Low Complexity Communication Codec (LC3)

***Bluetooth*® Test Suite**

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Contents

1 Scope

This Bluetooth document contains the Test Suite Structure (TSS) and test cases to test the implementation of the Bluetooth Low Complexity Communication Codec (LC3) Specification with the objective to provide a high probability of air interface interoperability between the tested implementation and other manufacturers' Bluetooth devices.

2 References, definitions, and abbreviations

2.1 References

This document incorporates provisions from other publications by dated or undated reference. These references are cited at the appropriate places in the text, and the publications are listed hereinafter. Additional definitions and abbreviations can be found in [1] and [2].

[1] Bluetooth Core Specification, Version 5.2 or later

[2] Test Strategy and Terminology Overview

[3] Low Complexity Communication Codec (LC3), Version 1.0

[4] European Broadcasting Union Sound Quality Assessment Material Recordings, European Broadcasting Union, https://qc.ebu.io/testmaterial/523/1/download/

[5] IBM & Microsoft, “Multimedia Programming Interface and Data Specification 1.0”, 1991

[6] “SoX”, Sound eXchange, https://sourceforge.net/projects/sox/files/sox/14.4.2/sox-14.4.2-win32.zip

[7] “Wine”, Wine-HQ, https://www.winehq.org

[8] LC3_conformance_interoperability_test_software.zip, latest version, https://www.bluetooth.org/docman/handlers/DownloadDoc.ashx?doc_id=582377&vId=628285

[9] LC3 ICS Proforma, LC3.ICS

[10] Recommendation ITU-R BS.1387-1: “Method for objective measurements of perceived audio quality”, November 2001

[11] gstPEAQ repository, https://github.com/HSU-ANT/gstpeaq/archive/refs/tags/version-0.6.1.zip

2.2 Definitions

In this Bluetooth document, the definitions from [1] and [2] apply.

2.3 Acronyms and abbreviations

In this Bluetooth document, the definitions, acronyms, and abbreviations from [1] and [2] apply.

Abbreviation	Description
Δ_{ODG}	Difference between two ODGs
DR	LC3 Reference Decoder
DuT	LC3 Decoder under Test
ER	LC3 Reference Encoder
EuT	LC3 Encoder under Test
LSB	Least Significant Bit
N	Total number of samples per channels
ODG	Objective Difference Grade
Out(n)	Output signal of decoder under test
PEAQ	Perceptual Evaluation of Audio Quality algorithm
ref_ref(n)	Signal processed with ER and DR
RMS	Root Mean Square

Abbreviation	Description
Seq(n)	Supplied test bitstream
tst_ref(n)	Signal processed with EuT and DR

Table 2.1: Symbols and abbreviations

3 Test Suite Structure (TSS)

3.1 Test Strategy

This test strategy validates an implementation of the codec using an LC3 Conformance Script [8] and does not require an over-the-air test to confirm conformance. Implementations use the script to test decoding and encoding against other implementations and/or a reference implementation.

The LC3 Conformance Script package includes configuration files for the various sample rates, bit rates, and frame sizes that include pass/fail thresholds. The Conformance Script implements the test procedures defined in Section 3.2.

The LC3 Encoder tests in Section 4.1.3 utilize the Conformance Script and cover the Encoder SQAM Test, Band Limitation Test, and Low Pass Test as specified in Section 3.2.6.

The LC3 Decoder tests in Section 4.3 utilize the Conformance Script and cover the Decoder SQAM Test as specified in Section 3.2.7.

The Encoder-Decoder tests in Section 4.4 validate that the implementation of the Encoder-Decoder chain meets the requirements for the audio quality.

The IUT can be a Windows, Mac OS, or Linux development environment to execute the LC3 Python Conformance Script using a configuration file with parameters to encode or decode the audio samples. The audio sample files are located at [4]. The Conformance Script outputs an HTML file with the pass or fail results.

A Bluetooth audio profile utilizing LC3 specifies the codec configuration to achieve operational modes for that profile.

Testing applies to implementations that encode or decode raw audio data and does not apply to implementations that transport previously encoded or decoded audio data.

This Test Suite contains Valid Behavior (BV) tests. There are no Invalid Behavior (BI) tests. Invalid input files, for example using a non-audio or corrupted audio file, will not invalidate the test but could result in a failed test result.

Note that all equations in this document are not part of the LC3 specification and are present only for the purpose of this Test Suite.

3.2 LC3 Conformance Test Suite

3.2.1 Bitstream Syntax

Each bitstream is tested for compliance with the syntactic and semantic syntax.

3.2.2 Test Item Selection

If not otherwise stated, each test (both encoder and decoder conformance) uses a selection of 9 reference audio tracks from the European Broadcasting Union Sound Quality Assessment Material EBU SQAM CD [4]. These items cover speech and different types of music to evaluate a wide range of LC3 features. In this Test Suite, the selected EBU items are subsetted according to the following table:

Track Name	EBU Track Number	Start [s]	Fragment Length [s]
ABBA	69	7	8
Castanets	27	0	8
Eddie_Rabbitt	70	0	8

Track Name	EBU Track Number	Start [s]	Fragment Length [s]
Female_Speech_German	53	0	8
Glockenspiel	35	0	10
Harpsichord	40	39	9
Male_Speech_English	50	0	8
Piano_Schubert	60	0	8
Violoncello	10	0	10

Table 3.1: LC3 Conformance test items

For all items, a fade-in of 0.5 s and a fade-out of 0.7 s is chosen to ensure a pleasant listening experience should it be necessary to listen to the coded files. Please refer to the LC3 Conformance Script [8] for the command lines used for preprocessing the test items.

3.2.3 Calculation of the Root Mean Square

All measurements are carried out relative to full scale where the output signals of the decoder and supplied test bitstreams are normalized to be in the range between -1.0 and +1.0.

The test bitstreams have a precision of 16 bits, where the most significant bit (MSB) is labeled bit 0 and the least significant bit (LSB) is labeled bit 15. The value of each bit is represented by the following equation, where *pos* is the position of the bit:

$$value = \frac{1}{2^{pos}}$$

The output signal of the decoder under test needs to be in the same format as the test bitstreams.

