# JCTVC-H0280 CE10.2.1:
# Reducing one pixel line buffer by modified deblocking filter for horizontal LCU boundaries

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- Proposed method

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# Summary

- This contribution presents modified vertical filtering with reading 3 pixels and writing 2 pixels (R3W2) in deblocking
  - In HM5.0:
    - R4W3 filtering is applied to all boundaries
  - In this proposal:
    - R3W2 filtering is applied to only horizontal boundaries
    - R4W3 filtering is applied to the rest boundaries

- This proposal can save one pixel line buffer for deblocking filter

- BD-bitrates and subjective quality are kept the same level as HM5.0
  - Average BD-bitrates show 0.0% in all conditions with unchanged run-time
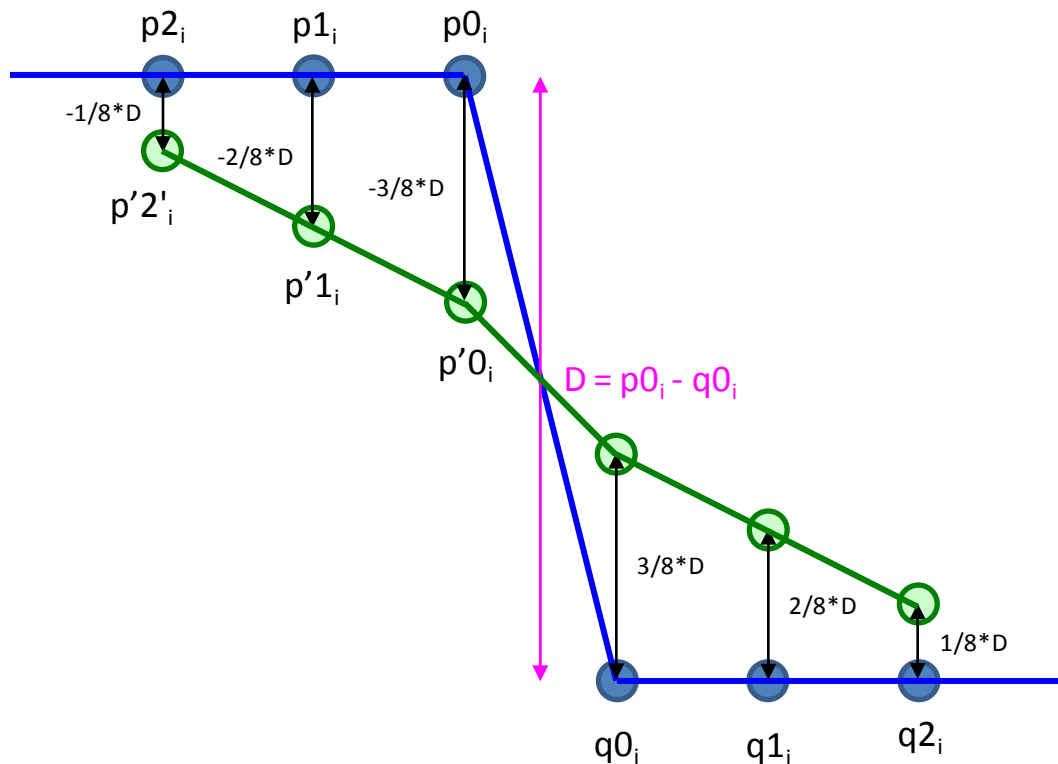
# Introduction

- Line buffer issue:
  - HEVC has 3 loop filters (DF/SAO/ALF) and totally requires a lot of line buffers for 4K coding in LCU-based processing.
  - In last Geneva, VB processing was adopted for ALF line buffer reduction, but DF still require 4 and 2 lines for both luma and chroma respectively

- Therefore more reduction is desired for DF

# Proposed method

- R3W2 filtering is applied to only horizontal LCU boundaries

- Strong/weak selection
  - Use $p2_i$ instead of $p3_i$

    $d < (\beta>>2)$ and $(|p2_i - p0_i| + |q0i - q'3_i|) < (\beta>>3)$ and $|p'0_i - q0_i| < ((5*tc+1)>>1)$

