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(54) **CONTROL CIRCUIT OF A MEMS GYROSCOPE, MEMS GYROSCOPE AND CONTROL METHOD**

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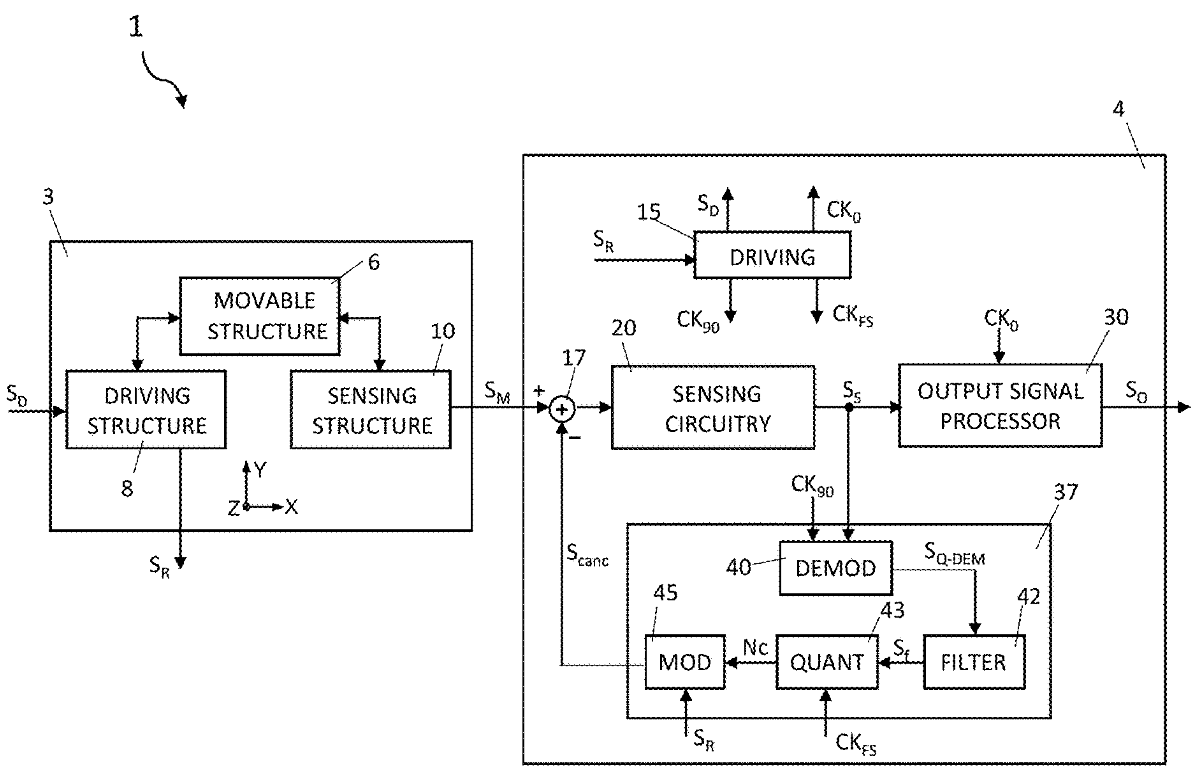
(57) **ABSTRACT**

The control circuit for a MEMS gyroscope is configured to receive a measurement signal which has a quadrature component and a sensing component. The control circuit has: an input stage which acquires an input signal, generating an acquisition signal, where the input signal is a function of the measurement signal and of a quadrature cancellation signal; a processing stage which extracts a first component of the acquisition signal, indicative of the sensing component of the measurement signal and having a sensing frequency band; and a quadrature correction stage which extracts a second component of the acquisition signal, indicative of the quadrature component of the measurement signal, and generates the quadrature cancellation signal from a reference signal. The quadrature cancellation signal is a signal modulated as a function of the second component of the acquisition signal, at an update frequency which is outside the sensing frequency band.



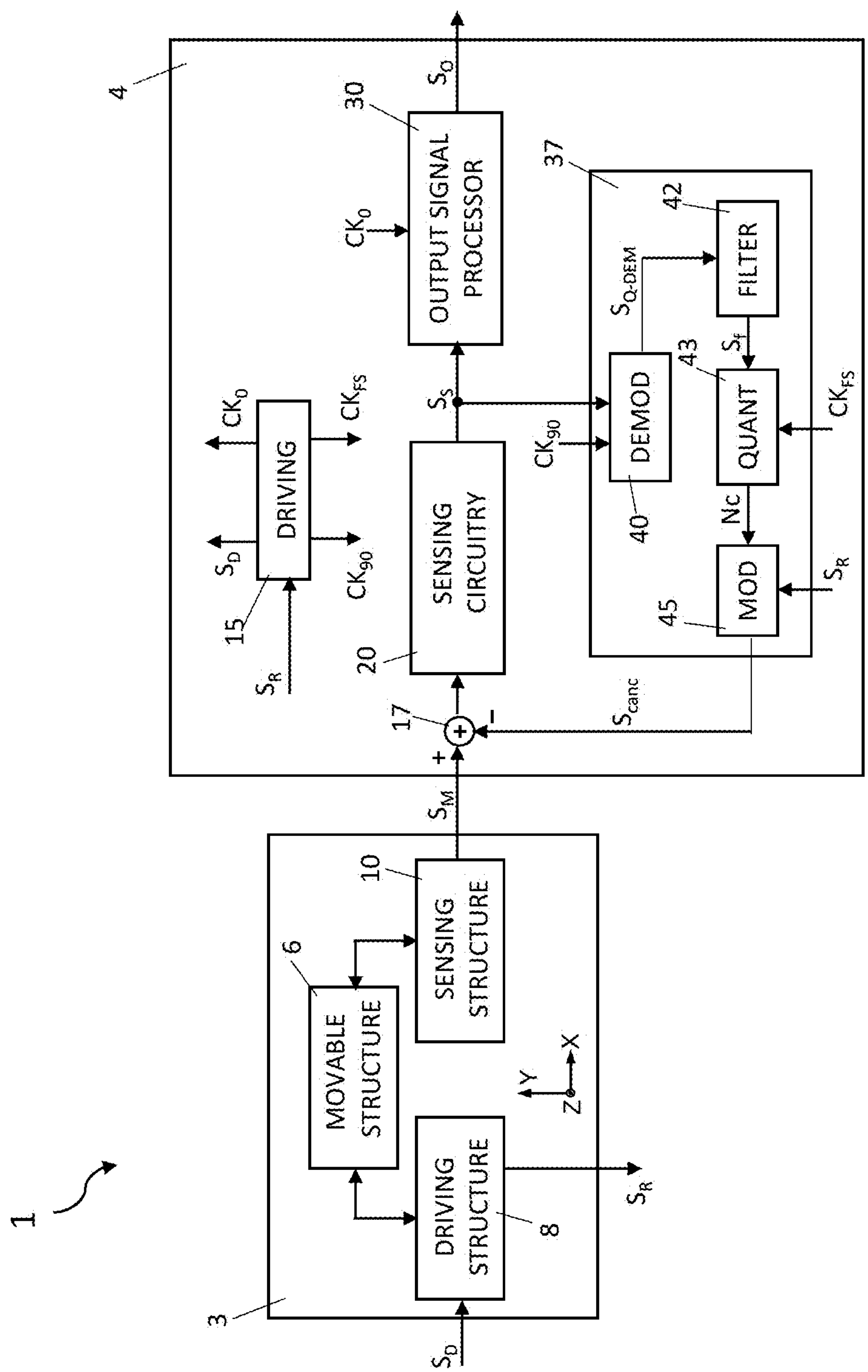
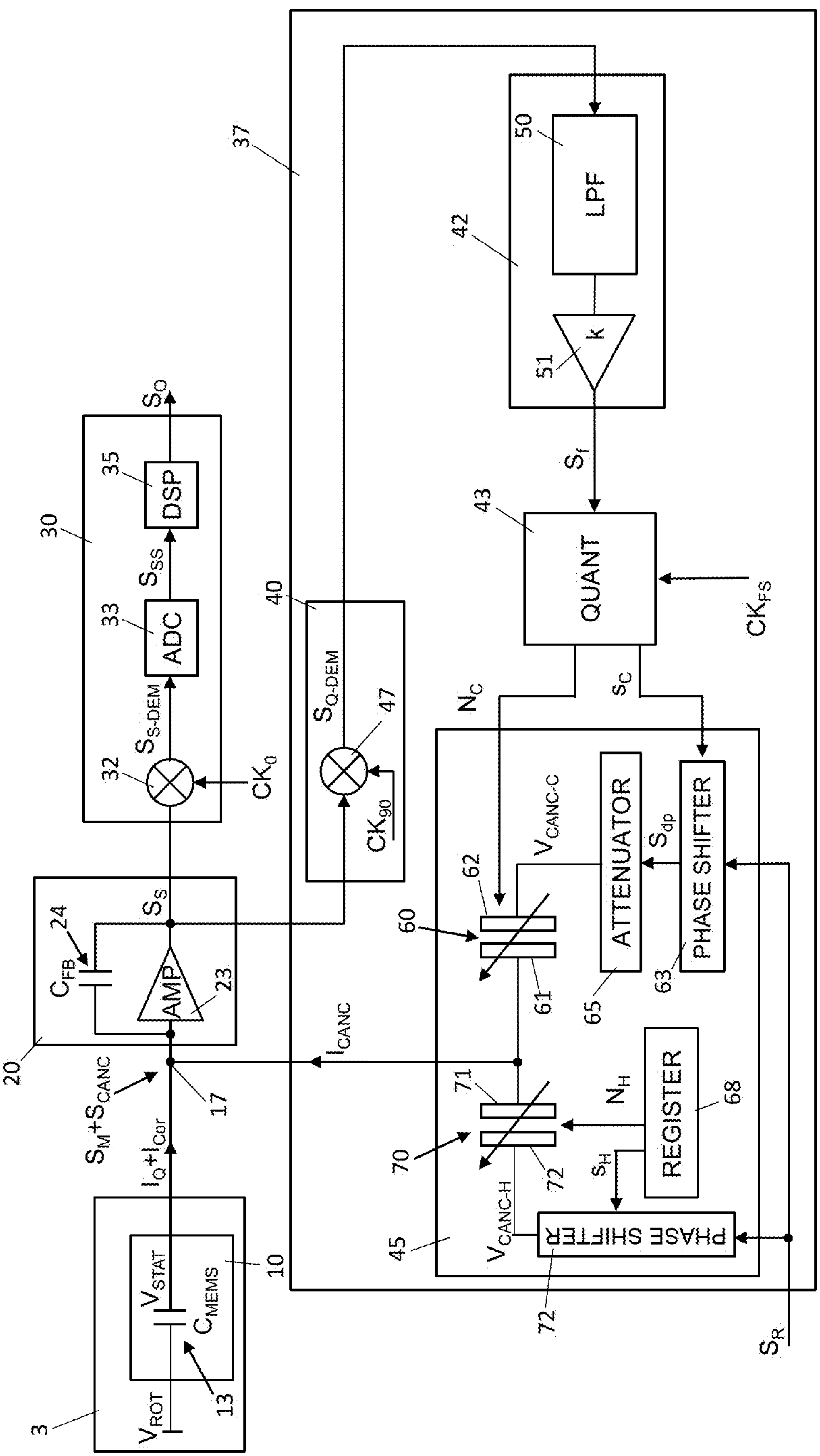

