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Autofocus actuator control method

Abstract

In accordance with the present disclosure, a method for controlling an autofocus actuator is provided such that the actual position of the autofocus actuator can be measured using capacitance sensing. In some embodiments, a rotor plate attached to a rotor and a stator plate attached to a stator in the autofocus actuator can be used to create a capacitance. When the rotor moves, a capacitance change value between the rotor plate and the stator plate can be measured. In these embodiments, the cost and the form factor of the aforementioned autofocus actuator are reduced compared to implementation of magnetic field sensors in the autofocus actuator.

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Background/Summary

FIELD OF THE INVENTION

(1) The present application generally pertains to control of autofocus actuator.

BACKGROUND OF THE INVENTION

(2) An actuator is a component of a machine that is responsible for moving and controlling a mechanism or system, for example by opening a valve. An actuator requires a control signal and a source of energy. The control signal is relatively low energy and may be electric voltage or current, pneumatic, or hydraulic fluid pressure, or even human power. The source of energy may be an electric current, hydraulic pressure, or pneumatic pressure. When the actuator receives a control signal, it responds by converting the source of energy into mechanical motion. In the electric, hydraulic, and pneumatic sense, it is a form of automation or automatic control.

BRIEF SUMMARY OF THE INVENTION

(3) In accordance with the present disclosure, a method for controlling an autofocus actuator is provided such that the actual position of the autofocus actuator can be measured using capacitance sensing. In some embodiments, a rotor plate attached to a rotor and a stator plate attached to a stator in the autofocus actuator can be used to create a capacitance. When the rotor moves, a capacitance change value between the rotor plate and the stator plate can be measured. In these

embodiments, the cost and the form factor of the aforementioned autofocus actuator are reduced compared to implementation of magnetic field sensors in the autofocus actuator.
(4) In some embodiments, a method for controlling an autofocus actuator is based on a capacitance measured between a rotor plate attached to a rotor and a stator plate attached to a stator in the autofocus actuator. In those embodiments, the method includes: determining, at an autofocus sensor, a predetermined distance and a predetermined direction for moving the rotor in an image autofocus process; determining, at a processing unit, a desired capacitance value between the rotor plate and the stator plate based on the predetermined distance and the predetermined direction; measuring, at a capacitance sensing circuit, the capacitance between the rotor plate and the stator plate; determining, at the processing unit, whether the measured capacitance value matches the desired capacitance value; and moving, at a rotor drive block, the rotor based on whether the measured capacitance value matches the desired capacitance value.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** illustrates an autofocus actuator control system **100**, according to an exemplary embodiment of the present disclosure.
(2) FIG. **2** illustrates another example of the autofocus actuator control system **100**, according to an exemplary embodiment of the present disclosure.
(3) FIG. **3** illustrates yet another example of the autofocus actuator control system **100**, according to an exemplary embodiment of the present disclosure.
(4) FIG. **4** illustrates still another example of the autofocus actuator control system **100**, according to an exemplary embodiment of the present disclosure.
(5) FIG. **5** illustrates an embodiment of a capacitance sensing circuit **114** and a processing unit **116**, according to an exemplary embodiment of the present disclosure.
(6) FIG. **6** illustrates another embodiment of the capacitance sensing circuit **114** and the processing unit **116**, according to an exemplary embodiment of the present disclosure.
(7) FIG. **7** illustrates still another example of the autofocus actuator control system **100**, according to an exemplary embodiment of the present disclosure.
(8) FIG. **8** illustrates an example method for controlling an autofocus actuator **102** in the autofocus actuator control system **100**.
(9) FIG. **9** illustrates an example method for determining a relationship between a predetermined distance and a desired capacitance value in the autofocus actuator control system **100**.
DETAILED DESCRIPTION OF THE INVENTION
(10) Particular embodiments of the invention are illustrated herein in conjunction with the drawings.
(11) Various details are set forth herein as they relate to certain embodiments. However, the method can also be implemented in ways which are different from those described herein. Modifications can be made to the discussed embodiments by those skilled in the art without departing from the method. Therefore, the method is not limited to particular embodiments disclosed herein.
(12) An actuator is a mechanism by which a control system acts upon to perform an operation or task. Various types of actuators are used in different applications including mechanical, thermal, electrical, camera, and/or other types of applications. In camera applications, an autofocus actuator may be configured to include a rotating mechanical focus ring to move a focusing lens towards or away from an autofocus sensor to accomplish an image autofocus process. The purpose of the image autofocus process is to control a position of convergence of a light such that the light converges precisely at a plane of the autofocus sensor. In this way, an image captured by the camera is in focus. As camera systems have become more widespread, improving autofocus speed

