

Linux on System z



# libica Programmer's Reference

*Version 2.2.0*



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*Version 2.2.0*

**Note**

Before using this document, be sure to read the information in "Notices" on page 177.

This edition applies to version 2.2.0 of libica and to all subsequent releases and modifications until otherwise indicated in new editions. This edition replaces SC34-2602-01.

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## Summary of changes

This revision reflects changes to the Development stream for libica Version 2.2.0.

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### Updates for libica Version 2.2.0

This revision reflects changes related to Version 2.2.0 of libica.

#### *New information*

- New APIs have been added. For details, see Chapter 3, “libica Version 2.2.0 Application Programming Interfaces (APIs),” on page 5.
  - ica\_3des\_cbc\_cs
  - ica\_3des\_cmac
  - ica\_3des\_cmac\_intermediate
  - ica\_3des\_cmac\_last
  - ica\_aes\_cbc\_cs
  - ica\_aes\_ccm
  - ica\_aes\_cmac\_intermediate
  - ica\_aes\_cmac\_last
  - ica\_aes\_gcm
  - ica\_des\_cbc\_cs
  - ica\_des\_cmac
  - ica\_des\_cmac\_intermediate
  - ica\_des\_cmac\_last
- New commands have been added. See Chapter 5, “libica tools,” on page 89.

#### *Changed information*

- Minor changes and corrections have been made to some of the APIs.

This revision also includes maintenance and editorial changes.

#### *Deleted information*

- Some obsolete examples have been removed.

---

### Updates for libica Version 2.1.0

This revision reflects changes related to Version 2.1.0 of libica.

#### *New information*

- Support for IBM® zEnterprise™ 196 has been added.
- New APIs have been added. See Chapter 3, “libica Version 2.2.0 Application Programming Interfaces (APIs),” on page 5.
- New examples have been added. See Chapter 6, “Examples,” on page 93.
- New defines and structs have been added. See Chapter 4, “libica defines, typedefs, structs, and return codes,” on page 85.

#### *Changed information*

- The example makefile has been updated. See “Makefile example” on page 169.

This revision also includes maintenance and editorial changes.

*Deleted information*

- The following functions are deprecated in libica Version 2.1.0, and no longer documented in this book. They are, however, still available in this version of libica. For documentation on these functions, see the Version 2.0 *libica Programmer’s Reference*.
  - ica\_des\_encrypt
  - ica\_des\_decrypt
  - ica\_3des\_encrypt
  - ica\_3des\_decrypt
  - ica\_aes\_encrypt
  - ica\_aes\_decrypt



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## About this document

This document describes how to install and use Version 2.2.0 of the Library for IBM Cryptographic Architecture (libica). libica Version 2.2.0 is a library of cryptographic functions used to write cryptographic applications on IBM System z<sup>®</sup>, both with and without cryptographic hardware.

Unless stated otherwise, the tools described in this book are available for the 64-bit architecture and 31-bit architectures with version 2.6 or higher of the Linux kernel.

You can find the latest version of this document on the developerWorks<sup>®</sup> website at:

[http://www.ibm.com/developerworks/linux/linux390/development\\_documentation.html](http://www.ibm.com/developerworks/linux/linux390/development_documentation.html)

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## How this document is organized

Chapter 1, “General information about libica,” on page 1 has general information about libica Version 2.2.0.

Chapter 2, “Installing and using libica Version 2.2.0,” on page 3 contains installation and set up instructions, and coexistence information for libica Version 2.2.0.

Chapter 3, “libica Version 2.2.0 Application Programming Interfaces (APIs),” on page 5 describes the libica Version 2.2.0 APIs.

Chapter 4, “libica defines, typedefs, structs, and return codes,” on page 85 lists the defines, typedefs, structs, and return codes for libica Version 2.2.0.

Chapter 5, “libica tools,” on page 89 contains tools to investigate the capabilities of your cryptographic hardware and how these capabilities are used by applications that use libica.

Chapter 6, “Examples,” on page 93 is a set of programming examples that use the libica Version 2.2.0 APIs.

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## Who should read this document

This document is intended for C programmers that want to access IBM System z hardware support for cryptographic methods. In particular, this document addresses programmers who write hardware-specific plug-ins for cryptographic libraries such as openssl and OpenCryptoki.

### Assumptions

The following general assumptions are made about your background knowledge:

- You have an understanding of basic computer architecture, operating systems, and programs.
- You have an understanding of Linux and IBM System z terminology.
- You have knowledge about cryptographic applications and solution design, as well as the required cryptographic functions and algorithms.

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## Distribution independence

This book does not provide information that is specific to a particular Linux distribution. The tools it describes are distribution independent.

---

## Conventions used in this book

This section informs you on the styles, highlighting, and assumptions used throughout the book.

### Terminology

In this book, the term *booting* is used for running boot loader code that loads the Linux operating system. *IPL* is used for issuing an IPL command or to load boot-loader code.

In this book, the term **Required hardware support** refers to specific processor instructions that must be available on the processor in order for the function to benefit from hardware support. Functions will fail on systems that do not provide the required hardware support, unless a software fallback is available as indicated in Table 2 on page 5. An example is that the `ica_des_cbc` function has KMC-DEA listed under **Required hardware support**. This function cannot benefit from hardware support unless the processor has the KMC-DEA instruction. However, `ica_des_cbc` will work on all processors because according to Table 2 on page 5 there is a software fallback for this function.

For more information, see:

- *The z/Architecture<sup>®</sup> Principles of Operation, SA22-7832-06*
- the IBM Redbooks<sup>®</sup> publication *System z Cryptographic Services and z/OS<sup>®</sup> PKI Services, SG24-7470-00*

IBM systems mentioned in this book have both long names and short names. They correspond as follows:

Table 1. IBM systems

Long name	Short name
IBM eServer <sup>™</sup> zSeries <sup>®</sup> 990	z990
IBM System z9 <sup>®</sup>	z9
IBM System z10 <sup>®</sup>	z10 <sup>™</sup>
IBM System z196	z196

### Highlighting

This book uses the following highlighting styles:

- Paths and URLs are highlighted in monospace.
- Variables are highlighted in *italics*.
- Commands in text are highlighted in **bold**.
- Input and output as normally seen on a computer screen is shown

within a screen frame.  
Prompts are shown as number signs:  
#

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## Other Linux on System z publications

Current versions of the Linux on System z publications can be found at:

[www.ibm.com/developerworks/linux/linux390/documentation\\_dev.html](http://www.ibm.com/developerworks/linux/linux390/documentation_dev.html)

- *Device Drivers, Features, and Commands*, SC33-8411
- *Using the Dump Tools*, SC33-8412
- *How to use FC-attached SCSI devices with Linux on System z*, SC33-8413
- *How to Improve Performance with PAV*, SC33-8414
- *How to use Execute-in-Place Technology with Linux on z/VM<sup>®</sup>*, SC34-2594
- *How to Set up a Terminal Server Environment on z/VM*, SC34-2596
- *Kernel Messages*
- *libica Programmer's Reference*, SC34-2602

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## Finding IBM books

The PDF version of this book contains URL links to much of the referenced literature.

For some of the referenced IBM books, links have been omitted to avoid pointing to a particular edition of a book. You can locate the latest versions of the referenced IBM books through the IBM Publications Center at:

<http://www.ibm.com/shop/publications/order>



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## Chapter 1. General information about libica

The libica library provides hardware support for cryptographic functions. The cryptographic adapters are used for asymmetric encryption and decryption. The CPACF instructions are used for symmetric encryption and decryption, pseudo random number generation, message authentication, and Secure Hashing. For some of these functions, if the hardware is not available or has failed, libica uses the low-level cryptographic functions of OpenSSL, if available.

This product includes software developed by the OpenSSL Project for use in the OpenSSL Toolkit (<http://www.openssl.org>). This product includes cryptographic software written by Eric Young ([ey@cryptsoft.com](mailto:ey@cryptsoft.com)).

The libica library is part of the openCryptoki project in SourceForge. It is primarily used by OpenSSL through the IBM OpenSSL CA engine or by OpenCryptoki through the ica\_s390 token. A higher level of security can be achieved by using it through the PKCS11 API implemented by OpenCryptoki.

The libica library works only on IBM System z hardware.

IBM reserves the right to change or modify this API at any time. However, an effort is made to keep the API compatible with later versions within a major release.

The **icastats** command, described in *Linux on System z: Device Driver, Features, and Commands*, is used to obtain statistics about cryptographic processes. The **icastats** command shows whether libica is using cryptographic hardware or software fallback for each specific libica function.

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### libica examples

There is a list of sample programs in the libica source for each API, as well as instructions about how to use the functions. You can find the open source version of libica at:

<http://sourceforge.net/projects/opencryptoki>

Sample programs area also in Chapter 6, “Examples,” on page 93.



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## Chapter 2. Installing and using libica Version 2.2.0

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### Installing libica Version 2.2.0

You can obtain the libica Version 2.2.0 library from the SourceForge website at:  
<http://sourceforge.net/projects/opencryptoki>

Follow the installation instructions on this website to download the libica Version 2.2.0 package. This package has a file named INSTALL that contains installation instructions.

---

### Using libica Version 2.2.0

The function prototypes are provided in the header file, `include/ica_api.h`. Applications using these functions must link libica and libcrypto. The libcrypto library is available from the OpenSSL package. You must have OpenSSL in order to run libica Version 2.2.0 programs.

---

### libica Version 1, Version 2, Version 2.1.0, and Version 2.2.0 coexistence

| Some of the libica Version 1 APIs are available in libica Version 2, libica Version  
| 2.1.0, and libica Version 2.2.0. Some of them, such as those APIs that work with an  
| environment other than Linux on IBM System z, were removed and are not present  
| in libica Version 2 or later versions. If your application program has calls to libica  
| Version 1 APIs, check to see whether these APIs are in libica Version 2.2.0. If they  
| are, these API calls should still work. However, we suggest that you convert your  
| application to use the equivalent libica Version 2.2.0 functions. See Chapter 3,  
| “libica Version 2.2.0 Application Programming Interfaces (APIs),” on page 5.

libica key generation is restricted to the limits imposed by the OpenSSL implementation. Thus, the value of a public exponent passed to libica cannot be greater than the maximum value that would fit in an unsigned long integer.





## Chapter 3. libica Version 2.2.0 Application Programming Interfaces (APIs)

Table 2 lists the APIs for libica Version 2.2.0.

Table 2. libica Version 2.2.0 APIs

Function	libica Version 2.2.0 API name	Key length in bits	Supported on			CPACF function	Software fallback
			z9	z10	z196		
<b>Open and close adapter functions</b>							
Open adapter handle	"ica_open_adapter" on page 8	N/A	Yes	Yes	Yes	No	N/A
Close adapter handle	"ica_close_adapter" on page 9	N/A	Yes	Yes	Yes	No	N/A
<b>Secure hash operations</b>							
Secure hash using the SHA-1 algorithm.	"ica_sha1" on page 11	N/A	Yes	Yes	Yes	Yes	Yes
Secure hash using the SHA-224 algorithm.	"ica_sha224" on page 12	N/A	No	Yes	Yes	Yes	Yes
Secure hash using the SHA-256 algorithm.	"ica_sha256" on page 14	N/A	Yes	Yes	Yes	Yes	Yes
Secure hash using the SHA-384 algorithm.	"ica_sha384" on page 15	N/A	No	Yes	Yes	Yes	Yes
Secure hash using the SHA-512 algorithm.	"ica_sha512" on page 17	N/A	No	Yes	Yes	Yes	Yes
<b>Random number generation</b>							
Generate a pseudo random number.	"ica_random_number_generate" on page 19	N/A	Yes	Yes	Yes	Yes	Yes
<b>RSA key generation functions</b>							
Generate RSA keys in modulus/exponent format.	"ica_rsa_key_generate_mod_expo" on page 21	N/A	Yes	Yes	Yes	No	Software only
Generate RSA keys in CRT format.	"ica_rsa_key_generate_crt" on page 22	N/A	Yes	Yes	Yes	No	Software only
<b>RSA encryption and decryption operations</b>							
RSA encryption and decryption operation using a key in modulus/exponent format.	"ica_rsa_mod_expo" on page 24	Depending on supported key size of Crypto Express feature	Yes	Yes	Yes	No	Key length maximum 4 K bits
RSA encryption and decryption operation using a key in Chinese-Remainder Theorem (CRT) format.	"ica_rsa_crt" on page 25	Depending on supported key size of Crypto Express feature	Yes	Yes	Yes	No	Key length maximum 4 K bits
<b>DES functions</b>							

Table 2. libica Version 2.2.0 APIs (continued)

Function	libica Version 2.2.0 API name	Key length in bits	Supported on			CPACF function	Software fallback
			z9	z10	z196		
DES with Cipher Block Chaining mode	"ica_des_cbc" on page 27	56	Yes	Yes	Yes	Yes	Yes
DES with CBC-Cipher text stealing mode	"ica_des_cbc_cs" on page 28	56	Yes	Yes	Yes	Yes	Yes
DES with Cipher Feedback mode	"ica_des_cfb" on page 30	56	No	No	Yes	Yes	No
DES with CMAC mode	"ica_des_cmac" on page 31	56	No	No	Yes	Yes	No
DES with CMAC mode process intermediate chunks	"ica_des_cmac_intermediate" on page 32	56	No	No	Yes	Yes	No
DES with CMAC mode process last chunk	"ica_des_cmac_last" on page 33	56	No	No	Yes	Yes	No
DES with Counter mode	"ica_des_ctr" on page 35	56	No	No	Yes	Yes	No
DES with Counter mode, using a list of counters	"ica_des_ctrlist" on page 37	56	No	No	Yes	Yes	No
DES with Electronic Codebook mode.	"ica_des_ecb" on page 39	56	Yes	Yes	Yes	Yes	Yes
DES with Output Feedback mode	"ica_des_ofb" on page 40	56	No	No	Yes	Yes	No
<b>TDES/3DES functions</b>							
TDES with Cipher Block Chaining mode	"ica_3des_cbc" on page 43	168	Yes	Yes	Yes	Yes	Yes
TDES with CBC-Cipher text Stealing mode	"ica_3des_cbc_cs" on page 44	168	Yes	Yes	Yes	Yes	Yes
TDES with Cipher Feedback mode	"ica_3des_cfb" on page 46	168	No	No	Yes	Yes	No
TDES with CMAC mode	"ica_3des_cmac" on page 47	168	No	No	Yes	Yes	No
TDES with CMAC mode process intermediate chunks	"ica_3des_cmac_intermediate" on page 48	168	No	No	Yes	Yes	No
TDES with CMAC mode process last chunk	"ica_3des_cmac_last" on page 49	168	No	No	Yes	Yes	No
TDES with Counter mode	"ica_3des_ctr" on page 51	168	No	No	Yes	Yes	No
TDES with Counter mode, using a list of counters	"ica_3des_ctrlist" on page 53	168	No	No	Yes	Yes	No
TDES with Electronic Codebook mode	"ica_3des_ecb" on page 55	168	Yes	Yes	Yes	Yes	Yes
TDES with Output Feedback mode	"ica_3des_ofb" on page 56	168	No	No	Yes	Yes	No
<b>AES functions</b>							
AES with Cipher Block Chaining mode.	"ica_aes_cbc" on page 59	128, 192, 256	Yes	Yes	Yes	Yes	Yes
AES with CBC-Cipher text stealing mode.	"ica_aes_cbc_cs" on page 60	128, 192, 256	Yes	Yes	Yes	Yes	Yes

Table 2. libica Version 2.2.0 APIs (continued)

Function	libica Version 2.2.0 API name	Key length in bits	Supported on			CPACF function	Software fallback
			z9	z10	z196		
AES with Counter with Cipher Block Chaining - Message Authentication Code mode.	"ica_aes_ccm" on page 62	128, 192, 256	No	No	Yes	Yes	No
AES with Cipher Feedback mode.	"ica_aes_cfb" on page 64	128, 192, 256	No	No	Yes	Yes	No
AES with CMAC mode	"ica_aes_cmac" on page 66	128, 192, 256	No	No	Yes	Yes	No
AES with CMAC mode process intermediate chunks	"ica_aes_cmac_intermediate" on page 68	128, 192, 256	No	No	Yes	Yes	No
AES with CMAC mode process last chunk	"ica_aes_cmac_last" on page 69	128, 192, 256	No	No	Yes	Yes	No
AES with Counter mode.	"ica_aes_ctr" on page 71	128, 192, 256	No	No	Yes	Yes	No
AES with Counter mode, using a list of counters	"ica_aes_ctrlist" on page 73	128, 192, 256	No	No	Yes	Yes	No
AES with Electronic Codebook mode.	"ica_aes_ecb" on page 75	128, 192, 256	Yes	Yes	Yes	Yes	Yes
AES with Galois / Counter mode.	"ica_aes_gcm" on page 76	128, 192, 256	No	No	Yes	Yes	No
AES with Output Feedback mode.	"ica_aes_ofb" on page 78	128, 192, 256	No	No	Yes	Yes	No
AES with XEX-based Tweaked CodeBook mode (TCB) with CipherText Stealing (CTS).	"ica_aes_xts" on page 79	128, 256	No	No	Yes	Yes	No
<b>Information retrieval functions</b>							
Return version information for libica.	"ica_get_version" on page 83	N/A	Yes	Yes	Yes	No	N/A

## Open and close adapter functions

These functions open or close the crypto adapter. It is recommended to open the crypto adapter before using any of the libica crypto functions, and to close it after the last usage of the libica crypto functions. However, in this version of the libica only the RSA-related functions **ica\_rsa\_mod\_expo** and **ica\_rsa crt** require a valid adapter handle as input. A pointer to the value DRIVER\_NOT\_LOADED indicates an invalid adapter handle. The parameter *ica\_adapter\_handle\_t* is a redefine of int.

These functions are included in: include/ica\_api.h.

## ica\_open\_adapter

### Purpose

Opens an adapter.

### Format

```
unsigned int ica_open_adapter(ica_adapter_handle_t *adapter_handle);
```

### Parameters

#### **ica\_adapter\_handle\_t \*adapter\_handle**

Pointer to the file descriptor for the adapter or to DRIVER\_NOT\_LOADED if opening the crypto adapter failed.

Opening an adapter succeeds if a cryptographic device is accessible for reading and writing. By default, cryptographic access must be available with one of the following path names: **/udev/z90crypt**, **/dev/z90crypt**, or **/dev/zcrypt** for the adapter open request to succeed. If the environment variable LIBICA\_CRYPT\_DEVICE is set to a valid path name of an accessible cryptographic device, accessing the device with that path name takes precedence over the default path names.

### Return codes

0        Success

For return codes indicating exceptions, see “Return codes” on page 87.

## **ica\_close\_adapter**

### **Purpose**

Closes an adapter.

### **Comments**

This API closes a device handle.

### **Format**

```
unsigned int ica_close_adapter(ica_adapter_handle_t adapter_handle);
```

### **Parameters**

**ica\_adapter\_handle\_t adapter\_handle**

Pointer to a previously opened device handle.

### **Return codes**

0       Success

For return codes indicating exceptions, see “Return codes” on page 87.

---

## Secure hash operations

These functions are included in: `include/ica_api.h`.

These functions perform secure hash on input data using the chosen algorithm of SHA-1, SHA-224, SHA-256, SHA-384, or SHA-512.

SHA context structs contain information about how much of the actual work was already performed. Also, it contains the part of the hash that is already produced. For the user, it is only interesting in cases where the message is not hashed at once, because the context is needed for further operations.

## ica\_sha1

### Purpose

Performs a secure hash operation on the input data using the SHA-1 algorithm.

### Format

```
unsigned int ica_sha1(unsigned int message_part,  
                    unsigned int input_length,  
                    unsigned char *input_data,  
                    sha_context_t *sha_context,  
                    unsigned char *output_data);
```

### Required hardware support

KIMD-SHA-1, or KLMD-SHA-1

### Parameters

#### unsigned int message\_part

The message chaining state. This parameter must be one of the following values:

##### SHA\_MSG\_PART\_ONLY

A single hash operation

##### SHA\_MSG\_PART\_FIRST

The first part

##### SHA\_MSG\_PART\_MIDDLE

The middle part

##### SHA\_MSG\_PART\_FINAL

The last part

#### unsigned int input\_length

Length in bytes of the input data to be hashed using the SHA-1 algorithm. This value must be greater than zero.

#### unsigned char \*input\_data

Pointer to the input data to be hashed.

#### sha\_context\_t \*sha\_context

Pointer to the SHA-1 context structure used to store intermediate values needed when chaining is used. The contents are ignored for message part `SHA_MSG_PART_ONLY` and `SHA_MSG_PART_FIRST`. This structure must contain the returned value of the preceding call to `ica_sha1` for message part `SHA_MSG_PART_MIDDLE` and `SHA_MSG_PART_FINAL`. For message part `SHA_MSG_PART_FIRST` and `SHA_MSG_PART_FINAL`, the returned value can be used for a chained call of `ica_sha1`. Therefore, the application must not modify the contents of this structure in between chained calls.

#### unsigned char \*output\_data

Pointer to the buffer to contain the resulting hash data. The resulting output data has a length of `SHA_HASH_LENGTH`. Make sure that the buffer is at least this size.

### Return codes

0 Success

For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_sha224

### Purpose

Performs a secure hash operation on the input data using the SHA-224 algorithm.

### Format

```
unsigned int ica_sha224(unsigned int message_part,  
    unsigned int input_length,  
    unsigned char *input_data,  
    sha256_context_t *sha256_context,  
    unsigned char *output_data);
```

### Required hardware support

KIMD-SHA-256, or KLMD-SHA-256

### Parameters

#### unsigned int message\_part

The message chaining state. This parameter must be one of the following values:

##### SHA\_MSG\_PART\_ONLY

A single hash operation

##### SHA\_MSG\_PART\_FIRST

The first part

##### SHA\_MSG\_PART\_MIDDLE

The middle part

##### SHA\_MSG\_PART\_FINAL

The last part

#### unsigned int input\_length

Length in bytes of the input data to be hashed using the SHA-224 algorithm. This value must be greater than zero.

#### unsigned char \*input\_data

Pointer to the input data to be hashed.

#### sha256\_context\_t \*sha256\_context

Pointer to the SHA-256 context structure used to store intermediate values needed when chaining is used. The contents are ignored for message part `SHA_MSG_PART_ONLY` and `SHA_MSG_PART_FIRST`. This structure must contain the returned value of the preceding call to `ica_sha224` for message part `SHA_MSG_PART_MIDDLE` and `SHA_MSG_PART_FINAL`. For message part `SHA_MSG_PART_FIRST` and `SHA_MSG_PART_FINAL`, the returned value can be used for a chained call of `ica_sha224`. Therefore, the application must not modify the contents of this structure in between chained calls.

**Note:** Due to the algorithm used by SHA-224, a SHA-256 context must be used.

#### unsigned char \*output\_data

Pointer to the buffer to contain the resulting hash data. The resulting output data has a length of `SHA224_HASH_LENGTH`. Make sure that the buffer is at least this size.

### Return codes

0 Success



For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_sha256

### Purpose

Performs a secure hash on the input data using the SHA-256 algorithm.

### Format

```
unsigned int ica_sha256(unsigned int message_part,  
    unsigned int input_length,  
    unsigned char *input_data,  
    sha256_context_t *sha256_context,  
    unsigned char *output_data);
```

### Required hardware support

KIMD-SHA-256, or KLMD-SHA-256

### Parameters

#### **unsigned int message\_part**

The message chaining state. This parameter must be one of the following values:

##### **SHA\_MSG\_PART\_ONLY**

A single hash operation

##### **SHA\_MSG\_PART\_FIRST**

The first part

##### **SHA\_MSG\_PART\_MIDDLE**

The middle part

##### **SHA\_MSG\_PART\_FINAL**

The last part

#### **unsigned int input\_length**

Length in bytes of the input data to be hashed using the SHA-256 algorithm. This value must be greater than zero.

#### **unsigned char \*input\_data**

Pointer to the input data to be hashed.

#### **sha256\_context\_t \*sha256\_context**

Pointer to the SHA-256 context structure used to store intermediate values needed when chaining is used. The contents are ignored for message part `SHA_MSG_PART_ONLY` and `SHA_MSG_PART_FIRST`. This structure must contain the returned value of the preceding call to `ica_sha256` for message part `SHA_MSG_PART_MIDDLE` and `SHA_MSG_PART_FINAL`. For message part `SHA_MSG_PART_FIRST` and `SHA_MSG_PART_FINAL`, the returned value can be used for a chained call of `ica_sha256`. Therefore, the application must not modify the contents of this structure in between chained calls.

#### **unsigned char \*output\_data**

Pointer to the buffer to contain the resulting hash data. The resulting output data has a length of `SHA256_HASH_LENGTH`. Make sure that the buffer is at least this size.

### Return codes

0 Success

For return codes indicating exceptions, see "Return codes" on page 87.

## ica\_sha384

### Purpose

Performs a secure hash on the input data using the SHA-384 algorithm.

### Format

```
unsigned int ica_sha384(unsigned int message_part,  
    uint64_t input_length,  
    unsigned char *input_data,  
    sha512_context_t *sha512_context,  
    unsigned char *output_data);
```

### Required hardware support

KIMD-SHA-512, or KLMD-SHA-512

### Parameters

#### unsigned int message\_part

The message chaining state. This parameter must be one of the following values:

##### SHA\_MSG\_PART\_ONLY

A single hash operation

##### SHA\_MSG\_PART\_FIRST

The first part

##### SHA\_MSG\_PART\_MIDDLE

The middle part

##### SHA\_MSG\_PART\_FINAL

The last part

#### uint64\_t input\_length

Length in bytes of the input data to be hashed using the SHA-384 algorithm. This value must be greater than zero.

#### unsigned char \*input\_data

Pointer to the input data to be hashed.

#### sha512\_context\_t \*sha512\_context

Pointer to the SHA-512 context structure used to store intermediate values needed when chaining is used. The contents are ignored for message part `SHA_MSG_PART_ONLY` and `SHA_MSG_PART_FIRST`. This structure must contain the returned value of the preceding call to `ica_sha384` for message part `SHA_MSG_PART_MIDDLE` and `SHA_MSG_PART_FINAL`. For message part `SHA_MSG_PART_FIRST` and `SHA_MSG_PART_FINAL`, the returned value can be used for a chained call of `ica_sha384`. Therefore, the application must not modify the contents of this structure in between chained calls.

**Note:** Due to the algorithm used by SHA-384, a SHA-512 context must be used.

#### unsigned char \*output\_data

Pointer to the buffer to contain the resulting hash data. The resulting output data has a length of `SHA384_HASH_LENGTH`. Make sure that the buffer is at least this size.

### Return codes

0 Success

For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_sha512

### Purpose

Performs a secure hash operation on input data using the SHA-512 algorithm.

### Format

```
unsigned int ica_sha512(unsigned int message_part,  
    uint64_t input_length,  
    unsigned char *input_data,  
    sha512_context_t *sha512_context,  
    unsigned char *output_data);
```

### Required hardware support

KIMD-SHA-512, or KLMD-SHA-512

### Parameters

#### unsigned int message\_part

The message chaining state. This parameter must be one of the following values:

##### SHA\_MSG\_PART\_ONLY

A single hash operation

##### SHA\_MSG\_PART\_FIRST

The first part

##### SHA\_MSG\_PART\_MIDDLE

The middle part

##### SHA\_MSG\_PART\_FINAL

The last part

#### uint64\_t input\_length

Length in bytes of the input data to be hashed using the SHA-512 algorithm. This value must be greater than zero.

#### unsigned char \*input\_data

Pointer to the input data to be hashed.

#### sha512\_context\_t \*sha512\_context

Pointer to the SHA-512 context structure used to store intermediate values needed when chaining is used. The contents are ignored for message part `SHA_MSG_PART_ONLY` and `SHA_MSG_PART_FIRST`. This structure must contain the returned value of the preceding call to `ica_sha512` for message part `SHA_MSG_PART_MIDDLE` and `SHA_MSG_PART_FINAL`. For message part `SHA_MSG_PART_FIRST` and `SHA_MSG_PART_FINAL`, the returned value can be used for a chained call of `ica_sha512`. Therefore, the application must not modify the contents of this structure in between chained calls.

#### unsigned char \*output\_data

Pointer to the buffer to contain the resulting hash data. The resulting output data has a length of `SHA512_HASH_LENGTH`. Make sure that the buffer is at least this size.

### Return codes

0 Success

For return codes indicating exceptions, see “Return codes” on page 87.

---

## Pseudo random number generation function

This function is included in: `include/ica_api.h`.

This function generates pseudo random data. Parameter *\*output\_data* is a pointer to a buffer of byte length *output\_length*. *output\_length* number of bytes of pseudo random data is placed in the buffer pointed to by *output\_data*.

libica initialization tries to seed the CPACF random generator. To get the seed, device `/dev/hwrng` is opened. Device `/dev/hwrng` provides true random data from crypto adapters over the crypto device driver (module name `z90crypt`). If that fails, the initialization mechanism uses device `/dev/urandom`. Within the initialization, a byte counter *s390\_byte\_count* is set to 0. If the CPACF pseudo random generator is available, after 4096 bytes of the pseudo random number are generated, the random number generator is seeded again. If the CPACF pseudo random generator is not available, random numbers are read from `/dev/urandom`.

## ica\_random\_number\_generate

### Purpose

Generates a pseudo random number.

### Format

```
unsigned int ica_random_number_generate(unsigned int output_length,  
    unsigned char *output_data);
```

### Required hardware support

KMC-PRNG

### Parameters

**unsigned int output\_length**

Length in bytes of the *output\_data* buffer, and the length of the generated pseudo random number.

**unsigned char \*output\_data**

Pointer to the buffer to receive the generated pseudo random number.

### Return codes

0        Success

For return codes indicating exceptions, see “Return codes” on page 87.

---

## RSA key generation functions

These functions are included in: `include/ica_api.h`.

These functions generate an RSA public/private key pair. These functions are performed using software through OpenSSL. Hardware is not used.



## ica\_rsa\_key\_generate\_mod\_expo

### Purpose

Generates RSA keys in modulus/exponent format.

### Comments

For specific information about some of these parameters, see the considerations in “Structs” on page 86.

### Format

```
unsigned int ica_rsa_key_generate_mod_expo(ica_adapter_handle_t adapter_handle,  
    unsigned int modulus_bit_length,  
    ica_rsa_key_mod_expo_t *public_key,  
    ica_rsa_key_mod_expo_t *private_key);
```

### Parameters

#### **ica\_adapter\_handle\_t adapter\_handle**

Pointer to a previously opened device handle.

#### **unsigned int modulus\_bit\_length**

Length in bits of the modulus. This value should comply with the length of the keys (in bytes), according to this calculation:

$$\text{key\_length} = (\text{modulus\_bits} + 7) / 8$$

#### **ica\_rsa\_key\_mod\_expo\_t \*public\_key**

Pointer to where the generated public key is to be placed. If the *exponent* element in the public key is not set, it is randomly generated. A poorly chosen *exponent* could result in the program looping endlessly. Common public exponents are 3 and 65537.

#### **ica\_rsa\_key\_mod\_expo\_t \*private\_key**

Pointer to where the generated private key in modulus/exponent format is to be placed. The length of both the private and public keys should be set in bytes. This value should comply with the length of the keys (in bytes), according to this calculation:

$$\text{key\_length} = (\text{modulus\_bits} + 7) / 8$$

### Return codes

0 Success

For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_rsa\_key\_generate\_crt

### Purpose

Generates RSA keys in Chinese-Remainder Theorem (CRT) format.

### Comments

For specific information about some of these parameters, see the considerations in “Structs” on page 86.

### Format

```
unsigned int ica_rsa_key_generate_crt(ica_adapter_handle_t adapter_handle,  
    unsigned int modulus_bit_length,  
    ica_rsa_key_mod_expo_t *public_key,  
    ica_rsa_key_crt_t *private_key);
```

### Parameters

#### **ica\_adapter\_handle\_t adapter\_handle**

Pointer to a previously opened device handle.

#### **unsigned int modulus\_bit\_length**

Length in bits of the modulus part of the key. This value should comply with the length of the keys (in bytes), according to this calculation:

$$\text{key\_length} = (\text{modulus\_bits} + 7) / 8$$

#### **ica\_rsa\_key\_mod\_expo\_t \*public\_key**

Pointer to where the generated public key is to be placed. If the *exponent* element in the public key is not set, it is randomly generated. A poorly chosen *exponent* can result in the program looping endlessly. Common public exponents are 3 and 65537.

#### **ica\_rsa\_key\_crt\_t \*private\_key**

Pointer to where the generated private key in CRT format is to be placed. Length of both private and public keys should be set in bytes. This value should comply with the length of the keys (in bytes), according to this calculation

$$\text{key\_length} = (\text{modulus\_bits} + 7) / 8$$

### Return codes

0 Success

For return codes indicating exceptions, see “Return codes” on page 87.

---

## RSA encrypt and decrypt operations

These functions are included in: `include/ica_api.h`.

These functions perform a modulus/exponent operation using an RSA key whose type is either `ica_rsa_key_mod_expo_t` or `ica_rsa_key_crt_t`.

## ica\_rsa\_mod\_expo

### Purpose

Performs an RSA encryption or decryption operation using a key in modulus/exponent format.

### Comments

Make sure that your message is padded before using this function.

### Format

```
unsigned int ica_rsa_mod_expo(ica_adapter_handle_t adapter_handle,  
    unsigned char *input_data,  
    ica_rsa_key_mod_expo_t *rsa_key,  
    unsigned char *output_data);
```

### Parameters

#### **ica\_adapter\_handle\_t adapter\_handle**

Pointer to a previously opened device handle.

#### **unsigned char \*input\_data**

Pointer to the input data to be encrypted or decrypted. This data must be in big endian format. Make sure that the input data is not longer than the bit length of the key. The byte length for the input data and the key must be the same. Right align the input data inside the data block.

#### **ica\_rsa\_key\_mod\_expo\_t \*rsa\_key**

Pointer to the key to be used, in modulus/exponent format.

#### **unsigned char \*output\_data**

Pointer to the location where the output results are to be placed. This buffer has to be at least the same size as *input\_data* and therefore at least the same size as the size of the modulus.

### Return codes

0        Success

For return codes indicating exceptions, see "Return codes" on page 87.

## ica\_rsa\_crt

### Purpose

Performs an RSA encryption or decryption operation using a key in CRT format.

### Comments

Make sure that your message is padded before using this function.

### Format

```
unsigned int ica_rsa_crt(ica_adapter_handle_t adapter_handle,  
    unsigned char *input_data,  
    ica_rsa_key_crt_t *rsa_key,  
    unsigned char *output_data);
```

### Parameters

#### **ica\_adapter\_handle\_t adapter\_handle**

Pointer to a previously opened device handle.

#### **unsigned char \*input\_data**

Pointer to the input data to be encrypted or decrypted. This data must be in big endian format. Make sure that the input data is not longer than the bit length of the key. The byte length for the input data and the key must be the same. Right align the input data inside the data block.

#### **ica\_rsa\_key\_crt\_t \*rsa\_key**

Pointer to the key to be used, in CRT format.

#### **unsigned char \*output\_data**

Pointer to the location where the output results are to be placed. This buffer must be as large as the *input\_data*, and as large as the length of the *modulus* specified in *rsa\_key*.

### Return codes

0        Success

For return codes indicating exceptions, see "Return codes" on page 87.

---

## DES functions

These functions are included in: `include/ica_api.h`.

These functions perform encryption and decryption and computation or verification of message authentication codes using a DES (DEA) key. A DES key has a size of 8 bytes. Each byte of a DES key contains one parity bit, such that each 64-bit DES key contains only 56 security-relevant bits. The cipher block size for DES is 8 bytes.

To securely apply DES encryption to messages that are longer than the cipher block size, modes of operation can be used to chain multiple encryption, decryption, or authentication operations. Most modes of operation require an initialization vector as additional input. As long as the messages are encrypted or decrypted using such a mode of operation, and have a size that is a multiple of a particular block size (mostly the cipher block size), the functions encrypting or decrypting according to a mode of operation also compute an output vector. This output vector can be used as the initialization vector of a chained encryption or decryption operation in the same mode with the same block size and the same key.

When decrypting a cipher text, these values used for the decryption function must match the corresponding settings of the encryption function that transformed the plain text into the cipher text:

- The mode of operation
- The key
- The initialization vector (if applicable)
- For the `ica_des_cfb` function, the *lcfb* parameter

## ica\_des\_cbc

### Purpose

Encrypt or decrypt data with a DES key using Cipher Block Chaining (CBC) mode, as described in NIST Special Publication 800-38A Chapter 6.2.

### Format

```
unsigned int ica_des_cbc(const unsigned char *in_data,
    unsigned char *out_data,
    unsigned long data_length,
    const unsigned char *key,
    unsigned char *iv,
    unsigned int direction);
```

### Required hardware support

KMC-DEA

### Parameters

#### **const unsigned char \*in\_data**

Pointer to a readable buffer that contains the message to be encrypted or decrypted. The size of the message in bytes is *data\_length*. This buffer must be at least as large as *data\_length*.

#### **unsigned char \*out\_data**

Pointer to a writable buffer to contain the resulting encrypted or decrypted message. The size of this buffer in bytes must be at least as large as *data\_length*.

#### **unsigned long data\_length**

Length in bytes of the message to be encrypted or decrypted, which resides at the beginning of *in\_data*. *data\_length* must be a multiple of the cipher block size (a multiple of 8 bytes for DES).

#### **const unsigned char \*key**

Pointer to a valid DES key of 8 bytes in length.

#### **unsigned char \*iv**

Pointer to a valid initialization vector of cipher block size number of bytes (8 bytes for DES). This vector is overwritten by this function. The result value in *iv* can be used as the initialization vector for a chained **ica\_des\_cbc** or **ica\_des\_cbc\_cs** call with the same key.

#### **unsigned int direction**

0      Use the decrypt function.  
1      Use the encrypt function.

### Return codes

0      Success

For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_des\_cbc\_cs

### Purpose

Encrypt or decrypt data with a DES key using Cipher Block Chaining with Ciphertext Stealing (CBC-CS) mode, as described in NIST Special Publication 800-38A, Chapter 6.2 and the Addendum to NIST Special Publication 800-38A on "Recommendation for Block Cipher Modes of Operation: Three Variants of Ciphertext Stealing for CBC Mode".

`ica_des_cbc_cs` can be used to encrypt or decrypt the last chunk of a message consisting of multiple chunks, where all chunks except the last one are encrypted or decrypted by chained calls to `ica_des_cbc`. To do this, the resulting *iv* of the last call to `ica_des_cbc` is fed into the *iv* of the `ica_des_cbc_cs` call, provided that the chunk is greater than the cipher block size (8 bytes for DES).

### Format

```
unsigned int ica_des_cbc_cs(const unsigned char *in_data,
    unsigned char *out_data,
    unsigned long data_length,
    const unsigned char *key,
    unsigned char *iv,
    unsigned int direction,
    unsigned int variant);
```

### Required hardware support

KMC-DEA

### Parameters

#### **const unsigned char \*in\_data**

Pointer to a readable buffer that contains the message to be encrypted or decrypted. The size of the message in bytes is *data\_length*. The size of this buffer must be at least as large as the *data\_length*.

#### **unsigned char \*out\_data**

Pointer to a writable buffer to contain the resulting encrypted or decrypted message. This buffer must be at least as large as *data\_length*.

#### **unsigned long data\_length**

Length in bytes of the message to be encrypted or decrypted, which resides at the beginning of *in\_data*. *data\_length* must be greater than or equal to the cipher block size (8 bytes for DES).

#### **const unsigned char \*key**

Pointer to a valid DES key of 8 bytes in length.

#### **unsigned char \*iv**

Pointer to a valid initialization vector of cipher block size number of bytes. This vector is overwritten during the function. For *variant* equal to 1 or *variant* equal to 2, the result value in *iv* can be used as the initialization vector for a chained `ica_des_cbc` or `ica_des_cbc_cs` call with the same key, if *data\_length* is a multiple of the cipher block size.

#### **unsigned int direction**

0 Use the decrypt function.

1 Use the encrypt function.

#### **unsigned int variant**



- |                   1        Use variant CBC-CS1 of the Addendum to NIST Special Publication  
|                            800-38A to encrypt or decrypt the message: always keep last two  
|                            blocks in order.
- |                   2        Use variant CBC-CS2 of the Addendum to NIST Special Publication  
|                            800-38A to encrypt or decrypt the message: switch order of the last two  
|                            blocks if *data\_length* is not a multiple of the cipher block size (a  
|                            multiple of 8 bytes for DES).
- |                   3        Use variant CBC-CS3 of the Addendum to NIST Special Publication  
|                            800-38A to encrypt or decrypt the message: always switch order of the  
|                            last two blocks.

|                   **Return codes**

|                   0        Success

|                   For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_des\_cfb

### Purpose

Encrypt or decrypt data with a DES key using Cipher Feedback (CFB) mode, as described in NIST Special Publication 800-38A Chapter 6.3.