1
3
4
MOVABLE STRUCTURE
6
DRIVING STRUCTURE
8
SENSING STRUCTURE
10
S_D
S_R
S_M
X
Y
Z
+
−
17
S_{canc}
SENSING CIRCUITRY
20
DRIVING
15
S_R
S_D
CK_0
CK_{90}
CK_{FS}
S_S
OUTPUT SIGNAL PROCESSOR
30
CK_0
S_O
37
DEMOD
40
CK_{90}
$S_{Q\text{-}DEM}$
FILTER
42
S_f
QUANT
43
CK_{FS}
Nc
MOD
45
S_R

Fig. 1



3
10
13
V_{ROT}
V_{STAT}
C_{MEMS}
I_Q+I_{Cor}
S_M+S_{CANC}
17
20
23
24
C_{FB}
AMP
S_S
30
32
33
35
$S_{S\text{-}DEM}$
ADC
S_{SS}
DSP
S_O
CK_0
37
40
47
$S_{Q\text{-}DEM}$
CK_{90}
I_{CANC}
42
50
51
LPF
k
S_f
43
QUANT
CK_{FS}
N_C
s_C
45
60
61
62
63
65
68
70
71
72
$V_{CANC\text{-}C}$
ATTENUATOR
S_{dp}
PHASE SHIFTER
REGISTER
N_H
s_H
$V_{CANC\text{-}H}$
S_R

