Description

The invention relates to a device for scanning a record carrier provided with substantially parallel tracks, which device comprises a closed-loop position control system with position and velocity feedback for controlling the scanning point towards the centre of a specific track, for which purpose the control system comprises a positioning system for moving the scanning point in a direction transverse to the tracks, a measuring system for generating a velocity signal which is indicative of the velocity with which the scanning point is moved in a direction transverse to the tracks, and for generating a first error signal which within a predetermined limited first range to either side of said specific track centre is substantially proportional to the deviation between the track centre and the scanning point, and a control circuit for controlling the positioning system depending on the first error signal and the velocity signal, whereby the measuring system is adapted to generate a tracking-error signal and a track-loss signal which in the case of a displacement of the scanning point in a direction transverse to the tracks vary periodically with a frequency corresponding to the number of tracks traversed per unit of time, the phase difference between said signals being substantially 90°, the tracking error, over a range corresponding to substantially a quarter track pitch to either side of each track being substantially indicative of the deviation between the scanning point and the centre of the nearest track, and the track-loss signal indicating whether the scanning point is situated substantially on a track or substantially between two tracks, the tracking-error signal being employed as the first error signal, the measuring system for the purpose of generating the velocity signal, comprising means for differentiating the the tracking error signal and means for multiplying the differentiated tracking error signal and the track-loss signal.

A device as defined in the opening paragraph is known from the Applicants United States Patent specification US-A-4,037,252.

Said Specification describes an optical scanning system for reading an optically readable disc-shaped record carrier. The velocity signal and the radial-error signal thus obtained are applied to the control circuit to derive the control signal for the positioning system depending on said signals. This yields a tracking control system with velocity feedback. The drawback of the known scanning system is that in the case of a deviation larger than half a track pitch the sign of the error signal will no longer correspond to the sign of the deviation. If as a result of a disturbance, in particular a mechanical shock, the tracking error becomes larger than half a track pitch, the scanning point will be controlled towards an adjacent track instead of the original track. This is problematic, in particular when the scanning system is used in an environment where it is frequently exposed to mechanical shocks, as for example in portable audio equipment or in automotive uses.

In such cases mechanical shocks will frequently result in the scanning spot being moved off the track to be followed.

Further US-A-4 659 972 discloses a servo system for positioning and driving a pick-up head of an optical reading system. Two different control signals are concerned, the first being used to position the pick-up head and the second is used to drive the pick-up head. The first one used to position is derived from a sinusuidal waveform and is considered to be substantially proportional to the deviation between the track centre and the scanning point. The second one is used to bring the pick-up with a constant velocity in the neighbourhood of the track centre.

It is an object of the invention to provide a device which is less sensitive to mechanical shocks.

According to the invention this object is achieved in a device as defined in the opening paragraph in that the device is characterized in that the control circuit comprises means for generating at least one substitute error signal which within a second range, outside the first range, has a sign which is indicative of the direction of the deviation, the control circuit being adapted to control the positioning system in response to the first error signal or a substitute error signal depending on whether the deviation is situated in the first or the second range, respectively, in such a way that the error signal used for position feedback depends on the magnitude of the deviation and the velocity signal used for velocity feedback is independent of the magnitude of said deviation.

Thus it is achieved that in the case of disturbances for which the deviation is so large that the detected error signal is no longer indicative of the deviation the control system employs a substitute signal of large magnitude whose sign is indicative of the direction of the deviation, so that the scanning point is rapidly returned to the original track. Since the velocity feedback is constantly operative the control mode employing the substitute signal smoothly changes over into the control mode employing the first error signal for position control. Moreover, during the return to the original track the velocity is limited as a result of the velocity feedback, which precludes overshooting of the track.

In this respect it is to be noted that it is known per se from United States Patent Specification US 4,359,635 to apply a substitute error signal to the control circuit in an optical scanning device in

response to a track loss indicated by the track-loss signal, by adding an additional signal of constant signal strength to the radial-error signal. A problem which then arises is that as a result of the additional signal the velocity of the scanning spot may become so high that when the track is reached it can no longer be slowed down fast enough, so that it overshoots the track. In order to preclude this the additional signal is generated only during a limited time interval. This in turn has the drawback that, if the scanning point has not yet approached the desired track closely enough when generation of the additional signal ceases, the scanning point will yet be controlled to an adjacent track.

When velocity feedback is applied as in the device in accordance with the invention, the velocity will remain limited as a result of this velocity feedback, so that the time interval for the generation of the substitute error signal need not be limited.

An embodiment of the scanning device which is attractive because of its simplicity is characterized in that the control circuit is adapted to control the positioning system in dependence upon a substitute error signal if the track-loss signal indicates that the scanning point is situated substantially between two tracks.

A further embodiment of the invention is characterized in that the control circuit comprises counting means for counting, by means of the track-loss signal and the tracking-error signal, the number of tracks traversed by the scanning point and means for controlling the positioning means depending on a substitute error signal dictated by the count in the case that the instantaneous count deviates from a predetermined count.

This embodiment has the advantage that in the case of loss of track, when the scanning point is shifted by more than one track as a result of a mechanical shock, the scanning point is returned to the original track automatically and in a controlled manner, after which the scanning point is maintained on the track by controlling the position of the scanning point in response to the first error signal (tracking). Since for returning the scanning point to the desired track the same velocity signal is employed as for tracking the control mode during which the scanning point is controlled towards said track in response to the substitute error signal changes smoothly to the control mode in which the scanning point is maintained on the track in response to the first error signal.

Moreover, this embodiment allows the scanning point to skip over a desired number of tracks. For this purpose the counting means should merely be loaded with a count dictated by the desired displacement. The scanning point is then moved towards the desired track with a controlled velocity. When the desired track is reached a positional error signal will become available, which is proportional to the deviation of the scanning point, enabling the scanning point to be moved towards and maintained on the centre of the desired track in a damped manner.

Since for the displacement over a large number of tracks and also for the purpose of tracking the same velocity signal can be employed the displacement control during track crossings changes over smoothly into tracking control.

A further embodiment of the device is characterized in that the magnitude of the substitute error signal dictated by the count increases as the difference between the instantaneous count and said predetermined count increases.

