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That's all there is to it! LZMA SDK 4.21

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LZMA SDK provides developers with documentation, source code, and sample code necessary to write software that uses LZMA compression.

LZMA is default and general compression method of 7z format in 7-Zip compression program (www.7-zip.org). LZMA provides high compression ratio and very fast decompression.

LZMA is an improved version of famous LZ77 compression algorithm. It was improved in way of maximum increasing of compression ratio, keeping high decompression speed and low memory requirements for decompressing.

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LZMA SDK Contents

LZMA SDK includes:

- C++ source code of LZMA Encoder and Decoder
- C++ source code for file->file LZMA compressing and decompressing
- ANSI-C compatible source code for LZMA decompressing
- Compiled file->file LZMA compressing/decompressing program for Windows system

ANSI-C LZMA decompression code was ported from original C++ sources to C.
Also it was simplified and optimized for code size.
But it is fully compatible with LZMA from 7-Zip.

UNIX/Linux version

To compile C++ version of file->file LZMA, go to directory
SRC/7zip/Compress/LZMA_Alone
and type "make" or "make clean all" to recompile all.

In some UNIX/Linux versions you must compile LZMA with static libraries.

To compile with static libraries, change string in makefile

LIB = -lm

to string

LIB = -lm -static

Files

SRC - directory with source code
lzma.txt - LZMA SDK description (this file)
7zFormat.txt - 7z Format description
7zC.txt - 7z ANSI-C Decoder description (this file)
methods.txt - Compression method IDs for .7z
LGPL.txt - GNU Lesser General Public License
CPL.html - Common Public License
lzma.exe - Compiled file->file LZMA encoder/decoder for Windows
history.txt - history of the LZMA SDK

Source code structure

SRC

Common - common files for C++ projects

Windows - common files for Windows related code

7zip - files related to 7-Zip Project

Common - common files for 7-Zip

Compress - files related to compression/decompression

LZ - files related to LZ (Lempel-Ziv) compression algorithm

BinTree - Binary Tree Match Finder for LZ algorithm

HashChain - Hash Chain Match Finder for LZ algorithm

Patricia - Patricia Match Finder for LZ algorithm

RangeCoder - Range Coder (special code of compression/decompression)

LZMA - LZMA compression/decompression on C++

LZMA_Alone - file->file LZMA compression/decompression

LZMA_C - ANSI-C compatible LZMA decompressor

LzmaDecode.h - interface for LZMA decoding on ANSI-C

LzmaDecode.c - LZMA decoding on ANSI-C (new fastest version)

LzmaDecodeSize.c - LZMA decoding on ANSI-C (old size-optimized version)

LzmaTest.c - test application that decodes LZMA encoded file

LzmaStateDecode.h - interface for LZMA decoding (State version)

LzmaStateDecode.c - LZMA decoding on ANSI-C (State version)

LzmaStateTest.c - test application (State version)

Branch - Filters for x86, IA-64, ARM, ARM-Thumb, PowerPC and SPARC code

Archive - files related to archiving

7z_C - 7z ANSI-C Decoder

Source code of LZMA SDK is only part of big 7-Zip project. That is why LZMA SDK uses such complex source code structure.

You can find ANSI-C LZMA decompressing code at folder SRC/7zip/Compress/LZMA_C
7-Zip doesn't use that ANSI-C LZMA code and that code was developed specially for this SDK. And files from LZMA_C do not need files from other directories of SDK for compiling.

7-Zip source code can be downloaded from 7-Zip's SourceForge page:

<http://sourceforge.net/projects/sevenzzip/>

LZMA Decompression features

- Variable dictionary size (up to 256 MB)
- Estimated compressing speed: about 500 KB/s on 1 GHz CPU
- Estimated decompressing speed:
 - 8-12 MB/s on 1 GHz Intel Pentium 3 or AMD Athlon
 - 500-1000 KB/s on 100 MHz ARM, MIPS, PowerPC or other simple RISC
- Small memory requirements for decompressing (8-32 KB + DictionarySize)
- Small code size for decompressing: 2-8 KB (depending from speed optimizations)

LZMA decoder uses only integer operations and can be implemented in any modern 32-bit CPU (or on 16-bit CPU with some conditions).

Some critical operations that affect to speed of LZMA decompression:

- 1) 32*16 bit integer multiply
- 2) Misspredicted branches (penalty mostly depends from pipeline length)
- 3) 32-bit shift and arithmetic operations

Speed of LZMA decompressing mostly depends from CPU speed. Memory speed has no big meaning. But if your CPU has small data cache, overall weight of memory speed will slightly increase.

