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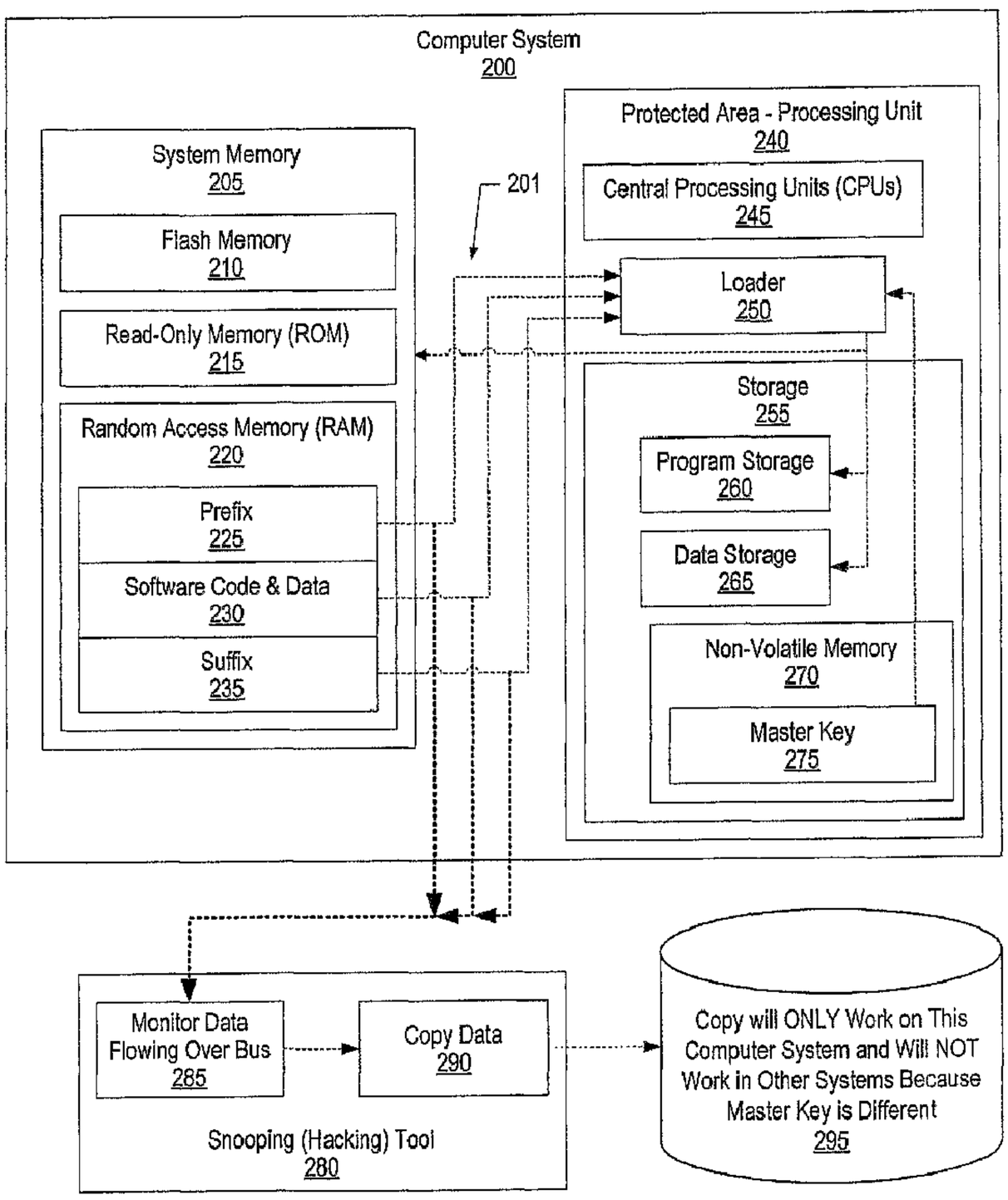
(54) Titre : SYSTEME ET PROCEDE D'AUTHENTIFICATION DE LOGICIEL AU MOYEN DE CLES INTERMEDIAIRES CACHEES

(54) Title: SYSTEM AND METHOD FOR AUTHENTICATING SOFTWARE USING HIDDEN INTERMEDIATE KEYS



(57) Abrégé/Abstract:
A processing unit (300) includes a read-only encryption key (394). Loader code image (250) is loaded into system memory (205) from non-volatile storage (270). Loader code image (250) includes a prefix value (225) and a suffix value (235). The prefix value

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(57) Abrégé(suite)/Abstract(continued):
(225) is combined with the master key (394) from the processing unit (300) to create a random value that is the seed for a hashing algorithm. The hashing algorithm uses the seed value with a signature formed from the blocks of code to form a result. During the hashing algorithm, intermediate key values are generated and stored in a memory area inaccessible by the user. The intermediate key values are used by the loader code after the loader has been authenticated and loaded. The loader combines one or more of the intermediate key values with prefix and suffix values that correspond to other software modules to authenticate the software, using a hashing algorithm, and load the software upon authentication.

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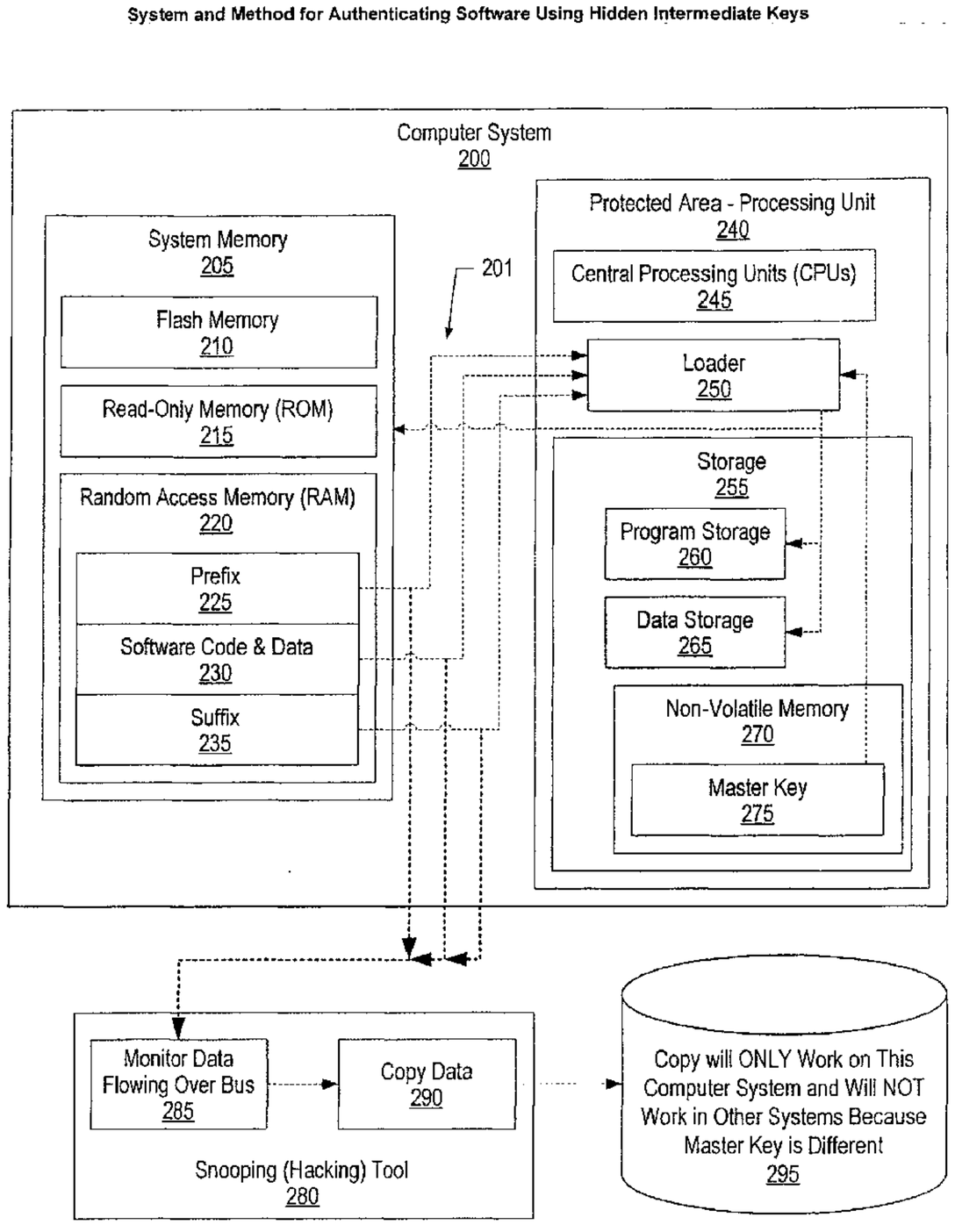
(54) Title: SYSTEM AND METHOD FOR AUTHENTICATING SOFTWARE USING HIDDEN INTERMEDIATE KEYS



(57) Abstract: A processing unit (300) includes a read-only encryption key (394). Loader code image (250) is loaded into system memory (205) from non-volatile storage (270). Loader code image (250) includes a prefix value (225) and a suffix value (235). The prefix value (225) is combined with the master key (394) from the processing unit (300) to create a random value that is the seed for a hashing algorithm. The hashing algorithm uses the seed value with a signature formed from the blocks of code to form a result. During the hashing algorithm, intermediate key values are generated and stored in a memory area inaccessible by the user. The intermediate key values are used by the loader code after the loader has been authenticated and loaded. The loader combines one or more of the intermediate key values with prefix and suffix values that correspond to other software modules to authenticate the software, using a hashing algorithm, and load the software upon authentication.

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System and Method for Authenticating Software Using Hidden Intermediate Keys

BACKGROUND OF THE INVENTION

1. Technical Field

The present invention relates in general to a system and method for authenticating software. More particularly, the present invention relates to a system and method for using a master key and hidden intermediate keys located on a computer system for authenticating software.

2. Description of the Related Art

In our modern society, software is increasingly becoming one of the most valuable technologies. Software controls devices, such as appliances, automobiles, telephones, and especially computer systems. Computer systems exist in a variety of forms. These forms include traditional desktop and notebook computers, as well as pervasive computing devices such as mobile telephones, and personal digital assistants (PDAs). In addition, software is used for entertainment purposes, such as games designed for personal computers as well as games designed for specialized gaming devices.

Large amounts of time, money, and resources are dedicated

towards creating software. Many companies derive all or most of their income from creating software. Software programs sold by these companies include customized software that is written for particular environment or client, as well as off-the-shelf software that is designed in written for larger group of users.

Because software is so valuable, and because computers make it easy to create an exact copy of a program, software piracy is widespread. Software pirates range from individual computer users to professionals who deal wholesale with stolen software. Software piracy exists in homes, schools, businesses, and governments.

Anti-piracy measures that have previously been employed include encrypting the software program. In this manner, the user is provided with a "key" for opening the software along with the encrypted software program. Only a user with the right key can decrypt the software. A challenge of this method, however, is that experienced hackers can analyze the memory containing the executable form of the decrypted code and create a non-encrypted version. The non-encrypted version can then be distributed to others who no longer need to use the "key" to open the software.

Another anti-piracy measure is to use a device, often

called a "dongle," that must be used in order for the software to operate. The device includes a key that is checked by the software before the software will operate. One challenge of this method is that users are often forced to have several devices that they must attach to computers prior to loading the software program. Another challenge is that experienced hackers can read the key being provided by the attached device and create a copy of the device or provide the key value using another software program.

Figure 1 is a block diagram showing how a hacker monitors a system bus to illegally copy program data in the prior art. Computer system **100** includes system memory **110** and processing core **130** that are interconnected with system bus **125**. System memory **110** is where software program and data **120** are stored, typically after being read from a nonvolatile storage area, such as a disk drive or a nonvolatile memory. Protected area **130** is a packaged component that includes one or more central processing units (CPUs) **135** and a small amount of storage **140** that is used for program storage **145** and data storage **150**. Storage **140** may include registers, RAM, and other types of memory. Because of size constraints of the protected area package, the amount of storage **140** is typically far less than the amount of memory included in system memory **110**, and is usually insufficient to contain a complete working copy of the

software program and data. This then requires the software code and data to reside in executable form in system memory **110**.

Even if the source of the software stored in system memory **110** is encrypted, the program and data must first be decrypted before it can be processed by the CPUs. A hacker may then use a hacking, or snooping, tool **170** in order to capture an executable form of the software program and data during this decryption process. The hacker's snooping tool monitors the decrypted data that flows over the system bus from the protected area to the system memory (step **175**) and copies the data (step **180**), creating illegal copy **190**. Illegal copy **190** is not encrypted (even if the original program was encrypted) and can be executed on any computer system that is compatible with the software.

Encryption and authentication keys are generally more susceptible of being hacked by a hacker the more times the hacker is able to view the results of using the encryption or authentication keys. The hacker is able to use algorithms and other techniques to identify an encryption key that remains constants. These algorithms and techniques tend to be more successful when the hacker has more results to analyze. What is needed, therefore, is a system and method for authenticating software using intermediate keys that are generated using a hidden algorithm that is performed on a

hidden master key in order to limit the hacker's ability to analyze results based upon the master key.

SUMMARY

A processing unit includes a read-only encryption key that is unique, random, and non-trivial. Software is loaded into a system memory area from a non-volatile storage device. The system memory area may include flash memory, read-only memory (ROM), random access memory (RAM) or any other type of storage. Code images that reside in the system storage area include a prefix value and a suffix value. The prefix value is combined with the master key from the processing unit to create a random value using a mathematical operation, such as an exclusive OR (XOR) operation. The random number is used as the "seed" or starting value for the hashing algorithm, such as SHA-256. The seed value is used as the initial result in the hashing algorithm. Software code that follows the seed value is read in blocks, such as 512 byte blocks. The hashing algorithm uses the seed value with a signature formed from the newly read block of code to form a result. This result is then used by the hashing algorithm along with the next block of code to form a new result. Processing loops through each block of code with read block producing a new intermediate

result value. Finally, after the last block has been processed, the final result value will be left as the result of the complete hashing operation.

Intermediate results from the hashing algorithm are stored in a secure memory area for use by programs, such as a software loader. In addition, intermediate results can be mathematically combined with the master key so that the intermediate keys can be subsequently authenticated using the secure master key. When exiting the secure state, an exit function cleans up the memory area storing the intermediate keys so that no one is able to analyze the keys and hack the master key that is stored on the processing unit.

In one embodiment, a "micro-loader" is stored in a protected area (i.e., ROM) of a semiconductor package along with a master key that is stored in a nonvolatile memory area in the semiconductor package. The micro-loader is used to authenticate a more full-functioning software loader using the master key. One or more intermediate keys resulting from the hashing algorithm that was performed on the full-functioning software loader are stored in a memory area (e.g., registers, nonvolatile memory, etc.) within the semiconductor package. The full-functioning software loader uses the intermediate keys to authenticate other software modules. In this manner, only the full-functioning software loader is authenticated

using the master key, while other software modules are authenticated using intermediate keys that do not expose the master key. When the full-functioning loader is finished analyzing a software module, the intermediate keys are erased from memory so that a hacker is unable to view the keys in his quest to discover the system's master key. In addition, while the micro-loader cannot be changed without modifying (i.e., replacing) the semiconductor package, the full-function loader can be replaced by providing the computer systems with a new or upgraded version of the full-function loader along with the prefix and suffix values for the new version of the loader.

The foregoing is a summary and thus contains, by necessity, simplifications, generalizations, and omissions of detail; consequently, those skilled in the art will appreciate that the summary is illustrative only and is not intended to be in any way limiting. Other aspects, inventive features, and advantages of the present invention, as defined solely by the claims, will become apparent in the non-limiting detailed description set forth below.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention may be better understood, and its numerous objects, features, and advantages made apparent to

those skilled in the art by referencing the accompanying drawings.

Figure 1 is a block diagram showing how a hacker monitors a system bus to illegally copy program data in the prior art;

Figure 2 is a block diagram showing the present invention preventing copies from executing on other devices;

Figure 3 is a block diagram of a computing device capable of implementing the present invention;

Figure 4 is a flowchart showing steps taken to initialize hardware with a protected master key that is inaccessible outside the processor core;

Figure 5 are high level flowcharts showing steps taken to distribute devices and software to customers and for the customers to load software;

Figure 6 is a flowchart showing steps taken to distribute software with authentication data;

Figure 7 is a flowchart showing steps taken at the customer's device to load software authenticated using a master key;

Figure 8 is a flowchart showing steps taken to authenticate software based upon hash results;

Figure 9 is a system diagram showing a micro-loader used to load a software loader into a protected area of a processing unit;

Figure 10 is a flowchart showing hardware initialization

with a micro-loader and master key written to a protected area of the processing core;

Figure 11 are high level flowcharts showing steps taken to distribute devices and software utilizing a micro-loader stored in a protected processing area and a loader which is authenticated by the micro-loader;

Figure 12 is a flowchart showing steps taken to distribute the device with a micro-loader, loader, and authentication keys;

Figure 13 is a flowchart showing steps taken to distribute software that is adapted to be loaded by a device using a micro-loader and a loader;

Figure 14 is a flowchart showing steps taken to prepare a software image with authentication information for delivery to a customer;

Figure 15 is a flowchart showing steps taken by a customer's device to load software using authentication by a micro-loader and loader;

Figure 16 is a flowchart showing steps taken to authenticate and load the loader software generating a secondary key; and

Figure 17 is a flowchart showing steps taken to authenticate and load the software using a secondary key.

DETAILED DESCRIPTION

The following is intended to provide a detailed description of an example of the invention and should not be taken to be limiting of the invention itself. Rather, any number of variations may fall within the scope of the invention, which is defined in the claims following the description.

