Gain and Equalization Adaptation to Optimize the Vertical Eye Opening in a Wireline Receiver

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Analog Front End Adaptation

Control signals should be generated automatically and should be able to adapt to a variety of channel conditions.
Outline

• Adaptation: existing and proposed technique

• Theory and implementation

• Simulated and measured results demonstrate validity
Analog Adaptation of EQ

- Filters consume large area
- Minimizing difference in high frequency content does not guarantee best equalization

BER-Based Adaptation of EQ

Ensures optimal eye opening but very complex and slow to converge

Proposed Architecture Test Setup

Adaptation can run continuously or in start-up calibration.
Variable Gain Preamplifier

- Gain controlled by analog signal $V_{\text{gain}}$

- Increased $V_{\text{gain}}$ results in decreased preamplifier gain

Analog Split-Path Equalizer

- High frequency peaking controlled by analog signal $V_{eq}$

- Increased $V_{eq}$ results in decreased low frequency gain and increased high frequency peaking

[10] Zhang, JSSC, 2005
EQ and VGA Simulation Results

**Variable gain amplifier:**
- 8 dB gain control
- Flat BW from 0 to 10 GHz

**Equalizer:**
- 8 dB low freq gain control
- high freq peaking

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Gain and Equalization Adaptation to Optimize the Vertical Eye Opening in a Wireline RX
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PDF Indicates Vertical Eye Quality

Transmitted Signal

\[ \text{X} \]

\[ V_{TH} \]

\[ V_{TL} \]

PDF

\[ t \]

Received Signal

\[ \text{X} \]

\[ V_{RH} \]

\[ V_{RL} \]

PDF

\[ t \]

‘x’ is a random variable created by sampling the PRBS data at the midpoint of each bit.
Threshold Sweep to Obtain PDF

PDF peak indicates equalization

Threshold at peak = $V_{RH}$
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Simulation Results – 10 m Cable

125 mV

30 mV
Simulation Results – Gain Setting

Eye Diagram - AFE Output

Amplitude

Time

Simulated Receiver PDF

Threshold Voltage (V)
Prototype in 65-nm CMOS

Vdd = 1.2 V

Adaptation performed off-chip with minimal additional hardware
1010 Pattern vs PRBS Data (2 Gb/s)

High peak = narrow PDF

Threshold at peak = eye amplitude
Measured Results – 2Gb PRBS

**Step 1:** Sweep $V_{eq}$ to find peak PDF

**Step 2:** Sweep $V_{gain}$ to set amplitude
Varying Channel Conditions

Coax Cable:
10 Gb/s (5 Gb/s for 30 m cable)

PCB Traces:
4 Gb/s for all lengths
Eye Diagrams – 10 Gb/s

10 m coaxial cable channel output

Receiver output after adaptation

Vertical: 100 mV/div

Horizontal: 50 ps/div
Conclusions

• Proposed adaptation technique:
  – Quickly optimizes vertical eye opening over a variety of channel types and lengths.
  – Optimizes equalizer peaking and preamplifier gain with a single set of data.
  – Can run continuously on parallel data line or at start up with minimal added circuitry.
Thank You
Channel Loss

S21 vs. Frequency

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