- Strong filter
  - 2 pixels above horizontal LCU boundaries are filtered
  - Filter coefficient for only 1 pixel is modified to keep the visual quality
    - The gate size is estimated at 210 gate under TSMC 65nm LP Multi Vth process (200MHz with 45% margin) and very small.
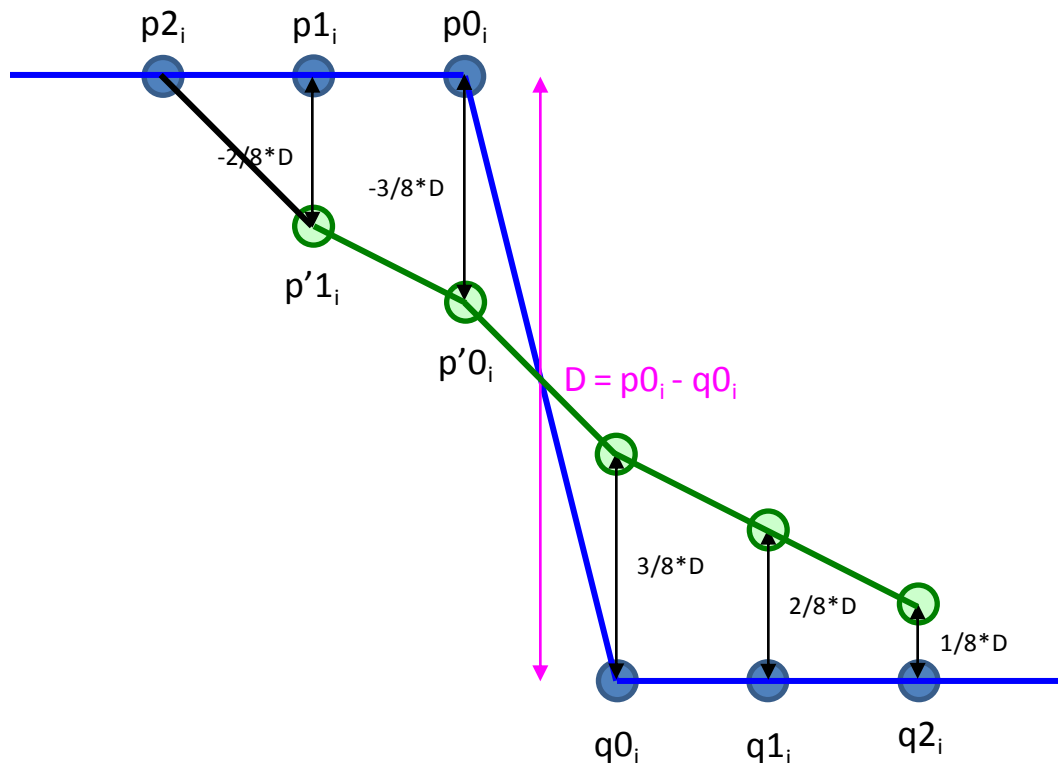
# Proposed method

- Currently strong filter is shown as green waveform

# Proposed method

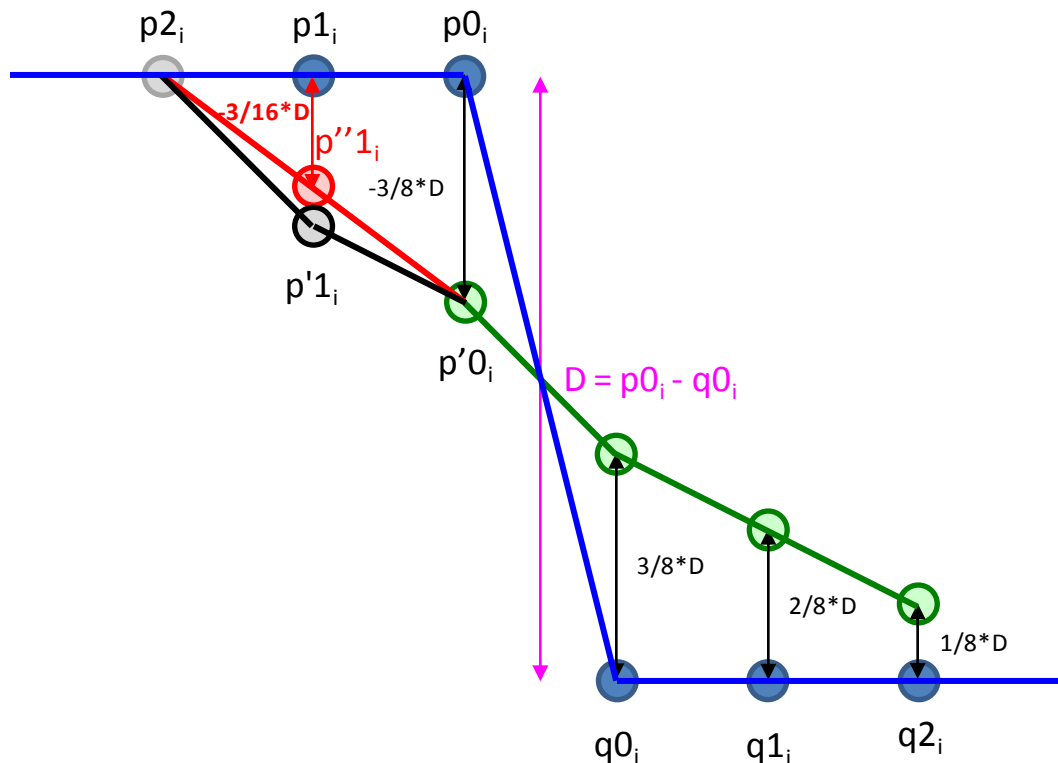- Currently strong filter is shown as green waveform

