May 31, 1966 M. SKLAROFF ETAL 3,254,225

PHOTOSENSITIVE MOTION-TO-CURRENT TRANSDUCERS

Filed March 26, 1962 2 Sheets-Sheet 1

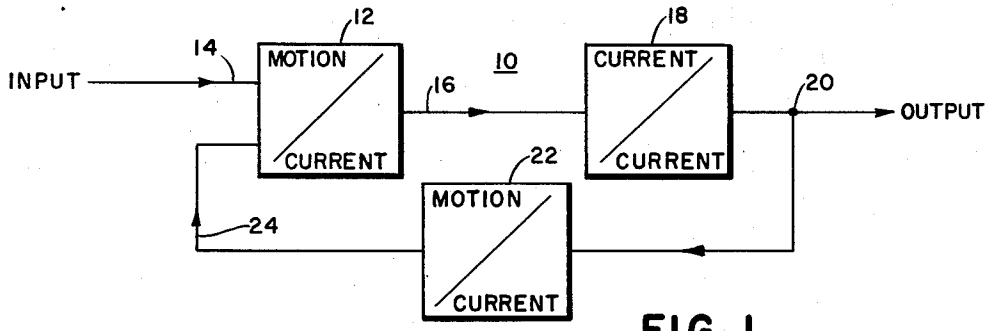

FIG. 1.

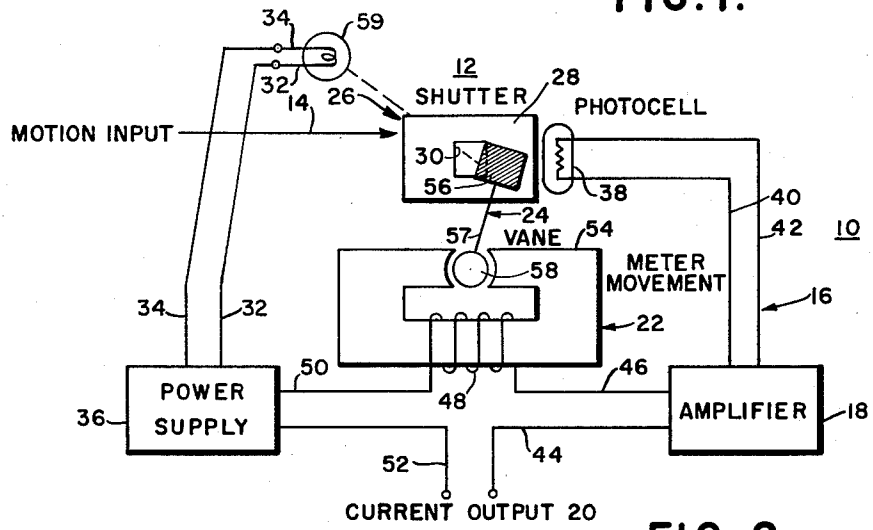

FIG. 2.

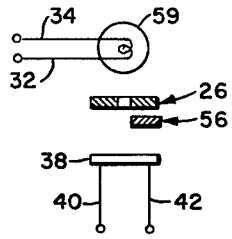

FIG. 3.

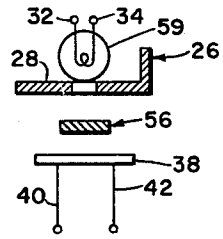

FIG. 4.

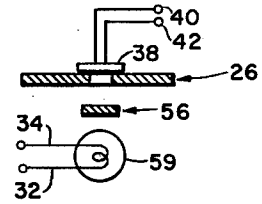

FIG. 5.

INVENTORS
Morton Sklaroff &
George Revesz

BY Herbert M. Rinch

ATTORNEY

May 31, 1966 M. SKLAROFF ETAL 3,254,225

PHOTOSENSITIVE MOTION-TO-CURRENT TRANSDUCERS

Filed March 26, 1962 2 Sheets-Sheet 2

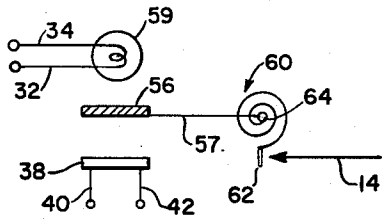

FIG. 6.

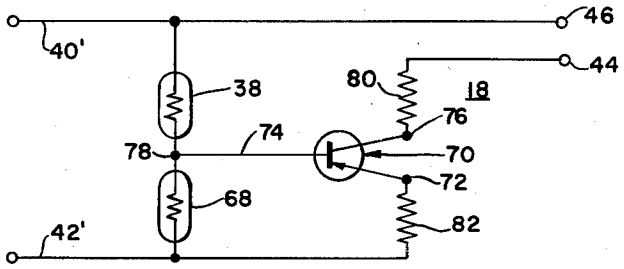

FIG. 7.

