A HIGH PERFORMANCE AND LOW ENERGY INTRA PREDICTION HARDWARE FOR HIGH EFFICIENCY VIDEO CODING

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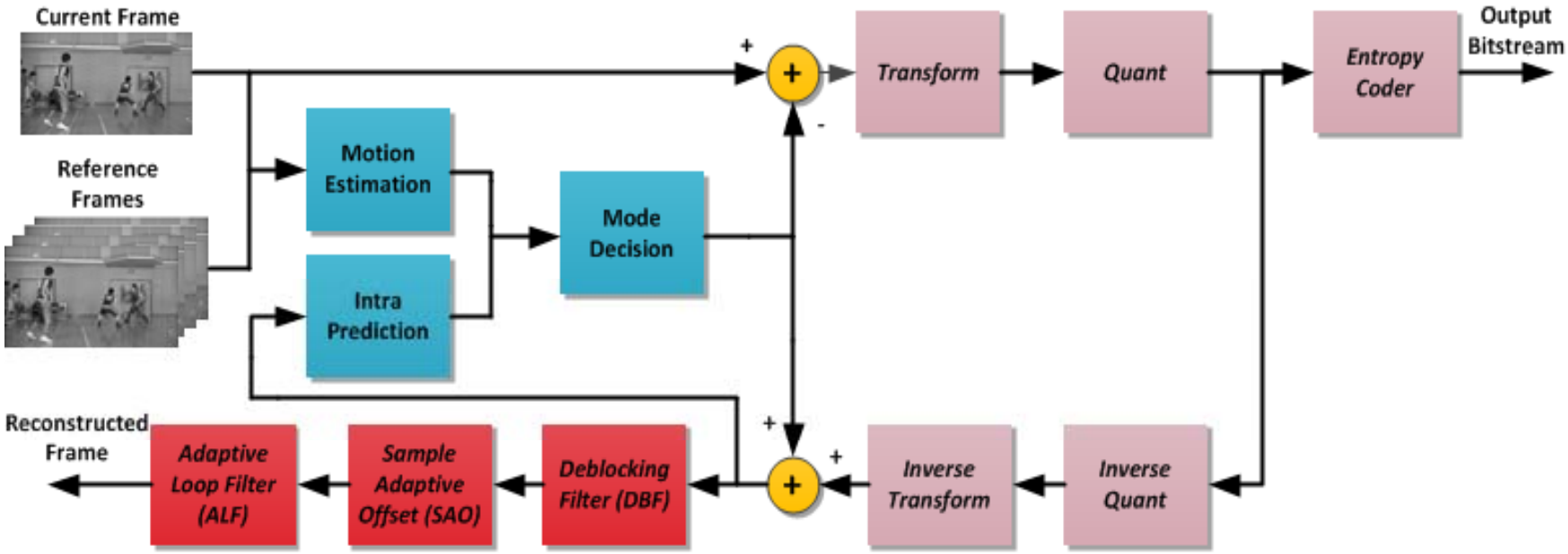
Outline

- HEVC Emerging Video Compression Standard
- HEVC Intra Prediction Algorithm
- Data Reuse Technique
- Pixel Equality based Computation Reduction Technique (PECR)
- Proposed HEVC Intra Prediction Hardware
- Energy Consumption Results

HEVC Video Compression Standard

HEVC has 36% better coding efficiency than H.264 video compression standard. It also provides 17% bit rate reduction for the intra prediction only case.



