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(54) SENSOR AND RUNNING METHOD THEREOF FOR ABSOLUTE POSITION MEASURING THE DISPLACEMENT OF A CAPACITIVE GRATING

SENSOR UND BETRIEBSVERFAHREN ZUR ABSOLUTEN POSITIONSMESSUNG DER VERSchiebung EINES KAPAZITIVEN GITTERS

CAPTEUR ET SON PROCÉDÉ D'UTILISATION POUR EFFECTUER DES MESURES DE POSITION ABSOLUE DU DÉPLACEMENT D'UN RÉSEAU CAPACITIF

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Description

Field of the Invention

[0001] The present invention relates to the capacitive displacement measurement technology, and more particularly to an absolute position measurement capacitive grating displacement measurement method, a sensor, and an operating method thereof.

Related Art

[0002] A capacitive grating displacement sensor is widely applied in the fields of linear/angular displacement measurement due to the characteristics thereof such as a low cost, a small size, and low power consumption. In terms of the realization principle, current capacitive grating displacement sensors are categorized into relative position measurement (an incremental type) capacitive grating displacement sensors and absolute position measurement (an absolute type) capacitive grating displacement sensors. The incremental type capacitive grating displacement sensor has been applied for about thirty years, and in this kind of sensors, a displacement amount needs to be rapidly accumulated, resulting in two defects: a measurement speed limit (lower than 1.5 m/s @150 KHz) and uninterruptible measurement (so further decrease of a working current is limited), such that the incremental type capacitive grating displacement sensor is gradually phased out. The absolute type capacitive grating displacement sensor is initiated by a Japanese company named Mitutoyo, and the implementation method thereof may be referred to patents CN89106051, US5053715, CN92101246, and CN93117701. This kind of sensor uses two or more code channels (wavelengths) to perform absolute positioning, so the requirement for rapid accumulation of a displacement amount is eliminated, and the work is in an intermittent measurement state (approximately 8 times per second), thereby overcoming the main defects of the incremental measurement. However, the existing absolute type capacitive grating displacement sensor has the following defects.

1. A sensor drive signal is a static (irrelevant to time) and spatially distributed waveform. A demodulated received signal is irrelevant to time (a direct current (DC) signal), and a harmonic effect cannot be alleviated through signal processing technologies.

2. In order to downsize a harmonic component, a sine waveform electrode that is difficult to make is required to be used.

3. Analog-to-digital (A/D) conversion of two orthogonal signals is required to be performed to determine a displacement amount in each wavelength.

4. An arctg operation is required to be performed to determine a displacement amount in each wavelength, which exceeds a real-time processing capability of a common Micro Controller Unit (MCU). In order to reduce a processing load of the MCU, linear approximation has to be adopted.

5. In order to reduce a linear approximation error, a sensor drive signal is required to be probed repeatedly to make a received signal close to a zero point.

6. In order to reduce the linear approximation error and a harmonic component effect, a relatively small fine wavelength (1.024 mm when the resolution is 0.01 mm) is required to be used.

7. The determination of the displacement amounts in all wavelengths hampers and influences each other, and during rapid movement, the algorithm does not converge.

[0003] In conclusion, the existing absolute type capacitive grating displacement sensor requires an MCU to be a core, software is based on an inefficient probing method, and peripheries require support of technologies such as complicated A/D conversion and a sine waveform electrode. Although a regular Single Chip Microcomputer (SCM) can indeed meet the aforementioned requirements on software and hardware, it is not easy to integrally install the system (made into a single-chip Application-Specific Integrated Circuit (ASIC)) on a handheld measurement tool to obtain a product that has a low cost, a small volume, low power consumption, and is suitable for mass production at the same time.

[0004] Patent ZL200710050658 introduces a round grating sensor for absolute position measurement, and the patented solution is applicable to angle measurement in a large distributed space. But an SCM is used for performing secondary processing on measurement results of two independent incremental type capacitive grating systems, which
SUMMARY OF THE INVENTION

0006 The present invention provides an absolute position measurement capacitive grating displacement sensor according to claim 1.

0007 An absolute position measurement capacitive grating displacement sensor of the present invention includes a transmission board and a reflection board capable of moving relative to each other and a measurement circuit. At least one of the transmission board and the reflection board can move along a measurement axis. A column of periodically arranged electrodes are disposed on the transmission board in a measurement axis direction, which are the transmission grating. A column of periodically arranged electrodes are disposed on the reflection board in the measurement axis direction, which are the reflection grating. The capacitive coupling between the transmission grating and the reflection grating changes accordingly with change of the relative position of the transmission board and the reflection board.

0008 Two columns of periodically arranged electrodes orderly connected to the reflection grating are further disposed on the reflection board, which form the conversion grating for generating required measurement wavelengths. Two columns of periodically arranged electrodes for capacitive coupling with the conversion grating are further disposed on the transmission board, which form the reception grating for generating a received signal reflecting displacement of a measured position in each wavelength.

0009 Each N transmission grating electrodes form a group, N is an integer, 3<N<16, and N is usually 8. The electrodes are periodically arranged at intervals of P/N. A pitch of a group of N transmission grating electrodes is P, P is N times of a fine wavelength Wf, and N is an odd number between 3 and 7. The requirements of both signal synthesis and wavelength conversion are taken into consideration, preferably N=3, that is, P=3Wf.

0010 The reflection grating electrodes on the reflection board are divided into two groups which are alternately and periodically arranged at intervals of P and P=Wf, respectively. The conversion grating electrodes on the reflection board are arranged along the measurement axis at respective intervals periodically. The two groups of reflection grating electrodes are orderly connected to the two columns of conversion grating electrodes respectively through wires.

0011 The electrodes of the transmission grating, reception grating, reflection grating, and conversion grating may be rectangular, triangular, and in a sine wave shape, and are normally rectangular that can be easily fabricated. The electrodes of each column are arranged according to a common base line, and the base line at a central area is preferably selected for ease of wiring.

0012 The electrodes of the transmission grating, reception grating, reflection grating, and conversion grating are arranged circumferentially in a concentric manner, and the pitch of the electrodes is calculated according to angles. Relative displacement between the transmission board and the reflection board is relative rotation of the transmission board and the reflection board with the base point being the center of the concentric circles, so that the present invention is applicable to angular displacement measurement.

0013 The measurement circuit of the absolute position measurement capacitive grating displacement sensor of the present invention includes an interface unit and a measurement unit. The measurement unit includes a drive signal generator and a signal processing circuit. The interface unit includes a timer, a keyboard interface circuit, a measurement interface circuit, a display drive circuit, and an Arithmetic Logic Unit (ALU).

0014 The measurement unit further includes an oscillator, a frequency divider, and a controller. The drive signal generator is a drive signal generator for generating a sensor drive signal having wave properties. A master clock output by the oscillator of the measurement unit is connected to the drive signal generator through the frequency divider. N output signals having wave properties generated by the drive signal generator are respectively connected to N electrodes of each of the groups of the transmission gratings.

0015 The signal processing circuit of the measurement unit of the present invention includes an analog processing circuit, a zero-cross detection circuit, a synchronous delay circuit, an addition counter, a synchronous capture circuit, and a Random Access Memory (RAM). The analog processing circuit includes a signal selection switch group, a differential amplifier, a synchronous demodulation circuit, and a low-pass filter. Two outputs of the reception gratings of the measured wavelength are connected to the differential amplifier through the signal selection switch group, and after differential amplification, are successively connected to the synchronous demodulation circuit, the low-pass filter, and the zero-crossing detection circuit, and then are input into the synchronous capture circuit.

0016 The master clock output by the oscillator is further connected to the controller, the synchronous demodulation circuit, the synchronous capture circuit, and the addition counter. A phase synchronization signal from the drive signal generator is connected to the synchronous delay circuit.

0017 An output of the synchronous delay circuit is connected to the synchronous capture circuit and the addition
counter. An output of the zero-crossing detection circuit is connected to the synchronous capture circuit. An output of the synchronous capture circuit is connected to the controller and the RAM. An output of the addition counter serves as a data input of the RAM.

[0018] The measurement interface circuit of the interface unit is connected to the controller of the measurement unit and the RAM.

[0019] The controller generates various control signals including an initialization signal, a displacement measurement signal, a memory address signal, and a processing request signal. Each output is respectively connected to the RAM, the drive signal generator, the signal selection switch group, and the measurement interface circuit of the interface unit. An input terminal of the controller is connected to an output terminal of the synchronous capture circuit, and an input clock thereof is connected to the master clock output by the oscillator.

[0020] The drive signal generator of the measurement unit of the present invention may adopt a twisted-ring counter, and mainly include a twisted-ring counter, a drive sequence selection switch, and an XOR modulator. An output of the oscillator passes through the frequency divider, and is then connected to the drive signal generator to serve as the input clock of the twisted-ring counter and the XOR modulator. The twisted-ring counter generates N output signals having wave properties, and the N output signals having wave properties are input into the XOR modulator through the drive sequence selection switch to form two drive signal application orders required by coarse/medium wavelength and fine wavelength measurement. N outputs of the XOR modulator are connected to the N electrodes of all groups of the transmission gratings.

[0021] The drive signal generator of the measurement unit of the present invention may also adopt a ROM solution, and mainly includes an address addition counter, a ROM, and the XOR modulator. The master clock output by the oscillator passes through the frequency divider, and is then connected to the address addition counter to serve as a counting clock of the address addition counter. An output of the address addition counter and the fine wavelength measurement signal together form a read address of the ROM. N-bit data output by the ROM is input into the XOR modulator. After XOR modulation, the N outputs are connected to the N electrodes of all groups of the transmission gratings.

[0022] According to an expected maximum measurement range, two wavelengths or three wavelengths may be selected for measurement. When three wavelengths are used for measurement, two columns of conversion gratings and two columns of reception gratings are respectively disposed. The two columns of conversion gratings of the reflection board are respectively called a medium wavelength conversion grating and a coarse wavelength conversion grating. The two columns of reception gratings of the corresponding transmission boards are respectively called a medium wavelength reception grating and a coarse wavelength reception grating. The medium wavelength conversion grating electrodes on the reflection board are arranged along the measurement axis at intervals of \( P_m \) periodically. The pitch \( P_m \) of the medium wavelength conversion grating is smaller than a pitch \( P_c \) of the reflection grating. According to the electrode arrangement and excitation method, it can be acquired that the medium wavelength \( W_m \) satisfies 
\[ W_m = \frac{P_m}{P_m/(P_c/P_m)}. \]
It is assumed that \( W_m = N_m W_c \), \( P_m = N_m W_c \), \( N_m \) is an integer, and \( N_t \) is an odd number between 3 and 7, so \( P_m = \frac{N_m W_c}{N_m + N_t} \), and when \( N_m = 16 \) and \( N_t = 3 \), \( P_m = 16W_c/19 \). The medium wavelength reception grating electrodes on the corresponding transmission boards are divided into two identical groups, which are arranged along the measurement axis at intervals of \( N_t P_m \) alternately and periodically, and the reception grating electrodes of the same group are connected to each other by wires. The layout of the electrodes of the coarse wavelength conversion grating and the coarse wavelength reception grating is similar to that of the medium wavelength. It is assumed that the coarse wavelength 
\[ W_c \] satisfies 
\[ W_c = \frac{N_c W_c}{N_c + N_t}, \]
and when \( N_c = 256 \) and \( N_t = 3 \), \( P_c = 256 W_c/259 \). The coarse wavelength reception grating electrodes are also divided into two identical groups arranged at intervals of \( N_t P_c \) alternately and periodically, and the reception grating electrodes of the same group are connected to each other by wires.

[0023] When two wavelengths are used for measurement, also two pairs of the conversion gratings and the reception gratings are disposed. The layout of the electrodes is similar to that of the three-wavelength measurement, and only the original medium wavelength conversion grating and medium wavelength reception grating are changed into a fine wavelength auxiliary conversion grating and a fine wavelength auxiliary reception grating.

[0024] An operating method of an absolute position measurement capacitive grating displacement sensor of the present invention is as follows.

[0025] The interface unit starts the measurement unit according to a preset measurement frequency. A drive signal having wave properties is changed into a received signal changing periodically with time (after synchronous demodulation) after capacitive coupling of the transmission grating and the reflection grating, pitch conversion of the reflection grating and the conversion grating, and capacitive coupling of the conversion grating and a reception grating. Displacement of a measured position in each wavelength is transformed into an initial phase of a time fundamental wave of the received signal (after synchronous demodulation).

[0026] The two received signals output by the reception grating electrodes of each wavelength are input into the differential amplifier through the signal selection switch group. After differential amplification, the signals successively...
pass through the synchronous demodulation circuit, the low-pass filter, and the zero-crossing detection circuit to be processed to generate a square-wave signal. The synchronous capture circuit generates a synchronous capture signal according to the square-wave signal and the output of the synchronous delay circuit, captures a counting result of the addition counter at a non-counting edge of the master clock, and writes the result into a designated unit of the RAM.

The controller uses the synchronous capture signal to generate the control signal required for measuring the displacement in the next wavelength, or requests the interface unit to perform subsequent processing.

The synchronous delay circuit controls the counting of the addition counter. Only after a valid drive signal is applied for a preset time and at a preset phase of the drive signal, that is, a preset phase zero point, the addition counter is allowed to start counting. The addition counter performs counting on the master clock output by the oscillator.

The controller (a state machine) generates various control signals including the initialization signal, the fine wavelength displacement measurement signal, the medium wavelength displacement measurement signal, the coarse wavelength displacement measurement signal, the memory address signal, and the processing request signal, so as to coordinate the operation of the measurement circuit or request the interface unit to perform subsequent processing.

After the measurement unit successively completes the measurement of the displacements of the measured position in the coarse wavelength, the medium wavelength, and the fine wavelength, the controller requests the interface unit to perform the subsequent processing. The interface unit turns off the measurement unit immediately after reading the value of the displacement in each the wavelength from the RAM of the measurement unit, calculates an absolute position according the value of the displacement in each wavelength, performs other conventional processing (such as measurement unit conversion and measurement reference point setting) according to requirements (input through a keyboard) of a user, and drives the Liquid Crystal Display (LCD) to display the measurement result.

An operating method according to the invention is defined in claim 8, and is an operating method using the absolute position measurement capacitive grating displacement sensor of the present invention.

A reflection board of the absolute position measurement capacitive grating displacement sensor corresponding to the steps is disposed with a coarse wavelength conversion grating and a medium wavelength conversion grating, and a corresponding transmission board thereof is disposed with a coarse wavelength reception grating and a medium wavelength reception grating. A coarse wavelength, a medium wavelength, and a fine wavelength are used for absolute measurement.

In Step I, a timer of an interface unit starts a measurement unit according to a preset measurement frequency. In Step II, displacement of a measured position in the coarse wavelength is determined.

A sensor drive signal (before XOR modulation) sweeping a transmission grating pitch at constant speed with a time period of T according to a time t may be represented as:

\[ E(x, t) = E_m \sin \left(2\pi \frac{x}{P_t} - 2\pi \frac{t}{T} \right) \]  

According to the Fourier series theory, the expression (a) is a fundamental wave component of the following functions:

\[ B(x, t) = \begin{cases} 
1 & E(x, t) > 0 \\
0 & E(x, t) \leq 0 
\end{cases} \]  

Sampling is performed on the signal of the expression (b) with a space period \(P_t/N\) and a time period \(T/N\) for space \(x\) and time \(t\), thereby acquiring a sequence \(B(x_m, t_n)\):

\[ B(x_m, t_n) = \begin{cases} 
\sin(2\pi \frac{m}{N} - 2\pi \frac{n}{N}) > 0 \\
\sin(2\pi \frac{m}{N} - 2\pi \frac{n}{N}) \leq 0 
\end{cases} \]  

where \(m\) and \(n\) are integers, \(0 \leq m < N\), and \(0 \leq n < N\).

