Compact Rotational Speed Sensor for Drive Systems

„LowHarmonics" Sine Wave Encoder with Commutation Track

The control system parameters „linear speed" (linear drives) and „rotational speed" (rotating drives) are required by servo drives with a highly dynamic transient response. For quasi-continuous control response, these parameters are processed by modern digital control units with scanning cycle times of about 100 µs.

The control unit must be provided with 10,000 measured values per second so that the linear speed or rotational speed can be determined from the difference per unit time. An incremental rotary encoder with 2,500 pulses per revolution and pulse edge evaluation for pulse quadrupling provides these 10,000 signals per revolution, however, the drive is then also limited to a minimum speed of 60 rpm, with smooth running. Uneven running can occur at lower speeds, a situation that can manifest itself as vibration (micro stepping) on the drive shaft. Resolvers cannot be used for precision drives as their resolution is normally significantly less than the 10,000 separate measured values required per revolution. In addition, in terms of the control system, it is unwise if a time lag occurs during rapid changes in speed. On resolvers a time lag is caused by the need to first sample the rotor position using a carrier frequency, and then to evaluate the amplitude modulation so gained using an A/D converter.

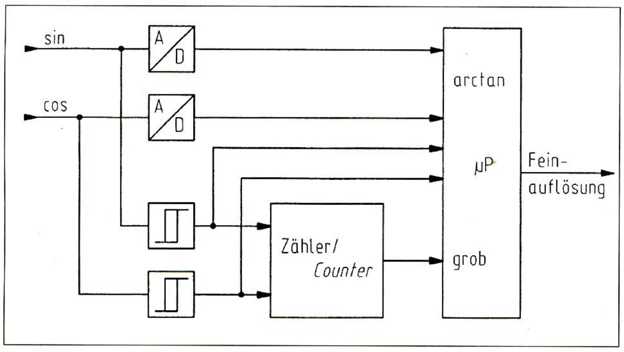

Figure 1 | Principle of deriving high resolution measurements using the „VeCon" chipset.

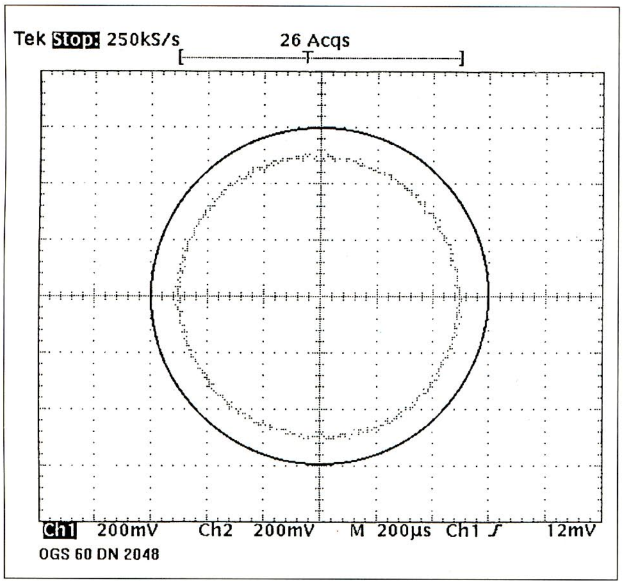

Figure 2 | On an x/y sampling oscilloscope, the LowHarmonics sine/cosine wave signals are characterised by a good circular shape inside a control circle.

Sine Wave Encoder for Highly Dynamic Drives

Speeds under 1 rpm (crawl speeds) require more than 1 million measured values per revolution. This can only be achieved with precision sine wave encoders. The two phase-offset sine wave signals from these encoders contain angle-dependent amplitude information from which, using appropriate interpolation circuitry, it is possible to derive positional information with much higher resolution than the number of zero crossings of the sine wave signal. Figure 1 shows the principle of operation of the technique for deriving high resolution measurements realised during the joint „VeCon" project: the coarse position is derived from the zero crossings of the sine and cosine wave signals, analogous to the evaluation of incremental encoders, whilst the fine positional information is calculated from the arc tangent of the A/D converted signals. When the rough and fine position information is combined to form the high resolution signal, the logic states of the comparator are used to determine the correct quadrant.

The accuracy of this interpolation is heavily dependent on the precision of the sine wave signals. The best preconditions for fulfilling this accuracy requirement are offered by opto-electronic scanning. Precision technologies are used during the manufacture of the scanning disk and mask; these technologies are similar to those used in semiconductor manufacture. Also of advantage is the large bandwidth of opto-electronic scannning, this results in it being possible to consider the response time to a step speed change to be almost immediate, an important prerequisite for highly dynamic control response.

The LowHarmonics Technique

On the sine wave encoders currently available, it is attempted to convert the triangular shaped signal (generated as the slots on the incremental disk pass the slots on the mask) into a sine wave-like signal with the intensity of light increasing not as a function of the angle of rotation, but changing over time. These techniques generate a sine wave-like signal on which particularly second and third order harmonics are superimposed. From these physically based results, it has been concluded that:

- The slots unavoidably produce signals containing harmonics, the amplitude and spectral composition of these signals is however similar.
- The harmonics can be removed if the slots are arranged on the mask such that the harmonics are in antiphase (they thus cancel each other by interference when superimposed in the optical receiver).

