## Contents

1. **Intel(R) Intelligent Storage Acceleration Library** ........................................... 1

2. **v2.21 Intel Intelligent Storage Acceleration Library Release Notes** ......................... 3

3. **Instruction Set Requirements for arch-specific functions (non-multibinary)** ................. 7

4. **Data Structure Index** .............................................................................................. 11
   4.1 **Data Structures** ................................................................................................. 11

5. **File Index** .................................................................................................................. 13
   5.1 **File List** ............................................................................................................. 13

6. **Data Structure Documentation** .................................................................................... 15
   6.1 **BitBuf2 Struct Reference** .................................................................................. 15
       6.1.1 **Detailed Description** ................................................................................ 15
   6.2 **inflate_huff_code_large Struct Reference** ......................................................... 16
   6.3 **inflate_huff_code_small Struct Reference** ......................................................... 16
   6.4 **inflate_state Struct Reference** ......................................................................... 16
       6.4.1 **Detailed Description** ................................................................................ 17
   6.5 **isal_huff_histogram Struct Reference** ............................................................... 17
       6.5.1 **Detailed Description** ................................................................................ 18
   6.6 **isal_hufftables Struct Reference** ....................................................................... 18
       6.6.1 **Detailed Description** ................................................................................ 18
   6.7 **isal_mod_hist Struct Reference** .......................................................................... 19
   6.8 **isal_zstate Struct Reference** ............................................................................. 19
       6.8.1 **Detailed Description** ................................................................................ 20
   6.9 **isal_zstream Struct Reference** ........................................................................... 20
       6.9.1 **Detailed Description** ................................................................................ 21
## 7 File Documentation

### 7.1 crc.h File Reference

<table>
<thead>
<tr>
<th>Subsection</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.1.1</td>
<td>Detailed Description</td>
</tr>
<tr>
<td>7.1.2</td>
<td>Function Documentation</td>
</tr>
<tr>
<td>7.1.2.1</td>
<td>crc16_t10dif()</td>
</tr>
<tr>
<td>7.1.2.2</td>
<td>crc16_t10dif_base()</td>
</tr>
<tr>
<td>7.1.2.3</td>
<td>crc16_t10dif_copy()</td>
</tr>
<tr>
<td>7.1.2.4</td>
<td>crc16_t10dif_copy_base()</td>
</tr>
<tr>
<td>7.1.2.5</td>
<td>crc32_gzip_refl()</td>
</tr>
<tr>
<td>7.1.2.6</td>
<td>crc32_gzip_refl_base()</td>
</tr>
<tr>
<td>7.1.2.7</td>
<td>crc32_ieee()</td>
</tr>
<tr>
<td>7.1.2.8</td>
<td>crc32_ieee_base()</td>
</tr>
<tr>
<td>7.1.2.9</td>
<td>crc32_iscsi()</td>
</tr>
<tr>
<td>7.1.2.10</td>
<td>crc32_iscsi_base()</td>
</tr>
</tbody>
</table>

### 7.2 crc64.h File Reference

<table>
<thead>
<tr>
<th>Subsection</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.2.1</td>
<td>Detailed Description</td>
</tr>
<tr>
<td>7.2.2</td>
<td>Function Documentation</td>
</tr>
<tr>
<td>7.2.2.1</td>
<td>crc64_ecma_norm()</td>
</tr>
<tr>
<td>7.2.2.2</td>
<td>crc64_ecma_norm_base()</td>
</tr>
<tr>
<td>7.2.2.3</td>
<td>crc64_ecma_norm_by8()</td>
</tr>
<tr>
<td>7.2.2.4</td>
<td>crc64_ecma_refl()</td>
</tr>
<tr>
<td>7.2.2.5</td>
<td>crc64_ecma_refl_base()</td>
</tr>
<tr>
<td>7.2.2.6</td>
<td>crc64_ecma_refl_by8()</td>
</tr>
<tr>
<td>7.2.2.7</td>
<td>crc64_iso_norm()</td>
</tr>
<tr>
<td>7.2.2.8</td>
<td>crc64_iso_norm_base()</td>
</tr>
<tr>
<td>7.2.2.9</td>
<td>crc64_iso_norm_by8()</td>
</tr>
<tr>
<td>7.2.2.10</td>
<td>crc64_iso_refl()</td>
</tr>
<tr>
<td>7.2.2.11</td>
<td>crc64_iso_refl_base()</td>
</tr>
</tbody>
</table>
CONTENTS

7.2.2.12 crc64_iso_refl_by8() .............................................................. 36
7.2.2.13 crc64_jones_norm() ............................................................... 36
7.2.2.14 crc64_jones_norm_base() ......................................................... 37
7.2.2.15 crc64_jones_norm_by8() .......................................................... 37
7.2.2.16 crc64_jones_refl() ................................................................. 38
7.2.2.17 crc64_jones_refl_base() .......................................................... 38
7.2.2.18 crc64_jones_refl_by8() .......................................................... 39

7.3 erasure_code.h File Reference ......................................................... 39

7.3.1 Detailed Description ..................................................................... 42
7.3.2 Function Documentation .............................................................. 42
7.3.2.1 ec_encode_data() ................................................................. 43
7.3.2.2 ec_encode_data_avx() ............................................................. 43
7.3.2.3 ec_encode_data_avx2() ........................................................... 44
7.3.2.4 ec_encode_data_base() ............................................................ 44
7.3.2.5 ec_encode_data_sse() .............................................................. 44
7.3.2.6 ec_encode_data_update() .......................................................... 45
7.3.2.7 ec_encode_data_update_avx() ................................................... 45
7.3.2.8 ec_encode_data_update_avx2() .................................................. 46
7.3.2.9 ec_encode_data_update_base() ................................................... 46
7.3.2.10 ec_encode_data_update_sse() ................................................... 46
7.3.2.11 ec_init_tables() ................................................................. 47
7.3.2.12 gf_2vect_dot_prod_avx() ......................................................... 47
7.3.2.13 gf_2vect_dot_prod_avx2() ....................................................... 48
7.3.2.14 gf_2vect_dot_prod_sse() ........................................................ 48
7.3.2.15 gf_2vect_mad_avx() ............................................................... 49
7.3.2.16 gf_2vect_mad_avx2() ............................................................. 50
7.3.2.17 gf_2vect_mad_sse() ............................................................... 50
7.3.2.18 gf_3vect_dot_prod_avx() ........................................................ 51
<table>
<thead>
<tr>
<th>Section</th>
<th>Function</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.5.3.6</td>
<td>isal_deflate_set_dict()</td>
<td>81</td>
</tr>
<tr>
<td>7.5.3.7</td>
<td>isal_deflate_set_hufftables()</td>
<td>81</td>
</tr>
<tr>
<td>7.5.3.8</td>
<td>isal_deflate_stateless()</td>
<td>82</td>
</tr>
<tr>
<td>7.5.3.9</td>
<td>isal_deflate_stateless_init()</td>
<td>82</td>
</tr>
<tr>
<td>7.5.3.10</td>
<td>isal_inflate()</td>
<td>83</td>
</tr>
<tr>
<td>7.5.3.11</td>
<td>isal_inflate_init()</td>
<td>83</td>
</tr>
<tr>
<td>7.5.3.12</td>
<td>isal_inflate_reset()</td>
<td>84</td>
</tr>
<tr>
<td>7.5.3.13</td>
<td>isal_inflate_set_dict()</td>
<td>84</td>
</tr>
<tr>
<td>7.5.3.14</td>
<td>isal_inflate_stateless()</td>
<td>85</td>
</tr>
<tr>
<td>7.5.3.15</td>
<td>isal_update_histogram()</td>
<td>85</td>
</tr>
<tr>
<td>7.6</td>
<td>raid.h File Reference</td>
<td>86</td>
</tr>
<tr>
<td>7.6.1</td>
<td>Detailed Description</td>
<td>86</td>
</tr>
<tr>
<td>7.6.2</td>
<td>Function Documentation</td>
<td>87</td>
</tr>
<tr>
<td>7.6.2.1</td>
<td>pq_check()</td>
<td>87</td>
</tr>
<tr>
<td>7.6.2.2</td>
<td>pq_check_base()</td>
<td>87</td>
</tr>
<tr>
<td>7.6.2.3</td>
<td>pq_check_sse()</td>
<td>88</td>
</tr>
<tr>
<td>7.6.2.4</td>
<td>pq_gen()</td>
<td>88</td>
</tr>
<tr>
<td>7.6.2.5</td>
<td>pq_gen_avx()</td>
<td>89</td>
</tr>
<tr>
<td>7.6.2.6</td>
<td>pq_gen_avx2()</td>
<td>89</td>
</tr>
<tr>
<td>7.6.2.7</td>
<td>pq_gen_base()</td>
<td>90</td>
</tr>
<tr>
<td>7.6.2.8</td>
<td>pq_gen_sse()</td>
<td>90</td>
</tr>
<tr>
<td>7.6.2.9</td>
<td>xor_check()</td>
<td>91</td>
</tr>
<tr>
<td>7.6.2.10</td>
<td>xor_check_base()</td>
<td>91</td>
</tr>
<tr>
<td>7.6.2.11</td>
<td>xor_check_sse()</td>
<td>92</td>
</tr>
<tr>
<td>7.6.2.12</td>
<td>xor_gen()</td>
<td>92</td>
</tr>
<tr>
<td>7.6.2.13</td>
<td>xor_gen_avx()</td>
<td>93</td>
</tr>
<tr>
<td>7.6.2.14</td>
<td>xor_gen_base()</td>
<td>93</td>
</tr>
<tr>
<td>7.6.2.15</td>
<td>xor_gen_sse()</td>
<td>94</td>
</tr>
<tr>
<td>7.7</td>
<td>types.h File Reference</td>
<td>94</td>
</tr>
<tr>
<td>7.7.1</td>
<td>Detailed Description</td>
<td>94</td>
</tr>
</tbody>
</table>

Index

95

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Chapter 1

Intel(R) Intelligent Storage Acceleration Library

ISA-L is a collection of optimized low-level functions targeting storage applications. ISA-L includes:

- Erasure codes - Fast block Reed-Solomon type erasure codes for any encode/decode matrix in GF(2^8).
- CRC - Fast implementations of cyclic redundancy check. Six different polynomials supported.
  - iscsi32, ieee32, t10dif, ecma64, iso64, jones64.
- Raid - calculate and operate on XOR and P+Q parity found in common RAID implementations.
- Compression - Fast deflate-compatible data compression.
- De-compression - Fast inflate-compatible data compression.

Also see:

- ISA-L for updates.
- For crypto functions see isa-l_crypto on github.
- The github wiki including a list of distros/ports offering binary packages.
- ISA-L mailing list.
- Contributing.

Building ISA-L

Prerequisites

- Assembler: nasm v2.11.01 or later (nasm v2.13 or better suggested for building in AVX512 support) or yasm version 1.2.0 or later.
- Compiler: gcc, clang, icc or VC compiler.
- Make: GNU ‘make’ or ‘nmake’ (Windows).
- Optional: Building with autotools requires autoconf/automake packages.
Autotools

To build and install the library with autotools it is usually sufficient to run:

```
./autogen.sh
./configure
make
sudo make install
```

Makefile

To use a standard makefile run:

```
make -f Makefile.unx
```

Windows

On Windows use nmake to build dll and static lib:

```
nmake -f Makefile.nmake
```

Other make targets

Other targets include:

- `make check`: create and run tests
- `make tests`: create additional unit tests
- `make perfs`: create included performance tests
- `make ex`: build examples
- `make other`: build other utilities such as compression file tests
- `make doc`: build API manual
Chapter 2

v2.21 Intel Intelligent Storage Acceleration Library
Release Notes

RELEASE NOTE CONTENTS

1. KNOWN ISSUES
2. FIXED ISSUES
3. CHANGE LOG & FEATURES ADDED

1. KNOWN ISSUES

• Perf tests do not run in Windows environment.
• 32-bit lib is not supported in Windows.

2. FIXED ISSUES

v2.20

• Inflate total_out behavior corrected for in-progress decompression. Previously total_out represented the total bytes decompressed into the output buffer or temp internal buffer. This is changed to be only the bytes put into the output buffer.
• Fixed issue with isal_create_hufftables_subset. Affects semi-dynamic compression use case when explicitly creating hufftables from histogram. The _hufftables_subset function could fail to generate length symbols for any length that were never seen.

v2.19

• Fix erasure code test that violates rs matrix bounds.
• Fix 0 length file and looping errors in igzip_inflate_test.

v2.18

• Mac OS X/darwin systems no longer require the –target=darwin config option. The autoconf canonical build should detect.

v2.17

• Fix igzip using 32K window and a shared object
• Fix igzip undefined instruction error on Nehalem.
• Fixed issue in crc performance tests where OS optimizations turned cold cache tests into warm tests.

v2.15

• Fix for windows register save in gf_6vect_mad_avx2.asm. Only affects windows versions of ec_encode_data_← update() running with AVX2. A GP register was not properly restored resulting in corruption on return.

v2.14

• Building in unit directories is no longer supported removing the issue of leftover object files causing the top-level make build to fail.

v2.10

• Fix for windows register save overlap in gf_[3-6]vect_dot_prod_sse.asm. Only affects windows versions of erasure code. GP register saves/restore were pushed to same stack area as XMM.

3. CHANGE LOG & FEATURES ADDED

v2.21

• Igzip improvements
  – New compression levels added. ISA-L fast deflate now has more levels to balance speed vs. target compression level. Level 0, 1 are as in previous generations. New levels 2 & 3 target higher compression roughly comparable to zlib levels 2-3. Level 3 is currently only optimized for processors with AVX512 instructions.
  – New T10dif & copy function - crc16_t10dif_copy()
    – CRC and copy was added to emulate T10dif operations such as DIF insert and strip. This function stitches together CRC and memcpy operations eliminating an extra data read.
• CRC32 iscsi performance improvements
- Fixes issue under some distributions where warm cache performance was reduced.

v2.20

- Igzip improvements
  - Removed alignment restrictions on input structure.

v2.19

- Igzip improvements
  - Add optimized Adler-32 checksum.
  - Implement zlib compression format.
  - Add stateful dictionary support.
  - Add struct reset functions for both deflate and inflate.
- Reflected IEEE format CRC32 is released out. Function interface is named crc32_gzip_refl.
- Exact work condition of Erasure Code Reed-Solomon Matrix is determined by new added program gen_rs_matrix_limits.

v2.18

- New 2-pass fully-dynamic deflate compression (level -1). ISA-L fast deflate now has two levels. Level 0 (default) is the same as previous generations. Setting to level 1 will switch to the fully-dynamic compression that will typically reach higher compression ratios.
- RAID AVX512 functions.

v2.17

- New fast decompression (inflate)
- Compression improvements (deflate)
  - Speed and compression ratio improvements.
  - Fast custom Huffman code generation.
  - New features:
    - Run-time option of gzip crc calculation and headers/trailer.
    - Choice of static header (BTYPE 01) blocks.
    - LARGE_WINDOW, 32K history, now default.
    - Stateless full flush mode.
- CRC64
  - Six new 64-bit polynomials supported. Normal and reflected versions of ECMA, ISO and Jones polynomials.
v2.16

- Units added: crc, raid, igzip (deflate compression).

v2.15

- Erasure code updates. New AVX512 versions.
- Nasm support. ISA-L ported to build with nasm or yasm assembler.
- Windows DLL support. Windows builds DLL by default.

v2.14

- Autoconf and autotools build allows easier porting to additional systems. Previous make system still available to embedded users with Makefile.unx.
- Includes update for building on Mac OS X/darwin systems. Add \-target=darwin to ./configure step.

v2.13

- Erasure code improvements
  - 32-bit port of optimized \texttt{gf\_vect\_dot\_prod()} functions. This makes \texttt{ec\_encode\_data()} functions much faster on 32-bit processors.
  - Avoton performance improvements. Performance on Avoton for \texttt{gf\_vect\_dot\_prod()} and \texttt{ec\_encode\_data()} can improve by as much as 20%.

v2.11

- Incremental erasure code. New functions added to erasure code to handle single source update of code blocks. The function \texttt{ec\_encode\_data\_update()} works with parameters similar to \texttt{ec\_encode\_data()} but are called incrementally with each source block. These versions are useful when source blocks are not all available at once.

v2.10

- Erasure code updates
  - New AVX and AVX2 support functions.
  - Changes min len requirement on \texttt{gf\_vect\_dot\_prod()} to 32 from 16.
  - Tests include both source and parity recovery with \texttt{ec\_encode\_data()}.
  - New encoding examples with Vandermonde or Cauchy matrix.

v2.8

- First open release of erasure code unit that is part of ISA-L.
Chapter 3

Instruction Set Requirements for arch-specific functions (non-multibinary)

- **Global crc64_ecma_norm_by8** (uint64_t init_crc, const unsigned char *buf, uint64_t len)
  - SSE3, CLMUL

- **Global crc64_ecma_refl_by8** (uint64_t init_crc, const unsigned char *buf, uint64_t len)
  - SSE3, CLMUL

- **Global crc64_iso_norm_by8** (uint64_t init_crc, const unsigned char *buf, uint64_t len)
  - SSE3, CLMUL

- **Global crc64_iso_refl_by8** (uint64_t init_crc, const unsigned char *buf, uint64_t len)
  - SSE3, CLMUL

- **Global crc64_jones_norm_by8** (uint64_t init_crc, const unsigned char *buf, uint64_t len)
  - SSE3, CLMUL

- **Global crc64_jones_refl_by8** (uint64_t init_crc, const unsigned char *buf, uint64_t len)
  - SSE3, CLMUL

- **Global ec_encode_data_avx** (int len, int k, int rows, unsigned char *gftbls, unsigned char **data, unsigned char **coding)
  - AVX

- **Global ec_encode_data_avx2** (int len, int k, int rows, unsigned char *gftbls, unsigned char **data, unsigned char **coding)
  - AVX2

- **Global ec_encode_data_sse** (int len, int k, int rows, unsigned char *gftbls, unsigned char **data, unsigned char **coding)
  - SSE4.1

- **Global ec_encode_data_update_avx** (int len, int k, int vec_i, unsigned char *g_tbls, unsigned char *data, unsigned char **coding)
  - AVX

- **Global ec_encode_data_update_avx2** (int len, int k, int vec_i, unsigned char *g_tbls, unsigned char *data, unsigned char **coding)
  - AVX2
Global `ec_encode_data_update_sse` (int len, int k, int rows, int vec_i, unsigned char *g_tbs, unsigned char *data, unsigned char **coding)
  SSE4.1

Global `gf_2vect_dot_prod_avx` (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest)
  AVX

Global `gf_2vect_dot_prod_avx2` (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest)
  AVX2

Global `gf_2vect_dot_prod_sse` (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest)
  SSE4.1

Global `gf_2vect_mad_avx` (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest)
  AVX

Global `gf_2vect_mad_avx2` (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest)
  AVX2

Global `gf_2vect_mad_sse` (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest)
  SSE4.1

Global `gf_3vect_dot_prod_avx` (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest)
  AVX

Global `gf_3vect_dot_prod_avx2` (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest)
  AVX2

Global `gf_3vect_dot_prod_sse` (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest)
  SSE4.1

Global `gf_3vect_mad_avx` (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest)
  AVX

Global `gf_3vect_mad_avx2` (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest)
  AVX2

Global `gf_3vect_mad_sse` (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest)
  SSE4.1

Global `gf_4vect_dot_prod_avx` (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest)
  AVX

