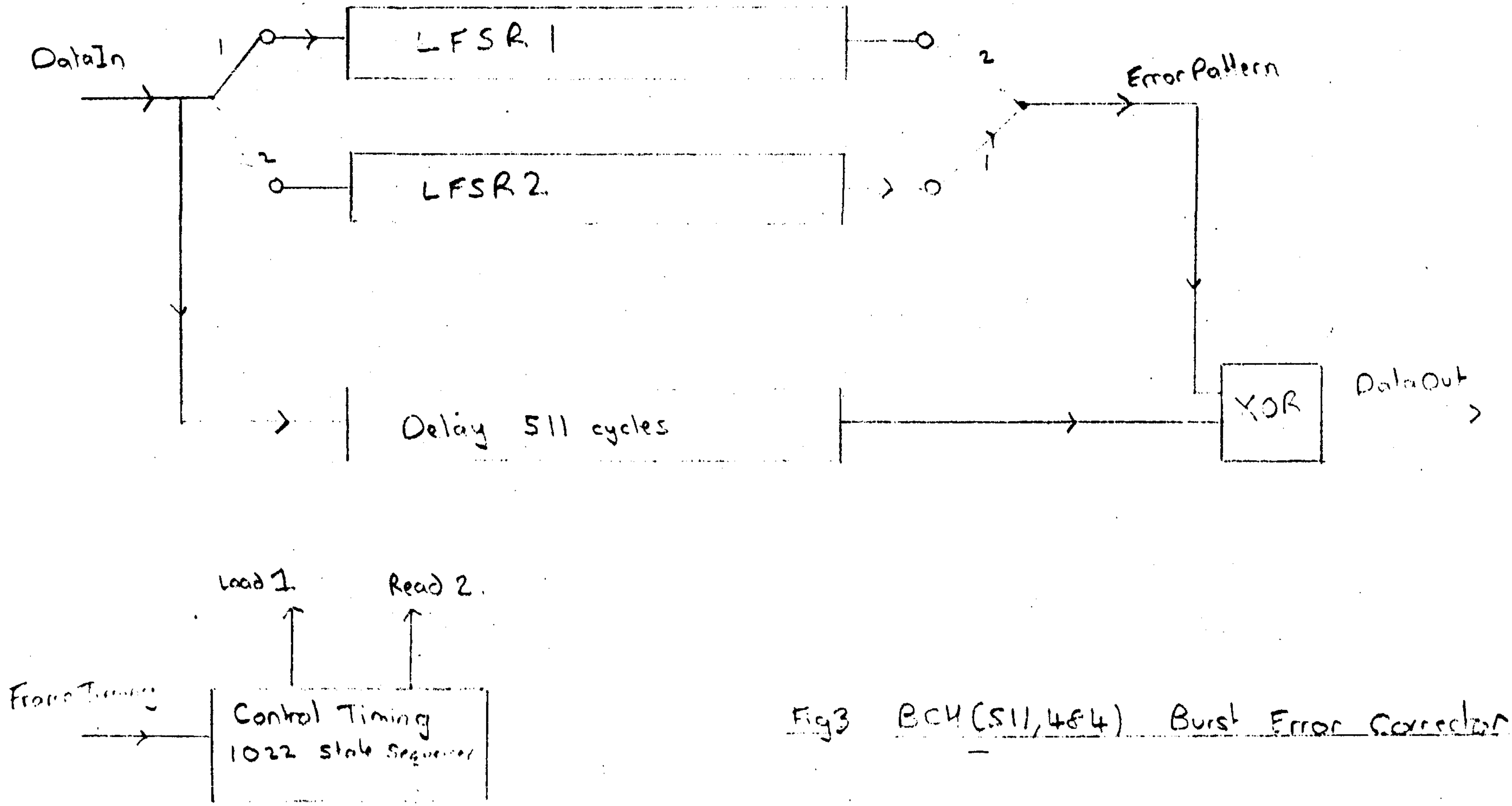


Fig3 BCH (511,484) Burst Error Corrector Decoder