SENSOR, PARTICULARLY FOR DETECTING METALS

A sensor for detecting objects, in particular metal objects, comprises a search oscillator (1), a reference oscillator (4) and a control system that sends a control signal for maintaining the search oscillator (1) at the same frequency as the reference oscillator (4). A possible metal object is detected by monitoring (10) the control signal. The sensor is practically insensible to temperature variations.
Background of the invention

[0001] This invention relates to a sensor, particularly for metals.

[0002] Specifically, but not exclusively, the present invention can be usefully applied to determining the presence and/or distance of electrically conductive objects, such as, for example, metal objects.

[0003] Patent publication US 2008/0197839 shows an inductive proximity sensor that uses a sigma delta modulator for evaluating an outlet signal of an LC resonating circuit, which LC circuit is inserted into a feedback loop system of the sigma delta modulator so as to become a component of the control circuit. The feedback in the control circuit means that the outlet signal of the resonating circuit, in particular the oscillation amplitude signal, can be controlled at a desired preset value. This known sensor substantially uses the variation in the losses of the resonator caused by the presence or absence of the metal, which causes a variation in the quality factor of the resonator and thus of the amplitude of the oscillation.

[0004] A sensor for metals is also known comprising a beat frequency oscillator (BFO) in which the presence of metal objects is determined on the basis of the comparison of the frequencies of a reference oscillator and of a search oscillator.

[0005] Sensors for metals are further known that have one transmitting reel and one or more receiving reels.

[0006] Known sensors for metals are not generally particularly stable in relation to the temperature variation, a reason for which the sensors normally have to be calibrated before use and again calibrated when the temperature varies noticeably.

Summary of the invention

[0007] An object of this invention is to provide a
particularly effective sensor, in particular to determine the presence and/or distance of an electrically conductive object.

[0008] An advantage of the present invention is to make a sensor that is relatively stable in relation to ambient variations, in particular to temperature variations.

[0009] Another advantage is to make a sensor available that is constructionally simple and economical.

[0010] Further advantages will be shown below in the present description.

[0011] These objects and advantages and still others are achieved by a sensor according to one or more of the claims set out below.

**Brief description of the drawings**

[0012] The invention can be better understood and implemented with reference to the attached drawings that illustrate some embodiments thereof by way of non-limiting example.

[0013] Figure 1 shows a block diagram of a first embodiment of the present invention.

[0014] Figure 2 shows a block diagram of a second embodiment of the present invention.

**Detailed description**

[0015] The sensor illustrated in figure 1 comprises a plurality of locks.

[0016] With 1 a search oscillator or voltage-controlled oscillator (VCO) is indicated that is configured for generating a magnetic field around the inductance of a resonator, with 2 the resonator reel, with 3 an (optional) capacitors bench for calibrating the sensor, with 4 a reference oscillator configured for supplying a signal with a reference frequency that can be substantially stable and independent of the presence or absence of the metal object to be detected, with 5 an (optional) phase frequency detector (PFD) that is configured for comparing the phase of the reference oscillator with the phase of the controlled search oscillator, with 6 a (optional) main divider configured for
dividing the frequency of the search oscillator controlled up to a comparison frequency, with 7 a (optional) reference divider configured for dividing the frequency of the reference oscillator up to the comparison frequency, with 8 an (optional) loop filter configured for ensuring the stability of the control loop and to ensure the reduction of noise and spurious signals on the control signal that will then be used for the purposes of detecting the metal object, with 9 an (optional) loading pump configured for supplying the gain used to amplify the phase signal at the detector input, with 10 an (optional) signal conditioning block configured for processing the control signal 11, i.e. the detection signal, to discriminate between various search situations of a metal object, with 12 an (optional) microprocessor configured for coordinating the various operating phases of the detection system.

