

The invention relates to a method and a circuit arrangement for automatically setting the control loop gain in a control system by superimposing on the reference input W a sine-wave signal of the frequency f in order to obtain a criterion for setting the control loop gain. Such a method is described in the book by Decaulne et al discussed further below.

Control systems are used e.g. in CD players to guide the optical scanning device on the data track of the compact disc and to focus the scanning light beam onto the disc surface. These servo systems, the track control system and the focus control system, have to operate precisely and be set accurately so that perfect sound reproduction is achieved. The setting of the gain in the case of the controllers usually takes place manually by adjustment of a potentiometer. These setting operations are relatively complicated and take up much time. Since in addition the electric components contained in control systems and in the optical scanning device age with the passage of time, the gain of the controllers frequently has to be re-set by hand. The setting by hand both at the production stage and during the servicing of the units is naturally a disadvantage, because it takes up time and hence also costs money.

In the book by Decaulne, Gille and Pélegrin "Introduction aux systèmes asservis extrémaux et adaptatifs" (Introduction to extreme and adaptive servo systems) there is described on p. 85 an adaptive control system which is illustrated in Figure 53 on the same page. The invention is based on such a control system in accordance with the preamble of patent claim 1.

In this adaptive control system there are connected in series a first and a second summation stage, a first servo amplifier, a third summation stage and the controlled system. The output of the controlled system is connected to the negative input of the second summation stage and to the input of a band-pass filter whose output is connected to the minus input of an amplitude detector. In addition the output of the controlled system is connected via a controllable amplifier to the minus input of the third summation stage. Two outputs of the band-pass filter are connected to the minus input of an amplitude detector and of a phase detector, the plus inputs of said amplitude detector and phase detector being connected to the output of a sine-wave generator. The sine-wave signal generated by the sine-wave generator is fed into the control system at the first summation stage together with the reference input $e(t)$. In the amplitude detector the root mean square value is formed from the sine-wave signal of the sine-wave generator and the filtered controlled variable $s(t)$, while the phase detector generates the correlation function from the sine-wave signal and the filtered controlled variable. The root mean square value is used to control the control loop gain in the case of the first servo amplifier; the correlation function determines the control loop gain of the second servo amplifier.

A first disadvantage of this adaptive control system lies in the fact that two servo amplifiers are required. It can be regarded

as a second disadvantage that for the setting of the control parameters both the root mean square value and the correlation function are formed from the sine-wave signal and the controlled variable.

The object of the invention is therefore to avoid, with the lowest possible expenditure on components, both the time-consuming setting operations at the production stage and also the re-settings of the control loop gain required later during the servicing.

The invention, a method for automatically setting the control loop gain in a control system, achieves this object by the fact that the amplitudes of the controlled variable x and the control difference x_d are compared with one another and that the control loop gain is varied until such time as the amplitudes of the controlled variable x and the control difference x_d are of equal value.

Fig. 1 shows a circuit arrangement for implementing the method according to the invention.

Fig. 2 shows an embodiment of the circuit arrangement shown in Fig. 1 for a CD player.

Fig. 3 shows a Bode diagram for explaining the invention.

In Fig. 1, as with a standard control system, the output of a controller RG is connected to the input of the controlled system RS whose output is connected to the second input of a summation stage SU. To the first input of the summation stage SU there is fed the reference input W, its output is connected to the input of the controller RG. The output of a frequency generator FG is connected to the first input of the summation stage SU, to the first input of a first synchronous rectifier S1 and to the first input of a second synchronous rectifier S2. The second input of the first synchronous rectifier S1, whose output is connected to the first input of a comparator VL, is connected to the output of the controlled system RS, the second input of the second synchronous rectifier S2, whose output is connected to the second input of the comparator VL, is on the other hand connected to the output of the summation stage SU. The output of the comparator VL is connected to the input of a control and monitoring circuit C whose output is connected to the input for setting the gain on the controller RG.

The circuit arrangement in Fig. 2 will be explained with reference to the Bode diagram shown in Fig. 3.

In Fig. 3a the magnitude of the control loop gain G , also called loop gain, is plotted versus the frequency f , in Fig. 3b the phase φ is so plotted. In the case of the frequency f_0 , the so-called critical frequency, the characteristic curve of the magnitude cuts the zero dB line. The loop gain comes in the case of the frequency f_0 to exactly one, the phase margin works out as $\frac{1}{2}\pi$.