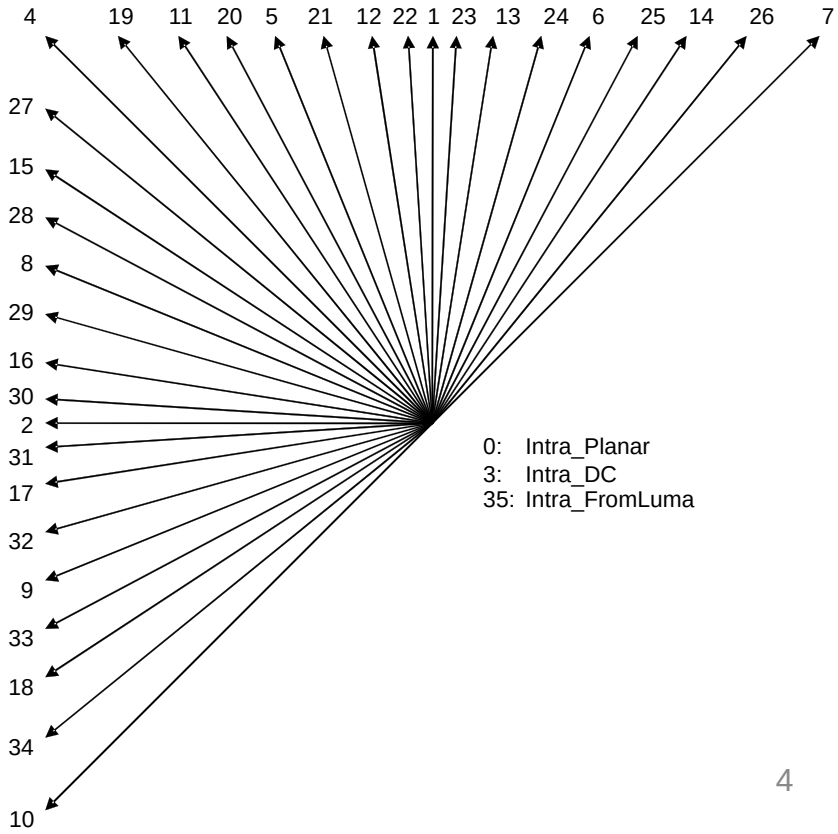
HEVC Encoder Block Diagram

HEVC Intra Prediction Algorithm

Intra prediction algorithm predicts the pixels in a MB using the pixels in the available neighboring blocks.

Intra prediction unit (PU) sizes can be from 4x4 up to 64x64 and number of intra prediction modes for a PU can be up to 35.

PU Size	# of Prediction Modes
4x4	17
8x8	34
16x16	34
32x32	34
64x64	4

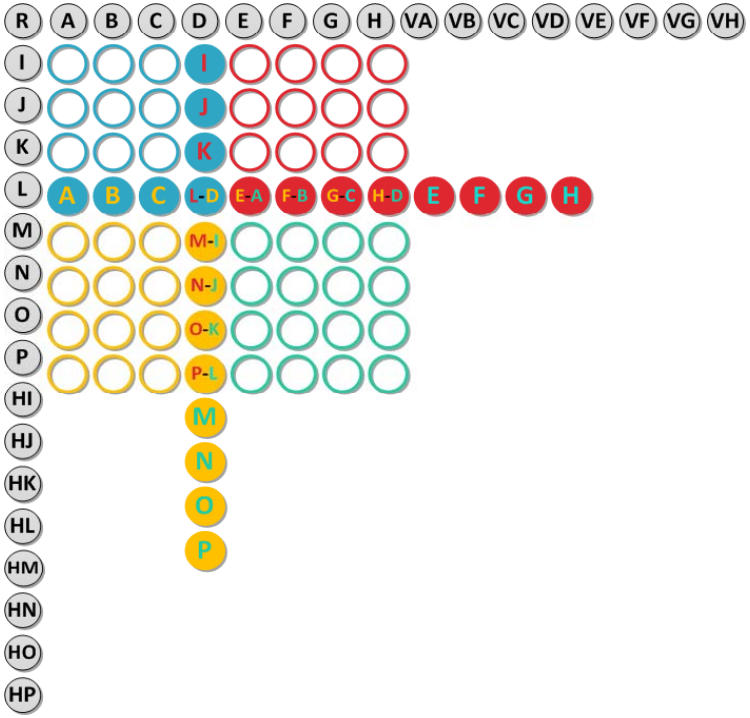


Data Reuse Technique

- HEVC intra 4x4 and 8x8 prediction modes have identical equations.
- There are identical equations between 4x4 and 8x8 luminance prediction modes as well.
- We calculated the common prediction equations for all 4x4 and 8x8 luminance prediction modes only once and used the results for the corresponding intra 4x4 and 8x8 prediction modes.

