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H4D 747 752 755 75X 782 783

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(54) IMPROVEMENTS IN OR RELATING TO DISTANCE MEASURING EQUIPMENT

(71) We, SIEMENS AKTIENGESELLSCHAFT, a German Company of Berlin and Munich, German Federal Republic, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to a distance measuring equipment of a type capable of effecting high-speed measurement of the range of an object from a reference plane and is an improvement in or modification of the invention claimed in our co-pending United Kingdom Patent Application No. 17,173/74 (Specification No. 1468406). In a preferred embodiment, the speed component of the object normal to the reference or datum plane may also be determined.

Our United Kingdom Patent Specification No. 1,432,801 describes and claims a distance measuring system for determining the range of an object from a datum plane, in which transmission means are provided for a laser beam to be deflected periodically and sweep a predetermined space, so that said beam is diffusely reflected by the object when the latter is within said predetermined space, and static detector means being provided to selectively receive light from a single specific direction that is predetermined so that any diffusely reflected light is detected by said detector means substantially at that instant when the laser becomes incident upon said object during the sweep of the beam, when operating, and the response of said detector means being fed to analysis means by which the range of said object is determined from the time difference between the commencement of a transmission sweep and the time of receipt of the reflected signal.

Preferably a piezo-electric deflector using an oscillatory mirror is employed to deflect the laser beam, and in the embodiment described this is driven by a triangular or saw-tooth voltage. If large oscillation amplitudes of the oscillating reflectors are to be attained and stabilised over long periods of time, such an arrangement imposes strict requirements upon the control of the deflecting device.

In our co-pending Application No. 17173/74 (Specification No. 1468406) a system of this type is described and claimed in which the laser beam is deflected by a deflector system driven by a sinusoidal control voltage from a generator whose frequency matches the natural resonance frequency of the deflector system and is so arranged that only the substantially linear portions of the sinusoidal waveform are used in the measurement processes. As the detector can only receive light from a given direction, and the distances are determined from the time difference Δt_d between one selected start of the beam deflection and the subsequent detector signal, reference pulses can be initiated at points of time t_{ref} in a separate reference detector in which a swinging mirror is situated such that the laser beams are reflected from a transparent plate that is situated on the reference line and so be directed to be incident on the reference detector.

In the parent Patent the beam deflection is energised by a generator producing a sinusoidal voltage at a frequency that preferably matches the individual resonances of the mechanical construction, only the substantially linear part of the sinusoidal waveform being utilised in the measurement.

A high degree of accuracy is thus achieved, and by the introduction of an extra reference detector and of a semi-transparent mirror disc defining the reference level, the reference time t_{ref} can be determined very exactly since these two parts of the structure are coordinated and finely tuned one against the other and against the amplitude of the light rays incident on them from the light source.

However, errors arise in the determination of the moment of measurement, i.e. of that moment when a ray reflected from the measured object is registered by the detector. Since this ray falls on the detector for only a little time, either the rising edge of the measurement pulse released by the detector or the null point of the differentiated measurement pulse is chosen as the instant of measurement. The first of these measurement instants depends very much on the amplitude of measurement and exact determinations of time, a stabilized detector pulse amplitude is required, which can only be achieved in the time taken for several reflections. The use of a single reflection for independent measurement is thus not possible.

On the other hand, if the null point of the differentiated measurement pulse is taken as the measurement instant, the amplitude of the detector pulse has less influence on the falsification of the measurement instant but the influence of the shape of the detector pulse increases. This pulse shape is influenced by the depth of focus, which differs from distance to distance with constant focussing of the picture display glass in front of the detector and by the shape of the light scattering at the surface of the object being measured.

One object of the present invention is to provide a construction which substantially eliminates these sources of error.

