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(54) METHODS AND SYSTEMS FOR SECURELY TRANSFERRING EMBEDDED CODE AND/OR DATA DESIGNED FOR A DEVICE TO A CUSTOMER

(71) Applicant: **Infineon Technologies AG**, Neubiberg (DE)

(72) Inventors: **Min Wei Ang**, Singapore (SG); **Gerd Dirscherl**, Muenchen (DE); **Arno Rabenstein**, Singapore (SG)

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(57) ABSTRACT

The invention relates to methods and systems for securely transferring embedded code or data to a customer, in particular to methods and systems for securely transferring embedded code, data files or program files designed for a device to a customer in order to prevent the embedded code, data files or program files from being used on unauthorized devices.

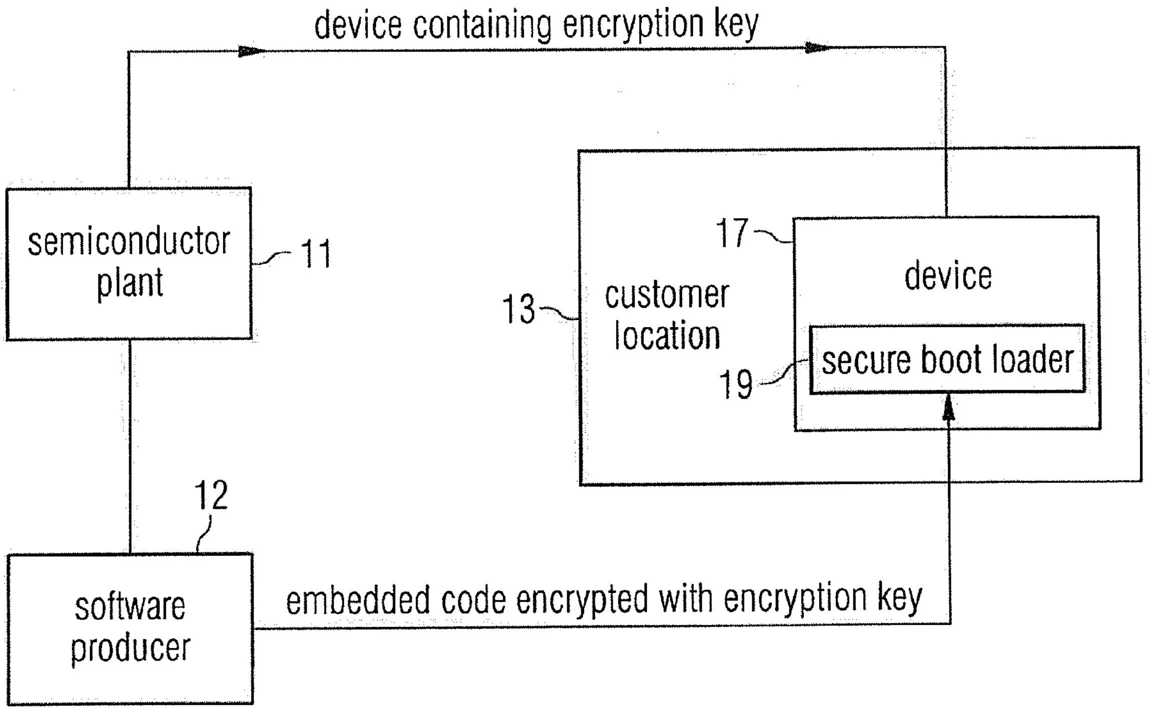


FIG 1

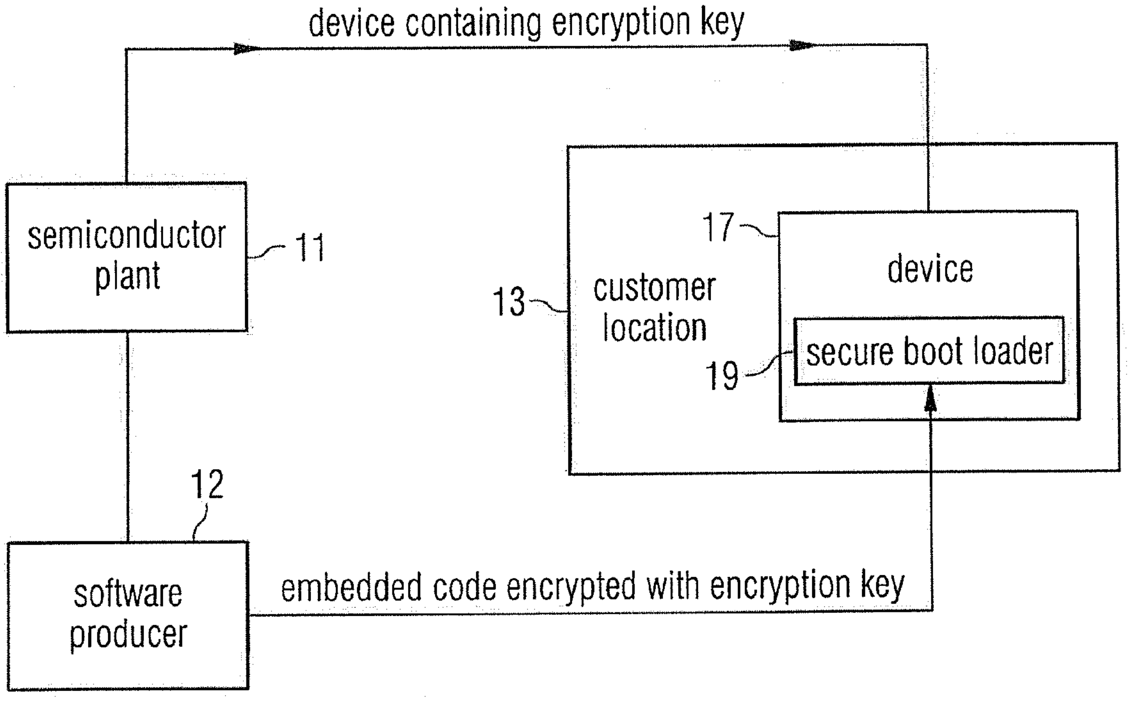

device containing encryption key
semiconductor plant
11
customer location
13
17
device
secure boot loader
19
12
software producer
embedded code encrypted with encryption key

