(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
23 February 2006 (23.02.2006)

PCT

(10) International Publication Number
WO 2006/017941 A1

(51) International Patent Classification[7]: G01B 21/00, G01D 11/30, G02B 23/16, G01B 11/00

(21) International Application Number: PCT/CA2005/001275

(22) International Filing Date: 19 August 2005 (19.08.2005)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
10/922,118 19 August 2004 (19.08.2004) US

(71) Applicant (*for all designated States except US*): **PACIFIC TELESCOPE CORP.** [CA/CA]; 115-11960Hammersmith Way, Richmond, British Columbia V7A 5C9 (CA).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): **CHEN, Jack, Chin, Chuan** [CA/CA]; 7531 Lucas Road, Richmond, British Columbia V6Y 1G1 (CA). **LIU, Nai, Chang** [CA/CA]; 120-5700 Arcadia Road, Richmond, British Columbia V6X 2G9 (CA).

(74) Agent: **ROMAN, Michael, J.**; Clark Wilson LLP, 800-885 West Georgia Street, Vancouver, British Columbia V6C 3H1 (CA).

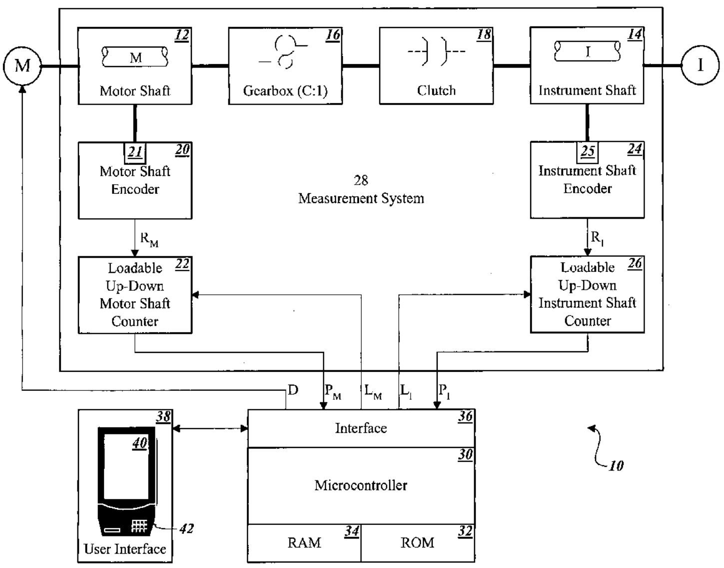
(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

[Continued on next page]

(54) Title: INSTRUMENT MOUNTING SYSTEM WITH DUAL ENCODERS



(57) Abstract: The present invention provides a way to measure the position of an instrument that is mounted on an instrument shaft within a clutched mounting system, the instrument shaft being driven through a reduction gearbox by a motor shaft. The position of the instrument is measured as a function of the position of the motor shaft and the position of the instrument shaft, the measurement of the position of the motor shaft providing greater precision than the position of the instrument shaft. Because the mounting system is clutched, it is necessary to check at intervals whether the measurement of the motor shaft position no longer accurately represents the position of the instrument, in which case the measurement of the motor shaft position is resynchronized to the measurement of the instrument shaft.

WO 2006/017941 A1

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

INSTRUMENT MOUNTING SYSTEM WITH DUAL ENCODERS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to mounting systems for aiming instruments, for example telescopes. More particularly, the invention relates to computerized mounting systems that permit both motorized and manual aiming.

2. Description of Related Art

Some instruments, such as telescopes, need to be aimed. There are a number of benefits that result from automating this aiming process. For example, an automatically aimed telescope might be programmed to target celestial objects that would be too difficult for a user to find. Furthermore, an automatically aimed telescope might be programmed to track such celestial objects over time, thus enabling time-lapse photography.

Generally, such automated systems are calibrated by first establishing the location of the instrument, for example in terms of latitude and longitude, and then aiming the instrument in a known direction, for example toward a well-known and easy-to-locate celestial object, such as the North Star, Polaris. Once the system has been calibrated, any aiming vector for the instrument may be calculated relative to the calibration coordinates.

To implement a set of axes with respect to which such aiming may be referenced and measured, the instrument is mounted for rotation upon one or more shafts ("instrument shafts") that correspond to each such axis respectively. In the most basic of these systems, each instrument shaft is directly coupled to a motor shaft, which is driven by a motor. This coupling is often implemented through a reduction gearbox to permit the use of a smaller motor. A typical gear reduction is 100:1.

The position of the instrument relative to the calibration coordinates can thus be calculated as a function of the rotation of each instrument shaft. It is well known in the art that such rotation can be measured using shaft encoders, for example optical shaft encoders like those manufactured by US Digital Corporation, 11100 NE 34th Circle, Vancouver, WA 98682 USA.

Although it is more direct to measure the rotation of an instrument shaft itself, there is a significant benefit if instead one measures the rotation of the directly coupled motor shaft. Because the motor shaft and the instrument shaft are typically coupled through a reduction gearbox, the motor shaft will rotate many times, for example 100 times, during each rotation of the instrument shaft. Therefore, when an encoder is used to measure rotation of the motor shaft instead of the instrument shaft, the result is a significant increase in precision, typically two orders of magnitude, with any loss in accuracy stemming mainly from whatever backlash might exist in the gearbox.

However, there is a serious shortcoming that results from the direct coupling of an instrument shaft to a motor shaft: the instrument can only be aimed under motor drive. If a user were to apply torque to the instrument shaft in order to manually aim the instrument, that torque would be transferred to the gearbox and the motor and might damage either or both.

One way to overcome this shortcoming has been to insert a normally-engaged clutch between the gearbox and the instrument shaft. When the motor is driven to apply a torque to the motor shaft, that torque is transferred through the gearbox and the clutch to the instrument shaft. However, when a user manually applies a torque to the instrument shaft, the clutch disengages to prevent the torque from acting upon the gearbox, the motor shaft, or the motor.

Although the introduction of this clutch overcomes the restriction against manually aiming the instrument, it does so at a cost. Because the motor shaft is no longer directly coupled to the instrument shaft, the rotation of the motor shaft is no longer an accurate representation of the position of the instrument shaft. In other words, if a user were to manually rotate the instrument shaft, the disengaged clutch would not urge the motor shaft to rotate and so the motor shaft would not rotate in synchronization with the instrument shaft and the instrument.

Conventionally, there have been three solutions to measuring the position of the instrument shaft in clutched systems. First, the encoder has been connected to measure the rotation of the instrument shaft, thereby assuring accuracy but surrendering precision, typically by two orders of magnitude. Second, the encoder has been replaced by a much more precise, and hence much more expensive encoder, which has been connected to measure the rotation of the instrument shaft, ensuring accuracy, precision, and expense. Third, the encoder has been connected to measure the rotation of the motor shaft, ensuring precision; however, to salvage accuracy, the instrument system has had to be recalibrated any time that a torque has been manually applied to the instrument shaft. Clearly, all of these solutions have shortcomings.

Accordingly, what is needed is a better way to measure the position of the instrument in a clutched system: a way that takes advantage of both the precision of motor shaft measurement and the accuracy of instrument shaft measurement.

SUMMARY OF THE INVENTION

The present invention is directed to this need.

According to one aspect of the present invention, there is provided an apparatus for measuring the position of an instrument, the apparatus comprising: a motor shaft adapted to receive torque from a motor; an instrument shaft adapted to mount the instrument for rotation; a linkage between the motor shaft and the instrument shaft, the linkage having alternative first and second operating modes, such that in the first operating mode, the instrument shaft is engaged with the motor shaft to rotate upon the urging of torque received from the motor shaft; and in the second operating mode, the instrument shaft is disengaged from the motor shaft and to rotate independently of the motor shaft; a motor shaft position detector ("MSP detector") to generate a motor shaft position signal ("MSP signal") responsive to the position of the motor shaft; an instrument shaft position detector ("ISP detector") to generate an instrument shaft position signal ("ISP signal") responsive to the position of the instrument shaft; and a controller coupled to receive the MSP signal from the MSP detector and to receive the ISP signal from the ISP detector and to measure the position of the instrument as a function of the MSP signal and the ISP signal.

The linkage may further comprise a clutch coupled between the instrument shaft and the motor shaft.

In one implementation, the MSP detector is synchronized to the ISP detector. For example, the MSP detector may be synchronized to the ISP detector in response to the ISP signal. The MSP detector may be synchronized to the ISP detector when the position of the instrument as a function of just the MSP signal differs from the position of the instrument as a function of just the ISP signal, such as differing by more than a threshold maximum error value. The threshold maximum error value might for example be equal to the absolute value of the maximum measured difference between the MSP signal and the ISP signal.

In one implementation, the function of the MSP signal and the ISP signal that measures the position of the instrument is defined as: if the MSP signal is in synchronization with the ISP signal, then the result of the function is the value represented by the MSP signal; else, the result of the function is the value represented by the ISP signal.

In one implementation, when the MSP signal is in synchronization with the ISP signal, then the MSP signal represents the position of the instrument more precisely than the ISP signal represents the position of the instrument.

In one implementation, the controller synchronizes the MSP detector. The MSP detector might comprise: a shaft encoder to generate a directional motor shaft rotation signal responsive to rotation of the motor shaft through a predetermined angle and an up-down counter coupled to the shaft encoder to receive motor shaft rotation signals and to tally the motor shaft rotation signals into the MSP signal. The up-down counter might be a loadable counter, such that the controller synchronizes the MSP detector by loading a synchronizing value into the up-down counter to replace the existing MSP signal. The synchronizing value might be a function of the ISP signal.

In one implementation, the linkage comprises a gearbox coupled between the motor shaft and the clutch and having a gear ratio, such that the function of the ISP signal used as a synchronizing value would be the product of the value represented by the ISP signal multiplied by the gear ratio.

In one implementation, there is also included a user interface coupled to the controller so as to receive information about the position of the instrument and to present information about the position of the instrument. There might also be included a motor adapted to apply torque to the motor shaft and to apply such torque in response to a drive signal generated by the controller. The controller might generate the drive signal in response to information received from the user interface and the result of the function of the MSP signal and the ISP signal that represents the position of the instrument.

According to another aspect of the present invention, there is provided a method for measuring the position of an instrument, comprising: mounting the instrument on an instrument shaft for rotation thereabout; linking the instrument shaft to a motor shaft adapted to receive torque from a motor, such that in a first operating mode, the instrument shaft is engaged with the motor shaft to rotate upon the urging of torque received from the motor shaft and in a second operating mode, the instrument shaft is disengaged from the motor shaft to rotate independently of the motor shaft; generating a motor shaft position signal ("MSP signal") responsive to the position of the motor shaft; generating an instrument shaft position signal ("ISP signal") responsive to the position of the instrument shaft; and measuring the position of the instrument as a function of the MSP signal and the ISP signal.

In one implementation, linking includes coupling a clutch between the instrument shaft and the motor shaft.

In one implementation, the method further includes synchronizing the MSP signal to the ISP signal. The synchronizing might be performed in response to the ISP signal, for example when the value represented by the MSP signal differs from the value represented by the ISP signal, for example differing from the value represented by the ISP signal by more than a threshold maximum error value. The threshold maximum error value might be equal to the absolute value of a historical maximum difference between the MSP signal and the ISP signal.

