How to Build Signal Eye Diagram

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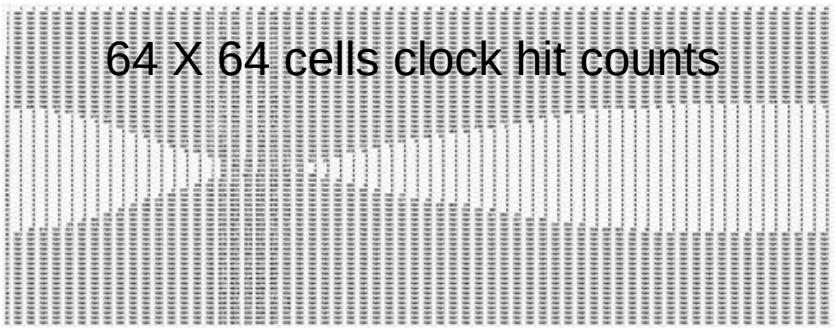
Eye Opening Monitor (EOM) description

- The LMH12XX on-chip Eye Opening Monitor (EOM) is used to analyze and diagnose the post-equalized waveform which is sampled in the phase and voltage domain across one unit interval
- The phase and voltage range is divided into 64 steps each. This results in an eye capture of 64 × 64 cells, with each cell specifying voltage and phase which indicates the number of hits relative to the main reference incoming eye diagram
- The number of hits registered at each point should be taken in context with the total number of bits observed at that voltage and phase offset to determine the corresponding probability for that point.



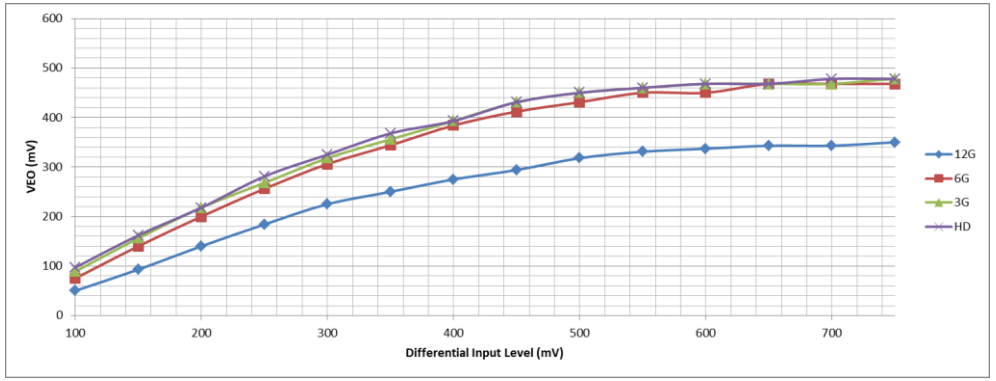
Eye-opening numerical representation: HEO / VEO

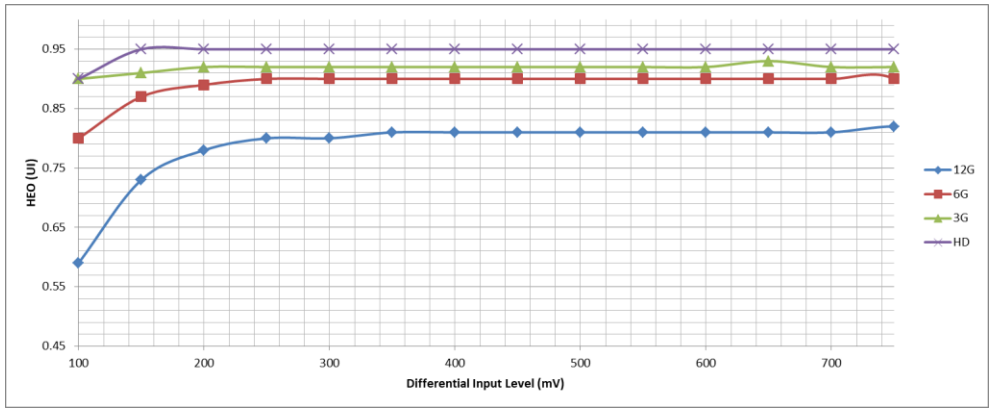
- **Horizontal Eye Opening (HEO):**
  - The value reported by LMH12xx should be converted to a decimal and then divided by 64.
    For example, If HEO is 0 x 20 or 32 decimal, therefore, we have 32/64 = 0.5 UI eye opening
- **Vertical Eye Opening (VEO):**
  - The value should be multiplied by 3.125 mV
    For example, if VEO is 0 x 40 or 64 d; therefore, 64 d * 3.125 = 200 mV VEO