Fig. 2

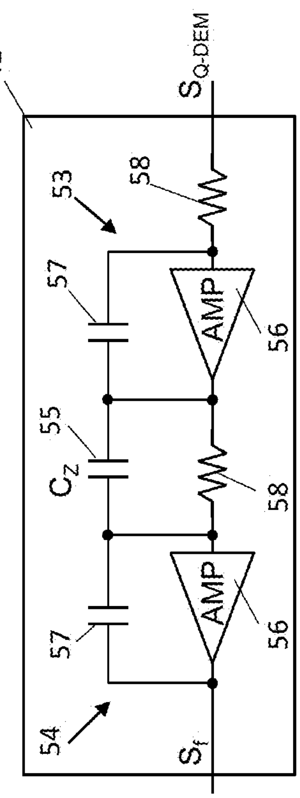

42
$S_{Q\text{-}DEM}$
53
58
57
AMP
56
55
C_Z
58
57
AMP
56
54
S_f

Fig. 3

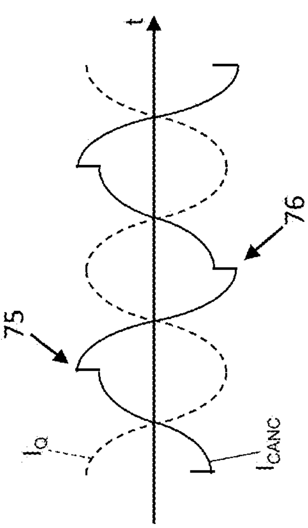

t
76
75
I_Q
I_{CANC}

Fig. 4

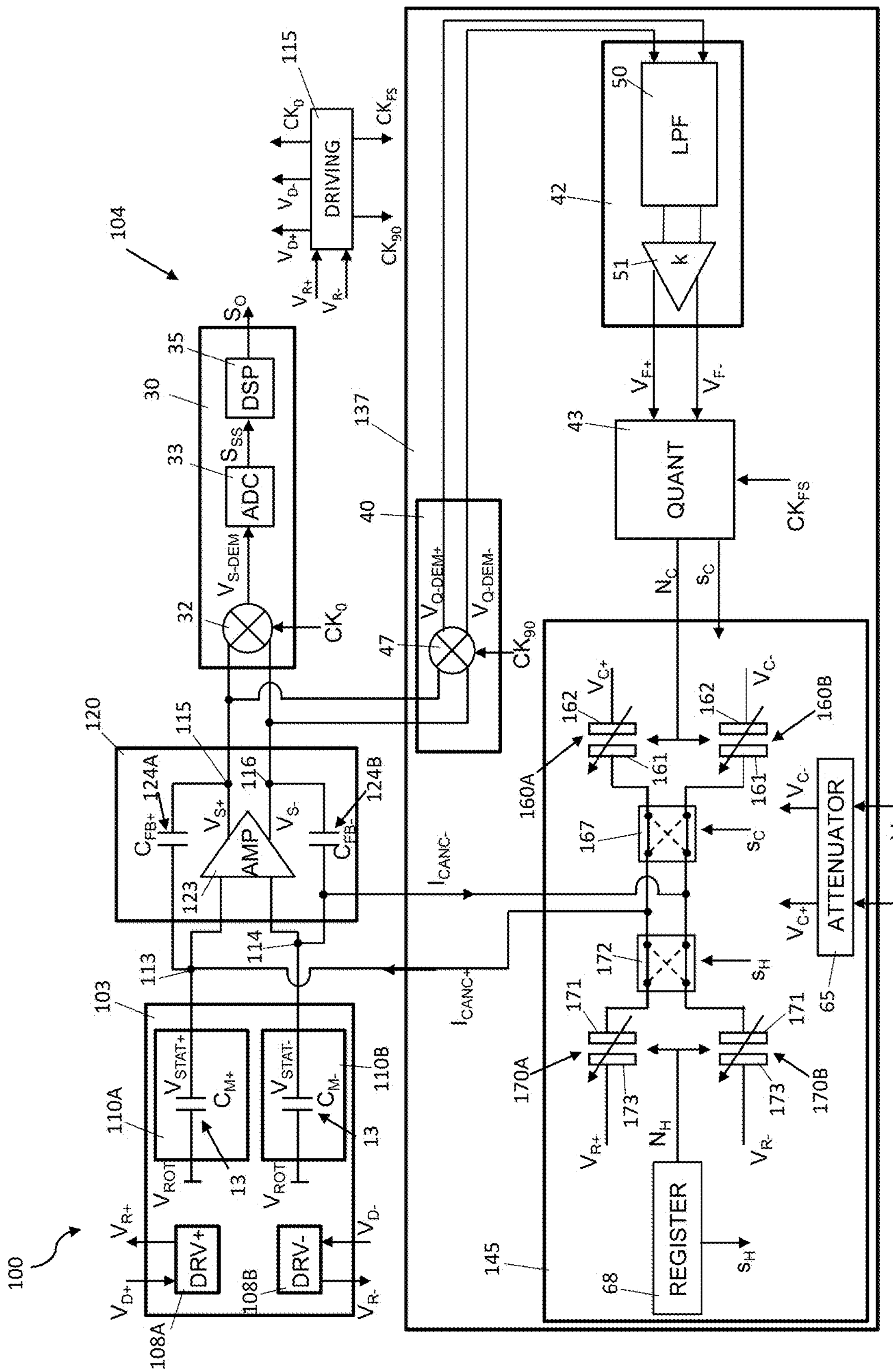


Fig. 5

CONTROL CIRCUIT OF A MEMS GYROSCOPE, MEMS GYROSCOPE AND CONTROL METHOD

BACKGROUND

Technical Field

[0001] The present disclosure relates to a control circuit of a MEMS gyroscope, to a MEMS gyroscope and to a control method.

Description of the Related Art

[0002] A gyroscope made using MEMS ("Micro Electro-Mechanical Systems") technology is formed in one or more dice of semiconductor material, for example silicon, wherein an oscillating system, a driving circuit and a sensing circuit, mutually coupled, are formed.

[0003] The oscillating system is formed by one or more movable masses suspended on a substrate and free to oscillate with respect to the substrate with one or more degrees of freedom. The oscillating system further comprises a driving structure, coupled to the driving circuit and configured to cause an oscillation of the one or more movable masses along a driving direction, and a sensing structure, coupled to the sensing circuit and configured to sense a movement of the one or more movable masses along a sensing direction perpendicular to the driving direction.

[0004] In some MEMS gyroscopes, driving and sensing may be based on different operating principles, e.g., electromagnetic, piezoelectric or capacitive.

[0005] When the MEMS gyroscope rotates with an angular velocity about a rotation axis, a movable mass that oscillates with a linear velocity along a direction perpendicular to the rotation axis is subject to a Coriolis force directed along a direction perpendicular to the rotation axis and to the direction of the linear velocity.

[0006] In use, the driving circuit provides a driving signal, for example a voltage in case of capacitive driving, to the driving structure, causing an oscillation of the oscillating structure along the driving direction.

[0007] The sensing structure senses a movement of the oscillating system along the sensing direction and provides a corresponding sensing signal to the sensing circuit.

[0008] In some MEMS gyroscopes, due to variability and imperfections associated with the manufacturing process of the MEMS gyroscope, the driving signal may generate a spurious movement of the one or more movable masses along the sensing direction, even in the absence of a rotation of the MEMS gyroscope. The spurious movement is sensed by the sensing structure, thus generating a spurious signal, known as a quadrature error, which adds to the sensing signal originating from the rotation of the MEMS gyroscope.

[0009] This reduces the sensitivity of the MEMS gyroscope.

[0010] In order to reduce the contribution of the quadrature error on the sensing signal, a sensing circuit may comprise a trimming circuit which generates a correction signal configured to cancel the spurious quadrature signal. However, the correction signal value is set during an initial calibration step of the MEMS gyroscope. As a result, this approach does not allow any variations in the spurious quadrature signal to be corrected while using the MEMS gyroscope.

[0011] The trimming circuit may be recalibrated multiple times during the life cycle of the MEMS gyroscope. However, this recalibration introduces noise into the MEMS gyroscope output signal, thereby compromising the sensing performances thereof.

BRIEF SUMMARY

[0012] The technical solutions of the present disclosure overcome the disadvantages of the prior art.

[0013] According to the present disclosure a control circuit of a MEMS gyroscope, a MEMS gyroscope and a control method are therefore provided.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0014] For a better understanding of the present disclosure, some embodiments thereof are now described, purely by way of non-limiting example, with reference to the attached drawings, wherein:

[0015] FIG. **1** shows a block diagram of the present MEMS gyroscope, according to an embodiment;

[0016] FIG. **2** shows a detailed block diagram of the MEMS gyroscope of FIG. **1**;

[0017] FIG. **3** shows a circuit diagram of a portion of the MEMS gyroscope of FIG. **2**;

[0018] FIG. **4** shows a plot of a trend over time of waveforms of the MEMS gyroscope of FIG. **2**; and

[0019] FIG. **5** shows a block diagram of the present MEMS gyroscope, according to a different embodiment.

DETAILED DESCRIPTION

[0020] FIGS. **1** and **2** show a MEMS gyroscope **1** comprising an oscillating system **3** and a control circuit **4**, which are operatively coupled.

[0021] The oscillating system **3** and the control circuit **4** may be formed in a single die of semiconductor material, eg., silicon, or in separate dice.

[0022] The oscillating system **3** is made using MEMS technology and comprises a movable and/or deformable structure, hereinafter referred to as movable structure **6**, having a resonance frequency f_r, a driving structure **8** and a sensing structure **10**, mutually coupled.

[0023] The driving structure **8** is configured to receive a driving signal Sp from the control circuit **4** and cause a movement, for example, an oscillation, of the movable structure **6** along a driving direction, using an actuation principle, e.g., of electromagnetic, piezoelectric or electrostatic type.

[0024] For example, considering a Cartesian reference system XYZ comprising a first axis X, a second axis Y and a third axis Z, the driving direction may be parallel to the first axis X.

[0025] Furthermore, in this embodiment, the driving structure **8** generates a position signal SR, indicative of a movement of the movable structure **6** along the driving direction, and provides the position signal S_R to the control circuit **4**.

[0026] For example, if the driving signal S_D causes an oscillation of the movable mass **6** at the resonance frequency f_r, then the position signal S_R is a periodic signal, for example, sinusoidal, having the resonance frequency f_r and whose amplitude is a function of the position variation of the movable structure **6**.

[0027] The position signal S_R may be generated using a sensing principle of capacitive, piezoelectric, piezoresistive or electromagnetic type, according to the specific application.

[0028] The sensing structure **10** is configured to sense a movement of the movable structure **6** along a sensing direction, for example perpendicular to the driving direction, for example parallel to the second axis Y, and generate a corresponding measurement signal S_M, which is provided to the control circuit **4**.

[0029] In this embodiment, as shown in FIG. **2**, the sensing structure **10** operates according to a capacitive sensing principle and is formed by a sensing capacitor **13** having, at rest, a capacitance C_{MEMS}.

[0030] However, the sensing structure **10** may generate the measurement signal S_M using a different sensing principle, e.g., of electromagnetic or piezoelectric type.

[0031] Here, the sensing capacitor **13** is schematically represented by a parallel plate capacitor; however, the sensing capacitor **13** may be of different type, e.g., an interdigitated capacitor.

[0032] The sensing capacitor **13** has a first terminal at a rotor voltage V_{ROT}, which may be applied by the control circuit **4**, and a second terminal at a stator voltage V_{STAT} forming the measurement signal S_M.

[0033] For example, the rotor voltage V_{ROT} is a DC voltage that allows to set a desired initial value of the potential difference of the sensing capacitor **13**, useful in specific applications, eg., to tune the sensing sensitivity of the sensing capacitor **13**.

[0034] The control circuit **4** provides the driving signal S_D to the oscillating system **3** and receives the measurement signal S_M from the oscillating system **3**.

[0035] In this embodiment, the control circuit **4** also receives the position signal S_R from the oscillating system **3**.

[0036] Furthermore, the control circuit **4** generates, from the measurement signal S_M, an output signal S_0, of digital type, having an output data rate (or frequency) f_0 for example comprised between 10 Hz and 10 KHz.

[0037] In detail, the control circuit **4** comprises a driving module **15** which receives the position signal S_R.

[0038] The driving module **15** generates the driving signal S_D, having a driving frequency f_D, e.g., a voltage having sinusoidal behavior over time, a sequence of pulses or a square wave, and provides the driving signal S_D to the driving structure **8**, for the actuation of the movable structure **6**.

