

Determination of an absolute transit time of signals

DESCRIPTION

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TECHNICAL FIELD

The disclosure relates to a computer-implemented method for determining an absolute transit time of a signal, and correspondingly to a system for data processing, a computer program, and
10 a computer-readable medium.

BACKGROUND OF THE INVENTION

Chips which determine a transit time from a start signal and a stop signal are known.
15 EP0829734B1 describes a method for determining the transit time and how a start signal and a stop signal can be generated. The mode of operation of this conventional approach is shown in FIG. 1. The transit time measurement is initiated by a pulse 28. A first threshold voltage 29 is set so that, in the case shown in FIG. 1, the second negative half-wave of a group of oscillations of a received signal 300 is detected. A transit time counter is stopped with the zero
20 crossing following the detected half-wave, marked in FIG. 1 by a circle 31. For this purpose, a signal for enabling the stop input at the transit time counter is generated with a rising edge 32 of an output signal 33 of a first comparator and the transit time counter is stopped with a rising edge 34 of an output signal 35 of a second comparator. A time $t_l + t_{offs}$ measured in this way is reduced computationally by a circuit-dependent and sensor-dependent time offset t_{offs} in
25 order to obtain the actual transit time t_l of the signal.

However, it has been shown that the first amplitudes of a signal do not have the full amplitude and, as a result, the comparator described in EP0829734B1 can generate an edge or not depending on the threshold value. As a result, it is unknown whether the measured time
30 corresponds to the real transit time of the signal. This applies to a particular extent to signals with transient response, such as, for instance, in the case of signals in which a mass is excited to oscillate, such as, for instance, in the case of ultrasound signals. This also applies, in particular, in the case of dynamic couplings of signals, such as, for instance, to a living organism. There, the transient response can be variable and the measured transit times can
35 also have an inaccuracy which is dependent on the frequency of the signal and of the medium.

As a result of the conventional approach, the determination of absolute transit times in the

case of ultrasound signals is not possible, for example in medicine, or is not reliable or is not sufficiently possible.

However, the unreliable or inaccurate determination of an absolute transit time of signals also has effects for other technical applications. Thus, electromagnetic signals cannot be clearly and unambiguously distinguished from disturbances as a result, such as, for instance, in the case of LIDAR or parking sensors of motor vehicles.

BRIEF DESCRIPTION OF THE INVENTION

Proceeding from the prior art mentioned at the outset, the disclosure is based on the object of finding a method with which the absolute transit time of signals can be determined more reliably, and in particular independently of a transient response.

The object is achieved with a computer-implemented method according to independent claim 1, with a system for data processing according to independent claim 14, with a computer program according to independent claim 15, and with a computer-readable medium according to independent claim 16. Preferred embodiments are described in the dependent claims, in the description and in the figures.

receiving a signal sequence, the signal sequence comprising: a first signal having a first signal frequency and a first number of periods of the first signal having the first signal frequency, and a second signal following the first signal and having a second signal frequency, wherein the second signal frequency is different from the first signal frequency;

determining the absolute transit time of the first signal since a start time assigned to the signal sequence using the determined time for the signal transition from the received first signal to the received second signal and the number of periods of the first signal.

As a result of the absolute transit time of the first signal being determined using the determined time for the signal transition from the received first signal to the received second signal, the absolute transit time of signals can be determined more reliably, and in particular independently of a transient response. Aspects according to the invention allow meaningful absolute transit times of real signals (and not of disturbances) to be determined. Preferred aspects of the disclosure are robust with respect to variable transient response. Aspects of the claimed solution can also be used to achieve high accuracies in the determination of the absolute transit time. In particular, aspects according to the invention can be used to detect smallest changes in a medium through which the signal propagates. This is due, in particular, to the fact that a transition between two signals having different frequencies can be determined

with high accuracy.

