

# PROPOSED SMPTE RECOMMENDED PRACTICE

## Measurement of Jitter in Bit-Serial Digital Interfaces

Table 11 - Summation of VITC and LTC code word bit definitions

VITC BIT NO.	VALUE (DEC/HEX)	SYMBOL ASSOCIATION	85-FIELD TELEVISION	86-FIELD TELEVISION	24-FRAME FLU	VITC BIT NO.
0		VITC SYNC BIT				0
1	0	VITC SYNC BIT				1
2	0	TV FRAME UNITS				2
3	0	TV FRAME UNITS				3
4	0	TV FRAME UNITS				4
5	0	TV FRAME UNITS				5
6	0	FIRST BINARY GROUP				6
7	0	FIRST BINARY GROUP				7
8	0	FIRST BINARY GROUP				8
9	0	FIRST BINARY GROUP				9
10	0	VITC SYNC BIT				10
11	0	VITC SYNC BIT				11
12	0	TV HOURS TENS				12
13	0	TV HOURS TENS				13
14	0	TV HOURS TENS				14
15	0	TV HOURS TENS				15
16	0	FLAG	UNLINED BIT	UNLINED BIT	UNLINED BIT	16
17	0	FLAG	UNLINED BIT	UNLINED BIT	UNLINED BIT	17
18	0	SECOND BINARY GROUP	UNLINED BIT	UNLINED BIT	UNLINED BIT	18
19	0	SECOND BINARY GROUP	UNLINED BIT	UNLINED BIT	UNLINED BIT	19
20	0	SECOND BINARY GROUP	UNLINED BIT	UNLINED BIT	UNLINED BIT	20
21	0	SECOND BINARY GROUP	UNLINED BIT	UNLINED BIT	UNLINED BIT	21
22	0	SECOND BINARY GROUP	UNLINED BIT	UNLINED BIT	UNLINED BIT	22
23	0	VITC SYNC BIT				23
24	0	VITC SYNC BIT				24
25	0	TV SECONDS UNITS				25
26	0	TV SECONDS UNITS				26
27	0	TV SECONDS UNITS				27
28	0	TV SECONDS UNITS				28
29	0	TV SECONDS TENS				29
30	0	TV SECONDS TENS				30
31	0	TV SECONDS TENS				31
32	0	TV SECONDS TENS				32
33	0	TV SECONDS TENS				33
34	0	TV SECONDS TENS				34
35	0	TV SECONDS TENS				35
36	0	TV SECONDS TENS				36
37	0	TV SECONDS TENS				37
38	0	TV SECONDS TENS				38
39	0	TV SECONDS TENS				39
40	0	TV SECONDS TENS				40
41	0	TV SECONDS TENS				41
42	0	TV SECONDS TENS				42
43	0	TV SECONDS TENS				43
44	0	TV SECONDS TENS				44
45	0	TV SECONDS TENS				45
46	0	TV SECONDS TENS				46
47	0	TV SECONDS TENS				47
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49	0	TV SECONDS TENS				49
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68	0	TV SECONDS TENS				68
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70	0	TV SECONDS TENS				70
71	0	TV SECONDS TENS				71
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74	0	TV SECONDS TENS				74
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78	0	TV SECONDS TENS				78
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80	0	TV SECONDS TENS				80
81	0	TV SECONDS TENS				81
82	0	TV SECONDS TENS				82
83	0	TV SECONDS TENS				83
84	0	TV SECONDS TENS				84
85	0	TV SECONDS TENS				85
86	0	TV SECONDS TENS				86
87	0	TV SECONDS TENS				87
88	0	TV SECONDS TENS				88
89	0	TV SECONDS TENS				89
90	0	TV SECONDS TENS				90
91	0	TV SECONDS TENS				91
92	0	TV SECONDS TENS				92
93	0	TV SECONDS TENS				93
94	0	TV SECONDS TENS				94
95	0	TV SECONDS TENS				95
96	0	TV SECONDS TENS				96
97	0	TV SECONDS TENS				97
98	0	TV SECONDS TENS				98
99	0	TV SECONDS TENS				99
100	0	TV SECONDS TENS				100

3.2 Jitter shall be specified with the parameters given in table 1.

### 1 Scope

This practice describes techniques for specifying and measuring output jitter from self-clocking bit-serial digital sources. It is specifically intended for, but not limited to, ANSI/SMPTE 259M serial systems.

