

# CAUI-4 Ad hoc

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# Agenda

- Patent Policy: The meeting is an official IEEE ad hoc. Please review the patent policy at the following site prior to the meeting. <http://www.ieee802.org/3/patent.html>
- Approval of Minutes from Aug 6 meeting
- TBD for CAUI-4 chip-to-chip
  - Transmit Equalizer
    - Ghiasi\_01\_081313\_cau
    - Moore\_01\_081313\_cau
  - COM
    - Reference receiver (ran\_01\_081313)

# Transmit equalizer

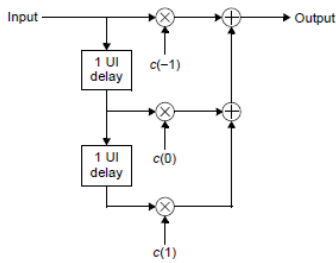


Table 83D-1—CAUI-4 transmitter characteristics at 1PUa

Parameter	Subclause Reference	Value	Units
Signaling rate per lane (range)	83E.3.1.1	25.78125 ± 100 ppm	Gbd
Differential peak-to-peak output voltage (max) Transmitter disabled Transmitter enabled	83D.3.1.1	< 30 1200	mV
Common-mode voltage (max)	83D.3.1.1	1.9	V
Common-mode voltage (min)	83D.3.1.1	0	V
Common-mode AC output voltage (max, RMS)	83D.3.1.1	12	mV
Differential output return loss (min)	83D.3.1.2	Equation (83D-2)	dB
Common-mode output return loss (min)	83D.3.1.2	Equation (83D-3)	dB
Transition time (min, 20% to 80%)	83D.3.1.3	8	ps
Output Jitter (max) Random jitter Deterministic jitter Total jitter	83D.3.1.4	< 0.15 0.15 0.28	UI
Transmitter eye mask definition X1	83D.3.1.5	0.14	UI
Transmitter eye mask definition X2	83D.3.1.5	0.4	UI
Transmitter eye mask definition Y1	83D.3.1.5	200	mV
Transmitter eye mask definition Y2	83D.3.1.5	600	mV
Minimum de-emphasis <sup>2</sup> Post Cursor Pre Cursor	83D.3.1.6	< TBD TBD	dB

<sup>2</sup>Independent of optimal setting used for transmitter jitter and output waveform measurements

**Minimum transmit equalizer range:  
Change TBD to tables shown on right**

- **Transmitter equalizer range**
- The CAUI-4 chip-to-chip transmitter includes programmable equalization to compensate for the frequency-dependent loss of the channel and to facilitate data recovery at the receiver. The functional model for the transmit equalizer is the three tap transversal filter shown in TBD. The minimum pre cursor equalization (c(-1)) supported is shown in table TBD.

Pre Cursor Equalizer Setting	Pre Cursor Equalization Value
1	0dB +/- 1dB
2	1.5dB +/- 1dB
3	3dB +/- 1dB

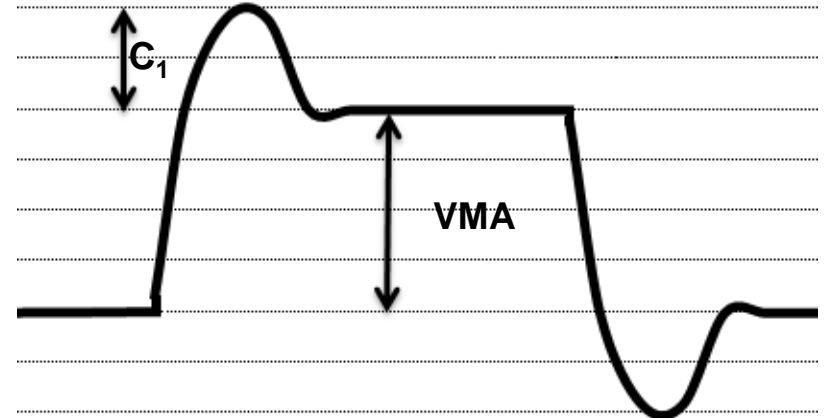
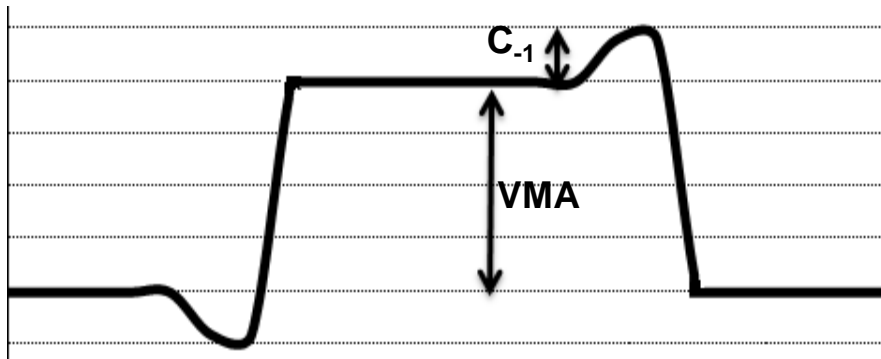
- The minimum post cursor equalization (c(1)) support is shown in table TBD

Post Cursor Equalizer Setting	Post Cursor Equalization Value
1	0dB +/- 1dB
2	2dB +/- 1dB
3	4dB +/- 1dB
4	6dB +/- 1dB

- The transmitter output equalization is characterized using the procedure described in TBD.