This embodiment has the advantage that in the case of large displacements the velocity can be high as long as the distance from the desired track is still large. As the desired track is approached, however, the velocity is reduced which prevents overshooting of the desired track. This enables a very rapid and controlled displacement over large distances to be obained.

The differentiating circuits employed in practice have a transfer function in which the differentiating term increases as the frequency increases up to a specific cross-over frequency after which the differentiating term decreases again. For determining the velocity signal this means that a velocity signal obtained by means of a differentiating circuit is suitable only for velocities corresponding to frequencies which are situated sufficiently far below said cross-over frequency in order to guarantee a stable control. In the case of displacements of the scanning point over large distances it may be desirable, in order to reduce the time required for this displacement, to move the scanning point at velocities in the proximity of the limit velocity defined by said cross-over frequency.

An embodiment of the device which meets this requirement is characterized in that the device comprises an additional velocity control system for controlling the scanning point velocity to obtain a velocity defined by a reference signal, the circuit comprising means which are responsive to the count of the counter to disable the position-control system in such a way that the determination of the velocity signal is maintained, and to render the velocity control operative if the deviation given by the magnitude of the count exceeds a predetermined value.

As in this embodiment the determination of the velocity signal is maintained during velocity control by means of the additional control system the initial conditions of control in response to the velocity signal have the correct value at the instant at which the position control system is rendered operative,

resulting in a smooth transition from one control mode to the other control mode.

A further embodiment of the device is characterized in that the additional velocity control system comprises means for determining the difference between a reference frequency and the frequency of the tracking-error signal or the track-loss signal, and means responsive to the frequency difference thus determined to control the velocity of the scanning point to a value dictated by the reference frequency.

This embodiment makes advantageous use of the fact that the frequency of the first error signal or the track-loss signal is a measure of the velocity of the displacement of the scanning point.

Although the invention is in principle suitable for use in other than optical scanning devices, for example magnetic scanning devices, it is particularly suitable for such optical scanning devices because in such scanning devices said error signal and track-loss signal can be obtained very simply.

Embodiments of the invention will now be described in more detail, by way of example, with reference to Figs 1 to 12, in which

Fig. 1 shows an example of a prior-art scanning device,

Fig. 2 shows the variation of the measurement signal generated in the device during the displacement in a direction transverse to the tracks,

Fig. 3 shows an example of a circuit for generating the error signal and the track-loss signal,

Fig. 4 shows these signals and the velocity signal derived from these signals as a function of time,

Fig. 5 shows an example of a prior-art control circuit,

Figs. 6, 8 and 11 show a number of different embodiments of a control circuit in accordance with the invention,

Fig. 6a is a block diagram of the control system obtained if the control circuit shown in Fig. 6 is employed in the scanning device shown in Fig. 1,

Figs. 7, 10 and 12 show a number of signal waveforms generated in the control circuits in accordance with the invention, and

Fig. 9 shows an example of a counting circuit for use in the control circuit in accordance with the invention.

Fig. 1 shows a prior-art scanning device. The scanning device shown is a device for optically scanning an optical record carrier 1, for example a "Compact Disc", which is rotated about an axis 17. Such a record carrier 1 comprises an information layer 5. The information layer 5 has tracks in which information is recorded as a pattern of optically detectable recording marks, for example in the form of pits. Fig. 2a shows a part of the tracks to a strongly enlarged scale, the recording marks bearing the reference numeral 21. The information recorded in the tracks can be read by scanning the tracks with a radiation beam and thus detecting the beam modulation produced by the recording marks 21. For this purpose the scanning device comprises an optical read head 2 of a customary type, which comprises a radiation source in the form of a laser 7. The beam generated by the laser 7 is aimed at the information layer 5 via a semi-transparent mirror 9, the beam being focused to form a tiny scanning spot P on the information layer 5 by means of a lens system 8. The beam which is reflected from the information layer 5 is projected onto an array of four optical detectors 11a, 11b, 11c and 11d via the semi-transparent mirror 9 and a beam splitter in the form of a roof prism 10.

The currents supplied by the optical detector are converted into signal voltages V1, V2, V3 and V4 by means of a current-voltage converter 12. A signal-processing circuit 13 derives an error signal RE and a track-loss signal $\overline{TL}$ from these signal voltages. The error signal RE is indicative of the tracking error, which is the deviation of the scanning point defined by the scanning spot P, and the centre of the track to be followed. The track-loss signal $\overline{TL}$ indicates whether the scanning point defined by the scanning spot P is situated in the centre of a track or in the middle between two tracks.

Fig. 3 shows diagrammatically a customary example of a signal-processing circuit 13. The signal-processing circuit 13 comprises a circuit 30 which determines the difference between the sum of the signal voltages V1 and V2 and the sum of the signal voltages V3 and V4. If a high-frequency signal component caused by the beam modulation is ignored, the detected difference is a measure of the position of the scanning point. The high-frequency signal component is removed by means of a low-pass filter 31. The output signal of the low-pass filter 31 constitutes the error signal RE.

A circuit 32 derives from the signal voltages V1, V2, V3 and V4 a signal HF which is indicative of the sum of these four signal voltages. By means of a customary envelope detector 33 and a comparator 34, which compares the output signal of the envelope detector with a reference value REF, the track-loss signal $\overline{TL}$ is derived from the signal HF. The signal HF is indicative of the beam modulation produced by the recording marks. This modulation is maximal if the beam is aimed at the centre of the track and is minimal if said beam is incident midway between two tracks, so that the measurement signal $\overline{TL}$ indicates whether the beam is aimed at the track or at the middle between two tracks. It will be evident that, in principle, the signal on the output of the envelope detector 33 is al-

ready an indication of whether the scanning point is situated substantially in the centre of a track, so that in principle this signal may also be employed as a track-loss signal. However a bivalent track-loss signal, such as a signal $\overline{TL}$, is to be preferred.

