FLAC Format Preservation Assessment

Document History

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1. Introduction

This document provides a high level, non-collection specific assessment of the FLAC file format with regard to preservation risks and the practicalities of preserving data in this format.

This format assessment is one of a series of assessments carried out by the British Library's Digital Preservation Team. An explanation of the criteria used in this assessment is provided in the italics below each heading.

1.1 Scope

This document will focus on the FLAC (Free Lossless Audio Codec) format.

Note that this assessment considers format issues only, and does not explore other factors essential to a preservation planning exercise, such as collection specific characteristics, that should always be considered before implementing preservation actions.

1.2 Summary

FLAC is a non-proprietary, open source audio file format standard designed for the lossless compression of digital audio [1]. It is specifically designed for compression of linear pulse-code modulation (LPCM) audio data, "with many of its default parameters tuned to CD-quality music data." [2]

FLAC is in some ways similar to MP3, but uses lossless compression, meaning that while the audio stream is compressed, it suffers no loss in quality. Unlike other lossless compression formats, such as Zip, FLAC benefits from being specifically designed for audio, resulting in smaller file sizes than is possible with more general compression algorithms. FLAC's audio quality can be equivalent to WAV and has the added benefits of a smaller file size, robust error-detection and streaming capabilities [3].

The Wikipedia entry on the format states that "digital audio compressed by FLAC's algorithm can typically be reduced to 50–60% of its original size and decompress to an identical copy of the original audio data." [1]. It adds that it compresses "raw audio data to a smaller size while maintaining the ability to decode to the exact same audio samples that it encoded". Therefore a Broadcast Wave Format (BWF) file could be 300 mb, compared with 100 mb for FLAC, while both – if decoded – would be identical [4].

FLAC files can be encoded with 4 to 32 bits per audio sample [5].

2. Assessment

2.1 Development Status

A summary of the development history of the format and an indication of its current status

Sources indicate that FLAC was developed by Josh Coalson in 2000; the FLAC website carries Coalson's name in copyright notices dated from 2000 forward [1]. The earliest date listed in the FLAC changelog is for 23 December 2000 (version 0.4). In 2003, FLAC was incorporated under the Xiph.Org banner [1]. The Xiph.Org Foundation is a non-profit organisation responsible for several free audio and video formats, such as Vorbis, Opus, and Theora [6].

No changes to the FLAC format have occurred since version 1.2.1 in 2007, indicating that it has a stable format specification. However, the official reference tools have seen continued improvement and support, with the latest release, FLAC 1.3.2, published on 1 January 2017 [7].

In terms of speed and features, FLAC is comparable to other lossless formats. On their website, a full comparison of FLAC with other formats is available: including level of disclosure,

player and hardware support, its suitability for streaming, decoding/encoding speed vs. compression and the cost with those of other lossless codecs [2] [8].

Apple has its own compressed lossless audio format called ALAC (also known as Apple Lossless). The compression is not quite as efficient as FLAC – which results in larger file sizes – but unlike FLAC, it is fully compatible with iTunes and Apple's operating system (MacOS) [9]. Whilst proprietary upon its release in 2004, ALAC has been open source since 2011 [10].

2.2 Adoption and Usage

An impression of how widely used the file format is, with reference to use in other memory organisations and their practical experiences of working with the format

Corrado and Moulaison note that "FLAC is a patent-free, open standard that utilizes lossless (reversible) compression. It may be a good alternative [to other audio formats] for some who are concerned about file size" [11].

FLAC appears to offer much to memory institutions with responsibility for looking after audio content. It is an open format and if there is a need to convert to another format in the future, verification options can ensure the converted audio is equivalent to the original. The reference encoder also has a verification option that "decodes the encoded stream in parallel with the encoding process and compares the result to the original, aborting with an error if there is a mismatch" [3].

However, despite it being a reasonably-stable, lossless format, there is little evidence of memory institutions adopting FLAC, e.g. as an alternative to lossless options such as WAV or BWF. Where adoption has taken place, it has tended to be in parallel with other audio formats [11]. The Library of Congress describes the adoption levels of FLAC as "moderate" [2].

The British Library currently receives small amounts of material in FLAC format, which, as of 2016, is routinely converted to WAV for archival and access purposes. Following the completion of this assessment, these procedures will be reviewed to take into account any new recommendations.

There has been some discussion about the use of FLAC, but little uptake by large institutions and organisations. For example, in 2005, the Library of Congress Motion Picture, Broadcasting, and Recorded Sound Division considered the use of FLAC files for use as "on-premises listening copies of preservation-project masters" [2]. However, by 2007, a redesign of systems and the availability of greater bandwidth meant that it was possible to make files available in their existing WAV form, and plans for delivering FLAC to users were shelved.

