

The invention is based on a control circuit according to the preamble of claim 1. A circuit of this kind is known from the EP-A2-0 238 041.

A control circuit of this kind for frequency control is required, for example, when using a recording medium in the form of a disc with a spiral track, e.g. a CD or an MOD disc. A pilot signal of a constant frequency is recorded along the spiral track on a disc of this kind, by means of which signal the rotational speed of the recording medium is controlled during recording and reproduction so as to obtain a constant circumferential speed at the location of the sampler and thus a constant sampling speed over the entire radius. The frequency which is sampled from the disc is delivered to a processor in which a pulse-width modulated signal is obtained from the frequency deviation, which signal then supplies via the change-over switch and the low-pass filter the analogue control voltage for the rotational speed of the recording medium. For controlling the speed of the motor, for example, a processor of this kind supplies a PWM signal with 256 steps over the total range of the frequency deviation which is to be controlled by the control circuit. Related to the coarse control range, which is essentially effective when the control circuit is closed and captured, this number of steps is generally sufficient. However the remaining number of steps is not sufficient for a satisfactory and accurate control of the motor speed for the steady-state, synchronous fine control range, which only represents a small proportion of the total coarse control range. What is rather desired in this synchronous state is greater resolution, which means a greater number of steps within the fine control range. This increase in the number of steps within the fine control range can be achieved with a processor with an appropriately increased number of steps of, for example, 2048 corresponding to 11 bits over the total control range. In practice, however, a processor of this kind is in many cases unavailable, so that a processor with PWM having 8 bits corresponding to 256 steps still has to be used.

The object of the invention is to develop a control circuit of the described type such that, without changing the number of steps of the PWM predetermined by the processor, it is possible to achieve a fine control range with increased resolution without this adversely affecting the coarse control range. This object is solved by the invention indicated in claim 1. Advantageous developments of the invention are indicated in the subclaims.

Also known is a PLL circuit (US-A-4 167 711) in which two pairs of current sources with different currents are provided which can be changed over in order to appropriately control the VCO of the PLL circuit. This circuit also comprises a low-pass filter which converts a binary control voltage into an analogue control voltage. This arrangement does not, however, provide for a change-over between a fine control range and a coarse control range with simultaneous change-over of the modulation factor of pulse-width modulation to achieve a continuous curve of the analogue control voltage which is generated over both control ranges.

Also known (DE-A-20 00 907) is a phase comparison circuit for generating a control voltage which is dependent on the phase relationship of two a.c. voltages, in which each of the a.c. voltages controls a switch such that it is periodically in the on state and the switches in each case close a recharging path for a common charging capacitor which supplies the control voltage.

According to the invention the two change-over switches, to which d.c. voltages of a different level are applied, provide two control ranges between which the selector switch changes over according to the respective deviation. The total number of steps of, for example, 256 of the PWM which is available in the processor is nevertheless used for the fine control range, which only represents a part of the total control range. A high resolution corresponding to the available number of steps of the PWM is therefore achieved

for the fine control, which is provided in the steady-state, synchronous mode, i.e. for the majority of the time. The coarse control range is not, however, reduced. Although the resolution within the coarse control range is correspondingly lower, this does not represent a disadvantage, as on one hand the coarse control range is only effective when the circuit is closed and for capturing and a smaller number of steps may then even be of advantage for accelerating the capturing process.

The invention can basically be applied for converting a pulse-width modulated signal into an analogue control voltage. An application of this kind may be put into effect in CD players, MOD players, television receivers and video recorders. It may also be used to demodulate a pulse-width modulated signal, i.e. to decode so-called PWM (pulse-width modulation) and recover the signal which has been modulated upon.

The invention is explained in the following in the light of the drawings and with reference to an embodiment for a frequency control circuit. In the drawings

Figure 1 is a basic representation of the known control circuit,

Figure 2 is the control circuit formed according to the invention,

Figures 3 and 4 are diagrams for illustrating the operating mode of the circuit according to Figure 2.

