



(51) International Patent Classification:

Not classified

(21) International Application Number:

PCT/GB2019/052941

(22) International Filing Date:

16 October 2019 (16.10.2019)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

1816864.1

16 October 2018 (16.10.2018)

GB

(71) Applicant: **CAMBRIDGE MECHATRONICS LIMITED** [GB/GB]; The Westbrook Centre, Building 6, Cambridge Cambridgeshire CB4 1YG (GB).

(72) Inventors: **DOUST, Alexander Bastiaan**; Cambridge Mechatronics Limited, The Westbrook Centre, Building 6, Milton Road, Cambridge Cambridgeshire CB4 1YG (GB). **DERRY, Bronwen Laura**; Cambridge Mechatronics Limited, The Westbrook Centre, Building 6, Milton Road, Cambridge Cambridgeshire CB4 1YG (GB). **BROWN, Andrew Benjamin Simpson**; Cambridge Mechatronics Limited, The Westbrook Centre, Building 6, Milton Road, Cambridge Cambridgeshire CB4 1YG (GB). **ROGERS, Ian**

Edward Charles; Cambridge Mechatronics Limited, The Westbrook Centre, Building 6, Milton Road, Cambridge Cambridgeshire CB4 1YG (GB).

(74) Agent: **CHUNG, Hoi Kan**; Cambridge Mechatronics Limited, The Westbrook Centre, Building 6, Cambridge Cambridgeshire, CB4 1YG (GB).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,

(54) Title: ELECTROMAGNETIC SCREENING OF AN IMAGE SENSOR FROM AN ACTUATOR IN A CAMERA

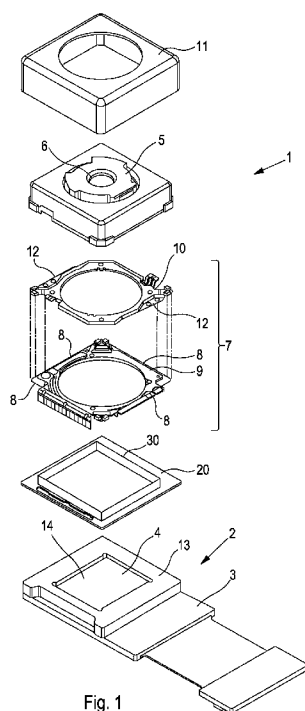


Fig. 1

(57) Abstract: A miniature camera comprises a support structure having an image sensor mounted thereon, a lens holder holding a lens arranged to form an image on the image sensor, and an actuator arranged to drive movement of the lens holder relative to the image sensor, the actuator including conductive components capable of conducting a pulse width modulation drive signal for driving the actuator. For providing electro-magnetic screening, a screening element formed by plural layers of material is located inside the conductive components of the actuator around the optical axis. The screening element improves the reduction of noise in the captured image.

TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,
KM, ML, MR, NE, SN, TD, TG).

Published:

- *without international search report and to be republished
upon receipt of that report (Rule 48.2(g))*

Electromagnetic Screening of an Image Sensor from an Actuator in a Camera

The present techniques relates to a camera including an actuator driven, in
5 use, by a pulse width modulation (PWM) drive signal.

According to the present techniques, there is provided a camera
comprising: a support structure having an image sensor mounted thereon; a lens
holder holding at least one lens having an optical axis and arranged to form an
10 image on the image sensor, the lens holder being arranged to move relative to
the image sensor; an actuator arranged to drive movement of the lens holder
relative to the image sensor, the actuator including conductive components
capable of conducting a pulse width modulation drive signal for driving the
actuator; and a screening element formed by plural layers of material for providing
15 electro-magnetic screening located inside the conductive components of the
actuator around the optical axis.

The screening element may be mounted to an external surface of the lens
holder. This is simple to manufacture as the screening element may be mounted
20 prior to the assembly of the camera without significantly complicating the
structure of the camera.

The camera may further comprise a screening plate for providing electro-
magnetic screening located at a position along the optical axis between the
25 conductive components of the actuator and the image sensor, the screening plate
extending around the image sensor. Such a screening plate may be arranged as
disclosed in International Patent Publication No. WO2018/015672. In this case,
compared to the screening plate alone, the screening element provides additional
electro-magnetic screening of the image sensor from electro-magnetic radiation
30 arising from the PWM drive scheme of the actuator, thereby reducing the
appearance of artefacts in the displayed image.

When a screening plate is present, the screening element may be mounted
to the screening plate. For example, the screening element may comprise a folded
35 or formed lip of the screening plate, a cylindrical plate or at least one layer of

material deposited on the screening plate.

The present techniques may be applied to an actuator that comprises shape memory alloy (SMA) material, for example SMA wire. In such embodiments, the actuator may comprise one SMA wire or one length of SMA wire, two SMA wires or two lengths of SMA wire, four SMA wires, or eight SMA wires. Additionally or alternatively, the present techniques may be applied to a voice coil motor (VCM) or voice coil actuator.

The camera may comprise a lens arranged to form an image on the image sensor, in which case the actuator may be arranged to drive movement of the lens relative to the image sensor, for example to provide focussing of the image formed on the image sensor and/or optical image stabilisation (OIS). The actuator of the camera may drive movement of the lens holder along the optical axis of the at least one lens, to provide focussing or autofocus. Additionally or alternatively, the actuator of the camera may drive movement of the lens holder in two orthogonal directions perpendicular to the optical axis of the at least one lens, to provide OIS.

