

# Xilinx Standalone Library Documentation

## *XilSecure Library v4.3*

UG1189 (v2020.2) November 18, 2020



# Table of Contents

<b>Chapter 1: Overview.....</b>	<b>3</b>
<b>Chapter 2: AES-GCM.....</b>	<b>4</b>
Functions.....	6
Definitions.....	12
<b>Chapter 3: AES-GCM Error Codes.....</b>	<b>13</b>
<b>Chapter 4: AES-GCM API Example Usage.....</b>	<b>14</b>
<b>Chapter 5: AES-GCM Usage to decrypt Boot Image.....</b>	<b>16</b>
<b>Chapter 6: RSA.....</b>	<b>17</b>
Functions.....	18
Definitions.....	21
<b>Chapter 7: RSA API Example Usage.....</b>	<b>22</b>
<b>Chapter 8: SHA-3.....</b>	<b>24</b>
Functions.....	25
<b>Chapter 9: SHA-3 API Example Usage.....</b>	<b>31</b>
<b>Appendix A: Additional Resources and Legal Notices.....</b>	<b>33</b>
Xilinx Resources.....	33
Documentation Navigator and Design Hubs.....	33
Please Read: Important Legal Notices.....	34

## Overview

The XilSecure library provides APIs to access cryptographic accelerators on the Zynq UltraScale+ MPSoC devices. The library is designed to run on top of Xilinx standalone BSPs. It is tested for A53, R5 and MicroBlaze. XilSecure is used during the secure boot process. The primary post-boot use case is to run this library on the PMU MicroBlaze with PMUFW to service requests from Uboot or Linux for cryptographic acceleration.

The XilSecure library includes:

- SHA-3/384 engine for 384 bit hash calculation.
- AES-GCM engine for symmetric key encryption and decryption using a 256-bit key.
- RSA engine for signature generation, signature verification, encryption and decryption. Key sizes supported include 2048, 3072, and 4096.



**CAUTION!** SDK defaults to using a software stack in DDR and any variables used by XilSecure will be placed in DDR. For better security, change the linker settings to make sure the stack used by XilSecure is either in the OCM or the TCM.

XilSecure provides an user configuration under BSP settings to enable or disable secure environment, this bsp parameter is valid only when BSP is build for the PMU MicroBlaze for post boot use cases and XilSecure is been accessed using the IPI response calls to PMUFW from Linux or U-boot or baremetal applications. When the application environment is secure and trusted this variable should be set to TRUE.

By default, PMUFW will not allow device key for any decryption operation requested through IPI response unless authentication is enabled. If the user space is secure and trusted PMUFW can be build by setting the secure\_environment variable. Only then the PMUFW allows usage of the device key for encrypting or decrypting the data blobs, decryption of bitstream or image.

Parameter	Description
secure_environment	Default = FALSE. Set the value to TRUE to allow usage of device key through the IPI response calls.

The source files for the library can be found at:

- [https://github.com/Xilinx/embeddedsw/tree/master/lib/sw\\_services/xilsecure/src/zynqmp](https://github.com/Xilinx/embeddedsw/tree/master/lib/sw_services/xilsecure/src/zynqmp)
- [https://github.com/Xilinx/embeddedsw/tree/master/lib/sw\\_services/xilsecure/src/common](https://github.com/Xilinx/embeddedsw/tree/master/lib/sw_services/xilsecure/src/common)

# AES-GCM

This software uses AES-GCM hardened cryptographic accelerator to encrypt or decrypt the provided data and requires a key of size 256 bits and initialization vector(IV) of size 96 bits.

XilSecure library supports the following features:

- Encryption of data with provided key and IV
- Decryption of data with provided key and IV
- Authentication using a GCM tag.
- Key loading based on key selection, the key can be either the user provided key loaded into the KUP key or the device key used during boot.

For either encryption or decryption the AES-GCM engine should be initialized first using the `XSecure_AesInitialize` function.

When all the data to be encrypted is available, the `XSecure_AesEncryptData()` can be used. When all the data is not available, use the following functions in the suggested order:

1. `XSecure_AesEncryptInit()`
2. `XSecure_AesEncryptUpdate()` - This function can be called multiple times till input data is completed.

When all the data to be decrypted is available, the `XSecure_AesDecryptData()` can be used. When all the data is not available, use the following functions in the suggested order:

1. `XSecure_AesDecryptInit()`
2. `XSecure_AesDecryptUpdate()` - This function can be called multiple times till input data is completed.

During decryption, the provided GCM tag is compared to the GCM tag calculated by the engine. The two tags are then compared in the software and returned to the user as to whether or not the tags matched.



**CAUTION!** when using the KUP key for encryption/decryption of the data, where the key is stored should be carefully considered. Key should be placed in an internal memory region that has access controls. Not doing so may result in security vulnerability.

Table 1: Quick Function Reference

Type	Name	Arguments
s32	<a href="#">XSecure_AesInitialize</a>	XSecure_Aes * InstancePtr XCsuDma * CsuDmaPtr u32 KeySel u32 * IvPtr u32 * KeyPtr
u32	<a href="#">XSecure_AesDecryptInit</a>	XSecure_Aes * InstancePtr u8 * DecData u32 Size u8 * GcmTagAddr
s32	<a href="#">XSecure_AesDecryptUpdate</a>	XSecure_Aes * InstancePtr u8 * EncData u32 Size
s32	<a href="#">XSecure_AesDecryptData</a>	XSecure_Aes * InstancePtr u8 * DecData u8 * EncData u32 Size u8 * GcmTagAddr
s32	<a href="#">XSecure_AesDecrypt</a>	XSecure_Aes * InstancePtr const u8 * Src u8 * Dst u32 Length
u32	<a href="#">XSecure_AesEncryptInit</a>	XSecure_Aes * InstancePtr u8 * EncData u32 Size
u32	<a href="#">XSecure_AesEncryptUpdate</a>	XSecure_Aes * InstancePtr const u8 * Data u32 Size
u32	<a href="#">XSecure_AesEncryptData</a>	XSecure_Aes * InstancePtr u8 * Dst const u8 * Src u32 Len
void	<a href="#">XSecure_AesReset</a>	XSecure_Aes * InstancePtr

# Functions

## XSecure\_AesInitialize

This function initializes the instance pointer.