Fig. 2b by way of illustration shows the signal HF in the case that the optical read head 2 is moved in a direction transverse to the tracks of the rotating record carrier 1. As is evident from Fig. 2b the amplitude signal HF will vary with a frequency corresponding to the number of tracks traversed per unit of time. Fig. 2c shows the error signal $\overline{TL}$ derived from the signal HF. The amplitude of the measurement signal HF is maximal if the scanning point corresponding to the point of incidence of the beam is situated in the centre of a track and this amplitude HF is minimal if the scanning point is situated midway between the two tracks.

Fig. 2d further shows the error signal RE. As the scanning point is moved the error signal RE will also vary with a frequency equal to the number of tracks traversed per unit of time. The error signal RE is 90° phase shifted relative to the track-loss signal $\overline{TL}$. Within a range of a quarter of the track pitch p around the centre of each track the measurement signal RE is substantially proportional to the distance between the scanning point and the track centre.

In the scanning device shown in Fig. 1 the signals $\overline{TL}$ and RE are applied to a circuit 17. The circuit 17 comprises a differentiating circuit 4 for differentiating the measurement signal RE and a multiplier 6 for multiplying the differentiated measurement signal ΔRE by the track-loss signal $\overline{TL}$. The output signal of the multiplier 6 bears the reference RS. The signals RE, ΔRE, $\overline{TL}$ and RS as produced in the case of a displacement of the scanning point are shown as a function of time t in Fig. 4. The amplitude of the signal ΔRE is proportional to the velocity with which the scanning point is moved. Moreover, as a result of the differentiation the signal is 90° phase-shifted relative to the signal RE and, consequently, it is in phase with or in phase opposition to the measurement signal $\overline{TL}$ depending on the direction of the displacement.

The sign of the velocity signal RS thus obtained therefore always indicates the direction of the displacement and the magnitude of the signal RS is an indication of the magnitude of the displacement velocity. The velocity signal RS together with the error signal RE and, if applicable, the track-loss signal $\overline{TL}$ is supplied to a control circuit 3.

Fig. 5 shows a prior-art circuit 3 in the case that the velocity signal RS is employed in order to realize a position control system with velocity feedback. The velocity signal RS and the error signal RE are then added by means of a summing circuit. The output signal of the summing circuit is applied to a control circuit 14, if required via low-pass filter 16, to generate a control signal $\overline{AS}$ for controlling an actuator 15 for positioning the read head 2. Depending on the output signal of the summing circuit 51 the control circuit 14 controls the actuator 15 in such a way that the tracking error represented by the signal RE is minimized.

The velocity feedback increases the damping of the feedback tracking system, which results in a more stable control which is more immune to mechanical shocks. When the circuit shown in Fig. 5 is employed the scanning point is maintained at the track centre, which means that a tracking system is obtained.

Fig. 6 shows an embodiment of a circuit 3 in accordance with the invention which provides a tracking which is even more immune to mechanical shocks than the embodiment shown in Fig. 5.

The circuit shown in Fig. 6 comprises an electronic switch 61 which is controlled by the track-loss signal $\overline{TL}$ and which applies a signal UC' to the summing circuit 51 as soon as the track-loss signal $\overline{TL}$ indicates that the scanning point is no longer situated substantially at the centre of a track. If the track-loss signal $\overline{TL}$ indicates that the scanning point is situated substantially on the track the switch 61 is switched to apply the error signal RE to the summing circuit 51 as the position-error signal PE. The signal UC' has a constant strength and a polarity corresponding to the sign of the error indicated by the signal RE.

The signal UC' is obtained by means of a multiplier 62 which multiplies a signal UC of fixed polarity with a sign signal RE' indicating the sign of the measurement signal RE. By means of a polarity detector, for example a comparator 63, the sign signal RE' is derived from the measurement signal RE. Fig. 7 shows the position-error signal PE on the output of the electronic switch 61 as a function of the distance x between the track centre and the scanning point.

Fig. 6a shows the block diagram of the control system which is obtained if the circuit 3 shown in Fig. 6 is used in the optical scanning device shown in Fig. 1. In this block diagram the blocks with the transfer functions of the differentiating circuit 4, the multiplier circuit 6, the summing circuit 51, the low-pass filter 16 and the electronic switch 61 bear the reference numerals 4', 6', 51', 16', and 61' respectively. The reference numeral 15' refers to the overall transfer function of the control circuit 14, the actuator 15, the read head 2, the current-voltage converter 12 and the signal-processing circuit 13. As long as the scanning point is situated substantially on a track the signal $\overline{TL}$ remains 1. The position-error signal PE is then identical to the error signal RE. The control system shown in Fig. 6 then

behaves as a position control system which controls the scanning point in such a way that the signal RE remains substantially zero. The open-loop transfer function Ho(s) of this position control system is as follows:

$$Ho(s) = \frac{K1}{s^2} \cdot \frac{1 + s\,\tau_1}{1 + s\,\tau_2}$$

Here
s is the Laplacian operator;
$\tau 1$ is the time constant of the differentiating circuit 4;
$\tau 2$ is the time constant of the low-pass filter 16;
K1 is the loop gain of the control loop.

The transfer characteristic Ho(s) represents a third-order system which is well known in control technology and which in the case of feedback is stable if the time constant $\tau 1$ is selected to be larger than the time constant $\tau 2$ (for example $\tau 1 \approx 10.\tau 2$).

It will be obvious to those skilled in the art that in principle the low-pass filter 16 may be removed from the control sytem. Indeed, in that case the time constant $\tau 2$ will be zero. However, the use of the low-pass filter 16 results in a substantial reduction of the noise produced by the control system, so that it is preferred to employ this filter. The use of velocity feedback results in a null in the open-loop transfer characteristic Ho(s), which greatly improves the stability of the feedback tracking control system. The tracking system thus formed with therefore be highly immune to disturbances such as for example mechanical shocks.