and accuracy in the image autofocus process has garnered some attention. The challenge is to control the autofocus actuator to move the focusing lens with high speed, high accuracy, and low cost to accomplish the image autofocus process.

(13) One necessary step in the image autofocus process is determination of a desired distance for moving the focusing lens. Once the desired distance is determined, the autofocus actuator is then configured to move the focusing lens for the desired distance. During movement of the focusing lens, to verify an actual position of the focusing lens, a magnetic field sensor can be used. The magnetic field sensor may be configured to detect changes of a magnetic field surrounding the autofocus actuator when the autofocus actuator moves. The changes in the magnetic field can be then converted to electric signals in the magnetic field sensor, and the electric signals can be sent to processing units for determining an actual position of the autofocus actuator and the focusing lens. Finally, the actual position of the focusing lens is compared to the desired distance to verify whether an image is in focus or not.

(14) One insight provided by the present disclosure is that implementation of magnetic field sensors in the image autofocus process can drive up a cost and a form factor (such as a size) of the autofocus actuator. Given the same form factor (such as a size) of an autofocus actuator, a large form factor (such as a size) of the magnetic field sensor would further limit the form factor (such as a size) of other parts of the autofocus actuator such as a rotor. A limited form factor (such as a size) of the rotor in the autofocus actuator will in turn decrease efficiency of the rotor in the autofocus actuator.

(15) In accordance with the present disclosure, a method for controlling an autofocus actuator is provided such that the actual position of the autofocus actuator can be measured using capacitance sensing. In some embodiments, a rotor plate attached to a rotor and a stator plate attached to a stator in the autofocus actuator can be used to create a capacitance. When the rotor moves, a capacitance change value between the rotor plate and the stator plate can be measured. In these embodiments, the cost and the form factor of the aforementioned autofocus actuator are reduced compared to implementation of magnetic field sensors in the autofocus actuator.

(16) FIG. **1** illustrates an autofocus actuator control system **100**, according to an exemplary embodiment of the present disclosure. In some embodiments, the autofocus actuator control system **100** comprises an autofocus actuator **102**, a capacitance sensing circuit **114**, a processing unit **116**, a rotor drive block **118**, an autofocus sensor **112**, and/or any other components. An autofocus actuator **102** may be referred to an actuator in an optical instrument that captures visual images configured to move a focusing lens within the optical instrument to accomplish autofocus. Examples of an autofocus actuator **102** include electromagnetic actuator, electric actuator, shape memory alloys actuator, and/or any other types of autofocus actuator.

(17) In some embodiments, the autofocus actuator **102** includes a stator **104**, a rotor **106**, a stator plate **108**, a rotor plate **110**, and/or any other component. The stator **104** may be referred to a stationary part of a rotary system such as electric generators, electric motors, sirens, mud motors, biological rotors, anti-vibration actuators, and/or any other rotary systems. Examples of a stator **104** include concentric single layer winding stator, concentric double layer winding stator, fractional concentric winding stator, and/or any other types of stators. The rotor **106** may be referred to a moving component of a rotary system. Examples of a rotor **106** include squirrel-cage rotor, wound rotor, salient pole rotor, non-salient rotor, and/or any other types of rotors. In this exemplary embodiment, the rotor **106** is attached to the rotor plate **110**, and the stator **104** is attached to the stator plate **108**. The stator plate **108** and the rotor plate **110** may be referred to two metal plates used to create a capacitor. Examples of a stator plate **108** and a rotor plate **110** include iron plate, copper plate, silver plate, aluminum plate, and/or other types of metal plate.

