Dual use driver for high speed links transmitters in the future high energy physics experiments

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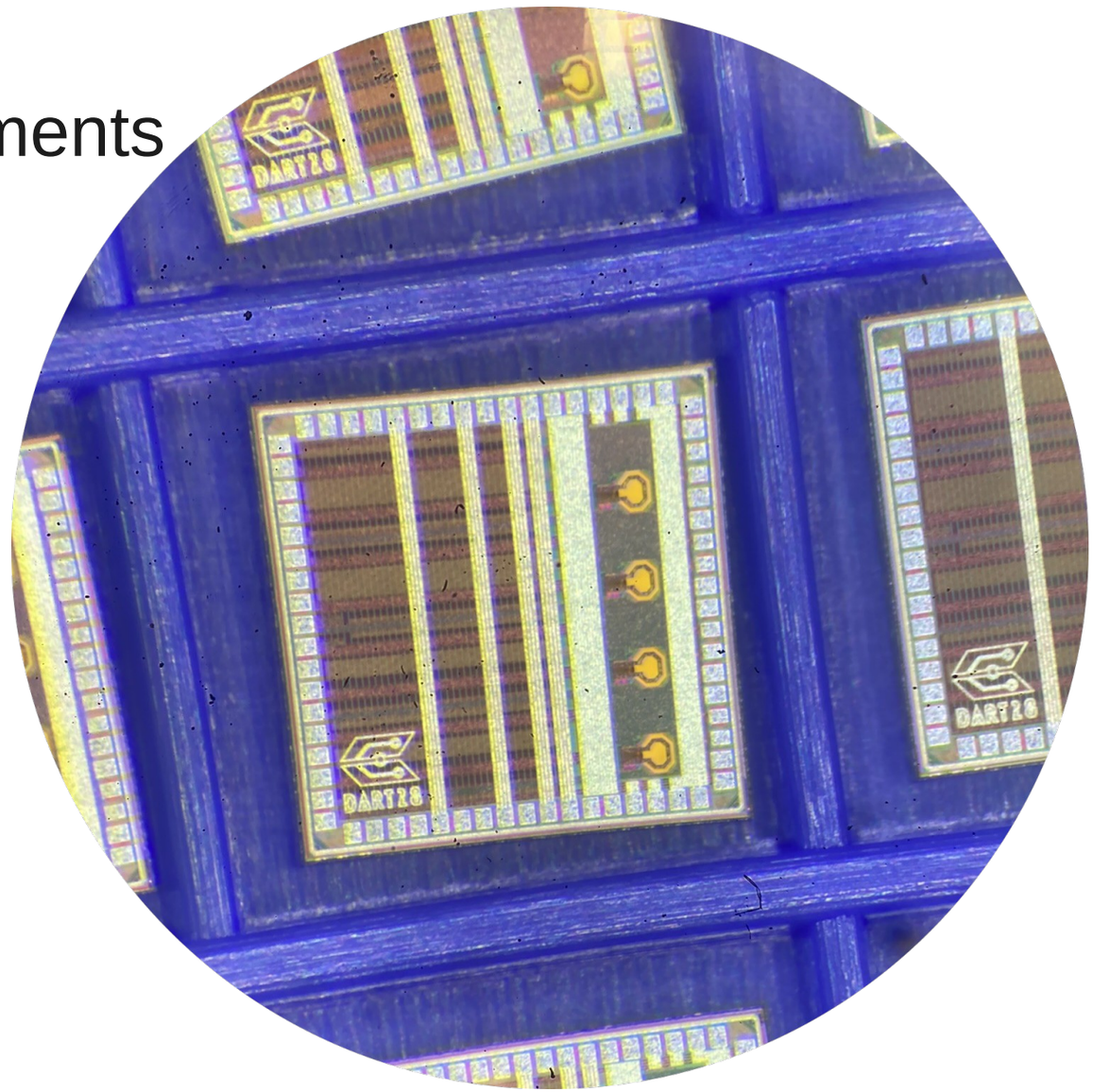
Outline

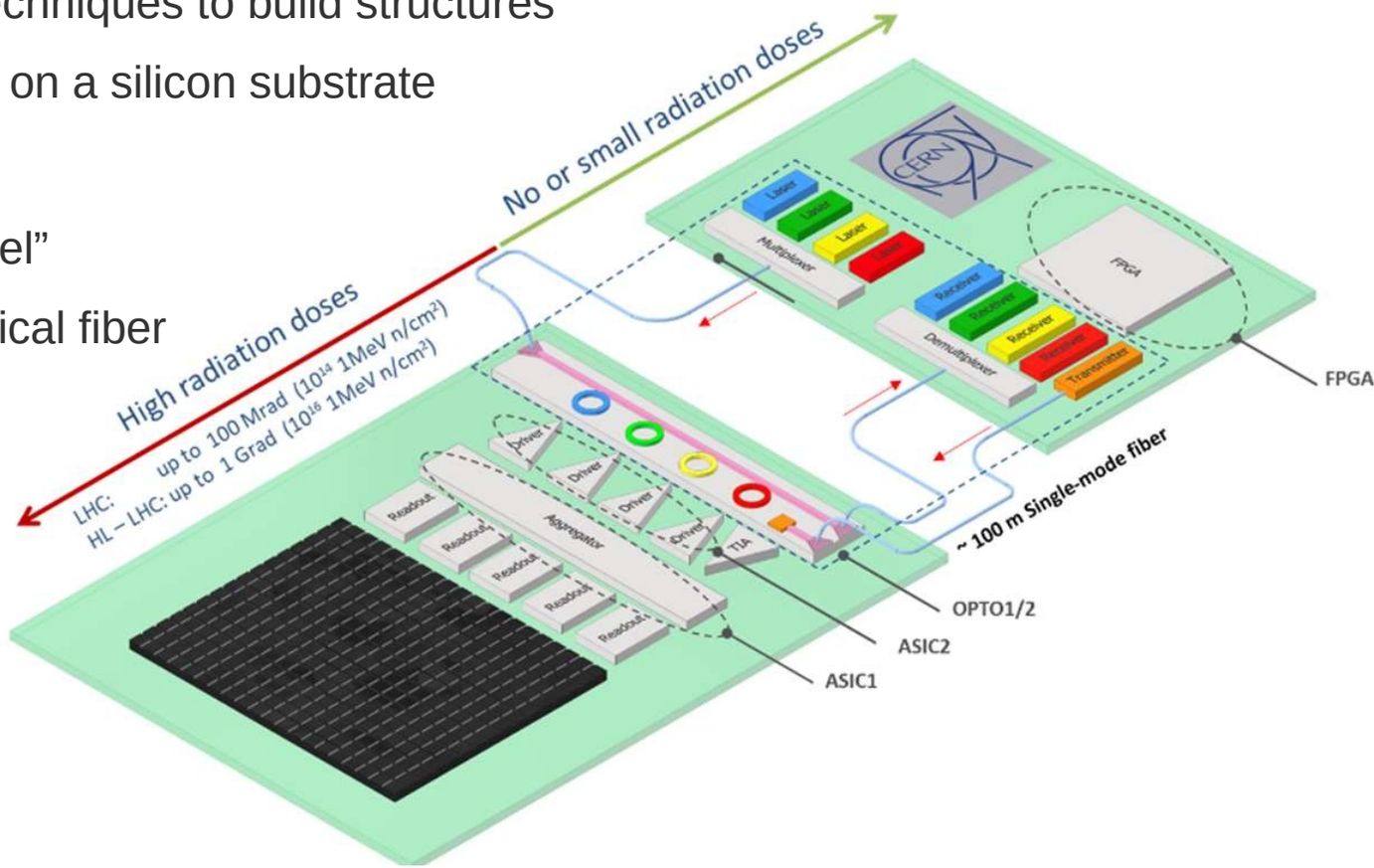
1. Strategic R&D Programme on Technologies for Future Experiments
2. DART28 ASIC
3. Dual Use Driver
   a) Architecture
   b) Output unit cell
   c) Modes of operation
      1) Full swing
      2) Reduced swing
      3) Transmission line
      4) Pre-emphasis



Future HEP Link Architecture

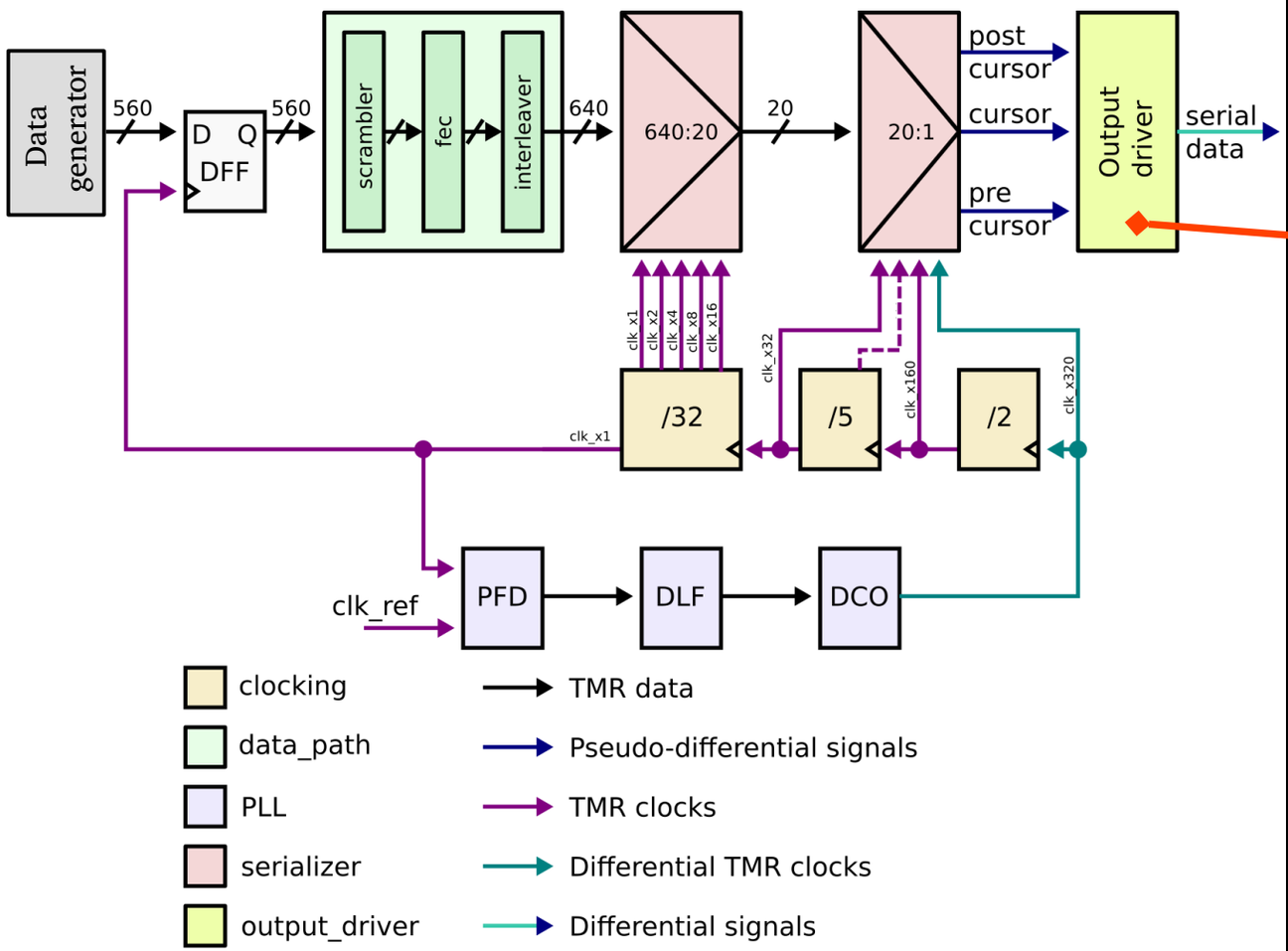
Strategic R&D Programme on Technologies for Future Experiments – WP6 High Speed Links (HSL)

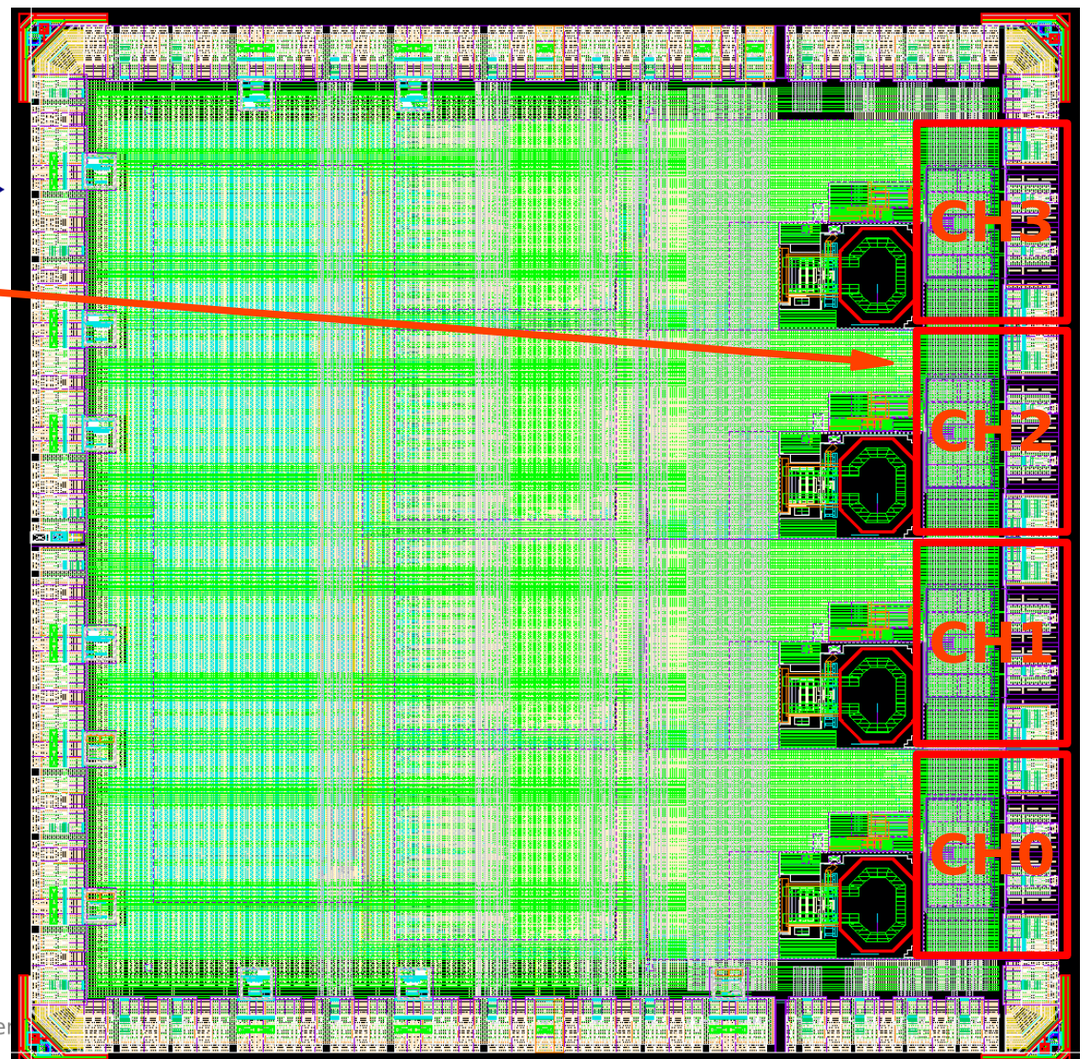
- More advanced CMOS ASIC processes
  - ➔ 28 nm CMOS
- Silicon Photonics
  - ➔ Using standard CMOS ASIC production techniques to build structures that manipulate light in optical waveguides on a silicon substrate
- Wavelength-Division Multiplexing (WDM)
  - ➔ using several wavelengths to send “parallel” data-streams down the same physical optical fiber
  - ➔ rates:
    - Lane: 25 Gbps NRZ / 50 Gbps PAM4
    - Fiber: 100 Gbps / 200 Gbps



DART28

DART28 - Demonstrator ASIC for Radiation-Tolerant Transmitter in 28 nm



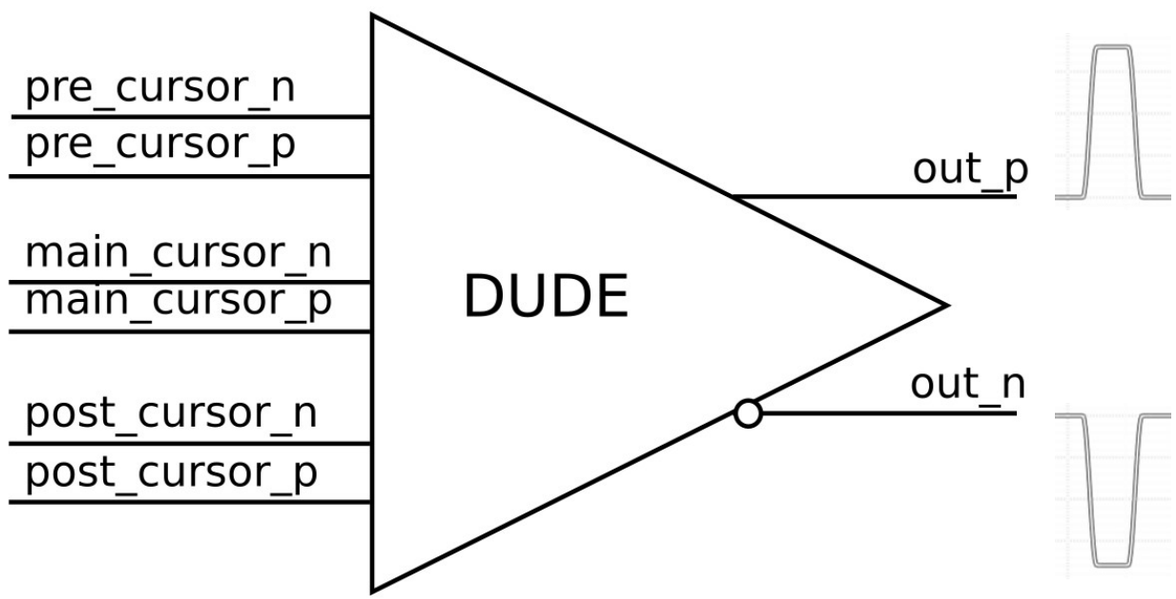


DART28NRZ/high_speed_transmitter

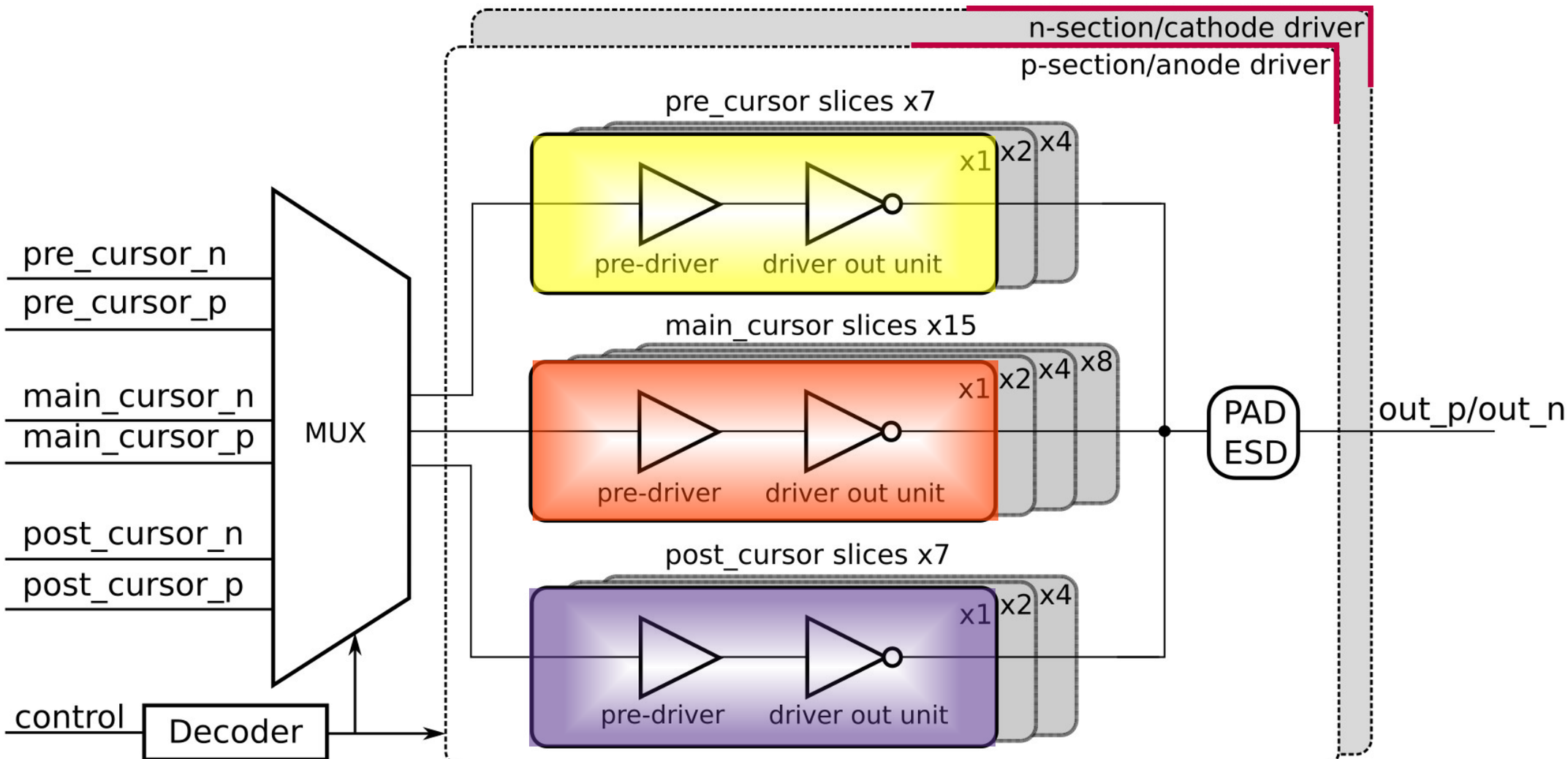
Dual Use Driver

Dual Use Driver (DUDE) specifications:

- Driver loads:
  - Optical Ring Modulator (ORM) [Capacitive]
  - 100 Ω Differential Transmission Lines [Resistive]
- Signalling:
  - ASIC: Four channels [lanes]
  - NRZ
  - 25.6 Gbps/lane
  - Differential output
- Channel Equalization:
  - For transmission lines
  - Bit-level pre-emphasis
  - Edge-pre-emphasis
- ORM driver:
  - Asymmetric Cathode/Anode driving
- Co-integration with WP6 Photonic Integrated Circuits (PICs) designs
- TID radiation tolerant



Driver architecture



Driver output unit cell

To fulfill the initial requirements driver output unit cell has to be able to work in the following modes of operation:

1) grounded output
2) high impedance output
3) full swing driver
4) reduced swing driver
5) 100 Ω transmission line driver

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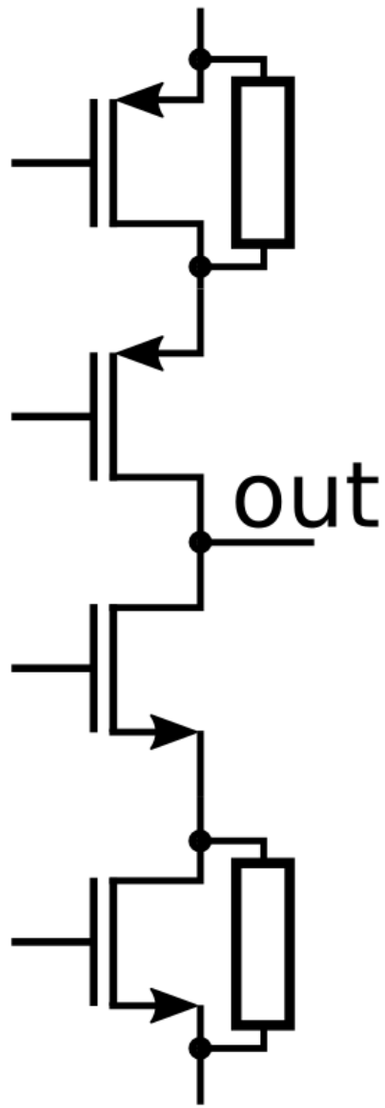
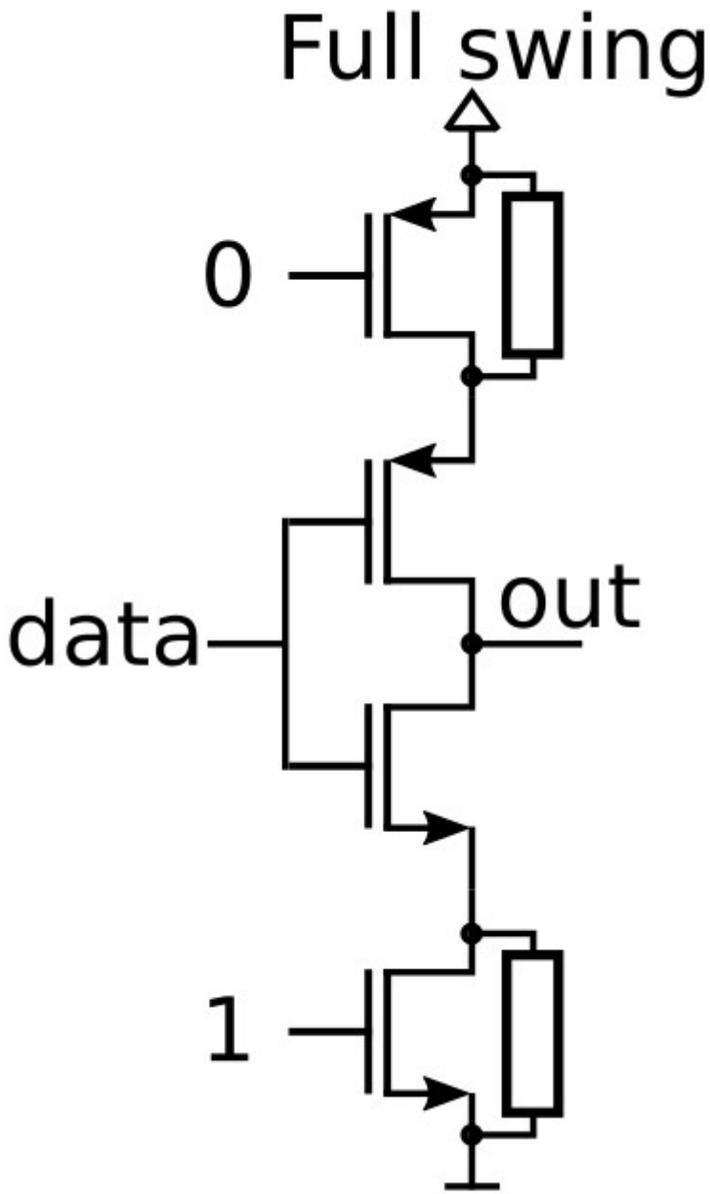


Modes of operation – full swing



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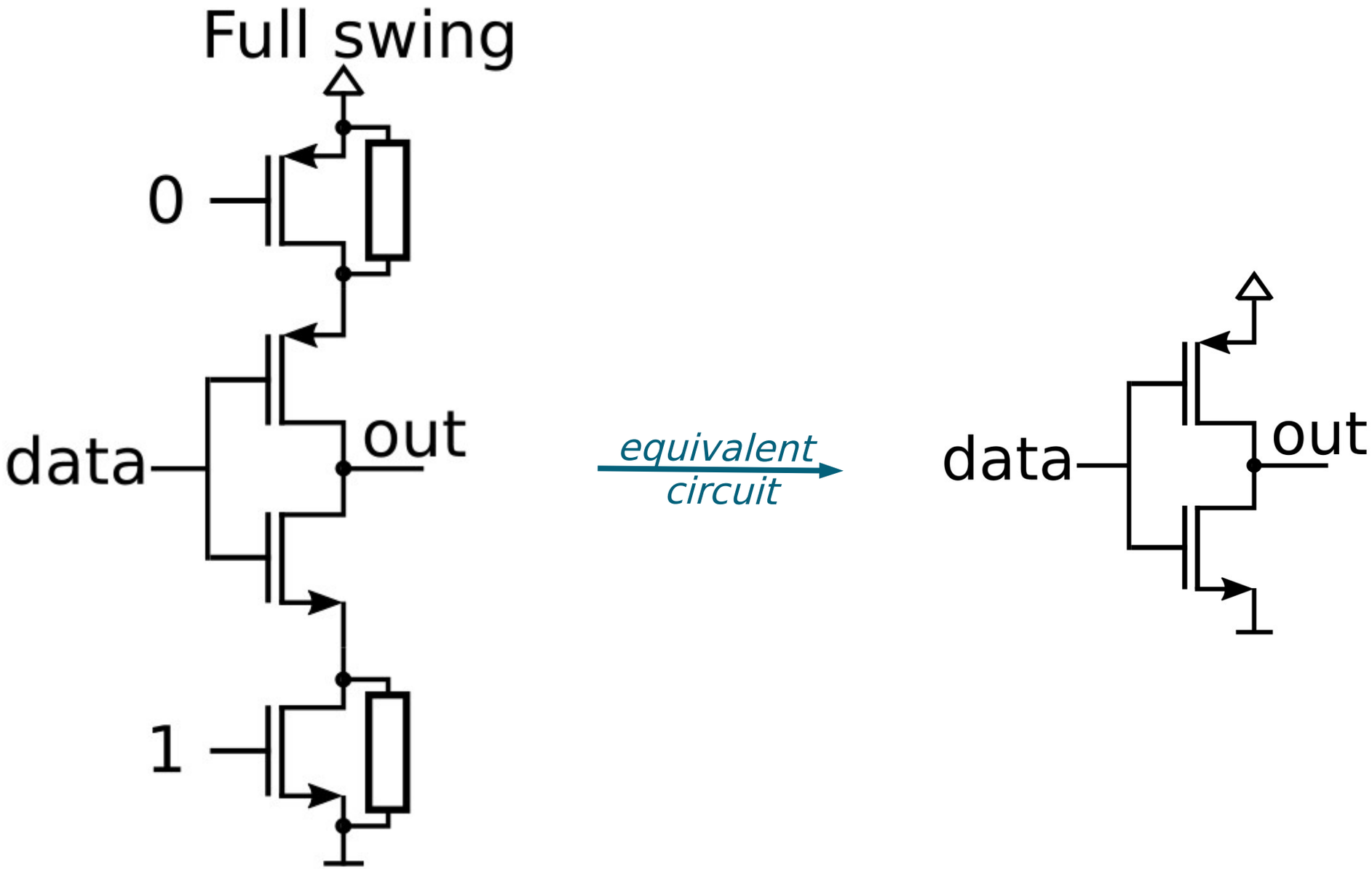
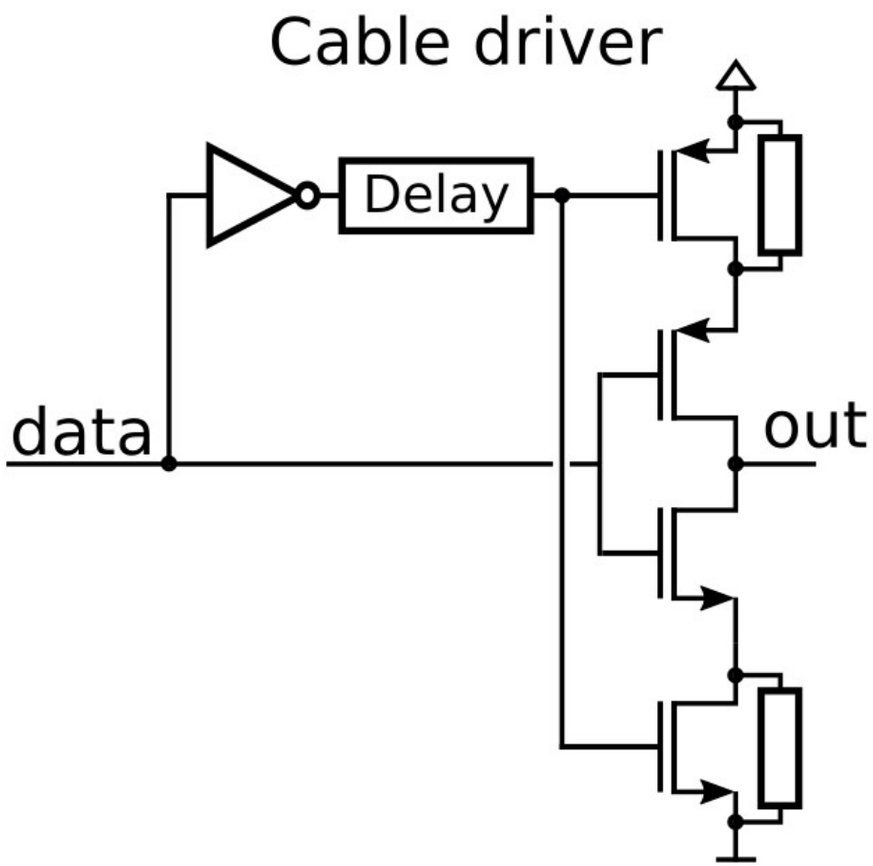


Modes of operation – transmission line



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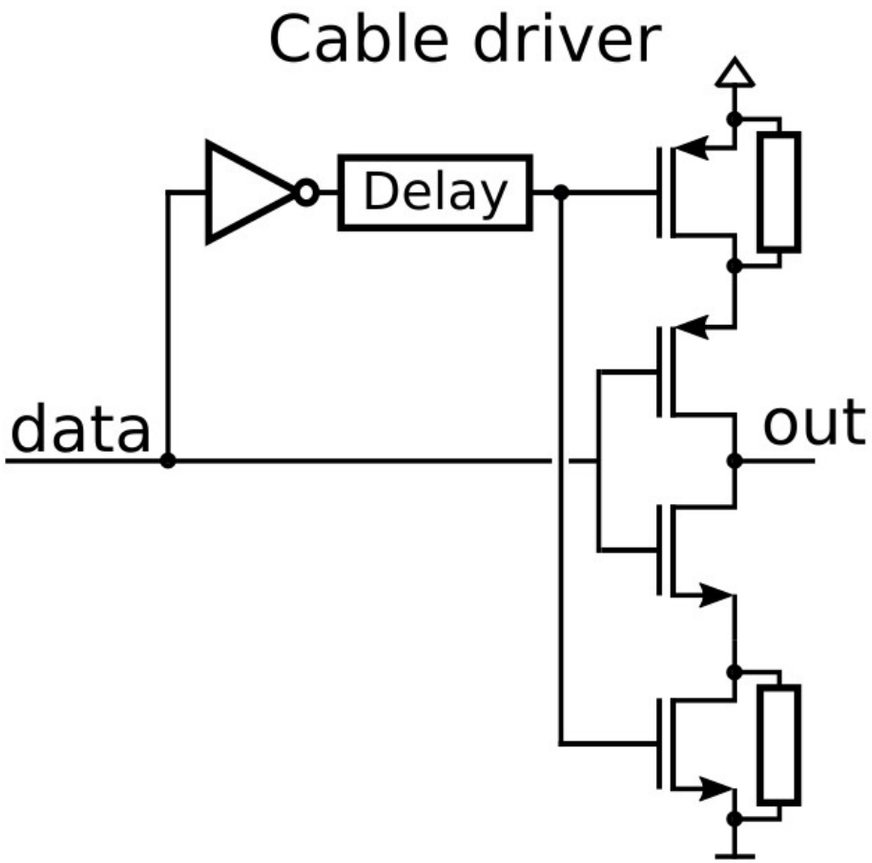

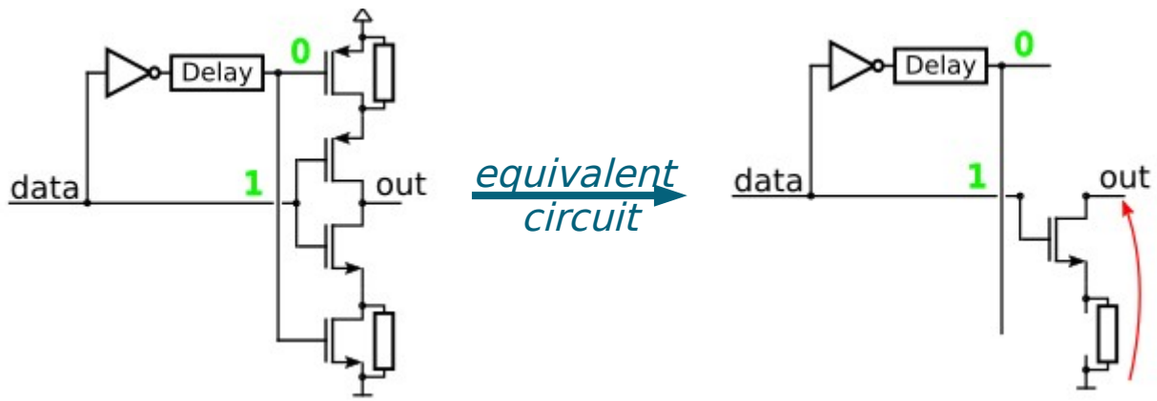

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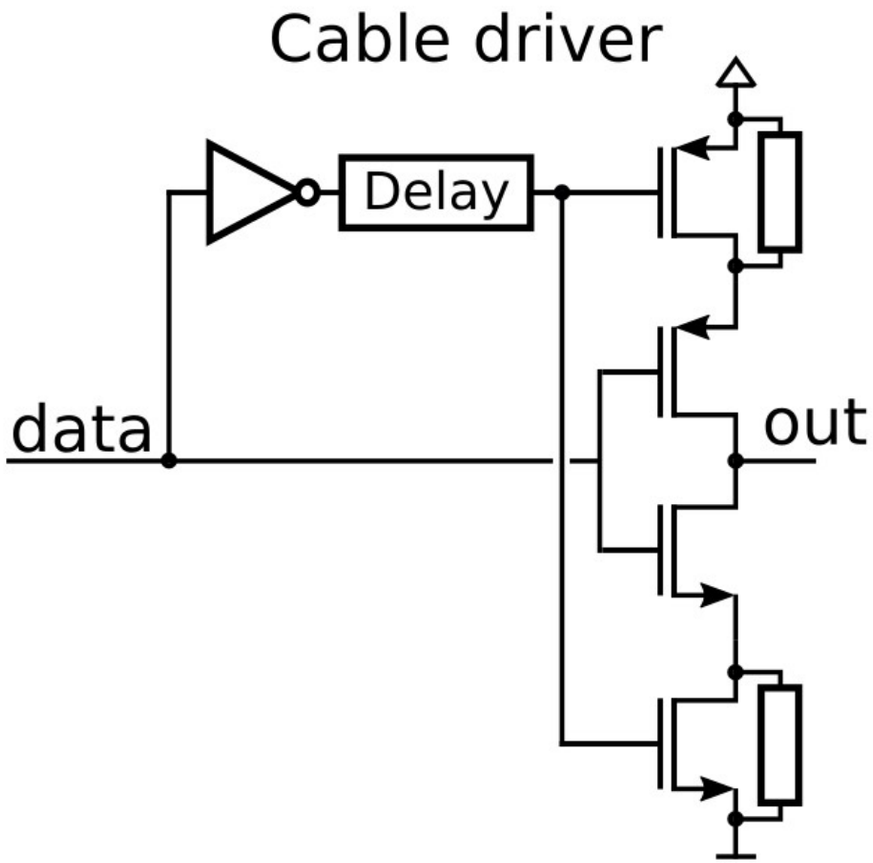

