

Recommendation

ITU-T G.191 (03/2023)

SERIES G: Transmission systems and media, digital systems and networks

International telephone connections and circuits – Software tools for transmission systems

Software tools for speech and audio coding standardization

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Recommendation ITU-T G.191

Software tools for speech and audio coding standardization

Summary

Recommendation ITU-T G.191 provides source code for speech and audio processing modules for narrowband, wideband and super-wideband telephony applications. The set includes codecs, filters, and noise generators.

This edition introduces changes to Annex A, which describes the ITU-T software tools library (STL) containing a high-quality, portable C code library for speech processing applications. This release of the STL, also known as STL2023, incorporates:

- An implementation of P.50 fullband modulated noise reference unit (MNRU) as described in Recommendation ITU-T P.810.
- A tool for automatic instrumentation of speech and audio codecs to measure their computational complexity and memory.

Recommendation ITU-T G.191 includes an electronic attachment containing STL2023 and a manual.

History

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* To access the Recommendation, type the URL <http://handle.itu.int/> in the address field of your web browser, followed by the Recommendation's unique ID. For example, <http://handle.itu.int/11.1002/1000/11830-en>.

FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure, e.g., interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

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Electronic attachment: STL2023 and manual.

Recommendation ITU-T G.191

Software tools for speech and audio coding standardization

1 Scope

This Recommendation¹ provides a set of common, coherent and portable signal processing tools to facilitate the development of speech and audio coding algorithms, in particular within the standardization environment where the following situations often happen:

- experimental results generated with different software tools may not be directly compared;
- software tools used by different organizations may not perfectly conform to related ITU-T Recommendations, which may delay ITU-T standardization processes;
- ITU-T Recommendations may leave scope for different implementations;
- new speech and audio coding standards are increasing in complexity, leading to non-bitexact specifications; furthermore, appropriate testing procedures to assure interoperability of different implementations are needed.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

- [ITU-T G.192] Recommendation ITU-T G.192 (1996), *A common digital parallel interface for speech standardization activities*.
- [ITU-T G.711] Recommendation ITU-T G.711 (1988), *Pulse code modulation (PCM) of voice frequencies*.
- [ITU-T G.712] Recommendation ITU-T G.712 (2001), *Transmission performance characteristics of pulse code modulation channels*.
- [ITU-T G.718] Recommendation ITU-T G.718 (2008), *Frame error robust narrow-band and wideband embedded variable bit-rate coding of speech and audio from 8-32 kbit/s*.
- [ITU-T G.722] Recommendation ITU-T G.722 (2012), *7 kHz audio-coding within 64 kbit/s*
- [ITU-T G.726] Recommendation ITU-T G.726 (1990), *40, 32, 24, 16 kbit/s Adaptive Differential Pulse Code Modulation (ADPCM)*.
- [ITU-T G.727] Recommendation ITU-T G.727 (1990), *5-, 4-, 3- and 2-bit/sample embedded adaptive differential pulse code modulation (ADPCM)*.
- [ITU-T G.728] Recommendation ITU-T G.728 (2012), *Coding of speech at 16 kbit/s using low-delay code excited linear prediction*.
- [ITU-T G.729.1] Recommendation ITU-T G.729.1 (2006), *G.729-based embedded variable bit-rate coder: An 8-32 kbit/s scalable wideband coder bitstream interoperable with G.729*.

¹ This Recommendation includes an electronic attachment containing STL2023 and a manual

[ITU-T O.41]	Recommendation ITU-T O.41 (1994), <i>Psophometer for use on telephone-type circuits.</i>
[ITU-T P.48]	Recommendation ITU-T P.48 (1988), <i>Specification for an intermediate reference system.</i>
[ITU-T P.56]	Recommendation ITU-T P.56 (2011), <i>Objective measurement of active speech level.</i>
[ITU-T P.341]	Recommendation ITU-T P.341 (2011), <i>Transmission characteristics for wideband digital loudspeaking and hands-free telephony terminals.</i>
[ITU-T P.810]	Recommendation ITU-T P.810 (2023), <i>Modulated noise reference unit (MNRU).</i>
[ITU-T P.811]	Recommendation ITU-T P.811 (2019), <i>Subjective test methodology for evaluating Speech oriented stereo communication systems over headphones.</i>
[ITU-R BS.1770]	Recommendation ITU-R BS.1770-4 (2015), <i>Algorithms to measure audio programme loudness and true-peak audio level.</i>