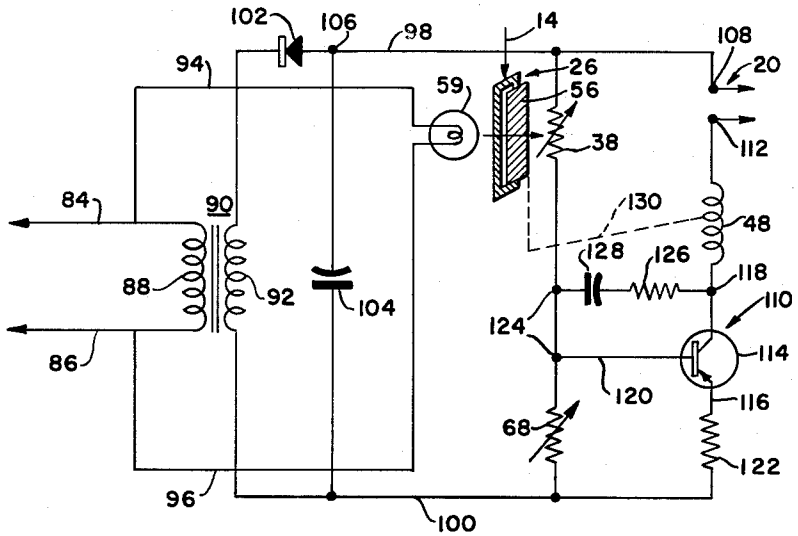

FIG. 8.

INVENTORS
Morton Sklaroff &
George Revesz

BY Herbert M. Birch

ATTORNEY

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3,254,225

PHOTOSENSITIVE MOTION-TO-CURRENT TRANSDUCERS

Morton Sklaroff, Philadelphia, and George Revesz, Bala Cynwyd, Pa., assignors to Robertshaw Controls Company, Richmond, Va., a corporation of Delaware

Filed Mar. 26, 1962, Ser. No. 182,357
31 Claims. (Cl. 250—231)

This invention relates to transducer means for producing an electric output current proportional to a mechanical input motion and more particularly, to a motion-to-current transducer of the servo-follower type.

It is, therefore, an object of this invention to provide a motion-to-current transducer of the servo-follower type.

Another object of this invention is to provide a motion-to-current transducer, wherein the motion sensing element comprises a photoelectric means.

Still another object of this invention is to provide a motion-to-current transducer of the servo-follower type having a current-to-motion feedback loop therein.

Still another object of this invention is to provide a motion-to-current transducer of the servo-follower type having a current-to-motion feedback loop therein, wherein the stability of individual components within the said loop does not affect the stability of the system.

Yet another object of this invention is to provide a motion-to-current transducer of the servo-follower type wherein a photoelectric means is variably exposed to a light source in proportion to an input motion to control a current amplifier and provide an output current in response to the said input motion and a follow-up or feedback loop is energized in response to the said output current to cause the photoelectric means to be shielded from the said light source to negate the effect of the said input motion.

These and other objects of this invention will become more apparent with reference to the following specification and drawings which relate to several preferred embodiments of the invention.

In the drawings:

FIGURE 1 is a block diagram of the invention;

FIGURE 2 is a schematic, in partial block diagram, of the invention;

FIGURE 3 is a detail of one embodiment of the invention;

FIGURE 4 is a detail of another embodiment of the invention;

FIGURE 5 is a detail of another embodiment of the invention;

FIGURE 6 is a detail of still another embodiment of the invention;

FIGURE 7 is a detail of yet another embodiment of the invention; and

FIGURE 8 is a schematic diagram of the invention including the detail of FIGURE 7.

Referring in detail to the drawings, and more particularly to FIGURE 1, the motion-to-current transducer of the present invention is shown to comprise a servo-follower system **10**.

The servo-follower **10** comprises a first transducer **12** having a motion input **14** and a current output **16**, the said first transducer **12** being a motion-to-current transducer; a second or output transducer **18** of the current-to-current type having as its input the current output **16** of the first transducer and having a current output **20** which is also the current output for the entire servo system **10**; and a third or feedback transducer **22** of the current-to-motion type having the current output **20** of the system **10** as its input and having a motion output **24**, constrained to follow the motion input **14**, connected as a second motion input to the first transducer **12**.

Referring now to FIGURE 2, the first motion input **14** to the first motion-to-current transducer **12** is shown as controlling a moving shutter **26** in the first transducer **12** comprising a flat plate **28** having a rectangular opening **30** therein. The shutter **26** is interposed between a light source (not shown), energized via a pair of leads **32** and **34** by a power source **36**, and a photocell **38**. The current output **16** from the photocell **38** is fed through a pair of leads **40** and **42** to the input of a current amplifier comprising the second transducer **18** of the system **10**.

