

1. Introduction

1.1. CRYPTO-BOX® SC a new generation of MARX USB security hardware

The CRYPTO-BOX SC (CBU SC) introduces a brand new generation of MARX USB security hardware. It utilizes the modern Atmel AT90SC family chipset - low-power, high-performance secure micro controllers built around SecureAVR® 8-/16-bit RISC architecture. This smart choice makes the device architecture extremely flexible. Reloadable firmware allows implementing in hardware the necessary logic and functionality, as a result obtaining required type of security hardware from a standard smart card in USB form-factor to a smart USB token - CBU SC(Protection and licensing device).

The CBU SC firmware provides 100% backward compatibility with the existing CRYPTO-BOX USB (CBU), adding such important features as:

- **Reprogrammable and remotely upgradable firmware:**
 - o more standard security features will be added (CBU SC firmware will be continuously improved and updated by MARX: new encryption algorithms and other useful universal security logic will be added);
 - o customer specific functionality can be added to the firmware upon request;
 - o secure remote firmware update (the secure remote update technology is embedded to the CBU SC firmware from the very beginning)
- **Hardware based RSA encryption:**
 - o 512/1024/2048 RSA encryption is supported in hardware;
 - o variable number of RSA keypairs, reprogrammable by customers (a new dedicated memory zone RAM4 is used for RSA key-pairs, by default containing space for 8 keypairs: 3 holding SmarxOS system objects and 5 available for application purposes)
 - o top security and highest level of access control for RSA keypairs:
 - the values can never be read;
 - a special login (UPW/APW) may be required (depending on the access rights preset for this key-pair upon creation) in order to:
 - use the key for encryption;
 - change its value (full keypair);
 - o a special encryption mode fully conforming to the PKCS#1 padding rules (allows to exchange RSA encrypted data with any standard cryptographic provider, like: OpenSSL, Windows CryptoAPI, .NET Cryptography, etc.)
- **Extended hardware implementation of AES encryption:**
 - o While CBU includes only three dedicated AES keys (Fixed, Private and Session), the CBU SC additionally contains a special new memory zone (RAM5) which can securely hold as many extra AES keys as required;
 - o Moreover, besides OFB (output feedback) mode of AES encryption supported by CBU, CBU SC allows to choose between OFB and CBC (cipher block chaining) encryption modes for AES keys stored in RAM5 memory zone;
 - o Top security and highest access control level for AES keys in RAM5 (similar to RSA access control):
 - the values can never be read;
 - a special login (UPW/APW) may be required (depending on the access rights preset for the key upon its creation) in order to:
 - use the key for encryption;
 - change its value.
- **CBU SC is ultra-fast:** up to 100 times faster than CBU, depending on the operation:
 - o approx. 120Kb/sec for read/write memory operations comparing to 2.6/1.3Kb/sec for CBU
 - o approx. 11Kb/sec for hardware based AES encryption comparing to 2.6Kb/sec for CBU
 - o more details on CBU SC timing and its comparison to CBU can be found in Appendix A
- **32KB of fast access internal memory:** approx. 120Kb/sec for read/write memory operations (see Appendix A for more details)

1.2. SmarxOS and CRYPTO-BOX® SC

The CBU SC is fully supported by SmarxOS from the very beginning. Being 100% backward compatible with CBU, CBU SC can simply replace it for all existing applications and solutions where CBU is currently used. Only re-compilation (or re-protection in case of AutoCrypt) will be required. In fact even this simple replacement will mean: ultra-fast CBU SC with 32KB of RAM. Plus hardware based RSA implementation, which automatically increases security of Remote License Management. The WEB API, OLM (Online License Management) and RU (Remote Update) MARX solutions are built on top of RSA.

However 100% backward CBU compatibility should be considered as an entry level only. Besides CBU compatibility, the CBU SC brings a lot of brand new features and options for SmarxOS customers, in particular:

1.2.1. CRYPTO-BOX® SC AES encryption extension

CBU SC AES encryption implementation dramatically extends the number of hardware supported AES keys. In addition to three predefined CBU keys (Session, Private and Fixed), the CBU SC allows customers to create as many AES keys in a special memory zone RAM5 as required and to specify access rights for them.