In the case that a mechanical shock causes the scanning point to be displaced so far that it no longer remains on the track, the sign of the signal $\overline{TL}$ will change, so that the constant signal Uc' is used as the position-error signal PE. This results in the control characteristic of the control system being changed. In fact the control system will now behave as a velocity control system which controls the velocity of the scanning point represented by the signal RS to the value given by the signal Uc'. The open-loop transfer function Hso(s) of this velocity control loop is as follows:

$$Hso(s) = \frac{K1 \cdot \tau_1}{s(1+s\,\tau_2)}$$

This transfer function Hso(s) represents a second-order system which is well known in control technology and which is also stable in the case of feedback. The sign of Uc' is the same as the sign of the signal RE, so that the scanning point is rapidly directed towards the track. The velocity control system limits the velocity to a value dictated by Uc'. At the instant at which the signal $\overline{TL}$ indicates that the track is reached the switch 61 is changed over again, causing the control system to behave as a tracking system. Since the velocity is limited when the track is reached it is ensured the scanning point cannot overshoot the track. Moreover, in both control modes (velocity control and tracking control) the same velocity signal is employed, so that always a smooth transition from one control mode to the other is obtained. Indeed, when a new control mode sets in the initial conditions are always correct, so that no transient effects occur.

Fig. 8 shows yet another embodiment of the circuit 3 in accordance with the invention, in which the scanning point is returned to the desired track in the event of a disturbance which causes the scanning point to be displaced over a number of tracks. The circuit shown in Fig. 8 comprises a customary counting circuit 80 which with the aid of the signals $\overline{TL}$ and RE counts the number of tracks traversed by the scanning point. Fig. 9 shows an example of such a counting circuit 80. The counting circuit 80 shown in Fig. 9 comprises a comparator 92, which converts the measurement signal RE into a bivalent signal.

This bivalent signal is applied to the inputs of two edge-triggered monostables 90 and 91. In response to a falling edge of the output signal of the comparator 92 the monostable 90 generates a pulse, which is applied to a first count input of an UP/DOWN counter 94 via a two-input AND gate 93. In response to a rising edge of the output signal of the comparator 92 the monostable 91 generates a pulse, which is applied to a second count input of the UP/DOWN counter 94 via a two-input AND gate 95. Moreover, the signal $\overline{TL}$ is applied to the other inputs of the AND gates 93 and 95 via an inverter circuit 95. The UP/DOWN counter 94 is of a type which increments the count by one in response to a pulse on the first count input and which decrements the count by one in response to a pulse on the second count input. The number of tracks passed is counted as follows. As the scanning point is moved the signal $\overline{TL}$ goes high during passage of the lands between the tracks. The polarity of the signal RE will then change from positive to negative or from negative to positive depending on the direction of the movement. If the polarity of the measurement signal RE changes from positive to negative the monostable 90 will generate a pulse. Since the inverted signal $\overline{TL}$ is

high this pulse is transferred to the gate 93, causing the count of the counter to be incremented by one. However, if during the passage of the land between two tracks the signal RE goes from negative to positive the monostable 91 will generate a ,pulse which is then applied to the second count input of the counter 94 via the AND gate 95, causing the count to be decremented by one.

The changes polarity of the signal RE during passage of the centre of the track do not affect the count because the pulses generated by the monostable are then not transferred by the AND gates 93 and 95 since the inverted signal $\overline{TL}$ is then low. Consequently, the count of the counter 94 is always indicative of the number of tracks passed. The count of the counter is applied to a decoder circuit 82 via a bus 81. In addition to the count of the counter 80 the signal $\overline{TL}$ and the sign signal RE' are applied to the decoder circuit.

On the basis of the count and the signals $\overline{TL}$ and RE the decoder circuit 82 produces a digital code, which is applied to a digital-to-analog converter 84 via a bus 85. The digital-to-analog converter 84 generates an error signal PE', whose signal strength corresponds to the digital value determined by the code which is received. The error signal PE' is applied to the summing circuit 51, which for this purpose is provided with a third input. The decoder circuit 82 further generates a control signal for an electroncially operated switch 83 arranged in the signal path to apply the signal RE to the summing circuit 51. The decoder circuit is constructed in such a way that the electronic switch 83 is closed by the generated control signal exclusively when both the count is zero and the signal level of the measurement signal $\overline{TL}$ is high. In this situation the decoder circuit moreover supplies a code to the digital-to-analog converter 84, as a result of which the signal PE' on the output of the digital-to-analog converter 84 is zero.

In the situation in which the count is zero and at the same time the signal level of the signal $\overline{TL}$ is high the decoder circuit generates a code with a polarity dictated by the sign signal RE' in such a way that the polarity of the output signal of the digital-to-analog converter is the same as the polarity of the signal RE. The sign of the error signal PE' is then the same as the sign of the error signal RE. For a non-zero count the decoder circuit generates a code representing an analog value of a polarity dictated by the sign of the count, such that the output signal of the digital-to-analog converter 84 causes the scanning point to be moved in a direction in which the absolute value of the count decreases.

The decoder circuit 82 may comprise, for example, a read-only memory (ROM) to which the count and the signals RE' and $\overline{TL}$ are applied as address signals and which is loaded with the output signals required for the various address signals. Alternatively, the decoder circuit 82 can be realized in a customary manner by means of logic gate circuits.

The circuit shown in Fig. 8 operates as follows. If the count of the counter 80 is not zero the signal PE' is applied to the summing circuit 51 via the digital-to-analog converter 84, said signal having a polarity dictated by the sign of the count. As a result of this, the scanning point will be moved in a direction determined by the sign of the count. The velocity feedback then ensures that the velocity of the displacement is controlled to a value dictated by the output signal PE' of the digital-to-analog converter 82. During the displacement the scanning point crosses the tracks, causing the count to change towards zero. As soon as the count zero is reached the signal PE' is applied to the summing circuit 51 via the digital-to-analog converter 84, the polarity of said signal PE' being determined by the sign signal RE', so that control of the displacement via the digital-to-analog converter 84 is sustained until the signal level of the signal $\overline{TL}$ goes high, after which the output signal of the digital-to-analog converter 84 becomes zero and the switch 83 is closed. The position of the scanning point is then controlled towards the centre of the track being scanned depending on the measurement signal RE. The velocity feedback is sustained, during the entire control action so that the control mode in which the scanning point traverses a number of tracks given by the initial count of the counter changes over smoothly into the control mode in which the scanning point is maintained at the centre of the desired track on the basis of the tracking error indicated by the measurement signal RE.

