

System for determining commands to be executed by a test machine for applying test stimuli and measurements onto at least one device to be tested, corresponding method, and test system

5 Technical field

The present invention generally pertains to the field of systems and methods for performing automated tests; more specifically, the invention relates to a system for determining commands to be executed by a test machine for applying test stimuli and test measurements
10 onto at least one device to be tested, a corresponding method and a test system.

Prior art

Whenever a device is designed, it is also necessary to define a testing procedure to verify its
15 correct operation after production. Indeed, any defects must be identified as early as possible to prevent their release to the market. This same procedure, known as functional testing, can also be used to determine characteristic parameters of the physically produced device, enabling its classification into different quality batches.

20 The physical system used to apply a testing procedure to a physical device is known as a “test machine.”

Test machines are not necessarily dedicated to the functional testing of a single device but can be adapted as needed by a hardware configurability (addition/removal of physical
25 modules) and software configurability (programming of the sequence of operations to be executed).

In the prior art, there is a considerable gap relating to the transfer of information from the design of a device to automatic test machines, by which functional testing on the designed
30 device is to be performed.

In the prior art, such transfer typically occurs through written documentation in human

language, known as the so called “functional test specification.” It is widely believed that the responsibility for defining such information is not clearly assigned.

In particular, to verify the performance of a device, the “functional test specification” defines:

- the operations to be performed;
- in which sequence these operations are to be performed.

Using a “functional test specification” written in human language to handle critical information for the testing step of a device results in significant costs in terms of human resources and time required to adapt it to a corresponding test machine.

In fact, the “functional test specification” expressed in human language must be interpreted to configure and program a dedicated test machine.

What makes these steps particularly burdensome and potential sources of errors is the fact that the use of a non-formalized human language introduces ambiguities in its interpretation. Furthermore, the operator responsible for the conversion must have detailed knowledge of both the device under test and the test machine that will be used.

Overall, this results in a waste of human resources and a prolongation of the time needed to achieve a correct functional test.

An improvement over the previously described approach involves the preparation by the test machine manufacturer of sufficiently generic algorithms that can be applied to entire families of devices to be tested (e.g., diodes, IGBTs, half-bridge modules) and the development of a user interface that allows to select the desired algorithm, as well to input its characteristic parameters (e.g., voltage or current values, pass/fail criteria, test times). The advantage of this solution is that “programming,” considered as software writing, is carried out once and for all by the test machine manufacturer, while the manufacturer of the device on which the functional test will be applied may create the desired sequence without any knowledge of the test machine and without software writing skills.

An alternative approach, but inspired by the same considerations, relies on the use of a formal language for defining the test sequence. This sequence will then be converted into a sequence of elementary operations, which varies depending on the test machine that will be
5 used to perform the functional test. The manufacturer of the device to be tested must create the test sequence in a formal language, while the test machine manufacturer must develop the program to convert the formal language into elementary instructions for the test machine.

In any case, all current solutions are strictly dependent on the test configuration for which
10 the test sequence was optimized, and any change in the test machine configuration, or the parallelism with which the test must be performed, necessarily requires the repetition of the entire process, a costly operation in terms of human resources and the time required.

Finally, none of the proposed solutions can automatically react to events such as failures of
15 subcomponents of the test machine, nor can they take advantage of potential overdimensioning of the test machine to automatically minimize the total time required to perform the functional test.

A first solution aiming at solving the aforementioned problems is described in
20 CN101896908 B. However, this solution is limited in that its implementation logic is solely based on information contained in a test document. Thus, the fact that the solution is solely based on information relating to the test to be performed does not allow for optimization of the use of available test resources provided by a potentially available test machine for performing the test.

25 Therefore, even in light of CN101896908 B, the aforementioned problems remain unresolved.

Summary of the invention

30 One purpose of the present invention is thus to provide solutions that enable the determination of the list of commands to be executed for the application of test stimuli and

test measurements on at least one device to be tested, adapting to any available test machine. In other words, the commands can be independent of a specific test machine but can be defined based on any available test machine.

- 5 Another objective is to reduce the cost in terms of human resources and time for determining the commands to be executed by a test machine for the application of test stimuli and test measurements on at least one device to be tested.

A further objective is to provide a solution that allows optimizing the use of available test
10 resources, thereby achieving a reduction in the overall testing cost.

The above and other objects and advantages are achieved:

- according to one aspect of the invention, by a system for determining commands to be executed by a test machine for applying test stimuli and test measurements onto at least
15 one device to be tested, having the features defined in claim 1;
- according to another aspect of the invention, by a test system having the features defined in claim 11; and
- according to yet another aspect of the invention, by a method for determining commands to be executed by a test machine for applying test stimuli and test measurements
20 onto at least one device to be tested, having the features defined in claim 16.

Preferred embodiments of the invention are defined in the dependent claims, the contents of which are to be considered an integral part of this description.

- 25 In other words, what clearly distinguishes the proposed invention from pre-existing ones is that the approach is completely “data-driven.” In other words, an operator does not need (unless explicitly desired) to define a temporal sequence of operations that constitute the functional test. The operator also does not need to limit to a finite number of existing stimulus and measurement tools in a real test system. It will be the task of the system and
30 method of the present invention to optimize the use of physical resources within the test system, by defining the sequence with which the functional test will be carried out.