As part of their Live Music Archive, the Internet Archive has a download facility which often allows for access to both FLAC and WAV files [2]. Many of their web pages state that concerts they have listed are available for download and streaming in formats including FLAC [12].

The European Broadcasting Union (EBU) uses an audio file transfer system for distributing concert recordings from their Euroradio satellite channels called Musipop. They are originally recorded as WAV files but are subsequently converted into FLAC for sending via satellite [13] [1].

Until recently, FLAC was not supported by Apple or Microsoft as they both offer their own lossless formats (ALAC and WAV respectively), but Microsoft has now added native support for FLAC with Windows 10 [14].

Many online music download sites offer FLAC as a download option now [15] , including labels and stores such as 7digital [16] and Bandcamp [17].

High-quality, lossless music streaming [18] is still a relatively new innovation for the music streaming market and those that do exist do use FLAC. TIDAL [19] and Deezer Elite [20]

(though this is only via the Sonos wireless hi-fi system) have been available since 2014. There is also the French Qobuz [21] service which has been available in the UK since 2013.

The Internet Engineering Steering Group (IETF) has recently approved the Codec Encoding for LossLess Archiving and Realtime transmission (CELLAR) working group's charter to focus on the standardisation of file formats – including FLAC – with a formal specification due in December 2016 [2] [22].

2.3 Software Support

2.3.1 Rendering Software Support

An overall impression of software support for rendering the format with reference to: typical desktop software; and current support on British Library reading room PCs

Whilst a wide range of applications can access and play FLAC files, compatibility with music players is still limited, when compared to other formats, e.g. WAV and MP3 [23]. Native FLAC support is included in Windows 10, Android 3.1, Blackberry 10 and Jolla devices [1], with web browser support provided in Chrome 56 [24] and Firefox 51 [25]. Software tools exist for encoding and decoding, including plug-ins for online media players like Winamp [26]. There are also a number of hardware devices with native support, a partial list of which can be found on the official FLAC website, along with other software, and online services which support the format [15].

Popular players for FLAC files include VLC media player [27] and Clementine [28], both of which are compatible with Windows, Mac and Linux operating systems. It is also supported by the default media players installed with Windows 10: Groove Music and Windows Media Player [29]. Other Windows-based, non-proprietary, open-source media players include Foobar2000 [30], Kodi (previously known as XBMC) [31], VUPlayer [32] and Media Monkey [33]. As mentioned above, FLAC is incompatible with iTunes, except through the use of XiphQT, software which allows the playback of FLAC files in certain versions of iTunes [34]. For Mac OS, Vox Player [35] and Cog are available [36], though the latter has not been updated since 2008.

Issues

Other than a lack of comprehensive playback (particularly Apple's lack of support for the format) there are no reported issues with FLAC playback.

2.3.2 Preservation Software Support

An impression of the availability and effectiveness of software for managing and preserving instances of the file format

Format identification

FLAC has the file extension .flac [1].

Whilst JHOVE is currently unable to identify FLAC, there are other tools available that do. For example, as of version 1.1, Apache Tika can identify FLAC as well as detect and extract metadata [37]. DROID uses internal signatures to identify and report the specific file format versions of digital files generated from information in the PRONOM technical registry, which includes FLAC [38]. FIDO also uses PRONOM [39]. Xena [40] is an open source tool which can detect FLAC, but is mainly used as a tool for migrating other audio files to the format (see below).

Validation and Detecting Preservation Risks

The FLAC format itself supports some level of fixity validation. Each FLAC file contains in its header, an MD5 checksum of the original encoded audio data. This is sometimes referred to as the "FLAC fingerprint" [41]. If the file becomes corrupted or altered in a way that could affect the audio portion, the FLAC file could be identified as unacceptable without needing an external checksum file [42]

FLAC also uses CRC (Cyclic Redundancy Check) checksums for "identifying corrupted frames when used in a streaming protocol." [1]

Dave Rice has commented that "because a FLAC file contains an MD5 checksum of all the encoded data and CRC checksums for each frame of encoded audio it is possible to discover [with] fairly accurate precision what areas are affected by corruption." [42] This gives it a distinct advantage over WAV files which would require external testing to get the same results.

FFmpeg can be used to identify damaged FLAC files and there are plans for detection to be added to the MediaConch tool [43].

