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(54) **GRINDING SYSTEM COMPRISING A GRINDER AND A GRINDING WHEEL AND METHOD TO EXCHANGE INFORMATION BETWEEN GRINDER AND GRINDING WHEEL**

SCHLEIFSYSTEM MIT SCHLEIFER UND SCHLEIFSCHEIBE UND VERFAHREN ZUM AUSTAUSCH VON INFORMATIONEN ZWISCHEN SCHLEIFER UND SCHLEIFSCHEIBE

SYSTÈME DE BROYAGE COMPRENANT UN BROYEUR ET UNE MEULE ET PROCÉDÉ D'ÉCHANGE D'INFORMATIONS ENTRE BROYEUR ET MEULE

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Description

TECHNICAL FIELD

[0001] The present invention relates to the field of tools and tool machines. In particular, the invention relates to a grinding system comprising a grinder and a grinding wheel, and a method to exchange information between the grinder and the grinding wheel of the grinding system.

BACKGROUND

[0002] In the production of mechanical products, the finishing processes of the product - such as deburring, grinding, sharpening and lapping - are fundamental in determining the quality of the same.

[0003] These processes are typically implemented by means of dedicated tool machines, called grinders or grinding machines. In detail, a grinder uses a tool, called grinding wheel, to carry out the finishing process. The grinding wheel has an abrasive surface, typically comprising a mixture of abrasive granules and a binding material. In use, the grinding wheel and a workpiece to be machined are placed in contact with each other and one, or both, are placed in motion. In this way, friction is generated by rubbing between the abrasive surface of the grinding wheel and the product being machined which causes an erosion of the grinding wheel and the desired finish of the product.

[0004] The friction between grinding wheel and product generates heat which can, in some cases, damage the grinding wheel and/or the machined product. To avoid this problem, grinding wheels have been proposed equipped with electronic devices designed to acquire information on the operation of the grinding wheel, for example a working temperature of the grinding wheel, and transmit it to a control unit of the grinder.

[0005] However, the operating conditions of the grinding wheel cause considerable complications in the exchange of signals between the grinding wheel and the grinder. In particular, the work environment is typically saturated with dust and noisy due to the interactions between grinding wheel and product being machined. In addition, during operation the grinding wheel rotates at high speeds and can be displaced along one or more processing axes, as well as being subjected to mechanical stresses of varying intensity due to the interactions between the grinding wheel and the product being machined.

[0006] Therefore, these working conditions make it difficult to implement in a simple and/or economical way efficient communication systems that provide for the transmission of signals by cable, or by optical or sound signalling.

[0007] The United States Patent no. US 7,840,305 describes an abrasive tool for chemical-mechanical polishing (cmp), comprising a substrate with two main opposite surfaces, and an abrasive material superimposed on at least one of the two main surfaces. Furthermore, the tool comprises a means, for example an RFID tag or a sensor, adapted to provide information on the cmp process to a transmitter positioned near the substrate. The transmitter is adapted to receive cmp information via wireless communication and transmitting it to a remote receiver.

[0008] The United States patent application US 2018/158707 describes a system for semiconductor chip processing equipped with apparatus for detecting, authenticating and tracing processing components comprised in the system. In particular, a cmp system is illustrated which comprises a plurality of remote communication devices (RFID) incorporated in a polishing disc and configured to communicate with one or more interrogation devices of a plurality of interrogation devices integrated in or coupled to components of the cmp system.

[0009] Although it allows overcoming some of the problems indicated above, the solutions proposed in the United States patent US 7,840,305 and in the United States patent application US 2018/158707 do not explain how to solve the problems related to the variability of the intensity of the signals exchanged between TAG and the RFID reader or one of the RFID readers. The movement of the grinding wheel when grinding a workpiece, and the consequent variation in the distance between TAG and the RFID reader, as well as the presence in variable amounts of dust and processing scraps, in particular metal scraps, affect the quality of the transmitted signal and make therefore a correct transmission of data between grinding wheel and grinder difficult.

OBJECTS AND SUMMARY OF THE INVENTION

[0010] An object of the present invention is to overcome the disadvantages of the prior art.

[0011] In particular, it is an object of the present invention to present a grinding system comprising a grinder and a grinding wheel which guarantees an exchange of information between grinding wheel and grinder that is reliable and robust.

[0012] It is also an object of the present invention to present a grinding system which comprises a communication system between grinding wheel and grinder which is simple to make but at the same time robust to interferences and insensitive to disturbances due to the working conditions of the system.

[0013] Furthermore, it is a further object of the present invention to present a method for transmitting information between the grinder and the grinding wheel in a simple and reliable manner.

[0014] These and other objects of the present invention are reached by a system and a method incorporating the characteristics of the appended claims, which form an integral part of the present description.

[0015] In one embodiment, a grinding system comprises a grinder and an abrasive grinding wheel. The grinder comprises an actuating arm adapted to receive the grinding wheel, an actuator coupled to the actuating arm to rotably drive or translate it along a driving axis, an electronic control unit operatively coupled to the actuator and a transceiver unit coupled to the control unit and adapted to transmit electromagnetic signals. The grinding wheel is fixed to the actuating arm of the grinder and comprises a body which has at least one abrasive surface intended to come into contact with a workpiece to be machined, and an electronic unit coupled to the body. The transceiver unit of the grinder, also indicated by the term PICK-UP, is located in the grinder separated from the abrasive grinding wheel and comprises a plurality of resonant circuits arranged aligned along an axis parallel to the driving axis of the actuating arm, while the electronic unit of the grinding wheel, also indicated by the term TAG, comprises a further resonant circuit having a resonant frequency close to (preferably within a range of 15%, or better of 10%) the resonant frequency of the resonant circuits of the transceiver unit, so as to allow an exchange of information between the electronic unit of the grinding wheel and the transceiver unit of the grinder. Furthermore, the resonant circuits of the transceiver unit are arranged so that the resonant circuit of the communication circuitry is electromagnetically coupled to at least one resonant circuit of the transceiver unit along substantially the entire travel allowed in use to the abrasive grinding wheel fixed to the actuating arm.

[0016] Thanks to this solution it is possible to guarantee a coupling between at least one of the resonance circuits of the transceiver unit of the grinder and the further resonant circuit of the electronic unit of the grinding wheel regardless of the effective position of the grinding wheel along the respective driving axis and/or of a movement of the grinding wheel along this driving axis. Therefore the grinder and the grinding wheel are able to acquire or transmit an electromagnetic resonance signal with a power, or at least an amplitude, adapted to allow a reliable exchange of information during the processing of an article.

[0017] Advantageously, the resonant circuits of the transceiver unit can have elongated shapes in the direction of advance of the grinding wheel, so as to optimize the reciprocal position with the TAG when the two units are facing one another. In particular, when the number of resonant circuits is small, the area of the inductors that compose them is greater, that is their active surface is more elongated. Furthermore, the resonant circuits of the transceiver unit can have active positions and surfaces that are different from each other within the same PICKUP.

[0018] In one embodiment, the resonant circuits of the Pickup are series resonant circuits and are connected in parallel to each other and selectively to an oscillator module of the transceiver unit. Advantageously, the oscillator module is adapted to provide an oscillating voltage signal at a common resonant frequency of the resonant circuits.

[0019] In this way, the resonant circuits are implemented in a simple manner, such as to be easily aligned along the axis parallel to the driving axis of the actuating arm and, at the same time, it is possible to selectively deliver the same oscillating voltage signal to these resonant circuits.

[0020] In one embodiment, the transceiver unit further comprises a signal processing module, connected to the electronic control unit, and to a switching element. The signal processing module is configured to switch the switching element from a condition in which the resonant circuits are connected to the oscillator module, to a condition in which the resonant circuits are connected to a reference potential based on an information to be transmitted.

[0021] Thanks to this solution it is possible to modify the selected resonant signal simply by checking the switching of the switching element. In other words, this solution makes it possible to modify the resonant signal, modulating the amplitude, in a fast and effective manner.

[0022] In one embodiment, the signal processing module is connected to each resonant circuit to monitor a respective resonance signal.

[0023] In this way, it is possible to monitor the resonance signals provided by each resonant circuit and, for example, identify one or more resonance signals having a predetermined characteristic, such as a resonance signal having the greatest amplitude among the monitored signals or greater than a predetermined value.

[0024] In one embodiment, the electronic unit of the Pickup comprises a signal processing module coupled to the resonant circuit to monitor a resonance signal at its ends. Furthermore, said electronic unit comprises a switch element arranged in electrical parallel between the signal processing module and the resonant circuit. The signal processing module is configured to switch the switch element between a state in which it short circuits the resonant circuit, and an open state in which it does not short circuit the resonant circuit, based on the information to be transmitted.

[0025] Thanks to this solution it is possible to modify in an extremely simple way a width of the resonant signal provided by the resonant circuit of the electronic unit by checking the closure on two distinct positions of the switch element. In other words, this solution makes it possible to modify the resonant signal, modulating the amplitude, in a fast and effective manner.

[0026] In one embodiment, the control unit comprises a logic module connected to the transceiver unit (Pickup) for exchanging information received and to be transmitted. The logic module, through the action on the switch connected to the resonant circuits, is able to send data/commands to the TAG unit inserted in the grinding wheel. Similarly, said logic module is able to receive information coming from the TAG through the modulation signals intercepted in proximity of the same resonant circuits. This digital data transmission and reception activity is governed by the control unit which also takes care of storing significant data coming from the TAG, for example the surface temperature of the grinding wheel, rotation speed, construction data of the grinding wheel itself, to then send them to a control system that governs the operation of the grinder.

[0027] In one embodiment, the grinding wheel further comprises a probe made of a good heat conducting material. The probe is thermally connected to a temperature sensor of the measuring circuitry. The heat flow, generated by friction of the abrasive surface with the workpiece subjected to the machining, passes through the body from the abrasive surface reaching the temperature sensor.

[0028] Thanks to this solution it is possible to acquire an effective temperature of the abrasive surface of the grinding wheel.

[0029] In addition or alternatively, the control unit of the grinding wheel comprises an RFID module connected to the logic module of the TAG for exchanging information therewith.

[0030] In this way, it is possible to provide information, for example identification information or operating parameters of the grinding wheel to an RFID reader device even when the grinding wheel is not used - for example, when stored in a warehouse. Furthermore, the logic module can modify and/or read information in the RFID module during the operation of the grinding system. Consequently, it is possible to update the information contained in the RFID module based on the use of the grinding wheel and/or to keep information relating to the operation of the grinding wheel (for example, a total duration of the operation, a trend in the operating temperatures over time, etc..).

[0031] In one embodiment, the electronic unit (TAG) comprises a battery which supplies electrical energy necessary for the operation of the same electronic unit. Preferably, a switch element is coupled to the battery and is adapted to selectively enable the supply of electrical energy. Advantageously, an enabling assembly is coupled to the switch element to close it at an intensity of the vibrations indicative of an actuation of the grinding wheel or due to the effect of the centrifugal force developed during its rotation.

[0032] Thanks to this solution it is possible to use a battery power supply and therefore to ensure sufficient and substantially uniform electrical energy for the operation of the electronic unit and at the same time to guarantee a consumption of electrical energy limited to the periods of use of the grinding wheel e, therefore, an efficient use of the electrical energy stored in the battery.

[0033] In one embodiment, the electronic unit includes an energy harvesting system. Advantageously, the energy harvesting system is adapted to generate electrical energy from sources external to the electronic unit such as, for example, vibrations to which the grinding wheel is subjected during operation, and/or electromagnetic energy exchanged during the time interval Δt, wherein PICKUP and TAG are facing one another.

[0034] In this way, it is possible to guarantee at least part of the electrical energy necessary for the operation of the electronic unit thus reducing, or eliminating, a dependence on batteries of the electronic unit.

[0035] A different aspect of the present invention proposes a method for exchanging an information between a grinder and a grinding wheel. A transceiver unit of the grinder is located in the grinder separated from the abrasive grinding wheel and comprises a plurality of resonant circuits arranged aligned along an axis parallel to a driving axis of the grinding wheel. Furthermore, an electronic unit of the grinding wheel comprises a resonant circuit having a resonance frequency identical or very close (for example ± 15%, preferably ± 10%) to the resonance frequency of the resonant circuits of the transceiver unit, so as to allow an exchange of information between the electronic unit of the grinding wheel and the transceiver unit of the grinder. Furthermore, the resonant circuits of the transceiver unit are arranged so that the resonant circuit of the communication circuitry is electromagnetically coupled to at least one resonant circuit of the transceiver unit along substantially the entire travel allowed in use to the abrasive grinding wheel fixed to the actuating arm. The method comprises the steps of selecting at least one resonance signal provided by a respective resonant circuit; selecting the information to be transmitted, and modifying the resonance signal selected to transmit the information.

[0036] Thanks to this solution it is possible to transmit an information reliably regardless of the position of the grinding wheel along the axis of movement.

[0037] In one embodiment, the method further comprising the steps of generating a digital signal based on the at least one resonance signal selected, comparing a logic value of the information with a logic value of the digital signal, and modifying the selected resonance signal based on this comparison.

[0038] In this way, it is necessary to alter the form of the resonant signal in an extremely simple manner.

[0039] For example, modifying the resonance signal based on the comparison between the logic value of the information with the logic value of the digital signal provides for maintaining the selected resonance signal unchanged in order to transmit an information having a first logic value, or altering the amplitude of the resonance signal in order to transmit an information having a second logic value.

[0040] Thanks to this solution it is possible to transmit two different pieces of information - for example, two different logic values - by modulating the amplitude of the resonance signal.