In one implementation, the function of the MSP signal and the ISP signal that measures the position of the instrument is defined as: if the MSP signal is in synchronization with the ISP signal, then the result of the function is the value represented by the MSP signal; else, the result of the function is the value represented by the ISP signal.

In one implementation, when the MSP signal is in synchronization with the ISP signal, then the MSP signal represents the position of the instrument more precisely than the ISP signal represents the position of the instrument.

In one implementation, measuring comprises synchronizing the MSP signal to the ISP signal.

In one implementation, generating an MSP signal responsive to the position of the motor shaft comprises: generating a directional motor shaft rotation signal responsive to rotation of the motor shaft through a predetermined angle; and counting the motor shaft rotation signals to produce the MSP signal. In this implementation, synchronizing the MSP signal includes replacing the count with a synchronizing value, which synchronizing value might be a function of the ISP signal.

In one implementation, linking includes creating mechanical advantage between the motor shaft and the clutch, the mechanical advantage being quantified by a mechanical advantage ratio. In this implementation, counting the motor shaft rotation signals to produce the MSP signal would include replacing the count with the product of the value represented by the ISP signal multiplied by the mechanical advantage ratio.

In one implementation, the method also includes presenting information about the position of the instrument on a user interface.

In one implementation, the method also includes applying torque to the motor shaft in response to a drive signal generated in response to measurement of position of the instrument as a function of the MSP signal and the ISP signal. Generating the drive signal might include generating the drive signal in response to receiving information from the user interface and resolving the function of the MSP signal and the ISP signal that represents the position of the instrument.

According to another aspect of the present invention, there is provided an instrument, comprising: means for mounting the instrument for rotation; means for mounting a motor, the motor mounting means being adapted to transmit torque received from the motor; means for linking the instrument mounting means to the motor mounting means, the linking means having first and second operating modes, such that in the first operating mode, the instrument mounting means is engaged with the motor mounting means to rotate upon the urging of torque received from the motor mounting means, and in the second operating mode, the instrument mounting means is disengaged from the motor mounting means to rotate independently of the motor mounting means; means for generating a motor mounting means position signal ("MMMP signal") responsive to the position of the motor mounting means; means for generating an instrument mounting means position signal ("IMMP signal") responsive to the position of the instrument mounting means; and means for measuring the position of the instrument as a function of the MMMP signal and the IMMP signal.

In one implementation, the linking means further comprises means for clutching the motor mounting means to the instrument mounting means.

In one implementation, the apparatus further includes means for synchronizing the MMMP signal to the IMMP signal. The synchronizing means might activate in response to the IMMP signal, for example when the value represented by the MMMP signal differs from the value represented by the IMMP signal, such as by more than a threshold maximum error value. The threshold maximum error value might be equal, for example, to the absolute value of the historical maximum difference measured between the MMMP signal and the IMMP signal.

In one implementation, the function of the MMMP signal and the IMMP signal that measures the position of the instrument is defined as: if the MMMP signal is in synchronization with the IMMP signal, then the result of the function is the value represented by the MMMP signal; else, the result of the function is the value represented by the instrument mounting means signal. When the MMMP signal is in synchronization with the IMMP signal, then the MMMP signal represents the position of the instrument more precisely than the IMMP signal represents the position of the instrument.

In one implementation, the measuring means comprises means for synchronizing the MMMP signal to the IMMP signal and the means for generating an MMMP signal responsive to the position of the motor mounting means comprises: means for generating a directional motor mounting means rotation signal responsive to rotation of the motor mounting means through a predetermined angle; and means for counting the motor mounting means rotation signals to produce the MMMP signal. The means for synchronizing the MMMP signal might include means for loading a synchronizing value into the counting means to replace the existing MMMP signal, a possible synchronizing value being for example the result of a function of the IMMP signal.

In one implementation, the linking means further includes means for providing mechanical advantage between the motor mounting means and the clutching means, the mechanical advantage means having a ratio of mechanical advantage, and thus the means for loading a value that is a function of the IMMP signal would include means for loading the product of the value represented by the IMMP signal multiplied by the gear ratio.

In one implementation, the apparatus further includes means for presenting information about the position of the instrument on a user interface.

In one implementation, the apparatus further includes means for applying torque to the motor mounting means in response to a drive signal generated by the measuring means, for example wherein the measuring means generates the drive signal in response to information received from the user interface and the result of the function of the MMMP signal and the IMMP signal.

According to yet another aspect of the present invention, there is provided a computer program embodied in a processor-readable medium for measuring the position of an instrument mounted on an instrument shaft for rotation thereabout, the instrument shaft being linked to a motor shaft adapted to receive torque from a motor such that in a first operating mode the instrument shaft is engaged with the motor shaft to rotate upon the urging of torque received from the motor shaft and in a second operating mode the instrument shaft is disengaged from the motor shaft and free to rotate independently of the motor shaft, the computer program comprising code segments that direct a processor to: generate a motor shaft position signal ("MSP signal") responsive to the position of the motor shaft; generate an instrument shaft position signal ("ISP signal") responsive to the position of the instrument shaft; and measure the position of the instrument as a function of the MSP signal and the ISP signal.

In one implementation, the computer program further comprises code segments that direct a processor to synchronize the MSP signal to the ISP signal, for example in response to the ISP signal, such as when the value represented by the MSP signal differs from the value represented by the ISP signal, including differing by more than a threshold maximum error value. The threshold maximum error value could be equal to the absolute value of the maximum measured difference between the MSP signal and the ISP signal.

In one implementation, the function of the MSP signal and the ISP signal is defined as: if the MSP signal is in synchronization with the ISP signal, then the result of the function is the value represented by the MSP signal; else, the result of the function is the value represented by the ISP signal.

In one implementation, the MSP signal generating code segments direct a processor to: generate a directional motor shaft rotation signal responsive to rotation of the motor shaft through a predetermined angle and tally the motor shaft rotation signals in a counter to produce the MSP signal.

In one implementation, the synchronization code segments direct a processor to load a synchronizing value into the counter to replace the existing MSP signal, for example to load a value that is a function of the ISP signal, such as the product of the value represented by the ISP signal multiplied by a mechanical advantage ratio between the motor shaft and the instrument shaft.

In one implementation, the computer program further includes code segments that direct a processor to present information about the position of the instrument on a user interface.

In one implementation, the computer program further includes code segments that direct a processor to generate a drive signal to command a motor to apply torque to the motor shaft in response to measurement of the position of the instrument as a function of the MSP signal and the ISP signal. The drive signal code segments might direct a processor to generate the drive signal in response to receiving information from the user interface and resolving the function of the MSP signal and the ISP signal that represents the position of the instrument.

According to still another aspect of the present invention, there is provided a computer data signal embodied in a carrier wave for measuring the position of an instrument mounted on an instrument shaft for rotation thereabout, the instrument shaft being linked to a motor shaft adapted to receive torque from a motor such that in a first operating mode the instrument shaft is engaged with the motor shaft to rotate upon the urging of torque received from the motor shaft and in a second operating mode the instrument shaft is disengaged from the motor shaft and free to rotate independently of the motor shaft, comprising code segments that direct a processor to: generate a motor shaft position signal ("MSP signal") responsive to the position of the motor shaft; generate an instrument shaft position signal ("ISP signal") responsive to the position of the instrument shaft; and measure the position of the instrument as a function of the MSP signal and the ISP signal.

In one implementation, the computer data signal further comprises code segments that direct a processor to synchronize the MSP signal to the ISP signal, for example in response to the ISP signal, such as when the value represented by the MSP signal differs from the value represented by the ISP signal, including differing by more than a threshold maximum error value. The threshold maximum error value could be equal to the absolute value of the maximum measured difference between the MSP signal and the ISP signal.

In one implementation, the function of the MSP signal and the ISP signal is defined as: if the MSP signal is in synchronization with the ISP signal, then the result of the function is the value represented by the MSP signal; else, the result of the function is the value represented by the ISP signal.

In one implementation, the MSP signal generating code segments direct a processor to: generate a directional motor shaft rotation signal responsive to rotation of the motor shaft through a predetermined angle and tally the motor shaft rotation signals in a counter to produce the MSP signal.

In one implementation, the synchronization code segments direct a processor to load a synchronizing value into the counter to replace the existing MSP signal, for example to load a value that is a function of the ISP signal, such as the product of the value represented by the ISP signal multiplied by a mechanical advantage ratio between the motor shaft and the instrument shaft.

In one implementation, the computer data signal further includes code segments that direct a processor to present information about the position of the instrument on a user interface.

In one implementation, the computer data signal further includes code segments that direct a processor to generate a drive signal to command a motor to apply torque to the motor shaft in response to measurement of the position of the instrument as a function of the MSP signal and the ISP signal. The drive signal code segments might direct a processor to generate the drive signal in response to receiving information from the user interface and resolving the function of the MSP signal and the ISP signal that represents the position of the instrument.

Further aspects and advantages of the present invention will become apparent upon considering the following drawings, description, and claims.

DESCRIPTION OF THE INVENTION

The invention will be more fully illustrated by the following detailed description of non-limiting specific embodiments in conjunction with the accompanying drawing figures. In the figures, similar components and/or features may have the same reference label. Further, various components of the same type may be distinguished by following the reference label with a second label that distinguishes among the similar components. If only the first reference label is identified in a particular passage of the detailed description, then that passage describes any one of the similar components having the same first reference label irrespective of the second reference label.

1. Brief Description of the Drawings

Figure 1 is a block diagram of an instrument mounting system with dual encoders, according to a first embodiment of the present invention.

Figure 2 is a block diagram of an instrument mounting system with dual encoders, according to a second embodiment of the present invention.

Figure 3 is a signal timing diagram, illustrating the operation of the first and second embodiments of the invention in a synchronized condition.

Figure 4 is a signal timing diagram, illustrating the operation of the first and second embodiments of the invention in an unsynchronized condition.

Figure 5 is a flowchart diagram of a basic synchronization process.

Figure 6 is a flowchart diagram of a more complicated synchronization process.

Figure 7 is a flowchart of a more streamlined synchronization process.

2. Detailed Description of Specific Embodiments

(a) Structure of Specific Embodiments

The structure of the invention will now be illustrated by way of non-limiting specific exemplary embodiments shown in the drawing figures and described in greater detail herein.

(i) First Embodiment

Figure 1 shows an instrument mounting system with dual encoders according to a first embodiment of the present invention, generally illustrated at ***10***. The mounting system ***10*** includes a motor shaft ***12*** configured to receive torque from a motor ***M*** and an instrument shaft ***14*** configured to apply torque to and receive torque from an instrument ***I***. The motor shaft ***12*** is coupled to the instrument shaft ***14*** through a gearbox ***16*** and a clutch ***18***. In essence, the clutch ***18*** and the gearbox ***16*** form two parts of a linkage between the motor shaft ***12*** and the instrument shaft ***14***, the linkage having alternative first and second operating modes, such that in the first operating mode, the instrument shaft ***14*** is engaged with the motor shaft ***12*** to rotate upon the urging of torque received from the motor shaft and in the second operating mode, the instrument shaft ***14*** is disengaged from the motor shaft ***12*** to rotate independently of the motor shaft ***12***.

