High Performance Cryptographic Hash Function On FPGA Using SHA-256

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Abstract:- ***Due to the rapid developments in the wireless communication area and personal communication systems, providing information security has become a more and more important subject. This security concept becomes a more complicated subject when next-generation system requirements and real-time computation speed are considered. In order to solve these security problems, lots of research and development activities are carried out and cryptography has been a very important part of any communication system in the recent years. Cryptographic hash functions are used to protect information integrity and authenticity in a wide range of applications. In this paper, we investigate high speed and low-area hardware architectures. The hardware is described in VHDL and verified on Xilinx FPGAs. The advantages and open issues of implementing hash functions using a processor structure are also discussed. The circuit realized through the FPGA is tested as a prototype.***

Index Terms— Cryptographic hash functions, SHA-2, VLSI implementations, low-power, latch memory.

I. INTRODUCTION

Cryptography is the branch of computer science that deals with security. It supports operations such as encryption and decryption. The cryptography is implemented in the form of hash functions, symmetric key algorithms, and public key algorithms. The symmetric and public key algorithms are used for encryption and decryption while hash functions are one way functions as they don't allow the retrieval of processed data. As MD5 and SHA are the two mostly used algorithms in the industry, this paper focuses on secure hash algorithm. Hash algorithms, also commonly called as message digest algorithms, are algorithms generating a unique fixed length bit vector for an arbitrary-length message *M*. The bit vector is called the hash of the message and it is here denoted as *H*. The hash can be considered as a fingerprint of the message. The hash function *H* must have the following properties:

- *One-way property*: for any given value *h*, it is computationally infeasible to find *x* such that $H(x) = h$.
- *Weak collision resistance*: for any given message *x*, it is computationally infeasible to find $y \neq x$ with $H(y) = H(x)$.
- *Strong collision resistance*: it is computationally infeasible to find any pair (x, y), such that $H(x) = H(y)$.

Hash Functions

Hash functions are used as a building block in various cryptographic applications. The most important uses are in the protection of information authentication and as a tool for digital signature schemes. A hash function is a function that maps an input of arbitrary length into a fixed number of output bits, the hash value. Hash functions can be divided into the following two basic categories:

- *One way hash functions*: these functions should be preimage and second preimage resistant, that is it should be hard to find a message with a given hash (preimage) or that hashes to the same value as a given message (second preimage).
- *Collision resistant*: it is one-way hash function for which it is hard to find two distinct messages that hash the same value.

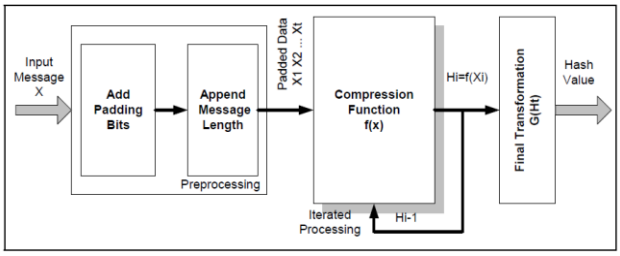


Figure 1: General Model of Hash Function

Most hash functions are designed to operate as iterative processes which hash input messages of arbitrary length. These functions process on fixed-size blocks of the input and produce a hash value of specified length (Fig. 1). The procedure is divided to pre-processing, compression and final transformation.

The pre processing mainly appends the necessary number of bits to the input message, in order to generate the padded data block of specified length. The padded data are divided to t blocks of equal length. Each block Xi serves as input to the compression function h, which computes each time a new transformed data message Hi, as a function of the previous Hi-1 and the input Xi. After a certain number of processing rounds, the data are finally modified by the final

transformation. In this way the hash value (message digest) is generated corresponding to the input message x.

The proposed architecture guarantees high security level, in all the applications requiring message authentication, via the construction of a message authentication code. The security strength and the advantages of the SHA-2 hash function that the proposed architecture is based on, ensures high security level, in the implementation of this authentication scheme Hash function 2 are cryptographic algorithms that take as input a message of arbitrary length, and that return a digest (or hash value) of fixed length (between 160 and 512 bits, in most applications). Hash functions are used in a multitude of protocols be it for digital signatures within high-end servers, or for authentication of embedded systems. Proposed design is a family of hash functions with internal state sizes: 256.