The invention consists in a distance measuring system as claimed in Claim 1 of our co-pending United Kingdom Patent Application No. 17,173/74 (Specification No. 1,468,406) in which the distances are determined from the time difference Δt_d between commencement of a sweep of the beam deflection produced by said oscillating reflector and the instant of response producing a detector signal from said detector means, whereby reference pulses are created in an extra reference detector at times t_{ref}, using a position of said oscillating reflector whereby the laser beam reflected on a semi-transparent disc situated on a reference line is incident on the reference detector, and means being provided to precisely measure the time different Δt_d from time t_{ref} to the middle of the measurement pulse produced by said detector means.

The measurement pulse of duration t_D is converted to a rectangular pulse in a pulse former. The length Δt_w of the rectangular pulse depends on the adjustment of the initiation threshold of a reinforcing voltage comparator and on the amplitude of measurement. Because of the very strong boost from the comparator, the length of pulse changes almost symmetrically around the centre of the rectangular pulse when the pulse amplitude alters. If the times from reference moment t_B to the rising edge and from the reference moment t_B to the falling edge of the rectangular pulse are summed for different pulse lengths Δt_w, the sum of both times remains constant even with varied pulse lengths Δt_w.

Thus the total time remains independent of the measurement pulse amplitude.

The invention will now be described with reference to the drawings, in which:—

Figure 1 is a block schematic diagram illustrating one exemplary embodiment constructed in accordance with the invention, utilising the time difference Δt_d from the time t_{ref} to the middle of the measurement pulse; and

Figure 2 schematically illustrates details of a modified embodiment;

Figure 3 schematically illustrates one alternative system; and

Figure 4 illustrates further details.

The system illustrated in Figure 1 has an oscillating reflector 4 mounted on a beam deflector 3 so that a laser beam transmitted from a laser transmitter 5 is reflected by the oscillating reflector 4 and sweeps a measurement plane in which an object 9 to be measured is situated. At a given position of the oscillating reflector 4 there arises a reflection direction 8 in which the laser beam is incident on the object 9 and propagated back on the requisite path to a measurement detector 10. This propogated light passes for only a short time over the light-sensitive surface of the detector 10, during which time a measurement signal is initiated at the output of detector 10 and which has a length which depends on the length of time the light is in contact with the light-sensitive surface. This signal is boosted in amplifier 11 and transmitted to a pulse shaper 12 which forms a rectangular waveform pulse voltage 72 from the signal. This pulse is fed in parallel to two separate differentiators 73 and 74, from the first of which only the rising edge 75 is transmitted and from the second of which only the falling edge 76 is transmitted, these being fed into the inputs of respective pulse discriminators 77 and 78.

A short time before the position of the oscillating reflector 4 which gives reflection direction 8, there is a mirror position which deflects the laser beam in a direction 79, where the thus reflected laser beam is further reflected from a semi-transparent disc 24 firmly connected to the beam transmitter apparatus, to reach a reference detector 25 in the requisite direction. The relevant swing mirror position occurs at a time t_{ref}. The reference signal subsequently arising in reference detector 25 is boosted in an amplifier 26, turned into a rectangular pulse in a pulse shaper 27, and the rising edge of the rectangular pulse differentiated in a differentiator 28 to be fed in parallel to the time discriminators 77 and 78. Here arise two pulses 81 and 82 with respective lengths proportional to the time difference relative to the rising edge 75 and to the falling edge 76 of the differentiated measurement pulse 72. The two pulses 81 and 82 are integrated in respective integrators 83 and 84 and the output passed to an adder 85 which sums the voltages from integrators 83 and 84 and halves the resultant to form an analogue value for display on an indicator instrument 86.

After a calibration of the measuring apparatus the displayed value is equal to the distance of the object from the display apparatus.

The accuracy of the display is improved if the lengths of pulses 81 and 82 are taken over several periods of the oscillating reflector operation and their average values then summed, halved and shown.

The halving is necessary because the total of the times between the mirror position giving reflection direction 79 and that giving reflection direction 8, i.e. Δt_d, is actually measured twice.