The motor shaft ***12*** is also coupled to a motor shaft encoder ***20***, which generates an electrical motor shaft rotation signal R_M in response to the motor shaft ***12*** rotating through a predetermined angle. Also encoded in the motor shaft rotation signal R_M is whether the motor shaft ***12*** rotated clockwise or counterclockwise, so that the motor shaft rotation signal R_M is directional.

The motor shaft encoder ***20*** itself is conventional and in this embodiment is implemented using incremental position encoding and infrared sensing; however, those skilled in the art will appreciate that analogous alternatives exist, including absolute position encoding and magnetic, electrical and mechanical sensing.

In this embodiment, the infrared sensing is implemented using two model LTE-302-M light emitting diodes as infrared transmitters (not illustrated) and two model LTR-5576DP1 phototransistors as infrared receivers (not illustrated), all from the Lite-On Technology Corporation, 22F No. 392 Ruey Kuang Road, Neihu, Taipei 114, Taiwan, R.O.C. Each respective light emitting diode is optically coupled to a respective phototransistor along an optical path, the two optical paths being substantially parallel but not coincident. Each respective phototransistor generates a first electrical signal in response to detecting infrared radiation from its respective light emitting diode and to generate a second electrical signal in response to not detecting infrared radiation from its respective light emitting diode.

The two optical paths are intersected by a disc (not illustrated) that is coupled to the motor shaft ***12*** for rotation in synchronization therewith, such that the rotation of the disc is an analogue for the rotation of the motor shaft ***12***. The disc may either be coupled directly to the motor shaft ***12*** are else, as illustrated in ***Figure 1***, may be coupled to the motor shaft through a reduction gearbox, in this case a motor shaft encoder gearbox ***21***.

The disc has alternating opaque and transparent portions for alternately blocking and transmitting infrared radiation from a respective light emitting diode to its respective phototransistor. In this embodiment, the disc is customer-fabricated and opaque; the transparent portions are formed as holes that pierce the disc in a pattern conventional for incrementally encoding its angular position. Additionally, the direction of the disc's angular motion can be determined by the relative position of the two phototransistors in combination with whether the electrical signal generated by one phototransistor leads or alternatively lags the electrical signal generated by the other phototransistor.

It has been found that a motor shaft encoder ***20*** so implemented can measure the angular position of the motor shaft ***12*** to a typical resolution of two degrees if directly coupled to the motor shaft ***12*** and to a typical resolution of 0.72 arc seconds if coupled to the motor shaft ***12*** through a 10,000:1 reduction gearbox, such as the motor shaft encoder gearbox ***21***. Those skilled in the art will appreciate that including a reduction gearbox may introduce inaccuracies caused by backlash between gears.

The motor shaft encoder ***20*** is coupled to supply the motor shaft rotation signal $\boldsymbol{R_M}$ to a loadable, up-down motor shaft counter ***22***, so as to increment the motor shaft counter ***22*** whenever the motor shaft ***12*** rotates clockwise through the predetermined angle and to decrement the motor shaft counter ***22*** whenever the motor shaft ***12*** rotates counterclockwise through the predetermined angle.

Similarly, the instrument shaft ***14*** is coupled to an instrument shaft encoder ***24***, which generates an electrical instrument shaft rotation signal $\boldsymbol{R_I}$ in response to the instrument shaft ***14*** rotating through a predetermined angle. Also encoded in the electrical instrument shaft rotation signal $\boldsymbol{R_I}$ is whether the instrument shaft ***14*** rotated clockwise or counterclockwise, so that the instrument shaft rotation signal R_I is directional.

The instrument shaft encoder **24** itself is conventional and in this embodiment is similar to the motor shaft encoder **20**. It has been found that an instrument shaft encoder **24** so implemented can measure the angular position of the instrument shaft **14** to a typical resolution of two degrees if directly coupled to the instrument shaft **14** and to a typical resolution of 480 arc seconds if coupled to the instrument shaft **14** through a 15:1 reduction gearbox, such as an instrument shaft encoder gearbox **25**.

Those skilled in the art will appreciate that analogous shaft encoding alternatives exist, including absolute position encoding and magnetic, electrical and mechanical sensing.

The instrument shaft encoder **24** is coupled to supply the instrument shaft rotation signal R_I to a loadable up-down instrument shaft counter **26**, so as to increment the instrument shaft counter **24** whenever the instrument shaft **14** rotates clockwise through the predetermined angle and to decrement the instrument shaft counter **26** whenever the instrument shaft **14** rotates counterclockwise through the predetermined angle.

So configured, the motor shaft **12**, the instrument shaft **14**, the gearbox **16**, the clutch **18**, the motor shaft encoder **20**, the motor shaft counter **22**, the instrument shaft encoder ***24***, and the instrument shaft counter ***26*** form a measurement system ***28*** for the motor ***M*** and the instrument ***I***.

The mounting system ***10*** further includes a microcontroller ***30***, which is configured as is well-known in the art to interact with a read only memory (ROM ***32***), a random access memory (RAM ***34***), and a set of interface ports ***36***, for example serial ports and/or parallel ports. In this embodiment, it has been found that the PIC16C63A microcontroller from Microchip Technology Inc., 2355 West Chandler Blvd., Chandler, Arizona, USA 85224-6199 is satisfactory as the microcontroller ***30***.

The ROM ***32*** is a medium for storing codes that instruct the microcontroller ***30*** to provide the functionality of the present invention as well as the functionality of more conventional instrument mounting systems. The RAM ***34*** provides the microcontroller ***30*** with volatile storage registers for performing and storing the results of the binary operations that implement such functionality. The interface ports ***36*** enable the microcontroller ***30*** to communicate with the motor shaft counter ***22***, the instrument shaft counter ***26***, the motor ***M***, and a user interface ***38*** having for example a display ***40*** and a keypad ***42***, as will be discussed in more detail below with regard to operation. In general terms, codes stored in the ROM ***32*** instruct the microcontroller ***30*** to control the speed and direction of the motor ***M*** in response to user-commands submitted through the user interface ***38*** and the position of the motor shaft ***12*** and the instrument shaft ***14*** as represented by the states of the motor shaft counter ***22*** and the instrument shaft counter ***26*** respectively.

Although for ease of explanation the motor shaft counter ***22*** and the instrument shaft counter ***26*** have been illustrated as being discretely implemented in hardware, those skilled in the art will appreciate that either or both might alternatively be implemented in software or as a register in the microcontroller ***30***.

(ii) Second Embodiment

Figure 2 shows an instrument mounting system with dual encoders according to a second embodiment of the present invention, generally illustrated at ***10'***. The mounting system ***10'*** includes an altitude measurement system $\boldsymbol{28^{AL}}$ coupled between an instrument ***I'*** and an altitude motor $\boldsymbol{M^{AL}}$ and an azimuth measurement system $\boldsymbol{28^{AZ}}$ coupled between the instrument ***I'*** and an azimuth motor $\boldsymbol{M^{AZ}}$. Those skilled in the art will recognize that the invention would also be suitable for use with other mounting geometries, for example an equatorial mount with right ascension and declination axes. Although as illustrated in the second embodiment the axes of rotation are orthogonal, the invention would also be suitable for nonorthogonal applications.

The mounting system ***10'*** further includes a microcontroller ***30'***, which is configured as is well-known in the art to interact with a read only memory (ROM ***32'***), a random access memory (RAM ***34'***), and a set of interface ports ***36'***, for example serial ports and/or parallel ports.

The ROM ***32'*** is a medium for storing codes that instruct the microcontroller ***30'*** to provide the functionality of the present invention as well as the functionality of more conventional instrument mounting systems. The RAM ***34'*** provides the microcontroller ***30'*** with volatile storage registers for performing and storing the results of the binary operations that implement such functionality. The interface ports ***36'*** enable the microcontroller ***30'*** to communicate with the altitude measurement system 28^{AL}, the azimuth measurement system 28^{AZ}, the altitude motor M^{AL}, the azimuth motor M^{AZ}, and a user interface ***38'*** having for example a display ***40'*** and a keypad ***42'***, as will be discussed in more detail below with regard to operation. In general terms, codes stored in the ROM ***32'*** instruct the microcontroller ***30'*** to control the speed and direction of the altitude motor M^{AL} and the azimuth motor M^{AZ} in response to user-commands submitted through the user interface ***38'*** and the position of the instrument ***I'*** as represented by the states of the altitude measurement system 28^{AL} and the azimuth measurement system 28^{AZ}.

Those skilled in the art will easily appreciate that this embodiment is extensible to additional or alternative axes beyond altitude and azimuth, which two axes where specifically selected only for purposes of illustration.

(b) Operation of Specific Embodiments

With reference now to ***Figures 1 through 7,*** the operation of these specific embodiments of the invention will now be described.

(i) First Embodiment

(A) Calibration

As can be best understood with reference first to ***Figure 1,*** operation of the mounting system ***10*** begins with a user planting the motorized mounting system ***10*** in place, securing the instrument ***I*** on the instrument shaft ***14,*** and then beginning to calibrate the mounting system ***10*** by manually rotating the instrument shaft ***14*** until the instrument ***I*** is aimed at a predetermined reference point, for example the North Star, Polaris. Using the keypad ***42***, the user then instructs the microcontroller ***30*** to begin a calibration process, in which the current location and aiming vector of the instrument ***I*** define the origin of a coordinate system. During this calibration process, the microcontroller ***30*** resets the motor shaft counter ***22*** and the instrument shaft counter ***26***, causing each to be loaded with a count in the middle of its range, for example by applying respective load signals L_M and L_I to the counters' respective load terminals. During this calibration process, the microcontroller ***30*** also receives data defining the location of the instrument ***I***, such as latitude and longitude coordinates, for example as output supplied by a global positioning satellite system (not shown) or as user-input supplied by the user via the keypad ***42***.

(B) General Use

Once the calibration process has been completed, the measurement system ***28*** measures the location of the instrument ***I*** relative to the calibration origin coordinates. As the instrument shaft ***14*** rotates, either as a result of torque applied manually be the user or else as a result of torque applied by the motor ***M*** via the motor shaft ***12***, the gearbox ***16*** and the clutch ***18***, the instrument shaft encoder ***24*** generates an electrical instrument shaft rotation signal R_I every time that the instrument shaft ***14*** rotates through a predetermined angle, the instrument shaft rotation signal R_I further encoding whether such rotation was in the clockwise or else the counterclockwise direction.

The instrument shaft encoder ***24*** supplies the instrument shaft rotation signal R_I to the up-down instrument shaft counter ***26***, which increments the instrument shaft counter ***26*** whenever the instrument shaft ***14*** rotates clockwise through the predetermined angle and decrements the instrument shaft counter ***26*** whenever the instrument shaft ***14*** rotates counterclockwise through the predetermined angle, thus tallying the instrument shaft rotation signals R_I. The instrument shaft counter ***26*** provides its count to the microcontroller ***30*** as an electrical instrument shaft position signal P_I supplied to one of the interface ports ***36***. The instrument shaft position signal ***PI*** is a multi-bit signal, the least significant bit ("LSB") of which is designated as P_{I0}. In essence, the instrument shaft encoder ***24*** and the instrument shaft counter ***26*** combine to become an instrument shaft position detector and means for generating an instrument shaft position signal responsive to the position of the instrument shaft ***14***.