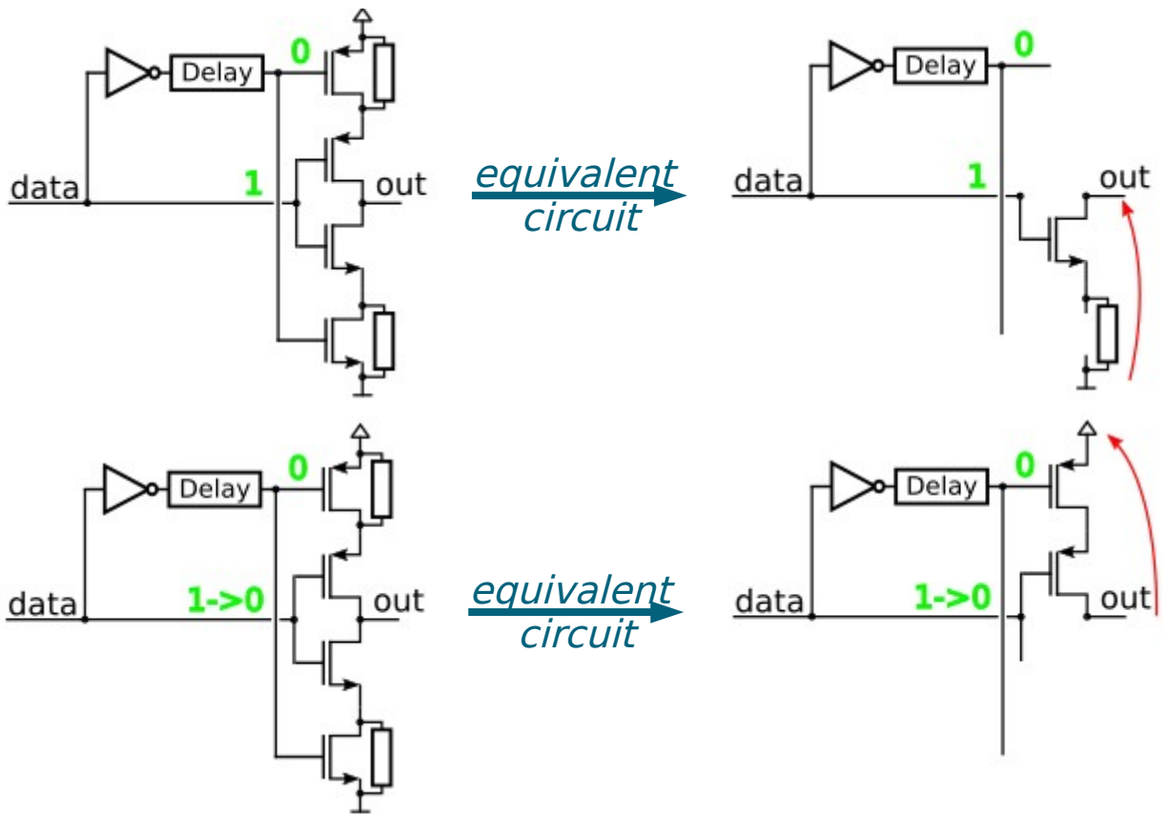

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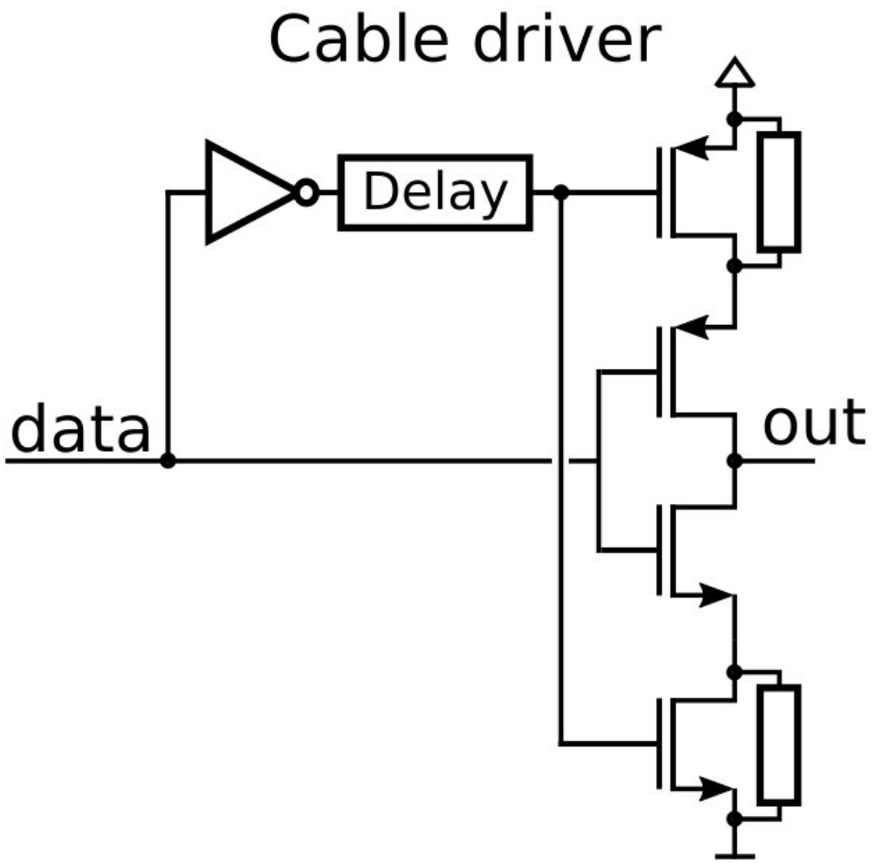
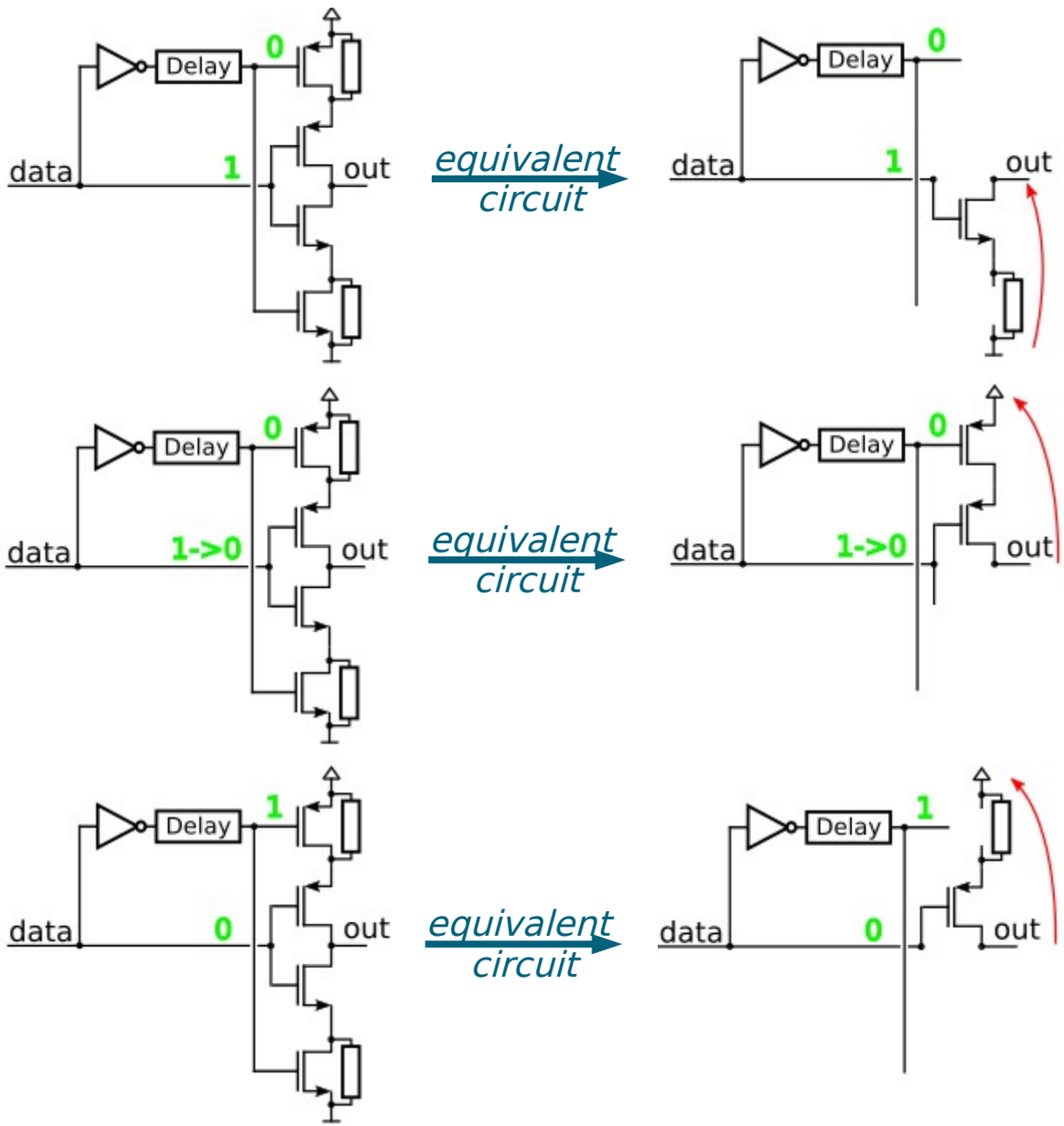
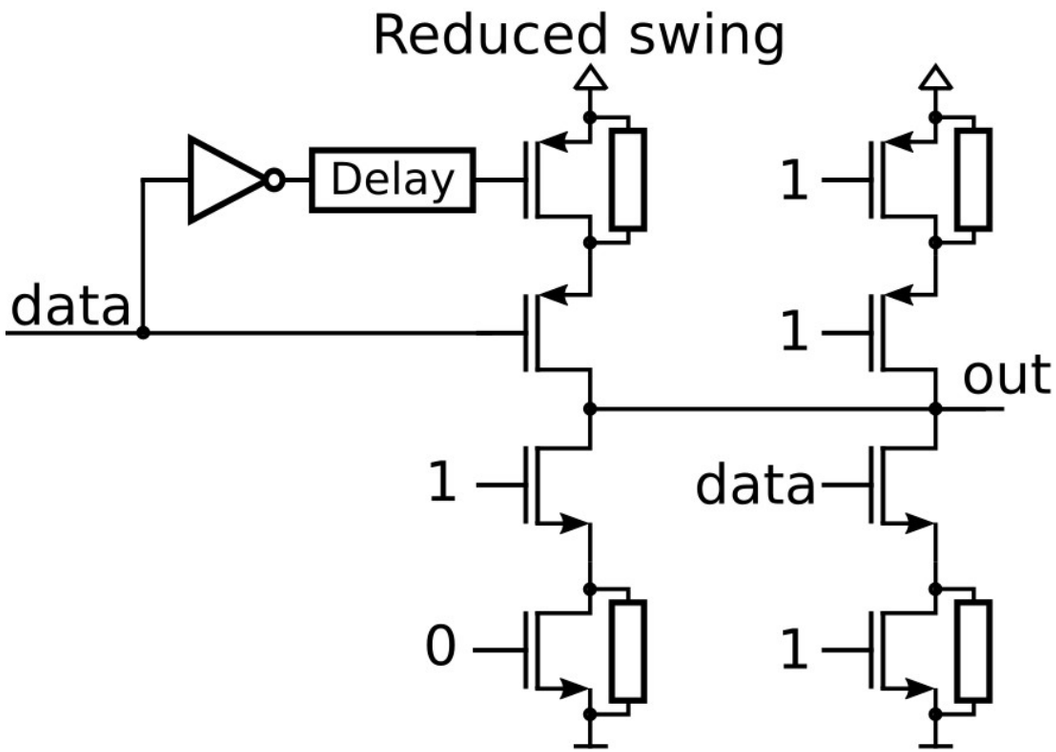




Modes of operation – reduced swing



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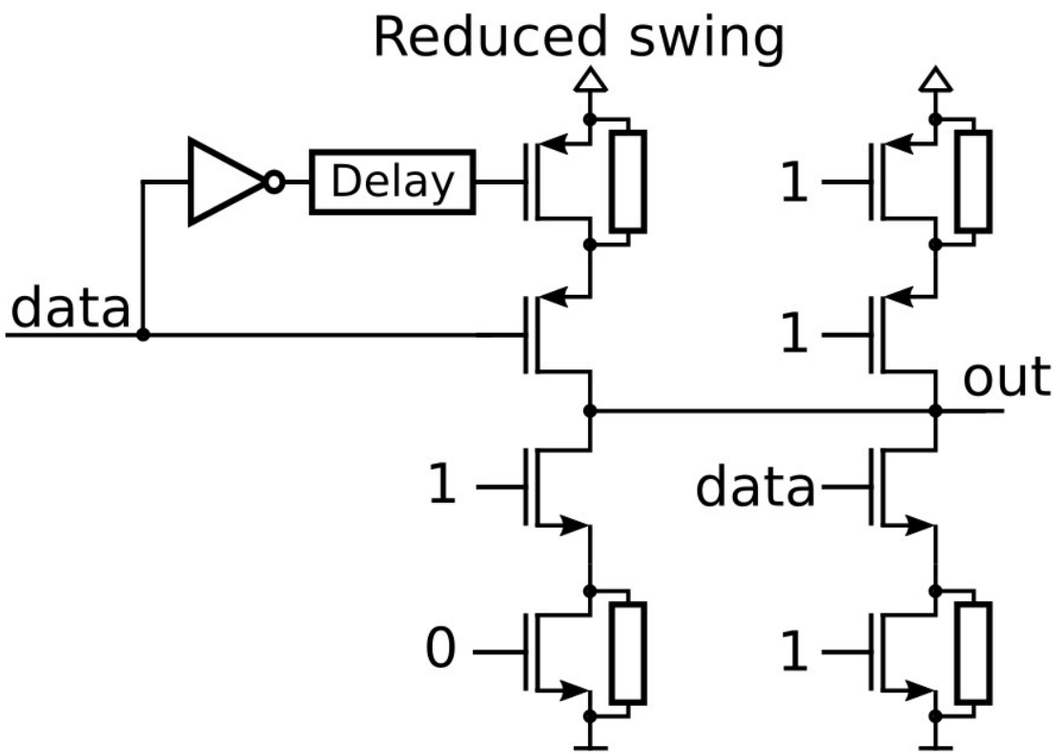
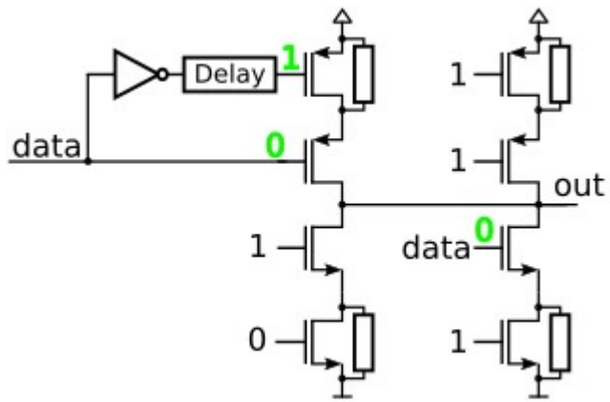
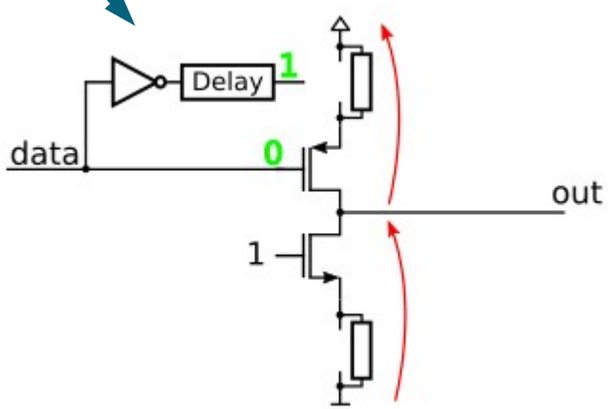
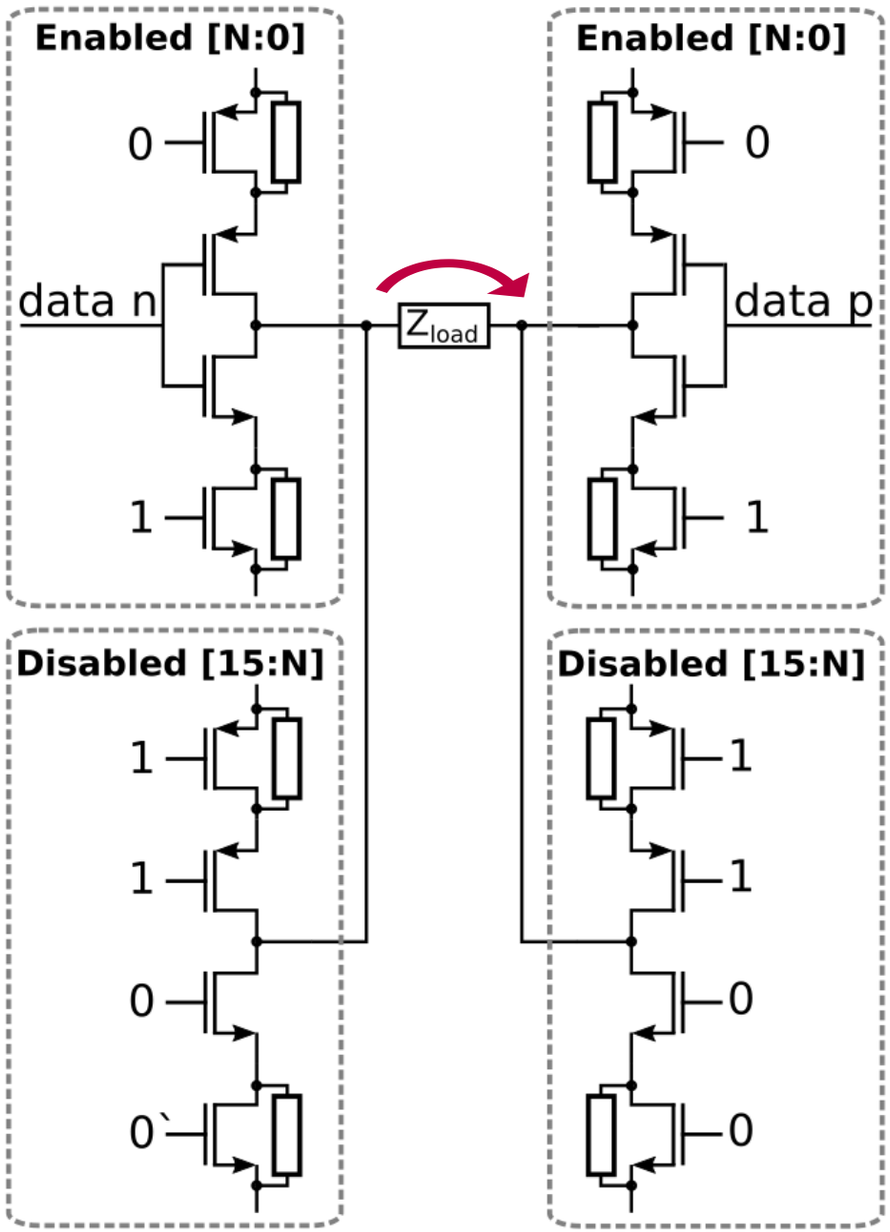




