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(71) Applicant: **MARPOSS SOCIETA' PER AZIONI** [IT/IT]; Via Saliceto 13, I-40010 Bentivoglio BO (IT).

(72) Inventors: **PADOVANI, Roberto**; via Grazioli 2/1, I-40061 Minerbio (BO) (IT). **DONDI, Daniele**; via Bologna, 18, I-40017 San Giovanni in Persiceto (BO) (IT).

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(54) Title: TOUCH PROBE AND RELATIVE CIRCUITS AND METHODS FOR SIGNAL PROCESSING

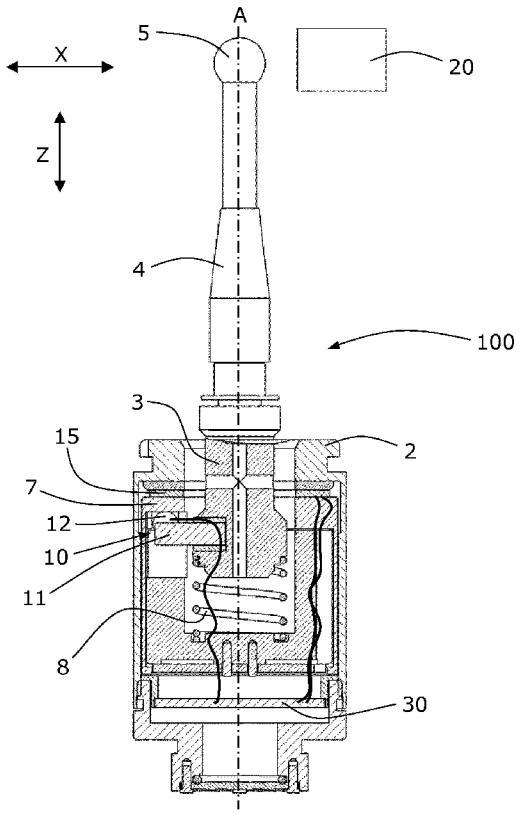


Fig. 1

(57) Abstract: A probe (100) comprises a frame (2), a movable armset (3) and a processing circuit (30; 30') for processing signals. The processing circuit is able to individually detect the state of contacts (13) defined by the cooperation between mechanical elements of the armset and mechanical elements of the frame, that is the closing or opening of the contacts, and provide a signal indicative of a rest position of the probe when it detects no more than one open contact. A method for processing signals uses said circuit in order to provide a signal indicative of a rest position of the probe. The circuit and the method for processing signals are advantageously implemented for processing the output signals of a touch probe adapted to check dimensions or position of a workpiece in coordinate measuring machines and machine tools.

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DESCRIPTION

« **TOUCH PROBE AND RELATIVE CIRCUITS AND METHODS FOR SIGNAL PROCESSING** »

Technical Field

The present invention relates to a touch probe for checking position and/or dimensions of a workpiece, comprising a support and protective frame with a rest and locating area, an armset that is movable with respect to and partly housed in the support and protective frame, comprising an arm carrying a feeler adapted to touch the workpiece to be checked, a thrust device adapted to urge the armset against the rest and locating area, a constraint and positioning system, arranged between the armset and the support and protective frame at the rest and locating area, comprising a rest system with reference mechanical stops and contacts that are closed when mechanical elements of the armset cooperate with mechanical elements of the support and protective frame, the reference mechanical stops being adapted to define a rest position of the touch probe, and a processing circuit adapted to detect the state of the contacts and to provide a signal indicative of the rest position when all the contacts are closed.

The invention also relates to a method for processing a signal that is output by a touch probe for checking position and/or dimensions of a workpiece, comprising a support and protective frame, an armset that is movable with respect to and partly housed in the support and protective frame, a rest system with reference mechanical stops and contacts that are closed when mechanical elements of the armset cooperate with mechanical elements of the support and protective frame, the reference mechanical stops being adapted to define a rest position of the touch probe, a processing circuit for detecting the state of the contacts and providing a signal indicative of the rest position when all the contacts are closed.

Prior Art

Touch probes are electromechanical tools widely used in coordinate measuring machines and machine tools, particularly machining centers and lathes, for checking workpieces, machined or to be machined, tools, machine tables, etc.

As described for example in U.S. patent number US4153998A, such probes generally include a support structure or frame, and an armset that is movable with respect to the frame and comprises an arm carrying a feeler adapted to touch the workpiece to be checked. In particular, the armset is coupled to the frame at reference mechanical stops between elements made of conductive material that define pairs of electrical contacts typically in series, being part of an electric circuit.

When the probe lies in rest position, the armset is coupled to the frame at all the reference mechanical stops under the thrust of a spring. The opening and closing of the electrical contacts are detected by checking, for example, variations in resistance across these contacts. When the feeler touches the workpiece, an external force acts in opposition to the thrust of the spring on the armset, causing the gradual release of the latter with respect to the frame in correspondence of at least one contact. The value of resistance across one or more contacts progressively increases until exceeding a determined threshold, giving rise to an output signal indicative of the probe moving away from the rest position, as a consequence of the touch between the feeler and the workpiece to be checked. In touch probes, in order that the checking is repeatable and reliable, it is important that, as the touch between the feeler and the workpiece ceases, the probe returns to its rest position.

This requirement is also present in probes wherein the touch between the feeler and the workpiece is detected by sensors of different types, for example piezoelectric

sensors or strain gauges which emit a signal indicative of the total force applied to the probe. In this case, the coupling between armset and frame and the corresponding electric circuit can be used as auxiliary devices for detecting whether or not there actually has been a contact between the feeler and the workpiece, and consequently the probe, respectively, does not stand in the rest position or it does. In more detail, as the sensors are not always able to transmit information about the state of the system and in particular about the deflection of the armset with respect to the frame, for example at the time that immediately follows the emission of the signal, said coupling and the relative electric circuit can be used to derive such information. A probe of this type is described in the international patent application published under number WO2012055866.

In the touch probes so far mentioned, particularly if used for repeatedly checking, the problem of incorrectly signaling the return of the probe in the rest position may arise in practice. In particular, as the touch between the feeler and the workpiece ceases, when the armset is coupled again to the frame at the reference mechanical stops under the thrust of the spring, the rest position may not be correctly restored and/or signaled, for example due to the fact that the resistance value detected in correspondence of at least one contact is not back below the determined threshold.