- p2 is not filtered in case of R3W2

  ⇒ Waveform between $p2_i$ and $p0'_i$ is not smoothed

# Proposed method

- Currently strong filter is shown as green waveform

- p2 is not filtered in case of R3W2

  ⇒ Waveform between $p2_i$ and $p0'_i$ is not smoothed

- Modify $p'1_i$ to $p''1_i$ to smooth the waveform

# Experimental results

With modified VB

- BD-bitrates and run-time are similar with HM5.0

- The visual quality for sequences including class-F and internal's is similar with HM5.0 in internal viewing

|  | All Intra HE | | | All Intra LC | | |
|---|---|---|---|---|---|---|
|  | Y | U | V | Y | U | V |
| Class A | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Class B | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Class C | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Class D | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Class E | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
|  |  |  |  |  |  |  |
| Overall | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
|  | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Class F | 0.4% | 0.0% | 0.0% | 0.4% | 0.0% | 0.0% |
| Enc Time[%] | | 99% | | | 99% | |
| Dec Time[%] | | 99% | | | 99% | |

|  | Random Access HE | | | Random Access LC | | | Random Access HE-10 | | |
|---|---|---|---|---|---|---|---|---|---|
|  | Y | U | V | Y | U | V | Y | U | V |
| Class A | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Class B | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% |
| Class C | 0.0% | -0.1% | 0.0% | 0.0% | 0.0% | 0.0% |  |  |  |
| Class D | 0.0% | -0.1% | -0.2% | 0.0% | 0.0% | 0.0% |  |  |  |
| Class E |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
| Overall | 0.0% | -0.1% | -0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
|  | 0.0% | -0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Class F | 0.3% | 0.1% | 0.1% | 0.2% | 0.0% | 0.0% |  |  |  |
| Enc Time[%] | | 100% | | | 100% | | | 100% | |
| Dec Time[%] | | 99% | | | 99% | | | 99% | |

|  | Low delay B HE | | | Low delay B LC | | |
|---|---|---|---|---|---|---|
|  | Y | U | V | Y | U | V |
| Class A |  |  |  |  |  |  |
| Class B | 0.0% | 0.1% | 0.2% | 0.0% | -0.2% | -0.1% |
| Class C | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.1% |
| Class D | 0.0% | -0.3% | -0.4% | 0.0% | 0.7% | -0.1% |
| Class E | 0.0% | 0.3% | 0.0% | 0.0% | -0.4% | 0.0% |
|  |  |  |  |  |  |  |
| Overall | 0.0% | 0.0% | -0.1% | 0.0% | 0.1% | 0.0% |
|  | 0.0% | 0.0% | -0.1% | 0.0% | 0.1% | 0.0% |
| Class F | 0.3% | -0.1% | -0.1% | 0.1% | -0.1% | -0.4% |
| Enc Time[%] | | 99% | | | 100% | |
| Dec Time[%] | | 100% | | | 100% | |

|  | Low delay P HE | | | Low delay P LC | | |
|---|---|---|---|---|---|---|
|  | Y | U | V | Y | U | V |
| Class A |  |  |  |  |  |  |
| Class B | 0.0% | 0.1% | -0.3% | 0.0% | 0.1% | -0.1% |
| Class C | 0.0% | 0.0% | -0.1% | 0.0% | 0.1% | 0.1% |
| Class D | 0.0% | 0.1% | -0.1% | -0.1% | -0.5% | 0.4% |
| Class E | 0.0% | -0.3% | 0.1% | 0.0% | -0.6% | -0.4% |
|  |  |  |  |  |  |  |
| Overall | 0.0% | 0.0% | -0.1% | 0.0% | -0.2% | 0.0% |
|  | 0.0% | 0.0% | -0.2% | 0.0% | -0.2% | 0.1% |
| Class F | 0.3% | 0.2% | 0.1% | 0.2% | -0.6% | 0.0% |
| Enc Time[%] | | 100% | | | 101% | |
| Dec Time[%] | | 100% | | | 102% | |