Global `gf_4vect_dot_prod_avx2` (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest)
  AVX2

Global `gf_4vect_dot_prod_sse` (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest)
  SSE4.1
Global \texttt{gf\_4vect\_mad\_avx} (int len, int vec, int vec\_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest) AVX

Global \texttt{gf\_4vect\_mad\_avx2} (int len, int vec, int vec\_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest) AVX2

Global \texttt{gf\_4vect\_mad\_sse} (int len, int vec, int vec\_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest) SSE4.1

Global \texttt{gf\_5vect\_dot\_prod\_avx} (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest) AVX

Global \texttt{gf\_5vect\_dot\_prod\_avx2} (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest) AVX2

Global \texttt{gf\_5vect\_dot\_prod\_sse} (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest) SSE4.1

Global \texttt{gf\_5vect\_mad\_avx} (int len, int vec, int vec\_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest) AVX

Global \texttt{gf\_5vect\_mad\_avx2} (int len, int vec, int vec\_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest) AVX2

Global \texttt{gf\_5vect\_mad\_sse} (int len, int vec, int vec\_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest) SSE4.1

Global \texttt{gf\_6vect\_dot\_prod\_avx} (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest) AVX

Global \texttt{gf\_6vect\_dot\_prod\_avx2} (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest) AVX2

Global \texttt{gf\_6vect\_dot\_prod\_sse} (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest) SSE4.1

Global \texttt{gf\_6vect\_mad\_avx} (int len, int vec, int vec\_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest) AVX

Global \texttt{gf\_6vect\_mad\_avx2} (int len, int vec, int vec\_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest) AVX2

Global \texttt{gf\_6vect\_mad\_sse} (int len, int vec, int vec\_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest) SSE4.1

Global \texttt{gf\_vect\_dot\_prod\_avx} (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char *dest) AVX

Generated by Doxygen
Global `gf_vect_dot_prod_avx2` (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char *dest)
AVX2

Global `gf_vect_dot_prod_sse` (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char *dest)
SSE4.1

Global `gf_vect_mad_avx` (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char *dest)
AVX

Global `gf_vect_mad_avx2` (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char *dest)
AVX2

Global `gf_vect_mad_sse` (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char *dest)
SSE4.1

Global `gf_vect_mul_avx` (int len, unsigned char *gftbl, void *src, void *dest)
AVX

Global `gf_vect_mul_sse` (int len, unsigned char *gftbl, void *src, void *dest)
SSE4.1

Global `pq_check_sse` (int vects, int len, void **array)
SSE4.1

Global `pq_gen_avx` (int vects, int len, void **array)
AVX

Global `pq_gen_avx2` (int vects, int len, void **array)
AVX2

Global `pq_gen_sse` (int vects, int len, void **array)
SSE4.1

Global `xor_check_sse` (int vects, int len, void **array)
SSE4.1

Global `xor_gen_avx` (int vects, int len, void **array)
AVX

Global `xor_gen_sse` (int vects, int len, void **array)
SSE4.1
Chapter 4

Data Structure Index

4.1 Data Structures

Here are the data structures with brief descriptions:

- **BitBuf2**
  - Holds Bit Buffer information
  - Page 15

- **inflate_huff_code_large**
  - Page 16

- **inflate_huff_code_small**
  - Page 16

- **inflate_state**
  - Holds decompression state information
  - Page 16

- **isal_huff_histogram**
  - Holds histogram of deflate symbols
  - Page 17

- **isal_hufftables**
  - Holds the huffman tree used to huffman encode the input stream
  - Page 18

- **isal_mod_hist**
  - Page 19

- **isal_zstate**
  - Holds the internal state information for input and output compression streams
  - Page 19

- **isal_zstream**
  - Holds stream information
  - Page 20
Chapter 5

File Index

5.1 File List

Here is a list of all documented files with brief descriptions:

- **crc.h**: CRC functions .......................................................... 23
- **crc64.h**: CRC64 functions .................................................. 29
- **erasure_code.h**: Interface to functions supporting erasure code encode and decode .......... 39
- **gf_vect_mul.h**: Interface to functions for vector (block) multiplication in GF($2^8$) ............ 71
- **igzip_lib.h**: This file defines the igzip compression and decompression interface, a high performance deflate compression interface for storage applications ........................................... 75
- **isa-l.h**: .............................................................................. ??
- **raid.h**: Interface to RAID functions - XOR and P+Q calculation ........................................ 86
- **types.h**: Defines standard width types ........................................................................... 94
Chapter 6

Data Structure Documentation

6.1 BitBuf2 Struct Reference

Holds Bit Buffer information.

#include <igzip_lib.h>

Data Fields

- uint64_t m_bits
  bits in the bit buffer
- uint32_t m_bit_count
  number of valid bits in the bit buffer
- uint8_t * m_out_buf
  current index of buffer to write to
- uint8_t * m_out_end
  end of buffer to write to
- uint8_t * m_out_start
  start of buffer to write to

6.1.1 Detailed Description

Holds Bit Buffer information.

The documentation for this struct was generated from the following file:

- igzip_lib.h
6.2 inflate_huff_code_large Struct Reference

The documentation for this struct was generated from the following file:

- igzip_lib.h

6.3 inflate_huff_code_small Struct Reference

The documentation for this struct was generated from the following file:

- igzip_lib.h

6.4 inflate_state Struct Reference

Holds decompression state information.

#include <igzip_lib.h>

Data Fields

- uint8_t * next_out
  Next output Byte.
- uint32_t avail_out
  Number of bytes available at next_out.
- uint32_t total_out
  Total bytes written out so far.
- uint8_t * next_in
  Next input byte.
- uint64_t read_in
  Bits buffered to handle unaligned streams.
- uint32_t avail_in
  Number of bytes available at next_in.
- int32_t read_in_length
  Bits in read_in.
- struct inflate_huff_code_large lit_huff_code
  Structure for decoding lit/len symbols.
- struct inflate_huff_code_small dist_huff_code
  Structure for decoding dist symbols.
- enum isal_block_state block_state
  Current decompression state.
- uint32_t dict_length
  Length of dictionary used.
6.5 isal_huff_histogram Struct Reference

Holds histogram of deflate symbols.

#include <igzip_lib.h>

Data Fields

- `uint64_t lit_len_histogram [ISAL_DEF_LIT_LEN_SYMBOLS]`
  Histogram of Literal/LEN symbols seen.
- `uint64_t dist_histogram [ISAL_DEF_DIST_SYMBOLS]`
  Histogram of Distance Symbols seen.
- `uint16_t hash_table [IGZIP_LVL0_HASH_SIZE]`
  Tmp space used as a hash table.
6.5.1 Detailed Description

Holds histogram of deflate symbols.

The documentation for this struct was generated from the following file:

- igzip_lib.h

6.6 isal_hufftables Struct Reference

Holds the huffman tree used to huffman encode the input stream.

#include <igzip_lib.h>

Data Fields

- uint8_t deflate_hdr [ISAL_DEF_MAX_HDR_SIZE]
  deflate huffman tree header
- uint32_t deflate_hdr_count
  Number of whole bytes in deflate_hdr.
- uint32_t deflate_hdr_extra_bits
  Number of bits in the partial byte in header.
- uint32_t dist_table [IGZIP_DIST_TABLE_SIZE]
  bits 4:0 are the code length, bits 31:5 are the code
- uint32_t len_table [IGZIP_LEN_TABLE_SIZE]
  bits 4:0 are the code length, bits 31:5 are the code
- uint16_t lit_table [IGZIP_LIT_TABLE_SIZE]
  literal code
- uint8_t lit_table_sizes [IGZIP_LIT_TABLE_SIZE]
  literal code length
- uint16_t dcodes [30 - IGZIP_DECODE_OFFSET]
  distance code
- uint8_t dcodes_sizes [30 - IGZIP_DECODE_OFFSET]
  distance code length

6.6.1 Detailed Description

Holds the huffman tree used to huffman encode the input stream.

The documentation for this struct was generated from the following file:

- igzip_lib.h
6.7 isal_mod_hist Struct Reference

The documentation for this struct was generated from the following file:

- igzip_lib.h

6.8 isal_zstate Struct Reference

Holds the internal state information for input and output compression streams.

#include <igzip_lib.h>

Data Fields

- uint32_t total_in_start
  Start of total_in (including buffered data) on function call.
- uint32_t block_next
  Start of current deflate block in the input.
- uint32_t block_end
  End of current deflate block in the input.
- struct BitBuf2 bitbuf
  Bit Buffer.
- uint32_t crc
  Current crc.
- enum isal_zstate_state state
  Current state in processing the data stream.
- uint8_t has_wrap_hdr
  keeps track of wrapper header
- uint8_t has_eob_hdr
  keeps track of eob hdr (with BFINAL set)
- uint8_t has_eob
  keeps track of eob on the last deflate block
- uint8_t has_hist
  flag to track if there is match history
- uint16_t has_level_buf_init
  flag to track if user supplied memory has been initialized.
- uint32_t count
  used for partial header/trailer writes
- uint8_t tmp_out_buff[16]
  temporary array
- uint32_t tmp_out_start
  temporary variable
- uint32_t tmp_out_end
  temporary variable
• uint32_t b_bytes_valid
  number of valid bytes in buffer
• uint32_t b_bytes_processed
  number of bytes processed in buffer
• uint8_t buffer [2 * IGZIP_HIST_SIZE + ISAL_LOOK_AHEAD]
  Internal buffer.
• uint16_t head [IGZIP_LVL0_HASH_SIZE]
  Hash array.

6.8.1 Detailed Description

Holds the internal state information for input and output compression streams.

The documentation for this struct was generated from the following file:

• igzip_lib.h

6.9 isal_zstream Struct Reference

Holds stream information.

#include <igzip_lib.h>

Data Fields

• uint8_t * next_in
  Next input byte.
• uint32_t avail_in
  number of bytes available at next_in
• uint32_t total_in
  total number of bytes read so far
• uint8_t * next_out
  Next output byte.
• uint32_t avail_out
  number of bytes available at next_out
• uint32_t total_out
  total number of bytes written so far
• struct isal_hufftables * hufftables
  Huffman encoding used when compressing.
• uint32_t level
  Compression level to use.
• uint32_t level_buf_size
  Size of level_buf.
• uint8_t * level_buf
User allocated buffer required for different compression levels.

- **uint16_t end_of_stream**
  
  *non-zero if this is the last input buffer*

- **uint16_t flush**
  
  *Flush type can be NO_FLUSH, SYNC_FLUSH or FULL_FLUSH.*

- **uint32_t gzip_flag**
  
  *Indicate if gzip compression is to be performed.*

- **struct isal_zstate internal_state**
  
  *Internal state for this stream.*

### 6.9.1 Detailed Description

Holds stream information.

The documentation for this struct was generated from the following file:

- igzip_lib.h
Chapter 7

File Documentation

7.1 crc.h File Reference

CRC functions.

#include <stdint.h>

Functions

- uint16_t crc16_t10dif (uint16_t init_crc, const unsigned char *buf, uint64_t len)
  Generate CRC from the T10 standard, runs appropriate version.
- uint16_t crc16_t10dif_copy (uint16_t init_crc, uint8_t *dst, uint8_t *src, uint64_t len)
  Generate CRC and copy T10 standard, runs appropriate version.
- uint32_t crc32_ieee (uint32_t init_crc, const unsigned char *buf, uint64_t len)
  Generate CRC from the IEEE standard, runs appropriate version.
- uint32_t crc32_gzip_refl (uint32_t init_crc, const unsigned char *buf, uint64_t len)
- unsigned int crc32_iscsi (unsigned char *buffer, int len, unsigned int init_crc)
  ISCSI CRC function, runs appropriate version.
- unsigned int crc32_iscsi_base (unsigned char *buffer, int len, unsigned int crc_init)
  ISCSI CRC function, baseline version.
- uint16_t crc16_t10dif_base (uint16_t seed, uint8_t *buf, uint64_t len)
  Generate CRC from the T10 standard, runs baseline version.
- uint16_t crc16_t10dif_copy_base (uint16_t init_crc, uint8_t *dst, uint8_t *src, uint64_t len)
  Generate CRC and copy T10 standard, runs baseline version.
- uint32_t crc32_ieee_base (uint32_t seed, uint8_t *buf, uint64_t len)
  Generate CRC from the IEEE standard, runs baseline version.
- uint32_t crc32_gzip_refl_base (uint32_t seed, uint8_t *buf, uint64_t len)
7.1.1 Detailed Description

CRC functions.

7.1.2 Function Documentation

7.1.2.1 crc16_t10dif()

```c
uint16_t crc16_t10dif (uint16_t init_crc, const unsigned char * buf, uint64_t len )
```

Generate CRC from the T10 standard, runs appropriate version.

This function determines what instruction sets are enabled and selects the appropriate version at runtime.

Returns

16 bit CRC

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>init_crc</code></td>
<td>initial CRC value, 16 bits</td>
</tr>
<tr>
<td><code>buf</code></td>
<td>buffer to calculate CRC on</td>
</tr>
<tr>
<td><code>len</code></td>
<td>buffer length in bytes (64-bit data)</td>
</tr>
</tbody>
</table>

7.1.2.2 crc16_t10dif_base()

```c
uint16_t crc16_t10dif_base (uint16_t seed, uint8_t * buf, uint64_t len )
```

Generate CRC from the T10 standard, runs baseline version.

Returns

16 bit CRC
Parameters

<table>
<thead>
<tr>
<th>seed</th>
<th>initial CRC value, 16 bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>buf</td>
<td>buffer to calculate CRC on</td>
</tr>
<tr>
<td>len</td>
<td>buffer length in bytes (64-bit data)</td>
</tr>
</tbody>
</table>

7.1.2.3  crc16_t10dif_copy()

```c
uint16_t crc16_t10dif_copy ( 
    uint16_t init_crc, 
    uint8_t * dst, 
    uint8_t * src, 
    uint64_t len )
```

Generate CRC and copy T10 standard, runs appropriate version.

Stitched CRC + copy function.

Returns

16 bit CRC

Parameters

<table>
<thead>
<tr>
<th>init_crc</th>
<th>initial CRC value, 16 bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>dst</td>
<td>buffer destination for copy</td>
</tr>
<tr>
<td>src</td>
<td>buffer source to crc + copy</td>
</tr>
<tr>
<td>len</td>
<td>buffer length in bytes (64-bit data)</td>
</tr>
</tbody>
</table>

7.1.2.4  crc16_t10dif_copy_base()

```c
uint16_t crc16_t10dif_copy_base ( 
    uint16_t init_crc, 
    uint8_t * dst, 
    uint8_t * src, 
    uint64_t len )
```

Generate CRC and copy T10 standard, runs baseline version.

Returns

16 bit CRC
### Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>init_crc</td>
<td>initial CRC value, 16 bits</td>
</tr>
<tr>
<td>dst</td>
<td>buffer destination for copy</td>
</tr>
<tr>
<td>src</td>
<td>buffer source to crc + copy</td>
</tr>
<tr>
<td>len</td>
<td>buffer length in bytes (64-bit data)</td>
</tr>
</tbody>
</table>

#### 7.1.2.5 crc32_gzip_refl()

```c
uint32_t crc32_gzip_refl(
    uint32_t init_crc,
    const unsigned char *buf,
    uint64_t len)
```


This function determines what instruction sets are enabled and selects the appropriate version at runtime.

Note: CRC32 IEEE standard is widely used in HDLC, Ethernet, Gzip and many others. Its polynomial is 0x04C11DB7 in normal and 0xEDB88320 in reflection (or reverse). In ISA-L CRC, function crc32_ieee is actually designed for normal CRC32 IEEE version. And function crc32_gzip_refl is actually designed for reflected CRC32 IEEE. These two versions of CRC32 IEEE are not compatible with each other. Users who want to replace their not optimized crc32 ieee with ISA-L's crc32 function should be careful of that. Since many applications use CRC32 IEEE reflected version, Please have a check whether crc32_gzip_refl is right one for you instead of crc32_ieee.

Returns

32 bit CRC

### Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>init_crc</td>
<td>initial CRC value, 32 bits</td>
</tr>
<tr>
<td>buf</td>
<td>buffer to calculate CRC on</td>
</tr>
<tr>
<td>len</td>
<td>buffer length in bytes (64-bit data)</td>
</tr>
</tbody>
</table>

#### 7.1.2.6 crc32_gzip_refl_base()

```c
uint32_t crc32_gzip_refl_base(
    uint32_t seed,
    uint8_t *buf,
    uint64_t len)
```

Generate by Doxygen

Returns

32 bit CRC

Parameters

<table>
<thead>
<tr>
<th>seed</th>
<th>initial CRC value, 32 bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>buf</td>
<td>buffer to calculate CRC on</td>
</tr>
<tr>
<td>len</td>
<td>buffer length in bytes (64-bit data)</td>
</tr>
</tbody>
</table>

7.1.2.7 crc32_ieee()

uint32_t crc32_ieee (  
  uint32_t init_crc,  
  const unsigned char * buf,  
  uint64_t len )

Generate CRC from the IEEE standard, runs appropriate version.

This function determines what instruction sets are enabled and selects the appropriate version at runtime. Note: CRC32 IEEE standard is widely used in HDLC, Ethernet, Gzip and many others. Its polynomial is 0x04C11DB7 in normal and 0xEDB88320 in reflection (or reverse). In ISA-L CRC, function crc32_ieee is actually designed for normal CRC32 IEEE version. And function crc32_gzip_refl is actually designed for reflected CRC32 IEEE. These two versions of CRC32 IEEE are not compatible with each other. Users who want to replace their not optimized crc32 ieee with ISA-L's crc32 function should be careful of that. Since many applications use CRC32 IEEE reflected version, Please have a check whether crc32_gzip_refl is right one for you instead of crc32_ieee.

Returns

32 bit CRC

Parameters

<table>
<thead>
<tr>
<th>init_crc</th>
<th>initial CRC value, 32 bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>buf</td>
<td>buffer to calculate CRC on</td>
</tr>
<tr>
<td>len</td>
<td>buffer length in bytes (64-bit data)</td>
</tr>
</tbody>
</table>

7.1.2.8 crc32_ieee_base()

uint32_t crc32_ieee_base (  

Generated by Doxygen
uint32_t seed,
uint8_t * buf,
uint64_t len)

Generate CRC from the IEEE standard, runs baseline version.

Returns
32 bit CRC

Parameters

<table>
<thead>
<tr>
<th>seed</th>
<th>initial CRC value, 32 bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>buf</td>
<td>buffer to calculate CRC on</td>
</tr>
<tr>
<td>len</td>
<td>buffer length in bytes (64-bit data)</td>
</tr>
</tbody>
</table>

7.1.2.9 crc32_iscsi()

unsigned int crc32_iscsi (  
    unsigned char * buffer,
    int len,
    unsigned int init_crc)

ISCSI CRC function, runs appropriate version.

This function determines what instruction sets are enabled and selects the appropriate version at runtime.

Returns
32 bit CRC

Parameters

<table>
<thead>
<tr>
<th>buffer</th>
<th>buffer to calculate CRC on</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>buffer length in bytes</td>
</tr>
<tr>
<td>init_crc</td>
<td>initial CRC value</td>
</tr>
</tbody>
</table>

7.1.2.10 crc32_iscsi_base()

unsigned int crc32_iscsi_base (  
    unsigned char * buffer,
ISCSI CRC function, baseline version.