The Root Mean Square (RMS) level is calculated as follows where *Out*(n) denotes output signal of the decoder under test, and *Seq*(n) denotes the supplied reference bitstream:

$$RMS = \sqrt{\frac{1}{N}\sum_{n=1}^{N}(Out(n) - Seq(n))^2}$$

To fulfill the RMS test at an accuracy level of K bits, an LC3 encoder and decoder IUT provides an output waveform such that the RMS level of the difference signal between the output of the decoder IUT and the output of the reference decoder is less than:

$$\frac{1}{2^{k-1} \cdot 12^{0.5}}$$

In addition, the difference signal has a maximum absolute value of at most $\frac{1}{2^{k-2}}$ relative to the maximum amplitude a system can represent. The RMS test is carried out for an accuracy level of k=14, the RMS tool and the LC3 conformance script use a maximum absolute difference threshold of 0.00148.

An RMS tool implementation is provided within the LC3 conformance script package as C source code. This code can be compiled and the binary can be used to compare two audio files and calculate the overall RMS in dB, with the maximum absolute difference of two audio samples and the reached RMS criterion expressed in bits. The RMS tool can be used with the following command line:

./rms file1.wav file2.wav

The following diagram illustrates the coding process and the calculation of the RMS value:

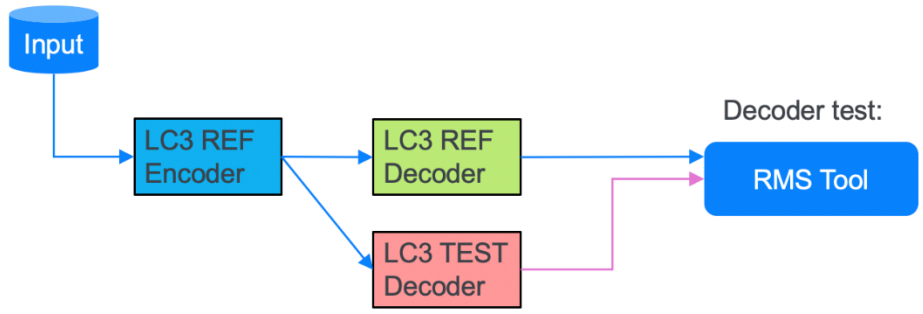

Figure 3.1: RMS calculation procedure for Decoder tests

3.2.4 Calculation of the ODG Value

To calculate the Objective Difference Grade (ODG) between two audio files, an ITU-BS.1387 (PEAQ – advanced [10]) implementation is used. In case an implementation of the PEAQ – advanced standard is not available, the tool gstPEAQ [11] can be used instead. If gstPEAQ is used, the threshold for ΔODG in Section 3.2.5 is 0.07 instead of 0.06. The Perceptual Evaluations of Audio Quality (PEAQ) algorithm binary calculates the ODG between a coded audio file and the reference audio file. Prior to calculating the ODG, both the reference file and the test file are upsampled to 48 kHz and delay-aligned using the maximum cross-correlation. The ODG value is then calculated for two files for each test permutation (see Section 3.2.3):

- ODG between reference audio and coded audio using LC3 Reference codec
- ODG between reference audio and coded audio using LC3 codec under test

The difference between the two ODGs (Δ_{ODG}) does not exceed a certain threshold according to Section 3.2.5.

To make sure that the test implementation produces an audio quality comparable to or better than the reference implementation then, ODG_{REF} - ODG_{TST} < ODG_{THR}, where ODG_{REF} is the ODG of the reference implementation, ODG_{TST} is the ODG of the test implementation, and ODG_{THR} is the ODG threshold defined in Section 3.2.5. The following diagram illustrates the coding process and the calculation of Δ_{ODG} for Encoder and Encoder-Decoder Tests:

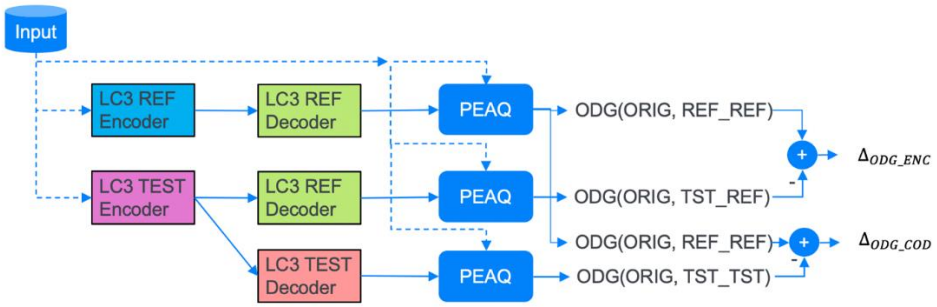

Figure 3.2: Δ_{ODG} calculation procedure for Encoder and Encdec tests

3.2.5 Pass and Fail Criteria

For each test permutation (see Section 3.2.2), the pass/fail criteria are checked. The pass criteria are defined as follows:

- Encoder Test: ODG criteria with maximum Δ_{ODG} of 0.06
- Decoder Test: RMS criteria with:
  - Minimum RMS value of -89 dB (equals k=14 in Section 3.2.3) and
  - Maximum absolute difference value of 0.00148
- Encoder-Decoder Test: ODG criteria with maximum Δ_{ODG} of 0.06

A test fails if at least one condition exceeds the threshold of the respective metric.