In order now to set the control loop gain, a sine-wave signal with the frequency f_0 is generated in the frequency generator FG and fed to the first input of the first and second synchronous rectifiers S1 and S2 respectively. In addition this signal is superimposed on the reference input W. Because the controlled variable x is fed to the input of the first synchronous rectifier, there is filtered out at the output of the latter from the controlled variable x that oscillation component whose frequency is equal to the frequency f_0 . Likewise there is filtered out at the output of the second synchronous rectifier S2 that oscillation component of the control difference x_d whose frequency is equal to the frequency f_0 , because there is fed to the second input of the second synchronous rectifier S2 the control difference x_d . In the comparator VL the instantaneous amplitudes of the oscillation components of the controlled variable x and the control difference x_d are compared with one another. The control and monitoring unit C now varies the gain of the controller RG until such time as the comparator VL indicates by a signal at its output that the filtered-out oscillation components with the frequency f_0 of the controlled variable x and of the control difference x_d are of equal value. If these two values are equal, the control loop gain is approximately one. Because however this setting is made at the critical frequency f_0 , the control loop gain is therefore also set approximately to the correct value. An exact setting of the control loop gain does not take place, however, because the oscillation components with the frequency f_0 of the controlled variable x and the control difference x_d are not in phase, but are offset from one another by the phase margin φ_0 , as is shown in Figures 3c and d.

In order to achieve an exact setting of the control loop gain to the value one at the frequency f_0 , the maximum amplitudes of the oscillation components of the frequency f_0 of the controlled variable x and the control difference x_d have to be compared with one another. This can be achieved by providing, instead of phase-dependent synchronous rectifiers, phase-independent ones. At the outputs of the phase-independent synchronous rectifiers the maximum amplitude of the oscillation components with the frequency f_0 of the controlled variable x and the control difference x_d can be picked off, so that in the comparator VL the maximum amplitudes are compared with one another. In this way the control loop gain is set exactly to the value one at the frequency f_0 .

The use of phase-dependent synchronous rectifiers nevertheless has the advantage that the phase margin φ_0 can be checked continuously. If it becomes too small - i.e. if it falls below a presettable threshold value -, the control loop gain is reduced. With this measure it is ensured that the stability of the control system is maintained.

Instead of the critical frequency f_0 another frequency f_1 can also be selected, assuming that the loop gain at this frequency f_1 is known. When comparing the amplitudes of the controlled variable x and the control difference x_d it must nevertheless be borne in mind that the amplitudes of the controlled variable x

and the control difference x_d differ by a particular amount because the loop gain is other than one. Let the loop gain be for example two at the selected frequency f_1 . The control and monitoring unit C in this case varies the gain of the controller RG until such time as the comparator VL indicates by a signal at its output that the filtered-out oscillation components with the frequency f_1 are twice as big in the case of the controlled variable x as in the case of the control difference x_d . If on the other hand the comparator VL checks for equality, as before, either an amplifier with a gain of $1/2$ has to be provided before the second input of the first synchronous rectifier S1 or an amplifier with a gain of two before the second input of the second synchronous rectifier S2.

Synchronous rectifiers and phase-independent synchronous rectifiers are described in U. Tietze, Ch. Schenk, Halbleiter-Schaltungstechnik (Semiconductor switching technology), 7th revised edition, Springer-Verlag, 1985, pp. 797-802. No further details, therefore, will be given of the construction and operation of a synchronous rectifier.

For many purposes it is sufficient to use simple synchronous rectifiers. In this case it is necessary to select a greater amplitude for the sine-wave signal generated by the frequency generator FG and possessing the frequency f_0 than if phase-independent synchronous rectifiers were used. The setting of the control loop gain is possible at any time, including during control mode. The cumbersome manual adjustments are dropped entirely. Any drifting of the parameters due to ageing and to temperature changes in the electronic components of the control system is automatically compensated for.

It is also possible, however, for the setting of the gain of the controller RG, to select a reference input W of zero and to pass to the first input of the summation stage SU only the sine-wave signal produced by the frequency generator FG, as a single "reference input".

Fig. 2 shows a circuit arrangement such as can be used in a CD player for the focus control or track control system. In this circuit arrangement the layout of the summation stage SU, the controller RG and the controlled system RS is shown.