# Transmit equalization characterization

- Measure VMA per 86A.5.3.5 using square wave or PRBS9 defined in 86-11 using a test system with a fourth-order Bessel-Thomson low-pass response with 33 GHz 3 dB bandwidth
- Set post cursor equalization to zero setting. Measure pre-cursor amplitude defined as the peak amplitude before a transition. Define  $C_0$ ,  $C_{-1}$  as normalized main tap, and pre cursor values per equations A and B. Calculate pre cursor value for each precursor setting using equation C
- Set pre cursor equalization to zero setting. Measure post-cursor amplitude defined as the peak amplitude after a transition. Define  $C_0$ ,  $C_1$  as normalized main tap, and post cursor values per equations D and E. Calculate post cursor value for each precursor setting using equation F



Equation A  $|C_0| + |C_{-1}| = 1$

Equation B  $VMA = (|C_0| - |C_{-1}|) \times Amplitude_{p-p}$

Equation C  $Preursor\_value(C_{-1}) = 20 * LOG_{10} \left( \frac{1}{C_0 - C_{-1}} \right)$

Equation D  $|C_0| + |C_1| = 1$

Equation E  $VMA = (|C_0| - |C_1|) \times Amplitude_{p-p}$

Equation F  $Postcursor\_value(C_1) = 20 * LOG_{10} \left( \frac{1}{C_0 - C_1} \right)$

# Transmit wave form

Table 83D-1—CAUI-4 transmitter characteristics at 1P0a

Parameter	Subclause Reference	Value	Units
Signaling rate per lane (range)	83E.3.1.1	$25.78125 \pm 100$ ppm	GBd
Differential peak-to-peak output voltage (max) (Transmitter disabled) (Transmitter enabled)	83D.3.1.1	< 30 1200	mV
Common-mode voltage (max)	83D.3.1.1	1.9	V
Common-mode voltage (min)	83D.3.1.1	0	V
Common-mode AC output voltage (max, RMS)	83D.3.1.1	12	mV
Differential output return loss (min)	83D.3.1.2	Equation (83D-2)	dB
Common-mode output return loss (min)	83D.3.1.2	Equation (83D-3)	dB
Transition time (min, 20% to 80%)	83D.3.1.3	8	ps
Output Jitter (max) (Random jitter) (Deterministic jitter) (Total jitter)	83D.3.1.4	< 0.15 0.15 0.28	UI
Transmitter eye mask definition X1	83D.3.1.5	0.14	UI
Transmitter eye mask definition X2	83D.3.1.5	0.4	UI
Transmitter eye mask definition Y1	83D.3.1.5	200	mV
Transmitter eye mask definition Y2	83D.3.1.5	600	mV
Minimum de-emphasis <sup>2</sup> (Post Cursor) (Pre Cursor)	83D.3.1.6	< TBD TBD	dB

<sup>2</sup>Independent of optimal setting used for transmitter jitter and output waveform measurements