A circuit and a method that intend to partially solve this problem are described in the European patent application published under number EP0501681A1. The application refers to a probe that includes an electrical circuit for signal processing comprising active components, for instance transistors, and a method for checking which comprises a step of cleaning the contacts. However, among the main disadvantages of this known technique, there are an increase in the response time of the probe due to delays introduced by the switching time of the active components

and the further step of cleaning the contacts, and the risk of damaging the surface of the contacts due to the high currents that may flow in the circuit.

More complex solutions give indication of the armset arrangement when the probe is not operational. For example, according to the solution presented in U.S. patent number US5090131A, each reference mechanical stop is equipped with strain gauges, which measure in all directions the deviations of the armset with respect to a predetermined reference position so that these deviations are taken into account in the later check. This known technique, however, requires complex circuits, that are expensive and in most cases difficult to manufacture.

Disclosure of the Invention

Object of the present invention is to realize a touch probe for checking position and/or dimensions of a workpiece, and a method for processing a signal, for example a signal that is output by a touch probe adapted to check position or dimensions of a workpiece in coordinate measuring machines or machine tools, said touch probe and method being free from the previously described inconveniences and, concurrently, easily and cheaply implemented.

According to the present invention, this and other objects are achieved by a touch probe and a method for signal processing according to claim 1 and claim 8, respectively, which form an integral part of the present description.

Objects and advantages of the present invention will be clear from the detailed description that follows, concerning a preferred embodiment of the invention, given only by way of non-restrictive example, with reference to the attached drawings.

Brief Description of the Drawings

The present invention is now described with reference to the attached sheets of drawings, given by way of non-limiting examples, wherein:

- figure 1 is a schematic view of a longitudinal section of a touch probe according to the present invention;
- figure 2 illustrates in a schematic way an enlarged longitudinal section of a component of the touch probe according to the present invention;
- figure 3 is a schematic circuit block diagram of a signal processing system in a touch probe according to a preferred embodiment of the invention;
- figure 4 is a schematic circuit block diagram of a signal conditioning unit within said processing system;
- figure 5 is a schematic circuit block diagram of a signal processing system in a touch probe according to a different embodiment of the invention; and
- figure 6 illustrates a finite state machine implemented by the processing electronics according to a different embodiment of the invention.

Best Modes for Carrying Out the Invention

Figure 1 shows in a schematic way the section of a touch probe **100** for checking position and/or dimensions of a workpiece **20**. In a preferred embodiment of the invention, the probe **100** includes, for example, a support and protective structure or frame **2** that defines a longitudinal axis **A**, and an armset **3** that is movable with respect to and partly housed in the frame **2**. The armset **3** comprises an arm **4** carrying a feeler **5** adapted to touch the workpiece **20** to be checked. A thrust device with a compression spring **8** is placed between the frame **2** and the armset **3**, and urges the latter against a rest and locating area **7** of the frame **2**.

A constraint and positioning system is arranged between the armset **3** and the frame **2**, at the rest and locating area **7**. Said constraint and positioning system comprises a rest system with reference mechanical stops **10**

defined by the cooperation of mechanical elements of the armset **3** with further mechanical elements of the frame **2**, ideally arranged in a circular way and equidistant from one another. For example, the rest system may be isostatic with three reference mechanical stops **10**, each of which is defined by two spheres **12** – only one of them is visible in figure 1 –, fixed to the frame **2** and adapted to define a V-shaped seat, and by a radial element **11** with cylindrical shape that is part of the armset **3**. The spheres **12** and the radial element **11** are entirely made, otherwise at least partially covered, by conductor or semiconductor material, in general characterized by a predetermined conductivity inside a given range of values. Each radial element **11** can separately cooperate with each of two spheres **12** at an ideally point area or contact **13** (figure 2), for instance an electrical contact.

At the rest and locating area **7**, the probe **100** includes also a detection system **15**, separate from the contacts **13**, comprising for example at least a laminar piezoelectric element or transducer connected to the frame **2** and substantially arranged on a plane perpendicular with respect to the longitudinal axis **A**. The laminar piezoelectric transducer has the capability of converting the compression or decompression events it is subjected to in electrical signals indicative of the force variation it undergoes. The detection system **15** with the laminar piezoelectric transducer transmits to a processing circuit **30** control signals that are processed and used in a way known per se for checking, as mentioned above, position and/or dimensions of the workpiece **20**. More details about a touch probe with a laminar piezoelectric transducer are described in the already cited international patent application published under number WO2012055866.

Processing electronics are located within the support structure **2** and include the processing circuit **30**, which both the spheres **12** and the detection system **15** are

connected to by means of electrical conductors represented by connections drown with thick line.

In a preferred embodiment of the invention, as schematically illustrated in figure 3, all the radial elements **11** are connected to a known potential, usually null, and each sphere **12** is connected for instance to a conditioning unit **29** of the processing circuit **30**. The contacts **13**, which are six in the illustrated example, to be more precise the circuit branches each comprising a contact **13** defined by one radial element **11** and one of the two spheres **12** which such radial element **11** cooperates with, and one conditioning unit **29**, are advantageously connected together in parallel. In such a way the processing circuit **30** is able to detect individually the state of each of the six contacts **13**, in other words whether each single contact **13** is closed or open. The processing circuit **30** includes also an analog/digital converter **35** and a microcontroller **36**. The latter is adapted, amongst other things, to process both control signals transmitted by the detection system **15** for the correct emission of the signal indicative of the total force variation, and the signals about the state of the spheres **12**, for instance the potential of each of them, that give indication about the number of closed contacts **13**, namely the mutual position between the armset **3** and the rest and locating area **7** of the frame **2**.

In order to better illustrate the processing circuit of a touch probe according to the present invention and a corresponding processing method, figure 4 shows some of the main components of a schematic circuit block diagram of only one conditioning unit **29**, such diagram being the same for the others. The potential associated to the sphere **12**, the latter being not visible in figure 4, is given by a voltage divider between a bias resistance **32** connected to a supply voltage V_A, and a contact resistance associated to the contact **13** between the sphere **12** and the radial element **11** it cooperates with.

The voltage divider generates, according to a known operating principle, a potential that is transmitted to a comparator **33**, the threshold thereof is fixed to a reference value V_T, preferably programmable, which produces a signal representative of the state of the corresponding contact **13**. When the contact **13** is closed, in theory the resistance across it is null, the input potential of the comparator **33** is null and its output potential is high, usually equal to the supply voltage of said comparator **33**. When the contact **13** is substantially open as the radial element **11** moved away from the sphere it rests on, in theory the resistance is infinite (in practice, greater than a determined value), the input potential of the comparator **33** corresponds to that of the voltage generator V_A and its output potential is low, for instance equal to zero. The conditioning unit **29** comprises also a signal adjusting circuit **34**, connected to the comparator **33** and designated for example for filtering and amplifying the signal.