(18) In this embodiment, the stator plate **108** and the rotor plate **110** are configured to face each other with a distance and an overlap area to create a capacitance: C=ε.sub.0.Math.A/d, where C is the created capacitance value, ε.sub.0 is an electric constant with ε.sub.0=8.854×10.sup.−12

F.Math.m.sup.−1, A is the overlap area between the stator plate **108** and the rotor plate **110**, and d is the distance between the stator plate **108** and the rotor plate **110**.

(19) The autofocus sensor **112** is operatively connected to the processing unit **116**. An autofocus sensor **112** may be referred to a device configured to measure relative focus of an image in a camera by assessing changes in image contrast where maximal contrast is assumed to correspond to maximal sharpness. Examples of an autofocus sensor **112** include contrast detection autofocus sensor, phase detection autofocus sensor, active autofocus sensor, and/or any other types of autofocus sensor. In one example, the autofocus sensor **112** shines a light-emitting diode (LED) light to a subject and calculates a distance between the autofocus sensor **112** and the subject based on a time it takes for the light to travel to the subject and back. Based on the calculated distance between the autofocus sensor **112** and the subject, the autofocus sensor **112** is configured to determine a predetermined distance and a predetermined direction for moving the rotor **106** to accomplish the image autofocus process.

(20) A processing unit **116** may be referred to an electronic circuitry configured to execute computer instructions to perform one or more specific tasks. Examples of a processing unit **116** include central processing unit, application-specific integrated circuit, and/or any other types of processing unit. In some embodiments, the processing unit **116** is configured to determine a desired capacitance value between the stator plate **108** and the rotor plate **110**. The desired capacitance value corresponds to a distance that the rotor **106** needs to move to accomplish the image autofocus process.

(21) In this embodiment, the capacitance sensing circuit **114** is operatively connected to the processing unit **116**. A capacitance sensing circuit **114** may be referred to an electronic circuit configured to measure a capacitance value between two electrically conducting plates. Examples of a capacitance sensing circuit **114** include relaxation oscillator, capacitive divider circuit, and/or any other types of capacitance sensing circuits. In some embodiments, the capacitance sensing circuit **114** is configured to measure a capacitance value between the stator plate **108** and the rotor plate **110**, and send the measured capacitance value to the processing unit **116**. The processing unit **116** is then configured to send a rotor control signal to the rotor drive block **118** based on a comparison between the desired capacitance value and the measured capacitance value. A rotor control signal may be referred to a digitally encoded electronic signal used to control the rotor **106**. Examples of a rotor control signal include digitally encoded electronic signal for move forward action, move backward action, move left action, move right action, move up action, move down action, move distance, and/or any other types of rotor control signals.

(22) In this embodiment, the rotor drive block **118** is operatively connected to the processing unit **116** and the rotor **106**. A rotor drive block **118** may be referred to a device configured to produce a force that generates a torque to move the rotor **106** based on a rotor control signal. Examples of a rotor drive block **118** include alternating current-based rotor drive block, magnetic field-based rotor drive block, and/or any other types of rotor drive block.

(23) In some examples, the capacitance sensing circuit **114** is connected to the rotor plate **110** and the stator plate **108** to measure the capacitance between the rotor plate **110** and the stator plate **108**. When the rotor **106** moves towards the predetermined direction for the predetermined distance, the rotor plate **110** moves along with the rotor **106**. Meanwhile, the stator **104** and the attached stator plate **108** are kept stationary. A stationary stator **104** and a stationary stator plate **108** may be referred to a stator **104** and a stator plate **108** that are non-moving. The moving rotor plate **110** and the stationary stator plate **108** will change either the overlap area A or the distance d between the two plates, resulting in an updated capacitance value measured at the capacitance sensing circuit **114** as C=ε.sub.0.Math.A/d. Then the processing unit **116** is configured to compare the updated capacitance value and the desired capacitance value. If the updated capacitance value matches the desired capacitance value, then the processing unit **116** sends a rotor control signal to the rotor drive block **118** to stop the rotor **106** from moving. Otherwise, if the updated capacitance value

does not match the desired capacitance value, the processing unit **116** sends a rotor control signal to the rotor drive block **118** to continue moving the rotor **106** towards the predetermined direction.