The following diagram illustrates the pass/fail decision:

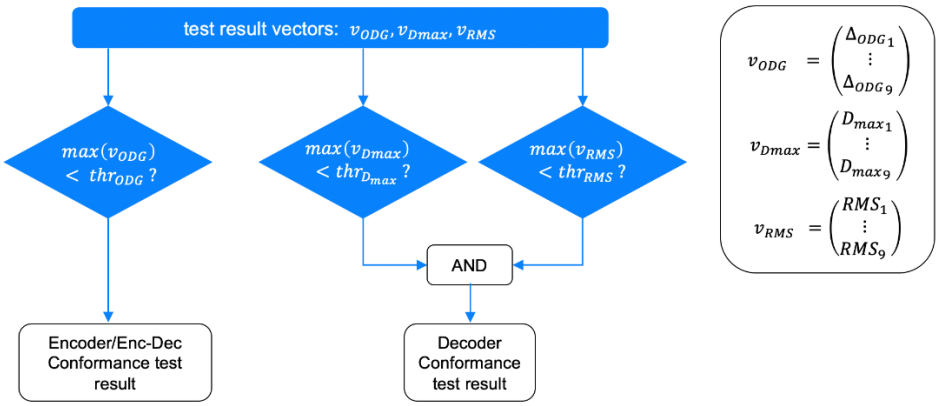

Figure 3.3: Pass/Fail criteria for LC3 conformance

3.2.6 Conformance Test of LC3 Encoder

All encoder tests use the EuT and the ER to produce two bitstreams for each configuration to be tested (tst.bin and ref.bin). These two bitstreams are then decoded using the DR producing two output PCM files (tst_ref.wav and ref_ref.wav). These two output PCM files and the input reference file are used to calculate the ODG value according to Section 3.2.4.

The conformance test of the EuT consists of the following tests, which should be carried out by the manufacturer:

- SQAM Test
- Band Limitation Test
- Low Pass Test

In the following sections, a detailed description for each of the tests is provided, including the respective pass criteria.

3.2.6.1 Encoder SQAM Test

This test uses the items described in Section 3.2.2 to compare the objective audio quality of the EuT against the ER. The items are encoded with the EuT and the ER, decoded with the DR according to Section 3.2.8.1; the objective metrics are calculated according to Section 3.2.4 and then compared according to Section 3.2.5.

Pass criteria:

This test passes if all test permutations have met the ODG criterion.

3.2.6.2 Encoder Band Limitation Test

The Band Limitation test verifies the correct implementation of the bandwidth detector inside the EuT.

Therefore, the item *Female_Speech_German* from the EBU SQAM CD is resampled and low pass filtered to create the following test configurations:

Sampling Rate [kHz]	Limited Bandwidth	Bit rate [kbps]
16	NB	32
24	NB, WB	48
32	NB, WB, SSWB	64
48	NB, WB, SSWB, SWB	96

Table 3.2: Test configurations for the Band Limitation test

The item is encoded according to Section 3.2.6.1.

Pass criteria:

This test passes if all test permutations have met the ODG criterion. For the calculation of the ODG, the band limited file is used as reference (denoted as ORIG in Figure 3.2) instead of the original input file.

3.2.6.3 Encoder Low Pass Test

This test verifies the correct implementation of the cutoff frequency of 20 kHz used in the EuT by performing the following steps:

1. Create a signal consisting of white noise above 20 kHz.
2. The signal is then encoded and decoded according to Section 3.2.8.1.
3. Calculate the energy E of the output PCM file according to the following formula, where *N* is the total number of audio samples.

$$E = 10 * log_{10} \sum_{n=1}^{N} (tst\_ref(n))^2$$

Pass criteria:

This test passes if the resulting E is below 70 dB.

3.2.7 Conformance Test of LC3 Decoder

All decoder tests use the ER to produce bitstreams for each configuration to be tested (ref.bin). These bitstreams are decoded using the DuT and the DR producing two output PCM files (ref_tst.wav and ref_ref.wav). The two output PCM files are used to calculate the RMS value.

3.2.7.1 Decoder SQAM Test

This test uses the test items in Section 3.2.2 to compare the RMS of the DuT against the DR. The items are encoded with the ER, decoded with the DuT and the DR according to Section 3.2.8.1; the metric is calculated according to Section 3.2.3 and then compared according to Section 3.2.5.

Pass criteria:

This test passes if all test permutations have met the RMS criterion.

3.2.8 Reference LC3 Encoder and Decoder

Reference executables for the Win32 platform are available for both the encoder and the decoder of the LC3 codec; the usage of these programs is explained herein. By typing: ./LC3 –h the usage can also be displayed.

The LC3 codec can operate at six sampling frequencies: 8, 16, 24, 32, 44.1, and 48 kHz. The sampling frequency is obtained from the encoder input file.

3.2.8.1 Reference LC3 Codec

Usage:

LC3 [-frame_ms] [-E] [-D] input.wav output.wav bitrate

Parameter	Meaning	Optional
-E	Run encoder only and produce bitstream as output. Input file in WAVE format, Output file in encoded bitstream format.	YES
-D	Run decoder only, decode bitstream, and produce wave as output. Input file in encoded bitstream format. Output file in WAVE format.	YES
-frame_ms	Frame duration in ms, 10 ms (default) or 7.5 ms.	YES
input	Input file in WAVE format.	NO
output	Output file in WAVE format.	NO
bitrate	Bit rate in kbps. Bit rate switching file can be used instead of fixed bit rate.	NO (except when “-D” parameter used)

Table 3.3: Reference LC3 Codec usage

Examples:

Command	Meaning
LC3 IN OUT BR	Encode wave IN and decode to wave OUT at BR bitrate
LC3 -E IN OUT BR	Encode wave IN to bitstream OUT at BR bitrate
LC3 -D IN OUT	Decode bitstream IN to wave OUT

Table 3.4: Examples of Reference LC3 Codec usage

3.2.8.2 Reference LC3 Codec Bitstream Format

This section describes the bitstream format of the LC3 reference codec. The implementation under test creates and decodes bitstreams in this format to allow testing against the reference codec. This format is intended for testing purposes only and is not standardized.