According to the sampling theorem, when \(N \geq 3\), the expression (a) can be regenerated and restored through the discretized signal sequence (c). Therefore, the discrete signal sequence \(B(x_m, t_n)\) is used as the sensor drive signal, and a response signal after regenerative filtering is completely equal to that as the expression (a) is used for driving.
Referring to FIG. 9, it is assumed that a drive signal on one pitch $P_t$ of the transmission grating changes according to the expression (a), and $P_t = 3P_r$, a distance between the measured position (that is, a base line of the transmission board) and a base line of the reflection board is $x$:

$$x = R \times 3P_c + y_0 = S \times 3P_r + x_0$$  \hspace{1cm} (d)

where $R$ and $S$ are integers, $x_0$ is a distance between the base line of the transmission board and a frontier of a reflection grating electrode group consisting of three pitches, and $y_0$ is a distance between the base line of the transmission board and a frontier of a conversion grating electrode group consisting of three pitches.

According to a capacitive voltage division formula, voltages induced on the three conversion electrodes of the coarse wavelength conversion grating are:

$$U_1 = K \int_{-x_0}^{-x_0 + 3P_r/2} E(x, t) dx = U_m \sin(2\pi \frac{t}{T} + \frac{5\pi}{6} + 2\pi \frac{x_0}{3P_r})$$  \hspace{1cm} (e)

$$U_2 = K \int_{-x_0 + 3P_r/2}^{-x_0 + 6P_r/2} E(x, t) dx = U_m \sin(2\pi \frac{t}{T} + \frac{5\pi}{6} + 2\pi \frac{x_0}{3P_r} - \frac{2\pi}{3})$$  \hspace{1cm} (f)

$$U_3 = K \int_{-x_0 + 6P_r/2}^{-x_0 + 9P_r/2} E(x, t) dx = U_m \sin(2\pi \frac{t}{T} + \frac{5\pi}{6} + 2\pi \frac{x_0}{3P_r} - \frac{4\pi}{3})$$  \hspace{1cm} (g)

where $K$ is a scale factor, and it is already assumed that $P_t = 3P_r$.

Phase differences between $U_1$, $U_2$, and $U_3$ are $2\pi/3$, which are consistent with physical locations of the electrodes thereof, so that the $U_1$, $U_2$, and $U_3$ can be regarded as results of sampling the variant $x$ through the following function with the period $P_c$:

$$U(x, t) = U_m \sin(2\pi \frac{t}{T} + \frac{5\pi}{6} + 2\pi \frac{x_0}{3P_r} - 2\pi \frac{x}{3P_c})$$  \hspace{1cm} (h)

Therefore, when the fundamental wave component of the received signal is deduced, it may be regarded that voltage distribution on the coarse wavelength conversion grating changes according to the expression (h). Capacitive coupling of the coarse wavelength reception grating and the coarse wavelength conversion grating is performed, and accordingly induced voltages on the two groups of reception electrodes can be acquired:

$$C_1 = K_c \int_{y_0}^{y_0 + 3P_r/2} U(x, t) dx = C_m \sin[(2\pi \frac{t}{T} + \frac{\pi}{3} - 2\pi \frac{y_0}{3P_c} - \frac{x_0}{3P_r})]$$  \hspace{1cm} (i)

$$C_2 = K_c \int_{y_0 + 3P_r/2}^{y_0 + 6P_r/2} U(x, t) dx = -C_m \sin[(2\pi \frac{t}{T} + \frac{\pi}{3} - 2\pi \frac{y_0}{3P_c} - \frac{x_0}{3P_r})]$$  \hspace{1cm} (j)

where $K_c$ is a scale factor. The fundamental wave signals on the two groups of reception electrodes of the coarse wavelength reception grating have equal sizes and inverted phases.

Therefore, during signal processing, the two received signals are differentiated ($C_1 - C_2$), and the expression (d) is substituted.
Specifically, determining the displacement in the coarse wavelength includes the following steps.

In Step II-i, the controller of the measurement unit outputs a coarse wavelength measurement signal, and switches the signal selection switch group to a position required for measuring the displacement in the coarse wavelength.

In Step II-ii, the controller outputs the initialization signal, sets the sequential logic of the drive signal generator, the synchronous delay circuit, and the synchronous capture circuit of the measurement unit to a preset initial state, and at the same time designates an address of a storage unit of the coarse wavelength displacement in the RAM.

In Step II-iii, the drive signal generator starts outputting valid sensor drive signals.

The sensor drive signal output by the drive signal generator is a result of XOR modulation of the expression (c).

In Step II-iv, after applying the drive signal for a preset time, and at a preset phase of the drive signal, that is, a preset phase zero point, the synchronous delay circuit allows the addition counter to start counting. The functions of the synchronous delay circuit include setting a phase reference point of the measurement and starting counting only after the signal becomes steady.

In Step II-v, the synchronous capture circuit synchronously captures a counting result of the addition counter at the valid edge of a zero-crossing detection signal, and writes the result into the designated unit of the RAM, which is the displacement of the measured position in the coarse wavelength (with a fixed offset).

The drive signal having wave properties is transferred through the electrode layout of the present invention, two phase-inverted received signals are induced on the two groups of coarse wavelength reception gratings, and a fundamental wave component of the expression (K) below is acquired after differentiating, demodulating, and filtering the two phase-inverted received signals.

Where

\[ W_c = \frac{P_c P_r}{P_r - P_c} \]  \hspace{1cm} (1)

\[ C_1 - C_2 = 2C_m \sin[(2\pi \frac{t}{T} + \frac{\pi}{3} - 2\pi \frac{x}{3P_c} - \frac{x}{3P_r})] \]

\[ = 2C_m \sin(2\pi \frac{t}{T} + \frac{\pi}{3} - 2\pi \frac{x}{W_c}) \]  \hspace{1cm} (k)

\[ W_c = \frac{3P_c P_r}{P_r - P_c} \]

Where

\[ W_c \] is the coarse wavelength, and it is already assumed that \( P_r = 3P_c \), \( C_1 \) and \( C_2 \) are two received signals of the coarse wavelength, and \( C_m \) is the amplitude of the fundamental wave component of the received signal of the coarse wavelength.

A time difference between the negative-to-positive zero-crossing point of the signal and the preset phase zero point (the moment that the addition counter starts) is the displacement of the measured position in the coarse wavelength (with the fixed offset), so that the counting result of the addition counter synchronously captured at the valid edge of the zero-crossing detection signal is the displacement of the measured position in the coarse wavelength.

In Step III, the displacement in the medium wavelength is determined.

In Step III-i, the controller outputs a medium wavelength measurement signal, and switches the signal selection switch group to a position required for measuring the displacement in the medium wavelength.

In Step III-ii, the controller outputs the initialization signal, sets the sequential logic of the drive signal generator,
the synchronous delay circuit, and the synchronous capture circuit of the measurement unit to a preset initial state, and at the same time designates an address of a storage unit of the medium wavelength displacement in the RAM.

In Step III-iii, the drive signal generator starts outputting valid sensor drive signals.

In Step III-iv, the synchronous delay circuit allows the addition counter to start counting.

In Step III-v, the synchronous capture circuit captures a counting result of the addition counter, and writes the result into the designated unit of the RAM, which is the displacement of the measured position in the medium wavelength (with a fixed offset).

Similar to that in Step II-v, the medium wavelength satisfies:

$$W_m = 3 \frac{P_t P_m}{P_r - P_m}$$  \hspace{1cm} (m)

In Step IV, displacement in a fine wavelength is determined.

The transmission grating pitch $P_t$ is different from the reflection grating pitch $P_r$. In order to make the fine wavelength $W_f$ satisfy $W_f = P_r$, the application order of the sensor drive signal is required to be adjusted. Referring to an exploded view of electrodes in FIG. 10, A represents conventional three groups of transmission grating electrodes, and when the sensor drive signal is applied orderly, a voltage signal with the wavelength equal to the pitch $P_r$ of the reflection grating is induced on the reflection grating electrode. For each three electrodes in the three groups of transmission grating electrodes represented by A, an electrode is selected, thereby resulting in a layout of electrodes represented by B, the drive signal of the electrode in B is the same as that in A, and the number of the electrodes in B just equals that of a group, so that if signals on three corresponding reflection grating electrodes are superposed, the layout of the electrodes of B is equivalent to a group of transmission gratings with the pitch equal to the pitch $P_r$ of the reflection gratings, and the wavelength of the induced signal is also equal to the pitch $P_r$ of the reflection grating. C is a result of spatial shift of $P_r/8$ (a spatial angle of $\pi/4$) of B, and D is a result of spatial shift of $P_r/4$ (a spatial angle of $\pi/2$) of B, so that the wavelength of an induced signal thereof is the same as that of B, and the phase shifts by $\pi/4$ successively. The spaces of B, C, and D are combined to form E, the pitch of transmission grating electrodes of E is widened to $3P_r = P_t$, the drive signal is the same as that of A, but the application order is already changed into 1-4-7-2-5-8-3-6 or 1-6-3-8-5-2-7-4 (reversed).

In view of the above, with the pitch of the transmission gratings $P_t = 3P_r$, the signal with the wavelength equal to the pitch $P_r$ of the reflection gratings can be induced. The premise is that: (1) the application order of the drive signal is adjusted to be 1-4-7-2-5-8-3-6 or 1-6-3-8-5-2-7-4; and (2) the signals induced on the reflection grating electrodes are superposed. Therefore, when the displacement of the measured position in the fine wavelength is determined, in addition to adjusting the application order of the drive signal, the two groups of electrodes of the coarse wavelength reception gratings are also required to be electrically connected (to be joined to form a complete rectangle) to form a group of fine wavelength reception electrodes, and the two groups of electrodes of the medium wavelength reception gratings are required to be electrically connected to form another group of fine wavelength reception electrodes (optional), so as to guarantee that the signals induced on the reflection grating electrode can be superposed on the reception grating through the coarse wavelength conversion grating and medium wavelength conversion grating.

After the above processing, an equivalent signal when the expression (a) drives the sensor according to the application order of 1-4-7-2-5-8-3-6 is:

$$E_v(x, t) = E_m \sin(2\pi \frac{x}{P_r} - 2\pi \frac{t}{T})$$  \hspace{1cm} (n)

In this case, an induced voltage on the two groups of reception electrodes of the fine wavelength is:

$$F_1 = F_2 = K \left[ \int_{-x_0}^{-x_0 + P_r/2} E_v(x, t) dx + \int_{-x_0 - P_r/8}^{-x_0 + P_r/2} E_v(x, t) dx + \int_{-x_0 - P_r/4}^{-x_0} E_v(x, t) dx \right]$$

$$= F_m \sin(2\pi \frac{t}{4} + \frac{3\pi}{4} + 2\pi \frac{x}{P_r})$$  \hspace{1cm} (o)

Accordingly, when the sensor is driven according to the application order of 1-6-3-8-5-2-7-4, an induced voltage
on the two groups of reception electrodes of the fine wavelength is:

\[ F_1 = -F_2 = K \left[ \int_{-x_0-P_r/8}^{x_0-P_r/8} E_s(-x,t) \, dx + \int_{-x_0-3P_r/8}^{x_0-3P_r/8} E_s(-x,t) \, dx \right] \]

\[ = F_m \sin \left( 2\pi \frac{t}{T} + \alpha + \pi - 2\pi \frac{x}{W_f} \right) \quad \text{(p)} \]

By combining both (o) and (p), a fine wavelength differential signal is:

\[ F_1 - F_2 = 2F_m \sin \left( 2\pi \frac{t}{T} + \alpha \pm 2\pi \frac{x}{W_f} \right) \quad \text{(q)} \]

where \( W_f = P_r \), \( W_f \) is the fine wavelength, and \( \alpha \) is a constant.

Specifically, determining the displacement in the fine wavelength includes the following steps.

In Step IV-i, the controller outputs a fine wavelength measurement signal, and switches the signal selection switch group to a position required for measuring the displacement in the fine wavelength.

In Step IV-ii, the controller outputs the initialization signal, sets the sequential logic of the drive signal generator, the synchronous delay circuit, and the synchronous capture circuit of the measurement unit to a preset initial state, and at the same time designates an address of a storage unit of the fine wavelength displacement in the RAM.

In Step IV-iii, the drive signal generator starts outputting a valid sensor drive signal, and in order to synthesize a required received signal, the application order thereof is changed from 1-2-3-4-5-6-7-8 during coarse/medium wavelength measurement when \( N=8 \) and \( P_T = 3P_r \) to 1-6-3-8-5-2-7-4 (reversed) or 1-4-7-2-5-8-3-6.

In Step IV-iv, the synchronous delay circuit allows the addition counter to start counting.

In Step IV-v, the synchronous capture circuit captures a counting result of the addition counter, and writes the result into the designated unit of the RAM, which is the displacement of the measured position in the fine wavelength (with a fixed offset).

The two groups of reception electrodes of the coarse wavelength are shorted by the switch to serve as a group of reception electrodes of the fine wavelength. The two groups of reception electrodes of the medium wavelength are shorted by the switch to serve as another group of reception electrodes of the fine wavelength. After the application order is adjusted, the drive signals induce two phase-inverted received signals at the two groups of reception electrodes, and a fundamental wave component of the following expression (q) is acquired after differentiating, demodulating, and filtering the two phase-inverted received signals:

\[ F_1 - F_2 = 2F_m \sin \left( 2\pi \frac{t}{T} + \alpha \pm 2\pi \frac{x}{W_f} \right) \quad \text{(q)} \]

where \( W_f = P_r \), \( W_f \) is the fine wavelength, \( W_f = P_r \), and \( F_1 \) and \( F_2 \) are two received signals of the fine wavelength, and \( F_m \) is the amplitude of the fundamental wave component of the received signal of the fine wavelength.

A time difference between a negative-to-positive zero-crossing point of the signal and a preset phase zero point (the moment that the addition counter starts counting) is the displacement of the measured position in the fine wavelength (with a fixed offset).

In Step V, the controller requests the interface unit to perform subsequent processing.

In Step VI, the interface unit turns off the measurement circuit after reading displacement data saved in the RAM of the measurement unit.

In Step VII, the interface unit performs processing and displays a measurement result.

When the displacements of the measured position in the coarse, medium, and fine wavelengths are determined, the distances between the measured positions and the measurement reference point in the coarse, medium, and fine wavelengths are determined accordingly. It is assumed that the distances between the measured position and the measurement reference point in the coarse, medium, and fine wavelengths respectively are \( x_c \), \( x_m \), and \( x_f \), the coarse, medium, and fine wavelengths respectively are \( W_c \), \( W_m \), and \( W_f \), the number of each wavelength being divided is \( 2^M \), and the measured length \( x \) is represented as:
where \( K_m \) and \( K_f \) are integers, \( K_m \) represents the number of the medium wavelengths, and \( K_f \) represents the number of the fine wavelengths.