This new functionality will be utilized by AutoCrypt to protect more than one application with one crypto-box using separate encryption. In case of CBU all protected applications share the same value of AES key for their hardware encryption. For CBU SC it is possible to have separate AES key for every application/set of applications.

In case of API based protection developers will use as many AES keys as necessary by the product licensing logic. Also such MARX technologies as: Document protection, Data Protection, Audio and Video encryption, and WEB based communication will benefit from this functionality, providing higher level of security and customization.

To help developers incorporating the extended AES functionality to their programs the DO API will include a special data object - "AES key".

1.2.2. Using hardware based RSA

CBU SC brings hardware based RSA and secure storage of RSA key-pairs (RAM4 area). With a special encryption mode fully conforming to the PKCS#1 padding rules the developers will be able to integrate CBU SC hardware based RSA to a wide range of standard and customer specific security solutions.

Really, OpenSSL or any other open RSA implementation (for example, see: www.bouncycastle.org) can be used on the server (trusted side), while CBU SC based RSA will be used by clients. Besides, an extended number of RSA key-pairs securely stored in RAM4 allow developers to utilize them also for software protection and licensing needs.

To help developers incorporating this new RSA functionality to their programs the following improvements are introduced in SmarxOS API:

- 1) in addition to currently supported driver level RSA implementation CBIOS API 1.5 also supports hardware based RSA
- 2) a special encryption mode fully compatible with PKCS#1 padding rules is supported in addition to the existing RSA support with non-standard padding mode
- 3) CBIOS 1.5 also includes software based RSA for both padding modes (identical to CBU SC hardware implementation) - it allows to consider CBU as RSA key storage for solutions with entry level security requirements
- 4) a new data object - "RSA keypair" will be introduced in DO API helping developers with RSA integration

1.3. PPK V: CRYPTO-BOX® SC support and evaluation

Starting with version V SmarxOS® PPK provides full support of CRYPTO-BOX® SC (CBU SC) for Windows platform (x86 and x64). All SmarxOS® solutions and components included to the PPK for Windows platform support CBU SC. Please, consider the following PPK folders for CBU SC evaluation:

< SmarxOS PPK root >

- \Doc - contains this document
- \Drivers\XP_Vista_Win7 - digitally signed CBU SC drivers for Win32 and Win64 platforms
- \SmarxOS\API\Win\Samples - different programming samples for Win platform, in particular:
 - \CBIOS\C++\MSVS2005 (Static VC)
 - C/C++ static linkage: two sample projects, demonstrating CBIOS (ver.1.5) functionality:
 - **CBIOS_Sample** - standard CBIOS API sample; works for CBU and CBU SC hardware
 - **CBU2_Sample** - demonstrates CBU SC specific features only, including hardware based RSA and AES, as well as hardware/software encryption and standard cryptography compatibility modes for RSA and AES;
 - \CBIOS\C#\MSVS2005 (CBIOS4NET)
 - **CBIOS4NETSmp.exe** - GUI sample, demonstrating CBIOS4NET syntax for CBU and CBU SC; includes CBU SC specific features: hardware based RSA and AES, as well as hardware/software encryption and standard cryptography compatibility modes for RSA and AES;
 - \CBIOS\C++\MSVS2003 (CBU2 COM)
 - **VC++ .NET COM based linkage: CBU2_Sample** - demonstrates CBU SC specific features only, including hardware based RSA and AES, as well as hardware/software encryption and standard cryptography compatibility modes for RSA and AES;
 - \CBIOS\Delphi\BDS2006 (CBU2)
 - \CBIOS\Delphi\BDS2006 (CBU2 COM)
 - \CBIOS\Delphi\RAD2010 (CBU2)
 - Delphi COM and static linkage (DCU) samples, demonstrating CBU SC specific features only, including hardware based RSA and AES, as well as hardware/software encryption and standard cryptography compatibility modes for RSA and AES

NOTE: The above list contains only samples demonstrating CBU SC specific features. All the rest samples for currently supported programming environments under Windows platform work for CBU and CBU SC, demonstrating standard CBIOS/DO/RFP API calls.