HEO / VEO parameters are a good indication of incoming signal eye quality

LMH1297 VEO vs. actual differential input level

- Key take away:
  - VEO is more linear at lower input voltage swing
  - VEO is a figure of merits
  - HEO/VEO is higher for lower rates
  - Jitter tolerance is 0.6 to 0.55UI:
    - Error Free operation: HEO>0.45



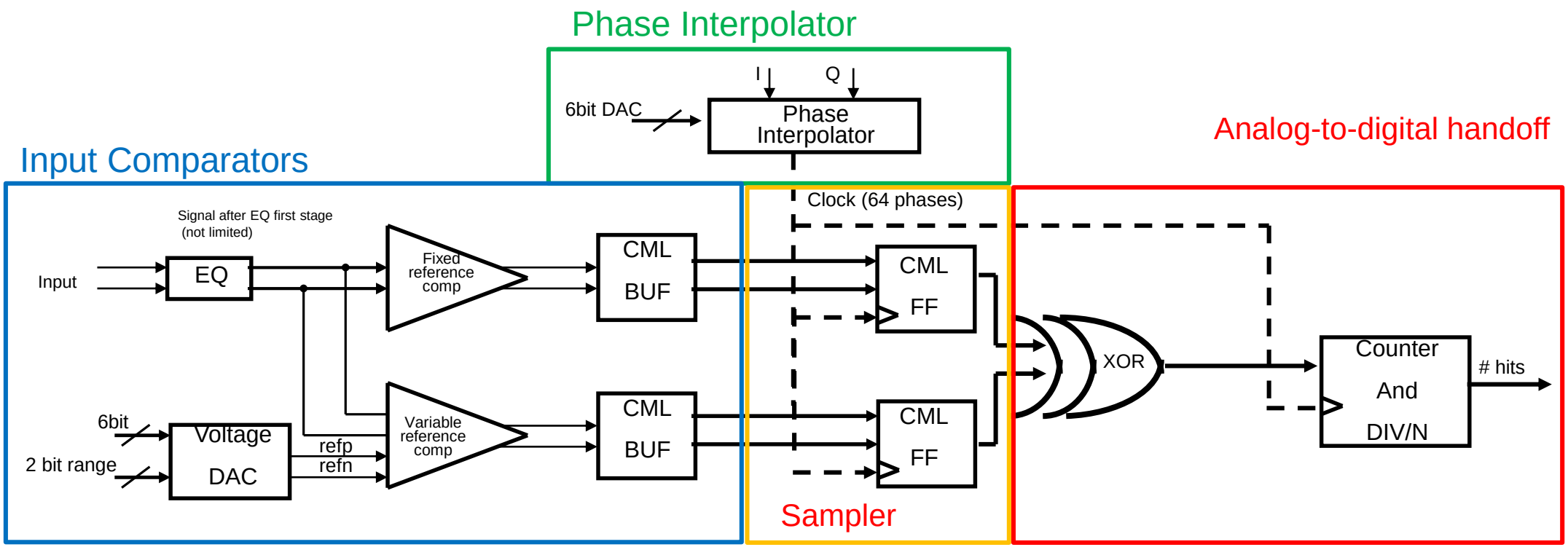


BERT -> LMH1297EVM IN0 Manual CTLE = 0x00

Error free operation when VEO > 150 mV AND HEO > 0.45 UI