**Note:** All the inputs are accepted in little endian format but the AES engine accepts the data in big endian format, The decryption and encryption functions in xsecure\_aes handle the little endian to big endian conversion using few API's, Xil\_Htonl (provided by Xilinx xil\_io library) and XSecure\_AesCsuDmaConfigureEndiannes for handling data endianness conversions. If higher performance is needed, users can strictly use data in big endian format and modify the xsecure\_aes functions to remove the use of the Xil\_Htonl and XSecure\_AesCsuDmaConfigureEndiannes functions as required.

### Prototype

```
s32 XSecure_AesInitialize(XSecure_Aes *InstancePtr, XCsuDma *CsuDmaPtr, u32 KeySel, u32 *IvPtr, u32 *KeyPtr);
```

### Parameters

The following table lists the XSecure\_AesInitialize function arguments.

Table 2: XSecure\_AesInitialize Arguments

Name	Description
InstancePtr	Pointer to the XSecure_Aes instance.
CsuDmaPtr	Pointer to the XCsuDma instance.
KeySel	Key source for decryption, can be KUP/device key <ul style="list-style-type: none"> <li>XSECURE_CSU_AES_KEY_SRC_KUP :For KUP key</li> <li>XSECURE_CSU_AES_KEY_SRC_DEV :For Device Key</li> </ul>
IvPtr	Pointer to the Initialization Vector for decryption
KeyPtr	Pointer to Aes key in case KUP key is used. Pass Null if the device key is to be used.

### Returns

XST\_SUCCESS if initialization was successful.

## XSecure\_AesDecryptInit

This function initializes the AES engine for decryption and is required to be called before calling XSecure\_AesDecryptUpdate.

**Note:** If all of the data to be decrypted is available, the `XSecure_AesDecryptData` function can be used instead.

## Prototype

```
u32 XSecure_AesDecryptInit(XSecure_Aes *InstancePtr, u8 *DecData, u32 Size,
u8 *GcmTagAddr);
```

## Parameters

The following table lists the `XSecure_AesDecryptInit` function arguments.

*Table 3: XSecure\_AesDecryptInit Arguments*

Name	Description
InstancePtr	Pointer to the XSecure_Aes instance.
DecData	Pointer in which decrypted data will be stored.
Size	Expected size of the data in bytes whereas the number of bytes provided should be multiples of 4.
GcmTagAddr	Pointer to the GCM tag which needs to be verified during decryption of the data.

## Returns

None

# XSecure\_AesDecryptUpdate

This function decrypts the encrypted data passed in and updates the GCM tag from any previous calls. The size from `XSecure_AesDecryptInit` is decremented from the size passed into this function to determine when the GCM tag passed to `XSecure_AesDecryptInit` needs to be compared to the GCM tag calculated in the AES engine.

**Note:** When Size of the data equals to size of the remaining data that data will be treated as final data. This API can be called multiple times but sum of all Sizes should be equal to Size mention in init. Return of the final call of this API tells whether GCM tag is matching or not.

## Prototype

```
s32 XSecure_AesDecryptUpdate(XSecure_Aes *InstancePtr, u8 *EncData, u32
Size);
```

## Parameters

The following table lists the `XSecure_AesDecryptUpdate` function arguments.

**Table 4: XSecure\_AesDecryptUpdate Arguments**

Name	Description
InstancePtr	Pointer to the XSecure_Aes instance.
EncData	Pointer to the encrypted data which needs to be decrypted.
Size	Expected size of data to be decrypted in bytes, whereas the number of bytes should be multiples of 4.

## Returns

Final call of this API returns the status of GCM tag matching.

- XSECURE\_CSU\_AES\_GCM\_TAG\_MISMATCH: If GCM tag is mismatched
- XSECURE\_CSU\_AES\_ZEROIZATION\_ERROR: If GCM tag is mismatched, zeroize the decrypted data and send the status of zeroization.
- XST\_SUCCESS: If GCM tag is matching.

## XSecure\_AesDecryptData

This function decrypts the encrypted data provided and updates the DecData buffer with decrypted data.

**Note:** When using this function to decrypt data that was encrypted with XSecure\_AesEncryptData, the GCM tag will be stored as the last sixteen (16) bytes of data in XSecure\_AesEncryptData's Dst (destination) buffer and should be used as the GcmTagAddr's pointer.

## Prototype

```
s32 XSecure_AesDecryptData(XSecure_Aes *InstancePtr, u8 *DecData, u8 *EncData, u32 Size, u8 *GcmTagAddr);
```

## Parameters

The following table lists the XSecure\_AesDecryptData function arguments.

**Table 5: XSecure\_AesDecryptData Arguments**

Name	Description
InstancePtr	Pointer to the XSecure_Aes instance.
DecData	Pointer to a buffer in which decrypted data will be stored.
EncData	Pointer to the encrypted data which needs to be decrypted.
Size	Size of data to be decrypted in bytes, whereas the number of bytes should be multiples of 4.
GcmTagAddr	Pointer to the GCM tag which needs to be verified during decryption of the data.



## Returns

This API returns the status of GCM tag matching.

- XSECURE\_CSU\_AES\_GCM\_TAG\_MISMATCH: If GCM tag was mismatched
- XST\_SUCCESS: If GCM tag was matched.

## XSecure\_AesDecrypt

This function will handle the AES-GCM Decryption.

**Note:** This function is used for decrypting the Image's partition encrypted by Bootgen

## Prototype

```
s32 XSecure_AesDecrypt(XSecure_Aes *InstancePtr, u8 *Dst, const u8 *Src,
u32 Length);
```

## Parameters

The following table lists the XSecure\_AesDecrypt function arguments.