[0041] In one embodiment, the method further comprises the steps of detecting a switching of the digital signal, and determining the logic value of the digital signal after a predetermined time starting from the switching of the digital signal.

[0042] In this way, it is possible to guarantee the sampling of a stable value of the resonance signal. For example, the predetermined time is an instant of time in which the resonance circuit of the electronic unit is aligned with the resonance circuits of the transmission unit, that is it lies on a plane delimited by the driving axis of the grinding wheel and the parallel axis along which the resonance circuits are arranged. In fact, with this arrangement a maximum electromagnetic coupling is obtained between the resonant circuits of the transceiver unit and the resonant circuit of the grinding wheel.

[0043] In one embodiment, the method comprises the steps of generating a digital signal based on the resonance signal provided by the further resonant circuit of the electronic unit, and identifying the information based on the logic value of the digital signal.

[0044] Thanks to this solution it is possible to determine the information transmitted in a fast and reliable manner.

[0045] In one embodiment, the method comprises the steps of detecting a switching of the digital signal, and determining the value of the digital signal after a further predetermined time starting from the switching of the digital signal.

[0046] In this way, the same advantages set forth above are obtained even in the case of the identification of the transmitted information.

[0047] Further features and objects of the present invention will be more apparent from the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0048] The invention will be described below with reference to some examples, provided for explanatory and non-limiting purposes, and illustrated in the appended drawings. These drawings illustrate different aspects and embodiments of the present invention and, where appropriate, reference numerals illustrating structures, components, materials and/or similar elements in different figures are indicated by similar reference numerals.

Figure 1 is a perspective view of an abrasive grinding wheel according to an embodiment of the present invention;

Figure 2 is a schematic representation of a grinder according to an embodiment of the present invention. In this figure, the grinder drives the grinding wheel of Figure 1;

Figure 3 is a schematic block representation of a grinding wheel and a grinder according to an embodiment of the present invention;

Figure 4 is a graph showing waveforms of signals transmitted from the grinder to the grinding wheel;

Figures 5A and 5B illustrate a flowchart of a method for the transmission of information from the grinder to the grinding wheel according to an embodiment of the present invention;

Figure 6 is a graph showing waveforms of signals transmitted from the grinding wheel to the grinder, and

Figures 7A and 7B illustrate a flowchart of a method for the transmission of information from the grinder to the grinding wheel according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0049] While the invention is susceptible to various modifications and alternative constructions, some preferred embodiments are shown in the drawings and are described hereinbelow in detail. It is in any case to be noted that there is no intention to limit the invention to the specific embodiment illustrated, rather on the contrary, the invention intends covering all the modifications, alternative and equivalent constructions that fall within the scope of the invention as defined in the claims.

[0050] The use of "for example", "etc.", "or" indicates non-exclusive alternatives without limitation, unless otherwise indicated. The use of "includes" means "includes, but not limited to", unless otherwise indicated.

[0051] Figure 1 is a perspective view of an abrasive grinding wheel 1 according to an embodiment of the present invention. The grinding wheel 1 comprises a typically disc-shaped body 10, which has a first main surface 11 and a second main surface, or abrasive surface 13, mutually opposite and separated by a side wall 15. In the example considered, the surfaces 11 and 13 are substantially circular with corresponding areas, and have a diameter greater than the distance separating them, that is the height of the side wall 15.

[0052] The body 10 of the grinding wheel 1 is at least partially made of abrasive material. In particular, the body 10 comprises a portion of abrasive material which extends from the abrasive surface 13 towards the first main surface 11. In one embodiment, this portion of abrasive material can correspond to the entire body. The abrasive material is suitable for use in subtractive manufacturing techniques, such as deburring, grinding, sharpening, lapping and the like. Typically, the abrasive material comprises a mixture of abrasive granules - having a hardness selected according to the material to be machined - and a support material, adapted to act as a binder in order to keep the granules joined in a predefined form.

[0053] Furthermore, the grinding wheel 1 comprises a connecting element 17, for example a through hole or a hub, preferably with a longitudinal axis coaxial to an axis L which corresponds, in use, to the axis of rotation of the grinding wheel 1.

[0054] In the example of figure 1, the connecting element 17 is a through hole that joins the centres of the surfaces 11 and 13. By means of this through hole, the grinding wheel 1 can be connected to a grinder 30, shown in Figure 3 and described below. For example, the grinder 30 can be provided with an arm that fits into the through hole 17; the through hole is fitted into the arm until abutting against an abutment surface of the arm and is fixed in position by means of a nut screwed on the free end of the arm.

[0055] In an alternative constructive form (not shown), the first surface can be fixed to a flange of the grinder by means of nuts embedded in the mixture of the grinding wheel. Said flange comprises or is connected to the connecting element 17 mentioned above in order to be mechanically connected to the grinder 30.

[0056] An electronic unit 20 is integrated in the grinding wheel 1, for example it is housed inside a seat which opens onto the side surface 15 of the body 10. Advantageously, as shown in Figure 2, the seat of the electronic unit 20 is arranged in proximity of the first main surface 11 and, therefore, distal to the abrasive surface 13 which is intended to come into contact with one or more products or workpieces 40 to be machined. In the aforementioned alternative embodiment, in which fixing nuts are embedded in the body of the grinding wheel, the housing seat of the electronic unit is positioned in the body portion 10 comprised between the first main surface 11 and the nut that is the furthest from this first main surface 11. In this way, the useful abrasive portion of the body is maximized 10.

[0057] In detail, as it is visible in Figure 3, the electronic unit 20 (hereinafter also referred to as TAG) comprises a logic module 21, adapted to govern the operation of the entire electronic unit 20, a power supply circuitry 23, adapted to supply electrical energy necessary for the operation of the components of the electronic unit, a measuring circuitry 25, adapted to measure a temperature of the grinding wheel 1, a communication circuitry 27, adapted to exchange data with the grinder 30, and optionally an RFID module 29 adapted to store and transmit data concerning the grinding wheel 1. Furthermore, the logic module 21 is connected to the communication circuitry 27 and to the RFID module 29 for exchanging data therewith, and to the measuring circuitry 25 for receiving temperature measurements.

[0058] The logic module 21 can comprise one or more from among a microcontroller, a microprocessor, an ASIC, an FPGA, a memory and, possibly, one or more ancillary circuits, such as a circuit for generating a synchrony signal (clock), amplifiers for input/output signals, etc.

[0059] The power supply circuitry 23 comprises a battery 231, a switch element, for example a transistor, 233, a piezoelectric sensor 235 and a conditioning module of the piezoelectric signal 237. The battery 231 is connected through a first terminal to the remaining components of the electronic unit 20, while a reference terminal (or ground) is selectively connected to a second terminal through the transistor 233. A control terminal of the transistor 233 is connected to the conditioning module of the piezoelectric signal 237 to which the piezoelectric sensor 235 is also connected. Briefly, the transistor 233, the conditioning module of the piezoelectric signal 237 and the piezoelectric sensor 235 form an enabling assembly which allows the electronic unit 20 to be supplied with power only when the grinding wheel 1 is used. In particular, the piezoelectric sensor 235 generates an electrical voltage proportional to the mechanical stresses to which the grinding wheel 1 is subjected. The conditioning module of the piezoelectric signal 237 is designed to adapt this electrical voltage so that, for a predetermined intensity of the vibrations - corresponding to an actuation of the grinding wheel (1), the transistor 233 enters into conduction, thereby allowing the battery to supply electrical energy to the other components of the electronic unit 20. As an alternative to the piezoelectric sensor 235, a switch device activated by the centrifugal force developed during the rotation of the grinding wheel can be advantageously used.

[0060] The measuring circuitry 25 comprises a temperature sensor 251 connected to a conditioning module of the temperature signal 253. The temperature sensor 251 preferably comprises a thermistor of the PTC type or, alternatively of the NTC type, and is connected to the conditioning module of the temperature signal 253. In turn, the conditioning module of the temperature signal 253 is connected to the logic module 21. During operation, the temperature sensor 251 generates an electrical voltage proportional to the temperature of the grinding wheel 1. The conditioning module of the temperature signal 253 is designed to adapt, for example to amplify or linearise, such electrical voltage so that it is correctly acquired by the logic module 21. Preferably, the temperature sensor 251 is mounted on the electronic board 20 so as to face the abrasive surface 13 when the electronic unit 20 is associated with the grinding wheel 1. The logic module 21 can also contain predictive algorithms that allow anticipating the temperature reading in order to take into account the delay due to the limited thermal diffusivity of the probe 50.

[0061] The communication circuitry 27 comprises a resonant circuit 271, connected in parallel to a switch element 273, which are both connected to a signal processing module 275. The signal processing module 275 is connected to the logic module 21 to exchange data therewith and can comprise signal demodulation circuits, and control circuitry of the switch element 273 for signal modulation. In particular, the signal processing module 275 comprises circuits suitable for modulating in amplitude a signal to be transmitted to the Pickup, and for demodulating in amplitude the signals coming from the Pickup.

[0062] The RFID module 29 comprises a non-volatile memory in which the ID identification data of the grinding wheel 1 such as a model code and/or operating parameters OP, are stored, for example an indication of the hardness of the grinding wheel 1, the dimensions of the abrasive surface 13, the height of the side wall 15, the rotation speed for which the wheel is designed, etc. In one embodiment, the RFID module also stores a threshold temperature value T_{TH} among the operating parameters OP of the grinding wheel 1 indicative of a maximum surface temperature Ts that can be reached by the abrasive surface 13 without incurring damage and/or deformation. In addition or as an alternative, the operating parameters OP of the grinding wheel 1 can comprise a second threshold value T_{MIN} indicative of a limit surface temperature Ts below which the performance and/or the productivity of the grinding wheel 1 is reduced. The ID identification data and the operating parameters OP can be read at any time - for example, during storage, distribution or during the installation of the grinding wheel 1 - also by means of an RFID reader device independent of the grinder 30 without requiring the activation of the rest of the electronic unit 20.

[0063] In a preferred embodiment of the present invention, the electronic unit also comprises a probe 50. The probe 50 extends in the grinding wheel 1 starting from the abrasive surface 13 up to the temperature sensor 29. In particular, the probe 50 is thermally coupled to a detection surface of the temperature sensor 29, that is the thermistor in the example considered. Preferably, a first end of the probe 50 is in contact with the thermistor of the temperature sensor 29, while a second end is flush with the abrasive surface 13.

[0064] Preferably, the probe 50 extends in a direction substantially transverse to the main surfaces 11 and 13 of the body 10 of the grinding wheel 1, therefore substantially parallel to the axis L of the grinding wheel 1. In particular, the probe 50 has an elongated conformation, e.g. like a wire or a stick, with a main dimension substantially greater than the others.

[0065] Advantageously, the probe 50 is made of a material that is a good thermal conductor. The probe 50 transfers the heat which develops at the abrasive surface 13 directly to the thermistor of the temperature sensor 29. Consequently, the temperature sensor 29 detects a temperature corresponding to the surface temperature Ts of the abrasive surface 13.

[0066] With reference to Figures 2 and 3, in use, the grinding wheel 1 is mounted on an actuating arm 31 of the grinder 30 to form a grinding system adapted to machine one or more products, or workpieces 40. For example, the actuating arm 31 comprises a pin which is inserted in the connecting element 17, and clamping elements which keep the grinding wheel 1 integral with the actuating arm 31.

[0067] The actuating arm 31 is operatively coupled to an actuator 33, for example an electric actuator. Typically, the actuator 33 is configured to impart a rotation about a driving axis of the grinding wheel - corresponding to the axis L - of the grinding wheel 1 mounted on the actuating arm 31, and a translational movement, for example along the same driving axis of the actuating arm 31.

[0068] The grinder 30 comprises an electronic control unit 35, which is configured to govern the operation of the grinder 30.

[0069] The control unit 35 of the grinder 30 can comprise one or more from among a microcontroller, a microprocessor, an ASIC, an FPGA, a PLC and, possibly, one or more ancillary circuits, such as a circuit for generating a synchrony signal (clock), amplifiers for input/output signals, power supply circuitry, etc...

[0070] Advantageously, the grinder 30 comprises a user interface 37 provided with input/output elements (not shown, for example a keypad and a screen) and operatively coupled to the control unit 35 to allow an operator (not shown) to check and/or set an operation of the grinder 30.

[0071] Furthermore, the grinder 30 can comprise - or be associated with - a spindle 38 adapted to keep the workpiece 40 to be machined in position, for example a spring. Advantageously, the spindle 38 is positioned so that the second surface 13 of the grinding wheel 1, mounted on the actuating arm 31, faces the workpiece 40 to be machined. The spindle 38 can be replaced by other positioning devices able to keep the workpiece to be machined in position during the interaction with the abrasive surface of the grinding wheel. For example, the spindle can be replaced by a pair of jaws. In an alternative embodiment (not shown), the workpieces to be machined (e.g. springs) are positioned on a workpiece-holder disc able to house different workpieces to be machined. The workpiece-holder disc preferably has an axis of rotation parallel to and spaced from the axis L of the grinding wheel itself. The continuous rotation of the workpiece-holder disc progressively subjects the workpieces to the abrasive action of the grinding wheel.

[0072] The grinder 30 also comprises a transceiver unit 39 operatively coupled to the control unit 35, which allows the exchange of information between the electronic unit 20 of the grinding wheel 1 and the control unit 35 of the grinder 30 as described below.