How To Use

Using LZMA encoder/decoder executable

Usage: LZMA <e|d> inputFile outputFile [<switches>...]

e: encode file

d: decode file

b: Benchmark. There are two tests: compressing and decompressing with LZMA method. Benchmark shows rating in MIPS (million instructions per second). Rating value is calculated from measured speed and it is normalized with AMD Athlon XP CPU results. Also Benchmark checks possible hardware errors (RAM errors in most cases). Benchmark uses these settings: (-a1, -d21, -fb32, -mfbt4). You can change only -d. Also you can change number of iterations. Example for 30 iterations:

LZMA b 30

Default number of iterations is 10.

<Switches>

-a{N}: set compression mode 0 = fast, 1 = normal, 2 = max
default: 2 (max)

d{N}: Sets Dictionary size - [0, 28], default: 23 (8MB)
The maximum value for dictionary size is 256 MB = 2²⁸ bytes.
Dictionary size is calculated as DictionarySize = 2^N bytes.
For decompressing file compressed by LZMA method with dictionary
size D = 2^N you need about D bytes of memory (RAM).

-fb{N}: set number of fast bytes - [5, 255], default: 128
Usually big number gives a little bit better compression ratio
and slower compression process.

-lc{N}: set number of literal context bits - [0, 8], default: 3
Sometimes lc=4 gives gain for big files.

-lp{N}: set number of literal pos bits - [0, 4], default: 0
lp switch is intended for periodical data when period is
equal 2^N. For example, for 32-bit (4 bytes)
periodical data you can use lp=2. Often it's better to set lc0,
if you change lp switch.

-pb{N}: set number of pos bits - [0, 4], default: 2
pb switch is intended for periodical data
when period is equal 2^N.

-mf{MF_ID}: set Match Finder. Default: bt4.
Compression ratio for all bt* and pat* almost the same.
Algorithms from hc* group doesn't provide good compression
ratio, but they often works pretty fast in combination with
fast mode (-a0). Methods from bt* group require less memory
than methods from pat* group. Usually bt4 works faster than
any pat*, but for some types of files pat* can work faster.

Memory requirements depend from dictionary size
(parameter "d" in table below).

MF_ID	Memory	Description
bt2	d*9.5 + 1MB	Binary Tree with 2 bytes hashing.
bt3	d*9.5 + 65MB	Binary Tree with 2-3(full) bytes hashing.
bt4	d*9.5 + 6MB	Binary Tree with 2-3-4 bytes hashing.
bt4b	d*9.5 + 34MB	Binary Tree with 2-3-4(big) bytes hashing.
pat2r	d*26 + 1MB	Patricia Tree with 2-bits nodes, removing.
pat2	d*38 + 1MB	Patricia Tree with 2-bits nodes.
pat2h	d*38 + 77MB	Patricia Tree with 2-bits nodes, 2-3 bytes hashing.
pat3h	d*62 + 85MB	Patricia Tree with 3-bits nodes, 2-3 bytes hashing.
pat4h	d*110 + 101MB	Patricia Tree with 4-bits nodes, 2-3 bytes hashing.
hc3	d*5.5 + 1MB	Hash Chain with 2-3 bytes hashing.
hc4	d*5.5 + 6MB	Hash Chain with 2-3-4 bytes hashing.

-eos: write End Of Stream marker. By default LZMA doesn't write
eos marker, since LZMA decoder knows uncompressed size
stored in .lzma file header.

-si: Read data from stdin (it will write End Of Stream marker).

-so: Write data to stdout

Examples:

1) LZMA e file.bin file.lzma -d16 -lc0

compresses file.bin to file.lzma with 64 KB dictionary ($2^{16}=64K$) and 0 literal context bits. -lc0 allows to reduce memory requirements for decompression.

2) LZMA e file.bin file.lzma -lc0 -lp2

compresses file.bin to file.lzma with settings suitable for 32-bit periodical data (for example, ARM or MIPS code).

3) LZMA d file.lzma file.bin

decompresses file.lzma to file.bin.

Compression ratio hints

Recommendations

To increase compression ratio for LZMA compressing it's desirable to have aligned data (if it's possible) and also it's desirable to locate data in such order, where code is grouped in one place and data is grouped in other place (it's better than such mixing: code, data, code, data, ...).

Using Filters

You can increase compression ratio for some data types, using special filters before compressing. For example, it's possible to increase compression ratio on 5-10% for code for those CPU ISAs: x86, IA-64, ARM, ARM-Thumb, PowerPC, SPARC.