The screening element may be not connected to an electrical earth. Thus, the screening element may electrically float. This provides as good a screen for the image sensor as if it were earthed and may even assist in the reduction of interference. This is surprising because electro-magnetic screening in other applications is often connected to an electrical earth, as for example a Faraday cage. The absence of connection to an electrical earth is advantageous, because adequate earthing for high frequency noise is difficult whilst achieving a compact design.

The screening element may comprise magnetically permeable material, for example having a high relative magnetic permeability. The magnetically permeable material may have a relative magnetic permeability greater than 2, preferably greater than 100, more preferably greater than 500.

The screening element may have a height (i.e. a length or dimension substantially parallel to the optical axis of the at least one lens) of greater than

100µm, preferably greater than 200µm, more preferably greater than 300µm. The screening element may in some cases have a height of greater than or equal to 400µm. The screening element may in some cases have a height of 900µm or more. The height may depend on mechanical and/or manufacturing limitations.

5 For example, the maximum height of the screening element may be restricted by other components of the camera, as the screening element should not interfere with the mechanical operation of the camera. In cases where the screening element comprises a formed lip of the screening plate, the maximum height of the screening element (lip) may be limited by manufacturing limitations of the forming
10 process. The width or thickness of the screening element may also be restricted by other components of the camera, to avoid interference with the mechanical operation of the camera.

The screening element may comprise electrically conductive material, for
15 example having a high electrical conductivity. The electrically conductive material may have an electrical conductivity higher than 2MS/m, preferably higher than 10MS/m, more preferably higher than 50MS/m.

The screening element may comprise plural metal layers having different
20 electro-magnetic properties, for example including a first layer comprising magnetically permeable material and a second layer comprising electrically conductive material. There may be at least one layer of insulating material between the metal layers, for example an adhesive used to adhere the layers together. Alternatively, the layers may adhere in any other way, for example one
25 or more the layers being a coating on another layer.

In one type of embodiment, the screening element comprises plural layers including at least one rigid layer and a coating layer coated on the at least one rigid layer. The rigid layer therefore provides structural rigidity and may also
30 provide some electro-magnetic screening, whereas the coating layer may provide different electro-magnetic properties that improve the screening. For example, the at least one rigid layer may comprise stainless steel and/or the coating may comprise copper.

35 Implementations of the present techniques will now be described, by way

of example only, with reference to the accompanying drawings, in which:

Figure 1 shows an exploded perspective view of a camera;

5 Figure 2 is a diagram of a control circuit connected to SMA wires in the camera;

Figure 3 is a plan view of a screening plate of the camera which acts as a screening element;

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Figure 4 is a side view of a modified form of the camera;

Figure 5 is a cross-section view of a screening plate and screening element formed of layers; and

15

Figure 6 is a side view of another modified form of the camera.

Broadly speaking, embodiments of the present techniques provide a miniature camera comprising a screening element for screening against
20 electromagnetic radiation that may cause image noise in images captured by the camera. The screening element therefore advantageously reduces noise in the captured image(s).

Cameras provided in consumer electronic devices such as smartphones,
25 tablet computers etc. often incorporate an electro-mechanical actuator. Such an actuator may drive movement of a lens relative to an image sensor, for example to adjust a focus position of the lens, often as part of an autofocus (AF) system, and/or to perform optical image stabilization (OIS). To achieve accurate positioning of the movable lens such actuators are typically driven with a linear
30 current feed. However, the use of such drives is inefficient and power consumption can be reduced if PWM drives are used. However, it is known that the use of a PWM drive circuit for driving an electro-mechanical actuator interferes with the image sensor of the camera, typically causing artefacts to appear in the resulting digital image such as a faint but noticeable horizontal lines or speckle.

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This is a particular problem for an actuator that comprises shape memory alloy (SMA) material, for example SMA wire. There are particular advantages in the use of SMA as an actuator in a camera, for example to drive movement of the lens relative to the image sensor. Compared to other actuation technologies SMA provides a high actuation force in a compact physical configuration, that may for example provide focussing of the image formed on the image sensor and/or OIS. In the case of an SMA actuator, it is desirable to use a PWM drive signal.

Various methods have been used to reduce or eliminate this noise, whilst maintaining use of the actuators driven by a PWM drive signal.

United States Patent No. US9,654,689 discloses one such example where two electrical drive circuits are attached to a voice coil motor (VCM) electro-mechanical actuator, a PWM drive circuit and a linear drive circuit. The linear circuit is used during the readout phase of operation of the image sensor, and the PWM drive circuit is used during the integration phase of operation of the image sensor. This approach is undesirable because it increases the cost and complexity of the electro-mechanical actuator drive circuit, as well as reducing the power efficiency of the device in use.

International Patent Publication No. WO2018/015762 discloses a camera in which a screening plate for screening the image sensor from an actuator that conducts a pulse width modulation drive signal is located at a position along the optical axis between the conductive components of the actuator and the image sensor, the screening plate extending around the image sensor. The screening plate provides electro-magnetic screening that is effective in reducing PWM noise without adding cost and complexity to the electronic drive circuit for the actuators. However, it would be desirable to provide further reduction of the PWM noise, but still without adding cost and complexity to the electronic drive circuit for the actuators.

In the present techniques, as will be explained in more detail below, the screening element is located in a different position from the screening plate in WO2018/015762 but in a similar manner to that screening plate provides electro-magnetic screening of the image sensor from electro-magnetic radiation arising

from the PWM drive scheme of the actuator, thereby reducing the appearance of artefacts in the displayed image.