FIG 2

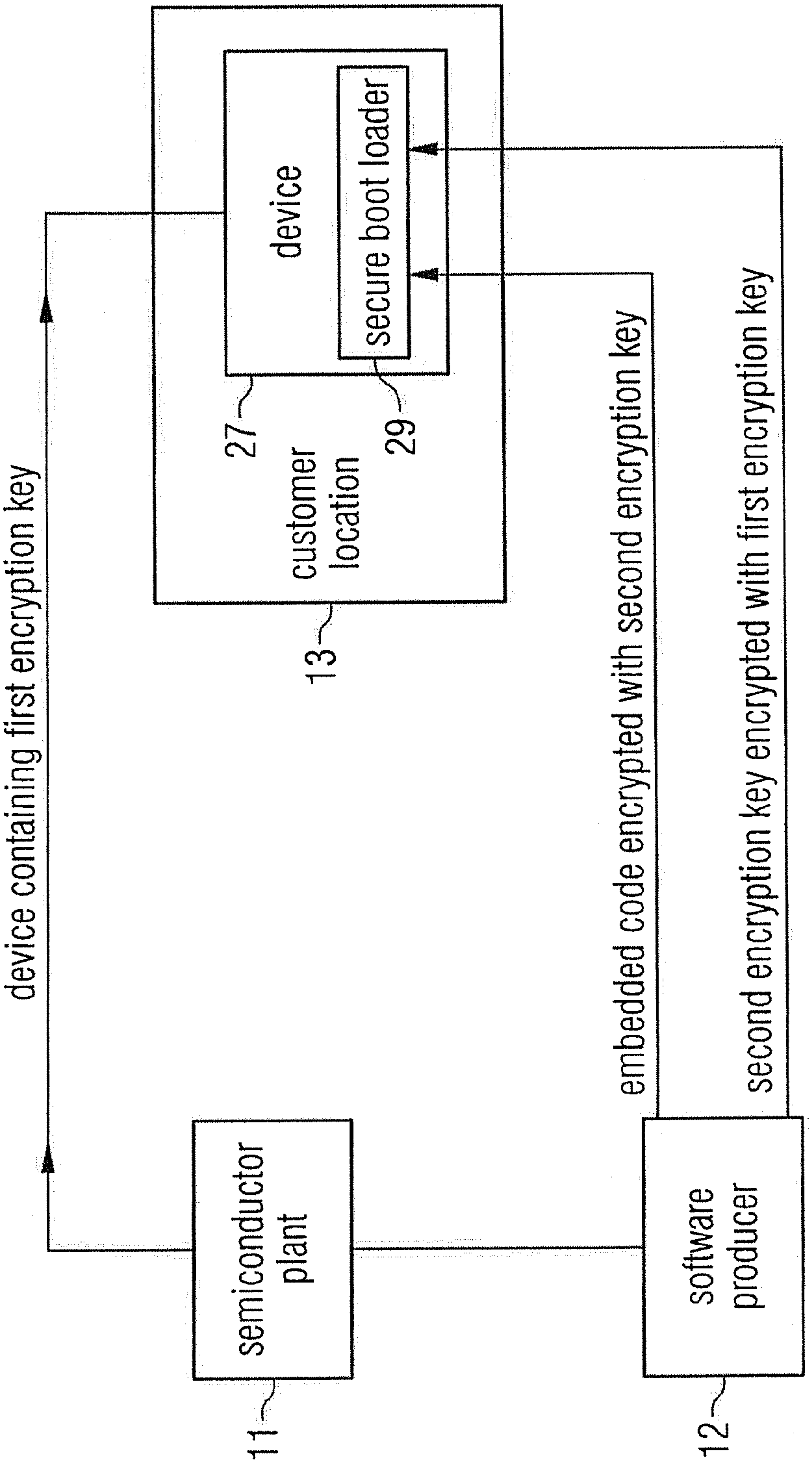