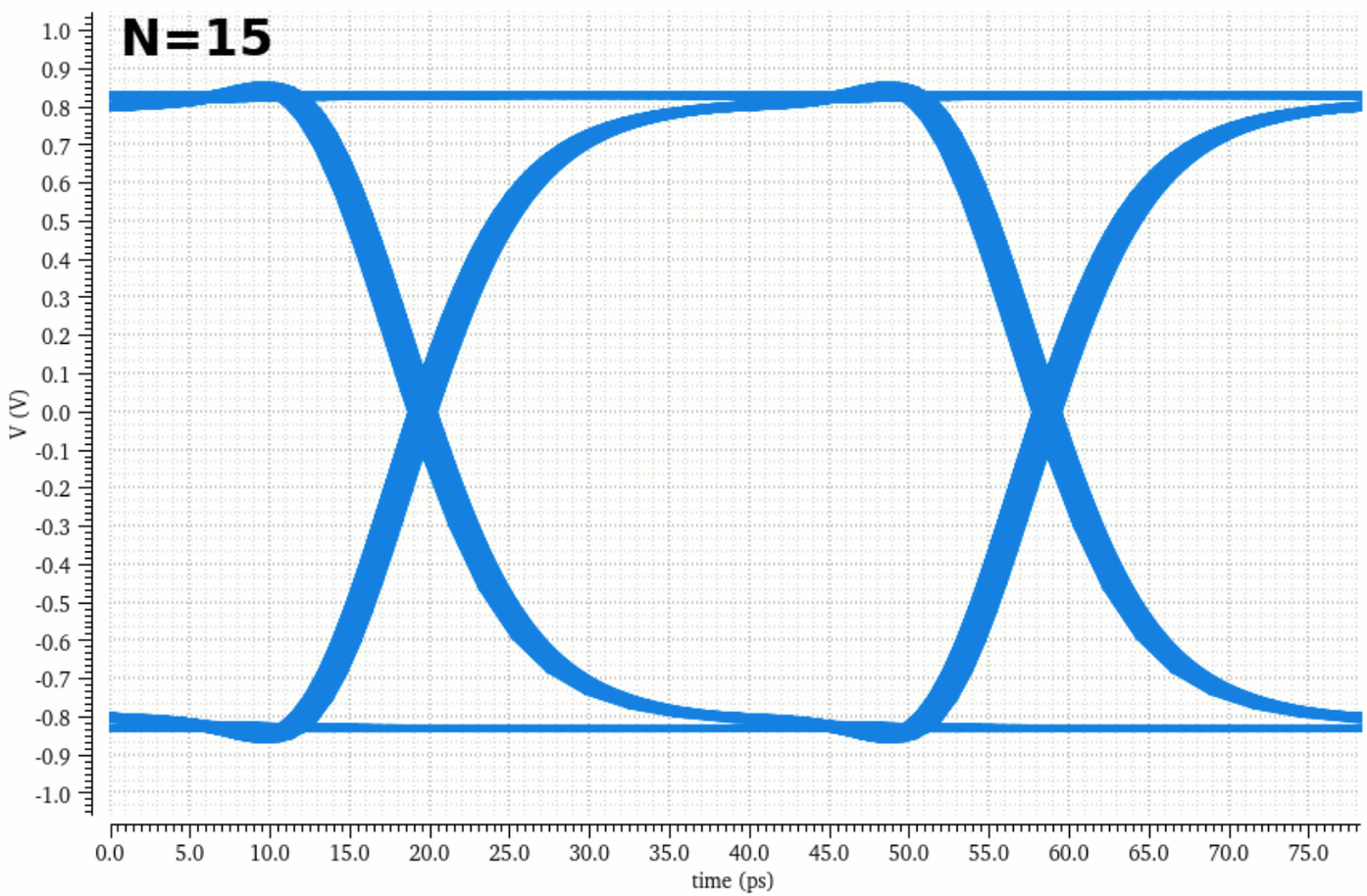
equivalent circuit



Full Swing – 100Ω loading



- Both positive and negative output of the driver are configured in the Full Swing mode
- Eye diagram characteristic depends on the number of enabled slices N

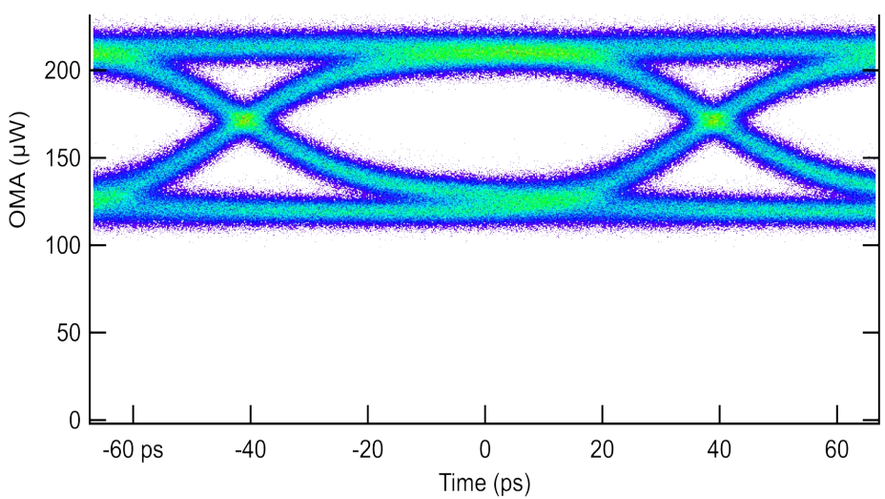


Reduced swing

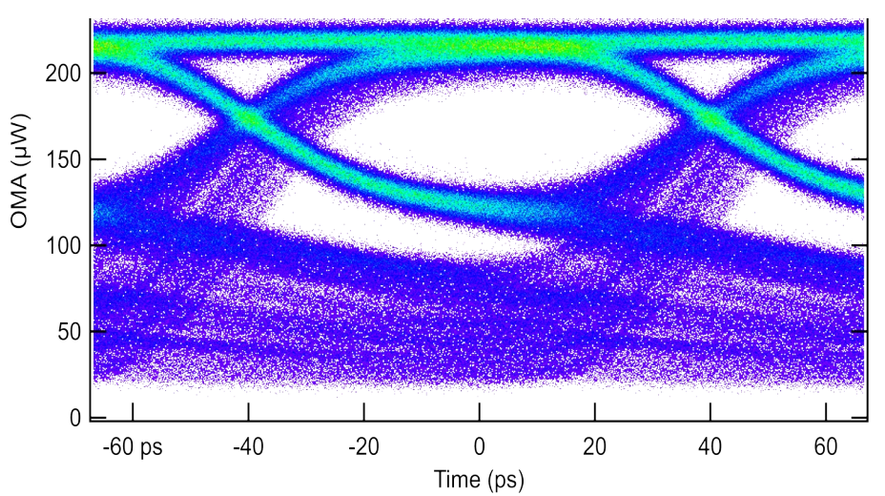
- The ring modulator is driven differentially to maximize the driving amplitude
- Reduced Swing mode limits the amplitude swing on the anode terminal

➔ too large forward biasing of the PN-junction of ring modulator degraded the performance

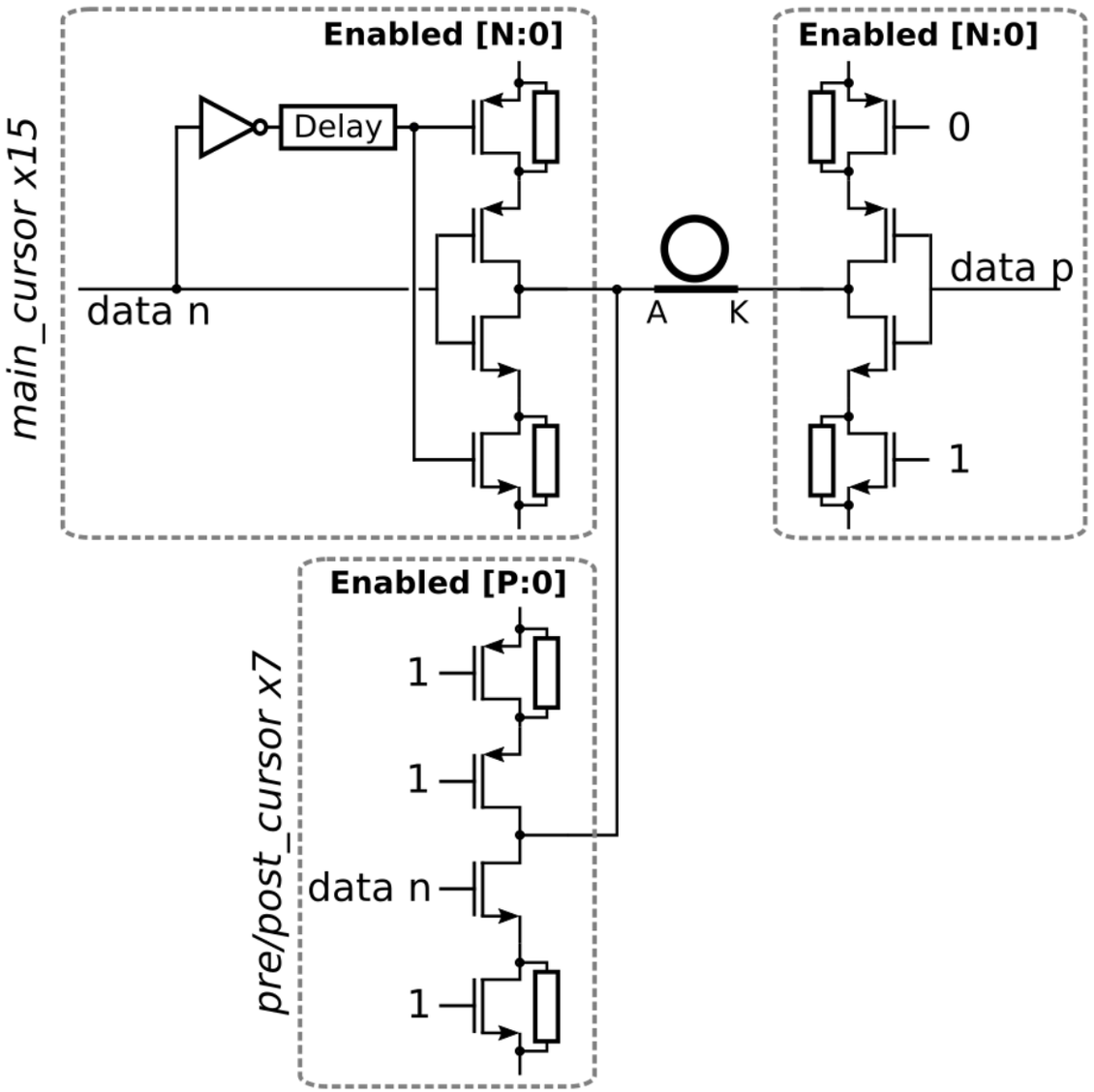
RM: Optical eye diagram when $V_{forward}$=0.5V



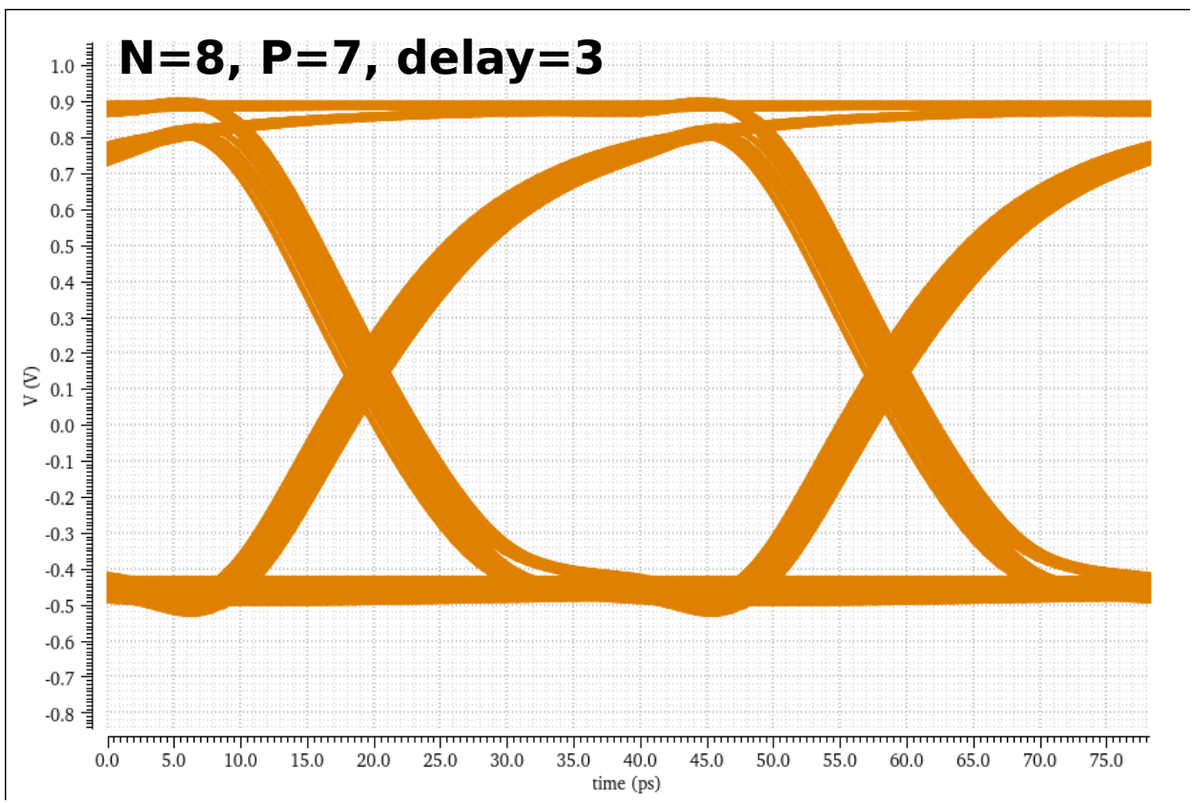
RM: Optical eye diagram when $V_{forward}$=0.9V



Reduced swing



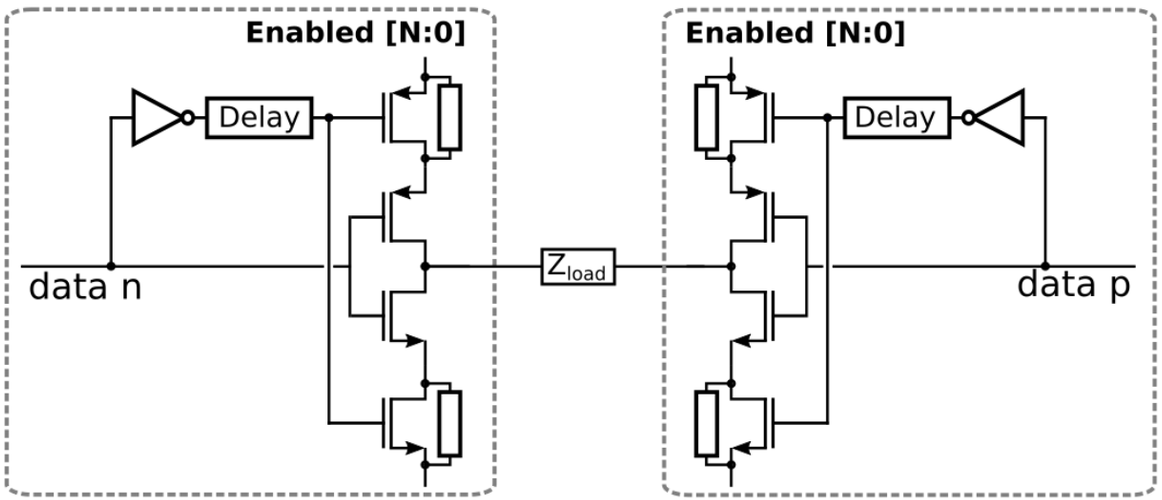
- The anode is driven using Reduced Swing mode and the cathode using Full swing mode
- Reduced swing mode is controlled by:
  - Number of enabled main_cursor slices N
  - Number of enabled pre/post_cursor slices P
  - Delay



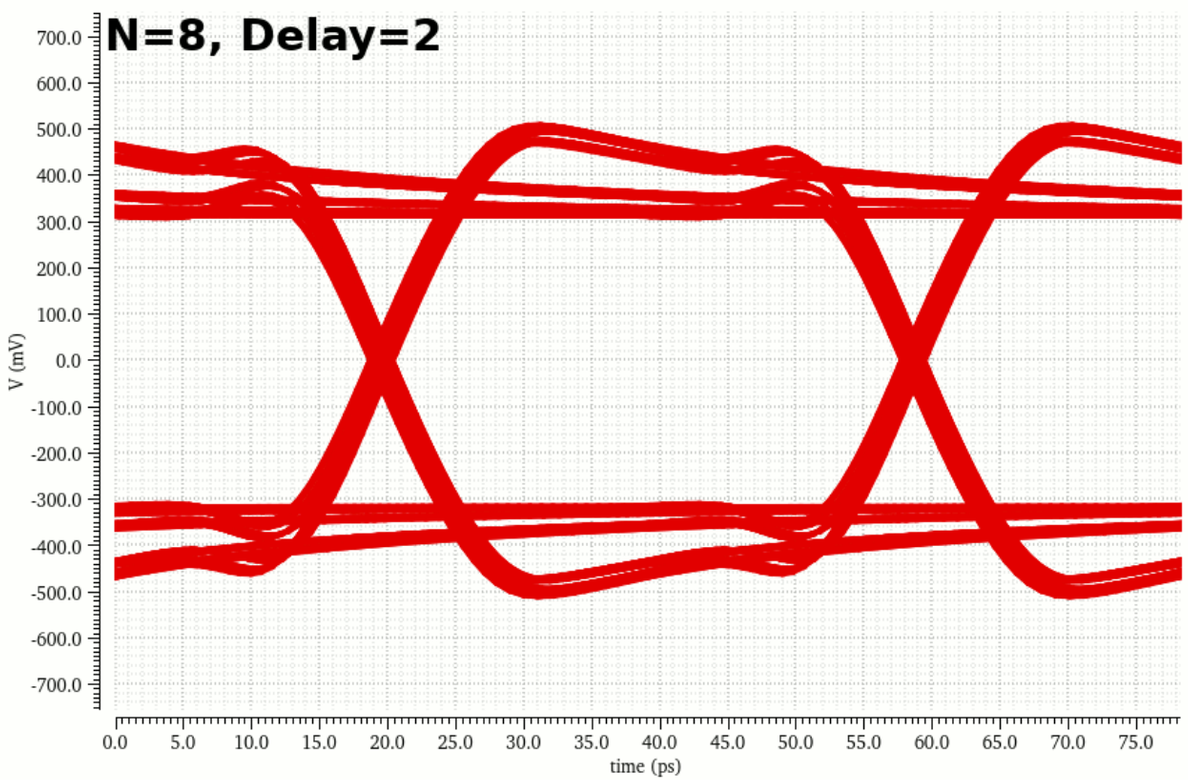
Transmission line driver

- The DUDE includes a pre-emphasis circuit which is able to compensate for the channel bandwidth limitations in order to minimize the inter symbol interference (ISI).
- Two modes of pre-emphasis are implemented:
  - Edge pre-emphasis
  - Two-tap Feed-Forward Equalization (bit-level pre-emphasis)

Line driver – edge pre-emphasis



- Edge pre-emphasis improves rise and fall times by providing increased current to the load during signal transitions and limit the loading current during steady states
- Line driver mode is controlled by:
  - ➔ Number of enabled slices N
  - ➔ Pre-emphasis delay



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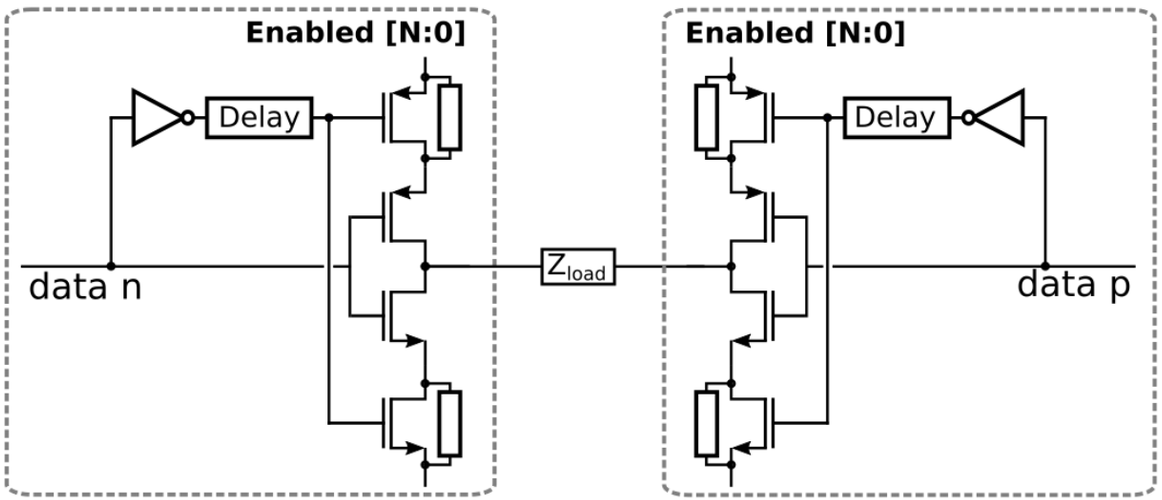

