

The present invention relates to a method for the compensation of the off-set in an apparatus for the reproduction of data which is readable by means of an optical scanning device from the data tracks of a record carrier, in which at least one light beam is focusable on the record carrier by means of a focusing control loop and is guidable onto the data tracks of the record carrier by means of a tracking control loop, wherein the light beam is reflected from the record carrier onto a photo-detector, which is built up of several photo-diodes, by means of which an electrical data signal, a focusing error signal as control signal for the focusing control loop and a tracking error signal as control signal for the tracking control loop are generated, wherein the difference of the output signals of a first and of a second photo-diode is formed in a servo amplifier.

Such apparatus e.g. CD players, recording and play-back magneto optic devices, recording and play-back devices for draw-disc or optical disc players are equipped with an optical scanning device consisting of a laser diode, a plurality of lenses, a prismatic beam splitter and a photo-detector. Construction and method of operation of an optical scanning device, of a so-called optical pick-up, are described in Electronic Components and Applications, Vol. 6, No. 4, 1984 at Pages 209 - 215.

The light beam emitted by the laser diode is focused onto the compact disc by means of lenses and reflected therefrom onto a photo-detector. The data stored on the compact disc and the control value for the focusing and for the tracking control loop are recovered from the output signal of the photo-detector. In the above mentioned reference, the control value for the focusing control loop is referred to as the focusing error while the phrase radial tracking error is selected for the control value of the tracking control loop.

A coil serves as adjusting member for the focusing control loop, an object lens being movable along the optical axis by means of its magnetic field. By displacement of the object lens, the focusing control loop thus causes the light beam emitted by the laser diode to be continually focused on the compact disc. The optical scanning device is movable in a radial direction relative to the compact disc by means of the tracking control loop, which is also often referred to as a radial drive. As a result, the light beam can be guided along the spirally shaped tracks of the compact disc.

In some devices, the radial drive is built up from a so-called coarse and a so-called fine drive. The coarse drive may, for example, be formed as a drive screw by means of which the whole optical scanning arrangement consisting of the laser diode, the lenses, the prismatic beam splitter and the photo-detector is radially displaceable. With the fine drive, the light beam can be swept in a radial direction e.g. over a predefined small angle, so that through this tilting motion alone, the light beam can travel a short distance along a radius of the compact disc.

The photo-detector PD of the optical scanning device of a CD player in which the three laser beams L1, L2 and L3 are focused on the compact disc is shown in the Fig. 1. In the above mentioned reference, such a scanning device is referred to as a three-beam pick-up.

In the photo-detector, four square shaped photodiodes A, B, C and D are fitted together such that they form yet another square. Two further, similarly square shaped photodiodes E and F are located diagonally opposite to each other with reference to this square formed by the four photodiodes A, B, C and D.

The central light beam L1 which is focused on the four photodiodes A, B, C and D produces the data signal $HF = AS + BS + CS + DS$ and the focusing error signal $FE = (AS + CS) - (BS + DS)$. The two outer light beams L2 and L3, of which the front one L2 falls on the photodiode E and the rear one L3 on the photodiode F, produce the tracking error signal $TE = ES - FS$. The photo-electric voltages of the photodiodes A, B, C, D, E and F are referenced respectively AS, BS, CS, DS, ES and FS. Because an effectively astigmatic collimator lens is provided in the optical path of the central light beam L1 in the optical scanning device, the central light beam L1 is in the shape of a circle when focused exactly on the large square which is formed by the photodiodes A, B, C and D while it takes on the form of an ellipse when defocused.

Figure 1a shows the case of the focusing and also of the exact tracking which will be gone into later on. Because the spot of light formed on the large square by the light beam L1 has the form of a circle, the ensuing focusing error signal is $FE = (AS + CS) - (BS + DS) = 0$. The focusing control loop recognises that there is an exact focusing from the zero value of the focusing error signal FE.

One of the cases of defocusing, where the object lens is located too far from the compact disc, is illustrated in Figure 1b. The focusing error signal FE is negative: $FE = (AS + CS) - (BS + DS) < 0$. The focusing control loop recognises that the distance between the object lens and the compact disc is too large from the negative value of the focusing error signal FE. Consequently, the object lens is moved towards the compact disc by the adjusting member of the focusing control loop until such time as the focusing error signal FE becomes zero.