A camera 1 is shown in Figure 1 and arranged as follows.

5

The camera 1 comprises a sensor assembly 2, which comprises a flexible circuit board 3, an image sensor 4 mounted on the flexible circuit board, and a surround 13 which is a rigid structural element extending around the image sensor 4. Thus, the surround 13 and the flexible circuit board 3 together form a support
10 structure for the image sensor 4. The image sensor 4 is implemented in an integrated circuit chip. An infra-red filter 14 is fixed to the surround 13 extending across the light-sensitive area of the image sensor 4.

The camera 1 also comprises a lens holder 5 holding a lens 6 that has an
15 optical axis O and is arranged to form an image on the image sensor 4. A single lens 6 is shown in Figure 1, but more than one lens 6 may be provided.

The camera 1 also comprises an SMA actuator assembly 7 which forms an actuator and is arranged outside the lens holder 5. The SMA actuator assembly 7
20 comprises plural SMA wires 8 connected between a static layer 9 (lowermost in Figure 1) and a movable layer 10 (uppermost in Figure 1). In the example of Figure 1, four SMA wires 8 are provided, but in general any number of SMA wires 8 may be used. In alternative embodiments, the actuator assembly may be or may comprise one or more voice coil motors (VCM).

25

The movable layer 10 can move relative to the static layer 9. In the example shown in Figure 1, the movable layer 10 can move relative to the static layer 9 laterally of the optical axis of the lens 6 of the lens holder, but in general the relative movement may be with any degree of freedom, for example translational
30 movement along any axis and/or rotational movement about any axis.

In the example shown in Figure 1, the SMA actuator assembly 7 includes a suspension system, formed by flexures 12 connected between the static layer 9 and the movable layer 10, which supports the movable layer 10 on the static layer
35 9 in a manner allowing the desired movement of the movable layer 10 relative to

the static layer 9. As an alternative, the suspension system could be formed in some other way, for example formed by ball bearings or a sliding bearing. As another alternative, the suspension system may be omitted in which case the movable layer 10 is supported on the static layer 9 solely by the SMA wires 8.

5

The static layer 9 is mounted to the sensor assembly 2 (via the screening plate 20 described below) and the movable layer 10 is connected to the lens holder 5, so that the movement of the movable layer 10 relative the static layer 9 moves the lens holder 5 relative to the image sensor 4.

10

Similarly, the SMA wires 8 are arranged to drive movement of the movable layer 10 relative to the static layer 9, and therefore to drive movement of the lens holder 5 relative to the image sensor 4.

15

The SMA actuator assembly 7 may have various different constructions, involving various numbers of SMA wires 8 in various configurations, and various forms of suspension system, so that the SMA wires 8 drive movement of the lens holder 5 relative to the image sensor 4 with various different degrees of freedom to provide different optical functions, for example as follows.

20

In one type of construction, the SMA actuator assembly 7 drives movement of the lens holder 5 relative to the image sensor 4 to provide focussing of the image formed on the image sensor, i.e. movement along the optical axis of the lens 6. In this case, the SMA actuator assembly 7 may, for example, have a construction as disclosed in more detail in International Patent Publication Nos. WO2007/001050, WO2008/099156 or WO2009/056822.

25

In another type of construction, the SMA actuator assembly 7 drives movement of the lens holder 5 relative to the image sensor 4 to provide optical image stabilisation, i.e. movement laterally of the optical axis of the lens 6. In this case, the SMA actuator assembly 7 may, for example, have a construction as disclosed in more detail in International Patent Publication Nos. WO2013/175197, WO2014/083318, or WO2017/055788.

30

In another type of construction, the SMA actuator assembly 7 drives

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movement of the lens holder 5 relative to the image sensor 4 to provide focussing of the image formed on the image sensor and optical image stabilisation. In this case, the SMA actuator assembly 7 may, for example, have a construction as disclosed in more detail in International Patent Publication Nos. WO2011/104518 or WO2012/066285.

Although the camera 1 shown in Figure 1 uses the SMA wires 8 in the SMA actuator assembly 7 as an actuator, any other form of actuator could alternatively be employed, for example a VCM. By way of example, Figures 4 and 6 show a modified form of the camera 1 in which the actuator is formed by a combination of (a) an SMA actuator assembly 7 as shown in Figure 1 which drives movement of the lens holder 5 relative to the image sensor 4 to provide optical image stabilisation, i.e. movement laterally of the optical axis of the lens 6, and (b) a VCM actuator assembly 17 which drives movement of the lens holder 5 relative to the image sensor 4 to provide focussing of the image formed on the image sensor, i.e. movement along the optical axis of the lens 6.

The camera 1 also includes a can 11 which encases the other components of the camera 1, providing mechanical protection and reducing ingress of dirt.

The camera 1 includes a control circuit 15 as shown in Figure 2 in a non-limitative example including four SMA wires 8 connected together at the movable layer 10. The control circuit 15 may be implemented in an integrated circuit chip attached to the sensor assembly 2. The control circuit 15 is connected to the SMA wires 8 and supplies PWM drive signals thereto. The drive signals are conducted by conductive components of the SMA actuator assembly 7 including the SMA wires 8 themselves and other conductive components electrically connected to the SMA wires 8.