The output of the frequency generator FG is connected to the non-inverting input of an operational amplifier OP1, which lies at reference potential across a resistor R1, and to the first input of the first and the second synchronous rectifiers S1 and S2. The output of the operational amplifier OP1 is fed back to its inverting input and connected across a resistor R2 to the inverting input of an operational amplifier OP2. The non-inverting input of the operational amplifier OP2 is connected across a resistor R3 to the output of the controlled system RS and to the second input of the synchronous rectifier S1. In addition it lies at reference potential across a resistor R4. The output of the operational amplifier OP2, which is fed back to its inverting input across a resistor R5, is connected to the input of the

controller RG, which is constructed as a PID controller with subsequent driver circuit T, and to the second input of the synchronous rectifier S2. As in Fig. 1, the output of the controller RG is connected to the input of the controlled system RS, which is composed of a control element or so-called actuator A, a photodetector PH acting as measurement probe for the actual value and a subsequent amplifier V. The output of the synchronous rectifier S1 is connected to the first input of the comparator VL, while the output of the synchronous rectifier S2 is connected to the second input of the comparator VL. The output of the comparator VL is connected to the input of the control and monitoring circuit C, whose output is connected to the input for the setting the gain on the P component of the controller RG. A further output of the control and monitoring circuit C is connected to the control input of the frequency generator FG. The summation stage SU is formed from the operational amplifiers OP1 and OP2, the gain of said operational amplifier OP2 being one, and the resistors R1 to R5. Because the synchronous rectifiers S1 and S2 filter the oscillation components of the frequency f_0 out of the controlled variable x and the control difference x_d , the amplitudes of these two components are compared with one another in the comparator VL. The control and monitoring circuit C varies the gain on the P component of the controller RG until such time as the comparator VL indicates by a signal that the amplitudes of the oscillation components with the frequency f_0 of the controlled variable x and control difference x_d are of equal value. If the amplitudes are equal, the control loop gain comes to one, because the gain of the operational amplifier OP2 has been selected as one.

Amplitude and frequency of the sine-wave signal generated by the frequency generator FG are controllable, so that for the focus control and the track control systems the critical frequency f_0 can be set by the control and monitoring circuit C in each case. In addition the amplitude of the sine-wave signal can be adjusted for phase-dependent and phase-independent synchronous rectifiers. In the case of CD players a far greater amplitude, e.g. greater by a factor of ten, can be chosen for the signal produced by the frequency generator FG if, instead of the synchronous rectifiers, low-pass and band-pass filters with subsequent peak value rectifiers are provided for filtering out the oscillation components with the frequency f_0 , without the reproduction quality of the unit suffering as a result. Setting of the control loop gain is possible even in playback mode. In an embodiment of the invention for CD players it is envisaged that the control and monitoring circuit C carries out the setting of the control loop gain in the intervals between pairs of musical items stored on the compact disc. The control loop gain is likewise re-set each time the CD player is turned on.

Thus not only is manual setting of the control loop gain by hand at the production stage dropped, but later corrections of the control loop gain, likewise to be carried out by hand, also become superfluous, because ageing of the components with which the control system is equipped and drift of its parameters due to temperature changes no longer play a role.

The operational amplifiers OP1 and OP2, the frequency generator FG, the synchronous rectifiers S1 and S2, the comparator VL and the control and monitoring circuit C can be easily integrated. Thus the Siemens unit TDA 4940, for example, is equipped with a phase-independent synchronous rectifier and subsequent comparator. At the connection 11 the controlled variable x or the control difference x_d is applied, while the sine-wave oscillation of the frequency f_0 is produced internally by means of a voltage-controlled oscillator. The frequency f_0 is determined by external wiring of the TDA 4940 unit with an RC element. The TDA 4940 unit is described on pages 577 to 581 of the "Siemens Datenbuch" (Siemens Data Book).

Claims

1. Method for automatically setting the control loop gain in a control system in which the reference input W is superimposed with a sine-wave signal of the frequency f in order to obtain a criterion for the setting of the control loop gain, characterised in that the amplitudes of the controlled variable x and the control difference x_d are compared with one another and that the control loop gain is varied until such time as the amplitudes of the controlled variable x and the control difference x_d are of equal value.
2. Method according to claim 1, characterised in that for the setting of the control loop gain the reference input W is selected as zero so that only the sine-wave signal of the frequency f acts as reference input.
3. Method according to claim 1 or 2, characterised in that the frequency f corresponds to the so-called critical frequency f_0 of the control system, at which the loop gain comes to one.
4. Method according to claim 3, characterised in that the control loop gain is varied until such time as the amplitudes of the controlled variable x and the control difference x_d are of equal value.
5. Circuit arrangement for implementing the method according to claim 4, characterised in that the output of a frequency generator (FG) is connected to the first input of a first synchronous rectifier (S1), to the first input of a second synchronous rectifier (S2) and to the first input of the summation stage (SU) of the control system to which the reference input W is supplied, that the output of the controlled system (RS) is connected to the second input of the summation stage (SU) and of the first synchronous rectifier (S1), that the output of the summation stage (SU)