Furthermore, the use of automated means makes the use efficiency of the test system independent of the specific expertise of the person using this invention.

Furthermore, to strictly adhere to a “data-driven” approach, the solution may have the following properties:

- Hierarchical approach: each module can interact exclusively with lower-level instances contained within it or with the higher-level instance containing it;
- Complete opacity of individual modules: they can be fully specified by defining an interface and a description of the externally visible behaviour of the object itself, with no visibility into its internal structure.

The term “module” can refer indiscriminately to hardware, software, or hybrid objects. A module can be considered an object of unspecified nature that performs a defined set of functions.

Brief description of the drawings

The functional and structural characteristics of some preferred embodiments of a system for determining commands to be executed by a test machine for applying test stimuli and measurements onto at least one device to be tested, a corresponding method, and a test system according to the invention will now be described. Reference is made to the accompanying drawings, wherein:

- Figure 1 illustrates a first embodiment of a system for determining commands to be executed by a test machine for applying test stimuli and measurements onto at least one device to be tested, according to the invention;
- Figure 2 illustrates an exemplary internal structure of a device to be tested;
- Figure 3 illustrates exemplary logical test components that may be connected to the device to be tested during the application of test stimuli and test measurements;
- Figure 4 illustrates an exemplary internal structure of a test machine;
- Figure 5 illustrates a first embodiment of a test system according to the invention;
- Figure 6 illustrates an additional embodiment of a test system according to the invention.

Detailed description

Before explaining in detail a plurality of embodiments of the invention, it should be clarified
5 that the invention is not limited in its application to the structural details and the
configuration of components described in the following description or illustrated in the
drawings. The invention may take other embodiments and be implemented or carried out
practically in different ways. It should also be understood that the terminology used herein
has a descriptive purpose and should not be considered limiting. The use of "include" and
10 "comprise" and their variations are intended to encompass the elements stated herein after
and their equivalents, as well as additional elements and equivalents thereof.

Referring initially to Figure 1, a first embodiment of a system 100 for determining
commands to be executed by a test machine 112 to apply test stimuli and measurements onto
15 at least one device to be tested, DUT ("Device Under Test"), is described below.

The device to be tested, DUT, may be any device, such as, for example, an electronic device,
a semiconductor device, a mechanical device, a pneumatic device, etc.

20 For instance, in the field of semiconductor devices, the following test functions, among
others, may be performed: DC testing, AC testing, time-domain testing, etc.

Generally, a test function can be defined by the test stimuli and test measurements that must
be applied to the device to be tested.

25

The system 100 includes electronic control means 102 configured to:

- receive as input information 104 relating to a structure of the at least one device to
be tested, DUT;
- receive as input information 106 relating to said test stimuli and test measurements
30 to be applied onto the at least one device to be tested, DUT;
- receive as input information 108 relating to the test machine 112 by which said test
stimuli and test measurements are to be applied onto the at least one device to be tested,

DUT.

For example, the electronic control means 102 may comprise or be at least one of: a processor, a microprocessor, a controller, a microcontroller, an FPGA, a PLC, or similar.

5

Furthermore, the electronic control means 102 are arranged to determine commands 110 that are arranged to be provided to the test machine 112 and to be executed by the test machine 112, to apply the said test stimuli and test measurements onto the at least one device to be tested, DUT.

10

In particular, the electronic control means 102 are arranged to determine the commands 110 based on at least the information relating to the structure of the at least one device to be tested, DUT, the information relating to the test stimuli and test measurements to be applied onto the at least one device to be tested, DUT, and the information relating to the test machine 112 by which the test stimuli and test measurements are to be applied onto the at least one device to be tested, which are received as input by said electronic control means 102.

15

In other words, the electronic control means 102 will be able to determine the commands 110 that will need to be applied by the test machine 112 based on the information 104, 106, and 108 received as input. In this way, it will not be necessary to develop a dedicated test machine 112 to apply the test stimuli and test measurements onto the at least one test device, DUT. Instead, according to the present invention, it is possible to automatically determine the commands 110 that need to be executed, based on the test stimuli and test measurements to be applied, which are described by the information 106 relating to the test stimuli and test measurements, the characteristics of the available test machine 112, which are described by the information 108 relating to the test machine 112, and the characteristics of the device to be tested, which are described by the information 104 relating to the structure of the at least one device to be tested, DUT.

20

25

30

Thus, it is no longer necessary to convert the “functional specification” written in human language into a dedicated functional test machine.

Preferably, the electronic control means 102, for determining the commands 110 based on at least the information relating to the structure of the at least one device to be tested, DUT, the information relating to said test stimuli and test measurements to be applied onto the at least one device to be tested, DUT, and the information relating to the test machine 112 by which the test stimuli and test measurements are to be applied onto the at least one device to be tested, DUT, received as input by the electronic control means 102, may be arranged to:

- based on the information relating to the test machine 112 by which the test stimuli and test measurements are to be applied onto the at least one device to be tested, DUT, transform the information relating to the structure of the at least one device to be tested, DUT, and the information relating to the test stimuli and test measurements to be applied onto the at least one device to be tested, DUT, into the commands 110 arranged to be provided to the test machine 112 and be executed by said test machine 112.