[0039] The driving frequency f_D may be chosen, at the design step, as a function of the electrical and/or mechanical characteristics of the oscillating system **3**, eg., as a function of the resonance frequency f_r of the movable structure **6**, and of the control circuit **4**.

[0040] The driving module **15** may adjust the driving signal S_D, eg., it may adjust the amplitude thereof in case of sinusoidal signal or the duty cycle in case of square wave, so that the movement of the movable structure **6** follows a desired profile over time, eg., has a desired oscillation amplitude, which may be chosen at the design step.

[0041] In this regard, the driving module **15** may adjust the driving signal S_D as a function of the position signal S_R, for example by comparing the position signal S_R with one or more values indicative of the desired movement profile of the movable structure **6**.

[0042] A gain with reference to FIG. **1**, the driving module **15** also generates an in-phase clock signal CK_0 and an out-of-phase clock signal CK_{90}, for example two periodic square wave signals, which have the driving frequency f_D and are mutually phase-shifted, for example, phase-shifted by 90°.

[0043] The in-phase clock signal CK_0 and the out-of-phase clock signal CK_{90} are, as a first approximation, except for latencies introduced by the driving module **15**, in quadrature and, respectively, in-phase with respect to the position signal S_R.

[0044] In detail, the rising (or falling) edges of the in-phase clock signal CK_0 are synchronized with the peaks (or valleys) of the position signal S_R.

[0045] The rising and falling edges of the out-of-phase clock signal CK_{90} are synchronized with the zero crossings of the position signal S_R.

[0046] Furthermore, since, as a first approximation, the position signal S_R is at the driving frequency f_D and is phase-shifted by 90° with respect to the driving signal S_D, the in-phase clock signal CK_0 and the out-of-phase clock signal CK_{90} are in-phase and, respectively, in quadrature, with respect to the driving signal SD.

[0047] The driving module **15** also generates a correction clock signal CK_{FS}, eg., a periodic square wave signal, having a frequency f_{F5} outside a frequency band of interest BW of the MEMS gyroscope **1**, for example greater than the output frequency f_0 of the output signal S_0, as described in detail hereinbelow.

[0048] Furthermore, the frequency f_{F5} of the correction clock signal CK_{FS} may be equal to or different from the driving frequency f_D, eg., greater than the driving frequency f_D, for example equal to double the driving frequency f_D.

[0049] According to an embodiment, the rising (or falling) edges of the correction clock signal CK_{F5} are synchronized with the zero crossings of the position signal S_R. This is useful when using the MEMS gyroscope **1**, as described herein.

[0050] In some embodiments, as also discussed herein, the control circuit **4** uses the position signal S_R as a reference signal.

[0051] The control circuit **4** has an input adder node **17** receiving the measurement signal S_M and a cancellation signal S_{CANC}, and a sensing circuitry **20**, coupled to the output of the input adder node **17** and configured to provide a sensing signal Ss.

[0052] In operation, the sensing circuitry **20** receives a combined signal S_M+S_{CANC} given by the superimposition of the measurement signal S_M and the cancellation signal S_{CANC}.

[0053] In some embodiments, as shown in FIG. **2**, the sensing circuitry **20** comprises an amplifier **23** and a feedback capacitor **24** having capacitance C_{FB} and coupled between input and output of the amplifier **23**.

[0054] Furthermore, in some embodiments, the input of the amplifier **23** is directly coupled to the second terminal of the sensing capacitor **13**, i.e, to the stator voltage V_{STAT}, through the input adder node **17** and the output of the amplifier **23** provides the sensing signal S_S.

[0055] The control circuit **4** comprises a signal processing module **30**, which receives the sensing signal S_S and the in-phase clock signal CK_0 and provides the output signal So.

[0056] In detail, the signal processing module **30** comprises a demodulator **32** and an analog-to-digital converter **33**.

[0057] The demodulator **32** receives the sensing signal S_S and the in-phase clock signal CK_0 and provides a demodulated sensing signal $S_{S\text{-}DEM}$.

[0058] The demodulated sensing signal $S_{S\text{-}DEM}$ is formed by a component of the sensing signal S_S which is in quadrature with the position signal S_R (and therefore in-phase with the driving signal S_D) and indicative of a movement of the movable mass **6** caused by a rotation of the MEMS gyroscope **1**.

[0059] The demodulated sensing signal $S_{S\text{-}DEM}$ comprises the frequency band of interest BW, comprised between a minimum frequency, eg., between 0 Hz and 50 Hz, and a maximum frequency, eg., comprised between 100 Hz and 10 KHz.

[0060] The frequency band of interest BW is used to determine the rotation extent of the MEMS gyroscope **1**, for example a rotation angular velocity, and may be chosen during the design step as a function of the electrical and mechanical characteristics of the oscillating system **3**, for example of the movable structure **6** and of the sensing structure **10**, and of the electrical characteristics of the signal processing module **30**.

[0061] The analog-to-digital converter **33** receives the demodulated sensing signal $S_{S\text{-}DEM}$ and discretizes it using a sampling frequency f_{SS}, generating a discretized signal S_{SS}.

[0062] The sampling frequency f_{SS} may be chosen at the design step as a function of the frequency band of interest BW, according to the specific application.

[0063] The sampling frequency f_{SS} may be lower than or equal to a maximum value that may be chosen as a function of the frequency band of interest BW, for example equal to double the maximum frequency of the frequency band of interest BW.

[0064] The analog-to-digital converter **33** may further comprise amplifiers and/or filters configured to condition the demodulated sensing signal $S_{S\text{-}DEM}$ before its discretization, according to the specific application.

[0065] Furthermore, in this embodiment, the signal processing module **30** also comprises a digital processor **35** configured to perform further processing of the discretized signal S_{SS} such as for example filtering and gain of the discretized signal S_{SS}, generating the output signal So.

[0066] Furthermore, the digital processor **35** may be configured to modify the sample rate of the discretized signal S_{SS}. In detail, the output frequency f_0 may be different, for example lower than or equal to the sampling frequency f_{SS} of the discretized signal S_{SS}.

[0067] The control circuit **4** further comprises a correction module **37** which operates as a quantization-noise shaper and generates the correction signal S_{canc}, as described hereinbelow.

[0068] In some embodiments, the correction module **37** comprises a quadrature demodulator **40**, a filtering stage **42**, a quantizer **43** and a correction modulator **45**, mutually coupled.

[0069] In some embodiments, the correction module **37** is a sigma-delta modulator.

[0070] The quadrature demodulator **40** comprises a demodulator **47** which receives the sensing signal S_S and the out-of-phase clock signal CK_{90} at input and provides a demodulated quadrature signal $S_{Q\text{-}DEM}$.

[0071] The demodulated quadrature signal $S_{Q\text{-}DEM}$ is formed by a component of the sensing signal S_S which is in-phase with the position signal S_R, and therefore in quadrature with respect to the driving signal S_D.

[0072] The filtering stage **42** has a cut-off frequency, receives the demodulated quadrature signal $S_{Q\text{-}DEM}$ and generates a filtered signal S_f.

[0073] The cut-off frequency of the filtering stage **42** may be chosen at the design step, according to the specific application.

[0074] For example, the cut-off frequency of the filtering stage **42** is chosen as a function of the frequency band of interest BW and/or of the sampling frequency f_{SS}, e.g., may be equal to the maximum frequency of the frequency band of interest BW.

[0075] In some embodiments, the filtering stage **42** comprises a low-pass filter **50**, receiving the demodulated quadrature signal $S_{Q\text{-}DEM}$, and an amplifier **51** having a gain k, coupled to an output of the low-pass filter **50** and configured to provide the filtered signal S_f.

[0076] FIG. **3** shows in detail the circuit diagram of an embodiment of the filtering stage **42**, here formed by an RC-type active circuit of the second order. For example, the filtering stage **42** comprises two RC filtering stages **53**, **54** mutually cascade-coupled through a capacitor **55** of capacitance C_Z, where each RC filtering stage comprises a respective amplifier **56**, a capacitor **57** and a resistor **58**.

[0077] However, the filtering stage **42** may be of an order N other than two and may be of different type, for example may be formed by transconductance elements or may be of passive type and formed by a network of inductors and capacitors.

[0078] With reference back to FIGS. **1** and **2**, the quantizer **43** receives the filtered signal Sf and the correction clock signal CK_{FS}.