Similarly, as the motor ***M*** operates, rotating in a direction and at a speed in response to an electrical drive signal ***D*** from the microcontroller ***30***, it applies a torque to the motor shaft ***12***, urging the motor shaft ***12*** to rotate. The motor shaft encoder ***20*** generates an electrical motor shaft rotation signal R_M every time that the motor shaft ***12*** rotates through a predetermined angle, the motor shaft rotation signal R_M further encoding whether such rotation was in the clockwise or else the counterclockwise direction.

The motor shaft encoder ***20*** supplies the motor shaft rotation signal R_M to the up-down motor shaft counter ***22***, which increments the motor shaft counter ***22*** whenever the motor shaft ***12*** rotates clockwise through the predetermined angle and decrements the motor shaft counter ***22*** whenever the motor shaft ***12*** rotates counterclockwise through the predetermined angle, thus tallying the motor shaft rotation signals R_M. The motor shaft counter ***22*** provides its count to the microcontroller ***30*** as an electrical motor shaft position signal P_M supplied to one of the interface ports ***36***. The motor shaft position signal P_M is a multi-bit signal, the LSB of which is designated as P_{M0}. In essence, the motor shaft encoder ***20*** and the motor shaft counter ***22*** combine to become a motor shaft position detector and means for generating a motor shaft position signal responsive to the position of the motor shaft ***12***.

As can be best understood with reference to ***Figures 1 and 3***, it will be appreciated that so long as the motor shaft ***12*** and the instrument shaft ***14*** are directly engaged through the clutch ***18***, every time the instrument shaft ***14*** rotates through a predetermine angle, the motor shaft will have rotated through a multiple of that predetermined angle, the multiple being a constant equal to the gear ratio ***C***. Thus in this condition, for every period of the LSB P_{I0} in the instrument shaft counter ***26***, there will exist ***C*** periods of the LSB P_{M0} in the motor shaft counter ***22***. Therefore, the counts respectively stored in the instrument shaft counter ***26*** and the motor shaft counter ***22*** will both accurately represent the position of the instrument shaft ***14*** (and thus the instrument ***I***) relative to the calibration origin coordinates; however, the count stored in the motor shaft counter ***22*** will be ***C***-times more precise.

As can be best understood with reference to ***Figures 1 and 4***, it will be appreciated that the motor shaft position signal P_M will cease to accurately represent the position of the instrument ***I*** whenever the clutch ***18*** is disengaged such that the motor shaft ***12*** and the instrument shaft ***14*** are free to rotate independently. Thus, as the instrument shaft ***14*** rotates through a predetermine angle, for example in response to a manually applied torque, the motor shaft may remain stationary or may rotate through a different angle and even in a different direction, upon the urging of the motor ***M***. Thus in this condition, for every period of the LSB P_{I0} in the instrument shaft counter ***26***, there will not necessarily exist ***C*** periods of the LSB P_{M0} in the motor shaft counter ***22***; there may be more than ***C*** periods of the LSB P_{M0} in the motor shaft counter ***22*** or less than ***C*** periods, as is illustrated in ***Figure 4***.

Thus the microcontroller ***30*** can measure the position of the instrument ***I*** as a function of the motor shaft position signal P_M and the instrument shaft position signal P_I. If the motor shaft position signal P_M is in synchronization with the instrument shaft position signal P_I, then both such signals are accurate and the microcontroller ***30*** can resolve the function as the more precise shaft position signal P_M. If however, the motor shaft position signal P_M is not in synchronization with the instrument shaft position signal P_I, then only the latter is accurate and the microcontroller ***30*** can resolve the function as the less precise but accurate instrument position signal P_I.

After the motor shaft position signal P_M has ceased to accurately represent the position of the instrument ***I***, it is desirable to restore that accuracy by resynchronizing the motor shaft position signal P_M with the instrument shaft position signal P_I. This resynchronization is performed by the microcontroller ***30*** under the direction of program code stored in the ROM ***32,*** three alternatives of which ***50***, ***50'***, ***50"*** are illustrated in flowchart form in ***Figures 5 through 7*** respectively.

(C) Basic Synchronization

As can be best understood with reference to ***Figures 4 and 5,*** the first alternative program code ***50*** will be discussed now. In a first step ***52***, the microcontroller ***30*** is interrupted by a transition in the instrument shaft position signal P_I. As illustrated, that transition is a transition in the instrument shaft position signal P_I LSB P_{I0} from a low state to a high state; however, those skilled in the art will recognize that one might instead chose a transition from a high state to a low state, a transition from either state to the opposite state, or a transition of a different bit in the instrument shaft position signal $\boldsymbol{P_I}$. Alternatively, one might interrupt the microcontroller ***30*** with a signal from the instrument shaft encoder ***24***.

In a second step ***54***, the microcontroller ***30*** is directed to read the contents of the instrument shaft counter ***26*** as represented by the instrument shaft position signal $\boldsymbol{P_I}$ and in a third step ***56***, the microcontroller ***30*** is directed to read the contents of the motor shaft counter ***22*** as represented by the motor shaft position signal $\boldsymbol{P_M}$.

In a fourth step ***58***, the microcontroller ***30*** is directed to evaluate the difference between the product of the value represented by the instrument shaft position signal $\boldsymbol{P_I}$ and a constant equal to the gear ratio ***C***, as minuend, and the value represented by the motor shaft position signal $\boldsymbol{P_M}$, as subtrahend.

If the difference is not equal to zero, then motor shaft counter ***22*** is out of synchronization with the instrument shaft counter ***26***, and so in a fifth step ***60*** the microcontroller ***30*** is directed to issue a load signal $\boldsymbol{L_M}$ to the motor shaft counter ***22*** to cause it to store a value equal to the product of the value represented by the instrument shaft position signal $\boldsymbol{P_I}$ and the constant equal to the gear ratio ***C***. Finally, in a sixth step ***62***, the microcontroller ***30*** is directed to terminate execution of the first alternative program code ***50***.

Alternatively, if the difference evaluated in the fourth step ***58*** is equal to zero, then the motor shaft counter ***22*** is in synchronization with the instrument shaft counter ***26***, and so the microcontroller ***30*** is immediately directed at the sixth step ***62*** to terminate execution of the first alternative program code ***50***.

Those skilled in the art will recognize that various changes, modifications, additions and substitutions can be made to the first alternative program code ***50*** without departing from the principle and scope of the invention. For example, if the motor shaft encoder ***20*** and the instrument shaft encoder ***24*** have different resolutions, then the minuend would be the product of the value represented by the instrument shaft position signal P_I and a constant equal to the product of the gear ratio ***C*** and the ratio between the respective resolutions of the motor shaft encoder ***20*** and the instrument shaft encoder ***24***.

(D) Complex Synchronization

As can be best understood with reference to ***Figure 6,*** the second alternative program code ***50'*** will be discussed now. The second alternative program code ***50'*** implements the recognition that in real world operation it is unlikely that the difference will ever evaluate to zero and that therefore the motor shaft counter ***22*** may be resynchronized every time that the first alternative program code ***50*** is executed. Such regular resynchronization could result in disadvantages, for example an unnecessary loss of precision when the motor shaft counter ***22*** was still accurate.

To overcome the potential for such disadvantages, in the second alternative program code ***50'*** the fourth step ***58'*** has been modified. In the modified fourth step ***58'***, the absolute value of the difference is compared to a threshold maximum acceptable error E_{max}.

If the absolute value of the difference is less than maximum acceptable error E_{max}, then the microcontroller ***30*** is immediately directed at the sixth step ***62'*** to terminate execution of the second alternative program code ***50'***, because the motor shaft counter ***22*** is still essentially in synchronization with the instrument shaft counter ***26***.

Alternatively, if the absolute value of the difference is not less than maximum acceptable error E_{max}, then the motor shaft counter ***22*** is unacceptably out of synchronization with the instrument shaft counter ***26***, and so microcontroller ***30*** is first directed at the fifth step ***60'*** to resynchronize the motor shaft counter ***22***, after which the microcontroller ***30*** is directed at the sixth step ***62'*** to terminate execution of the second alternative program code ***50'***.

In one implementation, the threshold maximum acceptable error E_{max} is simply the historical maximum error that has been encountered since the mounting system ***10*** was last calibrated. In this implementation, after the fifth step ***60'***, the microcontroller ***30*** is directed at a seventh step ***64'*** to set the threshold maximum acceptable error E_{max} equal to the absolute value of the difference that triggered resynchronization.

(E) Streamlined Synchronization

As can be best understood with reference to ***Figure 7,*** the third alternative program code ***50"*** will be discussed now. The third alternative program code ***50"*** implements in a different way the recognition that in real world operation it is unlikely that the difference will ever evaluate to zero and that therefore the motor shaft counter ***22*** may be resynchronized every time that the first alternative program code ***50*** is executed. In the case of such regular resynchronization, there is little benefit in error testing at all and such testing has computational costs.

To overcome the potential for such disadvantages, in the third alternative program code ***50"*** the second step ***54, 54'***, third step ***56, 56'***, fourth step ***58, 58'***, and seventh step ***64'*** have been eliminated and only the first step ***52"***, fifth step ***60"*** and sixth step ***62"*** have been retained.

In the third alternative program code ***50"***, every time that the microcontroller ***30*** is interrupted by a transition in the instrument shaft position signal P_I at the first step ***52"***, then at the fifth step ***60"*** the microcontroller ***30*** is directed to issue a load signal L_M to the motor shaft counter ***22*** to cause it to store a value equal to the product of the value represented by the instrument shaft position signal P_I and the constant equal to the gear ratio ***C***. Finally, in a sixth step ***62"***, the microcontroller ***30*** is directed to terminate execution of the third alternative program code ***50"***.

(ii) Second Embodiment

As can be best understood with reference to ***Figures 2 through 6***, the operation of the second embodiment of the mounting system ***10'*** is similar to the operation of the first embodiment of the mounting system ***10***, except for the fact that in the second embodiment of the mounting system ***10'*** multiple axes of rotation are being monitored and controlled, as illustrated altitude and azimuth.

(c) Description Summary

Thus, it will be seen from the foregoing embodiments and examples that there has been described a way to measure the position of an instrument that is mounted on an instrument shaft within a clutched mounting system, the instrument shaft being driven through a reduction gearbox by a motor shaft. The position of the instrument is measured as a function of the position of the motor shaft and the position of the instrument shaft, the measurement of the position of the motor shaft providing greater precision than the position of the instrument shaft. Because the mounting system is clutched, it is necessary to check at intervals whether the measurement of the motor shaft position no longer accurately represents the position of the instrument, in which case the measurement of the motor shaft position is resynchronized to the measurement of the instrument shaft.

While specific embodiments of the invention have been described and illustrated, such embodiments should be considered illustrative of the invention only and not as limiting the invention as construed in accordance with the accompanying claims.

It will be understood by those skilled in the art that various changes, modifications, additions, and substitutions can be made to the foregoing embodiments without departing from the principle and scope of the invention expressed in the claims made herein.

For simplicity of illustration, the position of the motor shaft ***12*** has been described as being measured directly and the position of the instrument shaft ***14*** has been described as being measured either directly or indirectly through measurement of the motor shaft ***12***. However, those skilled in the art will appreciate that the position of either such shaft could also be measured indirectly by measurement of another part engaged to the shaft through the mechanism, taking into account gear ratios (***C*** - as illustrated in the specific embodiments) and other forms of mechanical advantage, and recognizing that a resynchronization is necessary after the part has been disengaged from the shaft. Thus, any mention in this document of measuring the position of a shaft should be read broadly to include measuring a part engaged, at least some of the time, to the shaft.