- \SmarxOS\Network\Win32 and \Win64 - CBIOS Network Server now supports CBU and CBU SC for Windows
- \Tools\SmrxTiming - a special tool, allowing you to measure and profile CBU SC and CBU hardware operations (see Appendix A for standard timing results)

2. Evaluation: step-by-step

If you received CBU SC Evaluation Kit with SmarxOS PPK version 5.0 or higher, then CBU SC driver and required SmarxOS components are installed automatically in process of PPK setup. You can start CBU SC evaluation right away.

2.1. Installing CRYPTO-BOX® SC driver and SmarxOS® COM object

To start CBU SC evaluation on a computer without SmarxOS PPK you will need to install its driver and register SmarxOS® ActiveX/COM object(s) for your platform (Win32 or Win64) first. It is done automatically by CBUSetup utility. This utility is included to the PPK, its latest version is available online at www.marx.com for re-distribution to end-users. It detects the platform, installs suitable CBU and CBU SC drivers and registers required ActiveX/COM object(s).

We strongly recommend CBUSetup usage for CBU/CBU SC installation. However, if for some reason you need to perform installation manually, then here is the procedure:

2.1.1. Installing CRYPTO-BOX® SC driver

When you attach CBU SC to a USB port of your computer the very first time it will be recognized by Windows as "USB CrypToken II". At this point it is necessary to install CBU SC driver.



Win32 and Win64 versions of CBU SC driver are available (included to the PPK)

Point the "New Hardware Found" wizard to a directory containing the latest CBU SC driver for your platform (files: cbusb2.cat, cbusb2.sys, cbusb2.inf for Win32 platform, cbu2_64.cat, cbu2_64.sys, cbu2_64.inf for Win64):

```
< SmarxOS PPK Root > \Drivers\XP_Vista_Win7
```

The latest available version of the driver for now is: **CBUSB2 Ver.1.0** (dated 21Apr2009 - 1.0.9.421). Both drivers (for Win32 and 64) are digitally signed. Now the CBU SC hardware is resolved properly (as CBUSB2 device) and ready for evaluation.



When you attach the CBU SC to another USB port of your computer the very first time the system will resolve it automatically.

2.2. Testing

2.2.1. CBU compatibility level

Start evaluation with CBU compatibility level. Launch standard CBIOS test for CBU included to the PPK, for example:

```
< SmarxOS PPK root > \SmarxOS\API\Win\Samples\CBIOS\C + + \
MSVS2005 (Static VC)\Release\CBIOS_Sample.exe
```

and run it in local mode with CBU SC and/or CBU hardware attached to the computer.

You will notice that CBU SC is 100% backward compatible to CBU but tremendously fast.

Now it's time for CBIOS network evaluation. Run CBUSetup to install CBU SC support on some other computer (or several computers) on your local network to be used as CBIOS Server(s). See section 2.1 for details.

Install CBIOS Network Server on those computer(s) (< **SmarxOS PPK root** > \Redistributable\CBIOS **Network Server\CBIOS Network Server.msi**) and launch CBIOS Server (the CBIOSsrv.exe file). Attach CBU SC (and/or CBU) hardware to those computers with running CBIOS Server.

Now run the sample on your local computer and choose the network mode. You will see that CBU SC is fully compatible with CBIOS network mode.



Your local computer can be used for network mode evaluation too - just launch the CBIOS server on it and attach CBU SC (and/or CBU) hardware.

2.2.2. Testing CBU SC specific features

At this point it makes sense to look through chapters 3 and 4 of this document, describing RSA and AES encryption and all new and extended/updated CBIOS API calls and related data structures currently included to the Evaluation Kit.

Evaluating hardware based RSA and AES encryption

Launch CBU SC specific CBIOS test included to the Kit:

```
< SmarxOS PPK root > \SmarxOS\API\Win\Samples\CBIOS\C + + \
MSVS2005 (Static VC)\Release\CBU2_Sample.exe
```

Here you can test CBU SC hardware based RSA and AES encryption.

Provided RSA test scenarios include:

- RSA keypair generation;
- Its programming to CBU SC dedicated RSA memory;
- Performing:
 - hardware based encryption and decryption (option 3);
 - hardware based encryption and software based decryption (option 4);
 - CBU SC hardware RSA and standard WinCrypt compatibility demo (option 6).