The other case of defocusing, where the object lens is too close to the compact disc, is shown in Figure 1c. The focusing error signal FE has a positive value: $FE = (AS + CS) - (BS + DS) > 0$. The focusing control loop recognises that the object lens is too close to the compact disc from the positive value of the focusing error signal FE. Hence, the object lens is moved away from the compact disc by the adjusting member until such time as the focusing error signal FE becomes zero.

It will now be explained how the tracking control is effected by means of the tracking control loop.

The light beams L1, L2 and L3 in Figures 1a, 1b and 1c are following the track exactly. The tracking error signal TE has the value zero. $TE = ES - FS = 0$.

The case is illustrated in Figure 1d that the light beams L1, L2 and L3 are displaced to the right of the track. The tracking error signal TE takes on a negative value: $TE = ES - FS - 0$. The adjusting member of the tracking control loop now moves the optical scanning device to the left until such time as the tracking error signal TE becomes zero.

In the opposite case, that the light beams are displaced to the left of the track, the tracking error signal is positive: $TE = ES - FS - 0$. The adjusting member of the tracking control loop now moves the optical scanning device to the right until such time as the tracking error signal FE becomes zero.

The relationship between the input magnitudes, the actual value TE and the output voltage UA of the servo amplifier is apparent from the characteristic curve of the servo amplifier for the tracking control loop illustrated in Figure 2. The ideal operating point of the servo amplifier lies at the zero point of the co-ordinate system since the servo amplifier operates symmetrically at this position of the operating point. Its control sweep to both sides is equally great.

A circuit arrangement and a method for the compensation of the offset of a DC amplifier are known from the EP-A 0118 178.

The output of the DC amplifier is connected to the input of an analogue to digital converter whose output is connected to the input of a control unit. The output of the control unit is connected to the input of a digital to analogue converter whose output is connected to the first input of the DC amplifier.

By means of a change over switch, either the signal which is to be amplified or earth potential can be connected to the second input of the DC amplifier. The control unit is connected to the DC amplifier via control lines in order to adjust the amplification and the polarity of the DC amplifier.

For the off-set compensation, the second input of the DC amplifier is connected to earth. The level at the output of the DC amplifier is determined for normal and inverted polarity. An off-set compensation signal is generated from the difference of these two levels at the output of the DC amplifier and is applied to the first input of the DC amplifier.

Thus, the object of the invention is to so develop a method in accordance with the first part of the Claim 1, that the servo amplifier of the tracking control loop works as symmetrically as possible.

A first solution of this problem is characterised by the following method steps:

- a) a reference voltage is applied to the input of a first series circuit and of a second series circuit which are each built up of an amplifier, a low pass filter and a rectifier and their outputs are connected to the inputs of a comparator;
- b) for the compensation of the off-set of the comparator, a first compensating voltage is supplied to the input of one of the two series circuits and this is varied until such time as the comparator indicates that the levels at the outputs of the two series circuits are equally great;
- c) the first compensating voltage determined in this manner is retained;
- d) the output signal of the first photo-diode is supplied to the input of the first series circuit instead of the reference voltage, and the output signal of the second photo-diode is supplied to the input of the second series circuit;

e) for the off-set compensation, a second compensating voltage is applied to an input of the servo amplifier and is varied until such time as the levels at the input of the comparator are equally great;

f) the second compensating voltage determined in this manner is retained;

A second solution of this problem is characterised by the following method steps:

a) a first reference voltage is applied to the inputs of a differential amplifier;

b) the level at the output of the differential amplifier is compared with a second reference voltage in a comparator;

c) for the compensation of the off-set of the differential amplifier, a first compensating voltage is supplied to the one input of the differential amplifier and is varied until such time as the level at the output of the differential amplifier coincides with the second reference voltage;

d) the first compensating voltage determined in this manner is retained;

e) the output voltages of the first and of the second photo-diodes are applied to the inputs of the differential amplifier instead of the first reference voltage;

f) for the off-set compensation, a second compensating voltage is applied to an input of the servo amplifier and is varied until such time as the levels at the inputs of the differential amplifier are equally great;

g) the second compensating voltage determined in this manner is retained;

There is shown

Figure 3 a first embodiment

Figure 4 a second embodiment of the invention.