- Preferably, the electronic control means 102, for determining the commands 110 based on at least the information 104 relating to a structure of the at least one device to be tested, DUT, the information 106 relating to test stimuli and test measurements to be applied onto the at least one device to be tested, DUT, and the information 108 relating to the test machine 112 by which the test stimuli and test measurements are to be applied onto the at least one device to be tested, DUT, may be arranged to use an algorithm, for instance, of logical synthesis resource allocation.

- Preferably, the information relating to the structure of the at least one device to be tested, DUT, the information relating to the said test stimuli and test measurements to be applied to the at least one device to be tested, DUT, and the information relating to the test machine 112 by which the test stimuli and test measurements are to be applied onto the at least one device to be tested may be comprised in at least one digital document. In this case, the electronic control means 102 may be configured to receive as input the at least one digital document. Specifically, the electronic control means may include receiving means configured to receive information, such as, for example, a data port or transceiver means.

A digital document can be understood as a “file” in any format capable of representing the

information to be conveyed. Preferably, a standard format can be used to be able to use already existing serializers and deserializers without having to custom-develop them. Possible formats comprise, for example, XML and JSON, which are widely used in computing. The former may be preferable because the standard also provides a way to
5 define the syntactic and semantic validity of an XML file. This is achieved using DTD or XML-Schema languages, which allow precise definitions of types, values, and metadata for each object present in the XML file.

Preferably, the electronic control means 102 may be arranged to generate a digital document
10 of commands arranged to be provided to the test machine 112. In this case, the digital document of commands may contain the commands 110 determined by the electronic control means 102. Specifically, the electronic control means may comprise transmission means arranged to transmit information, such as, for example, a data port or transceiver means.

15 For instance, the digital document of commands may also be a generic “file”. This file could for example be in a format dependent on the test machine 112 and could contain the exact sequence of commands 110 to be executed.

Preferably, the information relating to the structure of the at least one device to be tested
20 may comprise at least one of the following information related to:

- type of structural elements 200 comprised in the device to be tested;
- connections 202 among the structural elements 200 that are comprised in the device
to be tested;
- hierarchy of structural elements 200 that are comprised in the device to be tested;
- 25 - operational constraints of the device to be tested;
- operational constraints of the structural elements 200 that are comprised in the
device to be tested.

Possible structural elements 200 of a device to be tested are exemplified in Figure 2.
30

For example, to define the number and type of structural elements 200 of the device to be tested, reference can be made to libraries of basic devices, such as diodes, transistors, half-

bridge modules, etc., which can be used to model the device to be tested, DUT.

Preferably, the information relating to the test stimuli and test measurements to be applied onto the at least one device to be tested, DUT, may comprise at least one of the following
5 information related to:

- elementary test units provided by the test stimuli and test measurements, these elementary test units comprising only data and/or formulae;

- dependencies between different elementary test units provided by the test stimuli and test measurements;

- 10 - logical test components 300 that are provided by the said test stimuli and test measurements, which are to be connected to the device to be tested during the application of the said test stimuli and test measurements.

As indicated above, possible instructions may only involve instructions of sets of values by
15 using constant parameters or formulae.

Relating to the data and/or formulae comprised in these elementary test units, given that a constant parameter is effectively also a formula, it is evident that the key point is the representation of formulae as generically and arbitrarily complex as possible. The formulae
20 used may have both scalar and vector quantities as input and, similarly, may generate either a scalar or a data vector. For instance, a formula could be devised to generate a voltage ramp as a function of time (scalar input, vector output) or a formula to calculate the average of a measurement (vector input, scalar output), or even to perform a time-frequency transform (vector input, vector output).

25

In Figure 3, by way of example, logical test components 300 are illustrated, which can be connected to the device to be tested, DUT, during the application of test stimuli and test measurements.

30 For example, to define the logical test components 300, one may refer to libraries of modules (generators, meters, passive components), which are used to specify the desired type of test. These logical test components 300 can be configured to be relating to or connected with the

device to be tested, DUT.

For example, the information relating to the structure 104 of the at least one device to be tested, DUT, and the information 106 relating to the said test stimuli and test measurements
5 to be applied to the at least one device to be tested may be comprised in a single file, which may be called the “Test Document.”

For instance, the structure of the Test Document can also take the form of a tree with an arbitrary number of levels, and therefore it may be stored as a file in any format capable of
10 representing it.

For instance, a device manufacturer can formally define the functional test they intend to perform. Specifically, the functional test may consist of a set of independent tests, each based on executing a certain number of steps. During each step, only the values of the physical
15 quantities to be applied to the inputs of the device under test, the termination conditions of the step, and the output physical quantities of the device, whose values are to be recorded, are defined. Optionally, although not necessarily, it is also possible to describe any constraints between the various tests that comprise the overall functional test. This set of data may form the so-called “Test Document”.

20

Preferably, the information 108 relating to the test machine 112 by which the test stimuli and test measurements are to be applied onto the at least one device to be tested, DUT, may include at least one of the following information related to:

- structural elements 400 that are comprised in the test machine;
- 25 - operational parameters of the structural elements 400 that are comprised in the test machine 112;
- connections 402 between the structural elements 400 that are comprised in the test machine 112;
- hierarchy of the structural elements 400 that are comprised in the test machine 112;
- 30 - operational constraints of the test machine 112;
- operational constraints of the structural elements 200 that are comprised in the test machine 112.