The output potentials of the signal adjusting circuits **34**, each conveniently converted in digital number through the analog/digital converter **35**, are processed by the microcontroller **36** in order to have an indication about the number of closed contacts **13** and provide, on the basis of such indication, a signal indicative of the probe **100** rest position.

A method for signal processing according to the present invention is described in the following.

When the probe **100** lies in the initial rest position, that is in the absence of touch between the feeler **5** and the workpiece **20** to be checked, under the action of the spring **8**, the three radial elements **11** are placed in the V-shaped seats realized by the spheres **12**, and the reference mechanical stops **10**, therefore the position of the armset **3** with respect to the frame **2**, are univocally defined. As it is shown in figure 2, that illustrates in a schematic way the transversal section of one of the reference mechanical

stops **10** in such initial rest position, each radial element **11** touches both the spheres **12** that define the V-shaped seat it is located in, closing the corresponding six contacts **13**. All the six comparators **33** have null input potential and transmit a potential equal to their supply voltage to the corresponding signal adjusting circuits **34**. The output signals of the signal adjusting circuits **34** are converted each in a digital number and suitably combined by the analog/digital converter **35**, then transmitted to the microcontroller **36**, that processes them and provides a signal indicative of said initial rest position.

Following mutual movements between the probe **100** and the workpiece **20** to be checked, for instance along a transversal direction indicated with a double arrow **X** in figure 1, the feeler **5** touches the workpiece **20**, and the latter applies a force to the armset **3** that is transmitted to the constraint and positioning system. The rest and locating area **7** is then subjected to compression or decompression events detected by the piezoelectric transducer of the detection system **15**, that converts them in control signals indicative of the force variation to be transmitted to the microcontroller **36** in order to process and emit both the stop control of said mutual movements and the signal indicative of the total force variation. In correspondence of at least one of the three reference mechanical stops **10**, a thrust action of the radial element **11** on the corresponding couple of spheres **12** also occurs, as well as a simultaneous action of releasing the thrust applied by the spring **8** at the other two - or the other one - reference mechanical stops **10** with consequent opening of one or more contacts **13**. Consistently, as the input potential of the comparators **33** corresponding to one or more open contacts **13** is changed, such comparators **33** individually have null output potentials that, suitably adjusted by the signal adjusting circuit **34**, combined and digitalized by the analog/digital converter **35**, signal to the microcontroller **36** that the cooperation fails at said

one or more open contacts **13** or, in other words, that said one or more contacts **13** are open. The microcontroller **36** processes such signals and detects the touch occurred between the feeler **5** and the workpiece **20**, that is an operating status of the probe **100**.

The same result is given by mutual movements along directions other than **X**, for instance along a direction **Z**, and following touch between the feeler **5** and the workpiece to be checked **20**, after which a release action in correspondence, at least theoretically, of all the three reference mechanical stops **10** occurs, with consequent opening of the six contacts **13** and decompression in the laminar piezoelectric transducer.

At the end of the checking and following mutual movements between the probe **100** and the workpiece **20**, for instance in mutually opposed senses along the transversal direction **X**, the contact between the feeler **5** and the workpiece **20** is released and the probe **100** returns in the rest position defined by the reference mechanical stops **10**. Said position, wherein, at least theoretically, compression and decompression events detectable by the piezoelectric transducer do not occur in the rest and locating area **7** and the cooperation is present at said contacts **13**, that is the six contacts **13** are all closed, is detected by the processing circuit **30** on the basis of the signals received from said contacts **13**. Experimental tests performed by the applicant of the present application proved that it is not infrequent a situation wherein, even though the rest position is correctly restored from a mechanical point of view, the presence of the cooperation at all the contacts **13** is not signaled from an electrical point of view, in other words it is not signaled that all the six contacts **13** are closed. On the basis of said experimental tests, in particular, the rest position can be considered fully restored from a mechanical point of view not only when it is detected that all the six contacts **13** are closed, but also when it is detected that only one of said six contacts

13 is not proven to be closed, namely when it is detected that five of the six contacts **13** are closed. The signaling relative to the closing of the sixth contact **13** may not occur, for instance, because of a partial wear of the relative reference mechanical stop **10**, or of an electrical malfunctioning due to the oxidation or to the deposit of a thin layer of oil (generally present inside the probe) between the sphere **12** and the radial element **11** that define said sixth contact **13**.

According to the preferred embodiment illustrated in figure 1 and figure 3, the rest position and the operating status of the probe **100** are detected by the processing electronics on the basis of the signals received from the contacts **13**. In particular, in a method for signal processing according to the present invention, the microcontroller **36** processes a signal indicative of the operating status of the probe **100** when, following the touch between the probe **100** and the workpiece **20** to be checked and the relative movement of the armset **3** with respect to the frame **2**, the cooperation is not present in correspondence of at least two of the six contacts **13**, or, in other words, at least two of the six contacts **13** are proven to be open, that is when the output potential of at least two of the six comparators **33** is null. As the touch ceases, indeed, at the moment when at least five contacts **13** are closed again, the corresponding at least five comparators **33** have null input potentials and output potentials equal to their supply voltage that, suitably adjusted by means of the signal adjusting circuit **34**, digitalized and combined by the analog/digital converter **35**, are transmitted to the microcontroller **36**. The microcontroller **36** receives the signaling of the cooperation in correspondence of at least five contacts **13** as input signal, that is it receives the indication that at least five contacts **13** are closed, and provides, on the basis of such indication, a signal indicative of the rest position of the probe **100**.

Variations to the method and the circuit for signal conditioning as described hitherto may be made without departing from the scope of the invention.

For example, the V-shaped seats and the radial elements **11** may be part of the armset **3** and of the support frame **2**, respectively, or the constraint and positioning system may be realized in a different manner, for instance with a different isostatic system such as the one known as Kelvin coupling.

As an alternative to the laminar piezoelectric transducer, the probe **100** may include detection devices of different nature and disposition, comprising various types of piezo-resistive transducers or pressure transducers.

It is to be noted that when the contact **13** is closed and, at least theoretically, the resistance across it is equal to zero, the input potential of the comparator **33** is equal to a known voltage different from zero.