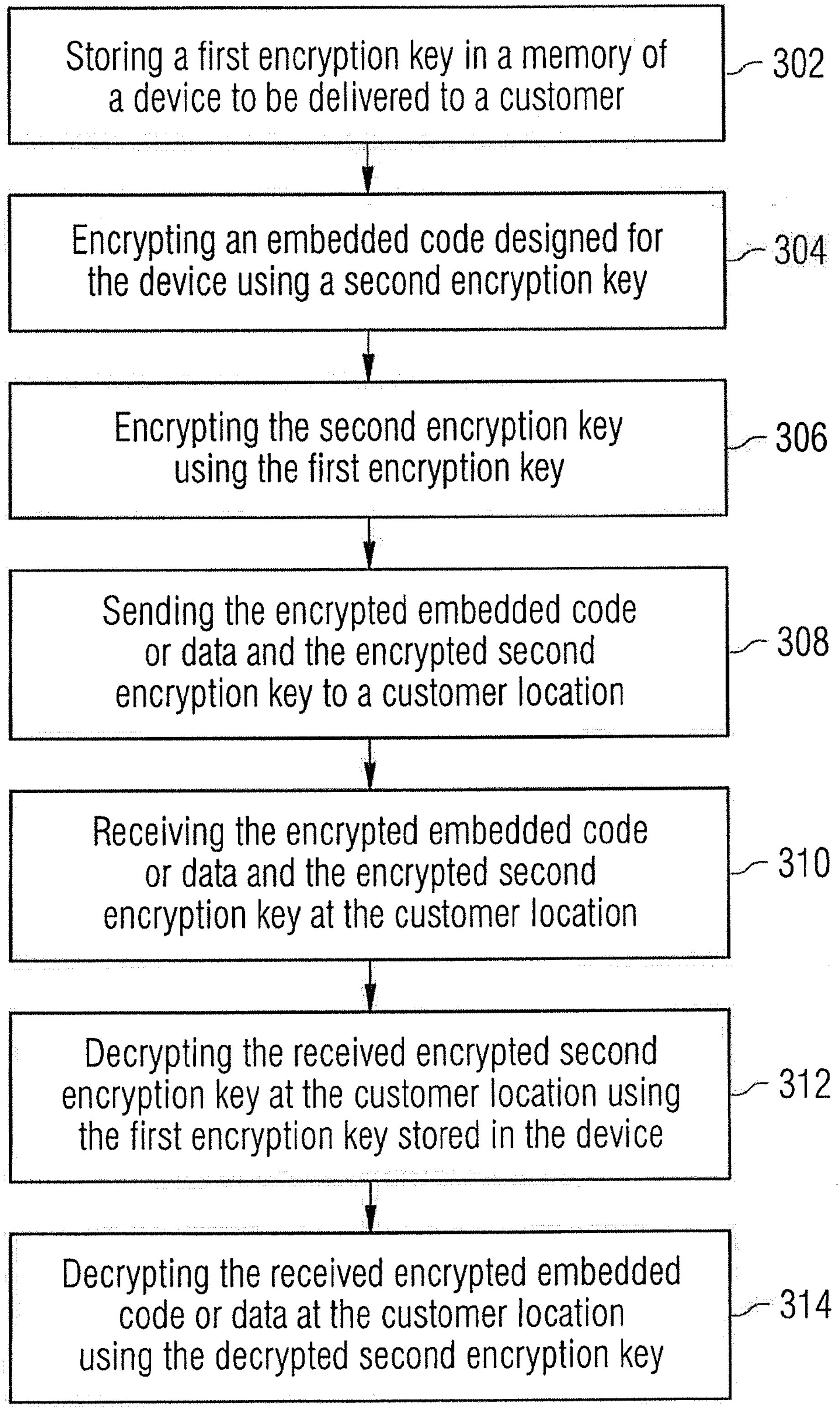

