The invention relates to a method and a circuit arrangement for focusing a light beam, which can be focused onto an optical recording medium by means of an optical system comprising a light source and an objective moveable by means of an adjusting element, which optical recording medium reflects the light beam onto a number of photo-elements, from the output voltages of which, by subtraction and addition of the differences thus determined, a first control voltage - the so-called focus error signal - is obtained, which first control voltage can be fed via a control amplifier to the adjusting element so that a control circuit is formed, where a second control voltage is generated by a signal generator and is changed by the signal generator until the light beam is focused onto the recording medium, whereupon the value W of the second control voltage assumed at this time is maintained and is fed as bias voltage to the adjusting element.

DE OS 33 02 240 has described a device for reading information items stored in spiral-shaped tracks on a disc-shaped recording medium. The CD of a CD player may be mentioned as an example of a disc-shaped recording medium. The items of information stored in the tracks of the CD, e.g. sound or picture signals, are read by means of an optical scanning device, which latter contains an objective and directs a light beam for scanning the information to the CD, the recording medium. The light beam is generated by a laser. A focusing control device displaces the objective along its optical axis such that its focal point comes to lie on the recording medium. This control process, which in principle corresponds to the sharp setting of a telescope, is referred to as focusing.

The light beam is reflected from the recording medium onto a light beam receiving device. To enable the information to be read satisfactorily from the recording medium, continuous

focusing is required by the focus control device, which latter represents a control circuit, since even slight deviations from the sharp focusing can lead to errors in the read-out of the information.

Since the thickness of the recording media varies relatively greatly from recording medium to recording medium, almost each time a different recording medium is inserted the objective must be displaced by a distance a by the focus control unit to cause the focal point to come to lie on the recording medium. However, this distance a is substantially greater than the distances by which the objective must be displaced in order to maintain the focal point on an inserted recording medium because the thickness of a recording medium varies significantly less than the thickness of recording medium to recording medium. DE OS 33 02 240 does not discuss the different thicknesses of the recording media or the longer control times and less accurate focusing caused thereby.

As shown in Figures 4a, 4B, 4C and 4D of the aforementioned DE OS, the light beam receiving device consists of four photo-diodes 14a, 14b, 14c and 14d which are arranged in a square such that they divide the square into four squares of equal size. The output voltages of the four photo-diodes 14a, 14b, 14c and 14d are fed to an operating circuit in which the two sums of the output voltages of two photo-diodes, in each case arranged diagonally opposite one another, are formed. The focusing error signal SF, obtained from the difference between these two sums, is fed to the focusing control device which moves the objective along its optical axis until the light beam is focused onto the recording medium.

Under the assumption that ideal, completely identical photo-diodes are used, the focusing error signal becomes zero when

the light beam is accurately focused onto the recording medium. In this case the reflected light beam is depicted as a circle on the four photo-diodes, as shown in Figure 4B of the aforementioned DE OS, so that each photo-diode is radiated with the same light energy. Because each photo-diode therefore supplies the same output voltage, the focusing error signal becomes zero. If, on the other hand, the objective is too close to the recording medium or too far removed therefrom, the reflected light beam is depicted on the four photo-diodes not as a circle, but, due to the astigmatic lens of the objective, as an ellipse. Since in this case of defocusing the photo-diodes supply different output voltages due to the different light energies with which they are radiated, the focusing error signal SF differs from zero. Therefore it brings about a displacement of the objective until it becomes zero, i.e. until the focal point is located on the recording medium.

Because real photo-diodes always vary in terms of their values, the focusing error signal does not however become precisely zero if the same light energy falls onto each photo-diode. Instead, it will assume a value different from zero. The value zero is assumed by the focusing error signal, depending upon the variation in the parameters of the photo-diodes, with more or less greatly differing light energies falling onto the individual photo-diodes. However, because the focus control device interprets the value zero of the focusing error signal as the correct value, the focal point of the objective will lie either before or after the recording medium. Thus a precise focusing is not always possible in the case of the device disclosed in DE-OS 33 02 240.

Furthermore, the control amplifier operates not symmetrically but asymmetrically in its control range. The deviation from accurate focusing is dependent upon the

variation in the diode parameters. If, for example, the device according to the aforementioned DE-OS is incorporated in CD players, the deviation also varies from device to device since it is impossible to install precisely identical photo-diodes in all CD players. This in turn leads to devices of different quality.