[0073] The transceiver unit 39 comprises a plurality of series resonant circuits 391 - ten in the non-limiting example of Figure 2 -, an oscillator module 395, a signal processing module 393 and a switching element 397. In detail, the resonant circuits 391 are arranged in parallel with each other between the reference potential (or ground) of the transceiver unit 39 and a common terminal of the switching element 397. The latter has a second terminal which can be connected alternately to the oscillator module 395 and a third terminal connected to the reference potential. Furthermore, each resonant circuit 391 is connected, via a respective intermediate terminal 3910, to a corresponding reading terminal of the signal processing module 393.

[0074] In turn, the signal processing module 393 is connected to the switching element 397 to control it.

[0075] Finally, the control unit 35 is connected both to the oscillator module 395 to supply it with power, and to the signal processing module 393 to supply it with power and exchange data with the latter.

[0076] In an alternative embodiment, the signal processing module 393 can be implemented in the control unit 35 of the grinder 30 instead of in the transceiver unit 39.

[0077] The transceiver unit 39 is positioned on the grinder 30 so as to be in proximity of the side wall 15 of the grinding wheel 1, when the latter is mounted on the actuating arm 31. Advantageously, the transceiver unit 39 is arranged in the grinder 30 in a side wall thereof in a position radial to the grinding wheel 1; for example, so as to be at a distance d - preferably, in the order of centimetres - from the side wall of the grinding wheel 1 - as shown in Figures 2 and 3. Alternatively, the transceiver unit 39 can be arranged in another position proximal to the grinding wheel 1, for example on the actuating arm. In other words, the transceiver unit 39 is located in the grinder 30 so as to be separated from the abrasive grinding wheel 1 fixed thereon. In particular, the term 'separate' means that the transceiver unit 39 and the abrasive grinding wheel 1 are not in direct contact nor are there any kind of wirings between them.

[0078] In particular, the resonant circuits 391 are arranged aligned - or with at least one of their inductive elements aligned - along a direction parallel to the driving axis of the actuating arm 31 and therefore to the axis L of the grinding wheel 1 coupled thereto. In this way, it is possible to guarantee a reliable electromagnetic coupling between the resonant circuit 271 of the communication circuitry 27 and one or more from among the resonant circuits 391 of the transceiver unit 39, even when the grinding wheel 1 and, therefore, the communication module 27, is displaced parallel to the axis of rotation. In fact, operationally, as the grinding wheel wears out, the grinder lowers the grinding wheel support to keep the abrasive surface 13 in contact with the workpieces to be machined. This involves displacing the resonant circuit in the direction of the workpiece to be machined. As the resonant circuit 271 lowers, it is coupled to a different resonant circuit 391. The transceiver unit 39 comprises a number of resonant circuits 391 suitably arranged so as to ensure an efficient electromagnetic coupling between resonant circuits 391 and 271 for the entire travel of the grinding wheel 1 in the grinder 30. Summarizing, the resonant circuits of the transceiver unit are arranged so that the resonant circuit of the communication circuitry 27 is electromagnetically coupled to at least one resonant circuit 391 of the transceiver unit 39 along the entire travel allowed, in use, to the abrasive grinding wheel 1.

[0079] Alternatively, if the transceiver unit (39) is composed of a single resonant circuit, such resonant circuit will be sufficiently large to couple to the communication circuitry (27) for the entire excursion of the abrasive grinding wheel 1.

[0080] The switch element 397 normally connects the oscillator module 395 to the resonant circuits 391 providing them with a carrier signal having a frequency substantially corresponding to the resonance frequency f_R of the resonant circuits 391 and 271. The term substantially corresponding is herein understood to mean that the resonance frequencies of the resonant circuits 391 and 271 differ by a maximum of 15%, or more preferably differ by a maximum of 10%.

[0081] In use, the control unit 35 of the grinder 30 drives the actuator 33 to put the actuating arm 31 and the grinding wheel 1 with it in a rotational and/or linear motion so as to bring the grinding wheel 1 in contact with the workpiece 40 to be machined. In order to effectively machine the workpiece 40, the control unit 35 of the grinder 30 exchanges information with - or at least receives information from - the electronic unit 20 of the grinding wheel 1. The control unit 35 uses this information to adjust the actuation of the actuator 31. Advantageously, the electronic unit 20 of the grinding wheel 1 and the transceiver unit 39 of the grinder 30 exchange information in a reliable and effective manner. The information transmitted by the electronic unit 20 of the grinding wheel 1 is then transferred from the transceiver unit 39 to the control unit 35 and, vice versa, the information provided by the control unit 35 is transmitted to the electronic unit 20 of the grinding wheel 1 from the transceiver unit 39.

[0082] In the preferred embodiment, the control unit 35 and the electronic unit 20 exchange information (for example binary data) by exploiting the electromagnetic coupling between the resonant circuit 271 and one or more of the resonant circuits 391. For this purpose, the inductive L_T, the capacitive C_T and the resistive R_T elements of the parallel resonant circuit 271 are dimensioned to resonate at the same frequency f_R at which the inductive L_n, the capacitive C_n and the resistive R_n elements (with $n = [1, 2, ..., 10]$ in the considered example) of each series resonant circuit 391 resonate.

[0083] The resonant circuits are able to periodically couple to each other for a communication time interval Δt. The periodicity of the coupling is equal to the rotation time T in which the grinding wheel 1 performs a rotation. In detail, during the rotation of the grinding wheel, the resonant circuit 271 periodically passes in a position proximal to the resonant circuits 391. As the grinding wheel rotates, the resonant circuit 271 approaches the resonant circuits 391 and coupled thereto; in these conditions, data transmission is now possible. As the rotation continues, the resonant circuit 271 begins to move away, so that after a communication time Δt the two resonant circuits are sufficiently far away so that they are no longer coupled. In these conditions, data transmission is not possible.

[0084] The control unit 35, through the transceiver unit 39, and the electronic unit 20 are configured to exchange information, for example an information corresponding to a single binary data, or bit during one or more communication time intervals Δt. Preferably, the control unit 35 is configured to operate as a main or master unit, while the electronic unit 20 is configured to operate as a secondary or slave unit.

[0085] Referring to Figures 4, 5A and 5B, in the case of transmission from the transceiver unit 39a to the electronic unit 20, the signal processing module 393 initially receives (block 601) from the control unit 35 the information to be transmitted, for example a string of one or more bits to be transmitted. In the example considered, the information is transmitted sequentially - for example, a bit Btx at a time -, each during a respective communication time interval Δt.

[0086] As illustrated in Figure 4, when the electronic unit 20 of the grinding wheel 1 passes in proximity of the resonant circuits 391, through the region which from now on we will define as operational, during the communication time interval Δt, one or more resonant circuits 391 resonate with the resonant circuit 271. The electromagnetic coupling between the resonant circuits of the TAG and the PickUp causes an amplitude variation of one or more of the resonance signals s_n (indicated with COIL1, COIL2,...COIL10 in Figure 4) provided by the resonant circuits 391 and a corresponding variation in the amplitude of the resonance signal s_m provided by the resonant circuit 271 of the electronic unit 20.

[0087] The signal processing module 393 of the transceiver unit 39 is configured to select (block 603) at least one resonance signal s_n, provided by a respective resonant circuit 391, to be used. Alternatively, the signal processing module 393 of the transceiver unit 39 is designed to make the sum of the signals s_n coming from the resonant circuits 391, so that, during the transition from a resonant circuit to the other, the amplitude of the demodulated sum signal remains almost constant.

[0088] The signal processing module 393 generates (block 606) a digital signal D_n based on the resonance signal s_n selected, or based on the sum of the resonance signals s_n received as input in the alternative described above. In detail, the signal processing module 393 is configured to demodulate - for example in amplitude - the resonance signal s_n - or the sum of the signals s_n- obtaining a corresponding demodulated signal sd_n. The demodulated signal sd_n is digitized by the signal processing module 393, which converts the crossings of a threshold value A_{thn} of the demodulated signal sd_n into corresponding switchings of the digital signal D_n from a low logic value (for example, the reference voltage) to a high logic value (for example, the power supply voltage) or vice versa.

[0089] Furthermore, the signal processing module 393 is configured to identify (decision block 609) the initial time instant to of the communication time interval Δt. For example, the signal processing module is configured to detect a switching from a first logic value to a second logic value of the digital signal D_n, corresponding to a (first) crossing of the threshold value A_{thn} by a demodulated signal sd_n. In this embodiment, therefore, the crossing of the threshold value A_{thn} by the demodulated signal sd_n is considered the start of the communication time interval Δt.

[0090] If the signal processing module 393 detects the start of the communication time interval Δt (output branch Y of the decision block 609 and time instant to in Figure 4), the signal processing module 393 selects (block 612) the information to be transmitted. In the example considered, the signal processing module 393 selects the logic value of a bit of the bit string to be transmitted received from the control unit 35, for example, a logic "zero" in the left portion of Figure 4 and a logic "one" in the right portion of Figure 4.

[0091] The signal processing module 393 is configured to measure an elapsed time of the communication time interval to detect (decision block 615) that a guard time Tp - lower than Δt - has been reached by the time instant to.

[0092] After the guard time Tp (output branch Y of the decision block 615) has elapsed, the signal processing module 393 is configured to modify the amplitude of the resonance signals s_n in order to transmit a bit having the desired value. In the example considered, the signal processing module 393 compares (decision block 618) the logic value of the bit to be transmitted and the logic value of the digital signal D_n with the instant Tp - for example, sampling the digital signal D_n - and determines the need to modify the amplitude trend of the resonance signal s_n based on a discrepancy between these logic values.

[0093] In the case wherein the logic value of the bit to be transmitted and the logic value of the digital signal D_n do not correspond (output branch N of the decision block 618), the signal processing module 393 maintains (block 621) the resonance signal s_n unchanged for the duration of the communication time interval Δt. In particular, the signal processing module 393 maintains the switching element 397 closed between the oscillator module 395 and the resonant circuits 391, thereby transmitting a bit at a first logic value, for example 0 as illustrated in the left portion of Figure 4.

[0094] Otherwise (output branch Y of the decision block 618), the signal processing module 393 is configured to alter (block 624) the resonance signal s_n, thereby transmitting a bit at a second logic value, for example 1, as illustrated in the right portion of Figure 4. In detail, the signal processing module 393 is configured to switch the switching element 397 so that it connects the resonant circuits 391 to the reference potential, rather than to the oscillator module 393, for example by switching a value of a control signal sp of the switching element 397. This quickly cancels out the amplitude of the resonance signal s_n and, consequently, the resonance signal s_m on the resonant circuit 271 of the communication module 27. Preferably, the signal processing module 393 is configured to maintain the resonant circuits 391 connected to the reference terminal at least until the end of the communication time interval Δt (that is, the closing time is greater than or equal to the difference between Δt and Tp). This causes the resonance signal s_n to remain nil for the remaining part of the communication time interval Δt (that is, Δt - Tp).

[0095] In parallel, the signal processing module 275 of the communication module 27 is configured to generate (block 627) a digital signal D_m based on the second resonance signal s_m at the ends of the resonant circuit 271. Similarly to what has been described above, the signal processing module 275 of the TAG device is configured to demodulate - for example in amplitude - the resonance signal s_m read at the ends of the resonant circuit 271, obtaining a demodulated signal sd_m. The demodulated signal sd_m is digitized by the signal processing module 393, which converts the crossings of a threshold value A_{thn} of the demodulated signal sd_m into corresponding switchings of the digital signal D_m from a low logic value (for example, the reference voltage) to a high logic value (for example, the power supply voltage) or vice versa.

[0096] Furthermore, the signal processing module 275 is configured to identify (decision block 630) the initial time instant to of the communication time interval Δt for a respective rotation period T of the grinding wheel 1. For example, the signal processing module 275 is configured to detect a switching from a first logic value to a second logic value of the digital signal D_m, that is a (first) crossing of the threshold value Athm by the demodulated signal sd_m, and to consider this logic switching with the start of the communication time interval Δt.

[0097] The signal processing module 275 is configured to measure an elapsed time of the communication time interval in order to detect (decision block 633) that a respective guard time T_T has been reached by the initial instant to of the communication time Δt.

[0098] After the guard time T_T (output branch Y of the decision block 633) has elapsed, the signal processing module 275 identifies (decision block 636) the bit contained in the second resonance signal s_m and records the reception of a bit B_{RX} accordingly to which the high logic value (block 639) or the low logic value (block 642) will be associated. In detail, the signal processing module 275 is configured to determine the logic value of the digital signal D_m. In the case wherein the digital signal D_m has a high logic value, the signal processing module 275 is configured to record in a memory buffer a bit at a low logic value (left portion of Figure 4) or, vice versa, to record a bit at a high logic value if the digital signal D_m has a low logic value (right portion of Figure 4).

[0099] Finally, the signal processing module 275 transfers the bits stored to the logic module 21 of the electronic unit 20 of the grinding wheel 1.

[0100] The method 600 described above is reiterated (returning to block 603) at each period T until the transmission of the bit string is completed and is implemented each time the control unit 35 transmits a bit string to the transceiver unit 39.

[0101] In a preferred embodiment, the transmission of one or more bits is provided from the electronic unit 20 to the control unit 35 of the grinder 30, preferably upon request of the control unit 35. For example, the control unit 35 is configured to transmit a predetermined bit string to the electronic unit 20 which is interpreted by the logic module 21 as an instruction for the transmission of a datum, for example one or more temperature measurements performed by the measuring circuitry 25.

[0102] The number of bits that can be transmitted is limited by the response speed of the electronic circuits of the involved TAG and PICKUP and by the time Δt available for data exchange. If the rotation speed of the grinding wheel is sufficiently low, it is possible to exchange a complete ASCII character, thereby increasing the rapidity of data exchange by a factor of 8 with respect to the case in which the data exchange is limited to a single bit.