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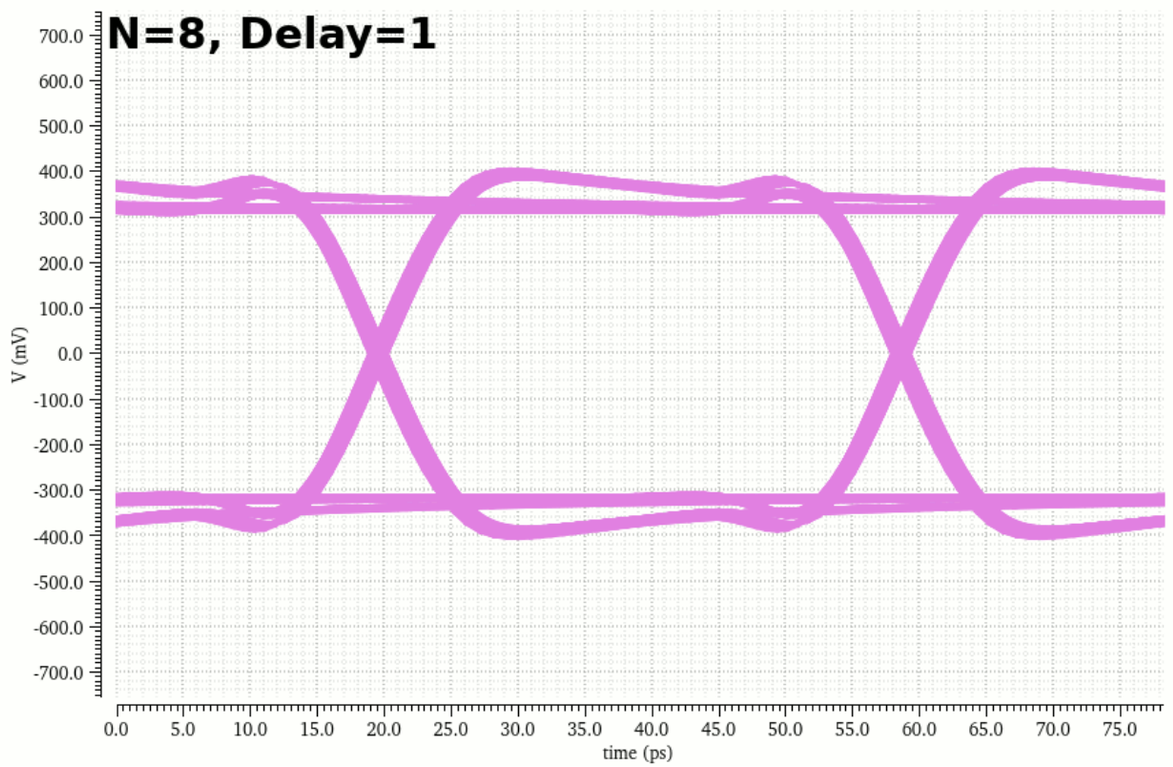
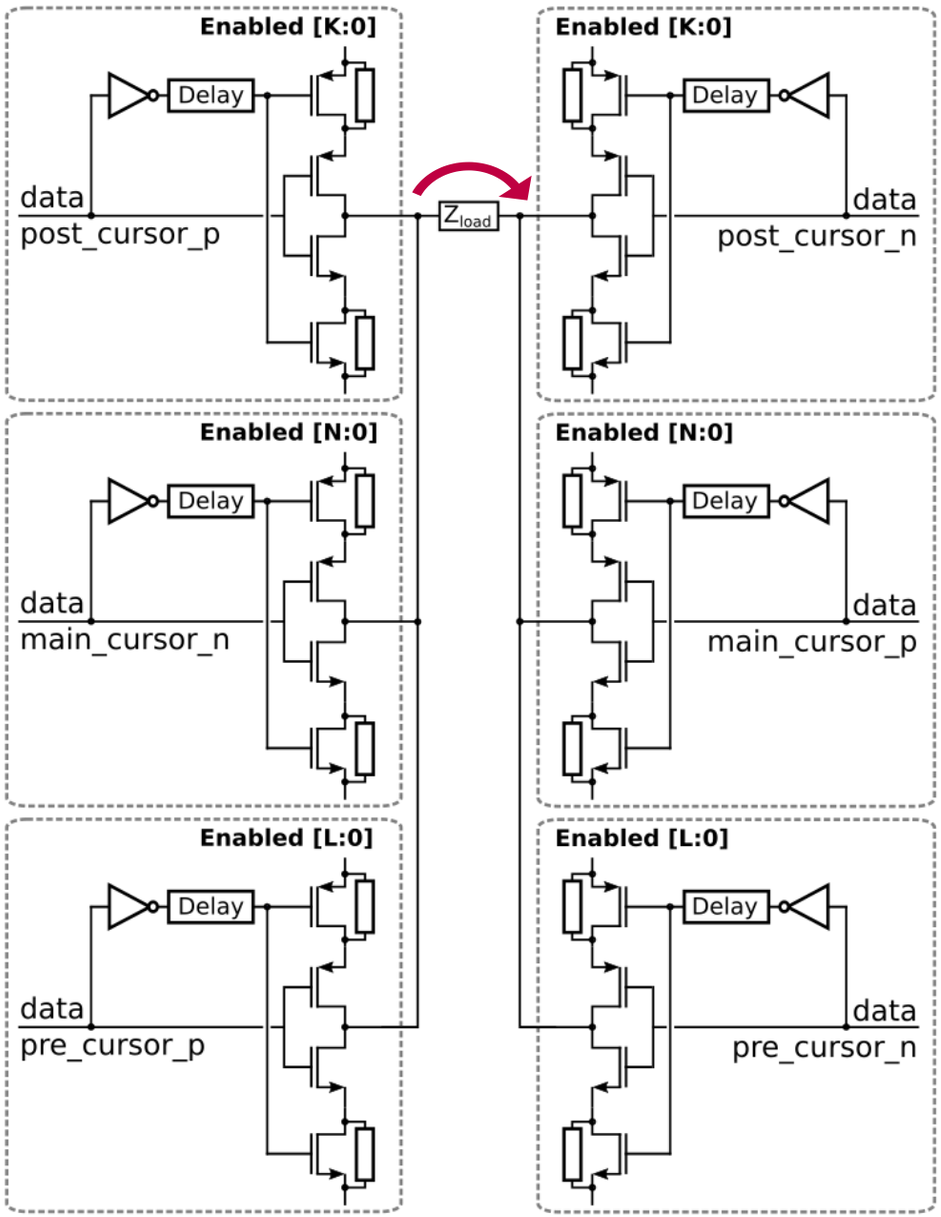


Line driver – bit-level pre-emphasis



- Feed-Forward Equalization is implemented by pre- and post-cursor drivers. Their driving strength is individually programmable allowing for optimal equalization of bandwidth-limited channels.
- bit-level pre-emphasis is controlled by:
  - Number of enabled slices in main-, pre-, post-cursor
  - Pre-emphasis delay

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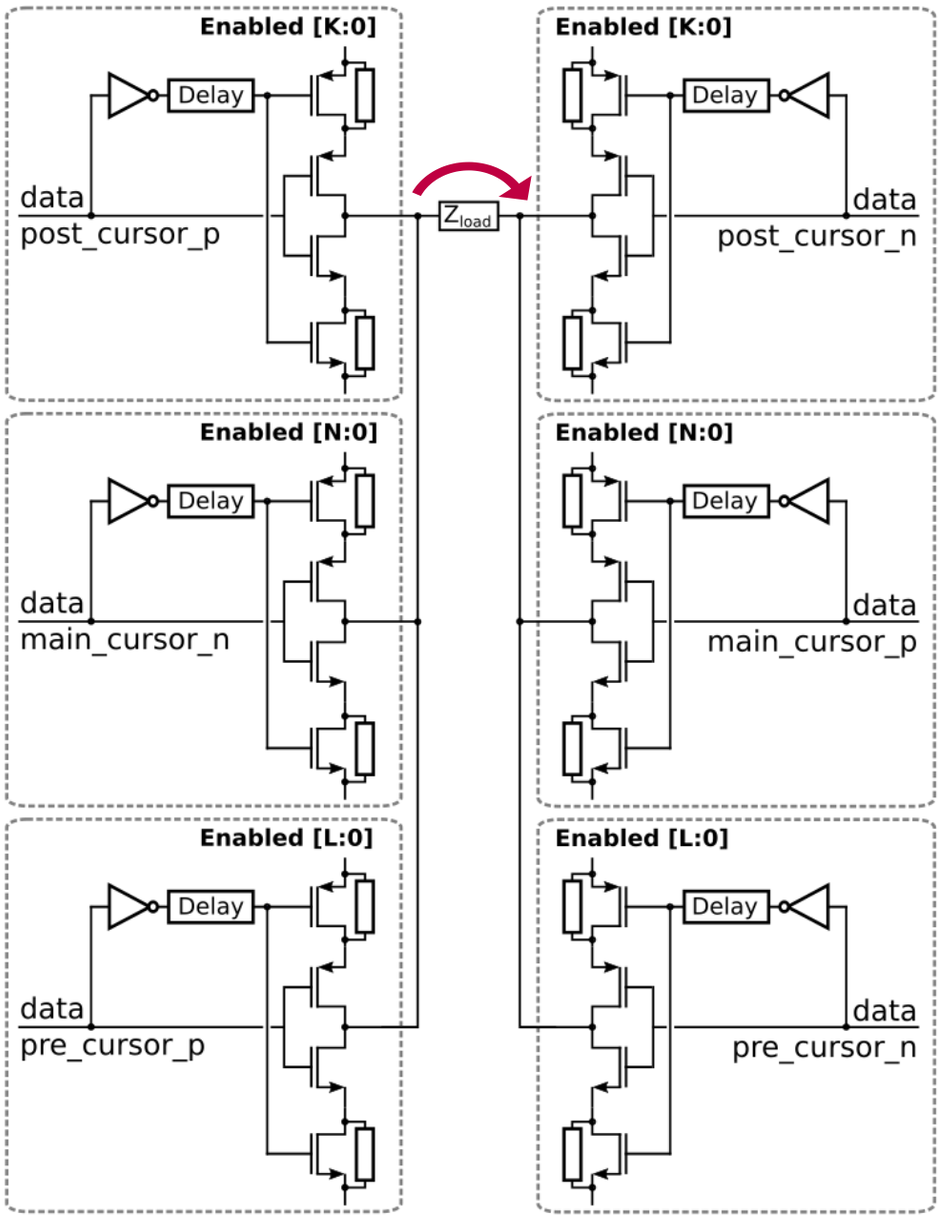

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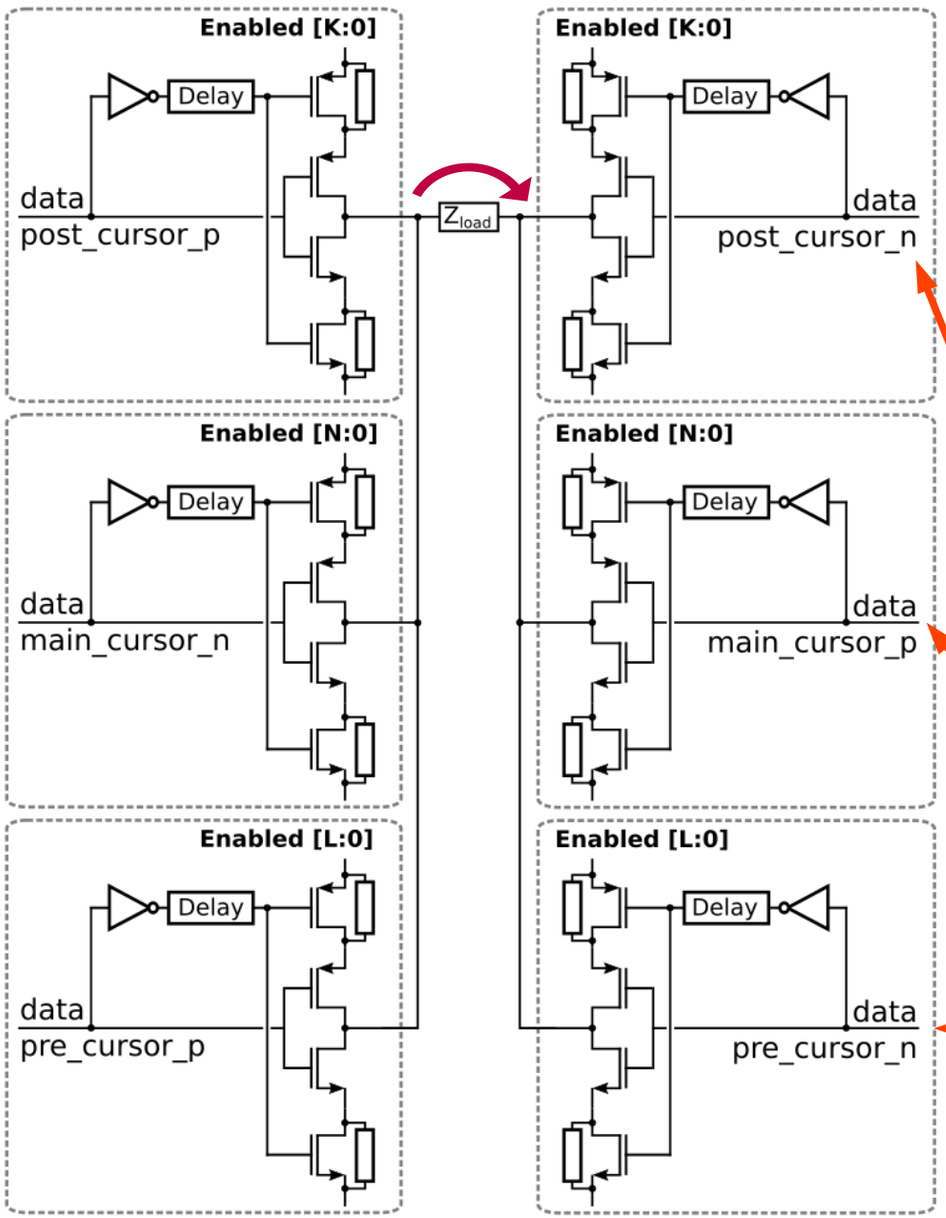

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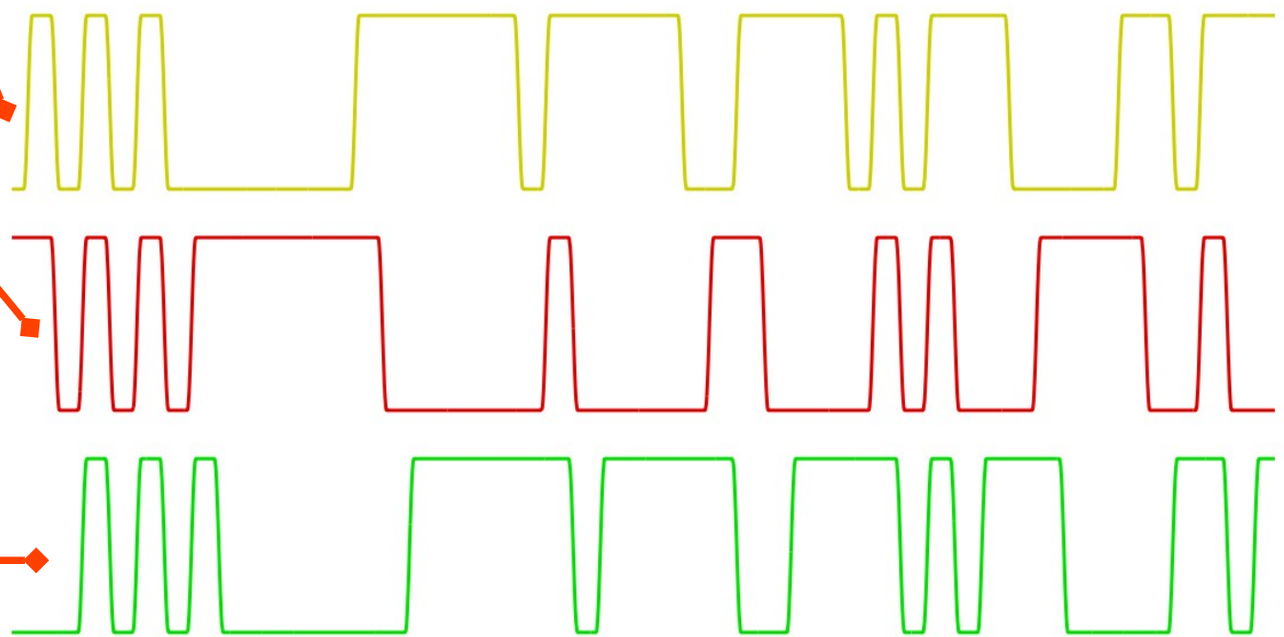

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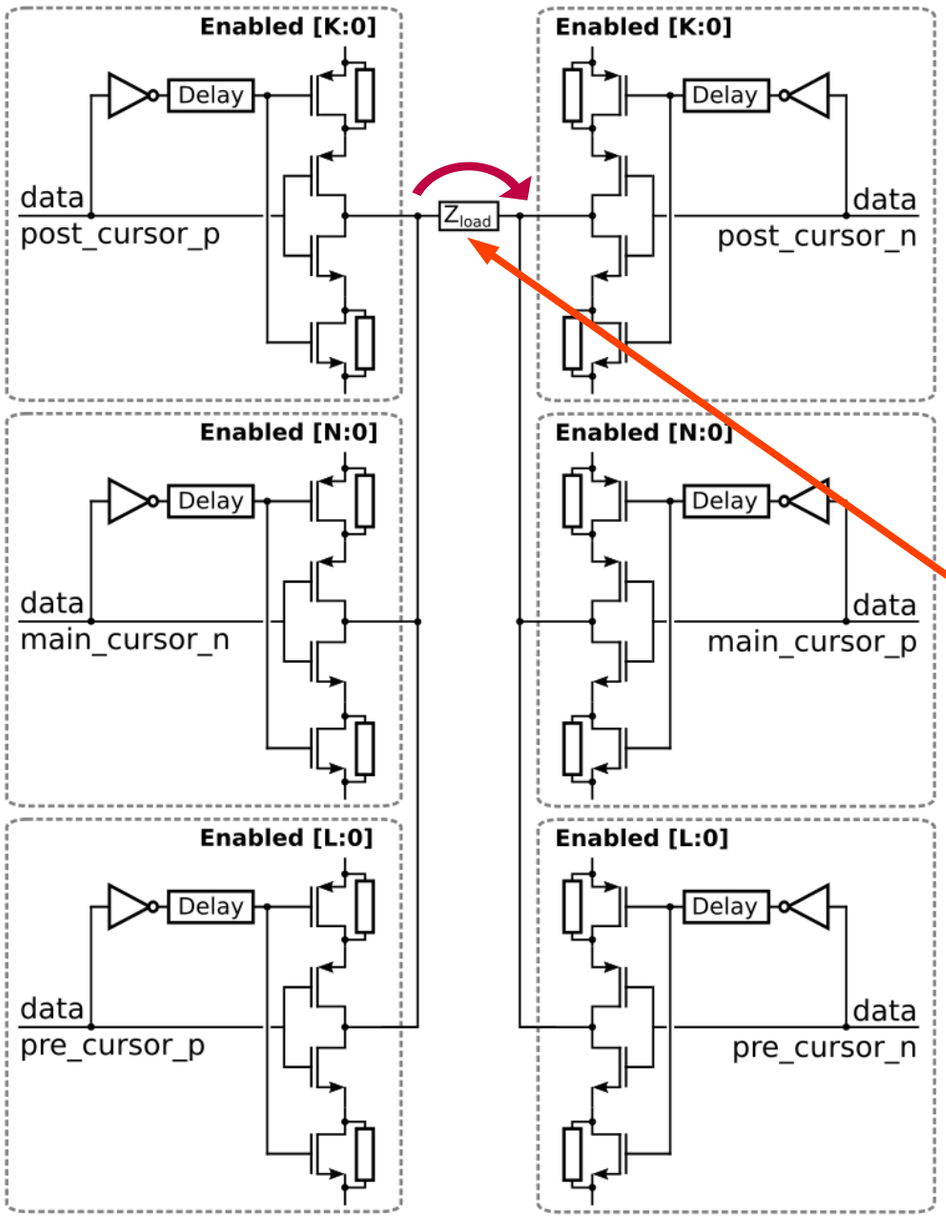