### 2 Definitions

**2.1 jitter:** The variation of a digital signal's transitions from their ideal positions in time.

**2.2 timing jitter:** The variation in position of a signal's transitions occurring at a rate greater than a specified frequency, typically 10 Hz or less. Variations occurring below this specified frequency are termed wander and are not addressed by this practice.

**2.3 alignment jitter:** The variation in position of a signal's transitions relative to those of a clock extracted from that signal.

**2.4 unit interval (UI):** Abbreviated UI, it is the period of one clock cycle. It corresponds to the nominal minimum time between transitions of the serial signal.

**2.5 jitter transfer function:** The ratio of the output jitter to the applied input jitter as a function of frequency.

### 3 Jitter specifications

**3.1 Jitter** shall be specified as a peak-to-peak quantity and measured over defined jitter frequency bands. Two measurement bands are specified, one of which is a subset of the other (see figure 1).

Table 1 - Specifications

Data rate	(b/s)	(Serial bit rate)
B1	(Hz)	(timing jitter lower band edge)
B2	(Hz)	(alignment jitter lower band edge)
B3	(Hz)	(upper band edge)
A1	(UI)	(timing jitter)
A2	(UI)	(alignment jitter)
Im	(sec)	(measurement time)
test signal		(test signal used for measurement)
n		(serial clock divider)

**3.2.1 B1 to B3** form the timing jitter measurement bandpass. The maximum peak-to-peak jitter allowed over this bandpass is specified as A1.

**3.2.2 B2 to B3** form the alignment jitter measurement bandpass. The maximum peak-to-peak jitter allowed over this bandpass is specified as A2.

**3.2.3 A1 and A2** shall be specified in unit intervals.

**3.2.4 Bandpass slopes** shall be 20 dB/decade or greater unless otherwise specified. Stop band rejection shall be at least 20 dB. Pass band ripple shall be less than ± 1 dB.

**3.2.5 A measurement time (tm)** may be specified. If this is omitted, the measurement time will be

determined by the characteristics of the measurement system such as discussed in 4.1.2.3).

**3.2.6** The test signal used for the measurement shall be specified.

**3.2.7** The serial clock divider, "n," used in the clock extractor (4.1) should be specified. The ratio of the serial clock frequency to the clock extractor frequency is "n." It is meaningful for clock extractor jitter measurement methods, but may not be applicable to other measurement techniques (see annex B for considerations in choosing "n").

**3.3** Numerical jitter values are provided in the appropriate SMPTE standards which reference this practice. The terminology shall comply with 3.2.

## 4 Measurement methodology

### 4.1 Clock extractor method

**4.1.1** The jitter in a signal output can be measured by using a device to extract clock and then trigger an oscilloscope or other indicating device (see figure 2). The clock extractor shall have the following characteristics:

- 1) It shall be capable of being put in series with the signal output and provide enough signal for the indicating device. It shall not modify the output signal characteristics in ways that obscure or modify the jitter on the signal.
- 2) To measure timing jitter (A1 in 3.2), the clock extractor shall have a clock recovery bandwidth of B1 (see 3.2). To measure alignment jitter (A2 in 3.2), the clock extractor shall have a clock recovery bandwidth of B2 (see 3.2). (See figure 3.)
- 3) The jitter transfer function of the clock extractor shall roll-off at 20 dB/decade or greater, unless otherwise specified. Ripple within the pass band shall be less than  $\pm 1$  dB (see figure 3).
- 4) The extracted clock frequency shall be the serial clock frequency divided by "n," where "n" is defined in 3.2.7.

**4.1.2** The indicating device used to observe the jitter shall have the following characteristics:

- 1) The horizontal and/or trigger bandwidth of the indicating device shall not attenuate the observed jitter. The trigger bandwidth shall be at least B2.
- 2) The indicating device shall not create intersymbol interference at the zero-crossing point. This requires a vertical system risetime of less than 1 UI.
- 3) The indicating device shall acquire sufficient samples so that peak-to-peak jitter can be determined. This requires sampling until the shape of the jitter distribution is known. The minimum acquisition time shall be the measurement time of 3.2.5, if it is specified. The maximum acquisition time will depend on the device sample rate and the type of jitter distribution; for example, a sinusoidal distribution will typically be determined with fewer samples than will a gaussian-like distribution.
- 4) If the indicating device is an oscilloscope, the jitter measurement is usually made at the eye crossing. A digital storage oscilloscope with infinite persistence is recommended.

**4.1.3** Alignment jitter is measured by connecting the equipment as shown in figure 2. The clock extractor is set to bandwidth B2. The indicating device is triggered by the extracted clock and the jitter observed.