Figure 1 is a block diagram showing how a hacker monitors a system bus to illegally copy program data in the prior art. See the background section, above, for details regarding the prior art.

Figure 2 is a block diagram showing the present invention preventing copies from executing on other devices. Computer system **200** includes system memory **205** and processing core **240** that are interconnected with system bus **201**. System memory **205** is where software code and data **230** are stored, typically after being read from a nonvolatile storage area, such as a disk drive or a nonvolatile memory. System memory may include flash memory **210**, read-only memory (ROM) **215**, and random-access memory (RAM) **220**. Unlike the prior art, the software image stored in system memory **205** includes prefix **225** and suffix **235** used to authenticate the software.

Protected area **240** is a packaged component that includes one or more central processing units (CPUs) **245** and a small

amount of storage **255** that is used for program storage **260** and data storage **265**. Storage **255** may include registers, RAM, and other types of memory. Because of size constraints of the protected area package, the amount of storage **255** is typically far less than the amount of memory included in system memory **205**. Storage **255** also includes a small amount of nonvolatile memory **270**, such as nonvolatile RAM or programmable fuses (e-fuses). Master key **275**, used to authenticate software, is stored in the nonvolatile memory. Master key **275** is designed to be a unique (per protected package), non-trivial and random number of sufficient length (i.e., 256 bits) to enable strong authentication. Because the master key is included in the protected package, the only way a hacker would be able to read the master key is by physically removing layers from the packaging in order to expose the value of the master key, destroying the protected area in the process. Thus, while the hacker could obtain the value of the master key in a particular machine, that machine would be destroyed by the hacker's process and the master key obtained would be different from the master keys stored on other machines.

Protected area **240** also includes loader **250**. Loader **250** is a specialized process used to load software and authenticate it using master key **275**. Because both loader **250** and master key **275** are within protected package **240**, the

master key is not transmitted over bus **201** or over any bus or communication line that exits the protected package.

A hacker uses a hacking, or snooping, tool **280** in order to attempt to copy the software program and data. The hacker's snooping tool monitors the data, including the prefix value, the software code and data, and the suffix value that flows over the system bus from the system memory to the protected area (step **285**) and copies the data (step **290**), creating copy **295**. However, because the master key was never transmitted over the bus, the hacker was unable to obtain the master key value. Because master key values are preferably unique, non-trivial, random numbers, the hacker's copy of the software will only operate on the computer system from which it was copied. Importantly, the copied data (prefix value, software code and data, and suffix value) will not operate on a different machine because the other machine has a different master key that will not work with the copy. See the description for **Figure 5**, below, for details on how the authentication process works using the prefix and suffix values.

Figure 3 illustrates information handling system **301** which is a simplified example of a computer system capable of performing the computing operations described herein. Computer system **301** includes processing unit **300** that is

packaged in a semiconductor package and coupled to host bus **305**. Protected processing unit includes one or more processors **391**, processor storage **392** used to load and execute software programs from main memory **308**, software loader **393** used to authenticate and load software programs, and locked nonvolatile memory area **394** which is used to store a master key that is only accessible from within processing unit **300** and is not transmitted across host bus **302**. Processing unit 300 is connected to host bus **302**. A level two (L2) cache memory **304** is also coupled to host bus **302**. Host-to-PCI bridge **306** is coupled to main memory **308**, includes cache memory and main memory control functions, and provides bus control to handle transfers among PCI bus **310**, processor **300**, L2 cache **304**, main memory **308**, and host bus **302**. Main memory **308** is coupled to Host-to-PCI bridge **306** as well as host bus **302**. Devices used solely by host processor(s) **300**, such as LAN card **330**, are coupled to PCI bus **310**. Service Processor Interface and ISA Access Pass-through **312** provides an interface between PCI bus **310** and PCI bus **314**. In this manner, PCI bus **314** is insulated from PCI bus **310**. Devices, such as flash memory **318**, are coupled to PCI bus **314**. In one implementation, flash memory **318** includes BIOS code that incorporates the necessary processor executable code for a variety of low-level system functions and system boot functions.

PCI bus **314** provides an interface for a variety of devices that are shared by host processor(s) **300** and Service Processor **316** including, for example, flash memory **318**. PCI-to-ISA bridge **335** provides bus control to handle transfers between PCI bus **314** and ISA bus **340**, universal serial bus (USB) functionality **345**, power management functionality **355**, and can include other functional elements not shown, such as a real-time clock (RTC), DMA control, interrupt support, and system management bus support. Nonvolatile RAM **320** is attached to ISA Bus **340**. Service Processor **316** includes JTAG and I2C busses **322** for communication L2 cache **304**, Host-to-PCI bridge **306**, and main memory **308** providing a communications path between the processor, the Service Processor, the L2 cache, the Host-to-PCI bridge, and the main memory. Service Processor **316** also has access to system power resources for powering down information handling device **301**.

Peripheral devices and input/output (I/O) devices can be attached to various interfaces(e.g., parallel interface **362**, serial interface **364**, keyboard interface **368**, and mouse interface **370** coupled to ISA bus **340**. Alternatively, many I/O devices can be accommodated by a super I/O controller (not shown) attached to ISA bus **340**.

In order to attach computer system **301** to another computer system to copy files over a network, LAN card **330** is

coupled to PCI bus **310**. Similarly, to connect computer system **301** to an ISP to connect to the Internet using a telephone line connection, modem **375** is connected to serial port **364** and PCI-to-ISA Bridge **335**.

While the computer system described in **Figure 3** is capable of executing the processes described herein, this computer system is simply one example of a computer system. Those skilled in the art will appreciate that many other computer system designs are capable of performing the processes described herein.

Figure 4 is a flowchart showing steps taken to initialize hardware with a protected master key that is inaccessible outside the processor core. Processing commences at **400** whereupon a random, unique, non-trivial master key value is generated (step **405**). At step **410**, processing attempts to write the generated master key value to a nonvolatile memory location in protected processor area **415** of the machine that is being initialized. The protected processor area includes a nonvolatile memory, such as a programmable "e-fuse" array **420**. The nonvolatile memory location to which the master key value is written is lockable so that once the master key value is written to the nonvolatile memory location and verified, the master key cannot be altered or removed. Lock key bit **425** includes a bit that, once set, cannot be changed. If the lock

key has been set, the path used to write to nonvolatile memory area **420** is made inoperative.

A determination is made as to whether the nonvolatile memory location to which the master key value is written has already been locked (decision **435**). If the nonvolatile memory location has already been locked, decision **435** branches to "yes" branch **445** whereupon an error is returned indicating that the nonvolatile memory location has already been locked (step **445**) and processing ends at **490**.

On the other hand, if the nonvolatile memory location has not already been locked, decision **435** branches to "no" branch **455** whereupon the lock key controlling access to the nonvolatile memory location is set (step **460**), permanently locking the nonvolatile memory location. The serial number of the machine being initialized is recorded along with the master key value (step **470**) in secure database **480**. Master key values are stored in a secure database (i.e., one that is protected using encryption and unable to be infiltrated by network hackers) so that hackers and other individuals do not gain access to the master key values which would allow the hacker to circumvent the software authenticity that is provided through the use of the master keys. Processing thereafter ends at **490**.

Figure 5 are high level flowcharts showing steps taken to distribute devices and software to customers and for the customers to load software. Distribute device processing commences at **500** whereupon the device (i.e., machine) is built with a unique master key stored in a locked nonvolatile memory location and a loader programmed to load and authenticate software based upon the master key (step **503**). As shown in **Figure 4**, the master key value and device identifier (i.e., serial number) are stored in secure database **512**. At step **506**, device **515** (with the included master key and loader) is shipped to a consumer. Distribute device processing thereafter ends at **509**.

Consumer processing commences at **518** whereupon the consumer receives the device with the embedded master key (step **521**). At step **524**, the consumer orders software for the device by sending order form **527** to a software distributor or retailer. Order form **527** may be electronic (i.e., an Internet order), paper based (i.e., a mailed form), a telephone order, or an order placed at a retail location.

Distribute software processing commences at **530** whereupon the software distributor receives the order along with the device identifier (i.e., serial number) of the consumer's device (step **533**). The master key value corresponding to the device is retrieved (step **536**) from secure database **512**. A

prefix value is created based upon the retrieved master key (step **539**). In one embodiment, an exclusive or (XOR) operation is performed between a random value and the retrieved master key to create the prefix value.

A hashing algorithm, such as SHA-256, is "seeded" with the random number used to generate the prefix value (step **542**). Seeding the hashing algorithm sets the initial result of the hashing algorithm to the seed value, whereupon the hashing algorithm uses the result along with a hash of all or a portion of the software code, to generate additional results. A suffix value is then generated (step **545**). In one embodiment, the final result from the hashing algorithm hashing the requested program code is XORed with the master key to create the suffix value. A software image that includes the prefix value, the software code, and the suffix value is packaged together into software image **550** and delivered to the consumer (step **548**). Distribute software processing thereafter ends at **551**.

Returning to consumer processing, the consumer receives the created software image at step **560**. When the user wishes to use the software, he installs and/or loads the software and invokes the software (step **563**). In some computing environments, software is first installed by copying the software image to a nonvolatile storage device, such as a hard

disk. In another environment, often used with game consoles, the software program is packaged onto a module that is inserted into the game console whereupon the software is automatically invoked.

During the loading process, the loader (located in the protected area of the device) determines the seed value used in the hashing algorithm based upon the prefix value included in the software image and the master key (step **566**). In one embodiment, the prefix value is XORed with the master key to generate the seed value. The hashing algorithm (e.g., SHA-256) is seeded with the seed value and hashes the software code included in the software image (step **569**). The final result from the hashing algorithm is retrieved (step **572**). An expected result value is generated using the master key to check the final result. In one embodiment, the expected result is generated by performing an exclusive OR operation on the suffix value read from the software image and the master key (step **575**).

A determination is made as to whether the result from the hashing algorithm is equal to the expected result (decision **578**). If the values are equal, decision **578** branches to "yes" branch **581** whereupon the software code is loaded (i.e., executed) by the processor, at step **584**. On the other hand, if the values are not equal (indicating that the software has

been altered or that the software is not being used on the device for which it was ordered), decision **578** branches to "no" branch **587** bypassing the loading operation shown in step **584**. Consumer processing thereafter ends at **590**.

Figure 6 is a flowchart showing steps taken to distribute software with authentication data. Distribution processing commences at **600** whereupon, at step **608**, order **604** is received for a particular software product. Order **604** includes both the customer's unique device identifier, such as a serial number, along with an identifier corresponding to the requested software product. At step **612**, the master key corresponding to the consumer's device is retrieved from secure master key data store **616**.

A prefix value is created based upon the master key at step **620**. In one embodiment, the prefix value is created by XORing a random number with the master key. In step **628**, a hashing algorithm, such as SHA-256, is seeded with a value based on the prefix value and the master key. In one embodiment, the hashing algorithm is seeded with the random number used to create the prefix value. The hashing algorithm is seeded by storing the seed value (e.g., the random number) as the initial value of the hashing result (memory location **632**).

At step **636**, the requested software is located in software library **640**. In the example shown, the requested software is software module **648**. At step **652**, the first block of software code is read from the requested software module **648**. At step **656**, the block of software code that was read is passed to a hashing algorithm, such as SHA-256. At step **660**, the hashing algorithm receives the block of software code and the seed value stored in result **632**. The result of the hashing algorithm is stored in result **632**, overwriting the previous (seed) result value.

A determination is made as to whether the end of file has been reached on the software code (decision **664**). If the end of file has not been reached, decision **664** branches to "no" branch **668** which loops back to read the next block of software code and process the next block using the hashing algorithm. This time, the hashing algorithm uses the read block of data along with the result from the prior hashing operation to hash the block of code. This looping continues until the end of file is reached on software code **648**, whereupon decision **664** branches to "yes" branch **672**.

At step **676**, a suffix value is created based upon the master key corresponding to the device and the final result from the hashing algorithm. In one embodiment, the suffix value is created by XORing the final result from the hashing

algorithm with the master key.

At step **684**, software image **688** is created by packaging the prefix value, the software code (i.e., software module **648**) and the suffix value into the software image file and sending the software image file to the customer. Distribution processing thereafter ends at **695**.

Figure 7 is a flowchart showing steps taken at the customer's device to load software authenticated using a master key. The loader is a process embedded within a protected semiconductor package within the device. The semiconductor package also includes one or more processors and the master key. In this manner, the loader is able to retrieve and use the master key without ever transmitting the master key across a system or memory bus outside of the protected semiconductor package.

Processing commences at **700** whereupon a load request is received for a particular software component (step **705**). At step **710**, master key **720** corresponding to the device is retrieved from locked nonvolatile memory area **715**. In one embodiment, the locked nonvolatile memory area is a set of programmable fuses (e-fuses) that, after being successfully loaded with the master key during creation of the device, is locked by setting a lock bit that prevents the master key from

being altered or removed.

At step **725**, prefix value **735** for the software module being loaded is retrieved from software image **732** stored on nonvolatile storage device **730**, such as a hard disk or nonvolatile memory, located outside of the protected semiconductor package. Software image **732** includes prefix value **735**, software code **745**, and suffix value **750**.

In step **755**, a hashing algorithm, such as SHA-256, is seeded with a value based on the prefix value and the master key. In one embodiment, the hashing algorithm is seeded with the random number used to create the prefix value. In one embodiment, the seed value is generated by XORing the master key and the prefix value. The hashing algorithm is seeded by storing the seed value (e.g., the random number) as the initial value of the hashing result (memory location **765**).

At step **770**, the first block of software code is read from the requested software module **745**. At step **775**, the block of software code that was read is passed to a hashing algorithm, such as SHA-256. At step **780**, the hashing algorithm receives the block of software code and the seed value stored in result **765**. The result of the hashing algorithm is stored in result **765**, overwriting the previous (seed) result value.

A determination is made as to whether the end of file has been reached on the software code (decision **782**). If the end of file has not been reached, decision **782** branches to "no" branch **784** which loops back to read the next block of software code and process the next block using the hashing algorithm. This time, the hashing algorithm uses the read block of data along with the result from the prior hashing operation to hash the block of code. This looping continues until the end of file is reached on software code **745**, whereupon decision **782** branches to "yes" branch **786**.

A determination is made as to whether to software has been altered or whether the master key for which the software was created is different from the master key included in the device (predefined process **790**, see **Figure 8** and corresponding text for processing details). Loader processing thereafter ends at **795**.

Figure 8 is a flowchart showing steps taken to authenticate software based upon hash results. This routine is called from predefined process **790**, shown in **Figure 7**.

The loader's check hash results processing commences at **800** whereupon, at step **805**, master key **815** is retrieved from nonvolatile memory area **810** that is included in the protected semiconductor package. At step **820**, suffix value **840** for the

software that is being loaded is retrieved. The suffix value is part of software image **828**. Software image **828** is stored in a storage area, such as system memory, outside of the protected semiconductor package. The software image also includes prefix value **830** and software code **835**.

An expected result value is computed based upon the retrieved suffix value and the master key (step **845**). In one embodiment, the expected result is generated by XORing the master key with the suffix value. At step **855**, the actual result from the hashing operation (result **860**) is retrieved from a memory location located inside of the protected semiconductor package. The actual result was previously generated using the processing shown on **Figure 7**.

A determination is made as to whether the expected result is equal to the actual result (decision **870**). If the expected result and the actual result are equal, decision **870** branches to "yes" branch **875** whereupon the software code is executed by the processor at step **880**. On the other hand, if the results are not the same, decision **870** branches to "no" branch **885** whereupon an error is returned at step **890** and the software code is not executed. When the expected result is not the same as the actual result, either the software code was altered or the software was created for a different device with a different master key than the device from which the

load request was issued. The loader's check hash results processing thereafter returns to the calling routine at **895**.

Figure 9 is a system diagram showing a micro-loader used to load a software loader into a protected area of a processing unit. Computer system **900** includes unprotected storage **905**, such as system memory, disk devices, and the like, and protected semiconductor package **955** that includes packaged semiconductor components that interconnect within the package without use of a bus. Unprotected storage **905** and protected semiconductor package **955** communicate with one another using one or more busses, **950**.

Unprotected storage **905** stores software loader image **910** and application program image **930**. Each of these software images include a prefix value (**915** and **935**, respectively), software code (**920** and **940**, respectively), and a suffix value (**925** and **945**, respectively).

Protected semiconductor package **955** includes one or more processors **960**, and storage **965**. Storage **965** includes a read-only memory (ROM) of micro-loader code **970**. The micro-loader is a scaled-down loader that is written to authenticate and load software loader **910**. Software loader is a more robust loader that is designed to load application programs, such as application **930**. In addition, micro-loader **970** is stored in

read-only memory and, therefore, cannot be changed or altered without replacing the protected semiconductor package. Software loader **910**, on the other hand, is stored in alterable memory, such as a hard disk, and can therefore be updated if errors in the loader are found or when enhancements or other modifications to the loader are created.

Storage **965** also includes program storage **975** into which both software loader **910** and application program **930** are loaded, in storage areas **980** and **985**, respectively, in order to be executed by the processors. Storage further includes a memory location for storing intermediate keys **990** that are generated by the micro-loader while loading the software loader. Finally, storage **965** includes a locked nonvolatile memory **992**, such as programmable fuses (e-fuses). Nonvolatile memory **992** is inaccessible from outside the protected semiconductor package. Nonvolatile memory **992** is used to store master key **995** which is a unique, random, nontrivial value of a sufficient length (e.g., 256 bits). After the device is created and the master key is stored in the nonvolatile memory, the nonvolatile memory is locked, thereby preventing further operations from altering or removing the master key.