3 Definitions

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ADPCM	Adaptive Differential Pulse Code Modulation
EID	Error Insertion Device
FFT	Fast Fourier Transform
FIR	Finite Impulse Response
FIR-IRS	Finite Impulse Response-Intermediate Reference System
IIR	Infinite Impulse Response
LSB	Least Significant Bit
MNRU	Modulated Noise Reference Unit
MSB	Most Significant Bit
PCM	Pulse Code Modulation
ROM	Read Only Memory
RPE-LTP	Regular Pulse Excitation-Long Term Prediction
STL	Software Tool Library
SIMD	Single Instruction Multiple Data
VLIW	Very Long Instruction Word
WMC	WMOPS and Memory Counting tool
WMOPS	Weighted Millions of Operations Per Second

5 Conventions

None.

6 Software tools

To clarify the use of the set of software tools, arranged as a software tool library (STL), ITU-T makes the following recommendations:

- 1) The software tools specified in Annex A should be used as building modules of signal processing blocks to be used in the process of generation of ITU-T Recommendations, particularly those concerned with speech and audio coding algorithms.
- 2) The software tools specified in Annex A should be used as building modules of signal processing blocks to be used in the process of generation of ITU-T Recommendations, particularly those concerned with speech and audio coding algorithms.
- 3) Some of the tools shall be used in procedures for the verification of interoperability of ITU-T standards, mainly of speech and audio coding algorithms whose description is in terms of non-bitexact specifications.
- 4) The use of these modules should be made strictly in accordance with the technical instructions of their attached documentation, and should respect the following terms:

The software tools are maintained on an open-source collaboration platform [b-STLgit]. The build toolchain is implemented using the CMake framework [b-CMake] to generate build scripts crafted for the target platform and to execute regression tests for each module in the STL.

7 Licence and copyright

The modules in the ITU-T STL are free software; they can be redistributed or modified under the terms of Annex B; this applies to any of the versions of the modules in the STL.

The STL has been carefully tested and it is believed that both the modules and the example programs on their usage conform to their description documents. Nevertheless, the ITU-T STL is provided "as is", in the hope that it will be useful, but without any warranty.

The STL is intended to help the scientific community to achieve new standards in telecommunications more efficiently, and for such must not be sold, entirely or in parts. The original developers, except where otherwise noted, retain ownership of their copyright, and allow their use under the terms and conditions of Annex B.

Annex A

List of software tools available

(This annex forms an integral part of this Recommendation.)

This annex contains a list with a short description of the software tools available in the ITU-T software tool library (STL). All the routines in the modules are written in C.

a) Example programs available

Associated header file: *ugstdemo.h*

The following programs are examples of the use of the modules:

<i>g711demo.c</i>	on the use of the ITU-T G.711 module.
<i>g726demo.c</i>	on the use of the ITU-T G.726 module.
<i>g727demo.c</i>	on the use of the ITU-T G.727 module.
<i>g722demo.c</i>	on the use of the ITU-T G.722 module.
<i>g728enc.c</i>	on the use of the ITU-T G.728 floating-point encoder.
<i>g728dec.c</i>	on the use of the ITU-T G.728 floating-point decoder.
<i>g728fpenc.c</i>	on the use of the ITU-T G.728 fixed-point encoder.
<i>g728fpdec.c</i>	on the use of the ITU-T G.728 fixed-point decoder.
<i>rpedemo.c</i>	on the use of the full-rate GSM 06.10 speech codec module.
<i>sv56demo.c</i>	on the use of the speech voltmeter module, and also the gain/loss routine.
<i>eiddemo.c</i>	on the use of the error insertion device for bit error insertion and frame erasure.
<i>eid-ev.c</i>	on the use of the error insertion device for bit error insertion for layered bitstreams, which can be used to apply errors to individual layers in layered bitstreams, such as [ITU-T G.718] or [ITU-T G.729.1].
<i>gen-patt.c</i>	on the use of generating bit error pattern files for error insertion in serial bitstreams encoded files that comply with [ITU-T G.192].
<i>gen_rate_profile.c</i>	on the use of the fast switching rate profile generation tool.
<i>firdemo.c</i>	on the use of the finite impulse response (FIR) high-quality low-pass and band-pass filters and of the FIR-IRS filters, associated with the rate change module.
<i>pcmdemo.c</i>	on the use of the ITU-T G.712 (standard PCM) infinite impulse response (IIR) filters, associated with the rate change module.
<i>filter.c</i>	on the use of both the IIR and the finite impulse response (FIR) filters available in the rate change module.
<i>mnrudemo.c</i>	on the use of the narrowband and wideband modulated noise reference unity (ITU-T P.810) module.
<i>p50fbmnruc</i>	on the use of the P.50 fullband modulated noise reference unit (MNRU).
<i>spdemo.c</i>	on the use of the serialization and parallelization routines of the utility module.
<i>g711iplc.c</i>	on the use of the packet loss concealment module of Appendix I of [ITU-T G.711].
<i>reverb.c</i>	on the use of the reverberation module.

<i>truncate.c</i>	on the use of the bitstream truncation module.
<i>freqresp.c</i>	on the use of the frequency response computation tool.
<i>stereoop.c</i>	on the use of stereo file operations.
<i>esdru.c</i>	on the use of energy-based spatial distortion reference unit [ITU-T P.811].
<i>wmc_tool.cpp</i>	on the use of WMC tool for speech and audio codecs complexity and memory measurement.

NOTE – The module for the basic operators does not have a demo program but it is supplemented by two tools: one to evaluate program read only memory (ROM) complexity for fixed-point code (*basop_cnt.c*), and another to evaluate complexity (including program ROM) of floating-point implementations (*flc_example.c*). Both reside in the basic operators module.

b) Rate change module with FIR (finite impulse response) routines

Name: *firflt.c*

Associated header file: *firflt.h*

The functions included are as follows:

<i>delta_sm_16khz_init</i>	initialize 16 kHz 1:1 deltaSM weighting filter.
<i>hq_down_2_to_1_init</i>	initialize 2:1 low-pass down-sampling filter.
<i>hq_down_3_to_1_init</i>	initialize 3:1 low-pass down-sampling filter.
<i>hq_up_1_to_2_init</i>	initialize 1:2 low-pass up-sampling filter.
<i>hq_up_1_to_3_init</i>	initialize 1:3 low-pass up-sampling filter.
<i>irs_8khz_init</i>	initialize 8-kHz ITU-T P.48 IRS weighting filter.
<i>irs_16khz_init</i>	initialize 16-kHz ITU-T P.48 IRS weighting filter.
<i>linear_phase_pb_2_to_1_init</i>	initialize 2:1 bandpass down-sampling filter.
<i>linear_phase_pb_1_to_2_init</i>	initialize 1:2 bandpass up-sampling filter.
<i>linear_phase_pb_1_to_1_init</i>	initialize 1:1 bandpass filter.
<i>mod_irs_16khz_init</i>	initialize 16-kHz send-side modified IRS weighting filter.
<i>mod_irs_48khz_init</i>	initialize 48-kHz send-side modified IRS weighting filter.
<i>psophometric_8khz_init</i>	initialize 1:1 ITU-T O.41 psophometric weighting filter.
<i>p341_16khz_init</i>	initialize 1:1 ITU-T P.341 send-part weighting filter for data sampled at 16 kHz.
<i>rx_mod_irs_16khz_init</i>	initialize 16-kHz modified IRS receive-side weighting filter.
<i>rx_mod_irs_8khz_init</i>	initialize 8-kHz modified IRS receive-side weighting filter.
<i>tia_irs_8khz_init</i>	initialize 8-kHz IRS weighting filter using the TIA coefficients.
<i>ht_irs_16khz_init</i>	initialize 16-kHz IRS weighting filter with a half-tilt inclination within the ITU-T P.48 mask.
<i>msin_16khz_init</i>	initialize mobile station weighting filter.
<i>bp5k_16khz_init</i>	initialize 50-Hz to 5-kHz-bandpass filter (16 kHz sampling).
<i>bp100_5k_16khz_init</i>	initialize a 100-Hz to 5-kHz-bandpass filter (16-kHz sampling).
<i>bp14k_32khz_init</i>	initialize a 50-Hz to 14-kHz-bandpass filter (32-kHz sampling).
<i>bp20k_48khz_init</i>	initialize a 20-Hz to 20-kHz-bandpass filter (48-kHz sampling).
<i>LP1p5_48kHz_init</i>	initialize a low-pass filter with a cut-off frequency of 1.5 kHz (48-kHz sampling).
<i>LP35_48kHz_init</i>	initialize a low-pass filter with a cut-off frequency of 3.5 kHz