semiconductor plant
11
software producer
12
device containing first encryption key
embedded code encrypted with second encryption key
second encryption key encrypted with first encryption key
customer location
13
device
27
secure boot loader
29

FIG 3


Storing a first encryption key in a memory of a device to be delivered to a customer
302
Encrypting an embedded code designed for the device using a second encryption key
304
Encrypting the second encryption key using the first encryption key
306
Sending the encrypted embedded code or data and the encrypted second encryption key to a customer location
308
Receiving the encrypted embedded code or data and the encrypted second encryption key at the customer location
310
Decrypting the received encrypted second encryption key at the customer location using the first encryption key stored in the device
312
Decrypting the received encrypted embedded code or data at the customer location using the decrypted second encryption key
314

METHODS AND SYSTEMS FOR SECURELY TRANSFERRING EMBEDDED CODE AND/OR DATA DESIGNED FOR A DEVICE TO A CUSTOMER

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This patent application is a continuation patent application claiming priority to U.S. patent application Ser. No. 13/687,066 filed Nov. 28, 2012 in the name of Min Wei Ang, et al. entitled "Methods and Systems for Securely Transferring Embedded Code and/or Data Designed for a Device to a Customer" and is hereby incorporated in its entirety.

FIELD

[0002] The invention relates to methods and systems for securely transferring embedded code and/or data to a customer, in particular to methods and systems for securely transferring embedded code, data files and/or program files designed for a device to a customer in order to prevent the embedded code, data files and/or program files from being used on unauthorized devices.