Table 6: XSecure\_AesDecrypt Arguments

Name	Description
InstancePtr	Pointer to the XSecure_Aes instance.
Src	Pointer to encrypted data source location
Dst	Pointer to location where decrypted data will be written.
Length	Expected total length of decrypted image expected.

## Returns

returns XST\_SUCCESS if successful, or the relevant errorcode.

## XSecure\_AesEncryptInit

This function is used to initialize the AES engine for encryption.

**Note:** If all of the data to be encrypted is available, the XSecure\_AesEncryptData function can be used instead.

## Prototype

```
u32 XSecure_AesEncryptInit(XSecure_Aes *InstancePtr, u8 *EncData, u32 Size);
```

## Parameters

The following table lists the `XSecure_AesEncryptInit` function arguments.

**Table 7: XSecure\_AesEncryptInit Arguments**

Name	Description
InstancePtr	Pointer to the XSecure_Aes instance.
EncData	Pointer of a buffer in which encrypted data along with GCM TAG will be stored. Buffer size should be Size of data plus 16 bytes.
Size	A 32 bit variable, which holds the size of the input data to be encrypted in bytes, whereas number of bytes provided should be multiples of 4.

## Returns

None

# XSecure\_AesEncryptUpdate

This function encrypts the clear-text data passed in and updates the GCM tag from any previous calls. The size from `XSecure_AesEncryptInit` is decremented from the size passed into this function to determine when the final CSU DMA transfer of data to the AES-GCM cryptographic core.

**Note:** If all of the data to be encrypted is available, the `XSecure_AesEncryptData` function can be used instead.

## Prototype

```
u32 XSecure_AesEncryptUpdate(XSecure_Aes *InstancePtr, const u8 *Data, u32 Size);
```

## Parameters

The following table lists the `XSecure_AesEncryptUpdate` function arguments.

**Table 8: XSecure\_AesEncryptUpdate Arguments**

Name	Description
InstancePtr	Pointer to the XSecure_Aes instance.
Data	Pointer to the data for which encryption should be performed.
Size	A 32 bit variable, which holds the size of the input data in bytes, whereas the number of bytes provided should be multiples of 4.

## Returns

None

## XSecure\_AesEncryptData

This function encrypts Len (length) number of bytes of the passed in Src (source) buffer and stores the encrypted data along with its associated 16 byte tag in the Dst (destination) buffer.

**Note:** If data to be encrypted is not available in one buffer one can call `XSecure_AesEncryptInit()` and update the AES engine with data to be encrypted by calling `XSecure_AesEncryptUpdate()` API multiple times as required.

### Prototype

```
u32 XSecure_AesEncryptData(XSecure_Aes *InstancePtr, u8 *Dst, const u8 *Src, u32 Len);
```

### Parameters

The following table lists the `XSecure_AesEncryptData` function arguments.

*Table 9: XSecure\_AesEncryptData Arguments*

Name	Description
InstancePtr	A pointer to the XSecure_Aes instance.
Dst	A pointer to a buffer where encrypted data along with GCM tag will be stored. The Size of buffer provided should be Size of the data plus 16 bytes
Src	A pointer to input data for encryption.
Len	Size of input data in bytes, whereas the number of bytes provided should be multiples of 4.

### Returns

None

## XSecure\_AesReset

This function sets and then clears the AES-GCM's reset line.

### Prototype

```
void XSecure_AesReset(XSecure_Aes *InstancePtr);
```

### Parameters

The following table lists the `XSecure_AesReset` function arguments.

Table 10: XSecure\_AesReset Arguments

Name	Description
InstancePtr	is a pointer to the XSecure_Aes instance.

### Returns

None

## Definitions

### XSecure\_AesWaitForDone

This macro waits for AES engine completes configured operation.

#### Definition

```
#define XSecure_AesWaitForDoneXil_WaitForEvent((InstancePtr)->BaseAddress +
XSECURE_CSU_AES_STS_OFFSET, \
XSECURE_CSU_AES_STS_AES_BUSY, \
0U, \
XSECURE_AES_TIMEOUT_MAX)
```

#### Parameters

The following table lists the XSecure\_AesWaitForDone definition values.

Table 11: XSecure\_AesWaitForDone Values

Name	Description
InstancePtr	Pointer to the XSecure_Aes instance.

### Returns

XST\_SUCCESS if the AES engine completes configured operation. XST\_FAILURE if a timeout has occurred.

## AES-GCM Error Codes

The table below lists the AES-GCM error codes.

Error Code	Error Value	Description
XSECURE_CSU_AES_GCM_TAG_MISMATCH	0x1	User provided GCM tag does not match with GCM calculated on data
XSECURE_CSU_AES_IMAGE_LEN_MISMATCH	0x2	When there is a Image length mismatch
XSECURE_CSU_AES_DEVICE_COPY_ERROR	0x3	When there is device copy error.
XSECURE_CSU_AES_ZEROIZATION_ERROR	0x4	When there is an error with Zeroization.  <b>Note:</b> In case of any error during Aes decryption, we perform zeroization of the decrypted data.
XSECURE_CSU_AES_KEY_CLEAR_ERROR	0x20	Error when clearing key storage registers after Aes operation.