(24) FIG. **2** illustrates another example of the autofocus actuator control system **100**, according to an exemplary embodiment of the present disclosure. As can be seen, in this example, the autofocus actuator **102** is protected by a metal shell **202**, and the autofocus actuator **102** comprises the rotor **106**, the rotor plate **110**, a metal piece **204**, and/or any other components. A metal shell **202** may be referred to a layer of metal used to protect the autofocus actuator **102**. Examples of a metal shell **202** include steel shell, iron shell, copper shell, silver shell, and/or any other types of metal shell. In some embodiments, the metal shell **202** comprises the stator plate **108**, and the stator plate **108** is positioned to face the rotor plate **110** to create a capacitance. In this way, the cost and the form factor of the autofocus actuator **102** are reduced compared to implementation of an autofocus actuator **102** with specifically designated stator plate **108**.

(25) In this embodiment, the metal piece **204** is attached to the rotor **106** and a power supply module **206**. A metal piece **204** may be referred to a part of an autofocus actuator necessary for operations the autofocus actuator. Examples of a metal piece **204** include steel piece, iron piece, copper piece, and/or any other types of metal piece. A power supply module **206** may be referred to an electrical device that supplies electric power to an electrical load. Examples of a power supply module **206** include electric battery, direct current (DC) power supply device, alternating current (AC) power supply device, and/or any other types of power supply modules. In some embodiments, the power supply module **206** is a necessary part in the autofocus actuator control system **100**. In these embodiments, the power supply module **206** is configured to supply an electric power to the rotor plate **110** through the metal piece **204** and the rotor **106**. The supplied electric power at the rotor plate **110** is necessary for creating the capacitance between the rotor plate **110** and the stator plate **108**. In this way, the cost and the form factor of the autofocus actuator **102** are reduced compared to implementation of dedicated power supply for the rotor plate **110** in the autofocus actuator **102**. Please reference FIG. **1** and its associated texts for structure and functions of other components included in this example.

(26) FIG. **3** illustrates yet another example of the autofocus actuator control system **100**, according to an exemplary embodiment of the present disclosure. As can be seen, in this example, the autofocus actuator control system **100** comprises an electromagnetic autofocus actuator **302** protected by the metal shell **202**, the capacitance sensing circuit **114**, the processing unit **116**, the rotor drive block **118**, and/or any other components. An electromagnetic autofocus actuator **302** may be referred to an autofocus actuator that produces force and torque by means of magnetic field. Examples of an electromagnetic autofocus actuator **302** include linear solenoid actuator, rotary solenoid actuator, moving coil actuator, micro-electro-mechanical systems (MEMS) magnetic actuator, and/or any other types of electromagnetic autofocus actuator.

(27) In this example, the electromagnetic autofocus actuator **302** comprises the rotor **106** attached to the rotor plate **110** and the metal piece **204**, an electromagnetic coil **304**, a magnet **306** attached to the metal shell **202**, and/or any other components. An electromagnetic coil **304** may be referred to an electrical conductor that contains a series of conductive wires wrapped around a ferromagnetic core that is cylindrical, toroidal, or disk-like. Examples of an electromagnetic coil include DC coil, audio-frequency coil, radio-frequency coil, and/or any other types of electromagnetic coil. In some embodiments, the electromagnetic coil **304** is a part of the electromagnetic autofocus actuator **302** necessary for operations of the electromagnetic autofocus actuator **302**.