BACKGROUND

[0003] Manufacturers of various devices, such as semiconductor manufacturers, for example, sell their devices, such as integrated circuit components, for example, to different customers. Specialized suppliers provide embedded code or data for the respective devices to configure and/or customize the respective devices according to the demands and requests of the customers. The customers may then program the devices bought from the manufacturer at their location with the embedded code or data obtained from the suppliers.

[0004] This transfer of embedded code or data involves a number of piracy risks. The embedded code or data could leak through grey channels to a pirate production plant which could then program clone hardware using available loader tools from the Internet. The customer could also try to pay less license fees to the software producer by under-declaring the number of produced devices containing the embedded code or data since this information is transparent to the software producer.

[0005] One approach for protecting embedded code or data is to provide the devices to be sold with unique identification numbers so that the software producers can include trap routines in the embedded code. These trap routines freeze the operation of the device if the embedded code is used illegally. However, besides increasing the code size, this scheme can still be reasonably hacked by replacing the trap routines with dummy code.

[0006] Therefore, there exists a need for a method and system for securely transferring embedded code and/or data designed for a device to a customer in order to prevent the embedded code or data from being used on unauthorized devices.

SUMMARY

[0007] In accordance with an aspect of the invention, there is provided a method for securely transferring embedded code and/or data designed by a supplier for a device produced by a manufacturer to a customer. The method comprises storing a first encryption key in a memory of a device to be delivered to a customer, encrypting embedded code and/or data designed for the device using a second encryption key, and encrypting the second encryption key using the first encryption key.

[0008] In accordance with a further aspect of the invention, there is provided a system for securely transferring embedded code and/or data designed for a device to a customer. The system comprises a secure boot loader and a first encryption key stored in a memory of a device. The secure boot loader is configured to receive a second encryption key encrypted with the first encryption key, receive embedded code and/or data designed for the device and encrypted with the second encryption key, decrypt the received encrypted second encryption key using the first encryption key stored in the device, and decrypt the embedded code and/or data using the decrypted second encryption key.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The accompanying drawings are included to provide a further understanding of the present invention and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments of the present invention and together with the description serve to explain the principles of the invention. Other embodiments of the present invention and many of the intended advantages of the present invention will be readily appreciated as they become better understood by reference to the following detailed description.

[0010] FIG. **1** shows a simplified schematic diagram of an example environment wherein a system according to an embodiment of the invention may be implemented.

[0011] FIG. **2** shows a simplified schematic diagram of a further example environment wherein a system according to a further embodiment of the invention may be implemented.

[0012] FIG. **3** shows an example method according to an embodiment of the invention.

DETAILED DESCRIPTION

[0013] In the following detailed description, reference is made to the accompanying drawings, which form a part thereof, and in which is shown by way of illustration specific embodiments in which the invention may be practiced. It is to be understood that other embodiments may be utilized and structural or other changes may be made without departing from the scope of the present invention. The following detailed description, therefore, is not to be taken in a limiting sense, and the scope of the present invention is defined by the appended claims.

[0014] FIG. **1** shows a simplified schematic diagram of an example environment wherein a system according to an embodiment of the invention may be implemented. A device **17** is produced by a manufacturer, e.g. a semiconductor manufacturer, at the manufacturer's location, e.g. a semiconductor plant **11**, sold to a customer and delivered to the customer location **13**. In addition, a supplier which can be a software producer **12** in this example, provides the customer with an embedded code or data designed for the device **17** bought by the customer. The customer will then program the device **17** bought from the manufacturer at their location **13** with the embedded code or data provided by the supplier or software producer **12** in this example. The customer can be a distributor which customizes the devices, a company which integrates the devices in their own products, or a user, for example.