The drive signals provide resistive heating of the SMA wires 8 to selectively vary their temperature, and hence the degree of their contraction. Heating is provided directly by the drive signal. Cooling is provided by reducing the power of the drive signal to allow the SMA wires 8 to cool by conduction, convection and radiation to their surroundings.

In general terms, the control circuit 15 may be configured to generate drive signals as disclosed in any of International Patent Publication Nos. WO2007/113478, WO2008/099156, WO2008/129291, WO2009/071898, or WO2010/089529, except that the drive signals are PWM drive signals.

5

The use of a PWM drive signal improves the efficiency of the drive circuit. The PWM drive signals are pulsed signals that are switched on and off to modulate the power of the drive signal. They may be derived from any type of current source, for example a constant current source or a constant voltage source and may in general be any type of switched signal. The duty cycle describes the ratio between the time that the drive signal is switched on to the overall period of the signal. The duty cycle is altered to modulate the power of the drive signal. A common approach that may be applied here is for the PWM drive signal to have a constant period, in which case the duty cycle is varied by changing the time that the drive signal is switched on. However, other approaches may alternatively be applied, for example having a constant time that the drive signal is switched on, in which case the duty cycle is varied by changing the overall period of the signal. Typically, the actuator is driven with square pulses at frequencies in the range of 30-100kHz.

20

When the PWM drive signal is pulsed through the SMA wires 8 and other conductive components, this current causes an electro-magnetic field to be formed according to Ampere's law. The pulsed fields interfere with the image sensor 4 and the tracks connected thereto, causing noise which, in some cases, could potentially cause artefacts to form on the displayed image.

25

To reduce this problem, the camera also includes a screening plate 20 and a screening element 30 which both provide electro-magnetic screening that screens the image sensor 4 from the PWM drive signals, thereby reducing the appearance of artefacts on the displayed image. The screening plate 20 and the screening element 30 are both therefore electrically isolated from the SMA actuator assembly 7, and in particular from the SMA wires 8 and the other conductive components that conduct the PWM drive signals. The screening plate 20 and the screening element 30 are electrically isolated from the image sensor 4.

35

Although not essential, the screening plate 20 and the screening element 30 may also not be connected to an electrical earth. Advantageously, it has been found that leaving the screening plate 20 and the screening element 30 floating provides as good a screen for the image sensor 4 as if the screening plate 20 was earthed. Adequate earthing for high frequency noise is difficult whilst achieving a compact design.

The screening plate 20 and the screening element 30 are arranged as follows.

The screening plate 20 is attached between the static layer 9 of the SMA actuator assembly 7 and the sensor assembly 2, as shown in Figure 1. Thus, the screening plate 20 is on top of the surround 13 of the sensor assembly, and so located at a position along the optical axis O between the conductive components of the SMA actuator assembly 7 and the image sensor.

The screening plate 20 is shown in isolation in Figure 3 and has a central aperture 21 that has a rectangular shape to match the shape of the light sensitive area of the image sensor 4 so that the screening plate extends around the image sensor 4 and does not interfere with image capture. As an alternative, the surface area of the screening plate 20 may be increased by changing the central aperture 21 to have a circular shape while ensuring that it does not clip any light collected by the lens that otherwise would be detected by the image sensor 4.

The screening plate 20, if provided without the screening element 30, would provide electro-magnetic screening that screens the image sensor 4 from the PWM drive signals, thereby reducing the appearance of artefacts on the displayed image. However, the screening element 30 provides additional electro-magnetic screening that improves this effect.

The screening element 30 is located inside the conductive components of the SMA actuator assembly 7 around the optical axis O. The screening element 30 extends in a direction along the optical axis O and thus has a vertical extent. In this example, the screening element 30 is parallel to the optical axis O, but that

is not essential and the screening element 30 could be inclined with respect to the optical axis provided that it has an extent in the direction along the optical axis. Thus, the screening element 30 extends forwardly from the screening plate 20 (i.e. in a direction away from the image sensor 4). It will be understood that the angle of the screening element 30 with respect to the optical axis may be limited by other components of the camera, as the screening element 30 should not interfere with the mechanical operation of the camera.

In this example, the screening element 30 extends entirely around the optical axis O, although it could just extend around partway around the optical axis O.

In the example shown in Figure 1, the screening element 30 is mounted to the screening plate 20 with no gap therebetween. Thus, the screening element 30 extends from the screening plate 20 forwardly (i.e. in a direction away from the image sensor 4).

In one option, mounting of the screening element 30 to the screening plate may be achieved by forming the screening element 30 as a folded lip of the screening plate 20. (This may be preferred if the screening plate 20 comprises a circular central aperture 21, as it may be simpler to fabricate.) This option has the advantage that a separate component is not needed, because the screening plate 20 may be shaped to form the screening element 20 prior to assembly of the camera 1.

In another option, mounting of the screening element 30 to the screening plate 20 may be achieved by the screening element being formed as a cylindrical plate which may be formed as a separate element from the screening plate 20. In this case, the screening element 30 may have the same or different construction as the screening plate 20, as described above.

As another example of this option, Figure 4 illustrates a modified form of the camera 1 in which the actuator is formed by a combination of (a) an SMA actuator assembly 7 and (b) a VCM actuator assembly 17 (as described above), and in which the screening element 30 is a cylindrical plate.

This option simplifies manufacture, as the screening element 30 may be manufactured separately from the screening plate 20 and subsequently assembled with the other components of the camera 1. For example, the screening element 30 and the screening plate 20 may be attached together before assembly, for example by adhesive or welding, or alternatively may be separately assembled into the camera 1 in which case they may be attached or left unattached.