Therefore the measured length of the highest measurement precision is:

\[
x = x_c \frac{W_c}{2^M} = K_m W_m + x_m \frac{W_m}{2^M} = K_m W_m + K_f W_f + x_f \frac{W_f}{2^M}
\]

the preferred parameters when the resolution is 0.01 mm are substituted: \( W_c = 256 W_f \), \( W_m = 16 W_f \), \( W_f = 2.56 \) mm, and \( 2^8 = 256 \):

\[
x \approx \left( 16 K_m + K_f \right) \times 256 + x_f \times 0.01 \text{ mm}.
\]

The sequence of Steps II, III, and IV for determining the displacements in the coarse, medium, and fine wavelengths is arbitrary.

The absolute position measurement capacitive grating displacement measurement method of the present invention has the following advantages.

1. With excitation of a sensor drive signal having wave properties, displacement information is changed into an initial phase of a time fundamental wave, displacement of a measured position in each wavelength can be determined through simple zero-crossing detection and an addition counter, so A/D conversion and linear approximation are not required anymore, at the same time the low-efficient method of repeated probing is abandoned, the control is convenient, and the implementation is easy.

2. With excitation of a sensor drive signal having wave properties, the received signal is converted into a periodic waveform of time, a harmonic component can be eliminated through a low-pass filter (second-order or above), so that no complex sine waveform reception electrode is required, and at the same time the length of the fine wavelength may be increased appropriately to increase a signal to noise ratio (for example, a pitch of 2.56 mm is adopted when the resolution is 0.01 mm).

The absolute position measurement capacitive grating displacement sensor and the operating method thereof of the present invention have the following advantages.

1. With excitation of a sensor drive signal having wave properties generated by a twisted-ring counter or a ROM, displacement information is changed into an initial phase of a time fundamental wave of a received signal, displacement of a measured position in each wavelength is determined through simple zero-crossing detection and an addition counter, the circuit is simple, the control is convenient, and the implementation is easy.

2. A harmonic component in a received signal is eliminated through a low-pass filter (second-order or above), a rectangular reception electrode that can be easily fabricated may be selected to greatly decrease the fabrication difficulty, and at the same time measurement errors are reduced, so that the length of the fine wavelength may be increased appropriately to increase a signal to noise ratio (for example, a pitch of 2.56 mm is adopted when the resolution is 0.01 mm).

3. Since intermittently operated multi-wavelength positioning is adopted, defects of the incremental type measurement are overcome, the power consumption is low, and a measurement speed is not limited.

4. A displacement amount in each wavelength is determined by hardware in a mutually independent manner, so not only processing is simplified, but also the problem of non-convergence of software algorithms is solved.

5. Determination of displacements of a measured position in coarse, medium, and fine wavelengths shares the same measurement circuit and method, all processing is performed orderly, no circulation or repetition is required, and the control is simple.
6. No complex MCU is required, the measurement circuit is realized through hardwired logic, system integration is
easy to fabricate an Application Specific IC (ASIC), and mass production is possible, so that a handheld measurement
tool product with a low cost, a small volume, and low power consumption can be obtained.

BRIEF DESCRIPTION OF THE DRAWINGS

[0083] The present invention will become more fully understood from the detailed description given herein below for
illustration only, and thus are not limitative of the present invention, and wherein:

FIG. 1 is a layout diagram of electrodes of an absolute position measurement capacitive grating displacement sensor
according to a first embodiment of the present invention;

FIG. 2 is a schematic view of a measurement circuit of an absolute position measurement capacitive grating dis-
placement sensor according to the first embodiment of the present invention;

FIG. 3 is a schematic circuit diagram of a solution of a twisted-ring counter of a drive signal generator in FIG. 2;

FIG. 4 is a layout diagram of electrodes of an absolute position measurement capacitive grating displacement sensor
according to a second embodiment of the present invention;

FIG. 5 is a schematic view of a measurement circuit of an absolute position measurement capacitive grating dis-
placement sensor according to the second embodiment of the present invention;

FIG. 6 is a schematic circuit diagram of a solution of a ROM of a drive signal generator in FIG. 5;

FIG. 7 is a layout diagram of electrodes of an absolute position measurement capacitive grating displacement sensor
according to a third embodiment of the present invention;

FIG. 8 is a flow chart of an operating method of an absolute position measurement capacitive grating displacement
sensor according to a first embodiment of the present invention;

FIG. 9 is a schematic view of relative positions of a measured position x, a group of transmission grating electrodes,
and corresponding reflection grating electrodes, conversion grating electrodes, and reception grating electrodes in
an operating method of an absolute position measurement capacitive grating displacement sensor of the present
invention;

FIG. 10 is an exploded view of transmission grating electrodes of fine wavelength measurement in an operating
method of an absolute position measurement capacitive grating displacement sensor of the present invention;

FIG. 11 is an oscillogram of signals in each step of an operating method of an absolute position measurement
capacitive grating displacement sensor of the present invention; and

FIG. 12 is a flow chart of an operating method of an absolute position measurement capacitive grating displacement
sensor according to a second embodiment of the present invention.

[0084] Symbols in the accompanying drawings are as follows:
1. Transmission board, 1.1 Transmission grating, 1.2 Medium wavelength reception grating, 1.3 Coarse wavelength
reception grating, 2. Reflection board, 2.1 Reflection grating, 2.2 Medium wavelength conversion grating, 2.3 Coarse
wavelength conversion grating, 3. First frequency divider, 4. Second frequency divider, 5. Drive signal generator, 5.1
Twisted-ring counter, 5.2 Drive sequence selection switch, 5.3 XOR modulator, 6. Signal selection switch group, and 7.
Differential amplifier.

DETAILED DESCRIPTION OF THE INVENTION

[0085] A sensor drive signal having wave properties excites each electrode of a transmission grating, and is changed
into a received signal changing periodically with time after capacitive coupling of the transmission grating and a reflection
grating, pitch conversion of the reflection grating and a conversion grating, and capacitive coupling of the conversion
grating and a reception grating, and displacement of a measured position in each wavelength is transformed into an

11
initial phase of a time fundamental wave of a received signal. A time difference between a negative-to-positive zero-crossing point of the fundamental wave signal and a preset phase zero point is the displacement of the measured position in a measured wavelength. The time difference is acquired by counting with an addition counter, so the displacement of the measured position in the measured wavelength is acquired.

A first embodiment of an absolute position measurement capacitive grating displacement sensor is as follows.

The first embodiment of the absolute position measurement capacitive grating displacement sensor is a sensor for linear displacement measurement, and provides measurement of a coarse wavelength, a medium wavelength, and a fine wavelength. A layout of the electrodes is shown in FIG. 1, which includes two components capable of moving relative to each other: a transmission board 1 and a reflection board 2. At least one of the transmission board 1 and the reflection board 2 can move along a measurement axis. In this embodiment, the transmission board 1 can move along the measurement axis, and the reflection board 2 is fixed.

In a measurement axis direction on the transmission board 1, a column of periodically arranged transmission grating electrodes 1.1 are disposed, and two columns of periodically arranged reception grating electrodes are further disposed. The two columns of periodically arranged reception grating electrodes respectively are a medium wavelength reception grating 1.2 and a coarse wavelength reception grating 1.3. Each N transmission grating electrodes form a group, in this embodiment, N=6, the electrodes are periodically arranged at intervals of P1/8. The pitch of a group of 8 transmission grating electrodes is P1, P1 is N times of the fine wavelength Wf, and in this embodiment, N=3, that is, P1=3Wf.

In the measurement axis direction on the reflection board 2, a column of periodically arranged reflection grating electrodes 2.1 are disposed, and two columns of periodically arranged conversion grating electrodes are further disposed in the measurement axis direction. The two columns of periodically arranged conversion grating electrodes respectively are medium wavelength conversion grating electrodes 2.2 and coarse wavelength conversion grating electrodes 2.3. The reflection grating electrodes are periodically arranged at intervals of P2, and the fine wavelength Wf satisfies Wf=Wf.

The medium wavelength conversion grating electrodes 2.2 are periodically arranged at intervals of Pm. The medium wavelength Wm satisfies Wm=Pm/P1/(Pt-Pm). It is assumed that the coarse wavelength Wc satisfies Wc=Wc=Pm/(Pt-Pc). The coarse wavelength Wc limits the maximum measurement range of the capacitive grating sensor, and the ratios of adjacent wavelengths, that is, both Wc/Wm and Wm/Wf are smaller than 32, so measurement of the absolute position in a larger range may occur. According to the absolute position measurement capacitive grating displacement sensor of this embodiment, normally the ratio of adjacent wavelengths is preferably 16, that is, Wc=16Wm and Wm=16Wf.

The coarse wavelength Wc determines the highest measurement precision of the capacitive grating sensor, and the fine wavelength Wf determines the highest measurement precision of the capacitive grating sensor. When a required ratio Wc/Wf of the coarse wavelength Wc to the fine wavelength Wf is too large, for example, larger than 32, errors easily occur when the integral number of the fine wavelengths included in the measured position is directly determined according to displacement of the coarse wavelength. In this embodiment, the sensor uses the medium wavelength Wm to decrease the ratios of adjacent wavelengths, that is, both Wc/Wm and Wm/Wf are smaller than 32, so measurement of the absolute position in a larger range may occur. According to the absolute position measurement capacitive grating displacement sensor of this embodiment, normally the ratio of adjacent wavelengths is preferably 16, that is, Wc=16Wm and Wm=16Wf. For example, with the measurement resolution being 0.01 mm and the fine wavelength Wf=2.56 mm, the maximum measurement range is Wc=16Wm=256 Wf=65.36 mm.

Eight output signals of a drive signal generator 5 are respectively connected to eight electrodes of each transmission grating group, two outputs of the reception gratings are connected to a signal processing circuit.

According to this embodiment, a measurement circuit of the absolute position measurement capacitive grating displacement sensor, as shown in FIG. 2, includes an interface unit and a measurement unit. The measurement unit includes an oscillator, a frequency divider, a controller, the drive signal generator 5, and the signal processing circuit. The interface unit includes a timer, a keyboard interface circuit, a measurement interface circuit, an LCD drive circuit,
and an ALU. The measurement interface circuit is connected to the controller of the measurement unit and a RAM.

According to this embodiment, the controller is a finite state machine, and generates the following control signals: an initialization signal INI, a fine wavelength measurement signal FINE, a medium wavelength measurement signal MED, a coarse wavelength measurement signal COARSE, a memory address ADDR, and a processing request signal REQ. An input terminal of the controller is connected to an output terminal of a synchronous capture circuit, and receives a signal WRITE output by the synchronous capture circuit, and an input clock thereof is the master clock output by the oscillator. The signals FINE, MED, and COARSE are connected to a control terminal of a signal selection switch group 6 for switching to positions required by corresponding wavelength measurement, the signal INI is connected to the drive signal generator 5, a synchronous delay circuit, and a synchronous capture circuit of the measurement unit for making them in a preset initial state. The ADDR is connected to the RAM to designate a storage address of displacement in each wavelength in the RAM (the signals FINE, MED, and COARSE may also play the role of the ADDR). The signal REQ is connected to the interface unit to notify the interface unit that the measurement is completed and request subsequent processing.

The signal processing circuit of the measurement unit includes an analog processing circuit, a zero-crossing detection circuit, a synchronous delay circuit, an addition counter, a synchronous capture circuit, and a RAM. The analog processing circuit includes the signal selection switch group 6, a differential amplifier 7, a synchronous demodulation circuit, and a low-pass filter. Two outputs of the reception of the measured wavelength are connected to the differential amplifier 7 through the signal selection switch group 6, and after differential amplification, are then successively connected to the synchronous demodulation circuit, the low-pass filter, and the zero-crossing detection circuit, and then are input into the synchronous capture circuit.

As shown in FIG. 2, the signal selection switch group 6 includes a first switch S1, a second switch S2, a third switch S3, and a fourth switch S4. An output terminal of the group of electrodes 1.3A of the coarse wavelength reception grating 1.3 and an output terminal of the group of electrodes 1.2A of the medium wavelength reception grating 1.2 are respectively connected to two input terminals of the third switch S3. An output terminal of the other group of electrodes 1.3B of the coarse wavelength reception grating 1.3 and an output terminal of the other group of electrodes 1.2B of the medium wavelength reception grating 1.2 are respectively connected to two input terminals of the fourth switch S4. A common terminal of the third switch S3 is connected to an input terminal of the differential amplifier 7, and a common terminal of the fourth switch S4 is connected to another input terminal of the differential amplifier 7. The first switch S1 is connected to the output terminals of the two groups of electrodes 1.2A and 1.2B of the medium wavelength reception 1.2, and the second switch S2 is connected to the output terminals of the two groups of electrodes 1.3A and 1.3B of the coarse wavelength reception grating 1.3.

The oscillator generates the master clock of the measurement unit. The master clock 16 is frequency divided by a first frequency divider 3, and then connected to the sensor drive signal generator to serve as a modulation pulse MOD. Two-way frequency division is performed on the modulation pulse MOD by a second frequency divider 4, and then the modulation pulse MOD is connected to a four-bit twisted-ring counter of the drive signal generator 5 to serve as a counting clock DCLK thereof. Therefore, one wavelength is divided into 16×2×8=256=2^8 parts, an 8-bit addition counter may be used to determine the displacement of the measured position in each wavelength. The number of the wavelength being divided into may be determined according to demands, and is preferably a power of 2 for ease of processing. The master clock output by the oscillator is further connected to the controller, the synchronous demodulation circuit, the synchronous capture circuit, and the addition counter. A phase synchronization signal of the drive signal generator 5 is connected to the synchronous delay circuit.

An output of the synchronous delay circuit is connected to the synchronous capture circuit and the addition counter. An output COUT of the zero-crossing detection circuit is connected to the synchronous capture circuit. An output of the synchronous capture circuit is input into the controller and the RAM at the same time. An output of the addition counter serves as a data input of the RAM.

The measurement interface circuit of the interface unit is connected to the controller of the measurement unit and the RAM.

According to this embodiment, the drive signal generator 5 of the measurement unit, as shown in FIG. 3, mainly includes a twisted-ring counter 5.1, drive sequence selection switches 5.2, and an XOR modulator 5.3. According to this embodiment, the twisted-ring counter 5.1 is a four-bit twisted-ring counter. The eight-way XOR modulator 5.3 includes 4 XOR gates and 4 NOT gates. Eight outputs of the drive signal generator 5 are orderly connected to the eight electrodes of each group of transmission gratings 1.1. For the two drive sequence selection switches 5.2, one is connected to the second XOR gate of the XOR modulator 5.3 and the second output terminal Q2 of the XOR modulator 5.3; and the other is connected to the fourth XOR gate of the XOR modulator 5.3 and the fourth output terminal Q4 or the eighth output terminal Q8 of the twisted-ring counter 5.1; During displacement measurement in the coarse wavelength or the medium wavelength, for the two drive sequence selection switches 5.2, one is connected to the second XOR gate of the XOR modulator 5.3 and the second output terminal Q2 of the twisted-ring counter 5.1;
and the other is connected to the fourth XOR gate of the XOR modulator 5.3 and the fourth terminal Q₄ of the twisted-ring counter 5.1. Outputs Q₁ to Q₄ of the four-bit twisted-ring counter 5.1 correspond to m=0 to 3 in the expression (c), and outputs Q₅ to Q₈ (that is, $\overline{Q}_1$ to $\overline{Q}_4$) correspond to m=4 to 7 in the expression (c). The drive signal generator 5 outputs drive signals in an application order of 1-2-3-4-5-6-7-8. During determination of the displacement in the fine wavelength, the FINE=1 output by the controller switches conducting contacts of the two drive sequence selection switches 5.2, one of which is connected to the second XOR gate of the XOR modulator 5.3 and the sixth output terminal Q₆ ($\overline{Q}_2$) of the twisted-ring counter, and the other is connected to the fourth XOR gate of the XOR modulator 5.3 and the eighth terminal Q₈ ($\overline{Q}_4$) of the twisted-ring counter 5.1. The drive signal generator outputs drive signals in an application order of 1-6-3-8-5-2-7-4. According to this embodiment, the drive signal generator 5 of the measurement unit generates 8 output signals having wave properties, and forms two drive signal application orders required by the coarse/medium wavelength measurement and the fine wavelength measurement to drive the 8 electrodes of each group of the transmission grating.