Hitachi Service Manual, TyNo 348E, DA- 1000, December 1982, page 22, Fig. 30 has disclosed a control circuit for focusing the light beam in a CD player. The offset voltage of the control amplifier IC 100 and of the light receiving- and evaluating circuit is compensated by manual adjustment of the potentiometer R 102. If the offset voltages change due to temperature fluctuations or ageing of the components, the quality of the CD player can noticeably deteriorate. In order to re-establish a satisfactory reproduction of the sound, it is necessary to re-adjust the control amplifier IC 100 by adjustment of the potentiometer R 102 in the workshop. Such servicing measures are not only unpleasant for the customer, but also cost money.

JP-A 59-188845 has disclosed an optical scanning device with a focus control circuit wherein a first control voltage for the focus control circuit is generated. A second step-like control voltage is generated by means of a clock pulse generator, a counter and a digital-analogue converter and is fed to a store and, via a controllable switch, to a focus error detector, the output of which is connected to the adjusting element of the focus control circuit. The optically scanned data signal is converted into an electrical LF signal which is referred to as sound signal. When the sound signal reaches a peak value, the value of the step-like second control voltage is stored in the store. At the same time the output of the digital-analogue converter is cut off from the focus error detector by the opening of a first switch, while at the same time, by the closure of a

second switch, the output of the store is connected to the focus error detector. The second control voltage stored in the store is now constantly applied to the focus error detector as compensation voltage.

However, a disadvantage of this arrangement consists in that the sound signal is required for the compensation of the offset voltage. Therefore compensation and focusing cannot be carried out until the light beam scans a data track on the recording medium. If, on the other hand, the light beam hits a region of the recording medium where no data can be read, neither compensation nor focusing of the light beam are possible. This can be the case for example when the light beam falls between two data tracks or if the recording medium is faulty, damaged or dirty. At the faulty, damaged or dirty locations neither compensation of the offset nor focusing are possible. Not until the light beam scans data and a sound signal is thereby generated can the compensation and focusing commence. Therefore under unfavourable circumstances it can take a relatively long time for the light beam to be accurately focused on the recording medium.

Since, as already mentioned, the thickness of the recording media varies relatively greatly, the focusing is impeded.

Therefore the aim of the invention is to adapt a method of focusing a light beam onto an optical recording medium to the different thicknesses of the recording media.

The invention fulfils this aim in that while the second control voltage is changed in order to focus the light beam onto the recording medium the sum of the first and second control voltages is fed via a filter to the control amplifier, which filter separates the first control voltage in respect of a.c. voltage but allows through the second control voltage.

The different thicknesses of different recording media are taken into consideration in that focusing takes place with the control circuit closed in respect of d.c. voltage but open in respect of a.c. voltage.

In the drawing:
Figure 1 illustrates a circuit arrangement according to Claim 10;
Figure 2 illustrates a circuit arrangement according to Claim 11;
Figure 3 illustrates a circuit arrangement according to Claim 12;
Figures 4, 5, 6, 7, 8 and 9 are voltage diagrams and Figures 10 and 11 illustrate so-called actuators with objective and coil.

The light receiving- and evaluating circuit 0 can for example be constructed as described in DE OS 33 02 240. It is equipped with four photo-diodes A, B, C and D. The voltage U_{FE} at the output of the light receiving- and evaluating circuit 0, which corresponds to the focusing error signal SF, is formed in accordance with the following formula:

$$U_{FE} = (A-D) + (B-C)$$

Under the assumption that the four photo-diodes A, B, C and D are ideal components, the voltage U_{FE} becomes zero when the focal point is located on the recording medium.

The circuit arrangement shown in Figure 1 and described in Claim 10 will now be explained.

The output of a light receiving- and evaluating circuit 0 is connected to the input of a focus detector FD and to the

first input of a summation point SU, the other input of which is connected to the output of a digital-analogue converter DA. The output of the summation point SU is connected to the input of a switching device SE, the output of which is connected to the input of a control amplifier RV. The output of the control amplifier RV is connected to the input of an adjusting element SG. The input E of a control unit K is connected to the output of a focus detector FD, a first output A1 of the control unit K is connected to the input of the digital-analogue converter DA, while a second output A2 of the control unit K is connected to the control input of the switching unit SE.

At the start of the focusing the control unit K emits a signal from its second output A2 to the switching unit SE which then cuts off the output of the summation point SU from the input of the control amplifier RV in respect of a.c. voltage in that it connects these two terminals in respect of a.c. voltage to reference potential, while the output of the summation point SU and the input of the control amplifier RV remain connected to one another in respect of d.c. voltage. The control unit K now changes the signal at its first output A1 such that the voltage at the output of the digital-analogue converter DA rises linearly. Because this linearly rising voltage is fed via the control amplifier RV to the adjusting element SG, the objective is moved.