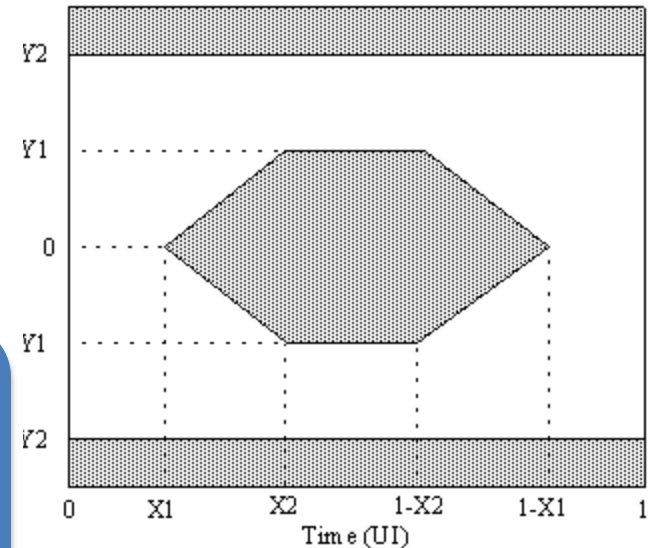


Figure 83D-7—Transmitter eye mask

# Measurement of Transmit Jitter

## Transmitter output jitter

- The components of the transmitter output jitter is defined in this subclause: total jitter (TJ), deterministic jitter (DJ), and random jitter (RJ).
- Transmitter output is measured at TP0a as defined in . All co-propagating and counter propagating CAUI-4 lanes are active during transmitter output jitter testing. Counter propagating lanes have a target differential peak-to-peak amplitude of 800 mV and transition time of 8 ps. All counter-propagating signals shall be asynchronous to the co-propagating signals using pattern 5 (with or without FEC encoding) pattern 3 or a valid 100GBASE-R signal. For the case of pattern 3, with at least 31 UI delay between the PRBS31 patterns on one lane and any other lane.
- The effect of a single-pole high-pass filter with 3 dB frequency of 10 MHz is applied to the jitter. The test pattern for jitter measurements is PRBS31. The voltage threshold for the measurement of BER or crossing times is the mid-point (0 V) of the AC-coupled differential signal.

## Total jitter

- The total jitter (TJ) of a signal is defined as the range (the difference between the lowest and highest values) of sampling times around the signal transitions for which the BER at these sampling times is greater than or equal to  $10^{-15}$ .
- Total jitter for a CAUI-4 chip-to-chip transmitter is than or equal to 0.28 UI and is measured with optimal transmit equalizer setting.

## Deterministic and random jitter

- The random jitter (RJ) of a signal is defined to be the difference between the TJ and DJ. DJ is derived from measured jitter distribution as follows
  - Measure the jitter  $J_n$  which is defined to be the interval that includes all but  $10^{-n}$  of the jitter distribution. If measured by plotting BER vs. decision time, it is the time interval between the two points with BER of  $10^{-n}/4$ . Measure two values:  $J_9$  and  $J_5$
  - For each  $J_n$  determine the associated  $Q_n$  from the inverse normal cumulative probability distribution adjusted for an assumed transition density of 0.5.  $Q_9$  is 5.998 and  $Q_5$  is 4.265
  - Calculate the effective DJ as shown in
- Deterministic jitter is less than or equal to 0.15 UI. Random jitter is less than or equal to 0.15 UI.

# Measurement Methodology for Eye Mask – Leverage 83E

## Transmitter output waveform

- The eye mask shown in is defined at a BER of  $10^{-15}$ , using the methodology described in TBD. Transmitter equalizer may be adjusted for optimum mask results.

## TBD section:

- Transmit output waveform in CAUI-4 chip-to-chip are measured using a fourth-order Bessel-Thomson low-pass filter response with 33 GHz 3 dB bandwidth. X1 is measured using the methodology described in 83D.3.1.4 where  $X1 = T/2$ . Y2 is measured using the methodology described in 83D.3.1.1. Y1 is measured using the following procedure using a PRBS9 waveform:
  - Capture the PRBS9 pattern using a clock recovery unit with 3 dB tracking bandwidth of 10 MHz and maximum peaking of 0.1 dB and a minimum sampling rate of 3 samples per bit. Collect sufficient samples equivalent to at least 4 million bits to allow for construction of a normalized cumulative distribution function (CDF) to a probability of  $10^{-6}$  without extrapolation.
  - Use the differential signal from step 1 to construct the CDF of the signal amplitude at X2, midpoint (0.5) and 1-X2, for both logic 1 (CDF1) and logic 0 (CDF0), as a distance from the center of the eye. Calculate the eye height for each point (EH6) as the difference in amplitude between CDF1 and CDF0 with a value of  $10^{-6}$ . CDF0 and CDF1 are calculated as the cumulative sum of histograms of the amplitude at the top and bottom of the eye normalized by the total number of sampled bits. For a well balanced number of ones and zeros the maximum value for CDF0 and CDF1 will be 0.5.
  - Apply the Dual-Dirac and tail fitting techniques to CDF1 and CDF0 to estimate the noise at X2, 0.5 and 1-X2 points. Calculate the best linear fit in Q-scale over the range of probabilities of  $10^{-4}$  and  $10^{-6}$  of CDF1 and CDF0 to yield relative noise one (RN1) and relative noise zero (RN0). The eye height for plotting against the eye mask at X2, 0.5, and 1-X2 is then given by
  - $EH15 = EH6 - 3.19 \times (RN0 + RN)$
- where
  - *EH15 peak is the eye height extrapolated to  $10^{-15}$  probability*
  - *EH6 is the eye height at  $10^{-6}$  probability*
  - *RN1 is the RMS value of the noise estimated from CDF1*
  - *RN0 is the RMS value of the noise estimated from CDF0*