### Format

```
unsigned int ica_des_cfb(const unsigned char *in_data,
    unsigned char *out_data,
    unsigned long data_length,
    const unsigned char *key,
    unsigned char *iv,
    unsigned int lcfb,
    unsigned int direction);
```

### Required hardware support

KMF-DEA

### Parameters

#### **const unsigned char \*in\_data**

Pointer to a readable buffer that contains the message to be encrypted or decrypted. The size of the message in bytes is *data\_length*. The size of this buffer must be at least as large as the *data\_length* parameter.

#### **unsigned char \*out\_data**

Pointer to a writable buffer to contain the resulting encrypted or decrypted message. The size of this buffer in bytes must be at least as large as the *data\_length* parameter.

#### **unsigned long data\_length**

Length in bytes of the message to be encrypted or decrypted, which resides at the beginning of *in\_data*.

#### **const unsigned char \*key**

Pointer to a valid DES key of 8 bytes in length.

#### **unsigned char \*iv**

Pointer to a valid initialization vector of cipher block size bytes (8 bytes for DES). This vector is overwritten during the function. The result value in *iv* can be used as the initialization vector for a chained **ica\_des\_cfb** call with the same key, if *data\_length* in the preceding call is a multiple of the *lcfb* parameter.

#### **unsigned int lcfb**

Length in bytes of the cipher feedback, which is a value greater than or equal to 1 and less than or equal to the cipher block size (8 bytes for DES).

#### **unsigned int direction**

0        Use the decrypt function.  
1        Use the encrypt function.

### Return codes

0        Success

For return codes indicating exceptions, see "Return codes" on page 87.

## ica\_des\_cmac

### Purpose

Authenticate data or verify the authenticity of data with a DES key using the Block Cipher Based Message Authentication Code (CMAC) mode, as described in NIST Special Publication 800-38B. `ica_des_cmac` can be used to authenticate or verify the authenticity of a complete message.

### Format

```
unsigned int ica_des_cmac(const unsigned char *message,  
    unsigned long message_length,  
    unsigned char *mac,  
    unsigned int mac_length,  
    const unsigned char *key,  
    unsigned int direction);
```

### Required hardware support

KMAC-DEA  
PCC-Compute-Last\_block-CMAC-Using-DEA

### Parameters

#### **const unsigned char \*message**

Pointer to a readable buffer of size greater than or equal to *message\_length* bytes. This buffer contains a message to be authenticated or of which the authenticity is to be verified.

#### **unsigned long message\_length**

Length in bytes of the message to be authenticated or verified.

#### **unsigned char \*mac**

Pointer to a buffer of size greater than or equal to *mac\_length* bytes. If *direction* is equal to 1, the buffer must be writable and a message authentication code for the message in *message* of size *mac\_length* bytes is written to the buffer. If *direction* is equal to 0, the buffer must be readable and contain a message authentication code to be verified against the message in *message*.

#### **unsigned int mac\_length**

Length in bytes of the message authentication code *mac*, which is less than or equal to the cipher block size (8 bytes for DES). It is recommended to use a *mac\_length* of 8.

#### **const unsigned char \*key**

Pointer to a valid DES key of 8 bytes in length.

#### **unsigned int direction**

0      Verify message authentication code.  
1      Compute message authentication code for the message.

### Return codes

0      Success

#### **EFAULT**

If *direction* is equal to 0 and the verification of the message authentication code fails.

For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_des\_cmac\_intermediate

### Purpose

Authenticate data or verify the authenticity of data with a DES key using the Block Cipher Based Message Authentication Code (CMAC) mode, as described in NIST Special Publication 800-38B. `ica_des_cmac_intermediate` and `ica_des_cmac_last` can be used when the message to be authenticated or to be verified using CMAC is supplied in multiple chunks. `ica_des_cmac_intermediate` is used to process all but the last chunk. All message chunks to be processed by `ica_des_cmac_intermediate` must have a size that is a multiple of the cipher block size (8 bytes for DES).

Note that `ica_des_cmac_intermediate` has no direction argument. This function can be used during authentication and during authenticity verification.

### Format

```
unsigned int ica_des_cmac_intermediate(const unsigned char *message,
                                     unsigned long message_length,
                                     const unsigned char *key,
                                     unsigned char *iv);
```

### Required hardware support

KMAC-DEA

### Parameters

#### **const unsigned char \*message**

Pointer to a readable buffer of size greater than or equal to *message\_length* bytes. This buffer contains a non-final part of a message to be authenticated, or of which the authenticity is to be verified.

#### **unsigned long message\_length**

Length in bytes of the message part in *message*. This value must be a multiple of the cipher block size.

#### **const unsigned char \*key**

Pointer to a valid DES key of 8 bytes in length.

#### **unsigned char \*iv**

Pointer to a valid initialization vector of cipher block size bytes (8 bytes for DES). For the first message part, this parameter must be set to a string of zeros. For processing the *n*-th message part, this parameter must be the resulting *iv* value of the `ica_des_cmac_intermediate` function applied to the (*n*-1)-th message part. This vector is overwritten during the function. The result value in *iv* can be used as the initialization vector for a chained call to `ica_des_cmac_initermediate`, or to `ica_des_cmac_last` with the same key.

### Return codes

0       Success

For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_des\_cmac\_last

### Purpose

Authenticate data or verify the authenticity of data with a DES key using the Block Cipher Based Message Authentication Code (CMAC) mode, as described in NIST Special Publication 800-38B. `ica_des_cmac_last` can be used to authenticate or verify the authenticity of a complete message or of the final part of a message for which all preceding parts were processed with `ica_des_cmac_intermediate`.

### Format

```
unsigned int ica_des_cmac_last(const unsigned char *message,  
    unsigned long message_length,  
    unsigned char *mac,  
    unsigned int mac_length,  
    const unsigned char *key,  
    unsigned char *iv,  
    unsigned int direction);
```

### Required hardware support

KMAC-DEA  
PCC-Compute-Last\_block-CMAC-Using-DEA

### Parameters

#### **const unsigned char \*message**

Pointer to a readable buffer of size greater than or equal to *message\_length* bytes. This buffer contains a message or the final part of a message, to be either authenticated or of which the authenticity is to be verified.

#### **unsigned long message\_length**

Length in bytes of the message to be authenticated or verified.

#### **unsigned char \*mac**

Pointer to a buffer of size greater than or equal to *mac\_length* bytes. If *direction* is equal to 1, the buffer must be writable and a message authentication code for the message in *message* of size *mac\_length* bytes is written to the buffer. If *direction* is equal to 0, the buffer must be readable and contain a message authentication code that is verified against the message in *message*.

#### **unsigned int mac\_length**

Length in bytes of the message authentication code *mac* that is less than or equal to the cipher block size (8 bytes for DES). It is recommended to use a *mac\_length* of 8.

#### **const unsigned char \*key**

Pointer to a valid DES key of 8 bytes in length.

#### **unsigned char \*iv**

Pointer to a valid initialization vector of cipher block size number of bytes. If *iv* is NULL, *message* is assumed to be the complete message to be processed. Otherwise, *message* is the final part of a composite message to be processed and *iv* contains the output vector resulting from processing all previous parts with chained calls to `ica_des_cmac_intermediate` (the value returned in *iv* of the `ica_des_cmac_intermediate` call applied to the penultimate message part).

#### **unsigned int direction**

0      Verify message authentication code.  
1      Compute message authentication code for the message.

| **Return codes**

| 0 Success

| **EFAULT**

| If *direction* is equal to 0 and the verification of the message authentication  
| code fails.

| For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_des\_ctr

### Purpose

Encrypt or decrypt data with a DES key using Counter (CTR) mode, as described in NIST Special Publication 800-38A Chapter 6.5. With the counter mode, each message block of the same size as the cipher block (8 bytes for DES) is combined with a counter value of the same size during encryption and decryption.

Starting with an initial counter value to be combined with the first message block, subsequent counter values to be combined with subsequent message blocks are derived from preceding counter values by an increment function. The increment function used in `ica_des_ctr` is an arithmetic increment without carry on the  $M$  least significant bytes in the counter, where  $M$  is a parameter to `ica_des_ctr`.

### Format

```
unsigned int ica_des_ctr(const unsigned char *in_data,
    unsigned char *out_data,
    unsigned long data_length,
    const unsigned char *key,
    unsigned char *ctr,
    unsigned int ctr_width,
    unsigned int direction);
```

### Required hardware support

KMCTR-DEA

### Parameters

#### `const unsigned char *in_data`

Pointer to a readable buffer that contains the message to be encrypted or decrypted. The size of the message in bytes is `data_length`. The size of this buffer must be at least as large as `data_length`.

#### `unsigned char *out_data`

Pointer to a writable buffer to contain the resulting encrypted or decrypted message. The size of this buffer in bytes must be at least as large as `data_length`.

#### `unsigned long data_length`

Length in bytes of the message to be encrypted or decrypted, which resides at the beginning of `in_data`.

#### `const unsigned char *key`

Pointer to a valid DES key of 8 bytes in length.

#### `unsigned char *ctr`

Pointer to a readable and writable buffer of the same size as the cipher block in bytes. `ctr` contains an initialization value for a counter function, and it is replaced by a new value. That new value can be used as the initialization value for a counter function in a chained `ica_des_ctr` call with the same key, if the `data_length` used in the preceding call is a multiple of the cipher block size.

#### `unsigned int ctr_width`

A number  $M$  between 1 and the cipher block size. This value is used by the counter increment function, which increments a counter value by incrementing without carry the least significant  $M$  bytes of the counter value.

#### `unsigned int direction`

0 Use the decrypt function.

1 Use the encrypt function.

## **Return codes**

0      Success

For return codes indicating exceptions, see “Return codes” on page 87.



## ica\_des\_ctrlist

### Purpose

Encrypt or decrypt data with a DES key using Counter (CTR) mode, as described in NIST Special Publication 800-38A ,Chapter 6.5. With the counter mode, each message block of the same size as the cipher block is combined with a counter value of the same size during encryption and decryption.

The `ica_des_ctrlist` function assumes that a list  $n$  of precomputed counter values is provided, where  $n$  is the smallest integer that is less than or equal to the message size divided by the cipher block size. This function is used to optimally utilize IBM System z hardware support for non-standard counter functions.

### Format

```
unsigned int ica_des_ctrlist(const unsigned char *in_data,
    unsigned char *out_data,
    unsigned long data_length,
    const unsigned char *key,
    const unsigned char *ctrlist,
    unsigned int direction);
```

### Required hardware support

KMCTR-DEA

### Parameters

#### `const unsigned char *in_data`

Pointer to a readable buffer that contains the message to be encrypted or decrypted. The size of the message in bytes is `data_length`. The size of this buffer must be at least as large as `data_length`.

#### `unsigned char *out_data`

Pointer to a writable buffer to contain the resulting encrypted or decrypted message. The size of this buffer in bytes must be at least as large as `data_length`.

#### `unsigned long data_length`

Length in bytes of the message to be encrypted or decrypted, which resides at the beginning of `in_data`.

Calls to `ica_des_ctrlist` with the same key can be chained if:

- With the possible exception of the last call in the chain the `data_length` used is a multiple of the cipher block size.
- The `ctrlist` argument of each chained call contains a list of counters that follows the counters used in the preceding call.

#### `const unsigned char *key`

Pointer to a valid DES key of 8 bytes in length.

#### `const unsigned char *ctrlist`

Pointer to a readable buffer of a size greater than or equal to `data_length`, and a multiple of the cipher block size (8 bytes for DES). `ctrlist` should contain a list of precomputed counter values, each of the same size as the cipher block.

#### `unsigned int direction`

- 0 Use the decrypt function.
- 1 Use the encrypt function.

### Return codes

0 Success

For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_des\_ecb

### Purpose

Encrypt or decrypt data with a DES key using Electronic Cook Book (ECB) mode, as described in NIST Special Publication 800-38A Chapter 6.1.

### Format

```
unsigned int ica_des_ecb(const unsigned char *in_data,
    unsigned char *out_data,
    unsigned long data_length,
    const unsigned char *key,
    unsigned int direction);
```

### Required hardware support

KM-DEA

### Parameters

#### **const unsigned char \*in\_data**

Pointer to a readable buffer that contains the message to be encrypted or decrypted. The size of the message in bytes is *data\_length*. The size of this buffer must be at least as large as *data\_length*.

#### **unsigned char \*out\_data**

Pointer to a writeable buffer to contain the resulting encrypted or decrypted message. The size of this buffer in bytes must be at least as large as *data\_length*.

#### **unsigned long data\_length**

Length in bytes of the message to be encrypted or decrypted, which resides at the beginning of *in\_data*. *data\_length* must be a multiple of the cipher block size (8 bytes for DES).

#### **const unsigned char \*key**

Pointer to a valid DES key of 8 bytes in length.

#### **unsigned int direction**

0 Use the decrypt function.

1 Use the encrypt function.

### Return codes

0 Success

For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_des\_ofb

### Purpose

Encrypt or decrypt data with a DES key using Output Feedback (OFB) mode, as described in NIST Special Publication 800-38A Chapter 6.4.

### Format

```
unsigned int ica_des_ofb(const unsigned char *in_data,
    unsigned char *out_data,
    unsigned long data_length,
    const unsigned char *key,
    unsigned int key_length,
    unsigned char *iv,
    unsigned int direction);
```

### Required hardware support

KMO-DEA

### Parameters

#### **const unsigned char \*in\_data**

Pointer to a readable buffer that contains the message to be encrypted or decrypted. The size of the message in bytes is *data\_length*. The size of this buffer must be at least as large as *data\_length*.

#### **unsigned char \*out\_data**

Pointer to a writable buffer that contains the resulting encrypted or decrypted message. The size of this buffer must be at least as large as *data\_length*.

#### **unsigned long data\_length**

Length in bytes of the message to be encrypted or decrypted, which resides at the beginning of *in\_data*.

#### **const unsigned char \*key**

Pointer to a valid DES key of 8 bytes in length.

#### **unsigned char \*iv**

Pointer to a valid initialization vector of the same size as the cipher block in bytes (8 bytes for DES). This vector is overwritten during the function. If *data\_length* is a multiple of the cipher block size (8 bytes for DES), the result value in *iv* can be used as the initialization vector for a chained **ica\_des\_ofb** call with the same key.

#### **unsigned int direction**

0      Use the decrypt function.

1      Use the encrypt function.

### Return codes

0      Success

For return codes indicating exceptions, see “Return codes” on page 87.

## Compatibility with earlier versions

In order to stay compatible with earlier versions of libica, the following DES interfaces remain supported:

```
unsigned int ica_des_encrypt(unsigned int mode,
    unsigned int data_length, unsigned char *input_data,
    ica_des_vector_t *iv, ica_des_key_single_t *des_key,
    unsigned char *output_data);
```

```
unsigned int ica_des_decrypt(unsigned int mode,
    unsigned int data_length, unsigned char *input_data,
    ica_des_vector_t *iv, ica_des_key_single_t *des_key,
    unsigned char *output_data);
```

Table 3 shows libica Version 2.0 DES functions calls, and their corresponding libica Version 2.2.0 DES function calls.

Table 3. Compatibility of libica Version 2.0 DES functions calls to libica Version 2.2.0 DES function calls

Calling this libica Version 2.0 DES function	Corresponds to calling this libica Version 2.2.0 DES function
<code>ica_des_encrypt(MODE_ECB, data_length, in_data, NULL, key, out_data);</code>	<code>ica_des_ecb(in_data, out_data, (long) data_length, key, 1);</code>
<code>ica_des_encrypt(MODE_CBC, data_length, in_data, iv, key, out_data);</code>	<code>ica_des_cbc(in_data, out_data, (long) data_length, key, iv, 1);</code>
<code>ica_des_decrypt(MODE_ECB, data_length, in_data, NULL, key, out_data);</code>	<code>ica_des_ecb(in_data, out_data, (long) data_length, key, 0);</code>
<code>ica_des_decrypt(MODE_CBC, data_length, in_data, iv, key, out_data);</code>	<code>ica_des_cbc(in_data, out_data, (long) data_length, key, iv, 0);</code>

The functions `ica_des_encrypt` and `ica_des_decrypt` remain supported, but their use is discouraged in favor of `ica_des_ecb` and `ica_des_cbc`.

For a detailed description of the earlier APIs, see *libica Programmers Reference* Version 2.0.

---

## TDES/3DES functions

These functions are included in: `include/ica_api.h`.

These functions perform encryption and decryption or computation and verification of message authentication codes using a triple-DES (3DES, TDES or TDEA) key. A 3DES key consists of a concatenation of three DES keys, each of which has a size of 8 bytes. Note that each byte of a DES key contains one parity bit, such that each 64-bit DES key contains only 56 security-relevant bits. The cipher block size for 3DES is 8 bytes.

3DES is known in two variants: a two key variant and a three key variant. This library implements only the three key variant. The two key variant can be derived from functions for the three key variant by using the same key as the first and third key.

To securely apply 3DES encryption to messages that are longer than the cipher block size, modes of operation can be used to chain multiple encryption, decryption, or authentication operations. Most modes of operation require an initialization vector as additional input. As long as the messages are encrypted or decrypted using such a mode of operation and have a size that is a multiple of a particular block size (mostly the cipher block size), the functions encrypting or decryption according to that mode of operation also compute an output vector that can be used as the initialization vector of a chained encryption or decryption operation in the same mode with the same block size and the same key.

Note that when decrypting a cipher text, the mode of operation, the key, the initialization vector (if applicable), and for `ica_3des_cfb` the *lcfb* value used for the decryption function must match the corresponding settings of the encryption function that was used to transform the plain text into the cipher text.

## ica\_3des\_cbc

### Purpose

Encrypt or decrypt data with an 3DES key using Cipher Block Chaining (CBC) mode, as described in NIST Special Publication 800-38A Chapter 6.2.

### Format

```
unsigned int ica_3des_cbc(const unsigned char *in_data,
    unsigned char *out_data,
    unsigned long data_length,
    const unsigned char *key,
    unsigned char *iv,
    unsigned int direction);
```

### Required hardware support

KMC-TDEA-192

### Parameters

#### **const unsigned char \*in\_data**

Pointer to a readable buffer that contains the message to be encrypted or decrypted. The size of the message in bytes is *data\_length*. The size of this buffer must be at least as large as *data\_length*.

#### **unsigned char \*out\_data**

Pointer to a writable buffer to contain the resulting encrypted or decrypted message. The size of this buffer in bytes must be at least as large as *data\_length*.

#### **unsigned long data\_length**

Length in bytes of the message to be encrypted or decrypted, which resides at the beginning of *in\_data*. *data\_length* must be a multiple of the cipher block size (8 bytes for 3DES).

#### **const unsigned char \*key**

Pointer to a valid 3DES key of 24 bytes in length.

#### **unsigned char \*iv**

Pointer to a valid initialization vector of cipher block size number of bytes.

This vector is overwritten during the function. The result value in *iv* can be used as the initialization vector for a chained `ica_3des_cbc` or `ica_3des_cbc_cs` call with the same key.

#### **unsigned int direction**

0 Use the decrypt function.

1 Use the encrypt function.

### Return codes

0 Success

For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_3des\_cbc\_cs

### Purpose

Encrypt or decrypt data with a 3DES key using Cipher Block Chaining with Ciphertext Stealing (CBC-CS) mode, as described in NIST Special Publication 800-38A Chapter 6.2 and the Addendum to NIST Special Publication 800-38A on "Recommendation for Block Cipher Modes of Operation: Three Variants of Ciphertext Stealing for CBC Mode".

`ica_3des_cbc_cs` can be used to encrypt or decrypt the last chunk of a message consisting of multiple chunks, where all chunks except the last one are encrypted or decrypted by chained calls to `ica_3des_cbc`. To do this, the resulting *iv* of the last call to `ica_3des_cbc` is fed into the *iv* of the `ica_3des_cbc_cs` call, provided that the chunk is greater than the cipher block size (8 bytes for 3DES).

### Format

```
unsigned int ica_3des_cbc_cs(const unsigned char *in_data,
    unsigned char *out_data,
    unsigned long data_length,
    const unsigned char *key,
    unsigned char *iv,
    unsigned int direction,
    unsigned int variant);
```

### Required hardware support

KMC-TDEA-192

### Parameters

#### **const unsigned char \*in\_data**

Pointer to a readable buffer that contains the message to be encrypted or decrypted. The size of the message in bytes is *data\_length*. The size of this buffer must be at least as large as *data\_length*.

#### **unsigned char \*out\_data**

Pointer to a writable buffer to contain the resulting encrypted or decrypted message. The size of this buffer in bytes must be at least as large as *data\_length*.

#### **unsigned long data\_length**

Length in bytes of the message to be encrypted or decrypted, which resides at the beginning of *in\_data*. *data\_length* must be greater than or equal to the cipher block size (8 bytes for 3DES).

#### **const unsigned char \*key**

Pointer to a valid 3DES key of 24 bytes in length.

#### **unsigned char \*iv**

Pointer to a valid initialization vector of the same size as the cipher block in bytes. This vector is overwritten during the function. For *variant* equal to 1 or *variant* equal to 2, the result value in *iv* can be used as the initialization vector for a chained `ica_3des_cbc` or `ica_3des_cbc_cs` call with the same key, if *data\_length* is a multiple of the cipher block size.

#### **unsigned int direction**

**0** Use the decrypt function.

**1** Use the encrypt function.

#### **unsigned int variant**



- |                   1        Use variant CBC-CS1 of the Addendum to NIST Special Publication  
|                            800-38A to encrypt or decrypt the message: always keep last two  
|                            blocks in order.
- |                   2        Use variant CBC-CS2 of the Addendum to NIST Special Publication  
|                            800-38A to encrypt or decrypt the message: switch order of the last two  
|                            blocks if *data\_length* is not a multiple of the cipher block size (a  
|                            multiple of 8 bytes for 3DES).
- |                   3        Use variant CBC-CS3 of the Addendum to NIST Special Publication  
|                            800-38A to encrypt or decrypt the message: always switch order of the  
|                            last two blocks.

|                   **Return codes**

|                   0        Success

|                   For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_3des\_cfb

### Purpose

Encrypt or decrypt data with a 3DES key using Cipher Feedback (CFB) mode, as described in NIST Special Publication 800-38A Chapter 6.3.

### Format

```
unsigned int ica_3des_cfb(const unsigned char *in_data,
    unsigned char *out_data,
    unsigned long data_length,
    const unsigned char *key,
    unsigned char *iv,
    unsigned int lcfb,
    unsigned int direction);
```

### Required hardware support

KMF-TDEA-192

### Parameters

#### **const unsigned char \*in\_data**

Pointer to a readable buffer that contains the message to be encrypted or decrypted. The size of the message in bytes is *data\_length*. The size of this buffer must be at least as large as *data\_length*.

#### **unsigned char \*out\_data**

Pointer to a writable buffer to contain the resulting encrypted or decrypted message. The size of this buffer in bytes must be at least as large as *data\_length*.

#### **unsigned long data\_length**

Length in bytes of the message to be encrypted or decrypted, which resides at the beginning of *in\_data*.

#### **const unsigned char \*key**

Pointer to a valid 3DES key of 24 bytes in length.

#### **unsigned char \*iv**

Pointer to a valid initialization vector of cipher block size number of bytes (8 bytes for 3DES). This vector is overwritten during the function. The result value in *iv* can be used as the initialization vector for a chained **ica\_3des\_cfb** call with the same key, if the *data\_length* in the preceding call is a multiple of *lcfb*.

#### **unsigned int lcfb**

Length in bytes of the cipher feedback, which is a value greater than or equal to 1 and less than or equal to the cipher block size (8 bytes for 3DES).

#### **unsigned int direction**

0        Use the decrypt function.  
1        Use the encrypt function.

### Return codes

0        Success

For return codes indicating exceptions, see "Return codes" on page 87.

## ica\_3des\_cmac

### Purpose

Authenticate data or verify the authenticity of data with an 3DES key using the Block Cipher Based Message Authentication Code (CMAC) mode, as described in NIST Special Publication 800-38B. `ica_3des_cmac` can be used to authenticate or verify the authenticity of a complete message.

### Format

```
unsigned int ica_3des_cmac(const unsigned char *message,  
    unsigned long message_length,  
    unsigned char *mac,  
    unsigned int mac_length,  
    const unsigned char *key,  
    unsigned int direction);
```

### Required hardware support

KMAC-TDEA-192

PCC-Compute-Last\_block-CMAC-Using-TDEA-192

### Parameters

#### **const unsigned char \*message**

Pointer to a readable buffer of size greater than or equal to *message\_length* bytes. This buffer contains a message to be authenticated, or of which the authenticity is to be verified.

#### **unsigned long message\_length**

Length in bytes of the message to be authenticated or verified.

#### **unsigned char \*mac**

Pointer to a buffer of size greater than or equal to *mac\_length* bytes. If *direction* is equal to 1, the buffer must be writable and a message authentication code for the message in *message* of size *mac\_length* bytes is written to the buffer. If *direction* is equal to 0, the buffer must be readable and contain a message authentication code to be verified against the message in *message*.

#### **unsigned int mac\_length**

Length in bytes of the message authentication code *mac*, which is less than or equal to the cipher block size (8 bytes for 3DES). It is recommended to use a *mac\_length* of 8.

#### **const unsigned char \*key**

Pointer to a valid 3DES key of 24 bytes in length.

#### **unsigned int direction**

0      Verify message authentication code.

1      Compute message authentication code for the message.

### Return codes

0      Success

#### **EFAULT**

If *direction* is equal to 0 and the verification of the message authentication code fails.

For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_3des\_cmac\_intermediate

### Purpose

Authenticate data or verify the authenticity of data with an 3DES key using the Block Cipher Based Message Authentication Code (CMAC) mode, as described in NIST Special Publication 800-38B. `ica_3des_cmac_intermediate` and `ica_3des_cmac_last` can be used when the message to be authenticated or to be verified using CMAC is supplied in multiple chunks. `ica_3des_cmac_intermediate` is used to process all but the last chunk. All message chunks to be processed by `ica_3des_cmac_intermediate` must have a size that is a multiple of the cipher block size (a multiple of 8 bytes for 3DES).

Note that `ica_3des_cmac_intermediate` has no direction argument. This function can be used during authentication and during authenticity verification.

### Format

```
unsigned int ica_3des_cmac_intermediate(const unsigned char *message,  
                                       unsigned long message_length,  
                                       const unsigned char *key,  
                                       unsigned char *iv);
```

### Required hardware support

KMAC-TDEA-192

### Parameters

#### **const unsigned char \*message**

Pointer to a readable buffer of size greater than or equal to *message\_length* bytes. This buffer contains a non-final part of a message to be authenticated, or of which the authenticity is to be verified.

#### **unsigned long message\_length**

Length in bytes of the message part in *message*. This value must be a multiple of the cipher block size.

#### **const unsigned char \*key**

Pointer to a valid 3DES key of 24 bytes in length.

#### **unsigned char \*iv**

Pointer to a valid initialization vector of size cipher block size (8 bytes for 3DES). For the first message part, this parameter must be set to a string of zeros. For processing the *n*-th message part, this parameter must be the resulting *iv* value of the `ica_3des_cmac_intermediate` applied to the (*n*-1)-th message part. This vector is overwritten during the function. The result value in *iv* can be used as the initialization vector for a chained call to `ica_3des_cmac_initermediate` or to `ica_3des_cmac_last` with the same key.

### Return codes

0        Success

For return codes indicating exceptions, see "Return codes" on page 87.

## ica\_3des\_cmac\_last

### Purpose

Authenticate data or verify the authenticity of data with an 3DES key using the Block Cipher Based Message Authentication Code (CMAC) mode, as described in NIST Special Publication 800-38B. `ica_3des_cmac_last` can be used to authenticate or verify the authenticity of a complete message or of the final part of a message, for which all preceding parts were processed with `ica_3des_cmac_intermediate`.

### Format

```
unsigned int ica_3des_cmac_last(const unsigned char *message,  
    unsigned long message_length,  
    unsigned char *mac,  
    unsigned int mac_length,  
    const unsigned char *key,  
    unsigned char *iv,  
    unsigned int direction);
```

### Required hardware support

KMAC-TDEA,-192

PCC-Compute-Last\_block-CMAC-Using-TDEA-192

### Parameters

#### **const unsigned char \*message**

Pointer to a readable buffer of size greater than or equal to *message\_length* bytes. It contains a message or the final part of a message to be authenticated, or of which the authenticity is to be verified.

#### **unsigned long message\_length**

Length in bytes of the message to be authenticated or verified.

#### **unsigned char \*mac**

Pointer to a buffer of size greater than or equal to *mac\_length* bytes. If *direction* is equal to 1, the buffer must be writable and a message authentication code for the message in *message* of size *mac\_length* bytes is written to the buffer. If *direction* is equal to 0, the buffer must be readable and contain a message authentication code that is to be verified against the message in *message*.

#### **unsigned int mac\_length**

Length in bytes of the message authentication code *mac* in bytes that is less than or equal to the cipher block size (8 bytes for 3DES). It is recommended to use a *mac\_length* of 8.

#### **const unsigned char \*key**

Pointer to a valid 3DES key of 24 bytes in length.

#### **unsigned char \*iv**

Pointer to a valid initialization vector of cipher block size number of bytes. If *iv* is NULL, *message* is assumed to be the complete message to be processed. Otherwise, *message* is the final part of a composite message to be processed and *iv* contains the output vector resulting from processing all previous parts with chained calls to `ica_des_cmac_intermediate` (the value returned in *iv* of the `ica_des_cmac_intermediate` call applied to the penultimate message part).

#### **unsigned int direction**

0        Verify message authentication code.

1        Compute message authentication code for the message.

| **Return codes**

| 0 Success

| **EFAULT**

| If *direction* is equal to 0 and the verification of the message authentication  
| code fails.

| For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_3des\_ctr

### Purpose

Encrypt or decrypt data with a triple-length DES key using Counter (CTR) mode, as described in NIST Special Publication 800-38A Chapter 6.5. With the counter mode, each message block of size cipher block size (8 bytes for 3DES) is combined with a counter value of the same size during encryption and decryption.

Starting with an initial counter value to be combined with the first message block, subsequent counter values to be combined with subsequent message blocks are derived from preceding counter values by an increment function. The increment function used in `ica_3des_ctr` is an arithmetic increment without carry on the  $M$  least significant bytes in the counter, where  $M$  is a parameter to `ica_3des_ctr`.

### Format

```
unsigned int ica_3des_ctr(const unsigned char *in_data,
    unsigned char *out_data,
    unsigned long data_length,
    const unsigned char *key,
    unsigned char *ctr,
    unsigned int ctr_width,
    unsigned int direction);
```

### Required hardware support

KMCTR-TDEA-192

### Parameters

#### **const unsigned char \*in\_data**

Pointer to a readable buffer that contains the message to be encrypted or decrypted. The size of the message in bytes is *data\_length*. The size of this buffer must be at least as large as *data\_length*.

#### **unsigned char \*out\_data**

Pointer to a writable buffer to contain the resulting encrypted or decrypted message. The size of this buffer in bytes must be at least as large as *data\_length*.

#### **unsigned long data\_length**

Length in bytes of the message to be encrypted or decrypted, which resides at the beginning of *in\_data*.

#### **const unsigned char \*key**

Pointer to a valid 3DES key of 24 bytes in length.

#### **unsigned char \*ctr**

Pointer to a readable and writable buffer of the same size as the cipher block in bytes. *ctr* contains an initialization value for a counter function that is replaced by a new value. The new value can be used as an initialization value for a counter function in a chained `ica_3des_ctr` call with the same key, if the *data\_length* used in the preceding call is a multiple of the cipher block size.

#### **unsigned int ctr\_width**

A number  $M$  between 1 and the cipher block size. The value is used by the counter increment function, which increments a counter value by incrementing without carry the least significant  $M$  bytes of the counter value.

#### **unsigned int direction**

0 Use the decrypt function.

1 Use the encrypt function.

## **Return codes**

0      Success

For return codes indicating exceptions, see “Return codes” on page 87.



## ica\_3des\_ctrlist

### Purpose

Encrypt or decrypt data with an 3DES key using Counter (CTR) mode, as described in NIST Special Publication 800-38A ,Chapter 6.5. With the counter mode, each message block of the same size as the cipher block is combined with a counter value of the same size during encryption and decryption.

The `ica_3des_ctrlist` function assumes that a list  $n$  of precomputed counter values is provided where  $n$  is the smallest integer that is less than or equal to the message size divided by the cipher block size. This function is used to optimally utilize IBM System z hardware support for non-standard counter functions.

### Format

```
unsigned int ica_3des_ctrlist(const unsigned char *in_data,
    unsigned char *out_data,
    unsigned long data_length,
    const unsigned char *key,
    const unsigned char *ctrlist,
    unsigned int direction);
```

### Required hardware support

KMCTR-TDEA-192

### Parameters

#### `const unsigned char *in_data`

Pointer to a readable buffer that contains the message to be encrypted or decrypted. The size of the message in bytes is `data_length`. The size of this buffer must be at least as large as `data_length`.

#### `unsigned char *out_data`

Pointer to a writable buffer to contain the resulting encrypted or decrypted message. The size of this buffer in bytes must be at least as large as `data_length`.

#### `unsigned long data_length`

Length in bytes of the message to be encrypted or decrypted, which resides at the beginning of `in_data`.

Calls to `ica_3des_ctrlist` with the same key can be chained if:

- With the possible exception of the last call in the chain the `data_length` used is a multiple of the cipher block size.
- The `ctrlist` argument of each chained call contains a list of counters that follows the counters used in the preceding call.

#### `const unsigned char *key`

Pointer to a valid 3DES key of 24 bytes in length.

#### `const unsigned char *ctrlist`

Pointer to a readable buffer that is both of size greater than or equal to `data_length`, and a multiple of the cipher block size (8 bytes for 3DES). `ctrlist` should contain a list of precomputed counter values, each of the same size as the cipher block.

#### `unsigned int direction`

- `0` Use the decrypt function.
- `1` Use the encrypt function.

## **Return codes**

0      Success

For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_3des\_ecb

### Purpose

Encrypt or decrypt data with an 3DES key using Electronic Cook Book (ECB) mode, as described in NIST Special Publication 800-38A Chapter 6.1.

### Format

```
unsigned int ica_3des_ecb(const unsigned char *in_data,  
    unsigned char *out_data,  
    unsigned long data_length,  
    const unsigned char *key,  
    unsigned int direction);
```

### Required hardware support

KM-DEA-192

### Parameters

#### **const unsigned char \*in\_data**

Pointer to a readable buffer that contains the message to be encrypted or decrypted. The size of the message in bytes is *data\_length*. The size of this buffer must be at least as large as *data\_length*.

#### **unsigned char \*out\_data**

Pointer to a writeable buffer to contain the resulting encrypted or decrypted message. The size of this buffer in bytes must be at least as large as *data\_length*.

#### **unsigned long data\_length**

Length in bytes of the message to be encrypted or decrypted, which resides at the beginning of *in\_data*. *data\_length* must be a multiple of the cipher block size (8 bytes for 3DES).

#### **const unsigned char \*key**

Pointer to a valid 3DES key of 24 bytes in length.

#### **unsigned int direction**

0        Use the decrypt function.  
1        Use the encrypt function.

### Return codes

0        Success

For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_3des\_ofb

### Purpose

Encrypt or decrypt data with an 3DES key using Output Feedback (OFB) mode, as described in NIST Special Publication 800-38A Chapter 6.4.

### Format

```
unsigned int ica_3des_ofb(const unsigned char *in_data,
    unsigned char *out_data,
    unsigned long data_length,
    const unsigned char *key,
    unsigned int key_length,
    unsigned char *iv,
    unsigned int direction);
```

### Required hardware support

KMO-TDEA-192

### Parameters

#### **const unsigned char \*in\_data**

Pointer to a readable buffer that contains the message to be encrypted or decrypted. The size of the message in bytes is *data\_length*. The size of this buffer must be at least as large as *data\_length*.

#### **unsigned char \*out\_data**

Pointer to a writable buffer that contains the resulting encrypted or decrypted message. The size of this buffer in bytes must be at least as large as *data\_length*.

#### **unsigned long data\_length**

Length in bytes of the message to be encrypted or decrypted, which resides at the beginning of *in\_data*.

#### **const unsigned char \*key**

Pointer to a valid 3DES key of 24 bytes in length.

#### **unsigned char \*iv**

Pointer to a valid initialization vector of the same size as the cipher block in bytes (8 bytes for 3DES). This vector is overwritten during the function. If *data\_length* is a multiple of the cipher block size (a multiple of 8 for 3DES), the result value in *iv* can be used as the initialization vector for a chained **ica\_3des\_ofb** call with the same key.

#### **unsigned int direction**

0      Use the decrypt function.

1      Use the encrypt function.

### Return codes

0      Success

For return codes indicating exceptions, see “Return codes” on page 87.

## Compatibility with earlier versions

In order to stay compatible with earlier versions of libica, the following 3DES interfaces remain supported:

```
unsigned int ica_3des_encrypt(unsigned int mode,
    unsigned int data_length, unsigned char *input_data,
    ica_des_vector_t *iv, ica_des_key_triple_t *des_key,
    unsigned char *output_data);
```

```
unsigned int ica_3des_decrypt(unsigned int mode,
    unsigned int data_length, unsigned char *input_data,
    ica_des_vector_t *iv, ica_des_key_triple_t *des_key,
    unsigned char *output_data);
```

Table 4 shows libica Version 2.0 TDES functions calls, and their corresponding libica Version 2.2.0 TDES function calls.

Table 4. Compatibility of libica Version 2.0 TDES functions calls to libica Version 2.2.0 TDES function calls

Calling this libica Version 2.0 TDES function	Corresponds to calling this libica Version 2.2.0 TDES function
<code>ica_3des_encrypt(MODE_ECB, data_length, in_data, NULL, key, out_data);</code>	<code>ica_3des_ecb(in_data, out_data, (long)data_length, key, 1);</code>
<code>ica_3des_encrypt(MODE_CBC, data_length, in_data, iv, key, out_data);</code>	<code>ica_3des_cbc(in_data, out_data, (long)data_length, key, iv, 1);</code>
<code>ica_3des_decrypt(MODE_ECB, data_length, in_data, NULL, key, out_data);</code>	<code>ica_3des_ecb(in_data, out_data, (long)data_length, key, 0);</code>
<code>ica_3des_decrypt(MODE_CBC, data_length, in_data, iv, key, out_data);</code>	<code>ica_3des_cbc(in_data, out_data, (long)data_length, key, iv, 0);</code>

The functions `ica_3des_encrypt` and `ica_3des_decrypt` remain supported, but their use is discouraged in favor of `ica_3des_ecb` and `ica_3des_cbc`.

For a detailed description of the earlier APIs, see *libica Programmers Reference* Version 2.0.

---

## AES functions

These functions are included in: `include/ica_api.h`.

These functions perform encryption and decryption or computation or verification of message authentication codes using an AES key. Supported key lengths are 16, 24 or 32 bytes for AES-128, AES-192 and AES-256 respectively. The cipher block size for AES is 16 bytes.

To securely apply AES encryption to messages that are longer than the cipher block size, modes of operation can be used to chain multiple encryption, decryption, or authentication operations. Most modes of operation require an initialization vector as additional input.

As long as the messages are encrypted or decrypted using such a mode of operation, have a size that is a multiple of a particular block size (mostly the cipher block size), the functions encrypting or decryption according to a mode of operation also compute an output vector. The output vector can be used as the initialization vector of a chained encryption or decryption operation in the same mode with the same block size and the same key.

Note that when decrypting a cipher text the mode of operation, the key, the initialization vector (if applicable), and for `ica_aes_cfb` the *lcfb* value used for the decryption function must match the corresponding settings of the encryption function that transformed the plain text into the cipher text.

## ica\_aes\_cbc

### Purpose

Encrypt or decrypt data with an AES key using Cipher Block Chaining (CBC) mode, as described in NIST Special Publication 800-38A Chapter 6.2.

### Format

```
unsigned int ica_aes_cbc(const unsigned char *in_data,
    unsigned char *out_data,
    unsigned long data_length,
    const unsigned char *key,
    unsigned int key_length,
    unsigned char *iv,
    unsigned int direction);
```

### Required hardware support

KMC-AES-128, KMC-AES-192, or KMC-AES-256

### Parameters

#### **const unsigned char \*in\_data**

Pointer to a readable buffer that contains the message to be encrypted or decrypted. The size of the message in bytes is *data\_length*. The size of this buffer must be at least as large as *data\_length*.

#### **unsigned char \*out\_data**

Pointer to a writable buffer to contain the resulting encrypted or decrypted message. The size of this buffer in bytes must be at least as large as *data\_length*.

#### **unsigned long data\_length**

Length in bytes of the message to be encrypted or decrypted, which resides at the beginning of *in\_data*. *data\_length* must be a multiple of the cipher block size (a multiple of 16 for AES).

#### **const unsigned char \*key**

Pointer to a valid AES key.