One side of the current output **20** from the second transducer **18** comprises a direct lead **44**. The other side of the current output **20** comprises a lead **46** connected from the amplifier **18** with one side of a meter coil or meter field winding **48**, the coil **48** being connected at its other end via a lead **50** in series with the power source **36** and thence via a lead **52** back to the other side of the said current output **20**. Thus, the current amplifier controls the amount of current through the meter coil **48** which can be supplied thereto by the power source **36**.

The meter coil or field winding **48** comprises the current input portion of the third or current-to-motion transducer **22** which is shown as comprising a meter movement including the meter coil **48** wound on a meter core **54** and a swinging vane **56** comprising the motion output **24** of the said third transducer. The vane **56** is of sufficient surface area to fully cover the opening **30** in the shutter **26** and thus mask same to prevent light from the light source (not shown) from impinging on the photocell. The vane **56** is mounted on the meter pointer **57**, which in turn is mounted on the meter armature **58**, immediately adjacent and parallel to the flat plate **28** of the shutter **30** and is movable relative thereto in response to the magnitude and direction of the current through the meter coil **48**.

Referring to FIGURE 3, the light source is shown as comprising a single bulb **59** connected across the leads **32** and **34** from the power source **36**. In this embodiment, the moving vane **56** is located between the moving shutter **26** and the photocell **38**. The photocell **38** and the light source **59** are stationary in this embodiment.

In the embodiment of FIGURE 4, the light source **59** may be mounted intergral with the flat plate **28** of the shutter **26** in registry with one side of the shutter opening **30** therein. The vane **56** is located between the other side of the shutter opening **30** and the photocell **38**, the photocell **38** being stationary in this embodiment. The light source **59**, being mounted integral with the shutter **26**, is thus made movable therewith.

The embodiment of FIGURE 5 is substantially the reverse of that shown in FIGURE 4, in that the photocell **38** is mounted integral with the flat plate **28** of the shutter **26** in registry with one side of the shutter opening **30** therein and the light source **59** is made stationary.

In the embodiment of FIGURE 6, the moving shutter is eliminated and the motion input **14** acts directly on the return spring **60** of the meter **22** (FIGURE 2) at the free end **62** thereof. The spring **60** is thus biased by the motion input **14** about a central pivot **64**, at which pivot the said spring **60** is connected to the meter pointer **57** comprising the supporting arm of the swinging vane **56** interposed between the light source **59** and the photocell **38**. Thus, a much simplified structure wherein both the light source **59** and the photocell **38** are stationary is provided by this embodiment.

While the stability of the follow-up system is generally not affected by component stability within the feedback loop, variation of photocell characteristics or the intensity of the light source as a result of ambient variations, supply voltage or aging will be adverse to system stability. This effect is compensated in the embodiment shown in FIGURE 7. The circuit shown comprises

a preferred embodiment of the current-to-current transducer or amplifier **18**. Instead of a single photocell **38**, however, a second compensating photocell **68** is connected in series therewith across the input and power leads **40'** and **42'** of the amplifier **18**. The active element of the current amplifier **18** comprises a transistor **70** having emitter, base and collector electrodes **72**, **74** and **76**, respectively. The base electrode **74** is directly connected to a node **78** comprising the central tap of a variable two-element voltage divider formed by the series connected photocells **38** and **68**, the node **78** being the common junction therebetween. The collector **76** is connected via a collector resistor **80** to one output terminal **44** while the line **40'** is connected directly to the other output terminal **46**. The emitter **72** is connected via an emitter resistor **82** to the line **42'**. It is to be noted that the input and power leads **40'** and **42'** of the amplifier **18** are similar in function to the leads **40** and **42** of FIGURE 2 although not identical thereto as regards their circuit connections.

A complete schematic of an embodiment of the invention including a compensating circuit similar to that of FIGURE 7 and the embodiment of FIGURE 3 is shown in FIGURE 8.

While the light source **59**, the shutter **26**, the motion input **14**, the vane **56**, the first photocell **38**, the second or compensating photocell **68**, the meter coil **48** and the current output terminals **20** all bear the same numerals as defined in the foregoing embodiments, the remaining elements of FIGURE 8 will bear new numerals.

Referring now in detail to FIGURE 8, power is brought into the circuit via leads **84** and **86** from a source (not shown) to the primary **88** of a transformer **90**, the transformer **90** having a secondary **92**.

The light source **59** is energized directly from the primary circuit of the transformer **90** via leads **94** and **96** connected, respectively, from the leads **84** and **86** to opposite sides of the light source **59**.