Figure 2 shows how a definition of the measurement time Δt_d can be obtained independently of the amplitudes of pulses 81 and 82. These two pulses are separately digitalized in two networks 88 and 89 which are controlled by a quartz oscillator 87, are averaged and halved in a storage device 90 and a following counter 91 and then displayed on a digital display apparatus 92.

Alternatively, as shown in Figure 3, it is possible to convert the digital values of pulses 81 and 82 emerging from networks 88 and 89 by digital-analogue converters 93 and 94 into analogue voltages and add the outputs obtained in an adder 95. The output is then a precise analogue value, but the speed of measurement is affected by the need for storage as is also the case for the arrangement shown in Figure 2. However, in this type of evaluation an average of several measurements is readily obtained, and thus the accuracy can be increased.

In Figure 4 is shown a system with which the measurement time Δt_d can be displayed digitally without reducing the speed of measurement.

The pulse 72 and the differentiated needle pulse 80 are produced in the manner described with reference to Figure 1. The pulse 72 is fed in parallel to a pulse discriminator 97 and an inverter 98. The amplitude 99 of the inverted pulse 100 is reduced to zero potential and the original nil potential 101 is raised to a positive potential. The pulse 100 is now led in parallel to the input of a NAND gate 102 and to an inverter 103. The second input of the NAND gate is connected to a quartz oscillator 104 which sends out an alternating voltage waveform of frequency f. As positive potential 101 lies at the right-hand input of the NAND gate during the period from t_{ref} to the rising edge of pulse 72, it allows the potential digitalized with frequency f to pass until a time t_M when the output of the NAND gate 102 is switched over to zero potential.

In the inverter 103 the pulse 100 is changed into a pulse 105 that its base value 106 is zero potential and its peak amplitude 107 has positive potential. Pulse 105 is fed to the right-hand input of another NAND gate 108. The left-hand input of this gate is connected with a frequency divider 109 which halves the frequency f of the alternating voltage sent out from the quartz oscillator 104.

During the time from t_{ref} to t_M there is zero potential at the right-hand input of the NAND gate 108. For this reason the alternating voltage of frequency $f/2$ which is fed to the left-hand input of gate 108, cannot pass. However, the output of gate 108 is switched over to positive potential during this time to provide a position potential at the right-hand input of another NAND gate 109. The left-hand input is connected to the output of gate 102 which supplies a positive potential digitalized with frequency f. Because of the positive potential at the right-hand input of gate 109, the positive potential digitalized with frequency f can pass through the gate 109 and is fed to the right-hand input of a gate 110.

The left-hand input of the gate 110 is connected to the pulse discriminator 97, which emits a direct voltage proportional to the time difference between the arrival of the needle pulse 80, at time t_{ref}, and the falling edge of pulse 72 at time t_{M1}. This voltage is positive and lies at the left-hand input of gate 110. Thus, during the time t_1 elapsing from t_{ref} to t_M, the alternating voltage with frequency f is let through by gate 110. In a subsequent counting instrument 111 is counted the number of pulses of the repetition frequency f that arrive in the time t_1 between t_{ref} and t_M.

Subsequently, for the duration of the pulse 72, during the time t_2 between t_M and t_{M1} the gate 102 is closed because at its right-hand input is the zero potential 99 of pulse 100. During this time, however, a positive potential is applied from the output of gate 102 to the left-hand input of gate 109. Gate 108 is opened, since during the time t_2 the positive potential 107 of pulse 105 lies at its right-hand input. Therefore the pulse 105 is digitalized with the frequency $f/2$ of the pulses emitted from the frequency divider 109 and the digitalized pulse train 105 passes gate 109 because, as mentioned above, a positive potential lies at its left-hand input. Since during the time t_2 a positive potential also lies at the left-hand input of gate 110, pulse 105 digitalized with frequency f/2 passes gate 110. The following counter 111 once more counts the individual pulses of the train which arrive in then time t_2.