Returns

32 bit CRC

Parameters

<table>
<thead>
<tr>
<th>buffer</th>
<th>buffer to calculate CRC on</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>buffer length in bytes</td>
</tr>
<tr>
<td>crc_init</td>
<td>initial CRC value</td>
</tr>
</tbody>
</table>

7.2  crc64.h File Reference

CRC64 functions.

#include <stdint.h>

Functions

- uint64_t crc64_ecma_refl (uint64_t init_crc, const unsigned char *buf, uint64_t len)
  
  Generate CRC from ECMA-182 standard in reflected format, runs appropriate version.

- uint64_t crc64_ecma_norm (uint64_t init_crc, const unsigned char *buf, uint64_t len)
  
  Generate CRC from ECMA-182 standard in normal format, runs appropriate version.

- uint64_t crc64_iso_refl (uint64_t init_crc, const unsigned char *buf, uint64_t len)
  
  Generate CRC from ISO standard in reflected format, runs appropriate version.

- uint64_t crc64_iso_norm (uint64_t init_crc, const unsigned char *buf, uint64_t len)
  
  Generate CRC from ISO standard in normal format, runs appropriate version.

- uint64_t crc64_jones_refl (uint64_t init_crc, const unsigned char *buf, uint64_t len)
  
  Generate CRC from "Jones" coefficients in reflected format, runs appropriate version.

- uint64_t crc64_jones_norm (uint64_t init_crc, const unsigned char *buf, uint64_t len)
  
  Generate CRC from "Jones" coefficients in normal format, runs appropriate version.

- uint64_t crc64_ecma_refl_by8 (uint64_t init_crc, const unsigned char *buf, uint64_t len)
  
  Generate CRC from ECMA-182 standard in reflected format.

- uint64_t crc64_ecma_norm_by8 (uint64_t init_crc, const unsigned char *buf, uint64_t len)
  
  Generate CRC from ECMA-182 standard in normal format.

- uint64_t crc64_ecma_refl_base (uint64_t init_crc, const unsigned char *buf, uint64_t len)
  
  Generate CRC from ECMA-182 standard in reflected format, runs baseline version.

- uint64_t crc64_ecma_norm_base (uint64_t init_crc, const unsigned char *buf, uint64_t len)
  
  Generate CRC from ECMA-182 standard in normal format, runs baseline version.

- uint64_t crc64_iso_refl_by8 (uint64_t init_crc, const unsigned char *buf, uint64_t len)
Generate CRC from ISO standard in reflected format.

- uint64_t crc64_iso_norm_by8 (uint64_t init_crc, const unsigned char *buf, uint64_t len)
  Generate CRC from ISO standard in normal format.
- uint64_t crc64_iso_refl_base (uint64_t init_crc, const unsigned char *buf, uint64_t len)
  Generate CRC from ISO standard in reflected format, runs baseline version.
- uint64_t crc64_iso_norm_base (uint64_t init_crc, const unsigned char *buf, uint64_t len)
  Generate CRC from ISO standard in normal format, runs baseline version.
- uint64_t crc64_jones_refl_by8 (uint64_t init_crc, const unsigned char *buf, uint64_t len)
  Generate CRC from "Jones" coefficients in reflected format.
- uint64_t crc64_jones_norm_by8 (uint64_t init_crc, const unsigned char *buf, uint64_t len)
  Generate CRC from "Jones" coefficients in normal format.
- uint64_t crc64_jones_refl_base (uint64_t init_crc, const unsigned char *buf, uint64_t len)
  Generate CRC from "Jones" coefficients in reflected format, runs baseline version.
- uint64_t crc64_jones_norm_base (uint64_t init_crc, const unsigned char *buf, uint64_t len)
  Generate CRC from "Jones" coefficients in normal format, runs baseline version.

### 7.2.1 Detailed Description

CRC64 functions.

### 7.2.2 Function Documentation

#### 7.2.2.1 crc64_ecma_norm()

```c
uint64_t crc64_ecma_norm (       
    uint64_t init_crc,          
    const unsigned char * buf, 
    uint64_t len )
```

Generate CRC from ECMA-182 standard in normal format, runs appropriate version.

This function determines what instruction sets are enabled and selects the appropriate version at runtime.

Returns

64 bit CRC

Parameters

<table>
<thead>
<tr>
<th>init_crc</th>
<th>initial CRC value, 64 bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>buf</td>
<td>buffer to calculate CRC on</td>
</tr>
<tr>
<td>len</td>
<td>buffer length in bytes (64-bit data)</td>
</tr>
</tbody>
</table>
7.2.2.2 crc64_ecma_norm_base()

```c
uint64_t crc64_ecma_norm_base ( 
    uint64_t init_crc, 
    const unsigned char * buf, 
    uint64_t len )
```

Generate CRC from ECMA-182 standard in normal format, runs baseline version.

Returns

64 bit CRC

Parameters

<table>
<thead>
<tr>
<th>init_crc</th>
<th>initial CRC value, 64 bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>buf</td>
<td>buffer to calculate CRC on</td>
</tr>
<tr>
<td>len</td>
<td>buffer length in bytes (64-bit data)</td>
</tr>
</tbody>
</table>

7.2.2.3 crc64_ecma_norm_by8()

```c
uint64_t crc64_ecma_norm_by8 ( 
    uint64_t init_crc, 
    const unsigned char * buf, 
    uint64_t len )
```

Generate CRC from ECMA-182 standard in normal format.

**Requires** SSE3, CLMUL

Returns

64 bit CRC

Parameters

<table>
<thead>
<tr>
<th>init_crc</th>
<th>initial CRC value, 64 bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>buf</td>
<td>buffer to calculate CRC on</td>
</tr>
<tr>
<td>len</td>
<td>buffer length in bytes (64-bit data)</td>
</tr>
</tbody>
</table>
7.2.2.4  crc64_ecma_refl()

```c
uint64_t crc64_ecma_refl (  
  uint64_t init_crc,  
  const unsigned char * buf,  
  uint64_t len )
```

Generate CRC from ECMA-182 standard in reflected format, runs appropriate version.

This function determines what instruction sets are enabled and selects the appropriate version at runtime.

Returns

64 bit CRC

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>init_crc</code></td>
<td>initial CRC value, 64 bits</td>
</tr>
<tr>
<td><code>buf</code></td>
<td>buffer to calculate CRC on</td>
</tr>
<tr>
<td><code>len</code></td>
<td>buffer length in bytes (64-bit data)</td>
</tr>
</tbody>
</table>

7.2.2.5  crc64_ecma_refl_base()

```c
uint64_t crc64_ecma_refl_base (  
  uint64_t init_crc,  
  const unsigned char * buf,  
  uint64_t len )
```

Generate CRC from ECMA-182 standard in reflected format, runs baseline version.

Returns

64 bit CRC

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>init_crc</code></td>
<td>initial CRC value, 64 bits</td>
</tr>
<tr>
<td><code>buf</code></td>
<td>buffer to calculate CRC on</td>
</tr>
<tr>
<td><code>len</code></td>
<td>buffer length in bytes (64-bit data)</td>
</tr>
</tbody>
</table>
7.2.2.6 crc64_ecma_refl_by8()

```c
uint64_t crc64_ecma_refl_by8 (
    uint64_t init_crc,
    const unsigned char * buf,
    uint64_t len )
```

Generate CRC from ECMA-182 standard in reflected format.

**Requires** SSE3, CLMUL

**Returns**

64 bit CRC

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>init_crc</td>
<td>initial CRC value, 64 bits</td>
</tr>
<tr>
<td>buf</td>
<td>buffer to calculate CRC on</td>
</tr>
<tr>
<td>len</td>
<td>buffer length in bytes (64-bit data)</td>
</tr>
</tbody>
</table>

7.2.2.7 crc64_iso_norm()

```c
uint64_t crc64_iso_norm ( 
    uint64_t init_crc,
    const unsigned char * buf, 
    uint64_t len )
```

Generate CRC from ISO standard in normal format, runs appropriate version.

This function determines what instruction sets are enabled and selects the appropriate version at runtime.

**Returns**

64 bit CRC

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>init_crc</td>
<td>initial CRC value, 64 bits</td>
</tr>
<tr>
<td>buf</td>
<td>buffer to calculate CRC on</td>
</tr>
<tr>
<td>len</td>
<td>buffer length in bytes (64-bit data)</td>
</tr>
</tbody>
</table>
7.2.2.8  crc64_iso_norm_base()

```c
uint64_t crc64_iso_norm_base ( 
    uint64_t init_crc, 
    const unsigned char * buf, 
    uint64_t len )
```

Generate CRC from ISO standard in normal format, runs baseline version.

Returns

64 bit CRC

Parameters

<table>
<thead>
<tr>
<th>init_crc</th>
<th>initial CRC value, 64 bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>buf</td>
<td>buffer to calculate CRC on</td>
</tr>
<tr>
<td>len</td>
<td>buffer length in bytes (64-bit data)</td>
</tr>
</tbody>
</table>

7.2.2.9  crc64_iso_norm_by8()

```c
uint64_t crc64_iso_norm_by8 ( 
    uint64_t init_crc, 
    const unsigned char * buf, 
    uint64_t len )
```

Generate CRC from ISO standard in normal format.

**Requires**  SSE3, CLMUL

Returns

64 bit CRC

Parameters

<table>
<thead>
<tr>
<th>init_crc</th>
<th>initial CRC value, 64 bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>buf</td>
<td>buffer to calculate CRC on</td>
</tr>
<tr>
<td>len</td>
<td>buffer length in bytes (64-bit data)</td>
</tr>
</tbody>
</table>
7.2.2.10 crc64_iso_refl()

```c
uint64_t crc64_iso_refl (  
    uint64_t init_crc,
    const unsigned char * buf,
    uint64_t len )
```

Generate CRC from ISO standard in reflected format, runs appropriate version.

This function determines what instruction sets are enabled and selects the appropriate version at runtime.

Returns

64 bit CRC

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>init_crc</code></td>
<td>initial CRC value, 64 bits</td>
</tr>
<tr>
<td><code>buf</code></td>
<td>buffer to calculate CRC on</td>
</tr>
<tr>
<td><code>len</code></td>
<td>buffer length in bytes (64-bit data)</td>
</tr>
</tbody>
</table>

7.2.2.11 crc64_iso_refl_base()

```c
uint64_t crc64_iso_refl_base (  
    uint64_t init_crc,
    const unsigned char * buf,
    uint64_t len )
```

Generate CRC from ISO standard in reflected format, runs baseline version.

Returns

64 bit CRC

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>init_crc</code></td>
<td>initial CRC value, 64 bits</td>
</tr>
<tr>
<td><code>buf</code></td>
<td>buffer to calculate CRC on</td>
</tr>
<tr>
<td><code>len</code></td>
<td>buffer length in bytes (64-bit data)</td>
</tr>
</tbody>
</table>
7.2.2.12  crc64_iso_refl_by8()

```c
uint64_t crc64_iso_refl_by8 (  
    uint64_t init_crc,  
    const unsigned char * buf,  
    uint64_t len )
```

Generate CRC from ISO standard in reflected format.

**Requires** SSE3, CLMUL

**Returns**

64 bit CRC

**Parameters**

<table>
<thead>
<tr>
<th>init_crc</th>
<th>initial CRC value, 64 bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>buf</td>
<td>buffer to calculate CRC on</td>
</tr>
<tr>
<td>len</td>
<td>buffer length in bytes (64-bit data)</td>
</tr>
</tbody>
</table>

7.2.2.13  crc64_jones_norm()

```c
uint64_t crc64_jones_norm (  
    uint64_t init_crc,  
    const unsigned char * buf,  
    uint64_t len )
```

Generate CRC from "Jones" coefficients in normal format, runs appropriate version.

This function determines what instruction sets are enabled and selects the appropriate version at runtime.

**Returns**

64 bit CRC

**Parameters**

<table>
<thead>
<tr>
<th>init_crc</th>
<th>initial CRC value, 64 bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>buf</td>
<td>buffer to calculate CRC on</td>
</tr>
<tr>
<td>len</td>
<td>buffer length in bytes (64-bit data)</td>
</tr>
</tbody>
</table>
7.2.2.14  crc64_jones_norm_base()

```c
uint64_t crc64_jones_norm_base (  
    uint64_t init_crc,  
    const unsigned char * buf,  
    uint64_t len )
```

Generate CRC from "Jones" coefficients in normal format, runs baseline version.

Returns

64 bit CRC

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>init_crc</code></td>
<td>initial CRC value, 64 bits</td>
</tr>
<tr>
<td><code>buf</code></td>
<td>buffer to calculate CRC on</td>
</tr>
<tr>
<td><code>len</code></td>
<td>buffer length in bytes (64-bit data)</td>
</tr>
</tbody>
</table>

7.2.2.15  crc64_jones_norm_by8()

```c
uint64_t crc64_jones_norm_by8 (  
    uint64_t init_crc,  
    const unsigned char * buf,  
    uint64_t len )
```

Generate CRC from "Jones" coefficients in normal format.

Requires  SSE3, CLMUL

Returns

64 bit CRC

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>init_crc</code></td>
<td>initial CRC value, 64 bits</td>
</tr>
<tr>
<td><code>buf</code></td>
<td>buffer to calculate CRC on</td>
</tr>
<tr>
<td><code>len</code></td>
<td>buffer length in bytes (64-bit data)</td>
</tr>
</tbody>
</table>
7.2.2.16  crc64_jones_refl()

```c
uint64_t crc64_jones_refl (  
    uint64_t init_crc,  
    const unsigned char * buf,  
    uint64_t len )
```

Generate CRC from "Jones" coefficients in reflected format, runs appropriate version.

This function determines what instruction sets are enabled and selects the appropriate version at runtime.

Returns

64 bit CRC

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>init_crc</code></td>
<td>initial CRC value, 64 bits</td>
</tr>
<tr>
<td><code>buf</code></td>
<td>buffer to calculate CRC on</td>
</tr>
<tr>
<td><code>len</code></td>
<td>buffer length in bytes (64-bit data)</td>
</tr>
</tbody>
</table>

7.2.2.17  crc64_jones_refl_base()

```c
uint64_t crc64_jones_refl_base (  
    uint64_t init_crc,  
    const unsigned char * buf,  
    uint64_t len )
```

Generate CRC from "Jones" coefficients in reflected format, runs baseline version.

Returns

64 bit CRC

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>init_crc</code></td>
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<td>buffer to calculate CRC on</td>
</tr>
<tr>
<td><code>len</code></td>
<td>buffer length in bytes (64-bit data)</td>
</tr>
</tbody>
</table>
7.3 erasure_code.h File Reference

7.2.2.18 crc64_jones_refl_by8()

```c
uint64_t crc64_jones_refl_by8 (  
    uint64_t init_crc,  
    const unsigned char * buf,  
    uint64_t len )
```

Generate CRC from "Jones" coefficients in reflected format.

**Requires**  
SSE3, CLMUL

Returns  
64 bit CRC

**Parameters**

<table>
<thead>
<tr>
<th>init_crc</th>
<th>initial CRC value, 64 bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>buf</td>
<td>buffer to calculate CRC on</td>
</tr>
<tr>
<td>len</td>
<td>buffer length in bytes (64-bit data)</td>
</tr>
</tbody>
</table>

7.3 erasure_code.h File Reference

Interface to functions supporting erasure code encode and decode.

```c
#include "gf_vect_mul.h"
```

**Functions**

- void **ec_init_tables** (int k, int rows, unsigned char *a, unsigned char *gftbls)  
  *Initialize tables for fast Erasure Code encode and decode.*

- void **ec_encode_data** (int len, int k, int rows, unsigned char *gftbls, unsigned char **data, unsigned char **coding)  
  *Generate or decode erasure codes on blocks of data, runs appropriate version.*

- void **ec_encode_data_sse** (int len, int k, int rows, unsigned char *gftbls, unsigned char **data, unsigned char **coding)  
  *Generate or decode erasure codes on blocks of data.*

- void **ec_encode_data_avx** (int len, int k, int rows, unsigned char *gftbls, unsigned char **data, unsigned char **coding)  
  *Generate or decode erasure codes on blocks of data.*

- void **ec_encode_data_avx2** (int len, int k, int rows, unsigned char *gftbls, unsigned char **data, unsigned char **coding)  
  *Generate or decode erasure codes on blocks of data.*
• void ec_encode_data_base (int len, int srcs, int dests, unsigned char *v, unsigned char **src, unsigned char **dest)
  
  Generate or decode erasure codes on blocks of data, runs baseline version.

• void ec_encode_data_update (int len, int k, int rows, int vec_i, unsigned char *g_tbls, unsigned char *data, unsigned char **coding)
  
  Generate update for encode or decode of erasure codes from single source, runs appropriate version.

• void ec_encode_data_update_sse (int len, int k, int rows, int vec_i, unsigned char *g_tbls, unsigned char *data, unsigned char **coding)
  
  Generate update for encode or decode of erasure codes from single source.

• void ec_encode_data_update_avx (int len, int k, int rows, int vec_i, unsigned char *g_tbls, unsigned char *data, unsigned char **coding)
  
  Generate update for encode or decode of erasure codes from single source.

• void ec_encode_data_update_avx2 (int len, int k, int rows, int vec_i, unsigned char *g_tbls, unsigned char *data, unsigned char **coding)
  
  Generate update for encode or decode of erasure codes from single source.

• void ec_encode_data_update_base (int len, int k, int rows, int vec_i, unsigned char *v, unsigned char *data, unsigned char **dest)
  
  Generate update for encode or decode of erasure codes from single source.

• void gf_vect_dot_prod_sse (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char *dest)
  
  GF($2^8$) vector dot product.

• void gf_vect_dot_prod_avx (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char *dest)
  
  GF($2^8$) vector dot product.

• void gf_vect_dot_prod_avx2 (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char *dest)
  
  GF($2^8$) vector dot product with two outputs.

• void gf_vect_dot_prod_avx2 (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest)
  
  GF($2^8$) vector dot product with two outputs.

• void gf_2vect_dot_prod_sse (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest)
  
  GF($2^8$) vector dot product with three outputs.

• void gf_2vect_dot_prod_avx (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest)
  
  GF($2^8$) vector dot product with three outputs.

• void gf_2vect_dot_prod_avx2 (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest)
  
  GF($2^8$) vector dot product with three outputs.

• void gf_3vect_dot_prod_sse (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest)
  
  GF($2^8$) vector dot product with four outputs.

• void gf_3vect_dot_prod_avx (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest)
  
  GF($2^8$) vector dot product with four outputs.

• void gf_3vect_dot_prod_avx2 (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest)
  
  GF($2^8$) vector dot product with four outputs.

• void gf_4vect_dot_prod_sse (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest)
  
  GF($2^8$) vector dot product with five outputs.

• void gf_4vect_dot_prod_avx (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest)
  
  GF($2^8$) vector dot product with five outputs.