The remainder of the system is powered via the secondary **92** having a first common power lead **98** and a second common power lead **100** extending therefrom on opposite ends thereof. The first power lead **98** includes a half-wave rectifier **102** adjacent the secondary winding **92** and poled for current flow into that end of the said winding. A smoothing capacitor **104** is provided in a shunt branch across the power leads **98** and **100** which engages the first lead **98** at a junction **106** on the off-side of the rectifier **102** with respect to the secondary **92**.

The first power lead **98** extends from the said off-side of the rectifier **102** to one side **108** of the current output terminals **20**. The second power lead **100** is connected through the emitter-collector circuit of a transistor current amplifier **110** (equivalent to the current-to-current transducer **18** of FIGURES 1 and 2) and the meter coil **48**, in series with the said emitter-collector circuit, to the other side **112** of the current output terminals **20**.

The transistor amplifier **110** comprises a single transistor **114** having emitter, collector and base terminals **116**, **118** and **120**, respectively, with the emitter-collector circuit thereof comprising an emitter resistor **122** connected from the second power lead **100** to the emitter **116** and thence through the said collector **118** which is connected in series with the meter coil **48**.

The first or sensor photocell **38** is shown (as in FIGURE 3) in proper position with the shutter **26** and moving vane **56** to receive light variations therethrough from the light source **59**. The sensor photocell **38** and the second or compensating photocell **68** are connected in series as a shunt branch between the first and second power leads **98** and **100**, respectively, and form a variable two element voltage divider having a center node or tap **124**.

The base electrode **120** of the transistor **114** in the current amplifier **110** is connected directly to the center node **124** of the said voltage divider and the collector electrode **118** is also connected thereto through an R-C load circuit comprising a series connected resistance **126** and capacitance **128**.

As indicated by dotted lines, a mechanical linkage **130** is provided between the meter coil **48** and the moving shutter **56** to indicate that the shutter **56** is, in fact, positioned in response to current flow in the meter coil **48**.

Operation

In general operation of the motion-to-current transducer system **10**, referring to FIGURE 1, a motion input **14** is transduced to a proportional current output **16** by the motion-to-current transducer **12** and the current output **16** is amplified by the current-to-current transducer or current amplifier **18** to produce an output current at the current output terminals **20** proportional to the original input motion at the motion input **14**. The motion-to-current transducer system **10** is stabilized by a feedback motion generated by a current-to-motion transducer **22** which produces a motion output **24** acting to nullify the effect on the system of the motion input **14**. Thus, a servo-follower action is achieved in the system **10** and the output current at the terminals **20** may be used for any desired control purpose dependent on the initial motion input **14**.

Referring now to FIGURE 2, the motion input **14** is applied directly to the shutter **26** whereby more or less illumination from the light source (not shown) is permitted to pass through the shutter opening **30** and impinge upon the photocell **38**. At this point in the operation, the swinging or moving vane **56** is stationary and is initially positioned to effectively close the shutter opening **30**. The combination of the shutter **26** moving relative to the vane **56** and the light source **59** and photocell **38** controlled thereby comprise the first or motion-to-current transducer **12** of the system. The resultant change in one or more of the electric parameters of the photocell **38** in response to the motion input **14** acting on the shutter **26** results in a current output **16** in the leads **40** and **42** proportional to the motion input **14**.

The current output is thus amplified in the current amplifier or current-to-current transducer **18** whereby a current output is produced at the output terminals **20** via lead **44** on one side and through lead **46**, meter coil **48**, lead **50**, the power source **36** and lead **52** on the other.

The output current through the meter coil **48** of the meter or current-to-motion transducer **22** causes the vane **56** mounted on the meter pointer **57** and armature **58**, which combination comprises the motion output **24**, to follow the movement of the shutter as determined by the magnitude of the current output of the amplifier **18** to thereby progressively close the shutter opening **30** until the motion of the shutter **26** has been duplicated by the vane **56**, thus causing the current output at the output terminals **20** to go to some predetermined quiescent level. Of course, as long as motion of the shutter **26** continues in response, for example, to a time varying motion input **14**, the current output at **20** and the motion of the vane **56** will be constrained to follow the shutter movement both electrically and mechanically, respectively.

With respect to the operation of the embodiments of FIGURES 3, 4 and 5, in each embodiment the shutter **26** is moved in response to a motion input and the vane **56** is constrained to follow the movement of the shutter.

The embodiment of FIGURE 3, by having both a stationary light source **59** and stationary photocell **38**, provides for simplicity of manufacture of a motion-to-current transducer system of the present invention. In this embodiment, however, a photocell of relatively large sensitive area is necessary to sufficiently provide for the full range of shutter movement.

The embodiment of FIGURE 4, by having the light source **59** mounted on the shutter **26**, provides a system wherein a small light source **59** and a small and simple

shutter and vane configuration may be utilized. The photocell **38** must, again, necessarily have a relatively large sensitive area to provide for a full range of movement of both the shutter **26** and the light source **59**.