Conformance Checking

Open source software tools such as MediaInfo provide a display of technical information and metadata about FLAC files including format, profile, duration, overall bit rate and writing application and library [44].

Whilst FLAC is primarily a lossless format, this doesn't mean that the original source of the audio might not itself have been lossy, like an MP3. Tools such as Audiochecker [45] allow automatic analysis of whether a lossless encoding has been migrated from a lossily compressed source. The use of spectrogram software, such as Spek, would also allow one to perform the same check through the manual analysis of a file's spectrogram for the tell-tale signs of lossy compression [46].

Metadata Extraction

FLAC can support up to 128 different types of metadata block, but currently only seven of these are defined [47]. These are [5] [48]:

- STREAMINFO
- APPLICATION
- PADDING
- SEEKTABLE – an optional block for storing seek points
- VORBIS_COMMENT – (also known as FLAC tags) for storing information such as the title, artist, album, track number or other information about the file [49]
- CUESHEET – a block for storing various information that can be used in a cue sheet, e.g. index points, that could be viewed as table of contents when a CD is ripped [3]
- PICTURE – for storing pictures associated with the file, most commonly cover artwork

Unlike the highly structured ID3 format in MP3, the VORBIS_COMMENT metadata block has no specific format for data values. Also, field names can be used several times, which encourages the use of multiple values [49]. There were attempts to introduce a more structured metadata format for FLAC called M3F [50], but this was discontinued in 2008.

In comparison to WAV, FLAC metadata may not contain as many types of non-audio [51] but is better at retaining tag data [52]. Earlier versions of FLAC didn't allow the preservation of migrated metadata until version 1.2.1 in September 2007. With the introduction of the "--keep-foreign-metadata" command line in FLAC, the format's changelog notes that "non-audio RIFF and AIFF chunks can be stored in FLAC files and recreated when decoding". This allows support for the archiving of BWF, RF64 and other WAVE files using tools that preserve the metadata [51] [53].

Several tools are available for the editing of FLAC metadata including the universal tag editor Mp3tag [54], Kid3 [55] or Tag [56].

There are also several tools available for the extraction of FLAC metadata including: Apache Tika [37], Exiftool [57] and the NLNZ Metadata Extraction tool [58].

Migration

There are a variety of options in terms of the programs available for converting audio files to and from FLAC [15]. These include:

- Xena [40] is an open source tool which converts files into an "openly specified format" [59]. This means during the process of normalization, Xena will convert supported audio file types (AIFF, MP3, OFF, WAV) to FLAC.
- dbPowerAMP Music Converter has mainly been used as an MP3 converter, but it also allows the conversion to and from FLAC (amongst many other formats, including WAV) [60].
- FFmpeg [61] is a conversion tool for multimedia formats. FFmpeg is used at the British Library for converting FLAC files to WAV.
- X Lossless Decoder is a product for the Mac Operating System which allows you to convert to and from a variety of lossless formats [62]
- Audacity's primary use is as a sound editor but will also allow you to export audio file formats as FLAC or import FLAC and convert to other formats such as MP3 [63].
- FLAC to MP3 conversion tools include the Faasoft FLAC to MP3 Converter [64], FlacSquisher [65] and Freemake's Free Audio Converter [66].
- There are also a few options for ripping CDs to the FLAC format: Exact Audio Copy [67], fre:ac [68], and Max [69].
- Whilst primarily music players foobar2000 [70], Winamp [26], Clementine [28] and Media Monkey [33] also feature conversion functionality (Foobar2000 requires an additional encoder pack to be downloaded). Foobar2000 is used at the British Library as a tool to convert FLAC to WAV.

For more information on metadata migration, see above.

2.4 Documentation and Guidance

An indication of the availability of practical documentation or guidance with specific reference to the facilitation of any recommended actions

FLAC is very well documented [1] and its own website has a wealth of information about the format as well as documentation [5] [71] [72].

Though there are no "formal standards for either the codec itself or its use in container formats", such items are currently under review for formalization by the aforementioned CELLAR working group [22].

2.5 Complexity

An impression of the complexity of the format with respect to the impact this is likely to have on the British Library managing or working with content in this format. What level of expertise in the format is required to have confidence in management and preservation?

As with all compressed audio, FLAC is necessarily more complex than uncompressed formats like WAV. However, the FLAC website outlines the overall structure in great detail [5].

A FLAC bitstream consists of the 'fLaC' marker at the beginning of the stream, followed by a mandatory metadata block (called the STREAMINFO block), any number of other metadata blocks, then the audio frames.