[0102] A second embodiment of an absolute position measurement capacitive grating displacement sensor is as follows.

[0103] The second embodiment of the absolute position measurement capacitive grating displacement sensor is a sensor for linear displacement measurement, a layout of electrodes thereof is shown in FIG. 4, and the sensor is used for two-wavelength measurement. A reflection board 2 is disposed with a column of reflection grating electrodes 2.1, a column of coarse wavelength conversion grating electrodes 2.3, and a column of fine wavelength auxiliary conversion grating electrodes 2.2. A transmission board 1 is disposed with a column of transmission grating electrodes 1.1, a column of coarse wavelength reception grating electrodes 1.3, and a column of fine wavelength auxiliary reception grating electrodes 1.2. For the two groups of reflection gratings 2.1, one group is connected to the coarse wavelength conversion grating electrodes 2.3, and the other group is connected to the fine wavelength auxiliary conversion grating electrodes 2.2. The fine wavelength auxiliary conversion grating electrodes 2.2 are periodically arranged with the pitch $P_c=W_f$, and the fine wavelength auxiliary reception grating electrodes 1.2 form a complete rectangle. The coarse wavelength auxiliary reception grating electrodes 2.2 are divided into two identical groups 1.3A and 1.3B, in which the electrodes are alternately and periodically arranged at intervals of 3$P_c$, and the reception grating electrodes of the same group are connected to each other by wires. The rest are the same as those in the first embodiment.

[0104] According to this embodiment, a measurement circuit of the absolute position measurement capacitive grating displacement sensor, as shown in FIG. 5, includes an interface unit and a measurement unit. The interface circuit in this embodiment is the same as that in the first embodiment. The measurement unit in this embodiment, similar to that in the first embodiment, includes an oscillator, a frequency divider, a controller, a drive signal generator 5, and a signal processing circuit.

[0105] The drive signal generator 5 is shown in FIG. 6, and in the circuit, an address addition counter and a ROM replace the twisted-ring counter and the drive sequence selection switch in the first embodiment, and includes the 3-bit address addition counter, the 16-unit 8-bit ROM, and an XOR modulator. Details of data pre-saved in the ROM are shown in Table 1. Outputs Qₐ to Qₐ of the address addition counter and a control signal FINE together form an input signal of a 4-bit address Aₐ to Aₐ of the ROM. An 8-bit output of the ROM after XOR modulation drives the eight electrodes of each group of the transmission gratings. Input signals DCLK, INI, FINE, and MOD of the circuit and realized functions thereof all are the same as those of the drive signal generator in the first embodiment, so the two are interchangeable.

<table>
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<tr>
<th>Address</th>
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</table>
The signal processing circuit of this embodiment, as shown in FIG. 5, is similar to that of the first embodiment, which includes an analog processing circuit, a zero-crossing detection circuit, a synchronous delay circuit, an addition counter, a synchronous capture circuit, and a RAM. The analog processing circuit includes a signal selection switch group 6, a differential amplifier 7, a synchronous demodulation circuit, and a low-pass filter. The signal selection switch group 6 of this embodiment includes a first switch S1 and a second switch S2. An output terminal of the fine wavelength auxiliary reception grating electrodes 1.2 and an output terminal of a group of electrodes 1.3A of the coarse wavelength reception grating are respectively connected to two input terminals of the second switch S2. A common terminal of the second switch S2 is connected to an input terminal of the differential amplifier. An output terminal of the other group of electrodes 1.3B of the coarse wavelength reception grating 1.3 is connected to another input terminal of the differential amplifier. The first switch S1 is connected to the output terminals of the two groups of electrodes 1.3A and 1.3B of the coarse wavelength reception grating 1.3.

During coarse wavelength measurement, the controller sends a control signal COARSE=1 and FINE=0 to the signal selection switch group 6, the first switch S1 is switched off, and the second switch S2 is connected to the output terminal of 1.3A. That is to say, the signal selection switch group 6 connects the output terminals of the two groups of electrodes 1.3A and 1.3B of the coarse wavelength reception grating 1.3 to the input terminals of the differential amplifier 7. During fine wavelength measurement, the controller sends a control signal FINE=1 and COARSE=0 to the signal selection switch group 6, the first switch S1 is switched on, the second switch S2 is connected to the output terminal of 1.2, and the first switch S1 joins the two groups of electrodes 1.3A and 1.3B of the coarse wavelength reception grating 1.3 to form a complete rectangle. That is to say, the signal selection switch group 6 connects the joined output terminals of the two groups of electrodes 1.3A and 1.3B of the coarse wavelength reception grating and the output terminal of the electrode of the fine wavelength auxiliary reception grating 1.2 to the input terminal of the differential amplifier 7 to provide two phase-inverted received signals for the fine wavelength measurement.

A third embodiment of an absolute position measurement capacitive grating displacement sensor is as follows. The absolute position measurement capacitive grating displacement sensor of the third embodiment is a sensor for angular displacement measurement, and a layout of electrodes of the sensor is shown in FIG. 7. Electrodes of a transmission grating, reception grating, reflection grating, and conversion grating are arranged circumferentially in a concentric manner, and the pitches of electrodes are calculated according to a central angle of concentric circles corresponding to the arc of the electrodes. A layout of other electrodes is the same as that in the first embodiment. A measurement circuit in this embodiment is the same as that in the first embodiment. A first embodiment of an operating method of an absolute position measurement capacitive grating displacement sensor is as follows.

The operating method of an absolute position measurement capacitive grating displacement sensor of this embodiment corresponds to the aforementioned first embodiment of the absolute position measurement capacitive grating displacement sensor. The flow chart of this method is shown in FIG. 8, an oscillogram of the signal in all steps is shown in FIG. 11, and the method mainly includes the following steps.

In Step I, a timer of an interface unit starts a measurement unit according to a preset measurement frequency.

In Step II, displacement in a coarse wavelength is determined.

In Step II-i, a controller of the measurement unit outputs a coarse wavelength measurement signal COARSE=1, MED=0, and FINE=0, and switches the signal selection switch group 6 to a position required for measuring the displacement in the coarse wavelength: first and second switches S1 and S2 are switched off, the third switch S3 is connected to an output terminal of 1.3A, and a fourth switch S4 is connected to an output terminal of 1.3B. That is to say, the signal selection switch group connects the output terminals of the two groups of electrodes 1.3A and 1.3B of a coarse wavelength reception grating 1.3 to an input terminal of a differential amplifier.

In Step II-ii, the controller outputs an initialization signal INI, and sets the sequential logic of a drive signal generator, a synchronous delay circuit, and a synchronous capture circuit of the measurement unit all to a preset initial
state. The initialization signal INI of the controller clears an output SDLY of the synchronous delay circuit to zero. The low level SDLY makes the addition counter stay in a zero-clearing state. The initialization signal INI further clears an output WRITE of the synchronous capture circuit to zero. Meanwhile, the controller further outputs an ADDR signal to designate an address of a storage unit of the coarse wavelength displacement in a RAM.

[0117] In Step II-iii, the drive signal generator starts outputting valid sensor drive signals. In this embodiment, the drive signal generator mainly includes a twisted-ring counter, drive sequence selection switches, and an XOR modulator. A signal generated by the twisted-ring counter is shown in an expression (c).

\[
B(x_m, t_n) = \begin{cases} 
1 & \sin(2\pi \frac{m}{8} - 2\pi \frac{n}{8}) > 0 \\
0 & \sin(2\pi \frac{m}{8} - 2\pi \frac{n}{8}) \leq 0 
\end{cases}
\]  

(c)

[0120] For the two drive sequence selection switches, one is connected to a second XOR gate and a second output terminal Q2 of the twisted-ring counter; and the other is connected to a fourth XOR gate and a fourth terminal Q4 of the twisted-ring counter. An application order of the output signals of the drive signal generator after XOR modulation of \(B(x_m, t_n)\) is 1-2-3-4-5-6-7-8. Output signals G1 to G8 of the drive signal generator are drive signals of this sensor.

[0121] After capacitive coupling of the transmission grating and the reflection grating, pitch conversion of the reflection grating and the conversion grating, and capacitive coupling of the conversion grating and the reception grating are performed on the drive signal having wave properties, two received signals output by the reception grating electrode of the coarse wavelength is regenerated and restored to a fundamental wave signal changing periodically with time as described by an expression (k) (referring to the summary part of the present invention) after being processed by the differential amplifier, a synchronous demodulation circuit, and a low-pass filter of an analog processing circuit. The fundamental wave signal transforms the displacement of a measured position in the coarse wavelength into an initial phase thereof.

[0122] In Step II-iv, after applying the drive signal for a preset time, and at a preset phase of the drive signal, that is, a preset phase zero point, the synchronous delay circuit allows the addition counter to start counting.

[0123] The fourth terminal Q4 (alternatively, other output terminals may be selected, which is represented by Qn in the following) of the twisted-ring counter of the drive signal generator is used as an input clock of the synchronous delay circuit. After a preset drive cycle \(N_D T, N_D \geq 3, T = 2M/f_M, 2M\) is the number of the wavelength being divided, and \(f_M\) is the frequency of the master clock), the valid SDLY (high level) is output, so that the addition counter is allowed to start counting for the master clock. A rising edge of the selected Qn is the preset phase zero point, and the delay time \(N_D T\) is used for waiting for the signal to be steady.

[0124] In Step II-v, the synchronous capture circuit synchronously captures a counting result of the addition counter at the valid edge of a zero-crossing detection signal, and writes the result into the designated unit of the RAM, which is the displacement of the measured position in the coarse wavelength (with a fixed offset).

[0125] The zero-crossing detection circuit transforms the fundamental wave signal obtained after processing by the analog processing circuit into a square-wave signal \(C_{OUT}\) for ease of digital processing. A valid edge of the square-wave signal corresponds to a negative-to-positive zero-crossing point of the fundamental wave signal, so that a time difference between the valid edge of the square-wave signal and the preset phase zero point represents the displacement of the measured position in the coarse wavelength (with a fixed offset). The time difference may be measured by the addition counter.

[0126] The drive signal having wave properties is transferred through the electrode layout of the present invention, two phase-inverted received signals \(C_1\) and \(C_2\) are induced on the two groups of coarse wavelength reception gratings, and a fundamental wave component of the expression (k) is acquired after differentiating, demodulating, and filtering the two phase-inverted received signals \(C_1\) and \(C_2\).

\[
C_1 - C_2 = 2C_m \sin\left[\left(2\pi \frac{t}{T} + \frac{\pi}{3} - 2\pi \left(\frac{x}{3P_r} - \frac{x}{3P_e}\right)\right)\right] \\
= 2C_m \sin\left(2\pi \frac{t}{T} + \frac{\pi}{3} - 2\pi \frac{x}{W_c}\right)
\]  

(k)
\[ W_c = 3 \frac{P_r P_c}{P_r - P_c} \]

where \( W_c \) is the coarse wavelength, and \( P_r = 3P_c \).

[0127] The displacement of the measured position in the coarse wavelength (with the fixed offset) is acquired according to a time difference between the negative-to-positive zero-crossing point of the signal and the preset phase zero point (the moment that the addition counter starts counting), so that the counting result of the addition counter synchronously captured at the valid edge of the zero-crossing detection signal is the displacement of the measured position in the coarse wavelength (\( x_1 \) and \( x_2 \) in FIG. 11 are equal after modulo of \( 2^M \)).

[0128] The initialization signal INI clears the output WRITE of the synchronous capture circuit to zero. Only when the output SDLY of the synchronous delay circuit is valid (high level), the valid edge (the rising edge) of the output COUT of the zero-crossing detection circuit triggers a valid WRITE signal at a non-counting edge (a falling edge) of the master clock. The valid edge (the rising edge) of the WRITE signal writes the counting result of the addition counter into a designated unit of the RAM, which is the displacement of the measured position in the coarse wavelength (with a fixed offset).

[0129] When the valid edge (the rising edge) of the WRITE signal jumps, it represents that the measurement of the current wavelength is completed, and accordingly the controller performs state transition according to a set order. In this embodiment, the set order is COARSE→MED→FINE→REQ, and the order of the displacement measurement in the coarse wavelength, the medium wavelength, and the fine wavelength can be chosen optionally.

[0130] In Step III, the displacement in the medium wavelength is determined.

[0131] In Step III-i, the controller outputs a medium wavelength measurement signal COARSE=0, MED=1, and FINE=0, and switches the signal selection switch group 6 to a position required for measuring the displacement in the medium wavelength. The first and second switches \( S_1 \) and \( S_2 \) are switched off, the third switch \( S_3 \) is connected to the output terminal of 1.2A, and the fourth switch \( S_4 \) is connected to the output terminal of 1.2B. That is to say, the signal selection switch group 6 connects the output terminals of the two groups of electrodes 1.2A and 1.2B of a medium wavelength reception grating 1.2 to the input terminal of the differential amplifier.

[0132] In Step III-ii, the controller outputs an initialization signal INI, sets a sequential logical circuit of the measurement unit to a preset initial state, and at the same time designates an address of a storage unit of the medium wavelength displacement in the RAM.

[0133] In Step III-iii, the drive signal generator starts outputting valid sensor drive signals \( G_1 \) to \( G_8 \).

[0134] In Step III-iv, the synchronous delay circuit allows the addition counter to start counting.

[0135] In Step III-v, the synchronous capture circuit captures a counting result of the addition counter, and writes the result into the designated unit of the RAM, which is the displacement of the measured position in the medium wavelength (with a fixed offset).

[0136] Similar to that in Step II-v, the medium wavelength satisfies:

\[ W_m = 3 \frac{P_r P_m}{P_r - P_m} \quad (m) \]

[0137] In Step IV, displacement in a fine wavelength is determined.

[0138] In Step IV-i, the controller outputs a fine wavelength measurement signal COARSE=0, MED=0, and FINE=1, and switches the signal selection switch group 6 to a position required for measuring the displacement in the fine wavelength. The first and second switches \( S_1 \) and \( S_2 \) are switched on, the third switch \( S_3 \) is connected to the output terminal of 1.2A, and the fourth switch \( S_4 \) is connected to the output terminal of 1.2B. The first switch \( S_1 \) joins the two groups of electrodes 1.3A and 1.3B of the coarse wavelength reception grating 1.3 to form a complete rectangle, and the second switch \( S_2 \) joins the two groups of electrodes 1.2A and 1.2B of the medium wavelength reception grating 1.2 to form a complete rectangle. That is to say, the signal selection switch group 6 connects the joined output terminal of the two groups of electrodes 1.3A and 1.3B of the coarse wavelength reception grating 1.3 and the joined output terminal of the two groups of electrodes 1.2A and 1.2B of the medium wavelength reception grating 1.2 to the input terminal of the differential amplifier to provide two phase-inverted received signals for the fine wavelength measurement.

[0139] In Step IV-ii, the controller outputs the initialization signal INI, sets the sequential logical circuit of the measurement unit to a preset initial state, and at the same time designates an address of a storage unit of the fine wavelength displacement in the RAM.