Thus, determining the time of the signal transition from the received first signal to the received second signal preferably comprises: for each period of at least a portion of the received first signal and a portion of the received second signal, determining a transit time of the period since the start time for the signal sequence; determining differences of the determined transit times (directly or indirectly) of consecutive periods of the first signal and the second signal; determining the time of the signal transition from the received first signal to the received second signal based on determining the time at which the determined differences of the determined transit times (directly or indirectly) of consecutive periods switches between the period duration of the first signal and the period duration of the second signal. By virtue of the fact that a switch in the period duration of oscillations from the period duration of the first signal to the period duration of the second signal can be determined with high reliability and high accuracy, these further optional features contribute to a particularly reliable and accurate determination of the absolute transit time.

Preferably, the absolute transit time of the first signal since the start time for the signal sequence is determined by the determined time for the signal transition from the first signal to the second signal, corrected by a first temporal correction term that is based on the number of periods of the first signal, preferably wherein the first correction term comprises the product of the number of periods of the first signal and the period duration of the first signal. The determination of the frequency transition makes it known that a frequency change after N periods results from the signal generation. The determined time of the frequency transition or of the transition between the two signals can thus be corrected with the number of periods of the first frequency of the first, preceding signal in such a way that the absolute transit time corresponds to the time of the transition between the signals minus the product of the number of periods of the first signal and the period duration of the first signal, wherein additional temporal corrections resulting from the transition of the signals (e.g. time period between the signals, no full periods of a signal up to the transition, etc.) can be taken into account. These further optional features contribute to an even more reliable and accurate determination of the absolute transit time of the signal.

According to a further preferred aspect, the method may comprise: amplifying the received signal sequence before determining the time of the signal transition from the received first signal to the received second signal. This amplification can increase the steepness of the signal edges and reduce the probability that the measured absolute transit times are influenced by a signal amplitude. Thus, an amplification, in particular into the saturated range, can ensure that the absolute transit time, in particular the stop signal, is completely independent of the signal

amplitude.

The method may preferably comprise converting the preferably amplified signal sequence into a binary signal, preferably wherein the converting is performed by means of a comparator, preferably a Schmitt trigger. Such operators, in particular Schmitt triggers with logic gates, amplify the steepness of the start signal defining the start time and of the stop signal for measuring the transit time of a period. The signal edges can be configured more unambiguously and steeper by means of a hysteresis of such comparators.

Aspects according to the invention allow scaling to any number of transit time measurements, wherein a frequency transition between two signals can be used for determining an absolute transit time.

The method according to the invention may preferably also comprise emitting or generating, and optionally previously optionally amplifying, the signal sequence. Emitting or generating and/or receiving the signal may comprise converting an ultrasound signal or electromagnetic signal into an electrical signal.

The signal sequence described here is preferably electrical. Other signal types are conceivable.

Other signal types, such as ultrasound signals, electromagnetic signals, electrostatic signals or magnetic signals, may also be converted into the preferably electrical signal sequence. Actuators operated with this signal sequence may also be different, e.g. ultrasound, LED, laser, coil (magnetic), capacitor (electrostatic field), etc.

Each of the signals described here may be a (quasi-)harmonic wave.

If this brief description of the disclosure describes features which are not listed in the patent claims, these features do not constitute essential features in the sense that these features are necessarily to be included in the patent claims for the purpose of describing the invention, but these features are particularly prominent preferred realizations of the claimed invention, may be combined with each of the patent claims and may also be combined with one another as desired.

BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 shows a conventional approach for determining an absolute transit time according to the prior art.

FIG. 2 shows a signal sequence comprising three successive, preferably quasi-harmonic, signals with three different frequencies.

FIG. 3 shows, for each period of the signal, a schematic representation of the measurement of the transit time since the start time for the signal sequence.

FIG. 4 shows, for a signal sequence comprising three signals with three different signal frequencies, the transit time differences of consecutive periods as a function of the index of the transit time differences.

FIG. 5 shows measurements of frequency transitions of three signals.