Again for simplicity of illustration, the motor shaft ***12*** and the instrument shaft ***14*** have been described as shafts; however, in many application other forms of rotating mechanisms could be substituted without departing from the principle and scope of the invention. For example, those skilled in the art will appreciate that a coupling, adapter, or receptacle might cooperate with or substitute for any such shaft.

Although as illustrated the mounting system ***10***, ***10'*** is controlled by a microcontroller ***30***, ***30'***, those skilled in the art will appreciate that other forms of control would also be suitable.

Although the microcontroller ***30***, ***30'*** and the user interface ***38***, ***38'*** might be hardwired to or located proximate to each other or to the measurement system ***28***, 28^{AL}, 28^{AZ}, the motor ***M***, M^{AL}, M^{AZ} and the instrument ***I***, ***I'***, neither such hardwiring nor such proximity is necessary. In some applications, wireless connection and/or remote location would be advantageous.

While the invention has been described as having particular application for telescopes, those skilled in the art will recognize it has wider application, for example for use with cameras, microscopes, microphones, antennas and other instruments and objects that involve aiming or targeting.

CLAIMS

WHAT IS CLAIMED IS:

1. An apparatus for measuring the position of an instrument, the apparatus comprising:

(a) a motor shaft adapted to receive torque from a motor;

(b) an instrument shaft adapted to mount the instrument for rotation,

(c) a linkage between the motor shaft and the instrument shaft, the linkage having alternative first and second operating modes, such that

(i) in the first operating mode, the instrument shaft is engaged with the motor shaft and operable to rotate upon the urging of torque received from the motor shaft; and

(ii) in the second operating mode, the instrument shaft is disengaged from the motor shaft and operable to rotate independently of the motor shaft;

(d) a motor shaft position detector ("MSP detector") operable to generate a motor shaft position signal ("MSP signal") responsive to the position of the motor shaft;

(e) an instrument shaft position detector ("ISP detector") operable to generate an instrument shaft position signal ("ISP signal") responsive to the position of the instrument shaft; and

(f) a controller coupled to receive the MSP signal from the MSP detector and to receive the ISP signal from the ISP detector and operable to measure the position of the instrument as a function of the MSP signal and the ISP signal.

2. An apparatus as claimed in Claim 1, wherein the linkage further comprises a clutch coupled between the instrument shaft and the motor shaft.

3. An apparatus as claimed in Claim 2, wherein the MSP detector is operable to be synchronized to the ISP detector.

4. An apparatus as claimed in Claim 3, wherein the MSP detector is operable to be synchronized to the ISP detector in response to the ISP signal.

5. An apparatus as claimed in Claim 3, wherein the MSP detector is operable to be synchronized to the ISP detector when the position of the instrument as a function of just the MSP signal differs from the position of the instrument as a function of just the ISP signal.

6. An apparatus as claimed in Claim 5, wherein the MSP detector is operable to be synchronized to the ISP detector when the position of the instrument as a function of the just MSP signal differs from the position of the instrument as a function of just the ISP signal by more than a threshold maximum error value.

7. An apparatus as claimed in Claim 6, wherein the threshold maximum error value is equal to the absolute value of the maximum measured difference between the MSP signal and the ISP signal.

8. An apparatus as claimed in Claim 6, wherein in the controller, the function of the MSP signal and the ISP signal that measures the position of the instrument is defined as:

if the MSP signal is in synchronization with the ISP signal, then the result of the function is the value represented by the MSP signal,

else, the result of the function is the value represented by the ISP signal.

9. An apparatus as claimed in Claim 8, wherein, when the MSP signal is in synchronization with the ISP signal, then the MSP signal represents the position of the instrument more precisely than the ISP signal represents the position of the instrument.

10. An apparatus as claimed in Claim 8, wherein the controller is operable to synchronize the MSP detector.

11. An apparatus as claimed in Claim 10, wherein the MSP detector comprises:

(a) a shaft encoder, operable to generate a directional motor shaft rotation signal responsive to rotation of the motor shaft through a predetermined angle; and

(b) an up-down counter coupled to the shaft encoder to receive motor shaft rotation signals and operable to tally the motor shaft rotation signals into the MSP signal.

12. An apparatus as claimed in Claim 11, wherein:

(a) the up-down counter is a loadable counter; and

(b) the controller is operable to synchronize the MSP detector by loading a synchronizing value into the up-down counter to replace the existing MSP signal.

13. An apparatus as claimed in Claim 12, wherein the synchronizing value is a function of the ISP signal.

14. An apparatus as claimed in Claim 13, wherein the linkage further comprises a gearbox coupled between the motor shaft and the clutch and having a gear ratio.

15. An apparatus as claimed in Claim 14, wherein the function of the ISP signal is the product of the value represented by the ISP signal multiplied by the gear ratio.

16. An apparatus as claimed in Claim 15, further comprising a user interface coupled to the controller so as to receive information about the position of the

instrument and operable to present information about the position of the instrument.

17. An apparatus as claimed in Claim 16, further comprising a motor adapted to apply torque to the motor shaft and operable to apply such torque in response to a drive signal generated by the controller.

18. An apparatus as claimed in Claim 17, wherein the controller generates the drive signal in response to information received from the user interface and the result of the function of the MSP signal and the ISP signal that represents the position of the instrument.

19. A method for measuring the position of an instrument, comprising:

(a) mounting the instrument on an instrument shaft for rotation thereabout;

(b) linking the instrument shaft to a motor shaft adapted to receive torque from a motor, such that:

(i) in a first operating mode, the instrument shaft is engaged with the motor shaft and operable to rotate upon the urging of torque received from the motor shaft; and

(ii) in a second operating mode, the instrument shaft is disengaged from the motor shaft and operable to rotate independently of the motor shaft;

(d) generating a motor shaft position signal ("MSP signal") responsive to the position of the motor shaft;

(e) generating an instrument shaft position signal ("ISP signal") responsive to the position of the instrument shaft; and

(f) measuring the position of the instrument as a function of the MSP signal and the ISP signal.

20. A method as claimed in Claim 19, wherein linking further comprises coupling a clutch between the instrument shaft and the motor shaft.

21. A method as claimed in Claim 20, further comprising synchronizing the MSP signal to the ISP signal.

22. A method as claimed in Claim 21, wherein synchronizing is performed in response to the ISP signal.

23. A method as claimed in Claim 21, wherein synchronizing is performed when the value represented by the MSP signal differs from the value represented by the ISP signal.

24. A method as claimed in Claim 23, wherein synchronizing is performed when the value represented by the MSP signal differs from the value represented by the ISP signal by more than a threshold maximum error value.

25. A method as claimed in Claim 23, wherein the threshold maximum error value is equal to the absolute value of the maximum measured difference between the MSP signal and the ISP signal.

26. A method as claimed in Claim 24, wherein the function of the MSP signal and the ISP signal that measures the position of the instrument is defined as:

if the MSP signal is in synchronization with the ISP signal, then the result of the function is the value represented by the MSP signal,

else, the result of the function is the value represented by the ISP signal.

27. A method as claimed in Claim 26, wherein, when the MSP signal is in synchronization with the ISP signal, then the MSP signal represents the position of the instrument more precisely than the ISP signal represents the position of the instrument.

28. A method as claimed in Claim 26, wherein measuring comprises synchronizing the MSP signal to the ISP signal.

29. A method as claimed in Claim 28, wherein generating an MSP signal responsive to the position of the motor shaft comprises:

(a) generating a directional motor shaft rotation signal responsive to rotation of the motor shaft through a predetermined angle; and

(b) counting the motor shaft rotation signals to produce the MSP signal.

30. A method as claimed in Claim 29, wherein synchronizing the MSP signal comprises replacing the count with a synchronizing value.

31. A method as claimed in Claim 30, wherein replacing the count comprises replacing the count with a value that is a function of the ISP signal.

32. A method as claimed in Claim 31, wherein linking further comprises creating mechanical advantage between the motor shaft and the clutch, the mechanical advantage being quantified by a mechanical advantage ratio.

33. A method as claimed in Claim 32, wherein counting comprises replacing the count with product of the value represented by the ISP signal multiplied by the mechanical advantage ratio.

34. A method as claimed in Claim 33, further comprising presenting information about the position of the instrument on a user interface.

35. A method as claimed in Claim 34, further comprising applying torque to the motor shaft in response to a drive signal generated in response to measurement of position of the instrument as a function of the MSP signal and the ISP signal.

36. A method as claimed in Claim 35, wherein generating the drive signal comprises generating the drive signal in response to receiving information from

the user interface and resolving the function of the MSP signal and the ISP signal that represents the position of the instrument.

37. An apparatus for measuring the position of an instrument, comprising:

(a) means for mounting the instrument for rotation;

(b) means for mounting a motor, the motor mounting means being adapted to transmit torque received from the motor;

(b) means for linking the instrument mounting means to the motor mounting means, the linking means having first and second operating modes, such that:

(i) in the first operating mode, the instrument mounting means is engaged with the motor mounting means and operable to rotate upon the urging of torque received from the motor mounting means; and

(ii) in the second operating mode, the instrument mounting means is disengaged from the motor mounting means and operable to rotate independently of the motor mounting means;

(d) means for generating a motor mounting means position signal ("MMMP signal") responsive to the position of the motor mounting means;

(e) means for generating an instrument mounting means position signal ("IMMP signal") responsive to the position of the instrument mounting means; and

(f) means for measuring the position of the instrument as a function of the MMMP signal and the IMMP signal.

38. An apparatus as claimed in Claim 37, wherein the linking means further comprises means for clutching the motor mounting means to the instrument mounting means.

39. An apparatus as claimed in Claim 38, further comprising means for synchronizing the MMMP signal to the IMMP signal.

40. An apparatus as claimed in Claim 39, wherein the synchronizing means activates in response to the IMMP signal.

41. An apparatus as claimed in Claim 39, wherein the synchronizing means activates when the value represented by the MMMP signal differs from the value represented by the IMMP signal.

42. An apparatus as claimed in Claim 41, wherein the synchronizing means activates when the value represented by the MMMP signal differs from the value represented by the IMMP signal by more than a threshold maximum error value.

43. An apparatus as claimed in Claim 42, wherein the threshold maximum error value is equal to the absolute value of the maximum measured difference between the MMMP signal and the IMMP signal.

44. An apparatus as claimed in Claim 42, wherein the function of the MMMP signal and the IMMP signal that measures the position of the instrument is defined as:

if the MMMP signal is in synchronization with the IMMP signal, then the result of the function is the value represented by the MMMP signal,

else, the result of the function is the value represented by the instrument mounting means signal.

45. An apparatus as claimed in Claim 44, wherein, when the MMMP signal is in synchronization with the IMMP signal, then the MMMP signal represents the position of the instrument more precisely than the IMMP signal represents the position of the instrument.

46. An apparatus as claimed in Claim 44, wherein the measuring means comprises means for synchronizing the MMMP signal to the IMMP signal.

47. An apparatus as claimed in Claim 46, wherein the means for generating an MMMP signal responsive to the position of the motor mounting means comprises:

(a) means for generating a directional motor mounting means rotation signal responsive to rotation of the motor mounting means through a predetermined angle; and

(b) means for counting the motor mounting means rotation signals to produce the MMMP signal.