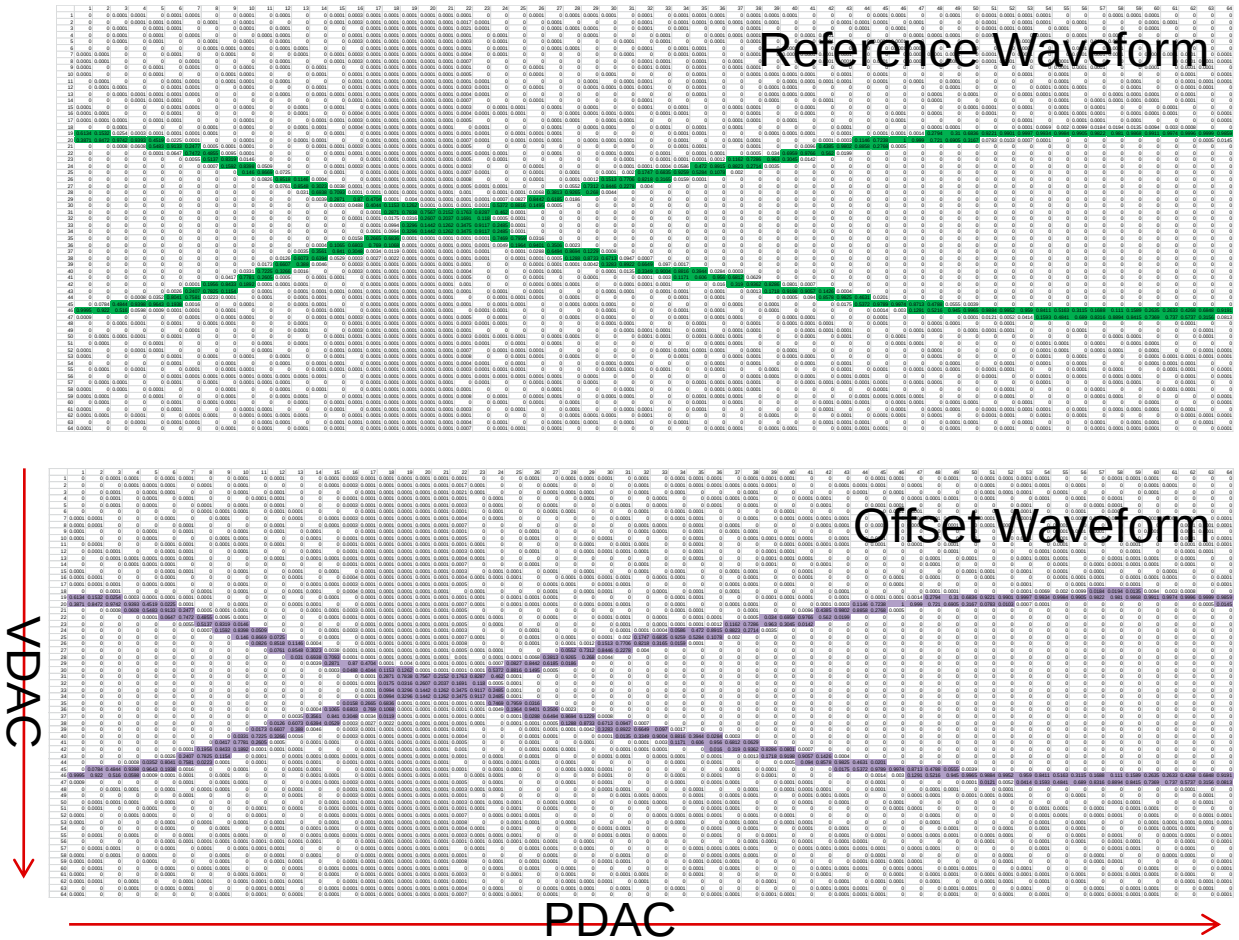
Detailed Block Diagram

- DAC controlled offset for variable comparator (**VDAC**)
- Comparison with fixed comparator (offset = 0) determines voltage level
- Variable and fixed comparators are sampled and compared
- Sweeping phase of sampling point using Phase interpolator (**PDAC**) determines zero crossing
- XOR is sampled and divided down for handoff to digital
- N full-rate “hits” overflow output counter and send digital toggle