The operational amplifiers OP1 and OP2, the frequency generator FG, the synchronous rectifiers S1 and S2, the comparator VL and the control and monitoring circuit C can be easily integrated. Thus the Siemens unit TDA 4940, for example, is equipped with a phase-independent synchronous rectifier and subsequent comparator. At the connection 11 the controlled variable x or the control difference x_d is applied, while the sine-wave oscillation of the frequency f_0 is produced internally by means of a voltage-controlled oscillator. The frequency f_0 is determined by external wiring of the TDA 4940 unit with an RC element. The TDA 4940 unit is described on pages 577 to 581 of the "Siemens Datenbuch" (Siemens Data Book).

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1. Method for automatically setting the control loop gain in a control system in which the reference input W is superimposed with a sine-wave signal of the frequency f in order to obtain a criterion for the setting of the control loop gain, characterised in that the amplitudes of the controlled variable x and the control difference x_d are compared with one another and that the control loop gain is varied until such time as the amplitudes of the controlled variable x and the control difference x_d are of equal value.
2. Method according to claim 1, characterised in that for the setting of the control loop gain the reference input W is selected as zero so that only the sine-wave signal of the frequency f acts as reference input.
3. Method according to claim 1 or 2, characterised in that the frequency f corresponds to the so-called critical frequency f_0 of the control system, at which the loop gain comes to one.
4. Method according to claim 3, characterised in that the control loop gain is varied until such time as the amplitudes of the controlled variable x and the control difference x_d are of equal value.
5. Circuit arrangement for implementing the method according to claim 4, characterised in that the output of a frequency generator (FG) is connected to the first input of a first synchronous rectifier (S1), to the first input of a second synchronous rectifier (S2) and to the first input of the summation stage (SU) of the control system to which the reference input W is supplied, that the output of the controlled system (RS) is connected to the second input of the summation stage (SU) and of the first synchronous rectifier (S1), that the output of the summation stage (SU)



is connected to the input of the controller (RG), whose output is connected to the input of the controlled system (RS), and to the second input of the second synchronous rectifier (S2), that the output of the first synchronous rectifier (S1) is connected to the first input of a comparator (VL), that the output of the second synchronous rectifier (S2) is connected to the second input of the comparator (VL), that the output of the comparator (VL) is connected to the input of a control and monitoring circuit (C) and that the output of the control and monitoring circuit (C) is connected to the input for setting the gain on the controller (RG).

6. Circuit arrangement according to claim 5, characterised in that the output of the frequency generator (FG) is connected to the non-inverting input of a first operational amplifier (OP1) which lies at reference potential across a first resistor (R1), that the output of the first operational amplifier (OP1) is fed back to its inverting input and is connected across a second resistor (R2) to the inverting input of a second operational amplifier (OP2), that the output of the controlled system (RS) and the second input of the first synchronous rectifier (S1) is connected across a third resistor (R3) to the non-inverting input of the second operational amplifier (OP2), which lies at reference potential across a fourth resistor (R4), and that the output of the second operational amplifier (OP2), which is fed back across a fifth resistor (R5) to its inverting input, is connected to the input of the controller (RG) and to the second input of the second synchronous rectifier (S2).
7. Circuit arrangement according to claim 5 or 6, characterised in that phase-independent synchronous rectifiers (S1, S2) are provided.
8. Circuit arrangement according to claim 5 or 6, characterised in that phase-dependent synchronous rectifiers (S1, S2) are provided, which measure the phase margin φ_0 , and that a further criterion for the setting of the control loop gain is derived from the measured phase margin φ_0 .
9. Circuit arrangement according to claim 8, characterised in that the control loop gain is reduced if the measured phase margin φ_0 falls below a presettable threshold value.
10. Circuit arrangement according to claim 5, 6, 7, 8 or 9, characterised in that amplitude and/or frequency of the sine-wave signal supplied by the frequency generator (FG) are variable.