(28) A magnet **306** may be referred to a material or object that produces a magnetic field. Examples of a magnet **306** include iron magnet, nickel magnet, steel magnet, and/or any other types of magnets. In some embodiments, the rotor drive block **118** is operatively connected to the electromagnetic coil **304** to pass a current through the electromagnetic coil **304** based on the rotor control signal obtained/received from the processing unit **116**. The current passed through the

electromagnetic coil **304** produces a magnetic field with a magnetic flux density at the electromagnetic coil **304**. Based on interactions between the electromagnetic coil **304** and the magnet **306**, a force proportional to the magnetic flux density and the current passed through the electromagnetic coil **304** is developed to move the rotor **106**.

(29) In this example, the magnet **306** is the stator plate **108** and the magnet **306** is positioned to face the rotor plate **110** to create a capacitance between the stator plate **108** and the rotor plate **110**. In this way, the cost and the form factor of the autofocus actuator **102** are reduced compared to implementation of an autofocus actuator **102** with a specifically designated stator plate **108**. Please reference FIG. **1**, FIG. **2** and their associated texts for structure and functions of other components included in this example.

(30) FIG. **4** illustrates still another example of the autofocus actuator control system **100**, according to an exemplary embodiment of the present disclosure. As can be seen, in this example, the autofocus actuator control system **100** comprises the electromagnetic autofocus actuator **302**, a magnetic metal **402**, the metal shell **202**, the capacitance sensing circuit **114**, the processing unit **116**, the rotor drive block **118**, and/or any other components. A magnetic metal **402** may be referred to a metal material used to confine a magnetic field produced at the electromagnetic coil **304**. Examples of a magnetic metal **402** include steel, silver, copper, iron, and/or any other types of magnetic metal.

(31) In this example, the electromagnetic autofocus actuator **302** is attached to the magnetic metal **402**. The electromagnetic autofocus actuator **302** and the magnetic metal **402** are protected by the metal shell **202**. The electromagnetic autofocus actuator comprises the rotor **106** attached to the rotor plate **110**, the electromagnetic coil **304**, the magnet **306**, and/or any other components. The magnetic metal **402** is configured to provide a magnetic confinement to the magnetic field produced at the electromagnetic coil **304**. The magnetic confinement provided by the magnetic metal **402** can increase the magnetic flux density in the magnetic field. The increased magnetic flux can further increase the force developed at the electromagnetic coil **304** to move the rotor **106**. In this way, the increased force to move the rotor **106** can result in a higher speed in moving the rotor **106** and improve an efficiency in the electromagnetic autofocus actuator **302**.

(32) In this example, the magnetic metal **402** comprises the stator plate **108**, and the stator plate **108** is positioned to face the rotor plate **110** to create a capacitance. In this way, the cost and the form factor of the electromagnetic autofocus actuator **302** are reduced compared to implementation of an electromagnetic autofocus actuator **302** with a specifically designated stator plate **108**. As can be seen in FIG. **4**, the magnet **306** is attached to the magnetic metal **402** with a contact area. This contact area does not overlap with the area of the capacitance created between the rotor plate **110** and the stator plate **108**. In this way, an interference caused by interactions between the magnet **306** and the created capacitance can be avoided. Please reference FIG. **1**, FIG. **2**, FIG. **3**, and their associated texts for structure and functions of other components included in this embodiment.

(33) FIG. **5** illustrates an embodiment of the capacitance sensing circuit **114** and the processing unit **116**. As can be seen, in this embodiment, the capacitance sensing circuit **114** comprises a voltage generator module **502**, an analog-to-digital converter module **504**, a clock module **506**, a capacitance calculation module **508**, and/or any other components. The processing unit **116** comprises a capacitance evaluation module **510**, and/or any other components.