The binary format has an 18-byte header composed of seven 16-bit little-endian ordered values and one 32-bit little-endian ordered value as outlined in Table 3.5:

Field	Bytes	Content
file_id	2	File identifier, value 0xcc1c
header_size	2	Total config header size in bytes
samplingrate	2	Sampling frequency / 100
bitrate	2	Bitrate / 100
channels	2	Number of channels
frame_ms	2	Frame duration in ms * 100
RFU	2	RFU
signal_len	4	Input signal length in samples

Table 3.5: Reference LC3 Codec Bitstream Header

The frames are stored directly after the header. Each frame starts with a 16-bit little-endian ordered value *size* that contains the length of the frame. It is followed by the payload data of *size* bytes.

3.2.8.3 Note to platform-dependent conformance

To prepare the audio samples for the conformance test, it is recommended to use SoX (Sound eXchange) [6] for any operations on the audio samples to prepare them for the conformance test. SoX behaves differently on different platforms, meaning that the same resampling operation on the same file will not be bit-exact if executed on different platforms. Therefore, to avoid such issues, it is recommended to use the SoX Windows-Binary (together with Wine [7] on non-Windows platforms). It is recommended that the version given in reference [6] is used. The LC3 Python Conformance Script automatically downloads the SoX Windows-Binary as well as the test audio items and prepares them at the first execution of the LC3 Python Conformance Script. If the items are already available from a previous run, they are not downloaded/prepared again.

3.3 Test groups

3.3.1 Encoder

Test the implementation of the LC3 encoder using the reference encoder script.

3.3.2 Decoder

Test the implementation of the LC3 decoder using the reference decoder script.

3.3.3 Encoder-Decoder Chain

Test the implementation of the entire LC3 encoder and decoder chain.

4 Test cases (TC)

4.1 Introduction

4.1.1 Test case identification conventions

Test cases are assigned unique identifiers per the conventions in [2]. The convention used here is: **<spec abbreviation>/<IUT role>**/<class>/**<feat>**/<func>/<subfunc>/<cap>/**<xx>-<nn>-<y>**.

Identifier Abbreviation	**Spec Identifier <spec abbreviation>**
LC3	LC3 Specification
Identifier Abbreviation	**Role Identifier <IUT role>**
DEC	Decoder feature
EDC	Encoder-Decoder Chain
ENC	Encoder feature
Identifier Abbreviation	**Feature Identifier <feat>**
FB	Full Band
NB	Narrow Band
SSWB	Semi Super Wide Band
SWB	Semi Wide Band
WB	Wide Band

Table 4.1: LC3 TC feature naming convention

4.1.2 Conformance

When conformance is claimed for a particular specification, all capabilities are to be supported in the specified manner. The mandated tests from this Test Suite depend on the capabilities to which conformance is claimed.

The Bluetooth Qualification Program may employ tests to verify implementation robustness. The level of implementation robustness that is verified varies from one specification to another and may be revised for cause based on interoperability issues found in the market.

Such tests may verify:

- That claimed capabilities may be used in any order and any number of repetitions not excluded by the specification
- That capabilities enabled by the implementations are sustained over durations expected by the use case
- That the implementation gracefully handles any quantity of data expected by the use case
- That in cases where more than one valid interpretation of the specification exists, the implementation complies with at least one interpretation and gracefully handles other interpretations
- That the implementation is immune to attempted security exploits

A single execution of each of the required tests is required to constitute a Pass verdict. However, it is noted that to provide a foundation for interoperability, it is necessary that a qualified implementation consistently and repeatedly pass any of the applicable tests.

In any case, where a member finds an issue with the test plan generated by the Bluetooth SIG qualification tool, with the test case as described in the Test Suite, or with the test system utilized, the member is required to notify the responsible party via an erratum request such that the issue may be addressed.

4.1.3 Pass/Fail verdict conventions

Each test case has an Expected Outcome section. The IUT is granted the Pass verdict when all the detailed pass criteria conditions within the Expected Outcome section are met.

The convention in this Test Suite is that, unless there is a specific set of fail conditions outlined in the test case, the IUT fails the test case as soon as one of the pass criteria conditions cannot be met. If this occurs, then the outcome of the test is a Fail verdict.

4.2 ENC, Implementation Verification of the Encoder

- Test Purpose

  Test that the implementation of the Encoder is within the threshold for the audio quality being tested at the specified sampling rate and bit rate.

- Reference

  [3] 3.3

  [8] LC3_Conformance Test Scripts

- Initial Condition

  - IUT(SRC) device is ready to perform LC3 encoding of an audio stream.
  - Lower Tester is the Conformance Test Scripts [8].

- Test Case Configuration

Test Case ID	Sampling Rate (kHz)	Bit Rate (kbps)	Octets Per Frame	Frame Rate (ms)
LC3/ENC/NB/BV-01-C [Encoder, Narrow Band, 8 kHz, 10 ms]	8	24	30	10
LC3/ENC/WB/BV-01-C [Encoder, Wideband, 16 kHz, 10 ms]	16	32	40	10
LC3/ENC/SSWB/BV-01-C [Encoder, Semi-Superwideband, 24 kHz, 10 ms]	24	48	60	10
LC3/ENC/SWB/BV-01-C [Encoder, Superwideband, 32 kHz, 10 ms]	32	64	80	10
LC3/ENC/FB/BV-01-C [Encoder, Full Band, 48 kHz, 80 kbps, 10 ms]	48	80	100	10
LC3/ENC/FB/BV-02-C [Encoder, Full Band, 48 kHz, 96 kbps, 10 ms]	48	96	120	10
LC3/ENC/FB/BV-03-C [Encoder, Full Band, 48 kHz, 124 kbps, 10 ms]	48	124	155	10
LC3/ENC/FB/BV-04-C [Encoder, Full Band, 44.1 kHz, 79.38 kbps, 10 ms]	44.1	79.38	108	10
LC3/ENC/FB/BV-05-C [Encoder, Full Band, 44.1 kHz, 95.55 kbps, 10 ms]	44.1	95.55	130	10