# AES-GCM API Example Usage

The following example illustrates the usage of AES encryption and decryption APIs.

```
static s32 SecureAesExample(void)
{
    XCsuDma_Config *Config;
    s32 Status;
    u32 Index;
    XCsuDma_CsuDmaInstance;
    XSecure_Aes Secure_Aes;

    /* Initialize CSU DMA driver */
    Config = XCsuDma_LookupConfig(XSECURE_CSUDMA_DEVICEID);
    if (NULL == Config) {
        return XST_FAILURE;
    }

    Status = XCsuDma_CfgInitialize(&CsuDmaInstance, Config,
                                   Config->BaseAddress);
    if (Status != XST_SUCCESS) {
        return XST_FAILURE;
    }

    /* Initialize the Aes driver so that it's ready to use */
    XSecure_AesInitialize(&Secure_Aes, &CsuDmaInstance,
                          XSECURE_CSU_AES_KEY_SRC_KUP,
                          (u32 *)Iv, (u32 *)Key);

    xil_printf("Data to be encrypted: \n\r");
    for (Index = 0; Index < XSECURE_DATA_SIZE; Index++) {
        xil_printf("%02x", Data[Index]);
    }
    xil_printf( "\r\n\n");

    /* Encryption of Data */
    /*
     * If all the data to be encrypted is contiguous one can call
     * XSecure_AesEncryptData API directly.
     */
    XSecure_AesEncryptInit(&Secure_Aes, EncData, XSECURE_DATA_SIZE);
    XSecure_AesEncryptUpdate(&Secure_Aes, Data, XSECURE_DATA_SIZE);

    xil_printf("Encrypted data: \n\r");
    for (Index = 0; Index < XSECURE_DATA_SIZE; Index++) {
        xil_printf("%02x", EncData[Index]);
    }
    xil_printf( "\r\n");

    xil_printf("GCM tag: \n\r");
    for (Index = 0; Index < XSECURE_SECURE_GCM_TAG_SIZE; Index++) {
        xil_printf("%02x", EncData[XSECURE_DATA_SIZE + Index]);
    }
}
```

```

xil_printf( "\r\n\n");

/* Decrypt's the encrypted data */
/*
 * If data to be decrypted is contiguous one can also call
 * single API XSecure_AesDecryptData
 */
XSecure_AesDecryptInit(&Secure_Aes, DecData, XSECURE_DATA_SIZE,
                      EncData + XSECURE_DATA_SIZE);
/* Only the last update will return the GCM TAG matching status */
Status = XSecure_AesDecryptUpdate(&Secure_Aes, EncData,
                                XSECURE_DATA_SIZE);
if (Status != XST_SUCCESS) {
    xil_printf("Decryption failure- GCM tag was not matched\n\r");
    return Status;
}

xil_printf("Decrypted data\n\r");
for (Index = 0; Index < XSECURE_DATA_SIZE; Index++) {
    xil_printf("%02x", DecData[Index]);
}
xil_printf( "\r\n");

/* Comparison of Decrypted Data with original data */
for(Index = 0; Index < XSECURE_DATA_SIZE; Index++) {
    if (Data[Index] != DecData[Index]) {
        xil_printf("Failure during comparison of the data\n\r");
        return XST_FAILURE;
    }
}

return XST_SUCCESS;
}

```

**Note:** Relevant examples are available in the <library-install-path>\examples folder. Where <library-install-path> is the XilSecure library installation path.

# AES-GCM Usage to decrypt Boot Image

The Multiple key(Key Rolling) or Single key encrypted images will have the same format. The images include:

- Secure header - This includes the dummy AES key of 32byte + Block 0 IV of 12byte + DLC for Block 0 of 4byte + GCM tag of 16byte(Un-Enc).
- Block N - This includes the boot image data for the block N of n size + Block N+1 AES key of 32byte + Block N+1 IV of 12byte + GCM tag for Block N of 16byte(Un-Enc).

The Secure header and Block 0 will be decrypted using the device key or user provided key. If more than one block is found then the key and the IV obtained from previous block will be used for decryption.

Following are the instructions to decrypt an image:

1. Read the first 64 bytes and decrypt 48 bytes using the selected Device key.
2. Decrypt Block 0 using the IV + Size and the selected Device key.
3. After decryption, you will get the decrypted data+KEY+IV+Block Size. Store the KEY/IV into KUP/IV registers.
4. Using Block size, IV and the next Block key information, start decrypting the next block.
5. If the current image size is greater than the total image length, perform the next step. Else, go back to the previous step.
6. If there are failures, an error code is returned. Else, the decryption is successful.



## RSA

The `xsecure_rsa.h` file contains hardware interface related information for the RSA hardware accelerator. This hardened cryptographic accelerator, within the CSU, performs the modulus math based on the Rivest-Shamir-Adelman (RSA) algorithm. It is an asymmetric algorithm.

The RSA driver instance can be initialized by using the `XSecure_RsaInitialize()` function.

The method used for RSA implementation can take a pre-calculated value of  $R^2 \bmod N$ . If you do not have the pre-calculated exponential value pass NULL, the controller will take care of the exponential value.

### Note:

- From the RSA key modulus, the exponent should be extracted.
- For verification, PKCS v1.5 padding scheme has to be applied for comparing the data hash with decrypted hash.

**Table 12: Quick Function Reference**

Type	Name	Arguments
s32	<a href="#">XSecure_RsaInitialize</a>	XSecure_Rsa * InstancePtr u8 * Mod u8 * ModExt u8 * ModExpo
u32	<a href="#">XSecure_RsaSignVerification</a>	u8 * Signature u8 * Hash u32 HashLen
s32	<a href="#">XSecure_RsaPublicEncrypt</a>	XSecure_Rsa * InstancePtr u8 * Input u32 Size u8 * Result
s32	<a href="#">XSecure_RsaPrivateDecrypt</a>	XSecure_Rsa * InstancePtr u8 * Input u32 Size u8 * Result

# Functions

## XSecure\_RsaInitialize

This function initializes a XSecure\_Rsa structure with the default values required for operating the RSA cryptographic engine.

**Note:** Modulus, ModExt and ModExpo are part of prtion signature when authenticated boot image is generated by bootgen, else the all of them should be extracted from the key.

### Prototype

```
s32 XSecure_RsaInitialize(XSecure_Rsa *InstancePtr, u8 *Mod, u8 *ModExt, u8 *ModExpo);
```

### Parameters

The following table lists the XSecure\_RsaInitialize function arguments.

