SHA256 Project

디지털설계및실험

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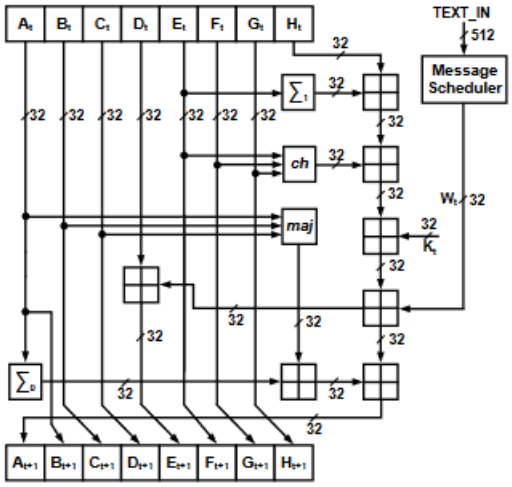
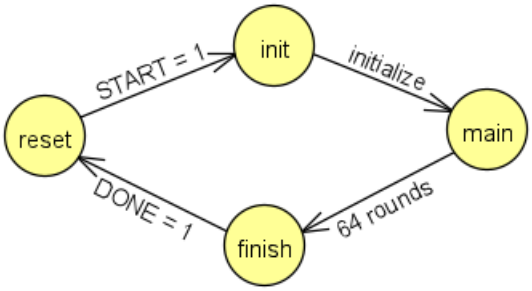
Datapath

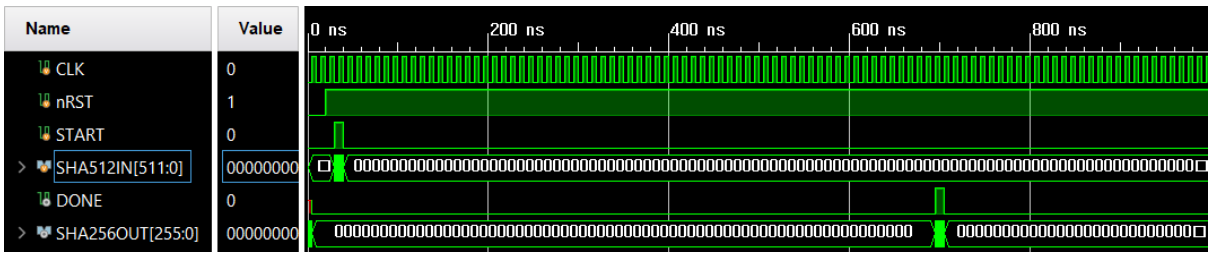


FSM



Waveforms

Behavioral simulation



Source description

C

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>

#define DEBUG 1

#define BYTE2BIT 8
#define WORD2BYTE 4
#define N_ROUND 64
#define MESSAGE_SIZE 512 / BYTE2BIT
#define HASH_SIZE 256 / BYTE2BIT / sizeof(int)

#define ROTR(x, n) (((x) >> (n)) | ((x) << (sizeof(int) * BYTE2BIT - (n))))

// SHA-256 Functions
#define CH(x, y, z) (((x) & (y)) ^ (~(x) & (z)))
#define MAJ(x, y, z) (((x) & (y)) ^ ((x) & (z)) ^ ((y) & (z)))
#define BSIG0(x) (ROTR((x), 2) ^ ROTR((x), 13) ^ ROTR((x), 22))
#define BSIG1(x) (ROTR((x), 6) ^ ROTR((x), 11) ^ ROTR((x), 25))
#define SSIG0(x) (ROTR((x), 7) ^ ROTR((x), 18) ^ ((x) >> 3))
#define SSIG1(x) (ROTR((x), 17) ^ ROTR((x), 19) ^ ((x) >> 10))