Test Case ID	Sampling Rate (kHz)	Bit Rate (kbps)	Octets Per Frame	Frame Rate (ms)
LC3/ENC/FB/BV-06-C [Encoder, Full Band, 44.1 kHz, 123.48 kbps, 10 ms]	44.1	123.48	168	10
LC3/ENC/NB/BV-02-C [Encoder, Narrow Band, 8 kHz, 7.5 ms]	8	27.734	26	7.5
LC3/ENC/WB/BV-02-C [Encoder, Wideband, 16 kHz, 7.5 ms]	16	32	30	7.5
LC3/ENC/SSWB/BV-02-C [Encoder, Semi-Superwideband, 24 kHz, 7.5 ms]	24	48	45	7.5
LC3/ENC/SWB/BV-02-C [Encoder, Superwideband, 32 kHz, 64 kbps, 7.5 ms]	32	64	60	7.5
LC3/ENC/SWB/BV-03-C [Encoder, Superwideband, 32 kHz, 61.867 kbps,7.5 ms]	32	61.867	58	7.5
LC3/ENC/FB/BV-07-C [Encoder, Full Band, 48 kHz, 80 kbps, 7.5 ms]	48	80	75	7.5
LC3/ENC/FB/BV-08-C [Encoder, Full Band, 48 kHz, 96 kbps, 7.5 ms]	48	96	90	7.5
LC3/ENC/FB/BV-09-C [Encoder, Full Band, 48 kHz, 124.8 kbps, 7.5 ms]	48	124.8	117	7.5
LC3/ENC/FB/BV-10-C [Encoder, Full Band, 44.1 kHz, 79.38 kbps, 7.5 ms]	44.1	79.38	81	7.5
LC3/ENC/FB/BV-11-C [Encoder, Full Band, 44.1 kHz, 95.06 kbps, 7.5 ms]	44.1	95.06	97	7.5
LC3/ENC/FB/BV-12-C [Encoder, Full Band, 44.1 kHz, 123.48 kbps, 7.5 ms]	44.1	123.48	126	7.5

Table 4.2: Encoder test case configuration

- Test Procedure

  1. The Upper Tester inputs sound samples as defined in Section 3.2.6 through the IUT to produce encoded results.
  2. The IUT sends the encoded results output to the Lower Tester.
  3. The Lower Tester outputs an HTML file with the results.

- Expected Outcome

  Pass verdict

  In Step 3, the Lower Tester output satisfies the requirement in Section 3.2.5.

4.3 DEC, Implementation Verification of the Decoder

- Test Purpose

  Test that the implementation of the Decoder is within the threshold for the audio quality being tested at the specified sampling rate and bit rate.

- Reference

  [3] 3.4

  [8] LC3_Conformance Test Scripts

- Initial Condition

  - IUT (SNK) is ready to perform the LC3 decoding mode of an audio stream.
  - Lower Tester is the LC3 Conformance Test Script [8].

- Test Case Configuration

Test Case ID	Sampling Rate (kHz)	Bit Rate (kbps)	Octets Per Frame	Frame Rate (ms)
LC3/DEC/NB/BV-01-C [Decoder, Narrow Band, 8 kHz, 10 ms]	8	24	30	10
LC3/DEC/WB/BV-01-C [Decoder, Wideband, 16 kHz, 10 ms]	16	32	40	10
LC3/DEC/SSWB/BV-01-C [Decoder, Semi-Superwideband, 24 kHz, 10 ms]	24	48	60	10
LC3/DEC/SWB/BV-01-C [Decoder, Superwideband, 32 kHz, 10 ms]	32	64	80	10
LC3/DEC/FB/BV-01-C [Decoder, Full Band, 48 kHz, 80 kbps, 10 ms]	48	80	100	10
LC3/DEC/FB/BV-02-C [Decoder, Full Band, 48 kHz, 96 kbps, 10 ms]	48	96	120	10
LC3/DEC/FB/BV-03-C [Decoder, Full Band, 48 kHz, 124 kbps, 10 ms]	48	124	155	10
LC3/DEC/FB/BV-04-C [Decoder, Full Band, 44.1 kHz, 79.38 kbps, 10 ms]	44.1	79.38	108	10
LC3/DEC/FB/BV-05-C [Decoder, Full Band, 44.1 kHz, 95.55 kbps, 10 ms]	44.1	95.55	130	10
LC3/DEC/FB/BV-06-C [Decoder, Full Band, 44.1 kHz, 123.48 kbps, 10 ms]	44.1	123.48	168	10
LC3/DEC/NB/BV-02-C [Decoder, Narrow Band, 8 kHz, 7.5 ms]	8	27.734	26	7.5
LC3/DEC/WB/BV-02-C [Decoder, Wideband, 16 kHz, 7.5 ms]	16	32	30	7.5
LC3/DEC/SSWB/BV-02-C [Decoder, Semi-Superwideband, 24 kHz, 7.5 ms]	24	48	45	7.5
LC3/DEC/SWB/BV-02-C [Decoder, Superwideband, 32 kHz, 64 kbps, 7.5 ms]	32	64	60	7.5

Test Case ID	Sampling Rate (kHz)	Bit Rate (kbps)	Octets Per Frame	Frame Rate (ms)
LC3/DEC/SWB/BV-03-C [Decoder, Superwideband, 32 kHz, 61.867 kbps, 7.5 ms]	32	61.867	58	7.5
LC3/DEC/FB/BV-07-C [Decoder, Full Band, 48 kHz, 80 kbps, 7.5 ms]	48	80	75	7.5
LC3/DEC/FB/BV-08-C [Decoder, Full Band, 48 kHz, 96 kbps, 7.5 ms]	48	96	90	7.5
LC3/DEC/FB/BV-09-C [Decoder, Full Band, 48 kHz, 124.8 kbps, 7.5 ms]	48	124.8	117	7.5
LC3/DEC/FB/BV-10-C [Decoder, Full Band, 44.1 kHz, 79.38 kbps, 7.5 ms]	44.1	79.38	81	7.5
LC3/DEC/FB/BV-11-C [Decoder, Full Band, 44.1 kHz, 95.06 kbps, 7.5 ms]	44.1	95.06	97	7.5
LC3/DEC/FB/BV-12-C [Decoder, Full Band, 44.1 kHz, 123.48 kbps, 7.5 ms]	44.1	123.48	126	7.5

Table 4.3: Decoder test case configuration

- Test Procedure

  1. The Upper Tester inputs the encoded data file through the IUT.
  2. The IUT sends the decoded results output to the Lower Tester.
  3. The Lower Tester outputs an HTML file with the results.