#### **unsigned int key\_length**

Length in bytes of the AES key. Supported sizes are 16, 24, and 32, for AES-128, AES-192, and AES-256 respectively. Therefore, you can use the definitions: `AES_KEY_LEN128`, `AES_KEY_LEN192`, and `AES_KEY_LEN256`.

#### **unsigned char \*iv**

Pointer to a valid initialization vector of the same size as the cipher block in bytes. This vector is overwritten during the function. The result value in *iv* can be used as the initialization vector for a chained `ica_aes_cbc` or `ica_aes_cbc_cs` call with the same key.

#### **unsigned int direction**

0      Use the decrypt function.  
1      Use the encrypt function.

### Return codes

0      Success

For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_aes\_cbc\_cs

### Purpose

Encrypt or decrypt data with an AES key using Cipher Block Chaining with Ciphertext Stealing (CBC-CS) mode, as described in NIST Special Publication 800-38A Chapter 6.2, and the Addendum to NIST Special Publication 800-38A on "Recommendation for Block Cipher Modes of Operation: Three Variants of Ciphertext Stealing for CBC Mode".

`ica_aes_cbc_cs` can be used to encrypt or decrypt the last chunk of a message consisting of multiple chunks, where all chunks except the last one are encrypted or decrypted by chained calls to `ica_aes_cbc`. To do this, the resulting *iv* of the last call to `ica_aes_cbc` is fed into the *iv* of the `ica_aes_cbc_cs` call, provided that the chunk is greater than the cipher block size (greater than 16 bytes for AES).

### Format

```
unsigned int ica_aes_cbc_cs(const unsigned char *in_data,
    unsigned char *out_data,
    unsigned long data_length,
    const unsigned char *key,
    unsigned int key_length,
    unsigned char *iv,
    unsigned int direction,
    unsigned int variant);
```

### Required hardware support

KMC-AES-128, KMC-AES-192 or KMC-AES-256

### Parameters

#### **const unsigned char \*in\_data**

Pointer to a readable buffer that contains the message to be encrypted or decrypted. The size of the message in bytes is *data\_length*. The size of this buffer must be at least as large as *data\_length*.

#### **unsigned char \*out\_data**

Pointer to a writable buffer to contain the resulting encrypted or decrypted message. The size of this buffer in bytes must be at least as large as *data\_length*.

#### **unsigned long data\_length**

Length in bytes of the message to be encrypted or decrypted, which resides at the beginning of *in\_data*. *data\_length* must be greater than or equal to the cipher block size (16 bytes for AES).

#### **const unsigned char \*key**

Pointer to a valid AES key.

#### **unsigned int key\_length**

Length in bytes of the AES key. Supported sizes are 16, 24, and 32, for AES-128, AES-192, and AES-256 respectively. . Therefore, you can use the definitions: `AES_KEY_LEN128`, `AES_KEY_LEN192`, and `AES_KEY_LEN256`.

#### **unsigned char \*iv**

Pointer to a valid initialization vector of cipher block size number of bytes. This vector is overwritten during the function. For *variant* equal to 1 or *variant* equal to 2, the result value in *iv* can be used as the initialization vector for a chained `ica_aes_cbc` or `ica_aes_cbc_cs` call with the same key, if *data\_length* is a multiple of the cipher block size.



|           **unsigned int direction**

- |           0        Use the decrypt function.  
|           1        Use the encrypt function.

|           **unsigned int variant**

- |           1        Use variant CBC-CS1 of the Addendum to NIST Special Publication  
|                    800-38A to encrypt or decrypt the message: always keep last two  
|                    blocks in order.  
|           2        Use variant CBC-CS2 of the Addendum to NIST Special Publication  
|                    800-38A to encrypt or decrypt the message: switch order of the last two  
|                    blocks if *data\_length* is not a multiple of the cipher block size (a  
|                    multiple of 16 bytes for AES).  
|           3        Use variant CBC-CS3 of the Addendum to NIST Special Publication  
|                    800-38A to encrypt or decrypt the message: always switch order of the  
|                    last two blocks.

|           **Return codes**

- |           0        Success

|           For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_aes\_ccm

### Purpose

Encrypt and authenticate or decrypt data and check authenticity of data with an AES key using Counter with Cipher Block Chaining Message Authentication Code (CCM) mode, as described in NIST Special Publication 800-38C. Formatting and counter functions are implemented according to NIST 800-38C Appendix A.

### Format

```
unsigned int ica_aes_ccm(unsigned char *payload,  
    unsigned long payload_length,  
    unsigned char *ciphertext_n_mac,  
    unsigned int mac_length,  
    const unsigned char *assoc_data,  
    unsigned long assoc_data_length,  
    const unsigned char *nonce,  
    unsigned int nonce_length,  
    const unsigned char *key,  
    unsigned int key_length,  
    unsigned int direction);
```

### Required hardware support

KMCTR-AES-128, KMCTR-AES-192, or KMCTR-AES-256  
KMAC-AES-128, KMAC-AES-192, or KMAC-AES-256

### Parameters

#### **unsigned char \*payload**

Pointer to a buffer of size greater than or equal to *payload\_length* bytes. If *direction* is equal to 1, the payload buffer must be readable and contain a payload message of size *payload\_length* to be encrypted. If *direction* is equal to 0, the payload buffer must be writable. If the authentication verification succeeds, the decrypted message in the most significant *payload\_length* bytes of *ciphertext\_n\_mac* is written to this buffer. Otherwise, the contents of this buffer is undefined.

#### **unsigned long payload\_length**

Length in bytes of the message to be encrypted or decrypted. This value can be 0 unless *assoc\_data\_length* is equal to 0.

#### **unsigned char \*ciphertext\_n\_mac**

Pointer to a buffer of size greater than or equal to *payload\_length* plus *mac\_length* bytes. If *direction* is equal to 1, the buffer must be writable and the encrypted message from *payload* followed by the message authentication code for the nonce, the payload, and associated data are written to that buffer. If *direction* is equal to 0, then the buffer is readable and contains an encrypted message of length *payload\_length* followed by a message authentication code of length *mac\_length*.

#### **unsigned int mac\_length**

Length in bytes of the message authentication code. Valid values are: 4, 6, 8, 10, 12, and 16.

#### **const unsigned char \*assoc\_data**

Pointer to a readable buffer of size greater than or equal to *assoc\_data\_length* bytes. The associated data in the most significant *assoc\_data\_length* bytes is subject to the authentication code computation, but is not encrypted.

```

| unsigned long assoc_data_length
|     Length of the associated data in assoc_data. This value can be 0 unless
|     payload_length is equal to 0.
|
| const unsigned char *nonce
|     Pointer to readable buffer of size greater than or equal to nonce_length bytes,
|     which contains a nonce (number used once) of size nonce_length bytes.
|
| unsigned int nonce_length
|     Length of the nonce in bytes. Valid values are greater than 6 and less than 14.
|
| const unsigned char *key
|     Specifies a pointer to a valid AES key.
|
| unsigned int key_length
|     Length in bytes of the AES key. Supported sizes are 16, 24, and 32 for AES-128,
|     AES-192 and AES-256 respectively. Therefore, you can use the definitions:
|     AES_KEY_LEN128, AES_KEY_LEN192, and AES_KEY_LEN256.
|
| unsigned int direction
|     0     Use the decrypt function.
|     1     Use the encrypt function.

```

### **Return codes**

```

| 0     Success
| EFAULT
|     If direction is equal to 0 and the verification of the message authentication
|     code fails.

```

For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_aes\_cfb

### Purpose

Encrypt or decrypt data with an AES key using Cipher Feedback (CFB) mode, as described in NIST Special Publication 800-38A Chapter 6.3.

### Format

```
unsigned int ica_aes_cfb(const unsigned char *in_data,
    unsigned char *out_data,
    unsigned long data_length,
    const unsigned char *key,
    unsigned int key_length,
    unsigned char *iv,
    unsigned int lcfb,
    unsigned int direction);
```

### Required hardware support

KMF-AES-128, KMF-AES-192, or KMF-AES-256

### Parameters

#### **const unsigned char \*in\_data**

Pointer to a readable buffer that contains the message to be encrypted or decrypted. The size of the message in bytes is *data\_length*. The size of this buffer must be at least as large as *data\_length*.

#### **unsigned char \*out\_data**

Pointer to a writable buffer to contain the resulting encrypted or decrypted message. The size of this buffer in bytes must be at least as large as *data\_length*.

#### **unsigned long data\_length**

Length in bytes of the message to be encrypted or decrypted, which resides at the beginning of *in\_data*.

#### **const unsigned char \*key**

Pointer to a valid AES key.

#### **unsigned int key\_length**

Length in bytes of the AES key. Supported sizes are 16, 24, and 32, for AES-128, AES-192, and AES-256 respectively. Therefore, you can use the definitions: `AES_KEY_LEN128`, `AES_KEY_LEN192`, and `AES_KEY_LEN256`.

#### **unsigned char \*iv**

Pointer to a valid initialization vector of the same size as the cipher block in bytes (16 bytes for AES). This vector is overwritten during the function. The result value in *iv* can be used as the initialization vector for a chained `ica_aes_cfb` call with the same key, if the *data\_length* in the preceding call is a multiple of *lcfb*.

#### **unsigned int lcfb**

Length in bytes of the cipher feedback, which is a value greater than or equal to 1 and less than or equal to the cipher block size (16 bytes for AES).

#### **unsigned int direction**

**0** Use the decrypt function.  
**1** Use the encrypt function.

### Return codes

**0** Success

For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_aes\_cmac

### Purpose

Authenticate data or verify the authenticity of data with an AES key using the Block Cipher Based Message Authentication Code (CMAC) mode, as described in NIST Special Publication 800-38B. `ica_aes_cmac` can be used to authenticate or verify the authenticity of a complete message.

### Format

```
unsigned int ica_aes_cmac(const unsigned char *message,
    unsigned long message_length,
    unsigned char *mac,
    unsigned int mac_length,
    const unsigned char *key,
    unsigned int key_length,
    unsigned int direction);
```

### Required hardware support

KMAC-AES-128, KMAC-AES-192 or KMAC-AES-256  
PCC-Compute-Last\_block-CMAC-Using-AES-128, PCC-Compute-Last\_block-CMAC-Using-AES-192, or PCC-Compute-Last\_block-CMAC-Using-AES-256

### Parameters

#### **const unsigned char \*message**

Pointer to a readable buffer of size greater than or equal to *message\_length* bytes. This buffer contains a message to be authenticated, or of which the authenticity is to be verified.

#### **unsigned long message\_length**

Length in bytes of the message to be authenticated or verified.

#### **unsigned char \*mac**

Pointer to a buffer of size greater than or equal to *mac\_length* bytes. If *direction* is equal to 1, the buffer must be writable and a message authentication code for the message in *message* of size *mac\_length* bytes is written to this buffer. If *direction* is equal to 0, this buffer must be readable and contain a message authentication code to be verified against the message in *message*.

#### **unsigned int mac\_length**

Length in bytes of the message authentication code *mac* in bytes, which is less than or equal to the cipher block size (16 bytes for AES). It is recommended to use values greater than or equal to 8.

#### **const unsigned char \*key**

Pointer to a valid AES key.

#### **unsigned int key\_length**

Length in bytes of the AES key. Supported sizes are 16, 24, and 32 for AES-128, AES-192, and AES-256 respectively. Therefore, you can use the definitions: `AES_KEY_LEN128`, `AES_KEY_LEN192`, and `AES_KEY_LEN256`.

#### **unsigned int direction**

0      Verify message authentication code.  
1      Compute message authentication code for the message.

### Return codes

0      Success

**EFAULT**

If *direction* is equal to 0 and the verification of the message authentication code fails.

For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_aes\_cmac\_intermediate

### Purpose

Authenticate data or verify the authenticity of data with an AES key using the Block Cipher Based Message Authentication Code (CMAC) mode, as described in NIST Special Publication 800-38B. `ica_aes_cmac_intermediate` and `ica_aes_cmac_last` can be used when the message to be authenticated or to be verified using CMAC is supplied in multiple chunks. `ica_aes_cmac_intermediate` is used to process all but the last chunk. All message chunks to be processed by `ica_aes_cmac_intermediate` must have a size that is a multiple of the cipher block size (a multiple of 16 bytes for AES).

Note that `ica_aes_cmac_intermediate` has no direction argument. This function can be used during authentication and during authenticity verification.

### Format

```
unsigned int ica_aes_cmac_intermediate(const unsigned char *message,
                                     unsigned long message_length,
                                     const unsigned char *key,
                                     unsigned int key_length,
                                     unsigned char *iv);
```

### Required hardware support

KMAC-AES-128, KMAC-AES-192, or KMAC-AES-256

### Parameters

#### **const unsigned char \*message**

Pointer to a readable buffer of size greater than or equal to *message\_length* bytes. This buffer contains a non-final part of a message, to be authenticated or of which the authenticity is to be verified.

#### **unsigned long message\_length**

Length in bytes of the message part in *message*. This value must be a multiple of the cipher block size.

#### **const unsigned char \*key**

Pointer to a valid AES key.

#### **unsigned int key\_length**

Length in bytes of the AES key. Supported sizes are 16, 24, and 32 for AES-128, AES-192, and AES-256 respectively. Therefore, you can use the definitions: `AES_KEY_LEN128`, `AES_KEY_LEN192`, and `AES_KEY_LEN256`.

#### **unsigned char \*iv**

Pointer to a valid initialization vector of cipher block size number of bytes (16 bytes for AES). For the first message part, this parameter must be set to a string of zeros. For processing the *n*-th message part, this parameter must be the resulting *iv* value of the `ica_aes_cmac_intermediate` function applied to the (*n*-1)-th message part. This vector is overwritten during the function. The result value in *iv* can be used as the initialization vector for a chained call to `ica_aes_cmac_initermediate` or to `ica_aes_cmac_last` with the same key.

### Return codes

0 Success

For return codes indicating exceptions, see “Return codes” on page 87.



## ica\_aes\_cmac\_last

### Purpose

Authenticate data or verify the authenticity of data with an AES key using the Block Cipher Based Message Authentication Code (CMAC) mode, as described in NIST Special Publication 800-38B. `ica_aes_cmac_last` can be used to authenticate or verify the authenticity of a complete message, or of the final part of a message for which all preceding parts were processed with `ica_aes_cmac_intermediate`.

### Format

```
unsigned int ica_aes_cmac_last(const unsigned char *message,  
    unsigned long message_length,  
    unsigned char *mac,  
    unsigned int mac_length,  
    const unsigned char *key,  
    unsigned int key_length,  
    unsigned char *iv,  
    unsigned int direction);
```

### Required hardware support

KMAC-AES-128, KMAC-AES-192 or KMAC-AES-256  
PCC-Compute-Last\_block-CMAC-Using-AES-128, PCC-Compute-Last\_block-  
CMAC-Using-AES-192, or PCC-Compute-Last\_block-CMAC-Using-AES-256

### Parameters

#### **const unsigned char \*message**

Pointer to a readable buffer of size greater than or equal to *message\_length* bytes. This buffer contains a message or the final part of a message to be authenticated, or of which the authenticity is to be verified.

#### **unsigned long message\_length**

Length in bytes of the message to be authenticated or verified.

#### **unsigned char \*mac**

Pointer to a buffer of size greater than or equal to *mac\_length* bytes. If *direction* is equal to 1, the buffer must be writable and a message authentication code for the message in *message* of size *mac\_length* bytes is written to the buffer. If *direction* is equal to 0, the buffer must be readable and contain a message authentication code that is verified against the message in *message*.

#### **unsigned int mac\_length**

Length in bytes of the message authentication code *mac* in bytes, which is less than or equal to the cipher block size (16 bytes for AES). It is recommended to use values greater than or equal to 8.

#### **const unsigned char \*key**

Pointer to a valid AES key.

#### **unsigned int key\_length**

Length in bytes of the AES key. Supported sizes are 16, 24, and 32 for AES-128, AES-192, and AES-256 respectively. Therefore, you can use the definitions: `AES_KEY_LEN128`, `AES_KEY_LEN192`, and `AES_KEY_LEN256`.

#### **unsigned char \*iv**

Pointer to a valid initialization vector of cipher block size number of bytes. If *iv* is NULL, *message* is assumed to be the complete message to be processed. Otherwise, *message* is the final part of a composite message to be processed, and *iv* contains the output vector resulting from processing all previous parts

| with chained calls to `ica_aes_cmac_intermediate` (the value returned in *iv* of  
| the `ica_aes_cmac_intermediate` call applied to the penultimate message part).

| **unsigned int direction**

| 0 Verify message authentication code.

| 1 Compute message authentication code for the message.

| **Return codes**

| 0 Success

| **EFAULT**

| If *direction* is equal to 0 and the verification of the message authentication  
| code fails.

| For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_aes\_ctr

### Purpose

Encrypt or decrypt data with an AES key using Counter (CTR) mode, as described in NIST Special Publication 800-38A Chapter 6.5. With the counter mode, each message block of size cipher block size (16 bytes for AES) is combined with a counter value of the same size during encryption and decryption.

Starting with an initial counter value to be combined with the first message block, subsequent counter values to be combined with subsequent message blocks are derived from preceding counter values by an increment function. The increment function used in `ica_aes_ctr` is an arithmetic increment without carry on the  $M$  least significant bytes in the counter where  $M$  is a parameter to `ica_aes_ctr`.

### Format

```
unsigned int ica_aes_ctr(const unsigned char *in_data,
    unsigned char *out_data,
    unsigned long data_length,
    const unsigned char *key,
    unsigned int key_length,
    unsigned char *ctr,
    unsigned int ctr_width,
    unsigned int direction);
```

### Required hardware support

KMCTR-AES-128, KMCTR-AES-192, or KMCTR-AES-256

### Parameters

#### **const unsigned char \*in\_data**

Pointer to a readable buffer that contains the message to be encrypted or decrypted. The size of the message in bytes is *data\_length*. The size of this buffer must be at least as large as *data\_length*.

#### **unsigned char \*out\_data**

Pointer to a writable buffer to contain the resulting encrypted or decrypted message. The size of this buffer in bytes must be at least as large as *data\_length*.

#### **unsigned long data\_length**

Length in bytes of the message to be encrypted or decrypted, which resides at the beginning of *in\_data*.

#### **const unsigned char \*key**

Pointer to a valid AES key.

#### **unsigned int key\_length**

Length in bytes of the AES key. Supported sizes are 16, 24, and 32 for AES-128, AES-192, and AES-256 respectively. Therefore, you can use the definitions: `AES_KEY_LEN128`, `AES_KEY_LEN192`, and `AES_KEY_LEN256`.

#### **unsigned char \*ctr**

Pointer to a readable and writable buffer of the same size as the cipher block in bytes. *ctr* contains an initialization value for a counter function, and it is replaced by a new value. That new value can be used as an initialization value for a counter function in a chained `ica_aes_ctr` call with the same key, if the *data\_length* used in the preceding call is a multiple of the cipher block size.

#### **unsigned int ctr\_width**

A number  $M$  between 1 and the cipher block size. The value is used by the

counter increment function, which increments a counter value by incrementing without carry the least significant  $M$  bytes of the counter value.

**unsigned int direction**

- 0 Use the decrypt function.
- 1 Use the encrypt function.

**Return codes**

- 0 Success

For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_aes\_ctrlist

### Purpose

Encrypt or decrypt data with an AES key using Counter (CTR) mode, as described in NIST Special Publication 800-38A ,Chapter 6.5. With the counter mode, each message block of the same size as the cipher block in bytes is combined with a counter value of the same size during encryption and decryption.

The `ica_aes_ctrlist` function assumes that a list  $n$  of precomputed counter values is provided, where  $n$  is the smallest integer that is less than or equal to the message size divided by the cipher block size. This function optimally uses IBM System z hardware support for non-standard counter functions.

### Format

```
unsigned int ica_aes_ctrlist(const unsigned char *in_data,
    unsigned char *out_data,
    unsigned long data_length,
    const unsigned char *key,
    unsigned int key_length,
    const unsigned char *ctrlist,
    unsigned int direction);
```

### Required hardware support

KMCTR-DEAKMCTR-AES-128, KMCTR-AES-192, or KMCTR-AES-256

### Parameters

#### **const unsigned char \*in\_data**

Pointer to a readable buffer that contains the message to be encrypted or decrypted. The size of the message in bytes is *data\_length*. The size of this buffer must be at least as large as *data\_length*.

#### **unsigned char \*out\_data**

Pointer to a writable buffer to contain the resulting encrypted or decrypted message. The size of this buffer in bytes must be at least as large as *data\_length*.

#### **unsigned long data\_length**

Length in bytes of the message to be encrypted or decrypted, which resides at the beginning of *in\_data*.

Calls to `ica_aes_ctrlist` with the same key can be chained if:

- With the possible exception of the last call in the chain the *data\_length* used is a multiple of the cipher block size.
- The *ctrlist* argument of each chained call contains a list of counters that follows the counters used in the preceding call.

#### **const unsigned char \*key**

Pointer to a valid AES key.

#### **unsigned int key\_length**

Length in bytes of the AES key. Supported sizes are 16, 24, and 32 for AES-128, AES-192, and AES-256 respectively. Therefore, you can use the definitions: `AES_KEY_LEN128`, `AES_KEY_LEN192`, and `AES_KEY_LEN256`.

#### **const unsigned char \*ctrlist**

Pointer to a readable buffer that is both of a size greater than or equal to *data\_length*, and a multiple of the cipher block size (16 bytes for AES). *ctrlist* should contain a list of precomputed counter values, each of the same size as the cipher block.

**unsigned int direction**

- 0 Use the decrypt function.
- 1 Use the encrypt function.

**Return codes**

- 0 Success

For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_aes\_ecb

### Purpose

Encrypt or decrypt data with an AES key using Electronic Cook Book (ECB) mode, as described in NIST Special Publication 800-38A Chapter 6.1.

### Format

```
unsigned int ica_aes_ecb(const unsigned char *in_data,
    unsigned char *output,
    unsigned int data_length,
    const unsigned char *key,
    unsigned int key_length,
    unsigned int direction);
```

### Required hardware support

KM-AES-128, KM-AES-192, or KM-AES-256

### Parameters

#### **const unsigned char \*in\_data**

Pointer to a readable buffer that contains the message to be encrypted or decrypted. The size of the message in bytes is *data\_length*. The size of this buffer must be at least as large as *data\_length*.

#### **unsigned char \*out\_data**

Pointer to a writable buffer to contain the resulting encrypted or decrypted message. The size of this buffer in bytes must be at least as large as *data\_length*.

#### **unsigned long data\_length**

Length in bytes of the message to be encrypted or decrypted, which resides at the beginning of *in\_data*. *data\_length* must be a multiple of the cipher block size (a multiple of 16 for AES).

#### **const unsigned char \*key**

Pointer to a valid AES key.

#### **unsigned int key\_length**

Length in bytes of the AES key. Supported sizes are 16, 24, and 32 for AES-128, AES-192, and AES-256 respectively. Therefore, you can use the definitions: **AES\_KEY\_LEN128**, **AES\_KEY\_LEN192**, and **AES\_KEY\_LEN256**.

#### **unsigned int direction**

**0** Use the decrypt function.  
**1** Use the encrypt function.

### Return codes

**0** Success

For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_aes\_gcm

### Purpose

Encrypt data and authenticate data or decrypt data and check authenticity of data with an AES key using the Galois/Counter (GCM) mode, as described in NIST Special Publication 800-38D. If no message needs to be encrypted or decrypted and only authentication or authentication checks are requested, then this method implements the GMAC mode.

### Format

```
unsigned int ica_aes_gcm(unsigned char *plaintext,
    unsigned long plaintext_length,
    unsigned char *ciphertext,
    const unsigned char *iv,
    unsigned int iv_length,
    const unsigned char *aad,
    unsigned long aad_length,
    unsigned char *tag,
    unsigned int tag_length,
    const unsigned char *key,
    unsigned int key_length,
    unsigned int direction);
```

### Required hardware support

KM-AES-128, KM-AES-192 or KM-AES-256

KIMD-GHASH

KMCTR-AES-128, KMCTR\_AES-192 or KMCTR-AES-256

### Parameters

#### **unsigned char \*plaintext**

Pointer to a buffer of size greater than or equal to *plaintext\_length* bytes. If *direction* is equal to 1, the *plaintext* buffer must be readable and contain a payload message of size *plaintext\_length* to be encrypted. If *direction* is equal to 0, the *plaintext* buffer must be writable and if the authentication verification succeeds, the decrypted message in the most significant *plaintext\_length* bytes of *ciphertext* is written to the buffer. Otherwise, the contents of the buffer are undefined.

#### **unsigned long plaintext\_length**

Length in bytes of the message to be encrypted or decrypted. This value can be 0 unless *aad\_length* is equal to 0. The value must be greater than or equal to 0 and less than  $(2^{**36}) - 32$ .

#### **unsigned char \*ciphertext**

Pointer to a buffer of size greater than or equal to *plaintext\_length* bytes. If *direction* is equal to 1, then this buffer must be writable and the encrypted message from *plaintext* is written to that buffer. If *direction* is equal to 0, then this buffer is readable and contains an encrypted message of length *plaintext\_length*.

#### **const unsigned char \*iv**

Pointer to a readable buffer of size greater than or equal to *iv\_length* bytes, which contains an initialization vector of size *iv\_length*.

#### **unsigned int iv\_length**

Length in bytes of the initialization vector in *iv*. The value must be greater than 0 and less than  $2^{**61}$ . A length of 12 is recommended.



| **const unsigned char \*aad**

| Pointer to a readable buffer of size greater than or equal to *aad\_length* bytes.  
| The additional authenticated data in the most significant *aad\_length* bytes is  
| subject to the message authentication code computation, but is not encrypted.

| **unsigned int aad\_length**

| Length in bytes of the additional authenticated data in *aad*. The value must be  
| greater than or equal to 0 and less than  $2^{*61}$ .

| **unsigned char \*tag**

| Pointer to a buffer of size greater than or equal to *tag\_length* bytes. If *direction*  
| is equal to 1, this buffer must be writable, and a message authentication code  
| for the additional authenticated data in *aad* and the plain text in *plaintext* of  
| size *tag\_length* bytes is written to this buffer. If *direction* is equal to 0, this buffer  
| must be readable and contain a message authentication code to be verified  
| against the additional authenticated data in *aad* and the decrypted cipher text  
| from *ciphertext*.

| **unsigned int tag\_length**

| Length in bytes of the message authentication code *tag* in bytes. Valid values  
| are: 4, 8, 12, 13, 14, 15, and 16.

| **const unsigned char \*key**

| Pointer to a valid AES key.

| **unsigned int key\_length**

| Length in bytes of the AES key. Supported sizes are 16, 24, and 32 for AES-128,  
| AES-192, and AES-256 respectively. Therefore, you can use the definitions:  
| **AES\_KEY\_LEN128**, **AES\_KEY\_LEN192**, and **AES\_KEY\_LEN256**.

| **unsigned int direction**

| 0 Verify message authentication code and decrypt encrypted payload.  
| 1 Encrypt payload and compute message authentication code for the  
| additional authenticated data and the payload.

| **Return codes**

| 0 Success

| **EFAULT**

| If *direction* is equal to 0 and the verification of the message authentication  
| code fails.

| For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_aes\_ofb

### Purpose

Encrypt or decrypt data with an AES key using Output Feedback (OFB) mode, as described in NIST Special Publication 800-38A Chapter 6.4.

### Format

```
unsigned int ica_aes_ofb(const unsigned char *in_data,
    unsigned char *out_data,
    unsigned long data_length,
    const unsigned char *key,
    unsigned int key_length,
    unsigned char *iv,
    unsigned int direction);
```

### Required hardware support

KMO-AES-128, KMO-AES-192, or KMO-AES-256

### Parameters

#### **const unsigned char \*in\_data**

Pointer to a readable buffer that contains the message to be encrypted or decrypted. The size of the message in bytes is *data\_length*. The size of this buffer must be at least as large as *data\_length*.

#### **unsigned char \*out\_data**

Pointer to a writable buffer that to contain the resulting encrypted or decrypted message. The size of this buffer in bytes must be at least as large as *data\_length*.

#### **unsigned long data\_length**

Length in bytes of the message to be encrypted or decrypted, which resides at the beginning of *in\_data*.

#### **const unsigned char \*key**

Pointer to a valid AES key.

#### **unsigned int key\_length**

Length in bytes of the AES key. Supported sizes are 16, 24, and 32 for AES-128, AES-192, and AES-256 respectively. Therefore, you can use the definitions: **AES\_KEY\_LEN128**, **AES\_KEY\_LEN192**, and **AES\_KEY\_LEN256**.

#### **unsigned char \*iv**

Pointer to a valid initialization vector of the same size as the cipher block, in bytes (16 bytes for AES). This vector is overwritten during the function. If *data\_length* is a multiple of the cipher block size (16 bytes for AES), the result value in *iv* can be used as the initialization vector for a chained **ica\_aes\_ofb** call with the same key.

#### **unsigned int direction**

0        Use the decrypt function.  
1        Use the encrypt function.

### Return codes

0        Success

For return codes indicating exceptions, see “Return codes” on page 87.

## ica\_aes\_xts

### Purpose

Encrypt or decrypt data with an AES key using the XEX Tweakable Bloc Cipher with Ciphertext Stealing (XTS) mode, as described in NIST Special Publication 800-38E and IEEE standard 1619-2007.

### Format

```
unsigned int ica_aes_xts(const unsigned char *in_data,
    unsigned char *out_data,
    unsigned long data_length,
    const unsigned char *key1,
    const unsigned char *key2,
    unsigned int key_length,
    unsigned char *tweak,
    unsigned int direction);
```

### Required hardware support

KM-XTS-AES-128, or KM-XTS-AES-256

PCC-Compute-XTS-Parameter-Using-AES-128, or PCC-Compute-XTS-Parameter-Using-AES-256

### Parameters

#### **const unsigned char \*in\_data**

Pointer to a readable buffer that contains the message to be encrypted or decrypted. The size of the message in bytes is *data\_length*. The size of this buffer must be at least as large as *data\_length*.

#### **unsigned char \*out\_data**

Pointer to a writable buffer to contain the resulting encrypted or decrypted message. The size of this buffer in bytes must be at least as large as *data\_length*.

#### **unsigned long data\_length**

Length in bytes of the message to be encrypted or decrypted, which resides at the beginning of *in\_data*. The minimal value of *data\_length* is 16.

#### **const unsigned char \*key1**

Pointer to a buffer containing a valid AES key. *key1* is used for the actual encryption of the message buffer, combined with some vector computed from the *tweak* value (Key1 in IEEE Std 1619-2007).

#### **const unsigned char \*key2**

Pointer to a buffer containing a valid AES key *key2* is used to encrypt the tweak (Key2 in IEEE Std 1619-2007).

#### **unsigned int key\_length**

The length in bytes of the AES key. XTS supported AES key sizes are 16 and 32, for AES-128 and AES-256 respectively. Therefore, you can use:

`2 * AES_KEY_LEN128` and `2 * AES_KEY_LEN256`.

#### **unsigned char \*tweak**

Pointer to a valid 16-byte tweak value (as in IEEE standard 1619-2007). This tweak is overwritten during the function. If *data\_length* is a multiple of the cipher block size (a multiple of 16 for AES), the result value in *tweak* can be used as the *tweak* value for a chained `ica_aes_xts` call with the same key pair.

#### **unsigned int direction**

**0** Use the decrypt function.

**1** Use the encrypt function.

## **Return codes**

0      Success

For return codes indicating exceptions, see “Return codes” on page 87.

## Compatibility with earlier versions

In order to stay compatible with earlier versions of libica, the following AES interfaces remain supported:

```
unsigned int ica_aes_encrypt(unsigned int mode,
    unsigned int data_length, unsigned char *input_data,
    ica_aes_vector_t *iv, unsigned int key_length, unsigned char *aes_key,
    unsigned char *output_data);

unsigned int ica_aes_decrypt(unsigned int mode,
    unsigned int data_length, unsigned char *input_data,
    ica_aes_vector_t *iv, unsigned int key_length, unsigned char *aes_key,
    unsigned char *output_data);
```

Table 5 shows libica Version 2.0 AES functions calls, and their corresponding libica Version 2.2.0 AES function calls.

Table 5. Compatibility of libica Version 2.0 AES functions calls to libica Version 2.2.0 AES function calls

Calling this libica Version 2.0 AES function	Corresponds to calling this libica Version 2.2.0 AES function
<code>ica_aes_encrypt(MODE_ECB, data_length, in_data, NULL, key_length, key, out_data);</code>	<code>ica_aes_ecb(in_data, out_data, (long) data_length, key, key_length, 1);</code>
<code>ica_aes_encrypt(MODE_CBC, data_length, in_data, iv, key_length, key, out_data);</code>	<code>ica_des_cbc(in_data, out_data, (long) data_length, key, key_length, iv, 1);</code>
<code>ica_aes_decrypt(MODE_ECB, data_length, in_data, NULL, key_length, key, out_data);</code>	<code>ica_aes_ecb(in_data, out_data, (long) data_length, key, key_length, 0);</code>
<code>ica_aes_decrypt(MODE_CBC, data_length, in_data, iv, key_length, key, out_data);</code>	<code>ica_aes_cbc(in_data, out_data, (long) data_length, key, key_length, iv, 0);</code>

The functions `ica_aes_encrypt` and `ica_aes_decrypt` remain supported, but their use is discouraged in favor of `ica_aes_ecb` and `ica_aes_cbc`.

For a detailed description of the earlier APIs, see *libica Programmers Reference* Version 2.0.

---

## Information retrieval function

This function is included in: `include/ica_api.h`.

This function return information about the libica version.

## ica\_get\_version

### Purpose

Return libica version information.

### Format

```
unsigned int ica_get_version(libica_version_info *version_info);
```

### Parameters

#### **libica\_version\_info \*version\_info**

Pointer to a *libica\_version\_info* structure. The structure is filled with the current libica version information.

### Return codes

0        Success

For return codes indicating exceptions, see “Return codes” on page 87.





---

## Chapter 4. libica defines, typedefs, structs, and return codes

These defines, typedefs, structs, and return codes are used when programming with the libica Version 2.2.0 APIs in Chapter 3, “libica Version 2.2.0 Application Programming Interfaces (APIs),” on page 5. To use them, include `ica_api.h` in your programs.

---

### Defines

These defines are new with libica Version 2.2.0 or were changed from libica Version 1 or libica Version 2. Use these defines instead of the equivalent libica Version 1 defines. There is no difference in their values.

```
#define ica_adapter_handle_t int
#define SHA_HASH_LENGTH 20
#define SHA1_HASH_LENGTH SHA_HASH_LENGTH
#define SHA224_HASH_LENGTH 28
#define SHA256_HASH_LENGTH 32
#define SHA384_HASH_LENGTH 48
#define SHA512_HASH_LENGTH 64
#define ica_aes_key_t ica_key_t
#define ICA_ENCRYPT 1
#define ICA_DECRYPT 0
```

---

### Typedefs

These typedefs are available to ensure compatibility with libica Version 1 types.

```
typedef ica_des_vector_t ICA_DES_VECTOR;
typedef ica_des_key_single_t ICA_KEY_DES_SINGLE;
typedef ica_des_key_triple_t ICA_KEY_DES_TRIPLE;
typedef ica_aes_vector_t ICA_AES_VECTOR;
typedef ica_aes_key_single_t ICA_KEY_AES_SINGLE;
typedef ica_aes_key_len_128_t ICA_KEY_AES_LEN128;
typedef ica_aes_key_len_192_t ICA_KEY_AES_LEN192;
typedef ica_aes_key_len_256_t ICA_KEY_AES_LEN256;
typedef sha_context_t SHA_CONTEXT;
typedef sha256_context_t SHA256_CONTEXT;
typedef sha512_context_t SHA512_CONTEXT;
typedef unsigned char ica_des_vector_t[8];
typedef unsigned char ica_des_key_single_t[8];
typedef unsigned char ica_key_t[8];
typedef unsigned char ica_aes_vector_t[16];
typedef unsigned char ica_aes_key_single_t[8];
typedef unsigned char ica_aes_key_len_128_t[16];
typedef unsigned char ica_aes_key_len_192_t[24];
typedef unsigned char ica_aes_key_len_256_t[32];
```

---

## Structs

These structs are used in the API of libica Version 2.2.0. For the definitions of older functions, see previous versions of this book. The older functions are no longer recommended for use, but they are supported.

```
typedef struct {
    unsigned int key_length;
    unsigned char* modulus;
    unsigned char* exponent;
} ica_rsa_key_mod_expo_t;

typedef struct {
    unsigned int key_length;
    unsigned char* p;
    unsigned char* q;
    unsigned char* dp;
    unsigned char* dq;
    unsigned char* qInverse;
} ica_rsa_key_crt_t;
```

Take note of these considerations:

- The buffers pointed to by members of type *unsigned char \** must be manually allocated and deallocated by the user.
- Key parts must always be right-aligned in their fields.
- All buffers pointed to by members *modulus* and *exponent* in struct *ica\_rsa\_key\_mod\_expo\_t* must be of length *key\_length*.
- All buffers pointed to by members *p*, *q*, *dp*, *dq*, and *qInverse* in struct *ica\_rsa\_key\_crt\_t* must be of size *key\_length* / 2 or larger.
- In the struct *ica\_rsa\_key\_crt\_t*, the buffers *p*, *dp*, and *qInverse* must contain 8 bytes of zero padding in front of the actual values.
- If an exponent is set in struct *ica\_rsa\_key\_mod\_expo\_t* as part of a public key for key generation, be aware that due to a restriction in OpenSSL, the public exponent cannot be larger than a size of unsigned long. Therefore, you must have zeros left padded in the buffer pointed to by *exponent* in the struct *ica\_rsa\_key\_mod\_expo\_t* struct. Be aware that this buffer also must be of size *key\_length*.
- This *key\_length* value should be calculated from the length of the modulus in bits, according to this calculation:

$$\text{key\_length} = (\text{modulus\_bits} + 7) / 8$$

```
typedef struct {
    uint64_t runningLength;
    unsigned char shaHash[LENGTH_SHA_HASH];
} sha_context_t;

typedef struct {
    uint64_t runningLength;
    unsigned char sha256Hash[LENGTH_SHA256_HASH];
} sha256_context_t;

typedef struct {
    uint64_t runningLengthHigh;
    uint64_t runningLengthLow;
    unsigned char sha512Hash[LENGTH_SHA512_HASH];
} sha512_context_t;

typedef struct {
    unsigned int major_version;
    unsigned int minor_version;
    unsigned int fixpack_version;
} libica_version_info;
```

---

## Return codes

The libica Version 2 and libica Version 2.2.0 functions use these standard Linux return codes:

**0** Success

**EFAULT**

The message authentication failed.

**EINVAL**

Incorrect parameter

**EIO** I/O error

**EPERM**

Operation not permitted by Hardware (CPACF).

**ENODEV**

No such device

**ENOMEM**

Not enough memory

**errno** When libica calls **open**, **close**, **begin\_sigill\_section**, or OpenSSL function **RSA\_generate\_key**, the error codes of these programs are returned.



---

## Chapter 5. libica tools

The libica package includes tools to investigate the capabilities of your cryptographic hardware and how these capabilities are used by applications that use libica.

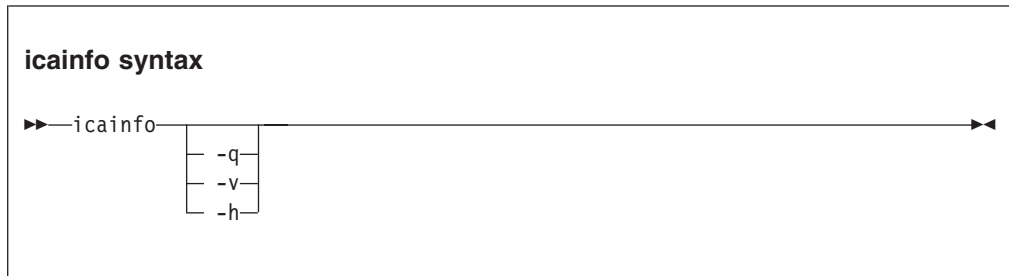
---

## icainfo - Show available libica functions

### Purpose

Use this command to find out which libica functions are available on your Linux system.

### Format



Where:

#### **-q or --quiet**

Suppresses an explanatory introduction to the list of functions in the command output.

#### **-v or --version**

Displays the version number of **icainfo**, then exits.

#### **-h or --help**

Displays help information for the command.