// SHA-256 Constants
const unsigned int K[N_ROUND] = {
        0x428a2f98, 0x71374491, 0xb5c0fbcf, 0xe9b5dba5, 0x3956c25b,
        0x59f111f1, 0x923f82a4, 0xab1c5ed5, 0xd807aa98, 0x12835b01,
        0x243185be, 0x550c7dc3, 0x72be5d74, 0x80deb1fe, 0x9bdc06a7,
        0xc19bf174, 0xe49b69c1, 0xefbe4786, 0x0fc19dc6, 0x240ca1cc,
        0x2de92c6f, 0x4a7484aa, 0x5cb0a9dc, 0x76f988da, 0x983e5152,
        0xa831c66d, 0xb00327c8, 0xbf597fc7, 0xc6e00bf3, 0xd5a79147,
        0x06ca6351, 0x14292967, 0x27b70a85, 0x2e1b2138, 0x4d2c6dfc,
        0x53380d13, 0x650a7354, 0x766a0abb, 0x81c2c92e, 0x92722c85,
        0xa2bfe8a1, 0xa81a664b, 0xc24b8b70, 0xc76c51a3, 0xd192e819,
        0xd6990624, 0xf40e3585, 0x106aa070, 0x19a4c116, 0x1e376c08,
        0x2748774c, 0x34b0bcb5, 0x391c0cb3, 0x4ed8aa4a, 0x5b9cca4f,
        0x682e6ff3, 0x748f82ee, 0x78a5636f, 0x84c87814, 0x8cc70208,
```

```
	0x90befffa, 0xa4506ceb, 0xbef9a3f7, 0xc67178f2
};

#if DEBUG
int count = 0;
#endif

void parse(unsigned char text[MESSAGE_SIZE], unsigned char text_parse[MESSAGE_SIZE]);
void process(unsigned char text_parse[MESSAGE_SIZE], unsigned int hash[HASH_SIZE]);
void print(unsigned int hash[HASH_SIZE]);

int main() {
	unsigned char text[MESSAGE_SIZE], text_parse[MESSAGE_SIZE] = {};
	// SHA-256 Initialization
	unsigned int hash[HASH_SIZE] = {
	0x6A09E667, 0xBB67AE85, 0x3C6EF372, 0xA54FF53A, 0x510E527F, 0x9B05688C,
0x1F83D9AB, 0x5BE0CD19
	};
	int i, j;

	printf("input text: ");
	scanf("%s", text);

	parse(text, text_parse);

#if DEBUG
	printf("input 512 bits: ");
	for (i = 0; i < MESSAGE_SIZE; i++) {
		printf("%02x", text_parse[i]);
	}
	printf("₩n₩n");
#endif

	process(text_parse, hash);

	printf("₩nresult: ");
	print(hash);

	return 0;
```

```
}

// SHA-256 Message Pading and Parsing
void parse(unsigned char text[MESSAGE_SIZE], unsigned char text_parse[MESSAGE_SIZE]) {
	int len, i;
	len = strlen(text);
	for (i = 0; i < len; i++) {
		text_parse[i] = text[i];
	}
	text_parse[i] = 1 << 7;
	text_parse[MESSAGE_SIZE - 1] = len * BYTE2BIT;
}

/*
 * SHA-256 Processing
 * 1. prepare the message schedule W
 * 2. initialize the working variables
 * 3. perform the main hash computation
 * 4. compute the hash value
 */
void process(unsigned char text_parse[MESSAGE_SIZE], unsigned int hash[HASH_SIZE]) {
	unsigned int W[N_ROUND] = {}, a, b, c, d, e, f, g, h, T1, T2;
	int i, j;

	// 1. prepare the message schedule W
	for (i = 0; i < 16; i++) {
		for (j = 0; j < WORD2BYTE; j++) {
			W[i] |= text_parse[WORD2BYTE * i + j] << BYTE2BIT * (WORD2BYTE -
(j + 1));
		}
	}
	for (; i < N_ROUND; i++) {
		W[i] = SSIG1(W[i - 2]) + W[i - 7] + SSIG0(W[i - 15]) + W[i - 16];
	}

	// 2. initialize the working variables
	a = hash[0];
	b = hash[1];
	c = hash[2];
```

```
	d = hash[3];
	e = hash[4];
	f = hash[5];
	g = hash[6];
	h = hash[7];