[0140] In Step IV-iii, the drive signal generator starts outputting valid sensor drive signals.

[0141] The control signal \( FINE=1 \) switches conducting contacts of the two drive sequence selection switches of the drive signal generator, one of which is connected to the second XOR gate and the sixth output terminal \( Q_6 \) (\( \bar{Q}_2 \)) of the twisted-ring counter, and the other is connected to the fourth XOR gate and the eighth terminal \( Q_8 \) (\( \bar{Q}_4 \)) of the twisted-
ring counter. The acquired application order of the drive signals of the fine wavelength is 1-6-3-8-5-2-7-4. The eight outputs G1 to G8 after XOR modulation drive the eight electrodes of each group of the transmission gratings.

[0142] In Step IV-iv, the synchronous delay circuit allows the addition counter to start counting.

[0143] In Step IV-v, the synchronous capture circuit captures a counting result of the addition counter, and writes the result into the designated unit of the RAM, which is the displacement of the measured position in the fine wavelength (with a fixed offset).

[0144] The two groups of reception electrodes of the coarse wavelength are shorted by the switch to serve as a group of reception electrodes of the fine wavelength. The two groups of reception electrodes of the medium wavelength are shorted by the switch to serve as another group of reception electrodes of the fine wavelength. After the application order is adjusted, the drive signals induce two phase-inverted received signals at the two groups of reception electrodes, and a fundamental wave component of the following expression is acquired after differentiating, demodulating, and filtering the two phase-inverted received signals.

\[ F_i - F_j = 2F_m \sin(\frac{2\pi I}{T} + \alpha + 2\pi \frac{x}{W_f}) \]  

where \( W_i \) is the fine wavelength, \( W_f = P, \) and \( \alpha \) is a constant.

[0145] A time difference between a negative-to-positive zero-crossing point of the signal and a preset phase zero point (the moment that the addition counter starts counting) is the displacement of the measured position in the fine wavelength (with a fixed offset).

[0146] In Step V, the controller requests the interface unit to perform subsequent processing.

[0147] In Step VI, the interface unit turns off the measurement circuit after reading displacement data of each wavelength saved in the RAM of the measurement unit.

[0148] In Step VII, the interface unit performs processing, and displays a measurement result.

[0149] When the displacements of the measured position in the coarse, medium, and fine wavelengths are determined, the distances between the measured positions and a measurement reference point in the coarse, medium, and fine wavelengths are determined accordingly. It is assumed that the distances between the measured positions and the measurement reference point in the coarse, medium, and fine wavelengths respectively are \( x_c, x_m, \) and \( x_f, \) the coarse, medium, and fine wavelengths respectively are \( W_c, W_m, \) and \( W_f, \) the number of each wavelength being divided is \( 2^M, \) and the measured length \( x \) is represented as:

\[ x = x_c \frac{W_c}{2^M} = K_m W_m + x_m \frac{W_m}{2^M} = K_m W_m + K_f W_f + x_f \frac{W_f}{2^M} \]  

where \( K_m \) and \( K_f \) are integers, \( K_m \) represents the number of the medium wavelengths, and \( K_f \) represents the number of the fine wavelengths. The expression (r) is two simultaneous equations, which can uniquely determine the two unknown values \( K_m \) and \( K_f, \) so the measured length having the highest measurement precision is:

\[ x = K_m W_m + K_f W_f + x_f \frac{W_f}{2^M} \]  

when the resolution of 0.01 mm is substituted, the preferred parameters are: \( W_c = 256 W_f, \) \( W_m = 16 W_f, \) \( W_f = 2.56 \) mm, and \( 2^8 = 256, \) \( x_f \approx [(16K_m + K_f) \times 256 + x_f] \times 0.01 \) mm.

[0150] At last, the interface unit displays the measurement result through an LCD according to requirements of a user.
designated unit of the RAM. The controller uses the synchronous capture signal to generate the control signal required for measuring the displacement in the next wavelength, or requests the interface unit to perform subsequent processing.  

After the measurement unit successfully completes the measurement of the displacements of the measured position in the coarse wavelength, the medium wavelength, and the fine wavelength, the controller requests the interface unit to perform subsequent processing. The interface unit turns off the measurement unit immediately after reading the value of the displacement from the RAM of the measurement unit, then calculates an absolute position according to the value of the displacement in each wavelength, performs other conventional processing (such as measurement unit conversion and setting of the measurement reference point) according to requirements (input through the keyboard) of a user, and drives the LCD to display the measurement result.

A second embodiment of an operating method of an absolute position measurement capacitive grating displacement sensor is as follows.

The operating method of the absolute position measurement capacitive grating displacement sensor in this embodiment corresponds to the aforementioned second embodiment of the absolute position measurement capacitive grating displacement sensor. The flow chart of the method is shown in FIG. 12, and the method mainly includes the following steps.

Step I is the same as Step I in the first embodiment.

In Step II, displacement in a coarse wavelength is determined.

In Step II-i, the controller of the measurement unit outputs a coarse wavelength measurement signal, COARSE=1 and FINE=0, the signal selection switch group 6 is switched to a position required for measuring displacement in the coarse wavelength, the switch $S_1$ is turned off, and the switch $S_2$ is connected to the output terminal of the 1.3A.

In Step II-ii, the same as Step II-ii in the first embodiment.

In Step II-iii, the drive signal generator starts outputting valid sensor drive signals.

In this embodiment, the drive signal generator mainly includes a ROM, a 3-bit address addition counter, and an XOR modulator.

An output signal of the 3-bit address addition counter and a control signal FINE=0 together serve as a 4-bit read address of the ROM. The ROM outputs data saved in first eight units orderly and repeatedly. After XOR modulation of the 8-bit data $D_0$ to $D_7$ output by the ROM, the drive signal generator outputs sensor drive signals $G_1$ to $G_8$ with the application order being 1-2-3-4-5-6-7-8.  

In Step II-iv, the same as Step II-iv in the first embodiment.

In Step II-v, the same as Step II-v in the first embodiment.

In Step III, displacement in a fine wavelength is determined.

In Step III-i, the controller outputs a fine wavelength measurement signal, COARSE=0 and FINE=1, the signal selection switch group 6 is switched to a position required for measuring displacement in the fine wavelength, the switch $S_1$ is turned on, and the switch $S_2$ is connected to the output terminal of the 1.2.

In Step III-ii, the same as Step IV-ii in the first embodiment.

In Step III-iii, the drive signal generator starts outputting valid sensor drive signals.

The output signal of the 3-bit address addition counter and the control signal FINE=1 together serve as the 4-bit read address of the ROM. The ROM outputs data saved in last eight units orderly and repeatedly. After XOR modulation of the 8-bit data $D_0$ to $D_7$ output by the ROM, sensor drive signals $G_1$ to $G_8$ are output with the application order being 1-6-3-8-5-2-7-4.  

In Step III-iv, the same as Step IV-iv in the first embodiment.

In Step III-v, the same as Step IV-v in the first embodiment.

In Step IV, the controller requests the interface unit to perform subsequent processing.  

In Step V, the interface unit turns off the measurement circuit after reading displacement data saved in the RAM of the measurement unit.

In Step VI, the interface unit performs processing, and displays a measurement result.

When the displacements of the measured position in the coarse and fine wavelengths are determined, the distances between the measured positions and a measurement reference point in the coarse and fine wavelengths are determined accordingly. It is assumed that the distances between the measured positions and the measurement reference point in the coarse and fine wavelengths respectively are $x_c$ and $x_f$, the coarse and fine wavelengths respectively are $W_c$ and $W_f$, the number of each wavelength being divided is $2^M$, and the measured length $x$ is represented as:

$$ x = x_c \frac{W_c}{2^M} = K_f W_f + x_f \frac{W_f}{2^M} \quad (1) $$

where $K_f$ is an integer representing the number of the fine wavelengths. Therefore the measured length having the highest measurement precision is:
The preferred parameters when the resolution is 0.01 mm are substituted: \( W_c = 16W_f, W_f = 2.56 \text{ mm}, \) and \( 2^8 = 256: \)

\[
x = (K_f \times 256 + x_f) \times 0.01 \text{ mm.}
\]

At last, the interface unit displays the measurement result through the LCD according to the requirements of the user.

A third embodiment of an operating method of an absolute position measurement capacitive grating displacement sensor is as follows.

The operating method of the absolute position measurement capacitive grating displacement sensor in this embodiment corresponds to the aforementioned third embodiment of the absolute position measurement capacitive grating displacement sensor. The operating method of this embodiment is the same as the first embodiment of the operating method, except that relative displacement between the transmission board 1 and the reflection board 2 is generated through rotation of the transmission board 1 and the reflection board 2 with the base point being the same center of the concentric circles.

The aforementioned embodiments are only specific examples for further description of the objectives, technical solutions, and beneficial effects of the present invention in detail, and the present invention is not limited thereto, but is solely defined by the scope of the appended claims.

Claims

1. An absolute position measurement capacitive grating displacement sensor, comprising a transmission board (1) and a reflection board (2) capable of moving relative to each other and a measurement circuit, wherein a column of periodically arranged electrodes are disposed on the transmission board (1) in a measurement axis direction, which form a transmission grating (1.1); a column of periodically arranged electrodes are disposed on the reflection board (2) in the measurement axis direction, which form a reflection grating (2.1); two columns of periodically arranged electrodes orderly connected to the reflection grating (2.1) are further disposed on the reflection board (2), which form a conversion grating; two columns of periodically arranged electrodes for capacitive coupling with the conversion grating are further disposed on the transmission board (1), which form a reception grating; each \( N \) electrodes of the transmission grating (1.1) form a group, \( N \) is an integer, \( 3 \leq N \leq 16 \), the electrodes are periodically arranged at intervals of \( Pt/N \), an electrode pitch of the transmission grating (1.1) having \( N \) electrodes in a group is \( Pt \), \( Pt \) is \( Nt \) times of a fine wavelength \( W_f \), and \( Nt \) is an odd number between 3 and 7; the electrodes of the reflection grating (2.1) are divided into two groups alternately and periodically arranged at intervals of \( Pr \), where \( Pr = W_f \), the conversion grating electrodes on the reflection board (2) are arranged along the measurement axis at respective intervals periodically, the two groups of electrodes of the reflection grating (2.1) are orderly connected to the two columns of conversion grating electrodes respectively by wires; the measurement circuit comprises an interface unit and a measurement unit; the interface unit comprises a timer, a keyboard interface circuit, a measurement interface circuit, a display drive circuit, and an Arithmetic Logic Unit (ALU); and the measurement unit comprises a drive signal generator and a signal processing circuit;

wherein

the measurement unit further comprises an oscillator, a frequency divider, and a controller; the drive signal generator (5) is a drive signal generator for generating a sensor drive signal having wave properties; a master clock output by the oscillator of the measurement unit is connected to the drive signal generator (5) through the frequency divider; \( N \) output signals of the drive signal generator (5) respectively are connected to \( N \) electrodes in each group of the transmission grating (1.1);

the signal processing circuit of the measurement unit comprises an analog processing circuit, a zero-crossing detection circuit, a synchronous delay circuit, an addition counter, a synchronous capture circuit, and a Random Access Memory (RAM); the analog processing circuit comprises a signal selection switch group (6), a differential amplifier (7), a synchronous demodulation circuit, and a low-pass filter; two outputs of the reception grating of the measured wavelength are connected to the differential amplifier (7) through the signal selection switch group (6), after differential amplification, are then successively connected to the synchronous demodulation circuit, the low-pass filter, and the zero-crossing detection circuit, and then are input into the synchronous capture circuit; the master clock output by the oscillator is further connected to the controller, the synchronous demodulation circuit,
the synchronous capture circuit, and the addition counter; a phase synchronization signal of the drive signal generator
(5) is connected to the synchronous delay circuit;
an output of the synchronous delay circuit is connected to the synchronous capture circuit and the addition counter;
an output of the zero-crossing detection circuit is connected to the synchronous capture circuit, an output of the
synchronous capture circuit is input into the controller and the RAM at the same time, an output of the addition
counter serves as a data input of the RAM;
the measurement interface circuit of the interface unit is connected to the controller of the measurement unit and
the RAM; and
outputs of the controller generating various control signals respectively are connected to the RAM, the drive signal
generator (5), the signal selection switch group (6), and the measurement interface circuit of the interface unit; an
input terminal of the controller is connected to an output terminal of the synchronous capture circuit, and the master
clock output by the controller is connected to a clock input terminal of the controller.

2. The absolute position measurement capacitive grating displacement sensor according to claim 1, characterized
in that
the drive signal generator (5) mainly comprises a twisted-ring counter (5.1), a drive sequence selection switch (5.2),
and an XOR modulator (5.3); an output of the oscillator passes through the frequency divider, and then is connected
to the drive signal generator (5) to serve as an input clock of the twisted-ring counter (5.1) and the XOR modulator
(5.3); the twisted-ring counter (5.1) generates N output signals having wave properties, and the N output signals
having wave properties are input into the XOR modulator (5.3) through the drive sequence selection switch (5.2);
and N outputs of the XOR modulator (5.3) are connected to the N electrodes of each of the groups of the transmission
grating (1.1).

3. The absolute position measurement capacitive grating displacement sensor according to claim 1, characterized
in that
the drive signal generator (5) mainly comprises an address addition counter, a Read-Only Memory (ROM), and an
XOR modulator, the master clock output by the oscillator passes through the frequency divider, and then is connected
to the address addition counter to serve as a counting clock of the address addition counter; an output of the address
addition counter and the fine wavelength measurement signal together form a read address of the ROM, N-bit data
output by the ROM is input into the XOR modulator, and after XOR modulation, N outputs are connected to the N
electrodes of each group of the transmission grating (1.1).

4. The absolute position measurement capacitive grating displacement sensor according to claim 1, characterized
in that
the electrodes of the transmission grating, reception grating, reflection grating, and conversion grating are arranged
circumferentially in a concentric manner, and the pitch of the electrodes is calculated according to an angle; relative
displacement between the transmission board (1) and the reflection board (2) is relative rotation of the transmission
board (1) and the reflection board (2) with the base point being the center of the concentric circles.