### Examples

1. To show which libica functions are available on your Linux system enter:

```
# icainfo
```

```
The following CP Assist for Cryptographic Function (CPACF) operations are supported by libica on this system:
```

```
SHA-1:      yes  
SHA-256:    yes  
SHA-512:    yes  
DES:        yes  
TDES-128:   yes  
TDES-192:   yes  
AES-128:    yes  
AES-192:    yes  
AES-256:    yes  
PRNG:       yes  
CCM-AES-128: yes  
CMAC-AES-128: yes  
CMAC-AES-192: yes  
CMAC-AES-256: yes
```

2. To list the libica functions without the introduction enter:

```
# icainfo -q  
SHA-1:      yes  
SHA-256:    yes  
SHA-512:    yes  
DES:        yes  
TDES-128:   yes  
TDES-192:   yes  
AES-128:    yes
```

```
| AES-192:    yes
| AES-256:    yes
| PRNG:       yes
| CCM-AES-128: yes
| CMAC-AES-128: yes
| CMAC-AES-192: yes
| CMAC-AES-256: yes
|
```

## icastats - Show use of libica functions

### Purpose

Use this command to find out whether libica uses hardware acceleration features or works with software fallbacks. The command also shows which specific functions of libica are used.

### Format

#### icastats syntax



Where:

#### **-r or --reset**

Sets the function counters to zero.

#### **-v or --version**

Displays the version number of **icastats**, then exits.

#### **-h or --help**

Displays help information for the command.

### Examples

To display the current use of libica functions issue:

```
# icastats
```

function	# hardware	# software
SHA-1	0	0
SHA-224	0	0
SHA-256	0	0
SHA-384	0	0
SHA-512	0	0
RANDOM	1	0
MOD EXPO	0	0
RSA CRT	0	0
DES ENC	0	0
DES DEC	0	0
3DES ENC	0	0
3DES DEC	0	0
AES ENC	0	0
AES DEC	0	0
CMAC GEN	0	0
CMAC VER	0	0
CCM ENC	0	0
CCM DEC	0	0
CCM AUTH	0	0
GCM ENC	0	0
GCM DEC	0	0
GCM AUTH	0	0



---

## Chapter 6. Examples

These sample program segments illustrate the libica Version 2.2.0 APIs. These sample programs are from the libica Version 2.2.0 RPM, and they were enhanced to use the libica Version 2.2.0 APIs.

These examples are released under the Common Public License - V1.0, which is stated in full at the end of this chapter. See “Common Public License - V1.0” on page 170.

Table 6 lists the examples for libica, and the makefile used to create the library.

*Table 6. libica examples*

Description	Location
DES with ECB mode example	“DES with ECB mode example” on page 94
SHA-256 example	“SHA-256 example” on page 97
Pseudo random number generation example	“Pseudo random number generation example” on page 103
Key generation example	“Key generation example” on page 105
RSA example	“RSA example” on page 112
DES with CTR mode example	“DES with CTR mode example” on page 117
Triple DES with CBC mode example	“Triple DES with CBC mode example” on page 120
AES with CFB mode example	“AES with CFB mode example” on page 123
AES with CTR mode example	“AES with CTR mode example” on page 136
AES with OFB mode example	“AES with OFB mode example” on page 146
AES with XTS mode example	“AES with XTS mode example” on page 155
CMAC example	“CMAC example” on page 165
Makefile example	“Makefile example” on page 169

---

## DES with ECB mode example

This program prints the version of libica and then encrypts the contents of a character array (plain\_data[]) using DES in ECE mode and a key stored in another character array (des\_key[]). The program then decrypts the result and prints it as a string. Intermediate results are written as hex dumps.

```
/* This program is released under the Common Public License V1.0
 *
 * You should have received a copy of Common Public License V1.0 along with
 * with this program.
 *
 * Copyright IBM Corp. 2011
 *
 */

#include <stdio.h>
#include <string.h>
#include <errno.h>

#include <ica_api.h>

#define DES_CIPHER_BLOCK_SIZE 8

/* Prints hex values to standard out. */
static void dump_data(unsigned char *data, unsigned long length);
/* Prints a description of the return value to standard out. */
static int handle_ica_error(int rc);

int main(char **argv, int argc)
{
    int rc;
    libica_version_info version;

    /* This example uses a static key. In real life you would
     * use your real DES key, which is negotiated between the
     * encrypting and the decrypting entity.
     *
     * Note: DES key size is cipher block size (DES_CIPHER_BLOCK_SIZE)
     */
    unsigned char des_key[] = {
        0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07,
    };

    /* This is the plain data, you want to encrypt. For the
     * encryption mode, used in this example, it is necessary,
     * that the length of the encrypted data is a multiple of
     * cipher block size (DES_CIPHER_BLOCK_SIZE).
     */
    unsigned char plain_data[] = {
        0x55, 0x73, 0x69, 0x6e, 0x67, 0x20, 0x6c, 0x69,
        0x62, 0x69, 0x63, 0x61, 0x20, 0x69, 0x73, 0x20,
        0x73, 0x6d, 0x61, 0x72, 0x74, 0x20, 0x61, 0x6e,
        0x64, 0x20, 0x65, 0x61, 0x73, 0x79, 0x21, 0x00,
    };

    unsigned char cipher_data[sizeof(plain_data)];
    unsigned char decrypt_data[sizeof(plain_data)];

    /* Print out libica version.
     */
    ica_get_version(&version);
    printf("libica version %i.%i.%i\n",
        version.major_version,
        version.minor_version,
        version.fixpack_version);
}
```

```

/* Dump key and plain data to standard output, just for
 * a visual control.
 */
printf("DES key:\n");
dump_data(des_key, DES_CIPHER_BLOCK_SIZE);
printf("plain data:\n");
dump_data(plain_data, sizeof(plain_data));

/* Encrypt plain data to cipher data, using libica API.
 */
rc = ica_des_ecb(plain_data, cipher_data, sizeof(plain_data),
                des_key,
                ICA_ENCRYPT);

/* Error handling (if necessary).
 */
if (rc)
    return handle_ica_error(rc);

/* Dump encrypted data.
 */
printf("encrypted data:\n");
dump_data(cipher_data, sizeof(plain_data));

/* Decrypt cipher data to decrypted data, using libica API.
 * Note: The same DES key must be used for encryption and decryption.
 */
rc = ica_des_ecb(cipher_data, decrypt_data, sizeof(plain_data),
                des_key,
                ICA_DECRYPT);

/* Error handling (if necessary).
 */
if (rc)
    return handle_ica_error(rc);

/* Dump decrypted data.
 * Note: Please compare output with the plain data, they are the same.
 */
printf("decrypted data:\n");
dump_data(decrypt_data, sizeof(plain_data));

/* Surprise... :-)
 * Note: The following will only work in this example!
 */
printf("%s\n", decrypt_data);
}

static void dump_data(unsigned char *data, unsigned long length)
{
    unsigned char *ptr;
    int i;

    for (ptr = data, i = 1; ptr < (data+length); ptr++, i++) {
        printf("0x%02x ", *ptr);
        if ((i % DES_CIPHER_BLOCK_SIZE) == 0)
            printf("\n");
    }
    if (i % DES_CIPHER_BLOCK_SIZE)
        printf("\n");
}

static int handle_ica_error(int rc)
{
    switch (rc) {
    case 0:
        printf("OK\n");
    }
}

```

```
    break;
case EINVAL:
    printf("Incorrect parameter.\n");
    break;
case EPERM:
    printf("Operation not permitted by Hardware (CPACF).\n");
    break;
case EIO:
    printf("I/O error.\n");
    break;
default:
    printf("unknown error.\n");
}

return rc;
}
```

---

## SHA-256 example

```
/* This program is released under the Common Public License V1.0
 *
 * You should have received a copy of Common Public License V1.0 along with
 * with this program.
 */

/* Copyright IBM Corp. 2005, 2009, 2011 */
/* (C) COPYRIGHT International Business Machines Corp. 2005, 2009 */
#include <fcntl.h>
#include <sys/errno.h>
#include <stdio.h>
#include <string.h>
#include "ica_api.h"

#define NUM_FIPS_TESTS 3

unsigned char FIPS_TEST_DATA[NUM_FIPS_TESTS][64] = {
    // Test 0: "abc"
    { 0x61,0x62,0x63 },
    // Test 1: "abcdcbcdcedefdefgefghfghighijhijkijkljklmklmnlmnomnopnopq"
    {
        0x61,0x62,0x63,0x64,0x62,0x63,0x64,0x65,0x63,0x64,0x65,0x66,0x64,0x65,0x66,0x67,
        0x65,0x66,0x67,0x68,0x66,0x67,0x68,0x69,0x67,0x68,0x69,0x6a,0x68,0x69,0x6a,0x6b,
        0x69,0x6a,0x6b,0x6c,0x6a,0x6b,0x6c,0x6d,0x6b,0x6c,0x6d,0x6e,0x6c,0x6d,0x6e,0x6f,
        0x6d,0x6e,0x6f,0x70,0x6e,0x6f,0x70,0x71,
    },
    // Test 2: 1,000,000 'a' -- don't actually use this... see the special case
    // in the loop below.
    {
        0x61,
    },
};

unsigned int FIPS_TEST_DATA_SIZE[NUM_FIPS_TESTS] = {
    // Test 0: "abc"
    3,
    // Test 1: "abcdcbcdcedefdefgefghfghighijhijkijkljklmklmnlmnomnopnopq"
    56,
    // Test 2: 1,000,000 'a'
    1000000,
};

unsigned char FIPS_TEST_RESULT[NUM_FIPS_TESTS][LENGTH_SHA256_HASH] =
{
    // Hash for test 0: "abc"
    {
        0xBA,0x78,0x16,0xBF,0x8F,0x01,0xCF,0xEA,0x41,0x41,0x40,0xDE,0x5D,0xAE,0x22,0x23,
        0xB0,0x03,0x61,0xA3,0x96,0x17,0x7A,0x9C,0xB4,0x10,0xFF,0x61,0xF2,0x00,0x15,0xAD,
    },
    // Hash for test 1: "abcdcbcdcedefdefgefghfghighijhijkijkljklmklmnlmnomnopnopq"
    {
        0x24,0x8D,0x6A,0x61,0xD2,0x06,0x38,0xB8,0xE5,0xC0,0x26,0x93,0x0C,0x3E,0x60,0x39,
        0xA3,0x3C,0xE4,0x59,0x64,0xFF,0x21,0x67,0xF6,0xEC,0xED,0xD4,0x19,0xDB,0x06,0xC1,
    },
    // Hash for test 2: 1,000,000 'a'
    {
        0xCD,0xC7,0x6E,0x5C,0x99,0x14,0xFB,0x92,0x81,0xA1,0xC7,0xE2,0x84,0xD7,0x3E,0x67,
        0xF1,0x80,0x9A,0x48,0xA4,0x97,0x20,0x0E,0x04,0x6D,0x39,0xCC,0xC7,0x11,0x2C,0xD0,
    },
};

void dump_array(unsigned char *ptr, unsigned int size)
{
    unsigned char *ptr_end;
    unsigned char *h;
```

```

int i = 1, trunc = 0;

if (size > 64) {
    trunc = size - 64;
    size = 64;
}
h = ptr;
ptr_end = ptr + size;
while (h < ptr_end) {
    printf("0x%02x ", *h);
    h++;
    if (i == 8) {
        if (h != ptr_end)
            printf("\n");
        i = 1;
    } else {
        ++i;
    }
}
printf("\n");
if (trunc > 0)
    printf("... %d bytes not printed\n", trunc);
}

int old_api_sha256_test(void)
{
    ICA_ADAPTER_HANDLE adapter_handle;
    SHA256_CONTEXT Sha256Context;
    int rc = 0, i = 0;
    unsigned char input_data[1000000];
    unsigned int output_hash_length = LENGTH_SHA256_HASH;
    unsigned char output_hash[LENGTH_SHA256_HASH];

    rc = icaOpenAdapter(0, &adapter_handle);
    if (rc != 0) {
        printf("icaOpenAdapter failed and returned %d (0x%x).\n", rc, rc);
        if (rc == ENODEV)
            printf("The usual cause of this on zSeries is that the CPACF instruction is not available.\n");
        return 2;
    }

    for (i = 0; i < NUM_FIPS_TESTS; i++) {
        // Test 2 is a special one, because we want to keep the size of the
        // executable down, so we build it special, instead of using a static
        if (i != 2)
            memcpy(input_data, FIPS_TEST_DATA[i], FIPS_TEST_DATA_SIZE[i]);
        else
            memset(input_data, 'a', FIPS_TEST_DATA_SIZE[i]);

        printf("\nOriginal data for test %d:\n", i);
        dump_array(input_data, FIPS_TEST_DATA_SIZE[i]);

        rc = icaSha256(adapter_handle,
                      SHA_MSG_PART_ONLY,
                      FIPS_TEST_DATA_SIZE[i],
                      input_data,
                      LENGTH_SHA256_CONTEXT,
                      &Sha256Context,
                      &output_hash_length,
                      output_hash);

        if (rc != 0) {
            printf("icaSha256 failed with errno %d (0x%x).\n", rc, rc);
            return 2;
        }
    }
}

```

```

    if (output_hash_length != LENGTH_SHA256_HASH) {
        printf("icaSha256 returned an incorrect output data length, %u (0x%x).\n",
            output_hash_length, output_hash_length);
        return 2;
    }

    printf("\nOutput hash for test %d:\n", i);
    dump_array(output_hash, output_hash_length);
    if (memcmp(output_hash, FIPS_TEST_RESULT[i], LENGTH_SHA256_HASH) != 0) {
        printf("This does NOT match the known result.\n");
    } else {
        printf("Yes, it's what it should be.\n");
    }
}

// This test is the same as test 2, except that we use the SHA256_CONTEXT and
// break it into calls of 1024 bytes each.
printf("\nOriginal data for test 2(chunks = 1024) is calls of 1024 'a's at a time\n");
i = FIPS_TEST_DATA_SIZE[2];
while (i > 0) {
    unsigned int shaMessagePart;
    memset(input_data, 'a', 1024);

    if (i == FIPS_TEST_DATA_SIZE[2])
        shaMessagePart = SHA_MSG_PART_FIRST;
    else if (i <= 1024)
        shaMessagePart = SHA_MSG_PART_FINAL;
    else
        shaMessagePart = SHA_MSG_PART_MIDDLE;

    rc = icaSha256(adapter_handle,
        shaMessagePart,
        (i < 1024) ? i : 1024,
        input_data,
        LENGTH_SHA256_CONTEXT,
        &Sha256Context,
        &output_hash_length,
        output_hash);

    if (rc != 0) {
        printf("icaSha256 failed with errno %d (0x%x) on iteration %d.\n", rc, rc, i);
        return 2;
    }

    i -= 1024;
}

if (output_hash_length != LENGTH_SHA256_HASH) {
    printf("icaSha256 returned an incorrect output data length, %u (0x%x).\n",
        output_hash_length, output_hash_length);
    return 2;
}

printf("\nOutput hash for test 2(chunks = 1024):\n");
dump_array(output_hash, output_hash_length);
if (memcmp(output_hash, FIPS_TEST_RESULT[2], LENGTH_SHA256_HASH) != 0) {
    printf("This does NOT match the known result.\n");
} else {
    printf("Yes, it's what it should be.\n");
}

// This test is the same as test 2, except that we use the SHA256_CONTEXT and
// break it into calls of 64 bytes each.
printf("\nOriginal data for test 2(chunks = 64) is calls of 64 'a's at a time\n");
i = FIPS_TEST_DATA_SIZE[2];
while (i > 0) {
    unsigned int shaMessagePart;

```

```

memset(input_data, 'a', 64);

if (i == FIPS_TEST_DATA_SIZE[2])
    shaMessagePart = SHA_MSG_PART_FIRST;
else if (i <= 64)
    shaMessagePart = SHA_MSG_PART_FINAL;
else
    shaMessagePart = SHA_MSG_PART_MIDDLE;

rc = icaSha256(adapter_handle,
               shaMessagePart,
               (i < 64) ? i : 64,
               input_data,
               LENGTH_SHA256_CONTEXT,
               &Sha256Context,
               &output_hash_length,
               output_hash);

if (rc != 0) {
    printf("icaSha256 failed with errno %d (0x%x) on iteration %d.\n", rc, rc, i);
    return 2;
}

i -= 64;
}

if (output_hash_length != LENGTH_SHA256_HASH) {
    printf("icaSha256 returned an incorrect output data length, %u (0x%x).\n",
           output_hash_length, output_hash_length);
    return 2;
}

printf("\nOutput hash for test 2(chunks = 64):\n");
dump_array(output_hash, output_hash_length);
if (memcmp(output_hash, FIPS_TEST_RESULT[2], LENGTH_SHA256_HASH) != 0) {
    printf("This does NOT match the known result.\n");
} else {
    printf("Yes, it's what it should be.\n");
}

printf("\nAll SHA256 tests completed successfully\n");

icaCloseAdapter(adapter_handle);

return 0;
}

int new_api_sha256_test(void)
{
    sha256_context_t sha256_context;
    int rc = 0, i = 0;
    unsigned char input_data[1000000];
    unsigned int output_hash_length = LENGTH_SHA256_HASH;
    unsigned char output_hash[LENGTH_SHA256_HASH];

    for (i = 0; i < NUM_FIPS_TESTS; i++) {
        // Test 2 is a special one, because we want to keep the size of the
        // executable down, so we build it special, instead of using a static
        if (i != 2)
            memcpy(input_data, FIPS_TEST_DATA[i], FIPS_TEST_DATA_SIZE[i]);
        else
            memset(input_data, 'a', FIPS_TEST_DATA_SIZE[i]);

        printf("\nOriginal data for test %d:\n", i);
        dump_array(input_data, FIPS_TEST_DATA_SIZE[i]);

        rc = ica_sha256(SHA_MSG_PART_ONLY, FIPS_TEST_DATA_SIZE[i], input_data,

```



```

    &sha256_context, output_hash);

if (rc != 0) {
    printf("icaSha256 failed with errno %d (0x%x).\n", rc, rc);
    return rc;
}

printf("\nOutput hash for test %d:\n", i);
dump_array(output_hash, output_hash_length);
if (memcmp(output_hash, FIPS_TEST_RESULT[i], LENGTH_SHA256_HASH) != 0)
    printf("This does NOT match the known result.\n");
else
    printf("Yes, it's what it should be.\n");
}

// This test is the same as test 2, except that we use the SHA256_CONTEXT and
// break it into calls of 1024 bytes each.
printf("\nOriginal data for test 2(chunks = 1024) is calls of 1024"
       " 'a's at a time\n");
i = FIPS_TEST_DATA_SIZE[2];
while (i > 0) {
    unsigned int sha_message_part;
    memset(input_data, 'a', 1024);

    if (i == FIPS_TEST_DATA_SIZE[2])
        sha_message_part = SHA_MSG_PART_FIRST;
    else if (i <= 1024)
        sha_message_part = SHA_MSG_PART_FINAL;
    else
        sha_message_part = SHA_MSG_PART_MIDDLE;

    rc = ica_sha256(sha_message_part, (i < 1024) ? i : 1024,
                   input_data, &sha256_context, output_hash);

    if (rc != 0) {
        printf("ica_sha256 failed with errno %d (0x%x) on"
               " iteration %d.\n", rc, rc, i);
        return rc;
    }
    i -= 1024;
}

printf("\nOutput hash for test 2(chunks = 1024):\n");
dump_array(output_hash, output_hash_length);
if (memcmp(output_hash, FIPS_TEST_RESULT[2], LENGTH_SHA256_HASH) != 0)
    printf("This does NOT match the known result.\n");
else
    printf("Yes, it's what it should be.\n");

// This test is the same as test 2, except that we use the
// SHA256_CONTEXT and break it into calls of 64 bytes each.
printf("\nOriginal data for test 2(chunks = 64) is calls of 64 'a's at"
       " a time\n");
i = FIPS_TEST_DATA_SIZE[2];
while (i > 0) {
    unsigned int sha_message_part;
    memset(input_data, 'a', 64);

    if (i == FIPS_TEST_DATA_SIZE[2])
        sha_message_part = SHA_MSG_PART_FIRST;
    else if (i <= 64)
        sha_message_part = SHA_MSG_PART_FINAL;
    else
        sha_message_part = SHA_MSG_PART_MIDDLE;

    rc = ica_sha256(sha_message_part, (i < 64) ? i : 64,
                   input_data, &sha256_context, output_hash);
}

```

```

if (rc != 0) {
    printf("ica_sha256 failed with errno %d (0x%x) on iteration"
           " %d.\n", rc, rc, i);
    return rc;
}
i -= 64;
}

printf("\nOutput hash for test 2(chunks = 64):\n");
dump_array(output_hash, output_hash_length);
if (memcmp(output_hash, FIPS_TEST_RESULT[2], LENGTH_SHA256_HASH) != 0)
    printf("This does NOT match the known result.\n");
else
    printf("Yes, it's what it should be.\n");

printf("\nAll SHA256 tests completed successfully\n");

return 0;
}

int main(int argc, char **argv)
{
    int rc = 0;
    rc = old_api_sha256_test();
    if (rc) {
        printf("old_api_sha256_test: returned rc = %i\n", rc);
        return rc;
    }

    rc = new_api_sha256_test();
    if (rc) {
        printf("new_api_sha256_test: returned rc = %i\n", rc);
        return rc;
    }

    return rc;
}

```

---

## Pseudo random number generation example

This example uses the old (libica Version 1) API. Examples for using the new (libica Version 2.2.0) API for random number generation are located in other examples, such as the DES with CTR mode example.

```
/* This program is released under the Common Public License V1.0
 *
 * You should have received a copy of Common Public License V1.0 along with
 * with this program.
 */

/* Copyright IBM Corp. 2010, 2011 */
#include <fcntl.h>
#include <sys/errno.h>
#include <stdio.h>
#include "ica_api.h"

unsigned char R[512];

extern int errno;

void dump_array(unsigned char *ptr, unsigned int size)
{
    unsigned char *ptr_end;
    unsigned char *h;
    int i = 1;

    h = ptr;
    ptr_end = ptr + size;
    while (h < (unsigned char *)ptr_end) {
        printf("0x%02x ",(unsigned char ) *h);
        h++;
        if (i == 8) {
            printf("\n");
            i = 1;
        } else {
            ++i;
        }
    }
    printf("\n");
}

int main(int ac, char **av)
{
    int rc;
    ICA_ADAPTER_HANDLE adapter_handle;

    rc = icaOpenAdapter(0, &adapter_handle);
    if (rc != 0) {
        printf("icaOpenAdapter failed and returned %d (0x%x).\n", rc, rc);
    }

    rc = icaRandomNumberGenerate(adapter_handle, sizeof R, R);
    if (rc != 0) {
        printf("icaRandomNumberGenerate failed and returned %d (0x%x).\n", rc, rc);
#ifdef __s390__
        if (rc == ENODEV)
            printf("The usual cause of this on zSeries is that the CPACF instruction is not available.\n");
#endif
    }
    else {
        printf("\nHere it is:\n");
    }

    dump_array(R, sizeof R);
}
```

```
if (!rc) {  
    printf("\nWell, does it look random?\n\n");  
}  
  
icaCloseAdapter(adapter_handle);  
return 0;  
}
```

---

## Key generation example

This example uses the various key generation APIs, as well as those to open and close an adapter, and random number generation.

```
/* This program is released under the Common Public License V1.0
 *
 * You should have received a copy of Common Public License V1.0 along with
 * with this program.
 */

/* (C) COPYRIGHT International Business Machines Corp. 2001, 2009          */
#include <sys/errno.h>
#include <fcntl.h>
#include <memory.h>
#include <stdio.h>
#include <stdlib.h>
#include <strings.h>
#include "ica_api.h"

#define KEY_BYTES ((key_bits + 7) / 8)
#define KEY_BYTES_MAX 256

extern int errno;

void dump_array(char *ptr, int size)
{
    char *ptr_end;
    char *h;
    int i = 1;

    h = ptr;
    ptr_end = ptr + size;
    while (h < ptr_end) {
        printf("0x%02x ",(unsigned char ) *h);
        h++;
        if (i == 8) {
            printf("\n");
            i = 1;
        } else {
            ++i;
        }
    }
    printf("\n");
}

int main(int argc, char **argv)
{
    ICA_ADAPTER_HANDLE adapter_handle;
    ICA_KEY_RSA_CRT crtkey;
    ICA_KEY_RSA_MODEXPO wockey, wockey2;
    unsigned char decrypted[KEY_BYTES_MAX], encrypted[KEY_BYTES_MAX],
        original[KEY_BYTES_MAX];
    int rc;
    unsigned int length, length2;
    unsigned int exponent_type = RSA_PUBLIC_FIXED, key_bits = 1024;

    length = sizeof wockey;
    length2 = sizeof wockey2;
    bzero(&wockey, sizeof wockey);
    bzero(&wockey2, sizeof wockey2);

    rc = icaOpenAdapter(0, &adapter_handle);
    if (rc != 0) {
        printf("icaOpenAdapter failed and returned %d (0x%x).\n", rc,
            rc);
    }
}
```

```

}
exponent_type = RSA_PUBLIC_FIXED;
printf("a fixed exponent . . .\n");
rc = icaRandomNumberGenerate(adapter_handle, KEY_BYTES,
    wockey.keyRecord);
if (rc != 0) {
    printf("icaRandomNumberGenerate failed and returned %d (0x%x)"
        ".\n", rc, rc);
    return -1;
}
wockey.nLength = KEY_BYTES / 2;
wockey.expLength = sizeof(unsigned long);
wockey.expOffset = SZ_HEADER_MODEXPO;
wockey.keyRecord[wockey.expLength - 1] |= 1;
if (argc > 1) {
    key_bits = atoi(argv[1]);
    if (key_bits > KEY_BYTES_MAX * 8) {
        printf("The maximum key length is %d bits.",
            KEY_BYTES_MAX * 8);
        exit(0);
    }
    wockey.modulusBitLength = key_bits;
    printf("Using %u-bit keys and ", key_bits);
    if (argc > 2) {
        switch (argv[2][0]) {
            case '3':
                exponent_type = RSA_PUBLIC_3;
                printf("exponent 3 . . .\n");
                wockey.expLength = 1;
                break;
            case '6':
                exponent_type = RSA_PUBLIC_65537;
                printf("exponent 65537 . . .\n");
                wockey.expLength = 3;
                break;
            case 'R':
            case 'r':
                exponent_type = RSA_PUBLIC_RANDOM;
                printf("a random exponent . . .\n");
                break;
            default:
                break;
        }
    }
}

rc = icaRandomNumberGenerate(adapter_handle, sizeof(original),
    original);
if (rc != 0) {
    printf("icaRandomNumberGenerate failed and returned %d (0x%x)"
        ".\n", rc, rc);
    return rc;
}
original[0] = 0;

rc = icaRsaKeyGenerateModExpo(adapter_handle, key_bits, exponent_type,
    &length, &wockey, &length2, &wockey2);
if (rc != 0) {
    printf("icaRsaKeyGenerateModExpo failed and returned %d (0x%x)"
        ".\n", rc, rc);
    return rc;
}

printf("Public key:\n");
dump_array((char *) wockey.keyRecord, 2 * KEY_BYTES);
printf("Private key:\n");
dump_array((char *) wockey2.keyRecord, 2 * KEY_BYTES);

```

```

bzero(encrypted, KEY_BYTES);
length = KEY_BYTES;
printf("encrypt \n");
rc = icaRsaModExpo(adapter_handle, KEY_BYTES, original, &wockey,
    &length, encrypted);
if (rc != 0) {
    printf("icaRsaModExpo failed and returned %d (0x%x).\n", rc, rc);
    return rc;
}
bzero(decrypted, KEY_BYTES);
length = KEY_BYTES;
printf("decrypt \n");
rc = icaRsaModExpo(adapter_handle, KEY_BYTES, encrypted, &wockey2,
    &length, decrypted);
if (rc != 0) {
    printf("icaRsaModExpo failed and returned %d (0x%x).\n", rc,
        rc);
    return rc;
}

printf("Original:\n");
dump_array((char *) original, KEY_BYTES);
printf("Result of encrypt:\n");
dump_array((char *) encrypted, KEY_BYTES);
printf("Result of decrypt:\n");
dump_array((char *) decrypted, KEY_BYTES);
if (memcmp(original, decrypted, KEY_BYTES) != 0) {
    printf("This does not match the original plaintext. Failure!\n");
    icaCloseAdapter(adapter_handle);
    return errno ? errno : -1;
} else {
    printf("Success! The key pair checks out.\n");
    if (memcmp(original, encrypted, KEY_BYTES) == 0) {
        printf("But the ciphertext equals the plaintext."
            "That can't be good.\n");
        return -1;
    }
}
fflush(stdout);

length = sizeof wockey;
length2 = sizeof crtkey;
bzero(&wockey, sizeof wockey);
wockey.expLength = sizeof(unsigned long);
if (exponent_type == RSA_PUBLIC_FIXED) {
    wockey.keyType = KEYTYPE_MODEXPO;
    wockey.keyLength = sizeof wockey;
    wockey.modulusBitLength = key_bits;
    wockey.nLength = KEY_BYTES;
    wockey.expOffset = SZ_HEADER_MODEXPO;
    wockey.expLength = sizeof(unsigned long);
    wockey.nOffset = KEY_BYTES + wockey.expOffset;
    rc = icaRandomNumberGenerate(adapter_handle, KEY_BYTES,
        wockey.keyRecord);
    if (rc != 0) {
        printf("icaRandomNumberGenerate failed and returned %d"
            "(0x%x).\n", rc, rc);
        return rc;
    }
    wockey.keyRecord[wockey.expLength - 1] |= 1;
}
rc = icaRsaKeyGenerateCrt(adapter_handle, key_bits, exponent_type,
    &length, &wockey, &length2, &crtkey);
printf("wockey.modulusBitLength = %i, crtkey.modulusBitLength = %i"
    "\n", wockey.modulusBitLength, crtkey.modulusBitLength);
if (rc != 0) {

```

```

printf("icaRsaKeyGenerateCrt failed and returned %d (0x%x)"
      ".\n", rc, rc);
return rc;
}

printf("Public key:\n");
dump_array((char *) wockey.keyRecord, 2 * KEY_BYTES);
printf("Private key:\n");
dump_array((char *) crtkey.keyRecord, 5 * KEY_BYTES / 2 + 24);

bzero(encrypted, KEY_BYTES);
length = KEY_BYTES;
rc = icaRsaModExpo(adapter_handle, KEY_BYTES, original, &wockey,
                  &length, encrypted);
if (rc != 0)
    printf("icaRsaModExpo failed and returned %d (0x%x).\n", rc, rc);

bzero(decrypted, KEY_BYTES);
length = KEY_BYTES;
rc = icaRsaCrt(adapter_handle, KEY_BYTES, encrypted, &crtkey, &length,
              decrypted);
if (rc != 0)
    printf("icaRsaCrt failed and returned %d (0x%x).\n", rc, rc);

printf("Original:\n");
dump_array((char *) original, KEY_BYTES);
printf("Result of encrypt:\n");
dump_array((char *) encrypted, KEY_BYTES);
printf("Result of decrypt:\n");
dump_array((char *) decrypted, KEY_BYTES);
if (memcmp(original, decrypted, KEY_BYTES) != 0) {
    printf("This does not match the original plaintext. Failure!\n");
    icaCloseAdapter(adapter_handle);
    return errno ? errno : -1;
} else {
    printf("Success! The key pair checks out.\n");
    if (memcmp(original, encrypted, KEY_BYTES) == 0) {
        printf("But the ciphertext equals the plaintext. That can't be good.\n");
        return -1;
    }
}
fflush(stdout);

printf("TEST NEW API - MOD_EXPO\n");
rc = ica_close_adapter(adapter_handle);
printf("ica_close_adapter rc = %i\n", rc);

rc = ica_open_adapter(&adapter_handle);
if (rc)
    printf("Adapter not open\n");
else
    printf("Adapter open\n");

ica_rsa_key_mod_expo_t modexpo_public_key;
unsigned char modexpo_public_n[KEY_BYTES];
bzero(modexpo_public_n, KEY_BYTES);
unsigned char modexpo_public_e[KEY_BYTES];
bzero(modexpo_public_e, KEY_BYTES);
modexpo_public_key.modulus = modexpo_public_n;
modexpo_public_key.exponent = modexpo_public_e;
modexpo_public_key.key_length = KEY_BYTES;
if (exponent_type == RSA_PUBLIC_65537)
    *(unsigned long*)((unsigned char *)modexpo_public_key.exponent +
                    modexpo_public_key.key_length -
                    sizeof(unsigned long)) = 65537;
if (exponent_type == RSA_PUBLIC_3)
    *(unsigned long*)((unsigned char *)modexpo_public_key.exponent +

```



```

    modexpo_public_key.key_length -
    sizeof(unsigned long)) = 3;

ica_rsa_key_mod_expo_t modexpo_private_key;
unsigned char modexpo_private_n[KEY_BYTES];
bzero(modexpo_private_n, KEY_BYTES);
unsigned char modexpo_private_e[KEY_BYTES];
bzero(modexpo_private_e, KEY_BYTES);
modexpo_private_key.modulus = modexpo_private_n;
modexpo_private_key.exponent = modexpo_private_e;
modexpo_private_key.key_length = KEY_BYTES;

rc = ica_rsa_key_generate_mod_expo(adapter_handle,
    key_bits,
    &modexpo_public_key,
    &modexpo_private_key);
if (rc)
    printf("ica_rsa_key_generate_mod_expo rc = %i\n",rc);

printf("Public key:\n");
dump_array((char *) (char *)modexpo_public_key.exponent, KEY_BYTES);
dump_array((char *) (char *)modexpo_public_key.modulus, KEY_BYTES);
printf("Private key:\n");
dump_array((char *) (char *)modexpo_private_key.exponent, KEY_BYTES);
dump_array((char *) (char *)modexpo_private_key.modulus, KEY_BYTES);

bzero(encrypted, KEY_BYTES);
length = KEY_BYTES;
printf("encrypt\n");
rc = ica_rsa_mod_expo(adapter_handle, original, &modexpo_public_key,
    encrypted);

if (rc != 0) {
    printf("ica_rsa_mod_expo failed and returned %d (0x%x).\n", rc,
        rc);
    return rc;
}
bzero(decrypted, KEY_BYTES);
length = KEY_BYTES;
printf("decrypt\n");
rc = ica_rsa_mod_expo(adapter_handle, encrypted, &modexpo_private_key,
    decrypted);
if (rc != 0) {
    printf("ica_rsa_mod_expo failed and returned %d (0x%x).\n", rc,
        rc);
    return rc;
}

printf("Original:\n");
dump_array((char *) original, KEY_BYTES);
printf("Result of encrypt:\n");
dump_array((char *) encrypted, KEY_BYTES);
printf("Result of decrypt:\n");
dump_array((char *) decrypted, KEY_BYTES);
if (memcmp(original, decrypted, KEY_BYTES) != 0) {
    printf("This does not match the original plaintext. Failure!\n");
    return -1;
} else {
    printf("Success! The key pair checks out.\n");
    if (memcmp(original, encrypted, KEY_BYTES) == 0) {
        printf("But the ciphertext equals the plaintext. That can't be good.\n");
        return -1;
    }
}
fflush(stdout);

printf("TEST NEW API - CRT\n");

```

```

ica_rsa_key_mod_exp_t public_key;
ica_rsa_key_crt_t private_key;

unsigned char public_n[KEY_BYTES];
bzero(public_n, KEY_BYTES);
unsigned char public_e[KEY_BYTES];
bzero(public_e, KEY_BYTES);
public_key.modulus = public_n;
public_key.exponent = public_e;
public_key.key_length = KEY_BYTES;

unsigned char private_p[(key_bits + 7) / (8 * 2) + 8];
bzero(private_p, KEY_BYTES + 1);
unsigned char private_q[(key_bits + 7) / (8 * 2)];
bzero(private_q, KEY_BYTES);
unsigned char private_dp[(key_bits + 7) / (8 * 2) + 8];
bzero(private_dp, KEY_BYTES + 1);
unsigned char private_dq[(key_bits + 7) / (8 * 2)];
bzero(private_dq, KEY_BYTES);
unsigned char private_qInverse[(key_bits + 7) / (8 * 2) + 8];
bzero(private_qInverse, KEY_BYTES + 1);
private_key.p = private_p;
private_key.q = private_q;
private_key.dp = private_dp;
private_key.dq = private_dq;
private_key.qInverse = private_qInverse;
private_key.key_length = (key_bits + 7) / 8;

if (exponent_type == RSA_PUBLIC_65537)
    *(unsigned long*)((unsigned char *)public_key.exponent +
        public_key.key_length -
        sizeof(unsigned long)) = 65537;
    if (exponent_type == RSA_PUBLIC_3)
        *(unsigned long*)((unsigned char *)public_key.exponent +
            public_key.key_length -
            sizeof(unsigned long)) = 3;

rc = ica_rsa_key_generate_crt(adapter_handle, key_bits, &public_key,
    &private_key);
if (rc != 0) {
    printf("ica_rsa_key_generate_crt failed and returned %d (0x%x)"
        ".\n", rc, rc);
    return rc;
}

printf("Public key:\n");
dump_array((char *) (char *)&public_key, 2 * KEY_BYTES);
printf("Private key:\n");
dump_array((char *) (char *)&private_key, 5 * KEY_BYTES / 2 + 24);

bzero(encrypted, KEY_BYTES);
length = KEY_BYTES;
rc = ica_rsa_mod_exp(adapter_handle, original, &public_key, encrypted);
if (rc != 0) {
    printf("ica_rsa_mod_exp failed and returned %d (0x%x).\n",
        rc, rc);
    return rc;
}
bzero(decrypted, KEY_BYTES);
length = KEY_BYTES;
rc = ica_rsa_crt(adapter_handle, encrypted, &private_key, decrypted);
if (rc != 0) {
    printf("icaRsaCrt failed and returned %d (0x%x).\n", rc, rc);
    return rc;
}

printf("Original:\n");

```

```

dump_array((char *) original, KEY_BYTES);
printf("Result of encrypt:\n");
dump_array((char *) encrypted, KEY_BYTES);
printf("Result of decrypt:\n");
dump_array((char *) decrypted, KEY_BYTES);
if (memcmp(original, decrypted, KEY_BYTES) != 0) {
    printf("This does not match the original plaintext."
        "Failure!\n");
} else {
    printf("Success! The key pair checks out.\n");
    if (memcmp(original, encrypted, KEY_BYTES) == 0) {
        printf("But the ciphertext equals the plaintext."
            "That can't be good.\n");
    }
}
fflush(stdout);
ica_close_adapter(adapter_handle);
return 0;
}