	// 3. perform the main hash computation
	for (i = 0; i < N_ROUND; i++) {
		T1 = h + BSIG1(e) + CH(e, f, g) + K[i] + W[i];
		T2 = BSIG0(a) + MAJ(a, b, c);
		h = g;
		g = f;
		f = e;
		e = d + T1;
		d = c;
		c = b;
		b = a;
		a = T1 + T2;
#if DEBUG
		printf("Round: %d --> A: %08x, B: %08x, C: %08x, D: %08x, E: %08x, F: %08x,
G: %08x, H: %08x, T1: %08x, T2: %08x₩n", ++count, a, b, c, d, e, f, g, h, T1, T2);
#endif
	}

	// 4. compute the hash value
	hash[0] = a + hash[0];
	hash[1] = b + hash[1];
	hash[2] = c + hash[2];
	hash[3] = d + hash[3];
	hash[4] = e + hash[4];
	hash[5] = f + hash[5];
	hash[6] = g + hash[6];
	hash[7] = h + hash[7];
}

// Print hash value
void print(unsigned int hash[HASH_SIZE]) {
	int i;
	for (i = 0; i < HASH_SIZE; i++) {
```

```
                printf("%08x", hash[i]);
        }
}
```

Verilog

```
`define OUT_SIZE 256
`define IN_SIZE 512
`define WORD_SIZE 32
`define N_ROUND 64

// SHA-256 Functions
`define ROTR(x, n) (((x) >> (n)) | ((x) << (`WORD_SIZE - (n))))
`define CH(x, y, z) (((x) & (y)) ^ (~(x) & (z)))
`define MAJ(x, y, z) (((x) & (y)) ^ ((x) & (z)) ^ ((y) & (z)))
`define BSIG0(x) (`ROTR((x), 2) ^ `ROTR((x), 13) ^ `ROTR((x), 22))
`define BSIG1(x) (`ROTR((x), 6) ^ `ROTR((x), 11) ^ `ROTR((x), 25))
`define SSIG0(x) (`ROTR((x), 7) ^ `ROTR((x), 18) ^ ((x) >> 3))
`define SSIG1(x) (`ROTR((x), 17) ^ `ROTR((x), 19) ^ ((x) >> 10))

module sha256(DONE, SHA256OUT, CLK, nRST, START, SHA512IN);

output reg DONE;
output reg [`OUT_SIZE - 1:0] SHA256OUT;
input CLK, nRST, START;
input [`IN_SIZE - 1:0] SHA512IN;

parameter reset = 2'd0,
                  init = 2'd1,
                  main = 2'd2,
                  finish = 2'd3;

reg [`IN_SIZE - 1:0] data;
reg [`OUT_SIZE - 1:0] hash;
reg [`WORD_SIZE - 1:0] a, b, c, d, e, f, g, h, T1, T2, K[0:`N_ROUND - 1], W[0:`N_ROUND - 1];
reg [1:0] state, next_state;
reg [6:0] round_counter;

initial begin
```

```
		// SHA-256 Constants
		K[0] = 32'h428a2f98; K[1] = 32'h71374491; K[2] = 32'hb5c0fbcf;
		K[3] = 32'he9b5dba5; K[4] = 32'h3956c25b; K[5] = 32'h59f111f1;
		K[6] = 32'h923f82a4; K[7] = 32'hab1c5ed5; K[8] = 32'hd807aa98;
		K[9] = 32'h12835b01; K[10] = 32'h243185be; K[11] = 32'h550c7dc3;
		K[12] = 32'h72be5d74; K[13] = 32'h80deb1fe; K[14] = 32'h9bdc06a7;
		K[15] = 32'hc19bf174; K[16] = 32'he49b69c1; K[17] = 32'hefbe4786;
		K[18] = 32'h0fc19dc6; K[19] = 32'h240ca1cc; K[20] = 32'h2de92c6f;
		K[21] = 32'h4a7484aa; K[22] = 32'h5cb0a9dc; K[23] = 32'h76f988da;
		K[24] = 32'h983e5152; K[25] = 32'ha831c66d; K[26] = 32'hb00327c8;
		K[27] = 32'hbf597fc7; K[28] = 32'hc6e00bf3; K[29] = 32'hd5a79147;
		K[30] = 32'h06ca6351; K[31] = 32'h14292967; K[32] = 32'h27b70a85;
		K[33] = 32'h2e1b2138; K[34] = 32'h4d2c6dfc; K[35] = 32'h53380d13;
		K[36] = 32'h650a7354; K[37] = 32'h766a0abb; K[38] = 32'h81c2c92e;
		K[39] = 32'h92722c85; K[40] = 32'ha2bfe8a1; K[41] = 32'ha81a664b;
		K[42] = 32'hc24b8b70; K[43] = 32'hc76c51a3; K[44] = 32'hd192e819;
		K[45] = 32'hd6990624; K[46] = 32'hf40e3585; K[47] = 32'h106aa070;
		K[48] = 32'h19a4c116; K[49] = 32'h1e376c08; K[50] = 32'h2748774c;
		K[51] = 32'h34b0bcb5; K[52] = 32'h391c0cb3; K[53] = 32'h4ed8aa4a;
		K[54] = 32'h5b9cca4f; K[55] = 32'h682e6ff3; K[56] = 32'h748f82ee;
		K[57] = 32'h78a5636f; K[58] = 32'h84c87814; K[59] = 32'h8cc70208;
		K[60] = 32'h90befffa; K[61] = 32'ha4506ceb; K[62] = 32'hbef9a3f7;
		K[63] = 32'hc67178f2;