In yet another option, mounting of the screening element 30 to the screening plate 20 may be achieved by the screening element being formed as one or more layers of material deposited on the screening plate. In embodiments, the actuator may comprise a laminate structure and the screening element may be provided by one or more layers of this laminate structure. For example, the laminate structure may comprise a base layer, an insulation layer and a layer comprising conductive electrical tracks. One or more of these layers may form the screening element in the proximity of the lens holder. In embodiments, the layer comprising conductive electrical tracks may comprise at least one 'dead track', i.e. a track which is not used to carry electrical current. This dead track may provide the screening element. Alternatively, the laminate structure may comprise a separate layer which comprises at least one dead track. These embodiments allow the screening element 30 to be formed by methods conventionally used to deposit tracks on a substrate, such as are typically used for forming conductive circuits on a substrate.

Figure 5 illustrates the construction of the screening plate 20 and the screening element 30 in an example in which the screening element 30 is formed by plural layers 31 of material (which may be the laminate structure of the actuator mentioned above).

As an alternative to the screening element 30 being mounted to the screening plate 20, the screening element 30 may be mounted to an external surface of the lens holder 5. As an example of this, Figure 6 illustrates a modified form of the camera 1 in which the actuator is formed by a combination of (a) an SMA actuator assembly 7 and (b) a VCM actuator assembly 17 (as described above), but which otherwise has the same construction as shown in Figure 1. In

this example, the screening element 30 is mounted to the external surface 32 of the lens holder 5, at the end of lens holder 5 facing the image sensor 4.

When mounted to an external surface of the lens holder 5, the screening
5 element 30 may extend beyond the end of the lens holder 5, for example as shown in Figure 6. This maximises the coverage of the gap between the end of the lens holder 5 and the screening plate 20. The extent of the screening element 30 beyond the end of the lens holder 5 is chosen so that the screening element 30 does not contact any other component of the camera 1 when the lens holder 5 is
10 at the limit of its range of movement that is closest to the image sensor 4.

In embodiments, the screening element 30 may be mounted to any one or more of: an external surface of the lens holder 5, an internal surface of the lens holder 5 (e.g. between the lens holder and the at least one lens), a surface of a
15 lens carriage of the camera, an external surface of the at least one lens, and a surface of the actuator. Thus, in some embodiments, the camera may comprise more than one screening element. Additionally or alternatively, a shielding coating (e.g. a metallic coating, such as a copper coating) may be provided on one or more components of the actuator or camera, where the coating provides
20 electromagnetic screening or shielding. The coating could be provided on the lens carriage/lens holder, or on the actuator (or components of the actuator), for instance.

The screening plate 20 and the screening element 30 may take various
25 constructions, including the forms of the screening plate disclosed in International Patent Publication No. WO2018/015762. The screening plate 20 and the screening element 30 may in general have the same or different constructions (except in the example where the screening element 30 is formed as a folded lip of the screening plate 20 and so has the same construction as the screening plate 20).

30

Some non-limitative examples of forms of the screening plate 20 and the screening element 30 are as follows.

In a first example, the screening plate 20 or the screening element 30 is
35 made from electrically conductive material having a high conductivity, and may

be a single layer of material. The electrically conductive material may have an electrical conductivity higher than 2MS/m, preferably higher than 10MS/m, even more preferably higher than 50MS/m. For example, the electrically conductive material may be copper. When the SMA wires 8 are driven with PWM drive signal, the resulting dynamic electro-magnetic field induces eddy currents in the electrically conductive material. The eddy current is formed to oppose the magnetic field and the sensor and connecting tracks are screened. Whilst the electrically conductive material is effective for higher frequencies, it is less effective for lower frequencies.

In a second example, the screening plate 20 or the screening element 30 is made from a magnetically permeable material having a high relative magnetic permeability, and may be a single layer of material. The magnetically permeable material may have a relative magnetic permeability greater than 2, preferably greater than 100, most preferably greater than 500. For example, magnetically permeable material may be a magnetic grade of stainless steel, such as 420. The high relative magnetic permeability causes the magnetic field generated by the current flowing through the SMA wires 8 to be drawn inside the material of the screening plate 20 or the screening element 30, which confines most of the magnetic field to lie within the material, thus reducing the magnitude of the magnetic field that passes through the image sensor 4 and circuitry connected thereto, and so reduces noise that appears on the displayed image.

In order to further reduce the image noise for the whole frequency range, a method of screening is required, which both addresses slow changes in magnetic field and faster changes. This may be achieved by forming the screening plate 20 or the screening element 30 from a single layer of material whose properties are appropriately selected, but the choice of material is restricted, because while some materials have one desirable property they may lack another. Properties that are typically of concern are the permeability, the electrical conductivity, the strength of the material (Young's modulus and yield stress), compatibility with the rest of the system (e.g. ability to be welded, corrosion resistance, thermal expansion coefficient) and cost.

In order to find a good compromise between these properties it may be

desirable that the screening plate 20 or the screening element 30 comprises plural conductive layers of different materials, typically metals, having different electro-magnetic properties. The layers may include one or more layers of electrically conductive material having a high conductivity and one or more layers of a magnetically permeable material having a high relative magnetic permeability. Some examples of this will now be described, wherein the electrically conductive material and the magnetically permeable material may have properties as described above with respect to the first and second examples.