```



```

unsigned char Bq[] =
{ 0xa0, 0x3a, 0x18, 0xa4, 0x1c, 0x3c, 0x49, 0x09,
  0xd0, 0x84, 0x4a, 0x8c, 0x7c, 0xce, 0xdf, 0x9e,
  0x90, 0x7d, 0xc4, 0xca, 0x7e, 0x2d, 0x3d, 0xbc,
  0x09, 0x71, 0x79, 0xd0, 0xc0, 0xae, 0xa6, 0xc1,
  0x9d, 0xf0, 0x16, 0xf0, 0x1f, 0x68, 0x9a, 0xc5,
  0x2b, 0xf3, 0x5a, 0xfc, 0x2c, 0xf5, 0xa7, 0xec,
  0xd9, 0xa2, 0xac, 0x49, 0xcc, 0x76, 0x9c, 0xd8,
  0x4c, 0x59, 0x5e, 0x38, 0xd2, 0x85, 0xd3, 0x3b };

unsigned char Np[] =
{ 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00,
  0xfb, 0xb7, 0x73, 0x24, 0x42, 0xfe, 0x8f, 0x16,
  0xf0, 0x6e, 0x2d, 0x86, 0x22, 0x46, 0x79, 0xd1,
  0x58, 0x6f, 0x26, 0x24, 0x17, 0x12, 0xa3, 0x1a,
  0xfd, 0xf7, 0x75, 0xd4, 0xcd, 0xf9, 0xde, 0x4b,
  0x8c, 0xb7, 0x04, 0x5d, 0xd9, 0x18, 0xc8, 0x26,
  0x61, 0x54, 0xe0, 0x92, 0x2f, 0x47, 0xf7, 0x33,
  0xc2, 0x17, 0xd8, 0xda, 0xe0, 0x6d, 0xb6, 0x30,
  0xd6, 0xdc, 0xf9, 0x6a, 0x4c, 0xa1, 0xa2, 0x4b };

unsigned char Nq[] =
{ 0xf0, 0x57, 0x24, 0xf6, 0x2a, 0x5a, 0x6d, 0x8e,
  0xb8, 0xc6, 0x6f, 0xd2, 0xbb, 0x36, 0x4f, 0x6d,
  0xd8, 0xbc, 0xa7, 0x2f, 0xbd, 0x43, 0xdc, 0x9a,
  0x0e, 0x2a, 0x36, 0xb9, 0x21, 0x05, 0xfa, 0x22,
  0x6c, 0xe8, 0x22, 0x68, 0x2f, 0x1c, 0xe8, 0x27,
  0xc1, 0xed, 0x08, 0x7a, 0x43, 0x70, 0x7b, 0xe3,
  0x46, 0x74, 0x02, 0x6e, 0xb2, 0xb1, 0xeb, 0x44,
  0x72, 0x86, 0x0d, 0x55, 0x3b, 0xc8, 0xbc, 0xd9 };

unsigned char U[] =
{ 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00,
  0x83, 0xf1, 0xca, 0x06, 0x58, 0x4a, 0x04, 0x5e,
  0x96, 0xb5, 0x30, 0x32, 0x40, 0x36, 0x48, 0xb9,
  0x02, 0x0c, 0xe3, 0x37, 0xb7, 0x51, 0xbc, 0x22,
  0x26, 0x5d, 0x74, 0x03, 0x47, 0xd3, 0x33, 0x20,
  0x8e, 0x75, 0x62, 0xf2, 0x9d, 0x4e, 0xc8, 0x7d,
  0x5d, 0x8e, 0xb6, 0xd9, 0x69, 0x4a, 0x9a, 0xe1,
  0x36, 0x6e, 0x1c, 0xbe, 0x8a, 0x14, 0xb1, 0x85,
  0x39, 0x74, 0x7c, 0x25, 0xd8, 0xa4, 0x4f, 0xde };

unsigned char R[128];

unsigned char A[] =
{ 0x00, 0x02, 0x08, 0x68, 0x30, 0x9a, 0x32, 0x08,
  0x57, 0xb0, 0x28, 0xaa, 0x76, 0x30, 0x3d, 0x84,
  0x5f, 0x92, 0x0d, 0x8e, 0x34, 0xe0, 0xd5, 0xcc,
  0x36, 0x97, 0xed, 0x00, 0x00, 0x01, 0x02, 0x03,
  0x04, 0x05, 0x06, 0x07, 0x08, 0x09, 0x0a, 0x0b,
  0x0c, 0x0d, 0x0e, 0x0f, 0x10, 0x11, 0x12, 0x13,
  0x14, 0x15, 0x16, 0x17, 0x18, 0x19, 0x1a, 0x1b,
  0x1c, 0x1d, 0x1e, 0x1f, 0x20, 0x21, 0x22, 0x23,
  0x24, 0x25, 0x26, 0x27, 0x28, 0x29, 0x2a, 0x2b,
  0x2c, 0x2d, 0x2e, 0x2f, 0x30, 0x31, 0x32, 0x33,
  0x34, 0x35, 0x36, 0x37, 0x38, 0x39, 0x3a, 0x3b,
  0x3c, 0x3d, 0x3e, 0x3f, 0x40, 0x41, 0x42, 0x43,
  0x44, 0x45, 0x46, 0x47, 0x48, 0x49, 0x4a, 0x4b,
  0x4c, 0x4d, 0x4e, 0x4f, 0x50, 0x51, 0x52, 0x53,
  0x54, 0x55, 0x56, 0x57, 0x58, 0x59, 0x5a, 0x5b,
  0x5c, 0x5d, 0x5e, 0x5f, 0x60, 0x61, 0x62, 0x63 };

unsigned char Ciphertext[] =
{ 0xb2, 0xb2, 0x82, 0xd7, 0x2c, 0x6f, 0x53, 0x29,

```

```

0xee, 0x4c, 0xd1, 0x77, 0xb7, 0x13, 0xf3, 0x1c,
0x51, 0x60, 0xd8, 0xa9, 0x4e, 0x52, 0x72, 0x43,
0x29, 0xfa, 0x51, 0xaa, 0xd8, 0xbc, 0x31, 0x21,
0xe0, 0xac, 0x9b, 0x4e, 0x0, 0x94, 0xac, 0x91,
0x7f, 0x1e, 0xfd, 0xfb, 0x1c, 0xfa, 0xa8, 0xe8,
0x56, 0x5a, 0x1, 0x17, 0xf1, 0x5f, 0x1, 0xba,
0xcd, 0x77, 0xa1, 0x8c, 0x74, 0x8a, 0xef, 0xfa,
0x64, 0x58, 0x79, 0x13, 0xaa, 0x54, 0x13, 0x2b,
0xaa, 0xe7, 0xc3, 0x50, 0x3b, 0x69, 0x3b, 0xb,
0x9a, 0xa9, 0x9d, 0x15, 0x8a, 0x6, 0x45, 0x71,
0x40, 0x7a, 0x80, 0x85, 0x4a, 0xbe, 0x68, 0x48,
0x6c, 0xe6, 0xdd, 0x96, 0xb0, 0xdc, 0xf4, 0x23,
0xa8, 0xea, 0x21, 0x9f, 0xbc, 0x6b, 0x15, 0xa4,
0x87, 0x6e, 0x93, 0x56, 0xae, 0xa7, 0x17, 0x4e,
0xd7, 0x14, 0xe4, 0x69, 0x4, 0xd5, 0x2e, 0x62 };

```

```
extern int errno;
```

```
void dump_array(unsigned char *ptr, unsigned int size)
```

```

{
    unsigned char *ptr_end;
    unsigned char *h;
    int i = 1;

    h = ptr;
    ptr_end = ptr + size;
    while (h < (unsigned char *)ptr_end) {
        printf("0x%02x ", (unsigned char) *h);
        h++;
        if (i == 8) {
            printf("\n");
            i = 1;
        } else {
            ++i;
        }
    }
    printf("\n");
}

```

```
int main()
```

```

{
    ICA_ADAPTER_HANDLE adapter_handle;
    ICA_KEY_RSA_CRT icakey;
    ICA_KEY_RSA_MODEXPO wockey;
    caddr_t key;
    caddr_t my_result;
    caddr_t my_result2;
    /* icaRsaModExpo_t rsawoc; */
    int i;
    unsigned int length;

    i = icaOpenAdapter(0, &adapter_handle);
    if (i != 0) {
        printf("icaOpenAdapter failed and returned %d (0x%x), errno=%d\n", i, i, errno);
        return i;
    }

    /*
     * encrypt with public key
     */

    printf("modulus size = %ld\n", (long)sizeof(modulus1024));
    bzero(&wockey, sizeof(wockey));
    wockey.keyType = KEYTYPE_MODEXPO;
    wockey.keyLength = sizeof(ICA_KEY_RSA_MODEXPO);
    wockey.modulusBitLength = sizeof(modulus1024) * 8;
}

```

```

wockey.nLength = sizeof(modulus1024);
wockey.expLength = sizeof(pubkey1024);

key = (caddr_t)wockey.keyRecord;

bcopy(&pubkey1024, key, sizeof(pubkey1024));
wockey.expOffset = key - (char *) &wockey;
key += sizeof(pubkey1024);
bcopy(&modulus1024, key, sizeof(modulus1024));
wockey.nOffset = key - (char *) &wockey;

my_result = (caddr_t) malloc(sizeof(A));
bzero(my_result, sizeof(A));
length = sizeof(A);

printf("wockey.modulusBitLength = %i\n", wockey.modulusBitLength);
if ((i = icaRsaModExpo(adapter_handle, sizeof(A), A,
                    &wockey, &length, (unsigned char *)my_result)) != 0) {
    printf("icaRsaModExpo failed and returned %d (0x%x).\n", i, i);
}

printf("\n\n\n\n result of encrypt with public key\n");
dump_array((unsigned char *)my_result, sizeof(A));
printf("Ciphertext\n");
dump_array(Ciphertext, sizeof(A));
if (memcmp(my_result, Ciphertext, sizeof(A))) {
    printf("Ciphertext mismatch\n");
    return 0;
} else {
    printf("ENCRYPT WORKED\n");
}

bzero(&icakey, sizeof(icakey));

/* Card level CRT operation */
icakey.keyType = KEYTYPE_PKCSCRT;
icakey.keyLength = sizeof(ICA_KEY_RSA_CRT);
icakey.modulusBitLength = sizeof(modulus1024)*8;

my_result2 = (caddr_t)malloc(sizeof(A));
bzero(my_result2, sizeof(A));

key = (caddr_t)icakey.keyRecord;
/*
 * Bp is copied into the key */
bcopy(Bp, key, sizeof(Bp));
icakey.dpLength = sizeof(Bp);
icakey.dpOffset = key - (char *)&icakey;
key += sizeof(Bp);
/*
 * Bq is copied into the key */
bcopy(Bq, key, sizeof(Bq));
icakey.dqLength = sizeof(Bq);
icakey.dqOffset = key - (char *)&icakey;
key += sizeof(Bq);
/*
 * Np is copied into the key */
bcopy(Np, key, sizeof(Np));
icakey.pLength = sizeof(Np);
icakey.pOffset = key - (char *)&icakey;
key += sizeof(Np);
/*
 * Nq is copied into the key */
bcopy(Nq, key, sizeof(Nq));
icakey.qLength = sizeof(Nq);
icakey.qOffset = key - (char *)&icakey;

```

```

key += sizeof(Nq);
/*
 * U is copied into the key */
bcopy(U,key,sizeof(U));
icakey.qInvLength = sizeof(U);
icakey.qInvOffset = key - (char *)&icakey;
key += sizeof(U);

/*    printf("size of Bp=%d\n",sizeof(Bp));
printf("size of Bq=%d\n",sizeof(Bq));
printf("size of Np=%d\n",sizeof(Np));
printf("size of Nq=%d\n",sizeof(Nq));
printf("size of U=%d\n",sizeof(U));
printf("size of R=%d\n",sizeof(R));

printf("icakey private Key record\n");
dump_array(&icakey,sizeof(ICA_KEY_RSA_CRT)); */

length = sizeof(Ciphertext);
icakey.modulusBitLength = length * 8;
icakey.keyLength = length;
if ((i = icaRsaCrt(adapter_handle, sizeof(Ciphertext), Ciphertext,
                &icakey, &length, (unsigned char *)my_result2)) != 0) {
    printf("icaRsaCrt failed and returned %d (0x%x).\n", i, i);
}

printf("Result of decrypt\n");
dump_array((unsigned char *)my_result2, sizeof(A));
printf("original data\n");
dump_array(A, sizeof(A));
if( memcmp(A,my_result2,sizeof(A)) != 0) {
    printf("Results do not match. Failure!\n");
    return -1;
} else {
    printf("Results match!\n");
}

icaCloseAdapter(adapter_handle);

return 0;
}

```



---

## DES with CTR mode example

```
/* This program is released under the Common Public License V1.0
 *
 * You should have received a copy of Common Public License V1.0 along with
 * with this program.
 */

/* Copyright IBM Corp. 2010, 2011 */
#include <fcntl.h>
#include <sys/errno.h>
#include <stdio.h>
#include <string.h>
#include <strings.h>
#include <stdlib.h>
#include "ica_api.h"

#define NR_RANDOM_TESTS 100

void dump_array(unsigned char *ptr, unsigned int size)
{
    unsigned char *ptr_end;
    unsigned char *h;
    int i = 1;

    h = ptr;
    ptr_end = ptr + size;
    while (h < (unsigned char *)ptr_end) {
        printf("0x%02x ",(unsigned char ) *h);
        h++;
        if (i == 8) {
            printf("\n");
            i = 1;
        } else {
            ++i;
        }
    }
    printf("\n");
}

void dump_ctr_data(unsigned char *iv, unsigned int iv_length,
                  unsigned char *key, unsigned int key_length,
                  unsigned char *input_data, unsigned int data_length,
                  unsigned char *output_data)
{
    printf("IV \n");
    dump_array(iv, iv_length);
    printf("Key \n");
    dump_array(key, key_length);
    printf("Input Data\n");
    dump_array(input_data, data_length);
    printf("Output Data\n");
    dump_array(output_data, data_length);
}

int random_des_ctr(int iteration, int silent, unsigned int data_length, unsigned int iv_length)
{
    unsigned int key_length = sizeof(ica_des_key_single_t);
    if (data_length % sizeof(ica_des_vector_t))
        iv_length = sizeof(ica_des_vector_t);

    printf("Test Parameters for iteration = %i\n", iteration);
    printf("key length = %i, data length = %i, iv length = %i\n",
           key_length, data_length, iv_length);

    unsigned char iv[iv_length];
    unsigned char tmp_iv[iv_length];
}
```

```

unsigned char key[key_length];
unsigned char input_data[data_length];
unsigned char encrypt[data_length];
unsigned char decrypt[data_length];

int rc = 0;
rc = ica_random_number_generate(data_length, input_data);
if (rc) {
    printf("random number generate returned rc = %i, errno = %i\n", rc, errno);
    return rc;
}
rc = ica_random_number_generate(iv_length, iv);
if (rc) {
    printf("random number generate returned rc = %i, errno = %i\n", rc, errno);
    return rc;
}

rc = ica_random_number_generate(key_length, key);
if (rc) {
    printf("random number generate returned rc = %i, errno = %i\n", rc, errno);
    return rc;
}
memcpy(tmp_iv, iv, iv_length);

rc = ica_des_ctr(input_data, encrypt, data_length, key, tmp_iv,
    32, 1);
if (rc) {
    printf("ica_des_ctr encrypt failed with rc = %i\n", rc);
    dump_ctr_data(iv, iv_length, key, key_length, input_data,
        data_length, encrypt);
    return rc;
}
if (!silent && !rc) {
    printf("Encrypt:\n");
    dump_ctr_data(iv, iv_length, key, key_length, input_data,
        data_length, encrypt);
}

memcpy(tmp_iv, iv, iv_length);
rc = ica_des_ctr(encrypt, decrypt, data_length, key, tmp_iv,
    32, 0);
if (rc) {
    printf("ica_des_ctr decrypt failed with rc = %i\n", rc);
    dump_ctr_data(iv, iv_length, key, key_length, encrypt,
        data_length, decrypt);
    return rc;
}

if (!silent && !rc) {
    printf("Decrypt:\n");
    dump_ctr_data(iv, iv_length, key, key_length, encrypt,
        data_length, decrypt);
}

if (memcmp(decrypt, input_data, data_length)) {
    printf("Decryption Result does not match the original data!\n");
    printf("Original data:\n");
    dump_array(input_data, data_length);
    printf("Decryption Result:\n");
    dump_array(decrypt, data_length);
    rc++;
}
return rc;
}

int main(int argc, char **argv)

```

```

{
unsigned int silent = 0;
unsigned int endless = 0;
if (argc > 1) {
    if (strstr(argv[1], "silent"))
        silent = 1;
    if (strstr(argv[1], "endless"))
        endless = 1;
}
int rc = 0;
int error_count = 0;
int i = 0;
unsigned int data_length = sizeof(ica_des_key_single_t);
unsigned int iv_length = sizeof(ica_des_key_single_t);

if (endless) {
    silent = 1;
    while (1) {
        printf("i = %i\n", i);
        rc = random_des_ctr(i, silent, 320, 320);
        if (rc) {
            printf("kat_des_ctr failed with rc = %i\n",
                rc);
            return rc;
        } else
            printf("kat_des_ctr finished successfully\n");
        i++;
    }
} else {
    for (i = 1; i < NR_RANDOM_TESTS; i++) {
        rc = random_des_ctr(i, silent, data_length, iv_length);
        if (rc) {
            printf("random_des_ctr failed with rc = %i\n",
                rc);
            error_count++;
        } else
            printf("random_des_ctr finished "
                "successfully\n");
        if (!(data_length % sizeof(ica_des_key_single_t))) {
            /* Always when the full_block size is reached use a
            * counter with the same size as the data */
            rc = random_des_ctr(i, silent,
                data_length, data_length);
            if (rc) {
                printf("random_des_ctr failed with "
                    "rc = %i\n", rc);
                error_count++;
            } else
                printf("random_des_ctr finished "
                    "successfully\n");
        }
        data_length++;
    }
}

if (error_count)
    printf("%i testcases failed\n", error_count);
else
    printf("All testcases finished successfully\n");

return rc;
}

```

---

## Triple DES with CBC mode example

```
/* This program is released under the Common Public License V1.0
 *
 * You should have received a copy of Common Public License V1.0 along with
 * with this program.
 */

/* Copyright IBM Corp. 2010, 2011 */
#include <fcntl.h>
#include <sys/errno.h>
#include <stdio.h>
#include <string.h>
#include <strings.h>
#include <stdlib.h>
#include "ica_api.h"

#define NR_RANDOM_TESTS 10000

void dump_array(unsigned char *ptr, unsigned int size)
{
    unsigned char *ptr_end;
    unsigned char *h;
    int i = 1;

    h = ptr;
    ptr_end = ptr + size;
    while (h < (unsigned char *)ptr_end) {
        printf("0x%02x ",(unsigned char ) *h);
        h++;
        if (i == 8) {
            printf("\n");
            i = 1;
        } else {
            ++i;
        }
    }
    printf("\n");
}

void dump_cbc_data(unsigned char *iv, unsigned int iv_length,
                  unsigned char *key, unsigned int key_length,
                  unsigned char *input_data, unsigned int data_length,
                  unsigned char *output_data)
{
    printf("IV \n");
    dump_array(iv, iv_length);
    printf("Key \n");
    dump_array(key, key_length);
    printf("Input Data\n");
    dump_array(input_data, data_length);
    printf("Output Data\n");
    dump_array(output_data, data_length);
}

int load_random_test_data(unsigned char *data, unsigned int data_length,
                          unsigned char *iv, unsigned int iv_length,
                          unsigned char *key, unsigned int key_length)
{
    int rc;
    rc = ica_random_number_generate(data_length, data);
    if (rc) {
        printf("ica_random_number_generate with rc = %i error = %i\n",
              rc, errno);
        return rc;
    }
    rc = ica_random_number_generate(iv_length, iv);
}
```

```

if (rc) {
    printf("ica_random_number_generate with rc = %i error = %i\n",
           rc, errno);
    return rc;
}
rc = ica_random_number_generate(key_length, key);
if (rc) {
    printf("ica_random_number_generate with rc = %i error = %i\n",
           rc, errno);
    return rc;
}
return rc;
}

int random_3des_cbc(int iteration, int silent, unsigned int data_length)
{
    unsigned int iv_length = sizeof(ica_des_vector_t);
    unsigned int key_length = sizeof(ica_des_key_triple_t);

    unsigned char iv[iv_length];
    unsigned char tmp_iv[iv_length];
    unsigned char key[key_length];
    unsigned char input_data[data_length];
    unsigned char encrypt[data_length];
    unsigned char decrypt[data_length];

    int rc = 0;
    memset(encrypt, 0x00, data_length);
    memset(decrypt, 0x00, data_length);

    load_random_test_data(input_data, data_length, iv, iv_length, key,
                          key_length);
    memcpy(tmp_iv, iv, iv_length);

    printf("Test Parameters for iteration = %i\n", iteration);
    printf("key length = %i, data length = %i, iv length = %i\n",
           key_length, data_length, iv_length);

    rc = ica_3des_cbc(input_data, encrypt, data_length, key, tmp_iv, 1);
    if (rc) {
        printf("ica_3des_cbc encrypt failed with rc = %i\n", rc);
        dump_cbc_data(iv, iv_length, key, key_length, input_data,
                      data_length, encrypt);
    }
    if (!silent && !rc) {
        printf("Encrypt:\n");
        dump_cbc_data(iv, iv_length, key, key_length, input_data,
                      data_length, encrypt);
    }

    if (rc) {
        printf("3DES CBC test exited after encryption\n");
        return rc;
    }

    memcpy(tmp_iv, iv, iv_length);

    rc = ica_3des_cbc(encrypt, decrypt, data_length, key, tmp_iv,
                      0);
    if (rc) {
        printf("ica_3des_cbc decrypt failed with rc = %i\n", rc);
        dump_cbc_data(iv, iv_length, key, key_length, encrypt,
                      data_length, decrypt);
    }
    return rc;
}

```

```

if (!silent && !rc) {
    printf("Decrypt:\n");
    dump_cbc_data(iv, iv_length, key, key_length, encrypt,
                 data_length, decrypt);
}

if (memcmp(decrypt, input_data, data_length)) {
    printf("Decryption Result does not match the original data!\n");
    printf("Original data:\n");
    dump_array(input_data, data_length);
    printf("Decryption Result:\n");
    dump_array(decrypt, data_length);
    rc++;
}
return rc;
}

int main(int argc, char **argv)
{
    // Default mode is 0. ECB,CBC and CFQ tests will be performed.
    unsigned int silent = 0;
    if (argc > 1) {
        if (strstr(argv[1], "silent"))
            silent = 1;
    }
    int rc = 0;
    int error_count = 0;
    int iteration;
    unsigned int data_length = sizeof(ica_des_vector_t);
    for(iteration = 1; iteration <= NR_RANDOM_TESTS; iteration++) {
        int silent = 1;
        rc = random_3des_cbc(iteration, silent, data_length);
        if (rc) {
            printf("random_3des_cbc failed with rc = %i\n", rc);
            error_count++;
            goto out;
        } else
            printf("random_3des_cbc finished successfully\n");
        data_length += sizeof(ica_des_vector_t);
    }
out:
    if (error_count)
        printf("%i testcases failed\n", error_count);
    else
        printf("All testcases finished successfully\n");

    return rc;
}

```

---

## AES with CFB mode example

```
/* This program is released under the Common Public License V1.0
 *
 * You should have received a copy of Common Public License V1.0 along with
 * with this program.
 */

/* Copyright IBM Corp. 2010, 2011 */
#include <fcntl.h>
#include <sys/errno.h>
#include <stdio.h>
#include <string.h>
#include <strings.h>
#include <stdlib.h>
#include "ica_api.h"

#define NR_TESTS 12
#define NR_RANDOM_TESTS 1000

/* CFB128 data -1- AES128 */
unsigned char NIST_KEY_CFB_E1[] = {
    0x2b, 0x7e, 0x15, 0x16, 0x28, 0xae, 0xd2, 0xa6,
    0xab, 0xf7, 0x15, 0x88, 0x09, 0xcf, 0x4f, 0x3c,
};

unsigned char NIST_IV_CFB_E1[] = {
    0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07,
    0x08, 0x09, 0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f,
};

unsigned char NIST_EXPECTED_IV_CFB_E1[] = {
    0x3b, 0x3f, 0xd9, 0x2e, 0xb7, 0x2d, 0xad, 0x20,
    0x33, 0x34, 0x49, 0xf8, 0xe8, 0x3c, 0xfb, 0x4a,
};

unsigned char NIST_TEST_DATA_CFB_E1[] = {
    0x6b, 0xc1, 0xbe, 0xe2, 0x2e, 0x40, 0x9f, 0x96,
    0xe9, 0x3d, 0x7e, 0x11, 0x73, 0x93, 0x17, 0x2a,
};

unsigned char NIST_TEST_RESULT_CFB_E1[] = {
    0x3b, 0x3f, 0xd9, 0x2e, 0xb7, 0x2d, 0xad, 0x20,
    0x33, 0x34, 0x49, 0xf8, 0xe8, 0x3c, 0xfb, 0x4a,
};

unsigned int NIST_LCFB_E1 = 128 / 8;

/* CFB128 data -2- AES128 */
unsigned char NIST_KEY_CFB_E2[] = {
    0x2b, 0x7e, 0x15, 0x16, 0x28, 0xae, 0xd2, 0xa6,
    0xab, 0xf7, 0x15, 0x88, 0x09, 0xcf, 0x4f, 0x3c,
};

unsigned char NIST_IV_CFB_E2[] = {
    0x3b, 0x3f, 0xd9, 0x2e, 0xb7, 0x2d, 0xad, 0x20,
    0x33, 0x34, 0x49, 0xf8, 0xe8, 0x3c, 0xfb, 0x4a,
};

unsigned char NIST_EXPECTED_IV_CFB_E2[] = {
    0xc8, 0xa6, 0x45, 0x37, 0xa0, 0xb3, 0xa9, 0x3f,
    0xcd, 0xe3, 0xcd, 0xad, 0x9f, 0x1c, 0xe5, 0x8b,
};

unsigned char NIST_TEST_DATA_CFB_E2[] = {
    0xae, 0x2d, 0x8a, 0x57, 0x1e, 0x03, 0xac, 0x9c,
    0x9e, 0xb7, 0x6f, 0xac, 0x45, 0xaf, 0x8e, 0x51,
};
```

```

};

unsigned char NIST_TEST_RESULT_CFB_E2[] = {
    0xc8, 0xa6, 0x45, 0x37, 0xa0, 0xb3, 0xa9, 0x3f,
    0xcd, 0xe3, 0xcd, 0xad, 0x9f, 0x1c, 0xe5, 0x8b,
};

unsigned int NIST_LCFB_E2 = 128 / 8;

/* CFB8 data -3- AES128 */
unsigned char NIST_KEY_CFB_E3[] = {
    0x2b, 0x7e, 0x15, 0x16, 0x28, 0xae, 0xd2, 0xa6,
    0xab, 0xf7, 0x15, 0x88, 0x09, 0xcf, 0x4f, 0x3c,
};

unsigned char NIST_IV_CFB_E3[] = {
    0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07,
    0x08, 0x09, 0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f,
};

unsigned char NIST_EXPECTED_IV_CFB_E3[] = {
    0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07, 0x08,
    0x09, 0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f, 0x3b,
};

unsigned char NIST_TEST_DATA_CFB_E3[] = {
    0x6b,
};

unsigned char NIST_TEST_RESULT_CFB_E3[] = {
    0x3b,
};

unsigned int NIST_LCFB_E3 = 8 / 8;

/* CFB8 data -4- AES128 */
unsigned char NIST_KEY_CFB_E4[] = {
    0x2b, 0x7e, 0x15, 0x16, 0x28, 0xae, 0xd2, 0xa6,
    0xab, 0xf7, 0x15, 0x88, 0x09, 0xcf, 0x4f, 0x3c,
};

unsigned char NIST_IV_CFB_E4[] = {
    0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07, 0x08,
    0x09, 0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f, 0x3b,
};

unsigned char NIST_EXPECTED_IV_CFB_E4[] = {
    0x02, 0x03, 0x04, 0x05, 0x06, 0x07, 0x08, 0x09,
    0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f, 0x3b, 0x79,
};

unsigned char NIST_TEST_DATA_CFB_E4[] = {
    0xc1,
};

unsigned char NIST_TEST_RESULT_CFB_E4[] = {
    0x79,
};

unsigned int NIST_LCFB_E4 = 8 / 8;

/* CFB 128 data -5- for AES192 */
unsigned char NIST_KEY_CFB_E5[] = {
    0x8e, 0x73, 0xb0, 0xf7, 0xda, 0x0e, 0x64, 0x52,
    0xc8, 0x10, 0xf3, 0x2b, 0x80, 0x90, 0x79, 0xe5,
    0x62, 0xf8, 0xea, 0xd2, 0x52, 0x2c, 0x6b, 0x7b,
};

unsigned char NIST_IV_CFB_E5[] = {

```



```

    0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07,
    0x08, 0x09, 0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f,
};

unsigned char NIST_EXPECTED_IV_CFB_E5[] = {
    0xcd, 0xc8, 0x0d, 0x6f, 0xdd, 0xf1, 0x8c, 0xab,
    0x34, 0xc2, 0x59, 0x09, 0xc9, 0x9a, 0x41, 0x74,
};

unsigned char NIST_TEST_DATA_CFB_E5[] = {
    0x6b, 0xc1, 0xbe, 0xe2, 0x2e, 0x40, 0x9f, 0x96,
    0xe9, 0x3d, 0x7e, 0x11, 0x73, 0x93, 0x17, 0x2a,
};

unsigned char NIST_TEST_RESULT_CFB_E5[] = {
    0xcd, 0xc8, 0x0d, 0x6f, 0xdd, 0xf1, 0x8c, 0xab,
    0x34, 0xc2, 0x59, 0x09, 0xc9, 0x9a, 0x41, 0x74,
};

unsigned int NIST_LCFB_E5 = 128 / 8;

/* CFB 128 data -6- for AES192 */
unsigned char NIST_KEY_CFB_E6[] = {
    0x8e, 0x73, 0xb0, 0xf7, 0xda, 0x0e, 0x64, 0x52,
    0xc8, 0x10, 0xf3, 0x2b, 0x80, 0x90, 0x79, 0xe5,
    0x62, 0xf8, 0xea, 0xd2, 0x52, 0x2c, 0x6b, 0x7b,
};

unsigned char NIST_IV_CFB_E6[] = {
    0xcd, 0xc8, 0x0d, 0x6f, 0xdd, 0xf1, 0x8c, 0xab,
    0x34, 0xc2, 0x59, 0x09, 0xc9, 0x9a, 0x41, 0x74,
};

unsigned char NIST_EXPECTED_IV_CFB_E6[] = {
    0x67, 0xce, 0x7f, 0x7f, 0x81, 0x17, 0x36, 0x21,
    0x96, 0x1a, 0x2b, 0x70, 0x17, 0x1d, 0x3d, 0x7a,
};

unsigned char NIST_TEST_DATA_CFB_E6[] = {
    0xae, 0x2d, 0x8a, 0x57, 0x1e, 0x03, 0xac, 0x9c,
    0x9e, 0xb7, 0x6f, 0xac, 0x45, 0xaf, 0x8e, 0x51,
};

unsigned char NIST_TEST_RESULT_CFB_E6[] = {
    0x67, 0xce, 0x7f, 0x7f, 0x81, 0x17, 0x36, 0x21,
    0x96, 0x1a, 0x2b, 0x70, 0x17, 0x1d, 0x3d, 0x7a,
};

unsigned int NIST_LCFB_E6 = 128 / 8;

/* CFB 128 data -7- for AES192 */
unsigned char NIST_KEY_CFB_E7[] = {
    0x8e, 0x73, 0xb0, 0xf7, 0xda, 0x0e, 0x64, 0x52,
    0xc8, 0x10, 0xf3, 0x2b, 0x80, 0x90, 0x79, 0xe5,
    0x62, 0xf8, 0xea, 0xd2, 0x52, 0x2c, 0x6b, 0x7b,
};

unsigned char NIST_IV_CFB_E7[] = {
    0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07,
    0x08, 0x09, 0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f,
};

unsigned char NIST_EXPECTED_IV_CFB_E7[] = {
    0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07, 0x08,
    0x09, 0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f, 0xcd,
};

```

```

unsigned char NIST_TEST_DATA_CFB_E7[] = {
    0x6b,
};

unsigned char NIST_TEST_RESULT_CFB_E7[] = {
    0xcd,
};

unsigned int NIST_LCFB_E7 = 8 / 8;

/* CFB 128 data -8- for AES192 */
unsigned char NIST_KEY_CFB_E8[] = {
    0x8e, 0x73, 0xb0, 0xf7, 0xda, 0x0e, 0x64, 0x52,
    0xc8, 0x10, 0xf3, 0x2b, 0x80, 0x90, 0x79, 0xe5,
    0x62, 0xf8, 0xea, 0xd2, 0x52, 0x2c, 0x6b, 0x7b,
};

unsigned char NIST_IV_CFB_E8[] = {
    0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07, 0x08,
    0x09, 0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f, 0xcd,
};

unsigned char NIST_EXPECTED_IV_CFB_E8[] = {
    0x02, 0x03, 0x04, 0x05, 0x06, 0x07, 0x08, 0x09,
    0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f, 0xcd, 0xa2,
};

unsigned char NIST_TEST_DATA_CFB_E8[] = {
    0xc1,
};

unsigned char NIST_TEST_RESULT_CFB_E8[] = {
    0xa2,
};

unsigned int NIST_LCFB_E8 = 8 / 8;

/* CFB128 data -9- for AES256 */
unsigned char NIST_KEY_CFB_E9[] = {
    0x60, 0x3d, 0xeb, 0x10, 0x15, 0xca, 0x71, 0xbe,
    0x2b, 0x73, 0xae, 0xf0, 0x85, 0x7d, 0x77, 0x81,
    0x1f, 0x35, 0x2c, 0x07, 0x3b, 0x61, 0x08, 0xd7,
    0x2d, 0x98, 0x10, 0xa3, 0x09, 0x14, 0xdf, 0xf4,
};

unsigned char NIST_IV_CFB_E9[] = {
    0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07,
    0x08, 0x09, 0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f,
};

unsigned char NIST_EXPECTED_IV_CFB_E9[] = {
    0xdc, 0x7e, 0x84, 0xbf, 0xda, 0x79, 0x16, 0x4b,
    0x7e, 0xcd, 0x84, 0x86, 0x98, 0x5d, 0x38, 0x60,
};

unsigned char NIST_TEST_DATA_CFB_E9[] = {
    0x6b, 0xc1, 0xbe, 0xe2, 0x2e, 0x40, 0x9f, 0x96,
    0xe9, 0x3d, 0x7e, 0x11, 0x73, 0x93, 0x17, 0x2a,
};

unsigned char NIST_TEST_RESULT_CFB_E9[] = {
    0xdc, 0x7e, 0x84, 0xbf, 0xda, 0x79, 0x16, 0x4b,
    0x7e, 0xcd, 0x84, 0x86, 0x98, 0x5d, 0x38, 0x60,
};

```

```

unsigned int NIST_LCFB_E9 = 128 / 8;

/* CFB128 data -10- for AES256 */
unsigned char NIST_KEY_CFB_E10[] = {
    0x60, 0x3d, 0xeb, 0x10, 0x15, 0xca, 0x71, 0xbe,
    0x2b, 0x73, 0xae, 0xf0, 0x85, 0x7d, 0x77, 0x81,
    0x1f, 0x35, 0x2c, 0x07, 0x3b, 0x61, 0x08, 0xd7,
    0x2d, 0x98, 0x10, 0xa3, 0x09, 0x14, 0xdf, 0xf4,
};

unsigned char NIST_IV_CFB_E10[] = {
    0xdc, 0x7e, 0x84, 0xbf, 0xda, 0x79, 0x16, 0x4b,
    0x7e, 0xcd, 0x84, 0x86, 0x98, 0x5d, 0x38, 0x60,
};

unsigned char NIST_EXPECTED_IV_CFB_E10[] = {
    0x39, 0xff, 0xed, 0x14, 0x3b, 0x28, 0xb1, 0xc8,
    0x32, 0x11, 0x3c, 0x63, 0x31, 0xe5, 0x40, 0x7b,
};

unsigned char NIST_TEST_DATA_CFB_E10[] = {
    0xae, 0x2d, 0x8a, 0x57, 0x1e, 0x03, 0xac, 0x9c,
    0x9e, 0xb7, 0x6f, 0xac, 0x45, 0xaf, 0x8e, 0x51,
};

unsigned char NIST_TEST_RESULT_CFB_E10[] = {
    0x39, 0xff, 0xed, 0x14, 0x3b, 0x28, 0xb1, 0xc8,
    0x32, 0x11, 0x3c, 0x63, 0x31, 0xe5, 0x40, 0x7b,
};

unsigned int NIST_LCFB_E10 = 128 / 8;

/* CFB8 data -11- for AES256 */
unsigned char NIST_KEY_CFB_E11[] = {
    0x60, 0x3d, 0xeb, 0x10, 0x15, 0xca, 0x71, 0xbe,
    0x2b, 0x73, 0xae, 0xf0, 0x85, 0x7d, 0x77, 0x81,
    0x1f, 0x35, 0x2c, 0x07, 0x3b, 0x61, 0x08, 0xd7,
    0x2d, 0x98, 0x10, 0xa3, 0x09, 0x14, 0xdf, 0xf4,
};

unsigned char NIST_IV_CFB_E11[] = {
    0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07,
    0x08, 0x09, 0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f,
};

unsigned char NIST_EXPECTED_IV_CFB_E11[] = {
    0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07, 0x08,
    0x09, 0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f, 0xdc,
};

unsigned char NIST_TEST_DATA_CFB_E11[] = {
    0x6b,
};

unsigned char NIST_TEST_RESULT_CFB_E11[] = {
    0xdc,
};

unsigned int NIST_LCFB_E11 = 8 / 8;

/* CFB8 data -12- for AES256 */
unsigned char NIST_KEY_CFB_E12[] = {
    0x60, 0x3d, 0xeb, 0x10, 0x15, 0xca, 0x71, 0xbe,
    0x2b, 0x73, 0xae, 0xf0, 0x85, 0x7d, 0x77, 0x81,
    0x1f, 0x35, 0x2c, 0x07, 0x3b, 0x61, 0x08, 0xd7,
    0x2d, 0x98, 0x10, 0xa3, 0x09, 0x14, 0xdf, 0xf4,
};

```

```

unsigned char NIST_IV_CFB_E12[] = {
    0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07, 0x08,
    0x09, 0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f, 0xdc,
};

unsigned char NIST_EXPECTED_IV_CFB_E12[] = {
    0x02, 0x03, 0x04, 0x05, 0x06, 0x07, 0x08, 0x09,
    0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f, 0xdc, 0x1f,
};

unsigned char NIST_TEST_DATA_CFB_E12[] = {
    0xc1,
};

unsigned char NIST_TEST_RESULT_CFB_E12[] = {
    0x1f,
};

unsigned int NIST_LCFB_E12 = 8 / 8;

void dump_array(unsigned char *ptr, unsigned int size)
{
    unsigned char *ptr_end;
    unsigned char *h;
    int i = 1;

    h = ptr;
    ptr_end = ptr + size;
    while (h < (unsigned char *)ptr_end) {
        printf("0x%02x ", (unsigned char) *h);
        h++;
        if (i == 8) {
            printf("\n");
            i = 1;
        } else {
            ++i;
        }
    }
    printf("\n");
}

void dump_cfb_data(unsigned char *iv, unsigned int iv_length,
                  unsigned char *key, unsigned int key_length,
                  unsigned char *input_data, unsigned int data_length,
                  unsigned char *output_data)
{
    printf("IV \n");
    dump_array(iv, iv_length);
    printf("Key \n");
    dump_array(key, key_length);
    printf("Input Data\n");
    dump_array(input_data, data_length);
    printf("Output Data\n");
    dump_array(output_data, data_length);
}

void get_sizes(unsigned int *data_length, unsigned int *iv_length,
              unsigned int *key_length, unsigned int iteration)
{
    switch (iteration) {
        case 1:
            *data_length = sizeof(NIST_TEST_DATA_CFB_E1);
            *iv_length = sizeof(NIST_IV_CFB_E1);
            *key_length = sizeof(NIST_KEY_CFB_E1);
            break;
    }
}

```

```

case 2:
    *data_length = sizeof(NIST_TEST_DATA_CFB_E2);
    *iv_length = sizeof(NIST_IV_CFB_E2);
    *key_length = sizeof(NIST_KEY_CFB_E2);
    break;
case 3:
    *data_length = sizeof(NIST_TEST_DATA_CFB_E3);
    *iv_length = sizeof(NIST_IV_CFB_E3);
    *key_length = sizeof(NIST_KEY_CFB_E3);
    break;
case 4:
    *data_length = sizeof(NIST_TEST_DATA_CFB_E4);
    *iv_length = sizeof(NIST_IV_CFB_E4);
    *key_length = sizeof(NIST_KEY_CFB_E4);
    break;
case 5:
    *data_length = sizeof(NIST_TEST_DATA_CFB_E5);
    *iv_length = sizeof(NIST_IV_CFB_E5);
    *key_length = sizeof(NIST_KEY_CFB_E5);
    break;
case 6:
    *data_length = sizeof(NIST_TEST_DATA_CFB_E6);
    *iv_length = sizeof(NIST_IV_CFB_E6);
    *key_length = sizeof(NIST_KEY_CFB_E6);
    break;
case 7:
    *data_length = sizeof(NIST_TEST_DATA_CFB_E7);
    *iv_length = sizeof(NIST_IV_CFB_E7);
    *key_length = sizeof(NIST_KEY_CFB_E7);
    break;
case 8:
    *data_length = sizeof(NIST_TEST_DATA_CFB_E8);
    *iv_length = sizeof(NIST_IV_CFB_E8);
    *key_length = sizeof(NIST_KEY_CFB_E8);
    break;
case 9:
    *data_length = sizeof(NIST_TEST_DATA_CFB_E9);
    *iv_length = sizeof(NIST_IV_CFB_E9);
    *key_length = sizeof(NIST_KEY_CFB_E9);
    break;
case 10:
    *data_length = sizeof(NIST_TEST_DATA_CFB_E10);
    *iv_length = sizeof(NIST_IV_CFB_E10);
    *key_length = sizeof(NIST_KEY_CFB_E10);
    break;
case 11:
    *data_length = sizeof(NIST_TEST_DATA_CFB_E11);
    *iv_length = sizeof(NIST_IV_CFB_E11);
    *key_length = sizeof(NIST_KEY_CFB_E11);
    break;
case 12:
    *data_length = sizeof(NIST_TEST_DATA_CFB_E12);
    *iv_length = sizeof(NIST_IV_CFB_E12);
    *key_length = sizeof(NIST_KEY_CFB_E12);
    break;
}
}

void load_test_data(unsigned char *data, unsigned int data_length,
    unsigned char *result,
    unsigned char *iv, unsigned char *expected_iv,
    unsigned int iv_length,
    unsigned char *key, unsigned int key_length,
    unsigned int *lcfb, unsigned int iteration)
{
    switch (iteration) {