The embodiment of FIGURE 5, by having the photocell **38** mounted on the shutter **26**, provides a system wherein a small inexpensive photocell may be used and wherein a fixed light source providing easy replacement may be utilized.

In the embodiment of FIGURE 6, the motion input **14** changes the zero set point of the meter spring **60** by moving the free end **62** thereof about the pivot point **64** and thus, causes the meter pointer **57** to move the vane **56**, to expose the photocell **38** to the light source **59** in proportion to the motion input **14**. The feedback through the meter coil **48** (FIGURE 2) will constrain the vane **56** to retrace its initial motion and tend to shield the photocell **38** from the light source **59**. This embodiment achieves extreme and practical simplicity in that the need for a shutter is entirely obviated.

With respect to the embodiment of FIGURE 7, the photocell **38** varies in impedance with the position of the shutter and/or vane, depending on which of the embodiments of FIGURES 3, 4, 5 and 6 are used therewith, while the impedance of the second or compensating photocell **68** varies with ambient light variations. Thus, the bias applied to the base **74** of the transistor **70** in the amplifier or current-to-current transducer **18** is a function of the motion input to the system and the ambient conditions. The potential appearing at the node **78** is therefore a function of two variables but is actually representative only of the motion input since the second or compensating photocell **68** completely nullifies the effect of ambient conditions on the first or sensor photocell **38**.

The variation in bias at the node **78** varies the base bias and hence the emitter-to-collector impedance of the transistor **70** in proportion to the motion input to the system, whereby the current output at the terminals **44** and **46** is also regulated in proportion thereto.

In the more fully detailed schematic of FIGURE 8, the motion input **14** drives the shutter **26** to expose the sensor photocell **38** to the light source **59** via the shutter opening **30** and thereby vary the potential of the node **124** between the sensor photocell **38** and the compensating photocell **68**.

The resulting variation in bias to the base **120** of the transistor **114** in the current-to-current transducer **110** varies the emitter-to-collector impedance characteristics of the said transistor **114** in proportion to the motion input **14** to thereby vary the current output of the amplifier **110** through the meter coil **48** to one side **112** of the current output **20** in proportion to the said motion input. Any suitable device to be controlled may be connected across the leads **108** and **112** of the current output **20** and thus be controlled as a proportionate function of the input motion **14**.

The output current in the meter coil or field winding **48** initiates a motion feedback through the dotted line meter linkage **130** to thereby constrain the vane **56** to follow the motion of the shutter **26** as imparted thereto by the motion input **14**.

Several important advantages are achieved by use of the compensating photocell **68**, as shown in FIGURES 7 and 8 in addition to ambient light compensation. Since the compensating cell **68** is of the same material as the first or sensing photocell **38**, temperature compensation is provided thereby. Since photocell resistance is a function of the applied voltage, line voltage compensation is also provided.

As can be seen from the foregoing specification and drawings this invention provides a new and motion-to-current transducer of the servo-follower type having extremely good stability and being compensated for ambient conditions. This system produces currents at the output thereof proportional to motions applied to the input for the purpose of effecting controls on and/or in response to the cause of the said input motion. Examples of motion inputs would be such things as Bourdon Tube expansion in response to pressure changes or liquid or gas filled bulbs expanding in response to temperature changes.

It is to be understood that the embodiments shown and described herein are for the purpose of example only and are not intended to limit the scope of the appended claims.

What is claimed is:

1. A motion-to-current transducer system comprising a motion input means providing a motion input; a current output means providing a current output; a motion-to-current first transducer comprising a light source, a photoelectric means and movable means between said light source and said photoelectric means connected with said motion input means; a current-to-current second transducer connected at its input to the output of said first transducer and having its output comprising said current output means, and a current-to-motion third transducer connected at its input to said current output means and at its output to the input of said first transducer to thereby provide a feedback motion relative to the said motion input as a function of the said current output of said current output means; said movable means comprising a shutter means, a shutter opening in said shutter means, and a vane relatively movable with respect to said shutter means, the relative movement between said shutter means and said vane acting to vary the light transmitted from said light source to said photoelectric means through said shutter opening; wherein said system further includes a power source and wherein said photoelectric means comprises a sensor photocell controlled by said movable means and a compensating photocell continuously controlled in response to ambient conditions, said photocells being connected in series across said power source and having a common node therebetween comprising an output terminal of said first transducer.

2. The invention defined in claim **1**, wherein said light source and said photoelectric means are maintained stationary.

3. The invention defined in claim **1**, wherein said light source is mounted on one side of said shutter means for movement therewith in registry with said shutter means opening and said photoelectric means is maintained stationary adjacent the opposite side of said shutter means.