Since pulse 105 is digitalized at half frequency, counter 111 registers the time from t_M to the middle of pulse 105.

After the addition of times t_1 and t_2 the digital display apparatus 112 shows the time Δt_d between t_{ref} and the middle of the measurement pulse.

At time t_{M^1} (falling edge of measurement pulse 72) there is zero potential at the left-hand input of gate 110, so that counting is stopped.

As described with reference to Figure 1, the time Δt_d is a measurement for the distance of the object 9 from a reference plane of the measurement apparatus.

The circuits described can also be used for precisely measuring any speed component of the object 9 normal to the reference plane or for the measurement of the thickness of objects.

WHAT WE CLAIM IS:—

1. A distance measuring system as claimed in Claim 1 of our co-pending United Kingdom Patent Application No. 17,173/74 (Specification No. 1,468,406), in which the distances are determined from the time difference Δt_d between commencement of a sweep of the beam deflection produced by said oscillating reflector and the instant of response producing a detector signal from said detector means, whereby reference pulses are created in an extra reference detector at times t_{ref}, using a position of said oscillating reflector whereby the laser beam reflected on a semi-transparent disc situated on a reference line is incident on the reference detector, and means being provided to precisely measure the time difference Δt_d from time t_{ref} to the middle of the measurement pulse produced by said detector means.

2. A system as claimed in Claim 1, in which pulse former produces a rectangular pulse to be fed in parallel to separate time differentiators, from which the measurement instants of the differentiated rising and falling edges are fed to a time discriminator for comparison with the moment t_{ref}.

3. A system as claimed in Claim 2, in which means are provided for pulses originating in a reference discriminator to have their pulse lengths and amplitudes to be evaluated, summed, and the sum value halved, the resultant being displayed in analogue form.

4. A system as claimed in Claim 2, in which means are provided for the pulses originating in said separate time discriminators to be digitalized.

5. A system as claimed in Claim 4, in which means are provided for the digitalized pulses to be summed, halved and the resultant displayed digitally.

6. A system as claimed in Claim 4, in which means are provided for the digitalized pulses to be converted into analogue pulses that are summed, halved and the resultant displayed in analogue form.

7. A system as claimed in Claim 1 in which a pulse shaper is provided to produce a rectangular pulse at the output of a pulse shaper transformer, to be fed both to a time discriminator which compares the moment of the falling edge of the rectangular pulse with time t_{ref}, and also to a further circuit in which the time between t_{ref} and the middle of the rectangular pulse is measured.

8. A system as claimed in Claim 7, in which means are provided which act during the time from t_{ref} to the rising edge of the rectangular pulse to produce a direct voltage that is digitalized with frequency f by means of a quartz oscillator, and the rectangular pulse is digitalized with a frequency f/2, the resultant number of pulses then being counted.

9. A distance measuring system substantially as described with reference to Figure 1 or Figure 4, or with reference to either Figure 1 or Figure 4 as modified by Figure 2 or Figure 3.