[0017] The search oscillator 1 is in a phase-locked with the reference oscillator 4 so that the frequency difference between the two oscillators 1 and 4 is maintained at zero. In particular, it should be noted that (unlike a known metal sensor of BFO type in which, when a metal object is detected, the frequency of the search oscillator varies and it is this variation that is measured to determine the presence of the metal object) in the specific embodiment of the invention illustrated here the controlled oscillator, i.e. the search oscillator 1, always remains at the same frequency, inasmuch as the control signal 11 maintains the search oscillator in a phase-locked with the reference oscillator 4 and the presence of the object is determined by monitoring the variation of the control signal that is used to return the oscillators in phase into the phase-locked loop control system.

[0018] In other embodiments that are not illustrated, the frequency, or another parameter, of the controlled oscillator, is controlled on the basis of a set control criterion in function of at least an outlet parameter of the reference oscillator, in which the control criterion is not
necessarily an equality criterion between the frequencies of the two search and reference oscillators.

[0019] Owing to the sensor disclosed here it is possible to detect the presence of metal objects by measuring the variation of the sent control signal to maintain constant the frequency of a controlled oscillator in a phase-locked loop, which variation is caused in particular by the presence of an object near the controlled resonator. This measurement also enables objects to be detected in an incremental manner.

[0020] In operation, the sensor operates so as to monitor the variation in the control signal 11, which is in turn determined so as to maintain the search oscillator 1 (controlled oscillator) in a phase-locked with the reference oscillator 4.

[0021] The control signal 11, which is the detection signal, varies according to the presence or not of metal objects near the reel of the resonator.

[0022] The detecting system operates, in greater detail, in the following manner.

[0023] Initialisation and calibration phase.

[0024] An initialisation and calibration phase is provided in which the search oscillator 1 (controlled oscillator) VCO and the reference oscillator 4 are in a phase-locked.

[0025] The bench of capacitators 3 is calibrated so as to take the detection signal (i.e. the control signal 11) to a value that is within a set window of values. This window of values is chosen so as to obtain a desired sensibility of the oscillator 1 VCO to the inductance variations induced by the presence of a metal object.

[0026] This initialisation and calibration phase also enables the undesired effects of frequency variation due to temperature and to the presence of metal near the sensor to be eliminated.

[0027] Repeating this calibration phase automatically when the control signal 11 exits the predefined values window is provided for.
Operating phase.

During the operating phase the detecting system monitors for the presence of a metal object by processing the control signal 11 (substantially coinciding with the detection signal) that controls the frequency of the search oscillator 1 VCO.

When an electrically conductive object disturbs the magnetic field around the resonator of the controlled oscillator 1, the frequency of the oscillator 1 would tend to vary, but this variation is substantially neutralised or substantially neutralised or contrasted by the phase-locked loop control system, which reacts by varying the control (or detection) signal 11 to return the frequency of the controlled oscillator 1 to the original frequency, i.e. substantially, to the frequency defined by the reference oscillator 4.

In this manner the control signal 11 can perform the function of a detection signal inasmuch as it contains at least one information indicating the presence or absence of a metal object, this information being in substance obtainable from the change in the value thereof compared with the initial value.

This variation is processed by the signal conditioning system 10 that, in function of the value of the aforesaid variation, is able to evaluate the presence and/or the distance of a possible metal object detected by the sensor.

Forced calibration phase.

If the control or detection signal 11 departs from the preset window values, for example owing to the temperature variation and/or because of the drift of the components that constitute the resonator and/or because of the variations in the surrounding metal environment, then the detecting system is commanded automatically to return to the initialisation and calibration phase.

As has been seen, the reference oscillator 4 and the (controlled) search oscillator 1 operate at the same
frequency, i.e. in a phase-locked. The presence of a metal object is perceived following the variation of the control signal 11 (detection signal) commanded to compensate for the phase variation.

[0036] The control signal 11 can be a digital-type signal if the search oscillator is a digitally controlled oscillator, or can be an analogue signal, for example a voltage or current signal, if the search oscillator is a voltage or current-controlled oscillator.