[0103] After that, the transmission of bits from the grinding wheel 1, or from the TAG, to the grinder 30, through the transceiver unit 39 (Pickup), occurs in a similar way to what previously described for the reverse transmission.

[0104] Referring to the Figures 6, 7A and 7B, the signal processing module 275 of the communication module 27 receives (block 701) from the logic module 21 a string of one or more bits B_{TX} to be transmitted and, possibly, a transmission enabling signal (not shown).

[0105] Furthermore, the signal processing module 275 of the communication module 27 is configured to generate (block 703) a digital signal D_m based on the resonance signal s_m that is generated at the ends of the resonant circuit 271 when it passes through the operational region, during the communication time interval Δt.

[0106] Furthermore, the signal processing module 275 is configured to identify (decision block 706) the start of the communication time interval Δt, in particular the initial time instant to of the communication time interval Δt. The identification of the start of the communication time interval Δt is preferably carried out using the same criterion adopted in the transceiver unit 39 of the PickUp, for example by verifying that the demodulated signal D_m changes logic value due to the electromagnetic coupling between the resonant circuits of the TAG (271) and the PickUp (391).

[0107] Once the start of the communication time interval Δt (output branch Y of the decision block 706) has been determined, the signal processing module 275 selects (block 709) the information to be transmitted.

[0108] The signal processing module 275 is configured to measure an elapsed time of the communication time interval Δt and to detect (decision block 712) that the guard time T_T has been reached starting from the initial instant to of the communication time Δt. Upon detection that the guard time T_T (output branch Y of the decision block 712) has been reached, the signal processing module 275 allows determining (decision block 715) whether the resonance signal s_m must be modified to transmit a bit at the desired logic value, in the same way as described above.

[0109] In the case wherein it is not necessary to modify the resonance signal s_m (output branch N of the decision block 715), the signal processing module 275 maintains (block 718) the resonance signal s_n unchanged for the duration of the communication time interval Δt. In particular, the signal processing module 275 maintains the switch element 273 open, thereby transmitting a bit at a first logic value, for example 0 as illustrated in the left portion of Figure 6.

[0110] Otherwise (output branch Y of the decision block 715), the signal processing module 275 is configured to modify (block 721) the resonance signal s_m, thereby transmitting a bit at a second logic value, for example 1, as illustrated in the right portion of Figure 6. In detail, the signal processing module 275 is configured to close the switch element 273 for example by switching a control signal s_t which controls the switch element 273. This forms a short circuit branch in parallel with the resonant circuit 271 and the signal processing module 275. Consequently, the amplitude of the resonance signal s_m cancels out quickly. Preferably, the signal processing module 275 is configured to maintain the switch element 273 closed at least until the end of the communication time interval Δt. This causes the resonance signal s_m to remain nil for the remaining part of the communication time interval Δt (that is for a time Δt - Tp).

[0111] In parallel, the signal processing module 393 of the transceiver unit 39 is configured to select (block 724) at least one resonance signal s_n, provided by a respective resonant circuit 391, to be used, similarly to what has been described above.

[0112] The signal processing module 393 of the transceiver unit 39 is configured to generate (block 727) a digital signal D_n built following the amplitude demodulation of the sum of one or more resonance signals s_n that develop at the ends of the resonant circuits 391 or, as mentioned above, of a resonance signal s_n selected (for example selected since it has a greater amplitude variation).

[0113] Furthermore, the signal processing module 393 is configured to identify (decision block 730) the start of the communication time Δt for a respective rotation period T of the grinding wheel 1.

[0114] The signal processing module 275 is configured to measure an elapsed time to detect (decision block 733) that the guard time Tp has been reached starting from the initial instant to of the communication time Δt.

[0115] As the guard time Tp has elapsed (output branch Y of the decision block 733), the signal processing module 393 is configured to identify (decision block 736) the bit transmitted by the TAG based on the logic value of the digital signal D_m and record in a memory buffer a bit B_{RX} received at the high logic value (block 739) or at the low logic value (block 742) accordingly.

[0116] The operations described above can be repeated at each rotation of the grinding wheel 1, that is with a period T, so as to transmit the entire bit string (bringing the operation back to block 703).

[0117] The invention thus conceived is susceptible to numerous modifications and variations, all falling within this invention as resulting from the appended claims.

[0118] For example, nothing precludes providing a housing for the electronic unit 20 exposed on the first main surface 11 of the grinding wheel 1.

[0119] In an alternative embodiment (not shown), the electronic unit 20 of the grinding wheel 1 can comprise a different power supply circuitry 23; for example, provided with an energy harvesting system from sources external to the electronic unit 20. For example, the power supply circuitry can comprise one or more piezoelectric elements coupled to an accumulator, for example a capacitor or a supercap, able to accumulate electrical energy generated by the piezoelectric element due to the vibrations of the grinding wheel. Alternatively, the energy used by the power supply circuit of the TAG 20 can be, all or in part, harvested by the resonant circuit 271 during the time communication interval Δt.

[0120] Furthermore, nothing precludes providing a grinder 30 in which the spindle 38 which receives the workpiece 40 to be machined is movable, in particular can be actuated in rotation and/or rigidly translatable in the space. In detail, the movable spindle 38 can be implemented in a grinder comprising the movable actuating arm 31 described above or, alternatively, in a grinder with a fixed support arm. As a further alternative, the workpieces to be machined can be arranged on a conveyor belt, so as to be brought sequentially into an operational position so as to be machined by the grinder 30.

[0121] Furthermore, it is possible to equip the grinder 30 with a movement means suitable for moving the transceiver unit 39 along an axis parallel to the driving axis (L) of the actuating arm, so as to maintain at least one of the resonance circuits 391 aligned with the resonance circuit 271 of the grinding wheel during a translation of the actuating arm. The two circuits are considered to be maintained "aligned" if, during their movement, a point of the resonant circuit 271 and a point of the at least one resonant circuit 391 lie, at tolerances lower than $\pm$ 5%, on a same plane transverse to the driving axis of the actuating arm. Said in other words, the movement means allows a synchronous movement (or substantially synchronous if the tolerances are considered) of the resonant circuits 271 and 391.

[0122] The movement means can be equipped with an autonomous movement system (for example it is possible to provide an electric motor controlled by the control unit 35), however to guarantee a better coupling between the resonant circuits avoiding complications due to an autonomous movement system, the movement means can be integral with the actuating arm. For example, such movement means can comprise a bracket fixed to the actuating arm; the transceiver unit 39 is then mounted on the bracket and is thus translated integrally with the actuating arm.

[0123] It is yet possible to provide for the movement of both the transceiver unit 39 and the control unit 35. However, preferably, the electronic control unit is fixed and connected to the transceiver unit by sufficiently long cables to maintain the connection during the movement of the transceiver unit 39 between two end-of-travel ends.

[0124] Even where movement means for moving the transceiver unit 39 is provided, instead of providing a plurality of resonant circuits 391 aligned along the driving axis L, it is also possible to provide a resonant circuit 391 only. The communication system and the circuit described above with reference to Figures 4 to 7 does not change except for the number of the resonant circuits

391. Finally, all details can be replaced by other technically equivalent elements. For example, nothing precludes providing a grinding wheel 1 with a different conformation, for example with a disc, a cup or a conical shape.

[0125] In an alternative embodiment (not shown), the side wall 15 is used as an abrasive surface. In this case, the electronic unit 20 is arranged in proximity of the connecting element 17 and the probe 50 extends radially from the temperature sensor 251 up to the side wall 15.

[0126] In an alternative embodiment, the transceiver unit 39 and the communication unit 27 are configured to exchange an information comprising more than one bit during a communication time interval Δt. For example, the resonance signals can be modulated to transmit a byte (8 bits).

[0127] In another embodiment, the signal processing module 393 of the transceiver unit 39 is configured to select two or more resonance signals. In this case, the signal processing module 393 can be configured to combine the resonance signals s_n and obtain a single digital reference signal.

[0128] In addition, nothing precludes implementing a procedure which envisages identifying which one/s of the resonant circuits 391 of the transceiver unit 39 couple/s to the resonant circuit 271 of the communication module 27, and determine a position or a direction of movement of the grinding wheel 1, for example to verify the effective positioning of the grinding wheel 1.

[0129] In alternative embodiments, the resonant circuits 391 illustrated in the figures can be replaced by parallel resonant circuits, that is of the resonant circuit type 271. In turn, in other embodiments, the resonant circuit 271 can be of the series type, such as those described above with reference to Figure 3. For the purposes of the present invention, it is therefore sufficient to provide for the TAG and PickUp to have resonant circuits that can be coupled to generate resonance signals, but the resonant circuits can be of the series type or of the parallel type.

Claims

1. Grinding system comprising:

- a grinder (30) comprising an actuating arm (31) adapted to receive an abrasive grinding wheel (1), an actuator (33) coupled to the actuating arm (31) to rotatably drive or translate it along a driving axis, an electronic control unit (35) operatively coupled to the actuator (33) and a transceiver unit (39) coupled to the control unit (35) and adapted to transmit electromagnetic signals, and
- an abrasive grinding wheel (1) fixed to the actuating arm (31) of the grinder (30), the grinding wheel (1) comprising a body (10) which has at least one abrasive surface (13) intended to come into contact with a workpiece to be machined, and an electronic unit (20) coupled to the body (10),

wherein the transceiver unit (39) is located in the grinder (30) separated from the abrasive grinding wheel (1),

characterised in that

the transceiver unit (39) of the grinder (30) comprises a plurality of resonant circuits (391) arranged aligned along an axis parallel to the driving axis of the actuating arm (31) and the electronic unit (20) of the grinding wheel (1) comprises a further resonant circuit (271) having a resonance frequency equal to, or more or less of 15%, preferably more or less of 10% different from the resonance frequency of the resonant circuits (391) of the transceiver unit (39), so as to allow an exchange of information between the electronic unit (20) of the grinding wheel (1) and the transceiver unit (39) of the grinder (30), and

wherein the resonant circuits (391) of the transceiver unit (39) are arranged so that the resonant circuit of the communication circuitry (27) is electromagnetically coupled to at least one resonant circuit (391) of the transceiver unit (39) along the entire travel allowed, in use, to the abrasive grinding wheel (1) fixed to the actuating arm (31).

2. Grinding system according to claim 1, wherein the resonant circuits (391) are series resonant circuits and are connected in parallel to an oscillator module (395) of the transceiver unit (39), the oscillator module (395) being adapted to provide an oscillating voltage signal at a common resonance frequency of the resonant circuits (391, 271).

3. Grinding system according to claim 2, wherein the transceiver unit (39) further comprises a signal processing module (393) connected to the electronic control unit (35) and to a switching element (397), wherein the signal processing module (393) is configured to switch the switching element (397) from a condition in which the resonant circuits (391) are connected to the oscillator module (395), to a condition in which the resonant circuits (391) are connected to a reference terminal based on an information to be transmitted.

4. Grinding system according to claim 3, wherein the signal processing module (393) is connected to each resonant circuit (391) to monitor a respective resonance signal.

5. Grinding system according to one of the preceding claims, wherein the electronic unit (20) comprises a signal processing module (275) coupled to the resonant circuit (271) to monitor a resonance signal at its ends and to a switch element (273) arranged in electrical parallel between the signal processing module (275) and the resonant circuit (271), the signal processing module (275) being configured to switch the switch element (273) between a closed state, in which it short circuits the resonant circuit (271), and an open state in which it does not short circuit the resonant circuit (271), based on the information to be transmitted.

6. Grinding system according to claim 5, wherein the control unit (20) further comprises a logic module (21) connected to the signal processing module (275) for exchanging information received and to be transmitted and
a measuring circuitry (25) adapted to measure a temperature of the abrasive surface (13) of the grinding wheel (1) and connected to the logic module (21) to provide one or more temperature measurements.

7. Grinding system according to claim 6, wherein the grinding wheel (1) further comprises at least one probe (50) made of a good heat conducting material, the probe (50) being thermally connected to a temperature sensor (251) of the measuring circuitry (25) and, passing through the body (10) from the abrasive surface (13), to the temperature sensor (251).

8. Grinding system according to one of the claims 5 to 7, wherein the control unit (20) further comprises a logic module (21) connected to the signal processing module (275) for exchanging information received and to be transmitted and an RFID module (29) connected to the logic module (21) for exchanging information therewith.

9. Grinding system according to any one of the preceding claims, wherein the electronic unit (20) comprises a battery (231) for supplying electrical operating energy and a switch element (233) coupled to the battery (231) and adapted to selectively enable the supply of electrical energy from the battery (231), and wherein an enabling assembly (231) is coupled to the switch element (233) to close it at an intensity of the vibrations, or alternatively by the centrifugal force, indicative of an actuation of the grinding wheel (1).

10. Grinding system according to any one of the preceding claims, wherein the electronic unit (20) comprises an energy harvesting system, the energy harvesting system being adapted to generate electrical energy from sources external to the electronic unit (20), in particular from the mechanical vibrations of the grinding wheel and/or from the energy exchanged by the resonant circuits during the communication interval Δt.