As will be apparent from the foregoing, the scanning point will always be returned to the original track in a smooth manner in the event of a mechanical shock causing loss of track. However, the circuit shown in Fig. 8 is also suitable if it is desired to move the scanning point over a specific known number of tracks, as is customary in performing search commands. This can be achieved simply by providing the counting circuit 80 with a counter which via a bus 85, can be loaded with a count representing the excursion relative to the desired track.

It is desirable that the movement of the scanning point to the desired track proceeds rapidly. This can be achieved simply by constructing the decoder circuit 82 in such a way that the absolute value of the signal values defined by the generated codes increases the number of tracks to be traversed increases. The velocity of the displacement will then be high in the case of a large distance between the scanning point and the desired track.

The velocity of the movement determined by the absolute value of the signal PE' decreases as the distance from the desired track decreases. In this way it is achieved that the displacement to the desired track proceeds rapidly, the velocity having decreased so far when the track is approached that overshooting of the desired track is not possible.

In the circuit shown in Fig. 8 the velocity with which the tracks are traversed during passage of the tracks cannot be increased to an unlimited extent. This is because at high velocities the velocity signal RS is no longer proportional to the actual velocity. Above this specific velocity the magnitude of the velocity signal RS will decrease at increasing velocity. Indeed, in practice the differentiating circuits employed have a transfer characteristic which exhibits at least one pole, so that the differentiating term in the transfer characteristic decreases above a cross-over frequency defined by said pole. This means that for velocities V of the movement of the scanning point above a specific velocity the velocity signal decreases at increasing velocity. This effect becomes even more pronounced when the low-pass filter 16 is used.

By way of illustration Fig. 10 gives the relationship between the velocity signal RS and the velocity V of the scanning point movement. Above a specific absolute value Vg of the velocity the absolute value of the velocity signal RS decreases as the absolute value of the velocity V increases.

In view of the risk of instability of the control system it is desirable that the circuit shown in Fig. 8 is employed only for controlling velocities sufficiently far from the limit velocity Vg.

Fig. 11 shows a modification of the circuit of Fig. 8 which enables the velocity of the movement of the scanning point in the case of displacements over a large number of tracks to be controlled at a velocity substantially corresponding to the limit value Vg. In the circuit shown in Fig. 11 the input of the low-pass filter 16 is connected directly to the output of the multiplier circuit 6. The output of the low-pass filter is connected to one of the inputs of the summing circuit 51 via an electronically controlled switch 110. The switch 110 is controlled by a control signal generated by a modified decoder circuit 82'. The circuit further comprises a frequency detector 111, which compares the frequency of the signal RE, or if applicable the frequency of the signal $\overline{TL}$, with the frequency of a clock signal of constant frequency generated by an oscillator 112. A signal which is at least indicative of the sign of the frequency difference thus determined is applied to the modified decoder circuit 82'. In addition to the functions of the decoder circuit 82 described above the modified decoder circuit 82' also performs some other functions.

If the abosulte value of the count is larger than nmax the switch 110 is opened by the decoder circuit 82' in order to inhibit application of the velocity signal RS to the summing circuit 51. Moreover, for the count above nmax the decoder circuit 82' supplies a code to the analog-to-digital converter 84, which code depends on the output signal of the frequency detector 111, in such a way that the sign of the signal PE' is dictated by the sign of the count and the sign of the output signal of the frequency detector 111. Thus, in the case of displacements over a number of tracks larger than nmax the velocity feedback is discontinued in response to the velocity signal RS and feedback velocity control is obtained by means of which the velocity of the displacement is controlled at a value for which the frequency of the signal RE is equal to the frequency of the clock signal supplied by the oscillator 112, the direction of the displacement being given by the sign of the count of the counting circuit 80. The frequency of the clock signal supplied by the oscillator 112 is selected in such a way that the corresponding velocity of the displacement corresponds to the value +Vg or -Vg indicated in Fig. 10, depending on the sign of the count.

Further, the decoder circuit 82' is constructed in such a way that for an absolute value of the count between nmax and n1 the signal PE' supplied to the summing circuit 51 via the analog-to-digital converter 84 corresponds to a controlled velocity v corresponding to +v2 or -v2 depending on the sign of the count. For a count having an absolute value between 1 and n1 the signal supplied via the analog-to-digital converter 84 corresponds to a velocity of +v1 or -v1.

Fig. 12 shows the variation of the velocity V and the count n as a function of time in the case that the scanning point is to be displaced over a number of tracks nb larger than nmax. At the instant to the counter is loaded with the count nb, after which the velocity is controlled towards the value Vg defined by the frequency of the clock signal 112 supplied by the oscillator. The velocity Vg is reached at the instant t1, after which the velocity is maintained at said value Vg until the instant t2 at which the count nmax is reached.

At the instant t2 velocity control on the basis of the frequency difference determined by the frequency detector 111 is terminated and the velocity signal is again applied to the adder circuit, after which the velocity is controlled towards the velocity v2 defined by the output signal of the analog-to-digital converter.

At the instant t3 the count reaches the value n1 and the signal PE' applied to the summing circuit 51 via the digital-to-analog converter 84 is changed, after which the velocity V is controlled

towards the value v1. When the desired track is reached , i.e. as soon as the count is zero and the signal level of the measurement signal $\overline{TL}$ is high, the output signal of the digital-to-analog converter becomes zero at the instant t4 and the switch 83 is closed. From the instant t4 the scanning point is controlled towards and maintained at the track on the basis of the tracking error represented by the measurement signal RE.

In the embodiments described in the foregoing the velocity signal is always derived from the signals $\overline{TL}$ and RE. However, the velocity signal may also be derived in another manner, for example by means of a velocity transducer which is mechanically coupled to the read head.

In the embodiments described above the tracking-error signal is a signal which is proportional to the tracking error over a range of a quarter of the track pitch to either side of the track. However, it is to be noted that the error signal for the tracking control may alternatively be a signal which is proportional to the tracking error over a larger range, as is described for example in Netherlands Patent Application NL-A-8602911.

