Blue-Salmon HURRICANE-Series 2W encoder

v01.1a

1. Introduction

Core Overview

The HURRICANE-Series 2W encoder is a RTL code that implements an optimized Blue-Salmon (BS) encoder core.

BS codes are a class of error-correcting codes used to detect and correct errors that might be introduced into digital data when it is transmitted or stored. Error-correcting codes incorporate redundancy in data. With this redundancy, only a subset of all possible transmissions contains valid messages. This means the valid codes are separated from each other so errors are not likely to corrupt one valid code into another. The encoded data can then be transmitted or stored.

When recovering data, a decoder first determines if a received message is valid. This step is called error detection. If an error is detected, the decoder finds the valid message "closest" to the received one. Provided the number of corrupted symbols (bytes) does not exceed a specified range, the message found is the one that was transmitted. Thus, the decoder conducts error correction.

Blue-Salmon forward error correction can be used where extreme speed and ultra-low latency are important and good error correction performance is required. For example, the core can be used in high-speed wired networking, satellite and space communications, digital video broadcast, and data storage.

An interesting property is reasonable burst error correction performance, as it does not matter how many bits are received in error within a single input symbol. BS codes can be used in concatenation with other codes. The BS code can correct some bursts of errors that sometimes occur when the concatened decoder fails. If necessary, the burst error correction capability can be further improved by using interleaved Blue-Salmon cores.

Key Features

- HURRICANE-Series 2W encoder - designed for high data rate.

- Double Width - 2 symbols per clock cycle.
- Ultra-low latency (3 clock cycles).

- Extreme performance error correction solution when paired with a decoder of the Blue-Salmon family.
- Parameterizable Blue-Salmon encoder core.
- Compatible with all other members of the Blue-Salmon Error Correction System.
- Encoded block size selectable from 2 to 254 symbols, in steps of 2.
- Fully synchronous design using a single clock.
- Supports continuous output data with no gap between encoded blocks.
- Low resources and modest core area.

2. Functional Description

Theory of Operation

Properties of Blue-Salmon codes

The BS code is a block code generally designated as BS(n, k) with m-bit symbols, where k is the number of data symbols per block, n is the number of symbols the encoded message contains, and the symbol size can be in a range from one to several bits. The encoded message called "encoded block" has $n - k$ redundant parity symbols. The code can correct up to $t = (n - k) / 2$ symbols.

The Blue-Salmon Error Correction System has the following characteristics:

‣ $m = 8$ number of bits per symbol
‣ $n = 2$ to 254   number of symbols per block, in steps of 2
                                  restricted range for the HURRICANE-Series 2W
‣ $k = n - 2$ number of data symbols per block
‣ $t = 1$ number of symbols that can be corrected

The BS code is a systematic code, since the encoder simply appends the parity symbols to the otherwise unchanged original data sequence.

The BS code is a linear code. In practice, this means that every possible 8-bit word is a valid symbol. For instance, any 8-bit word can be transmitted directly in the data part of an encoded block, so the encoder does not care what the nature of the data is, whether it is a binary stream separated into blocks of 8-bit symbols, ASCII codes, etc. Given a symbol size 8, the theoretical maximum BS encoded block size is 255.

A corrupted symbol can have one or more (up to 8) erroneous bits. The BS code can correct one symbol error containing one to eight corrupted bits. This property makes the Blue-Salmon system a useful tool for protecting data impacted by burst errors.

Galois field math

BS codes are based on Galois fields (GFs), also called finite fields. Rules of the GF arithmetic are different from the usual arithmetic rules. For instance, GFs are finite fields. This means that any field element, as well as a result of the element addition and multiplication, can be presented by a fixed-length binary word. To generate and decode a BS code of 8-bit symbols, an 8-bit-wide GF is used.

Shortened codes

A shortened encoded block contains fewer symbols than the maximum 255. The shortened encoded block keeps the same number of parity symbols, 2, to correct 1 symbol error. Therefore, the number of data symbols in the shortened code is reduced by the same amount as the overall encoded block length. For instance, BS(192, 190) is the shortened code of BS(255, 253). Both codes have a symbol width of 8 and use the same number of parity symbols, 2.