48. An apparatus as claimed in Claim 47, wherein the means for synchronizing the MMMP signal comprises means for loading a synchronizing value into the counting means to replace the existing MMMP signal.

49. An apparatus as claimed in Claim 48, wherein the means for loading a synchronizing value comprises means for loading a value that is a function of the IMMP signal.

50. An apparatus as claimed in Claim 49, wherein the linking means further comprises means for providing mechanical advantage between the motor mounting means and the clutching means, the mechanical advantage means having a ratio of mechanical advantage.

51. An apparatus as claimed in Claim 50, wherein the means for loading a value that is a function of the IMMP signal comprises means for loading the product of the value represented by the IMMP signal multiplied by the gear ratio.

52. An apparatus as claimed in Claim 51, further comprising means for presenting information about the position of the instrument on a user interface.

53. An apparatus as claimed in Claim 52, further comprising means for applying torque to the motor mounting means in response to a drive signal generated by the measuring means.

54. An apparatus as claimed in Claim 53, wherein the measuring means generates the drive signal in response to information received from the user interface and the result of the function of the MMMP signal and the IMMP signal.

55. A computer program embodied in a processor-readable medium for measuring the position of an instrument mounted on an instrument shaft for rotation thereabout, the instrument shaft being linked to a motor shaft adapted to receive torque from a motor such that in a first operating mode the instrument shaft is engaged with the motor shaft to rotate upon the urging of torque received from the motor shaft and in a second operating mode the instrument shaft is disengaged from the motor shaft and free to rotate independently of the motor shaft, comprising code segments that direct a processor to:

(a) generate a motor shaft position signal ("MSP signal") responsive to the position of the motor shaft;

(b) generate an instrument shaft position signal ("ISP signal") responsive to the position of the instrument shaft; and

(c) measure the position of the instrument as a function of the MSP signal and the ISP signal.

56. A computer program as claimed in Claim 55, further comprising code segments that direct a processor to synchronize the MSP signal to the ISP signal.

57. A computer program as claimed in Claim 56, wherein the synchronization code segments direct a processor to synchronize the MSP signal to the ISP signal in response to the ISP signal.

58. A computer program as claimed in Claim 56, wherein the synchronization code segments direct a processor to synchronize the MSP signal to the ISP signal when the value represented by the MSP signal differs from the value represented by the ISP signal.

59. A computer program as claimed in Claim 58, wherein the synchronization code segments direct a processor to synchronize the MSP signal to the ISP signal when the value represented by the MSP signal differs from the value represented by the ISP signal by more than a threshold maximum error value.

60. A computer program as claimed in Claim 58, wherein the threshold maximum error value is equal to the absolute value of the maximum measured difference between the MSP signal and the ISP signal.

61. A computer program as claimed in Claim 59, wherein in the measurement code segments, the function of the MSP signal and the ISP signal is defined as:

if the MSP signal is in synchronization with the ISP signal, then the result of the function is the value represented by the MSP signal,

else, the result of the function is the value represented by the ISP signal.

62. A computer program as claimed in Claim 61, wherein the MSP signal generating code segments direct a processor to:

(a) generate a directional motor shaft rotation signal responsive to rotation of the motor shaft through a predetermined angle; and

(b) tally the motor shaft rotation signals in a counter to produce the MSP signal.

63. A computer program as claimed in Claim 62, wherein the synchronization code segments direct a processor to load a synchronizing value into the counter to replace the existing MSP signal.

64. A computer program as claimed in Claim 63, wherein the loading code segments direct a processor to load a value that is a function of the ISP signal.

65. A computer program as claimed in Claim 64, wherein the loading code segments direct a processor to load the product of the value represented by the

ISP signal multiplied by a mechanical advantage ratio between the motor shaft and the instrument shaft.

66. A computer program as claimed in Claim 65, further comprising code segments that direct a processor to present information about the position of the instrument on a user interface.

67. A computer program as claimed in Claim 66, further comprising code segments that direct a processor to generate a drive signal to command a motor to apply torque to the motor shaft in response to measurement of the position of the instrument as a function of the MSP signal and the ISP signal.

68. A computer program as claimed in Claim 67, wherein the drive signal code segments direct a processor to generate the drive signal in response to receiving information from the user interface and resolving the function of the MSP signal and the ISP signal that represents the position of the instrument.

69. A computer data signal embodied in a carrier wave for measuring the position of an instrument mounted on an instrument shaft for rotation thereabout, the instrument shaft being linked to a motor shaft adapted to receive torque from a motor such that in a first operating mode the instrument shaft is engaged with the motor shaft to rotate upon the urging of torque received from the motor shaft and in a second operating mode the instrument shaft is disengaged from the motor

shaft and free to rotate independently of the motor shaft, comprising code segments that direct a processor to:

(a) generate a motor shaft position signal ("MSP signal") responsive to the position of the motor shaft;

(b) generate an instrument shaft position signal ("ISP signal") responsive to the position of the instrument shaft; and

(c) measure the position of the instrument as a function of the MSP signal and the ISP signal.

70. A computer data signal as claimed in Claim 69, further comprising code segments that direct a processor to synchronize the MSP signal to the ISP signal.

71. A computer data signal as claimed in Claim 70, wherein the synchronization code segments direct a processor to synchronize the MSP signal to the ISP signal in response to the ISP signal.

72. A computer data signal as claimed in Claim 70, wherein the synchronization code segments direct a processor to synchronize the MSP signal to the ISP signal when the value represented by the MSP signal differs from the value represented by the ISP signal.

73. A computer data signal as claimed in Claim 72, wherein the synchronization code segments direct a processor to synchronize the MSP signal to the ISP signal when the value represented by the MSP signal differs from the value represented by the ISP signal by more than a threshold maximum error value.

74. A computer data signal as claimed in Claim 72, wherein the threshold maximum error value is equal to the absolute value of the maximum measured difference between the MSP signal and the ISP signal.

75. A computer data signal as claimed in Claim 73, wherein in the measurement code segments, the function of the MSP signal and the ISP signal is defined as:

if the MSP signal is in synchronization with the ISP signal, then the result of the function is the value represented by the MSP signal,

else, the result of the function is the value represented by the ISP signal.

76. A computer data signal as claimed in Claim 75, wherein the MSP signal generating code segments direct a processor to:

(a) generate a directional motor shaft rotation signal responsive to rotation of the motor shaft through a predetermined angle; and

(b) tally the motor shaft rotation signals in a counter to produce the MSP signal.

77. A computer data signal as claimed in Claim 76, wherein the synchronization code segments direct a processor to load a synchronizing value into the counter to replace the existing MSP signal.

78. A computer data signal as claimed in Claim 77, wherein the loading code segments direct a processor to load a value that is a function of the ISP signal.

79. A computer data signal as claimed in Claim 78, wherein the loading code segments direct a processor to load the product of the value represented by the ISP signal multiplied by a mechanical advantage ratio between the motor shaft and the instrument shaft.

80. A computer data signal as claimed in Claim 79, further comprising code segments that direct a processor to present information about the position of the instrument on a user interface.

81. A computer data signal as claimed in Claim 80, further comprising code segments that direct a processor to generate a drive signal to command a motor to apply torque to the motor shaft in response to measurement of the position of the instrument as a function of the MSP signal and the ISP signal.

82. A computer data signal as claimed in Claim 81, wherein the drive signal code segments direct the processor to generate the drive signal in response to

receiving information from the user interface and resolving the function of the MSP signal and the ISP signal that represents the position of the instrument.

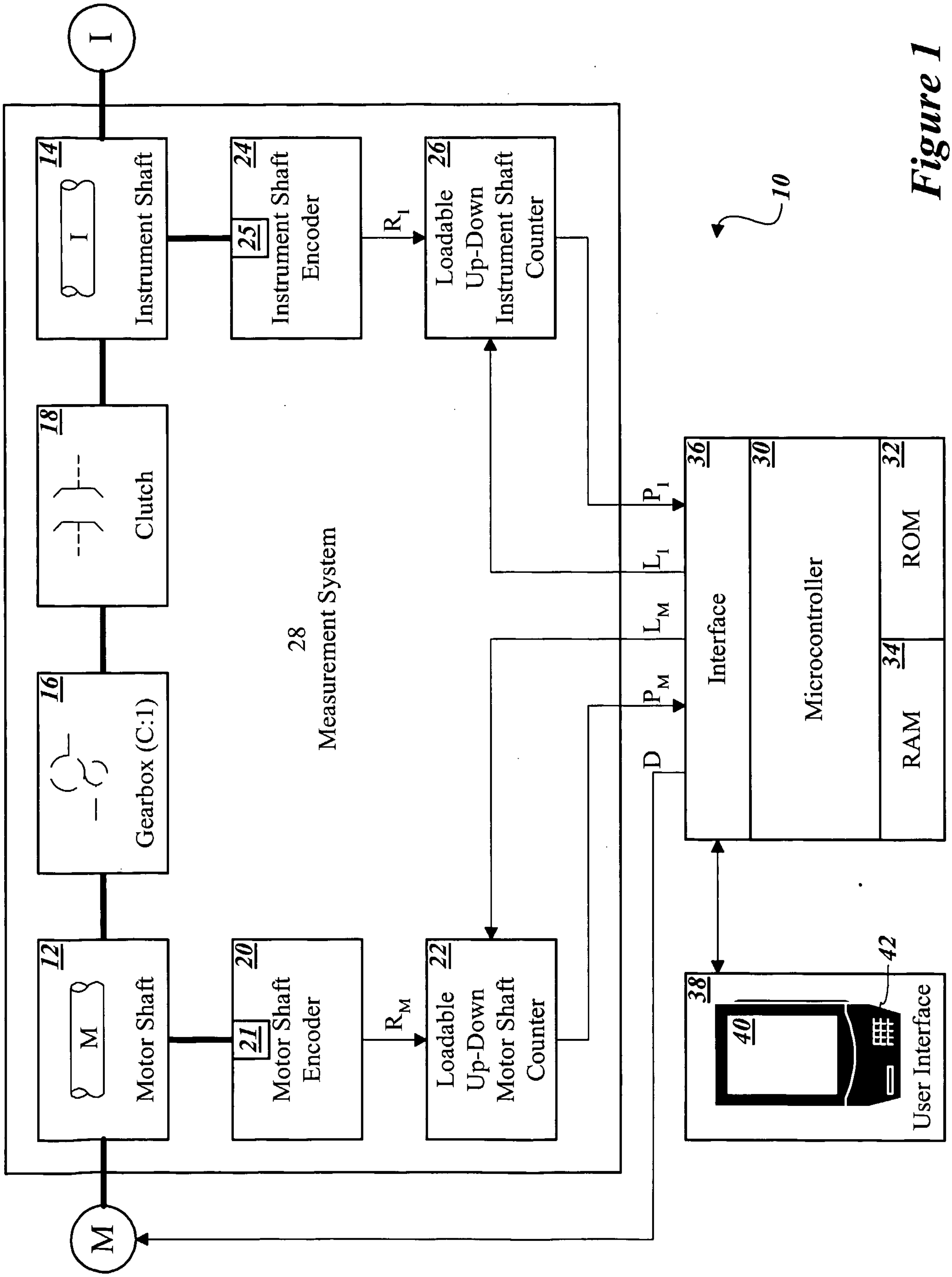

I
14
Instrument Shaft
24
25
Instrument Shaft Encoder
R_I
26
Loadable Up-Down Instrument Shaft Counter
18
Clutch
16
Gearbox (C:1)
28
Measurement System
12
M
Motor Shaft
20
21
Motor Shaft Encoder
R_M
22
Loadable Up-Down Motor Shaft Counter
M
P_I
L_I
L_M
P_M
D
36
Interface
30
Microcontroller
32
ROM
34
RAM
10
38
40
42
User Interface