11. Method for exchanging information between a grinder (30) and a grinding wheel (1), wherein a transceiver unit (39) is located in the grinder (30) physically separated from the abrasive grinding wheel (1) and comprises a plurality of resonant circuits (391) arranged aligned along an axis parallel to an axis of movement of the grinding wheel (1), and wherein
an electronic unit (20) of the grinding wheel (1) comprising a resonant circuit (271) having a resonance frequency corresponding, within an interval of ± 15%, to the resonance frequency of the resonant circuits (391) of the transceiver unit (39), so as to allow an exchange of information between the electronic unit (20) of the grinding wheel (1) and the transceiver unit (39) of the grinder (30), and
wherein the resonant circuits (391) of the transceiver unit (39) are arranged so that the resonant circuit of the communication circuitry (27) is electromagnetically coupled to at least one resonant circuit (391) of the transceiver unit (39) along the entire travel allowed, in use, to the abrasive grinding wheel (1) fixed to the actuating arm (31),
the method comprising the steps of:

- selecting (603) at least one first resonance signal (s_n) provided by a respective resonant circuit (391);
- selecting (612) a bit value to be transmitted,
- checking (621,624) the amplitude of the first resonance signal selected to transmit the bit value,
- monitoring the amplitude of a second resonance signal (s_m) present in the resonant circuit (271) of the grinding wheel,
- recording in a memory buffer of the electronic unit (20) of the grinding wheel (1) a bit value depending on the variation or the absence of variation of the amplitude of the second resonance signal (s_m).

12. Method according to claim 11, further comprising the steps of:

- generating (606) a digital signal (D_n) based on the at least a first resonance signal selected,
- comparing (618) the bit value to be transmitted with a logic value of the digital signal, and
- checking the amplitude of the at least a first resonance signal selected based on said comparison.

13. Method according to claim 12, wherein the step of checking the amplitude of the first resonance signal envisages:

- maintaining (621) unchanged the selected resonance signal to transmit an information having a first logic value, or

- altering (624) the amplitude of the resonance signal to transmit an information having a second logic value.

14. Method according to claim 12 or 13, further comprising the steps of:

- detecting (609) a first switching of the digital signal, and
- determining (615,618) the logic value of the digital signal after a predetermined time starting from the first switching of the digital signal.

15. Method according to any one of the preceding claims 12 to 14, further comprising the steps of:

- generating (606) a second digital signal (D_m) based on the resonance signal provided by the resonant circuit (271) of the electronic unit (20), and
- identifying (636) the bit value received based on the variation or absence of variation of the logic value of the second digital signal.

Patentansprüche

1. Schleifsystem, umfassend:

- eine Schleifmaschine (30) mit einem Betätigungsarm (31), der zur Aufnahme einer Schleifscheibe (1) geeignet ist, einem mit dem Betätigungsarm (31) gekoppelten Aktuator (33), um diesen drehbar anzutreiben oder entlang einer Antriebsachse zu verschieben, einer elektronischen Steuereinheit (35), die operativ mit dem Aktuator (33) gekoppelt ist, und einer mit der Steuereinheit (35) gekoppelten Sende-/Empfangseinheit (39), die zur Übertragung elektromagnetischer Signale geeignet ist, und
- eine Schleifscheibe (1), die an dem Betätigungsarm (31) der Schleifmaschine (30) befestigt ist, wobei die Schleifscheibe (1) einen Körper (10) umfasst, der mindestens eine Schleiffläche (13) aufweist, die dazu bestimmt ist, mit einem zu bearbeitenden Werkstück in Kontakt zu kommen, und eine Elektronikeinheit (20), die mit dem Körper (10) gekoppelt ist,

wobei die Sende-/Empfangseinheit (39) in der Schleifmaschine (30) getrennt von der Schleifscheibe (1) angeordnet ist,
dadurch gekennzeichnet, dass
die Sende-/Empfangseinheit (39) der Schleifmaschine (30) eine Vielzahl von Resonanzkreisen (391) aufweist, die entlang einer Achse parallel zur Antriebsachse des Betätigungsarms (31) ausgerichtet sind, und die Elektronikeinheit (20) der Schleifscheibe (1) einen weiteren Resonanzkreis (271) aufweist mit einer Resonanzfrequenz, die gleich oder mehr oder weniger als 15 %, vorzugsweise mehr oder weniger als 10 % von der Resonanzfrequenz der Resonanzkreise (391) der Sende-/Empfangseinheit (39) abweicht, um einen Informationsaustausch zwischen der Elektronikeinheit (20) der Schleifscheibe (1) und der Sende-/Empfangseinheit (39) der Schleifmaschine (30) zu ermöglichen, und wobei die Resonanzkreise (391) der Sende-/Empfangseinheit (39) so angeordnet sind, dass der Resonanzkreis der Kommunikationsschaltung (27) elektromagnetisch mit mindestens einem Resonanzkreis (391) der Sende-/Empfangseinheit (39) entlang des gesamten Weges gekoppelt ist, der im Gebrauch der am Betätigungsarm (31) befestigten Schleifscheibe (1) erlaubt ist.

2. Schleifsystem nach Anspruch 1, wobei die Resonanzkreise (391) Serienresonanzkreise sind und parallel zu einem Oszillatormodul (395) der Sende-/Empfangseinheit (39) geschaltet sind, wobei das Oszillatormodul (395) dazu ausgebildet ist, ein oszillierendes Spannungssignal bei einer gemeinsamen Resonanzfrequenz der Resonanzkreise (391, 271) bereitzustellen.

3. Schleifsystem nach Anspruch 2, wobei die Transceivereinheit (39) ferner ein Signalverarbeitungsmodul (393) umfasst, das mit der elektronischen Steuereinheit (35) und mit einem Schaltelement (397) verbunden ist, wobei das Signalverarbeitungsmodul (393) derart konfiguriert ist, dass es das Schaltelement (397) aus einem Zustand, in dem die Resonanzkreise (391) mit dem Oszillatormodul (395) verbunden sind, basierend auf einer zu übertragenden Information in einen Zustand schaltet, in dem die Resonanzkreise (391) mit einem Referenzanschluss verbunden sind.

4. Schleifsystem nach Anspruch 3, wobei das Signalverarbeitungsmodul (393) mit jedem Resonanzkreis (391) verbunden ist, um ein jeweiliges Resonanzsignal zu überwachen.

5. Schleifsystem nach einem der vorhergehenden Ansprüche, wobei die Elektronikeinheit (20) ein Signalverarbeitungsmodul (275) aufweist, das mit dem Resonanzkreis (271) zur Überwachung eines Resonanzsignals an dessen Enden und mit einem Schaltelement (273) gekoppelt ist, das elektrisch parallel zwischen dem Signalverarbeitungsmodul (275) und dem Resonanzkreis (271) angeordnet ist, wobei das Signalverarbeitungsmodul (275) derart konfiguriert ist, dass es das Schaltelement (273) basierend auf der zu übertragenden Information zwischen einem geschlossenen Zustand, in dem es den Resonanzkreis (271) kurzschließt, und einem offenen Zustand, in dem es den Resonanzkreis (271) nicht kurzschließt, umschaltet.

6. Schleifsystem nach Anspruch 5, wobei die Steuereinheit (20) ferner ein Logikmodul (21), das mit dem Signalverarbeitungsmodul (275) verbunden ist, um empfangene und zu übertragende Informationen auszutauschen,
und eine Messschaltung (25) aufweist, die geeignet ist, eine Temperatur der Schleifoberfläche (13) der Schleifscheibe (1) zu messen, und die mit dem Logikmodul (21) verbunden ist, um eine oder mehrere Temperaturmessungen bereitzustellen.

7. Schleifsystem nach Anspruch 6, wobei die Schleifscheibe (1) ferner mindestens eine Sonde (50) aus einem gut wärmeleitenden Material aufweist, wobei die Sonde (50) thermisch mit einem Temperatursensor (251) der Messschaltung (25) und von der Schleiffläche (13) durch den Körper (10) hindurch mit dem Temperatursensor (251) verbunden ist.

8. Schleifsystem nach einem der Ansprüche 5 bis 7, wobei die Steuereinheit (20) ferner ein mit dem Signalverarbeitungsmodul (275) verbundenes Logikmodul (21) zum Austausch von empfangenen und zu übertragenden Informationen und ein mit dem Logikmodul (21) verbundenes RFID-Modul (29) zum Austausch von Informationen mit diesem aufweist.

9. Schleifsystem nach einem der vorhergehenden Ansprüche, wobei die Elektronikeinheit (20) eine Batterie (231) zum Zuführen von elektrischer Betriebsenergie und ein mit der Batterie (231) gekoppeltes Schaltelement (233) aufweist, das dazu ausgelegt ist, die Zufuhr von elektrischer Energie von der Batterie (231) selektiv freizugeben, und wobei eine Freigabeanordnung (231) mit dem Schaltelement (233) gekoppelt ist, um es bei einer Intensität der Vibrationen oder alternativ durch die Zentrifugalkraft zu schließen, die eine Betätigung der Schleifscheibe (1) anzeigt.

10. Schleifsystem nach einem der vorhergehenden Ansprüche, wobei die Elektronikeinheit (20) ein Energiegewinnungssystem aufweist, wobei das Energiegewinnungssystem derart ausgebildet ist, um elektrische Energie aus Quellen außerhalb der Elektronikeinheit (20) zu erzeugen, insbesondere aus den mechanischen Vibrationen der Schleifscheibe und/oder aus der Energie, die von den Resonanzkreisen während des Kommunikationsintervalls Δt ausgetauscht wird.

11. Verfahren zum Austausch von Informationen zwischen einer Schleifmaschine (30) und einer Schleifscheibe (1), wobei eine Sende-/Empfangseinheit (39) in der Schleifmaschine (30) räumlich getrennt von der Schleifscheibe (1) angeordnet ist und eine Vielzahl von Resonanzkreisen (391) aufweist, die entlang einer Achse parallel zu einer Bewegungsachse der Schleifscheibe (1) ausgerichtet sind, und wobei
eine Elektronikeinheit (20) der Schleifscheibe (1) einen Resonanzkreis (271) mit einer Resonanzfrequenz aufweist, die innerhalb eines Intervalls von ± 15 % der Resonanzfrequenz der Resonanzkreise (391) der Sende-/Empfangseinheit (39) entspricht, um einen Informationsaustausch zwischen der Elektronikeinheit (20) der Schleifscheibe (1) und der Sende-/Empfangseinheit (39) des Schleifers (30) zu ermöglichen, und
wobei die Resonanzkreise (391) der Sende-/Empfangseinheit (39) derart angeordnet sind, dass der Resonanzkreis der Kommunikationsschaltung (27) elektromagnetisch mit mindestens einem Resonanzkreis (391) der Sende-/Empfangseinheit (39) entlang des gesamten Weges gekoppelt ist, der im Gebrauch der am Betätigungsarm (31) befestigten Schleifscheibe (1) erlaubt ist,
wobei das Verfahren die folgenden Schritte aufweist:

- Auswählen (603) mindestens eines ersten Resonanzsignals (s_m), das von einem entsprechenden Resonanzkreis (391) bereitgestellt wird;
- Auswählen (612) eines zu übertragenden Bitwertes,
- Überprüfen (621, 624) der Amplitude des ersten Resonanzsignals, das zur Übertragung des Bitwerts ausgewählt wurde,
- Überwachen der Amplitude eines zweiten Resonanzsignals (s_m), das in dem Resonanzkreis (271) der Schleifscheibe vorhanden ist,
- Aufzeichnen eines Bitwertes in einem Speicherpuffer der Elektronikeinheit (20) der Schleifscheibe (1) in Abhängigkeit von der Veränderung oder dem Fehlen einer Veränderung der Amplitude des zweiten Resonanzsignals (s_m).

12. Verfahren nach Anspruch 11, aufweisend ferner die folgenden Schritte:

- Erzeugen (606) eines digitalen Signals (D_n) basierend auf dem mindestens einen ausgewählten ersten Resonanzsignal,
- Vergleichen (618) des zu übertragenden Bitwertes mit einem logischen Wert des digitalen Signals, und
- Prüfen der Amplitude des mindestens einen ersten ausgewählten Resonanzsignals basierend auf dem Vergleich.

13. Verfahren nach Anspruch 12, wobei der Schritt des Überprüfens der Amplitude des ersten Resonanzsignals vorsieht:

- das ausgewählte Resonanzsignal unverändert beizubehalten (621), um eine Information mit einem ersten logischen Wert zu übertragen, oder
- Ändern (624) der Amplitude des Resonanzsignals, um eine Information mit einem zweiten logischen Wert zu übertragen.

14. Verfahren nach Anspruch 12 oder 13 aufweisend ferner die folgenden Schritte:

- Erfassen (609) eines ersten Umschaltens des digitalen Signals, und
- Bestimmen (615, 618) des logischen Wertes des digitalen Signals nach einer vorbestimmten Zeit ab dem ersten Schalten des digitalen Signals.

15. Verfahren nach einem der vorangehenden Ansprüche 12 bis 14, ferner umfassend die Schritte

- Erzeugen (606) eines zweiten digitalen Signals (D_m) auf der Grundlage des vom Resonanzkreis (271) der Elektronikeinheit (20) bereitgestellten Resonanzsignals, und
- Identifizieren (636) des empfangenen Bitwerts auf der Grundlage der Variation oder des Fehlens einer Variation des Logikwerts des zweiten digitalen Signals.