When the focal point is located on the recording medium, the focus detector FD emits a signal to the control unit K which then maintains the voltage connected at this time to its first output A1 and emits a signal at its second output A2 to the switching unit SE which again connects the output of the summation point SU in respect of a.c. voltage to the input of the control amplifier RV. Because the control circuit is thus completely closed again, the objective is

guided by the adjusting element SG in such manner that the focal point always remains on the recording medium.

Figure 4 illustrates the curve of the voltage U_{FE} at the output of the light receiving- and evaluating circuit 0 and the signal FZ at the output of the focus detector FD when the objective is moved commencing from the largest possible distance from the recording medium towards the recording medium and up to the smallest possible distance therefrom. When the curve intersects the abscissa, the focal point is located on the recording medium.

In Figures 5 and 6 the voltages at the input of the adjusting element SG, at the output of the light receiving- and evaluating circuit 0 and at the output of the focus detector FD as well as the state of the control circuit - open or closed - are plotted over time.

As shown in Figure 6, the voltage at the input of the adjusting element SG can firstly be increased, not linearly but in stepped fashion, until the focus detector FD emits a signal for the first time to the control unit K. This is the case when the focal point comes to lie for the first time on the recording medium. This first signal of the focus detector FD causes the voltage at the input of the adjusting element SG to be reduced by the last step in order then to rise again linearly until the focus detector FD emits a signal for a second time to the control unit K. This is the case when the focal point is located on the recording medium again. The second signal at the output of the focus detector FD causes the control circuit to be closed by the control unit K. Due to the stepped rise in the voltage at the input of the adjusting element S, focusing takes place more rapidly than in the case of a linear rise.

Because the fluctuations in the offset voltages, the values of which are not known in advance, are substantially greater than the control voltage required to bring the objective into the position in which the focal point is located on the recording medium, it is effective to commence the compensation not with zero volts but with a compensation voltage of maximum amount.

The circuit arrangement has the advantage that simultaneously to the focusing, the offset voltage of the control amplifier RV and of the light receiving- and evaluating circuit 0 are compensated. Because focusing takes place with the control circuit closed in respect of d.c. voltage, different thicknesses of different recording media are taken into account. However this circuit arrangement has the disadvantage that when the recording medium is not inserted in the device coarse focusing is critical because overdriving of the control amplifier RV and thus also of the adjusting element SG is to be expected.

This disadvantage can be eliminated in the circuit arrangement shown in Figure 2 and described in Claim 11 in that in addition to the switching unit SE a controllable switch S is provided following the control amplifier RV, the control input of said switch S being connected to a third output A3 of the control unit K.

The controllable switch S remains closed in the case of disturbance-free operation. Only when, for whatever reasons, the focusing is unsuccessful, is the controllable switch S opened by the control unit K to prevent the adjusting element SG from being overdriven. The controllable switch S therefore only has a protective function.

Figure 3 illustrates and Claim 12 describes a third circuit arrangement which differs from the circuit arrangement according to Figure 1 only in that the input of the focus detector FD is not connected to the first input but to the output of the summation point SU.

By virtue of the measure of arranging the focus detector FD after the summation point SU, the offset voltage of the light receiving- and evaluating circuit 0, which is brought about by different parameters of the four photo-diodes A, B, C and D, is detected and compensated separately from the offset voltage of the control amplifier RV.

The compensation is facilitated in that when the recording medium is not inserted, none of the four photo-diodes A, B, C and D of the light receiving- and evaluating circuit 0 receive any light from the light source of the optical system irrespectively of the position of the objective. Because the four photo-diodes are therefore in the dark, they emit only the so-called dark currents which, as already explained in the introduction, vary.

The focus detector FD emits a first signal to the control unit K when the voltage at the output of the summation point SU becomes zero. However, this is the case precisely when the offset voltage of the light receiving- and evaluating circuit 0, brought about by the different dark currents of the four photo-diodes, is compensated by the voltage at the output of the digital-analogue converter DA. This compensation voltage is maintained.