Pixel	Equations	PU Size	Used Modes	Pred. Pixels
I,J	[27I+5J+16] >> 5	4x4	1	4
		8x8	3	9
J,K	[22J+10K+16] >> 5	4x4	2	5
		8x8	4	9
K,L	[17K+15L+16] >> 5	4x4	1	4
		8x8	1	6
L,M	[12L+20M+16] >> 5	4x4	3	7
		8x8	5	11
M,N	[6M+26N+16] >> 5	4x4	0	0
		8x8	4	6
N,O	[30N+2O+16] >> 5	4x4	0	0
		8x8	4	9
O,P	[8O+24P+16] >> 5	4x4	0	0
		8x8	5	12
A,R	[11A+21R+16] >> 5	4x4	1	2
		8x8	1	2
A,B	[5A+27B+16] >> 5	4x4	1	4
		8x8	1	6
B,C	[10B+22C +16] >> 5	4x4	2	5
		8x8	2	7

The equation [27I+5J+16] >> 5 is used in 1 mode for 4 pixels in 4x4, and in 3 modes for 9 pixels in 8x8.



Pixel Equality based Computation Reduction Technique (PECR)

- Pixel Equality based Computation Reduction (PECR) technique compares the pixels used in the prediction equations of intra prediction modes. If the pixels used in a prediction equation are equal, this prediction equation simplifies to a constant value and prediction calculation for this equation becomes unnecessary.

Pixel	Equations	# of Add.	# of Shift
I,J	[27I+5J+16] >> 5	6	5
J,K	[22J+10K+16] >> 5	5	6
K,L	[17K+15L+16] >> 5	6	5
L,M	[12L+20M+16] >> 5	4	5
M,N	[6M+26N+16] >> 5	5	6
N,O	[30N+2O+16] >> 5	5	6
O,P	[8O+24P+16] >> 5	3	4
A,R	[11A+21R+16] >> 5	6	5
A,B	[5A+27B+16] >> 5	6	5
B,C	[10B+22C +16] >> 5	5	6

- Mode 8
  - pred[0, 0] = 27I + 5J + 16 >> 5
  - If I = J

    pred[0,0] = [32I+16] >> 32 = I

    pred[y,x] = I

- Overhead: 2914560 comparisons for an HD frame and 6557760 comparisons for a full HD frame
- No PSNR and bit rate loss

Percentages of 8x8 PUs with Equal Pixels

	Tennis (%)			Kimono (%)			Vidyo 1 (%)			Vidyo 3 (%)		
	QP			QP			QP			QP		
Pixels	**28**	**35**	**42**	**28**	**35**	**42**	**28**	**35**	**42**	**28**	**35**	**42**
I,J	45.6	42.9	46.7	42.3	41.5	45.1	54.5	50.4	49.8	60.5	59.8	62.2
J,K	43.8	45.0	51.5	43.9	45.5	49.6	57.4	56.9	47.1	64.4	63.7	66.4
K,L	44.9	45.8	52.7	43.9	46.0	51.1	57.7	57.0	58.5	63.9	63.9	66.8
L,M	46.2	46.3	53.8	43.1	46.0	51.1	57.5	57.3	58.7	62.8	64.8	67.1
A,R	62.9	68.6	72.8	39.9	42.0	47.8	37.5	38.1	37.9	51.3	53.0	51.1
A,B	73.3	74.3	75.4	46.0	46.0	51.0	43.8	41.1	38.6	59.1	58.5	56.7
B,C	77.5	79.6	81.0	47.7	50.0	55.4	44.8	44.9	44.4	62.7	61.9	61.1
C,D	77.0	79.4	82.0	47.6	50.8	57.0	45.7	45.3	46.3	63.4	63.2	62.0
D,E	77.2	79.3	81.8	46.9	50.6	57.2	45.5	45.8	45.7	62.7	61.5	62.1
HI,HJ	79.4	82.2	83.0	56.9	57.5	61.0	66.4	64.9	66.6	71.0	71.6	73.7
VA,VB	58.4	58.2	62.9	56.4	57.5	62.4	55.1	53.9	52.7	67.6	68.3	66.8