[0079] The quantizer **43**, for example having a single-bit or multibit architecture, eg., of FLASH type or of the Successive Approximation Register (SAR) type, generates a fine capacitance signal N_C, discrete, as a function of the value of the filtered signal S_f, with a frequency equal to the frequency f_{FS} of the correction clock signal CK_{FS}.

[0080] According to an embodiment, the quantizer **43** may be configured to compare the value of the filtered signal S_f with a threshold value Vth, at each event, for example a rising or falling edge, of the correction clock signal CK_{FS}.

[0081] For example, the threshold value Vth may be equal to zero and if the filtered signal S_f, in modulus, is greater than the threshold value Vth, then the quantizer **43** may increase (or decrease) the value of the fine capacitance signal N_C by one unit.

[0082] For example, the quantizer **43** may generate the fine capacitance signal N_C so that the fine capacitance signal N_C is equal to the numerical value, eg., in binary format, of the ratio between the filtered signal S_f and a conversion reference signal, for example equal to the threshold value Vth.

[0083] However, the quantizer **43** may be configured to modify the value of the fine capacitance signal N_C in a different manner, for example by using a non-binary coding code, for example, of thermometric type.

[0084] Additionally or alternatively, the quantizer **43** may be configured to have a dithering function on the fine capacitance signal N_C.

[0085] In operation, the quantizer **43** updates the value of the fine capacitance signal N_C with a frequency equal to the frequency f_{FS} of the correction clock signal CK_{FS}.

[0086] In some embodiments, the quantizer **43** further provides a fine sign signal sc, indicative of the sign of the filtered signal S_f, and therefore of the demodulated quadrature signal S_{Q-DEM}. In operation, the fine sign signal s_C indicates the phase-shift sign of the quadrature component of the sensing signal S_S with respect to the position signal S_R, eg., whether the quadrature component of the sensing signal S_S is phase-shifted by 0° or by 180° with respect to the position signal S_R.

[0087] The correction modulator **45** receives the fine capacitance signal N_C and the position signal S_R, and generates the cancellation signal S_{canc}.

[0088] In this embodiment, the correction modulator **45** comprises a first variable capacitor **60**, whose capacitance value is controlled by the fine capacitance signal N_C. For example, the first variable capacitor **60** may be formed by a plurality of parallel-coupled capacitive modules, each of which may be activated or deactivated as a function of the value indicated by the fine capacitance signal N_C.

[0089] The correction modulator **45** further comprises a first phase shifter **63**, receiving the position signal S_R and the fine sign signal s_C, and an attenuator **65** coupled to an output of the first phase shifter **63**.

[0090] The first phase shifter **63** provides a phase-shifted signal S_{dp} to the attenuator **65**. The phase-shifted signal S_{dp} is equal to the position signal S_R or to the position signal S_R with a phase shift, for example, a phase-shift of 180°, as a function of the sign value indicated by the fine sign signal s_C.

[0091] The attenuator **65** attenuates the phase-shifted signal S_{dp} generating a fine cancellation voltage V_{CANC-C}.

[0092] The first variable capacitor **60** has a first terminal **61** coupled to the input adder node **17** and a second terminal **62** coupled to the output of the attenuator **65**, i.e., to the fine cancellation voltage V_{CANC-C}.

[0093] In this embodiment, the correction modulator **45** further comprises a register **68**, a second variable capacitor **70** and a second phase shifter **72**.

[0094] The register **68** provides the second variable capacitor **70** with a coarse capacitance signal N_H that is configured to set the capacitance value of the second variable capacitor **70**.

[0095] For example, the second variable capacitor **70** may be formed by a plurality of parallel-coupled capacitive modules, each of which may be activated or deactivated as a function of the value indicated by the coarse capacitance signal N_H.

[0096] The value of the coarse capacitance signal N_H may be determined during an initial calibration step of the MEMS gyroscope **1** and/or may be modified in case of subsequent calibration steps of the MEMS gyroscope **1**.

[0097] The register **68** further provides a coarse sign signal S_H to the second phase shifter **72**, indicative of an initial sign of the phase-shift between the quadrature component of the sensing signal S_S and the position signal S_R, measured in the initial calibration step.

[0098] The second phase shifter **72** receives the position signal S_R and provides a coarse cancellation voltage V_{CANC-H}. The coarse cancellation voltage V_{CANC-H} is equal to the position signal S_R or to the position signal S_R with a phase shift, for example a phase shift of 180°, as a function of the sign value indicated by the coarse sign signal S_H.

[0099] The second variable capacitor **70** has a first terminal **71** coupled to the input adder node **17** and a second terminal **72** coupled to the output of the second phase shifter **72**, i.e., to the coarse cancellation voltage V_{CANC-H}.

[0100] In operation, the driving signal S_D causes an oscillation of the driving structure **8** along the driving direction, eg., the first axis X. In the presence of a rotation of the MEMS gyroscope **1** about an axis transverse to the driving direction, eg., about the third axis Z, the movable structure **6** undergoes a displacement along the sensing direction, parallel to the second axis Y in the considered example. The movement of the movable structure **6** modifies the capacitance value C_{MEMS} of the sensing capacitor **13**. As a result, the sensing capacitor **13** generates a measurement current I_{Cor}, indicative of the rotation of the MEMS gyroscope **1**.

[0101] Due to manufacturing imperfections of the oscillating system **3**, the driving signal S_D may cause a spurious movement of the movable structure **6** along the sensing direction even in the absence of rotations of the MEMS gyroscope **1**. The spurious movement may be sensed by the sensing capacitor **13**, which therefore also generates a quadrature current I_Q which adds to the measurement current I_{Cor}.

[0102] The quadrature current I_Q is phase-shifted with respect to the measurement current I_{Cor}, for example phase-shifted by 90°, thus introducing a quadrature component in the measurement signal S_M.

[0103] The correction signal S_{CANC} here comprises a cancellation current I_{CANC} generated by the first and the second variable capacitors **60**, **70** from the reference signal, here the position signal S_R. In detail, the capacitance of the fine variable capacitor **60** and of the coarse variable capacitor **70** cause the cancellation current I_{CANC} to have an amplitude that is equal, in modulus, to the quadrature current I_Q, as shown in the graph of FIG. **4**, wherein the quadrature current I_Q is indicated by a dashed line.

[0104] Furthermore, the first and the second phase shifters **63**, **72** cause the cancellation current I_{CANC} to have an opposite sign or direction with respect to the quadrature current I_Q, as again shown in FIG. **4**.

[0105] In operation, the cancellation current I_{CANC} cancels the quadrature current I_Q; therefore, the amplifier **23** receives and amplifies, as a first approximation, only the component of the measurement signal S_M given by the rotation of the MEMS gyroscope **1**.

[0106] The fact that the capacitance of the fine variable capacitor **60** is updated, in operation, at the frequency f_{FS} of the correction clock signal CK_{FS}, causes a possible noise introduced by the quantization of the filtered signal S_f to be at a frequency which is outside the band of interest BW of the demodulated sensing signal S_{S-DEM} that is used to sense the rotation of the MEMS gyroscope **1**.

[0107] The frequency f_{FS} of the correction clock signal CK_{FS} may be greater than the maximum frequency of the frequency band of interest BW.

[0108] For example, the frequency f_{FS} of the correction clock signal CK_{FS} may be greater than the output frequency f_0 of the output signal S_0.

[0109] In operation, the correction module **37**, for example the fine variable capacitor **60**, allows the correction signal

S_{CANC} to be modulated in an adaptive manner, so as to compensate for variations in the quadrature current I_Q, when using the MEMS gyroscope **1**, without introducing noise in the frequency band of interest BW. The MEMS gyroscope **1** is therefore able to effectively compensate for variations in the quadrature error component of the measurement signal S_M, without compromising the sensing sensitivity of a rotation of the MEMS gyroscope **1**.

[0110] According to an embodiment, as shown for example in FIG. **4**, the cancellation current I_{CANC} is updated in update time instants **75**, **76**, corresponding respectively to peaks and valleys of the cancellation current I_{CANC}.

[0111] The peaks and valleys of the cancellation current I_{CANC} correspond to the instants when the coarse cancellation voltage V_{CANC-C} has maximum slope, i.e, when it crosses the zero value. In practice, the correction clock signal CK_{FS} is synchronized with the zero crossings of the position signal S_R.