- Expected Outcome

  Pass verdict

  In Step 3, the audio output satisfies the requirement in Section 3.2.5.

4.4 EDC, Implementation Verification of the Encoder-Decoder Chain

- Test Purpose

  Test that the implementation of the Encoder-Decoder chain is within the threshold for the audio quality being tested at the specified sampling rate and bit rate.

- Reference

  [3] 3.3, 3.4

  [8] LC3_Conformance_Informal_IoP Test Scripts

- Initial Condition

  - IUT(SRC) device is ready to perform LC3 encoding mode of an audio stream.
  - IUT(SNK) device is ready to perform LC3 decoding mode of an audio stream.
  - Lower Tester is the Conformance Test Script [8].

- Test Case Configuration

Test Case ID	Sampling Rate (kHz)	Bit Rate (kbps)	Octets Per Frame	Frame Rate (ms)
LC3/EDC/NB/BV-01-C [Encoder-Decoder, Narrow Band, 8 kHz, 10 ms]	8	24	30	10
LC3/EDC/WB/BV-01-C [Encoder-Decoder, Wideband, 16 kHz, 10 ms]	16	32	40	10
LC3/EDC/SSWB/BV-01-C [Encoder-Decoder, Semi-Superwideband, 24kHz, 10 ms]	24	48	60	10
LC3/EDC/SWB/BV-01-C [Encoder-Decoder, Superwideband, 32 kHz, 10 ms]	32	64	80	10
LC3/EDC/FB/BV-01-C [Encoder-Decoder, Full Band, 48 kHz, 80 kbps, 10 ms]	48	80	100	10
LC3/EDC/FB/BV-02-C [Encoder-Decoder, Full Band, 48 kHz, 96 kbps, 10 ms]	48	96	120	10
LC3/EDC/FB/BV-03-C [Encoder-Decoder, Full Band, 48 kHz, 124 kbps, 10 ms]	48	124	155	10
LC3/EDC/FB/BV-04-C [Encoder-Decoder, Full Band, 44.1 kHz, 79.38 kbps, 10 ms]	44.1	79.38	108	10
LC3/EDC/FB/BV-05-C [Encoder-Decoder, Full Band, 44.1 kHz, 95.55 kbps, 10 ms]	44.1	95.55	130	10
LC3/EDC/FB/BV-06-C [Encoder-Decoder, Full Band, 44.1 kHz, 123.48 kbps, 10 ms]	44.1	123.48	168	10
LC3/EDC/NB/BV-02-C [Encoder-Decoder, Narrow Band, 8 kHz, 7.5 ms]	8	27.734	26	7.5
LC3/EDC/WB/BV-02-C [Encoder-Decoder, Wideband, 16 kHz, 7.5 ms]	16	32	30	7.5
LC3/EDC/SSWB/BV-02-C [Encoder-Decoder, Semi-Superwideband, 24 kHz, 7.5 ms]	24	48	45	7.5
LC3/EDC/SWB/BV-02-C [Encoder-Decoder, Superwideband, 32 kHz, 64 kbps, 7.5 ms]	32	64	60	7.5
LC3/EDC/SWB/BV-03-C [Encoder-Decoder, Superwideband, 32 kHz, 61.867 kbps, 7.5 ms]	32	61.867	58	7.5
LC3/EDC/FB/BV-07-C [Encoder-Decoder, Full Band, 48 kHz, 80 kbps, 7.5 ms]	48	80	75	7.5
LC3/EDC/FB/BV-08-C [Encoder-Decoder, Full Band, 48 kHz, 96 kbps, 7.5 ms]	48	96	90	7.5
LC3/EDC/FB/BV-09-C [Encoder-Decoder, Full Band, 48 kHz, 124.8 kbps, 7.5 ms]	48	124.8	117	7.5
LC3/EDC/FB/BV-10-C [Encoder-Decoder, Full Band, 44.1 kHz, 79.38 kbps, 7.5 ms]	44.1	79.38	81	7.5

Test Case ID	Sampling Rate (kHz)	Bit Rate (kbps)	Octets Per Frame	Frame Rate (ms)
LC3/EDC/FB/BV-11-C [Encoder-Decoder, Full Band, 44.1 kHz, 95.06 kbps, 7.5 ms]	44.1	95.06	97	7.5
LC3/EDC/FB/BV-12-C [Encoder-Decoder, Full Band, 44.1 kHz, 123.48 kbps, 7.5 ms]	44.1	123.48	126	7.5

Table 4.4: Encoder/Decoder test case configuration

- Test Procedure

  1. The Upper Tester inputs test bitstreams in [4] into the IUT(SRC).
  2. The output from the IUT(SRC) is sent to the input of IUT(SNK) to be decoded.
  3. The IUT(SNK) sends the decoded output to the Lower Tester.
  4. The Lower Tester outputs an HTML file with the results.

- Expected Outcome

  Pass verdict

  In Step 4, the audio output of the implementation satisfies the requirement in Section 3.2.5.

5 Test case mapping

The Test Case Mapping Table (TCMT) maps test cases to specific requirements in the ICS. The IUT is tested in all roles for which support is declared in the ICS document.

The columns for the TCMT are defined as follows:

Item: Contains a logical expression based on specific entries from the associated ICS document. Contains a logical expression (using the operators AND, OR, NOT as needed) based on specific entries from the applicable ICS document(s). The entries are in the form of y/x references, where y corresponds to the table number and x corresponds to the feature number as defined in the ICS document for LC3 [9].

If a test case is mandatory within the respective layer, then the y/x reference is omitted.

Feature: A brief, informal description of the feature being tested.