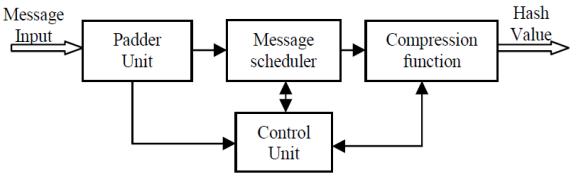
- Proposed Design-256 is our primary proposal.
- Proposed Design-256 is our low-memory variant.
- This allows the design to hash configuration data along with the input text in every block, and make every instance of the compression function unique.
- This property directly addresses many attacks on hash functions, and greatly improves Proposed Design's flexibility.

Efficient FPGA Hardware Implementation of Secure Hash Function SHA-2 Using VHDL Language to improve its performances in terms of area, frequency or throughput.

In this Thesis, we proposed a new design for the SHA-256 functions. Moreover, the proposed design has been implemented on Xilinx Virtex-6 FPGA. Its area, frequency and throughput have been compared and it is shown that the proposed design achieves good performance in term of area with a bit compromise in speed.

ALGORITHM SPECIFICATION

In previous year research paper several hardware optimization techniques for the SHA-2 hashing functions were explored. A new architecture that is Round Pipelined Technique was proposed for the SHA-2 core, which eliminates the data dependency between iteration using data forwarding to improve the throughput per area. The fully iterative and Round Pipelined Techniques were investigated and developed using HDL. Implementation result indicate that the Round Pipelined technique can help to achieve good tradeoff between throughput and area. Proposed research investigates optimization techniques in terms of area and resources for SHA-2 hash functions on the FPGA and achieves higher stable circuit with lowest number of hardware used hence increases the power efficiency although speed is bit slow.



Simplified architecture of the SHA-2 algorithm

SHA-2 has two main versions: SHA-32 and SHA512-64. This section gives a brief specification of these algorithms. A complete specification can be found in [7]. The BLAKE-32 algorithm operates on 32-bit words and returns a 256-bit hash value. It is based on the iteration of a compression function, described below.

1) Compression Function: Henceforth we shall use the following notations: if m is a message (a bit string), mi denotes its i-th 16-word block, and mij is the j-th word of the i-th block of m. Indices start from zero, for example a N-block message m is decomposed as

m= m0,m1,m2..... mN-1 and

the block m0 is composed of words .

m0= m01 ,m0 2,m03..... m015

Idem for other bit strings. Endianness conventions are described in [7]. The compression function of SHA-256 takes as input four values:

- a chaining value h = h0, . . . , h7.
- a message block m = m0, . . . ,m15.
- a salt s = s0, . . . , s3.
- a counter t = t0, t1.

These inputs represent 30 words in total (i.e., 960 bits). The salt is an optional input for special applications, such as randomized hashing [11]. The output of the compression function is a new chaining value h' = h'0, h'1,..... h'7. of eight words (i.e., 256 bits). We write h' := compress(h,m,s,t).

The compression function compress() can be decomposed into three main steps

a) Initialization: b) Round Function: c) Finalization:

2) Hashing a Message: When hashing a message, the function starts from an initial value (IV), and the iterated hash process computes intermediate hash values that are called chaining values. Before being processed, a message is first padded so that its length is a multiple of the block size (512 bits). It is then processed block per block by the compression function, as described below:

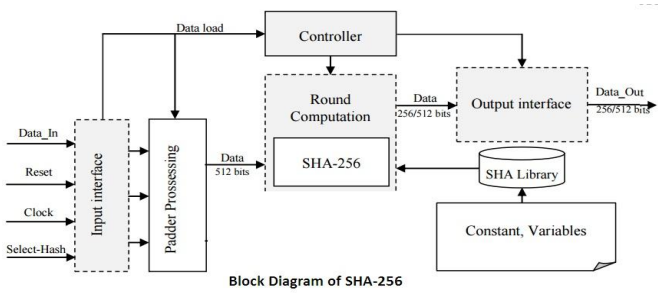
h0 := IV

for i = 0, . . . ,N − 1

hi+1 := compress(hi,mi,s,li)

return hN

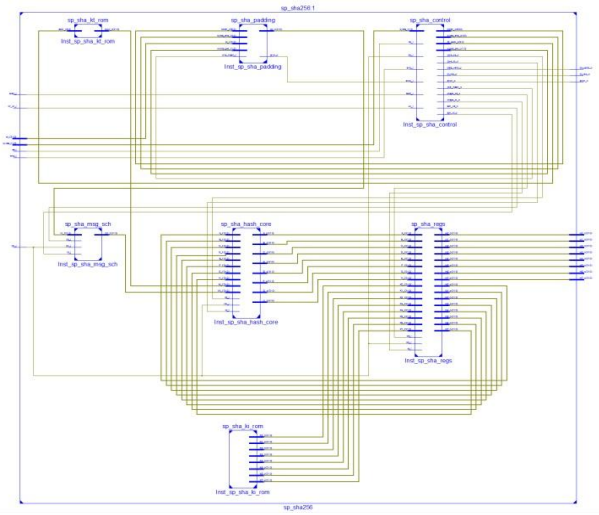
Here, li is the number of message bits in m0,m1,.....mi, that is, excluding the bits added by the padding. It is used to avoid certain generic attacks on the iterated hash (e.g., [12]). The salt s is chosen by the user, and set to zero by default.



Block Diagram of SHA-256

VLSI Implementation of SHA-2

The aim is to implement the designed hash function core on VHDL. The whole package and separate modules were synthesized and analyzed using Xilinx ISE 12.1 tool for the targeted Virtex-VI FPGA.



Complete Top Level Logic Design of SHA-256

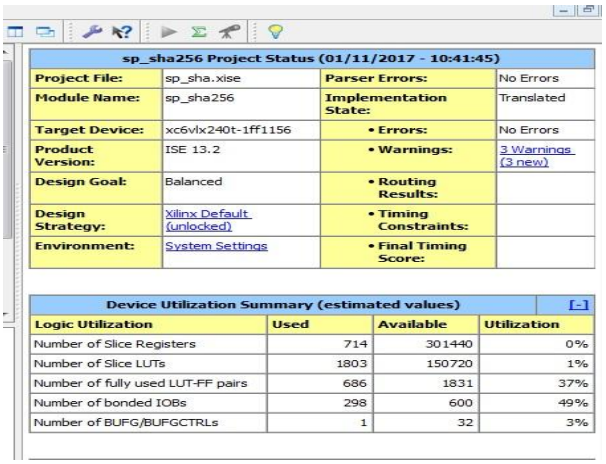
The VHDL implementation was divided into five modules:

- *Initial module:* - It collects the serial input bits and sends 512 bit blocks to the next module.
- *Round module:* - It performs the hashing calculations and operations on the input message block and previous hash output to generate a new hash value.
- *Last Block module:* - At the end of the message bit stream the final message block of 512 bits has to be prepared by adding 64 bits of message length at the end of 448 bits of input message block, padded accordingly to suffice the word size requirement. This final message block does this function of preparing the last message block.
- *Final module:* - This module computes the hash value by adding the previous hash value to the new hash value achieved from the Round module. Then it sends the 256 bit hash value, bit by bit (serially).
- *Top module:* - This module is the control unit for controlling the functioning of the rest of the modules and to ensure that the SHA-2 algorithm flow is followed and maintained

Result

• For testing the effectiveness and efficiency of the proposed design a performance comparison has been made in terms clock frequency, latency, area (gate equivalents) and throughput with the existing competitors of same bit size. The table below depicts the comparison.