• void gf_4vect_dot_prod_avx2 (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest)
  
  GF($2^8$) vector dot product with five outputs.
7.3 erasure_code.h File Reference 41

- void gf_6vect_dot_prod_sse (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest)
  GF(2^8) vector dot product with six outputs.
- void gf_6vect_dot_prod_avx (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest)
  GF(2^8) vector dot product with six outputs.
- void gf_6vect_dot_prod_avx2 (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char **dest)
  GF(2^8) vector dot product with six outputs.
- void gf_vect_dot_prod_base (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char *dest)
  GF(2^8) vector dot product, runs baseline version.
- void gf_vect_dot_prod (int len, int vlen, unsigned char *gftbls, unsigned char **src, unsigned char *dest)
  GF(2^8) vector dot product, runs appropriate version.
- void gf_vect_mad_int (len, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char *dest)
  GF(2^8) vector multiply accumulate, runs appropriate version.
- void gf_vect_mad_sse (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest)
  GF(2^8) vector multiply accumulate, arch specific version.
- void gf_vect_mad_avx (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest)
  GF(2^8) vector multiply accumulate, arch specific version.
- void gf_vect_mad_avx2 (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest)
  GF(2^8) vector multiply accumulate, arch specific version.
- void gf_vect_mad_base (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char *dest)
  GF(2^8) vector multiply accumulate, baseline version.
- void gf_2vect_mad_sse (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest)
  GF(2^8) vector multiply with 2 accumulate. SSE version.
- void gf_2vect_mad_avx (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char *dest)
  GF(2^8) vector multiply with 2 accumulate. AVX version of gf_2vect_mad_sse().
- void gf_2vect_mad_avx2 (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char *dest)
  GF(2^8) vector multiply with 2 accumulate. AVX2 version of gf_2vect_mad_sse().
- void gf_3vect_mad_sse (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest)
  GF(2^8) vector multiply with 3 accumulate. SSE version.
- void gf_3vect_mad_avx (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest)
  GF(2^8) vector multiply with 3 accumulate. AVX version of gf_3vect_mad_sse().
- void gf_3vect_mad_avx2 (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest)
  GF(2^8) vector multiply with 3 accumulate. AVX2 version of gf_3vect_mad_sse().
- void gf_4vect_mad_sse (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest)
  GF(2^8) vector multiply with 4 accumulate. SSE version.
- void gf_4vect_mad_avx (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest)
  GF(2^8) vector multiply with 4 accumulate. AVX version of gf_4vect_mad_sse().
- void gf_4vect_mad_avx2 (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest)
  GF(2^8) vector multiply with 4 accumulate. AVX2 version of gf_4vect_mad_sse().
- void gf_5vect_mad_sse (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest)
**GF(2^8) vector multiply with 5 accumulate. SSE version.**

- void *gf_5vect_mad_sse* (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest)

**GF(2^8) vector multiply with 5 accumulate. AVX version.**

- void *gf_5vect_mad_avx* (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest)

**GF(2^8) vector multiply with 5 accumulate. AVX2 version.**

- void *gf_5vect_mad_avx2* (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest)

**GF(2^8) vector multiply with 6 accumulate. SSE version.**

- void *gf_6vect_mad_sse* (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest)

**GF(2^8) vector multiply with 6 accumulate. AVX version.**

- void *gf_6vect_mad_avx* (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest)

**GF(2^8) vector multiply with 6 accumulate. AVX2 version.**

- void *gf_6vect_mad_avx2* (int len, int vec, int vec_i, unsigned char *gftbls, unsigned char *src, unsigned char **dest)

**unsigned char *gf_mul* (unsigned char a, unsigned char b)**

*Single element GF(2^8) multiply.*

**unsigned char *gf_inv* (unsigned char a)**

*Single element GF(2^8) inverse.*

- void *gf_gen_rs_matrix* (unsigned char *a, int m, int k)

*Generate a matrix of coefficients to be used for encoding.*

- void *gf_gen_cauchy1_matrix* (unsigned char *a, int m, int k)

*Generate a Cauchy matrix of coefficients to be used for encoding.*

- int *gf_invert_matrix* (unsigned char *in, unsigned char *out, const int n)

*Invert a matrix in GF(2^8)*

### 7.3.1 Detailed Description

**Interface to functions supporting erasure code encode and decode.**

This file defines the interface to optimized functions used in erasure codes. Encode and decode of erasures in GF(2^8) are made by calculating the dot product of the symbols (bytes in GF(2^8)) across a set of buffers and a set of coefficients. Values for the coefficients are determined by the type of erasure code. Using a general dot product means that any sequence of coefficients may be used including erasure codes based on random coefficients. Multiple versions of dot product are supplied to calculate 1-6 output vectors in one pass. Base GF multiply and divide functions can be sped up by defining GF_LARGE_TABLES at the expense of memory size.

### 7.3.2 Function Documentation
7.3.2.1  ec_encode_data()

void ec_encode_data (  
  int len,  
  int k,  
  int rows,  
  unsigned char * gftbls,  
  unsigned char ** data,  
  unsigned char ** coding )

Generate or decode erasure codes on blocks of data, runs appropriate version.

Given a list of source data blocks, generate one or multiple blocks of encoded data as specified by a matrix of \( G \rightarrow F(2^{m}\times 8) \) coefficients. When given a suitable set of coefficients, this function will perform the fast generation or decoding of Reed-Solomon type erasure codes.

This function determines what instruction sets are enabled and selects the appropriate version at runtime.

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>Length of each block of data (vector) of source or dest data.</td>
</tr>
<tr>
<td>k</td>
<td>The number of vector sources or rows in the generator matrix for coding.</td>
</tr>
<tr>
<td>rows</td>
<td>The number of output vectors to concurrently encode/decode.</td>
</tr>
<tr>
<td>gftbls</td>
<td>Pointer to array of input tables generated from coding coefficients in ec_init_tables(). Must be of size ( 32 \times k \times \text{rows} )</td>
</tr>
<tr>
<td>data</td>
<td>Array of pointers to source input buffers.</td>
</tr>
<tr>
<td>coding</td>
<td>Array of pointers to coded output buffers.</td>
</tr>
</tbody>
</table>

Returns

none

7.3.2.2  ec_encode_data_avx()

void ec_encode_data_avx (  
  int len,  
  int k,  
  int rows,  
  unsigned char * gftbls,  
  unsigned char ** data,  
  unsigned char ** coding )

Generate or decode erasure codes on blocks of data.

Arch specific version of ec_encode_data() with same parameters.

Requires  AVX
7.3.2.3 ec_encode_data_avx2()

```c
void ec_encode_data_avx2 (
    int len,
    int k,
    int rows,
    unsigned char * gftbls,
    unsigned char ** data,
    unsigned char ** coding )
```

Generate or decode erasure codes on blocks of data.

Arch specific version of `ec_encode_data()` with same parameters.

**Requires** AVX2

7.3.2.4 ec_encode_data_base()

```c
void ec_encode_data_base ( 
    int len,
    int srcs,
    int dests,
    unsigned char * v,
    unsigned char ** src,
    unsigned char ** dest )
```

Generate or decode erasure codes on blocks of data, runs baseline version.

Baseline version of `ec_encode_data()` with same parameters.

7.3.2.5 ec_encode_data_sse()

```c
void ec_encode_data_sse ( 
    int len,
    int k,
    int rows,
    unsigned char * gftbls,
    unsigned char ** data,
    unsigned char ** coding )
```

Generate or decode erasure codes on blocks of data.

Arch specific version of `ec_encode_data()` with same parameters.

**Requires** SSE4.1
7.3.2.6 ec_encode_data_update()

```c
void ec_encode_data_update (  
    int len,  
    int k,  
    int rows,  
    int vec_i,  
    unsigned char * g_tbls,  
    unsigned char * data,  
    unsigned char ** coding )
```

Generate update for encode or decode of erasure codes from single source, runs appropriate version.

Given one source data block, update one or multiple blocks of encoded data as specified by a matrix of GF(2^8) coefficients. When given a suitable set of coefficients, this function will perform the fast generation or decoding of Reed-Solomon type erasure codes from one input source at a time.

This function determines what instruction sets are enabled and selects the appropriate version at runtime.

**Parameters**

<table>
<thead>
<tr>
<th>len</th>
<th>Length of each block of data (vector) of source or dest data.</th>
</tr>
</thead>
<tbody>
<tr>
<td>k</td>
<td>The number of vector sources or rows in the generator matrix for coding.</td>
</tr>
<tr>
<td>rows</td>
<td>The number of output vectors to concurrently encode/decode.</td>
</tr>
<tr>
<td>vec_i</td>
<td>The vector index corresponding to the single input source.</td>
</tr>
<tr>
<td>g_tbls</td>
<td>Pointer to array of input tables generated from coding coefficients in ec_init_tables(). Must be of size 32<em>k</em>rows</td>
</tr>
<tr>
<td>data</td>
<td>Pointer to single input source used to update output parity.</td>
</tr>
<tr>
<td>coding</td>
<td>Array of pointers to coded output buffers.</td>
</tr>
</tbody>
</table>

**Returns**

none

---

7.3.2.7 ec_encode_data_update_avx()

```c
void ec_encode_data_update_avx (  
    int len,  
    int k,  
    int rows,  
    int vec_i,  
    unsigned char * g_tbls,  
    unsigned char * data,  
    unsigned char ** coding )
```

Generate update for encode or decode of erasure codes from single source.

Arch specific version of ec_encode_data_update() with same parameters.

---

Generated by Doxygen
Requires AVX

7.3.2.8 ec_encode_data_update_avx2()

```c
void ec_encode_data_update_avx2 (  
    int len,  
    int k,  
    int rows,  
    int vec_i,  
    unsigned char * g_tbls,  
    unsigned char * data,  
    unsigned char ** coding )
```

Generate update for encode or decode of erasure codes from single source.
Arch specific version of ec_encode_data_update() with same parameters.
Requires AVX2

7.3.2.9 ec_encode_data_update_base()

```c
void ec_encode_data_update_base (  
    int len,  
    int k,  
    int rows,  
    int vec_i,  
    unsigned char * v,  
    unsigned char * data,  
    unsigned char ** dest )
```

Generate update for encode or decode of erasure codes from single source.
Baseline version of ec_encode_data_update().

7.3.2.10 ec_encode_data_update_sse()

```c
void ec_encode_data_update_sse (  
    int len,  
    int k,  
    int rows,  
    int vec_i,  
    unsigned char * g_tbls,  
    unsigned char * data,  
    unsigned char ** coding )
```

Generate update for encode or decode of erasure codes from single source.
Arch specific version of ec_encode_data_update() with same parameters.
Requires SSE4.1
7.3.2.11 ec_init_tables()

```c
void ec_init_tables (
    int k,
    int rows,
    unsigned char * a,
    unsigned char * gftbls )
```

Initialize tables for fast Erasure Code encode and decode.

Generates the expanded tables needed for fast encode or decode for erasure codes on blocks of data. 32bytes is generated for each input coefficient.

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>k</td>
<td>The number of vector sources or rows in the generator matrix for coding.</td>
</tr>
<tr>
<td>rows</td>
<td>The number of output vectors to concurrently encode/decode.</td>
</tr>
<tr>
<td>a</td>
<td>Pointer to sets of arrays of input coefficients used to encode or decode data.</td>
</tr>
<tr>
<td>gftbls</td>
<td>Pointer to start of space for concatenated output tables generated from input coefficients. Must be of size 32<em>k</em>rows.</td>
</tr>
</tbody>
</table>

**Returns**

None

7.3.2.12 gf_2vect_dot_prod_avx()

```c
void gf_2vect_dot_prod_avx (
    int len,
    int vlen,
    unsigned char * gftbls,
    unsigned char ** src,
    unsigned char ** dest )
```

GF(2^8) vector dot product with two outputs.

Vector dot product optimized to calculate two outputs at a time. Does two GF(2^8) dot products across each byte of the input array and two constant sets of coefficients to produce each byte of the outputs. Can be used for erasure coding encode and decode. Function requires pre-calculation of a 2*32*vlen byte constant array based on the two sets of input coefficients.

**Requires** AVX

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>Length of each vector in bytes. Must be &gt;= 16.</td>
</tr>
<tr>
<td>vlen</td>
<td>Number of vector sources.</td>
</tr>
<tr>
<td>gftbls</td>
<td>Pointer to 2<em>32</em>vlen byte array of pre-calculated constants based on the array of input coefficients.</td>
</tr>
<tr>
<td>src</td>
<td>Array of pointers to source inputs.</td>
</tr>
<tr>
<td>dest</td>
<td>Array of pointers to destination data buffers.</td>
</tr>
</tbody>
</table>
7.3.2.13  *gf_2vect_dot_prod_avx2()*

```c
void gf_2vect_dot_prod_avx2 (  
    int len,  
    int vlen,  
    unsigned char * gftbls,  
    unsigned char ** src,  
    unsigned char ** dest )
```

GF($2^8$) vector dot product with two outputs.

Vector dot product optimized to calculate two outputs at a time. Does two GF($2^8$) dot products across each byte of the input array and two constant sets of coefficients to produce each byte of the outputs. Can be used for erasure coding encode and decode. Function requires pre-calculation of a $2 \times 32 \times vlen$ byte constant array based on the two sets of input coefficients.

**Requires** AVX2

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>Length of each vector in bytes. Must be $\geq 32$.</td>
</tr>
<tr>
<td>vlen</td>
<td>Number of vector sources.</td>
</tr>
<tr>
<td>gftbls</td>
<td>Pointer to $2 \times 32 \times vlen$ byte array of pre-calculated constants based on the array of input coefficients.</td>
</tr>
<tr>
<td>src</td>
<td>Array of pointers to source inputs.</td>
</tr>
<tr>
<td>dest</td>
<td>Array of pointers to destination data buffers.</td>
</tr>
</tbody>
</table>

**Returns**

none

7.3.2.14  *gf_2vect_dot_prod_sse()*

```c
void gf_2vect_dot_prod_sse (  
    int len,  
    int vlen,  
    unsigned char * gftbls,  
    unsigned char ** src,  
    unsigned char ** dest )
```

Generated by Doxygen
GF($2^8$) vector dot product with two outputs.

Vector dot product optimized to calculate two outputs at a time. Does two GF($2^8$) dot products across each byte of the input array and two constant sets of coefficients to produce each byte of the outputs. Can be used for erasure coding encode and decode. Function requires pre-calculation of a 2 x 32 x vlen byte constant array based on the two sets of input coefficients.

**Requires** SSE4.1

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>len</code></td>
<td>Length of each vector in bytes. Must be $\geq 16$.</td>
</tr>
<tr>
<td><code>vlen</code></td>
<td>Number of vector sources.</td>
</tr>
<tr>
<td><code>gftbls</code></td>
<td>Pointer to 2 x 32 x vlen byte array of pre-calculated constants based on the array of input coefficients.</td>
</tr>
<tr>
<td><code>src</code></td>
<td>Array of pointers to source inputs.</td>
</tr>
<tr>
<td><code>dest</code></td>
<td>Array of pointers to destination data buffers.</td>
</tr>
</tbody>
</table>

**Returns**

none

### 7.3.2.15 gf_2vect_mad_avx()

```c
void gf_2vect_mad_avx (  
  int len,  
  int vec,  
  int vec_i,  
  unsigned char * gftbls,  
  unsigned char * src,  
  unsigned char ** dest )
```

GF($2^8$) vector multiply with 2 accumulate. AVX version of `gf_2vect_mad_sse()`. 

**Requires** AVX
7.3.2.16  gf_2vect_mad_avx2()

```c
void gf_2vect_mad_avx2 (  
    int  _len,  
    int  _vec,  
    int  _vec_i,  
    unsigned char * _gftbls,  
    unsigned char * _src,  
    unsigned char ** _dest )
```

GF($2^{\wedge}8$) vector multiply with 2 accumulate. AVX2 version of gf_2vect_mad_sse().

**Requires** AVX2

7.3.2.17  gf_2vect_mad_sse()

```c
void gf_2vect_mad_sse (  
    int  _len,  
    int  _vec,  
    int  _vec_i,  
    unsigned char * _gftbls,  
    unsigned char * _src,  
    unsigned char ** _dest )
```

GF($2^{\wedge}8$) vector multiply with 2 accumulate. SSE version.

Does a GF($2^{\wedge}8$) multiply across each byte of input source with expanded constants and add to destination arrays. Can be used for erasure coding encode and decode update when only one source is available at a time. Function requires pre-calculation of a 32+vec byte constant array based on the input coefficients.

**Requires** SSE4.1

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>len</em></td>
<td>Length of each vector in bytes. Must be $\geq 32$.</td>
</tr>
<tr>
<td><em>vec</em></td>
<td>The number of vector sources or rows in the generator matrix for coding.</td>
</tr>
<tr>
<td><em>vec_i</em></td>
<td>The vector index corresponding to the single input source.</td>
</tr>
<tr>
<td><em>gftbls</em></td>
<td>Pointer to array of input tables generated from coding coefficients in ec_init_tables(). Must be of size 32+vec.</td>
</tr>
<tr>
<td><em>src</em></td>
<td>Pointer to source input array.</td>
</tr>
<tr>
<td><em>dest</em></td>
<td>Array of pointers to destination input/outputs.</td>
</tr>
</tbody>
</table>
7.3 erasure_code.h File Reference

Returns

none

7.3.2.18  gf_3vect_dot_prod_avx()

void gf_3vect_dot_prod_avx {
   int len,
   int vlen,
   unsigned char * gftbls,
   unsigned char ** src,
   unsigned char ** dest )

GF(2^8) vector dot product with three outputs.

Vector dot product optimized to calculate three outputs at a time. Does three GF(2^8) dot products across each byte of the input array and three constant sets of coefficients to produce each byte of the outputs. Can be used for erasure coding encode and decode. Function requires pre-calculation of a 3*32*vlen byte constant array based on the three sets of input coefficients.

Requires  AVX

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>Length of each vector in bytes. Must be &gt;= 16.</td>
</tr>
<tr>
<td>vlen</td>
<td>Number of vector sources.</td>
</tr>
<tr>
<td>gftbls</td>
<td>Pointer to 3<em>32</em>vlen byte array of pre-calculated constants based on the array of input coefficients.</td>
</tr>
<tr>
<td>src</td>
<td>Array of pointers to source inputs.</td>
</tr>
<tr>
<td>dest</td>
<td>Array of pointers to destination data buffers.</td>
</tr>
</tbody>
</table>

Returns

none

7.3.2.19  gf_3vect_dot_prod_avx2()

void gf_3vect_dot_prod_avx2 {
   int len,
   int vlen,
   unsigned char * gftbls,
   unsigned char ** src,
   unsigned char ** dest )
GF($2^{\times}8$) vector dot product with three outputs.

Vector dot product optimized to calculate three outputs at a time. Does three GF($2^{\times}8$) dot products across each byte of the input array and three constant sets of coefficients to produce each byte of the outputs. Can be used for erasure coding encode and decode. Function requires pre-calculation of a $3\times32\times\text{vlen}$ byte constant array based on the three sets of input coefficients.

**Requires** AVX2

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>Length of each vector in bytes. Must be $\geq 32$.</td>
</tr>
<tr>
<td>vlen</td>
<td>Number of vector sources.</td>
</tr>
<tr>
<td>gftbls</td>
<td>Pointer to $3\times32\times\text{vlen}$ byte array of pre-calculated constants based on the array of input coefficients.</td>
</tr>
<tr>
<td>src</td>
<td>Array of pointers to source inputs.</td>
</tr>
<tr>
<td>dest</td>
<td>Array of pointers to destination data buffers.</td>
</tr>
</tbody>
</table>

**Returns**

none

---

### 7.3.2.20 gf_3vect_dot_prod_sse()

```c
void gf_3vect_dot_prod_sse (  
    int len,  
    int vlen,  
    unsigned char * gftbls,  
    unsigned char ** src,  
    unsigned char ** dest )
```

GF($2^{\times}8$) vector dot product with three outputs.

