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INFORMATION TECHNOLOGY -

GENERIC CODING OF MOVING PICTURES AND ASSOCIATED AUDIO:
Real-Time Interface Specification

ISO/IEC 13818-9

International Standard

Real-Time Interface Specification

Introduction

Conformance for ISO/IEC 13818-1 Transport Streams is specified in terms of the normative specifications defined therein. These specifications include, among other requirements, a Transport Stream System Target Decoder (T-STD) (ISO/IEC 13818-1 section 2.4.2) which specifies the behaviour of an idealized decoder when the stream is input to such a decoder. The T-STD model, and the associated verification, do not include information concerning the stream in real time.

This part of ISO/IEC 13818 specifies the timing of the real-time delivery of the bytes of Transport Stream packets at a Real Time Interface (RTI). Equipment which includes some type of interface for Transport Stream data, the timing characteristics of which are said to comply with the RTI specification, must be able to operate normally with any input which complies with the RTI specification. In no case, however, is a piece of equipment required to implement an RTI interface.

1. Scope

This part of ISO/IEC 13818 does not change or supercede any of the requirements in ISO/IEC 13818-1. All Transport Streams, whether or not they are delivered in accordance with the RTI shall comply with ISO/IEC 13818-1. In particular, the accuracy requirement in ISO/IEC 13818-1 for PCRs in Transport Streams is not changed by the requirements of ISO/IEC 13818-9. Compliance with ISO/IEC 13818-9 is not required for compliance with ISO/IEC 13818-1.

ISO/IEC 13818-9 does not address decoder requirements related to clock acquisition and slew rate constraints. For example, suppose a system utilizes the 27 MHz system clock to derive an ITU-R PAL chroma clock of 4.434 MHz, with a 0.1 Hz/sec slew rate limitation. With a source clock of 0.1 ppm accuracy, a decoder clock of 30 ppm accuracy, and straightforward phase-locked loop clock recovery circuitry, a decoder could require about 305,000 bits to prevent buffer under/overflow during frequency acquisition, even with low-jitter delivery. The actual number of bits a decoder requires for this purpose could be higher or lower, depending on the implementation.

Figure 1 provides a simplified view of the scope of ISO/IEC 13818-9. This figure shows a Data Link Interface Adaptor, a Real-Time Interface Decoder (RTD), and the location of the Transport Stream which complies with the RTI Specification. It should be noted that the Data Link Interface Adaptor is responsible for removing any data link protocol or data structures, as well as any timing variations (i.e. jitter) in order to produce a compliant RTI Transport Stream.

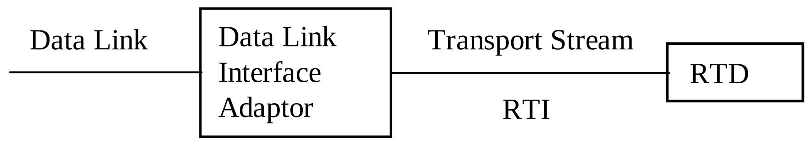

Figure 1 - Scope of RTI

2. Real-Time Interface Requirements

2.1 The Real-Time Interface Decoder Model

The Real-Time Interface Decoder Model, called the RTD, is a conceptual model used to define the RTI normative requirements. The RTD is used only for this purpose. Neither its architecture nor the timing described precludes uninterrupted, synchronized playback by a variety of decoders with different architectures or timing schedules.

The RTD is exactly the same as the T-STD model defined in ISO/IEC 13818-1, except that:

- the byte delivery schedule defined in the T-STD is replaced by the actual byte arrival time in the RTD;
- real-time constraints are imposed on the values of PCR in relation to their arrival time in the RTD;
- the buffer sizes defined in the T-STD are different in the RTD; and
- there is an extra requirement on the Transport Buffer occupancy (see the end of section 2.4).

2.2 Clock Frequency Requirements

The requirements on the system clock with respect to frequency and frequency slew given in ISO/IEC 13818-1 section 2.4.2.1 are also mandatory for the Real-Time Interface.

2.3 PCR Accuracy Requirements

This subclause defines a single constraint on the relationship between the arrival time of all the bytes containing the last bit of a program_clock_reference_base field for a single program of a Transport Stream, and the value carried in the corresponding program clock references.