[0037] The bandwidth of the phase-locked loop system can be optimised to obtain an operation with relatively low noise so as to be able to obtain very high sensibility.

[0038] Further, the phase closure and the simple calibration thereof enable operation to take place at a relatively high frequency (typically in the order of a few megahertz) without the need for continuous calibration due to the frequency drift as in the case of metal sensors of known type. This relatively high frequency also enables metal objects to be detected that are much smaller than those detectable with systems of known type operating at lower frequencies.

[0039] With reference to the example embodiment in figure 2 (in which the analogue elements have been numbered as in figure 1), it should be noted that it is possible to synchronise one or more sensors, connecting the search oscillators 1 to a single reference oscillator 4.

[0040] This enables a detecting sensor or system to be made with several sensor members that are all in phase between one another. An advantage of this configuration consists of greater insensitivity of the system to the reciprocal interaction between two sensor members. In this manner the two sensor members can be arranged at a reciprocal distance that is relatively very reduced.

[0041] It should be noted that a sensor made in accordance with the present invention could also be used in different application fields from that of detecting metals.

[0042] By way of example we can cite sensors for detecting
humidity, density, proximity (capacitive inductive sensor), temperature, pressure, etc, the list not being exhaustive.

[0043] In general, the sensor according to the present invention could be used in all the cases in which an oscillator or a resonating element is able to vary one of its operating parameters, such as, in particular resonance frequency according to a given factor/parameter to be measured.
CLAIMS

1. Sensor comprising:
   - a search oscillator configured for emitting a search signal influenced by a factor/parameter to be detected;
   - a reference oscillator configured for emitting a reference signal;
   - a control system configured for emitting a control signal for said search oscillator on the basis of said reference signal;
   - an evaluation system configured for evaluating said factor/parameter to be detected on the basis of said control signal.

2. Sensor according to claim 1, wherein said control system is configured for maintaining said search oscillator in a phase-locked with said reference oscillator.

3. Sensor according to claim 1 or 2, wherein said control system is configured for maintaining a control parameter of said search oscillator in a preset relationship with a reference parameter of said reference oscillator.

4. Sensor according to claim 3, wherein said control parameter is a control frequency of said search oscillator.

5. Sensor according to claim 3 or 4, wherein said reference parameter is a reference frequency of said reference oscillator.

6. Sensor according to any preceding claim, wherein said preset relationship is a relationship of equality between a value of said control parameter and a value of said reference parameter.

7. Sensor according to any preceding claim, wherein said control system comprises a feedback control system having a set point that is determined by said reference signal.

8. Sensor according to any preceding claim, comprising a phase comparator configured for comparing a phase of said reference oscillator with a phase of said search
oscillator.

9. Sensor according to any preceding claim, comprising a calibrating system configured for modifying said control signal so as to return the control signal within a preset set of acceptable values.

10. Sensor according to claim 9, wherein said evaluation system is configured for automatically activating said calibrating system in response to a departure of said control signal from said set of acceptable values.

11. Sensor according to any preceding claim, wherein said factor/parameter to be detected comprises the presence or the distance of an electrically conductive object.

12. Sensor according to any preceding claim, wherein said sensor is comprised in a group comprising a humidity sensor, a density sensor, a proximity sensor, a temperature sensor, a pressure sensor.

13. Sensor according to any preceding claim, comprising:
   - at least a further search oscillator configured for emitting at least a further search signal influenced by a factor/parameter to be detected;
   - at least a further control system configured for emitting at least a further control signal for said further search oscillator on the basis of said reference signal, said further control signal being used to evaluate said factor/parameter to be detected by said evaluation system or by a further evaluation system configured for evaluating said factor/parameter to be detected on the basis of said further control signal.
### A. CLASSIFICATION OF SUBJECT MATTER

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

#### B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

GOIV

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

Electronic database consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal , WPI Data

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

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