Relating to the hierarchy of structural elements, since a given test machine may exist in different configurations and the type and number of modules/structural elements within it are not known a priori, it is possible to have data exchange only between adjacent levels,
5 while communication between objects belonging to the same hierarchical level may be strictly prohibited.

Therefore, preferably, when said information relating to a test machine 112 by which the test stimuli and test measurements are to be applied onto the at least one device to be tested
10 comprises at least information relating to the structural elements 400 comprised in the test machine, information relating to the connections 402 between the structural elements 400 that are comprised in the test machine 112, and information relating to the hierarchy of the structural elements 400 in the test machine 112, the electronic control means 102 may be arranged to determine the commands 110 in such a way that structural elements 400 having
15 a first hierarchy may only communicate with structural elements 400 having a second hierarchy, lower than said first hierarchy.

In this way, each module/structural element does not need to have prior knowledge of the test machine configuration, and this enables the test machine to be modified on site.
20

In Figure 4, exemplary structural elements 400 of a test machine 112 are illustrated.

For instance, to define the structural elements 400, 402 (modules or connections) comprised in the test machine 112, one may refer to a library of hardware modules corresponding to
25 physical modules which can be actually found within a test machine. For instance, besides functionalities, each structural element 400 may have associated allowed operational parameters. Information relating to the test machine by which the test stimuli and test measurements are to be applied onto the at least one device to be tested may, therefore, represent how the test machine 112 is assembled by interconnecting structural elements in
30 the exact hierarchical order.

For instance, the information 108 relating to the test machine may be comprised in a single

file, which may be referred to as the “Machine Description.”

The Machine Description may also have a tree structure. This machine description may contain all physical and/or logical modules that make up the test machine. The hierarchy
5 used should be consistent with the internal connection scheme. For instance, if a master module can control a slave module, the latter must appear as a child of the master node.

Each module may also include a list of parameters characterizing its nature and intended use, both in terms of functionality (e.g., voltage generator, inductance, current meter) that in
10 terms of performance (e.g., minimum voltage, maximum voltage, minimum and maximum deliverable current, resolution, rate of change).

Given the possibility of using feedback loops, both local to the module (intra-module) and external to it (inter-module), one of the data items that may be provided is the input/output
15 latency, to ensure the unconditional stability of inter-module feedbacks. For consistency with the format of the test document, the machine description may also be a file in XML format, with the corresponding DTD or XML-Scheme.

Relating to the test system description, it may initially be generated manually by an expert
20 operator, by mapping the hardware architecture bi-uniquely with the XML description. Secondly, since the hardware modules within the test system are aware of their own characteristics, an automatic enumeration process could be used to collect parameters directly from the modules and build the XML machine description file. This operation could be performed every time the test system is powered on, ensuring that the machine description
25 always reflects the current state of the system, thus automatically accounting for any failures or hardware modifications. This greatly reduces the potential for human error.

For instance, the test system manufacturer (possibly composed of multiple interconnected test machines) may formally define the test machine architecture. Alternatively, to make the
30 management of reconfigurable hardware test machines more efficient, each functional module of which the machine is made may contain a formal description of itself, allowing an overall machine description to be automatically generated by a simple enumeration of the

modules therein and their iterative interrogation. It is also possible to use non-“compatible” test machines, provided they can be described using the same formalism. This set of data can form the aforementioned “Machine Description”

- 5 Preferably, the electronic control means 102 may also be arranged to determine the execution order and/or execution time of the commands 110, arranged to be provided to the test machine 112 and executed by said test machine, for applying the test stimuli and test measurements onto the at least one device to be tested.
- 10 The electronic control means 102 may also be arranged to determine the execution order and/or execution time of the commands 110 based on at least the information 104 relating to the structure of the at least one device to be tested, the information 106 relating to the test stimuli and test measurements to be applied onto the at least one device to be tested, and the information 108 relating to the test machine 112 by which the test stimuli and test
- 15 measurements are to be applied onto the at least one device to be tested, which have been received as input by the electronic control means 102.

- Preferably, when the information relating to the structure of the at least one device to be tested, DUT, comprises at least one of information of operational constraints of the device
- 20 to be tested, information of operational constraints of the structural elements 200 that are comprised in the device to be tested, and when said information relating to a test machine 112 by which the test stimuli and test measurements are to be applied onto the at least one device to be tested comprises at least one of information of operational constraints of the test machine 112, and information of operational constraints of the structural elements 200 that
- 25 are comprised in the test machine 112, the electronic control means 102 can be arranged to determine the execution order and/or execution time of said commands 110 so that the operational constraints comprised in the information relating to the structure of the at least one device to be tested, DUT, and the operational constraints comprised in the information relating to a test machine 112, by which the test stimuli and test measurements are to be
- 30 applied onto the at least one device to be tested, are respected.

In other words, the electronic control means 102 are responsible for transforming the Test

Document (i.e., the information relating to the structure of the at least one device to be tested and the information relating to the test stimuli and test measurements to be applied onto the at least one device to be tested), sequence completely abstract and independent of the test machine hardware, into the exact sequence of commands that will be executed by the test machine (by the structural/external elements included in/associated with the test machine).