AES test scenarios include:

- CBU SC hardware AES (option 5);
- Standard WinCrypt and CBU SC hardware AES compatibility demo (option 7);

All tests can be done in local or network mode. All supplementary CBIOS calls (RSA keypair generation, setting access rights, getting info on RSA keypair, etc.) are demonstrated.

3. CRYPTO-BOX® SCand RSA encryption

3.1. CRYPTO-BOX® USB and RSA encryption

The RSA encryption for the CRYPTO-BOX USB (CBU) is implemented inside the system level software: driver and low-level library. This implementation is supported by the SmarxOS® API and used in various MARX solutions and technologies, such as: WEB API, OLM and Remote Update.

The RSA implementation in the CBU driver uses different padding rules comparing to other popular RSA implementations (e.g. OpenSSL, WinCrypt, etc.), which use PKCS#1 padding rules:

3.1.1. PKCS#1 padding rules

D: data

P: padding, (k - 3 - length of D) bytes, where k: key length in bytes

Encryption

- Public Key encryption:

00 || 02 || P || 00 || D

P: pseudorandom, nonzero bytes

- Private Key encryption:

00 || 01 || P || 00 || D

P: all bytes have value 0xFF

Decryption

- Public Key decryption (message was encrypted with private key):

- after decryption checks for block starting with 00 || 01
- checks for 0xFF padding bytes
- gets beginning of data from 0x00 separator

- Private Key decryption (message was encrypted with public key):
 - after decryption checks for block starting with 00 || 02
 - gets beginning of data from 0x00 separator

While the actual (pure) RSA operations are just Encryption and Decryption, however there are four RSA operations after taking these standard padding rules into account:

RSA Public Encryption
RSA Private Encryption
RSA Public Decryption
RSA Private Decryption

3.1.2. Padding rules used in CBU RSA implementation

The RSA implementation in the CBU driver uses a slightly different RSA padding:

D: data
L: length of DATA
P: padding, (k - 4 - length of D) bytes, where k: key length in bytes

- Encryption:
00 || 01 || L || P || 00 || D
P: all bytes have value 0xFF

- CBU Decryption
 - after decryption checks for block starting with 00 || 01
 - gets L
 - checks for 0xFF padding bytes
 - checks for 0x00 separator

As a consequence of this approach the CBU RSA implementation is not compatible to standard RSA implementation conforming to the PKCS#1 padding rules. However if a crypto library has API calls for the plain RSA operations without any padding, they could be used to implement CBU compatible padding.

3.2. RSA for CBU: Conclusion

As described above, the CBU RSA implementation is not fully compatible to standard RSA implementations conforming to the PKCS#1 padding rules. For CBU2 PKCS#1 padding mode is fully supported, in addition to CBU RSA compatible padding.

For CBU MARX provides RSA implementation sources with CBU compatible padding for such popular environments as Java, PHP, and C#.NET as a part of MARX WEB API solution. These sources are based on standard RSA implementation adjusted for CBU RSA padding rules:

- included to GMP.PHP and BCMath.PHP
- provided by: <http://www.bouncycastle.org> for Java and C#.

The CBU RSA implementation is also fully supported in CBIOS API and can be efficiently used for virtually any server side environment to establish secure encrypted channel with remote client as well as for any other RSA based solutions.

3.3. CRYPTO-BOX® SC: hardware RSA implementation

CBU SC includes RSA implementation in its firmware. It contains a special memory zone (RAM4) storing RSA keypairs. There is no way to read key values; they can only be used for encryption. Special access restrictions can be added: APW/UPW login requirements for encryption and/or change key values.

For compatibility purposes CBU SC firmware RSA implementation uses CBU padding rules. In addition it also includes standard PKCS#1 padding extending RSA support to any standard scenario. The CBIOS API related calls include a special parameter (dwMode) reserved for defining padding rules: CBU / PKCS#1 modes.

See section 4.2 for more details on CBU2 RSA support in CBIOS API.

4. SmarxOS API: new and extended calls and structures

4.1. Introducing CBIOS 1.5

The CBIOS ver.1.5 is the first CBIOS kernel supporting both CBU and CBU SC.

It utilizes CBU SC specific features and contains serious improvements of CBIOS internal architecture for local and network modes.

4.2. CBIOS 1.5: RSA encryption support

The CBIOS API (ver.1.5) supports all CBU related RSA calls “as is” for both CBU and CBU SC hardware.