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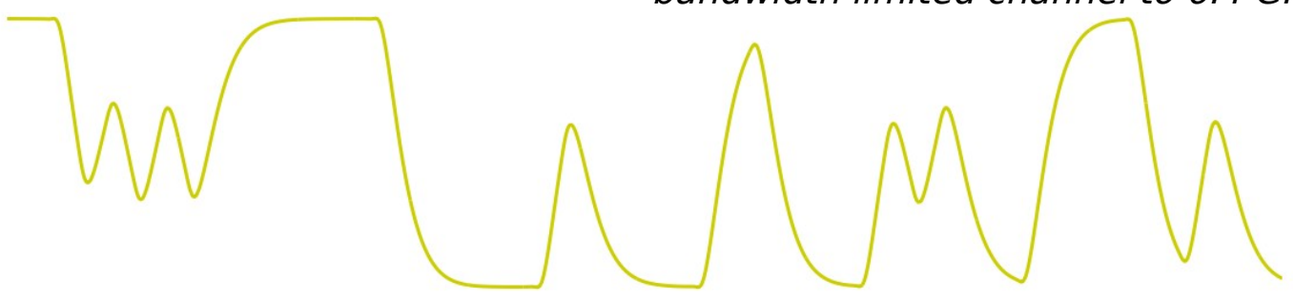
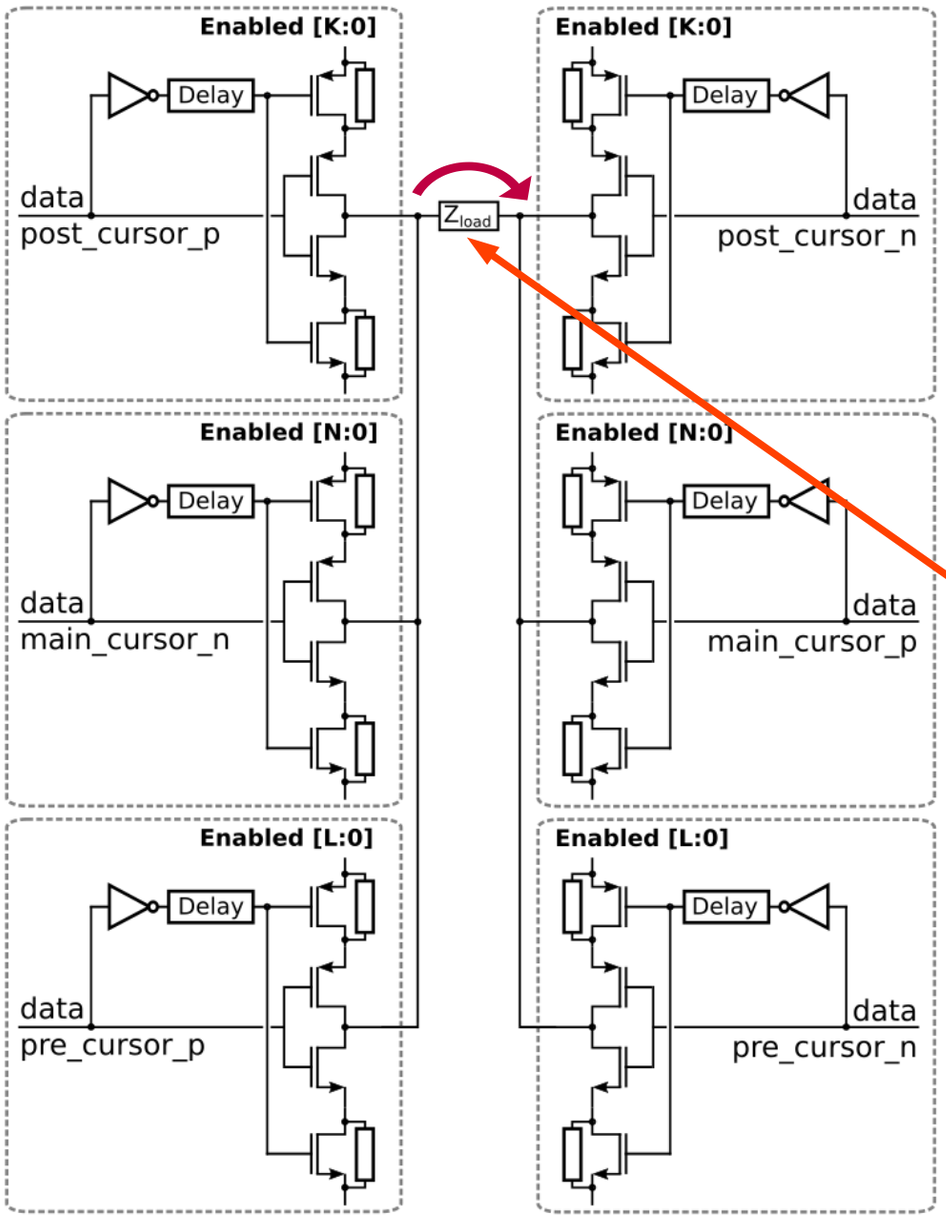
bandwidth limited channel to 6.4 GHz



Line driver – bit-level pre-emphasis



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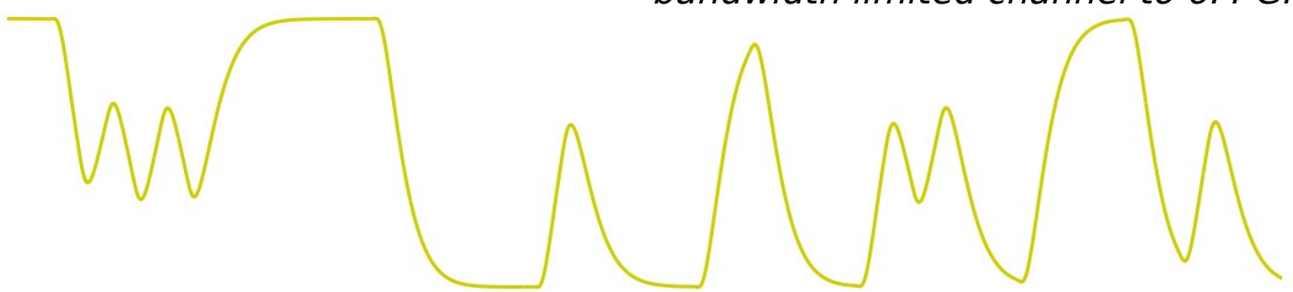

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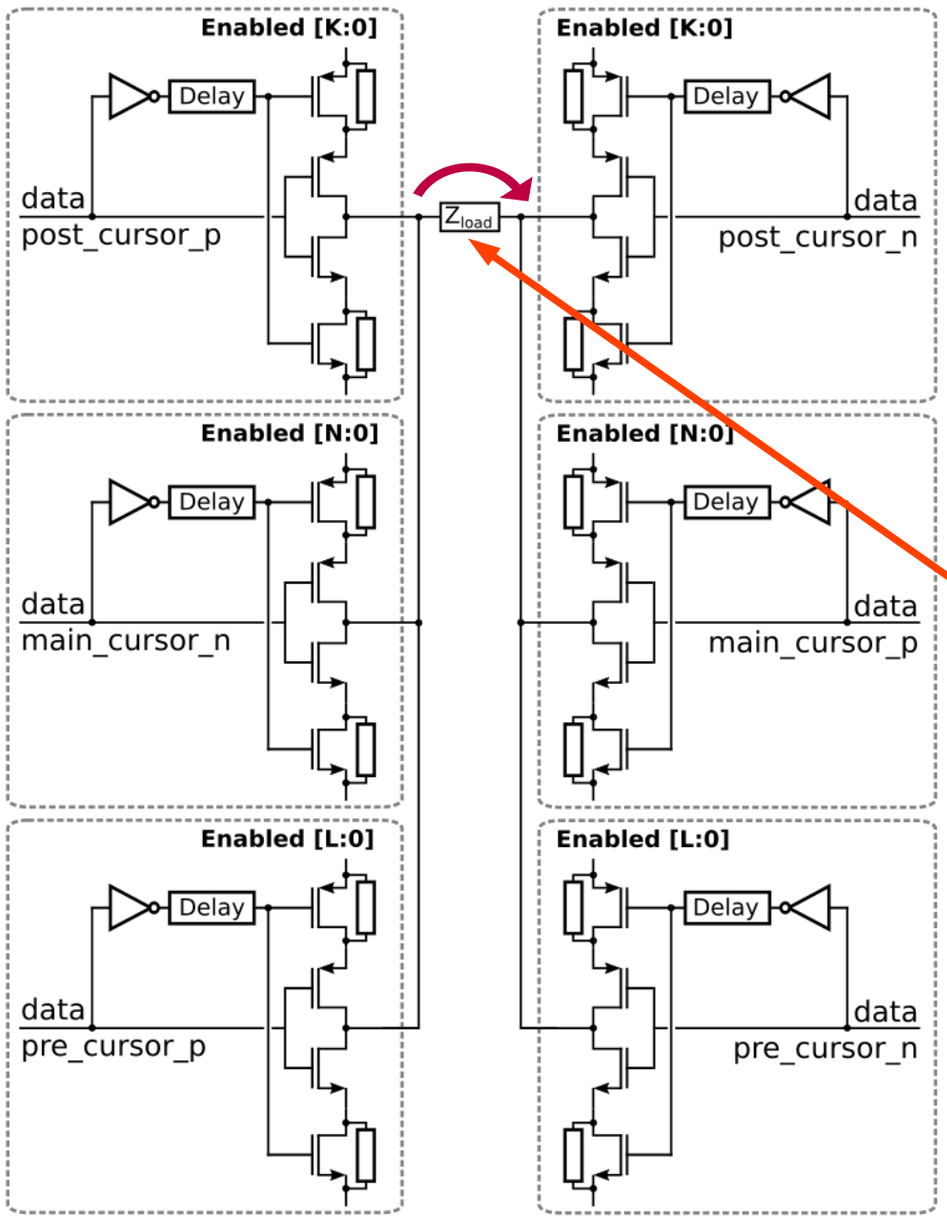

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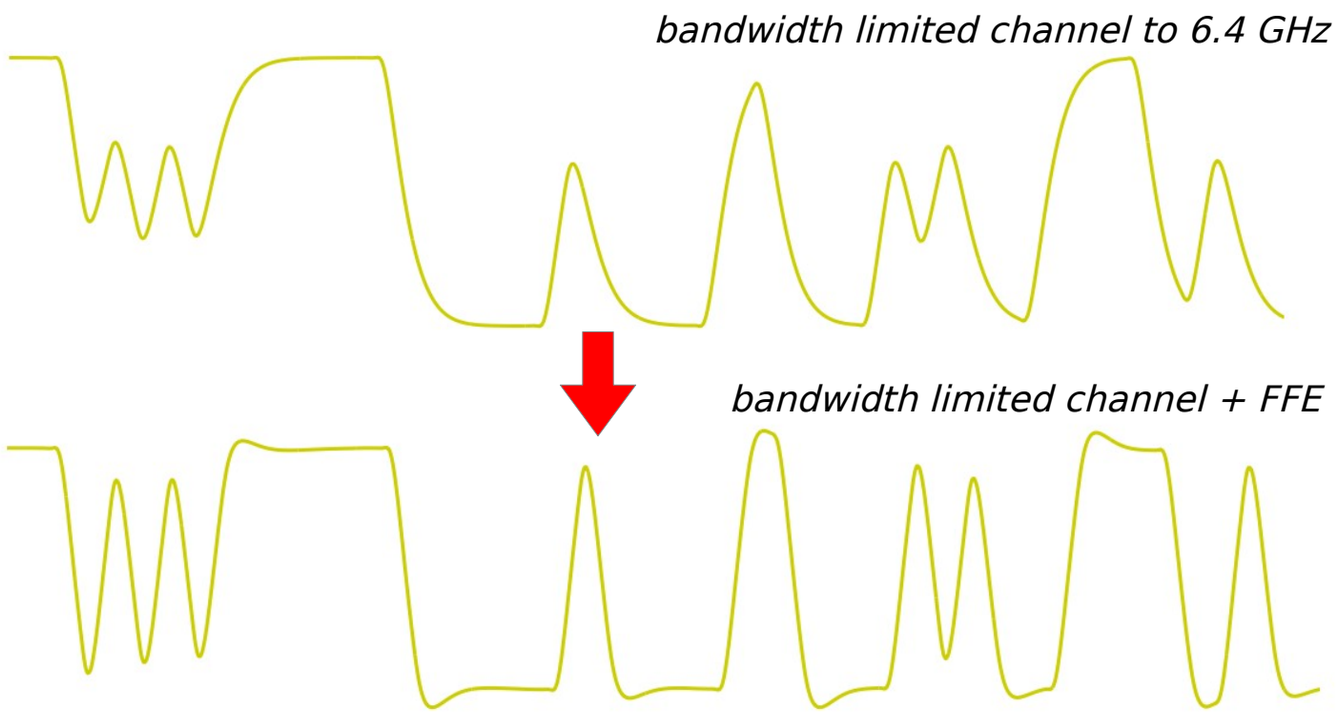
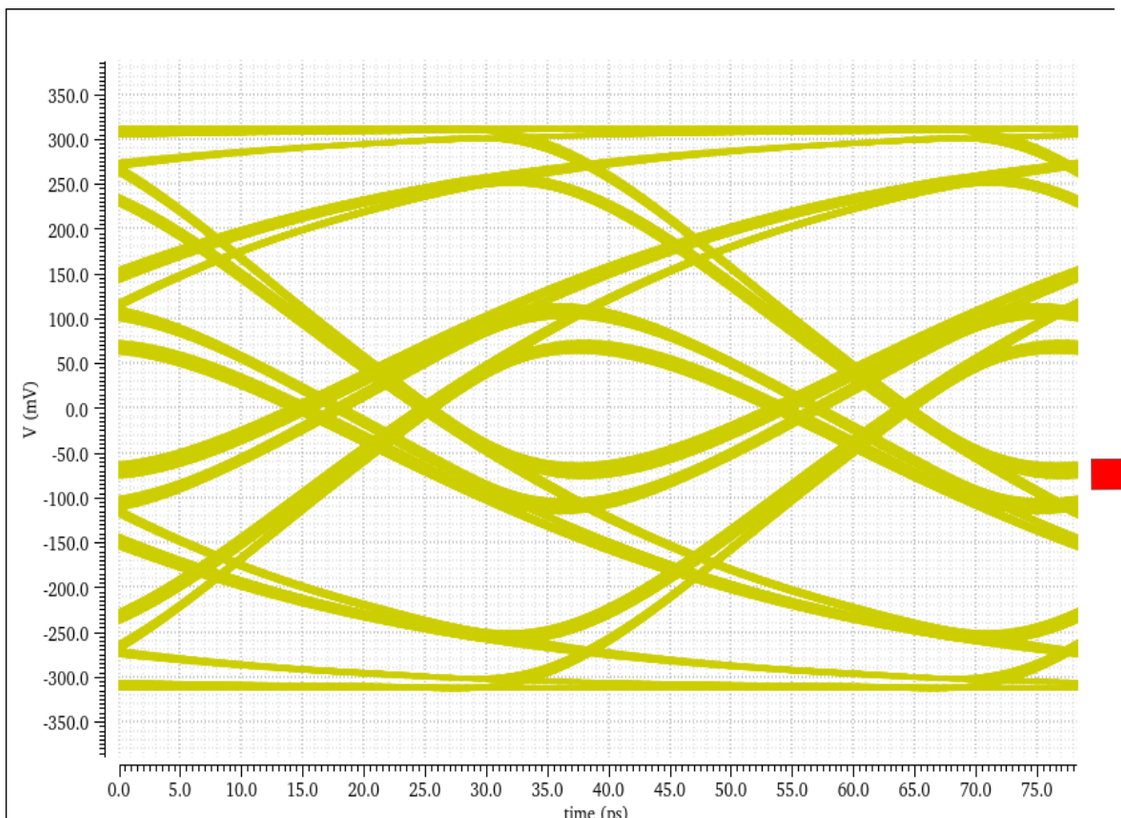
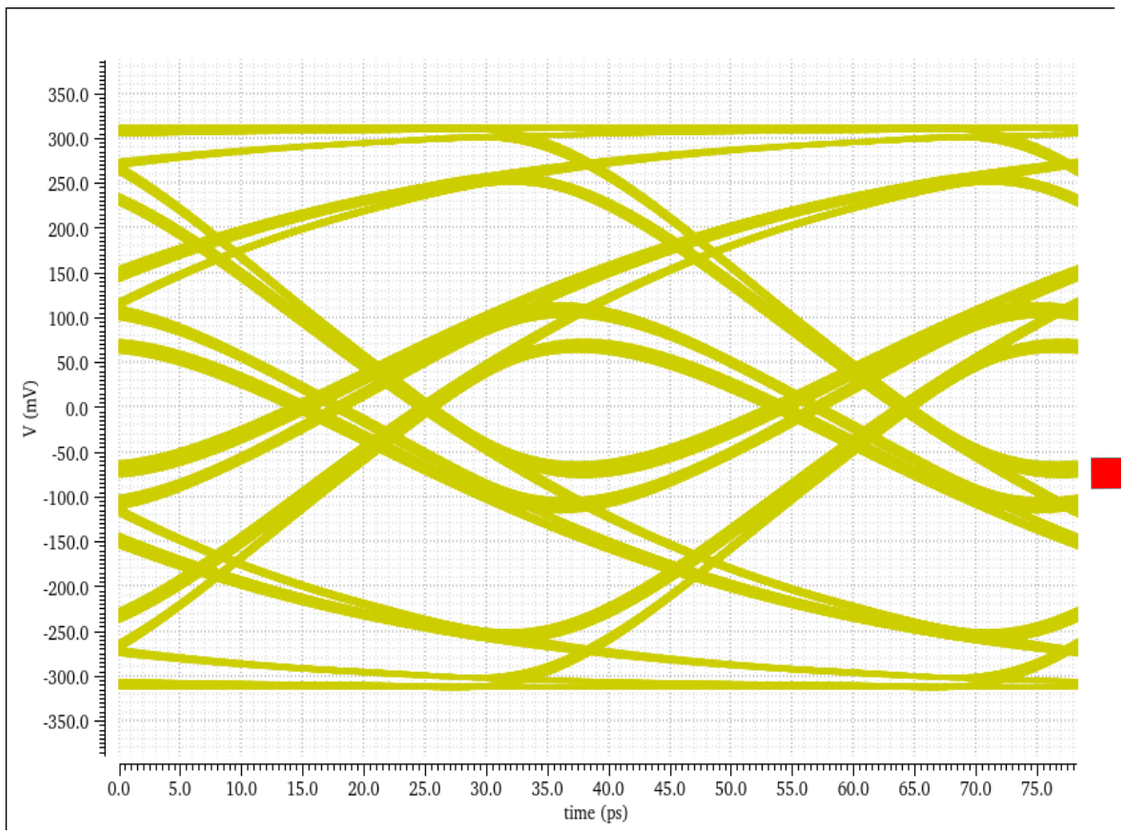