```

```

case 1:
    memcpy(data, NIST_TEST_DATA_CFB_E1, data_length);
    memcpy(result, NIST_TEST_RESULT_CFB_E1, data_length);
    memcpy(iv, NIST_IV_CFB_E1, iv_length);
    memcpy(expected_iv, NIST_EXPECTED_IV_CFB_E1, iv_length);
    memcpy(key, NIST_KEY_CFB_E1, key_length);
    *lcfb = NIST_LCFB_E1;
    break;
case 2:
    memcpy(data, NIST_TEST_DATA_CFB_E2, data_length);
    memcpy(result, NIST_TEST_RESULT_CFB_E2, data_length);
    memcpy(iv, NIST_IV_CFB_E2, iv_length);
    memcpy(expected_iv, NIST_EXPECTED_IV_CFB_E2, iv_length);
    memcpy(key, NIST_KEY_CFB_E2, key_length);
    *lcfb = NIST_LCFB_E2;
    break;
case 3:
    memcpy(data, NIST_TEST_DATA_CFB_E3, data_length);
    memcpy(result, NIST_TEST_RESULT_CFB_E3, data_length);
    memcpy(iv, NIST_IV_CFB_E3, iv_length);
    memcpy(expected_iv, NIST_EXPECTED_IV_CFB_E3, iv_length);
    memcpy(key, NIST_KEY_CFB_E3, key_length);
    *lcfb = NIST_LCFB_E3;
    break;
case 4:
    memcpy(data, NIST_TEST_DATA_CFB_E4, data_length);
    memcpy(result, NIST_TEST_RESULT_CFB_E4, data_length);
    memcpy(iv, NIST_IV_CFB_E4, iv_length);
    memcpy(expected_iv, NIST_EXPECTED_IV_CFB_E4, iv_length);
    memcpy(key, NIST_KEY_CFB_E4, key_length);
    *lcfb = NIST_LCFB_E4;
    break;
case 5:
    memcpy(data, NIST_TEST_DATA_CFB_E5, data_length);
    memcpy(result, NIST_TEST_RESULT_CFB_E5, data_length);
    memcpy(iv, NIST_IV_CFB_E5, iv_length);
    memcpy(expected_iv, NIST_EXPECTED_IV_CFB_E5, iv_length);
    memcpy(key, NIST_KEY_CFB_E5, key_length);
    *lcfb = NIST_LCFB_E5;
    break;
case 6:
    memcpy(data, NIST_TEST_DATA_CFB_E6, data_length);
    memcpy(result, NIST_TEST_RESULT_CFB_E6, data_length);
    memcpy(iv, NIST_IV_CFB_E6, iv_length);
    memcpy(expected_iv, NIST_EXPECTED_IV_CFB_E6, iv_length);
    memcpy(key, NIST_KEY_CFB_E6, key_length);
    *lcfb = NIST_LCFB_E6;
    break;
case 7:
    memcpy(data, NIST_TEST_DATA_CFB_E7, data_length);
    memcpy(result, NIST_TEST_RESULT_CFB_E7, data_length);
    memcpy(iv, NIST_IV_CFB_E7, iv_length);
    memcpy(expected_iv, NIST_EXPECTED_IV_CFB_E7, iv_length);
    memcpy(key, NIST_KEY_CFB_E7, key_length);
    *lcfb = NIST_LCFB_E7;
    break;
case 8:
    memcpy(data, NIST_TEST_DATA_CFB_E8, data_length);
    memcpy(result, NIST_TEST_RESULT_CFB_E8, data_length);
    memcpy(iv, NIST_IV_CFB_E8, iv_length);
    memcpy(expected_iv, NIST_EXPECTED_IV_CFB_E8, iv_length);
    memcpy(key, NIST_KEY_CFB_E8, key_length);
    *lcfb = NIST_LCFB_E8;
    break;
case 9:
    memcpy(data, NIST_TEST_DATA_CFB_E9, data_length);
    memcpy(result, NIST_TEST_RESULT_CFB_E9, data_length);

```

```

    memcpy(iv, NIST_IV_CFB_E9, iv_length);
    memcpy(expected_iv, NIST_EXPECTED_IV_CFB_E9, iv_length);
    memcpy(key, NIST_KEY_CFB_E9, key_length);
    *lcfb = NIST_LCFB_E9;
    break;
case 10:
    memcpy(data, NIST_TEST_DATA_CFB_E10, data_length);
    memcpy(result, NIST_TEST_RESULT_CFB_E10, data_length);
    memcpy(iv, NIST_IV_CFB_E10, iv_length);
    memcpy(expected_iv, NIST_EXPECTED_IV_CFB_E10, iv_length);
    memcpy(key, NIST_KEY_CFB_E10, key_length);
    *lcfb = NIST_LCFB_E10;
    break;
case 11:
    memcpy(data, NIST_TEST_DATA_CFB_E11, data_length);
    memcpy(result, NIST_TEST_RESULT_CFB_E11, data_length);
    memcpy(iv, NIST_IV_CFB_E11, iv_length);
    memcpy(expected_iv, NIST_EXPECTED_IV_CFB_E11, iv_length);
    memcpy(key, NIST_KEY_CFB_E11, key_length);
    *lcfb = NIST_LCFB_E11;
    break;
case 12:
    memcpy(data, NIST_TEST_DATA_CFB_E12, data_length);
    memcpy(result, NIST_TEST_RESULT_CFB_E12, data_length);
    memcpy(iv, NIST_IV_CFB_E12, iv_length);
    memcpy(expected_iv, NIST_EXPECTED_IV_CFB_E12, iv_length);
    memcpy(key, NIST_KEY_CFB_E12, key_length);
    *lcfb = NIST_LCFB_E12;
    break;
}
}

int kat_aes_cfb(int iteration, int silent)
{
    unsigned int data_length;
    unsigned int iv_length;
    unsigned int key_length;

    get_sizes(&data_length, &iv_length, &key_length, iteration);

    unsigned char iv[iv_length];
    unsigned char tmp_iv[iv_length];
    unsigned char expected_iv[iv_length];
    unsigned char key[key_length];
    unsigned char input_data[data_length];
    unsigned char encrypt[data_length];
    unsigned char decrypt[data_length];
    unsigned char result[data_length];

    int rc = 0;
    unsigned int lcfb;
    memset(encrypt, 0x00, data_length);
    memset(decrypt, 0x00, data_length);

    load_test_data(input_data, data_length, result, iv, expected_iv,
                  iv_length, key, key_length, &lcfb, iteration);
    memcpy(tmp_iv, iv, iv_length);

    printf("Test Parameters for iteration = %i\n", iteration);
    printf("key length = %i, data length = %i, iv length = %i,"
          " lcfb = %i\n", key_length, data_length, iv_length, lcfb);

    if (iteration == 3)
    rc = ica_aes_cfb(input_data, encrypt, lcfb, key, key_length, tmp_iv,
                    lcfb, 1);

```

```

else
rc = ica_aes_cfb(input_data, encrypt, data_length, key, key_length,
    tmp_iv, lcfb, 1);
if (rc) {
    printf("ica_aes_cfb encrypt failed with rc = %i\n", rc);
    dump_cfb_data(iv, iv_length, key, key_length, input_data,
        data_length, encrypt);
}
if (!silent && !rc) {
    printf("Encrypt:\n");
    dump_cfb_data(iv, iv_length, key, key_length, input_data,
        data_length, encrypt);
}

if (memcmp(result, encrypt, data_length)) {
    printf("Encryption Result does not match the known ciphertext!\n");
    printf("Expected data:\n");
    dump_array(result, data_length);
    printf("Encryption Result:\n");
    dump_array(encrypt, data_length);
    rc++;
}

if (memcmp(expected_iv, tmp_iv, iv_length)) {
    printf("Update of IV does not match the expected IV!\n");
    printf("Expected IV:\n");
    dump_array(expected_iv, iv_length);
    printf("Updated IV:\n");
    dump_array(tmp_iv, iv_length);
    printf("Original IV:\n");
    dump_array(iv, iv_length);
    rc++;
}
if (rc) {
    printf("AES OFB test exited after encryption\n");
    return rc;
}

memcpy(tmp_iv, iv, iv_length);
if (iteration == 3)
rc = ica_aes_cfb(encrypt, decrypt, lcfb, key, key_length, tmp_iv,
    lcfb, 0);
else
rc = ica_aes_cfb(encrypt, decrypt, data_length, key, key_length,
    tmp_iv, lcfb, 0);
if (rc) {
    printf("ica_aes_cfb decrypt failed with rc = %i\n", rc);
    dump_cfb_data(iv, iv_length, key, key_length, encrypt,
        data_length, decrypt);
    return rc;
}

if (!silent && !rc) {
    printf("Decrypt:\n");
    dump_cfb_data(iv, iv_length, key, key_length, encrypt,
        data_length, decrypt);
}

if (memcmp(decrypt, input_data, data_length)) {
    printf("Decryption Result does not match the original data!\n");
    printf("Original data:\n");
    dump_array(input_data, data_length);
    printf("Decryption Result:\n");
    dump_array(decrypt, data_length);
    rc++;
}

```



```

    return rc;
}

int load_random_test_data(unsigned char *data, unsigned int data_length,
    unsigned char *iv, unsigned int iv_length,
    unsigned char *key, unsigned int key_length)
{
    int rc;
    rc = ica_random_number_generate(data_length, data);
    if (rc) {
        printf("ica_random_number_generate with rc = %i error = %i\n",
            rc, errno);
        return rc;
    }
    rc = ica_random_number_generate(iv_length, iv);
    if (rc) {
        printf("ica_random_number_generate with rc = %i error = %i\n",
            rc, errno);
        return rc;
    }
    rc = ica_random_number_generate(key_length, key);
    if (rc) {
        printf("ica_random_number_generate with rc = %i error = %i\n",
            rc, errno);
        return rc;
    }
    return rc;
}

int random_aes_cfb(int iteration, int silent, unsigned int data_length,
    unsigned int lcfb)
{
    unsigned int iv_length = sizeof(ica_aes_vector_t);
    unsigned int key_length = AES_KEY_LEN128;

    unsigned char iv[iv_length];
    unsigned char tmp_iv[iv_length];
    unsigned char key[key_length];
    unsigned char input_data[data_length];
    unsigned char encrypt[data_length];
    unsigned char decrypt[data_length];

    int rc = 0;
    for (key_length = AES_KEY_LEN128; key_length <= AES_KEY_LEN256; key_length += 8) {
        memset(encrypt, 0x00, data_length);
        memset(decrypt, 0x00, data_length);

        load_random_test_data(input_data, data_length, iv, iv_length, key,
            key_length);
        memcpy(tmp_iv, iv, iv_length);

        printf("Test Parameters for iteration = %i\n", iteration);
        printf("key length = %i, data length = %i, iv length = %i,"
            " lcfb = %i\n", key_length, data_length, iv_length, lcfb);

        rc = ica_aes_cfb(input_data, encrypt, data_length, key, key_length,
            tmp_iv, lcfb, 1);
        if (rc) {
            printf("ica_aes_cfb encrypt failed with rc = %i\n", rc);
            dump_cfb_data(iv, iv_length, key, key_length, input_data,
                data_length, encrypt);
        }
        if (!silent && !rc) {
            printf("Encrypt:\n");
            dump_cfb_data(iv, iv_length, key, key_length, input_data,
                data_length, encrypt);
        }
    }
}

```

```

if (rc) {
    printf("AES OFB test exited after encryption\n");
    return rc;
}

memcpy(tmp_iv, iv, iv_length);

rc = ica_aes_cfb(encrypt, decrypt, data_length, key, key_length,
    tmp_iv, lcfb, 0);
if (rc) {
    printf("ica_aes_cfb decrypt failed with rc = %i\n", rc);
    dump_cfb_data(iv, iv_length, key, key_length, encrypt,
        data_length, decrypt);
    return rc;
}

if (!silent && !rc) {
    printf("Decrypt:\n");
    dump_cfb_data(iv, iv_length, key, key_length, encrypt,
        data_length, decrypt);
}

if (memcmp(decrypt, input_data, data_length)) {
    printf("Decryption Result does not match the original data!\n");
    printf("Original data:\n");
    dump_array(input_data, data_length);
    printf("Decryption Result:\n");
    dump_array(decrypt, data_length);
    rc++;
}
}
return rc;
}

int main(int argc, char **argv)
{
    unsigned int silent = 0;
    unsigned int endless = 0;
    if (argc > 1) {
        if (strstr(argv[1], "silent"))
            silent = 1;
        if (strstr(argv[1], "endless"))
            endless = 1;
    }
    int rc = 0;
    int error_count = 0;
    int iteration;
    for(iteration = 1; iteration <= NR_TESTS; iteration++) {
        rc = kat_aes_cfb(iteration, silent);
        if (rc) {
            printf("kat_aes_cfb failed with rc = %i\n", rc);
            error_count++;
        } else
            printf("kat_aes_cfb finished successfully\n");
    }

    unsigned int data_length = 1;
    unsigned int lcfb = 1;
    unsigned int j;
    for(iteration = 1; iteration <= NR_RANDOM_TESTS; iteration++) {
        for (j = 1; j <= 3; j++) {
            int silent = 1;
            if (!(data_length % lcfb)) {
                rc = random_aes_cfb(iteration, silent, data_length, lcfb);
            }
        }
    }
}

```

```

if (rc) {
    printf("random_aes_cfb failed with rc = %i\n", rc);
    error_count++;
} else
    printf("random_aes_cfb finished successfully\n");
}
switch (j) {
    case 1:
        lcfb = 1;
        break;
    case 2:
        lcfb = 8;
        break;
    case 3:
        lcfb = 16;
        break;
}
}
if (data_length == 1)
    data_length = 8;
else
    data_length += 8;
}
if (error_count)
    printf("%i testcases failed\n", error_count);
else
    printf("All testcases finished successfully\n");

return rc;
}

```

---

## AES with CTR mode example

```
/* This program is released under the Common Public License V1.0
 *
 * You should have received a copy of Common Public License V1.0 along with
 * with this program.
 */

/* Copyright IBM Corp. 2010, 2011 */
#include <fcntl.h>
#include <sys/errno.h>
#include <stdio.h>
#include <string.h>
#include <strings.h>
#include <stdlib.h>
#include "ica_api.h"

#define NR_TESTS 7

/* CTR data - 1 for AES128 */
unsigned char NIST_KEY_CTR_E1[] = {
    0x2b, 0x7e, 0x15, 0x16, 0x28, 0xae, 0xd2, 0xa6,
    0xab, 0xf7, 0x15, 0x88, 0x09, 0xcf, 0x4f, 0x3c,
};

unsigned char NIST_IV_CTR_E1[] = {
    0xf0, 0xf1, 0xf2, 0xf3, 0xf4, 0xf5, 0xf6, 0xf7,
    0xf8, 0xf9, 0xfa, 0xfb, 0xfc, 0xfd, 0xfe, 0xff,
};

unsigned char NIST_EXPECTED_IV_CTR_E1[] = {
    0xf0, 0xf1, 0xf2, 0xf3, 0xf4, 0xf5, 0xf6, 0xf7,
    0xf8, 0xf9, 0xfa, 0xfb, 0xfc, 0xfd, 0xff, 0x00,
};

unsigned char NIST_TEST_DATA_CTR_E1[] = {
    0x6b, 0xc1, 0xbe, 0xe2, 0x2e, 0x40, 0x9f, 0x96,
    0xe9, 0x3d, 0x7e, 0x11, 0x73, 0x93, 0x17, 0x2a,
};

unsigned char NIST_TEST_RESULT_CTR_E1[] = {
    0x87, 0x4d, 0x61, 0x91, 0xb6, 0x20, 0xe3, 0x26,
    0x1b, 0xef, 0x68, 0x64, 0x99, 0x0d, 0xb6, 0xce,
};

/* CTR data - 2 for AES128 */
unsigned char NIST_KEY_CTR_E2[] = {
    0x2b, 0x7e, 0x15, 0x16, 0x28, 0xae, 0xd2, 0xa6,
    0xab, 0xf7, 0x15, 0x88, 0x09, 0xcf, 0x4f, 0x3c,
};

unsigned char NIST_IV_CTR_E2[] = {
    0xf0, 0xf1, 0xf2, 0xf3, 0xf4, 0xf5, 0xf6, 0xf7,
    0xf8, 0xf9, 0xfa, 0xfb, 0xfc, 0xfd, 0xfe, 0xff,
};

unsigned char NIST_EXPECTED_IV_CTR_E2[] = {
    0xf0, 0xf1, 0xf2, 0xf3, 0xf4, 0xf5, 0xf6, 0xf7,
    0xf8, 0xf9, 0xfa, 0xfb, 0xfc, 0xfd, 0xff, 0x03,
};

unsigned char NIST_TEST_DATA_CTR_E2[] = {
    0x6b, 0xc1, 0xbe, 0xe2, 0x2e, 0x40, 0x9f, 0x96,
    0xe9, 0x3d, 0x7e, 0x11, 0x73, 0x93, 0x17, 0x2a,
    0xae, 0x2d, 0x8a, 0x57, 0x1e, 0x03, 0xac, 0x9c,
    0x9e, 0xb7, 0x6f, 0xac, 0x45, 0xaf, 0x8e, 0x51,
    0x30, 0xc8, 0x1c, 0x46, 0xa3, 0x5c, 0xe4, 0x11,
};
```

```

0xe5, 0xfb, 0xc1, 0x19, 0x1a, 0x0a, 0x52, 0xef,
0xf6, 0x9f, 0x24, 0x45, 0xdf, 0x4f, 0x9b, 0x17,
0xad, 0x2b, 0x41, 0x7b, 0xe6, 0x6c, 0x37, 0x10,
};

```

```

unsigned char NIST_TEST_RESULT_CTR_E2[] = {
0x87, 0x4d, 0x61, 0x91, 0xb6, 0x20, 0xe3, 0x26,
0x1b, 0xef, 0x68, 0x64, 0x99, 0x0d, 0xb6, 0xce,
0x98, 0x06, 0xf6, 0x6b, 0x79, 0x70, 0xfd, 0xff,
0x86, 0x17, 0x18, 0x7b, 0xb9, 0xff, 0xfd, 0xff,
0x5a, 0xe4, 0xdf, 0x3e, 0xdb, 0xd5, 0xd3, 0x5e,
0x5b, 0x4f, 0x09, 0x02, 0x0d, 0xb0, 0x3e, 0xab,
0x1e, 0x03, 0x1d, 0xda, 0x2f, 0xbe, 0x03, 0xd1,
0x79, 0x21, 0x70, 0xa0, 0xf3, 0x00, 0x9c, 0xee,
};

```

```

/* CTR data - 3 - for AES192 */
unsigned char NIST_KEY_CTR_E3[] = {
0x60, 0x3d, 0xeb, 0x10, 0x15, 0xca, 0x71, 0xbe,
0x2b, 0x73, 0xae, 0xf0, 0x85, 0x7d, 0x77, 0x81,
0x1f, 0x35, 0x2c, 0x07, 0x3b, 0x61, 0x08, 0xd7,
0x2d, 0x98, 0x10, 0xa3, 0x09, 0x14, 0xdf, 0xf4,
};

```

```

unsigned char NIST_IV_CTR_E3[] = {
0xf0, 0xf1, 0xf2, 0xf3, 0xf4, 0xf5, 0xf6, 0xf7,
0xf8, 0xf9, 0xfa, 0xfb, 0xfc, 0xfd, 0xfe, 0xff,
};

```

```

unsigned char NIST_EXPECTED_IV_CTR_E3[] = {
0xf0, 0xf1, 0xf2, 0xf3, 0xf4, 0xf5, 0xf6, 0xf7,
0xf8, 0xf9, 0xfa, 0xfb, 0xfc, 0xfd, 0xff, 0x00,
};

```

```

unsigned char NIST_TEST_DATA_CTR_E3[] = {
0x6b, 0xc1, 0xbe, 0xe2, 0x2e, 0x40, 0x9f, 0x96,
0xe9, 0x3d, 0x7e, 0x11, 0x73, 0x93, 0x17, 0x2a,
};

```

```

unsigned char NIST_TEST_RESULT_CTR_E3[] = {
0x60, 0x1e, 0xc3, 0x13, 0x77, 0x57, 0x89, 0xa5,
0xb7, 0xa7, 0xf5, 0x04, 0xbb, 0xf3, 0xd2, 0x28,
};

```

```

/* CTR data - 4 - for AES192 */
unsigned char NIST_KEY_CTR_E4[] = {
0x60, 0x3d, 0xeb, 0x10, 0x15, 0xca, 0x71, 0xbe,
0x2b, 0x73, 0xae, 0xf0, 0x85, 0x7d, 0x77, 0x81,
0x1f, 0x35, 0x2c, 0x07, 0x3b, 0x61, 0x08, 0xd7,
0x2d, 0x98, 0x10, 0xa3, 0x09, 0x14, 0xdf, 0xf4,
};

```

```

unsigned char NIST_IV_CTR_E4[] = {
0xf0, 0xf1, 0xf2, 0xf3, 0xf4, 0xf5, 0xf6, 0xf7,
0xf8, 0xf9, 0xfa, 0xfb, 0xfc, 0xfd, 0xff, 0x00,
};

```

```

unsigned char NIST_EXPECTED_IV_CTR_E4[] = {
0xf0, 0xf1, 0xf2, 0xf3, 0xf4, 0xf5, 0xf6, 0xf7,
0xf8, 0xf9, 0xfa, 0xfb, 0xfc, 0xfd, 0xff, 0x01,
};

```

```

unsigned char NIST_TEST_DATA_CTR_E4[] = {
0xae, 0x2d, 0x8a, 0x57, 0x1e, 0x03, 0xac, 0x9c,
0x9e, 0xb7, 0x6f, 0xac, 0x45, 0xaf, 0x8e, 0x51,
};

```

```

unsigned char NIST_TEST_RESULT_CTR_E4[] = {
    0xf4, 0x43, 0xe3, 0xca, 0x4d, 0x62, 0xb5, 0x9a,
    0xca, 0x84, 0xe9, 0x90, 0xca, 0xca, 0xf5, 0xc5,
};

```

```

/* CTR data 5 - for AES 256 */
unsigned char NIST_KEY_CTR_E5[] = {
    0x60, 0x3d, 0xeb, 0x10, 0x15, 0xca, 0x71, 0xbe,
    0x2b, 0x73, 0xae, 0xf0, 0x85, 0x7d, 0x77, 0x81,
    0x1f, 0x35, 0x2c, 0x07, 0x3b, 0x61, 0x08, 0xd7,
    0x2d, 0x98, 0x10, 0xa3, 0x09, 0x14, 0xdf, 0xf4,
};

```

```

unsigned char NIST_IV_CTR_E5[] = {
    0xf0, 0xf1, 0xf2, 0xf3, 0xf4, 0xf5, 0xf6, 0xf7,
    0xf8, 0xf9, 0xfa, 0xfb, 0xfc, 0xfd, 0xfe, 0xff,
};

```

```

unsigned char NIST_EXPECTED_IV_CTR_E5[] = {
    0xf0, 0xf1, 0xf2, 0xf3, 0xf4, 0xf5, 0xf6, 0xf7,
    0xf8, 0xf9, 0xfa, 0xfb, 0xfc, 0xfd, 0xff, 0x03,
};

```

```

unsigned char NIST_TEST_DATA_CTR_E5[] = {
    0x6b, 0xc1, 0xbe, 0xe2, 0x2e, 0x40, 0x9f, 0x96,
    0xe9, 0x3d, 0x7e, 0x11, 0x73, 0x93, 0x17, 0x2a,
    0xae, 0x2d, 0x8a, 0x57, 0x1e, 0x03, 0xac, 0x9c,
    0x9e, 0xb7, 0x6f, 0xac, 0x45, 0xaf, 0x8e, 0x51,
    0x30, 0xc8, 0x1c, 0x46, 0xa3, 0x5c, 0xe4, 0x11,
    0xe5, 0xfb, 0xc1, 0x19, 0x1a, 0x0a, 0x52, 0xef,
    0xf6, 0x9f, 0x24, 0x45, 0xdf, 0x4f, 0x9b, 0x17,
    0xad, 0x2b, 0x41, 0x7b, 0xe6, 0x6c, 0x37, 0x10,
};

```

```

unsigned char NIST_TEST_RESULT_CTR_E5[] = {
    0x60, 0x1e, 0xc3, 0x13, 0x77, 0x57, 0x89, 0xa5,
    0xb7, 0xa7, 0xf5, 0x04, 0xbb, 0xf3, 0xd2, 0x28,
    0xf4, 0x43, 0xe3, 0xca, 0x4d, 0x62, 0xb5, 0x9a,
    0xca, 0x84, 0xe9, 0x90, 0xca, 0xca, 0xf5, 0xc5,
    0x2b, 0x09, 0x30, 0xda, 0xa2, 0x3d, 0xe9, 0x4c,
    0xe8, 0x70, 0x17, 0xba, 0x2d, 0x84, 0x98, 0x8d,
    0xdf, 0xc9, 0xc5, 0x8d, 0xb6, 0x7a, 0xad, 0xa6,
    0x13, 0xc2, 0xdd, 0x08, 0x45, 0x79, 0x41, 0xa6,
};

```

```

/* CTR data 6 - for AES 256.
 * Data is != BLOCK_SIZE */
unsigned char NIST_KEY_CTR_E6[] = {
    0x60, 0x3d, 0xeb, 0x10, 0x15, 0xca, 0x71, 0xbe,
    0x2b, 0x73, 0xae, 0xf0, 0x85, 0x7d, 0x77, 0x81,
    0x1f, 0x35, 0x2c, 0x07, 0x3b, 0x61, 0x08, 0xd7,
    0x2d, 0x98, 0x10, 0xa3, 0x09, 0x14, 0xdf, 0xf4,
};

```

```

unsigned char NIST_IV_CTR_E6[] = {
    0xf0, 0xf1, 0xf2, 0xf3, 0xf4, 0xf5, 0xf6, 0xf7,
    0xf8, 0xf9, 0xfa, 0xfb, 0xfc, 0xfd, 0xfe, 0xff,
};

```

```

unsigned char NIST_EXPECTED_IV_CTR_E6[] = {
    0xf0, 0xf1, 0xf2, 0xf3, 0xf4, 0xf5, 0xf6, 0xf7,
    0xf8, 0xf9, 0xfa, 0xfb, 0xfc, 0xfd, 0xff, 0x03,
};

```

```

unsigned char NIST_TEST_DATA_CTR_E6[] = {
    0x6b, 0xc1, 0xbe, 0xe2, 0x2e, 0x40, 0x9f, 0x96,
    0xe9, 0x3d, 0x7e, 0x11, 0x73, 0x93, 0x17, 0x2a,
};

```

```

0xae, 0x2d, 0x8a, 0x57, 0x1e, 0x03, 0xac, 0x9c,
0x9e, 0xb7, 0x6f, 0xac, 0x45, 0xaf, 0x8e, 0x51,
0x30, 0xc8, 0x1c, 0x46, 0xa3, 0x5c, 0xe4, 0x11,
0xe5, 0xfb, 0xc1, 0x19, 0x1a, 0x0a, 0x52, 0xef,
0xf6, 0x9f, 0x24, 0x45, 0xdf, 0x4f, 0x9b, 0x17,
};

unsigned char NIST_TEST_RESULT_CTR_E6[] = {
0x60, 0x1e, 0xc3, 0x13, 0x77, 0x57, 0x89, 0xa5,
0xb7, 0xa7, 0xf5, 0x04, 0xbb, 0xf3, 0xd2, 0x28,
0xf4, 0x43, 0xe3, 0xca, 0x4d, 0x62, 0xb5, 0x9a,
0xca, 0x84, 0xe9, 0x90, 0xca, 0xca, 0xf5, 0xc5,
0x2b, 0x09, 0x30, 0xda, 0xa2, 0x3d, 0xe9, 0x4c,
0xe8, 0x70, 0x17, 0xba, 0x2d, 0x84, 0x98, 0x8d,
0xdf, 0xc9, 0xc5, 0x8d, 0xb6, 0x7a, 0xad, 0xa6,
};

/* CTR data 7 - for AES 256
 * Counter as big as the data. Therefore the counter
 * should not be updated. Because it is already pre
 * computed. */
unsigned char NIST_KEY_CTR_E7[] = {
0x60, 0x3d, 0xeb, 0x10, 0x15, 0xca, 0x71, 0xbe,
0x2b, 0x73, 0xae, 0xf0, 0x85, 0x7d, 0x77, 0x81,
0x1f, 0x35, 0x2c, 0x07, 0x3b, 0x61, 0x08, 0xd7,
0x2d, 0x98, 0x10, 0xa3, 0x09, 0x14, 0xdf, 0xf4,
};

unsigned char NIST_IV_CTR_E7[] = {
0xf0, 0xf1, 0xf2, 0xf3, 0xf4, 0xf5, 0xf6, 0xf7,
0xf8, 0xf9, 0xfa, 0xfb, 0xfc, 0xfd, 0xfe, 0xff,
0xf0, 0xf1, 0xf2, 0xf3, 0xf4, 0xf5, 0xf6, 0xf7,
0xf8, 0xf9, 0xfa, 0xfb, 0xfc, 0xfd, 0xff, 0x00,
0xf0, 0xf1, 0xf2, 0xf3, 0xf4, 0xf5, 0xf6, 0xf7,
0xf8, 0xf9, 0xfa, 0xfb, 0xfc, 0xfd, 0xff, 0x01,
0xf0, 0xf1, 0xf2, 0xf3, 0xf4, 0xf5, 0xf6, 0xf7,
0xf8, 0xf9, 0xfa, 0xfb, 0xfc, 0xfd, 0xff, 0x02,
};

unsigned char NIST_EXPECTED_IV_CTR_E7[] = {
0xf0, 0xf1, 0xf2, 0xf3, 0xf4, 0xf5, 0xf6, 0xf7,
0xf8, 0xf9, 0xfa, 0xfb, 0xfc, 0xfd, 0xfe, 0xff,
0xf0, 0xf1, 0xf2, 0xf3, 0xf4, 0xf5, 0xf6, 0xf7,
0xf8, 0xf9, 0xfa, 0xfb, 0xfc, 0xfd, 0xff, 0x00,
0xf0, 0xf1, 0xf2, 0xf3, 0xf4, 0xf5, 0xf6, 0xf7,
0xf8, 0xf9, 0xfa, 0xfb, 0xfc, 0xfd, 0xff, 0x01,
0xf0, 0xf1, 0xf2, 0xf3, 0xf4, 0xf5, 0xf6, 0xf7,
0xf8, 0xf9, 0xfa, 0xfb, 0xfc, 0xfd, 0xff, 0x02,
};

unsigned char NIST_TEST_DATA_CTR_E7[] = {
0x6b, 0xc1, 0xbe, 0xe2, 0x2e, 0x40, 0x9f, 0x96,
0xe9, 0x3d, 0x7e, 0x11, 0x73, 0x93, 0x17, 0x2a,
0xae, 0x2d, 0x8a, 0x57, 0x1e, 0x03, 0xac, 0x9c,
0x9e, 0xb7, 0x6f, 0xac, 0x45, 0xaf, 0x8e, 0x51,
0x30, 0xc8, 0x1c, 0x46, 0xa3, 0x5c, 0xe4, 0x11,
0xe5, 0xfb, 0xc1, 0x19, 0x1a, 0x0a, 0x52, 0xef,
0xf6, 0x9f, 0x24, 0x45, 0xdf, 0x4f, 0x9b, 0x17,
0xad, 0x2b, 0x41, 0x7b, 0xe6, 0x6c, 0x37, 0x10,
};

unsigned char NIST_TEST_RESULT_CTR_E7[] = {
0x60, 0x1e, 0xc3, 0x13, 0x77, 0x57, 0x89, 0xa5,
0xb7, 0xa7, 0xf5, 0x04, 0xbb, 0xf3, 0xd2, 0x28,
0xf4, 0x43, 0xe3, 0xca, 0x4d, 0x62, 0xb5, 0x9a,
0xca, 0x84, 0xe9, 0x90, 0xca, 0xca, 0xf5, 0xc5,
0x2b, 0x09, 0x30, 0xda, 0xa2, 0x3d, 0xe9, 0x4c,
};

```

```

0xe8, 0x70, 0x17, 0xba, 0x2d, 0x84, 0x98, 0x8d,
0xdf, 0xc9, 0xc5, 0x8d, 0xb6, 0x7a, 0xad, 0xa6,
0x13, 0xc2, 0xdd, 0x08, 0x45, 0x79, 0x41, 0xa6,
};

```

```

void dump_array(unsigned char *ptr, unsigned int size)
{
    unsigned char *ptr_end;
    unsigned char *h;
    int i = 1;

    h = ptr;
    ptr_end = ptr + size;
    while (h < (unsigned char *)ptr_end) {
        printf("0x%02x ",(unsigned char ) *h);
        h++;
        if (i == 8) {
            printf("\n");
            i = 1;
        } else {
            ++i;
        }
    }
    printf("\n");
}

```

```

void dump_ctr_data(unsigned char *iv, unsigned int iv_length,
                  unsigned char *key, unsigned int key_length,
                  unsigned char *input_data, unsigned int data_length,
                  unsigned char *output_data)
{
    printf("IV \n");
    dump_array(iv, iv_length);
    printf("Key \n");
    dump_array(key, key_length);
    printf("Input Data\n");
    dump_array(input_data, data_length);
    printf("Output Data\n");
    dump_array(output_data, data_length);
}

```

```

void get_sizes(unsigned int *data_length, unsigned int *iv_length,
              unsigned int *key_length, unsigned int iteration)
{
    switch (iteration) {
        case 1:
            *data_length = sizeof(NIST_TEST_DATA_CTR_E1);
            *iv_length = sizeof(NIST_IV_CTR_E1);
            *key_length = sizeof(NIST_KEY_CTR_E1);
            break;
        case 2:
            *data_length = sizeof(NIST_TEST_DATA_CTR_E2);
            *iv_length = sizeof(NIST_IV_CTR_E2);
            *key_length = sizeof(NIST_KEY_CTR_E2);
            break;
        case 3:
            *data_length = sizeof(NIST_TEST_DATA_CTR_E3);
            *iv_length = sizeof(NIST_IV_CTR_E3);
            *key_length = sizeof(NIST_KEY_CTR_E3);
            break;
        case 4:
            *data_length = sizeof(NIST_TEST_DATA_CTR_E4);
            *iv_length = sizeof(NIST_IV_CTR_E4);
            *key_length = sizeof(NIST_KEY_CTR_E4);
            break;
        case 5:

```



```

    *data_length = sizeof(NIST_TEST_DATA_CTR_E5);
    *iv_length = sizeof(NIST_IV_CTR_E5);
    *key_length = sizeof(NIST_KEY_CTR_E5);
    break;
case 6:
    *data_length = sizeof(NIST_TEST_DATA_CTR_E6);
    *iv_length = sizeof(NIST_IV_CTR_E6);
    *key_length = sizeof(NIST_KEY_CTR_E6);
    break;
case 7:
    *data_length = sizeof(NIST_TEST_DATA_CTR_E7);
    *iv_length = sizeof(NIST_IV_CTR_E7);
    *key_length = sizeof(NIST_KEY_CTR_E7);
    break;
}
}

void load_test_data(unsigned char *data, unsigned int data_length,
    unsigned char *result,
    unsigned char *iv, unsigned char *expected_iv,
    unsigned int iv_length,
    unsigned char *key, unsigned int key_length,
    unsigned int iteration)
{
    switch (iteration) {
    case 1:
        memcpy(data, NIST_TEST_DATA_CTR_E1, data_length);
        memcpy(result, NIST_TEST_RESULT_CTR_E1, data_length);
        memcpy(iv, NIST_IV_CTR_E1, iv_length);
        memcpy(expected_iv, NIST_EXPECTED_IV_CTR_E1, iv_length);
        memcpy(key, NIST_KEY_CTR_E1, key_length);
        break;
    case 2:
        memcpy(data, NIST_TEST_DATA_CTR_E2, data_length);
        memcpy(result, NIST_TEST_RESULT_CTR_E2, data_length);
        memcpy(iv, NIST_IV_CTR_E2, iv_length);
        memcpy(expected_iv, NIST_EXPECTED_IV_CTR_E2, iv_length);
        memcpy(key, NIST_KEY_CTR_E2, key_length);
        break;
    case 3:
        memcpy(data, NIST_TEST_DATA_CTR_E3, data_length);
        memcpy(result, NIST_TEST_RESULT_CTR_E3, data_length);
        memcpy(iv, NIST_IV_CTR_E3, iv_length);
        memcpy(expected_iv, NIST_EXPECTED_IV_CTR_E3, iv_length);
        memcpy(key, NIST_KEY_CTR_E3, key_length);
        break;
    case 4:
        memcpy(data, NIST_TEST_DATA_CTR_E4, data_length);
        memcpy(result, NIST_TEST_RESULT_CTR_E4, data_length);
        memcpy(iv, NIST_IV_CTR_E4, iv_length);
        memcpy(expected_iv, NIST_EXPECTED_IV_CTR_E4, iv_length);
        memcpy(key, NIST_KEY_CTR_E4, key_length);
        break;
    case 5:
        memcpy(data, NIST_TEST_DATA_CTR_E5, data_length);
        memcpy(result, NIST_TEST_RESULT_CTR_E5, data_length);
        memcpy(iv, NIST_IV_CTR_E5, iv_length);
        memcpy(expected_iv, NIST_EXPECTED_IV_CTR_E5, iv_length);
        memcpy(key, NIST_KEY_CTR_E5, key_length);
        break;
    case 6:
        memcpy(data, NIST_TEST_DATA_CTR_E6, data_length);
        memcpy(result, NIST_TEST_RESULT_CTR_E6, data_length);
        memcpy(iv, NIST_IV_CTR_E6, iv_length);
        memcpy(expected_iv, NIST_EXPECTED_IV_CTR_E6, iv_length);
        memcpy(key, NIST_KEY_CTR_E6, key_length);

```

```

    break;
case 7:
    memcpy(data, NIST_TEST_DATA_CTR_E7, data_length);
    memcpy(result, NIST_TEST_RESULT_CTR_E7, data_length);
    memcpy(iv, NIST_IV_CTR_E7, iv_length);
    memcpy(expected_iv, NIST_EXPECTED_IV_CTR_E7, iv_length);
    memcpy(key, NIST_KEY_CTR_E7, key_length);
    break;
}
}

int random_aes_ctr(int iteration, int silent, unsigned int data_length, unsigned int iv_length)
{
    unsigned int key_length = AES_KEY_LEN256;
    if (data_length % sizeof(ica_aes_vector_t))
        iv_length = sizeof(ica_aes_vector_t);

    printf("Test Parameters for iteration = %i\n", iteration);
    printf("key length = %i, data length = %i, iv length = %i\n",
        key_length, data_length, iv_length);

    unsigned char iv[iv_length];
    unsigned char tmp_iv[iv_length];
    unsigned char key[key_length];
    unsigned char input_data[data_length];
    unsigned char encrypt[data_length];
    unsigned char decrypt[data_length];

    int rc = 0;
    rc = ica_random_number_generate(data_length, input_data);
    if (rc) {
        printf("random number generate returned rc = %i, errno = %i\n", rc, errno);
        return rc;
    }
    rc = ica_random_number_generate(iv_length, iv);
    if (rc) {
        printf("random number generate returned rc = %i, errno = %i\n", rc, errno);
        return rc;
    }

    rc = ica_random_number_generate(key_length, key);
    if (rc) {
        printf("random number generate returned rc = %i, errno = %i\n", rc, errno);
        return rc;
    }
    memcpy(tmp_iv, iv, iv_length);

    rc = ica_aes_ctr(input_data, encrypt, data_length, key, key_length,
        tmp_iv, 32, 1);
    if (rc) {
        printf("ica_aes_ctr encrypt failed with rc = %i\n", rc);
        dump_ctr_data(iv, iv_length, key, key_length, input_data,
            data_length, encrypt);
        return rc;
    }
    if (!silent && !rc) {
        printf("Encrypt:\n");
        dump_ctr_data(iv, iv_length, key, key_length, input_data,
            data_length, encrypt);
    }

    memcpy(tmp_iv, iv, iv_length);
    rc = ica_aes_ctr(encrypt, decrypt, data_length, key, key_length,
        tmp_iv, 32, 0);
    if (rc) {
        printf("ica_aes_ctr decrypt failed with rc = %i\n", rc);
    }
}