[0112] In this manner, the capacitance variation of the first variable capacitor **60** occurs when the voltage across the first variable capacitor **60** has the value zero, thus avoiding the occurrence of peak currents associated with the charging and discharging of the first variable capacitor **60** during the updating of the respective capacitance value, which might compromise the performances of the MEMS gyroscope **1**.

[0113] For example, if the frequency f_{FS} of the correction clock signal CK_{FS} is equal to double the driving frequency f_D, as shown in FIG. **4**, the update frequency of the coarse capacitance signal N_C and therefore of the cancellation current I_{CANC} may be maximized.

[0114] FIG. **5** shows a different embodiment of the present MEMS gyroscope, here indicated by **100**. The MEMS gyroscope **100** has a general structure similar to that of the MEMS gyroscope **1**; accordingly, elements in common are indicated by the same reference numerals and are not further described.

[0115] The MEMS gyroscope **100** has a differential architecture and is formed here again by an oscillating system, here indicated by **103**, and comprising a movable structure, not shown here, a first and a second driving structure **108**A, **108**B, and a first and a second sensing structure **110**A, **110**B, and by a control circuit, here indicated by **104**.

[0116] The first and the second sensing structures **110**A, **110**B are equal to the sensing structure **10** of the MEMS gyroscope **1**. In detail, the first sensing structure **110**A forms a sensing capacitor **13** having capacitance C_{M+} and whose terminals are at a rotor voltage V_{ROT} and at a positive stator voltage V_{STAT+}, respectively.

[0117] The second sensing structure **110**B forms a sensing capacitor **13** having capacitance C_{M-} and whose terminals are at the rotor voltage V_{ROT} and at a negative stator voltage V_{STAT-}, respectively.

[0118] In practice, the first and the second sensing structures **110**A, **110**B are configured to sense, in a differential manner, a movement of the movable structure along the sensing direction.

[0119] The first and the second driving structures **108**A, **108**B are each equal to the driving structure **8** of the MEMS gyroscope **1**. In this embodiment, the first driving structure **108**A receives a driving signal, here a positive driving voltage V_{D+}, and generates a position signal, here a positive position voltage V_{R+}, and the second driving structure **108**B receives a driving signal, here a negative driving voltage V_{D-}, and generates a position signal, here a negative position voltage V_{R-}.

[0120] In operation, the first and the second driving structures **108**A, **108**B are configured to drive the movable structure and sense the movement of the movable structure along the driving direction, in a differential manner.

[0121] The control circuit **104** comprises a sensing circuitry, here indicated by **120**, the signal processing module **30**, a driving module, here indicated by **115**, and a correction module, here indicated by **137**.

[0122] The driving module **115** generates the positive driving voltage V_{D+} and the negative driving voltage V_{D-}, mutually phase-shifted by 180°, each having the driving frequency f_D.

[0123] The driving module **115** receives the positive position voltage V_{R+} and the negative position voltage V_{R-} and generates here again the in-phase clock signal CK_0, the out-of-phase clock signal CK_{90} and the correction clock signal CK_{FS}.

[0124] The in-phase clock signal CK_0 is in quadrature with a difference signal V_{R+}-V_{R-} given by the difference between the positive position voltage V_{R+} and the negative position voltage V_{R-}.

[0125] In detail, the rising (or falling) edges of the in-phase clock signal CK_0 are synchronized with the peaks (or valleys) of the difference signal V_{R+}-V_{R-}. The rising (or falling) edges of the out-of-phase clock signal CK_{90} are synchronized with the zero crossings of the difference signal V_{R+}-V_{R-}.

[0126] The sensing circuitry **120** comprises an amplifier **123**, of differential type, having two inputs, of which a positive input **113** and a negative input **114**, and two outputs, of which a negative output **115** and a positive output **116**.

[0127] The positive input **113** is coupled to the terminal of the first sensing structure **110**A at the positive stator voltage V_{STAT+}, and the negative input **114** is coupled to the terminal of the second sensing structure **110**B at the negative stator voltage V_{STAT-},

[0128] The sensing circuitry **120** further comprises a first feedback capacitor **124**A, having capacitance C_{FB+} and coupled between the positive input **113** and the negative output **115** of the amplifier **123**, and a second feedback capacitor **124**B, having capacitance C_{FB-} and coupled between the negative input **114** and the positive output **116** of the amplifier **123**.

[0129] The negative output **115** and the positive output **116** of the amplifier **123** are respectively at a positive sensing voltage V_{S+} and at a negative sensing voltage V_{S-}.

[0130] In this embodiment, the signal processing module **30** receives the positive sensing voltage V_{S+} and the negative sensing voltage V_{S-}. The demodulator **32** demodulates the positive sensing voltage V_{S+} and the negative sensing voltage V_{S-} using the in-phase clock signal CK_0 and generates the demodulated sensing signal, herein indicated by V_{S-DEM}.

[0131] The analog-to-digital converter **33** and the digital processor **35** generate, from the demodulated sensing signal V_{S-DEM}, the output signal S_0 at the output frequency f_0, as described above for the MEMS gyroscope **1**.

[0132] The correction module **137** comprises the quadrature demodulator **40** including the demodulator **47**, the filtering stage **42** including the filter **50** and the amplifier **51**, the quantizer **43** and the correction modulator, here indicated by **145**.

[0133] The demodulator **47** receives and demodulates the positive sensing voltage V_{S+} and the negative sensing voltage V_{S-} using the out-of-phase clock signal CK_{90}, from which it generates a positive demodulated quadrature voltage $V_{Q\text{-}DEM+}$ and a negative demodulated quadrature voltage $V_{Q\text{-}DEM-}$, respectively.

[0134] The filtering stage **42** receives the positive demodulated quadrature voltage $V_{Q\text{-}DEM+}$ and the negative demodulated quadrature voltage V Q-DEM-, from which it generates a positive filtered voltage V_{f+} and a negative filtered voltage V_{f-}, respectively.

[0135] The quantizer **43** receives the positive filtered voltage V_{f+} and the negative filtered voltage V_{f-} and provides the fine capacitance signal N_C.

[0136] In some embodiments, the value of the fine capacitance signal N_C is updated at the frequency f_{FS} of the correction clock signal CK_{FS} and depends on the difference between the positive filtered voltage V_{f+} and the negative filtered voltage V_{f-}, for example with respect to a threshold voltage, which may be determined during the calibration step.

[0137] Also here, the quantizer **43** provides the fine sign signal s_C, indicative of the sign of the difference between the positive filtered voltage V_{f+} and the negative filtered voltage V_{f-}.

[0138] The correction module **145** comprises the attenuator **65**, a first and a second fine variable capacitor **160**A, **160**B, equal to each other, and a first signal switch or deviator **167**.

[0139] The attenuator **65** receives and attenuates the positive position voltage V_{R+} and the negative position voltage V_{R-}, from which it generates a positive cancellation voltage V_{C+} and a negative cancellation voltage V_{C-}, respectively.

[0140] The first and the second fine variable capacitors **160**A, **160**B receive the fine capacitance signal N_C, which controls the capacitance value thereof. For example, the first and the second fine variable capacitors **160**A, **160**B may each be formed by a plurality of capacitive modules mutually coupled in parallel which may be activated or deactivated as a function of the value indicated by the fine capacitance signal N_C.

[0141] The first and the second fine variable capacitors **160**A, **160**B each have a first terminal **161** coupled to a respective input of the first deviator **167**, and a second terminal **162** to the positive cancellation voltage V_{C+} and, respectively, to the negative cancellation voltage V_{C-}.

[0142] The first deviator **167** is controlled by the fine sign signal sc and has a first output coupled to the positive input **113** of the amplifier **123** and a second output coupled to the negative input **114** of the amplifier **123**.

[0143] For example, when the fine sign signal sc indicates a negative sign, the first deviator **167** couples (as indicated in FIG. **5** by the dashed lines inside the first deviator **167**) the first fine variable capacitor **160**A to the negative input **114** of the amplifier **123** and the second fine variable capacitor **160**B to the positive input **113** of the amplifier **123**.

[0144] Conversely, when the fine sign signal s_C indicates a positive sign, the first deviator **167** couples (as indicated in FIG. **5** by the solid lines inside the first deviator **167**) the first fine variable capacitor **160**A to the positive input **113** of the amplifier **123** and the second fine variable capacitor **160**B to the negative input **114** of the amplifier **123**.

[0145] The modulation block **145** further comprises the register **68**, which stores the coarse capacitance signal N_H and the coarse sign signal S_H, a first and a second coarse variable capacitor **170**A, **170**B, and a second deviator **172**.