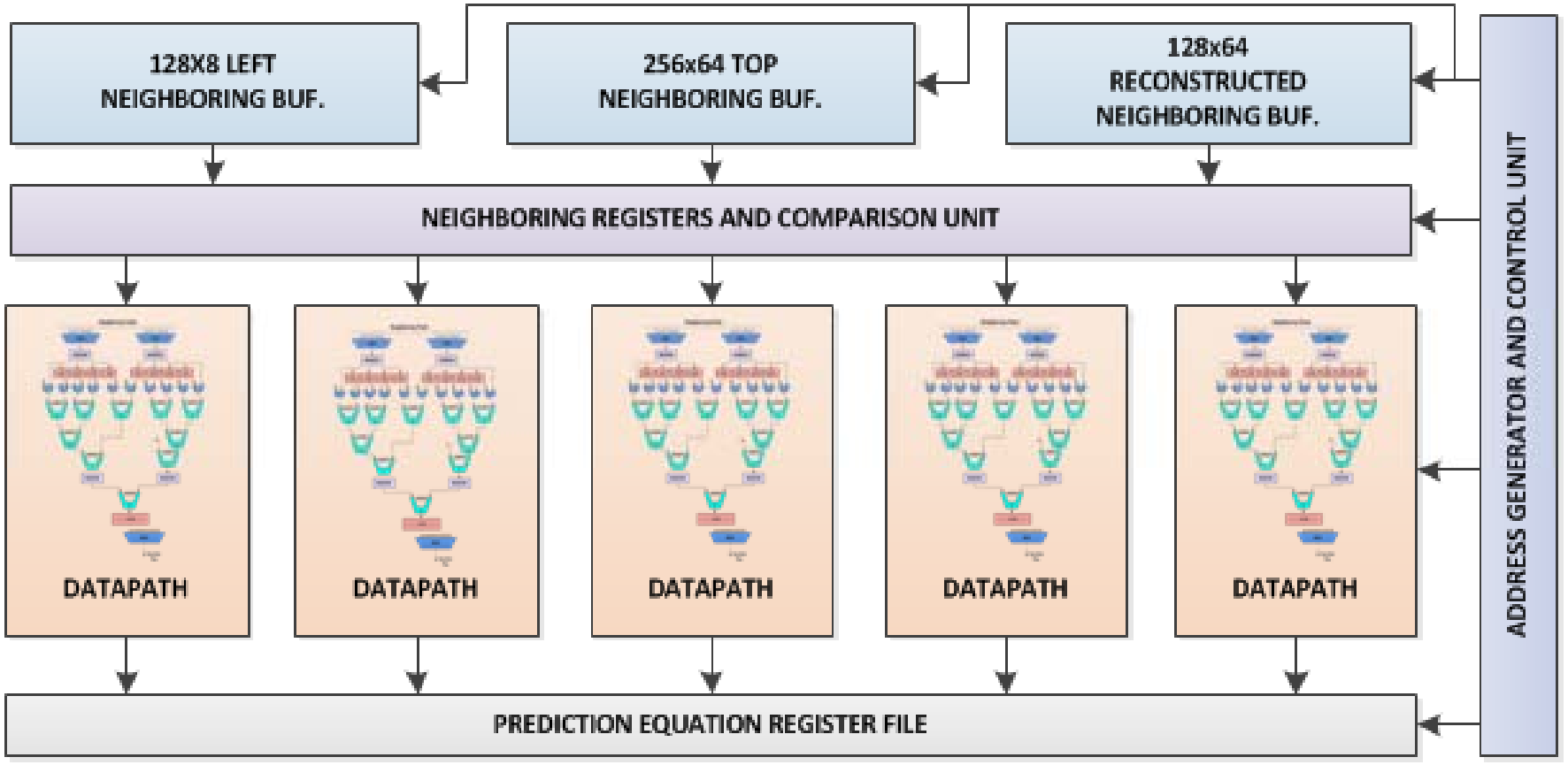
Computation Reduction Results

Frame Size		4x4 Only		8x8 Only		One 8x8 and Four 4x4	
		# of Add.	# of Shift	# of Add.	# of Shift	# of Add.	# of Shift
1280 x 720	Original	50462720	50462720	121425920	128902400	323276800	330753280
	Data Reuse	21514240	20782080	39283200	40381440	51336356	52060566
	Reduction	**57.37%**	**58.59%**	**67.65%**	**68.67%**	**84.12%**	**84.26%**
1920 x 1080	Original	113541120	113541120	273208320	290030400	727372800	744194880
	Data Reuse	48407040	46759680	88387200	90858240	115441920	117120960
	Reduction	**57.37%**	**58.59%**	**67.65%**	**68.67%**	**84.12%**	**84.26%**