Following the insertion of the recording medium the control unit K emits a variable voltage from its first output A1 which is superimposed upon the compensation voltage. As a result, the objective is moved by the adjusting element SG until the focus detector FD establishes that the focal point

is located on the recording medium and emits a signal to the control unit K which subsequently maintains the voltage emitted at this time from its first output A1. Additionally, the control unit K causes the switching unit SE to reconnect the control amplifier RV and the summation point SU to one another in respect of a.c. voltage. Because the control circuit is now completely closed, the objective is guided in such manner that the focal point remains on the recording medium.

In Figure 7 the voltages at the output of the adjusting element SG and at the output of the focus detector FD together with the state of the control circuit - open or closed - are plotted over time.

It is also possible for the control unit K to emit a pulse-breadth-modulated voltage U_{PWM} from its output A1 at the start of the focusing when the control circuit has been opened in respect of a.c. voltage, where the pulse breadth of said voltage U_{PWM} is periodically changed. The digital-analogue converter DA, which can be constructed for example as an integrator, therefore emits a sawtooth or triangular voltage U_s from its output to the adjusting element SG depending upon its construction.

Figure 8 illustrates the pulse-breadth-modulated voltage U_{PWM} and the sawtooth voltage U_s. Figure 9 illustrates the pulse-breadth-modulated voltage U_{PWM} and the triangular voltage U_s.

The described circuit arrangements have the advantage that with each focusing attempt and thus each time the device is switched on again, both the offset voltage of the control amplifier RV and also that of the light receiving- and evaluating circuit 0 are compensated.

In the production of CD players which are equipped with one of the circuit arrangements shown in Figures 1, 2 or 3 no manual adjustment of the control amplifiers on a potentiometer is required, as is the case with the circuit arrangement according to Figure 30 on page 22 of the Hitachi Service Manual. Because the offset voltages are recompensated each time the device is switched on, long-term drifts in the offset voltages due to ageing of the components have no effect. Therefore the situation cannot arise that the control amplifier of the focus control circuit of a CD player, which was initially playing satisfactorily but whose sound quality noticeably deteriorates after a relatively long period of time, will need to be re-adjusted in the workshop. The fact that such servicing measures are not required is to be considered as a further advantage since the servicing of a device is not only unpleasant for the customer but also costs him money.

Figure 10 illustrates a so-called actuator with a limited mechanical focus range.

The objective 20 with an objective shaft 21 is maintained in its centre position and centred by leaf springs 24. Permanent magnets are arranged on the objective shaft 21 and an embedded coil 22 in the tube 23 has been indicated. Such known actuators are complex and costly.

Figure 11 illustrates a similar, likewise known actuator with a cylindrical objective shaft 21, an objective 20 and a tube 23 in which the objective shaft 21 can move freely. At the top and the bottom the objective shaft 21 is mechanically delimited by stop means 26 and 25 and is secured against rotation.

The disadvantage of such a system is that friction and mechanical asymmetries make the objective 20 and objective

shaft 21 difficult to control in the case of slow and small movements. If no movement of the objective shaft 21 and objective 20 occurs, tilting in the tube 23 can also occur. If a control signal caused by a jolt of the recording medium now occurs on the coil, the coil requires substantially more energy to free the objective shaft 21 from its tilted state than would be necessary for the required adjusting- and focus follow-up movement. The result is an increase in the control signal because the objective shaft 21 does not execute any movement until the energy is sufficiently great to overcome the break-away moment. As a consequence, excess oscillation of the objective shaft 21 and objective 20 can occur, substantially lengthening the control time.

Such excess oscillations of the objective shaft can be avoided in that an a.c. component is constantly superimposed upon the control signal. Because the a.c. component continuously maintains the objective shaft in motion, since it oscillates about a central position, tilting is eliminated. Due to the continuous back and forth movement of the objective shaft 21 in the tube 23, only a sliding friction, and no longer the more substantial static friction, occurs between these two parts. Therefore a much smaller force is required to displace the oscillating objective shaft 21 than would be the case when the objective shaft 21 is at rest. However, with a superimposed a.c. component, focusing cannot be carried out so accurately as with no superimposition.

It is also possible to store the value W of the second control voltage for different types of recording media, e.g. discs of different thicknesses.

During focusing, with a specific type of recording medium, the second control voltage is then changed commencing from the characteristic value stored for this type. This measure

brings the advantage that focusing can take place more rapidly since the objective is already in the vicinity of the correct position at the start of the focusing.