[0146] The first and the second coarse variable capacitors **170**A, **170**B receive the coarse capacitance signal N_H, which controls the capacitance value thereof. For example, the first and the second coarse variable capacitors **170**A, **170**B may each be formed by a plurality of capacitive modules mutually coupled in parallel which may be activated or deactivated as a function of the value indicated by the coarse capacitance signal N_H.

[0147] The first and the second coarse variable capacitors **170**A, **170**B each have a first terminal **171** coupled to a respective input of the second deviator **172**, and a second terminal **173** to the positive position voltage V_{R+} and, respectively, to the negative position voltage V_{R-}.

[0148] The second deviator **172** is controlled by the coarse sign signal S_H and has a first output coupled to the positive input **113** of the amplifier **123** and a second output coupled to the negative input **114** of the amplifier **123**.

[0149] For example, when the coarse sign signal S_H indicates a negative sign, the second deviator **172** couples the first coarse variable capacitor **170**A to the negative input **114** of the amplifier **123** and the second coarse variable capacitor **170**B to the positive input **113** of the amplifier **123**, as indicated in FIG. **5** by the dashed lines inside the second deviator **172**.

[0150] Conversely, when the coarse sign signal S_H indicates a positive sign, the second deviator **172** couples the first coarse variable capacitor **170**A to the positive input **113** of the amplifier **123** and the second coarse variable capacitor **170**B to the negative input **114** of the amplifier **123**, as indicated in FIG. **5** by the solid lines inside the second deviator **172**.

[0151] In operation, the correction modulator **145** allows a positive cancellation current I_{CANC+} and a negative cancellation current I_{CANC-} to be generated, in a manner similar to what has been discussed above for the correction modulator **45** of the MEMS gyroscope **1**. The positive cancellation current I_{CANC+} and the negative cancellation current I_{CANC-} cancel any quadrature component generated by the sensing capacitors **13** of the first and the second sensing structures **110**A, **110**B.

[0152] At the input of the amplifier **123**, the quadrature components of the measurement signal S_M are thus compensated. The output signal S_0 of the MEMS gyroscope **100** is not affected by the quadrature error and the MEMS gyroscope **100** has a high sensing sensitivity.

[0153] Furthermore, in this embodiment, the first and the second deviators **167**, **172** allow, in use, the sign of the cancellation signal S_{CANC}, here obtained in a differential manner from the positive cancellation current I_{CANC+} and from the negative cancellation current I_{CANC-}, to be inverted.

[0154] Finally, it is clear that modifications and variations may be made to the MEMS gyroscope **1**, **100** described and illustrated herein without thereby departing from the scope of the present disclosure, as defined in the attached claims.

[0155] The coarse variable capacitor **70** and/or the first and the second coarse variable capacitors **170**A, **170**B may also be controlled by a respective capacitance signal generated by a respective quantizer.

[0156] Alternatively or additionally, the correction modulator **45** may be formed by a single modulation group comprising the fine variable capacitor **60** and the first phase shifter **63**. Similarly, the correction modulator **145** may be formed by a single modulation group comprising the first and the second fine variable capacitors **160**A, **160**B and the first deviator **167**.

[0157] For example, in the MEMS gyroscope **1** of FIG. **2**, the mutual arrangement of the attenuator **65** and the first phase shifter **63** may be inverted.

[0158] Furthermore, for example, in the correction modulators **45**, **145**, the cancellation signals I_{CANC}, I_{CANC+}, I_{CANC-} may be generated directly from the respective position signals S_R, V_{R+}, V_{R-}, i.e, without the position signals being subject to attenuation.

[0159] The correction modulators **45**, **145** may be configured to generate the cancellation signal S_{CANC} in a different manner.

[0160] For example, with reference to the modulation block **45** of the MEMS gyroscope **1**, the cancellation current I_{CANC} may be obtained by maintaining the fine cancellation voltage V_{CANC-C} constant over time and varying the capacitance of the fine variable capacitor **60** at the driving frequency over time.

[0161] For example, the control circuit **4** may comprise an analog-to-digital converter so that the quadrature demodulator **40** and/or the filtering stage **42** may be implemented using a digital architecture, rather than an analog architecture.

[0162] For example, the MEMS gyroscope **1**, **100** may be of monoaxial, biaxial or triaxial type.

[0163] For example, the movable structure **6** may comprise one or more movable masses, according to the specific application of the MEMS gyroscope **1**, **100**. In case the movable structure **6** comprises a plurality of movable masses, the MEMS gyroscope **1**, **100** may comprise a plurality of driving structures, for example one for each movable mass. Alternatively, the MEMS gyroscope **1**, **100** may comprise a single driving structure coupled to a movable driving mass and the remaining movable masses may be suitably elastically coupled to the movable driving mass.

[0164] Finally, the described embodiments may be combined to form further solutions.

[0165] A control circuit (**4**; **104**) for a MEMS gyroscope (**1**; **100**), configured to receive a measurement signal (S_M) having a quadrature component (I_Q) and a sensing component (I_{Cor}) from the MEMS gyroscope, the control circuit may be summarized as including an input stage (**17**, **20**; **113**, **114**, **120**) configured to acquire an input signal (S_M+S_{CANC}) and to generate an acquisition signal (S_S; V_{S+}, V_{S-}) in response to the acquisition of the input signal, the input signal being a function of the measurement signal and of a quadrature cancellation signal (S_{CANC}, I_{CANC}; I_{CANC+}, I_{CANC-}); a processing stage (**30**) configured to extract a first component (S_{S-DEM}; V_{S-DEM}) of the acquisition signal (S_S; V_{S+}, V_{S-}), the first component of the acquisition signal being indicative of the sensing component of the measurement signal and having a sensing frequency band; and a quadrature correction stage (**37**; **137**) configured to extract a second component (S_{Q-DEM}; V_{Q-DEM+}, V_{Q-DEM-}) of the acquisition signal (S_S; V_{S+}, V_{S-}), the second component of the acquisition signal being indicative of the quadrature component of the measurement signal, and to generate the quadrature cancellation signal (S_{CANC}, I_{CANC}; I_{CANC+}, I_{CANC-}) from a reference signal (S_R, V_{CANC-C}; V_{C+}, V_{C-}), wherein the quadrature cancellation signal is a signal modulated as a function of the second component of the acquisition signal, at an update frequency (f_{FS}) which is outside the sensing frequency band.

[0166] The quadrature correction stage may be a sigma-delta modulator.

[0167] The quadrature correction stage (**37**; **137**) may include a filtering stage (**42**) configured to filter the second component (S_{Q-DEM}; V_{Q-DEM+}, V_{Q-DEM-}) of the acquisition signal (S_S; V_{S+}, V_{S-}), generating a filtered signal (S_f; V_{F+}, V_{F-}); a quantizer (**43**) configured to receive an update clock signal (CK_{FS}) having the update frequency (f_{FS}) and to generate a digital correction signal (N_C, s_C), from the filtered signal, having a data rate equal to the update frequency; and a modulator (**45**; **145**) configured to generate the quadrature cancellation signal (S_{CANC}, I_{CANC}; I_{CANC+}, I_{CANC-}), modulating the amplitude and/or phase thereof as a function of the digital correction signal, so as to cancel the quadrature component (I_Q) of the measurement signal in the input signal (S_M+S_{CANC}).

[0168] The input stage (**20**; **120**) may have an input node (**17**; **113**, **114**) configured to receive the measurement signal, the modulator may include a first variable capacitor (**60**; **160**A, **160**B) having a first terminal (**61**; **162**) coupled to the input node of the input stage and a second terminal (**62**; **161**) configured to receive an input voltage (V_{CANC-C}; V_{C+}, V_{C-}) that is a function of the reference signal, the digital correction signal (N_C) being configured to modify the capacitance of the first variable capacitor and modulate the amplitude of the quadrature cancellation signal.

[0169] The correction signal may include a sign signal (s_C) indicative of a phase-shift sign of the filtered signal (S_f), the modulator further including a phase-shift block (**63**; **167**) configured to invert the phase of the quadrature cancellation signal (S_{CANC}, I_{CANC}; I_{CANC+}, I_{CANC-}) as a function of the sign signal.

[0170] The update clock signal (CK_{FS}) may be synchronized with the zero crossings of the reference signal (S_R; V_{R+}, V_{R-}).

[0171] The reference signal may have a first frequency (f_D) and the update frequency (f_{FS}) may be equal to double the first frequency.