4.3. CBIOS 1.5: CBU RSA calls

The following four groups of CBIOS API calls cover existing CBU RSA functionality:

- 1) Software generation and creation of RSA keypairs:

CBIOS_GenerateKeyPairRSA() – generates RSA keypair in computer memory and writes its public and private keys to specified offset in CBU RAM1/2/3 memory;
CBIOS_PrepareRSAKey() – convert externally obtained RSA key to CBU RSA format, can be later stored to CBU memory with **CBIOS_SetKeyPublicRSA()** / **CBIOS_SetKeyPrivateRSA()**

- 2) Reading/writing values of RSA keys to/from CBU memory:

CBIOS_GetKeyPublicRSA() / **CBIOS_GetKeyPrivateRSA()**
CBIOS_SetKeyPublicRSA() / **CBIOS_SetKeyPrivateRSA()**

- 3) CBU RSA data encryption/decryption:

CBIOS_EncryptRSA() / **CBIOS_DecryptRSA()**

- 4) CBU RSA data encryption/decryption using predefined SmarxOS system RSA keypairs (Client/Distributor):

CBIOS_EncryptInternalRSA() / **CBIOS_DecryptInternalRSA()**

As mentioned above this functionality is fully supported for CBU SC. The next two sections address differences in CBU SC interpretation of CBU RSA calls. It's important to mention that these differences only improve RSA calls processing, preserving full compatibility.

4.3.1. CBU SC: hardware support for SmarxOS system RSA keypairs (Distributor and Client)

The first difference between CBU and CBU SC is internal implementation of SmarxOS system RSA keypairs: Distributor and Client. These two predefined RSA keypairs are included to every SmarxOS formatted CBU or CBU SC box. They are used by MARX WEB API/OLM, Remote Update scenarios, as well as by any customer specific implementations requiring establishing of secure client/server channel.

As mentioned in the previous section CBIOS API includes two calls working with these system SmarxOS keypairs:

CBIOS_EncryptInternalRSA()/ CBIOS_DecryptInternalRSA()

For CBU SC these calls are based on hardware RSA implementation and SmarxOS system keypairs are stored in specially reserved cells of RAM4 (RSA dedicated memory zone), making impossible any access to their values, other than their usage for encryption/decryption.

4.3.2. CBU SC: ignoring login password parameter for CBU RSA calls

Those CBU RSA CBIOS API calls which work with CBU hardware contain a special parameter (bPass), allowing UPW/APW password submission for this very call. When required, this parameter value is used internally during the call processing for CBU login/logout while accessing its RAM1/2 memory zones storing RSA key and/or data buffer. CBU SC low-level implementation assumes UPW/APW login to be performed in advance (prior to RSA related call) in case if it is required. Thus this parameter value is not needed and is ignored in case of CBU SC.

4.4. CBIOS 1.5: CBU SC RSA calls

Besides CBIOS set of functions representing CBU RSA implementation, CBIOS 1.5 also introduces the following brand new functions covering CBU SC specific RSA functionality:

- 1) Software generation of RSA keypairs for CBU SC:
CBIOS_GenerateKeyPairRSAEx() – generates CBU SC RSA keypair in computer memory
- 2) Writing RSA keypairs to special cells in CBU SC dedicated memory (RAM4):
CBIOS_CBU2_SetKeyRSA()
- 3) Setting/getting/controlling access rights for RSA keys in CBU SC:
CBIOS_CBU2_SetKeyInfoRSA() / **CBIOS_CBU2_GetKeyInfoRSA ()**
CBIOS_CBU2_LockKeyRSA()
- 4) Hardware based RSA data encryption./decryption for CBU2:
CBIOS_CBU2_EncryptRSA() / **CBIOS_CBU2_DecryptRSA()**
- 5) Software based RSA data encryption/decryption (CBU2 compatible):
CBIOS_EncryptRSAEx() / **CBIOS_DecryptRSAEx()**

The above set of CBIOS calls introduces also two new structures specific to CBU SC: **CBIOS_RSA_KEY**, **CBIOS_RSA_KEY_INFO**. The following subsections describe CBU SC specific RSA calls and related data structures, constants and error codes in detail.