In a third example, the screening plate 20 or the screening element 30 is made one or more rigid layers and a coating layer coated thereon. The rigid layer therefore provides structural rigidity and may also provide some electro-magnetic screening, whereas the coating layer may provide different electro-magnetic properties that improve the screening. For example, the at least one rigid layer may comprise stainless steel and/or the coating layer may comprise copper. The coating layer may be formed by any of numerous manufacturing techniques, such as plating, sputtering, or spraying.

In other examples, the screening plate 20 or the screening element 30 may comprise any of:

- a first layer of magnetically permeable material and a second layer of electrically conductive material placed on one side of the first layer, for example between the SMA wires 8 and the first layer;
- a first layer of magnetically permeable material and two layers of electrically conductive material on opposite sides of the first layer which may be electrically connected;
- a layer of magnetically permeable material is encapsulated by electrically conductive material, which may be applied as a coating or plating; or
- larger numbers of alternate layers of electrically conductive material and magnetically permeable material.

Where the screening plate 20 or the screening element 30 comprises plural conductive layers of different materials, the layers may be attached together by any method of coating or applying layers as known to those skilled in the art, such

as sputtering, metal vapour deposition, rolling etc. Further masks may be applied to the material so as to expose spots for attaching the can 11, or for making other connections as required.

5 Where the screening plate 20 or the screening element 30 comprises plural conductive layers of different materials, it may further comprise insulating material between some or all of the metal layers, for example adhesive used to attach the layers as a lamination.

10 While the camera 1 relates to an example where both the screening plate 20 or the screening element 30 are provided, the screening plate 20 may be omitted while still achieving similar screening performance. In such a case, the vertical extent of the screening element 30 may be increased.

15 The effectiveness of the screening element 30 in the modified form of the camera 1 shown in Figure 6 has been demonstrated as follows. For test purposes, the screening plate 20 was formed as a rigid layer of 304 stainless steel coated by a coating layer of copper. A comparison was made between the camera 1 with and without the screening element 30. Image noise data was captured using
20 measurement equipment from LiteOn (LAON PEOPLE, LPMC-900CK) derived from using images captured under pitch-black conditions, with the following conditions: 32.9kHz PWM frequency; 75ns slew rate; Vsync OFF; and 64x gain. Data was taken with the SMA undriven (3x4 RAW images) and SMA driven (10x4 images). Image analysis of the captured images was performed to provide a noise metric
25 that quotes image noise values based on analysis of line-by-line changes in pixel responses of the image sensor 4. Typically, the noise metric increases when SMA is driven.

 One test was conducted by comparing image noise in a camera comprising
30 a screening plate 20 formed of stainless steel with that of a camera comprising a screening plate 20 that is coated with copper. In this test, no screening element 30 was present. The test showed that the screening plate 20 coated with copper achieved a reduction in image noise of about 29% compared to a screening plate 20 formed only of stainless steel.

Another test was conducted by comparing image noise in a camera comprising a screening plate 20 formed of stainless steel with that of a camera comprising a screening plate 20 formed of stainless steel and a screening element 30 formed of copper. Specifically, the screening element 30 was formed of copper in the form of a tape of thickness $60\mu\text{m}$, which was mounted to an external surface of the lens holder 5, as shown in Figure 6. This left a gap of $300\mu\text{m}$ between the screening plate 20 and the screening element 30, with the height of the SMA actuator assembly 7 being of the order of $300\mu\text{m}$. In this test, a reduction in image noise of 33% was obtained for the combination of the screening plate and screening element, compared to the screening plate alone. Thus, an improvement is achieved despite the existence of the gap. It is expected that screening performance will be further improved in the arrangements where there is no gap between the screening plate 20 and the screening element 30. Screening performance is expected to be further improved in arrangements comprising a copper or copper-coated screening plate 20 and a copper screening element 30.

Those skilled in the art will appreciate that while the foregoing has described what is considered to be the best mode and where appropriate other modes of performing present techniques, the present techniques should not be limited to the specific configurations and methods disclosed in this description of the preferred embodiment. Those skilled in the art will recognise that present techniques have a broad range of applications, and that the embodiments may take a wide range of modifications without departing from any inventive concept as defined in the appended claims.

CLAIMS

1. A camera comprising:
 - a support structure having an image sensor mounted thereon;
 - 5 a lens holder holding at least one lens having an optical axis and arranged to form an image on the image sensor, the lens holder being arranged to move relative to the image sensor;
 - an actuator arranged to drive movement of the lens holder relative to the image sensor, the actuator including conductive components capable of
 - 10 conducting a pulse width modulation drive signal for driving the actuator; and
 - a screening element formed by plural layers of material for providing electro-magnetic screening located inside the conductive components of the actuator around the optical axis.
- 15 2. The camera according to claim 1, further comprising a screening plate for providing electro-magnetic screening located at a position along the optical axis between the conductive components of the actuator and the image sensor, the screening plate extending around the image sensor.
- 20 3. The camera according to claim 2, wherein the screening element is mounted to the screening plate.
4. The camera according to claim 3, wherein the screening element comprises a folded or formed lip of the screening plate.
- 25 5. The camera according to claim 3, wherein the screening element comprises a cylindrical plate.
6. The camera according to claim 2, wherein the plural layers of material forming the screening element comprises at least one layer of material deposited
- 30 on the screening plate.
7. The camera according to claim 2 wherein the actuator comprises a laminate structure, and the plural layers of material forming the screening element is
- 35 provided by one or more layers of the laminate structure.