Claims

1. A device for scanning a record carrier (1) provided with substantially parallel tracks, which device comprises a closed-loop position control system with position and velocity feedback for controlling the scanning point (P) towards the centre of a specific track for which purpose the control system comprises a positioning system (15) for moving the scanning point in a direction transverse to the tracks, a measuring system (4, 6, 9, 10, 11, 12, 13) for generating a velocity signal which is indicative of the velocity with which the scanning point is moved in a direction transverse to the tracks, and for generating a first error signal which within a predetermined limited first range to either side of said specific track centre is substantially proportional to the deviation between the track centre ad the scanning point, and a control circuit (3) for controlling the positioning system depending on the first error signal and the velocity signal, whereby the measuring system is adapted to generate a tracking-error signal (RE) and a track-loss signal (TL) which in the case of a displacement of the scanning point in a direction transverse to the tracks vary periodically with a frequency corresponding to the number of tracks traversed per unit of time, the phase difference between said signals being substantially 90°, the tracking error, over a range corresponding to substantially a quarter track pitch to either side of each track centre being substantially indicative of the deviation between the scanning point (P) and the centre of the nearest track, and the track-loss signal (TL) indicating whether the scanning point is situated substantially on a track or substantially between two tracks, the tracking-error signal (RE) being employed as the first error signal, the measuring system for the purpose of generating the velocity signal (RS), comprising means (4) for differentiating the tracking error signal (RE) and means (6) for multiplying the differentiated tracking error signal (ΔRE) by the track-loss signal (TL), characterized in that the control circuit (3) comprises means for generating at least one substitute error signal (PE', UC') which within a second range, outside the first range, has a sign which is indicative of the direction of the deviation, the control circuit (3) being adapted to control the positioning system (15) in response to the first error signal or a substitute error signal depending on whether the deviation is situated in the first range or the second range respectively, in such a way that the error signal used for position feedback depends on the magnitude of the deviation and the velocity signal used for velocity feedback is independent of the magnitude of said deviation.

2. A device as claimed in Claim 1, characterized in that the control circuit (3) is constructed to control the positioning system in dependence upon a substitute error signal (PE', UC') if the track-loss signal (TL) indicates that the scanning point is situated substantially between two tracks.

3. A device as claimed in Claim 1 or 2, characterized in that the control circuit (3) comprises counting means (80) for counting, by means of the track-loss signal (TL) and the tracking-error signal (RE), the number of tracks traversed by the scanning point (P), and means for controlling the positioning means (15) depending on a substitute error signal (PE') dictated by the count in the case that the instantaneous count deviates from a predetermined count.

4. A device as claimed in Claim 2, characterized in that the magnitude of the substitute error signal (PE') dictated by the count increases as the difference between the instantaneous count and said predetermined count increases.

5. A device as claimed in Claim 3 or 4, characterized in that the device comprises an additional velocity control system (111, 112, 82') for controlling the scanning-point velocity to obtain a

towards the value v1. When the desired track is reached , i.e. as soon as the count is zero and the signal level of the measurement signal $\overline{TL}$ is high, the output signal of the digital-to-analog converter becomes zero at the instant t4 and the switch 83 is closed. From the instant t4 the scanning point is controlled towards and maintained at the track on the basis of the tracking error represented by the measurement signal RE.

In the embodiments described in the foregoing the velocity signal is always derived from the signals $\overline{TL}$ and RE. However, the velocity signal may also be derived in another manner, for example by means of a velocity transducer which is mechanically coupled to the read head.

In the embodiments described above the tracking-error signal is a signal which is proportional to the tracking error over a range of a quarter of the track pitch to either side of the track. However, it is to be noted that the error signal for the tracking control may alternatively be a signal which is proportional to the tracking error over a larger range, as is described for example in Netherlands Patent Application NL-A-8602911.

Claims

1. A device for scanning a record carrier (1) provided with substantially parallel tracks, which device comprises a closed-loop position control system with position and velocity feedback for controlling the scanning point (P) towards the centre of a specific track for which purpose the control system comprises a positioning system (15) for moving the scanning point in a direction transverse to the tracks, a measuring system (4, 6, 9, 10, 11, 12, 13) for generating a velocity signal which is indicative of the velocity with which the scanning point is moved in a direction transverse to the tracks, and for generating a first error signal which within a predetermined limited first range to either side of said specific track centre is substantially proportional to the deviation between the track centre ad the scanning point, and a control circuit (3) for controlling the positioning system depending on the first error signal and the velocity signal, whereby the measuring system is adapted to generate a tracking-error signal (RE) and a track-loss signal (TL) which in the case of a displacement of the scanning point in a direction transverse to the tracks vary periodically with a frequency corresponding to the number of tracks traversed per unit of time, the phase difference between said signals being substantially 90°, the tracking error, over a range corresponding to substantially a quarter track pitch to either side of each track centre being substantially indicative of the deviation between the scanning point (P) and the centre of the nearest track, and the track-loss signal (TL) indicating whether the scanning point is situated substantially on a track or substantially between two tracks, the tracking-error signal (RE) being employed as the first error signal, the measuring system for the purpose of generating the velocity signal (RS), comprising means (4) for differentiating the tracking error signal (RE) and means (6) for multiplying the differentiated tracking error signal (ΔRE) by the track-loss signal (TL), characterized in that the control circuit (3) comprises means for generating at least one substitute error signal (PE', UC') which within a second range, outside the first range, has a sign which is indicative of the direction of the deviation, the control circuit (3) being adapted to control the positioning system (15) in response to the first error signal or a substitute error signal depending on whether the deviation is situated in the first range or the second range respectively, in such a way that the error signal used for position feedback depends on the magnitude of the deviation and the velocity signal used for velocity feedback is independent of the magnitude of said deviation.

2. A device as claimed in Claim 1, characterized in that the control circuit (3) is constructed to control the positioning system in dependence upon a substitute error signal (PE', UC') if the track-loss signal (TL) indicates that the scanning point is situated substantially between two tracks.

3. A device as claimed in Claim 1 or 2, characterized in that the control circuit (3) comprises counting means (80) for counting, by means of the track-loss signal (TL) and the tracking-error signal (RE), the number of tracks traversed by the scanning point (P), and means for controlling the positioning means (15) depending on a substitute error signal (PE') dictated by the count in the case that the instantaneous count deviates from a predetermined count.