Specifically,

- let system_clock_counter(t) be a counter that counts cycles of a system clock that satisfies the frequency requirements specified in clause 2.2 above, where t represents time;
- let i" be the index of a byte containing the last bit of a program_clock_reference_base field;
- let t(i") be the time at which byte i" arrives in the RTD; and
- let PCR(i") be the value of the program clock reference associated with byte i";

then there shall exist such a system_clock_counter(t), a sequence of times e(i"), and a constant t_jitter (see ISO/IEC 13818-1 Annex J) that satisfy

$$PCR(i'') = system\_clock\_counter((t(i'') + e(i''))\%(300 \times 2^{33})), \text{ and}$$

$$- t\_jitter/2 \le e(i'') \le t\_jitter/2.$$

2.4 Buffer Requirements

The buffers in the RTD have the same names as those in the T-STD, but are denoted with a "_r" suffix. Their sizes are:

$$TBS\_r_n = TBS_n + (t\_jitter \times Rx_n) + 188 \text{ bytes}$$
$$TBS\_r_{sys} = TBS_{sys} + (t\_jitter \times Rx_n) + 188 \text{ bytes}$$
$$sb\_size\_r = sb\_size + (t\_jitter \times sb\_leak\_rate) + 188 \text{ bytes}$$

It should be noted that the use of the smoothing buffer (see ISO/IEC 13818-1 section 2.6.30) is optional for this part of ISO/IEC 13818, as it is in ISO/IEC 13818-1.

The multiplex buffer (for video) and the decoder buffer (for audio and systems data) in the RTD have the sizes:

$$MBS\_r_n = MBS_n + (2\times t\_jitter \times Rx_n),$$
$$BS\_r_n = BS_n + (2 \times t\_jitter \times Rx_n), \text{ and}$$
$$BS\_r_{sys} = BS_{sys} + (2 \times t\_jitter \times Rx_n),$$

respectively. Note that in all these equations, Rx_n, which is identical in definition to the same variable in the T-STD, is expressed in bytes/second for convenience.

Given the RTD buffers as defined above, and a system clock that fulfils the above requirements, the RTD imposes that all the buffer constraints imposed by the T-STD in ISO/IEC 13818-1 be complied with.

In addition, the buffer state of the buffer TB_r_n in the RTD at the arrival of the first byte of any Transport Stream packet shall be no more than the size of that buffer minus 188 bytes.

2.5 Real-Time Interface for Low Jitter Applications

This subclause specifies the Real-Time Interface for Low Jitter Applications (RTI-LJ). For a bitstream and its byte delivery schedule to comply with the RTI-LJ, they must obey all of the compliance tests in section 3 below with t_jitter equal to 50 microseconds. For a decoder to comply with the RTI-LJ, the decoder shall be capable of operating correctly when fed by any such bitstream and byte delivery schedule.

2.6 Other Applications

Applications other than those described in section 2.5 may use ISO/IEC 13818-9 to specify interoperability constraints on bitstream delivery and bitstream decoders. In such usage, compliance with ISO/IEC 13818-9 *shall* be stated relative to a specified value for t_jitter. For example, a decoder may be called "RTI-compliant for t_jitter equals *x*".

3. Compliance Testing for RTI

3.1 Objectives

The objectives of a testing procedure for this part of ISO/IEC 13818 are the following:

1. Test for compliance with the system clock frequency accuracy specification,
2. Test for compliance with the system clock slew rate specification,
3. Test for compliance with the PCR jitter specification in this part (t_jitter), and
4. Test for compliance with the buffer requirements in this part.

For some Transport Streams, e.g. very short streams or streams with frequent PCR discontinuities, it may be impossible to verify all of these requirements. In streams with many closely spaced PCR discontinuities it is not possible to distinguish between system clock inaccuracy and jitter. Streams need to have a minimum duration of continuous PCRs for accurate determination of system clock frequency error. The duration of continuous PCRs must be sufficient so that the random component of arrival time inaccuracy due to jitter is much smaller than the steadily increasing arrival time inaccuracy caused by system clock frequency error.

3.2 Testing System Clock Frequency Accuracy, System Clock Slew Rate, and PCR Jitter

The compliance test is carried out for one program at a time. The procedure uses a plot of PCR values (which represent the system clock time at which the data was transmitted) against PCR arrival times, as illustrated in Figure 2. The arrival times are plotted on the X axis and represent accurate time at the receiver. The PCR values are plotted on the Y axis.