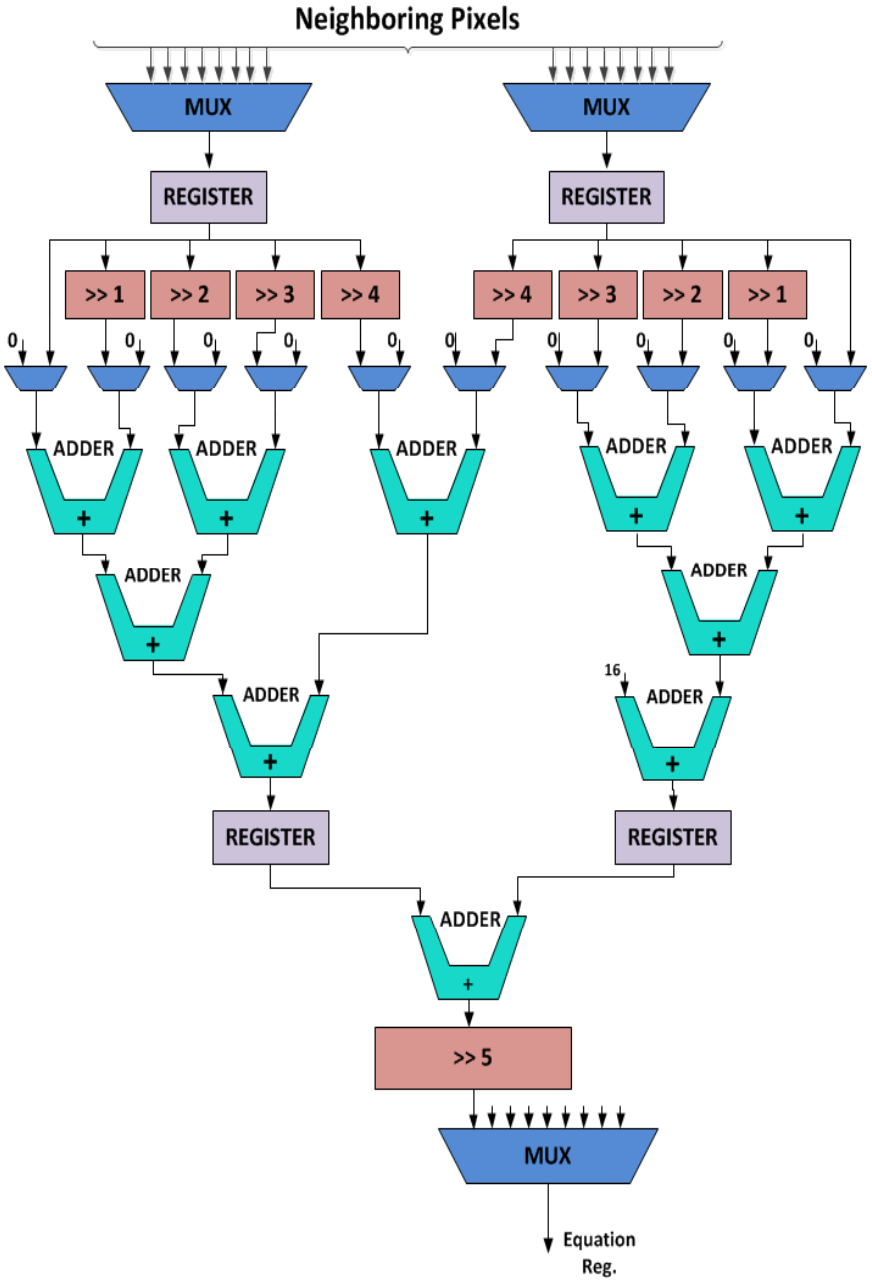
Frame	QP	4x4 Only		8x8 Only		One 8x8 and Four 4x4	
		Addition Reduction	Shift Reduction	Addition Reduction	Shift Reduction	Addition Reduction	Shift Reduction
Vidyo 1 (1280x720)	28	50.88%	50.87%	50.88%	50.87%	50.88%	52.99%
	42	50.04%	49.91%	51.02%	51.00%	50.82%	52.86%
Vidyo 3 (1280x720)	28	61.82%	61.73%	61.82%	61.73%	61.84%	63.78%
	42	62.89%	62.81%	62.89%	62.81%	62.92%	64.91%
Tennis (1920x1080)	28	58.25%	58.08%	60.17%	60.09%	59.76%	59.66%
	42	62.92%	62.74%	65.73%	65.63%	65.11%	64.99%
Kimono (1920x1080)	28	44.75%	44.62%	46.15%	46.14%	45.84%	45.82%
	42	50.60%	50.47%	52.65%	52.62%	52.20%	52.16%