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Fig.1

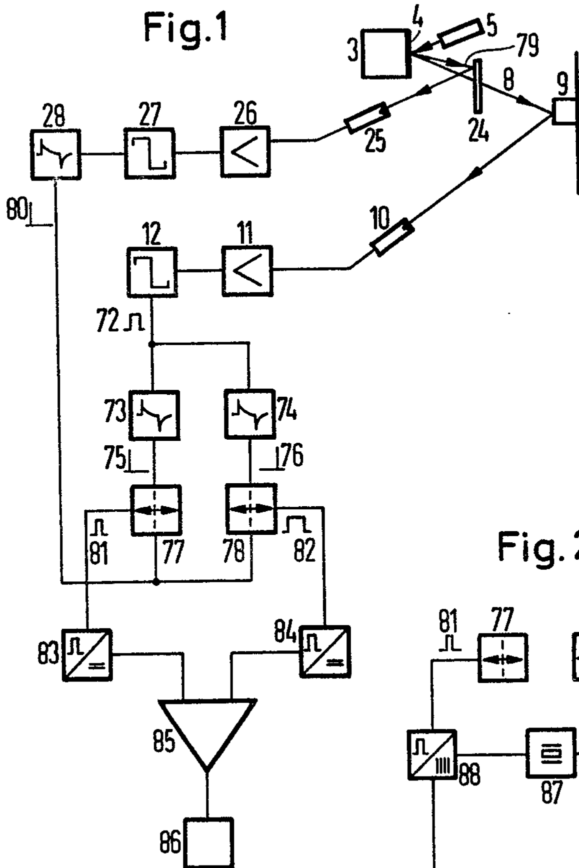
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Fig. 2

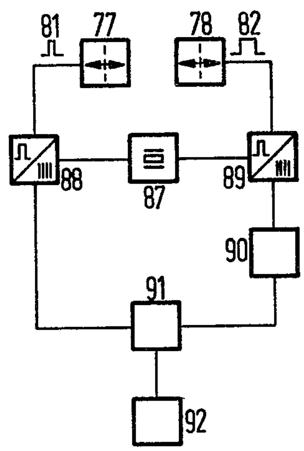
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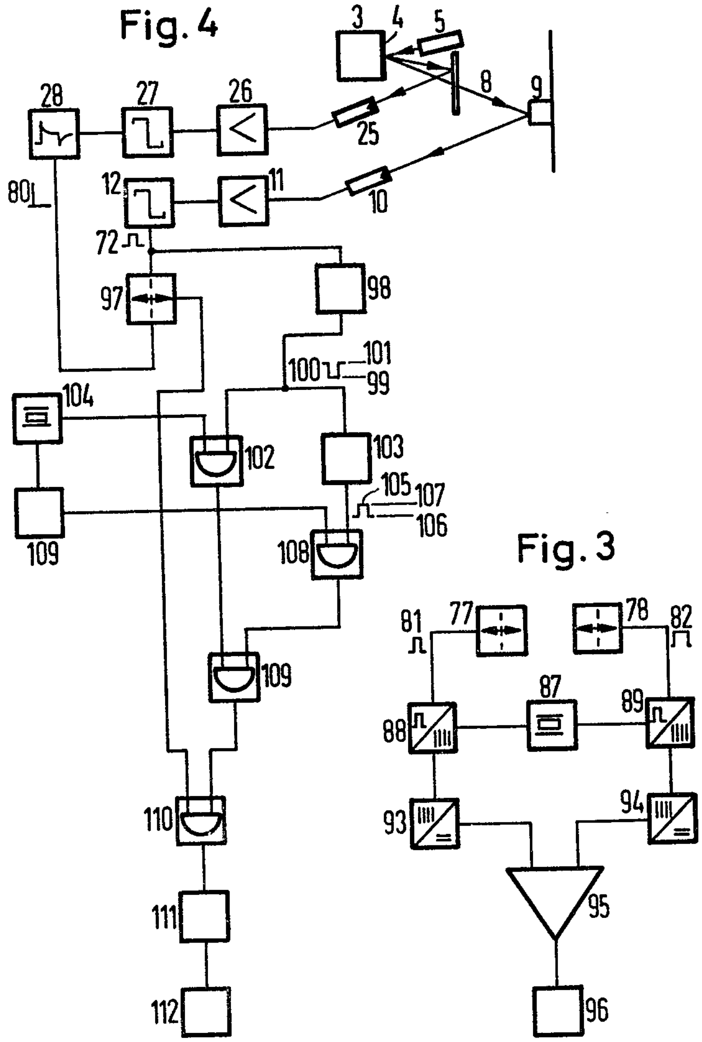
Fig. 4

Fig. 3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