APPENDIX A

MTCMOS

THRESHOLD VOLTAGES
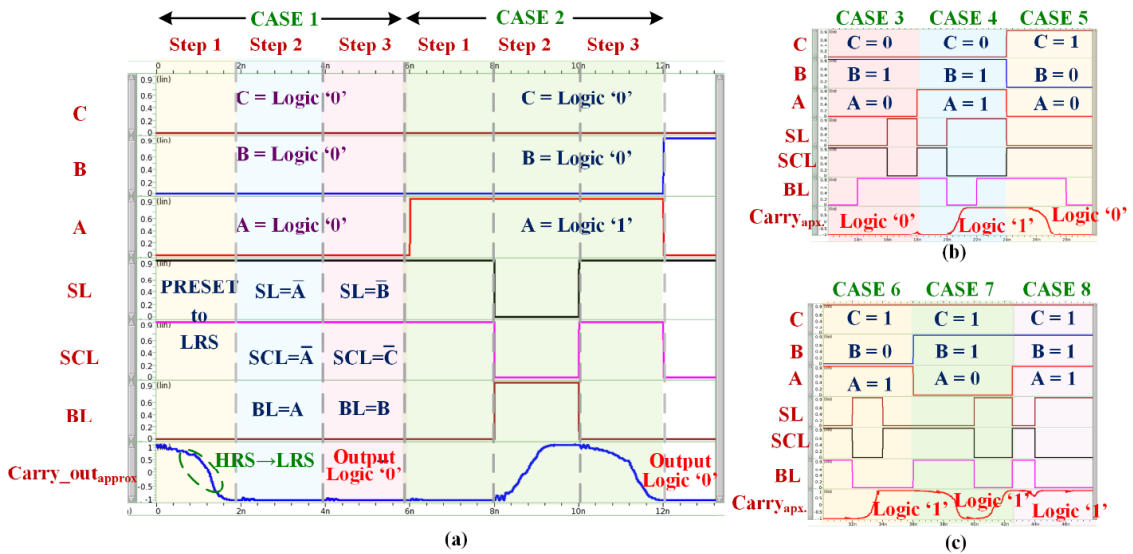
	Low Threshold Voltage ($V_{th,low}$)	High Threshold Voltage ($V_{th,high}$)
NMOS	0.322	0.6078
PMOS	-0.3021	-0.5044

APPENDIX B

SIMULATION RESULTS FOR APPROXIMATE ADDER
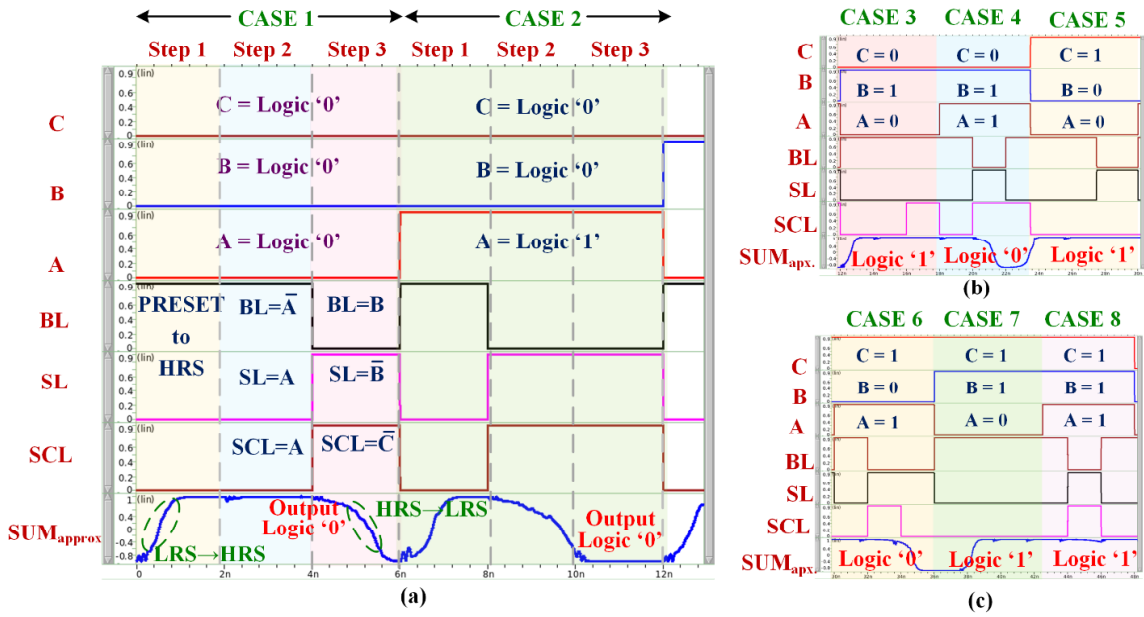
Simulation waveform to validate the SUM$_{approx}$ output of proposed approximate full adder for all the input combinations