4.4.1. CBIOS API: CBU SC RSA new API calls

4.4.1.1. CBIOS_GenerateKeyPairRSAEx

Generates RSA keypair

```
DWORD WINAPI CBIOS_GenerateKeyPairRSAEx( CBIOS_RSA_KEY*   pRSAKeyPair,
                                          CBIOS_RSA_KEY*   pRSAPublicKey,
                                          WORD             bits,
                                          BYTE*           randomPool);
```

pRSAKeyPair	[in] Pointer to a structure receiving generated RSA keypair
pRSAPublicKey	[in] Pointer to a structure receiving public part of generated RSA keypair
bits	[in] RSA key size
randomPool	[in] Array of random bytes. Length of array must be at least CBIOS_RAND_POOL_SIZE(bits)
[return]	CBIOS Error code

Description: This function generates CBU SC RSA keypair of 512/1024/2048 bits size (**bits**) and saves the resulting keypair to the **pRSAKeyPair** structure.

In addition it saves the public part of the keypair separately to the **pRSAPublicKey** structure. The generation is software based and is supposed to be done on trusted computer. If **pRSAPublicKey** is null, then this parameter is ignored.

Further the resulting keypair can be saved to one of the cells in CBU SC dedicated memory (RAM4 zone) with the **CBIOS_CBU2_SetKeyRSA()** call. If necessary its access rights can be adjusted with the **CBIOS_CBU2_SetKeyInfoRSA()** function. Then it can be used for CBU SC RSA encryption: **CBIOS_EncryptRSAEx()/CBIOS_DecryptRSAEx()**.

Example: the **Test_RSA_HW()** function of **CBU2_Sample.c** included to the CBU SC Evaluation Kit illustrates this call usage.

4.4.1.2. CBIOS_CBU2_SetKeyRSA

Writes RSA keypair to one of CBU SC RSA cells

```
DWORD WINAPI CBIOS_CBU2_SetKeyRSA( DWORD           dwKeyIndex,
                                   CBIOS_RSA_KEY*   pRSAKeyPair,
                                   CBIOS_RSA_KEY_INFO* pRSAKeyInfo );
```

dwKeyIndex	[in] Index of RSA cell in CBU SC RAM4 zone for this keypair (starting from 0)
pRSAKeyPair	[in] Pointer to RSA keypair to write
pRSAKeyInfo	[in] Pointer to RSA keypair information (optional)
[return]	CBIOS Error code

Description: This function writes CBU SC RSA keypair (**pRSAKeyPair**) to one of CBU SC cells (**dwKeyIndex**) in dedicated memory (RAM4 zone).

The **pRSAKeyInfo** structure can optionally set access rights on this keypair, including:

- its usage for encryption,
- obtaining access rights info and/or changing the keypair value/access rights.

See section 4.4.2 for more details on how to define access rights and limitations in **CBIOS_RSA_KEY_INFO** structure.

- 2) **CBIOS_CBU2_ACCESS_ALWAYS** – this value means free access (no limitations).
- 3) **CBIOS_CBU2_ACCESS_UPW** – UPW login is required
- 4) **CBIOS_CBU2_ACCESS_APW** – APW login is required
- 1) **CBIOS_CBU2_ACCESS_LOCK** – the access will be locked, only MARX distributor can unlock it.

The **CBIOS_AES_KEY_INFO** structure is used in the following CBIOS calls:

- CBIOS_CBU2_SetKeyAES()**
- CBIOS_CBU2_SetKeyInfoAES()**
- CBIOS_CBU2_GetKeyInfoAES()**

4.7. New CBIOS constants

Box type

New field of **CBIOS_BOX_INFO_ADV** structure (wType)