Test Case(s): The applicable test case identifiers are required for Bluetooth Qualification if the corresponding y/x references defined in the Item column are supported. Further details about the function of the TCMT are elaborated in [2].

For the purpose and structure of the ICS/IXIT, refer to [2].

Item	Feature	Test Case(s)
LC3 Encoder		
LC3 3/1 AND LC3 4/2	Narrow Band, 8 kHz, Encoder, 10 ms	LC3/ENC/NB/BV-01-C
LC3 3/2 AND LC3 4/2	Wideband, 16 kHz, Encoder, 10 ms	LC3/ENC/WB/BV-01-C
LC3 3/3 AND LC3 4/2	Semi-Superwideband, 24 kHz, Encoder, 10 ms	LC3/ENC/SSWB/BV-01-C
LC3 3/4 AND LC3 4/2	Superwideband, 32 kHz, Encoder, 10 ms	LC3/ENC/SWB/BV-01-C
LC3 3/6 AND LC3 4/2	Full Band, 48 kHz, Encoder, 10 ms	LC3/ENC/FB/BV-01-C LC3/ENC/FB/BV-02-C LC3/ENC/FB/BV-03-C
LC3 3/5 AND LC3 4/2	Full Band, 44.1 kHz, Encoder, 10 ms	LC3/ENC/FB/BV-04-C LC3/ENC/FB/BV-05-C LC3/ENC/FB/BV-06-C
LC3 3/1 AND LC3 4/1	Narrow Band, 8 kHz, Encoder, 7.5 ms	LC3/ENC/NB/BV-02-C
LC3 3/2 AND LC3 4/1	Wideband, 16 kHz, Encoder, 7.5 ms	LC3/ENC/WB/BV-02-C
LC3 3/3 AND LC3 4/1	Semi-Superwideband, 24 kHz, Encoder, 7.5 ms	LC3/ENC/SSWB/BV-02-C
LC3 3/4 AND LC3 4/1	Superwideband, 32 kHz, Encoder, 7.5 ms	LC3/ENC/SWB/BV-02-C LC3/ENC/SWB/BV-03-C
LC3 3/6 AND LC3 4/1	Full Band, 48 kHz, Encoder, 7.5 ms	LC3/ENC/FB/BV-07-C LC3/ENC/FB/BV-08-C LC3/ENC/FB/BV-09-C
LC3 3/5 AND LC3 4/1	Full Band, 44.1 kHz, Encoder, 7.5 ms	LC3/ENC/FB/BV-10-C LC3/ENC/FB/BV-11-C LC3/ENC/FB/BV-12-C

Item	Feature	Test Case(s)
LC3 Decoder		
LC3 5/1 AND LC3 6/2	Narrow Band, 8 kHz, Decoder, 10 ms	LC3/DEC/NB/BV-01-C
LC3 5/2 AND LC3 6/2	Wideband, 16 kHz, Decoder, 10 ms	LC3/DEC/WB/BV-01-C
LC3 5/3 AND LC3 6/2	Semi-Superwideband, 24 kHz, Decoder, 10 ms	LC3/DEC/SSWB/BV-01-C
LC3 5/4 AND LC3 6/2	Superwideband, 32 kHz, Decoder, 10 ms	LC3/DEC/SWB/BV-01-C
LC3 5/6 AND LC3 6/2	Full Band, 48 kHz, Decoder, 10 ms	LC3/DEC/FB/BV-01-C LC3/DEC/FB/BV-02-C LC3/DEC/FB/BV-03-C
LC3 5/5 AND LC3 6/2	Full Band, 44.1 kHz, Decoder, 10 ms	LC3/DEC/FB/BV-04-C LC3/DEC/FB/BV-05-C LC3/DEC/FB/BV-06-C
LC3 5/1 AND LC3 6/1	Narrow Band, 8 kHz, Decoder, 7.5 ms	LC3/DEC/NB/BV-02-C
LC3 5/2 AND LC3 6/1	Wideband, 16 kHz, Decoder, 7.5 ms	LC3/DEC/WB/BV-02-C
LC3 5/3 AND LC3 6/1	Semi-Superwideband, 24 kHz, Decoder, 7.5 ms	LC3/DEC/SSWB/BV-02-C
LC3 5/4 AND LC3 6/1	Superwideband, 32 kHz, Decoder, 7.5 ms	LC3/DEC/SWB/BV-02-C LC3/DEC/SWB/BV-03-C
LC3 5/6 AND LC3 6/1	Full Band, 48 kHz, Decoder, 7.5 ms	LC3/DEC/FB/BV-07-C LC3/DEC/FB/BV-08-C LC3/DEC/FB/BV-09-C
LC3 5/5 AND LC3 6/1	Full Band, 44.1 kHz, Decoder, 7.5 ms	LC3/DEC/FB/BV-10-C LC3/DEC/FB/BV-11-C LC3/DEC/FB/BV-12-C
LC3 Encoder-Decoder		
LC3 2/3 AND LC3 3/1 AND LC3 4/2 AND LC3 5/1 AND LC3 6/2	Narrow Band, 8 kHz, Encoder-Decoder, 10 ms	LC3/EDC/NB/BV-01-C
LC3 2/3 AND LC3 3/2 AND LC3 4/2 AND LC3 5/2 AND LC3 6/2	Wideband, 16kHz, Encoder-Decoder, 10 ms	LC3/EDC/WB/BV-01-C
LC3 2/3 AND LC3 3/3 AND LC3 4/2 AND LC3 5/3 AND LC3 6/2	Semi-Superwideband, 24 kHz, Encoder-Decoder, 10 ms	LC3/EDC/SSWB/BV-01-C
LC3 2/3 AND LC3 3/4 AND LC3 4/2 AND LC3 5/4 AND LC3 6/2	Superwideband, 32 kHz, Encoder-Decoder, 10 ms	LC3/EDC/SWB/BV-01-C