Alternatively, the conditioning unit **29** and the analog/digital converter **35** may be realized within the microcontroller **36**.

In a different embodiment of the processing electronics, the analog/digital converter **35** may be removed and the conditioning unit **29** may be modified, for instance by including appropriately sized resistors in the signal adjusting circuit **34** so as the values of resistance are equal or in scale with each others, and connecting the modified conditioning units **29** to each other in order that, considered as a whole, they act as a single voltage divider which takes input potentials associated with all the spheres **12** and provides a signal representative of the number of the closed contacts **13**. In particular, said voltage divider, the working principles thereof are known, is characterized by a voltage ratio which varies depending on the number of co-operations present between the mechanical components of the armset **3** and the mechanical components of the frame **2**, i.e. the number of open or

closed contacts **13**, and generates an indication of the number of open otherwise closed contacts **13**.

In a different embodiment of the invention, the microcontroller **36**, that processes the output potentials of the comparators **33** in order to emit a signal indicative of the total force variation, may be substituted with logic gates or programmable logic units, for instance FPGA.

Advantageously, the circuits and the method described hitherto enable the compensation the intrinsic limits of the detection system **15** related to the information about the position of the probe **100**, for example after the emission of the signal indicative of the total force variation, when the detection system **15**, as already said, may be not able to transmit information about the displacement of the armset **3** with respect to the frame **2**. The circuits described hitherto may be also advantageously used when the mutual movements between the probe **100** and the workpiece **20** are relatively slow and, even though they effectively cause the touch between the workpiece **20** and the feeler **5**, the laminar piezoelectric transducer emits a signal with magnitude less than that necessary for the microcontroller **36** to detect the touch occurred, then process and emit the stop control of the mutual movements and the signal indicative of the total force variation. Therefore, the probe **100** not only would fail the checking of the workpiece **20**, but it also would run the risk of being subjected to excessive mechanical stresses and/or breaks because of the undue continuation of said mutual movements instead of stopping as they should do after the occurred touch and the so-called overstroke of the feeler **5**. According to the present invention, the described problems are overcome by a touch probe including the above-described separate electrical circuit comprising the contacts **13**, adapted to transmit signals indicative of the mutual position between the armset **3** and the frame **2** at the rest and locating areas **7**.

In addition, the methods and the circuits of the touch probes object of the present invention allow to obtain excellent results with simple, solid and compact components.

Other possible methods for signal processing according to the present invention may be obtained by using the processing electronics in order to implement a finite state machine, for example a Mealy machine, as illustrated in figure 6, that individually and asymmetrically evaluates the presence of the cooperation at the contacts **13**, in other words the opening or closing of the contacts **13**, for processing the signal indicative of the probe **100** rest position. As it is well known to someone of ordinary skill in the art, the Mealy machine has finite states characterized by output values, for instance the number of closed contacts **13**, determined both by current state and current input value, for instance the opening **-1** or closing **1** of the contacts **13**. For each pair of state and input value, a single transition is possible, generally represented by an arrow from the current state to the future state. The states and the transitions of the Mealy machine according to the present invention are described in the following.

The initial state is, for example, a state S_0 characterized by six closed contacts **13**, wherein the probe **100** lies in the already mentioned initial rest position. Following mutual movements between the probe **100** and the workpiece **20** to be checked that determine the displacement of the armset **3** with respect to the frame **2**, the already mentioned compression and decompression events occur in the rest and locating area **7**, as well as the variation in resistance so in potential at the involved contacts **13**. In this case, as soon as the microcontroller **36** receives the signaling of the failing cooperation at one of the contacts **13**, that is at the opening **-1** of just one contact **13**, the microcontroller **36** is able to detect the touch occurred between the feeler **5** and the workpiece **20**, provide a signal

indicative of the fact that the probe **100** moved away from the rest position and emit the stop control of said mutual movements. Accordingly, the current state of the probe **100** is a state S_1 characterized by five closed contacts **13** and only one open contact **13**, corresponding to a position other than the rest position, indicative of an operating status of the probe **100**. Starting from this state S_1, the probe **100** may alternatively assume two different future states determined by the closing **1** of the only one open contact **13** or by the opening **-1** of at least one of said five closed contacts **13**, respectively.

In the first case, the only one open contact **13** closes again, for instance as the initial touch with the workpiece **20** to be checked ceases, and the microcontroller **36** receives a signaling which indicates that the probe **100** moved in a rest position with current state S_0 characterized by all the six contacts **13** closed. Therefore, the probe **100** shows, for this characteristic, a behavior similar to that of the known ones, for example the one shown in the already mentioned international patent application published under number WO2012055866.

In the second case, at least one of the five closed contacts **13** opens, for example because of the progress of the mutual movements between the probe **100** and the workpiece **20**. The microcontroller **36** receives the signaling of at least a further opening **-1**, which reveals that the probe **100** holds in the operating status, in a current state S_2 or S_3 or S_4 or S_5 or S_6 characterized by no more than four closed contacts **13**, that is at least two open contacts **13**. In more detail, further opening **-1** of the five closed contacts **13**, one per time, determines as much transitions to future states, in order S_2, S_3, S_4, S_5 and S_6, characterized by a number of closed contacts **13** progressively decreased by one, the last state S_6 being characterized by no closed contacts **13**, that is six open contacts **13**. Starting from the state S_6, if, for instance, the mutual movements between the probe **100** and the

workpiece **20** reverse, the six open contacts **13** close presumably one per time. The closing **1** of four of the six open contacts **13**, one after one, determines as much transitions from the current state S_6 characterized by no closed contacts **13** to the future states, in order S_5, S_4, S_3 and S_2, characterized by a number of closed contacts **13** progressively increased by one, the state S_2, as already said, being characterized by four closed contacts **13**, that is two open contacts **13**. When one of the two open contacts **13** closes, that is five contacts **13** are proven to be closed, the microcontroller **36** receives the signaling of said closing **1** and, on the basis of said signaling, according to the present invention, provides a signal indicative of the fact that the probe **100** is back in the rest position though one of the six contacts **13** is proven to be open, in a state S_7 characterized by five closed contacts **13** Starting from this latest state S_7, indicative of the rest position, there are again two possibilities: at the opening of at least a second contact **13** the probe **100** returns to the previous operating status with current states characterized by at least two open contacts **13**. Alternatively, at the closing of the only one open contact **13** the probe **100** holds the rest position with the current state S_0 characterized by six closed contacts **13**.