4. The invention defined in claim **1**, wherein said photoelectric means is mounted on one side of said shutter means for movement therewith in registry with said shutter means opening and said light source is maintained stationary adjacent the opposite side of said shutter means.

5. A motion-to-current transducer system comprising a motion input means providing a motion input; a current output means providing a current output; a motion-to-current first transducer comprising a light source, a photoelectric means and movable means between said light source and said photoelectric means connected with said motion input means; a current-to-current second transducer connected at its input to the output of said first transducer and having its output comprising said current output means, and a current-to-motion third transducer connected at its input to said current output means and at its output to the input of said first transducer to thereby provide a feedback motion relative to the said motion input as a function of the said current output of said current output means; said movable means comprising a shutter means, a shutter opening in said shutter, and a vane relatively movable with respect to said shutter means, the relative movement between said shutter means and said vane acting to vary the light transmitted from said light source to said photoelectric means through said shutter opening; and wherein said system includes a power source and wherein second transducer comprises a current amplifier including a transistor having base, collec-

tor and emitter terminals, said base terminal being connected to the output of said first transducer and the emitter-to-collector path of said transistor being connected across said power source and comprising the output circuit of said second transducer.

6. The invention defined in claim 5, wherein said light source and said photoelectric means are maintained stationary.

7. The invention defined in claim 5, wherein said light source is mounted on one side of said shutter means for movement therewith in registry with said shutter opening and said photoelectric means is maintained stationary adjacent the opposite side of said shutter means.

8. The invention defined in claim 5, wherein said photoelectric means is mounted on one side of said shutter means for movement therewith in registry with said shutter opening and said light source is maintained stationary adjacent the opposite side of said shutter means.

9. The invention defined in claim 5, wherein said photoelectric means comprises a sensor photocell controlled by said movable means and a compensating photocell continuously controlled in response to ambient conditions, said photocells being connected in series across said power source and having a common node therebetween comprising an output terminal of said first transducer.

10. A motion-to-current transducer system comprising a motion input meas providing a motion input; a current output means providing a current output; a motion-to-current first transducer comprising a light source, a photoelectric means and movable means between said light source and said photoelectric means connected with said motion input means; a current-to-current second transducer connected at its input to the output of said first transducer and having its output comprising said current output means, and a current-to-motion third transducer connected at its input to said current output means and at its output to the input of said first transducer to thereby provide a feedback motion relative to the said motion input as a function of said current output of said current output means; said movable means comprising a shutter means, a shutter opening in said shutter means, and a vane relatively movable with respect to said shutter means, the relative movement between said shutter means and said vane acting to vary the light transmitted from said light source to said photoelectric means through said shutter opening; and wherein said third transducer comprises a driving means proportionally energized by said current output, means connecting said shutter means with said motion input means, and means connecting said vane of said movable means with said driving means whereby said vane is constrained by said driving means in response to said current output to follow the movement of said shutter means imparted thereto by said motion input means, whereby the light transmitted from said light source to said photoelectric means is varied

11. The invention defined in claim 10, wherein said system further includes a power source and wherein said photoelectric means comprises a sensor photocell controlled by said movable means and a compensating photocell continuously controlled in response to ambient conditions, said photocells being connected in series across said power source and having a common node therebetween comprising an output terminal of said first transducer.

12. The invention defined in claim 10, wherein said driving means comprises a current responsive meter movement including an armature and said means connecting said vane with said driving means comprises a supporting arm mounted on said armature and extending to said vane to thereby mount said vane for movement with said armature.

13. A motion-to-current transducer system comprising a motion input means providing a motion input; a current output means providing a current output; a motion-to-current first transducer comprising a light source, a photoelectric means and movable means between said light source and said photoelectric means connected with said motion input means; a current-to-current second transducer connected at its input to the output of said first transducer and having its output comprising said current output means, and a current-to-motion third transducer connected at its input to said current output means and at its output to the input of said first transducer to thereby provide a feedback motion relative to the said motion input as a function of the said current output of said current output means; said movable means comprising a shutter means, a shutter opening in said shutter, and a vane relatively movable with respect to said shutter means, the relative movement between said shutter means and said vane acting to vary the light transmitted from said light source to said photoelectric means through said shutter opening; and wherein said second transducer comprises a current amplifier including a transistor having base, collector and emitter terminals, said base terminal being connected to the output of said first transducer and the emitter-to-collector path of said transistor being connected across said power source and comprising the output circuit of said second transducer; and wherein said third transducer comprises a driving means including a field winding connected in series with the said output circuit of said second transducer, whereby said driving means is proportionally energized in response to said current output and means connecting said driving means with said movable means.

14. The invention defined in claim 13, wherein said driving means further includes an armature and said means connecting said driving means with said movable means comprises means integral with said armature.