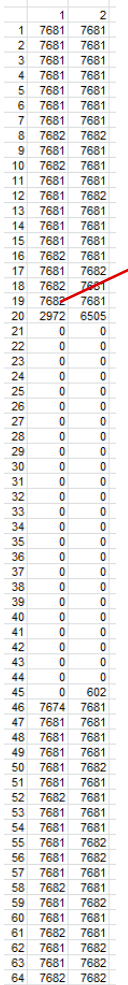


How eye-opening capture works

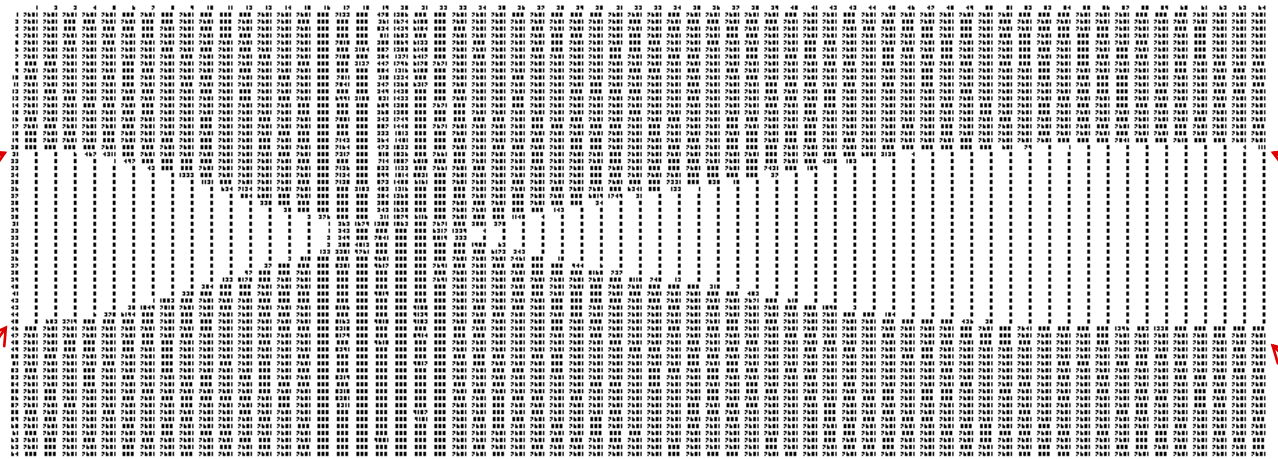
1) Offset waveform PDAC is held constant while VDAC is swept from lowest to highest value
2) Next PDAC is increased by one step and again VDAC is swept across its range
3) This continues until 64 X 64 (or 4096) cells are recorded.
4) Number of hits where two waveforms are overlapped are counted as hits

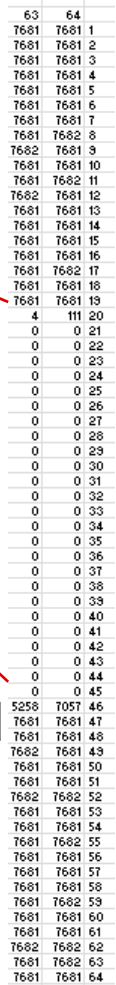


Clock pattern fast eye data stream format



	1	2
1	7681	7681
2	7681	7681
3	7681	7681
4	7681	7681
5	7681	7681
6	7681	7681
7	7681	7681
8	7682	7682
9	7681	7681
10	7682	7681
11	7681	7681
12	7681	7682
13	7681	7681
14	7681	7681
15	7681	7681
16	7682	7681
17	7681	7682
18	7682	7681
19	7682	7681
20	2972	6505
21	0	0
22	0	0
23	0	0
24	0	0
25	0	0
26	0	0
27	0	0
28	0	0
29	0	0
30	0	0
31	0	0
32	0	0
33	0	0
34	0	0
35	0	0
36	0	0
37	0	0
38	0	0
39	0	0
40	0	0
41	0	0
42	0	0
43	0	0
44	0	0
45	0	602
46	7674	7681
47	7681	7681
48	7681	7681
49	7681	7681
50	7681	7682
51	7681	7681
52	7682	7681
53	7681	7681
54	7681	7681
55	7681	7682
56	7681	7682
57	7681	7681
58	7682	7681
59	7681	7682
60	7681	7681
61	7682	7681
62	7681	7682
63	7681	7682
64	7682	7682