For further information, figure 6 shows also that the invariance **0** of the contacts **13**, that is contacts **13** do not open nor close, irrespective of the current state, always determines the permanence in the latter, that is the future state corresponds to the current state.

In view of a greater computational complexity of the processing electronics **30**, this alternative method for signal processing according to the present invention exhibits new advantages in addition to the already cited advantages of the preferred method, for example because it features a definitely reduced pre-stroke. Also for this reason, the signaling of the opening and closing of the contacts **13** can be used not only to have information about

the rest position or the operating status of the probe **100**, but also as an alternative to the control signals transmitted by the detection system **15** in order to signal the touch occurred between the feeler **5** and the workpiece **20**. On this regard it is to be noted that, while the probe **100** uses anyway the control signal transmitted by the detection system **15** in order to detect the touch occurred between the feeler **5** and the workpiece **20** on account of the better performance that can be achieved with the piezoelectric transducer, as far as the much faster response time and the isotropic behavior are concerned, a different probe can be provided, such probe using the above mentioned alternative method for signal processing according to the present invention and not needing the piezoelectric transducer, and in general a separate detection system.

A further different embodiment according to the present invention comprises a different processing circuit **30'**, as figure 5 shows, also able to individually detect the state of each of said contacts **13**. The processing circuit **30'** includes the only one voltage divider, already mentioned and with known operating principle, referred to with reference **40** in figure 5. The voltage divider **40** is connected in cascade to both a pulse generator or trigger **42**, adapted to detect the opening of one of the contacts **13** starting from a state wherein all the contacts **13** are closed and generate a corresponding pulse signal, and a threshold comparator **41**, adapted to generate a two-level output signal, one level is indicative of the failing cooperation in correspondence of at least two contacts **13**, that is of a state wherein at least two contacts **13** are open, the other level is indicative of the failing cooperation at no more than one contact **13**, that is of a state wherein no more than one contact **13** is open (in the illustrated example, at least five contacts **13** are closed). In particular, as only one of the six closed contacts **13** opens, the trigger **42** generates a corresponding pulse

signal indicative of said opening, whereas, as one of the five closed contacts **13** opens while only one contact **13** is already open, or, otherwise, as only one of the two open contacts **13** closes while the other four contacts **13** are closed, the output signal of the threshold comparator **41** shifts from one level to the other. The output signals of the threshold comparator **41** and the trigger **42** are transmitted to the microcontroller **36**. This further different embodiment considers that the microcontroller **36** uses the signals received from the threshold comparator **41** (two-level output signal) and the trigger **42** (pulse signal) in order to process the signal indicative of the rest position of the probe **100**, according to a method for signal processing similar to that implemented by the finite state machine previously described, that asymmetrically considers the presence of the cooperation at the contacts **13**, that is the opening and the closing of the contacts **13**. In particular, the microcontroller **36** detects the probe **100** moved away from the rest position when, at the opening of a first contact **13**, it receives the pulse signal indicative of said opening from the trigger **42**.

In case the only one open contact **13** closes again, for example as the initial touch between the feeler **5** and the workpiece **20** to be checked ceases, the trigger **42** does not transmit any signal to the microcontroller **36**. The failure of such transmission, however, does not compromise the correct processing of the control signals received by the microcontroller **36** from the detection system **15** for precisely emitting the signal indicative of the total force variation.

In case, instead, one of the five closed contacts **13** opens, for example because of the progress of the mutual movements between the probe **100** and the workpiece **20**, the output signal of the threshold comparator **41** opportunely goes to the level indicative of the failing cooperation in correspondence of at least two contacts **13**, that is of the fact that at least two contacts **13** are open, and the

microcontroller **36** keeps detecting that the probe **100** is in the operating status. When the closed contacts **13** switch from four to five, for example as a consequence of reversing the mutual movements between the probe **100** and the workpiece **20**, the output signal of the threshold comparator **41** opportunely goes to the level indicative of the failing cooperation at no more than one contact **13**, that is of the fact that at least five contacts **13** are closed, and the microcontroller **36** processes the received signals, so it detects and signals that the probe **100** lies in the rest position. Starting from said rest position, the microcontroller **36** detects and signals a new operating status if one of the five closed contacts **13** opens and the output signal of the threshold comparator **41** goes again to the level indicative of the failing cooperation in correspondence of at least two contacts **13**, that is of the state wherein at least two contacts **13** are open. A new operating status is detected and signaled by the microcontroller **36** even when, after the single contact **13** is closed, one of the six closed contacts **13** opens thereafter, and the trigger **42** generates the corresponding pulse signal indicative of said new operating status.

The probe with this circuit and the relative alternative method for signal processing according to the present invention show new advantages in addition to those already mentioned for the preferred embodiment. As the previously described finite state machine, this embodiment too is characterized by a reduced pre-stroke, but, unlike said finite state machine, it shows the further advantage of having a lower production cost. Moreover, the circuit occupies less space inside the probe **100**. In addition, this alternative embodiment can use the signaling obtained on the basis of the opening and closing of the contacts **13** in order to also signal the touch occurred between the feeler **5** and the workpiece **20** in probes wherein a separate detection system **15** is not present.

CLAIMS

1. Touch probe (100) for checking position and/or dimensions of a workpiece (20), comprising

- a support and protective frame (2) with a rest and locating area (7),

- an armset (3) that is movable with respect to and partly housed in the support and protective frame (2), comprising an arm (4) carrying a feeler (5) adapted to touch the workpiece (20) to be checked,

- a thrust device adapted to urge the armset (3) against the rest and locating area (7),

- a constraint and positioning system (17) arranged between the armset (3) and the support and protective frame (2) at the rest and locating area (7), comprising a rest system with reference mechanical stops (10) and contacts (13) that are closed when mechanical elements of the armset (3) cooperate with mechanical elements of the support and protective frame (2), the reference mechanical stops (10) being adapted to define a rest position of the touch probe (100), and

- a processing circuit (30; 30') adapted to detect the state of the contacts (13) and to provide a signal indicative of said rest position when all the contacts (13) are closed, characterized in that

- the processing circuit (30; 30') is able to individually detect the state of each of said contacts (13),

- the processing circuit (30; 30') is adapted to provide said signal indicative of the rest position even when it detects that one of said contacts (13) is not closed.

2. Touch probe (100) according to claim 1, wherein said contacts (13) are electrical contacts.

3. Touch probe (100) according to claim 1 or claim 2, wherein each of said contacts (13) is comprised in a

circuital branch of the processing circuit (30; 30') and said circuital branches are connected in parallel.