CBIOS_BOX_UNKNOWN	Unknown box type
CBIOS_BOX_CBU	CBU box
CBIOS_BOX_CBU2	CBU2 box

4.8. CBU2 specific CBIOS error codes

CBIOS_CBU2_ERR_CONFIG_LOCKED	Box configuration is locked (Reserved for future usage)
CBIOS_CBU2_ERR_LOAD_FIRMWARE	Firmware upload error (Reserved for future usage)
CBIOS_CBU2_ERR_RAM4_NOT_EXIST	No RAM for RSA keys
CBIOS_CBU2_ERR_RAM5_NOT_EXIST	No RAM for AES keys (Reserved for future usage)
CBIOS_CBU2_ERR_KEY_LOCKED	RSA Key is locked
CBIOS_CBU2_ERR_KEY_NOTUSED	RSA Key is not used (not set)
CBIOS_CBU2_ERR_CRYPTO_FAILED	Crypto operation failed
CBIOS_CBU2_ERR_NO_SPACE_IN_RAM4	Not enough space in ram 4
CBIOS_CBU2_ERR_NO_SPACE_IN_RAM5	Not enough space in ram 5 (Reserved for future usage)

5. Appendix A: CBU(K and CBU timing

Configuration used for tests:

Processor: **AMD Sempron® Processor 3200 + 1815.00 MHz**
RAM: **2Gb 333 MHz**
Motherboard: **ASUS A8N-VM CSM**
OS: **Windows XP SP3 x86**
CBU SC driver: **CBUSB2.SYS 1.0.9.421**
CBU driver: **CBUSB.SYS 2.0.7.214**

Timing for: read/write operations

Function	Box Type\ Firmware	Box Size	Memory buffer size						
			100	1K	2K	4K	8K	16K	24K
CBIOS_ReadRAM / WriteRAM	CBU SC 2.2	32K	3/4	11/10	20/18	36/35	68/66	132/130	196/194
	CBU1 2.3		45/85	394/765	778/1512	1546/3007	3082/5997	6155/11976	9227/17954

Conclusions:

- * CBU SC and CBU read/write operation timing does not depend on OS;
- ** CBU SC and CBU read/write operation speed doesn't depend on the buffer size
- *** The read and write operations speed is almost the same for CBU SC

CBU SC: Read/Write: ~ **120 Kb/sec** (< + -10%)

CBU1: Read/Write: ~ **2.6 / 1.3 Kb/sec** (< + -10%)

CBU SC \ CBU1 Read\Write ratio: 46x\92x

Timing for: symmetric encryption (AES)

Function	Box Type \ Firmware	Box Size	Key	Memory buffer size				
				100	1K	10K	30 K	60K
CBIOS_CryptFixed / Private / Session	CBU SC 2.2	32K	Fixed	11	92	892	2694	5288
	CBU1 2.3			45	387	3844	11548	23047
	CBU SC 2.2		Private	12	92	898	2654	5291
	CBU1 2.3			45	387	3860	11536	23047
	CBU SC 2.2		Session	12	91	898	2649	5285
	CBU1 2.3			45	398	3845	11525	23049
CBIOS_CBU2_CryptAES	CBU SC 2.2	OFB	12	90	882	2642	5283	
		*CBC	25	208	2044	6125	12246	

NOTE: Time is measured for both operations (encrypt + decrypt)

Conclusions:

- * CBU SC and CBU encryption operation timing does not depend on OS;
- ** CBU SC and CBU encryption operation speed doesn't depend on the buffer size
- *** For CBC mode the time value should be divided by 2.

CBU2: ~ **11 Kb/sec** (< + -10%)

CBU1: ~ **2.6 Kb/sec** (< + -10%)

CBU2 \ CBU1 symmetric encryption ratio: 4.2x

Timing for: asymmetric encryption (RSA)

Function	Firmware	Box Size	Key	Memory buffer size				
				100	1K	10K	30 K	52K
CBIOS_Encrypt + DecryptRSA	CBU SC	32K	priv + pub	45	290	2687	8191	13952
	CBU1 2.3			165	430	2976	8151	14443
	CBU SC		pub + priv	43	282	2767	8157	13737
	CBU1 2.3			164	431	2861	8380	14588
CBIOS_CBU2_Encrypt + DecryptRSA	CBU SC 2.2		priv + pub	123	1065	10478	31043	54732
			pub + priv	124	1066	10477	31568	54275

Conclusions:

CBU SC hardware based asymmetric encryption operation timing does not depend on OS.

Its value is: ~ **0.95 Kb/sec** (< + -10%)

For CBU software based asymmetric encryption (RSA) implementation depends on OS and system overall productivity. Its value for the system used for tests is: ~ **3.5 Kb/sec**

For asymmetric encryption there is no reason to calculate the ratio value, because of different implementation.