Vector dot product optimized to calculate three outputs at a time. Does three GF($2^{\times}8$) dot products across each byte of the input array and three constant sets of coefficients to produce each byte of the outputs. Can be used for erasure coding encode and decode. Function requires pre-calculation of a $3\times32\times\text{vlen}$ byte constant array based on the three sets of input coefficients.

**Requires** SSE4.1

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>Length of each vector in bytes. Must be $\geq 16$.</td>
</tr>
<tr>
<td>vlen</td>
<td>Number of vector sources.</td>
</tr>
<tr>
<td>gftbls</td>
<td>Pointer to $3\times32\times\text{vlen}$ byte array of pre-calculated constants based on the array of input coefficients.</td>
</tr>
<tr>
<td>src</td>
<td>Array of pointers to source inputs.</td>
</tr>
<tr>
<td>dest</td>
<td>Array of pointers to destination data buffers.</td>
</tr>
</tbody>
</table>
7.3 erasure_code.h File Reference

Returns

none

7.3.2.21  gf_3vect_mad_avx()

```c
void gf_3vect_mad_avx (
    int len,
    int vec,
    int vec_i,
    unsigned char * gftbls,
    unsigned char * src,
    unsigned char ** dest )
```

GF($2^{\times}8$) vector multiply with 3 accumulate. AVX version of \textit{gf_3vect_mad_sse()}.

\textbf{Requires}  AVX

7.3.2.22  gf_3vect_mad_avx2()

```c
void gf_3vect_mad_avx2 ( 
    int len,
    int vec,
    int vec_i,
    unsigned char * gftbls,
    unsigned char * src,
    unsigned char ** dest )
```

GF($2^{\times}8$) vector multiply with 3 accumulate. AVX2 version of \textit{gf_3vect_mad_sse()}.

\textbf{Requires}  AVX2

7.3.2.23  gf_3vect_mad_sse()

```c
void gf_3vect_mad_sse ( 
    int len,
    int vec,
    int vec_i,
    unsigned char * gftbls,
    unsigned char * src,
    unsigned char ** dest )
```

GF($2^{\times}8$) vector multiply with 3 accumulate. SSE version.

Does a GF($2^{\times}8$) multiply across each byte of input source with expanded constants and add to destination arrays. Can be used for erasure coding encode and decode update when only one source is available at a time. Function requires pre-calculation of a 32*vec byte constant array based on the input coefficients.

\textbf{Requires}  SSE4.1
Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>len</code></td>
<td>Length of each vector in bytes. Must be $\geq 32$.</td>
</tr>
<tr>
<td><code>vec</code></td>
<td>The number of vector sources or rows in the generator matrix for coding.</td>
</tr>
<tr>
<td><code>_i</code></td>
<td>The vector index corresponding to the single input source.</td>
</tr>
<tr>
<td><code>gftbls</code></td>
<td>Pointer to array of input tables generated from coding coefficients in <code>ec_init_tables()</code>. Must be of size $32 \times \text{vec}$.</td>
</tr>
<tr>
<td><code>src</code></td>
<td>Pointer to source input array.</td>
</tr>
<tr>
<td><code>dest</code></td>
<td>Array of pointers to destination input/outputs.</td>
</tr>
</tbody>
</table>

Returns

none

7.3.2.24 `gf_4vect_dot_prod_avx()`

```c
void gf_4vect_dot_prod_avx (  
  int len,  
  int vlen,  
  unsigned char * gftbls,  
  unsigned char ** src,  
  unsigned char ** dest )
```

GF($2^8$) vector dot product with four outputs.

Vector dot product optimized to calculate four outputs at a time. Does four GF($2^8$) dot products across each byte of the input array and four constant sets of coefficients to produce each byte of the outputs. Can be used for erasure coding encode and decode. Function requires pre-calculation of a $4 \times 32 \times \text{vlen}$ byte constant array based on the four sets of input coefficients.

Requires AVX

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>len</code></td>
<td>Length of each vector in bytes. Must be $\geq 16$.</td>
</tr>
<tr>
<td><code>vlen</code></td>
<td>Number of vector sources.</td>
</tr>
<tr>
<td><code>gftbls</code></td>
<td>Pointer to $4 \times 32 \times \text{vlen}$ byte array of pre-calculated constants based on the array of input coefficients.</td>
</tr>
<tr>
<td><code>src</code></td>
<td>Array of pointers to source inputs.</td>
</tr>
<tr>
<td><code>dest</code></td>
<td>Array of pointers to destination data buffers.</td>
</tr>
</tbody>
</table>

Returns

none
7.3.2.25  **gf_4vect_dot_prod_avx2()**

```c
void gf_4vect_dot_prod_avx2 (  
    int len,  
    int vlen,  
    unsigned char * gftbls,  
    unsigned char ** src,  
    unsigned char ** dest )
```

GF($2^8$) vector dot product with four outputs.

Vector dot product optimized to calculate four outputs at a time. Does four GF($2^8$) dot products across each byte of the input array and four constant sets of coefficients to produce each byte of the outputs. Can be used for erasure coding encode and decode. Function requires pre-calculation of a 4\*32\*vlen byte constant array based on the four sets of input coefficients.

**Requires**  AVX2

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>len</code></td>
<td>Length of each vector in bytes. Must be $\geq 32$.</td>
</tr>
<tr>
<td><code>vlen</code></td>
<td>Number of vector sources.</td>
</tr>
<tr>
<td><code>gftbls</code></td>
<td>Pointer to 4*32*vlen byte array of pre-calculated constants based on the array of input coefficients.</td>
</tr>
<tr>
<td><code>src</code></td>
<td>Array of pointers to source inputs.</td>
</tr>
<tr>
<td><code>dest</code></td>
<td>Array of pointers to destination data buffers.</td>
</tr>
</tbody>
</table>

**Returns**

`none`

7.3.2.26  **gf_4vect_dot_prod_sse()**

```c
void gf_4vect_dot_prod_sse (  
    int len,  
    int vlen,  
    unsigned char * gftbls,  
    unsigned char ** src,  
    unsigned char ** dest )
```

GF($2^8$) vector dot product with four outputs.

Vector dot product optimized to calculate four outputs at a time. Does four GF($2^8$) dot products across each byte of the input array and four constant sets of coefficients to produce each byte of the outputs. Can be used for erasure coding encode and decode. Function requires pre-calculation of a 4\*32\*vlen byte constant array based on the four sets of input coefficients.

**Requires**  SSE4.1
Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>Length of each vector in bytes. Must be &gt;= 16.</td>
</tr>
<tr>
<td>vlen</td>
<td>Number of vector sources.</td>
</tr>
<tr>
<td>gftbls</td>
<td>Pointer to 4×32×vlen byte array of pre-calculated constants based on the array of input coefficients.</td>
</tr>
<tr>
<td>src</td>
<td>Array of pointers to source inputs.</td>
</tr>
<tr>
<td>dest</td>
<td>Array of pointers to destination data buffers.</td>
</tr>
</tbody>
</table>

Returns

none

7.3.2.27  \texttt{gf\_4vect\_mad\_avx()}

\begin{verbatim}
void gf_4vect_mad_avx (  
    int len,  
    int vec,  
    int vec_i,  
    unsigned char * gftbls,  
    unsigned char * src,  
    unsigned char ** dest )
\end{verbatim}

GF(2^8) vector multiply with 4 accumulate. AVX version of \texttt{gf\_4vect\_mad\_sse()}.  

\textbf{Requires} AVX

7.3.2.28  \texttt{gf\_4vect\_mad\_avx2()}

\begin{verbatim}
void gf_4vect_mad_avx2 (  
    int len,  
    int vec,  
    int vec_i,  
    unsigned char * gftbls,  
    unsigned char * src,  
    unsigned char ** dest )
\end{verbatim}

GF(2^8) vector multiply with 4 accumulate. AVX2 version of \texttt{gf\_4vect\_mad\_sse()}.  

\textbf{Requires} AVX2
7.3.2.29  

**gf_4vect_mad_sse()**

```c
void gf_4vect_mad_sse (
    int len,
    int vec,
    int vec_i,
    unsigned char * gftbls,
    unsigned char * src,
    unsigned char ** dest )
```

GF($2^8$) vector multiply with 4 accumulate. SSE version.

Does a GF($2^8$) multiply across each byte of input source with expanded constants and add to destination arrays. Can be used for erasure coding encode and decode update when only one source is available at a time. Function requires pre-calculation of a 32×vec byte constant array based on the input coefficients.

**Requires** SSE4.1

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>Length of each vector in bytes. Must be $\geq$ 32.</td>
</tr>
<tr>
<td>vec</td>
<td>The number of vector sources or rows in the generator matrix for coding.</td>
</tr>
<tr>
<td>vec_i</td>
<td>The vector index corresponding to the single input source.</td>
</tr>
<tr>
<td>gftbls</td>
<td>Pointer to array of input tables generated from coding coefficients in ec_init_tables(). Must be of size 32×vec.</td>
</tr>
<tr>
<td>src</td>
<td>Pointer to source input array.</td>
</tr>
<tr>
<td>dest</td>
<td>Array of pointers to destination input/outputs.</td>
</tr>
</tbody>
</table>

**Returns**
none

7.3.2.30  

**gf_5vect_dot_prod_avx()**

```c
void gf_5vect_dot_prod_avx (
    int len,
    int vlen,
    unsigned char * gftbls,
    unsigned char ** src,
    unsigned char ** dest )
```

GF($2^8$) vector dot product with five outputs.

Vector dot product optimized to calculate five outputs at a time. Does five GF($2^8$) dot products across each byte of the input array and five constant sets of coefficients to produce each byte of the outputs. Can be used for erasure coding encode and decode. Function requires pre-calculation of a 5×32×vlen byte constant array based on the five sets of input coefficients.

**Requires** AVX
Parameters

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>Length of each vector in bytes. Must $\geq 16$.</td>
</tr>
<tr>
<td>vlen</td>
<td>Number of vector sources.</td>
</tr>
<tr>
<td>gftbls</td>
<td>Pointer to $5 \times 32 \times vlen$ byte array of pre-calculated constants based on the array of input coefficients.</td>
</tr>
<tr>
<td>src</td>
<td>Array of pointers to source inputs.</td>
</tr>
<tr>
<td>dest</td>
<td>Array of pointers to destination data buffers.</td>
</tr>
</tbody>
</table>

Returns

none

7.3.2.31  gf_5vect_dot_prod_avx2()

```c
void gf_5vect_dot_prod_avx2 (  
    int len,  
    int vlen,  
    unsigned char * gftbls,  
    unsigned char ** src,  
    unsigned char ** dest )
```

GF($2^8$) vector dot product with five outputs.

Vector dot product optimized to calculate five outputs at a time. Does five GF($2^8$) dot products across each byte of the input array and five constant sets of coefficients to produce each byte of the outputs. Can be used for erasure coding encode and decode. Function requires pre-calculation of a $5 \times 32 \times vlen$ byte constant array based on the five sets of input coefficients.

**Requires** AVX2

Parameters

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>Length of each vector in bytes. Must $\geq 32$.</td>
</tr>
<tr>
<td>vlen</td>
<td>Number of vector sources.</td>
</tr>
<tr>
<td>gftbls</td>
<td>Pointer to $5 \times 32 \times vlen$ byte array of pre-calculated constants based on the array of input coefficients.</td>
</tr>
<tr>
<td>src</td>
<td>Array of pointers to source inputs.</td>
</tr>
<tr>
<td>dest</td>
<td>Array of pointers to destination data buffers.</td>
</tr>
</tbody>
</table>

Returns

none
### 7.3.2.32 gf_5vect_dot_prod_sse()

```c
void gf_5vect_dot_prod_sse (
    int len,
    int vlen,
    unsigned char * gftbls,
    unsigned char ** src,
    unsigned char ** dest )
```

GF($2^8$) vector dot product with five outputs.

Vector dot product optimized to calculate five outputs at a time. Does five GF($2^8$) dot products across each byte of the input array and five constant sets of coefficients to produce each byte of the outputs. Can be used for erasure coding encode and decode. Function requires pre-calculation of a 5x32xvlen byte constant array based on the five sets of input coefficients.

**Requires** SSE4.1

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>Length of each vector in bytes. Must $\geq 16$.</td>
</tr>
<tr>
<td>vlen</td>
<td>Number of vector sources.</td>
</tr>
<tr>
<td>gftbls</td>
<td>Pointer to 5x32xvlen byte array of pre-calculated constants based on the array of input coefficients.</td>
</tr>
<tr>
<td>src</td>
<td>Array of pointers to source inputs.</td>
</tr>
<tr>
<td>dest</td>
<td>Array of pointers to destination data buffers.</td>
</tr>
</tbody>
</table>

**Returns**

none

### 7.3.2.33 gf_5vect_mad_avx()

```c
void gf_5vect_mad_avx (
    int len,
    int vec,
    int vec_i,
    unsigned char * gftbls,
    unsigned char * src,
    unsigned char ** dest )
```

GF($2^8$) vector multiply with 5 accumulate. AVX version.

**Requires** AVX

---

Generated by Doxygen
7.3.2.34  **gf_5vect_mad_avx2()**

```c
void gf_5vect_mad_avx2 ( 
    int len, 
    int vec, 
    int vec_i, 
    unsigned char * gftbls, 
    unsigned char * src, 
    unsigned char ** dest )
```

GF($2^8$) vector multiply with 5 accumulate. AVX2 version.

**Requires** AVX2

7.3.2.35  **gf_5vect_mad_sse()**

```c
void gf_5vect_mad_sse ( 
    int len, 
    int vec, 
    int vec_i, 
    unsigned char * gftbls, 
    unsigned char * src, 
    unsigned char ** dest )
```

GF($2^8$) vector multiply with 5 accumulate. SSE version.

**Requires** SSE4.1

7.3.2.36  **gf_6vect_dot_prod_avx()**

```c
void gf_6vect_dot_prod_avx ( 
    int len, 
    int vlen, 
    unsigned char * gftbls, 
    unsigned char ** src, 
    unsigned char ** dest )
```

GF($2^8$) vector dot product with six outputs.

Vector dot product optimized to calculate six outputs at a time. Does six GF($2^8$) dot products across each byte of the input array and six constant sets of coefficients to produce each byte of the outputs. Can be used for erasure coding encode and decode. Function requires pre-calculation of a 6×32×vlen byte constant array based on the six sets of input coefficients.

**Requires** AVX
Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>\textit{len}</td>
<td>Length of each vector in bytes. Must be (\geq 16).</td>
</tr>
<tr>
<td>\textit{vlen}</td>
<td>Number of vector sources.</td>
</tr>
<tr>
<td>\textit{gftbls}</td>
<td>Pointer to (6\times32\times\text{vlen}) byte array of pre-calculated constants based on the array of input coefficients.</td>
</tr>
<tr>
<td>\textit{src}</td>
<td>Array of pointers to source inputs.</td>
</tr>
<tr>
<td>\textit{dest}</td>
<td>Array of pointers to destination data buffers.</td>
</tr>
</tbody>
</table>

Returns

none

\textbf{7.3.2.37} \texttt{gf\_6vect\_dot\_prod\_avx2()}

\begin{verbatim}
void gf_6vect_dot_prod_avx2 ( 
    int \textit{len},
    int \textit{vlen},
    unsigned char * \textit{gftbls},
    unsigned char ** \textit{src},
    unsigned char ** \textit{dest} )
\end{verbatim}

GF\((2^8)\) vector dot product with six outputs.

Vector dot product optimized to calculate six ouputs at a time. Does six GF\((2^8)\) dot products across each byte of the input array and six constant sets of coefficients to produce each byte of the outputs. Can be used for erasure coding encode and decode. Function requires pre-calculation of a \(6\times32\times\text{vlen}\) byte constant array based on the six sets of input coefficients.

\textbf{Requires} AVX2

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>\textit{len}</td>
<td>Length of each vector in bytes. Must be (\geq 32).</td>
</tr>
<tr>
<td>\textit{vlen}</td>
<td>Number of vector sources.</td>
</tr>
<tr>
<td>\textit{gftbls}</td>
<td>Pointer to (6\times32\times\text{vlen}) byte array of pre-calculated constants based on the array of input coefficients.</td>
</tr>
<tr>
<td>\textit{src}</td>
<td>Array of pointers to source inputs.</td>
</tr>
<tr>
<td>\textit{dest}</td>
<td>Array of pointers to destination data buffers.</td>
</tr>
</tbody>
</table>

Returns

none
7.3.2.38  gf_6vect_dot_prod_sse()

void gf_6vect_dot_prod_sse (
    int len,
    int vlen,
    unsigned char * gftbls,
    unsigned char ** src,
    unsigned char ** dest )

GF(2^8) vector dot product with six outputs.

Vector dot product optimized to calculate six outputs at a time. Does six GF(2^8) dot products across each byte of the input array and six constant sets of coefficients to produce each byte of the outputs. Can be used for erasure coding encode and decode. Function requires pre-calculation of a 6×32×vlen byte constant array based on the six sets of input coefficients.

Requires  SSE4.1

Parameters

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>len</strong></td>
<td>Length of each vector in bytes. Must be &gt;= 16.</td>
</tr>
<tr>
<td><strong>vlen</strong></td>
<td>Number of vector sources.</td>
</tr>
<tr>
<td><strong>gftbls</strong></td>
<td>Pointer to 6×32×vlen byte array of pre-calculated constants based on the array of input coefficients.</td>
</tr>
<tr>
<td><strong>src</strong></td>
<td>Array of pointers to source inputs.</td>
</tr>
<tr>
<td><strong>dest</strong></td>
<td>Array of pointers to destination data buffers.</td>
</tr>
</tbody>
</table>

Returns

none

7.3.2.39  gf_6vect_mad_avx()

void gf_6vect_mad_avx (
    int len,
    int vec,
    int vec_i,
    unsigned char * gftbls,
    unsigned char * src,
    unsigned char ** dest )

GF(2^8) vector multiply with 6 accumulate. AVX version.

Requires  AVX
7.3.2.40  

```c
void gf_6vect_mad_avx2 (  
    int len,  
    int vec,  
    int vec_i,  
    unsigned char * gftbls,  
    unsigned char * src,  
    unsigned char ** dest )
```

GF($2^8$) vector multiply with 6 accumulate. AVX2 version.

Requires AVX2

7.3.2.41  

```c
void gf_6vect_mad_sse (  
    int len,  
    int vec,  
    int vec_i,  
    unsigned char * gftbls,  
    unsigned char * src,  
    unsigned char ** dest )
```

GF($2^8$) vector multiply with 6 accumulate. SSE version.

Requires SSE4.1

7.3.2.42  

```c
void gf_gen_cauchy1_matrix (  
    unsigned char * a,  
    int m,  
    int k )
```

Generate a Cauchy matrix of coefficients to be used for encoding.

Cauchy matrix example of encoding coefficients where high portion of matrix is identity matrix I and lower portion is constructed as $\frac{1}{i+j}$ | i != j, i:{0,k-1} j:{k,m-1}. Any sub-matrix of a Cauchy matrix should be invertable.
7.3.2.43  gf_gen_rs_matrix()

```c
void gf_gen_rs_matrix (  
    unsigned char ∗ a,  
    int m,  
    int k )
```

Generate a matrix of coefficients to be used for encoding.