Figure 1 shows the motor M, which drives a CD or MOD disc P with a spiral track. The sampler A for the disc P supplies a signal 1, which has already been recorded, of a frequency of 22 kHz. For a constant sampling speed the rotational speed of the disc P must be controlled, i.e. reduced towards the outer disc edge, such that the signal 1 always has a frequency of 22 kHz, in spite of the change in the

respective radius for sampling. The signal 1 is delivered to the processor 2, where it is evaluated in terms of frequency. On the basis of the frequency evaluation of the signal 1, the processor 2 supplies the pulse-width modulated signal 3 of a frequency of 8 kHz, which, starting from a pulse duty factor of 1:1, is modulated in terms of pulse width according to the respective frequency deviation. The signal 3 controls the change-over switch 4, the output of which is thereby changed over between the d.c. voltages of $+U_1$ and $-U_1$. The low-pass filter 5 connected to the output of the change-over switch 4 supplies a control voltage U_r . The level of this control voltage is dependent, in terms of amplitude and polarity, on the respective frequency deviation of the signal 1. The control voltage U_r passes via the amplifier 6 to an input of the motor M and controls the latter's speed to give a constant frequency of the signal 1 and thus a constant sampling speed of the sampler A.

In Figure 2 the signal 3 simultaneously controls two change-over switches 4a and 4b, to which d.c. voltages of a different level, i.e. ± 1 V and ± 8 V, are applied. The input of the low-pass filter 5 can be changed over by the selector switch 7 between the two outputs of the change-over switches 4a and 4b according to the frequency deviation in the signal 1. This change-over is effected by a correcting variable U_s , which is determined in the processor 2 in accordance with the actual frequency deviation in the signal 1 and causes a change-over between a fine control range and a coarse control range. These two ranges are described in the following.

Fine control range

In Figure 3 the fine control range is represented by the deviations of $-f_1$ and $+f_1$ from the nominal frequency f_0 of the signal 1. The selector switch 7 is switched to the output of the change-over switch 4a for this control range, so that a maximum control voltage U_r of ± 1 V can be obtained. The processor 2 operates within this control range such that a frequency deviation of $-f_1$ or $+f_1$ causes a

pulse-width modulation of 100% in the signal 3. The total number of steps of 256 which the processor 2 has available for the modulated signal 3 is therefore allotted to the fine control range B1 so as to result in a change in the control voltage U_r of $2000 \text{ mV} : 256 = 7.8 \text{ mV}$ for each step S. This value is sufficiently low for the desired fine frequency control of the motor M in the steady-state synchronous range B1.

Coarse control range

If the frequency deviation in the voltage 1 exceeds the values of $-f_1$ or $+f_1$, the control circuit would stop operating, as it cannot supply a control voltage greater than $+1 \text{ V}$ or -1 V with the change-over switch 4a. The selector switch 7 is therefore changed over by the correcting variable U_s to the output of the change-over switch 4b at the transition point P of the control range B1 to the control range B2. On account of the increased d.c. voltage of 8 V at the inputs of the change-over switch 4b, the control voltage U_r can now assume values between -8 V and $+8 \text{ V}$. If, however, the modulation of the signal 3 remains 100% unchanged at the transition point P, the control voltage would jump by this factor at this point. The modulation factor of the PWM of the signal 3 at the transition point P is therefore changed over to a lower value in synchronism with the operation of the selector switch 7 such that the control voltage U_r which is generated initially remains constant, in spite of the increase in the d.c. voltage from 1 V to 8 V . The change-over is effected, for example, between a modulation factor of 99% and a modulation factor of 56%. The circuit now operates with the increased control range B2 between $-f_2$ and $+f_2$ in accordance with the desired coarse control. The number of steps of the PWM is still 256, so this number is now allotted to the control voltage range of -8 V to $+8 \text{ V}$. This results in a lower resolution of $1600 \text{ mV} : 256 = 62.5 \text{ mV}$ for each step S of the PWM modulation of the signal 3. The resolution is therefore reduced accordingly as desired with respect to the range B1. According to Figure 4, this coarse control would

also function as such in the range B1 with correspondingly lower resolution. However it is disconnected in this range by the selector switch 7 by connecting the fine control with the change-over switch 4a.