Figure 1

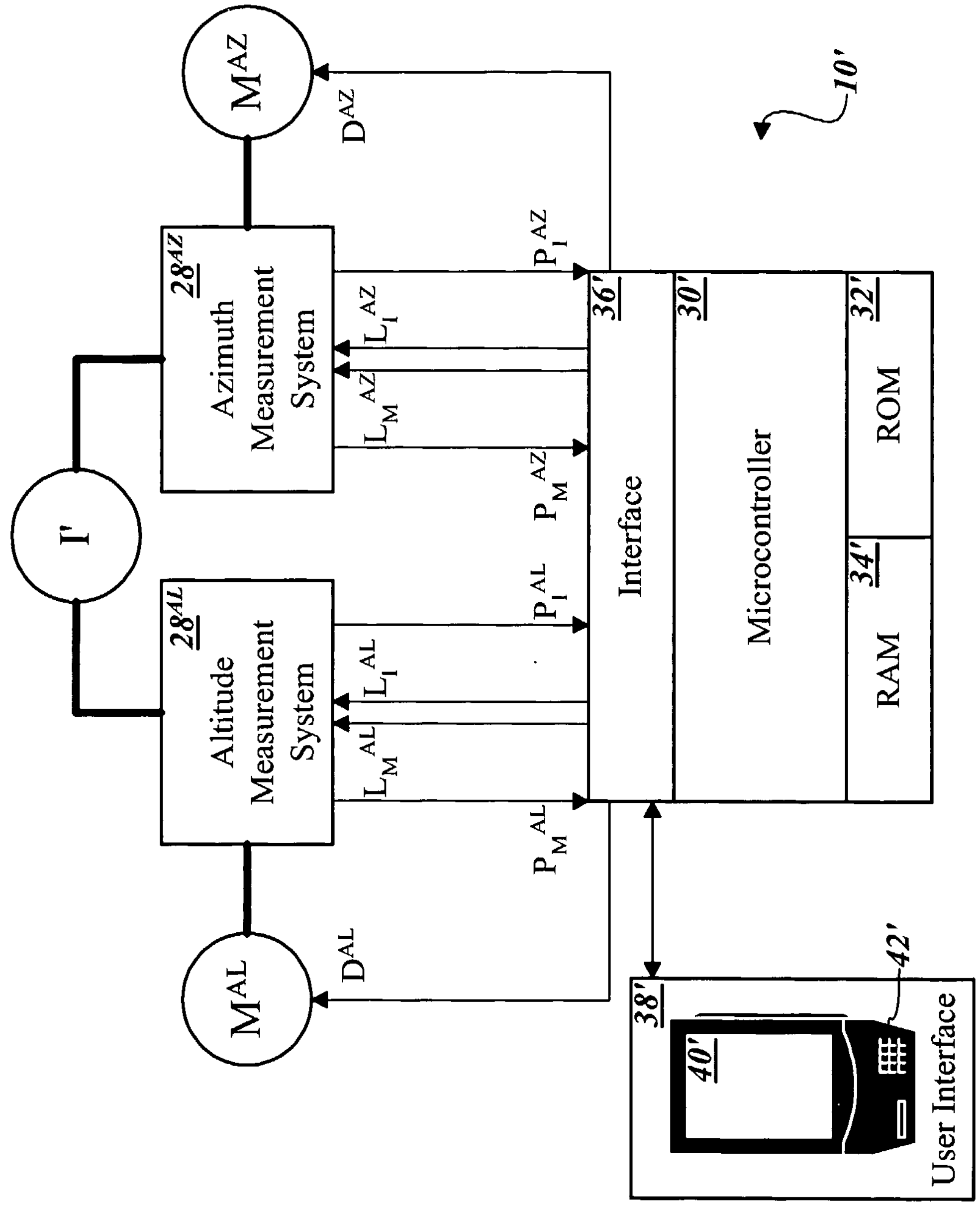

M^AZ
D^AZ
Azimuth Measurement System
28^AZ
Γ'
Altitude Measurement System
28^AL
M^AL
D^AL
P_I^AZ
L_I^AZ
L_M^AZ
P_M^AZ
P_I^AL
L_I^AL
L_M^AL
P_M^AL
Interface
36'
Microcontroller
30'
ROM
32'
RAM
34'
10'
User Interface
38'
40'
42'

Figure 2

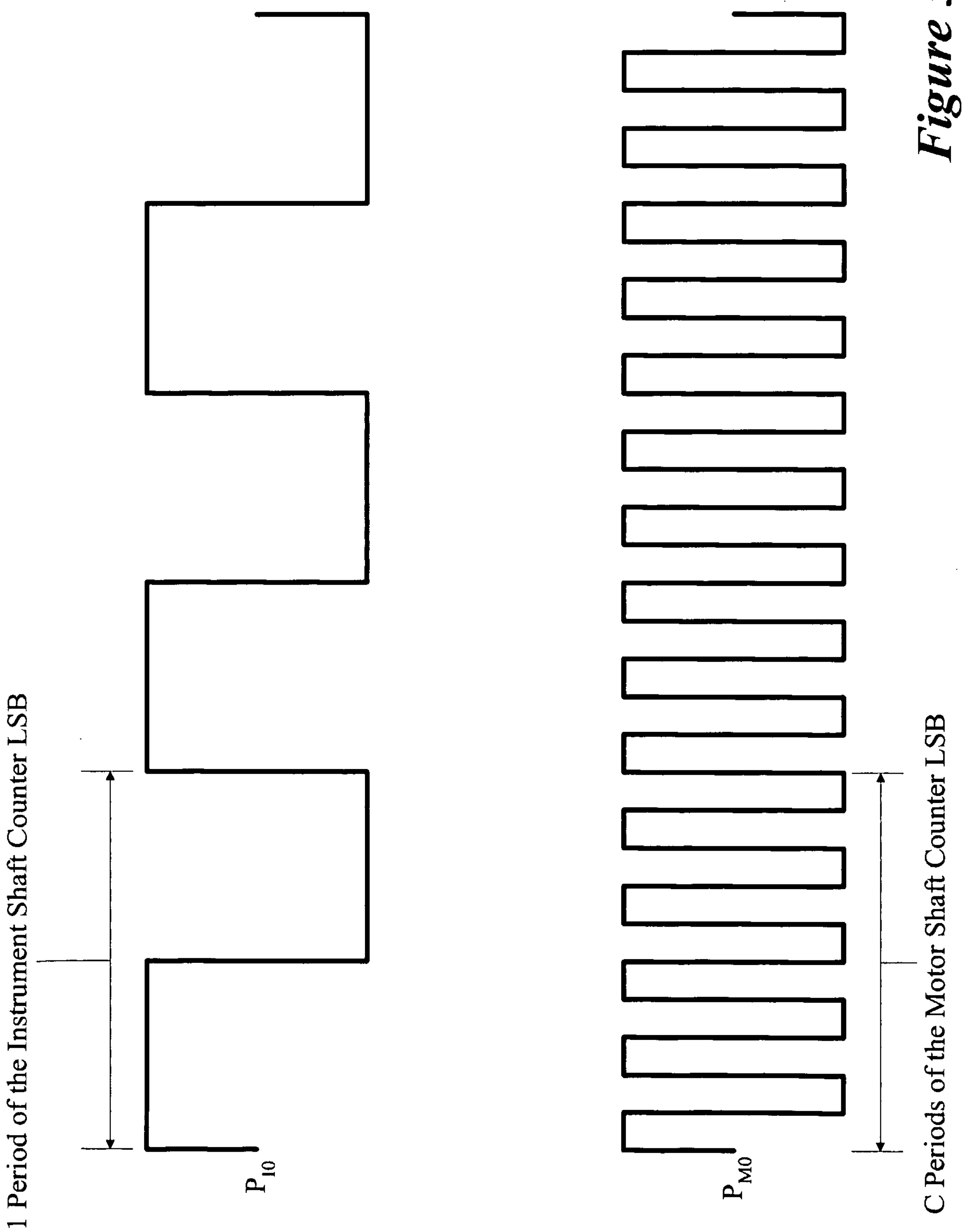

1 Period of the Instrument Shaft Counter LSB
P_{I0}
P_{M0}
C Periods of the Motor Shaft Counter LSB

Figure 3

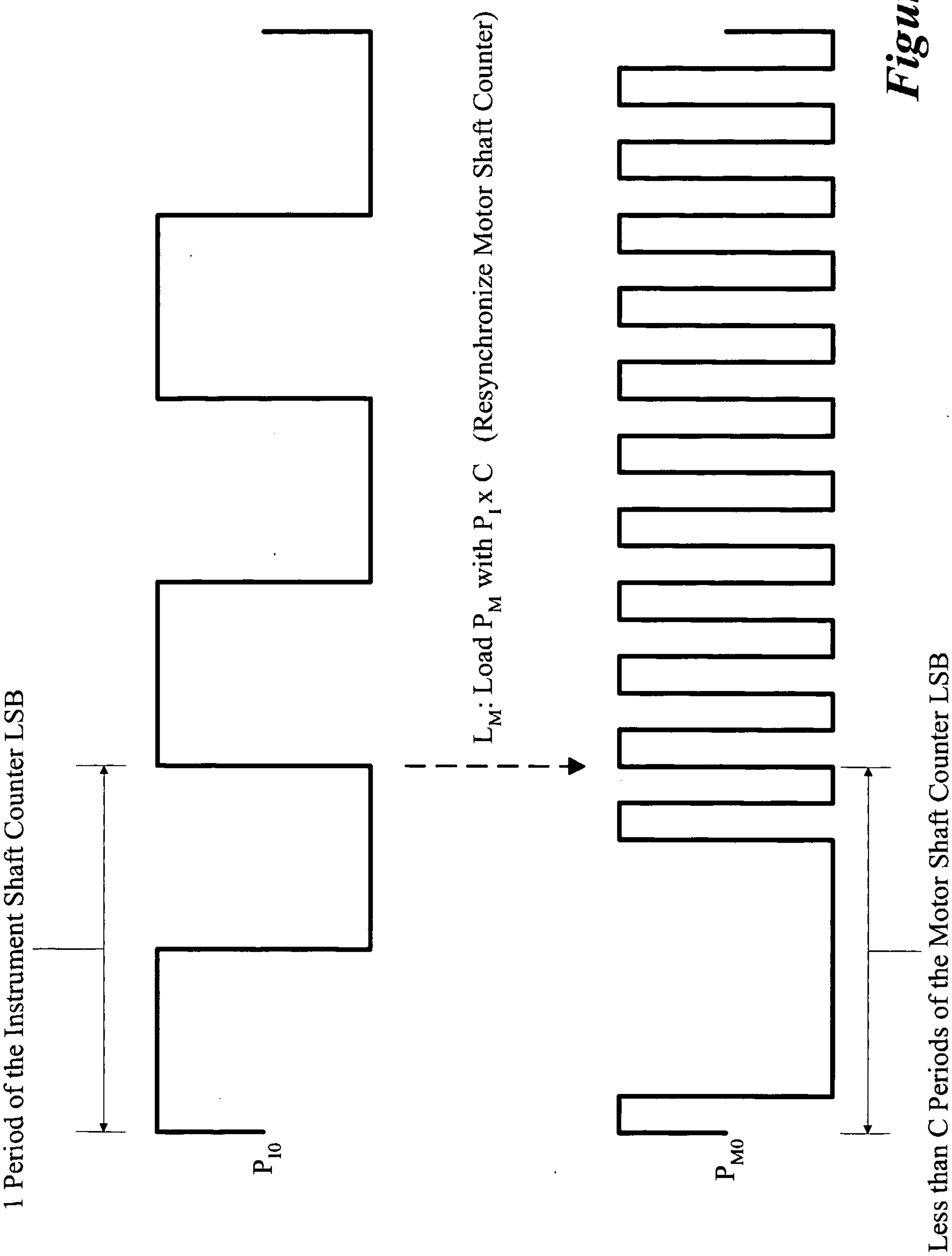

1 Period of the Instrument Shaft Counter LSB
P_I0
L_M: Load P_M with P_I x C (Resynchronize Motor Shaft Counter)
P_M0
Less than C Periods of the Motor Shaft Counter LSB