Vandermonde matrix example of encoding coefficients where high portion of matrix is identity matrix I and lower portion is constructed as $2^i \cdot [(j-k+1)]_{i:[0,k-1]} \cdot [k,m-1]$. Commonly used method for choosing coefficients in erasure encoding but does not guarantee invertable for every sub matrix. For large pairs of m and k it is possible to find cases where the decode matrix chosen from sources and parity is not invertable. Users may want to adjust for certain pairs m and k. If m and k satisfy one of the following inequalities, no adjustment is required:

- $k \leq 3$
- $k = 4, m \leq 25$
- $k = 5, m \leq 10$
- $k \leq 21, m-k = 4$
- $m - k \leq 3$.
7.3.2.44  \textit{gf\_inv()}

\texttt{unsigned char \_gf\_inv (}
\begin{verbatim}
    unsigned char \texttt{a }
\end{verbatim}
\texttt{)}

Single element GF(2\(^8\)) inverse.

Parameters

\begin{center}
\begin{tabular}{|c|l|}
\hline
\texttt{a} & Input element \\
\hline
\end{tabular}
\end{center}

Returns

Field element \( b \) such that \( a \times b = \{1\} \)

7.3.2.45  \textit{gf\_invert\_matrix()}

\texttt{int \_gf\_invert\_matrix (}
\begin{verbatim}
    unsigned char * \texttt{in},
    unsigned char * \texttt{out},
    const int \texttt{n }
\end{verbatim}
\texttt{)}

Invert a matrix in GF(2\(^8\))

Parameters

\begin{center}
\begin{tabular}{|c|l|}
\hline
\texttt{in} & input matrix \\
\texttt{out} & output matrix such that \([\text{in}] \times [\text{out}] = [I]\) - identity matrix \\
\texttt{n} & size of matrix \([nxn]\) \\
\hline
\end{tabular}
\end{center}

Returns

0 successful, other fail on singular input matrix

7.3.2.46  \textit{gf\_mul()}

\texttt{unsigned char \_gf\_mul (}
\begin{verbatim}
    unsigned char \texttt{a},
    unsigned char \texttt{b }
\end{verbatim}
\texttt{)}

Single element GF(2\(^8\)) multiply.
Parameters

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>Multiplicand (a)</td>
</tr>
<tr>
<td>(b)</td>
<td>Multiplicand (b)</td>
</tr>
</tbody>
</table>

Returns

Product of \(a\) and \(b\) in \(\text{GF}(2^8)\)

7.3.2.47  \texttt{gf\_vect\_dot\_prod()}

```c
void gf_vect_dot_prod (  
    int \textit{len},  
    int \textit{vlen},  
    unsigned char * \textit{gftbls},  
    unsigned char ** \textit{src},  
    unsigned char * \textit{dest} )
```

\(\text{GF}(2^8)\) vector dot product, runs appropriate version.

Does a \(\text{GF}(2^8)\) dot product across each byte of the input array and a constant set of coefficients to produce each byte of the output. Can be used for erasure coding encode and decode. Function requires pre-calculation of a \(32 \times \textit{vlen}\) byte constant array based on the input coefficients.

This function determines what instruction sets are enabled and selects the appropriate version at runtime.

Parameters

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>\textit{len}</td>
<td>Length of each vector in bytes. Must be (\geq 32).</td>
</tr>
<tr>
<td>\textit{vlen}</td>
<td>Number of vector sources.</td>
</tr>
<tr>
<td>\textit{gftbls}</td>
<td>Pointer to (32 \times \textit{vlen}) byte array of pre-calculated constants based on the array of input coefficients.</td>
</tr>
<tr>
<td>\textit{src}</td>
<td>Array of pointers to source inputs.</td>
</tr>
<tr>
<td>\textit{dest}</td>
<td>Pointer to destination data array.</td>
</tr>
</tbody>
</table>

Returns

none

7.3.2.48  \texttt{gf\_vect\_dot\_prod\_avx()}

```c
void gf_vect_dot_prod_avx (  
    int \textit{len},  
```

Generated by Doxygen
int vlen,
unsigned char * gftbls,
unsigned char ** src,
unsigned char * dest )

GF(2^8) vector dot product.

Does a GF(2^8) dot product across each byte of the input array and a constant set of coefficients to produce each byte of the output. Can be used for erasure coding encode and decode. Function requires pre-calculation of a 32+vlen byte constant array based on the input coefficients.

**Requires** AVX

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>Length of each vector in bytes. Must be &gt;= 16.</td>
</tr>
<tr>
<td>vlen</td>
<td>Number of vector sources.</td>
</tr>
<tr>
<td>gftbls</td>
<td>Pointer to 32+vlen byte array of pre-calculated constants based on the array of input coefficients.</td>
</tr>
<tr>
<td>src</td>
<td>Array of pointers to source inputs.</td>
</tr>
<tr>
<td>dest</td>
<td>Pointer to destination data array.</td>
</tr>
</tbody>
</table>

**Returns**

none

7.3.2.49 `gf_vect_dot_prod_avx2()`

```c
void gf_vect_dot_prod_avx2 ( int len,
int vlen,
unsigned char * gftbls,
unsigned char ** src,
unsigned char * dest )
```

GF(2^8) vector dot product.

Does a GF(2^8) dot product across each byte of the input array and a constant set of coefficients to produce each byte of the output. Can be used for erasure coding encode and decode. Function requires pre-calculation of a 32+vlen byte constant array based on the input coefficients.

**Requires** AVX2

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>Length of each vector in bytes. Must be &gt;= 32.</td>
</tr>
<tr>
<td>vlen</td>
<td>Number of vector sources.</td>
</tr>
<tr>
<td>gftbls</td>
<td>Pointer to 32+vlen byte array of pre-calculated constants based on the array of input coefficients.</td>
</tr>
<tr>
<td>src</td>
<td>Array of pointers to source inputs.</td>
</tr>
<tr>
<td>dest</td>
<td>Pointer to destination data array.</td>
</tr>
</tbody>
</table>
Returns
  none

7.3.2.50  gf_vect_dot_prod_base()

```c
void gf_vect_dot_prod_base (
    int len,
    int vlen,
    unsigned char * gftbls,
    unsigned char ** src,
    unsigned char * dest )
```

GF($2^8$) vector dot product, runs baseline version.

Does a GF($2^8$) dot product across each byte of the input array and a constant set of coefficients to produce each byte of the output. Can be used for erasure coding encode and decode. Function requires pre-calculation of a 32-vlen byte constant array based on the input coefficients.

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>Length of each vector in bytes. Must be $\geq 16$.</td>
</tr>
<tr>
<td>vlen</td>
<td>Number of vector sources.</td>
</tr>
<tr>
<td>gftbls</td>
<td>Pointer to 32-vlen byte array of pre-calculated constants based on the array of input coefficients. Only elements $32 \times \text{CONST} \times j + 1$ of this array are used, where $j = (0, 1, 2...)$.CONST is the number of elements in the array of input coefficients. The elements used correspond to the original input coefficients.</td>
</tr>
<tr>
<td>src</td>
<td>Array of pointers to source inputs.</td>
</tr>
<tr>
<td>dest</td>
<td>Pointer to destination data array.</td>
</tr>
</tbody>
</table>

Returns
  none

7.3.2.51  gf_vect_dot_prod_sse()

```c
void gf_vect_dot_prod_sse (
    int len,
    int vlen,
    unsigned char * gftbls,
    unsigned char ** src,
    unsigned char * dest )
```

GF($2^8$) vector dot product.

Does a GF($2^8$) dot product across each byte of the input array and a constant set of coefficients to produce each byte of the output. Can be used for erasure coding encode and decode. Function requires pre-calculation of a 32-vlen byte constant array based on the input coefficients.
7.3 erasure_code.h File Reference

Requires  
SSE4.1

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>Length of each vector in bytes. Must be &gt;= 16.</td>
</tr>
<tr>
<td>vlen</td>
<td>Number of vector sources.</td>
</tr>
<tr>
<td>gftbls</td>
<td>Pointer to 32+vlen byte array of pre-calculated constants based on the array of input coefficients.</td>
</tr>
<tr>
<td>src</td>
<td>Array of pointers to source inputs.</td>
</tr>
<tr>
<td>dest</td>
<td>Pointer to destination data array.</td>
</tr>
</tbody>
</table>

Returns

none

7.3.2.52  
gf_vect_mad()

void gf_vect_mad (  
    int len,  
    int vec,  
    int vec_i,  
    unsigned char * gftbls,  
    unsigned char * src,  
    unsigned char * dest )

GF(2^8) vector multiply accumulate, runs appropriate version.

Does a GF(2^8) multiply across each byte of input source with expanded constant and add to destination array. Can be used for erasure coding encode and decode update when only one source is available at a time. Function requires pre-calculation of a 32+vec byte constant array based on the input coefficients.

This function determines what instruction sets are enabled and selects the appropriate version at runtime.

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>Length of each vector in bytes. Must be &gt;= 32.</td>
</tr>
<tr>
<td>vec</td>
<td>The number of vector sources or rows in the generator matrix for coding.</td>
</tr>
<tr>
<td>vec_i</td>
<td>The vector index corresponding to the single input source.</td>
</tr>
<tr>
<td>gftbls</td>
<td>Pointer to array of input tables generated from coding coefficients in ec_init_tables(). Must be of size 32+vec.</td>
</tr>
<tr>
<td>src</td>
<td>Array of pointers to source inputs.</td>
</tr>
<tr>
<td>dest</td>
<td>Pointer to destination data array.</td>
</tr>
</tbody>
</table>
Returns

none

7.3.2.53  gf_vect_mad_avx()

void gf_vect_mad_avx (  
    int len,  
    int vec,  
    int vec_i,  
    unsigned char * gftbls,  
    unsigned char * src,  
    unsigned char * dest )

GF($2^8$) vector multiply accumulate, arch specific version.

Arch specific version of gf_vect_mad() with same parameters.

**Requires** AVX

7.3.2.54  gf_vect_mad_avx2()

void gf_vect_mad_avx2 (  
    int len,  
    int vec,  
    int vec_i,  
    unsigned char * gftbls,  
    unsigned char * src,  
    unsigned char * dest )

GF($2^8$) vector multiply accumulate, arch specific version.

Arch specific version of gf_vect_mad() with same parameters.

**Requires** AVX2
7.3.2.55  \texttt{gf\_vect\_mad\_base()}

```c
void gf_vect_mad_base ( 
    int \texttt{len}, 
    int \texttt{vec}, 
    int \texttt{vec}_i, 
    unsigned char * \texttt{v}, 
    unsigned char * \texttt{src}, 
    unsigned char * \texttt{dest} )
```

GF($2^8$) vector multiply accumulate, baseline version.

Baseline version of \texttt{gf\_vect\_mad()} with same parameters.

7.3.2.56  \texttt{gf\_vect\_mad\_sse()}

```c
void gf_vect_mad_sse ( 
    int \texttt{len}, 
    int \texttt{vec}, 
    int \texttt{vec}_i, 
    unsigned char * \texttt{gftbls}, 
    unsigned char * \texttt{src}, 
    unsigned char * \texttt{dest} )
```

GF($2^8$) vector multiply accumulate, arch specific version.

Arch specific version of \texttt{gf\_vect\_mad()} with same parameters.

\textbf{Requires} \hspace{1em} SSE4.1

7.4  \texttt{gf\_vect\_mul.h} File Reference

Interface to functions for vector (block) multiplication in GF($2^8$).

Functions

- \texttt{int \texttt{gf\_vect\_mul\_sse}} (int \texttt{len}, unsigned char *\texttt{gftbl}, void *\texttt{src}, void *\texttt{dest}) 
  \textit{GF($2^8$) vector multiply by constant.}
- \texttt{int \texttt{gf\_vect\_mul\_avx}} (int \texttt{len}, unsigned char *\texttt{gftbl}, void *\texttt{src}, void *\texttt{dest}) 
  \textit{GF($2^8$) vector multiply by constant.}
- \texttt{int \texttt{gf\_vect\_mul}} (int \texttt{len}, unsigned char *\texttt{gftbl}, void *\texttt{src}, void *\texttt{dest}) 
  \textit{GF($2^8$) vector multiply by constant, runs appropriate version.}
- \texttt{void \texttt{gf\_vect\_mul\_init}} (unsigned char c, unsigned char *\texttt{gftbl})
  \textit{Initialize 32-byte constant array for GF($2^8$) vector multiply.}
- \texttt{void \texttt{gf\_vect\_mul\_base}} (int \texttt{len}, unsigned char *\texttt{a}, unsigned char *\texttt{src}, unsigned char *\texttt{dest}) 
  \textit{GF($2^8$) vector multiply by constant, runs baseline version.}
7.4.1 Detailed Description

Interface to functions for vector (block) multiplication in GF(2^8).

This file defines the interface to routines used in fast RAID rebuild and erasure codes.

7.4.2 Function Documentation

7.4.2.1 gf_vect_mul()

```c
int gf_vect_mul (int len, unsigned char *gftbl, void *src, void *dest)
```

GF(2^8) vector multiply by constant, runs appropriate version.

Does a GF(2^8) vector multiply b = Ca where a and b are arrays and C is a single field element in GF(2^8). Can be used for RAID6 rebuild and partial write functions. Function requires pre-calculation of a 32-element constant array based on constant C. gftbl(C) = {C{00}, C{01}, C{02}, ... , C{0f} }, {C{00}, C{10}, C{20}, ... , C{f0} }. Len and src must be aligned to 32B.

This function determines what instruction sets are enabled and selects the appropriate version at runtime.

Parameters

<table>
<thead>
<tr>
<th>len</th>
<th>Length of vector in bytes. Must be aligned to 32B.</th>
</tr>
</thead>
<tbody>
<tr>
<td>gftbl</td>
<td>Pointer to 32-byte array of pre-calculated constants based on C.</td>
</tr>
<tr>
<td>src</td>
<td>Pointer to src data array. Must be aligned to 32B.</td>
</tr>
<tr>
<td>dest</td>
<td>Pointer to destination data array. Must be aligned to 32B.</td>
</tr>
</tbody>
</table>

Returns

0 pass, other fail

7.4.2.2 gf_vect_mul_avx()

```c
int gf_vect_mul_avx (int len, unsigned char *gftbl,
```

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void * src,
void * dest )

GF(2^8) vector multiply by constant.

Does a GF(2^8) vector multiply b = Ca where a and b are arrays and C is a single field element in GF(2^8). Can be used for RAID6 rebuild and partial write functions. Function requires pre-calculation of a 32-element constant array based on constant C. gftbl(C) = {C(00), C(01), C(02), ... , C(0f) }, {C(00), C(10), C(20), ... , C(f0) }. Len and src must be aligned to 32B.

Requires AVX

Parameters

<table>
<thead>
<tr>
<th>len</th>
<th>Length of vector in bytes. Must be aligned to 32B.</th>
</tr>
</thead>
<tbody>
<tr>
<td>gftbl</td>
<td>Pointer to 32-byte array of pre-calculated constants based on C.</td>
</tr>
<tr>
<td>src</td>
<td>Pointer to src data array. Must be aligned to 32B.</td>
</tr>
<tr>
<td>dest</td>
<td>Pointer to destination data array. Must be aligned to 32B.</td>
</tr>
</tbody>
</table>

Returns

0 pass, other fail

7.4.2.3 gf_vect_mul_base()

void gf_vect_mul_base ( 
  int len,
  unsigned char * a,
  unsigned char * src,
  unsigned char * dest )

GF(2^8) vector multiply by constant, runs baseline version.

Does a GF(2^8) vector multiply b = Ca where a and b are arrays and C is a single field element in GF(2^8). Can be used for RAID6 rebuild and partial write functions. Function requires pre-calculation of a 32-element constant array based on constant C. gftbl(C) = {C(00), C(01), C(02), ... , C(0f) }, {C(00), C(10), C(20), ... , C(f0) }. Len and src must be aligned to 32B.

Parameters

<table>
<thead>
<tr>
<th>len</th>
<th>Length of vector in bytes. Must be aligned to 32B.</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Pointer to 32-byte array of pre-calculated constants based on C. only use 2nd element is used.</td>
</tr>
<tr>
<td>src</td>
<td>Pointer to src data array. Must be aligned to 32B.</td>
</tr>
<tr>
<td>dest</td>
<td>Pointer to destination data array. Must be aligned to 32B.</td>
</tr>
</tbody>
</table>
### 7.4.2.4  

**gf_vect_mul_init()**

```c
void gf_vect_mul_init {
    unsigned char c,
    unsigned char * gftbl }
```

Initialize 32-byte constant array for GF($2^8$) vector multiply.

Calculates array \{C\{00\}, C\{01\}, C\{02\}, ... , C\{0f\} \}, \{C\{00\}, C\{10\}, C\{20\}, ... , C\{f0\} \} as required by other fast vector multiply functions.

**Parameters**

<table>
<thead>
<tr>
<th>c</th>
<th>Constant input.</th>
</tr>
</thead>
<tbody>
<tr>
<td>gftbl</td>
<td>Table output.</td>
</tr>
</tbody>
</table>

### 7.4.2.5  

**gf_vect_mul_sse()**

```c
int gf_vect_mul_sse {
    int len,
    unsigned char * gftbl,
    void * src,
    void * dest }
```

GF($2^8$) vector multiply by constant.

Does a GF($2^8$) vector multiply \( b = Ca \) where \( a \) and \( b \) are arrays and \( C \) is a single field element in GF($2^8$). Can be used for RAID6 rebuild and partial write functions. Function requires pre-calculation of a 32-element constant array based on constant \( C \). \( gftbl(C) = \{C\{00\}, C\{01\}, C\{02\}, ... , C\{0f\} \}, \{C\{00\}, C\{10\}, C\{20\}, ... , C\{f0\} \} \). Len and src must be aligned to 32B.

**Requires** SSE4.1

**Parameters**

<table>
<thead>
<tr>
<th>len</th>
<th>Length of vector in bytes. Must be aligned to 32B.</th>
</tr>
</thead>
<tbody>
<tr>
<td>gftbl</td>
<td>Pointer to 32-byte array of pre-calculated constants based on C.</td>
</tr>
<tr>
<td>src</td>
<td>Pointer to src data array. Must be aligned to 32B.</td>
</tr>
<tr>
<td>dest</td>
<td>Pointer to destination data array. Must be aligned to 32B.</td>
</tr>
</tbody>
</table>
Returns

0 pass, other fail

7.5  igzip_lib.h File Reference

This file defines the igzip compression and decompression interface, a high performance deflate compression interface for storage applications.

#include <stdint.h>
#include "types.h"

Data Structures

- struct isal_huff_histogram
  
  Holds histogram of deflate symbols.
- struct isal_mod_hist
- struct BitBuf2
  
  Holds Bit Buffer information.
- struct isal_zstate
  
  Holds the internal state information for input and output compression streams.
- struct isal_hufftables
  
  Holds the huffman tree used to huffman encode the input stream.
- struct isal_zstream
  
  Holds stream information.
- struct inflate_huff_code_large
- struct inflate_huff_code_small
- struct inflate_state
  
  Holds decompression state information.