[0015] This transfer of embedded code or data involves a number of piracy risks. The embedded code or data could leak through grey channels to a pirate production plant which could then program clone hardware using available loader tools from the Internet. The customer could also try to pay less license fees to the supplier by under-declaring the number of produced devices containing the embedded code or data since this information is transparent to the supplier.

[0016] In order to protect the embedded code or data from unauthorized access and use, an encryption scheme for securely transferring the embedded code or data to a customer has been developed.

[0017] According to an embodiment of the invention, the (semiconductor) manufacturer provides each device with an encryption key which may be stored in a memory, such as a flash memory, of the device **17**. Thus, the customer obtains an encryption key together with the ordered device **17**.

[0018] The supplier or, in this example, software producer **12**, provides the embedded code or data designed for the device **17** to the customer in encrypted form, i.e. encrypted with the encryption key.

[0019] However, in order to avoid revealing the encryption key to the software producer, the (semiconductor) manufacturer may perform the encryption of the embedded code or data with the encryption key.

[0020] Alternatively, the manufacturer may provide the software producer with an identification (ID) number allocated to the respective device to enable the software producer to generate the encryption key based on the ID number using a master key or a database. The thus generated encryption key is used to encrypt the embedded code or data without revealing the encryption key itself. Though the software producer may generate the encryption key as an intermediate result, this intermediate result is a direct input to the encryption of the embedded code or data and is otherwise not accessible. Thus, also in this case, the software producer does not get knowledge of the encryption key as this key is an intermediate result within a closed process which is protected from external access.

[0021] The software producer **12** may then transmit the encrypted code/data to the customer location **13**. At the customer location **13**, the encrypted embedded code/data is received and fed to the secure boot loader **19** of the device **17** to program the device **17**. The secure boot loader **19** decrypts the encrypted embedded code/data and stores the decrypted embedded code/data in a memory, in particular a flash memory, of the device **17**.

[0022] FIG. **2** shows a simplified schematic diagram of a further example environment wherein a system according to a further embodiment of the invention may be implemented.

[0023] A device **27** is produced by a manufacturer, e.g. a semiconductor manufacturer, at the manufacturers location, e.g. a semiconductor plant **11**, sold to a customer and delivered to the customer location **13**. In addition, a supplier which can be a software producer **12** in this example, provides the customer with an embedded code or data designed for the device **27** bought by the customer. The customer will then program the device **27** bought from the manufacturer at their location **13** with the embedded code or data provided by the supplier or software producer **12** in this example. The customer can be a distributor which customizes the devices, a company which integrates the devices in their own products or a user, for example.

[0024] In this embodiment which provides an increased protection of the embedded code or data, the (semiconductor) manufacturer provides each device with a first encryption key which may be stored in a memory, such as a flash memory, of the device **27**. Thus, the customer obtains the first encryption key together with the ordered device **27**.

[0025] The supplier or, in this example, software producer **12** provides the embedded code or data designed for the device **27** to the customer in encrypted form, in this case, encrypted with a second, different encryption key. The second encryption key for encrypting the embedded code or data is also transmitted to the customer in encrypted form, wherein the second encryption key is encrypted with the first encryption key.

[0026] However, in order to avoid revealing the first encryption key to the supplier, the manufacturer may perform the encryption of the second encryption key with the first encryption key and provide the software producer with the encrypted second encryption key.

[0027] Alternatively, the semiconductor manufacturer may provide the software producer **12** with an identification (ID) number allocated to the respective device to enable the software producer **12** to generate the first encryption key based on the ID number using a master key or a database. The reproduced first encryption key is used to encrypt the second encryption key without revealing the first encryption key itself: Though the software producer **12** may generate the first encryption key as an intermediate result, this intermediate result is directly input to the encryption process for the second encryption key and is otherwise not accessible. Thus, also in this case, the software producer does not get knowledge of the first encryption key as it is an intermediate result within a closed process which is protected from external access.

[0028] The software producer **12** then transmits both the encrypted embedded code/data and the encrypted second encryption key to the the customer location.