The operation performed by the electronic control means 102 may be considered analogous to a procedure for compiling a high-level source code, independent of the hardware on which it will be executed, into machine code, which here is specific to each possible microprocessor.

In this context, the individual elementary functions of the test machine structural elements, and thus the commands sent to the latter, are similar to assembly language instructions, while the Test Document is equivalent to a source code in the C code language.

Continuing this analogy, it becomes clear that execution time optimization can be achieved in this case as well, first of all by reordering the test steps but also, in cases of multiple similar structural elements within the test machine, by leveraging the machine's intrinsic parallelism.

Relating to the definition of the execution order and/or the execution time of the commands 110, which are based on the possibility of performing the test (application of the test stimuli and test measurements) in an order different from that described in the Test Document, as well as exploiting parallelism, the introduction of additional constraints within the Test Document may be foreseen. These constraints may be used to impose spatial or temporal limitations in the reordering operations carried out by the electronic control means 102. For example, it may be necessary to impose a temporal order for certain commands that must all be executed before another command. A typical case is the initialization of multiple generators used in a test (e.g., stimulus generators). Initializations can be performed in an arbitrary order, possibly even in parallel. But they must however all be completed before the actual test begins. Furthermore, if for example one wishes to test the independent branches of a three-phase bridge, having sufficient resources, this may be then done in parallel on

three different test execution flows. However, this may be incorrect if the three tests carried out in parallel exceed a critical parameter of the device under test, such as overall dissipation. Therefore, two different types of constraints can be specified in the Test Document in a way that is abstract from the test machine. These constraints can, in fact, be tied to the specificity
5 of the device to be tested rather than to the characteristics of the test machine.

For example, it suffices to imagine the existence of a step that does absolutely nothing except impose a restriction on the electronic control means. If one wants to simulate a temporal barrier, it is possible to introduce a step of this kind, which the electronic control means
10 cannot bypass in their command allocation processes, either by moving forward or backward in time.

Similarly, if one wants to prevent the expression of intrinsic parallelism, it will be possible to introduce, at the beginning of the command sequence to be executed in a purely
15 sequentially manner, a step with exclusive execution, i.e. which cannot be parallelized by replication.

In one example, software executable by the electronic control means 102, known as the “allocator,” can receive the “Machine Description” and the “Test Document” as inputs and
20 for each elementary test, it can allocate the modules that constitute the test machine in order to carry out an independent test sequence. Subsequently, the allocator can order the independent test sequences in the “Test Document” to optimize the total time required for performing the functional test, while simultaneously satisfying any constraints in the “Test Document.” It is clear that any change in the physical configuration of the machine, whether
25 voluntary or accidental, will require only re-running the allocator. It is also clear that, in the case of redundant hardware modules within the test system, the allocator can independently decide to parallelize independent tests, always with the goal of minimizing the total time required to perform the functional test, possibly allowing simultaneous testing of multiple devices.

30

In another aspect, the present invention also relates to a test system 500 for applying test stimuli and test measurements onto at least one device to be tested.

With reference to Figure 5, in a first embodiment, the test system 500 comprises:

- a system 100 for determining commands to be executed by a test machine 112 to apply test stimuli and test measurements onto at least one device to be tested, DUT, according to any of the previously described embodiments; and
- a test machine 512 arranged to receive the commands determined by the electronic control means 102 of the system 100 for determining commands to be executed by a test machine 112.

10 The test machine 512 is also arranged to execute the commands 110 received, for the application of the test stimuli and test measurements onto the at least one device to be tested.

For example, the test machine 512 may comprise one or more structural elements, such as, for example, at least one probe card, at least one needle probe card, at least a contact disc, at least a current and/or voltage meter, at least one current and/or voltage generator, etc.

For example, during each step of the test execution, the commands 110 may change the module parameters (e.g., corresponding to an interface) by specifying a constant value or a function that links the parameter to other values. It will therefore suffice to define a format for specifying the equations that represent the formulae, compact enough to be transmitted with reduced cost and sufficiently simple to decode, to minimize the amount of calculations required for computation. Such commands could also include those for modifying the configuration of the connection matrix between the DUT and the test system.

25 Preferably, the test system 500 may comprise an interconnection network arranged to connect said system for determining commands to be executed by a test machine 112 to said test machine 512, to transmit the commands 110 determined by the system for determining commands to be executed by a test machine 112.

30 For communication through the interconnection network, logical addressing can be introduced. For example, each structural element/module of the test machine can be assigned a unique number, allowing unequivocal identification within the test machine.

This same identifier can also be used within the previously described machine description document. This way, the commands generated by the electronic control means 102 can be directed to the correct structural element/module of the test machine. For this addressing
5 step, in an alternative embodiment, an external module to the electronic control means can also be provided, configured to handle the proper routing of the commands based on logical addressing to the specific physical element/module of the test machine.

Preferably, the test machine for receiving the commands determined by the electronic control
10 means may be arranged to receive the at least one digital document of commands, which comprises the commands determined by the electronic control means.