# Conclusions

- MediaTek and Sony propose R3W2 technique to reduce one pixel line buffer

- The average experimental results show 0.0% for all conditions with unchanged run-time

- The subjective quality is kept as the same level as HM5.0

# Appendix

# Experimental results

Without modified VB

- BD-bitrates and run-time are similar with HM5.0

- The visual quality for sequences including class-F and internal's is similar with HM5.0 in internal viewing

| | All Intra HE | | | All Intra LC | | | All Intra HE-10 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Y | U | V | Y | U | V | Y | U | V |
| Class A | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | | | |
| Class B | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | | | |
| Class C | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | | | |
| Class D | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | | | |
| Class E | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | | | |
| Overall | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | | | |
| | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | | | |
| Class F | 0.4% | 0.0% | 0.0% | 0.4% | 0.0% | 0.0% | | | |
| Enc Time[%] | | 100% | | | 99% | | | | |
| Dec Time[%] | | 99% | | | 99% | | | | |

| | Random Access HE | | | Random Access LC | | | Random Access HE-10 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Y | U | V | Y | U | V | Y | U | V |
| Class A | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.1% |
| Class B | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% |
| Class C | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | | | |
| Class D | 0.0% | -0.1% | -0.1% | 0.0% | 0.0% | 0.0% | | | |
| Class E | | | | | | | | | |
| Overall | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% |
| | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% |
| Class F | 0.3% | 0.1% | 0.1% | 0.2% | 0.0% | 0.0% | | | |
| Enc Time[%] | | 100% | | | 100% | | | 100% | |
| Dec Time[%] | | 100% | | | 99% | | | 100% | |

| | Low delay B HE | | | Low delay B LC | | | Low delay B HE-10 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Y | U | V | Y | U | V | Y | U | V |
| Class A | | | | | | | | | |
| Class B | 0.0% | 0.0% | 0.3% | 0.0% | -0.2% | -0.1% | | | |
| Class C | 0.0% | 0.0% | 0.1% | 0.0% | 0.1% | 0.1% | | | |
| Class D | -0.1% | -0.3% | -0.2% | 0.0% | 0.7% | -0.1% | | | |
| Class E | 0.0% | -0.7% | -0.2% | 0.0% | -0.4% | 0.0% | | | |
| Overall | 0.0% | -0.2% | 0.0% | 0.0% | 0.1% | 0.0% | | | |
| | 0.0% | -0.2% | 0.0% | 0.0% | 0.1% | 0.0% | | | |
| Class F | 0.3% | -0.3% | -0.2% | 0.1% | -0.1% | -0.4% | | | |
| Enc Time[%] | | 100% | | | 100% | | | | |
| Dec Time[%] | | 100% | | | 100% | | | | |

| | Low delay P HE | | | Low delay P LC | | | Low delay P HE-10 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Y | U | V | Y | U | V | Y | U | V |
| Class A | | | | | | | | | |
| Class B | 0.0% | 0.1% | -0.3% | 0.0% | 0.1% | -0.1% | | | |
| Class C | 0.1% | -0.1% | -0.2% | 0.0% | 0.1% | 0.1% | | | |
| Class D | 0.0% | 0.2% | -0.2% | -0.1% | -0.5% | 0.4% | | | |
| Class E | 0.0% | 0.0% | 0.3% | 0.0% | -0.6% | -0.4% | | | |
| Overall | 0.0% | 0.0% | -0.1% | 0.0% | -0.2% | 0.0% | | | |
| | 0.0% | 0.0% | -0.1% | 0.0% | -0.2% | 0.1% | | | |
| Class F | 0.4% | 0.3% | 0.2% | 0.2% | 0.0% | 0.0% | | | |
| Enc Time[%] | | 100% | | | 101% | | | | |
| Dec Time[%] | | 99% | | | 102% | | | | |