Line driver – bit-level pre-emphasis



eye diagram with bandwidth limitation to 6.4GHz

Line driver – bit-level pre-emphasis



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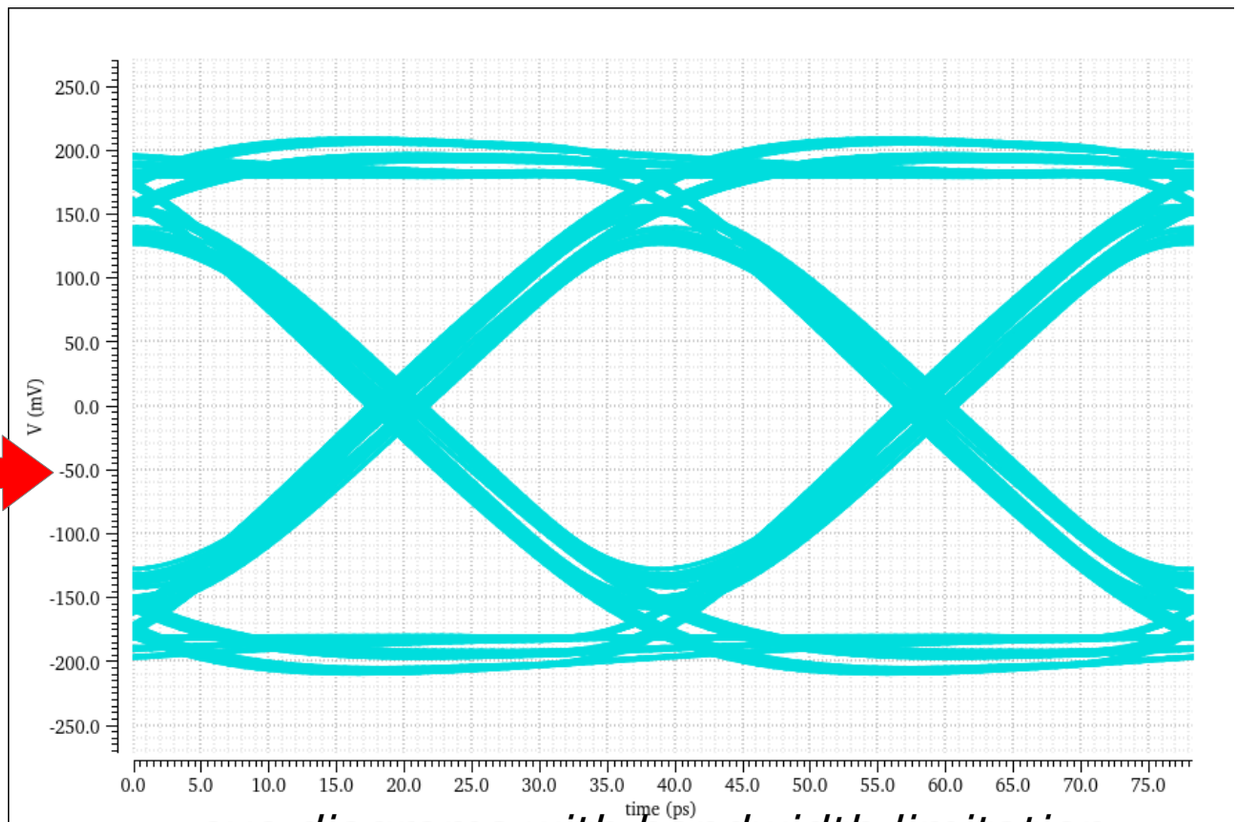
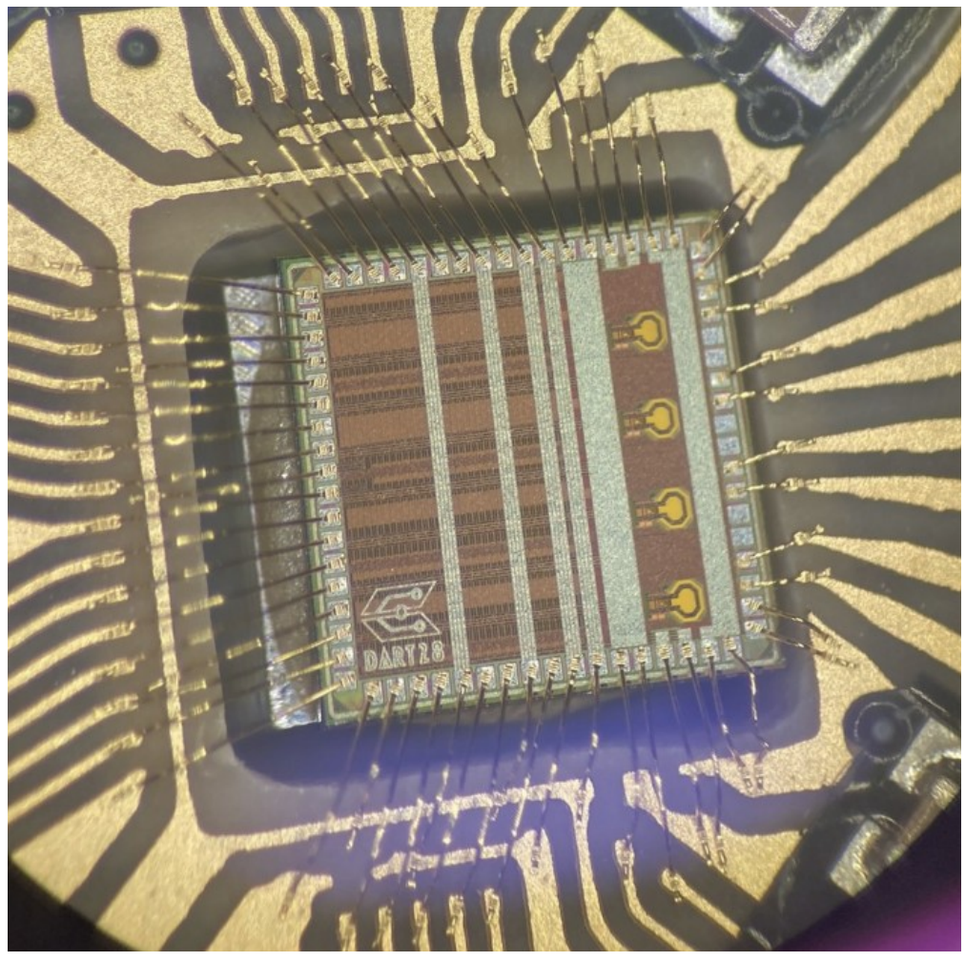


eye diagrams with bandwidth limitation to 6.4GHz and tuned pre-emphasis to reduce jitter and eye hight

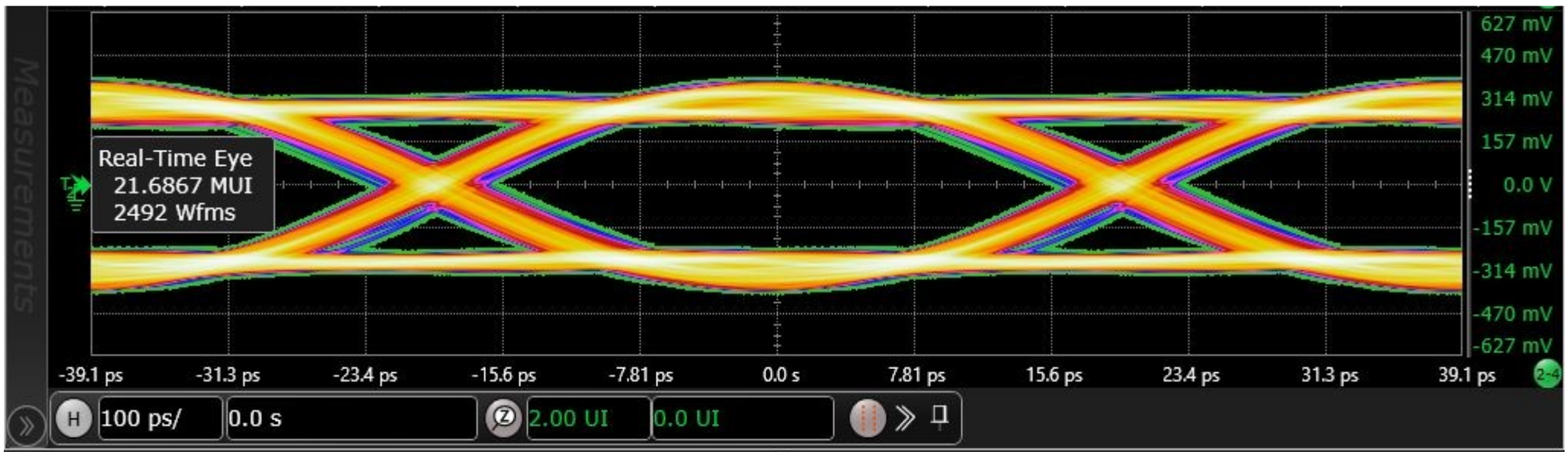
First tests

DART28 ASIC is fully operational:

- All the components work properly
- Circuit is able to transmit data at 25.6 Gbps
- Power supply delivery challenge
  - ➔ supply noise is critical for high performance
  - ➔ power supply noise modulate the propagation delays which increases jitter
  - ➔ long wire bonds – too large inductance
  - ➔ issue will be address in the next test system



25.6 Gbps NRZ transmission



Results (Measure All Edges)

Measurements

Measurement	Current	Mean	Min	Max	Range (Max-Min)	Std Dev	Count
1 Q-factor(2-4)	8.84	8.835	8.83	8.84	10 m	2 m	42
2 Eye jit RMS(2-4)	797 fs	797.7 fs	786 fs	823 fs	37 fs	4.7 fs	42
3 Eye width(2-4)	30.701 ps	30.7850 ps	30.701 ps	31.616 ps	916 fs	173.7 fs	42

Conditions:

- 1 channel is enabled
- PRBS7 input sequence
- Line driver mode
  - edge pre-emphasis
  - 12 segments enabled

Conclusions

Objective has been achieved - the Dual Use Driver developed for the DART28 ASIC is fully operational:

- It operates at 25.6 Gbps
- It is programmable to adapt to different loading conditions
- Flexible output stage design:
  - ➔ full swing
  - ➔ reduced swing
  - ➔ transmission line driver with:
    - Edge pre-emphasis
    - Feed-Forward Equalization – bit-level pre-emphasis
- It is capable of driving:
  - ➔ 100 Ω transmission lines
  - ➔ Optical ring modulators
- Next step: optimize power supply delivery

Digital duty cycle correction system for clock paths in radiation-tolerant high-speed wireline transmitters

Oct 5, 2023, 5:40 PM
1h 20m

Poster | Radiation-Tolerant C... | Thursday posters sessi...

Adam Klekotko

Test Bench of a 100G Radiation Hardened Link for Future Particle Accelerators

Oct 6, 2023, 10:10 AM
20m
Sirocco Room

Oral | Optoelectronics and... | Optoelectronics and El...

Francesco Martina (CERN)

Thank you!

Dual use driver for high speed links transmitters in the future high energy physics experiments

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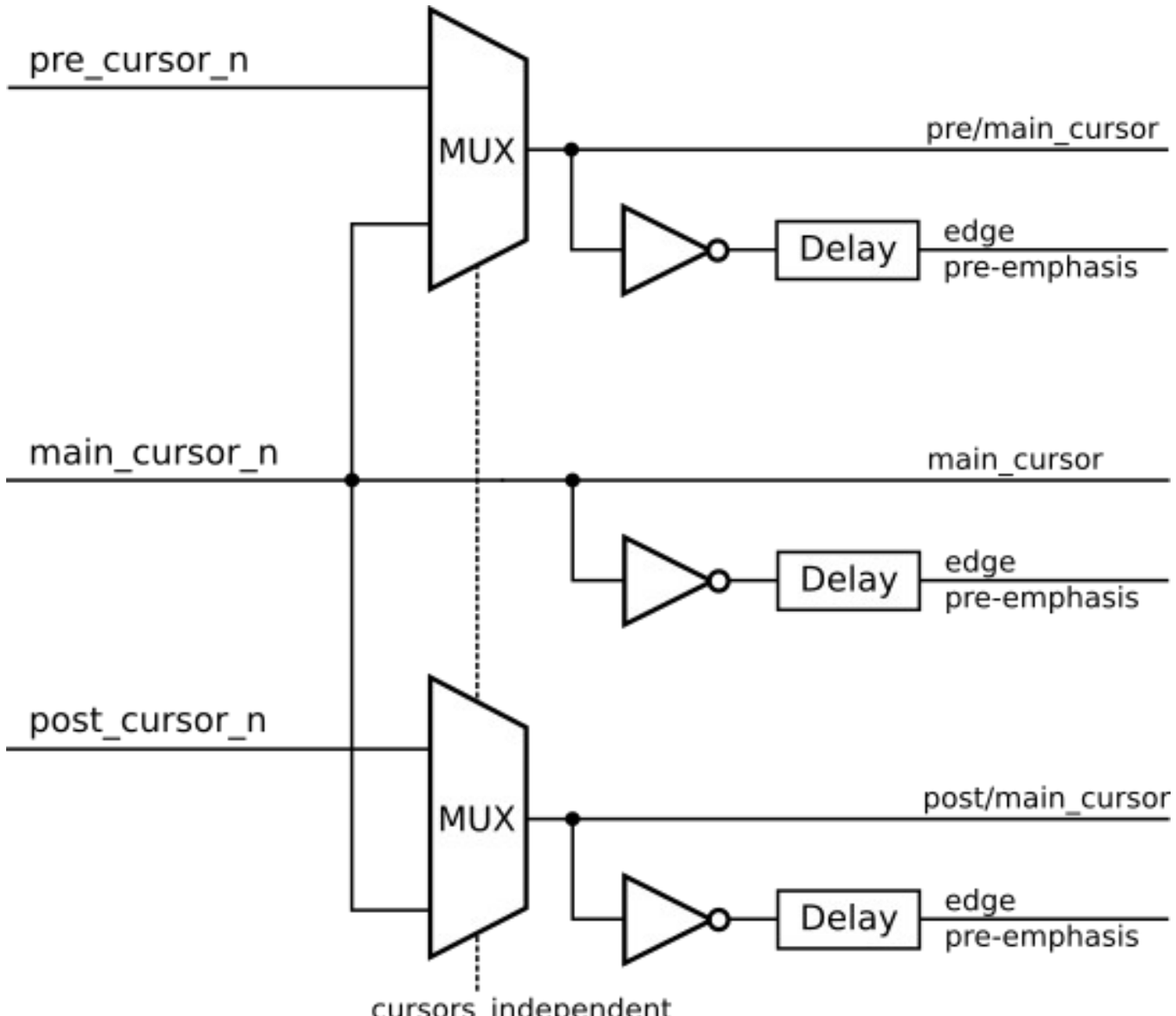
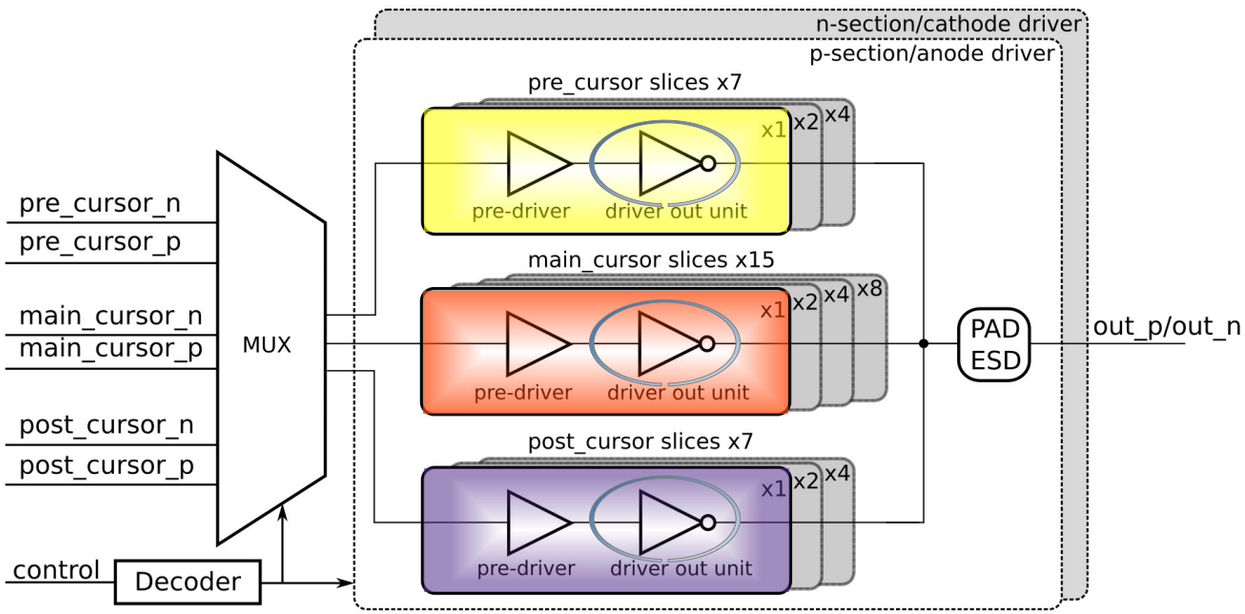
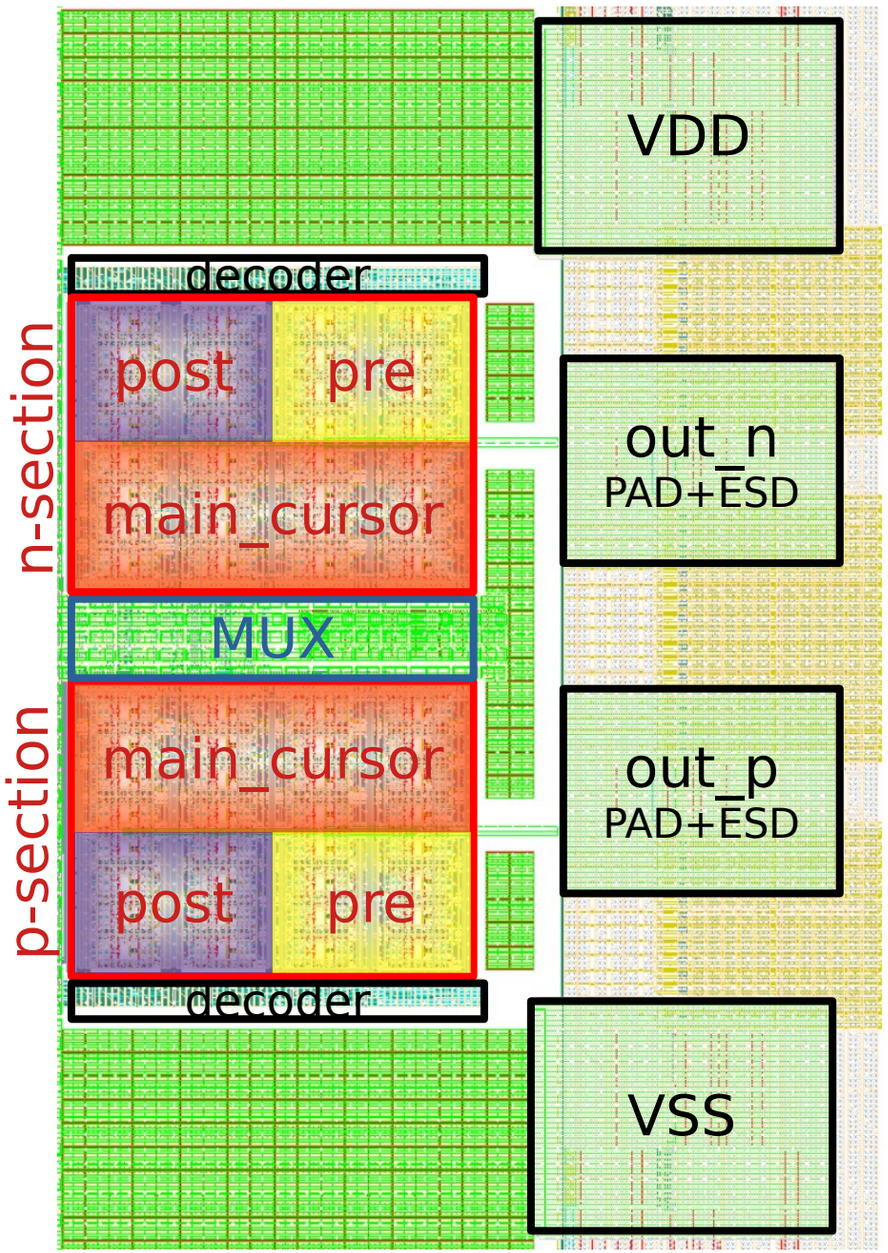
Input multiplexer