[0029] At the customer location, the encrypted embedded code/data and the encrypted second encryption key are received and fed to the secure boot loader **29** of the device **27**. The secure boot loader **29** decrypts the encrypted second encryption key using the first encryption key stored within the device **27**, decrypts the embedded code or data using the decrypted second encryption key and stores the decrypted embedded code/data in a memory, e.g. a flash memory, of the device **27**. The embedded code or data can then be used for programming the device **27**.

[0030] In both embodiments described above, received encrypted data may be downloaded first into a random access memory (RAM) of the device **17** and **27**, respectively, using the secure boot loader **19** and **29**, respectively, which may be part of the firmware of the device **17** and **27**, respectively. The secure boot loader **19** and **29**, respectively, may be in the form of a flash memory as well. Based on the type of data, the secure boot loader **19** and **29**, respectively, may then perform the decryption and programming to targeted locations on a flash memory.

[0031] With the encryption key controlled system, the specific number of devices authorized to run or use the embedded code or data is controllable and may also be provided to the software producers as a value-added service. By including different (first) encryption keys in the devices produced by the semiconductor manufacturer, the number of devices which can use the encrypted embedded code or data is limited. The group of devices which are allocated a common encryption key is arbitrary. For example, one unique encryption key may be allocated to one batch of devices or to all devices provided to a certain customer. Even a unique encryption key could be allocated to each single device which would, however, involve rather high administrative effort.

[0032] In the embodiment wherein the software producer generates a second encryption key, the software producer obtains a rough estimation of distributed embedded codes/data. Given that a separate second encryption key is generated for each first encryption key, the total number of distributed codes/data may be obtained by multiplying the number of generated second encryption keys by the number of devices which are furnished with a common first encryption key.

[0033] With the encryption key controlled system and/or the corresponding method described above, further data and/or codes for configuring devices may securely be transferred, too. The task of device variant configuration may be delegated to the customer by providing the customer with an encrypted file which performs the desired configuration when executed. For example, special hardware features may be enabled or disabled, such as access to memory regions, etc. In particular, a specific set of hardware features required for a certain embedded code may also be activated by such a file transmitted in encrypted form. Similarly, an encrypted peripheral activation code (PAC) may be transmitted to the customer so that the customer can tailor a feature set according to the application's needs and unlock dedicated peripherals. Furthermore, a customer may also be offered the possibility to upgrade a device bought in the past by purchasing the appropriate encrypted file which activates the desired additional features when executed.

[0034] Furthermore, an update of the second encryption key may be facilitated by securely transferring the new second encryption key in encrypted form, encrypted with the first encryption key, for example.

[0035] Any encryption algorithm may be used in order to provide suitable encryption means for the embodiments of the invention. Accordingly, encryption may be based on symmetric encryption algorithms such as AES (Advanced Encryption Standard), DES (Data Encryption Standard), Triple-DES, Blowfish, Serpent, Twofish, etc., or public-key cryptography also called asymmetric key cryptography which uses asymmetric key algorithms (e.g. RSA). One embodiment of the invention uses AES as encryption algorithm.

[0036] A hybrid cryptosystem may also be used. The hybrid cryptosystem is itself a public-key system, which encapsulates a symmetric-key scheme. Thus, for a large library software, the bulk of the work in encryption/decryption could be done by the more efficient symmetric-key scheme, while the inefficient public-key scheme is only used to encrypt/decrypt a short session key value. As soon as the session key is decrypted using the private key, the efficient implementation of the symmetric-key decryption may be used for flash programming. In a hybrid system, the first encryption key used in embodiments described above may be an asymmetric key and the second encryption key may be a symmetric key, for example.