4. Touch probe (100) according to any one of the preceding claims, wherein the processing circuit (30') comprises a voltage divider (40) adapted to provide a signal representative of the number of closed contacts (13).

5. Touch probe (100) according to claim 4, wherein the processing circuit (30') comprises a pulse generator (42) and a threshold comparator (41), both connected to said voltage divider (40), the pulse generator (42) being adapted to detect the opening of one contact (13) starting from a state wherein all the contacts (13) are closed and to generate a pulsed signal, the comparator (41) being adapted to generate a two level output signal, one level being indicative of a state wherein at least two of said contacts (13) are open, the other level being indicative of a state wherein no more than one contact (13) is open, said pulsed signal and two level output signal being used to process the signal indicative of the rest position.

6. Touch probe (100) according to any one of the preceding claims, comprising, at the rest and locating area (7), a detection system (15) adapted to provide a control signal.

7. Touch probe (100) according to claim 6, wherein said detection system (15) comprises at least one piezoelectric transducer.

8. Method for processing a signal that is output by a touch probe (100) for checking position and/or dimensions of a workpiece (20), comprising a support and protective frame (2), an armset (3) that is movable with respect to and partly housed in the support and protective frame (2), a rest system with reference mechanical stops (10) and contacts (13) that are closed when mechanical elements of the armset (3) cooperate with mechanical elements of the support and protective frame (2), the reference mechanical stops (10) being adapted to define a rest position of the

touch probe (100), a processing circuit (30; 30') for detecting the state of the contacts (13)and providing a signal indicative of said rest position when all the contacts (13) are closed, the method being characterized by the following steps:

- individually detecting the state of each of the contacts (13) by means of the processing circuit (30; 30'), and

- providing said signal indicative of the rest position by means of the processing circuit (30; 30') even when the processing circuit (30; 30') detects that one of said contacts (13) is not closed.

9. Method according to claim 8, comprising the step of detecting the number of the closed contacts (13).

10. Method according to claim 9, wherein said contacts (13) of the touch probe (100) are six and said signal indicative of the rest position is provided when five closed contacts (13) are detected.

11. Method according to any one of the claims from 8 to 10, wherein

- a pulsed signal is generated when, starting from a state wherein all the contacts (13) are closed, the opening of one contact (13) is detected, and

- a two-level output signal is generated, one level being indicative of a state wherein at least two of said contacts (13) are open, the other level being indicative of a state wherein no more than one contact (13) is open,

- said pulsed signal and two-level output signal being used to process the signal indicative of the rest position.

12. Method according to any one of the claims from 8 to 11, comprising the further step of providing control signals to the processing circuit (30; 30'), and processing the control signals for said checking position and/or dimensions of the workpiece (20).

13. Method according to claim 12, wherein the control signals are provided by means of a detection system (15) separate from said contacts (13).

14. Method according to claim 8, wherein the signal indicative of the rest position is provided when, starting from a state wherein one or two contacts (13) are open, and pursuant to mutual movements between the armset (3) and the support and protective frame (2), it is detected that one of such one or two contacts (13) is closed.