Figure 10 is a flowchart showing hardware initialization with a micro-loader and master key written to a protected area

of the processing core. Hardware initialization commences at **1000** whereupon, at step **1004**, a random, unique, nontrivial master key value is generated of a sufficient length (i.e., 256 bits). The generated master key is stored in memory location **1008**.

In step **1012**, a prefix value is created based upon the generated master key and stored in memory location **1016**. In one embodiment, the prefix value is created by XORing the generated master key with another random number. In step **1020**, a hashing algorithm, such as SHA-256, is seeded using a value based upon the prefix value, such as the random number used to generate the prefix value. The seed value is used as an initial result **1024** of the hashing algorithm.

At step **1028**, the first block of software loader code is read. The software loader code is the software loader that is loaded by the micro-loader. At step **1032**, the block of software code that was read is passed to a hashing algorithm, such as SHA-256. At step **1036**, the hashing algorithm receives the block of the software loader code and the seed value stored in result **1024**. The result of the hashing algorithm is stored in result **1024**, overwriting the previous (seed) result value.

A determination is made as to whether the end of file has

been reached on the software loader code (decision **1040**). If the end of file has not been reached, decision **1040** branches to "no" branch **1042** which loops back to read the next block of software loader code and process the next block using the hashing algorithm. This time, the hashing algorithm uses the read block of software loader code along with the result from the prior hashing operation to hash the block of code. This looping continues until the end of file is reached on the software loader, whereupon decision **1040** branches to "yes" branch **1044**.

At step **1048**, a suffix value is created based upon the master key and the final result resulting from the hashing algorithm and stored in memory location **1052**. In one embodiment, the master key and final result are XORed to create the suffix value. At step **1056**, the software loader image **1078** is created by packaging the loader code along with the prefix and suffix values and stored. Software loader image **1078** is stored on nonvolatile storage device **1076**, such as a disk drive or nonvolatile memory, which is accessible from protected processing core **1064** and included in information handling system **1060**. Protected processing core **1064** also includes micro-loader software, stored in ROM, that is programmed to use the master key to load and authenticate the loader code included in loader image **1078**.

At step **1080**, the generated master key is written to nonvolatile memory **1070** located within protected processing core **1064**. Nonvolatile memory **1070** is also locked using lock key **1072**. Locking the nonvolatile memory prevents any process from altering or removing the master key.

At step **1084**, the unique identifier, such as a serial number, of the hardware being initialized is written to secure database **1088** along with the device's master key value and the version of the software loader (loader image **1078**) that was stored on the device's nonvolatile storage device. Hardware initialization processing thereafter ends at **1095**.

Figure 11 are high level flowcharts showing steps taken to distribute devices and software utilizing a micro-loader stored in a protected processing area and a loader which is authenticated by the micro-loader. Provider processing, used to distribute devices and software, commences at **1100**. The device is built with a unique master key included in a protected processor core area (predefined process **1110**, see **Figure 12** and corresponding text for processing details) and the master key value and device identifier written to secure database **1115**. At step **1120**, the device (device **1125**) is shipped to a customer.

Consumer processing commences at **1130** whereupon, at step

1135, the consumer receives the device that has a master key embedded in its protected processor core area. At step **1140**, the consumer orders software for the device and transmits order **1145** to a producer of the software.

Returning to producer processing, the producer receives customer's order **1145** that includes the unique identifier, such as the device serial number. The producer retrieves the master key value corresponding to the device from database **1115** in order to create software image **1170** (predefined process **1150**, see **Figures 13** and **14** and corresponding text for processing details). Thereafter, producer processing ends at **1160**.

Returning to consumer processing, the consumer receives the software image corresponding to the ordered software at step **1175**. When the consumer uses the device to load the software, the software loader is loaded by the micro-loader (predefined process **1180**, see **Figures 15** and **16** and corresponding text for processing details). Once the software loader has been loaded and authenticated, the software loader loads and authenticates the software program (predefined process **1190**, see **Figures 15** and corresponding text for processing details). Consumer processing thereafter ends at **1195**.

Figure 12 is a flowchart showing steps taken to distribute the device with a micro-loader, loader, and authentication keys. The processing shown in **Figure 12** is called from predefined process **1110** shown in **Figure 11**.

Device creation processing commences at **1200** whereupon, at step **1205**, a unique, random, and nontrivial master key is generated and stored in memory location **1210**. At step **1215**, the master key is stored in a nonvolatile memory area located within protected area **1225** of the processor core within device **1220**. After the master key is stored, the nonvolatile memory area in the protected area is locked so that the master key cannot be altered or removed.

At step **1240**, micro-loader program **1235** is stored in ROM in the processor core. The micro-loader is unable to be read or altered from outside the protected area of the device. At step **1245**, another random number is generated. A prefix value is calculated based upon the generated random number and the master key (step **1250**). In one embodiment, the prefix is calculated by XORing the master key with the random number.

At step **1255**, a hashing algorithm, such as SHA-256, is seeded with the random number generated in step **1245** and software loader **1260** is hashed using the hashing algorithm. A suffix value is then calculated, at step **1265**, by combining

the result of the hashing algorithm with the master key. In one embodiment, the master key and the result from the hashing algorithm are XORed to create the suffix value. At step **1270**, loader image **1275** is created using the prefix value, the suffix value, and the loader code. The loader image is stored in an unprotected area, such as a disk drive or other nonvolatile memory location, within device **1220** in an area accessible by the protected processor core.

At step **1280**, the device identifier (i.e., serial number) is stored along with the device's master key value, loader version, and prefix value in secure database **1285**. Device creation processing thereafter returns at **1295**.

Figure 13 is a flowchart showing steps taken to distribute software that is adapted to be loaded by a device using a micro-loader and a loader. The processing shown in **Figure 13** is called from predefined process **1150** shown in **Figure 11**.

Software distribution processing commences at **1300** whereupon the master key, loader version, and loader prefix value corresponding to the customer's device are retrieved (step **1305**) from secure database **1310**. At step **1315**, a hashing algorithm, such as SHA-256, is seeded with a value based upon the loader prefix and the master key. In one

embodiment, the seed value is created by XORing the master key with the loader prefix value. The hashing algorithm is seeded by storing the seed value (e.g., the random number resulting from the XOR operation) as the initial value of the hashing result (memory location **1320**).

A secondary key count is retrieved at step **1325**. The secondary key count indicates the number of iterations of the hashing algorithm that are performed after which the current result is used as a secondary key value. For example, if the secondary key count is "10", then after the hashing algorithm iterates 10 times, whatever result is in result memory area **1320** is used as a secondary key by the software loader. At step **1330**, a counter that is used to track the number of iterations is initialized to zero.

At step **1335**, the first block of the loader code that is installed on the customer's device is read from memory area **1340**. At step **1345**, the counter is incremented to indicate that the hashing algorithm has been performed once and, at step **1350**, the block of code is processed using the hashing algorithm. At step **1355**, the hashing algorithm receives the block of software code and the seed value stored in result **1320**. The result of the hashing algorithm is stored in result **1320**, overwriting the previous (seed) result value.

A determination is made as to whether the counter is equal to the secondary key count constant (decision **1360**). If the counter has not yet reached the secondary key count, decision **1360** branches to "no" branch **1365** whereupon processing loops back to process the next block of loader code and increment the counter. This looping continues until the counter is equal to the secondary key count, at which point decision **1360** branches to "yes" branch **1370**.

At step **1375**, the secondary key value is set to the current result resulting from a number of iterations of the hashing algorithm. The software application, such as an application program or game software, is then processed using the secondary key value (predefined process **1380**, see **Figure 14** and corresponding text for processing details). Processing thereafter returns to the calling procedure at **1395**.

Figure 14 is a flowchart showing steps taken to prepare a software image with authentication information for delivery to a customer. The processing shown in **Figure 14** is called from predefined process **1380** shown in **Figure 13**.

Processing to create an image of the requested software commences at **1400** whereupon a random number is generated at step **1410**. A prefix value is determined based upon the random number and the secondary key value (step **1420**, see **Figure 13**

for a details on the creation of the secondary key value). In one embodiment, an exclusive or (XOR) operation is performed between the random value and the secondary key value to create the prefix value. In step **1425**, a hashing algorithm, such as SHA-256, is seeded using a value based upon the prefix value, such as the random number used to generate the prefix value. The seed value is used as an initial result **1430** of the hashing algorithm.

At step **1435**, the first block of software code **1438** requested by the user is read. At step **1440**, the block of software code that was read is passed to a hashing algorithm, such as SHA-256. At step **1445**, the hashing algorithm receives the block of the software code and the seed value stored in result **1430**. The result of the hashing algorithm is stored in result **1430**, overwriting the previous (seed) result value.

A determination is made as to whether the end of file has been reached on the software code (decision **1450**). If the end of file has not been reached, decision **1450** branches to "no" branch **1455** which loops back to read the next block of software code and process the next block using the hashing algorithm. This time, the hashing algorithm uses the read block of software code along with the result from the prior hashing operation to hash the block of code. This looping continues until the end of file is reached on the software

code, whereupon decision **1450** branches to "yes" branch **1460**.

At step **1470**, a suffix value is created based upon the secondary key and the final result resulting from the hashing algorithm. In one embodiment, the secondary key and final result are XORed to create the suffix value. At step **1475**, software image **1480** is created by packaging the software code along with the prefix and suffix values. At step **1490**, software image **1480** is sent to the customer, either on a nonvolatile medium, through the Internet, or in any other fashion. Processing thereafter returns to the calling routine at **1495**.

Figure 15 is a flowchart showing steps taken by a customer's device to load software using authentication by a micro-loader and loader. The processing shown in **Figure 15** is called from predefined processes **1180** and **1190** shown in **Figure 11**.

The process of loading software on the customer's device commences at **1500** whereupon master key **1515**, located in a locked, nonvolatile storage area within the device's operating core is used to authenticate and load software loader image **1520** and generate secondary key **1525** ((predefined process **1510**, see **Figure 16** and corresponding text for processing details).

A determination is made as to whether the loader was authenticated by the micro-loader (decision **1530**). If the loader was not authenticated, decision **1530** branches to "no" branch **1535** and processing ends at **1540**. On the other hand, if the loader was authenticated by the micro-loader, decision**1530** branches to "yes" branch **1545** whereupon the software requested to be executed by the customer (image **1560**) is authenticated and loaded using the loader software and the secondary key value (predefined process **1550**, see **Figure 17** and corresponding text for processing details).

A determination is made as to whether the software was authenticated (decision **1570**). If the software was not authenticated, decision **1570** branches to "no" branch **1574** whereupon the secondary key values are removed (cleaned up) from processor core storage memory (step **1590**). On the other hand, if the software was authenticated, decision **1570** branches to "yes" branch **1578** whereupon the software code is executed by the processor at step **1580** and the secondary keys are removed (cleaned up) from processor core storage memory at step **1590**. Processing thereafter returns to the calling routine at **1595**.

Figure 16 is a flowchart showing steps taken to authenticate and load the loader software generating a secondary key. The processing shown in **Figure 16** is called

from predefined processes **1510** shown in **Figure 15**.

Micro-loader processing used to authenticate and load the software loader commences at **1600** whereupon, in step **1605**, master key **1615** for the device is retrieved by the micro-loader from locked nonvolatile memory and the prefix value corresponding to software loader image **1610** is retrieved from a non-protected area (e.g., system memory).

At step **1620**, a hashing algorithm, such as SHA-256, is seeded with a value based upon the loader prefix and the master key. In one embodiment, the seed value is created by XORing the master key with the loader prefix value. The hashing algorithm is seeded by storing the seed value (e.g., the random number resulting from the XOR operation) as the initial value of the hashing result (memory location **1625**).

A secondary key count is retrieved at step **1630**. The secondary key count indicates the number of iterations of the hashing algorithm that are performed after which the current result is used as a secondary key value. For example, if the secondary key count is "10", then after the hashing algorithm iterates 10 times, whatever result is in result memory area **1625** is used as a secondary key by the software loader. In one embodiment, the secondary key count is retrieved from the locked nonvolatile memory area that is used to store the master key. At step **1635**, a counter that is used to track the

number of iterations is initialized to zero.

At step **1640**, the first block of the loader code that is installed on the customer's device is read from loader image **1610**. At step **1645**, the counter is incremented to indicate that the hashing algorithm has been performed once and, at step **1650**, the block of code is processed using the hashing algorithm. At step **1655**, the hashing algorithm receives the block of software code and the seed value stored in result **1625**. The result of the hashing algorithm is stored in result **1625**, overwriting the previous (seed) result value.

A determination is made as to whether the counter is equal to the secondary key count constant (decision **1660**). If the counter has not yet reached the secondary key count, decision **1660** branches to "no" branch **1662** whereupon processing loops back to process the next block of loader code and increment the counter. This looping continues until the counter is equal to the secondary key count, at which point decision **1660** branches to "yes" branch **1668** whereupon, at step **1669**, the secondary key value is set to the current result resulting from a number of iterations of the hashing algorithm.

A determination is made as to whether the end of the software loader file has been reached (decision **1670**). If the end of the file has not been reached, decision **1670** branches

to "no" branch **1672** whereupon processing loops back to process the next block of code from the software loader using the hashing algorithm. This looping continues until the end of file has been reached, at which point decision **1670** branches to "yes" branch **1674**.

At step **1675**, the expected result is determined based upon the suffix value and the master key. In one embodiment, the expected result is calculated by XORing the master key with the suffix value. A determination is made as to whether the result resulting from the hashing algorithm is equal to the expected result (decision **1680**). If the result from the hashing algorithm is equal to the expected result, decision **1680** branches to "yes" branch **1685** whereupon the software loader is executed at step **1690**. On the other hand, if the result resulting from the hashing algorithm is not equal to the expected result (indicating that either the loading program was altered or that the loading program found on the device is a different loading program than the one originally shipped with the device), then decision **1680** branches to "no" branch **1692** bypassing the execution of the software loading program. Processing thereafter returns to the calling routine at **1695**.

Figure 17 is a flowchart showing steps taken to authenticate and load the software using a secondary key. The

processing shown in **Figure 17** is called from predefined processes **1550** shown in **Figure 15** after the secondary key has been determined using the processing shown in **Figure 16**.

In **Figure 17**, processing used to authenticate and load software using a secondary key value commences at **1700**. At step **1710**, the secondary key value (determined using the processing shown on **Figure 16** and stored in a memory area within the protected processing core) is retrieved along with the prefix value for software image **1725**.

In step **1725**, a hashing algorithm, such as SHA-256, is seeded using a value based upon the prefix value, such as a random number that was used to generate the prefix value. The seed value is used as initial result **1740** of the hashing algorithm. In one embodiment, an exclusive or (XOR) operation is performed between secondary key **1720** and the prefix value resulting in the random number that was originally used in creating the prefix value. This random number is used to seed the hashing algorithm.

At step **1750**, the first block of the software code included in software image **1725** is read. At step **1755**, the block of software code that was read is passed to a hashing algorithm, such as SHA-256. At step **1760**, the hashing algorithm receives the block of the software code and the seed

value stored in result **1740**. The result of the hashing algorithm is stored in result **1740**, overwriting the previous (seed) result value.

A determination is made as to whether the end of file has been reached on the software code (decision **1765**). If the end of file has not been reached, decision **1765** branches to "no" branch **1768** which loops back to read the next block of software code and process the next block using the hashing algorithm. This time, the hashing algorithm uses the read block of software code along with the result from the prior hashing operation to hash the block of code. This looping continues until the end of file is reached on the software code, whereupon decision **1765** branches to "yes" branch **1770**.

At step **1775**, an expected result value is created using the suffix value from software image **1725** and secondary key value **1720**. In one embodiment, these two values are XORed to generate the expected result. A determination is made as to whether the result resulting from the hashing algorithm is equal to the expected result (decision **1780**). If the result from the hashing algorithm is equal to the expected result, decision **1780** branches to "yes" branch **1785** whereupon the software program is executed at step **1790**. On the other hand, if the result resulting from the hashing algorithm is not equal to the expected result (indicating that either the

software program was altered or that the software program found on the device was created for a different device using a different set of keys), then decision **1780** branches to "no" branch **1792** bypassing the execution of the software program. Processing thereafter returns to the calling routine at **1795**.

One of the preferred implementations of the invention is a client application, namely, a set of instructions (program code) in a code module that may, for example, be resident in the random access memory of the computer. Until required by the computer, the set of instructions may be stored in another computer memory, for example, in a hard disk drive, or in a removable memory such as an optical disk (for eventual use in a CD ROM) or floppy disk (for eventual use in a floppy disk drive), or downloaded via the Internet or other computer network. Thus, the present invention may be implemented as a computer program product for use in a computer. In addition, although the various methods described are conveniently implemented in a general purpose computer selectively activated or reconfigured by software, one of ordinary skill in the art would also recognize that such methods may be carried out in hardware, in firmware, or in more specialized apparatus constructed to perform the required method steps.

The use of the words "prefix" and "suffix" to describe authentication values used herein does not imply that such

values need to be located in any particular area relative to the corresponding software code. Rather, such terms are used to describe when the values are used in conjunction with the authentication process. The prefix value is used to determine a seed value for the authentication process, while the suffix value is used to generate an expected result that is in turn compared with a result from the hashing algorithm. The actual prefix and suffix values can be stored either along with their respective software modules, or can be stored separately in a location distinct and apart from the software module.

While particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the art that, based upon the teachings herein, that changes and modifications may be made without departing from this invention and its broader aspects. Furthermore, it is to be understood that the invention is solely defined by the appended claims. It will be understood by those with skill in the art that if a specific number of an introduced claim element is intended, such intent will be explicitly recited in the claim, and in the absence of such recitation no such limitation is present. For non-limiting example, as an aid to understanding, the

following appended claims contain usage of the introductory phrases "at least one" and "one or more" to introduce claim elements. However, the use of such phrases should not be construed to imply that the introduction of a claim element by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim element to inventions containing only one such element, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an"; the same holds true for the use in the claims of definite articles.