*Table 13: XSecure\_RsaInitialize Arguments*

Name	Description
InstancePtr	Pointer to the XSecure_Rsa instance.
Mod	A character Pointer which contains the key Modulus of key size.
ModExt	A Pointer to the pre-calculated exponential ( $R^2 \text{ Mod } N$ ) value. <ul style="list-style-type: none"> <li>NULL - if user doesn't have pre-calculated <math>R^2 \text{ Mod } N</math> value, control will take care of this calculation internally.</li> </ul>
ModExpo	Pointer to the buffer which contains key exponent.

### Returns

XST\_SUCCESS if initialization was successful.

## XSecure\_RsaSignVerification

This function verifies the RSA decrypted data provided is either matching with the provided expected hash by taking care of PKCS padding.

### Prototype

```
u32 XSecure_RsaSignVerification(u8 *Signature, u8 *Hash, u32 HashLen);
```

## Parameters

The following table lists the `XSecure_RsaSignVerification` function arguments.

**Table 14: XSecure\_RsaSignVerification Arguments**

Name	Description
Signature	Pointer to the buffer which holds the decrypted RSA signature
Hash	Pointer to the buffer which has the hash calculated on the data to be authenticated.
HashLen	Length of Hash used. <ul style="list-style-type: none"> <li>For SHA3 it should be 48 bytes</li> </ul>

## Returns

- `XST_SUCCESS` if decryption was successful.
- `XST_FAILURE` in case of mismatch.

## XSecure\_RsaPublicEncrypt

This function handles the RSA encryption with the public key components provided when initializing the RSA cryptographic core with the `XSecure_RsaInitialize` function.

**Note:** The Size passed here needs to match the key size used in the `XSecure_RsaInitialize` function.

## Prototype

```
s32 XSecure_RsaPublicEncrypt(XSecure_Rsa *InstancePtr, u8 *Input, u32 Size, u8 *Result);
```

## Parameters

The following table lists the `XSecure_RsaPublicEncrypt` function arguments.

**Table 15: XSecure\_RsaPublicEncrypt Arguments**

Name	Description
InstancePtr	Pointer to the <code>XSecure_Rsa</code> instance.
Input	Pointer to the buffer which contains the input data to be encrypted.
Size	Key size in bytes, Input size also should be same as Key size mentioned. Inputs supported are <ul style="list-style-type: none"> <li><code>XSECURE_RSA_4096_KEY_SIZE</code></li> <li><code>XSECURE_RSA_2048_KEY_SIZE</code></li> <li><code>XSECURE_RSA_3072_KEY_SIZE</code></li> </ul>

Table 15: XSecure\_RsaPublicEncrypt Arguments (cont'd)

Name	Description
Result	Pointer to the buffer where resultant decrypted data to be stored .

### Returns

- XST\_SUCCESS if encryption was successful.
- Error code on failure

## XSecure\_RsaPrivateDecrypt

This function handles the RSA decryption with the private key components provided when initializing the RSA cryptographic core with the XSecure\_RsaInitialize function.

**Note:** The Size passed in needs to match the key size used in the XSecure\_RsaInitialize function..

### Prototype

```
s32 XSecure_RsaPrivateDecrypt(XSecure_Rsa *InstancePtr, u8 *Input, u32
Size, u8 *Result);
```

### Parameters

The following table lists the XSecure\_RsaPrivateDecrypt function arguments.

Table 16: XSecure\_RsaPrivateDecrypt Arguments

Name	Description
InstancePtr	Pointer to the XSecure_Rsa instance.
Input	Pointer to the buffer which contains the input data to be decrypted.
Size	Key size in bytes, Input size also should be same as Key size mentioned. Inputs supported are <ul style="list-style-type: none"> <li>• XSECURE_RSA_4096_KEY_SIZE,</li> <li>• XSECURE_RSA_2048_KEY_SIZE</li> <li>• XSECURE_RSA_3072_KEY_SIZE</li> </ul>
Result	Pointer to the buffer where resultant decrypted data to be stored .

### Returns

- XST\_SUCCESS if decryption was successful.
- XSECURE\_RSA\_DATA\_VALUE\_ERROR - if input data is greater than modulus.
- XST\_FAILURE - on RSA operation failure.

---

## Definitions

### XSECURE\_RSA\_BYTE\_PAD\_LENGTH

PKCS Byte Padding

#### Definition

```
#define XSECURE_RSA_BYTE_PAD_LENGTH( 3U)
```

### XSECURE\_RSA\_T\_PAD\_LENGTH

PKCS T Padding

#### Definition

```
#define XSECURE_RSA_T_PAD_LENGTH( 19U)
```

### XSECURE\_RSA\_BYTE\_PAD1

PKCS T Padding Byte

#### Definition

```
#define XSECURE_RSA_BYTE_PAD1( 0X00U)
```

### XSECURE\_RSA\_BYTE\_PAD2

PKCS T Padding Byte

#### Definition

```
#define XSECURE_RSA_BYTE_PAD2( 0X01U)
```

### XSECURE\_RSA\_BYTE\_PAD3

PKCS T Padding Byte

#### Definition

```
#define XSECURE_RSA_BYTE_PAD3( 0XFFU)
```

## RSA API Example Usage

The following example illustrates the usage of the RSA library to encrypt data using the public key and to decrypt the data using private key.