Revendications

1. Système de meulage, comprenant :

- une machine à meuler (30) comprenant un bras d'actionnement (31) conçu pour recevoir une meule abrasive (1), un actionneur (33) couplé au bras d'actionnement (31) pour entraîner en rotation ou déplacer en translation celui-ci le long d'un axe d'entraînement, une unité de commande électronique (35) couplée de manière fonctionnelle à l'actionneur (33), et une unité d'émetteur-récepteur (39) couplée à l'unité de commande (35) et conçue pour transmettre des signaux électromagnétiques, et
- une meule abrasive (1) fixée au bras d'actionnement (31) de la machine à meuler (30), la meule (1) comprenant un corps (10) qui a au moins une surface abrasive (13) destinée à entrer en contact avec une pièce à travailler, et une unité électronique (20) couplée au corps (10),

l'unité d'émetteur-récepteur (39) étant située dans la machine à meuler (30), séparée de la meule abrasive (1),
caractérisé par le fait que
l'unité d'émetteur-récepteur (39) de la machine à meuler (30) comprend une pluralité de circuits résonants (391) disposés de manière alignée le long d'un axe parallèle à l'axe d'entraînement du bras d'actionnement (31), et l'unité électronique (20) de la meule (1) comprend un autre circuit résonant (271) ayant une fréquence de résonance égale à ou différente de plus ou moins 15 %, de préférence différente de plus ou moins 10 %, de la fréquence de résonance des circuits résonants (391) de l'unité d'émetteur-récepteur (39), de façon à autoriser un échange d'informations entre l'unité électronique (20) de la meule (1) et l'unité d'émetteur-récepteur (39) de la machine à meuler (30), et
les circuits résonants (391) de l'unité d'émetteur-récepteur (39) étant disposés de telle sorte que le circuit résonant des circuits de communication (27) est couplé électromagnétiquement à au moins un circuit résonant (391) de l'unité d'émetteur-récepteur (39) le long de l'ensemble du déplacement permis, en utilisation, à la meule abrasive (1) fixée au bras d'actionnement (31).

2. Système de meulage selon la revendication 1, dans lequel les circuits résonants (391) sont des circuits résonants en série et sont reliés en parallèle à un module d'oscillateur (395) de l'unité d'émetteur-récepteur (39), le module d'oscillateur (395) étant conçu pour fournir un signal de tension oscillante à une fréquence de résonance commune des circuits résonants (391, 271).

3. Système de meulage selon la revendication 2, dans lequel l'unité d'émetteur-récepteur (39) comprend en outre un module de traitement de signal (393) connecté à l'unité de commande électronique (35) et à un élément de commutation (397), le module de traitement de signal (393) étant configuré pour commuter l'élément de commutation (397) d'un état dans lequel les circuits résonants (391) sont connectés au module d'oscillateur (395), à un état dans lequel les circuits résonants (391) sont connectés à un terminal de référence, sur la base d'une information à transmettre.

4. Système de meulage selon la revendication 3, dans lequel le module de traitement de signal (393) est connecté à chaque circuit résonant (391) pour surveiller un signal de résonance respectif.

5. Système de meulage selon l'une quelconque des revendications précédentes, dans lequel l'unité électronique (20) comprend un module de traitement de signal (275) couplé au circuit résonant (271) pour surveiller un signal de résonance à ses bornes, et à un élément de commutation (273) disposé en parallèle électrique entre le module de traitement de signal (275) et le circuit résonant (271), le module de traitement de signal (275) étant configuré pour commuter l'élément de commutation (273) entre un état fermé, dans lequel il court-circuite le circuit résonant (271), et un état ouvert dans lequel il ne court-circuite pas le circuit résonant (271), sur la base des informations à transmettre.

6. Système de meulage selon la revendication 5, dans lequel l'unité de commande (20) comprend en outre un module logique (21) connecté au module de traitement de signal (275) pour échanger des informations reçues et à transmettre, et des circuits de mesure (25) conçus pour mesurer une température de la surface abrasive (13) de la meule (1) et connectés au module logique (21) pour fournir une ou plusieurs mesures de température.

7. Système de meulage selon la revendication 6, dans lequel la meule (1) comprend en outre au moins une sonde (50) faite d'un matériau de bonne conductivité thermique, la sonde (50) étant reliée thermiquement à un capteur de température (251) des circuits de mesure (25) et, en traversant le corps (10) à partir de la surface abrasive (13), jusqu'au capteur de température (251).

8. Système de meulage selon l'une des revendications 5 à 7, dans lequel l'unité de commande (20) comprend en outre un module logique (21) connecté au module de traitement de signal (275) pour échanger des informations reçues et à transmettre, et un module d'identification par radiofréquence (RFID) (29) connecté au module logique (21) pour échanger des informations avec celui-ci.

9. Système de meulage selon l'une quelconque des revendications précédentes, dans lequel l'unité électronique (20) comprend une batterie (231) pour délivrer de l'énergie de fonctionnement électrique, et un élément de commutation (233) couplé à la batterie (231) et conçu pour permettre de manière sélective la délivrance d'énergie électrique depuis la batterie (231), et un ensemble d'activation (231) étant couplé à l'élément de commutation (233) pour le fermer à une intensité des vibrations, ou en variante par la force centrifuge, indiquant un actionnement de la meule (1).

10. Système de meulage selon l'une quelconque des revendications précédentes, dans lequel l'unité électronique (20) comprend un système de récupération d'énergie, le système de récupération d'énergie étant conçu pour générer de l'énergie électrique à partir de sources externes à l'unité électronique (20), en particulier à partir des vibrations mécaniques de la meule et/ou à partir de l'énergie échangée par les circuits résonants pendant l'intervalle de communication Δt.

11. Procédé pour échanger des informations entre une machine à meuler (30) et une meule (1), une unité d'émetteur-récepteur (39) étant située dans la machine à meuler (30), physiquement séparée de la meule abrasive (1), et comprenant une pluralité de circuits résonants (391) disposés de manière alignée le long d'un axe parallèle à un axe de mouvement de la meule (1), et
une unité électronique (20) de la meule (1) comprenant un circuit résonant (271) ayant une fréquence de résonance correspondant, à l'intérieur d'un intervalle de $\pm$ 15 %, à la fréquence de résonance des circuits résonants (391) de l'unité d'émetteur-récepteur (39), de façon à autoriser un échange d'informations entre l'unité électronique (20) de la meule (1) et l'unité d'émetteur-récepteur (39) de la machine à meuler (30), et
les circuits résonants (391) de l'unité d'émetteur-récepteur (39) étant disposés de telle sorte que le circuit résonant des circuits de communication (27) est couplé électromagnétiquement à au moins un circuit résonant (391) de l'unité d'émetteur-récepteur (39) le long de l'ensemble du déplacement permis, en utilisation, à la meule abrasive (1) fixée au bras d'actionnement (31),
le procédé comprenant les étapes :

- choisir (603) au moins un premier signal de résonance (s_n) fourni par un circuit résonant respectif (391),
- choisir (612) une valeur de bit à transmettre,
- vérifier (621, 624) l'amplitude du premier signal de résonance choisi pour transmettre la valeur de bit,
- surveiller l'amplitude d'un second signal de résonance (s_m) présent dans le circuit résonant (271) de la meule,
- enregistrer, dans une mémoire tampon de l'unité électronique (20) de la meule (1), une valeur de bit en fonction de la variation ou de l'absence de variation de l'amplitude du second signal de résonance (s_m).

12. Procédé selon la revendication 11, comprenant en outre les étapes :

- générer (606) un signal numérique (D_n) sur la base de l'au moins un premier signal de résonance choisi,
- comparer (618) la valeur de bit à transmettre avec une valeur logique du signal numérique, et
- vérifier l'amplitude de l'au moins un premier signal de résonance choisi, sur la base de ladite comparaison.

13. Procédé selon la revendication 12, dans lequel l'étape de vérification de l'amplitude du premier signal de résonance prévoit de :

- maintenir (621) inchangé le signal de résonance choisi pour transmettre une information ayant une première valeur logique, ou
- modifier (624) l'amplitude du signal de résonance pour transmettre une information ayant une seconde valeur logique.

14. Procédé selon la revendication 12 ou 13, comprenant en outre les étapes :

- détecter (609) une première commutation du signal numérique, et
- déterminer (615, 618) la valeur logique du signal numérique après une durée prédéterminée commençant à partir de la première commutation du signal numérique.

15. Procédé selon l'une quelconque des revendications 12 à 14, comprenant en outre les étapes :

- générer (606) un second signal numérique (D_m) sur la base du signal de résonance fourni par le circuit résonant (271) de l'unité électronique (20), et
- identifier (636) la valeur de bit reçue sur la base de la variation ou de l'absence de variation de la valeur logique du second signal numérique.