	(48-kHz sampling).
<i>LP7_48kHz_init</i>	initialize a low-pass filter with a cut-off frequency of 7 kHz (48-kHz sampling).
<i>LP10_48kHz_init</i>	initialize a low-pass filter with a cut-off frequency of 10 kHz (48 kHz sampling).
<i>LP12_48kHz_init</i>	initialize a low-pass filter with a cut-off frequency of 12 kHz at (48-kHz sampling).
<i>LP14_48kHz_init</i>	initialize a low-pass filter with a cut-off frequency of 14 kHz at 48-kHz sampling).
<i>LP20_48kHz_init</i>	initialize a low-pass filter with a cut-off frequency of 20 kHz (48-kHz sampling).
<i>hq_kernel</i>	FIR filtering function.
<i>hq_reset</i>	clear state variables.
<i>hq_free</i>	deallocate FIR-filter memory.

c) Rate change module with infinite impulse response routines

Name: *iirflt.c*

Associated header file: *iirflt.h*

The functions included are as follows:

<i>stdpcm_kernel</i>	parallel-form IIR kernel filtering routine.
<i>stdpcm_16khz_init</i>	initialization of a parallel-form IIR standard PCM-filter for input and output data at 16 kHz.
<i>stdpcm_1_to_2_init</i>	as "stdpcm_16khz_init()", but needs input with sampling frequency of 8 kHz and returns data at 16 kHz.
<i>stdpcm_2_to_1_init</i>	as "stdpcm_16khz_init()", but needs input with sampling frequency of 16 kHz and returns data at 8 kHz.
<i>stdpcm_reset</i>	clear state variables (needed only if another signal should be processed with the same filter) for a parallel-form structure.
<i>stdpcm_free</i>	deallocate filter memory for a parallel-form state variable structure.
<i>cascade_iir_kernel</i>	cascade-form IIR filtering routine.
<i>iir_G712_8khz_init</i>	initialization of a cascade-form IIR standard PCM filter for data sampled at 8 kHz.
<i>iir_irs_8khz_init</i>	initialization of a cascade-form IIR ITU-T P.48 IRS filter for data sampled at 8 kHz.
<i>iir_casc_1p_3_to_1_init</i>	initialization of a cascade-form IIR low-pass filter for asynchronization filtering of data and downsampling by a factor of 3:1.
<i>iir_casc_1p_1_to_3_init</i>	initialization of a cascade-form IIR low-pass filter for asynchronization filtering of data and upsampling by a factor of 3:1.
<i>cascade_iir_reset</i>	clear state variables (needed only if another signal should be processed with the same filter) for a cascade-form structure.
<i>cascade_iir_free</i>	deallocate filter memory for a cascade-form state variable structure.
<i>direct_iir_kernel</i>	direct-form IIR filtering routine.
<i>iir_dir_dc_removal_init</i>	Initialize a direct-form IIR filter structure for a 1:1 DC removal filtering.
<i>direct_reset</i>	clear state variables (needed only if another signal should be processed