(34) A voltage generator module **502** may be referred to an electronic device that generates voltage signals with set properties of amplitude, frequency, and wave shape. Examples of a voltage generator module **502** include function generator, sinusoidal signal generator, pulse-width modulation (PWM) signal generator, arbitrary waveform generator, digital pattern generator, and/or any other types of voltage generators. An analog-to-digital converter module **504** may be referred to an electronic device that converts an analog voltage signal into a digital signal. Examples of an analog-to-digital converter module **504** include flash analog-to-digital converter, successive-approximation analog-to-digital converter, ramp-compare analog-to-digital converter, and/or any

other types of analog-to-digital converter. A clock module **506** may be referred to an electronic oscillator that produces a voltage signal that oscillates between a high and a low state at a predetermined frequency. Examples of a clock module **506** include variable frequency oscillator, quartz piezo-electric oscillator, and/or any other types of oscillators.
(35) A capacitance calculation module **508** may be referred to a digital circuit configured to determine a capacitance value between the stator plate **108** and the rotor plate **110** based on a digital voltage value received/obtained from the analog-to-digital converter module **504**. A capacitance evaluation module **510** may be referred to a digital circuit configured compare a calculated capacitance value received/obtained from the capacitance calculation module **508** to a desired capacitance value. Examples of a capacitance calculation module **508** and a capacitance evaluation module **510** include application-specific integrated circuit, complex programmable logic device, and/or any other types of modules.
(36) In this embodiment, the voltage generator module **502** and the analog-to-digital converter module **504** are operatively connected to two terminals of a capacitor. The analog-to-digital converter module **504** is operatively connected to the capacitance calculation module **508** and the clock module **506**. The capacitance calculation module **508** is operatively connected to the capacitance evaluation module **510** in the processing unit **116**. The capacitance evaluation module **510** is operatively connected to the autofocus sensor **112**.
(37) In one example, the voltage generator module **502** generates a sinusoidal voltage signal at one terminal of the capacitor. A corresponding output voltage signal is created at the other terminal of the capacitor due to existence of a capacitance C between the two terminals of the capacitor. In this example, the analog-to-digital converter module **504** is configured to convert the output voltage signal to a digital signal proportional to the output signal. The conversion from the output voltage signal to the digital signal is synchronized by the clock module **506**. Based on the digital signal converted at the analog-to-digital converter module **504** and the sinusoidal voltage signal generated at the voltage generator module **502**, the capacitance calculation module **508** is configured to calculate the capacitance C between the two terminals of the capacitor.
(38) In this example, the capacitance calculation module **508** is operatively connected to the capacitance evaluation module **510** in the processing unit **116**. The capacitance evaluation module **510** is configured to receive/obtain the calculated capacitance value from the capacitance calculation module **508**. The capacitance evaluation module **510** is also configured to receive/obtain the predetermined distance and direction from the autofocus sensor **112**. Based on the received/obtained predetermined distance and direction, the capacitance evaluation module **510** is configured determine a desired capacitance value. In some embodiments, the capacitance evaluation module **510** compares the calculated capacitance value to the desired capacitance value. If the calculated capacitance value matches the desired capacitance value, then the capacitance evaluation module **510** sends a rotor control signal to the rotor drive block **118** to stop the rotor **106** from moving. If the calculated capacitance value does not match the desired capacitance value, the capacitance evaluation module **510** sends a rotor control signal to the rotor drive block **118** to continue to move the rotor **106**.
(39) FIG. **6** illustrates another embodiment of the capacitance sensing circuit **114** and the processing unit **116**. As can be seen, in this embodiment, the capacitance sensing circuit **114** comprises a clock module **506**, a capacitance calculation module **508**, a counter module **602**, a comparator **604**, three resistors R**1**, R**2**, R**3**, one ground, and/or any other components. The processing unit **116** comprises the capacitance evaluation module **510**, and/or any other components. A counter module **602** may be referred to a digital circuit configured to count a number of times a particular event or process has occurred. Examples of a counter module **602** include decade counter, ring counter, Johnson counter, and/or any other types of counters. The comparator **604** may be referred to an electronic circuit that compares two voltages and outputs a digital signal indicating which is larger. Examples of a comparator **604** include operational