5. The absolute position measurement capacitive grating displacement sensor according to any one of claims 1 to 4,
characterized in that
two columns of conversion gratings and two columns of reception gratings are respectively disposed, the two columns
of conversion gratings of the reflection board (2) are respectively called a medium wavelength conversion grating
(2.2) and a coarse wavelength conversion grating (2.3), the two columns of reception gratings of the corresponding
transmission board (1) are respectively called a medium wavelength reception grating (1.2) and a coarse wavelength
reception grating (1.3); the electrodes of the medium wavelength conversion grating (2.2) on the reflection board
(2) are arranged along the measurement axis at intervals of Pm periodically; the medium wavelength Wm satisfies
Wm=Pt-Pm; it is assumed that Wm=NmWf, Pt=NtWf, Nm is an integer, and Nt is an odd number between 3 and
7, so Pm=NmWf/(Nm+Nt); the electrodes of the medium wavelength reception grating (1.2) on the corresponding
transmission board (1) are divided into two identical groups (1.2A and 1.2B) arranged along the measurement axis
at intervals of NtPm alternately and periodically, the reception grating electrodes of the same group are connected
to each other by wires; the electrodes of the coarse wavelength conversion grating (2.3) on the reflection board (2)
are arranged along the measurement axis at intervals of Pm periodically; the coarse wavelength Wc satisfies Wc=Pc
-Pm; it is assumed that Wc=NcWf, Pc=NtWf, Nc is an integer, and Nt is an odd number between 3 and 7, the
pitch Pc of the electrodes of the coarse wavelength conversion grating (2.3) satisfies Pc=NcWf/(Nc+Nt); the electrodes
of the coarse wavelength reception grating (1.3) on the corresponding transmission board (1) are also divided into
two identical groups (1.3A and 1.3B) arranged at intervals of NtPc alternately and periodically, and the reception
grating electrodes of the same group are connected to each other by wires.
6. The absolute position measurement capacitive grating displacement sensor according to claim 5, characterized in that
the signal selection switch group (6) comprises a first switch (S1), a second switch (S2), a third switch (S3), and a fourth switch (S4); an output terminal of the group of electrodes (1.3A) of the coarse wavelength reception grating (1.3) and an output terminal of the group of electrodes (1.2A) of the medium wavelength reception grating (1.2) are respectively connected to two input terminals of the third switch (S3), an output terminal of the other group of electrodes (1.3B) of the coarse wavelength reception grating (1.3) and an output terminal of the other group of electrodes (1.2B) of the medium wavelength reception grating (1.2) are respectively connected to two input terminals of the fourth switch (S4); a common terminal of the third switch (S3) is connected to an input terminal of the differential amplifier (7), and a common terminal of the fourth switch (S4) is connected to another input terminal of the differential amplifier (7); the first switch (S1) is connected to the output terminals of the two groups of electrodes (1.2A and 1.2B) of the medium wavelength reception grating (1.2), and the second switch (S2) is connected to the output terminals of the two groups of electrodes (1.3A and 1.3B) of the coarse wavelength reception grating (1.3).

7. The absolute position measurement capacitive grating displacement sensor according to any one of claims 1 to 4, characterized in that
two columns of conversion gratings and two columns of reception gratings are respectively disposed, the two columns of conversion gratings of the reflection board (2) are respectively called a coarse wavelength conversion grating (2.3) and a fine wavelength auxiliary conversion grating (2.2), the two columns of reception gratings of the corresponding transmission board (1) are respectively called a coarse wavelength reception grating (1.3) and a fine wavelength auxiliary reception grating (1.2); the electrodes of the fine wavelength auxiliary conversion grating (2.2) on the reflection board (2) are arranged along the measurement axis at intervals of \(P_c\), \(P_t=W_f\) periodically; the electrodes of the fine wavelength auxiliary reception grating (1.2) on the corresponding transmission board (1) form a complete rectangle; the electrodes of the coarse wavelength conversion grating (2.3) on the reflection board (2) are arranged along the measurement axis at intervals of \(P_c\) periodically; the coarse wavelength \(W_s\) satisfies \(W_s=P_t-P_c\), \(W_s=P_f\); it is assumed that \(W_s=W_f\), \(P_t=W_f\), \(N_w\) is an integer, and \(N_w\) is an odd number between 3 and 7, the pitch \(P_c\) of the electrodes of the coarse wavelength conversion grating (2.3) satisfies \(P_c=N_w W_f/(N_w+1)\); the electrodes of the coarse wavelength reception grating (1.3) on the corresponding transmission board (1) are also divided into two identical groups (1.3A and 1.3B) arranged at intervals of \(N_w P_c\) alternately and periodically, and the reception grating electrodes of the same group are connected to each other by wires.

8. An operating method using an absolute position measurement capacitive grating displacement sensor according to any one of claims 1 to 4, wherein
the interface unit starts the measurement unit according to a preset measurement frequency, the controller of the measurement unit successively generates various control signals comprising an initialization signal, a displacement measurement signal, a memory address signal, and a processing request signal; and each output is respectively connected to the RAM, the drive signal generator (5), the signal selection switch group (6), and the measurement interface circuit of the interface unit;
a sensor drive signal having wave properties generated by the drive signal generator (5) is changed into a received signal changing periodically with time after capacitive coupling of the transmission grating and the reflection grating, pitch conversion of the reflection grating and the conversion grating, and capacitive coupling of the conversion grating and the reception grating, and the displacement of a measured position in the measured wavelength is transformed into an initial phase of a time fundamental wave of a received signal;
two received signals output by the reception grating electrodes of the measured wavelength are input into the differential amplifier (7) through the signal selection switch group (6), after differential amplification, the signals are successively processed by the synchronous demodulation circuit, the low-pass filter, and the zero-crossing detection circuit, and then are converted into a square-wave signal; the synchronous capture circuit generates a synchronous capture signal according to the square-wave signal and the output of the synchronous delay circuit, captures a counting result of the addition counter at a non-counting edge of the master clock, and writes the result into a designated unit of the RAM; and the controller uses the synchronous capture signal to generate the control signal required for measuring the displacement in the next wavelength, or requests the interface unit to perform subsequent processing;
the synchronous delay circuit controls the counting of the addition counter; only after a valid drive signal is applied for a preset time and at a preset phase of the drive signal, the addition counter is allowed to start counting, and the addition counter performs counting on the master clock output by the oscillator; and
after the measurement unit successively completes the measurement of the displacement of the measured position in each wavelength, the controller requests the interface unit to perform subsequent processing; the interface unit turns off the measurement unit immediately after reading the value of the displacement in each wavelength from
the RAM of the measurement unit, calculates an absolute position according to the value of the displacement in each wavelength, and displays the measurement result.

9. The operating method of an absolute position measurement capacitive grating displacement sensor according to claim 8, characterized in that a reflection board (2) of the absolute position measurement capacitive grating displacement sensor is disposed with a coarse wavelength conversion grating (2.3) and a medium wavelength conversion grating (2.2), and a corresponding transmission board (1) is disposed with a coarse wavelength reception grating (1.3) and a medium wavelength reception grating (1.2); a coarse wavelength, a medium wavelength, and a fine wavelength are used for absolute position measurement; and the method mainly comprises:

I. starting, by a timer of an interface unit, a measurement unit according to a preset measurement frequency;
II. determining the displacement of a measured position in the coarse wavelength;
   II-i. outputting, by the controller of the measurement unit, a coarse wavelength measurement signal, and switching the signal selection switch group (6) to a position required for measuring the displacement in the coarse wavelength;
   II-ii. outputting, by the controller, the initialization signal, setting the sequential logic of the drive signal generator (5), the synchronous delay circuit, and the synchronous capture circuit of the measurement unit to a preset initial state, and at the same time designating an address of a storage unit of the coarse wavelength displacement in the RAM;
   II-iii. starting, by the drive signal generator (5), outputting valid sensor drive signals;
   II-iv. after the drive signal is applied for a preset time, and at a preset phase of the drive signal, that is, a preset phase zero point, allowing, by the synchronous delay circuit, the addition counter to start counting;
   II-v. synchronously capturing, by the synchronous capture circuit, a counting result of the addition counter at a valid edge of a zero-crossing detection signal, and writing the result into the designated unit of the RAM, and the result is the displacement of the measured position in the coarse wavelength (with a fixed offset);
III. determining the displacement in the medium wavelength;
   III-i. outputting, by the controller, a medium wavelength measurement signal, and switching the signal selection switch group (6) to a position required for measuring the displacement in the medium wavelength;
   III-ii. outputting, by the controller, the initialization signal, setting the sequential logic of the drive signal generator (5), the synchronous delay circuit, and the synchronous capture circuit of the measurement unit to a preset initial state, and at the same time designating an address of a storage unit of the medium wavelength displacement in the RAM;
   III-iii. starting, by the drive signal generator (5), outputting valid sensor drive signals;
   III-iv. allowing, by the synchronous delay circuit, the addition counter to start counting;
   III-v. capturing, by the synchronous capture circuit, a counting result of the addition counter, and writing the result into the designated unit of the RAM, and the result is the displacement of the measured position in the medium wavelength (with a fixed offset);
IV. determining the displacement in the fine wavelength;
   IV-i. outputting, by the controller, a fine wavelength measurement signal, and switching the signal selection switch group (6) to a position required for measuring the displacement in the fine wavelength;
   IV-ii. outputting, by the controller, the initialization signal, setting the sequential logic of the drive signal generator (5), the synchronous delay circuit, and the synchronous capture circuit of the measurement unit to a preset initial state, and at the same time designating an address of a storage unit of the fine wavelength displacement in the RAM;
   IV-iii. starting, by the drive signal generator (5), outputting valid sensor drive signals;
   IV-iv. allowing, by the synchronous delay circuit, the addition counter to start counting;
   IV-v. capturing, by the synchronous capture circuit, a counting result of the addition counter, and writing the result into the designated unit of the RAM, and the result is the displacement of the measured position in the fine wavelength (with a fixed offset);
V. requesting, by the controller, the interface unit to perform subsequent processing;
VI. turning off, by the interface unit, the measurement circuit after reading displacement data saved in the RAM of the measurement unit; and
VII. performing, by the interface unit, processing, and displaying a measurement result; wherein

a sequence of Steps II, III, and IV for determining the displacements in the coarse, medium, and fine wavelengths is arbitrary.
Kapazitiver Gitterverschiebungssensor für Absolutpositionsmessung nach Anspruch 1, umfassend eine Transmissionsplatine (1) und eine Reflexionsplatine (2), die sich relativ zueinander bewegen können, und eine Messschaltung, wobei eine Spalte von periodisch angeordneten Elektroden auf der Transmissionsplatine (1) in einer Messachsenrichtung angeordnet ist, die ein Transmissionsgitter (1.1) bildet; eine Spalte von periodisch angeordneten Elektroden auf der Reflexionsplatine (2) in der Messachsenrichtung angeordnet ist, die ein Reflexionsgitter (2.1) bilden; zwei Spalten von periodisch angeordneten Elektroden geordnet mit dem Reflexionsgitter (2.1) verbunden ferner auf der Reflexionsplatine (2) angeordnet sind, die ein Konversionsgitter bilden; zwei Spalten von periodisch angeordneten Elektroden für kapazitive Kopplung mit dem Konversionsgitter ferner auf der Transmissionsplatine (1) angeordnet sind, die ein Empfangsgitter bilden; jeweils N Elektroden des Transmissionsgitters (1.1) eine Gruppe bilden, wobei N eine ganze Zahl 3 ≤ N ≤ 16 ist, die Elektroden periodisch in Intervallen von Pt/N angeordnet sind, eine Elektrodenenteilung des Transmissionsgitters (1.1) mit N Elektroden in einer Gruppe Pt ist, Pt Nt mal eine Feinwellenlänge W f ist und Nt von jeder der Gruppen des Transmissionsgitters (1.1) verbunden werden; und N Ausgänge des XOR-Modulators (5.3) mit den N Elektroden (5.1) und des XOR-Modulators (5.3) zu dienen; der Drehringzähler (5.1) N Ausgangssignale mit Welleneigenschaften ist; ein vom Oszillator der Messeinheit ausgegebener Haupttakt mit dem Ansteuerungssignalgenerator (5) durch den Frequenzteiler verbunden ist; N Ausgangssignale des Ansteuerungssignalgenerators (5) jeweils mit der Messeinheit ferner einen Oszillator, einen Frequenzteiler und eine Steuerung umfasst; der Ansteuerungssignalgenerator (5) ein Ansteuerungssignalgenerator zum Erzeugen eines Sensoransteuerungssignals mit Welleneigenschaften ist; ein Oszillator mit einer Messeinheit ausgegebener Haupttakt mit dem Ansteuerungssignalgenerator (5) durch den Frequenzteiler verbunden ist; N Ausgangssignale des Ansteuerungssignalgenerators (5) jeweils mit der Messeinheit in jeder Gruppe des Transmissionsgitters (1.1) verbunden sind; die Signalverarbeitungsschaltung der Messeinheit eine analoge Verarbeitungsschaltung, eine Nullurchangerkennungsschaltung ein erweiterter Verzögerungsschaltung, ein Additionszähler, eine synchrone Erfassungsschaltung und einen Direktzugriffsspeicher (RAM) umfasst; die analoge Verarbeitungsschaltung eine Signalauswahlschaltergruppe (6), einen Differentialverstärker (7), eine synchrone Demodulationsschaltung und ein Tiefpassfilter umfasst; zwei Ausgänge des Empfangsgitters der gemessenen Wellenlänge mit dem Differentialverstärker (7) durch die Signalauswahlschaltergruppe (6) nach Differentialverstärkung verbunden sind, dann nacheinander mit der synchrone Demodulationsschaltung, dem Tiefpassfilter und der Nullurchangerserkennungsschaltung verbunden sind und dann in die synchrone Erfassungsschaltung eingegeben werden; der vom Oszillator ausgegebene Haupttakt ferner mit der Steuerung, der synchrone Demodulationsschaltung, der synchrone Erfassungsschaltung und dem Additionszähler verbunden ist; ein Phasensynchronisationssignal des Ansteuerungssignalgenerators (5) mit der synchrone Verzögerungsschaltung verbunden ist; ein Ausgang der synchrone Verzögerungsschaltung der synchrone Erfassungsschaltung und dem Additionszähler verbunden ist; ein Ausgang der Nullurchangerkennungsschaltung der synchrone Erfassungsschaltung verbunden ist; ein Ausgang der synchrone Erfassungsschaltung gleichzeitig in die Steuerung und den RAM eingegeben wird, ein Ausgang des Additionszählers als Dateneingang des RAM dient; die Messschnittstellenschaltung der Schnittstelleneinheit mit der Steuerung der Messeinheit und dem RAM verbunden ist; und Ausgänge der verschiede Numerosignale erzeugenden Steuerung jeweils mit dem RAM, dem Ansteuerungssignalgenerator (5), der Signalauswahlschaltergruppe (6) und der Messschnittstellenschaltung der Schnittstelleneinheit verbunden sind; ein Eingangsanschluss der Steuerung mit einem Ausgangsanschluss der synchrone Erfassungsschaltung verbunden ist und der vom Oszillator ausgegebene Haupttakt mit einem Takteingangsanschluss der Steuerung verbunden ist.
3. Kapazitiver Gitterverschiebungssensor für Absolutpositionsbestimmung nach Anspruch 1, **dadurch gekennzeichnet**, dass
der Ansteuerungssignalgenerator (5) hauptsächlich einen Adressadditionszähler, einen Festwertspeicher (ROM) und einen XOR-Modulator umfasst, der durch den Oszillator ausgegebene Haupttakt durch den Frequenzteller geht und dann mit dem Adressadditionszähler verbunden wird, um als Zähltakt des Adressadditionszählers zu dienen; ein Ausgang des Adressadditionszählers und das Feinwellenlängenmesssignal zusammen eine Leseadresse des ROM bilden, die vom ROM ausgegebenen N-Bit-Daten in den XOR-Modulator eingegeben werden und nach der XOR-Modulation N Ausgänge mit den N Elektroden jeder Gruppe des Transmissionsgitters (1.1) verbunden werden.

4. Kapazitiver Gitterverschiebungssensor für Absolutpositionsbestimmung nach Anspruch 1, **dadurch gekennzeichnet**, dass
die Elektroden des Transmissionsgitters, Empfangsgitters, Reflexionsgitters und Konversionsgitters umfangsmäßig auf konzentrische Weise angeordnet sind und die Teilung der Elektroden gemäß einem Winkel berechnet wird; die relative Verschiebung zwischen den Transmissionsplatten (1) und der Reflexionsplatte (2) eine relative Rotation der Transmissionsplatten (1) und der Reflexionsplatten (2) ist, wobei der Basispunkt der konzentrischen Kreise ist.