In the Figure 3, a voltage $+U_B$ is applied to the interconnected cathodes of the photo-diodes E and F of the photo detector PD. The anode of the photo-diode E is connected to the first input

of a controllable change over switch U1 and via a resistor R1 to the inverting input of the servo amplifier TR from whose output the tracking control signal TE is obtainable. The anode of the diode F is connected to the first input of a controllable change over switch U2 and via a resistor R2 to the non-inverting input of the servo amplifier TR whose output is fed back via a resistor R3 to its inverting input. An alternating voltage UR is applied to the interconnected second inputs of the controllable change over switches U1 and U2 as reference value. The output of the controllable change over switch U1 is connected to the input of an amplifier V1 whose output is connected to the input of a low pass filter TP1. The output of the controllable change over switch U2 is connected to the input of an amplifier V2 whose output is connected to the input of a low pass filter TP2. The output of the low pass filter TP1 is connected to the input of a rectifier G1 whose output is connected to the inverting input of a comparator K. The output of the low pass filter TP2 is connected to the input of a rectifier G2 whose output is connected to the non-inverting input of the comparator K. The output of the comparator K is connected to the input of a control unit MP whose first output A1 is connected to the input of a digital to analogue converter DA1, whose second output A2 is connected to the input of a digital to analogue converter DA2 and whose third output A3 is connected to the control inputs of the controllable change over switches U1 and U2.

In operation of the CD player, the controllable change over switches U1 and U2 are connected at predetermined periodic intervals to the reference voltage UR by the control unit MP, for which a microprocessor is particularly suitable, so that the same voltage is present at both inputs of the comparator K. If however, because of an off-set voltage in the two signal paths in which the amplifiers V1 and V2, the low pass filters TP1 and TP2, the rectifiers G1 and G2 as well as the comparator K itself lie, the comparator K indicates that the voltages at its inputs are different, although they are equally great, then the control unit MP alters the digital value at its output A2 until such time as the comparator K indicates at its output that there is equality of its input voltages. The digital value at the output A2 of the control unit MP is converted by means of the digital to analogue converter DA2 into an analogue off-set compensating voltage which compensates the off-set voltages of the amplifiers V1 and V2 as well as of the comparator K.

During the remaining time, the controllable change over switches U1 and U2 are in the other position so that the photo-diodes E and F are connected via the amplifiers V1 and V2, the low pass filters TP1 and TP2, the rectifiers G1 and G2 to the comparator

K. The low frequency components are filtered out from the output voltages of the photo-diodes E and F by means of the low pass filters TP1 and TP2 and are supplied as peak, effective, or average values to the inputs of the comparator K because the rectifiers G1 and G2 are effective to form peak values, average values, or effective values.

If the comparator K of the control unit MP indicates that its input voltages are different, the control unit MP alters the digital value at its output A1, which is applied to the non-inverting input of the servo amplifier TR as analogue off-set compensating voltage by means of the digital to analogue converter DA1, until such time as the input voltages to the comparator K are equally great.

Manual adjustment during the production and equally re-adjustments because of temperature fluctuations or because of aging of the components are dispensed with since automatic re-adjustment constantly occurs during the operation.

In the second embodiment which is depicted in Figure 4, a voltage $+U_B$ is similarly applied to the interconnected cathodes of the photo-diodes E and F. The anode of the photo-diode E is connected to the first input of a controllable change over switch U1 and via the resistor R1 to the inverting input of the servo amplifier TR from whose output the tracking control signal TE is obtainable. The anode of the diode F is connected to the first input of a controllable change over switch U2 and via a resistor R2 to the non-inverting input of the servo amplifier TR whose output is fed back via a resistor R3 to its inverting input. The interconnected second inputs of the controllable change over switches U1 and U2 are connected to an alternating reference voltage UR. The output of the controllable change over switch U1 is connected to the inverting input of a differential amplifier V whose output is connected to the input of a low pass filter TP. The output of the controllable change over switch U2 is connected to the non-inverting input of the differential amplifier V. The output of the low pass filter TP is connected to the one contact of a controllable switch S and via a capacitance C2 to the non-inverting input of a comparator K1 whose inverting input is at reference potential. The non-inverting input of a comparator K2 is connected to the other contact of the controllable switch S, the inverting input is at reference potential. A capacitance C1 is located between the two inputs of the comparator K2. The output of the comparator K1 is connected to the controllable input of the controllable switch S and to the first input E1 of a control unit MP whose second input E2 is connected to the output of the comparator K2. The

first output A1 of the control unit MP is connected to the input of a digital to analogue converter DA1, whose output is connected to the non-inverting input of the servo amplifier TR. The second output A2 of the control unit MP is connected to the input of a digital to analogue converter DA2 whose output is connected to the non-inverting input of the differential amplifier V. The third output A3 of the control unit MP is connected to the control inputs of the two controllable change over switches U1 and U2.