**4.1.4** Timing jitter is measured by connecting the equipment as shown in figure 2. The clock extractor is set to bandwidth B1. The indicating device is triggered by the extracted clock and the jitter observed.

**4.1.5** A block diagram of the clock extractor appears in figure 4.

### 4.2 Other methods

**4.2.1** It is not the intent of this practice to exclude other measurement methods, such as demodulator techniques. They may, however, yield different results than the clock extractor approach. This practice assumes that the clock extractor of 4.1 is used. If another method is used, it shall be specified and shown to be equivalent.

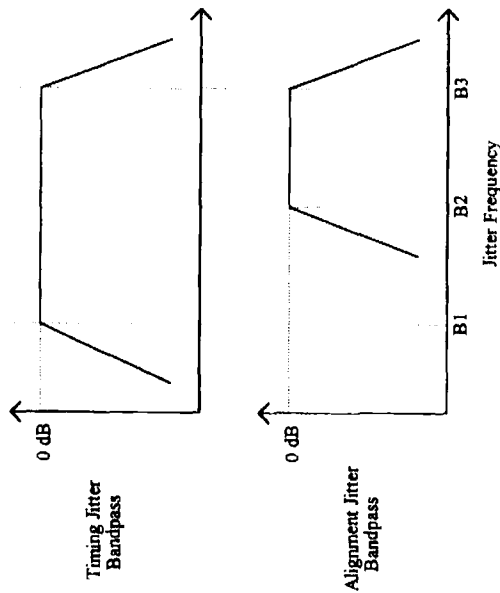


Figure 1 - Jitter measurement bandpasses

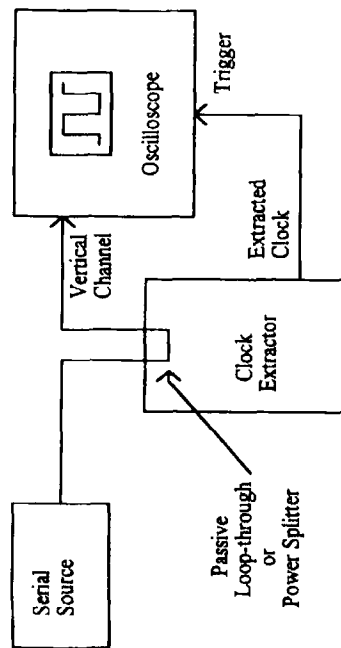


Figure 2 - Jitter measurement using a clock extractor

**Annex A (informative)**  
**Frequency dependent jitter specification**

This practice specifies jitter as a function of frequency. This is because low and high frequency jitter have very different effects on a receiver system. Jitter frequencies that are beyond the receiver clock recovery bandwidth will not be transferred to the recovered clock, and the recovered clock to data timing margin is degraded. Within this frequency band incoming signal jitter must be substantially less than 1 UI p-p to avoid data recovery errors (the exact value depends on recovered clock static phase error and post-equalization vertical eye opening). On the other hand, the recovered clock will accurately track incoming signal jitter when the jitter frequency is well within the clock recovery bandwidth. Typically many unit intervals of low frequency jitter can be tolerated by a receiver without causing data