		// SHA-256 Initialization
		hash = {
			32'h6A09E667, 32'hBB67AE85, 32'h3C6EF372, 32'hA54FF53A, 32'h510E527F,
32'h9B05688C, 32'h1F83D9AB, 32'h5BE0CD19
		};
		next_state = 2'd0;
		round_counter = 5'd0;
end

always @(START) begin
		if (START) begin
			data = SHA512IN;
		end
end
```

```
always @(DONE) begin
	if (DONE) begin
		SHA256OUT = hash;
	end else begin
		SHA256OUT = 256'd0;
	end
end

always @(state or START or DONE) begin
	case (state)
		reset: begin
			if (START) begin
				next_state = init;
			end
		end
		init: begin
			next_state = main;
		end
		main: begin
			next_state = finish;
		end
		finish: begin
			if (DONE) begin
				next_state = reset;
			end
		end
	endcase
end

always @(posedge CLK) begin
	if (nRST) begin
		if (state == main) begin
			if (round_counter == `N_ROUND) begin
				state <= next_state;
			end
		end else begin
			state <= next_state;
		end
	end else begin
```

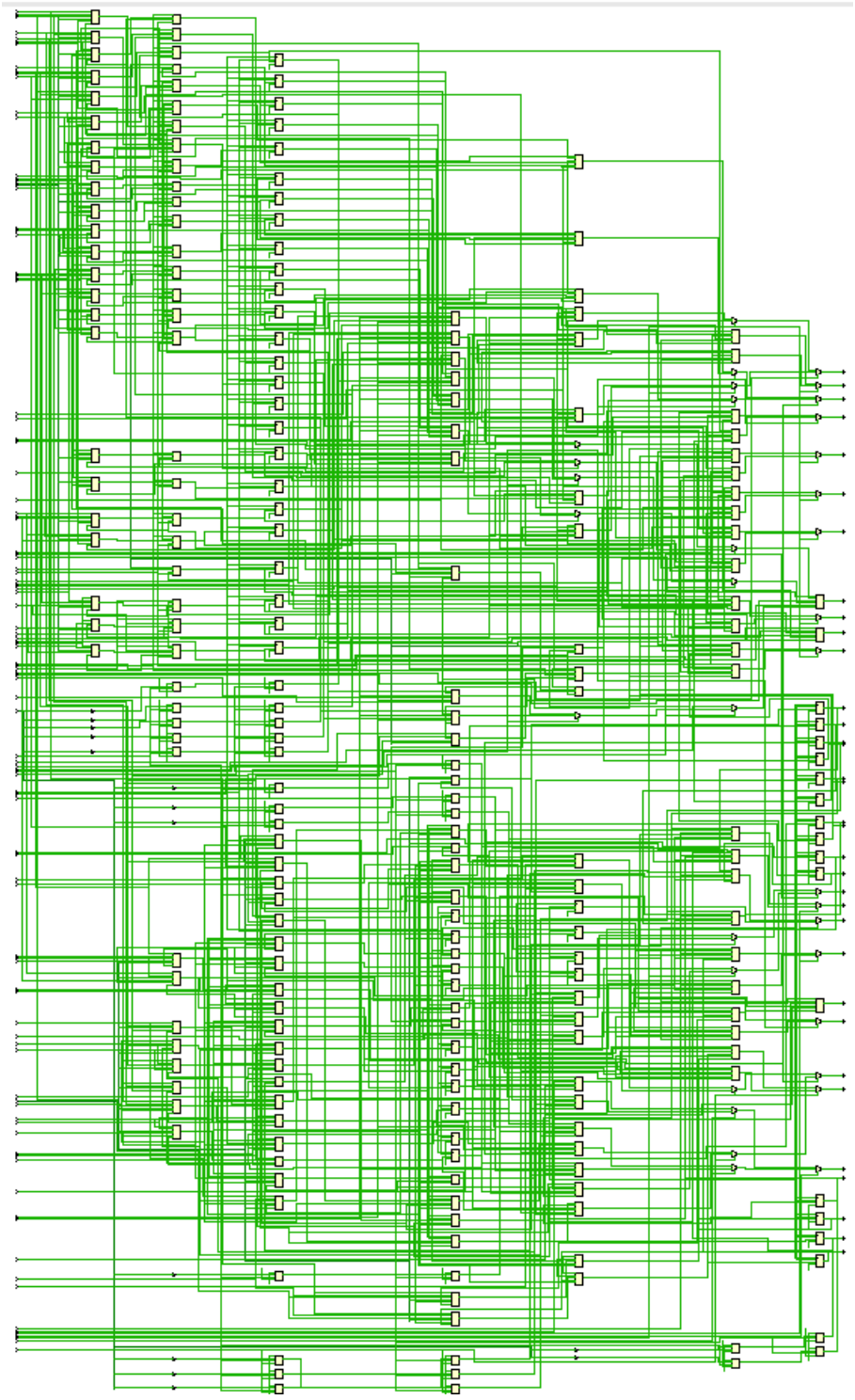
```
                state <= reset;
        end
end

always @(state) begin
        case (state)
                // Prepare the message schedule W[0] ~ W[15]
                // and initialize the working variables
                init: begin