3. Interface Descriptions

Ports

The port signals for the HURRICANE-Series 2W encoder are defined as follows:

Signal	Direction	Description
clk	Input	Clock
clken	Input	Clock enable
clr_n	Input	Clear, active low
arst_n	Input	Asynchronous reset, active low
data_a_in[7:0] data_b_in[7:0]	Input	Data input, a and b
aux_in[NAB-1:0]	Input	Auxiliary input
val_r1_in	Input	Valid data/aux, input side (when rdy_in = '1')
val_r0_in	Input	Valid aux, input side (when rdy_in = '0')
sync_in	Input	Synchronization of encoded block, input side
rdy_in	Output	Ready to accept data, input side
data_a_out[7:0] data_b_out[7:0]	Output	Data output, a and b
aux_out[NAB-1:0]	Output	Auxiliary output
val_out	Output	Valid data/aux, output side
sync_out	Output	Synchronization of encoded block, output side

Signal Functionality

clk - input

Clock. Rising edge clock signal.

clken - input

Clock enable. When this signal is at level '0' the core is frozen. In this state all inputs (except **arst_n**) are ignored and the core retains its current state. Connect to '1' if not used.

clr_n - input

Clear, active low. Synchronous signal. Reset all registers to their initial state. Connect to '1' if not used.

arst_n - input

Asynchronous reset, active low. Reset all registers to their initial state. Connect to '1' if not used.

data_a_in[7:0] - input

data_b_in[7:0] - input

Data input, a and b. Data to be encoded. The symbols order is a then b.

aux_in[NAB-1:0] - input

Auxiliary input. This input is used to pass information through the BS encoder with exactly the same latency as data_#_in. This could be used to tag each symbol with marker bits, for example. The number of aux_in bits (NAB) is parameterizable. Connect to '0' if not used.

val_r1_in - input

Valid data/aux, input side. This input is relevant only when rdy_in = '1'. In the other case it is ignored. This signal is used to inform the BS encoder that valid data and auxiliary information is present at the data_#_in and aux_in inputs.

val_r0_in - input

Valid aux, input side. This input is relevant only when rdy_in = '0'. In the other case it is ignored. This signal is used to inform the BS encoder that valid auxiliary information is present at the aux_in inputs. Connect to '1' if not used.

sync_in - input

Synchronization of encoded block, input side. This input can be used to inform the BS encoder that the symbols present at the data_#_in are the first symbols of an encoded block. This signal is not required for regular operation, however it can be used to resynchronize the data flow. When this signal is set to '1' during the first symbols of an encoded block nothing happens. On the contrary, when this signal is set to '1' in the middle of an encoded block the BS encoder restarts the coding operations from this point. Connect to '0' if not used.

rdy_in - output

Ready to accept data, input side. This signal is set to '1' during the input of the data to be encoded and set to '0' during the dead time reserved for the insertion of the two redundancy symbols. When this signal is set to '1' the BS encoder is ready to accept new data at the data_#_in input and new auxiliary information at the aux_in input. When this signal is set to '0' the BS encoder is not ready to accept data, however it can continue to accept auxiliary information at the aux_in input.

data_a_out[7:0] - output

data_b_out[7:0] - output

Data output, a and b. Encoded data. The symbols order is a then b.

aux_out[NAB-1:0] - output

Auxiliary output. Unencoded auxiliary information. Leave unconnected if not used.

val_out - output

Valid data/aux, output side. This signal is used to inform that the BS encoder has valid data and auxiliary information present at the **data_#_out** and **aux_out** outputs.

sync_out - output

Synchronization of encoded block, output side. This signal is used to inform that the symbols present at the **data_#_out** are the first symbols of an encoded block. Leave unconnected if not used.

Configuration Parameters

The configuration parameters for the HURRICANE-Series 2W encoder are defined as follows:

Name	Range	Description
SBS	2 to 254 in steps of 2	Size of BS encoded block (number of symbols).
NAB	1 to 64	Number of **aux_in** and **aux_out** bits.

Core Characteristics

The Blue-Salmon encoder core has the following characteristics:

Name	Value	Description
Latency	3 clock cycles	Delay between the data input and output.
Data rate	2 symbols per clock cycle	Continuous data rate out of the encoder.

4. Product Support

Website

You can browse a variety of technical and non-technical information about the Blue-Salmon Error Correction System at:

bs.arrigonline.ch

5. List of Changes

Encoder Core

The following table lists the critical changes that were made in each revision of the encoder core:

Revision	Changes
v01.1 (August 2013)	First core version.

Documentation

The following table lists the critical changes that were made in each revision of the documentation:

Revision	Changes
v01.1a (August 2013)	Preliminary Data Sheet.