FIG. 6 shows measurements of the absolute transit time of a signal according to FIG. 5 as a function of the continuous time, here after filtering in order to reduce noise.

FIGS. 7A to 7C show block diagrams of the signal technology of possible implementations of aspects according to the invention.

Components which are shown in several figures bear the same reference signs.

DETAILED DESCRIPTION

The disclosure relates to a computer-implemented method for determining an absolute transit time of a signal, and correspondingly to a system for data processing, a computer program, and a (non-volatile or non-transitory) computer-readable (memory) medium.

FIG. 2 shows, by way of example, a signal sequence comprising three successive, preferably quasi-harmonic, signals with three different frequencies. However, it is sufficient for the determination of an absolute transit time if the signal sequence has two signals with two different frequencies. In the case of three or more signals in the signal sequence, it is also sufficient if two successive signals have two different frequencies. Within the signal sequence, frequencies can therefore be repeated. The two or more signals of the signal sequence follow one another, wherein two successive signals immediately adjoin one another in time or there can be a time gap between the two signals. If reference is made in this disclosure to successive signals or periods, temporally directly or indirectly successive signals or periods can be meant, and both possibilities are possible in any case.

receiving a signal sequence 100, the signal sequence 100 comprising: a first signal 10 having a

first signal frequency f_1 and a first number N_1 of periods of the first signal having the first signal frequency, and a second signal 20 following the first signal 10 (directly or indirectly) and having a second signal frequency f_2 , wherein the second signal frequency is different from the first signal frequency (correspondingly, the period durations T_1 , T_2 of the two signals are also different); determining a time T_{12} of a signal transition 101 from the received first signal 10 to the received second signal 20; and determining the absolute transit time, $absTOF_1$, of the first signal 10 since a start time, t_{start} (e.g. at zero seconds), for the signal sequence 100 using the determined time, t_{12} , for the signal transition 101 from the received first signal 10 to the received second signal 20 and the number, N_1 , of periods of the first signal 10 (the number of periods N_1 is preferably the total number of periods of the first signal 10 from the beginning of the first signal to the end of the first signal before the time t_{12}).

The same can apply to the signal pair 20 and 30. The signal sequence 100 in FIG. 2 further comprises a third signal 30 following the second signal 20 and having a third signal frequency f_3 , wherein the third signal frequency f_3 is different from the second signal frequency f_2 (but f_3 can be equal to f_1), and wherein the method further comprises: determining a time t_{23} of a signal transition 102 from the received second signal 20 to the received third signal 30; and determining the absolute transit time of the second signal 20 since the start time t_{start} for the signal sequence 100 using the determined time t_{23} for the signal transition 102 from the received second signal 20 to the received third signal 30 and a number, N_2 , of periods of the second signal 20 (the number of periods N_2 is preferably the total number of periods of the second signal 20 from the beginning of the second signal to the end of the second signal before the time t_{23}).

FIG. 3 shows, for each period i of the signal, a schematic representation of the measurement of the transit time since the start time for the signal sequence.

Determining the time t_{12} of the signal transition 101 from the received first signal 10 to the received second signal 20 therefore preferably comprises: for each period i of at least a portion of the received first signal 10 and a portion of the received second signal 20, determining a transit time TOF_i of the period i since the start time t_{start} for the signal sequence 100; determining differences of the determined transit times TOF_i (directly or indirectly) of consecutive periods i of the first signal 10 and the second signal 20; determining the time t_{12} of the signal transition 101 from the received first signal 10 to the received second signal 20 based on determining the time t_{12} at which the determined differences of the determined transit times TOF_i (directly or indirectly) of consecutive periods switch between the period duration T_1 of the first signal 10 and the period duration T_2 of the second signal 20.