15. The invention defined in claim 10, wherein said light source and said photoelectric means are maintained stationary.

16. The invention defined in claim 10, wherein said light source is mounted on one side of said shutter means for movement therewith in registry with said shutter opening and said photoelectric means is maintained stationary adjacent the opposite side of said shutter means.

17. The invention defined in claim 10, wherein said photoelectric means is mounted on one side of said shutter means for movement therewith in registry with said shutter opening and said light source is maintained stationary adjacent the opposite side of said shutter means.

18. A motion-to-current transducer system comprising a power source, a motion input means providing a motion input, a current output means providing a current output, a motion-to-current first transducer connected with said motion input means and having an output, a current-to-current second transducer connected at its input to the output of said first transducer and having its output comprising said current output means, and a current-to-motion third transducer connected at its input to said current output means and at its output to the input of said first transducer to thereby provide a feedback motion at said motion input means as a function of said current output; wherein said system includes a power source; wherein said first transducer comprises a light source, a photoelectric means and movable means between said light source and said photoelectric means connected with said motion input means and movable thereby to variably exposed said photoelectric means to said light source as a function of said motion input to thereby cause said photoelectric means to produce a variable output as a function of said motion input, said movable means comprising a shutter means, a shutter opening in said shutter, and a vane relatively movable with respect to said shutter means, the relative movement between said shutter means and said vane acting to vary the light transmitted from said light source to photoelectric means through said shutter opening, said shutter means being connected with said motion input means; wherein said second transducer comprises a current amplifier includ-

ing a transistor having base, collector and emitter terminals, said base terminal being connected to the output of said first transducer and the emitter-to-collector path of said transistor being connected across said power source and comprising the output circuit of said second transducer; and wherein said third transducer comprises a driving means including a field winding connected in series with the said output circuit of said second transducer; whereby said driving means is proportionally energized in response to said current output, and means connecting said vane with said driving means whereby said vane is constrained by said driving means in response to said current output to follow the movement of said shutter means imparted thereto by said motion input means.

19. The invention defined in claim **18**, wherein said photoelectric means are maintained stationary.

20. The invention defined in claim **18**, wherein said light source is mounted on one side of said shutter means for movement therewith in registry with said shutter opening and said photoelectric means is maintained stationary adjacent the opposite side of said shutter means.

21. The invention defined in claim **18**, wherein said photoelectric means is mounted on one side of said shutter means for movement therewith in registry with said shutter opening and said light source is maintained stationary adjacent the opposite side of said shutter means.

22. The invention defined in claim **18**, wherein said photoelectric means comprises a sensor photocell controlled by said movable means and a compensating photocell continuously controlled in response to ambient conditions, said photocells being connected in series across said power source and having a common node therebetween comprising an output terminal of said first transducer.

23. The invention defined in claim **18**, wherein said driving means further includes an armature and said means connecting said vane with said driving means comprises a supporting arm mounted on said armature and extending to said vane to thereby mount said vane for movement with said armature.

24. A motion-to-current transducer system comprising a motion input means providing a motion input; a current output means providing a current output; a motion-to-current first transducer comprising a light source, a photoelectric means and movable means between said light source and said photoelectric means connected with said motion input means; a current-to-current second transducer connected at its input to the output of said first transducer and having its output comprising said current output means, and a current-to-motion third transducer connected at its input to said current output and at its output to the input of said first transducer to thereby provide a feedback motion at said motion input means as a function of the current output of said current output means; said movable means comprising a vane, a supporting arm for said vane connected at one end to said vane and having a pivotal mounting at the other end, a resilient means connected at one of its ends to said other end of said arm and biasing said arm in a given direction about the said pivotal mounting, the other end of said resilient means being coupled with said motion input means; wherein said system further includes a power source and wherein said photoelectric means comprises a sensor photocell controlled by said movable means and a compensating photocell continuously controlled in response to ambient conditions, said photocells being connected in series across said power source and having a common node therebetween comprising an output terminal of said transducer.

25. A motion-to-current transducer system comprising a motion input means providing a motion input; a current output means providing a current output; a motion-to-current first transducer comprising a light source, a photoelectric means and movable means between said light source and said photoelectric means connected with said motion input means; a current-to-current second transducer connected at its input to the output of said first transducer and having its output comprising said current output means, and a current-to-motion third transducer connected at its input to said current output means and at its output to the input of said first transducer to thereby provide a feedback motion relative to the said motion input as a function of the said current output of said current output means; said movable means comprising a shutter means, a shutter opening in said shutter, and a vane relatively movable with respect to said shutter means said shutter means and said vane being arranged to be connected one with said motion input means and one with the said output of said third transducer means whereby one will respond to said motion input and the other will respond to said feedback motion, the relative movement between said shutter means and said vane acting to vary the light transmitted from said light source to photoelectric means through said shutter opening.