```

```

    dump_ctr_data(iv, iv_length, key, key_length, encrypt,
                 data_length, decrypt);
    return rc;
}

if (!silent && !rc) {
    printf("Decrypt:\n");
    dump_ctr_data(iv, iv_length, key, key_length, encrypt,
                 data_length, decrypt);
}

if (memcmp(decrypt, input_data, data_length)) {
    printf("Decryption Result does not match the original data!\n");
    printf("Original data:\n");
    dump_array(input_data, data_length);
    printf("Decryption Result:\n");
    dump_array(decrypt, data_length);
    rc++;
}
return rc;
}

int kat_aes_ctr(int iteration, int silent)
{
    unsigned int data_length;
    unsigned int iv_length;
    unsigned int key_length;

    get_sizes(&data_length, &iv_length, &key_length, iteration);

    printf("Test Parameters for iteration = %i\n", iteration);
    printf("key length = %i, data length = %i, iv length = %i\n",
          key_length, data_length, iv_length);

    unsigned char iv[iv_length];
    unsigned char tmp_iv[iv_length];
    unsigned char expected_iv[iv_length];
    unsigned char key[key_length];
    unsigned char input_data[data_length];
    unsigned char encrypt[data_length];
    unsigned char decrypt[data_length];
    unsigned char result[data_length];

    int rc = 0;

    load_test_data(input_data, data_length, result, iv, expected_iv,
                  iv_length, key, key_length, iteration);
    memcpy(tmp_iv, iv, iv_length);

    if (iv_length == 16)
        rc = ica_aes_ctr(input_data, encrypt, data_length, key, key_length,
                        tmp_iv, 32, 1);
    else
        rc = ica_aes_ctrlist(input_data, encrypt, data_length, key, key_length,
                             tmp_iv, 1);
    if (rc) {
        printf("ica_aes_ctr encrypt failed with rc = %i\n", rc);
        dump_ctr_data(iv, iv_length, key, key_length, input_data,
                     data_length, encrypt);
    }
    if (!silent && !rc) {
        printf("Encrypt:\n");
        dump_ctr_data(iv, iv_length, key, key_length, input_data,
                     data_length, encrypt);
    }
}

```

```

if (memcmp(result, encrypt, data_length)) {
    printf("Encryption Result does not match the known ciphertext!\n");
    printf("Expected data:\n");
    dump_array(result, data_length);
    printf("Encryption Result:\n");
    dump_array(encrypt, data_length);
    rc++;
}

if (memcmp(expected_iv, tmp_iv, iv_length)) {
    printf("Update of IV does not match the expected IV!\n");
    printf("Expected IV:\n");
    dump_array(expected_iv, iv_length);
    printf("Updated IV:\n");
    dump_array(tmp_iv, iv_length);
    printf("Original IV:\n");
    dump_array(iv, iv_length);
    rc++;
}
if (rc) {
    printf("AES CTR test exited after encryption\n");
    return rc;
}

memcpy(tmp_iv, iv, iv_length);
rc = ica_aes_ctr(encrypt, decrypt, data_length, key, key_length,
    tmp_iv, 32,0);
if (rc) {
    printf("ica_aes_ctr decrypt failed with rc = %i\n", rc);
    dump_ctr_data(iv, iv_length, key, key_length, encrypt,
        data_length, decrypt);
    return rc;
}

if (!silent && !rc) {
    printf("Decrypt:\n");
    dump_ctr_data(iv, iv_length, key, key_length, encrypt,
        data_length, decrypt);
}

if (memcmp(decrypt, input_data, data_length)) {
    printf("Decryption Result does not match the original data!\n");
    printf("Original data:\n");
    dump_array(input_data, data_length);
    printf("Decryption Result:\n");
    dump_array(decrypt, data_length);
    rc++;
}
return rc;
}

int main(int argc, char **argv)
{
    // Default mode is 0. ECB,CBC and CFQ tests will be performed.
    unsigned int silent = 0;
    unsigned int endless = 0;
    if (argc > 1) {
        if (strstr(argv[1], "silent"))
            silent = 1;
        if (strstr(argv[1], "endless"))
            endless = 1;
    }
    int rc = 0;
    int error_count = 0;
    int iteration;
    if (!endless)

```

```

for(iteration = 1; iteration <= NR_TESTS; iteration++) {
    rc = kat_aes_ctr(iteration, silent);
    if (rc) {
        printf("kat_aes_ctr failed with rc = %i\n", rc);
        error_count++;
    } else
        printf("kat_aes_ctr finished successfully\n");
}
int i = 0;
if (endless)
while (1) {
    printf("i = %i\n",i);
    silent = 1;
    rc = random_aes_ctr(i, silent, 320, 320);
    if (rc) {
        printf("kat_aes_ctr failed with rc = %i\n", rc);
        return rc;
    } else
        printf("kat_aes_ctr finished successfully\n");
    i++;
}

if (error_count)
    printf("%i testcases failed\n", error_count);
else
    printf("All testcases finished successfully\n");

return rc;
}

```

---

## AES with OFB mode example

```
/* This program is released under the Common Public License V1.0
 *
 * You should have received a copy of Common Public License V1.0 along with
 * with this program.
 */

/* Copyright IBM Corp. 2010, 2011 */
#include <fcntl.h>
#include <sys/errno.h>
#include <stdio.h>
#include <string.h>
#include <strings.h>
#include <stdlib.h>
#include "ica_api.h"

#define NR_TESTS 6
#define NR_RANDOM_TESTS 10000

/* OFB data - 1 for AES128 */
unsigned char NIST_KEY_OFB_E1[] = {
    0x2b, 0x7e, 0x15, 0x16, 0x28, 0xae, 0xd2, 0xa6,
    0xab, 0xf7, 0x15, 0x88, 0x09, 0xcf, 0x4f, 0x3c,
};

unsigned char NIST_IV_OFB_E1[] = {
    0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07,
    0x08, 0x09, 0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f,
};

unsigned char NIST_EXPECTED_IV_OFB_E1[] = {
    0x50, 0xfe, 0x67, 0xcc, 0x99, 0x6d, 0x32, 0xb6,
    0xda, 0x09, 0x37, 0xe9, 0x9b, 0xaf, 0xec, 0x60,
};

unsigned char NIST_TEST_DATA_OFB_E1[] = {
    0x6b, 0xc1, 0xbe, 0xe2, 0x2e, 0x40, 0x9f, 0x96,
    0xe9, 0x3d, 0x7e, 0x11, 0x73, 0x93, 0x17, 0x2a,
};

unsigned char NIST_TEST_RESULT_OFB_E1[] = {
    0x3b, 0x3f, 0xd9, 0x2e, 0xb7, 0x2d, 0xad, 0x20,
    0x33, 0x34, 0x49, 0xf8, 0xe8, 0x3c, 0xfb, 0x4a,
};

/* OFB data - 2 for AES128 */
unsigned char NIST_KEY_OFB_E2[] = {
    0x2b, 0x7e, 0x15, 0x16, 0x28, 0xae, 0xd2, 0xa6,
    0xab, 0xf7, 0x15, 0x88, 0x09, 0xcf, 0x4f, 0x3c,
};

unsigned char NIST_IV_OFB_E2[] = {
    0x50, 0xfe, 0x67, 0xcc, 0x99, 0x6d, 0x32, 0xb6,
    0xda, 0x09, 0x37, 0xe9, 0x9b, 0xaf, 0xec, 0x60,
};

unsigned char NIST_EXPECTED_IV_OFB_E2[] = {
    0xd9, 0xa4, 0xda, 0xda, 0x08, 0x92, 0x23, 0x9f,
    0x6b, 0x8b, 0x3d, 0x76, 0x80, 0xe1, 0x56, 0x74,
};

unsigned char NIST_TEST_DATA_OFB_E2[] = {
    0xae, 0x2d, 0x8a, 0x57, 0x1e, 0x03, 0xac, 0x9c,
    0x9e, 0xb7, 0x6f, 0xac, 0x45, 0xaf, 0x8e, 0x51,
};
```

```

unsigned char NIST_TEST_RESULT_OFB_E2[] = {
    0x77, 0x89, 0x50, 0x8d, 0x16, 0x91, 0x8f, 0x03,
    0xf5, 0x3c, 0x52, 0xda, 0xc5, 0x4e, 0xd8, 0x25,
};

/* OFB data - 3 - for AES192 */
unsigned char NIST_KEY_OFB_E3[] = {
    0x8e, 0x73, 0xb0, 0xf7, 0xda, 0x0e, 0x64, 0x52,
    0xc8, 0x10, 0xf3, 0x2b, 0x80, 0x90, 0x79, 0xe5,
    0x62, 0xf8, 0xea, 0xd2, 0x52, 0x2c, 0x6b, 0x7b,
};

unsigned char NIST_IV_OFB_E3[] = {
    0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07,
    0x08, 0x09, 0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f,
};

unsigned char NIST_EXPECTED_IV_OFB_E3[] = {
    0xa6, 0x09, 0xb3, 0x8d, 0xf3, 0xb1, 0x13, 0x3d,
    0xdd, 0xff, 0x27, 0x18, 0xba, 0x09, 0x56, 0x5e,
};

unsigned char NIST_TEST_DATA_OFB_E3[] = {
    0x6b, 0xc1, 0xbe, 0xe2, 0x2e, 0x40, 0x9f, 0x96,
    0xe9, 0x3d, 0x7e, 0x11, 0x73, 0x93, 0x17, 0x2a,
};

unsigned char NIST_TEST_RESULT_OFB_E3[] = {
    0xcd, 0xc8, 0x0d, 0x6f, 0xdd, 0xf1, 0x8c, 0xab,
    0x34, 0xc2, 0x59, 0x09, 0xc9, 0x9a, 0x41, 0x74,
};

/* OFB data - 4 - for AES192 */
unsigned char NIST_KEY_OFB_E4[] = {
    0x8e, 0x73, 0xb0, 0xf7, 0xda, 0x0e, 0x64, 0x52,
    0xc8, 0x10, 0xf3, 0x2b, 0x80, 0x90, 0x79, 0xe5,
    0x62, 0xf8, 0xea, 0xd2, 0x52, 0x2c, 0x6b, 0x7b,
};

unsigned char NIST_IV_OFB_E4[] = {
    0xa6, 0x09, 0xb3, 0x8d, 0xf3, 0xb1, 0x13, 0x3d,
    0xdd, 0xff, 0x27, 0x18, 0xba, 0x09, 0x56, 0x5e,
};

unsigned char NIST_EXPECTED_IV_OFB_E4[] = {
    0x52, 0xef, 0x01, 0xda, 0x52, 0x60, 0x2f, 0xe0,
    0x97, 0x5f, 0x78, 0xac, 0x84, 0xbf, 0x8a, 0x50,
};

unsigned char NIST_TEST_DATA_OFB_E4[] = {
    0xae, 0x2d, 0x8a, 0x57, 0x1e, 0x03, 0xac, 0x9c,
    0x9e, 0xb7, 0x6f, 0xac, 0x45, 0xaf, 0x8e, 0x51,
};

unsigned char NIST_TEST_RESULT_OFB_E4[] = {
    0xfc, 0xc2, 0x8b, 0x8d, 0x4c, 0x63, 0x83, 0x7c,
    0x09, 0xe8, 0x17, 0x00, 0xc1, 0x10, 0x04, 0x01,
};

/* OFB data 5 - for AES 256 */
unsigned char NIST_KEY_OFB_E5[] = {
    0x60, 0x3d, 0xeb, 0x10, 0x15, 0xca, 0x71, 0xbe,
    0x2b, 0x73, 0xae, 0xf0, 0x85, 0x7d, 0x77, 0x81,
    0x1f, 0x35, 0x2c, 0x07, 0x3b, 0x61, 0x08, 0xd7,
    0x2d, 0x98, 0x10, 0xa3, 0x09, 0x14, 0xdf, 0xf4,
};

```

```

unsigned char NIST_IV_OFB_E5[] = {
    0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07,
    0x08, 0x09, 0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f,
};

unsigned char NIST_EXPECTED_IV_OFB_E5[] = {
    0xb7, 0xbf, 0x3a, 0x5d, 0xf4, 0x39, 0x89, 0xdd,
    0x97, 0xf0, 0xfa, 0x97, 0xeb, 0xce, 0x2f, 0x4a,
};

unsigned char NIST_TEST_DATA_OFB_E5[] = {
    0x6b, 0xc1, 0xbe, 0xe2, 0x2e, 0x40, 0x9f, 0x96,
    0xe9, 0x3d, 0x7e, 0x11, 0x73, 0x93, 0x17, 0x2a,
};

unsigned char NIST_TEST_RESULT_OFB_E5[] = {
    0xdc, 0x7e, 0x84, 0xbf, 0xda, 0x79, 0x16, 0x4b,
    0x7e, 0xcd, 0x84, 0x86, 0x98, 0x5d, 0x38, 0x60,
};

/* OFB data 6 - for AES 256 */
unsigned char NIST_KEY_OFB_E6[] = {
    0x60, 0x3d, 0xeb, 0x10, 0x15, 0xca, 0x71, 0xbe,
    0x2b, 0x73, 0xae, 0xf0, 0x85, 0x7d, 0x77, 0x81,
    0x1f, 0x35, 0x2c, 0x07, 0x3b, 0x61, 0x08, 0xd7,
    0x2d, 0x98, 0x10, 0xa3, 0x09, 0x14, 0xdf, 0xf4,
};

unsigned char NIST_IV_OFB_E6[] = {
    0xb7, 0xbf, 0x3a, 0x5d, 0xf4, 0x39, 0x89, 0xdd,
    0x97, 0xf0, 0xfa, 0x97, 0xeb, 0xce, 0x2f, 0x4a,
};

unsigned char NIST_EXPECTED_IV_OFB_E6[] = {
    0xe1, 0xc6, 0x56, 0x30, 0x5e, 0xd1, 0xa7, 0xa6,
    0x56, 0x38, 0x05, 0x74, 0x6f, 0xe0, 0x3e, 0xdc,
};

unsigned char NIST_TEST_DATA_OFB_E6[] = {
    0xae, 0x2d, 0x8a, 0x57, 0x1e, 0x03, 0xac, 0x9c,
    0x9e, 0xb7, 0x6f, 0xac, 0x45, 0xaf, 0x8e, 0x51,
};

unsigned char NIST_TEST_RESULT_OFB_E6[] = {
    0x4f, 0xeb, 0xdc, 0x67, 0x40, 0xd2, 0x0b, 0x3a,
    0xc8, 0x8f, 0x6a, 0xd8, 0x2a, 0x4f, 0xb0, 0x8d,
};

void dump_array(unsigned char *ptr, unsigned int size)
{
    unsigned char *ptr_end;
    unsigned char *h;
    int i = 1;

    h = ptr;
    ptr_end = ptr + size;
    while (h < (unsigned char *)ptr_end) {
        printf("0x%02x ", (unsigned char) *h);
        h++;
        if (i == 8) {
            printf("\n");
            i = 1;
        } else {
            ++i;
        }
    }
}

```



```

    printf("\n");
}

void dump_ofb_data(unsigned char *iv, unsigned int iv_length,
                  unsigned char *key, unsigned int key_length,
                  unsigned char *input_data, unsigned int data_length,
                  unsigned char *output_data)
{
    printf("IV \n");
    dump_array(iv, iv_length);
    printf("Key \n");
    dump_array(key, key_length);
    printf("Input Data\n");
    dump_array(input_data, data_length);
    printf("Output Data\n");
    dump_array(output_data, data_length);
}

void get_sizes(unsigned int *data_length, unsigned int *iv_length,
               unsigned int *key_length, unsigned int iteration)
{
    switch (iteration) {
    case 1:
        *data_length = sizeof(NIST_TEST_DATA_OFB_E1);
        *iv_length = sizeof(NIST_IV_OFB_E1);
        *key_length = sizeof(NIST_KEY_OFB_E1);
        break;
    case 2:
        *data_length = sizeof(NIST_TEST_DATA_OFB_E2);
        *iv_length = sizeof(NIST_IV_OFB_E2);
        *key_length = sizeof(NIST_KEY_OFB_E2);
        break;
    case 3:
        *data_length = sizeof(NIST_TEST_DATA_OFB_E3);
        *iv_length = sizeof(NIST_IV_OFB_E3);
        *key_length = sizeof(NIST_KEY_OFB_E3);
        break;
    case 4:
        *data_length = sizeof(NIST_TEST_DATA_OFB_E4);
        *iv_length = sizeof(NIST_IV_OFB_E4);
        *key_length = sizeof(NIST_KEY_OFB_E4);
        break;
    case 5:
        *data_length = sizeof(NIST_TEST_DATA_OFB_E5);
        *iv_length = sizeof(NIST_IV_OFB_E5);
        *key_length = sizeof(NIST_KEY_OFB_E5);
        break;
    case 6:
        *data_length = sizeof(NIST_TEST_DATA_OFB_E6);
        *iv_length = sizeof(NIST_IV_OFB_E6);
        *key_length = sizeof(NIST_KEY_OFB_E6);
        break;
    }
}

void load_test_data(unsigned char *data, unsigned int data_length,
                   unsigned char *result,
                   unsigned char *iv, unsigned char *expected_iv,
                   unsigned int iv_length,
                   unsigned char *key, unsigned int key_length,
                   unsigned int iteration)
{
    switch (iteration) {
    case 1:
        memcpy(data, NIST_TEST_DATA_OFB_E1, data_length);
        memcpy(result, NIST_TEST_RESULT_OFB_E1, data_length);
    }
}

```

```

    memcpy(iv, NIST_IV_OFB_E1, iv_length);
    memcpy(expected_iv, NIST_EXPECTED_IV_OFB_E1, iv_length);
    memcpy(key, NIST_KEY_OFB_E1, key_length);
    break;
case 2:
    memcpy(data, NIST_TEST_DATA_OFB_E2, data_length);
    memcpy(result, NIST_TEST_RESULT_OFB_E2, data_length);
    memcpy(iv, NIST_IV_OFB_E2, iv_length);
    memcpy(expected_iv, NIST_EXPECTED_IV_OFB_E2, iv_length);
    memcpy(key, NIST_KEY_OFB_E2, key_length);
    break;
case 3:
    memcpy(data, NIST_TEST_DATA_OFB_E3, data_length);
    memcpy(result, NIST_TEST_RESULT_OFB_E3, data_length);
    memcpy(iv, NIST_IV_OFB_E3, iv_length);
    memcpy(expected_iv, NIST_EXPECTED_IV_OFB_E3, iv_length);
    memcpy(key, NIST_KEY_OFB_E3, key_length);
    break;
case 4:
    memcpy(data, NIST_TEST_DATA_OFB_E4, data_length);
    memcpy(result, NIST_TEST_RESULT_OFB_E4, data_length);
    memcpy(iv, NIST_IV_OFB_E4, iv_length);
    memcpy(expected_iv, NIST_EXPECTED_IV_OFB_E4, iv_length);
    memcpy(key, NIST_KEY_OFB_E4, key_length);
    break;
case 5:
    memcpy(data, NIST_TEST_DATA_OFB_E5, data_length);
    memcpy(result, NIST_TEST_RESULT_OFB_E5, data_length);
    memcpy(iv, NIST_IV_OFB_E5, iv_length);
    memcpy(expected_iv, NIST_EXPECTED_IV_OFB_E5, iv_length);
    memcpy(key, NIST_KEY_OFB_E5, key_length);
    break;
case 6:
    memcpy(data, NIST_TEST_DATA_OFB_E6, data_length);
    memcpy(result, NIST_TEST_RESULT_OFB_E6, data_length);
    memcpy(iv, NIST_IV_OFB_E6, iv_length);
    memcpy(expected_iv, NIST_EXPECTED_IV_OFB_E6, iv_length);
    memcpy(key, NIST_KEY_OFB_E6, key_length);
    break;
}
}

int load_random_test_data(unsigned char *data, unsigned int data_length,
    unsigned char *iv, unsigned int iv_length,
    unsigned char *key, unsigned int key_length)
{
    int rc;
    rc = ica_random_number_generate(data_length, data);
    if (rc) {
        printf("ica_random_number_generate with rc = %i errno = %i\n",
            rc, errno);
        return rc;
    }
    rc = ica_random_number_generate(iv_length, iv);
    if (rc) {
        printf("ica_random_number_generate with rc = %i errno = %i\n",
            rc, errno);
        return rc;
    }
    rc = ica_random_number_generate(key_length, key);
    if (rc) {
        printf("ica_random_number_generate with rc = %i errno = %i\n",
            rc, errno);
        return rc;
    }
    return rc;
}

```

```

}

int random_aes_ofb(int iteration, int silent, unsigned int data_length)
{
    int i;
    int rc = 0;
    unsigned int iv_length = sizeof(ica_aes_vector_t);
    unsigned int key_length = AES_KEY_LEN128;
    unsigned char iv[iv_length];
    unsigned char tmp_iv[iv_length];
    unsigned char input_data[data_length];
    unsigned char encrypt[data_length];
    unsigned char decrypt[data_length];
    for (i = 0; i <= 2; i++) {

        unsigned char key[key_length];

        memset(encrypt, 0x00, data_length);
        memset(decrypt, 0x00, data_length);

        load_random_test_data(input_data, data_length, iv, iv_length, key,
                               key_length);
        memcpy(tmp_iv, iv, iv_length);
        printf("Test Parameters for iteration = %i\n", iteration);
        printf("key length = %i, data length = %i, iv length = %i\n",
               key_length, data_length, iv_length);

        rc = ica_aes_ofb(input_data, encrypt, data_length, key, key_length,
                          tmp_iv, 1);
        if (rc) {
            printf("ica_aes_ofb encrypt failed with rc = %i\n", rc);
            dump_ofb_data(iv, iv_length, key, key_length, input_data,
                           data_length, encrypt);
        }
        if (!silent && !rc) {
            printf("Encrypt:\n");
            dump_ofb_data(iv, iv_length, key, key_length, input_data,
                           data_length, encrypt);
        }
        if (rc) {
            printf("AES OFB test exited after encryption\n");
            return rc;
        }

        memcpy(tmp_iv, iv, iv_length);

        rc = ica_aes_ofb(encrypt, decrypt, data_length, key, key_length,
                          tmp_iv, 0);
        if (rc) {
            printf("ica_aes_ofb decrypt failed with rc = %i\n", rc);
            dump_ofb_data(iv, iv_length, key, key_length, encrypt,
                           data_length, decrypt);
            return rc;
        }

        if (!silent && !rc) {
            printf("Decrypt:\n");
            dump_ofb_data(iv, iv_length, key, key_length, encrypt,
                           data_length, decrypt);
        }

        if (memcmp(decrypt, input_data, data_length)) {
            printf("Decryption Result does not match the original data!\n");
            printf("Original data:\n");
            dump_array(input_data, data_length);
        }
    }
}

```

```

    printf("Decryption Result:\n");
    dump_array(decrypt, data_length);
    rc++;
    return rc;
}
key_length += 8;
}

return rc;
}

int kat_aes_ofb(int iteration, int silent)
{
    unsigned int data_length;
    unsigned int iv_length;
    unsigned int key_length;

    get_sizes(&data_length, &iv_length, &key_length, iteration);

    printf("Test Parameters for iteration = %i\n", iteration);
    printf("key length = %i, data length = %i, iv length = %i\n",
        key_length, data_length, iv_length);

    unsigned char iv[iv_length];
    unsigned char tmp_iv[iv_length];
    unsigned char expected_iv[iv_length];
    unsigned char key[key_length];
    unsigned char input_data[data_length];
    unsigned char encrypt[data_length];
    unsigned char decrypt[data_length];
    unsigned char result[data_length];

    int rc = 0;

    load_test_data(input_data, data_length, result, iv, expected_iv,
        iv_length, key, key_length, iteration);
    memcpy(tmp_iv, iv, iv_length);

    rc = ica_aes_ofb(input_data, encrypt, data_length, key, key_length,
        tmp_iv, 1);
    if (rc) {
        printf("ica_aes_ofb encrypt failed with rc = %i\n", rc);
        dump_ofb_data(iv, iv_length, key, key_length, input_data,
            data_length, encrypt);
    }
    if (!silent && !rc) {
        printf("Encrypt:\n");
        dump_ofb_data(iv, iv_length, key, key_length, input_data,
            data_length, encrypt);
    }

    if (memcmp(result, encrypt, data_length)) {
        printf("Encryption Result does not match the known ciphertext!\n");
        printf("Expected data:\n");
        dump_array(result, data_length);
        printf("Encryption Result:\n");
        dump_array(encrypt, data_length);
        rc++;
    }

    if (memcmp(expected_iv, tmp_iv, iv_length)) {
        printf("Update of IV does not match the expected IV!\n");
        printf("Expected IV:\n");
        dump_array(expected_iv, iv_length);
        printf("Updated IV:\n");
        dump_array(tmp_iv, iv_length);
        printf("Original IV:\n");
    }
}

```

```

    dump_array(iv, iv_length);
    rc++;
}
if (rc) {
    printf("AES OFB test exited after encryption\n");
    return rc;
}

memcpy(tmp_iv, iv, iv_length);
rc = ica_aes_ofb(encrypt, decrypt, data_length, key, key_length,
                tmp_iv, 0);
if (rc) {
    printf("ica_aes_ofb decrypt failed with rc = %i\n", rc);
    dump_ofb_data(iv, iv_length, key, key_length, encrypt,
                  data_length, decrypt);
    return rc;
}

if (!silent && !rc) {
    printf("Decrypt:\n");
    dump_ofb_data(iv, iv_length, key, key_length, encrypt,
                  data_length, decrypt);
}

if (memcmp(decrypt, input_data, data_length)) {
    printf("Decryption Result does not match the original data!\n");
    printf("Original data:\n");
    dump_array(input_data, data_length);
    printf("Decryption Result:\n");
    dump_array(decrypt, data_length);
    rc++;
}
return rc;
}

int main(int argc, char **argv)
{
    unsigned int silent = 0;
    if (argc > 1) {
        if (strstr(argv[1], "silent"))
            silent = 1;
    }
    int rc = 0;
    int error_count = 0;
    int iteration;
    unsigned int data_length = sizeof(ica_aes_vector_t);
    for(iteration = 1; iteration <= NR_TESTS; iteration++) {
        rc = kat_aes_ofb(iteration, silent);
        if (rc) {
            printf("kat_aes_ofb failed with rc = %i\n", rc);
            error_count++;
        } else
            printf("kat_aes_ofb finished successfully\n");
    }
    for(iteration = 1; iteration <= NR_RANDOM_TESTS; iteration++) {
        int silent = 1;
        rc = random_aes_ofb(iteration, silent, data_length);
        if (rc) {
            printf("random_aes_ofb failed with rc = %i\n", rc);
            error_count++;
            goto out;
        } else
            printf("random_aes_ofb finished successfully\n");
        data_length += sizeof(ica_aes_vector_t);
    }
}

```

```
out:
  if (error_count)
    printf("%i testcases failed\n", error_count);
  else
    printf("All testcases finished successfully\n");

  return rc;
}
```

---

## AES with XTS mode example

```
/* This program is released under the Common Public License V1.0
 *
 * You should have received a copy of Common Public License V1.0 along with
 * with this program.
 */

/* Copyright IBM Corp. 2010, 2011 */
#include <fcntl.h>
#include <sys/errno.h>
#include <stdio.h>
#include <string.h>
#include <strings.h>
#include <stdlib.h>
#include "ica_api.h"

#define NR_TESTS 5
#define NR_RANDOM_TESTS 20000

/* XTS data -1- AES128 */
unsigned char NIST_KEY_XTS_E1[] = {
    0x46, 0xe6, 0xed, 0x9e, 0xf4, 0x2d, 0xcd, 0xb3,
    0xc8, 0x93, 0x09, 0x3c, 0x28, 0xe1, 0xfc, 0x0f,
    0x91, 0xf5, 0xca, 0xa3, 0xb6, 0xe0, 0xbc, 0x5a,
    0x14, 0xe7, 0x83, 0x21, 0x5c, 0x1d, 0x5b, 0x61,
};

unsigned char NIST_TWEAK_XTS_E1[] = {
    0x72, 0xf3, 0xb0, 0x54, 0xcb, 0xdc, 0x2f, 0x9e,
    0x3c, 0x5b, 0xc5, 0x51, 0xd4, 0x4d, 0xdb, 0xa0,
};

/* TWEAK should not be updated, so the expected tweak is the same as the
 * original TWEAK.
 */
unsigned char NIST_EXPECTED_TWEAK_XTS_E1[] = {
    0x72, 0xf3, 0xb0, 0x54, 0xcb, 0xdc, 0x2f, 0x9e,
    0x3c, 0x5b, 0xc5, 0x51, 0xd4, 0x4d, 0xdb, 0xa0,
};

unsigned char NIST_TEST_DATA_XTS_E1[] = {
    0xe3, 0x77, 0x8d, 0x68, 0xe7, 0x30, 0xef, 0x94,
    0x5b, 0x4a, 0xe3, 0xbc, 0x5b, 0x93, 0x6b, 0xdd,
};

unsigned char NIST_TEST_RESULT_XTS_E1[] = {
    0x97, 0x40, 0x9f, 0x1f, 0x71, 0xae, 0x45, 0x21,
    0xcb, 0x49, 0xa3, 0x29, 0x73, 0xde, 0x4d, 0x05,
};

/* XTS data -2- AES128 */
unsigned char NIST_KEY_XTS_E2[] = {
    0x93, 0x56, 0xcd, 0xad, 0x25, 0x1a, 0xb6, 0x11,
    0x14, 0xce, 0xc2, 0xc4, 0x4a, 0x60, 0x92, 0xdd,
    0xe9, 0xf7, 0x46, 0xcc, 0x65, 0xae, 0x3b, 0xd4,
    0x96, 0x68, 0x64, 0xaa, 0x36, 0x26, 0xd1, 0x88,
};

unsigned char NIST_TWEAK_XTS_E2[] = {
    0x68, 0x88, 0x27, 0x83, 0x65, 0x24, 0x36, 0xc4,
    0x85, 0x7a, 0x88, 0xc0, 0xc3, 0x73, 0x41, 0x7e,
};

unsigned char NIST_EXPECTED_TWEAK_XTS_E2[] = {
    0x68, 0x88, 0x27, 0x83, 0x65, 0x24, 0x36, 0xc4,
    0x85, 0x7a, 0x88, 0xc0, 0xc3, 0x73, 0x41, 0x7e,
};
```

```

};

unsigned char NIST_TEST_DATA_XTS_E2[] = {
    0xce, 0x17, 0x6b, 0xdd, 0xe3, 0x39, 0x50, 0x5b,
    0xa1, 0x5d, 0xea, 0x36, 0xd2, 0x8c, 0xe8, 0x7d,
};

unsigned char NIST_TEST_RESULT_XTS_E2[] = {
    0x22, 0xf5, 0xf9, 0x37, 0xdf, 0xb3, 0x9e, 0x5b,
    0x74, 0x25, 0xed, 0x86, 0x3d, 0x31, 0x0b, 0xe1,
};

/* XTS data -3- AES128 */
unsigned char NIST_KEY_XTS_E3[] = {
    0x63, 0xf3, 0x6e, 0x9c, 0x39, 0x7c, 0x65, 0x23,
    0xc9, 0x9f, 0x16, 0x44, 0xec, 0xb1, 0xa5, 0xd9,
    0xbc, 0x0f, 0x2f, 0x55, 0xfb, 0xe3, 0x24, 0x44,
    0x4c, 0x39, 0x0f, 0xae, 0x75, 0x2a, 0xd4, 0xd7,
};

unsigned char NIST_TWEAK_XTS_E3[] = {
    0xcd, 0xb1, 0xbd, 0x34, 0x86, 0xf3, 0x53, 0xcc,
    0x16, 0x0a, 0x84, 0x0b, 0xea, 0xdf, 0x03, 0x29,
};

unsigned char NIST_EXPECTED_TWEAK_XTS_E3[] = {
    0xcd, 0xb1, 0xbd, 0x34, 0x86, 0xf3, 0x53, 0xcc,
    0x16, 0x0a, 0x84, 0x0b, 0xea, 0xdf, 0x03, 0x29,
};

unsigned char NIST_TEST_DATA_XTS_E3[] = {
    0x9a, 0x01, 0x49, 0x88, 0x8b, 0xf7, 0x61, 0x60,
    0xa8, 0x14, 0x28, 0xbc, 0x91, 0x40, 0xec, 0xcd,
    0x26, 0xed, 0x18, 0x36, 0x8e, 0x24, 0xd4, 0x9b,
    0x9c, 0xc5, 0x12, 0x92, 0x9a, 0x88, 0xad, 0x1e,
    0x66, 0xc7, 0x63, 0xf4, 0xf5, 0x6b, 0x63, 0xbb,
    0x9d, 0xd9, 0x50, 0x8c, 0x5d, 0x4d, 0xf4, 0x65,
    0xad, 0x98, 0x82, 0x14, 0x82, 0xfc, 0x71, 0x94,
    0xee, 0x23, 0x54, 0xa3, 0xfa, 0xdc, 0xe9, 0x23,
    0x18, 0x54, 0x8e, 0x8c, 0xe9, 0x45, 0x20, 0x81,
    0x60, 0x49, 0x7b, 0x93, 0x05, 0xd9, 0xab, 0x10,
    0x91, 0xab, 0x41, 0xd1, 0xf0, 0x9a, 0x0c, 0x7b,
    0xfa, 0xf9, 0xf9, 0x4f, 0xe7, 0xc8, 0xf1, 0xea,
    0x96, 0x8f, 0x8f, 0x9a, 0x71, 0x3a, 0xca, 0xde,
    0x18, 0xb6, 0x82, 0x32, 0x10, 0x6f, 0xfd, 0x6d,
    0x42, 0x81, 0xe9, 0x9e, 0x11, 0xd6, 0xa4, 0x28,
    0xb5, 0x16, 0x53, 0xc0, 0xc7, 0xdd, 0xe5, 0xa0,
    0xf2, 0x73, 0xe7, 0x4f, 0xf0, 0x15, 0xce, 0x80,
    0x27, 0x7d, 0x74, 0x30, 0xf5, 0xda, 0xea, 0x8f,
    0x73, 0x40, 0x64, 0x5e, 0x0b, 0xec, 0x25, 0xf4,
    0x04, 0x0f, 0xa1, 0x3c, 0x0b, 0x33, 0x06, 0x93,
    0xb1, 0x00, 0x83, 0xa8, 0xb9, 0xbc, 0x10, 0x8f,
    0xe6, 0x4f, 0x3a, 0x5b, 0x61, 0x3c, 0xbb, 0x56,
    0x5a, 0xee, 0x2f, 0x09, 0xf5, 0xb2, 0x04, 0xae,
    0xe1, 0x72, 0x28, 0xfe, 0x65, 0x31, 0xc7, 0x0c,
    0x0e, 0xc9, 0x47, 0xd2, 0xa5, 0x14, 0x7b, 0x45,
    0xc5, 0x1a, 0xc7, 0xdc, 0x8e, 0x85, 0x87, 0x03,
    0x87, 0xeb, 0x8d, 0xb6, 0x25, 0x13, 0x68, 0x36,
    0x8b, 0xf5, 0xf2, 0x46, 0xb2, 0x95, 0x7d, 0xaf,
    0xf7, 0x02, 0xe3, 0x79, 0x02, 0x2e, 0x99, 0x16,
    0x17, 0x49, 0xe6, 0xbe, 0x8e, 0xb7, 0x9d, 0x51,
    0x97, 0x99, 0xaa, 0xe0, 0x7c, 0x18, 0x31, 0xbd,
    0x0e, 0xe7, 0x25, 0x50, 0xb8, 0x53, 0x33, 0xab,
    0x9e, 0x96, 0xa5, 0x33, 0xe2, 0x97, 0x25, 0xd7,
    0x02, 0x3d, 0x82, 0x1a, 0xbe, 0x1c, 0xe3, 0xa7,
    0x44, 0xbe, 0x02, 0xe0, 0x52, 0x56, 0x8f, 0x84,
    0xe6, 0xe3, 0xf7, 0x44, 0x42, 0xbb, 0xa5, 0x0d,

```



```

0x02, 0xad, 0x2d, 0x6c, 0xa5, 0x8a, 0x69, 0x1f,
0xd2, 0x43, 0x9a, 0xa3, 0xaf, 0x0c, 0x03, 0x3a,
0x68, 0xc4, 0x38, 0xb2, 0xd9, 0xa0, 0xa0, 0x1d,
0x78, 0xc4, 0xf8, 0x7c, 0x50, 0x9f, 0xea, 0x0a,
0x43, 0x5b, 0xe7, 0x1b, 0xa2, 0x37, 0x06, 0xd6,
0x08, 0x2d, 0xcb, 0xa6, 0x26, 0x25, 0x99, 0x9e,
0xce, 0x09, 0xdf, 0xb3, 0xfc, 0xbe, 0x08, 0xeb,
0xb6, 0xf2, 0x15, 0x1e, 0x2f, 0x12, 0xeb, 0xe8,
0xa5, 0xbf, 0x11, 0x62, 0xc2, 0x59, 0xf2, 0x02,
0xc1, 0xba, 0x47, 0x8b, 0x5f, 0x46, 0x8a, 0x28,
0x69, 0xf1, 0xe7, 0x6c, 0xf5, 0xed, 0x38, 0xde,
0x53, 0x86, 0x9a, 0xdc, 0x83, 0x70, 0x9e, 0x21,
0xb3, 0xf8, 0xdc, 0x13, 0xba, 0x3d, 0x6a, 0xa7,
0xf6, 0xb0, 0xcf, 0xb3, 0xe5, 0xa4, 0x3c, 0x23,
0x72, 0xe0, 0xee, 0x60, 0x99, 0x1c, 0xe1, 0xca,
0xd1, 0x22, 0xa3, 0x1d, 0x93, 0x97, 0xe3, 0x0b,
0x92, 0x1f, 0xd2, 0xf6, 0xee, 0x69, 0x6e, 0x68,
0x49, 0xae, 0xee, 0x29, 0xe2, 0xb4, 0x45, 0xc0,
0xfd, 0x9a, 0xde, 0x65, 0x56, 0xc3, 0xc0, 0x69,
0xc5, 0xd6, 0x05, 0x95, 0xab, 0xbd, 0xf5, 0xba,
0xe2, 0xcc, 0xc7, 0x9a, 0x49, 0x6e, 0x83, 0xcc,
0xab, 0x95, 0x74, 0x0e, 0xb8, 0xe4, 0xf2, 0x92,
0x5d, 0xbf, 0x72, 0x97, 0xa8, 0xc9, 0x92, 0x75,
0x6e, 0x62, 0x87, 0x0e, 0xdc, 0xe9, 0x8f, 0x6c,
0xba, 0x1a, 0xa0, 0xd5, 0xb8, 0x6f, 0x09, 0x21,
0x43, 0xb1, 0x6d, 0xa1, 0x44, 0x15, 0x47, 0xd1,
0xd4, 0x2b, 0x80, 0x06, 0xfa, 0xce, 0x69, 0x5b,
0x03, 0xfd, 0xfa, 0xe6, 0x45, 0xf9, 0x5b, 0xd6,
};

```

```

unsigned char NIST_TEST_RESULT_XTS_E3[] = {
0x0e, 0xee, 0xf2, 0x8c, 0xa1, 0x59, 0xb8, 0x05,
0xf5, 0xc2, 0x15, 0x61, 0x05, 0x51, 0x67, 0x8a,
0xb7, 0x72, 0xf2, 0x79, 0x37, 0x4f, 0xb1, 0x40,
0xab, 0x55, 0x07, 0x68, 0xdb, 0x42, 0xcf, 0x6c,
0xb7, 0x36, 0x37, 0x64, 0x19, 0x34, 0x19, 0x5f,
0xfc, 0x08, 0xcf, 0x5a, 0x91, 0x88, 0xb8, 0x2b,
0x84, 0x0a, 0x00, 0x7d, 0x52, 0x72, 0x39, 0xea,
0x3f, 0x0d, 0x7d, 0xd1, 0xf2, 0x51, 0x86, 0xec,
0xae, 0x30, 0x87, 0x7d, 0xad, 0xa7, 0x7f, 0x24,
0x3c, 0xdd, 0xb2, 0xc8, 0x8e, 0x99, 0x04, 0x82,
0x7d, 0x3e, 0x09, 0x82, 0xda, 0x0d, 0x13, 0x91,
0x1d, 0x0e, 0x2d, 0xbb, 0xbb, 0x2d, 0x01, 0x6c,
0xbe, 0x4d, 0x06, 0x76, 0xb1, 0x45, 0x9d, 0xa8,
0xc5, 0x3a, 0x91, 0x45, 0xe8, 0x3c, 0xf4, 0x2f,
0x30, 0x11, 0x2c, 0xa6, 0x5d, 0x77, 0xc8, 0x93,
0x4a, 0x26, 0xee, 0x00, 0x1f, 0x39, 0x0f, 0xfc,
0xc1, 0x87, 0x03, 0x66, 0x2a, 0x8f, 0x71, 0xf9,
0xda, 0x0e, 0x7b, 0x68, 0xb1, 0x04, 0x3c, 0x1c,
0xb5, 0x26, 0x08, 0xcf, 0x0e, 0x69, 0x51, 0x0d,
0x38, 0xc8, 0x0f, 0xa0, 0x0d, 0xe4, 0x3d, 0xef,
0x98, 0x4d, 0xff, 0x2f, 0x32, 0x4e, 0xcf, 0x39,
0x89, 0x44, 0x53, 0xd3, 0xe0, 0x1b, 0x3d, 0x7b,
0x3b, 0xc0, 0x57, 0x04, 0x9d, 0x19, 0x5c, 0x8e,
0xb9, 0x3f, 0xe4, 0xd9, 0x5a, 0x83, 0x00, 0xa5,
0xe6, 0x0a, 0x7c, 0x89, 0xe4, 0x0c, 0x69, 0x16,
0x79, 0xfb, 0xca, 0xfa, 0xd8, 0xeb, 0x41, 0x8f,
0x8d, 0x1f, 0xf7, 0xb9, 0x11, 0x75, 0xf8, 0xeb,
0x3c, 0x6f, 0xf2, 0x87, 0x2d, 0x32, 0xee, 0x4c,
0x57, 0x36, 0x9e, 0x61, 0xb6, 0x6d, 0x16, 0x6f,
0xd0, 0xa4, 0x34, 0x57, 0x47, 0x82, 0x75, 0xfe,
0x14, 0xbf, 0x34, 0x63, 0x8a, 0x9e, 0x4e, 0x1d,
0x25, 0xcc, 0x5a, 0x5f, 0x9e, 0x25, 0x7e, 0x61,
0x7a, 0xdc, 0xdd, 0xe6, 0x5e, 0x25, 0x57, 0x40,
0x53, 0x62, 0xc8, 0x91, 0xe6, 0x54, 0x6a, 0x6d,
0xee, 0xaa, 0x8f, 0xc0, 0x3b, 0x12, 0x2a, 0x55,
0x87, 0x4d, 0x33, 0xe0, 0xa7, 0x73, 0x52, 0x34,