• The proposed design gives better performance. The table below shows the effectiveness of our design. In the next chapter we have given the snapshots of RTL logic and their simulation waveforms

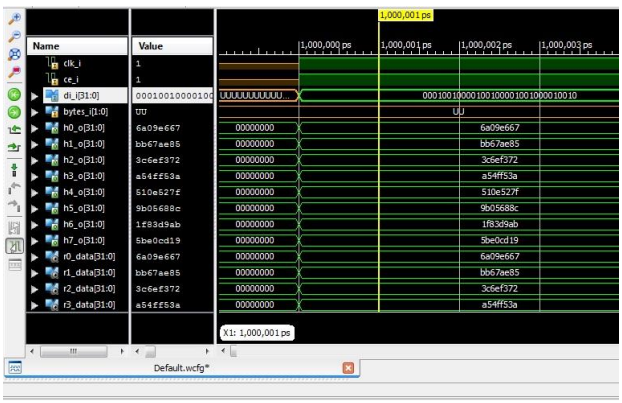


sp_sha256 Project Status (01/11/2017 - 10:41:45)			
Project File:	sp_sha.xise	Parser Errors:	No Errors
Module Name:	sp_sha256	Implementation State:	Translated
Target Device:	xc6vlx240t-1ff1156	• Errors:	No Errors
Product Version:	ISE 13.2	• Warnings:	3 Warnings (3 new)
Design Goal:	Balanced	• Routing Results:	
Design Strategy:	Xilinx Default (unlocked)	• Timing Constraints:	
Environment:	System Settings	• Final Timing Score:	

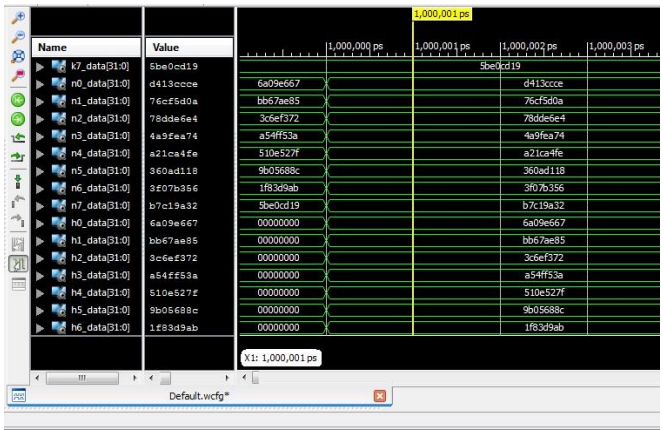
Device Utilization Summary (estimated values)			[-]
Logic Utilization	Used	Available	Utilization
Number of Slice Registers	714	301440	0%
Number of Slice LUTs	1803	150720	1%
Number of fully used LUT-FF pairs	686	1831	37%
Number of bonded IOBs	298	600	49%
Number of BUFG/BUFGCTRLs	1	32	3%

Architecture	R.Lien [2]	M D Rote	Proposed
Device	Virtex- 4	Virtex-6	Virtex-6
Slice	841	905	714
Frequency (MHz)	156.5	271	148.3
Throughput	1178	2040.47	1186.4
Throughput per	1.4	2.25	1.661

Comparative Table



Simulation Table 1



Simulation Table 2

CONCLUSION

The future cryptographic hash standard SHA-2 should be suitable and flexible for a wide range of applications, featuring at the same time an optimal security strength. In this work,we presented a complete hardware characterization of the SHA-2. A round rescheduling technique and a special-purpose memory design are also proposed. Post-synthesis results , a low-power compact implementation of SHA-2 has been Implemented. I believe that a similar approach for compact VLSI implementations of cryptographic protocols is a valuable choice to reduce the area and power consumption of the integrated circuit. The wide spectrum of achieved performances paves the way for the application of the SHA-2 function to various hardware implementations.

Concluding remarks are,

- 'Lightweight' is the rising star of cryptography. The term 'lightweight' alone covers a very wide range, such as lightweight in terms of area, speed, power consumption, energy consumption, or a combination of these, depending on the specific application.
- This research solely concentrates on the lightweight for area, which also results in lightweight for average power consumption in most applications.
- The use of block memories is avoided for compatibility on different platforms.
- We have been successful in reaching our target of lowest gate count, and even managed to surpass some of the recently proposed lightweight hash functions in terms of compactness and throughput.

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