AUS9-2003-0406CA1

What is claimed is:

1. A computer implemented method for authenticating software, said method comprising:

authenticating a first computer file stored on a nonvolatile storage area accessible by a computer system, the authenticating of the first computer file performed by:

hashing the first software program using a seed value determined from a prefix value and a master key value that is located in a nonvolatile memory of the computer system inaccessible to a user to create a hash result;

generating one or more intermediate key values during the hashing of the first software program;

storing the intermediate key values in a memory of the computer system inaccessible to the user;

responsive to a determination the hash result matches an expected hash value using the master key value and a suffix value, authenticating a second computer file stored on the nonvolatile storage area, the authenticating of the second computer file performed by hashing the second computer file using a seed value determined from a prefix value of the second computer file and one or more of the intermediate key values to create a hashed result; and

responsive to a determination the hashed result matches an expected hash value result using the intermediate key values and a suffix value of the second computer file, indicating authentication.

2. The method of claim 1 wherein the first computer file is a loader software module, the authentication of the loader software module further comprising:

reading a prefix value and a suffix value from the nonvolatile storage area, wherein the prefix and suffix values correspond to the loader software module;

generating the seed value using the prefix value and the master key value;

seeding the hashing algorithm used to authenticate the loader software module with the seed value;

generating an expected hash value using the suffix value and the master key value;

retrieving a hash result resulting from the hashing of the loader software module; and

comparing the expected hash value of the loader software module with the hash result of the loader software module.

3. The method of claim 2 wherein the generation of the seed value is performed by calculating an exclusive OR value between the master key value and the prefix value.

4. The method of claim 2 wherein the authentication of the loader software module is performed by a micro-loader module.

5. The method of claim 4 wherein the micro-loader is stored on a read-only memory, and wherein the computer system's processor, the read only memory, the nonvolatile memory, and the memory are all packaged within a common semiconductor package.

6. The method of claim 5 wherein the loader software module, the suffix value, and the prefix value are each located on the nonvolatile storage area, wherein the nonvolatile storage area is outside of the common semiconductor package.

7. The method of claim 1 wherein the nonvolatile memory is a locked nonvolatile storage area included in a semiconductor package, the semiconductor package also including one or more processors.

8. The method of claim 1 further comprising:

erasing the intermediate key values following the authentication of the second computer file.

9. The method of claim 1 wherein the first computer file is a loader software module and the second computer file is a software program, the authentication of the software program further comprising:

reading the prefix value and the suffix value from the nonvolatile storage area, the prefix and suffix values corresponding to the software program;

generating the seed value using the prefix value of the software program and one of the intermediate key values;

seeding the hashing algorithm used to authenticate the software program with the seed value;

generating an expected hash value using the suffix value the software program and the intermediate key value;

retrieving a hash result resulting from the hashing of the software program; and

comparing the expected hash value of the software program with the hash result of the software program.

10. The method of claim 9 wherein the authentication of the software program is performed by the software loader module after the software loader module has been authenticated and loaded.

11. The method of claim 9 wherein the generation of the seed value is performed by calculating an exclusive OR value between one of the intermediate key values and the prefix value of the software program.

12. The method of claim 9 wherein a micro-loader is stored on a read-only memory, and wherein the computer system's processor, the read only memory, the nonvolatile memory, and the memory are all packaged within a common semiconductor package, the method further comprising:

invoking the micro-loader to authenticate the loader software module using the master key value, a loader prefix value, and a loader suffix value;

loading and invoking the loader software module in response to the loader software module being authenticated by the micro-loader, wherein the software program is authenticated by the loader software module using the prefix and suffix values of the software module in combination with at least one of the intermediate key values; and

loading and executing the software program in response to the software program being authenticated by the loader software module.

13. An information handling system comprising:

a semiconductor package that includes one or more processors, a memory area, and a locked nonvolatile memory, wherein the locked nonvolatile memory includes a master key value and wherein the locked nonvolatile memory is inaccessible from outside the semiconductor package;

a system memory interconnected to the processors with a bus;

a software loader image comprising a loader prefix value, a software loader routine, and a loader suffix value, wherein the software loader routine is adapted to authenticate and load computer data files, wherein the software loader image is located outside of the semiconductor package; and

a micro-loader routine located within the semiconductor package which is also inaccessible from outside the semiconductor package, wherein the micro-loader is adapted to authenticate and load the software loader routine from the system memory by using the master key value and the prefix and suffix values of the software loader and generate one or more intermediate key values that are stored in the memory area of the semiconductor package.

14. The information handling system of claim 13 further comprising the system, wherein the micro-loader is enabled to:

read the prefix value and a suffix value from a nonvolatile storage area;

generate a seed value using the prefix value of the software loader and the master key value;

seed a hashing algorithm used to authenticate the loader software module with the seed value;

generate an expected hash value using the suffix value of the loader and the master key value;

retrieve a hash result resulting from the hashing of the loader software module; and

compare the expected hash value with the hash result.

15. The information handling system of claim 14 wherein, to generate the seed value, the micro-loader is further enabled to calculate an exclusive OR value between the master key value and the prefix value.

16. The information handling system of claim 13 wherein the locked nonvolatile memory is an array of programmable fuses.

17. The information handling system of claim 13 wherein the software loader routine is enabled to:

read a prefix value and a suffix value from the system memory, the prefix and suffix values corresponding to one of the computer data files;

generate a seed value using the prefix value of the computer data file and one of the intermediate key values;

seed a hashing algorithm used to authenticate the computer data file with the seed value;

generate an expected hash value using the suffix value of the computer data file and the intermediate key value;

retrieve a hash result resulting from the hashing of the computer data file; and

compare the expected hash value with the hash result.

18. The information handling system of claim 17 wherein the authentication of the computer data file is performed by the software loader routine after the software loader routine has been authenticated and loaded by the micro-loader.

19. The information handling system of claim 17 wherein, to generate the seed value, the software loader routine is enabled to calculate an exclusive OR value between one of the intermediate key values and the computer data file's prefix value.

20. The information handling system of claim 17 wherein, to authenticate and load one of the computer data files, the micro-loader is invoked and enabled to:

authenticate the software loader routine using the master key value, the loader prefix value, and the loader suffix value;

create and store the intermediate key values generated during the authentication of the software loader routine;

invoke the software loader routine in response to the software loader routine being authenticated by the micro-loader, wherein the software loader routine, upon being invoked, is enabled to:

authenticate the computer data file using the prefix and suffix values of the computer data file in combination with at least one of the intermediate key values; and

load the computer data file in response to the computer data file being authenticated by the loader software module.

21. The information handling system of claim 20 wherein the computer data file is a software program and the software loader routine is further enabled to execute the software program after the software program is loaded.

22. A computer program product for authenticating software, said computer program product comprising:

processor executable code stored in a computer operable storage media, comprising:

processor executable code for authenticating a first computer file stored on a nonvolatile storage area accessible by a computer system, the authentication of the first computer file performed by processor executable code for hashing the first software program using a seed value determined from a prefix value and a master key value that is located in a nonvolatile memory of the computer system inaccessible to a user to create a hash result;

processor executable code for generating one or more intermediate key values during the hashing of the first software program;

processor executable code for storing the intermediate key values in a memory of the computer system inaccessible to the user; and

processor executable code responsive to a determination the hash result matches an expected hash value using the master key value and a suffix value, for authenticating a second computer file stored on the nonvolatile storage area, the authentication of the second computer file performed by processor executable code for hashing the second computer file using a seed value determined from a prefix value of the second computer file and one or more of the intermediate key values to create a hashed result; and

responsive to a determination the hashed result matches an expected hash value result using the intermediate key values and a suffix value of the second computer file, indicating authentication.

23. The computer program product of claim 22 wherein the first computer file is a loader software module, the authentication of the loader software module further comprising:

processor executable code for reading a prefix value and a suffix value from the nonvolatile storage area, the prefix and suffix values corresponding to the loader software module;

processor executable code for generating a seed value using the loader's prefix value and the master key value;

processor executable code for seeding the hashing algorithm used to authenticate the loader software module with the seed value;

processor executable code for generating an expected hash value using the loader's suffix value and the master key value;

processor executable code for retrieving a hash result resulting from the hashing of the loader software module; and

processor executable code for comparing the expected hash value with the hash result.

24. The computer program product of claim 23 wherein the generation of the seed value is performed by processor executable code for calculating an exclusive OR value between the master key value and the prefix value.

25. The computer program product of claim 23 wherein the authentication of the loader software module is performed by processor executable code for a micro-loader module.

26. The computer program product of claim 25 wherein processor executable code for the micro-loader is stored on a read-only memory, and wherein the computer system processor, the read only memory, the nonvolatile memory, and the memory are all packaged within a common semiconductor package.

27. The computer program product of claim 26 wherein the loader software module, the suffix value, and the prefix value are each located on the nonvolatile storage area, wherein the nonvolatile storage area is outside of the common semiconductor package.

28. The computer program product of claim 22 wherein the nonvolatile memory is a locked nonvolatile storage area included in a semiconductor package, the semiconductor package also including one or more processors.

29. The computer program product of claim 22 further comprising:

processor executable code for erasing the intermediate key values following the authentication of the second computer file.

30. The computer program product of claim 22 wherein the first computer file is a loader software module and the second computer file is a software program, the authentication of the software program further comprising:

processor executable code for reading a prefix value and a suffix value from the nonvolatile storage area, the prefix and suffix values corresponding to the software program;

processor executable code for generating a seed value using the software program's prefix value and one of the intermediate key values;

processor executable code for seeding the hashing algorithm used to authenticate the software program with the seed value;

processor executable code for generating an expected hash value using the suffix value of the software program and the intermediate key value;

processor executable code for retrieving a hash result resulting from the hashing of the software program; and

processor executable code for comparing the expected hash value with the hash result.

31. The computer program product of claim 30 wherein the authentication of the software program is performed by processor executable code of the software loader module after the software loader module has been authenticated and loaded.

32. The computer program product of claim 30 wherein the generation of the seed value is performed by processor executable code for calculating an exclusive OR value between one of the intermediate key values and the prefix value of the software program.

33. The computer program product of claim 30 wherein a micro-loader is stored on a read-only memory, and wherein the computer system's processor, the read only memory, the nonvolatile memory, and the memory are all packaged within a common semiconductor package, the computer program product further comprising:

processor executable code for invoking the micro-loader to authenticate the loader software module using the master key value, a loader prefix value, and a loader suffix value; means for loading and invoking the loader software module in response to the loader software module being authenticated by the micro-loader, wherein the software program is authenticated by the loader software module using the software module's prefix and suffix values in combination with at least one of the intermediate key values; and means for loading and executing the software program in response to the software program being authenticated by the loader software module.

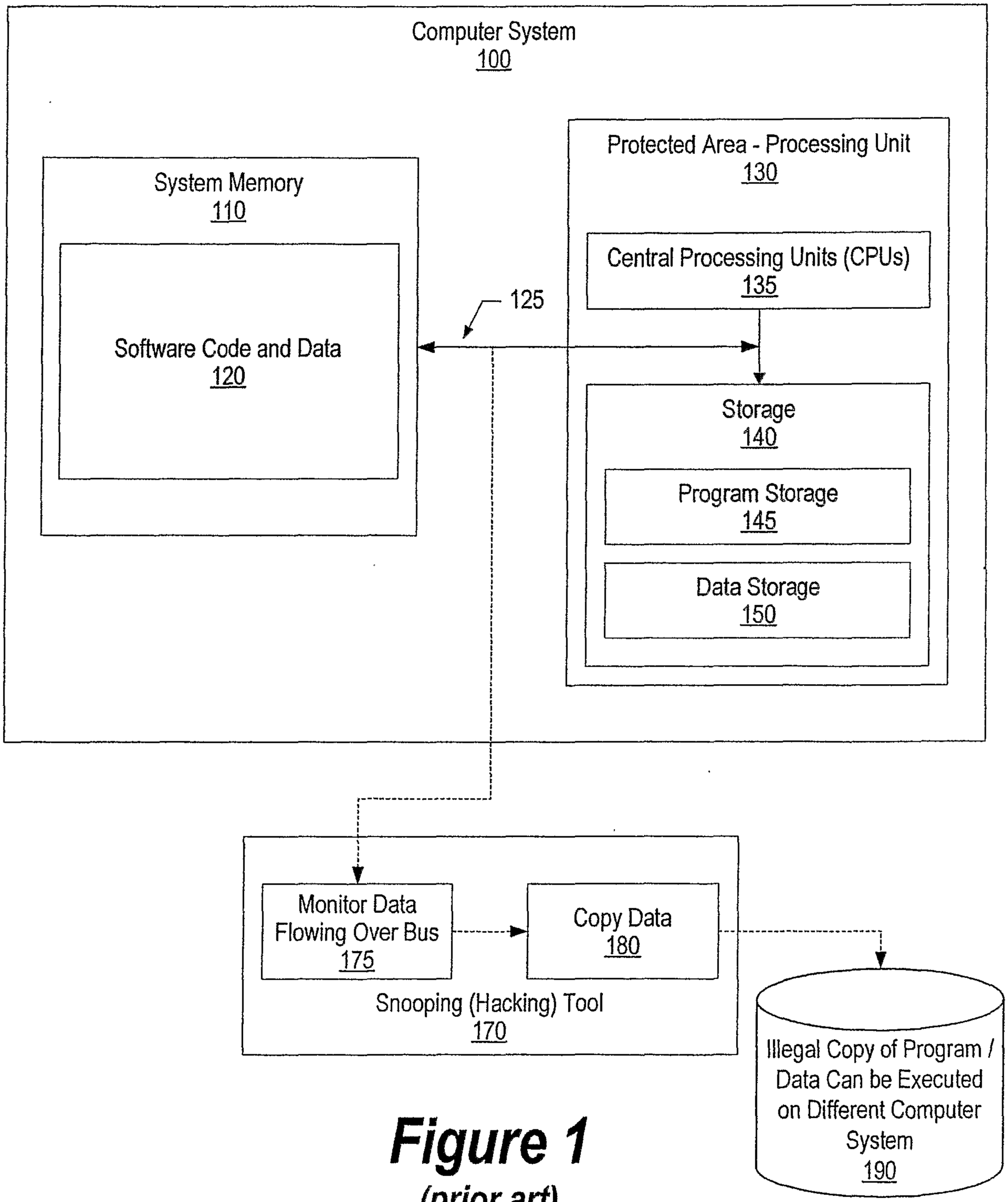

Figure 1
(prior art)

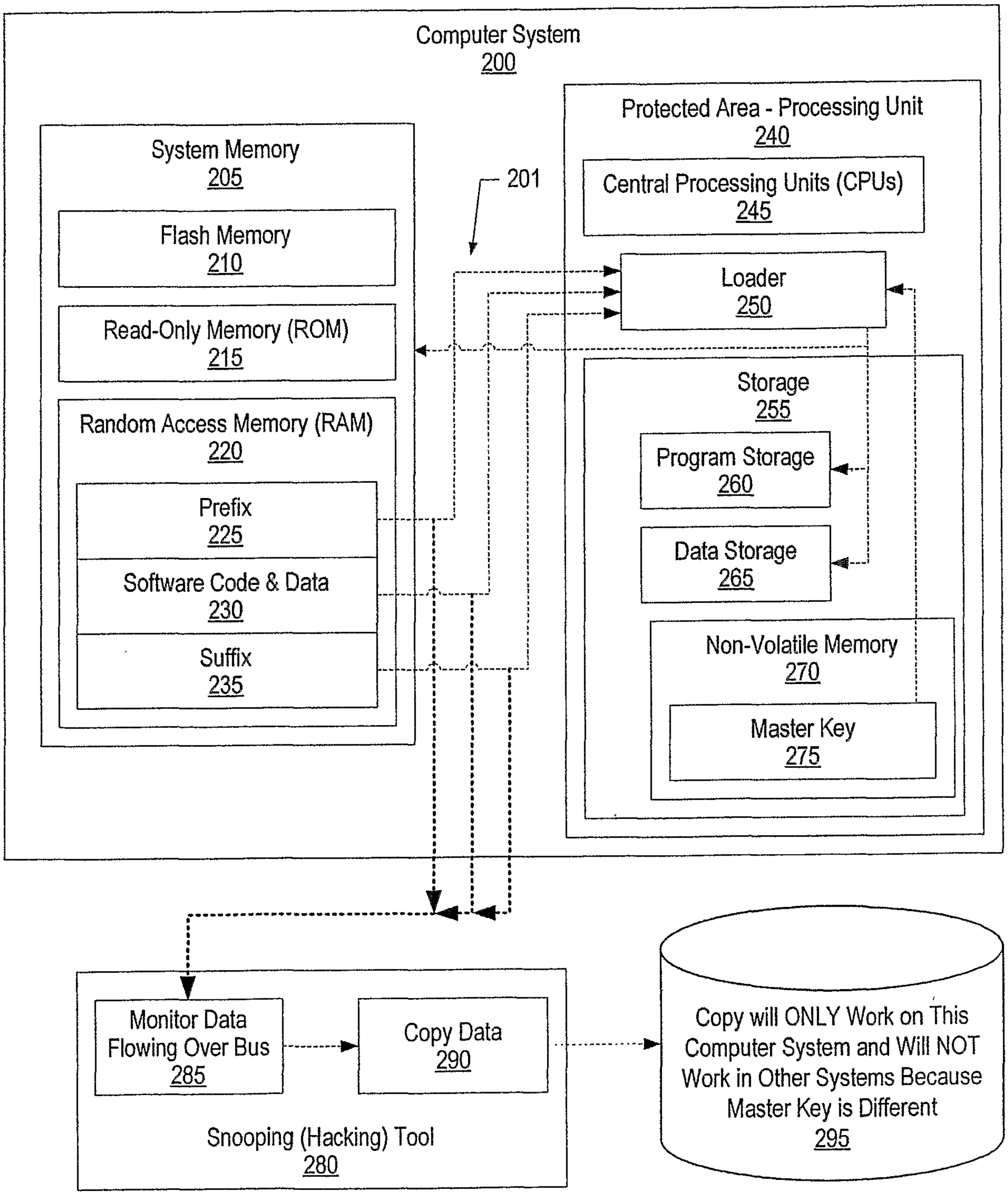
Computer System
200
Protected Area - Processing Unit
240
Central Processing Units (CPUs)
245
201
System Memory
205
Flash Memory
210
Read-Only Memory (ROM)
215
Random Access Memory (RAM)
220
Prefix
225
Software Code & Data
230
Suffix
235
Loader
250
Storage
255
Program Storage
260
Data Storage
265
Non-Volatile Memory
270
Master Key
275
Monitor Data Flowing Over Bus
285
Copy Data
290
Snooping (Hacking) Tool
280
Copy will ONLY Work on This Computer System and Will NOT Work in Other Systems Because Master Key is Different
295