Computation Reduction by PECR Technique for Intra Prediction after Data Reuse

Proposed HEVC Intra Prediction Hardware



Datapath



- Five parallel datapaths calculate all 4x4 and 8x8 intra prediction modes.
- One 8x8 and four 4x4 PU calculation takes 160 clock cycle.
- The Proposed Hardware can process 30 full HD (1920x1080) video frames per second.

Hardware Implementation

- The proposed hardware architecture is implemented using Verilog HDL.
- The implementation is synthesized and mapped to a XC6VLX75T Xilinx Virtex 6 FPGA with speed grade 3 using Xilinx ISE 12.3.
- The power consumption of the proposed hardware implementation on this FPGA is estimated at 125 MHz using Xilinx Xpower Analyzer.
  - Timing simulation of the placed and routed netlist is performed using ModelSim and the switching activities are stored in Value Change Dump (VCD) file.
  - This VCD file is used by Xilinx Xpower Analyzer for estimating the power consumption of the hardware implementation.

Energy Consumption Results

Category	Tennis				Kimono				Vidyo 1			
	Intra Pred. Hardware		Intra Pred. Hardware. with PECR		Intra Pred. Hardware		Intra Pred. Hardware. with PECR		Intra Pred. Hardware		Intra Pred. Hardware. with PECR	
	QP 28	QP 42	QP 28	QP 42	QP 28	QP 42	QP 28	QP 42	QP 28	QP 42	QP 28	QP 42
Time (ms)	42.101	42.101	32.180	31.467	42.101	42.101	33.427	31.890	18.711	18.711	15.134	13.425
Clock (mW)	13.27	13.27	17.12	16.35	13.27	13.27	17.17	16.84	13.27	13.27	15.31	15.27
Logic (mW)	13.87	13.43	9.37	8.99	13.78	13.89	10.14	9.33	12.68	12.39	10.14	9.45
Signal (mW)	14.48	14.18	8.48	7.94	14.34	14.01	9.27	8.58	13.95	13.79	9.77	9.06
BRAM (mW)	2.98	2.87	2.98	3.17	2.98	2.87	2.97	2.97	2.77	2.87	2.77	3.17
Power (mW)	44.6	43.75	37.95	36.45	44.37	44.04	39.55	37.72	42.67	42.32	37.99	36.95
Energy (mJ)	1877.7	1841.9	1221.2	1146.9	1868.0	1854.1	1322.0	1202.8	798.4	791.8	574.9	496.1
Energy Red.			**34.96%**	**37.73%**			**29.23%**	**35.12%**			**27.99%**	**37.35%**