amplifier comparator, dynamic latched comparator, and/or any other types of comparators.
(40) In this embodiment, terminal **1** of the resistor R**2** is connected to the “minus” input of the comparator **604** and the rotor plate **110**. Terminal **2** of the resistor R**1** and the resistor R**3** is connected to the “plus” input of the comparator **604**. Terminal **3** of the resistor R**2** and the resistor R**3** is connected to the output of the comparator **604** and the counter module **602**. In some examples, the resistors R**1**, R**2**, and R**3** have a resistance value of R, and the comparator **604** is powered up by a higher voltage V.sub.DD and a lower voltage V.sub.SS. A period T of oscillation created at the output of the comparator **604** can be calculated by a formula:
(41) $T = (R \text{ .Math. } C)[\ln(\frac{2V_{SS} - V_{DD}}{V_{SS}}) + \ln(\frac{2V_{DD} - V_{SS}}{V_{DD}})]$.
The period T is detected at the counter module **602** by measuring a time between two consecutive rising edges of an oscillation at the output of the comparator **604** using the clock module **506**. The counter module **602** then sends a value of T to the capacitance calculation module **508**. In this way, with known T, R, V.sub.DD and V.sub.SS values, the capacitance C between the stator plate **108** and the rotor plate **110** can be calculated at the capacitance calculation module **508** using a formula:
(42) $C = T / [R \text{ .Math. } \ln(\frac{2V_{SS} - V_{DD}}{V_{SS}}) + R \text{ .Math. } \ln(\frac{2V_{DD} - V_{SS}}{V_{DD}})]$.
Please reference FIG. **5** and its associated texts for structure and functions of other components included in this example.
(43) FIG. **7** illustrates still another example of the autofocus actuator control system **100**, according to an exemplary embodiment of the present disclosure. As can be seen, in this example, the autofocus actuator **102** comprises the rotor **106**, stator plates **108***a-n* as shown, rotor plates **110***a-n* as shown, capacitance sensing circuits **114***a-n* as shown, rotor drive blocks **118***a-n* as shown, the processing unit **116**, and/or any other components. In this example, the processing unit **116** is operatively connected to the autofocus sensor **112** to receive/obtain a-n predetermined distances and a-n predetermined directions.
(44) In this example, a-n capacitances are created by a-n pairs of rotor plates and stator plates: the pair of the stator plate **108***a* and the rotor plate **110***a*, . . . , the pair of the stator plate **108***n* and the rotor plate **110***n*. The capacitance sensing circuits **114***a-n* are configured to measure a-n capacitance values corresponding to the a-n created capacitances. The processing unit **116** is configured to receive/obtain the a-n measured capacitance values from the capacitance sensing circuits **114***a-n*. Based on the a-n predetermined distances and the a-n predetermined directions, the processing unit **116** is configured to determine a-n desired capacitance values. The processing unit **116** is then configured to send a-n rotor control signals to the rotor drive blocks **118***a-n* based on comparisons between the a-n measured capacitance values and the a-n desired capacitance values. Please reference FIG. **1**, FIG. **5**, FIG. **6** and their associated texts for structure and functions of other components included in this example.
(45) FIG. **8** illustrates an example method **800** for controlling the autofocus actuator **102** in the autofocus actuator control system **100**. The operations of method **800** presented below are intended to be illustrative. In some embodiments, method **800** may be accomplished with one or more additional operations not described and/or without one or more of the operations discussed. Additionally, the order in which the operations of method **800** are illustrated in FIG. **8** and described below is not intended to be limiting.
(46) At step **802**, a predetermined distance and a predetermined direction for moving a rotor in an autofocus actuator are determined.
(47) At step **804**, a desired capacitance value between a stator plate and a rotor plate is determined based on the predetermined distance and the predetermined direction.
(48) At step **806**, a capacitance is measured between the stator plate and the rotor plate at a capacitance sensing circuit. The stator plate is attached to a stator, and the rotor plate is attached to the rotor in the autofocus actuator. When the rotor moves, a distance or an overlap area between the stator plate and the rotor plate changes, resulting in a change of the capacitance between the stator