**Note:** Application should take care of the padding.

```
u32 SecureRsaExample(void)
{
    u32 Index;

    /* RSA signature decrypt with private key */
    /*
     * Initialize the Rsa driver with private key components
     * so that it's ready to use
     */
    XSecure_RsaInitialize(&Secure_Rsa, Modulus, NULL, PrivateExp);

    if(XST_SUCCESS != XSecure_RsaPrivateDecrypt(&Secure_Rsa, Data,
                                                Size, Signature)) {
        xil_printf("Failed at RSA signature decryption\n\r");
        return XST_FAILURE;
    }

    xil_printf("\r\n Decrypted Signature with private key\r\n ");

    for(Index = 0; Index < Size; Index++) {
        xil_printf(" %02x ", Signature[Index]);
    }
    xil_printf(" \r\n ");

    /* Verification if Data is expected */
    for(Index = 0; Index < Size; Index++) {
        if (Signature[Index] != ExpectedSign[Index]) {
            xil_printf("\r\nError at verification of RSA
signature"
                    " Decryption\n\r");
            return XST_FAILURE;
        }
    }

    /* RSA signature encrypt with Public key components */
    /*
     * Initialize the Rsa driver with public key components
     * so that it's ready to use
     */
    XSecure_RsaInitialize(&Secure_Rsa, Modulus, NULL, (u8 *)&PublicExp);

    if(XST_SUCCESS != XSecure_RsaPublicEncrypt(&Secure_Rsa, Signature,
                                                Size,
```

```

EncryptSignatureOut)) {
    xil_printf("\r\nFailed at RSA signature encryption\n\r");
    return XST_FAILURE;
}
xil_printf("\r\n Encrypted Signature with public key\r\n ");

for(Index = 0; Index < Size; Index++) {
    xil_printf(" %02x ", EncryptSignatureOut[Index]);
}

/* Verification if Data is expected */
for(Index = 0; Index < Size; Index++) {
    if (EncryptSignatureOut[Index] != Data[Index]) {
        xil_printf("\r\nError at verification of RSA
signature"
                    " encryption\n\r");
        return XST_FAILURE;
    }
}

return XST_SUCCESS;
}

```

**Note:** Relevant examples are available in the <library-install-path>\examples folder. Where <library-install-path> is the XilSecure library installation path.

## SHA-3

This block uses the NIST-approved SHA-3 algorithm to generate a 384-bit hash on the input data. Because the SHA-3 hardware only accepts 104 byte blocks as the minimum input size, the input data will be padded with user selectable Keccak or NIST SHA-3 padding and is handled internally in the SHA-3 library.

The SHA-3 driver instance can be initialized using the `XSecure_Sha3Initialize()` function.

A pointer to CsuDma instance has to be passed during initialization as the CSU DMA will be used for data transfers to the SHA module.

When all the data is available on which the SHA3 hash must be calculated, the `XSecure_Sha3Digest()` can be used with the appropriate parameters as described. When all the data is not available, use the SHA3 functions in the following order:

1. `XSecure_Sha3Start()`
2. `XSecure_Sha3Update()` - This function can be called multiple times until all input data has been passed to the SHA-3 cryptographic core.
3. `XSecure_Sha3Finish()` - Provides the final hash of the data. To get intermediate hash values after each `XSecure_Sha3Update()`, you can call `XSecure_Sha3_ReadHash()` after the `XSecure_Sha3Update()` call.

**Table 17: Quick Function Reference**

Type	Name	Arguments
s32	<code>XSecure_Sha3Initialize</code>	<code>XSecure_Sha3 * InstancePtr</code> <code>XCsuDma * CsuDmaPtr</code>
void	<code>XSecure_Sha3Start</code>	<code>XSecure_Sha3 * InstancePtr</code>
u32	<code>XSecure_Sha3Update</code>	<code>XSecure_Sha3 * InstancePtr</code> <code>const u8 * Data</code> <code>const u32 Size</code>
u32	<code>XSecure_Sha3Finish</code>	<code>XSecure_Sha3 * InstancePtr</code> <code>u8 * Hash</code>



Table 17: Quick Function Reference (cont'd)

Type	Name	Arguments
u32	<a href="#">XSecure_Sha3Digest</a>	XSecure_Sha3 * InstancePtr const u8 * In const u32 Size u8 * Out
void	<a href="#">XSecure_Sha3_ReadHash</a>	XSecure_Sha3 * InstancePtr u8 * Hash
s32	<a href="#">XSecure_Sha3PadSelection</a>	XSecure_Sha3 * InstancePtr XSecure_Sha3PadType Sha3Type
s32	<a href="#">XSecure_Sha3LastUpdate</a>	XSecure_Sha3 * InstancePtr
u32	<a href="#">XSecure_Sha3WaitForDone</a>	XSecure_Sha3 * InstancePtr

## Functions

### XSecure\_Sha3Initialize

This function initializes a XSecure\_Sha3 structure with the default values required for operating the SHA3 cryptographic engine.

**Note:** The base address is initialized directly with value from xsecure\_hw.h The default is NIST SHA3 padding, to change to KECCAK padding call [XSecure\\_Sha3PadSelection\(\)](#) after [XSecure\\_Sha3Initialize\(\)](#).

#### Prototype

```
s32 XSecure_Sha3Initialize(XSecure_Sha3 *InstancePtr, XCsuDma *CsuDmaPtr);
```

#### Parameters

The following table lists the XSecure\_Sha3Initialize function arguments.

Table 18: XSecure\_Sha3Initialize Arguments

Name	Description
InstancePtr	Pointer to the XSecure_Sha3 instance.
CsuDmaPtr	Pointer to the XCsuDma instance.

## Returns

XST\_SUCCESS if initialization was successful

## XSecure\_Sha3Start

This function configures Secure Stream Switch and starts the SHA-3 engine.

## Prototype

```
void XSecure_Sha3Start(XSecure_Sha3 *InstancePtr);
```

## Parameters

The following table lists the XSecure\_Sha3Start function arguments.

Table 19: XSecure\_Sha3Start Arguments

Name	Description
InstancePtr	Pointer to the XSecure_Sha3 instance.

## Returns

None

## XSecure\_Sha3Update

This function updates the SHA3 engine with the input data.

## Prototype

```
u32 XSecure_Sha3Update(XSecure_Sha3 *InstancePtr, const u8 *Data, const u32 Size);
```

## Parameters

The following table lists the XSecure\_Sha3Update function arguments.