```

```

0x68, 0x32, 0x5e, 0xc2, 0x4d, 0x4f, 0xaf, 0xfb,
0x63, 0xc0, 0x52, 0xc8, 0x11, 0xa1, 0xc0, 0x22,
0xba, 0xfc, 0xcb, 0x97, 0x98, 0x8b, 0x7e, 0x45,
0x67, 0xb2, 0x47, 0xd4, 0x04, 0x4b, 0x05, 0x2f,
0xf7, 0x3f, 0x4c, 0x67, 0x1d, 0x27, 0xe0, 0x52,
0xe2, 0xeb, 0xc7, 0x2d, 0x00, 0x57, 0xcb, 0x21,
0x7c, 0x52, 0x59, 0xb6, 0x09, 0x50, 0xe3, 0xc8,
0xb3, 0xd9, 0xe3, 0xe7, 0x63, 0x0f, 0x9e, 0xcb,
0xe5, 0x48, 0xb9, 0xe3, 0x62, 0x20, 0xf3, 0x3c,
0x2b, 0x45, 0x68, 0x30, 0x7c, 0xd0, 0x37, 0x5b,
0xba, 0x13, 0x35, 0xe5, 0x8b, 0xfb, 0xcd, 0xe8,
0x5c, 0xc8, 0x4c, 0x9c, 0x9c, 0x1c, 0xe7, 0x4f,
0x44, 0xb2, 0x8e, 0xa1, 0xb6, 0x97, 0x30, 0x5b,
0xb6, 0xba, 0x3b, 0x46, 0x4e, 0x5a, 0xb7, 0x45,
0x01, 0x29, 0x3e, 0xf9, 0x15, 0x2c, 0x0f, 0x5d,
0x33, 0x07, 0xd2, 0x6a, 0x1f, 0x07, 0x41, 0xc5,
0xe5, 0x72, 0x1a, 0x71, 0x3d, 0x1b, 0x86, 0xc1,
0x80, 0x82, 0x11, 0xf5, 0x7a, 0xad, 0x09, 0xa9,
0x50, 0xb6, 0x86, 0x30, 0xaf, 0xce, 0x4f, 0x0a,
0xd9, 0xf3, 0x2e, 0x67, 0x69, 0xb5, 0xfe, 0x31,
0x92, 0x9c, 0x44, 0x6f, 0x7a, 0x33, 0x55, 0xf4,
0x58, 0x84, 0xc7, 0x48, 0xc9, 0x05, 0x54, 0x15,
0xe6, 0x37, 0xd9, 0xad, 0x87, 0xd9, 0x4c, 0x46,
0x57, 0xb1, 0xad, 0x03, 0x4c, 0xb1, 0x4d, 0x9a,
0x72, 0xea, 0x74, 0x5f, 0xe5, 0x2d, 0x7a, 0x71,
0x1b, 0xa4, 0x1c, 0xa0, 0x35, 0x85, 0x6a, 0x5a,
0x44, 0x89, 0xa4, 0x27, 0x0b, 0xb3, 0x0d, 0x5b,
0x63, 0xf4, 0x9c, 0x05, 0x12, 0xfe, 0xd4, 0xb4
};

```

```

/* XTS data -4- AES256 */

```

```

unsigned char NIST_KEY_XTS_E4[] = {
0x97, 0x09, 0x8b, 0x46, 0x5a, 0x44, 0xca, 0x75,
0xe7, 0xa1, 0xc2, 0xdb, 0xfc, 0x40, 0xb7, 0xa6,
0x1a, 0x20, 0xe3, 0x2c, 0x6d, 0x9d, 0xbf, 0xda,
0x80, 0x72, 0x6f, 0xee, 0x10, 0x54, 0x1b, 0xab,
0x47, 0x54, 0x63, 0xca, 0x07, 0xc1, 0xc1, 0xe4,
0x49, 0x61, 0x73, 0x32, 0x14, 0x68, 0xd1, 0xab,
0x3f, 0xad, 0x8a, 0xd9, 0x1f, 0xcd, 0xc6, 0x2a,
0xbe, 0x07, 0xbf, 0xf8, 0xef, 0x96, 0x1b, 0x6b,
};

```

```

unsigned char NIST_TWEAK_XTS_E4[] = {
0x15, 0x60, 0x1e, 0x2e, 0x35, 0x85, 0x10, 0xa0,
0x9d, 0xdc, 0xa4, 0xea, 0x17, 0x51, 0xf4, 0x3c,
};

```

```

unsigned char NIST_EXPECTED_TWEAK_XTS_E4[] = {
0x15, 0x60, 0x1e, 0x2e, 0x35, 0x85, 0x10, 0xa0,
0x9d, 0xdc, 0xa4, 0xea, 0x17, 0x51, 0xf4, 0x3c,
};

```

```

unsigned char NIST_TEST_DATA_XTS_E4[] = {
0xd1, 0x9c, 0xfb, 0x38, 0x3b, 0xaf, 0x87, 0x2e,
0x6f, 0x12, 0x16, 0x87, 0x45, 0x1d, 0xe1, 0x5c,
};

```

```

unsigned char NIST_TEST_RESULT_XTS_E4[] = {
0xeb, 0x22, 0x26, 0x9b, 0x14, 0x90, 0x50, 0x27,
0xdc, 0x73, 0xc4, 0xa4, 0x0f, 0x93, 0x80, 0x69,
};

```

```

/* XTS data -5- AES256 */

```

```

unsigned char NIST_KEY_XTS_E5[] = {
0xfb, 0xf0, 0x77, 0x6e, 0x7d, 0xbe, 0x49, 0x10,
0xfb, 0x0c, 0x12, 0x0f, 0x41, 0x85, 0x71, 0x21,
};

```

```

0x92, 0x6c, 0x05, 0x2f, 0xd6, 0x5a, 0x27, 0x8c,
0xd2, 0xf0, 0xd9, 0x8d, 0xa5, 0x4e, 0xdf, 0xd5,
0x08, 0x03, 0xa4, 0x2f, 0xbe, 0x6f, 0xd1, 0x33,
0x58, 0x49, 0x00, 0xe8, 0xdc, 0x7a, 0x11, 0x52,
0x39, 0x1f, 0x82, 0x2d, 0x76, 0xa7, 0x56, 0x68,
0xcf, 0xce, 0x7f, 0x8d, 0xde, 0x20, 0x3e, 0xc8,
};

unsigned char NIST_TWEAK_XTS_E5[] = {
0x39, 0x5b, 0x6a, 0xcf, 0x9a, 0xdc, 0xd2, 0x91,
0xc2, 0xc9, 0x48, 0x86, 0x36, 0x33, 0xaf, 0xf8,
};

unsigned char NIST_EXPECTED_TWEAK_XTS_E5[] = {
0x39, 0x5b, 0x6a, 0xcf, 0x9a, 0xdc, 0xd2, 0x91,
0xc2, 0xc9, 0x48, 0x86, 0x36, 0x33, 0xaf, 0xf8,
};

unsigned char NIST_TEST_DATA_XTS_E5[] = {
0x3e, 0x2e, 0x26, 0x9d, 0x78, 0x3a, 0x2b, 0x29,
0xe8, 0x73, 0xd6, 0x73, 0x47, 0x9f, 0x51, 0x16,
0x73, 0x4f, 0xe0, 0x3e, 0xe3, 0x29, 0x65, 0xed,
0xc4, 0x79, 0x35, 0xc0, 0xea, 0x99, 0xa0, 0x64,
0xbd, 0x44, 0x4b, 0xec, 0x12, 0x5b, 0x2c, 0x78,
0x9d, 0xb9, 0xde, 0x6d, 0x18, 0x35, 0x92, 0x05,
0x3b, 0x48, 0xa8, 0x77, 0xa9, 0x5a, 0xc2, 0x55,
0x9c, 0x3d, 0xdf, 0xc7, 0xb4, 0xdb, 0x99, 0x07,
};

unsigned char NIST_TEST_RESULT_XTS_E5[] = {
0x4c, 0x70, 0xbd, 0xbb, 0x77, 0x30, 0x2b, 0x7f,
0x1f, 0xdd, 0xca, 0x50, 0xdc, 0x70, 0x73, 0x1e,
0x00, 0x8a, 0x26, 0x55, 0xd2, 0x2a, 0xd0, 0x20,
0x0c, 0x11, 0x1f, 0xd3, 0x2a, 0x67, 0x5a, 0x7e,
0x09, 0x97, 0x11, 0x43, 0x6f, 0x98, 0xd2, 0x1c,
0x72, 0x77, 0x2e, 0x0d, 0xd7, 0x67, 0x2f, 0xf5,
0xfd, 0x00, 0xdd, 0xcb, 0xe1, 0x1e, 0xb9, 0x7e,
0x69, 0x87, 0x83, 0xbf, 0xa4, 0x05, 0x46, 0xe3,
};

void dump_array(unsigned char *ptr, unsigned int size)
{
    unsigned char *ptr_end;
    unsigned char *h;
    int i = 1;

    h = ptr;
    ptr_end = ptr + size;
    while (h < (unsigned char *)ptr_end) {
        printf("0x%02x ", (unsigned char) *h);
        h++;
        if (i == 8) {
            printf("\n");
            i = 1;
        } else {
            ++i;
        }
    }
    printf("\n");
}

void dump_xts_data(unsigned char *tweak, unsigned int tweak_length,
                  unsigned char *key, unsigned int key_length,
                  unsigned char *input_data, unsigned int data_length,
                  unsigned char *output_data)
{
    printf("TWEAK \n");
}

```

```

dump_array(tweak, tweak_length);
printf("Key \n");
dump_array(key, key_length);
printf("Input Data\n");
dump_array(input_data, data_length);
printf("Output Data\n");
dump_array(output_data, data_length);
}

void get_sizes(unsigned int *data_length, unsigned int *tweak_length,
              unsigned int *key_length, unsigned int iteration)
{
switch (iteration) {
case 1:
    *data_length = sizeof(NIST_TEST_DATA_XTS_E1);
    *tweak_length = sizeof(NIST_TWEAK_XTS_E1);
    *key_length = sizeof(NIST_KEY_XTS_E1);
    break;
case 2:
    *data_length = sizeof(NIST_TEST_DATA_XTS_E2);
    *tweak_length = sizeof(NIST_TWEAK_XTS_E2);
    *key_length = sizeof(NIST_KEY_XTS_E2);
    break;
case 3:
    *data_length = sizeof(NIST_TEST_DATA_XTS_E3);
    *tweak_length = sizeof(NIST_TWEAK_XTS_E3);
    *key_length = sizeof(NIST_KEY_XTS_E3);
    break;
case 4:
    *data_length = sizeof(NIST_TEST_DATA_XTS_E4);
    *tweak_length = sizeof(NIST_TWEAK_XTS_E4);
    *key_length = sizeof(NIST_KEY_XTS_E4);
    break;
case 5:
    *data_length = sizeof(NIST_TEST_DATA_XTS_E5);
    *tweak_length = sizeof(NIST_TWEAK_XTS_E5);
    *key_length = sizeof(NIST_KEY_XTS_E5);
    break;
}
}

void load_test_data(unsigned char *data, unsigned int data_length,
                   unsigned char *result,
                   unsigned char *tweak, unsigned char *expected_tweak,
                   unsigned int tweak_length,
                   unsigned char *key, unsigned int key_length,
                   unsigned int iteration)
{
switch (iteration) {
case 1:
    memcpy(data, NIST_TEST_DATA_XTS_E1, data_length);
    memcpy(result, NIST_TEST_RESULT_XTS_E1, data_length);
    memcpy(tweak, NIST_TWEAK_XTS_E1, tweak_length);
    memcpy(expected_tweak, NIST_EXPECTED_TWEAK_XTS_E1,
           tweak_length);
    memcpy(key, NIST_KEY_XTS_E1, key_length);
    break;
case 2:
    memcpy(data, NIST_TEST_DATA_XTS_E2, data_length);
    memcpy(result, NIST_TEST_RESULT_XTS_E2, data_length);
    memcpy(tweak, NIST_TWEAK_XTS_E2, tweak_length);
    memcpy(expected_tweak, NIST_EXPECTED_TWEAK_XTS_E2,
           tweak_length);
    memcpy(key, NIST_KEY_XTS_E2, key_length);
    break;
case 3:

```

```

memcpy(data, NIST_TEST_DATA_XTS_E3, data_length);
memcpy(result, NIST_TEST_RESULT_XTS_E3, data_length);
memcpy(tweak, NIST_TWEAK_XTS_E3, tweak_length);
memcpy(expected_tweak, NIST_EXPECTED_TWEAK_XTS_E3,
        tweak_length);
memcpy(key, NIST_KEY_XTS_E3, key_length);
break;
case 4:
memcpy(data, NIST_TEST_DATA_XTS_E4, data_length);
memcpy(result, NIST_TEST_RESULT_XTS_E4, data_length);
memcpy(tweak, NIST_TWEAK_XTS_E4, tweak_length);
memcpy(expected_tweak, NIST_EXPECTED_TWEAK_XTS_E4,
        tweak_length);
memcpy(key, NIST_KEY_XTS_E4, key_length);
break;
case 5:
memcpy(data, NIST_TEST_DATA_XTS_E5, data_length);
memcpy(result, NIST_TEST_RESULT_XTS_E5, data_length);
memcpy(tweak, NIST_TWEAK_XTS_E5, tweak_length);
memcpy(expected_tweak, NIST_EXPECTED_TWEAK_XTS_E5,
        tweak_length);
memcpy(key, NIST_KEY_XTS_E5, key_length);
break;
}
}

int kat_aes_xts(int iteration, int silent)
{
    unsigned int data_length;
    unsigned int tweak_length;
    unsigned int key_length;

    get_sizes(&data_length, &tweak_length, &key_length, iteration);

    unsigned char tweak[tweak_length];
    unsigned char tmp_tweak[tweak_length];
    unsigned char expected_tweak[tweak_length];
    unsigned char key[key_length];
    unsigned char input_data[data_length];
    unsigned char encrypt[data_length];
    unsigned char decrypt[data_length];
    unsigned char result[data_length];

    int rc = 0;
    memset(encrypt, 0x00, data_length);
    memset(decrypt, 0x00, data_length);

    load_test_data(input_data, data_length, result, tweak, expected_tweak,
                  tweak_length, key, key_length, iteration);
    memcpy(tmp_tweak, tweak, tweak_length);

    printf("Test Parameters for iteration = %i\n", iteration);
    printf("key length = %i, data length = %i, tweak length = %i,",
           key_length, data_length, tweak_length);

    rc = ica_aes_xts(input_data, encrypt, data_length,
                    key, key+(key_length/2), (key_length/2),
                    tmp_tweak, 1);
    if (rc) {
        printf("ica_aes_xts encrypt failed with rc = %i\n", rc);
        dump_xts_data(tweak, tweak_length, key, key_length, input_data,
                    data_length, encrypt);
    }
    if (!silent && !rc) {
        printf("Encrypt:\n");
        dump_xts_data(tweak, tweak_length, key, key_length, input_data,

```

```

        data_length, encrypt);
    }

    if (memcmp(result, encrypt, data_length)) {
        printf("Encryption Result does not match the known ciphertext!\n");
        printf("Expected data:\n");
        dump_array(result, data_length);
        printf("Encryption Result:\n");
        dump_array(encrypt, data_length);
        rc++;
    }

    if (memcmp(expected_tweak, tmp_tweak, tweak_length)) {
        printf("Update of TWEAK does not match the expected TWEAK!\n");
        printf("Expected TWEAK:\n");
        dump_array(expected_tweak, tweak_length);
        printf("Updated TWEAK:\n");
        dump_array(tmp_tweak, tweak_length);
        printf("Original TWEAK:\n");
        dump_array(tweak, tweak_length);
        rc++;
    }
}

if (rc) {
    printf("AES XTS test exited after encryption\n");
    return rc;
}

memcpy(tmp_tweak, tweak, tweak_length);
rc = ica_aes_xts(encrypt, decrypt, data_length,
    key, key+(key_length/2), (key_length/2),
    tmp_tweak, 0);
if (rc) {
    printf("ica_aes_xts decrypt failed with rc = %i\n", rc);
    dump_xts_data(tweak, tweak_length, key, key_length, encrypt,
        data_length, decrypt);
    return rc;
}

if (!silent && !rc) {
    printf("Decrypt:\n");
    dump_xts_data(tweak, tweak_length, key, key_length, encrypt,
        data_length, decrypt);
}

if (memcmp(decrypt, input_data, data_length)) {
    printf("Decryption Result does not match the original data!\n");
    printf("Original data:\n");
    dump_array(input_data, data_length);
    printf("Decryption Result:\n");
    dump_array(decrypt, data_length);
    rc++;
}
return rc;
}

int load_random_test_data(unsigned char *data, unsigned int data_length,
    unsigned char *iv, unsigned int iv_length,
    unsigned char *key, unsigned int key_length)
{
    int rc;
    rc = ica_random_number_generate(data_length, data);
    if (rc) {
        printf("ica_random_number_generate with rc = %i errno = %i\n",
            rc, errno);
        return rc;
    }
}

```

```

rc = ica_random_number_generate(iv_length, iv);
if (rc) {
    printf("ica_random_number_generate with rc = %i errno = %i\n",
        rc, errno);
    return rc;
}
rc = ica_random_number_generate(key_length, key);
if (rc) {
    printf("ica_random_number_generate with rc = %i errno = %i\n",
        rc, errno);
    return rc;
}
return rc;
}

int random_aes_xts(int iteration, int silent, unsigned int data_length)
{
    int i;
    int rc = 0;
    unsigned int iv_length = sizeof(ica_aes_vector_t);
    unsigned int key_length = AES_KEY_LEN128 * 2;
    unsigned char iv[iv_length];
    unsigned char tmp_iv[iv_length];
    unsigned char input_data[data_length];
    unsigned char encrypt[data_length];
    unsigned char decrypt[data_length];
    for (i = 1; i <= 2; i++) {

        unsigned char key[key_length];

        memset(encrypt, 0x00, data_length);
        memset(decrypt, 0x00, data_length);

        load_random_test_data(input_data, data_length, iv, iv_length, key,
            key_length);
        memcpy(tmp_iv, iv, iv_length);
        printf("Test Parameters for iteration = %i\n", iteration);
        printf("key length = %i, data length = %i, iv length = %i\n",
            key_length, data_length, iv_length);

        rc = ica_aes_xts(input_data, encrypt, data_length,
            key, key+(key_length/2), (key_length/2),
            tmp_iv, 1);
        if (rc) {
            printf("ica_aes_xts encrypt failed with rc = %i\n", rc);
            dump_xts_data(iv, iv_length, key, key_length, input_data,
                data_length, encrypt);
        }
        if (!silent && !rc) {
            printf("Encrypt:\n");
            dump_xts_data(iv, iv_length, key, key_length, input_data,
                data_length, encrypt);
        }

        if (rc) {
            printf("AES XTS test exited after encryption\n");
            return rc;
        }

        memcpy(tmp_iv, iv, iv_length);

        rc = ica_aes_xts(encrypt, decrypt, data_length,
            key, key+(key_length/2), (key_length/2),
            tmp_iv, 0);
        if (rc) {
            printf("ica_aes_xts decrypt failed with rc = %i\n", rc);
            dump_xts_data(iv, iv_length, key, key_length, encrypt,

```

```

        data_length, decrypt);
return rc;
}

if (!silent && !rc) {
printf("Decrypt:\n");
dump_xts_data(iv, iv_length, key, key_length, encrypt,
        data_length, decrypt);
}

if (memcmp(decrypt, input_data, data_length)) {
printf("Decryption Result does not match the original data!\n");
printf("Original data:\n");
dump_array(input_data, data_length);
printf("Decryption Result:\n");
dump_array(decrypt, data_length);
rc++;
return rc;
}
key_length = AES_KEY_LEN256 * 2;
}

return rc;
}

int main(int argc, char **argv)
{
unsigned int silent = 0;
if (argc > 1) {
if (strstr(argv[1], "silent"))
    silent = 1;
}
int rc = 0;
int error_count = 0;
int iteration;
unsigned int data_length = sizeof(ica_aes_vector_t);
for(iteration = 1; iteration <= NR_TESTS; iteration++) {
rc = kat_aes_xts(iteration, silent);
if (rc) {
printf("kat_aes_xts failed with rc = %i\n", rc);
error_count++;
} else
printf("kat_aes_xts finished successfully\n");
}
for(iteration = 1; iteration <= NR_RANDOM_TESTS; iteration++) {
int silent = 1;
rc = random_aes_xts(iteration, silent, data_length);
if (rc) {
printf("random_aes_xts failed with rc = %i\n", rc);
error_count++;
goto out;
} else
printf("random_aes_xts finished successfully\n");
data_length += sizeof(ica_aes_vector_t) / 2;
}

out:
if (error_count)
printf("%i testcases failed\n", error_count);
else
printf("All testcases finished successfully\n");

return rc;
}

```



---

## CMAC example

```
/* This program is released under the Common Public License V1.0
 *
 * You should have received a copy of Common Public License V1.0 along with
 * with this program.
 */

/* Copyright IBM Corp. 2010, 2011 */
#include <fcntl.h>
#include <sys/errno.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include "ica_api.h"

#define BYTE 8

#define NUM_TESTS 12

unsigned int key_length[12] = {16, 16, 16, 16, 24, 24, 24, 24, 32, 32, 32,
                               32};
unsigned char key[12][32] = {{
    0x2b, 0x7e, 0x15, 0x16, 0x28, 0xae, 0xd2, 0xa6, 0xab, 0xf7, 0x15,
    0x88, 0x09, 0xcf, 0x4f, 0x3c},{
    0x2b, 0x7e, 0x15, 0x16, 0x28, 0xae, 0xd2, 0xa6, 0xab, 0xf7, 0x15,
    0x88, 0x09, 0xcf, 0x4f, 0x3c},{
    0x2b, 0x7e, 0x15, 0x16, 0x28, 0xae, 0xd2, 0xa6, 0xab, 0xf7, 0x15,
    0x88, 0x09, 0xcf, 0x4f, 0x3c},{
    0x2b, 0x7e, 0x15, 0x16, 0x28, 0xae, 0xd2, 0xa6, 0xab, 0xf7, 0x15,
    0x88, 0x09, 0xcf, 0x4f, 0x3c},{
    0x8e, 0x73, 0xb0, 0xf7, 0xda, 0x0e, 0x64, 0x52, 0xc8, 0x10, 0xf3,
    0x2b, 0x80, 0x90, 0x79, 0xe5, 0x62, 0xf8, 0xea, 0xd2, 0x52, 0x2c,
    0x6b, 0x7b},{
    0x8e, 0x73, 0xb0, 0xf7, 0xda, 0x0e, 0x64, 0x52, 0xc8, 0x10, 0xf3,
    0x2b, 0x80, 0x90, 0x79, 0xe5, 0x62, 0xf8, 0xea, 0xd2, 0x52, 0x2c,
    0x6b, 0x7b},{
    0x8e, 0x73, 0xb0, 0xf7, 0xda, 0x0e, 0x64, 0x52, 0xc8, 0x10, 0xf3,
    0x2b, 0x80, 0x90, 0x79, 0xe5, 0x62, 0xf8, 0xea, 0xd2, 0x52, 0x2c,
    0x6b, 0x7b},{
    0x8e, 0x73, 0xb0, 0xf7, 0xda, 0x0e, 0x64, 0x52, 0xc8, 0x10, 0xf3,
    0x2b, 0x80, 0x90, 0x79, 0xe5, 0x62, 0xf8, 0xea, 0xd2, 0x52, 0x2c,
    0x6b, 0x7b},{
    0x60, 0x3d, 0xeb, 0x10, 0x15, 0xca, 0x71, 0xbe, 0x2b, 0x73, 0xae,
    0xf0, 0x85, 0x7d, 0x77, 0x81, 0x1f, 0x35, 0x2c, 0x07, 0x3b, 0x61,
    0x08, 0xd7, 0x2d, 0x98, 0x10, 0xa3, 0x09, 0x14, 0xdf, 0xf4},{
    0x60, 0x3d, 0xeb, 0x10, 0x15, 0xca, 0x71, 0xbe, 0x2b, 0x73, 0xae,
    0xf0, 0x85, 0x7d, 0x77, 0x81, 0x1f, 0x35, 0x2c, 0x07, 0x3b, 0x61,
    0x08, 0xd7, 0x2d, 0x98, 0x10, 0xa3, 0x09, 0x14, 0xdf, 0xf4},{
    0x60, 0x3d, 0xeb, 0x10, 0x15, 0xca, 0x71, 0xbe, 0x2b, 0x73, 0xae,
    0xf0, 0x85, 0x7d, 0x77, 0x81, 0x1f, 0x35, 0x2c, 0x07, 0x3b, 0x61,
    0x08, 0xd7, 0x2d, 0x98, 0x10, 0xa3, 0x09, 0x14, 0xdf, 0xf4},
    0x08, 0xd7, 0x2d, 0x98, 0x10, 0xa3, 0x09, 0x14, 0xdf, 0xf4}
};

unsigned char last_block[3][16] = {{
    0x7d, 0xf7, 0x6b, 0x0c, 0x1a, 0xb8, 0x99, 0xb3, 0x3e, 0x42, 0xf0,
    0x47, 0xb9, 0x1b, 0x54, 0x6f},{
    0x22, 0x45, 0x2d, 0x8e, 0xa8, 0xa5, 0x93, 0x9f, 0x73, 0x21,
    0xce, 0xea, 0x6d, 0x51, 0x4b},{
    0xe5, 0x68, 0xf6, 0x81, 0x94, 0xcf, 0x76, 0xd6, 0x17, 0x4d, 0x4c,
    0xc0, 0x43, 0x10, 0xa8, 0x54}
};

unsigned long mlen[12] = { 0, 16, 40, 64, 0, 16, 40, 64, 0, 16, 40, 64};
```

```

unsigned char message[12][512] = {{
    0x00},{
    0x6b, 0xc1, 0xbe, 0xe2, 0x2e, 0x40, 0x9f, 0x96, 0xe9, 0x3d, 0x7e,
    0x11, 0x73, 0x93, 0x17, 0x2a},{
    0x6b, 0xc1, 0xbe, 0xe2, 0x2e, 0x40, 0x9f, 0x96, 0xe9, 0x3d, 0x7e,
    0x11, 0x73, 0x93, 0x17, 0x2a, 0xae, 0x2d, 0x8a, 0x57, 0x1e, 0x03,
    0xac, 0x9c, 0x9e, 0xb7, 0x6f, 0xac, 0x45, 0xaf, 0x8e, 0x51, 0x30,
    0xc8, 0x1c, 0x46, 0xa3, 0x5c, 0xe4, 0x11},{
    0x6b, 0xc1, 0xbe, 0xe2, 0x2e, 0x40, 0x9f, 0x96, 0xe9, 0x3d, 0x7e,
    0x11, 0x73, 0x93, 0x17, 0x2a, 0xae, 0x2d, 0x8a, 0x57, 0x1e, 0x03,
    0xac, 0x9c, 0x9e, 0xb7, 0x6f, 0xac, 0x45, 0xaf, 0x8e, 0x51, 0x30,
    0xc8, 0x1c, 0x46, 0xa3, 0x5c, 0xe4, 0x11, 0xe5, 0xfb, 0xc1, 0x19,
    0x1a, 0x0a, 0x52, 0xef, 0xf6, 0x9f, 0x24, 0x45, 0xdf, 0x4f, 0x9b,
    0x17, 0xad, 0x2b, 0x41, 0x7b, 0xe6, 0x6c, 0x37, 0x10},{
    0x00},{
    0x6b, 0xc1, 0xbe, 0xe2, 0x2e, 0x40, 0x9f, 0x96, 0xe9, 0x3d, 0x7e,
    0x11, 0x73, 0x93, 0x17, 0x2a},{
    0x6b, 0xc1, 0xbe, 0xe2, 0x2e, 0x40, 0x9f, 0x96, 0xe9, 0x3d, 0x7e,
    0x11, 0x73, 0x93, 0x17, 0x2a, 0xae, 0x2d, 0x8a, 0x57, 0x1e, 0x03,
    0xac, 0x9c, 0x9e, 0xb7, 0x6f, 0xac, 0x45, 0xaf, 0x8e, 0x51, 0x30,
    0xc8, 0x1c, 0x46, 0xa3, 0x5c, 0xe4, 0x11},{
    0x6b, 0xc1, 0xbe, 0xe2, 0x2e, 0x40, 0x9f, 0x96, 0xe9, 0x3d, 0x7e,
    0x11, 0x73, 0x93, 0x17, 0x2a, 0xae, 0x2d, 0x8a, 0x57, 0x1e, 0x03,
    0xac, 0x9c, 0x9e, 0xb7, 0x6f, 0xac, 0x45, 0xaf, 0x8e, 0x51, 0x30,
    0xc8, 0x1c, 0x46, 0xa3, 0x5c, 0xe4, 0x11, 0xe5, 0xfb, 0xc1, 0x19,
    0x1a, 0x0a, 0x52, 0xef, 0xf6, 0x9f, 0x24, 0x45, 0xdf, 0x4f, 0x9b,
    0x17, 0xad, 0x2b, 0x41, 0x7b, 0xe6, 0x6c, 0x37, 0x10},{
    0x00},{
    0x6b, 0xc1, 0xbe, 0xe2, 0x2e, 0x40, 0x9f, 0x96, 0xe9, 0x3d, 0x7e,
    0x11, 0x73, 0x93, 0x17, 0x2a},{
    0x6b, 0xc1, 0xbe, 0xe2, 0x2e, 0x40, 0x9f, 0x96, 0xe9, 0x3d, 0x7e,
    0x11, 0x73, 0x93, 0x17, 0x2a, 0xae, 0x2d, 0x8a, 0x57, 0x1e, 0x03,
    0xac, 0x9c, 0x9e, 0xb7, 0x6f, 0xac, 0x45, 0xaf, 0x8e, 0x51, 0x30,
    0xc8, 0x1c, 0x46, 0xa3, 0x5c, 0xe4, 0x11},{
    0x6b, 0xc1, 0xbe, 0xe2, 0x2e, 0x40, 0x9f, 0x96, 0xe9, 0x3d, 0x7e,
    0x11, 0x73, 0x93, 0x17, 0x2a, 0xae, 0x2d, 0x8a, 0x57, 0x1e, 0x03,
    0xac, 0x9c, 0x9e, 0xb7, 0x6f, 0xac, 0x45, 0xaf, 0x8e, 0x51, 0x30,
    0xc8, 0x1c, 0x46, 0xa3, 0x5c, 0xe4, 0x11, 0xe5, 0xfb, 0xc1, 0x19,
    0x1a, 0x0a, 0x52, 0xef, 0xf6, 0x9f, 0x24, 0x45, 0xdf, 0x4f, 0x9b,
    0x17, 0xad, 0x2b, 0x41, 0x7b, 0xe6, 0x6c, 0x37, 0x10}
};

unsigned char expected_cmac[12][16] = {{
    0xbb, 0x1d, 0x69, 0x29, 0xe9, 0x59, 0x37, 0x28, 0x7f, 0xa3, 0x7d,
    0x12, 0x9b, 0x75, 0x67, 0x46},{
    0x07, 0x0a, 0x16, 0xb4, 0x6b, 0x4d, 0x41, 0x44, 0xf7, 0x9b, 0xdd,
    0x9d, 0xd0, 0x4a, 0x28, 0x7c},{
    0xdf, 0xa6, 0x67, 0x47, 0xde, 0x9a, 0xe6, 0x30, 0x30, 0xca, 0x32,
    0x61, 0x14, 0x97, 0xc8, 0x27},{
    0x51, 0xf0, 0xbe, 0xbf, 0x7e, 0x3b, 0x9d, 0x92, 0xfc, 0x49, 0x74,
    0x17, 0x79, 0x36, 0x3c, 0xfe},{
    0xd1, 0x7d, 0xdf, 0x46, 0xad, 0xaa, 0xcd, 0xe5, 0x31, 0xca, 0xc4,
    0x83, 0xde, 0x7a, 0x93, 0x67},{
    0x9e, 0x99, 0xa7, 0xbf, 0x31, 0xe7, 0x10, 0x90, 0x06, 0x62, 0xf6,
    0x5e, 0x61, 0x7c, 0x51, 0x84},{
    0x8a, 0x1d, 0xe5, 0xbe, 0x2e, 0xb3, 0x1a, 0xad, 0x08, 0x9a, 0x82,
    0xe6, 0xee, 0x90, 0x8b, 0x0e},{
    0xa1, 0xd5, 0xdf, 0x0e, 0xed, 0x79, 0x0f, 0x79, 0x4d, 0x77, 0x58,
    0x96, 0x59, 0xf3, 0x9a, 0x11},{
    0x02, 0x89, 0x62, 0xf6, 0x1b, 0x7b, 0xf8, 0x9e, 0xfc, 0x6b, 0x55,
    0x1f, 0x46, 0x67, 0xd9, 0x83},{
    0x28, 0xa7, 0x02, 0x3f, 0x45, 0x2e, 0x8f, 0x82, 0xbd, 0x4b, 0xf2,
    0x8d, 0x8c, 0x37, 0xc3, 0x5c},{
    0xaa, 0xf3, 0xd8, 0xf1, 0xde, 0x56, 0x40, 0xc2, 0x32, 0xf5, 0xb1,
    0x69, 0xb9, 0xc9, 0x11, 0xe6},{
    0xe1, 0x99, 0x21, 0x90, 0x54, 0x9f, 0x6e, 0xd5, 0x69, 0x6a, 0x2c,
    0x05, 0x6c, 0x31, 0x54, 0x10}
};

```

```

};

unsigned int i = 0;

void dump_array(unsigned char *ptr, unsigned int size)
{
    unsigned char *ptr_end;
    unsigned char *h;
    int i = 1, trunc = 0;
    int maxsize = 2000;

    puts("Dump:");

    if (size > maxsize) {
        trunc = size - maxsize;
        size = maxsize;
    }
    h = ptr;
    ptr_end = ptr + size;
    while (h < ptr_end) {
        printf("0x%02x ", *h);
        h++;
        if (i == 16) {
            if (h != ptr_end)
                printf("\n");
            i = 1;
        } else {
            ++i;
        }
    }
    printf("\n");
    if (trunc > 0)
        printf("... %d bytes not printed\n", trunc);
}

unsigned char *cmac;
unsigned int cmac_length = 16;

int api_cmac_test(void)
{
    printf("Test of CMAC api\n");
    int rc = 0;
    for (i = 0; i < NUM_TESTS; i++) {
        if (!(cmac = malloc(cmac_length)))
            return EINVAL;
        memset(cmac, 0, cmac_length);
        rc = (ica_aes_cmac(message[i], mlen[i],
                           cmac, cmac_length,
                           key[i], key_length[i],
                           ICA_ENCRYPT));
        if (rc) {
            printf("ica_aes_cmac generate failed with errno %d (0x%x)."\n",rc,rc);
            return rc;
        }
        if (memcmp(cmac, expected_cmac[i], cmac_length) != 0) {
            printf("This does NOT match the known result. "\n",rc,rc);
            printf("Testcase %i failed\n",i);
            printf("\nOutput MAC for test %d:\n", i);
            dump_array((unsigned char *)cmac, cmac_length);
            printf("\nExpected MAC for test %d:\n", i);
            dump_array((unsigned char *)expected_cmac[i], 16);
            free(cmac);
            return 1;
        }
    }
    printf("Expected MAC has been generated.\n");
    rc = (ica_aes_cmac(message[i], mlen[i],
                       cmac, cmac_length,

```

```

        key[i], key_length[i],
        ICA_DECRYPT));
if (rc) {
    printf("ica_aes_cmac verify failed with errno %d (0x%x).\n",
        rc, rc);
    free(cmac);
    return rc;
}
free(cmac);
if (!rc)
    printf("MAC was successful verified. testcase %i "
        "succeeded\n",i);
else {
    printf("MAC verification failed for testcase %i "
        "with RC=%i\n",i,rc);
    return rc;
}
}
return 0;
}

int main(int argc, char **argv)
{
    int rc = 0;

    rc = api_cmac_test();
    if (rc) {
        printf("api_cmac_test failed with rc = %i\n", rc);
        return rc;
    }
    printf("api_cmac_test was succesful\n");
    return 0;
}

```

---

## Makefile example

```
# Specify include directory. Leave blank for default system location.
INCDIR =

# Specify library directory. Leave blank for default system location.
LIBDIR =

# Specify library.
LIBS = -lica

TARGETS = example_des_ecb

all: $(TARGETS)

%.c: %.c
    gcc $(INCDIR) $(LIBDIR) $(LIBS) -o $@ $^

clean:
    rm -f $(TARGETS)
```

---

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## Glossary

### **Central Processor Assist for Cryptographic Function (CPACF)**

Hardware that provides support for symmetric ciphers and secure hash algorithms (SHA) on every central processor. Hence the potential encryption/decryption throughput scales with the number of central processors in the system.

### **Chinese-Remainder Theorem (CRT)**

A mathematical problem described by Sun Tsu Suan-Ching using the remainder from a division operation.

### **Cipher Block Chaining (CBC)**

A method of reducing repetitive patterns in ciphertext by performing an exclusive-OR operation on each 8-byte block of data with the previously encrypted 8-byte block before it is encrypted.

### **Cipher block length**

The length of a block that can be encrypted or decrypted by a symmetric cipher. Each symmetric cipher has a specific cipher block length.

### **CPACF instructions**

Instruction set for the CPACF hardware.

### **Crypto Express2 (CEX2)**

The two PCI-X adapters on a CEX2 feature can be configured in two ways: Either as cryptographic Coprocessor (CEX2C) for secure key encrypted transactions, or as cryptographic Accelerator (CEX2A) for Secure Sockets Layer (SSL) acceleration. A CEX2A works only in clear key mode. Both adapters can be of the same type, or you can configure one adapter as CEX2A and the other as CEX2C.

### **Crypto Express3 (CEX3)**

Successor to the Crypto Express2 feature. The two PCI-X adapters on a CEX3 feature can be configured in two ways: Either as cryptographic Coprocessor (CEX3C) for secure key encrypted transactions, or as cryptographic Accelerator (CEX3A) for Secure Sockets Layer (SSL) acceleration. A CEX3A works only in clear key mode. Both adapters can be of the same type, or you can configure one adapter as CEX3A and the other as CEX3C.

### **electronic code book mode (ECB mode)**

A method of enciphering and deciphering data in address spaces or data spaces. Each 64-bit block of plaintext is separately enciphered and each block of the ciphertext is separately deciphered.

**libica** Library for IBM Cryptographic Architecture.

### **Mode of operation**

A schema describing how to apply a symmetric cipher to encrypt or decrypt a message that is longer than the cipher block length. The goal of most modes of operation is to keep the security level of the cipher by avoiding the situation where blocks that occur more than once will always be translated to the same value. Some modes of operations allow handling messages of arbitrary lengths.

### **modulus-exponent (Mod-Expo)**

A type of exponentiation performed using a modulus.

**Rivest-Shamir-Adleman (RSA)**

An algorithm used in public key cryptography. These are the surnames of the three researchers responsible for creating this asymmetric or public/private key algorithm.

**Secure Hash Algorithm (SHA)**

An encryption method in which data is encrypted in a way that is mathematically impossible to reverse. Different data can possibly produce the same hash value, but there is no way to use the hash value to determine the original data.

**symmetric cipher**

An encryption method that uses the same key for encryption and decryption. Keys of symmetric ciphers are private keys.

**z90crypt**

Linux device driver for cryptographic adapters of IBM System z. The libica Version 2, libica Version 2.1.0, and libica Version 2.2.0 libraries interact directly with the z90crypt device driver.

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