Claims

1. A method of focusing a light beam which can be focused onto an optical recording medium by means of an optical system comprising a light source and an objective moveable by means of an adjusting element (SG), which recording medium reflects the light beam onto a number of photo-elements (A, B, C, D), from the output voltages of which, by subtraction and addition of the differences thus determined, a first control voltage - the so-called focus error signal (U_{FE}) - is obtained, which first control voltage can be fed via a control amplifier (RV) to the adjusting element (SG) so that a control circuit is formed, where a second control voltage (U_s) is generated by a signal generator (SR) and is changed by the signal generator (SR) until the light beam is focused on the recording medium, whereupon the value W of the second control voltage (U_s) assumed at this time is maintained and is fed as bias voltage to the adjusting element (SG), characterised in that while the second control voltage (U_s) is changed in order to focus the light beam on the recording medium the sum of the first and second control voltages (U_{FE}, U_s) is fed via a filter (SE) to the control amplifier (RV), which filter separates the first control voltage (U_{FE}) in respect of a.c. voltage but allows through the second control voltage (U_s).

2. A method as claimed in Claim 1, characterised in that the value W of the second control voltage (U_s) for different types of recording media can be stored and that during focusing in the case of a specific type of recording medium the second control voltage is changed commencing from the value W stored for this type.

3. A method as claimed in Claim 1 or 2, characterised in that the second control voltage (U_s) is changed by pulse modulation.

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4. A method as claimed in Claim 3, characterised in that pulse breadth modulation is provided as pulse modulation method.

5. A method as claimed in Claim 4, characterised in that the second control voltage (U_s) is designed to be sawtooth-shaped.

6. A method as claimed in Claim 4, characterised in that the second control voltage (U_s) is designed to be triangular.

7. A method as claimed in Claim 1, 2, 3, 4, 5 or 6, characterised in that an a.c. voltage is superimposed upon the control voltage.

8. A circuit arrangement for focusing a light beam which can be focused onto an optical recording medium by means of an optical system comprising a light source and an objective moveable by means of an adjusting element (SG), which recording medium reflects the light beam onto a number of photo-elements (A, B, C, D) from the output voltages of which, by subtraction and addition of the differences thus determined, a first control voltage - the so-called focus error signal (U_{FE})- is obtained, which first control voltage can be fed via a control amplifier (RV) to the adjusting element (SG) so that a control circuit is formed, where means are provided for the generation of a second control voltage (U_s) by a signal generator (SR), which second control voltage is changed by the signal generator (SR) until the light beam is focused on the recording medium, whereupon the value W of the second control voltage (U_s) assumed at this time is maintained and fed as bias voltage to the adjusting element (SG), characterised in that a filter (SE) can be inserted before the control amplifier (RV), which filter separates the first control voltage (U_{FE})

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in respect of a.c. voltage but allows through the second control voltage (U_s).

9. A circuit arrangement as claimed in Claim 8, characterised in that means are provided such that the value W of the second control voltage (U_s) for different types of recording media can be stored and that during focusing in the case of a specific type of recording medium the second voltage is changed commencing from the value W stored for this type.

10. A circuit arrangement as claimed in Claim 8, characterised in that the output of a light receiving- and evaluating circuit (0) is connected to the input of a focus detector (FD) and to the first input of a summation point (SU), the other input of which is connected to the output of a digital-analogue converter (DA), that the output of the focus detector (FD) is connected to the input (E) of a control unit (K), the first output (A1) of which is connected to the input of the digital-analogue converter (DA) and the second output (A2) of which is connected to the control input of the switchable filter (SE), that the output of the summation point (SU) is connected to the input of the filter (SE), the output of which is connected to the input of the control amplifier (RV), and that the output of the control amplifier (RV) is connected to the input of the adjusting element (SG).

11. A circuit arrangement as claimed in Claim 10, characterised in that between the control amplifier (RV) and the adjusting element (SG) is arranged a controllable switch (S), the control input of which is connected to a third output (A3) of the control unit (K).

12. A circuit arrangement as claimed in Claim 8, characterised in that the output of a light receiving- and evaluating circuit (0) is connected to the first input of a

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summation point (SU), the other input of which is connected to the output of a digital-analogue converter (DA), that the input of the digital-analogue converter (DA) is connected to the first output (A1) of a control unit (K), the second output (A2) of which is connected to the control input of the switchable filter (SE) and the input (E) of which is connected to the output of a focus detector (FD), that the output of the summation point (SU) is connected to the input of the focus detector (FD) and to the input of the filter (SE), the output of which is connected to the input of the control amplifier (RV) and that the output of the control amplifier (RV) is connected to the input of the adjusting element (SG).

* C L M S *