Having the exact sequence of commands 110 to be sent to the structural elements/modules to correctly execute the test, a specifically developed application can be provided to read the
15 commands from the digital document/file containing them and send them to the different modules via the internal interconnection network of the test system/test machine. It is worth noting that some commands may be signals intended for the operator, for example, to indicate a test failure, so that the application responsible for executing the test could also have a user interface, either textual or, more appropriately, graphical. The same user
20 interface could be used to finely control the execution process, similar to the way a conventional debugger operates. In this way, it would be possible to perform a test step-by-step or to halt execution upon the occurrence of a specific condition.

Preferably, as illustrated in Figure 6, the test system may further comprise second electronic
25 control means 600 arranged to provide the test machine with at least:

- information 104 relating to the structure of the at least one device to be tested;
- information 106 relating to test stimuli and measurements to be applied onto the at least one device to be tested;
- information 108 relating to said test machine by which the test stimuli and test
30 measurements must be applied onto the at least one device to be tested.

For instance, the second electronic control means 600 may comprise or be at least one of: a

processor, a microprocessor, a controller, a microcontroller, an FPGA, a PLC, or similar. For example the second electronic control means could be included within a computer or processor.

- 5 Preferably, the second electronic control means 600 may be arranged to determine the information 104 relating to the structure of the at least one device to be tested, the information relating to the test stimuli and test measurements to be applied onto the at least one device to be tested, and the information relating to the test machine by which the test stimuli and test measurements must be applied onto the at least one device to be tested, based
10 on data provided by a user via a specific software platform or data generated by an automatic software.

For example, a software module with a graphical interface can be used to facilitate the preparation work. This software, for example might allow to graphically create libraries of
15 basic devices, such as diodes, transistors, and half-bridge modules, from which the designer can draw to model the device to be tested. Additionally, the same software can allow the creation of libraries of modules (generators, meters, passive components), which are also used for defining the type of test to be applied by connecting them graphically to the terminals of the device to be tested. Finally, through the same graphical software interface,
20 it may also be possible to define the temporal sequence of operations required to actually perform the test on the at least one device to be tested. Similarly to the above, the machine description file, if not automatically generated, can also be created by an appropriate graphical software interface.

- 25 Preferably, for timing synchronization of the test system, the test system 500 may comprise a global synchronization mechanism among the elements/modules within the test system. In practice, this means that each structural element/module, by using either hardware or software tools, can incorporate or be associated with a local timer synchronized within precise limits with all other structural elements/modules in the test system. For example, the
30 NTP standard, commonly used on Internet networks, provides this type of synchronization using a purely software-based approach. Similarly, the EtherCAT communication standard inherently provides, in hardware, a real-time timer or clock within the slave device, capable

of achieving very high precision.

In one example, additional software, known as the “executor,” may be responsible for distributing the sequence of elementary steps generated by the allocator to the various
5 modules within the test system and synchronizing their execution based on temporal information and the status information of individual modules.

Advantageously, what clearly distinguishes the proposed methodology from existing ones is that the approach is entirely “data-driven”. The operator does not need to define the temporal
10 sequence of operations constituting the functional test unless explicitly desired. For instance, based on the data dependencies described in the “Test Document” and optimizing the use of the physical resources within the test system, the allocator has the task of determining the sequence followed by the functional test during its execution.

15 Moreover, the use of automated means makes the efficiency of the test system independent of the specific expertise of the person writing the “Test Document”.

In another aspect, the present invention relates to a method for determining commands to be executed by a test machine 112 for applying test stimuli and test measurements onto at least
20 one device to be tested, DUT, implemented by electronic control means.

In a first embodiment, the method comprises the steps of:

- receiving information relating to the structure of the at least one device to be tested;
- receiving information relating to test stimuli and measurements to be applied onto
25 the at least one device to be tested;
- receiving information relating to a test machine by which the test stimuli and test measurements are to be applied onto the at least one device to be tested;
- determining the commands arranged to be provided to said test machine and to be executed by said test machine, for applying the test stimuli and test measurements onto the
30 at least one device to be tested, based on at least the information relating to the structure of the least one device to be tested, the information relating to the test stimuli and test measurements to be applied onto the at least one device to be tested, and the information

relating to a test machine by which the test stimuli and test measurements are to be applied onto the at least one device to be tested, received as input by said electronic control means.

Preferably, the process may also comprise the step of:

- 5 - based on the information relating to the test machine 112 by which the test stimuli and test measurements are to be applied onto the at least one device to be tested, DUT, transforming the information relating to the structure of the at least one device to be tested, DUT, and the information relating to the test stimuli and test measurements to be applied onto the at least one device to be tested, DUT, into the commands 110 arranged to be
10 provided to said test machine 112 and to be executed by said test machine 112.

The embodiments described above for the system for determining commands to be executed by a test machine for applying test stimuli and measurements onto at least one device to be tested, and not repeated here unless otherwise indicated, can also be similarly applied to the
15 method described above.

In this description, “information” may refer to one or more data items conveying respective information but not necessarily source code in a programming language.

- 20 Advantageously, by considering the information 104 relating to a structure of the at least one device to be tested, DUT, and the information 108 relating to the test machine 112, if accompanied by a mathematical model, it is possible to validate through simulation the electrical behaviours of the device to be tested and the test machine. Similarly, through solution proposed by the present invention solution, a simulated test time can be obtained.
- 25 Based on the simulated test time, it is possible to appropriately adjust the set of available resources described by the information 108 relating to the test machine 112 to achieve the lowest possible testing cost. This type of simulations is not feasible using the solutions of the prior art discussed earlier in this description.