Enumerations

- enum isal_zstate_state {
  
  ZSTATE_NEW_HDR, ZSTATE_HDR, ZSTATE_CREATE_HDR, ZSTATE_BODY,
  ZSTATE_FLUSH_READ_BUFFER, ZSTATE_TYPE0_BODY, ZSTATE_SYNC_FLUSH, ZSTATE_FLUSH_WRITE_BUFFER,
  ZSTATE_TRL, ZSTATE_END, ZSTATE_TMP_NEW_HDR, ZSTATE_TMP_HDR,
  ZSTATE_TMP_CREATE_HDR, ZSTATE_TMP_BODY, ZSTATE_TMP_FLUSH_READ_BUFFER, ZSTATE_TMP_TYPE0_BODY,
  ZSTATE_TMP_SYNC_FLUSH, ZSTATE_TMP_FLUSH_WRITE_BUFFER, ZSTATE_TMP_TRL, ZSTATE_TMP_SYNC_WRITE_BUFFER,
  ZSTATE_TMP_TRL, ZSTATE_TMP_END
}

Compression State please note ZSTATE_TRL only applies for GZIP compression.
Functions

- **void isal_update_histogram (uint8_t *in_stream, int length, struct isal_huff_histogram *histogram)**
  
  Updates histograms to include the symbols found in the input stream. Since this function only updates the histograms, it can be called on multiple streams to get a histogram better representing the desired data set. When first using histogram it must be initialized by zeroing the structure.

- **int isal_create_hufftables (struct isal_hufftables *hufftables, struct isal_huff_histogram *histogram)**
  
  Creates a custom huffman code for the given histograms in which every literal and repeat length is assigned a code and all possible lookback distances are assigned a code.

- **int isal_create_hufftables_subset (struct isal_hufftables *hufftables, struct isal_huff_histogram *histogram)**
  
  Creates a custom huffman code for the given histograms like isal_create_hufftables() except literals with 0 frequency in the histogram are not assigned a code.

- **void isal_deflate_init (struct isal_zstream *stream)**
  
  Initialize compression stream data structure.

- **void isal_deflate_reset (struct isal_zstream *stream)**
  
  Reinitialize compression stream data structure. Performs the same action as isal_deflate_init, but does not change user supplied input such as the level, flush type, compression wrapper (like gzip), hufftables, and end_of_stream_flag.

- **int isal_deflate_set_hufftables (struct isal_zstream *stream, struct isal_hufftables *hufftables, int type)**
  
  Set stream to use a new Huffman code.

- **void isal_deflate_stateless_init (struct isal_zstream *stream)**
  
  Initialize compression stream data structure.

- **int isal_deflate_set_dict (struct isal_zstream *stream, uint8_t *dict, uint32_t dict_len)**
  
  Set compression dictionary to use.

- **int isal_deflate (struct isal_zstream *stream)**
  
  Fast data (deflate) compression for storage applications.

- **int isal_deflate_stateless (struct isal_zstream *stream)**
  
  Fast data (deflate) stateless compression for storage applications.

- **void isal_inflate_init (struct inflate_state *state)**
  
  Initialize decompression state data structure.

- **void isal_inflate_reset (struct inflate_state *state)**
  
  Reinitialize decompression state data structure.

- **int isal_inflate_set_dict (struct inflate_state *state, uint8_t *dict, uint32_t dict_len)**
  
  Set decompression dictionary to use.

- **int isal_inflate (struct inflate_state *state)**
  
  Fast data (deflate) decompression for storage applications.

- **int isal_inflate_stateless (struct inflate_state *state)**
  
  Fast data (deflate) stateless decompression for storage applications.

7.5.1 Detailed Description

This file defines the igzip compression and decompression interface, a high performance deflate compression interface for storage applications.

Deflate is a widely used compression standard that can be used standalone, it also forms the basis of gzip and zlib compression formats. Igzip supports the following flush features:

- **No Flush**: The default method where no special flush is performed.
• Sync flush: whereby isal_deflate() finishes the current deflate block at the end of each input buffer. The deflate block is byte aligned by appending an empty stored block.

• Full flush: whereby isal_deflate() finishes and aligns the deflate block as in sync flush but also ensures that subsequent block's history does not look back beyond this point and new blocks are fully independent.

Igzip also supports compression levels from ISAL_DEF_MIN_LEVEL to ISAL_DEF_MAX_LEVEL.

Igzip contains some behaviour configurable at compile time. These configureable options are:

• IGZIP_HIST_SIZE - Defines the window size. The default value is 32K (note K represents 1024), but 8K is also supported. Powers of 2 which are at most 32K may also work.

• LONGER_HUFFTABLES - Defines whether to use a larger hufftables structure which may increase performance with smaller IGZIP_HIST_SIZE values. By default this option is not defined. This define sets IGZIP_HIST_SIZE to be 8 if IGZIP_HIST_SIZE > 8K.

As an example, to compile gzip with an 8K window size, in a terminal run

gmake D="-D IGZIP_HIST_SIZE=8*1024"

on Linux and FreeBSD, or with

nmake -f Makefile.nmake D="-D * IGZIP_HIST_SIZE=8*1024"

on Windows.

7.5.2 Enumeration Type Documentation

7.5.2.1 isal_zstate_state

enum isal_zstate_state

Compression State please note ZSTATE_TRL only applies for GZIP compression.

 Enumerator

<table>
<thead>
<tr>
<th>Enumerators</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZSTATE_NEW_HDR</td>
<td>Header to be written.</td>
</tr>
<tr>
<td>ZSTATE_HDR</td>
<td>Header state.</td>
</tr>
<tr>
<td>ZSTATE_CREATE_HDR</td>
<td>Header to be created.</td>
</tr>
<tr>
<td>ZSTATE_BODY</td>
<td>Body state.</td>
</tr>
<tr>
<td>ZSTATE_FLUSH_READ_BUFFER</td>
<td>Flush buffer.</td>
</tr>
<tr>
<td>ZSTATE_TYPE0_BODY</td>
<td>Type0 block header to be written. Type0 block body to be written</td>
</tr>
<tr>
<td>ZSTATE_SYNC_FLUSH</td>
<td>Write sync flush block.</td>
</tr>
<tr>
<td>ZSTATE_FLUSH_WRITE_BUFFER</td>
<td>Flush bitbuf.</td>
</tr>
<tr>
<td>ZSTATETRL</td>
<td>Trailer state.</td>
</tr>
<tr>
<td>ZSTATE_END</td>
<td>End state.</td>
</tr>
</tbody>
</table>

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### Enumerator

<table>
<thead>
<tr>
<th>Enumerator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZSTATE_TMP_NEW_HDR</td>
<td>Temporary Header to be written.</td>
</tr>
<tr>
<td>ZSTATE_TMP_HDR</td>
<td>Temporary Header state.</td>
</tr>
<tr>
<td>ZSTATE_TMP_CREATE_HDR</td>
<td>Temporary Header to be created state.</td>
</tr>
<tr>
<td>ZSTATE_TMP_BODY</td>
<td>Temporary Body state.</td>
</tr>
<tr>
<td>ZSTATE_TMP_FLUSH_READ_BUFFER</td>
<td>Flush buffer.</td>
</tr>
<tr>
<td>ZSTATE_TMP_TYPE0_BODY</td>
<td>Temporary Type0 block header to be written. Temporary Type0 block body to be written.</td>
</tr>
<tr>
<td>ZSTATE_TMP_SYNC_FLUSH</td>
<td>Write sync flush block.</td>
</tr>
<tr>
<td>ZSTATE_TMP_FLUSH_WRITE_BUFFER</td>
<td>Flush bitbuf.</td>
</tr>
<tr>
<td>ZSTATE_TMP_TRL</td>
<td>Temporary Trailer state.</td>
</tr>
<tr>
<td>ZSTATE_TMP_END</td>
<td>Temporary End state.</td>
</tr>
</tbody>
</table>

### 7.5.3 Function Documentation

#### 7.5.3.1 isal_create_hufftables()

```c
int isal_create_hufftables ( 
    struct isal_hufftables * hufftables, 
    struct isal_huff_histogram * histogram )
```

Creates a custom huffman code for the given histograms in which every literal and repeat length is assigned a code and all possible lookback distances are assigned a code.

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>hufftables</td>
<td>the output structure containing the huffman code</td>
</tr>
<tr>
<td>histogram</td>
<td>histogram containing frequency of literal symbols, repeat lengths and lookback distances</td>
</tr>
</tbody>
</table>

**Returns**

Returns a non zero value if an invalid huffman code was created.

#### 7.5.3.2 isal_create_hufftables_subset()

```c
int isal_create_hufftables_subset ( 
    struct isal_hufftables * hufftables, 
    struct isal_huff_histogram * histogram )
```

Creates a custom huffman code for the given histograms like `isal_create_hufftables()` except literals with 0 frequency in the histogram are not assigned a code.
7.5.3 isal_deflate()

```c
int isal_deflate ( 
    struct isal_zstream *stream )
```

Fast data (deflate) compression for storage applications.

The call to `isal_deflate()` will take data from the input buffer (updating `next_in`, `avail_in`) and write a compressed stream to the output buffer (updating `next_out`, `avail_out`). The function returns when either the input buffer is empty or the output buffer is full.

On entry to `isal_deflate()`, `next_in` points to an input buffer and `avail_in` indicates the length of that buffer. Similarly, `next_out` points to an empty output buffer and `avail_out` indicates the size of that buffer.

The fields `total_in` and `total_out` start at 0 and are updated by `isal_deflate()`. These reflect the total number of bytes read or written so far.

When the last input buffer is passed in, signaled by setting the `end_of_stream`, the routine will complete compression at the end of the input buffer, as long as the output buffer is big enough.

The compression level can be set by setting `level` to any value between `ISAL_DEF_MIN_LEVEL` and `ISAL_DEF_MAX_LEVEL`. When the compression level is `ISAL_DEF_MIN_LEVEL`, hufftables can be set to a table trained for the specific data type being compressed to achieve better compression. When a higher compression level is desired, a larger generic memory buffer needs to be supplied by setting `level_buf` and `level_buf_size` to represent the chunk of memory. For level `x`, the suggest size for this buffer this buffer is `ISAL_DEFL_LVLx_DEFAULT`. The defines `ISAL_DEFL_LVLx_MIN`, `ISAL_DEFL_LVLx_SMALL`, `ISAL_DEFL_LVLx_MEDIUM`, `ISAL_DEFL_LVLx_LARGE`, and `ISAL_DEFL_LVLx_EXTRA_LARGE` are also provided as other suggested sizes.

The equivalent of the zlib `FLUSH_SYNC` operation is currently supported. Flush types can be `NO_FLUSH`, `SYNC_FLUSH` or `FULL_FLUSH`. Default flush type is `NO_FLUSH`. A `SYNC_` OR `FULL_` flush will byte align the deflate block by appending an empty stored block once all input has been compressed, including the buffered input. Checking that the `out_buffer` is not empty or that `internal_state.state = ZSTATE_NEW_HDR` is sufficient to guarantee all input has been flushed. Additionally `FULL_FLUSH` will ensure look back history does not include previous blocks so new blocks are fully independent. Switching between flush types is supported.

If a compression dictionary is required, the dictionary can be set calling `isal_deflate_set_dictionary` before calling `isal_deflate`.

If the `gzip_flag` is set to `IGZIP_GZIP`, a generic gzip header and the gzip trailer are written around the deflate compressed data. If `gzip_flag` is set to `IGZIP_GZIP_NO_HDR`, then only the gzip trailer is written.
Parameters

*stream* | Structure holding state information on the compression streams.

Returns

COMP_OK (if everything is ok), INVALID_FLUSH (if an invalid FLUSH is selected), ISAL_INVALID_LEVEL (if an invalid compression level is selected), ISAL_INVALID_LEVEL_BUF (if the level buffer is not large enough).

7.5.3.4 isal_deflate_init()

```c
void isal_deflate_init ( 
    struct isal_zstream * stream )
```

Initialize compression stream data structure.

Parameters

*stream* | Structure holding state information on the compression streams.

Returns

none

7.5.3.5 isal_deflate_reset()

```c
void isal_deflate_reset ( 
    struct isal_zstream * stream )
```

Reinitialize compression stream data structure. Performs the same action as isal_deflate_init, but does not change user supplied input such as the level, flush type, compression wrapper (like gzip), hufftables, and end_of_stream_flag.

Parameters

*stream* | Structure holding state information on the compression streams.

Returns

none
7.5.3.6 isal_deflate_set_dict()

```c
int isal_deflate_set_dict ( 
    struct isal_zstream * stream, 
    uint8_t * dict, 
    uint32_t dict_len )
```

Set compression dictionary to use.

This function is to be called after isal_deflate_init, or after completing a SYNC_FLUSH or FULL_FLUSH and before the next call do isal_deflate. If the dictionary is longer than IGZIP_HIST_SIZE, only the last IGZIP_HIST_SIZE bytes will be used.

Parameters

| stream | Structure holding state information on the compression streams. |
| dict   | Array containing dictionary to use.                            |
| dict_len | Length of dict.                                             |

Returns

COMP_OK, ISAL_INVALID_STATE (dictionary could not be set)

7.5.3.7 isal_deflate_set_hufftables()

```c
int isal_deflate_set_hufftables ( 
    struct isal_zstream * stream, 
    struct isal_hufftables * hufftables, 
    int type )
```

Set stream to use a new Huffman code.

Sets the Huffman code to be used in compression before compression start or after the successful completion of a SYNC_FLUSH or FULL_FLUSH. If type has value IGZIP_HUFFTABLE_DEFAULT, the stream is set to use the default Huffman code. If type has value IGZIP_HUFFTABLE_STATIC, the stream is set to use the deflate standard static Huffman code, or if type has value IGZIP_HUFFTABLE_CUSTOM, the stream is set to use the isal_hufftables structure input to isal_deflate_set_hufftables.

Parameters

| stream | Structure holding state information on the compression stream. |
| hufftables | new huffman code to use if type is set to IGZIP_HUFFTABLE_CUSTOM. |
| type    | Flag specifying what huffman to use.                        |
Returns

Returns INVALID_OPERATION if the stream was unmodified. This may be due to the stream being in a state where changing the huffman code is not allowed or an invalid input is provided.

7.5.3.8   isal_deflate_stateless()

    int isal_deflate_stateless (  
        struct isal_zstream  * stream  )

Fast data (deflate) stateless compression for storage applications.

Stateless (one shot) compression routine with a similar interface to isal_deflate() but operates on entire input buffer at one time. Parameter avail_out must be large enough to fit the entire compressed output. Max expansion is limited to the input size plus the header size of a stored/raw block.

When the compression level is set to 1, unlike in isal_deflate(), level_buf may be optionally set depending on what performance is desired.

For stateless the flush types NO_FLUSH and FULL_FLUSH are supported. FULL_FLUSH will byte align the output deflate block so additional blocks can be easily appended.

If the gzip_flag is set to IGZIP_GZIP, a generic gzip header and the gzip trailer are written around the deflate compressed data. If gzip_flag is set to IGZIP_GZIP_NO_HDR, then only the gzip trailer is written.

Parameters

| stream     | Structure holding state information on the compression streams. |

Returns

COMP_OK (if everything is ok), INVALID_FLUSH (if an invalid FLUSH is selected), ISAL_INVALID_Level (if an invalid compression level is selected), ISAL_INVALID_Level_BUF (if the level buffer is not large enough), STATELESS_OVERFLOW (if output buffer will not fit output).

7.5.3.9   isal_deflate_stateless_init()

    void isal_deflate_stateless_init (  
        struct isal_zstream  * stream  )

Initialize compression stream data structure.
Parameters

| stream | Structure holding state information on the compression streams. |

Returns

none

7.5.3.10 isal_inflate()

int isal_inflate (  
    struct inflate_state * state  )

Fast data (deflate) decompression for storage applications.

On entry to isal_inflate(), next_in points to an input buffer and avail_in indicates the length of that buffer. Similarly next_out points to an empty output buffer and avail_out indicates the size of that buffer.

The field total_out starts at 0 and is updated by isal_inflate(). This reflects the total number of bytes written so far.

The call to isal_inflate() will take data from the input buffer (updating next_in, avail_in and write a decompressed stream to the output buffer (updating next_out and avail_out). The function returns when the input buffer is empty, the output buffer is full or invalid data is found. The current state of the decompression on exit can be read from state->block_state. If the crc_flag is set to ISAL_GZIP_NO_HDR the gzip crc of the output is stored in state->crc. Alternatively, if the crc_flag is set to ISAL_ZLIB_NO_HDR the adler32 of the output is stored in state->crc.

If a dictionary is required, a call to isal_inflate_set_dict will set the dictionary.

Parameters

| state | Structure holding state information on the compression streams. |

Returns

ISAL_DECOMP_OK (if everything is ok), ISAL_END_INPUT (if all input was decompressed), ISAL_OUT_OVE→RFLOW (if output buffer ran out of space), ISAL_INVALID_BLOCK, ISAL_INVALID_SYMBOL, ISAL_INVALID_→LOOKBACK.

7.5.3.11 isal_inflate_init()

void isal_inflate_init (  
    struct inflate_state * state  )

Initialize decompression state data structure.
Parameters

\textbf{state} | Structure holding state information on the compression streams.

Returns

none

7.5.3.12 isal_inflate_reset()

\begin{verbatim}
void isal_inflate_reset ( 
    struct inflate_state * state )
\end{verbatim}

Reinitialize decompression state data structure.

Parameters

\textbf{state} | Structure holding state information on the compression streams.

Returns

none

7.5.3.13 isal_inflate_set_dict()

\begin{verbatim}
int isal_inflate_set_dict ( 
    struct inflate_state * state, 
    uint8_t * dict, 
    uint32_t dict_len )
\end{verbatim}

Set decompression dictionary to use.

This function is to be called after isal_inflate_init. If the dictionary is longer than IGZIP_HIST_SIZE, only the last IGZIP_HIST_SIZE bytes will be used.

Parameters

\begin{tabular}{|c|w{10cm}|}
\hline
\textbf{state} & Structure holding state information on the decompression stream. \\
\hline
\textbf{dict} & Array containing dictionary to use. \\
\hline
\textbf{dict_len} & Length of dict. \\
\hline
\end{tabular}
Returns

COMP_OK, ISAL_INVALID_STATE (dictionary could not be set)

7.5.3.14 isal_inflate_stateless()

int isal_inflate_stateless (  
    struct inflate_state * state )

Fast data (deflate) stateless decompression for storage applications.

Stateless (one shot) decompression routine with a similar interface to isal_inflate() but operates on entire input buffer at one time. Parameter avail_out must be large enough to fit the entire decompressed output.

Parameters

| state          | Structure holding state information on the compression streams. |

Returns

ISAL_DECOMP_OK (if everything is ok), ISAL_END_INPUT (if all input was decompressed), ISAL_OUT_OVF
RFLOW (if output buffer ran out of space), ISAL_INVALID_BLOCK, ISAL_INVALID_SYMBOL, ISAL_INVALID_LOOKBACK.

7.5.3.15 isal_update_histogram()

void isal_update_histogram (  
    uint8_t * in_stream,
    int length,
    struct isal_huff_histogram * histogram )

Updates histograms to include the symbols found in the input stream. Since this function only updates the histograms, it can be called on multiple streams to get a histogram better representing the desired data set. When first using histogram it must be initialized by zeroing the structure.

Parameters

| in_stream | Input stream of data. |
| length | The length of start_stream. |
| histogram | The returned histogram of lit/len/dist symbols. |
7.6 raid.h File Reference

Interface to RAID functions - XOR and P+Q calculation.

Functions

- `int xor_gen (int vects, int len, void **array)`
  Generate XOR parity vector from N sources, runs appropriate version.

- `int xor_check (int vects, int len, void **array)`
  Checks that array has XOR parity sum of 0 across all vectors, runs appropriate version.

- `int pq_gen (int vects, int len, void **array)`
  Generate P+Q parity vectors from N sources, runs appropriate version.