                        W[0] = data[16 * `WORD_SIZE - 1:15 * `WORD_SIZE];
                        W[1] = data[15 * `WORD_SIZE - 1:14 * `WORD_SIZE];
                        W[2] = data[14 * `WORD_SIZE - 1:13 * `WORD_SIZE];
                        W[3] = data[13 * `WORD_SIZE - 1:12 * `WORD_SIZE];
                        W[4] = data[12 * `WORD_SIZE - 1:11 * `WORD_SIZE];
                        W[5] = data[11 * `WORD_SIZE - 1:10 * `WORD_SIZE];
                        W[6] = data[10 * `WORD_SIZE - 1:9 * `WORD_SIZE];
                        W[7] = data[9 * `WORD_SIZE - 1:8 * `WORD_SIZE];
                        W[8] = data[8 * `WORD_SIZE - 1:7 * `WORD_SIZE];
                        W[9] = data[7 * `WORD_SIZE - 1:6 * `WORD_SIZE];
                        W[10] = data[6 * `WORD_SIZE - 1:5 * `WORD_SIZE];
                        W[11] = data[5 * `WORD_SIZE - 1:4 * `WORD_SIZE];
                        W[12] = data[4 * `WORD_SIZE - 1:3 * `WORD_SIZE];
                        W[13] = data[3 * `WORD_SIZE - 1:2 * `WORD_SIZE];
                        W[14] = data[2 * `WORD_SIZE - 1:1 * `WORD_SIZE];
                        W[15] = data[1 * `WORD_SIZE - 1:0 * `WORD_SIZE];