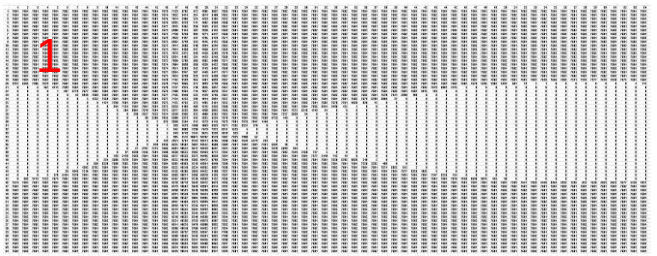


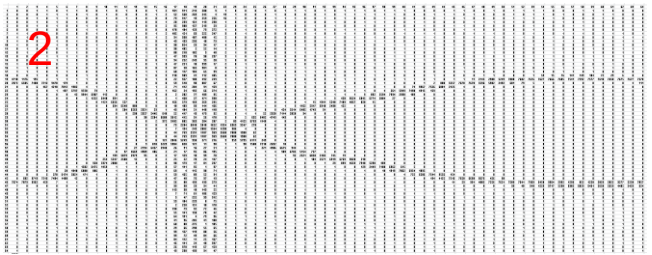
63	64	
7681	7681	1
7681	7681	2
7681	7681	3
7681	7681	4
7681	7681	5
7681	7681	6
7681	7681	7
7681	7682	8
7682	7681	9
7681	7681	10
7681	7682	11
7682	7681	12
7681	7681	13
7681	7681	14
7681	7681	15
7681	7681	16
7681	7682	17
7681	7681	18
7681	7681	19
4	111	20
0	0	21
0	0	22
0	0	23
0	0	24
0	0	25
0	0	26
0	0	27
0	0	28
0	0	29
0	0	30
0	0	31
0	0	32
0	0	33
0	0	34
0	0	35
0	0	36
0	0	37
0	0	38
0	0	39
0	0	40
0	0	41
0	0	42
0	0	43
0	0	44
0	0	45
5258	7057	46
7681	7681	47
7681	7681	48
7682	7681	49
7681	7681	50
7681	7681	51
7682	7682	52
7681	7681	53
7681	7681	54
7681	7682	55
7681	7681	56
7681	7681	57
7681	7681	58
7681	7682	59
7681	7681	60
7681	7681	61
7682	7682	62
7681	7682	63
7681	7681	64

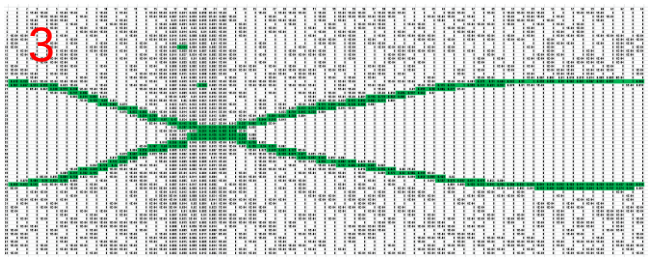
1. 64 X 64 Cells Hit Counts Streamed Raw Data:
    1. 1UI of data
    2. Based on device, it could be from eye crossing to eye crossing or within eye
2. 64 Cells of column on left is streamed out first – top to bottom – followed by second column – top to bottom – until we go through 64 columns
3. Maximum hit count is about 7681. If we don't get maximum hits:
    1. There is no eye crossing
    2. Or range register setting is too low

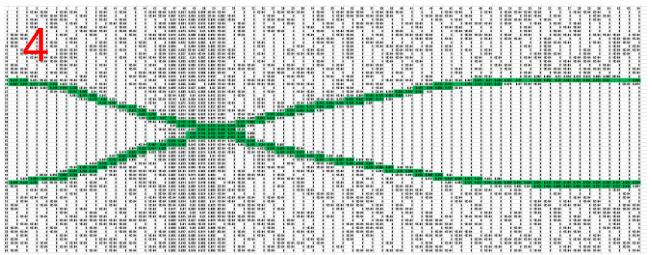
12G 1010.. Clock pattern fast EOM data

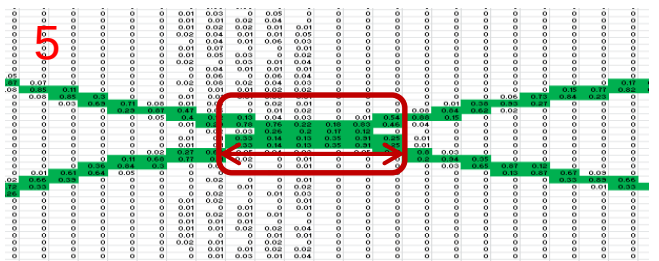
1. Raw 64 X 64 EOM raw data
2. Hit count subtracted from next vertical cell
3. Normalized by maximum hit count
4. Cleanup hits due to limited sampling rate
5. HEO Calculation:
    1. Jitter = 6 columns = 6/64 ~ 0.1
    2. HEO = 1 – 0.1 = 0.9UI
6. VEO Calculation:
    1. VEO = 28 Rows X 12.5mV = 350mV
        1. Vrange reg 0x11 = 12.5mV per step