[0172] The control circuit configured to receive the reference signal (S_R; V_{R+}, V_{R-}) from an oscillating system (**3**; **103**) of the MEMS gyroscope, the control circuit may further include a driving module (**15**; **115**) configured to generate a driving signal (S_D, V_{D+}, V_{D-}) having a first frequency (f_D) and configured to cause a driving oscillation of the oscillating system (**3**; **103**), the reference signal being indicative of the driving oscillation of the oscillating system.

[0173] The driving module may be configured to generate a first demodulating signal (CK_0) having the first frequency and in quadrature with respect to the reference signal, a second demodulating signal (CK_{90}) having the first frequency and in-phase with respect to the reference signal, the processing stage (**30**) being configured to extract the first component of the acquisition signal using the first demodulating signal, the quadrature correction stage (**37**; **137**) being configured to extract the second component of the acquisition signal using the second demodulating signal.

[0174] The modulator may further include a second variable capacitor (**70**; **170**A, **170**B) and a register (**68**), the second variable capacitor having a first terminal (**71**; **173**) coupled to the input node (**17**; **113**, **114**) of the input stage (**20**; **120**) and a second terminal (**72**; **171**) configured to receive a second input voltage (V_{CANC-H}; V_{R+}, V_{R-}) that is a function of the reference signal, the register (**68**) being configured to generate a calibration correction signal (N_H, S_H), the calibration correction signal (N_C) being configured to set a calibration capacitance value of the second variable capacitor.

[0175] The input stage (**120**) may have a first input (**113**) and a second input (**114**) and may be configured to receive a measurement signal of differential type from the MEMS gyroscope and a quadrature cancellation signal (I_{CANC+}, I_{CANC-}) of differential type from the quadrature correction stage (**137**).

[0176] A MEMS gyroscope (**1**; **100**) may be summarized as including a control circuit (**4**; **104**) according to any of the preceding claims and an oscillating system (**3**; **103**) configured to generate the measurement signal (S_M).

[0177] A control method for a MEMS gyroscope (**1**; **100**) may be summarized as including a control circuit (**4**; **104**), the control method comprising, by the control circuit: receiving a measurement signal (S_M) having a quadrature component (IQ) and a sensing component (I_{Cor}) from the MEMS gyroscope; acquiring an input signal (S_M+S_{CANC}), the input signal being a function of the measurement signal and of a quadrature cancellation signal (S_{CANC}, I_{CANC}; I_{CANC+}, I_{CANC-}); generating an acquisition signal (S_S; V_{S+}, V_{S-}) in response to the acquisition of the input signal; extracting a first component (S_{S-DEM}; V_{S-DEM}) of the acquisition signal (S_S; V_{S+}, V_{S-}) indicative of the sensing component of the measurement signal, the first component of the acquisition signal having a sensing frequency band; extracting a second component (S_{Q-DEM}; V_{Q-DEM+}, V_{Q-DEM-}) of the acquisition signal (S_S; V_{S+}, V_{S-}) indicative of the quadrature component of the measurement signal; and generating the quadrature cancellation signal (S_{CANC}, I_{CANC}; I_{CANC+}, I_{CANC-}) from a reference signal (S_R, V_{CANC-C}; V_{C+}, V_{C-}), wherein the quadrature cancellation signal is a signal modulated as a function of the second component of the acquisition signal, at an update frequency (f_{FS}) which is outside the sensing frequency band.

[0178] Generating the quadrature cancellation signal may include filtering the second component of the acquisition signal, generating a filtered signal (S_f; V_{F+}, V_{F-}); generating, from the filtered signal and by a quantizer (**43**) controlled by an update clock signal (CK_{FS}) having the update frequency, a digital correction signal (N_C, s_C) having a data rate equal to the update frequency; and modulating amplitude and/or phase of the quadrature cancellation signal as a function of the digital correction signal, to cancel the quadrature component (I_Q) of the measurement signal in the input signal (S_M+S_{CANC}).

[0179] The update clock signal may be synchronized with the zero crossings of the reference signal (S_R, V_{R+}, V_{R-}).

[0180] The various embodiments described above can be combined to provide further embodiments. Aspects of the embodiments can be modified, if necessary to employ concepts of the various embodiments to provide yet further embodiments.

[0181] These and other changes can be made to the embodiments in light of the above-detailed description. In general, in the following claims, the terms used should not be construed to limit the claims to the specific embodiments disclosed in the specification and the claims, but should be construed to include all possible embodiments along with the full scope of equivalents to which such claims are entitled. Accordingly, the claims are not limited by the disclosure.

1. A control circuit for a MEMS gyroscope, comprising:
- an input stage configured to acquire an input signal and to generate an acquisition signal in response to the input signal;
- a processing stage configured to obtain a first component of the acquisition signal; and
- a quadrature correction stage configured to extract a second component of the acquisition signal and to generate a quadrature cancellation signal based on a reference signal, the second component of the acquisition signal being indicative of a quadrature component of a measurement signal.

2. The control circuit of claim **1**, wherein the input signal is a function of the measurement signal and of the quadrature cancellation signal.

3. The control circuit of claim **1**, wherein the quadrature cancellation signal is a signal modulated as a function of the second component of the acquisition signal, at an update frequency which is outside of a sensing frequency band.

4. The control circuit of claim **1**, wherein the first component of the acquisition signal is indicative of a sensing component of the measurement signal and having a sensing frequency band.

5. The control circuit of claim **1**, wherein the processing stage includes a demodulator, an analog-to-digital converter, and a digital processor.

6. The control circuit of claim **5**, wherein the demodulator extracts the first component of the acquisition signal and the analog-to-digital converter discretizes the first component of the acquisition signal.

7. The control circuit of claim **1**, wherein the quadrature correction stage includes a quadrature demodulator, a filtering stage, a quantizer, and a correction modulator.

8. The control circuit of claim **7**, wherein the filtering stage includes a low-pass filter and an amplifier.

9. The control circuit of claim **8**, wherein the quadrature demodulator receives the acquisition signal and outputs a demodulated quadrature signal, the low-pass filter receives the demodulation quadrature signal, and the amplifier generates a filtered signal that is received by the quantizer.

10. The control circuit of claim **9**, wherein the quantizer compares a value of the filter signal with a threshold value and generates a fine capacitance signal.

11. The control circuit of claim **10**, wherein the fine capacitance signal is a numerical value of a ratio between the filtered signal and a conversion reference signal, wherein the conversion reference signal equals the threshold value.

12. The control circuit of claim **10**, wherein the correction modulator includes a first variable capacitor, a first phase shifter, an attenuator, a register, a second variable capacitor, and a second phase shifter.

13. The control circuit of claim **12**, wherein a first capacitance of the first variable capacitor is controlled by the fine capacitance signal and a second capacitance of the second variable capacitor is controlled by a coarse capacitance signal.

14. A method, comprising:
- receiving a measurement signal from a MEMS gyroscope;
- generating an acquisition signal as a function of the measurement signal

extracting a first component of the acquisition signal having a sensing frequency band;

extracting a second component of the acquisition signal; and

generating a quadrature cancellation signal that is modulated based on the second component of the acquisition signal.

15. The method of claim **14**, wherein the measurement signal has a quadrature component and a sensing component, the first component of the acquisition signal being indicative of the sensing component of the measurement signal and the second component of the acquisition signal being indicative of the quadrature component of the measurement signal.

16. The method of claim **14**, comprising acquiring an input signal, the input signal being a function of the measurement signal and of the quadrature cancellation signal, wherein the generating the acquisition signal is in response to the acquiring the input signal.

17. The method of claim **14**, wherein the quadrature cancellation signal is modulated based on the second component of the acquisition signal at an update frequency which is outside the sensing frequency band.

18. A device comprising:

an oscillating system; and

a control circuit, the control circuit including:

a driving module;

a sensing circuit coupled to an output of the oscillating system;

a signal processing module; and

a correction module including a quadrature demodulator, a filtering stage, a quantizer, and a correction module.

19. The device of claim **18**, wherein the oscillating system includes a movable structure, a driving structure, and a sensing structure that includes a sensing capacitor, and the sensing circuit an amplifier coupled to the sensing structure and a feedback capacitor.

20. The device of claim **19**, wherein the signal processing module includes a demodulator, an analog-to-digital converter, and a digital processor, the signal processing module being configured to obtain a first component of an acquisition signal, and wherein the correction module is configured to extract a second component of the acquisition signal and to generate a quadrature cancellation signal based on a reference signal, the second component of the acquisition signal being indicative of a quadrature component of a measurement signal.

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