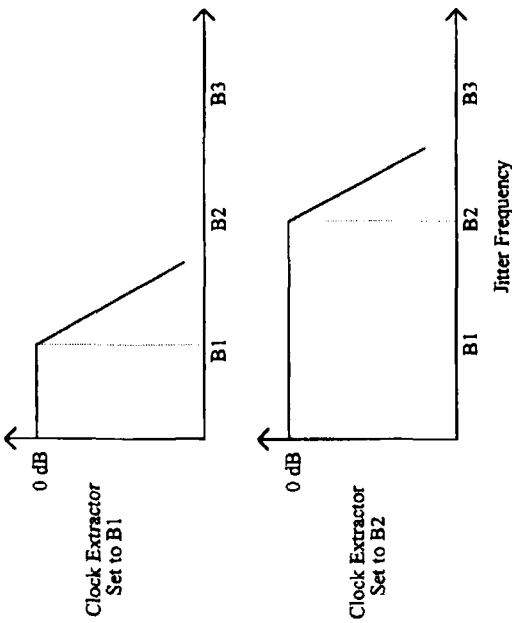


Figure 3 - Clock extractor jitter transfer function

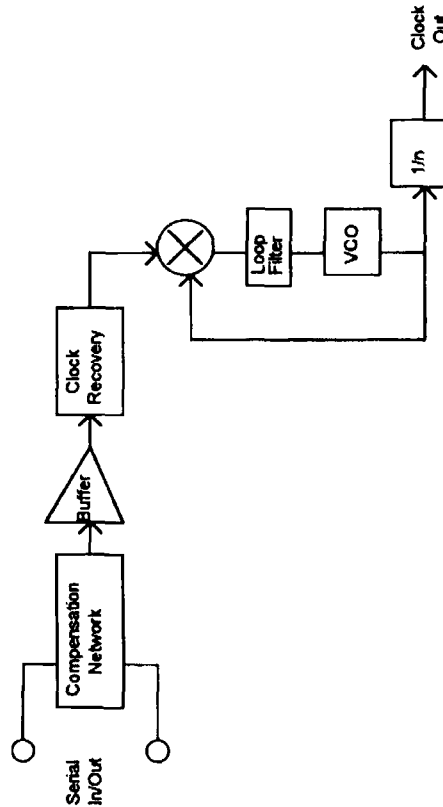


Figure 4 - Block diagram - clock extractor

errors. Clearly, the jitter spectrum must be considered to determine whether a given magnitude of jitter will cause data recovery errors.

The specification method "weights" the jitter by two separate bandpasses: one wide, extending from low frequency to high frequency (B1 to B3), and one narrower, extending from medium frequency to high frequency (B2 to B3). With proper choice of B2 and B3, this second bandpass can estimate whether an "unknown" jitter will cause a given receiver to fail. The wide bandpass (B1 to B3) is useful for estimating "total" jitter that may be of concern at multiplexing locations or where very stable clocks need to be recovered (such as for clocking D/A converters).

**Annex B (informative)**  
**Considerations in choosing "n," the serial clock divider**

The serial clock divider "n," used in the clock extractor can affect the measurement results. Values of "n" that are equal to the number of bits per word will cause any word-related periodic jitter to be correlated. Jitter values may vary between adjacent zero crossings, repeating at the word rate. Values of "n" which produce a remainder of 1, when divided by the number of bits per word will uncorrelate any word-related periodic jitter, providing a peak value of jitter at all zero crossings. For 10-bit word systems, "n" values of 9 and 11 are examples. For general jitter measurements, these ratios are preferred.

Often the most practical choice for "n" will be equal to the number of bits per word. This is because deserializer blocks often output word-rate clocks. This will correlate word-rate jitter. Although most systems will have some word-correlated jitter, the amount may be small compared to the jitter limit to which the system is being measured. In such situations, the simpler "n=10" (for 10-bit systems) clock extractor is appropriate.

**Annex C (informative)**  
**Measuring timing jitter greater than 1 UI**

Timing jitter greater than 1 UI p-p can be measured as follows. The clock extractor requires simultaneous outputs at bandwidths B1 and B2. Apply one clock to the oscilloscope trigger and the second to the vertical (see figure C-1). Up to "n" unit intervals can be measured, where "n" is the serial clock divider defined in 3.2.7.

This technique only measures the jitter in the B1 to B2 bandpass, while timing jitter is defined over B1 to B3. But since the alignment jitter (A2) is typically specified at a small fraction of a unit interval, the error caused by removing the B2 to B3 frequency band is small when timing jitter (A1) exceeds 1 UI.

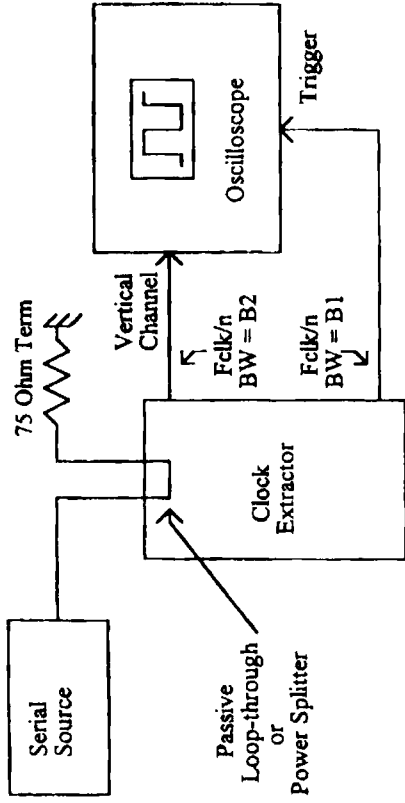


Figure C.1 – Measuring timing jitter greater than 1 UI

**Annex D (informative)**  
**Bibliography**

ANSI/SMPTE 259M-1993, Television — 10-Bit 4:2:2 Component and 4/4s NTSC Composite Digital Signals — Serial Digital Interface