According to the magnitude of the frequency deviation in the signal 1, either the fine control range B1 between $-f_1$ and $+f_1$ with a range of control voltage U_r of -1 V to $+1$ V and high resolution or a coarse control range B2 between a frequency deviation of $-f_2$ and $+f_2$ with low resolution is therefore effective. The two change-over switches 4a and 4b with applied d.c. voltages of a different magnitude could be replaced by just one change-over switch which is operated by the signal 3 and to the inputs of which d.c. voltages of a different magnitude are selectively applied. The inputs of the single change-over switch may be supplied by an electronically stabilized power supply unit, the output voltage of which is electronically changed over by acting on the control circuit between 1 V and 8 V via the correcting variable U_s . The selector switch 7 would then be unnecessary, while the correcting variable U_s acts on the power supply unit controlling the single change-over switch 4 to effect a change-over between the ranges B1 and B2. It is also possible to provide more than two change-over switches 4, to which d.c. voltages of a different magnitude are accordingly applied for differentiation into more than two control ranges. The d.c. voltages which are in each case applied to the inputs of a change-over switch need not necessarily be of the same negative and positive value. They may also have different amplitudes of the same polarity. The control voltage U_r would then have a mean d.c. voltage value for the previously described case of $U_r = 0$, if the signal 1 has the nominal frequency f_0 of 22 kHz. It is thus in particular possible to adapt to different motors with different operating points at the nominal speed. The fact that this is a microprocessor control means that this adaptation can be effected in a short test run (approximately 1 second long) each time the device is connected. Aging of the motor and variation in the motor

data, for example, can as a result be compensated.

CLAIMS



1. Control circuit in which a pulse-width modulated signal (3) obtained from a frequency deviation changes over the output of a change-over switch (4) between two d.c. voltages (+U, -U) of a different level, and the output is connected to the input of a low-pass filter (5) which supplies an analogue control voltage (U_r), characterised in that, in order to form a fine control range (B1) and a coarse control range (B2) with the same number of steps of the pulse-width modulation, the input of the low-pass filter (5) can be changed over by a selector switch (7), which is operated according to the deviation (f_1 , f_2), to the output of a second change-over switch (4b), which is controlled by the same pulse-width modulated signal (3) and to which d.c. voltages are applied which are of a magnitude (± 8 V) which is different to that of the voltages applied to the first change-over switch (4a), and that the modulation factor of the pulse-width modulation is reduced at the transition point (P) from the fine control range (B1) to the coarse control range (B2) according to the increase in the d.c. voltages (1 V and 8 V) applied to the respective effective change-over switch (4a, 4b) so as to produce a continuous curve of the analogue control voltage (U_r) which is generated over both control ranges (B1, B2).

2. Circuit according to claim 1, characterised in that the two d.c. voltages (± 1 V; ± 8 V) which are in each case applied to the inputs of a change-over switch (4a, 4b) have the same value and opposite signs.

3. Circuit according to claim 1, characterised in that a first change-over switch (4a) with low applied d.c. voltages (± 1 V) is provided for a fine control range (B1) for small frequency deviations ($\pm f_1$) with 100% pulse-width modulation and a second change-over switch (4b) with higher applied d.c. voltages (± 8 V) is provided for a coarse control range (B2) with large frequency deviations ($\pm f_2$) and 100% pulse-width modulation.



4. Circuit according to claim 1, characterised in that the two change-over switches (4a, 4b) and the selector switch (7) are replaced by one change-over switch, to the inputs of which d.c. voltages (1 V, 8 V) of a different level are selectively applied.

5. Circuit according to claim 1, characterised in that the position of the fine control range (B1) formed by one change-over switch (4a) lies at any desired point within the coarse control range (B2) formed by the other change-over switch (4b).

6. Circuit according to claim 5, characterised in that the fine control range (B1) is narrow and thus the resolution fine with respect to the coarse control range (B2).