5. Kapazitiver Gitterverschiebungssensor für Absolutpositionsbestimmung nach einem der Ansprüche 1 bis 4, **dadurch gekennzeichnet**, dass
zwei Spalten von Konversionsgittern und zwei Spalten von Empfangsgittern jeweils angeordnet sind, wobei die zwei Spalten von Konversionsgittern der Reflexionsplatte (2) jeweils als Mittelwellenlängen-Konversionsgitter (2.2) und als Grobwellenlängen-Konversionsgitter (2.3) bezeichnet werden, wobei die beiden Spalten von Empfangsgittern der entsprechenden Transmissionsplatten (1) jeweils als Mittelwellenlängen-Empfangsgitter (1.2) und als Grobwellenlängen-Empfangsgitter (1.3) bezeichnet werden; die Elektroden des Mittelwellenlängen-Konversionsgitters (2.2) auf der Reflexionsplatte (2) entlang der Messachse in Intervallen von \( P_m \) periodisch angeordnet sind; die Mittelwellenlänge \( W_m = W_m P_m / (P_r - P_m) \) erfüllt; wobei angenommen wird, dass \( W_m = N_m W_f \); \( P_r = N_r W_i \) ist, \( N_m \) eine ganze Zahl ist und \( N_t \) eine ungerade Zahl zwischen 3 und 7 ist; die Elektroden des Mittelwellenlängen-Empfangsgitters (1.2) auf der entsprechenden Transmissionsplatte (1) in zwei identische Gruppen (1.2A und 1.2B) unterteilt werden, die entlang der Messachse in Intervallen von \( N_r P_m \) abwechselnd und periodisch angeordnet sind, die Empfangsgitterelektroden derselben Gruppe durch Drähte miteinander verbunden sind; die Elektroden des Grobwellenlängen-Konversionsgitters (2.3) auf der Reflexionsplatte (2) entlang der Messachse in Intervallen von \( P_c \) periodisch angeordnet sind; die Grobwellenlänge \( W_c = W_c P_c / (P_r - P_c) \) erfüllt; wobei angenommen wird, dass \( W_c = N_c W_f \); \( P_c = N_c W_f \) ist, \( N_c \) eine ganze Zahl ist und \( N_t \) eine ungerade Zahl zwischen 3 und 7 ist; die Teilung \( P_c \) der Elektroden des Grobwellenlängen-Konversionsgitters (2.3) erfüllt; die Elektroden des Grobwellenlängen-Empfangsgitters (1.3) auf der entsprechenden Transmissionsplatte (1) ebenfalls in zwei identische Gruppen (1.3A und 1.3B) unterteilt werden, die in Intervallen von \( N_r P_c \) abwechselnd und periodisch angeordnet sind, und die Empfangsgitterelektroden derselben Gruppe durch Drähte miteinander verbunden sind.

6. Kapazitiver Gitterverschiebungssensor für Absolutpositionsbestimmung nach Anspruch 5, **dadurch gekennzeichnet**, dass
die Signalauswahlschaltergruppe (6) einen ersten Schalter (S₁), einen zweiten Schalter (S₂), einen dritten Schalter (S₃) und einen vierten Schalter (S₄) umfasst; ein Ausgangsanschluss der Gruppe von Elektroden (1.2A) des Mittelwellenlängen-Empfangsgitters (1.3) und ein Ausgangsanschluss der Gruppe von Elektroden (1.2A) des Grobwellenlängen-Empfangsgitters (1.2) jeweils mit zwei Eingangsanschlüssen des dritten Schalters (S₃) verbunden sind, ein Ausgangsanschluss der anderen Gruppe von Elektroden (1.3B) des Grobwellenlängen-Empfangsgitters (1.3) und ein Ausgangsanschluss der anderen Gruppe von Elektroden (1.2B) des Mittelwellenlängen-Empfangsgitters (1.2) jeweils mit zwei Eingangsanschlüssen des vierten Schalters (S₄) verbunden sind; ein gemeinsamer Anschluss des dritten Schalters (S₃) mit einem Eingangsanschluss des Differentialverstärkers (7) verbunden ist und ein gemeinsamer Anschluss des vierten Schalters (S₄) mit einem anderen Eingangsanschluss des Differentialverstärkers (7) verbunden ist; der erste Schalter (S₁) mit den Ausgangsanschlüssen der beiden Gruppen von Elektroden (1.2A und 1.2B) des Mittelwellenlängen-Empfangsgitters (1.2) verbunden ist und der zweite Schalter (S₂) mit den Ausgangsanschlüssen der beiden Gruppen von Elektroden (1.3A und 1.3B) des Grobwellenlängen-Empfangsgitters (1.3) verbunden ist.

7. Kapazitiver Gitterverschiebungssensor für Absolutpositionsbestimmung nach einem der Ansprüche 1 bis 4, **dadurch gekennzeichnet**, dass
zwei Spalten von Konversionsgittern und zwei Spalten von Empfangsgittern jeweils angeordnet sind, die beiden Spalten von Konversionsgittern der Reflexionsplatte (2) jeweils als Grobwellenlängen-Konversionsgitter (2.3) und
als Feinwellenlängen-Zusatzzinkonversionsgitter (2.2) bezeichnet werden, die beiden Spalten von Empfangsgittern der entsprechenden Transmissionsplatinen (1) jeweils als Grobwellenlängen-Empfangsgitter (1.3) und als Feinwellenlängen-Zusatzzempfangsgitter (1.2) bezeichnet werden; die Elektroden des Feinwellenlängen-Zusatzzinkonversionsgitters (2.2) auf der Reflexionsplatine (2) entlang der Messachse in Intervallen von \( P_c, P_c=W_f \) periodisch angeordnet sind; die Elektroden des Feinwellenlängen-Zusatzzempfangsgitters (1.2) auf der entsprechenden Transmissionsplatine (1) ein vollständiges Rechteck bilden; die Elektroden des Grobwellenlängen-Konversionsgitters (2.3) auf der Reflexionsplatine (2) entlang der Messachse in Intervallen von \( P_c \) periodisch angeordnet sind; die Grobwellenlänge \( W_c = \frac{P_c P_e}{P_c - P_e} \) erfüllt; wobei angenommen wird, dass \( W_c = \frac{N_c W_f}{N_c + N_t} \) ist, \( N_c \) eine ganze Zahl ist und \( N_t \) eine ungerade Zahl zwischen 3 und 7 ist, die Teilung \( P_c = \frac{N_c W_f}{N_c + N_t} \) erfüllt; die Elektroden des Grobwellenlängen-Empfangsgitters (1.3) auf der entsprechenden Transmissionsplatine (1) ebenfalls in zwei identische Gruppen (1.3A und 1.3B) unterteilt werden, die in Intervallen von \( N_c P_c \) abwechselnd und periodisch angeordnet sind, und die Empfangsgitterelektroden derselben Gruppe durch Drähte miteinander verbunden sind.


drei von der Empfangsgitterelektrode der gemessenen Wellenlänge ausgegebene empfangene Signale durch die Signalauswahlsschaltergruppe (6) nach Differentialverstärkung in den Differentialverstärker (7) eingegeben werden, die Signale sukzessiv durch die synchrone Demodulationsschaltung, das Tiefpassfilter und die Nullendurchgangsschaltung verarbeitet und dann in ein Rechteckwellensignal konvertiert werden; die synchrone Erfassungsschaltung ein synchrones Erfassungssignal gemäß dem Rechteckwellensignal und dem Ausgang der synchrone Verzögerungsschaltung erzeugt, ein Zählergebnis des Additionszählers an einer Nicht-Zählflanke des Haupttakts erfasst und das Ergebnis in eine designierte Einheit des RAM schreibt; und die Steuerung das synchron Erfassungssignal zum Erzeugen des Steuersignals benutzt, das zum Messen der Verschiebung in der nächsten Wellenlänge benötigt wird, oder die Schnittstelleneinheit zum Durchführen einer nachfolgenden Verarbeitung aufordert;

die synchrone Verzögerungsschaltung das Zählen des Additionszählers steuert; der Additionszähler erst nach dem Anlegen eines gültigen Ansteuerungssignals für eine voreingestellte Zeit und mit einer voreingestellten Phase des Ansteuerungssignals mit dem Zählen beginnen darf, und der Additionszähler das Zählen an dem vom Ozillator ausgegebenen Haupttakt durchführt; und

die Steuerung nach Abschluss der Messung der Verschiebung der gemessenen Position in jeder Wellenlänge sukzessiv durch die Messeinheit der Schnittstelleneinheit auffordert, eine Folgeverarbeitung durchzuführen; die Schnittstelleneinheit die Messeinheit unmittelbar nach dem Lesen des Wertes der Verschiebung in jeder Wellenlänge vom RAM der Messeinheit abschaltet, eine Absolutposition gemäß dem Wert der Verschiebung in jeder Wellenlänge berechnet und das Messergebnis anzeigt.

9. Betriebsverfahren eines kapazitiven Gitterverschiebungssensors für AbsolutpositionsMessung nach Anspruch 8, dadurch gekennzeichnet, dass

9.1. Starten, durch einen Timer einer Schnittstelleneinheit, einer Messeinheit gemäß einer voreingestellten Messfrequenz;
II. Bestimmen der Verschiebung einer gemessenen Position in der Grobwellenlänge;
   II-i. Ausgeben, durch die Steuerung der Messeinheit, eines Grobwellenlängen-Messsignals und Schalten der Signalauwa{
   schaltergruppe (6) in eine Position, die zum Messen der Verschiebung der Grobwellenlänge benötigt wird;
   II-ii. Ausgeben, durch die Steuerung, des Initialisierungssignals, Einstellen der sequentiellen Logik des Ansteu-
   erungsanzeigengenerators (5), der synchronen Verzögerungsschaltung und der synchronen Erfassungsschaltung der Messeinheit in einen voreingestellten Anfangszustand, und gleichzeitig Designieren einer Adresse einer Speichereinheit der Grobwellenlängenverschiebung im RAM;
   II-iii. Starten, durch den Ansteuerungsanzeigengenerator (5), der Ausgabe von gültigen Sensoransteuerungssig-
   nalen;
   II-iv. Zulassen, nach dem Anlegen des Ansteuerungssignals für eine voreingestellte Zeit und mit einer vorein-
   gestellten Phase des Ansteuerungssignals, das heißt einem voreingestellten Phasennullpunkt, durch die syn-
   chron Verzögerungsschaltung, dass der Additionszähler mit dem Zählen beginnt;
   II-v. synchrones Erfassen, durch die synchrone Erfassungsschaltung, eines Zählergebnisses des Additions-
   zählers an einer gültigen Flanke eines Nulldurchgangserkennungssignals, und Schreiben des Ergebnisses in
die designierte Einheit des RAM, und das Ergebnis ist die Verschiebung der gemessenen Position in der
einer Verschiebung in der Mittelwellenlänge (mit einem festen Versatz);
   III. Bestimmen der Verschiebung in der Mittelwellenlänge;
   III-i. Ausgeben, durch die Steuerung, eines Mittelwellenlängen-Messsignals und Schalten der Signalauwa-
schaltergruppe (6) in eine Position, die zum Messen der Verschiebung der Mittelwellenlänge benötigt wird;
   III-ii. Ausgeben, durch die Steuerung, des Initialisierungssignals, Einstellen der sequentiellen Logik des Ansteu-
erungsanzeigengenerators (5), der synchronen Verzögerungsschaltung und der synchronen Erfassungsschaltung der Messeinheit in einen voreingestellten Anfangszustand, und gleichzeitig Designieren einer Adresse einer Speichereinheit der Mittelwellenlängenverschiebung im RAM;
   III-iii. Starten, durch den Ansteuerungsanzeigengenerator (5), der Ausgabe von gültigen Sensoransteuerungssig-
   nalen;
   III-iv. Zulassen, durch die synchrone Verzögerungsschaltung, dass der Additionszähler mit dem Zählen beginnt;
   III-v. Erfassen, durch die synchrone Erfassungsschaltung, eines Zählergebnisses des Additionszählers und
   Schreiben des Ergebnisses in die designierte Einheit des RAM, und das Ergebnis ist die Verschiebung der
gemessenen Position in der Mittelwellenlänge (mit einem festen Versatz);
   IV. Bestimmen der Verschiebung in der Feinwellenlänge;
   IV-i. Ausgeben, durch die Steuerung, eines Feinwellenlängen-Messsignals und Schalten der Signalauwa-
schaltergruppe (6) in eine Position, die zum Messen der Verschiebung in der Feinwellenlänge benötigt wird;
   IV-ii. Ausgeben, durch die Steuerung, des Initialisierungssignals, Einstellen der sequentiellen Logik des An-
   steuerungsanzeigengenerators (5), der synchronen Verzögerungsschaltung und der synchronen Erfassungsschal-
tung der Messeinheit in einen voreingestellten Anfangszustand, und gleichzeitig Designieren einer Adresse
   einer Speichereinheit der Feinwellenlängenverschiebung im RAM;
   IV-iii. Starten, durch den Ansteuerungsanzeigengenerator (5), der Ausgabe von gültigen Sensoransteuerungssig-
   nalen;
   IV-iv. Zulassen, durch die synchrone Verzögerungsschaltung, dass der Additionszähler mit dem Zählen beginnt;
   IV-v. Erfassen, durch die synchrone Erfassungsschaltung, eines Zählergebnisses des Additionszählers und
   Schreiben des Ergebnisses in die designierte Einheit des RAM, und das Ergebnis ist die Verschiebung der
gemessenen Position in der Feinwellenlänge (mit einem festen Versatz);
   V. Auffordern, durch die Steuerung, der Schnittstelleneinheit zum Durchführen von nachfolgender Verarbeitung;
   VI. Ausschalten, durch die Schnittstelleneinheit, der Messschaltung nach dem Lesen von im RAM der Mess-
einheit gespeicherten Verschiebungsdaten; und
   VII. Durchführen, durch die Schnittstelleneinheit, von Verarbeitung und Anzeigen eines Messergebnisses; wobei
   eine Folge von Schritten II, III und IV zum Bestimmen der Verschiebungen in der Grob-, Mittel- und Feinwellenlänge
   arbitrar ist.

Revendications

1. Un capteur de déplacem-ent de réseau capacitif de mesure de position absolue, comprenant une carte de trans-
mission (1) et une carte de réflexion (2) capables de se déplacer l’une par rapport à l’autre et un circuit de mesure,
ou une colonne d’électrodes agencées périodiquement sont disposées sur la carte de transmission (1) dans une
direction d’axe de mesure, qui forment un réseau de transmission (1.1) ; une colonne d’électrodes agencées pé-

27
Le capteur de déplacement de réseau capacitif de mesure de position absolue selon la Revendication 1, caractérisé en ce que

2. Le capteur de déplacement de réseau capacitif de mesure de position absolue selon la Revendication 1, caractérisé en ce que

le générateur de signaux d’attaque (5) comprend principalement un compteur à anneau torsadé (5.1), un commutateur de sélection de séquence d’attaque (5.2) et un modulateur XOR (5.3) ; une sortie de l’oscillateur passe au travers du diviseur de fréquence et ensuite est raccordée au générateur de signaux d’attaque (5) de façon à servir d’horloge d’entrée au compteur à anneau torsadé (5.1) et au modulateur XOR (5.3) ; le compteur à anneau torsadé (5.1) génère N signaux en sortie possédant des propriétés d’onde, et les N signaux en sortie possédant des propriétés d’onde sont entrés dans le modulateur XOR (5.3) par l’intermédiaire du commutateur de sélection de séquence d’attaque (5.2), et N sorties du modulateur XOR (5.3) sont raccordées aux N électrodes de chacun des groupes du réseau de transmission (1.1).