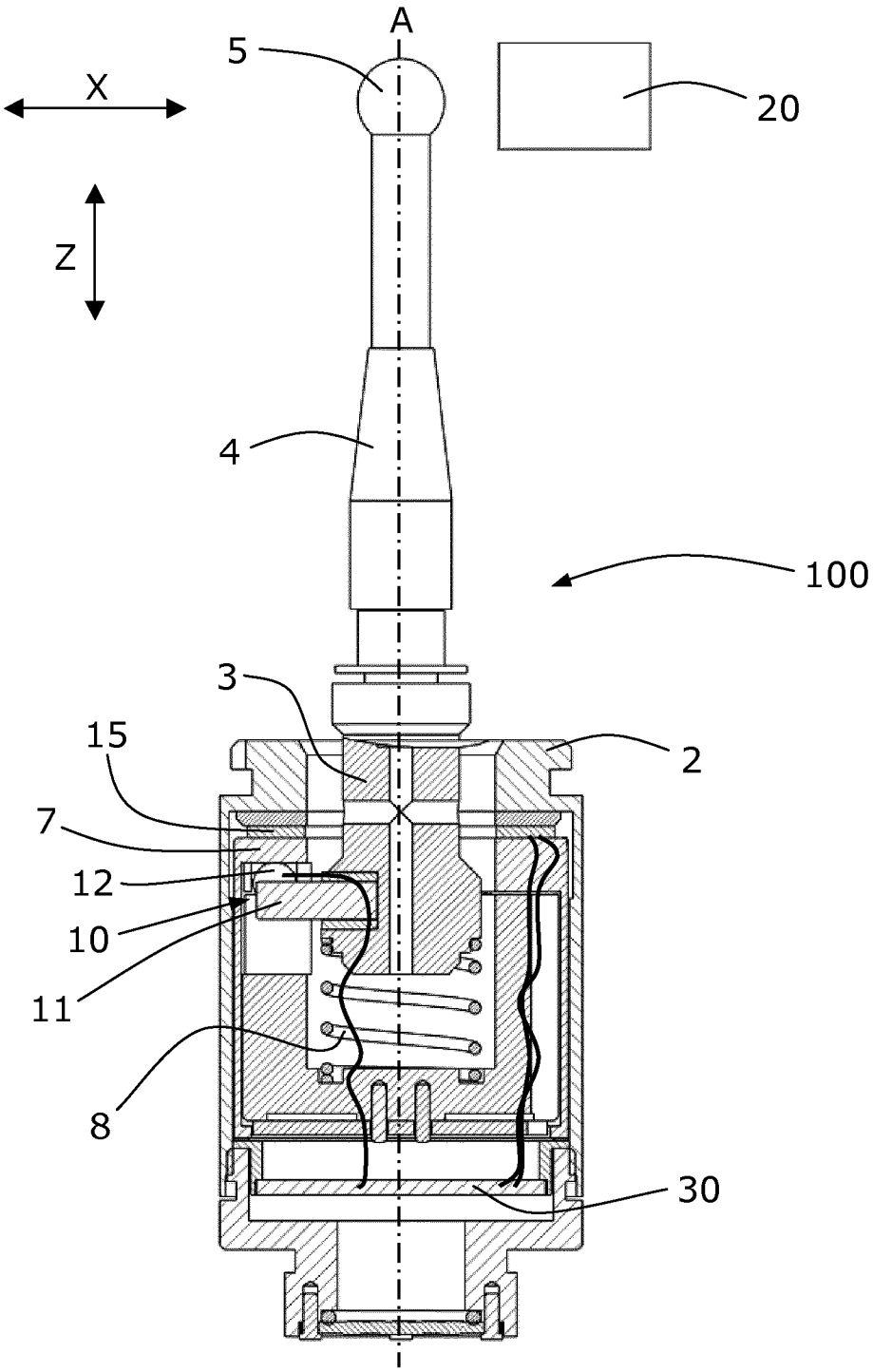


Fig. 1

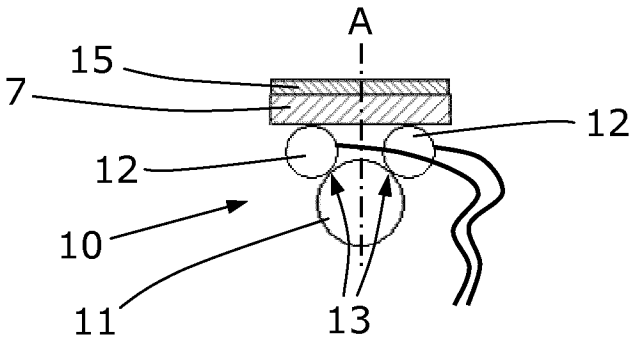


Fig. 2

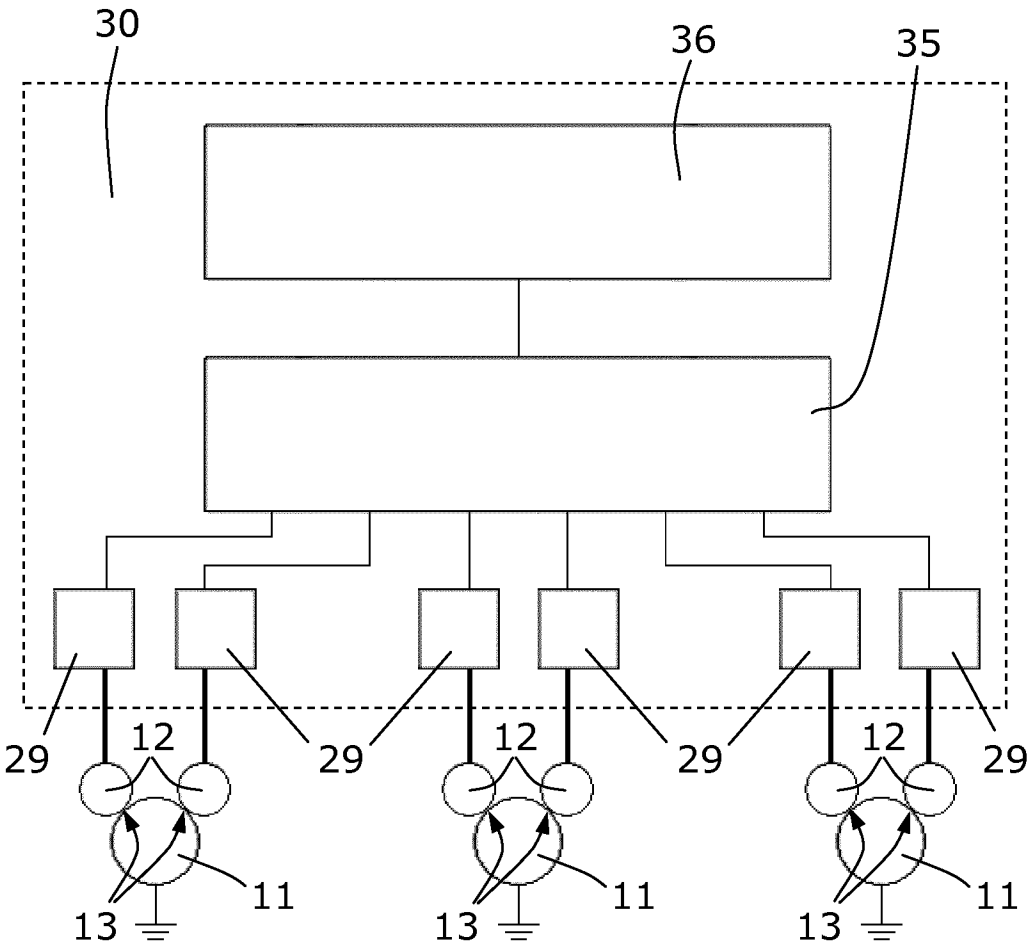


Fig. 3

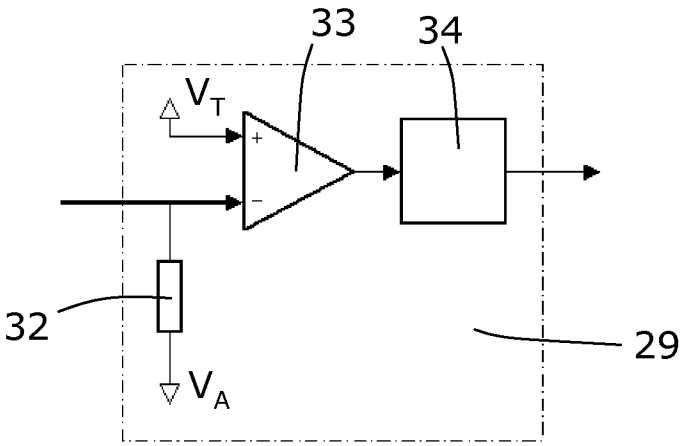


Fig. 4

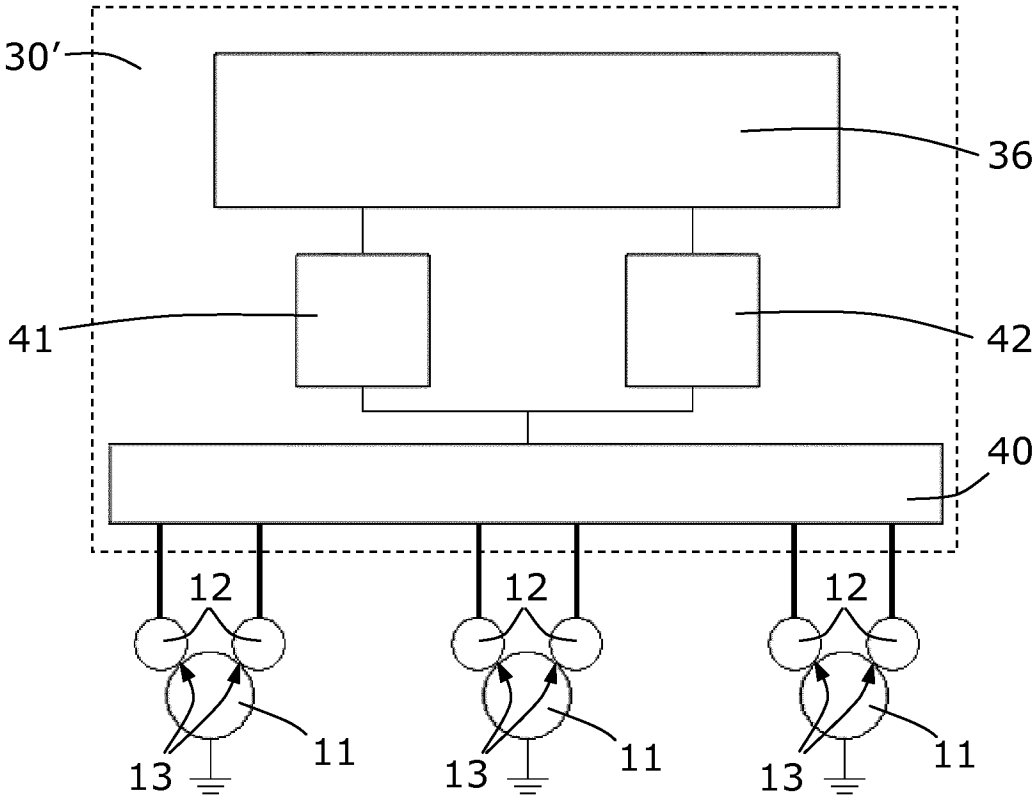


Fig. 5

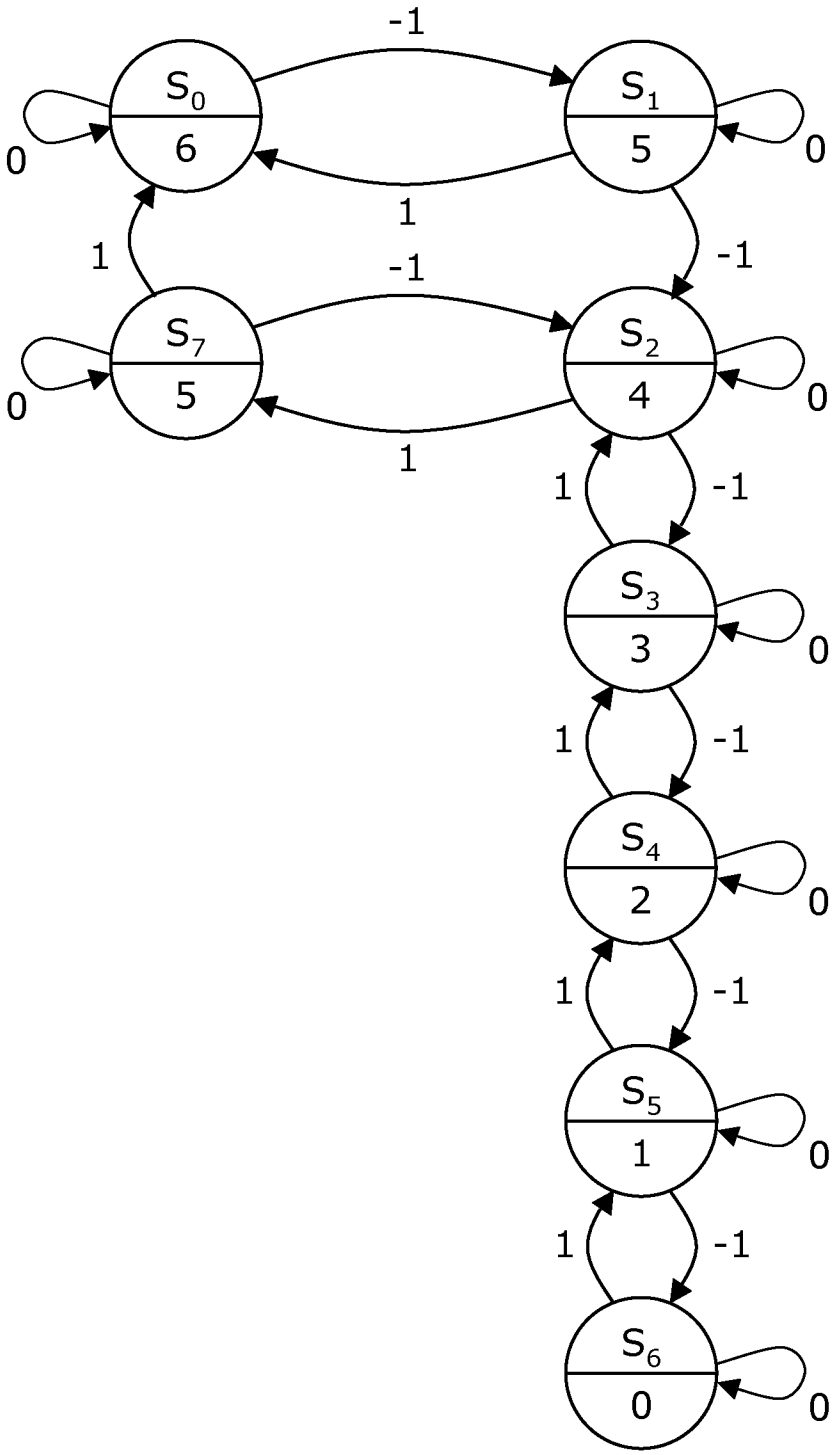


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/066407

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01B21/04 G01B5/012 G01B7/012
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 92/09862 A1 (RENISHAW PLC [GB]) 11 June 1992 (1992-06-11) page 1, line 3 - page 5, line 20 page 6, line 36 - page 8, line 8; figures 2,3	1-14
A	EP 0 254 903 A2 (ZEISS CARL FA [DE]; ZEISS STIFTUNG [DE]) 3 February 1988 (1988-02-03) column 1, line 1 - column 2, line 25 page 3, line 45 - page 4, line 40; figures 1,2	1-14

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 September 2014	16/09/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Petelski, Torsten

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/066407

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	EP 0 501 681 A1 (RENISHAW METROLOGY LTD [GB]) 2 September 1992 (1992-09-02) page 1, line 1 - page 4, line 22; figure 1	1-14

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