8. The camera according to claim 1 or 2, wherein the screening element is mounted to any one or more of: an external surface of the lens holder, an internal surface of the lens holder, a surface of a lens carriage of the camera, an external surface of the at least one lens, and a surface of the actuator.

9. The camera according to any one of the preceding claims, wherein the actuator comprises shape memory alloy material.

10. The camera according to claim 9, wherein the shape memory alloy actuator comprises shape memory alloy wire.

11. The camera according to any one of the preceding claims, wherein the actuator is configured to drive movement of the lens relative to the image sensor to provide focussing of the image formed on the image sensor.

12. The camera according to any one of the preceding claims, wherein the actuator is configured to drive movement of the lens relative to the image sensor to provide optical image stabilisation.

13. The camera according to any one of the preceding claims, further comprising a suspension system supporting the lens holder on the support structure in a manner allowing the lens holder to move relative to the image sensor.

14. The camera according to any one of the preceding claims, wherein the screening element is not connected to an electrical earth.

15. The camera according to any one of the preceding claims, wherein the screening element contains magnetically permeable material having a relative magnetic permeability greater than 2, preferably greater than 100, more preferably greater than 500.

16. The camera according to any one of the preceding claims, wherein the screening element contains electrically conductive material having a conductivity

greater than 2MS/m, preferably greater than 10MS/m, more preferably greater than 50MS/m.

17. The camera according to any one of the preceding claims, wherein the screening element comprises plural layers having different electro-magnetic properties.

18. The camera according to claim 17, wherein the plural layers comprise plural metal layers having different electro-magnetic properties.

19. The camera according to claim 17 or 18, wherein the plural layers include at least one rigid layer and a coating layer coated on the at least one rigid layer.

20. The camera according to claim 17 or 18, wherein the at least one rigid layer comprises stainless steel.

21. The camera according to claim 17 or 18, wherein the coating layer comprises copper.

22. The camera according to any one of the preceding claims, further comprising a control circuit arranged to supply the pulse width modulation drive signal to the conductive components of the actuator.

23. The camera according to any preceding claim wherein the screening element has a height of greater than 100µm, preferably greater than 200µm, more preferably greater than 300µm.

24. The camera according to any one of claims 1 to 23 wherein the actuator drives movement of the lens holder along the optical axis of the at least one lens.

25. The camera according to any one of claims 1 to 24 wherein the actuator drives movement of the lens holder in two orthogonal directions perpendicular to the optical axis of the at least one lens.

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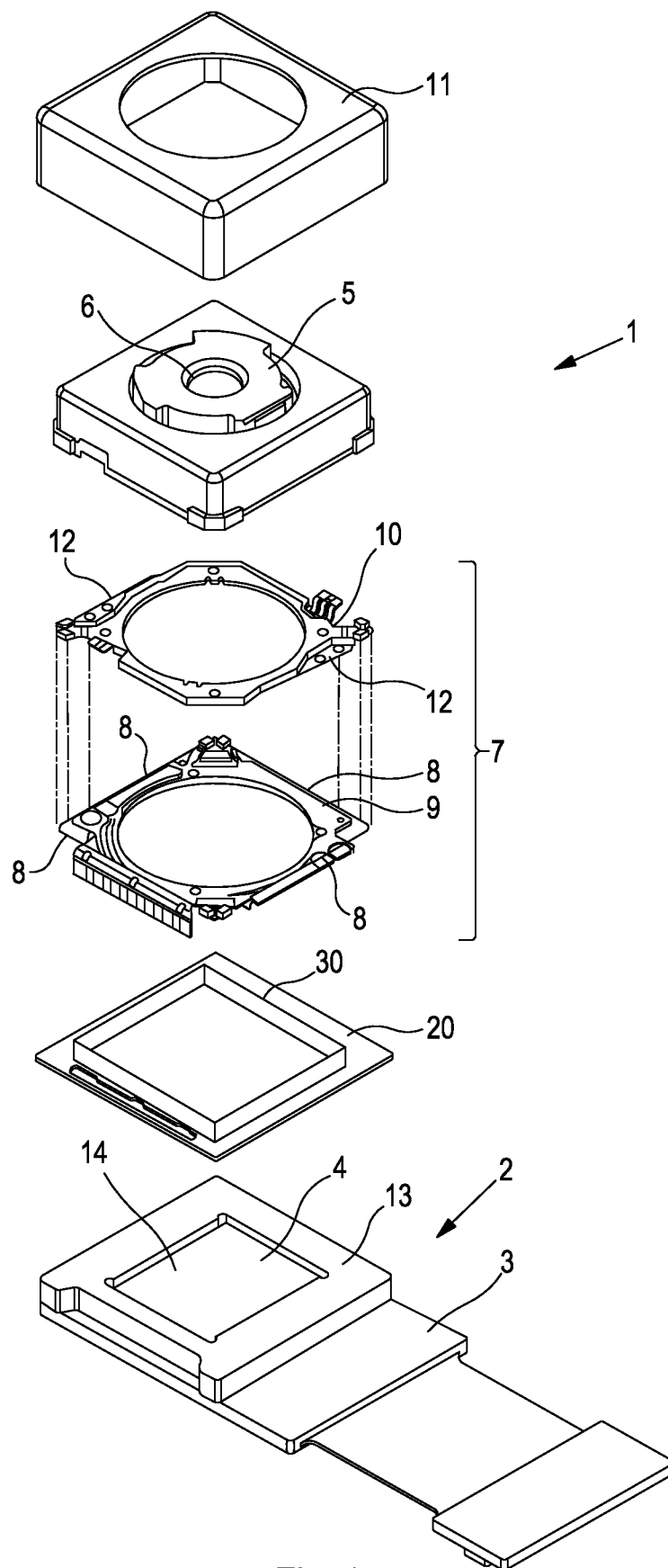