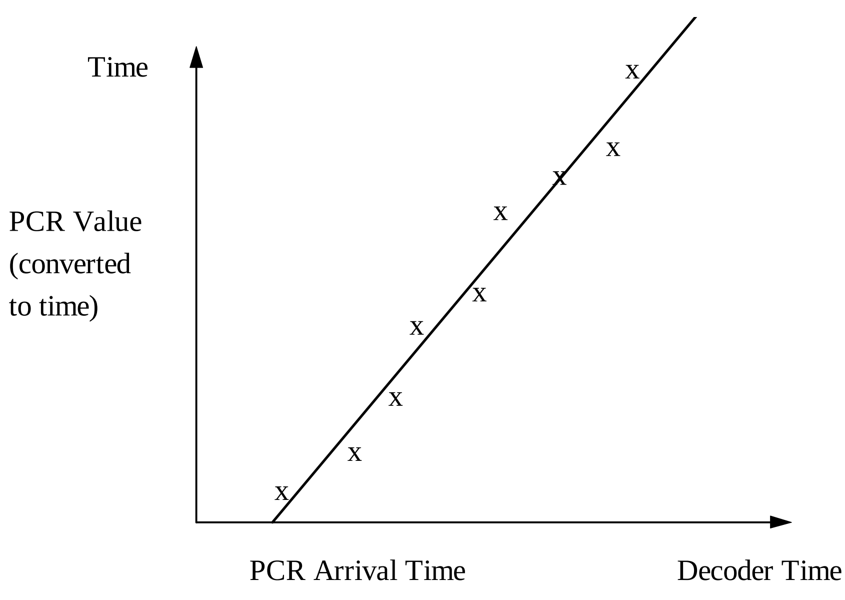

Figure 2 - Plot of PCR values versus Arrival Time

If the PCR values are converted to system clock time values, this plot has the following properties:

- If there is no system clock frequency error and no jitter, the plot will be a straight line with unity slope.

- If there is jitter in the arrival times, the average slope will remain unity but the points will be scattered to the left and right of the best fit unity slope line. The jitter of each arriving value is the horizontal distance between the average line and the plotted point.
- If there is frequency error in the system clock, the slope of the plotted points is no longer unity The frequency error can be determined from the slope of the line (the first derivative).
- If the system clock frequency is changing (slewing), then the plot will no longer be a straight line. The rate of change of the system clock frequency (amount of slew) can be determined from the rate of change of the slope (the second derivative).

In general, there will be system clock frequency error and slew as well as jitter. As noted above, separating these three to the desired level of accuracy may not always be possible, depending on the amount of arrival time jitter and how often PCR discontinuities occur.

The basic procedure is described for one program called P:

1. For each byte that carries the last bit of a PCR field for P, the arrival time of that byte and the value of the corresponding PCR itself are noted. These values are called t(i) and PCR(i), respectively. PCR(i) can be converted to a system clock time value. (In what follows, rollover of the PCR register is ignored.)
2. When all PCR values in the segment of stream to be tested have been noted, their values are plotted against their arrival times.

The stream is compliant if a curve can be drawn such that everywhere its slope is compliant with the system clock frequency accuracy requirement, its second derivative everywhere does not exceed the maximum system clock frequency slew rate, and its horizontal distance to any of the points (t(i), PCR(i)) is not greater than t_jitter/2 in any case.

A stream is compliant whenever such a graph can be found, and a stream is not proven non-compliant until it can be proven that no such graph exists. This can be proven in some cases by for example taking a suspect point (t(i), PCR(i)) and drawing a region which includes all other permissible points in the bitstream. If another point falls outside that region, the stream is non-compliant. A stream shall be assumed to be compliant unless it can be proven to be non-compliant.

3.3 Approximate Tests for System Clock Frequency Accuracy and PCR jitter

In cases which are nearly compliant, finding such a curve, as discussed above, will sometimes prove to be difficult. Presented below are two tests which provide approximate solutions to this problem.

Since the allowed system clock slew is small (10 ppm/hour), and in practice system clock slew is unlikely to be a problem, short sections of Transport Stream data can be tested by ignoring system clock slew, i.e. assuming the system clock frequency is constant.

3.3.1 Diverging Lines Test

The test of permissible points described at the end of Section 3.2 can be approximated by assuming zero slew, and drawing two straight lines.

1. The first starts (t_jitter) to the left of the starting point and has slope corresponding to a system clock running 30 ppm fast.
2. The second starts (t_jitter) to the right of the starting point and has slope corresponding to a system clock running 30 ppm slow.

The increasing width area enclosed by these lines to the right of and above the starting point should contain all subsequent plotted points from the stream under test (until the next PCR discontinuity).

This test can be done on each point plotted, and the full set of tests approximately tests the stream for compliance with system clock frequency accuracy and t_jitter.

3.3.2 Parallel Lines Test

This test of a section of a Transport Stream with continuous PCRs and no system clock slew is also based on the plot of PCR(i) versus t(i) described in Section 3.2.

The stream is compliant if it is possible to find two parallel straight lines, with horizontal separation of (t_jitter), and with slope corresponding to a frequency error of less than 30 ppm, with all the plotted points contained between the lines.

3.4 Buffer Compliance Testing

The buffer compliance test shall be performed exactly as the corresponding test for the T-STD (ISO/IEC 13818-1 section 2.4.2), except for obvious changes due to different arrival times and buffer sizes, as well as the extra requirement for TB_r_n occupancy at the arrival of the first byte of a Transport Stream Packet.