In other words, a signal sequence 100 with at least two signals 10, 20 of different frequencies f_1 , f_2 and one or more known numbers N_1 , N_2 of periods is generated or received. In each period i , for example in each zero crossing in a predetermined direction (e.g. from + to – or vice versa), of the respective received signal 10, 20, a stop signal is generated. Transit times TOF_i for each period i of the respective received signal 10, 20 are determined from the stop signal and the start time t_{start} of the signal sequence 100 . The difference between the TOF_i (directly or indirectly) of consecutive or adjacent periods i of the respective received signals is formed, wherein the differences are intended to result in the period durations T_1 or T_2 of the respective signals 10 or 20 . A change in these time differences (period durations) results from a change in the signal frequency, such that a change in the signal frequency and therefore a transition from the first signal 10 to the second signal 20 can be determined by means of a change in the time differences or period durations. By means of the number N_1 of periods of the first signal known for the first signal 10, it is possible to determine when this frequency transition, or transition of the signals, is expected. The determined time t_{12} of the frequency transition can consequently be corrected with the number N_1 of the periods of the first signal, specifically in such a way that a correction term comprising the product of the number N_1 of the periods of the first signal 10 and the period duration T_1 of the first signal 10 is subtracted from the determined time t_{12} of the frequency transition or signal transition 101 . If the first signal 10 is received before the frequency transition or signal transition 101, this correction term is subtracted from the determined time t_{12} of the frequency transition or signal transition 101 in order to obtain the absolute transit time $absTOF$ of the first signal 10 .

The same can apply to the signal pair 20 and 30 in order to determine a further absolute transit time. Thus, for example, the absolute transit time of the second signal 20 can be determined by virtue of the second signal being followed (directly or indirectly) by the third signal 30 which has a third frequency f_3 which is different from the second frequency f_2 . Here too, the frequency transition or signal transition 102 between the second signal 20 and the third signal 30 can be used to determine the absolute transit time of the second signal 20 . Aspects according to the invention allow scaling to any number of transit time measurements $absTOF_i$ for any number of signals, wherein a frequency transition between two (directly or indirectly) successive signals can be used for determining an absolute transit time $absTOF_i$.

FIGS. 4-6 show simulated and experimental data which were generated with a signal sequence, here comprising, by way of example, three different signals with three different signal frequencies. FIG. 4 shows simulated transit time differences of (directly) successive periods. FIG. 5 shows experimentally determined frequencies from transit time differences of (directly) successive periods. FIG. 6 shows the time profile of the determined absolute transit time.

With such a signal sequence with three frequency components, ultrasound measurements were carried out on a dynamically coupling system, namely on a subject, and corresponding simulations were carried out in order to demonstrate the functionality of aspects according to the invention.

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FIG. 4 shows simulated data for a signal sequence comprising three signals with the three different signal frequencies f_1, f_2, f_3 , the differences of the TOF_i of (directly) successive periods i of the three signals as a function of the index of the transit time differences of the periods. The frequencies in the signal sequence from FIG. 4 correspond to $f_1=1$ MHz, $f_2=1.2$ MHz, and $f_3=1.4$ MHz with a period number $N_1=N_2=N_3$ of 30 periods in each case. The three different period durations T_1, T_2, T_3 resulting from the three different frequencies can be inferred from the measurement points and the Y axis.

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FIG. 5 shows experimental data for a signal sequence comprising three signals with the three different signal frequencies f_1, f_2, f_3 from FIG. 4, the two frequency transitions 12 and 23 between first and second signal or between second and third signal. The frequencies in this signal sequence correspond to $f_1=1.0$ MHz, $f_2=1.2$ MHz, and $f_3=1.4$ MHz with a period number of 30 periods in each case.

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From the two frequency transitions 12, 23 (here, by way of example, index 26 or 56) in FIG. 5 or the times t_{12} or t_{23} of the frequency transitions 12, 23, it is possible to determine two absolute transit times, namely those of the first signal 10 and of the second signal 20. In the example in the individual measurement under consideration, these are at $t_{12}=131.1762$ μs and $t_{23}=156.3001$ μs . It should be mentioned here that, for each signal transition or frequency transition between two signals, the corresponding index or time of the last or latest period of the earlier signal, the corresponding index or time of the ramp or of the transition (see “12” and “23” in FIG. 5) between the two signals, or the corresponding index or time of the first or earliest period of the later signal of the two signals can be used as T_{12} or t_{23} for the subsequent calculation of the absolute transit time $absTOF$. A different selection for t_{12} or t_{23} is possible.