4. A device as claimed in Claim 2, characterized in that the magnitude of the substitute error signal (PE') dictated by the count increases as the difference between the instantaneous count and said predetermined count increases.

5. A device as claimed in Claim 3 or 4, characterized in that the device comprises an additional velocity control system (111, 112, 82') for controlling the scanning-point velocity to obtain a

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velocity defined by a reference signal, the circuit comprising means (110) which are responsive to the count of the counter (80) to disable the position control system in such a way that the determination of the velocity signal is maintained, and to render the velocity control system (111, 112, 82') operative if the deviation given by the magnitude of the count exceeds a predetermined value.

6. A device as claimed in Claim 5, characterized in that the additional velocity control system (111, 112, 82') comprises means (111) for determining the difference between a reference frequency and the frequency of the tracking-error signal (RE) or the track-loss signal (TL), and means (82') responsive to the frequency difference thus determined to control the velocity of the scanning point to a value dictated by the reference frequency.

7. A device as claimed in any one of the preceding Claims, characterized in that the device is an optical scanning device for scanning optically readable record carriers.

Patentansprüche

1. Einrichtung zum Abtasten eines Aufzeichnungsträgers (1) mit nahezu parallelen Spuren, die ein geschlossenes Positionsregelsystem mit Positions- und Geschwindigkeitsrückkopplung zum Steuern des Abtastpunkts (P) in Richtung der Mitte einer bestimmten Spur, wofür das Regelsystem ein Positionierungssystem (15) zum Bewegen des Abtastpunkts in einer Richtung quer zu den Spuren umfaßt sowie ein Meßsystem (4, 6, 9, 10, 11, 12, 13) zum Erzeugen eines Geschwindigkeitssignals, das eine Anzeige für die Geschwindigkeit ist, mit der der Abtastpunkt in einer Richtung quer zu den Spuren bewegt wird, und zum Erzeugen eines ersten Fehlersignals, das innerhalb eines zuvor bestimmten begrenzten ersten Bereichs zu beiden Seiten der genannten bestimmten Spurmitte nahezu proportional zur Abweichung zwischen der Spurmitte und dem Abtastpunkt ist, und eine Regelschaltung (3) zum Steuern des Positionierungssystems in Abhängigkeit von dem ersten Fehlersignal und dem Geschwindigkeitssignal, wobei das Meßsystem eingerichtet ist, ein Spurfolgefehlersignal (RE) und ein Spurverlustsignal (TL) zu erzeugen, die im Falle einer Verlagerung des Abtastpunkts in einer Richtung quer zu den Spuren periodisch mit einer der Anzahl der pro Zeiteinheit überquerten Spuren entsprechenden Frequenz variieren, wobei die Phasendifferenz zwischen den genannten Signalen nahezu 90° beträgt, der Spurfolgefehler, über einen im wesentlichen einem viertel Spurabstand zu beiden Seiten jeder Spurmitte entsprechenden Bereich im wesentlichen eine Anzeige für die Abweichung zwischen dem Abtastpunkt (P) und der Mitte der nächstgelegenen Spur ist, und wobei das Spurverlustsignal (TL) anzeigt, ob der Abtastpunkt nahezu auf einer Spur liegt oder nahezu zwischen zwei Spuren, wobei das Spurfolgefehlersignal (RE) als erstes Fehlersignal genutzt wird und das Meßsystem zum Erzeugen des Geschwindigkeitssignals (RS) Mittel (4) zum Differenzieren des Spurfolgefehlersignals (RE) und Mittel (6) zum Multiplizieren des differenzierten Spurfolgefehlersignals (ΔRE) mit dem Spurverlustsignal (TL) umfaßt, dadurch gekennzeichnet, daß die Regelschaltung (3) Mittel zum Erzeugen mindestens eines Ersatzfehlersignals (PE', UC') umfaßt, das innerhalb eines zweiten Bereichs, außerhalb des ersten Bereichs, ein Vorzeichen hat, daß eine Anzeige für die Richtung der Abweichung ist, wobei die Regelschaltung (3) eingerichtet ist, das Positionierungssystem (15) in Reaktion auf das erste Fehlersignal oder ein Ersatzfehlersignal zu steuern, in Abhängigkeit davon, ob sich die Abweichung in dem ersten bzw. dem zweiten Bereich befindet, in solcher Weise, daß das für die Positionsrückkopplung verwendete Fehlersignal von der Größe der Abweichung abhängt und das für Geschwindigkeitsrückkopplung verwendete Geschwindigkeitssignal von der Größe der genannten Abweichung unabhängig ist.

2. Einrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die Regelschaltung (3) eingerichtet ist, um das Positionierungssystem in Abhängigkeit von einem Ersatzfehlersignal (PE', UC') zu steuern, wenn das Spurverlustsignal (TL) angibt, daß der Abtastpunkt nahezu innerhalb zweier Spuren liegt.

3. Einrichtung nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß die Regelschaltung (3) Zählmittel (80) zum Zählen, mit Hilfe des Spurverlustsignals (TL) und des Spurfolgefehlersignals (RE), der Anzahl von von dem Abtastpunkt (P) überquerten Spuren umfaßt sowie Mittel zur Steuerung der Positionierungsmittel (15) in Abhängigkeit von einem von dem Zählerstand bestimmten Ersatzfehlersignal (PE')-,für den Fall, daß der momentane Zählerstand von einem zuvor bestimmten Zählerstand abweicht.

4. Einrichtung nach Anspruch 2, dadurch gekennzeichnet, daß die Stärke des von dem Zählerstand bestimmten Ersatzfehlersignals (PE') zunimmt, wenn die Differenz zwischen dem momentanen Zählerstand und dem zuvor bestimmten Zählerstand zunimmt.