Figure 2

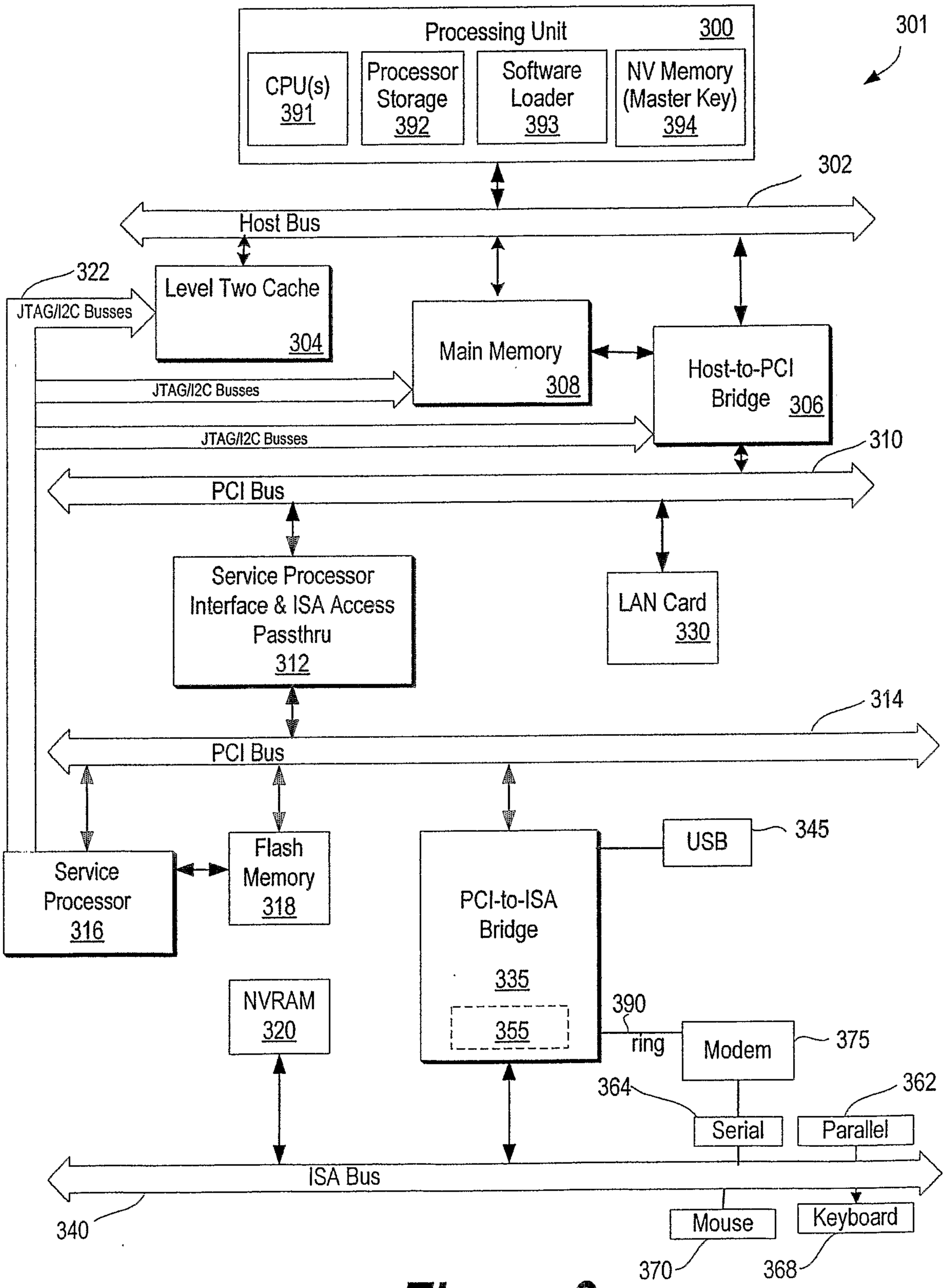
Processing Unit
300
301
CPU(s)
391
Processor
Storage
392
Software
Loader
393
NV Memory
(Master Key)
394
302
Host Bus
322
JTAG/I2C Busses
Level Two Cache
304
Main Memory
308
Host-to-PCI
Bridge
306
JTAG/I2C Busses
JTAG/I2C Busses
310
PCI Bus
Service Processor
Interface & ISA Access
Passthru
312
LAN Card
330
314
PCI Bus
Service
Processor
316
Flash
Memory
318
PCI-to-ISA
Bridge
335
355
USB
345
NVRAM
320
390
ring
Modem
375
364
362
Serial
Parallel
ISA Bus
340
Mouse
Keyboard
370
368

Figure 3

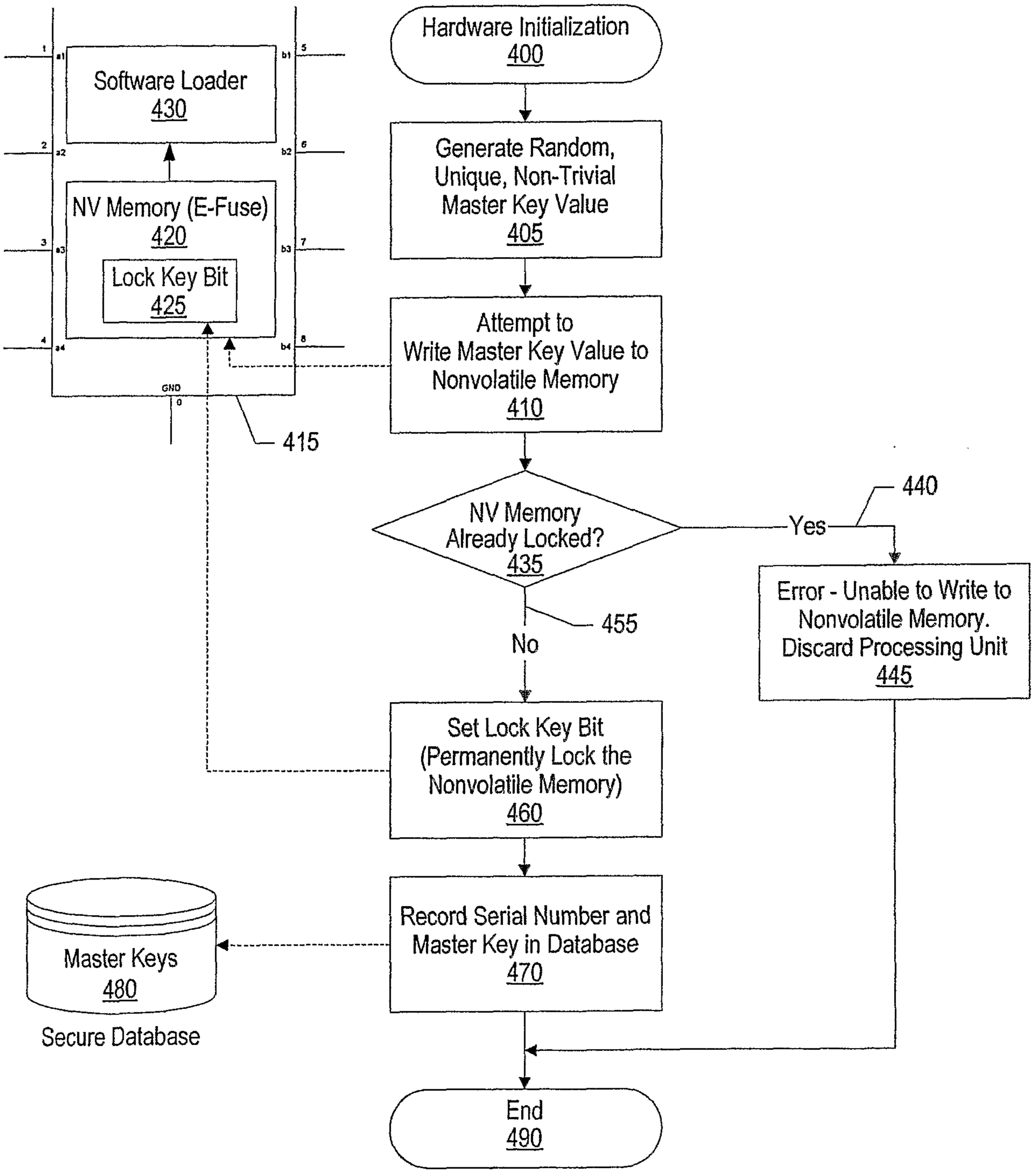
Hardware Initialization
400
Generate Random, Unique, Non-Trivial Master Key Value
405
Attempt to Write Master Key Value to Nonvolatile Memory
410
NV Memory Already Locked?
435
Yes
440
Error - Unable to Write to Nonvolatile Memory. Discard Processing Unit
445
455
No
Set Lock Key Bit (Permanently Lock the Nonvolatile Memory)
460
Record Serial Number and Master Key in Database
470
End
490
Software Loader
430
NV Memory (E-Fuse)
420
Lock Key Bit
425
415
GND
Master Keys
480
Secure Database

Figure 4

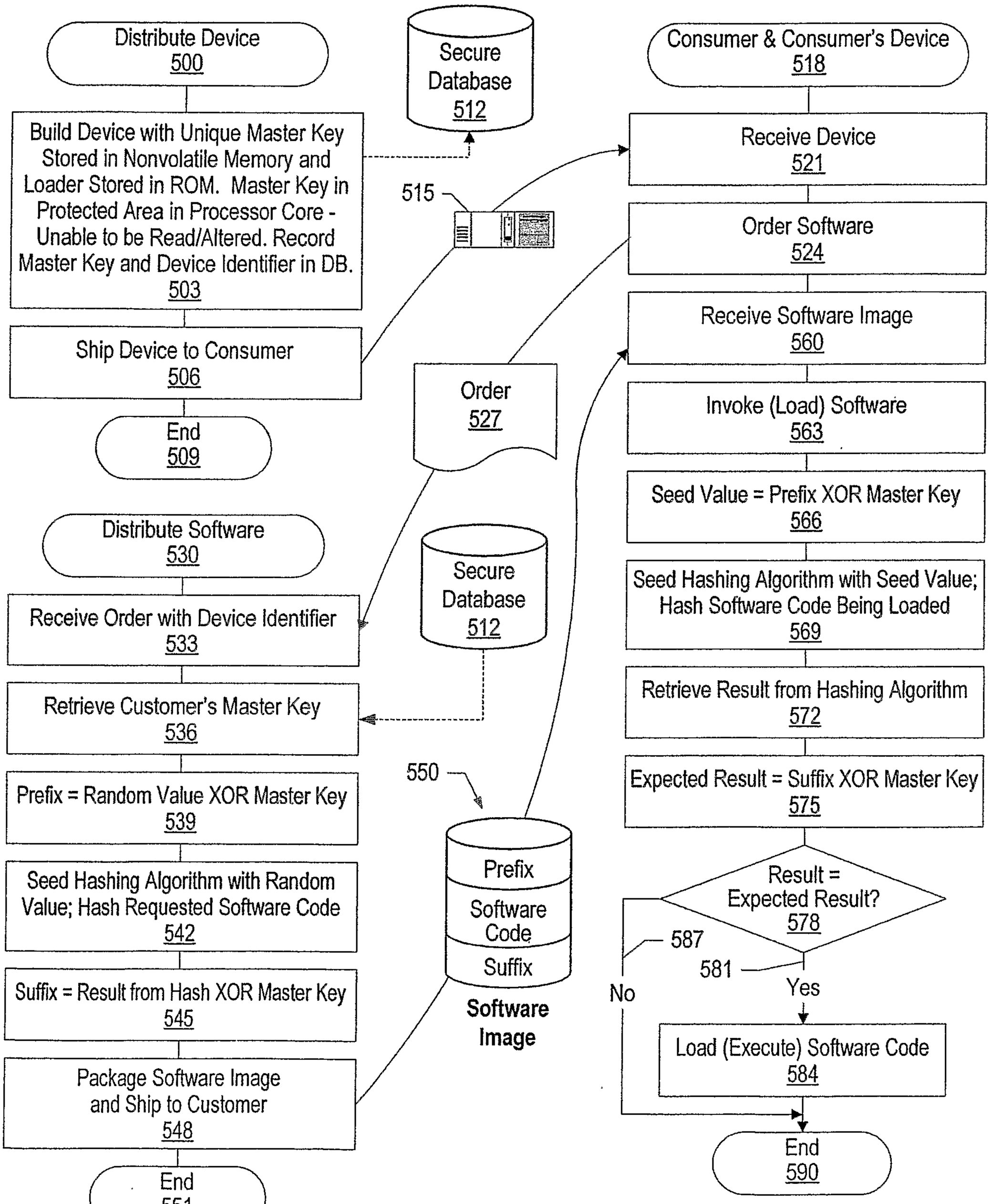
Distribute Device
500
Build Device with Unique Master Key Stored in Nonvolatile Memory and Loader Stored in ROM. Master Key in Protected Area in Processor Core - Unable to be Read/Altered. Record Master Key and Device Identifier in DB.
503
Ship Device to Consumer
506
End
509
Secure Database
512
515
Consumer & Consumer's Device
518
Receive Device
521
Order Software
524
Receive Software Image
560
Invoke (Load) Software
563
Seed Value = Prefix XOR Master Key
566
Seed Hashing Algorithm with Seed Value; Hash Software Code Being Loaded
569
Retrieve Result from Hashing Algorithm
572
Expected Result = Suffix XOR Master Key
575
Result = Expected Result?
578
587
581
No
Yes
Load (Execute) Software Code
584
End
590
Order
527
Distribute Software
530
Receive Order with Device Identifier
533
Retrieve Customer's Master Key
536
Prefix = Random Value XOR Master Key
539
Seed Hashing Algorithm with Random Value; Hash Requested Software Code
542
Suffix = Result from Hash XOR Master Key
545
Package Software Image and Ship to Customer
548
End
551
Secure Database
512
550
Prefix
Software Code
Suffix
Software Image

Figure 5

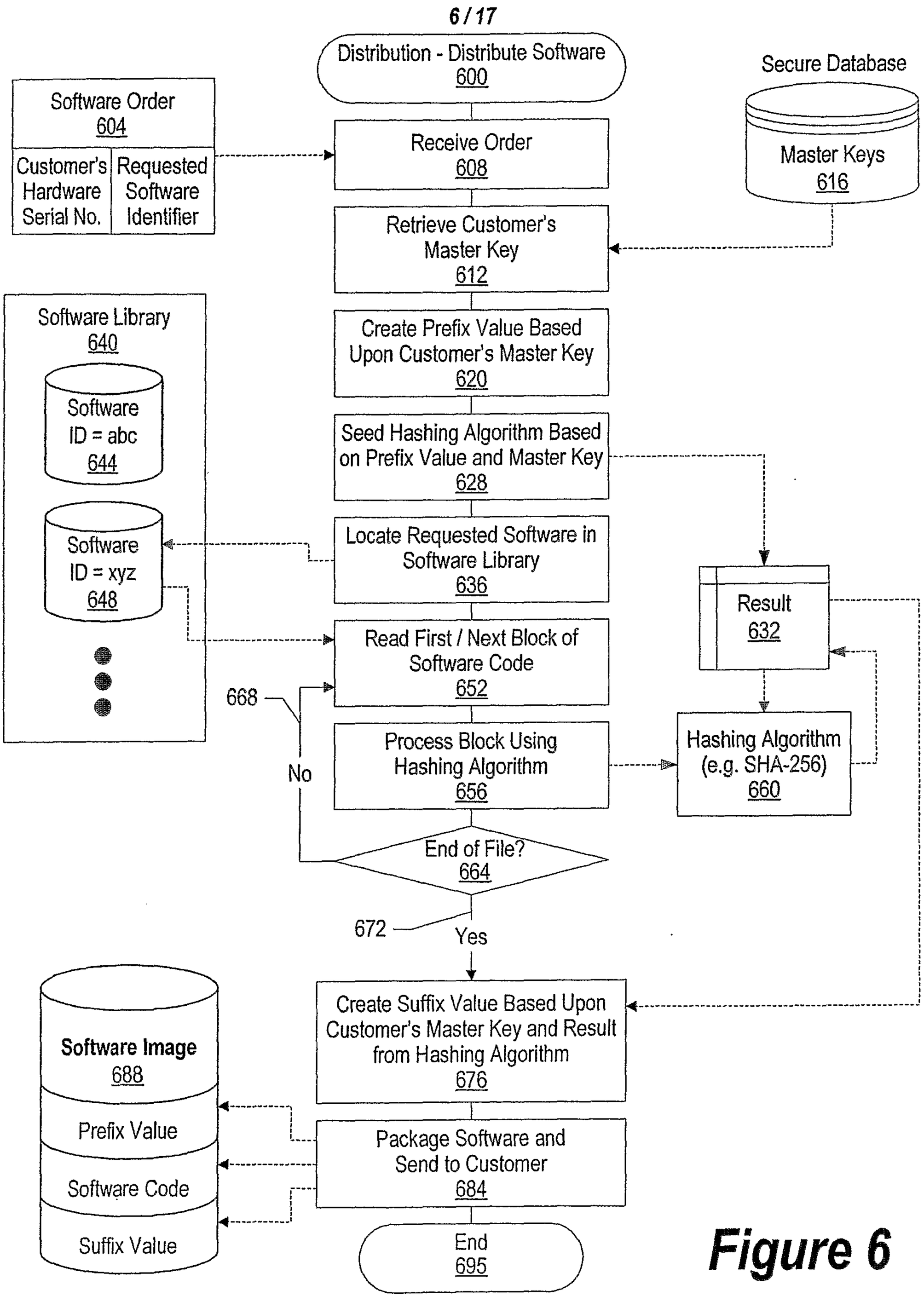
Distribution - Distribute Software
600
Secure Database
Master Keys
616
Software Order
604
Customer's Hardware Serial No.
Requested Software Identifier
Receive Order
608
Retrieve Customer's Master Key
612
Software Library
640
Create Prefix Value Based Upon Customer's Master Key
620
Software ID = abc
644
Seed Hashing Algorithm Based on Prefix Value and Master Key
628
Software ID = xyz
648
Locate Requested Software in Software Library
636
Result
632
Read First / Next Block of Software Code
652
668
No
Process Block Using Hashing Algorithm
656
Hashing Algorithm (e.g. SHA-256)
660
End of File?
664
672
Yes
Create Suffix Value Based Upon Customer's Master Key and Result from Hashing Algorithm
676
Software Image
688
Prefix Value
Software Code
Suffix Value
Package Software and Send to Customer
684
End
695