Table 20: XSecure\_Sha3Update Arguments

Name	Description
InstancePtr	Pointer to the XSecure_Sha3 instance.
Data	Pointer to the input data for hashing.
Size	Size of the input data in bytes.

## Returns

XST\_SUCCESS if the update is successful XST\_FAILURE if there is a failure in SSS config

## XSecure\_Sha3Finish

This function updates SHA3 engine with final data which includes SHA3 padding and reads final hash on complete data.

## Prototype

```
u32 XSecure_Sha3Finish(XSecure_Sha3 *InstancePtr, u8 *Hash);
```

## Parameters

The following table lists the XSecure\_Sha3Finish function arguments.

Table 21: XSecure\_Sha3Finish Arguments

Name	Description
InstancePtr	Pointer to the XSecure_Sha3 instance.
Hash	Pointer to location where resulting hash will be written

## Returns

XST\_SUCCESS if finished without any errors XST\_FAILURE if Sha3PadType is other than KECCAK or NIST

## XSecure\_Sha3Digest

This function calculates the SHA-3 digest on the given input data.

## Prototype

```
u32 XSecure_Sha3Digest(XSecure_Sha3 *InstancePtr, const u8 *In, const u32 Size, u8 *Out);
```

## Parameters

The following table lists the XSecure\_Sha3Digest function arguments.

Table 22: XSecure\_Sha3Digest Arguments

Name	Description
InstancePtr	Pointer to the XSecure_Sha3 instance.
In	Pointer to the input data for hashing

Table 22: XSecure\_Sha3Digest Arguments (cont'd)

Name	Description
Size	Size of the input data
Out	Pointer to location where resulting hash will be written.

### Returns

XST\_SUCCESS if digest calculation done successfully XST\_FAILURE if any error from Sha3Update or Sha3Finish.

## XSecure\_Sha3\_ReadHash

This function reads the SHA3 hash of the data and it can be called between calls to XSecure\_Sha3Update.

### Prototype

```
void XSecure_Sha3_ReadHash(XSecure_Sha3 *InstancePtr, u8 *Hash);
```

### Parameters

The following table lists the XSecure\_Sha3\_ReadHash function arguments.

Table 23: XSecure\_Sha3\_ReadHash Arguments

Name	Description
InstancePtr	Pointer to the XSecure_Sha3 instance.
Hash	Pointer to a buffer in which read hash will be stored.

### Returns

None

## XSecure\_Sha3PadSelection

This function provides an option to select the SHA-3 padding type to be used while calculating the hash.

**Note:** The default provides support for NIST SHA-3. If a user wants to change the padding to Keccak SHA-3, this function should be called after `XSecure_Sha3Initialize()`

### Prototype

```
s32 XSecure_Sha3PadSelection(XSecure_Sha3 *InstancePtr, XSecure_Sha3PadType Sha3PadType);
```

## Parameters

The following table lists the `XSecure_Sha3PadSelection` function arguments.

**Table 24: XSecure\_Sha3PadSelection Arguments**

Name	Description
InstancePtr	Pointer to the XSecure_Sha3 instance.
Sha3Type	Type of SHA3 padding to be used. <ul style="list-style-type: none"> <li>For NIST SHA-3 padding - XSECURE_CSU_NIST_SHA3</li> <li>For KECCAK SHA-3 padding - XSECURE_CSU_KECCAK_SHA3</li> </ul>

## Returns

XST\_SUCCESS if pad selection is successful. XST\_FAILURE if pad selection is failed.

# XSecure\_Sha3LastUpdate

This function is to notify this is the last update of data where sha padding is also been included along with the data in the next update call.

## Prototype

```
s32 XSecure_Sha3LastUpdate(XSecure_Sha3 *InstancePtr);
```

## Parameters

The following table lists the `XSecure_Sha3LastUpdate` function arguments.

**Table 25: XSecure\_Sha3LastUpdate Arguments**

Name	Description
InstancePtr	Pointer to the XSecure_Sha3 instance.
XSecure_Sha3PadType	

## Returns

XST\_SUCCESS if last update can be accepted

# XSecure\_Sha3WaitForDone

This inline function waits till SHA3 completes its operation.

## Prototype

```
u32 XSecure_Sha3WaitForDone(XSecure_Sha3 *InstancePtr);
```

## Parameters

The following table lists the `XSecure_Sha3WaitForDone` function arguments.

**Table 26: XSecure\_Sha3WaitForDone Arguments**

Name	Description
InstancePtr	Pointer to the XSecure_Sha3 instance.

## Returns

XST\_SUCCESS if the SHA3 completes its operation. XST\_FAILURE if a timeout has occurred.

## SHA-3 API Example Usage

The `xilsecure_sha_example.c` file is a simple example application that demonstrates the usage of SHA-3 accelerator to calculate a 384-bit hash on the Hello World string. A typical use case for the SHA3 accelerator is for calculation of the boot image hash as part of the authentication operation. This is illustrated in the `xilsecure_rsa_example.c`.