As outlined above, FLAC would be able to support up to 128 different types of metadata block, but currently only seven of these are defined [47]. STREAMINFO has information about the whole stream, like sample rate, number of channels, total number of samples, etc. "Also included in the STREAMINFO block is the MD5 signature of the unencoded audio data." [5]
As outlined previously, files are playable on most media players currently available.

2.6 Embedded or Attached Content

The potential for embedding or attaching files of similar or different formats, and the likely implications of this

As outlined above, FLAC can embed various type of metadata in blocks. The CUESHEET block can store information that could be used in a cue sheet including track order, gaps in the audio and a "general purpose cueing mechanism for playback" [5] [1].

The PICTURE block allows the embedding of images in a FLAC file. In most cases, this would be the album artwork associated with music files. The block's contents aren't restricted to any particular image formats, nor are any explicitly recommend, though support for PNG under some circumstances may be inferred [5].

2.7 External Dependencies

An indication of the possibility of content external to an instance of the file format that is complimentary or even essential to the intellectual content of the instance

Besides embedded images, the PICTURE block can also support referencing external images through URLs [5].

Like many audio formats, separate FLAC files can be given an order, or structure, through their inclusion in external cue sheets [70], or other playlist formats such as M3U [68] and PLS [69].

2.8 Legal Issues

Legal impediments to the use, management or preservation of instances of the file format

None. FLAC is a non-proprietary, open source format and is not covered by any known or associated patents [1] [73]. FLAC is free for commercial or non-commercial use, with no licensing fees or royalties of any kind for the distribution, selling or streaming of the format [73].

2.9 Technical Protection Mechanisms

Encryption, Digital Rights Management and any other technical mechanisms that might restrict usage, management or preservation of instances of the file format

There is no method to add copy prevention or DRM to FLAC although it could have been encrypted if it was migrated from another format [3].

2.10 Other Preservation Risks

Other evidence based preservation risks, noting that many known preservation risks are format specific and do not easily fit under any of the sustainability factors above

With FLAC being a relatively new format compared to WAV, there could be concerns over its longevity, though current indicators generally point to continued growth and wider support.

2.11 Preservation Risk Summary

A summary of preservation risks and recommended actions (where possible).

The evidence discussed above presents very few risks associated with the format and continues to demonstrate a growth in terms of commercial availability, but with relatively little adoption amongst the archival and broadcasting communities. Much of this may be due to the de facto predominance of the WAV format, meaning that there is little desire to change or convert, even if FLAC were to offer benefits for organisations, such as those with storage capacity concerns.

The main issues include:

- **External references**

- Metadata images referenced through URLs may be subject to change or loss.

- **Misidentification of low-quality audio**
  - Like other lossless audio formats, FLAC files may contain audio data at a level of quality identical to that of any lossy formats from which they are migrated, such as MP3. Given this, FLAC files received from third-party sources shouldn't be assumed to contain high-quality audio. Such files could be checked, where necessary, to ascertain whether their level of quality is consistent with migration from a high-quality audio source, or a lossy format.
- **Documentation**
  - There is a large amount of documentation available, and it is currently going through a standardisation process, but there is currently no formal standards specification.

3. Recommendations for Action

Recommended actions in usage and handling of the format. Recommend actions in the support or development of software applications that provide, or have the potential to provide, significant risk mitigation for the format. Note that these recommendations do not take into account other requirements such as those driven by specific British Library collections, or non-preservation issues such as resourcing.

FLAC has much to recommend it as a format for audio content and its adoption by music service providers confirms that there is a growing market for it in the wider community. The format's long-term viability could be the main concern amongst the archival community, although so far we see no evidence to warrant such a concern.

Handling Recommendations

Based on the analysis and risks outlined above, FLAC should be considered a preferred archival format for audio. As such, FLAC files should not be converted to WAV if submitted for repository ingest. Doing so would increase the file's size and remove the internal checksums which allow for the location of any errors that may already exist in the file.

Additionally, FLAC files received from external sources should not be assumed to contain high-quality audio. If high-quality audio is required from a source, files received should be checked for signs of migration from lower-quality, lossily-compressed audio formats.

Software Recommendations

As outlined above, the official encoder supports validation using internal checksums as well as analysis reporting. FFmpeg could also be used to identify damaged FLAC files and would be a useful tool for error detection [43].

Monitoring Recommendations

Despite the low risks, a wide acceptance of FLAC is unlikely in the short term. However, the benefits of the format mean a fairly regular review of the format would be beneficial alongside a general awareness of digital audio developments and other potential lossless alternatives.

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