plate and the rotor plate.
(49) At step **808**, the measured capacitance value is compared to the desired capacitance value. If the measured capacitance value matches the desired capacitance value, a rotor control signal is sent to a rotor drive block to stop the rotor from moving. If the measured capacitance value does not match the desired capacitance value, the rotor control signal is sent to the rotor drive block to continue moving the rotor.
(50) At step **810**, the rotor is stopped from moving and is kept stationary as the measured capacitance value matches the desired capacitance value.
(51) At step **812**, the rotor is moved for the predetermined distance at the predetermined direction. In some embodiments, a rotor control signal is sent to the rotor drive block to increase or decrease a speed for moving the rotor based on the comparison between the measured capacitance value and the desired capacitance value.
(52) Though the method for controlling an autofocus actuator is disclosed by way of specific embodiments as described above, those embodiments are not intended to limit the present method. Based on the methods and the technical aspects disclosed herein, variations and changes may be made to the presented embodiments by those of skill in the art without departing from the spirit and the scope of the present method.
(53) FIG. **9** illustrates an example method **900** for determining a relationship between the predetermined distance and the desired capacitance value in the autofocus actuator control system **100**. The operations of method **900** presented below are intended to be illustrative. In some embodiments, method **900** may be accomplished with one or more additional operations not described and/or without one or more of the operations discussed. Additionally, the order in which the operations of method **900** are illustrated in FIG. **9** and described below is not intended to be limiting.
(54) At step **902**, a rotor is moved to a bottom of an autofocus actuator and a value 0 is assigned to a variable named “step”.
(55) At step **904**, a moving distance d of the rotor is measured. An actual capacitance value c between a stator plate and a rotor plate is also measured.
(56) At step **906**, the rotor is moved away from the bottom of the autofocus actuator for a step distance d′, and the variable step is updated as: step=step+1. In some embodiments, a rotor control signal is sent to a rotor drive block to move the rotor for the step distance d′.
(57) At step **908**, updated variable step is compared to a predetermined total step number. If the updated variable step matches the predetermined total step number, step **910** is executed. If the updated variable step does not match the predetermined total step number, step **904** is executed.
(58) At step **910**, a relationship between a predetermined distance and a desired capacitance value is determined based the measured d and c values at step **904**. In some embodiments, a polynomial function of degree 2 is determined to express the relationship between the predetermined distance and the desired capacitance value.
(59) Though the method for determining the relationship between the predetermined distance and the desired capacitance value is disclosed by way of specific embodiments as described above, those embodiments are not intended to limit the present method. Based on the methods and the technical aspects disclosed herein, variations and changes may be made to the presented embodiments by those of skill in the art without departing from the spirit and the scope of the present method.

Claims

1. A method for controlling an autofocus actuator based on a capacitance measured between a rotor plate attached to a rotor and a stator plate attached to a stator in the autofocus actuator, and the method comprising: determining, at an autofocus sensor, a predetermined distance and a

predetermined direction for moving the rotor in an image autofocus process; determining, at a processing unit, a desired capacitance value between the rotor plate and the stator plate corresponding to the predetermined distance and the predetermined direction; and until the measured capacitance value matches the desired capacitance value; measuring, at a capacitance sensing circuit, a capacitance between the rotor plate and the stator plate; determining, at the processing unit, whether the measured capacitance value matches the desired capacitance value; and lineally moving, at a rotor drive block, the rotor in the direction.
2. The method in claim 1, further comprising measuring the capacitance between the rotor plate and the stator plate by providing a power supply to the rotor plate from a power supply module through a metal piece in the autofocus actuator.
3. The method in claim 1, wherein the autofocus actuator is protected by a metal shell, and wherein the metal shell comprises the stator plate.
4. The method in claim 1, wherein the autofocus actuator is an electromagnetic autofocus actuator comprising a magnet, wherein the magnet is the stator plate.
5. The method in claim 1, wherein the autofocus actuator is an electromagnetic autofocus actuator comprising a magnetic metal configured to facilitate a movement of the autofocus actuator, wherein the magnetic metal comprises the stator plate.