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The absolute transit times are calculated by means of the times for the determined frequency transitions (t_{12}, t_{23}), with optional correction terms, k_1, k_2 , and the number of transmitted periods, and, in the exemplary measurement under consideration,

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$$absToF1 = t_{12} - \frac{30}{f_1} + k_1 = 101.2593 \mu s$$

$$k_1 = \frac{0.5}{f_1} - \frac{0.5}{f_2} = \frac{0.5}{1MHz} - \frac{0.5}{1.2MHz} = 0.083 \mu s$$

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$$absToF2 = t_{23} - \frac{30}{f_1} - \frac{30}{f_2} + k_2 = 101.4431 \mu s$$

$$k_2 = \frac{0.5}{f_1} - \frac{0.5}{f_3} = \frac{0.5}{1MHz} - \frac{0.5}{1.4MHz} = 0.143 \mu s$$

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For the calculation of the absolute transit time $absTOF_1$ of the first signal 10, firstly the time t_{12} is determined for the transition from the first signal 10 to the second signal 20 . Subtracted from this is the product of the number $N_1=30$ of the periods of the first signal and the period duration $T_1=1/f_1$ of the first signal. Optionally further correction terms, k_1 , can be added (k_1 can also be zero), which can be given by the design of the transition of the signals (e.g. time gap between the signals 10, 20).

For the calculation of the absolute transit time $absTOF_2$ of the second signal 20, firstly the time t_{23} is determined for the transition from the second signal 20 to the third signal 30 . Subtracted from this is the product of the number $N_1=30$ of the periods of the first signal and the period duration $T_1=1/f_1$ of the first signal, and the product of the number $N_2=30$ of the periods of the second signal and the period duration $T_2=1/f_2$ of the second signal. Further correction terms, summarized as k_2 , can be added, which can be given by the design of the transition of the signals (e.g. time gap between the signals). In this example, $k_2=0.5/f_1-0.5/f_3$. In each of the above equations for $absTOF_i$, correction terms (k_1, k_2) can be taken into account, which can take into account circumstances such as a delayed start signal (t_{start}), which is dependent on the 1. frequency, and/or a half period of one or both signals at the frequency change at which the absolute transit time is to be determined. It is a system- or signal-profile-dependent constant. The correction terms can also be determined via a calibration.

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FIG. 5 is a measurement on the human head, as a result of which inhomogeneities and boundary layers can occur in the sound path.

FIG. 6 shows a detail of measurements of the absolute transit time $absTOF$ of one of the three signals according to FIG. 5 as a function of the continuous time since the start of the measurement (here after filtering in order to reduce noise). For this purpose, the signal sequence is emitted and received repeatedly or continuously. Since these measurements are based on ultrasound signals which propagated through a head of a subject, the periodicity of approximately 1 second, which can be seen in FIG. 6, results from the heart rate of the subject. However, the trend of the curve, which can be seen in FIG. 6, can be attributed to changes in the medium or in its speed of sound or sound path, which illustrates the accuracy with which the absolute transit time and changes in the absolute transit time can be determined by aspects

according to the invention.

FIGS. 7A to 7C show block diagrams of the signal technology of possible implementations of aspects according to the invention.

5 As shown in FIGS. 7A and 7B, a system 1 for data processing, comprising a computer/controller and (memory) medium, controls a signal generator 2 . Before the signal is (optionally converted and) transmitted by a transmitter 4, the signal can optionally be amplified by an amplifier 3, for example in order to keep the further signal processing technology (e.g. 8) better in a dynamic range. However, if the signal strength has sufficient intensity and/or stability,
10 such an amplifier 3 is not necessary.