26. The invention defined in claim **25**, wherein said light source and said photoelectric means are maintained stationary.

27. A motion-to-current transducer system comprising a motion input means providing a motion input; a current output means providing a current output; a motion-to-current first transducer comprising a light source, a photoelectric means and movable means between said light source and said photoelectric means connected with said motion input means; a current-to-current second transducer connected at its input to the output of said first transducer and having its output comprising said current output means, and a current-to-motion third transducer connected at its input to said current output means and at its output to the input of said first transducer to thereby provide a feedback motion relative to the said motion input as a function of the said current output of said current output means; said movable means comprising a shutter means, a shutter opening in said shutter means, and a vane relatively movable with respect to said shutter means, the relative movement between said shutter means and said vane acting to vary the light transmitted from said light source to photoelectric means through said shutter opening; and wherein said light source is mounted on one side of said shutter means for movement therewith in registry with said shutter opening and said photoelectric means is maintained stationary adjacent the opposite side of said shutter means.

28. A motion-to-current transducer system comprising a motion input means providing a motion input; a current output means providing a current output; a motion-to-current first transducer comprising a light source, a photoelectric means and movable means between said light source and said photoelectric means connected with said motion input means; a current-to-current second transducer connected at its input to the output of said first transducer and having its output comprising said current output means, and a current-to-motion third transducer connected at its input to said current output means and at its output to the input of said first transducer to thereby provide a feedback motion relative to the said motion input as a function of the said current output of said current output means; said movable means comprising a shutter means, a shutter opening in said shutter means, and a vane relatively movable with respect to said shutter means, the relative movement between said shutter means and said vane acting to vary the light transmitted from said light source to photoelectric means through said shutter opening; and wherein said photoelectric means is mounted on one side of said shutter means for movement therewith in registry with said shutter opening and said light source is maintained stationary adjacent the opposite side of said shutter means.

29. A motion-to-current transducer system comprising a motion input means providing a motion input; a cur-

rent output means providing a current output; a motion-to-current first transducer comprising a light source, a photoelectric means and movable means between said light source and said photoelectric means connected with said motion input means; a current-to-current second transducer connected at its input to the output of said first transducer and having its output comprising said current output means, and a current-to-motion third transducer connected at its input to said current output means and at its output to the input of said first transducer to thereby provide a feedback motion at said motion input means as a function of said current output of said current output means; wherein said third transducer comprises a driving means proportionally energized by said current output, said driving means comprising a current responsive meter movement including an armature, and means on said armature for connecting said driving means with said movable means; and wherein said movable means comprises a vane, a supporting arm for said vane connected at one end to said vane and having pivot means at the other end, and a resilient means connected at one of its ends to said other end of said arm and biasing said arm in a given direction about the pivot, the other end of said resilient means being coupled with said motion input means; and wherein said armature has an axis of rotation common with said pivot means on said supporting arm, and means on said armature for retaining said arm on said armature for motion therewith about said pivot.

30. In a system of the class described including a light source, a motion-to-current transducer comprising a light source, a photoelectric means and movable means between said light source and said photoelectric means connected with a motion input means providing a motion input, said movable means comprising a shutter means, a shutter opening in said shutter means, and a vane relatively movable with respect to said shutter means, the relative movement between said shutter means and said vane acting to vary the light transmitted from said light source to said photoelectric means through said shutter opening as a function of said motion input to thereby cause said photoelectric means to produce a variable output as a function of said motion input; wherein said light source is mounted on one side of said shutter means for movement therewith in registry with said shutter opening and said photoelectric means is maintained stationary adjacent the opposite side of said shutter means.

31. In a system of the class described including a light source, a motion-to-current transducer comprising a light source, a photoelectric means and movable means between said light source and said photoelectric means connected with a motion input means providing a motion input, said movable means comprising a shutter means, a shutter opening in said shutter means, and a vane relatively movable with respect to said shutter means, the relative movement between said shutter means and said vane acting to vary the light transmitted from said light source to said photoelectric means through said shutter opening as a function of said motion input to thereby cause said photoelectric means to produce a variable output as a function of said motion input; wherein said photoelectric means is mounted on one side of said shutter means for movement therewith in registry with said shutter opening and said light source is maintained stationary adjacent the opposite said of said shutter means.

References Cited by the Examiner

UNITED STATES PATENTS

1,523,149	1/1925	Wheeler	250—231 X
2,141,175	12/1938	Dawson	250—231 X
2,335,163	11/1943	Smith	250—231 X
2,978,954	4/1961	Watson	250—209 X
3,062,961	11/1962	Kalns et al.	250—209 X

RALPH G. NILSON, *Primary Examiner.*

WALTER STOLWEIN, *Examiner.*