You can find C/C++ source code of such filters in folder "7zip/Compress/Branch"

You can check compression ratio gain of these filters with such 7-Zip commands (example for ARM code):

No filter:

```
7z a a1.7z a.bin -m0=lzma
```

With filter for little-endian ARM code:

```
7z a a2.7z a.bin -m0=bc_arm -m1=lzma
```

With filter for big-endian ARM code (using additional Swap4 filter):

```
7z a a3.7z a.bin -m0=swap4 -m1=bc_arm -m2=lzma
```

It works in such manner:

Compressing = Filter_encoding + LZMA_encoding

Decompressing = LZMA_decoding + Filter_decoding

Compressing and decompressing speed of such filters is very high,

so it will not increase decompressing time too much.
Moreover, it reduces decompression time for LZMA_decoding,
since compression ratio with filtering is higher.

These filters convert CALL (calling procedure) instructions
from relative offsets to absolute addresses, so such data becomes more
compressible. Source code of these CALL filters is pretty simple
(about 20 lines of C++), so you can convert it from C++ version yourself.

For some ISAs (for example, for MIPS) it's impossible to get gain from such filter.

LZMA compressed file format

Offset Size Description
0 1 Special LZMA properties for compressed data
1 4 Dictionary size (little endian)
5 8 Uncompressed size (little endian). -1 means unknown size
13 Compressed data

ANSI-C LZMA Decoder

To compile ANSI-C LZMA Decoder you can use one of the following files sets:

- 1) LzmaDecode.h + LzmaDecode.c + LzmaTest.c (fastest version)
- 2) LzmaDecode.h + LzmaDecodeSize.c + LzmaTest.c (old size-optimized version)
- 3) LzmaStateDecode.h + LzmaStateDecode.c + LzmaStateTest.c (zlib-like interface)

Memory requirements for LZMA decoding

LZMA decoder doesn't allocate memory itself, so you must
allocate memory and send it to LZMA.

Stack usage of LZMA decoding function for local variables is not
larger than 200 bytes.

How To decompress data

LZMA Decoder (ANSI-C version) now supports 5 interfaces:

- 1) Single-call Decompressing
- 2) Single-call Decompressing with input stream callback
- 3) Multi-call Decompressing with output buffer
- 4) Multi-call Decompressing with input callback and output buffer
- 5) Multi-call State Decompressing (zlib-like interface)

Variant-5 is similar to Variant-4, but Variant-5 doesn't use callback functions.

Decompressing steps

- 1) read LZMA properties (5 bytes):
 unsigned char properties[LZMA_PROPERTIES_SIZE];
- 2) read uncompressed size (8 bytes, little-endian)
- 3) Decode properties:

```
CLzmaDecoderState state; /* it's 24-140 bytes structure, if int is 32-bit */
```

```
if (LzmaDecodeProperties(&state.Properties, properties, LZMA_PROPERTIES_SIZE) != LZMA_RESULT_OK)  
    return PrintError(rs, "Incorrect stream properties");
```

4) Allocate memory block for internal Structures:

```
state.Probs = (CProb *)malloc(LzmaGetNumProbs(&state.Properties) * sizeof(CProb));  
if (state.Probs == 0)  
    return PrintError(rs, kCantAllocateMessage);
```

LZMA decoder uses array of CProb variables as internal structure.
By default, CProb is unsigned_short. But you can define `_LZMA_PROB32` to make it unsigned_int. It can increase speed on some 32-bit CPUs, but memory usage will be doubled in that case.

5) Main Decompressing

You must use one of the following interfaces:

5.1 Single-call Decompressing

When to use: RAM->RAM decompressing
Compile files: LzmaDecode.h, LzmaDecode.c
Compile defines: no defines
Memory Requirements:
- Input buffer: compressed size
- Output buffer: uncompressed size
- LZMA Internal Structures (~16 KB for default settings)

Interface:

```
int res = LzmaDecode(&state,  
    inStream, compressedSize, &inProcessed,  
    outStream, outSize, &outProcessed);
```

5.2 Single-call Decompressing with input stream callback

When to use: File->RAM or Flash->RAM decompressing.
Compile files: LzmaDecode.h, LzmaDecode.c
Compile defines: `_LZMA_IN_CB`
Memory Requirements:
- Buffer for input stream: any size (for example, 16 KB)
- Output buffer: uncompressed size
- LZMA Internal Structures (~16 KB for default settings)

Interface:

```
typedef struct _CBuffer  
{  
    ILzmaInCallback InCallback;  
    FILE *File;  
    unsigned char Buffer[kInBufferSize];  
} CBuffer;
```

```
int LzmaReadCompressed(void *object, const unsigned char **buffer, SizeT *size)  
{  
    CBuffer *bo = (CBuffer *)object;  
    *buffer = bo->Buffer;
```

```

    *size = MyReadFile(bo->File, bo->Buffer, kInBufferSize);
    return LZMA_RESULT_OK;
}