The contents of the `xilsecure_sha_example.c` file are shown below:

```
u32 SecureSha3Example()
{
    XSecure_Sha3 Secure_Sha3;
    XCsuDma CsuDma;
    XCsuDma_Config *Config;
    u8 Out[SHA3_HASH_LEN_IN_BYTES];
    u32 Status = XST_FAILURE;
    u32 Size = 0U;

    Size = Xil_Strnlen(Data, SHA3_INPUT_DATA_LEN);
    if (Size != SHA3_INPUT_DATA_LEN) {
        xil_printf("Provided data length is Invalid\n\r");
        Status = XST_FAILURE;
        goto END;
    }

    Config = XCsuDma_LookupConfig(0);
    if (NULL == Config) {
        xil_printf("config failed\n\r");
        Status = XST_FAILURE;
        goto END;
    }

    Status = XCsuDma_CfgInitialize(&CsuDma, Config, Config->BaseAddress);
    if (Status != XST_SUCCESS) {
        Status = XST_FAILURE;
        goto END;
    }

    /*
     * Initialize the SHA-3 driver so that it's ready to use
     */
    XSecure_Sha3Initialize(&Secure_Sha3, &CsuDma);

    XSecure_Sha3Digest(&Secure_Sha3, (const u8*)Data, Size, Out);

    xil_printf(" Calculated Hash \r\n ");
    SecureSha3PrintHash(Out);

    Status = SecureSha3CompareHash(Out, ExpHash);
END:
    return Status;
}
```

```

}

/
*****
/
u32 SecureSha3CompareHash(u8 *Hash, u8 *ExpectedHash)
{
    u32 Index;
    u32 Status = XST_FAILURE;

    for (Index = 0U; Index < SHA3_HASH_LEN_IN_BYTES; Index++) {
        if (Hash[Index] != ExpectedHash[Index]) {
            xil_printf("Expected Hash \r\n");
            SecureSha3PrintHash(ExpectedHash);
            xil_printf("SHA Example Failed at Hash Comparison \r\n");
            break;
        }
    }
    if (Index == SHA3_HASH_LEN_IN_BYTES) {
        Status = XST_SUCCESS;
    }

    return Status;
}

/
*****
/
void SecureSha3PrintHash(u8 *Hash)
{
    u32 Index;

    for (Index = 0U; Index < SHA3_HASH_LEN_IN_BYTES; Index++) {
        xil_printf(" %0x ", Hash[Index]);
    }
    xil_printf(" \r\n ");
}

```

**Note:** The `xilsecure_sha_example.c` and `xilsecure_rsa_example.c` example files are available in the <library-install-path>\examples folder. Where <library-install-path> is the XilSecure library installation path.



# Additional Resources and Legal Notices

---

## Xilinx Resources

For support resources such as Answers, Documentation, Downloads, and Forums, see [Xilinx Support](#).

---

## Documentation Navigator and Design Hubs

Xilinx<sup>®</sup> Documentation Navigator (DocNav) provides access to Xilinx documents, videos, and support resources, which you can filter and search to find information. To open DocNav:

- From the Vivado<sup>®</sup> IDE, select **Help** → **Documentation and Tutorials**.
- On Windows, select **Start** → **All Programs** → **Xilinx Design Tools** → **DocNav**.
- At the Linux command prompt, enter `docnav`.

Xilinx Design Hubs provide links to documentation organized by design tasks and other topics, which you can use to learn key concepts and address frequently asked questions. To access the Design Hubs:

- In DocNav, click the **Design Hubs View** tab.
- On the Xilinx website, see the [Design Hubs](#) page.

**Note:** For more information on DocNav, see the [Documentation Navigator](#) page on the Xilinx website.

---

## Please Read: Important Legal Notices

The information disclosed to you hereunder (the "Materials") is provided solely for the selection and use of Xilinx products. To the maximum extent permitted by applicable law: (1) Materials are made available "AS IS" and with all faults, Xilinx hereby DISCLAIMS ALL WARRANTIES AND CONDITIONS, EXPRESS, IMPLIED, OR STATUTORY, INCLUDING BUT NOT LIMITED TO WARRANTIES OF MERCHANTABILITY, NON-INFRINGEMENT, OR FITNESS FOR ANY PARTICULAR PURPOSE; and (2) Xilinx shall not be liable (whether in contract or tort, including negligence, or under any other theory of liability) for any loss or damage of any kind or nature related to, arising under, or in connection with, the Materials (including your use of the Materials), including for any direct, indirect, special, incidental, or consequential loss or damage (including loss of data, profits, goodwill, or any type of loss or damage suffered as a result of any action brought by a third party) even if such damage or loss was reasonably foreseeable or Xilinx had been advised of the possibility of the same. Xilinx assumes no obligation to correct any errors contained in the Materials or to notify you of updates to the Materials or to product specifications. You may not reproduce, modify, distribute, or publicly display the Materials without prior written consent. Certain products are subject to the terms and conditions of Xilinx's limited warranty, please refer to Xilinx's Terms of Sale which can be viewed at <https://www.xilinx.com/legal.htm#tos>; IP cores may be subject to warranty and support terms contained in a license issued to you by Xilinx. Xilinx products are not designed or intended to be fail-safe or for use in any application requiring fail-safe performance; you assume sole risk and liability for use of Xilinx products in such critical applications, please refer to Xilinx's Terms of Sale which can be viewed at <https://www.xilinx.com/legal.htm#tos>.

### AUTOMOTIVE APPLICATIONS DISCLAIMER

AUTOMOTIVE PRODUCTS (IDENTIFIED AS "XA" IN THE PART NUMBER) ARE NOT WARRANTED FOR USE IN THE DEPLOYMENT OF AIRBAGS OR FOR USE IN APPLICATIONS THAT AFFECT CONTROL OF A VEHICLE ("SAFETY APPLICATION") UNLESS THERE IS A SAFETY CONCEPT OR REDUNDANCY FEATURE CONSISTENT WITH THE ISO 26262 AUTOMOTIVE SAFETY STANDARD ("SAFETY DESIGN"). CUSTOMER SHALL, PRIOR TO USING OR DISTRIBUTING ANY SYSTEMS THAT INCORPORATE PRODUCTS, THOROUGHLY TEST SUCH SYSTEMS FOR SAFETY PURPOSES. USE OF PRODUCTS IN A SAFETY APPLICATION WITHOUT A SAFETY DESIGN IS FULLY AT THE RISK OF CUSTOMER, SUBJECT ONLY TO APPLICABLE LAWS AND REGULATIONS GOVERNING LIMITATIONS ON PRODUCT LIABILITY.

### Copyright

© Copyright 2020 Xilinx, Inc. Xilinx, the Xilinx logo, Alveo, Artix, Kintex, Spartan, Versal, Virtex, Vivado, Zynq, and other designated brands included herein are trademarks of Xilinx in the United States and other countries. All other trademarks are the property of their respective owners.