The signal, for example an ultrasound signal, is then transmitted by a transmitter 4, for example an ultrasound probe, through a medium, for example a head of a human, and, after passing through the medium, is received by a receiver 5, for example an ultrasound probe. On the part of the transmitter 4, the ultrasound probe can convert an electrical signal generated
15 by the signal generator 2 and optionally amplified into a mechanical longitudinal wave. The receiver 5, for example an ultrasound probe, captures the transmitted signal, wherein, in the case of an ultrasound signal as the received ultrasound signal, the ultrasound probe converts it into an electrical signal.

After the receiver 5, the received and optionally converted signal is optionally amplified by a
20 preamplifier 6 (e.g. in saturation). Alternatively or additionally, a comparator 7, such as a Schmitt trigger, can convert the received signal into a binary signal. Each of these two measures can configure edges of the signals more steeply individually and in combination and have the effect that the further transit time measurements can be performed completely independently of amplitudes.

25 One or more sensors 8 are actuated and read by the system 1 in order to determine transit times TOF_i of individual periods i of the received signals and to determine the transition t_{12} , t_{23} between two of the signals of different frequencies f_1 , f_2 , f_3 by means of software. The system 1 determines an absolute transit time $absTOF_i$ of one of the received signals 10, 20, 23 from the determined time t_{12} , t_{23} of the signal transition (and thus frequency transition 12,
30 23) by means of software.

If the sensor 8 is designed to measure all transit times TOF_i of the entire number of periods from the first signal to the second signal, a single sensor is sufficient. However, sensor 8 may also comprise a plurality of individual sensors which are interconnected and are controlled and read by the computer/controller. FIG. 7C shows an example in which sensor 8 comprises

sixteen individual sensors TDC1 to TDC16 (TDC: time-to-digital chip, digital stop clock). For example, each of the sensors TDC_i may be designed to measure five TOF_i for five periods i, such that the transit time measurements can be carried out for a total of eighty periods.

5 The system 1 executes software which ensures that the TDC1-16 do not measure the same zero crossings, but rather perform measurements in a cascaded manner (always measure the next period). The last measurement time of the TDC1 determines the first measurement time of the TDC2. The last measurement time of the TDC2 determines the first measurement time of the TDC3, etc.

10 The start time may define the start point of the measurements by the one or more sensors 8. This may be given when it is determined by the system 1 and the optional amplifier 3 that the subsequent signal technology, in particular the sensors 8, operate in a dynamic range.

15 By virtue of the aspects according to the invention described here, the absolute transit time of signals can be determined more reliably, independently of a transient response, and more accurately. This leads to a new quality of signal processing in a wide variety of applications, such as medical technology or traffic technology.

The software, computer programs, methods, systems for data processing, computers, (memory) media, and controllers described here can be implemented by any software or computer technology.

20 Preferred embodiments of the subject matter claimed by the appended claims are described in the description and in the figures. The optional features disclosed in the above description, the claims, and the drawings can be used both individually and in any combination for the implementation of the subject matter claimed here in accordance with the appended claims in its various configurations.

25 The various aspects and embodiments described above can be combined to create yet further embodiments. These and other changes can be made to the embodiments in light of the above detailed description. In general, the terms used in the following claims should not be construed to limit the claims to the specific aspects and embodiments disclosed in the specification and claims, but to include all possible embodiments along with the full scope of equivalents to which such claims are entitled.