- 30 The achieved advantage is thus the provision of solutions that allow:

- determining the list of commands to be executed by a test machine for the application of test stimuli and measurements onto at least one DUT, adapting to the available

test machine;

- reducing the costs in terms of human resources and time for determining the commands to be executed by a test machine for the application of test stimuli and measurements onto at least one DUT.

5

Various aspects and embodiments of a system for determining commands to be executed by a test machine to apply test stimuli and measurements onto at least one device to be tested, a corresponding method, and a test system according to the invention have been described.

It is intended that each embodiment can be combined with any other embodiment. The

10 invention moreover is not limited to the described embodiments but may be varied within the scope defined by the appended claims.

CLAIMS

1. System (100) for determining commands to be executed by a test machine (112), for applying test stimuli and test measurements onto at least one device to be tested (DUT),
- 5 wherein said system (100) comprises electronic control means (102) arranged to:
- receive as input information (104) relating to a structure of the at least one device to be tested (DUT);
 - receive as input information (106) relating to said test stimuli and said test measurements to be applied onto the at least one device to be tested (DUT);
 - 10 - receive as input information (108) relating to the test machine (112) by means of which said test stimuli and said test measurements are to be applied onto the at least one device to be tested (DUT);
- wherein said electronic control means (102) are further arranged to determine the commands (110) arranged to be provided to said test machine (112) and to be executed by
- 15 said test machine (112), for applying said test stimuli and said test measurements onto the at least one device to be tested (DUT);
- wherein said electronic control means (102) are arranged to determine the commands (110) based on at least the information relating to the structure of the at least one device to be tested (DUT), the information relating to said test stimuli and said test measurements to be applied onto the at least one device to be tested (DUT), and the information relating to
- 20 the test machine (112) by means of which said test stimuli and said test measurements are to be applied onto the at least one device to be tested (DUT), received as input by said electronic control means (102).
- 25 2. System (100) according to claim 1, wherein said electronic control means (102), for determining the commands (110) based on at least the information relating to the structure of the at least one device to be tested (DUT), the information relating to said test stimuli and said test measurements to be applied onto the at least one device to be tested (DUT), and the information relating to the test machine (112) by means of which said test stimuli and said
- 30 test measurements are to be applied onto the at least one device to be tested (DUT), received as input by said electronic control means (102), are arranged to:
- based on the information relating to the test machine (112) by means of which said

test stimuli and said test measurements are to be applied onto the at least one device to be tested (DUT), transform the information relating to the structure of the at least one device to be tested (DUT) and the information relating to said test stimuli and said test measurements to be applied onto the at least one device to be tested (DUT) into the commands (110) arranged to be provided to said test machine (112) and to be executed by said test machine (112).

3. System (100) according to claim 1 or 2, wherein said information relating to the structure of the at least one device to be tested (DUT), said information relating to said test stimuli and said test measurements to be applied onto the at least one device to be tested (DUT), and said information relating to the test machine (112) by means of which said test stimuli and said test measurements are to be applied onto the at least one device to be tested (DUT) are comprised in at least one digital document;

wherein said electronic control means (102) are arranged to receive as input said at least one digital document.

4. System (100) according to any of the preceding claims, wherein said electronic control means (102) are arranged to generate a digital document of commands arranged to be provided to the test machine (112);

wherein said digital document of commands comprises the commands (110) determined by said electronic control means (102).

5. System (100) according to any of the preceding claims, wherein the information relating to the structure of the at least one device to be tested (DUT) comprises at least one of the following information:

- the number and type of structural elements (200) comprised in the device to be tested;
- connections (202) between structural elements (200) that are comprised in the device to be tested;
- hierarchy of structural elements (200) that are comprised in the device to be tested;
- operational constraints of the device to be tested;
- operational constraints of the structural elements (200) that are comprised in the

device to be tested.

6. System (100) according to any of the preceding claims, wherein the information relating to said test stimuli and said test measurements to be applied onto the at least one
5 device to be tested (DUT) comprises at least one of the following information:

- elementary test units provided by said test stimuli and said test measurements, said elementary test units comprising exclusively data and/or formulae;

- dependencies between different elementary test units provided by said test stimuli and said test measurements;

- 10 - logical test components (300) that are provided by said test stimuli and said test measurements and that need to be connected to the device to be tested during the application of said test stimuli and said test measurements.

7. System according to any of the preceding claims, wherein the information relating to
15 a test machine (112) by means of which said test stimuli and said test measurements are to be applied onto the at least one device to be tested comprises at least one of the following information:

- structural elements (400) that are comprised in the test machine;

- operating parameters of the structural elements (400) that are comprised in the test
20 machine (112);

- connections (402) between structural elements (400) that are comprised in the test machine (112);

- hierarchy of the structural elements (400) that are comprised in the test machine (112);

- 25 - operational constraints of the test machine (112);

- operational constraints of the structural elements (400) that are comprised in the test machine (112).