Figure 6

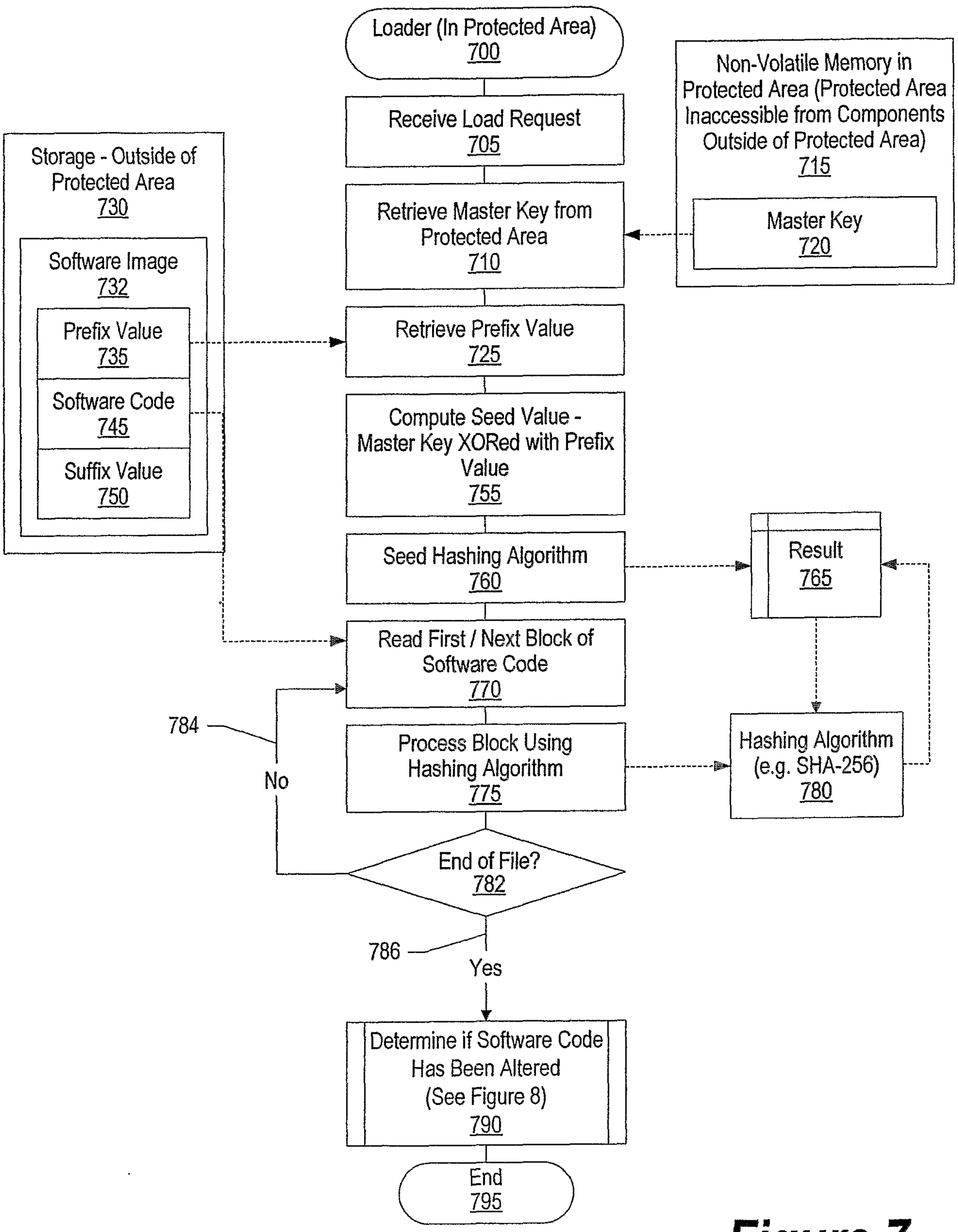
Loader (In Protected Area)
700
Receive Load Request
705
Retrieve Master Key from Protected Area
710
Retrieve Prefix Value
725
Compute Seed Value - Master Key XORed with Prefix Value
755
Seed Hashing Algorithm
760
Read First / Next Block of Software Code
770
Process Block Using Hashing Algorithm
775
End of File?
782
No
784
Yes
786
Determine if Software Code Has Been Altered (See Figure 8)
790
End
795
Storage - Outside of Protected Area
730
Software Image
732
Prefix Value
735
Software Code
745
Suffix Value
750
Non-Volatile Memory in Protected Area (Protected Area Inaccessible from Components Outside of Protected Area)
715
Master Key
720
Result
765
Hashing Algorithm (e.g. SHA-256)
780

Figure 7

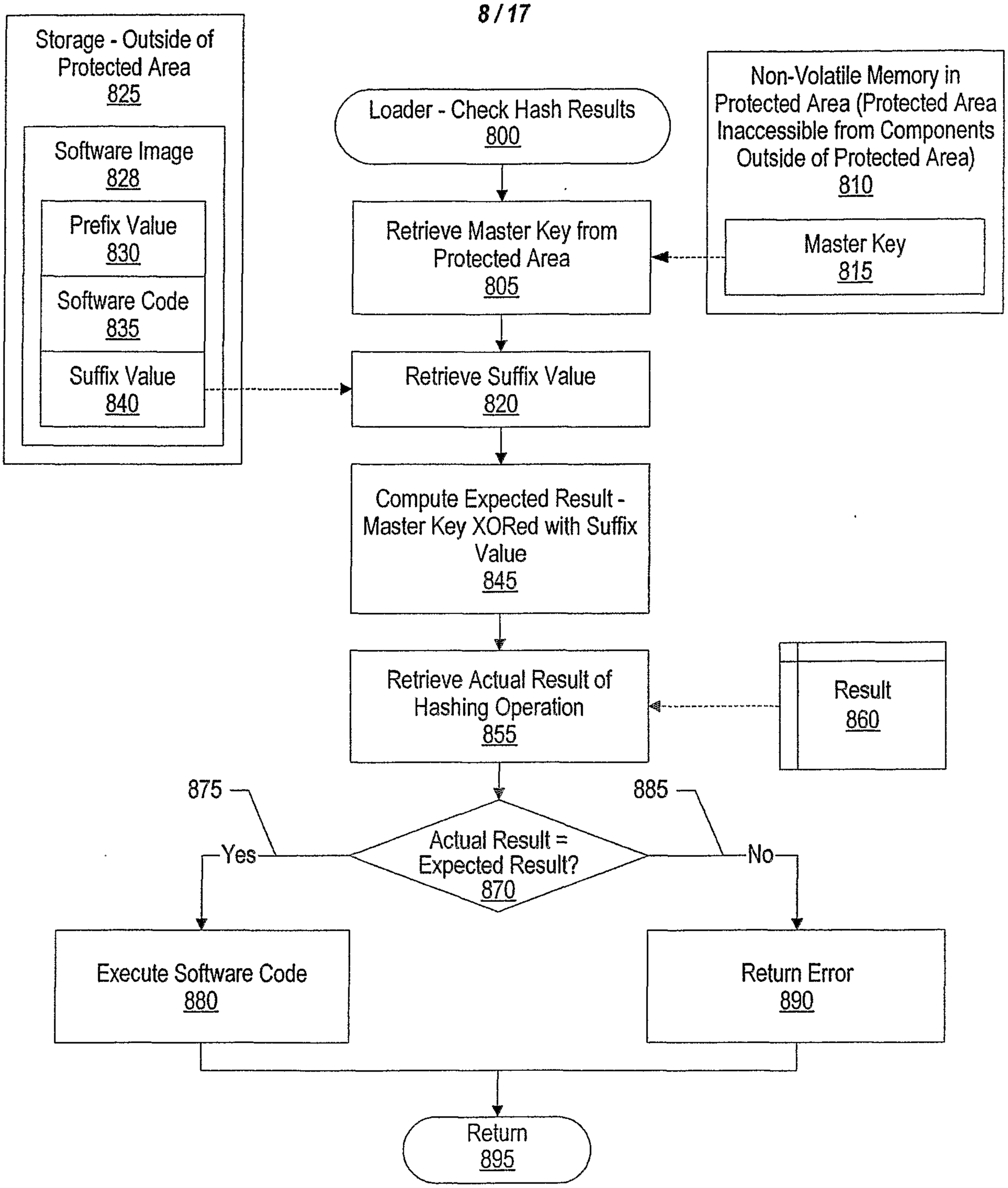
Storage - Outside of Protected Area
825
Software Image
828
Prefix Value
830
Software Code
835
Suffix Value
840
Loader - Check Hash Results
800
Retrieve Master Key from Protected Area
805
Non-Volatile Memory in Protected Area (Protected Area Inaccessible from Components Outside of Protected Area)
810
Master Key
815
Retrieve Suffix Value
820
Compute Expected Result - Master Key XORed with Suffix Value
845
Retrieve Actual Result of Hashing Operation
855
Result
860
875
885
Actual Result = Expected Result?
870
Yes
No
Execute Software Code
880
Return Error
890
Return
895

Figure 8

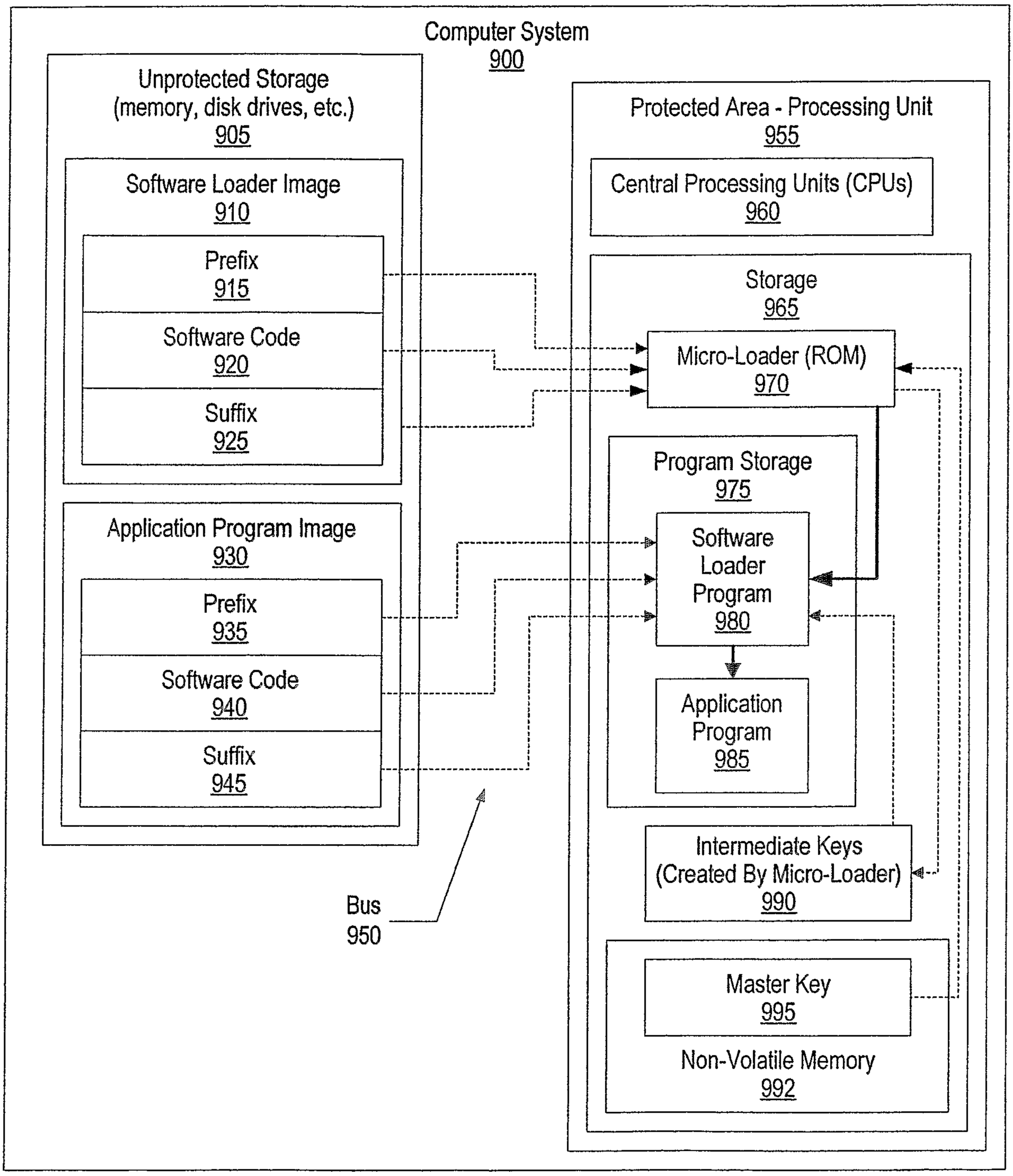
Computer System
900
Unprotected Storage
(memory, disk drives, etc.)
905
Software Loader Image
910
Prefix
915
Software Code
920
Suffix
925
Application Program Image
930
Prefix
935
Software Code
940
Suffix
945
Bus
950
Protected Area - Processing Unit
955
Central Processing Units (CPUs)
960
Storage
965
Micro-Loader (ROM)
970
Program Storage
975
Software Loader Program
980
Application Program
985
Intermediate Keys
(Created By Micro-Loader)
990
Master Key
995
Non-Volatile Memory
992