[0037] FIG. **3** shows an example method according to an embodiment of the invention, in particular, a method for securely transferring embedded code or data designed by a supplier for a device produced by a manufacturer to a customer. The example method comprises storing a first encryption key in a memory of a device to be delivered to a customer at **302**, and encrypting embedded code or data designed for the device using a second encryption key at **304**. The method further comprises encrypting the second encryption key using the first encryption key at **306**, sending the encrypted embedded code or data and the encrypted second encryption key to a customer location at **308**, and receiving the encrypted embedded code or data and the encrypted second encryption key at the customer location at **310**. Still further, the method comprises decrypting the received encrypted second encryption key at the customer location using the first encryption key stored in the device at **312**, and decrypting the received encrypted embedded code or data at the customer location using the decrypted second encryption key at **314**. It is, however, to be appreciated that the order of steps depicted in FIG. **3** and described above is only one example sequence and many other sequences of actions are also possible.

[0038] Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that a variety of alternate and/or equivalent implementations may be substituted for the specific embodiments shown and described without departing from the scope of the present invention. This application is intended to cover any adaptations or variations of the specific embodiments discussed herein. Therefore, it is intended that this invention be limited only by the claims and the equivalents thereof.

1. A device comprising:

a secure boot loader;

a first encryption key stored in a memory of the device;

wherein the secure boot loader is configured to:

receive a second encryption key encrypted with the first encryption key;

receive embedded code or data encrypted with the second encryption key;

decrypt the received encrypted second encryption key using the first encryption key; and

generate decrypted embedded code or data using the decrypted second encryption key.

2. The device of claim **1**, wherein the decrypted embedded code comprises embedded software code to program the device.

3. The device of claim **1**, wherein the secure boot loader is further configured to:

store the decrypted embedded code or data in a data storage of the device.

4. The device of claim **3**, wherein the data storage comprises a flash memory.

5-**7**. (canceled)

8. The device of claim **1**, wherein the device is a semiconductor device.

9. The device of claim **1**, wherein a firmware is stored on the device, the firmware comprising the secure boot loader.

10. (canceled)

11. The device of claim **1**, wherein the first encryption key is based on an identification number (ID) associated with the device.

12. A system for securely decrypting embedded code or data, the system comprising:

a device comprising a boot loader; and

a first encryption key,

wherein the boot loader is configured to:

receive a second encryption key encrypted with the first encryption key; and decrypt the received encrypted second encryption key using the first encryption key.

13. The system of claim **12**, wherein the boot loader is further configured to:

receive embedded code or data designed for the device and encrypted with the second encryption key; and

decrypt the embedded code or data using the decrypted second encryption key.

14. The system of claim **13**, comprising:

a plurality of devices, each of the plurality of devices comprising a respective boot loader configured to:

receive the second encryption key encrypted with the first encryption key;

receive the embedded code or data encrypted with the second encryption key;

decrypt the received encrypted second encryption key using the first encryption key; and

decrypt the embedded code or data using the decrypted second encryption key.

15. A method for decrypting embedded code or data by a device comprising a boot loader, the method comprising:

receiving a second encryption key encrypted with a first encryption key;

receiving embedded code or data encrypted with the second encryption key;

decrypting the received encrypted second encryption key using the first encryption key; and

generating, by the boot loader of the device, decrypted embedded code or data using the decrypted second encryption key.

16. The method of claim **15**, wherein the first encryption key is generated based on an identification number of the device.

17. The method of claim **15**, wherein the second encryption key is generated by a manufacturer of the device.

18. The method of claim **15**, wherein the decrypted embedded code comprises code to enable a feature set of the device.

19. The method of claim **15**, wherein the decrypted embedded code comprises code to enable or disable special hardware features of the device.

20. The method of claim **15**, wherein the decrypted embedded code comprises peripheral activation code (PAC).

21. The device of claim **1**, wherein the decrypted embedded code comprises code to enable a feature set of the device.

22. The device of claim **1**, wherein the decrypted embedded code comprises code to enable or disable special hardware features of the device.

23. The device of claim **1**, wherein the decrypted embedded code comprises peripheral activation code (PAC).

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