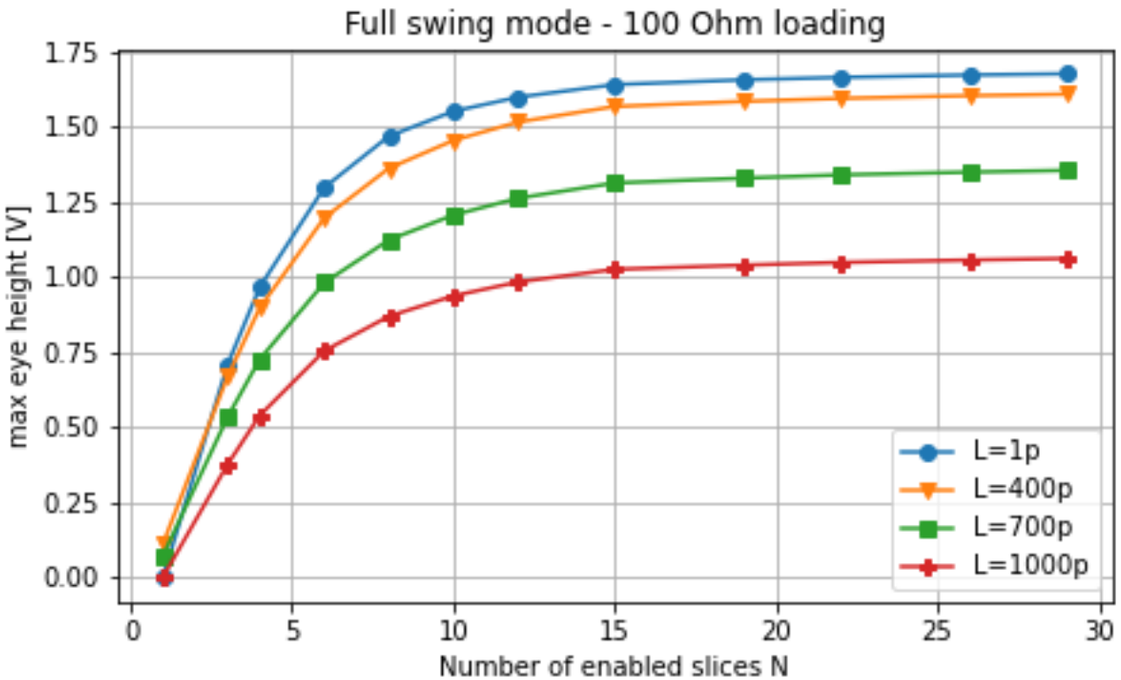


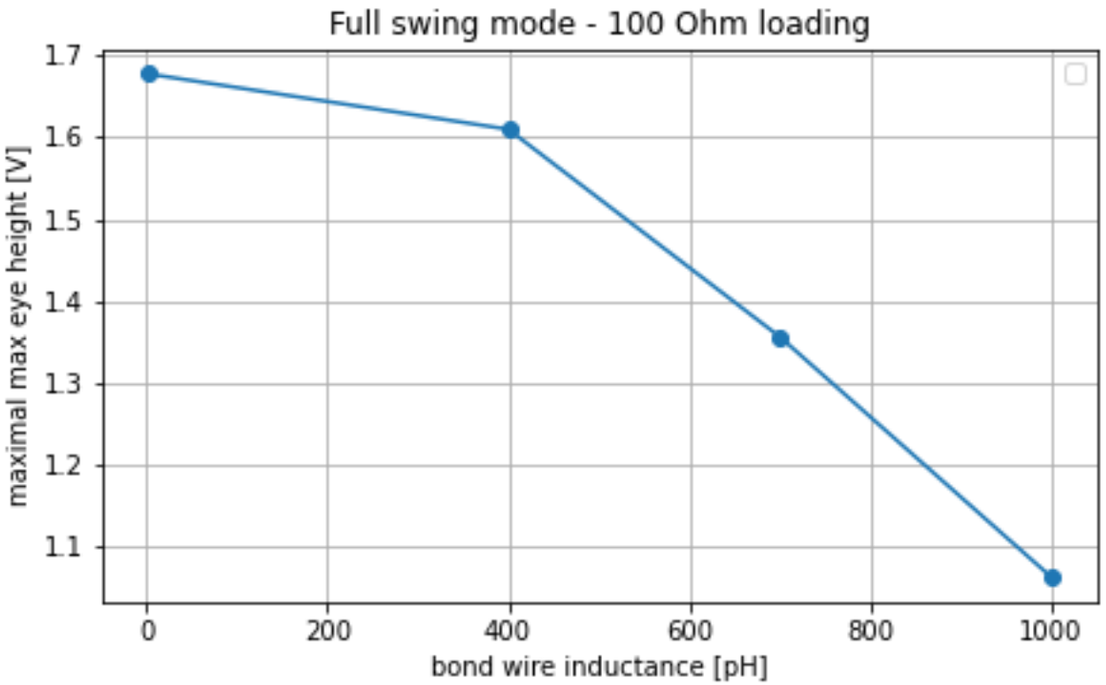
Driver layout



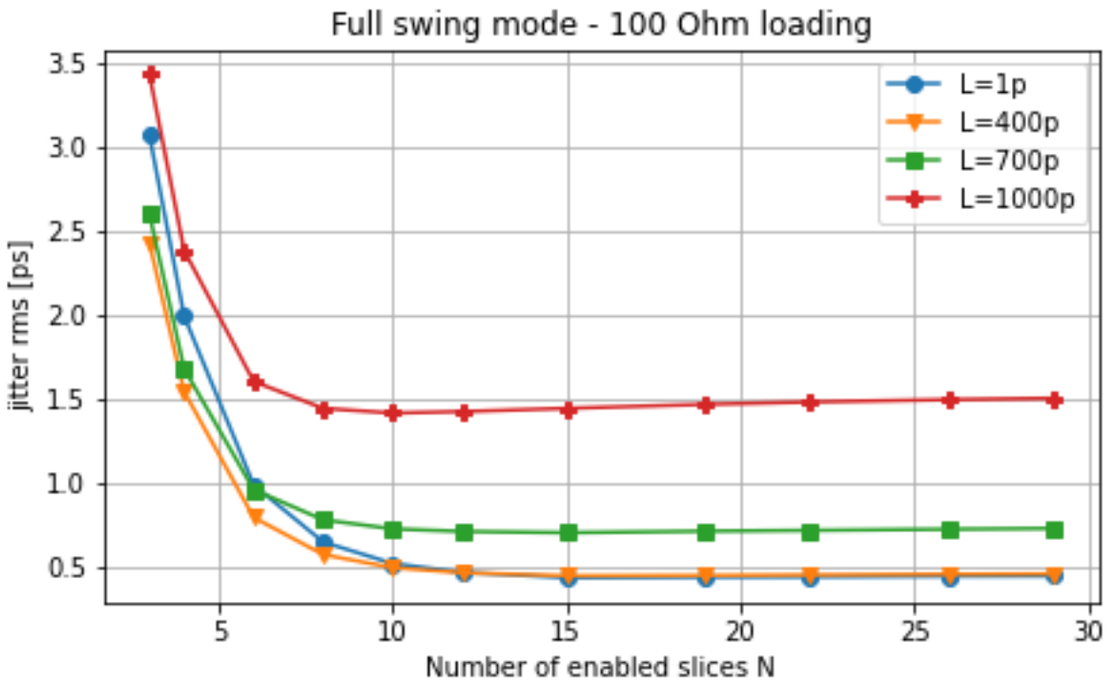


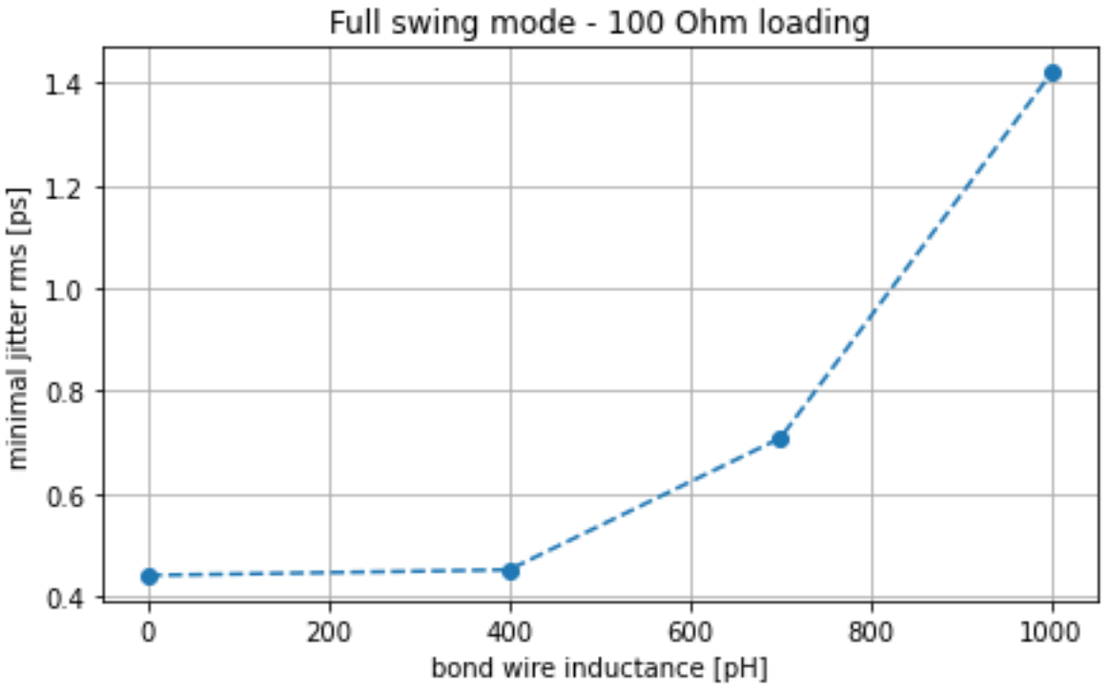
Full swing – 100Ω loading



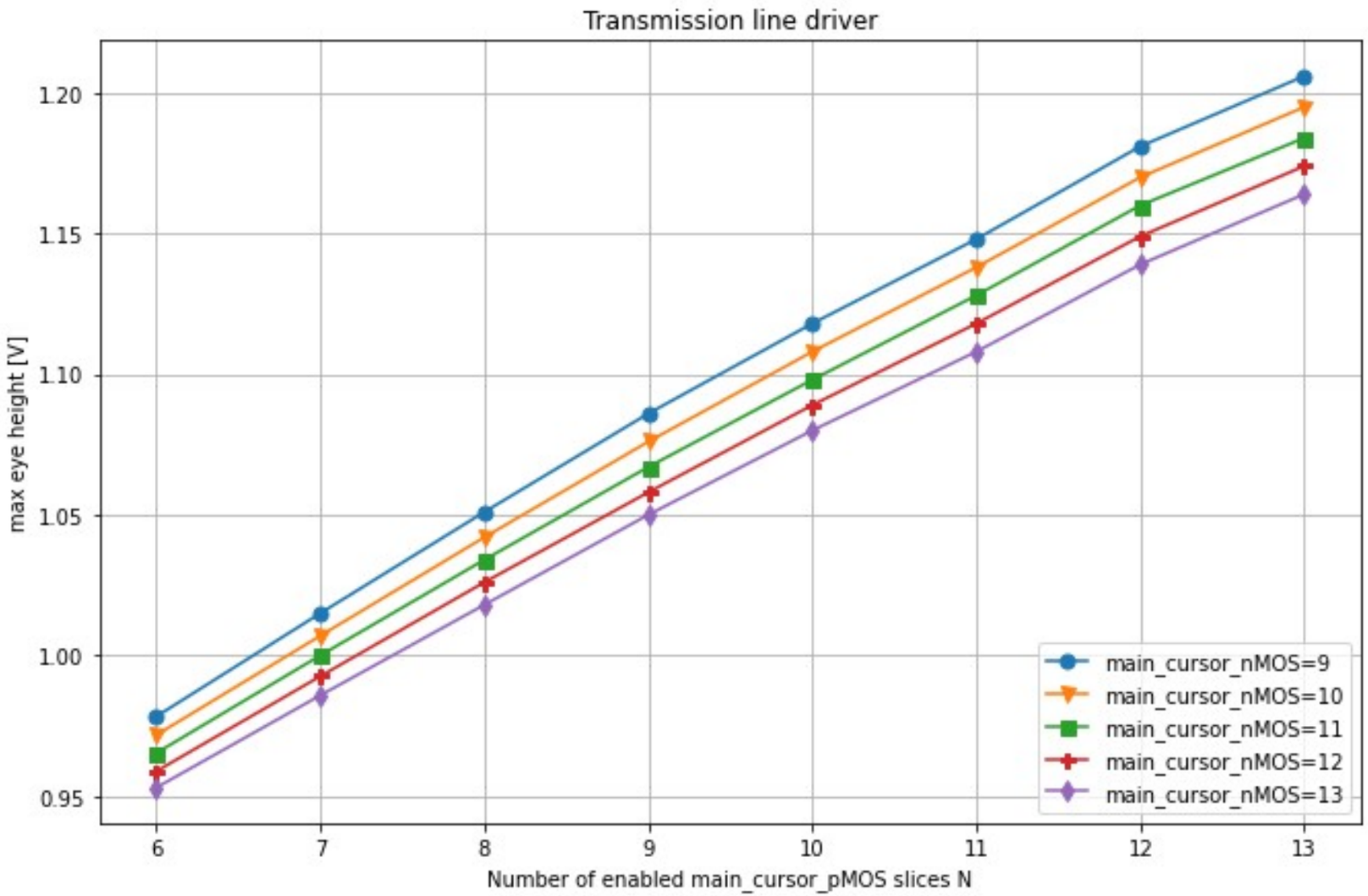


Full swing – 100Ω loading

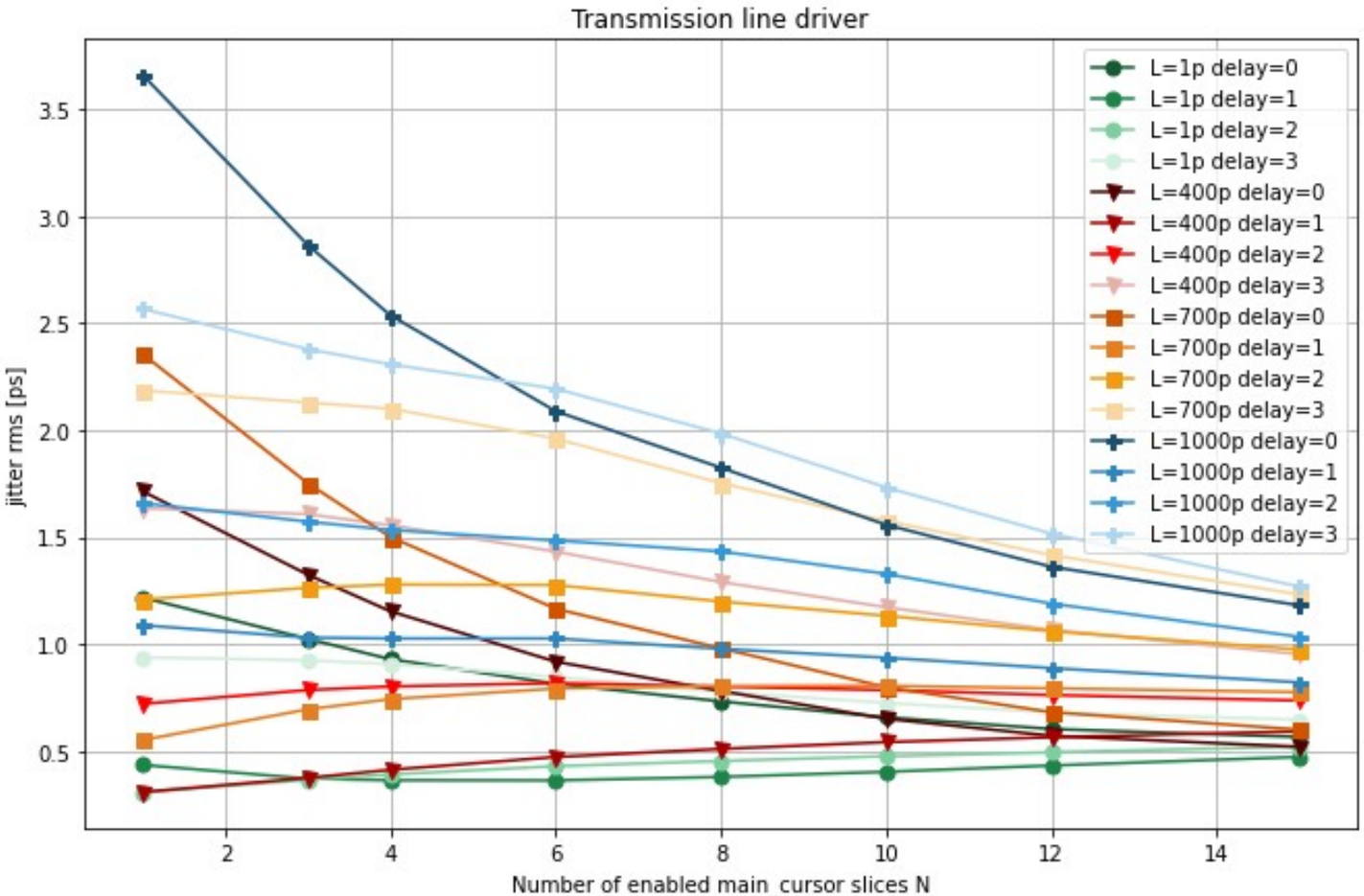


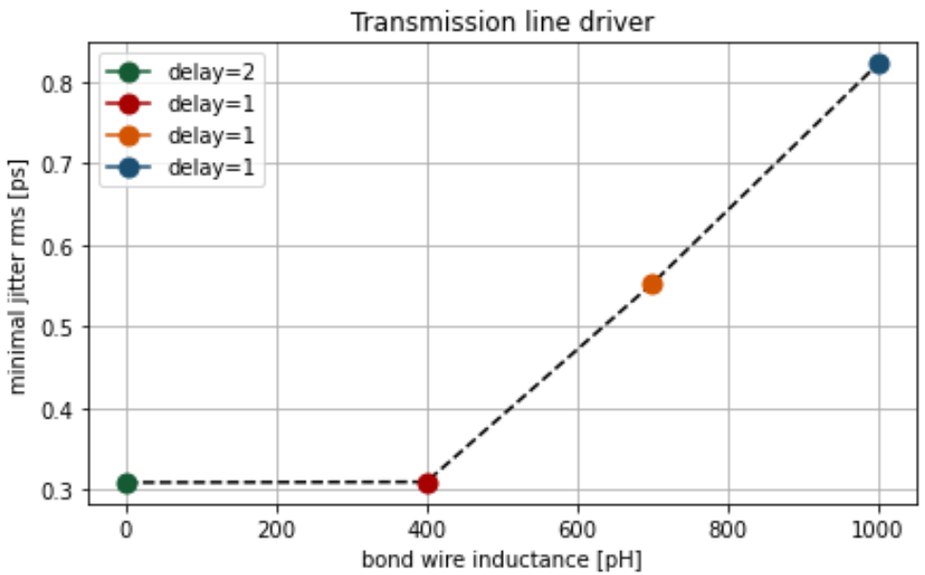


Reduced swing



Line driver – edge pre-emphasis





line driver - bit-level pre-emphasis

- By modulating the strength of pre-cursor and post-cursor it is possible to improve the parameters of eye diagram (the colored region on the plots)
- Dashed line presents parameters of the eye diagram when the pre-emphasis is turned of.