Figure 9

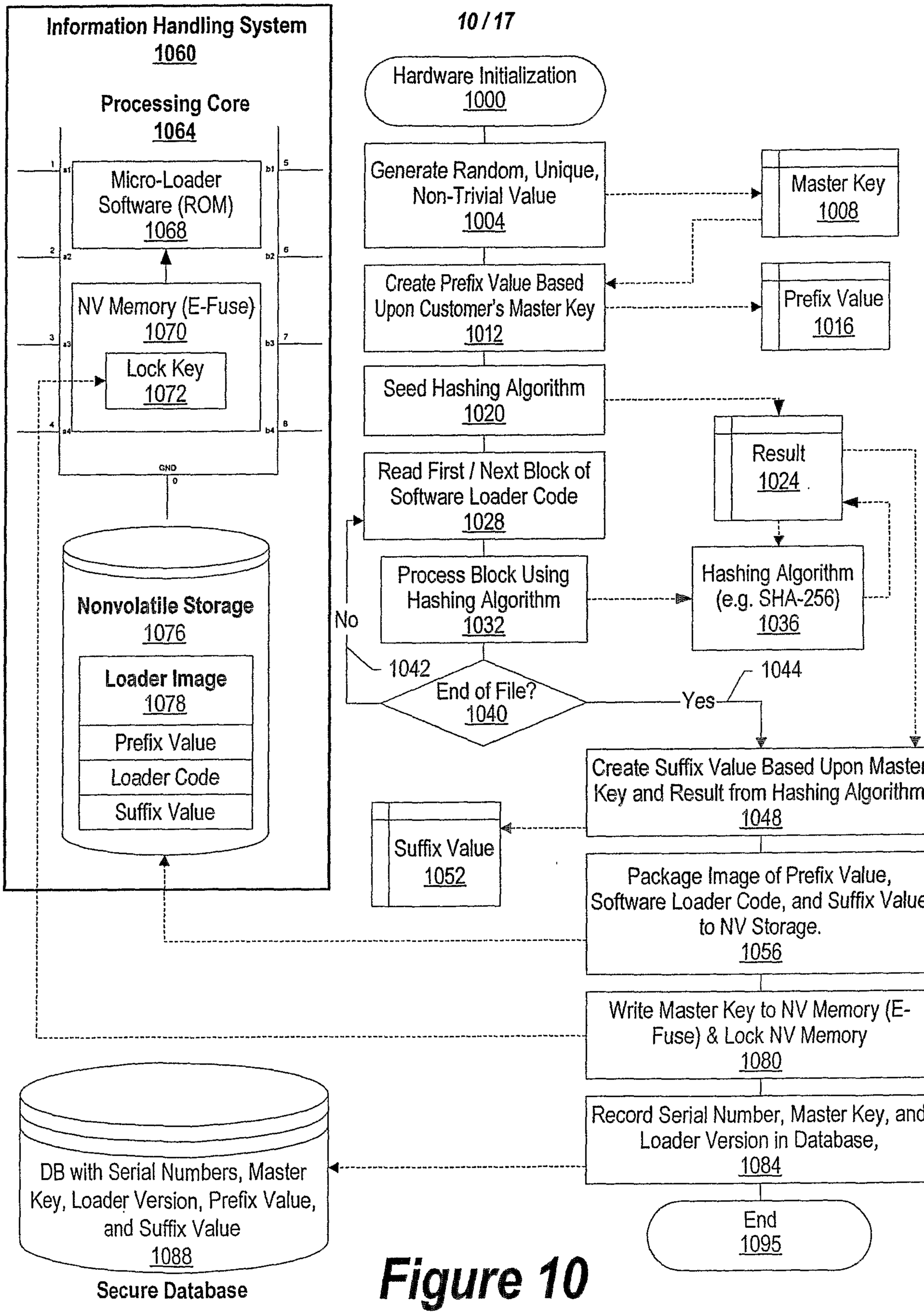
Information Handling System
1060
Processing Core
1064
Micro-Loader Software (ROM)
1068
NV Memory (E-Fuse)
1070
Lock Key
1072
GND
Nonvolatile Storage
1076
Loader Image
1078
Prefix Value
Loader Code
Suffix Value
Hardware Initialization
1000
Generate Random, Unique, Non-Trivial Value
1004
Master Key
1008
Create Prefix Value Based Upon Customer's Master Key
1012
Prefix Value
1016
Seed Hashing Algorithm
1020
Result
1024
Read First / Next Block of Software Loader Code
1028
Process Block Using Hashing Algorithm
1032
Hashing Algorithm (e.g. SHA-256)
1036
No
1042
End of File?
1040
Yes
1044
Create Suffix Value Based Upon Master Key and Result from Hashing Algorithm
1048
Suffix Value
1052
Package Image of Prefix Value, Software Loader Code, and Suffix Value to NV Storage.
1056
Write Master Key to NV Memory (E-Fuse) & Lock NV Memory
1080
Record Serial Number, Master Key, and Loader Version in Database,
1084
End
1095
DB with Serial Numbers, Master Key, Loader Version, Prefix Value, and Suffix Value
1088
Secure Database

Figure 10

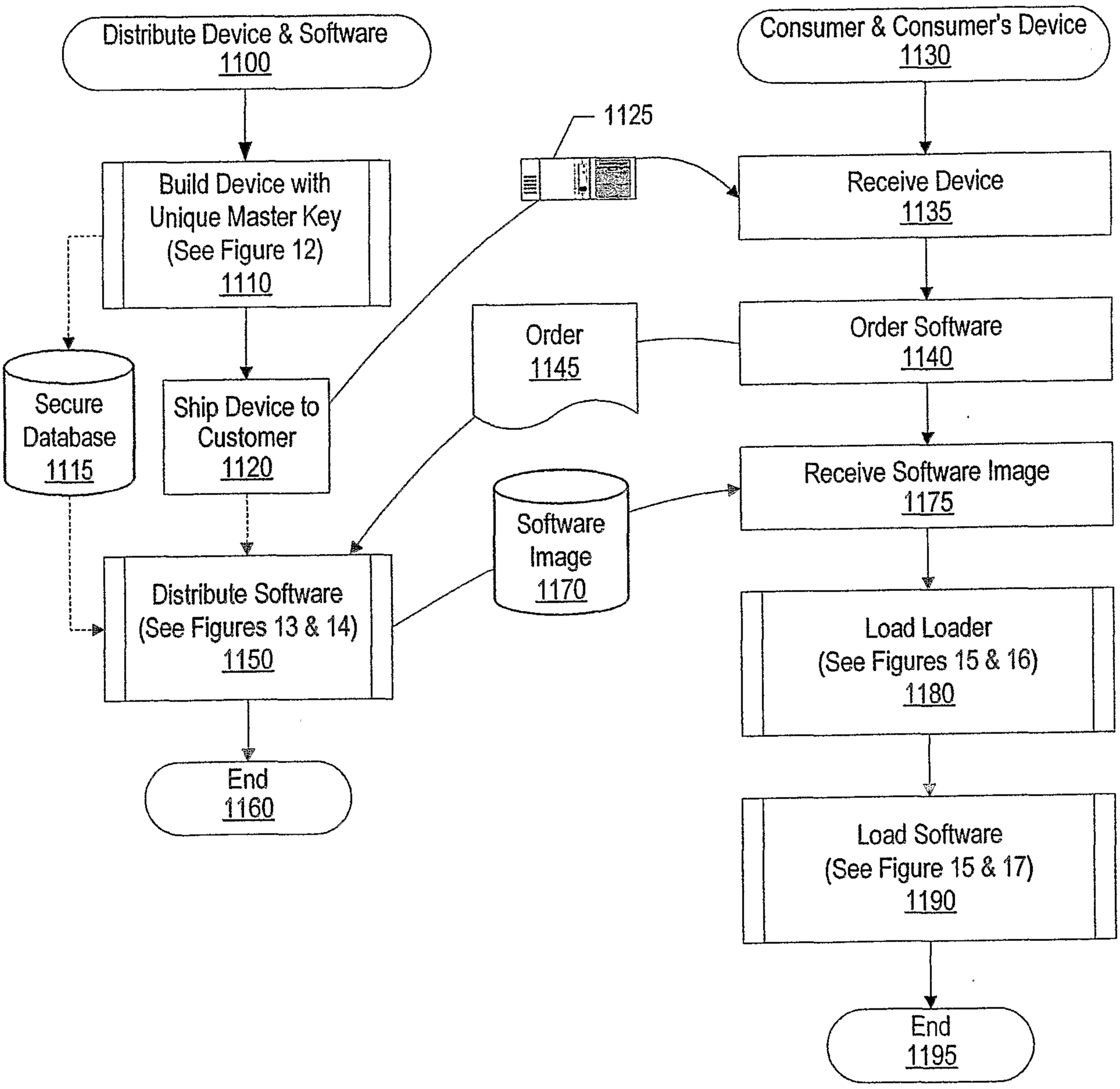
Distribute Device & Software
1100
Build Device with Unique Master Key (See Figure 12)
1110
Secure Database
1115
Ship Device to Customer
1120
Distribute Software (See Figures 13 & 14)
1150
End
1160
1125
Consumer & Consumer's Device
1130
Receive Device
1135
Order
1145
Order Software
1140
Software Image
1170
Receive Software Image
1175
Load Loader (See Figures 15 & 16)
1180
Load Software (See Figure 15 & 17)
1190
End
1195

Figure 11

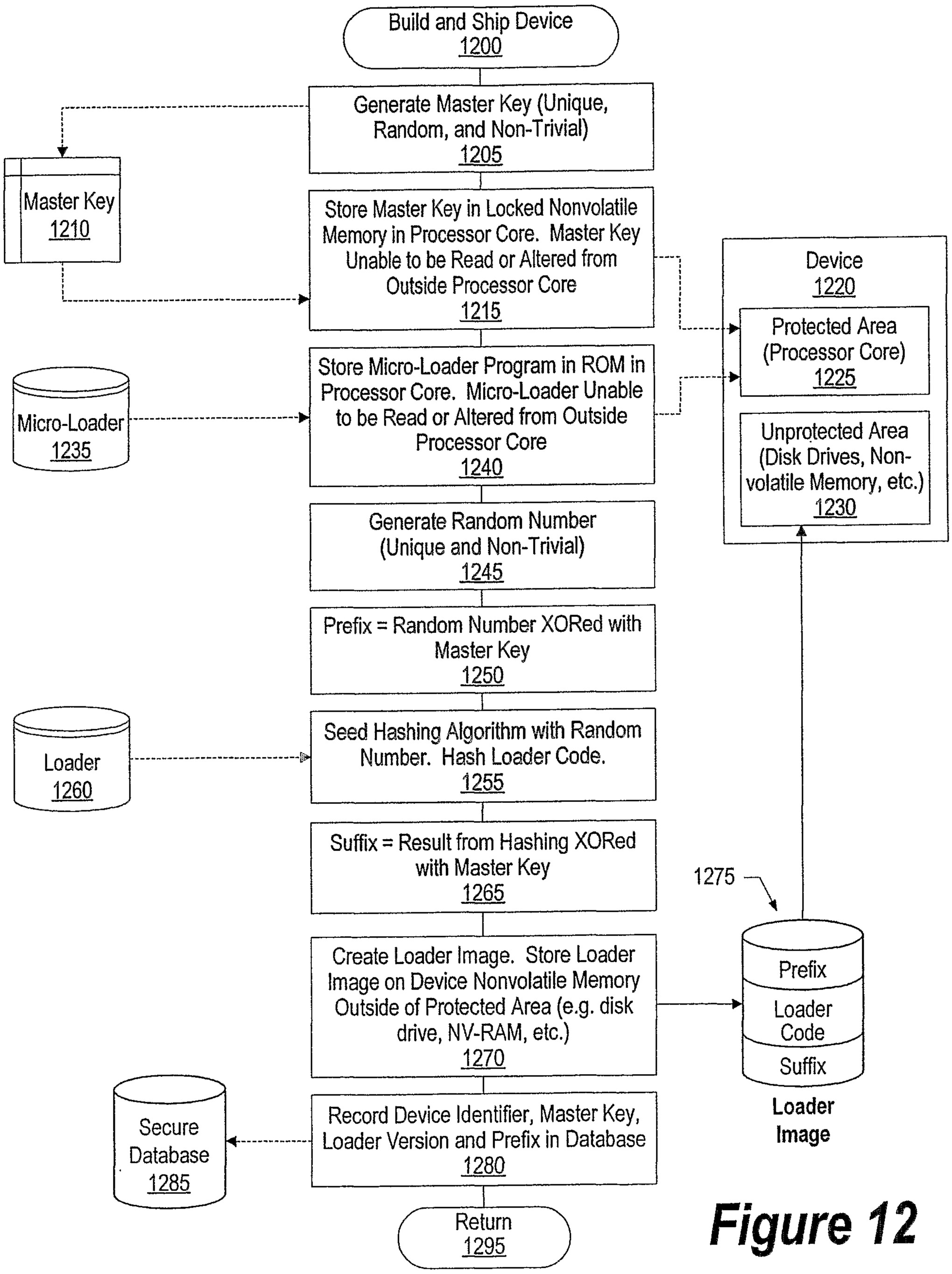
Build and Ship Device
1200
Generate Master Key (Unique, Random, and Non-Trivial)
1205
Master Key
1210
Store Master Key in Locked Nonvolatile Memory in Processor Core. Master Key Unable to be Read or Altered from Outside Processor Core
1215
Device
1220
Protected Area (Processor Core)
1225
Unprotected Area (Disk Drives, Non-volatile Memory, etc.)
1230
Micro-Loader
1235
Store Micro-Loader Program in ROM in Processor Core. Micro-Loader Unable to be Read or Altered from Outside Processor Core
1240
Generate Random Number (Unique and Non-Trivial)
1245
Prefix = Random Number XORed with Master Key
1250
Loader
1260
Seed Hashing Algorithm with Random Number. Hash Loader Code.
1255
Suffix = Result from Hashing XORed with Master Key
1265
1275
Create Loader Image. Store Loader Image on Device Nonvolatile Memory Outside of Protected Area (e.g. disk drive, NV-RAM, etc.)
1270
Prefix
Loader Code
Suffix
Loader Image
Secure Database
1285
Record Device Identifier, Master Key, Loader Version and Prefix in Database
1280
Return
1295

Figure 12

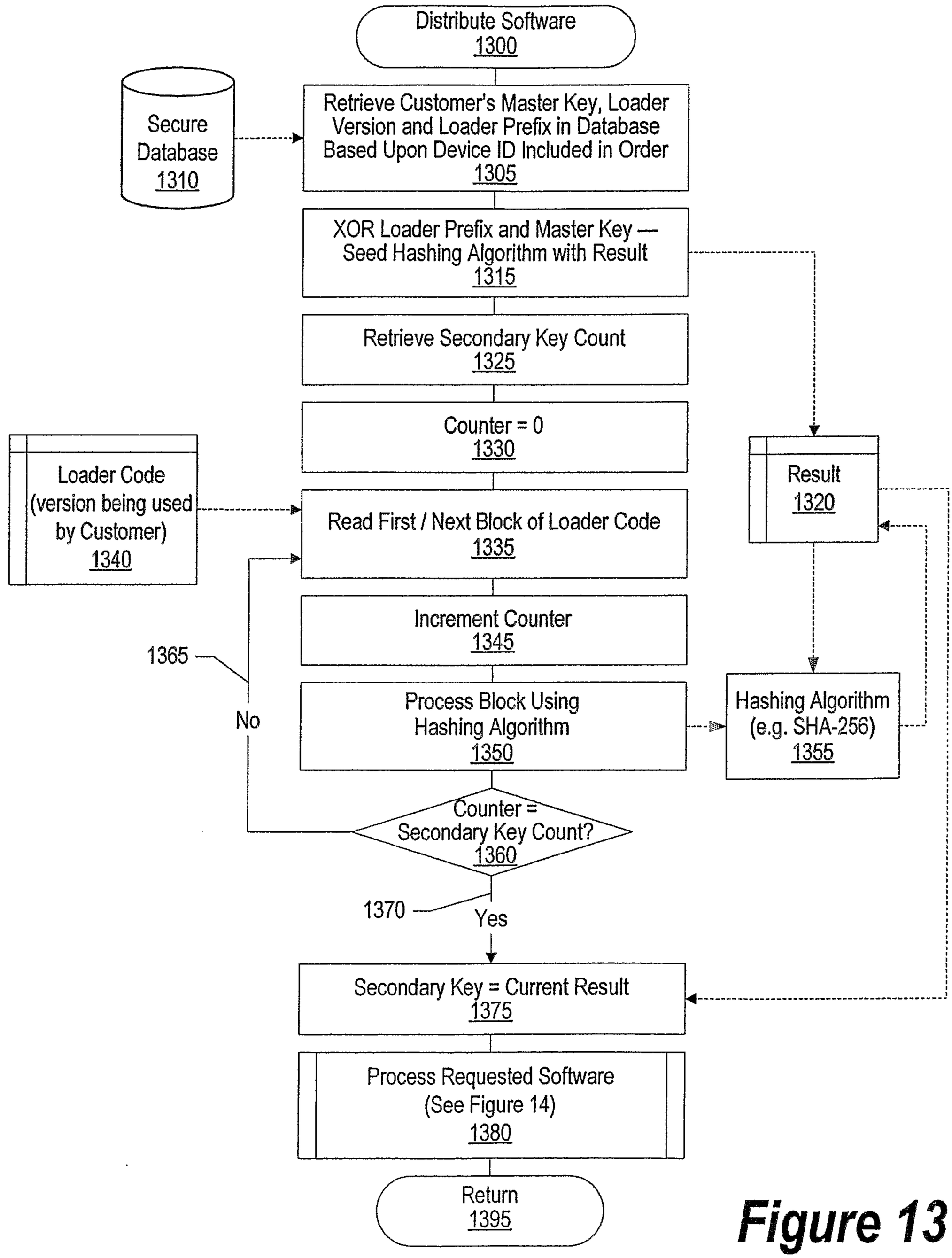
Distribute Software
1300
Secure Database
1310
Retrieve Customer's Master Key, Loader Version and Loader Prefix in Database Based Upon Device ID Included in Order
1305
XOR Loader Prefix and Master Key — Seed Hashing Algorithm with Result
1315
Retrieve Secondary Key Count
1325
Counter = 0
1330
Loader Code (version being used by Customer)
1340
Read First / Next Block of Loader Code
1335
Increment Counter
1345
1365
No
Process Block Using Hashing Algorithm
1350
Hashing Algorithm (e.g. SHA-256)
1355
Result
1320
Counter = Secondary Key Count?
1360
1370
Yes
Secondary Key = Current Result
1375
Process Requested Software
(See Figure 14)
1380
Return
1395