- `int pq_check (int vects, int len, void **array)`
  Checks that array of N sources, P and Q are consistent across all vectors, runs appropriate version.

- `int xor_gen_sse (int vects, int len, void **array)`
  Generate XOR parity vector from N sources.

- `int xor_gen_avx (int vects, int len, void **array)`
  Generate XOR parity vector from N sources.

- `int xor_check_sse (int vects, int len, void **array)`
  Checks that array has XOR parity sum of 0 across all vectors.

- `int pq_gen_sse (int vects, int len, void **array)`
  Generate P+Q parity vectors from N sources.

- `int pq_gen_avx (int vects, int len, void **array)`
  Generate P+Q parity vectors from N sources.

- `int pq_gen_avx2 (int vects, int len, void **array)`
  Generate P+Q parity vectors from N sources.

- `int pq_check_sse (int vects, int len, void **array)`
  Checks that array of N sources, P and Q are consistent across all vectors.

- `int pq_gen_base (int vects, int len, void **array)`
  Generate P+Q parity vectors from N sources, runs baseline version.

- `int xor_gen_base (int vects, int len, void **array)`
  Generate XOR parity vector from N sources, runs baseline version.

- `int xor_check_base (int vects, int len, void **array)`
  Checks that array has XOR parity sum of 0 across all vectors, runs baseline version.

- `int pq_check_base (int vects, int len, void **array)`
  Checks that array of N sources, P and Q are consistent across all vectors, runs baseline version.

7.6.1 Detailed Description

Interface to RAID functions - XOR and P+Q calculation.

This file defines the interface to optimized XOR calculation (RAID5) or P+Q dual parity (RAID6). Operations are carried out on an array of pointers to sources and output arrays.
### 7.6.2 Function Documentation

#### 7.6.2.1 pq_check()

```c
int pq_check (  
    int vcts,  
    int len,  
    void ** array  
)
```

Checks that array of N sources, P and Q are consistent across all vectors, runs appropriate version.

This function determines what instruction sets are enabled and selects the appropriate version at runtime.

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>vcts</code></td>
<td>Number of vectors in array including P&amp;Q.</td>
</tr>
<tr>
<td><code>len</code></td>
<td>Length of each vector in bytes. Must be 16B aligned.</td>
</tr>
<tr>
<td><code>array</code></td>
<td>Array of pointers to source and P, Q. P and Q parity are assumed to be the last two pointers in the array. All pointers must be aligned to 16B.</td>
</tr>
</tbody>
</table>

**Returns**

0 pass, other fail

#### 7.6.2.2 pq_check_base()

```c
int pq_check_base (  
    int vcts,  
    int len,  
    void ** array  
)
```

Checks that array of N sources, P and Q are consistent across all vectors, runs baseline version.

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>vcts</code></td>
<td>Number of vectors in array including P&amp;Q.</td>
</tr>
<tr>
<td><code>len</code></td>
<td>Length of each vector in bytes. Must be 16B aligned.</td>
</tr>
<tr>
<td><code>array</code></td>
<td>Array of pointers to source and P, Q. P and Q parity are assumed to be the last two pointers in the array. All pointers must be aligned to 16B.</td>
</tr>
</tbody>
</table>
Returns
0 pass, other fail

7.6.2.3 pq_check_sse()

int pq_check_sse (  
    int vects,  
    int len,  
    void **array  
)

Checks that array of N sources, P and Q are consistent across all vectors.

Requires  SSE4.1

Parameters

<table>
<thead>
<tr>
<th>vects</th>
<th>Number of vectors in array including P&amp;Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>Length of each vector in bytes. Must be 16B aligned.</td>
</tr>
<tr>
<td>array</td>
<td>Array of pointers to source and P, Q. P and Q parity are assumed to be the last two pointers in the array. All pointers must be aligned to 16B.</td>
</tr>
</tbody>
</table>

Returns
0 pass, other fail

7.6.2.4 pq_gen()

int pq_gen (  
    int vects,  
    int len,  
    void **array  
)

Generate P+Q parity vectors from N sources, runs appropriate version.

This function determines what instruction sets are enabled and selects the appropriate version at runtime.

Parameters

<table>
<thead>
<tr>
<th>vects</th>
<th>Number of source+dest vectors in array.</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>Length of each vector in bytes. Must be 32B aligned.</td>
</tr>
<tr>
<td>array</td>
<td>Array of pointers to source and dest. For P+Q the dest is the last two pointers. ie array[vects-2], array[vects-1]. P and Q parity vectors are written to these last two pointers. Src and dest pointers must be aligned to 32B.</td>
</tr>
</tbody>
</table>
Returns

0 pass, other fail

7.6.2.5  pq_gen_avx()

```c
int pq_gen_avx (  
    int vcts,  
    int len,  
    void ** array )
```

Generate P+Q parity vectors from N sources.

**Requires** AVX

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>vects</code></td>
<td>Number of source+dest vectors in array.</td>
</tr>
<tr>
<td><code>len</code></td>
<td>Length of each vector in bytes. Must be 16B aligned.</td>
</tr>
<tr>
<td><code>array</code></td>
<td>Array of pointers to source and dest. For P+Q the dest is the last two pointers. ie array[vcts-2], array[vcts-1]. P and Q parity vectors are written to these last two pointers. Src and dest pointers must be aligned to 16B.</td>
</tr>
</tbody>
</table>

Returns

0 pass, other fail

7.6.2.6  pq_gen_avx2()

```c
int pq_gen_avx2 (  
    int vcts,  
    int len,  
    void ** array )
```

Generate P+Q parity vectors from N sources.

**Requires** AVX2
Parameters

<table>
<thead>
<tr>
<th>vects</th>
<th>Number of source+dest vectors in array.</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>Length of each vector in bytes. Must be 32B aligned.</td>
</tr>
<tr>
<td>array</td>
<td>Array of pointers to source and dest. For P+Q the dest is the last two pointers. ie array[vects-2], array[vects-1]. P and Q parity vectors are written to these last two pointers. Src and dest pointers must be aligned to 32B.</td>
</tr>
</tbody>
</table>

Returns

0 pass, other fail

7.6.2.7 pq_gen_base()

```c
int pq_gen_base {
    int vects,
    int len,
    void ** array }
```

Generate P+Q parity vectors from N sources, runs baseline version.

Parameters

<table>
<thead>
<tr>
<th>vects</th>
<th>Number of source+dest vectors in array.</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>Length of each vector in bytes. Must be 16B aligned.</td>
</tr>
<tr>
<td>array</td>
<td>Array of pointers to source and dest. For P+Q the dest is the last two pointers. ie array[vects-2], array[vects-1]. P and Q parity vectors are written to these last two pointers. Src and dest pointers must be aligned to 16B.</td>
</tr>
</tbody>
</table>

Returns

0 pass, other fail

7.6.2.8 pq_gen_sse()

```c
int pq_gen_sse {
    int vects,
    int len,
    void ** array }
```

Generate P+Q parity vectors from N sources.

Requires  SSE4.1
Parameters

<table>
<thead>
<tr>
<th>vects</th>
<th>Number of source+dest vectors in array.</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>Length of each vector in bytes. Must be 16B aligned.</td>
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<tr>
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<td>Array of pointers to source and dest. For P+Q the dest is the last two pointers. ie array[vects-2], array[vects-1]. P and Q parity vectors are written to these last two pointers. Src and dest pointers must be aligned to 16B.</td>
</tr>
</tbody>
</table>

Returns

0 pass, other fail

7.6.2.9 xor_check()

```c
int xor_check ( 
    int vects,
    int len,
    void ** array )
```

Checks that array has XOR parity sum of 0 across all vectors, runs appropriate version.

This function determines what instruction sets are enabled and selects the appropriate version at runtime.

Parameters

<table>
<thead>
<tr>
<th>vects</th>
<th>Number of vectors in array.</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>Length of each vector in bytes.</td>
</tr>
<tr>
<td>array</td>
<td>Array of pointers to vectors. Src and dest pointers must be aligned to 16B.</td>
</tr>
</tbody>
</table>

Returns

0 pass, other fail

7.6.2.10 xor_check_base()

```c
int xor_check_base ( 
    int vects,
    int len,
    void ** array )
```

Checks that array has XOR parity sum of 0 across all vectors, runs baseline version.
Parameters

<table>
<thead>
<tr>
<th>vects</th>
<th>Number of vectors in array.</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>Length of each vector in bytes.</td>
</tr>
<tr>
<td>array</td>
<td>Array of pointers to vectors. Src and dest pointers must be aligned to 16B.</td>
</tr>
</tbody>
</table>

Returns

0 pass, other fail

7.6.2.11 xor_check_sse()

```c
int xor_check_sse (  
    int vects,
    int len,  
    void ** array )
```

Checks that array has XOR parity sum of 0 across all vectors.

**Requires** SSE4.1

Parameters

<table>
<thead>
<tr>
<th>vects</th>
<th>Number of vectors in array.</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>Length of each vector in bytes.</td>
</tr>
<tr>
<td>array</td>
<td>Array of pointers to vectors. Src and dest pointers must be aligned to 16B.</td>
</tr>
</tbody>
</table>

Returns

0 pass, other fail

7.6.2.12 xor_gen()

```c
int xor_gen (  
    int vects,
    int len,  
    void ** array )
```

Generate XOR parity vector from N sources, runs appropriate version.

This function determines what instruction sets are enabled and selects the appropriate version at runtime.
Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>vects</code></td>
<td>Number of source+dest vectors in array.</td>
</tr>
<tr>
<td><code>len</code></td>
<td>Length of each vector in bytes.</td>
</tr>
<tr>
<td><code>array</code></td>
<td>Array of pointers to source and dest. For XOR the dest is the last pointer. ie array[vects-1]. Src and dest pointers must be aligned to 32B.</td>
</tr>
</tbody>
</table>

Returns

0 pass, other fail

7.6.2.13 xor_gen_avx()

```c
int xor_gen_avx {
    int vects,
    int len,
    void **array }
```

Generate XOR parity vector from N sources.

Requires AVX

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>vects</code></td>
<td>Number of source+dest vectors in array.</td>
</tr>
<tr>
<td><code>len</code></td>
<td>Length of each vector in bytes.</td>
</tr>
<tr>
<td><code>array</code></td>
<td>Array of pointers to source and dest. For XOR the dest is the last pointer. ie array[vects-1]. Src and dest pointers must be aligned to 32B.</td>
</tr>
</tbody>
</table>

Returns

0 pass, other fail

7.6.2.14 xor_gen_base()

```c
int xor_gen_base {
    int vects,
    int len,
    void **array }
```

Generate XOR parity vector from N sources, runs baseline version.

Generated by Doxygen
Parameters

<table>
<thead>
<tr>
<th>vects</th>
<th>Number of source+dest vectors in array.</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>Length of each vector in bytes.</td>
</tr>
<tr>
<td>array</td>
<td>Array of pointers to source and dest. For XOR the dest is the last pointer. i.e. array[vects-1]. Src and dest pointers must be aligned to 32B.</td>
</tr>
</tbody>
</table>

Returns

0 pass, other fail

7.6.2.15 xor_gen_sse()

```c
int xor_gen_sse (  
   int vects,  
   int len,  
   void ** array )
```

Generate XOR parity vector from N sources.

Requires SSE4.1

Parameters

<table>
<thead>
<tr>
<th>vects</th>
<th>Number of source+dest vectors in array.</th>
</tr>
</thead>
<tbody>
<tr>
<td>len</td>
<td>Length of each vector in bytes.</td>
</tr>
<tr>
<td>array</td>
<td>Array of pointers to source and dest. For XOR the dest is the last pointer. i.e. array[vects-1]. Src and dest pointers must be aligned to 16B.</td>
</tr>
</tbody>
</table>

Returns

0 pass, other fail

7.7 types.h File Reference

Defines standard width types.

7.7.1 Detailed Description

Defines standard width types.
Index

BitBuf2, 15

crc.h, 23
crc16_t10dif, 24
crc16_t10dif_base, 24
crc16_t10dif_copy, 25
crc16_t10dif_copy_base, 25
crc32_gzip_refl, 26
crc32_gzip_refl_base, 26
crc32_ieee, 27
crc32_ieee_base, 27
crc32_iscsi, 28
crc32_iscsi_base, 28
crc16_t10dif
crc.h, 24
crc16_t10dif_base
crc.h, 24
crc16_t10dif_copy
crc.h, 25
crc16_t10dif_copy_base
crc.h, 25
crc32_gzip_refl
crc.h, 26
crc32_gzip_refl_base
crc.h, 26
crc32_ieee
crc.h, 27
crc32_ieee_base
crc.h, 27
crc32_iscsi
crc.h, 28
crc32_iscsi_base
crc.h, 28
crc64.h, 29
crc64_ecma_norm, 30
crc64_ecma_norm_base, 30
crc64_ecma_norm_by8, 31
crc64_ecma_refl, 32
crc64_ecma_refl_base, 32
crc64_ecma_refl_by8, 32
crc64_iso_norm, 33
crc64_iso_norm_base, 33
crc64_iso_norm_by8, 34
crc64_iso_refl, 34
crc64_iso_refl_base, 35
crc64_iso_refl_by8, 35
crc64_jones_norm, 36
crc64_jones_norm_base, 36
crc64_jones_norm_by8, 37
crc64_jones_refl, 37
crc64_jones_refl_base, 38
crc64_jones_refl_by8, 38
crc64_ecma_norm
crc64.h, 30
crc64_ecma_norm_base
crc64.h, 31
crc64_ecma_norm_by8
crc64.h, 31
crc64_ecma_refl
crc64.h, 32
crc64_ecma_refl_base
crc64.h, 32
crc64_ecma_refl_by8
crc64.h, 32
crc64_iso_norm
crc64.h, 33
crc64_iso_norm_base
crc64.h, 33
crc64_iso_norm_by8
crc64.h, 34
crc64_iso_refl
crc64.h, 34
crc64_iso_refl_base
crc64.h, 35
crc64_iso_refl_by8
crc64.h, 35
crc64_jones_norm
crc64.h, 36
crc64_jones_norm_base
crc64.h, 36
crc64_jones_norm_by8
crc64.h, 37
crc64_jones_refl
crc64.h, 37
crc64_jones_refl_base
crc64.h, 38
crc64_jones_refl_by8
crc64.h, 38

ec_encode_data

erasure_code.h, 42
ec_encode_data_avx
erasure_code.h, 43
ec_encode_data_avx2
    erasure_code.h, 43
ec_encode_data_base
    erasure_code.h, 44
ec_encode_data_sse
    erasure_code.h, 44
ec_encode_data_update
    erasure_code.h, 44
ec_encode_data_update_avx
    erasure_code.h, 45
ec_encode_data_update_avx2
    erasure_code.h, 46
ec_encode_data_update_base
    erasure_code.h, 46
ec_encode_data_update_sse
    erasure_code.h, 46
ec_init_tables
    erasure_code.h, 46
erasure_code.h, 43
gf_2vect_dot_prod_avx
    erasure_code.h, 47
gf_2vect_dot_prod_avx2
    erasure_code.h, 48
gf_2vect_dot_prod_sse
    erasure_code.h, 48
gf_2vect_mad_avx
    erasure_code.h, 49
gf_2vect_mad_avx2
    erasure_code.h, 49
gf_2vect_mad_sse
    erasure_code.h, 50
gf_3vect_dot_prod_avx
    erasure_code.h, 51
gf_3vect_dot_prod_avx2
    erasure_code.h, 51
gf_3vect_dot_prod_sse
    erasure_code.h, 52
gf_3vect_mad_avx
    erasure_code.h, 53
gf_3vect_mad_avx2
    erasure_code.h, 53
gf_3vect_mad_sse
    erasure_code.h, 53
gf_4vect_dot_prod_avx
    erasure_code.h, 54
gf_4vect_dot_prod_avx2
    erasure_code.h, 54
gf_4vect_dot_prod_sse
    erasure_code.h, 55
gf_4vect_mad_avx
    erasure_code.h, 56
gf_4vect_mad_avx2
    erasure_code.h, 56
gf_4vect_mad_sse
    erasure_code.h, 56
gf_5vect_dot_prod_avx
    erasure_code.h, 57
gf_5vect_dot_prod_avx2
    erasure_code.h, 58
gf_5vect_dot_prod_sse
    erasure_code.h, 58
gf_5vect_mad_avx
    erasure_code.h, 59
gf_5vect_mad_avx2
    erasure_code.h, 59
gf_5vect_mad_sse
    erasure_code.h, 60
gf_6vect_dot_prod_avx
    erasure_code.h, 60
gf_6vect_dot_prod_avx2
    erasure_code.h, 61
gf_6vect_dot_prod_sse
    erasure_code.h, 61
gf_6vect_mad_avx
    erasure_code.h, 62
gf_6vect_mad_avx2
    erasure_code.h, 62
gf_6vect_mad_sse
    erasure_code.h, 63
gf_gen_cauchy1_matrix
    erasure_code.h, 63
gf_gen_rs_matrix
    erasure_code.h, 64
gf_inv
    erasure_code.h, 64
gf_invert_matrix
    erasure_code.h, 65
gf_mul
    erasure_code.h, 66
gf_vect_dot_prod
    erasure_code.h, 66
gf_vect_dot_prod_avx
    erasure_code.h, 66
gf_vect_dot_prod_avx2
    erasure_code.h, 67
gf_vect_dot_prod_base
    erasure_code.h, 68
gf_vect_dot_prod_sse
    erasure_code.h, 68
gf_vect_mad
    erasure_code.h, 69
gf_vect_mad_avx
    erasure_code.h, 70
gf_vect_mad_avx2
    erasure_code.h, 70
gf_vect_mad_base
    erasure_code.h, 70
gf_vect_mad_sse
    erasure_code.h, 71
isal_deflate_set_hufftables
  igzip_lib.h, 81
isal_deflate_stateless
  igzip_lib.h, 82
isal_deflate_stateless_init
  igzip_lib.h, 82
isal_huff_histogram, 17
isal_hufftables, 18
isal_inflate
  igzip_lib.h, 83
isal_inflate_init
  igzip_lib.h, 83
isal_inflate_reset
  igzip_lib.h, 84
isal_inflate_set_dict
  igzip_lib.h, 84
isal_inflate_stateless
  igzip_lib.h, 85
isal_mod_hist, 19
isal_update_histogram
  igzip_lib.h, 85
isal_zstate, 19
isal_zstate_state
  igzip_lib.h, 77
isal_zstream, 20

pq_check
  raid.h, 87
pq_check_base
  raid.h, 87
pq_check_sse
  raid.h, 88
pq_gen
  raid.h, 88
pq_gen_avx
  raid.h, 89
pq_gen_avx2
  raid.h, 89
pq_gen_base
  raid.h, 90
pq_gen_sse
  raid.h, 90

raid.h, 86
  pq_check, 87
  pq_check_base, 87
  pq_check_sse, 88
  pq_gen, 88
  pq_gen_avx, 89
  pq_gen_avx2, 89
  pq_gen_base, 90
  pq_gen_sse, 90
  xor_check, 91
  xor_check_base, 91
  xor_check_sse, 92

xor_gen, 92
xor_gen_avx, 93
xor_gen_base, 93
xor_gen_sse, 94

types.h, 94

xor_check
  raid.h, 91
xor_check_base
  raid.h, 91
xor_check_sse
  raid.h, 92
xor_gen
  raid.h, 92
xor_gen_avx
  raid.h, 93
xor_gen_base
  raid.h, 93
xor_gen_sse
  raid.h, 94