3. Le capteur de déplacement de réseau capacitif de mesure de position absolue selon la Revendication 1, caractérisé en ce que
Le capteur de déplacement de réseau capacitif de mesure de position absolue selon la Revendication 1, caractérisé en ce que
les électrodes du réseau de transmission, du réseau de réception, du réseau de réflexion et du réseau de conversion sont agencées circonférentiellement de manière concentrique et le pas des électrodes est calculé selon un angle ; un déplacement relatif entre la carte de transmission (1) et la carte de réflexion (2) est une rotation relative de la carte de transmission (1) et de la carte de réflexion (2), le point de base étant le centre des cercles concentriques.

Le capteur de déplacement de réseau capacitif de mesure de position absolue selon l'une quelconque des Revendications 1 à 4, caractérisé en ce que
deux colonnes de réseaux de conversion et deux colonnes de réseaux de réception sont disposées respectivement, les deux colonnes de réseaux de conversion de la carte de réflexion (2) sont respectivement appelées un réseau de conversion de longueur d'onde moyenne (2.2) et un réseau de conversion de longueur d'onde approximative (2.3), les deux colonnes de réseaux de réception de la carte de transmission correspondante (1) sont respectivement appelées un réseau de réception de longueur d'onde moyenne (1.2) et un réseau de réception de longueur d'onde approximative (1.3) ; les électrodes du réseau de conversion de longueur d'onde moyenne (2.2) sur la carte de réflexion (2) sont agencées le long de l'axe de mesure à des intervalles de $P_c$ périodiquement ; la longueur d'onde moyenne $W_m$ satisfait $W_m = P_m (P_r - P_m)$ ; il est fait l'hypothèse que $W_m = N_m W_f$, $P_r = N_r W_f$, $N_m$ est un entier et $N_r$ est un nombre impair entre 3 et 7, ainsi $P_m = N_m W_f/(N_m + N_r)$ ; les électrodes du réseau de réception de longueur d'onde moyenne (1.2) sur la carte de transmission correspondante (1) sont divisées en deux groupes identiques (1.2A et 1.2B) agencés le long de l'axe de mesure à des intervalles de $N_r P_m$ de manière alternée et périodiquement, les électrodes de réseau de réception du même groupe sont raccordées les unes aux autres par des fils ; les électrodes du réseau de conversion de longueur d'onde approximative (2.3) sur la carte de réflexion (2) sont agencées le long de l'axe de mesure à des intervalles de $P_c$ périodiquement ; la longueur d'onde approximative $W_c$ satisfait $W_c = P_c (P_r - P_c)$ ; il est fait l'hypothèse que $W_c = N_c W_f$, $P_r = N_r W_f$, $N_c$ est un entier et $N_r$ est un nombre impair entre 3 et 7, le pas $P_c$ des électrodes du réseau de conversion de longueur d'onde approximative (2.3) satisfait $P_c = N_c W_f/(N_c + N_r)$ ; les électrodes du réseau de réception de longueur d'onde approximative (1.3) sur la carte de transmission correspondante (1) sont également divisées en deux groupes identiques (1.3A et 1.3B) agencés à des intervalles de $N_r P_c$ de manière alternée et périodiquement, et les électrodes de réseau de réception du même groupe sont raccordées les unes aux autres par des fils.

Le capteur de déplacement de réseau capacitif de mesure de position absolue selon la Revendication 5, caractérisé en ce que
le groupe de commutateurs de sélection de signal (6) comprend un premier commutateur ($S_1$), un deuxième commutateur ($S_2$), un troisième commutateur ($S_3$) et un quatrième commutateur ($S_4$) ; une borne de sortie du groupe d'électrodes (1.3A) du réseau de réception de longueur d'onde approximative (1.3) et une borne de sortie du groupe d'électrodes (1.2A) du réseau de réception de longueur d'onde moyenne (1.2) sont respectivement raccordées à deux bornes d'entrée du troisième commutateur ($S_3$), une borne de sortie de l'autre groupe d'électrodes (1.3B) du réseau de réception de longueur d'onde approximative (1.3) et une borne de sortie de l'autre groupe d'électrodes (1.2B) du réseau de réception de longueur d'onde moyenne (1.2) sont respectivement raccordées à deux bornes d'entrée du quatrième commutateur ($S_4$) ; une borne commune du troisième commutateur ($S_3$) est raccordée à une borne d'entrée de l'amplificateur différentiel (7), et une borne commune du quatrième commutateur ($S_4$) est raccordée à une autre borne d'entrée de l'amplificateur différentiel (7) ; le premier commutateur ($S_1$) est raccordé aux bornes de sortie des deux groupes d'électrodes (1.2A et 1.2B) du réseau de réception de longueur d'onde moyenne (1.2), et le deuxième commutateur ($S_2$) est raccordé aux bornes de sortie des deux groupes d'électrodes (1.3A et 1.3B) du réseau de réception de longueur d'onde approximative (1.3).

Le capteur de déplacement de réseau capacitif de mesure de position absolue selon l’une quelconque des Revendications 1 à 4, caractérisé en ce que
deux colonnes de réseaux de conversion et deux colonnes de réseaux de réception sont disposées respectivement, les deux colonnes de réseaux de conversion de la carte de réflexion (2) sont respectivement appelées un réseau
de conversion de longueur d'onde approximative (2.3) et un réseau de conversion auxiliaire de longueur d'onde fine (2.2), les deux colonnes de réseaux de réception de la carte de transmission correspondante (1) sont respectivement appelées un réseau de réception de longueur d'onde approximative (1.3) et un réseau de réception auxiliaire de longueur d'onde fine (1.2) ; les électrodes du réseau de conversion auxiliaire de longueur d'onde fine (2.2) sur la carte de réflexion (2) sont agencées le long de l'axe de mesure à des intervalles de \( P_c \) périodiquement ; les électrodes du réseau de réception auxiliaire de longueur d'onde fine (1.2) sur la carte de transmission correspondante (1) forment un rectangle complet ; les électrodes du réseau de conversion de longueur d'onde approximative (2.3) sur la carte de réflexion (2) sont agencées le long de l'axe de mesure à des intervalles de \( P_c \) périodiquement ; la longueur d'onde approximative \( W_c \) satisfait \( W_c = P_c W_f / (N_c + N_t) \) ; les électrodes du réseau de réception de longueur d'onde approximative (1.3) sur la carte de transmission correspondante (1) sont également divisées en deux groupes identiques (1.3A et 1.3B) agencés à des intervalles de \( N_t P_c \) de manière alternée et périodiquement, et les électrodes de réseau de réception du même groupe sont raccordées les unes aux autres par des fils.

8. Un procédé de fonctionnement utilisant un capteur de déplacement de réseau capacitif de mesure de position absolue selon l'une quelconque des Revendications 1 à 4, où l'unité d'interface démarre l'unité de mesure selon une fréquence de mesure prédéfinie, le dispositif de commande de l'unité de mesure génère successivement divers signaux de commande comprenant un signal d'initialisation, un signal de mesure de déplacement, un signal d'adresse mémoire et un signal de demande de traitement, et chaque sortie est respectivement raccordée à la RAM, au générateur de signaux d’attaque (5), au groupe de commutateurs de sélection de signal (6) et au circuit d'interface de mesure de l'unité d'interface ; un signal d'attaque de capteur possédant des propriétés d'onde généré par le générateur de signaux d'attaque (5) est modifié en un signal reçu qui change périodiquement avec le temps après un couplage capacitif du réseau de transmission et du réseau de réception, une conversion de pas du réseau de réflexion et du réseau de conversion et un couplage capacitif du réseau de conversion et du réseau de réception, et le déplacement d'une position mesurée dans la longueur d'onde mesurée est transformé en une phase initiale d'une onde fondamentale temporelle d'un signal reçu ; deux signaux reçus produits en sortie par l'électrode de réseau de réception de la longueur d'onde mesurée sont entrés dans l'amplificateur différentiel (7) par l'intermédiaire du groupe de commutateurs de sélection de signal (6), après une amplification différentielle, les signaux sont successivement traités par le circuit de démodulation synchronisé, le filtre passe-bas et le circuit de détection de passage par zéro, et ils sont ensuite convertis en un signal à onde carrée ; le circuit de capture synchronie génère un signal de capture synchronie en fonction du signal à onde carrée, et la sortie du circuit à retard synchronie capture un résultat de décompte du compteur additionneur au niveau d’un bord de non-décompte de l'horloge maître et inscrit le résultat dans une unité désignée de la RAM ; et le dispositif de commande utilise le signal de capture synchronie de façon à générer le signal de commande nécessaire à la mesure du déplacement dans la longueur d’onde suivante ou demande à l'unité d'interface d'exécuter un traitement subséquent ; le circuit à retard synchronie commande le décompte du compteur additionneur ; uniquement après l'application d'un signal d'attaque valide pendant un temps prédéfini et à une phase prédéfinie du signal d'attaque, le compteur additionneur est autorisé à démarrer le décompte, et le compteur additionneur exécute le décompte sur l'horloge maître produite en sortie par l'oscillateur, et après l'achèvement avec succès par l'unité de mesure de la mesure du déplacement de la position mesurée dans chaque longueur d'onde, le dispositif de commande demande à l'unité d'interface d'exécuter un traitement subséquent ; l'unité d'interface désactive l'unité de mesure immédiatement après la lecture de la valeur du déplacement dans chaque longueur d’onde à partir de la RAM de l’unité de mesure, calcule une position absolue en fonction de la valeur du déplacement dans chaque longueur d’onde et affiche le résultat de la mesure.

9. Le procédé de fonctionnement d’un capteur de déplacement de réseau capacitif de mesure de position absolue selon la Revendication 8, caractérisé en ce que

une carte de réflexion (2) du capteur de déplacement de réseau capacitif de mesure de position absolue est disposée avec un réseau de conversion de longueur d'onde approximative (2.3) et un réseau de conversion de longueur d’onde moyenne (2.2), et une carte de transmission correspondante (1) est disposée avec un réseau de réception de longueur d’onde approximative (1.3) et un réseau de réception de longueur d’onde moyenne (1.2) ; une longueur d'onde approximative, une longueur d’onde moyenne et une longueur d’onde fine sont utilisées pour une mesure de position absolue, et le procédé comprend principalement :

I. le démarrage, par une horloge d’une unité d’interface, d’une unité de mesure en fonction d’une fréquence de
mesure prédéfinie,
II. la détermination du déplacement d'une position mesurée dans la longueur d'onde approximative,
   II-i. la production en sortie, par le dispositif de commande de l'unité de mesure, d'un signal de mesure de
   longueur d'onde approximative, et la commutation du groupe de commutateurs de sélection de signal (6) vers
   une position nécessaire à la mesure du déplacement dans la longueur d'onde approximative,
   II-ii. la production en sortie, par le dispositif de commande, du signal d'initialisation, le réglage de la logique
   séquentielle du générateur de signaux d'attaque (5), du circuit à retard synchrone et du circuit de capture
   synchrone de l'unité de mesure sur un état initial prédéfini, et simultanément la désignation d'une adresse d'une
   unité à mémoire du déplacement de longueur d'onde approximative dans la RAM,
   II-iii. le démarrage, par le générateur de signaux d'attaque (5), de la production en sortie de signaux d'attaque
   de capteur valides,
   II-iv. après l'application du signal d'attaque pendant un temps prédéfini et à une phase prédéfinie du signal
   d'attaque, qui est un point zéro de phase prédéfini, l'autorisation, donnée par le circuit à retard synchrone au
   compteur additionneur, de démarrer le décompte,
   II-v. la capture synchrone, par le circuit de capture synchrone, d'un résultat de décompte du compteur addi-
   tionneur au niveau d'un bord valide d'un signal de détection de passage par zéro, et l'inscription du résultat
   dans l'unité désignée de la RAM, et le résultat est le déplacement de la position mesurée dans la longueur
   d'onde approximative (avec un décalage fixe),
III. la détermination du déplacement dans la longueur d'onde moyenne,
   III-i. la production en sortie, par le dispositif de commande, d'un signal de mesure de longueur d'onde moyenne,
   et la commutation du groupe de commutateurs de sélection de signal (6) vers une position nécessaire à la
   mesure du déplacement dans la longueur d'onde moyenne,
   III-ii. la production en sortie, par le dispositif de commande, du signal d'initialisation, le réglage de la logique
   séquentielle du générateur de signaux d'attaque (5), du circuit à retard synchrone et du circuit de capture
   synchrone de l'unité de mesure sur un état initial prédéfini, et simultanément la désignation d'une adresse d'une
   unité à mémoire du déplacement de longueur d'onde moyenne dans la RAM,
   III-iii. le démarrage, par le générateur de signaux d'attaque (5), de la production en sortie de signaux d'attaque
   de capteur valides,
   III-iv. l'autorisation, donnée par le circuit à retard synchrone au compteur additionneur, de démarrer le décompte,
   III-v. la capture, par le circuit de capture synchrone, d'un résultat de décompte du compteur additionneur et
   l'inscription du résultat dans l'unité désignée de la RAM, et le résultat est le déplacement de la position mesurée
   dans la longueur d'onde moyenne (avec un décalage fixe),
IV. la détermination du déplacement dans la longueur d'onde fine,
   IV-i. la production en sortie, par le dispositif de commande, d'un signal de mesure de longueur d'onde fine,
   et la commutation du groupe de commutateurs de sélection de signal (6) vers une position nécessaire à la mesure
   du déplacement dans la longueur d'onde fine,
   IV-ii. la production en sortie, par le dispositif de commande, du signal d'initialisation, le réglage de la logique
   séquentielle du générateur de signaux d'attaque (5), du circuit à retard synchrone et du circuit de capture
   synchrone de l'unité de mesure sur un état initial prédéfini, et simultanément la désignation d'une adresse d'une
   unité à mémoire du déplacement de longueur d'onde fine dans la RAM,
   IV-iii. le démarrage, par le générateur de signaux d'attaque (5), de la production en sortie de signaux d'attaque
   de capteur valides,
   IV-iv. l'autorisation, donnée par le circuit à retard synchrone au compteur additionneur, de démarrer le décompte,
   IV-v. la capture, par le circuit de capture synchrone, d'un résultat de décompte du compteur additionneur et
   l'inscription du résultat dans l'unité désignée de la RAM, et le résultat est le déplacement de la position mesurée
   dans la longueur d'onde fine (avec un décalage fixe),
V. la demande, par le dispositif de commande, adressée à l'unité d'interface d'exécuter un traitement subséquent,
VI. la désactivation, par l'unité d'interface, du circuit de mesure après la lecture de données de déplacement
   sauvegardées dans la RAM de l'unité de mesure, et
VII. l'exécution, par l'unité d'interface, d'un traitement, et l'affichage d'un résultat de mesure, où
   une séquence des opérations II, III et IV destinée à la détermination des déplacements dans les longueurs d'onde
   approximative, moyenne et fine est arbitraire.
FIG. 3
FIG. 6

FIG. 7
Start

Start a measurement unit

Determine displacement of a coarse wavelength

Determine displacement of a medium wavelength

Determine displacement of a fine wavelength

Read displacement data

Turn off the measurement unit

Process a measurement result

End

FIG. 8
Start

Start a measurement unit

Determine displacement of a coarse wavelength

Determine displacement of a fine wavelength

Read displacement data

Turn off the measurement unit

Process a measurement result

End

FIG. 12
REFERENCES CITED IN THE DESCRIPTION

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