5. Einrichtung nach Anspruch 3 oder 4, dadurch gekennzeichnet, daß die Einrichtung ein zusätzliches Geschwindigkeitsregelsystem (111, 112, 82') zur Regelung der Abtastpunktgeschwindigkeit, um eine durch ein Bezugssignal definierte Geschwindigkeit zu erhalten, wobei die Schaltung Mittel (110) umfaßt, die auf den Zählerstand des Zählers (80) ansprechen, um das Positionsregelsystem so zu blockieren, daß die Bestimmung des Geschwindigkeitssignals erhalten bleibt und um das Geschwindigkeitsregelsystem (111, 112, 82') in Betrieb zu setzen, wenn die durch die Höhe des Zählerstandes angegebene Abweichung einen zuvor bestimmten Wert überschreitet.

6. Einrichtung nach Anspruch 5, dadurch gekennzeichnet, daß das zusätzliche Geschwindigkeitsregelsystem (111, 112, 82') Mittel (111) zur Bestimmung der Differenz zwischen einer Bezugsfrequenz und der Frequenz des Spurfolgefehlersignals (RE) oder des Spurverlustsignals (TL) umfaßt sowie auf die so bestimmte Differenz ansprechende Mittel (82') zur Regelung der Geschwindigkeit des Abtastpunkts auf einen von der Bezugsfrequenz bestimmten Wert.

7. Einrichtung nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß die Einrichtung eine optische Abtastvorrichtung für das Abtasten optisch lesbarer Aufzeichnungsträger ist.

Revendications

1. Dispositif d'exploration d'un support d'enregistrement (1) pourvu de pistes sensiblement parallèles, comportant un système de réglage de position à boucle fermée et à réaction de position et de vitesse pour régler le point d'exploration (P) vers le centre d'une piste déterminée, raison pour laquelle le système de réglage comporte un système de positionnement (15) pour déplacer le point d'exploration dans une direction transversale aux pistes, un système de mesure (4, 6, 9, 10, 11, 12, 13) pour engendrer un signal de vitesse indicatif de la vitesse à laquelle le point d'exploration est déplacé dans une direction transversale aux pistes, et pour engendrer un premier signal d'erreur qui, dans un premier domaine limité prédéterminé et situé de part et d'autre dudit centre de piste déterminé est sensiblement proportionnel à l'écart entre le centre de piste et le point d'exploration, et un circuit de réglage (3) pour régler le système de positionnement en fonction du premier signal d'erreur et du signal de vitesse, le système de mesure étant agencé pour engendrer un signal d'erreur de suivi de piste (RE) et un signal de perte de piste (TL) qui, lors d'un déplacement du point d'exploration dans une direction transversale aux pistes, varie périodiquement à une fréquence correspondant au nombre de pistes traversées par unité de temps, la différence de phase entre lesdits signaux étant sensiblement égale à 90°, l'erreur de suivi de piste, sur un domaine correspondant à peu près au quart du pas de piste de part et d'autre de chaque de piste, étant sensiblement indicative de l'écart entre le point d'exploration (P) et le centre de la piste la plus proche, signal de perte de piste (TL) qui indique que le point d'exploration est situé à peu près sur une piste ou à peu près entre deux pistes, signal d'erreur de suivi de piste (RE) qui est utilisé comme premier signal d'erreur et le système de mesure qui, pour la génération du signal de vitesse (RS), comporte des moyens (4) pour différencier le signal d'erreur de suivi de piste (RE) et des moyens (6) pour multiplier le signal d'erreur de suivi de piste différencié (ΔRE) par le signal de perte de piste (TL), caractérisé en ce que le dispositif est caractérisé en ce que le circuit de réglage (3) comporte des moyens pour engendrer au moins un signal d'erreur de remplacement (PE', UC') qui, dans un second domaine, situé en dehors du premier domaine, a un signe qui est indicatif de la direction de l'écart, le circuit de réglage (3) étant agencé pour commander le système de positionnement (15) en réaction au premier signal d'erreur ou à un signal d'erreur de remplacement selon que l'écart se situe dans le premier domaine ou le second domaine, de telle manière que le signal d'erreur utilisé pour la réaction de position dépende de la valeur de l'écart et en ce que le signal de vitesse utilisé pour la réaction de vitesse soit indépendant de la valeur dudit écart.

2. Dispositif selon la revendication 1, caractérisé en ce que le circuit de réglage (3) est agencé pour commander le système de positionnement en fonction d'un signal d'erreur de remplacement (PE', UC') si le signal de perte de piste (TL) indique que le point d'exploration est situé sensiblement entre deux pistes.

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3. Dispositif selon la revendication 1 ou 2, caractérisé en ce que le circuit de réglage (3) comporte des moyens de comptage (80) pour compter, au moyen du signal de perte de piste (TL) et du signal d'erreur de suivi de piste (RE), le nombre de pistes traversées par le point d'exploration (P) et des moyens pour commander les moyens de positionnement (15) en fonction d'un signal d'erreur de remplacement (PE'), déterminé par le compte, dans le cas où le compte momentané diffère d'un compte prédéterminé.

4. Dispositif selon la revendication 2, caractérisé en ce que la valeur du signal d'erreur de remplacement (PE') déterminée par le compte augmente au fur et à mesure de l'augmentation de la différence entre le compte momentané et ledit compte prédéterminé.

5. Dispositif selon la revendication 3 ou 4, caractérisé en ce que le dispositif comporte un système de réglage de vitesse additionnel (111, 112, 82') pour régler la vitesse du point d'exploration à une vitesse déterminée par un signal de référence, circuit comportant des moyens (110) servant, en réaction du compte du compteur (80), à rendre inactif le système de réglage de position de façon que la détermination du signal de vitesse soit maintenue, et à rendre actif le système de réglage de vitesse (111, 112, 82') si l'écart donné par la valeur du compte dépasse une valeur prédéterminée.

6. Dispositif selon la revendication 5, caractérisé en ce que le système de réglage de vitesse additionnel (111, 112, 82') comporte des moyens (111) pour déterminer la différence entre une fréquence de référence et la fréquence du signal d'erreur de suivi de piste (RE) ou du signal de perte de piste (TL) et des moyens (82') servant, en réaction à la différence de fréquence ainsi déterminée, à régler la vitesse du point d'exploration à une valeur déterminée par la fréquence de référence.

7. Dispositif selon l'une quelconque des revendications précédentes, caractérisé en ce que le dispositif est un dispositif d'exploration optique pour explorer des supports d'enregistrement à lecture optique.