Item	Feature	Test Case(s)
LC3 2/3 AND LC3 3/6 AND LC3 4/2 AND LC3 5/6 AND LC3 6/2	Full Band, 48 kHz, Encoder-Decoder, 10 ms	LC3/EDC/FB/BV-01-C LC3/EDC/FB/BV-02-C LC3/EDC/FB/BV-03-C
LC3 2/3 AND LC3 3/5 AND LC3 4/2 AND LC3 5/5 AND LC3 6/2	Full Band, 44.1 kHz, Encoder-Decoder, 10 ms	LC3/EDC/FB/BV-04-C LC3/EDC/FB/BV-05-C LC3/EDC/FB/BV-06-C
LC3 2/3 AND LC3 3/1 AND LC3 4/1 AND LC3 5/1 AND LC3 6/1	Narrow Band, 8 kHz, Encoder-Decoder, 7.5 ms	LC3/EDC/NB/BV-02-C
LC3 2/3 AND LC3 3/2 AND LC3 4/1 AND LC3 5/2 AND LC3 6/1	Wideband, 16kHz, Encoder-Decoder, 7.5 ms	LC3/EDC/WB/BV-02-C
LC3 2/3 AND LC3 3/3 AND LC3 4/1 AND LC3 5/3 AND LC3 6/1	Semi-Superwideband, 24 kHz, Encoder-Decoder, 7.5 ms	LC3/EDC/SSWB/BV-02-C
LC3 2/3 AND LC3 3/4 AND LC3 4/1 AND LC3 5/4 AND LC3 6/1	Superwideband, 32 kHz, Encoder-Decoder, 7.5 ms	LC3/EDC/SWB/BV-02-C LC3/EDC/SWB/BV-03-C
LC3 2/3 AND LC3 3/6 AND LC3 4/1 AND LC3 5/6 AND LC3 6/1	Full Band, 48 kHz, Encoder-Decoder, 7.5 ms	LC3/EDC/FB/BV-07-C LC3/EDC/FB/BV-08-C LC3/EDC/FB/BV-09-C
LC3 2/3 AND LC3 3/5 AND LC3 4/1 AND LC3 5/5 AND LC3 6/1	Full Band, 44.1 kHz, Encoder-Decoder, 7.5 ms	LC3/EDC/FB/BV-10-C LC3/EDC/FB/BV-11-C LC3/EDC/FB/BV-12-C

Table 5.1: Test case mapping

6 Revision history and acknowledgments

Revision History

Publication Number	Revision Number	Date	Comments
0	p0	2020-09-22	Approved by BTI on 2020-09-02. LC3 v1.0 specification adopted by BoD on 2020-09-15. Prepared for publication.
	p1r00	2021-03-29	TSE 16496 (rating 2): To address E15858, specified reference file for band limitation test, updated Pass criteria for “Encoder Band Limitation Test” section. TSE 16497 (rating 2): To address E15859, changed wrong Ediff symbol, updated Pass criteria for “Encoder Low Pass Test” section. TSE 16544 (rating 2): To clarify that the implementation products can produce audio quality comparable to or better than the reference implementation, updated the “Calculation of the ODG Value” section.
1	p1	2021-07-13	Approved by BTI on 2021-06-01. Prepared for TCRL 2021-1 publication.
	p1ed2r00	2021-07-22	TSE 17054 (rating 1): Added a reference to “Recommendation ITU-R BS.1387-1” and included a cross reference to that new reference in the “Calculation of the ODG Value” section. TSE 17228 (rating 1): Updated the LC3 conformance interoperability test software title and link in the References section.
	p1 edition 2	2021-08-20	Approved by BTI on 2021-08-19. Prepared for edition 2 publication.
	p1ed3r00	2021-08-26	TSE 17380 (rating 1): Updated an unsupported bitrate in the “Encoder Band Limitation Test” table. TSE 17392 (rating 1): To address Encoder Sanity Checks being removed from the script, updated the “Test Strategy” and “Conformance Test of LC3 Encoder” sections to remove Encoder Sanity Checks and removed the entire “Encoder Sanity Checks” section.
	p1 edition 3	2021-09-28	Approved by BTI on 2021-09-27. Prepared for edition 3 publication.
	p2r00–r01	2022-02-08 – 2022-03-24	TSE 18099 (rating 2): Added ICS entry to the TCMT for Encoder-Decoder test cases. Performed template-related formatting fixes. Updated copyright page to align with v2 of the DNMD. Consistency checker findings: Updated TCID description to match TS template (using [ ]).
2	p2	2022-06-28	Approved by BTI on 2022-06-20. Prepared for TCRL 2022-1 publication.

Publication Number	Revision Number	Date	Comments
	p3r00	2022-08-18	TSE 19183 (rating 4): Added new test cases LC3/DEC/SWB/BV-03-C, LC3/EDC/SWB/BV-03-C, and LC3/ENC/SWB/BV-03-C to cover a new bitrate for the 32 kHz, 7.5 ms configuration due to the LC3 SWB enhancement in HFP. Updated the TCMT accordingly. Also specified the kbps of LC3/DEC/SWB/BV-02-C, LC3/EDC/SWB/BV-02-C, and LC3/ENC/SWB/BV-02-C. Template-related editorials, including removing the pre-p0 (draft) rev history entries.
3	p3	2023-02-07	Approved by BTI on 2022-12-19. Prepared for TCRL 2022-2 publication.
	p4r00–r02	2024-08-12 – 2024-08-19	TSE 25000 (rating 1): Per E24260, updated the “Calculation of the ODG Value” section to allow use of the gstPEAQ software tool and added a reference to the gstPEAQ repository. TSE 25118 (rating 1): Updated reference link to test software for Low Complexity Communication Codec 1.0 to always provide the latest version.
4	p4	2024-10-08	Approved by BTI on 2024-09-11. LC3 v1.0.1 adopted by the BoD on 2024-10-01. Prepared for TCRL 2024-2-addition publication.
	p5r00	2024-11-11	TSE 26186 (rating 1): Updated the link for reference 4 in the References section.
5	p5	2025-02-18	Approved by BTI on 2025-02-09. Prepared for TCRL 2025-1 publication.

Acknowledgments

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