Just as in the first embodiment, whilst the CD player is in operation, the reference alternating voltage UR is applied to the inputs of the differential amplifier V by means of the controllable change over switches U1 and U2. If the differential amplifier V has an off-set voltage then the comparator K1 of the control unit MP, for which a microprocessor is preferably provided, indicates that the output signal of the differential amplifier V differs from zero. Thereupon, the control unit MP alters the digital value at its output A2 until such time as the off-set voltage of the differential amplifier V is compensated by the off-set compensating voltage at the output of the digital to analogue converter DA2. During the remaining time, the anodes of the photo-diodes E and F are connected via the controllable change over switches U1 and U2 to the inputs of the differential amplifier V.

The comparator K2, to which the dc components of the voltage at the output of the low pass filter are supplied, indicates to the control unit MP which sign the difference of the voltages of the photo-diodes E and F has. By contrast, the comparator K1, on whose input the alternating components of the voltage at the output of the low pass filter TP are present, indicates to the control unit MP what amount the difference of the voltages of the photo-diodes E and F has. Thereupon, the control unit MP alters the digital value at its output A1, which is applied as analogue off-set compensating voltage to the non-inverting input of the servo amplifier TR by means of the digital to analogue converter DA1, until such time as the voltages at the inputs of the differential amplifier V are equally great. The control unit MP then opens the controllable switch S which has been closed up till now.

The invention is just as suitable for DRAW disc players, magneto optic devices and optical disc players as for CD players.



Claims

1. Method for the off-set compensation in an apparatus for the reproduction of data which is readable by means of an optical scanning device from the data tracks of a record carrier, in which at least one light beam is focusable on the record carrier by means of a focusing control loop and is guidable onto the data tracks of the record carrier by means of a tracking control loop, wherein the light beam is reflected from the record carrier onto a photo-detector (PD), which is built up of several photo-diodes (A, B, C, D, E, F), by means of which an electrical data signal (HF), a focusing error signal (FE) as control signal for the focusing control loop and a tracking error signal (TE) as control signal for the tracking control loop are generated, in which the difference of the output signals of a first and of a second photo-diode (E, F) is formed in a servo amplifier (TR), characterised by the following method steps:

- a) a reference voltage (UR) is applied to the input of a first series circuit and of a second series circuit which are each built up of an amplifier (V1, V2), a low pass filter (TP1, TP2) and a rectifier (G1, G2) and their outputs are connected to the inputs of a comparator (K);
- b) for the compensation of the off-set of the comparator (K), a first compensating voltage is supplied to the input of one of the two series circuits and this is varied until such time as the comparator (K) indicates that the levels at the outputs of the two series circuits are equally great;
- c) the first compensating voltage determined in this manner is retained;
- d) the output signal of the first photo-diode (E) is supplied to the input of the first series circuit instead of the reference voltage (UR), and the output signal of the second photo-diode (F) is supplied to the input of the second series circuit;
- e) for the off-set compensation, a second compensating voltage is applied to an input of the servo amplifier (TR) and is varied until such time as the levels at the input of the comparator (K) are equally great.

2. Method for the off-set compensation in an apparatus for the reproduction of data which is readable by means of an optical scanning device from the data tracks of a record carrier, in which at least one light beam is focusable on the record carrier by means of a focusing control loop and is guidable onto the



data tracks of the record carrier by means of a tracking control loop, wherein the light beam is reflected from the record carrier onto a photo-detector (PD), which is built up of several photo-diodes (A, B, C, D, E, F), by means of which an electrical data signal (HF), a focusing error signal (FE) as control signal for the focusing control loop and a tracking error signal (TE) as control signal for the tracking control loop are generated, wherein the difference of the output signals of a first and of a second photo-diode (E, F) is formed in a servo amplifier (TR), characterised by the following method steps:

- a) a first reference voltage (UR) is applied to the inputs of a differential amplifier (V);
- b) the level at the output of the differential amplifier (V) is compared with a second reference voltage in a comparator (K1);
- c) for the compensation of the off-set of the differential amplifier (V), a first compensating voltage is supplied to the one input of the differential amplifier (V) and is varied until such time as the level at the output of the differential amplifier (V) coincides with the second reference voltage;
- d) the first compensating voltage determined in this manner is retained;
- e) the output voltages of the first and of the second photo-diodes (E, F) are applied to the inputs of the differential amplifier (V) instead of the first reference voltage (UR);
- f) for the off-set compensation, a second compensating voltage is applied to an input of the servo amplifier (TR) and is varied until such time as the levels at the inputs of the differential amplifier (V) are equally great.

3. Apparatus for carrying out the method according to Claim 1, characterised in that, one electrode of the photo-diode (E), whose photo electric voltage serves for the generation of the tracking error control signal (TE), is connected to the inverting input of the servo amplifier (TR) of the tracking control loop and to the first input of a controllable change over switch (U1) whose output is connected to the inverting input of a comparator (K) via a series circuit comprising a first low pass filter (TP1) and a first rectifier (G1), that the same electrode of the other diode (F), whose photo electric voltage likewise serves for the generation of the tracking error control signal (TE), is connected to the non-inverting input of the servo amplifier (TR) of the tracking control loop and to the



first input of a second controllable change over switch (U2) whose output is connected via a series circuit comprising a second low pass filter (TP2) and a second rectifier (G2) to the non-inverting input of the comparator (K) whose output is connected to the input (E1) of a control unit (MP), that the first output (A1) of the control unit (MP) is connected to the input of a first digital to analogue converter (DA1) whose output is connected to the non-inverting input of the servo amplifier (TR) of the tracking error control loop, that the second output (A2) of the control unit (MP) is connected to the input of a second digital to analogue converter (DA2) whose output is connected to the output of one of the two controllable change over switches (U2), that a reference voltage (UR) is present on the second input of the two controllable change over switches (U1, U2), and that a third output (A3) of the control unit (MP) is connected to the control inputs of the two controllable change over switches (U1, U2).

4. Apparatus in accordance with Claim 3, characterised in that, an amplifier (V1, V2) is provided between each of the photo-diodes (E, F) and the low pass filters (TP1, TP2).

5. Apparatus in accordance with Claim 3 or 4, characterised in that, the rectifiers (G1, G2) are effective to form peak values, average values, or effective values.

6. Apparatus for carrying out the method in accordance with Claim 2, characterised in that, the one electrode of the one photo-diode (E), whose photo electric voltage serves for the generation of the tracking error control signal (TE), is connected to the inverting input of the servo amplifier (TR) of the tracking control loop and to the first input of a first controllable change over switch (U1) whose output is connected to the one input of a differential amplifier (V), that the same electrode of the other diode (F), whose photo electric voltage likewise serves for the generation of the tracking error control signal (TE), is connected to the non-inverting input of the servo amplifier (TR) of the tracking control loop and to the first input of a second controllable change over switch (U2) whose output is connected to the other input of the differential amplifier (V), whose output is connected to the input of a low pass filter (TP), that the output of the low pass filter (TP) is connected via a first capacitance (C2) to the one input of a first comparator (K1) and via a controllable switch (S) to the one input of a second comparator (K2), that the other input of the first comparator (K1), whose output is connected to the first input (E1) of a control unit (MP) and to the control input of the controllable switch (S), is at reference potential, that



the other input of the second comparator (K2) is likewise at reference potential, that a second capacitance (C1) is provided between the inputs of the second comparator (K2), that the output of the second comparator (K2) is connected to the second input (E2) of the control unit (MP), whose first output (A1) is connected to the input of a first digital to analogue converter (DA1), that the output of the first digital to analogue converter (DA1) is connected to the non-inverting input of the servo amplifier (TR) of the tracking control loop, that a second output (A2) of the control unit (MP) is connected to the input of a second digital to analogue converter (DA2), whose output is connected to one input of the differential amplifier (V), that a reference voltage (UR) is present on the respective second input of the two controllable change over switches (U1, U2) and that a third output (A3) of the control unit (MP) is connected to the control inputs of the two controllable change over switches (U1, U2).

7. Apparatus in accordance with Claim 3, 4, 5 or 6, characterised in that, a microprocessor is provided for the control unit (MP).