Figure 4

Figure 5

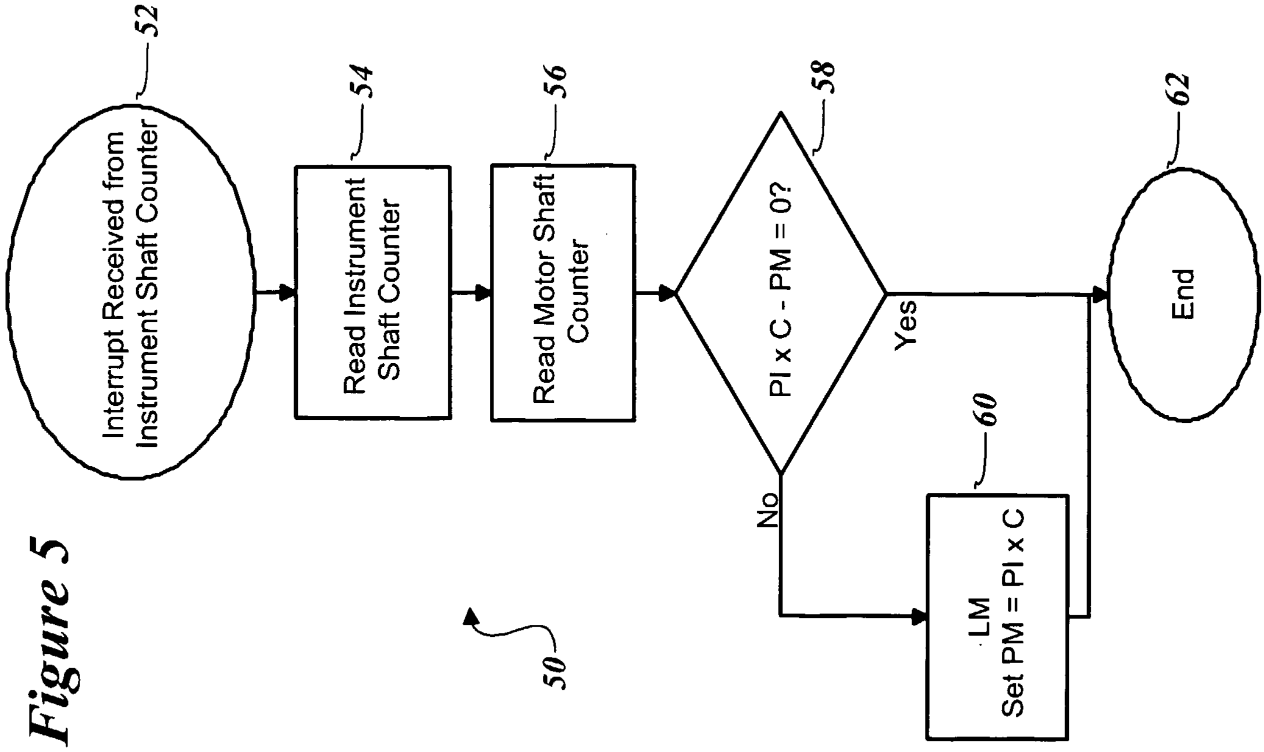
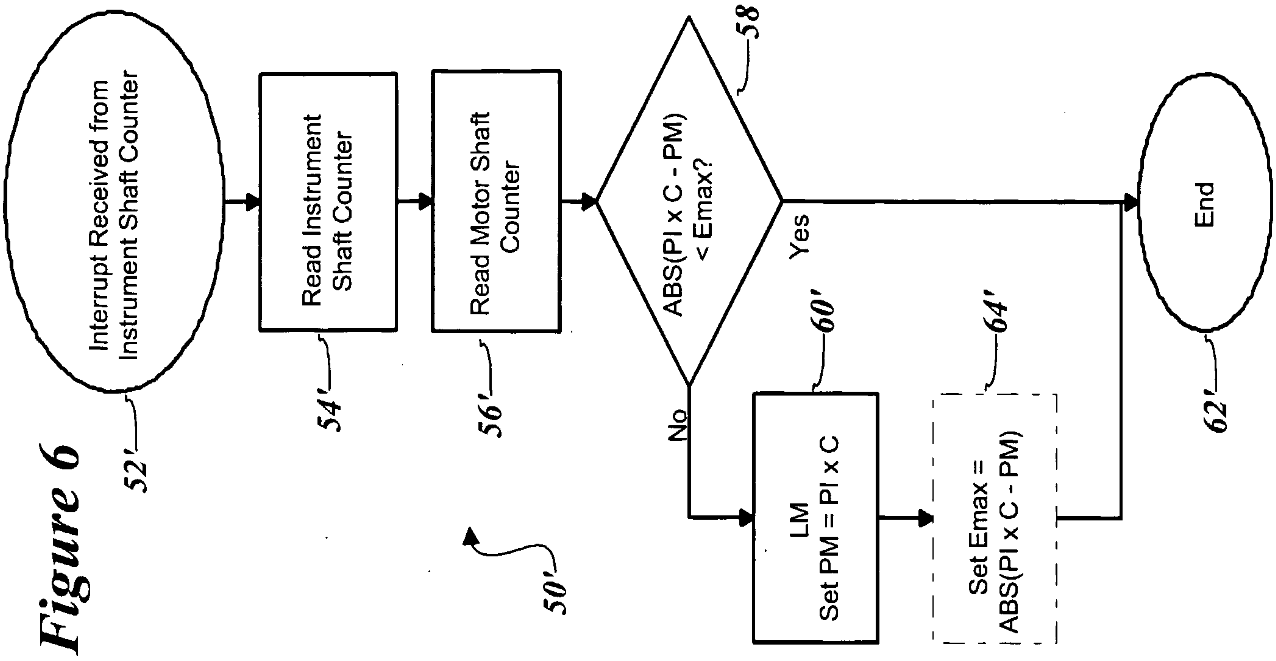


Figure 6



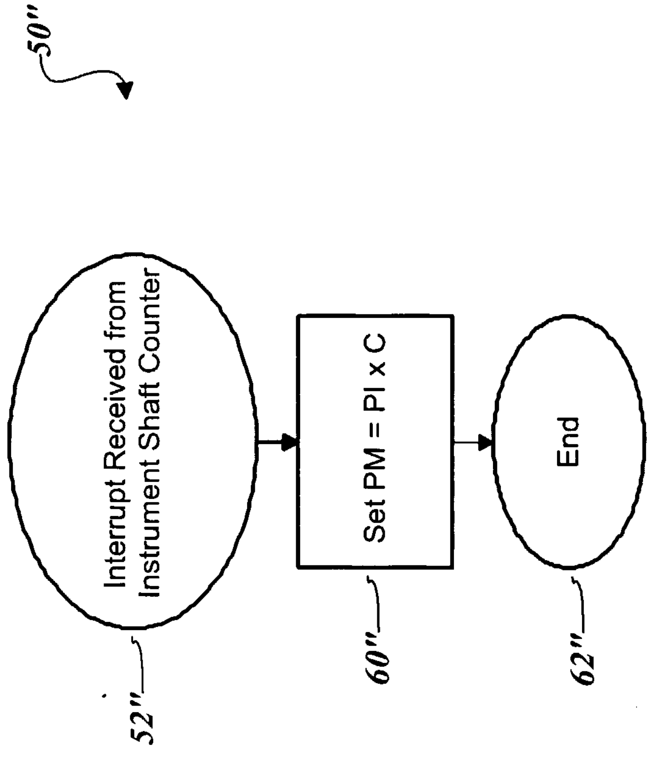

50''
Interrupt Received from Instrument Shaft Counter
52''
Set PM = PI x C
60''
End
62''

Figure 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2005/001275

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7): G01B 21/00, G01D 11/30, G02B 23/16, G01B 11/00

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(7): G01B, G01D, G02B
USCL: 0.73/1.75; 073/1.79; 318/11; 318/15; 318/590; 318/671; 318/652; 702/ 113; 702/150

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

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
Canadian Patent Database, USPTO, Delphion, Qweb, Esp@cenet, Internet
keywords: position, motor, instrument, shaft, detector, signal, synchronisation, linkage

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	**US5101143**, 31 March 1992 (31-03-1992), **EBA,** (see whole document)	1, 19, 37
Y		2-18, 20-36, 38-54
Y	**US3946298**, 23 March 1976 (23-03-1976), **VAN DE LOO**, (see whole document)	2-18, 20-36, 38-54

[ ] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 November 2005 (08-11-2005)	5 December 2005 (05-12-2005)

Name and mailing address of the ISA/CA	Authorized officer
Canadian Intellectual Property Office Place du Portage I, C114 - 1st Floor, Box PCT 50 Victoria Street Gatineau, Quebec K1A 0C9 Facsimile No.: 001(819)953-2476	Goran Basic (819) 953-2098

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of the first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons :

1. [ ] Claim Nos. :
because they relate to subject matter not required to be searched by this Authority, namely :

2. [ ] Claim Nos. :
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically :

3. [ ] Claim Nos. :
because they are dependant claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows :

(see extra sheet)

1. [ ] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. [X] As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claim Nos. :

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim Nos. :

Remark on Protest [ ] The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

[ ] The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

[ ] No protest accompanied the payment of additional search fees.

(continuation of Box No III)

Claims 1-54 are directed to an apparatus and a method for measuring the position of an instrument comprising a motor shaft, an instrument shaft, a linkage between the shafts and where a motor shaft position detector and an instrument shaft position detector generate corresponding shaft position signals and where a controller which receives those signals is able to measure the position of the instrument shaft.

Claims 55-82 are directed to a computer program and a signal for measuring the position of an instrument, the system comprising a motor shaft, an instrument shaft, a linkage between the shafts and where a code is directing a processor to generate a motor and an instrument shaft position signals and where processor measures the position of the instrument based on those signals.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/CA2005/001275

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
US5101143	31-03-1992	JP2610051B2 B2	14-05-1997
US3946298	23-03-1976	DE2443087 A1	18-12-1975