Claims

1. A computer-implemented method for determining an absolute transit time of a signal, comprising
5 receiving a signal sequence (100), the signal sequence (100) comprising:
a first signal (10) having a first signal frequency and a first number of periods of the first signal (10) having the first signal frequency, and
a second signal (20) following the first signal and having a second signal frequency, wherein the second signal frequency is different from the first signal
10 frequency;
determining a time of a signal transition (101) from the received first signal (10) to the received second signal (20); and
determining the absolute transit time of the first signal (10) since a start time assigned to the signal sequence (100) using the determined time for the signal transition (101)
15 from the received first signal (10) to the received second signal (20) and the number of periods of the first signal (10).
2. The method of claim 1, wherein determining the time of the signal transition (101) from the received first signal to the received second signal comprises:
20 for each period of at least a portion of the received first signal (10) and a portion of the received second signal (20), determining a transit time of the period since the start time for the signal sequence (100);
determining differences of the determined transit times of consecutive periods of the first signal (10) and the second signal (20);
25 determining the time of the signal transition (101) from the received first signal (10) to the received second signal (20) based on determining the time at which the determined differences of the determined transit times of consecutive periods switches between the period duration of the first signal (10) and the period duration of the second signal (20).
3. The method of claim 1 or 2, wherein the absolute transit time of the first signal (10) since the start time of the signal sequence (100) is determined by the determined time for the signal transition (101) from the first signal (10) to the second signal (20), corrected by a first temporal correction term that is based on the number of periods of the first signal (10).
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4. The method of claim 3, wherein the first correction term comprises the product of the number of periods of the first signal (10) and the period duration of the first signal (10).
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5. The method of any one of the preceding claims, further comprising amplifying the received signal sequence (100) before determining the time of the signal transition (101) from the received first signal (10) to the received second signal (20).

6. The method of claim 5, further comprising converting the preferably amplified signal sequence (100) into a binary signal, preferably wherein the converting is performed by means of a comparator (7), preferably a Schmitt trigger.

7. The method of claim 5 or 6, wherein determining the transit time of each period since the start time is performed by means of an edge of the respective binary signal in a predetermined direction.

8. The method of any one of the preceding claims, wherein the signal sequence (100) further comprises a third signal (30) following the second signal (20) and having a third signal frequency, wherein the third signal frequency is different from the second signal frequency, and wherein the method further comprises:

determining a time of a signal transition (102) from the received second signal (20) to the received third signal (30); and

determining the absolute transit time of the second signal (20) since the start time for the signal sequence (100) using the determined time for the signal transition (102) from the received second signal (20) to the received third signal (30) and a number of periods of the second signal (20).

9. The method of claim 8, wherein determining the time of the signal transition (102) from the received second signal (20) to the received third signal (30) comprises:

for each period of at least a portion of the received second signal (20) and a portion of the received third signal, determining a transit time of the period since the start time for the signal sequence (100);

determining differences of the determined transit times of consecutive periods of the second signal (20) and the third signal;

determining the time of the signal transition (102) from the received second signal (20) to the received third signal based on determining the time at which the determined differences of the determined transit times of consecutive periods switches between the period duration of the second signal (20) and the period duration of the third signal.

10. The method of claim 8 or 9, wherein the absolute transit time of the second signal (20) since the start time of the signal sequence (100) is determined by the determined time for the signal transition (102) from the second signal (20) to the third signal, corrected

by a second temporal correction term that is based on the number of periods of the second signal (20).

5 11. The method of claim 10, wherein the second correction term comprises the product of the number of periods of the second signal (20) and the period duration of the second signal (20).

10 12. The method of any one of the preceding claims 3-11, wherein the first and/or second correction term further comprises one or more further temporal corrections given by the start time and/or the transition (101, 102) of the respective signals (10, 20, 30).

15 13. The method of any one of the preceding claims 2-12, wherein determining the transit time of each period since the start time is performed at the time of a zero crossing of the respective signal in a predetermined direction of the signal switching.

14. A system (1) for data processing, comprising means for performing the method of any one of the preceding claims.

20 15. A computer program comprising instructions which, when the program is executed by a computer, cause the computer to carry out the method of any one of the preceding claims 1-13.

25 16. A computer readable medium comprising instructions which, when the program is executed by a computer, cause the computer to carry out the method of any one of the preceding claims 1-13.