```

```

CBuffer g_InBuffer;

```

```

g_InBuffer.File = inFile;
g_InBuffer.InCallback.Read = LzmaReadCompressed;
int res = LzmaDecode(&state,
    &g_InBuffer.InCallback,
    outStream, outSize, &outProcessed);

```

5.3 Multi-call decompressing with output buffer

 When to use: RAM->File decompressing
 Compile files: LzmaDecode.h, LzmaDecode.c
 Compile defines: `_LZMA_OUT_READ`

Memory Requirements:

- Input buffer: compressed size
- Buffer for output stream: any size (for example, 16 KB)
- LZMA Internal Structures (~16 KB for default settings)
- LZMA dictionary (dictionary size is encoded in stream properties)

Interface:

```

state.Dictionary = (unsigned char *)malloc(state.Properties.DictionarySize);

```

```

LzmaDecoderInit(&state);
do
{
    LzmaDecode(&state,
        inBuffer, inAvail, &inProcessed,
        g_OutBuffer, outAvail, &outProcessed);
    inAvail -= inProcessed;
    inBuffer += inProcessed;
}
while you need more bytes

```

see LzmaTest.c for more details.

5.4 Multi-call decompressing with input callback and output buffer

 When to use: File->File decompressing
 Compile files: LzmaDecode.h, LzmaDecode.c
 Compile defines: `_LZMA_IN_CB`, `_LZMA_OUT_READ`

Memory Requirements:

- Buffer for input stream: any size (for example, 16 KB)
- Buffer for output stream: any size (for example, 16 KB)
- LZMA Internal Structures (~16 KB for default settings)
- LZMA dictionary (dictionary size is encoded in stream properties)

Interface:

```

state.Dictionary = (unsigned char *)malloc(state.Properties.DictionarySize);

```

```

LzmaDecoderInit(&state);
do
{

```

```

LzmaDecode(&state,
  &bo.InCallback,
  g_OutBuffer, outAvail, &outProcessed);
}
while you need more bytes

```

see LzmaTest.c for more details:

5.5 Multi-call State Decompressing (zlib-like interface)

When to use: file->file decompressing

Compile files: LzmaStateDecode.h, LzmaStateDecode.c

Compile defines:

Memory Requirements:

- Buffer for input stream: any size (for example, 16 KB)
- Buffer for output stream: any size (for example, 16 KB)
- LZMA Internal Structures (~16 KB for default settings)
- LZMA dictionary (dictionary size is encoded in stream properties)

Interface:

```
state.Dictionary = (unsigned char *)malloc(state.Properties.DictionarySize);
```

```

LzmaDecoderInit(&state);
do
{
  res = LzmaDecode(&state,
    inBuffer, inAvail, &inProcessed,
    g_OutBuffer, outAvail, &outProcessed,
    finishDecoding);
  inAvail -= inProcessed;
  inBuffer += inProcessed;
}
while you need more bytes

```

see LzmaStateTest.c for more details:

6) Free all allocated blocks

EXIT codes

LZMA decoder can return one of the following codes:

```

#define LZMA_RESULT_OK 0
#define LZMA_RESULT_DATA_ERROR 1

```

If you use callback function for input data and you return some error code, LZMA Decoder also returns that code.

LZMA Defines

`_LZMA_IN_CB` - Use callback for input data

`_LZMA_OUT_READ` - Use read function for output data

`_LZMA_LOC_OPT` - Enable local speed optimizations inside code.

`_LZMA_LOC_OPT` is only for `LzmaDecodeSize.c` (size-optimized version).

`_LZMA_LOC_OPT` doesn't affect `LzmaDecode.c` (speed-optimized version) and `LzmaStateDecode.c`

`_LZMA_PROB32` - It can increase speed on some 32-bit CPUs, but memory usage will be doubled in that case

`_LZMA_UINT32_IS_ULONG` - Define it if `int` is 16-bit on your compiler and `long` is 32-bit.

`_LZMA_SYSTEM_SIZE_T` - Define it if you want to use system's `size_t`. You can use it to enable 64-bit sizes supporting

C++ LZMA Encoder/Decoder

~~~~~  
C++ LZMA code use COM-like interfaces. So if you want to use it, you can study basics of COM/OLE.

By default, LZMA Encoder contains all Match Finders. But for compressing it's enough to have just one of them. So for reducing size of compressing code you can define:

```
#define COMPRESS_MF_BT  
#define COMPRESS_MF_BT4
```

and it will use only bt4 match finder.

---

<http://www.7-zip.org>  
<http://www.7-zip.org/support.html>

1.3 regina-rexx 3.5

1.3.1 Available under license :

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