This task can be accomplished using a patented mask layout on which the slots are specifically placed on the mask at the positions related to the harmonics to be removed. The harmonics are reduced to less than -50 dB, resulting in the remainder being lost in the noise. In terms of scanning, the LowHarmonics technique offers an optimal absence of harmonics.

Avoiding Other Sources of Error

An initial indication of the accuracy of the sine wave signals is offered by the oscilloscope image in Figure 2:

- Is the Lissajous figure a circle? (Indication of the similarity of the sine and cosine amplitudes, 90° phase shift, harmonics content, noise).
- Is the centre of the circle correct? (Indication of DC offset).

The quality of the sine wave signals must not be impaired by interference on transmission to the control unit (in particular the switched current pulses to the drive). Analogous to the transmission of TTL signals as per the RS-422 interface standard, the two sine wave signals K1, K2 and the marker signal K0, as well as the inverted signals K1, K2 and K0 are transmitted differentially. The input differential amplifiers then provide the full AC signal with 1 V_{pp}.

Commutation Signals as an Option

Servomotors with permanent magnet excitation require information on the position of the rotor for start up. Sine wave encoders suitable for this purpose provide, in addition to the high resolution sine wave signals, sine/cosine wave commutation signals from which the position of the rotor can be determined using the arc tangent. Additional wiring is normally required for this feature. A different, cost saving method is shown in Figure 3: to start the drive, the control electronics set the marker pulse line K0 to ground. This action is detected in the sine wave encoder by the comparator; this then switches over the MUX. Sine/cosine wave absolute signals are now transmitted via the normal line driver and cabling. Following evaluation of the rotor position, the buffer is reset to the tri-state condition and, in the process, the MUX switched over to transmission of high resolution sine/cosine wave signals. From then on, the commutation signals are derived from the high resolution sine wave signals with the marker pulse.

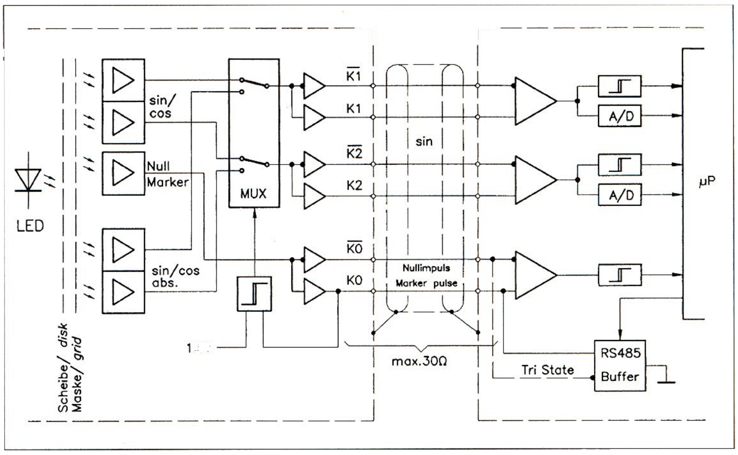

Figure 3 | When the drive is started up, the MUX permits low cost transmission of the commutation signals over the normal signal lines.

Figure 4 | Compact LowHarmonics sine wave encoder with additional commutation signals and hollow through shaft for direct installation on servomotors.

A compact sine wave encoder with 1024 sine/cosine cycles per revolution and, in addition, three sine/cosine wave commutation cycles for controlling a 6-pole servo motor with permanent magnet excitation is shown in Figure 4. This encoder was developed jointly by the group Hübner, Berlin, and Thalheim, Eschwege. The unit, with a housing diameter of 58 mm and a 14-mm hollow through shaft, is intended for direct installation on the non-drive end of the servomotor.

Connection can be made using low cost ribbon cable, or optionally using an axial or radial cable arrangement. The big „brother“ for low speed, direct lift motor drives can be seen in Fig. 5. The advantages of the LowHarmonics technique are particularly effective here: the sine wave encoder shown, with 70-mm hollow shaft, with 1024 sine/cosine cycles per revolution, has a relatively „coarse“ line pattern on the pulse disk. For the given area for opto-electronic scanning, there are only relatively few line cycles for scanning. As, however, the LowHarmonics technique works correctly with only a few lines, this feature is not a limitation. In summary, it can be stated that the patented LowHarmonics technique sets a new quality standard in digital drive systems.

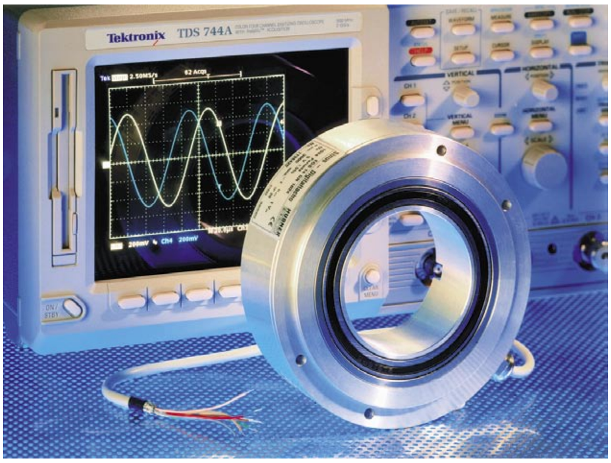

Figure 5 | The LowHarmonics technique also permits large sine wave encoders to be installed, for example for low speed lift motor drives.

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