Figure 13

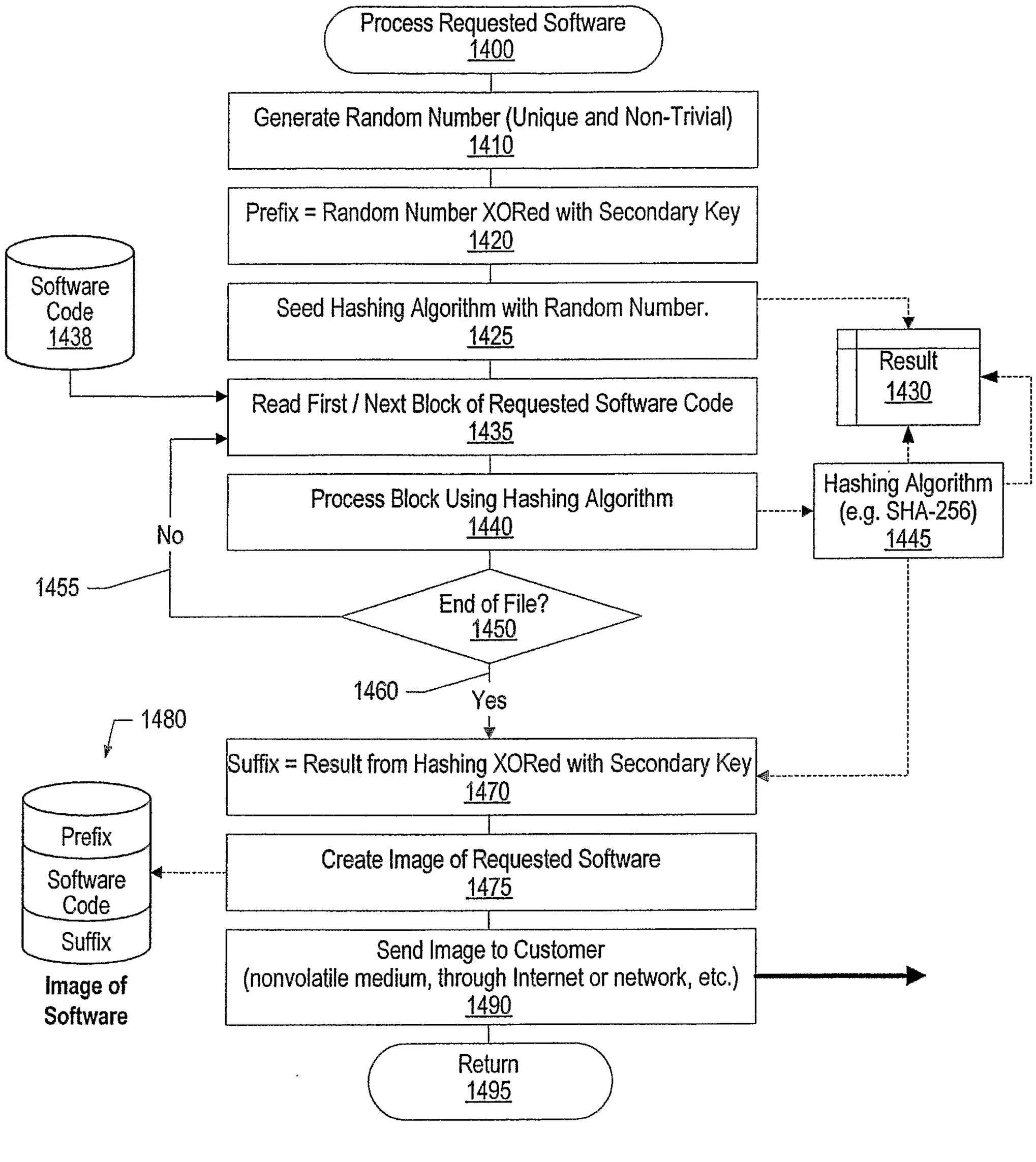
Process Requested Software
1400
Generate Random Number (Unique and Non-Trivial)
1410
Prefix = Random Number XORed with Secondary Key
1420
Software Code
1438
Seed Hashing Algorithm with Random Number.
1425
Result
1430
Read First / Next Block of Requested Software Code
1435
Process Block Using Hashing Algorithm
1440
Hashing Algorithm (e.g. SHA-256)
1445
No
1455
End of File?
1450
1460
Yes
1480
Suffix = Result from Hashing XORed with Secondary Key
1470
Prefix
Software Code
Suffix
Image of Software
Create Image of Requested Software
1475
Send Image to Customer
(nonvolatile medium, through Internet or network, etc.)
1490
Return
1495

Figure 14

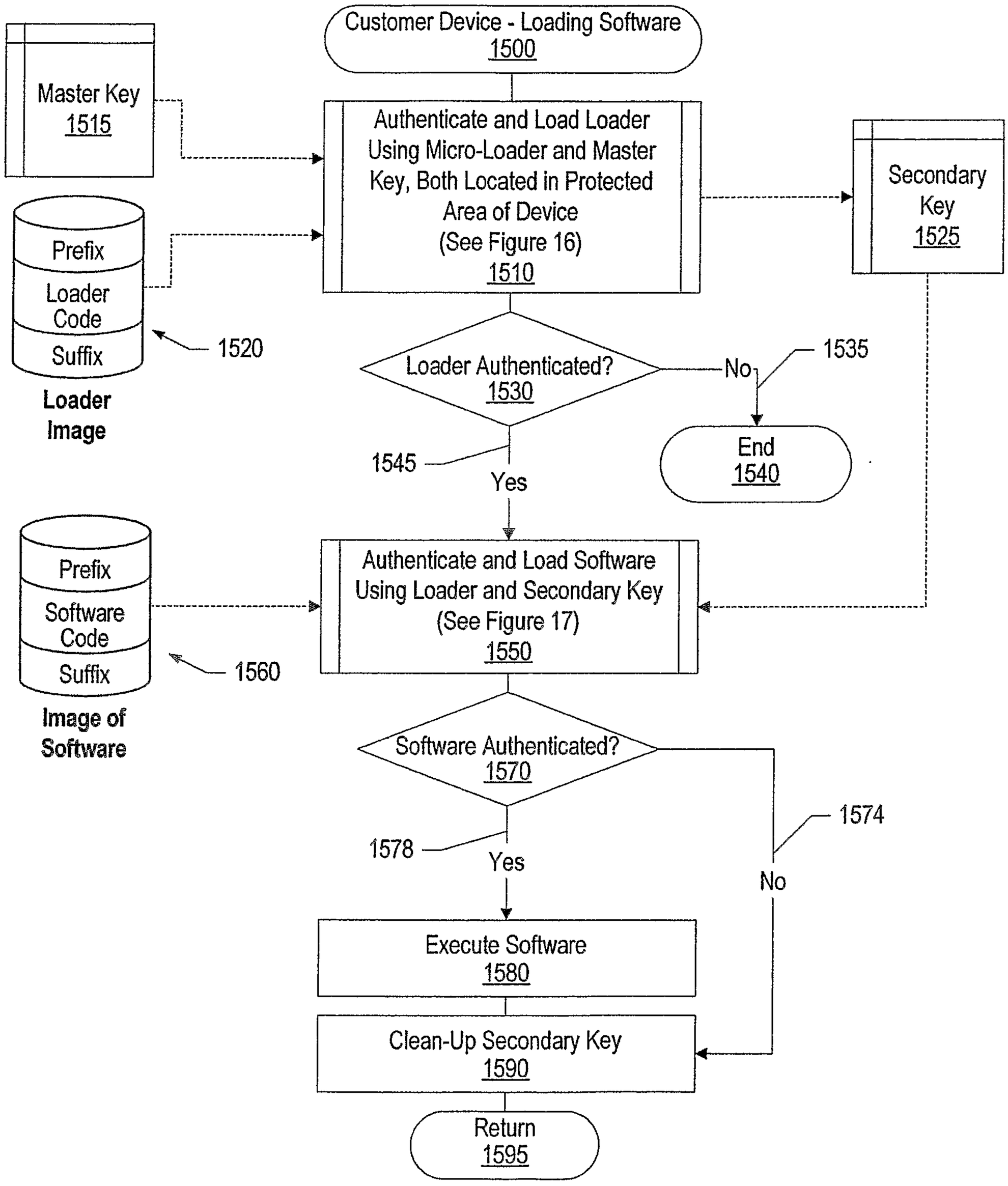
Customer Device - Loading Software
1500
Master Key
1515
Authenticate and Load Loader Using Micro-Loader and Master Key, Both Located in Protected Area of Device
(See Figure 16)
1510
Secondary Key
1525
Prefix
Loader Code
Suffix
1520
Loader Image
Loader Authenticated?
1530
No
1535
End
1540
1545
Yes
Prefix
Software Code
Suffix
1560
Image of Software
Authenticate and Load Software Using Loader and Secondary Key
(See Figure 17)
1550
Software Authenticated?
1570
1574
1578
Yes
No
Execute Software
1580
Clean-Up Secondary Key
1590
Return
1595

Figure 15

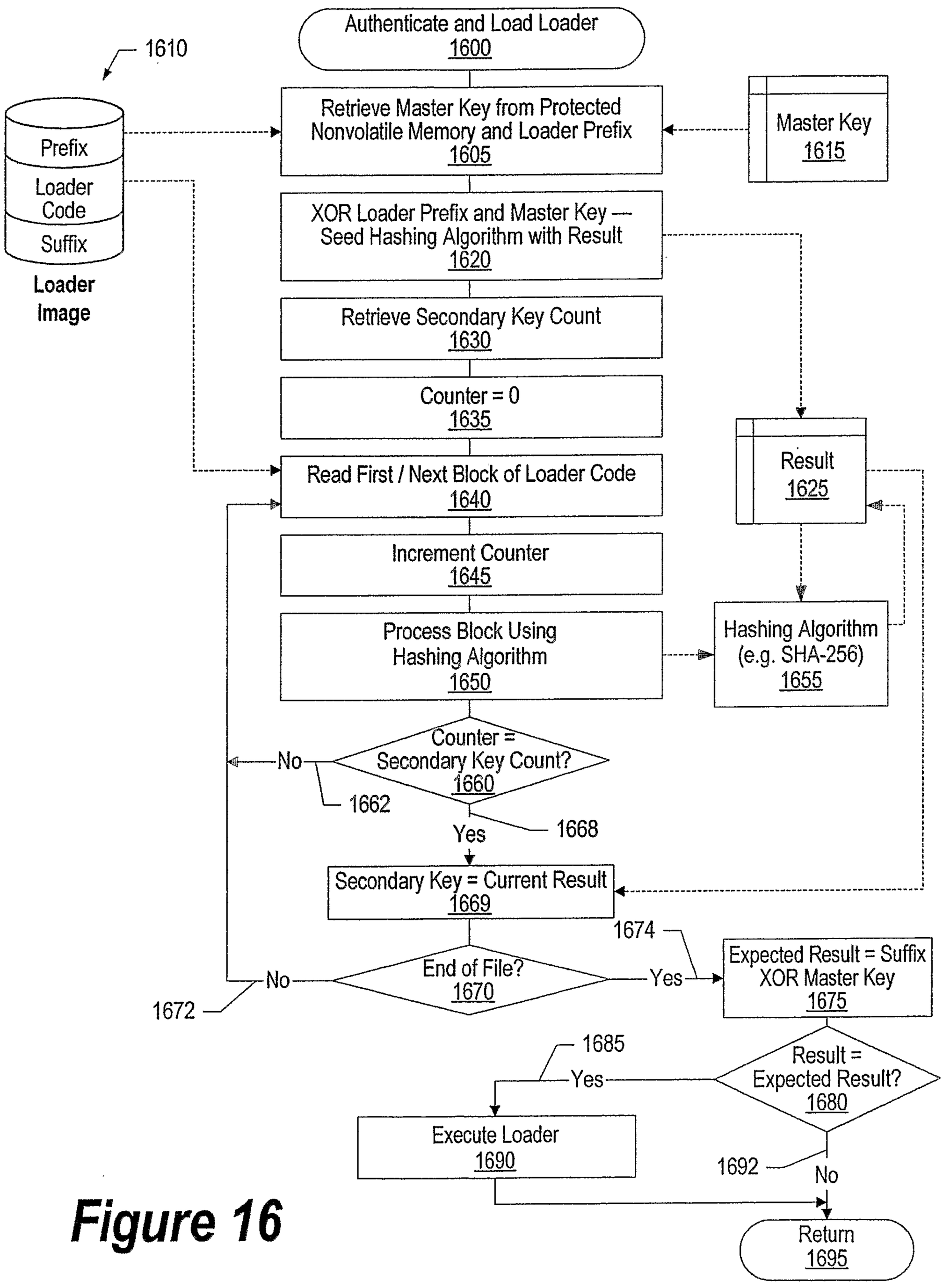
Authenticate and Load Loader
1600
1610
Prefix
Loader Code
Suffix
Loader Image
Retrieve Master Key from Protected Nonvolatile Memory and Loader Prefix
1605
Master Key
1615
XOR Loader Prefix and Master Key — Seed Hashing Algorithm with Result
1620
Retrieve Secondary Key Count
1630
Counter = 0
1635
Read First / Next Block of Loader Code
1640
Increment Counter
1645
Process Block Using Hashing Algorithm
1650
Result
1625
Hashing Algorithm (e.g. SHA-256)
1655
Counter = Secondary Key Count?
1660
No
1662
Yes
1668
Secondary Key = Current Result
1669
1674
End of File?
1670
No
1672
Yes
Expected Result = Suffix XOR Master Key
1675
1685
Yes
Result = Expected Result?
1680
Execute Loader
1690
1692
No
Return
1695

Figure 16

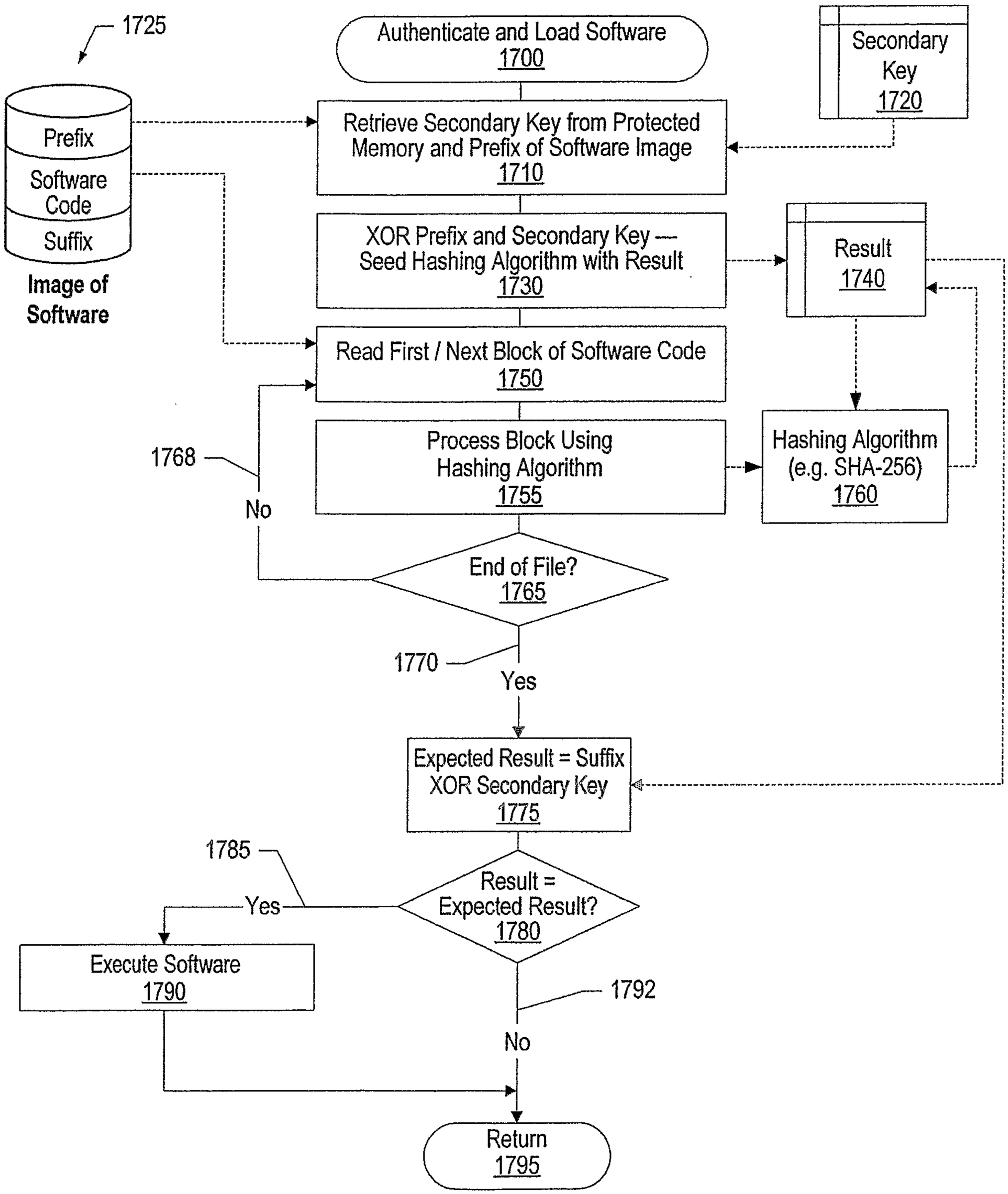
1725
Prefix
Software Code
Suffix
Image of Software
Authenticate and Load Software 1700
Retrieve Secondary Key from Protected Memory and Prefix of Software Image 1710
Secondary Key 1720
XOR Prefix and Secondary Key — Seed Hashing Algorithm with Result 1730
Result 1740
Read First / Next Block of Software Code 1750
Process Block Using Hashing Algorithm 1755
Hashing Algorithm (e.g. SHA-256) 1760
1768
No
End of File? 1765
1770
Yes
Expected Result = Suffix XOR Secondary Key 1775
1785
Yes
Result = Expected Result? 1780
Execute Software 1790
1792
No
Return 1795

Figure 17

Computer System
200

System Memory
205

Flash Memory
210

Read-Only Memory (ROM)
215

Random Access Memory (RAM)
220

Prefix
225

Software Code & Data
230

Suffix
235

201

Protected Area - Processing Unit
240

Central Processing Units (CPUs)
245

Loader
250

Storage
255

Program Storage
260

Data Storage
265

Non-Volatile Memory
270

Master Key
275

Monitor Data Flowing Over Bus
285

Copy Data
290

Snooping (Hacking) Tool
280

Copy will ONLY Work on This Computer System and Will NOT Work in Other Systems Because Master Key is Different
295