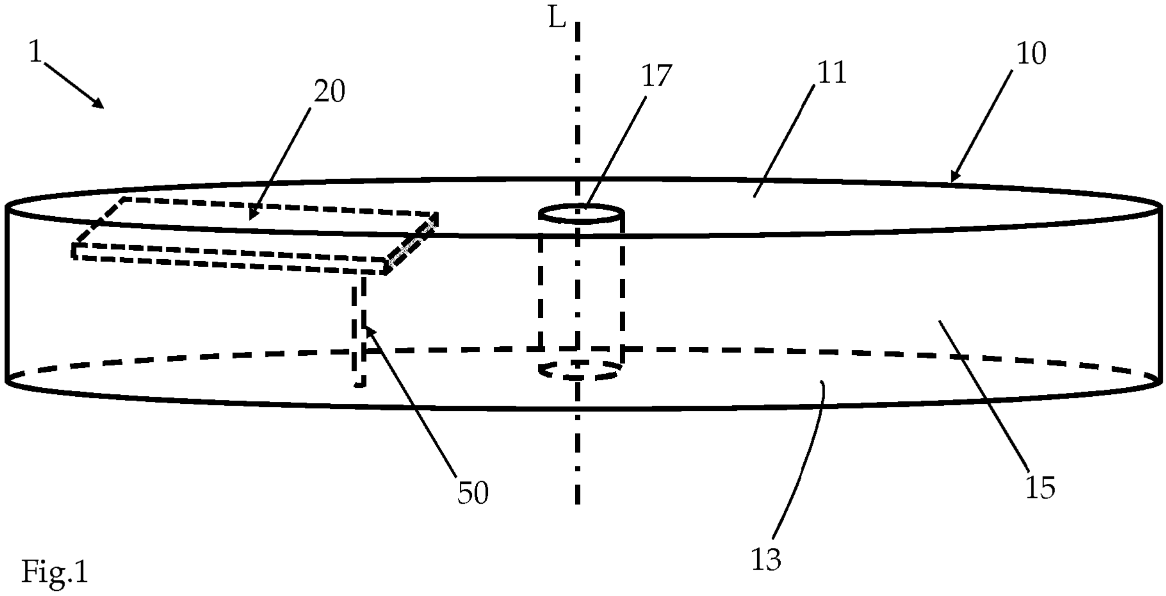


Fig.1

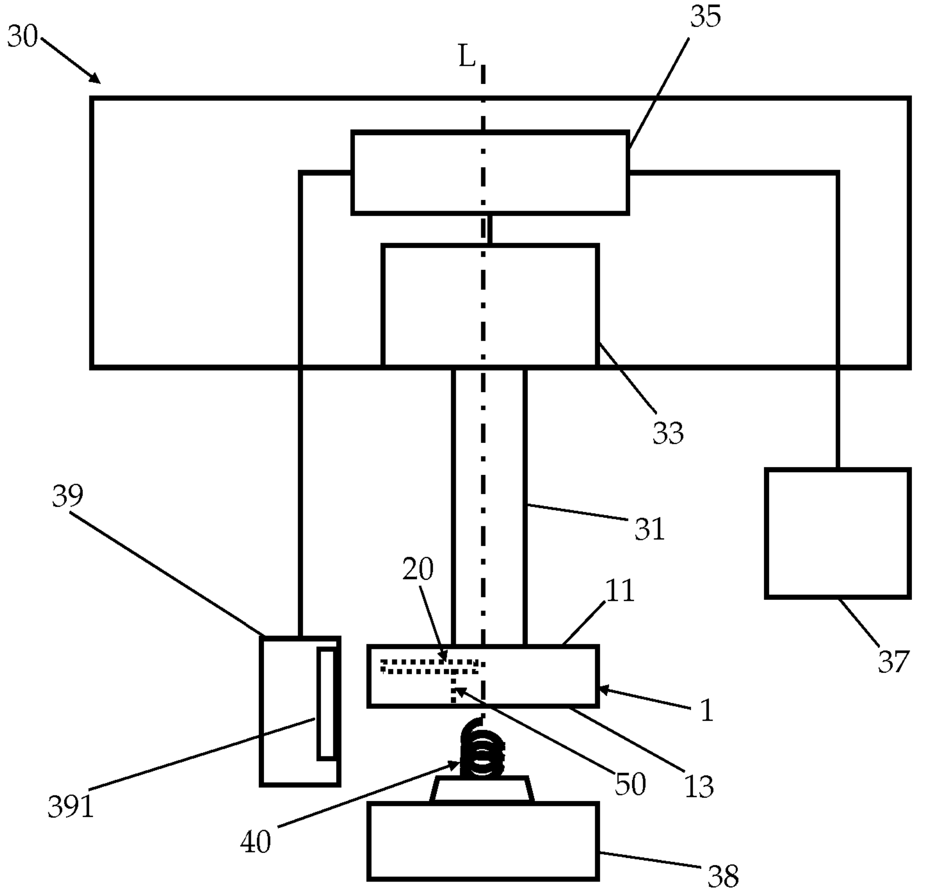


Fig.2

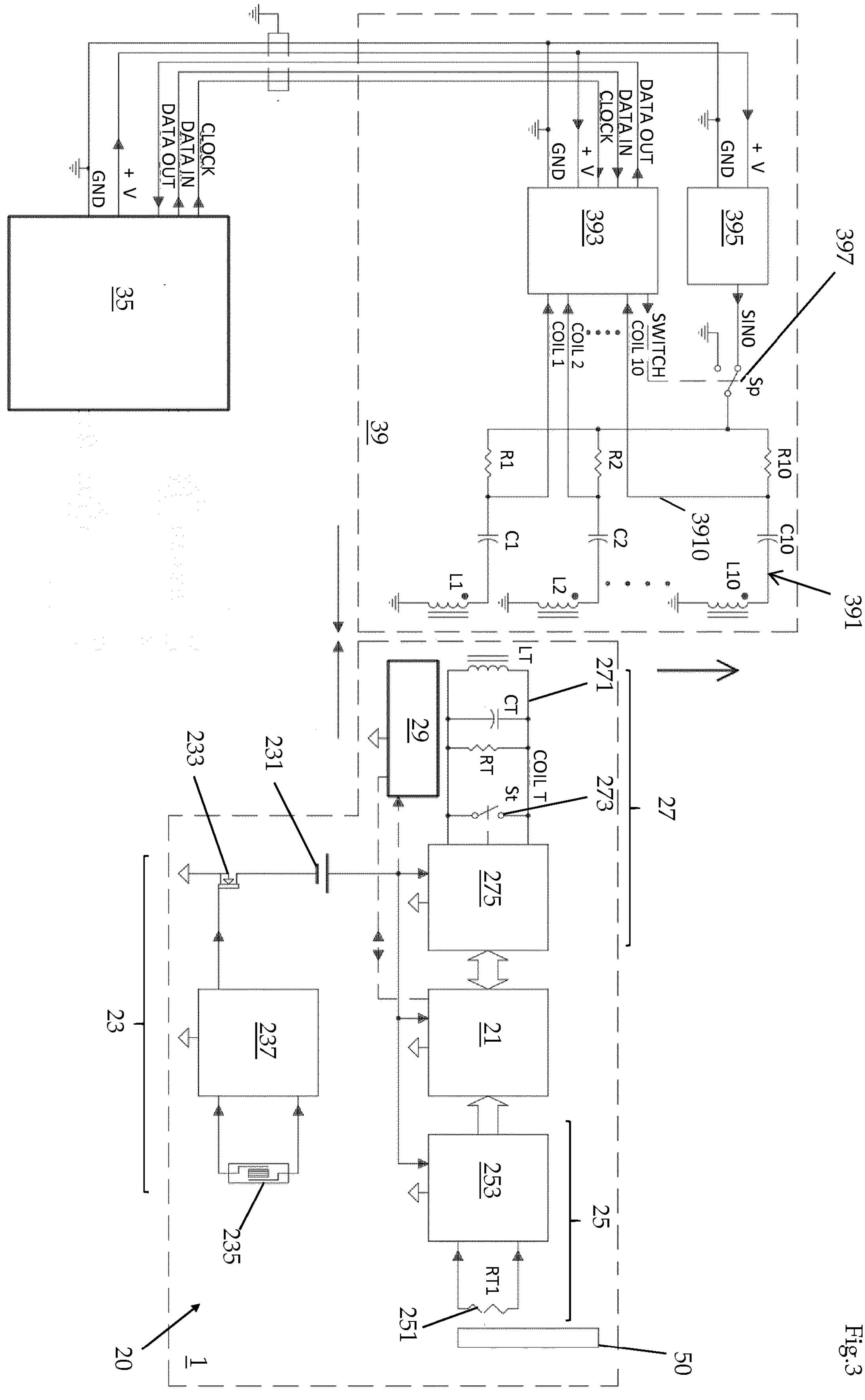
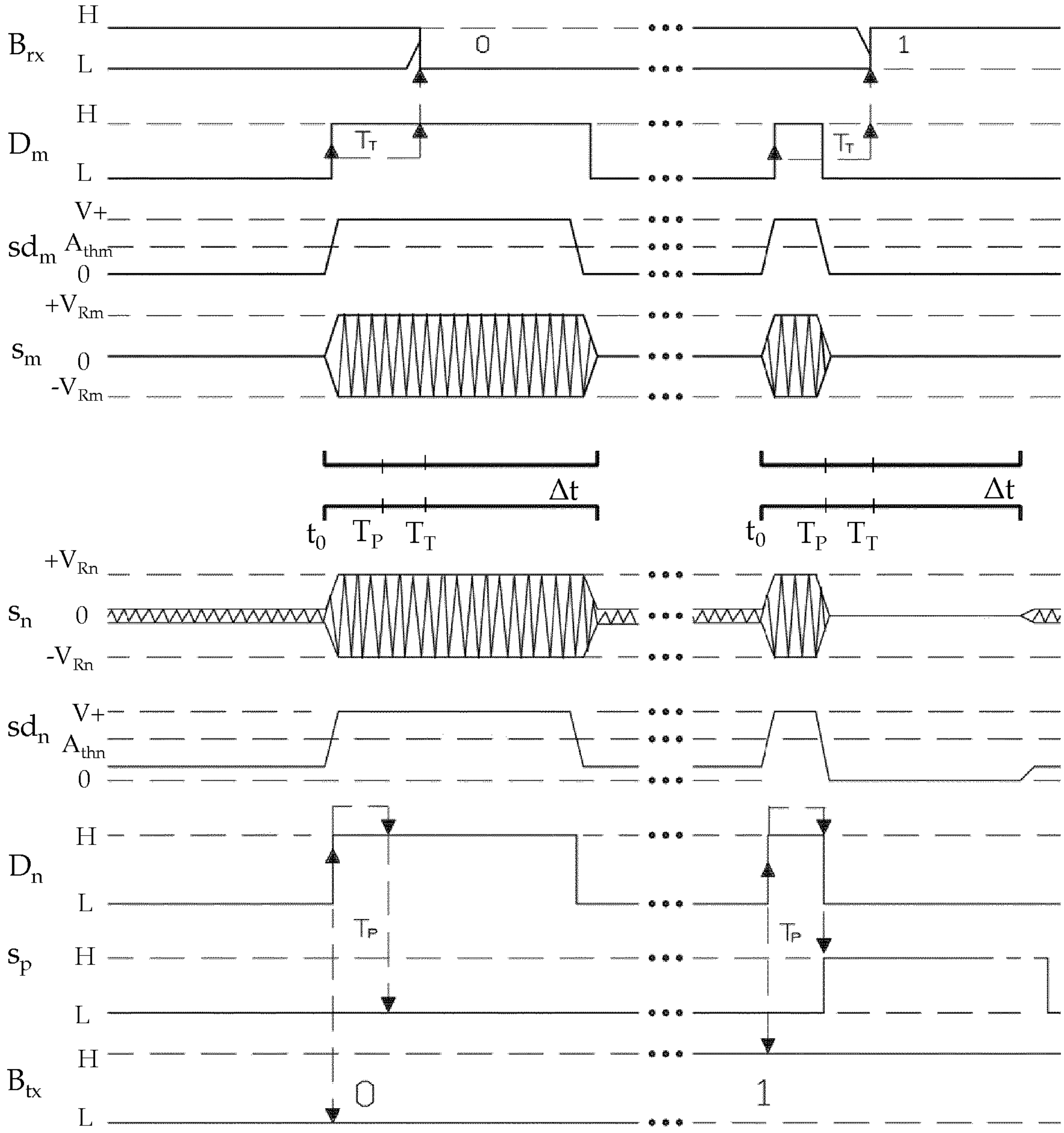

GND
+ V
DATA OUT
DATA IN
CLOCK
35
39
393
395
397
SWITCH
COIL 1
COIL 2
COIL 10
SIN0
Sp
R1
R2
R10
C1
C2
C10
L1
L2
L10
3910
391
LT
CT
RT
St
COIL T
271
273
27
29
275
21
253
25
RT1
251
50
233
231
237
23
235
20
1

Fig.3



B rx
H
L
0
1
D m
H
L
T T
sd m
V+
A thm
0
s m
+V Rm
0
-V Rm
Δt
t 0
T P
T T
s n
+V Rn
0
-V Rn
sd n
V+
A thn
0
D n
H
L
T P
s p
H
L
B tx
H
L
0
1

Fig.4

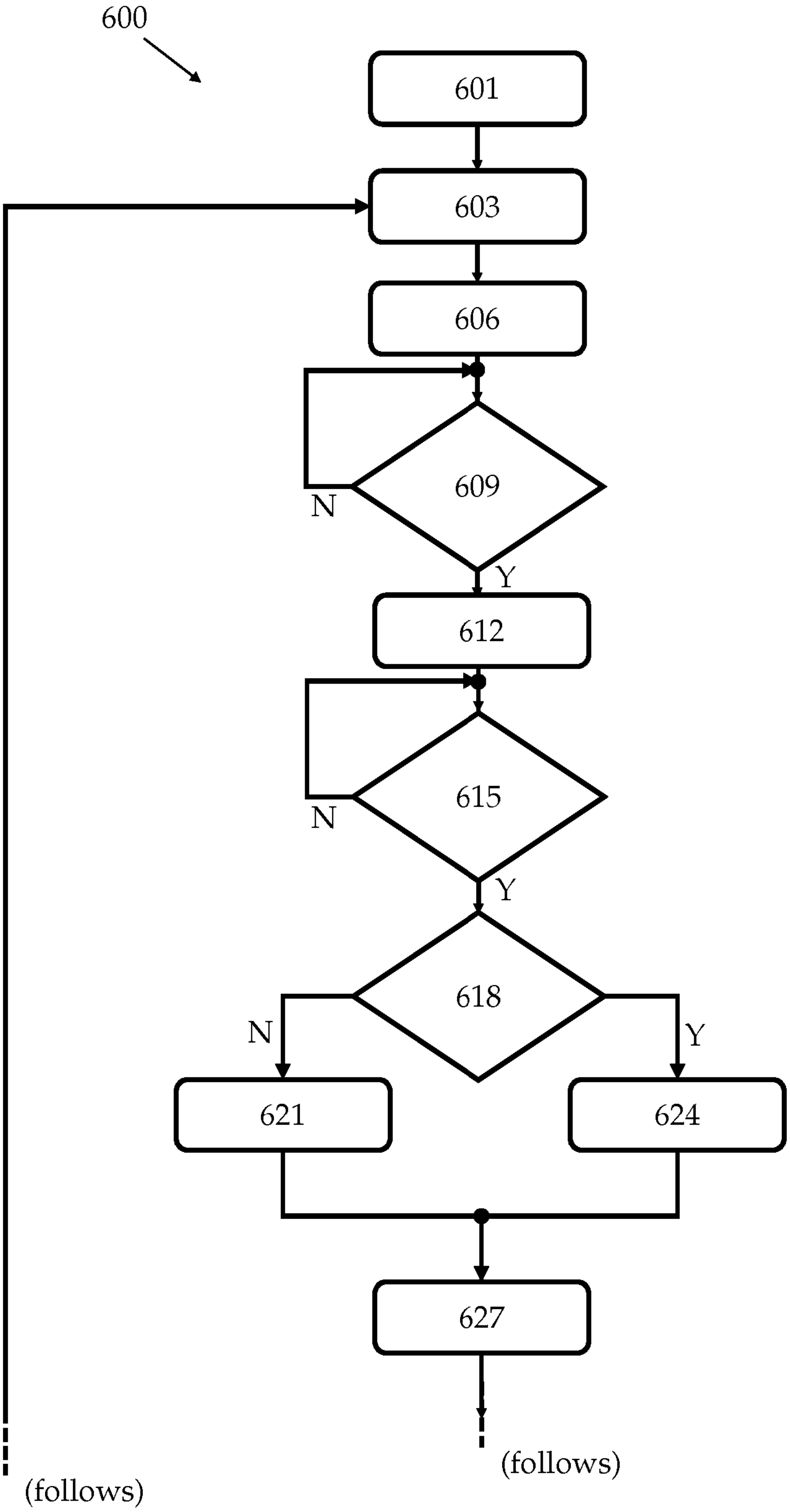

600
601
603
606
609
N
Y
612
615
N
Y
618
N
Y
621
624
627
(follows)
(follows)