Simulation waveform to validate the Carry_out$_{approx}$ output of proposed approximate full adder for all the input combinations

APPENDIX C

A Case Study of Image Processing: Edge Detection using Approximate Adder

We present a case study of sobel edge detection algorithm to demonstrate the application of proposed approximate adder in image processing. The simplicity of sobel edge detection algorithm lies in the fact that it can be mainly implemented using only addition operator. Therefore, we utilize proposed approximate adder to detect edges of a 512 X512 image. The convolution operation in sobel edge detection algorithm is implemented using both the approximate and the accurate/conventional adder as shown in Figure 1. The K number of LSB bits of the weighted neighbor elements (Temp_y) are given as input to the proposed approximate adder block while rest of the N^2-K bits are given as input to the accurate adder block. The carry from the approximate adder block is also given as input to the exact adder block. The final SUM is formed by combining results S_1-S_K of approximate block and S_{K+1} to S_N of exact adder block.
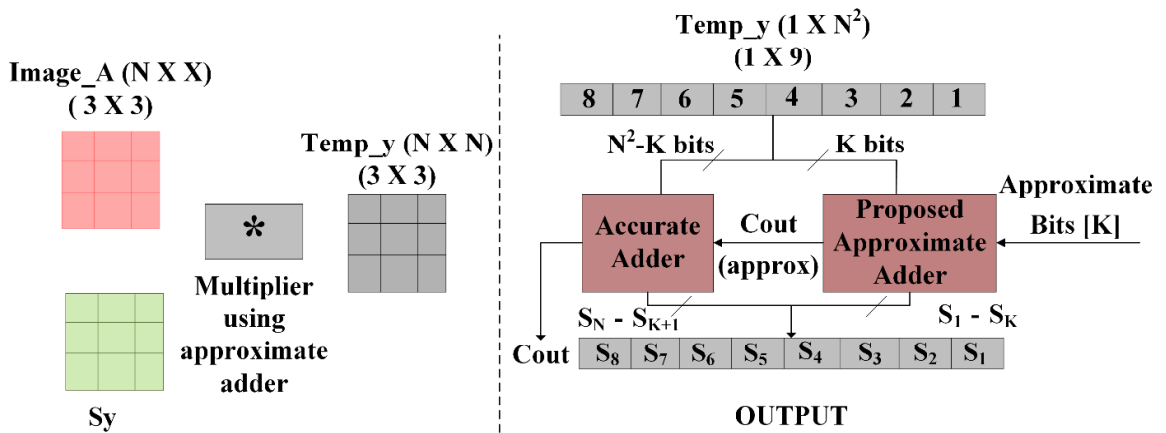
Performing convolution operation in sobel edge detection algorithm using approximate adder

To analyze the effect of approximation and determine the quality of resultant image and analyze the effect of approximation, following image quality metrics are calculated using MATLAB: Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR) and Structural Similarity Index (SSIM). Table I below tabulates the parameters with respect to K (number of LSB approximate bits) where K is varied from 1 to 4. From Table I, it is observed that the degradation in quality of resultant image increases with increasing K. Figure 2 shows the

resultant approximate images with calculated MSE, PSNR and SSIM value. Therefore, based on the computational accuracy requirement of the application optimal value of K can be selected.

TABLE I: IMAGE QUALITY METRICS FOR ANALYZING THE EFFECT OF APPROXIMATION

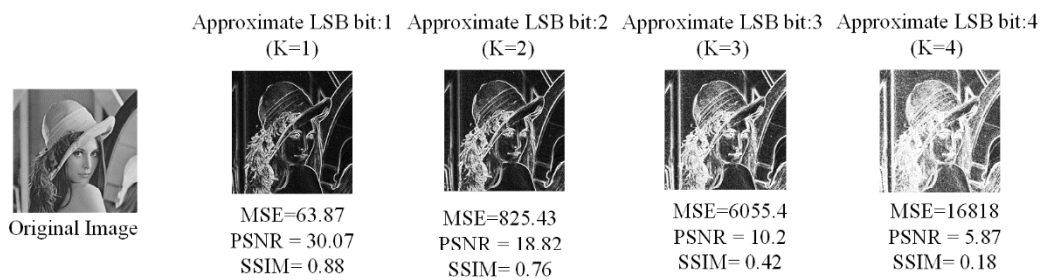| K	MSE	PSNR	SSIM
1 LSB	63.87	30.07	0.88
2 LSB	852.43	18.82	0.76
3 LSB	6055.4	10.30	0.42
4 LSB	16818	5.87	0.18

Figure 2: Resultant approximate images after implementing sobel edge algorithm on Image (512 X 512) with approximate adders