Fig. 1

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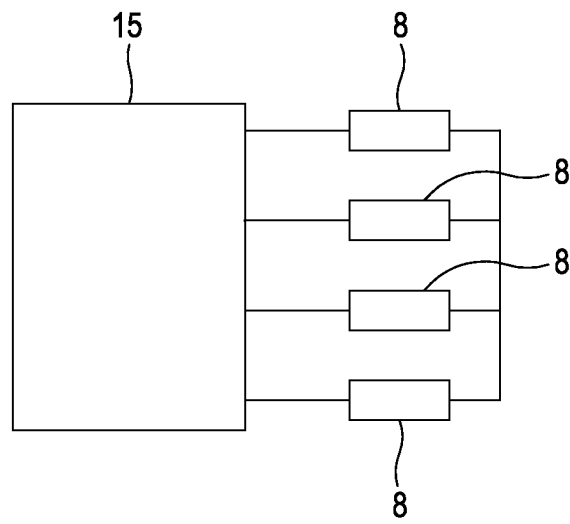


Fig. 2

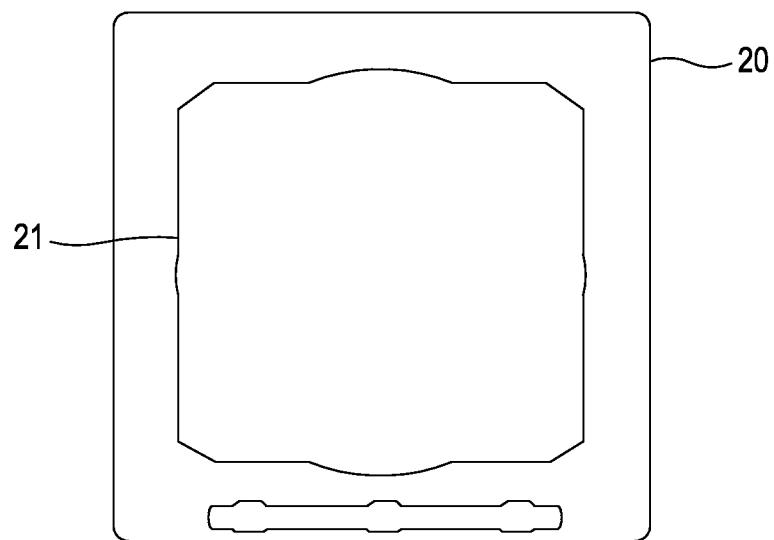


Fig. 3

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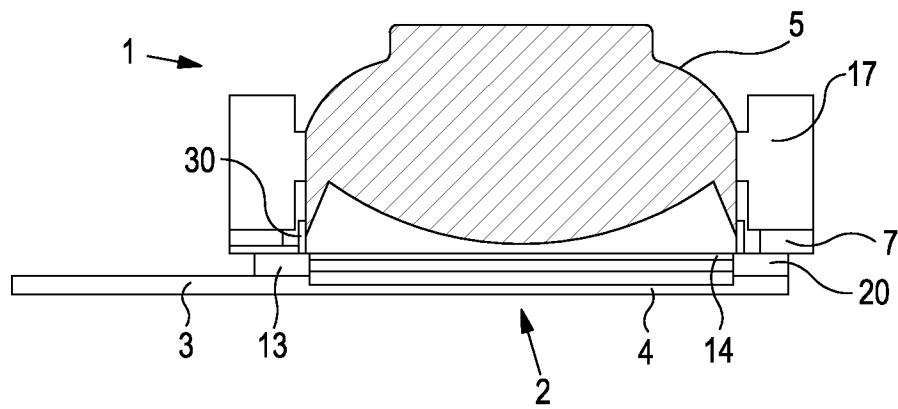


Fig. 4



Fig. 5

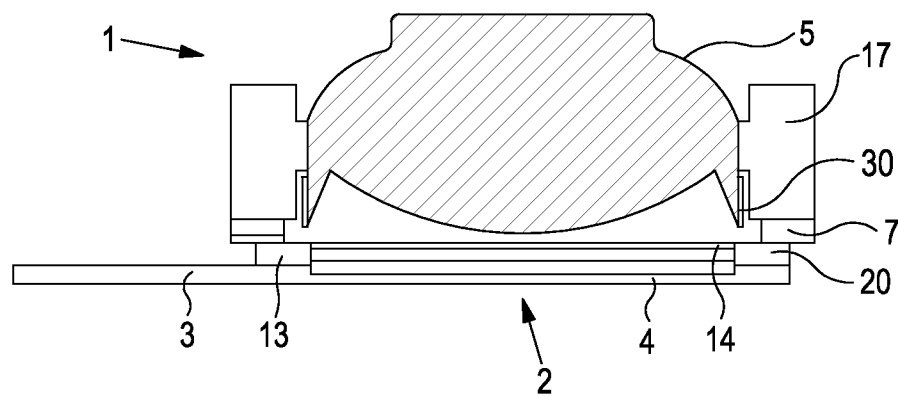


Fig. 6