                        a = hash[`WORD_SIZE * 8 - 1:`WORD_SIZE * 7];
                        b = hash[`WORD_SIZE * 7 - 1:`WORD_SIZE * 6];
                        c = hash[`WORD_SIZE * 6 - 1:`WORD_SIZE * 5];
                        d = hash[`WORD_SIZE * 5 - 1:`WORD_SIZE * 4];
                        e = hash[`WORD_SIZE * 4 - 1:`WORD_SIZE * 3];
                        f = hash[`WORD_SIZE * 3 - 1:`WORD_SIZE * 2];
                        g = hash[`WORD_SIZE * 2 - 1:`WORD_SIZE * 1];
                        h = hash[`WORD_SIZE * 1 - 1:`WORD_SIZE * 0];
                end
                // Compute the hash value
                finish: begin
                        hash[`WORD_SIZE * 8 - 1:`WORD_SIZE * 7] = a + hash[`WORD_SIZE *
8 - 1:`WORD_SIZE * 7];
```

```
                        hash[`WORD_SIZE * 7 - 1:`WORD_SIZE * 6] = b + hash[`WORD_SIZE *
7 - 1:`WORD_SIZE * 6];
                        hash[`WORD_SIZE * 6 - 1:`WORD_SIZE * 5] = c + hash[`WORD_SIZE *
6 - 1:`WORD_SIZE * 5];
                        hash[`WORD_SIZE * 5 - 1:`WORD_SIZE * 4] = d + hash[`WORD_SIZE *
5 - 1:`WORD_SIZE * 4];
                        hash[`WORD_SIZE * 4 - 1:`WORD_SIZE * 3] = e + hash[`WORD_SIZE *
4 - 1:`WORD_SIZE * 3];
                        hash[`WORD_SIZE * 3 - 1:`WORD_SIZE * 2] = f + hash[`WORD_SIZE * 3
- 1:`WORD_SIZE * 2];
                        hash[`WORD_SIZE * 2 - 1:`WORD_SIZE * 1] = g + hash[`WORD_SIZE *
2 - 1:`WORD_SIZE * 1];
                        hash[`WORD_SIZE * 1 - 1:`WORD_SIZE * 0] = h + hash[`WORD_SIZE *
1 - 1:`WORD_SIZE * 0];
                        DONE = 1'b1;
                end
                default: begin
                        DONE = 1'b0;
                end
        endcase
end

always @(posedge CLK) begin
        if (state == main) begin
                // Prepare the message schedule W[16] ~ W[63]
                if (round_counter >= 16) begin
                        W[round_counter] = `SSIG1(W[round_counter - 2]) + W[round_counter
- 7] + `SSIG0(W[round_counter - 15]) + W[round_counter - 16];
                end
                // Perform the main hash computation
                T1 = h + `BSIG1(e) + `CH(e, f, g) + K[round_counter] + W[round_counter];
                T2 = `BSIG0(a) + `MAJ(a, b, c);
                h = g;
                g = f;
                f = e;
                e = d + T1;
                d = c;
                c = b;
                b = a;
```

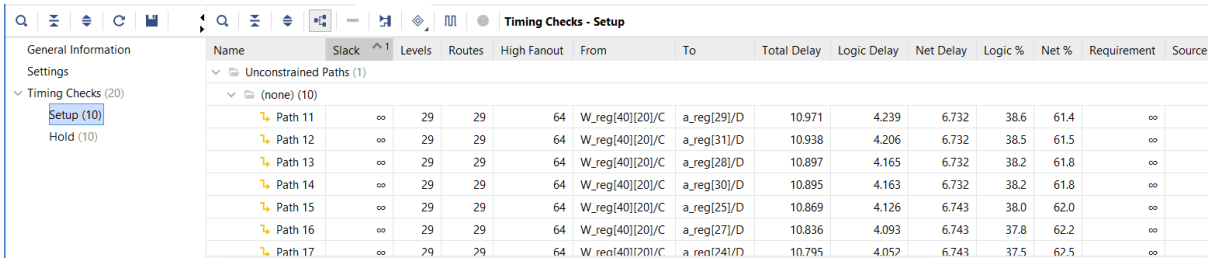
```
                    a = T1 + T2;
                    round_counter = round_counter + 1;
            end
end

endmodule
```

Synthesis

Schematic



Report timing



Report power