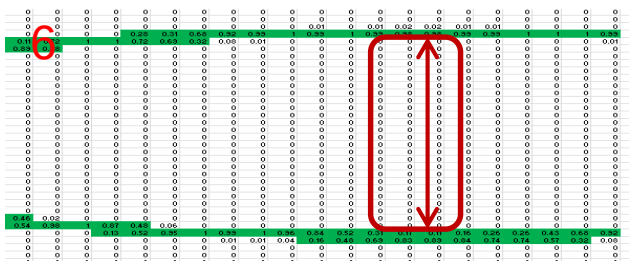








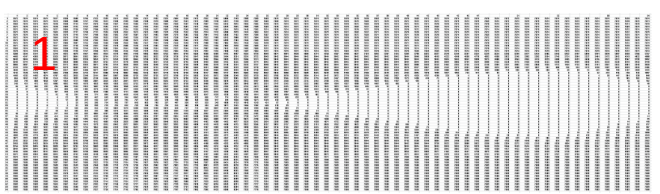


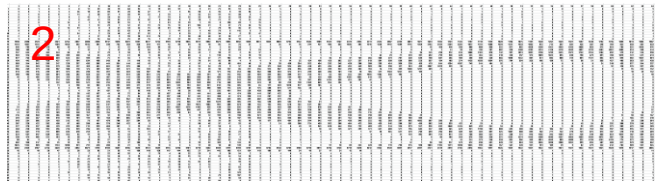


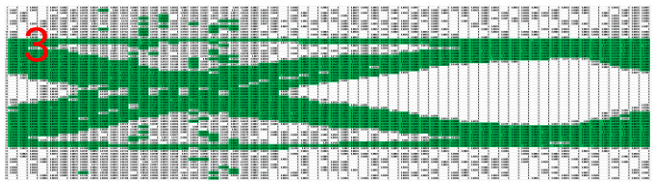
Setup: BERT -> LMH1228EVM -> 3m B1694A -> LMH1219EVM

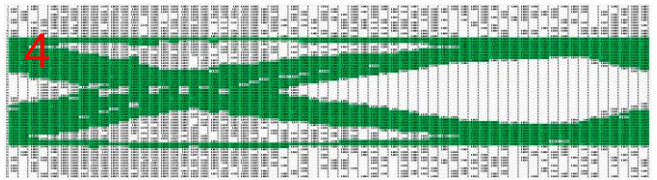
12G PRBS10 50m B1694A pattern fast EOM data

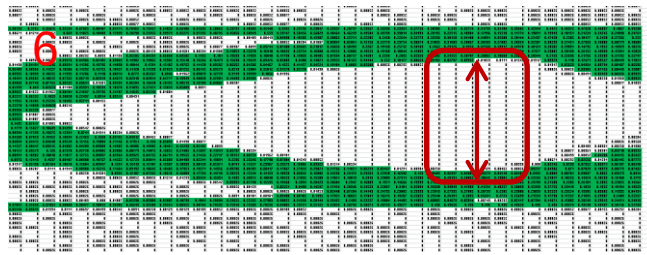
1. Raw 64 X 64 EOM raw data
2. Hit count subtracted from next cell
3. Normalized by maximum hit count
4. Processed hits - due to limited sampling rate
5. HEO Calculation:
    1. Jitter = 22 columns = 22/64 = 0.0.35
    2. HEO = 1 – 0.35 = 0.65UI
6. VEO Calculation:
    1. VEO = 25 Rows X 12.5mV = 312mV
        1. Vrange reg 0x11 = 12.5mV per step











Setup: BERT -> LMH1228EVM -> 50m B1694A -> LMH1219EVM

Eye Diagram Hit Count Processing

- For visual observation, hit count can be normalized and scaled
- Reg 0x2A content indicates length of time to capture hit counts per cell
  - Hit count duration per cell = 256*reg 1218. 0x2A(decimal)*(32/data rate)
  - Example: 11.88Gbps, reg 0x2A = 0x30 = 48 Decimal
    - Hit counts duration per cell = 256*48*(32/11.88E9)=33uS
    - Total time to capture 64X64 = 4096 cells = 4096*33uS = 135mS

Summary

- On-chip Eye Opening Monitor (EOM) is used to analyze and diagnose the post-equalized waveform and this is used as a guideline for analyzing signal integrity during development or remote diagnostics
- EOM Capture can be used while user data is going through the device
- HEO/VEO can be optioned to cause interrupt when certain a threshold is reached
- Please refer to the programming guide for detailed HEO / VEO and Eye Opening Monitor detailed register settings