8. System according to any of the preceding claims, wherein said electronic control
30 means (102) are also arranged to determine the execution order and/or execution time of the commands (110) arranged to be provided to said test machine (112) and to be executed by said test machine, for applying said test stimuli and said test measurements onto the at least

one device to be tested;

wherein said electronic control means (102) are arranged to determine the execution order and/or execution time of said commands (110) based on at least the information (104) relating to the structure of the at least one device to be tested, the information (106) relating to said test stimuli and said test measurements to be applied onto the at least one device to be tested, and the information (108) relating to the test machine (112) by means of which said test stimuli and said test measurements are to be applied onto the at least one device to be tested (DUT), received as input by said electronic control means (102).

10 **9.** System according to any of the preceding claims, when dependent on claim 5 and claim 7, wherein,

when said information relating to the structure of the at least one device to be tested (DUT) comprises at least one of the following information:

- operational constraints of the device to be tested;
- 15 - operational constraints of the structural elements (200) comprised in the device to be tested;
- and

when the information relating to a test machine (112) by means of which said test stimuli and said test measurements are to be applied onto the at least one device to be tested comprises at least one of the following information:

- operational constraints of the test machine (112); and
- operational constraints of the structural elements (200) that are comprised in the test machine (112);

the electronic control means (102) are arranged to determine the execution order and/or the execution time of said commands (110) so that the operational constraints comprised in the information relating to the structure of the at least one device to be tested (DUT) and the operational constraints comprised in the information relating to a test machine (112), by means of which said test stimuli and said test measurements are to be applied onto the at least one device to be tested, are respected.

30

10. System according to any of the preceding claims, when dependent on claim 7, wherein,

when said information relating to a test machine (112) by means of which said test stimuli and said test measurements are to be applied onto the at least one device to be tested comprises information relating to the structural elements (400) that are comprised in the test machine, information relating to the connections (402) between structural elements (400) that are included in the test machine (112), and information relating to the hierarchy of the structural elements (400) that are comprised in the test machine (112),

the electronic control means (102) are arranged to determine said commands (110) so that structural elements (400) having a first hierarchy communicate only with structural elements (400) having a second hierarchy, lower than said first hierarchy.

11. Test system (500) for the application of test stimuli and test measurements on the at least one device to be tested, comprising:

- a system (100) for determining commands to be executed by a test machine (112), for applying test stimuli and test measurements onto at least one device to be tested (DUT), according to any of the preceding claims;

- a test machine (512) arranged to receive the commands determined by the electronic control means (102) of the system (100) for determining commands to be executed by a test machine (112);

wherein said test machine (512) is further arranged to execute said commands (110) received, for applying said test stimuli and said test measurements onto the at least one device to be tested.

12. Test system (500) according to claim 11, comprising an interconnection network (502) arranged to connect said system (100) for determining commands to be executed by a test machine (112) to said test machine (512), for transmitting said commands (110) determined by the system (100) for determining commands to be executed by a test machine (112).

13. Test system according to claim 11 or 12, when said system for determining commands to be executed by a test machine (112), for applying test stimuli and test measurements onto the at least one device to be tested (DUT), is implemented according to claim 4, wherein said test machine arranged to receive the commands determined by said

electronic control means is arranged to receive the at least one digital document of commands comprising the commands determined by said electronic control means.

- 14.** Test system according to any of claims 11 to 13, further comprising second electronic control means arranged to provide said test machine with at least:
- information relating to the structure of the at least one device to be tested;
 - information relating to said test stimuli and said test measurements to be applied onto the at least one device to be tested;
 - information relating to said test machine by means of which said test stimuli and said test measurements are to be applied onto the at least one device to be tested.

- 15.** Test system according to claim 14, wherein said second electronic control means are arranged to determine said information relating to the structure of the at least one device to be tested, said information relating to said test stimuli and said test measurements to be applied onto the at least one device to be tested, and said information relating to said test machine by means of which said test stimuli and said test measurements are to be applied onto the at least one device to be tested, based on data provided by a user through a specific software platform or on data generated by automatic software.

- 16.** Method for determining commands to be executed by a test machine (112), for applying test stimuli and test measurements onto the at least one device to be tested (DUT), implemented by electronic control means, comprising the steps of:
- receiving information relating to the structure of the at least one device to be tested;
 - receiving information relating to said test stimuli and said test measurements to be applied onto the at least one device to be tested;
 - receiving information relating to a test machine by means of which said test stimuli and said test measurements are to be applied onto the at least one device to be tested;
 - determining the commands arranged to be provided to said test machine and executed by said test machine, for applying said test stimuli and said test measurements onto the at least one device to be tested, based on at least the information relating to the structure of the at least one device to be tested, the information relating to said test stimuli and said test measurements to be applied onto the at least one device to be tested and the information

relating to a test machine by means of which said test stimuli and said test measurements are to be applied onto the at least one device to be tested, received as input by said electronic control means.

- 5 **17.** Method according to claim 16, further comprising the step of:
- based on the information relating to the test machine (112) by means of which said test stimuli and said test measurements are to be applied onto the at least one device to be tested (DUT), transform the information relating to the structure of the at least one device to be tested (DUT) and the information relating to said test stimuli and said test measurements
- 10 to be applied onto the at least one device to be tested (DUT) into the commands (110) arranged to be provided to said test machine (112) and to be executed by said test machine (112).