Fig.5A

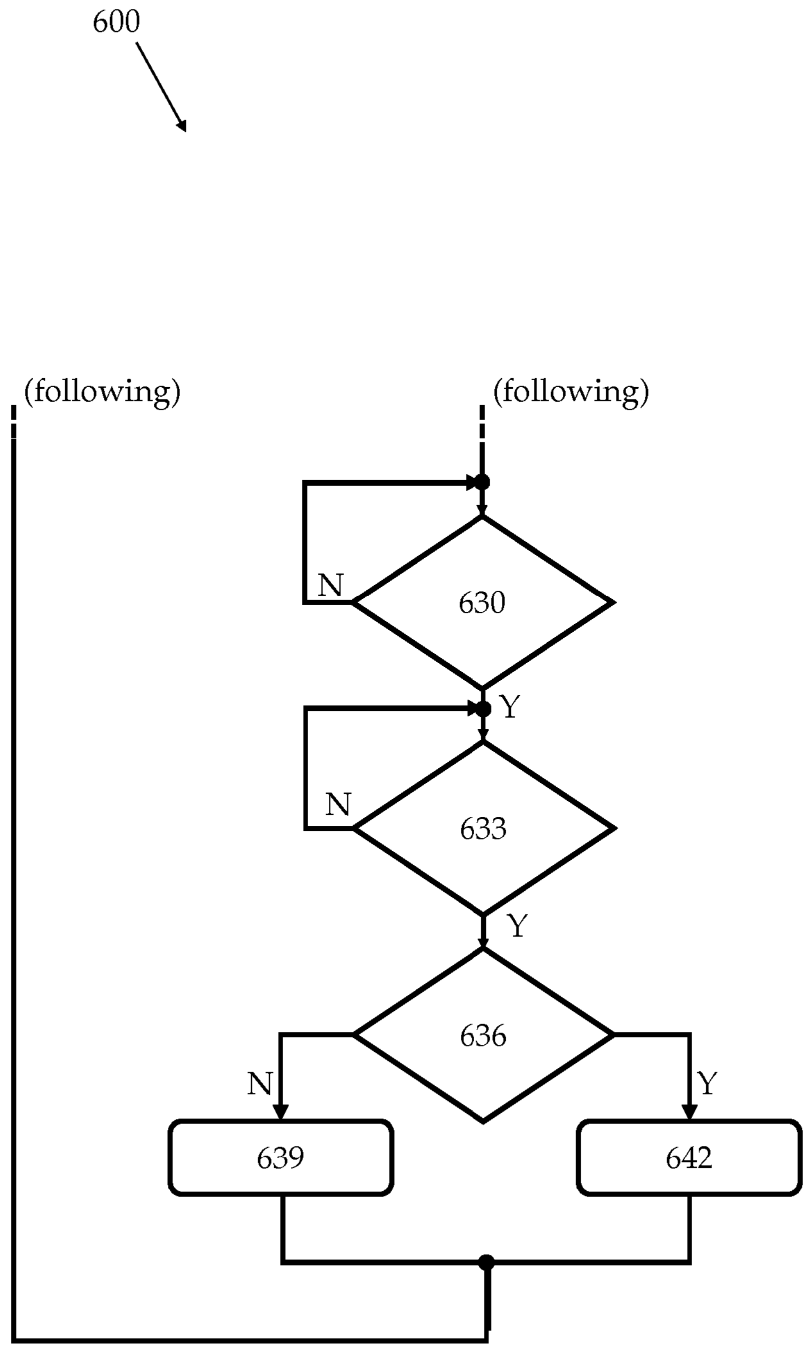
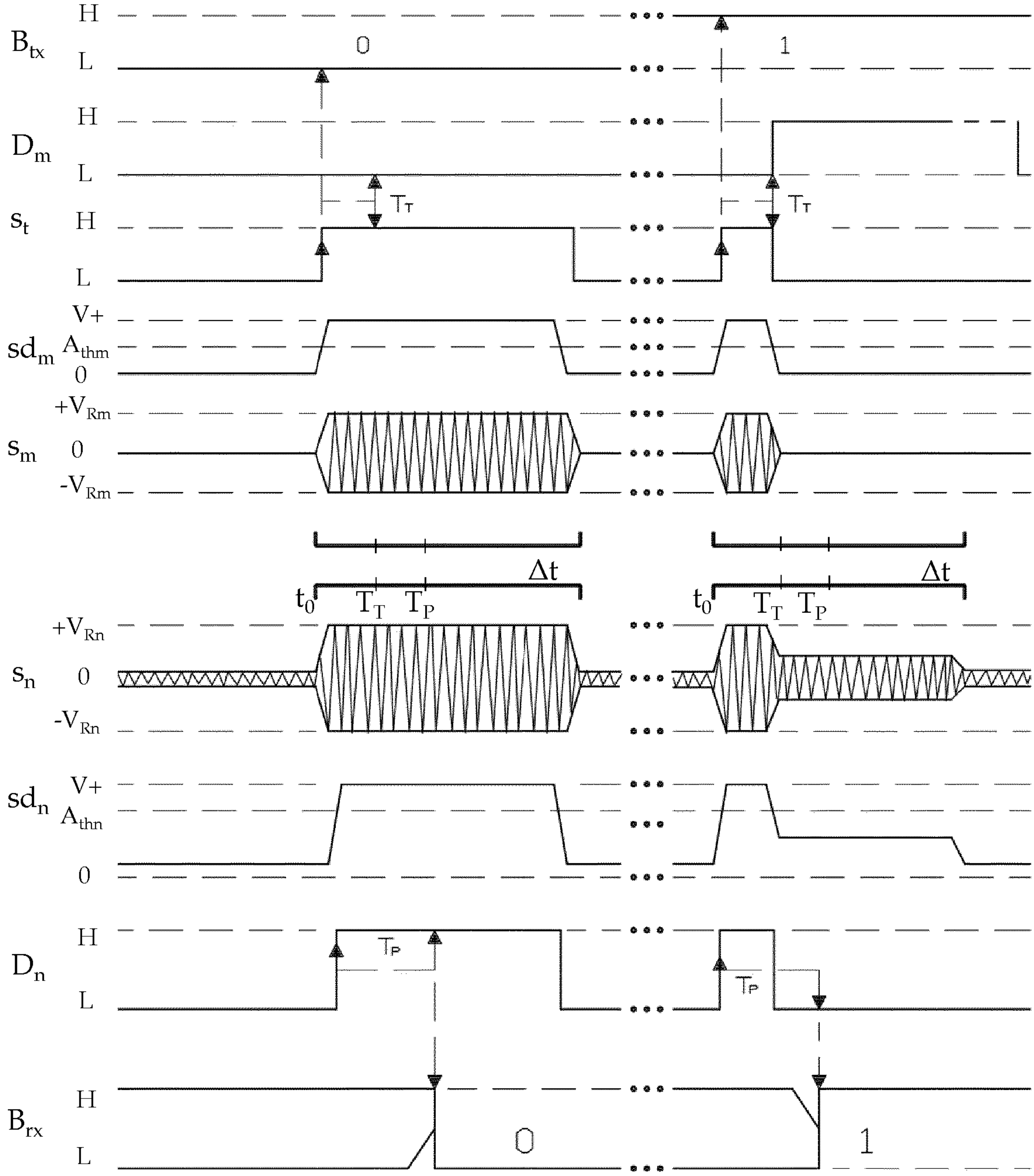


Fig.5B



H
B_{tx}
L
0
1
H
D_m
L
T_T
T_T
s_t
H
L
V+
sd_m
A_{thm}
0
$+V_{Rm}$
s_m
0
$-V_{Rm}$
Δt
Δt
t_0
T_T
T_P
t_0
T_T
T_P
$+V_{Rn}$
s_n
0
$-V_{Rn}$
V+
sd_n
A_{thn}
0
H
D_n
L
T_P
T_P
H
B_{rx}
L
0
1

Fig.6

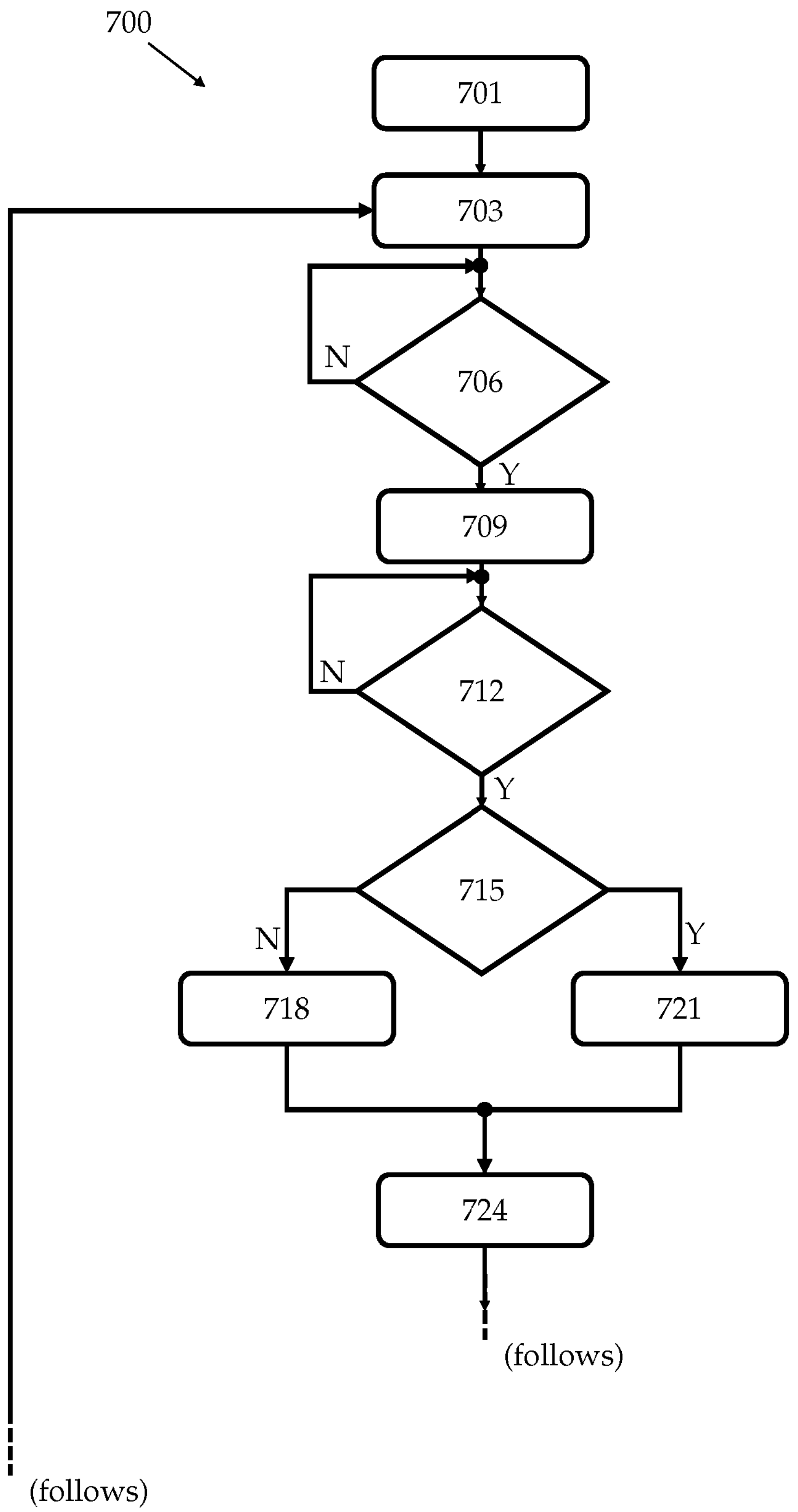

700
701
703
N
706
Y
709
N
712
Y
715
N
Y
718
721
724
(follows)
(follows)

Fig.7A

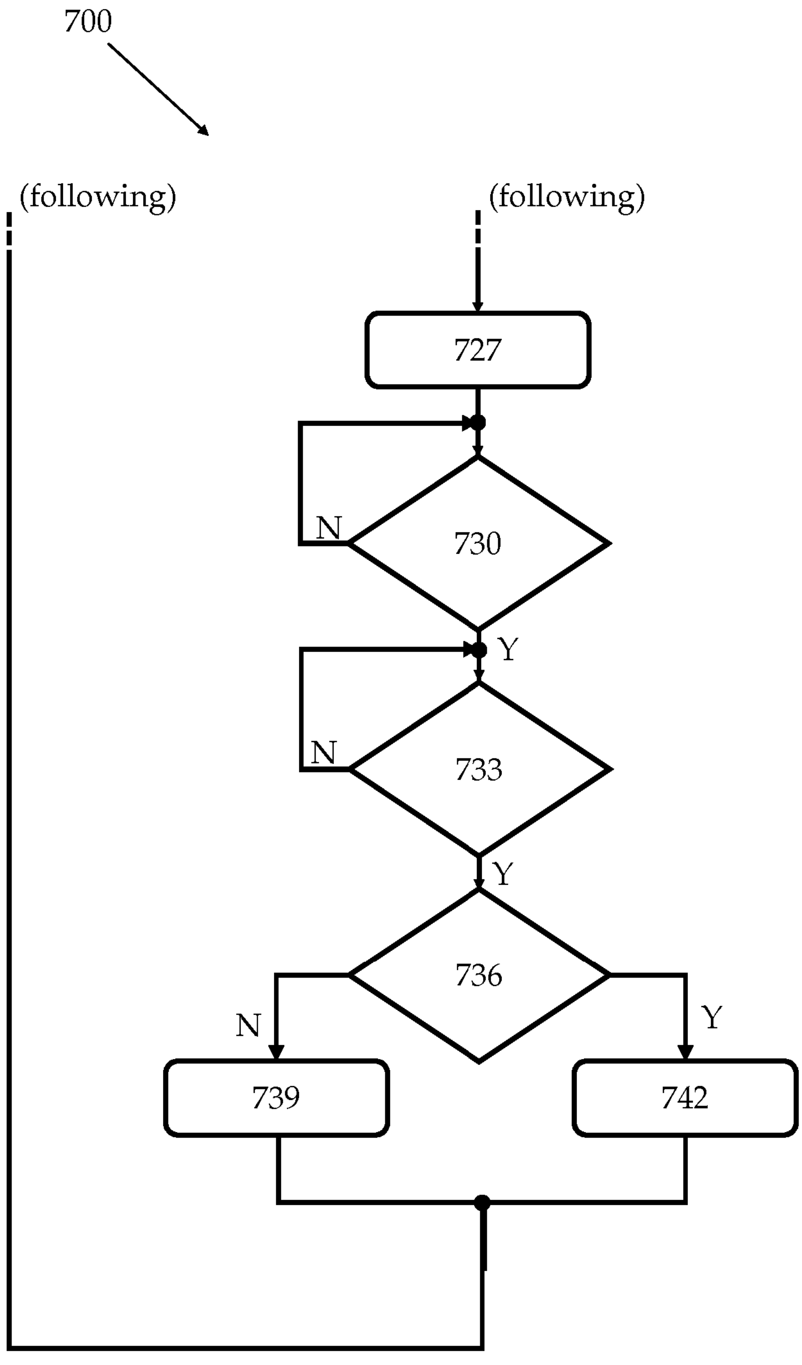


Fig.7B

REFERENCES CITED IN THE DESCRIPTION

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